The Southern Hemisphere subtropical SSS-max regimes

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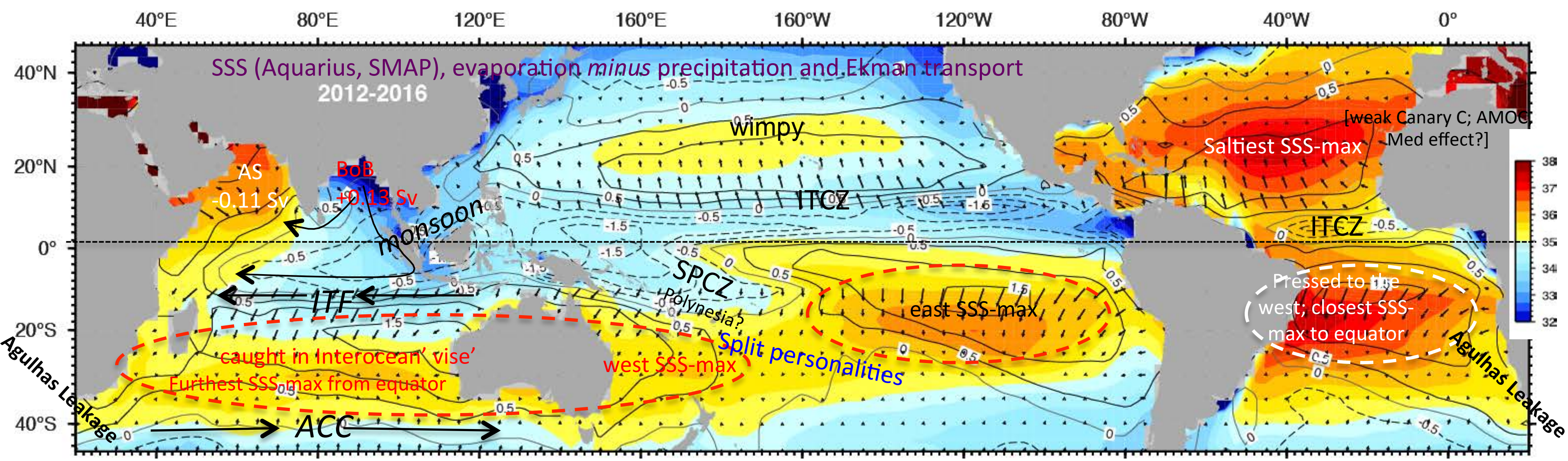
Salinity Workshop at WHOI, 22-25 May 2017

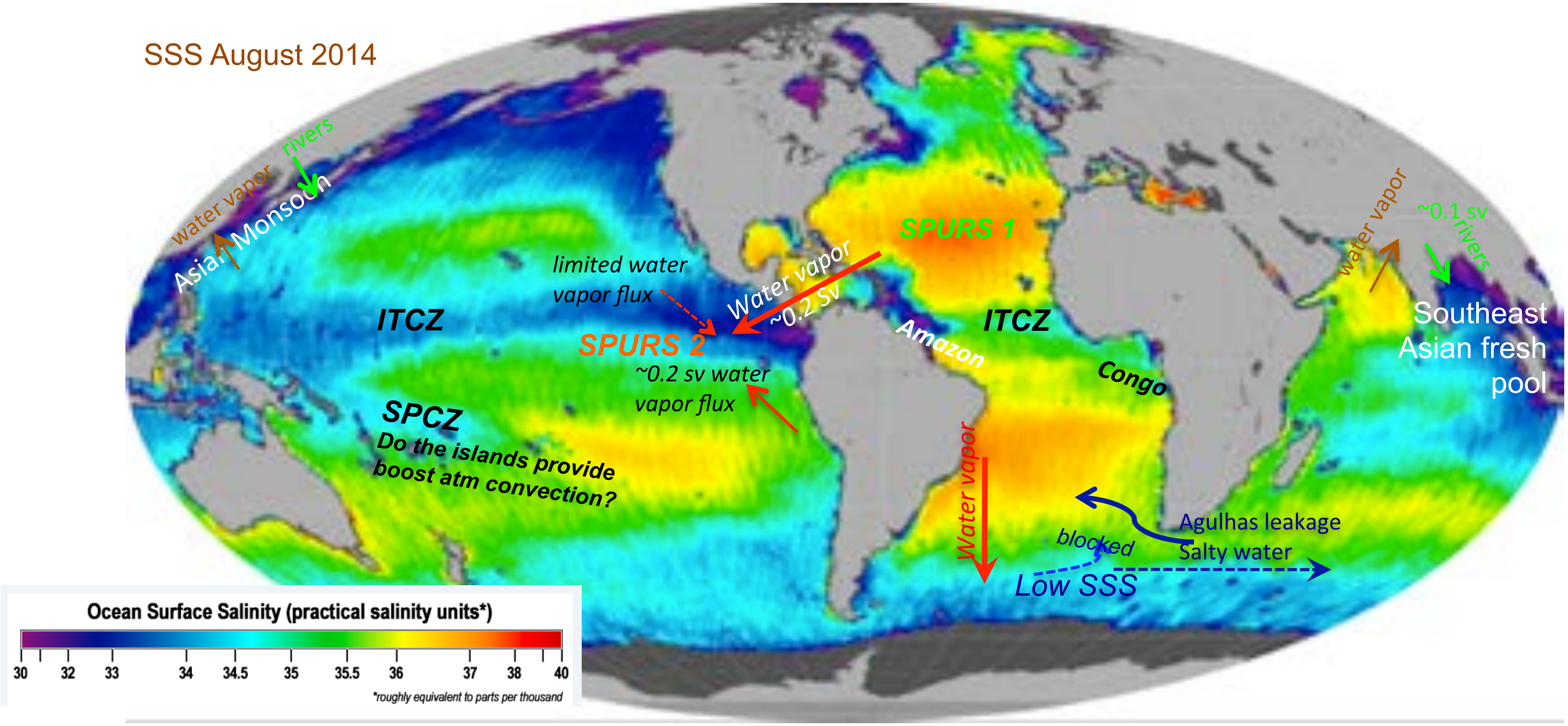
The salty subtropical regimes of the world ocean display significant differences. Evaporation alone is not sufficient to explain the spatial and temporal characteristics of the salty subtropical regimes, the wind also shapes sea surface salinity maximum (SSS-max), both at seasonal and inter annual time scales. However, even the combination of regional air-sea water flux and the wind stress is insufficient to fully explain the SSS-max patterns. The SSS-max regimes are also influenced by their place in the global ocean system. This is particularly relevant to the southern hemisphere SSS-max regimes. The South Atlantic and the southern Indian Ocean SSS-max are affected by the Agulhas leakage around the southern rim of Africa, as well as the deflection of the South Equatorial Current into the northern hemisphere as part of AMOC. The southern Indian Ocean is also affected by the low SSS plume of Indonesian Throughflow water crossing the Indian Ocean between 10 and 15°S. The super wide South Pacific seems to have two distinct regimes, the 'normal' eastern SSS-max and the western regime shaped by a branch of the ITCZ in southern hemisphere. The difference of the SSS-max regimes is a sensitive indicator of the ocean and climate systems.

Gordon, A. L., C. F. Giulivi, J. Busecke, F. M. Bingham (2015) "~~Similarities and~~ Differences Among Subtropical Surface Salinity Patterns". SPURS special issue of Oceanography, 28(1) 20-27*

** Well OK, they are all salty*



I will focus on the South Atlantic SSS-max with some words about the south Indian SSS-max



Water vapor:

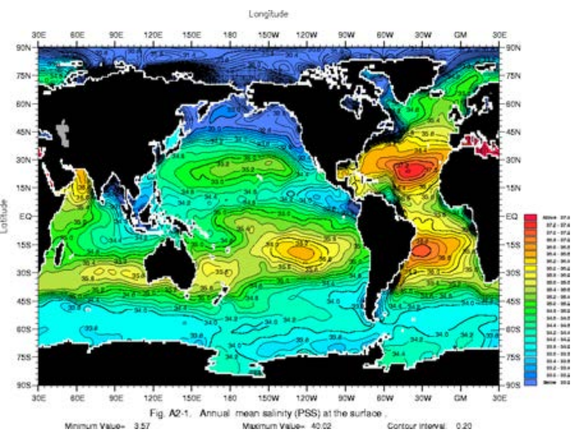
- North Atlantic to Pacific water vapor ~0.2 SV
- South Atlantic to ACC
- Arabian Sea to Bay of Bengal
- SPCZ (polynesian island effect?)

