



Earth Gauge

A National Environmental Education Foundation Program

Mid to Long-Range Weather Forecasting and Winter Weather Prediction

A Brief History of Long-Range Weather Forecasting

In the western world around the seventh century BCE, thinkers began looking at observable phenomena to better understand and predict weather cycles. The Babylonians and ancient Greeks looked to the stars to predict weather, which led to construction of Greco-Roman calendars relating astronomical and weather phenomena. Belief in this relationship survived into the Renaissance and was advocated by famous astronomers such as Tycho Brahe and Johannes Kepler at the beginning of the Scientific Revolution. Since 1818, the Farmers Almanac has used a secret formula based partially on sunspot and lunar cycles for predicting the weather as far as several years out.

Mid to Long-Range Weather Forecasting Today

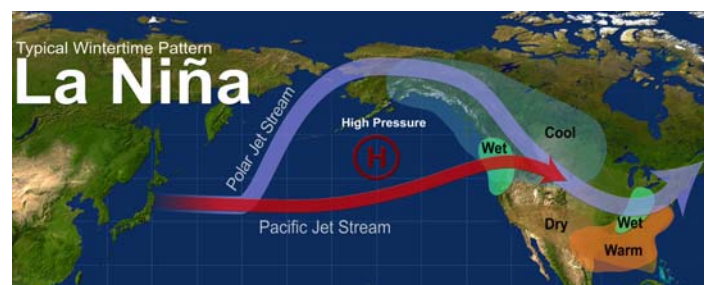
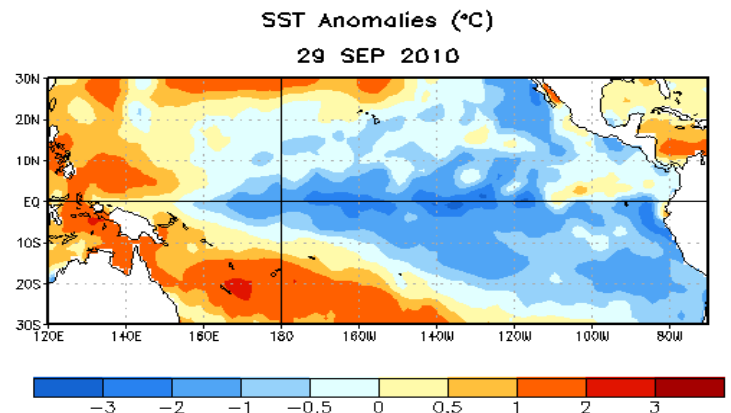
Instead of looking to the moon and stars to predict the weather beyond four or five days, modern day meteorologists and climatologists look primarily at patterns of deep convection in the tropics. For seasonal outlooks, forecasters look to tropical sea surface temperature distributions, which both control and are influenced by tropical convective systems. On longer, decadal time scales, cycles of warm and cool water distributions in the North Pacific and North Atlantic Oceans can be useful for analyzing general, regional trends.

Why Ocean Surface Temperatures?

The ocean holds about 1000 times as much heat as the atmosphere does. Large ocean currents move masses of water around in cycles lasting longer than a single year and a complete mixing of the ocean, or complete exchange of deep and surface waters, takes centuries. Between the annual cycle and the longer deep ocean circulation cycle, there are cycles of sea-surface temperature distributions and associated deep convection that influence global atmospheric circulation, particularly the position of the jet streams and mid-latitude storm tracks. The greatest difference in temperature between the ocean and land exists during winter, the time when sea surface temperature cycles and associated fluctuations in convection and atmospheric circulation have the most noticeable effects on weather on mid-latitude regions such as the United States. This fact sheet discusses some of the key cycles used to predict America's weather on time scales longer than a few days, focusing on winter weather prediction.

ENSO: Over a period of three to seven years, the tropical Pacific Ocean switches between phases where warm and cool water masses dominate the eastern part of the basin. This phenomenon is called the *El Niño-Southern Oscillation* (ENSO). The two most extreme phases of this cycle are La Niña (cool) phases and El Niño (warm) phases. Changes in the distribution of warm and cool water masses reflect large movements of energy in the ocean. Large movements of energy in the ocean change large scale convective patterns and atmospheric circulation. Most pertinently for America's winter weather, these changes affect the strength and position of the Polar and Pacific jet streams. These changes are reflected in regional differences in winter temperature and precipitation in the United States.

Right: A typical La Niña wintertime pattern for the Pacific and Polar Jet Streams, and the corresponding regional winter temperature and precipitation anomalies experienced in the United States. Images NOAA CPC.

