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SMOS BARCELONA EXPERT CENTRE

Towards an estimation of water masses formation areas from SMOS-based T-S diagrams

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EGU 2014 - Vienna, Austria, 28.04.2014

European Space Agency

Datasets, 2011

Sea Surface Salinity (SSS):

- SMOS Level 3 SSS optimal interpolated

Sea Surface Temperature (SST):

- Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA)

In-situ:

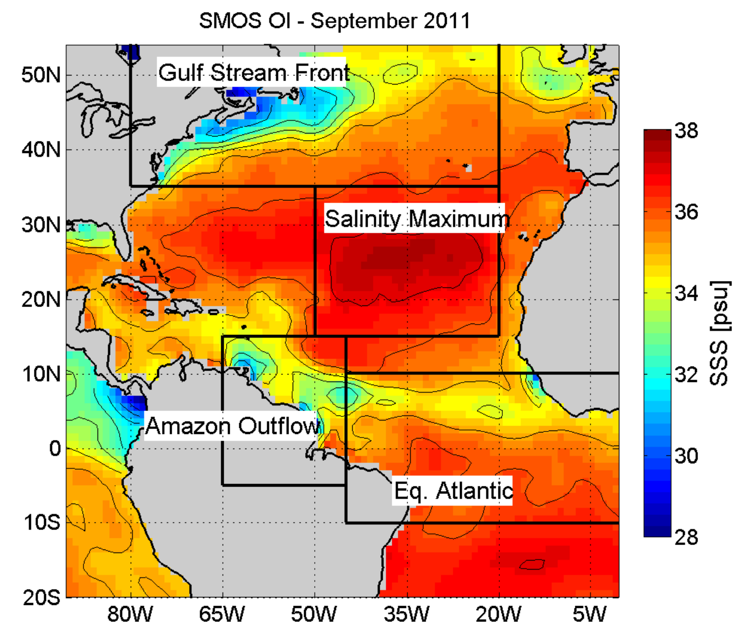
- ARGO ISAS Near Real Time (produced at Ifremer, Gaillard et al, 2009)

Climatology:

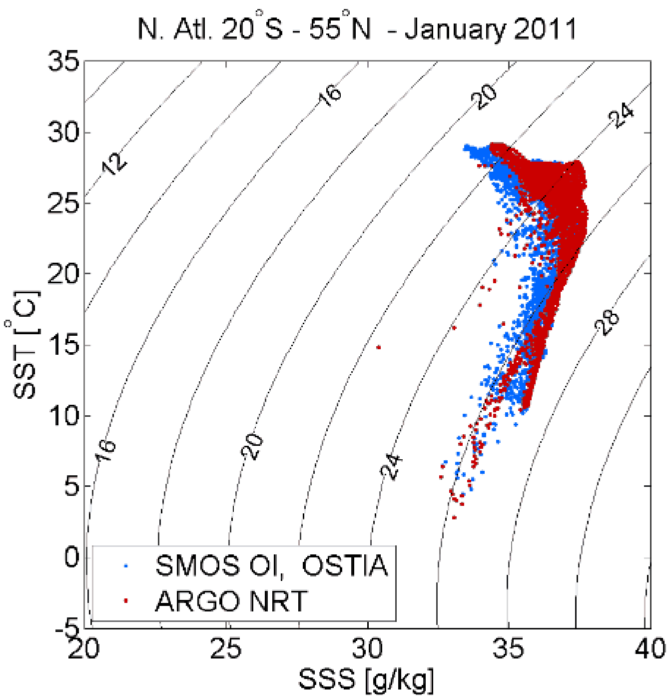
- World Ocean Atlas 2009 (WOA 09)

Additional data:

- CMORPH precipitation
- OAFlux evaporation
- SSM-I wind speed
- NOCS Surface Flux Data Set v2.0



T-S Diagrams and Water masses



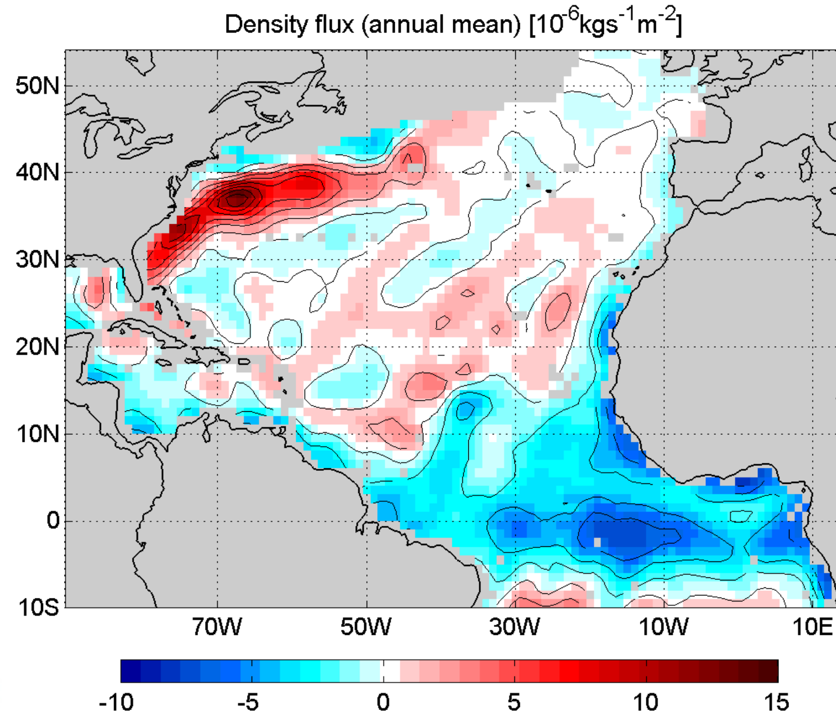
- **Temperature-Salinity (T-S) diagrams** emphasize the mutual variability of ocean Temperature and Salinity, relating them to the corresponding **density**.
- In [Sabia et al./Klockmann et al., 2012/2013, now submitted to JGR-Oceans special issue SMOS-Aquarius] it has been studied:
  - satellite-based surface **T-S diagrams variability**;
  - additional **geophysical signal** embedded in remote sensing data.

- Currently, the main focus of the study deals with the exploitation of the T-S diagrams as a prognostic tool to derive **water masses formation areas**.
- Water masses are characterized by a **range of T-S values**; they are formed at the surface by interaction with the atmosphere, mostly in winter.
- SMOS mission is now providing the possibility of studying temporal and spatial patterns in water masses formation. **Which** water masses can we observe at the surface? **When** and **where** are they formed?

