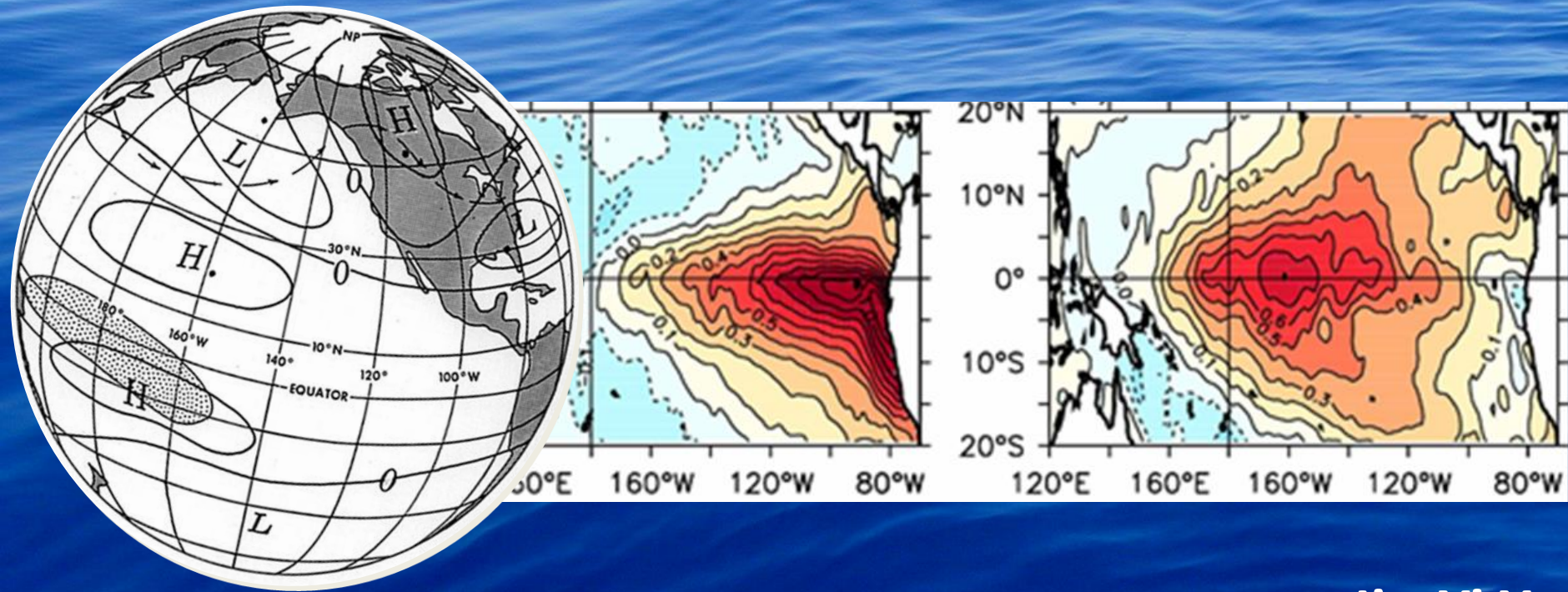


The Changing El Niño in the 21st Century: Properties, Dynamics, and Impacts



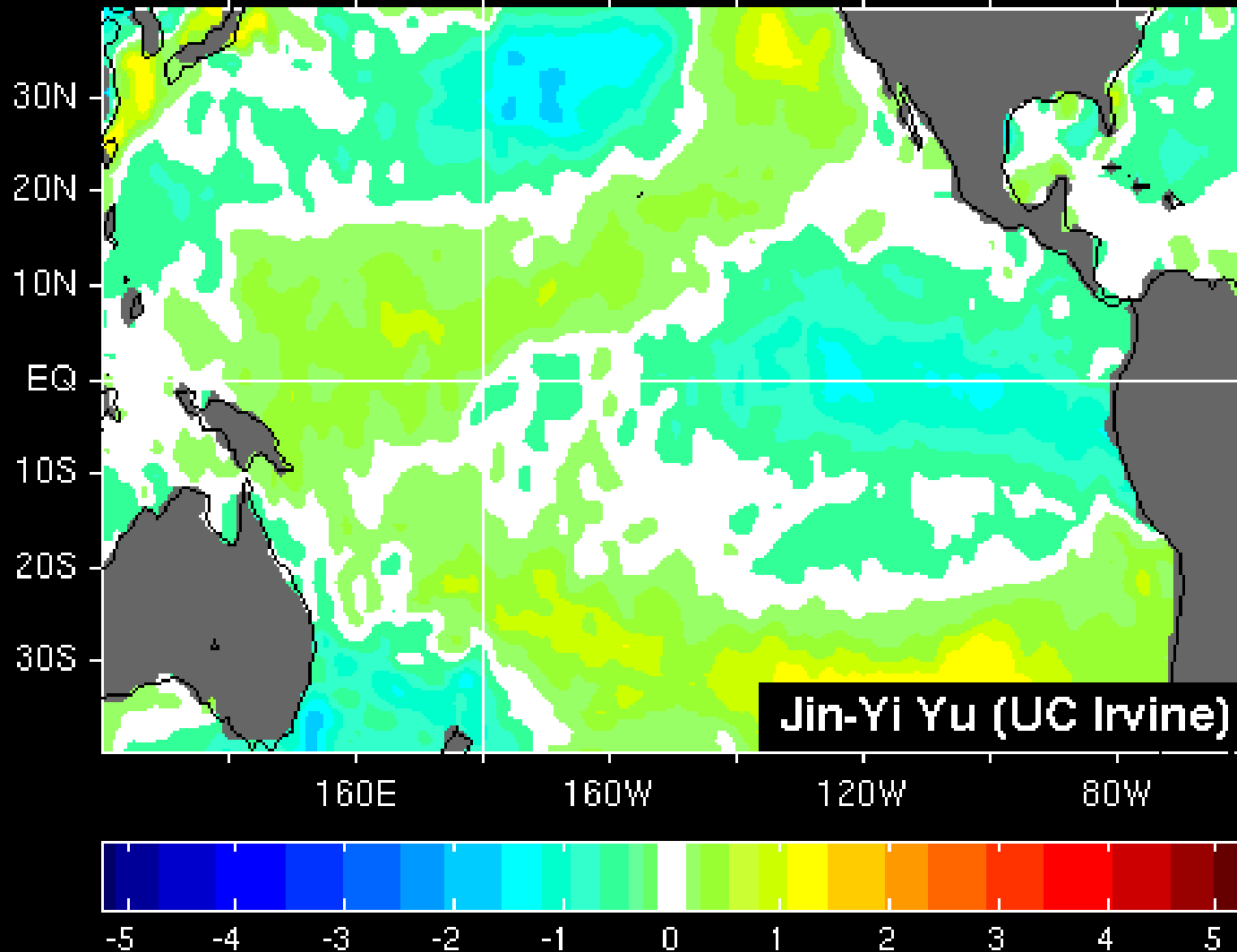
Jin-Yi Yu

Department of Earth System Science

University of California, Irvine

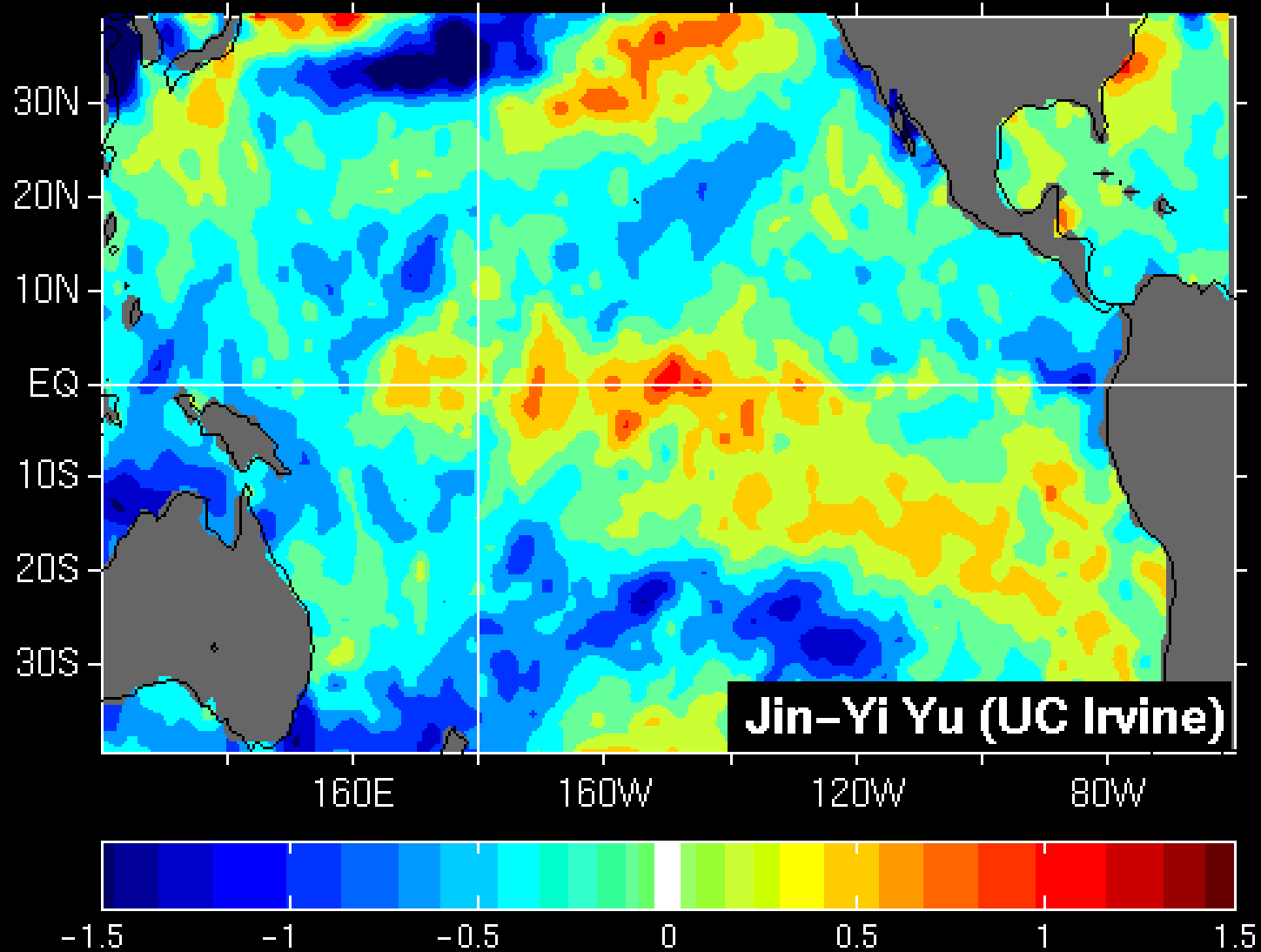
1997-98 El Niño

1997 Jan



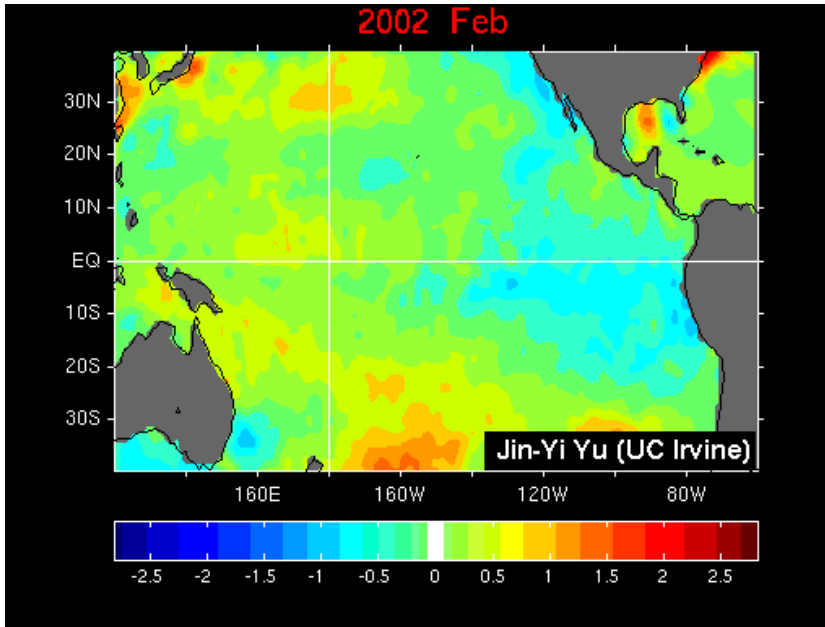
1977-78 El Niño

1977 Jul

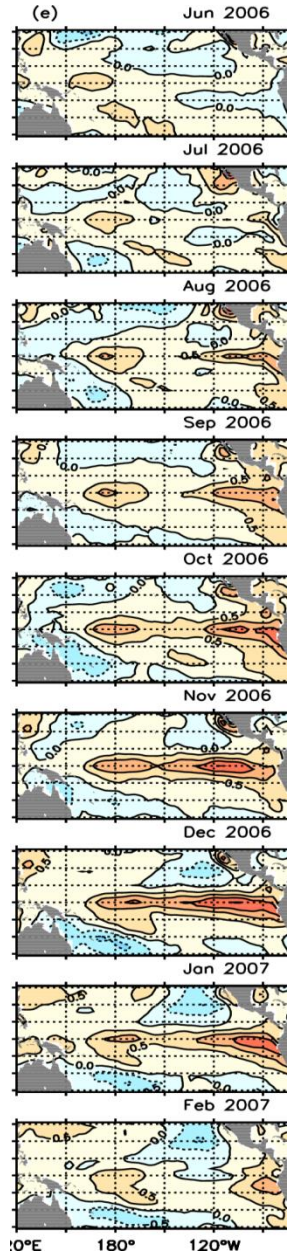
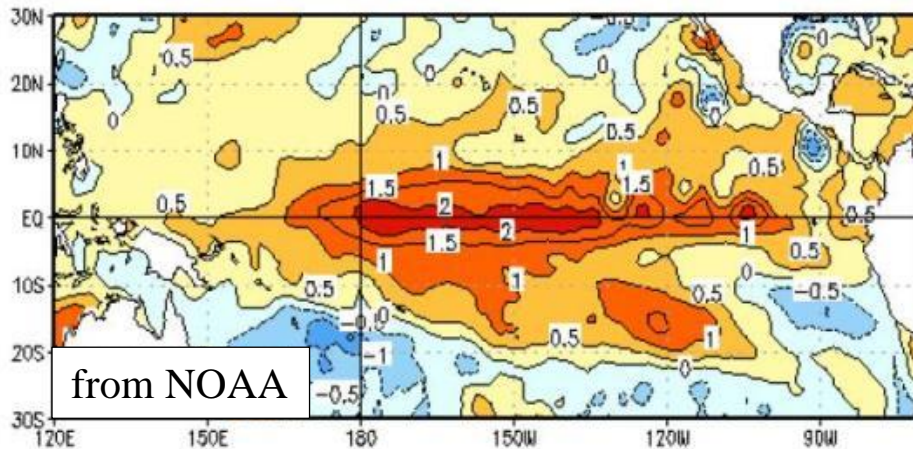


El Niño Events in the 21st Century

2002-03 and 2004-05 El Niño Events



Average SST Anomalies
1 NOV 2009 – 28 NOV 2009

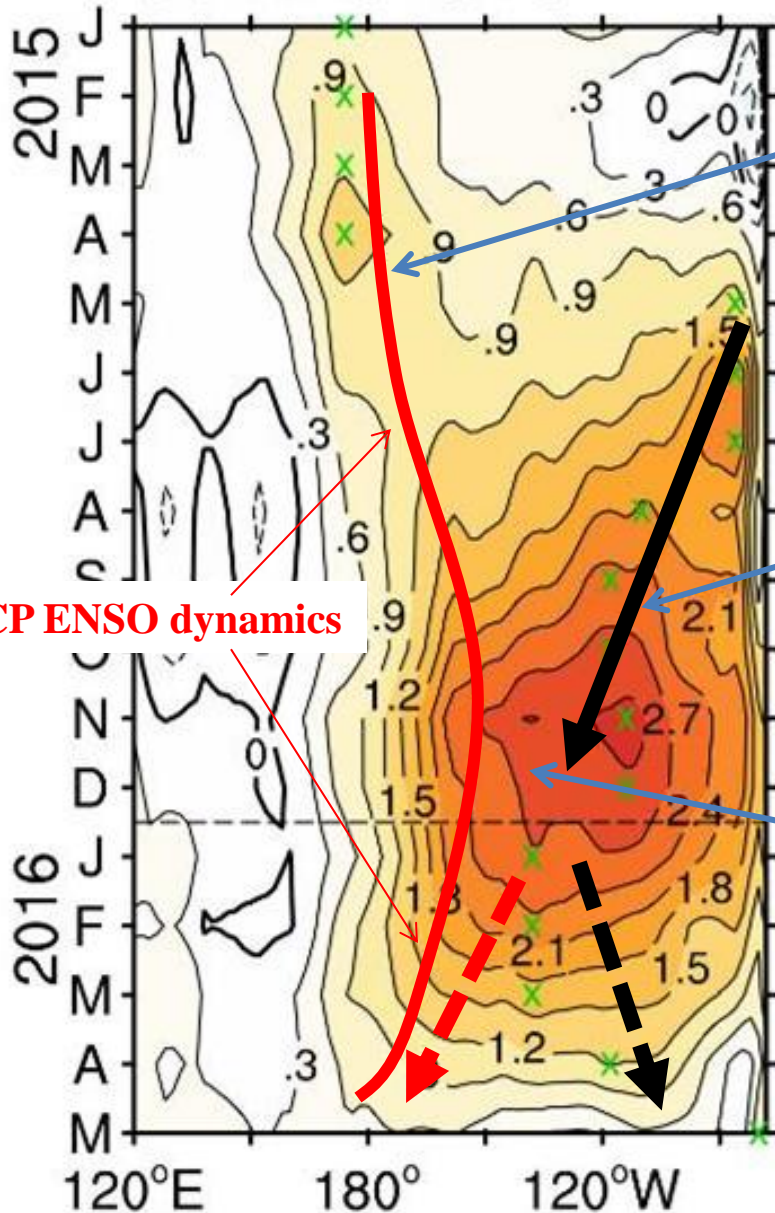


2006-07
El Niño

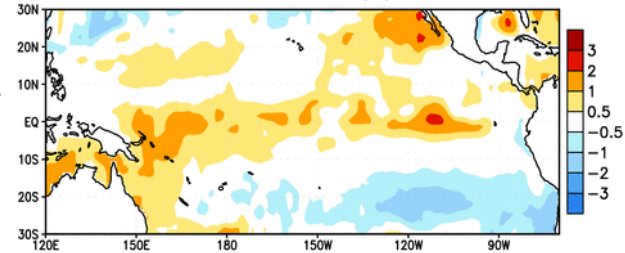
(Yu and Kim 2013)

The 2015/16 Extreme El Niño

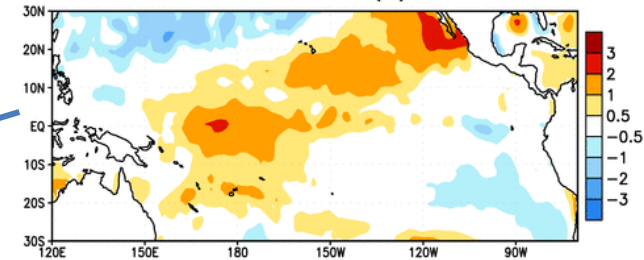
SST: 2015/16



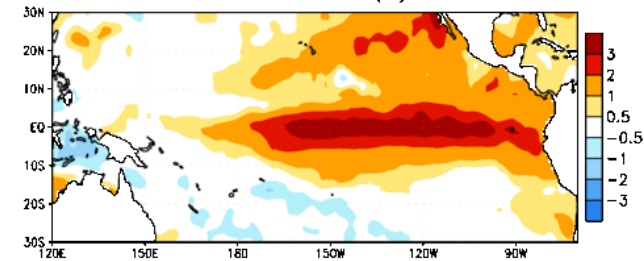
Week centered on 24 DEC 2014
SST Anomalies (°C)



Week centered on 25 FEB 2015
SST Anomalies (°C)

