EL NINO/LA NINA: THE OCEAN-ATMOSPHERE CONNECTION

Part 1:

Educational Outcomes: Stretching nearly one-third of the way around the globe and covering a fifth of the Earth's surface, the tropical Pacific is a coupled ocean/atmosphere system that makes its presence known far beyond its boundaries. Its influence worldwide as a short-term (inter-annual) climate control can lead to major ecological, societal, and economic disruptions. Within the ocean, especially in coastal areas, marine organisms from plankton to fishes and seabirds are impacted. Occurrence of EI Nino every three to seven years and the less frequent La Nina demonstrates that there are swings in ocean/atmosphere conditions, weather, and climate which operate on other than annual timetables.

Materials: EI Nino!-La Nina! slide chart

A. Background

Originally, EI Nino was the name given to a short-term, weak seasonal warming of ocean water that ran southward along the coast of Peru and Ecuador around Christmas and resulted in poor fishing. Today, EI Nino refers to a large-scale, persistent disturbance of ocean and atmosphere in the tropical Pacific Ocean. A persistent El Nino can be accompanied by major shifts in planetary-scale atmospheric and oceanic circulations and weather extremes worldwide.

EI Nino lasts an average 12 to 18 months and occurs about once every three to seven years. Ten occurred during a recent 42-year period, with one of the most intense of the 20th century in 1997-98. Sometimes, but not always, EI Nino is followed by La Nina, a period of unusually strong trade winds and vigorous upwelling in the eastern tropical Pacific. During La Nina, changes in SSTs and extremes in weather are essentially opposite those observed during EI Nino. Associated with these changes are major impacts on marine ecosystems.

B. The Tropical Pacific During Long-Term Average (Neutral) Conditions

Examine EI Nino!-La Nina! with the slide insert pushed all the way into the device so that Long-Term Average appears in the indentation along the bottom of the large window. (Note: If La Nina appears when fully inserted, pull the slide out, flip it to the other side, and reinsert.)

I. Look at the large window. It displays a schematic of the Pacific Ocean along the equator (greatly exaggerated in the vertical). The scene depicts the ocean surface with atmosphere above and a vertical cross-section of the ocean below.

Fair weather appears in the eastern tropical Pacific while [(fair) (stormy)] weather prevails in the western tropical Pacific.

2. Small windows depict conditions in the western, central, and eastern portions of the tropical Pacific. Dark blue triangles below the atmosphere windows and above the ocean windows point to the locations in the large window where conditions portrayed in the small windows are observed. The windows to your left represent a location in the [(eastern) (western)] tropical Pacific.

3. The arrows in the Trade Winds windows point in the direction toward which the prevailing winds are blowing. The lengths of the arrows denote relative wind speeds; the longer the arrow, the greater the wind speed. As indicated in the windows, long. term average (prevailing) winds blow toward the (east) (west)] and the wind speed is (higher) (lower)] in the eastern Pacific than in the western Pacific.

4. The smaller windows below the large window provide ocean information. Arrows in the Surface Currents window indicate that during long-term average conditions, surface water flows towards the (east) (west)].

5. According to the values reported in the windows, the highest sea surface temperatures (SSTs) during long-term average conditions occur in the (easlern) (western») tropical Pacific, This SST pattern is caused by relatively strong trade winds pushing sun warmed surface water (eastward) (westward)], as evidenced by the direction of surface currents.

6. Strong trade winds also cause the warm surface waters to pile up in the western tropical Pacific so that the sea surface height in the western Pacific is (lower) (higher)] than in the eastern Pacific, Transport of surface waters to the west also causes the thermocline (the transition zone between warm surface water and cold deep water) to be [(deeper) (shallower») in the eastern Pacific than in the western Pacific.

7. Warm surface water transported by the wind away from the South American coast is replaced by cold water rising from below in a process called upwelling. Upwelling of cold deep water results in relatively (high) (low)] SSTs in the eastern Pacific compared to the western Pacific. Associated with the upwelling are conditions favorable for high biological productivity.

8. Cold surface water cools the air above it, which leads to increases in the surface air pressure, Warm surface water adds heat and water vapor to the atmosphere, lowering surface air pressure. As shown in the Surface Air Pressure windows, these effects result in tropical surface air pressure being [(highest) (lowest)] in the eastern Pacific and [(highest) (lowest)] in the western Pacific.