In addition to the interocean advective links, there is interocean water vapor flux and rivers

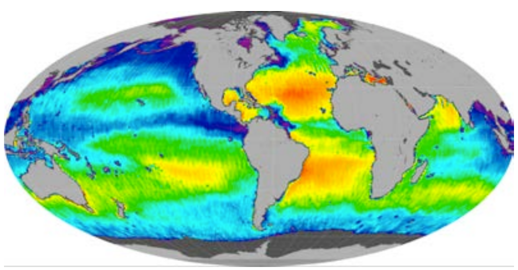
South Atlantic water vapor flux: Gordon, A.L. & A. R. Piola (1983); Agulhas leakge: Gordon 1985, 1986

Central America Gap winds calculated Gordon and Giulivi May 2014 from data: http://www.ecmwf.int/ Dee, D. P., et al.. (2011) The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. doi: 10.1002/qj.828

The sea surface salinity (SSS) displays fluctuations that are not solely in response to local air-sea flux of freshwater, but also reflect ocean circulation and mixing processes.



blurry atlas views of salinity, built from many decades of data gathering, depicting a climatology that never exists at all points at the same time, have now beed replaced by:

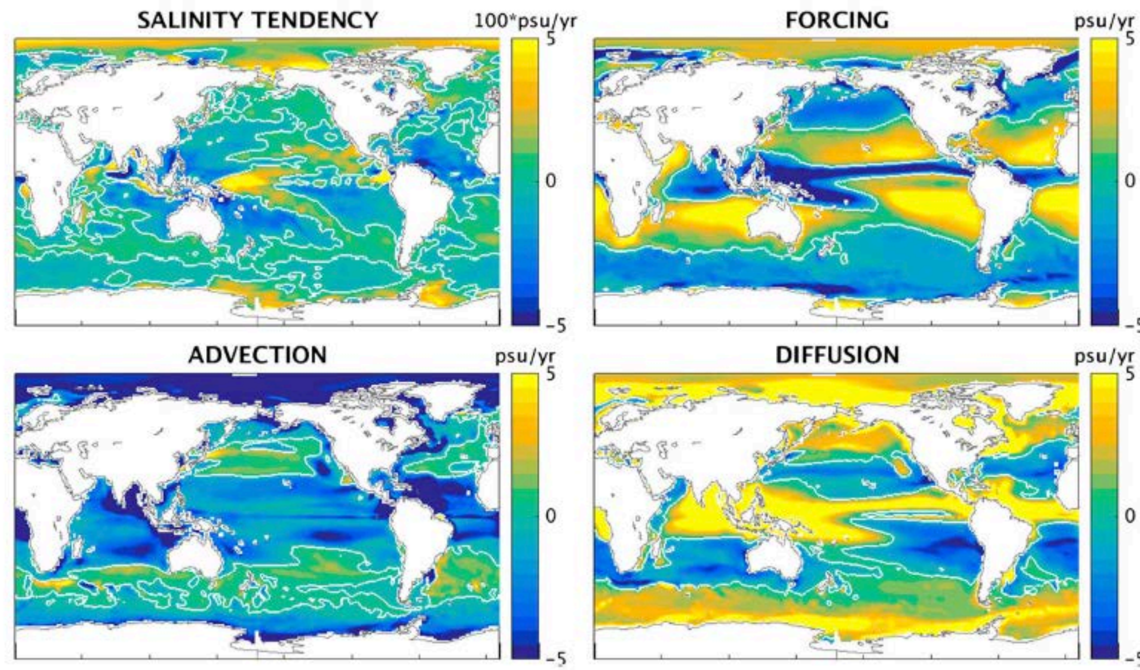


Near synpotic global views of the sea surface salinity (SSS) from orbiting satellites, opening views of the marine hyrdological cycle

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

Ponte, R. M. and N. T. Vinogradova (2016) An assessment of basic processes controlling mean surface salinity over the global ocean. *Geo.Phys.Letts* doi: 10.1002/2016GL069857.

Gordon, A. L. (2016), The marine hydrological cycle: The ocean's floods and droughts, *Geophys. Res. Lett.* , 43, doi:10.1002/2016GL070279



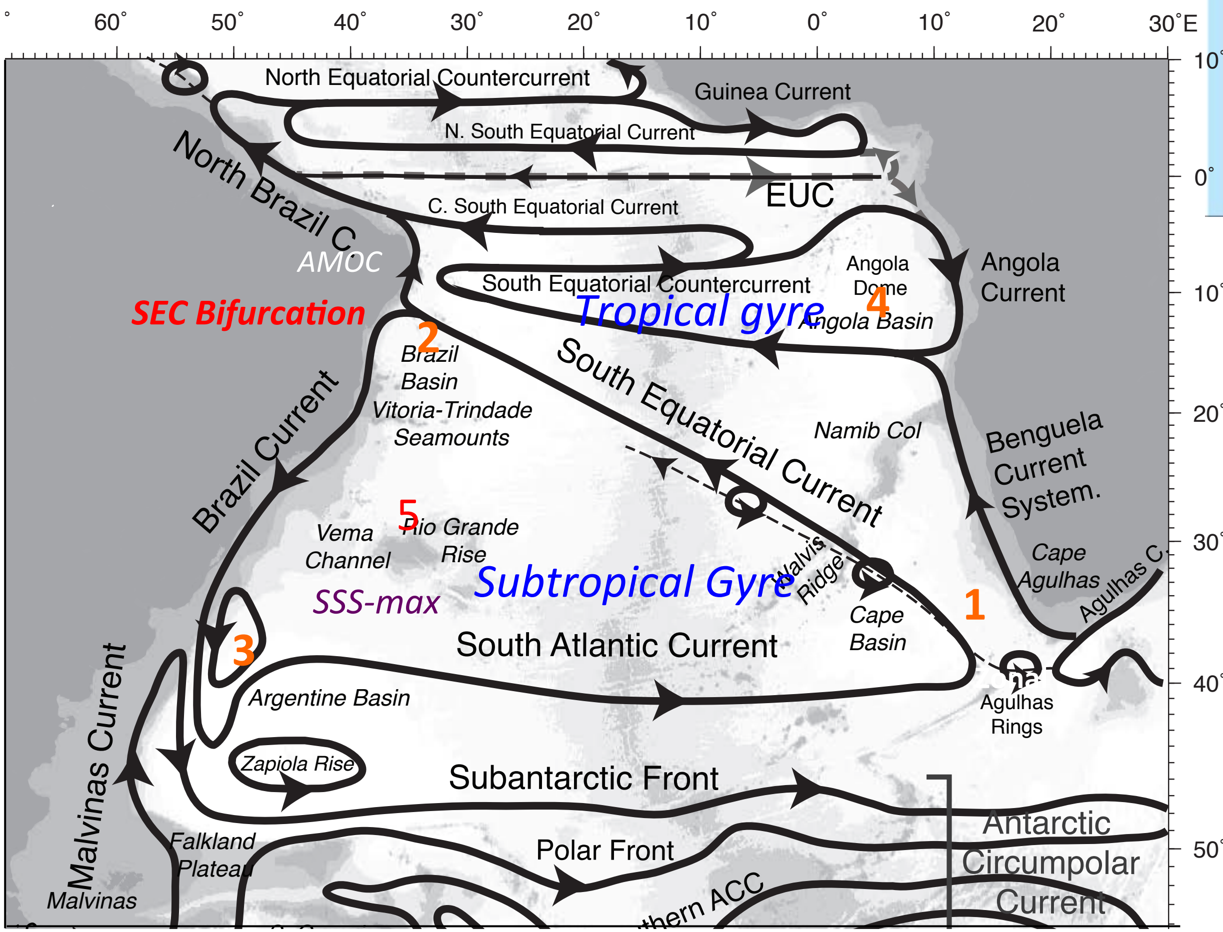
From Ponte & Vinogradova

Figure 2. Time averaged salinity tendency (S') and advective, diffusive, and forcing fluxes, as in equation (1). White contour lines mark the zero value. Note the different scale for S' term.

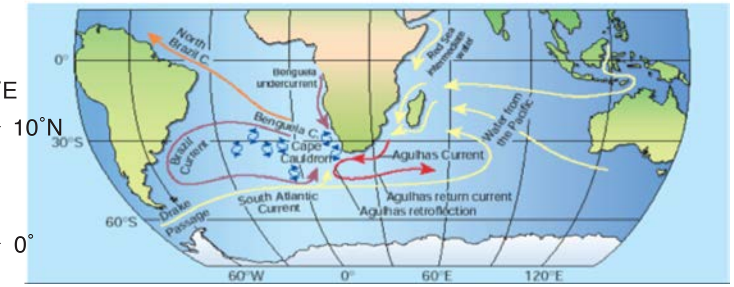
See: Schmitt, R.W. (2008). Salinity and the global water cycle. *Oceanography* 21(1):12–19.

