Sea Surface Salinity remote sensing from Space: A new tool to monitor the oceanic freshwater cycle

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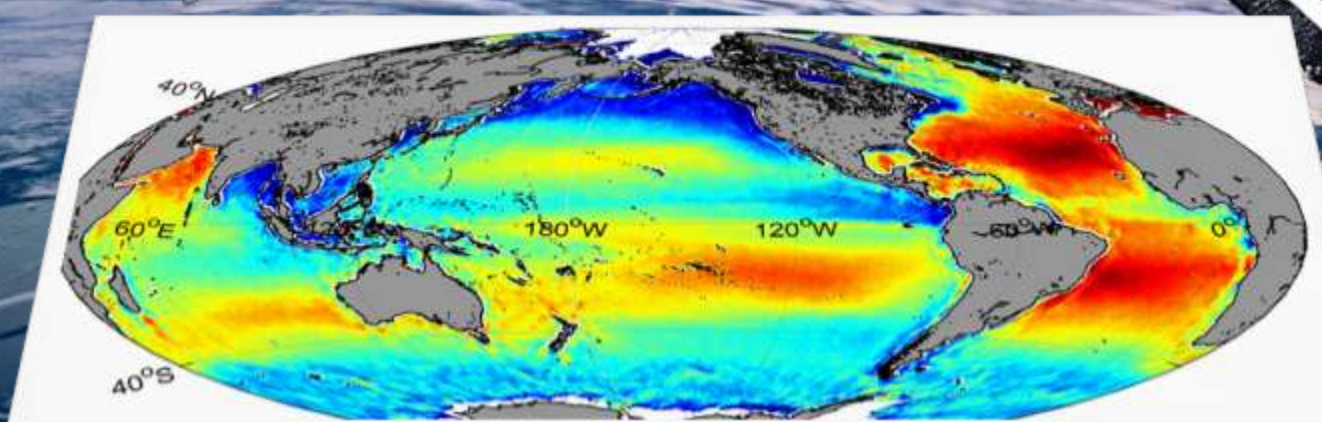
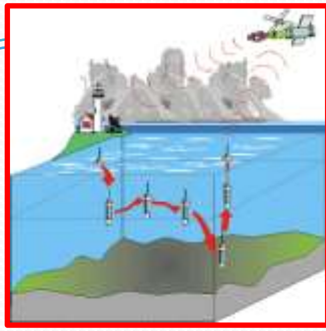


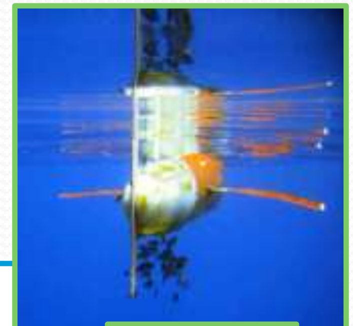
Outline

- Scientific rational behind Sea Surface Salinity measurements from Space
- Measurement plateforms & principles
- Examples of the Spaceborne Systems Capabilities
- Perspectives

In Situ measurements of Salinity



Profilers from the Argo network



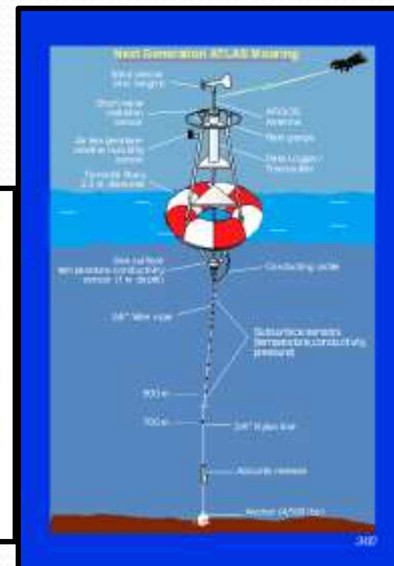
Gliders

Surface 'Drifters'

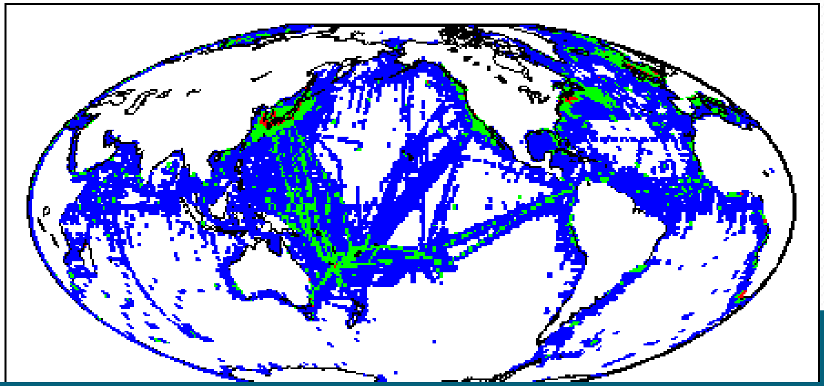
Equipped Mammals

Thermo-salinographs
Installed onboard reasearch
Vessels and ships of opportunity

Permanent Moorings



Historical Density of surface observations 1874-2002



White - N < 10
Blue - 10 < N < 100
Green- 100 < N < 1000
Red - 1000 < N

F. Bingham et al, 2002

1.3 million SSS observations distributed over the global ocean since 125 years:

✓ No data in 27% elementary oceanic 1° x1° area, not accounting for arctic zones.

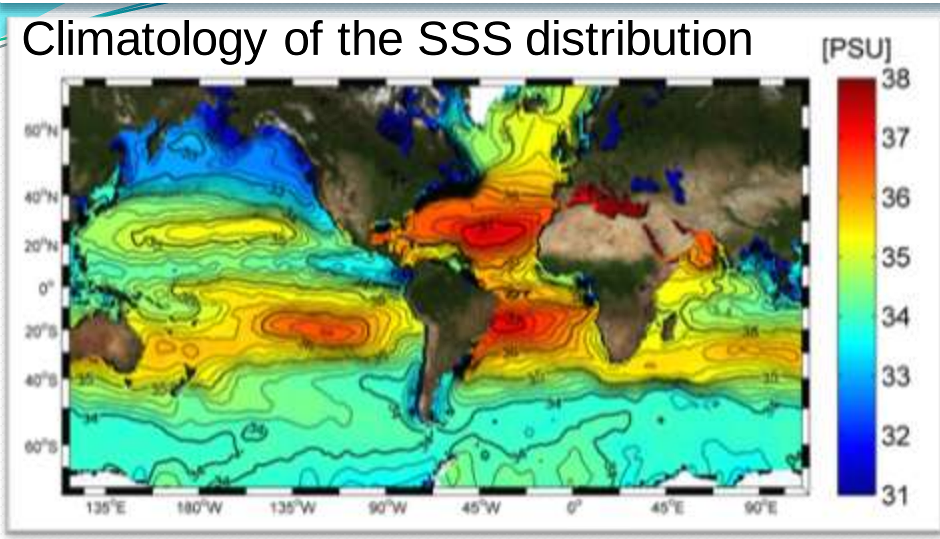
✓70% of these surfaces present at most 10 historical observations

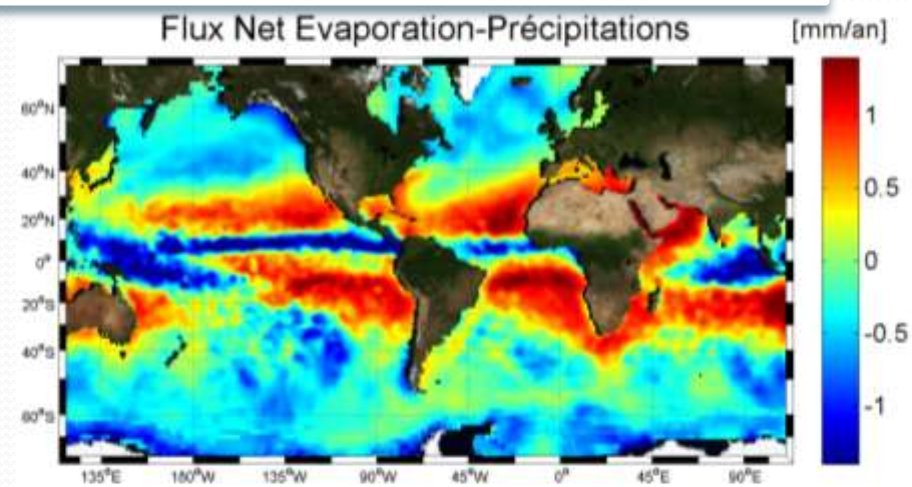
✓28% of all observations were sampled in the coastal domain

✓ Up to 1960, there was no more than 10,000 observations/year ⇔ 1 observation per 4°X4° cell

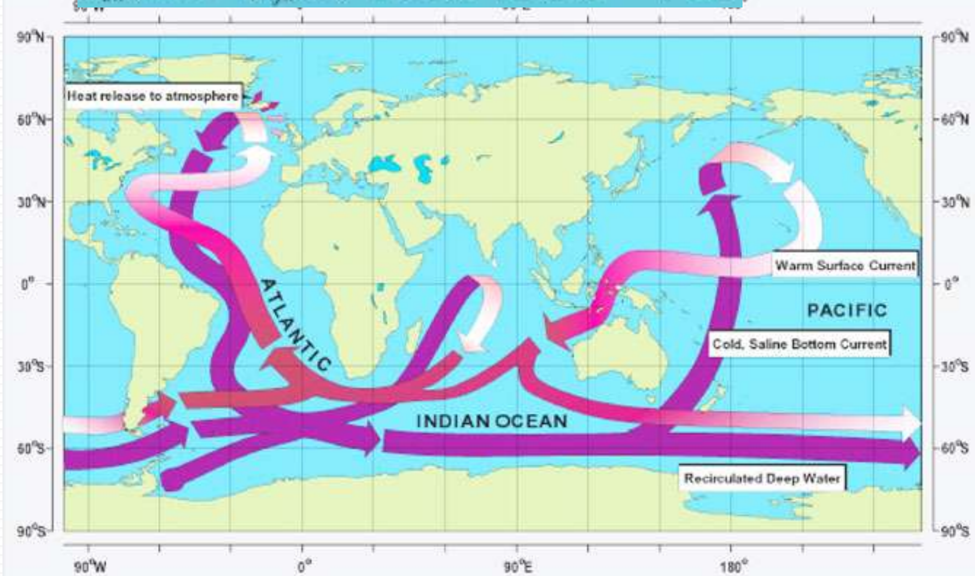
✓Since 2002, very net increase in the density of measurements (ARGO network)

Understanding Interactions between Ocean Circulation, the Global water cycle and the Climat by measuring Sea surface Salinity





$$\rho_{sw}(S,T) = \rho_{fw}(T) + b(T)S + c(T)S^{3/2} + dS^2$$



The salinity variations are determined by Precipitation, Evaporation, River Run-off, Sea Ice Melting and pounding

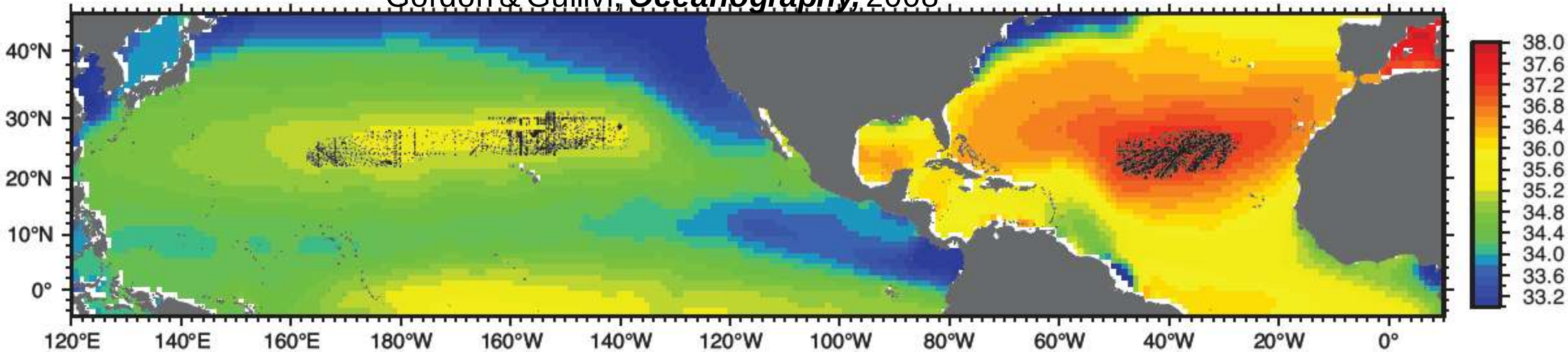
Salinity affects sea water density which governs the thermo-haline circulation and the climat

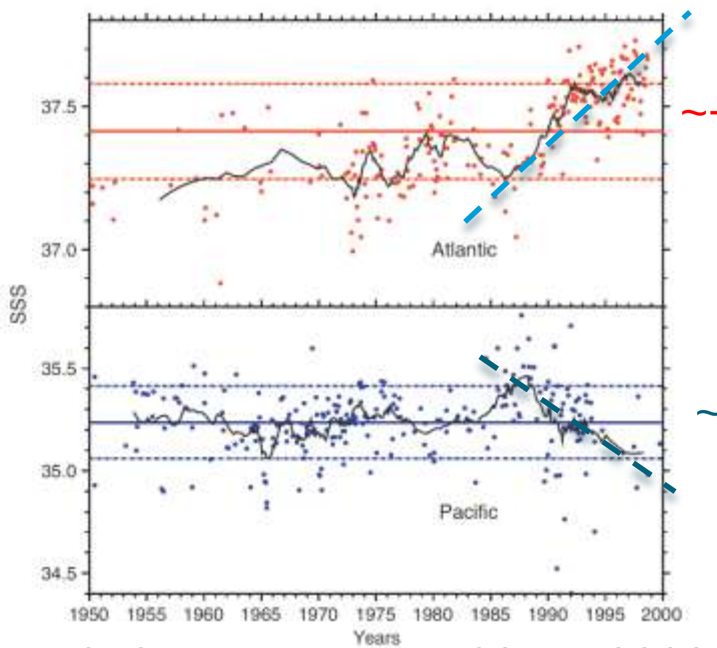
Spaceborne Measurements of SSS shall help Better estimating surface currents from Altimetry

Sea Surface salinity: a climatic indicator

Trends in Sea Surface Salinity in Pacific and Atlantic Oceans

Gordon & Guilivi, ***Oceanography,*** 2008

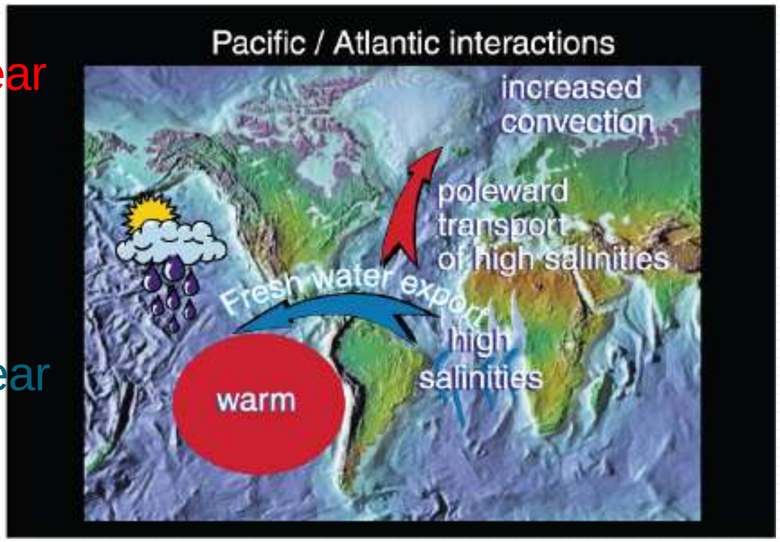




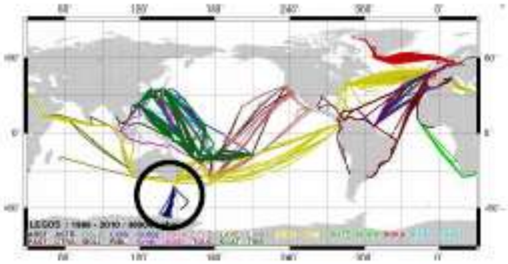
~+0.03 psu/year

~-0.03 psu/year

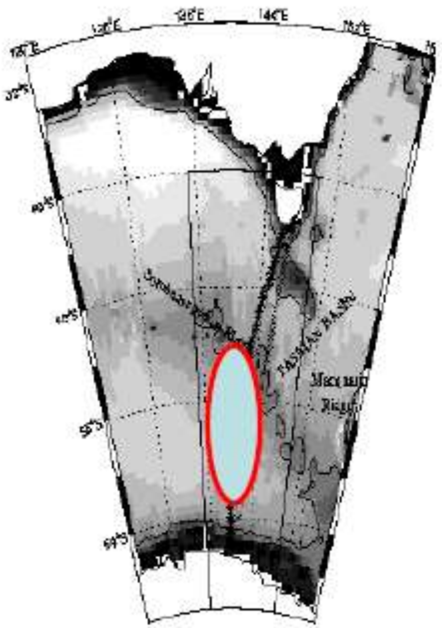
1950 1987 2000



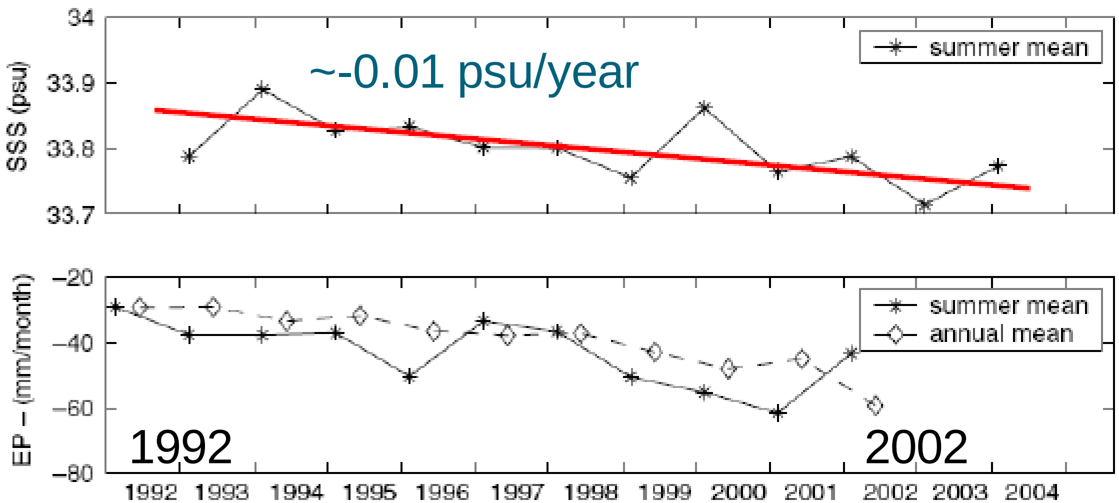
Trends in SSS in the Antarctic Ocean



10 sections /year
since 1993



Decadal decrease in SSS related to increase in P

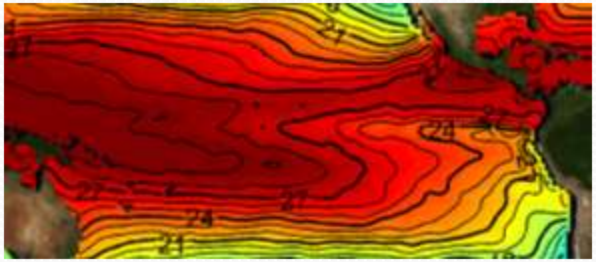


(Morrow et al., 2008)

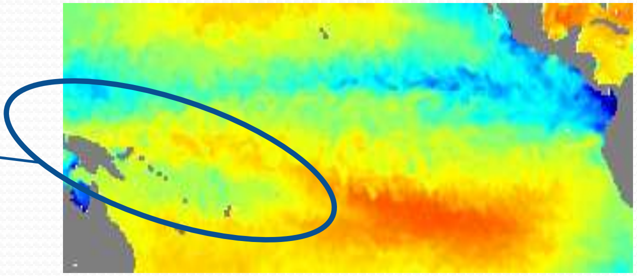
Trends in Sea Surface Salinity in the Western Tropical Pacific Warm Pool

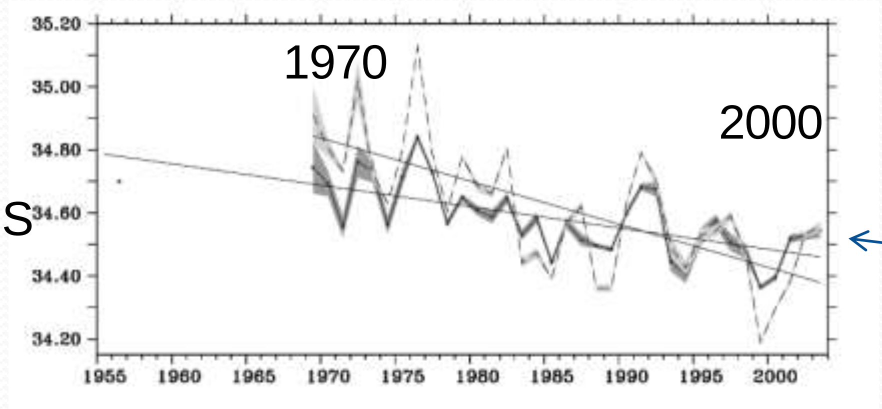
The surface extension of the Warm Pool (equivalent to Europe Area with temperatures>28°C) is associated with a surface salinity freshening

Temperature



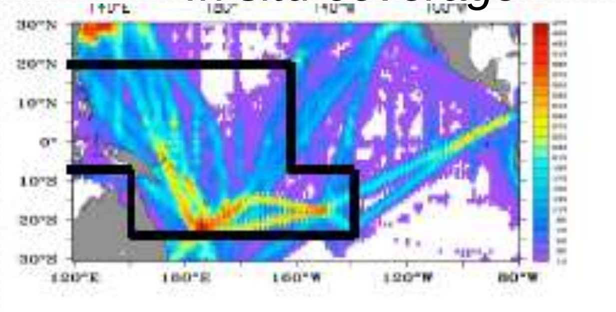
Salinity





~-0.013 psu/year

In situ coverage



Cravatte et al., 2009

Large scale freshening at high latitudes

3 decades of decrease in salinity of the subpolar gyre and Nordic Seas

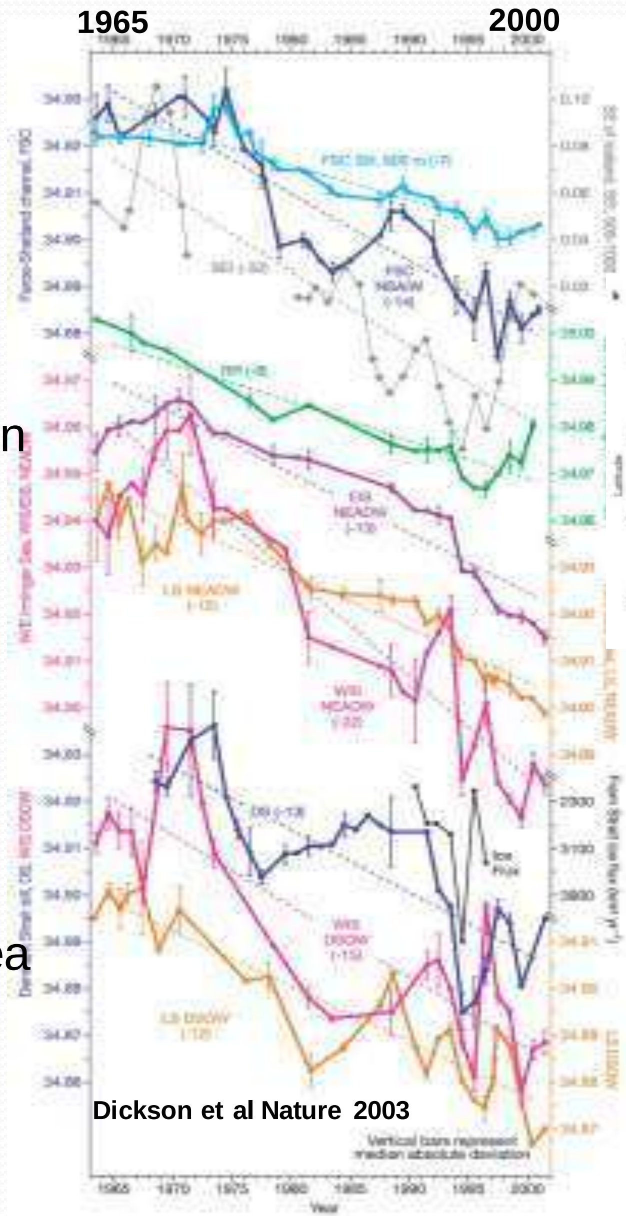
(here, the overflows,
gyre
and
Labrador Sea
from 1960 –2002)

Fram Strait

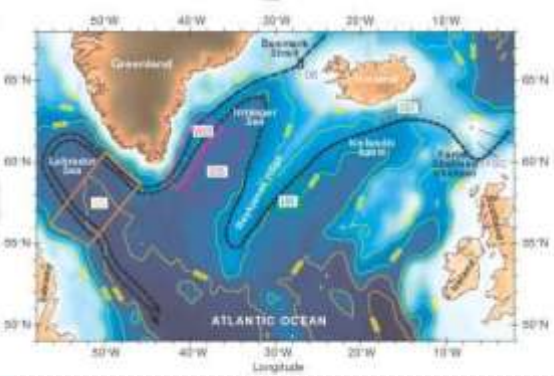
Iceland Basin

Denmark Strait

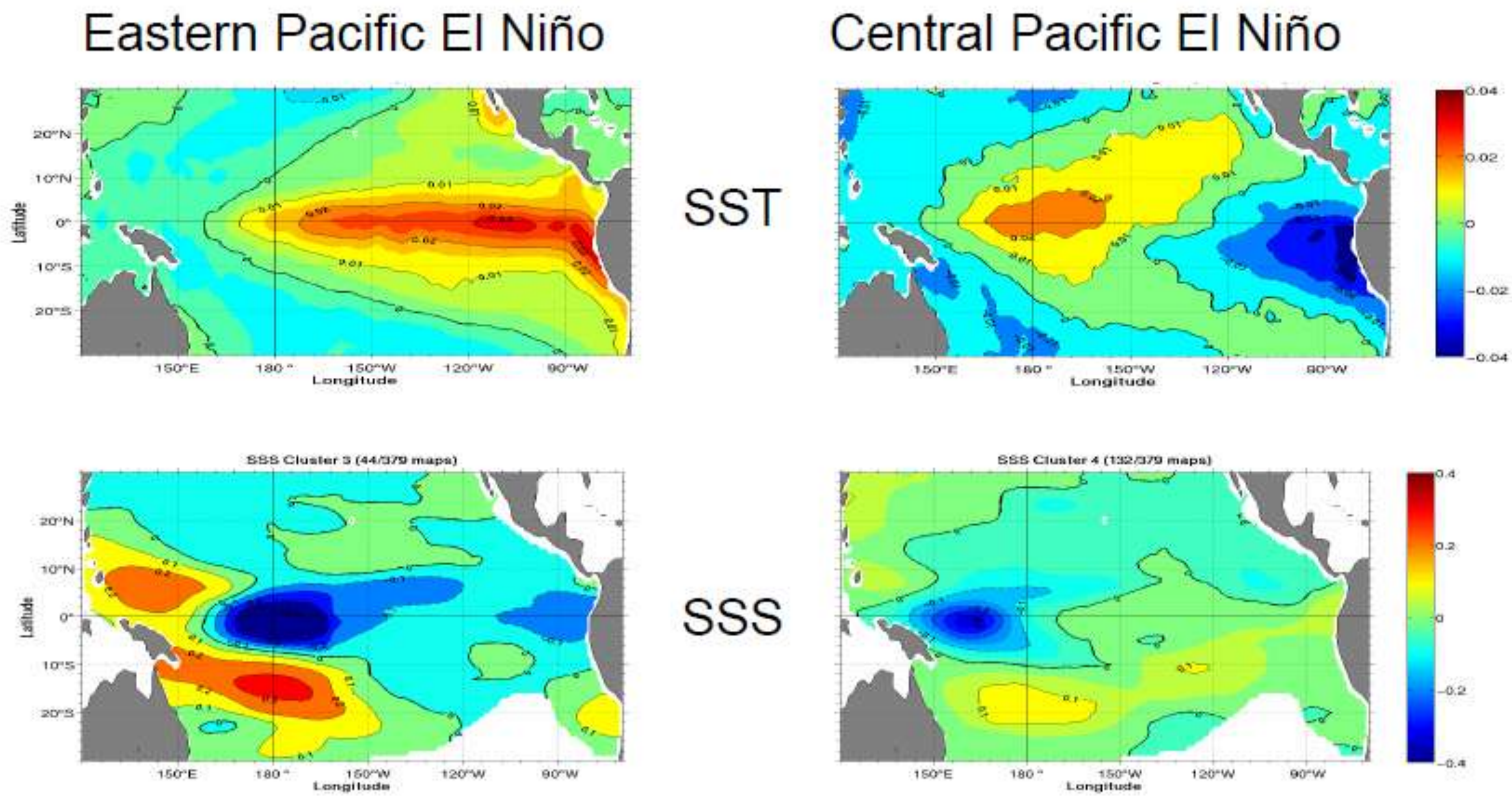
Labrador Sea



North Atlantic Nord



The spicy waters that change El Niño

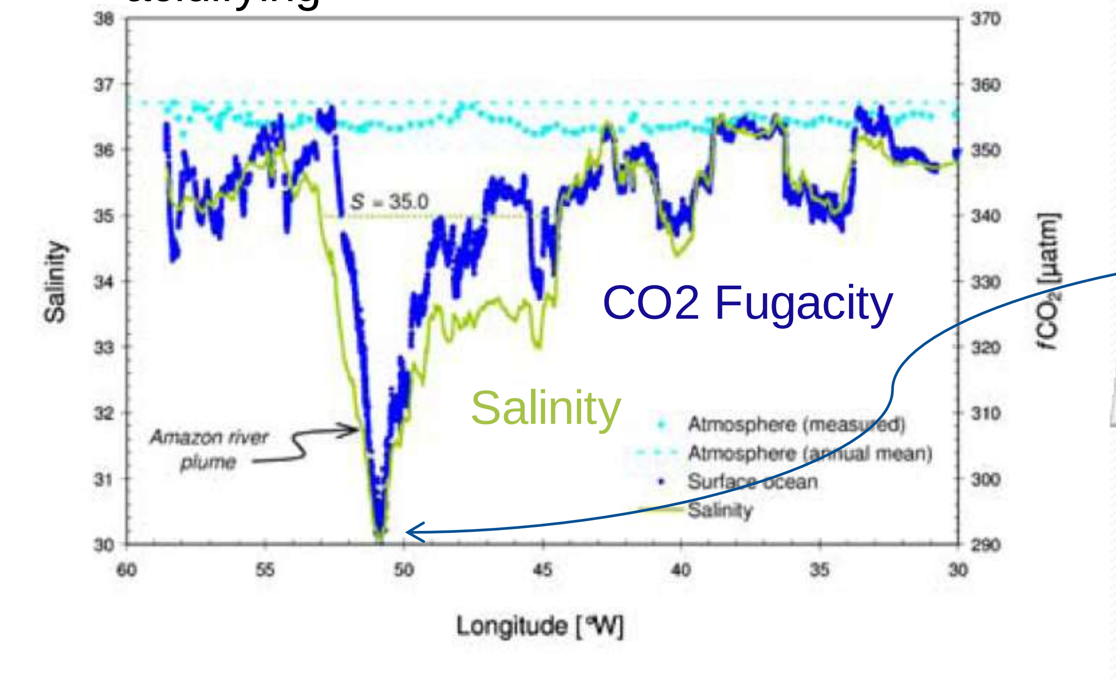


Christophe Maes, 2002
Singh et al., 2010

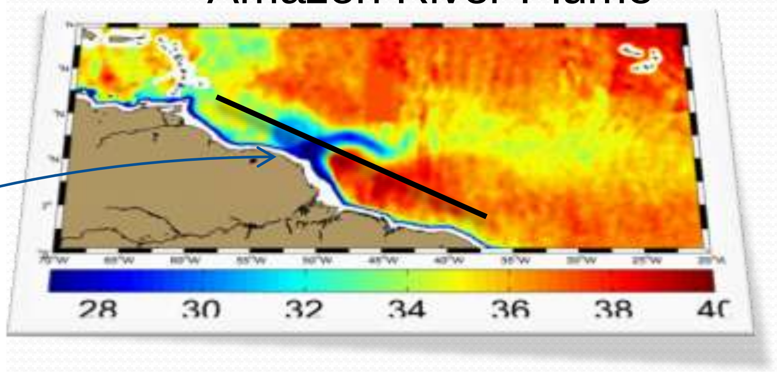
Salinity of the upper ocean play an important role (barrier-layer effects) in the on-set of the phenomenon. Monitoring this variable will help in better predicting El Niño.

SSS & CO_2

Ocean is the first global think of carbone, however it is saturated and start acidifying



Amazon River Plume

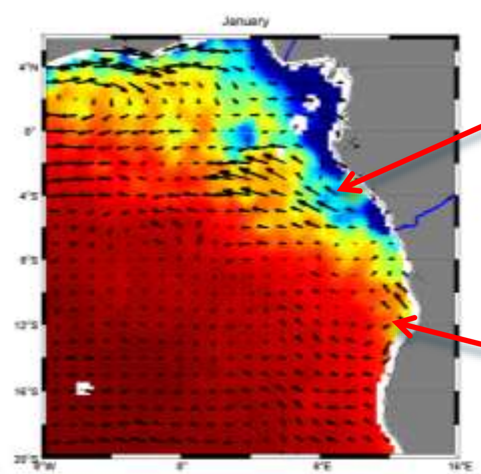


Kortzinger, 2000

Through its links with Alcaliny (ability to resist to an acidic attact),
Sea surface salinity is a key parameter of the **CO2 fluxes at the oceanic surface**

Surface Salinity & fishes

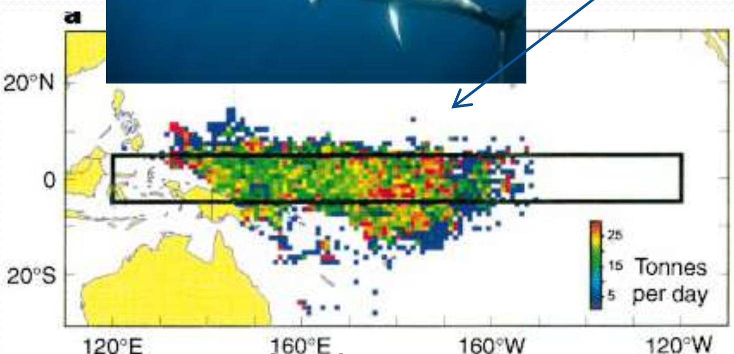
Salinity is of the key environmental factor for the living of fishes and marine biology

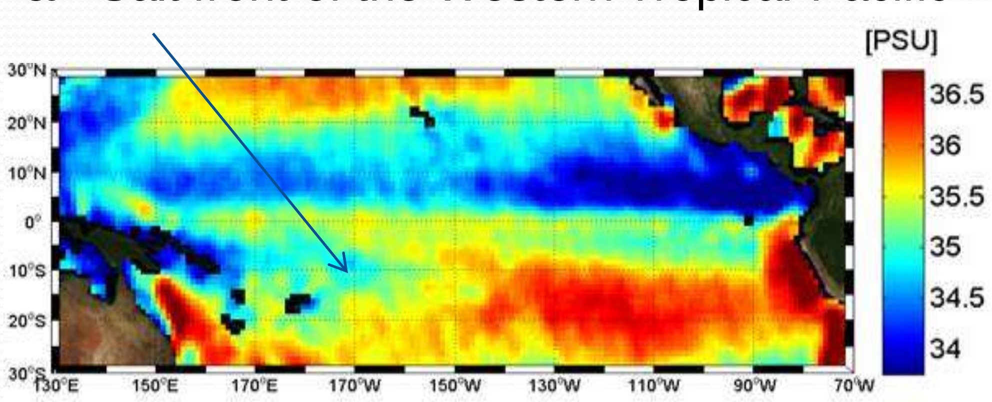


S. Maderensis lives in warm freshwaters (rain effects, runoffs from Niger, Congo rivers,..)

S. Aurita lives in the cold and salty waters of the Bengela upwellings

Tunna takes & Salt front of the Western Tropical Pacific





Lehodey, 1997

Why mesurearing SSS from Space ?

•**Key Role of salinity for the dynamics of the oceans, biology, bio-chemistry and climate**

✓Global freshwater cycle proxy (freshwater fluxes E-P-R at the surface)

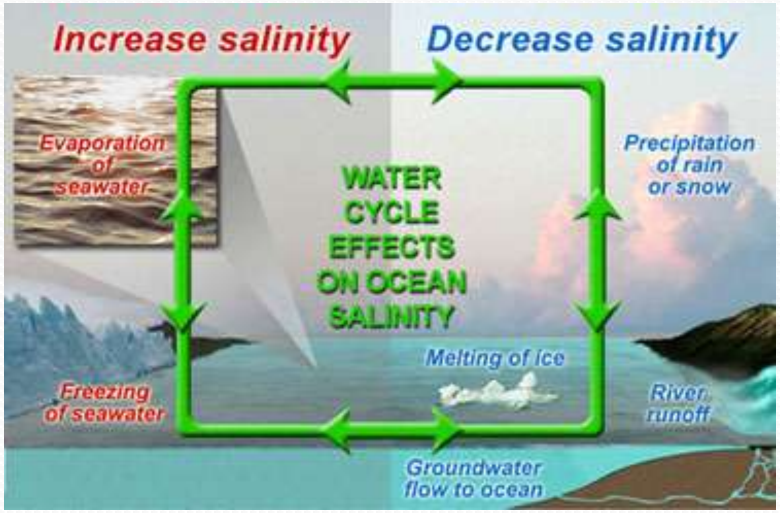
✓Thermo-haline Circulation

✓Coupled Ocean-atmosphere system (e.g., El Niño, CO_2 oceanic absorption rate)

✓Fish stocks

•**Lack of global SSS data**

✓Weaknesses of climatologies & limits of operational *in situ* observing systems



GOOS (Global Ocean Observing System) scientific plan :

« There is a clear need to obtain spaceborne measurements of SSS» with an accuracy on the order of ~**0.1-0.2 psu for monthly average estimates over 100-200 km²**

Two dedicated Satellite missions

SMOS

Launched November 2009

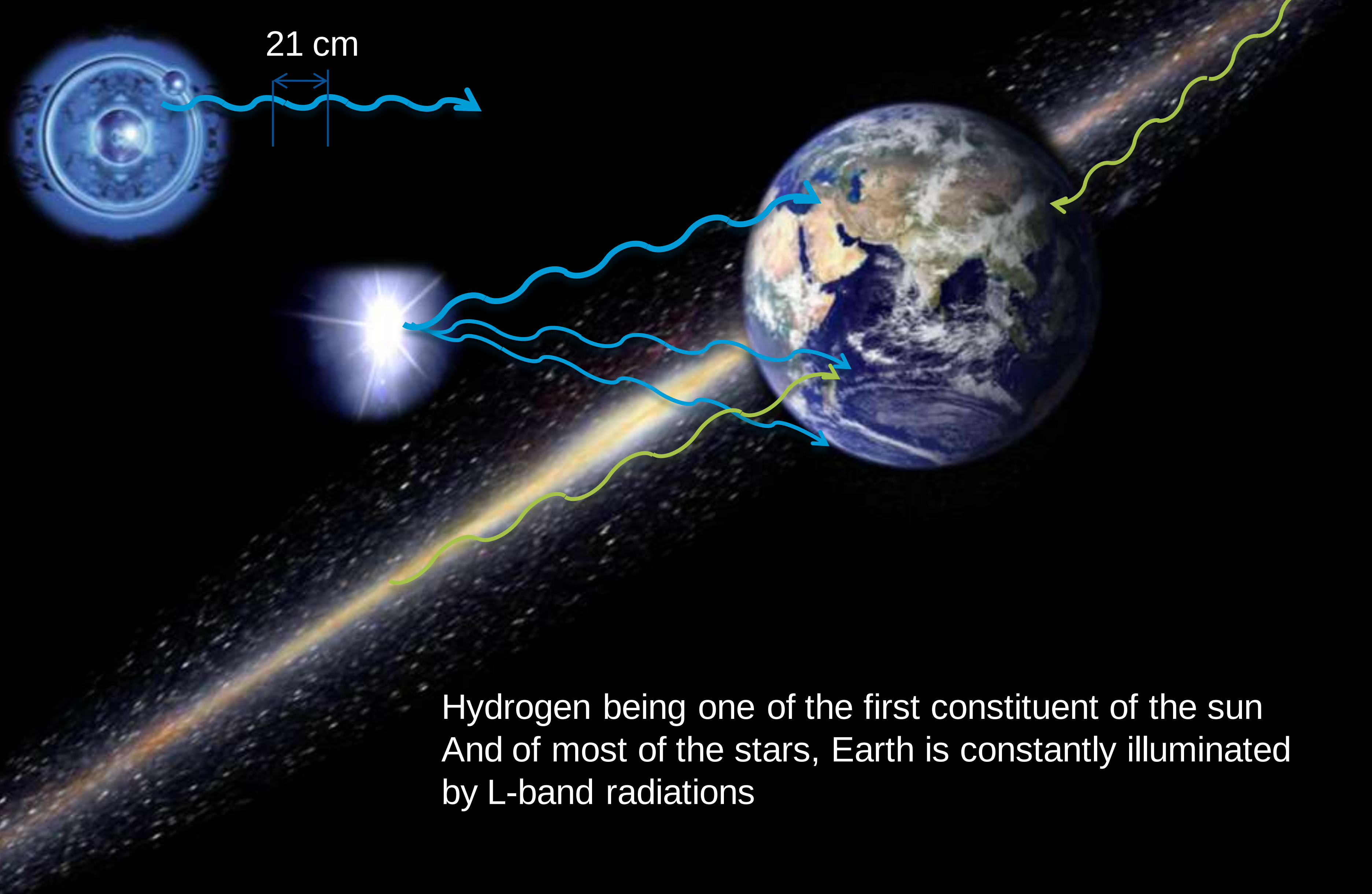
AQUARIUS/SAC-D

Launched August 2011

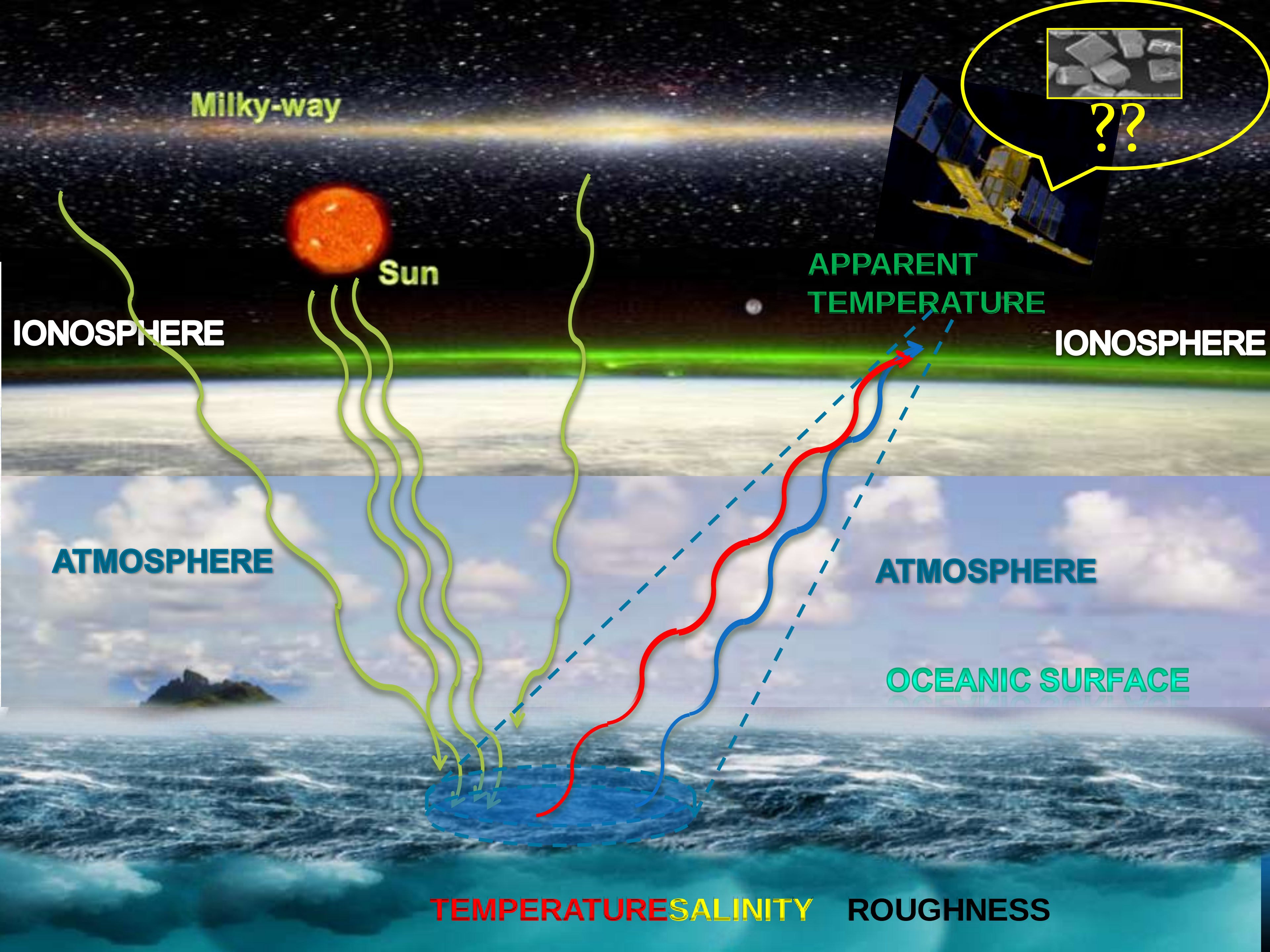
Measurement principles

How can one detect sea salt variations of 0.1 g/kg in the first centimeters below the ocean surface from an altitude of 750 Km?