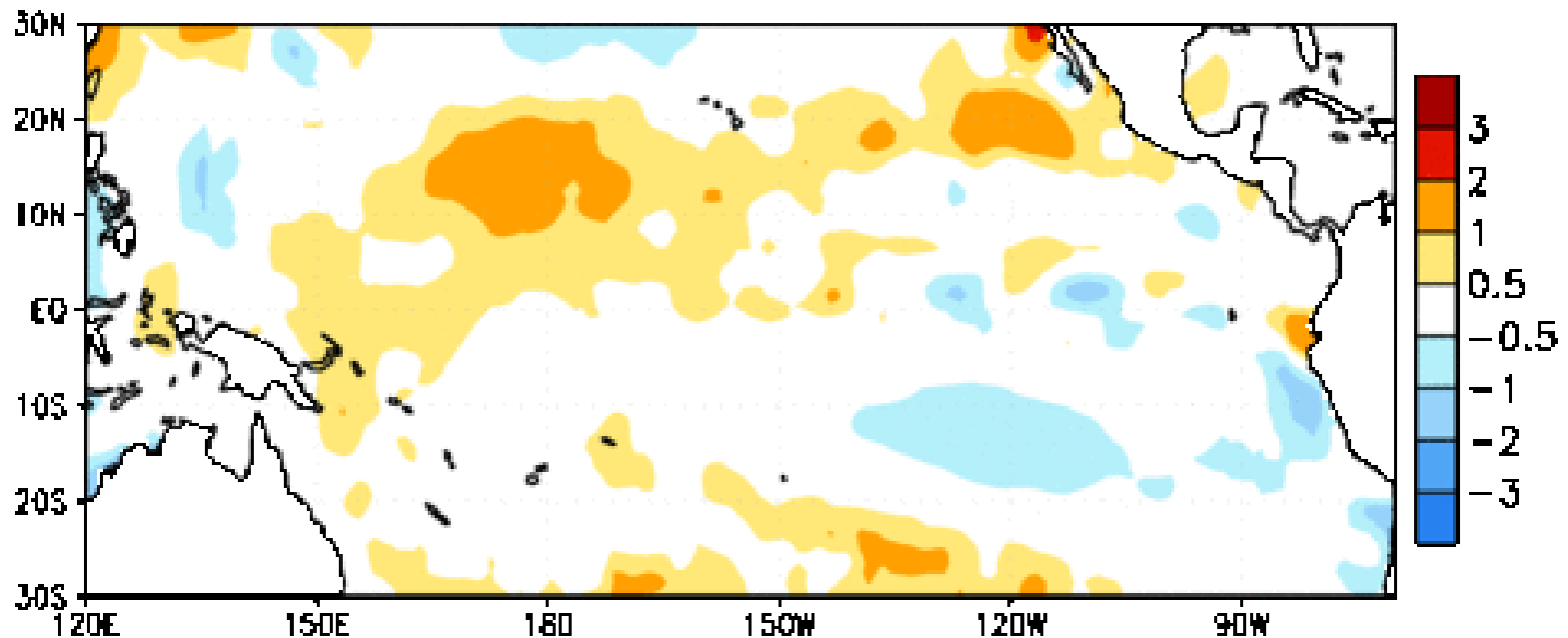


Week centered on 04 NOV 2015
SST Anomalies (°C)



The 2018-19 El Niño

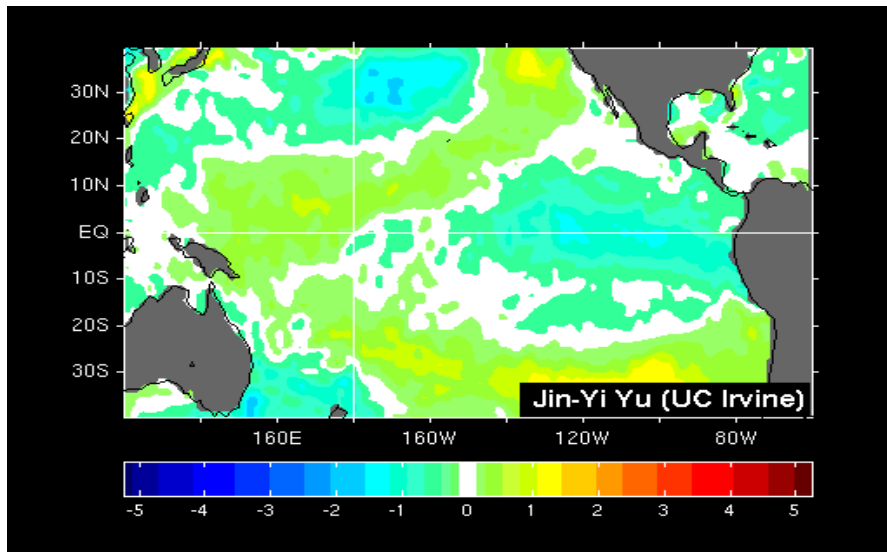
Week centered on 08 AUG 2018
SST Anomalies (°C)



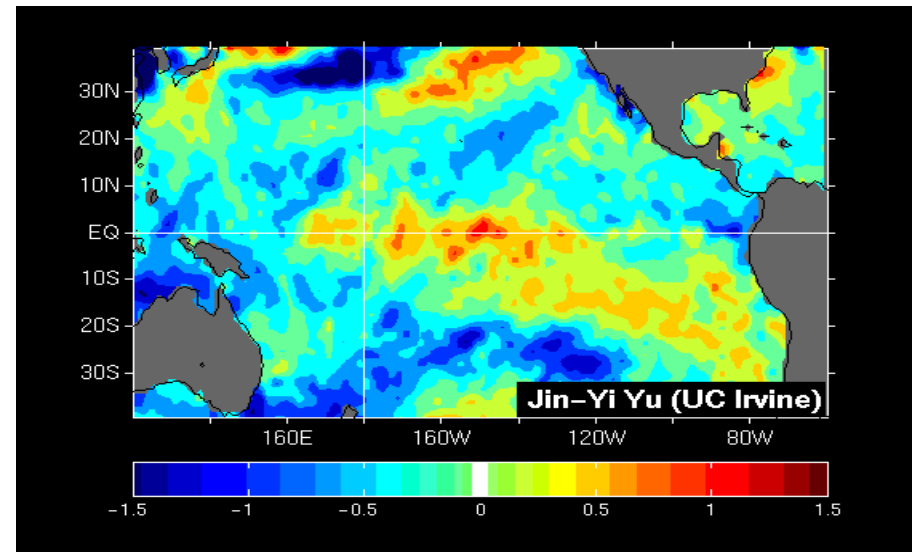
(from NOAA/CPC)

20th vs. 21st-century El Niño

20th-Century El Niño



21st-Century El Niño



Eastern Pacific El Niño

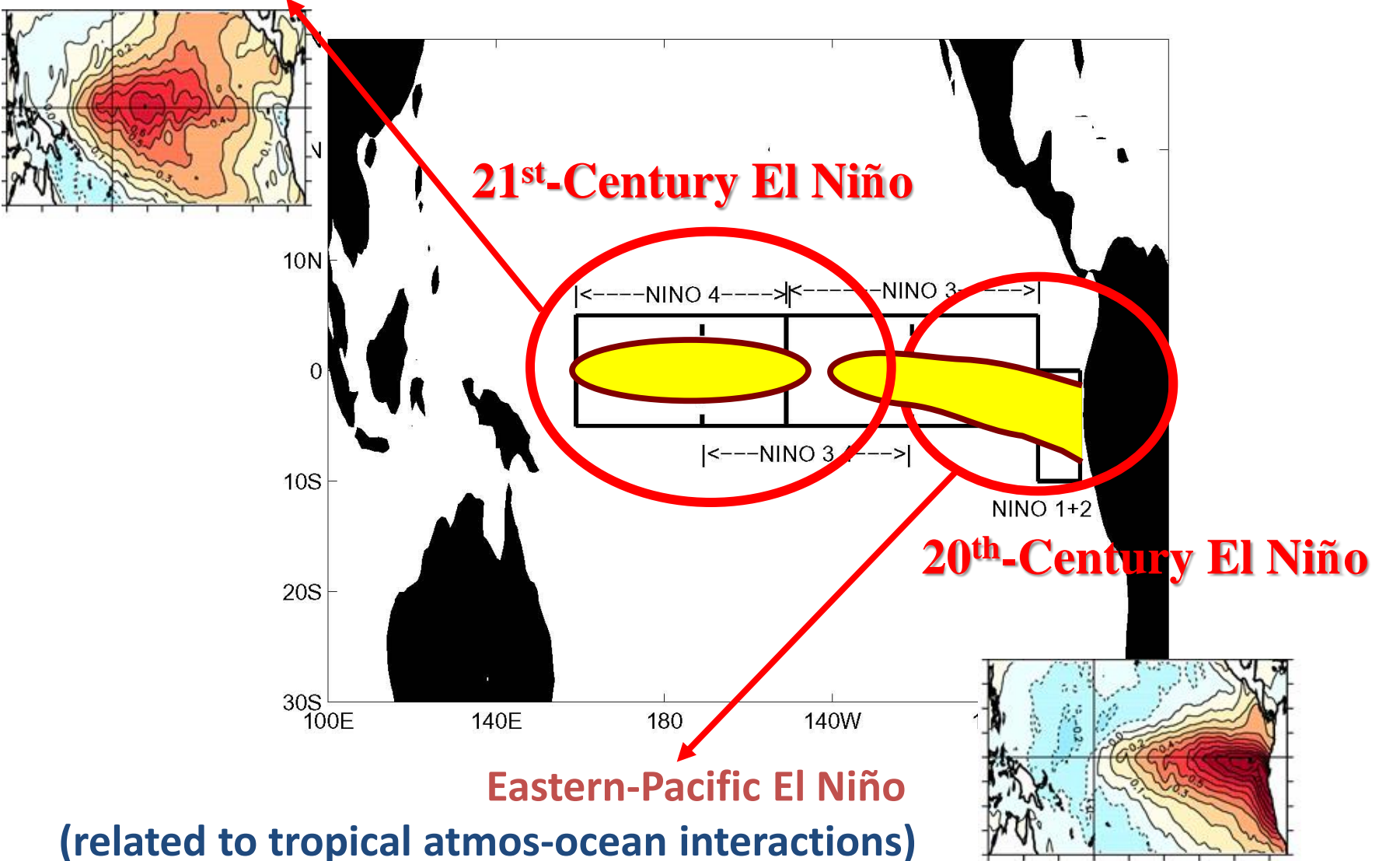
Central Pacific El Niño

(Yu and Kao 2007; Kao and Yu 2009)

Two Types of El Niño

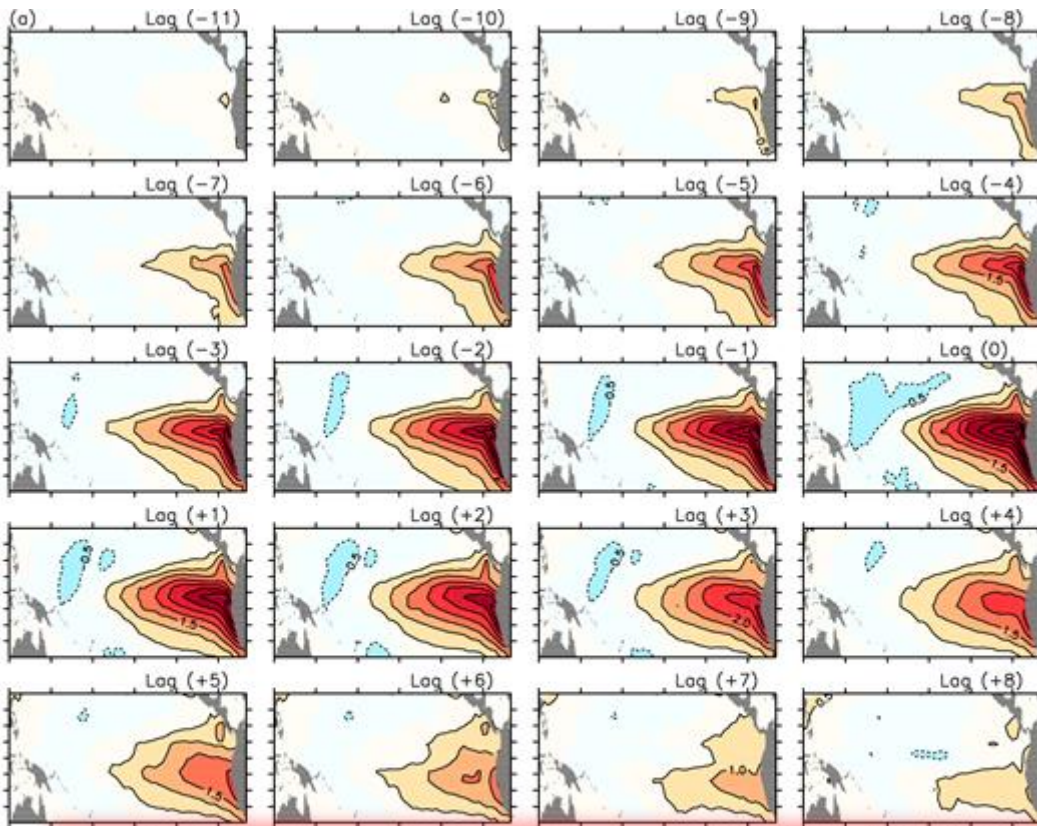
(Yu and Kao 2007; Kao and Yu 2009)

Central-Pacific El Niño (related to subtropical atmos-ocean interactions)

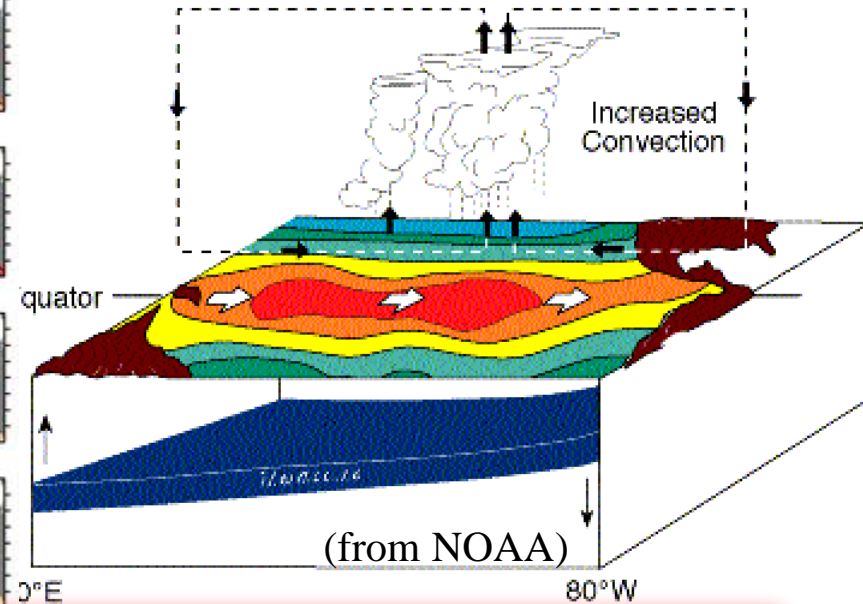


EP El Niño / Walker Circulation

Eastern Pacific El Niño

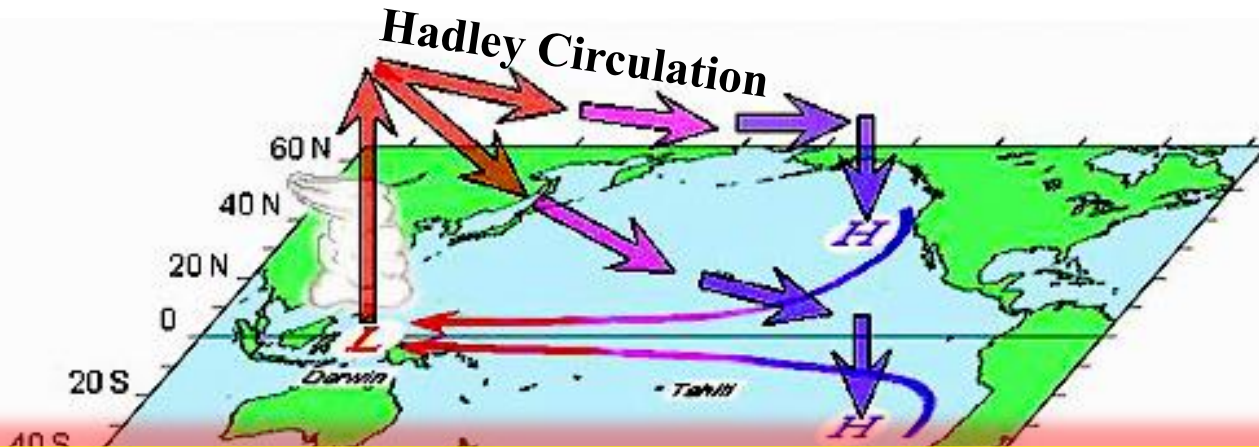


Walker Circulation

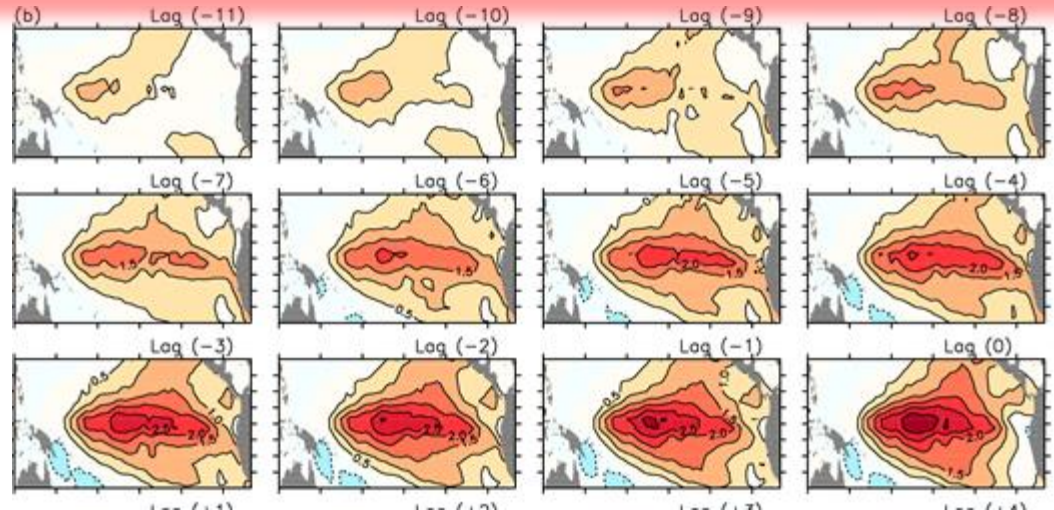


Tropical ocean interacts with tropical atmosphere

CP El Niño / Hadley Circulation



Tropical ocean interacts with subtropical atmosphere



Different Dynamics for CP and EP El Niño

Forcing from
Extratropical
Atmosphere

Seasonal Footprinting Mechanism

less predictable

CP ENSO

Mixed-Layer Dynamics

Kao and Yu (2009)

Yu et al. (2010)

Yu and Kim (2010)

Yu and Kim (2011)

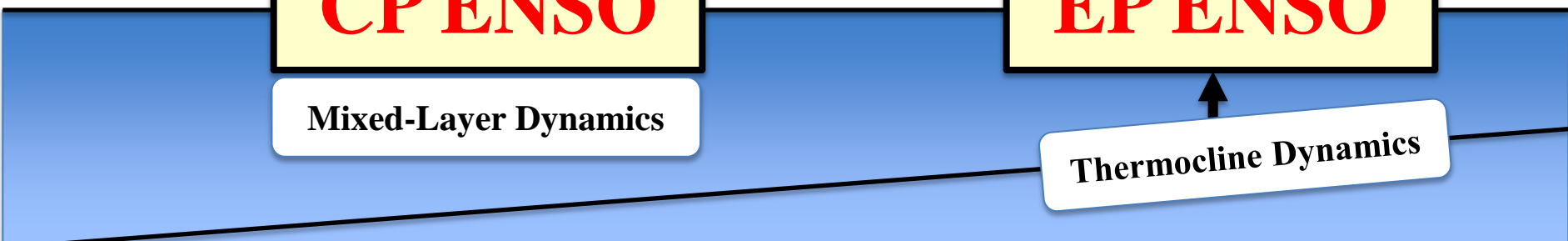
Yu and Houk (2015)

more predictable

Charged-Discharged Mechanism

EP ENSO

Thermocline Dynamics

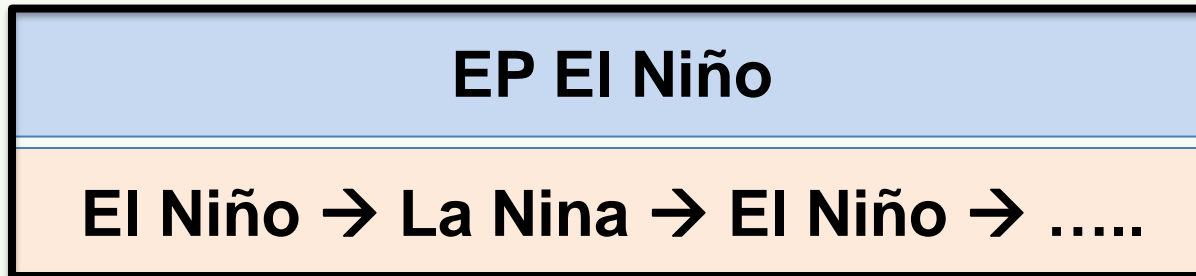


Different El Niño Evolution Patterns

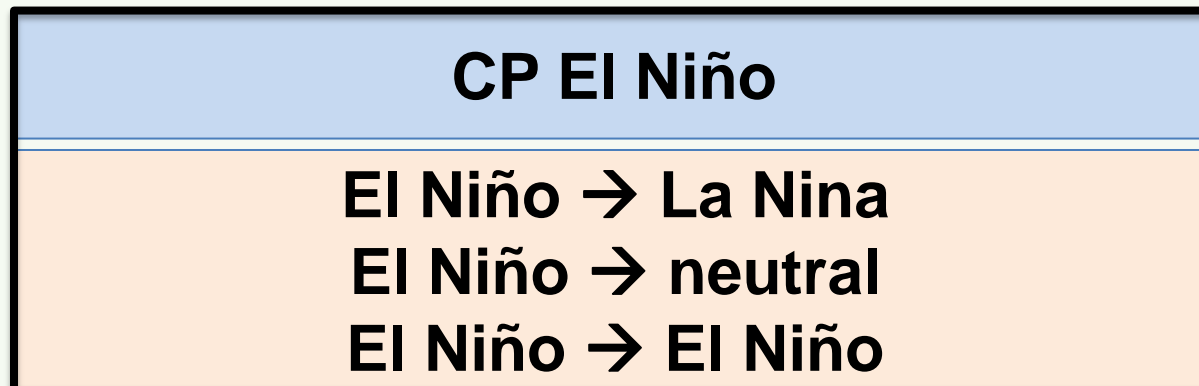
(Yu and Fang 2018)

The 21st-century El Niño has a more complex evolution pattern than the 20th-century El Niño and becomes more difficult to predict.

