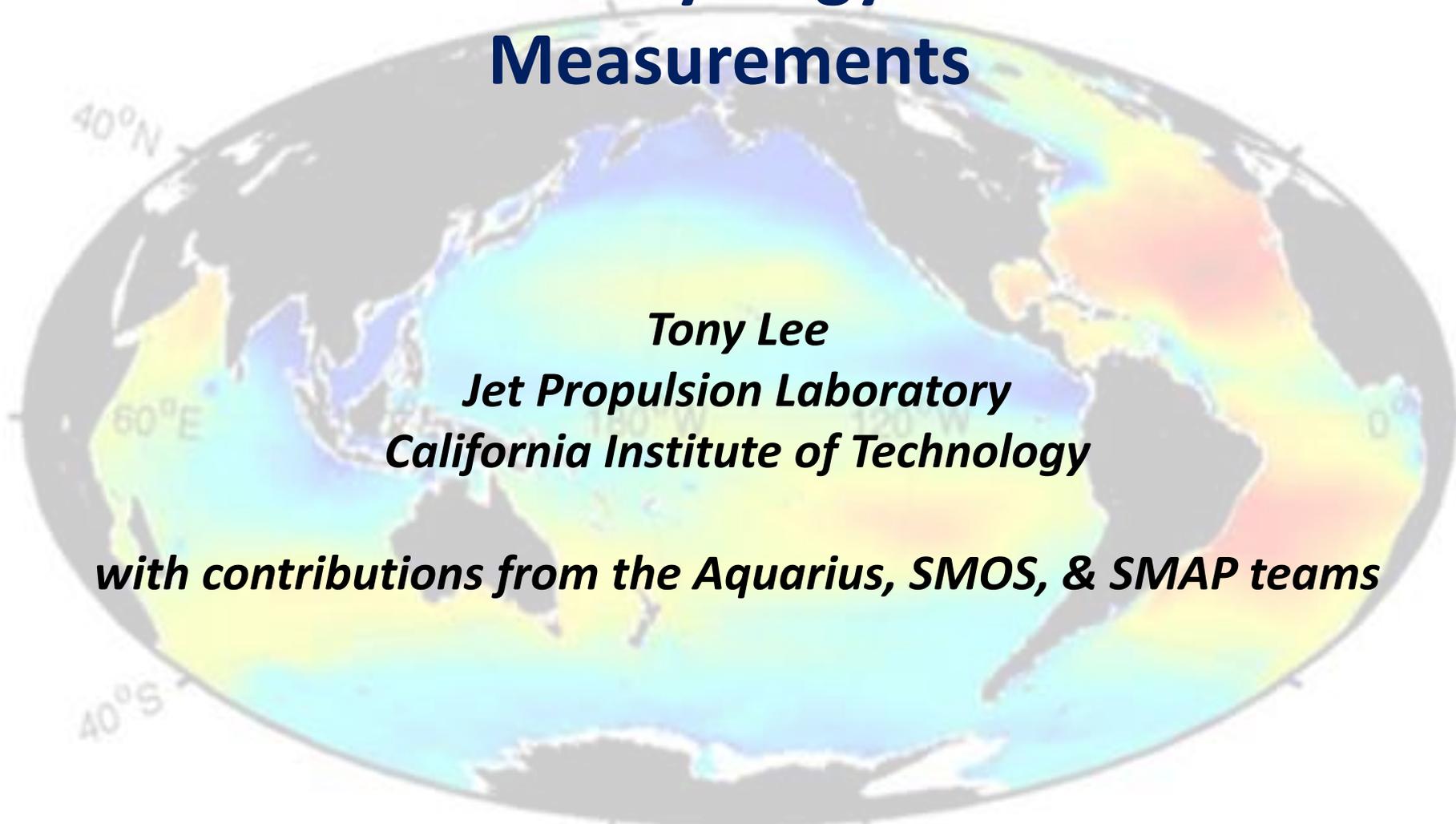


# L-band Satellite Salinity for Ocean/Climate Research and Synergy With Other Measurements



***Tony Lee***  
***Jet Propulsion Laboratory***  
***California Institute of Technology***

***with contributions from the Aquarius, SMOS, & SMAP teams***

The image shows the Soil Moisture and Ocean Salinity (SMOS) satellite in orbit. It is a yellow satellite with several solar panel arrays extending from its body. The Earth's surface is visible in the background.

Soil Moisture &  
Ocean Salinity  
(SMOS)  
Launched Nov. 2009  
ESA

The image shows the Aquarius/Satellite Application of Ocean Color Dynamics (SAC-D) satellite. It features a large, circular, gold-colored antenna dish and various instruments on its body. The Earth is visible below.

Aquarius/SAC-D  
June 2011-June 2015  
NASA/CONAE

**Main Mission Objectives:**  
SMOS: SM & SSS  
Aquarius: SSS  
SMAP: SM

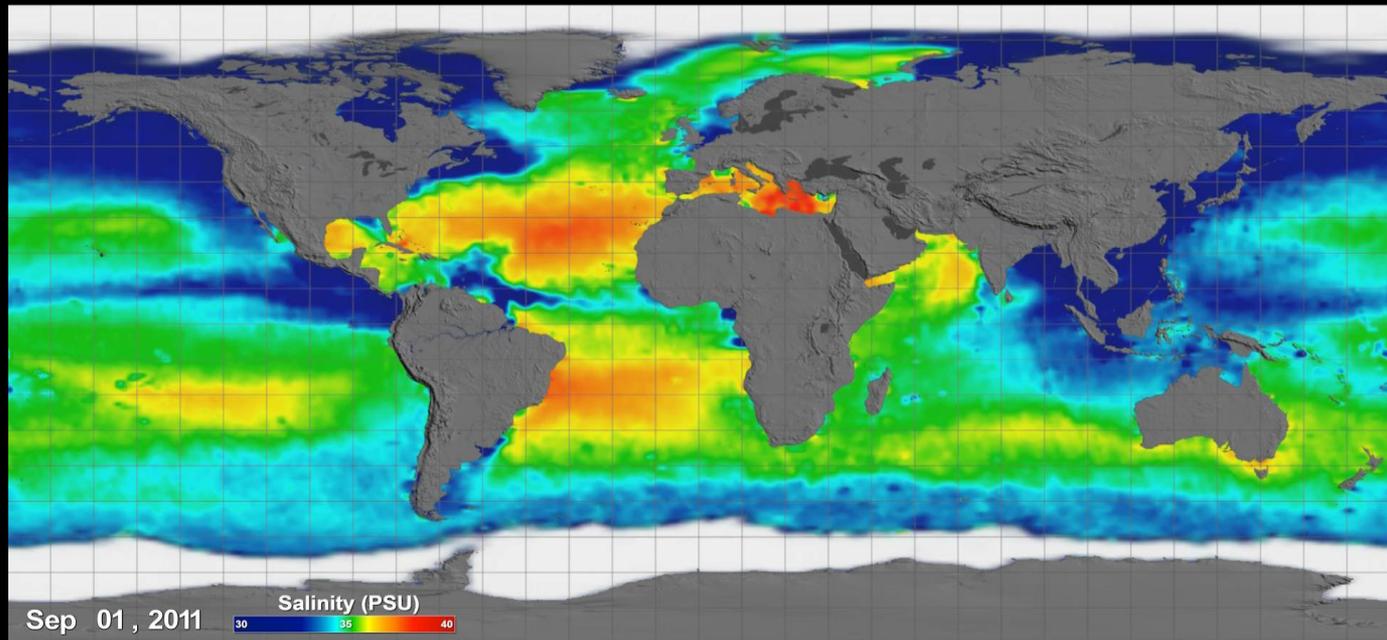
The three L-band  
(~1.4 GHz) satellite  
missions that have  
pioneered SSS  
measurement from  
space

The image shows the Soil Moisture Active Passive (SMAP) satellite. It is a small satellite with a large, green, circular antenna dish. The Earth is visible in the background.

Soil Moisture Active  
Passive (SMAP)  
Launched Jan. 2015  
NASA

**Aquarius SSS  
(V4.0)  
09/2011-  
05/2015**

**~100 km  
resolution**



**SMAP: Soil Moisture + Sea Surface Salinity  
Apr 18 - Apr 25, 2015**

cm<sup>3</sup>/cm<sup>3</sup> (soil moisture)

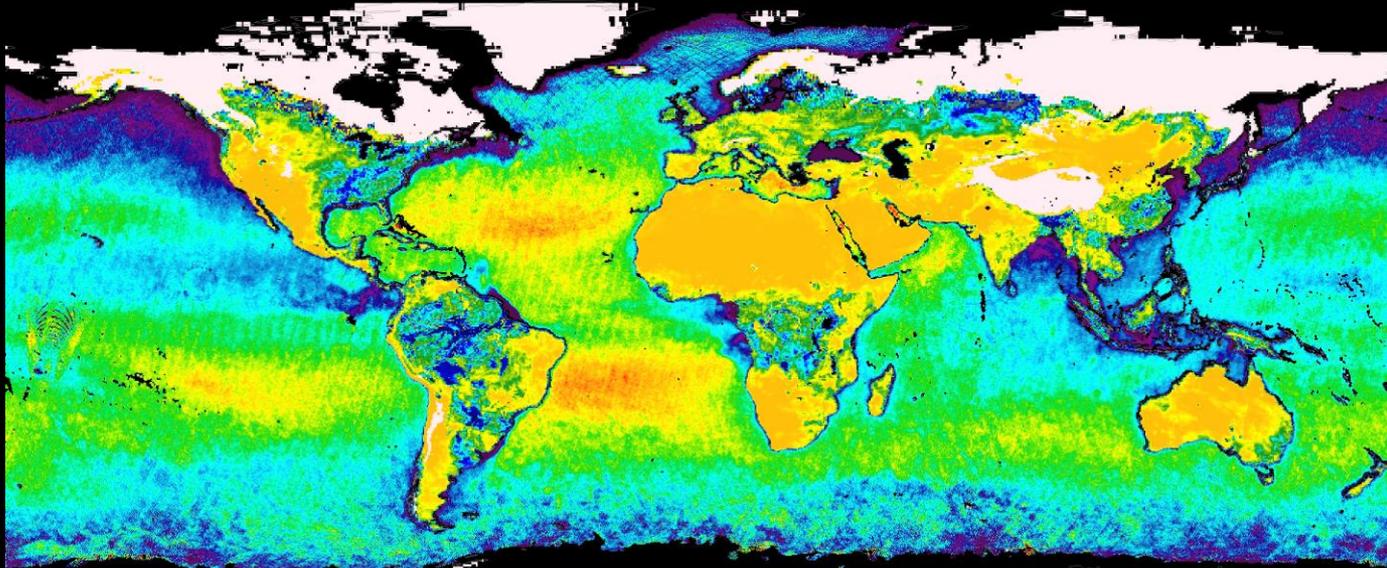
0.0 0.1 0.2 0.3 0.4 0.5 0.6

psu (sea surface salinity)

30.0 32.0 34.0 36.0 38.0 40.0

**SMAP  
SM & SSS  
04/2015  
onward**

**~40 km  
resolution  
(similar to  
SMOS)**



# Advantages of satellite Sea Surface Salinity (SSS) (relative to in situ)

- Systematic monitoring of features with smaller scales and shorter periods: important for cross-scale interactions
- More uniform spatiotemporal sampling improves the ability to estimate horizontal gradients: important for frontal genesis, eddy-mean flow interaction, and biogeochemistry
- Global coverage: important for studying teleconnections & land-sea linkages.

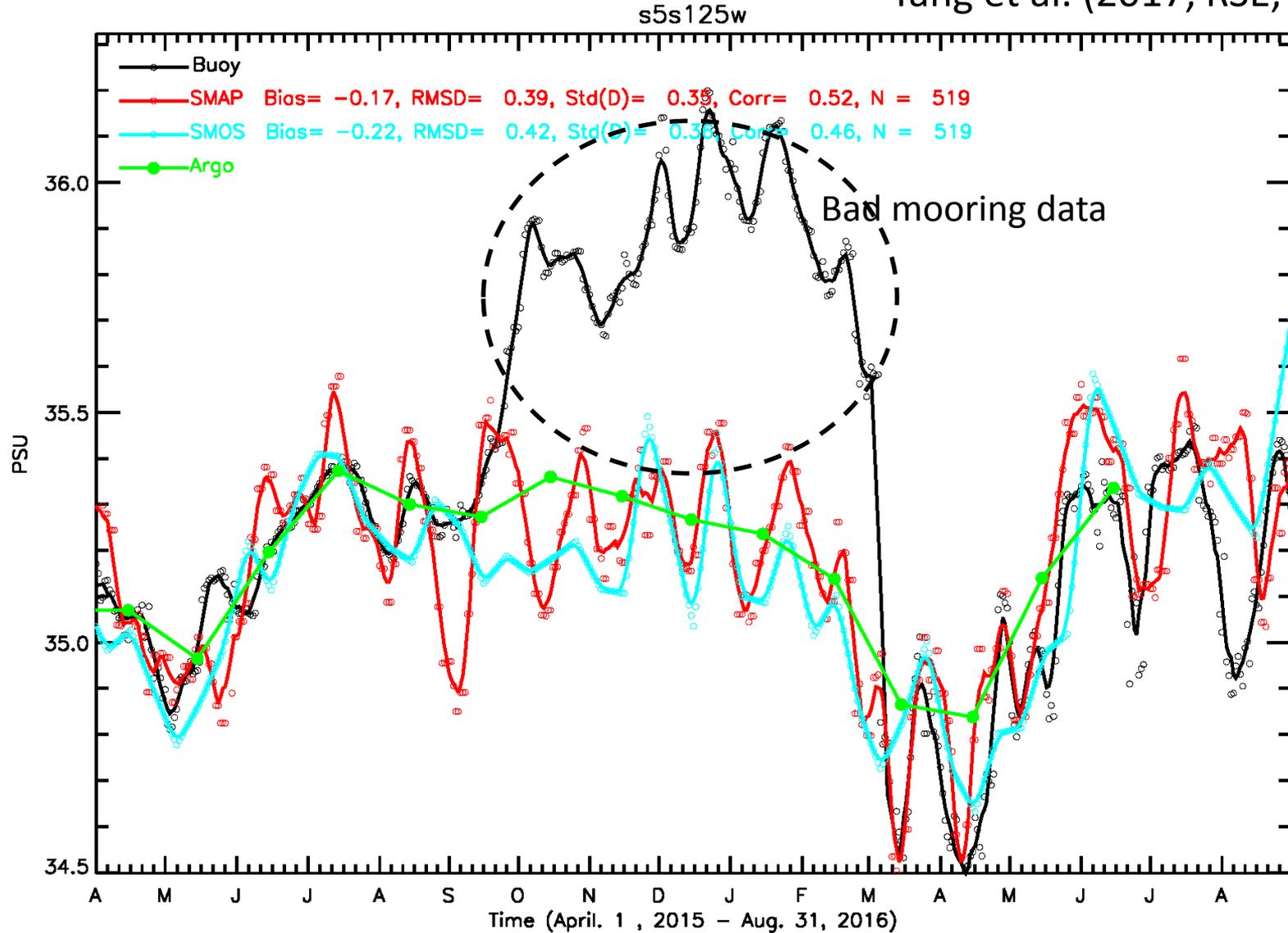
L-band radiometry is the only viable technology for systematic, synoptic monitoring of mesoscale SSS, coastal ocean & marginal sea SSS.

# Complementarity with in-situ observations

- Linking surface & subsurface structure
- In-situ measurements important to cal/val of satellite SSS
- Stable L-band satellites can help identify mooring conductivity sensor drifts

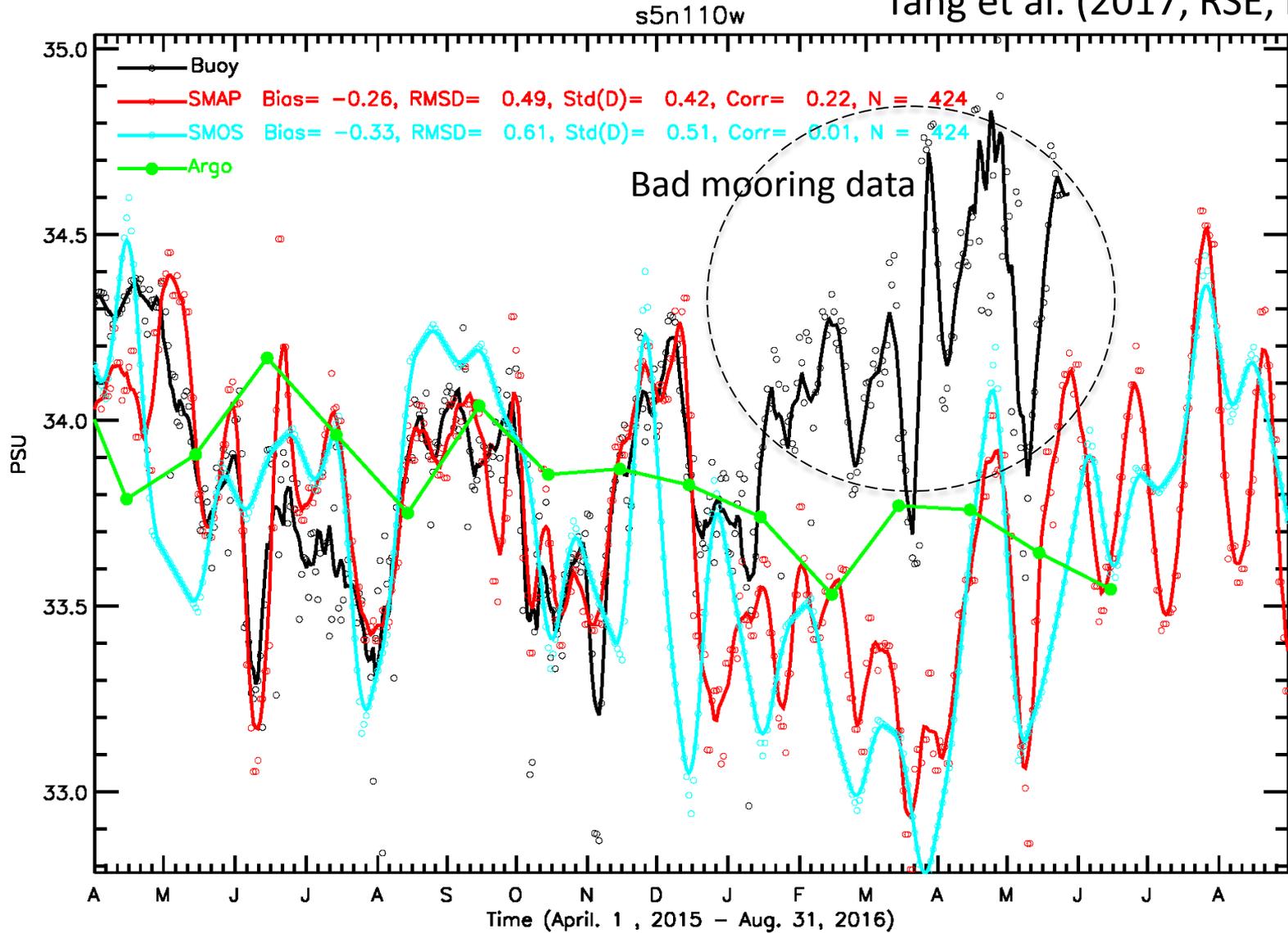
# Comparison of SMAP & SMOS SSS with mooring 1-m and Argo 2.5 m salinity

Tang et al. (2017, RSE, in press)



# Comparison of SMAP & SMOS SSS with mooring 1-m and Argo 2.5 m salinity

Tang et al. (2017, RSE, in press)



# Summary of key achievements by L-band satellite SSS

- Oceanic features/processes (e.g., hurricane haline wake, TIWs, Rossby waves, river plumes, eddies, fronts, marginal sea salinity, cross-shelf exchanges, dynamics of  $S_{MAX}$  &  $S_{MIN}$  zones)
- Linkages with the water cycle (atmosphere, land).
- Relationships with climate variability (MJO, IOD, ENSO, etc.).
- Constraining ocean models & improving seasonal prediction.
- Emerging biogeochemical applications (e.g., TA, ocean acidification,  $fCO_2$ ).

