CHAPTER 13: THE CLIMATE SYSTEM

REFERENCE: The Blue Planet

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CLIMATE: THE AVERAGE WEATHER CONDITIONS OF ANY PLACE ON EARTH.

This world map shows the locations of some of the major climatic zones as classified by the Köppen system.
PLATE TECTONICS AND EARTH CLIMATE
What is Climate Change?

It is the change in the "average weather conditions" that a given region experiences.

- Average weather includes all the features we associate with it such as temperature, wind patterns and precipitation.

- When we speak of climate change on a global scale, we are referring to changes in the climate of the Earth as a whole.

- The rate and magnitude of global climate changes over the long term have many implications for natural ecosystems.
The blue line shows how temperatures have varied from 1 million years ago to the present. Note the cyclical variation between temperature minima (the glacial periods) and temperature maxima (the interglacials).
A temperature anomaly is a departure from long-term average. A positive anomaly indicates warmer temperature and a negative anomaly indicates cooler than the reference (average of 20th century).
In the late nineteenth century, Findelen Glacier in the Swiss Alps covered all the bare, rocky terrain seen here in the lower part of its valley. Since that time, the glacier terminus has retreated far upvalley in response to a general warming of the climate.
El cambio climático abre una nueva ruta comercial para China

- Pekín envía su primer mercante a Europa a través del estrecho de Bering
- Los expertos del país prevén que el 15% de su comercio exterior circule por esta vía en 2020
- Réords en pérdida de hielo ártico y aumento del nivel del mar en 2012

El cambio climático se perfila como gran aliado de las navieras chinas. En el 2013 el Yong Sheng, un buque de 19.461 toneladas de la empresa Cosco, inició en el puerto de Dalian (provincia de Liaoning) un viaje de 33 días que lo llevó a Rotterdam (Holanda) tras pasar el estrecho de Bering y navegar a lo largo de la costa norte rusa, según la prensa oficial china. Se trató del primer mercante del país asiático que utilizó el llamado paso del Noreste del Ártico —o ruta marítima del Norte— para llegar a Europa; una vía que podría suponer una revolución para el comercio mundial a largo plazo. Se prevé que acorte alrededor de un 30% la duración del viaje entre China y Europa, lo que representará un fuerte ahorro. Analistas internacionales, en todo caso, son prudentes y advierten de que pasarán años hasta que el trayecto sea comercialmente viable y una alternativa real al canal de Suez.
The majority of the evidence of climatic change comes from the geologic record.

We refer to the climates of ancient times as *paleoclimates*.

Reconstruction of paleoclimates relies on records of natural events that are influenced by climate, which are called *climate proxy records*. 

Human records of climate proxies
Fossil pollen can be used to reconstruct past vegetation and climate. Windborne pollen grains from trees and shrubs fall into a nearby pond where they are incorporated as part of the accumulating sediments.
GROWTH RINGS AS CLIMATE PROXIES
ICE CORES AS CLIMATE PROXIES

Antarctic Ice Core

(A) Antarctic Ice Core

(B) Ice Core Analysis

Graph showing temperature variation and CO₂ concentration over time.
Estimate of global temperature based on deep-ocean sediments over the last 60 million years ago to the present.
Coastlines lie farther seaward owing to a fall of sea level of about 120 m. Sea-surface temperatures are based on analysis of microfossils in deep-sea cores. Circled numbers show estimated temperature lowering, relative to present temperatures, at selected sites based on climate-proxy evidence.
WHY CLIMATE CHANGE
One hypothesis regarding the cause of glacial events is that fluctuations in the energy output of the Sun result in cooling of Earth’s climate when the output is low and warming when the output is high.
A. **Precession**-The Earth wobbles on its axis like a spinning top, making one revolution every 26,000 years. The axis of the Earth's elliptical orbit also rotates, though more slowly, in the opposite direction. These motions together cause a progressive shift, or precession, of the spring and autumn equinoxes, with each cycle lasting about 23,000 years.

B. **Tilt**-The tilt of the Earth's axis, which now is about 23.5 degrees, ranges from 21.5 to 24.5 degrees. Each cycle lasts about 41,000 years. Increasing the tilt means a greater difference, for each hemisphere, between the amount of solar radiation received in summer and that received in winter.

C. **Eccentricity**-The Earth's orbit is an ellipse with the Sun at one focus. Over 100,000 years, the shape of the orbit changes from almost circular (low eccentricity) to more elliptical (high eccentricity). The higher the eccentricity, the greater the seasonal variation in radiation received at any point on the Earth's surface.
ORBITAL INFLUENCE ON GLACIAL CYCLES
SHIFTING CONTINENTS

