Earth Gauge
A National Environmental Education Foundation Program

Oscillations and Teleconnections

INTERANNUAL AND MULTIDECADAL CYCLES: WHAT AND WHY?

While diurnal and annual cycles create obvious patterns of weather variability, how and why a region's weather varies on interrannual and longer time scales is more complicated. The last few decades of research, however, have made it clear that regular and mulit-year sea-surface temperature distribution patterns control atmospheric circulation patterns, which in turn cause changes in regional climates. These links between sea-surface temperature distributions and weather in other parts of the globe are examples of *teleconnections*: strong statistical relationships between weather in different parts of the Earth. Regular shifts in sea-surface temperature distributions from one state to another are known as *oscillations*. The *oscillations* are ultimately caused by the ocean's status as a "heat reservoir." It takes centuries for heat accumulating at the surface of the ocean to distribute to the depths and vice-versa. The primary mechanism for this heat distribution is Earth's thermohaline circulation (THC) system, which connects the North Atlantic, the North Pacific and the tropical Pacific oceans. These locations are where the most pronounced and impactful oscillations occur.

ATLANTIC MULTIDECADAL OSCILLATION (AMO)

During periods of about 65 years, the waters in the North Atlantic ocean move between predominately warm and predominately cool conditons. As the image to the right illustrates, warm AMO phases mean above average temperatures in most of the northern hemisphere and below average temperatures in most of the southern. Warm AMO phases have been associated with increased North Atlantic tropical cyclone activity due to reduced vertical wind shear. Warm phases are also associated with decreased productivity in the Grand Banks fishing ground due to a northward shifted Gulf Stream. The AMO also has significant teleconnection potential, as illustrated by the strong warming and accompanied drying, and increased wildfire activity in the America's west during warm phases.

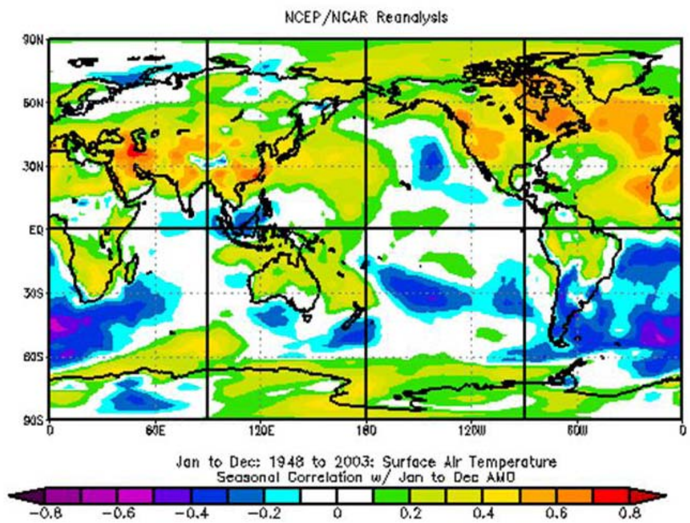
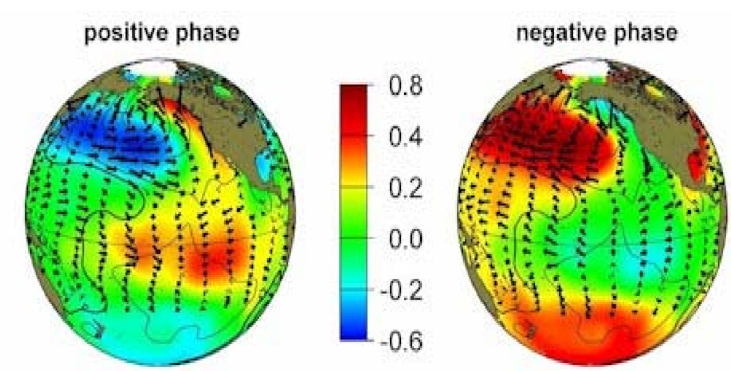


Image Courtesy of NOAA



Pacific Ocean temperature distribution anomalies during different PDO phases. Image courtesy of NOAA.

PACIFIC DECADAL OSCILLATION (PDO)

The North Pacific also oscillates between warm (postive) and cool (negative) phases, with the temperature anomaly distribution shown at left. The idea of the PDO was coined by a fisheries scientist in the mid-1990s, who noticed regular decadal shifts in the relative concentrations of certain fish species, which was presumably reflective of the regular shifts in Pacific Ocean temperatures. Cool phases (cool along America's west coast) are accompanied by phases when anchovy stocks there are robust. As the oscillation transitions into a warm phase, anchovy stocks decline but sardine stocks grow. The opposite fisheries conditions are observed for the western North Pacific around Japan.