A change of state in the Hydrogen atom energy generates micro-wave electromagnetic radiations at a frequency of 1420 MHz (L band) ≡length 21 cm known as the « Hydrogen line »



Hydrogen being one of the first constituent of the sun And of most of the stars, Earth is constantly illuminated by L-band radiations

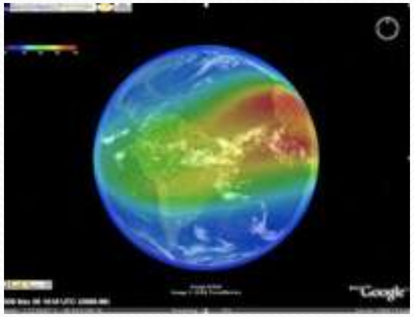


Milky-way
Sun
??
APPARENT
TEMPERATURE
IONOSPHERE
IONOSPHERE
ATMOSPHERE
ATMOSPHERE
OCEANIC SURFACE
TEMPERATURE
SALINITY
ROUGHNESS

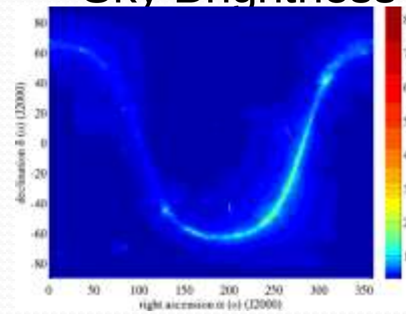
Retrieving SSS from Space: a challenge !

SMOS data

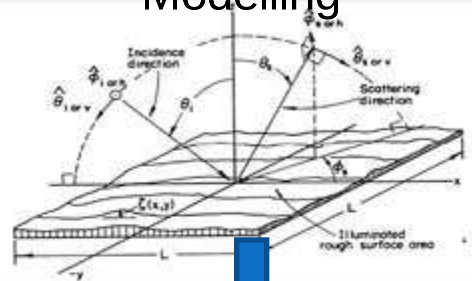
Ionosphere



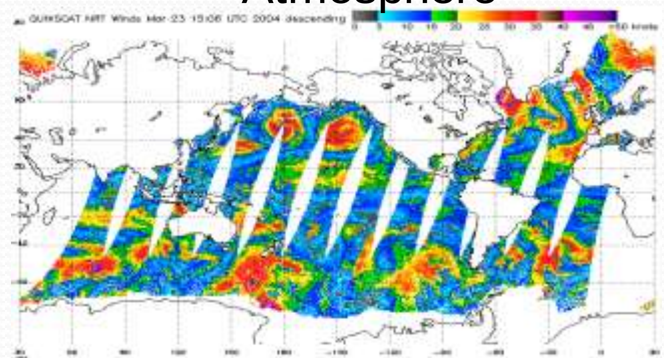
Sky Brightness



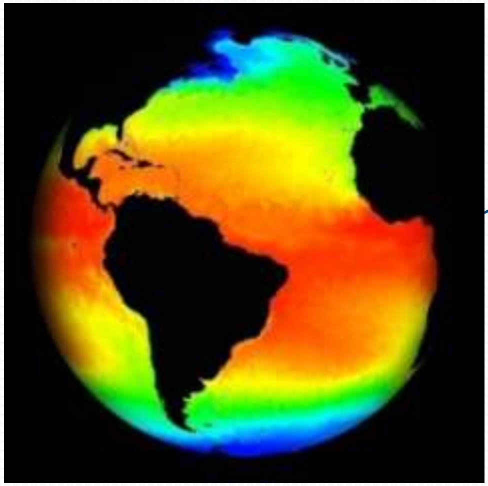
Electromagnetic Modelling



Atmosphere

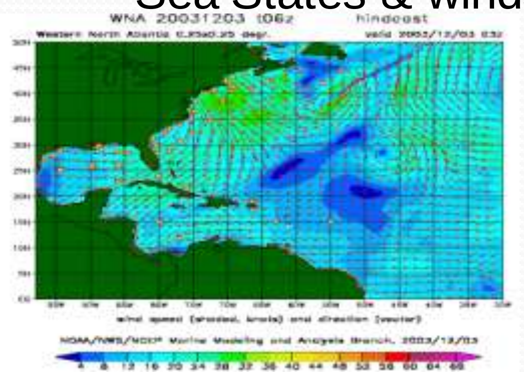


Sea Surface Temperature



Salts

Sea States & winds



How SMOS works ?

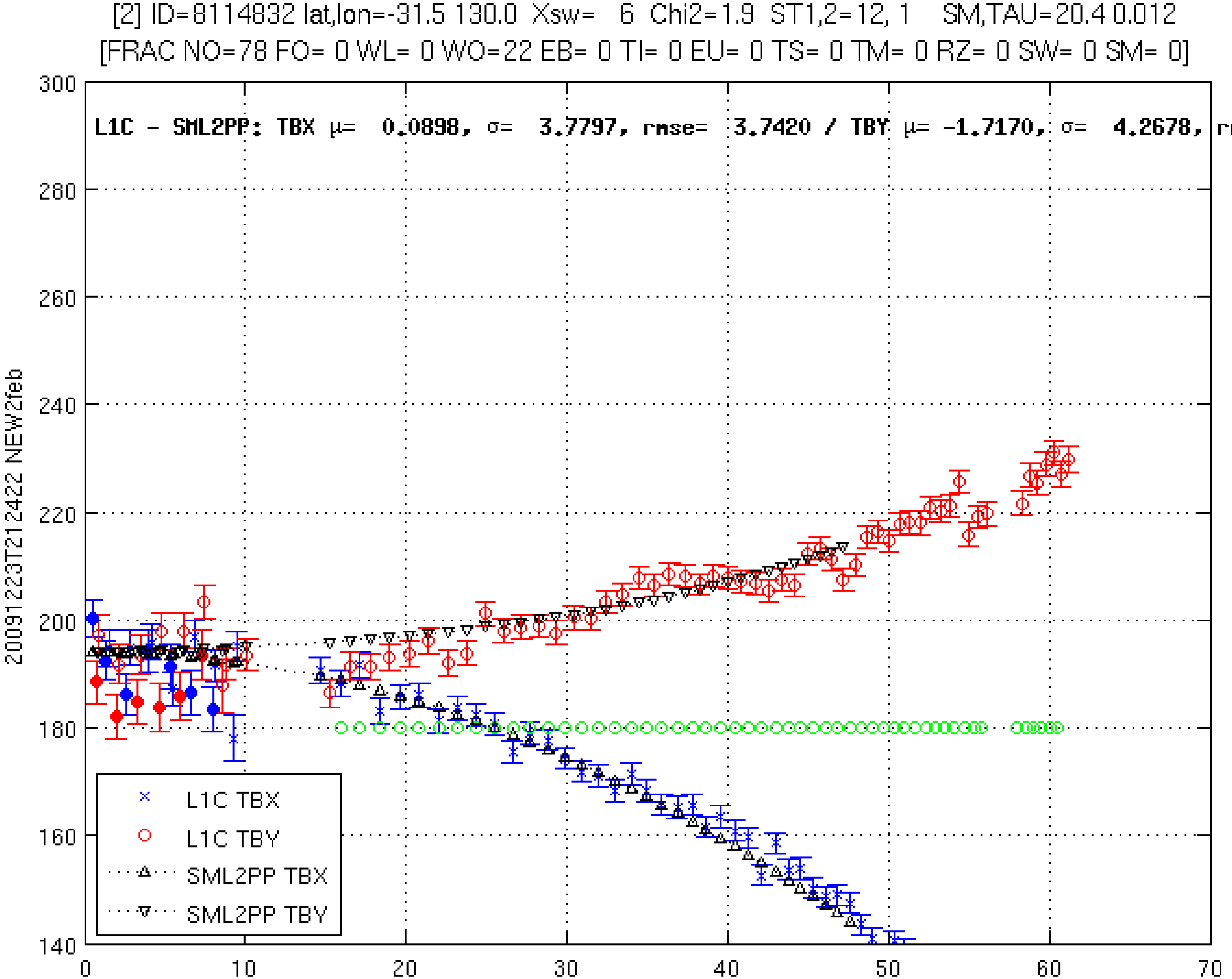
Interferometry

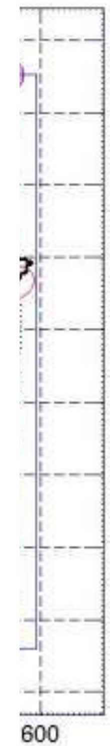
- Spatial Resolution is determined by the maximum distance between antenna elements
- Correlation products

s(1)*s(2) $\rightarrow$ Visibility function $V(D/\lambda)$

- Inverse Fourier Transform $V \rightarrow T_B(\theta)$

375λ,





•Ea
(2.4
acq
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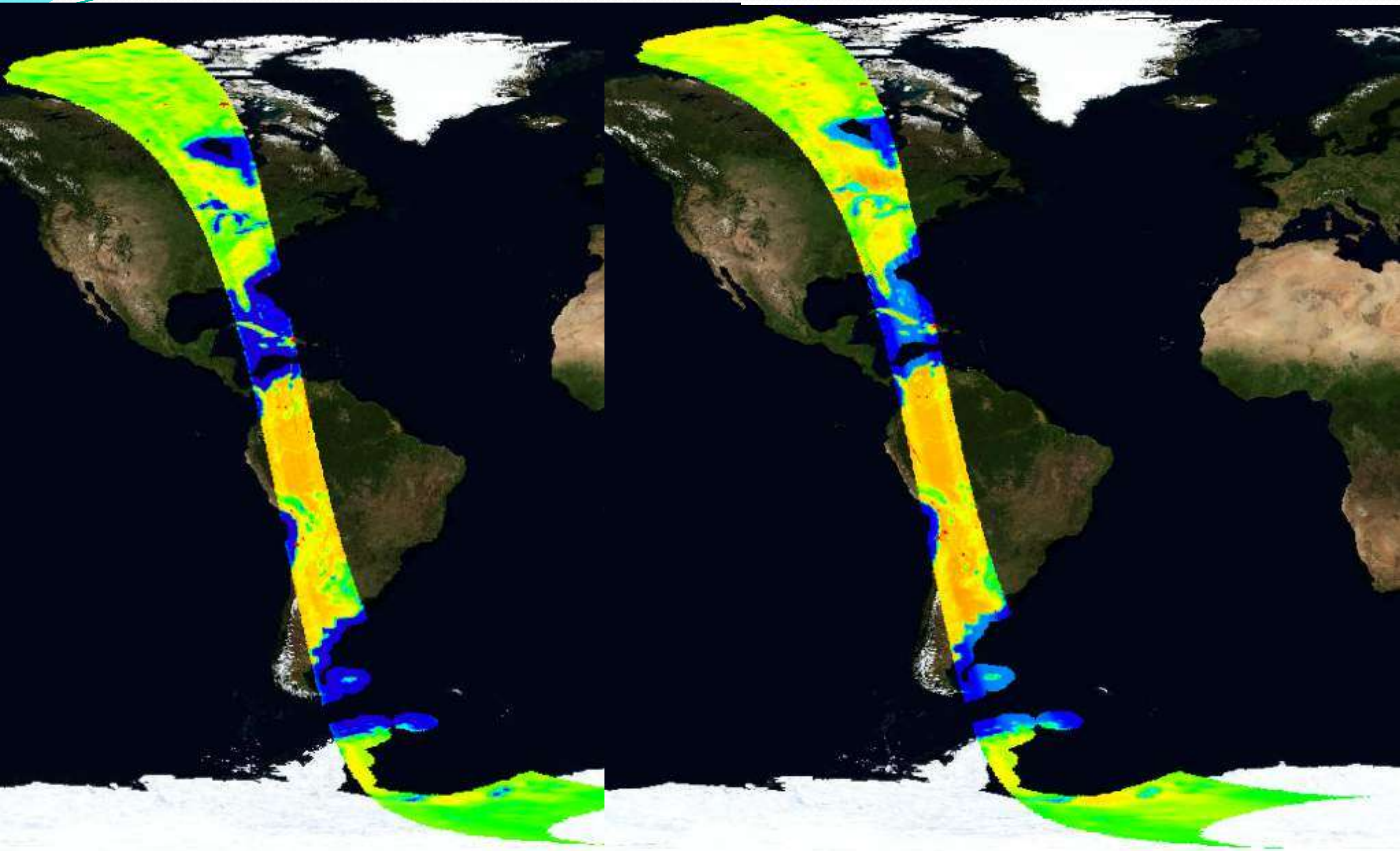
acquisitions 3 days

P. Waldteufel, 2003
P. Richaume, 2010

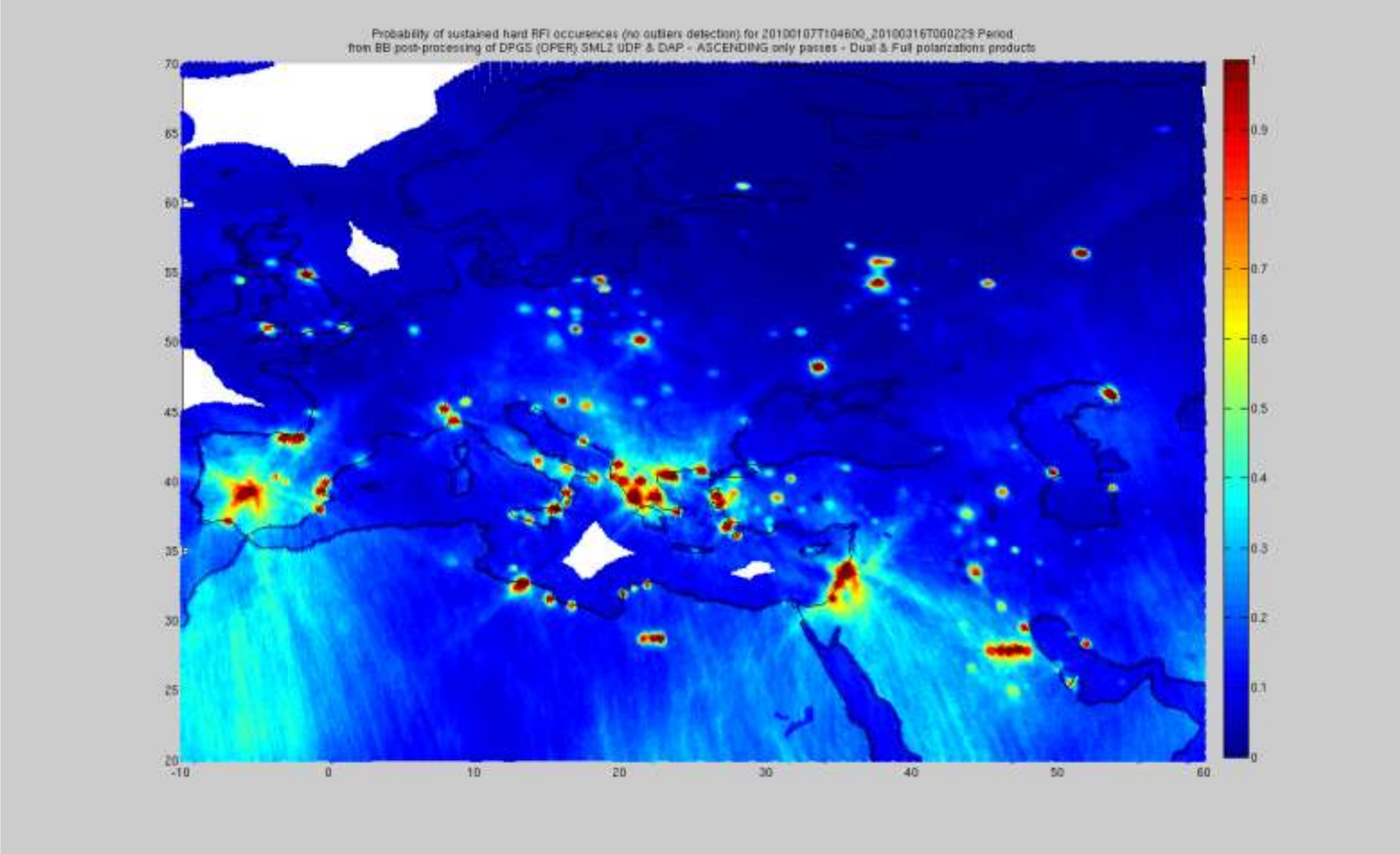
First Images in X and Y pol



But …. A big problem:

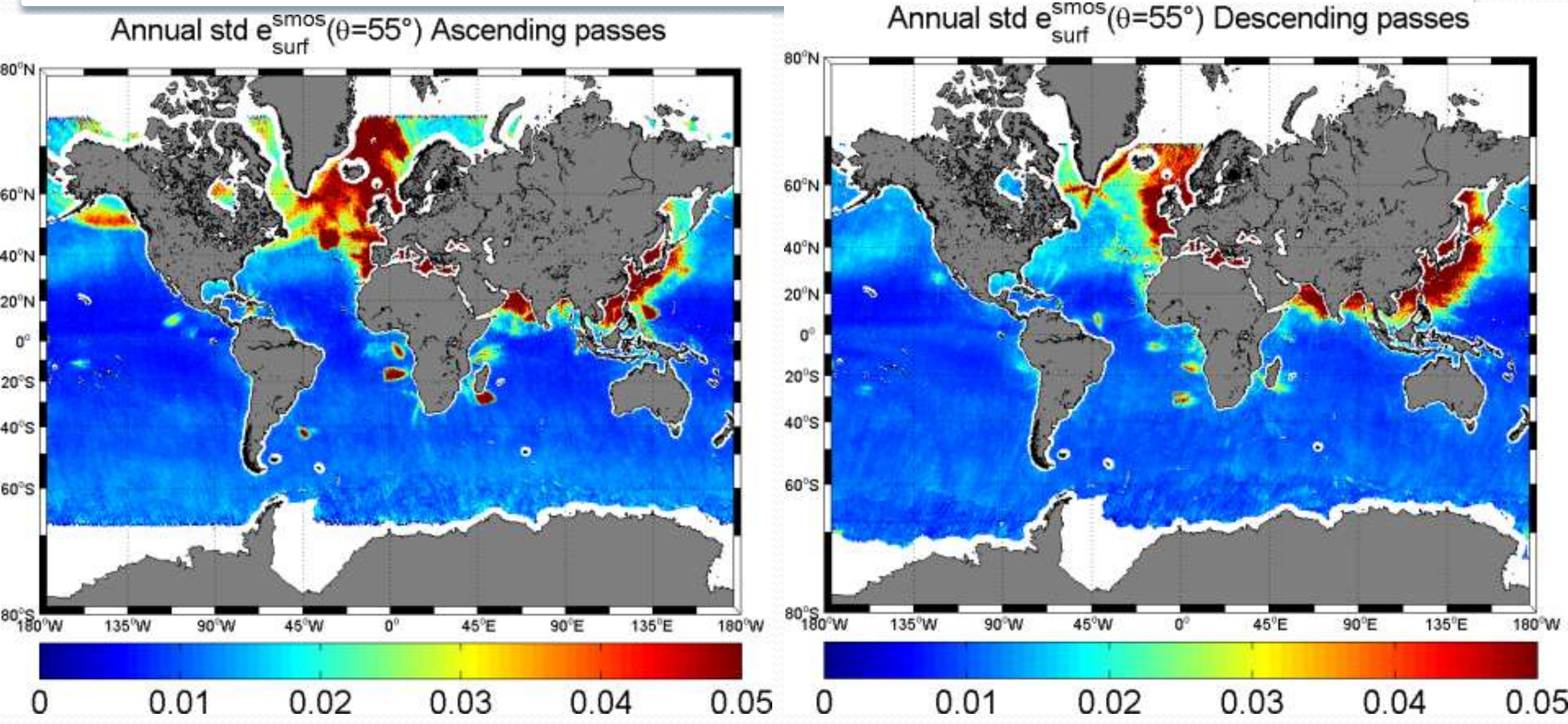
The protected L-band
is not
well protected…

Issue of Radio Frequency Interferences → Europe



P. Richaume

The RFI contamination issue Over the oceans



Annual Variance of the surface emissivity over 2010 from 15° to 55° incidence -both passes

All area with variances higher than 0.03-0.04 are clearly RFI contaminated zones

A considerable data processing is required to meet the mission requirements

Brightness temperatures have to be cleaned out for RFIs

Very accurate calibration is needed:=> radiometer stability (sky targets, Dome C)

Image reconstruction process is very complex (aliases, sun radiation effects,..) and not yet fully understood which introduce artefacts

Geophysical corrections are numerous (sst, roughness, extra-terrestrial, inosphere)
⇒Source of flaws in the algorithm

Low accuracy swath SSS acquisition need to be merged to build up more accurate composite products:

This is done at Level 3 in dedicated national centers:

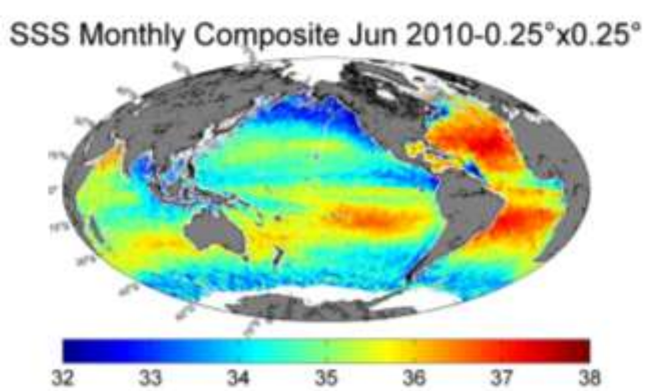
The french CNES/CESBIO/IFREMER ground segment CATDS (Ifremer/Brest)
&
The Spannish CP34 (Barcelona)

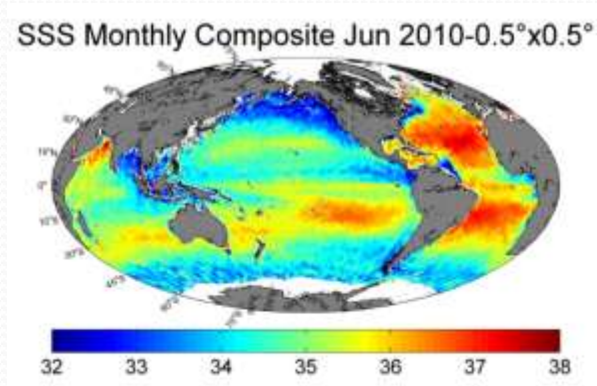
The Centre Aval de Traitement des Données SMOS
Research Level 3 Composite Sea Surface Salinity products

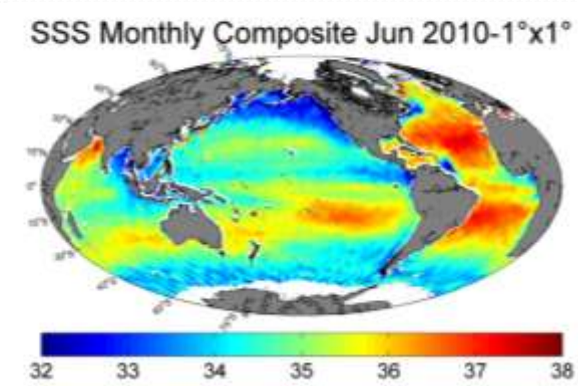
Ifremer CATDS cnes

3 type of Products for year 2010:

•**Monthly composite SSS at 0.25°, 0.5° and 1° degree resolution**:



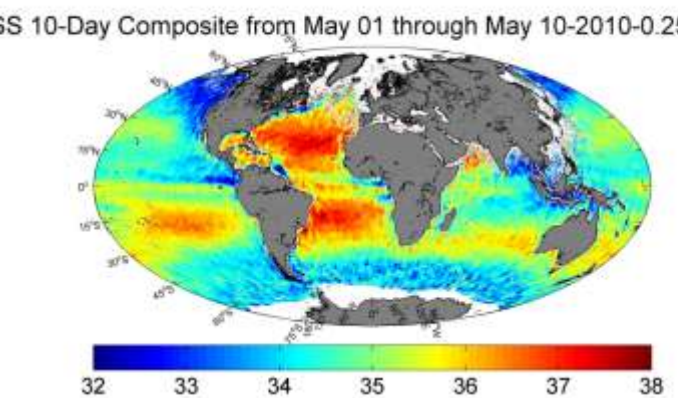


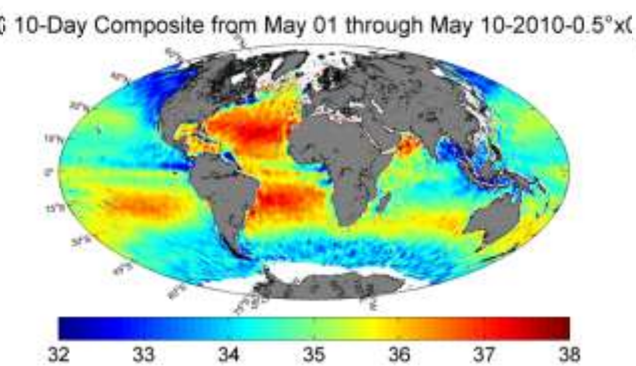


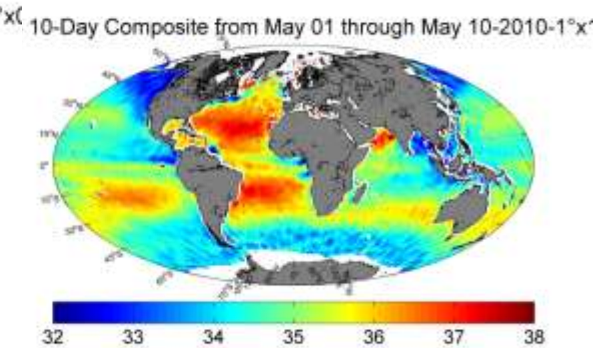
The Centre Aval de Traitement des Données SMOS
Research Level 3 Composite Sea Surface Salinity products

Products for year 2010:

•**10 –day composite at 0.25°, 0.5° and 1° degree resolution**:



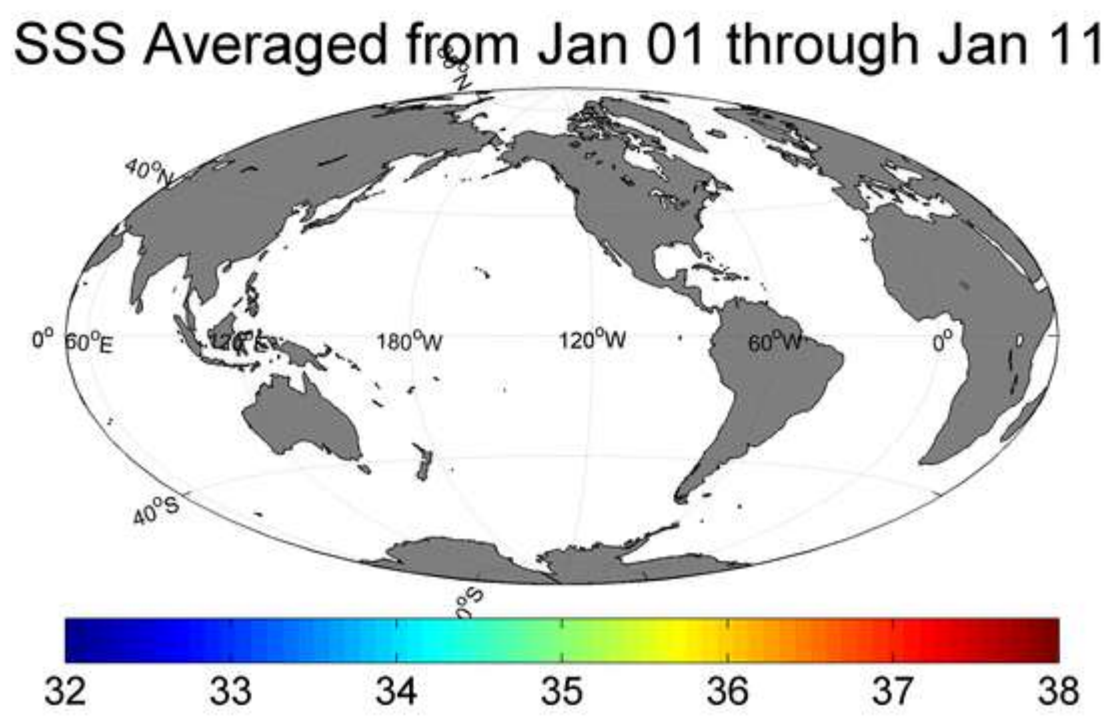




The Centre Aval de Traitement des Données SMOS Research Level 3 Composite Sea Surface Salinity products

Products for year 2010:

•**Daily running 10-days composite** at 0.25 degree resolution



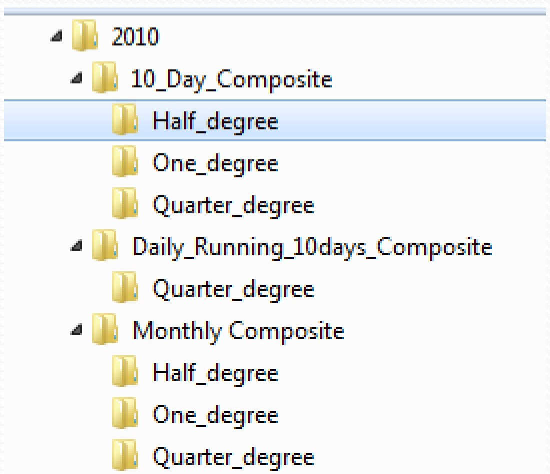
CATDS Level 3 Composite Sea Surface Salinity Research products RELEASE and ACCESS

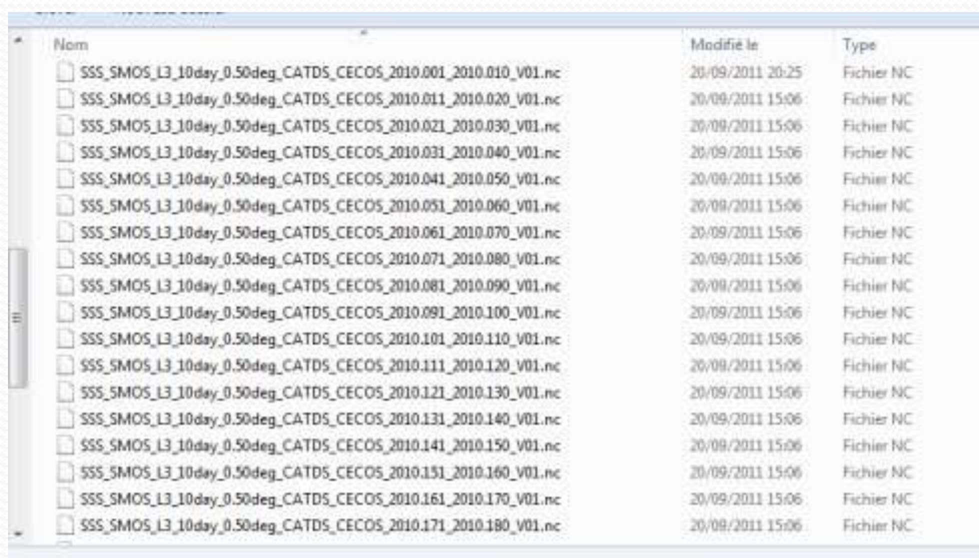
OFFICIAL RELEASE of the « Research » Products:

- Netcdf Data access at http://www.catds.fr/
  access under =>Data=>**Research Products from Expertise Centers**

- ftp : eftp.ifremer.fr, password protected

- Free access upon email request : support@catds.fr





- Documentation : Product User Manual & Validation Report, ATBD

- Reprocessed Year 2011 Jan->September: should be accessible end-october

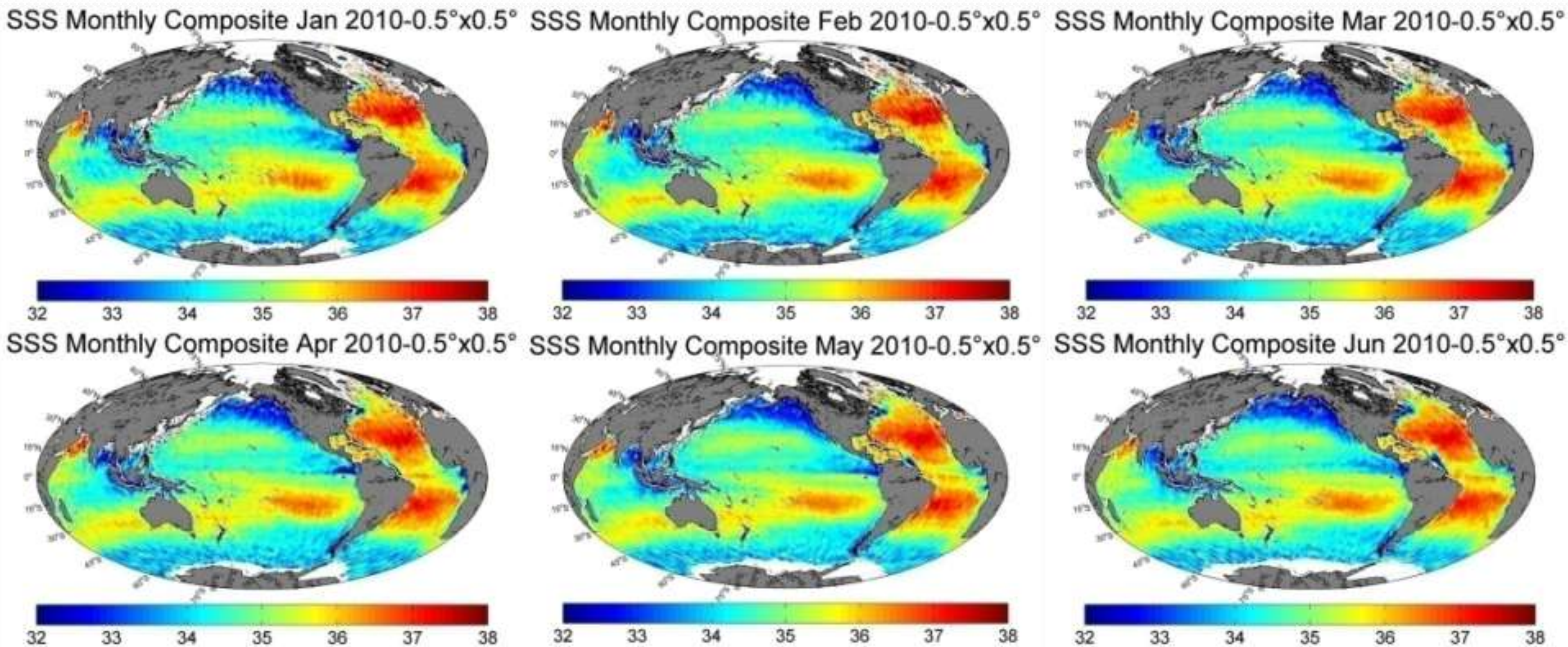
The L3 SSS CATDS-CECOS Products

Product Validation

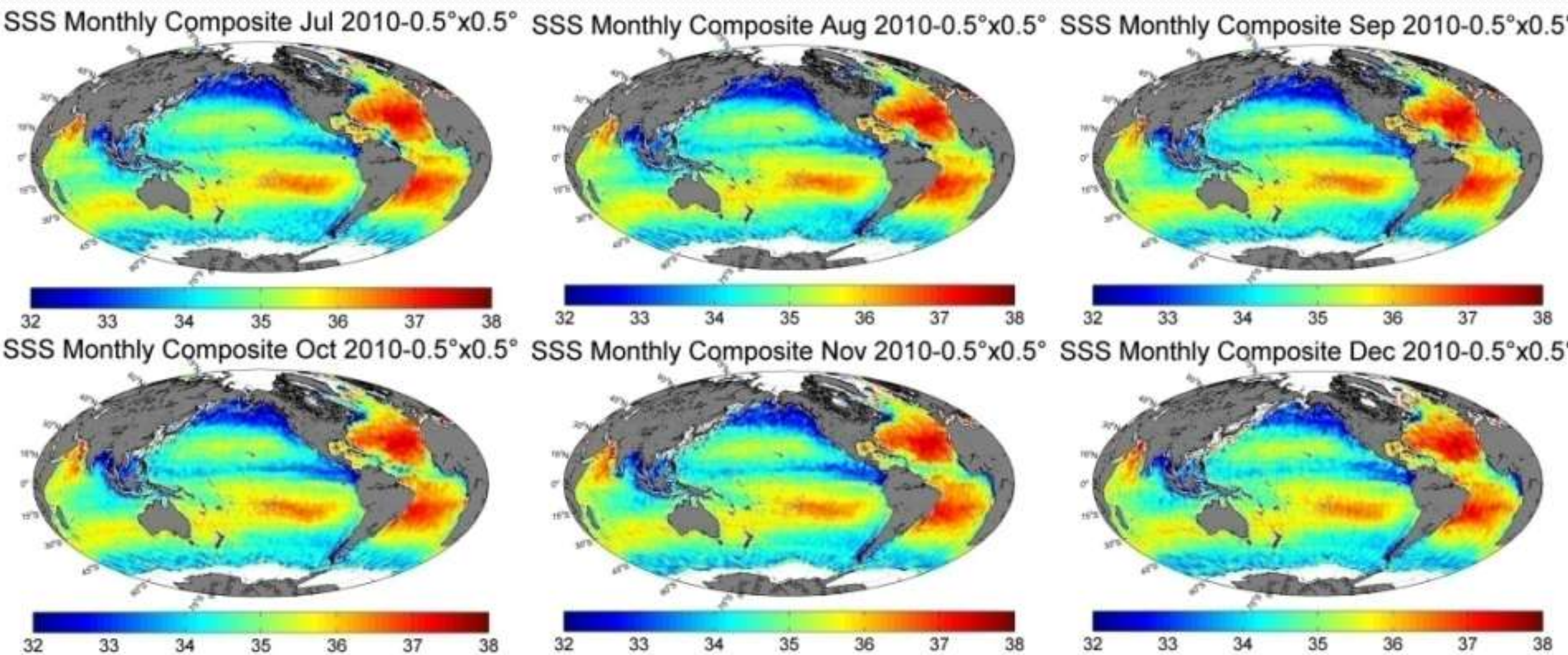
&

Oceanographic consistency

Exemple Monthly products at 0.5° Res: January to June 2010

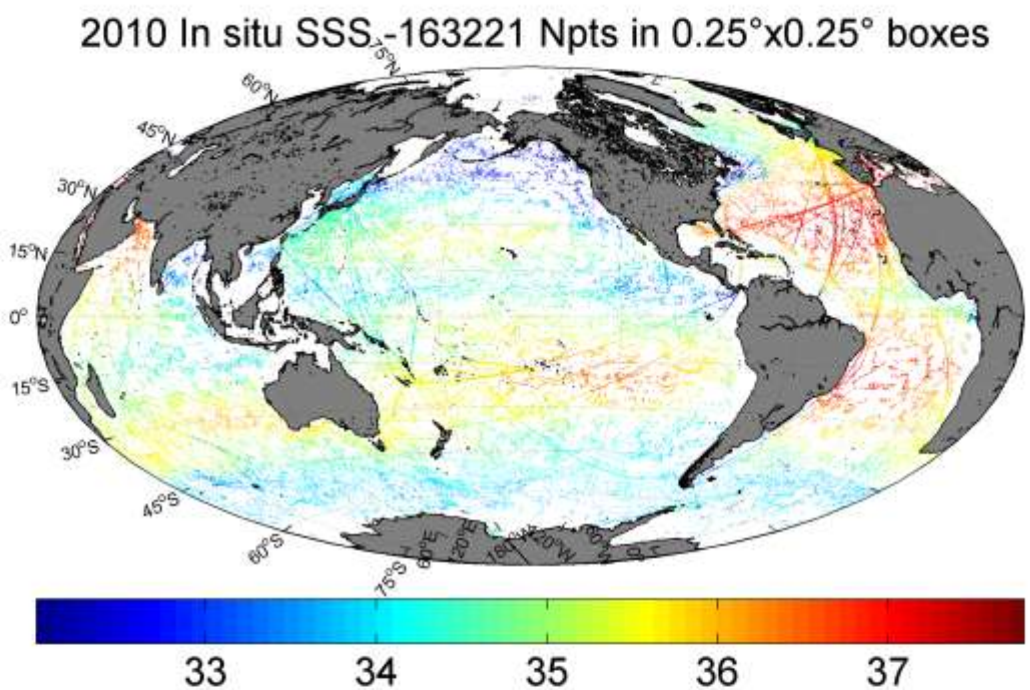


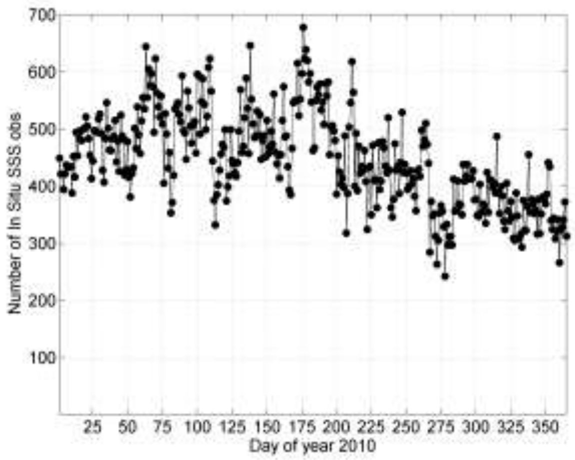
Exemple Monthly products at 0.5° Res: July to December 2010



Validation
Still on going but …

Ensemble of qualified In situ data (Argo+Moorings+CTD+TSG) year 2010
Depth <10 m → GLOSCAL project





→ Averaging at the same spatio-temporal resolution than the L3 products

Validation of the Monthly L3 SSS composite

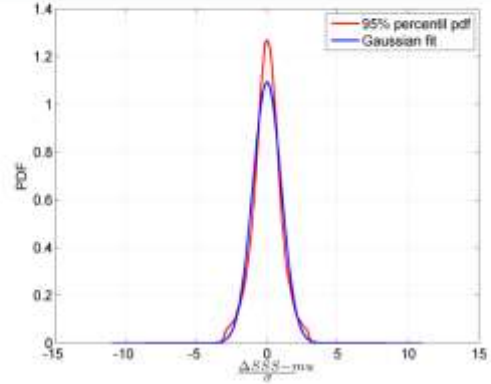


Figure 4: Exemple of the Probability distribution function of the 95% percentile of the ΔSSS data differences: $\Delta SSS = SSS_{in\,situ} - SSS_{SMOS}$ between *in Situ* SSS and co-localized SMOS L3 SSS, considering all months of 2010 and the Global ocean data. Here *mu*=0.0081 is the mean ΔSSS and σ=0.365 is the standard deviation.

