



# Is ENSO a cycle or a series of events?

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(Kessler, GRL, 2002)

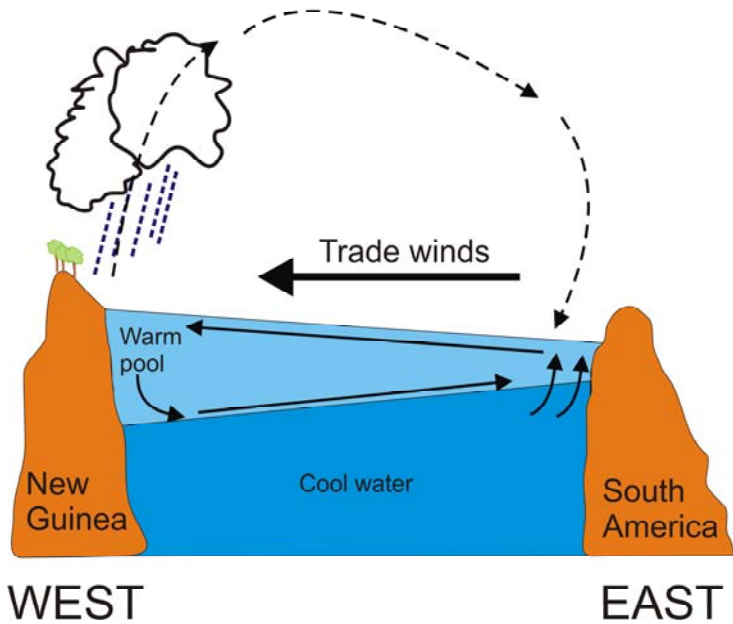


# Outline of the talk

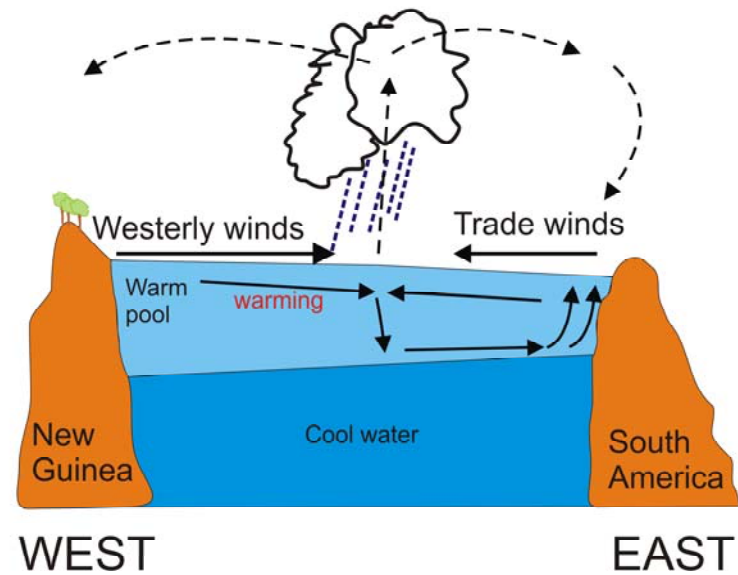
- Introduction:
  - Connection with dr. Kessler's talk
  - About oscillatory nature of ENSO
- Two concepts of ENSO:
  - Self-sustained oscillation
  - A series of random events
- ENSO as an oscillation:
  - Delayed oscillator model
  - Jin paradigm
- Data analysis:
  - Is ENSO a cycle or a series of events?
- Conclusions

# Normal situation vs. El Nino situation

The «normal» situation

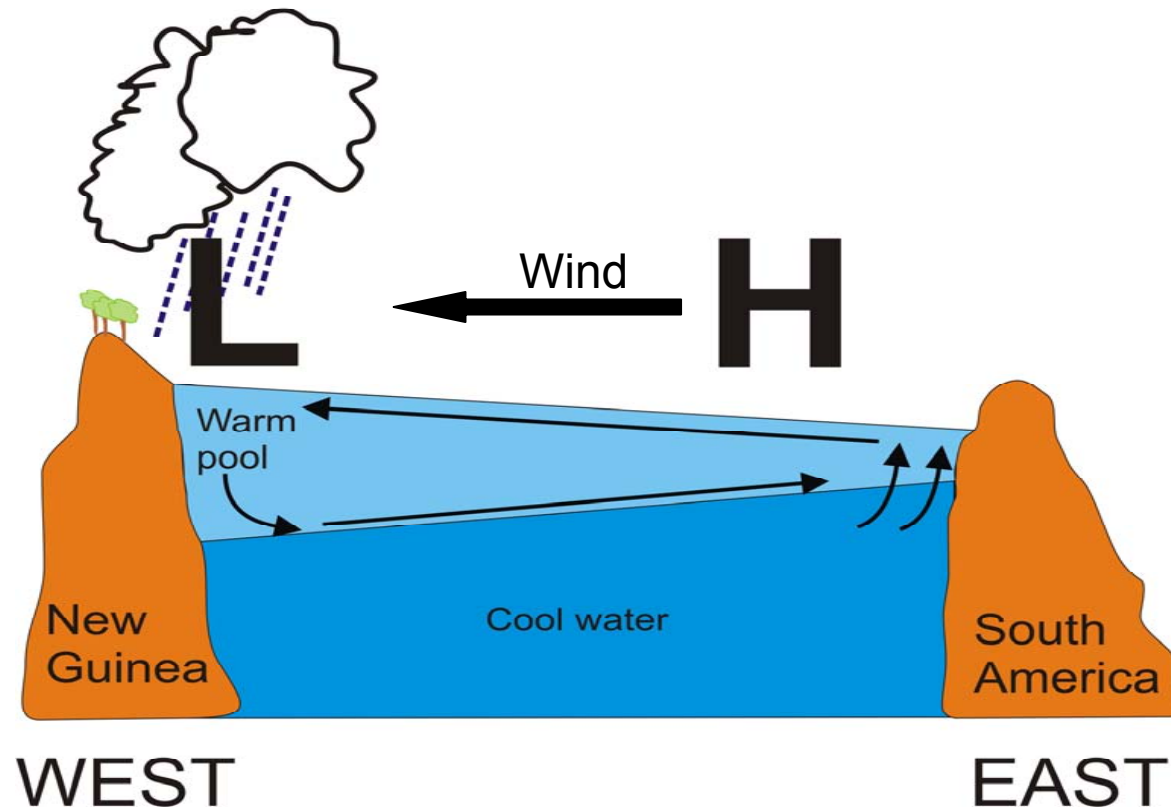


El Nino



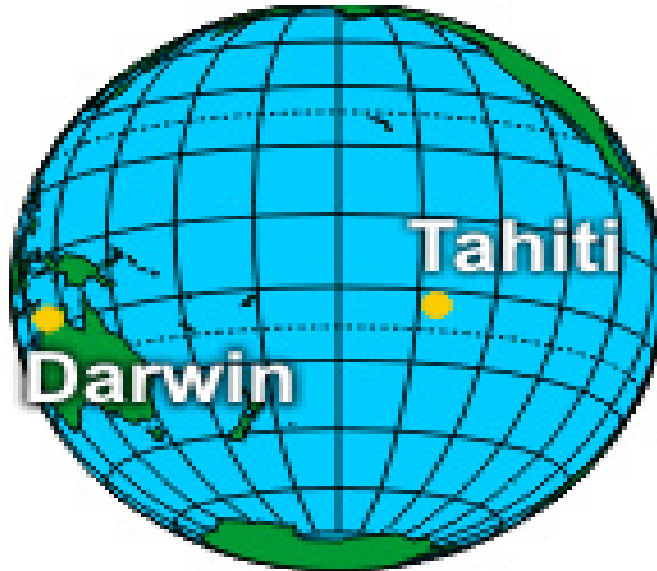
# Normal situation vs. El Nino situation