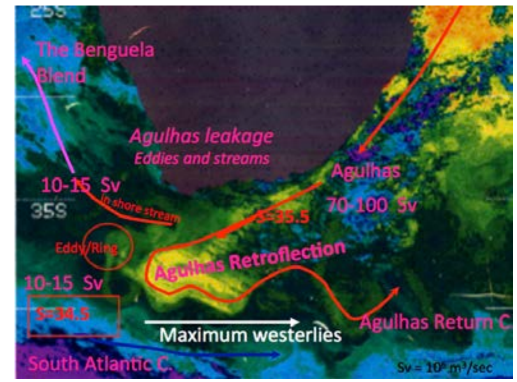
Schanze, J. J., R. W. Schmitt, and L. L. Yu (2010), The global oceanic fresh-water cycle: A state-of-the-art-quantification, *J. Mar. Res.*, 68 (3-4), 569595, doi:10.1357/002224010794657164.

South Atlantic



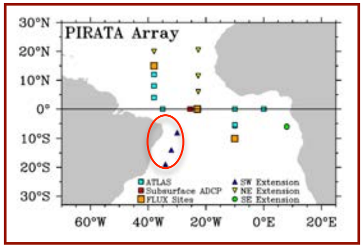
Schott et al., 1998; Stramma and Peterson, 1990; Talley, 2001.



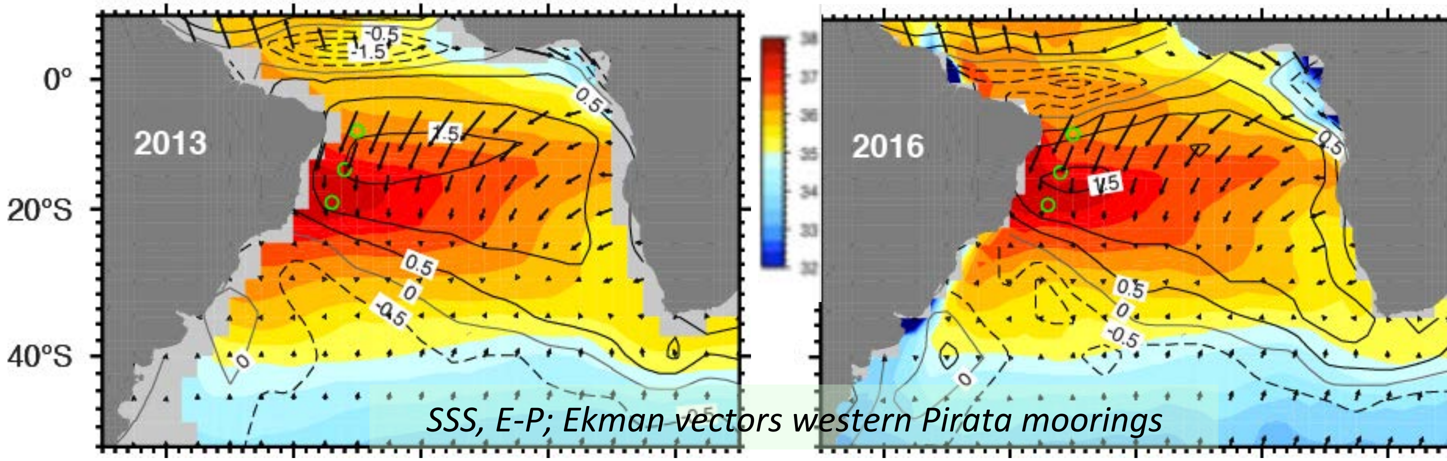


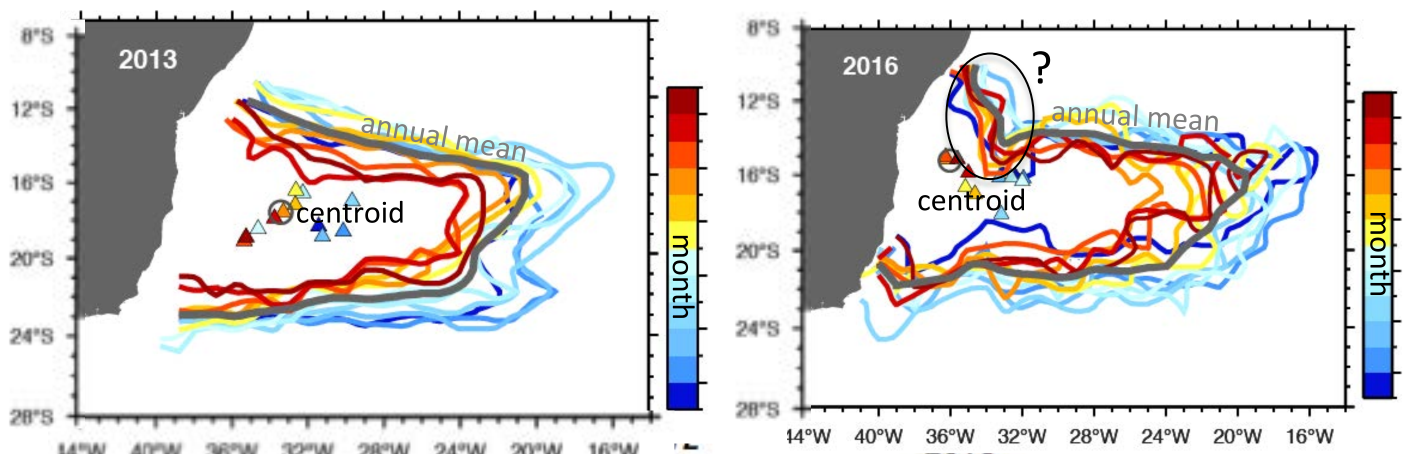
1. The Agulhas leakage: injection of Indian Ocean water into S.Atl;
2. The SEC bifurcation: regulates the inter-hemispheric exchange vs. recirculation;
3. The Brazil-Malvinas confluence: regulates the return flow to the East *[Atl/Ind ‘super-gyre’];*
4. Tropical ‘Angola dome’ cyclonic gyre;
5. SSS-max core, a response to larger scale and to regional air-sea fluxes

Surface circulation: the subtropical anticyclonic and tropical cyclonic bounded by zonal currents in the tropics and subantarctic regions, with injection of Indian Ocean Water via the Agulhas leakage and loss to the North Atlantic, the South Atlantic enables the North Atlantic reach into the global ocean: **AMOC**.



More 'pressed to the west' in 2016. Due to the SSS-ref pattern in NW region. Change in western boundary current? SEC bifurcation latitude shift?