9. Whenever air pressure changes over distance, a force will act on air to move it from where the pressure is relatively high to where pressure is relatively low. The trade winds blow from east to the west because from east to west the surface air pressure (increases) (decreases)].

10. Rainfall in the tropical Pacific is also related to SST patterns. There are reasons for this relationship. The higher the SST, the greater the rate of evaporation of seawater and the more vigorous is atmospheric convection. Consequently, during long-term average conditions, rainfall is greatest in the (weslern) (eastern)] Pacific where SSTs are [(highest) (lowest)].

C. The Tropical Pacific During EI Nino

Slowly pull the insert out of EI Nino!-La Nina! while watching the changing scene in the large window. Note that the stormy conditions move eastward. Continue pulling until the EI Nino label is lined up in the large window indentation. Now you are viewing atmospheric and oceanic conditions that are expected during a typical El Nino. While no two El Nino episodes are exactly alike, all of them exhibit most of the characteristics described in EI Nino!-La Nina!.

11. With the onset of El Nino, tropical surface air pressure patterns change. Compare the red El Nino readings in the western and central tropical Pacific windows with the black marks along the sides of the windows. The black marks indicate long-term average readings at those locations. During long-term average conditions, the surface air pressure in the central Pacific is higher than to the west. During El Nino, the surface air pressure to the west is [(higher) (lower)] than in the central Pacific. This seesaw pattern of pressure variation is called the Southern Oscillation.

12. In response to changes in the air pressure pattern across the tropical Pacific, the Trade Winds weaken (and may even reverse direction, especially over the western tropical Pacific). No longer being pushed toward and piled up in the western Pacific, the warm surface water reverses flow direction. As seen in the Surface Currents window, the surface water currents during El Nino flow toward the [(east) (west)]. As evident in the appropriate Sea Surface Temperature window, this causes SSTs in the eastern tropical Pacific to be [(higher) (lower)] than long-term average values.

13. During the 1997-98 time period when an El Nino event occurred, the eastern equatorial Pacific Galapagos Islands experienced record-high SSTs of about 29°C, well above the temperatures critical for coral bleaching. The result was the devastation of a rich coral reef ecosystem. These high SSTs [(are) (are not)] consistent with those predicted for an El Nino episode by the El Nino!-La Nina! slide chart.

14. In response to surface currents, sea surface heights in the eastern tropical Pacific are [(higher) (lower)] than long-term average levels. At the same time,

the arrival of the warmer water causes the surface warm-water layer to thicken. Evidence of this is the ((shallower) (deeper)] depth of the thermocline compared to long-term average conditions.

15. Differences between existing conditions and long-term average conditions are called anomalies. If El Nino readings are higher than the respective long-term averages (shown by the black reference lines next to the windows), the anomalies are positive. If El Nino values are lower, the anomalies are negative. In the eastern tropical Pacific during El Nino, the SST anomaly is ((negative)(positive)], the sea-surface height anomaly is [(negative) (positive)], the surface air pressure anomaly is [(negative) (positive)], and the rainfall anomaly is ((negative) (positive)].

D. The Tropical Pacific During La Nina

16. The tropical Pacific at times experiences trade winds stronger than the long-term average with SSTs lower than usual in the eastern tropical Pacific and higher than usual in the western tropical Pacific. Associated with these La Nina conditions are anomalies generally opposite those occurring during El Nino. Remove the slide insert from the sleeve and turn it to the other side. Slide the insert back into the sleeve until Long Term Average appears in the indentation along the bottom of the large window. (Note that the Long-Term Average conditions on both sides of the insert are identical.) Then

continue pushing the insert in until La Nina appears in the indentation. The stormy weather in the western Pacific has been displaced [(westward) (eastward)] from its Long-Term Average position.

17. During La Nina the stronger trade winds are driven by an air pressure pattern that ((ill creases) (decreases)] westward across the tropical Pacific. ~e air pressure difference between the eastern and western tropical Pacific is [(less) (greater)] than during the Long-Term Average (as shown by the black marks along the windows). The trade winds drive surface currents toward the [(west) (east)], resulting in sea surface temperatures in the western tropical Pacific that are slightly (higher) (lower)] than the Long-Term Average while the eastern tropical Pacific experiences (positive) (negative)] SST anomalies.

18. The La Nina wind and current pattern produce a thermocline depth in the eastern tropical Pacific that is (deeper) (shallower)] than the long-term average value, leading to (weaker) (stronger)] upwelling than average (note the large curved arrows). These conditions (suppress) (enhance)] biological productivity.