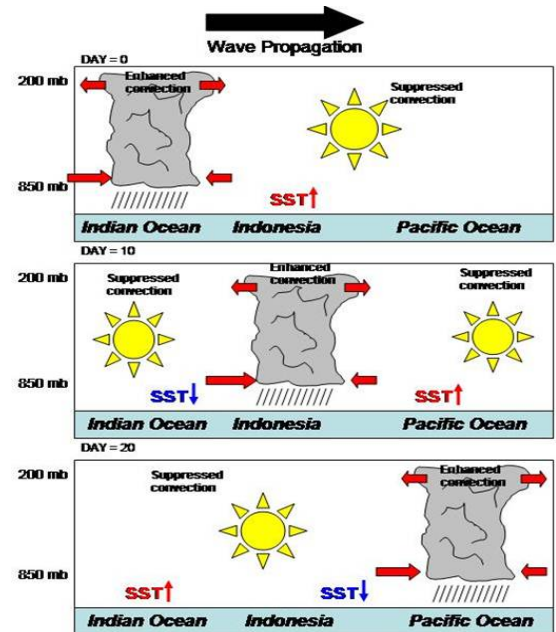


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MJO: On a period of 30-60 days, a combined pattern of large-scale enhanced and suppressed rainfall moves eastward across the Tropics at a rate of four to eight meters per second. This travelling system, known as the *Madden-Julian Oscillation* (MJO), is most active from November through March and often is episodic in nature (i.e., strong activity can be followed by periods of little or no activity). The system's upper level divergence often affects the position of high and low pressure centers and jet streams in the mid-latitudes. MJO activity is particularly useful for predicting winter weather in America's West on time scales from two to four weeks. The famous wintertime "pineapple express," or an intrusion of a tropical moisture plume into the West Coast that brings warm temperatures and heavy rains, is linked to the MJO affecting the position of the Pacific jet stream.

Interactions between ENSO and the MJO: By modulating sea surface temperatures in the tropical Pacific, ENSO modifies the background state for tropical moist convection, thus influencing the behavior of the MJO. The MJO tends to be most active during neutral ENSO phases, and is often not active at all during strong El Niño phases. Its behavior during La Niña phases is highly variable. Conversely, the MJO itself modifies winds and sea surface temperatures in the Tropics, and may affect the development and evolution of La Niña and El Niño events.

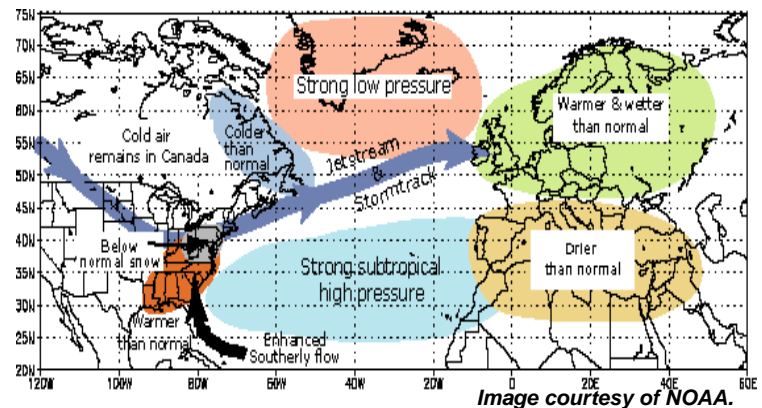


Above: A schematic diagram of the MJO and its effects on winds and sea surface temperatures as it moves from the Indian to the central tropical Pacific. Image by Jon Gottschalk, courtesy of NOAA.

The MJO's effects on global weather patterns vary depending on the ENSO phase. Certain effects on mid latitude weather are more pronounced during La Niña phases versus El Niño phases and vice-versa. There are even some MJO related anomalies that occur during one phase of ENSO that have no counterpart during the opposite phase. For example, during La Niña phases when the MJO system is in the East Indian Ocean, polar air masses tend to intrude into the western United States. When the MJO is in the same position during El Niño phases, such intrusion does not tend to happen. The behavior of the MJO also appears to affect the *North Atlantic Oscillation* (NAO, see below); during La Niña phases, the MJO's effect on the NAO is more pronounced.

NAO: The *North Atlantic Oscillation* (NAO) is a fluctuation in the pressure difference between the Icelandic Low and Azores High pressure centers. The greater this pressure difference is, the stronger the jet stream and mid-latitude storm tracks are over the North Atlantic. This phenomena is related to the larger Arctic Oscillation (AO), which reflects a difference in total atmospheric mass distribution between the mid latitudes and the North Pole region.

Positive phases of the NAO (image right), when the pressure difference is higher than normal, mean stronger storm tracks and jet streams. Stronger winds serve as a "blocking mechanism" that keeps frigid Arctic air masses from invading the lower latitudes. This keeps the Arctic colder than normal during winter and mid-latitude areas warmer than normal. The opposite is true when the difference between the pressure centers is less, a negative phase. Negative phases mean the winds and blocking mechanism are weaker and cold air masses invade the lower latitudes more frequently; the December 2009-January 2010 cold snap in the eastern United States happened during a period when the NAO was strongly negative.



The AMO and PDO: Two other cycles, the *Atlantic Multidecadal Oscillation* (AMO) and the *Pacific Decadal Oscillation* (PDO), also influence America's winter weather, but on decadal as opposed to seasonal time scales. The AMO is a shift in North Atlantic sea surface temperatures on time periods of about 65 years. During warm AMO phases, the Great Plains and western United States tend to be warmer and drier than during cool phases. This is reflected in the increased wildfire activity that has been prevalent during warm phases for at least the past 500 years. The PDO is a shift in North Pacific sea surface temperature distributions that fluctuate on two periodicities, one being a 15-20 year cycle and the other being a 50-70 year cycle. This decadal variability influences wintertime precipitation, particularly in the western United States. Warm phases of the PDO tend to shift storm tracks farther to the North, bringing more wintertime snowfall to Alaska's coastal glaciers and less wintertime snowfall to glaciers in the Pacific Northwest. For regions farther inland, such as the Intermountain West, cool PDO phases tend to encourage the dominance of continental air masses and drier winters.

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