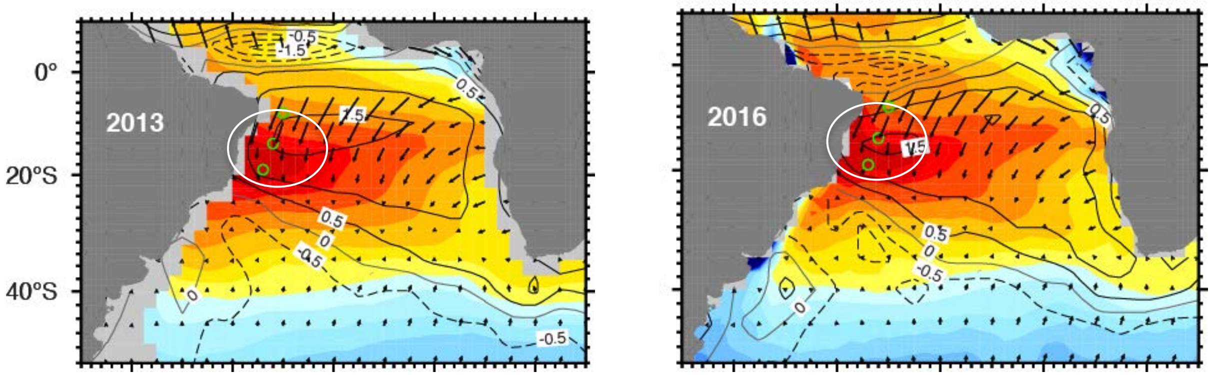




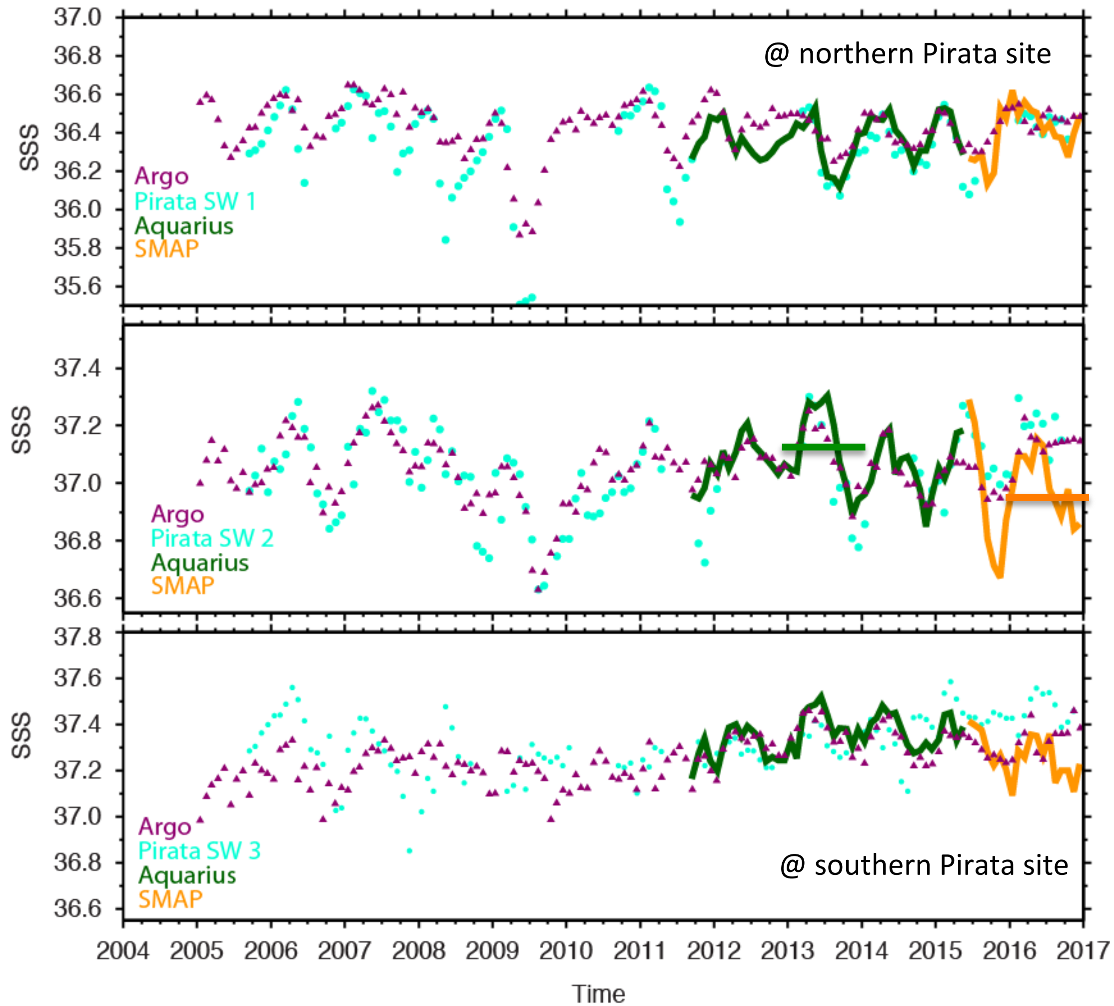
SSS-ref monthly isohaline

Solid line : Aquarius SSS
Dashed line: Argo (JAMSTEC)

Time series of SSS anomaly relative ("*peakyness*") to the basin sal reference. S Atlantic largest.



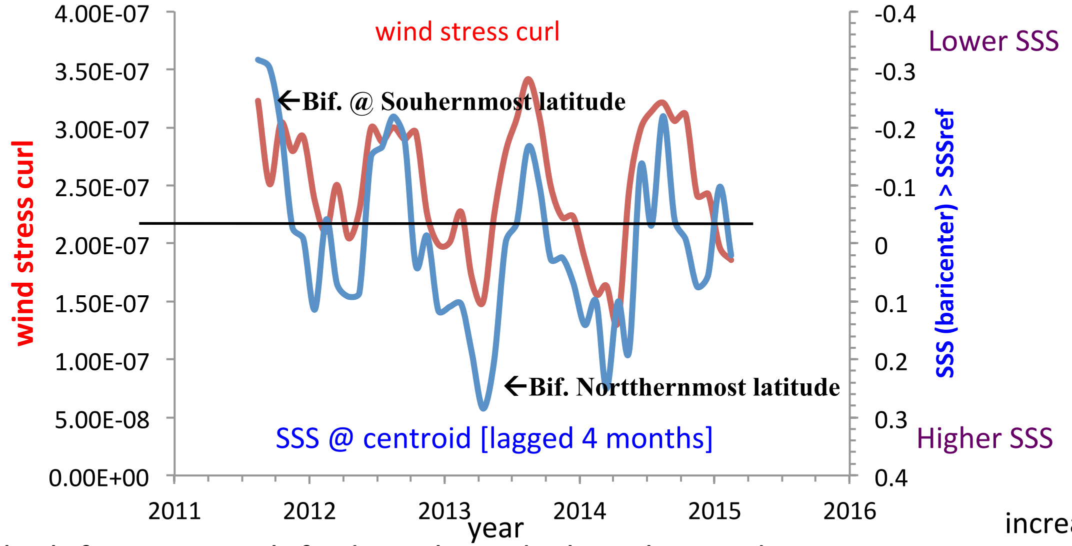
SSS, E-P; Ekman vectors;
3 Pirata moorings

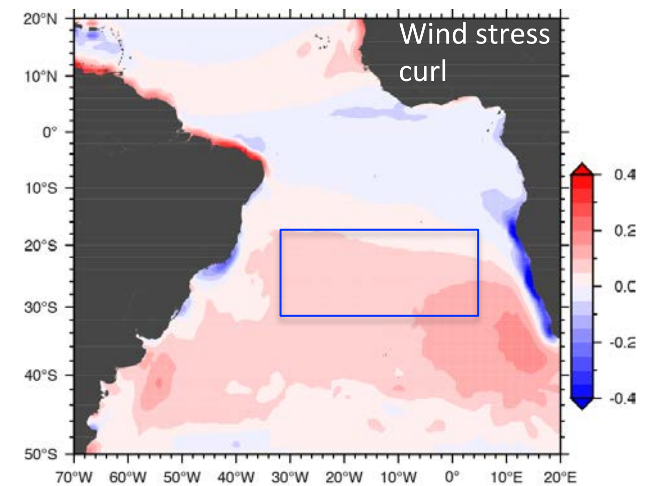


2016 lower SSS at central Pirata than in 2013. More feed of tropical water into the Brazil Current in 2016? less into North Atlantic?

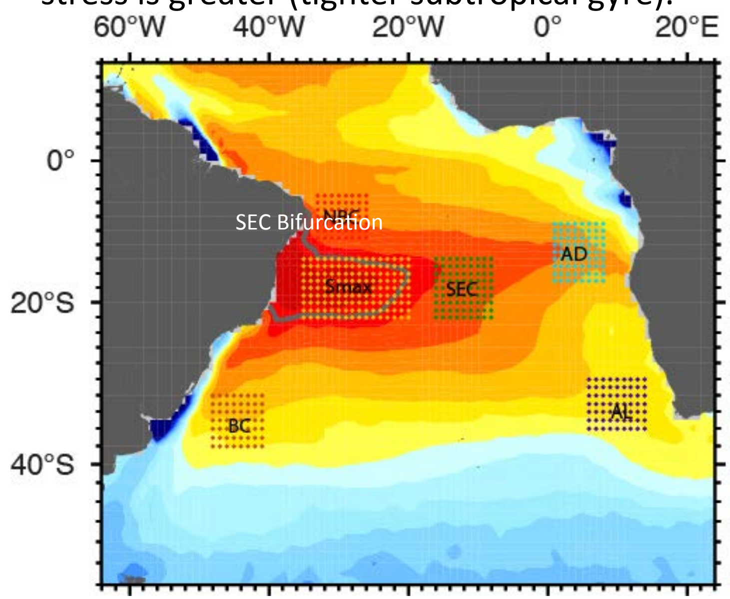
Bifurcation factor?

Wind stress curl within the subtropical gyre center (15-30S, 35W-5E), NOAA NCEP-NCAR CDAS-1 monthly surface wind stress and SSSb anomalies (lagged 4 months).