TABLE III: **SMOS LEVEL 3 1°x1°** MONTHLY COMPOSITE ΔSSS 95% PERCENTILE ERROR STATISTICS (PSS) OVER THE COMPLTE YEAR 2010

Statistics	Global Ocean	Arctic Ocean	North Atlantic	Tropical Atlantic	South Atlantic	North Pacific	Tropical Pacific	South Pacific	Indian Ocean	Southern Ocean
Mean	0.0060	1.6256	-0.0473	0.0698	0.0528	0.0132	0.0170	-0.0151	0.0279	-0.0266
Standard Deviation	**0.2876**	**1.0250**	**0.5720**	**0.2775**	**0.2580**	**0.3046**	**0.2525**	**0.2095**	**0.2470**	**0.2559**
Skewness	-0.1261	0.4331	-0.4957	0.0663	-0.1922	-0.2166	-0.1290	-0.0055	0.0734	-0.0131
Kurtosis	3.5370	2.2593	4.7825	3.3019	2.7914	3.6553	3.0009	2.7185	3.1277	2.7806

Averaged Spatial Distribution of $\Delta SSS = SSS_{in\ situ} - SSS_{SMOS}$

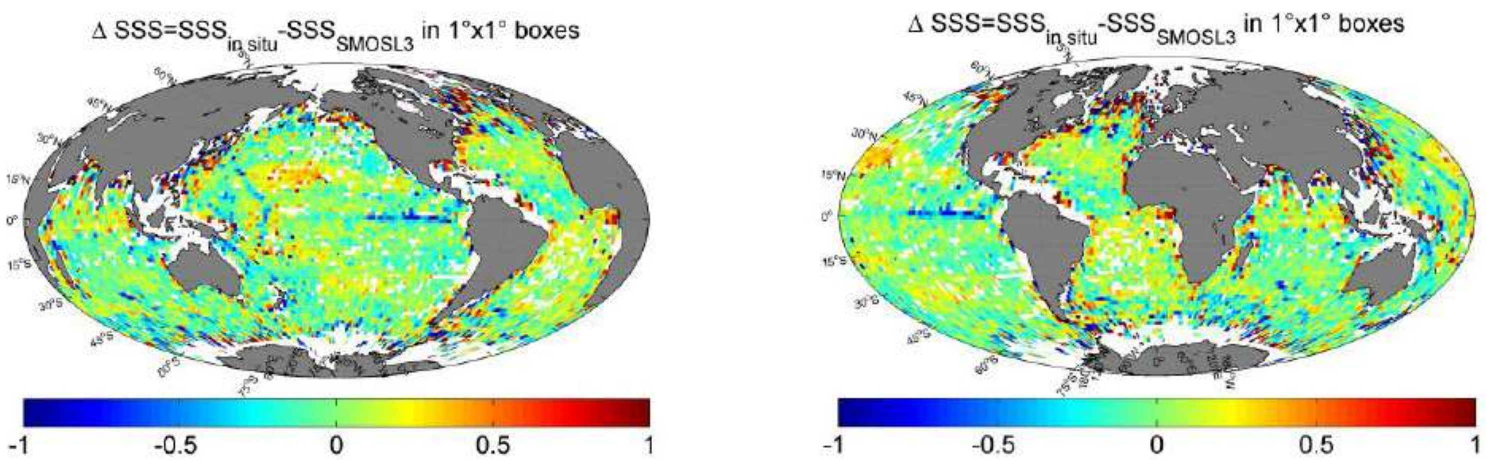
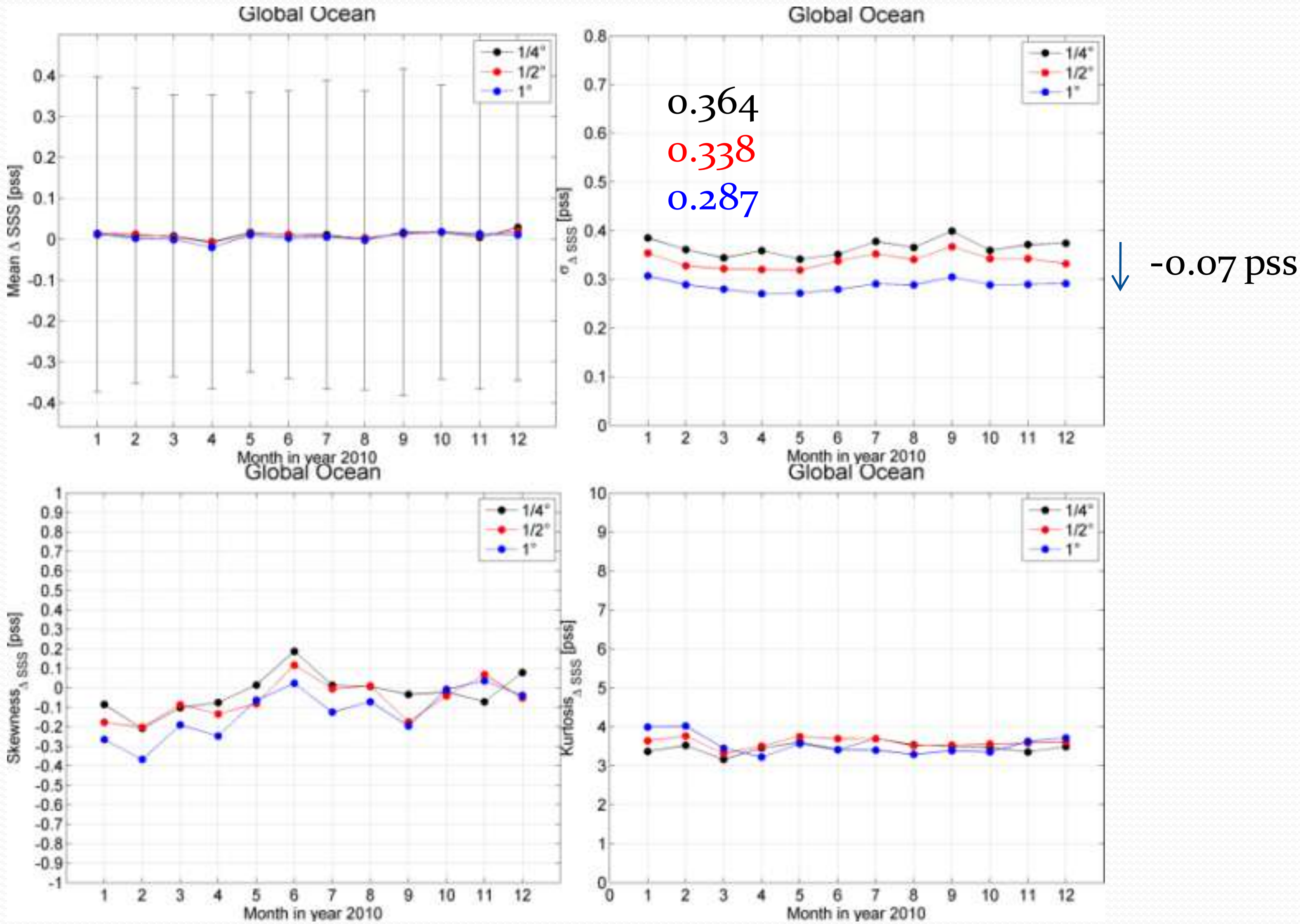
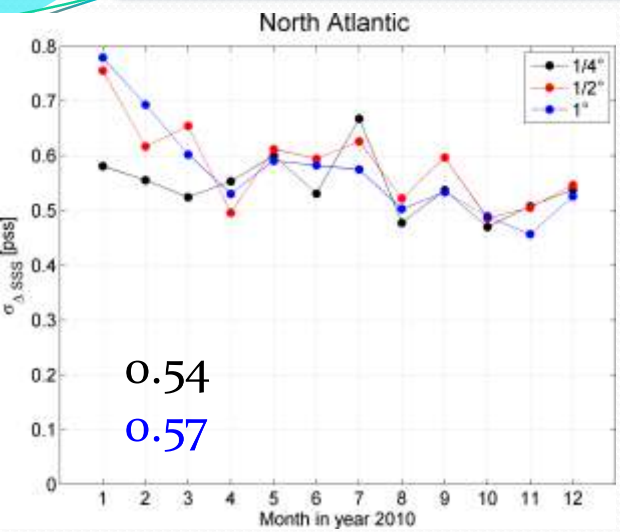


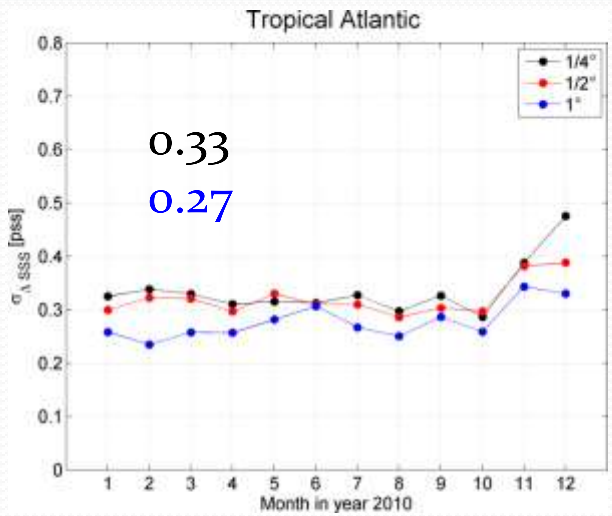
Figure: Spatial distribution of $SSS_{in\ situ} - SSS_{SMOS}$ monthly composite data at 0.25° resolution after averaging the ΔSSS 2010 data over 1°x1° boxes. Left: Map centered on the pacific. right: same map but centered on the Atlantic. Note that positive values signify $SSS_{SMOS} < SSS_{in\ situ}$

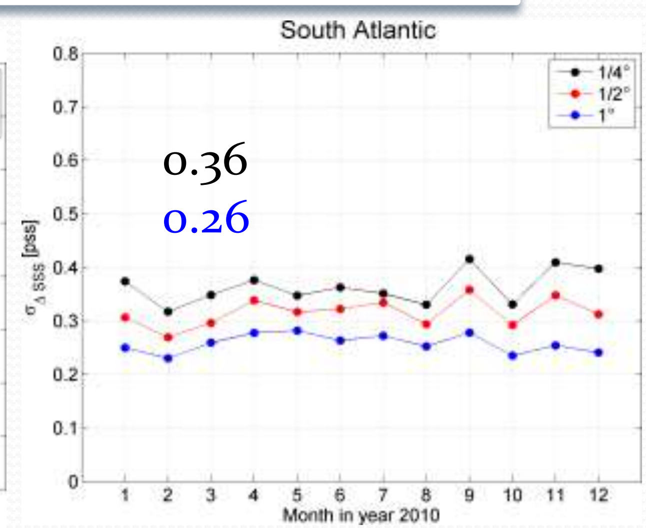
Temporal evolution of the statistics of the $\Delta SSS = SSS_{in\ situ} - SSS_{SMOS}$

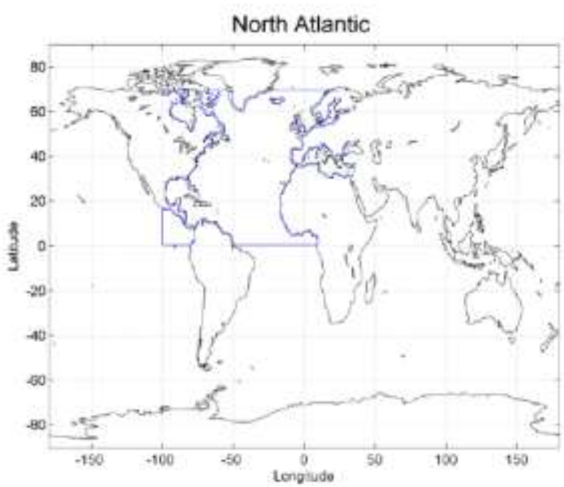


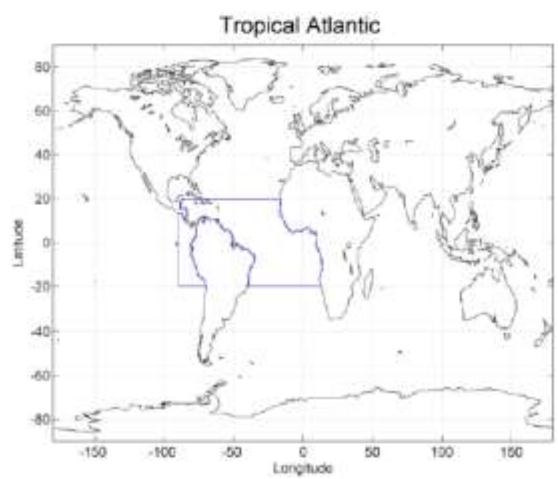
Temporal evolution of the error standard deviation per oceanic zones
Atlantic Ocean

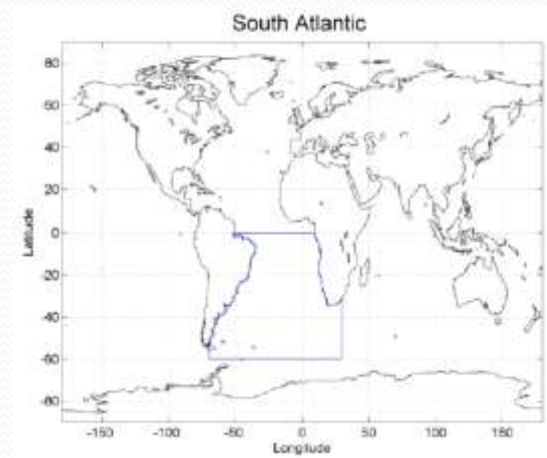




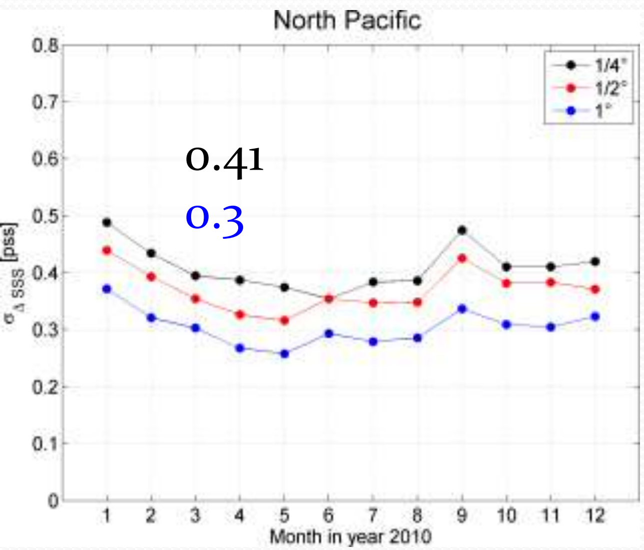


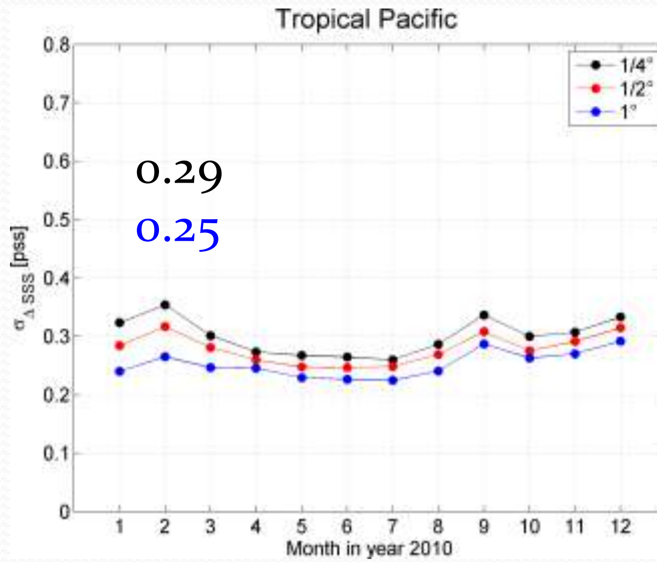


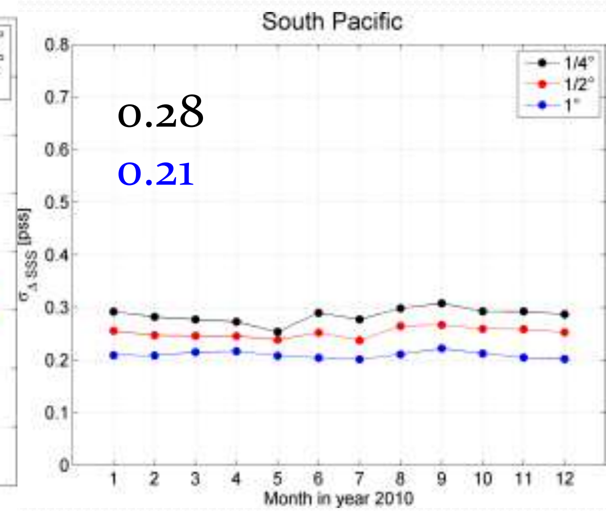


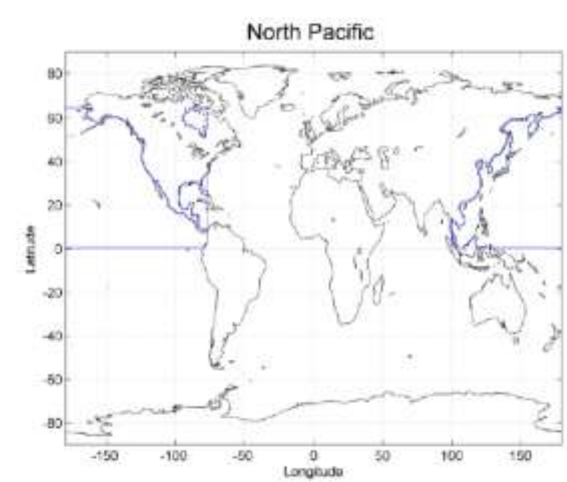


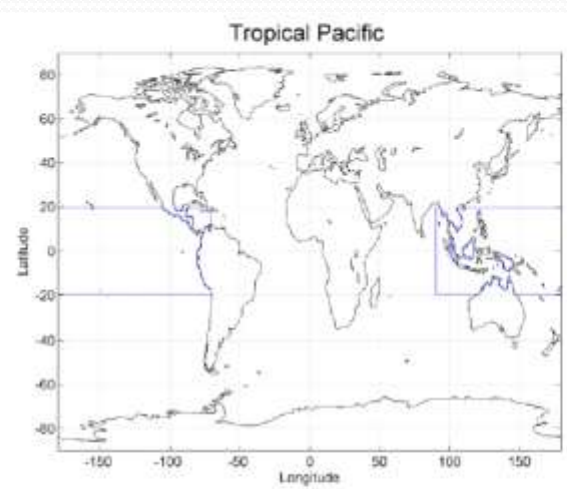
Temporal evolution of the error standard deviation per oceanic zones
Pacific Ocean

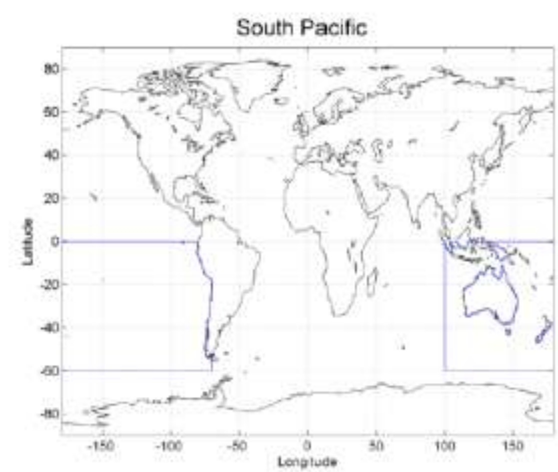




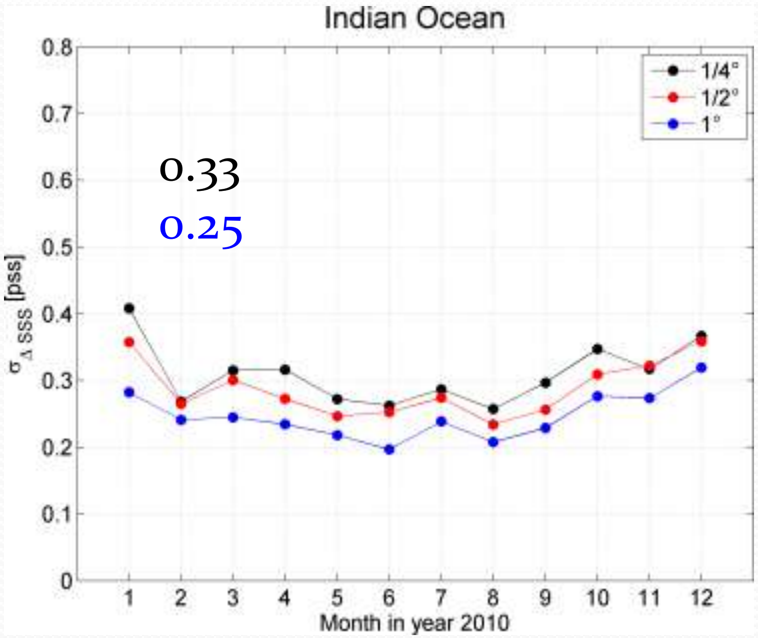


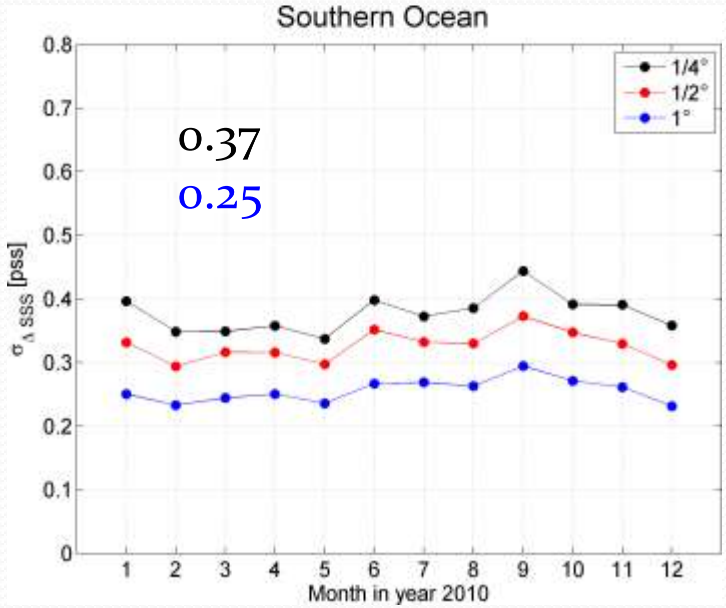


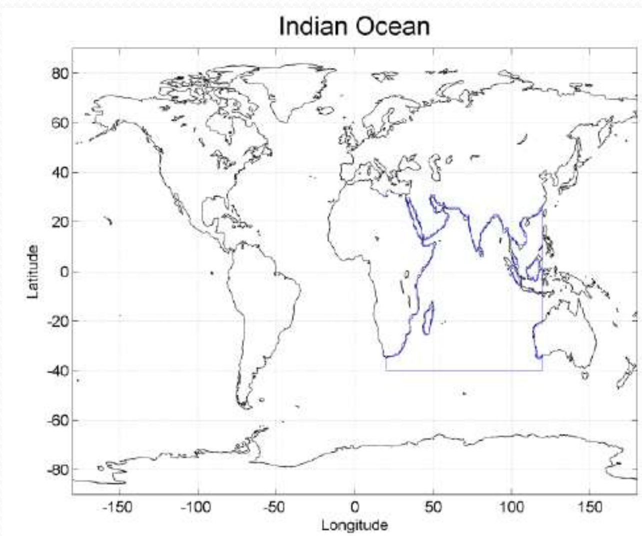


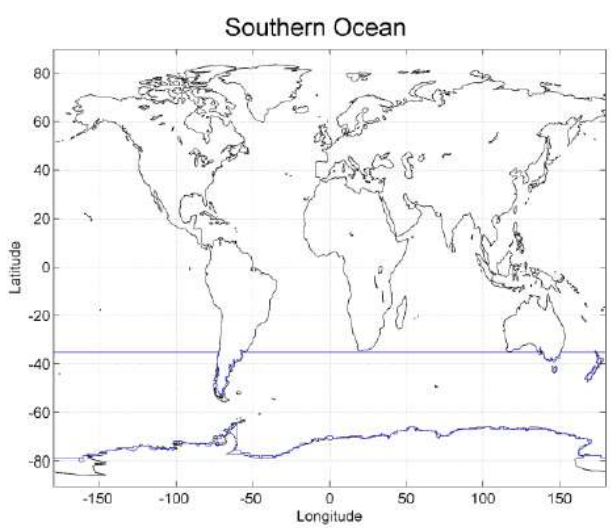


Temporal evolution of the error standard deviation per oceanic zones: Indian & Southern Oceans





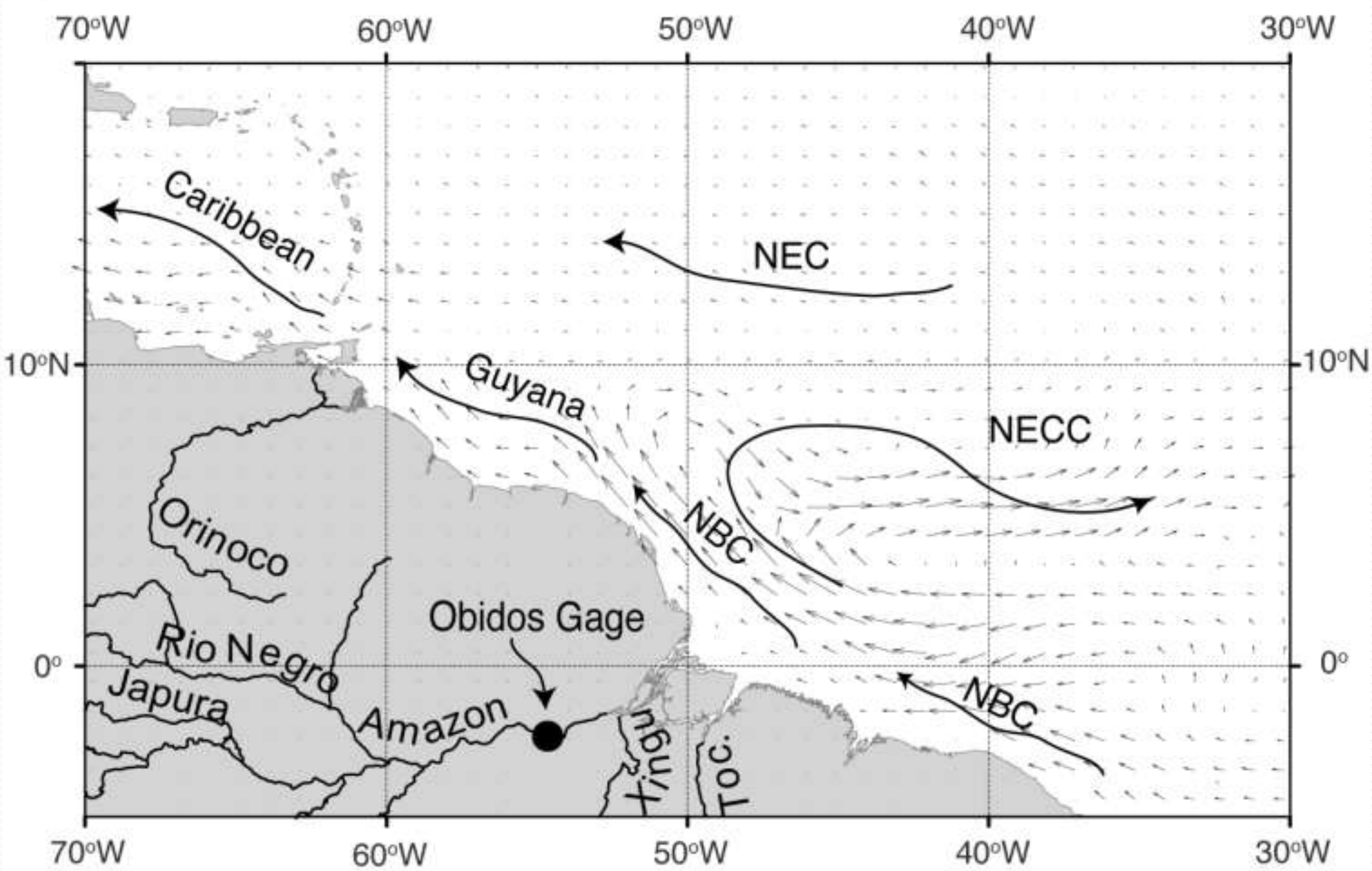




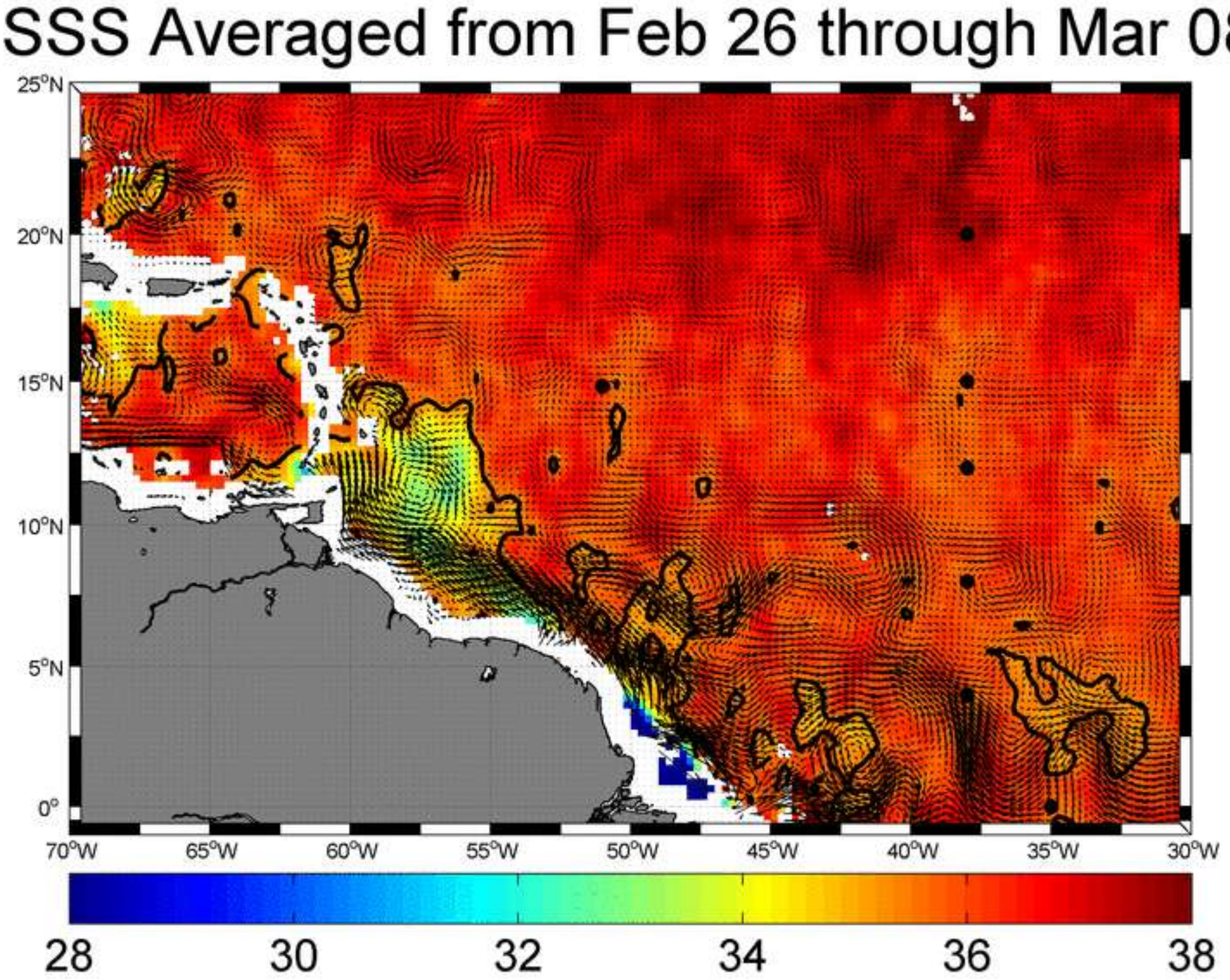
Major Tropical
Oceanic freshwater Pool as seen from space

The NorthWestern Tropical Atlantic freshwater Pool

Local Ocean Currents



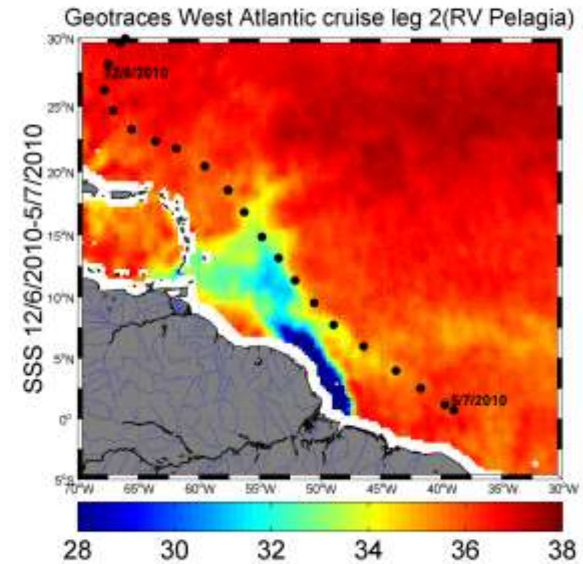
SSS Spatio-temporal monitoring from SMOS year 2010, 0.25 degree resolution, 10 days



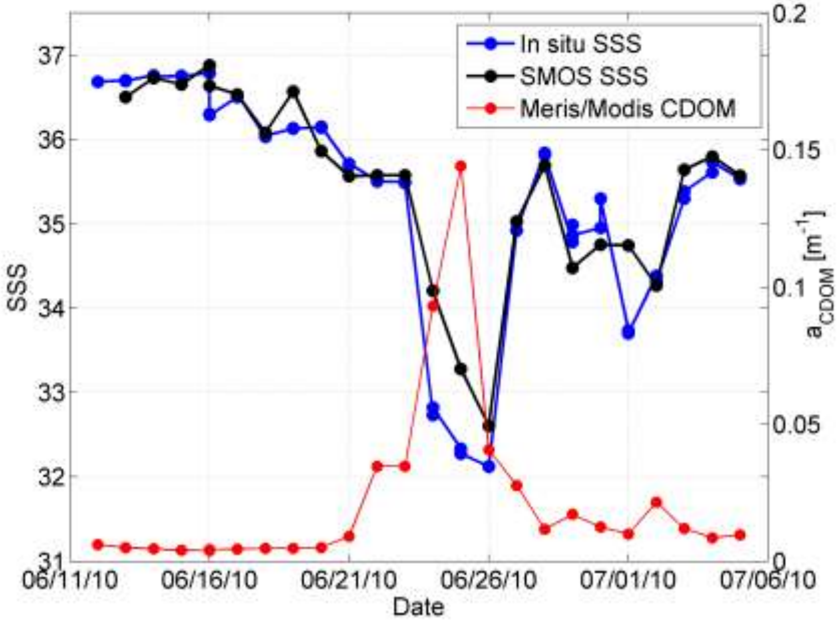
Animation available at http://www.salinityremotesensing.ifremer.fr

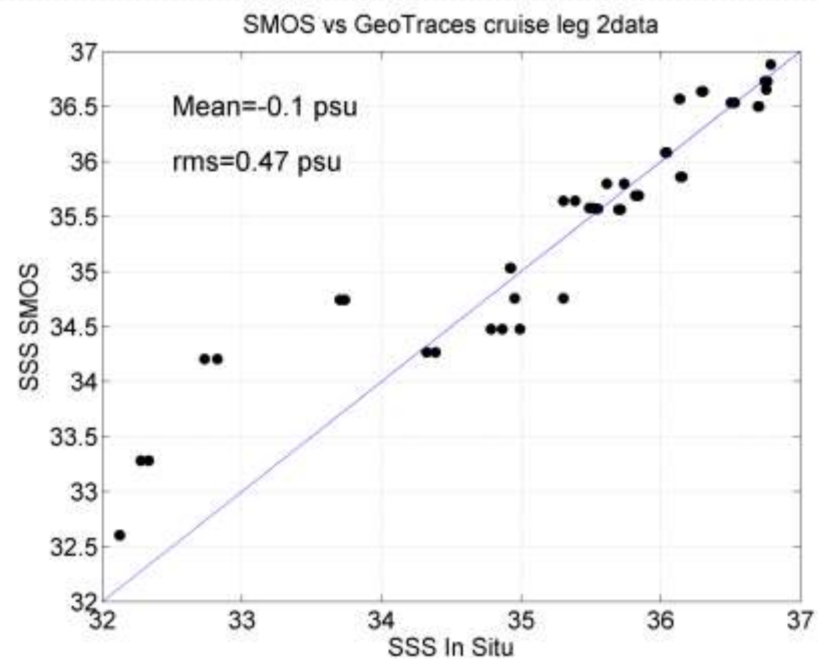
SMOS SSS Validation

Extensive validation has been conducted



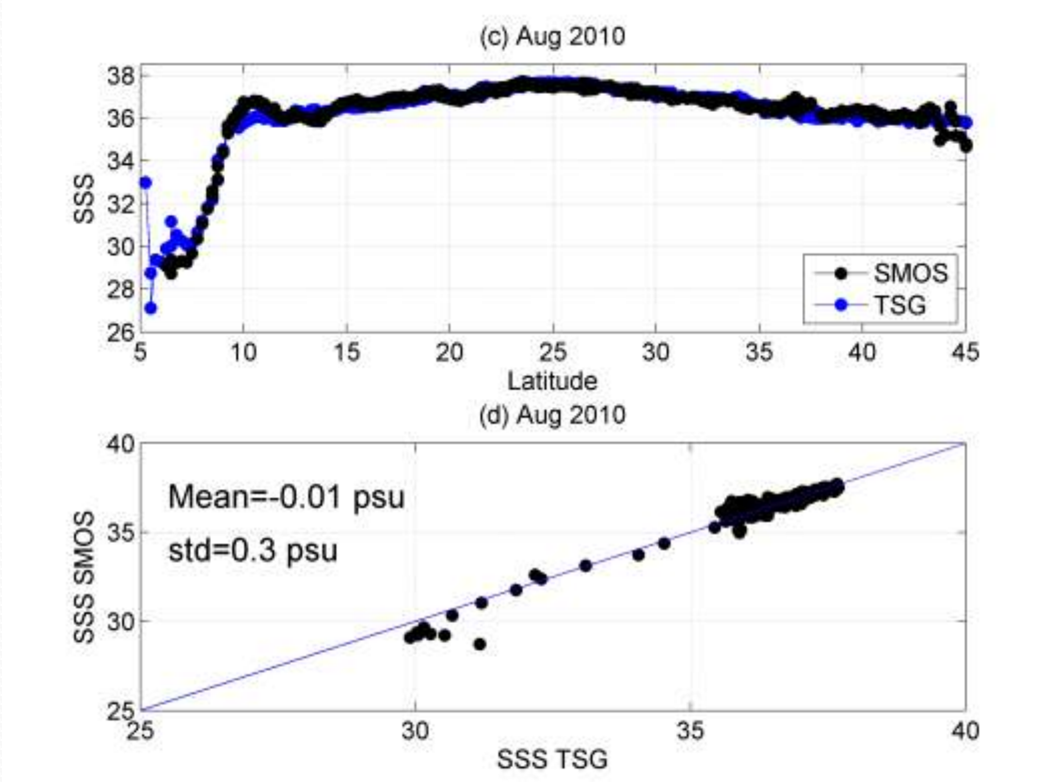
Monthly products: rms ~0.3 psu
10 days/0.25°: rms ~0.5 psu