Approach

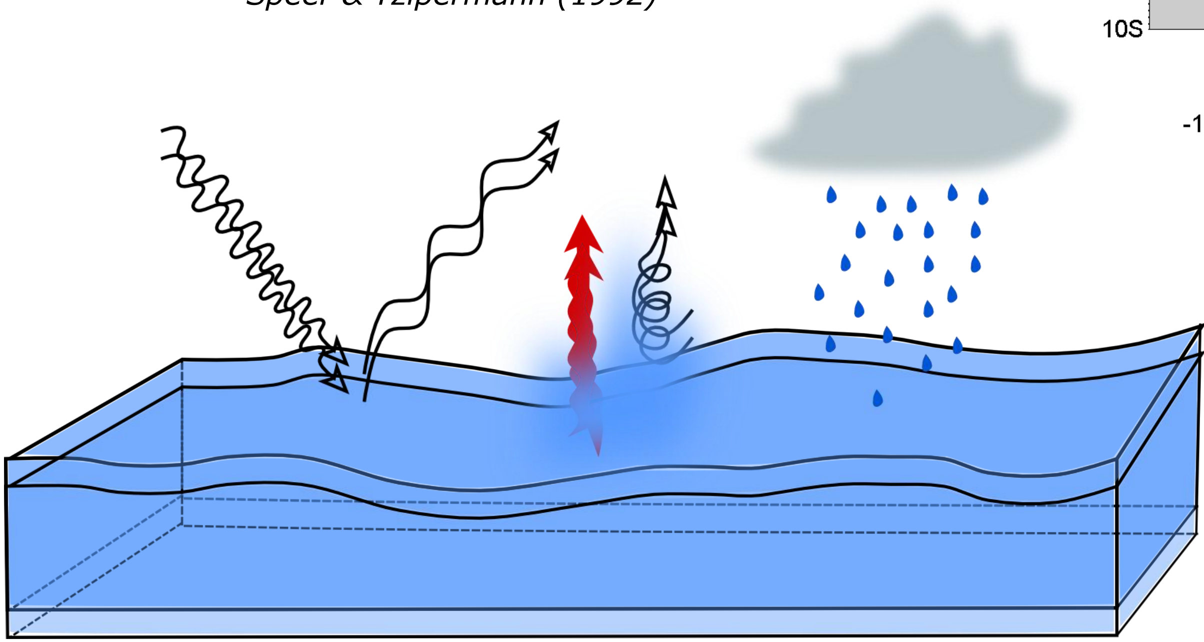
Surface density flux: change in density induced by surface fluxes of heat and freshwater

$$f_\rho =$$



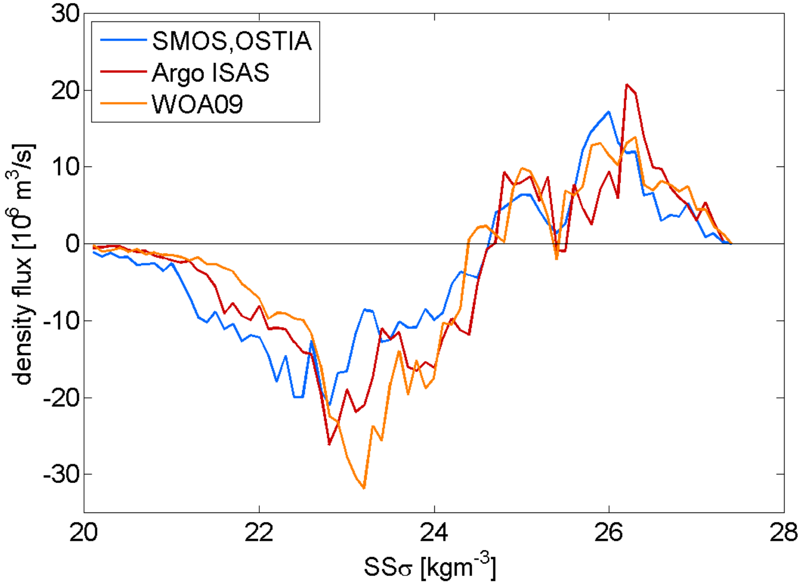
"Transformation equation"

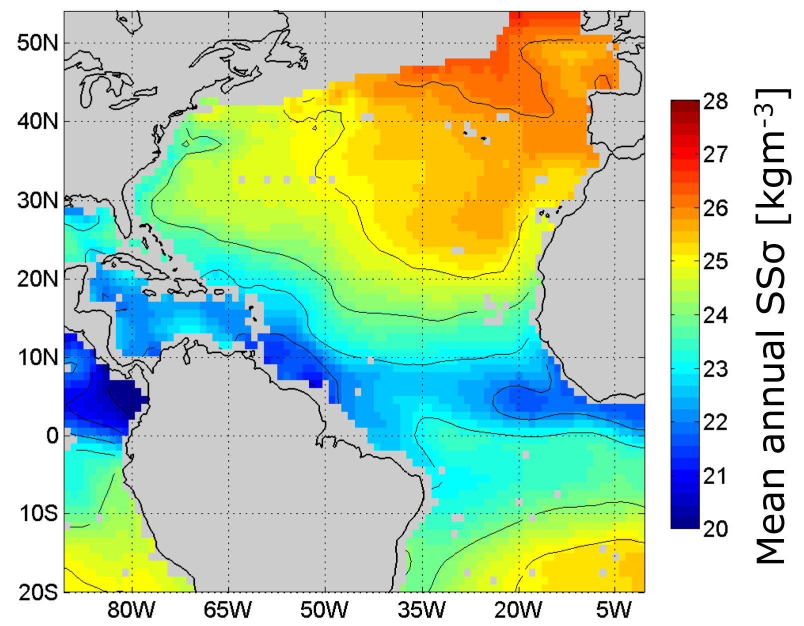
Speer & Tzipermann (1992)

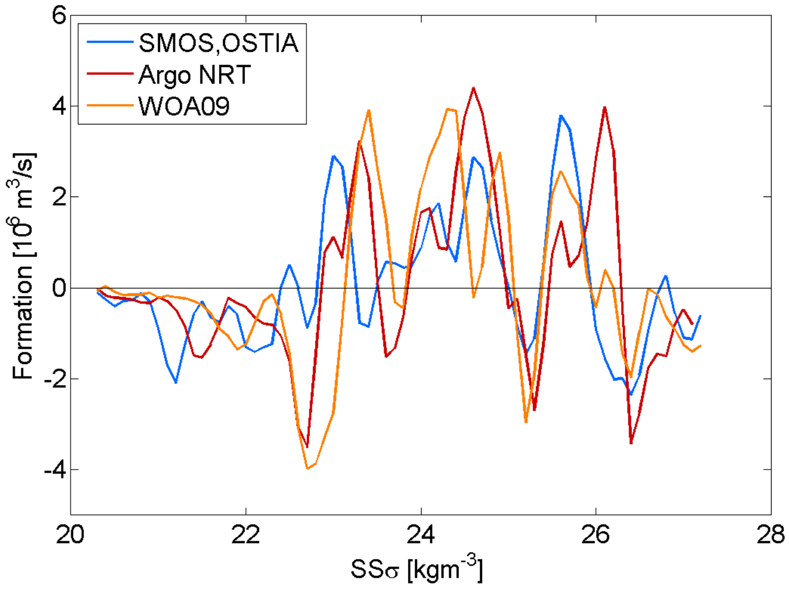


- Short and long wave radiation
- Sensible and latent heat flux
- Evaporation
- Precipitation