20th-Century El Niño / Tropical Pacific Coupling

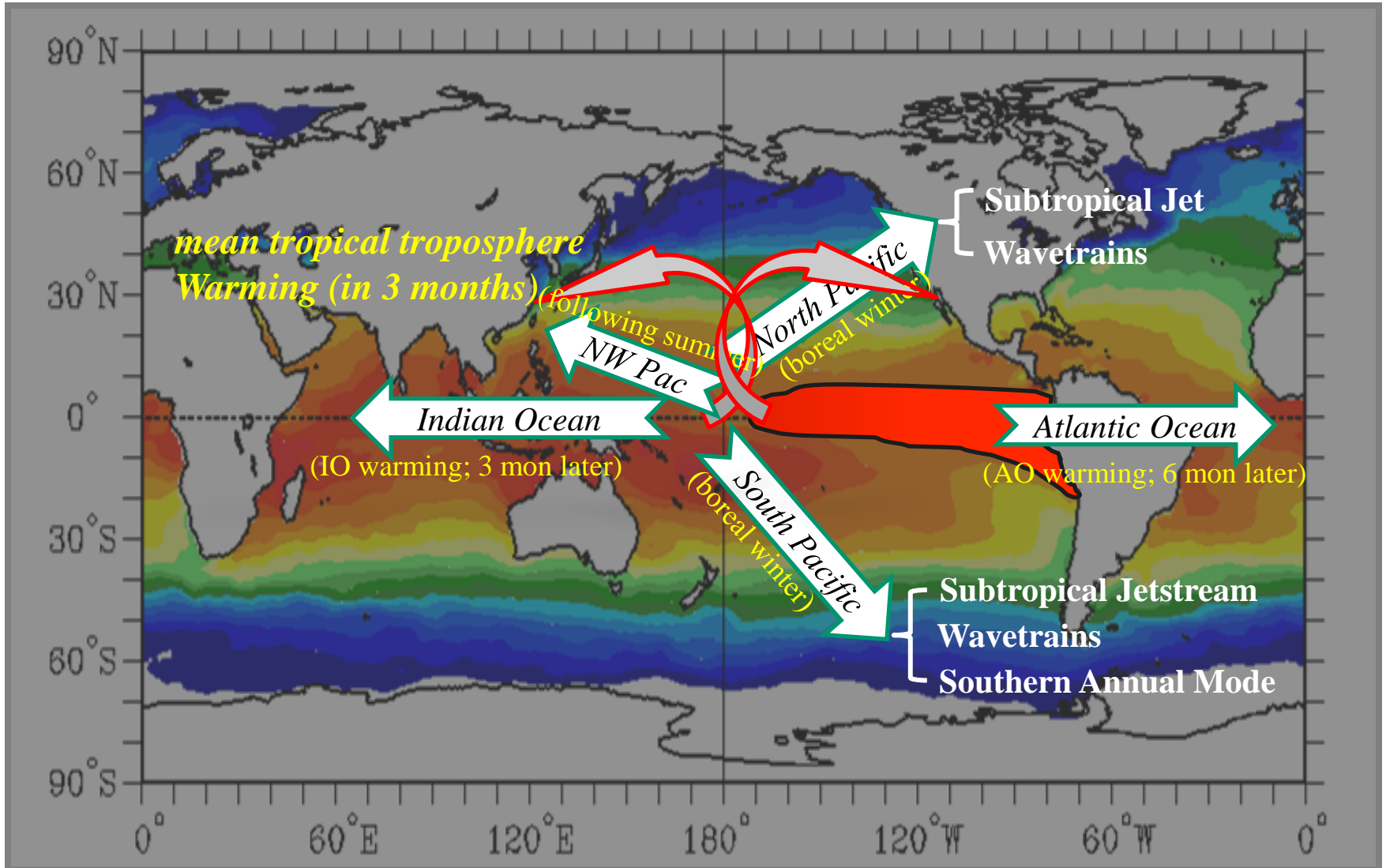


21st-Century El Niño / Subtropical Pacific Coupling

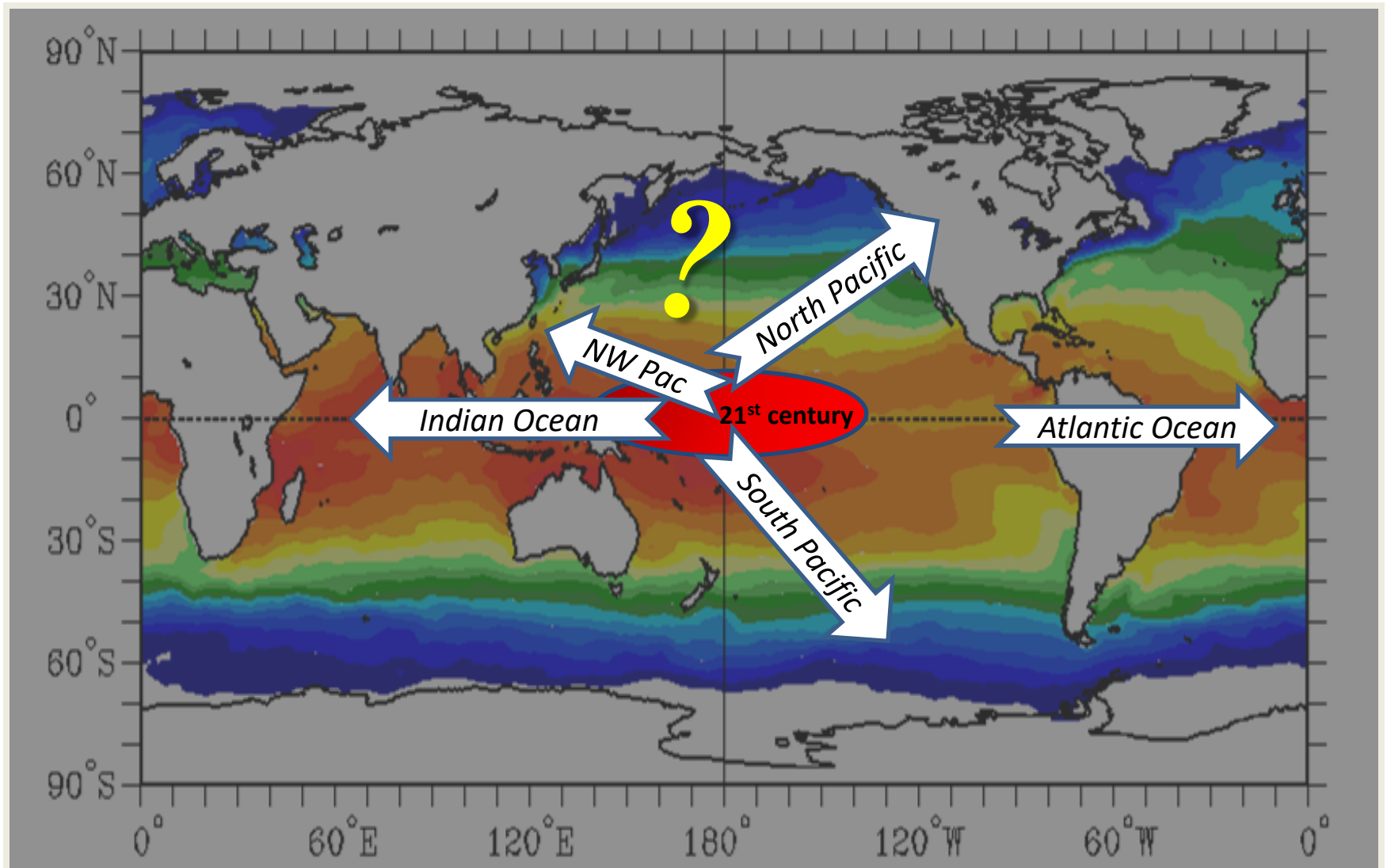


different climate impacts...

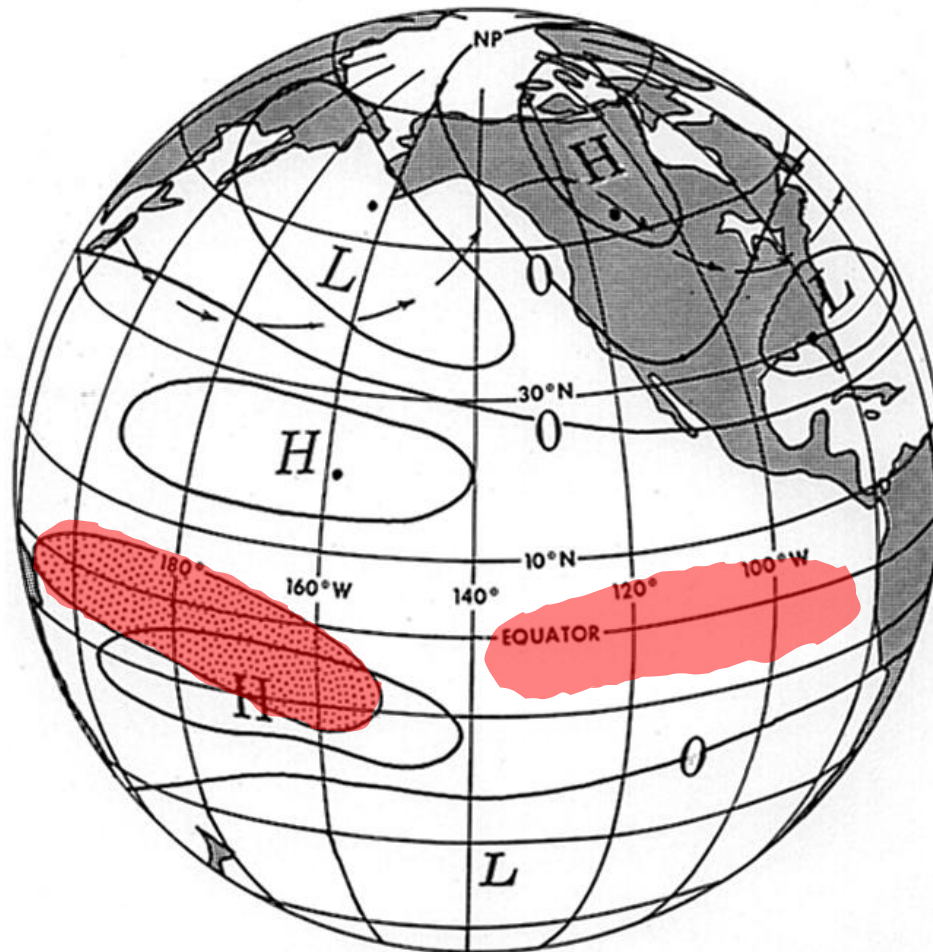
20th-Century El Niño Impacts



21st-Century El Niño Impacts



El Niño events excite atmospheric waves to affect US climate



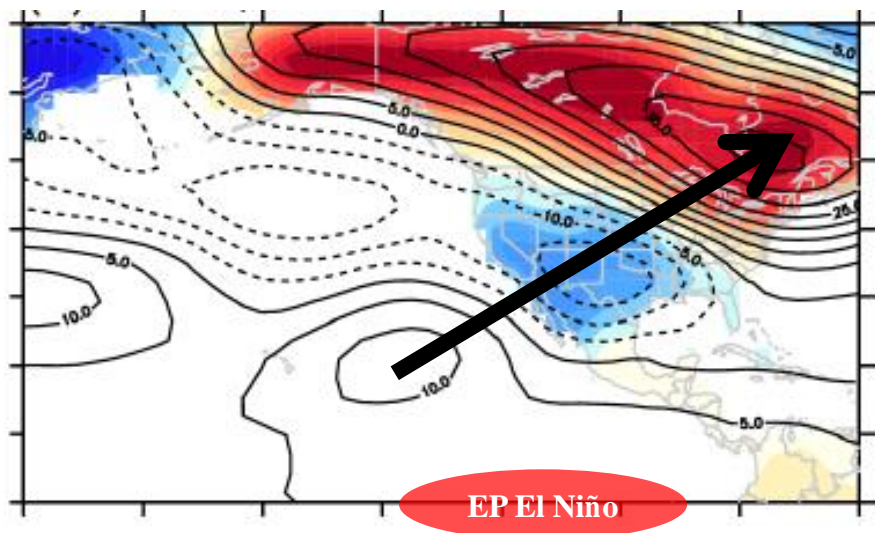
(modified from Horel and Wallace 1981)

Atmospheric Response to EP/CP El Niño

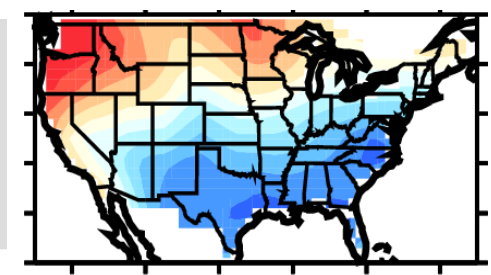
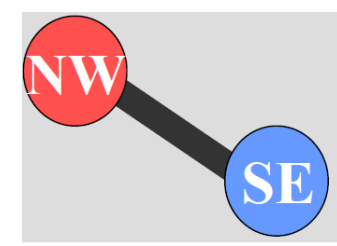
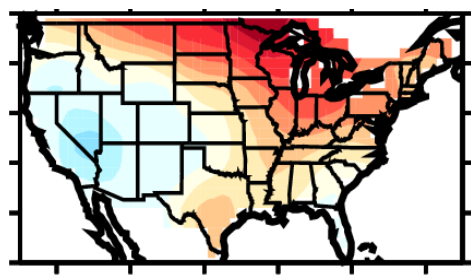
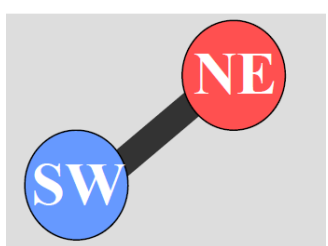
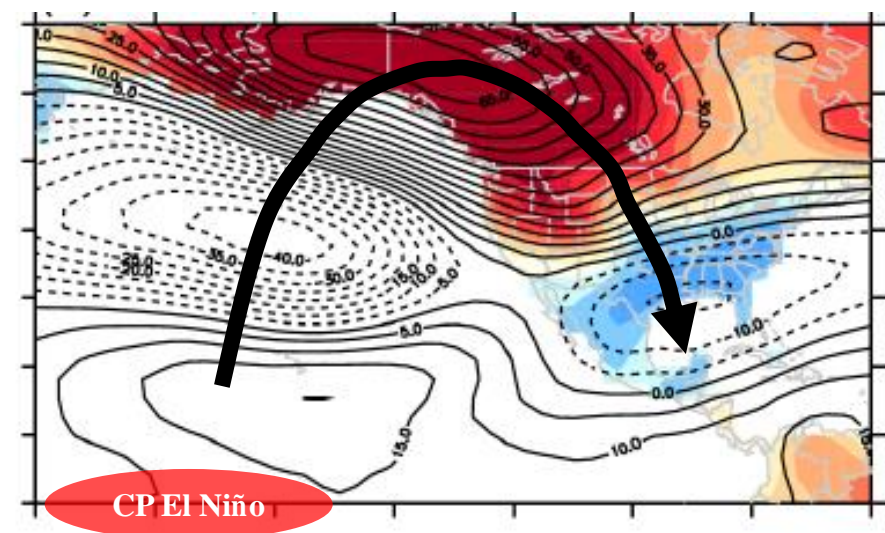
$\Phi_{500\text{mb}}$ Anomalies Regressed with EP/CP Index

(Yu et al. 2012)

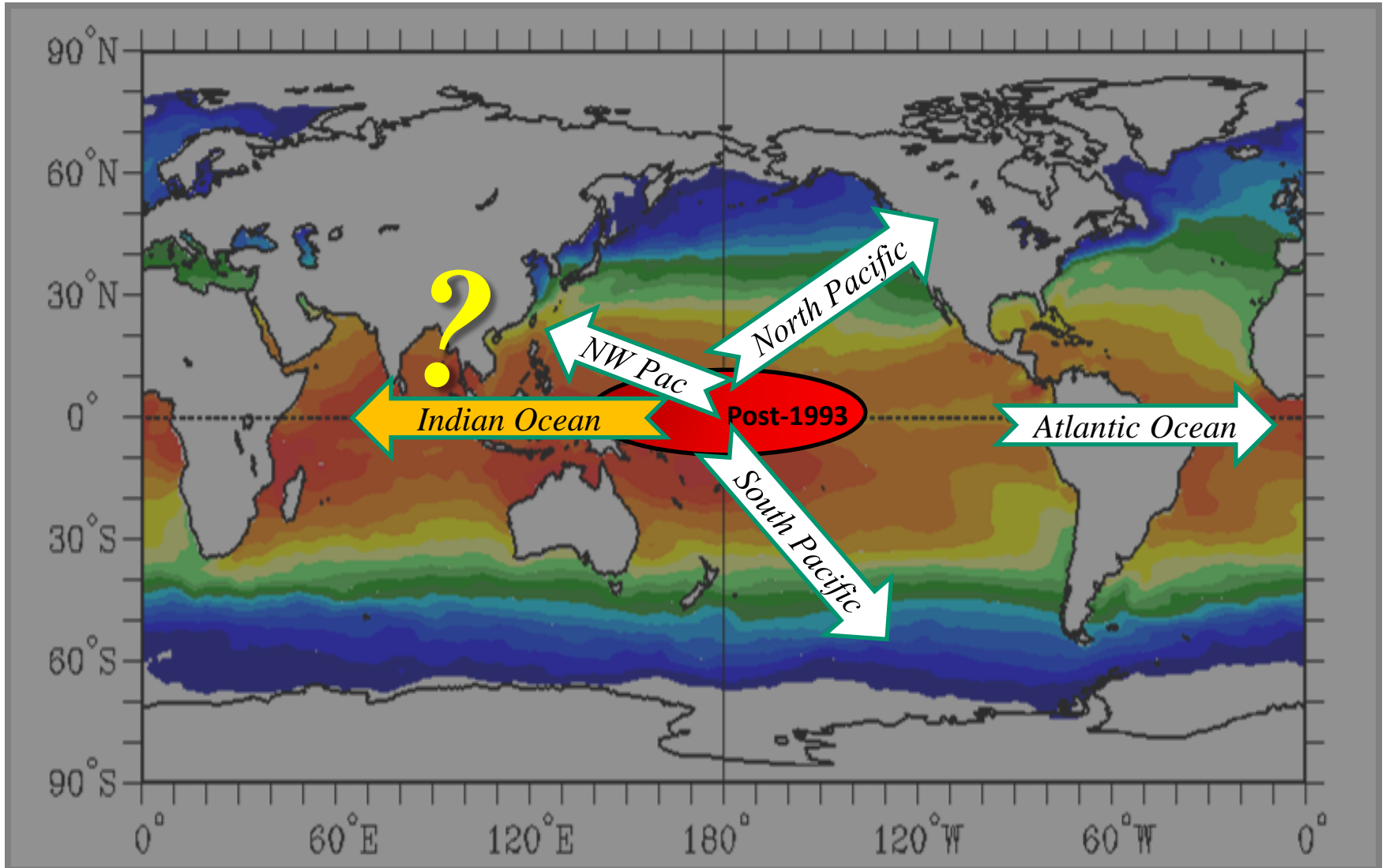
EP: Polarward Wave Train Pattern



CP: Pacific North America Pattern

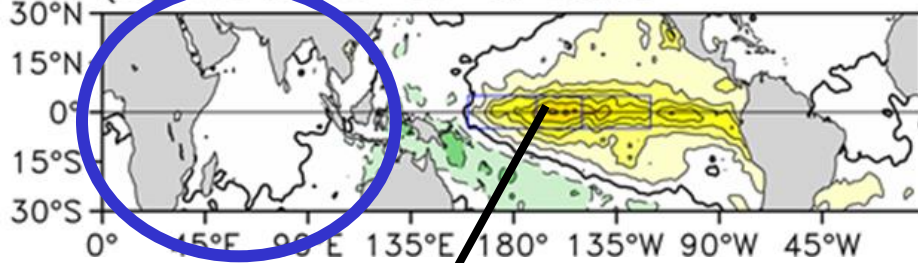


Changing Impacts on Indian Ocean

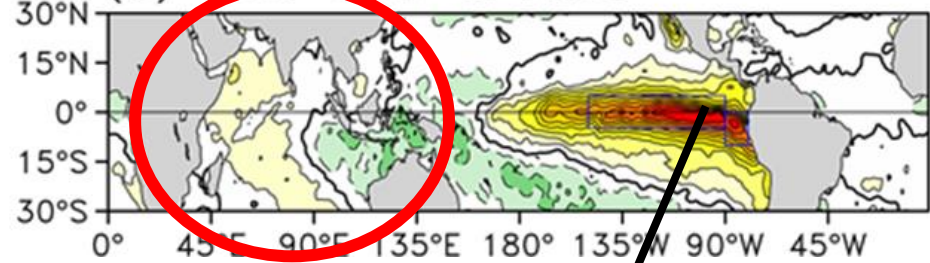


CP El Niño → Indian Ocean?

