A Puerto Rican in the South Pole

Armando Caussade

A PUERTO RICAN IN THE SOUTH POLE

Third edition

ARMANDO CAUSSADE

Foreword by James M. Madsen, PhD

Puerto Rico Astronomy Society, Inc.
An Affiliate of NASA Puerto Rico Space Grant Consortium
2016

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Written, illustrated and designed by Armando Caussade.
Foreword and technical review by James M. Madsen, PhD.
Third edition: November 1, 2016.

Published by the Puerto Rico Astronomy Society, Inc.
PO Box 362846 • San Juan, PR 00936–2846.
+1 (787) 531–7277 • astronomiapr@gmail.com • http://www.astronomiapr.org/ or .net

Editorial support was also provided by the Wisconsin IceCube Particle Astrophysics Center.
22W Washington Ave, Suite 500 • Madison, WI 53703.
+1 (608) 890–0550 • http://wipac.wisc.edu/

Download link: http://www.polartrec.com/resources/article/a-puerto-rican-in-the-south-pole

This material is based upon work supported by the National Science Foundation under grant numbers 0956825 (PolarTREC) and 0236449 (IceCube). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

ISBN-10: 0–9971755–4–0
ISBN-13: 978–0–9971755–4–7

Un puertorriqueño en el polo sur

Redactado, ilustrado y montado por Armando Caussade.
Prólogo y revisión técnica por James M. Madsen, PhD.
Tercera edición: 1.º de noviembre de 2016.

Publicado por la Sociedad de Astronomía de Puerto Rico, Inc.
Con asistencia editorial ofrecida por el Centro de Astrofísica de Partículas IceCube de Wisconsin.

For my mother Carmencita and my late grandmother Belén,

without whose prayers, blessings and encouragement

the amazing journey that is the subject of this book

would never have been successfully completed.

Contents

About the author

Armando is an astronomy educator who has taught at all academic levels, from primary school to university. His experience also comprises delivery of continuing education and teacher training, along with curriculum development. Enjoying what he does has been the key to his success, which has been well documented through regular feedback by students, staff and the community.

After a competitive review process Armando was selected as a participant of the 2014–2015 Antarctic field season of PolarTREC, a program funded by the National Science Foundation (NSF). In January 2015 he traveled to the Amundsen–Scott South Pole Station where he successfully conducted maintenance and support work at the IceCube Neutrino Observatory.

Armando's career includes over a decade in the information technology field, hence his affinity for computers. He volunteered as a Solar System Ambassador with the National Aeronautics and Space Administration (NASA) and has consistently served in leadership roles—notably at the *Puerto Rico Astronomy Society*, a NASA-affiliated group which he chaired for six years.

Because of his reputation as a talented communicator of science Armando is repeatedly requested as a speaker, having delivered hundreds of lectures to groups as large as 500. This is also a result of his broad and varied connections across academia, non-profits and government. His endeavors are regularly reported by the media, with coverage spanning all seven continents.

Armando is a recipient of the *Antarctica Service Medal of the United States of America* (2015) from the NSF. His work has additionally been recognized by the Puerto Rico Science Teachers Association (2015), the UNESCO Center for Culture (2013), the International Astronomical Union (2010), the Puerto Rico Academy of Arts and Sciences (2008), and NASA / JPL (2005).

He lives, works and writes in San Juan, Puerto Rico.

Foreword

It is hard to believe that as I write this twenty months have passed since PolarTREC teacher Armando Caussade returned from the ice. This book captures his journey, from his early interest in astronomy and fascination with Antarctica, to his application to and selection by the National Science Foundation PolarTREC program and the IceCube Collaboration, through his training and deployment to the South Pole's IceCube Neutrino Observatory, and finally his follow-up activities. It is an inspiring story by an amazing educator, meticulously documented with stunning photography.

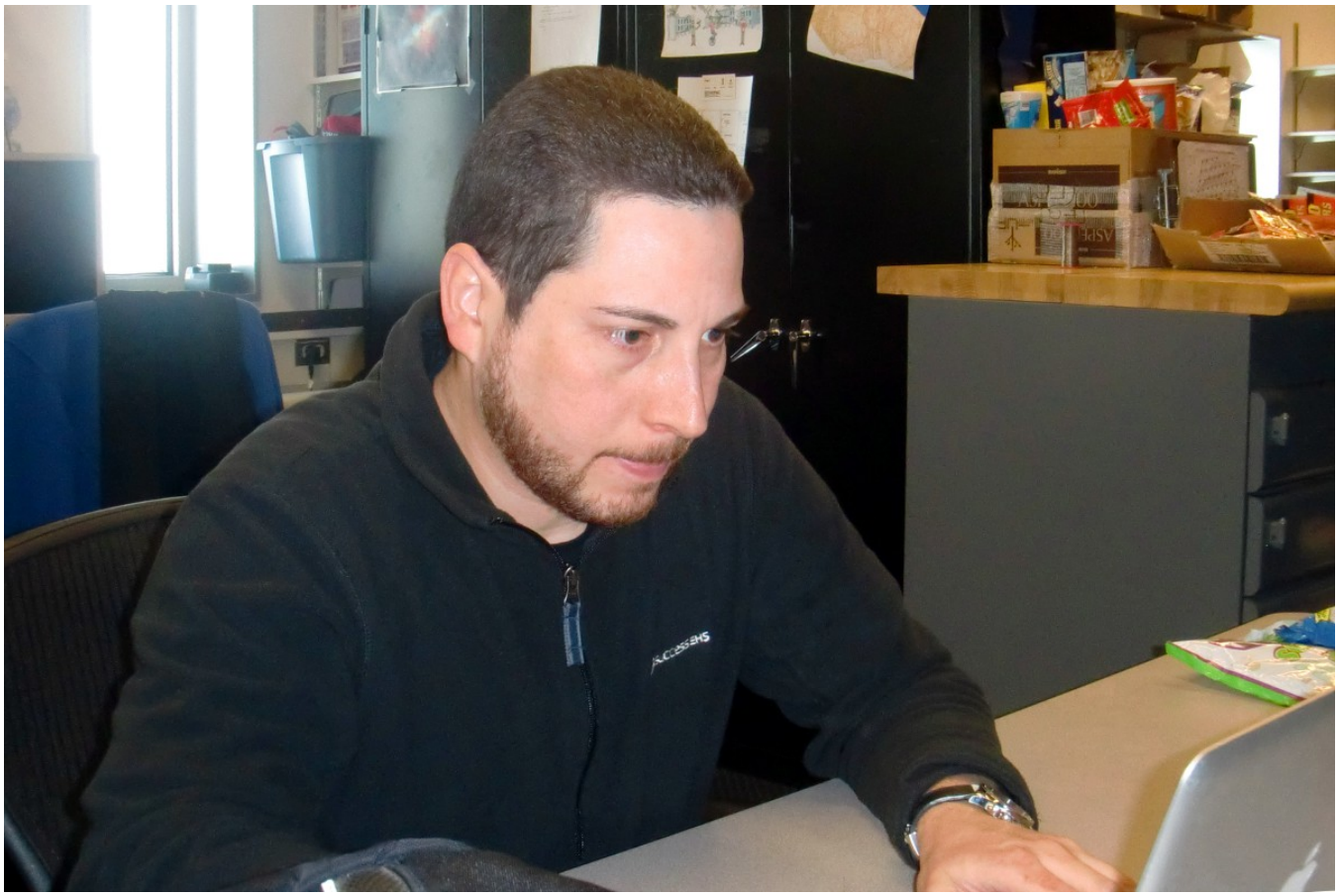
As Armando conveys so eloquently, getting to the South Pole is a dream that few realize. I have had the good fortune to work on the IceCube project, and its predecessor, AMANDA (Antarctic Muon And Neutrino Detector Array) since 1998. During this time, there have been annual deployments to the South Pole. When interviewed and asked to talk about working on the IceCube project, almost all started with the people, and how much their colleagues meant to them.

Since the 2000–2001 season, the IceCube and AMANDA collaborations have hosted seven teachers at the South Pole, with Armando being the most recent in the 2014–2015 season. I have had the privilege of working with this incredible group of bright, dedicated professionals who believe in the power of education to change lives. But beyond that, they shared a common desire to see how science was done first-hand, and experience life and work in one of the most extreme environments on Earth. Most importantly, they were willing to invest time and battle long odds. For their efforts, they were rewarded with the trip of a lifetime, and the opportunity to contribute to the birth of a new field, *neutrino astronomy*.

Armando's book conveys in words and pictures this whole process. It is a great story, even more remarkable because it all happened. I was immediately transported back to the ice when I read this book. I think you will be equally moved.

James M. Madsen, PhD

Professor and Chair at the Physics Department, University of Wisconsin–River Falls
Associate Director for Education and Outreach, IceCube Collaboration



Drafting one of the online journals that would later be included as Part II of this book. January 13, 2015 at 6:13 pm — Amundsen–Scott South Pole Station, Antarctica.

Introduction

This book is the story of my journey to the South Pole, which was successfully accomplished in January 2015. As the most elaborate and comprehensive publication to date on my PolarTREC expedition to the IceCube Neutrino Observatory, I intend this volume to be the definitive work on the subject.

My book is not primarily an account of Antarctic geography or neutrino research, although I do cover these topics with reasonable detail. The main purpose is to provide a memoir of my journey, told from the perspective of an astronomy educator and from the viewpoint of a resident of the tropics.

This volume consists of two parts: Part I (*The Story*) and Part II (*The Journals*). The former expounds on my involvement with PolarTREC and IceCube from a wider perspective comprising a full three-year period, while the latter covers only the actual 24-day journey but tells the story in greater detail.

Part II was originally written in January 2015 as daily journals that I posted to the PolarTREC website, http://www.polartrec.com/expeditions/ice-cube-neutrino-observatory-2014/. Later on I reread the entire text, correcting for typographical errors and checking for accuracy and consistency. I also filled in additional details—where warranted—and generally polished up the style. The results are here.

Part I was composed during the spring of 2016 and consists mostly of unpublished material. Because from the beginning the content for this part was fresh in my mind after mulling it over during a year, I was able to draft the narrative in just a few sittings. I am also including some unused text and images that I had collected over time, together with three pieces that others wrote about my journey.

The text is profusely illustrated with 288 full-color images, mostly original photography made by me during my 18-day stay in Antarctica. Although I ended up swapping a couple of pictures between parts I and II, the 176 illustrations that were originally featured with the journals are all included. As always, each photograph has been digitally processed from the original to achieve optimal image quality.

The book contains 18 panoramas that have been reproduced as two-page spreads. In order to properly view them I suggest using a dedicated PDF viewer working in two-page mode, with even-numbered pages at the left and odd-numbered pages at the right. The PDF file should be readable in a smartphone or a tablet, but it will be best enjoyed if viewed using a full HD (1920 × 1080) computer screen.

If you like this book, please let me know. I can be reached through the publisher, via telephone, e-mail or by letter (see contact information on the copyright page). I am also available for free presentations and media interviews which, again, can be requested through the publisher. And one last note: Internet links are shown as they existed at the time of publication, and may have changed or disappeared.

Having shared these thoughts, I now give you *A Puerto Rican in the South Pole*.

Armando Caussade

San Juan, Puerto Rico
October 2016

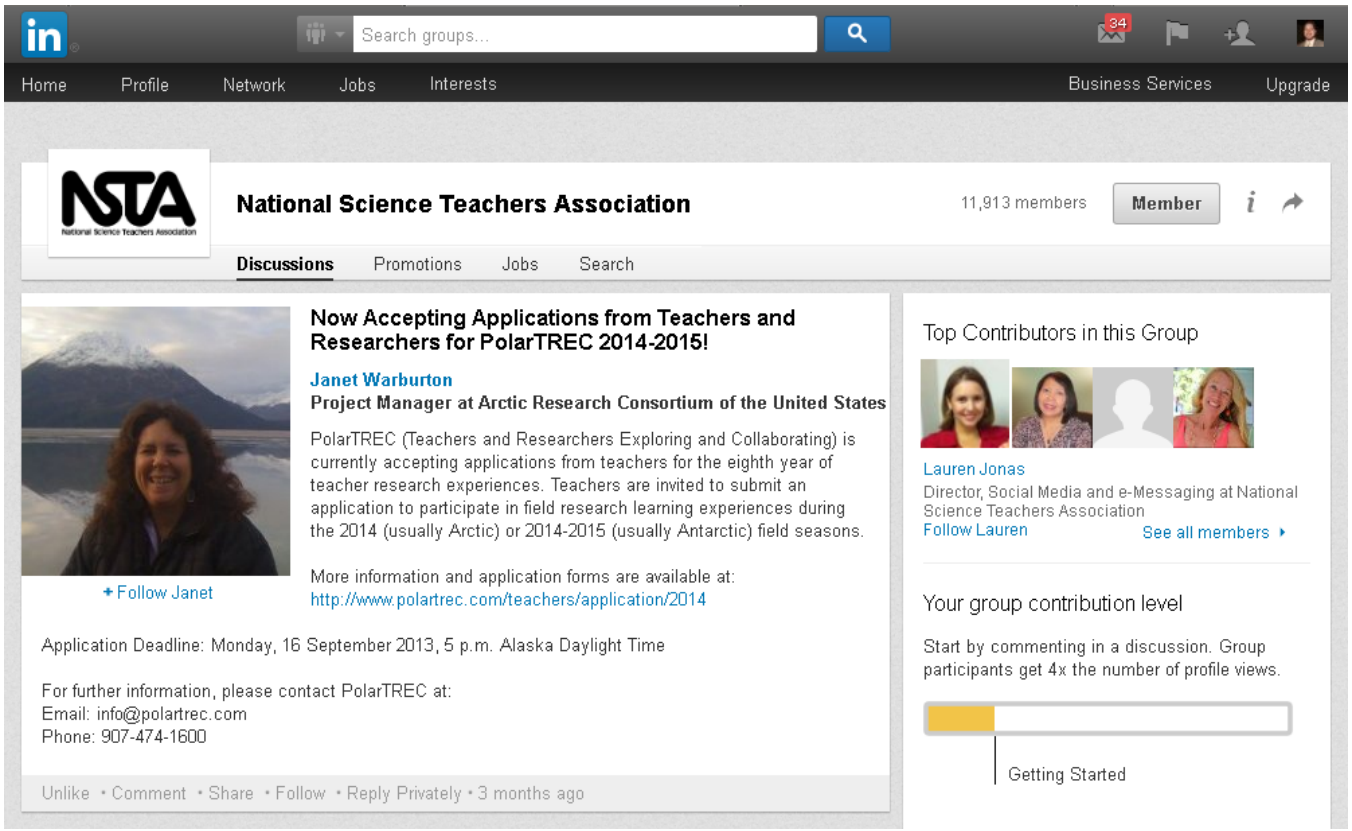
PART I:

THE STORY

1. Selection as a PolarTREC participant

God works in mysterious ways and life is full of surprises. Earning an opportunity to visit Antarctica, and more specifically to assist with research at the South Pole—the most remote spot on Earth, a place that has only been visited by 10,000 people at the most—is something I would never have imagined.

For years I had read, studied and enjoyed every piece of information about Antarctica that came into my hands. I knew the geography of the continent and had become knowledgeable with its climate and the peculiar configuration of the seasons. I had learned about the flora and fauna, and had even reviewed the history of exploration in the region. Naturally I dreamed about visiting one day, but was also aware that few people are fortunate enough to ever set foot on this southernmost landmass. So, how did I end up at the South Pole? Let us go back to the summer of 2013, when I was 42 years of age.



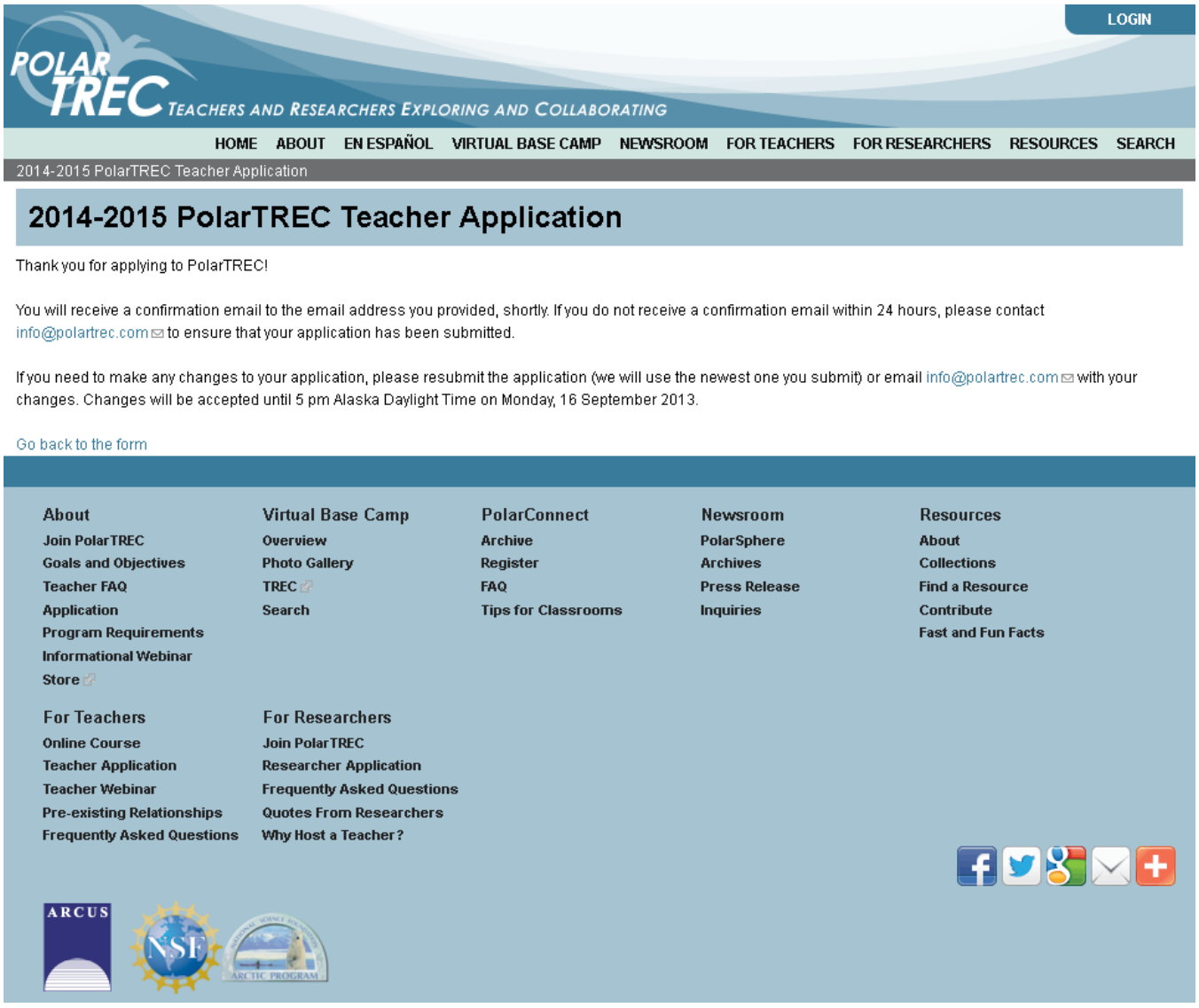
On September 2, 2013 I saw an advertisement posted by Janet Warburton (a project manager at the Arctic Research Consortium of the United States, ARCUS) on a discussion board for the National Science Teachers Association in the LinkedIn website. It read: "PolarTREC (Teachers and Researchers Exploring and Collaborating) is currently accepting applications from teachers for the eighth year of teacher research experiences." The announcement directed potential applicants to fill out the appropriate forms and to submit all documentation no later than September 16.

This advertisement immediately clicked with me. I had always felt an interest in earth science and PolarTREC would allow me to obtain hands-on experience through travel to the polar regions, while

also assisting with research and connecting with scientists. So there it was: a chance to fulfill—all within a single, coherent project—a number of professional interests that might not otherwise easily converge. In exchange for the expedition I would be responsible for developing elaborate plans to share my adventure not only with students at the classroom, but also with other teachers and the community.

At that time I was employed as an astronomy specialist teacher with G Works, Inc., an after-school science program supporting three schools for the Puerto Rico Department of Education, under a grant from the 21st Century Community Learning Centers federal program. I was also an astronomy lecturer at Saint John the Baptist Regional Major Seminary (i.e., *Seminario Mayor Regional San Juan Bautista*), a Catholic inter-diocesan seminary and extension center at Pontifical Catholic University of Puerto Rico.

In April 2014 I would also become an astronomy instructor at Metropolitan University–Cupey.



I started working with the application right away and spent long hours drafting and editing my responses to the essay questions so that they were clear and meaningful. In order to make my application more effective, I reviewed the *2013 Teacher and Researcher Informational Webinar*, a 90-minute presentation

that gave a complete overview of the PolarTREC program, its goals and objectives. I did a final proofreading of the text early on September 16 and went on to submit the application electronically via PolarTREC's website (http://www.polartrec.com/) about ten hours before the 5:00 pm deadline.

Thereafter, and in preparation for my potential selection, I spent days browsing the PolarTREC website and learning from past teacher expeditions. I passionately delved into the polar regions, conducting a comprehensive Internet search for Antarctic pictures that revamped my interest in the continent. I still have many of those images on my computer, some of which were featured in my early presentations from 2014, following my appointment to the program but before actually deploying to Antarctica.

Time went on quickly, and in November 7 an e-mail from Sarah Bartholow (also a project manager at ARCUS) popped into my computer, informing that I had entered the finalist pool of 45 candidates—out of a national pool of 190 applicants for the 2014–2015 season of PolarTREC—and further stating that I would be opportunely notified for an interview. Those 45 finalists would eventually be matched against a dozen researchers (for a dozen open positions), which meant my odds were now about one to four. "This is getting interesting," I thought, and from that moment the chain of events began to gain speed.

On November 18 my telephone rang. With great excitement Sarah explained that—taking into account my academic interests, as per my application—I had been preliminarily paired with Dr. James M. Madsen of the IceCube South Pole Neutrino Observatory. "So," I asked, "am I really being considered as a candidate to go on an expedition to the South Pole?" "Yes you are!" said Sarah. She was wanting to set up a three-way telephone interview from Fairbanks, Alaska, together with me in Puerto Rico, and Jim in Wisconsin. Sarah suggested November 25 at 3:00 pm, which fit well with my schedule.

The 70-minute interview covered several important topics including academic interests and teaching style, along with future plans for using the PolarTREC experience in and out of the classroom. I was specifically asked about my handling of unfamiliar situations and unexpected circumstances, something for which I would be tested in the field a year later, when I experienced an unplanned extension on the Antarctic coast due to poor weather conditions. Although I was nervous for the first few instants, both Sarah and Jim conveyed a great deal of friendliness that allowed me to relax in no time.

I truly felt the interview was successful, and only two days later, on Thanksgiving eve (November 27, 2013) I got the good news. It came totally as a surprise, as I had been anticipating a two-week wait and did not expect a call that early. Around 7:30 pm Sarah left me speechless, when she called to inform that Jim had selected me to work with his team at the IceCube telescope in the South Pole. With its carefully thought timing, this telephone call made for my best ever Thanksgiving weekend.

Being that astronomy is my main teaching interest I was very glad to be paired with Jim and his team, as from the beginning my belief was that the IceCube Neutrino Observatory would be the optimal PolarTREC match for me. Jim Madsen, my mentor, was then—and remains, as of this writing—a professor and chair at the Physics Department in the University of Wisconsin–River Falls, as well as an associate director of IceCube, responsible for the collaboration's education and outreach efforts.

Having being appointed by PolarTREC as a field science assistant with the observatory meant that I won the opportunity to spend three weeks assisting with the research, and in addition get to experience Antarctica first-hand. As will be seen further in this book, my work with IceCube at the South Pole aroused much public interest, sparking a string of media appearances and allowing me to lecture before live audiences in every age group and in all sorts of venues, both academic and non-academic.

2. Antarctica and the South Pole

Before proceeding any further, I would like to tackle a few topics about Antarctica which will provide a minimum of background information that is relevant to a proper understanding of my journey.

Physical geography

In contrast to the Arctic—a sea that is partly covered by a thin layer of ice—Antarctica is a true continent, a landmass that is blanketed almost completely by a thick sheet of ice. Antarctica contains the South Pole but the Antarctic Peninsula extends as far north as latitude 63½°, which translates into three degrees above the Antarctic Circle and almost 3,000 kilometers away from the Pole. The continent covers an area of 14 million square kilometers, which is almost twice the size of the contiguous United States (or Australia). Approximately 98% of the land remains permanently under ice, leaving about 2% that is mostly bare rock found in sparse mountainous outcrops or isolated coastal areas.

With an average elevation of 2,300 meters above sea level, Antarctica is the highest continent on Earth. The ice sheet that covers most of the surface is extremely thick, averaging about 1,700 meters and reaching a maximum of 4,700 meters near the so-called *pole of cold* at the Russian Vostok station in the Antarctic Plateau. Hidden beneath the ice are mountain ranges with tall peaks and deep canyons, a network of subglacial lakes (the largest being Lake Vostok, found right below its Russian namesake), and even subglacial volcanoes at the base of the ice sheet (one of which is believed to have undergone a powerful eruption around 2,200 years ago). The continent is also the driest and windiest on the planet.

Antarctica is surrounded by a belt of sea ice that remains mostly solid throughout the year, but some areas transition into open water at the height of the austral summer. McMurdo Sound—an inlet of the Ross Sea that reaches as far south as the 78th parallel and is usually ice-free around February—is one of the southernmost navigable stretches of ocean and home to the southernmost sea port in the world. The Antarctic coastline additionally encompasses over 40 *ice shelves*, which are huge floating platforms of ice that grow out from the inland glaciers into the neighboring seawater. The Ross Ice Shelf and the Filchner-Ronne Ice Shelf—the two largest shelves—are each over 400,000 square kilometers in area and similar in size to the state of California (or about 50 times the island of Puerto Rico).

Seasons of Antarctica

The South Pole experiences six continuous months of daylight from September to March, during which the sun moves sideways around the sky in a counterclockwise fashion. Once a year, at the Southern Solstice around December 21, the sun reaches its maximum visibility at an elevation of 23½° above the horizon, with the actual height rising gradually every day from 0° to 23½° between sunrise around September 22 and the solstice, and then decreasing between the solstice and sunset around March 20. Away from the Pole the periods of unbroken light and darkness get progressively shorter towards the Antarctic Circle at a latitude of 66½°, where the regular cycle of day and night is reestablished.

Considering that the seasons are reversed in the northern and southern hemispheres, the austral summer —when most work is done at the Pole, and in Antarctica generally—corresponds to the North American winter and vice versa. The Earth goes through seasons because its rotation axis is not in exact alignment with its orbit around the sun, as the equator is inclined by 23½° with respect to the ecliptic.

Antarctica's high magnetic latitude makes it a prime location to view the aurora, which can be enjoyed during the long polar night throughout the austral autumn and winter. The continent's extreme atmospheric conditions also allow for beautiful phenomena involving high-altitude ice crystals, such as *solar halos* and *polar stratospheric clouds* (otherwise known as nacreous clouds).

Flora and fauna

Vegetation is very sparse and found almost exclusively within the scant 2% of land that remains mostly free of ice. Antarctica only supports lichens, mosses, fungi and a handful of plants, as the climate is too cold for trees to grow. Two flowering species inhabit the continent, namely the Antarctic hair grass (*Deschampsia antarctica*) and the Antarctic pearlwort (*Colobanthus quitensis*), both encountered along the western edge of the Antarctic Peninsula and in surrounding islands, as far south as latitude 68°. But plants have also been identified around *fumaroles*—openings in the Earth's crust that form around volcanoes and where clouds of hot steam produce a warmer environment with occasional liquid water.

Antarctica has no land mammals, although the Weddell seal (*Leptonychotes weddellii*) is a common sight along the shore, all the way down to Ross Island at a latitude of 78° below the equator. At least four bird species are established residents of the Antarctic coast, including the south polar skua (*Stercorarius maccormicki*), the snow petrel (*Pagodroma nivea*), the Adélie penguin (*Pygoscelis adeliae*) and the emperor penguin (*Aptenodytes forsteri*). These birds rarely travel far into the interior, although off-course skuas and petrels have occasionally been seen overflying the South Pole. A number of terrestrial invertebrates, such as arthropods, nematodes and tardigrades have been identified, too.

Life is plentiful in the surrounding seas. As the colder and denser water rises to the surface, a layer loaded in nutrients results. The plankton that forms the first link of the food chain encourages an abundant marine fauna that includes a variety of whales, crustaceans such as the ever-present Antarctic krill (*Euphausia superba*), and approximately 100 species of fish like the white-blooded mackerel icefish (*Champsocephalus gunnari*) and the large Antarctic toothfish (*Dissostichus mawsoni*).

History of exploration

Antarctica was first sighted by sea in 1820 over the course of three independent maritime expeditions led by Fabian Gottlieb von Bellingshausen (from Russia), Edward Bransfield (from Great Britain), and Nathaniel Palmer (from the United States). The first landing probably occurred in 1821 although this has been heavily contested, and in any case the early explorers refrained from venturing far inland. During his search for the magnetic South Pole the Englishman James Clark Ross reached the 78th south parallel in 1841, discovering the Ross Sea, the Ross Ice Shelf, and Ross Island—a 2,460-square-kilometer volcanic formation off the coast of Antarctica and partly embedded in the ice shelf. The volcanoes Erebus and Terror, in Ross Island, today bear the name of his two expedition vessels.

The *Heroic Age of Antarctic Exploration*, lasting from 1897 until 1922, saw the launch of 16 major expeditions, some of which resulted in death or serious injury to its participants. The South Pole was first reached in December 1911 by Roald Amundsen (from Norway) and in January 1912 by Robert Falcon Scott (from Great Britain). With the end of the Heroic Age the continent entered a period of decreased scrutiny until a number of permanent, year-round facilities—including McMurdo Station and the Amundsen–Scott South Pole Station—were established in the 1950's during a surge of exploration activity that became a prelude to the momentous *1957–1958 International Geophysical Year* (IGY). Since then the continent has seen consistent and increasing human presence.

The Antarctic Treaty

Asides from temporary visitors Antarctica remains uninhabited. There are no permanent residents and no country owns the continent. Seven nations had already made territorial claims before June 23, 1961, as of the coming into force of the Antarctic Treaty, but the agreement explicitly suspended all future territorial claims and has de facto inhibited an enforcement of the existing claims.

The *Antarctic Treaty*—which was signed on December 1, 1959 by the 12 countries that were active in the continent during the IGY—agreed to set aside Antarctica as an international reserve for the pursuit of science. It emphatically states that the continent must be used exclusively for peaceful purposes, prohibiting "any measures of a military nature, such as the establishment of military bases and fortifications, the carrying out of military maneuvers, as well as the testing of any type of weapons". *Antarctica Day*, an annual event started in 2010 to promote global awareness of both the continent and the treaty, has since been observed worldwide the 1st of December every year.

The Antarctic Treaty applies to everything below latitude 60° south, which means that its jurisdiction extends well beyond the Antarctica mainland to include the surrounding seas, islands, and ice shelves. During its 55-year history the treaty has proven remarkably effective in promoting peace and scientific cooperation between nations, leading to its recognition as one of the most successful international agreements ever. Forty-one other countries have since acceded, and in recent years the name *Antarctic Treaty System*—meaning the original treaty plus related agreements—has come into general use.

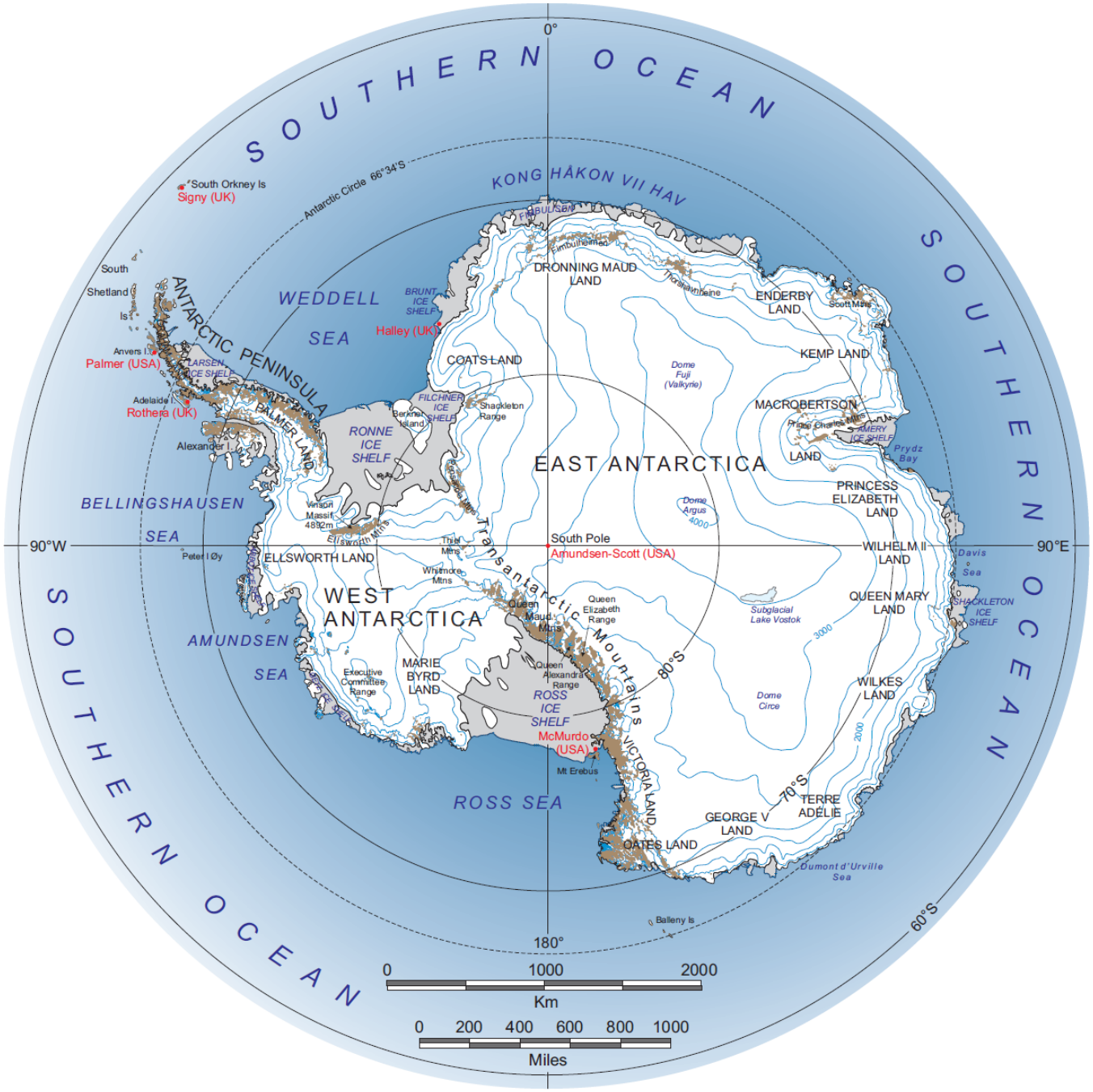
Travel and logistics

Contrary to some people's understanding, Antarctica is potentially open to anyone and not only to scientists and technicians. The Antarctic Treaty recognizes tourism as a legitimate activity, subject to regulations. With an average of 35,000 people visiting the continent every year, the environmental effect of tourism is being monitored to minimize the damage, especially along the Antarctic Peninsula where most visitors arrive via cruise ships. Private expeditions to the interior of the continent are now becoming popular, but they are not allowed to request governmental assistance (unless in an emergency) and their participants need to be extensively trained and thoroughly self sufficient.

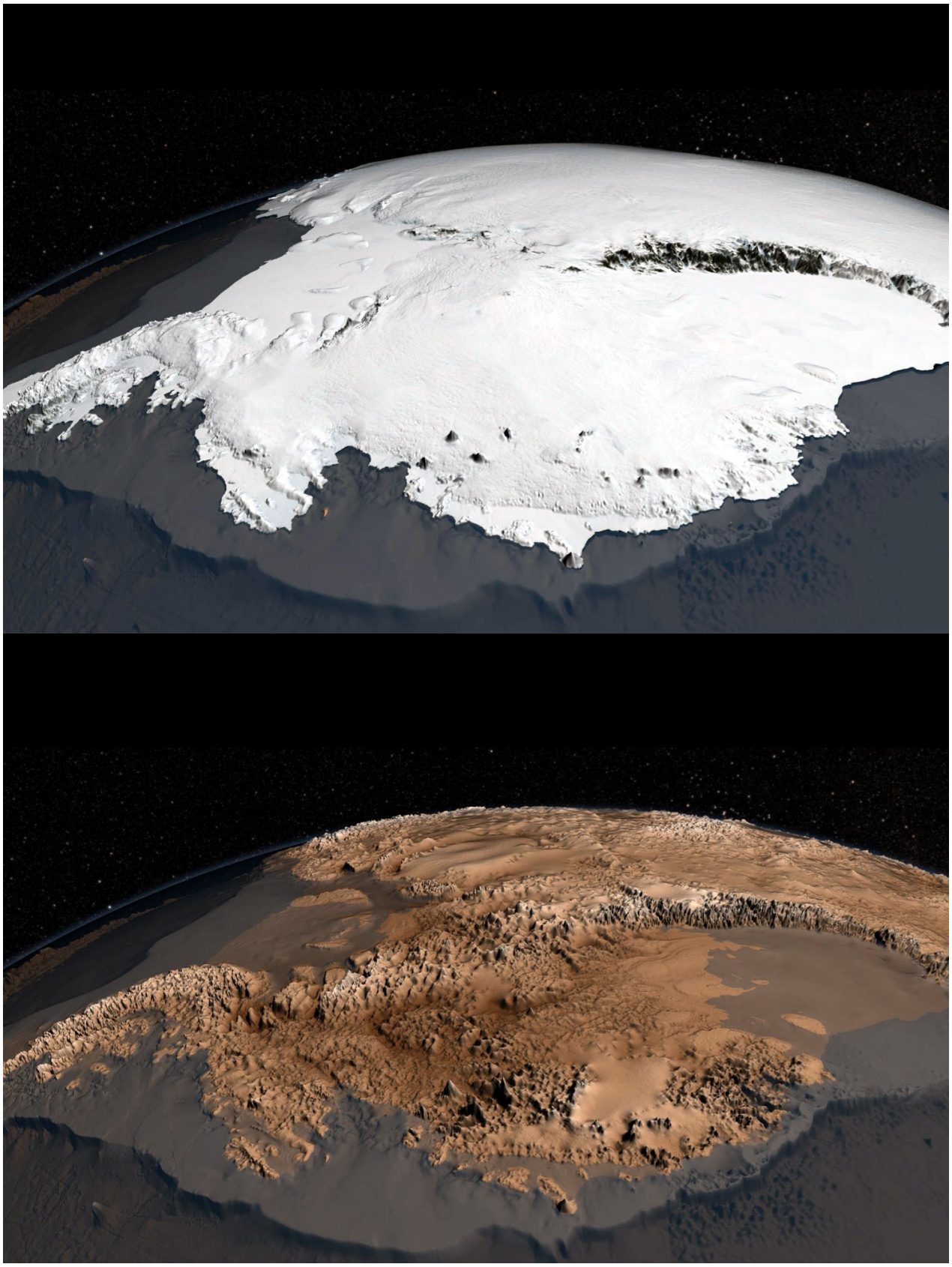
Countries with a scientific interest in Antarctica have established their own national Antarctic programs which at present maintain approximately 45 permanent stations where research is conducted. For example, the *United States Antarctic Program* (USAP), a governmental organization managed and funded by the National Science Foundation, operates three year-round stations around the continent (i.e., Palmer, McMurdo and Amundsen–Scott) plus a number of smaller field camps that are generally active during the austral summer. The USAP additionally operates two icebreaking research ships.

There are two small civilian settlements in the Antarctic Peninsula, one each from Chile and Argentina, but these exist only to provide accommodation and school services to families of deployed personnel.

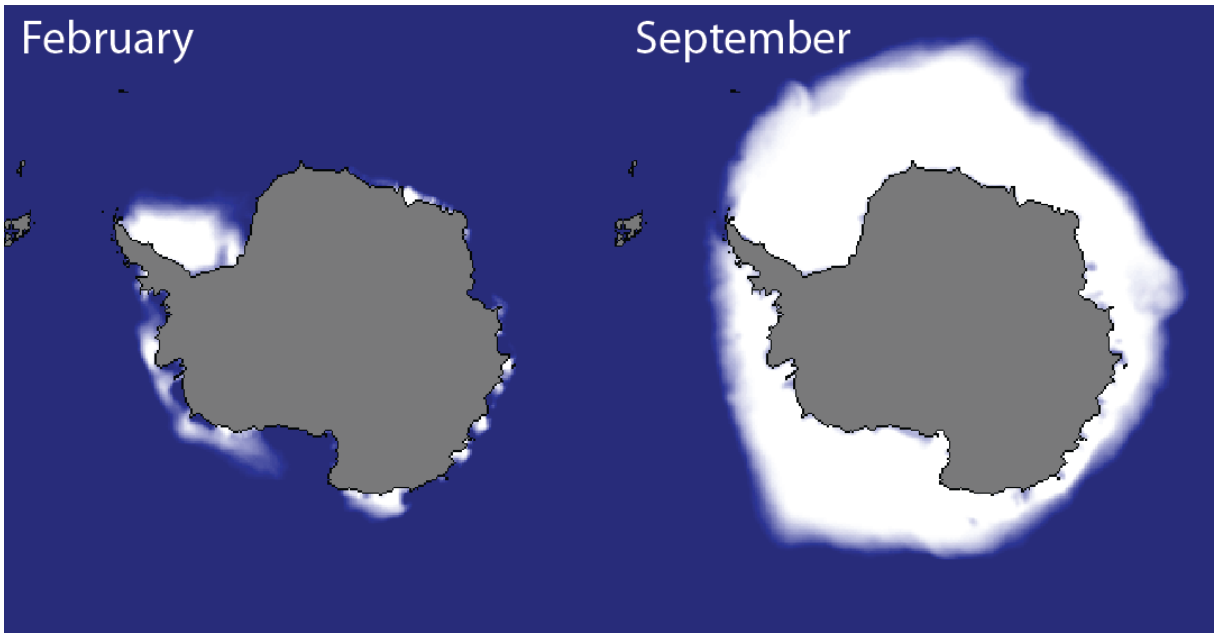
Living and working in Antarctica—a remote location with limited medical facilities—demands a high level of physical fitness plus clearance of pre-existing health conditions. For this reason, individuals considered for deployment under the support of a national program are routinely requested to pass stringent examinations which include medical and dental consultations, as well as X-ray imaging and laboratory tests. The USAP, for instance, uses the *medical prequalification process* (also known as PQ) which asks for requirements personalized for each potential participant.



