



# *El Niño and Its Effects on the Galapagos Islands*

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Blue-footed  
Booby

# *The Galapagos Islands*

- *Between 89° W and 92° W along the equator*
- *~1000 km west of Ecuador*
- *13 main islands*
- *Known for its unique marine and terrestrial wildlife*



# *Biological Diversity*

- *Much of the flora and fauna is endemic to the islands*
- *Geography and oceanography allows for the study of evolution, as Darwin did when he wrote *On the Origin of Species*...*
- *Some interesting animals include the Galapagos Tortoise, the Marine iguana, and the Galapagos Penguins*



Brown Pelican

*How can penguins survive  
on the equator?*



*Because of the Currents  
surrounding the Islands!*

# *Important Concepts*

- *The ocean and atmosphere are directly coupled*
- *The ocean and atmosphere are considered fluids; they obey all the laws of physics*
- *Major forces which affect the ocean are gravity, frictional forces arising from wind-stress, and buoyancy*
- *Thermocline- depth at which the temperature of the ocean declines rapidly- has the most nutrients*
- *ITCZ (Intertropical Convergence Zone)- The region where northeasterly and southeasterly tradewinds converge creating an area of low pressure along the equator*



Frigatebird

# Important Concepts: The Coriolis Force



- *A fictitious force resulting from the Earth's rotation*
- *Gravity loosely couples the ocean to the Earth*

- *Air and water masses are deflected to the right in the northern hemisphere and to the left in the southern hemisphere*
- *The Coriolis Force strengthens as one moves poleward*

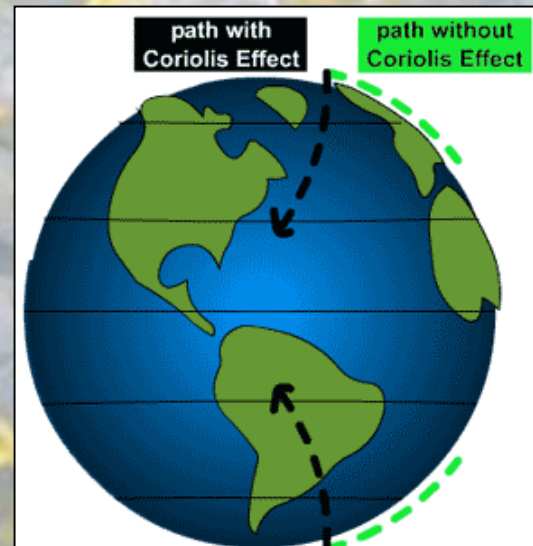


Photo courtesy of NASA

# *Important Concepts: Geostrophic Currents*

- *Horizontal Pressure Gradients arise from currents encountering continental boundaries*

- *Water will try to flow "down" the slope of the gradient*

*But Remember the Coriolis Effect!!!*





# *Oceanography in the Equatorial Pacific*

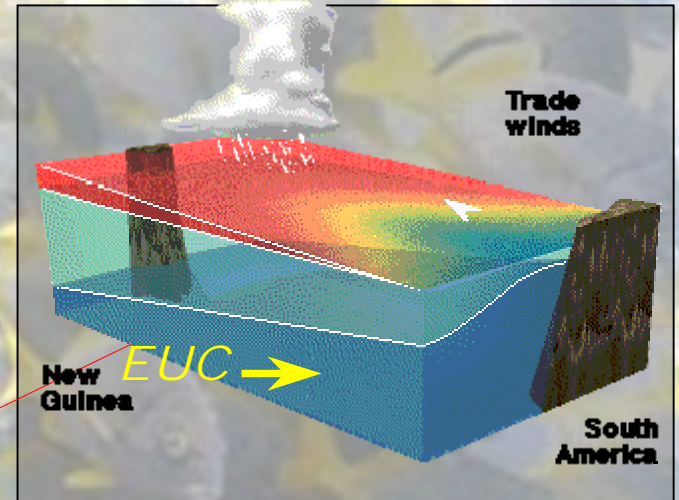
- *Galapagos Islands are located in the equatorial Pacific, therefore it is important to understand its oceanography*
- *Trade Winds cause the North Equatorial and South Equatorial Currents*
- *At the equator, winds are unaffected by Coriolis*
- *Wind stress causes a horizontal pressure gradient as warm surface waters are piled up at the western boundary (Australia and Asia)*
- *The weight of the warm water forces the thermocline to a deeper depth*



