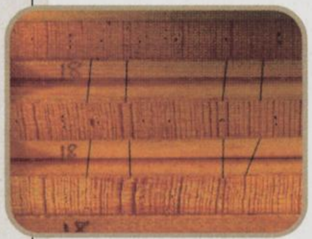
Myriad Ways to Reconstruct Past Climate

How fast can climate change? How drastic are the swings? What parts of the world will be hit with typhoons or drought? To answer questions like these, climate scientists look at records of past climate. Direct measurements, such as thermometer records, extend back about 2 centuries. Humans have also noted aspects of climate change for about 1000 years in historical records of cherry blossoms in Japan and grape harvests in Europe, and Egyptian hieroglyphs tell of 4000-year-old droughts. For older evidence of past climate—such as the so-called Last Glacial Maximum depicted on this map, roughly 20,000 years ago—a wide variety of records span different times and areas. This illustration presents a sample of them and their uses. Further information can be found at www.ngdc.noaa.gov/paleo and gcmd.gsfc.nasa.gov

—Erik Stokstad



Tree rings

Information: Temperature and rainfall—even seasonal changes—from ring width and density; records contain patterns of cycles such as El Niño and the Pacific decadal oscillation; ring scars can be used to reconstruct frequency and area of wildfires.

Resolution: Annual.

Dating: Counting of rings; radiometric carbon; correlation between trees, as shown in 700-year-old Douglas firs (*left*) from El Malpais National Monument in New Mexico.

Comments: Only terrestrial record with widespread and continuous annual resolution. Limited use in tropical and subtropical regions, where trees don't form well-defined rings. Interpretation complicated because tree growth is influenced by many local factors.

Time range: Typically 500 to 700 years ago to present. In a few cases, 11,000 years ago to present. One 1200-year record extends back to 50,000 years ago.

Areas studied:

Pollen

Information: Shifts in vegetation patterns can reveal temperature and moisture.

Resolution: Typically 50 years, depending on deposition rate, down to subannual in some places.

Dating: Radiocarbon in lake sediment or wetlands; volcanic ash layers or oxygen isotope correlation in marine sediments.

Comments: Pollen grains such as this *Tilia* (*left*) are very good for revealing temperature. Useful only as far back as analogies to modern vegetation hold. Can work on a variety of scales from microclimate of a small lake to average conditions over an entire continent.

Time range: Present to several million years ago.

Areas studied:

Geomorphology

Information: Many aspects of past climates can be traced in the shape of the landscape. The extent of glaciers and ice sheets, for example, is revealed by erratic boulders, rounded valleys, or long piles of gravel and rocks, called moraines, like these (*right*) from the Last Glacial Maximum of New Zealand. Sea level can be reconstructed from ancient wave-cut terraces on coastal hillsides and from the shape of sea bottom.

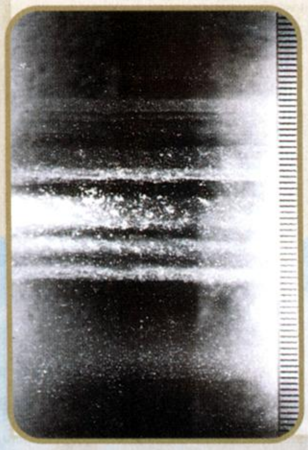
Resolution: Varies.

Dating: All sorts, including radiocarbon dating of wood in moraines or coral stranded on hillsides after sea level dropped.

Time range: From glaciation 2.9 billion years ago to the Little Ice Age of the 19th century.

Areas studied: Worldwide.

CREDITS: (TOP TO BOTTOM) H. D. GRISSINO-MAYER; D. PETEET; G. DENTON



ICE CORES

INFORMATION: Volume of continental ice from oxygen isotopic composition of the oceans; levels of CO_2 and methane in the atmosphere from trapped gas bubbles; wind strength and source from dust, sea salt, pollen; surface temperature from isotopic ratios in ice, borehole temperatures, gas fractionation, melt layers; snow accumulation rates from thickness of annual layers; sunspot cycles from isotopes formed by solar cosmic rays.

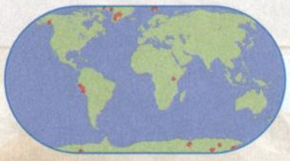
RESOLUTION: Subseasonal to decadal; highly accurate to 40,000 years.

DATING: Counting of annual layers, such as these (*left*) from Greenland; correlation to other cores; ice-flow models.

COMMENTS: These cores provide a direct sample of the atmosphere. Cores also contain information about places ranging from the local environment to distant deserts, which helps scientists figure out which aspects of climate change at the same time.

TIME RANGE: 440,000 years ago to present.

AREAS STUDIED:



CORALS

INFORMATION: Sea surface temperature from oxygen isotopes and elemental ratios, also salinity. River discharge and precipitation cycles on land from isotopes. Records reveal El Niño frequency, impacts, and relation to background climate; sea level from dating of coral. Oxygen isotopes in coral from Kenya (*right*) show a connection to El Niño in the Pacific.

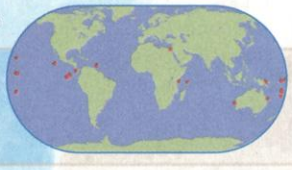
RESOLUTION: Typically months; weekly in exceptional cases.

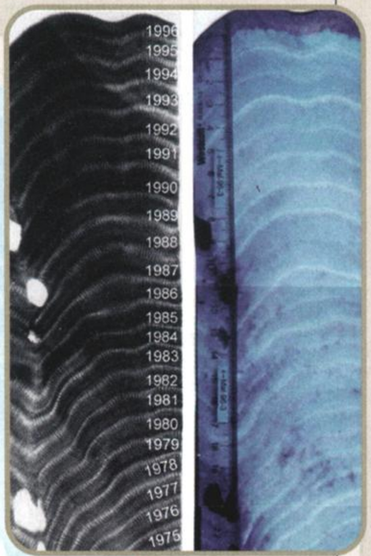
DATING: Annual banding from coral density, stable-isotope ratios, or elemental ratios.

COMMENTS: One of the few tropical records that show seasonal changes in ocean systems. Accurate multivariate data sets. Disadvantage: hard to find records that are 400 or more years long.

TIME RANGE: Continuous records to about 400 years. Large fossil corals give short time intervals about 130,000 years ago.

AREAS STUDIED:





MARINE SEDIMENTS

INFORMATION: Isotopes in microfossils reveal temperature, salinity, ice volume, atmospheric CO_2, and ocean circulation. Sands can reveal ocean currents, dust storms, and iceberg calving.

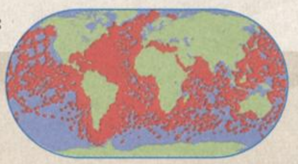
RESOLUTION: Typically thousands of years to centuries; in rare settings, seasonal.

DATING: Radiometric for fossils as old as about 40,000 years. Correlated by stable isotopes to regular changes in Earth's orbit going back millions of years.

COMMENTS: Marine sediments cover much of Earth and provide continuous records that are often protected from erosion, although some layers have been mixed by burrowing animals or are subject to dissolution or diagenesis. Cores of sediment contain proxies for both local and global changes, synchronizing different events.

TIME RANGE: As far back as 180 million years in some places. Higher resolution records are increasingly available from shorter, more recent intervals, such as the last 20,000 years.

AREAS STUDIED:



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