Geophysical map of Antarctica, with elevation contours shown at 500-meter intervals. The map shows the continental ice sheet (white), ice-free areas (brown) and ice shelves (gray). The three permanent stations from the United States are also shown, along with research facilities from the United Kingdom. Credit: British Antarctic Survey.



Antarctica with and without ice, from Bedmap2, a tool developed by the British Antarctic Survey. Credit: NASA / Goddard Space Flight Center.



Minimum and maximum extent of sea ice surrounding Antarctica, based on data from 1981 to 2010. Credit: National Snow and Ice Data Center, University of Colorado.

An icebreaker ship from the United States Coast Guard—the Polar Star—at the harbor in McMurdo. January 23, 2015. Credit: Hans Niederhausen, IceCube / NSF.

The Dry Valleys near McMurdo are a prominent area of bare ground. This is Wright Valley as seen in 2005 from Bull Pass. Credit: David Saul, Wikimedia Commons / public domain.

About 98% of the continent is covered by ice. This is a typical view of the Antarctic Plateau. January 20, 2015 — Near the Amundsen–Scott South Pole Station.

Nacreous clouds during twilight near McMurdo Station, photographed in August 25, 2009. Credit: Alan R. Light, Flickr CC–BY–2.0, with modifications by Armando Caussade.

Nacreous clouds over the NASA radome in McMurdo, photographed in August 23, 2009. Credit: Alan R. Light, Flickr CC–BY–2.0, with modifications by Armando Caussade.

South polar skuas (Stercorarius maccormicki) photographed in flight.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

Weddell seals (Leptonychotes weddellii) lying in the ice floor.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

Adélie penguins (Pygoscelis adeliae) near the Antarctica coast.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

Adélie penguins (Pygoscelis adeliae) near the Antarctica coast.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

A 4-day crescent moon viewed near the Antarctic Peninsula on December 6, 2013.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

A sunset near the Antarctic coast photographed on December 3, 2013.
Credit: Reeve Jolliffe, Flickr CC–BY–NC–ND–2.0.

3. The WIPAC interview

On December 3, 2013—a week after my appointment by PolarTREC—I got an e-mail from Laurel Norris requesting a written interview. Laurel, who was then a communications manager at the Wisconsin IceCube Particle Astrophysics Center (WIPAC), wanted to write a short news item for the WIPAC website about my selection as the new IceCube teacher for the 2014–2015 Antarctic season. She worked with my mentor, Jim Madsen, who is in charge of education and outreach for IceCube.

As requested I promptly submitted a batch of pictures, followed in December 10 by a detailed draft that Jim read with much interest and commented upon, exclaiming "Wow!" The draft provided Laurel with a wealth of useful material, prompting her to compose a longer piece that would opportunely be published on the website a couple of months later. The 750-word interview, which became the first public announcement of my involvement with PolarTREC and IceCube, appears below.

PUERTO RICAN STEM EDUCATOR ARMANDO CAUSSADE SELECTED AS 2014 ICECUBE POLARTREC TEACHER

By Laurel Norris
March 31, 2014 — 10:00 am

Wisconsin IceCube Particle Astrophysics Center (WIPAC)
http://wipac.wisc.edu/news/article/puerto-rican-stem-educator-armando-caussade-selected-2014-icecube-polartrec-teacher

Since 2009, teachers have gained research experience at the South Pole through a partnership between WIPAC and PolarTREC, a National Science Foundation program that pairs scientists with teachers to provide field deployments to polar regions.

We are excited to announce that Armando Caussade, a STEM educator from Puerto Rico, will travel to the South Pole, Antarctica, during the 2014–2015 polar season to support maintenance work on the IceCube Neutrino Observatory. An experienced communicator inside and outside the classroom, Caussade is passionate about science and, in particular, astronomy.

"Astronomy is a very open-ended discipline that links easily to other branches of science such as physics, chemistry, geoscience and even biology," explains Caussade, "and since many people display a natural curiosity and inclination to astronomy, it is an easy way to approach other sciences."

Caussade is a STEM educator at G Works' Eco-STEAM project in Juncos, Puerto Rico—a partnership with the Puerto Rico Department of Education—and an astronomy lecturer at the Pontifical Catholic University of Puerto Rico / St. John the Baptist Regional Major Seminary in San Juan. His work includes everything from designing course content to leading workshops for students, teachers, and community members.

His start as an astronomy educator was accidental. "My first astronomy presentation was given on a

Saturday afternoon in early 1985, at my school's annual Open House event. The talk was not scheduled —I just happened to be at the library and they simply requested it, on the fly. The library staff knew I had been following updates on Halley's upcoming 1986 apparition," says Caussade. By 1994, he was regularly giving lectures, publishing articles, and even appearing on TV.

Armando Caussade has experience as a STEM educator with a wide variety of audiences: high school and college students, life-long learners, and public audiences. April 23, 2013 — Guaynabo, Puerto Rico. Credit: Genoveva Negrón, Atlantic University College.

In September 2013, Caussade saw an advertisement for PolarTREC teacher experiences and applied for the opportunity. Given his astronomy knowledge, he was paired with Dr. James Madsen, a physics professor at UW–River Falls and associate director for education and outreach at UW–Madison's Wisconsin IceCube Particle Astrophysics Center, or WIPAC.

Madsen, a longtime IceCube collaborator, helps arrange educational opportunities for high school students, teachers, and public audiences. He has collaborated with PolarTREC in the past, supporting teacher visits by Casey O'Hara in 2009, Katherine Shirey in 2010, and Liz Ratliff in 2012.

After interviewing a number of strong applicants, Caussade was selected to work with the IceCube team at the South Pole. Madsen speaks highly of Caussade, "His passion for astronomy was apparent from our first conversations. He has a wealth of experience with a wide range of audiences—high school students, college students, and the public."

In addition to his current work in STEM education, Caussade is an advisor to and former president of the *Puerto Rico Astronomy Society* and was a NASA Jet Propulsion Laboratory Solar System Ambassador from 2004 to 2006.

Participating in PolarTREC and working with IceCube will help Caussade satisfy a need he sees for polar science and geoscience education in Puerto Rico. "The idea is to bring not only the facts of polar science, but also the story of my South Pole expedition—a unique, personal experience with an authentic, original voice that will be both captivating and memorable," he says.

"Interest in STEM learning is very evident—especially in the 12- to 18-year age group—but the opportunities are limited," he explains. "Puerto Rico is a Hispanic territory, and historically is underserved and underrepresented in STEM disciplines."

As part of PolarTREC teacher training, Caussade will learn about various polar research projects, even traveling to Alaska where the Arctic Research Consortium of the United States (ARCUS, http://www.arcus.org/) is located. ARCUS manages the PolarTREC program, which is funded by the National Science Foundation Division of Polar Programs.

Caussade sees the experience as a way to explore his own interests in science, improve his knowledge base, and serve as a role model to encourage Puerto Rican educators to engage in "real, meaningful research projects" and connect directly with scientists.

"There is certainly hope for science and technology education in Puerto Rico, and I humbly wish for my IceCube research experience to serve as a catalyst for change and as an inspiration to the new generation of Puerto Rican scientists," says Caussade.

As part of the PolarTREC experience, Armando Caussade is blogging regularly on the PolarTREC IceCube Neutrino Observatory 2014 expedition page (http://www.polartrec.com/expeditions/ice-cube-neutrino-observatory-2014/journals/2014-02-12). His posts are available in English and Spanish.

4. PolarTREC orientation week

PolarTREC was launched during the International Polar Year in 2007 to provide educators with field expeditions in the Arctic and in Antarctica. To this end, participants are paired with a variety of research projects according to each educator's skills and interests. PolarTREC was preceded by TREC (Teachers and Researchers Exploring and Collaborating), a program focusing on the Arctic that ran from 2004 to 2006, which was in turn preceded by TEA (Teachers Experiencing the Arctic), from 1997 to 2004.

By Christmas 2013 all selections for the 2014–2015 field season of PolarTREC had been finalized, and each successful candidate was issued an acceptance packet containing forms to sign and mail back, as well as directions for a questionnaire to gauge the level of experience with computers. As instructed, I sent in a short biography along with a headshot image. A 90-minute *Meet and Greet Webinar*—a live Internet presentation where participant teachers are introduced to PolarTREC—was held on January 14.

On February 7, 2014 I traveled to Fairbanks, Alaska, in order to attend the required *PolarTREC Orientation*. This week-long event provides a venue for newly-selected participants to get to know each other, to become acquainted with computers, cameras and communication technology, and to adapt to the cold weather of central Alaska—a subarctic climate with typical winter temperatures ranging from −12 °C to −32 °C. But the essential goal is to learn how to document an expedition using PolarTREC's blog-style Internet platform, and in establishing a habit of posting regular updates.

I flew for 20 hours with the excitement of knowing that I would meet face-to-face with the people that were making my Antarctic journey possible, and who so far I knew only via telephone and e-mail. At my arrival the thermometer read −18 °C, the coldest to that point in my life and also the warmest that I would see throughout the week, with an exception in the hours before my departure on February 14. Fairbanks was then experiencing temperatures lower than the average for February, with readings between −22 °C and −32 °C. In fact, this exposure to the rigors of cold weather, ahead of time, provided practical knowledge that proved crucial for me 11 months later when I finally traveled to Antarctica.

By midnight I had settled in the Westmark Hotel, enjoying a much needed warm shower. The next day I was greeted by Janet Warburton and Sarah Bartholow with the best ever hug and smile, making me feel incredibly welcome. I ran into them while peeking into the Yukon meeting room, which was being prepared to host the event beginning early the following day. I also met with fellow participants—from both the current and past PolarTREC seasons—who all shared the same interests and a passion for science. There was energy in the air as we discussed past expeditions as well as the upcoming ones.

As the program started on February 9 I was acknowledged for flying from as far away as the Caribbean. "This year, Armando gets our farthest traveler award!" Janet announced, with great emotion. Early during orientation I was assigned an Apple MacBook portable computer that would later go with me all the way to the South Pole. PolarTREC also assigned me a Casio Exilim EX-G1 digital camera with a 12-megapixel sensor. As a backup I had my old and trusty Kodak EasyShare CX7300, a 3-megapixel camera that in spite of its lesser resolution is still capable of taking amazing photographs. After all, the CX7300 ended up doing 40% of my imaging in Alaska, as well as 8% of my Antarctic pictures.

The agenda provided for a number of field excursions which included the following: (1) a two-hour stop at the ARCUS headquarters where we were treated to a delicious buffet lunch, on February 11; (2) a visit

to the Museum of the North at the University of Alaska–Fairbanks, followed by a presentation on the hibernation of Arctic ground squirrels by biologist Jeanette Moore, also on February 11; (3) a visit to the warehouse in CH2M Hill Polar Services—the logistics contractor for United States operations in the Arctic—to try on clothing for safe work in polar environments, on February 12; and (4) a stopover at the Alaska Oil Pipeline, followed by a presentation and a tour of the permafrost tunnel at the Cold Regions Research and Engineering Laboratory in Fort Wainwright Army Post, on February 13.

Of great benefit to me personally was connecting with PolarTREC alumni such as John Wood, a teacher from California who worked for six years supporting logistics in Antarctica. His passion for all things Antarctic was evident, which led me to listen and absorb everything he explained. His vivid description of Observation Hill in McMurdo Station was a highlight that I still recall. I additionally spoke with Susan Steiner, Lisa Seff, and notably Michelle Brown, who kindly shared the experience of her own South Pole deployment in December 2011 and offered many useful suggestions.

The orientation was an excellent program and I enjoyed every minute of it. Indeed, everything in Alaska exceeded my expectations, and the only disillusion was happening to visit during an episode of reduced solar activity—ironically, at the peak of Solar Cycle 24—and thus losing a golden opportunity to watch the aurora that is so frequently seen in Fairbanks, as the city lies right below the so-called *aurora oval*.

A part of the 2014–2015 PolarTREC cohort during an outing at the Alaska Oil Pipeline. Armando is in the middle, while polar veteran John Wood is at left wearing an orange jacket. February 13, 2014 — Near Fairbanks, Alaska. Credit: B. Zebulon Polly, ARCUS.

PolarTREC orientation with staff, participant teachers and alumni at the Westmark Hotel. February 10, 2014 at 12:55 pm — Fairbanks, Alaska.

Susan Steiner, Armando Caussade and Dominique Richardson at the ARCUS headquarters. February 11, 2014 at 1:28 am — Fairbanks, Alaska.

Armando by the sidewalk next to the Westmark Hotel. Temperature was −23 °C.
February 9, 2014 at 12:52 pm — Fairbanks, Alaska.

Armando Caussade and Lisa Seff at the shore of a small frozen lake.
February 11, 2014 at 5:19 pm — Fairbanks, Alaska.

Trying on a pair of extreme weather boots at the warehouse in CH2M Hill Polar Services. February 12, 2014 at 4:06 pm — Fairbanks, Alaska.

About to enter the permafrost tunnel at the Cold Regions Research and Engineering Laboratory. February 13, 2014 at 1:48 pm — Fort Wainwright Army post, near Fairbanks, Alaska.

The 2014–2015 PolarTREC cohort at the Museum of the North.
Janet and Sarah are both in the front row, near the middle.
February 11, 2014 — Fairbanks, Alaska. Credit: B. Zebulon Polly, ARCUS.

Armando next to the welcome sign at the University of Alaska–Fairbanks.
February 11, 2014 at 2:12 pm — Fairbanks, Alaska.

Sub-freezing temperatures prevail in central Alaska from October to April each year.
February 9, 2014 at 12:41 pm — Fairbanks, Alaska.

A beautiful winter day with clear, blue skies. A first quarter moon is plainly visible.
February 8, 2014 at 2:30 pm — Fairbanks, Alaska.

Morning ice fog as seen from Armando's window at the Westmark Hotel.
February 9, 2014 at 9:23 am — Fairbanks, Alaska.

A colorful sunset as seen from the Westmark Hotel. The Alaska Range is in the background.
February 10, 2014 at 5:06 pm — Fairbanks, Alaska.

5. Connecting with the IceCube Neutrino Observatory

After my return from Alaska I started planning a media tour, which was launched on April 1, 2014 and resulted in two television interviews and 47 press clippings from both local and overseas sources. Having dealt with the media extensively in the past—and fully aware of how people in the island admire the accomplishments of fellow Puerto Ricans—I knew how strong the response would be, and indeed it was. The announcement spread quickly via PolarTREC's own channels and through social networking sites in the Internet, sparking hundreds of comments from individuals of every walk of life.

On April 26, 2014 Jim Madsen and I first met in person for dinner at *Vaca Brava* restaurant in Old San Juan. He had flown to the island with his wife Linda to rest for a few days, but also to connect with me and to assist the *Puerto Rico Astronomy Society* (PRAS)—an organization where I belong and which I led for six years—with its program of public outreach. We shared much time together over the following week, which provided opportunities to learn about IceCube, ask questions and clarify my concerns. Jim explained that, while he would not personally travel to the South Pole during the 2014–2015 season, he would be in charge of my work, mentorship and field deployment, and would inform me about relevant people with whom I should team up while in Antarctica.

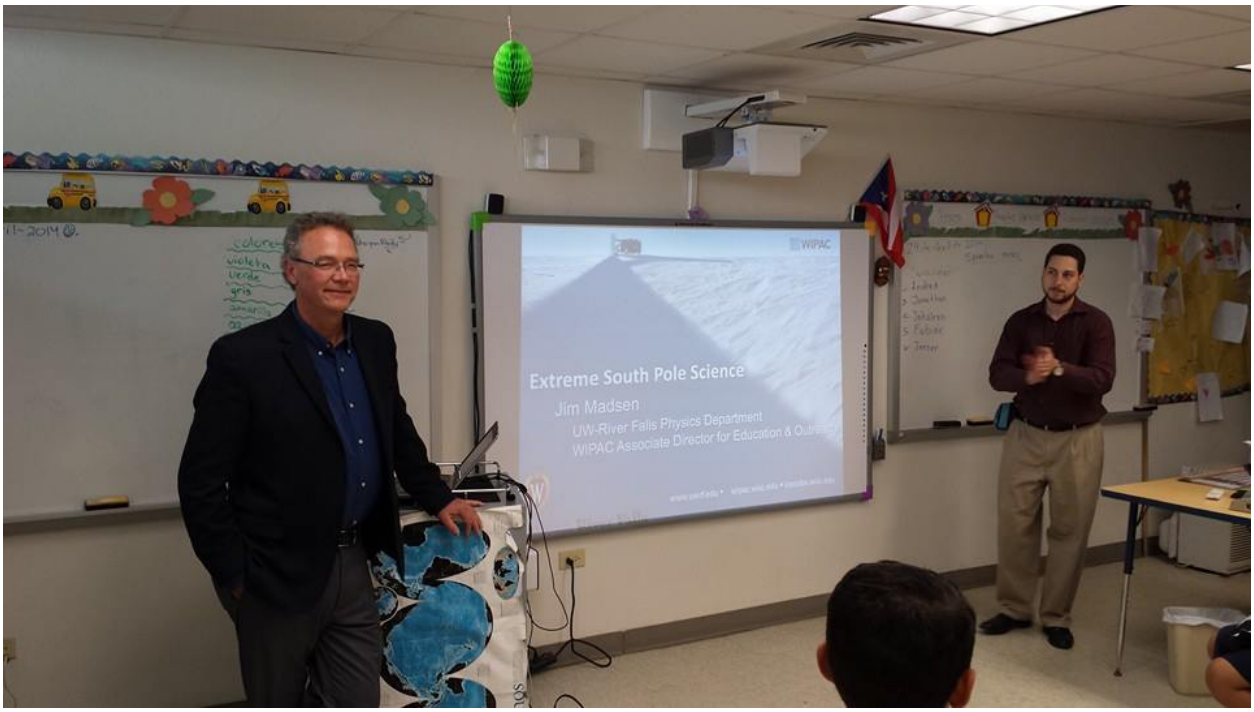
Starting April 29, Jim and I went on a lecture tour that yielded 12 talks in four days—a record amount for each of us—with the irony of driving over 600 kilometers on an island that only measures 160 kilometers across. We spoke before audiences of all kinds, reaching a total of 340 most of whom had never before heard about the IceCube Neutrino Observatory or even neutrinos. One salient highlight of the tour was Jim's presentation before PRAS on April 30, which featured an unforgettable screening of *Chasing the Ghost Particle*, a documentary film that he had recently co-directed. Another was our full-day visit to the Arecibo Observatory on May 2, where Jim was welcomed as a VIP and given a tour of the control room where the huge 305-meter radio dish is operated and monitored.

I additionally took Jim with me to class at all three academic venues where I taught, namely, Saint John the Baptist Regional Major Seminary (in San Juan), Metropolitan University–Cupey (also in San Juan), and G Works, Inc., where we visited two out of three secondary schools where I rotated during the year, i.e., Alfonso Díaz-Lebrón and Pedro Rivera-Molina (both in Juncos, Puerto Rico).

In the summer I traveled to meet with Jim at the University of Wisconsin–River Falls, and more specifically to work as an Upward Bound science instructor under his supervision. *Upward Bound* is a federal program that helps secondary-level students from low-income communities in their preparation for entrace into college, with participants attending summer classes at the university and living in the dormitories. Starting July 7, 2014 I taught 36 teenagers from Wisconsin and Minnesota, together with four other educators—three of whom were PolarTREC (or TEA) alumni, plus a pre-service teacher—using a science curriculum developed around topics related to research by IceCube.

On July 17 Jim and I drove four hours from River Falls to Madison, and in July 18 we attended *Astrophysics in the Classroom: A Workshop for High School Teachers*, a one-day event hosted by the Wisconsin IceCube Particle Astrophysics Center (WIPAC). While there we also met with IceCube staff to fine-tune a number of details concerning my Antarctic deployment. Particularly beneficial was my meeting with Dr. Michael A. DuVernois, a senior scientist at the University of Wisconsin–Madison and a key person in the project who would eventually be assigned as my direct field supervisor.

Greg García, Armando Caussade and Jim Madsen at the Puerto Rico Astronomy Society. April 30, 2014 at 7:58 pm — Bayamón, Puerto Rico. Credit: Armando Caussade, PRAS.



Jim Madsen lecturing at Pedro Rivera-Molina school where Armando taught.
May 1, 2014 — Juncos, Puerto Rico. Credit: Miguel Piñero, Puerto Rico Department of Education.

Upward Bound teachers and students at the University of Wisconsin–River Falls.
July 10, 2014 — River Falls, Wisconsin. Credit: Katherine Shirey.

Workshop at the Wisconsin IceCube Particle Astrophysics Center (WIPAC).
July 18, 2014 at 10:20 am — Madison, Wisconsin.

Megan Madsen, Armando Caussade and Jim Madsen at WIPAC.
July 18, 2014 at 6:43 pm — Madison, Wisconsin.

Walking around in Madison, with the Wisconsin State Capitol in the background.
July 19, 2014 at 11:16 am — Madison, Wisconsin.

Armando with his astronomy students at Metropolitan University–Cupey.
May 20, 2014 — San Juan, Puerto Rico. Credit: María A. Juncos, Metropolitan University.

Teaching an astronomy class at Metropolitan University–Cupey.
September 30, 2014 — San Juan, Puerto Rico. Credit: Armando Caussade, PRAS.

6. Preparations for Antarctica and arrival in New Zealand

A journey to Antarctica requires a myriad of preparations, particularly when traveling under the auspices of a national Antarctic program such as the United States Antarctic Program (USAP).

On May 30, 2014 I joined a conference call with Sarah Bartholow of PolarTREC and Elaine Hood, a communications specialist at the Antarctic Support Contract (ASC) in Centennial, Colorado, a division of Lockheed Martin that provides logistical support for United States operations in Antarctica. Elaine gave a webcast presentation that explained topics such as travel logistics, life at the South Pole, polar clothing and many etceteras, but the emphasis was on getting started with the *medical prequalification process* (PQ), as flights are booked only after successful review and approval of the PQ.

Elaine requested a PQ packet on my behalf, which contained 14 pages of medical forms that took two entire days to fill out, one at Hospital Auxilio Mutuo plus another at Concilio de Salud Integral de Loíza.

Other arrangements included completing—and mailing back to Elaine—a questionnaire with personal and emergency contact information, along with desired travel dates and a form specifying clothing sizes for the polar gear that I would be assigned at my arrival in New Zealand. I was also instructed to complete an information security training and to obtain insurance for emergency medical evacuation.

Time flew and before I knew it was December. Airline tickets were issued with a departure date of January 2, and I spent the whole Christmas season keeping abreast of new developments and double-checking everything. Meanwhile, Greg García, then the president of the *Puerto Rico Astronomy Society* wrote a piece about me in his December column at *El Observador*, and an interview I gave yielded 51 media hits, including a story in the December 31 edition of *El Nuevo Día*, the island's main periodical.

At 11:30 am on January 2, 2015 I arrived at Luis Muñoz Marín International Airport near San Juan, Puerto Rico, where two hours later I boarded a flight to Miami, followed by another to Los Angeles. I then flew to Sydney, Australia (a 15-hour flight), and later on to Christchurch, New Zealand, where I landed after midnight on January 5 [see flight route on page 53]. Because I crossed the International Date Line in the Pacific early on January 3—losing one complete day—January 3 did not exist for me.

I went through immigration carrying my visa letter from ASC, which stated my status as an Antarctic traveler and gave me the privilege of receiving a 12-month visa instead of the usual 3-month visitor visa.

At 9:30 am on January 5 I arrived at the USAP Clothing Distribution Center in Christchurch, where I concentrated on three main things: (1) attending orientation; (2) having my portable computer checked before connecting to the USAP network; and most importantly, (3) receiving and trying on my red parka, boots, gloves and additional cold weather gear. I also met two new friends and members of IceCube, James D. Casey and Hans Niederhausen, who would likewise fly to Antarctica the following day.

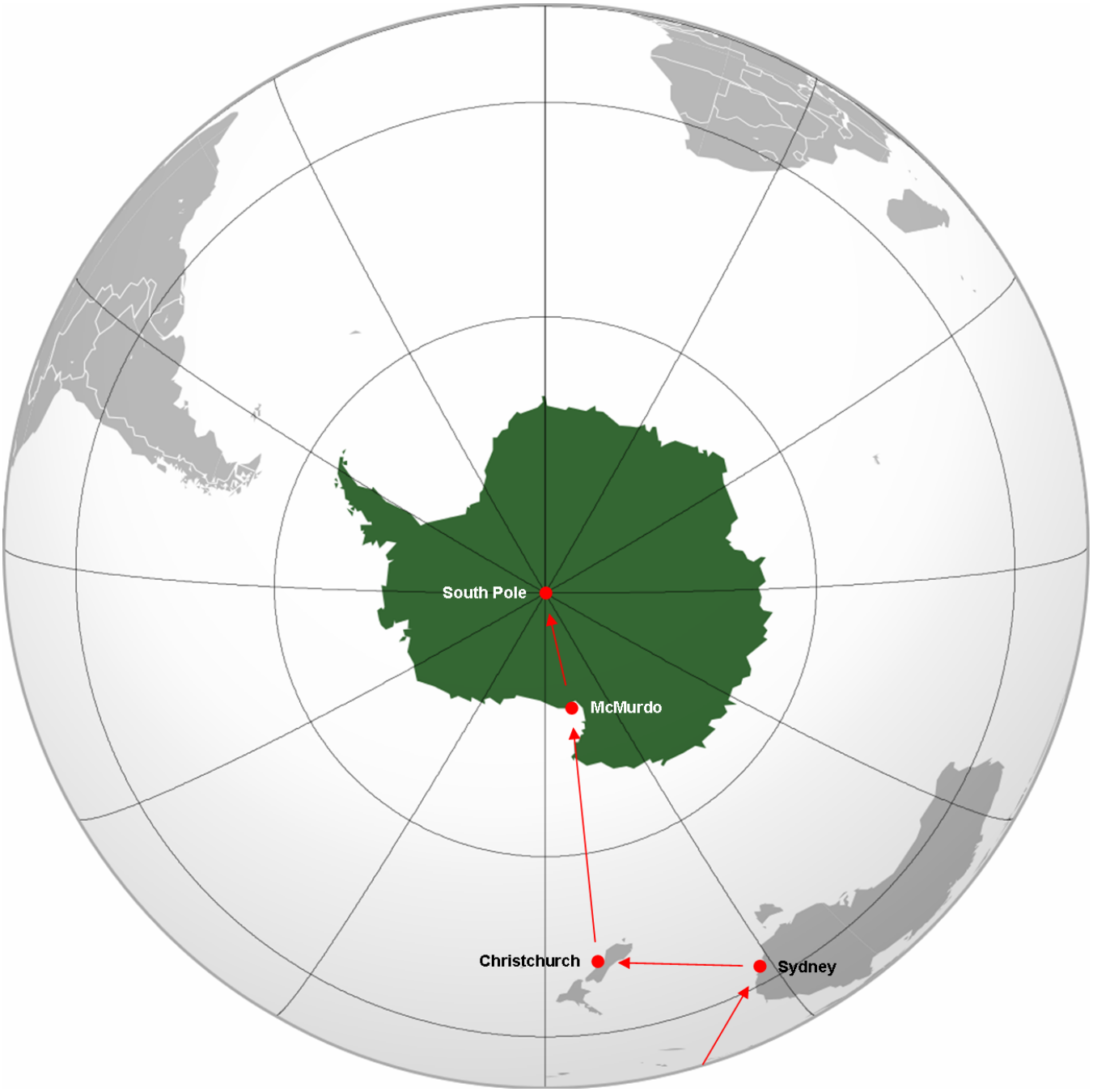
Early on January 6 I gathered with 32 other participants to hear a final briefing on the do's and don'ts of Antarctica. We were reminded that littering, removing soil or rocks, or disturbing wildlife, are violations of the Antarctic Treaty that may carry severe penalties. And then at 8:25 am, after proceeding through the terminal and being transported out to the runway, I was allowed to board the LC-130 Hercules that would take me on my much awaited journey to the seventh continent.


VICTORIA MANSIONS

Walking around in Christchurch near the Victoria Clock Tower.
January 5, 2015 at 5:42 pm — Christchurch, New Zealand.

The LC-130 Hercules, a ski-equipped aircraft.
Credit: Charles Kaminski, NSF (USAP Photo Library).

Inside the LC-130, en route from New Zealand to Antarctica.
January 6, 2015 at 1:34 pm.



Armando's flight route is shown in this orthographic map of Antarctica and its surroundings. Credit: Heraldry, Wikimedia Commons GNU–1.2, with modifications by Armando Caussade.

7. Arrival and initial stay in McMurdo

On January 6, 2015 I arrived in Antarctica—or, in Antarctic parlance, set foot "in the ice". As the LC-130 landed on its skis over the Ross Ice Shelf near the Antarctic coast, I felt elated. Not only had I made it to the seventh continent—where few people ever get to set their feet—but I was also well on the way to my final destination: the IceCube South Pole Neutrino Observatory, the biggest science project ever attempted in Antarctica and the kind of experiment that many would only dream of working with. The airplane gently came to a stop, and a few minutes later I was finally *in the ice!* Everything looked white, from the zenith to the nadir, and all the way around. No other hue was in sight, as heavy, pearly clouds covered the sky above, and a 50-meter-deep blanket of ice completely hid the sea below.

With a population around 1,200 every summer, McMurdo Station is the largest settlement in Antarctica. Established in 1955 in the predominantly ice-free southern tip of Ross Island, McMurdo has earned recognition as the continent's leading research center. After rapid expansion in its initial years, "Mac-Town"—as affectionately known by its residents—is now a community of over 100 buildings, sprawling over an area of four square kilometers and containing facilities for desalination and sewage treatment, extensive laboratories, and also a hospital and a chapel. There are approximately 15 dormitory buildings and even two ATM machines, so far the only automated tellers to be installed in the continent.

Following the required stop at the Chalet, I arrived at building 155 in McMurdo—generally considered the main hub of the station—and went straight to get dinner. I was pleasantly surprised with the quality of the food, as well as its amount and diversity. Later on I went out with Hans and two other people to do the "mandatory" climbing of Observation Hill, the 230-meter extinct volcanic cone on the eastern edge of town that is a landmark of McMurdo. After a quick break halfway to the top we continued on a steep path up the slope, arriving at the summit where we found a view totally worthy of the hike. As I recalled John Wood's brilliant description of the hill and its surroundings I shot many photographs, and the panorama on top of pages 60 and 61 shows the spectacular vista that can be enjoyed from this place. I contend that a visit to McMurdo would never be complete without an ascent of Observation Hill.

Hiking the surrounding mountains and glaciers is only allowed after attending a safety briefing, while major expeditions require more training and additional paperwork. But Observation Hill does not carry any such requirements, meaning that we were free to walk up the hill as long as the weather was good, which indeed it was. The *Antarctica Weather Danger Classification* describes the inclement polar climate using a scale with three levels in order of severity, namely, condition 3 (pleasant), condition 2 (unpleasant), and condition 1 (dangerous). Restrictions on movement may be established on the basis of weather, and all travel is prohibited during condition 1. And, as I personally found out, elements such as temperature, wind and visibility can change quickly in Antarctica and over very short distances.

I was set to leave for the South Pole on January 7, but as travel depends so strongly on the weather my flight was successively postponed, day by day, until January 11. This meant a longer, unplanned stay, but one that I could use to my advantage, such as exploring the town and its surroundings. I did a number of outings around Discovery Hut, which is as far as I was permitted to go, pending the safety training that was offered once a week. The persistent cloudiness and occasional fog severely limited my enjoyment of the scenery. But as soon as the sun broke through the clouds—which sadly happened only once, for about four hours in the afternoon of January 8—I ran outside with my camera, shooting the photographs that I would later combine to produce the panoramas on pages 60 to 65.

I always abided by the rules, however, and thus withheld all major plans of exploration until satisfying the requirement of the safety lecture. This I did at the first chance on January 10, which officially allowed me to venture out of McMurdo proper. That afternoon I set out with Hans to do the *Hut Point Ridge Loop Trail*, where we saw an amazing landscape that included unexpected areas of liquid water. But after 75 minutes—about halfway into the hike—we ran into a sudden event of heavy snowfall and reduced visibility that almost ended in a condition 2 and forced our immediate retreat.

Every evening I would go straight to the computer and log in to the PolarTREC website, establishing in this way a routine that I faithfully followed for 18 days. Completing a journal entry would typically involve five steps: (1) downloading photographs from my camera, reviewing the images and selecting the best eight or so; (2) drafting the English version of the post, along with a complete description for each image; (3) rewriting the post and the descriptions in Spanish; (4) proofreading the day's journal and re-reading the post from the previous day; and lastly, (5) answering all comments from previous posts received within the last 24 hours. The whole process would take anywhere from four to six hours.

After five eventful days that provided me with a taste of Antarctica, I left McMurdo on January 11, 2015 flying aboard a ski-equipped Basler BT-67 with eight windows per side that gave me a fantastic view of the Transantarctic Mountains, which are found in the middle of the 1,400-kilometer route to the Pole.

A short stop halfway during the ascent of Observation Hill. Left to right: Armando, Jamie and Keith. The wooden cross near the summit was erected in 1913 as a memorial to Robert Falcon Scott. January 6, 2015 at 8:45 pm. Credit: Hans Niederhausen, IceCube / NSF.

Hans Niederhausen, James Casey and Armando Caussade with the wooden McMurdo sign. January 6, 2015 at 11:10 pm. Credit: Hans Niederhausen, IceCube / NSF.

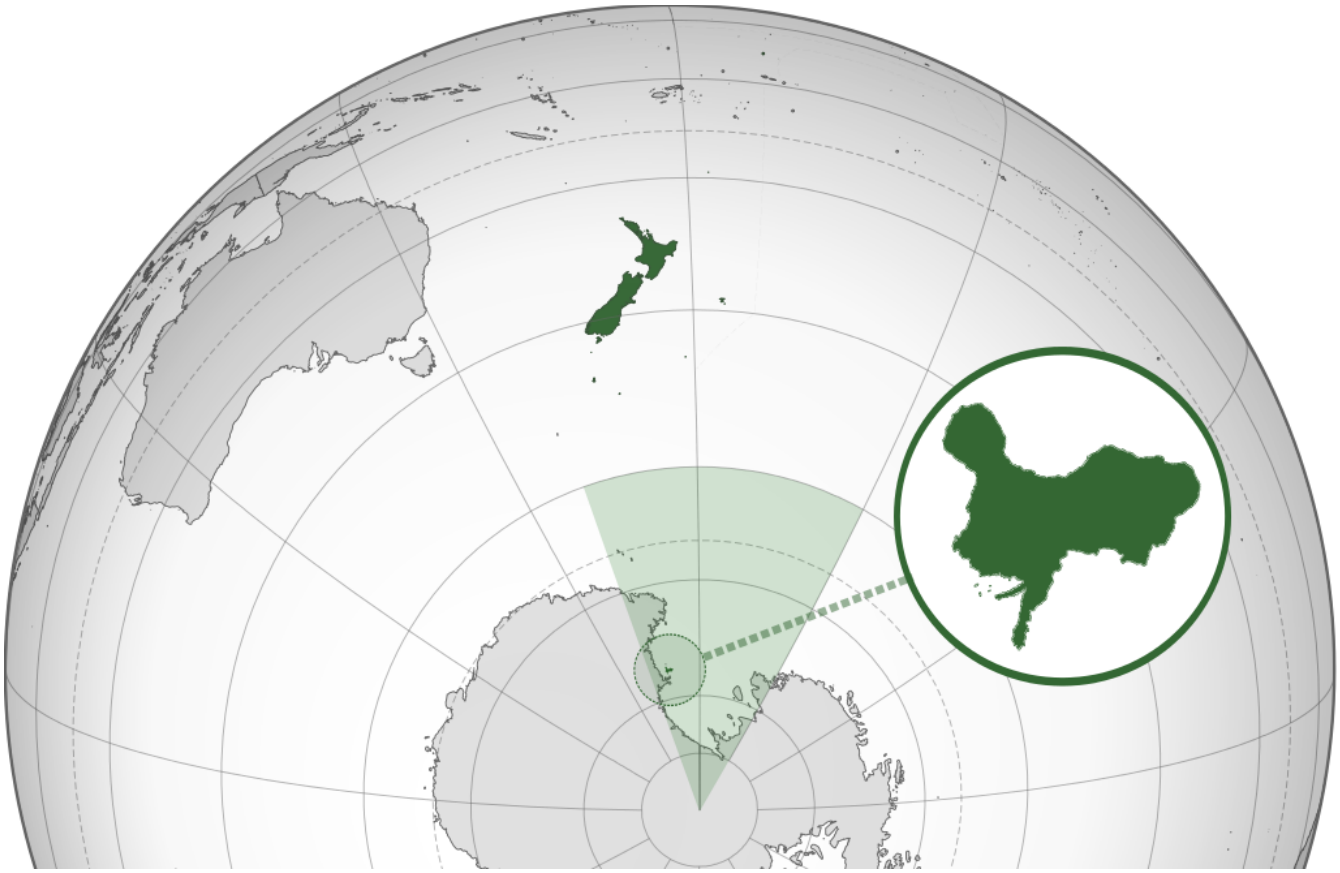
A large and comfortable room was assigned at building 155 in McMurdo. Credit: Hans Niederhausen, IceCube / NSF.

The dining facility at building 155 in McMurdo, the social center 'par excellence' of the station. January 9, 2015 at 12:17 pm. Credit: James D. Casey, IceCube / NSF.

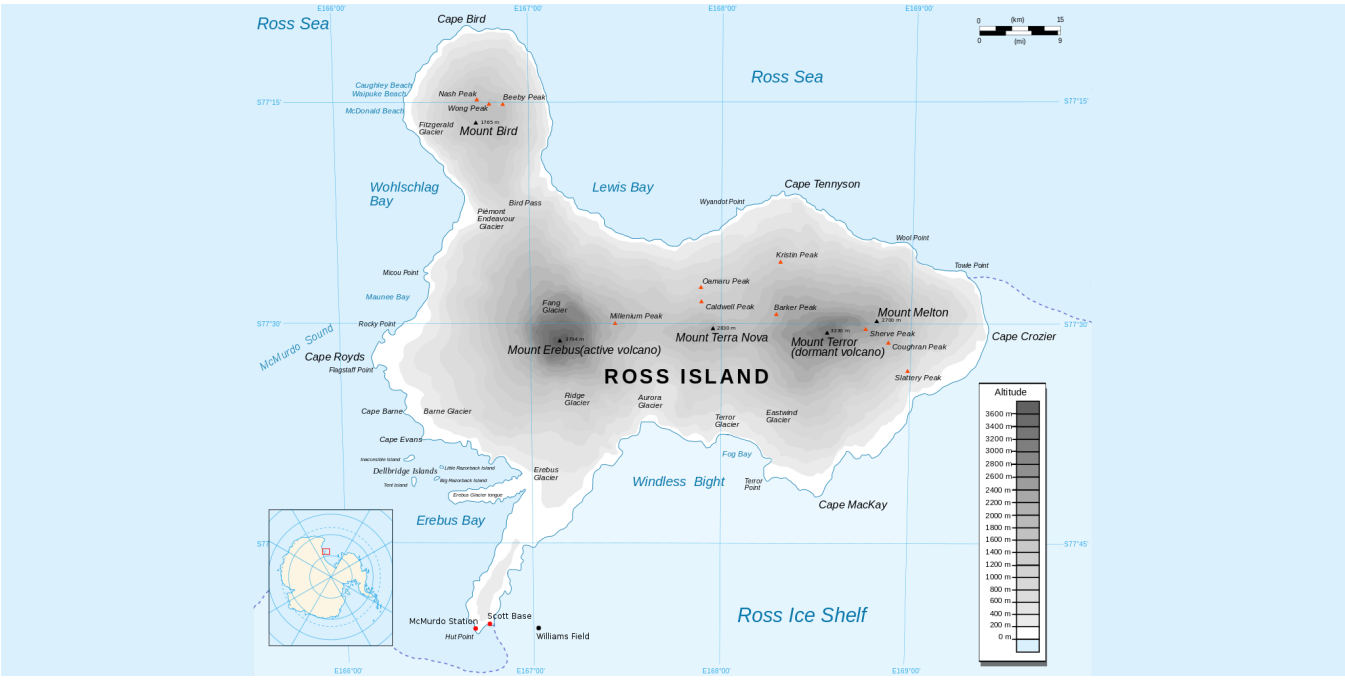
Leaving the dining hall after lunch. Left to right: Tammy, Neal, Hans and Armando. January 9, 2015 at 1:04 pm. Credit: James D. Casey, IceCube / NSF.

Hiking the Hut Point Ridge Loop Trail, near McMurdo, a few minutes before bad weather struck. January 10, 2015 at 5:36 pm. Credit: Hans Niederhausen, IceCube / NSF.

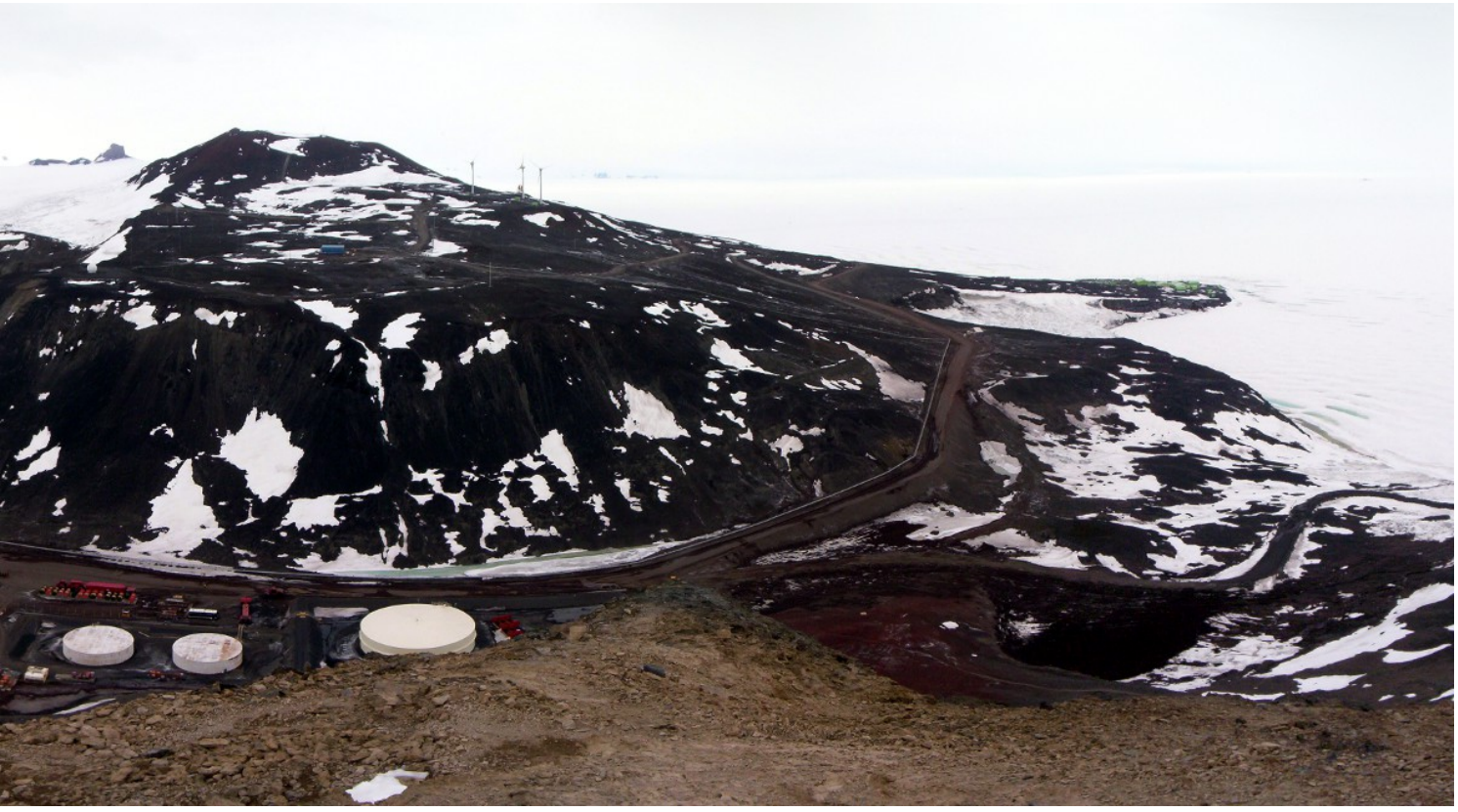
Retreating from Hut Point Ridge after initial signs of bad weather. January 10, 2015 at 5:57 pm. Credit: Hans Niederhausen, IceCube / NSF.