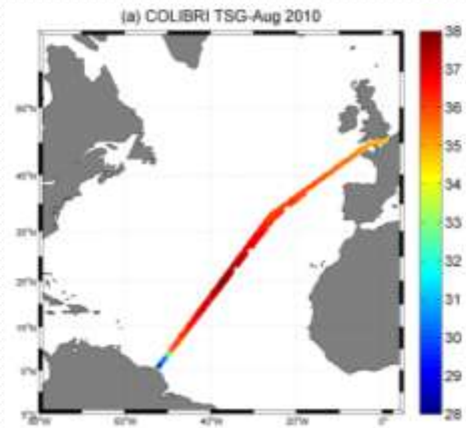


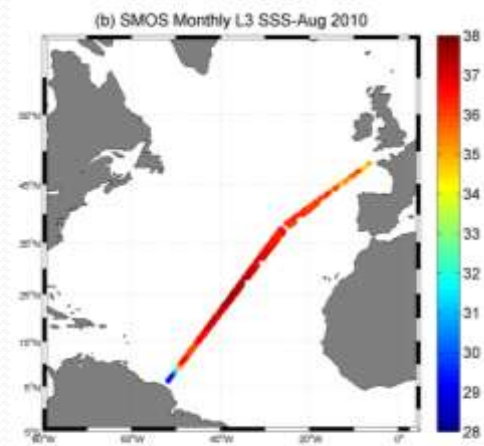


Local Validation Tropical Atlantic

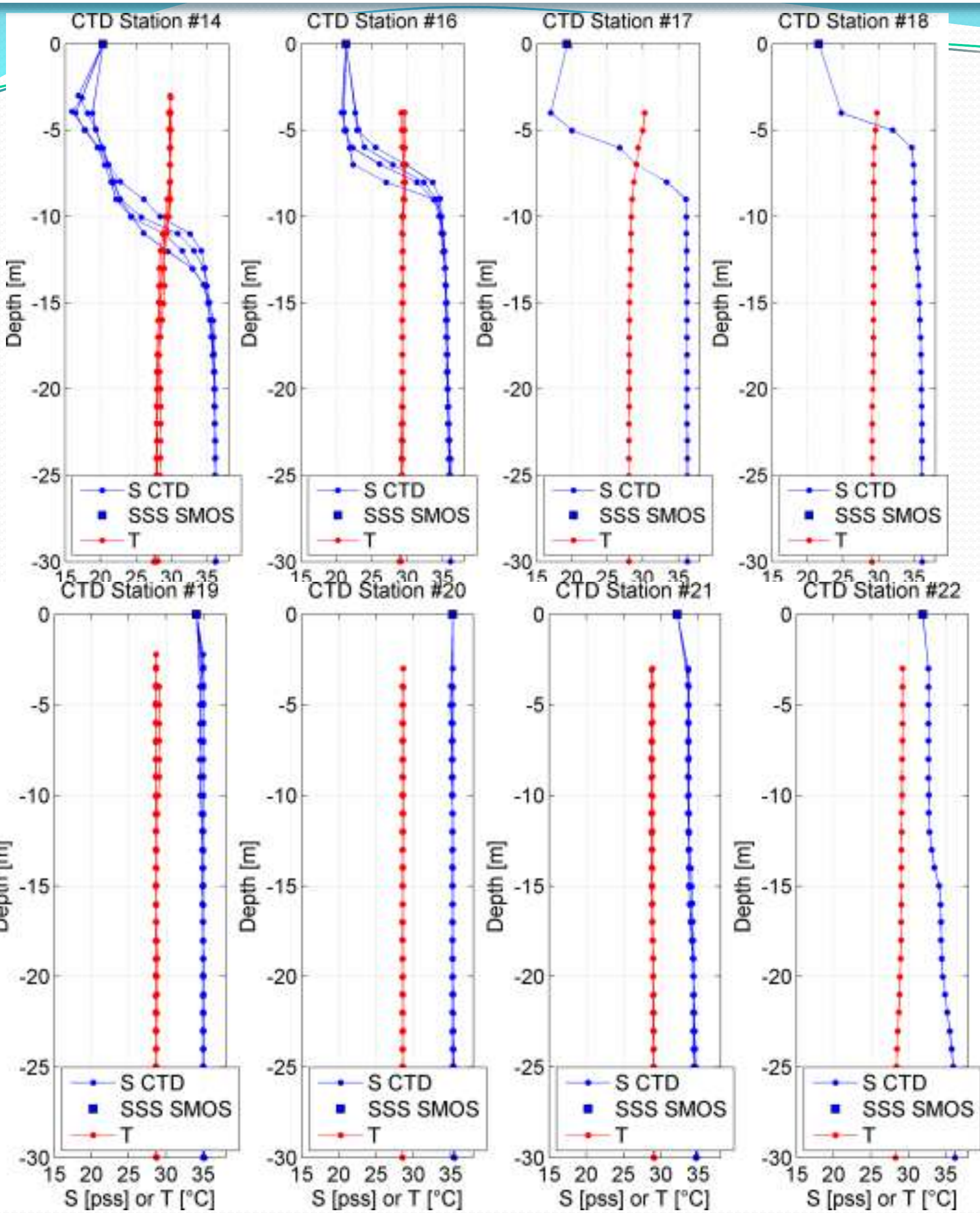
Comparison with Thermosalinograph data aquired on board ships of opportunity

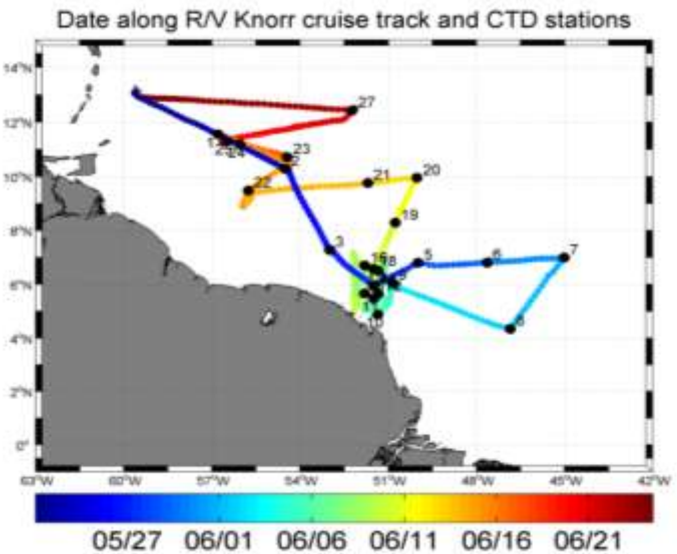






Consistency of SMOS SSS with Plume vertical Structure

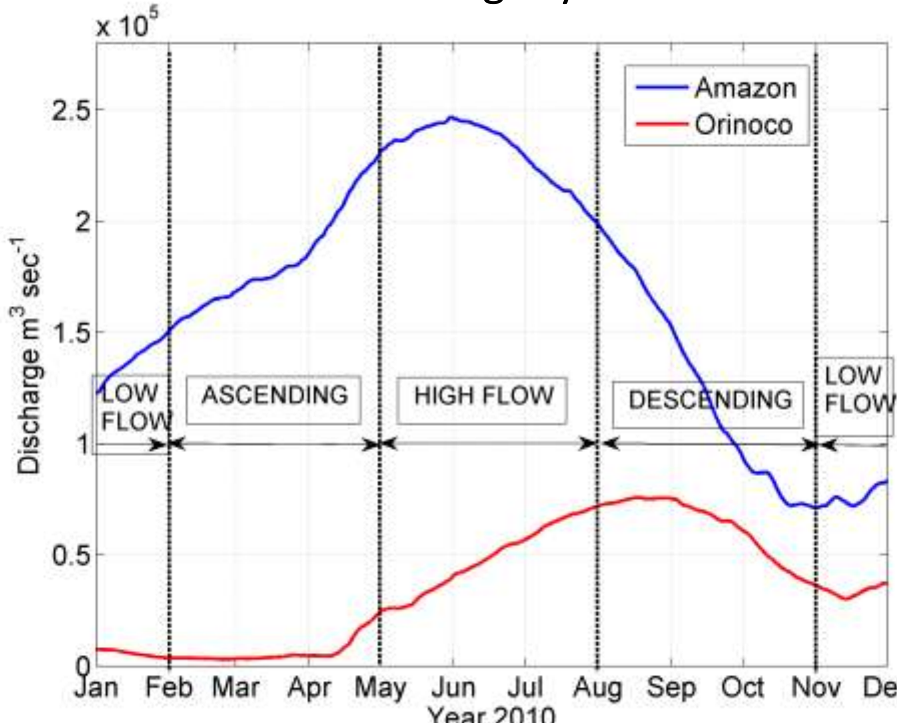


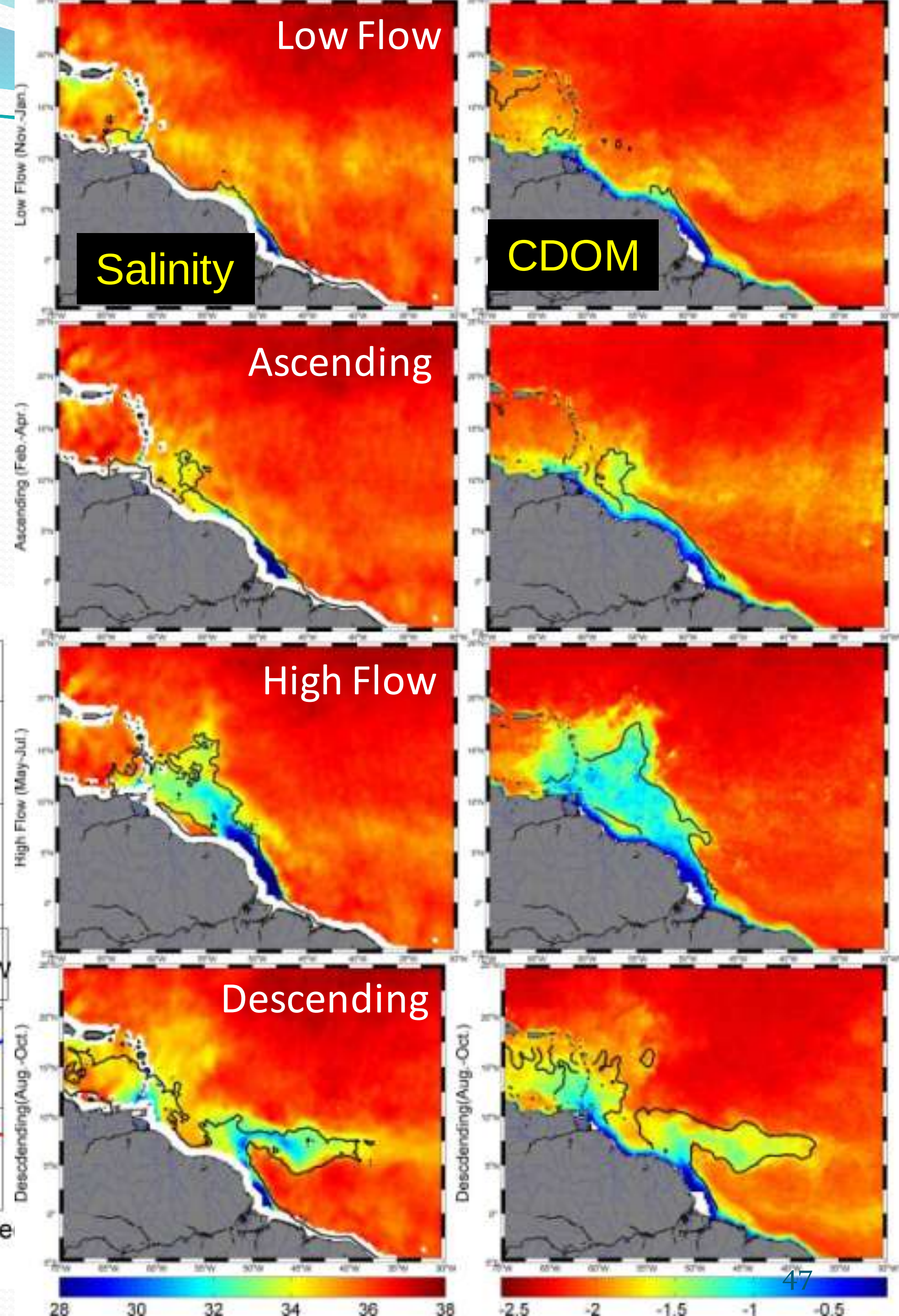


Seasonal cycle of the freshwater plume signals

Salisbury et al., JGR 2011

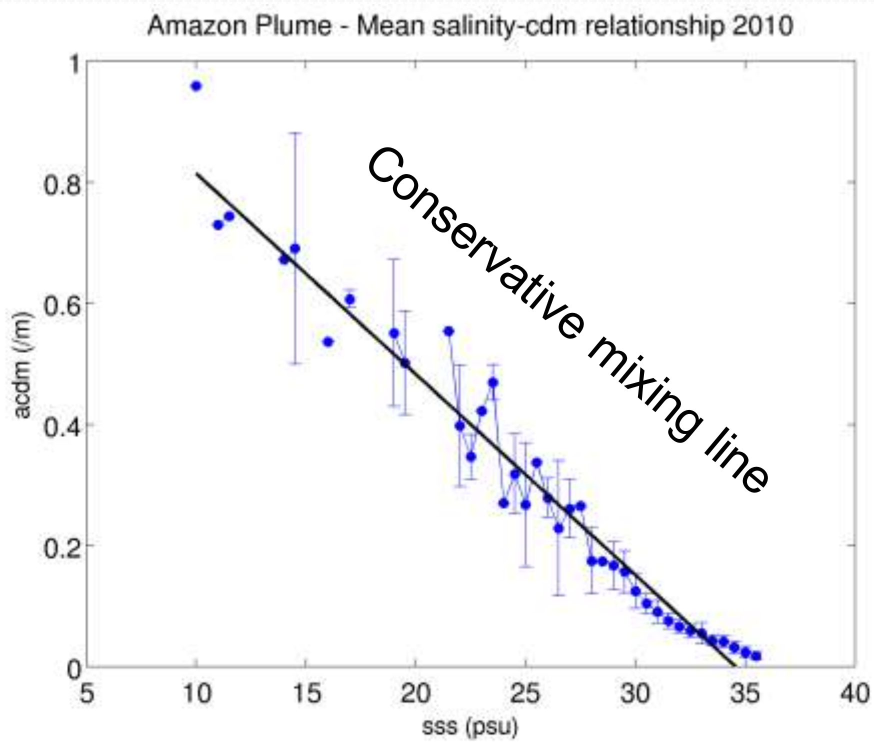
River discharge cycle



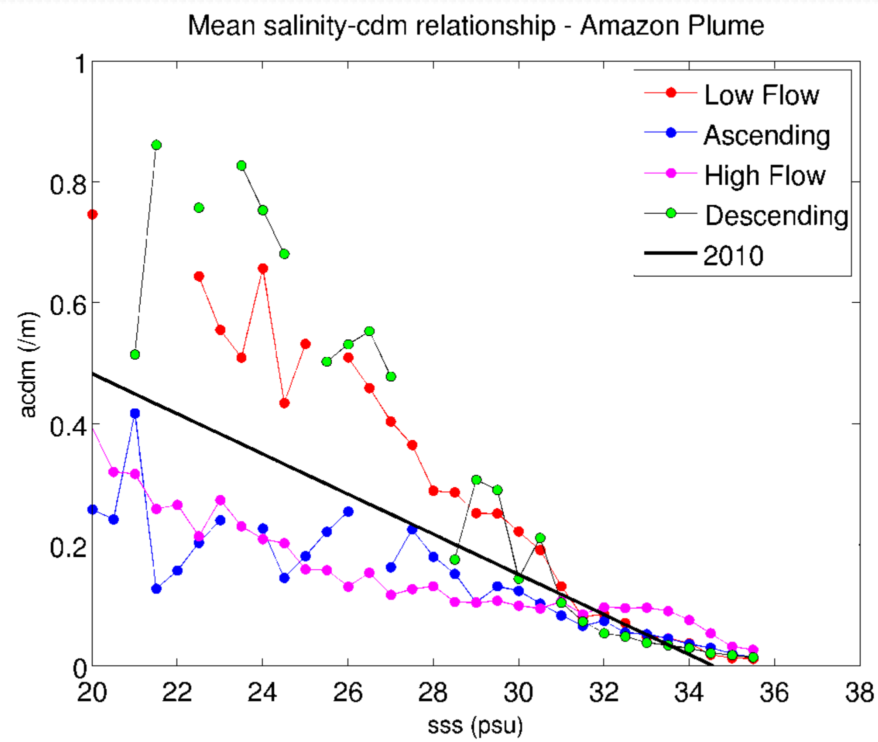


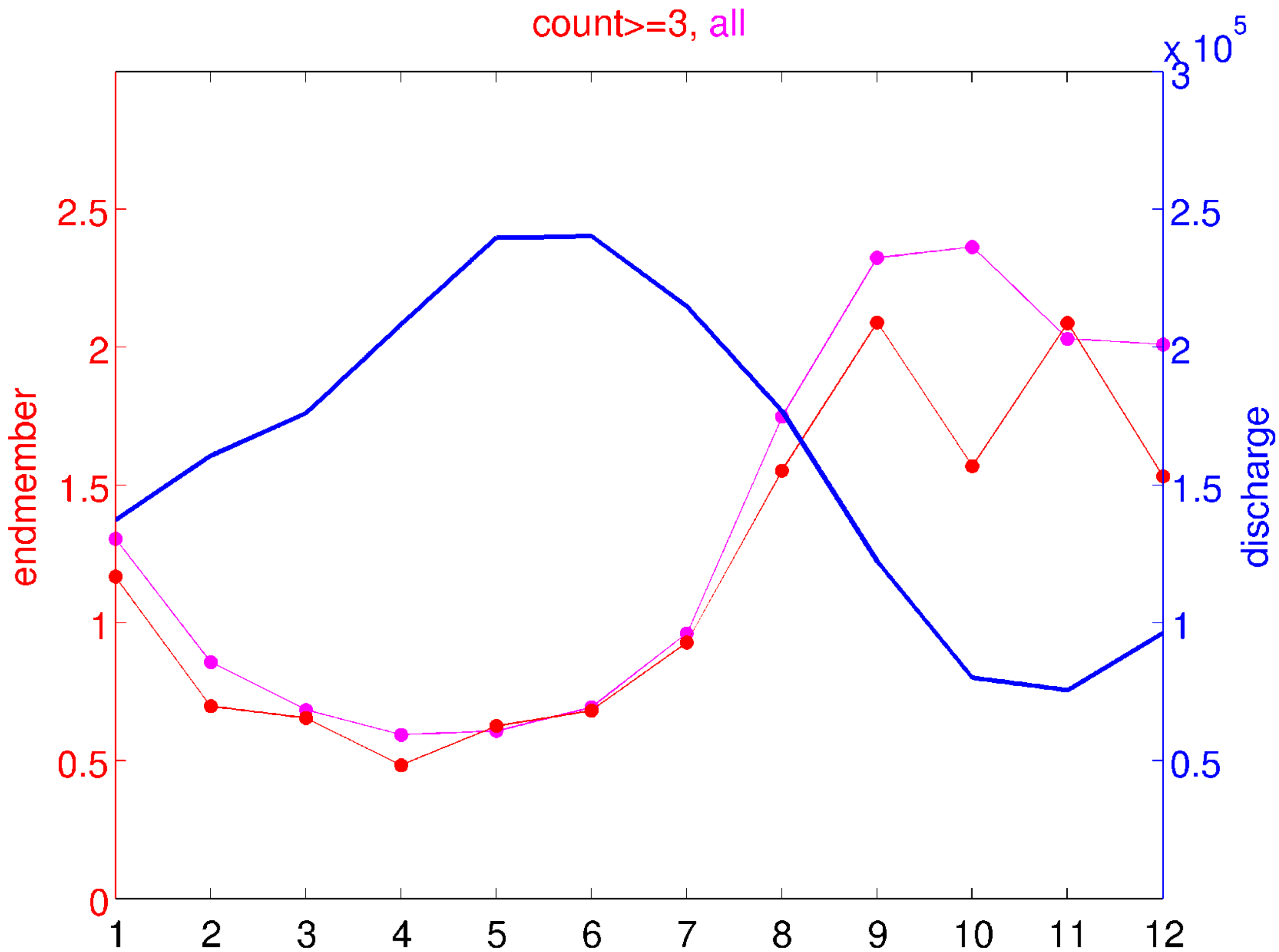
Observed seasonal cycle in the SSS/Acdm relationship

Annual average



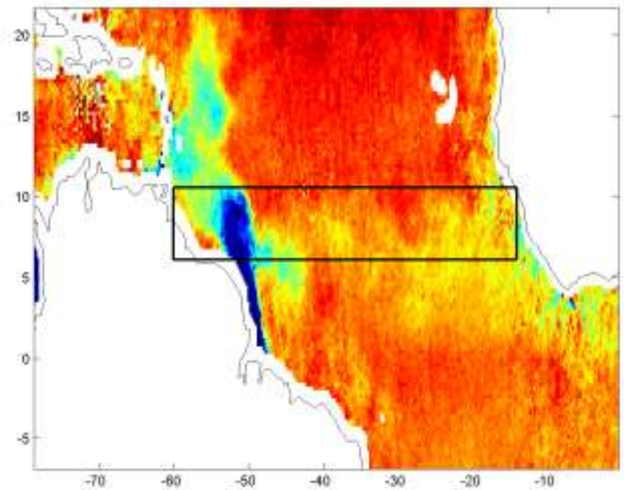
Seasonal average





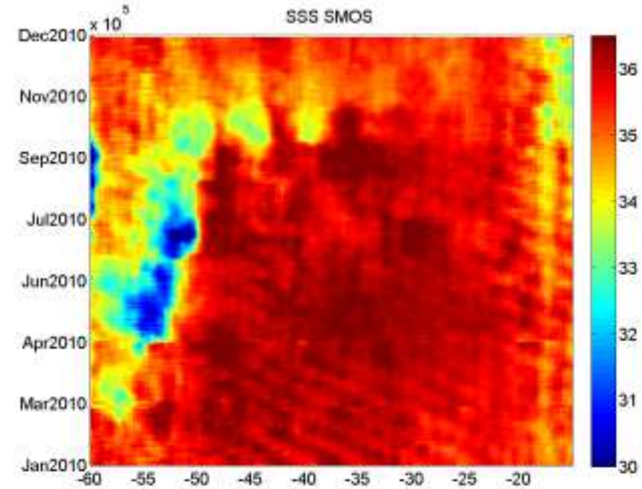
Running mean: month +/- 1 month

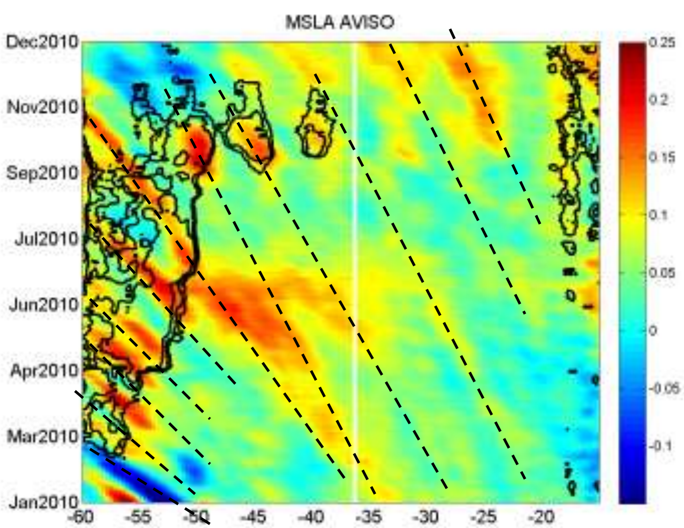
Strong potential of SMOS SSS to help improving our understanding of Tropical Atlantic Instability waves

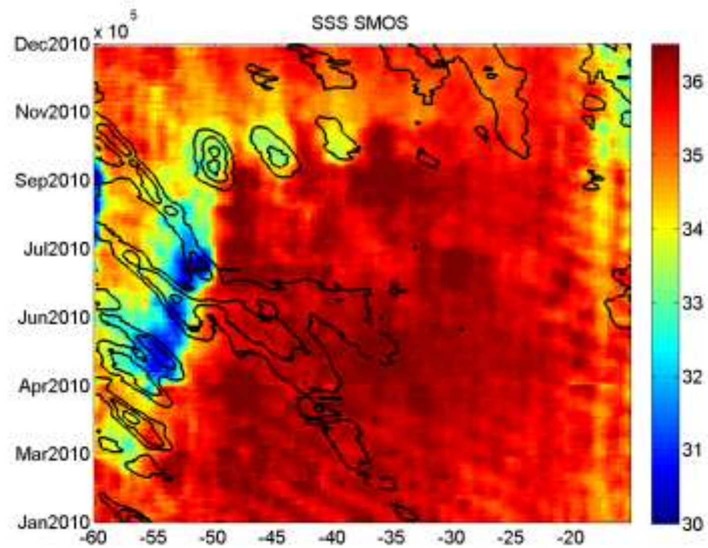


Time

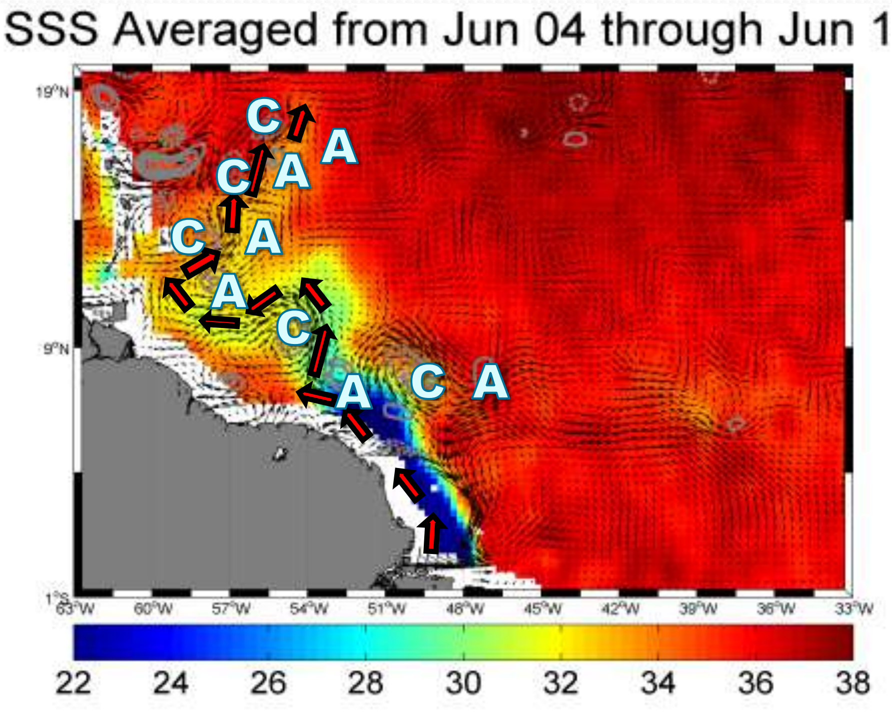
Longitude
Plot



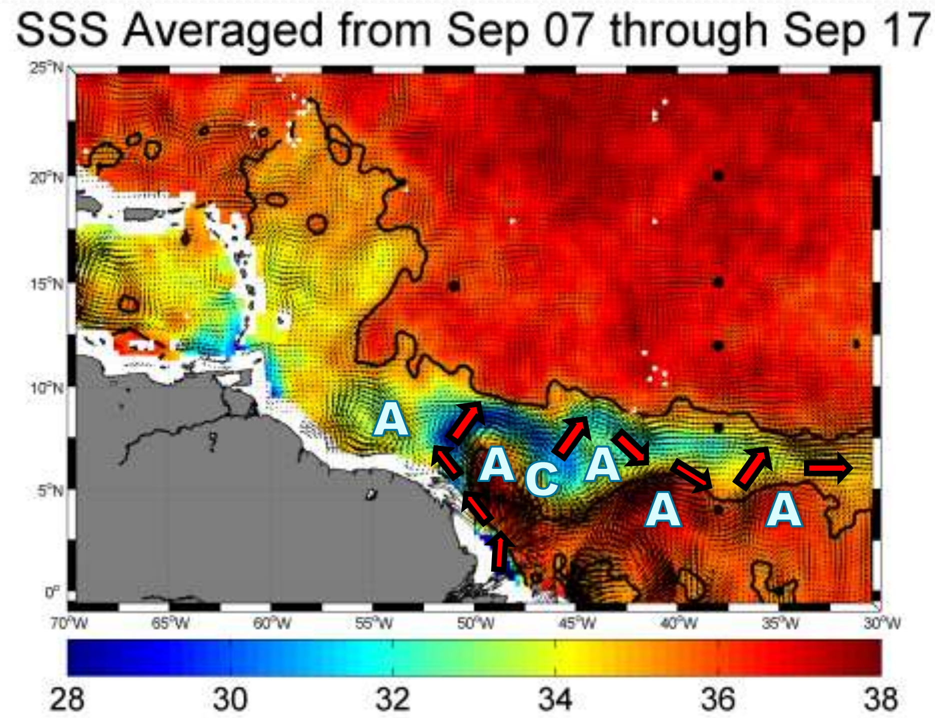




2 Major pathways for the freshwater surface layer advection



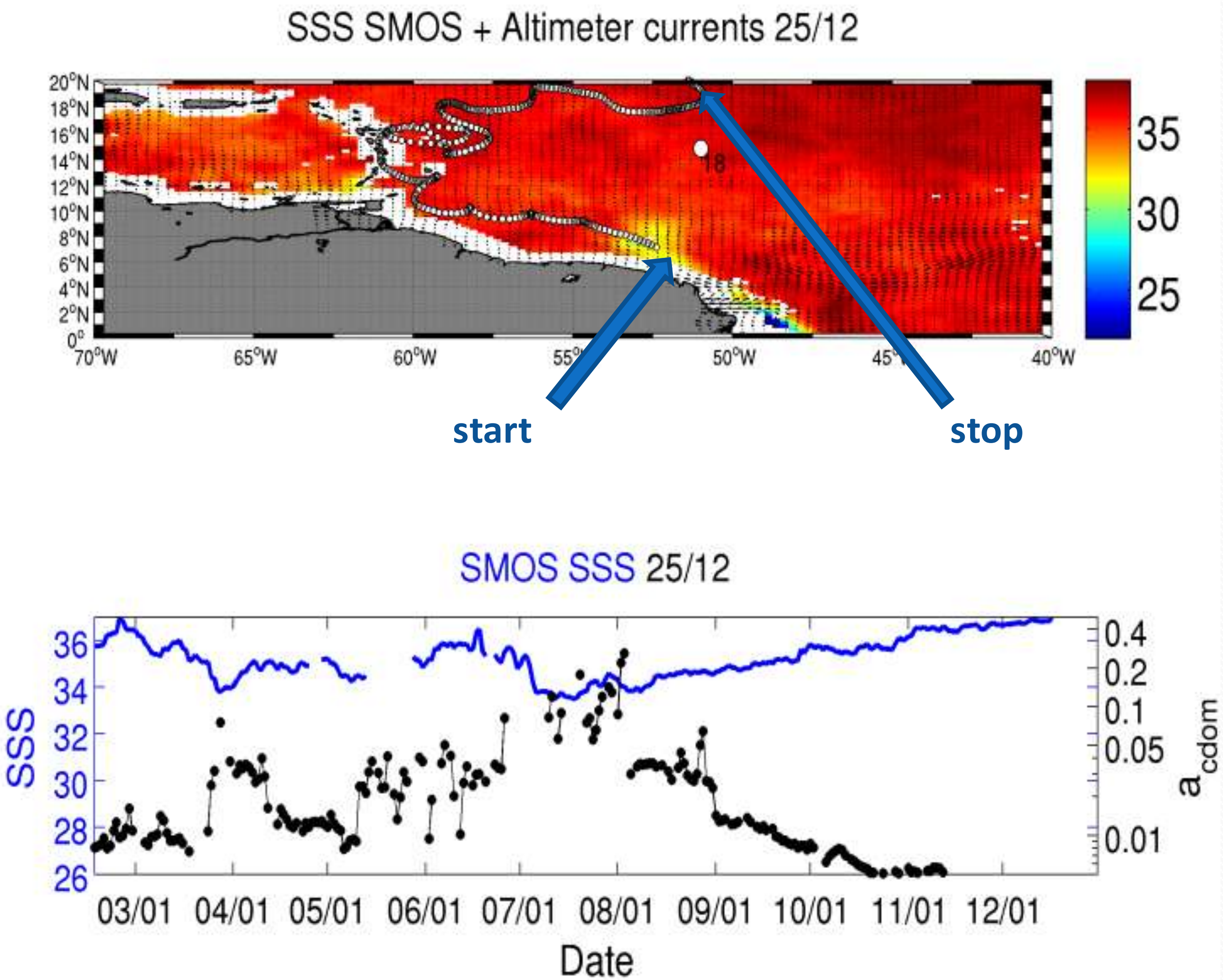
NorthWestward



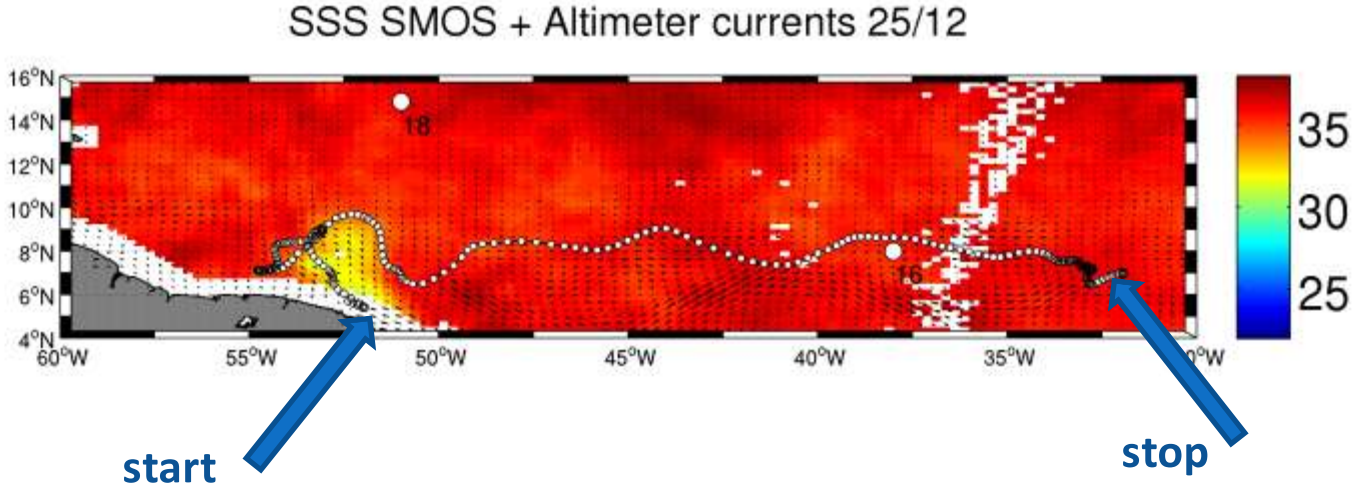
Eastward

Lagrangian transport

NorthWestward



Eastward


SSS SMOS + Altimeter currents 25/12
16°N
14°N
12°N
10°N
8°N
6°N
4°N
60°W
55°W
50°W
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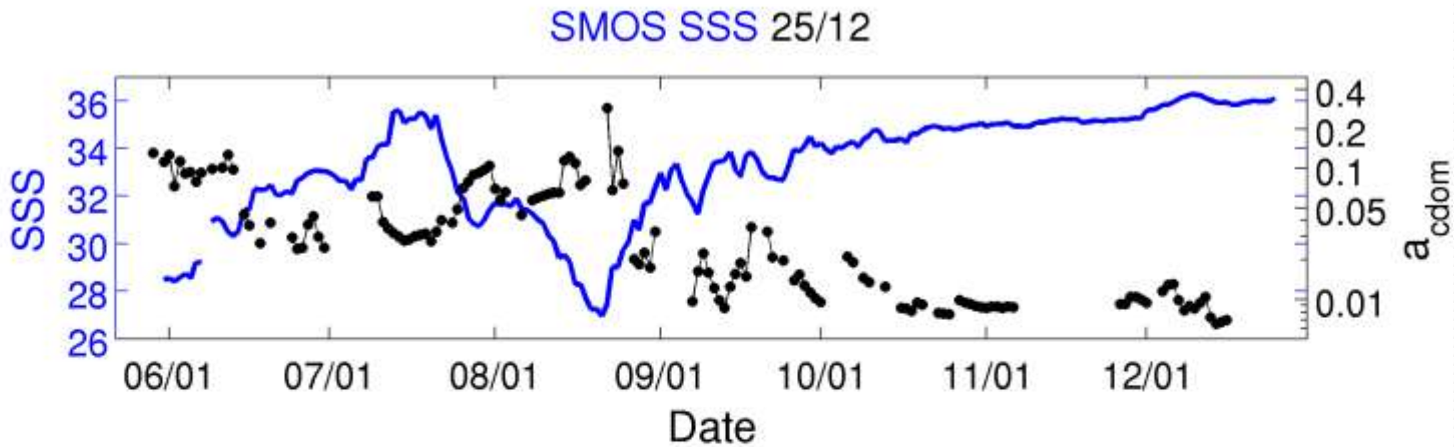
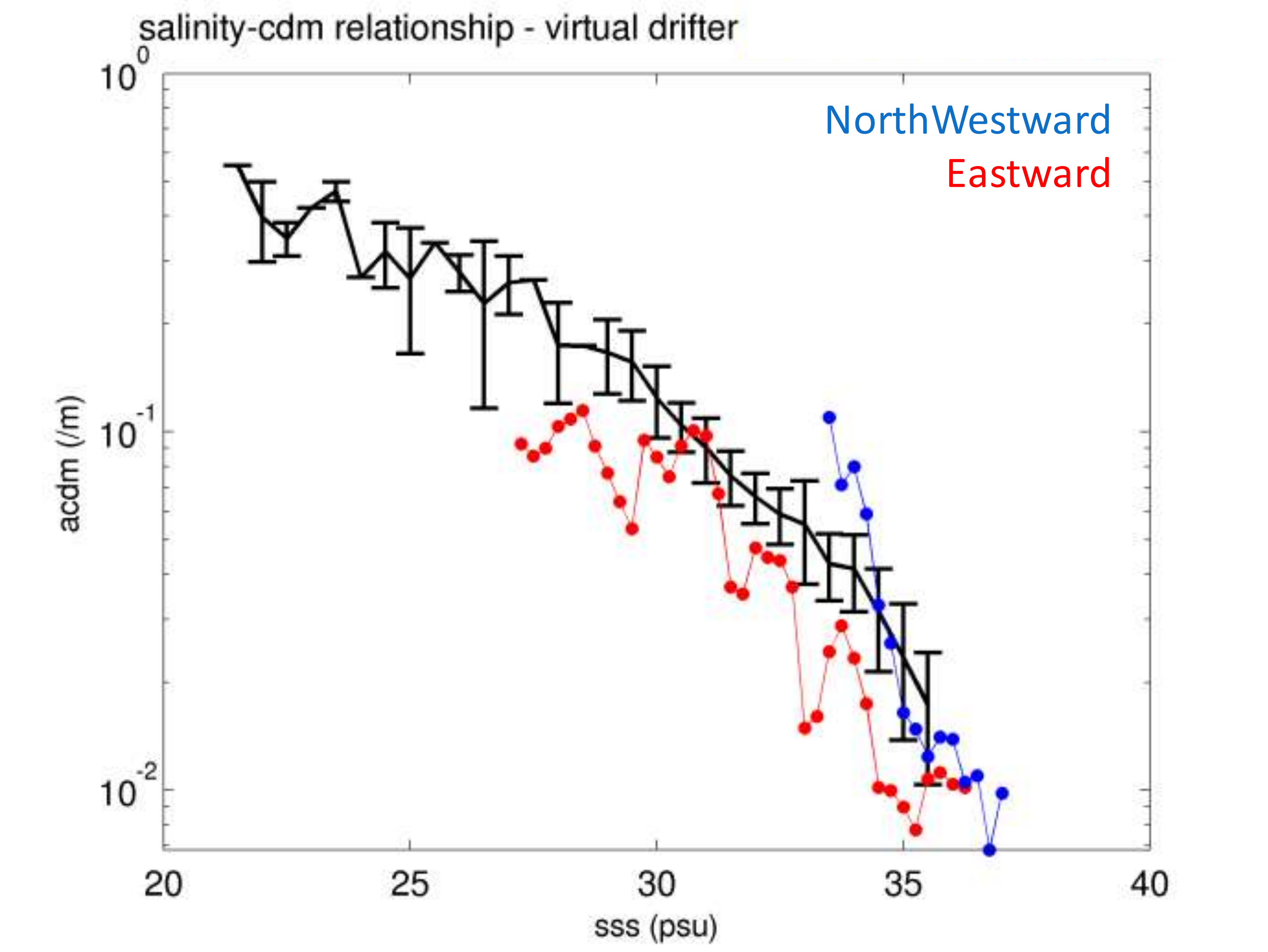
35
30
25
start
stop


SMOS SSS 25/12
SSS
36
34
32
30
28
26
0.4
0.2
0.1
0.05
0.01
a_{cdom}
06/01
07/01
08/01
09/01
10/01
11/01
12/01
Date

- CDM/SSS relationship variability along the 2 pathways



Consistent with seasonal cycle variability

Salt Transfer
Induced by Strong Ocean-Atmosphere Interactions under Tropical cyclones

Amazon and Orinoco River Plumes and NBC Rings: Bystanders or Participants in
Hurricane Events?