Filling significant SSS observing system gaps (spatiotemporal scales & regions not/inadequately sampled by in-situ platforms).

# Highlights of satellite SSS applications to study ocean & climate processes

(focusing on examples showing advantages of satellite SSS, as well as the synergy with other satellite measurements)

- Tropical instability waves (TIWs)
- Mesoscale eddies
- River plumes & linkages to water cycle
- Relationships to climate variability (MJO example)

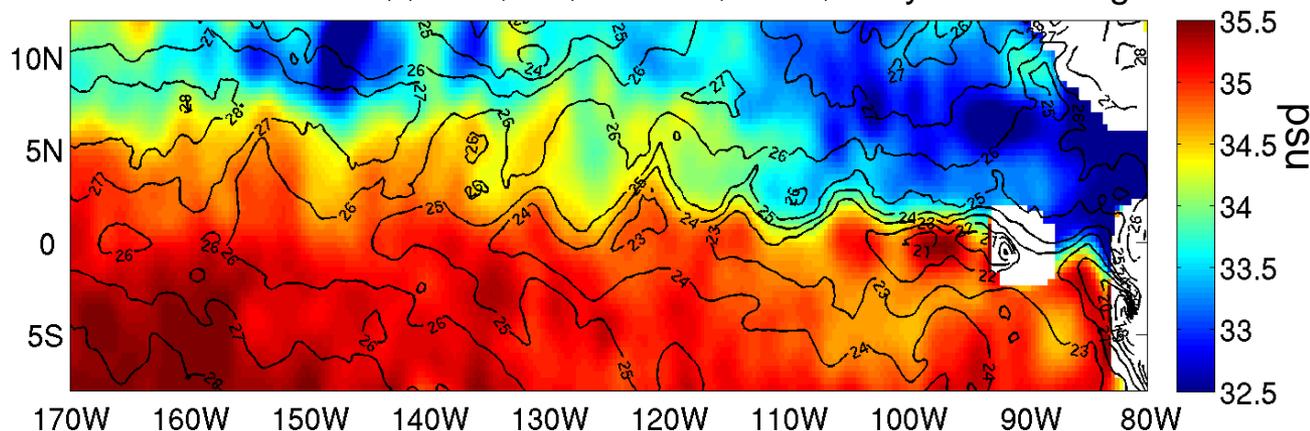
# Aquarius & SMOS observed new features of Pacific TIWs

*Lee et al. (2012), Yin et al. (2014)*

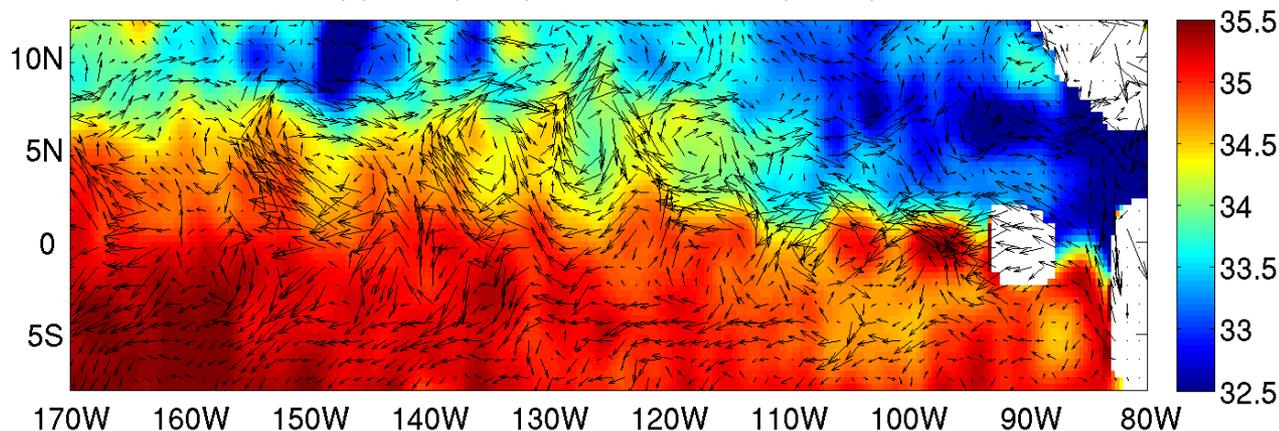
**SSS from Aquarius (color shading), SST (contours in a),  
surface currents (arrows in b) on Dec. 11, 2011 (7-day maps)**

- TIWs are important to ocean, air-sea interaction, & BCG
- Satellite SSS revealed new features of Pacific TIWs

(a) SSS (color) and SST (contour) Reynolds 1/4-deg OI

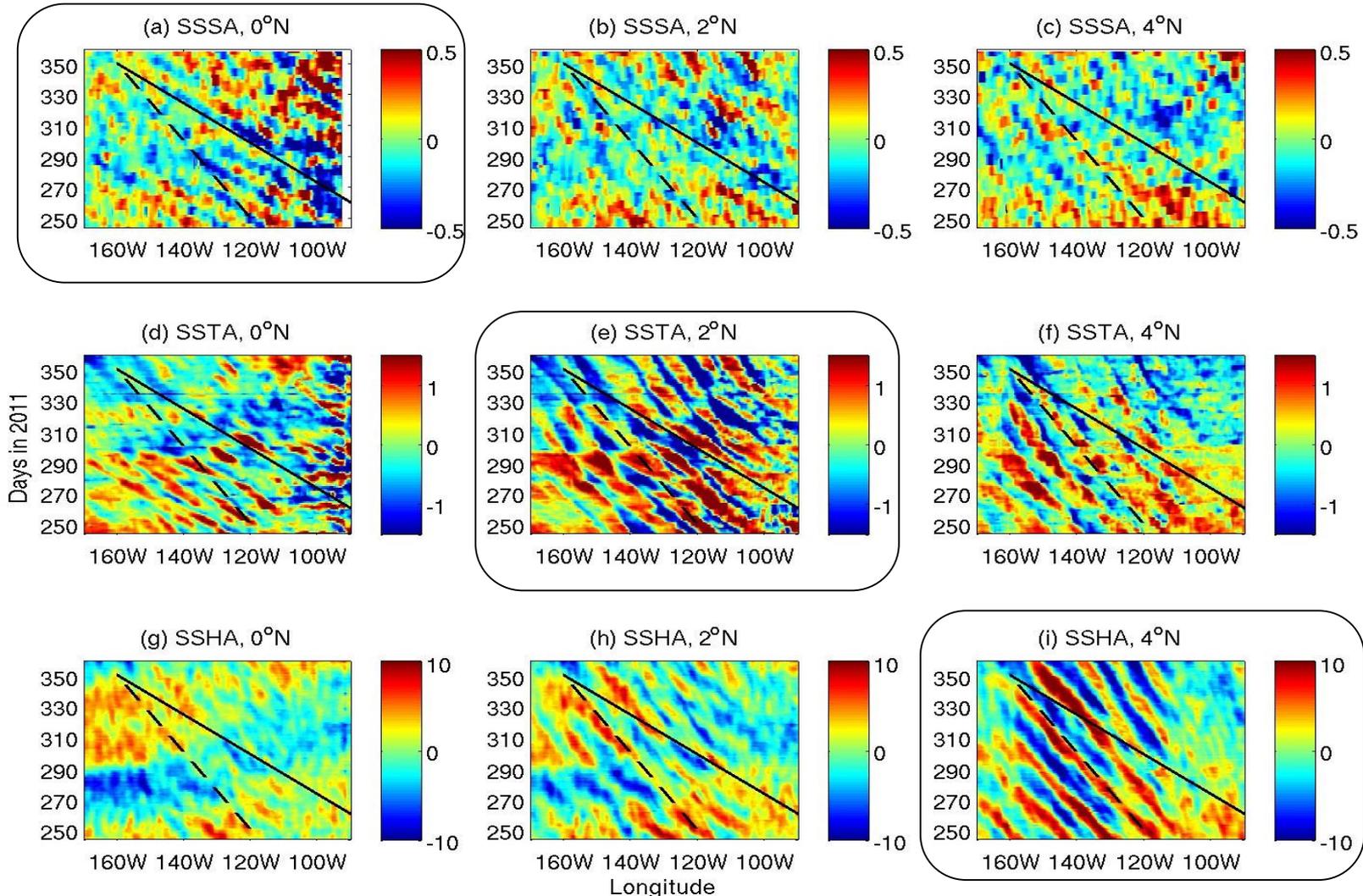


(b) SSS (color) & surface current (vector) OSCAR



# Aquarius revealed faster TIW speed near than off equator

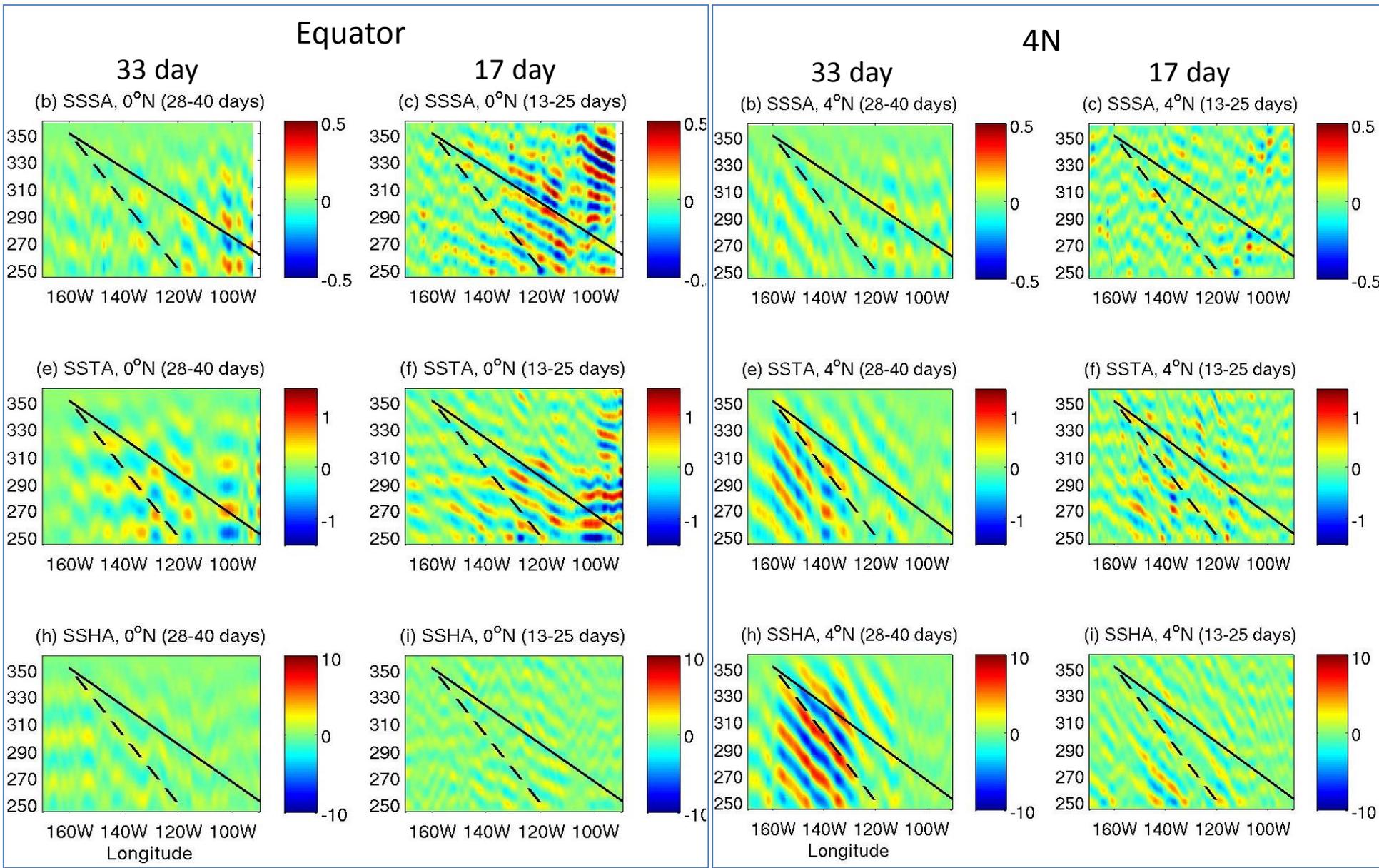
- Twice as fast as that off the equator observed by SST & SSHA (during 2011)
  - Not reported in the past few decades of literature
- Lee et al. (2012)



SSS, SST, SSH show strongest signals at 0, 2, 4N, complementary

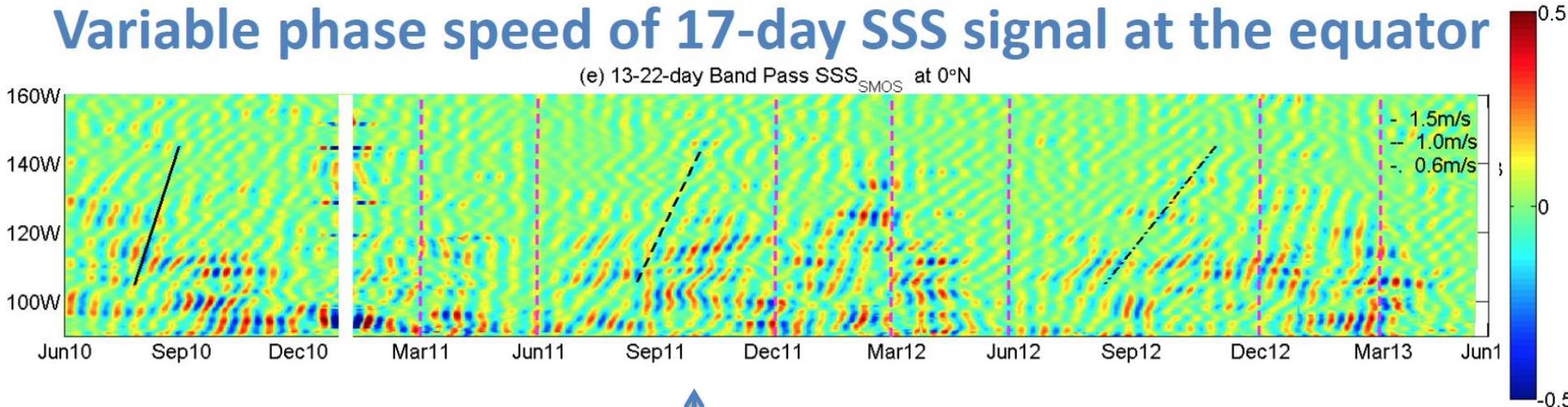
# TIWs near the equator: 17-day dominant period (Yanai Waves)

## TIWs away from equator: 33-day dominant period (Rossby waves)



# SMOS data revealed interannual variation of TIW speed at the equator, faster during La Nina

## Variable phase speed of 17-day SSS signal at the equator

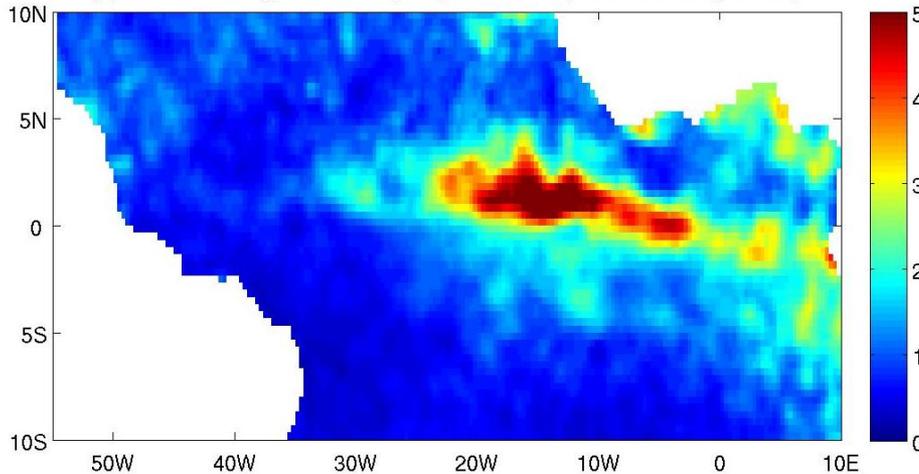


Consistent with  
Aquarius result  
(Lee et al. 2012)  
during this period

# Aquarius reveals importance of salinity in energy budget of Tropical Atlantic instability waves (*Lee et al 2014*)

## Surface EPE considering only SST effect

(a) Potential energy considering only SST effect (20-50 instability waves)



**Science question:** How important is salinity to Tropical Atlantic TIW energetics?

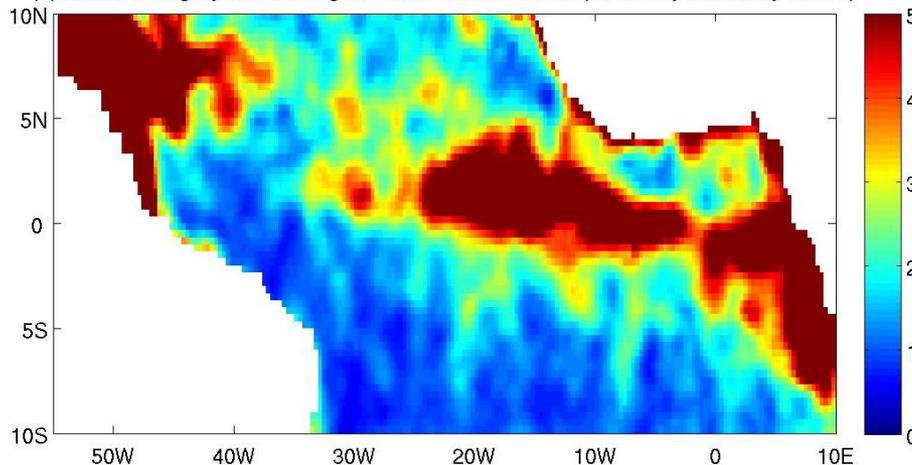
**Result:** ignoring SSS effect would under-estimate TIW-related Eddy Potential Energy (EPE) by 3 times

## Significance/implication:

- SSS need to be considered in energy budget and studies of wave-mean flow interaction.
- Revisit the relative roles of baroclinic vs barotropic instabilities

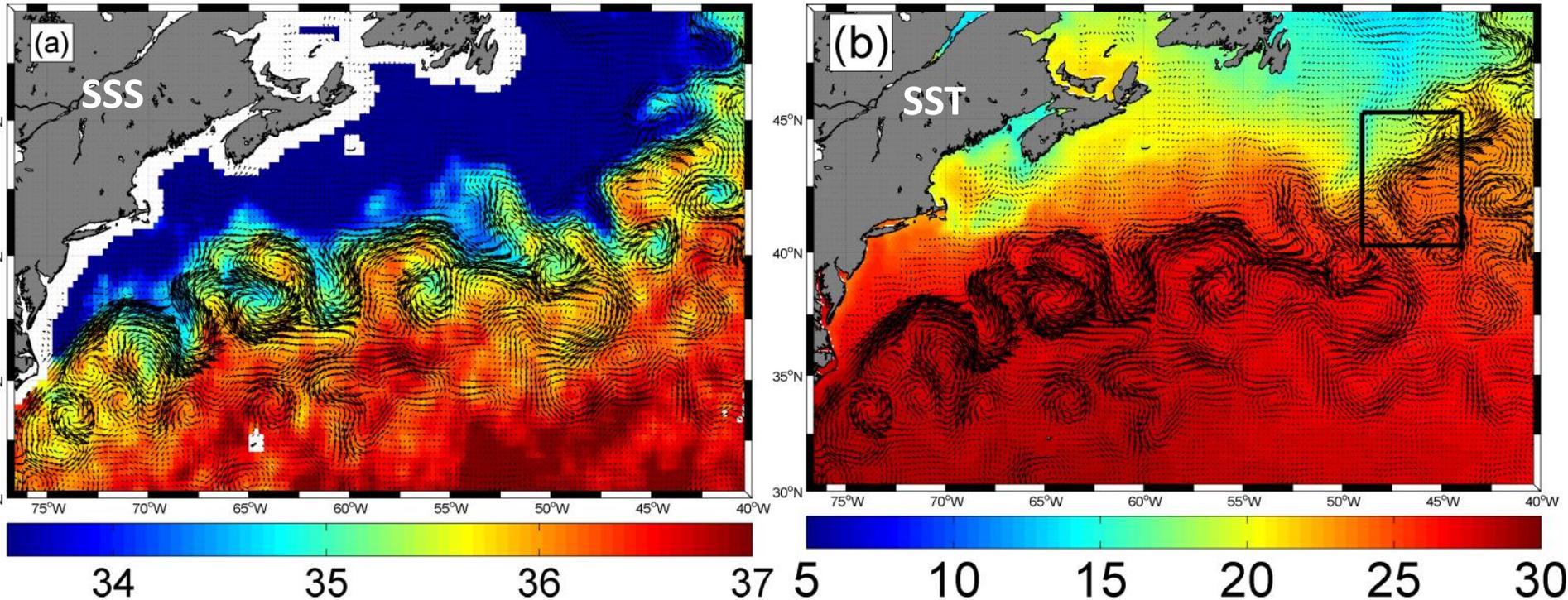
## Surface EPE considering both SST & SSS effects