Map of the Pacific coast of Antarctica showing the location of Ross Island.
Credit: TooncesB, Wikimedia Commons / public domain, with modifications by Armando Caussade.



Map of Ross Island showing the location of McMurdo Station, Scott Base and Williams Field.
Credit: Chief Mike, Wikimedia Commons GNU–1.2, with modifications by Armando Caussade.



A 160-degree panorama of McMurdo Station viewed from the 230-meter summit of Observation Hill. The blue, rectangular structure to the left is building 155, the busiest place in McMurdo Station. January 6, 2015 at 9:18 pm.

A panorama of McMurdo Station during a rare, brief moment of predominantly clear skies. January 8, 2015 at 2:13 pm.

A panorama of McMurdo Station as seen from Hut Point.
Observation Hill—the iconic landmark of McMurdo—is the cone-shaped summit to the right.
The wooden structure seen seen left of center (near the green containers) is Discovery Hut,
built by Robert Falcon Scott in 1902 during the Heroic Age of Antarctic Exploration.
January 8, 2015 at 2:26 pm.

A 140-degree panorama of McMurdo Sound as seen from Hut Point.
White Island and Black Island—due south—are visible in the background (to the left),
while Mount Discovery (center) and the Royal Society Mountains (right) are partly hidden by clouds.
The seawater ice is starting to melt as the summer heat warms up the Antarctica coast.
January 8, 2015 at 2:27 pm.

A four-picture panorama of McMurdo Sound as seen from Hut Point.
January 8, 2015 at 2:28 pm.

A meltwater pond along the Hut Point Ridge Loop Trail, near McMurdo. January 10, 2015 at 5:38 pm.

8. The WIPAC article

PUERTO RICAN EDUCATOR ARMANDO CAUSSADE TO JOIN ICECUBE AT THE SOUTH POLE

By Lauren Boritzke and Jim Madsen
January 9, 2015 — 10:45 am

Wisconsin IceCube Particle Astrophysics Center (WIPAC)
http://wipac.wisc.edu/news/article/puerto-rican-educator-armando-caussade-join-icecube-south-pole

Caussade enjoying the view from Observation Hill at McMurdo Station.

The IceCube Neutrino Observatory team is anxiously awaiting the arrival of Armando Caussade at the South Pole. Caussade's long journey from Puerto Rico to the frozen, windy desert that he will call home for a couple of weeks started on January 2, 2015. Although he arrived as scheduled at McMurdo Station on the coast of Antarctica on January 6, 2015, the last leg of his journey to the South Pole has been delayed three days so far due to poor weather.

Caussade was chosen to work with IceCube and the National Science Foundation PolarTREC program

based on his exemplary skills teaching and presenting science and astronomy to diverse audiences. For example, he provides after-school science activities for K–12 students in G Work's (http://gworksinc.org/) Eco-STEAM project in Juncos, Puerto Rico and teaches astronomy at the Pontifical Catholic University of Puerto Rico. His passion for learning, and for astronomy in particular, is infectious and has inspired many who now see the night sky with greater appreciation and awe.

Caussade upon his arrival at the McMurdo airfield,
which is about 12 kilometers away from the main station.

Armando is very proud to represent Puerto Rico and readily embraces his responsibilities as a role model. He hopes his trip will inspire other students and teachers to pursue their dreams and take advantage of the incredible opportunities a science education provides. During his time at the Pole, he will be able to experience the extreme Antarctic environment. He will assist the team in taking measurements on the surface tanks that make up the IceTop array, and he will get a chance to clear snow at −30 °C. That's pretty extreme weather for anyone but especially so for someone used to one of the most comfortable and constant climates in the world—Puerto Rico temperatures typically stay between 24 °C and 30 °C year round.

Follow Caussade's adventure on his PolarTREC blog (http://www.polartrec.com/expeditions/ice-cube-neutrino-observatory-2014/journals). You can also hear from him directly from the South Pole during webcasts on January 13 (9:00 am CST, English) and 15 (8:00 am CST, Spanish), 2015. Go to http://icecube.wisc.edu/outreach/webcasts for instructions on how to join a webcast.

9. Arrival and stay at the South Pole

When I landed at the South Pole at noon, on January 11, 2015, I felt as if I had set foot on a different planet. Only two colors were to be found throughout the vast expanse of the Antarctic Plateau: blue and white, plus the occasional tinge of yellow from the sun. And only one kind of texture was to be discerned: the granular—but occasionally bumpy—consistency of the polar snowpack. With the possible exception of the Greenland Ice Sheet, no other place on Earth looks like this. I was enthralled by the flatness of the terrain and also by how uniform the horizon looked in every direction. What I saw was the simplest and most perfect landform that had ever come before my eyes, the prime example of a minimal landscape. And the pictures hardly do it justice, but the panorama on pages 84 and 85 is a good visual rendition that reasonably conveys what I have put into words here.

An unexpected treat was the glitter from tiny snow crystals in the ground as they were lit by the sun. That was astonishing! I had never read or heard about this, so it came as a complete surprise. I additionally saw a similar phenomenon known as *diamond dust*, which looks like glitter in the air.

The South Pole is among the coldest locations in the world, but it is also a place of extreme dryness and persistent winds—factors that, in my opinion, weigh in as much as the cold. I had seen temperatures as low as −29 °C during my stay in Alaska the year before, but with the wind and the dryness in Antarctica, that same −29 °C mark that I encountered upon my landing at the Plateau felt more like −38 °C. In addition, the air feels extremely thin because the Pole lies atop a 2,800-meter-high plateau with an average barometric pressure of 680 millibars, meaning that one-third of all atmospheric oxygen is gone. Moreover, polar residents must endure a regimen of continuous 24-hour sunshine, which extends for six months every year and can potentially wreak havoc on the body's internal clock.

After calling back home on my first day, the *Puerto Rico Astronomy Society* issued a successful press release announcing my arrival at the Amundsen–Scott South Pole Station, which attracted heavy media coverage and brought forth significant public awareness of my work with IceCube.

My responsibilities during the next ten days would span four main areas: (1) testing the Askaryan Radio Array (ARA), a new experiment that will measure radio waves generated by the interaction of neutrinos with the Antarctic ice; (2) troubleshooting of muon taggers at the IceTop experiment, which studies high-energy particles from space known as cosmic rays; (3) measurement of snow accumulation over IceTop tanks to identify possible detrimental effects of snow coverage on cosmic ray detection; and (4) support of public outreach efforts for IceCube, which included writing online, daily journals, as well as participating in live Internet presentations from the Pole. The first six days were allotted to tasks 1 and 2, while the last four days were devoted to task 3. Assignment number 4 ran through all ten days.

My workday extended from 8:00 am to about 6:00 pm, with a one-hour break for lunch, and work again from 8:00 pm to 1:00 am. A typical day for me at the South Pole started with a meeting at the Science Laboratory where the IceCube team—headed by Mike DuVernois—would set plans for the day. I might then join Sam De Ridder and Elisa Pinat for at least one outing, but usually two—one each in the morning and afternoon—with additional time sometimes required at the IceCube Laboratory. When not in the field, I would routinely be found in the Science Laboratory (refer to the panorama on pages 78 and 79) or in the computer room, where I moved every "night" to finish composing my journal entries and upload them to the PolarTREC website. The days were exhausting but exhilarating.

Transportation around the Pole is usually by tracked vehicle, but we also did much work by foot, which I found enticing since it allowed me to better connect with the landscape and to absorb it with all senses.

Being an educator myself, assisting the IceCube Neutrino Observatory with its public outreach initiatives would be a pivotal role by which my deployment in Antarctica was to be evaluated. To this end I gladly joined the IceCube team for two webcasts that were viewed by hundreds of people worldwide—some of the highest attendance numbers ever. Likewise, I was diligent in producing a complete journal every day and uploading it in a timely manner, and particularly in using good visual content (all in all, I would end up sharing a total of 176 pictures in 22 posts). The hard work paid off, and judging by the enthusiastic reaction of viewers the journals were a huge success. This material would also form the basis for future lectures in class and invited public presentations.

I was driven by the zeal of making good photography, which is evident in the images used in this book. To this effect, I had to overcome a number of technical issues, such as the batteries that ran out of power in no time (because of the cold) and the constant need to recharge them. I also took extreme care when using electronic appliances—particularly USB flash drives on a computer—as static electricity shocks are habitual at the South Pole due to the complete lack of humidity.

Whereas cloudiness is the norm at McMurdo and other coastal locations in Antarctica, the Pole and most of the interior see generally clear skies. This clarity is especially enjoyable during the long polar night.

Yet, I saw five days in a row (January 13 to January 17) of gray, overcast skies. On a few occasions the clouds started to clear and the sun would timidly peek through, but the break-up was never complete nor lasting. I began to worry about the weather not allowing me to shoot proper photographs (meaning pictures with good lighting and clear skies) and every evening following dinner I glanced through the windows to look for any sign of improvement. Then on Sunday, January 18, wanting to enjoy what would be my only day off, I went out for an afternoon walk and saw the most perfect, brilliant and rich blue sky ever. However, with the sunshine also came a heavy breeze which brought about the coldest windchill that I ever experienced in Antarctica: officially −43 °C—according to the local weather report—but in some instances the windchill felt appreciably colder than that, reaching as far down as −48 °C.

The South Pole is the most isolated place in the world, which means that life and work depend on critical transportation and communication links. During the austral summer food and fuel are shipped by air from McMurdo using ski-equipped aircraft, and increasingly by land through the recently completed *South Pole Traverse*, a road of compacted snow with McMurdo at its northern terminus. Landing is impossible during an 8-month period between March and October, but airdrop deliveries are sometimes done. Internet connectivity is achieved via communication satellites that act as relay stations.

But in spite of its remoteness, the Amundsen–Scott South Pole Station consistently provides its residents with all the comforts of modern life, and I can truly say that I felt like at home. The temperature inside was always kept at a comfortable 18 °C—warm enough to walk around in shorts and T-shirts. Meals were served buffet-style (just like in McMurdo) with delicious choices and the opportunity to determine my own portion size. I was also assigned a private room with LAN and Internet access, VoIP telephony, and even a window that I covered at "night" to keep the sun out and get some sleep.

After a stay of ten days in this amazing place where nature displays its rawest form, I left on January 21, 2015. Those days account for slightly over half the length of my 18-day visit in Antarctica, with the balance of eight days corresponding to my stopovers in McMurdo while in transit to and from the Pole.

Just out of the airplane after arriving at the Amundsen–Scott South Pole Station.
January 11, 2015 at 12:49 pm.

Writing a first draft for a PolarTREC journal at the Science Laboratory.
January 13, 2015 at 1:55 pm.

The main hallway at the first level inside the Amundsen–Scott South Pole Station. There are interesting exhibits and artwork in the walls around the hallways. A mural entitled "100 Års Jubileum" which commemorates the 100th anniversary of Amundsen's arrival at the Pole in 1911 is pictured here. January 18, 2015 at 2:45 am.

At the South Pole ice can take different colors and shapes. January 12, 2015 at 3:01 pm. January 17, 2015 at 5:31 pm.

The ceremonial South Pole with the flags of the original twelve Antarctic Treaty signatories.
January 20, 2015 at 1:10 pm.

The geographic South Pole with the sign and the United States flag.
January 20, 2015 at 1:13 pm.

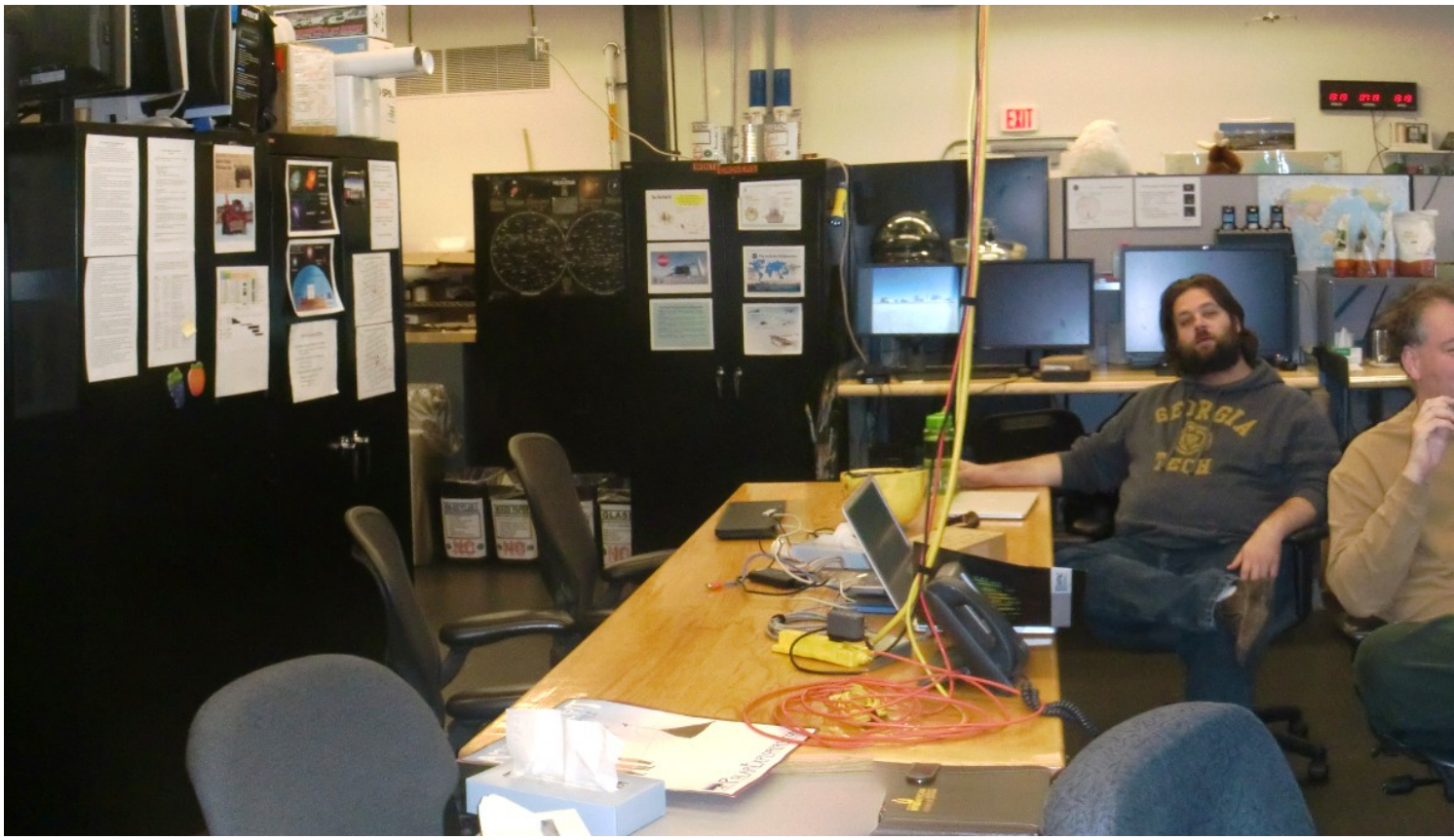
Standing next to the sign and marker at the geographic South Pole.
January 18, 2015 at 5:28 pm.

Selfie photograph taken at the South Pole with the Antarctic Plateau in the background.
January 20, 2015 at 1:18 pm.

Leaving the elevated station to work with the IceTop array.
January 13, 2015 at 2:26 pm.

This is what the IceCube team drove in the field—a PistenBully continuous track vehicle.
January 17, 2015 at 3:40 pm.

Armando Caussade and Sam De Ridder during an outing for the IceTop experiment. January 16, 2015 at 3:09 pm.


EXIT
GEORGIA
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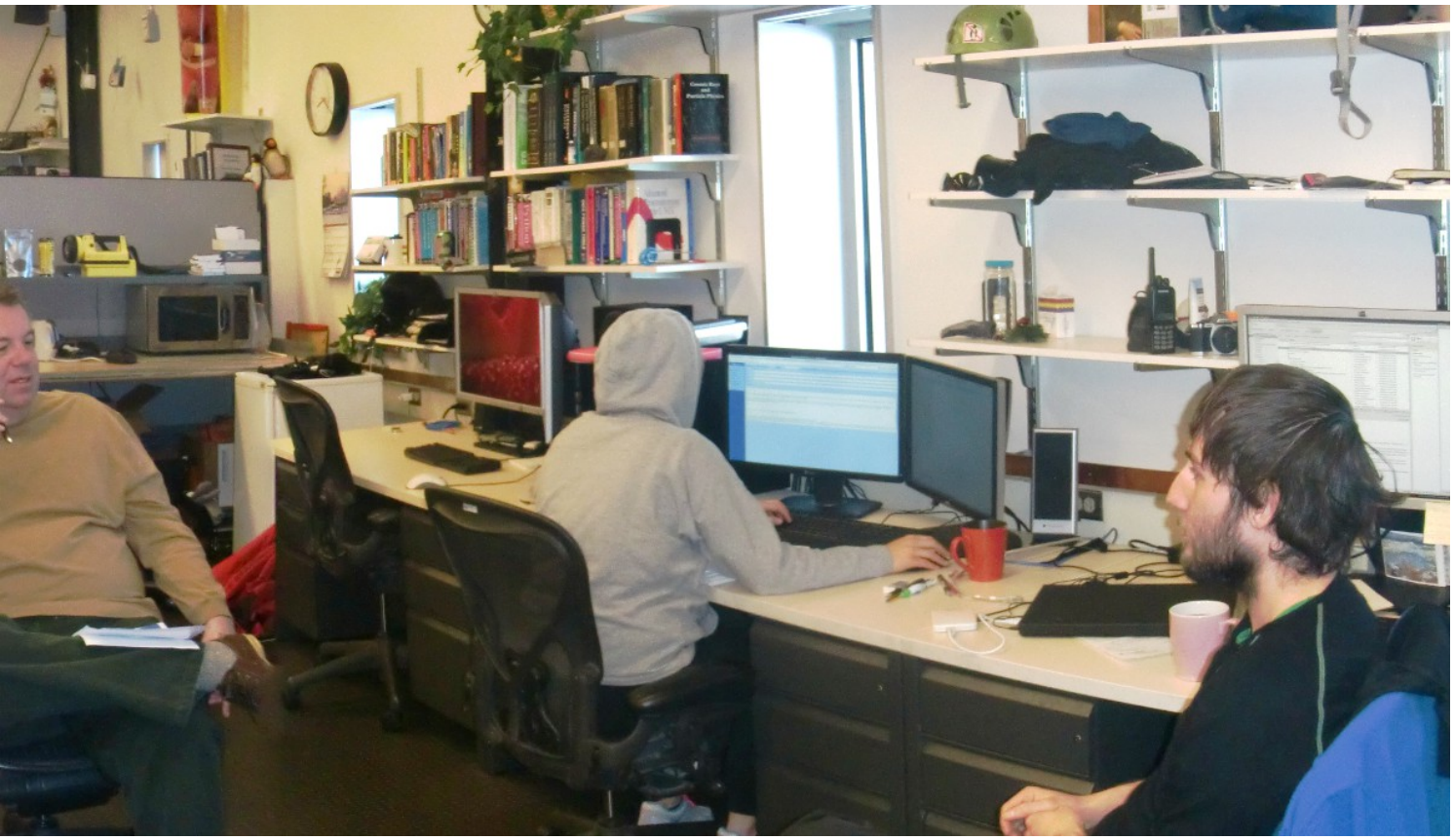
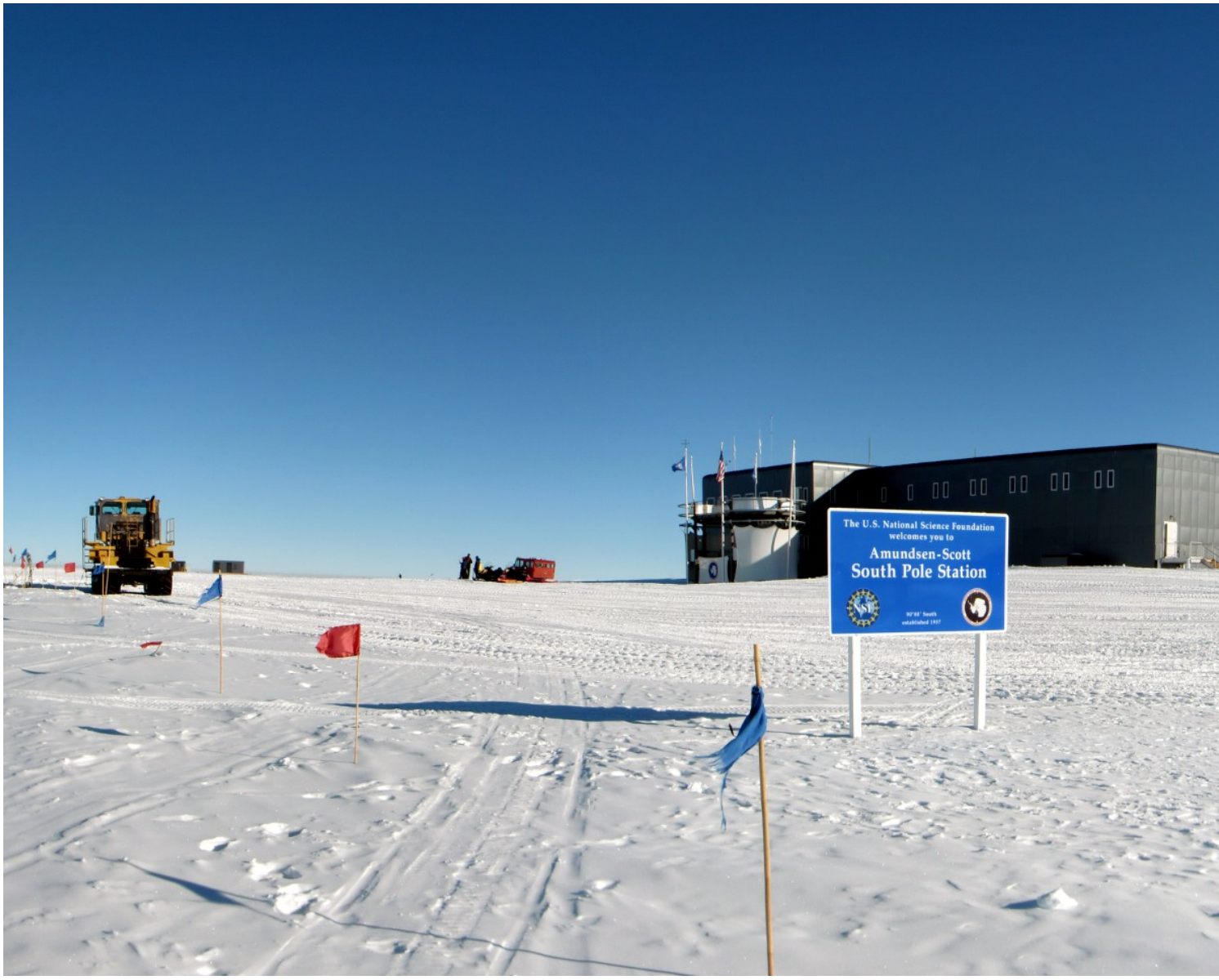
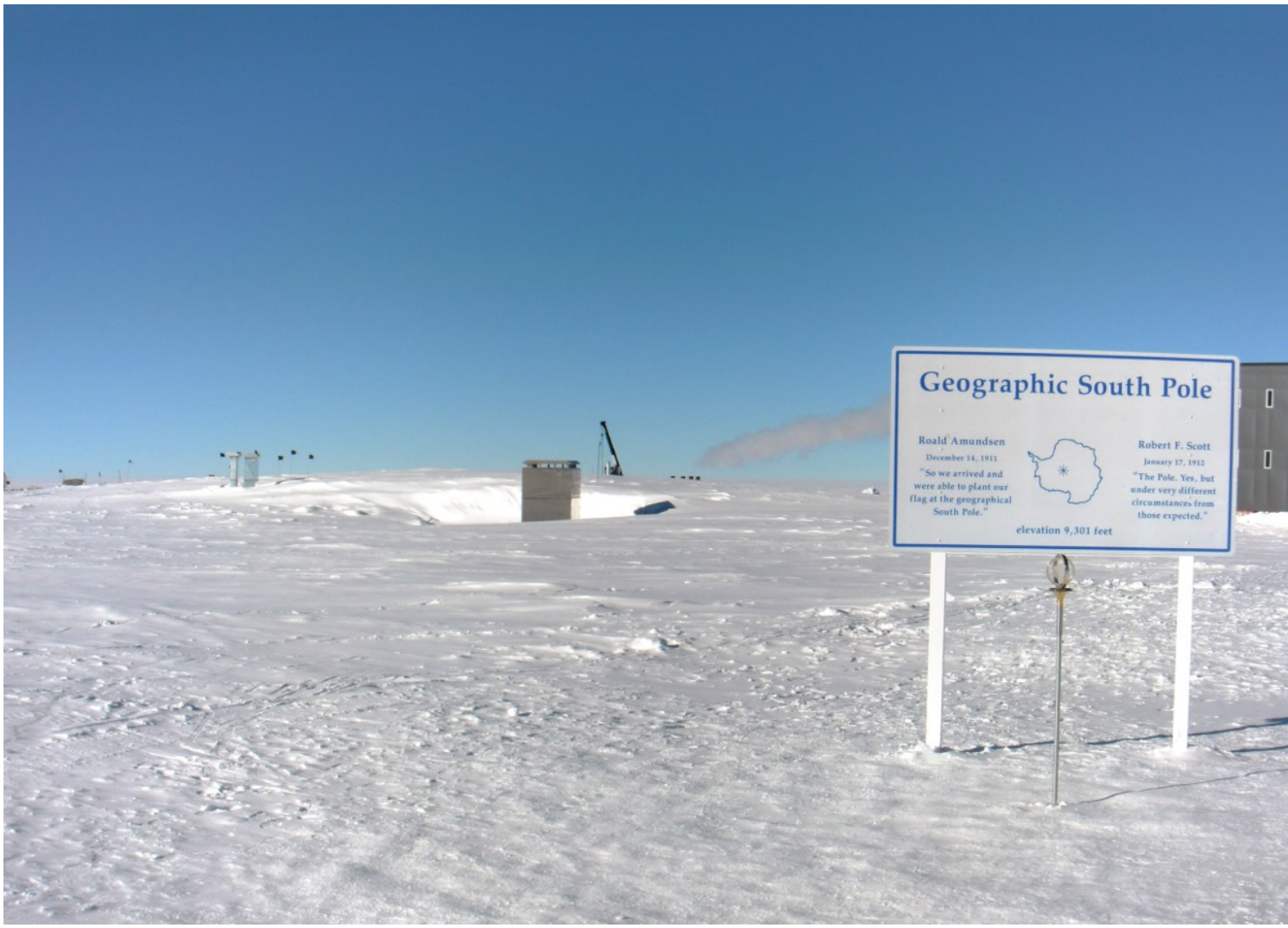


The IceCube section at the Science Laboratory inside the Amundsen–Scott South Pole Station.
This is where Armando spent most of his working hours when not outside in the field.
From left to right: James Casey, Mike DuVernois, Elisa Pinat and Stephan Richter.
January 12, 2015 at 8:20 am.


The U.S. National Science Foundation
welcomes you to
Amundsen-Scott
South Pole Station

Front side of the the Amundsen–Scott South Pole Station, as seen from the welcome signboard.
This is the view obtained by newcomers when arriving from the airplane runway.
January 18, 2015 at 2:26 pm.


Geographic South Pole
Roald Amundsen
December 14, 1911
"So we arrived and were able to plant our flag at the geographical South Pole."
Robert F. Scott
January 17, 1912
"The Pole. Yes, but under very different circumstances from those expected."
elevation 9,301 feet

Rear side of the Amundsen–Scott South Pole Station, as seen from the geographic South Pole. Next to the sign is a marker that identifies the exact location of the Pole. January 18, 2015 at 5:43 pm.

A view of the ARA-2 site which lies about three kilometers away from the main station.
This is the farthest that Armando ventured out from the actual South Pole.
The scenery is typical of the Antarctic Plateau that dominates the continent's interior.
January 12, 2015 at 2:06 pm.

10. High-energy astronomy, neutrinos and the IceCube telescope

I will now give a quick overview of high-energy astronomy that will clarify aspects of my work with the IceCube Neutrino Observatory. At the risk of redundancy I will recycle a few passages that were originally written for my PolarTREC journals. The excerpted text—found here interspersed along with newer content—comes from my post of January 14, 2015 that is reproduced in pages 170 and 171.

High-energy astronomy

High-energy astronomy studies violent objects such as exploding stars (or *supernovae*) and stellar corpses such as neutron stars and stellar black holes which are frequently surrounded by *accretion disks*, i.e., gigantic rings of hot gas found in orbital motion around their respective stars. Of particular interest to high-energy astronomers are supermassive black holes that presumably dwell at the center of most galaxies, and gamma-ray bursts, which are the most energetic events observed to date in the universe.

The extreme processes undergone by these objects produce a significant amount of electromagnetic radiation in the form of high-energy photons—X-rays and gamma rays—that can be seen and studied by specialized telescopes in satellites that orbit around the Earth. These celestial bodies also send into space a flow of high-speed particles such as *cosmic rays* (fragments of atoms) and *neutrinos* (a type of subatomic particle) that can be likewise detected by instruments at or below ground level on Earth. Since many astronomical phenomena shine more intensely in these types of radiation than in visible light, high-energy astronomy provides information that is simply unavailable to optical telescopes.

Neutrinos

Neutrinos are fast and highly penetrating particles, smaller than atoms. Being the most numerous particles in the cosmos—excepting photons—they pervade everything, but rarely interact with matter. A staggering number of neutrinos ($\sim 10^{12}$) travel, unnoticed, each second through a person's body. Because they sail intact through vast expanses of matter they have been nicknamed as "the ghost particle".

The ability to slip through matter is important because distant astronomical settings are usually blocked from our view. Photons are weakened—and eventually stopped—by intervening matter. Cosmic rays are problematic, too, as they consist of electrically charged particles whose paths can be deflected by magnetic fields found along the way. But neutrinos, with their incredible penetrating power and straight paths, arrive on Earth mostly undisturbed after traveling huge distances across space. Undoubtedly, neutrinos make the ideal messenger particle to study cataclysmic environments in the universe.

The IceCube telescope

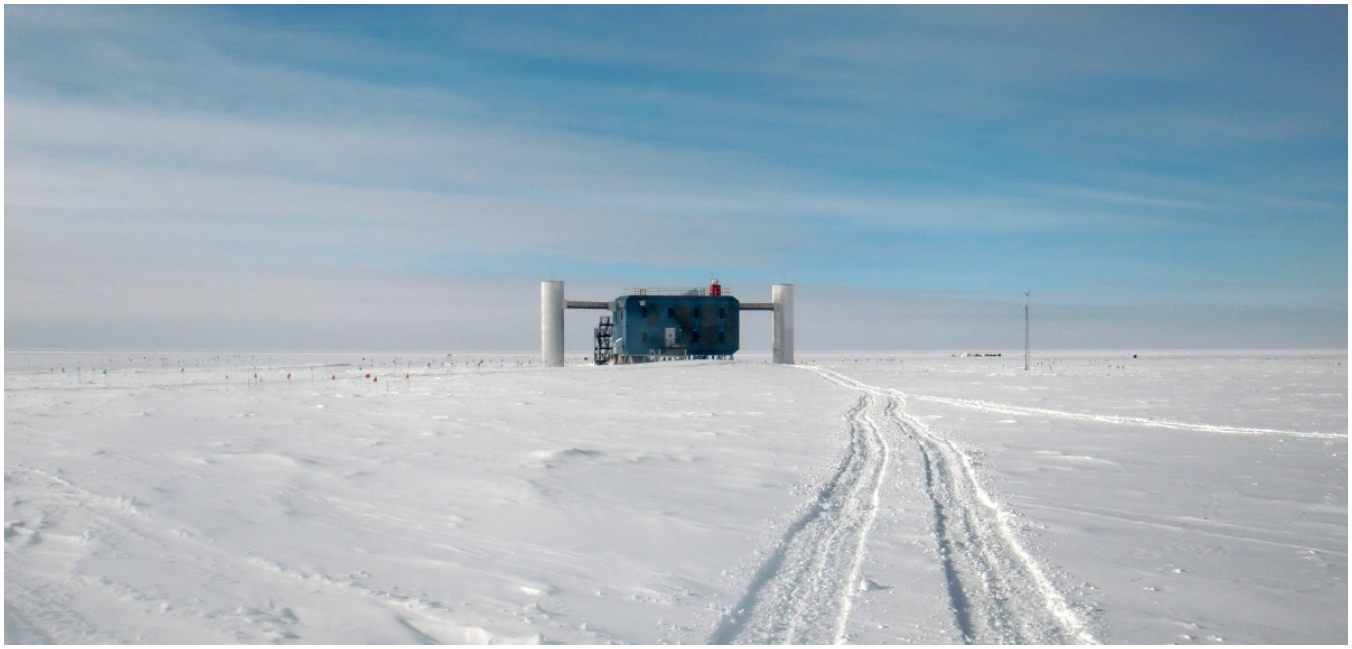
The IceCube Neutrino Observatory is the world's strangest telescope. Its main purpose is to study neutrinos from beyond our Solar System carrying the highest energy levels. The IceCube detector was constructed over a seven-season period between 2005 and 2010 at the Amundsen–Scott South Pole Station by an international collaboration involving dozens of institutions. The National Science Foundation—an organization of the United States government—provided the primary funding with assistance from partner funding agencies around the world. The University of Wisconsin–Madison is the lead institution with responsibility for the maintenance and operations of the observatory.

IceCube uses 5,160 optical sensors that are suspended from 86 strings buried deep below the South Pole surface inside a cubic kilometer of ice, which is the cleanest and optically purest on Earth. This is possible because the Antarctic Plateau consists of a huge glacier that rises three kilometers above the bedrock. The sensors were inserted into holes made with a hot water drill and are spaced 17 meters apart vertically, between depths of 1,450 and 2,450 meters. The light sensors, *photomultipliers*, face down toward the center of the Earth. The telescope is pointed down in order to use the whole planet as a barrier to block cosmic rays and other energetic particles that the experiment is also capable of detecting. Neutrinos are the only known particles that are adept at penetrating such large volumes of matter.

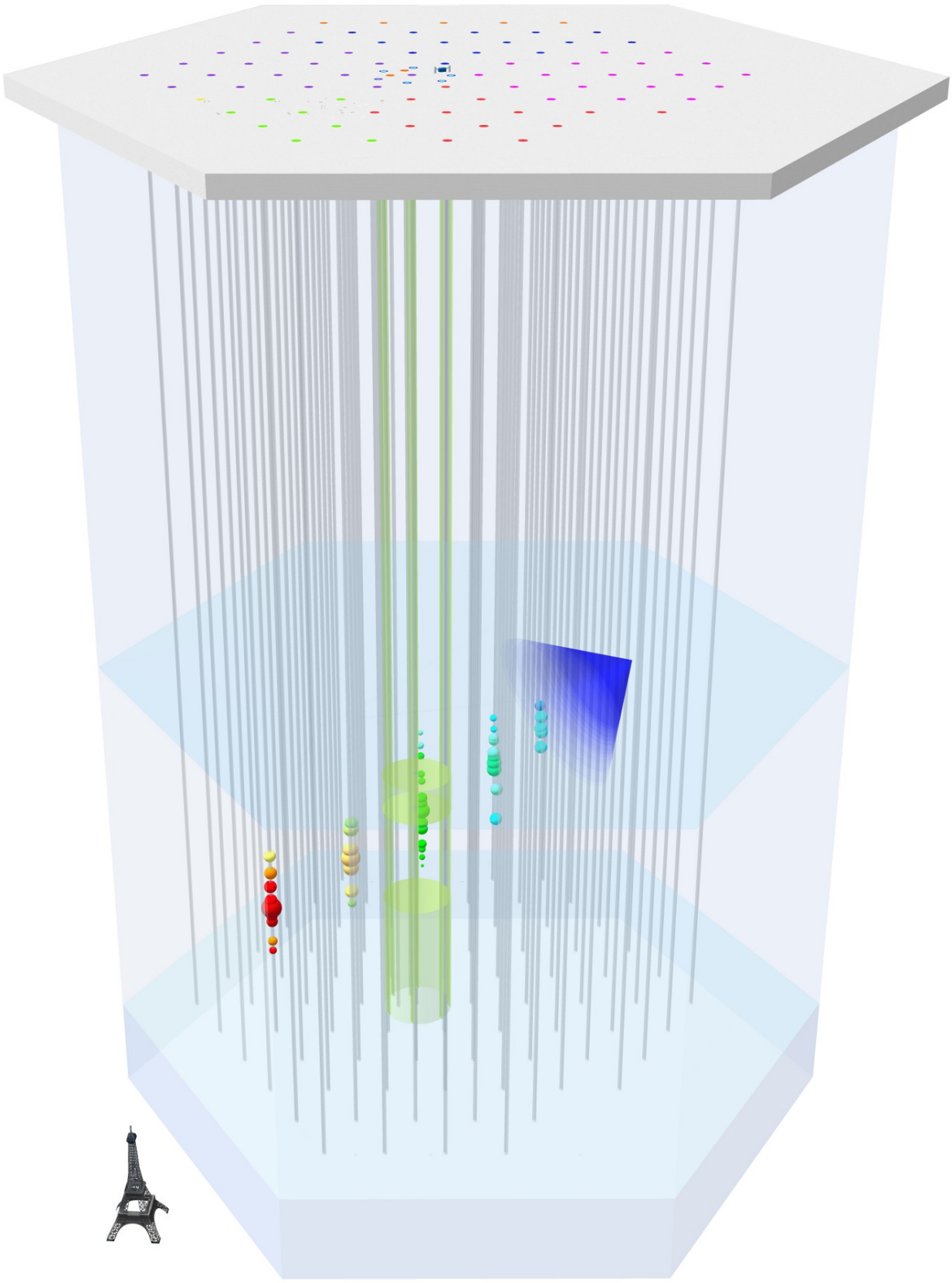
The IceCube sensors (otherwise known as *digital optical modules*, or DOMs) are able to detect and measure radiation from high-speed charged particles generated by neutrino interactions with the ice. Although neutrinos cannot be directly detected, when a particular type of neutrino hits the nucleus of an atom they produce secondary particles called *muons*, which leave along their paths an intense trail of blue Ĉerenkov light that can be measured by the photomultiplier tubes in each DOM. The energy content and the direction of the originating neutrino can be ascertained by studying this light.

The laboratory building at the surface hosts the computers that collect and store the data from the underground sensors. Meaningful findings are relayed via Internet to North America for further study.

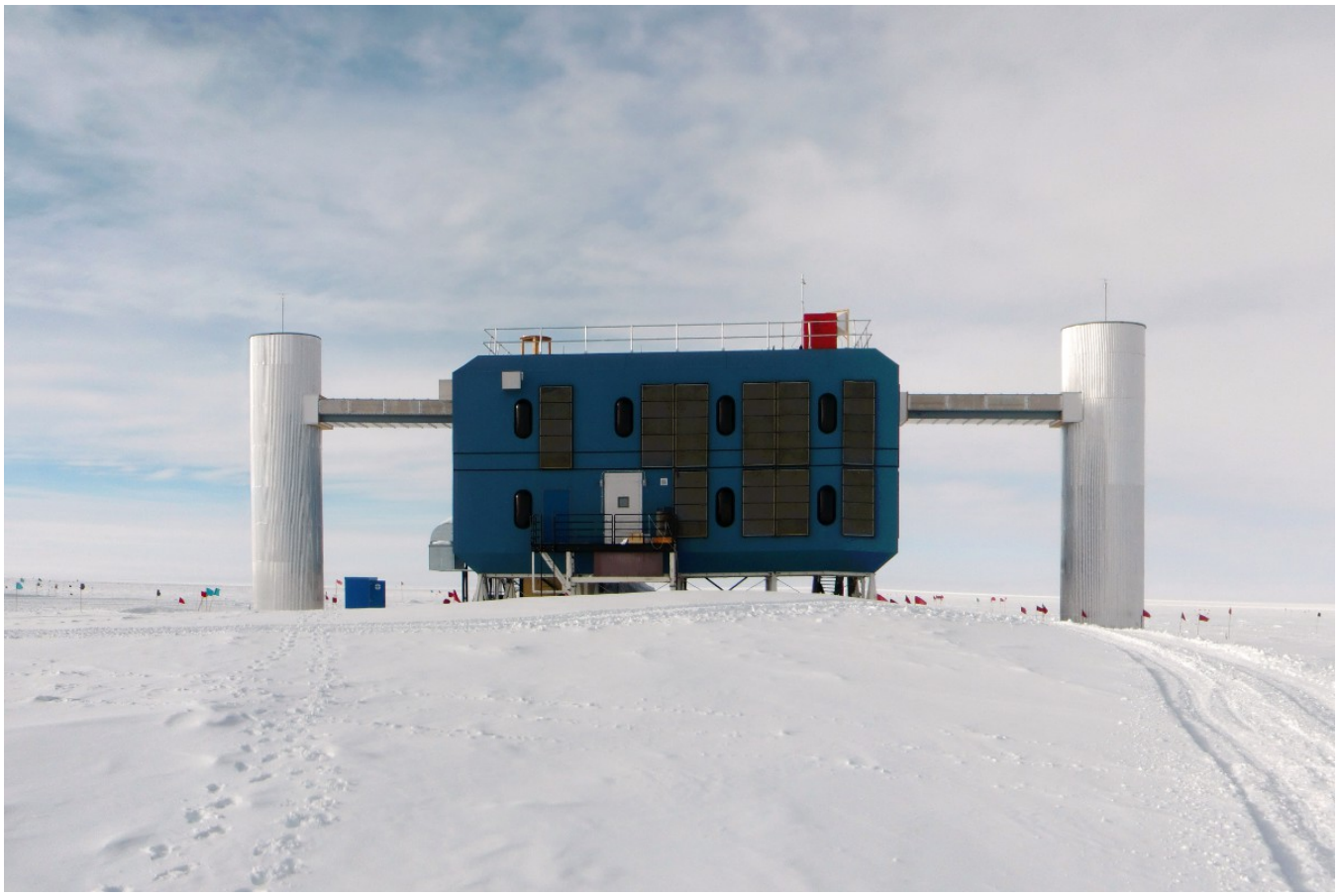
After analyzing three years of data IceCube recorded hundreds of thousands of neutrino events, including 37 extremely special ones—the first solid evidence for neutrinos of cosmic origin. Three specific events nicknamed as *Bert*, *Ernie* and *Big Bird* are due to neutrinos with some of the highest energies ever observed. The data was also used to achieve something that has never been done before, at least with particles of this energy level: create a neutrino map of the sky [see chart on page 120]. This is an ongoing project, still in its early stages, that will allow scientists to pinpoint (with an accuracy of about 1°) the actual directions where these particles appear to come from.