Galapagos Tortoise

# Oceanography in the Equatorial Pacific

- *Cold water in the suppressed western thermocline is forced towards the east*
- *Thermoclinic waters will travel eastward in the form of a Kelvin wave across the Pacific basin*



- *This jet of thermocline waters is called the Equatorial Undercurrent*
- *Upwelling of cool, nutrient-rich water along the coast of Peru and Ecuador is responsible for the tremendous biological productivity in the Peru Upwelling Zone*

# Oceanography of the Galapagos

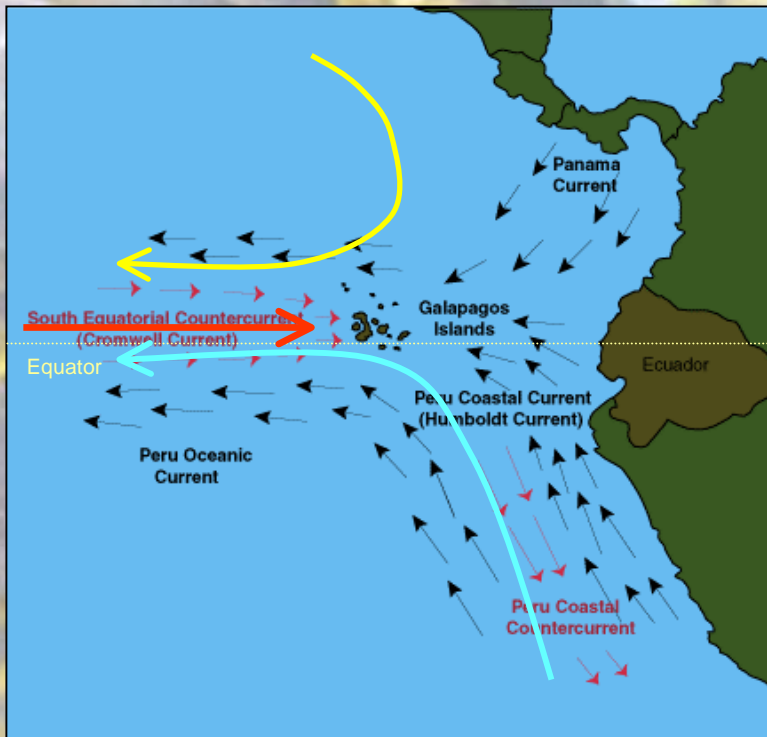


Image courtesy of John Merck, UMD

- North Equatorial Current (**NEC**) brings warm tropical waters to the northeast side of the island
- South Equatorial Current (**SEC**) brings cool, subtropical waters from the Antarctica Circumpolar Current (Penguins!)
- The SEC also carries cool upwelled water from the Peru Upwelling Zone
- To the west the Equatorial Undercurrent (**EUC**) reaches the Galapagos. The EUC runs into the islands around 50 m depth, similar to a hose hitting a screen, the water will spread through the islands carrying cool, high-nutrient upwelled water
- In the middle of the archipelago, all the waters mix and the result is subtropical regions

