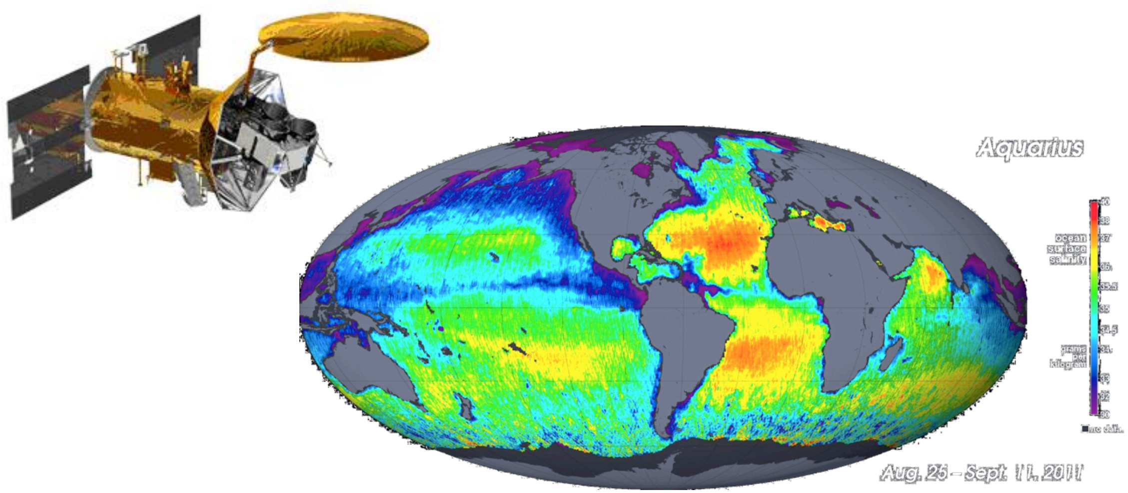
Where can the ocean be a rain gauge?

– Establishing a dynamic framework to implement the Ocean Rain-Gauge Concept

Lisan Yu

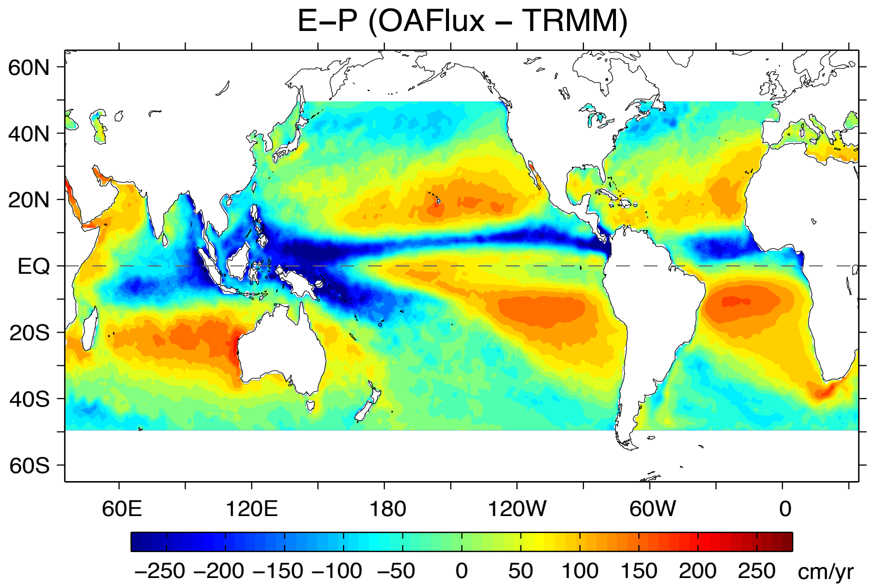
Woods Hole Oceanographic Institution

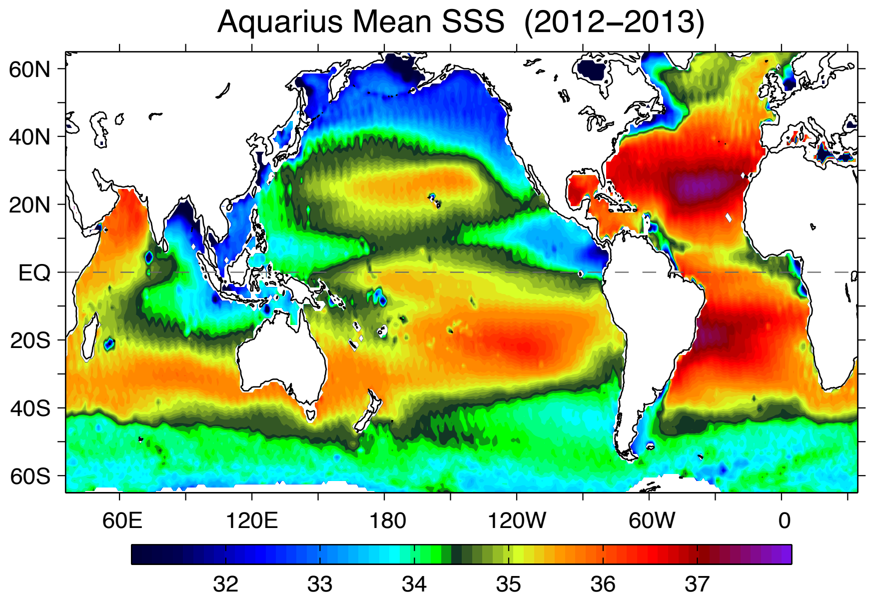


NASA Ocean Salinity Science Team Meeting
November 11-14, 2014. Seattle, WA.

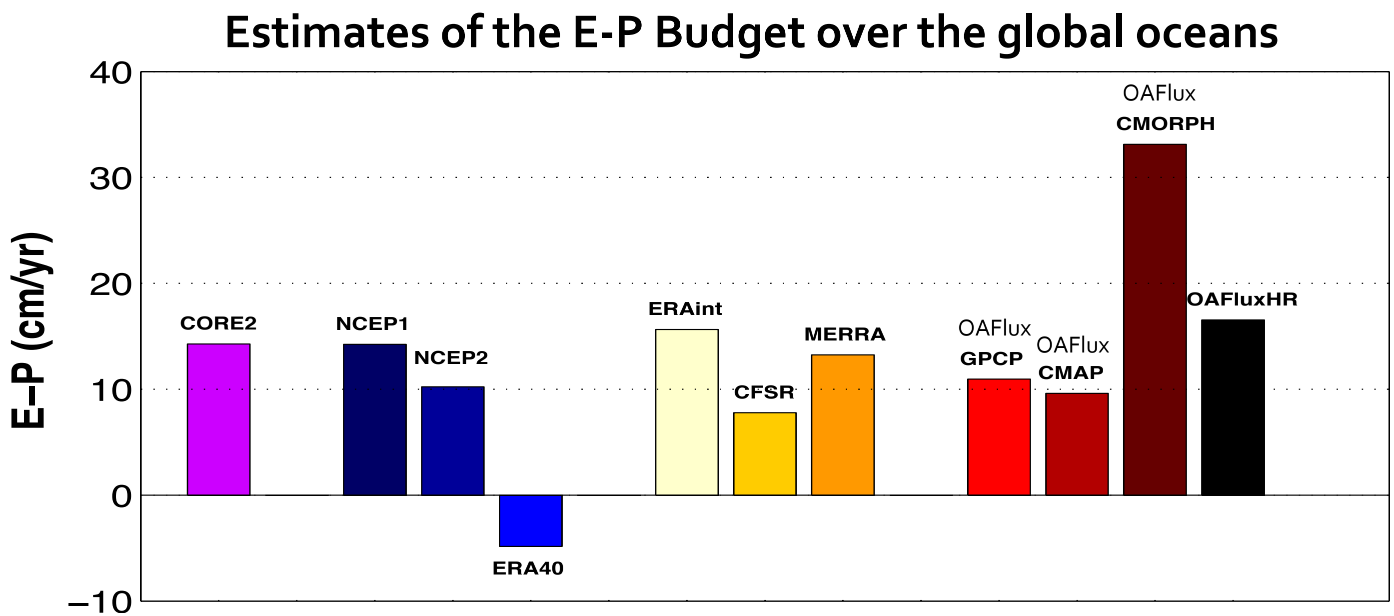
What is the ocean rain-gauge concept?

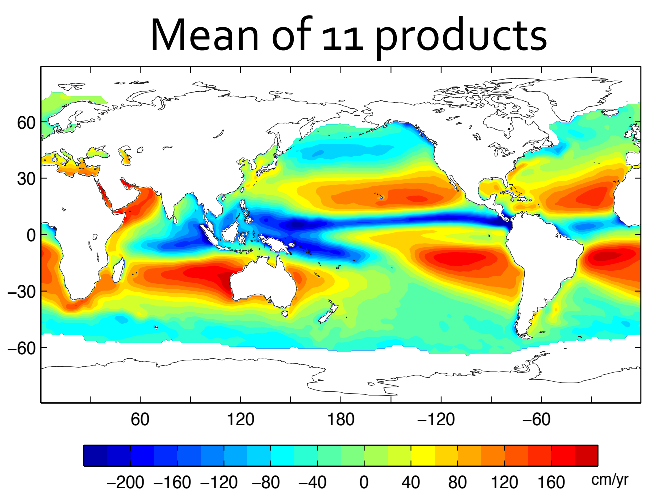
- The water cycle leaves an imprint on ocean salinity through evaporation and precipitation.
- Can ocean salinity help to detect the change in the water cycle and reduce the uncertainties in E-P?