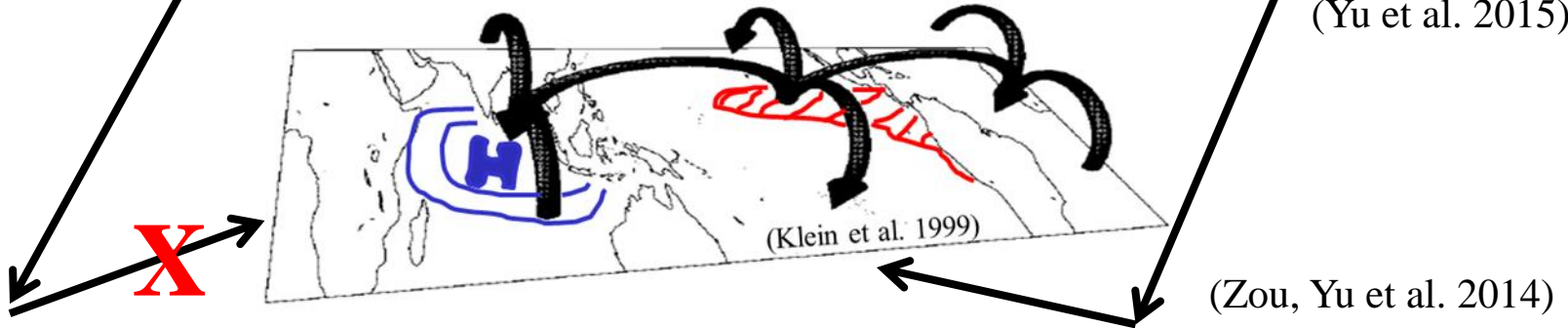
(a) SST: 13 CP El Niño



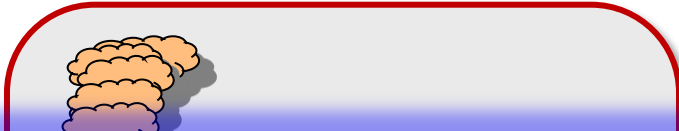
(b) SST: 8 EP El Niño



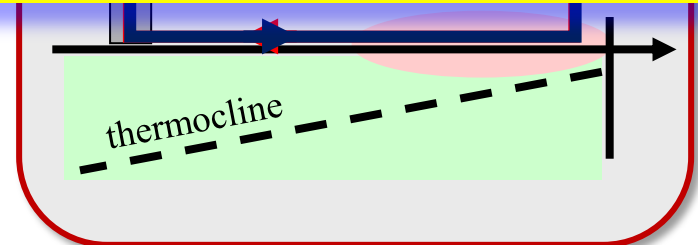
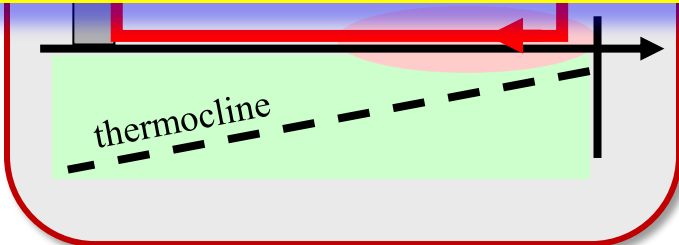
(Yu et al. 2015)



(Zou, Yu et al. 2014)



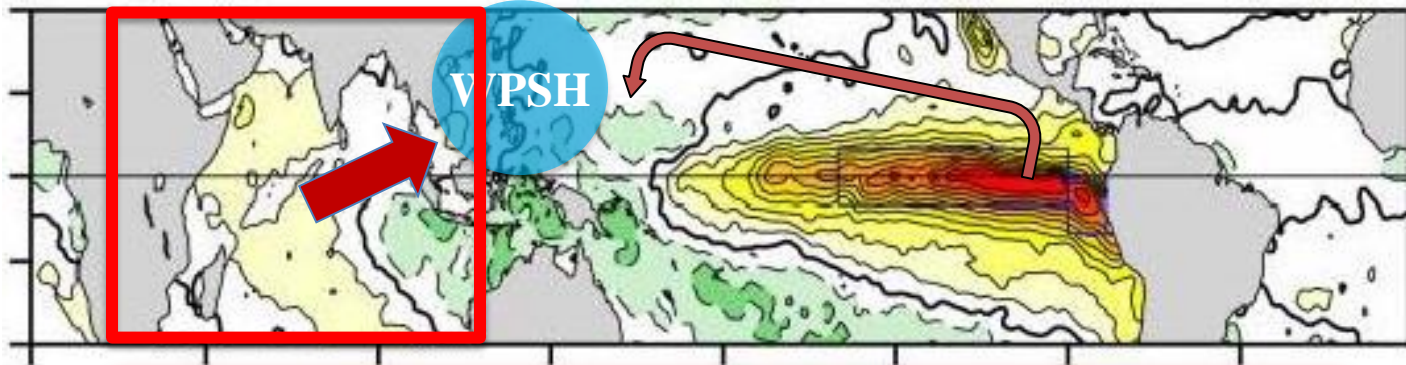
The Indian Ocean has become more independent from the Pacific Ocean in the 21st century.



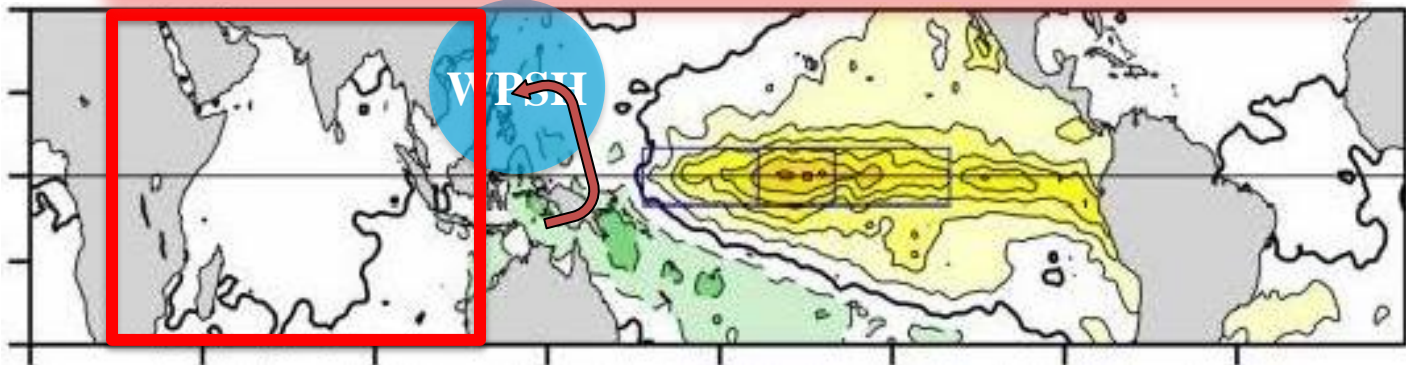
Composite SST Anomalies

(Yu, Paek, Saltzman, Lee; 2015)

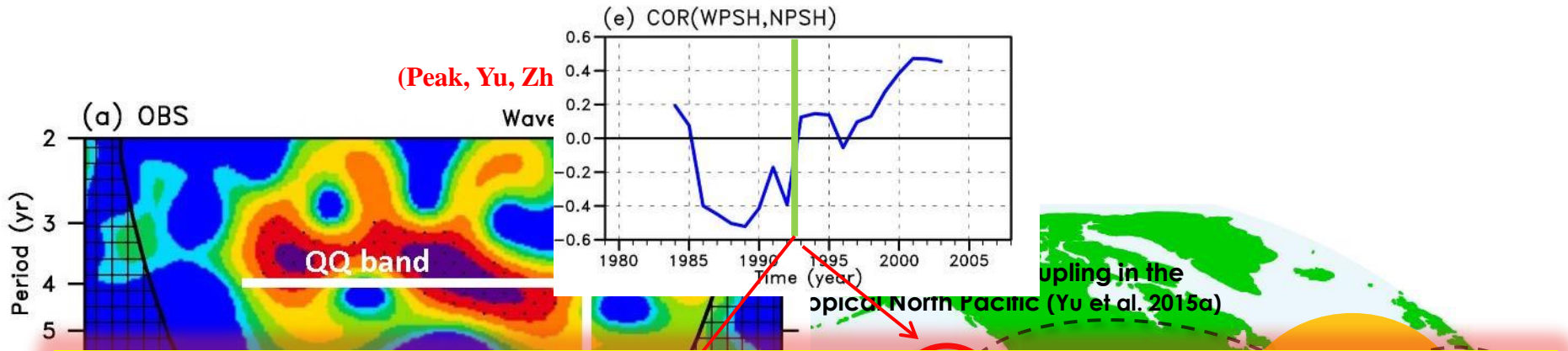
Eastern Pacific El Niño



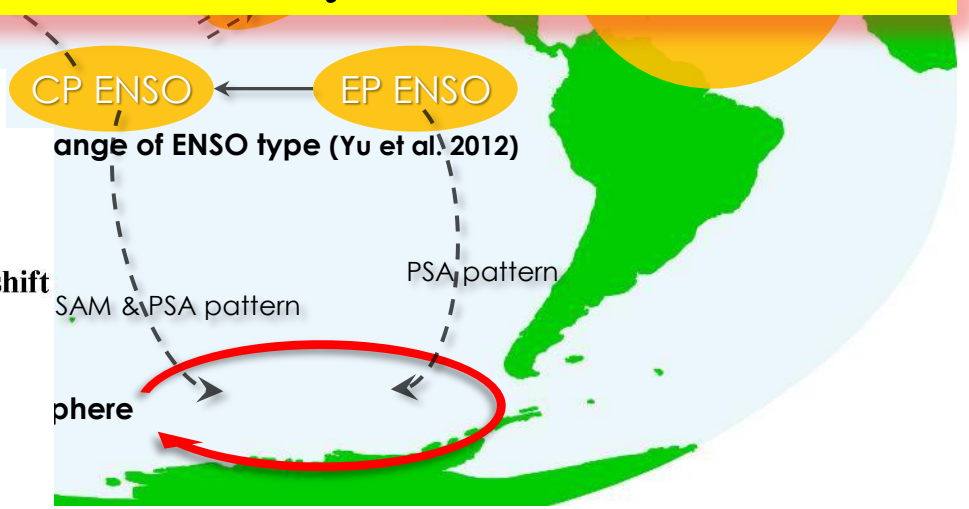
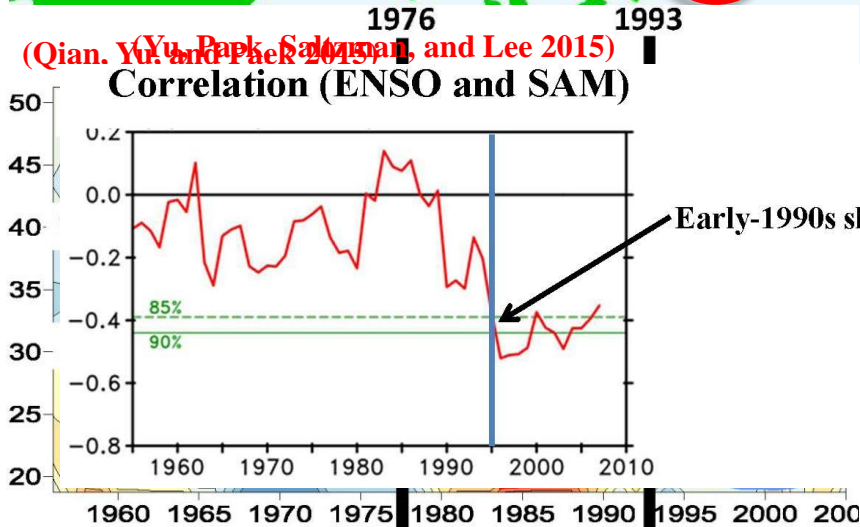
The Western Pacific climate has become more connected with the Maritime Continent climate in the 21st century.



Evidence of changing El Niño Impacts around the Pacific



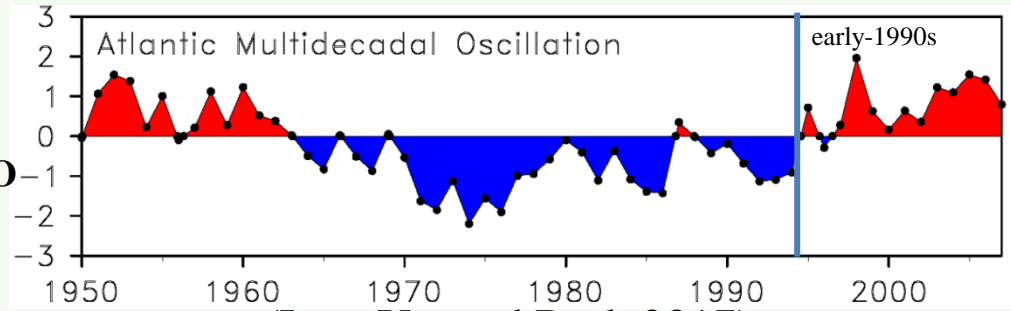
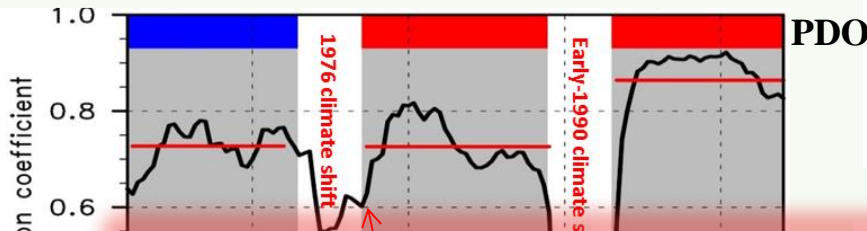
The 21st-century El Niño produces different climate impacts around the Asian-Pacific region than the 20th-century El Niño did.



Why El Niño Changed in the 21st Century?

(Yu et al. 2015)

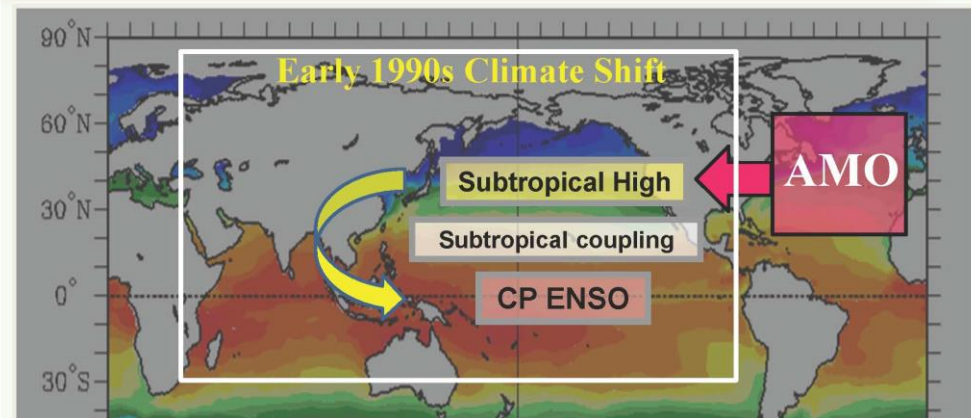
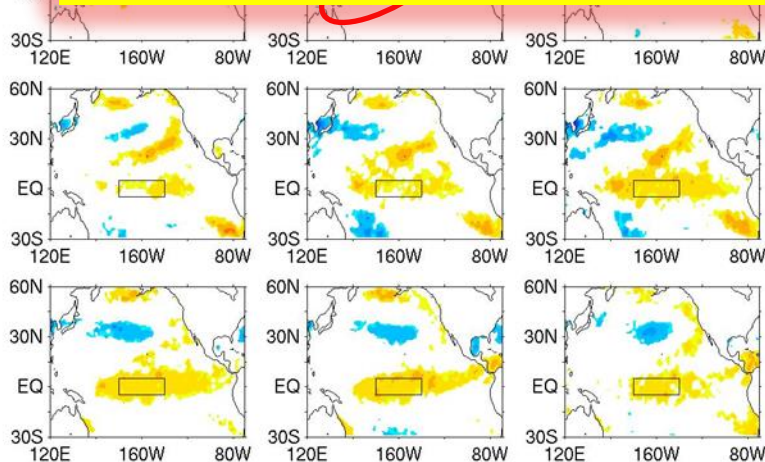
Correlation btw SST and Sfc Wind



(Lyu, Yu, and Paek 2017)

The Changing El Niño so far in the 21st century may be related to the warming phase of the Atlantic Multi-decadal Oscillation (AMO).

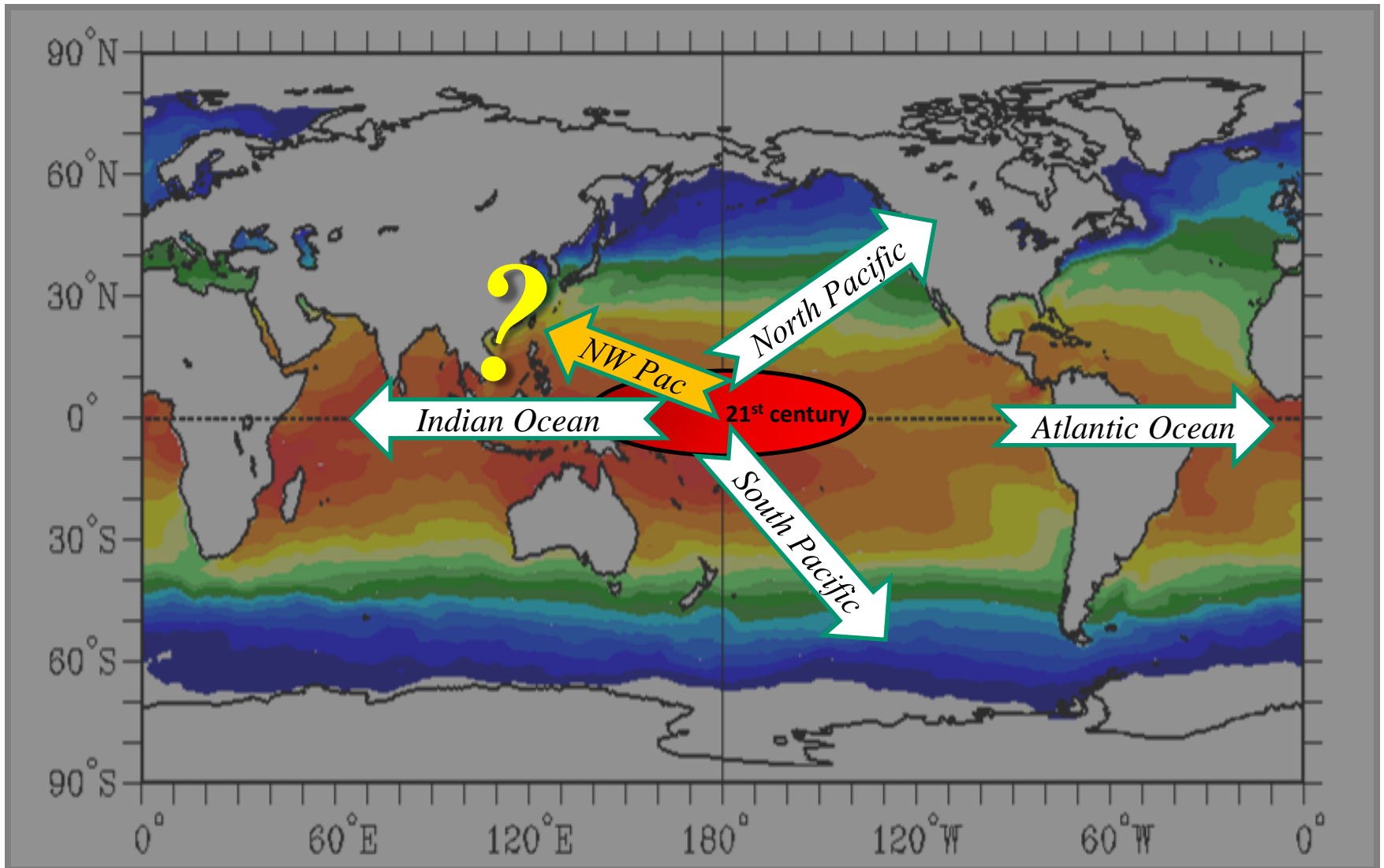
➔ The El Niño may change back to the traditional one if the AMO switches back to the cold phase in the future.



Summary

- The 21st-century El Niño is different from the 20th-century El Niño in its properties, dynamics, and impacts.
- The 21st-century El Niño is more complex and more difficult to predict than the 20st-century El Niño.
- The changing El Niño offers a great opportunity for the research community to understand better how our climate system works and how we should better prepare for the El Niño impacts in the future.