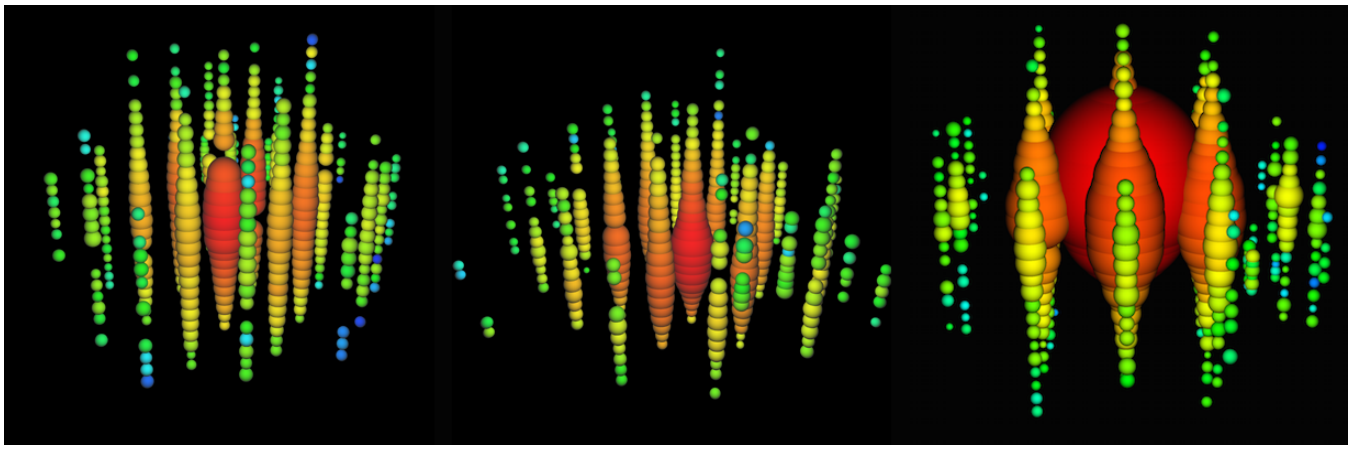
The laboratory building at the IceCube Neutrino Observatory.
January 14, 2015 at 4:11 pm.



Schematic view of a neutrino detected in IceCube at a depth of approximately 2,000 meters. Credit: IceCube Collaboration.



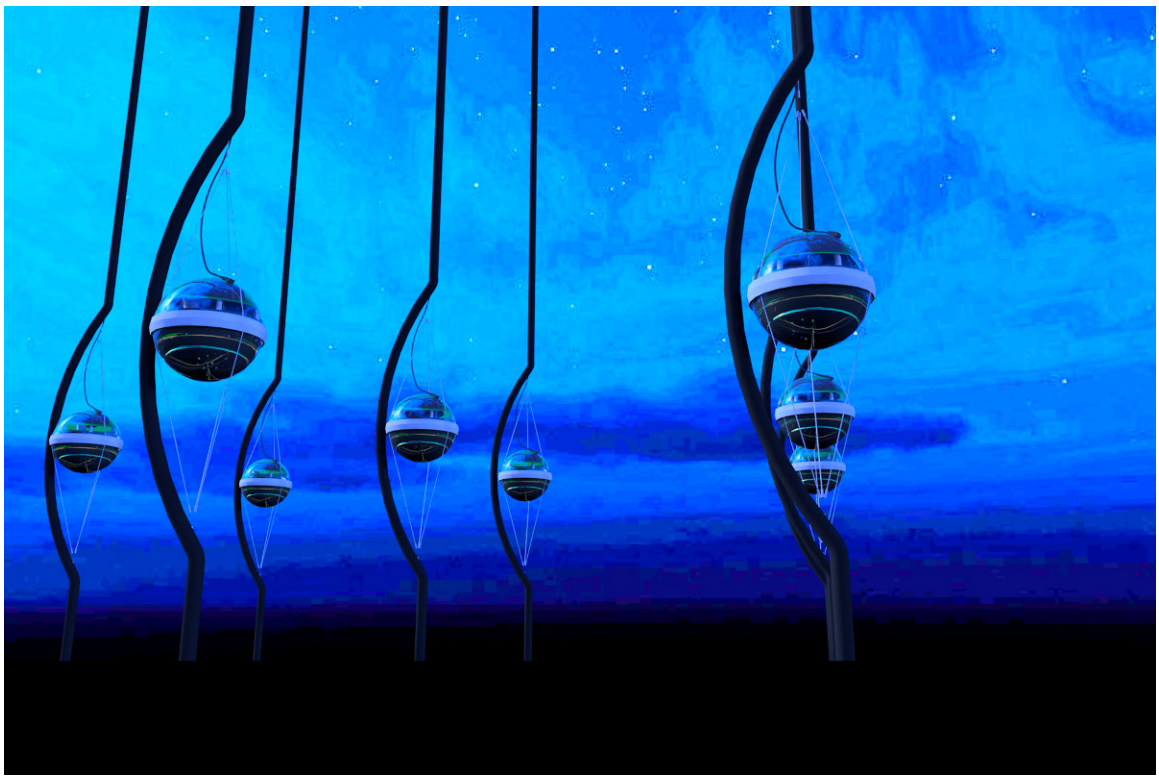
The IceCube Laboratory under partly cloudy skies.
January 15, 2015 at 5:36 pm.



This is a representation of three high-energy neutrino events seen by IceCube: Bert, Ernie and Big Bird. Each of the colored spots represents an optical module in IceCube where a particle was detected.

Color indicates time elapsed (red is where the particle interaction began), whereas the size of the spot refers to the intensity of the Ĉerenkov light that was observed (which is proportional to the energy carried by the neutrino). Big Bird, recorded on December 4, 2012 and pictured at the right, is the second highest-energy cosmic neutrino ever detected, as of this writing. Credit: IceCube Collaboration.

An IceCube sensor (or digital optical module) displayed at the IceCube Laboratory. Each sensor contains a photomultiplier tube encased in a 35-centimeter sphere of glass.



Artistic rendering of IceCube sensors (or DOMs) below the Antarctic ice. Credit: Jamie Yang, IceCube Collaboration.

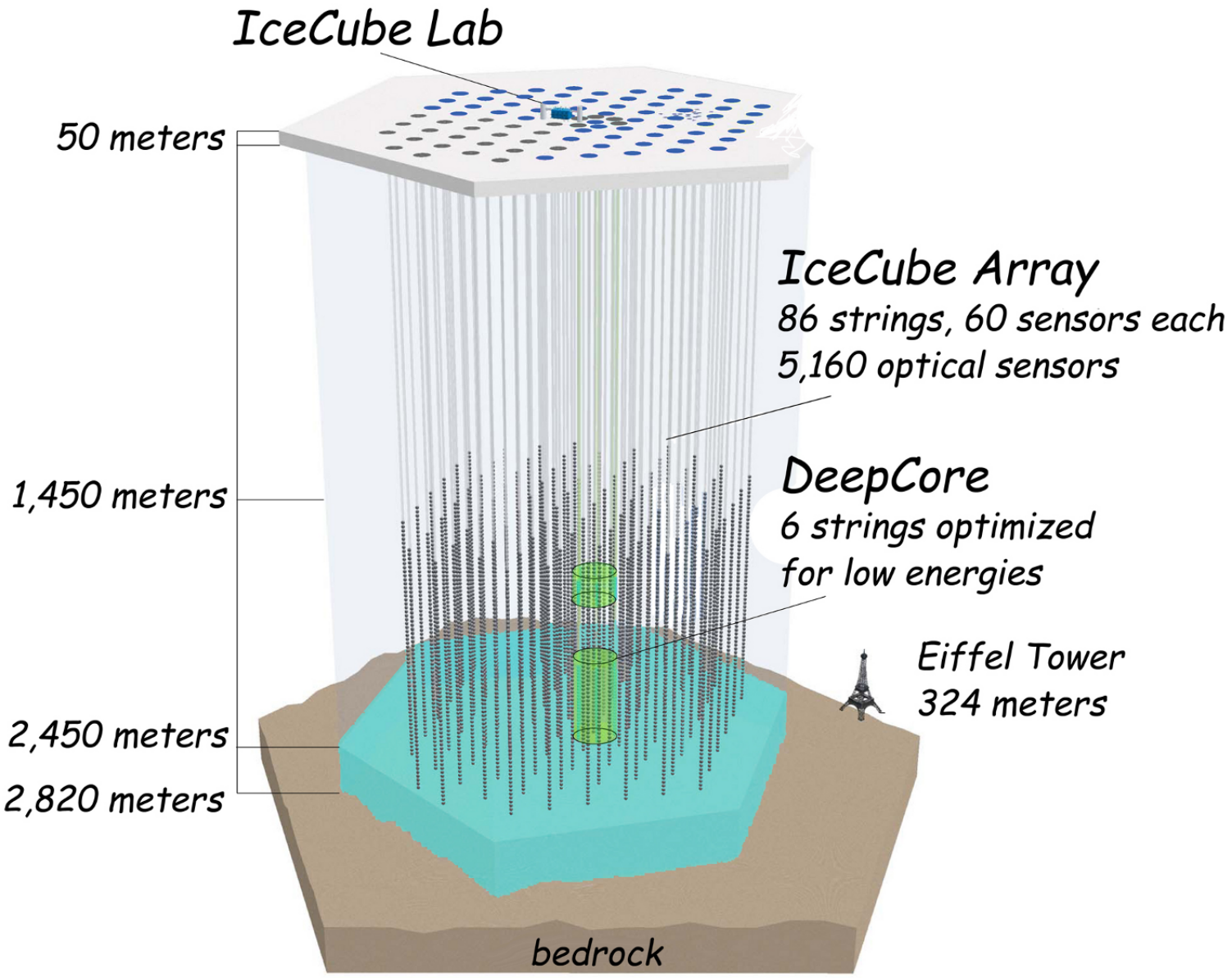
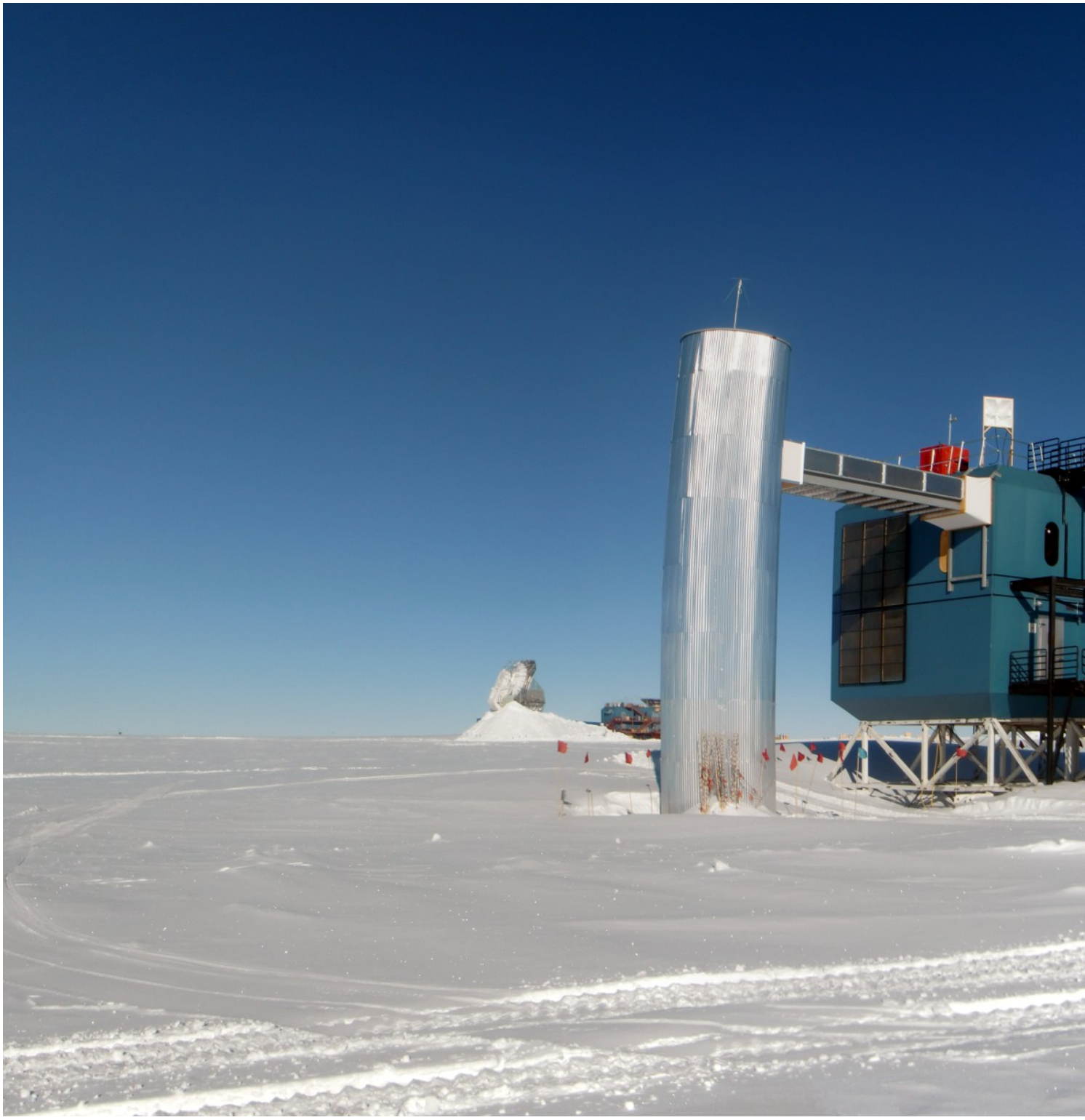
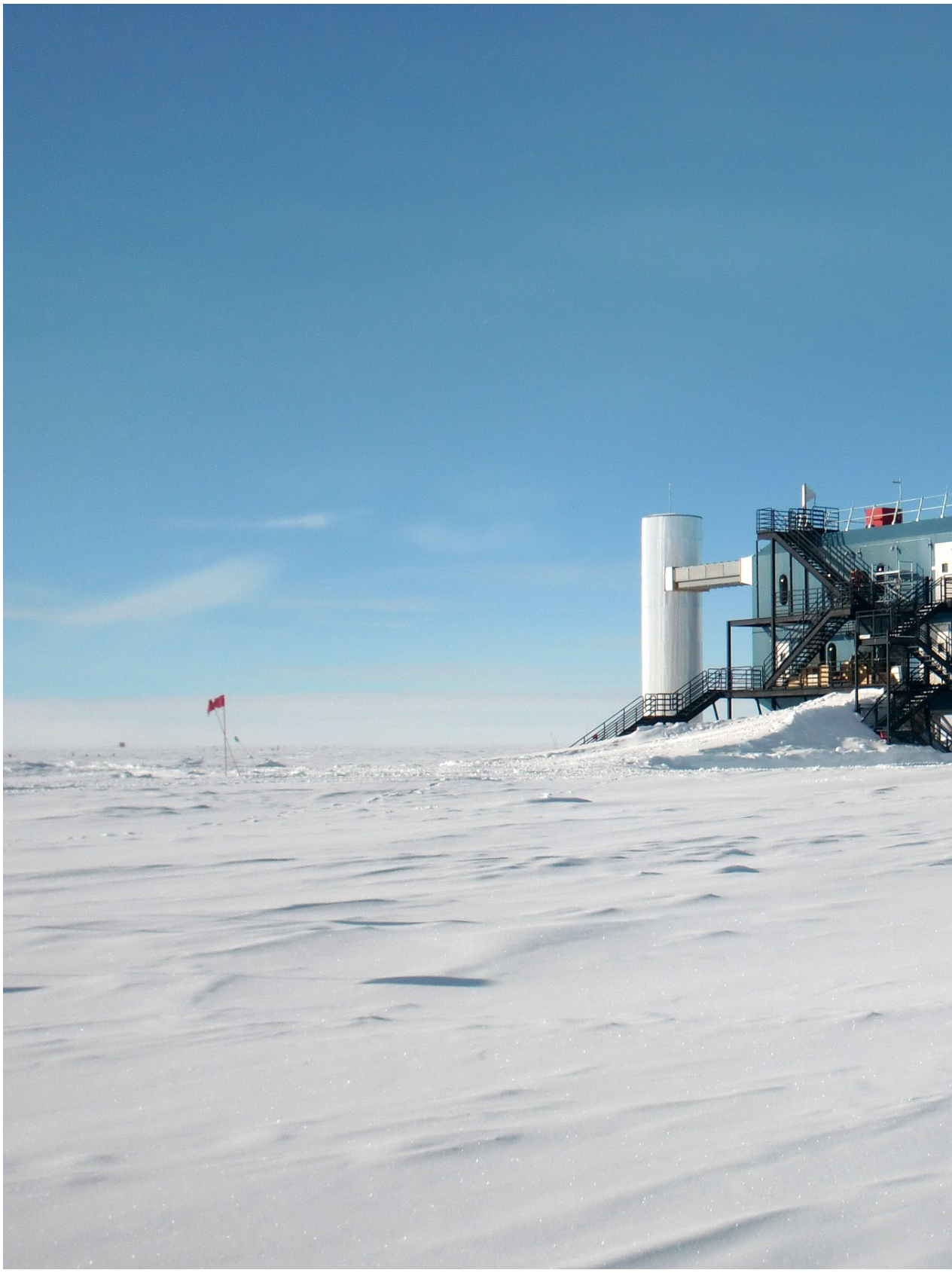


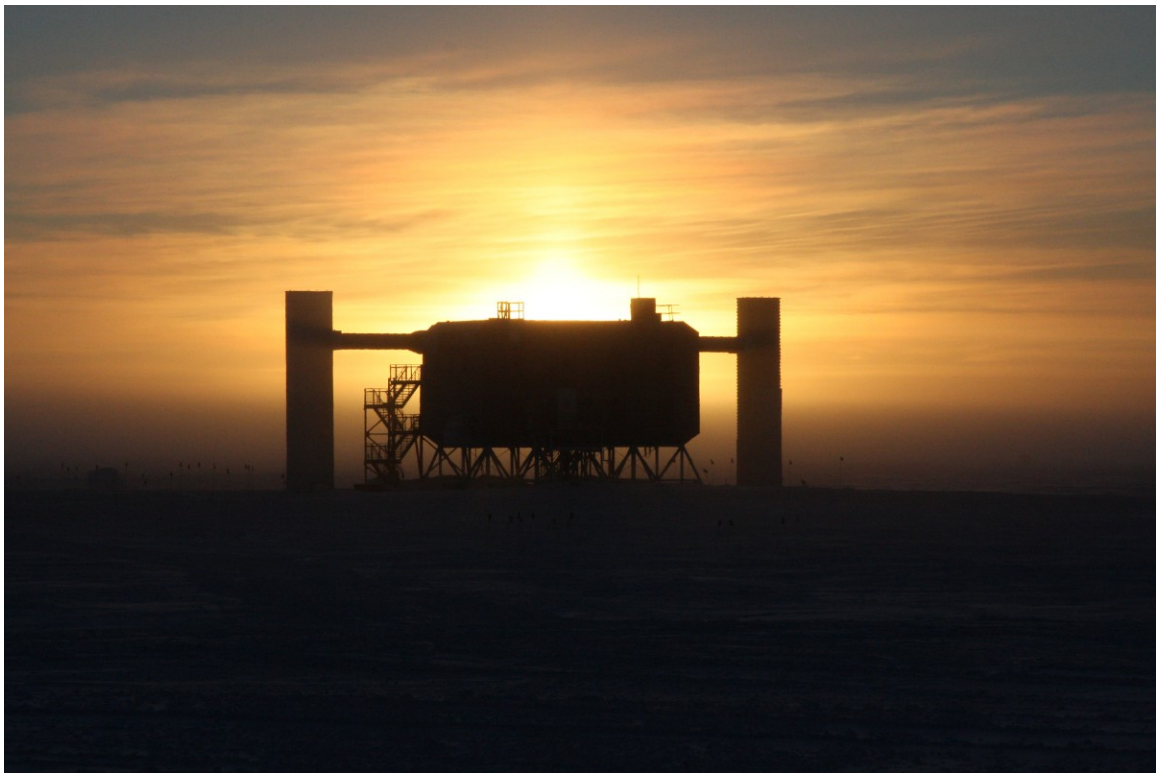
Diagram of the IceCube Neutrino Observatory where each individual dot represents a sensor. IceCube uses 5,160 optical sensors that are suspended from 86 strings buried deep below the South Pole surface inside a cubic kilometer of ice, which is the cleanest and optically purest on Earth. Credit: IceCube Science Team / Francis Halzen, University of Wisconsin–Madison.



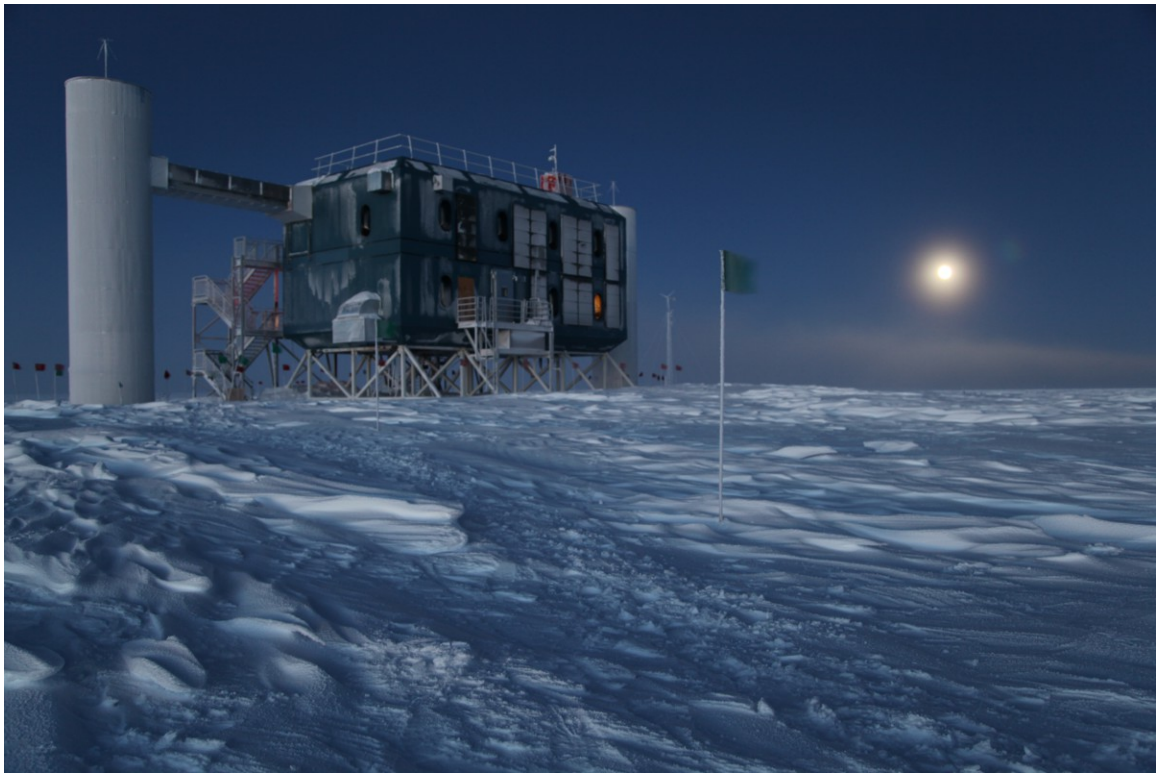
The IceCube Laboratory seen in broad daylight, with solar rays at the near-maximum inclination of 22°. This building hosts the computers that collect and store the data from the underground sensors. January 12, 2015 at 9:51 am.



Another view of the IceCube Laboratory.
January 19, 2015 at 9:24 am.



Sunset behind the IceCube Laboratory as viewed on March 19, 2008.
Credit: Keith Vanderlinde, IceCube / NSF.



The IceCube Laboratory with the full moon photographed on April 6, 2012.
Credit: Sven Lidström, IceCube / NSF.

The IceCube Laboratory under the stars photographed on April 20, 2013.
Credit: Felipe Pedreros, IceCube / NSF.

The IceCube Laboratory with the Milky Way and the aurora as viewed on July 30, 2014.
Credit: Ian Rees, IceCube / NSF.

This is the scenery when looking away at a distance from the Amundsen–Scott South Pole Station. The IceCube Laboratory—seen here at a distance of approximately 1,500 meters—is at left. The South Pole Telescope and the BICEP experiment are both in the building at the middle, while the Martin A. Pomerantz Observatory is the third and last building to the right. January 20, 2015 at 4:24 pm.

11. Return and stopover in McMurdo

Antarctica is a land of contrasts. Upon my return to the coast on January 21, 2015, after ten days in the continental plateau, I was astounded by the radical disparity in the physical geography between the two areas. Not only the ground where I walked was different, but even the air felt distinct.

Although I only experienced marginal effects from the rarefied, dry air of the Antarctic Plateau, the heavier, humid atmosphere of the coast was like a godsend. Breathing felt more relaxed, and the air felt softer and more natural. Being able to walk on bare ground wearing regular shoes, after ten days of boots over ice, was another treat. Besides, water at the South Pole exists only as a solid or a gas—like on planet Mars—but McMurdo partially supports liquid water, the main element of life on Earth. The sight of open water was thus a highlight for me, as would be to any other human. Furthermore, the cycle of day and night begins to gain a semblance of normality following the jump from latitude 90° to 78°.

Upon boarding the LC-130 that took me from the Pole to McMurdo I accidentally sat over my sunglasses and broke them. Ugh! But I did not notice and rather spent the whole trip brainstorming about where to find them. The flight itself was as satisfying as it could be, but my anxiety over the missing glasses was escalating. The ski-equipped airplane approached Ross Island and made its descent which ended with a long, magnificent glide over the Ross Ice Shelf. An amazing landing for sure, but as I arose from my seat I immediately caught sight of the shattered remains of my eyewear. These polarized shades had gone with me on many adventures throughout the world, and I wanted to keep them as a memento of my journey. I always wore them when outdoors in Antarctica because the area below latitude 60° south is at high risk for increased solar ultraviolet light. And those sunglasses had survived being inadvertently tossed around like a million times, but sadly, this time they gave in.

Following my arrival in town I learned that the next airplane on schedule was set for January 24, meaning that my stay would last for at least three days. This seemed unusual, as the stopover for people in transit to and from the Pole does not regularly exceed one day, except for the possibility of bad weather, which in my opinion did not seem to be the case here. I was delighted, however, that this second sojourn in McMurdo—with improved weather and better visibility—might finally afford a chance to see, photograph and enjoy the natural wonders that I had missed on my previous visit.

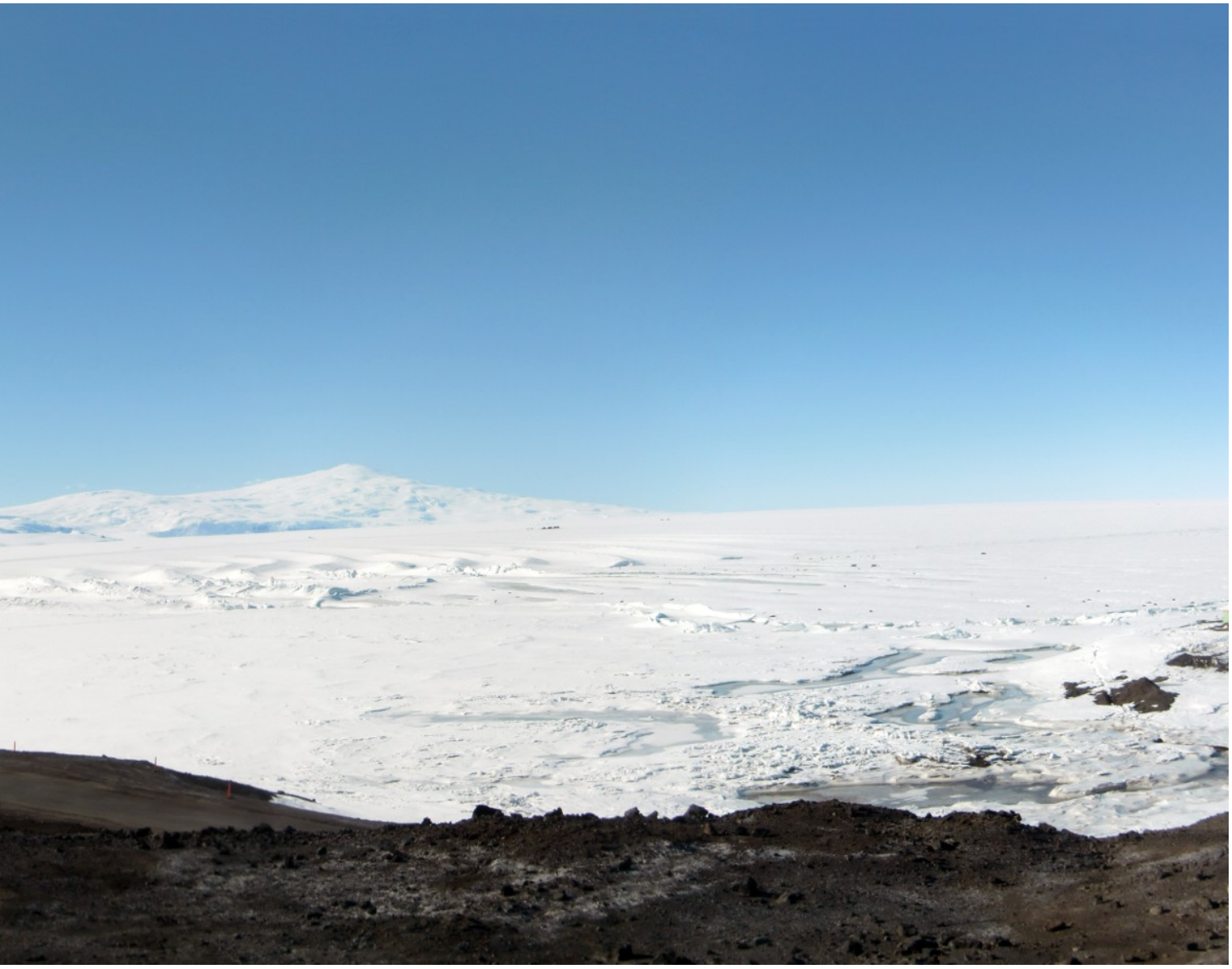
On January 22 an opportunity arose to visit the store at New Zealand's Scott Base—together with James, Sam and Elisa—where I bought a couple of last minute gifts. Conditions were mostly cloudy, but the occasional clear views around McMurdo were a confirmation that the actual visibility was good.

My wish came true on January 23, and the panoramas on pages 102 to 107 speak for themselves. A bright sun under perfectly clear skies allowed me to witness the imposing beauty of the twin volcanoes of Ross Island: Mount Erebus and Mount Terror. Two smaller islets, appropriately named as White Island and Black Island, looked very conspicuous in the distance across the ice shelf, while Mount Discovery and the mountains of the Royal Society Range—both a part of continental Antarctica—rose prominently across the frozen seawater at the far side of McMurdo Sound. The air was so transparent that one could see mountains as far as 100 kilometers away, yet they appeared like no distance at all.

The views that I got that day were so striking that they have remained permanently etched in my mind. I have to add that, under the right weather conditions, Antarctica is truly a photographer's dream.

Armando preparing to leave McMurdo for Scott Base. Observation Hill is behind. January 22, 2015 at 3:06 pm.

The road from Scott Base to McMurdo Station, with Observation Hill in the background. January 23, 2015 at 2:48 pm.



A 100-degree panorama of the twin volcanoes of Ross Island.
This view to the northeast, looking from the coast into the island's mountainous interior,
was obtained a few steps outside of New Zealand's Scott Base.

The contrast of the dark, volcanic soil with the ice is particularly striking in this photograph.
Mount Erebus—which lies 42 kilometers away—can be seen with a plume of smoke,
while Mount Terror is to its right and the inconspicuous Mount Terra Nova lies in the middle.

January 23, 2015 at 3:07 pm.

Mount Erebus as seen from the outskirts of Scott Base.
January 23, 2015 at 3:10 pm.

A 90-degree panorama looking due south from the road in Ross Island.
Pressure ridges can be seen in the frozen seawater right out of the coast,
while the flat, featureless, Ross Ice Shelf which borders the ocean lies behind.

White Island is plainly visible farther out in the background, followed by Black Island to its right.
Mount Discovery—an inactive volcano about 75 kilometers away—is seen further to the right,
with the Brown Peninsula of mainland Antarctica along the foreground at the base of the volcano.

January 23, 2015 at 2:57 pm.

12. Return to New Zealand and the journey back home

When I returned from McMurdo to Christchurch, New Zealand, on January 24, 2015, I saw a sunset, a twilight, the moon and the stars for the first time in 18 days. The colors of dusk and even the twinkling of the stars were especially conspicuous after almost three weeks of continuous daylight. A four-day, waxing crescent moon—which I found lovelier than ever—hanged low in the northwest, about to set. But there was something different, a tilt where the sunlit side was flipped when compared to what I was used to see at home in the northern hemisphere. The bright limb was left instead of right.

A number of asterisms that are either invisible or hard to spot from the northern hemisphere appeared distinct and unmistakable in New Zealand. The first-magnitude stars Canopus and Achernar both shone near the zenith, while another famous pair, namely α Centauri and β Centauri, crawled low in the south. The Southern Cross—a national symbol of New Zealand and a prominent feature of its flag—hovered in the southeast after emerging from the depths of its circumpolar path. Sirius—the brightest star in the sky—was seen high in the east, while the constellation Orion was observed in an inverted position, where the red star Betelgeuse lay at the bottom and bluish Rigel on top. Seeing Orion upside down from a latitude of 43° south was something that, while expected, I still found novel and amusing.

This quick glance at the moon and the stars, plus a relaxing warm bath at the hotel room, was all it took for me to get back to normal life again after my three-week stay in Antarctica.

My stopovers in New Zealand were far too brief, lasting only 32 hours (in early January) and 14 hours (this one in late January). I was wanting to see the Christchurch Botanic Gardens, or even do the tour of Edoras from *The Lord of the Rings* film series, which sets out from Christchurch on a two-hour drive to Mount Potts. A longer stay in this beautiful country would have been a delight, but well, duty calls.

I arose the following morning feeling very refreshed for the journey back home, one that would take me across the Pacific Ocean and then all the way to the Caribbean, lasting over 24 hours and covering just shy of 20,000 kilometers in the air. First I flew from Christchurch to Sydney, where I got a chance to go online and answer a few e-mails during my 6-hour layover. The flight from Australia to North America was particularly enjoyable, as the airplane was almost empty and I had an entire row to myself. I ate well and the 15½-hour trip resulted in not only the lengthiest, but my best flying experience so far.

I arrived in the United States via Dallas, Texas, where I regained cell phone service and went on to dial my first wireless call in over three weeks. I boarded what supposedly would be my final flight, but an airplane malfunction forced us to return to Dallas after traveling for about an hour. We safely got back, and the airline arranged at once for another plane and put us again on our way to the island.

On January 26, 2015 at 3:00 am I landed at the airport near San Juan, Puerto Rico, where I was greeted and picked up by a female friend and admirer who had been a follower of my PolarTREC journals. She drove me home where I slept for a while, reporting to work six hours later on that same Monday. The 17-hour jet lag that I suffered upon my return felt worse that at my arrival in Antarctica earlier in the month—where I barely experienced any ill effects, either from the jet lag or whatever else—and took approximately one week to subside. But all in all, I felt a powerful sense of accomplishment. I was jubilant with the successful completion of my work with IceCube, and moreover, I was grateful to God that the journey went smoothly and every single detail fell into place so perfectly.

13. Interview with Puerto Rican newspaper *El Nuevo Día*

I immediately settled back into my normal routine, but it still took a few days to overcome the tiredness from the jet lag. Soon I started feeling very at ease, and in February 4 went on to give a short talk to a group of 5th and 6th grade students at Colegio Puertorriqueño Marinel, a private school in Levittown, Puerto Rico, that I have been visiting as a guest speaker for over ten years.

On February 18, 2015 I gave the first large-scale presentation on my PolarTREC expedition before the *Puerto Rico Astronomy Society* (PRAS), where I serve as an advisor and former president. This lecture was immensely gratifying, as I found myself surrounded by the people that share my interests and whose company I enjoy. The event achieved substantial media coverage, a sample of which appears below.

The late Víctor Román—who asides from being PRAS' Vice President and an editor for its monthly magazine, was also my right-hand colleague and unconditional friend—got in contact with *El Nuevo Día*, the newspaper with the highest circulation in the island and a readership of 1.2 million. My story caught immediate interest and the paper sent Brenda I. Peña, a talented journalist who upon listening my two-hour lecture was able to capture my journey in its essence and with a fresh perspective.

The 900-word interview appeared both as a web feature on February 19, and as a whole-page, full-color item on page 59 in the February 20 edition of *El Nuevo Día*. Much appropriately, this turned out as the most comprehensive media report that would come out on my work in Antarctica, as well as the most widely viewed of all, achieving 3,724 likes and 68 comments after three days. Other local periodicals such as *Primera Hora* and *Índice* followed suit and carried the interview, too.

A note on language: Puerto Ricans often identify themselves as "Boricua", derived from the Taíno word "Borikén", to illustrate their recognition of the island's Taíno heritage. The word Borikén translates to "the great land of the valiant and noble Lord". Borikén was used by the original Taíno population to refer to the island of Puerto Rico before the arrival of the Spanish. (Adapted from Wikipedia.)

THE STORY OF A 'BORICUA' IN THE SOUTH POLE
He spent 18 days without seeing the sunset

By Brenda I. Peña-López. Translated from the Spanish by Michelle Kantrow-Vázquez
February 19, 2015 — 5:53 pm

El Nuevo Día
http://www.elnuevodia.com/noticias/locales/nota/relatodeunboricuaenelpolosur-2009908/

Professor Armando Caussade had studied much about Antarctica and the South Pole, but in his view, books fall short when analyzing all of the knowledge acquired in the 18 days he spent in the distant and cold continent.

He gained a significant amount of scientific knowledge as part of his participation in the PolarTREC program—administered by the Arctic Research Consortium of the United States and sponsored by the

National Science Foundation—but at the personal level, one of the highest rewards was to understand the experience of polar explorers Norwegian Roald Amundsen and Brit Robert Falcon Scott.

"I always had these two gentlemen on my mind; Amundsen, who arrived in 1911, and Scott, in 1912. The latter, who made it there, lost his life on the way back. When I climbed all those hills [in Ross Island] and hiked around the snow, I began to understand what these people experienced and what they saw when they came to this place," he said highlighting the grueling routines.

Two things left Caussade in awe: the reflecting effect the sun caused on the small ice crystals that are embedded in the ground, and 24 hours of sunlight during the austral summer, which happens in January.

Two things left Caussade in awe: the reflecting effect the sun caused on the small ice crystals, and 24 hours of sunlight during the austral summer, which happens in January.

"I had studied a lot, I had read a lot, but when I got off the plane at the South Pole, I saw what the books don't tell you because pictures don't capture it. It's as if it were covered in diamonds. What you see are small pieces of ice—there are some pieces that are semitransparent—that upon reflecting the sun, you see it. The cool thing is that when you're moving around, some go off and others light up," said the educator, while emphasizing that this effect only occurs on a sunny day.

He said he felt the same fascination upon returning to New Zealand, when seeing his first sunset in 18 days.

"I hadn't realized it until I got to New Zealand, after 18 days in Antarctica with the sun out all the time for 18 days, that I had had no nights during all that time. I saw that sunset and I enjoyed it so much because I had spent 18 days without seeing one," he added.

He also also said the adventure at the South Pole made him appreciate the planet's geographical diversity.

"I had never seen a volcano, and much less expelling materials, or a sky as blue as that one because a good chunk of the atmosphere is beneath one's feet. Seeing a place like that is an experience that touches you in many ways. What you see is very different, for example, from what you'd see in your backyard, what you feel is something different, like the cold you feel on your face, the air you breathe is pure. It's an experience that involves all the senses," he said.

In turn, he said Antarctica is a well-regulated area. Throwing trash on the ground or even disturbing the natives species could represent the expulsion of the visitor who violates the rules of the place, which is characterized as a place whose only human existence is that of the professionals working in research stations.

Among these research venues is the IceCube Neutrino Observatory, located at the Amundsen–Scott South Pole Station, and home to the world's largest neutrino telescope. It was there that the astronomy professor deployed as part of his selection to participate in the PolarTREC program.

The importance of the research on these subatomic particles is to validate certain scientific theories, Caussade said on Wednesday [February 18, 2015], when speaking of his experience before members of the *Puerto Rico Astronomy Society,* at the Caribbean University in Bayamón.

"The theories and models we have predict that these violent events in the universe, such as supermassive black holes—which is what is believed to be in the center of galaxies—and neutron stars, in addition to exploding stars known as supernovas, produce neutrinos. These are intense processes that, fortunately for us, occur very far away. If neutrinos weren't detected, the problem would be that all these theories would fall apart and we would have to rewrite almost every science book," said Caussade.

Since the IceCube Laboratory began full operation in 2010, 37 neutrino events of cosmic origin have been detected, he said.

"We know that the theories and models that we have are headed in the right direction. We would have experienced a huge shock if those 37 events had not been registered. As neutrinos continue to be detected, the questions that we'll want to answer are where do they come from, if from a supernova, or from a supermassive black hole..." he explained.

In IceCube, his work specifically focused on the troubleshooting of instrument performance, as well as support, maintenance and measurement of ice coverage, he told this media outlet.