(Trans-)Formation



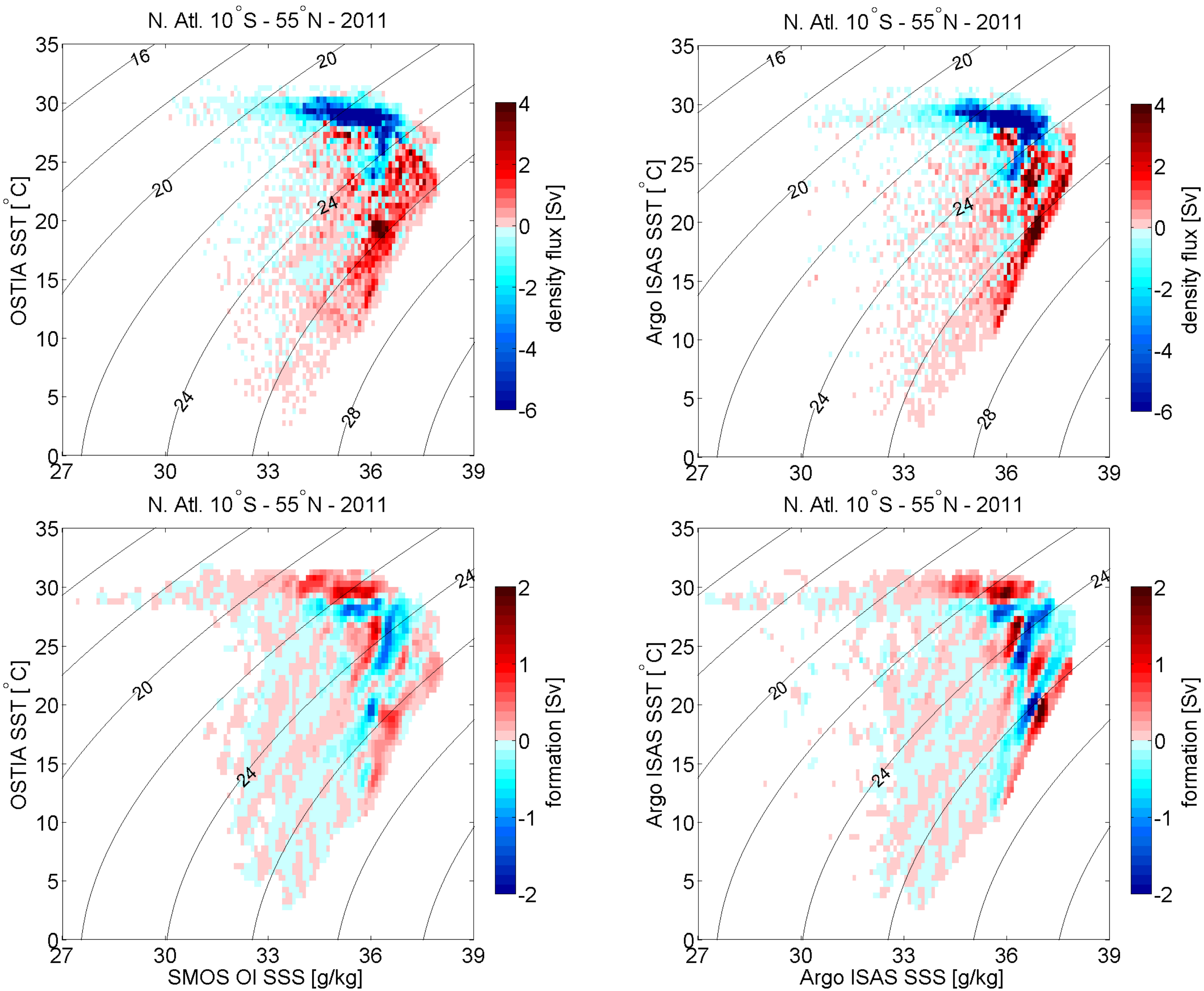




$$F = \frac{\partial}{\partial \rho} \iint f(\rho) dt\, dA \qquad [Sv = 10^6 m^3 s^{-1}]$$

"Formation equation"

