Variations of the tropical Atlantic and Pacific SSS minimum zones and their relations to the ITCZ/SPCZ rain bands (1979-2009)

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Sea Surface Salinity is an Essential Climate Variable (**SSS is an ECV**)

- **Role in changing:**
  - Sea water density (geostrophic current, subduction)
  - Ocean Mixed Layer & Barrier Layer Depths

- **Useful to improve the understanding of:**
  - River discharges
  - Barrier layer formation
  - Climate modes and predictions (ENSO, ....)
  - Sea level changes (halosteric contribution)
  - Long-term marine water cycle changes ....
Motivation: The South Pacific SSS Maximum (2/3)

Mean SSS, mean E-P, and SSS trends

- SSS decreases where P dominates
- SSS increases where E dominates
  ‘wet-get-wetter’, ‘dry-get-drier’

AND

- Low frequency migration of:
  - low SSS cores
  - high SSS cores

SSS change: 2008 minus 1950 derived from the linear trend.

(Adapted from Rhein et al., IPCC, AR5, chap. 3: Observations: Ocean)
Two gridded fields of SSS
- Atlantic ocean: Reverdin et al. (2009)
- Pacific ocean: Delcroix et al. (2011)
- Based on:
  - Voluntary Observing Ships (SNO-SSS)
  - TAO, TRITON, PIRATA moorings
  - Argo floats
  - Cruise-derived CTDs

E, P, SST and Wind
- E : OAFlux (Yu et al., 2008)
- P : GPCP (Adler et al., 2003)
- SST: TropFlux (Praveen Kumar et al., 2012)
- Wind: ECMWF-ERAi (Dee et al., 2011)

Climate mode indices
- AMD: from Servain et al. (1999)
Outline of the SSS (& E-P) data analysis

• Gridded fields in SSS(x, y, t): 1°x1°x1 month
• Common period = 1979-2009

Then:
1. Latitudes of the minimum SSS: LatMinSSS(x,t) in 0-15°N for the ITCZ and 0°-20°S for the SPCZ,
2. Climatological mean, standard deviation, PDF,
3. EOF analysis on ‘high’ frequency (T≤12 months) signal, to analyse the seasonal variability,
4. EOF analysis on ‘low’ frequency (T>12 months) signal, to analyse the interannual variability,
5. Focus on ‘long-term’ trend
Mean Latitudes (and std) of the SSS & E-P minima (P max)

Pacific ITCZ  Atlantic ITCZ  Pacific SPCZ

<1979-2009>
Seasonal changes in the latitude of the SSS & E-P minima (P max)

EOF#1 (70 to 80% of the ‘high frequency’ variance)

Pacific ITCZ

Atlantic ITCZ

Pacific SPCZ
Interannual changes in the latitude of the SSS & E-P minima (P max)

EOF#1 (70 to 90% of the ‘low frequency’ variance)

- Pacific ITCZ
- Atlantic ITCZ
- Pacific SPCZ

La Nina

El Nino

(AMD >0 => SSTA 5°N-20°S warmer than SSTA 5°N-30°N)
Changes in the latitude of the SSS & E-P minima (P maxima)

Linear trends, °latitude per 31 years (1979-2009)

- Pacific ITCZ
- Atlantic ITCZ
- Pacific SPCZ
Changes in the latitude of the SSS & E-P minima (P max)

1979-2009 trends: possible causes for the ...

- Poleward shift of the E-P minima in the Pacific and Atlantic

![Graphs showing changes in SSS and E-P minima](image)

[SST trend](image)

[ITCZ/SPCZ shift to warmer regions?](image)
1979-2009 trends: possible causes for the ...

- Meridional shifts of the SSS minima in the Pacific and Atlantic

Meridional Ekman transport?

Zonal Wind trend
1. SSS minima: 6-12°N & 2°S-10°S in the Pacific, 5-7°N in the Atlantic.
2. SSS minima located about 200 km further poleward than E-P minima, consistent with meridional Ekman salt transport.
3. Changes (std) in the latitudes of the SSS and E-P minima are of ~2-6° latitude.
4. At the seasonal time scale, the latitudes of the SSS and E-P minima vary:
   - consistently in the Atlantic ITCZ, Pacific SPCZ, and in the eastern part of the Pacific ITCZ, reaching their polewardmost position during late summer.
   - out-of-phase in the western-central Pacific ITCZ: the E-P minimum reaches its northermost positions during boreal summer, the SSS minimum during boreal winter. Due to Ekman dynamics (see Yu, 2014)
5. At the interannual time scale, the SSS and E-P minima move (±2-4°) in phase:
   - with ENSO in the Pacific, being closer to the equator when the SOI is <0 (El Nino)
   - with the AMD in the Atlantic, being closer to the equator when the AMD is <0
   - Poleward shifts of E-P minima in the Atlantic ITCZ and Pacific ITCZ/SPCZ, consistent with SST trend ⇒ Poleward shift of the ascending branch of the Hadley circulation, expansion of the tropics.
   - Poleward shift of SSS minima in the Pacific SPCZ, consistent with zonal wind trends and related Ekman salt transport.
   - Unconsistent with climate change effects? Interdecadal variability?