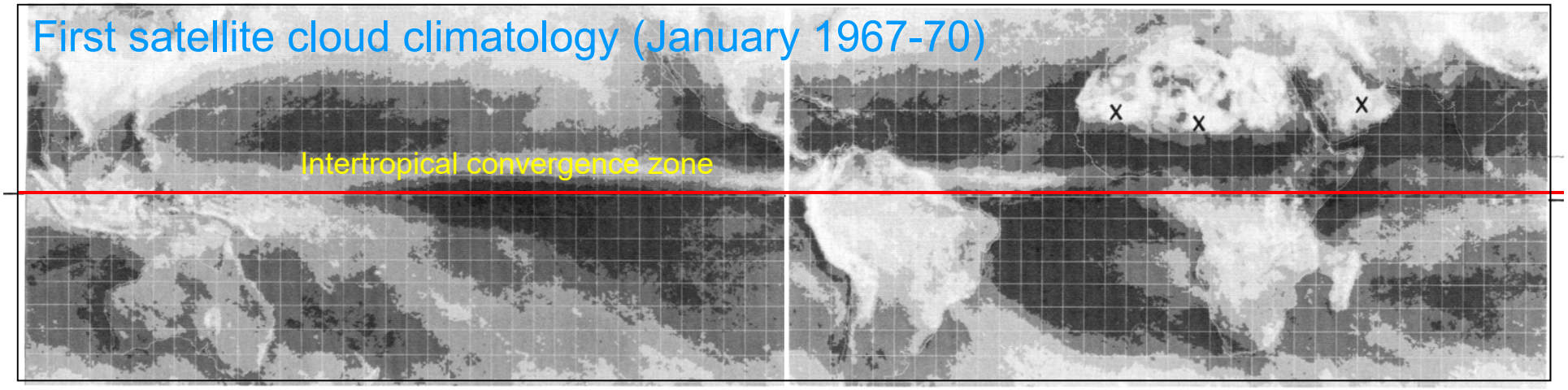
1. Tropical Ocean-Atmosphere Feedback

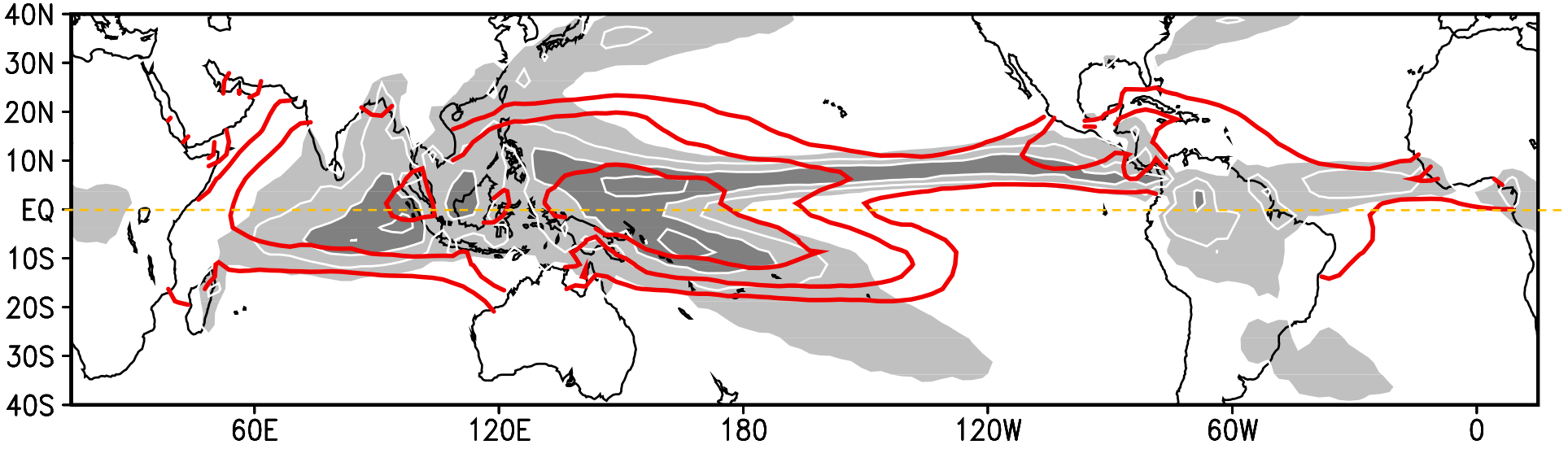
2. Interannual variability of summer monsoon



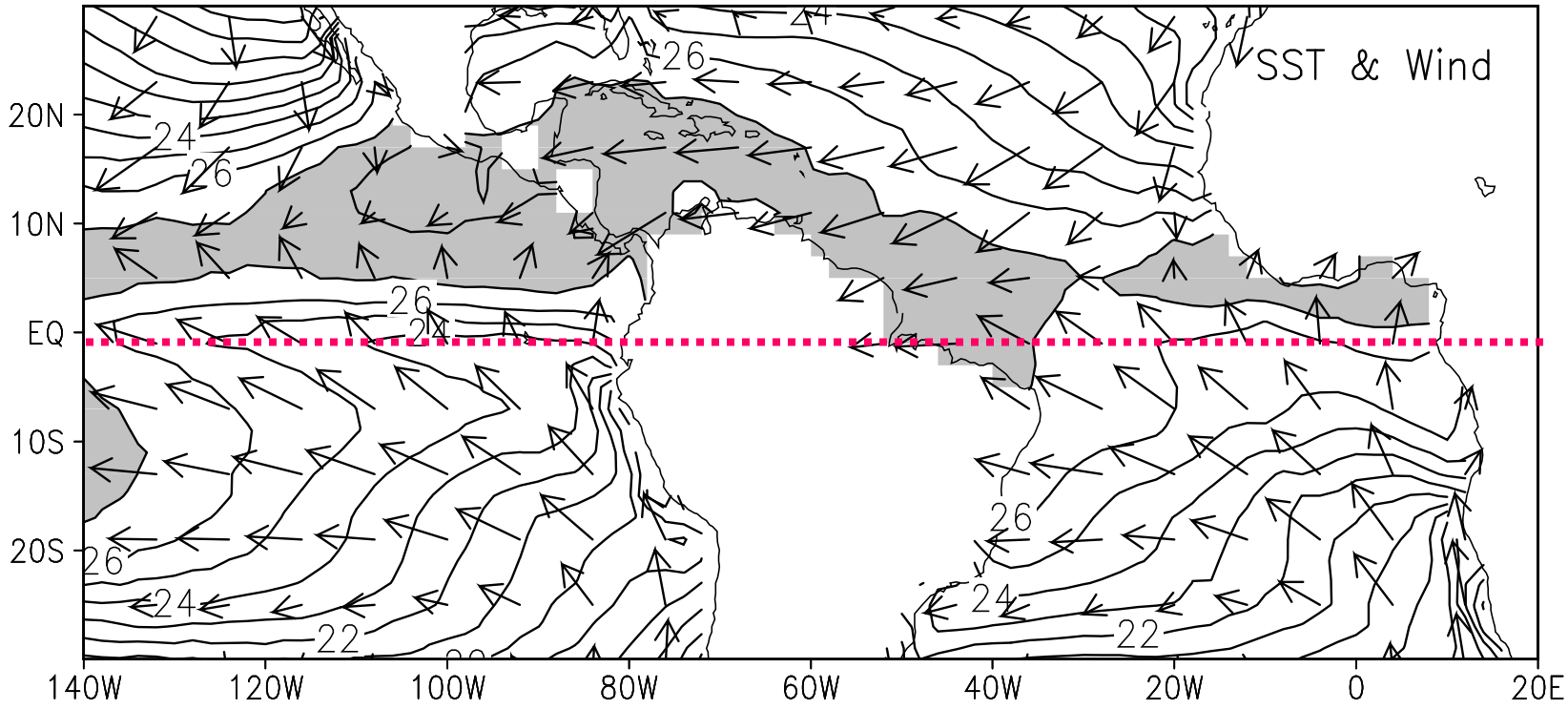
Peculiar features inexplicable from solar radiation