AMY FFIELD=> J CLIM 2007

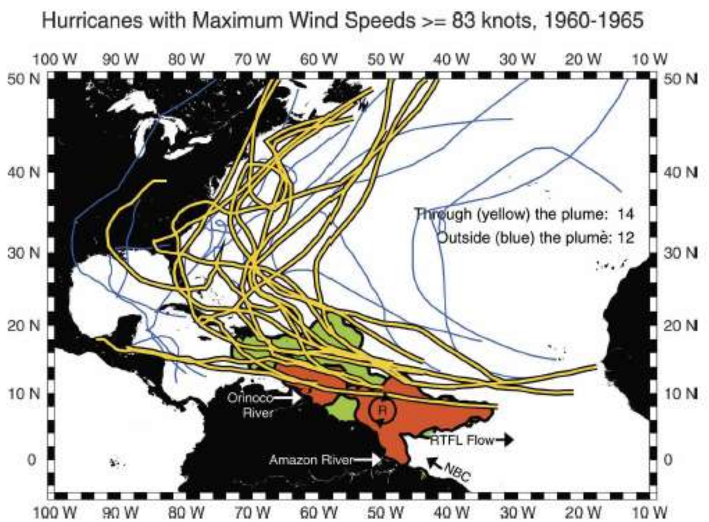


TABLE 1. The distribution of 1960–2000 hurricanes by location. With increasing category (hurricane strength), an increasing (decreasing) percentage of hurricanes pass through (outside) the plume region. For example, for category 5 hurricanes, 68% passed through the plume region, while only 32% passed outside the plume region.

Hurricanes	Through plume		Outside plume		All hurricanes
1960–2000	No.	No./total	No.	No./total	Total
Category 1	17	17%	84	83%	101
Category 2	13	29%	32	71%	45
Category 3	18	45%	22	55%	40
Category 4	18	60%	12	40%	30
Category 5	13	68%	6	32%	19

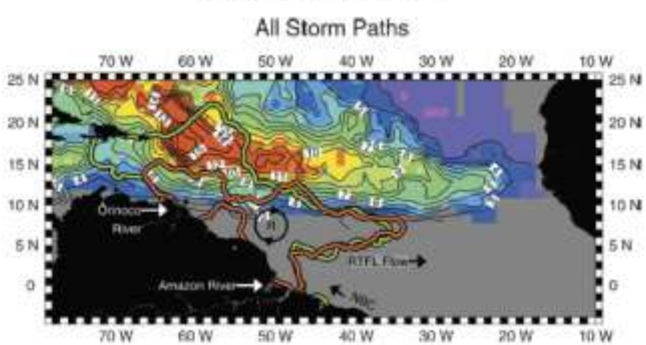


FIG. 3. The number of 1950 through 2003 "best track" tropical storms and hurricanes per one degree square (smoothed by a 3° × 3° block average). The tropical cyclones initially travel westward.

Surface area~ 89000 km²> Lake Superior, the world largest freshwater lake: a transfer of 1 GTo of Salt in 5 days

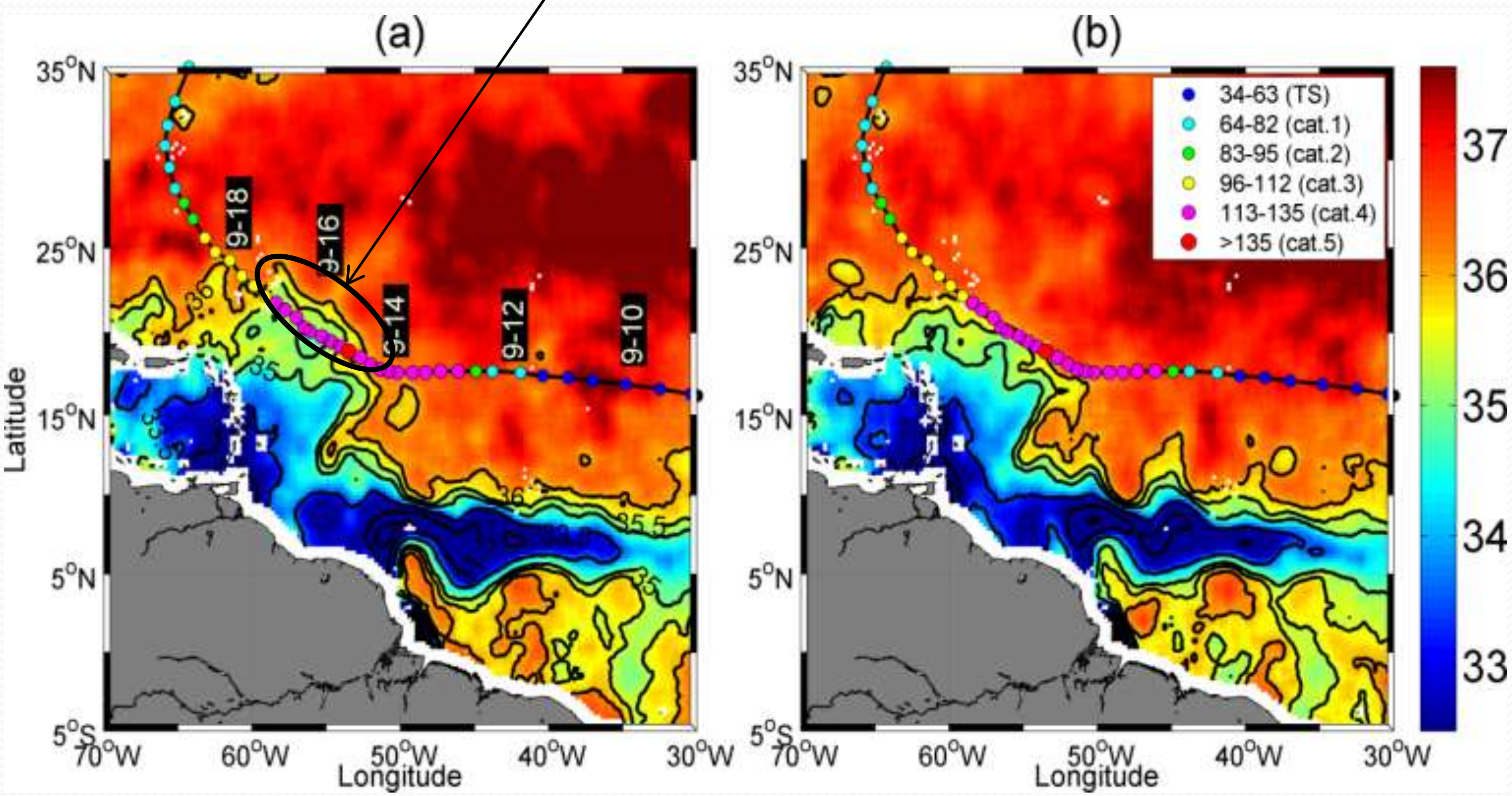
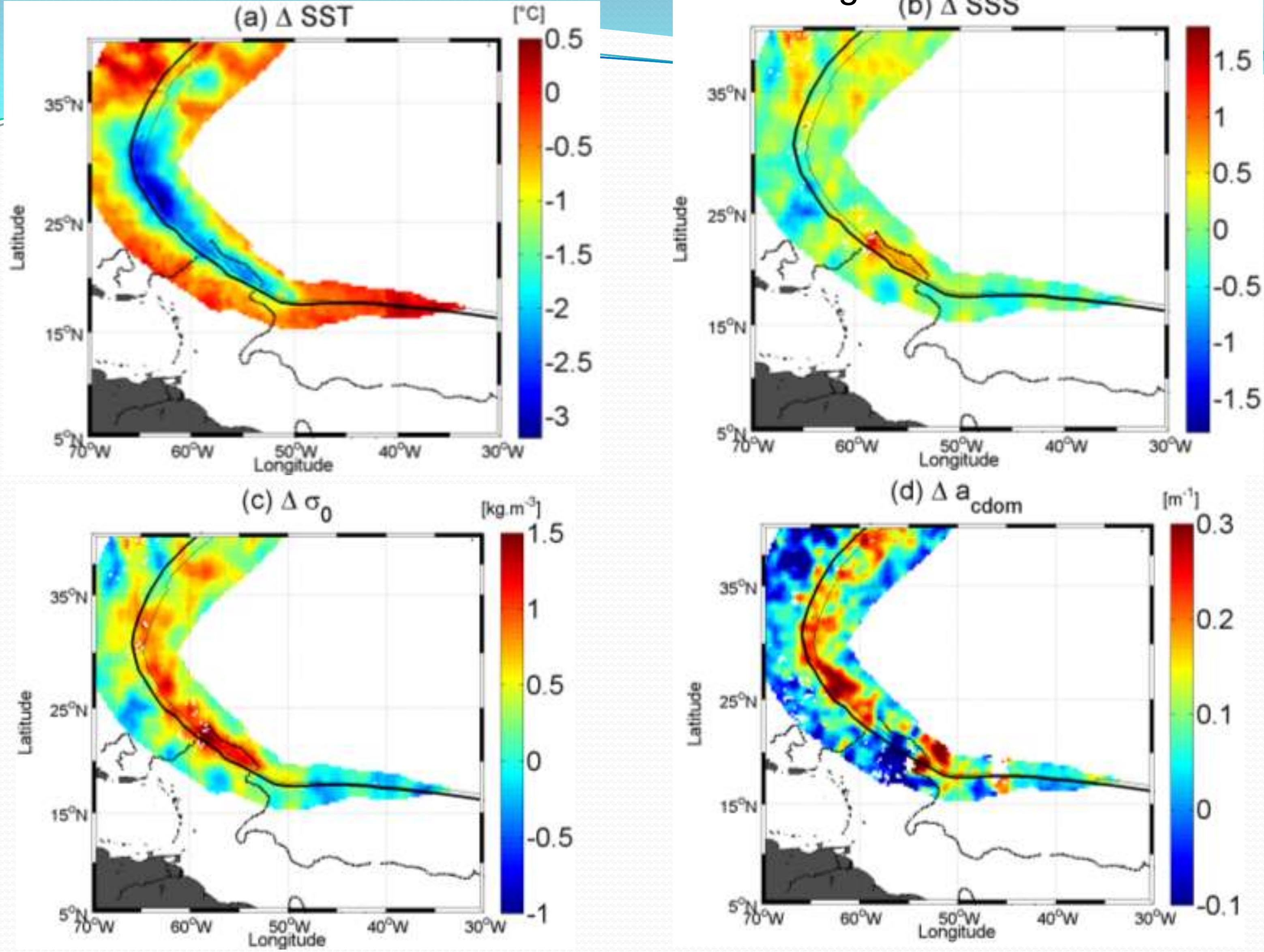


Figure 2: Two SMOS microwave satellite-derived SSS composite images of the Amazon plume region revealing the SSS conditions (a) before and (b) after the passing of Hurricane Igor, a category 5 hurricane that attained wind speeds of 136 knots in September 2010. Color-coded circles mark the successive hurricane eye positions and maximum 1-min sustained wind speed values in knots.
Seven days of data centered on (a) 10 Sep 2010 and (b) 22 Sep 2010 have been averaged to construct the SSS images, which are smoothed by a 1° x 1° block average.

Reul et al=> in preparation J CLIM 2012

Surface wakes of Igor



Six days of data centered on t_o–(+) 4 days have been averaged to construct the pre (post)-cyclonic quantities.

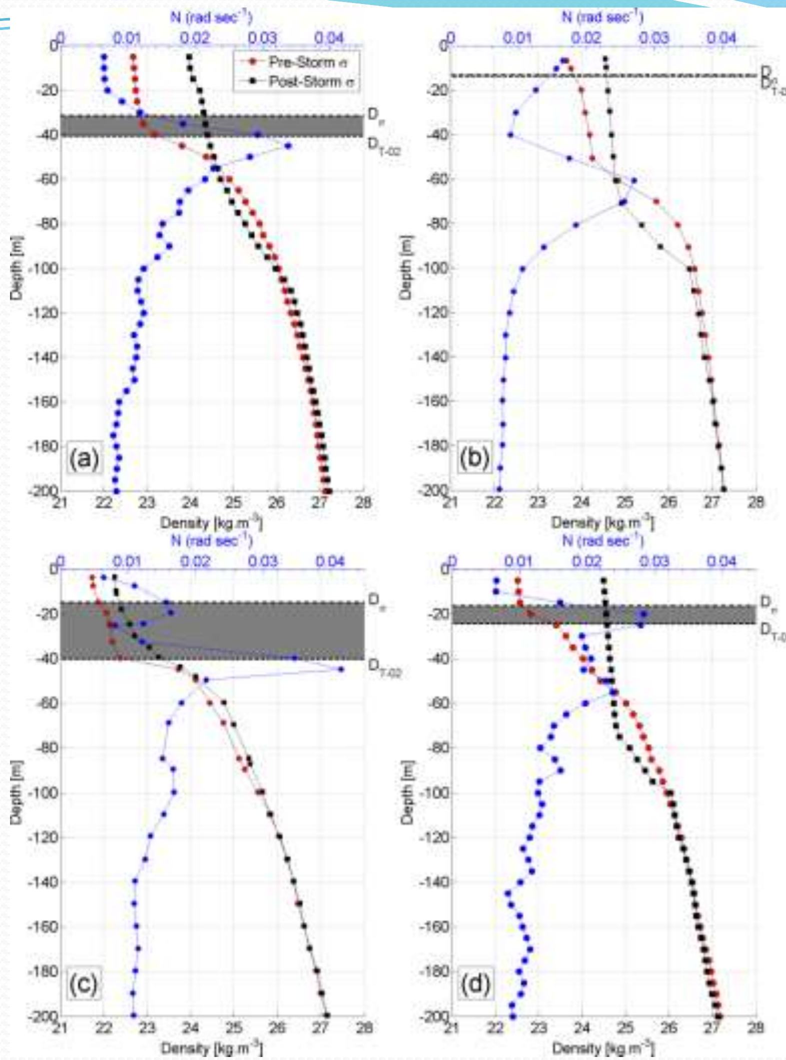
Here
$a_{cdom} = a_d + ag$

ag: CDOM (dissolved matter)

ad: non living particulate organic material, bacteria, inorganic material and bubbles

Figure 4: Surface wakes of Hurricane Igor. Post minus Pre-hurricane (a) Sea Surface Temperature (ΔSST) (b) Sea surface Salinity (ΔSSS), (c) Sea Surface Density ($\Delta\sigma_o$) and (d) Sea Surface CDOM absorption coefficient .The thick and thin curves are showing the hurricane eye track and the locii of maximum winds, respectively. The dotted lines is showing the pre-hurricane plume extent.
ΔSST, ΔSSS, $\Delta\sigma_o$ wakes were only evaluated at spatial locations around the eye track for which the wind exceeded 34 knots during the passing of the hurricane.

Observed ocean stratification differences



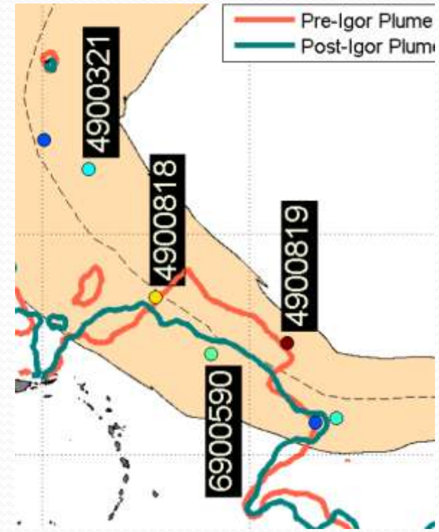
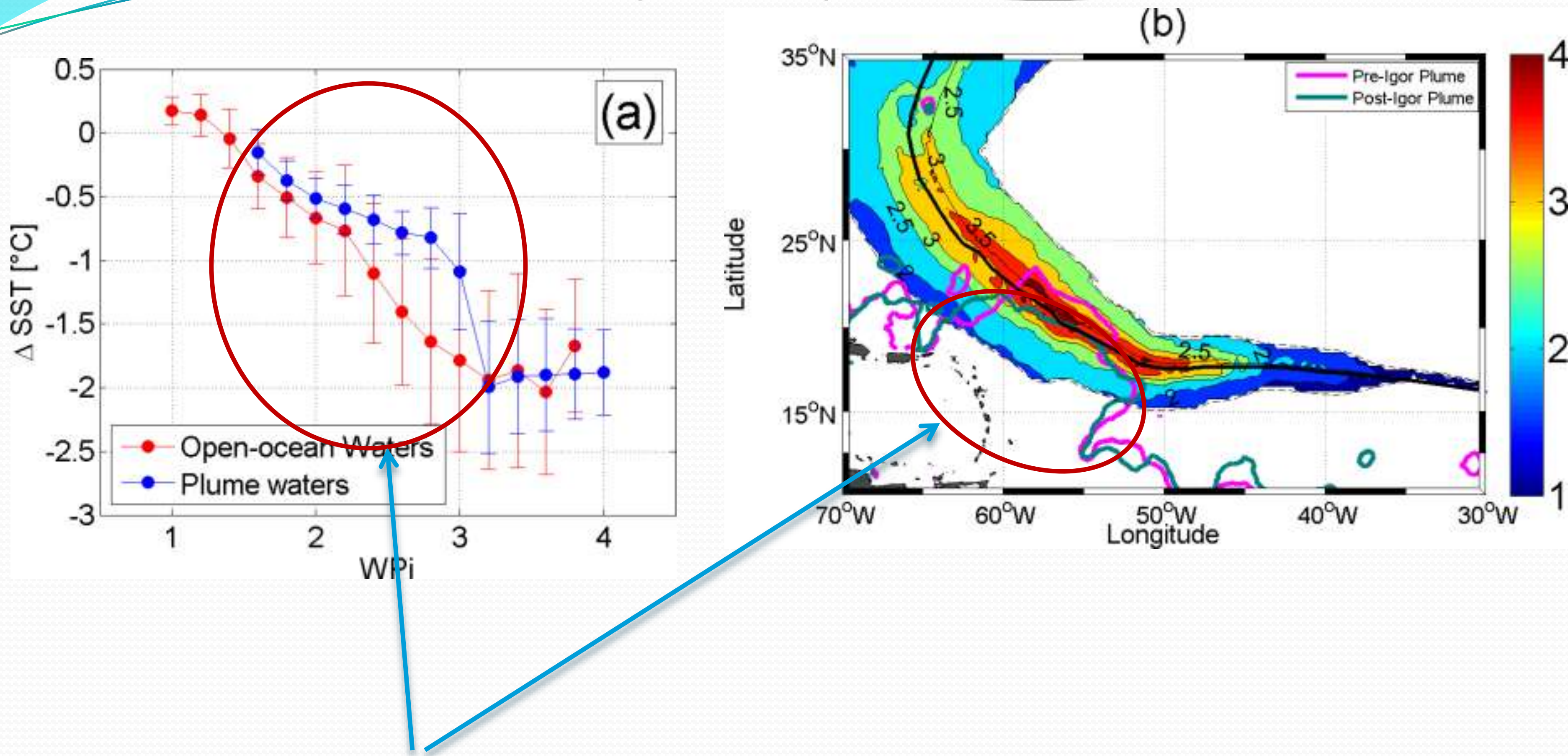


Figure 11: Vertical Profiles of Density measured before the storm (red circles) and after the storm (black squares) at four ARGO floats with WMO # (a) 4900818, (b) 4900321, (c) 6900590 and (d) 4900819. For each Argo float, the pre-storm stratification represented by the Brunt-Vaisala frequency N(z) is illustrated by the blue dotted curves. The depths D_σ and D_{T-02} of the pre-storm mixed layer (depth where $\sigma(z=0)-\sigma(z=10m) > \Delta\sigma$ equivalent to 0.2 degC decrease in T at salinity=S(z=10m) are indicated by horizontal dashed lines. The thickness of the pre-storm barrier layer is defined as $D_{T-02}-D_\sigma$ and is indicated by the gray shaded area.

Evidence of reduced cooling over the plume on the TC left-hand side



The Plume ssts with Wpi < 3 are dominantly located on the left-hand side of the Storm. So for an equivalent Wpi value there is a clear reduced cooling on the Left hand side of the plume compared to open-ocean waters

=> Good demonstration of the cooling inhibition by pre-storm ocean stratification

The Eastern Equatorial Atlantic freshwater Pools

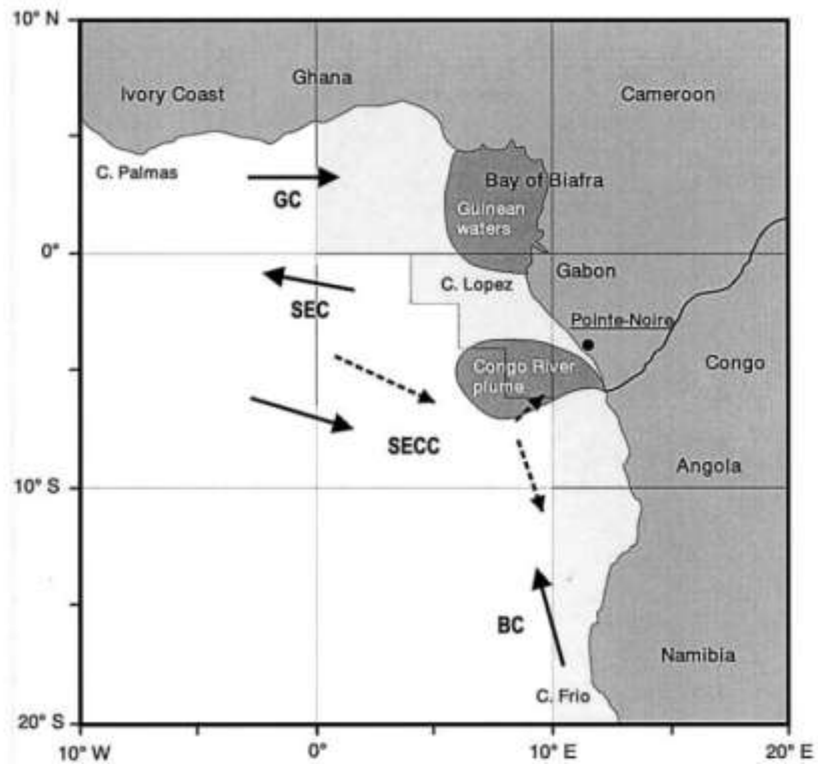
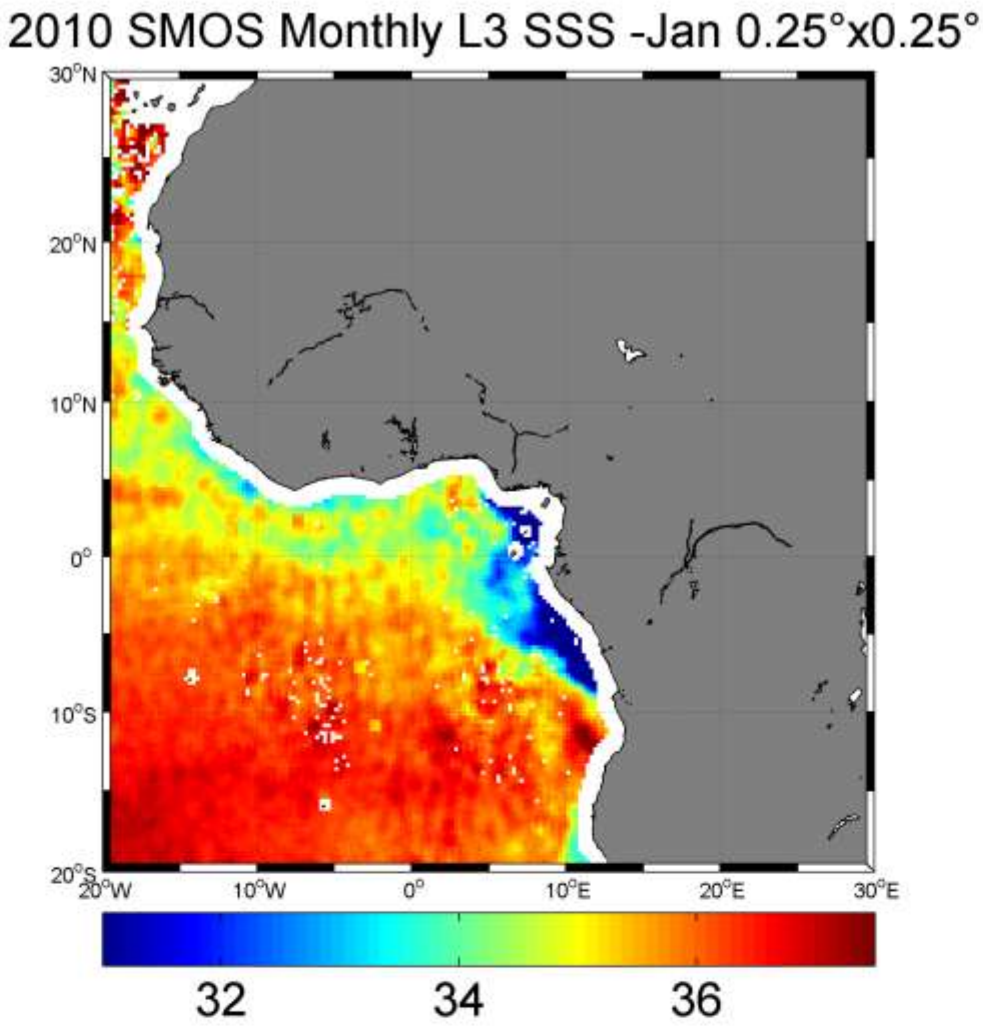
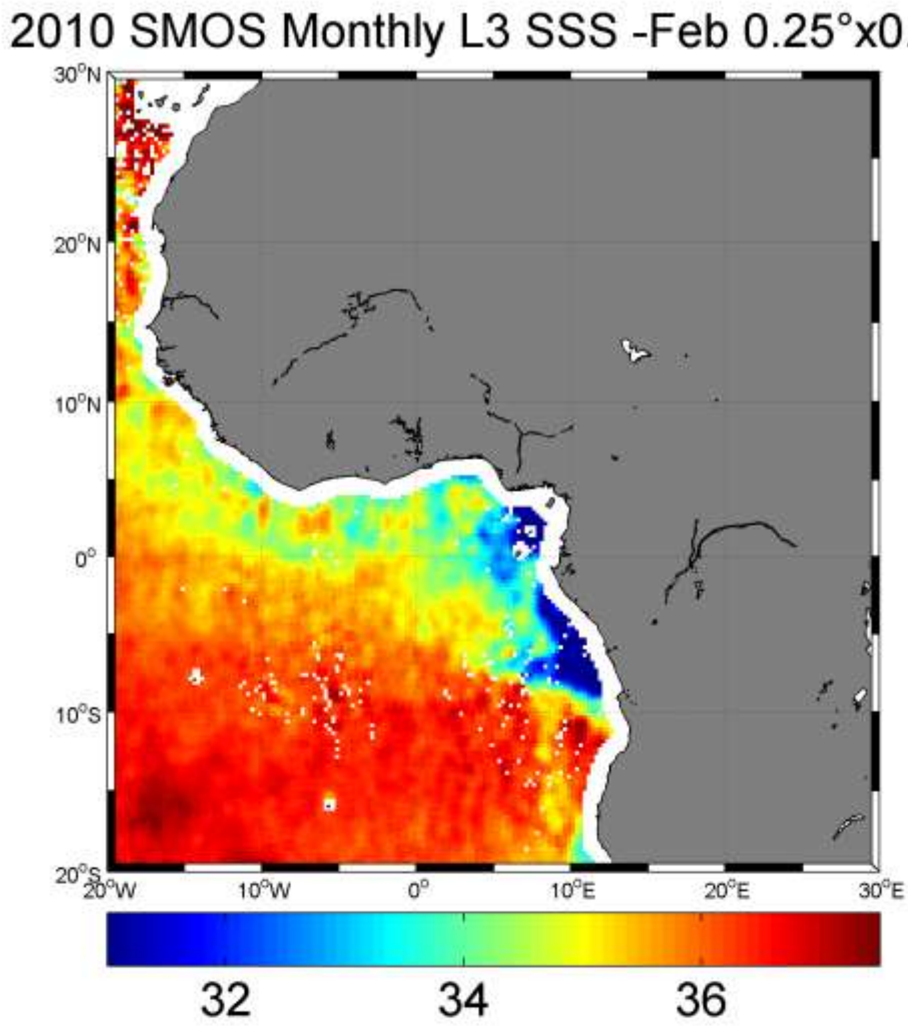


Figure 1. Map of the Gulf of Guinea and Southeast Atlantic Ocean indicating the three areas (light shadow) from which the sea surface temperatures are averaged: 'Guinea' (0°–6°N, 0°–10°E), 'Gabon–Angola' (0°–10°S) and 'Benguela' (10°–20°S). Dark shadowed areas: fresh water pools of Guinean water and the Congo River plume. GC: Guinea current, SEC: south equatorial current, SECC: south equatorial counter current in normal years (full line) and during warm events (broken line), BC: Benguela current.