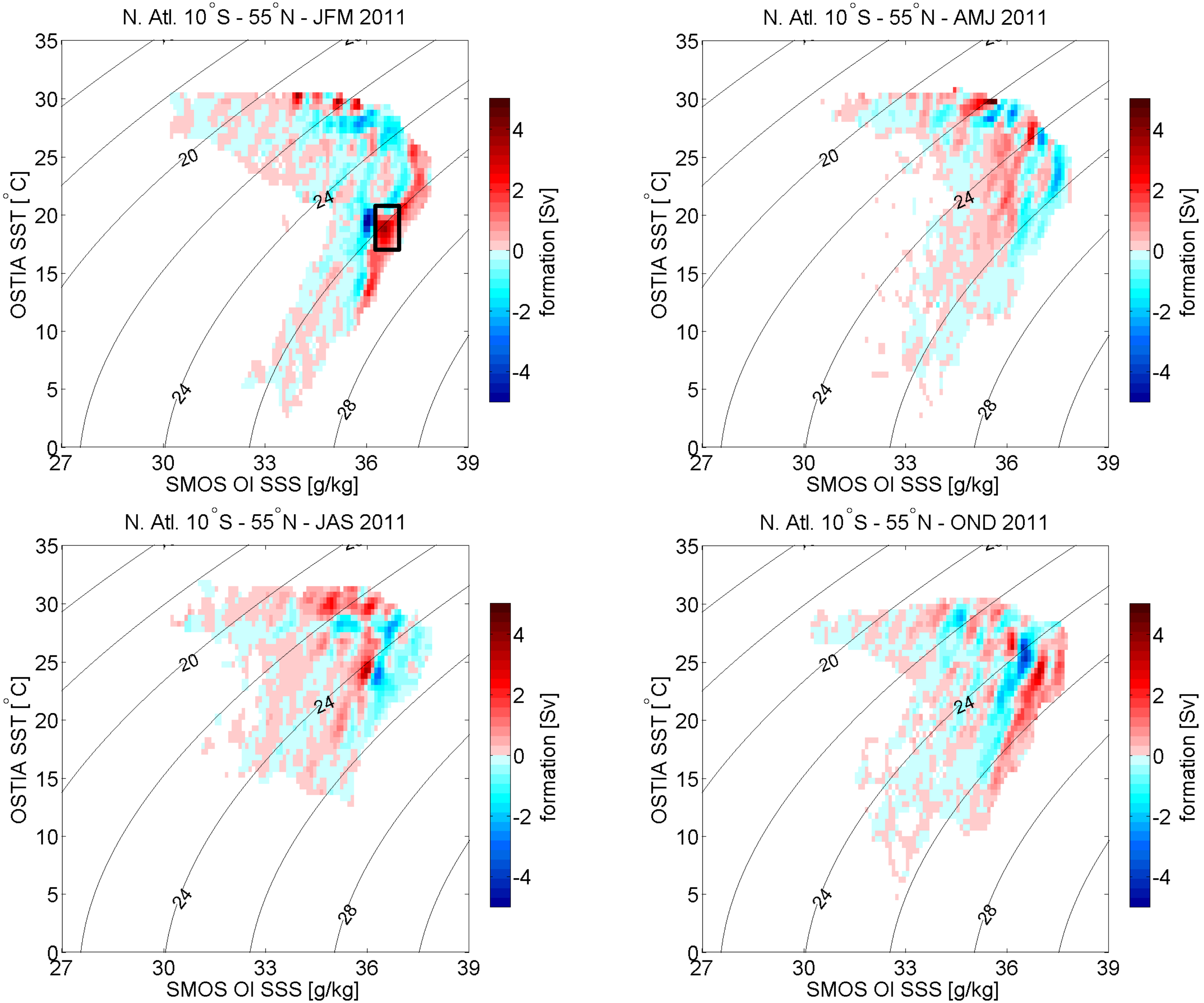
(Trans-)Formation in T-S space



Transformation

Formation

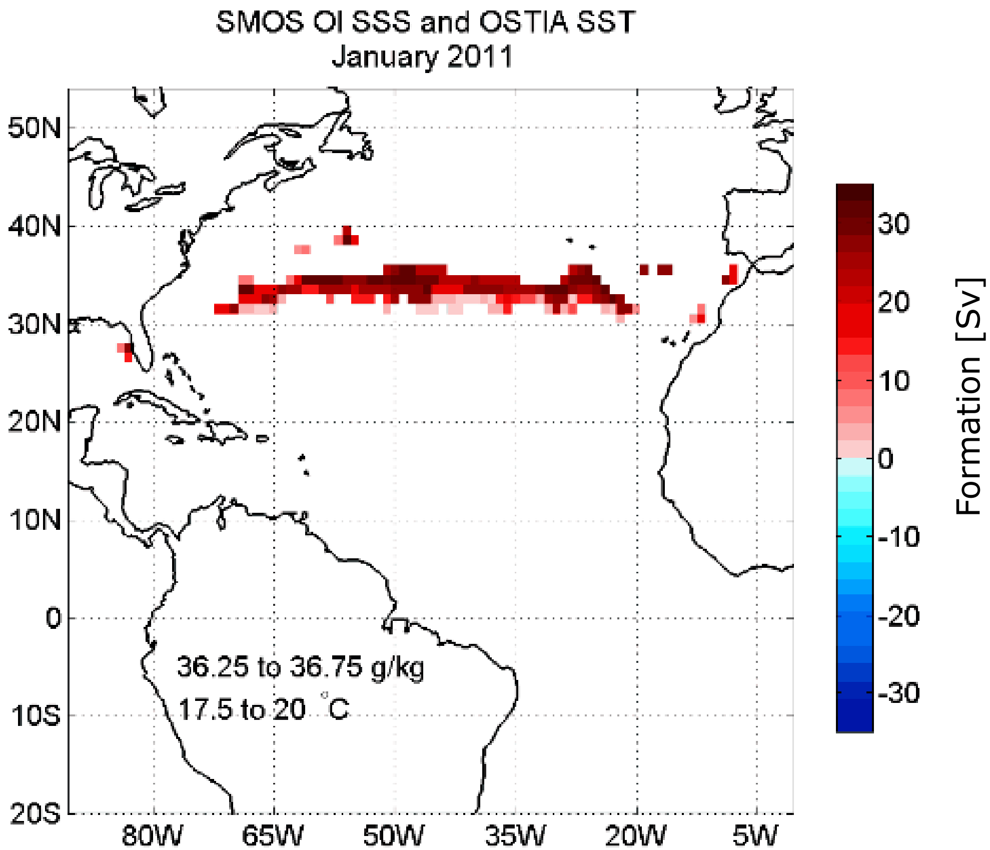
Formation in T-S space (seasonal)

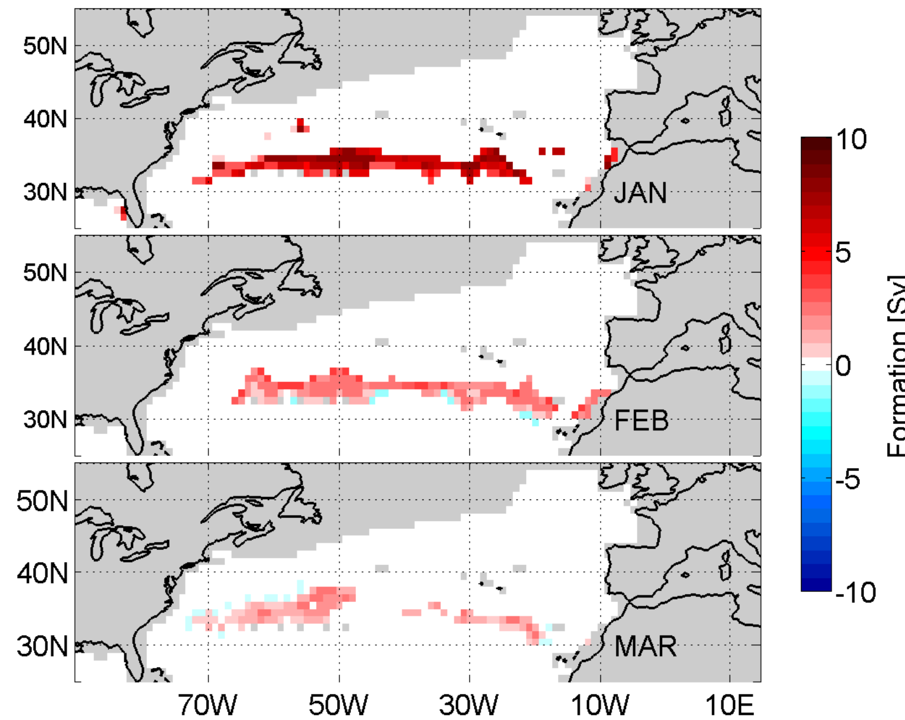


Seasonal Formation

Formation areas

Eighteen degree water
(36.25 to 36.75 psu and 17.5 to 19.5°C





January to March 2011
(evolution of the formation peaks)

Discussion and outlook

- Good **qualitative agreement** with literature; quantitative comparison is subject to current efforts, besides extension to **additional ocean basins**.
- The method is not taking into account **advection/mixing** processes.
- Uncertainties associated with the choice of the input data need to be assessed further and quantified.
- This approach allows to pinpoint the range of SST and SSS in the T-S diagrams where a specific **water mass** is formed. Known water masses can be **identified** and their formation **traced** in time and space.
- The geographical representation of these points, ultimately, allows to provide a relevant temporal series of the spatial extent of the water masses **formation areas**.
- Longer time series will contribute to the understanding of the **temporal variability** in water mass formation (both in T-S and geographical domains).
- Future work aims at exploring additional datasets and at connecting the surface information to the **vertical structure** and to **buoyancy-driven** ocean circulation processes.