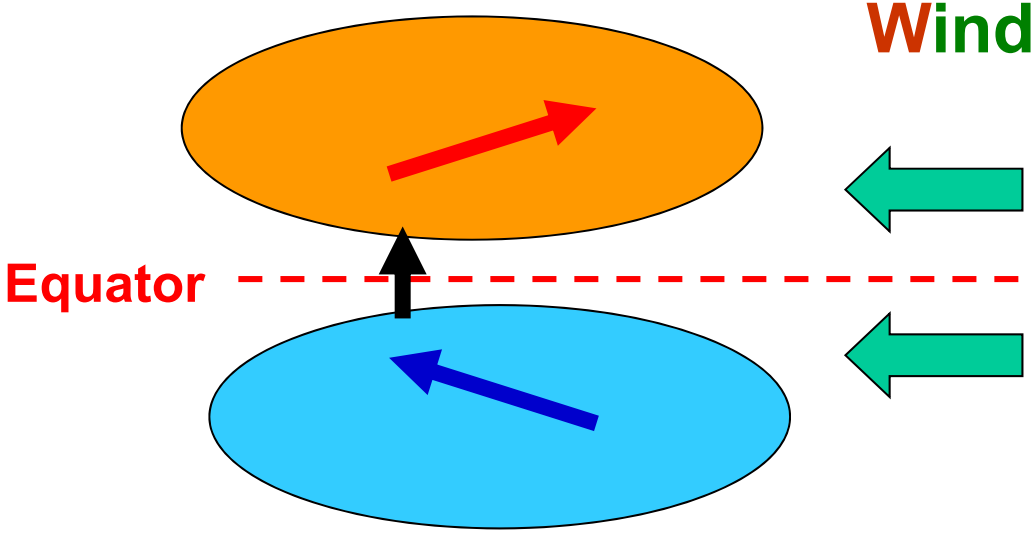
- **WES feedback + → Northward displaced ITCZ**
- **Bjerknes feedback → cold tongue on the equator**

Precipitation & SST (annual-mean)



- The thermal equator/ITCZ is displaced north of the equator over the western hemisphere oceans (East Pacific and Atlantic).
- The displaced ITCZ is due to warmer SST, but the warmer SST is due to the displaced ITCZ at the same time → circular arguments are indicative of ocean-atmosphere interaction.



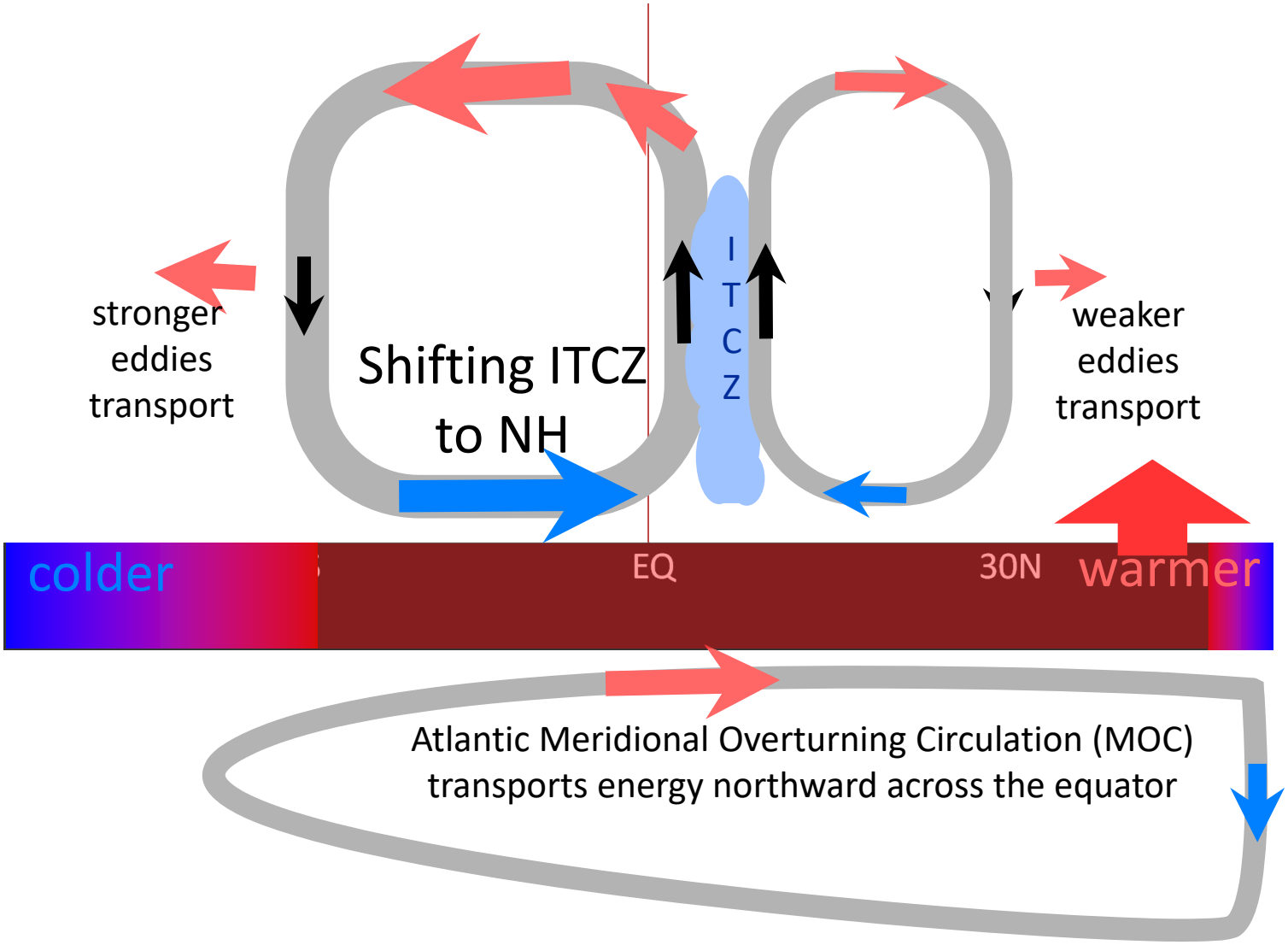


Wind-Evaporation-SST (WES) Feedback

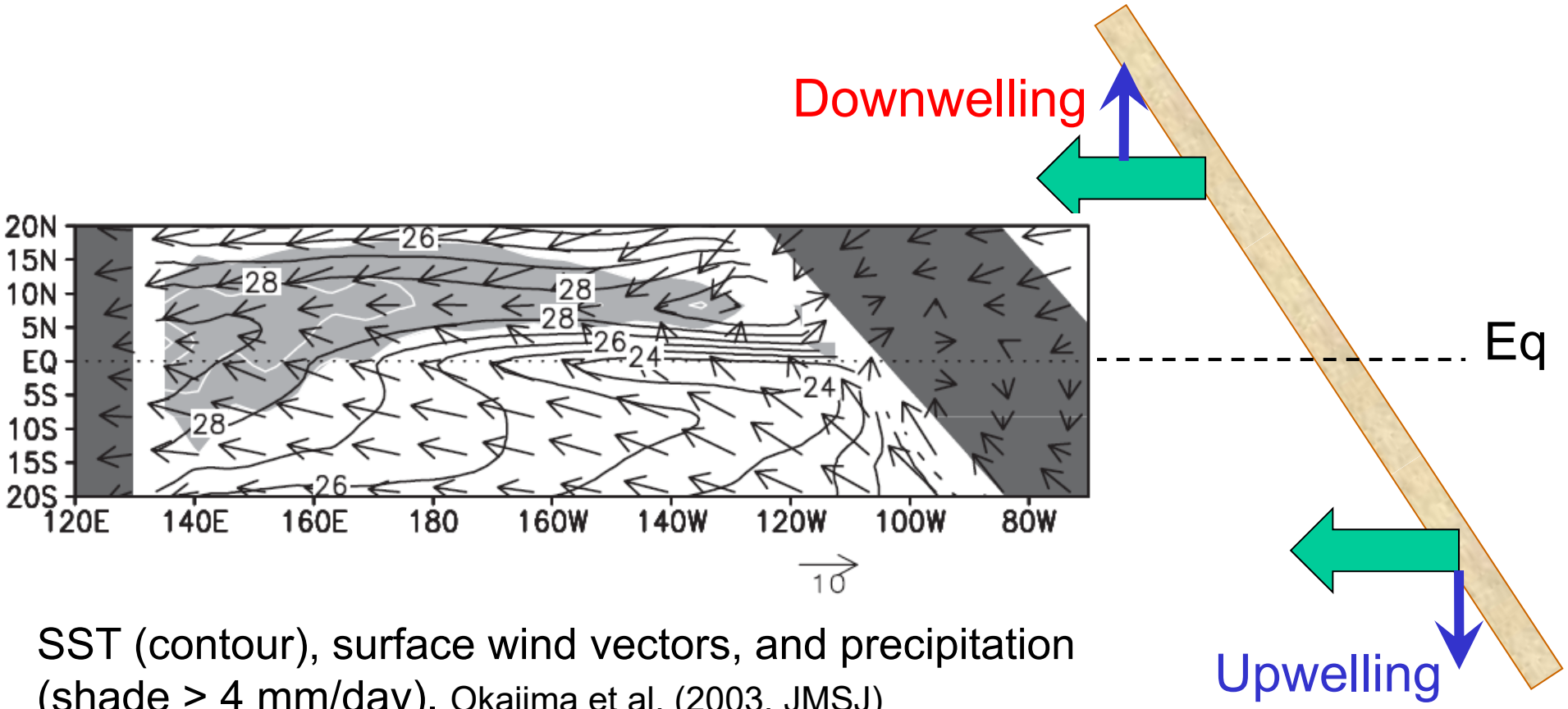
Xie & Philander (1994, *Tellus*)