# Oceanography of the Galapagos: Seasons

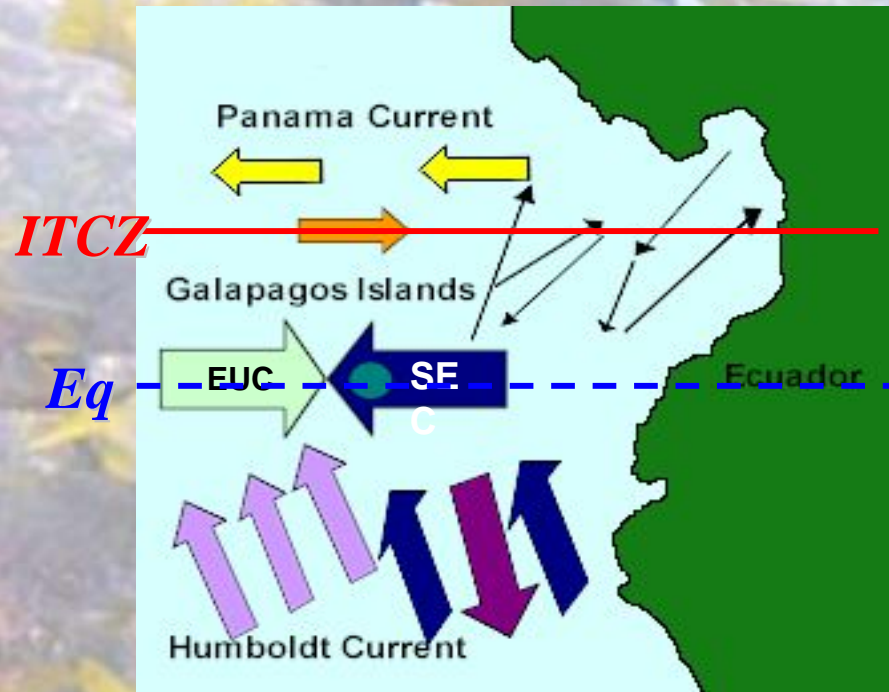


Image courtesy of Galapagos Online

- The Humboldt Current (part of the South Pacific Gyre) brings cool, Antarctic waters from June to November
- Winds from the Southeast bring a light mist, called the 'garúa' in the highlands. However, the mist never condenses so there is very little rainfall

- These months are considered the Dry Season



# Oceanography of the Galapagos: Seasons

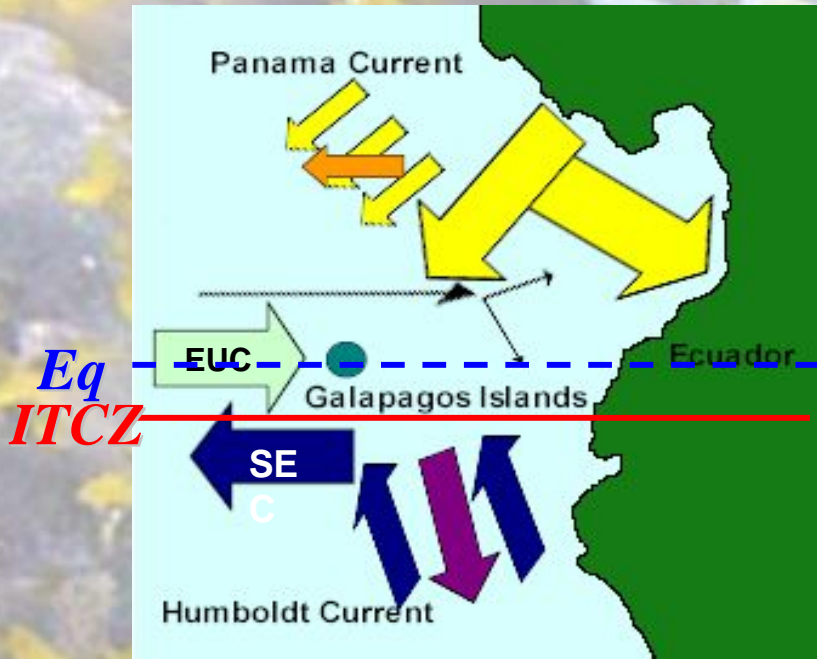


Image courtesy of Galapagos Online

- Warm surface waters from the Panama Current (part of the North Pacific Gyre) replace the Humboldt in December
- The air temperature is no longer cool
- These months are the Wet season