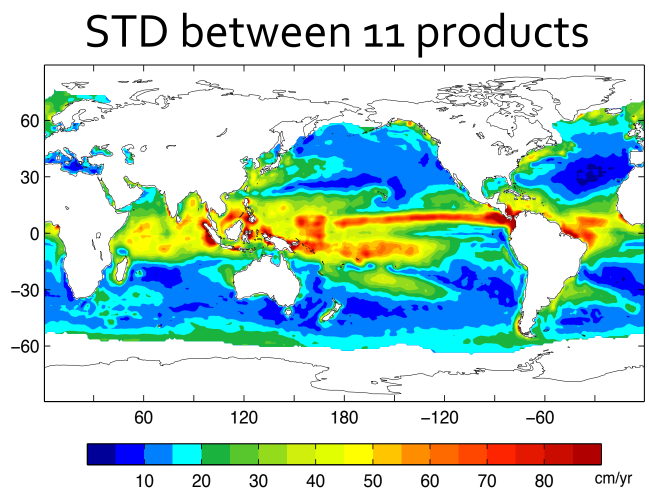




Do we need the ocean as a rain gauge?
- Uncertainties in E-P estimates are large



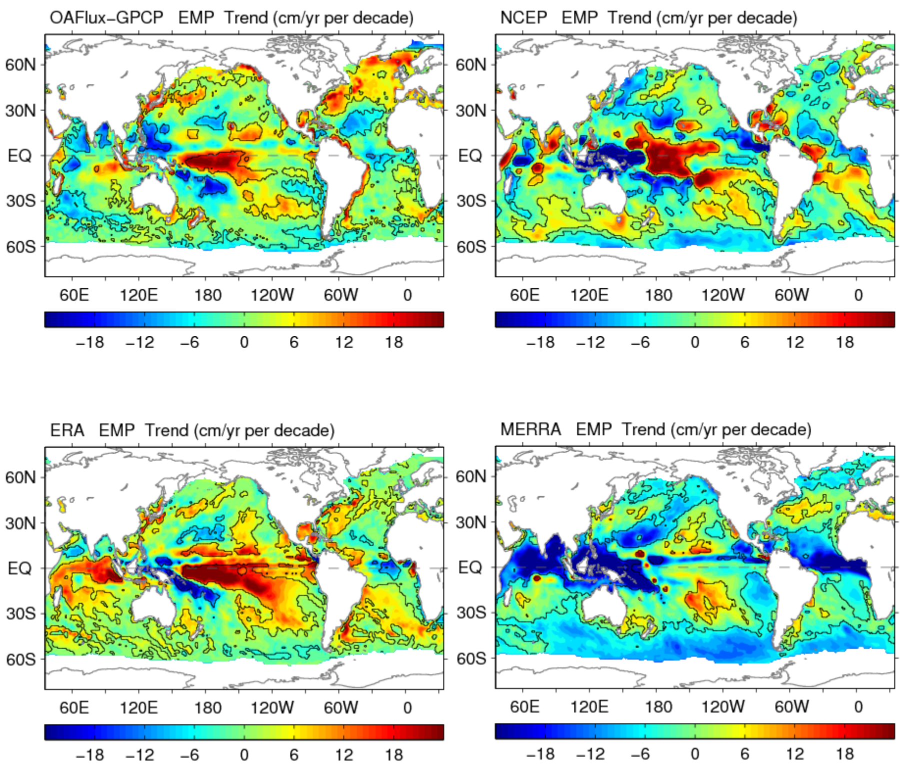




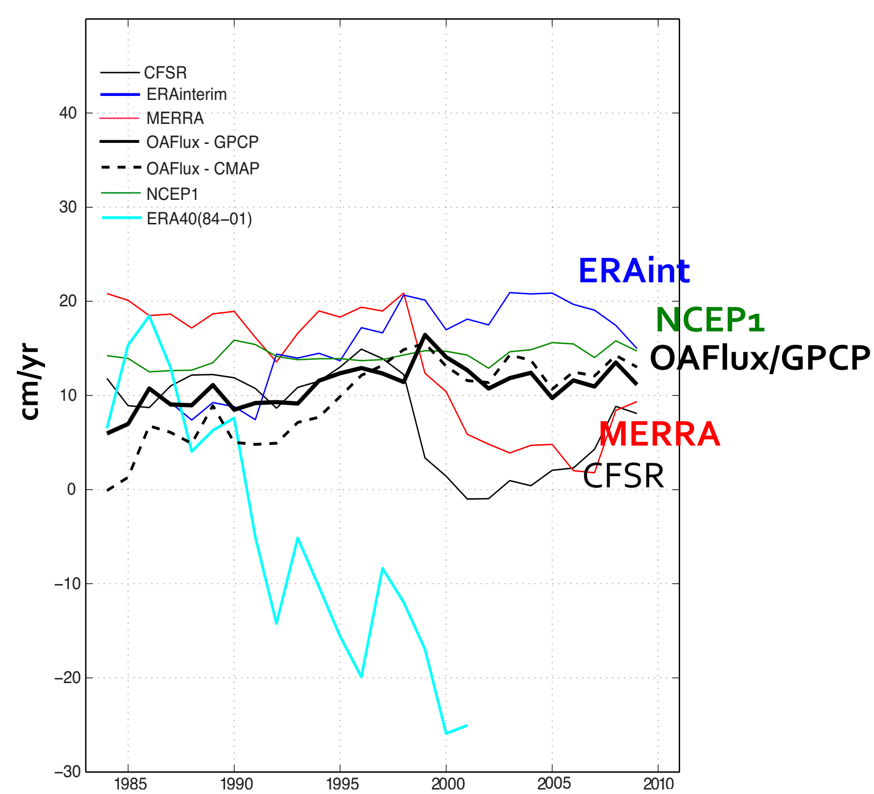
Major uncertainties of the E-P mean pattern reside in the ITCZ region.

Uncertainties in the estimates of E-P variability are also large.

Linear trends 1979-2012



E-P averaged over the global open ocean 1984 -

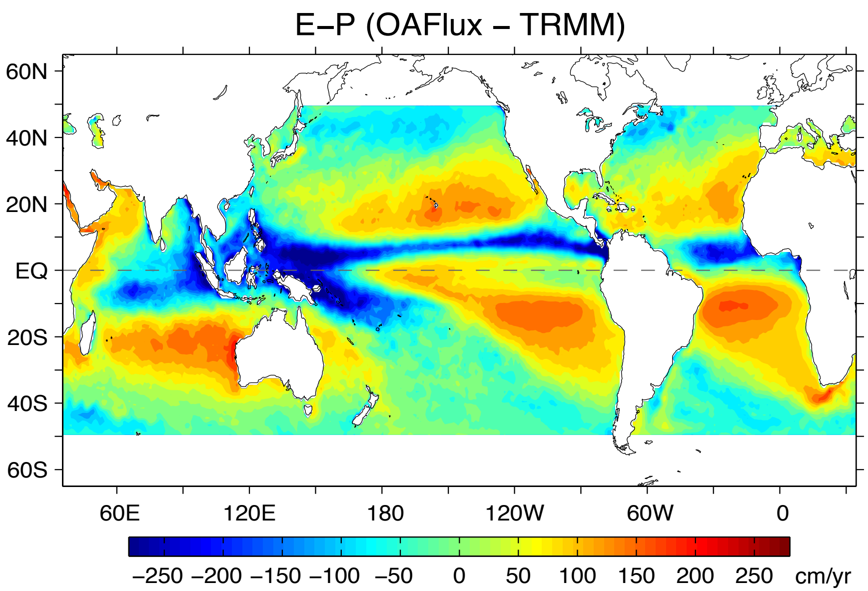


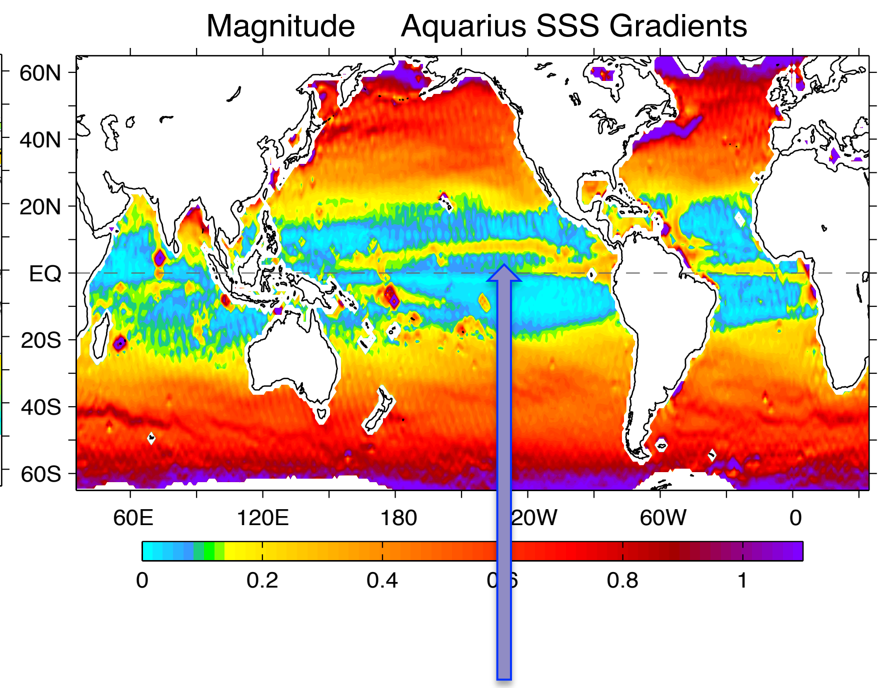
Major uncertainties in the pattern of the E-P variability reside also in the ITCZ region.

Can the ocean salinity detect the ITCZ rain variability?

The tropical rain region receives more than 450 cm of precipitation on the annual mean basis. Where are the ITCZ-induced low-salinity waters distributed ?