GLOBAL-SCALE WEATHER LINKAGES

Part 2:

Educational Outcomes: Scientific evidence points to significant relationships between weather changes occurring at great distances from each other. Meteorologists refer to these linkages between weather conditions in widely separated regions of the globe as teleconnections. Perhaps the most extensively researched teleconnections (and best known to the public) are those associated with El Nino and La Nina. Although no two El Nino events are the same (and no two La Nina events are the same), certain anomalies in temperature and/or precipitation tend to accompany El Nino (or La Nina).

How can conditions in the ocean and the lower atmosphere in the tropical Pacific affect weather patterns around the world? The key to answering this question is a chain of oceanic and atmospheric processes that begin with the warm waters of the Pacific. Ocean surface heating spurs convection and the development of towering cumulonimbus clouds that bring heavy rain to the western Pacific during normal or La Nina episodes and to the central tropical Pacific during El Nino. Compensating for areas of rising air motion are areas of sinking air about half an ocean away along the equator, producing in those locations extended periods of little or no precipitation.

The compensating upward, outward, downward, inward flows of the tropical Pacific atmospheric convection cell also act in a north-south direction. Movements of broad expanses of warm Pacific surface waters in response to the Trade Winds and its variations, ultimately force changes in the direction and strength of the westerly winds of the mid latitudes. The upper-tropospheric midlatitude winds (with embedded high-speed jet streams) shift and cause the weather systems which they steer to follow different paths. Consequent changes in precipitation and temperature patterns impact the weather of numerous localities worldwide. Whereas some changes in weather patterns may be welcomed, such as warmer than usual winters at higher latitudes and precipitation in dry areas, other changes increase the probability of floods, droughts, or shoreline erosion and considerable hardship accompanied by human misery.

A. Background

Figure I shows precipitation and temperature anomalies (departures from long-term averages) and typical jet stream patterns during EI Nino and La Nina conditions. (The original color-coded figure may be seen at: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/nawinter.htm/).

During EI Nino, as shown in the Figure I upper image, the winter-season upper-level wind patterns across the eastern North Pacific and North America exhibit two main changes. First, the flow becomes more west-to-east, with smaller than usual north-south excursions (called zonal flow). Second, the Pacific jet strengthens in a more easterly position and at lower latitudes than usual. These changes bring wetter and cooler than average conditions across much of the southern coterminous U.S., and milder than usual weather over much of the northern states accompanied by drier conditions in some areas.
La Nina, as depicted in the Figure I lower image, tends to produce three changes in the longterm average pattern of westerlies across North America during winter. First, the wave pattern of the jet stream becomes more north-south (called meridional flow). Second, meridional flow increases the likelihood of blocking circulation patterns that favor persistence of warm or cold episodes at certain locations. Third, the variable positioning of the meridional jet can enhance storminess in the northwestern U.S. and southwest Canada. These circulation changes also mean a greater tendency for increased storminess in the central U.S. with higher precipitation amounts, often in the form of snow, followed by outbreaks of Arctic air. This pattern also leads to more variability in storminess and precipitation from month-to-month.

B. Teleconnections

1. Based on the Figure I upper image, during EI Nino the winter storm track crosses [(southern) (northern)] U.S. The depiction shows that residents of [(Indiana) (Florida)] can expect to receive a greater than average amount of winter precipitation during EI Nino.

2. The Figure 1. El Niño conditions map shows Ohio and neighboring states can expect [(*wetter*) (*drier*)] conditions compared to long-term average winter precipitation.