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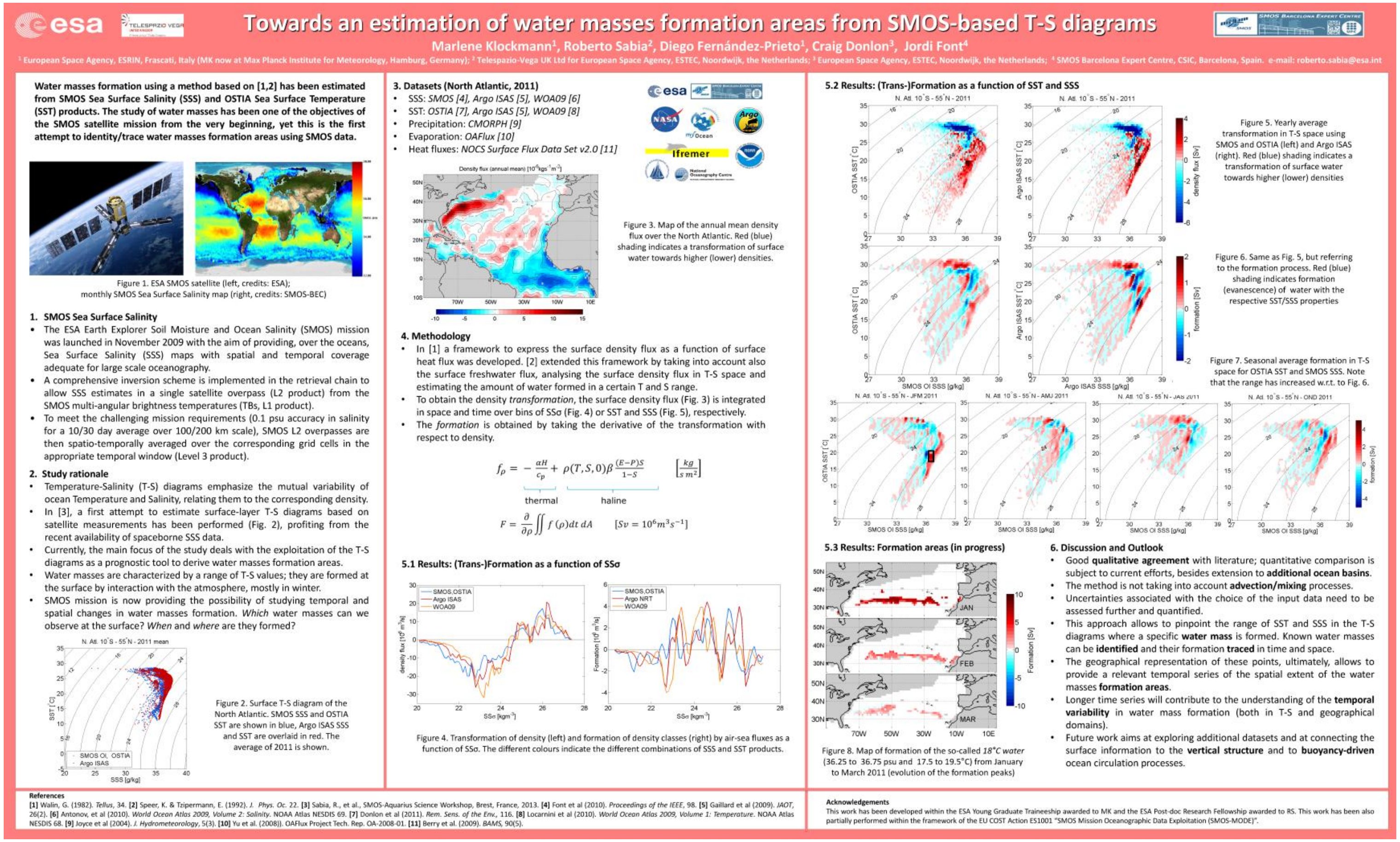
Feel free to pass by…

Poster B946 (EGU2014-15423) – Klockmann et al. (Mo 28.04: 17.30-19.00)



Towards an estimation of water masses formation areas from SMOS-based T-S diagrams

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Water masses formation using a method based on [1,2] has been estimated from SMOS Sea Surface Salinity (SSS) and OSTIA Sea Surface Temperature (SST) products. The study of water masses has been one of the objectives of the SMOS satellite mission from the very beginning, yet this is the first attempt to identity/trace water masses formation areas using SMOS data.

Figure 1. ESA SMOS satellite (left, credits: ESA); monthly SMOS Sea Surface Salinity map (right, credits: SMOS-BEC)

1. SMOS Sea Surface Salinity

- The ESA Earth Explorer Soil Moisture and Ocean Salinity (SMOS) mission was launched in November 2009 with the aim of providing, over the oceans, Sea Surface Salinity (SSS) maps with spatial and temporal coverage adequate for large scale oceanography.
- A comprehensive inversion scheme is implemented in the retrieval chain to allow SSS estimates in a single satellite overpass (L2 product) from the SMOS multi-angular brightness temperatures (TBs, L1 product).
- To meet the challenging mission requirements (0.1 psu accuracy in salinity for a 10/30 day average over 100/200 km scale), SMOS L2 overpasses are then spatio-temporally averaged over the corresponding grid cells in the appropriate temporal window (Level 3 product).

2. Study rationale

- Temperature-Salinity (T-S) diagrams emphasize the mutual variability of ocean Temperature and Salinity, relating them to the corresponding density.
- In [3], a first attempt to estimate surface-layer T-S diagrams based on satellite measurements has been performed (Fig. 2), profiting from the recent availability of spaceborne SSS data.
- Currently, the main focus of the study deals with the exploitation of the T-S diagrams as a prognostic tool to derive water masses formation areas.
- Water masses are characterized by a range of T-S values; they are formed at the surface by interaction with the atmosphere, mostly in winter.
- SMOS mission is now providing the possibility of studying temporal and spatial changes in water masses formation. *Which* water masses can we observe at the surface? *When* and *where* are they formed?

Figure 2. Surface T-S diagram of the North Atlantic. SMOS SSS and OSTIA SST are shown in blue, Argo ISAS SSS and SST are overlaid in red. The average of 2011 is shown.

3. Datasets (North Atlantic, 2011)

- SSS: *SMOS [4], Argo ISAS [5], WOA09 [6]*
- SST: *OSTIA [7], Argo ISAS [5], WOA09 [8]*
- Precipitation: *CMORPH [9]*
- Evaporation: *OAFlux [10]*
- Heat fluxes: *NOCS Surface Flux Data Set v2.0 [11]*

Figure 3. Map of the annual mean density flux over the North Atlantic. Red (blue) shading indicates a transformation of surface water towards higher (lower) densities.

4. Methodology

- In [1] a framework to express the surface density flux as a function of surface heat flux was developed. [2] extended this framework by taking into account also the surface freshwater flux, analysing the surface density flux in T-S space and estimating the amount of water formed in a certain T and S range.
- To obtain the density *transformation*, the surface density flux (Fig. 3) is integrated in space and time over bins of SSσ (Fig. 4) or SST and SSS (Fig. 5), respectively.
- The *formation* is obtained by taking the derivative of the transformation with respect to density.

$$f_\rho = \underbrace{-\frac{\alpha H}{c_p}}_{\text{thermal}} + \underbrace{\rho(T,S,0)\beta\frac{(E-P)S}{1-S}}_{\text{haline}} \qquad \left[\frac{kg}{s\,m^2}\right]$$

$$F = \frac{\partial}{\partial\rho}\iint f(\rho)dt\,dA \qquad [Sv = 10^6 m^3 s^{-1}]$$

5.1 Results: (Trans-)Formation as a function of SSσ

Figure 4. Transformation of density (left) and formation of density classes (right) by air-sea fluxes as a function of SSσ. The different colours indicate the different combinations of SSS and SST products.

5.2 Results: (Trans-)Formation as a function of SST and SSS

Figure 5. Yearly average transformation in T-S space using SMOS and OSTIA (left) and Argo ISAS (right). Red (blue) shading indicates a transformation of surface water towards higher (lower) densities

Figure 6. Same as Fig. 5, but referring to the formation process. Red (blue) shading indicates formation (evanescence) of water with the respective SST/SSS properties

Figure 7. Seasonal average formation in T-S space for OSTIA SST and SMOS SSS. Note that the range has increased w.r.t. to Fig. 6.

5.3 Results: Formation areas (in progress)

Figure 8. Map of formation of the so-called *18°C water* (36.25 to 36.75 psu and 17.5 to 19.5°C) from January to March 2011 (evolution of the formation peaks)

6. Discussion and Outlook

- Good **qualitative agreement** with literature; quantitative comparison is subject to current efforts, besides extension to **additional ocean basins**.
- The method is not taking into account **advection/mixing** processes.
- Uncertainties associated with the choice of the input data need to be assessed further and quantified.
- This approach allows to pinpoint the range of SST and SSS in the T-S diagrams where a specific **water mass** is formed. Known water masses can be **identified** and their formation **traced** in time and space.
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- Future work aims at exploring additional datasets and at connecting the surface information to the **vertical structure** and to **buoyancy-driven** ocean circulation processes.