The «normal» situation



# The Southern Oscillation Index (SOI)

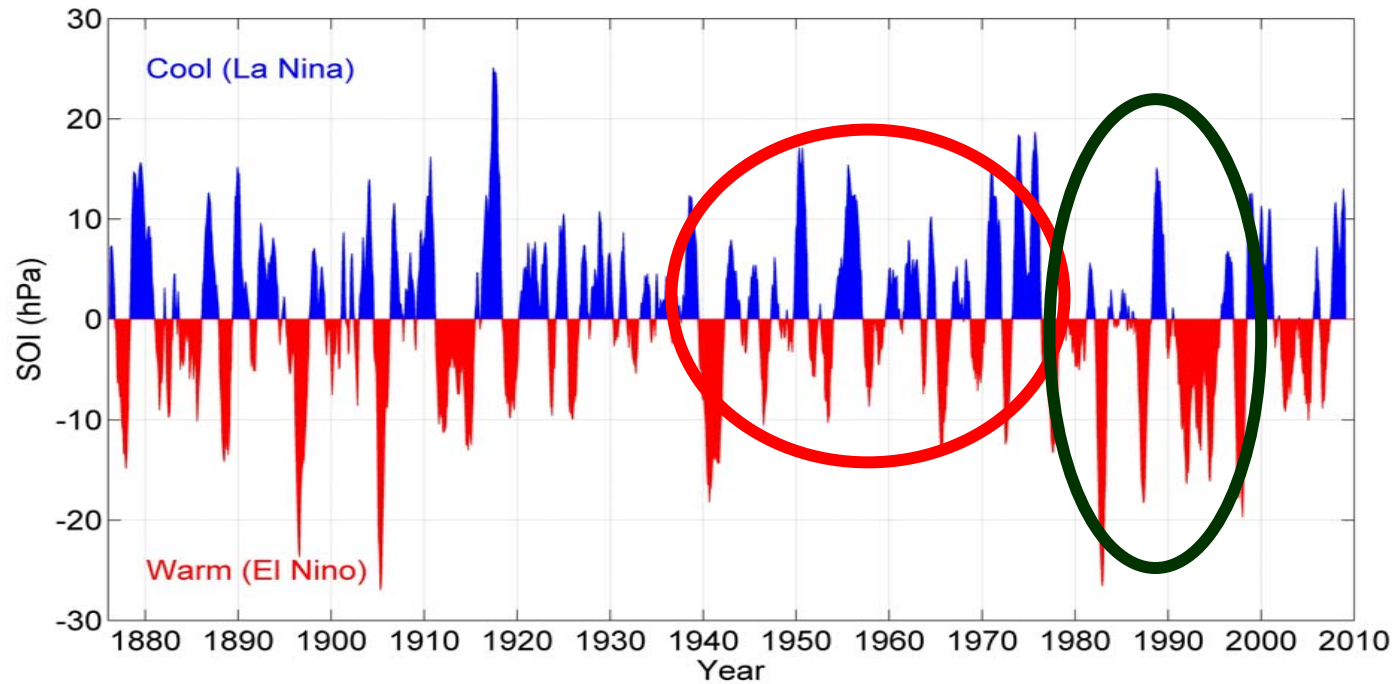
**Southern Oscillation Index** – a difference of monthly sea level pressure anomalies between Tahiti and Darwin.



**Positive SOI:** Normal situation  
**Negative SOI:** El Niño situation

(<http://www.srh.noaa.gov/jetstream//tropics/enso.htm>)

# The SOI time series



(7 months running mean)

(data from: <http://www.cgd.ucar.edu/cas/catalog/climind/soi.html>)



# The ENSO nature

- Self-sustained oscillations vs. individual events.
- Instability vs. stability:
  - **Instability:** system oscillates without external triggers -> **ENSO as an oscillation**
    - **EL NIÑO IS PREDICTABLE FAR IN ADVANCE!**
  - **Stability:** system stays in normal state unless pushed with some external force (and then it goes back to the normal state) -> **ENSO as a series of individual events**
    - **EL NIÑO IS NOT PREDICTABLE UNTIL SHORTLY BEFORE IT BEGINS!**

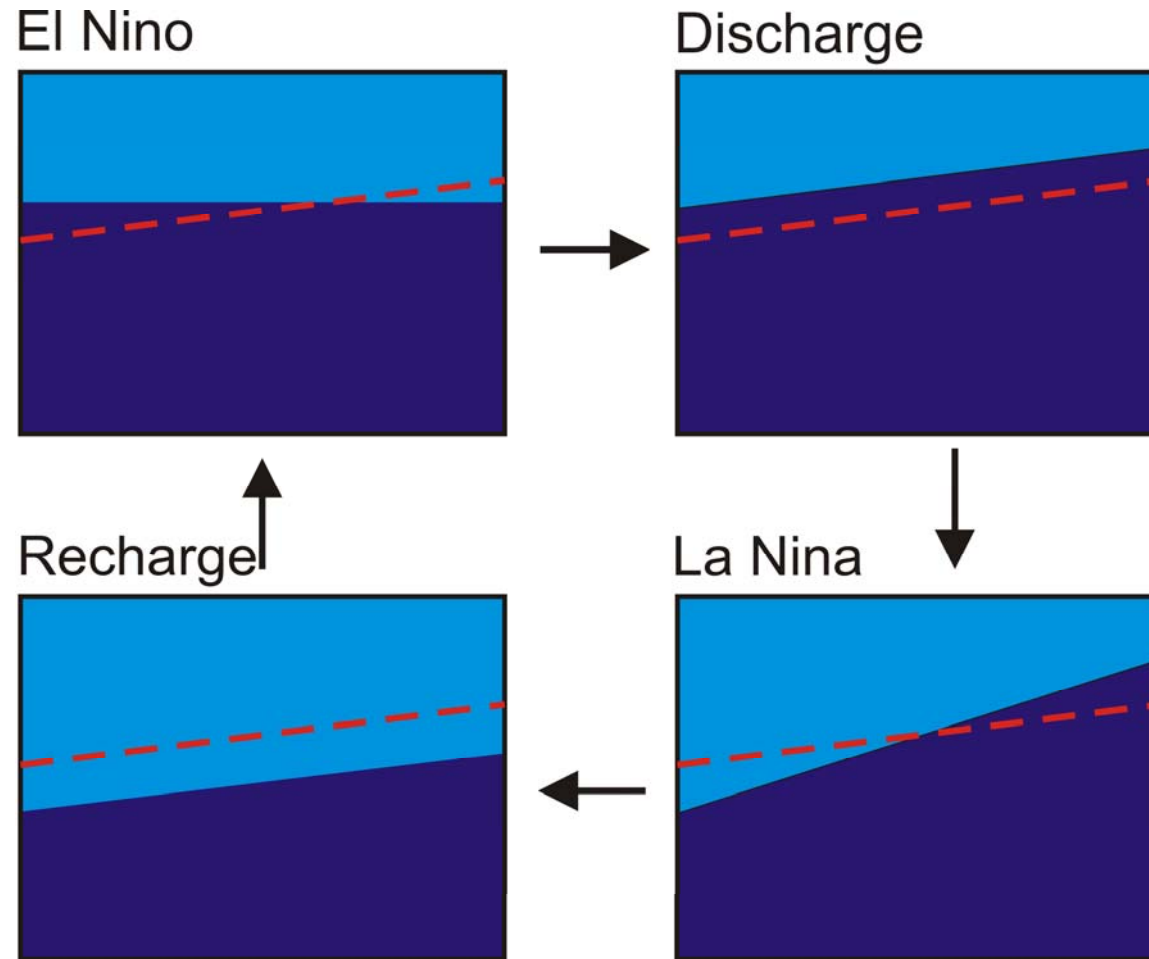


# ENSO as an oscillation

- Two basic concepts of ENSO as an oscillatory system:
  - Delayed oscillator paradigm (Suarez and Schopf, 1988)
  - Jin model (Jin, 1997)
- Both models suppose that ENSO is an oscillation going through four stages:
  - 1. El Niño
  - 2. Discharge (minimum content of warm water in the equatorial Pacific)
  - 3. La Niña
  - 4. Recharge (maximum content of warm water in the equatorial Pacific)