Red billed tropicbird

# *El Niño-Southern Oscillation (ENSO)*

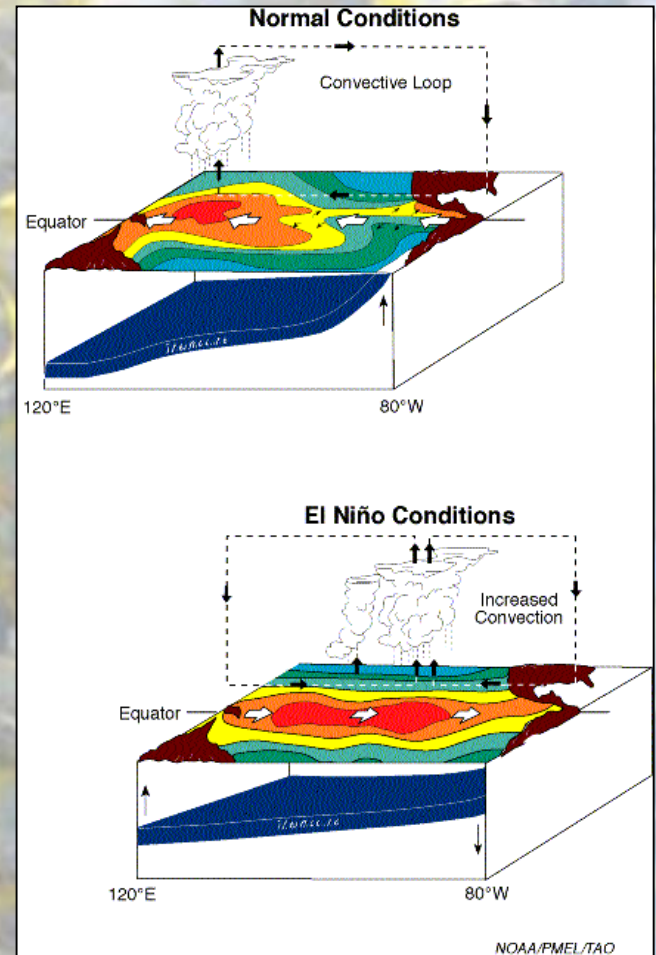
- Occurs every 2 to 7 years*
- Named “the Christ Child” because it occurs around Christmas*
- Uncertain whether the events begin in the ocean or atmosphere, but both are affected*



