Project Atmosphere Canada

MODULE 5

El Niño: The Atmosphere-Ocean Connection

Teacher's guide

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

Environment Canada
Environnement Canada

Canada

Project Atmosphere Canada

Project Atmosphere Canada (PAC) is a collaborative initiative of Environment Canada and the Canadian Meteorological and Oceanographic Society (CMOS) directed towards teachers in the primary and secondary schools across Canada. It is designed to promote an interest in meteorology amongst young people, and to encourage and foster the teaching of the atmospheric sciences and related topics in Canada in grades K-12.

Material in the Project Atmosphere Canada Teacher's Guide has been duplicated or adapted with the permission of the American Meteorological Society (AMS) from its Project ATMOSPHERE teacher guides.

Acknowledgements

The Meteorological Service of Canada and the Canadian Meteorological and Oceanographic Society gratefully acknowledge the support and assistance of the American Meteorological Society in the preparation of this material.

Projects like PAC don't just happen. The task of transferring the hard copy AMS material into electronic format, editing, re-writing, reviewing, translating, creating new graphics and finally formatting the final documents required days, weeks, and for some months of dedicated effort. I would like to acknowledge the significant contributions made by Environment Canada staff and CMOS members across the country and those from across the global science community who granted permission for their material to be included in the PAC Teacher's Guide.

Eldon J. Oja
Project Leader Project Atmosphere Canada
On behalf of
Environment Canada and the Canadian Meteorological and Oceanographic Society

Published by Environment Canada
Cat. no. En56-172/2001E-IN
ISBN 0-662-31474-3

Project Atmosphere Canada

Contents

MODULE 5 El Niño: The Atmosphere-Ocean Connection

INTRODUCTION

EL Niño: The Atmosphere-Ocean Connection

The term *El Niño* originally described a weak warming of the ocean water that ran southward along the coast of Peru and Ecuador about Christmastime each year and resulted in poor fishing. Today, El Niño refers to a large-scale disturbance of the ocean and atmosphere in the tropical Pacific. A persistent El Niño can be accompanied by major shifts in planetary-scale atmospheric and oceanic circulations and weather extremes that bring major ecological, social and economic disruptions world-wide.

Most of the time, westward-blowing trade winds drive warm surface water westward, away from the west coast of South America. In the western tropical Pacific, this pool of transported warm surface water results in low air pressure and abundant rainfall. In the eastern tropical Pacific, the warm surface water is replaced by colder water that wells up from below, a process known as *upwelling*. Relatively cold surface water favours high air pressure and meager precipitation. Upwelling also exposes nutrient-rich water from below to sunlight, stimulating the growth of phytoplankton which support fisheries.

The first sign of El Niño in progress is a weakening of the trade winds. Normally, the contrast between relatively high air pressure over the eastern tropical Pacific and low air pressure over the western tropical Pacific drives the trade winds. With the onset of El Niño, air pressure falls over the eastern tropical Pacific and rises in the west, with the greatest pressure drop over the central Pacific. As the air pressure gradient across the tropical Pacific weakens, trade winds slacken and may even reverse in the west. The seesaw variation in air pressure between the western and central tropical Pacific is known as the Southern Oscillation. El Niño and Southern Oscillation are abbreviated as ENSO.

During El Niño, changes in atmospheric circulation over the tropical Pacific are accompanied by changes in ocean currents and sea-surface temperature (SST) patterns. The pool of warm surface water normally driven westward by the trade winds now drifts eastward. At the same, changes take place in the thermocline, the zone of transition between relatively warm surface water and cold deep water. The thermocline sinks in the east, greatly weakening or even cutting off cold-water upwelling along the west coast of South America. Changes in the trade wind circulation alter tropical weather patterns. In turn, these changes shift the planetary-scale winds, including jet streams, that steer storms and air masses at higher latitudes, causing weather extremes in many areas of the globe outside of the tropics.

El Niño , lasting an average 12 to 18 months, occurs about once every two to seven years. Ten El Niños occurred during a recent 42-year period, with one of the most intense of the century in 1997- 98.

Sometimes, but not always, El Niño alternates with La Niña, a period of unusually strong trade winds and vigorous upwelling over the eastern tropical Pacific. During La Niña, changes in SSTs and extremes in weather are essentially opposite those observed during El Niño.