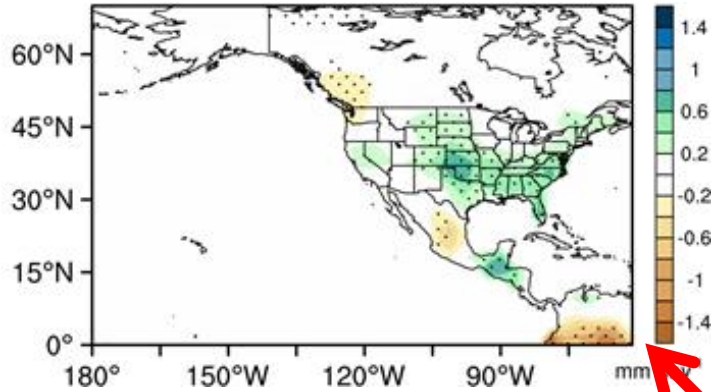
Changing Impacts on Western Pacific



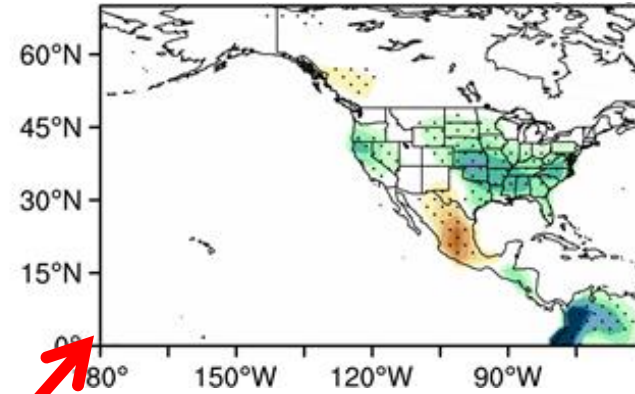
2015/16 vs 1997/98 El Niño / SSTA evolution

(Paek, Yu, and Qian 2017)

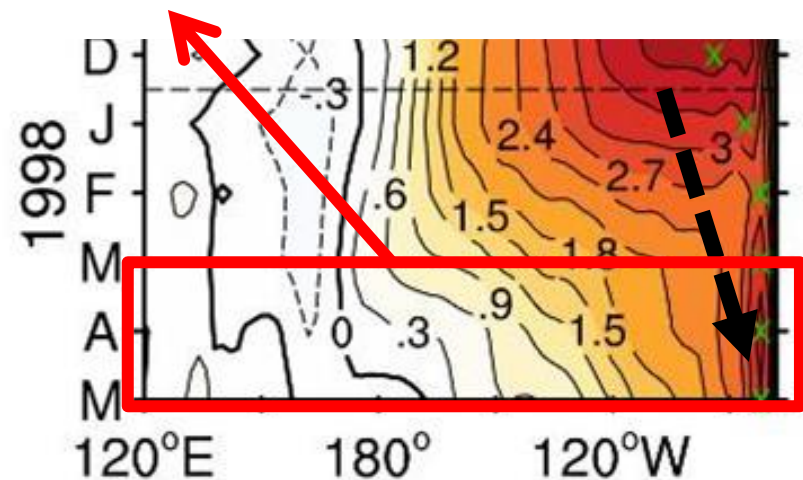
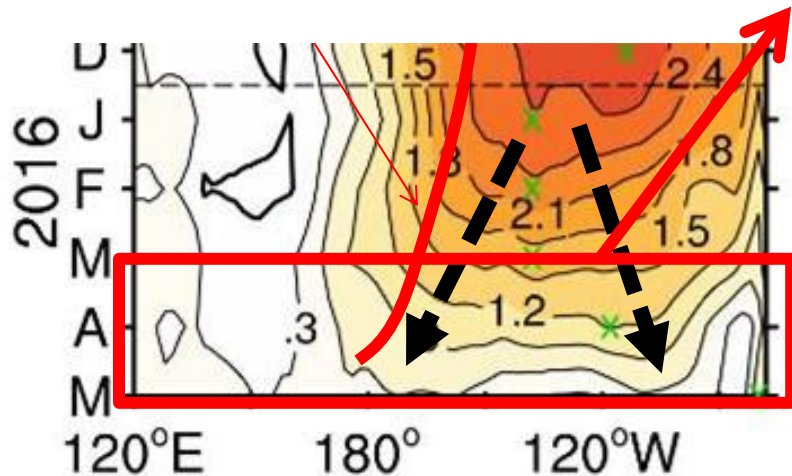
SST: 2015/16



SST: 1997/98

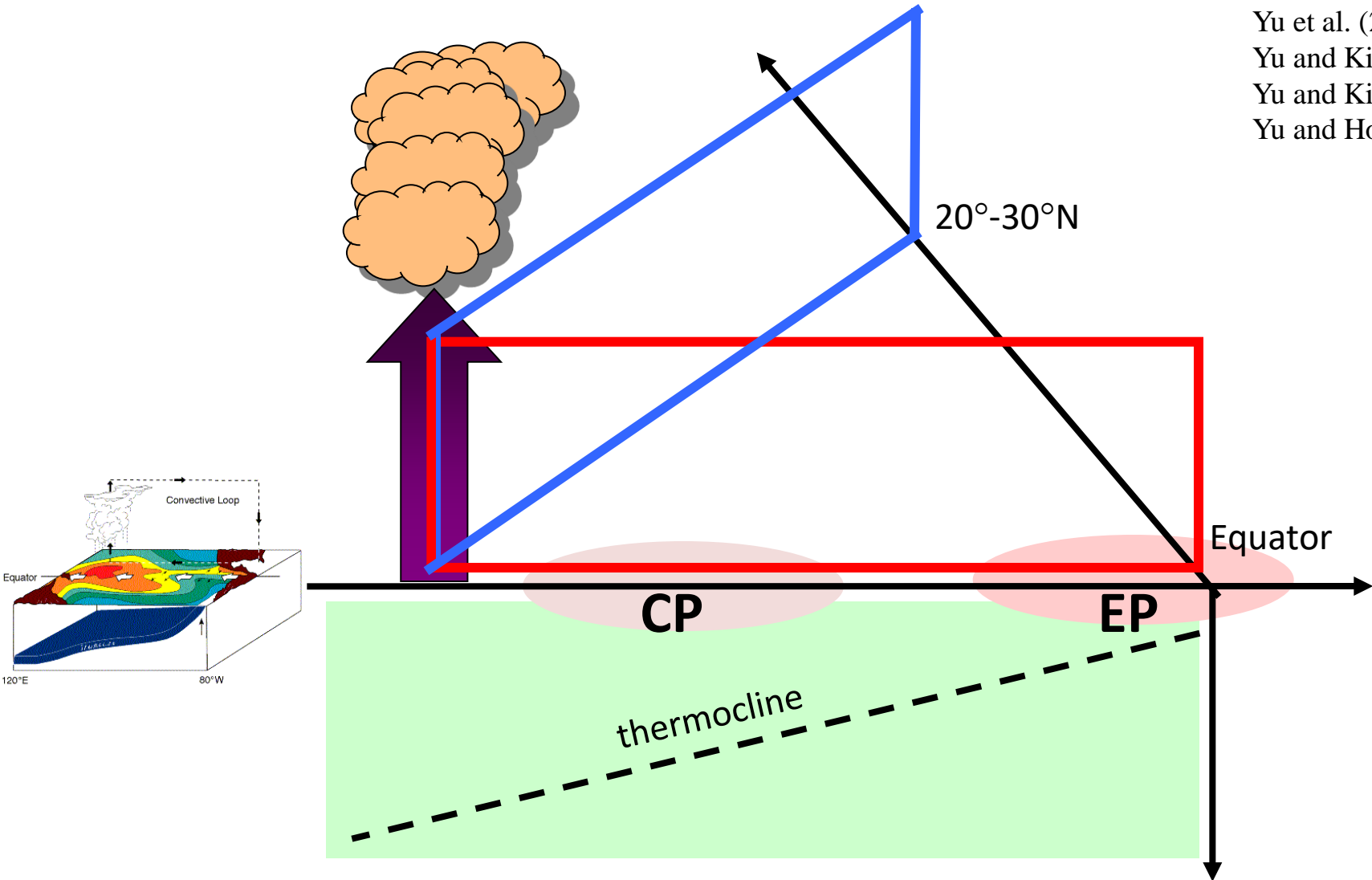


CAM5
50-members
Ensemble Experiments

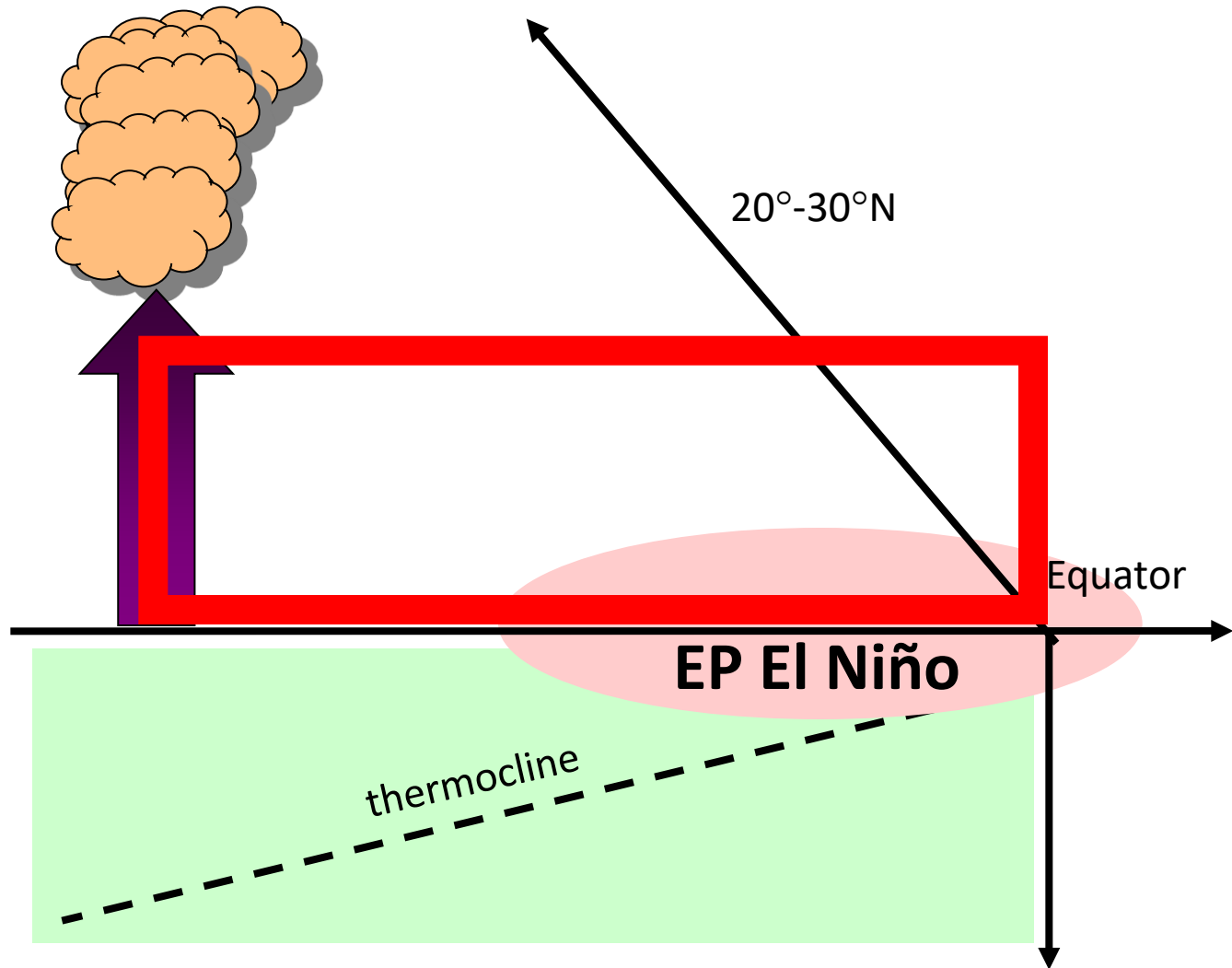


Walker and Hadley Circulations

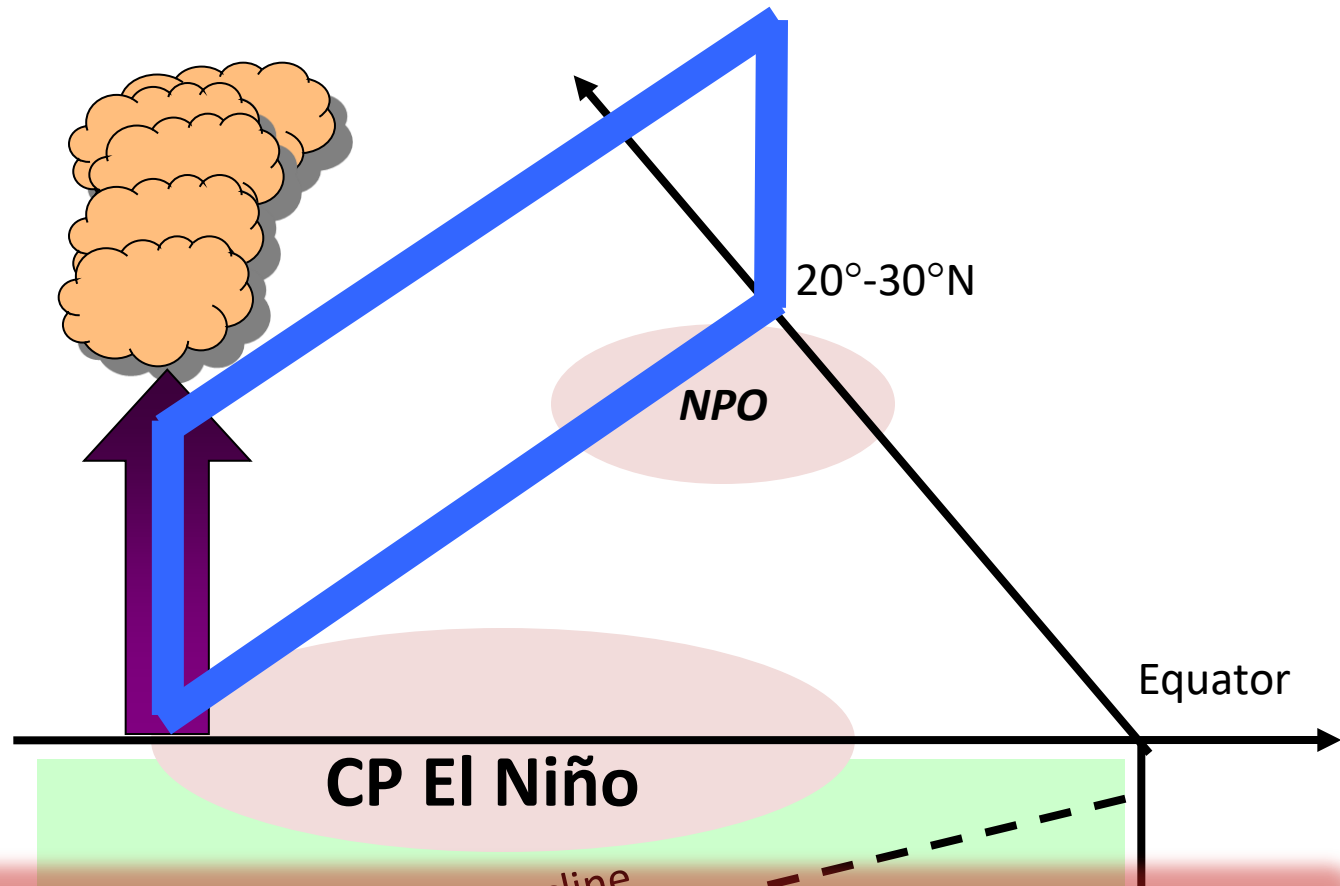
Kao and Yu (2009)
Yu et al. (2010)
Yu and Kim (2010)
Yu and Kim (2011)
Yu and Houk (2015)



When Walker Circulation Is Stronger...



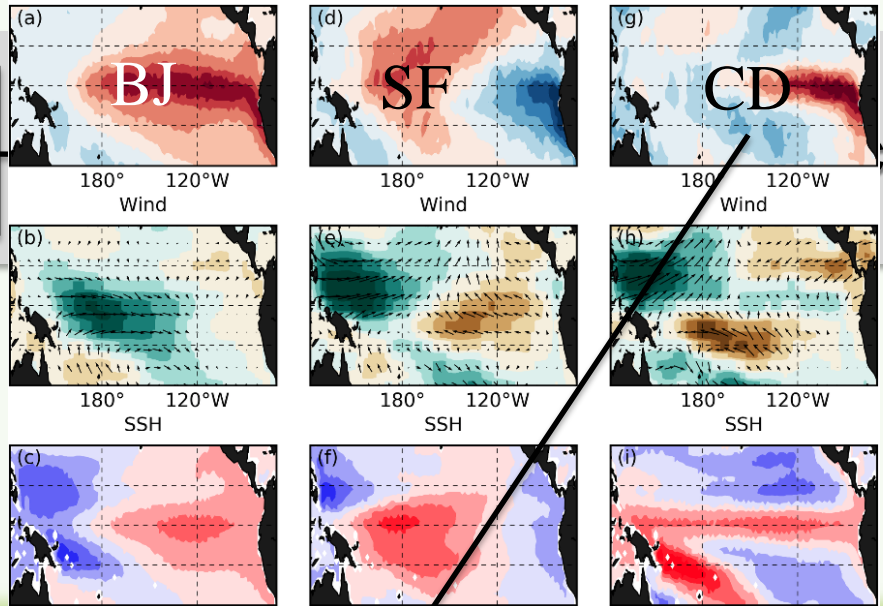
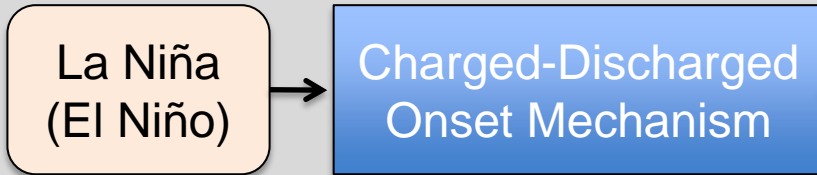
When Hadley Circulation Is Stronger...



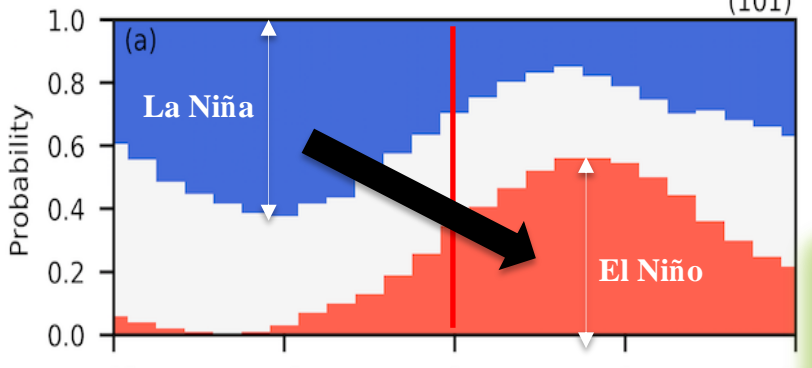
It is possible that global warming has changed the relative strengths between Hadley and Walker circulation to increase the occurrence of the Central Pacific type of El Niño.

ENSO Evolution / associated with the CD Mechanism

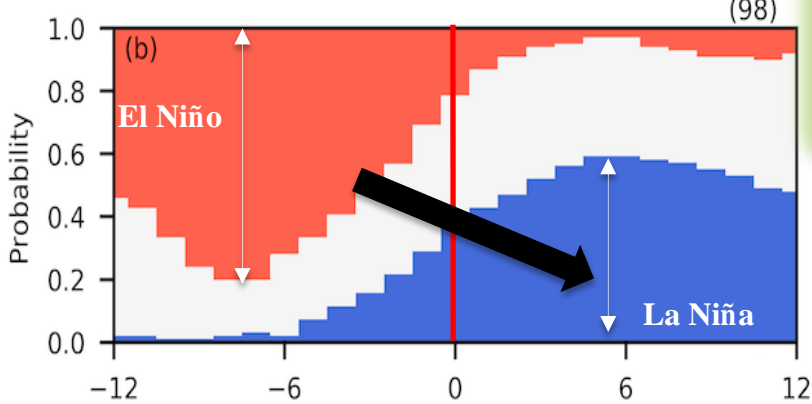
(composites from strong CD events)



Strong Positive CD-onset Events (101)



Strong Negative CD-onset Events (98)



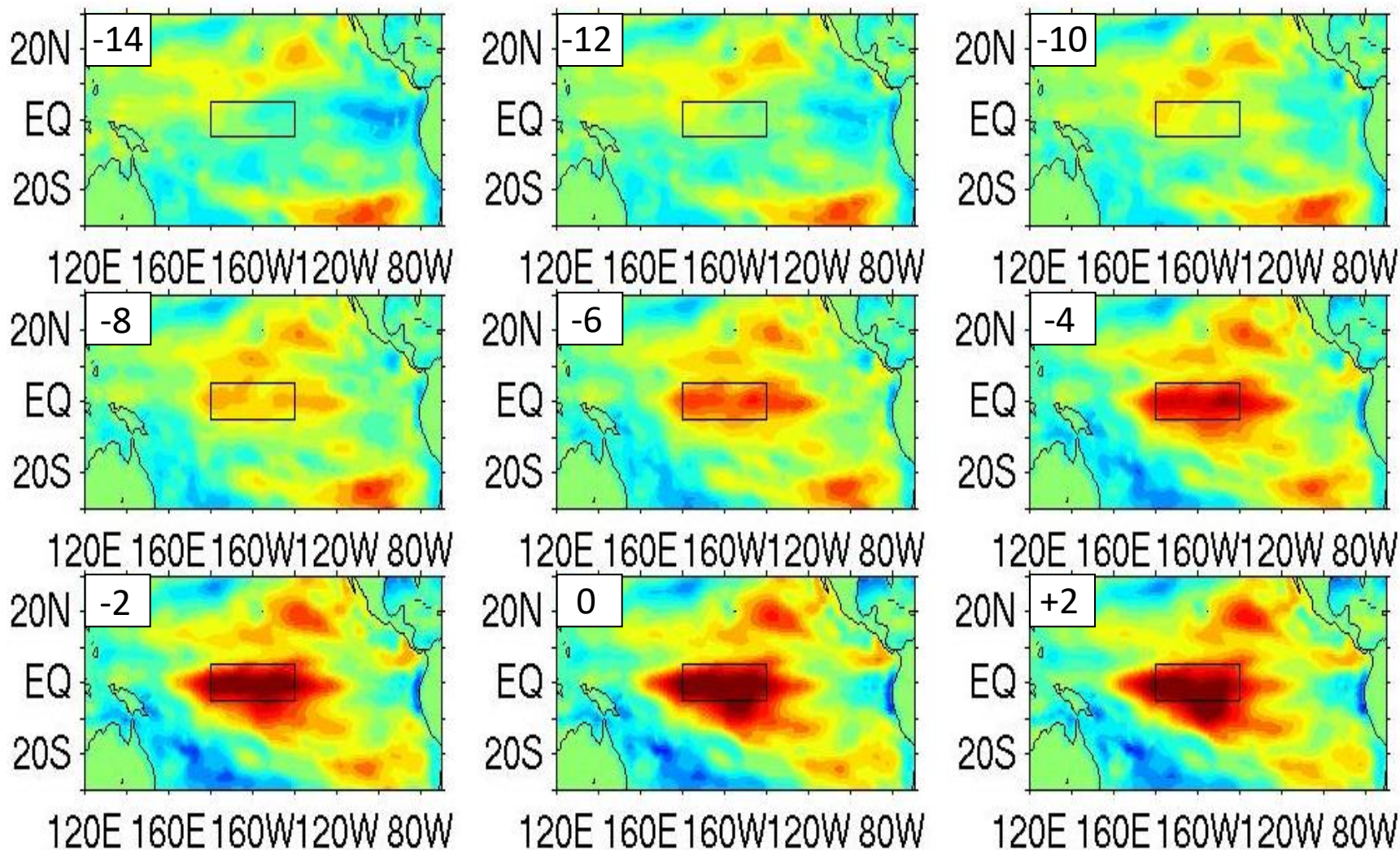
The **charged-discharged mechanism** acts to reduce the **PCENSO** complexity.