(A) PANGAEA

PERMIAN
225 million years ago

(B) CRETACEOUS
65 million years ago
New evidence has led to the hypothesis that superplumes, rising slowly from the core-mantle boundary, build huge lava plateaus when they reach the top of the lithosphere. Simultaneous large-scale degassing of CO$_2$ could greatly enhance the atmospheric greenhouse effect. Smaller plumes rising from the base of the upper mantle at 670 km would produce much more-restricted hot spots that generate volcanoes like those of the Hawaiian chain.
Curves comparing changes in carbon dioxide and methane with temperature changes based on oxygen-isotope values in samples from a deep ice core drilled at Vostok Station, Antarctica. Concentrations of these greenhouse gases were high during the early part of the last interglaciation, just as they are during the present interglaciation, but they were lower during glacial times. The curves are consistent with the hypothesis that the atmospheric concentration of these gases contributed to warm interglacial climates and cold glacial climates.
Short-wavelength radiation from the Sun passes through the glass roof (or the atmosphere) and heats the ground. Some of the heat from the ground then warms the air in the greenhouse; the rest is re-radiated back as infrared radiation, which is then trapped by the glass roof, producing additional heating inside. The warmed air emits long-wavelength radiation which passes through the glass and escapes into the atmosphere. When a balance is reached, the incoming radiation equals the escaping radiation.
A geochemical reconstruction of changing atmospheric CO₂ concentration and average global temperature over the past 100 million years. High CO₂ values and high temperatures in the Middle Cretaceous contrast with much lower modern values. Other intervals of higher temp. and CO₂ occurred during the Eocene and the Middle Pliocene.
400 Thousand Years of Atmospheric Carbon Dioxide Concentration and Temperature Change

CO₂ Concentration (from Antarctic Ice Cores)

Temperature Change (°C) (from Antarctic Ice Cores)

Thousands of years BP (before present)

Data Source CO₂: ftp://cdiac.ornl.gov/pub/trends/co2/vostok.icecore.co2

Graphic: Michael Ernst, The Woods Hole Research Center
Greenhouse Gases

- Carbon Dioxide (CO₂)
- Methane (CH₄)
- Nitrous Oxide (N₂O)

Accelerated increase in the last decades
It is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation. Warming of the climate system is unequivocal, and scientists are 95-100% certain that it is primarily caused by increasing concentrations of greenhouse gases produced by human activities.
El informe presenta evidencia que demuestra que en la última década el aumento en gases de invernadero en la atmósfera, principalmente el dióxido de carbono, ha afectado la cantidad de radiación solar que entra y sale de nuestro planeta.

La quema de combustibles fósiles y el cambio en el uso del terreno son los principales responsables para el aumento en ese gas.

El calentamiento global ha ido en ascenso en las últimas décadas y la influencia humana en ese proceso es evidente.
El informe del IPCC dice que de continuar iguales las emisiones de gases de invernadero, el planeta se seguirá calentando y que a pesar de que hagamos enormes reducciones en la emisión de dichos gases no lograremos rápidos cambios en el sistema climático.
"As the world’s two largest economies, energy consumers and emitters of greenhouse gases, we have a special responsibility to lead the global effort against climate change," Obama said Wednesday in a joint press conference with Xi.

Obama said he hopes the announcement will spur other nations to tackle climate change.

"We hope to encourage all major economies to be ambitious -- all countries, developing and developed -- to work across some of the old divides, so we can conclude a strong global climate agreement next year," Obama said.

The White House said the ultimate target is to "achieve deep economy-wide reductions on the order of 80% by 2050."
Global Mean Surface Air Temperature

(Departure from 1880-1920 base period.)

- Red: Model (CO₂ + IPCC Aerosol estimate)
- Blue: Observed (Jones, et al., pers. comm., 1996)
Sea Level Rise

Thermal Expansion Only, Source: GFDL climate model

- 4xCO₂
- 2xCO₂

meters vs. Year

feet

0 100 200 300 400 500
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
0 2 4 6
1 metro será difícil de evitar en pocos siglos, sólo por la expansión térmica y el derretimiento de los glaciares.

Adapted from Franco Einaudi

USA: Florida
Weiss and Overpeck
The University of Arizona
REMOTE SENSING AS A TOOL FOR MONITORING CLIMATE CHANGE
Watch the YouTube video called
“No Turning Back - West Antarctic Glaciers in Irreversible Decline”
<table>
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<tr>
<th><strong>Estado del Clima de Puerto Rico</strong></th>
<th>Evaluación de vulnerabilidades socio-ecológicas en un clima cambiante</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperaturas observadas y proyectadas de la superficie de Puerto Rico</strong></td>
<td>0.012 a 0.014 °C/año</td>
</tr>
<tr>
<td><strong>Observaciones y proyecciones de cambios en precipitación para Puerto Rico</strong></td>
<td>No son claras -0.01 y -0.1 mm/día/año</td>
</tr>
<tr>
<td><strong>Cambios observados en el nivel del mar</strong></td>
<td>1.4 mm/año</td>
</tr>
<tr>
<td><strong>Tendencias observadas de tormentas y huracanes desde 1970</strong></td>
<td>Intensidad, duración y frecuencia han aumentado</td>
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</tbody>
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6.27. Gabion wall unwisely built in Rincón. The recreational beach is narrowing in front of the wall, which is already experiencing backwall scouring. A gabion wall is a poor choice for ocean shorelines because the mesh will quickly corrode and break, allowing the stone fill to spill out onto the beach, creating an unsightly hazard for beach users.

measure was ineffective, however, and 50-year-old garbage continues to spill into the sea. The truth will continue to become evident as neighboring beaches begin to erode and the tourist-based economy of the area suffers. Users of the marina should share the costs of periodic dredging to lessen the environmental impact.

Punta Higüero to Río Grande (municipio