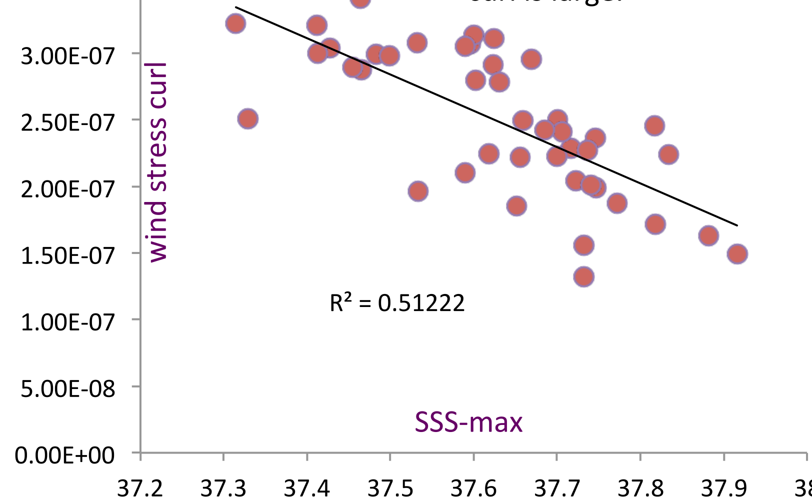


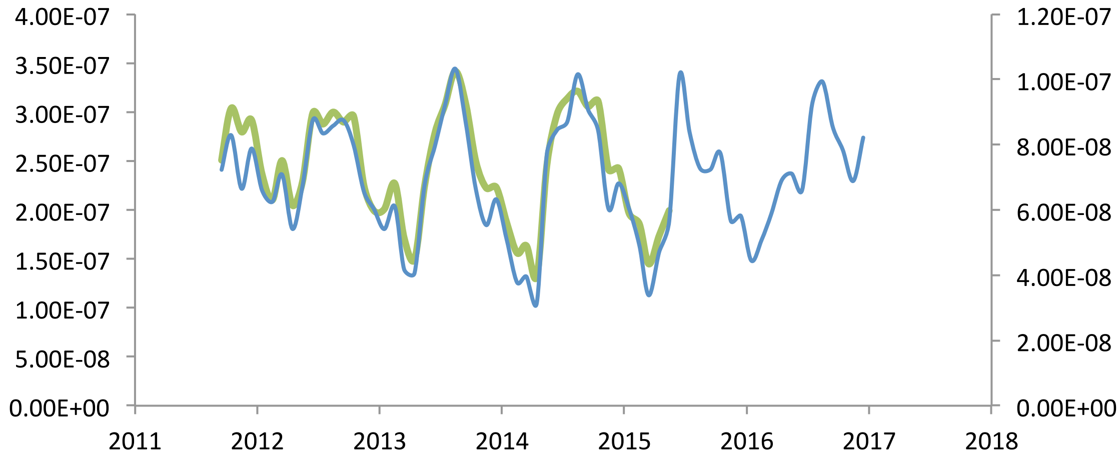


The bifurcation is shifted southward when the wind stress is greater (tighter subtropical gyre).



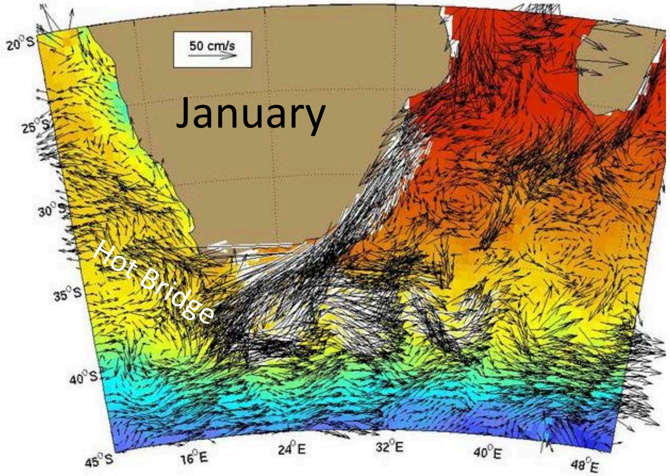
increase wind stress curl leads to lower SSS in the SSS-max, the SSS lags the curl by 4 months. The connection of the wind to the SSS is mainly in the relation of the E-P to the wind curl: more rain, more Ekman convergence, when curl is large.





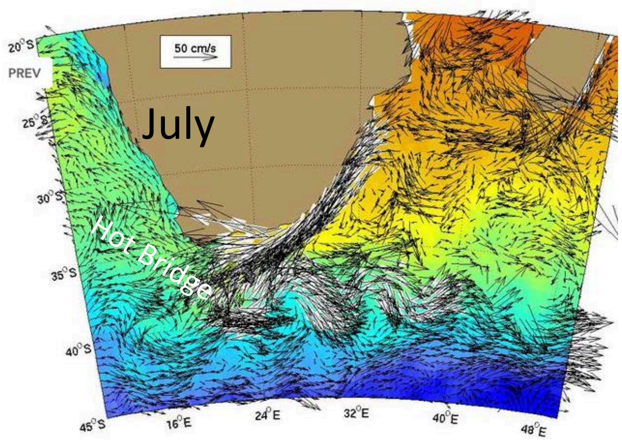
Arnold this is the wind stress curl for the box, in green the series we already had, in blue the updated. I'm using NCEP data from IRI (same as before) the magnitudes are different, but the patterns are the same (they are constantly updating the data). There is a different behavior for 2016. The amplitude (peak to peak) is reduced, but overall increasing throughout the year, the values for the end of 2016 are very high.

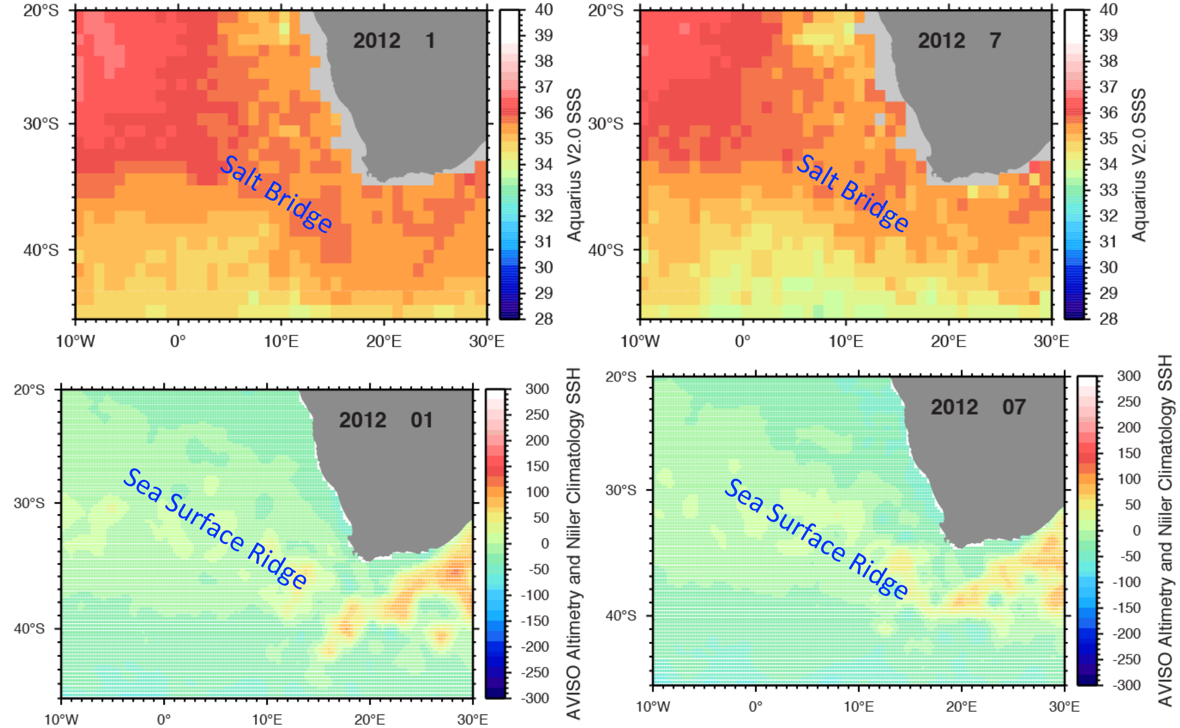
2016 curl spends more time in small values: Bif northward



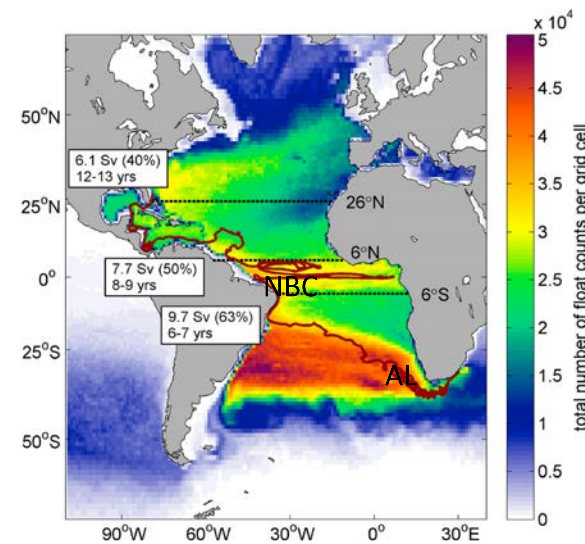
SST and Oscar currents

http://oceancurrents.rsmas.miami.