AMOC Effect on ITCZ

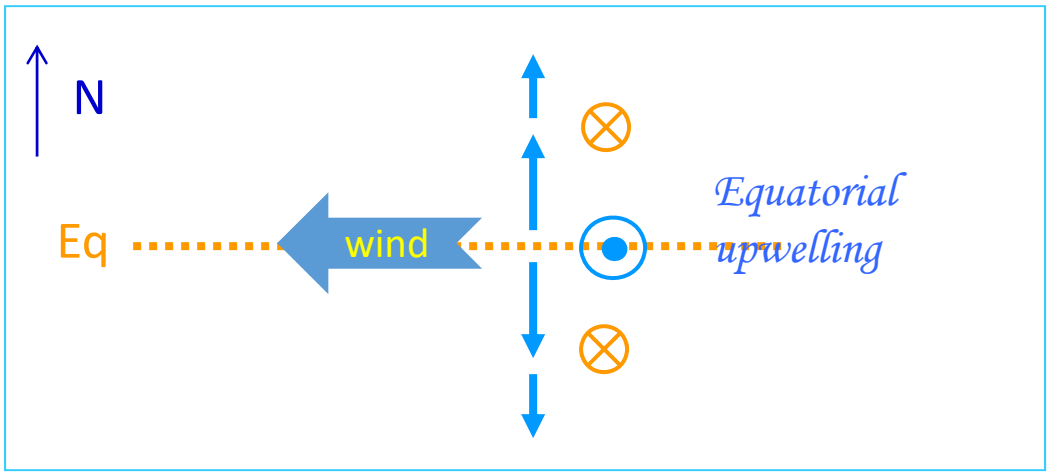
(Kang et al. 2008; Frierson et a. 2013; Marshall et al. 2014…)

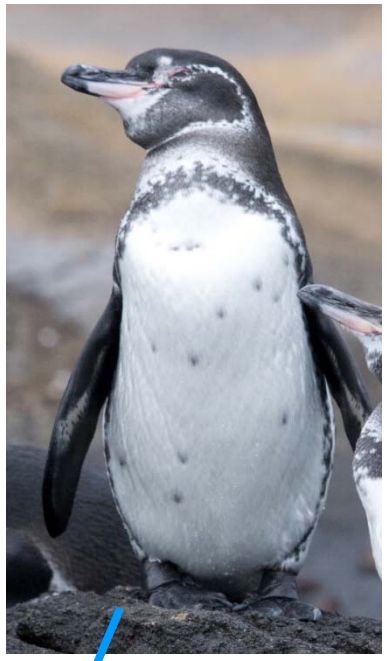


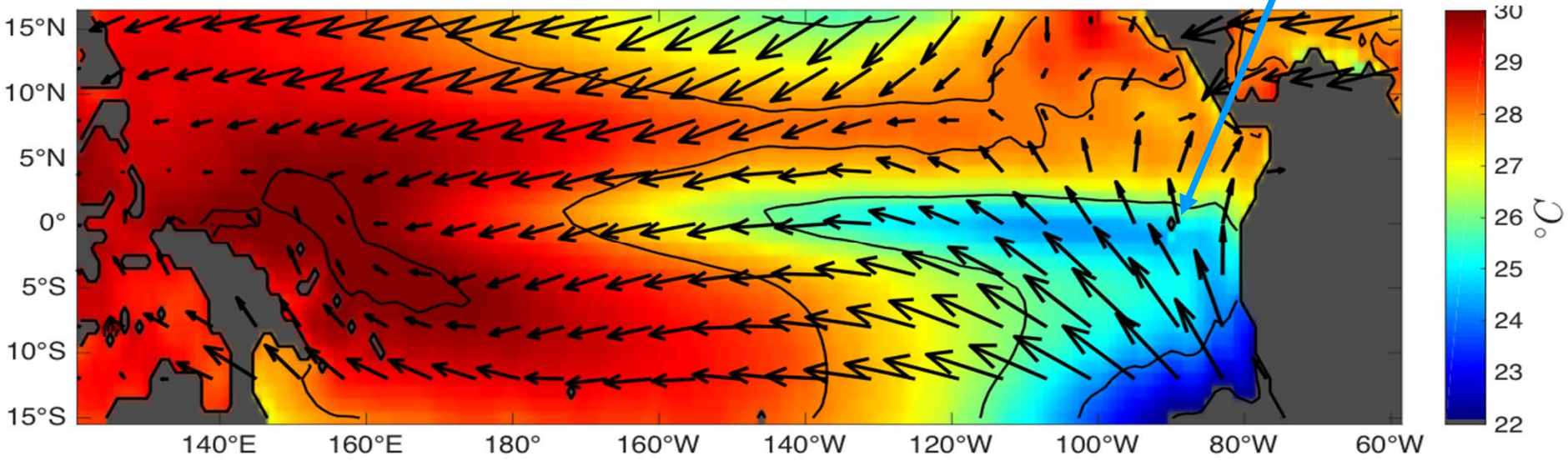
Tilted coastline breaks the equatorial symmetry

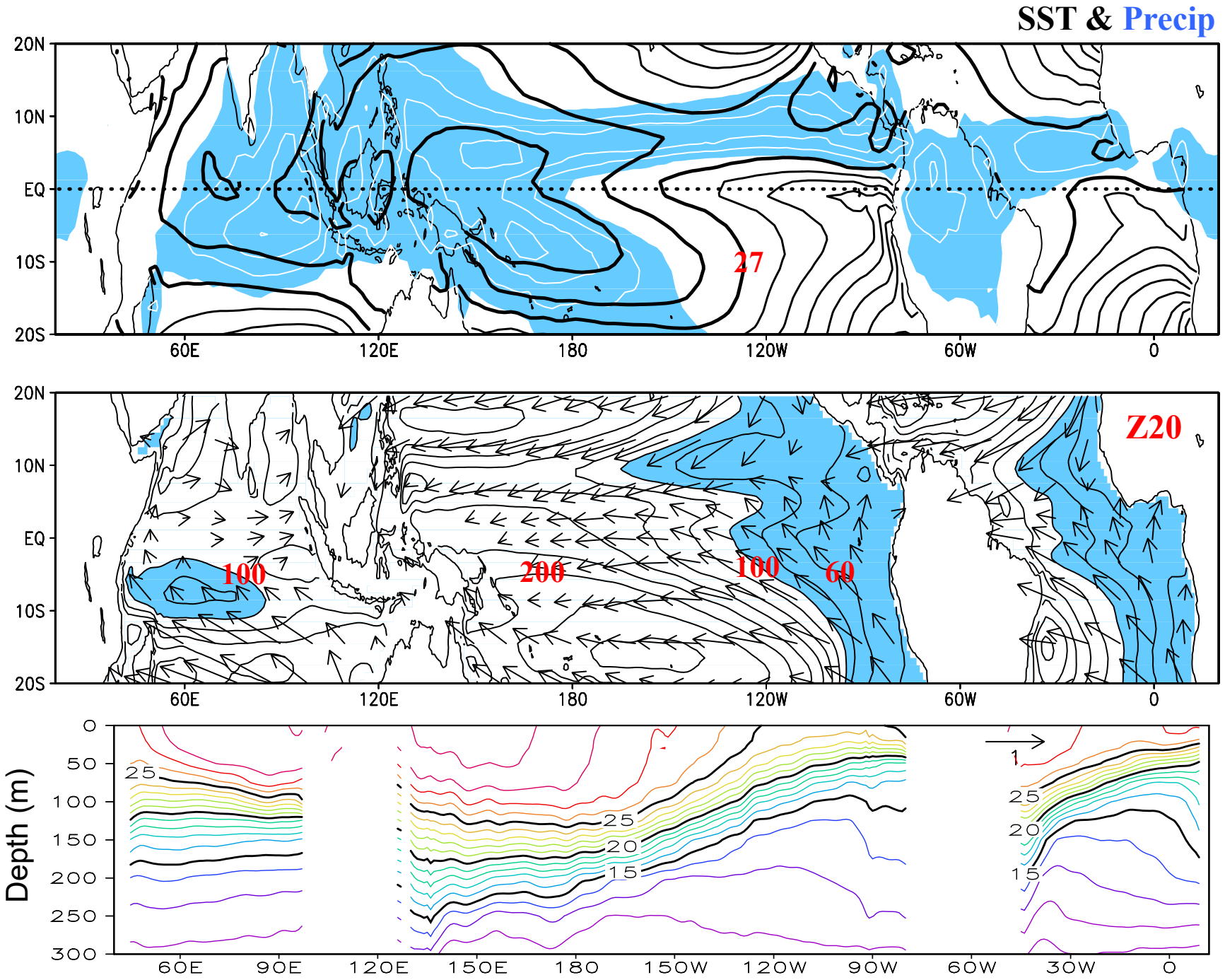


SST (contour), surface wind vectors, and precipitation (shade > 4 mm/day). Okajima et al. (2003, JMSJ)