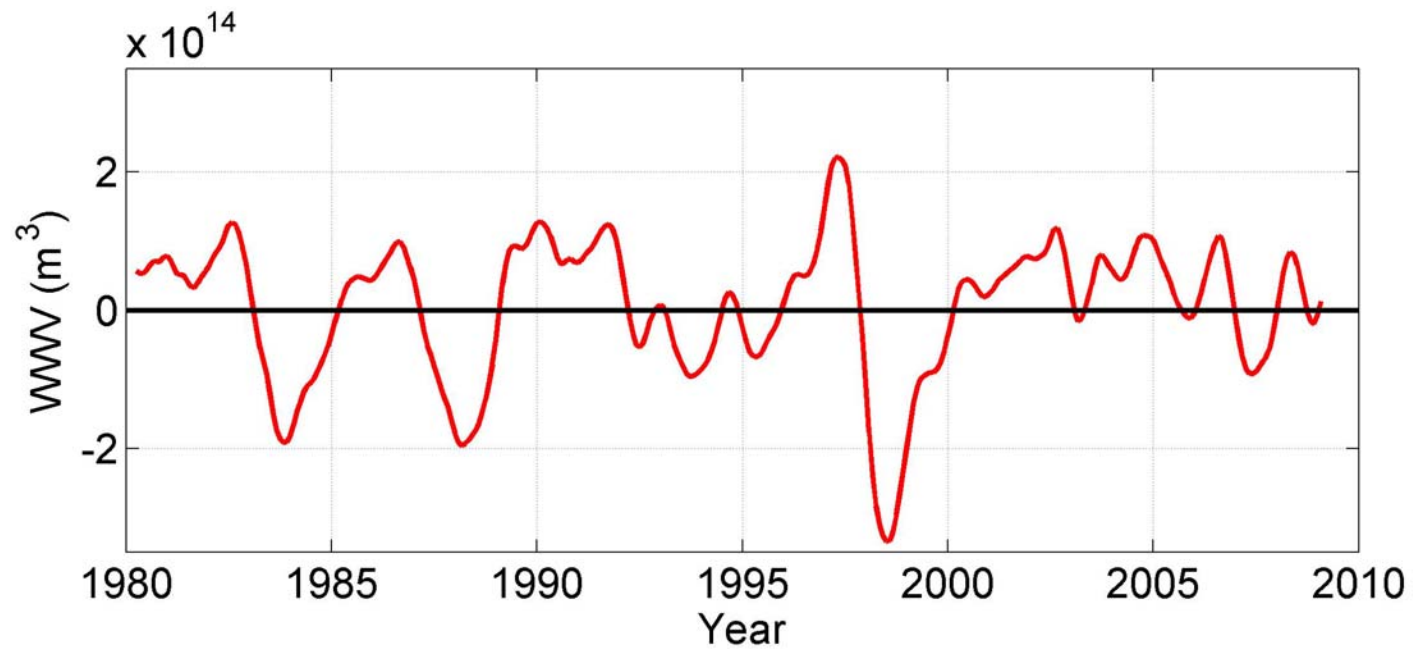


# ENSO as an oscillation



(After Jin, 1997)

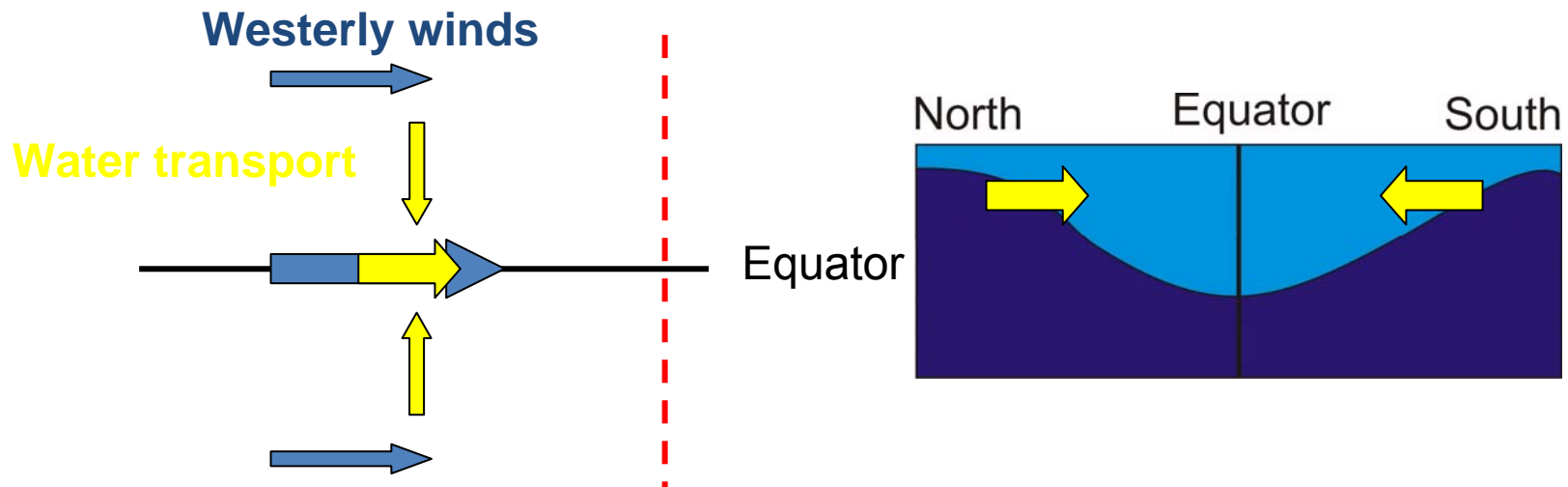
# ENSO as an oscillation



(7 months running mean)

(data from: [http://www.pmel.noaa.gov/tao/el\\_nino/wwv/](http://www.pmel.noaa.gov/tao/el_nino/wwv/))

# Delayed oscillator paradigm – El Niño



Westerly winds blowing strong on the Equator and weaker to the north and south of the equator.