(b) Potential energy considering both SST & SSS effects (20-50 day instability waves)



# SMOS reveal SSS structure of the Gulf Stream & cold-core eddies with unprecedented spatiotemporal resolutions

*Reul et al. (2014)*



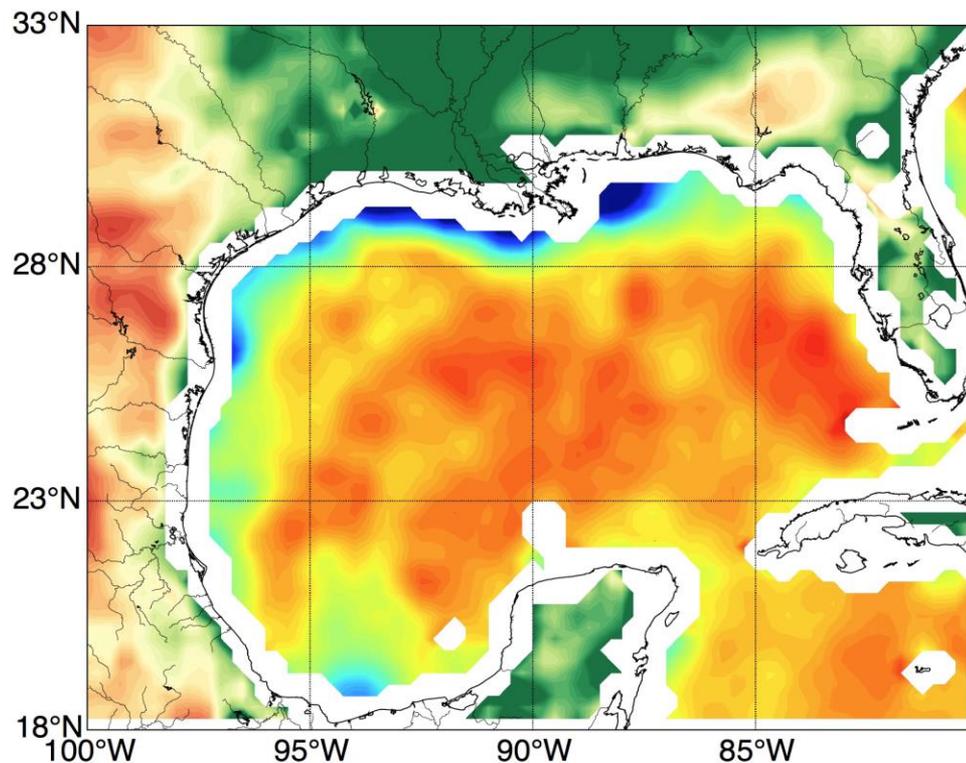
- Cold/fresh Core rings are better captured by SSS than SST during summer.
- Implication: cross-gyre salt transport by eddies

Several related studies (focusing on cross-shelf exchanges):

e.g., Grodsky, S.A., Reul, N., Chapron, et al. (2017). Interannual Surface Salinity in Northwest Atlantic Shelf, JGR, 122, 3638–3659.

# Improving environmental assessment: SMAP sea surface salinity & soil moisture during & after the May'15 extreme flooding event in Texas

SMAP SSS & SM - 2015-04-04



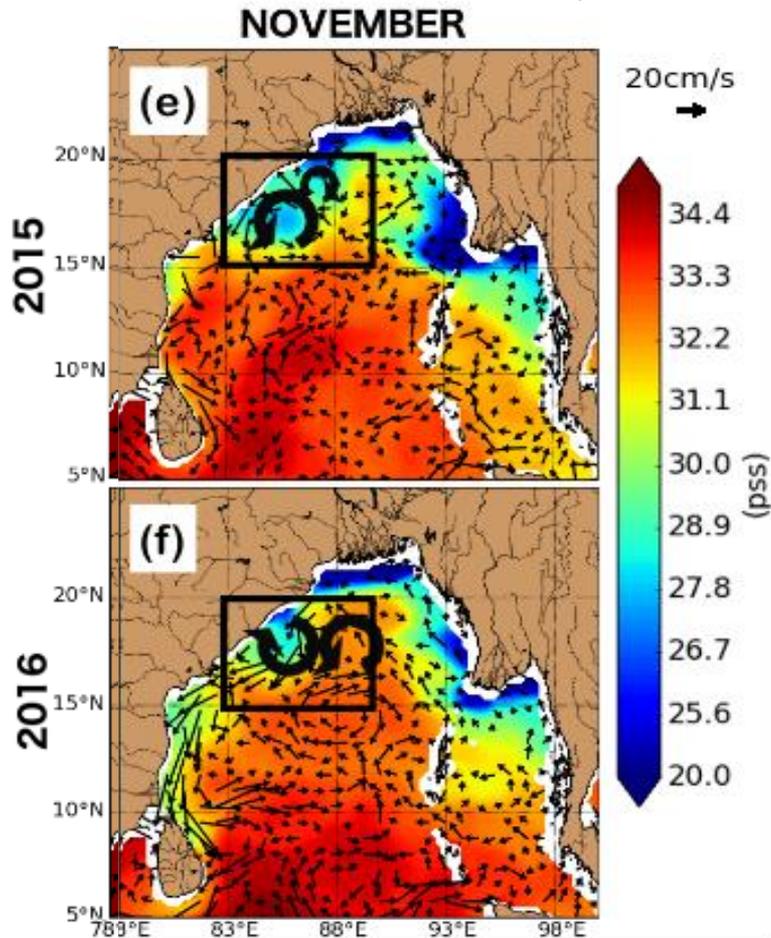
0.00 0.06 0.12 0.18 0.24 0.30  
SMAP Soil Moisture (cm<sup>3</sup>.cm<sup>3</sup>)

32.00 33.02 34.04 35.06 36.08 37.10  
SMAP SSS (pss)

**Unusually large freshwater plume in the central Gulf of Mexico was caused  
by runoff to Texas shelf (*Fournier et al. 2016a*)**

# Modulation of the Bay of Bengal river plume by the Indian Ocean Dipole (IOD) and ocean eddies inferred from satellite data

(Fournier et al. 2017a)



SMAP SSS for November 2015 & 2016 with ocean surface currents superimposed.

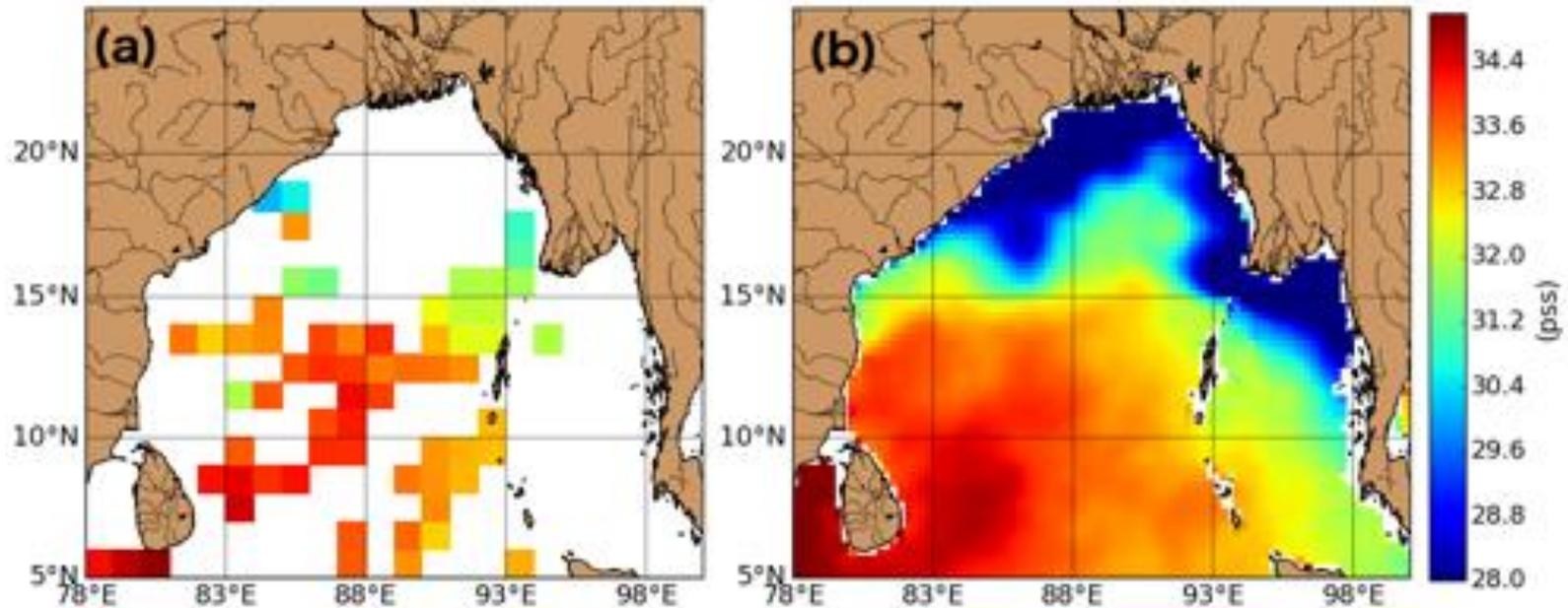
Thick arrows highlight eddies.

**Science question:** What processes influence the variability of the climatically and biologically important Ganges-Brahmaputra (GB) River plume in the Bay of Bengal (BoB)?

**Finding:** (1) Negative IOD in 2016 caused a stronger East India Coastal Current (EEIC) that carried the GB river plume ~600 km further south. (2) Ocean mesoscale eddies help transport river freshwater plume offshore.

**Significance/implication:** Satellite SSS provide new resources to monitor intraseasonal to interannual variability of the GB river plume & study its impacts on monsoon, cyclones, and biological productivity.

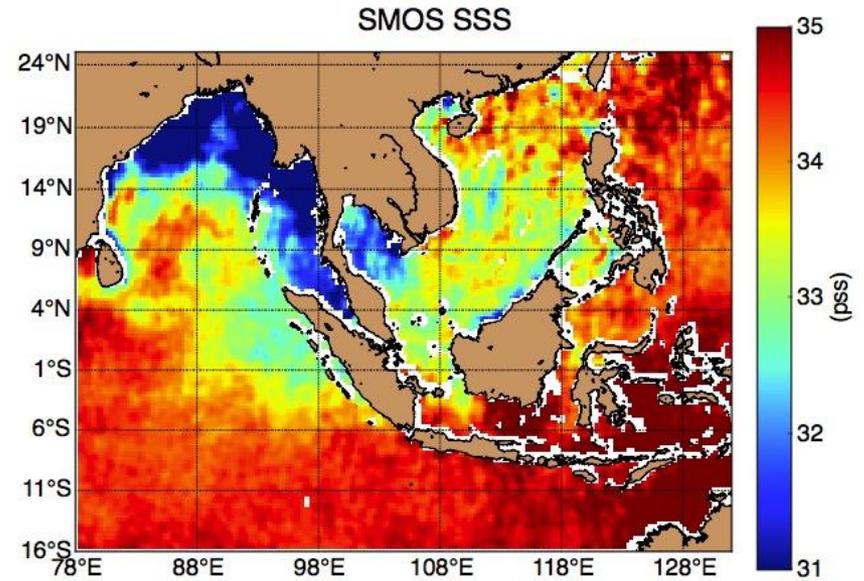
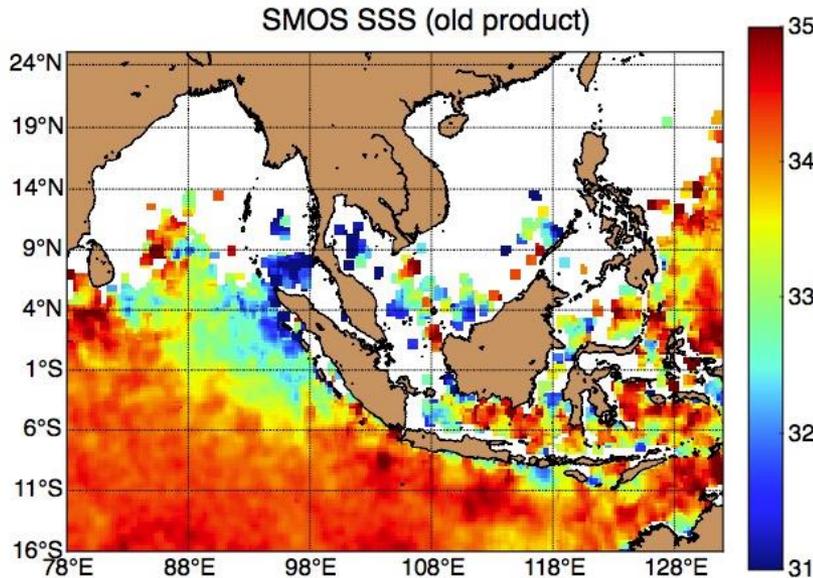
## Satellite SSS provide much better spatiotemporal coverage



**(a)** September-November 2015 Argo 5-m SSS measurements averaged within 1 degree pixels and **(b)** September-November 2015 average map of SMAP SSS (complete coverage was actually achieved in 8 days)

Fournier et al. (2017a)

# Improvement of new SMOS SSS product & consistency with SMAP SSS



New SMOS SSS product (CATDS, Boutin et al. 2017) brought significant improvements in marginal seas & coastal oceans.

New SMOS SSS very consistent with SMAP SSS

SMOS & SMAP SSS further enhanced sampling

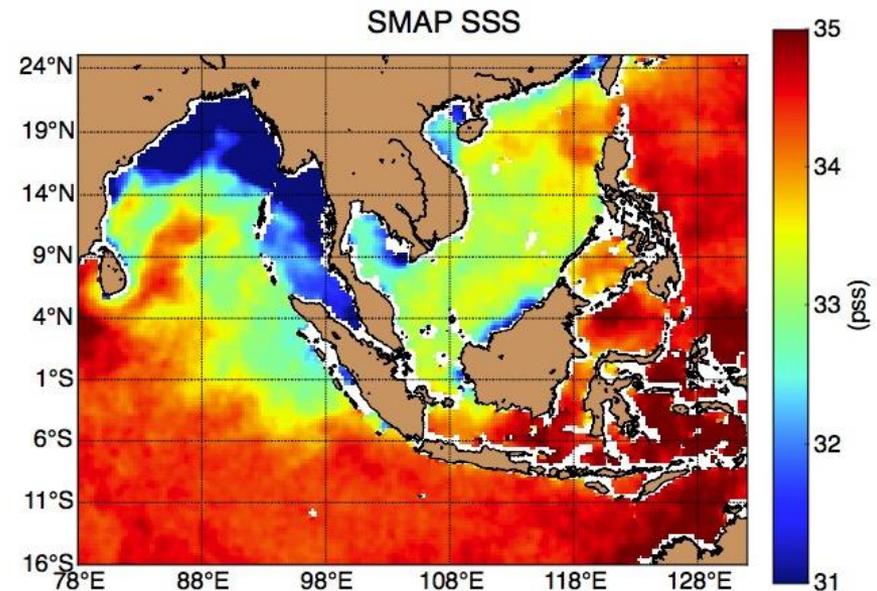


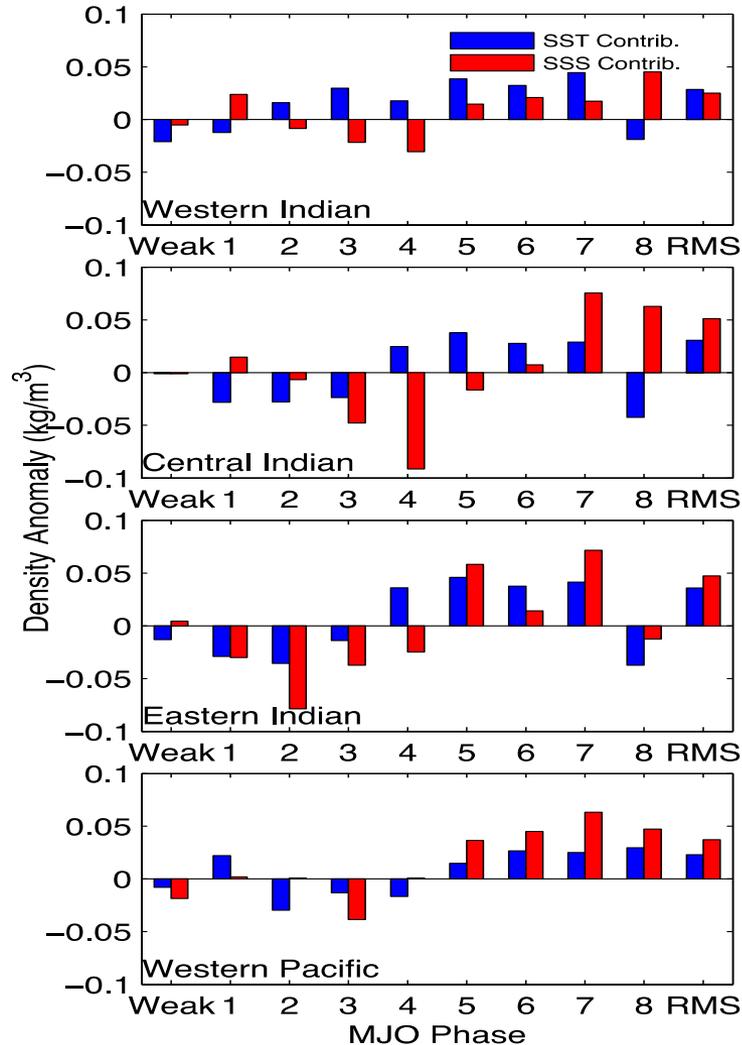
Image credit: Severine Fournier

# Sea surface salinity (SSS) & the Madden-Julian Oscillation (MJO)

(Guan et al. 2014)

Contribution of SST & SSS to surface density anomalies during a composite MJO life cycle

(Phases 1-8, in different regions)



**Problem:** Relative contributions of SSS & SST to MJO-related changes in ocean surface density are poorly known.

**Finding:** Aquarius SSS together with satellite SST suggest that SSS has a similar or larger contribution as SST to MJO-related variation in surface density.

**Significance/Implication:** Modeling and assimilation products need to properly account for SSS effects in order to correctly represent mixed layer variability associated with the MJO and the related ocean-atmosphere coupling.