N
Eq
wind
Equatorial
upwelling

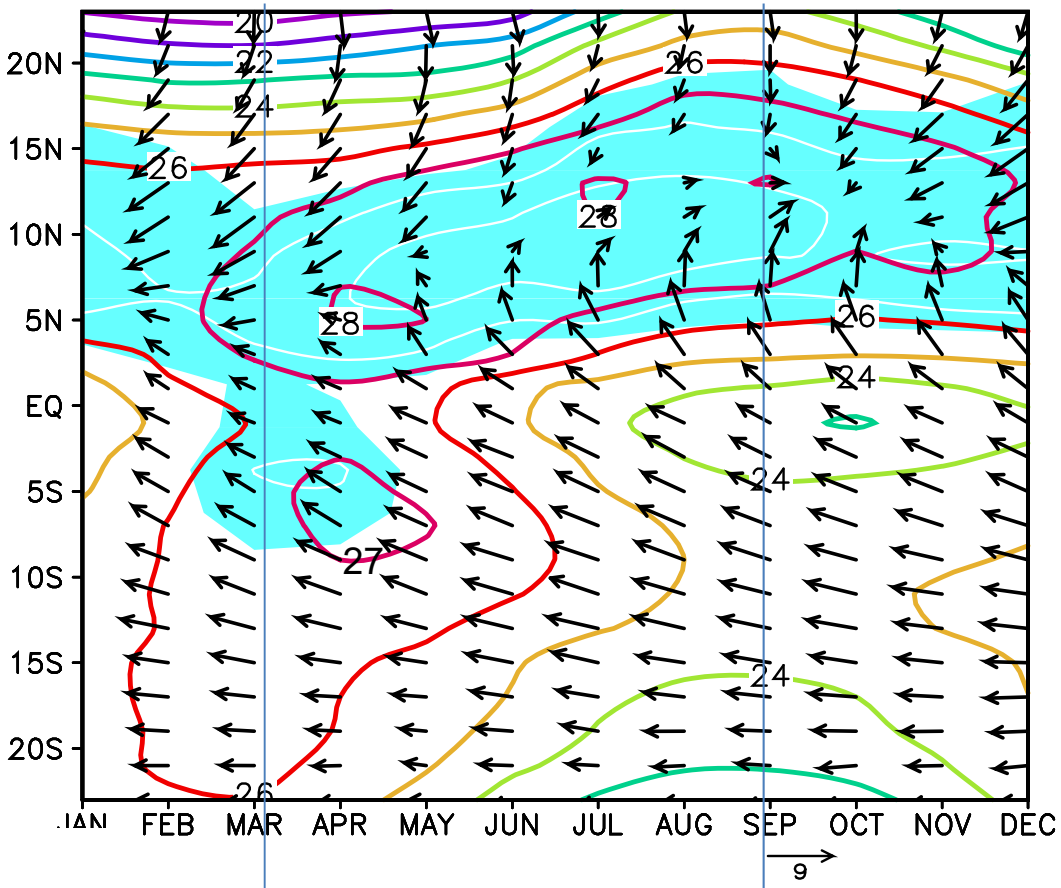



15°N
10°N
5°N
0°
5°S
10°S
15°S
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W
60°W
30
29
28
27
26
25
24
23
22
°C


SST & Precip
20N
10N
EQ
10S
20S
60E
120E
180
120W
60W
0
27
Z20
100
200
100
60
Depth (m)
0
50
100
150
200
250
300
90E
150E
150W
90W
30W
25
20
15
1