1960 1970 1980 1990 2000 2010

CP-ENSO SST Variations

Seasonal Footprinting Mechanism

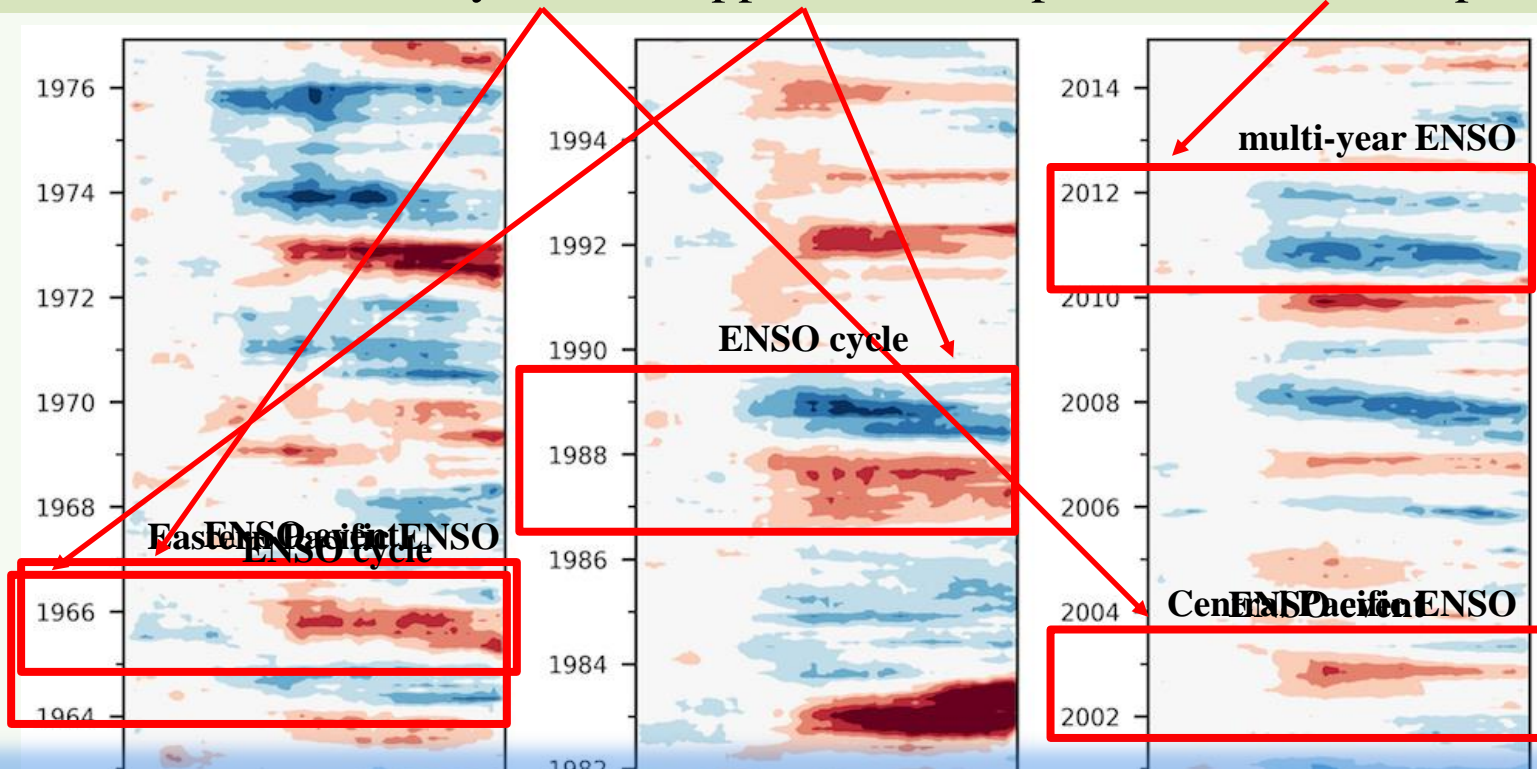
(Yu et al, 2010)



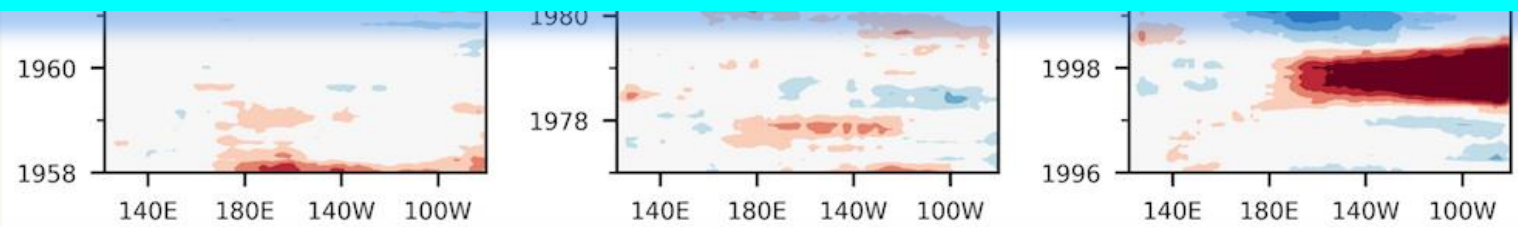
ENSO Complexity

Type: Eastern Pacific (EP) ENSO vs. Central Pacific (CP) ENSO

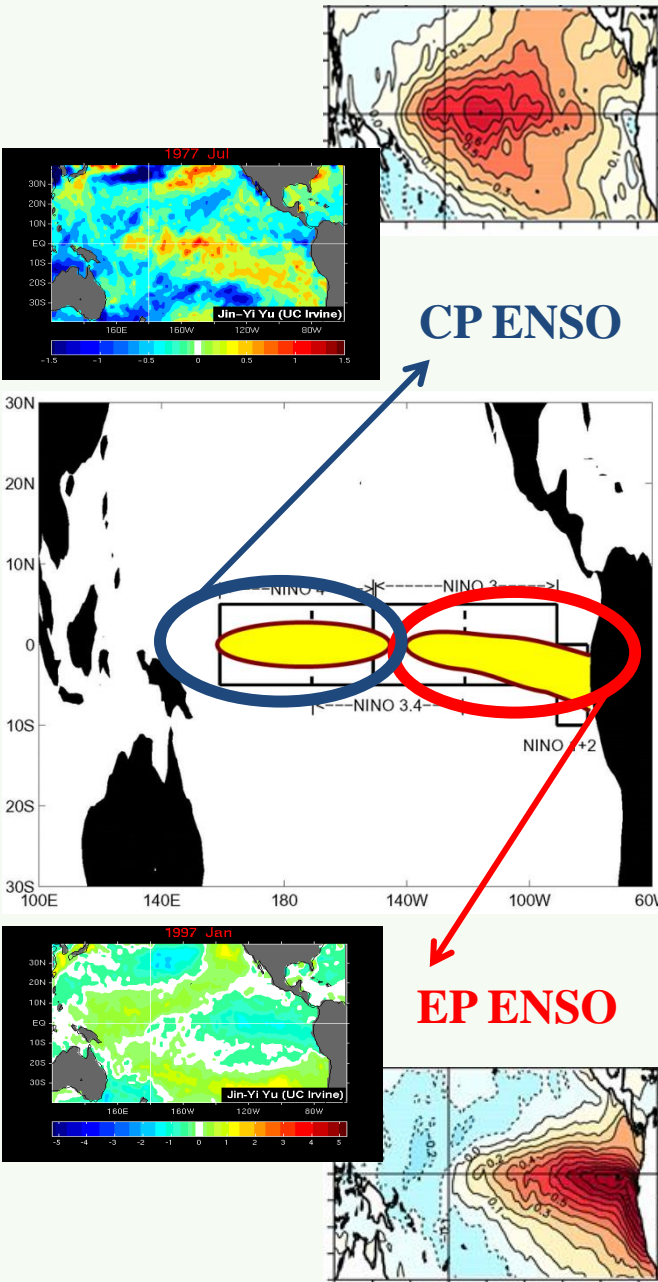
Evolution: followed by neutral, opposite ENSO phase, same ENSO phase



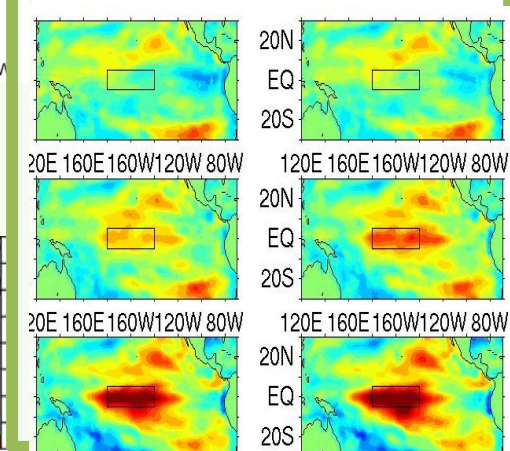
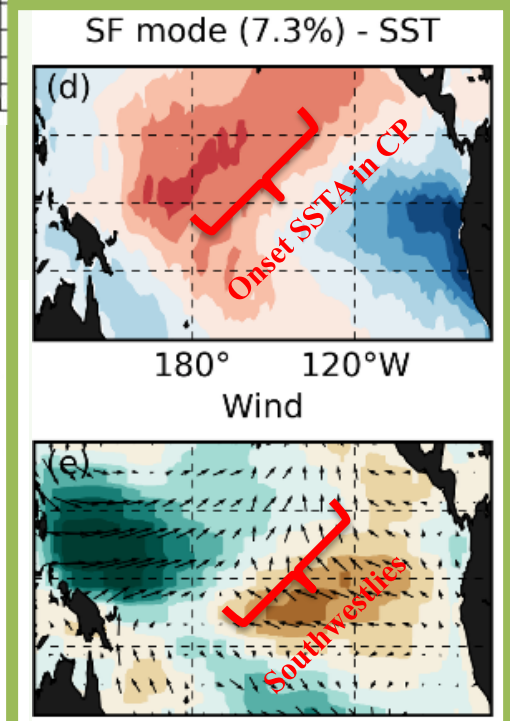
Three evolution patterns → Why?



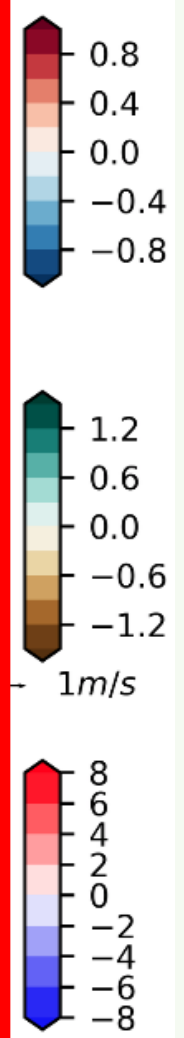
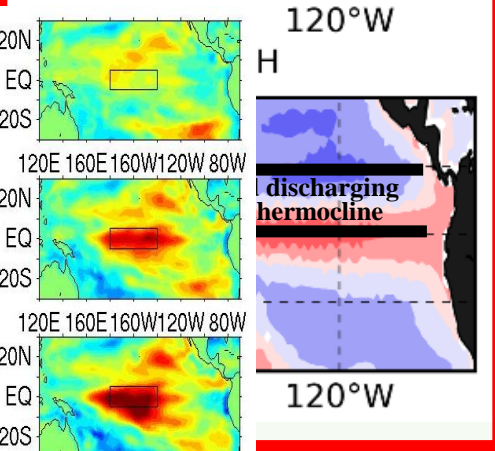
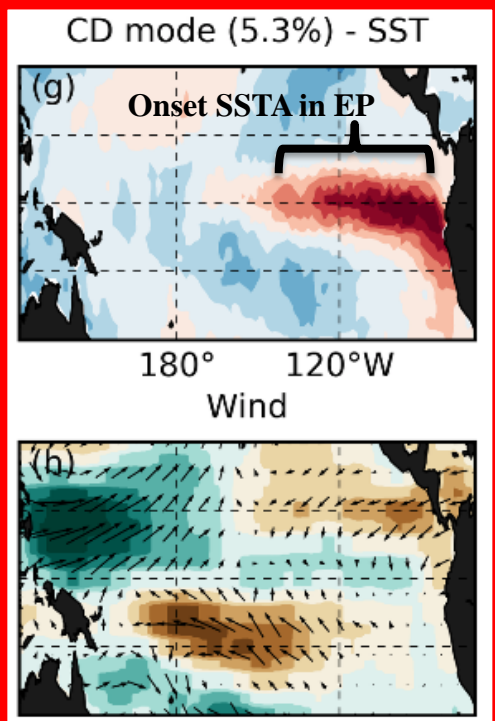
The Complexity in ENSO Type



Seasonal Footprinting Process



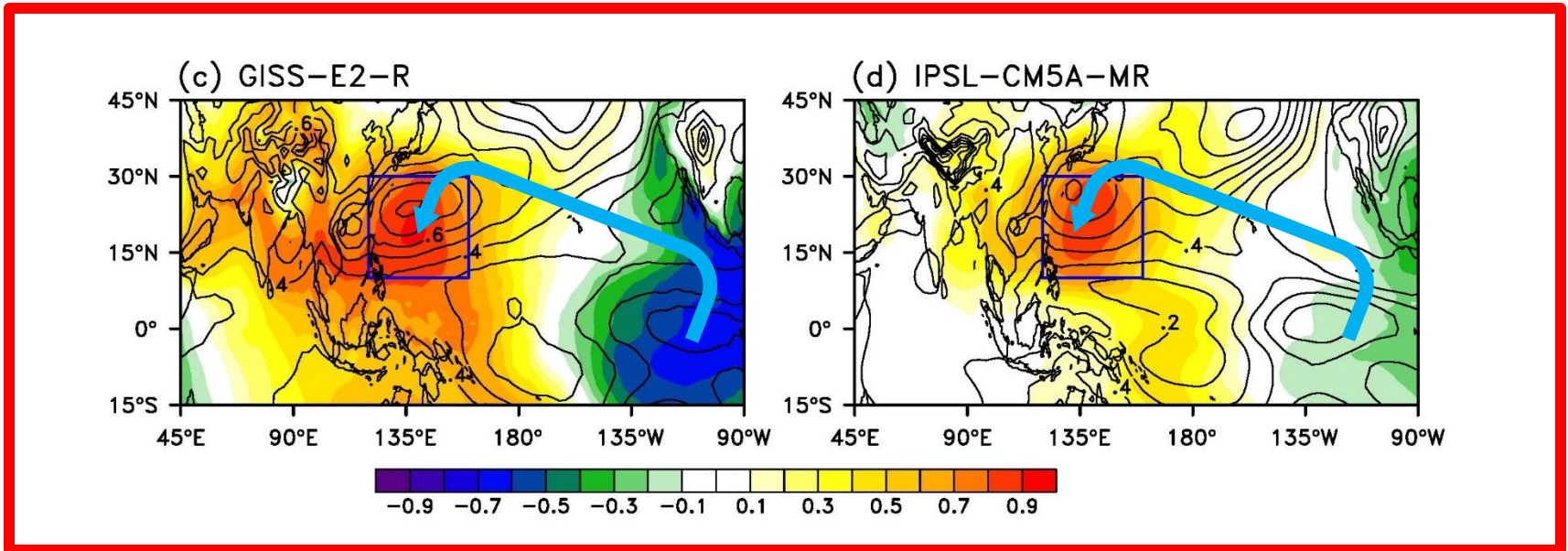
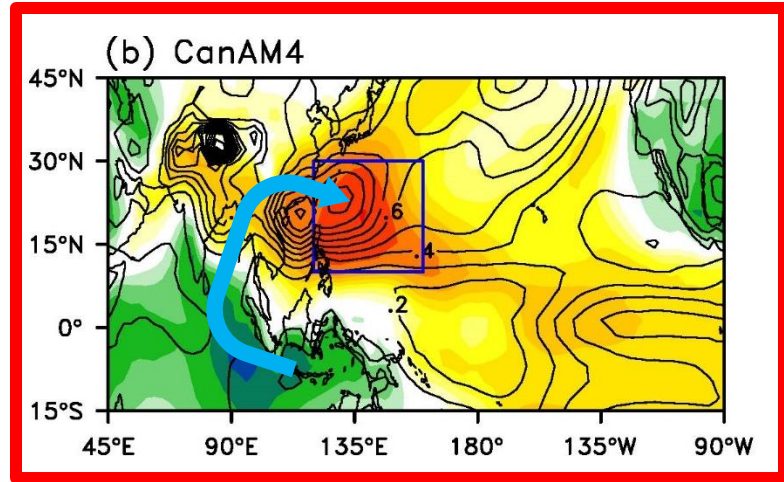
Charged-Discharged Process



CMIP5-AMIP simulations

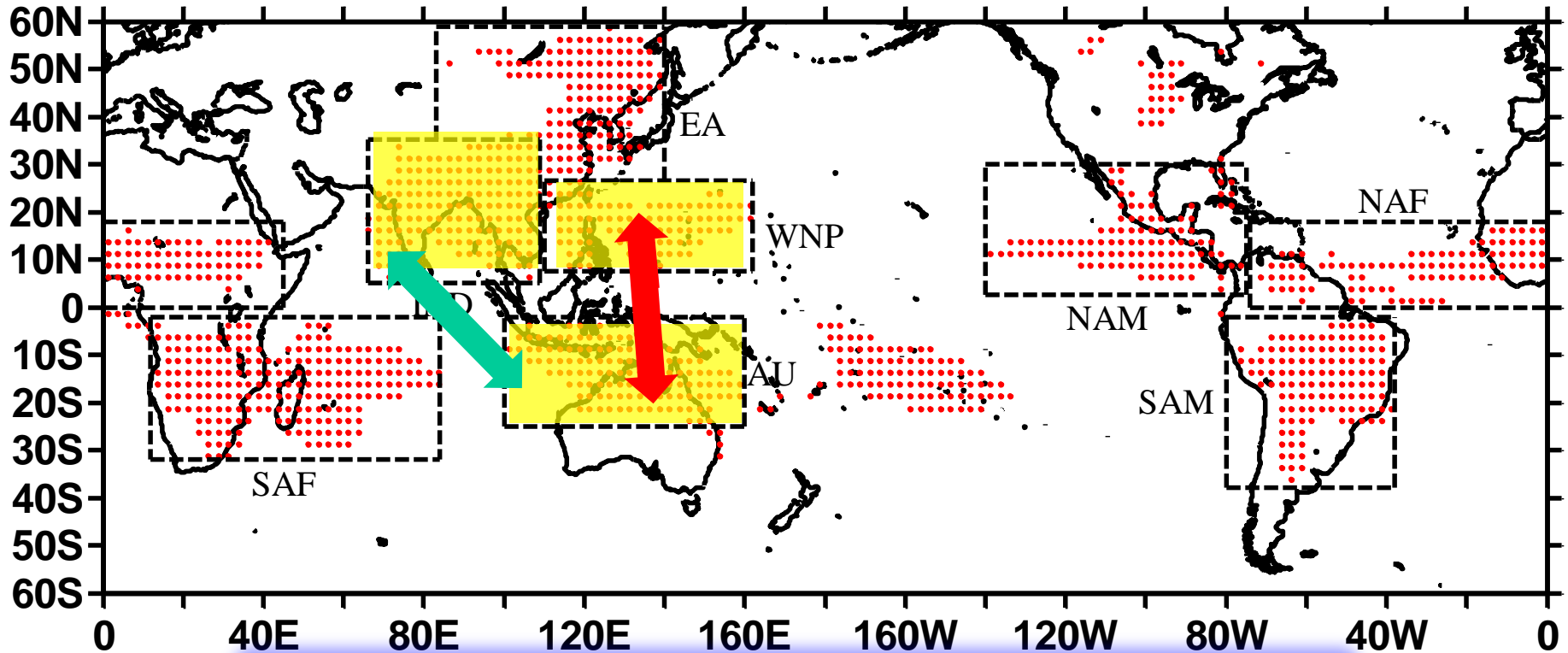
(Paek and Yu et al. 2015)

Some AGCMs overestimate the MC role in the WPSH dynamics.