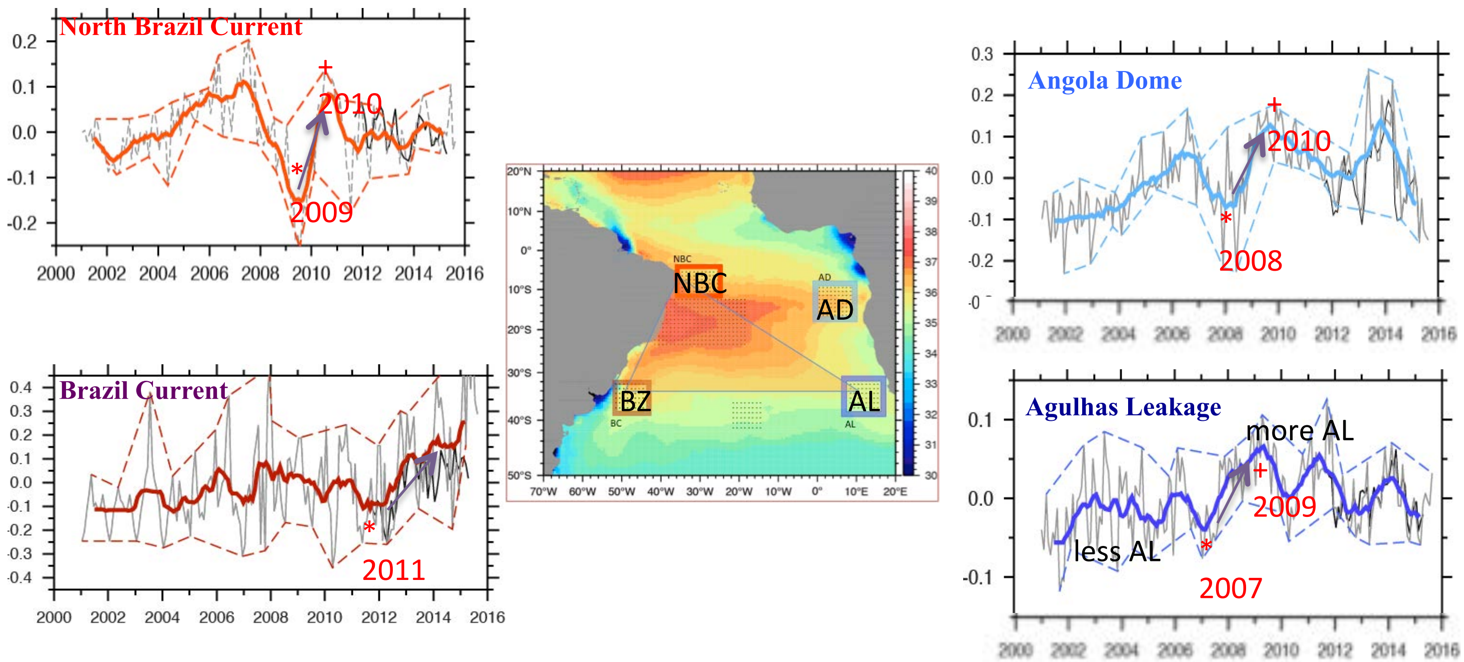
Salt Bridge and SSH ridge, inhibit folding low SSS subAnt water into the S.Atl subtropical gyre: sverdrup balance partially achieved by Agulhas Leakage



Rühs, S., et al (2013), Advective timescales and pathways of Agulhas leakage, Geophys. Res. Lett., 40, doi:10.1002/grl.50782.): results from a Lagrangian analysis were evaluated, with virtual floats advected within an eddy-permitting ocean model (ORCA025).

~6- 7 years from Agulhas Leakage (AL) to North Brazil (coastal) Current (NBC)

2007-2009 increase in Agulhas Leakage. Is there an advective signal of this salt injection across the South Atlantic subtropical gyre? Maybe…
~ 1 to 2 yr lag between Agulhas Leakage and North Brazil Current SSS anomalies, ~4 year AL to BZ SSS anomalies?



Sea surface salinity anomalies. *Time series of SSS anomalies (SSSa) for the color boxes shown on the SSS map. Aquarius salinity (v4 L3) times series (black) with Argo surface salinity data (gray). The dashed lines represent the annual min/max for the Argo dataset. The thick solid lines represent a 12-month running mean. Note the difference in range of the SSSa axis.*

Might agulhas eddies deliver the AL message to the BZ. The eddy westwarddrift may agree with the 4 year lag Byrne et al...

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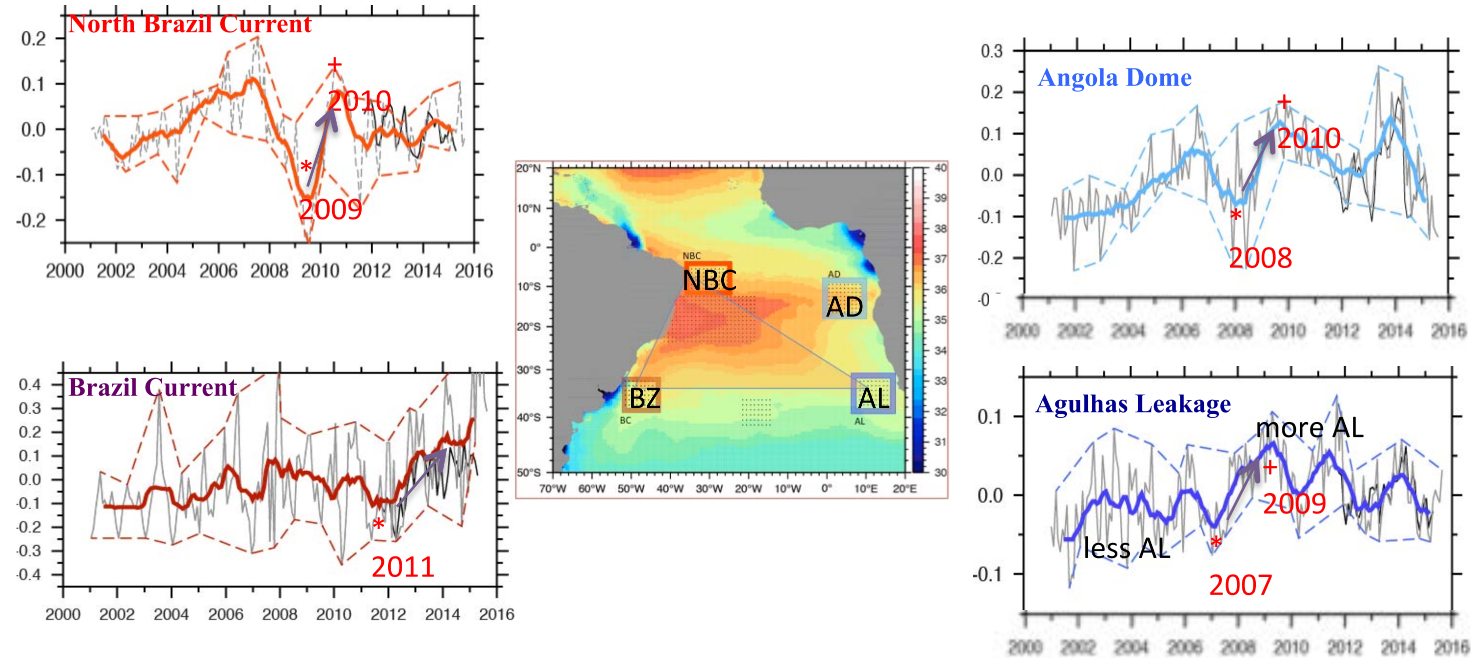