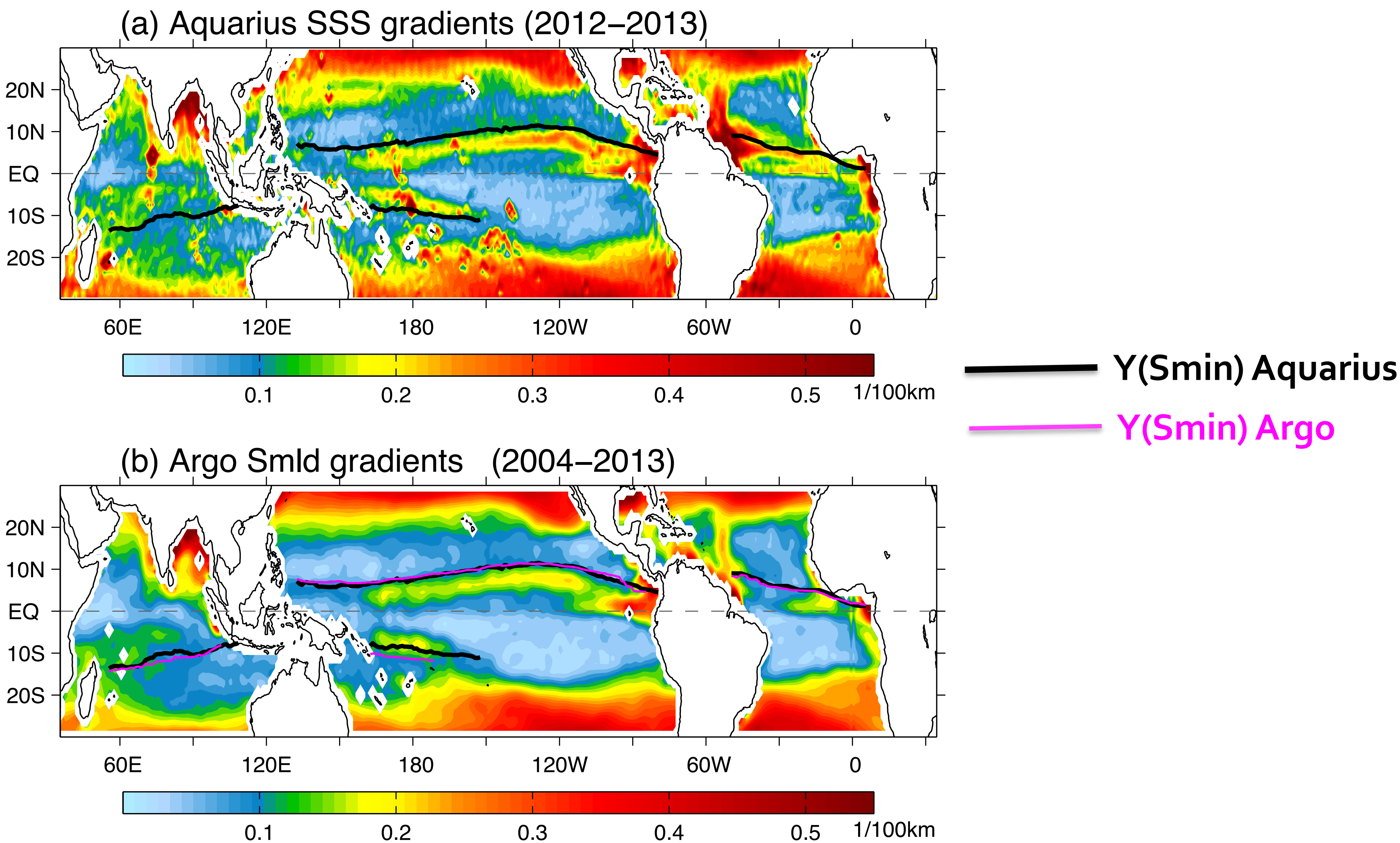
The ITCZ precipitation has a strong imprint on the tropical ocean: The surface-salinity front





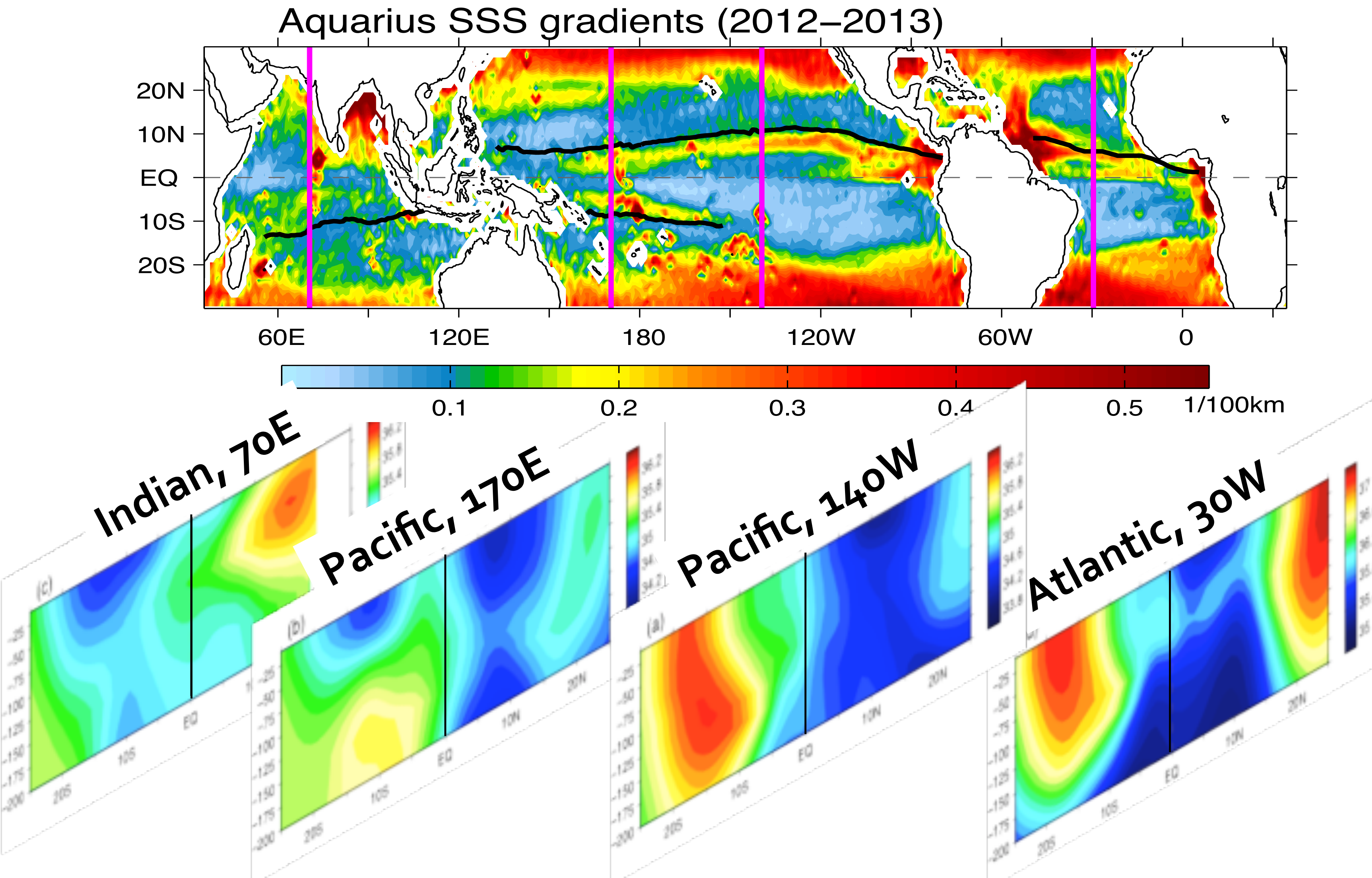
Salinity front is the location where water masses with two different salinities converge.

The salinity front vs. the location of Smin



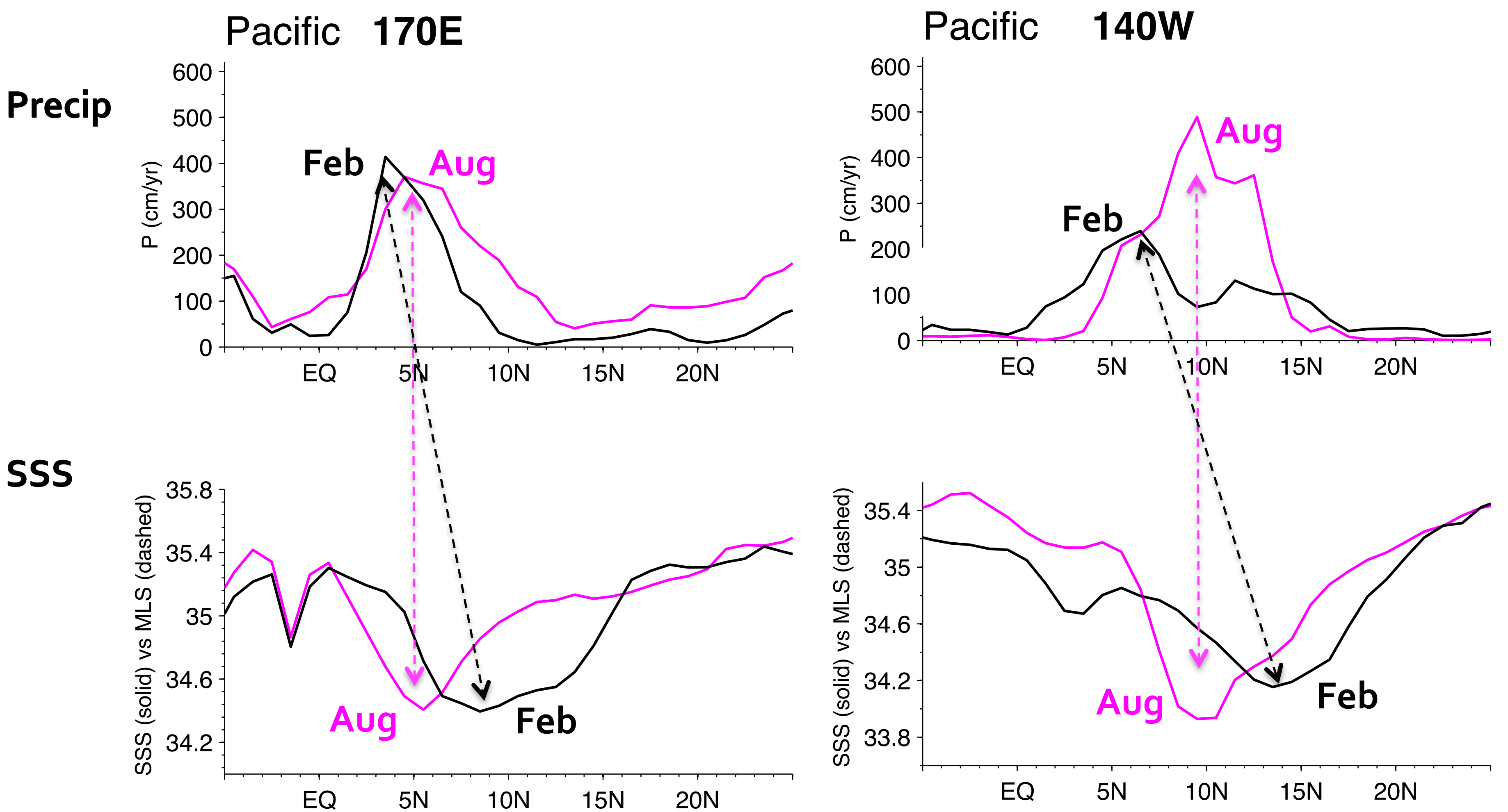
Smin is located on the poleward edge of the SSS front.
Although the magnitude is weaker, Argo has a smiliar depiction as Aquarius.