BASIC UNDERSTANDINGS El Niño

El Niño, the Southern Oscillation, ENSO, and La Niña

1. Originally, El Niño was the name given by Peruvian fishermen to a period of warm waters and poor fishing that often coincided with the Christmas season.
2. Today, El Niño refers to a significant departure from the average state of the ocean-atmosphere system in the tropical Pacific that has important consequences, including those for weather and climate in the tropics and other regions of the globe.
3. El Niño typically persists for 12 to 18 months and recurs approximately every two to seven years. The ten El Niños recorded over a recent 42-year period include the extreme events of 1982-83 and 1997-98.
4. The Southern Oscillation is a seesaw variation in air pressure between the central and western tropical Pacific. These pressure changes alter the strength of the trade winds and affect surface ocean currents as parts of El Niño. Scientists often combine El Niño and the Southern Oscillation as the acronym, ENSO.
5. The occurrence of ocean/atmosphere conditions essentially opposite those of El Niño is called la Niña. La Niña sometimes, but not always, alternates with El Niño.

Long-Term Average Conditions in the Tropical Pacific

1. Normally, strong trade winds drive warm surface water westward and away from the west coast of South America.
2. In the tropical eastern Pacific, colder water rising up from the depths replaces the warm surface water that is driven westward from the area, a process called upwelling.
3. Upwelling delivers cold nutrient-rich water from below into sunlit surface regions, greatly enhancing biological productivity. Most of the important commercial fisheries are located in areas of upwelling.
4. In the tropical eastern Pacific, offshore transport of warm surface water results in a locally lower sea level, a rise in the thermocline (the transition zone separating warmer surface water from colder deep water), and a drop in sea-surface temperature. Cooler surface waters are responsible for relatively high air pressure and mostly fair weather. Low precipitation amounts over adjacent land areas give rise to desert conditions.
5. Piling up of wind-driven warm surface water in the western tropical Pacific causes a higher sea level, a deeper thermocline, and higher sea-surface temperatures than in the central and eastern tropical Pacific. Warm surface waters produce relatively low air pressure and spurs atmospheric convection that is responsible for heavy rainfall.

El Niño Conditions in the Tropical Pacific

1. During El Niño, the trade winds are weaker than average over the tropical Pacific and may even reverse direction, especially in the west.
2. In the tropical western Pacific, weakening or reversal of the trade winds causes the pool of warm surface water in the western tropical Pacific to drift eastward along the equator toward the coast of South America.
3. In the tropical western Pacific, an eastward transport of warm surface water is accompanied by a drop in sea level and a rise in the thermocline. Slightly cooler surface waters produce higher than usual air pressure, weaker atmospheric convection, and reduced rainfall.
4. Arrival of the pool of warm surface water along the coast of South America greatly diminishes or eliminates upwelling of nutrient-rich cold bottom water so that biological productivity declines sharply.
5. In the tropical eastern Pacific, the piling up of warm surface water results in a local rise in sea level, a deeper thermocline, and higher sea-surface temperatures. Warm surface waters produce relatively low air pressure and enhance atmospheric convection that brings more than usual rainfall.
6. The concurrent rise in air pressure over the western tropical Pacific and fall in air pressure over the central tropical Pacific (which weakens the trade winds) is part of a regular see-saw variation in surface air pressure known as the Southern Oscillation.

Global El Niño and La Niña Conditions

1. Changes in oceanic and atmospheric circulation in the tropical Pacific impact weather and climate in the tropics and well beyond.
2. Temperature governs the rate at which water molecules escape a water surface and enter the atmosphere; that is, warm water evaporates more readily than cool water. Regions of relatively warm surface waters heat the atmosphere and add moisture to the atmosphere. Thunderstorms more readily develop in this warm, humid air. Towering thunderstorms help shape the planetary-scale atmospheric circulation, altering the course of jet streams and moisture transport at higher latitudes.
3. Changes in the planetary-scale atmospheric circulation during El Niño and La Niña often give rise to weather extremes, including drought and excessive rainfall, in many areas of the globe outside the tropics.
4. No two El Niño or La Niña events are exactly the same, so that in some areas weather extremes may or may not accompany a particular El Niño or La Niña.
5. In Canada, El Niño winters tend to be mild and less wet than normal. The exceptions are the Atlantic provinces

and the territory of Nunavut in the Canadian Arctic which are usually milder but wetter than normal. La Niña, on the other hand, usually results in colder temperatures in Canada in winter. La Niña winters are usually also wetter than normal in western Canada, southern Ontario and Quebec, and the Atlantic provinces, while being drier than normal elsewhere.

Ecological, Social, and Environmental Impacts

1. Many aspects of the environment and global economy are impacted by variations in the ocean/atmosphere system of the tropical Pacific. These impacts also have human and social consequences. Some of the larger impacts of El Niño and La Niña are experienced by developing countries in the tropical and subtropical regions that are most vulnerable to climate catastrophes.