**Need PMW SST as well as SSS for convective systems like MJO!**

# Use of satellite SSS for constraining E-P forcing & ocean models

## Ocean model salinity are affected by:

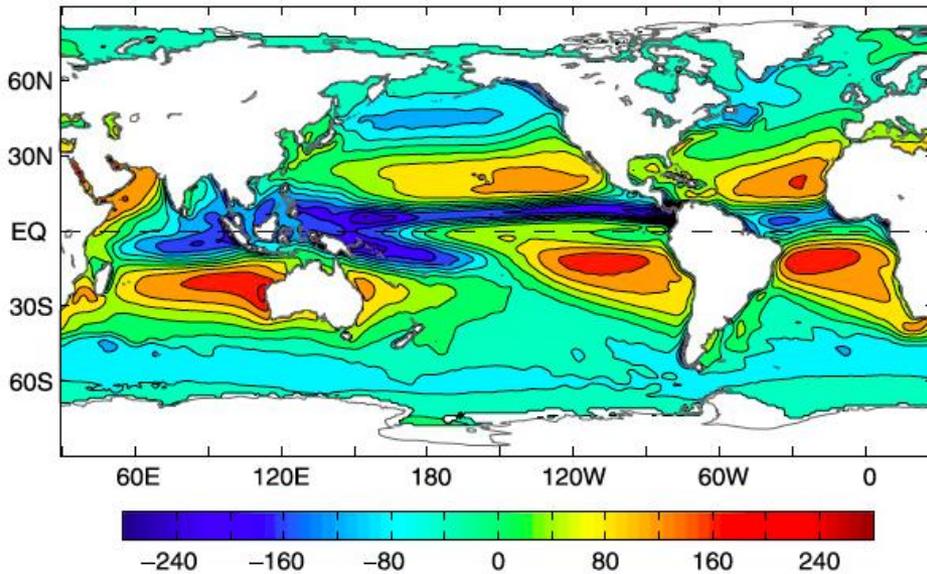
- significant E-P forcing error;
- use of river discharge climatology;
- relaxation to SSS climatology;
- errors in model physics (e.g., advection & mixing) & numerics

**Satellite SSS have the potential alleviate these limitations**

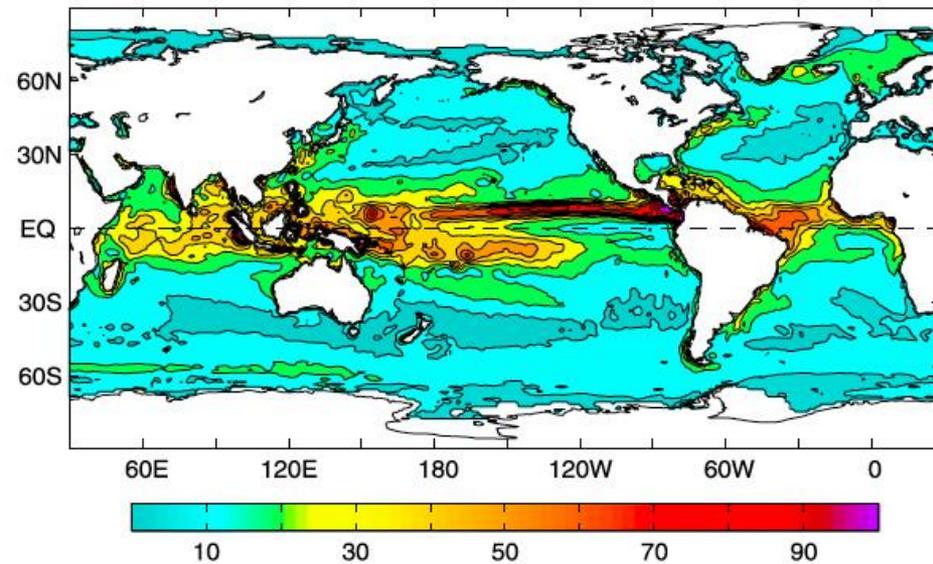
# Large spread among 12 E-P products

(Yu et al. 2017)

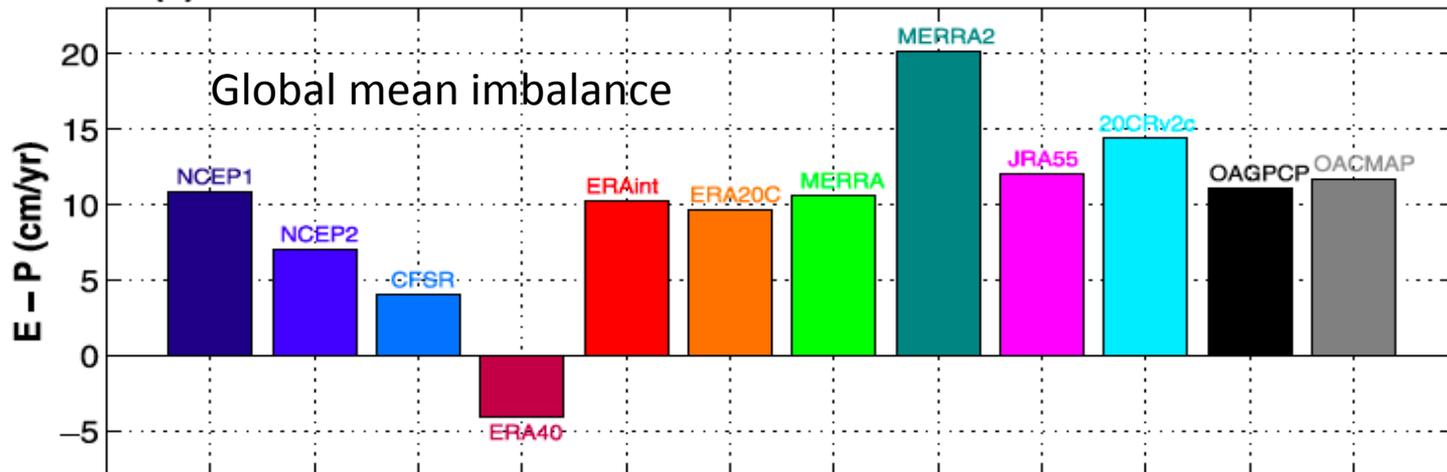
(a) Mean E-P (cm/yr)



(d) STD (Mean Spread) E-P (cm/yr)

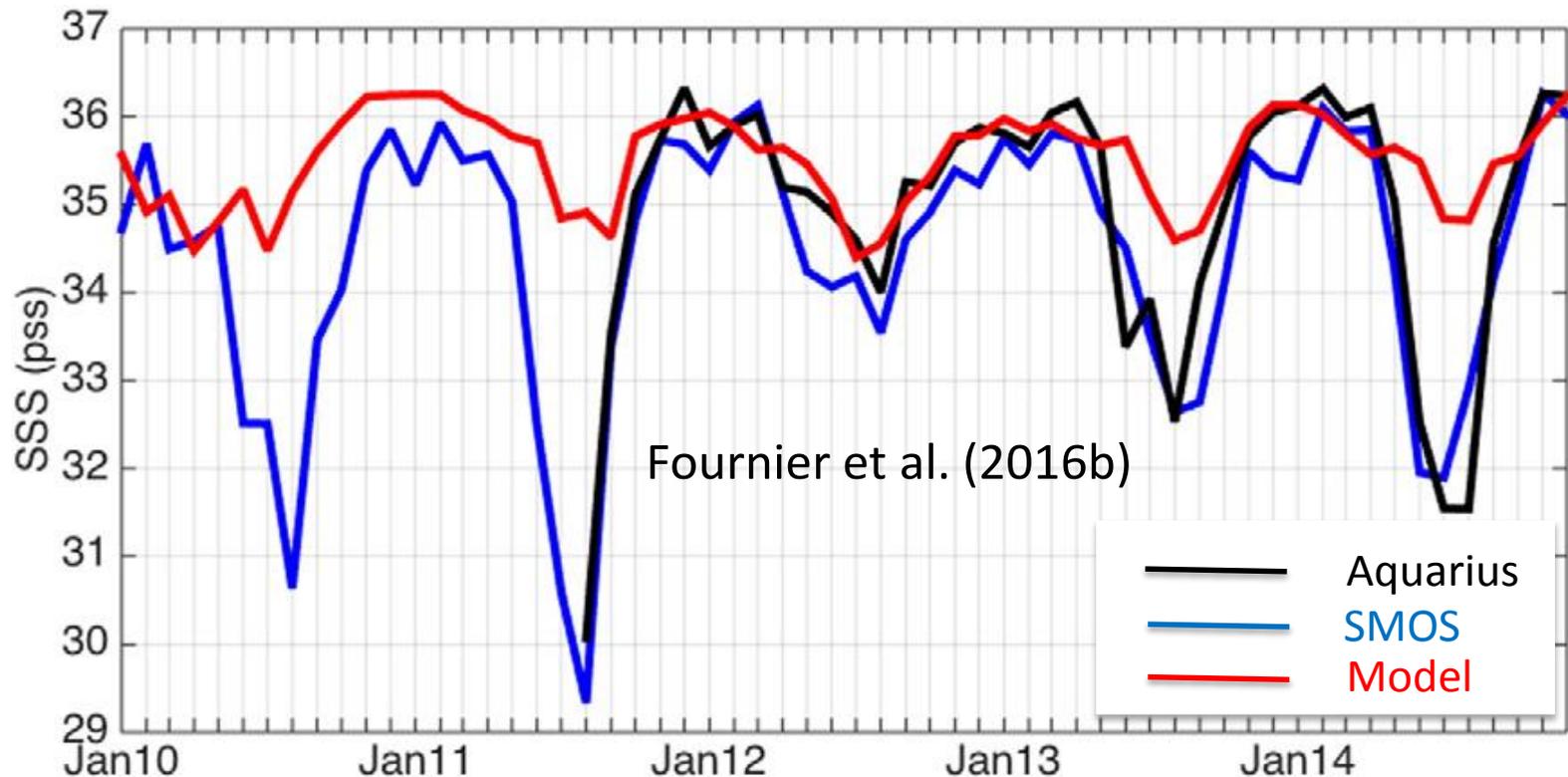


(a)



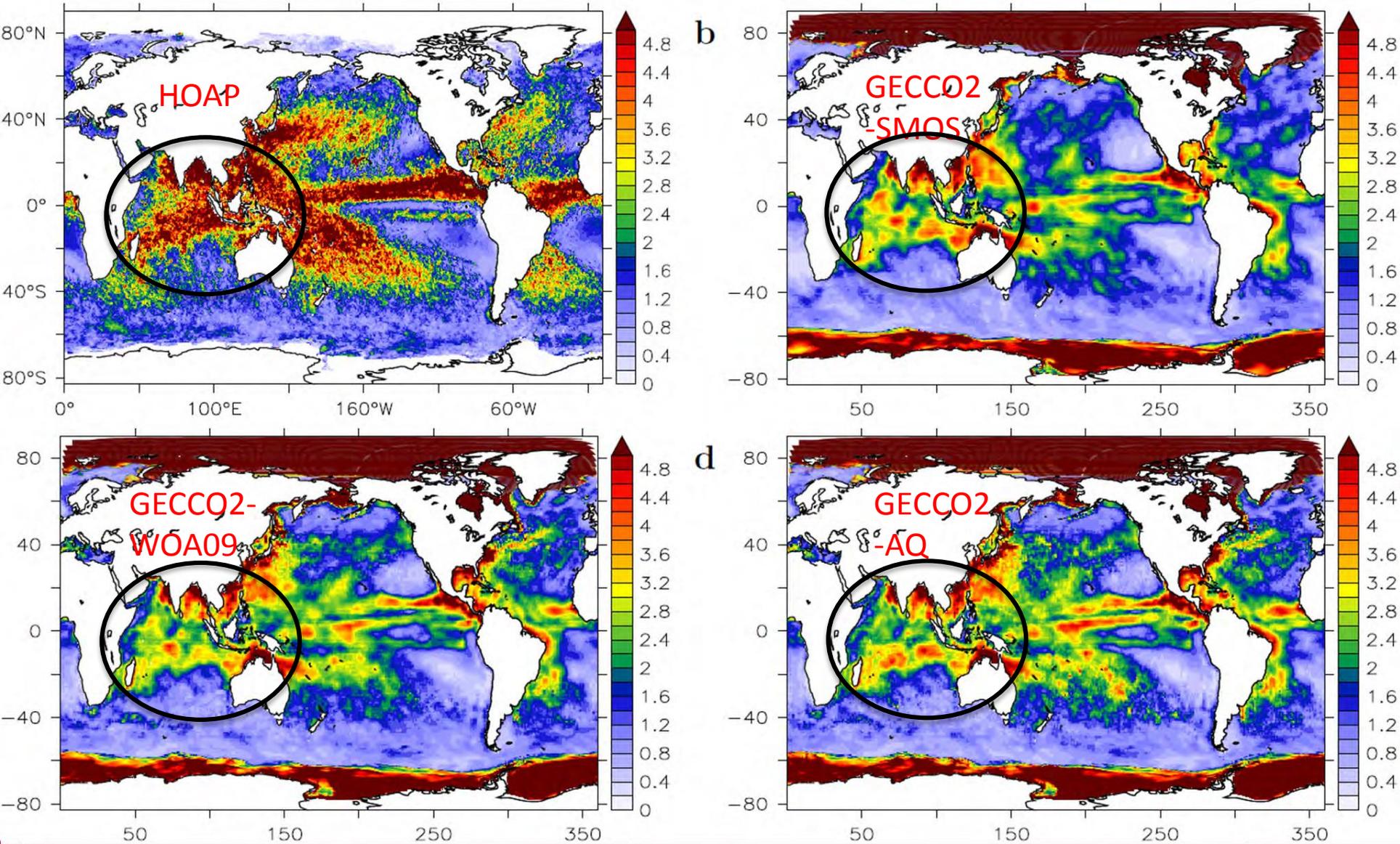
# Lack of interannual variations of SSS near river mouths in ocean models

SSS near the Mississippi River mouth from Aquarius, SMOS, and an operational global ocean assimilation product



Significant implications to marine biogeochemistry

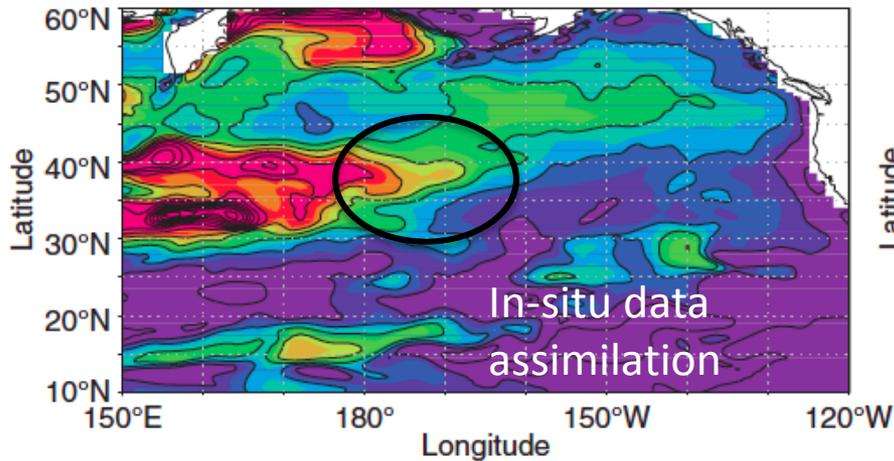
# Impact of satellite SSS assimilation on inverse estimate of E-P variability in GECCO2 (Köhl et al. 2014)



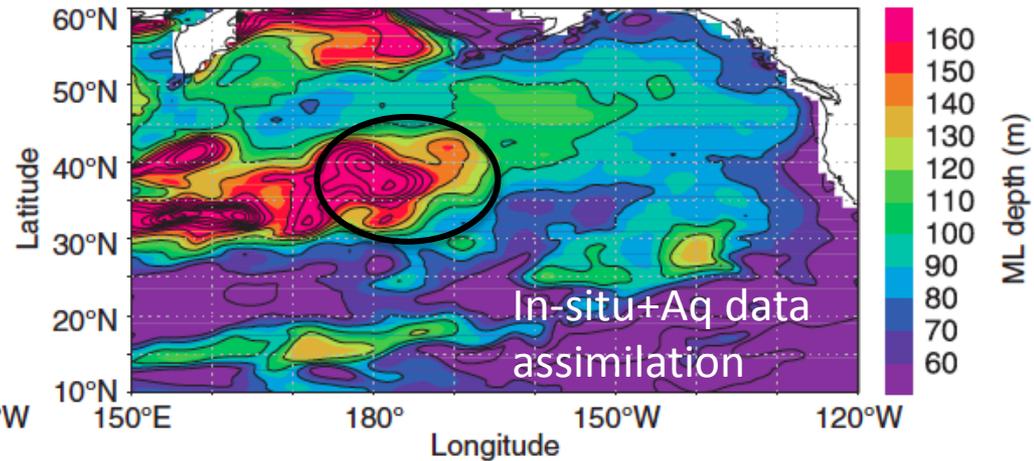
# Improvements of JMA/MRI global ocean data assimilation system by assimilating Aquarius SSS (*Toyoda et al. 2014*)