Aquarius and Argo: 3-D view of the SSS front



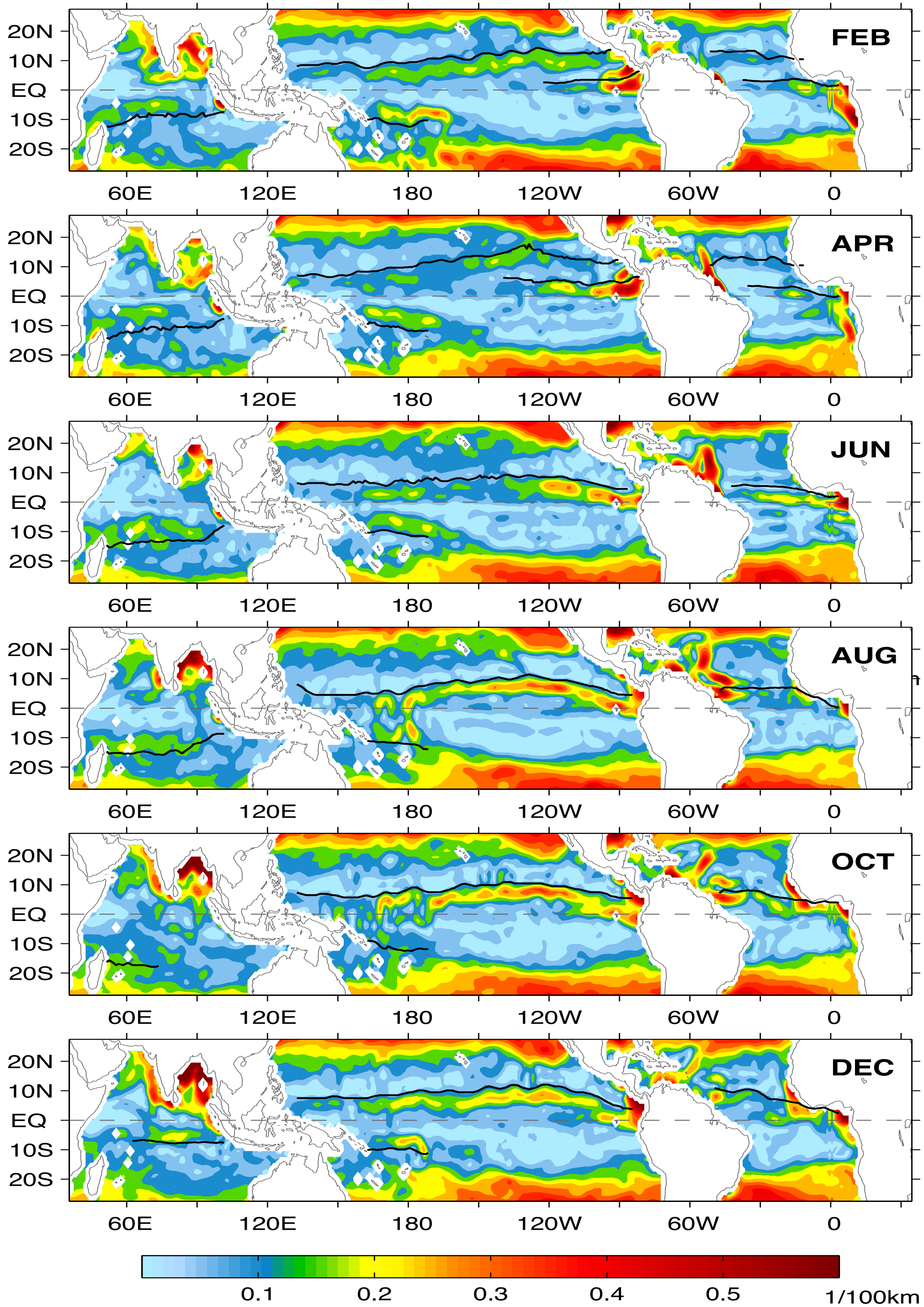
There exists a low-salinity zone under the SSS front!

Seasonal relationship between Smin and Pmax

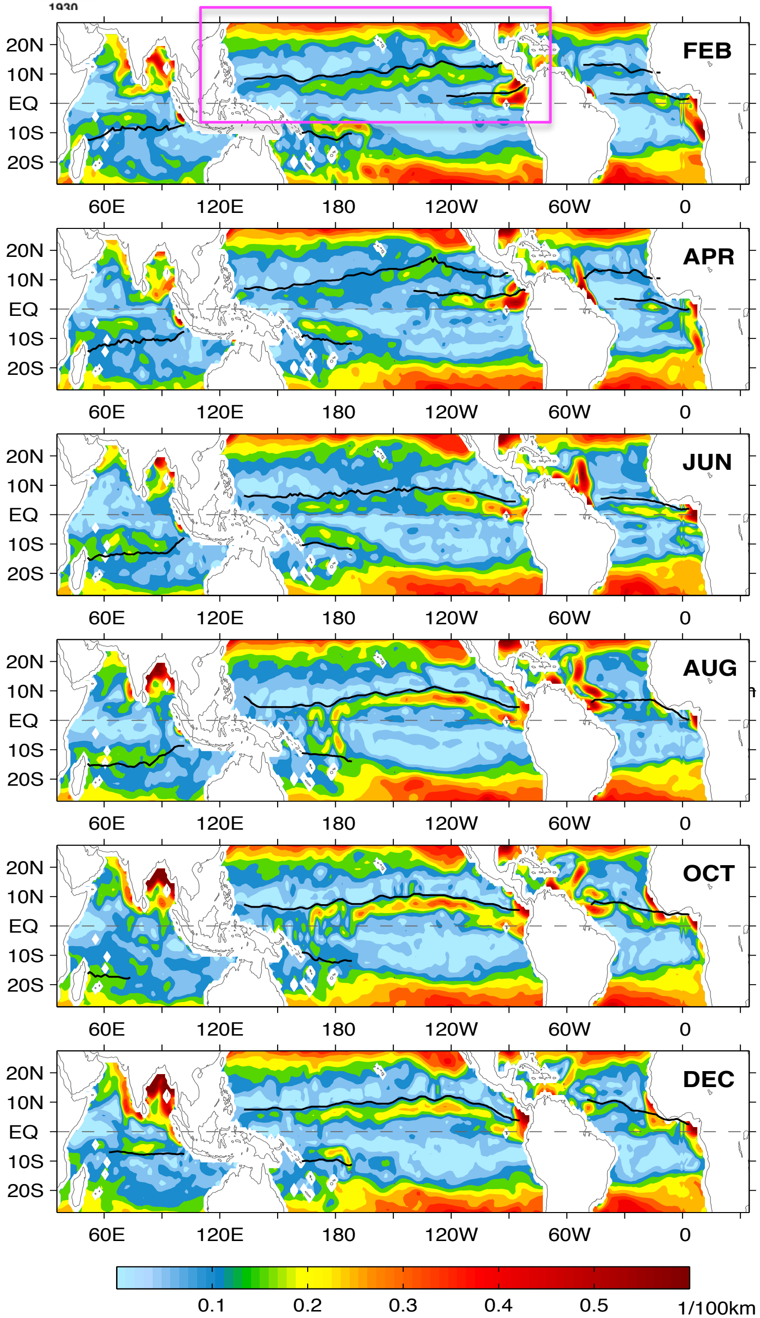


The ITCZ rain migrates poleward in the summer and equatorward in the summer,
The low-salinity zone moves, but the movement does **NOT** follow the ITCZ.

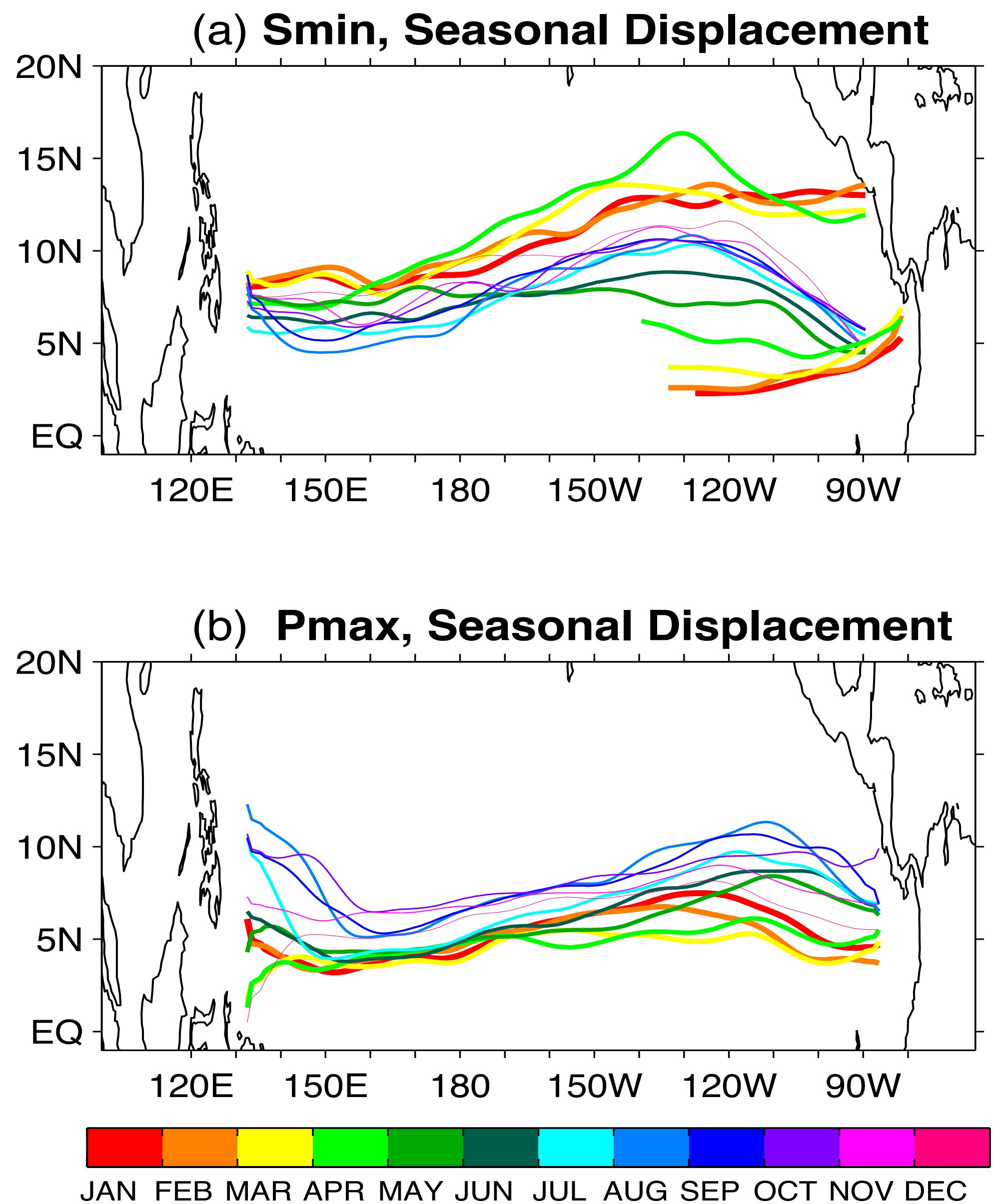
Tracking the seasonal movement of Smin & the SSS front