The educator reiterated his interest in delivering the presentation he offered Wednesday at Amphitheater 5 of Caribbean University in Bayamón, free of charge, to different groups throughout the island. By talking about his experience in Antarctica, he seeks to motivate young people to pursue studies in science.

14. Spreading the word

In early February I began to put some order to the copious amount of material that I had gathered, especially visual content which spanned a total of 1,448 of my own photographs, plus additional images from other sources. I used computer software to enhance the quality of a number of selected pictures—the ones that would later be featured in my presentations—and to digitally stitch over 20 panoramas.

Starting in mid-February I went on to share the experience both at the classroom and with the public, reaching 60 educators, 190 students, and about 1,200 people in just over three months. I taught 80 hours of class—at three different venues and at every level of education—where my work at the Pole was directly discussed, out of 200 hours that I logged throughout the semester. Additionally, I had the privilege of lecturing on the topics of Antarctica and IceCube as a guest speaker on 27 occasions, as of May 27, 2015. Public interest remained consistently high, and I was informed about people memorizing my classes and lectures and then retelling them, complete with details, to others.

Also in February I was given the cover page at *El Observador*, a neat surprise that had been covertly arranged by Greg García and Víctor Román of the *Puerto Rico Astronomy Society* (PRAS). Furthermore, PRAS put valuable resources at my disposal, including access to an event coordinator, first Natalia Sosa and then Sylka J. Quiñones, who both expertly managed my agenda of speaking engagements, as well as a press advisor, Juan Villafañe (a long-time associate and close friend), whose devoted work allowed me to score over 100 media hits and two major television interviews.

My level of performance during deployment in Antarctica was rated by Jim Madsen as "outstanding" in the official *PolarTREC Post-field Report* dated February 28, 2015. Jim further stated that I "took advantage of every opportunity, stayed focused, and was really impressive as a team member." The report was compiled by Sarah Bartholow (of PolarTREC) following a conference call with Jim and me.

On May 27 I submitted my *PolarTREC Public Science Report*, a detailed account that is written by participant teachers upon return from the field, dwelling on the benefits they gained from the expedition and the impact on their teaching and public outreach. The report is a public document that can be obtained online at the following address: http://www.polartrec.com/resources/report/public-science-report-armando-caussade/. Four weeks later, on June 24, I attended the *PolarTREC Antarctic Wrap-Up Webinar*, a live Internet presentation where I shared the results of my expedition with fellow teachers.

I met with Jim at the University of Wisconsin–River Falls where, starting July 6, I again taught for two weeks as an Upward Bound summer instructor. Also, in the 12-month period between May 28, 2015 and May 31, 2016, I would do an additional 25 invited presentations (not counting class lectures) including one as a keynote speaker during the 2016 Puerto Rico Regional Competition of FameLab. And in September 2016 PolarTREC appointed me to the Selection Committee for the 2017–2018 field season, which will allow me to participate in the review process leading to a finalist pool of applicants.

And so the story ends, at least for now. As far as my knowledge goes I became the first actual resident of Puerto Rico to ever visit the Amundsen–Scott South Pole Station. This I state with humility, to encourage people to explore their potential and to achieve great goals in their lives. If my story serves as an inspiration to the Puerto Rican community, and moreover, if it helps to stimulate an interest in science among the public and particularly children, my purpose will then be achieved.

Television interview with Carmen Jovet at WIPR-TV (channel 6).
February 24, 2015 — San Juan, Puerto Rico.
Credit: Carmen Jovet, Ahora Podemos Hablar / PR Public Broadcasting Corporation.

Television interview with Silverio Pérez at WIPR-TV (channel 6).
March 2, 2015 — San Juan, Puerto Rico.
Credit: Silverio Pérez, ¿Qué es lo que pasa? / PR Public Broadcasting Corporation.

Lecture to the Puerto Rico Astronomy Society and the press, given at Caribbean University.
February 18, 2015 — Bayamón, Puerto Rico.
Credit: Gloria M. Isidro, Caribbean University.

Lecture before students, faculty and the press at Bayamón Central University.
March 25, 2015 — Bayamón, Puerto Rico.
Credit: Elaine Núñez, Bayamón Central University.

Lecture before students at SU Pedro María Dominicci Elementary and Middle School.
September 29, 2015 — Cidra, Puerto Rico.
Credit: Javier Flores, Puerto Rico Department of Education.

Lecture to the Boys & Girls Club, given at María M. Simmons Elementary School.
October 15, 2015 — Vieques, Puerto Rico.
Credit: Ángel Negrón, Puerto Rico Astronomy Society.

PART II:

THE JOURNALS

January 2. Departing to the South Pole

Today, January 2, 2015, I will be departing to the South Pole. The purpose of this journey is to participate, as a PolarTREC teacher, in a field expedition where I will conduct three weeks of maintenance and support work at the IceCube Neutrino Observatory. The adventure is about to begin!

There has been meaningful media coverage about my journey in the last few days, and Internet links to major press clippings will be posted soon. I will be doing two—or possibly three—live video presentations from the Pole between January 13 and January 17, with at least one of them in Spanish. Registration via the IceCube website may be necessary to participate, so make sure to sign up early. Stay tuned for details.

Lots of people have been calling and e-mailing to express their support, and I am grateful to everyone. I would like to personally thank each and every person, but due to the high volume of messages this may not be possible at the time. But rest assured that I read everything in my inbox. Please be aware that I may not have access to LinkedIn or to my personal e-mail during my stay in Antarctica. Priority will be given to communication that is channeled using my PolarTREC e-mail or the PolarTREC website.

I will maintain an Internet blog—hosted by PolarTREC—in which I will post daily journals in both English and Spanish to keep the public informed of everything I do in Antarctica. Please refer to the link below. There is a comments section that I can access and which can be used to contact me.

Armando Caussade: Ice Cube Neutrino Observatory 2014
http://www.polartrec.com/expeditions/ice-cube-neutrino-observatory-2014

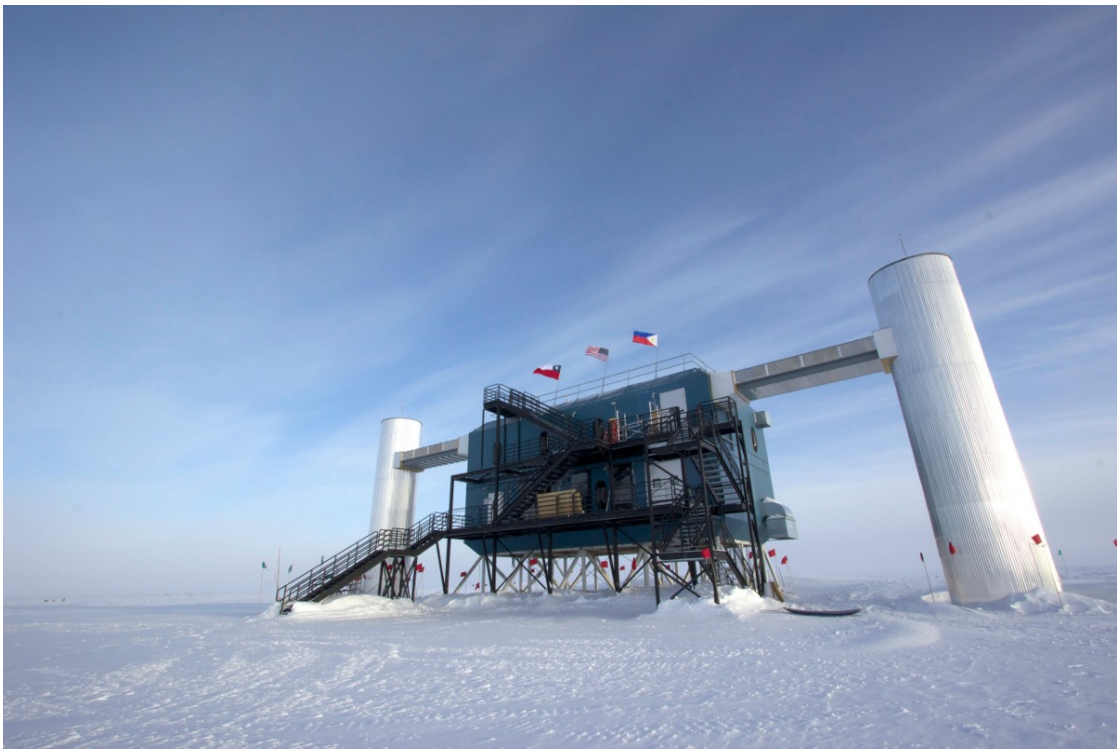
I will be available to do free lectures and media interviews after my return from the field in late January. Inquiries are welcome.

My expedition has been scheduled as follows:

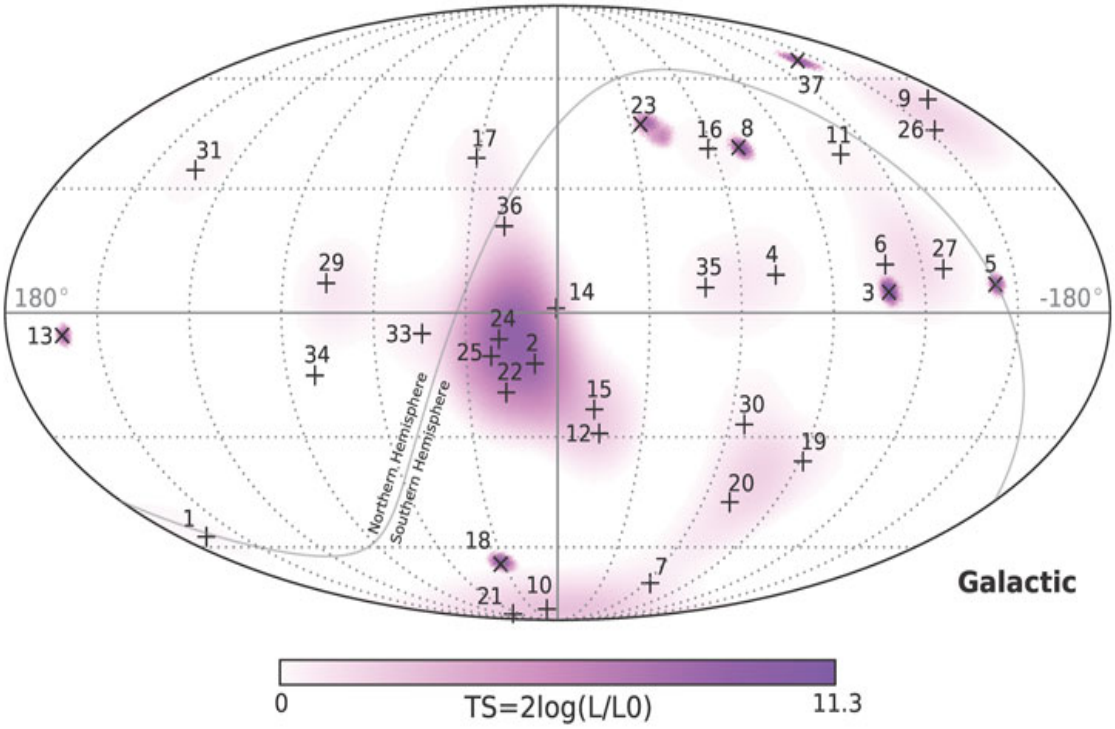
Friday, January 2, 2015:	Departure from San Juan, Puerto Rico.
Tuesday, January 6, 2015:	Arrival at Amundsen–Scott South Pole Station.
Tuesday, January 20, 2015:	Departure from Amundsen–Scott South Pole Station.
Thursday, January 22, 2015:	Arrival at San Juan, Puerto Rico.

I will transit through Christchurch, New Zealand, January 5, 2015, and again on January 21.
I will transit through McMurdo Station, in the Antarctic coast, January 6, 2015, and again on January 20.

The schedule depends on contingencies such as weather and may change at any time.



The laboratory building at the IceCube Neutrino Observatory.
Credit: Felipe Pedreros, IceCube / NSF.



All-sky map with arrival directions of the 37 high-energy neutrino events found in IceCube after analyzing three years of data (May 2010 to May 2013). Credit: IceCube Collaboration.

January 5. Arrival in New Zealand and orientation at USAP

Today at 9:00 am I was picked up at the Pavilions hotel by a shuttle bus and taken to the United States Antarctic Program (USAP) facilities here in Christchurch, New Zealand. It is a requirement for anyone traveling to Antarctica under sponsorship of the USAP to report here first, in order to attend orientation and also to collect the cold weather gear that is issued by the program.

At my arrival at the USAP Clothing Distribution Center (CDC) I met Hans Niederhausen and James Casey who are likewise heading to the IceCube Neutrino Observatory. I had already exchanged a couple of e-mails with Hans in the days prior to my departure, and it was gratifying when we finally met in person. Additionally, I saw maybe a dozen people from different research projects in the continent who, like us, also reported to the CDC and with whom we both chatted and exchanged impressions.

I had already been assigned my extreme cold weather clothing, which comes carefully packed into two large orange bags. The USAP knew exactly what would be right for me since two months before my departure I had filled a form on clothing sizes. I tried the clothing right away and fortunately everything was the right fit. A couple of individuals needed to exchange a few items, though, something that can be easily done through the on-site warehouse.

As part of orientation we all sat down and watched four short videos for about half an hour, which emphasized travel logistics and safety precautions, as well as the stringent ecological regulations that are in effect in Antarctica. Briefings like these are given to everyone—whether a tourist or a scientist—before ever setting foot on the continent. Afterwards, we all went on to complete additional requirements such as medical and information technology clearances. Around noon, Hans and I moved to the computer room from where we will both be posting to our respective websites.

We will be released later on in the day, returning to the hotel with some time to spare and maybe a quick outing for dinner. Of course, we have been asked to report again tomorrow at 6:30 am to prepare for our tentative flight to McMurdo Station on the Antarctic coast. After 24 hours or so there, we will catch yet another airplane which will take us to the South Pole.

Post scriptum

Since this journal was posted so early in the day I wanted to add a few notes. Hans and I left for lunch very late, around 1:45 pm, taking a few pictures out in the street (two of which I am appending to the journal) as we left the International Antarctic Center where the USAP facilities are located. We returned after a quick meal and did not leave for the hotel until about 3:45 pm, as we still had errands to run.

At 5:30 pm we met with James—who was also staying at Pavilions—and all three went for a walk in downtown Christchurch, as the hotel is conveniently located just a few blocks from all the main attractions. We moved south on Papanui Road, stopping for a few pictures next to the clock tower at the crossroad of Victoria, Montreal and Salisbury streets. We continued on Victoria Street down to Avon River, and toured around the central city for at least a couple of hours.

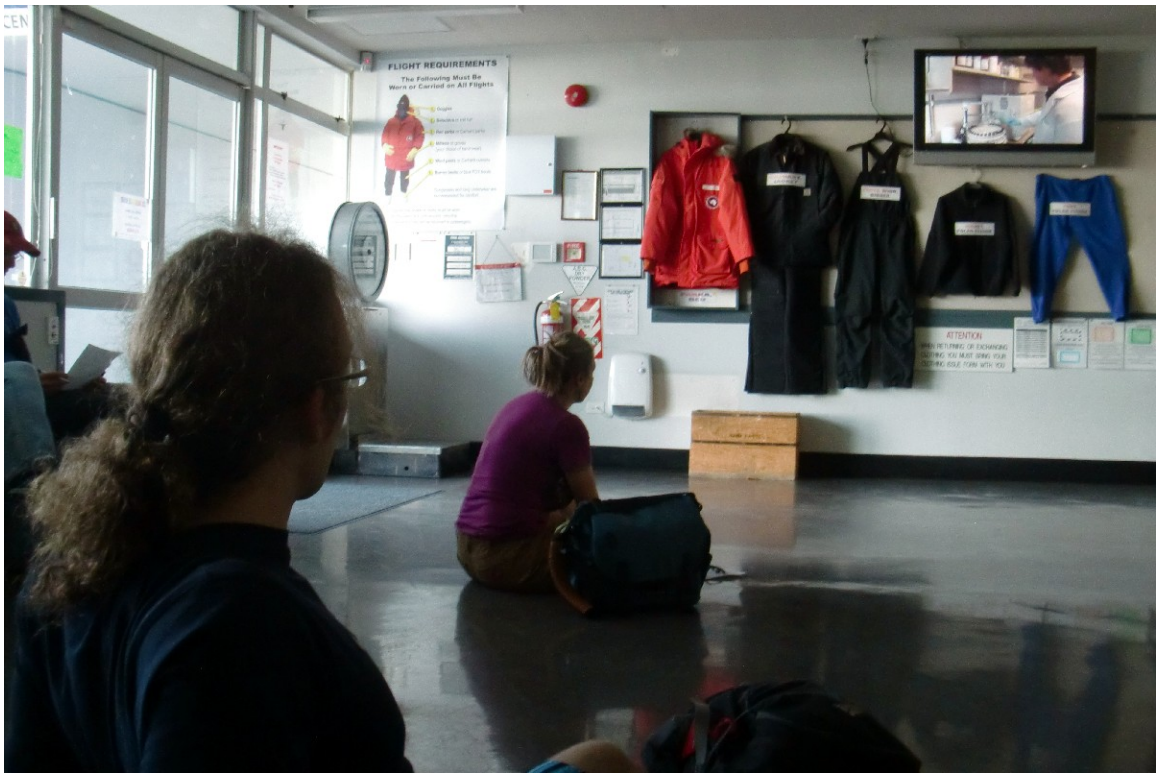
Finally we sat for dinner in the outdoor area at *The Brewers Arm* on Papanui Road, where we chatted for over an hour before returning to the hotel about 10:00 pm.

Clothing Distribution Center at the United States Antarctic Program (USAP) in Christchurch, New Zealand.

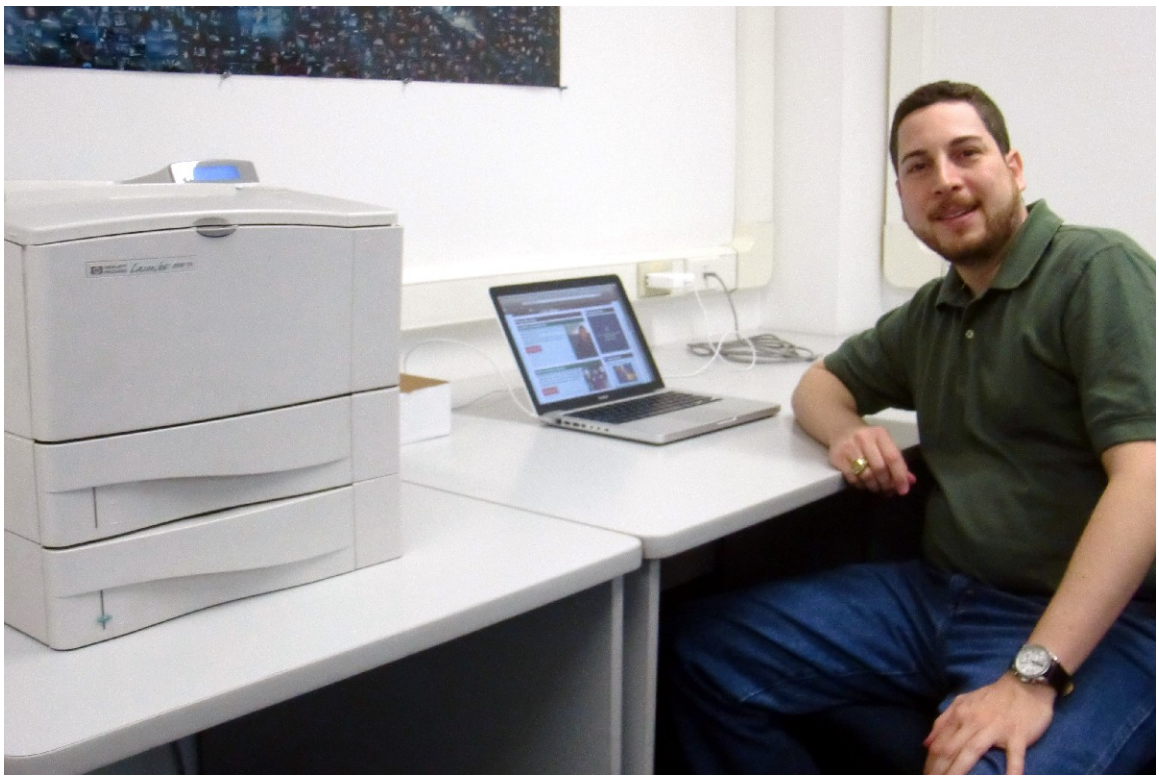
Each person got two orange bags full of extreme cold weather clothing.

Armando trying out his red parka.

Warehouse at the Clothing Distribution Center.



Short videos are shown during orientation at the USAP. Hans is at left.



Preparing to post a PolarTREC journal at the USAP computer room.

Leaving the International Antarctic Center, where the USAP facilities are located.

Near the International Antarctic Center, next to Christchurch International Airport.

January 6. Flight to Antarctica and arrival at McMurdo Station

I woke up today at 5:15 am with great excitement, knowing that in a couple of hours I would be boarding my flight to Antarctica. Here is a summary of this exciting day.

Yesterday we had left the United States Antarctic Program (USAP) facility here in Christchurch at around 3:45 pm, and later on headed off to downtown where we stopped for dinner. I went to bed at about 10:00 pm and woke up feeling well rested and refreshed. I picked up my luggage—which I had already packed the night before—and checked out of Pavilions Hotel. A shuttle bus came for us at exactly 6:00 am, as per the requirement to report to USAP at 6:30 am. There were about eight people in the vehicle, including three members of IceCube: James, Hans and I.

A few minutes later we arrived at the USAP building. I collected the extreme cold weather gear that I had been issued—the same items that I had tried on yesterday—and put them in. This is standard procedure when flying to, from or throughout the continent, as no one is permitted to board an Antarctic airplane unless wearing the red USAP parka, wind pants, boots, plus three other key items. There were multiple posters on the walls detailing all procedures and explaining everything.

At 7:20 am we went in for a briefing explaining all aspects of travel to the continent that USAP participants and grantees need to know. Travel logistics were again explained, as well as security and safety precautions, plus the strict ecological guidelines to abide to while visiting Antarctica. At 8:00 am we took yet another bus that transported us to the airfield. We all boarded the ski-equipped LC-130 airplane, engines were started and we took to the air at exactly 9:25 am. Flight time to McMurdo Station would turn out to be exactly eight hours, just as told.

Thirty-six people were in the airplane: 32 passengers and 4 crew members. There were among us a number of participants of the Antarctica New Zealand program, who were headed for New Zealand's Scott Base, which is located in Ross Island just steps away from McMurdo Station. Once inside the plane we were allowed to shed part of our cold weather gear, on condition that it remained in hand for use immediately after landing.

Unlike regular commercial airplanes, cargo aircraft—such as the one I flew in—use windows very sparingly. Yet, there usually are two or three small windows on each side, and I was fortunate to sit exactly by one of those. I glanced out and started seeing drift ice in the ocean about halfway during the trip, which would translate into a latitude of approximately 60° south. Later on, beginning about three quarters of the way—around latitude 70° and beyond—I began seeing large packs of ice.

The plane landed at 5:25 pm in the northern edge of the Ross Ice Shelf, about 12 kilometers from McMurdo Station. There are at present three airfields serving McMurdo, and I am almost certain that the one that we used was Williams Field. The actual landing of the ski-equipped airplane felt softer than that of commercial aircraft, and the airliner went on gliding over the ice for a few kilometers before finally stopping down. Although fast, the maneuvering felt extremely smooth and stable. The glide was absolutely graceful and is something that deserves to be experienced.

The Ross Ice Shelf is a large, flat block of freshwater ice floating atop the ocean—an outgrowth of inland glaciers pushing out into the sea—but the section we landed in borders with Ross Island, which

lies off the coast of Antarctica proper. Landing in the ice shelf allowed us to experience an amazing vista where ice is everywhere and the surface looks completely bleached [see photograph at the bottom of page 131]. Since it was cloudy, the sky also looked whitish. I found the monochromatic scenery that was laid before me a beautiful, impressive sight, but the view may perhaps be overwhelming for the unprepared. The temperature was a balmy 2 °C, warmer than what the landscape seemingly conveyed.

A USAP vehicle was already waiting for us: the venerable 'Ivan' the Terra Bus, a 30-metric-ton truck that has been transporting people around McMurdo for over 20 years. We slowly crawled up a hill on an unpaved—but very well kept—road built over dark, volcanic gravel. Safety is paramount in Antarctica and vehicles must observe strict speed limits—25 kilometers per hour, in this case.

The ride to McMurdo itself took about half an hour, including a quick stop near Scott Base to drop some eight passengers. Around 6:00 pm we officially arrived in town and were welcomed at the National Science Foundation office ("the Chalet") by the station manager who gave us a 30-minute briefing. We then headed to building 155 to get our room assignments.

Following a short break for dinner I went out for a walk with Hans and two other people. Naturally, we ended up hiking the *Observation Hill Summit Track*—a quick trip that does not require a permit—arriving at the top near the memorial monument to Robert Falcon Scott where we remained for about 20 minutes. Climbing the hill is like a rite of passage for newcomers to McMurdo. We returned to the room in building 155 around 10:00 pm to get some sleep, but knowing our stay in McMurdo will be short we promptly went out again.

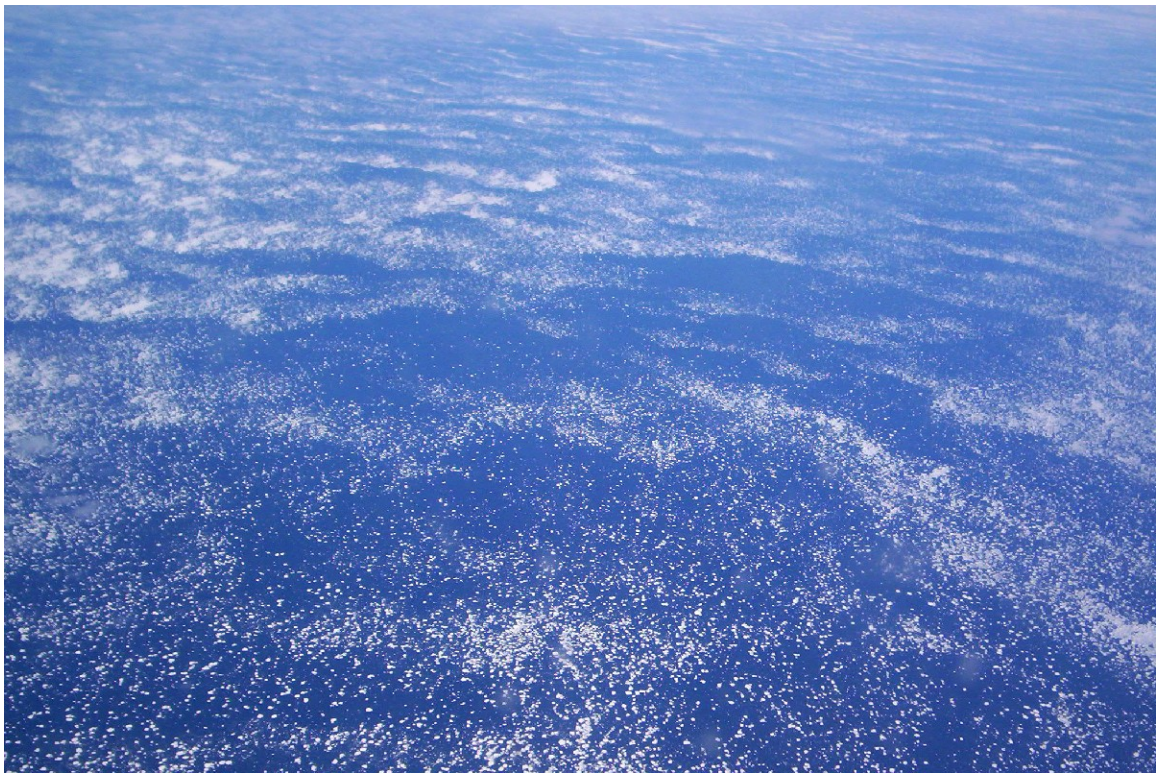
Hans and I joined with James for a tour through town, shooting a number of pictures along the way. Time went past like a snap of the fingers, and before I knew it was already 11:00 pm. Considering that here the sun is up all the time, one simply does not notice how late it gets. I went out wearing my sunglasses which is vital in Antarctica, as the ozone hole in the atmosphere opens up right above the continent and dangerous levels of ultraviolet light from the sun reach down to ground level. But then, I realized that I could not recall ever wearing sunglasses at eleven in the evening!

5:56 am: Boarding the bus to the USAP facility in Christchurch, New Zealand.

6:44 am: Armando getting ready with his extreme cold weather gear.

8:25 am: Boarding the LC-130 airplane to Antarctica.

9:37 am: Inside the LC-130 while flying down to Antarctica.



2:24 pm: The view from the airplane, around latitude 64° south.

4:14 pm: The view further on, around latitude 73° south.

5:25 pm: Arrival at Williams Field, about 12 kilometers away from McMurdo Station.

5:26 pm: Scenery around Williams Field as Armando stepped out of the airplane. The airfield is located in the Ross Ice Shelf at a latitude of 78° south.

6:11 pm: Arrival at the NSF Antarctic Office (the Chalet) in McMurdo Station. This building is the usual first stop for newcomers to Antarctica.

11:11 pm: With the wooden McMurdo sign at eleven in the evening. Conditions were cloudy and calm. Temperature was about 1 °C .

January 7. Extended stay in McMurdo and penguin sighting

The weather has not been very cooperative lately, so it seems that I will stay for a couple of days here at McMurdo Station on the coast of Antarctica. Our flight to the South Pole has already been postponed two times, yet for the moment everything is fine down here. We reported to the MCC (Movement Control Center) at 3:15 pm and again at 4:15 pm, as scheduled, but to no avail.

Travel in Antarctica depends strongly on external factors such as weather, so plans and schedules need to be flexible. An unwritten but essential requirement for people deploying to the ice is to see the brighter side of things and learn to take things as they come. Since the beginning I knew it might be like this, so I was prepared for the challenge. I also recall the words from my mentor, Jim Madsen, who always stressed the need to be ready and prepared for the unexpected.

McMurdo Station (reachable by both sea and air) is the largest of three permanent United States stations in the continent, with over one thousand people working at once every summer. Additionally, there is Palmer Station in the Antarctic Peninsula (supplied from Chile and reachable only by sea) and the Amundsen–Scott South Pole Station (normally accessible by air, and exceptionally by land) where I will travel within the next few days. Because of McMurdo's status as the primary facility for United States operations in Antarctica—plus its convenient location about three-fourths of the way from New Zealand to the Pole—people and cargo traveling to the South Pole must first pass through McMurdo.

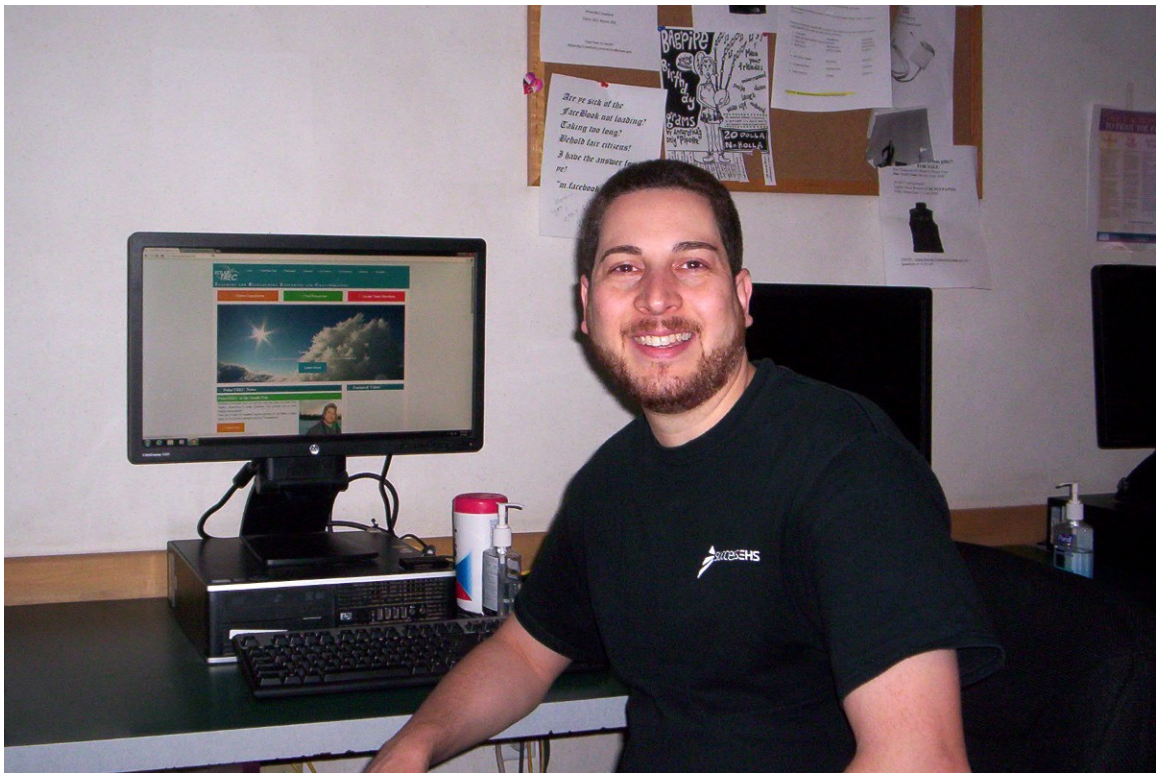
So far my stay has been first class, and I cannot put it any other way. Awesome in every sense. The station is large, modern and well equipped, with comfortable living quarters and good food. Today they had a Mexican buffet and I finally had my Mexican fix. I have had lots of time to walk around and even get some rest, which was great as the last time I had slept an eight-hour night had been December 31.

I had previously written about two other members of IceCube with whom I will be working, so I will take a moment to introduce them. They are Hans Niederhausen from Stony Brook University in New York, and James Casey from the Georgia Institute of Technology. Hans has deployed to the ice to install an all-sky camera, while James will do some calibration work at the IceCube Laboratory.

Today, during an outing with Hans and James, I experienced a temperature of −4 °C coupled with fierce winds of about 100 kilometers per hour near Captain Scott's Discovery Hut here in McMurdo. This combination yielded a strong windchill that felt quite dramatic. Now I see what the poor Scott had to endure, particularly on those last days of his return trip when the weather turned unpleasant. I have read the story and know all the facts, and had also learned about the geography and the climate patterns before setting foot in Antarctica. But now I have obtained real life experience that puts everything into perspective and allows a better appreciation of everything I had studied so far.

We also sighted a penguin! What we found was an Adélie penguin which was seen at a distance during our hike near Discovery Hut, in the outskirts of the station. Since penguins are unknown of at the South Pole where I will spend the majority of my time, I am glad that I spotted one here in McMurdo.

I will report again to the MCC tomorrow at 7:15 am as I might luckily catch an airplane to the Pole. Naturally I am looking forward to my arrival at the IceCube Laboratory, where I will meet the rest of the team and assist with maintenance work at the observatory.



Writing a PolarTREC journal at the computer room in building 155 in McMurdo Station.

Main hallway (colloquially known as highway #1) in building 155 in McMurdo Station.

Left to right: Hans Niederhausen, James Casey and Armando Caussade.

Enjoying dinner. Left to right: Jamie, Armando, James and Hans.

This is what the combined chill of the cold air plus the breeze feels like.
Credit: Hans Niederhausen, IceCube / NSF.

An Adélie penguin near Discovery Hut, in the outskirts of McMurdo Station.
Credit: Hans Niederhausen, IceCube / NSF.

January 8. McMurdo Station, Observation Hill and the Hut Point Ridge

Well, our flight was postponed again today. As instructed, we reported to the MCC at 7:15 am and again at 3:15 pm, but the flights had been canceled. But I hear people say that there is an actual chance that tomorrow we could finally fly to the South Pole. As always safety in flying is vital in Antarctica, so flights are postponed if there is any weather concern whatsoever.

Today was the first day of reasonably clear skies here in McMurdo. I had devised a plan for an outing—as an improvement in the weather was expected—and it was to go out after lunch, between 1:00 pm and 3:00 pm, when the sun is highest above the horizon (about 34° at this specific place and time of the year). The temperature was just above freezing with a light breeze. Indeed it felt wonderful, very mild and pleasant. I put on all my gear and was was perhaps overdressed for the weather, but my skirmish with the cold yesterday is still fresh and I would not run any risks. I walked over to the area around Discovery Hut and did an extensive photo shoot, which allowed me obtain some stunning panoramic shots. My plan paid out as the rays from the 34-degree-elevation sun really brought out the details in the frozen seawater of McMurdo Sound and in the volcanic terrain from the surrounding hills of Hut Point Ridge. With photography, good illumination from the right direction is the key.

A friend and PolarTREC alumni, John Wood, asked what do I think so far. An answer can be found in one of the pictures that I posted on January 6 [see photograph at the bottom of page 131]. This impressive sight is not exactly of the so-called *Antarctic whiteout*—which can be a severe weather event—but rather it shows average conditions for the season and the location we are at. When I stepped out of the airplane I was astonished to be greeted with a scene like that, even as I was already familiar with similar views from Internet websites and television documentaries. Arriving in Antarctica is an amazing experience because when you see, hear and feel the surroundings your five senses are awakened, and it is simply not possible to attain something like that from a television screen or a computer monitor. As I explained in an earlier post, to be confronted with a monochromatic, minimal landscape all around can be overwhelming or even frightening for the unprepared. That could be one way of putting it.

John also asked if, so far, this is how I expected it to be. And I have to say that everything has turned out even better than expected. Much better, in every sense of the word. As told, the views are real-life, panoramic and enveloping. I hiked to Observation Hill the other day at my arrival, and upon reaching the summit I realized that I had finally reached the continent of extremes. I looked down and beheld the Ross Ice Shelf, White Island and Black Island, as well as the Royal Society Mountain Range in the Antarctica mainland. I had seen tons of pictures before, but none compares to what I actually experienced in terms of color, detail and immersiveness. And then, there is the sense of touch. Ice, snow and frost cannot be divorced from cold, and as I felt the cool breeze over my face, and the sparse snow flurries that flew in the air swirling with the breeze, I understood what Antarctica really is like.

Finally, I would like to share a couple of video clips, one in English and one in Spanish. Viewer comments for the Spanish version started to appear within moments of uploading, stating that a number of my own students in Puerto Rico are jumping up in joy with the videos. I am so grateful for that and I will certainly attempt to do additional clips, but I must also make people aware that in Antarctica it can be challenging to upload any video material because Internet bandwidth is limited. In order to upload, I ended up waiting until 11:30 pm after most people retire to bed and go offline, to make the files go up faster. I cannot promise anything, but I will try to post new clips in the future.

The videos were selfies but they turned up pretty good, and they do a superb job at capturing the surrounding scenery. Also, the sound of wind makes the video feel real. I hope you enjoy them.

English: Hello PolarTREC, from Armando Caussade in Antarctica
January 8, 2015 at 2:33 pm. http://www.youtube.com/watch?v=nKyxoo_wQAM

Spanish: Hello EcoSTEAM @ Pedro Rivera-Molina School, from Armando Caussade in Antarctica
January 8, 2015 at 2:33 pm. http://www.youtube.com/watch?v=j90lnCjbsLU

Halfway to the summit of Observation Hill.
Credit: Hans Niederhausen, IceCube / NSF.

McMurdo Station as seen from halfway to the summit of Observation Hill.

Enjoying the view from the summit of Observation Hill.
Left to right: Keith, Armando and Jamie. Credit: Hans Niederhausen, IceCube / NSF.

At the summit of Observation Hill in McMurdo Station.
Temperature was a balmy 2 °C with very light wind.

Outside view of building 155, where Armando lodged while in McMurdo.

The Chapel of the Snows in McMurdo.

Observation Hill as seen from Discovery Hut, in the outskirts of McMurdo Station.

A view of the hills in the Hut Point Peninsula, a few steps out from McMurdo Station.

McMurdo Sound as seen from Discovery Hut, with Black Island in the background. A row of Weddell seals can be seen lying in the ice just below Black Island.

Selfie photograph taken near Discovery Hut. In the background across McMurdo Sound is Mount Discovery (far left, and partly hidden by clouds) with the hills of Brown Peninsula.

January 9. Midnight sun in McMurdo

Well, after reporting twice to the MCC on building 140—a short but steep 150-meter walk, uphill from building 155—at 12:15 pm and at 3:15 pm, we were postponed again. And since they do not usually fly on weekends, we will likely stay here in McMurdo until Monday, January 12. Reporting to the MCC sometimes entails what is known as *bag drag*, the process of checking in and weighing the luggage.

In spite of that, everything has gone by the book during my three-day stay here. I have had many opportunities to walk around, observe and photograph the area. In addition, food has been a highlight from the beginning, and I cannot recall a single meal that I did not enjoy and relish. And although I am not a fanatic of snack foods, I once succumbed to popcorn which is available around the clock.

I had previously written about the extreme seasonal changes concerning the visibility of the sun from the polar regions, and particularly at (and near) the South Pole. Well, I am now going to share a picture of the midnight sun that I took here in McMurdo very early today, around 1:00 am.

In January McMurdo sees the sun all the time, but in contrast to the Pole—where our star maintains a constant height above the horizon—here at 78° south latitude there is some variation. The sun is seen to move horizontally around the sky in a counterclockwise direction, crossing the meridian an hour after noon, at exactly 1:00 pm (or 2:00 pm under daylight saving time, which is in effect now) when the sun attains 34° above the northern horizon, and then passing through the meridian again after midnight, at exactly 1:00 am with an elevation of 10°. Solar illumination is visibly reduced late in the evening, but daylight remains. Around 7:00 am and 7:00 pm, the sun can be seen due east and west, respectively.

Had we seen a sunny evening instead of clouds, the McMurdo sundial would have displayed a solar shadow at 1:00 am! Also, some people have asked if I have had any difficulties so far going to bed under a 24-hour daylight regime, but I fortunately sleep well and have no issues to report.

On a different note, I wanted to share that we will be attending a lecture tomorrow that is required for people wanting to venture out of McMurdo proper. I have been anticipating this for days, and since we are staying for the weekend I am not going to miss this opportunity to go out and explore. We are planning a three- or four-hour hike of the trails in the surrounding hills here in Ross Island, and we intend to do this as soon as possible after listening to the talk.

The only expectation that I have not been able to address so far in McMurdo might be a decent sight of Mount Erebus, which is located only 42 kilometers away, here in Ross Island. The actual peak is hidden from view by nearby hills that rise above the northern horizon, as viewed from McMurdo itself. Besides, the bad weather that has been plaguing us for days has not allowed for good visibility beyond a few kilometers. But I am optimistic about the possibility of seeing the volcano—as well as obtaining a reasonable camera shot—once we drive back to the airfield, which will happen in the next few days.