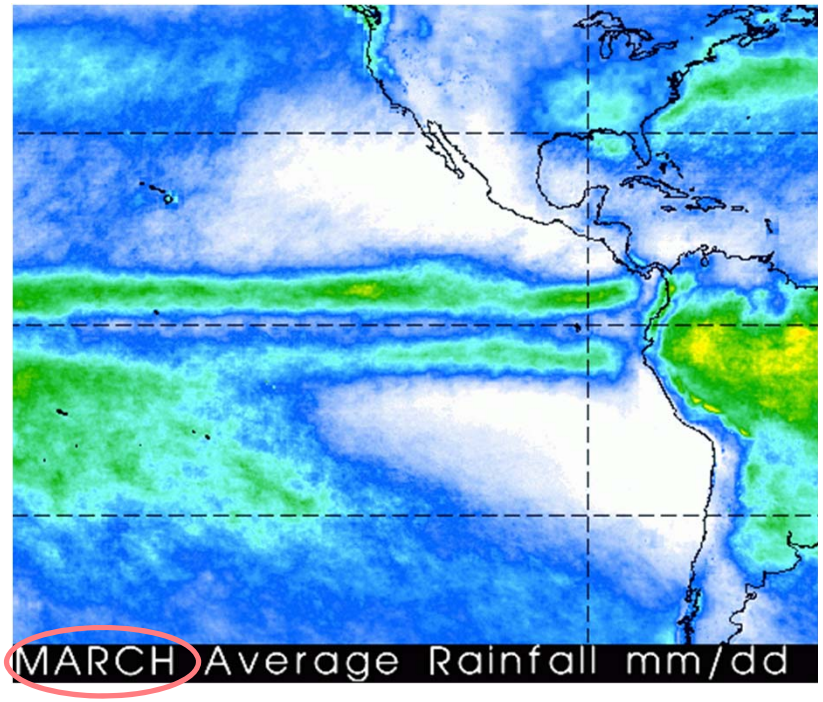
Obs. Precip., SST & wind

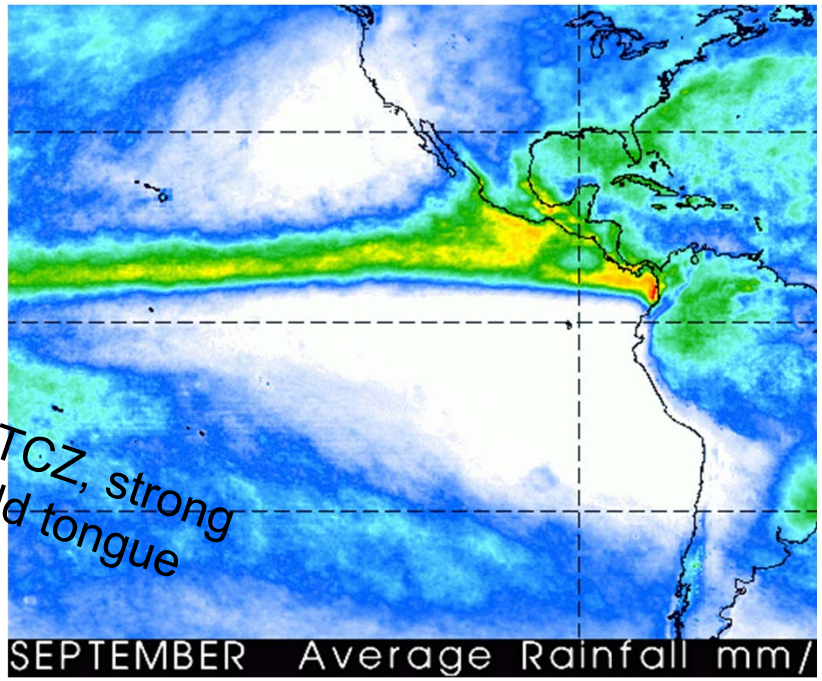
120-115°W

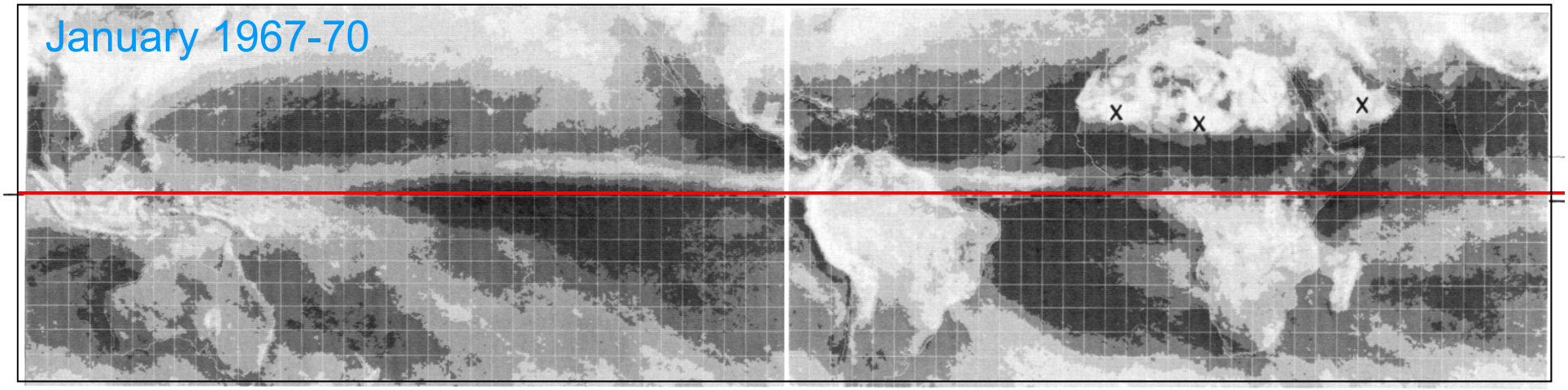


FMA: Double ITCZ & weak southerlies

ASO: N-displaced ITCZ, strong southerlies & Eq. cold tongue







Summary

Coupled (WES) feedback ← Continental geometry: tropical vs. global

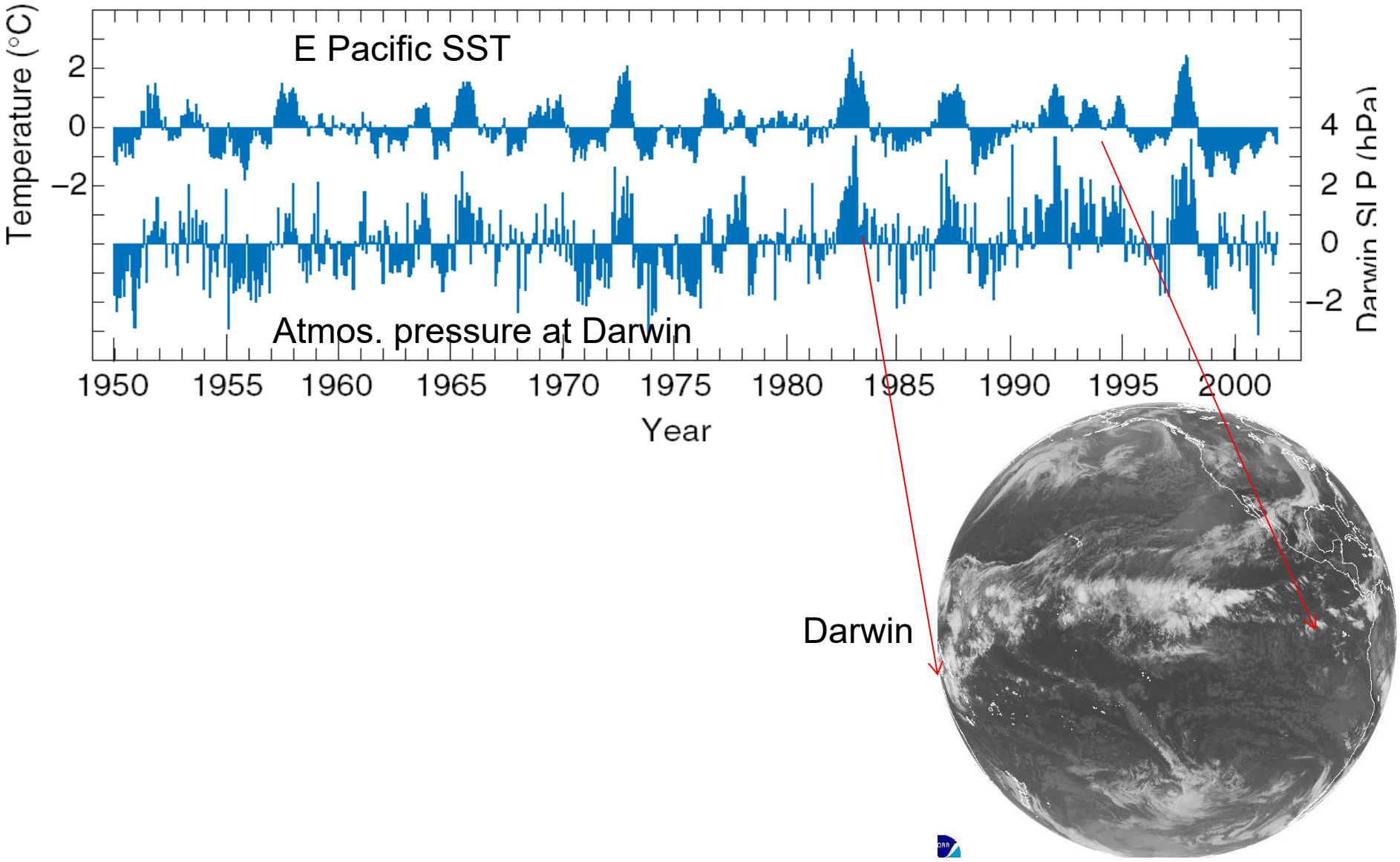
↓

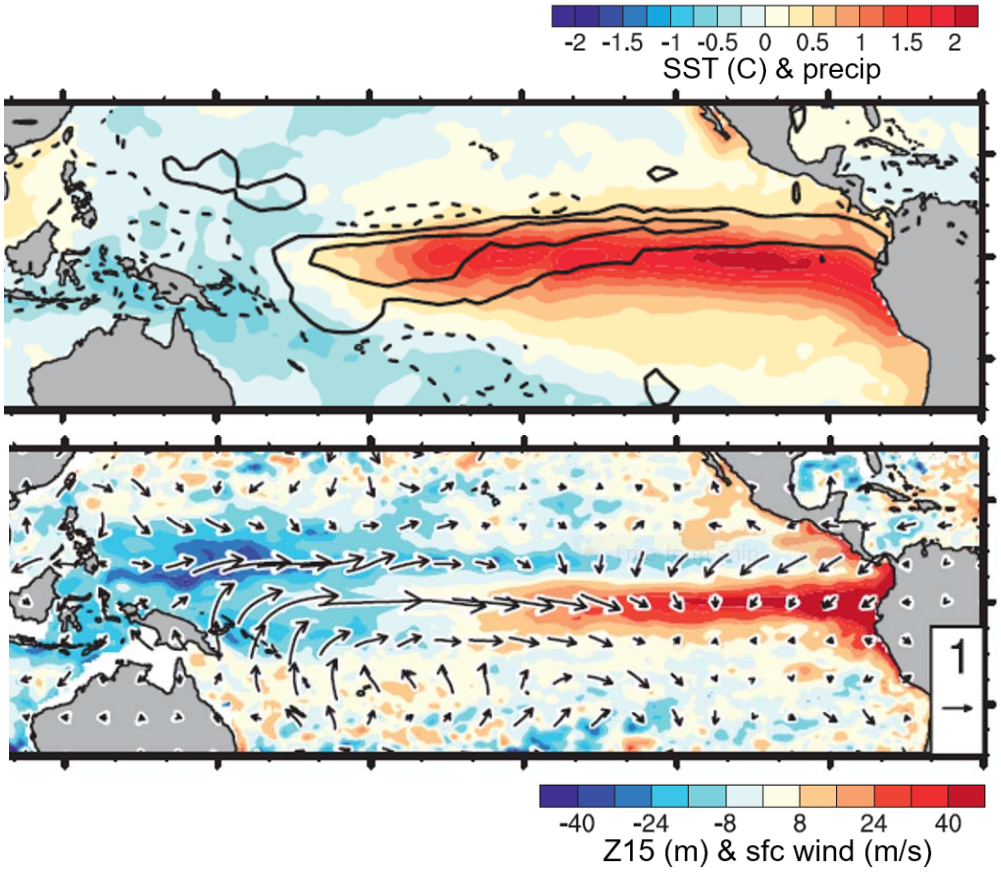
Northward-displaced ITCZ

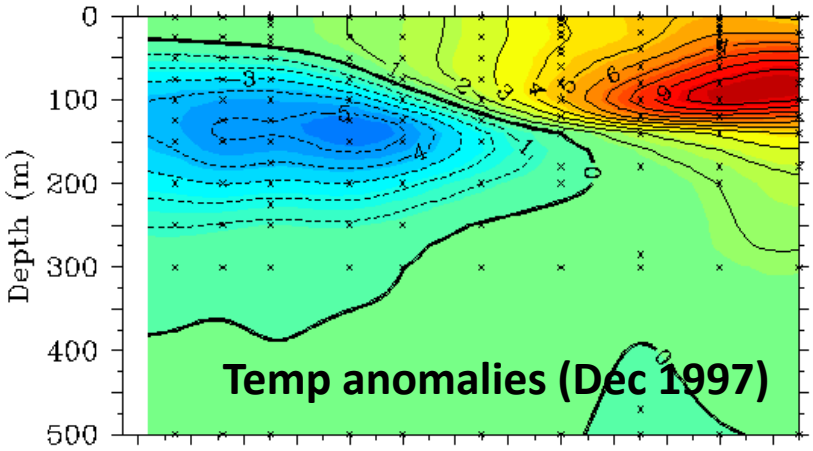
↓

Equatorial annual cycle

El Nino and the Southern Oscillation (ENSO)







