INTERNATIONAL
POLAR YEAR

Changing Earth

In the 4.6 billion year history of our planet, the present arrangement of cold ice-covered regions at the northern and southern poles represents a recent development. An unprecedented combination of continental positions and orbital conditions has allowed the current 'icehouse' climate to develop and stimulated, within the past 1 million years, an oscillation of 'rapid' glacial and interglacial events. Within this global icehouse condition, cycles of ocean atmosphere interaction give rise to regional climate variations on scales of decades to centuries. Predicting the impacts of human-induced climate change requires a careful understanding of natural forces of planetary change.

Antarctic

The present location of the Antarctic continent at the southern pole and its separations from Australia and South America, all part of continuing tectonic processes, date from about 35 million years before present. With South American and Australian gateways open, a circumpolar Southern Ocean developed with dramatic consequences for Antarctica and for the global ocean circulation system. Ice sheets started to form on Antarctica at this time, and apparently became widespread and persistent by 12 million years before present. These changes in the southern continent represented an initial stage from a warmer (hothouse) to a colder (icehouse) global climate. Evidence for these changes occurs in ocean sediments, in the structure and composition of surface rocks (including those currently under Antarctic ice), and in careful measurements of contemporary land surface and subsurface motions.

Arctic

Sea ice cover on the present Arctic Ocean appears to have started 3 million years ago. Tectonic changes in ocean gateways in Central America (closure of the Isthmus of Panama) and near Indonesia set the stage for Arctic cooling. Then, small changes in the earth's orbit that reduced the solar energy received by polar regions and summer hemispheres may have instigated freezing in the Arctic Ocean. When layers of ice isolated atmosphere from ocean, regional and hemispheric patterns of oceanic and atmospheric circulation also changed. Evidence for these changes lies in sediments of the Arctic and other Oceans and in landforms across the northern hemisphere.

Ice Ages

With continents and ocean gateways in their present configuration, and with large ice masses in Antarctica and perennial ice coverage of the Arctic Ocean, the climate system began to oscillate. These oscillations,

known popularly as ice ages, involve cool glacial periods interspersed with warm interglacial periods - they have occurred for nearly 2 million years. For the past 1 million years, the glacial-interglacial oscillations have occurred with remarkable regularity, almost entirely in synchrony with orbital changes. The current tectonic, oceanic and climatic conditions of the planet appear to make it sensitive to small variations in the ellipticity of the earths orbit, to small changes in the tilt of the earth within that orbit, and to slow precession or wobble about that tilt angle. These orbital changes, occurring in predictable frequencies, influence the amount of sunlight reaching each hemisphere during each season, and the percentage of that energy that directly impacts polar regions. Evidence for the ice ages, and for the orbital cycles, comes from ice cores and from surface landforms throughout the northern hemisphere. Indirect evidence comes from records of sea level rise or fall around the planet.

Human Time Scales

Humans appeared on the planet a few ice ages ago; they migrated to and through polar regions during and since the last glacial maximum 22,000 years ago. Human civilizations, including cities, agriculture, transportation and writing, arose within the past 10,000 years. Large scale consumption of fossil fuels started 150 years ago. As we discover physical and ecological complexities of our planet, we begin to recognize subtle natural patterns of climate not, apparently, tied to geological or glaciological factors. These modes of variability in the ocean and atmosphere have regional names: the El Nino Southern Oscillation system; in polar regions the North Atlantic Oscillation, the Pacific North American Oscillation and the Southern Annular Mode. Individually and in combination they affect weather patterns over most of the globe, on annual, decadal, and perhaps centennial time scales.

Human-induced Changes

In addition to natural changes, human activities will impose a doubling of atmospheric greenhouse gases that will result in temperature increases on time scales of 50 to 100 years. Human impacts may induce changes in the regional oscillations or changes in the ice age patterns. Eventually, orbital and tectonic changes will intervene. As caretakers and beneficiaries of ecosystems and civilizations adapted to specific climate conditions, we need to give serious effort to understanding and predicting natural and human-induced change.

Changing Earth Activity: Make a Time Line

Materials:

- Rope, 6.5 metres long (10 cm = 1 million years).
- Cardboard signs and markers.

Preparation: The rope represents earth's history from present to 65 million years ago. Mark the rope into 65 equal sections, every 10 cm. Make one card for each time event from the chart below. Add events of your own choosing.

Procedure: Choose an event. Place the sign for that event on the rope at the appropriate location.

Discussion: How many metres of rope would you need to go back to the formation of the earth 4.6 billion years ago? Where would you mark your birth date on this time line?

Find these and other educational materials in: Kaiser, 2010, Polar Science and Global Climate, An International Resource for Eduation and Outreach, ISBN 978 1 84959 593 3, www.pearson.co.uk.

Events	Years Ago	Rope Distance
Age of DInosaurs Ends	65 000 000	6.5 m
First Antarctic Ice Sheet	34 000 000	3.5 m
Persistent Antarctic Ice Sheets	12 000 000	1.2 m
Sea Ice Covers Arctic Ocean	3 000 000	30 cm
Ice Ages Start	1 800 000	18 cm
Last Glacial Maximum	22 000	2.2 mm
Humans Cross Bering Land Bridge	12 000	1.2 mm
Egyptian Pyramids	4 000	0.4 mm
Fossil Fuels add CO2 to Atmosphere	150	0.015 mm
Warmest Decade in 1000 Years	10	0.001 mm

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