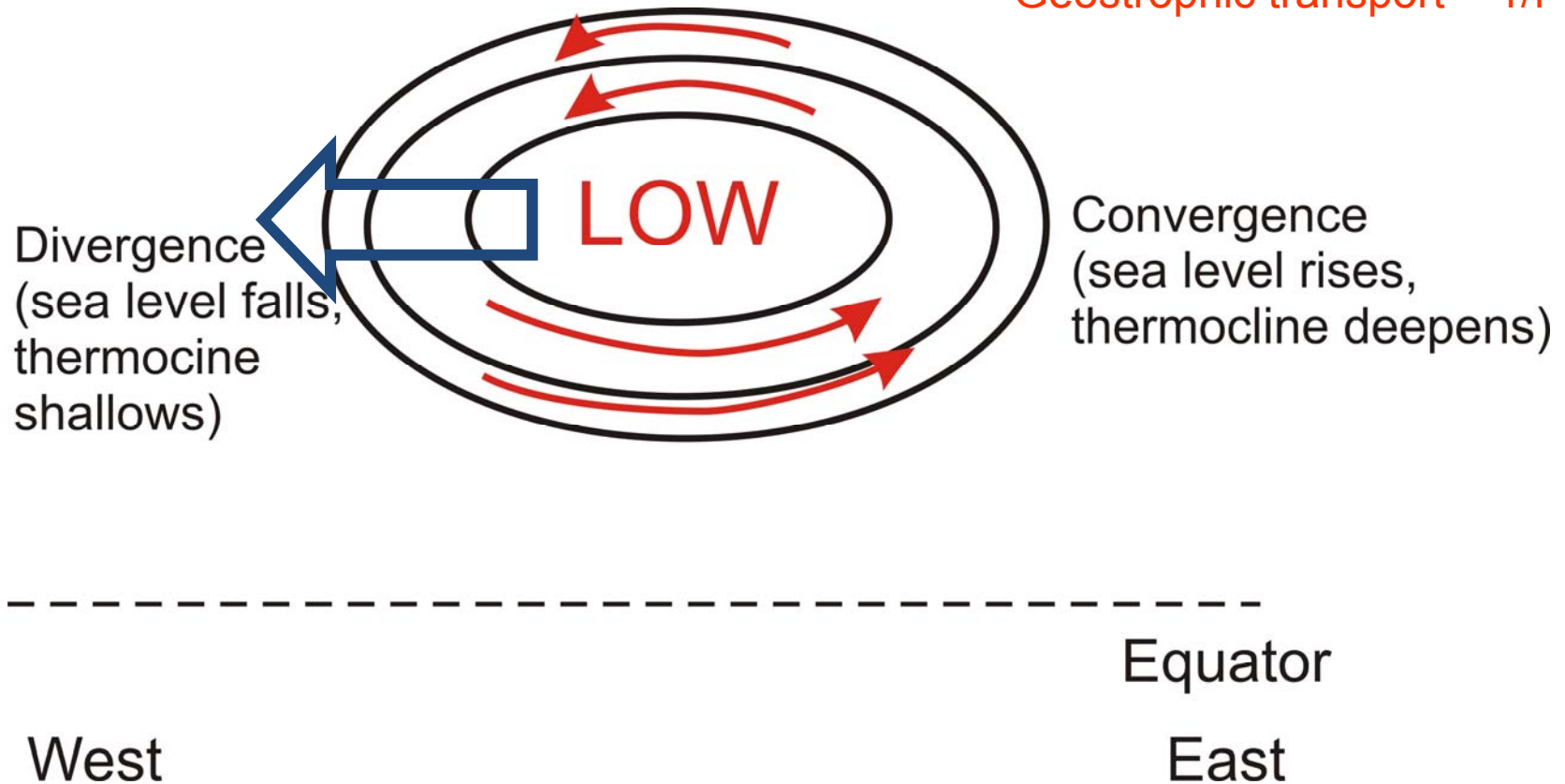
Thermocline on the Equator and to the east deepens, thermocline off the Equator shallows.

**Deep thermocline on the equator generates equatorial Kelvin waves.  
Shallow thermoclines off the equator generates Rossby waves.**

# Delayed oscillator paradigm – El Niño

## Rossby wave

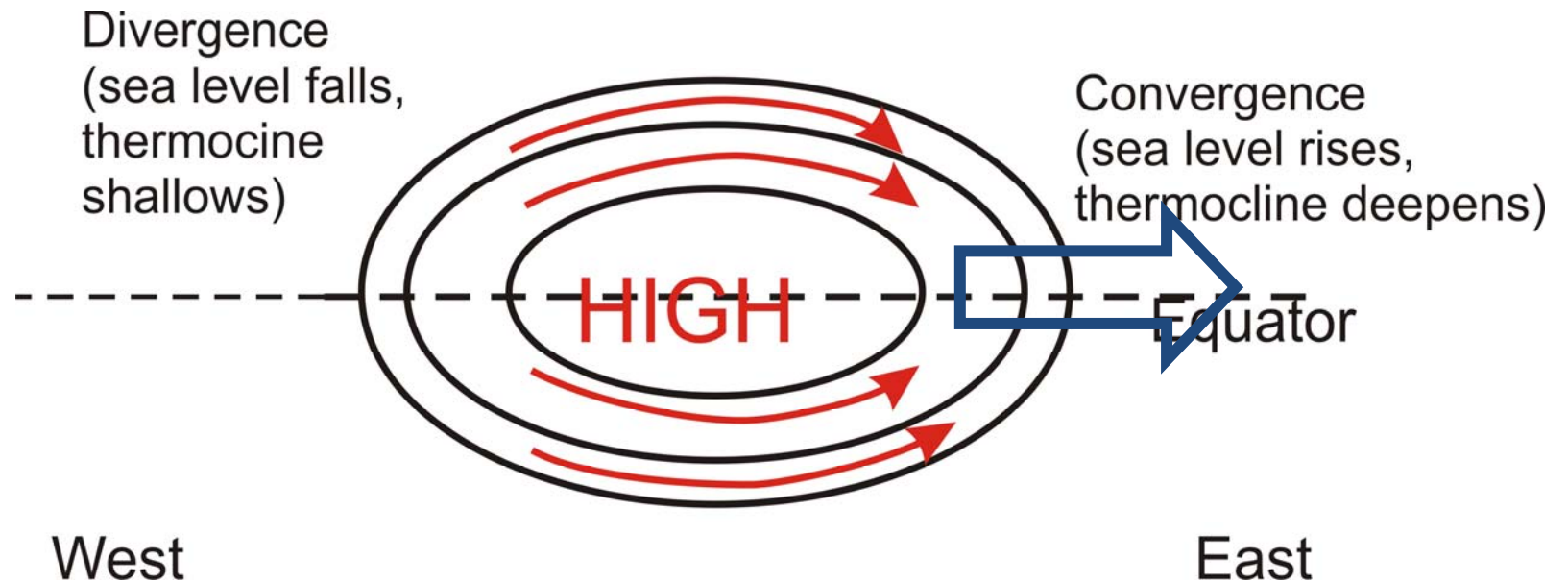
Geostrophic transport  $\sim 1/f$



(after William Kessler)

# Delayed oscillator paradigm – El Niño

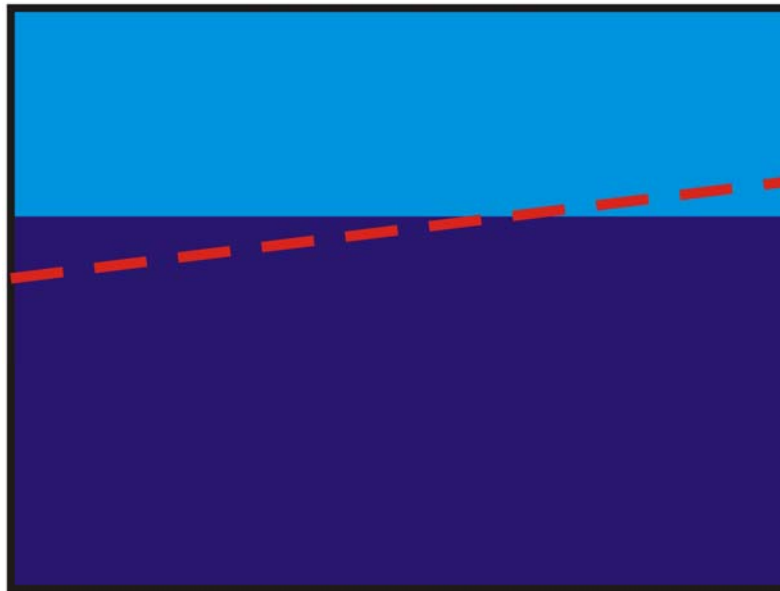
## Equatorial Kelvin wave



(after William Kessler)