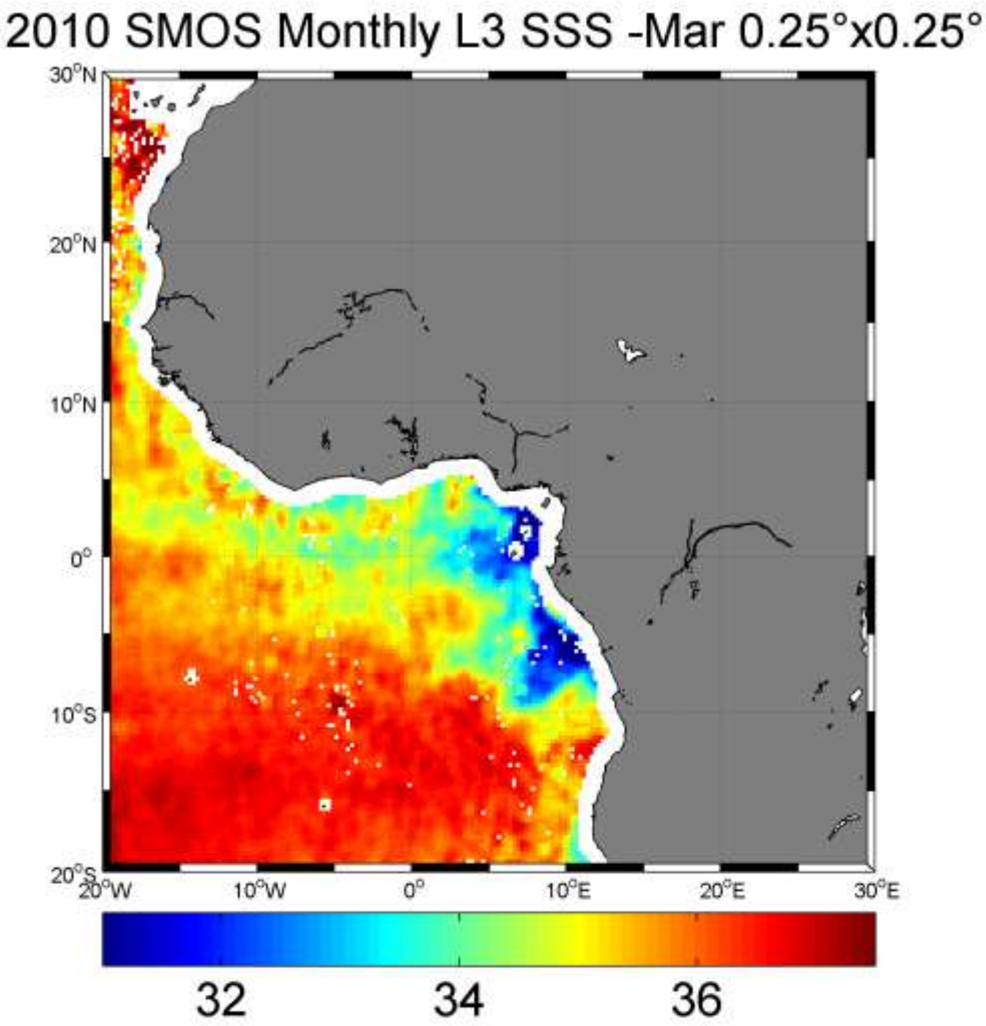
Congo Plume Seasonal Cycle



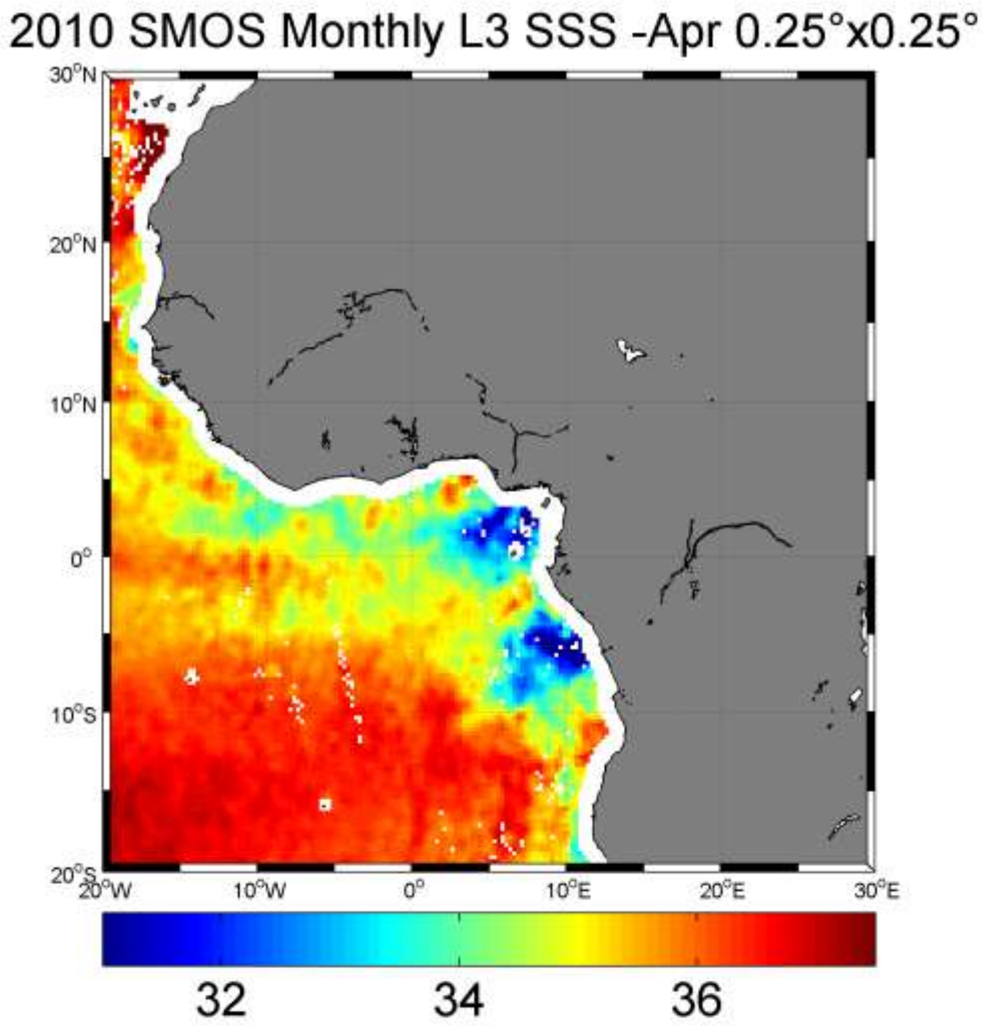
Congo Plume Seasonal Cycle



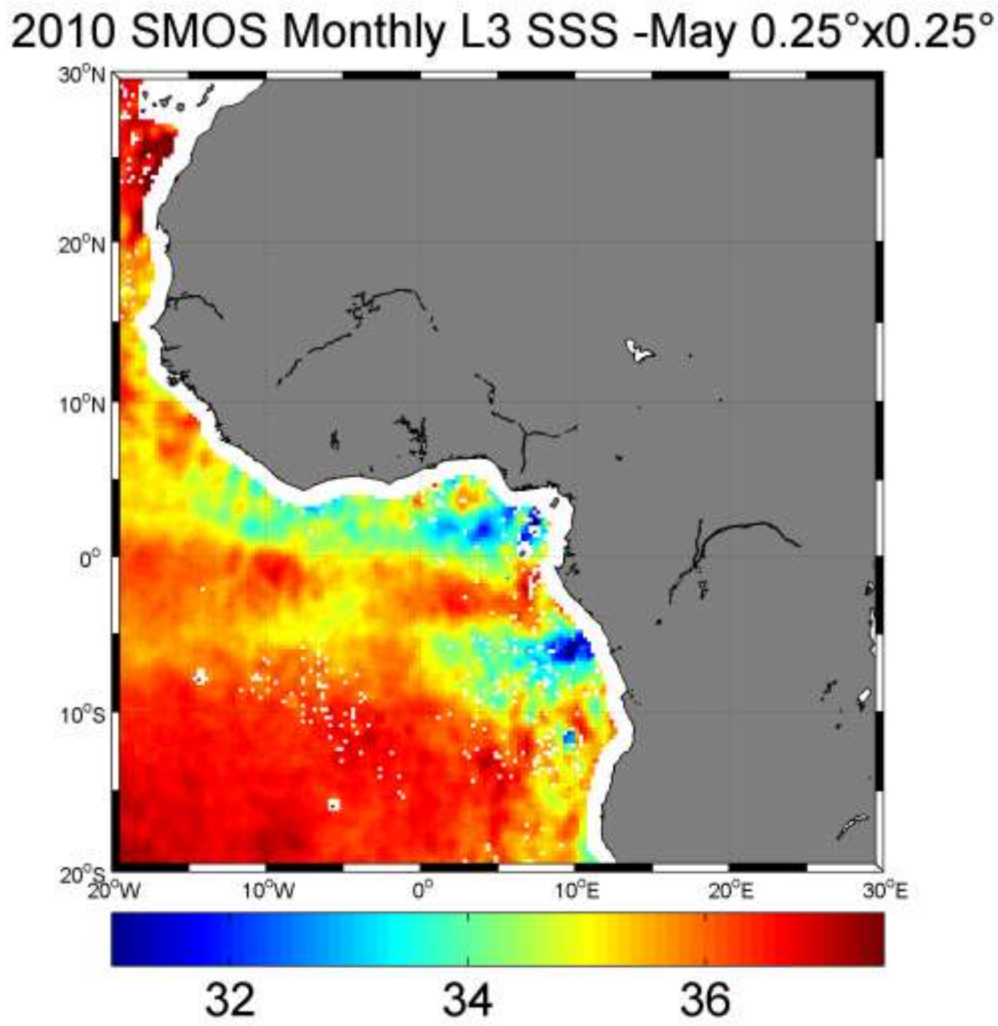
Congo Plume Seasonal Cycle



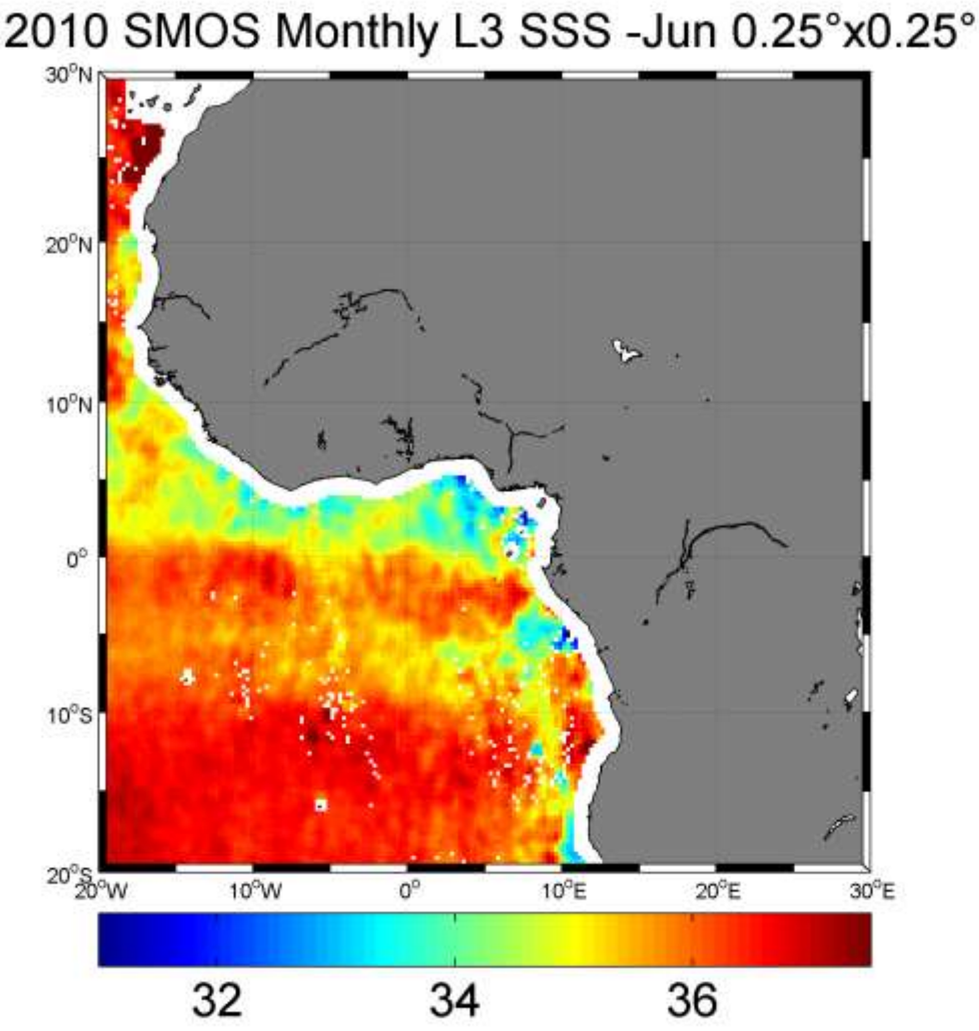
Congo Plume Seasonal Cycle



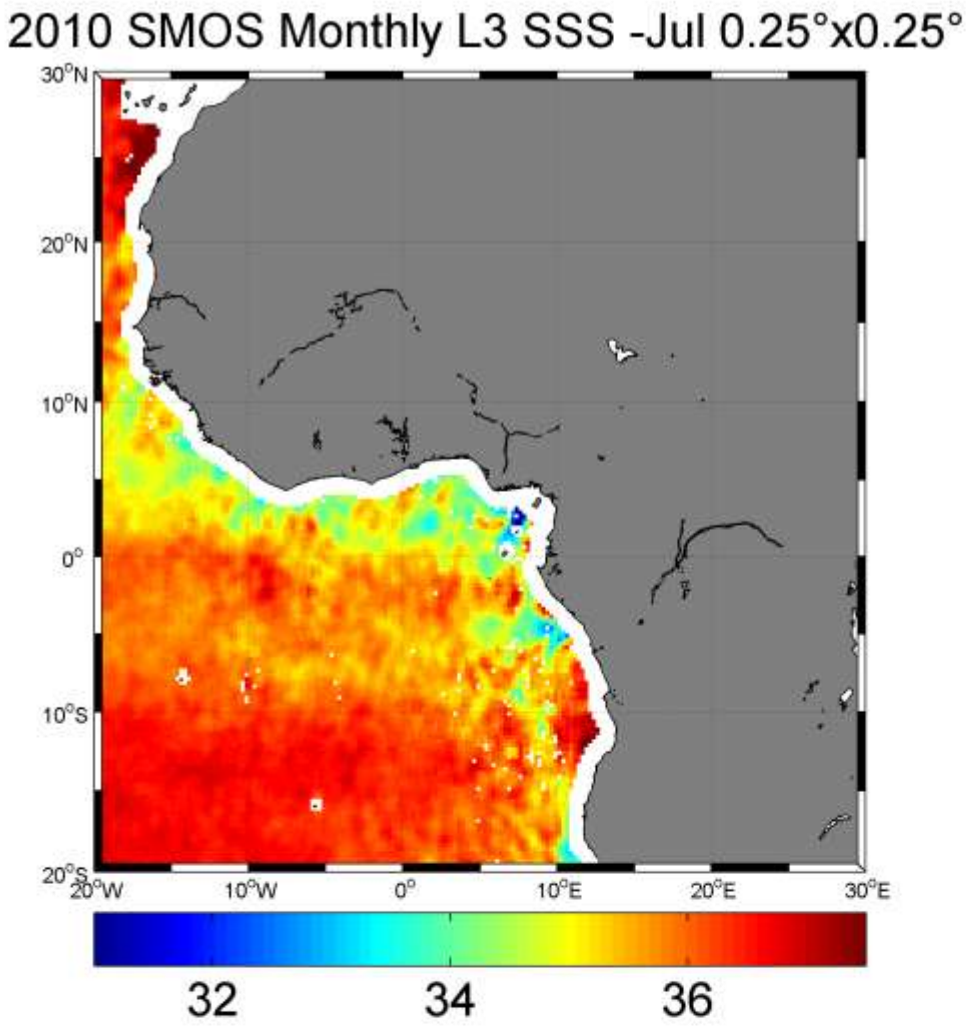
Congo Plume Seasonal Cycle



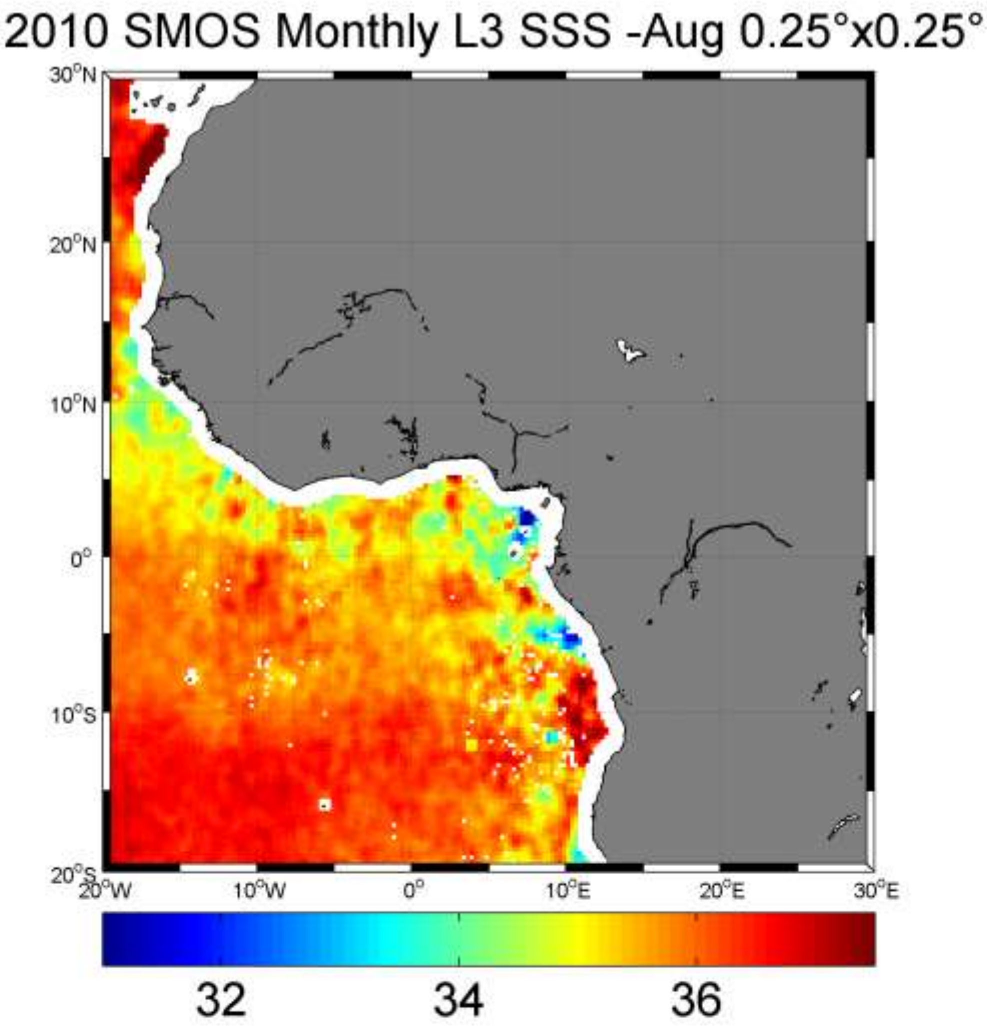
Congo Plume Seasonal Cycle



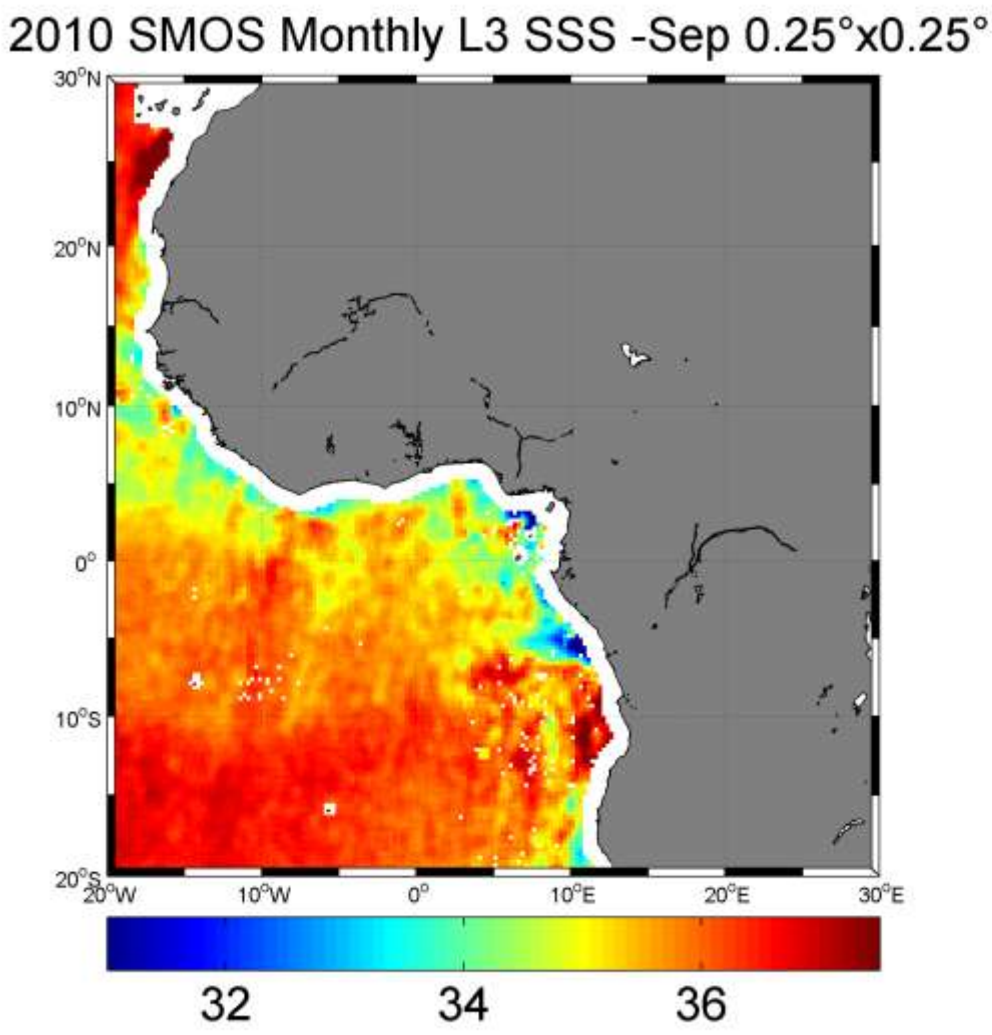
Congo Plume Seasonal Cycle



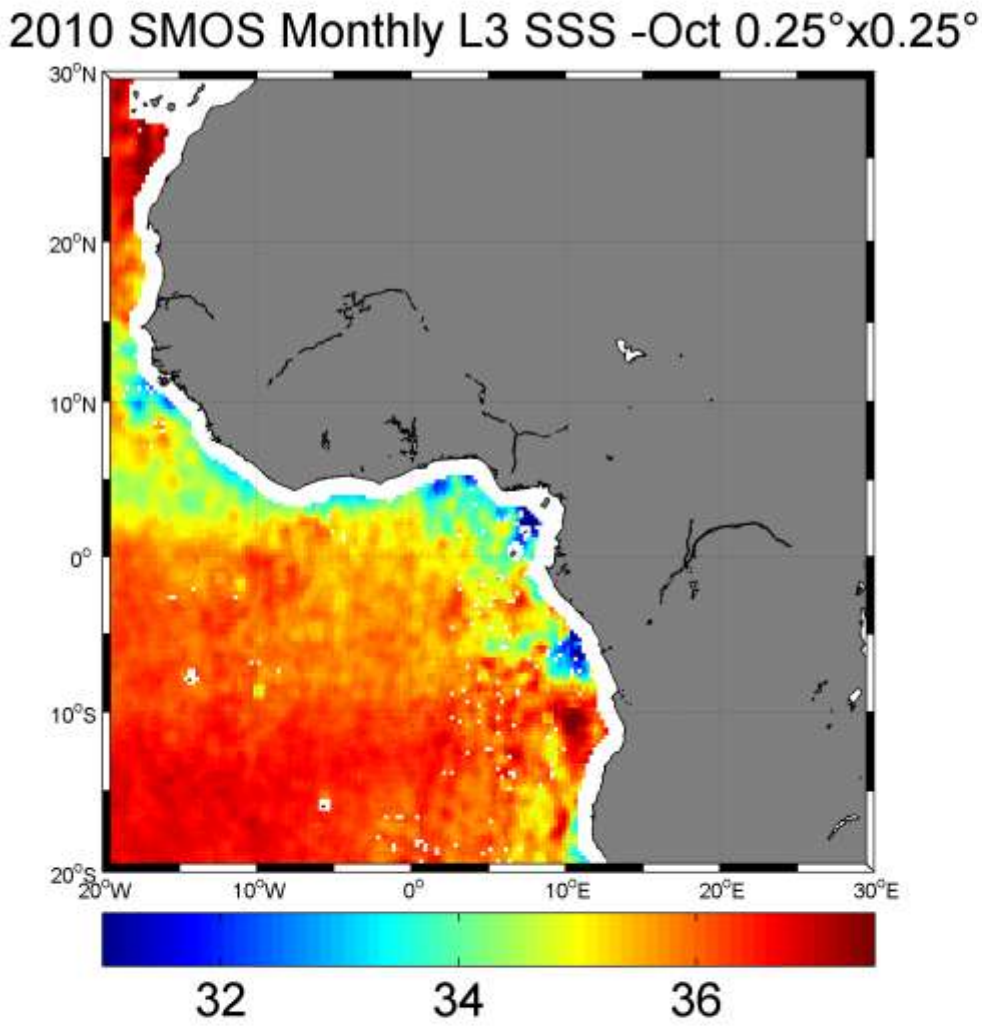
Congo Plume Seasonal Cycle



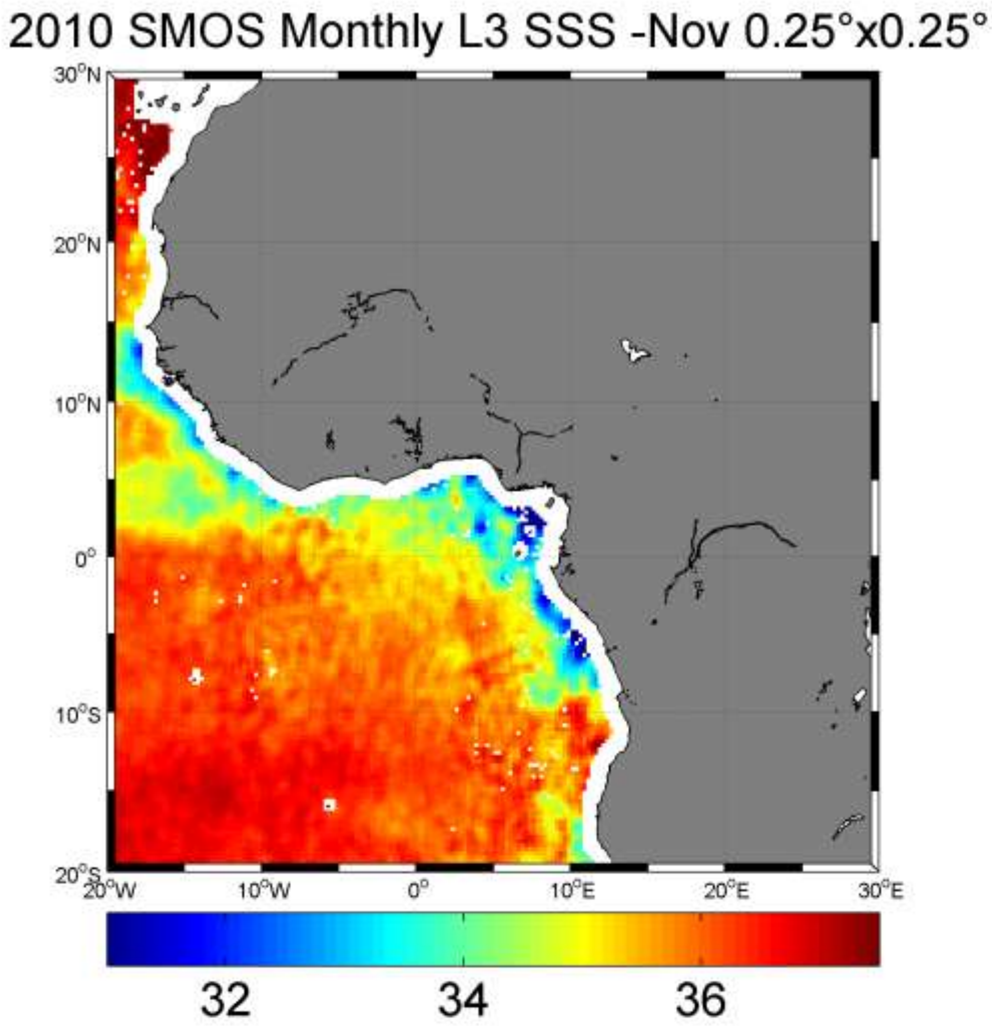
Congo Plume Seasonal Cycle



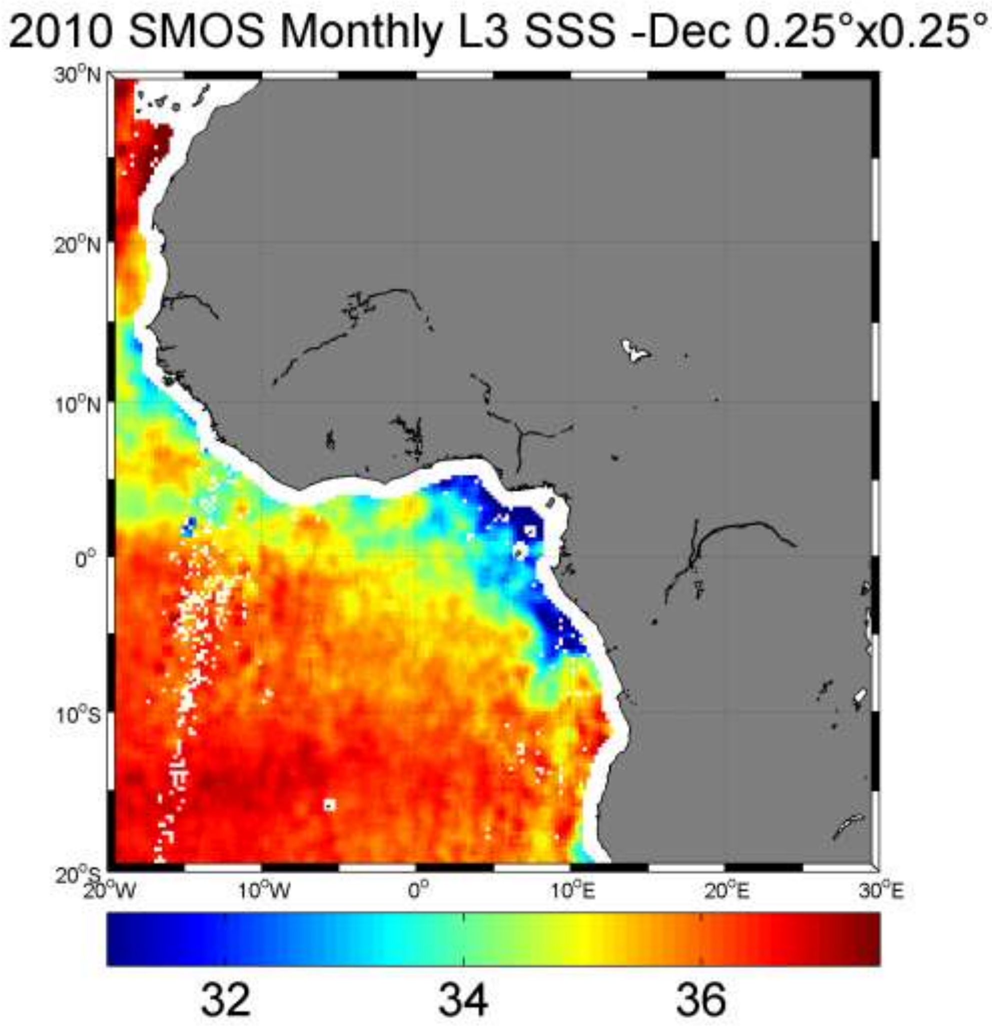
Congo Plume Seasonal Cycle



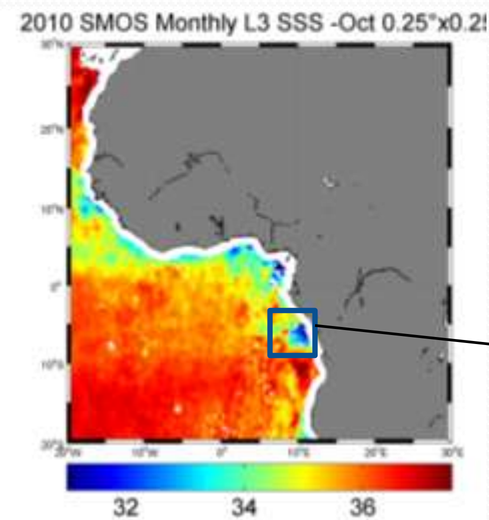
Congo Plume Seasonal Cycle

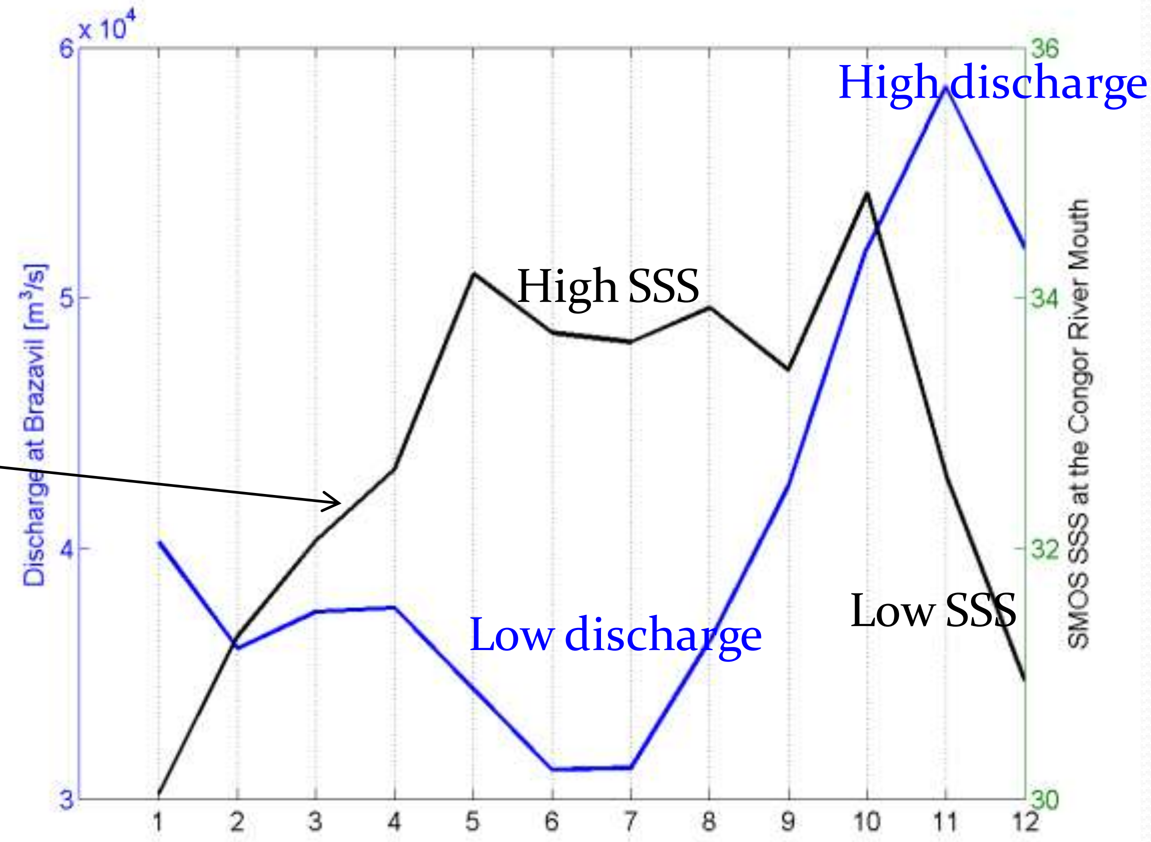


Congo Plume Seasonal Cycle

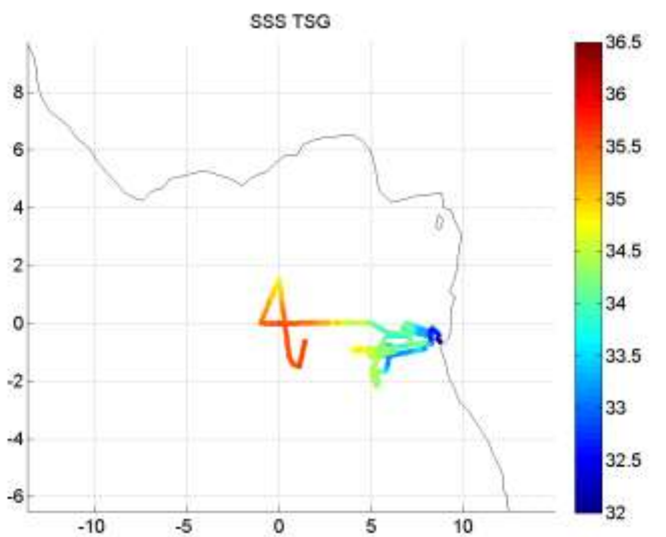


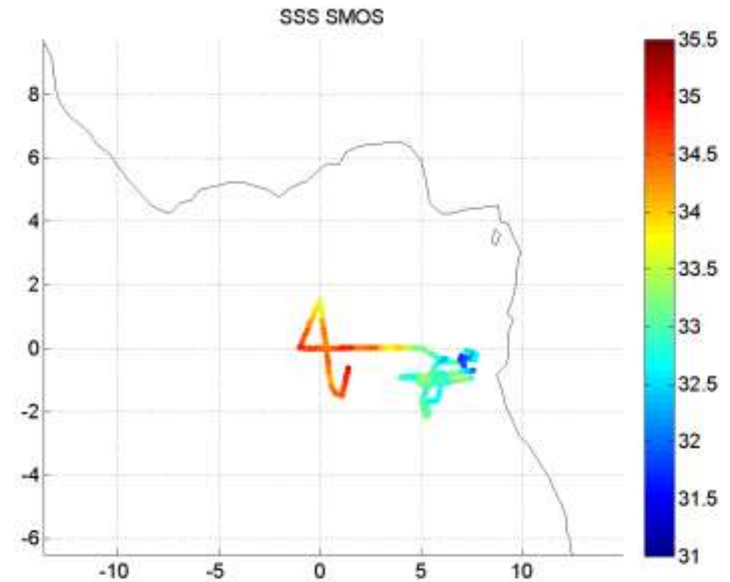
Correlation SSS at the mouth with River Discharge at Brazaville

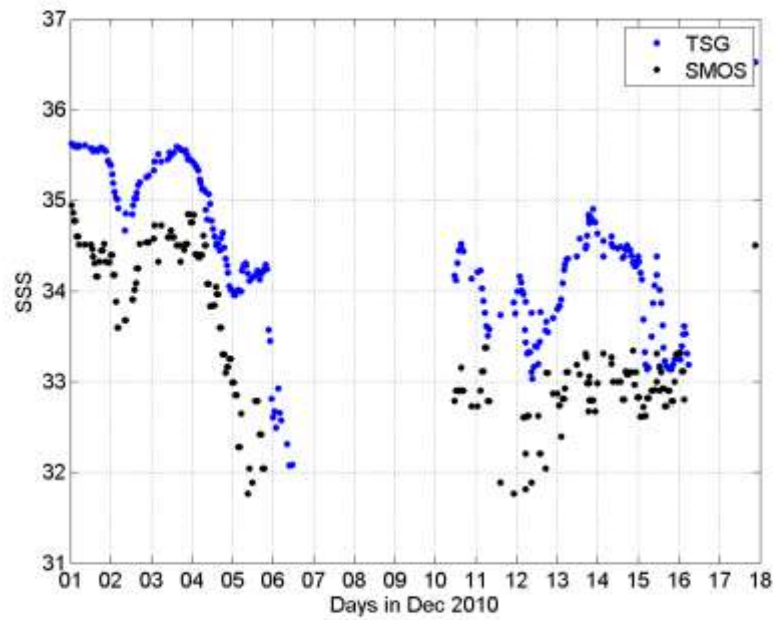


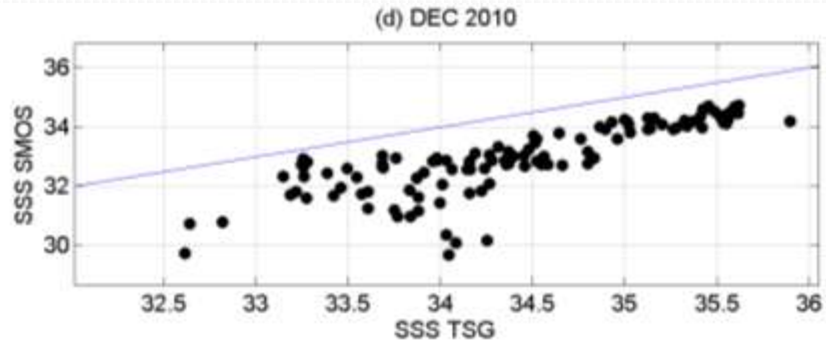


1 pss Bias: 5 m depth TSG versus SMOS surface ?

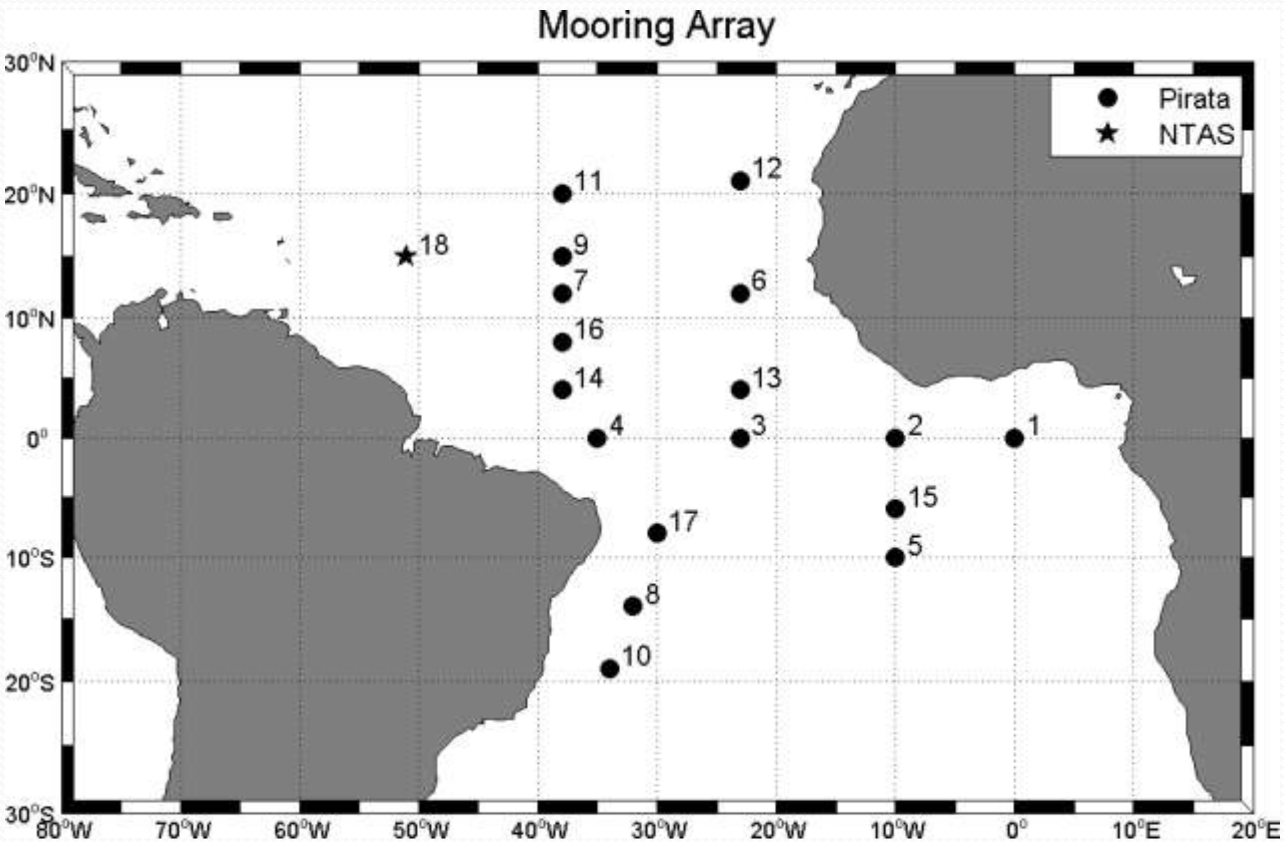








Comparison with Pirata Mooring time series



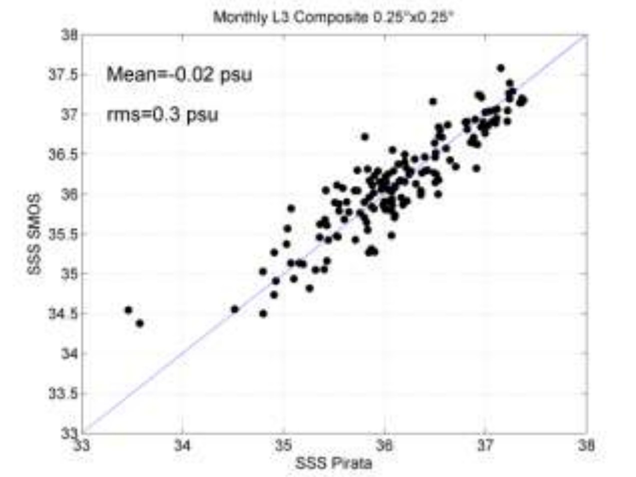
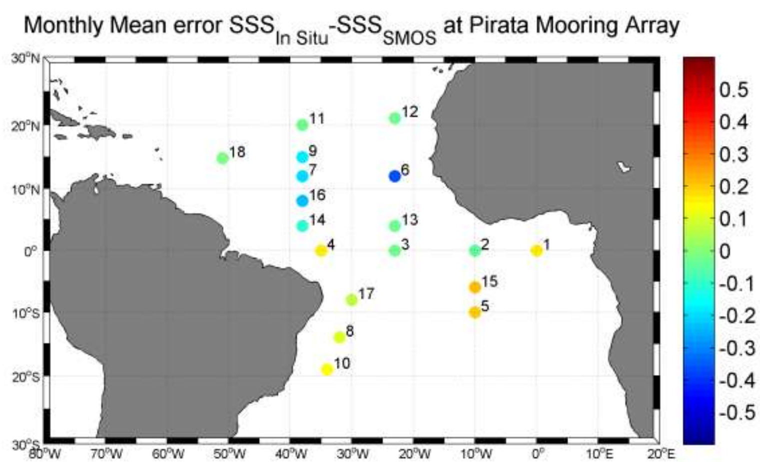
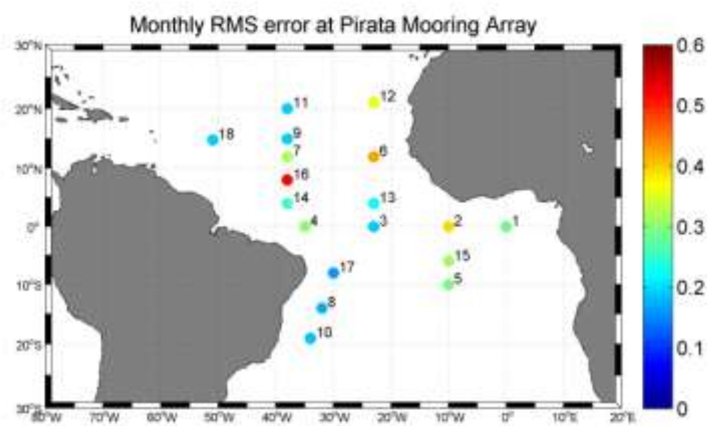
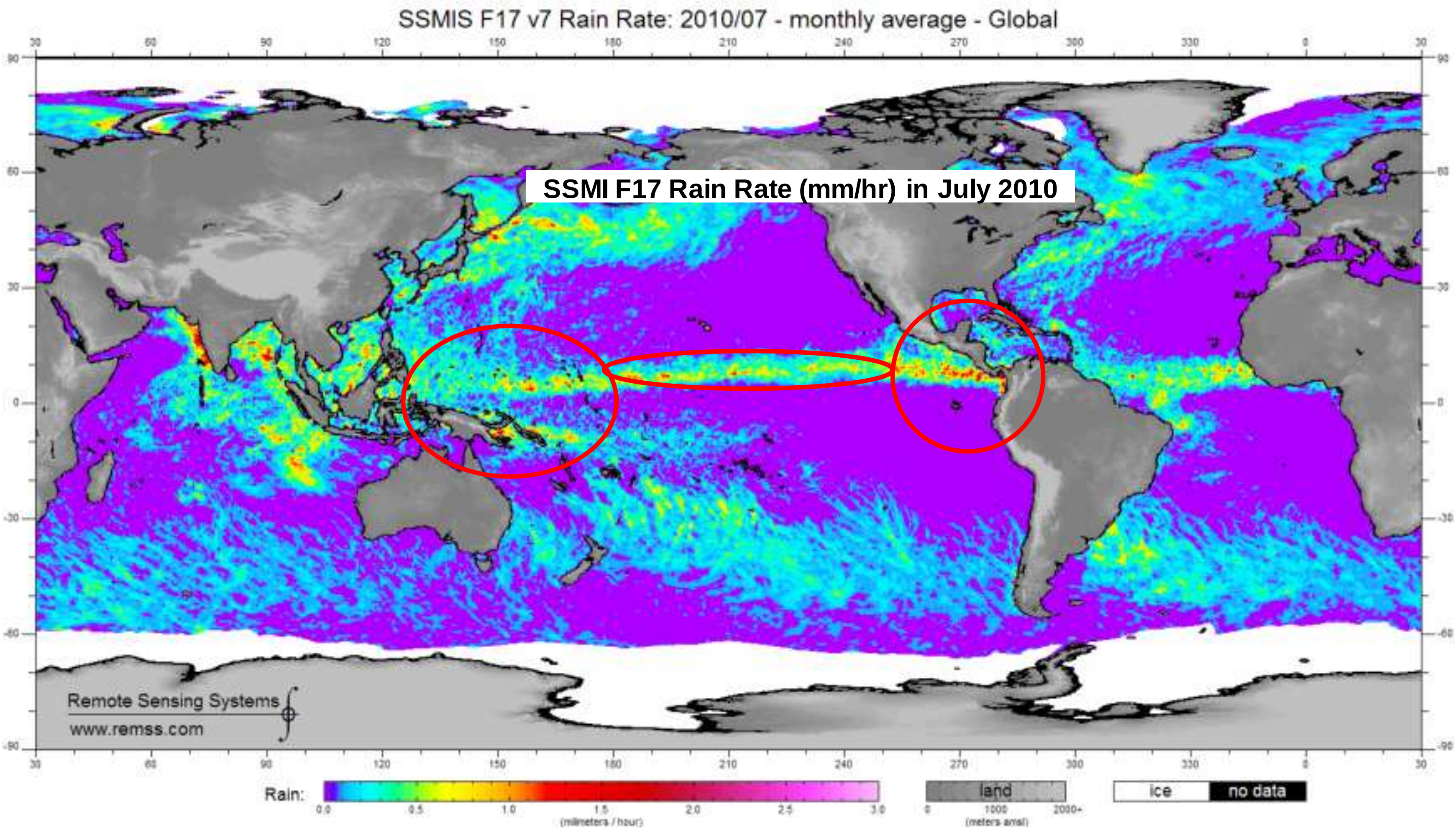


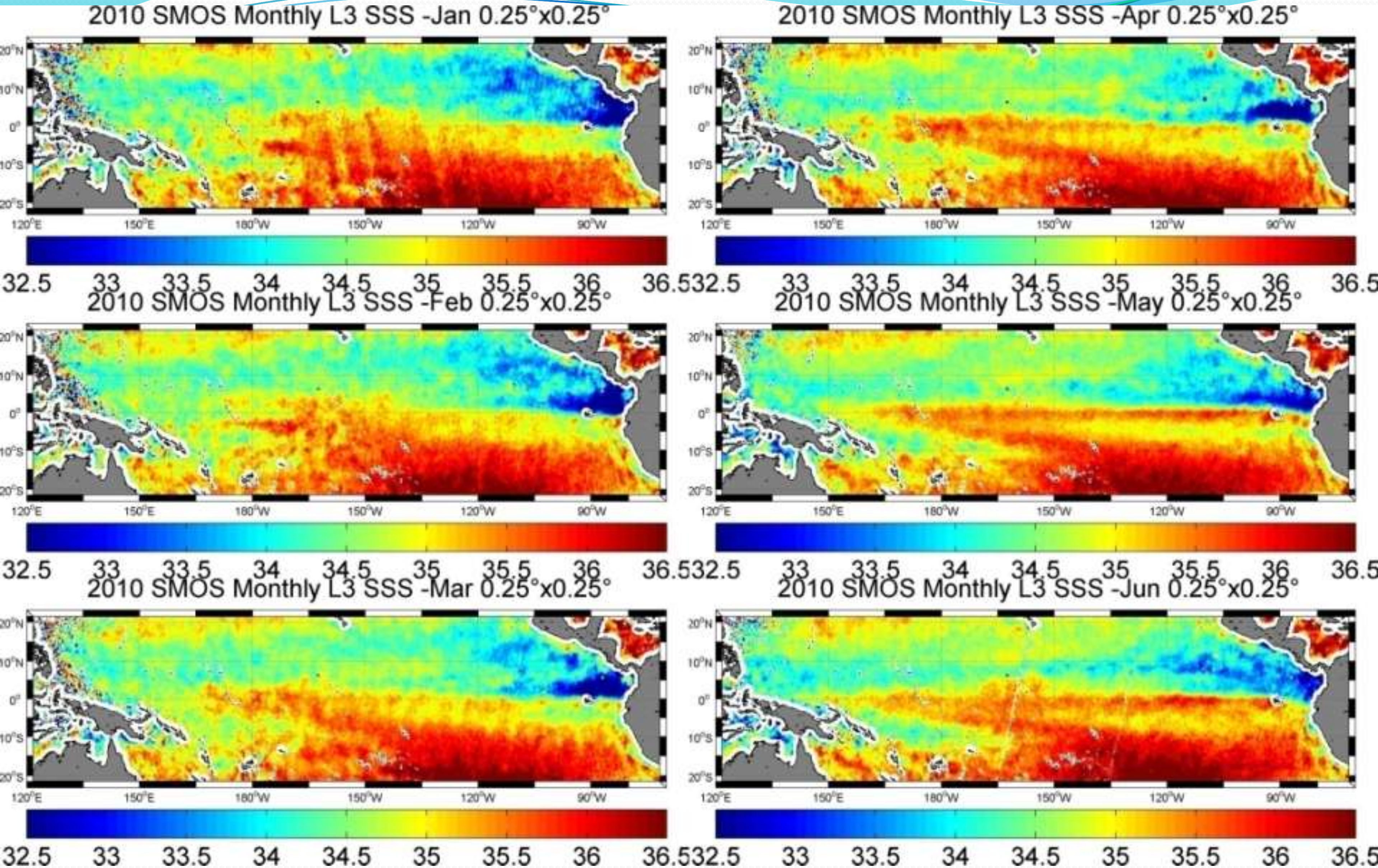
Figure 14: Monthly SSS of the SMOS L3 composite at 0.25°x0.25° as function of Pirata monthly averaged SSS data at 1 m depth. The data for all the eighteen pirata moorings and all months of year 2010 are combined together.