El Nino composite (1958-2007)

Sept-Nov

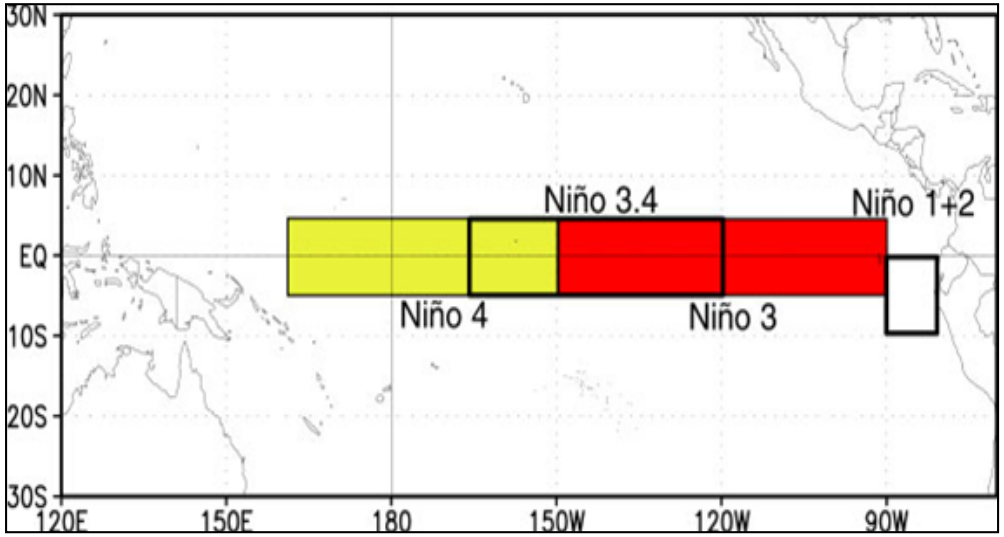
Bjerknes feedback

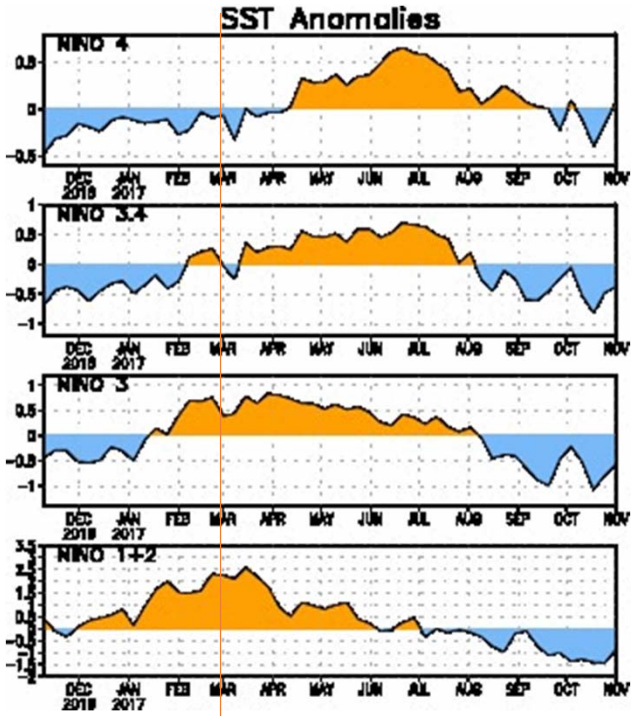
- Westerly wind anomalies in the western basin
- Maximum warming in the eastern basin ← Eq. wave adjustment.
- Weak precip response over the cold tongue ← cool mean SST

(Deser et al. 2012, *JC*)

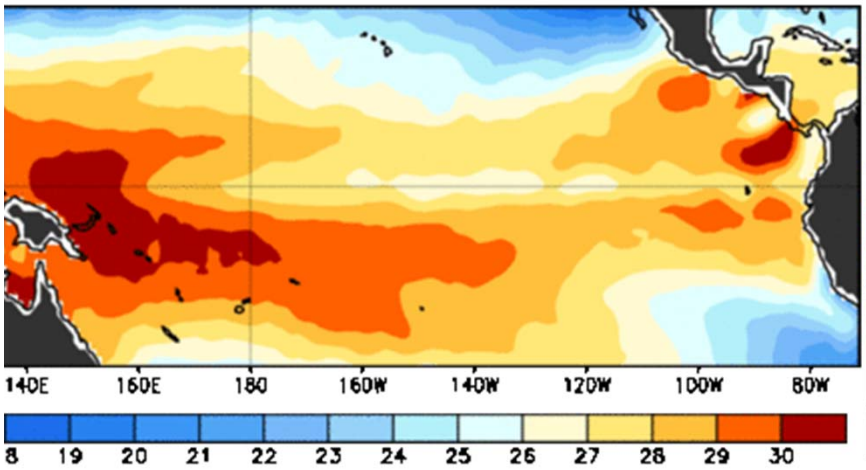
Residents wade through water as a flash flood brings mud and debris in Trujillo, Peru on March 18, 2017.

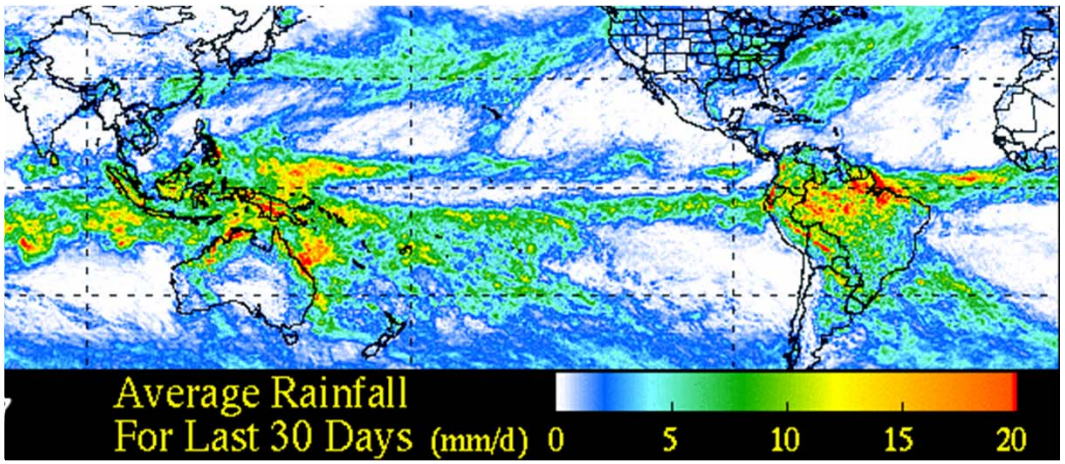
During January-March 2017, rainfall reached **631 mm, compared to annual climatology of 75** mm.



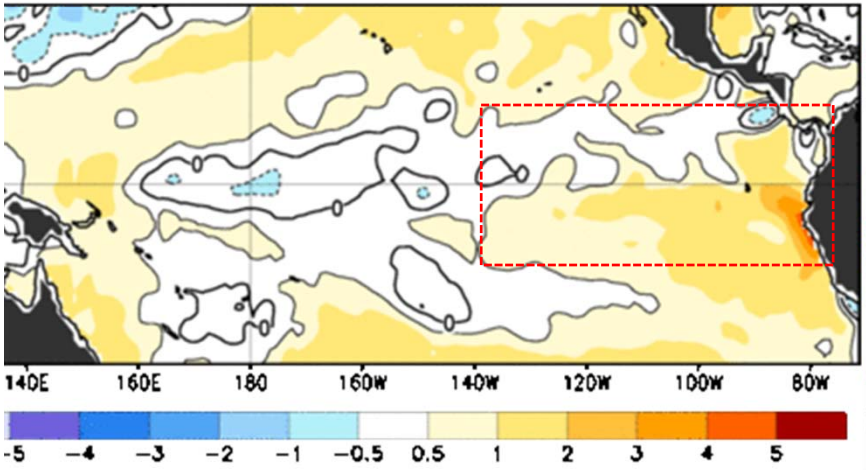


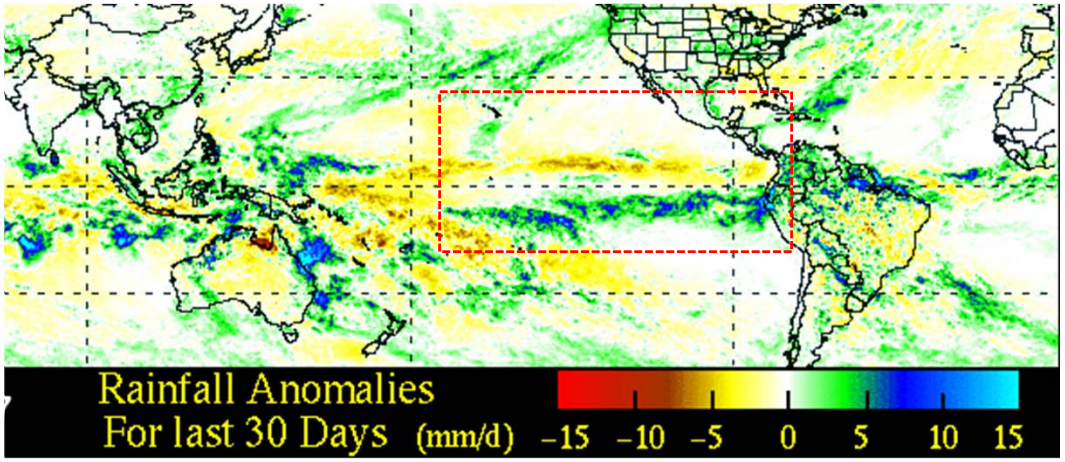
Observed Sea Surface Temperature (°C)