Mount Erebus, with a height of 3,794 meters, is not only the southernmost active volcano on Earth, but also the most active hotspot in Antarctica.

Outing in McMurdo Station right after midnight. Local time 1:06 am.

The midnight sun in McMurdo shining behind the clouds. Local time 1:09 am.

A view of McMurdo Station at midnight.

Another view of McMurdo at midnight.

A midnight walk around building 155.

The sundial at McMurdo Station.

January 10. Hut Point Ridge hiking trail near McMurdo

Today's post is going to be a photojournal of my afternoon hike at the *Hut Point Ridge Loop Trail*.

Hans, James and I started the day with the outdoor safety lecture that is given every Saturday at 10:30 am on Crary Lab. This was attended by a dozen people or so who, like us, were wanting to venture out of town. The 30-minute talk emphasizes how to avoid hazards in the Ross Island Trail System, such as falling into a *crevasse*, which is an often invisible and treacherous crack found in an ice field.

The *Ross Island Trail System* includes—in ascending order of length—the Observation Hill Summit Track (0.6 kilometers), the Hillary Track (0.7 kilometers), the Hut Point Ridge Loop Trail (4 kilometers), the Observation Hill Loop Trail (5 kilometers), the Cape Armitage Trail (8 kilometers), and the challenging Castle Rock Loop Trail (16 kilometers) which includes an optional Summit Trail.

After reviewing a map of the area Hans and I proceeded with the hike, which lasted from 4:45 pm to 6:00 pm until a sudden spell of bad weather—with heavy fog, wind and snow—forced us to retreat [see photograph at the bottom of page 152]. Conditions deteriorated rapidly on our return, compelling us to stop just outside of Discovery Hut and take shelter by the leeward side of the structure. Fortunately, after 20 minutes the weather moderated and we were able to walk back safely to the station.

All in all it was worth it, even if we only did like half the trail. The views from the surrounding hills—as the images in the next four pages show—were breathtaking and I took many photographs. The sight of Antarctic animals, including mammals and birds, was particularly exciting, as was also the finding of freshwater ponds in a place where even summer temperatures remain mostly below freezing.

Outdoor safety lecture at Crary Lab in McMurdo Station.

Overlooking McMurdo Sound near the George T. Vince memorial cross.

Hiking the Hut Point Ridge Loop Trail near McMurdo.

Armando standing next to the George T. Vince memorial cross.
Credit: Hans Niederhausen, IceCube / NSF.

Hans pulling up right ahead of Armando.

A south polar skua was found right in the middle of the trail.
Armando and Hans kept a distance and sat down waiting until the bird flew away.

Surface water can be found in sheltered areas of the Antarctic coast.

Weather conditions deteriorated rapidly and forced Armando and Hans to retreat.

January 11. Flight to the Pole and arrival at the Amundsen–Scott Station

Good news! I have finally arrived at the Amundsen–Scott South Pole Station.

I had been thinking all along that we would end up staying in McMurdo at least up to Monday (January 12), until Hans told me—yesterday around early evening—that we could possibly be departing on Sunday morning, and that a special flight had been arranged for us. "Are you sure?" I asked him. "Absolutely," he answered. "Who told you that?" "Someone who is knowledgeable and trustworthy." "But, I mean, is this person a reliable source of information?" "Oh yes, she is!"

After so many postponements I was reluctant to take anything for granted. But this was entirely credible, so we all got up early and headed to McMurdo's bus station today at 7:00 am. And what a neat surprise to find a bus there, already waiting there for us! We quickly got in and started our descent down the McMurdo road into the ice shelf. Upon reaching the ice the driver stopped to strap snow chains into the tires, and then started driving over this frozen block of freshwater that floats above the South Pacific Ocean. The 12-kilometer ride was completed in about half an hour.

We boarded the aircraft—a retrofitted DC-3—and at 8:15 am we took off. I counted fourteen people in total, 11 passengers and 3 crew members. To my delight, this airplane had numerous, decent windows that allowed comfortable viewing from every seat, so I knew we were in for a show. I had already been told that the sight of the Transantarctic Mountains—which lie right in the middle of the route—can be quite dramatic, so I had my camera ready to shoot. It was overcast upon leaving McMurdo, like all five days that I stayed there, minus a period of about four hours in the afternoon of January 8.

The airliner flew across the cloud deck and rapidly rose atop the clouds, and although it became clear and sunny overhead I remained unable to discern anything below. At that moment we were flying above the Ross Ice Shelf, between the 78th and 82nd south parallels.

About an hour and a half into the flight the clouds broke down and I started seeing mountains of epic proportions that were covered almost entirely in snow, with the occasional rocky outcrop or patch of barren dark soil protruding above the icecap [see photographs on page 157]. Without a doubt, this is the most captivating view that I have ever obtained from the air on a passenger window. The landscape displayed only three basic colors: blue, black and white. And then the sun—shining low in the sky, at a height of only 22° above the horizon—produced an array of long, elegant shades that meandered down the mountain slopes. I enjoyed the sight of this majestic range of mountains for about 90 minutes.

Upon flying from Ross Island to the Pole, the Transantarctic Mountains are seen between latitudes 82° and 86°. As we went on, the higher summits gradually steered away to the east and started transitioning into the flat—although not entirely featureless—Antarctic Plateau. It was interesting to watch the patterns that had been etched on the surface by the action of the elements, something that has also been observed in icecaps on other planets, such as Mars. The ice just took the strangest shapes ever. The scenery, again, struck me as exceedingly plain, but I submit that there is beauty in simplicity.

At 12:45 pm we landed safely on the runway just outside of Amundsen–Scott South Pole Station. Total flight time was four and a half hours. As I stepped out of the airplane I beheld a fascinating landscape. The sky was clear with the deepest shade of blue, while the terrain looked the purest, brightest white. I

stared down at the ground and saw sparkle everywhere, caused by tiny snow crystals that shone with light reflected from the sun, with individual crystals going on and off as one strolled around. It looked like thousands of small diamonds strewn all around the surface.

In keeping with tradition, a number of people from the station had assembled on the runway and greeted us, one by one, as we set foot over the ice. I was approached at once by Mike DuVernois of the University of Wisconsin–Madison, and also by Elisa Pinat of Université libre de Bruxelles (in Belgium), who were both extremely friendly and gave me the warmest welcome ever.

The thermometer read −29 °C, which is typical for the Pole at this time of the year. As I walked over to the station, passing by the blue welcome sign, I looked around and remained mesmerized by the scenery. The blinding sunlight, the sharp feel of the cold wind hitting my face, and the bone-chilling sound of my boots stepping over the snow contributed to the overall atmosphere of eeriness. The South Pole has to be seen, heard and felt in real life in order to be understood, and the pictures out there simply do not render this place in its full splendor.

The dining hall usually closes at 1:00 pm or shortly thereafter, but as they had been informed ahead of time of our imminent arrival they kept serving food until all of us had eaten, well after 1:00 pm. I feel particularly grateful for this gesture as a hot meal is always welcome.

Around 2:00 pm we left the main station for the IceCube Laboratory. Since the laboratory is located 1,500 meters away from the elevated station, we drove there using a PistenBully continuous track vehicle, something that was quite an experience since I had never traveled like that before. We then enjoyed a two-hour tour of the IceCube Laboratory, which was expertly guided by Mike and was also attended by people from other affiliations and research projects. He took us to all areas of the building and gave a comprehensive explanation of how the detector works.

Instead of being assigned to work on this first day, I was rather advised to avoid physical exertion and retire to bed early. By 5:00 pm I was back at the station, where I will drink plenty of water and take things easy for the remainder of the day, to allow my body to acclimatize to the 2,800-meter elevation of the Amundsen–Scott South Pole Station. I have remained very attentive to any symptoms that could be an indication of altitude sickness, but so far I can inform that I feel better than ever.

In the next few days I will elaborate on the IceCube Neutrino Observatory and its role in the field of high-energy astronomy.

7:05 am: Departing from McMurdo Station.
Left to right: Armando Caussade, James Casey and Hans Niederhausen.

7:27 am: Driving over the Ross Ice Shelf, just outside of McMurdo Station.

7:59 am: About to board the DC-3 airplane at the Williams Field skiway.

8:00 am: Inside the airplane just before take-off.

10:43 am: The Transantarctic Mountains around latitude 84° south.
This area is known as the Queen Alexandra Range.

11:00 am: The Transantarctic Mountains around latitude 85° south.
Around this area the mountains start to descend into the Antarctic Plateau.

12:53 pm: Arrival at the Amundsen–Scott South Pole Station.
Temperature was −29 °C and windchill was approximately −38 °C.

12:55 pm: Welcome sign at the Amundsen–Scott South Pole Station.
The signboard matches the prevailing colors of the landscape: blue and white.

2:12 pm: Arrival at the IceCube Laboratory after leaving the Amundsen–Scott Station. The laboratory is located 1,500 meters away from the main building.

3:26 pm: Inside the IceCube Laboratory. Left to right: Mike DuVernois, Hans Niederhausen, James Casey and Armando Caussade.

January 12. Working with the ARA detector at the South Pole

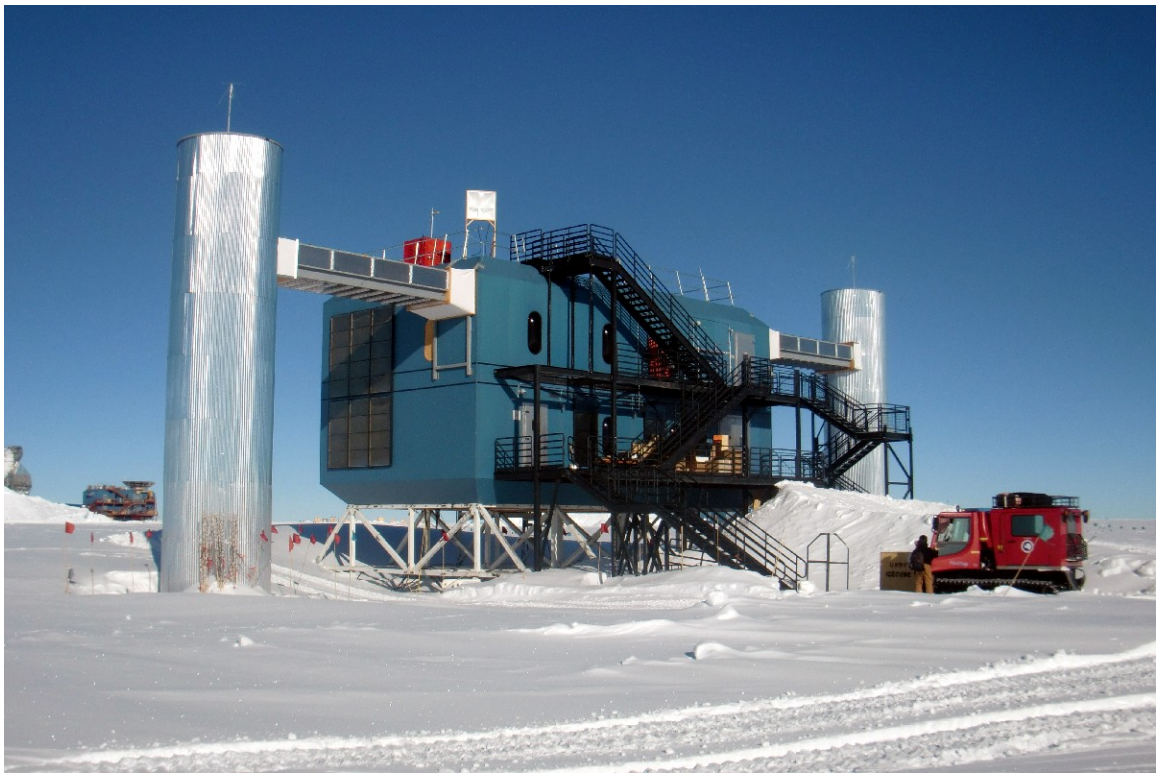
Today's post will again be a photojournal.

Right after breakfast we met with Mike at the Science Laboratory to set the agenda for the day. There were seven of us: Elisa Pinat, Sam De Ridder, Stephan Richter, Hans Niederhausen, James Casey, Mike and I. We decided to spend the morning working with electronics at the IceCube Laboratory, while later on in the afternoon three of us would go to work in the field with the ARA neutrino detector.

ARA (Askaryan Radio Array) is a new experiment undergoing its initial stages of construction at the South Pole, which the aim of measuring radio waves generated by the interaction of ultra-high-energy neutrinos with the Antarctic ice. As the ARA website explains (http://ara.wipac.wisc.edu/home) the radio pulses come from the so-called *Askaryan effect* where a shower of particles traveling in a dense material—faster than the velocity of light in that medium—emits coherent radio waves.

Since neutrinos rarely interact with matter, very large detectors are needed to discover them, and ARA is no exception. Three detector elements consisting of receiver antennas (i.e., ARA-1, 2 and 3) have already been deployed in the ice at about 200 meters below the surface, with 34 more to come for a total of 37. The individual elements in ARA are widely separated—by about 2 kilometers—and the entire detector and will eventually spread to cover an area of approximately 100 square kilometers.

As planned, Mike, James and I went out to ARA where we ended up working for two hours. Because of the size of the detector we drove a PistenBully for 15 minutes until we arrived at the ARA-2 site, where we ran a number of diagnostic tests from the ARA bunker which lies half a meter below the surface.

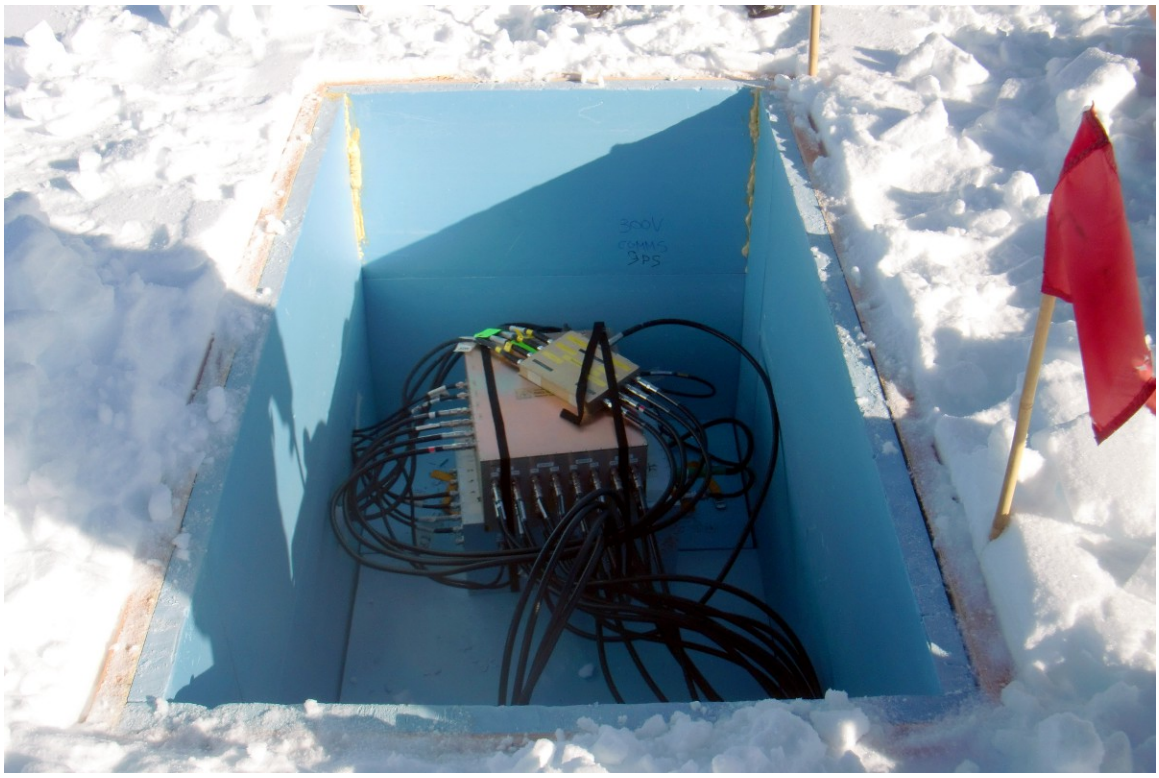


The IceCube Laboratory at mid-morning, under blue skies and bright sunlight.

Ready to work with the Askaryan Radio Array (ARA) detector at the South Pole.

Arrival at the ARA-2 site by PistenBully vehicle.
The site is located about three kilometers from the main station.

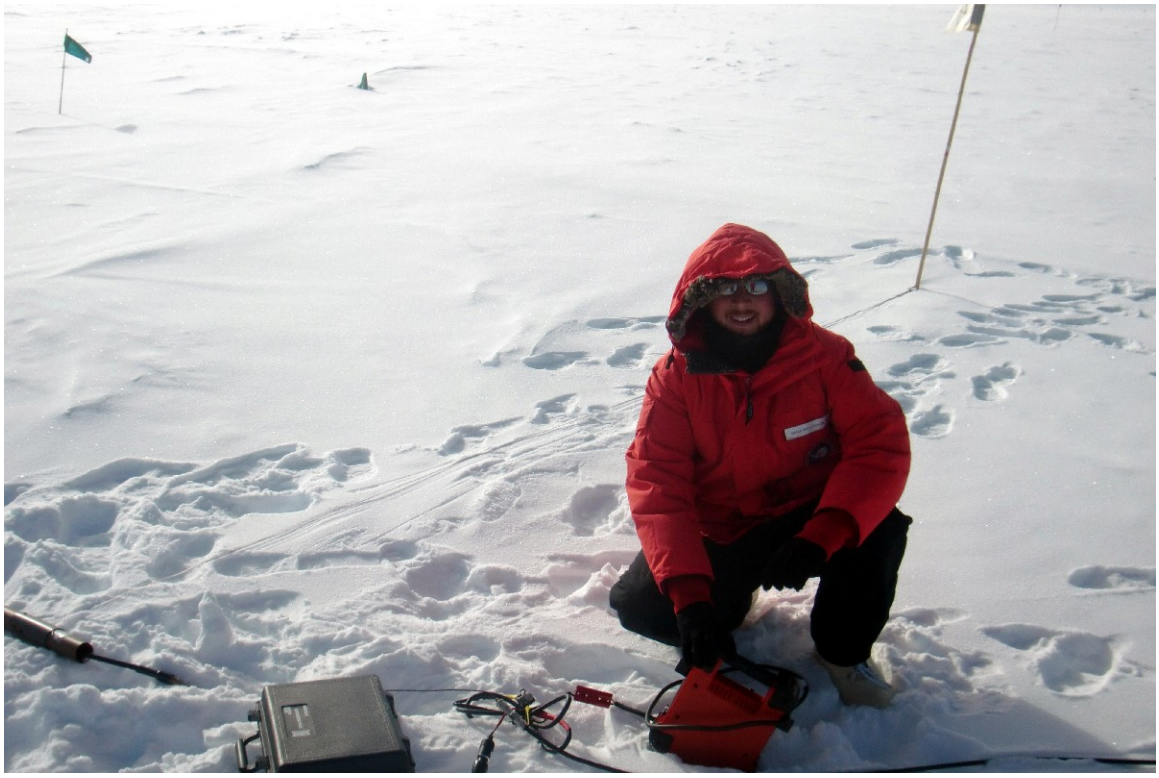
After shoveling about 50 centimeters of snow the ARA bunker is uncovered.
Left to right: Mike DuVernois and James Casey.



ARA instrumentation was found inside.

Armando helped as Mike went down into the bunker.

Temporary cabling was installed in order to do tests from 5, 10, 20, 30 and 50 meters away.



Armando holding a jump starter as he launched the first test run.

January 13. Testing cosmic ray sensors at the IceTop experiment

Well, I finally got my own picture with the sign at the geographic South Pole. Since work keeps us busy I had not come upon a chance until today. Moreover, as the day turned out to be overcast the sky shone with a whitish, diffuse light that was not conductive to a good camera shot. Fortunately I will be staying here for an additional week, so at the first chance I will go out and make a better image.

We spent part of the morning at the Science Laboratory right here in the elevated station, where the IceCube team meets and works when not at the IceCube Laboratory or in the field. I also stopped over at the computer room and spoke with the information technology people in order to ensure that—as far as possible—we attain reliable Internet connectivity during tomorrow's IceCube webcast.

In addition to the main detector, the IceCube Neutrino Observatory also hosts the IceTop experiment which is designed to study cosmic rays. IceTop is a one-square-kilometer surface array of 162 cylindrical tanks at a depth of approximately one meter below ground level, gathered in 81 stations located right above their corresponding IceCube strings. Each tank is equipped with two standard IceCube sensors that are capable of detecting light from high-energy charged particles from neutrino interactions or cosmic ray showers, with IceTop focusing on the latter. Its goal is to measure the number of particles as a function of energy, and to compare compare cosmic rays identified by the surface array (IceTop) with those spotted using the deep detector (IceCube). The ratio obtained by this comparison can in turn be used to determine the distribution of atomic nuclei in cosmic rays.

Cosmic rays are electrically charged particles of galactic origin—and for the highest energies, of extragalactic origin—that arrive on Earth in great numbers, traveling at nearly the speed of light. Hydrogen nuclei (i.e., single protons) account for about 88% of cosmic rays, while helium nuclei (i.e., two protons plus two neutrons) account for about 10%. Heavier atomic nuclei represent 1% and free electrons contribute the remaining 1%. Their exact origin is unknown—a problem that has plagued science for a century—since the particles do not necessarily follow straight paths and are thus very hard to trace back. Recent observations, however, suggest that the bulk of high-energy cosmic rays originate in energetic environments such as supernovae and accretion disks surrounding supermassive black holes. The sources of the very highest energy cosmic rays remain a mystery.

As soon as we finished lunch Sam and I went out to troubleshoot a pair of data acquisition modules (DAQs). Yesterday, Sam had spent some time in the field deploying these DAQs at ground level, right above the surface tanks that comprise the IceTop array, and today he asked me to assist him. We took our red parkas and climbed into the PistenBully, drove past the IceCube Laboratory, and at 2:30 pm arrived in an area located approximately 500 meters away from the laboratory and about 1,500 meters from the main station. As a matter of fact, one of the treats of working with IceCube is that, because it comprises a number of related experiments and its infrastructure is spread out over a wide expanse of space, one is able to take a diverse set of field work assignments all around the Pole area.

After arriving at the site we ran diagnostic tests which confirmed that two of three DAQs that had been deployed the previous day needed some fixing. Sam suggested returning everything to the IceCube Laboratory in order to see what went wrong, so we actually ended up picking up all three DAQs and heading back for the laboratory. The actual sensors where the DAQs are embedded—with their built-in wooden stands, and steered at inclinations of 30° and 45°—were left out in the field.

Selfie photograph with the sign at the geographic South Pole.

The IceCube team at the Science Laboratory in the main station.
Left to right: James Casey, Mike DuVernois, Armando Caussade and Sam De Ridder.

Armando while drafting a PolarTREC journal with his notebook computer.
He usually started writing in the laboratory, relocating to the computer room after dinner.

Departing from the main station after lunch. Destination: IceTop array.

Cosmic rays sensors out in the field, right above an IceTop tank.
The PistenBully vehicle that the team drove is behind.

The sensors are attached to the wooden stands, while the data acquisition modules (DAQs) are housed in the Pelican cases. The IceCube Laboratory is in the background.

Sam while checking up the DAQs.

Armando picking up the DAQs for their return to the IceCube Laboratory.

January 14. An IceCube primer, webcast #1 and another day with IceTop

As promised, today's post will be to explain what the IceCube Neutrino Observatory does, and why this is important. I will also summarize the events of the day.

An IceCube primer

The IceCube Neutrino Observatory was constructed over a seven-season period between 2005 and 2010 at the Amundsen–Scott South Pole Station by an international collaboration involving dozens of institutions. The National Science Foundation provided the primary funding with assistance from partner funding agencies around the world. The University of Wisconsin–Madison is the lead institution with responsibility for the maintenance and operations of the observatory.

The main purpose of IceCube is to study high-energy neutrinos to learn about how and where they are produced. According to current theories they originate from astrophysical sources such as supernovae, gamma-ray bursts, and accretion disks around dense objects such as neutron stars and black holes.

Neutrinos are fast and highly penetrating particles, smaller than atoms. Being the most numerous particles in the cosmos—excepting photons—they pervade everything, but rarely interact with matter. A staggering number of neutrinos ($\sim 10^{12}$) travel, unnoticed, each second through a person's body. Because they sail intact through vast expanses of matter they have been nicknamed as "the ghost particle".

The ability to slip through matter is important because distant astronomical settings are usually blocked from our view, and are therefore unreachable using optical telescopes. Photons are weakened—and eventually stopped—by intervening matter. Cosmic rays are problematic, too, as they consist of electrically charged particles whose paths can be deflected by magnetic fields found along the way. But neutrinos, with their incredible penetrating power and straight paths, arrive on Earth mostly undisturbed after traveling huge distances across space. Undoubtedly, neutrinos make the ideal messenger particle to study cataclysmic environments in the universe.

The IceCube Neutrino Observatory is the world's strangest telescope. It uses 5,160 optical sensors that are suspended from 86 strings buried deep below the South Pole surface inside a cubic kilometer of ice, which is the cleanest and optically purest on Earth. This is possible because the Antarctic Plateau consists of a huge glacier that rises three kilometers above the bedrock. The sensors were inserted into holes made with a hot water drill and are spaced 17 meters apart vertically, between depths of 1,450 and 2,450 meters. The light sensors, *photomultipliers*, face down toward the center of the Earth.

The IceCube sensors (otherwise known as *digital optical modules*, or DOMs) are able to detect and measure radiation from high-speed charged particles generated by neutrino interactions with the ice. Although neutrinos cannot be directly detected, when a muon neutrino hits the nucleus of an atom they produce secondary particles called *muons*, which leave along their paths an intense trail of blue Čerenkov light that can be measured by the photomultiplier tubes in each DOM. The energy content and the direction of the originating neutrino can be ascertained by studying this light.

The laboratory building at the surface hosts the computers that collect and store the data from the underground sensors. Meaningful findings are relayed via Internet to North America for further study.

Webcast #1 and another day with IceTop

Early in the morning I did—together with my colleagues—the first of two scheduled IceCube video presentations, live from the Pole. We were informed that a large number of school and colleges would be joining, from Puerto Rico and every part of the United States, to Italy, Pakistan and India, amounting to an audience that easily surpassed 500 people. Four of us took part in the webcast: Sam, Elisa, Hans and I. We also had Stephan Richter (an IceCube winterover, here at the Pole) and Megan Madsen (from Madison, Wisconsin) assisting with the webcast.

It was enjoyable sharing our work with the public, and once finished with the event some of us went on to grab a couple additional hours of sleep. What most people never realized was that, in order to fit the webcast within a reasonable time frame for schools in North America (the agenda read January 13 at 10:00 am Eastern Standard Time), we at the South Pole ended up scheduled in January 14 at 4:00 am!

A frequently asked question has to do with time in Antarctica. As the Pole lies near the center of the continent, Antarctica spans all 24 time zones, but individual stations keep the time of either their own countries or their immediate supply areas. For example, McMurdo and the South Pole are both synchronized with New Zealand, which is UTC+13:00 during the austral summer when daylight saving time is in effect. This is 17 hours ahead of Atlantic Standard Time (used in Puerto Rico and the eastern Caribbean) and 18 hours ahead of Eastern Standard Time (used in the east coast of the United States).

Later in the morning I joined Sam and Elisa to assist them in troubleshooting the surface tanks that make up the IceTop array. Going outside takes a lot of preparation and, as always, I went through the 15-minute routine of putting on my extreme cold weather gear. My basic layer is what I usually wear while inside, a T-shirt and jeans. Then comes a thick fleece sweater and wind pants. Next are boot liners and glove liners, a scarf and a balaclava. Finally come the red USAP parka, the heavy white boots and a pair of gloves. I always wear polarized sunglasses while outside, and my parka hood is usually up.

We left the elevated station around 11:30 am and drove the PistenBully for a kilometer and a half, arriving near the IceCube Laboratory, exactly at the same location where we had spent time yesterday. There, we remained for about an hour while deploying and testing a new set of data acquisition modules (DAQs). Although the day was cold and windy, I felt fine as the stay outside was brief.

For lunch we drove back to the station, leaving again later for the IceCube Laboratory where we picked up some electronics before setting out to the field again. This time we headed to a different IceTop station, and after running the usual diagnostic tests and ensuring that everything was in order, went on to collect the daily readings for cosmic rays that were stored in memory inside of each DAQ.

The weather gradually began to improve and the clouds started to break. The unyielding Antarctic wind subsided and I started feeling the warmth of the sun. By 4:00 pm it was mostly clear, calm and much warmer than it had been before lunch. We ended up staying out for much longer than we did in the morning, with the treat that the improved weather allowed us to work more comfortably.

IceCube webcast #1 at the Amundsen–Scott South Pole Station.
Left to right: Elisa Pinat, Sam De Ridder, Hans Niederhausen and Armando Caussade.

IceCube webcast #1 at Pedro Rivera-Molina School in Juncos, Puerto Rico.
Credit: Miguel Piñero, Puerto Rico Department of Education.

Morning outing: Armando and Sam while troubleshooting the sensors.

Early afternoon: The operator room inside the IceCube Laboratory.
Left to right: Sam De Ridder, Armando Caussade and James Casey.

Afternoon outing: Armando holding a rope that was used to make measurements. The South Pole Telescope is in the background.

Armando near the IceCube Laboratory around 4:00 pm, when the sky partially cleared up for a couple of hours.

January 15. The Amundsen–Scott South Pole Station

Living and working at the Amundsen–Scott South Pole Station—the last place on Earth, an oasis of life surrounded by an endless desert of snow and ice—is a life-changing experience that instills a sense of humbleness upon the spirit. The facility is located a scant 200 meters from the geographic South Pole in the remote Antarctic Plateau, at an elevation of 2,833 meters above sea level. To give an idea of how things work at this exotic location, I will provide an explanation along with a couple of relevant images.

The main installation is an elevated building three meters above the surface, supported by 60-centimeter columns. These pillars allow the structure to be raised up twice during its lifetime, in order to stay clear of the gradual built-up of snow. Amazing as it may seem, the building is actually moving away from the Pole, as the Antarctic ice sheet (the field of ice where the structure is anchored) slides over the continental bedrock at a rate that—in the area around the South Pole—averages 10 meters per year.

The building—a two-level structure with a total area of 7,400 square meters—is extremely safe, comfortable and even luxurious, considering the extreme environment that surrounds it. Aptly described as a technological and engineering marvel, it features a modern architectural design with a metallic dark gray color that conveys a futuristic look. After nine years of construction work the building was inaugurated in 2008, replacing the old dome whose removal was completed in 2010.

The Amundsen–Scott South Pole Station—comprising the main building plus nearby structures—is run by the United States Antarctic Program (USAP), which in turn is funded and managed by the National Science Foundation. The station, one of three permanent United States deployments in Antarctica, was established in 1957 in preparation for the *1957–1958 International Geophysical Year* (IGY). The IGY was a pivotal event that brought renewed international interest in the study of the polar regions.

With a capacity for 140 people, the station hosts a number of ongoing research projects in areas such as astronomy, atmospheric physics, meteorology and glaciology. It houses state-of-the-art laboratories, a large computer room and administrative offices, plus dining facilities and living quarters. There are long, wide halls on both levels one and two that—along with three sets of stairs—connect all areas together. Work is done 10 to 12 hours a day and six days a week, except on Sundays.

In addition, the station is equipped with a medical facility (which includes a dental chair), a library, a United States post office and a hydroponic greenhouse facility. It also features amenities such as a gymnasium, a game room with a pool table, an arts and crafts workroom and even a souvenir store. Water and energy are used very conscientiously, and approximately 60% of all waste is recycled. Non-recyclable waste is carefully collected and shipped back to the United States.

As explained in previous posts, at this time of the year the Pole experiences 24 hours a day of sunlight. Since sunrise and sunset only occur once a year, the sun does not appear to rise or set, but rather moves parallel to the horizon in a counter-clockwise direction. Its height above the horizon changes according to the solar declination—which varies by the day, and not by the hour—that in January translates into an elevation range of 23° to 18°, with a gradual daily decrease as the month advances.

All this put together makes a stay at the Amundsen–Scott South Pole Station a remarkable experience. As a picture is worth a thousand words, I am sharing a few original photographs of the station.

The Amundsen–Scott South Pole Station as viewed when coming from the airplane runway.

Main entrance to the station (i.e., Destination Alpha).

Mike DuVernois opening the massive steel door at the main entrace.

First level main hallway next to the cargo entrance (i.e., Destination Zulu).

The food growth chamber (or greenhouse facility).

The dining facility.

Dormitory hall at wing A4.

Armando's room at wing A4.

Midnight view out of Armando's window. Local time 12:01 am.

Armando during his afternoon outing while working with the IceTop array.

January 16. Webcast #2 and IceTop once again

I started my day at 3:00 am with the second IceCube webcast, a Spanish-language presentation that was moderated by Dr. Silvia Bravo of the Wisconsin IceCube Particle Astrophysics Center (WIPAC). The webcast—which lasted a full hour and fifteen minutes and included an extensive questions-and-answers session—was particularly fulfilling for me personally, as I had been appointed to be the primary speaker. I used my 30-minute presentation to give a summary of my work with PolarTREC so far, starting with my selection as a participant back in November 2013 and up to my current work with IceCube here at the South Pole. As with the previous webcast, I also had Stephan and Megan assisting with the webcast.

Among the attendance were Gretchen B. Guzmán from G Works, together with teachers and students from Pedro Rivera-Molina School in Juncos, Puerto Rico, where I teach. The webcast was also attended by (1) Sandra from Alfonso Díaz-Lebrón School—also in Juncos and where I have taught in the past—who attended along with a sizeable segment of the school community; by (2) Amarilis and her group at Coleen Vázquez-Urrutia School in Naranjito, Puerto Rico; by (3) Ruth and a large audience of school kids at the Arecibo Observatory Visitor Center and Science Museum; and by (4) Rachelis from Niños de Nueva Esperanza community project in Levittown, Puerto Rico.

To my surprise a number of public officers showed up at the webcast, including the Hon. Ángel R. Peña-Ramírez of the Puerto Rico House of Representatives and Rubén Correa of the Juncos Municipal Education Department, as well as key officials from the Puerto Rico Department of Education including Ingrid Mercado who heads the 21st Century Community Learning Centers federal initiative.

Participation was conservatively estimated around 300, but I have reasons to believe that it probably reached as high as 500. At my own school alone—Pedro Rivera-Molina—the excitement was such that they counted over 200 students connecting at one time or another from at least five different classrooms.

The IceCube team has been dutifully working with the IceTop experiment, so I went out with Sam walking over for about a kilometer and a half until we arrived at the surface sensors above one of the IceTop stations. Because of routine vehicle maintenance we not able to drive the PistenBully. The hike was done at a very brisk pace, and so far it has been the only instance where I have come to notice the thinness of the air that is so characteristic of the Antarctic Plateau. After a quick break we continued our walk, arriving a few minutes later. We troubleshooted the sensors right there in the field, picking up a pair of faulty data acquisition modules (DAQs) and taking them back to the IceCube Laboratory.

We carried them by foot for approximately half a kilometer, under a dirty white sky on this fourth day in a row of overcast conditions. Temperatures were surprisingly mild, however (−24 °C), and after a comfortable walk done at a more modest speed we arrived at the second level in the laboratory, where the operator room and server room are located. There I learned that Hans managed to get his all-sky camera up and running, and that James was able to achieve his calibrations and is now almost done.

Following dinner—in what has become a daily routine—I proceeded to the computer room at the second level of the Amundsen-Scott Station where I sorted the pictures of the day and started drafting what would later become this journal entry. I work here every "night" for about five hours, staying usually until 1:00 am. Internet connectivity at the South Pole is available for only ten hours a day, but nowadays there is the advantage of having the satellite coming around conveniently around 9:00 pm.

IceCube webcast #2 at Pedro Rivera-Molina School in Juncos, Puerto Rico.
Credit: Miguel Piñero, Puerto Rico Department of Education.

IceCube webcast #2 at Alfonso Díaz-Lebrón School in Juncos, Puerto Rico.
Credit: Sandra Jiménez, Puerto Rico Department of Education.

IceCube webcast #2 at the Arecibo Observatory Visitor Center in Puerto Rico. Credit: Ruth E. Torres, Arecibo Observatory / SRI / USRA / Metropolitan University.

Armando arriving back at the Amundsen–Scott station after his afternoon outing.

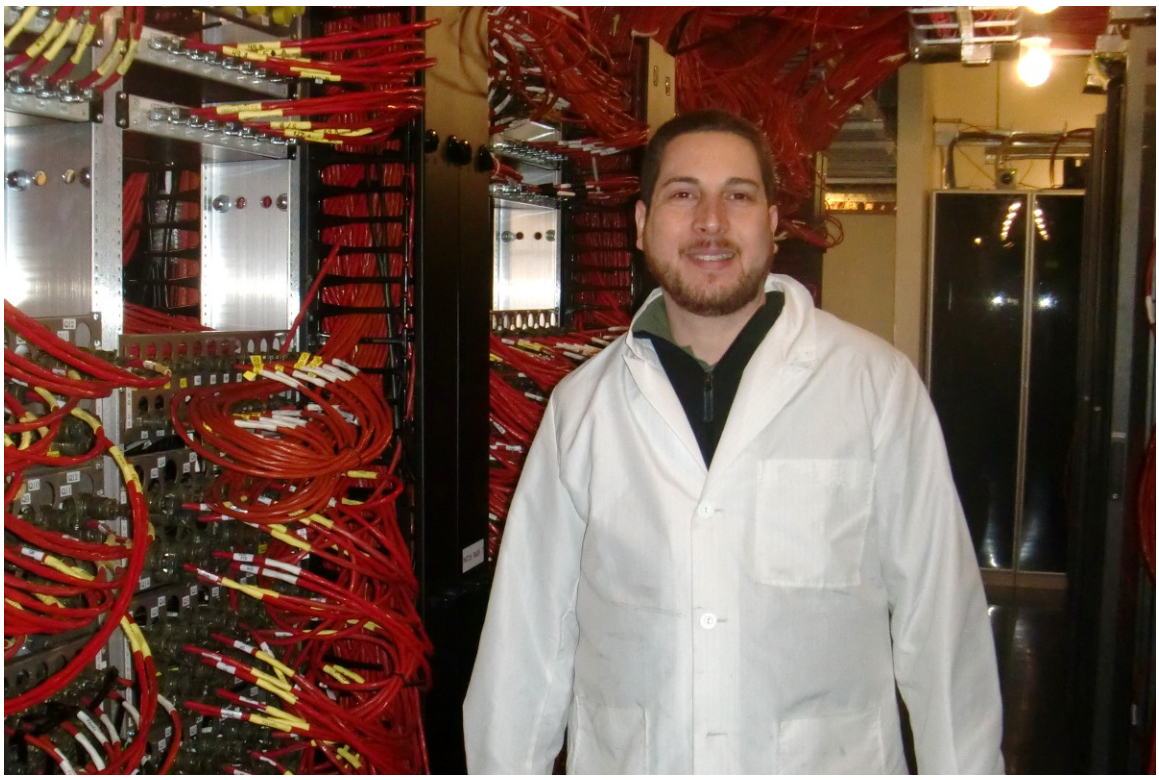
Sam while checking up the data acquisition modules (DAQs) above an IceTop station.

Armando picking up the DAQs for their return to the IceCube Laboratory.
The elevated station is in the background.

Armando heading to the IceCube Laboratory half a kilometer away.

Almost there.

Sam at the server room in the IceCube Laboratory.



Armando at the server room in the IceCube Laboratory.

January 17. Snow accumulation measurements and IceTop explained

Today I again went out with Sam for our afternoon outing with IceTop. We had set ourselves an ambitious goal: use a measuring stick to gauge accumulated snow over the last year above the entire set of 162 IceTop tanks, which are found across an area of one square kilometer. Elisa, who also joined us, was of great help as she would be in charge of writing down the measurements that we did.

Because it has been found that the gradual accumulation of snow above IceTop's tanks can affect cosmic ray detection, the IceCube team is wanting to further investigate this topic. The numbers that we obtained will be compared with similar measurements made last year, thus revealing the precise depth of the layer that accumulated over the last 12 months. These results are vital, as the cosmic ray results obtained with IceTop will need to be corrected for the attenuation caused by the build-up of snow.

We actually ended up surveying about 154 out of 162, completing all measurements in about three and a half hours, something that I still cannot believe myself. Because the tanks were constructed in pairs, this number translates into 77 different locations that we drove to. Since the snow was measured all around the IceCube Laboratory and out to a radius of about 500 meters, in some instances we would end up next to the South Pole Telescope with its 10-meter dish, and the Martin A. Pomerantz Observatory, too.

Today's outing was a pleasurable experience, something that may sound ironic for a place where the natural environment is so harsh. Despite the −27 °C mark that the thermometer officially recorded—and the generally cloudy conditions of late, which inhibit the sun's heat—the weather felt incredibly mild, due apparently to the almost calm conditions that prevailed through the day. The above-average level of physical exertion today may also have played a part with us remaining warm throughout.

I additionally felt great personal satisfaction with the successful completion of today's work, as I knew beforehand that I would go on to exert a meaningful role with this particular aspect of IceTop. I will post photographs that show how the measurements for snow were done, and I will let the pictures speak for themselves. I am also posting two diagrams of IceTop, plus a description of this season's research (written and kindly shared by Elisa) that will provide details for the technically-minded.

The IceTop experiment explained
By Elisa Pinat

Our project for the current summer season at the South Pole concerns studying the effects of snow accumulation on top of IceTop tanks on the charge spectrum of cosmic ray particles.

IceTop is an array that uses the same physics principle of the IceCube detector and the same hardware, but instead of being buried deep in the ice, IceTop sensors are deployed at the surface and aim to study mainly cosmic rays, more so than neutrinos. Snow is naturally blown up by winds in the Antarctic Plateau, which brings accumulation on top of IceTop tanks. One of the effects of snow accumulation has been already noticed by the IceTop Collaboration: the electromagnetic component of the charge spectrum of cosmic ray particles has been significantly weakened in those tanks which have accumulated the greatest amount of snow. It is yet to be determined whether the muonic part of the charge spectrum is affected as well or not. So the main goal is to identify and understand all possible effects of snow accumulations over the tanks.