The seasonal movement of Smin and Pmax

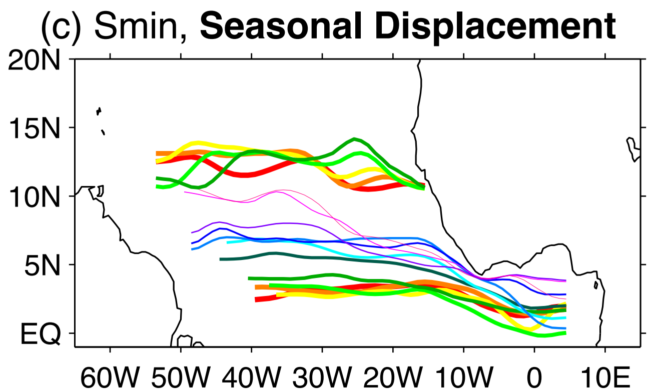


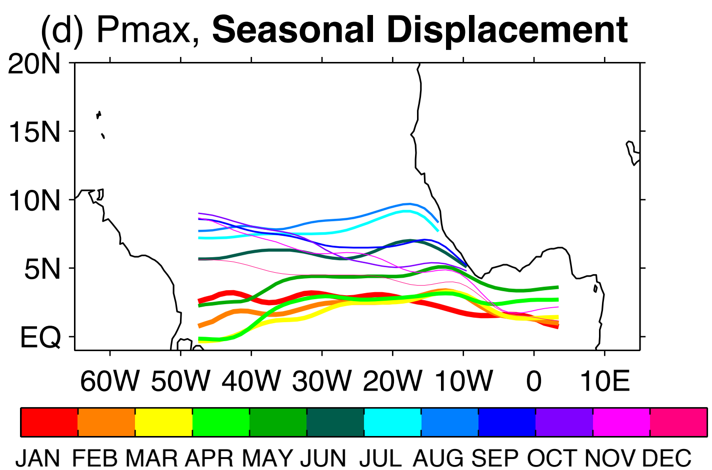
Tropical North Pacific



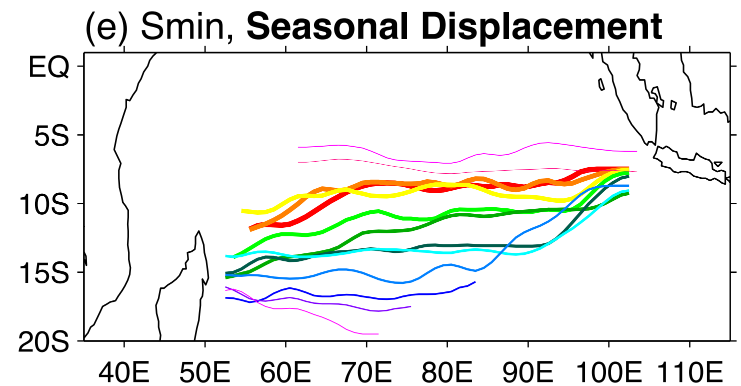
Smin shifts poleward once generated near the equator, unlike Pmax that migrates north- and southward with season.