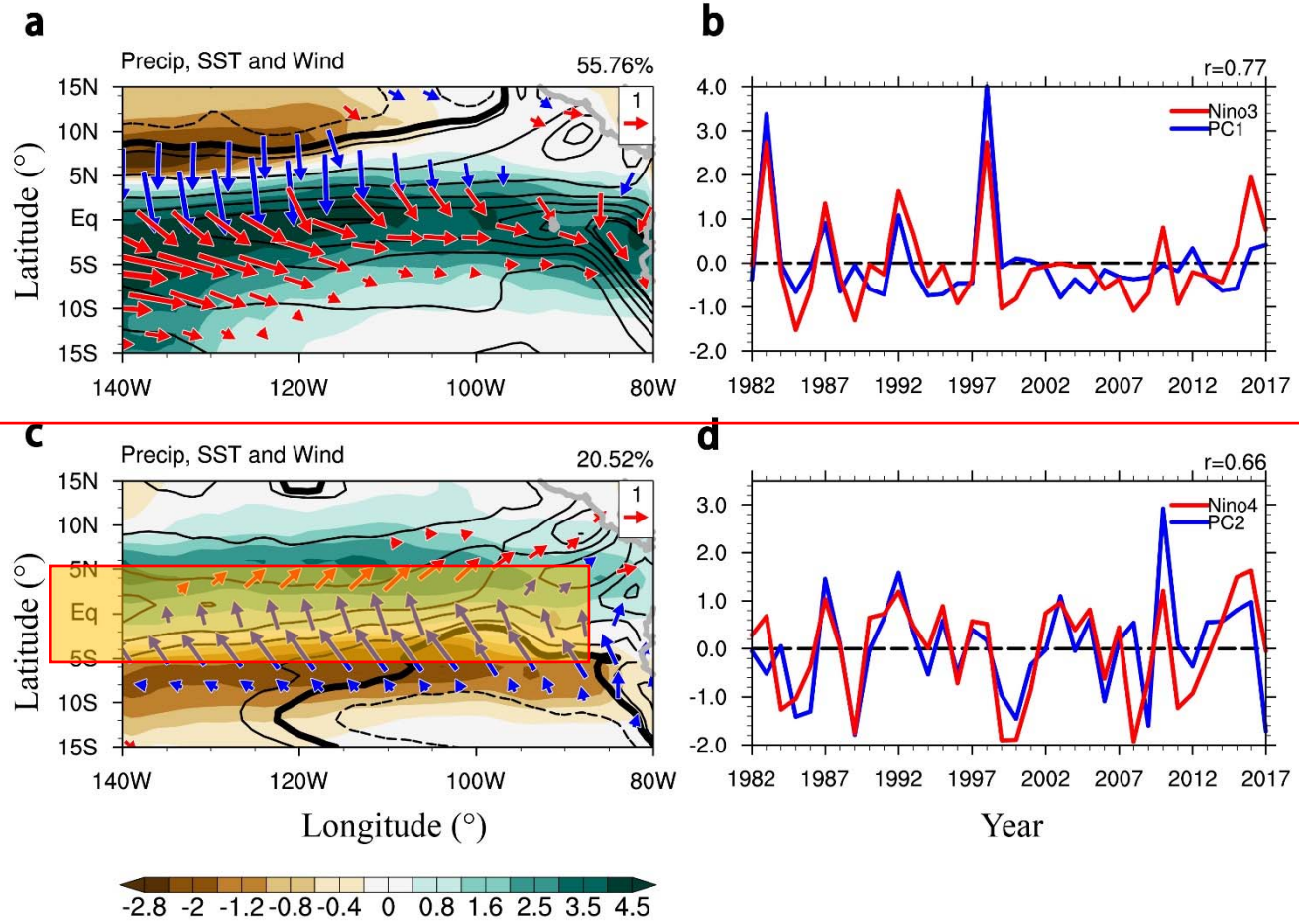
Observed Sea Surface Temperature Anomalies (°C)





7-day Average Centered on 22 March 2017

EOF of FMA rainfall



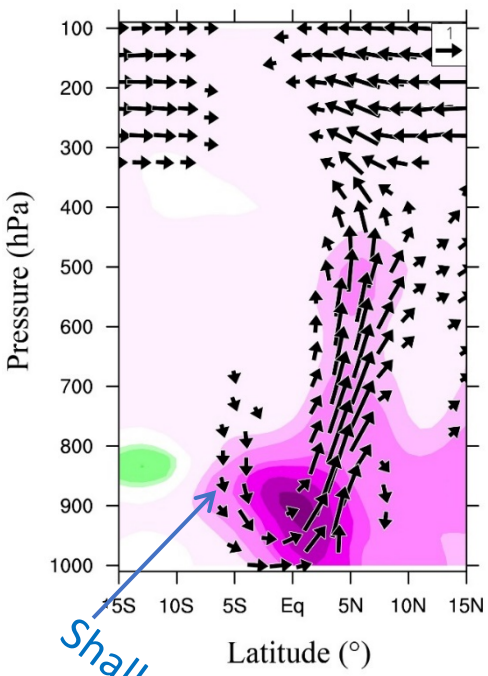
EOF1
→ Extreme El Nino
No La Nina

EOF2
→ Moderate/CP
El Nino & La Nina

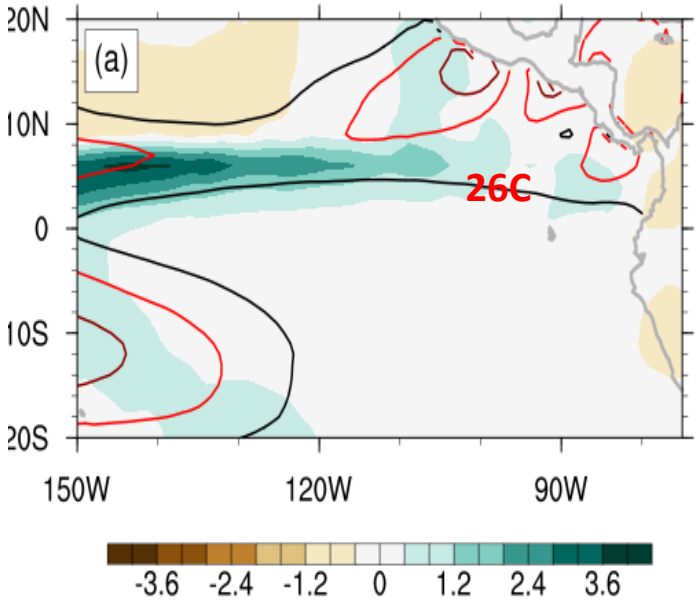
East Pac ITCZ dipole (EPID) w/ WES feedback