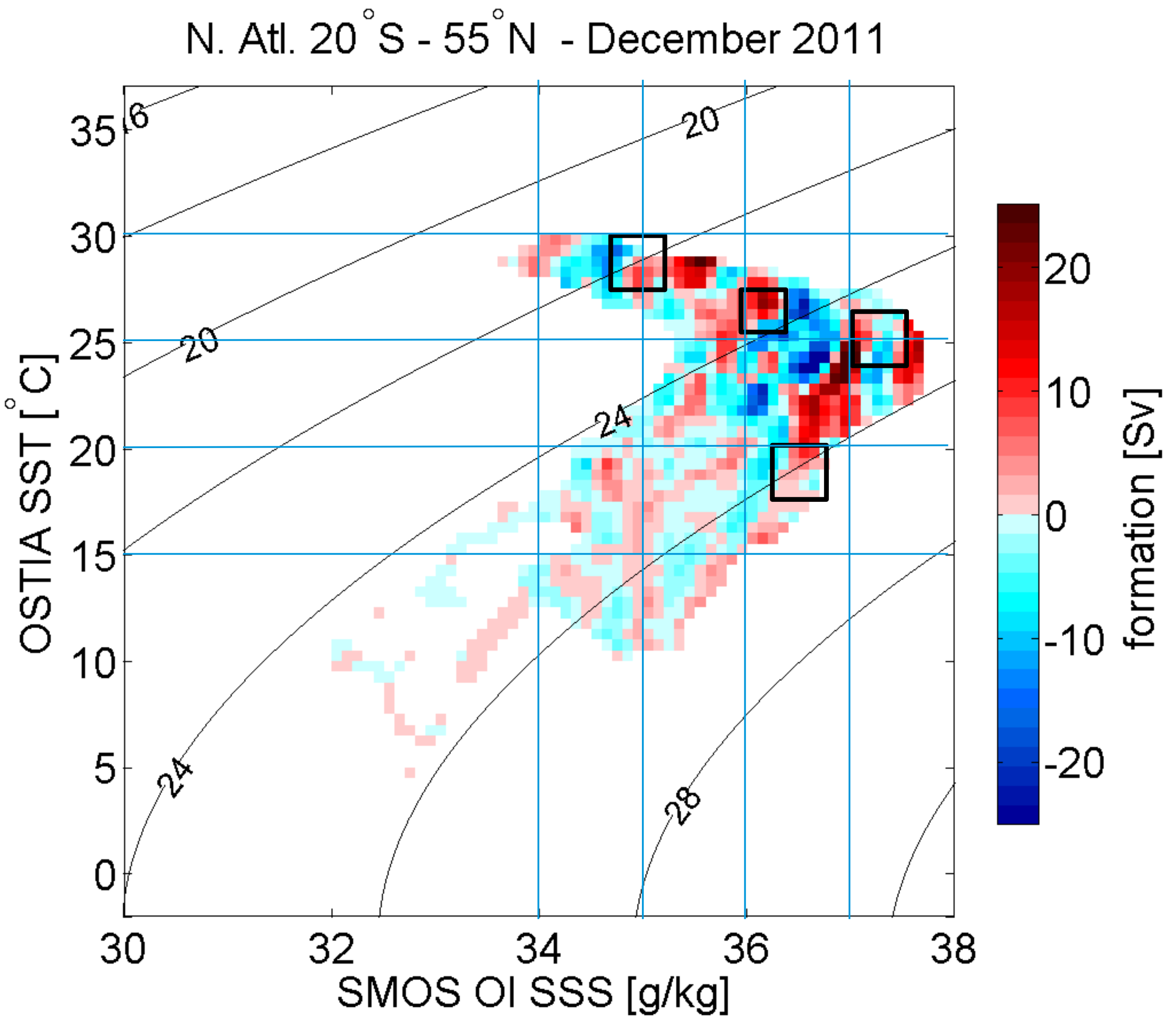
References
[1] Walin, G. (1982). *Tellus*, 34. [2] Speer, K. & Tzipermann, E. (1992). *J. Phys. Oc.* 22. [3] Sabia, R., et al., SMOS-Aquarius Science Workshop, Brest, France, 2013. [4] Font et al (2010). *Proceedings of the IEEE*, 98. [5] Gaillard et al (2009). *JAOT*, 26(2). [6] Antonov, et al (2010). *World Ocean Atlas 2009, Volume 2: Salinity*. NOAA Atlas NESDIS 69. [7] Donlon et al (2011). *Rem. Sens. of the Env.*, 116. [8] Locarnini et al (2010). *World Ocean Atlas 2009, Volume 1: Temperature*. NOAA Atlas NESDIS 68. [9] Joyce et al (2004). *J. Hydrometeorology*, 5(3). [10] Yu et al. (2008)). OAFlux Project Tech. Rep. OA-2008-01. [11] Berry et al. (2009). *BAMS*, 90(5).

Acknowledgements
This work has been developed within the ESA Young Graduate Traineeship awarded to MK and the ESA Post-doc Research Fellowship awarded to RS. This work has been also partially performed within the framework of the EU COST Action ES1001 "SMOS Mission Oceanographic Data Exploitation (SMOS-MODE)".