# Delayed oscillator paradigm – El Niño

## El Niño

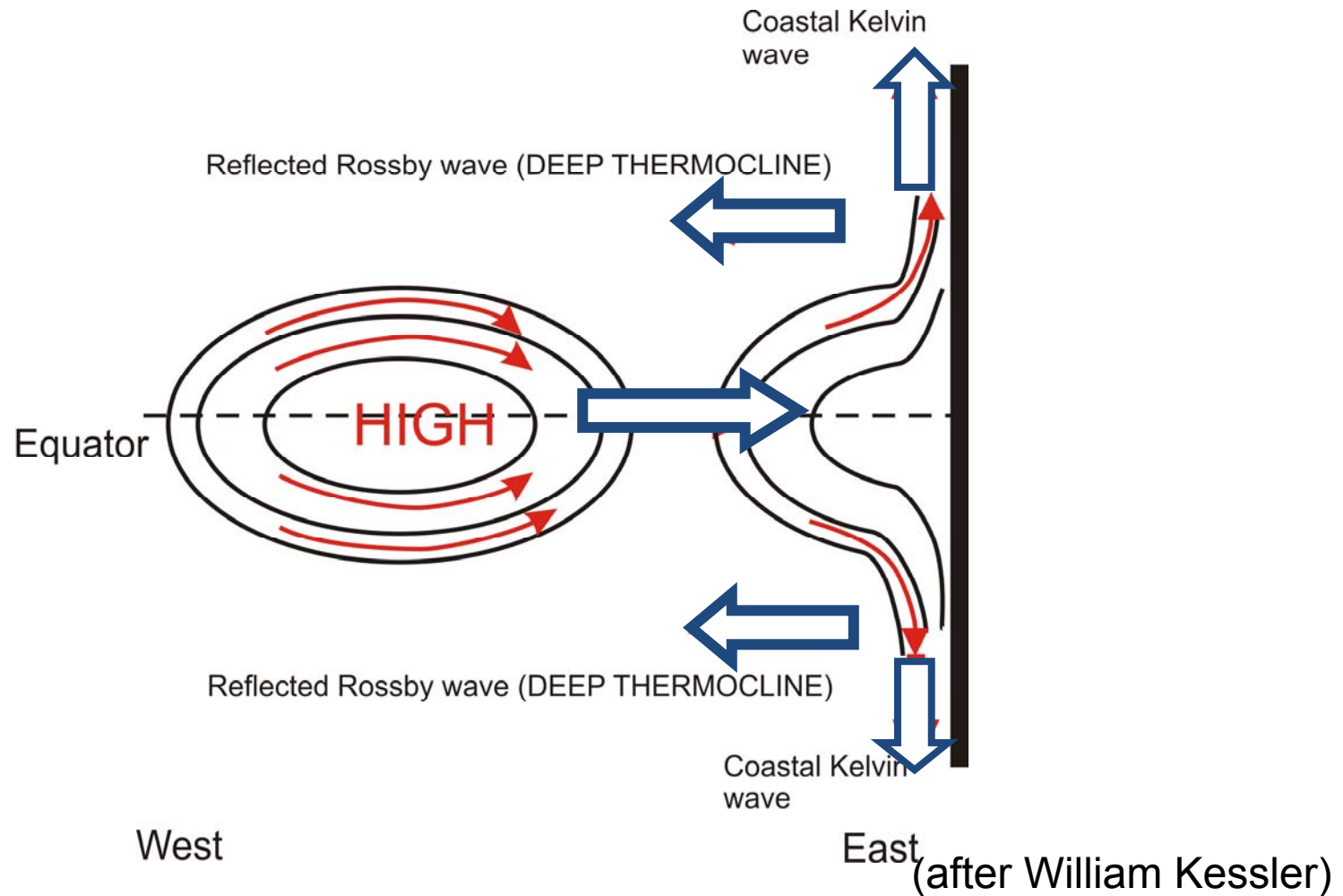


Warm water transported towards the equator and the east.

Flattening of the thermocline.

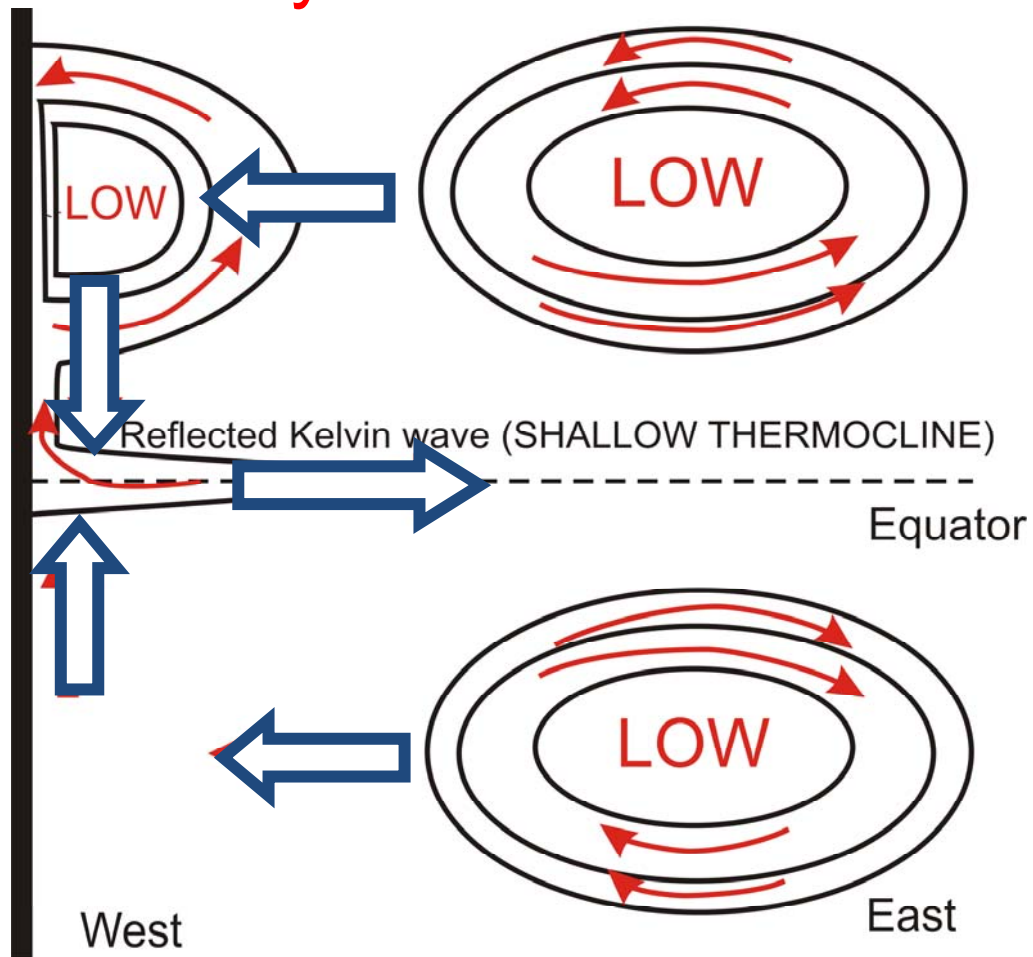
# Delayed oscillator paradigm – Discharge

## Equatorial Kelvin wave reflection



# Delayed oscillator paradigm – Discharge

## Rossby waves reflection

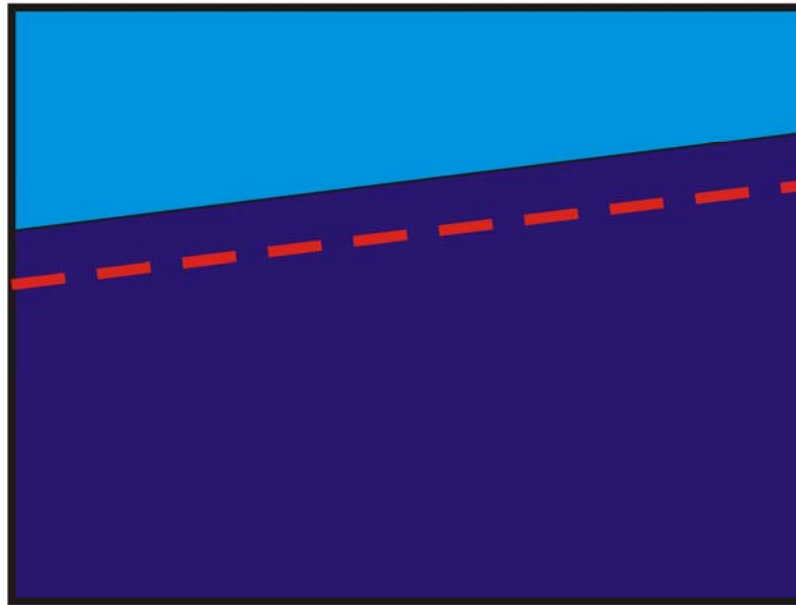


(after William Kessler)