ENSO evolution: NDJ

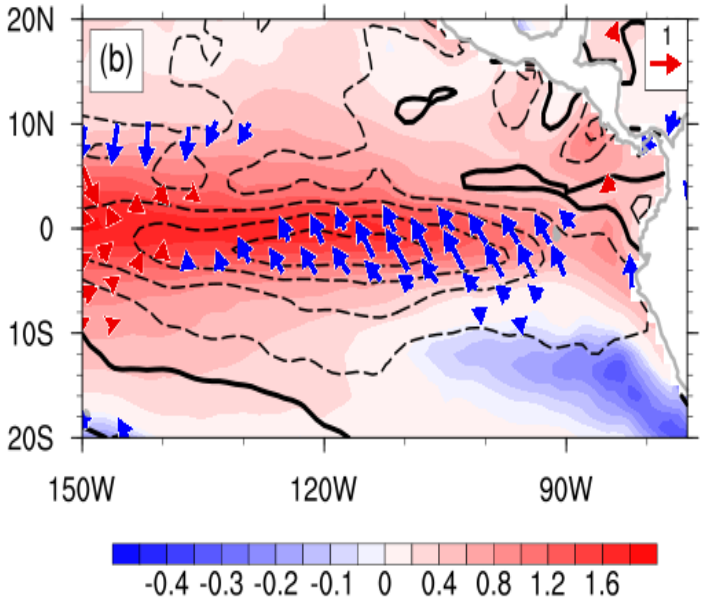
Humidity & circulation



Shallow circulation



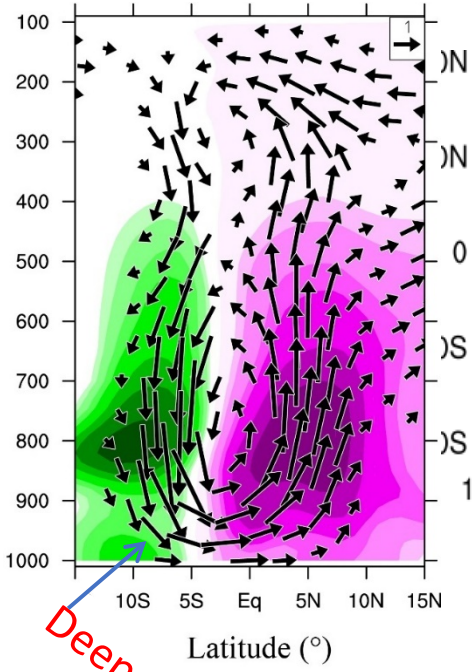
Precip (shaded) & mean SST (contours)



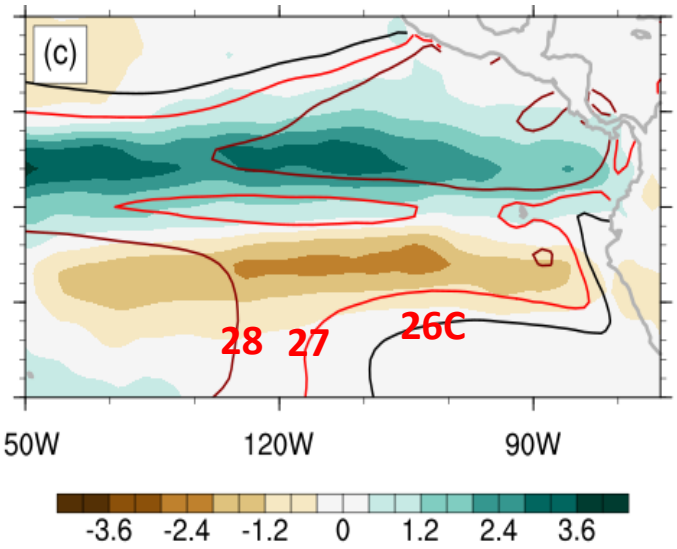
SST (shaded), sfc wind & latent heat flux (contours)

ENSO evolution: FMA

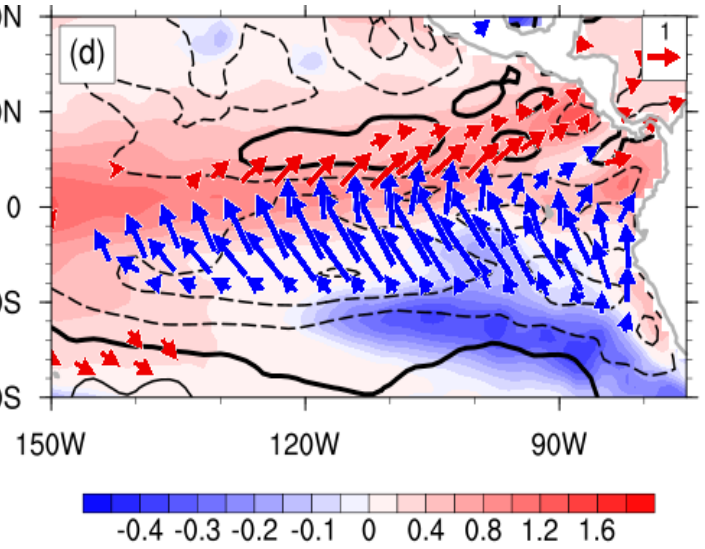
Humidity & circulation



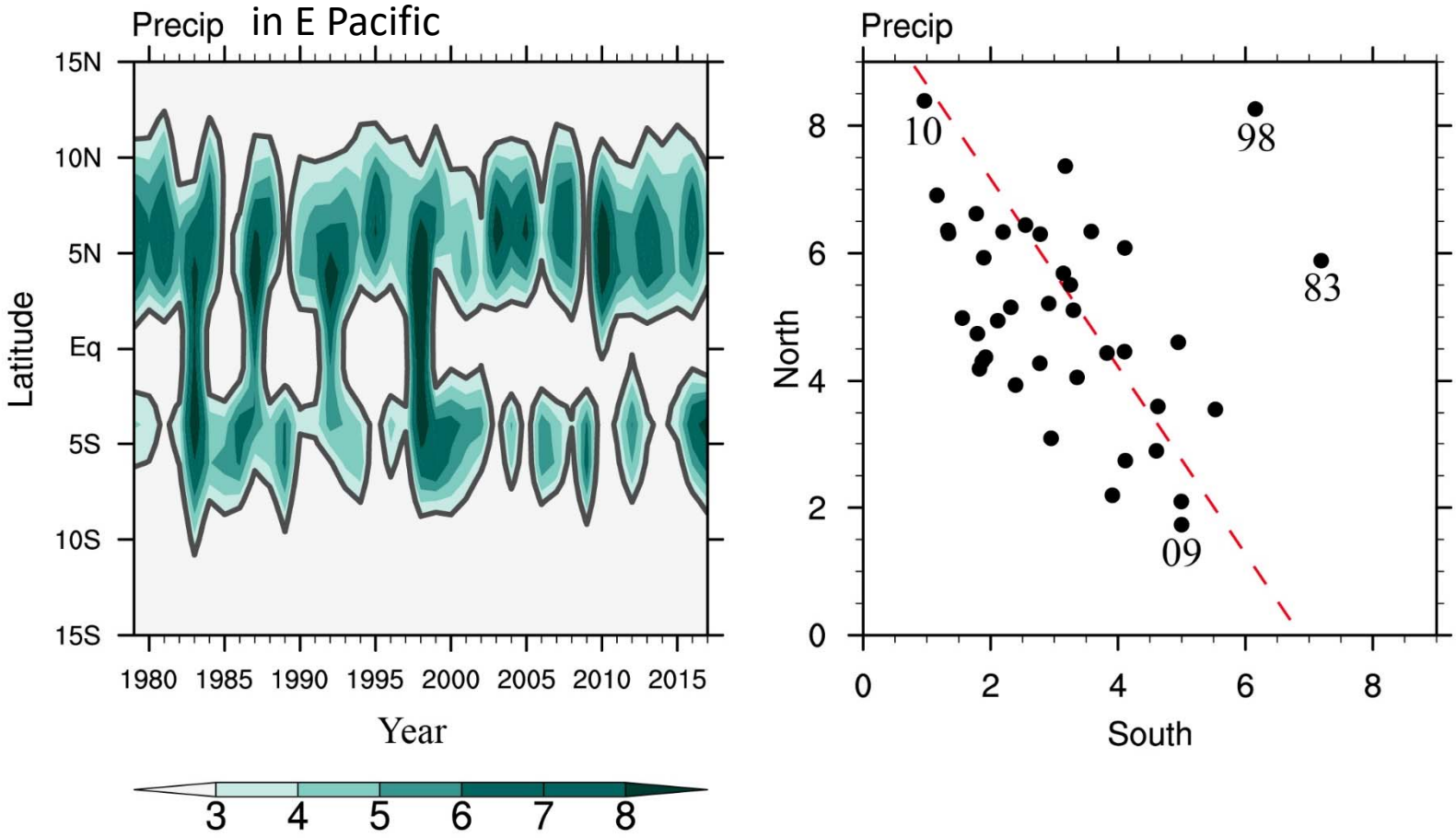
Deep circulation



Precip (shaded) & mean SST (contours)



SST (shaded), sfc wind & latent heat flux (contours)


Precip in E Pacific
15N
10N
5N
Eq
5S
10S
15S
Latitude
1980 1985 1990 1995 2000 2005 2010 2015
Year
3 4 5 6 7 8
Precip
10
98
83
09
North
South
0 2 4 6 8

Conclusions

- Eastern Pacific ITCZ dipole (EPID): a WES mode in FMA when the mean state is symmetric (and atmospheric feedback is strongest).
- Represents interannual variability in relative intensity of the double ITCZ.
- EPID is preceded by moderate ENSO and causes the rapid termination of moderate ENSO.
- Extreme El Nino decays slowly because of local Bjerkness feedback in the eastern Pacific, by causing deep convection there.

Xie, S.-P. et al., 2018: Eastern Pacific ITCZ dipole and ENSO diversity. *J. Climate*, 31, 4449