EL NIÑO-SOUTHERN OSCILLATION (ENSO)

Probably the best known of Earth's regular oscillations, ENSO is essentially the "sloshing" back and forth of warm water between the eastern and western tropical Pacific. El Niño phases (warmer eastern tropical Pacific temperatures) have been associated with:

- increased fire frequency in the tropics and increased rates of carbon accumulation in the atmosphere;
- warmer winter temperatures in the northern U.S. and cooler winter temperatures in the southern U.S.;
- decreased tropical cyclone activity in the Atlantic and increased tropical cyclone activity in the Pacific;
- increases in cold season severe weather (i.e. lightning strikes and tornadoes) in the southeastern U.S.;
- increased winter storm activity on the California coast.

The last 30 years have seen more frequent and more pronounced El Niño events. ENSO has been a dominant climatic cycle for the past two million years, with its origins about five million years ago when the closing of the Panama seaway altered ocean circulation patterns. The connections between ENSO and the PDO and AMO, which are discussed below, suggest that the modern make-up of these cycles probably evolved simultaneously.

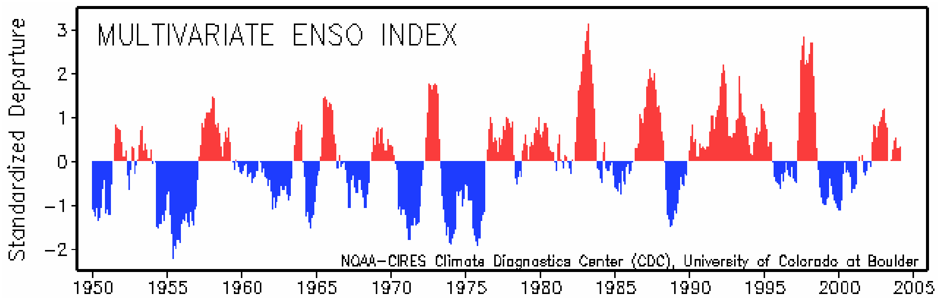
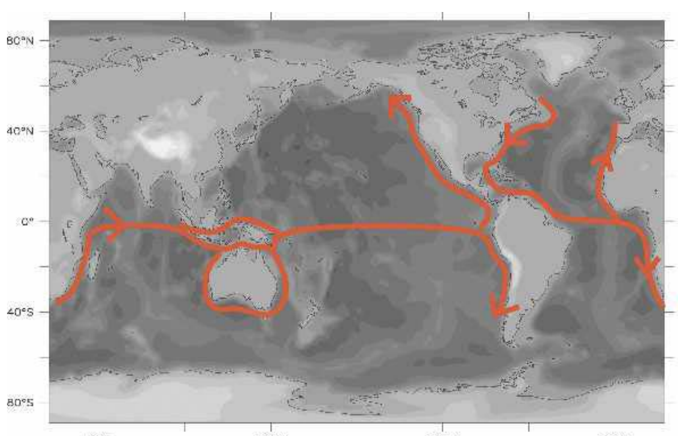


Image Courtesy of NOAA

ENSO, AMO, PDO and THC

AMO warm phases correspond to a strengthening of the Gulf Stream, the segment of Earth's thermohaline ciculation system that brings warm waters from the equatorial Atlantic to the North Atlantic. Once this stream reaches the Greenland ice sheet, it mixes with the cold meltwater and becomes a deep ocean current that transports cold and fresh water to the lower latitudes, a phenomenon known as the *meridional overturning circulation* (MOC). It is believed that during *Heinrich events* (events featuring rapid releases of freshwater into the Atlantic as the Northern Hemisphere deglacified near the end of past ice ages), sudden freshwater injections caused a halt of the MOC. As the diagram below illustrates, there is a clear connection between the Atlantic and Pacific components of the circulation. Models suggest that it takes at least 50 years for the "shock waves" of a Heinrich event to move down the Atlantic around Africa, through the Indian Ocean and into the tropical Pacific, and that between 30 and 60 percent of the energy of these "shock waves" could work to alter Pacific circulation patterns. Specifically, a sudden weakening of the THC will be reflected some decades later through a decrease in the amplitude of ENSO (i.e. both La Niña and El Niño events become less pronounced, or the tropical Pacific temperature becomes less variable) due to increased mixing in the tropical Pacific between surface and deep water. Such waves that transfer signals from one oceanic basin to another are knowns as *oceanic seiches*.



The structure of the major currents connecting Earth's ocean basins. Image Courtesy of AMS Journal of Climate.

The atmosphere is also capable of translating signals between different ocean basins, through what are known as *atmospheric bridges*. Warming of the Atlantic corresponds to a weakening in the anomalous easterly winds that blow over the tropical Pacific. This leads to less instablity between the surface and deep layers of the ocean and a weakening of ENSO. Observations and models of past climates demonstrate an Atlantic-Pacific "see saw," where periods of Atlantic MOC shut-down are accompanied by the development of a North Pacifc MOC and warming of the waters there. This phenomena illustrates the connection between the THC, the North Atlantic and the North Pacific.

Analysis of 20th century climate records indicate that there are interractions between ENSO and the PDO as well. La Niña phases are more pronounced during cool (negative) PDO phases, while the connection between El Niño events and the different PDO phases is less clear.

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