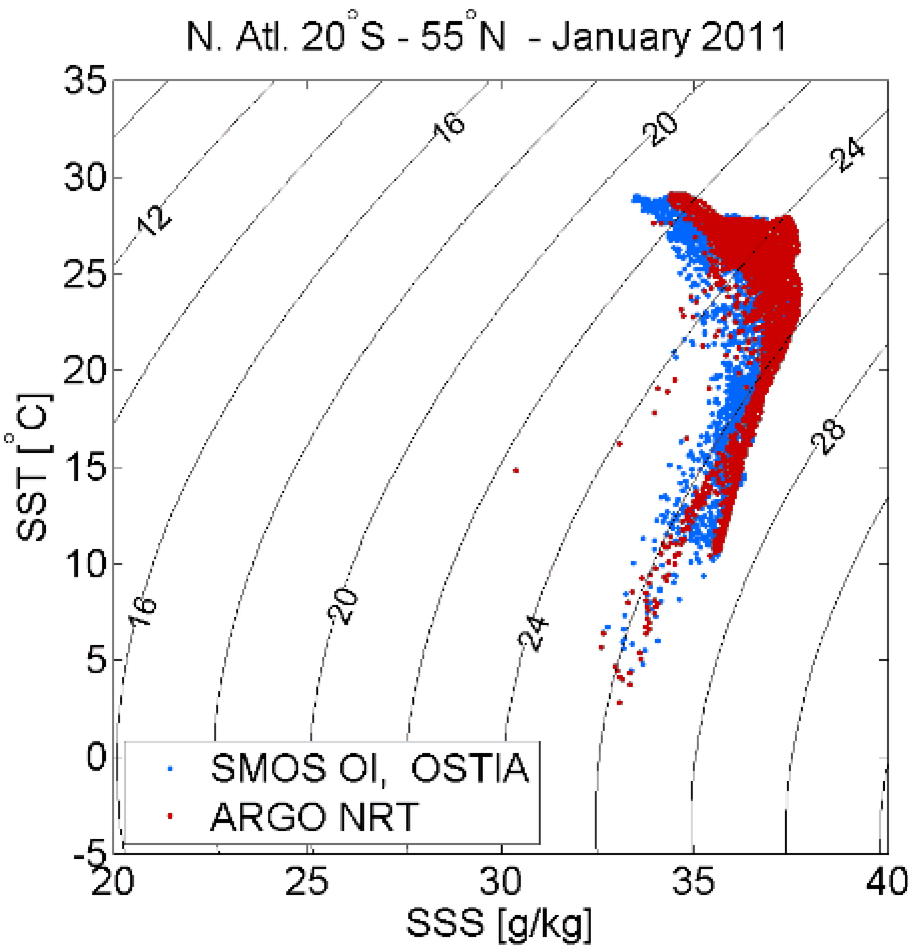
Thank you

Back-up slides

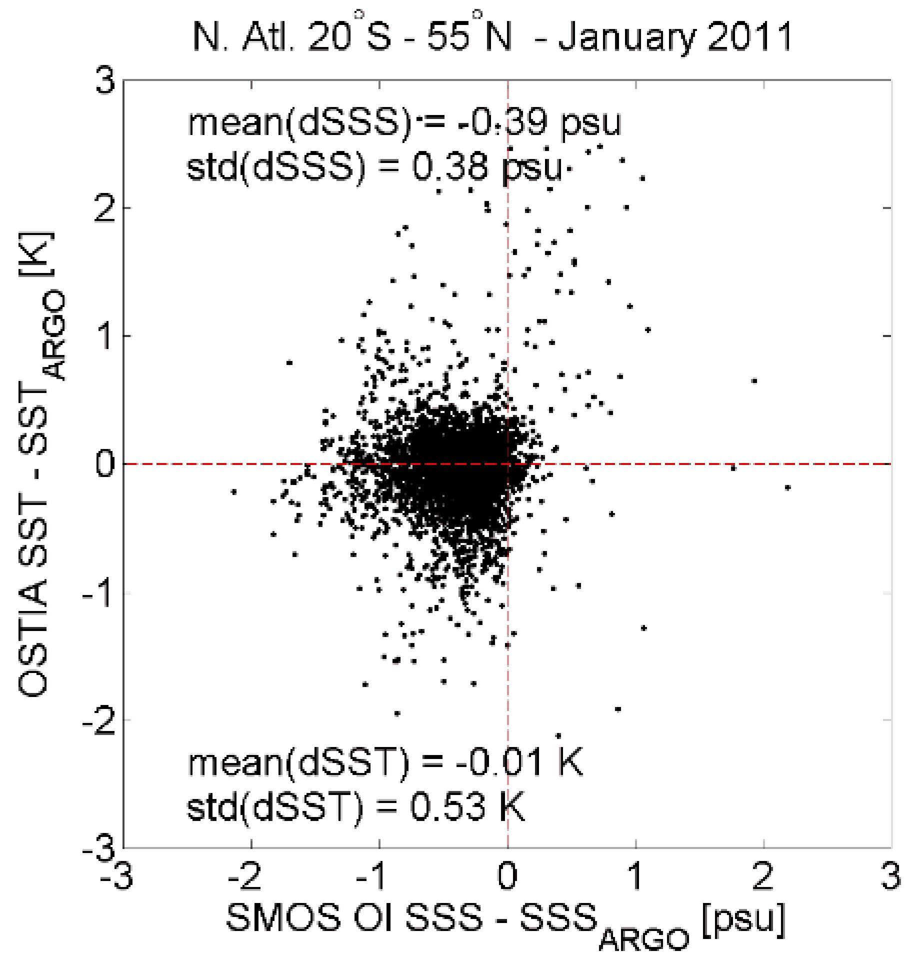
Specific water masses – monthly means



T-S diagrams

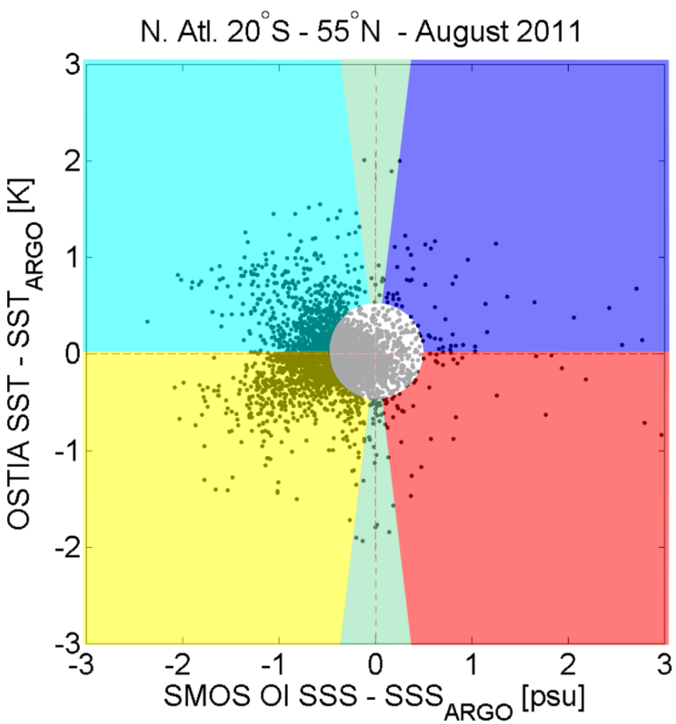


N. Atl. 20°S - 55°N - January 2011
SST [°C]
SSS [g/kg]
SMOS OI, OSTIA
ARGO NRT

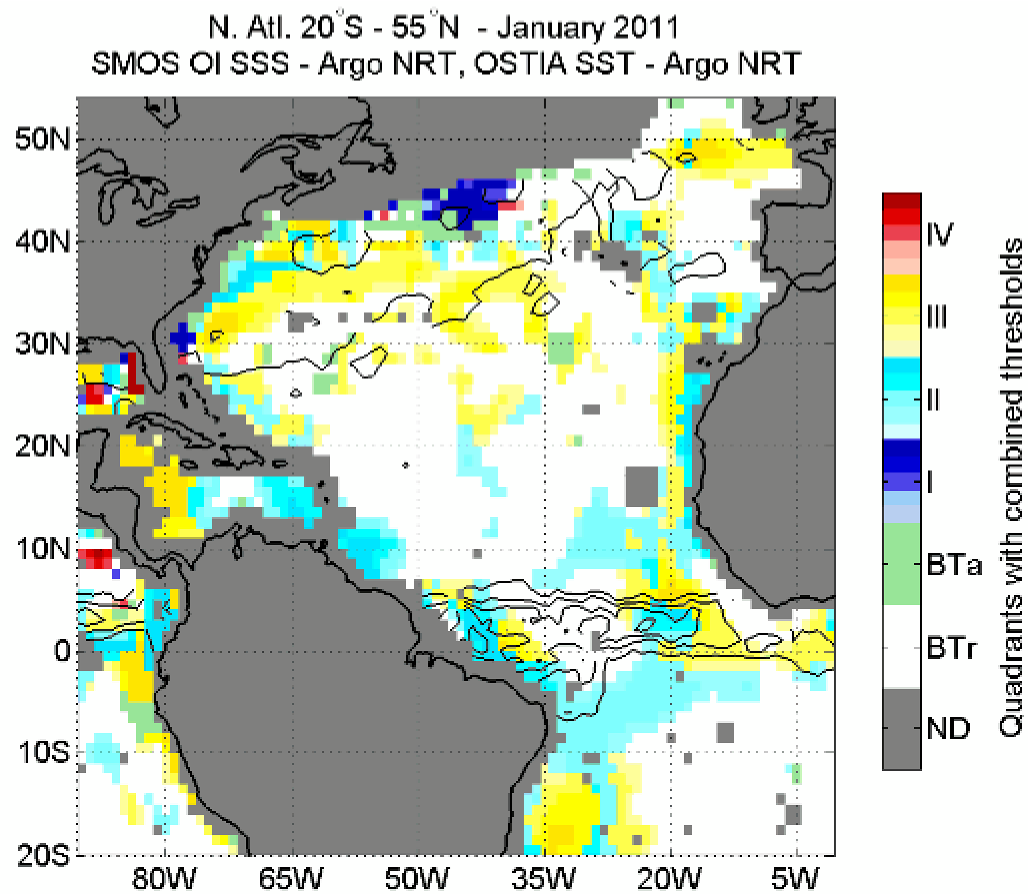


N. Atl. 20°S - 55°N - January 2011
mean(dSSS) = -0.39 psu
std(dSSS) = 0.38 psu
mean(dSST) = -0.01 K
std(dSST) = 0.53 K
OSTIA SST - SST$_{ARGO}$ [K]
SMOS OI SSS - SSS$_{ARGO}$ [psu]