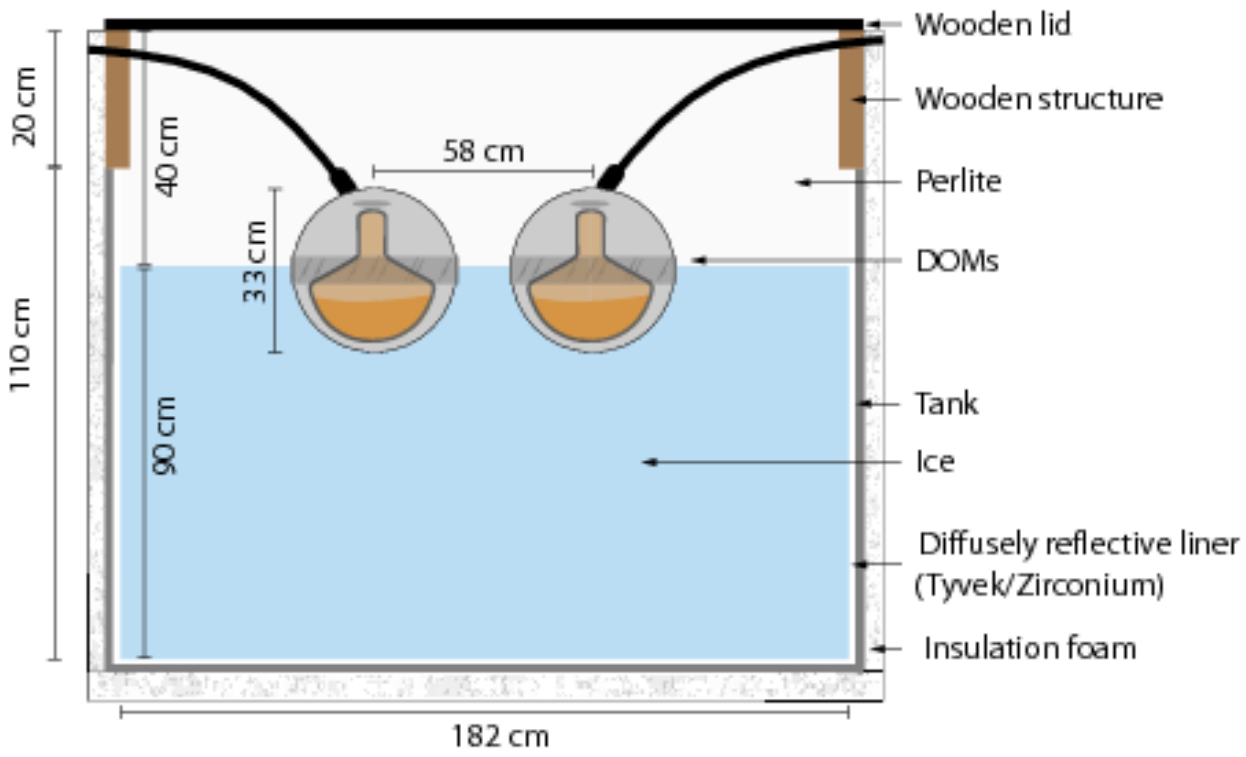
In order to achieve this we are using the so called *muon taggers*. Muon taggers are simple, visible light detectors based on the scintillation principle. Two plastic scintillators have been coupled with photomultiplier tubes (PMTs) which are later enclosed in wooden boxes to prevent interaction with external light. When a charged particle interacts with both the surface detector (IceTop) and the underground detector (IceCube), with both producing scintillation light at the same time, a coincident event has happened. This charged particle is called a muon.

Indeed, at this elevation above sea level (about 3,000 meters) cosmic ray particles impinging on the surface are mainly muons and electrons. Only muons possess an energy content high enough to interact with both scintillators. On the other hand, electrons are lighter, so they range out more quickly than the muons.

These coincident events are always recorded and get a time stamp from a GPS antenna. Further analysis will focus on comparing IceCube events with IceTop ones to see if the same event that lit both scintillators could indeed have enough energy to interact with the IceTop tank as well. By doing this, we have just tagged a muon!

We are currently using two types of muon taggers: small (with red boxes) and big (with flashy colorful boxes). These boxes are held by a wooden structure to keep the proper alignment, either vertical or with an inclination to the horizon, during the entire length of the data collection period. Data acquisition modules (DAQs) for these detectors are kept in heavy-duty plastic suitcases which are lined with a thick insulating layer to prevent them from getting too cold. These DAQs include a GPS antenna to do the time stamps, a high voltage battery for the PMTs, and an USB drive to store the data and provide a booting sequence for the electronics inside the DAQs.

Field work has consisted so far in deploying these detectors at the surface, on top of IceTop tanks, which is usually done in the morning. After connecting all cables and providing adequate power, data acquisition starts. Standard data runs last eight hours, so usually by the end of the day we will have retrieved all the DAQ suitcases and carried them inside the IceCube Laboratory (ICL) to allow warming up overnight. Afterwards, these time stamps will be used to grab the signals left by these particles in the IceTop tanks.



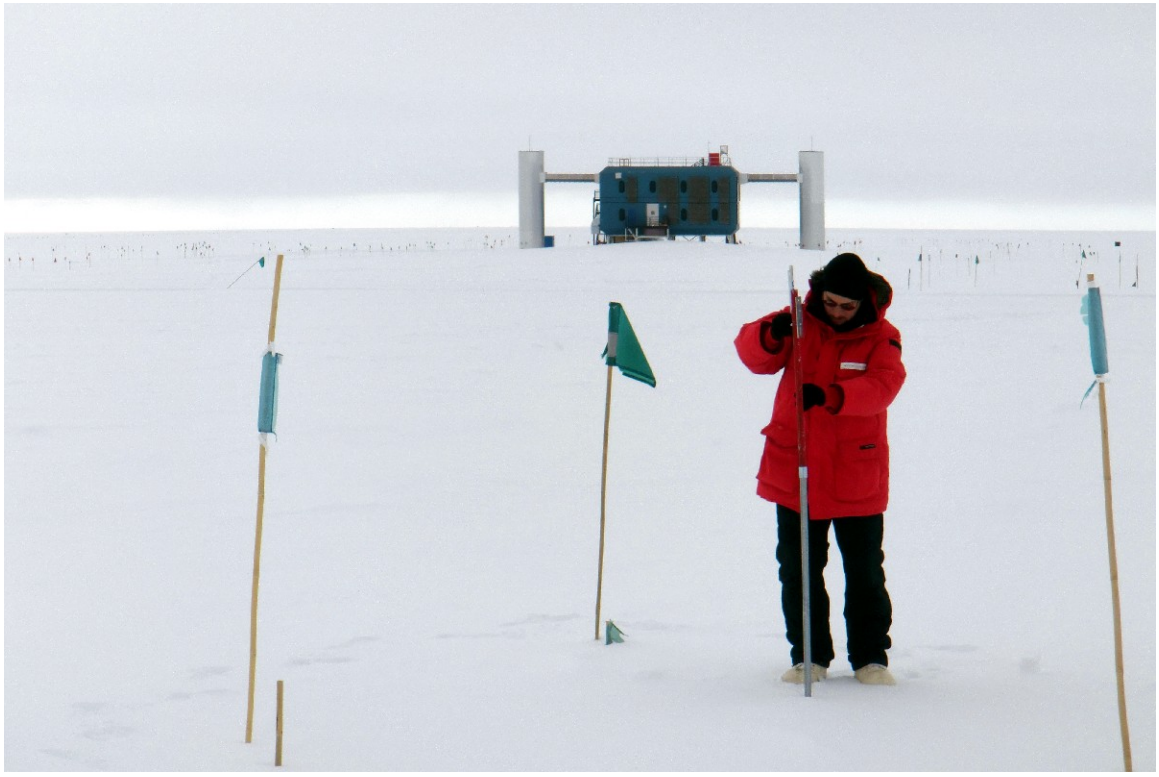
Cross-sectional view of an IceTop tank.
Credit: IceCube Collaboration.

Photograph of a frozen IceTop tank ready to be closed.
Credit: IceCube Collaboration.

Sam while driving the PistenBully.
The team drove to 77 different locations in less than four hours.

Armando taking measurements above IceTop tank 35-B. Elisa remained inside the vehicle while writing down the numbers. The IceCube Laboratory is behind.

Measurements of accumulated snow above an IceTop station.



More measurements, with the IceCube Laboratory in the background.

Armando's boots sinking into the snow.

Back at the station after three and a half hours in the field.
Armando is plugging in the vehicle's engine block heater.

January 18. Sunday photo shoot at the geographic South Pole

Today's post is going to be a photojournal of my Sunday shoot at the South Pole.

After a week at the Amundsen–Scott Station I finally got a chance to obtain a few decent pictures at the geographic South Pole. There is one major reason for this delay: weather. Even as the Pole habitually enjoys mostly clear weather, the area is just out of a spell of five days of near-total cloudiness. So, at the first sign of sunlight, I ran outside. Plus being a Sunday, there is time to spare with photographic pursuits. I am sharing the pictures for you all to enjoy.

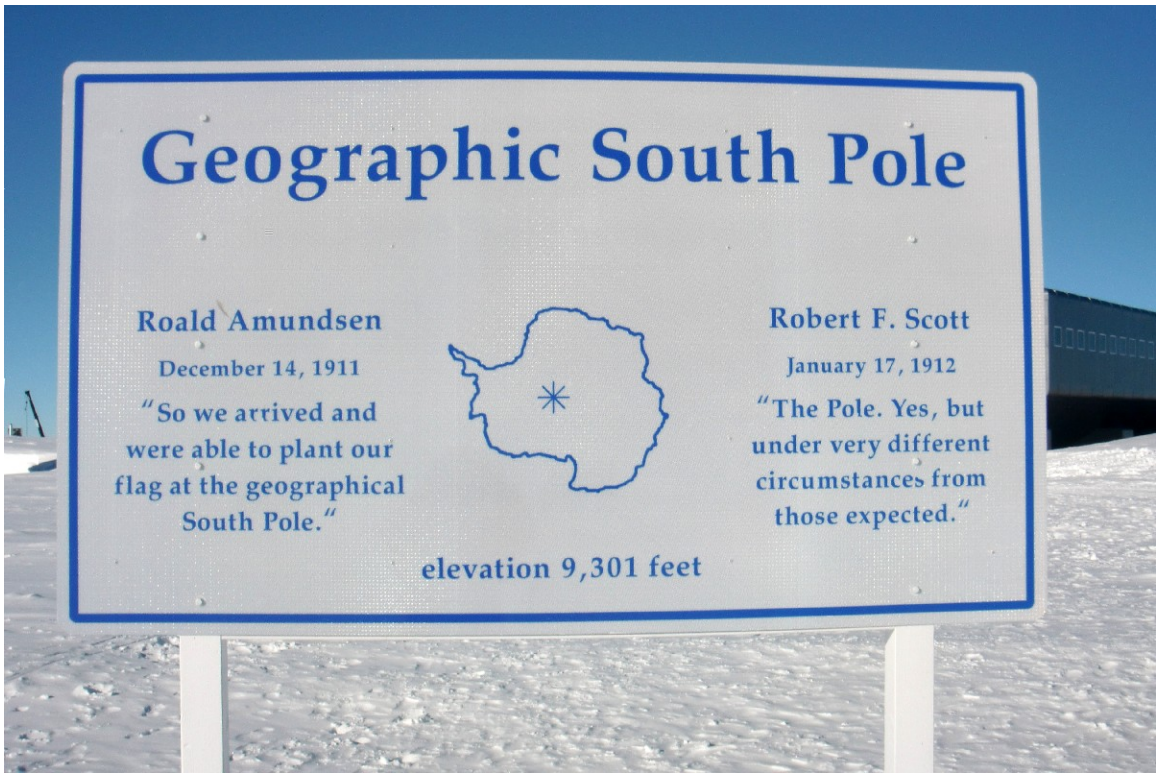
As a matter of fact, today has been the coldest day so far during my stay here. Just looking at the picture of me on the next page will give an idea of how cold it was. It was an absolutely beautiful day, with bright sunlight and a deep blue sky, but it was also extremely windy, so we ended up with a severe windchill that I would subjectively put around −48 °C.

As I have said before, food has been one of the highlights of my stay in Antarctica. Not a single day has gone by that I have not eaten with gusto. For dinner tonight I enjoyed the best pork ribs ever.

They also give science lectures on Sunday evenings, and following dinner I attended a one-hour talk on the Super Trans-Iron Galactic Element Recorder (Super-TIGER), a cosmic ray experiment by NASA using balloons that fly high over Antarctica. Super-TIGER will attempt to measure the individual abundances of heavy elements—in the 30 to 42 atomic number range—within the flux of high-energy cosmic rays reaching the Earth. With a duration of 55 days in early 2013, the Super-TIGER experiment broke the record for the longest flight of large scientific balloons anywhere in the world.

Selfie picture taken outside the Amundsen–Scott South Pole Station.
January 18 was Armando's coldest day in Antarctica, with a windchill around −48 °C.

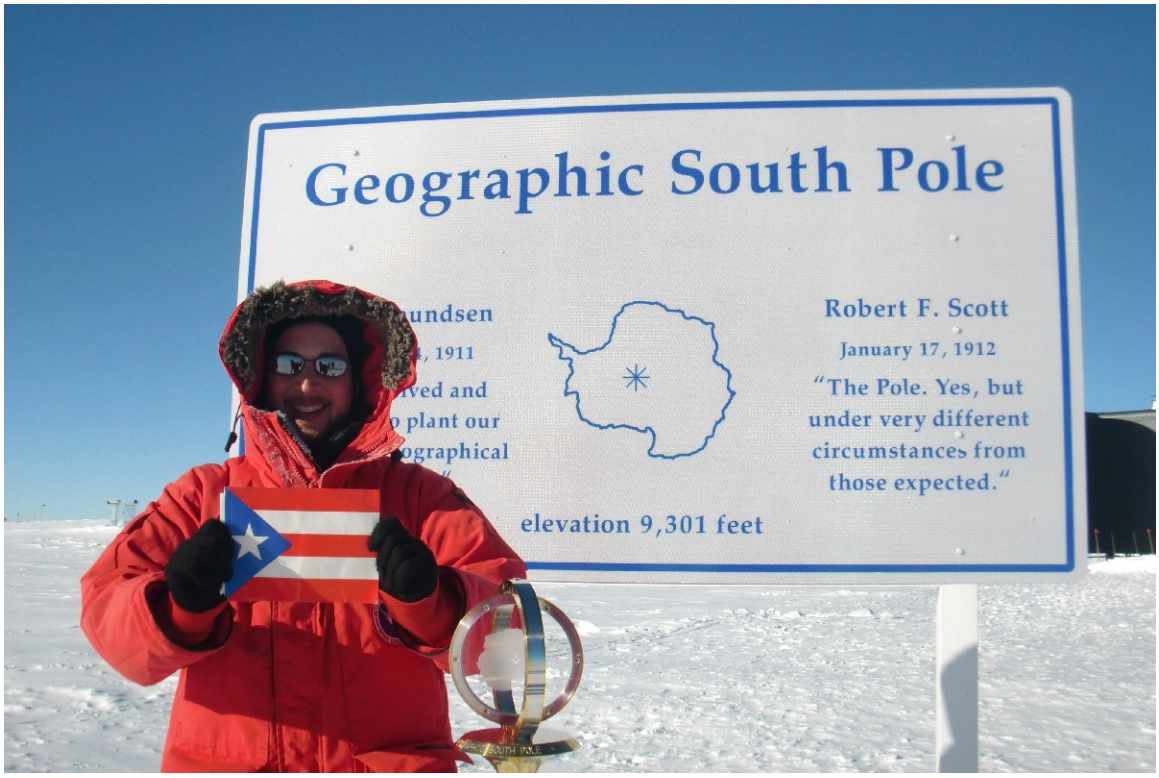
Armando at the Ceremonial South Pole which lies about 180 meters from the actual pole.
This area has been set aside for gatherings and photo opportunities.



The sign at the geographic South Pole. This is the new signboard that was installed in 2011 to commemorate Roald Amundsen's pioneering arrival at the Pole in 1911.

Armando at the geographic South Pole with the sign and the marker.
The Pole marker is moved the 1st of January every year to account for the shifting ice.

With the sign and the Pole marker.



Holding the Puerto Rican flag.

Pointing out to the South Pole.

The Amundsen–Scott South Pole Station as viewed from the geographic pole.

January 19. IceTop wrap-up and climate at the South Pole

Today could be my last day at the Pole, assuming the flight tomorrow is not canceled. I am set to leave on Tuesday, January 20, at a time yet to be determined. But there is no absolute certainty and it will be necessary to remain flexible, as Antarctic travel depends strongly on weather plus a large number of other factors that are out of our reach. I will keep you all posted.

IceTop wrap-up

At 9:00 am I went out with Sam and Elisa to finish the snow coverage measurements that we had started two days ago. We completed everything in less than half an hour, and later on proceeded to make highly detailed measurements of snow coverage over a randomly-selected sample of four IceTop stations. We did this as follows: (1) defined an imaginary cross one meter across in the snow above each station; (2) used a measuring tape to mark five regular intervals in each arm of the cross—10 centimeters, 20 centimeters, and so on; (3) used a stick to prick a hole in the snow, carefully driving the stick down until it hit the IceTop tank below; and (4) measured the actual depth of the tank at the specific place where the stick slid in. The total number of measurements for each IceTop station was 20—all of them obtained within an area of exactly one square meter above each of the four locations that were sampled.

I asked Sam what his thoughts were concerning the data we were collecting, and he responded as follows: "The winds at the South Pole create small hills and valleys of snow called *sastrugi*, which of course are sometimes seen on top of the IceTop tanks. Hence, we will need to measure how snow accumulates at several locations over a few sample IceTop tanks, and we also need to take these sastrugi formations into account when analyzing IceCube data." The sky remained clear throughout the day, although there was a strong, steady breeze which translated into serious windchills around −42 °C.

I would like to share a pleasant surprise that I got last week, specifically on January 13. While browsing the books at the IceCube bookshelf in the Science Laboratory I unexpectedly came upon a copy of *Basic Physics of the Solar System*, a 1961 textbook by Víctor M. Blanco and Sidney W. McCuskey. Although dated, the book is a classic from the early space age that was used to train a number of early NASA specialists. Its co-author Víctor M. Blanco (1918–2011) was a renowned Puerto Rican astronomer who later on went to become director at Cerro Tololo Interamerican Observatory in Chile.

It was a treat being able to skim the book, as I had so many times seen references to it, but never before found a chance to actually hold a copy. I would never have imagined that I might end up finding such a book here, at the South Pole! Totally off-topic, but it was meaningful to me and I wanted to share it.

Climate at the South Pole

On a different line, people have been asking about climate and weather conditions at the Pole, and I have been wanting to tackle the topic for a while. So, here is a summary.

The South Pole experiences cold temperatures all year round primarily because of its southerly location. This occurs because at high latitudes in each hemisphere, the sun, which rides in the sky along the ecliptic—near the celestial equator—never rises much above the horizon. Solar rays remain oblique, and because of their longer path across the Earth's atmosphere, the solar heat is weakened.

But there are three other factors that also need to be taken into consideration: (a) the Pole's position in the interior of the continent and away from the moderating thermal influence of the ocean; (b) its considerable elevation of 2,800 meters above sea level; and (c) the Earth's yearly movement around the sun, which carries the planet at its farthest in July and can potentially make winters in the southern hemisphere—and most notably, in Antarctica—slightly colder. None of these factors are observed at the North Pole, explaining why there it never gets quite as cold as at the South Pole.

Average temperatures at the Pole are −26 °C in January and −58 °C in July, while the all-time records are −12 °C and −83 °C. The −12 °C mark is particularly revealing, indicating that even at its warmest the Pole remains permanently below the freezing point. But these are direct thermometer readings that ignore the windchill effect, which needs to be accounted for, as Antarctica is by far the windiest continent. For instance, windchills as cold as −100 °C have been occasionally recorded at the Pole.

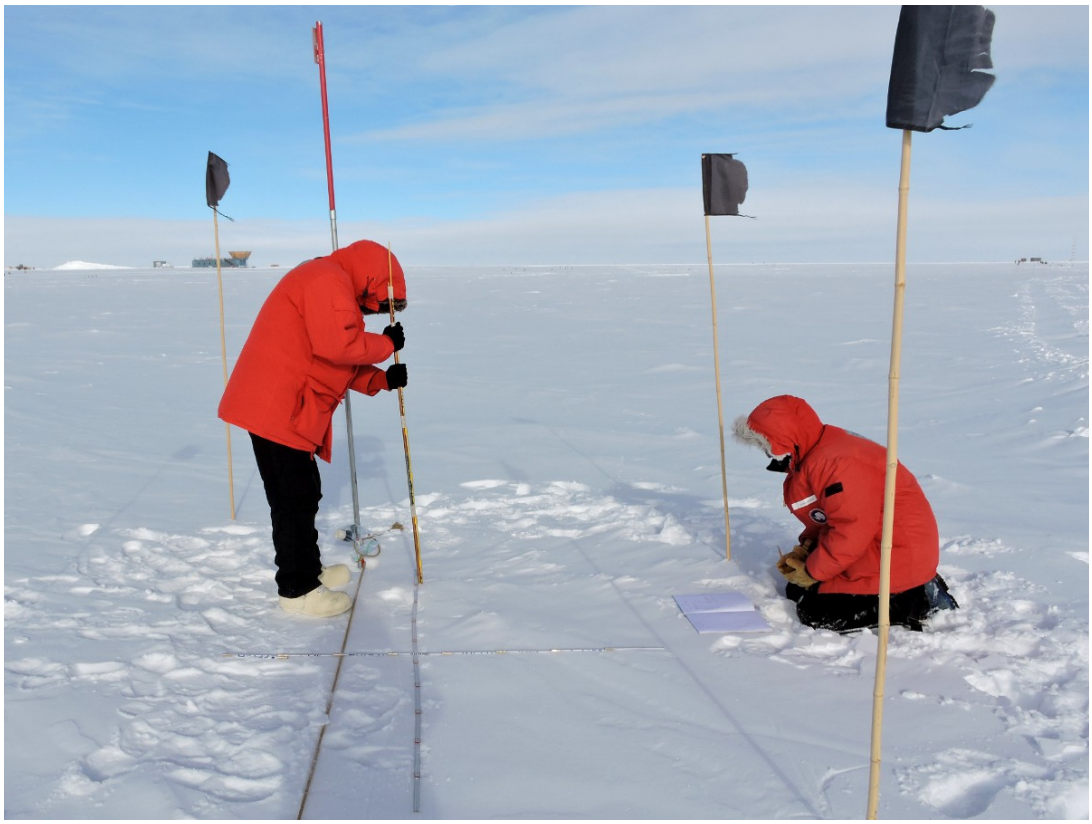
With near-zero precipitation, the South Pole is exceptionally dry. But the low prevailing temperatures also play a role here, because as the air goes cold it loses its ability to hold moisture. If this air is later circulated and heated at room temperature—which is exactly what happens inside the main building—relative humidity falls sharply and can drop to extreme values below 1%.

Another issue at the Pole is the marked decrease in atmospheric pressure, resulting in a lower amount of oxygen. The actual barometric elevation—or *pressure altitude*, meaning the altitude equivalent that is actually felt by a person—averages about 3,200 meters during the austral summer, which is physiologically harsher than the real topographic elevation of 2,800 meters. This happens because the decrease in pressure due to height occurs faster under low temperatures, and not because of a flattening of the atmosphere due to the Earth's rotation as is mistakenly believed.

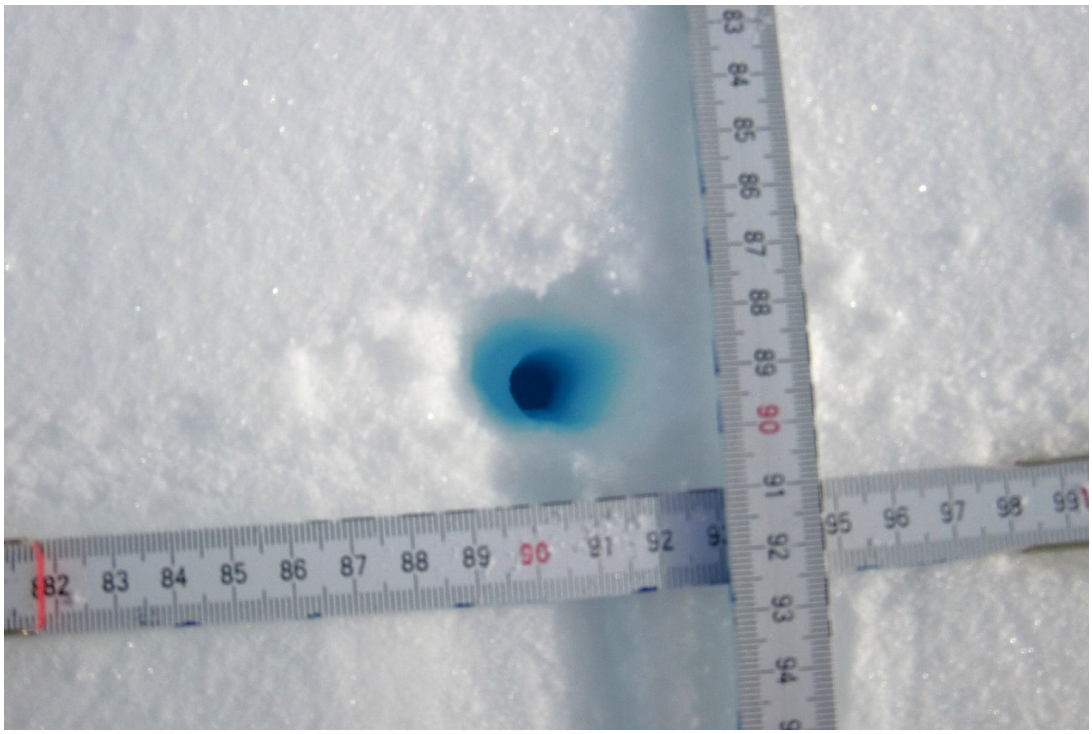
Also seen are solar halos, a splendid phenomenon that occurs frequently near the Poles due to the refraction of sunlight as it passes through ice crystals high in the atmosphere. Additionally, weather at the South Pole—and in Antarctica, generally—can sometimes change drastically in a matter of minutes, something that I have experienced myself on quite a number of occasions.

Armando doing measurements of accumulated snow above an IceTop tank. The IceCube Laboratory can be prominently seen in the background.

Doing more measurements for the IceTop experiment. Credit: Sam De Ridder, IceCube / NSF.

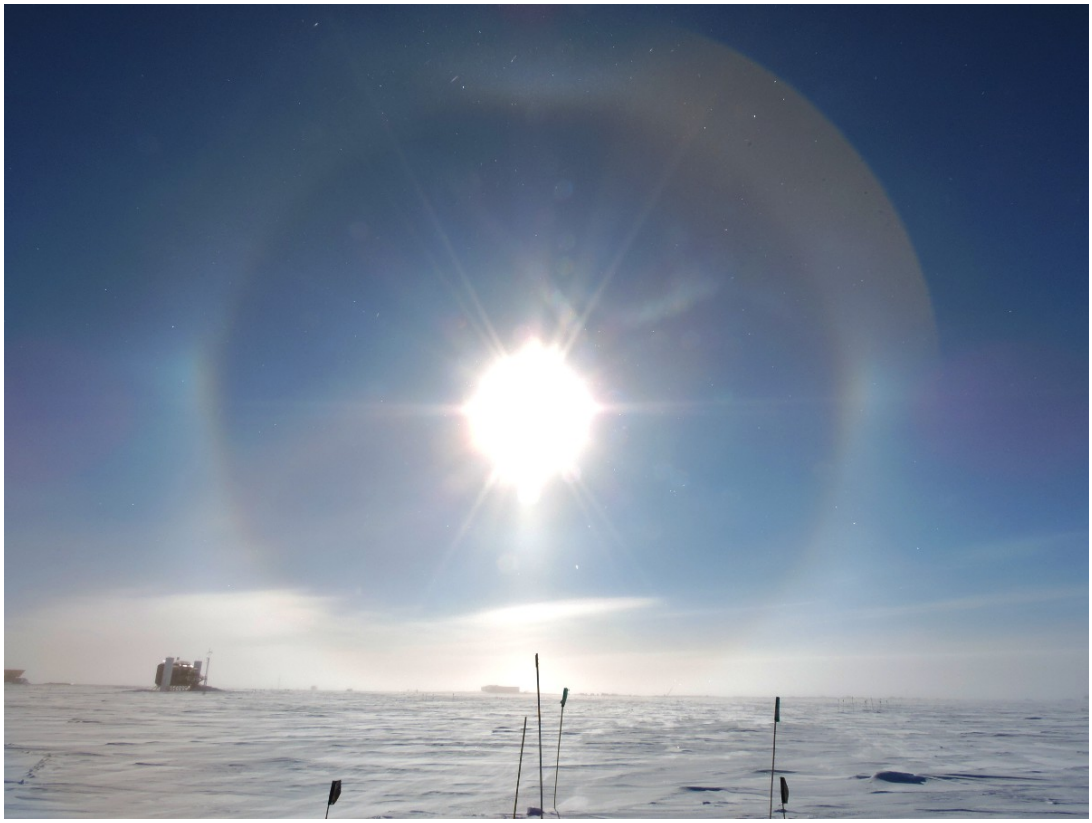


Armando gets the numbers while Elisa takes notes.
Credit: Sam De Ridder, IceCube / NSF.

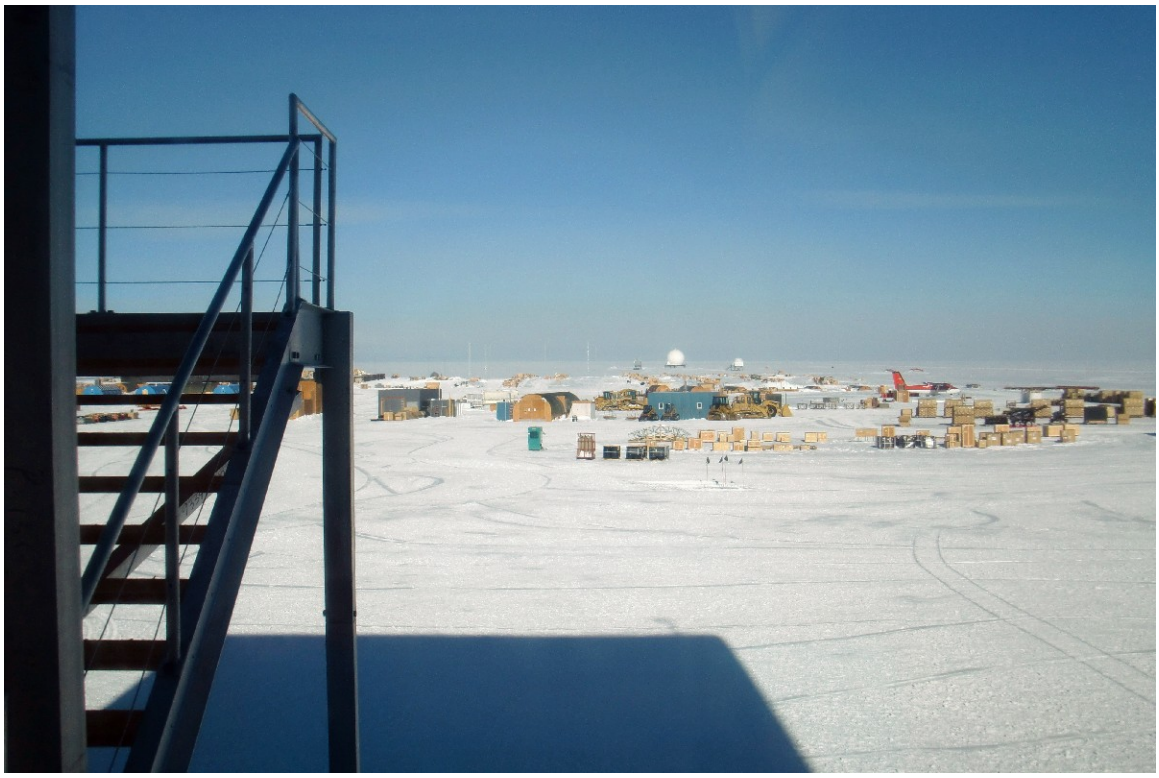


The measurements left a number of holes, and the ice inside looked blue.

At the South Pole the sun stays up for months in a row, maintaining the same height above the horizon (approximately 20°) throughout December and January each year.

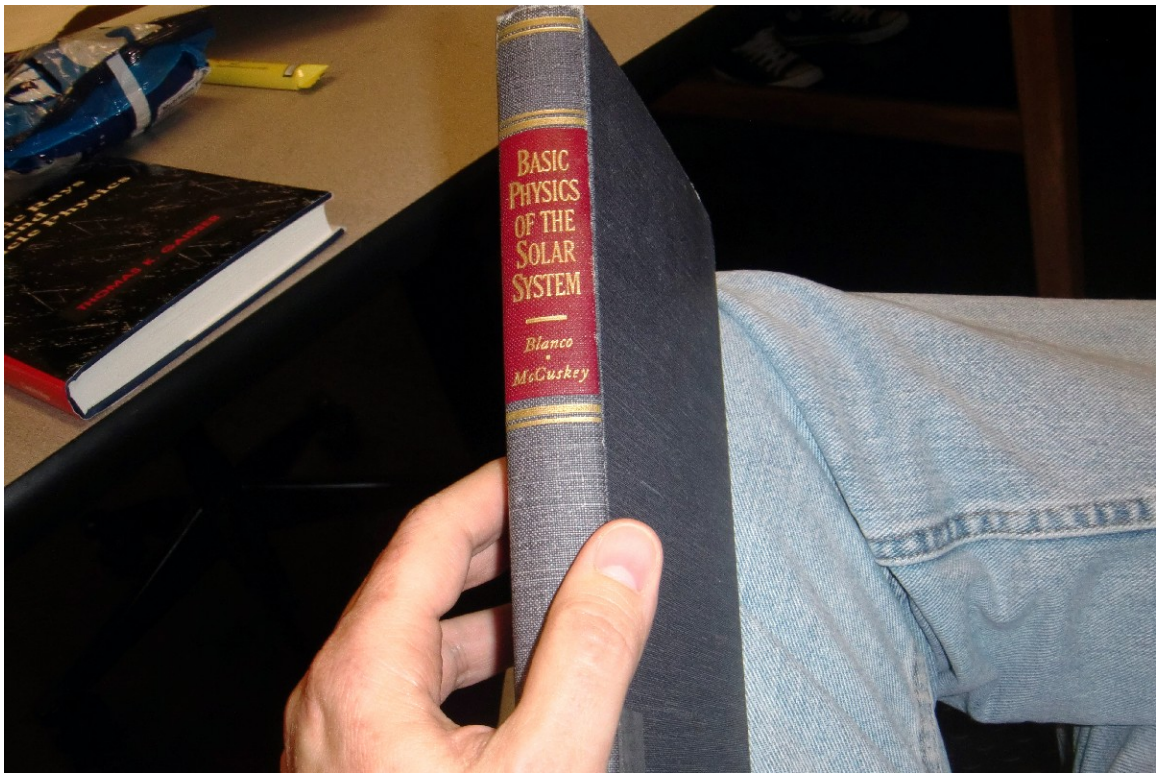


A common type of solar halo, known as "22° halo", with bright spots called "parhelia" on each side of the sun. Credit: Sam De Ridder, IceCube / NSF.

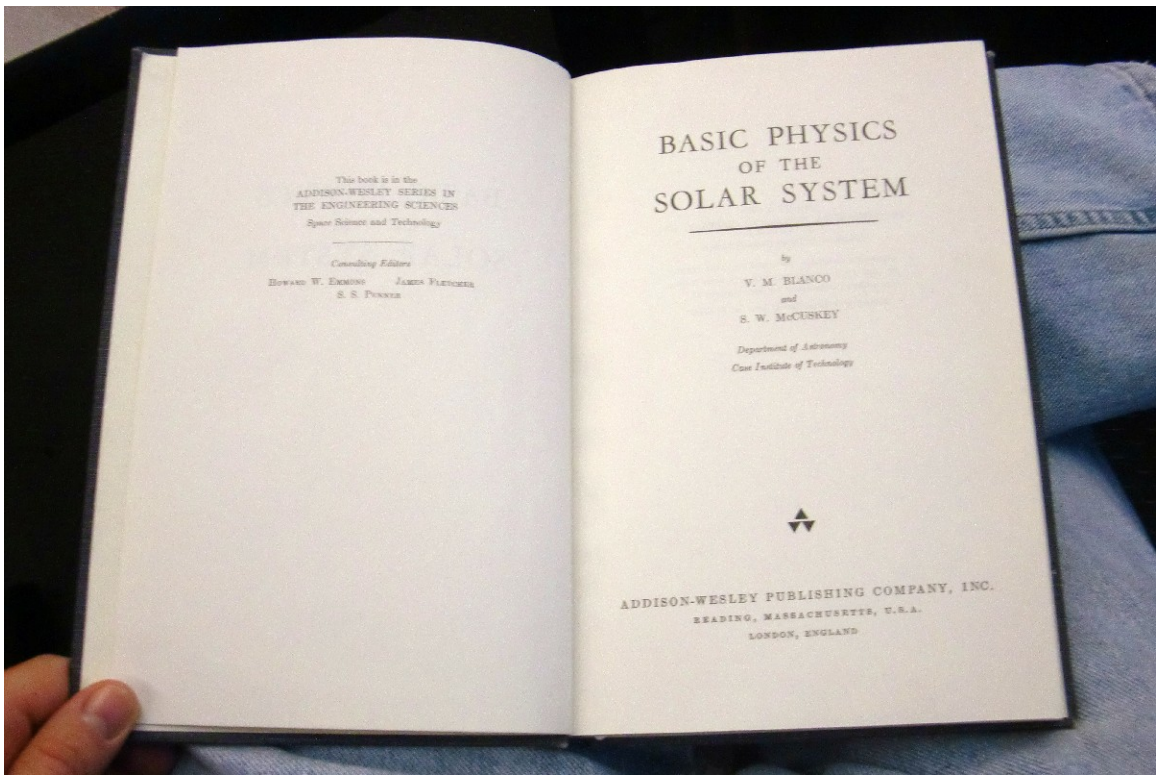


Looking out through a hallway window from A4 wing. Local time 12:01 am.

Same view, less than two hours later. Local time 1:55 am.



Spine of the astronomy classic 'Basic Physics of the Solar System'
by Victor M. Blanco and Sidney W. McCuskey (1961).



Title page of the astronomy classic 'Basic Physics of the Solar System'
by Victor M. Blanco and Sidney W. McCuskey (1961).

January 20. Last full day at the Pole

Today's post will again be a photojournal.

The flight to McMurdo was canceled, but it seems very likely that we will fly tomorrow. Since today will presumably be my last full day at the Pole, I wanted to share a picture of the IceCube team [see photograph on top of page 206] that was taken during our day off on Sunday, January 18. That was also the day when the windchill felt outrageously cold, which can be discerned by watching the pose, face and gestures of the people there, and likewise by them wearing heavier clothing than usual.

Having completed our work for the season and now ready to depart, I saw the possibility of enjoying a short time off to reflect and philosophize. In the afternoon I left the elevated station, alone, leisurely walking to the geographic pole, where I stopped and relaxed. I stood there, arms crossed, beholding a commanding scenery of the Antarctic Plateau and mulling over the fact that I was standing atop an actual glacier of monumental proportions, one that went three kilometers deep. Gusts of wind blew, and I felt the cold, dry wind hitting my face. I drank in the views—so tangible and real—saddened by the knowledge that they would soon recede into my mind and remain there only as distant memories.

Lately I have been gathering a number of photographs that somehow did not seem to fit with my previous posts. Well, two of those are now here, along with two other that I shot today [bottom of page 206 to top of page 208]. In addition, Hans has shared his amazing photograph collection with me, and it turns out that I have been prominently featured on a number of them [bottom of page 208 to bottom of page 210]. Sam also provided 37 of his own photographs, three of which I used on yesterday's post.

The IceCube team at the ceremonial pole: Sam De Ridder, Hans Niederhausen, James Casey, Lionel Brayeur, Elisa Pinat, Marcel Usner, Armando Caussade, Mike DuVernois and Stephan Richter.

January 20: Selfie photograph with the sign at the geographic South Pole. This was taken during a short time off when Armando went out for a walk, alone, to reflect on his experience.

January 20: Close-up of the snowpack at the South Pole.

January 14: In this picture Armando seems to be in a hurry, but that was not the case.

January 6: Boarding 'Ivan' the Terra Bus for the 12-kilometer ride from Williams Field to McMurdo Station, in the Antarctica coast.

January 6: Arrival at Williams Field. Keith and Armando are in the foreground. Credit: Hans Niederhausen, IceCube / NSF.

January 11: At the IceCube Laboratory after arriving at the Pole. Armando Caussade and Elisa Pinat are in the foreground. Credit: Hans Niederhausen, IceCube / NSF.

January 13: The IceCube team at the Science Laboratory in the main station. Credit: Hans Niederhausen, IceCube / NSF.

January 15: Armando while documenting an IceTop outing.
Credit: Hans Niederhausen, IceCube / NSF.

January 18: Armando being photographed by Sam (this image corresponds to the picture on top of page 196). Credit: Hans Niederhausen, IceCube / NSF.

January 21. Departure from the Pole and flight back to McMurdo

As expected, I finally flew back to McMurdo Station in the coast of Antarctica. We got news that an airplane from McMurdo had taken to the air at 9:00 am and was already en route, with an expected arrival time around noon. There are television monitors at both the Amundsen–Scott and McMurdo stations that list all planned arrivals and departures, and we spent part of the morning following up on those reports. But the unpredictability of weather means that anything can happen when traveling in Antarctica. Indeed, yesterday—the day originally set for our departure—an airliner had left McMurdo for the Pole, but was forced to turn back as the flight had to be aborted halfway. But to make a long story short, the plane today arrived like clockwork.

Right after lunch we all went out in front of the building, where the airplane was being prepared for the flight. The sun shone timidly through a layer of tiny crystals of ice high in the atmosphere, producing a beautiful solar halo. Heads went up everywhere to admire this wonder of nature [see photograph at the top of page 214], but as an astronomy educator I have to remind that one should *never look directly at the sun, as this can result in permanent, incurable blindness*.

When I first arrived at the South Pole I had seen sparkle on the ground, but now I saw sparkle in the air! I watched a tide of snow grains as they were flown over by the wind, and the twinkling effect this created was amazing. This phenomenon—usually known as *diamond dust*, and sometimes as *ice crystals*—is common to Antarctica. However, like the snow crystals that I glimpsed everywhere when direct sunlight hit the ground, I found impossible—or at least beyond my abilities as a photographer, or the capabilities of my equipment—to accurately capture on camera this magnificent episode of nature.

Six IceCube members were waiting to embark (Mike, Elisa, Sam, Hans, James and I) while four other members stayed. Two of them (Marcel and Lionel) are scheduled to leave next week, while Stephan and Erik will remain in the station as winterovers until November 2015. As the IceCube website explains (http://icecube.wisc.edu/news/view/84) *winterovers* are people who essentially remain stranded at the Amundsen–Scott South Pole Station, from the time the last airplane flies out in mid-February until the next flight arrives, over eight months later around early November.