Waved Albatross

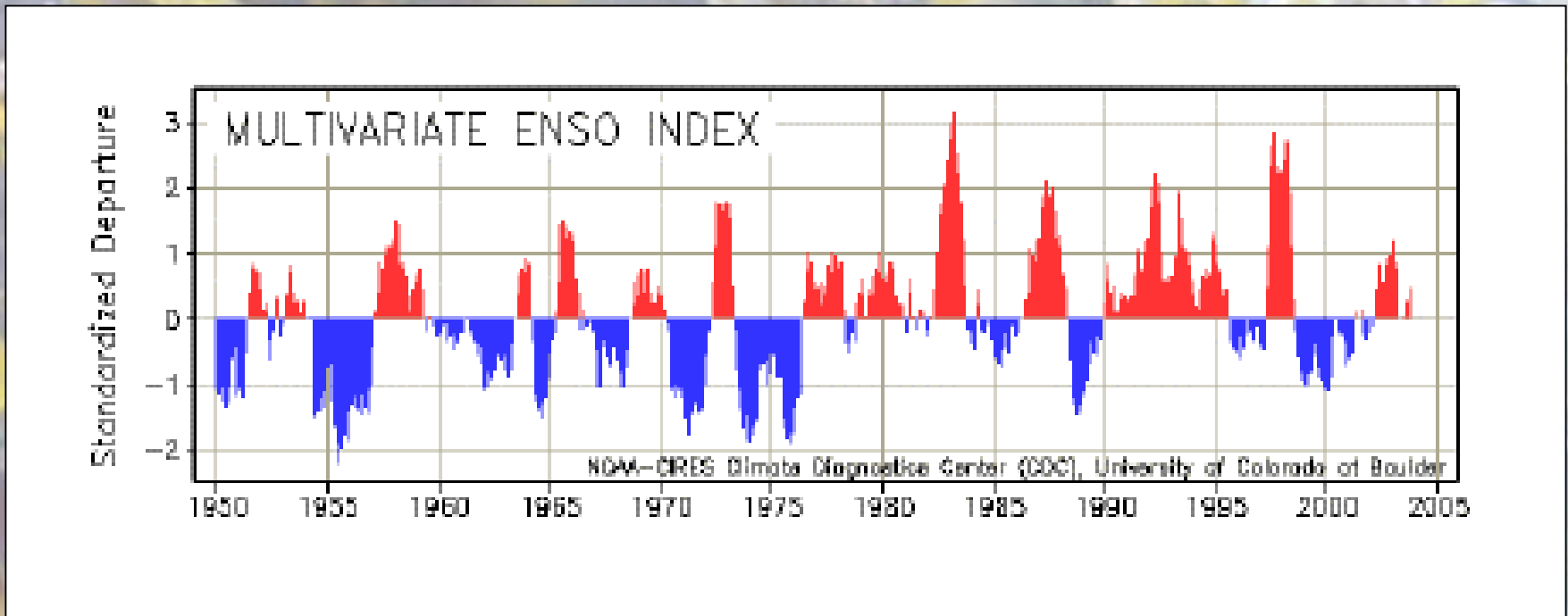
# ENSO: Southern Oscillation

- *In normal conditions there exists a low over Indonesia and a high over the Southeastern Pacific (air moves from high to low) but in the Southern Oscillation, the two begin to weaken*
- *Without the wind stress, the gradient will flatten, warm mixed-water flows toward the east in a series of Kelvin waves, causing the thermocline to level*
- *Upwelling of cool, nutrient-rich water may stop, or only raise warm, nutrient-poor waters*



# ENSO

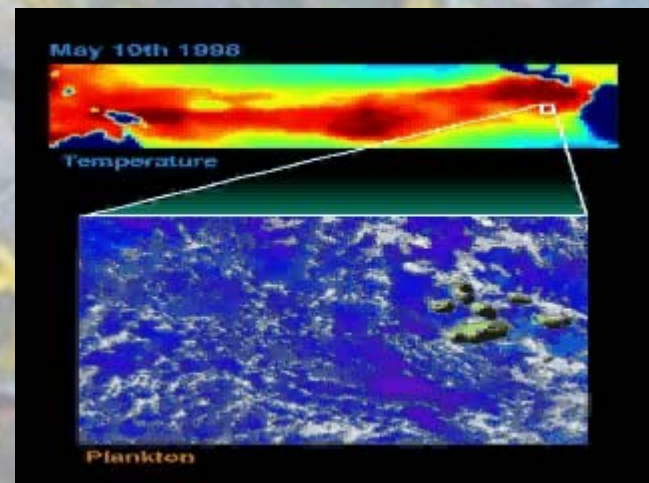
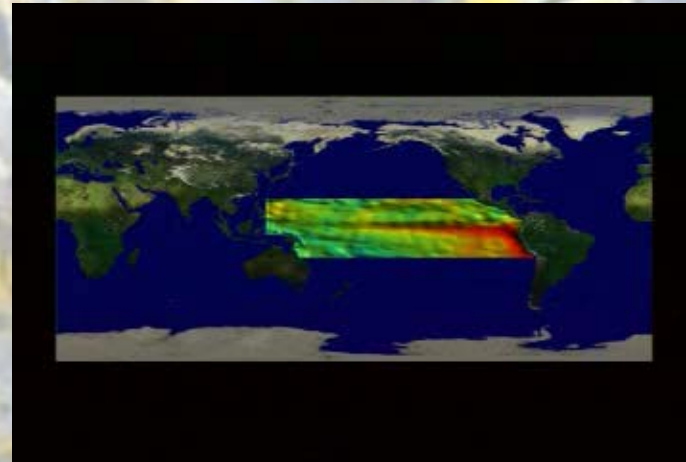
- *When Kelvin waves that are reflected back to the west in the form of Rossby waves reach the western basin, El Niño is believed to be over*