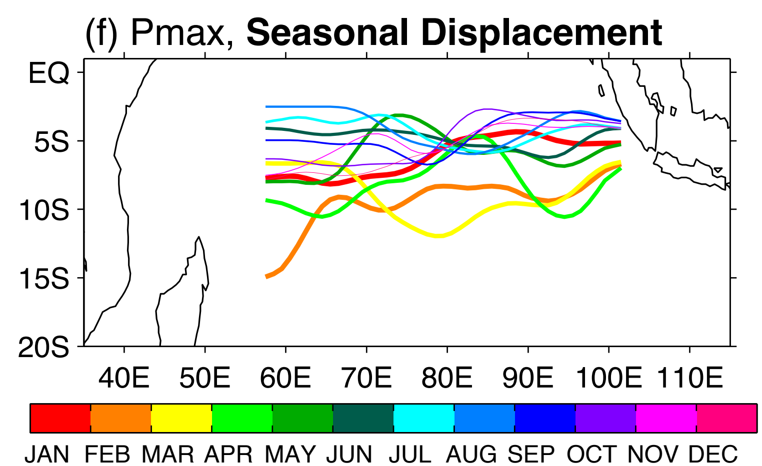
Tropical North Atlantic



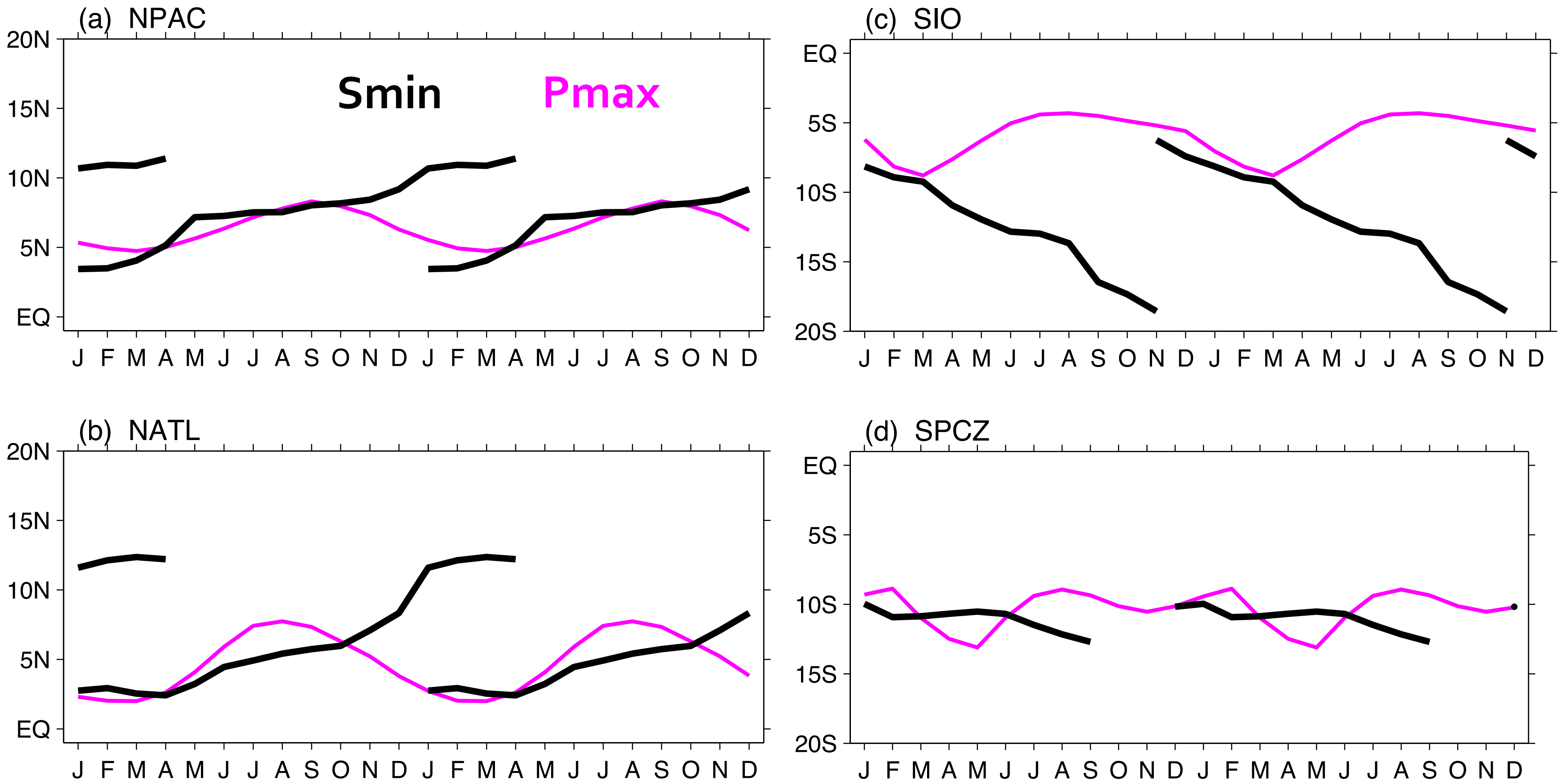


Tropical South Indian Ocean

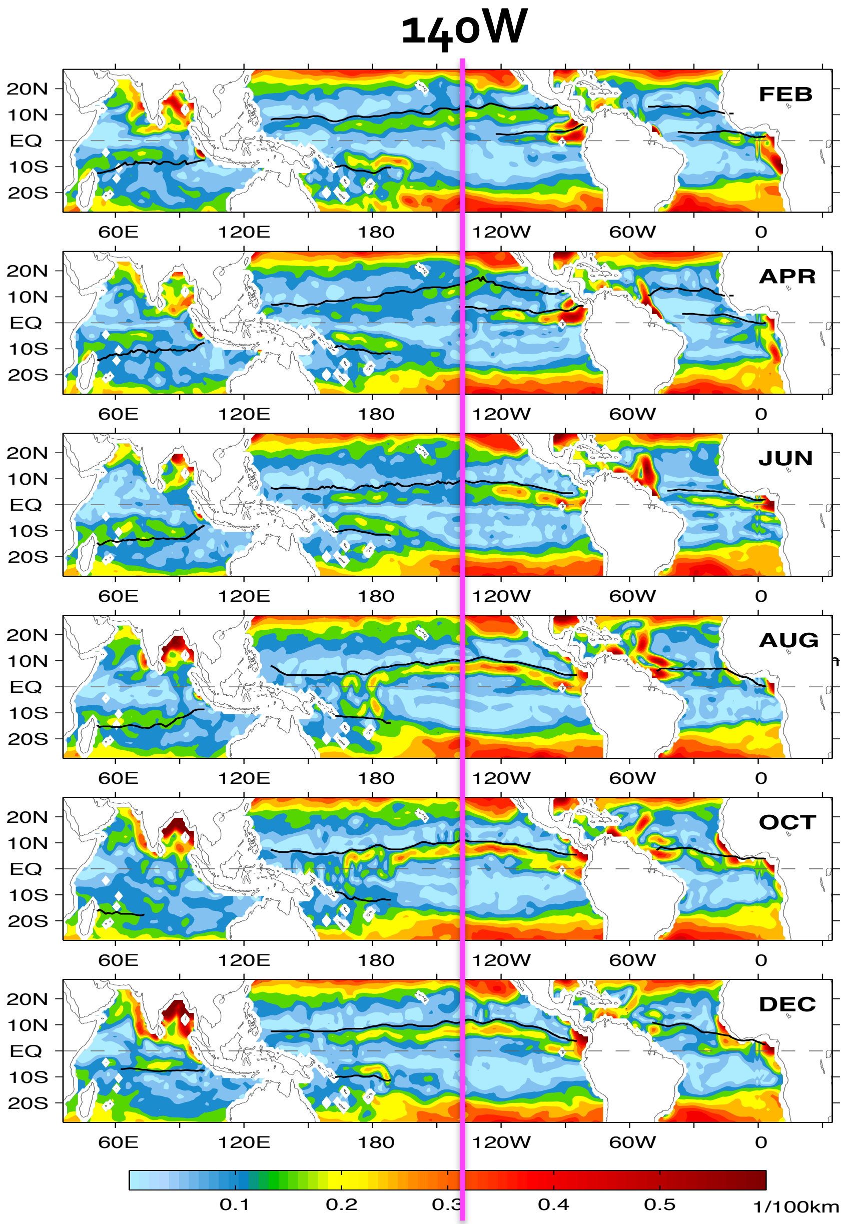


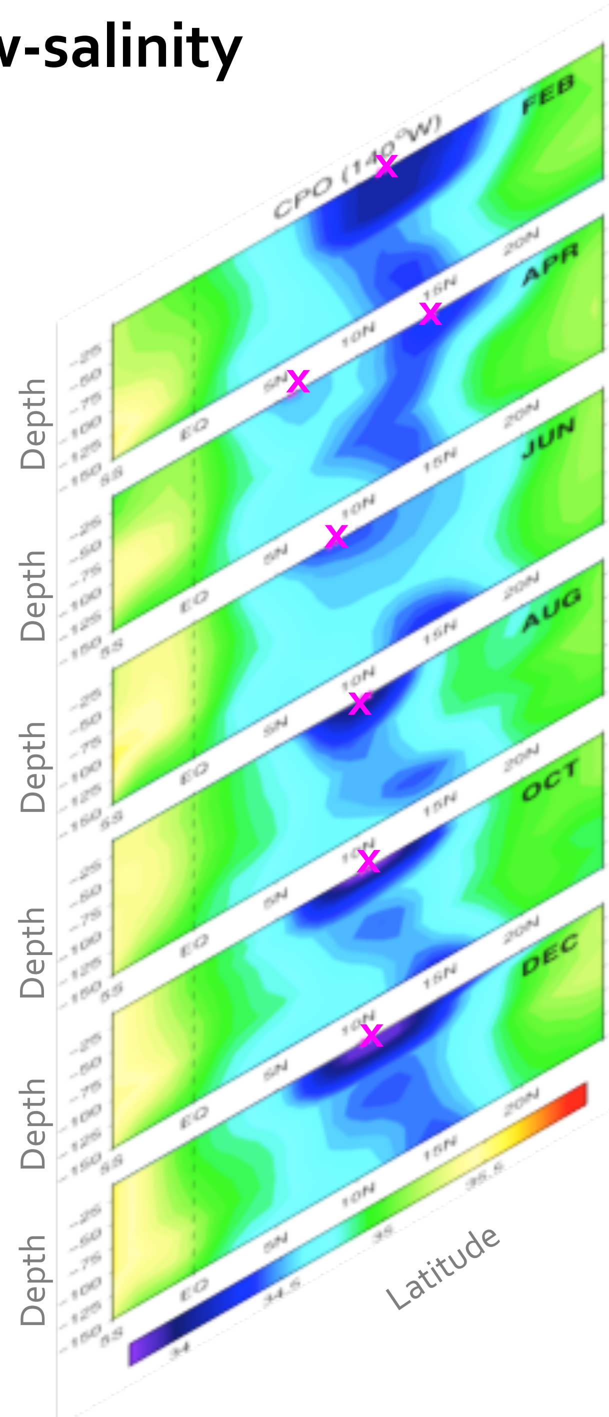


The ocean counterpart of the ITCZ: poleward propagation



Can Argo capture the two low-salinity zones in the subsurface? Yes.



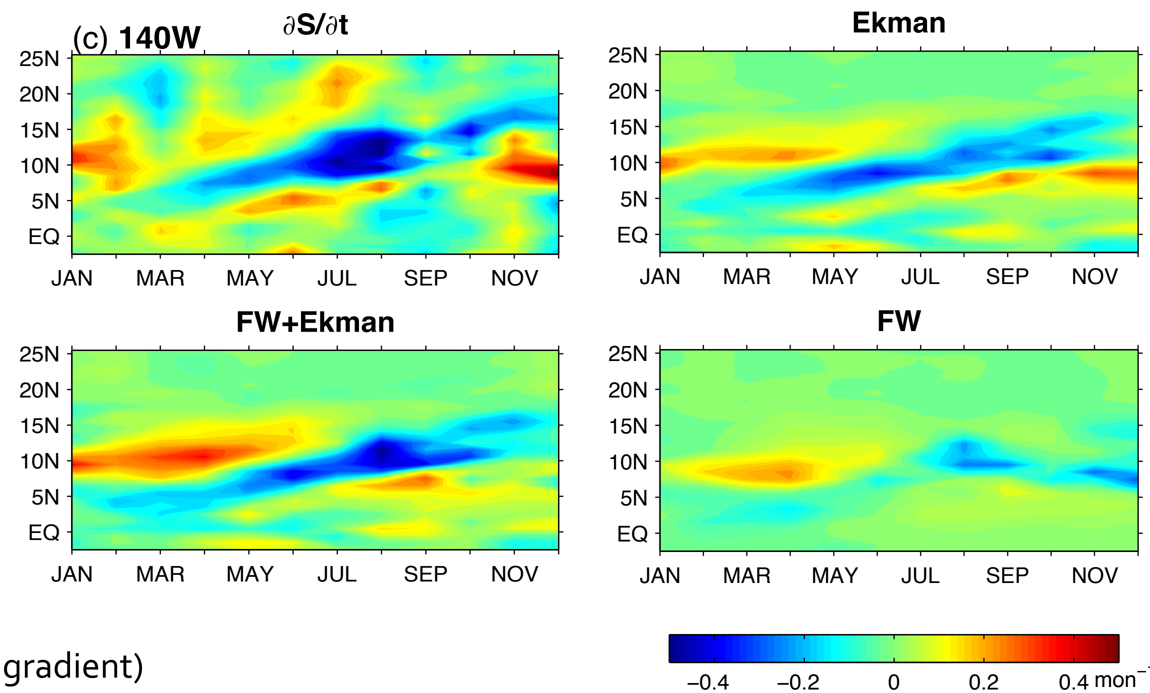


2 Smins in April

What causes the poelward shift of the low-salinity zones? - the Ekman salt transport

Salt budget equation:

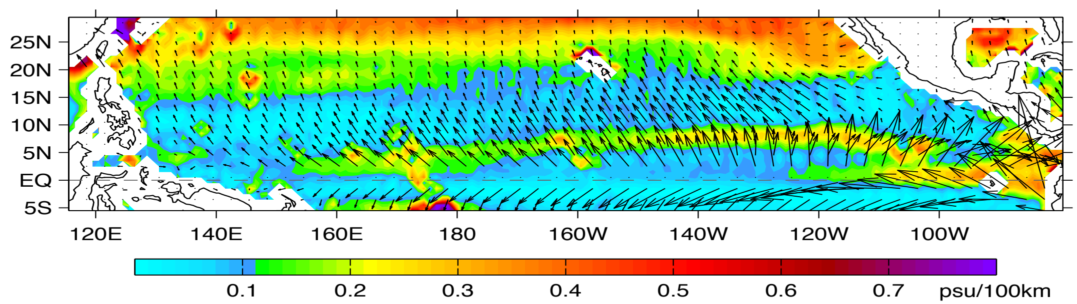
$$\frac{\partial S'}{\partial t} \approx \frac{S_0(E'-P')}{\bar{h}} - \bar{\mathbf{U}}_{Ek}\cdot\nabla S' - \bar{\mathbf{U}}_{Geo}\cdot\nabla S' - \mathbf{U}'_{Ek}\cdot\nabla\bar{S} - \mathbf{U}'_{Geo}\cdot\nabla\bar{S} - \frac{(\Gamma(w_e)(S-S_b))'}{\bar{h}} + \kappa\nabla^2 S'$$