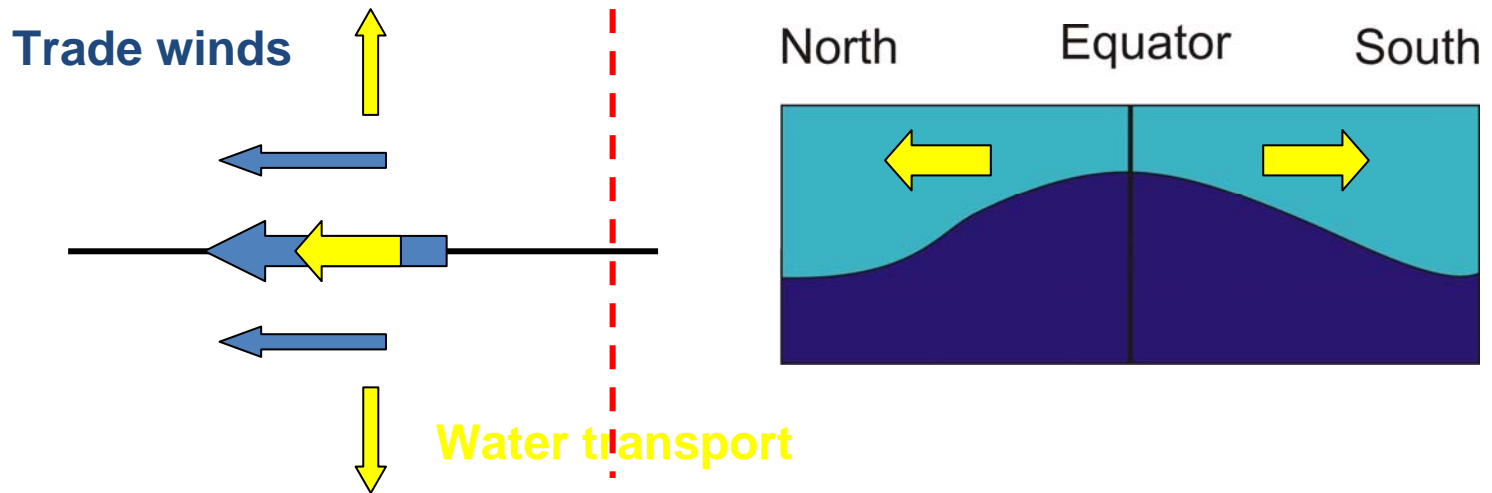
# Delayed oscillator paradigm – Discharge

## Discharge

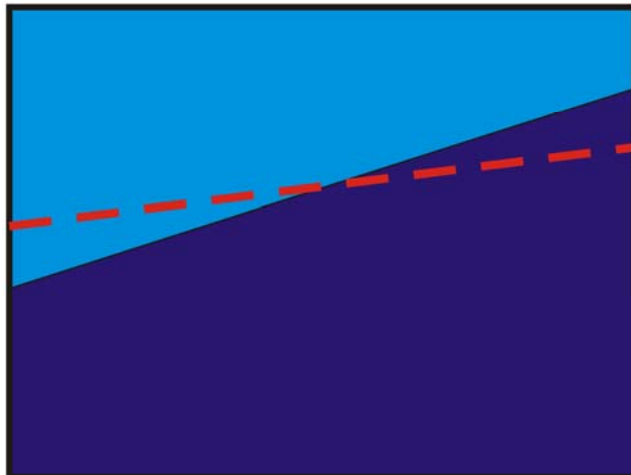


Thermocline is lifted along the Equator.  
Shallow thermocline in the east cools SST (Sea Surface Temperature) => westerly wind anomalies weaken and **trade winds** start.

# Delayed oscillator paradigm – La Niña



## La Nina

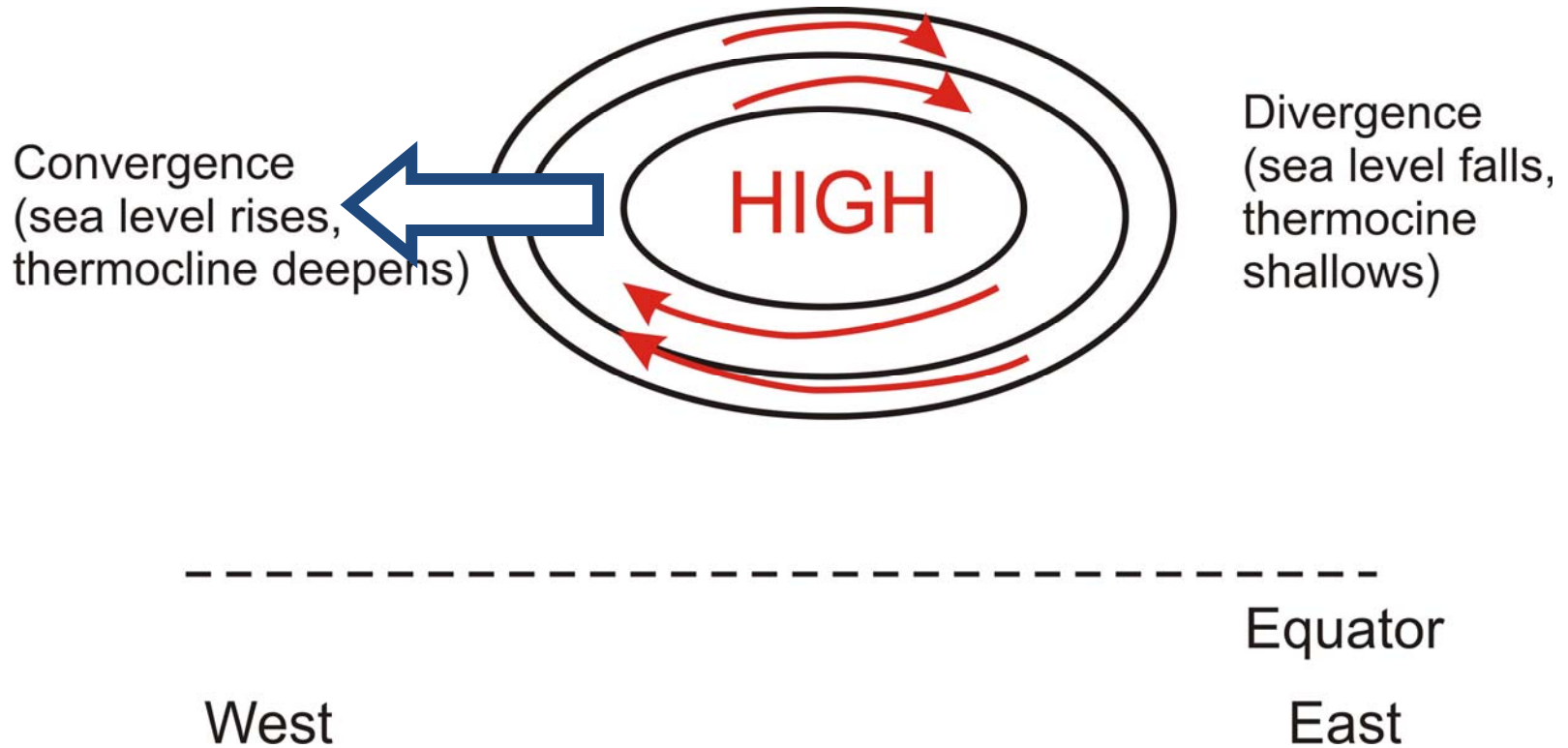


The thermocline deepens to the North and South of the Equator.