# *El Niño's Effects on the Galapagos Islands: Oceanography*

- *Winds will not "churn up" the cool sub-thermocline waters from the Equatorial Undercurrent because of the depression of the thermocline*
- *The Humboldt Current is cutoff as the trade winds no longer blow at normal strength*
- *Without these nutrient rich waters, the food chain is interrupted*



# *El Niño's Effects on the Galapagos Islands: Biology*

- Rainfall increases, plants thrive*
- Introduced populations increase, such as fireants, cats, dogs, goats, tree frogs, etc.*
- This is doubly damaging to endemic species*



Red-footed  
Booby

# *The Effects of El Niño*

Large algal beds die, depriving marine iguanas, turtles and many fish of their staple diet.



Once weakened, strong swells and sea urchins break apart complex coral habitats that sustain diverse species changing the environment.

Increased sea levels affect animals living in the the intertidal zone



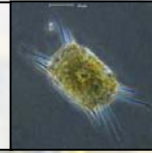
Fishing pressure remains the same, so capture is taken from further down the food web



Marine birds such as the blue footed booby, petrels, noddys, brown pelicans, albatross and magnificent frigate cannot feed their offspring. They have less resources and number of eggs are reduced.



Primary production from phytoplankton bringing food to the islands grinds to a halt



Ecosystems starve from the bottom up affecting first the top end predators like sea-lions

Corals are stressed by the sustained higher temperatures “bleaching” as the symbiotic zooxanthellae are expelled.

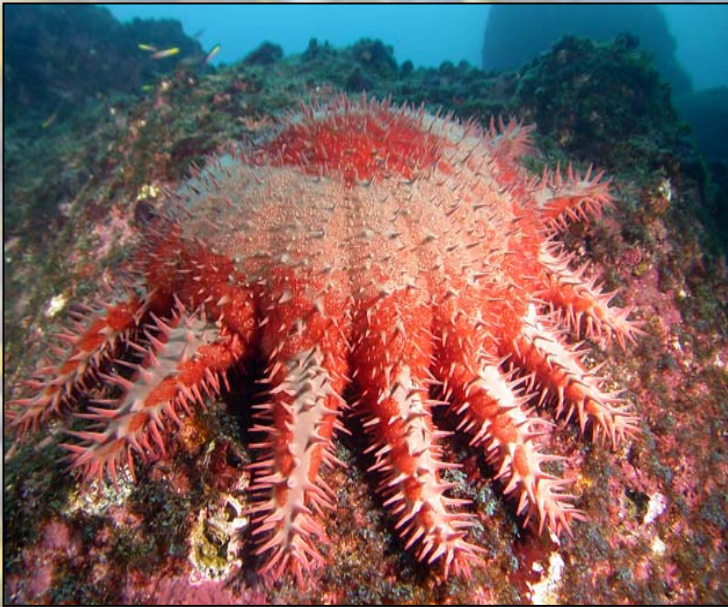


Mobile species such as sharks probably move offshore in the search of food in deeper water.

Species like Galapagos penguins and flightless cormorants, forage close to their colonies and are heavily affected by the lack of food.



# *Coral Bleaching*



*Highly productive coral reef  
before an El Niño event*



*Last large coral reefs after the  
1982/83 and 97/98 El Niño*

# Discussion

- *“The biology [of the Galapagos Islands] changes because the physics changes.” –M. Moss*
- *The study of the driving force of these changes is the difference between marine biology and physical oceanography*
- *The Galapagos Islands are “ground zero” for studying El Niño; a thorough understanding will help to forecast weather changes*



Marine Iguana

# *Thank you*

This information is from a collaborative effort between the Charles Darwin Foundation for the Galapagos Islands, UNCW and NC State

## *Other References:*

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NOAA

NASA

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