We boarded around 1:20 pm and took off about 15 minutes later. The airplane was again an LC-130, the same type that had previously taken us from New Zealand to Antarctica. The engines can be so loud that passengers are routinely issued ear plugs to wear during the flight. But flying in an LC-130—among the few ski-equipped aircraft in regular use today—is quite an experience. Its flight is powerful but relaxed, and as explained in my post of January 6, its landings are quite graceful.

After a short and pleasant flight we landed at Williams Field, an airfield which is located right at the surface of the Ross Ice Shelf—a field of floating freshwater ice, nearly the size of France. This is next to Ross Island and about 12 kilometers from McMurdo Station proper. The airplane arrived at 4:20 pm, with a total flight time of exactly 2 hours and 45 minutes. I did not do a passenger count, but there seemed to be about 25 people, plus maybe 5 crew members as usual.

Upon arrival I found a scenery of incomparable beauty. In contrast to the bland, gray weather I had experienced during my previous five-day stay in McMurdo, this time the sky was clear and blue, and the sun was shining brightly at a height of 29° above the horizon.

As I stepped down from the airplane I saw the same place that I had left ten days ago, but in a totally different light. The mountains in the distance looked alive and vibrant, and the landscape felt particularly welcoming. The Royal Society Range was an easy target due west, while the volcanic peaks of Ross Island loomed to the north. Mike pointed out and I immediately recognized the silhouette of Mount Erebus, the world's southernmost active volcano. After admiring its beauty for a few seconds I grabbed my camera and shot a picture [see photograph at the top of page 217]. Farther to the right I saw Mount Terror which, although a tad less high and a bit farther away from the airfield, still looked impressive. Because of the uncooperative weather during my previous stay these views were simply not attainable, which is why I had been so eager for these sights upon my return to the Antarctica coast.

As I set foot in the ice shelf I was also startled with the temperature. Officially it was around freezing (~0 °C), yet it felt incredibly mild, even warm, compared with the Pole. Most people took immediate notice and were commenting on this, too.

We were driven to the station using the massive Kress vehicle, a recent acquisition in McMurdo that can take both people and cargo, and is likely the largest truck in town. At our arrival 30 minutes later, I got a room at once and was glad to be assigned again to building 155, the legendary blue structure covering 6,300 square meters and generally considered as the hub of the station. Building 155—being host to the dining hall, the retail store, and also the main public computer room—is without a doubt a very convenient place to stay.

Together with the keys to my room I got a note with a name and a number to page. I had already been told that people from the National Science Foundation (NSF) had taken an interest in my PolarTREC journals, and I was pleasantly surprised to learn that NSF officers were present at the station and wanted to meet for an informal conversation. So I talked to Katy who at once introduced me to Lisa (a program director at NSF) and Erika (an Einstein Distinguished Educator fellow). We met for dinner and had a most interesting chat. Later on we all attended a lecture at the Crary Lab Science Hall on diatom ecology in the McMurdo Dry Valleys where I was, in turn, introduced to Dr. Diane McKnight of the University of Colorado–Boulder (one of the presenters) who was doing astrobiology work in Antarctica.

This unexpected encounter with Katy, Lisa, Erika and Diane was my highlight for today, as it is always gratifying to be recognized for one's work.

Armando with the LC-130 airplane in the background.

Mike DuVernois and Armando Caussade preparing for departure.

A 22° solar halo that caught the attention of everyone.

Armando Caussade and Stephan Richter admiring the halo around the sun.
Credit: Marcel Usner, IceCube / NSF.

Snow grain precipitation started to accumulate on Armando's luggage.

Last picture before boarding: Hans Niederhausen, James Casey, Sam De Ridder, Lionel Brayeur, Elisa Pinat, Mike DuVernois and Armando Caussade. Credit: Marcel Usner, IceCube / NSF.

Departure from the Amundsen–Scott South Pole Station.

Arrival at McMurdo's Williams Field after a short and pleasant flight.

Mount Erebus—the southernmost active volcano in the world—as seen from Williams Field.

Boarding the huge Kress vehicle for the 12-kilometer ride to the station.

January 22. Walking in and around McMurdo

It appears my stay in McMurdo will last at least until Saturday, January 24, so I decided to go out and do some sightseeing in and around town. At 3:00 pm I met with James, Sam and Elisa, and together walked over to the nearby New Zealand's Scott Base to do some last-minute shopping. The complete round trip is a six-kilometer hike—three each way—which at first sight seems much longer than reality, since it is done on the gravel road that straddles the northern slope of Observation Hill.

The hike was much easier and faster than expected, and as I warmed up from the walk the air temperature (around 0 °C) began to feel very pleasant. The contrast with the South Pole was astounding: not only it felt much warmer here, but in addition to the ice there were large patches of barren land and even a few isolated spots of liquid water. Occasionally, birds flew around. We all wore lighter clothing than at the Pole and were also able to move faster. Although I had barely felt any ill effects from the elevation at the South Pole, I did notice that the hike here at sea level felt more relaxed.

After about three-quarters of an hour we came at the footsteps of Scott Base. We stayed for only a few minutes, since our sole purpose there was to do some shopping at the gift shop. The store was well stocked with an assortment of hand-crafted ornaments and gifts, among which I found a glass penguin figurine that I bought as a present to my mother. And it was a relief to learn that they took United States dollars, as we all had lately been running low in New Zealand currency.

At our departure we coincidentally ran into Lisa and Erika who had just arrived from McMurdo and were likewise headed to the store. Upon leaving the premises we stared out to the ocean and saw *pressure ridges*—undulations in the sea ice that run parallel to the coastline and are a common sight around Scott Base. These are caused by a collision of the nearby Ross Ice Shelf with the sea ice, which in turn is squeezed against the shore of Ross Island. We also noticed large cracks in the sea ice, with a group of seals laying gracefully along them after coming out of the water.

On the way back to McMurdo we walked up the *Hillary Track*, which after a hike of 700 meters eventually winds up at the main road. Although unpaved, this highway is wide, smooth and well maintained. At its highest point the road has vantage areas that offer some impressive vistas of land, ice, and occasionally water. There is also the blue signboard that welcomes newcomers to the station, as well as a beautiful panorama of Observation Hill that becomes more immersive as one draws closer to town. Moreover, all the prime species of Antarctic fauna can be found and observed in the area.

The sky was gray again, but the mild temperatures and calm air made for a very pleasant outing. Interestingly, the visibility was better today than with previous episodes of cloudiness, and distant landmarks such as White Island, Black Island, Mount Erebus and even the Royal Society Range (a prominent section of the Transantarctic Mountains, in continental Antarctica) were in plain sight.

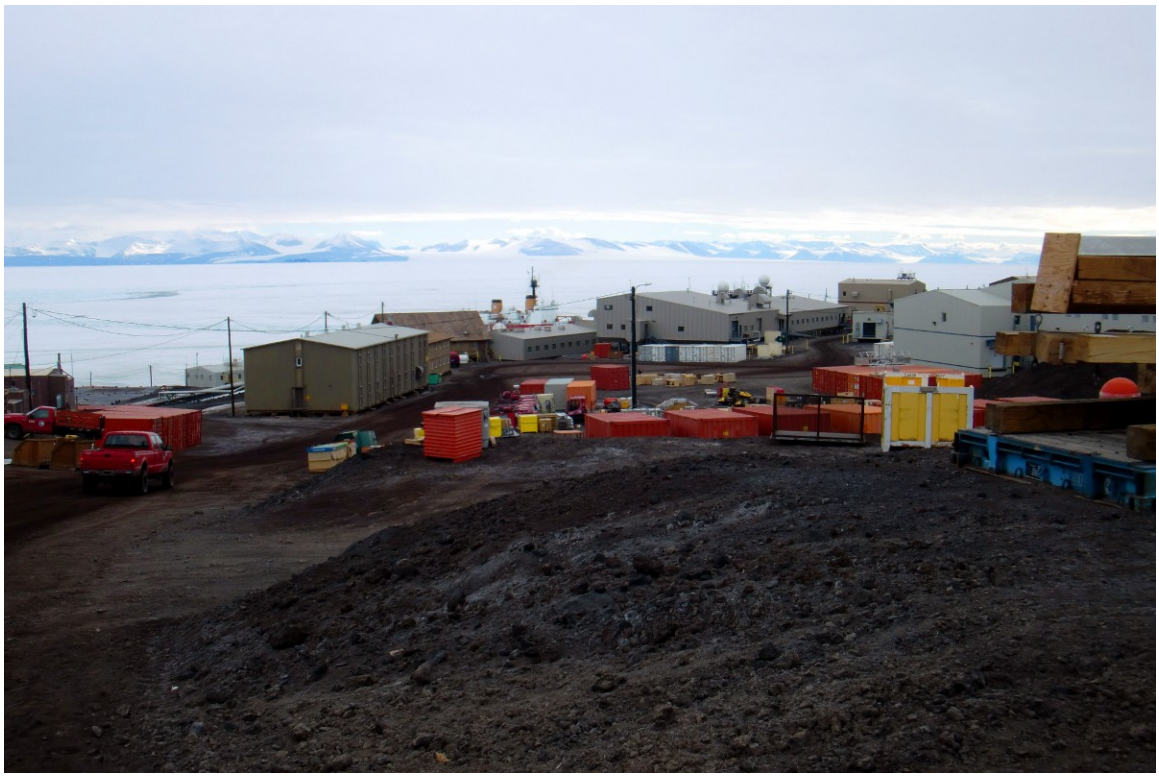
We returned to McMurdo's building 155 around 5:00 pm, and soon afterwards arrived at the dining hall. After days of staying late with the journals, I plan to hit the bed early today and get some needed rest.

New Zealand's Scott Base seen in the distance with buildings painted in green.

Armando gazing towards Scott Base, with Black Island in the background

Leaving the gift shop at Scott Base. Behind the buildings are cracks in the sea ice and a group of Weddell seals. Further back is White Island.

Right off the road with the blue McMurdo sign and Observation hill behind. This was taken about halfway from Scott Base to McMurdo Station.



Arriving in McMurdo with the Royal Society Range in the background.
The well-known Dry Valleys area lies adjacent to this range.

The Antarctic Fire Department in McMurdo.
Unbeknownst to most people there are actual firefighters in Antarctica.

January 23. Meeting with fellow teacher and photo shoot near Mt. Erebus

Today I was blessed with an entire day of perfect weather. The sky was crystal clear with a vivid shade of blue, and the sun was shining as brightly as it is possible from Antarctica. The temperature was near freezing, but with the sun and the calm air, the weather felt surprisingly mild. And I was glad to finally experience one of those "warm" Antarctic days about which I had read so much on the Internet.

I started my day bright and early with a visit to the Albert P. Crary Science and Engineering Center here in McMurdo. Crary Lab—one of the largest structures in town, with 4,320 square meters of working area and appropriately labeled as building number 1—serves as the main laboratory and research facility, and additionally features an impressive number of exhibits relating to Antarctica.

My visit to Crary Lab was to attend a PolarConnect live video presentation with Yamini Bala, a fellow PolarTREC teacher who is also staying here in McMurdo. Yamini has just returned from a field camp at the West Antarctic Ice Sheet Divide (or WAIS Divide) where she studied the microstructure of ice crystals together with the VeLveT Ice team. We started the webcast at 8:00 am and I feel she did an awesome job of explaining what the science and research at WAIS Divide were, which made for a unique learning experience. Furthermore, I had the pleasure to meet her researcher, glaciologist Dr. Erin Pettit from the University of Alaska–Fairbanks, as well as other members of the group.

Yamini's PolarTREC journal is available from the following Internet address:
http://www.polartrec.com/expeditions/west-antarctic-ice-sheet-microstructures

Around 2:00 pm and taking advantage of having the right weather conditions, exactly as I wanted them, and also the right time of the day, as the sun had just passed the meridian—attaining its maximum height of 32°—I went out and walked down the road from the United States' McMurdo Station to New Zealand's Scott Base, in order to obtain a better view of Mount Erebus. About halfway during the 45-minute hike I spotted a pair of south polar skuas flying high above the road. These birds are a common sight along the Antarctic coast as they feed on the abundant fish in the surrounding sea.

The road climbs steadily and reaches a high point about two-thirds of the way from McMurdo to Scott Base. With an elevation around 150 meters the area provides sweeping views of a breathtaking coastal panorama that spreads out from south to west. When the sky is clear as it was today, White Island can be prominently seen due south, just across the Ross Ice Shelf, with Black Island to its right. Mount Discovery—an isolated volcano that is located about 75 kilometers to the southwest—and the Brown Peninsula of mainland Antarctica are also easily discerned further to the right.

As explained, since my arrival in the continent I had been wanting to get an unobstructed, panoramic view of Mount Erebus and its surroundings. This volcano—the most active in Antarctica out of a total of 36, and undoubtedly the finest natural landmark in Ross Island—cannot be observed from McMurdo proper due to nearby hills blocking the view. It can be seen from the summit of Observation Hill right behind the rocky outcrop of Castle Rock, but a comparable sight can be obtained at ground level from the southeastern side of the Hut Point Peninsula, just outside of Scott Base.

As I continued—with many photographic stops along the way—the road came to a quick descent and I reached the outskirts of Scott Base. I then found myself standing in a coastal field with an open view to

the peaks of Ross Island. I looked north and was treated to an amazing view of Mount Erebus, which is blanketed almost completely by snow and ice. Since the air was absolutely transparent and the mountain looked so crisp, the fact that this landmark stood 42 kilometers away seemed unbelievable. There was a plume of smoke rising above its summit [see photographs on page 227] that, because of the permanent lava lake that sits inside the crater—one of only five on Earth—is a common occurrence. But for me this sight was noteworthy, as never before I had witnessed volcanic activity in person.

Turning my head to the right (due northeast) I was able to discern the silhouette of Mount Terror, another of Ross Island's volcanoes which, like Mount Erebus, is also under snow and ice. But in spite of its visual majesty, Mount Terror is thought to be either dormant or extinct. Preliminary studies of rocks around the mountain show no signs of volcanic activity within the last million years.

I stood there for maybe half an hour, shooting with my camera from the shoulder of the road. As I savored the arresting landscape a human figure walking along the road emerged from the distance. The person moved fast and kept getting closer, until a young woman's voice with a friendly attitude made itself audible: "Hey! How are you? What a beautiful day! Admiring the view?" I knew the voice and I immediately recognized the person: She was Rachel, an engineer involved with the BICEP3 telescope who I had originally met at the Pole. We enthusiastically chatted for a while, until we both noticed a sport-utility vehicle coming in our direction and hitched a ride back to McMurdo Station.

I made a grand total of 118 pictures along the road and at the outskirts of Scott Base, perhaps the most comprehensive photo shoot so far during my stay in Antarctica. However, most of those images were not conceived primarily as stand-alone pictures, but rather as parts of panoramic arrays made up of four, five or six photographs that I will later on digitally stitch together using specialized software.

At my return around 4:00 pm I grabbed a seat at the main computer laboratory in building 155, where I have been for hours now and where I will likely stay past midnight. Drafting these journals takes time, particularly when one accounts not only for the writing, but also for the selection and publication of the pictures. But this has become my most rewarding task so far with PolarTREC, and after my departure tomorrow I will miss my evenings at the computer room in building 155, here in McMurdo.

PolarConnect webcast event with Dr. Erin Pettit and PolarTREC teacher Yamini Bala.

PolarTREC teacher Yamini Bala while talking to the audience.

Main entrace at the Crary Lab (i.e., Albert P. Crary Science and Engineering Center), the main laboratory and research facility in McMurdo Station.

A pair of South polar skuas flying above the road.

Pressure ridges in the frozen seawater near New Zealand's Scott Base,
with the flat, featureless, Ross Ice Shelf right behind, and White Island in the background.

Mount Discovery (elevation 2,681 meters), a conspicuous but inactive volcano.
The hills of Brown Peninsula are seen at the base of the volcano and towards the right.

Wide field view of Mount Erebus and its surroundings.
Elevation 3,794 meters.

Zoomed-in view of Mount Erebus with smoke arising from its summit.

Selfie photograph with Mount Erebus in the background.

Zoomed-in view of Mount Terror.
Elevation 3,262 meters.

January 24. Departure from Antarctica and flight back to New Zealand

As scheduled, today I successfully flew from McMurdo Station in Antarctica to Christchurch, New Zealand, together with James Casey and Yamini Bala. I almost lost the flight, as I stayed until 2:30 am working with the Mount Erebus journal and overslept when my alarm clock failed to wake me up. But I was alerted by a timely phone call from Yamini around 7:30 am, for which I am extremely grateful.

At my arrival at Williams Field I was able to take one last peek at Mount Erebus, and what a spectacular view was that! There was a lenticular cloud floating right above the volcano, something that—like the plume of smoke that I saw yesterday—I had never watched before. The cloud hid the upper half of the volcano, but the sky was clear just out and around the cloud, and the sun directed its rays against the lower slopes. That was the scenery I had before my eyes as I said farewell to Antarctica.

We boarded the airplane around 9:15 am, took our seats and were each given a pair of ear plugs to wear during the flight, as the aircraft engines are very loud. About 40 people were flying and the crew announced that we would be in for a cramped flight, but everything went fine and I cannot say that I felt uncomfortable at any moment. The plane was again a ski-equipped LC-130 with people sitting parallel to the fuselage in the front, along with a heavy load of cargo in the rear compartment.

Passengers traveling between Antarctica and New Zealand are usually given light meals to eat during the flight. But today I somehow got more than the usual share, with three ham and cheese sandwiches (each loaded with real, thick-cut sliced ham), a hamburger, plus an unexpected sausage sub, which of course was the first to go. Weather conditions were good all the way through, and eight hours later—about 5:15 pm—we landed safely at Christchurch International Airport in New Zealand's South Island.

I cleared immigration and customs in less than 15 minutes and promptly headed towards the International Antarctic Center, which is conveniently located next to the airport and can be reached by foot in 10 minutes. After 18 days in Antarctica, the 22 °C weather of Christchurch felt oppressively hot and humid, but the sight of lush vegetation and the smell of flowers was a pleasant surprise. Upon leaving the airport I marveled at the display of green, luxuriant plants of all kinds.

I immediately proceeded to the Clothing Distribution Center where I turned over the extreme cold weather gear that had been issued to me three weeks before. I shed all my winter clothing and changed to jeans and a polo shirt that are more in tune with the warm summer weather of New Zealand. We were then all given woven patches with the United States Antarctic Program (USAP) logo to keep as a gift, and were also provided with hotel destinations and updated flight itineraries.

A shuttle bus came to pick us up and the driver turned out to be the same friendly gentleman that had come for me at the airport when I first arrived in Christchurch in early January. Along the way I caught sight of beautiful gardens—which are found everywhere in New Zealand—sprinkled with flowers of every hue and form. Soon after, we arrived at Hotel Elms in downtown Christchurch.

Tomorrow I will board a commercial flight that will take me to Sydney, Australia, followed by another to Dallas, Texas, in turn followed by a final flight to San Juan, Puerto Rico. Afterwards, I intend to post one or two additional journal entries explaining my return to the classroom and acknowledging all who helped make my South Pole journey possible.

Mount Erebus as seen from Williams Field near McMurdo.
A lenticular cloud is hiding the summit of the volcano.

Last picture in Antarctica, taken while departing from Williams Field.

Arrival of the LC-130 at Christchurch International Airport in New Zealand.

Passenger terminal for the United States Antarctic Program (USAP) at Christchurch International Airport.

Armando leaving the airport on his way to the International Antarctic Center.

The International Antarctic Center where the USAP Clothing Distribution Center is located.

The USAP Clothing Distribution Center—same place Armando had visited 18 days before.

View out of Armando's window at Hotel Elms in Christchurch, New Zealand.

January 26. Arrival in Puerto Rico and return to the classroom

Today at 4:00 am I safely arrived home in San Juan, Puerto Rico.

I had already decided to immediately go back to work, and at 9:00 am I reported at the Seminary in San Juan where I teach astronomy and mathematics. Later on I made the 32-kilometer drive to Juncos, showing up by 3:00 pm at Pedro Rivera-Molina Elementary and Middle School where I found my full cohort of 90 students anxiously waiting for my arrival. Unbeknownst to me, the school had been planning a greeting party, complete with pizza, soda end even a cake! The kids had assembled at the school's stadium and I spoke to them for about 30 minutes on my South Pole expedition.

Following a short introduction I answered questions on every conceivable topic concerning polar exploration, including how to cope with temperature, elevation and dryness. I also took a number of queries on neutrinos, cosmic rays and the IceCube experiment. Afterwards, I devoured three pizza slices of the meat-lovers variety—had not eaten, yet—and went on to chat with a group of fellow teachers.

Now that I was back in the island I was finally able to see things in perspective, and particularly to review my definitive expedition itinerary. After returning home from work I sat down and did a comparison with the preliminary schedule that I had posted on January 2. As my mentor Jim Madsen had anticipated, the two timetables ended up looking very different. The realities of Antarctic travel demand the utmost flexibility and willingness to accept a change of plans. That was my mindset from the beginning, and I saw every change as an opportunity and not a hindrance.

My final schedule turned out as follows:

Friday, January 2, 2015:	Departure from San Juan, Puerto Rico.
Monday, January 5, 2015:	Arrival in Christchurch, New Zealand.
Tuesday, January 6, 2015:	Arrival at McMurdo Station on the coast of Antarctica.
Sunday, January 11, 2015:	Arrival at Amundsen–Scott Station at the South Pole.
Wednesday, January 21, 2015:	Departure from Amundsen–Scott Station at the South Pole.
Saturday, January 24, 2015:	Departure from McMurdo Station on the coast of Antarctica.
Sunday, January 25, 2015:	Departure from Christchurch, New Zealand.
Monday, January 26, 2015:	Arrival in San Juan, Puerto Rico.

So, the total duration of my PolarTREC expedition was 24 days, of which 18 days correspond to my actual stay in Antarctica. All in all, it was a wonderful journey and a truly memorable experience.

Back at school in Juncos, Puerto Rico, greeting the students and signing autographs.
Credit: Gretchen B. Guzmán, G Works Inc.

Teachers and students had assembled at the school's stadium.
Credit: Miguel Piñero, Puerto Rico Department of Education.

Chatting with fellow teachers while enjoying pizza and soda. Armando Caussade, Miguel Piñero, Gretchen B. Guzmán and Lymari Hernández. Credit: Carlos Muñoz, G Works Inc.

At his arrival Armando was presented with a cake.
Credit: Carlos Muñoz, G Works Inc.

Back at the classroom: undergraduate astronomy class at the Seminary.
Credit: Armando Caussade, PRAS.

Seminarians enrolled in the astronomy class.
Credit: Armando Caussade, PRAS.

ACKNOWLEDGMENTS

A. Expedition Acknowledgments

February 4, 2015
San Juan, Puerto Rico

I am now back and a new adventure has just begun, as I start sharing my experience with students, fellow teachers and the community. I am already seeing the fruits as I watch my own students picking up an interest in high-energy astronomy and polar exploration. I sincerely hope a number of them will eventually follow careers in science and do even better things than what I did.

Armando's best selfie photograph from Antarctica, taken at the South Pole in January 20, 2015. Temperature was −30 °C and windchill was around −40 °C.

First of all, I would like to convey my heartfelt gratitude to four key persons: Janet and Sarah of PolarTREC (Alaska), as well as Jim and Megan at the IceCube headquarters (Wisconsin). In a very real way, I owe it all to them, and words will never be enough to thank them for providing me this opportunity to travel to the South Pole, the most remote spot on Earth. Janet, a program manager at ARCUS—a non-profit that manages PolarTREC—was the first person with whom I had contact, as early as September 2013. Sarah—a program manager at ARCUS along with Janet—and Jim, chair of

the Physics Department at the University of Wisconsin–River Falls (and also an associate director of the IceCube Collaboration, where he leads the education and outreach team) came to me a bit later, between October and November 2013. Megan, an education and outreach coordinator for the Wisconsin IceCube Particle Astrophysics Center (WIPAC), also entered the scene around this time.

Jim: I am incredibly grateful and honored that you gave me the privilege of joining the IceCube team and working with the IceCube telescope at the South Pole. In all honesty, I cannot think of an astronomy experiment that conveys more wonder and excitement than IceCube. I thoroughly enjoyed your visit to Puerto Rico in April–May 2014, and was again pleased to visit you in Wisconsin in July 2014. You (together with Megan) were the guiding force behind all of the planning—which went on for a full year—and you also provided valuable advice and direction, for which I will forever remain indebted. Thank you, Jim!

Janet: I always recall when you encouraged me to apply back in September 2013 and I totally appreciate it. You were also extremely helpful when I visited Fairbanks in February 2014, and I thank you for that. I have very happy memories of that trip.

Sarah: You called me to break the news of my selection on Thanksgiving eve in November 2013, and that made for my best Thanksgiving celebration ever. And I am also grateful that you patiently guided me through each step of the PolarTREC process through an entire year.

Zeb and Ronnie, information technicians at PolarTREC, provided prompt assistance with technical issues while I was in the field. On the IceCube side, Silvia and Jim (Haugen) have been particularly helpful throughout the project, while Lauren and Jean have provided material for WIPAC News. Elaine from the Antarctic Support Contract and Joshua from BCD Travel were pivotal people, and my journey would not have come to fruition without their assistance. In addition, fellow PolarTREC participants and alumni such as John, Michelle, Susan, Lisa, Peggy, Lucy, Lollie, and last but not least, Yamini—who I actually met while in Antarctica—have all been an inspiration. I also met Dr. Pettit from the University of Alaska–Fairbanks, who aptly suggested that I could help encourage high school girls from Puerto Rico to apply to the Girls on Ice program, which I enthusiastically did starting the same day I returned to the island, on January 26.

My gratitude also goes to the members of the IceCube team that I encountered at the Amundsen–Scott South Pole Station, listed here in no particular order: Mike, Elisa, Marcel, Lionel, James, Hans, Stephan and Sam. Mike—my on-site supervisor—was particularly friendly and welcoming, and I thoroughly enjoyed his keen sense of humor. I spent lots of time with Sam, who always took the time to explain everything with great detail. Elisa provided technical details on IceTop, while Stephan was instrumental in preparing for the IceCube webcasts. Hans and James were helpful in many ways, especially while in McMurdo and New Zealand. During my stay in McMurdo I encountered Katy, who in turn introduced me to Lisa (a program director at the National Science Foundation, who has been following my PolarTREC journals) and Erika (an Einstein Distinguished Educator fellow).

I would also like to thank webcast attendees Rachelis and Amarilis (who each brought their own student cohorts), Ruth from the Arecibo Observatory in Puerto Rico, and the Hon. Ángel R. Peña-Ramírez of the Puerto Rico House of Representatives.

My employers have all consistently supported my participation with PolarTREC from the beginning. I am particularly grateful to the following individuals: Gretchen and Carlitos (both of G Works), school

administrators Yadira and Miguel (from Pedro Rivera-Molina middle school, where I teach), fellow teachers Lymari, Shirley and Yobán, and outstanding students like Kiany, Antonio, Jan, Rocío, Nashaley and many others. Sandra (from Alfonso Díaz-Lebrón middle school, where I teach summer classes). María and Jennifer (from Metropolitan University's Center for Sustainable Development Studies, where I teach), as well as my full student body, but notably Nelson, Lyzzette and Osvaldo. Fr. Juan Luis, Fr. Iván and Maritza from the Seminary—where I started my teaching career—and in particular my students from this semester's undergraduate astronomy class: Emmanuel, Edwin O., Jorge and Guevnex.

The *Puerto Rico Astronomy Society* (PRAS) assisted in many ways providing public relations, event hosting and even arranging a magazine cover. A number of people there have been supportive in one way or another, such as Rubén and wife Alicia, Greg, Víctor, Natalia, José (Colom), José (Candelaria), Carmen, Héctor and wife Jomary, Juan V. and Dr. Peña-Hevia (from UPR–Río Piedras). Jacqueline and Digna, both of the Puerto Rico Science Teachers Association, and Genoveva, a good friend from academia, were among the early group of people who knew about my application to and selection by PolarTREC, back in 2013. Antonio Molina, founder and president of the UNESCO Center for Culture (i.e., Puerto Rico UNESCO Association), and Joseph Bergkamp of the Knights of Columbus—both good friends and mentors—have provided outstanding wisdom, encouragement and moral support.

Other people lent their expertise with writing and media engagement. Laurel (formerly of the Wisconsin IceCube Particle Astrophysics Center) did an amazing interview with me back in March 2014, which is available online at: http://icecube.wisc.edu/news/view/215. Deborah wrote a press release which let the local media know of my South Pole expedition. This release was very successful and yielded over 40 media hits, including two television interviews. I am also grateful to all who have followed my PolarTREC journals, and in particular those faithful readers of my daily posts like Rubén, Lymari, Willie (from Vega Baja, Puerto Rico), Carlos F. (from Panama) and Anne (from Belgium).

Several health providers were involved with my medical prequalification (PQ) process. I would like to thank the good people at the Members Office (i.e, *Oficina de Socios*) at Hospital Auxilio Mutuo—without a doubt, the island's most advanced and comprehensive medical facility—who arranged lab tests and immunization. I am particularly indebted to Dr. Aponte (dentist) and Dr. Romero (physician), both of Concilio de Salud Integral de Loíza—a federally qualified health center—who each saw me twice and took care of the extensive medical and dental paperwork that was required. Wilnelia and Migdalia (both at the reception desk) as well as Mr. Rodríguez-Román (executive director) were also helpful.

Above all, I would like to thank my mother Carmencita and my father Armando who were my biggest supporters from the beginning. They were the very first teachers of my life, who taught me to aim high and settle for nothing less than the best. I am fortunate to still have them both. My gratitude also goes to my two brothers Carlos R. and Jorge A., and to all relatives and good friends who in one way or another have conveyed their support and good wishes. Many have followed this project from day one and have stayed abreast via PolarTREC's website or via social media. They are too numerous to mention here, but my sincere appreciation goes to each and every one of them.

Finally and most important, I am grateful to all those who prayed for a successful expedition. The Almighty was there all along the way, working behind the scenes and ensuring everything ran like clockwork.

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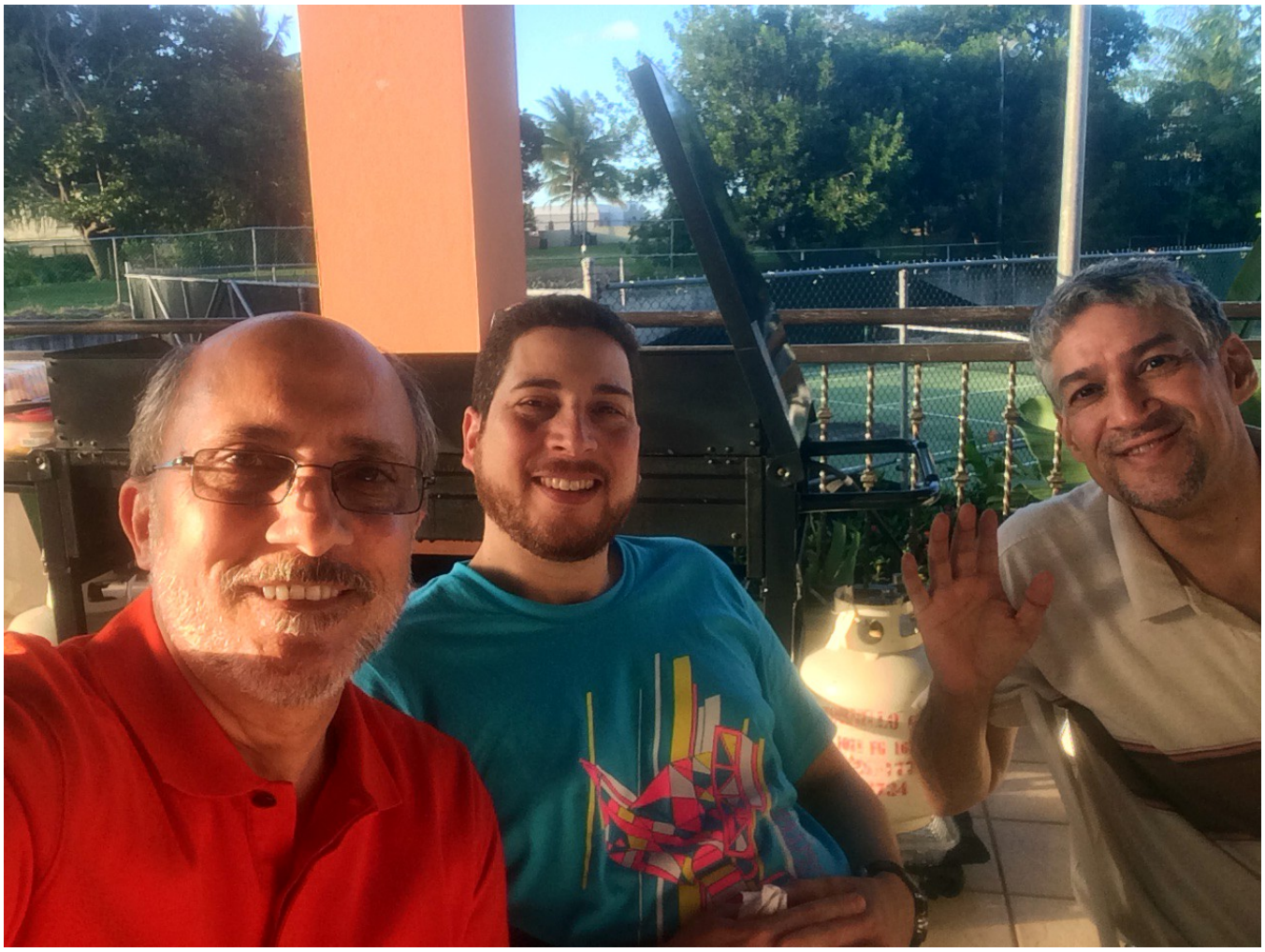

Rubén Miranda, Armando Caussade and the late Víctor Román, posing for a group selfie during an informal gathering at the Puerto Rico Astronomy Society (PRAS) that was held only six days after Armando's return to the island. February 1, 2015 — Dorado, Puerto Rico. Credit: Rubén Miranda, PRAS.

Rubén Miranda—a PRAS board member and avid amateur astronomer—was a faithful follower and commenter of Armando's PolarTREC journals. In his comments to the post of January 19, 2015, he shared his thoughts as follows: "You have left not only your footprints on the snow there, but also your dedication, passion and spirit of kindness in the hearts of those who gain a new friend. […] Reading your daily journals and replying, has become a pleasant routine. All the best, and Godspeed."

Víctor Román—who was then Vice President at PRAS—enjoyed ample access to the media and was instrumental in communicating Armando's story to the larger public. The image above is the last known photograph to feature Víctor before his untimely death in April 10, 2015, at the age of 50. A memorial book entitled *Víctor Román-Cordero: The Legacy of a Puerto Rican Astronomer*, was recently published by PRAS with Armando as editor-in-chief. It can be obtained free from the PRAS website.

B. Book Acknowledgments

To the Heavenly Father and to my parents, Armando and Carmencita, for everything.

To Jim Madsen of the University of Wisconsin and the IceCube Collaboration, my expedition mentor, who conducted a technical review of the draft and additionally wrote the foreword of this book. He was attending a conference in Asia when he received the preprint, but still was very prompt in his replies. To Janet Warburton, manager of PolarTREC at the Arctic Research Consortium of the United States (ARCUS), for making available the PolarTREC website to host this book, and also to Sarah Bartholow, formerly of PolarTREC, who from the beginning supported the idea for a book like this.

To Isaac Cruz, a former president of the Columbus Astronomical Society in Ohio and also a member of the *Puerto Rico Astronomy Society* (PRAS), who saw the preprint and conveyed his enthusiasm. To Greg García, the original PRAS founding father and president emeritus, a friend of 31 years who passed away on September 24, 2016, two days after the release of the first edition of this book. Also to Michelle Kantrow and Juan Villafañe—a former president of PRAS and the current president, respectively—for their kind assistance with translation work and media engagement, again respectively.

And last but not least to Jennifer Cruz, an administrative assistant at Metropolitan University, where I teach, for providing a venue for the launch of the second edition of this book, in October 12, 2016.

Launch of the second edition of this book.
October 12, 2016 — San Juan, Puerto Rico. Credit: Linda Díaz, PRAS.

C. About PolarTREC

PolarTREC (Teachers and Researchers Exploring and Collaborating) is a program in which K–12 teachers spend three to six weeks participating in hands-on field research experiences in the polar regions. The goal of PolarTREC is to invigorate polar science education and understanding by bringing K–12 educators and polar researchers together.

Goals and objectives

By fostering the integration of research and education, PolarTREC will continue the momentum established during the International Polar Year (IPY) by addressing the following objectives:

1. To improve teachers' STEM content knowledge of the Polar Regions and transfer to the classroom.

2. To increase teachers' knowledge and use of STEM practices with their students in the classroom.

3. To develop teachers' educational leadership skills and give opportunities to teacher to be influential leaders in their professional community.

4. To improve the evidence base of successful strategies that utilize teacher leadership skills for the purpose of broadening participation in polar STEM learning.

5. To increase students' understanding and engagement in the Polar Regions and interest in polar-related STEM careers.

6. To develop long-term professional relationships between the education and research communities.

Funding and support

The PolarTREC program is managed by the Arctic Research Consortium of the United States (ARCUS), a non-profit based in Alaska and Washington DC. ARCUS is a consortium of educational and scientific members that have a substantial commitment to Arctic research. ARCUS was awarded funding from the National Science Foundation Division of Polar Programs for PolarTREC during the International Polar Year (2007–2009) project and then awarded continued funding from 2010 through 2013. In 2014, ARCUS received additional funding for one year (2014–2015). In November 2015, ARCUS was awarded funding for an additional year (2016–2017).

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D. About the IceCube Neutrino Observatory

The IceCube Neutrino Observatory is the first detector of its kind, designed to observe the cosmos from deep within the South Pole ice. An international group of scientists responsible for the scientific research makes up the IceCube Collaboration.

Encompassing a cubic kilometer of ice, IceCube searches for nearly massless subatomic particles called neutrinos. These high-energy astronomical messengers provide information to probe the most violent astrophysical sources: events like exploding stars, gamma-ray bursts, and cataclysmic phenomena involving black holes and neutron stars.

The Antarctic neutrino observatory, which also includes the surface array IceTop and the dense infill array DeepCore, was designed as a multipurpose experiment. IceCube collaborators address several big questions in physics, like the nature of dark matter and the properties of the neutrino itself. IceCube also observes cosmic rays that interact with the Earth's atmosphere, which have revealed fascinating structures that are not presently understood.

Approximately 300 physicists from 48 institutions in 12 countries make up the IceCube Collaboration. The international team is responsible for the scientific program, and many of the collaborators contributed to the design and construction of the detector. Exciting new research conducted by the collaboration is opening a new window for exploring our universe.

The National Science Foundation (NSF) provided the primary funding for the IceCube Neutrino Observatory, with assistance from partner funding agencies around the world. The University of Wisconsin–Madison is the lead institution, responsible for the maintenance and operations of the detector. Funding Agencies in each collaborating country support their scientific research efforts.

Funding agencies supporting IceCube construction

Primary funding source: National Science Foundation, USA

This project would not have been possible without the United States Antarctic Program, Raytheon Polar Services Company, the Antarctic Support Contract (a program by Lockheed Martin) and the New York Air National Guard.

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E. About the United States Antarctic Program

Without interruption since 1956, Americans have been studying the Antarctic and its interactions with the rest of the planet. These investigators and supporting personnel make up the United States Antarctic Program (USAP), which carries forward the Nation's goals of supporting the Antarctic Treaty, fostering cooperative research with other nations, protecting the Antarctic environment, and developing measures to ensure only equitable and wise use of resources. The program comprises research by scientists selected from universities and other research institutions and operations and support by a contractor and other agencies of the United States Government.

The National Science Foundation (the United States government agency that promotes the progress of science) funds and manages the program. Approximately, 3,000 Americans are involved each year.

The research has three goals: to understand the region and its ecosystems; to understand its effects on (and responses to) global processes such as climate; and to use the region as a platform to study the upper atmosphere and space. Antarctica's remoteness and extreme climate make field science more expensive than in most places. Research is done in the Antarctic only when it cannot be performed at more convenient locations.

The program has three year-round research stations. In summer (the period of extensive sunlight and comparative warmth that lasts roughly October through February) additional camps are established for glaciologists, earth scientists, biologists, and others. Large, ski-equipped LC-130 airplanes, which only the United States has, provide air logistics. Air National Guard crews operate these planes. Helicopters, flown by a contractor, provide close support for many research teams. Tracked or wheeled vehicles provide transport over land and snow; small boats are used in coastal areas.

Funding

The United States Antarctic Program, funded by the National Science Foundation's Office of Polar Programs, supports only that research that can be done exclusively in Antarctica or that can be done best from Antarctica.

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F. About the Puerto Rico Astronomy Society

The *Puerto Rico Astronomy Society, Inc.* (PRAS), i.e., *Sociedad de Astronomía de Puerto Rico, Inc.*, is a private, non-profit corporation, established and incorporated in 1985. PRAS is the island's oldest and largest astronomy organization. Its mission is to watch and enjoy the night sky, promote the popularization of astronomy, and foster astronomical research at the amateur level. PRAS is a NASA Puerto Rico Space Grant Consortium affiliate and is fully endorsed and supported by them in its educational efforts.

PRAS is the proud publisher of *El Observador* (i.e., "The Observer"), a NASA-sponsored, bilingual, quarterly 40-page magazine. Circulation is about 300 with distribution targeting not only members, but also 100+ schools, colleges and the local scientific community. *El Observador* started non-stop publication in 1985 and is internally refereed by accomplished astronomy educators. As an ongoing program for 31 years, this is the flagship project at PRAS.

PRAS runs a strong, well established astronomy outreach program which is available for the benefit of colleges, schools and the community in general. Yearly live audience numbers surpass the 5,000 mark. PRAS has also partnered with local universities to design and offer continuing education programs that emphasize night sky observation and provide a visual, descriptive view of the universe.

PRAS provides regular and student membership to anyone with an interest in astronomy, whether amateur or professional. Honorary members are also designated when deemed appropriate. The membership is composed primarily of amateurs and also includes astronomy educators and researchers.

Funding

The Puerto Rico Astronomy Society is funded by member fees and donations, and additionally through a grant by NASA Puerto Rico Space Grant Consortium (award number NNX15AI11H).

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A PUERTO RICAN IN THE SOUTH POLE

After a competitive review process the author was selected as a participant for the 2014–2015 Antarctic field season of PolarTREC, a professional development program geared to teachers and funded by the National Science Foundation.

In January 2015 he traveled to the Amundsen–Scott South Pole station to conduct maintenance and support work at the IceCube Neutrino Observatory—a memorable experience which is the subject of this book.

The text is profusely illustrated with 288 full-color images, mostly original photography made by the author during his 18-day stay in Antarctica.

The author is an astronomy educator who has taught at all academic levels. He lives, works and writes in San Juan, Puerto Rico.

ISBN-10: 0–9971755–4–0
ISBN-13: 978–0–9971755–4–7