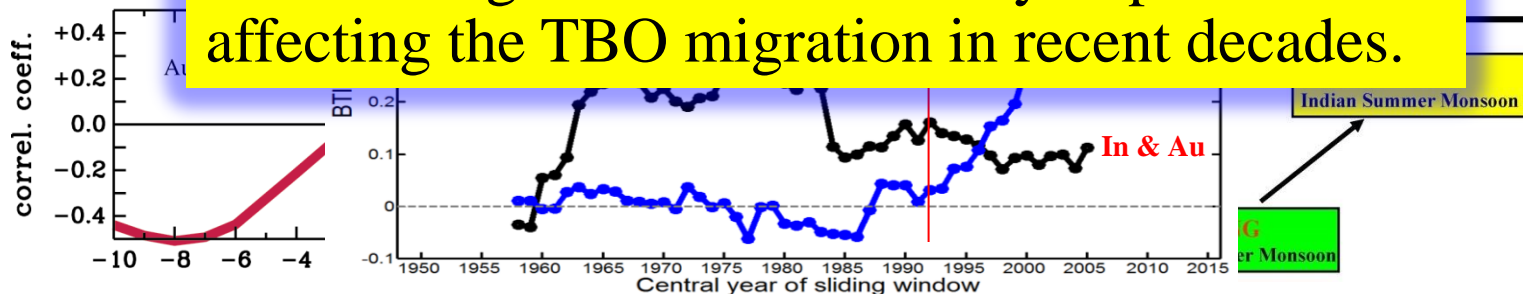


Tropospheric Biennial Oscillation (TBO)

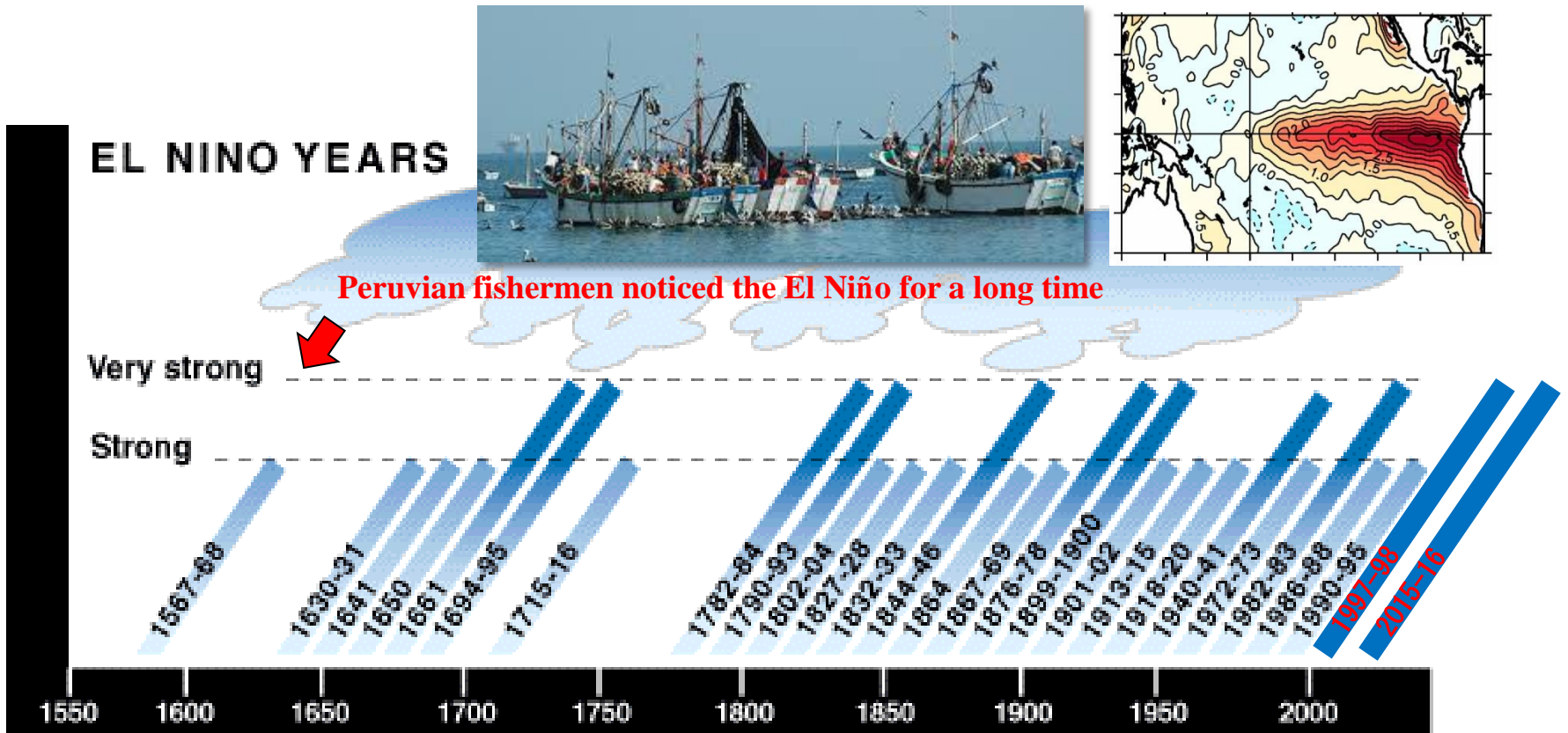
(L. Wang and Yu; to be submitted)



The MC region has become very important in affecting the TBO migration in recent decades.

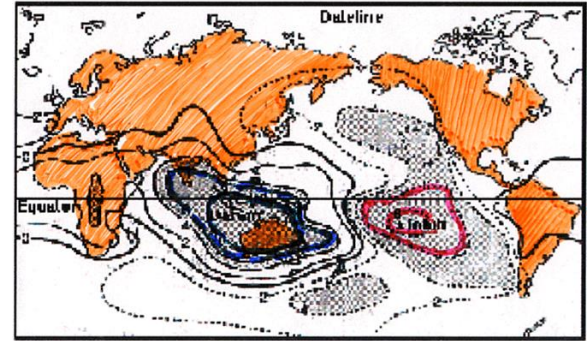
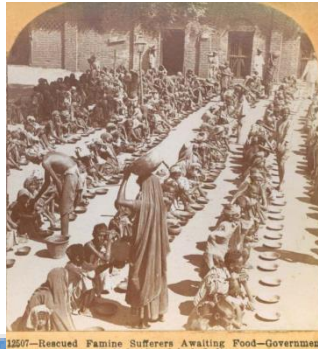


History of El Niño Events



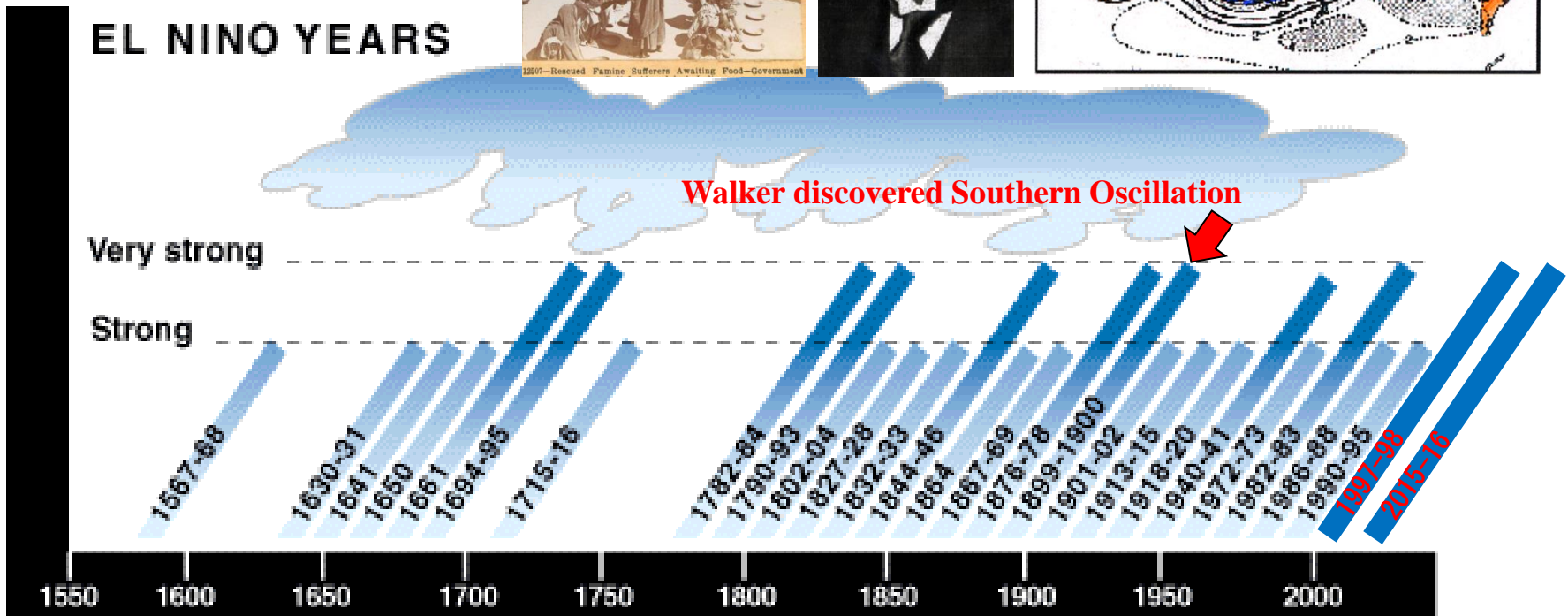
(modified from Environmental News Network)

Southern Oscillation



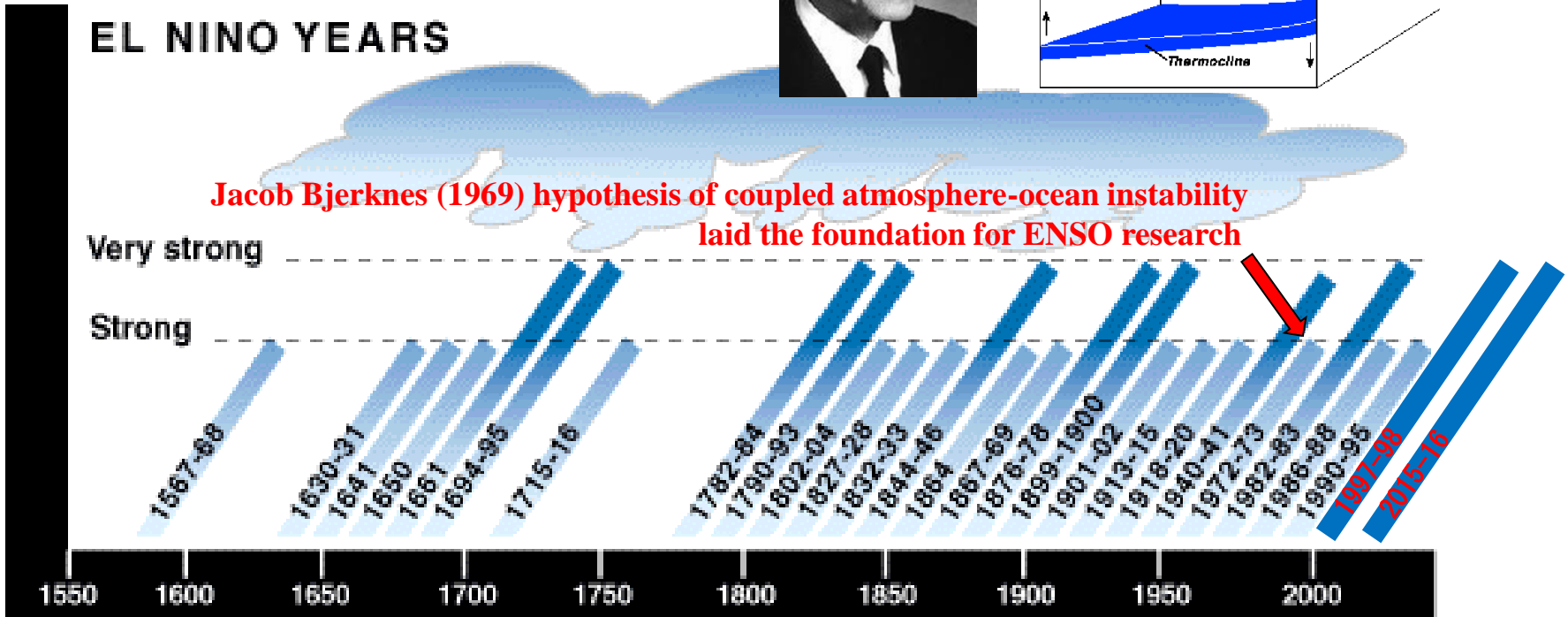
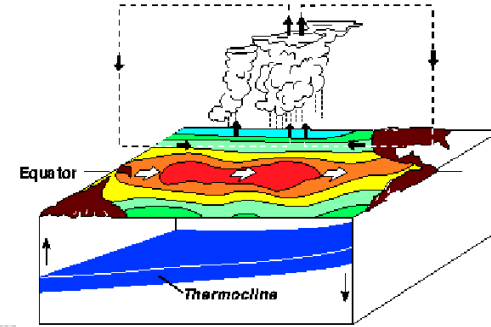
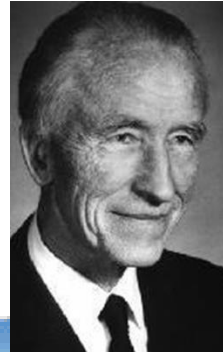
EL NINO YEARS

Walker discovered Southern Oscillation



(modified from Environmental News Network)

El Niño–Southern Oscillation (ENSO)



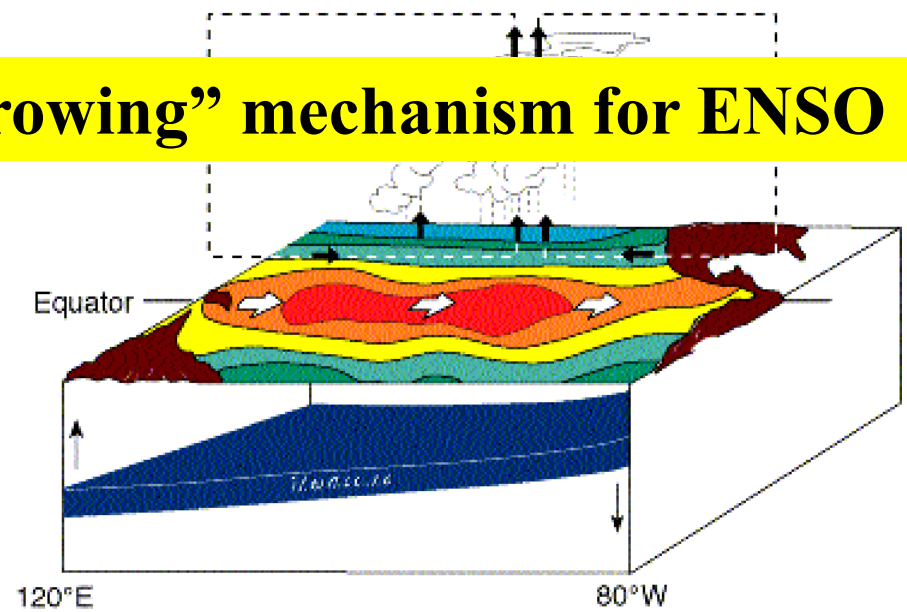
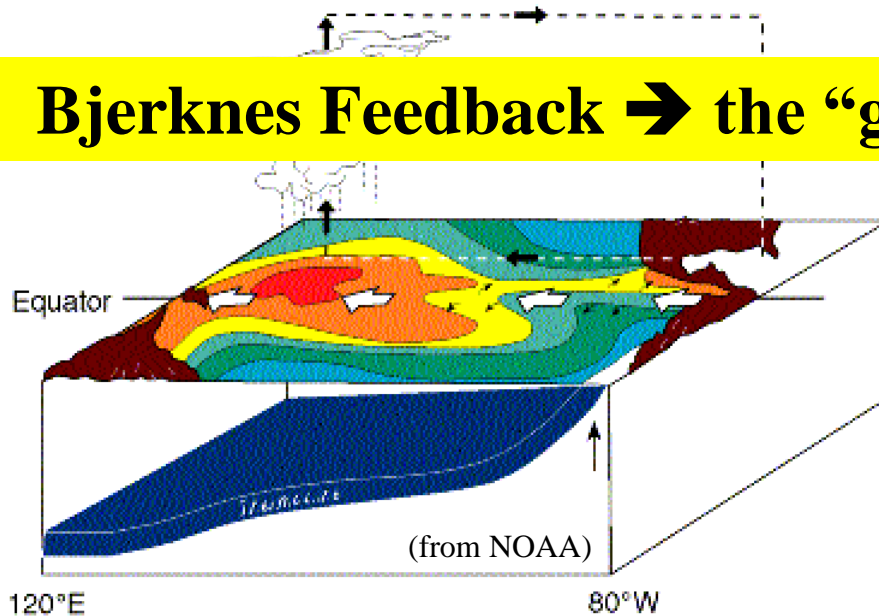
(modified from Environmental News Network)

How El Niño Grows – Bjerknes Feedback Mechanism

Normal Condition

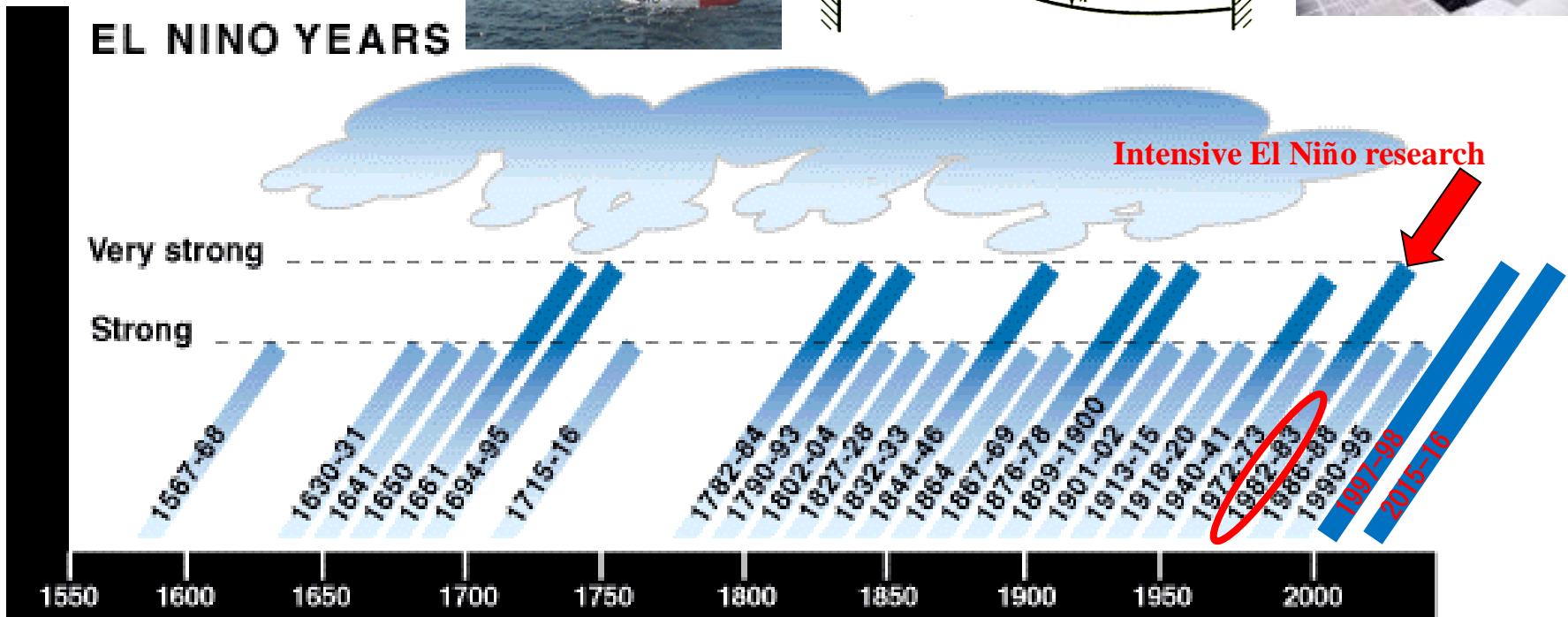
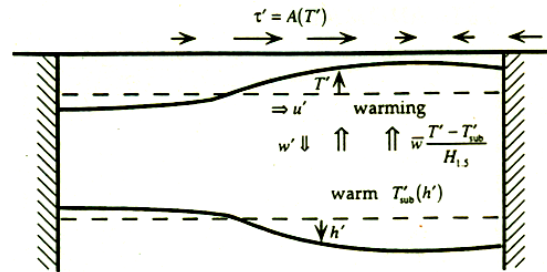
El Niño Condition

Bjerknes Feedback → the “growing” mechanism for ENSO



The foundation of ENSO research.