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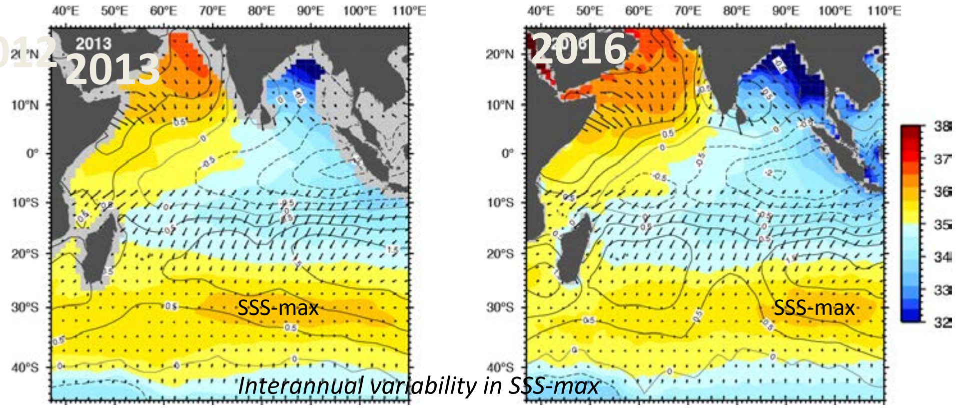
2 year lag is too fast? *Rühs, S., et al (2013) has 6- 7 years*

To paraphrase what was stated above: **sea surface salinity displays fluctuations that are not solely in response to advection, but also local air-sea flux of freshwater and mixing processes.** i.e. its complicated, but near synoptic views of SSS and other satellite based and in-situ (Argo, drifters) are allowing quantitative disection of these governing factors and associated marine hydrographic cycle.

Research in Progress…

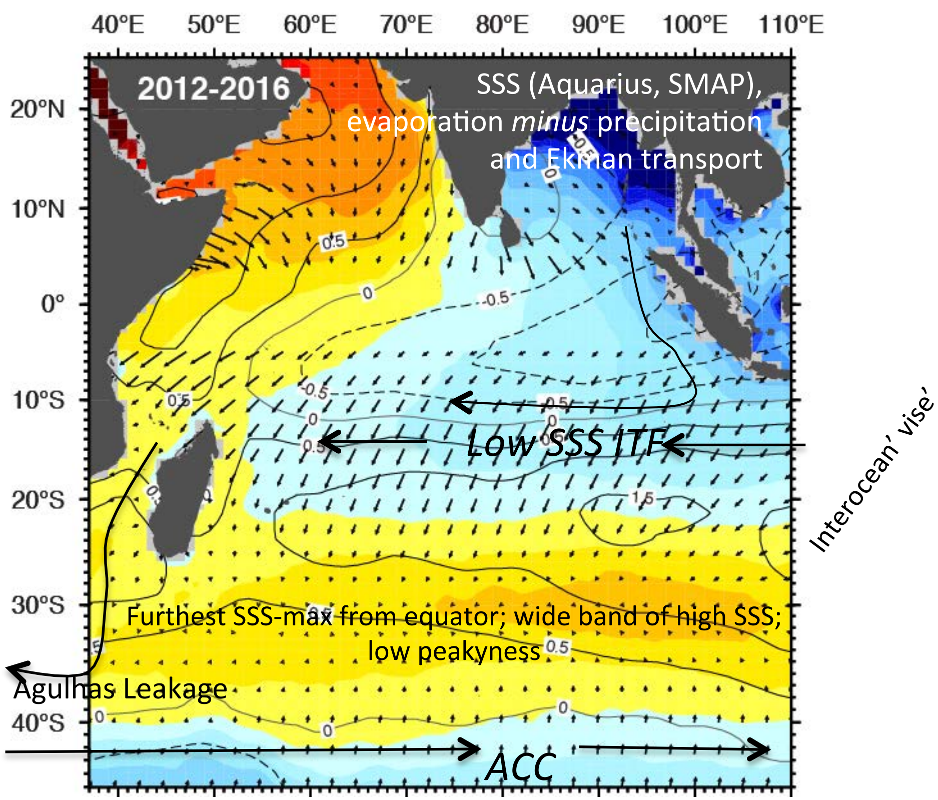
Southern Indian SSS-max

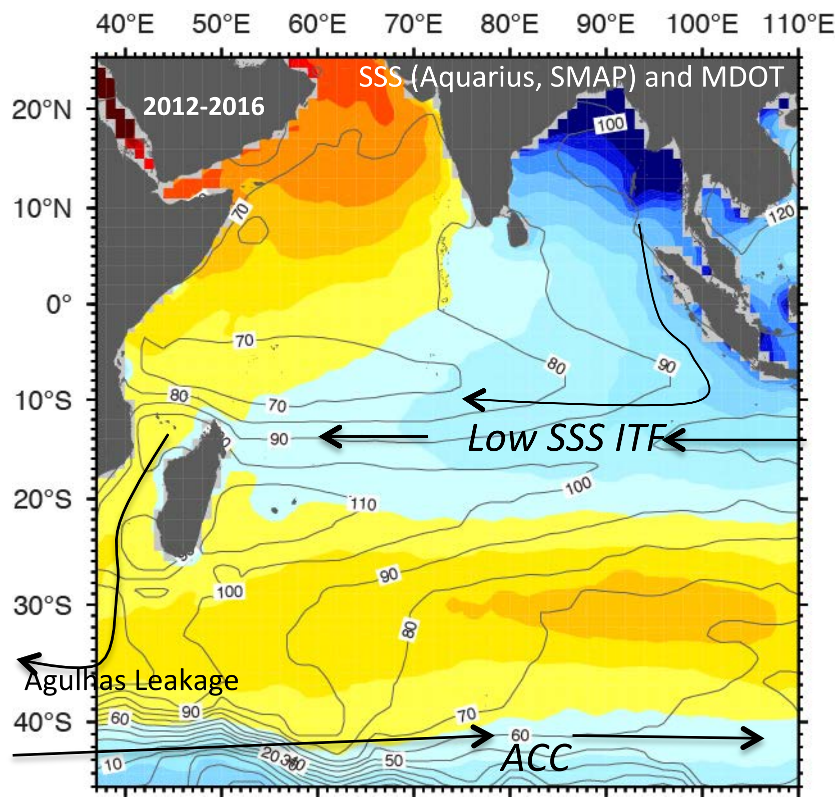


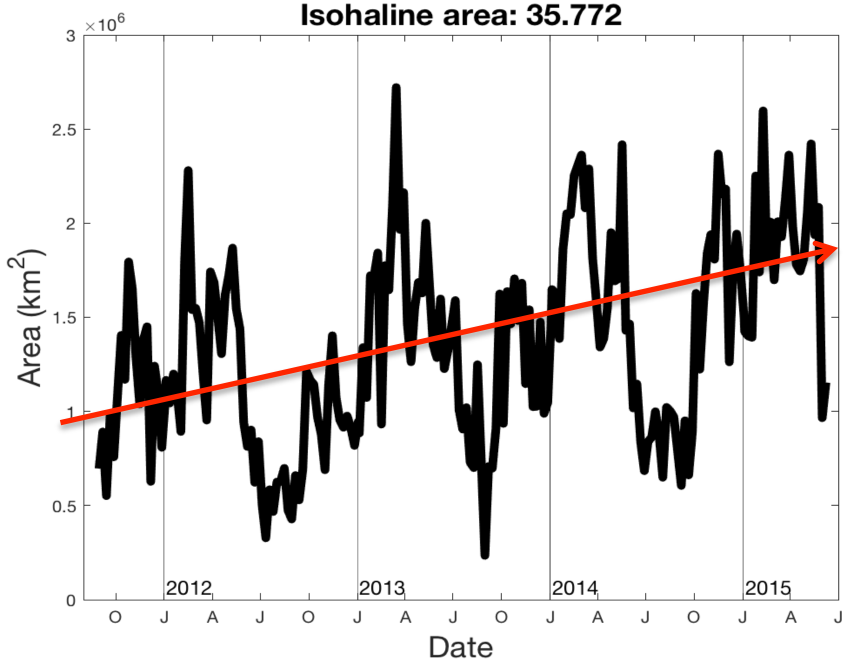
Interocean advective 'vise': low SSS along 10-15°S fed by the Indonesian Throughflow (ITF) and export of low SSS from eastern Bay of Bengal: advected southward by Ekman transport; and low SSS South Atlantic water advected eastward south of 40°S [northern limbs of the ACC], that also enables injection of low SSS by Ekman transport into the evaporative zone.