Example for North Pacific Mode Water distribution in winter of 2012

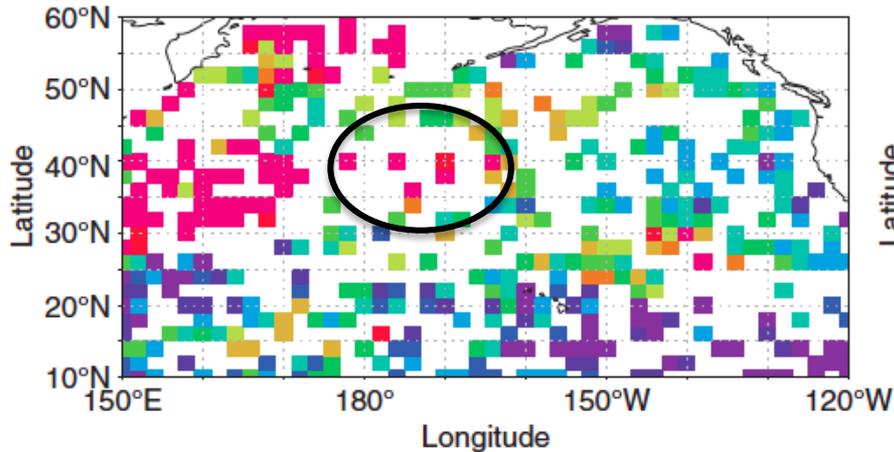
(a) MLD CTL Feb 2012



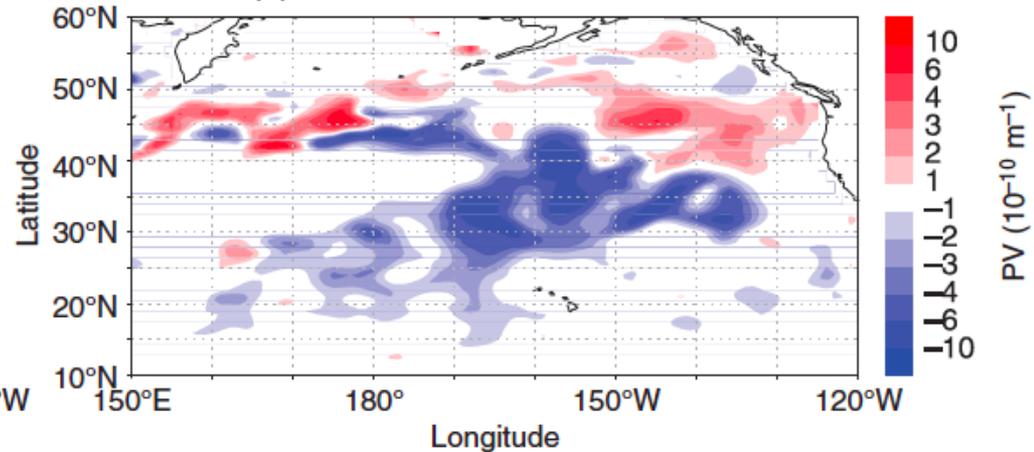
(b) MLD ASA Feb 2012



(c) MLD MILA-GPV Feb 2012



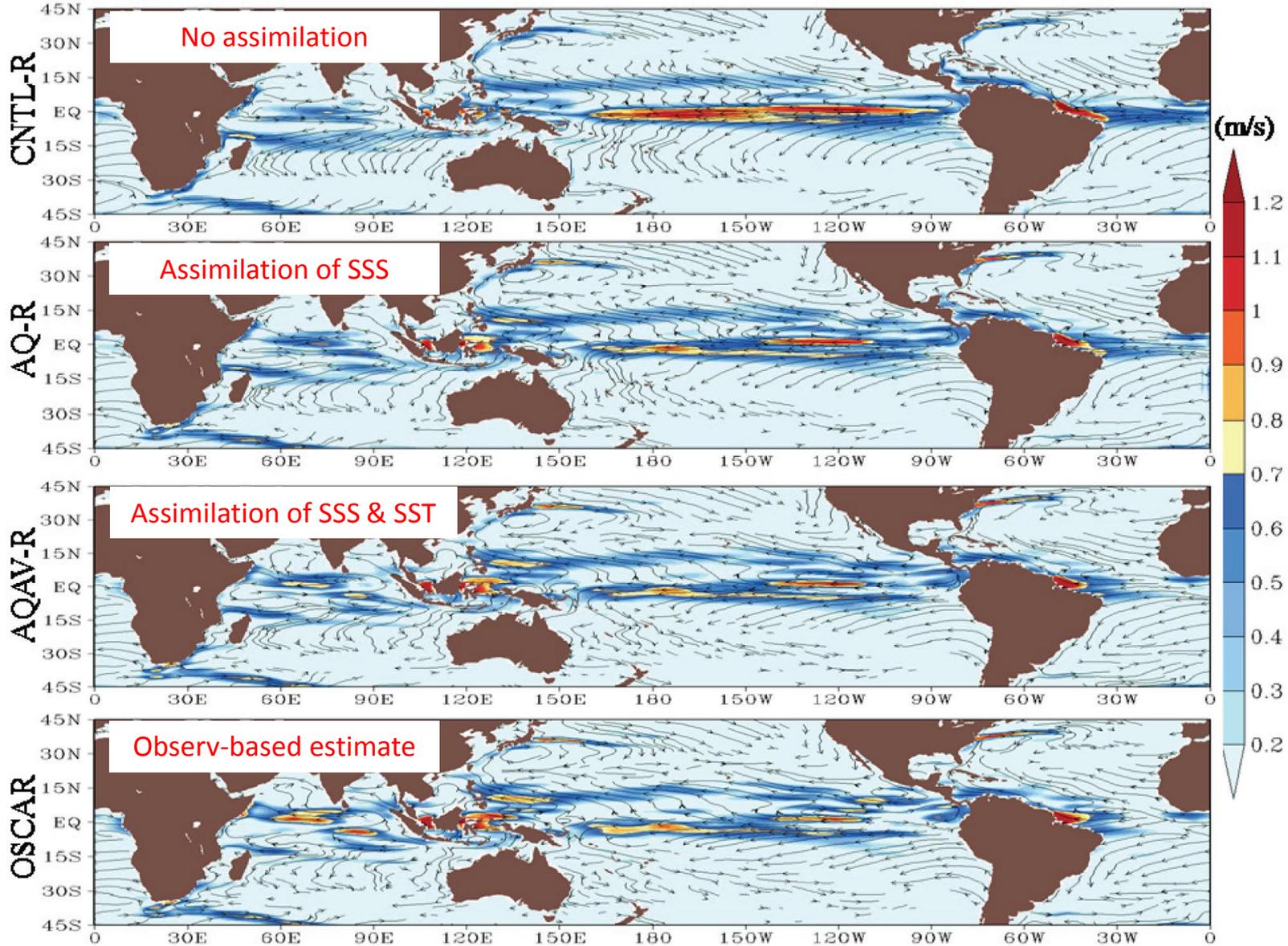
(d) PV 100m ASA-CTL Feb 2012



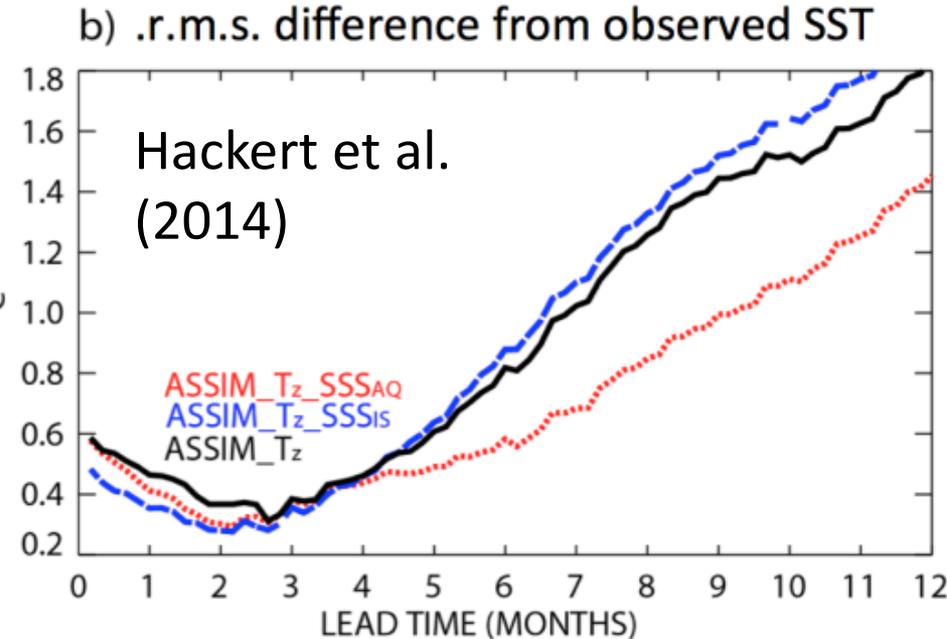
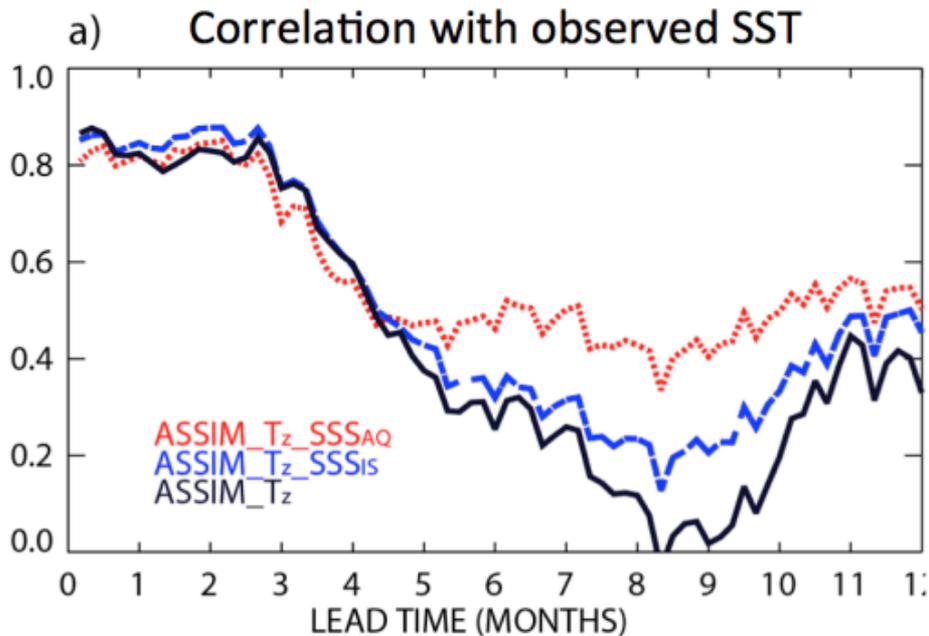
# Assimilation of Aquarius SSS & AVHRR SST improves representation of ocean surface currents (Chakraborty et al. 2014)

*Spatial amplitude of the 1<sup>st</sup> EOF mode of surface currents*

Indian Global Ocean Data Assimilation System



# Impact of satellite SSS assimilation on seasonal-to-interannual prediction for 2011-2014



ASSIM\_Tz: baseline experiment, assimilation of all subsurface temperature data.

ASSIM\_Tz\_SSS<sub>IS</sub>: assimilation of all subsurface temperature and in-situ salinity data.

ASSIM\_Tz\_SSS<sub>AQ</sub>: assimilation of all subsurface temperature and Aquarius SSS data.

The latter has higher correlation & lower RMSE wrt observed SST for lead times > 4 months.

Need long data record (covering many ENSO events) to establish the robustness of impacts on prediction

-> continuity of L-band mission important

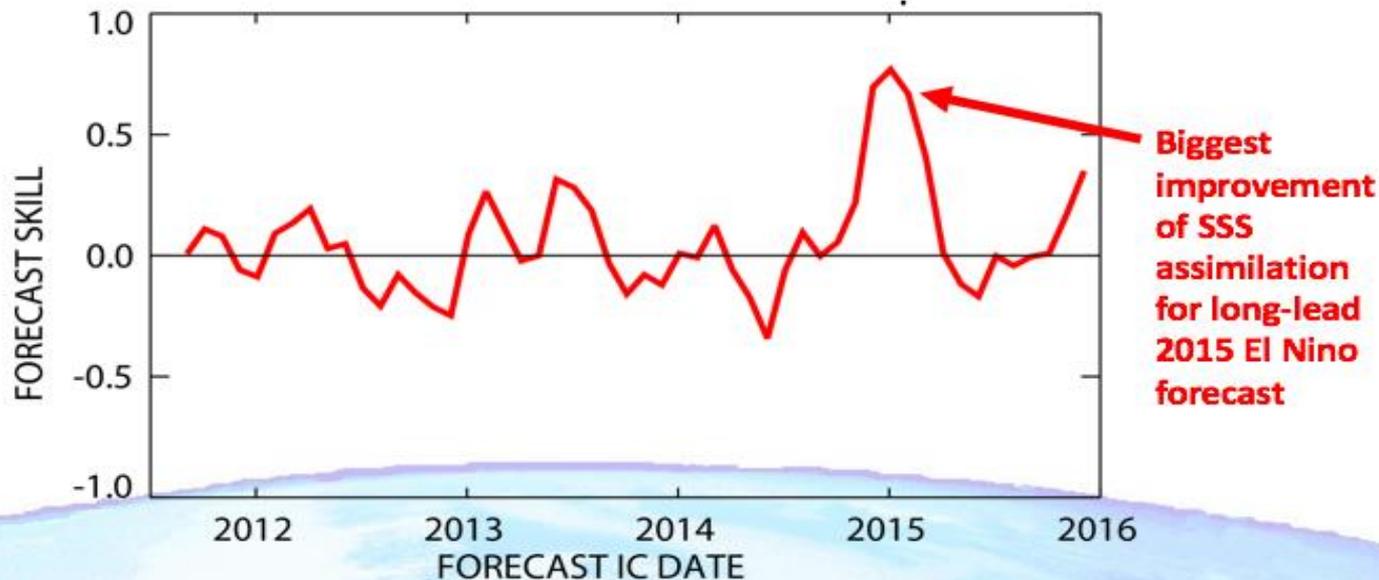
# Ongoing work based on NASA/GMAO ocean data assimilation & coupled model hindcasts

## Experiment Design

Experiment Name	Period	Assimilation Variables
ASSIM_SL_SST_T <sub>z</sub> S <sub>z</sub> "Control"	Jan 1993 – Dec 2016	SL, SST, T <sub>z</sub> and S <sub>z</sub>
ASSIM_SL_SST_SSS_T <sub>z</sub> S <sub>z</sub> Known as "SSS Assimilation"	Sep 2011 – Dec 2016*	SSS from <b>Aquarius</b> Version 4.0 combined with <b>SMAP</b> Version 2.0 Level 3 data and SL, SST, T <sub>z</sub> , and S <sub>z</sub>

Courtesy of  
Eric Hackert  
NASA/GMAO

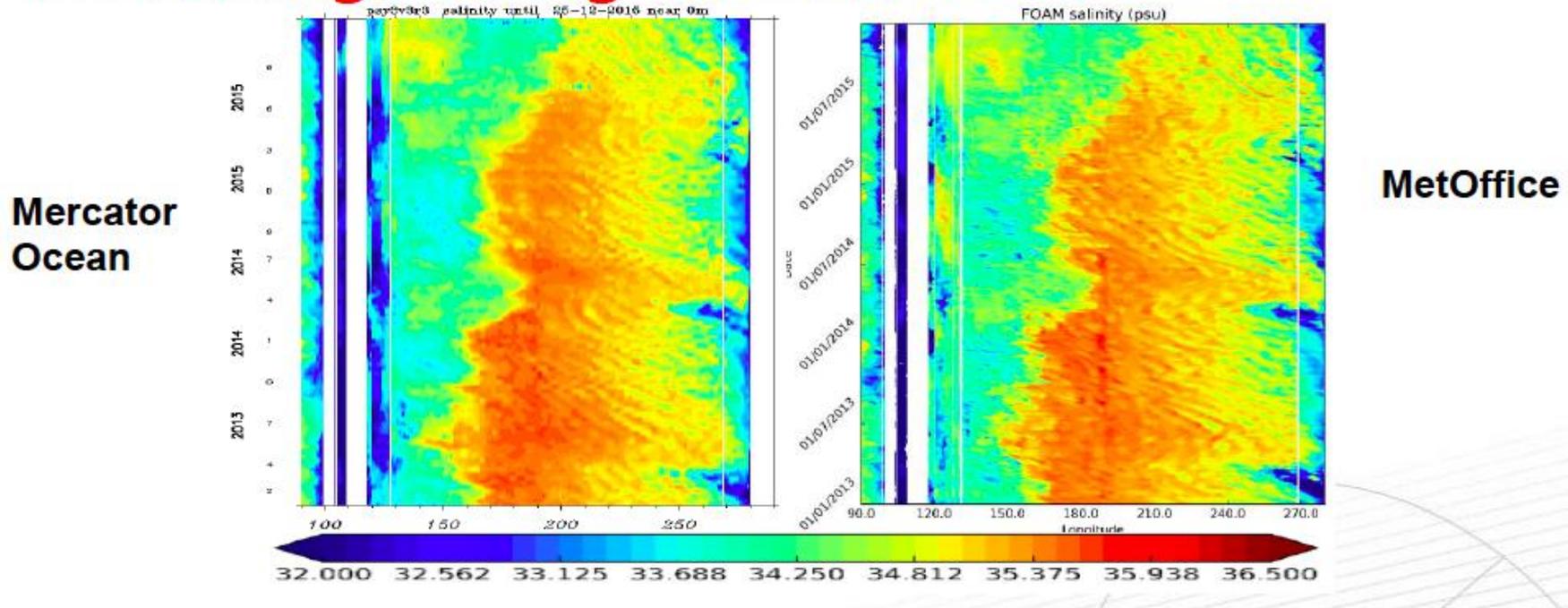
NINO 3.4 SST Diff CORR OVER 12 MON FORE



# SMOS-NINO15 Project funded by ESA

Coordinated experiments between **UK Met Office & Mercator Ocean** to investigate the impacts of assimilating satellite SSS from SMOS, Aquarius and SMAP on simulating the 2015/16 El Niño period.

## Freshening during El-Niño 2015

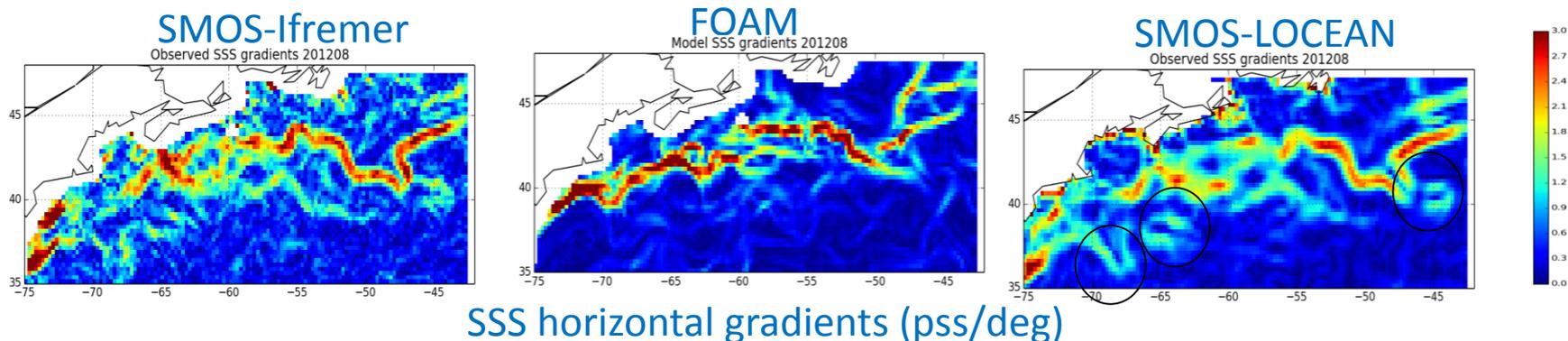


Courtesy of Matt Martin and Benoit Tranchant (Mercator Ocean)

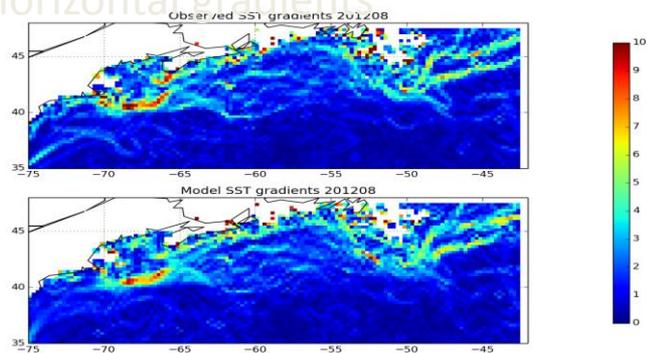
# Ongoing effort for satellite SSS assimilation at UKMO

## Spatial information in satellite SSS data

[Martin, M.J., 2016, doi:10.1016/j.rse.2016.02.004.](https://doi.org/10.1016/j.rse.2016.02.004)



## SST horizontal gradients



- SSS fronts agree reasonably well between model and obs.
- SMOS data shows some frontal structures in the main part of the Gulf Stream which the model doesn't represent.
- Surface warming has masked the underlying structures in SST in August.

Courtesy of Matt Martin, UK Met Office

# Other ongoing efforts for satellite SSS assimilation

- Estimating the Circulation & Climate of the Ocean (ECCO) 4D-VAR
- NOAA: Global Real-time Ocean Forecasting System (RTOFS); West Coast Ocean Forecasting System (WCOFS)
- Chinese National Marine Environmental Forecasting Center

## Estimating the Circulation & Climate of the Ocean



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### THE ECCO CONSORTIUM

ECCO was established in 1998 as part of the World Ocean Circulation Experiment (WOCE) with the goal of combining a general circulation model (GCM) with diverse observations in order to produce a quantitative depiction of the time-evolving global ocean state. The importance of such an endeavor is recognized by numerous national and international organizations, such as the WMO's World Climate Research Programme (WCRP) and UNESCO's Intergovernmental Oceanographic Commission (IOC). These programs have all noted the necessity of synthesizing the diverse remotely-sensed and in-situ observations with known dynamics and thermodynamics through a GCM. ECCO products are in support of the Climate Variability and Predictability (CLIVAR) programme and the Global Ocean Data Assimilation Experiment (GODAE). [more](#)

### ECCO PRODUCTS

ECCO products as well as input fields and quality-controlled observations are freely available from several data servers through various applications (including DODS/OPeNDAP, LAS, GDS, Dapper, SRB, Ingrid).

[A summary of available ECCO products and data servers can be found here.](#)

### ECCO'S GENERAL CIRCULATION MODEL

The ECCO code is based on the MIT general circulation model (MITgcm), a numerical model designed for study of the atmosphere, ocean, and climate. It comes with a variety of packages including physical parameterizations, a sea-ice model, biochemical components, and allows flexible porting across various HPC platforms. [For more details on the MITgcm click here.](#)

### AUTOMATIC/ALGORITHMIC DIFFERENTIATION (AD)

Since the mid-1990's, groups at MIT, SIO, JPL and GFDL have applied automatic/algorithmic differentiation (AD) tools for generating tangent linear and adjoint code for ocean circulation and climate studies. ECCO relies heavily on the AD tool TAPC and its commercial successor TAF. The ECCO group is also involved in the development of a new open-source AD tool OpenAD. [More details can be found here.](#)

### IN THE NEWS

November 2017: ECCO Tutorial @ Ocean Sciences 2018:

National Weather Service  
**Environmental Modeling Center**

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News

Local forecast by "City, St" or Zip Code

City, St

Go

[Text-only version](#)

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## Global Real-Time Ocean Forecast System

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**NOTICE:** As of 17 Oct 2017 at 0Z, the Global RTOFS model has been upgraded to version 1.1.2. Changes include:

- The number of vertical layers has increased from 32 to 41.
- The core HYCOM model has been coupled to the Los Alamos Laboratory's Community Sea Ice model (CICE)
- Updated bathymetry
- Updated climatology
- Updated Equation of State from 9 to 17 terms

More information on the upgrade can be found in the [Release Notes \(pdf\)](#).