Intensive ENSO Research



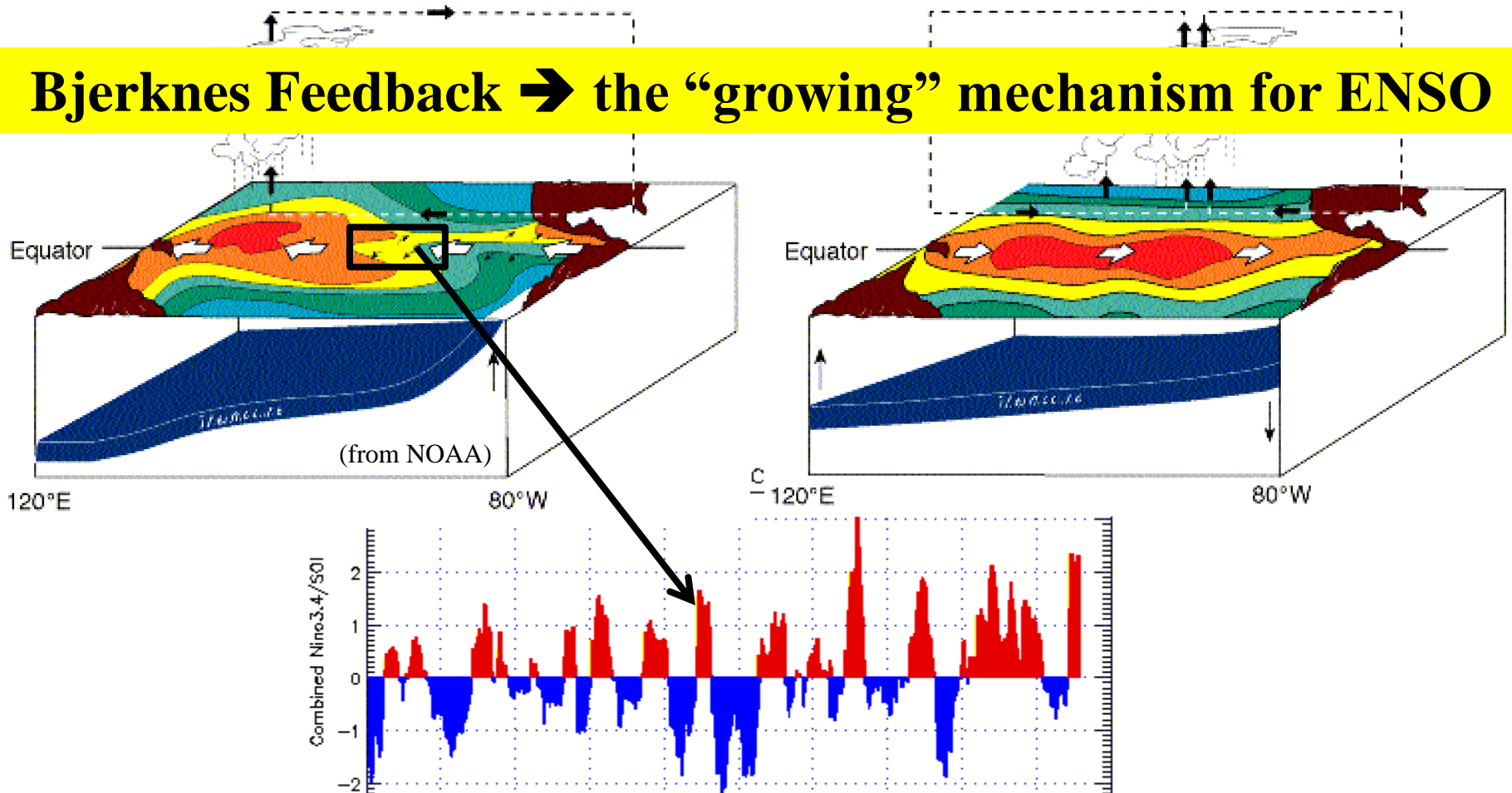
(modified from Environmental News Network)

How El Niño switches to La Niña?

Normal Condition

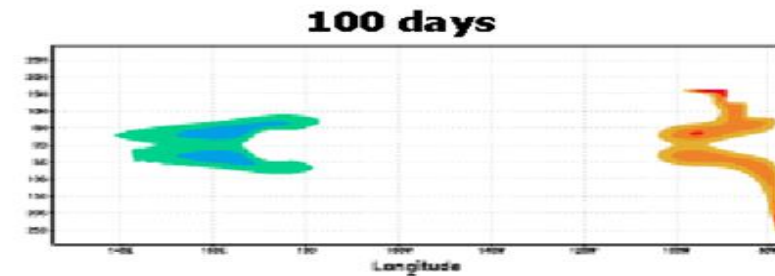
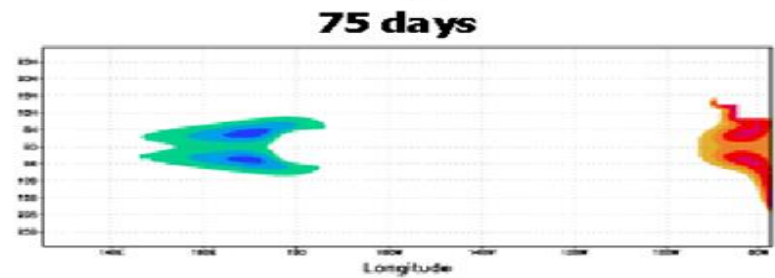
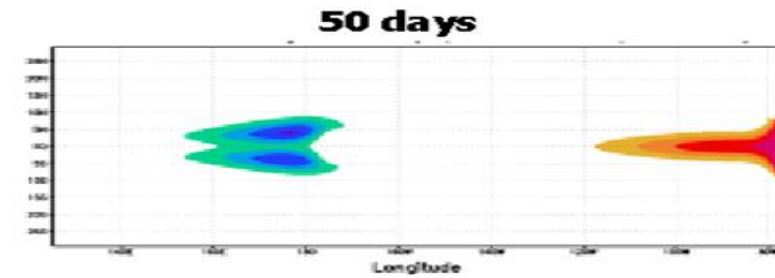
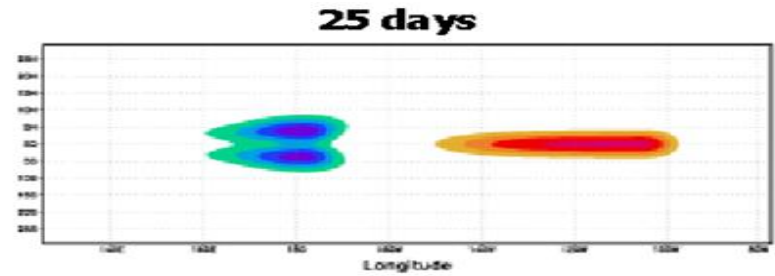
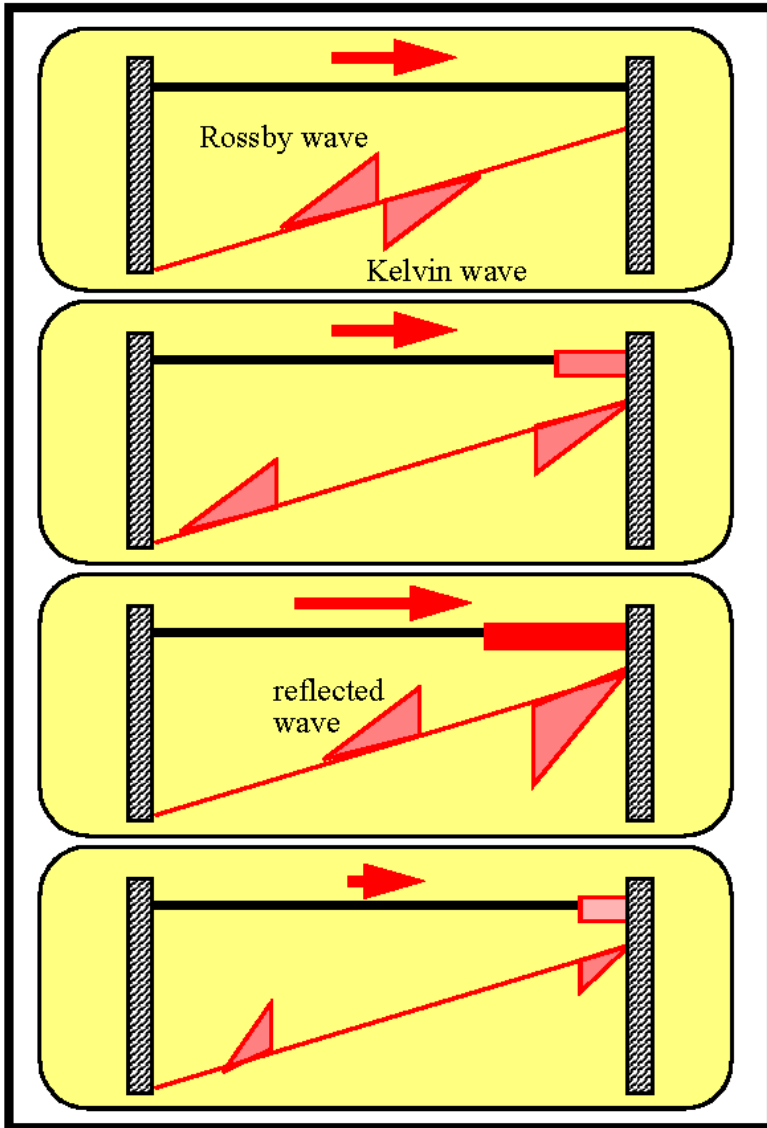
El Niño Condition

Bjerknes Feedback → the “growing” mechanism for ENSO

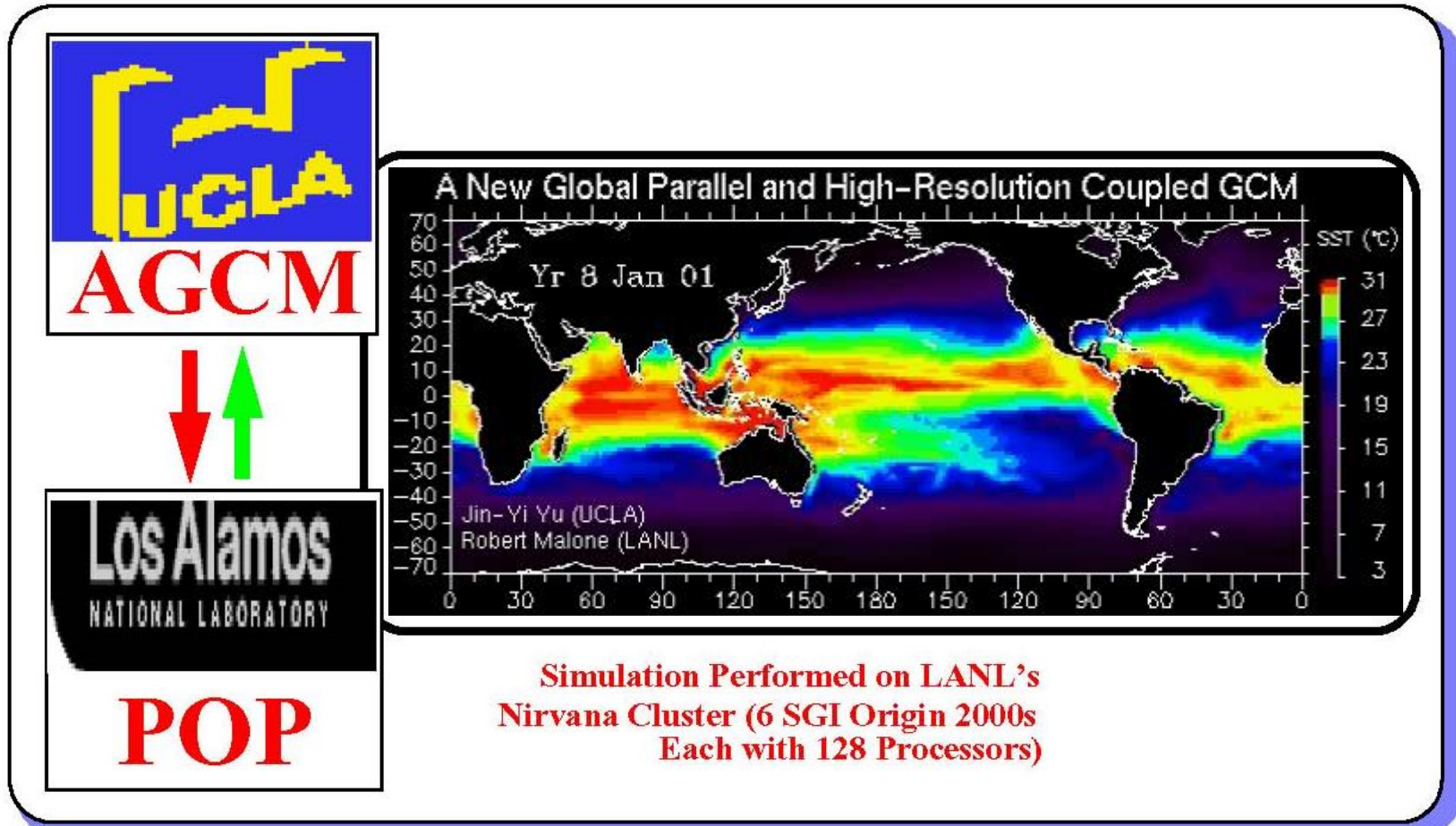


We need a negative feedback to switch the ENSO phase

Delayed Oscillator Theory



Coupled Atmosphere-Ocean General Circulation Model (CGCM)



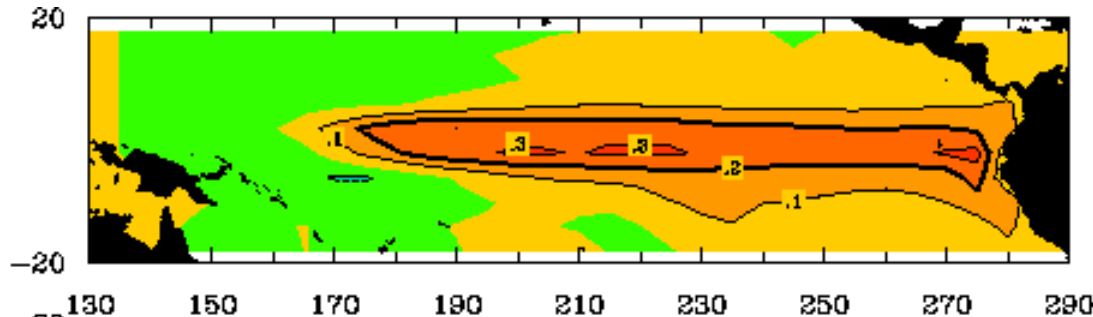
A DECADAL CLIMATE VARIABILITY RESEARCH PROJECT
FUNDED BY LOS ALAMOS NATIONAL LABORATORY

PI: JIN-YI YU

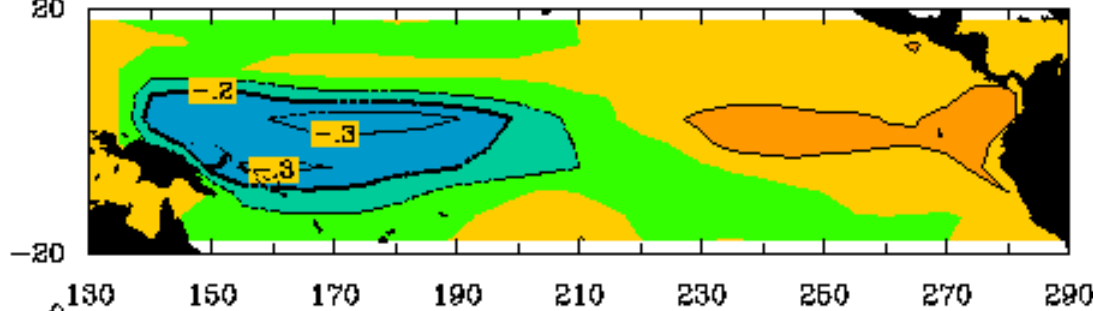
CO-PI: BOB MALONE



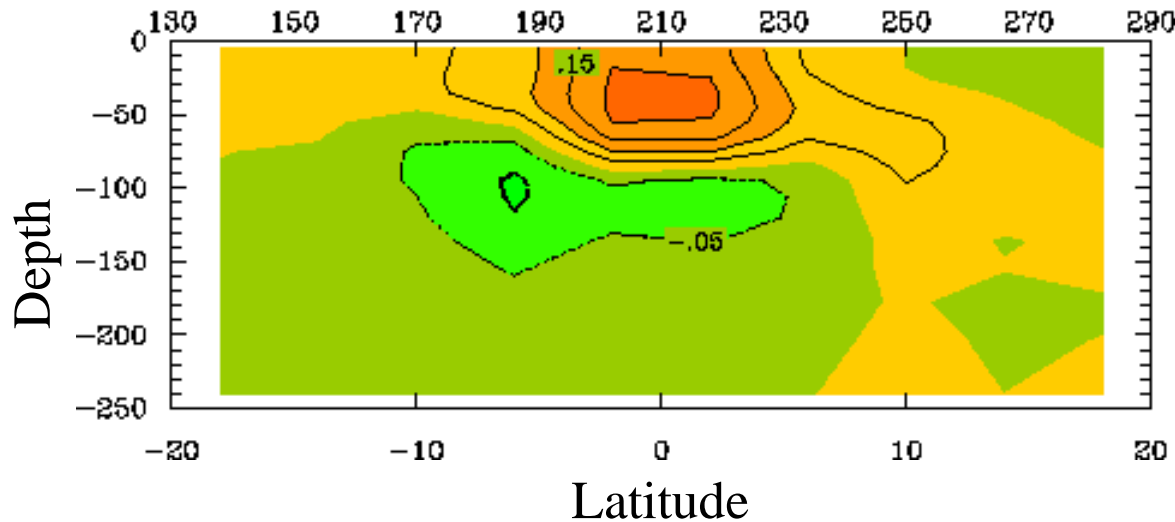
ENSO Simulation by CGCM



Surface Ocean Temperature



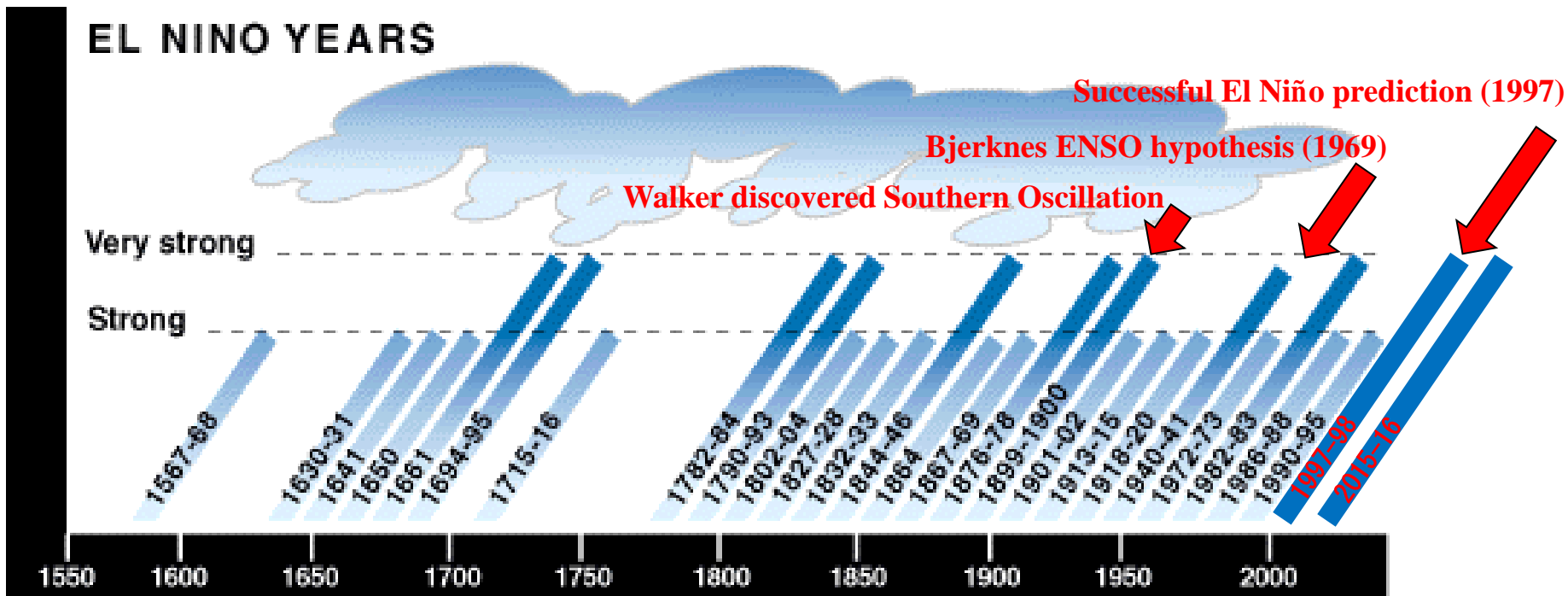
Sub_Surface Temperature



Vertical Cross Section

(Jin-Yi Yu, 1997)

20th-Century El Niño and ENSO Research



(modified from Environmental News Network)