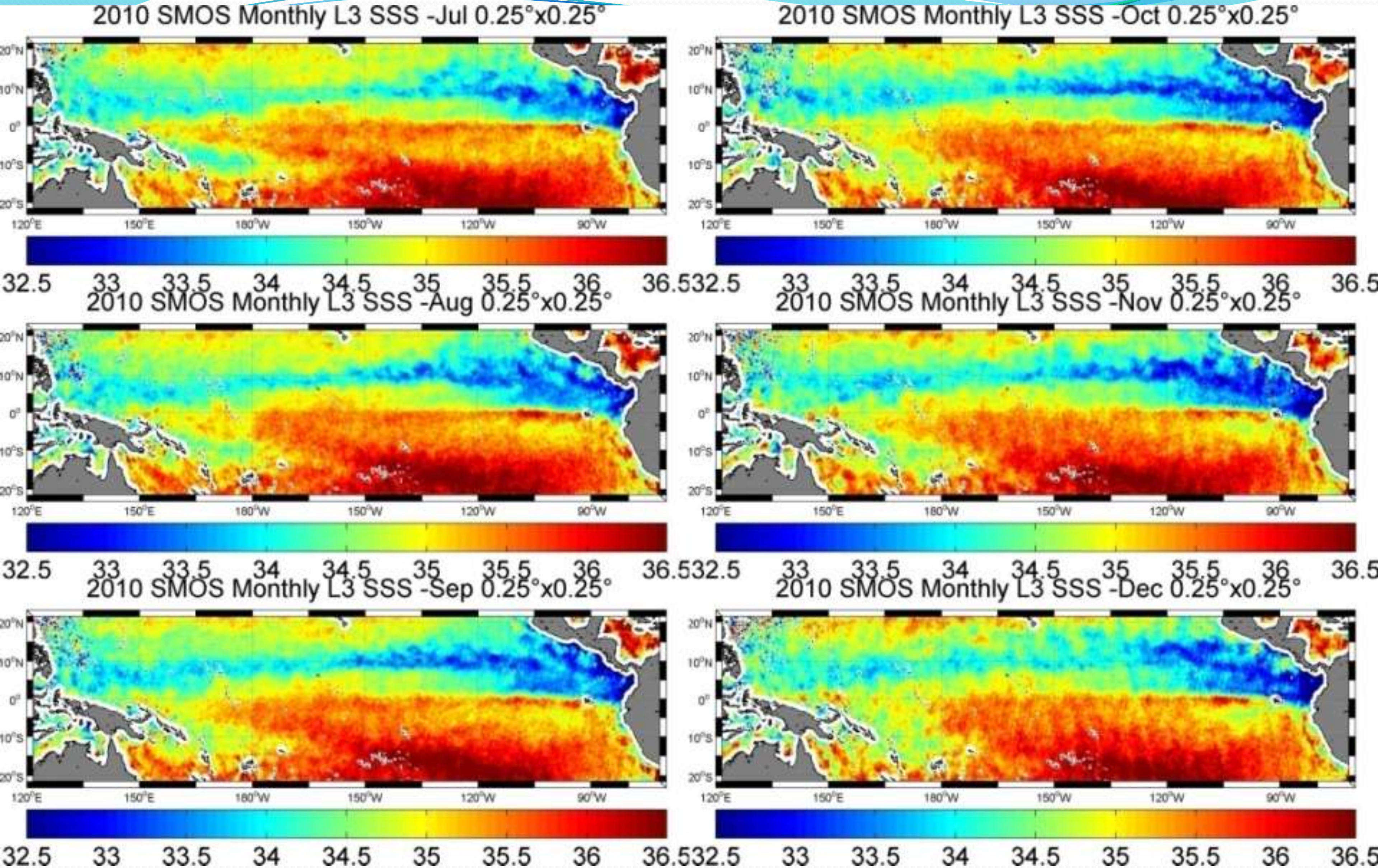


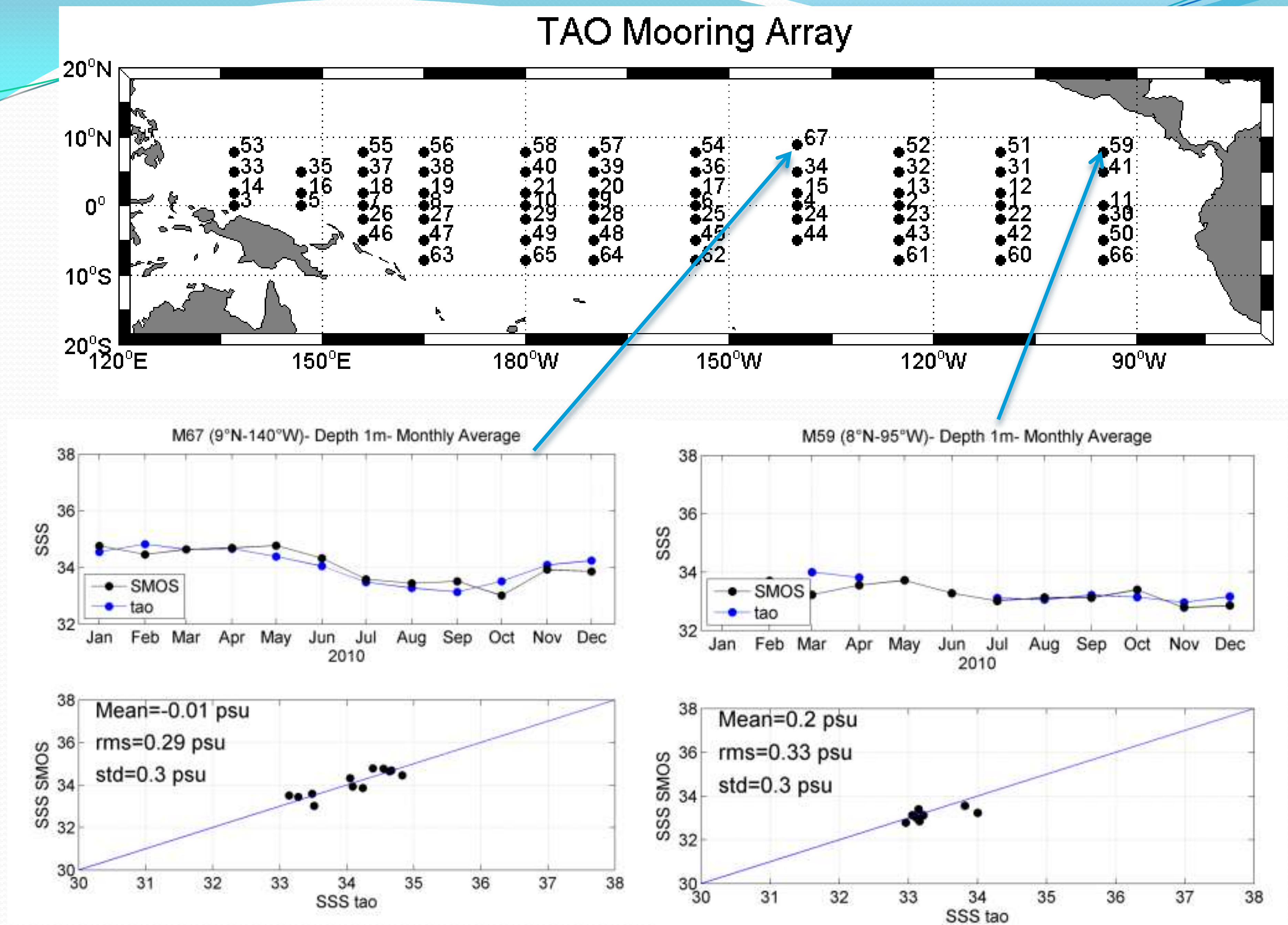


TheTropical Pacific freshwater Pools



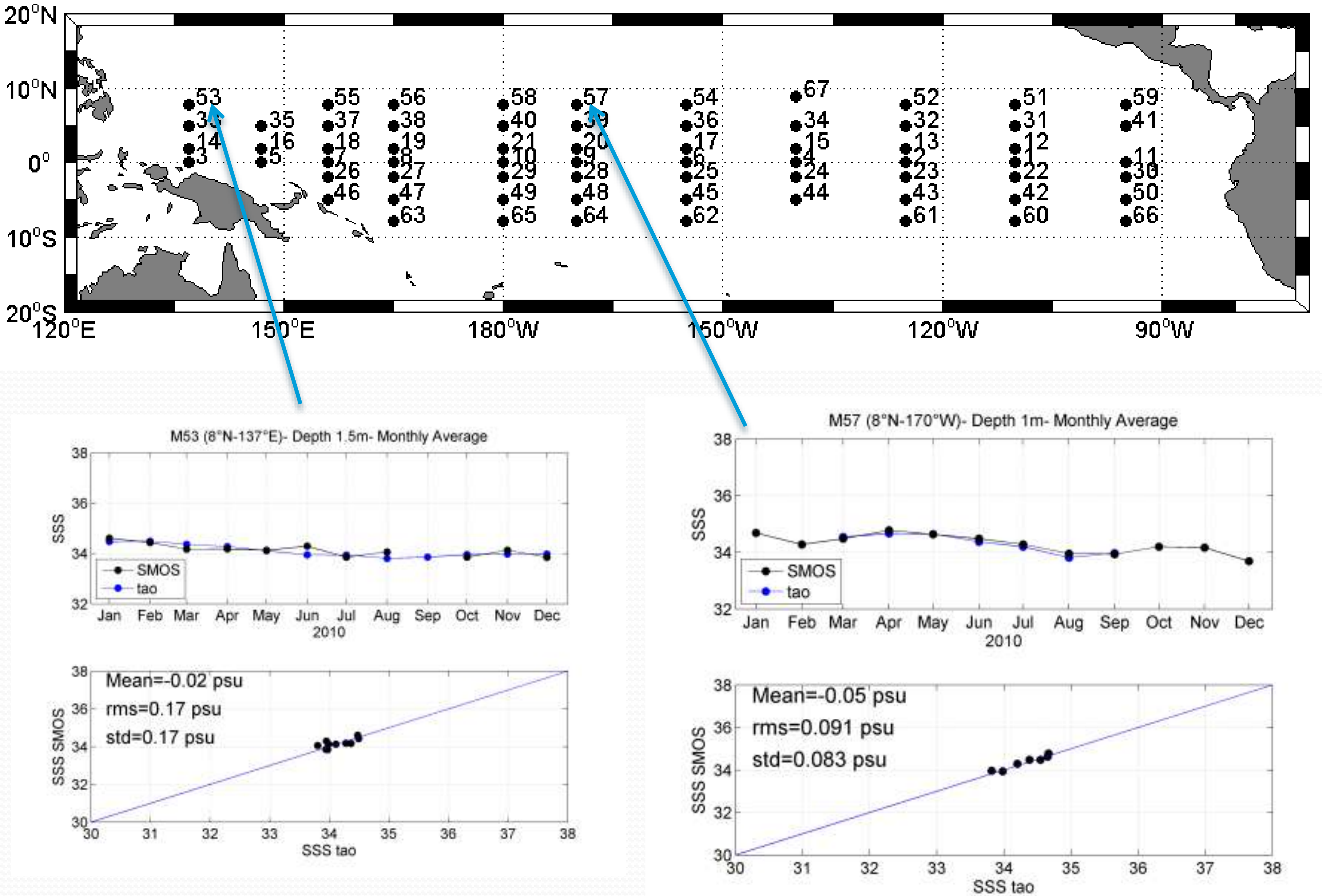

2010 SMOS Monthly L3 SSS -Jan 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Apr 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Feb 0.25°x0.25°
2010 SMOS Monthly L3 SSS -May 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Mar 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Jun 0.25°x0.25°
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W
32.5
33
33.5
34
34.5
35
35.5
36
36.5

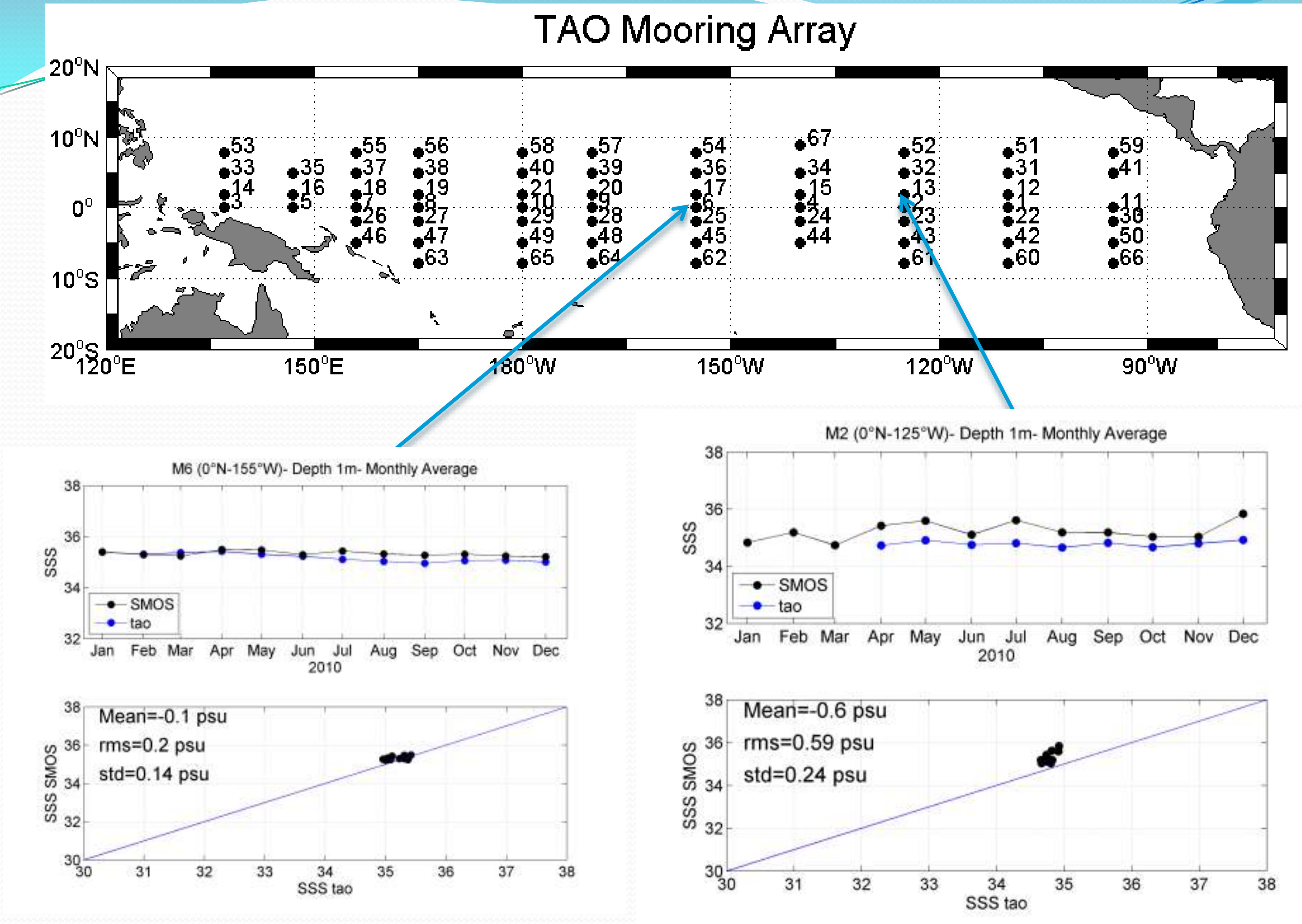

2010 SMOS Monthly L3 SSS -Jul 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Oct 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Aug 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Nov 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Sep 0.25°x0.25°
2010 SMOS Monthly L3 SSS -Dec 0.25°x0.25°
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W
32.5
33
33.5
34
34.5
35
35.5
36
36.5

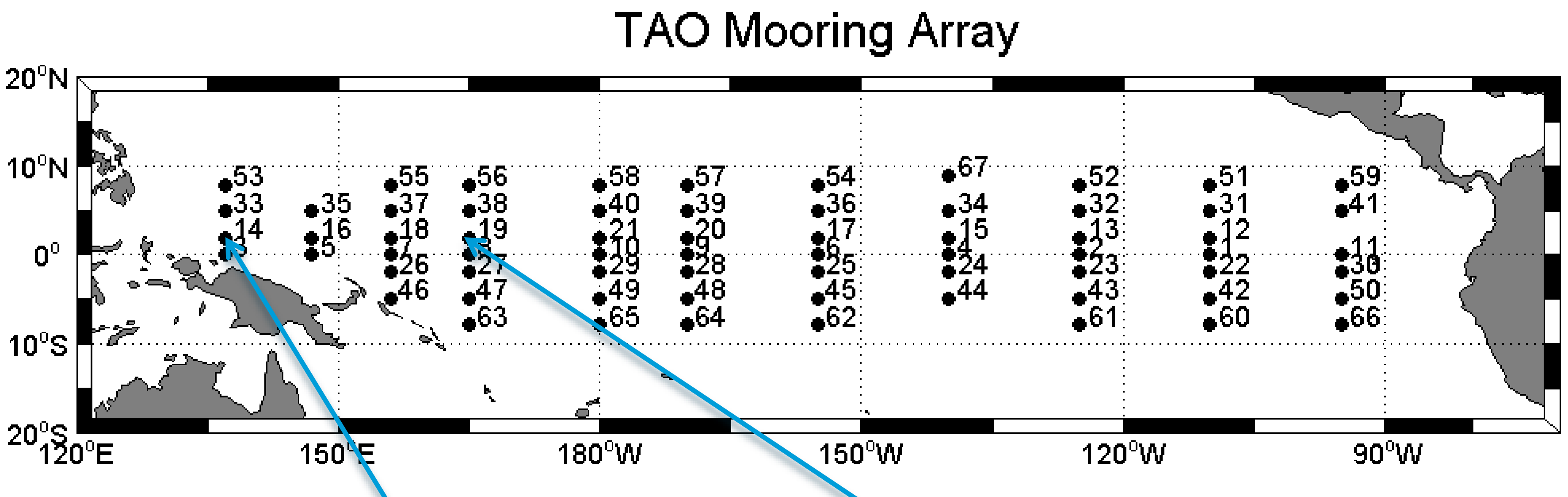


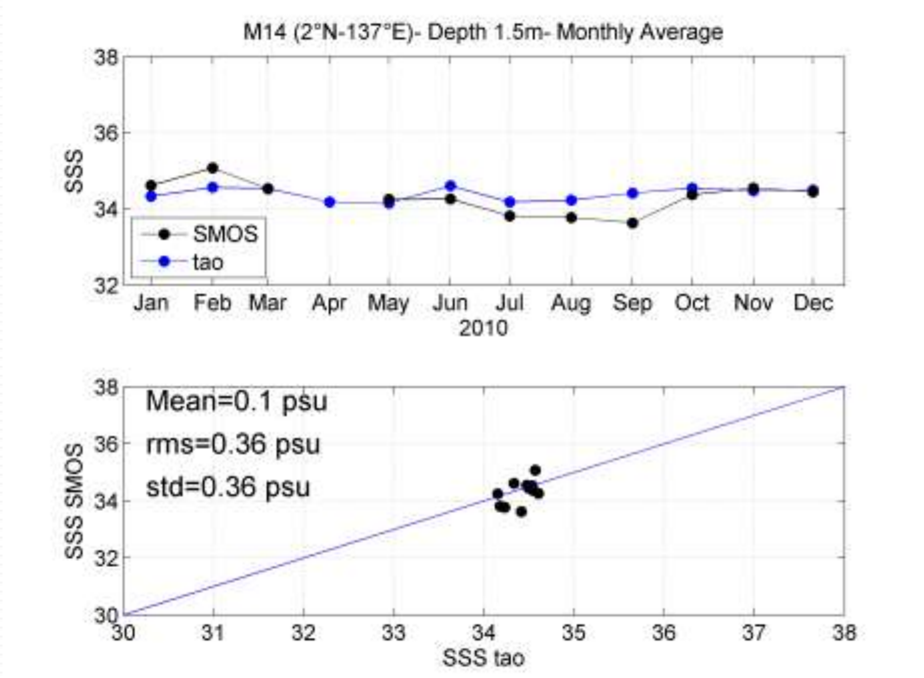
TAO Mooring Array
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W
M67 (9°N-140°W)- Depth 1m- Monthly Average
M59 (8°N-95°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=-0.01 psu
rms=0.29 psu
std=0.3 psu
Mean=0.2 psu
rms=0.33 psu
std=0.3 psu
SSS SMOS
SSS tao

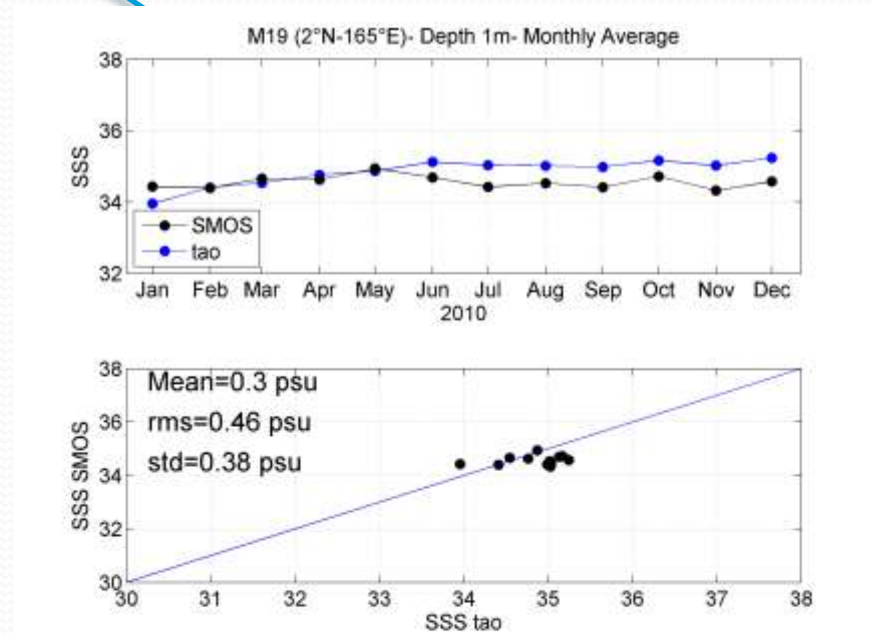
TAO Mooring Array

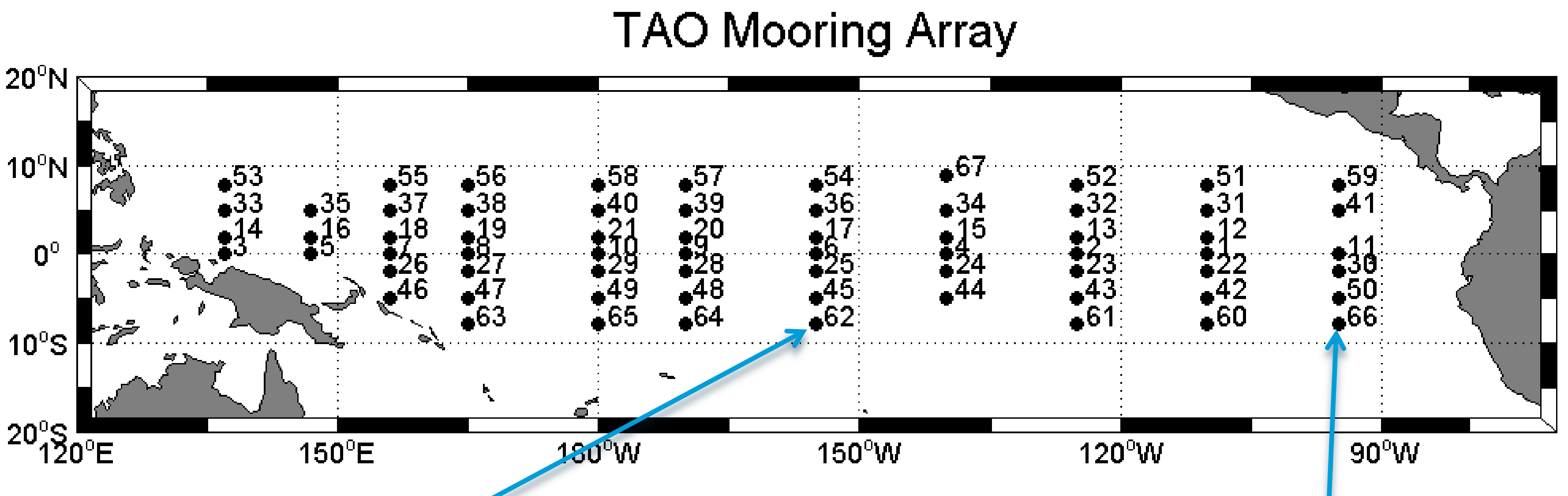


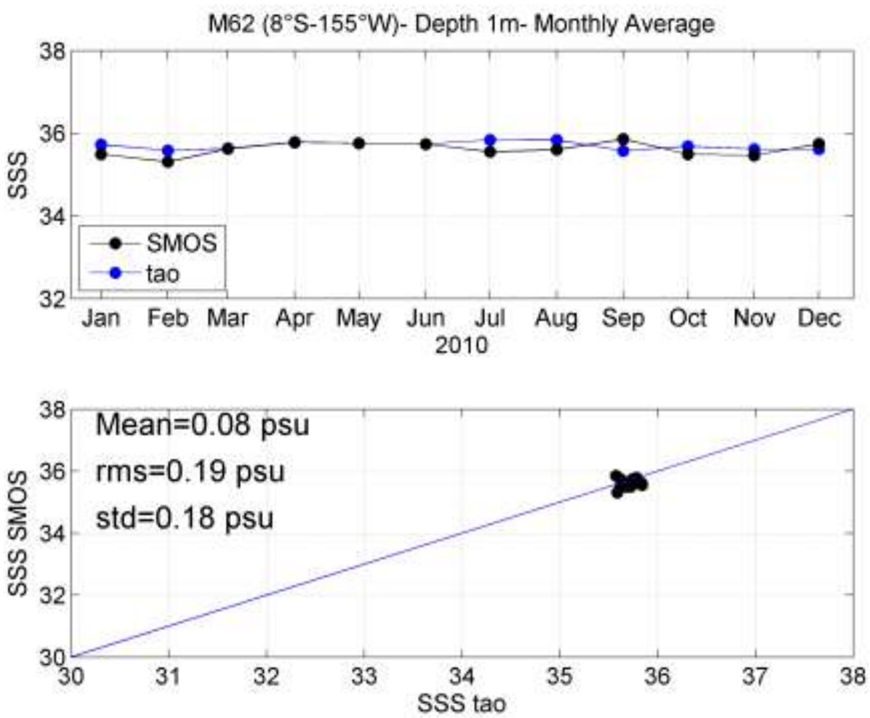

TAO Mooring Array
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W
M6 (0°N-155°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=-0.1 psu
rms=0.2 psu
std=0.14 psu
SSS SMOS
SSS tao
M2 (0°N-125°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=-0.6 psu
rms=0.59 psu
std=0.24 psu
SSS SMOS
SSS tao

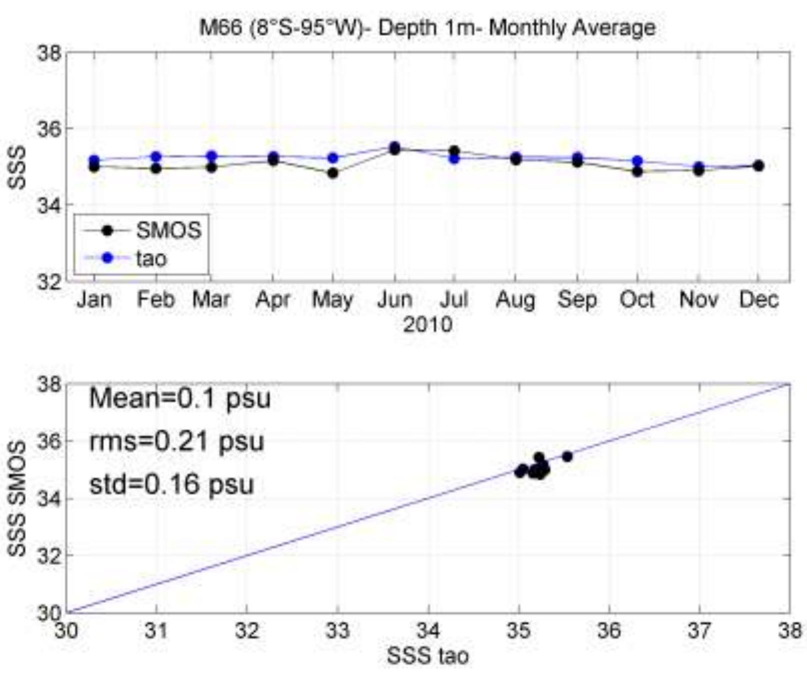

TAO Mooring Array
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W

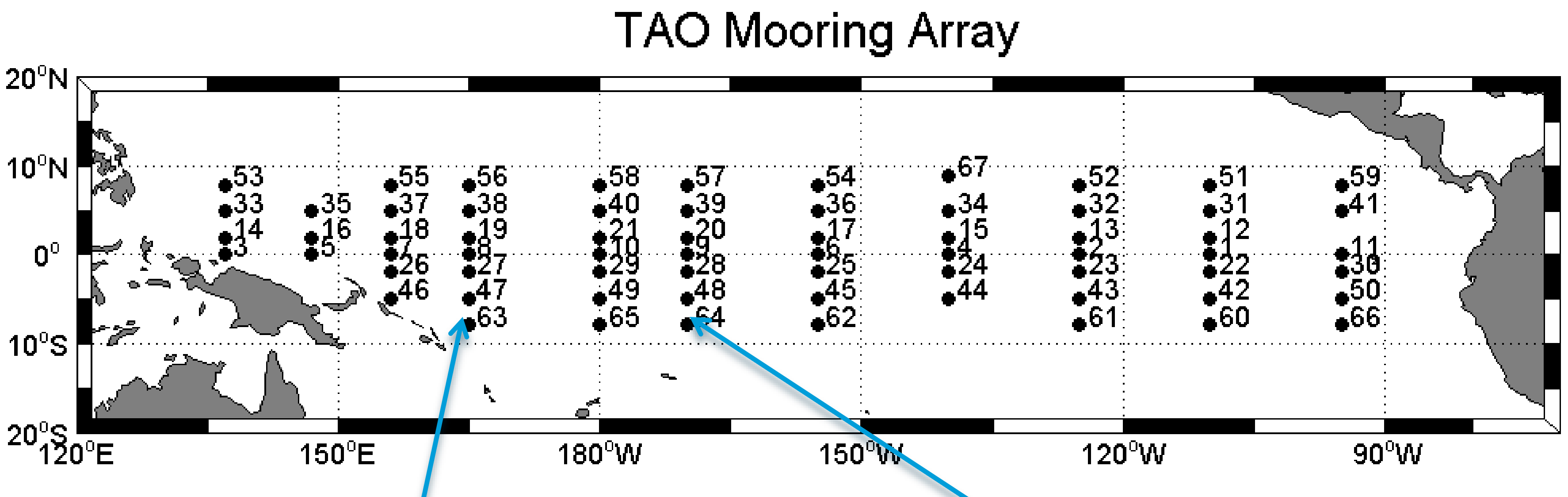

M14 (2°N-137°E)- Depth 1.5m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.1 psu
rms=0.36 psu
std=0.36 psu
SSS SMOS
SSS tao

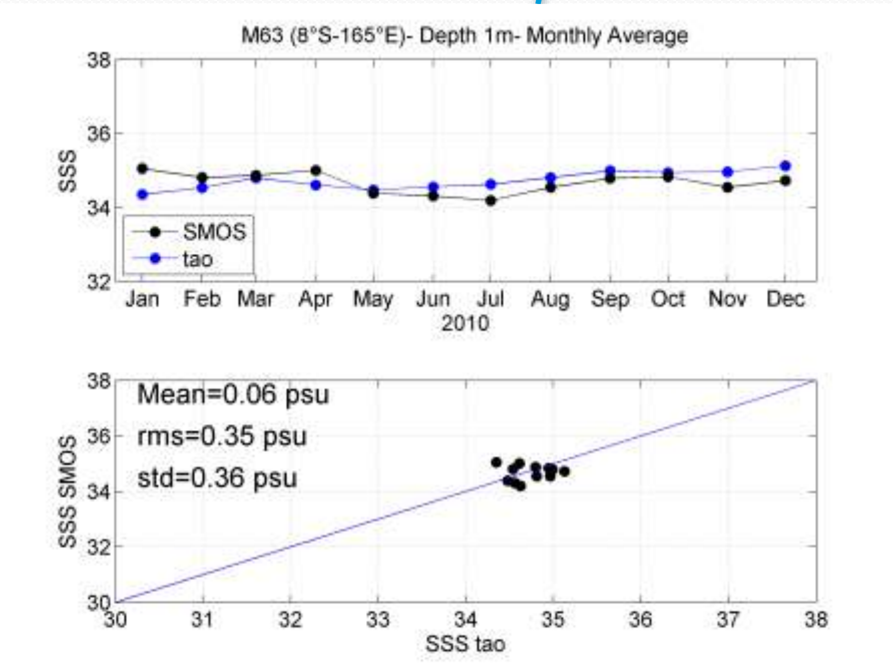

M19 (2°N-165°E)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.3 psu
rms=0.46 psu
std=0.38 psu
SSS SMOS
SSS tao

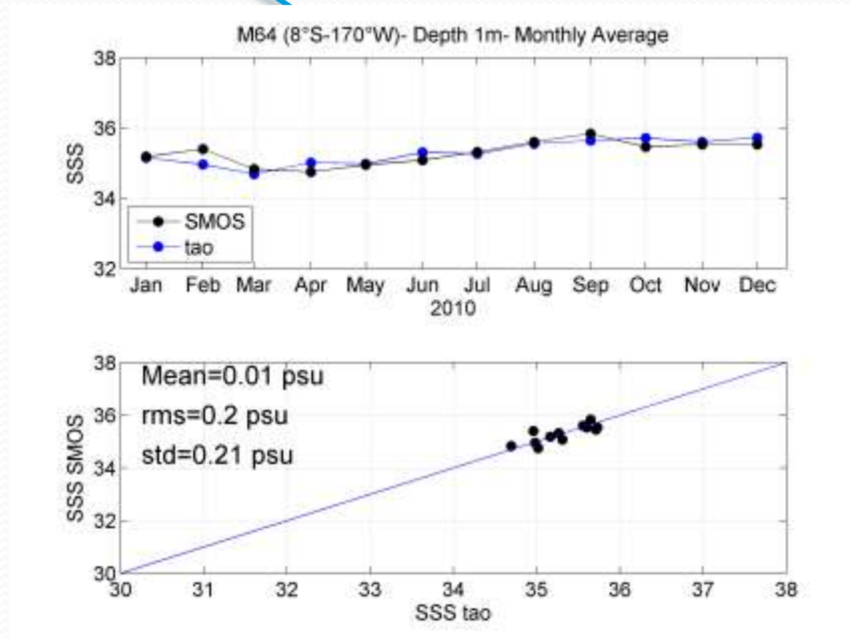

TAO Mooring Array
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W


M62 (8°S-155°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.08 psu
rms=0.19 psu
std=0.18 psu
SSS SMOS
SSS tao

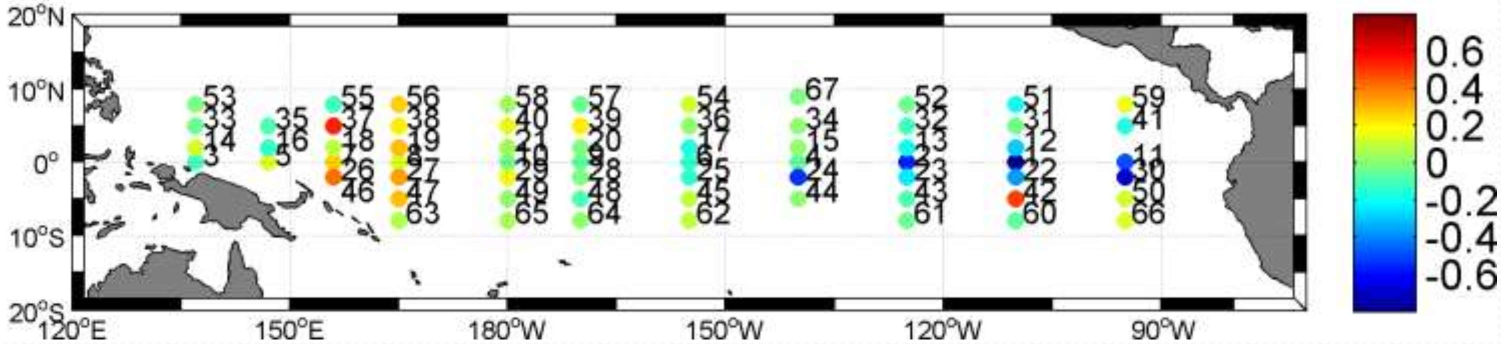

M66 (8°S-95°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.1 psu
rms=0.21 psu
std=0.16 psu
SSS SMOS
SSS tao


TAO Mooring Array
20°N
10°N
0°
10°S
20°S
120°E
150°E
180°W
150°W
120°W
90°W

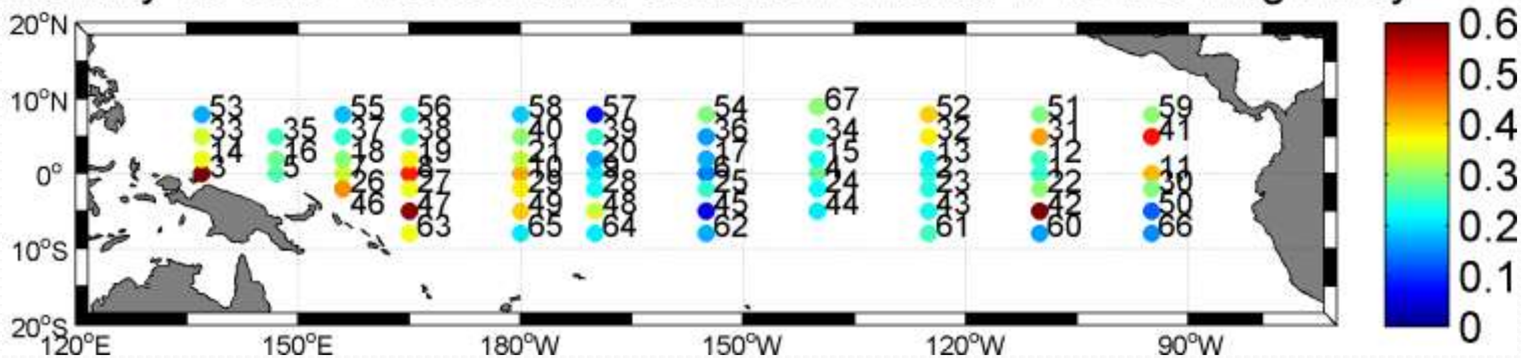

M63 (8°S-165°E)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.06 psu
rms=0.35 psu
std=0.36 psu
SSS SMOS
SSS tao


M64 (8°S-170°W)- Depth 1m- Monthly Average
SSS
SMOS
tao
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
2010
Mean=0.01 psu
rms=0.2 psu
std=0.21 psu
SSS SMOS
SSS tao

Monthly L3 0.25° res Mean error $SSS_{In\ Situ}$-SSS_{SMOSL3} at TAO Mooring Array

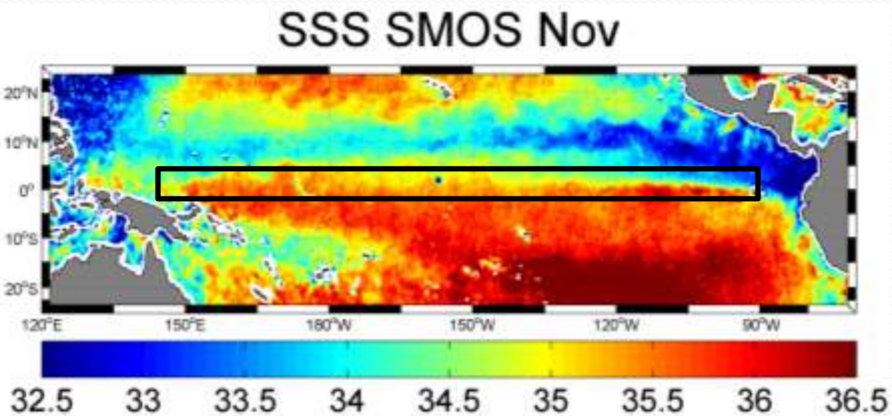


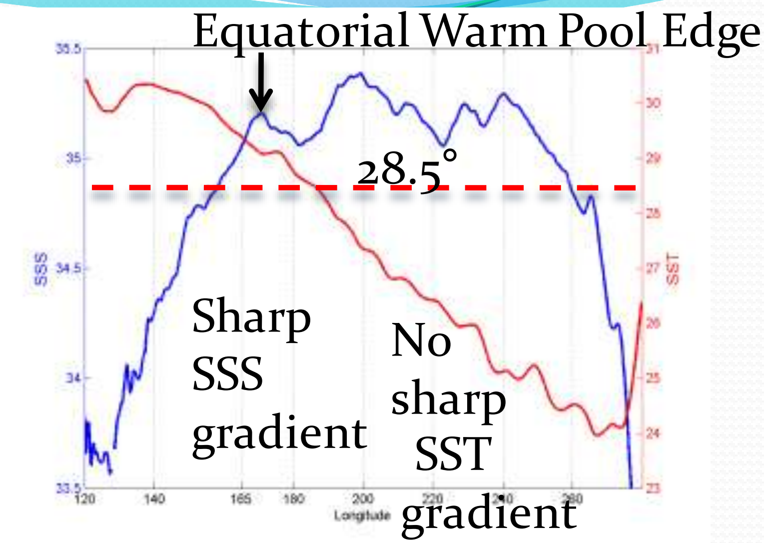
Monthly L3 0.25° res standard deviation error at TAO Mooring Array