The global operational Real-Time Ocean Forecast System (Global RTOFS) at the National Centers for Environmental Prediction is based on an eddy resolving 1/12° global HYCOM (HYbrid Coordinates Ocean Model) and is part of a larger national backbone capability of ocean modeling at the National Weather Service in a strong partnership with the US Navy.

# **Future challenges & requirements for satellite SSS**

(based on community inputs to US Decadal Survey 2017-2027)

- Continuity to extend data record
- Enhancing spatial resolution and getting closer to the coasts.
- Improving accuracy, esp. at high-latitude oceans

# Community white papers in response to US Decadal Survey advocating for future requirements of satellite SSS

## Response to Decadal Survey RFI: Linkage of the Water Cycle, Ocean Circulation, and Climate

Tong Lee (Jet Propulsion Laboratory, California Institute of Technology)

### *US co-authors (in last-name alphabetical order):*

Eric Bayler (National Oceanic and Atmospheric Administration)  
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Subrahmanyam Bulusu (University of South Carolina)  
Jim Carton (University of Maryland)  
Kyla Drushka (University of Washington)  
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Seymour Grodsky (University of Maryland)  
Eric Hackert (University of Maryland)  
Gary Lagerloef (Earth and Space Research)  
Tim Liu (Jet Propulsion Laboratory, California Institute of Technology)  
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Ray Schmitt (Woods Hole Oceanographic Institution)  
Tony Song (Jet Propulsion Laboratory, California Institute of Technology)  
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Christine Gommenginger (National Oceanographic Centre, UK)  
Johnny Johannessen (Nansen Environmental and Remote Sensing Center, Norway)  
Nicolas Kolodziejczyk (University of Brest, France)  
Arndt Köhl (University of Hamburg, Germany)  
Christophe Maes (French Research Inst. for Exploitation of the Sea –IFREMER, France)  
Nicolas Reul (French Research Inst. for Exploitation of the Sea –IFREMER, France)  
Gilles Reverdin (University of Paris, France)  
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Roberto Sabia (European Space Agency ESRIN, Italy)  
Meric Srokosz (National Oceanographic Centre, UK)  
Detlef Stammer (University of Hamburg, Germany)  
Antonio Turiel (Institute of Marine Sciences, Spain)  
Susan Wijffels (Commonwealth Scientific & Industrial Research Organization, Australia)

Response to NRC 2017-2027 Decadal Survey Request for Information #2:

## “Linkages of salinity with ocean circulation, water cycle, and climate variability”

Tong Lee (Jet Propulsion Laboratory, California Institute of Technology)  
Simon Yueh (Jet Propulsion Laboratory, California Institute of Technology)  
Gary Lagerloef (Earth and Space Research)  
Mike Steele (University of Washington)  
Andrew Thompson (California Institute of Technology)  
Mar Flexas (California Institute of Technology)  
Arnold Gordon (Columbia University)  
Shannon Brown (Jet Propulsion Laboratory, California Institute of Technology)  
Tim Liu (Jet Propulsion Laboratory, California Institute of Technology)

### *Other US co-authors (in last-name alphabetical order):*

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Georgy Manucharayan (California Institute of Technology)  
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Meric Srokosz (National Oceanographic Centre, UK)  
Detlef Stammer (University of Hamburg, Germany)



# Enhancing spatial resolution and getting closer to the coasts

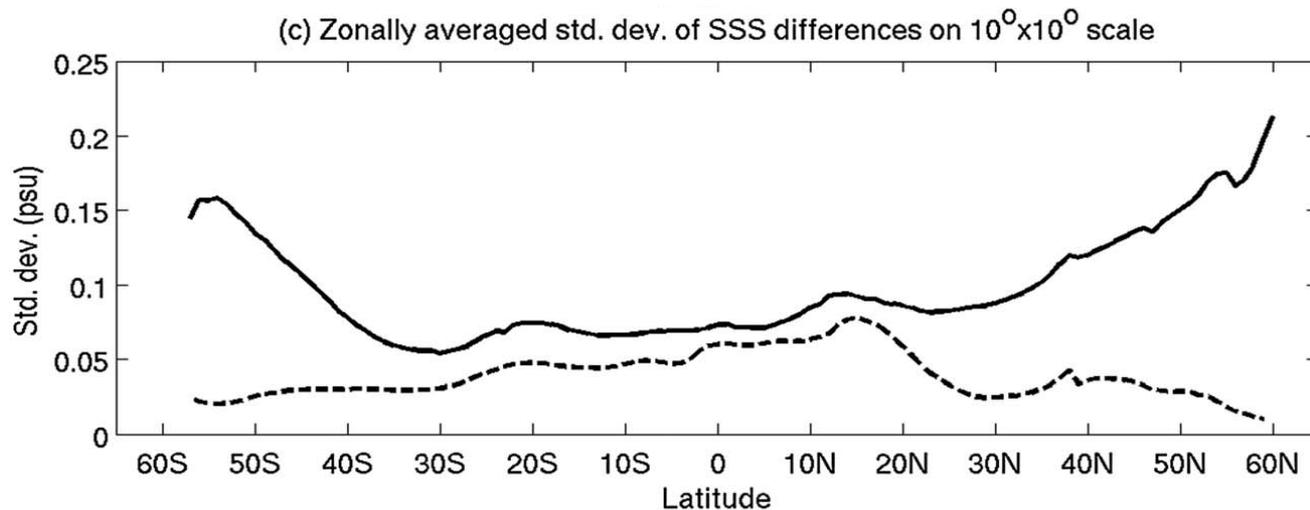
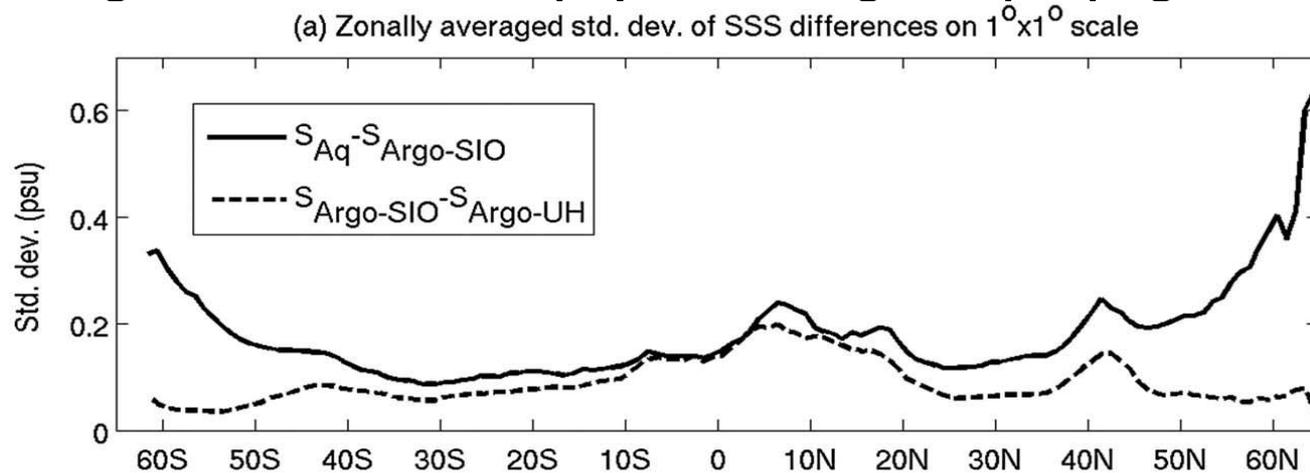
- Meso- & sub-mesoscale ocean dynamics
- Shelf-open ocean interactions
- Linkage of ocean and terrestrial element of the water cycle.
- Importance to biogeochemistry.



# Improving high-latitude SSS accuracies

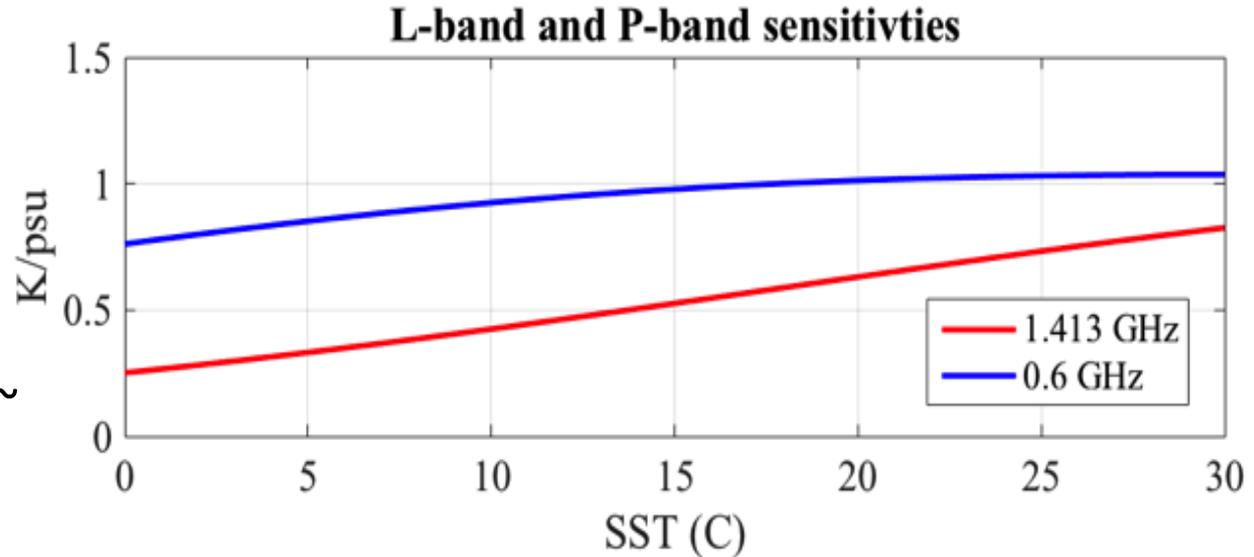
L-band SSS accuracies: Tropics & subtropics ✓ high-latitudes ✗

Zonally averaged STD of  $\Delta$ SSS for (Aquarius - Argo-SIO) & (Argo-SIO - Argo-UH)



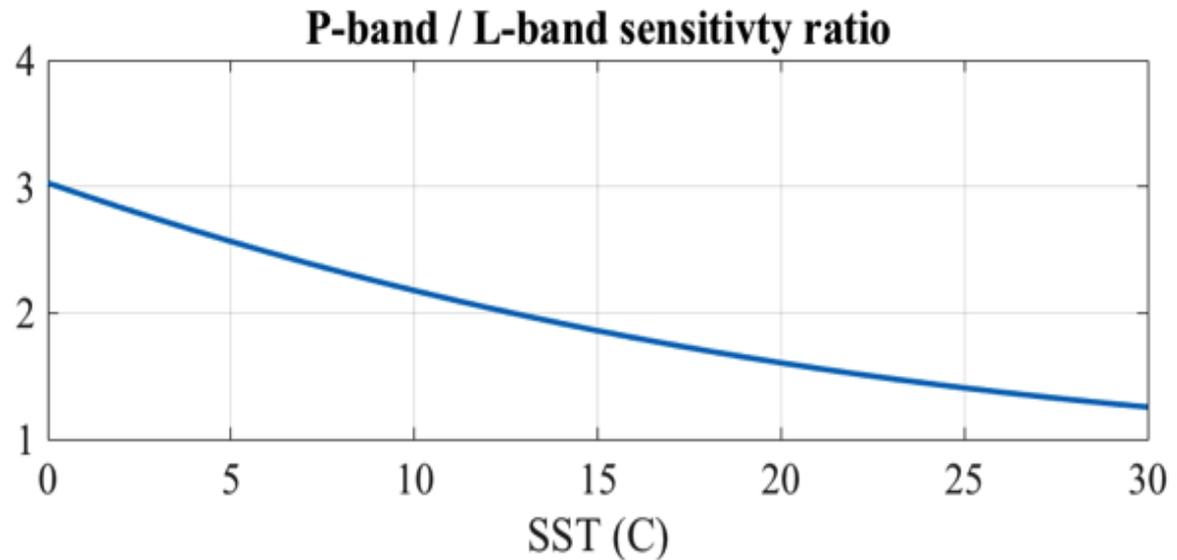
# Community input to US Decadal Survey: adding P-band to L-band to improve high-latitude SSS & sea ice thickness measurements

(Lee et al. 2016, NRC)



## Rationale:

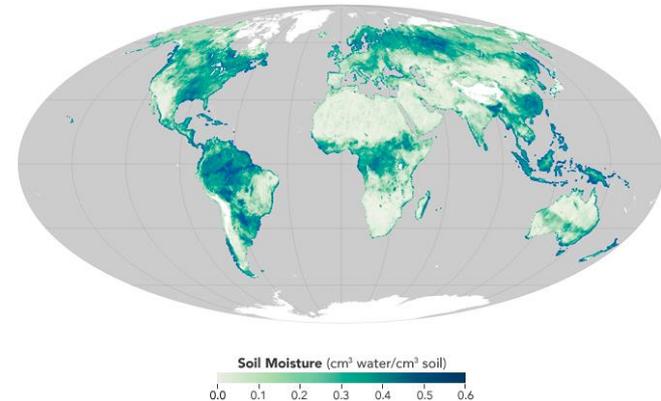
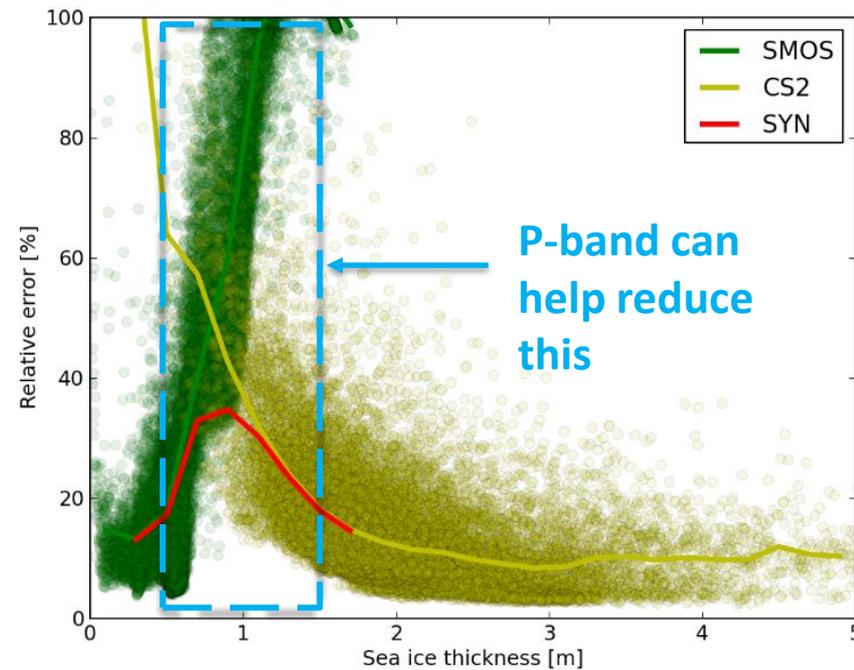
$T_B$  at P-band has  $\sim$  3 times better sensitivity to SSS than at L-band at high-latitude oceans



# Additional values of P-band radiometry

- Improving sea ice thickness measurements by complementing radar and L-band radiometry measurements
- Better thickness measurements for 1<sup>st</sup>-year ice in turn help improve SSS retrievals near sea ice.
- Other applications: ice shelf, land (e.g., soil moisture, evapotranspiration).

## Sea-ice thickness measurement error (Kaleschke et al. 2015)



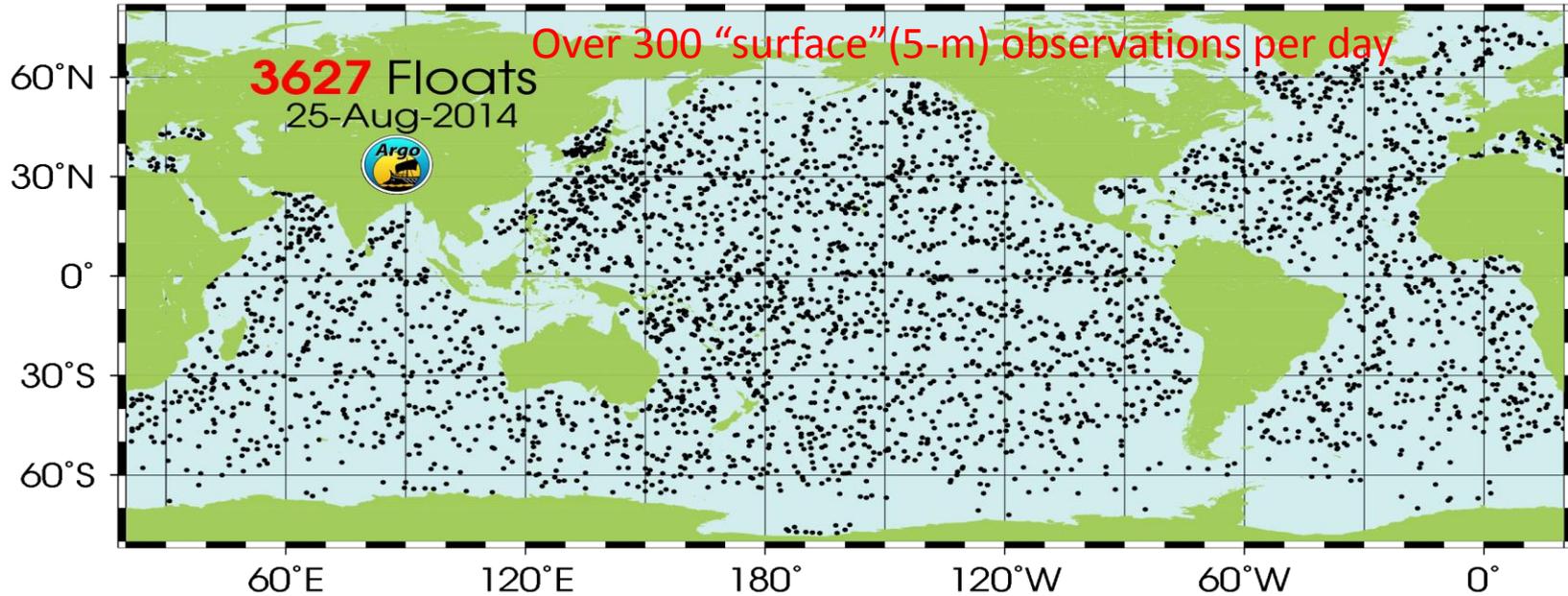
# Summary

- L-band satellite SSS have demonstrated the values to improve
  - the understanding of ocean processes and their linkages with the water cycle & climate variability;
  - environmental monitoring/assessment;
  - ocean state estimation & seasonal prediction
    - Important to understanding satellite SSS error characteristics, and take into account sampling differences from in-situ data
- L-band SSS have unique advantages while being synergistic to other observations to study Earth System Science.
- Requirements for future satellite SSS:
  - Continuity
  - Enhancing resolution
  - Improving accuracy, esp. in high-latitude oceans
    - Technology; retrievals