EAST: The thermocline shallows

WEST: The thermocline deepens

# Delayed oscillator paradigm – La Niña





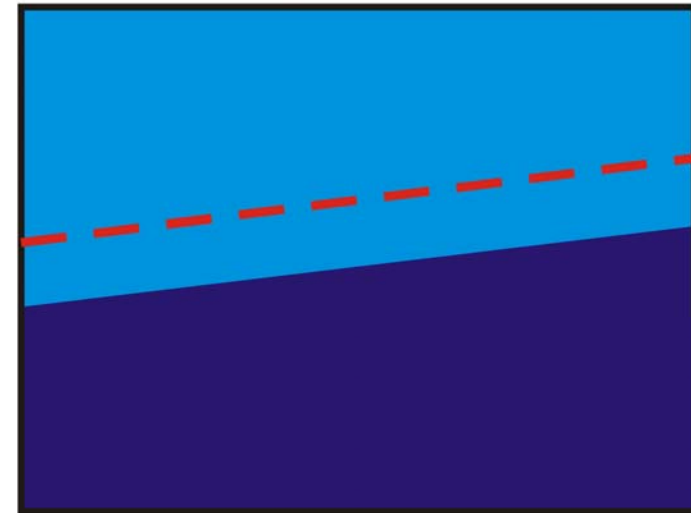
# Delayed oscillator paradigm – Recharge

Deep thermocline Kelvin wave propagates from the west towards the east and deepens the thermocline along the Equator.

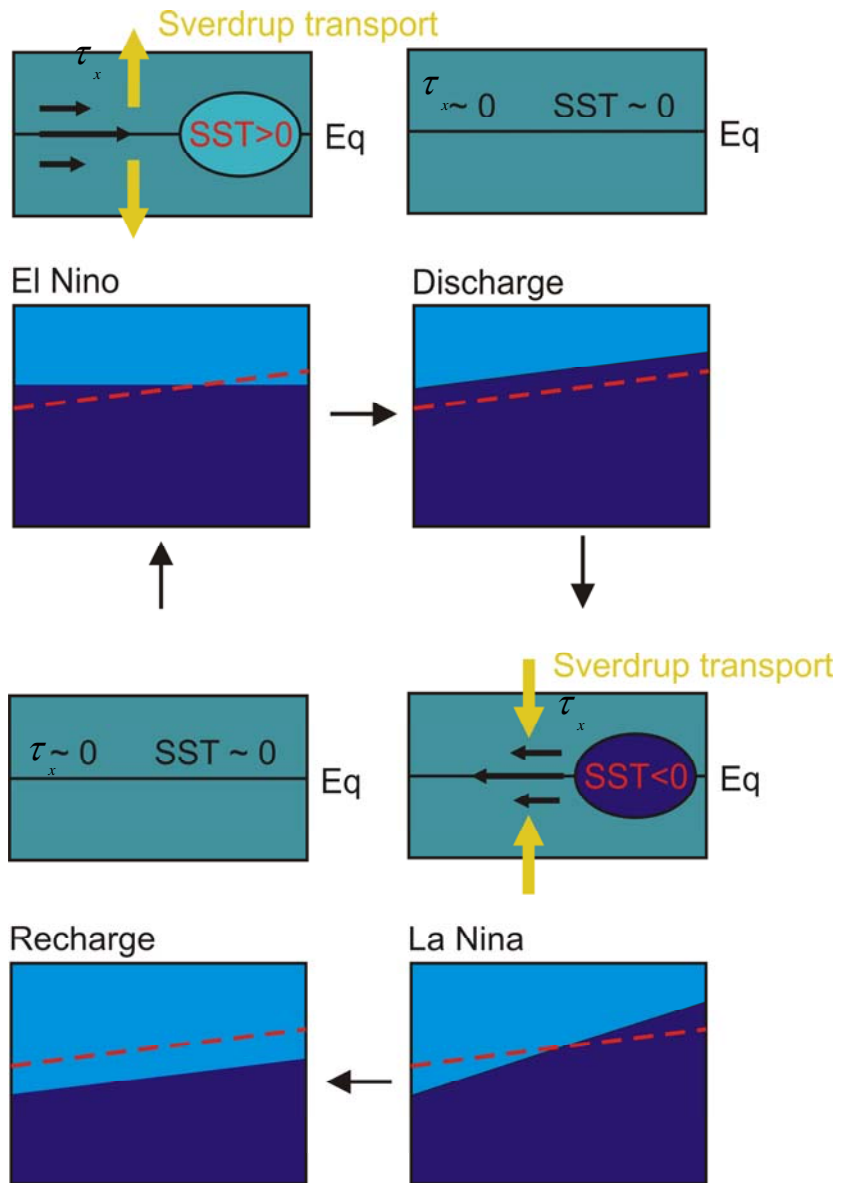
Large warm water volume in the east rises the sea surface temperature (SST) in the central and east Pacific – trade winds weaken – westerly winds can start blowing –

it is time for EL NIÑO again! Back to the stage 1!

## Recharge

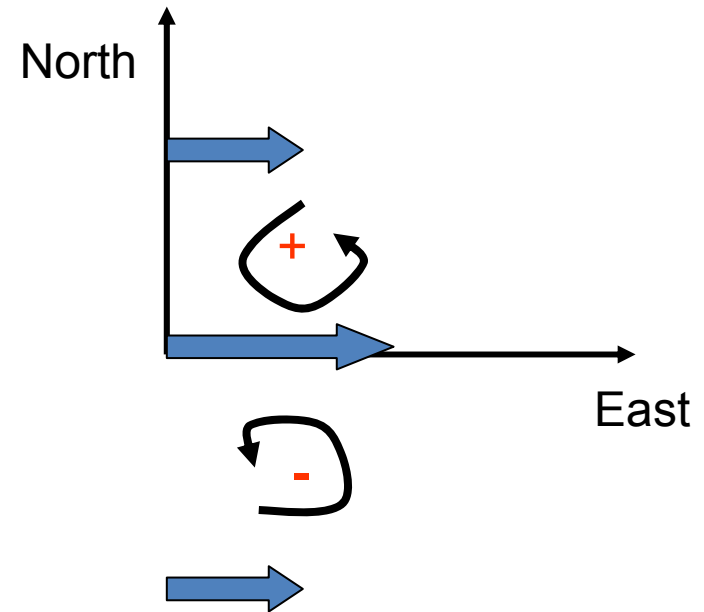


# Jin model



Sverdrup transport:

$$M_y = -\frac{1}{\beta} \frac{\partial \tau_x}{\partial y}$$



(after Jin, 1997)