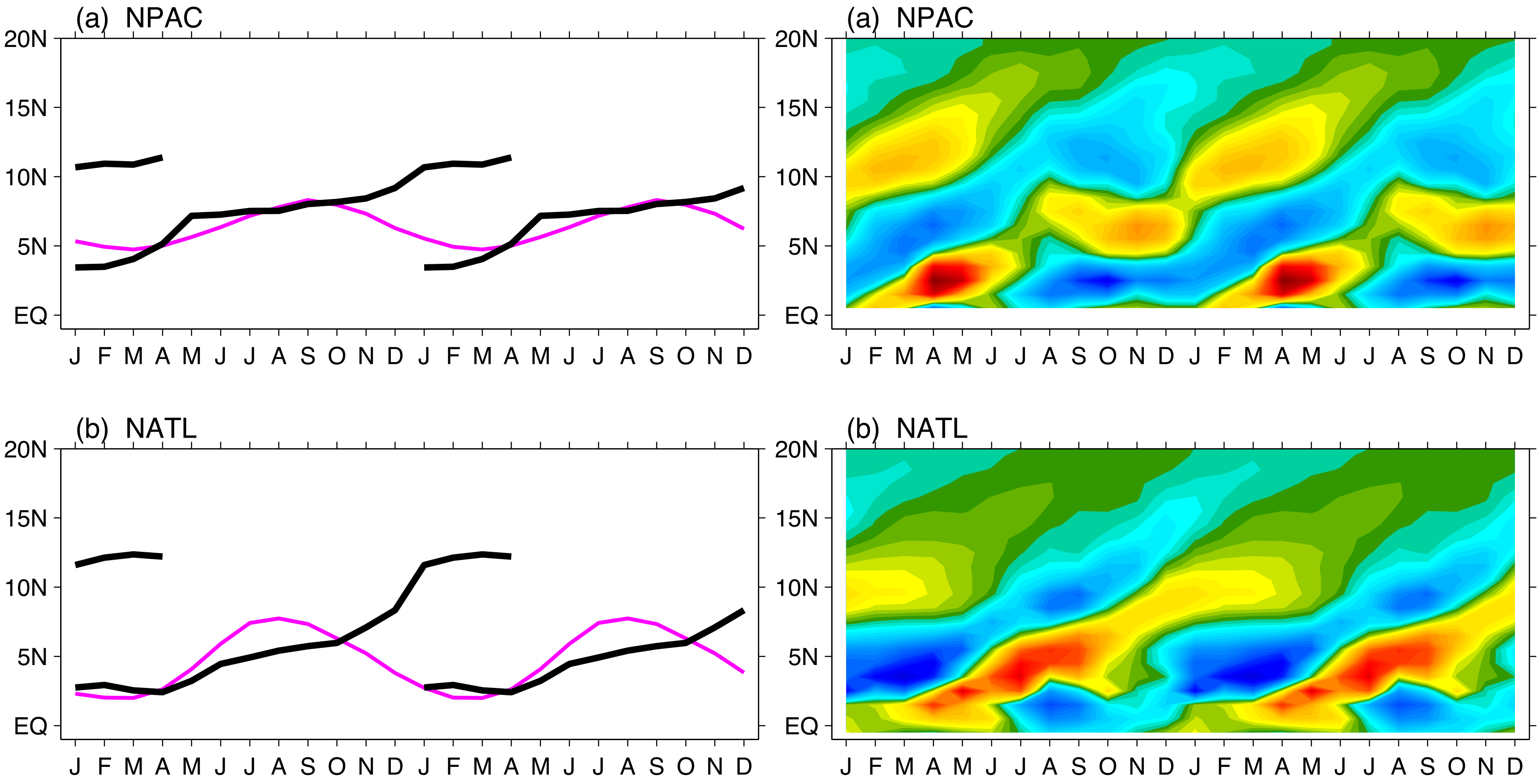
Wind-driven currents:

$$U_{EK} = \frac{\tau \times k}{\rho f}$$

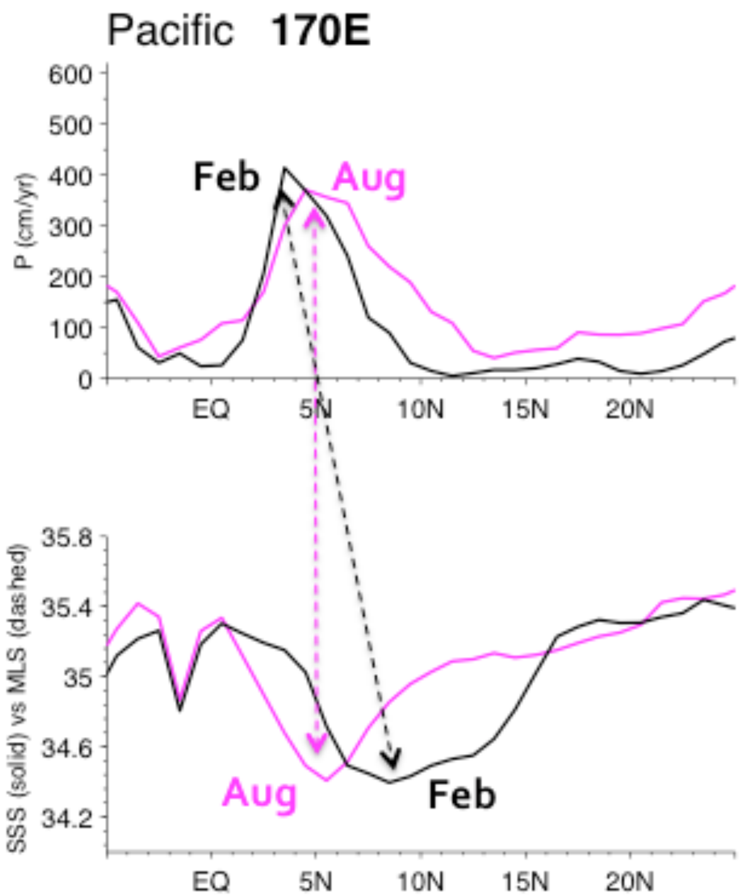
Ekman transport (background: SSS gradient)

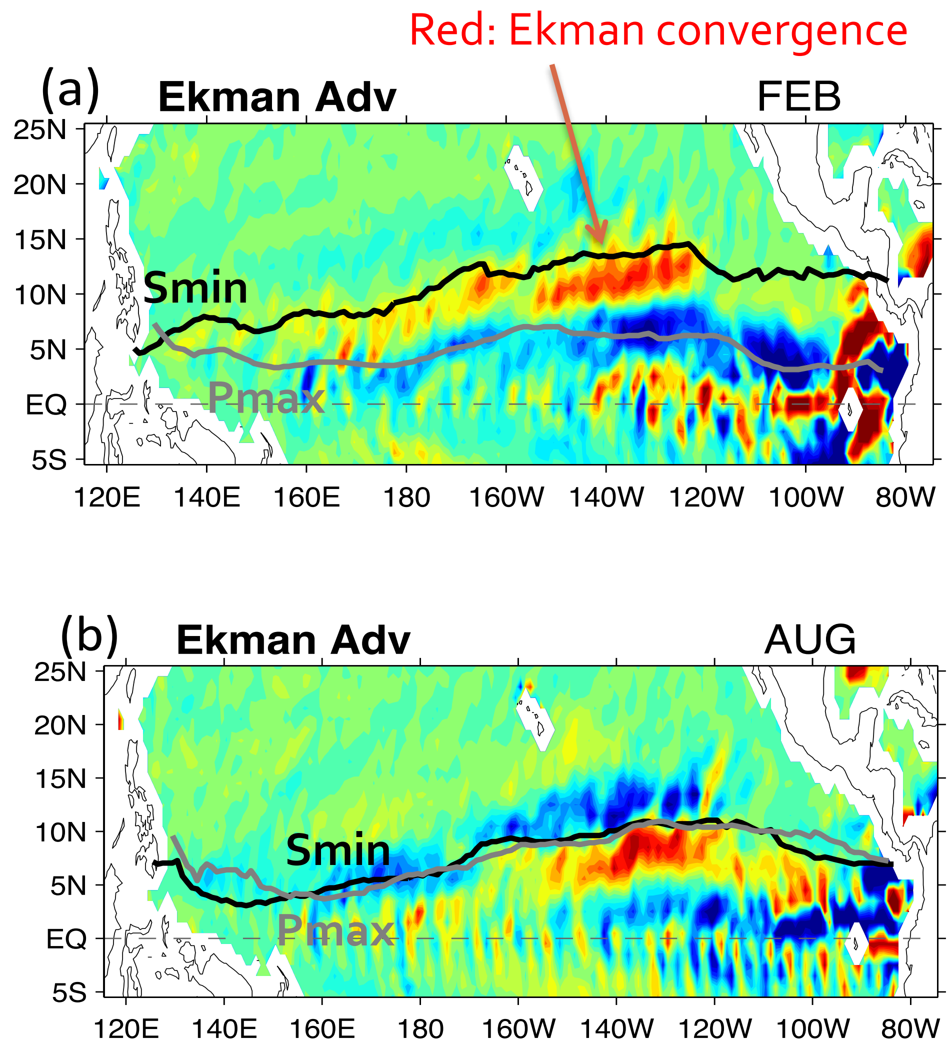


Zonal averages of the Ekman salt transport



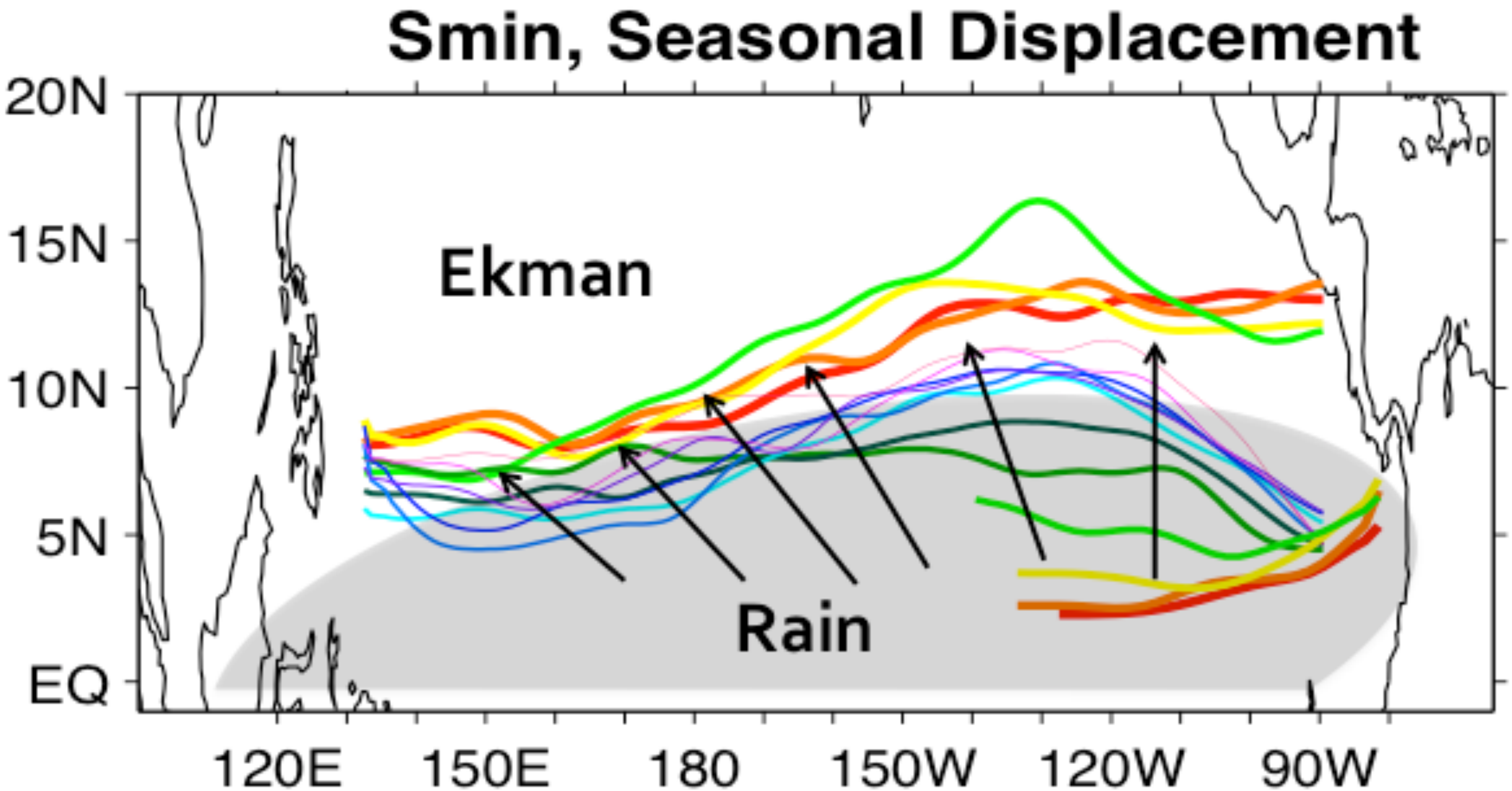
Ekman salt transport versus Freshwater flux





Smin is located on the poleward edge of the Ekman convergence zone. The low-salinity zone is a low-salinity convergence zone.