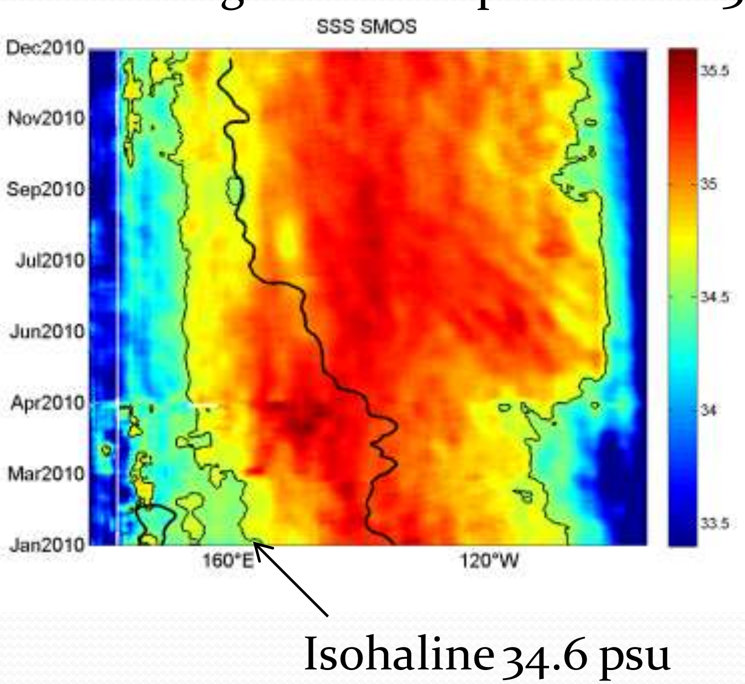
Detection of the Eastern Edge of the Equatorial Pacific Warm Pool

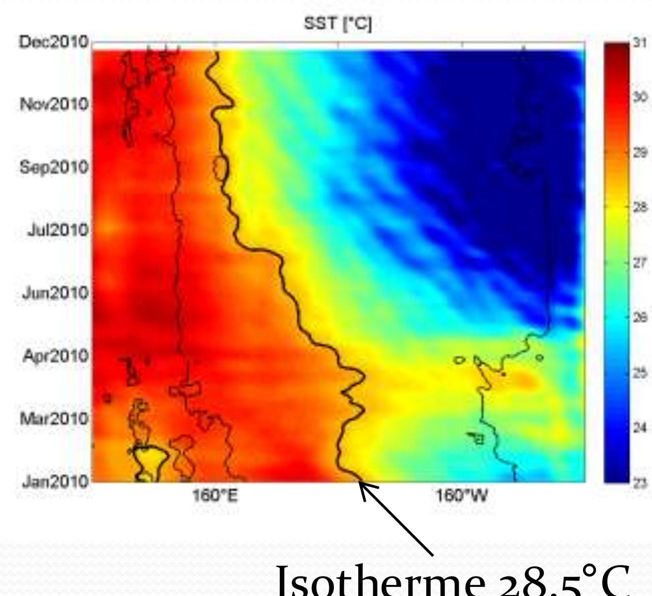
=>Maes et al. GRL, 2006



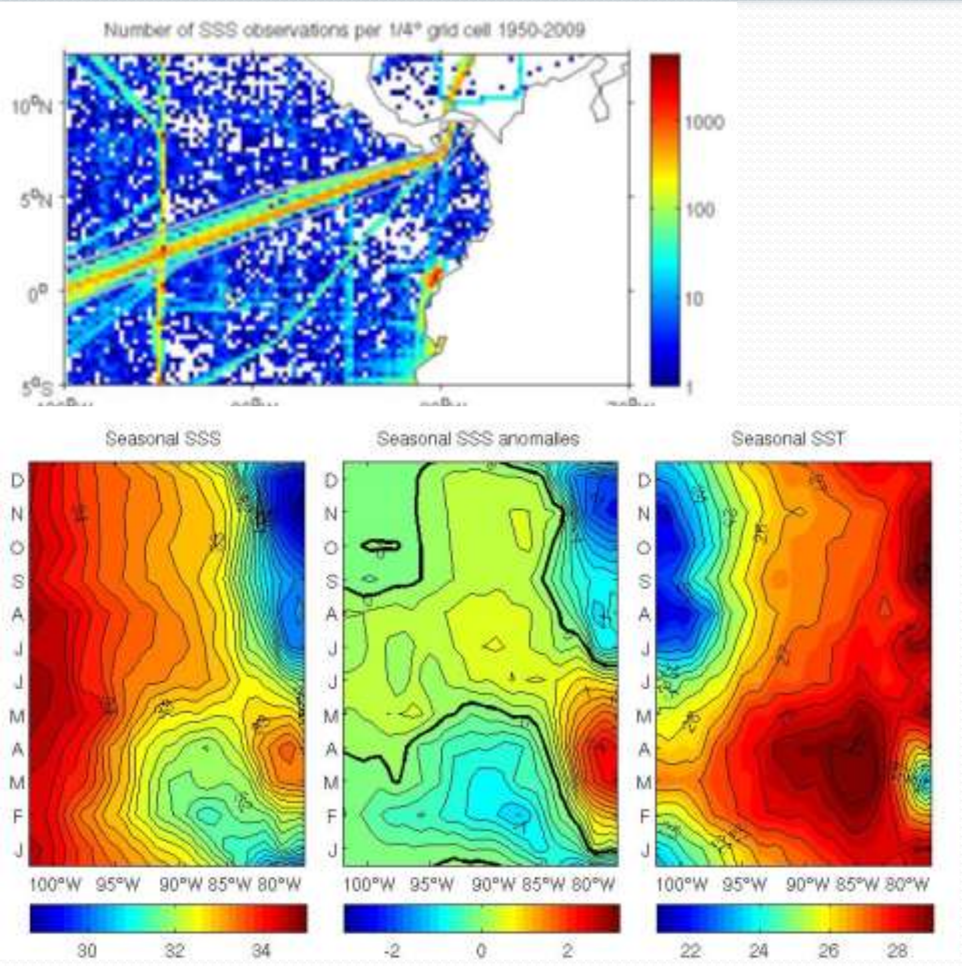


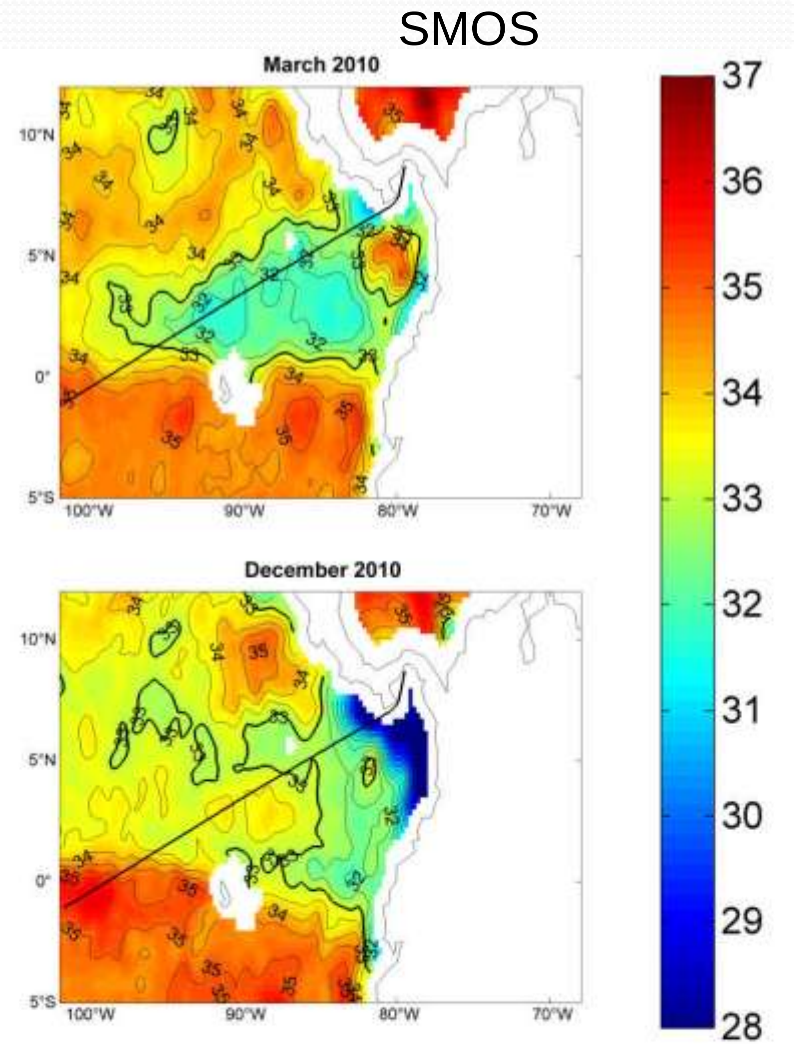
longitude-time plots of the 3°N–3°S averaged SSS and SST





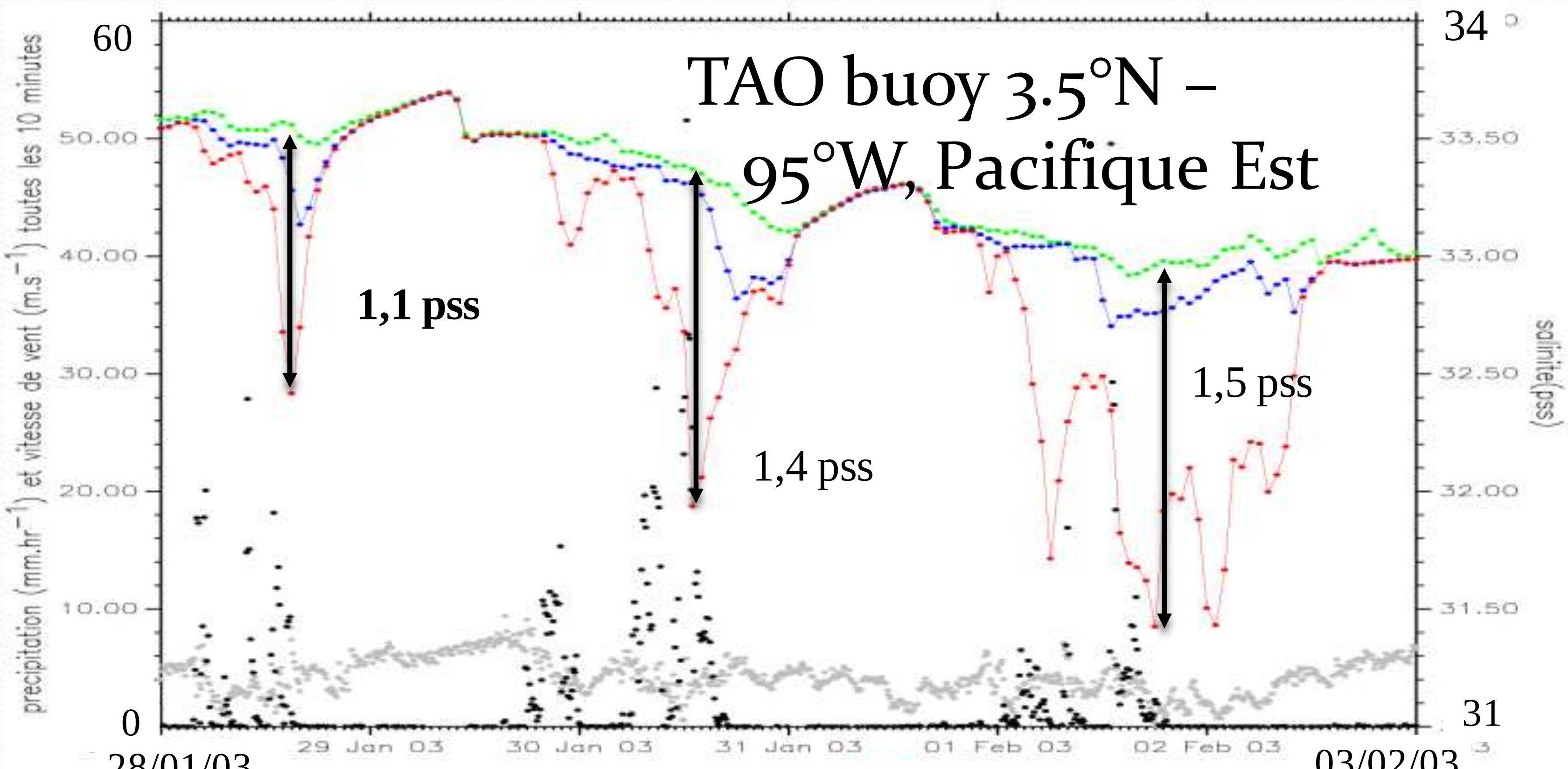
Seasonal dynamics of Sea Surface Salinity off Panama: the Far Eastern Pacific Fresh Pool





Alory et al.=> in preparation JGR 2012

Impact of Rain on In situ SSS measurements :
large salinity stratification in case of rain

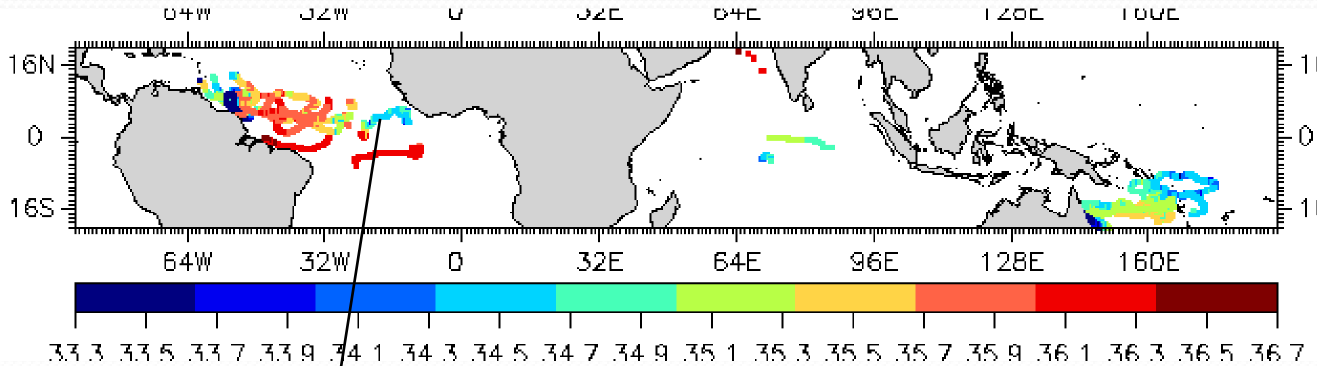


Precipitation rate (mm/hr)
Wind speed (m/s)

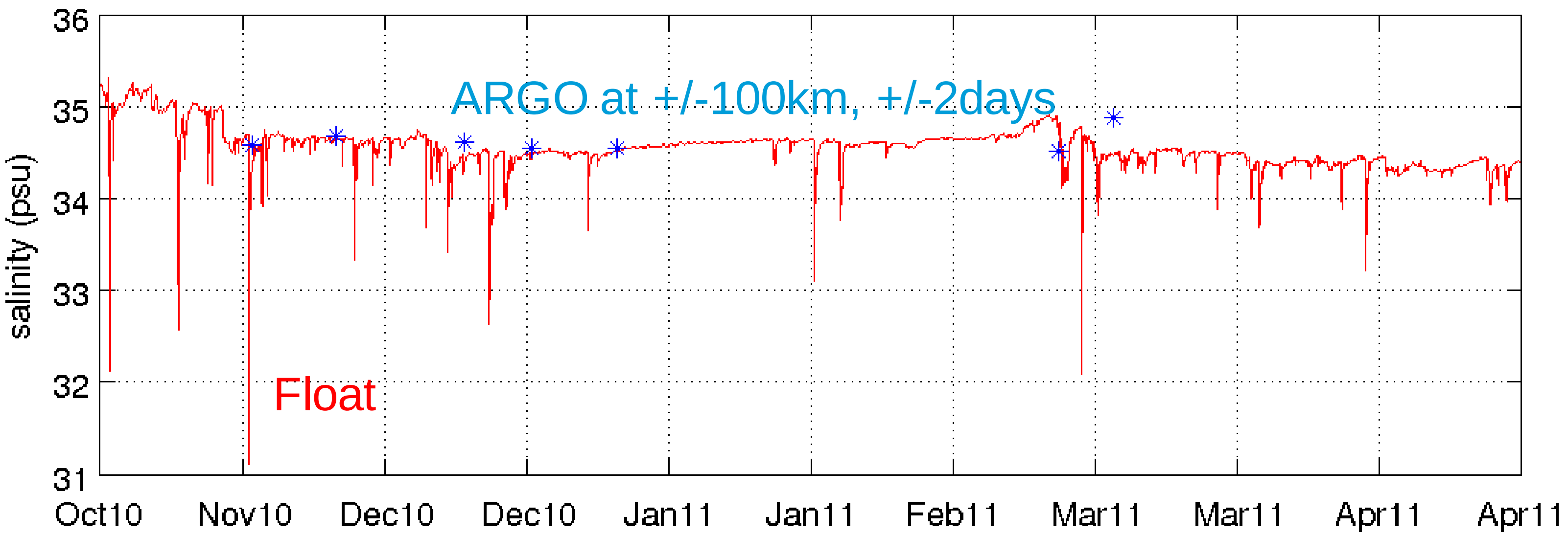
salinity at 1 m depth
salinity at 5 m depth
salinity at 10 m depth

Hénocq et al., JAOT, 2010

Autonomous drifter (~50cm depth)

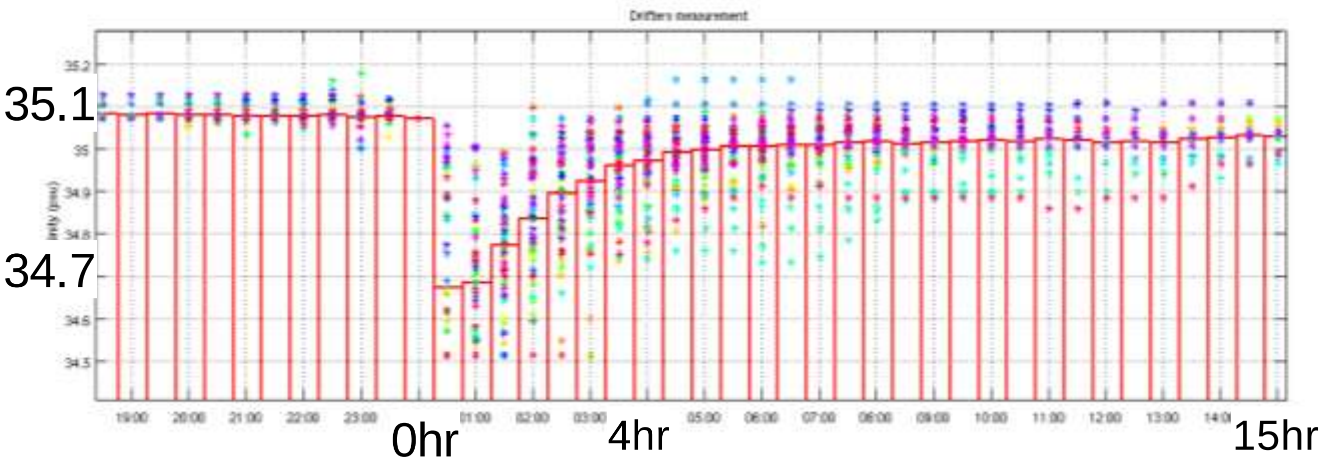


Example of SSS freshening in Atlantic ITCZ

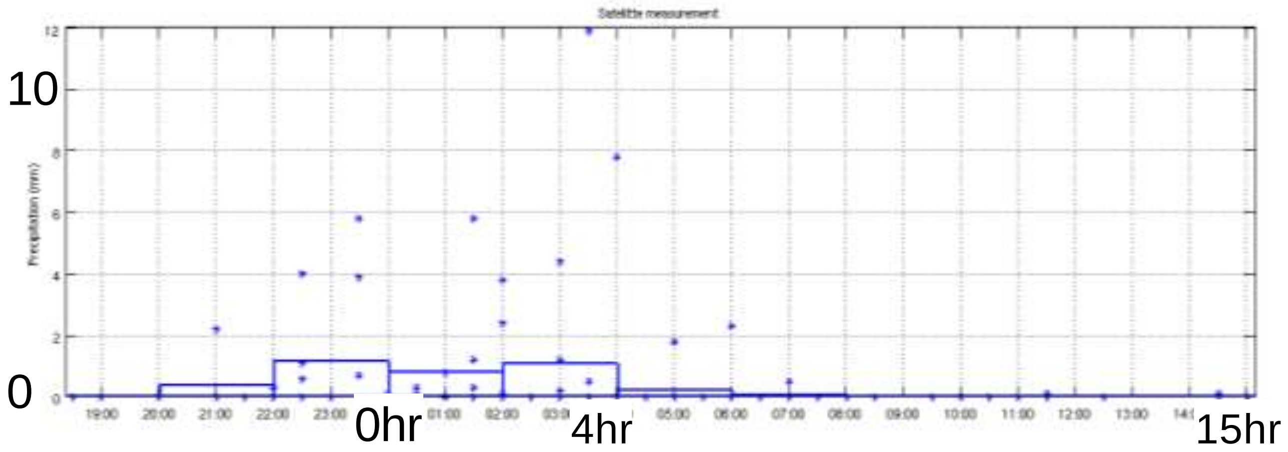


See poster Morrisset, et al; Reverdin et al. JGR 2011, in revision

SSS rain-freshening temporal evolution as seen by 60 drifters in the tropical Oceans



SSS temporal evolution after a freshening event (time 0)



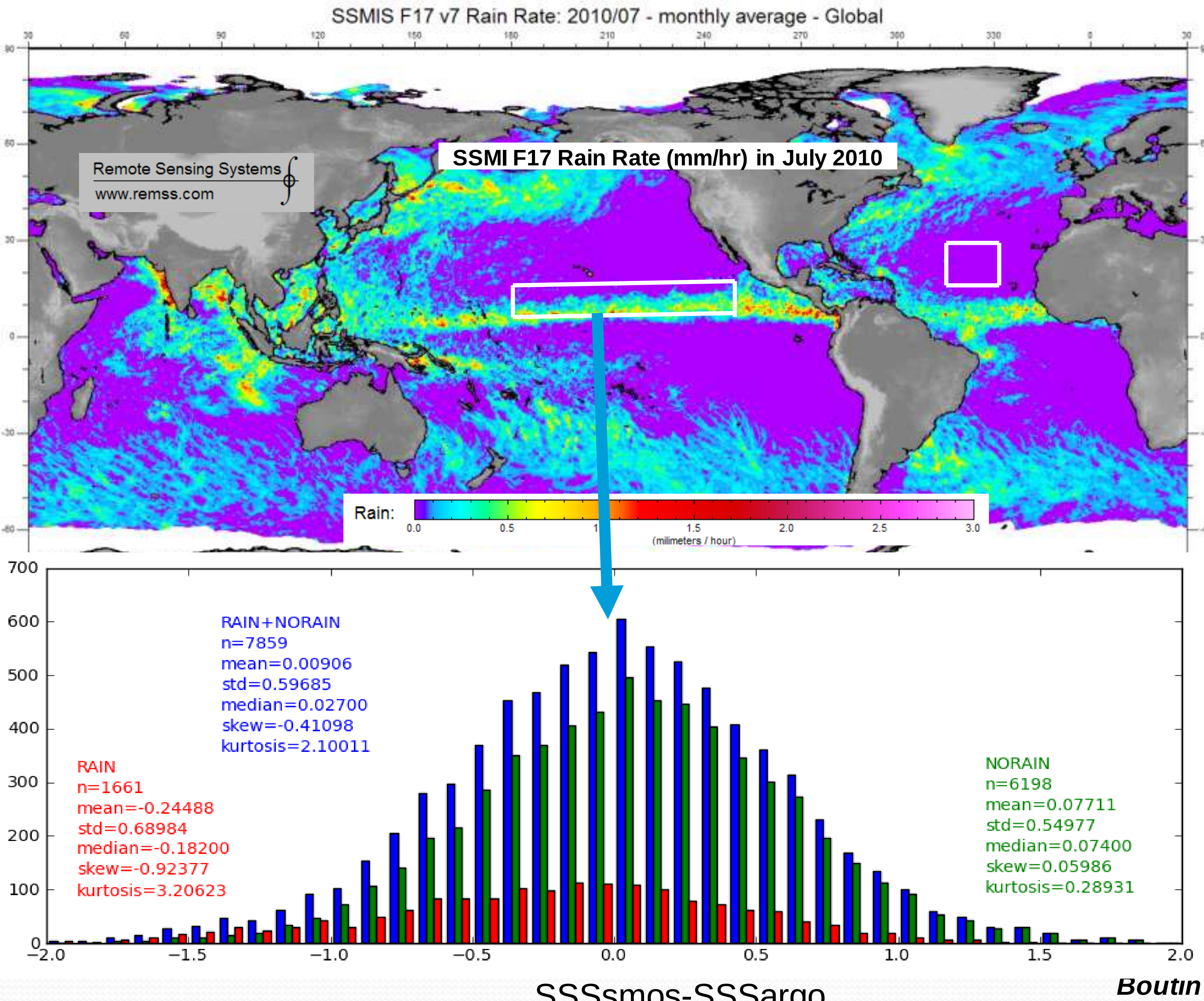
Satellite Rain Rates (SSM/I, TMI, AMSRE (www.ssmi.com)) colocated with floats SSS

Figure 7: Average cycle of salinity (upper panel) among 60 salinity drop events (relative to a common time of beginning of event). Individual records are shifted to a common salinity value at the initial drop time and the magnitude of the drop is adjusted to the mean drop. The average is plotted as well as individual events. The associated average reported rainfall (mm/hour) is plotted in the lower panel by 2-hour average, as well as the individual values at the exact time of reports.

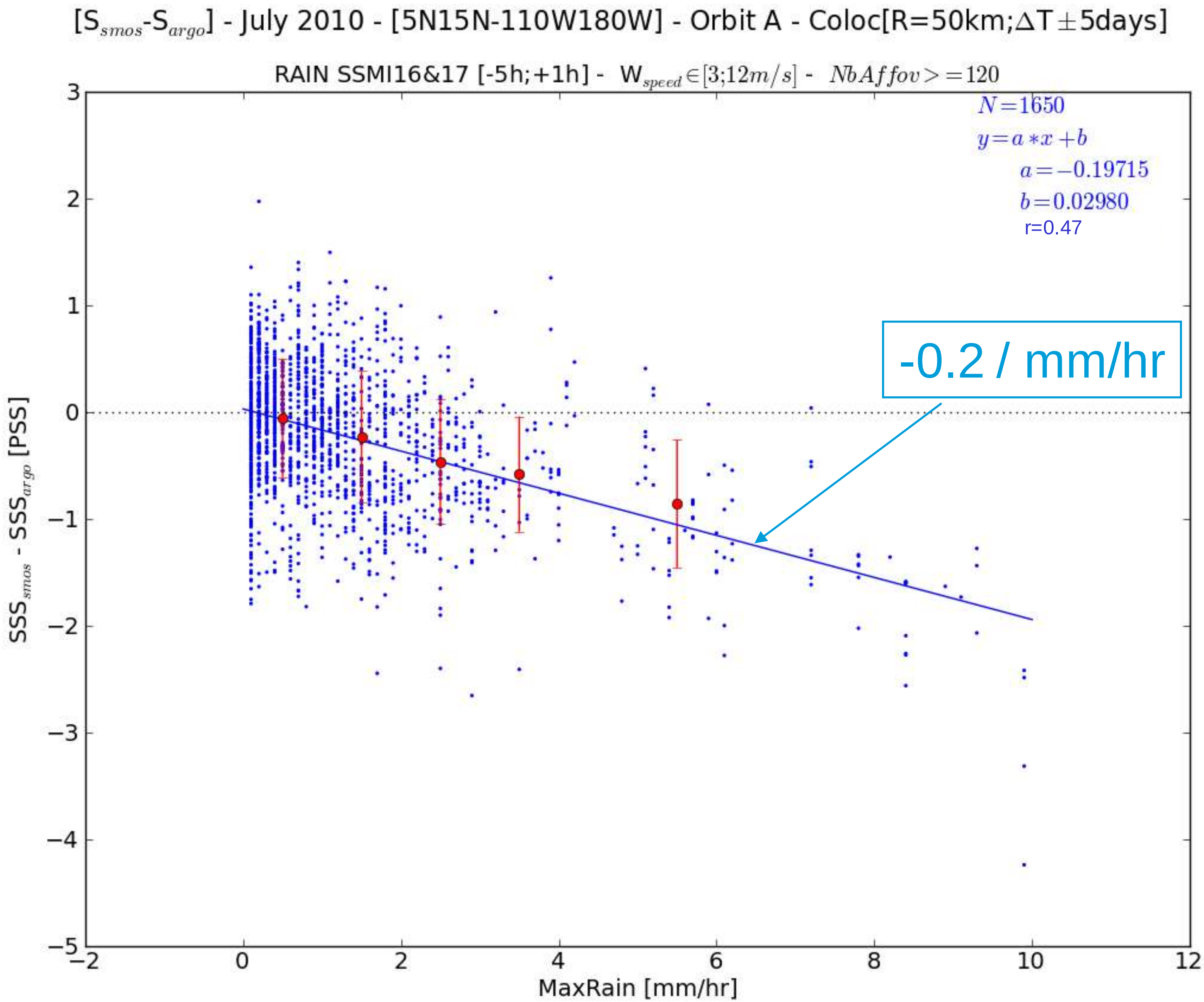
See poster Morrisset, et al; Reverdin et al. JGR 2011, in revision

SMOS SSS & Rain colocation

- **SMOS SSS - 40km resolution** retrieved from ~150 Tbs measured at various incidence angles, 2 polarisations=> **SSS and ECMWF adjusted wind speed**
- Rain Rate deduced from SSMI F16 and F17 (RemSS version 7); 32km spatial resolution
- Colocation of SMOS SSS and SSMI Rain Rate: Maximum of RR (within -5hours and +1hour to SMOS time) and falling in the SMOS ISEA grid point
- **Statistics of SSSsmos-SSSargo depending on Maximum RR within -5h/+1h of SMOS SSS**

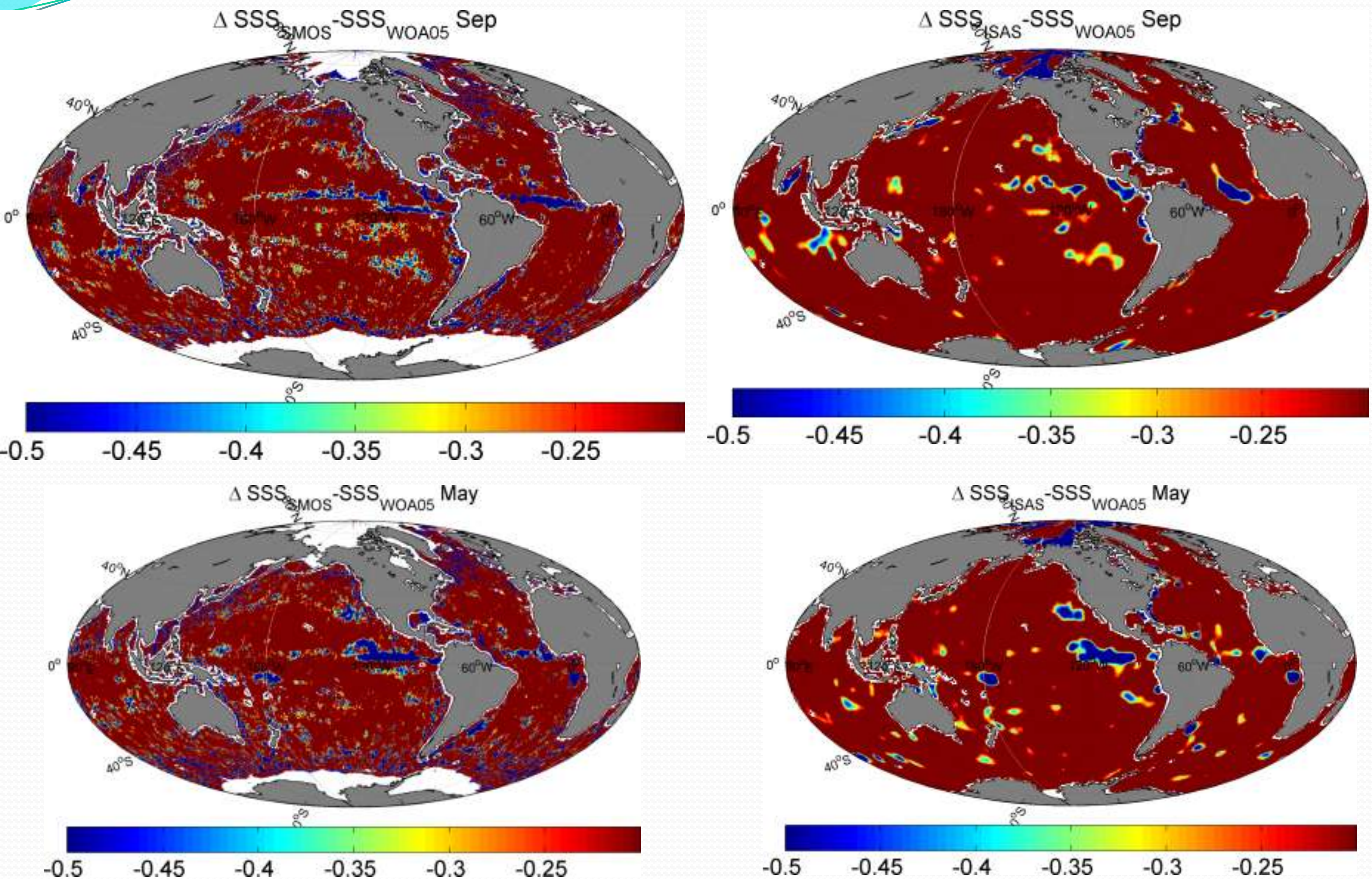


Boutin et al. 2011

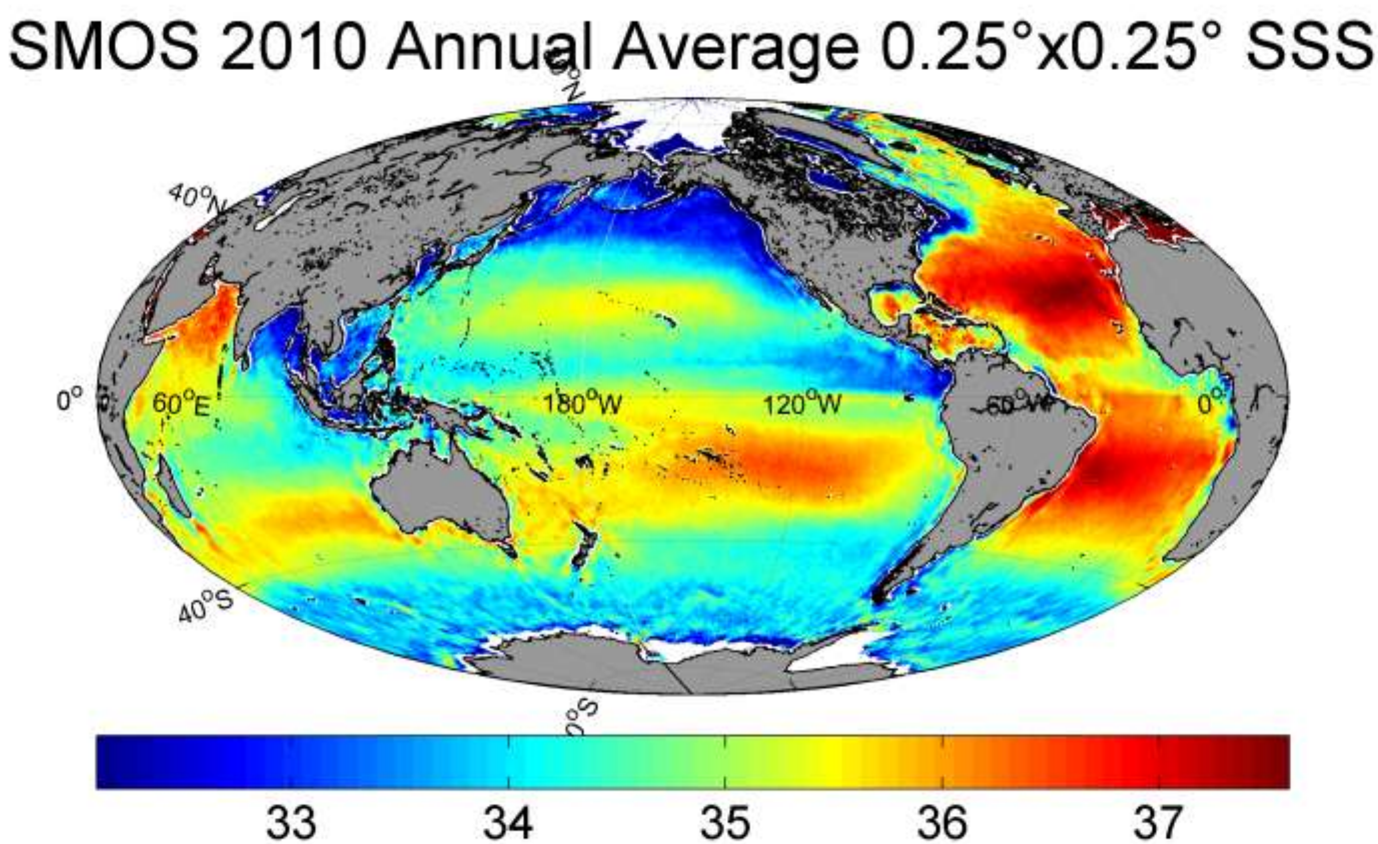


[S_{smos}-S_{argo}] - July 2010 - [5N15N-110W180W] - Orbit A - Coloc[R=50km;ΔT±5days]
RAIN SSMI16&17 [-5h;+1h] - $W_{speed} \in [3;12m/s]$ - $NbAffov >= 120$
$N = 1650$
$y = a*x+b$
$a = -0.19715$
$b = 0.02980$
r=0.47
-0.2 / mm/hr
SSS_{smos} - SSS_{argo} [PSS]
MaxRain [mm/hr]

fresh water SSS anomalies detected by SMOS



First Annual Average SSS map Measured from Space



Conclusions

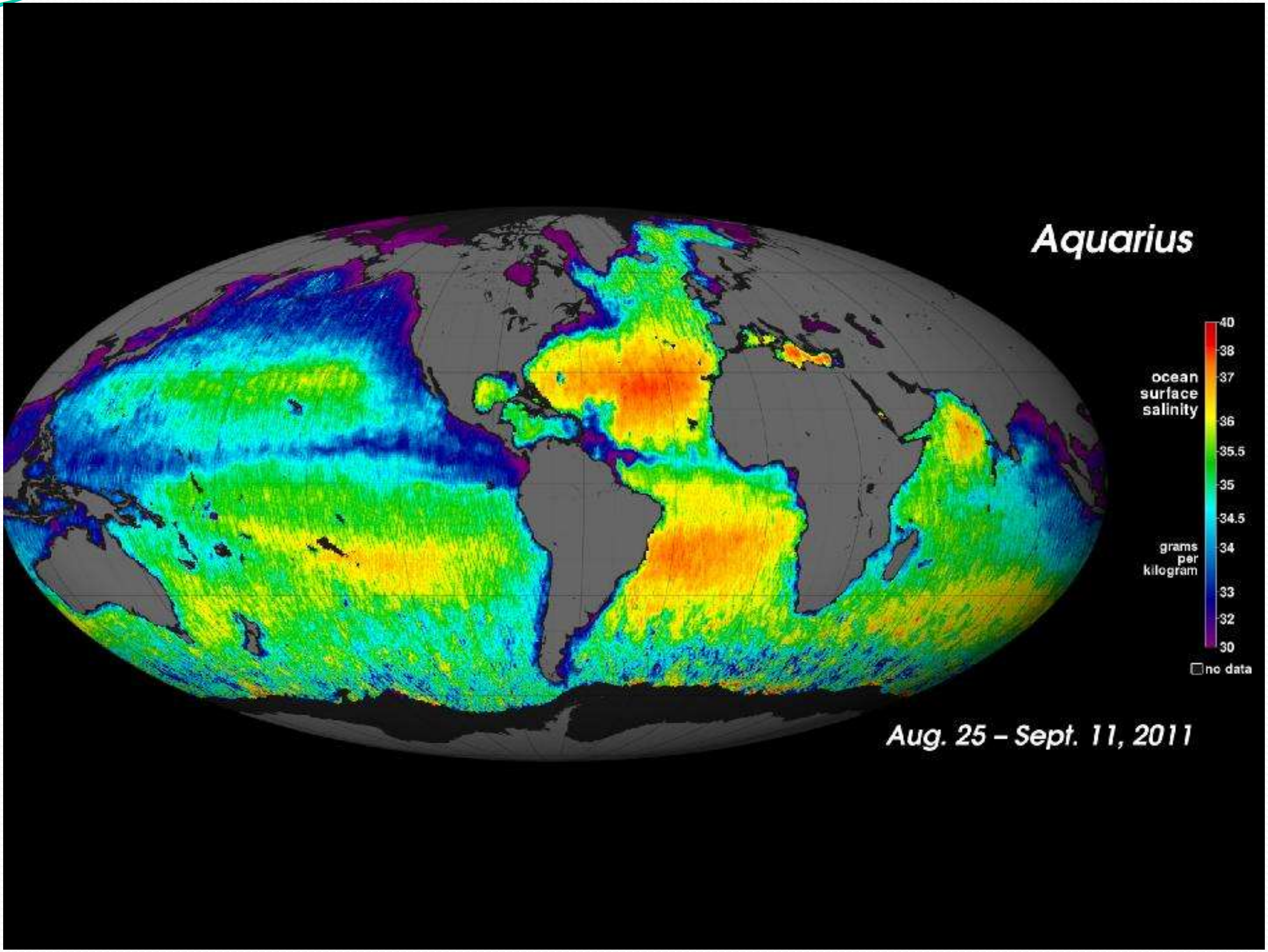
Next steps:

galactic noise model improvments,
Direct sun masking or correction
Roughness correction refinement

L4 merging with :

in situ
Aquarius

Thanks for your attention !


Aquarius
ocean surface salinity
40
38
37
36
35.5
35
34.5
34
33
32
30
grams per kilogram
no data
Aug. 25 – Sept. 11, 2011