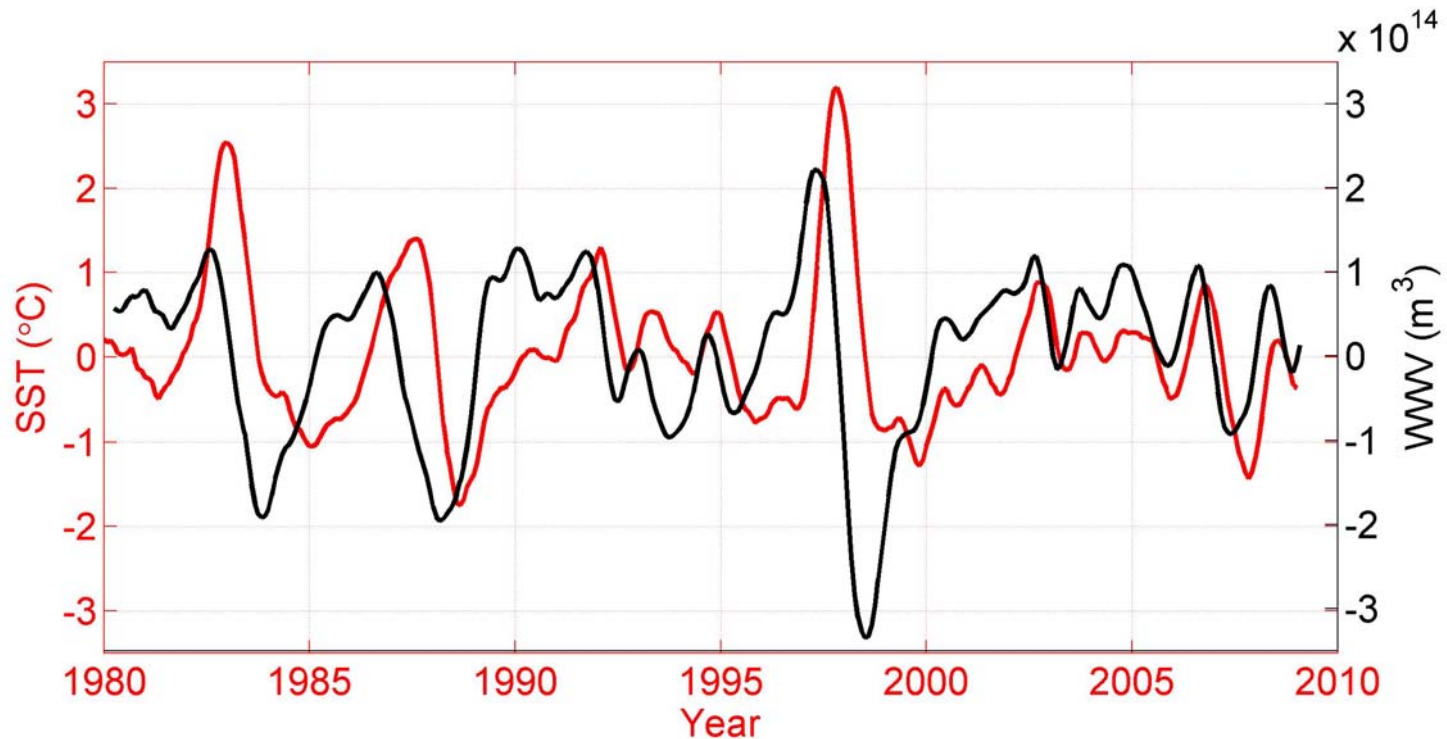


# So...

- This suggests that ENSO is an oscillation:
  - Oscillatory time series
  - Logical and coherent explanations of its cyclic nature!
- **BUT WAIT**
- **Let's analyse some more data**

# SST and WWV anomalies time series

- SST - Sea surface temperature
- WWV – Warm water volume



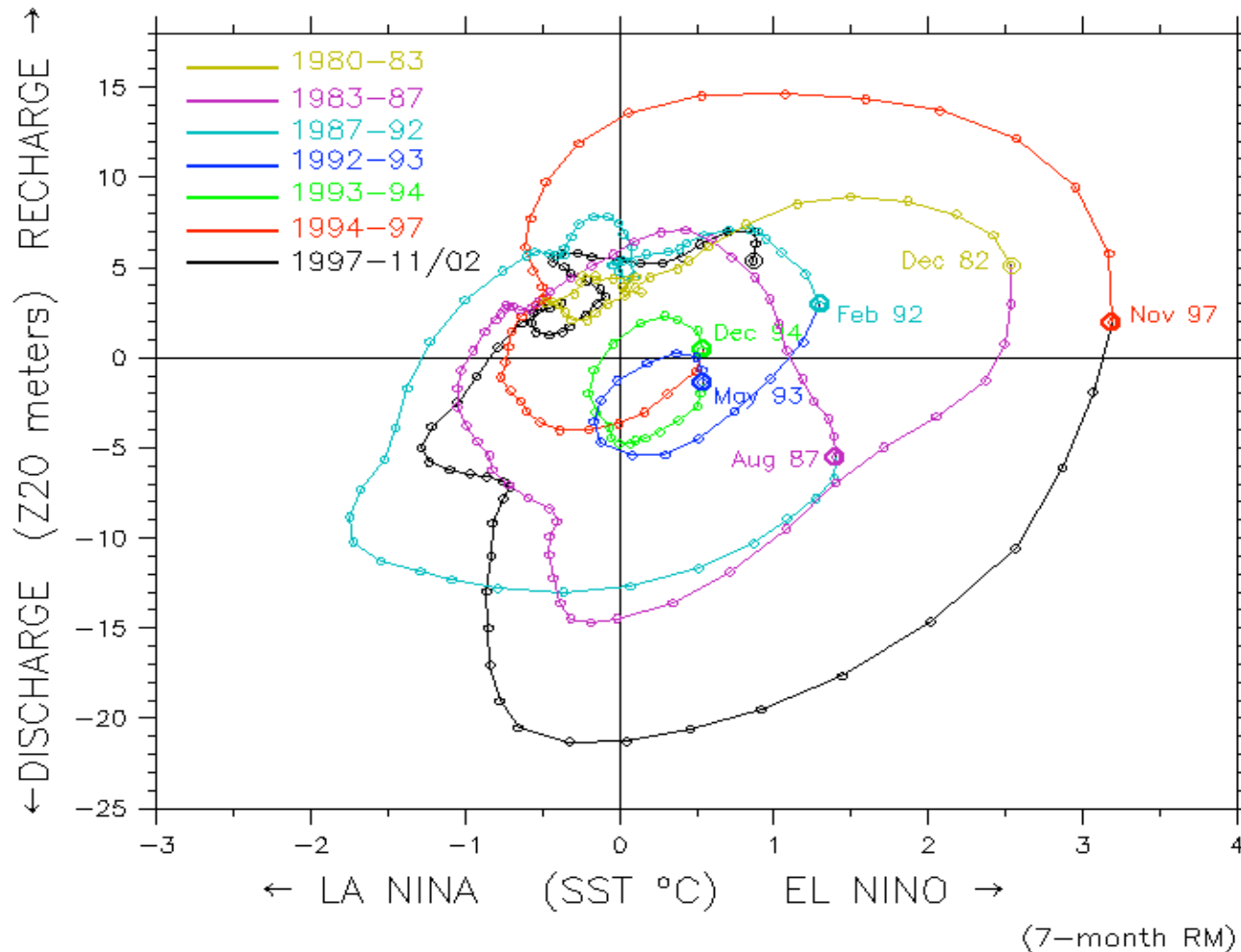
(7 month running means)

(after Kessler, 2002)

# Phase diagram of SST - WWV

Nino3 SST and Upper Layer Thickness phase ellipses

ULT is 5°S–5°S, 130°E–80°W average Z20 (BMRC XBT/TAO). Circulation is clockwise







# Conclusions

- System goes swiftly and predictably through recharge – El Niño – discharge stages
- Amplitudes of recharge – El Niño – discharge stages are highly correlated
- System spends unpredictable period of time in a weak La Niña stage
- Amplitudes of discharge – La Niña – recharge stages are not significantly correlated

**El Niño is unpredictable too much in advance! But, it can be predicted once the Pacific is in a recharge stage.**

- If El Niño is not an oscillation, what triggers it? Let's ask Maristella!

The background of the entire slide is a close-up, high-angle shot of water with numerous bubbles of various sizes. The water is a deep blue color, and the bubbles are bright blue and white, creating a textured, shimmering effect. The bubbles are more densely packed in the upper right and lower right areas, with some larger bubbles in the center and left.

**Thank you for your  
attention!**

**Questions?**