2. Too little or too much precipitation can have devastating effects. In some areas, drought, especially when accompanied by high temperatures, causes crops to wither and die, reduces the public water supply, and increases the likelihood of wildfire. In other areas, exceptionally heavy rains trigger flash flooding that drowns crops, washes away motor vehicles, destroys houses and other buildings, and disrupts public utilities.

3. Weather extremes associated with El Niño and La Niña have implications for public health by creating conditions that increase the incidence of diseases such as malaria, dengue fever, encephalitis, cholera, and plague. Also, smoke from wildfires in drought-stricken regions can case respiratory problems for people living up to 1,500 kilometres from the fires.

4. Advance warning of El Niño and La Niña and their accompanying weather extremes could save lives and billions of dollars in property and crop damage by allowing adequate time for preparedness and development of appropriate response strategies.

5. More details on how El Niño can affect Canadian temperature and precipitation patterns can be found at ***http://www.msc-smc.ec.gc.ca/elnino/index_e.cfm***
   Similarly, Canadian La Niña effects can be found at ***http://www.msc-smc.ec.gc.ca/lanina/index_e.cfm***

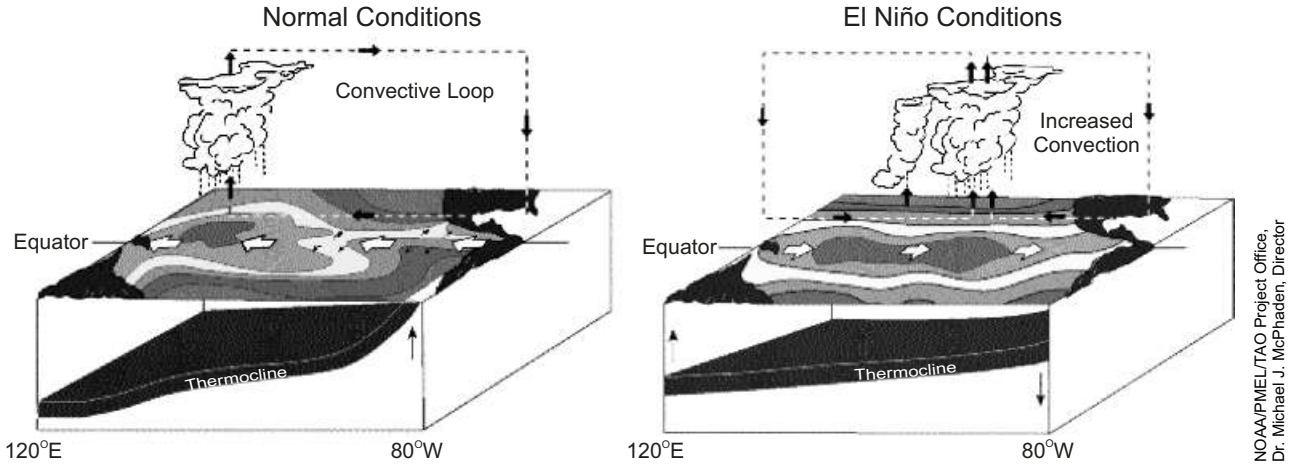
El Niño and La Niña Research

1. Scientists are actively investigating the tropical Pacific ocean/atmosphere system for answers to many questions including: What gets El Niño and La Niña started? Why do they stop? Why do regional impacts differ from one El Niño (or La Niña) to the next? When will scientists be able to reliably predict the duration and impact of El Niño and La Niña?

2. Observations of conditions in the tropical Pacific are essential for the investigation and prediction of short

term climate variations like El Niño. A wide variety of sensors are used to obtain ocean and atmospheric data from this vast and remote region of the ocean.

3. Satellite-borne temperature sensors and altimeters are being used to tract the movement of warm surface water across the tropical Pacific. Additional information is provided by a network of buoys that directly measures temperature, currents, and winds along the equatorial band.
4. Predicting the onset and duration of El Niño and La Niña is critical in helping water, energy, and transportation managers, and farmers plan for, mitigate, or avoid potential losses.
5. Advances in El Niño and La Niña prediction are expected to significantly enhance economic opportunities, particularly for the agriculture, fishing, forestry, and energy sectors, as well as provide opportunities for social benefits.



Three dimensional view depicting the atmospheric and oceanographic circulations over the tropical Pacific during normal conditions and then during El Niño conditions.