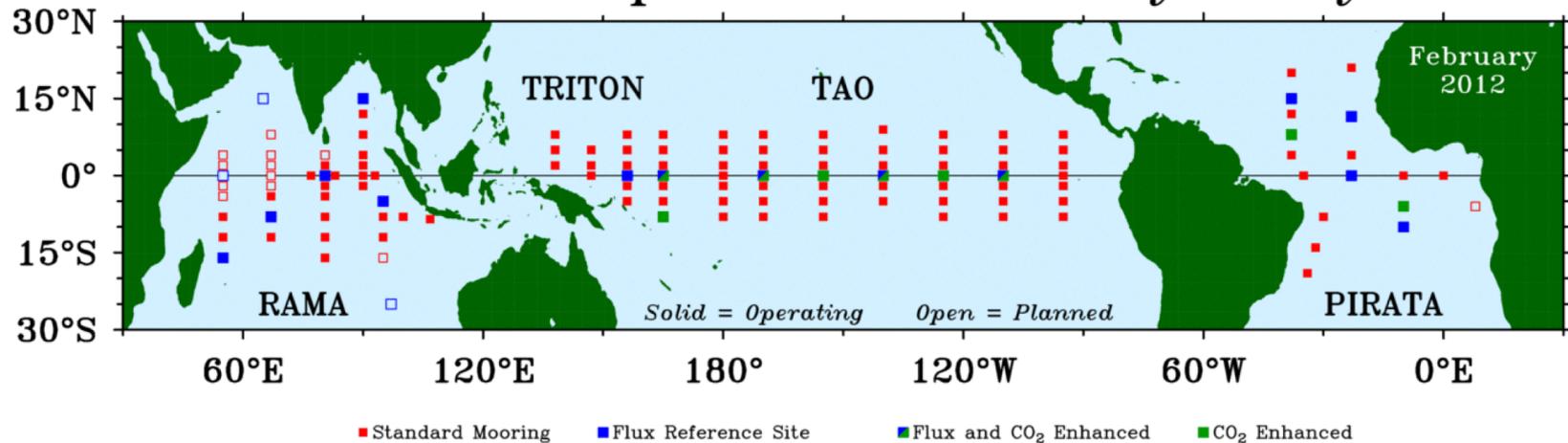
# Backup

# Main Sources of validation data for Satellite SSS

## Distribution of Argo floats



## Global Tropical Moored Buoy Array



Also ship-based measurements, esp. high-resolution thermosalinograph (TSG) data

# Two important issues in assessing the accuracies of satellite SSS

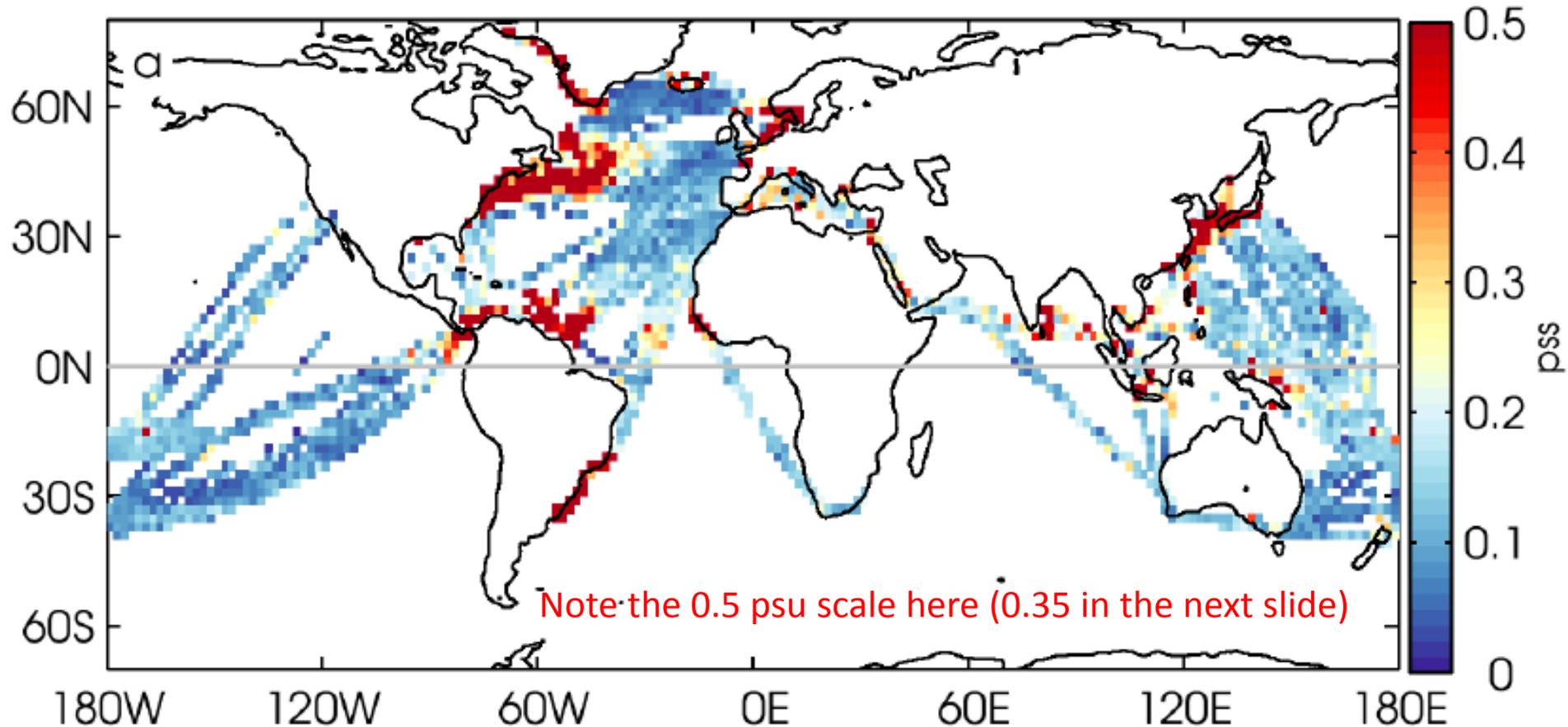
## 1. Sampling differences between satellite & in-situ measurements

- Satellite SSS: averages within footprints (& time windows for L-3 data)
- In-situ measurements: point-wise, instantaneous
- Significant differences between the two in regions of strong spatiotemporal variability (e.g., rain bands, river plumes, strong eddying currents)
- **Caution needed for interpreting differences between satellite & in situ salinity differences (esp. for level-2 SSS & “co-located” individual in-situ data)**

## 2. Effect of near-surface salinity stratification

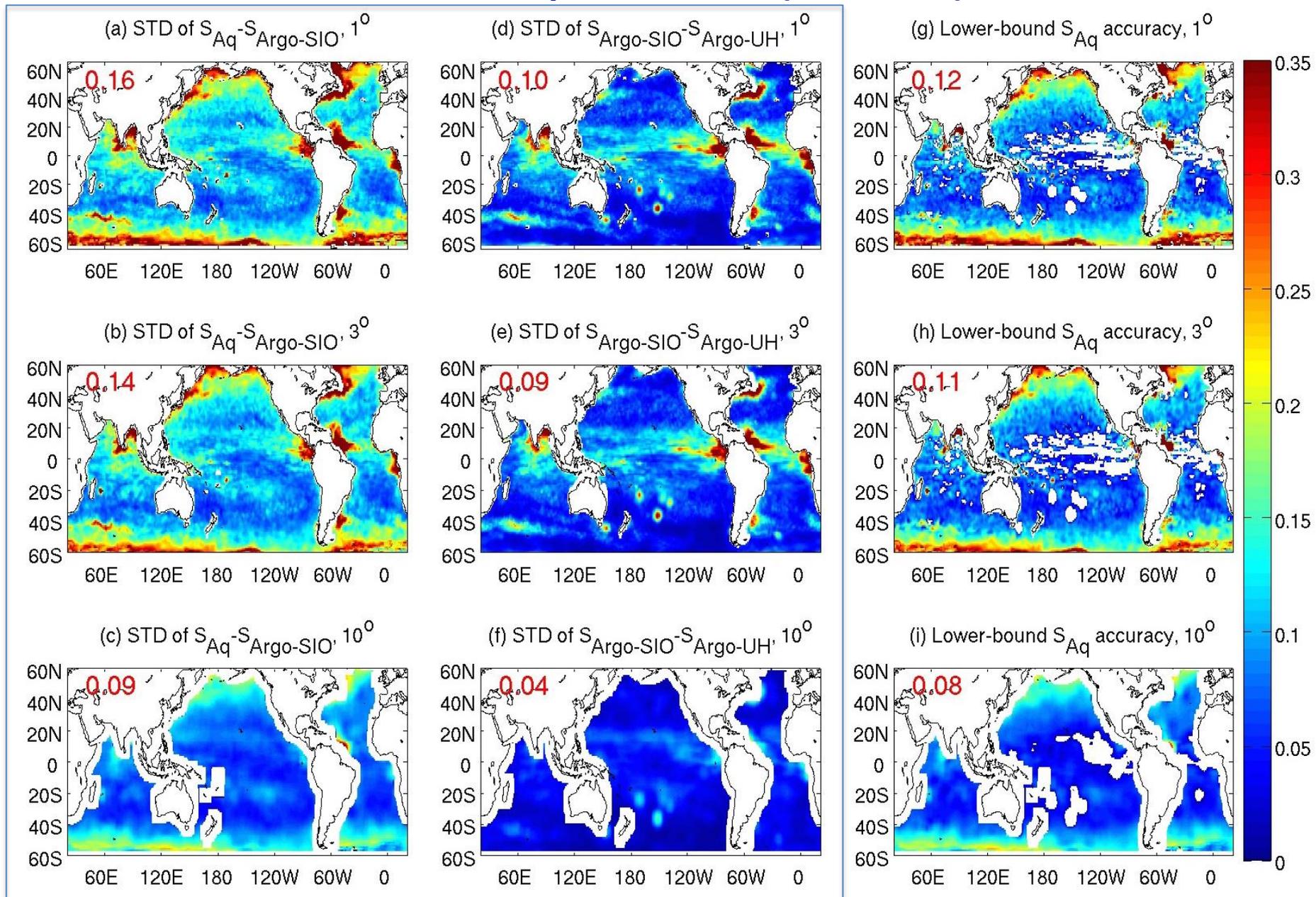
- Satellites measure salinity in the upper cm
- Most in-situ measurements are  $\geq 5$  m (Argo) or  $\geq 1$  m (mooring)
- Importance of salinity stratification in the upper meter under certainty conditions (e.g., during SPURS & SPURS2 field campaigns)

# High-res TSG observations show large std. dev. of SSS within 100-km intervals in regions with strong variability



Boutin et al. (2016, BAMS)

# STD of SSS Difference for Aquarius - Argo-SIO & Argo-SIO vs. Argo-UH for different spatial scales (Lee 2016)



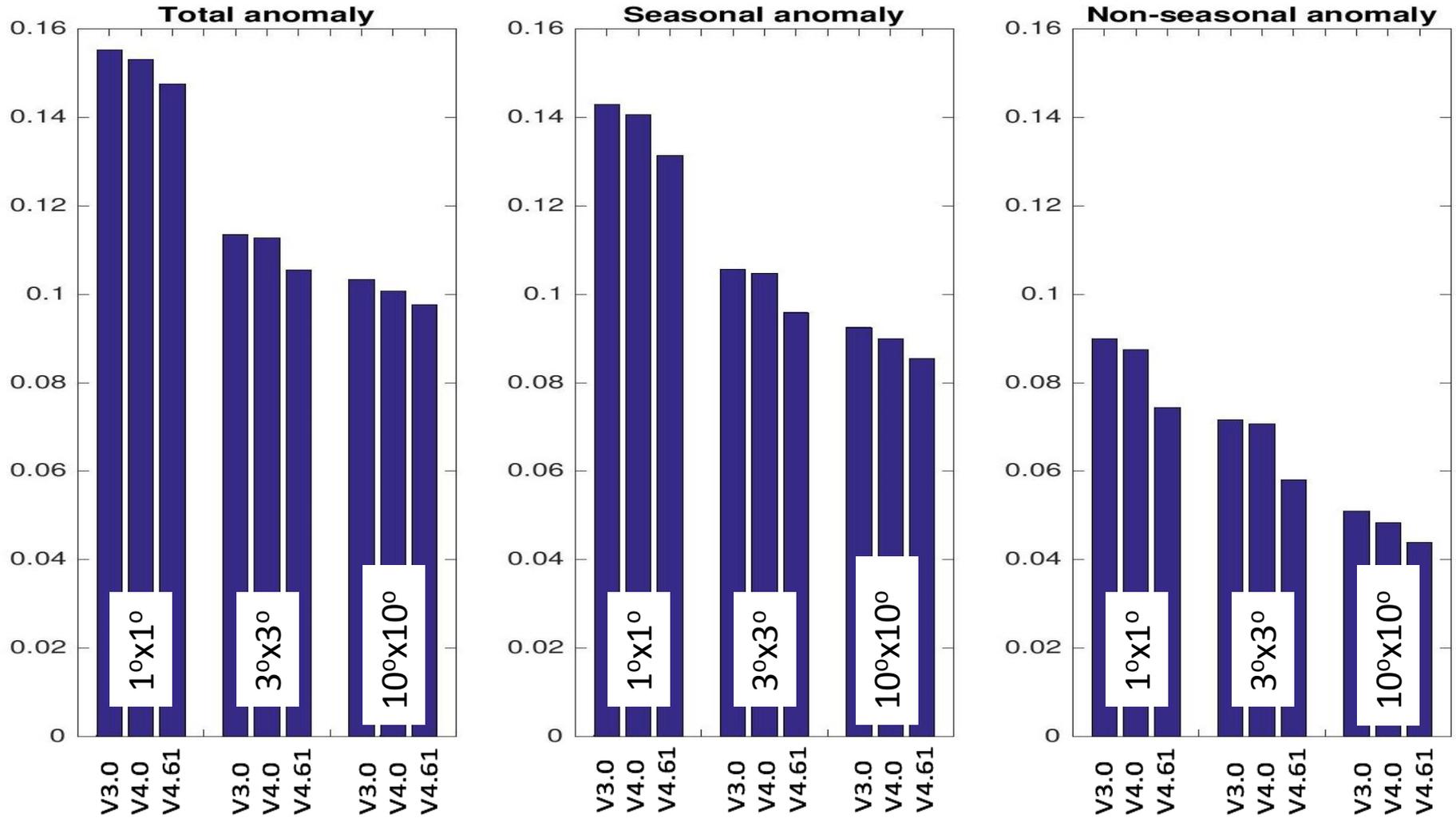
## “Global” (65N-65S) area-weighted averages STD of SSS differences for Aquarius vs. Argo-SIO & Argo-SIO vs. Argo-UH for different spatial scales: seasonal time scales

Table 1. Globally averaged standard deviation values (in psu) between Aquarius and Argo-SIO and between Argo-SIO and Argo-UH.

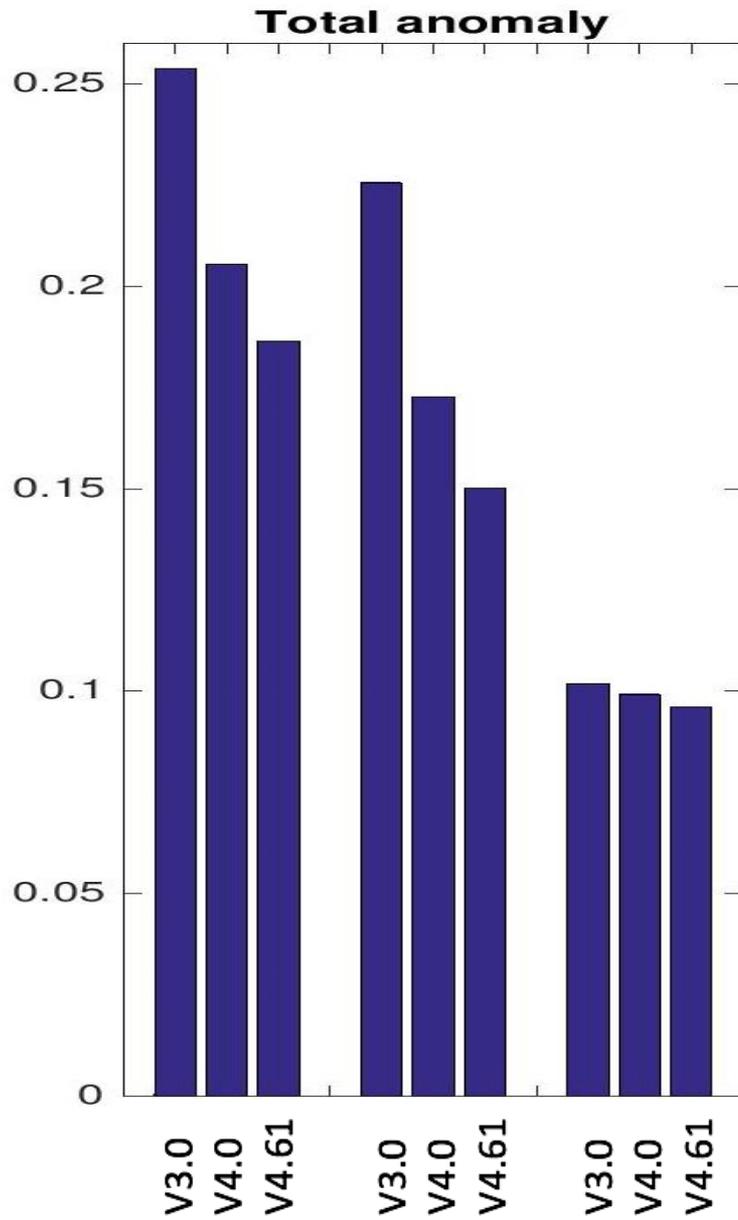
	1°x1°	3°x3°	10°x10°
Aquarius vs. Argo-SIO (total)	0.16	0.14	0.09
Argo-SIO vs. Argo-UH (total)	0.10	0.09	0.04
Aquarius vs. Argo-SIO (seasonal)	0.11	0.11	0.07
Argo-SIO vs. Argo-UH (seasonal)	0.06	0.05	0.02
Aquarius vs. Argo-SIO (non-seasonal)	0.10	0.09	0.05
Argo-SIO vs. Argo-UH (non-seasonal)	0.07	0.06	0.03

- Uncertainty of Aquarius SSS in estimating large-scale SSS changes is < 0.05 psu on monthly & longer time scales.
- Time averaging could further reduce the uncertainty.