Ekman Dynamics dictate the relationship between ocean low-salinity and the ITCZ rain

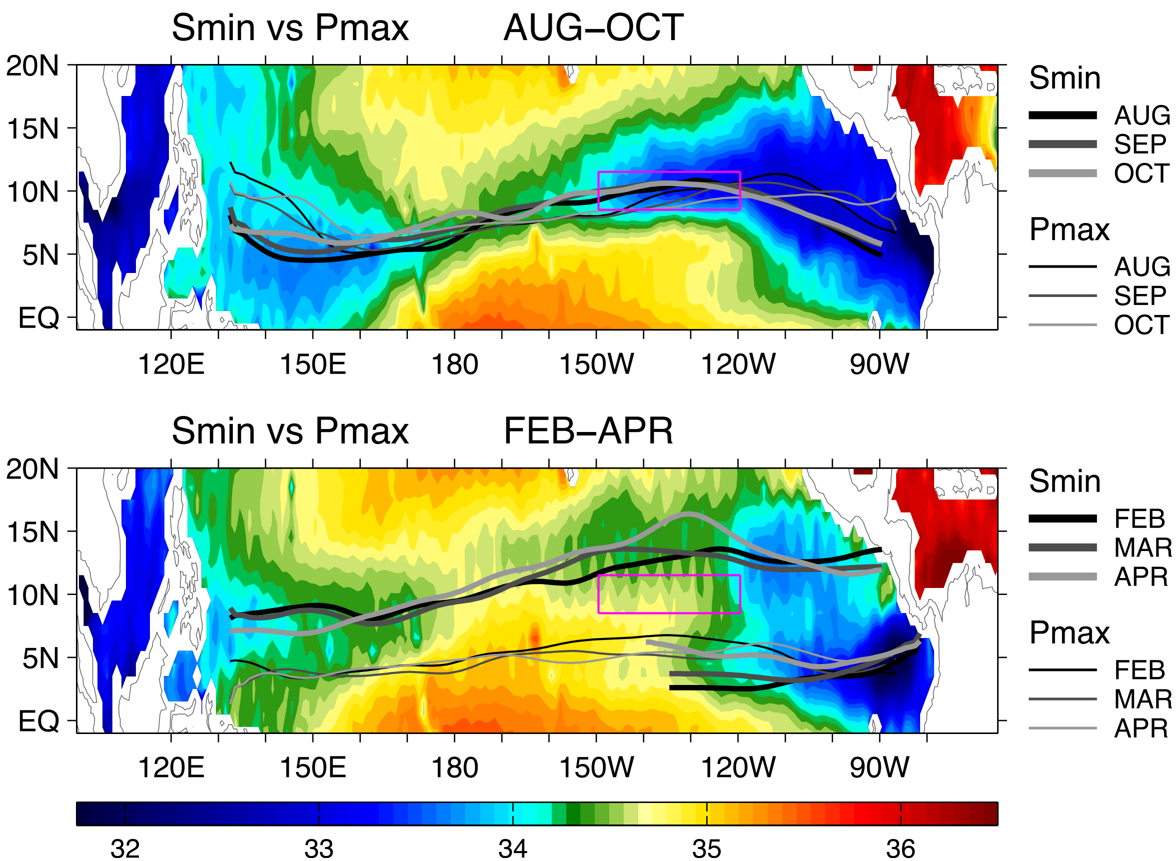


The fresher water formed under the ITCZ rainfall is carried away by Ekman transport and converged into subsurface along the Ekman convergence zone.

Establishing a SSS window to the tropical water cycle

The low-salinity zone carries the information of the ITCZ rain, but the zone moves.

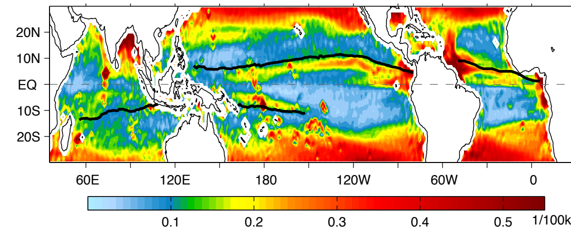
Approaches for linking SSS to the ITCZ freshwater input:
(i) Follow the zone. (ii) Fix the test locations.



Summary and conclusion (1)

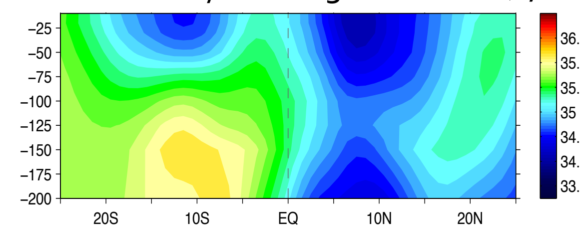
- The raindrops on the ocean surface do not stay locally. This study focuses on the basin-wide adjustment of the low-salinity waters on seasonal timescales.

Tropical SSS fronts and Smin location



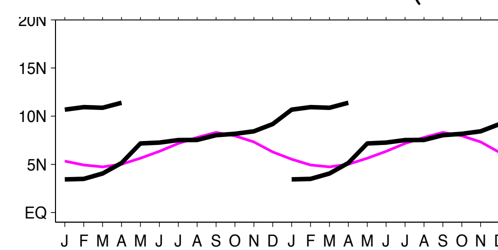
- The prominent tropical SSS fronts observed by Aquarius and Argo observations are the surface manifestation of **the low-salinity convergence zone.**

Low-salinity convergence zone (170E)



- The low-salinity zone is sourced from the ITCZ rain, but its formation and movement are controlled by the Ekman dynamics. Once the fresher surface waters are formed under the ITCZ rainfall at near-equatorial latitudes, they carried away by Ekman transport and converged into subsurface along the Ekman convergence zone.

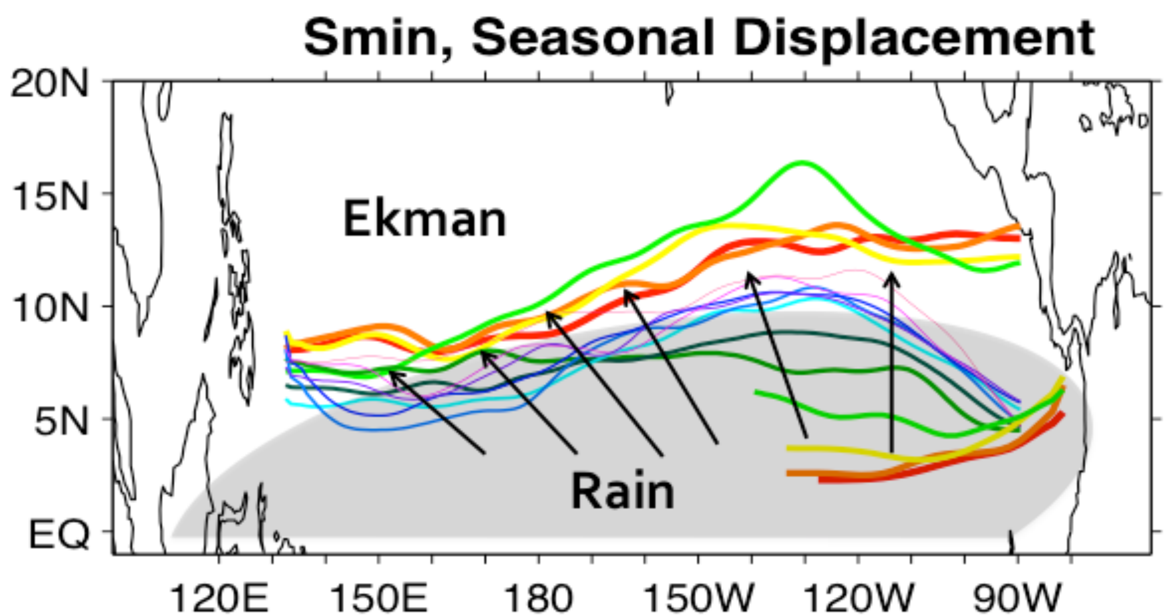
Poleward shift of Smin (black)



- The oceanic convergence zones differ from the atmospheric convergence zones in that the former shifts poleward monotonically, while the latter migrates north- and southward with the season.

Summary and conclusion (2)

- The important finding of the study is that **Ekman dynamics dictates the relationship between ocean salinity and the tropical water cycle.** The implementation of the ocean rain gauge requires a good understanding of the role of ocean dynamic processes.
- Work is underway to design a SSS window to link to the ITCZ freshwater variability by best using the given dynamic framework.



We thank the support of the NASA Ocean Salinity Science Team.

The following datasets are used in the study:

- **Aquarius CAP Level 3, v3.0** (S. Yueh)
- **Argo subsurface from JAMSTEC** (Hosoda et al. 2008)
- **TRMM Precipitation** (Hoffman et al. 2007)
- **OAFlux evaporation** (Yu et al. 2008)
- **OAFlux vector winds** (Yu and Jin 2014 a&b)

Materials in this presentation are developed from the following work:

Yu, L. (2014), The ocean counterpart of the ITCZ: The intertropical low-salinity convergence zone. To be submitted.

Yu, L. (2014), Coherent Evidence from Aquarius and Argo for the Existence of a Shallow Low-Salinity Convergence Zone beneath the Pacific ITCZ. *J. Geophys. Res.*, **119**, doi: 10.1002/2014JC010030.

Yu, L. (2011), A global relationship between the ocean water cycle and near-surface salinity, *J. Geophys. Res.*, **116**, C10025, doi:10.1029/2010JC006937.

Yu, L. (2010), On surface salinity skin effect under evaporation conditions and implications for remote sensing of ocean salinity. *J. Phys. Oceanogr*. **40**, 85-102.