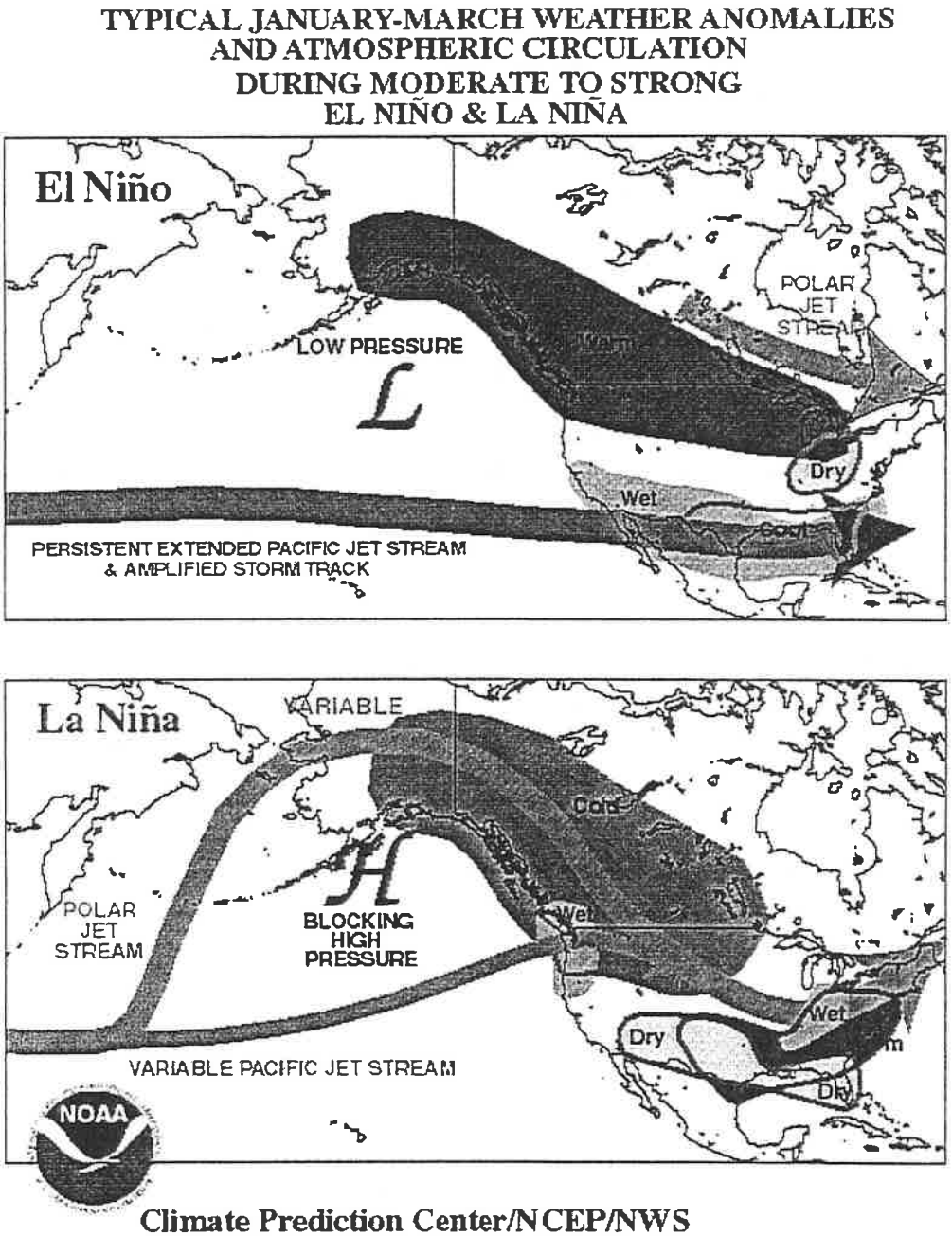

Figure 1. El Nino and La Niña-Related Winter Features over North America

3. Based on the Figure 1 lower image, during La Nina, the winter storm track crosses [(Indiana) (Florida)]. The depiction also shows that residents of [(Indiana) (Florida)] can expect to receive a greater than average amount of precipitation.

4. The Figure 1, La Nina conditions map shows Florida can expect [(wetter) (drier)] conditions compared to long-term average winter precipitation. This could lead to a(n) [(decreased) (increased)] threat of forest fires in that state.

Go to the backside of the EI Nino!-La Nina! slide chart. The two maps display Northern Hemisphere winter global impacts of El Nino and La Nina.

5. Examine the Northern Hemisphere portions of the two maps. Generally (but not always!), El Nino episodes are associated on a global scale with [(warmer and or drier) (colder and wetter)] than long-term average conditions where Northern Hemisphere El Nino impacts are detected. During La Nina episodes, [(warmer and/or drier) (colder and/or wetter)] than long-term average conditions are generally detected in the Northern Hemisphere during the December-February period. Exceptions to both of these generalizations cover an area that includes [(Indiana) (Florida)].

6. During February 2000 Mozambique and neighboring southeastern Africa countries were devastated by record-breaking floods. At the same time, the tropical Pacific was experiencing La Nina. According to the La Nina map, there is a possibility that such flooding [(could) (could not)] have been teleconnected with La Nina.

7. According to the maps, [(Japan) (France) (Brazil)] is least likely to be subjected to December-February EI Nino or La Nino impacts.