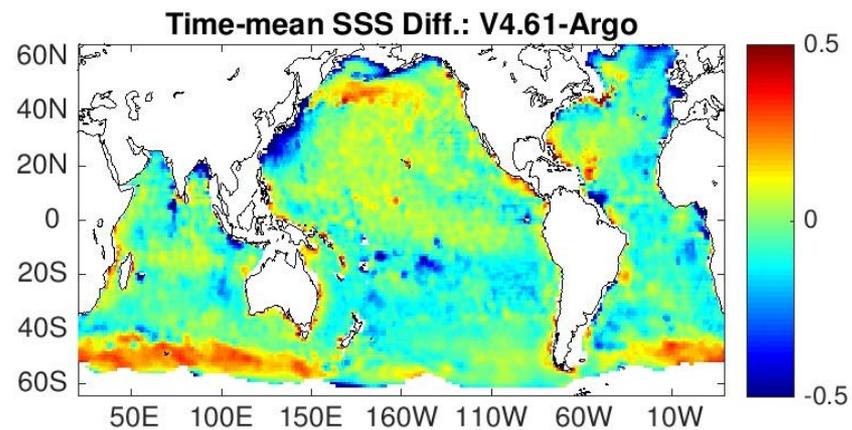
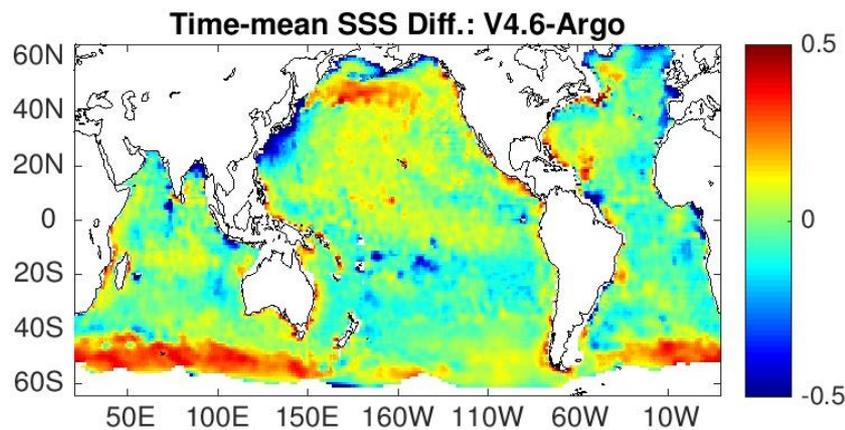
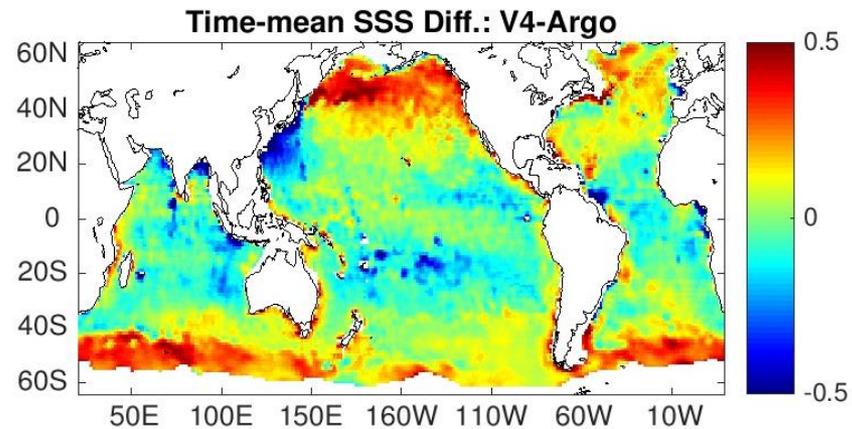
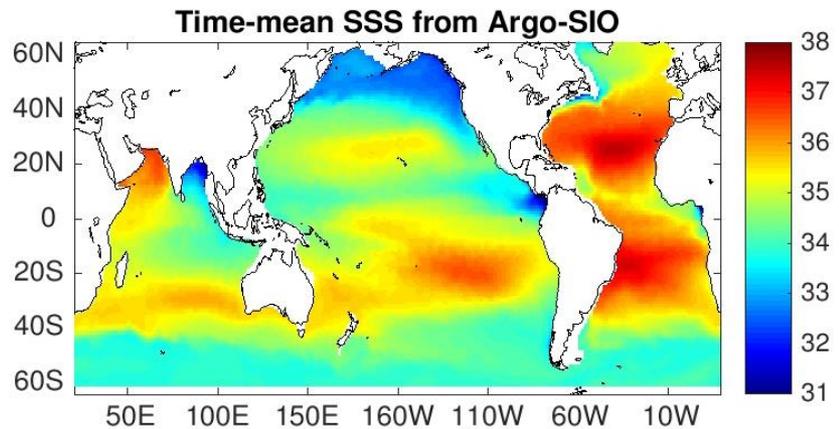
# Global STD of Aquarius-Argo SSS for various spatial & temporal scales



# Global **RMSD** of Aquarius-Argo SSS for various spatial & temporal scales



# Time-mean SSS (09/2011-05/2015)



# Where to get satellite SSS products?

For all Aquarius & SMAP SSS: <https://podaac.jpl.nasa.gov/>



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Gravity **Sea Surface Salinity** Sea Surface Temperature (SST) Ocean Currents & Circulation Ocean Surface Topography Ocean Wind Sea Ice

AQUARIUS

SMAP  
SPURS

## Sea Surface Salinity

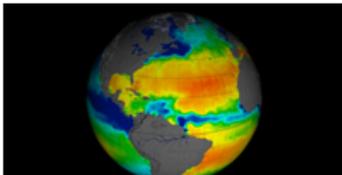
### Related Mission



Aquarius/SAC-D

The Aquarius/SAC-D observatory launched on June 10, 2011 will take a "skin " reading of ocean salt content.

### What is Sea Surface Salinity?



Salinity in the ocean is defined as the grams of salt per 1000 grams of water. One gram of salt per 1000 grams of water is defined as one practical salinity unit or one PSU. Salinity varies due to evaporation and precipitation over the ocean as well as river runoff and ice melt. Along with temperature, it is a major factor in contributing to changes in density of seawater and therefore ocean circulation.

### Data Links

- **Browse Datasets** for Aquarius Project Data
- **FTP Data Access**

### Tools and Services

- **FTP**
- **OPeNDAP**
- **THREDDS:** Salinity/Density, Ocean Winds
- **PODAAC-WS**
- **Aquarius Level 3 Image Browser**
- **State of the Oceans (SOTO 3D and SOTO 2D )**
- **LAS**
- **HITIDE**

### Related Links

# Where to get satellite SSS products? (cont'd)

For all L-band satellite SSS:

ESA funded **SMOS Pilot Mission Exploitation Platform (SMOS Pi-MEP)**:

<https://pimep-project.odl.bzh/data>

has http links to various level-2 to level-4 satellite SSS products

Overview Data Processings Tools Case studies Contact Follow us

**Blog**

Sept 14, ESA Advanced Ocean Remote Sensing Training Course	2017/09/13
Mai 3, 2017 : PI-MEP Science Advisory Group meeting	2017/04/27

**Documents**

PIMEP DATASETS.xlsx	2017/05/19
3_2_PI_MEP_SMOS_SAG_v2.pptx	2017/04/27
PIMEP_SAG_CM1_agenda_final.pdf	2017/04/27

**Agenda**

21	
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## Other useful resources:

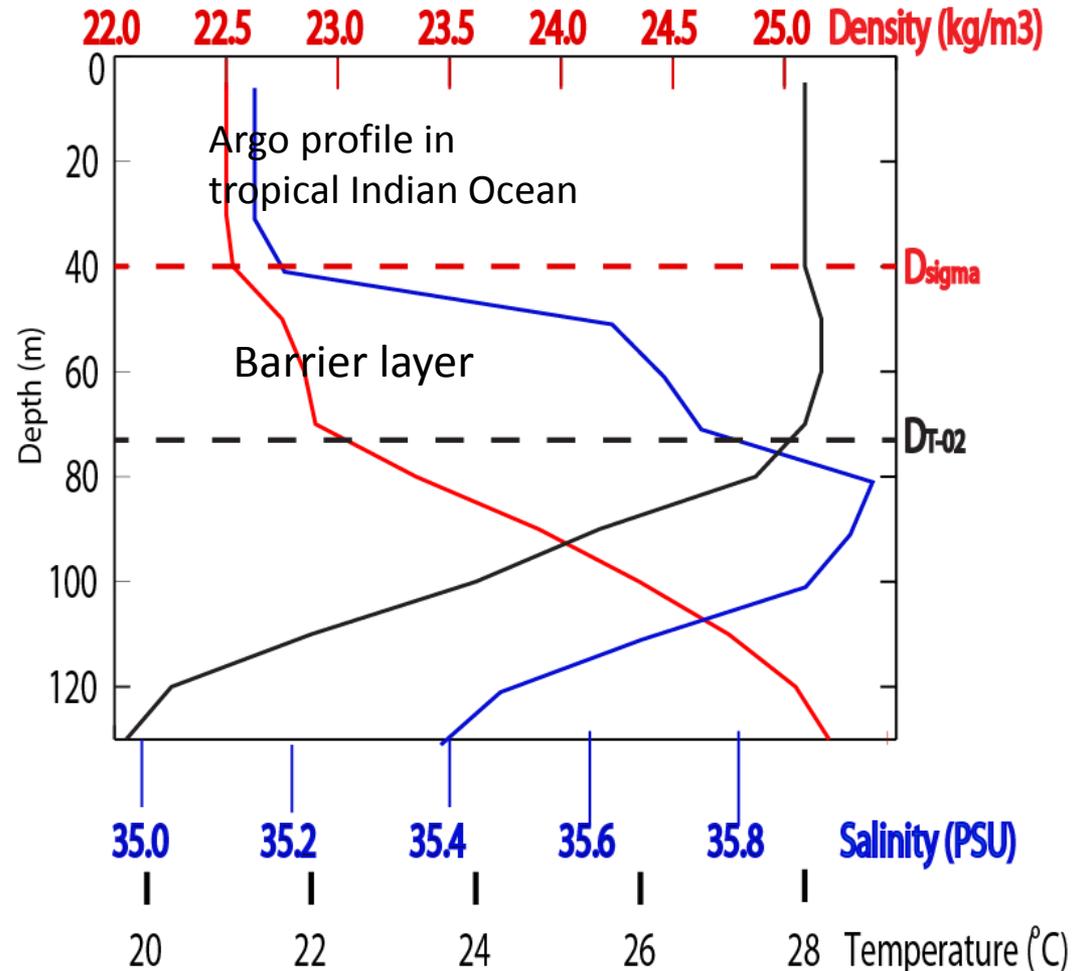
Satellite and In-situ Salinity (SISS) Working Group: <http://siss.locean-ipsl.upmc.fr/>

Aquarius: <https://aquarius.nasa.gov>

# Indirect effect of salinity on SST (thus air-sea interaction): example – effects of the barrier layer

**Barrier layer:** a S stratified, T uniform layer below the mixed layer but within the isothermal layer

Barrier layer tends to inhibit the vertical mixing of heat between the mixed layer and thermocline; amplifies SST response to surface heat flux.



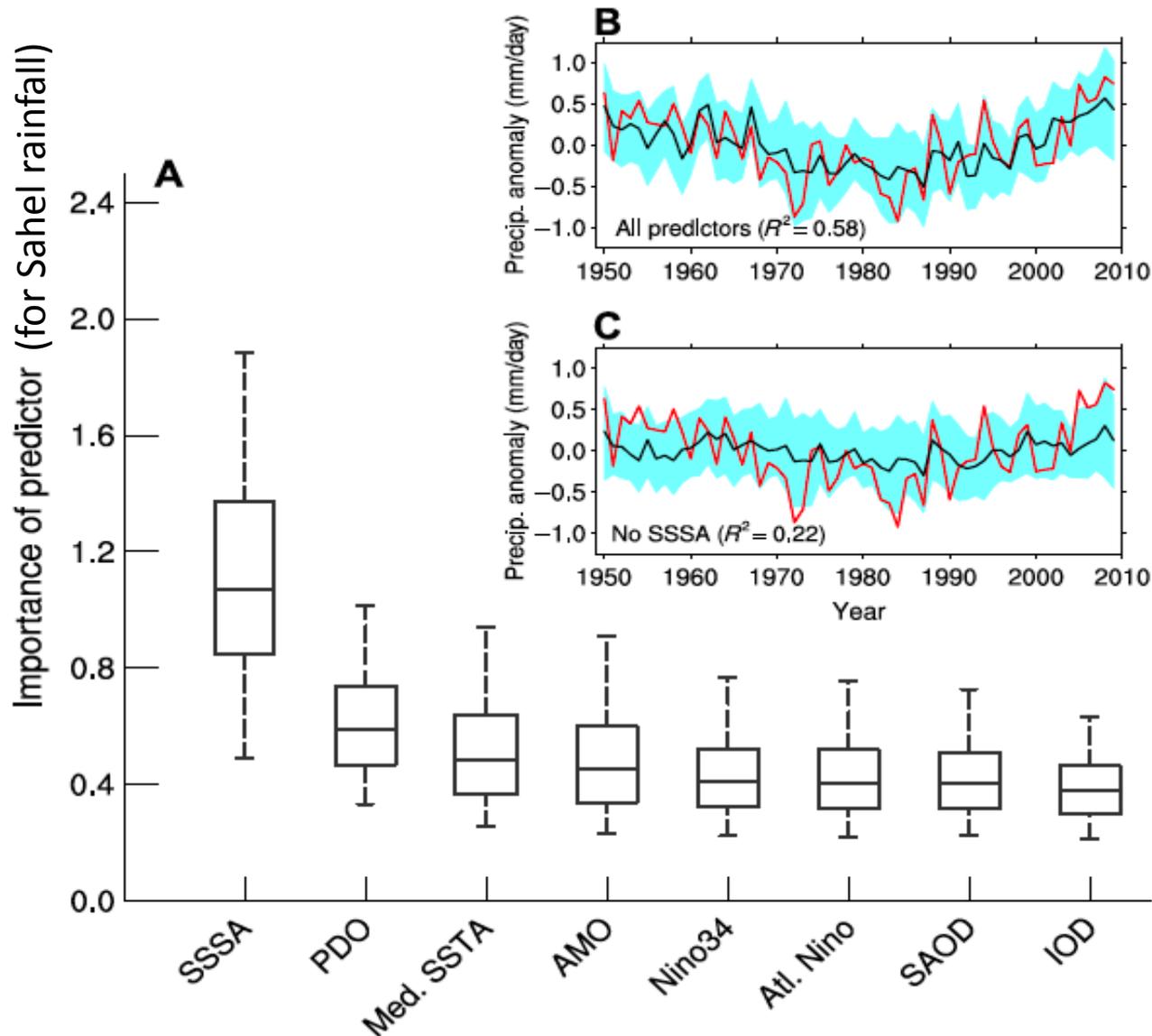
(e.g., Lukas & Lindstrom 1991, Sprintall & Tomczak 1982, Maes et al. 2005 )

**“Take a grain of salt when studying SST”**

# SSS as an indicator of global water cycle changes

- Large uncertainties in E-P estimates
- Difficulty to measure global river discharges
- SSS directly respond to E-P, river discharge, and sea ice formation/melt

# Subtropical N.Atl. SSS as a predictor of Terrestrial Rainfall



Li et al. (2016a, Science Advance): for Sahel rainfall

Li et al. (2016b, J. Clim): for US Midwest rainfall

# SSS trend 1950-2000: intensification of global water cycle?

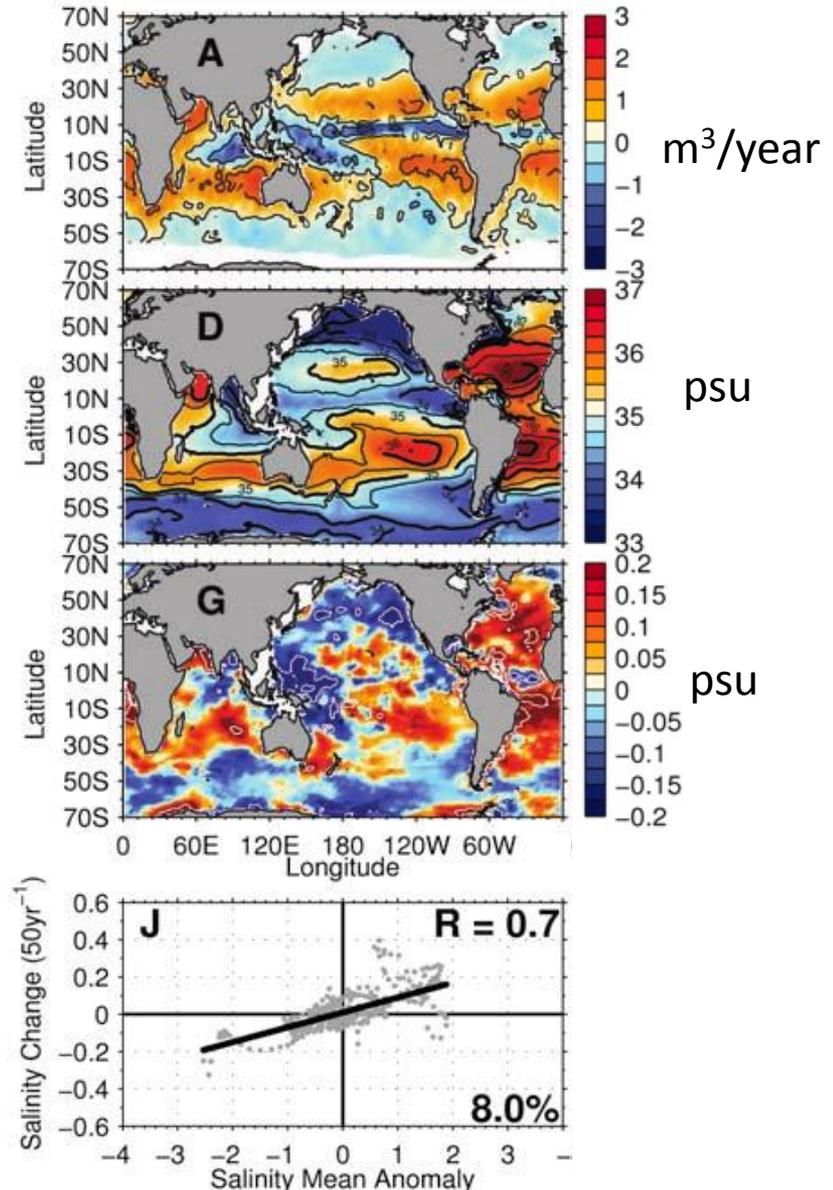
*Durack et al. (2012, Science)*

Net freshwater flux (evaporation – precipitation)

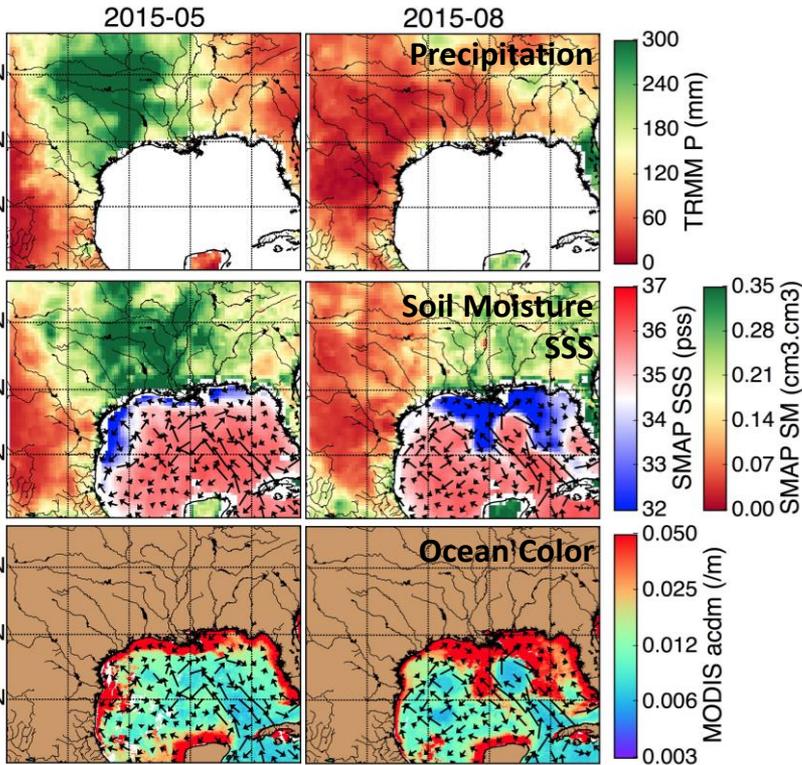
Mean sea surface salinity (SSS)

Observed 50-year SSS trend

Correlation of SSS change & mean SSS  
(fresh gets fresher, salty gets saltier)



# A combined land/sea assessment of the impacts of the May 2015 severe Texas flooding event



**Problem:** How does the May'15 severe flooding in Texas affect terrestrial hydrologic conditions, marine environment, and their linkage?

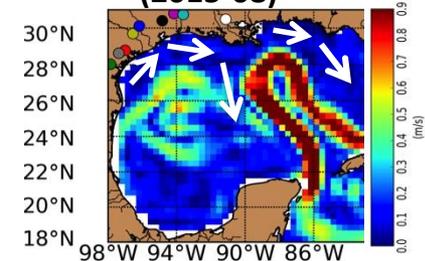
**Finding:** Intense rainfall in May'15 over Texas caused saturated soil & record river discharges into the Gulf of Mexico (GoM). The unusually strong Loop Current & its eddy shaped the freshwater into a “horseshoe” pattern, affecting regions not normally influenced by river plume.

**Significance:** Implications to the extent of the GoM hypoxic zone and the Flower Garden Bank coral reef ecosystem. Multi-variate satellite observations (e.g., SMAP, GPM/TRMM, MODIS, JASON-2, GRACE, and SMOS) are essential to provide integrated assessment of land/sea impacts associated with flooding.

**Current Speed & schematics (2015-08)**

*May and August 2015 GPM precipitation, SMAP soil moisture and sea surface salinity (SSS) and MODIS Ocean Color.. Vectors: JASON-2 surface currents.*

*August 2015 surface current speed (JASON-2) showing the Loop Current, its eddy, and schematics of the flow pattern that shaped the “horseshoe” freshwater plume*



# Improving ancillary data (e.g., SST) for SSS retrievals at high-latitude oceans also important

- L-band brightness temperature has weak sensitivity to SSS at high latitudes
- accuracy of ancillary SST becomes more important
- but high-latitude satellite SST also have significant errors

## Comparison of GHRSSST blended SST products an Arctic buoy SST