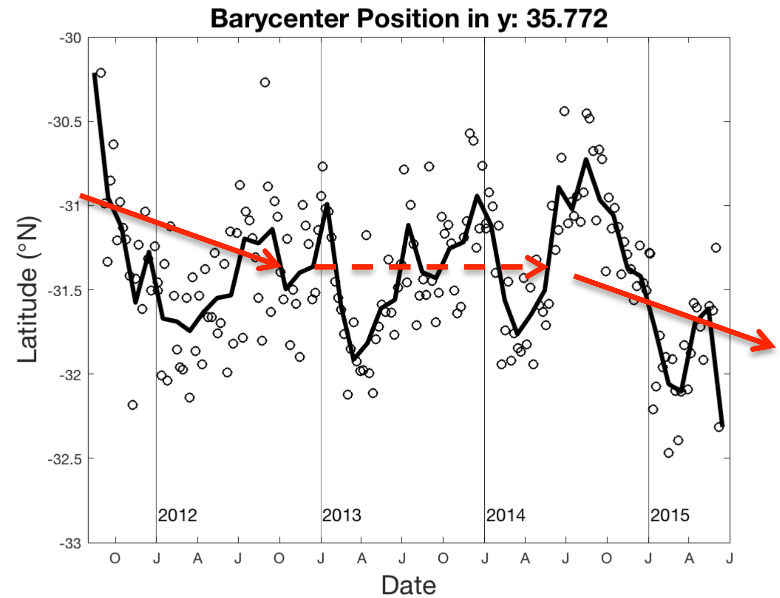
See: Melzer, B. A., and B. Subrahmanyam (2015), Investigating decadal changes in SSS in oceanic subtropical gyres, GRL, 42, 7631–7638,

Annual SSS (Aquarius, SMAP), evaporation *minus* precipitation and Ekman transport





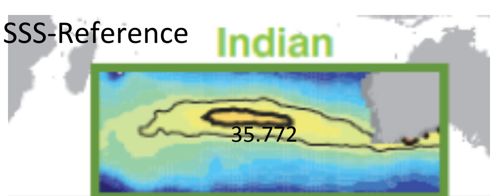


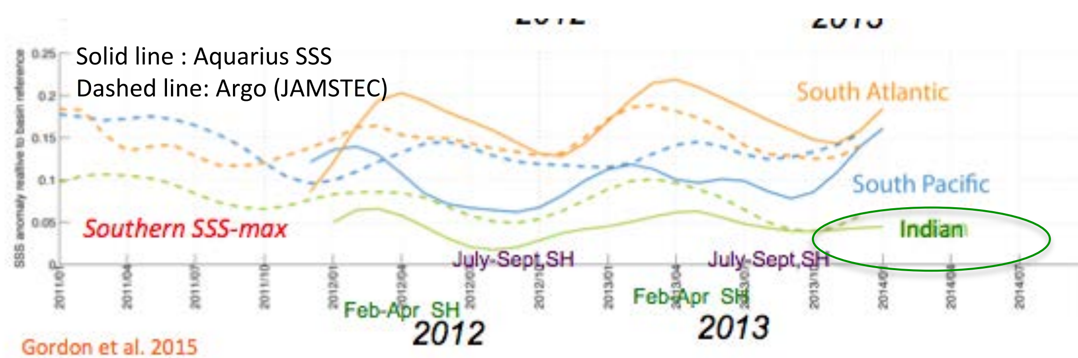


Time series from Fred Bingham, 20 May 2016

Southern Indian SSS-max area seasonal cycle, maximum in austral summer – July-Aug. There also appears to be a secular trend of increasing area. In latitude, there is also distinct variability: The farthest south is reached in austral summer. The latiude variation is small~0.5°. Southweard shift 2011-2015?

Changes in the 'Vise' (ITF, ACC)?; Wind; E-P Ekman patterns? Relvance to AMOC and Agulhas Leakage





Research in Progress…

Time series of SSS anomaly relative ("*peakyness*") to the basin sal reference. S Indian smallest.

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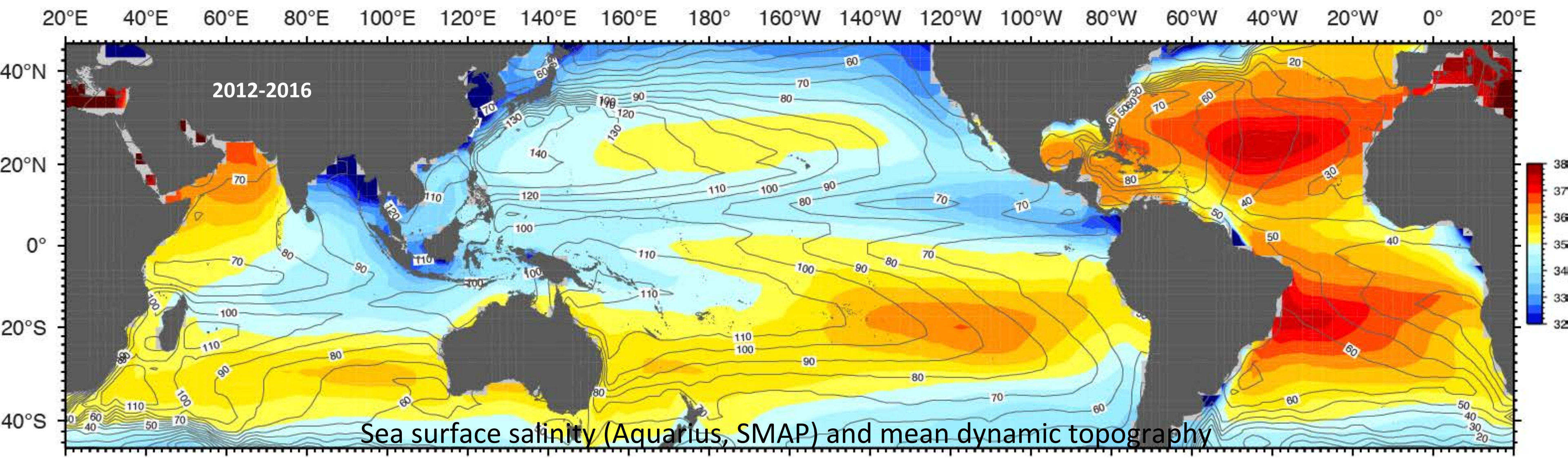
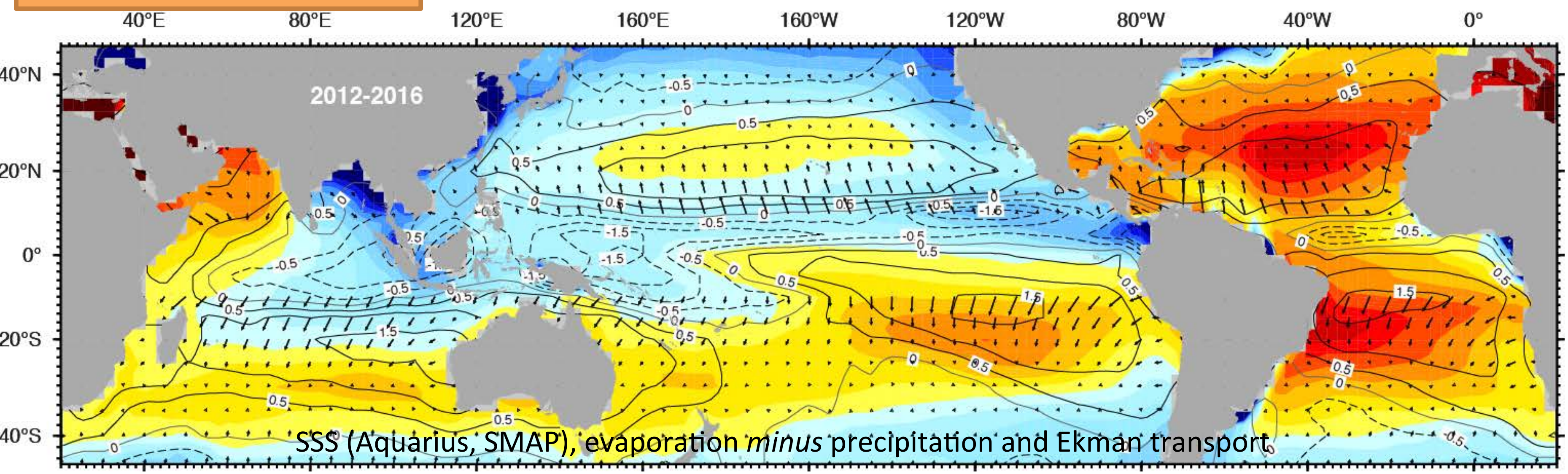


Sea surface salinity (Aquarius, SMAP) and mean dynamic topography

Research in Progress…



SSS (Aquarius, SMAP), evaporation *minus* precipitation and Ekman transport