Mismatches

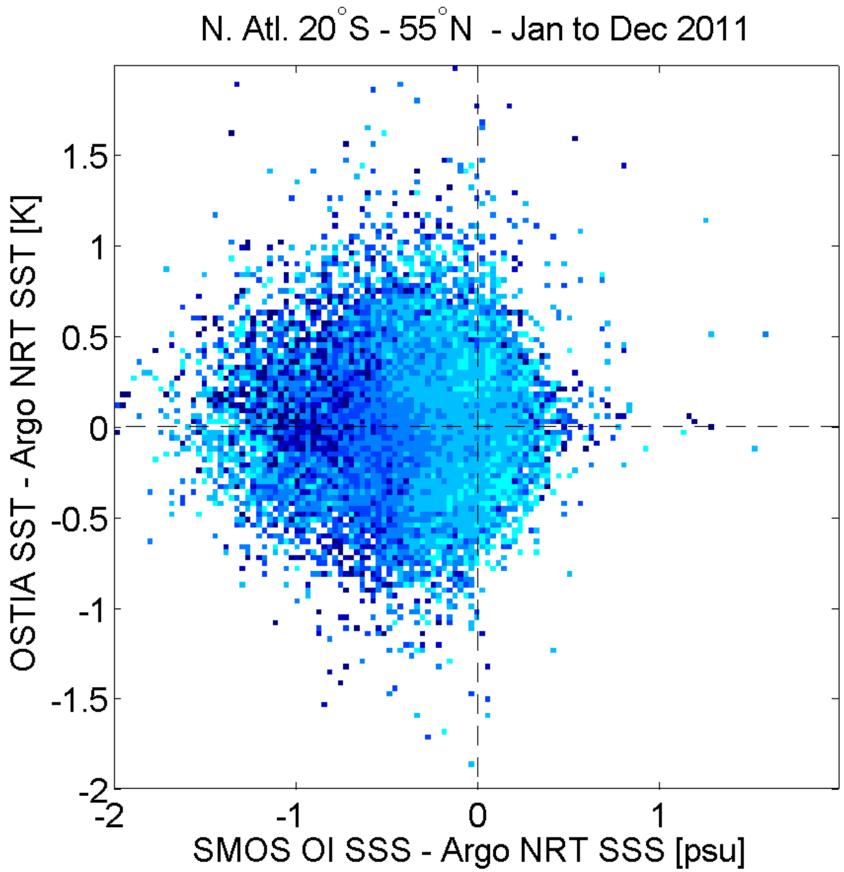


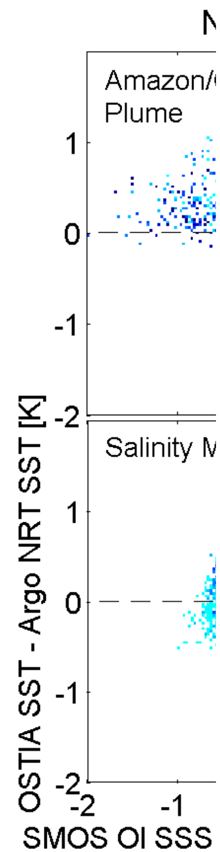
N. Atl. 20°S - 55°N - August 2011
OSTIA SST - SST_{ARGO} [K]
SMOS OI SSS - SSS_{ARGO} [psu]

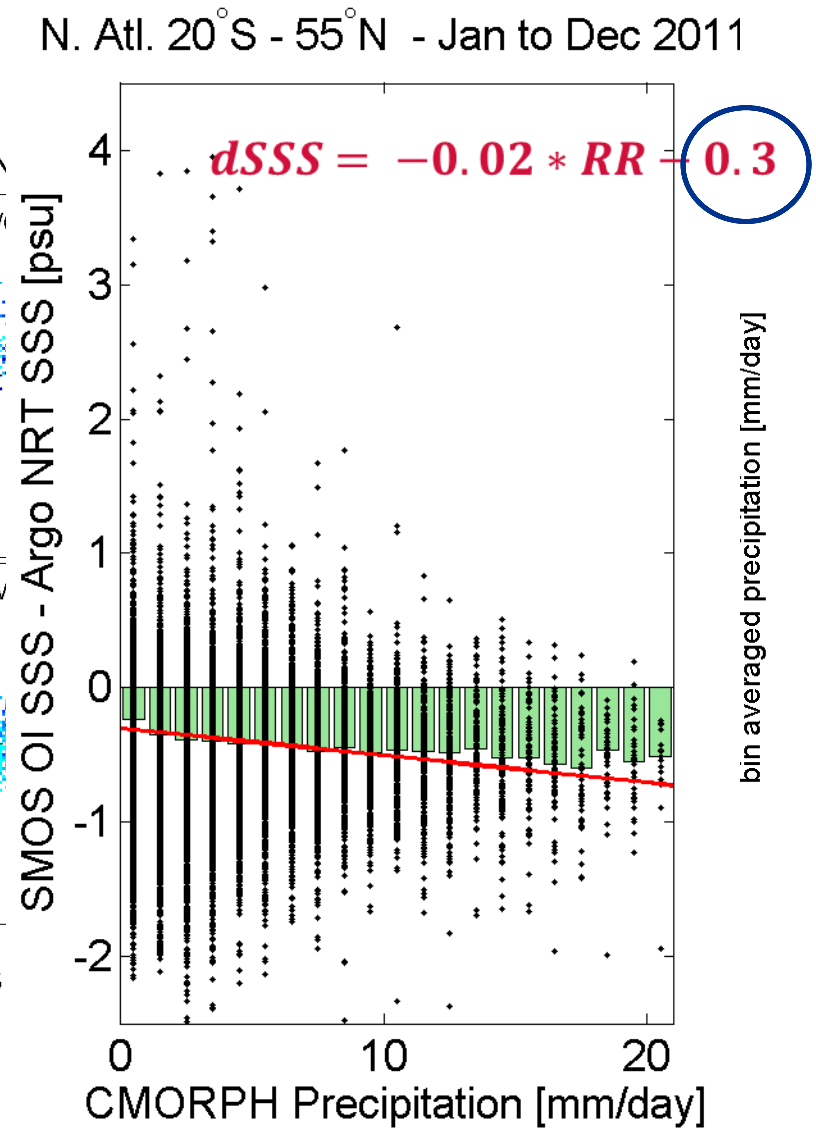


N. Atl. 20°S - 55°N - January 2011
SMOS OI SSS - Argo NRT, OSTIA SST - Argo NRT
IV
III
II
I
BTa
BTr
ND
Quadrants with combined thresholds

Effect of precipitation

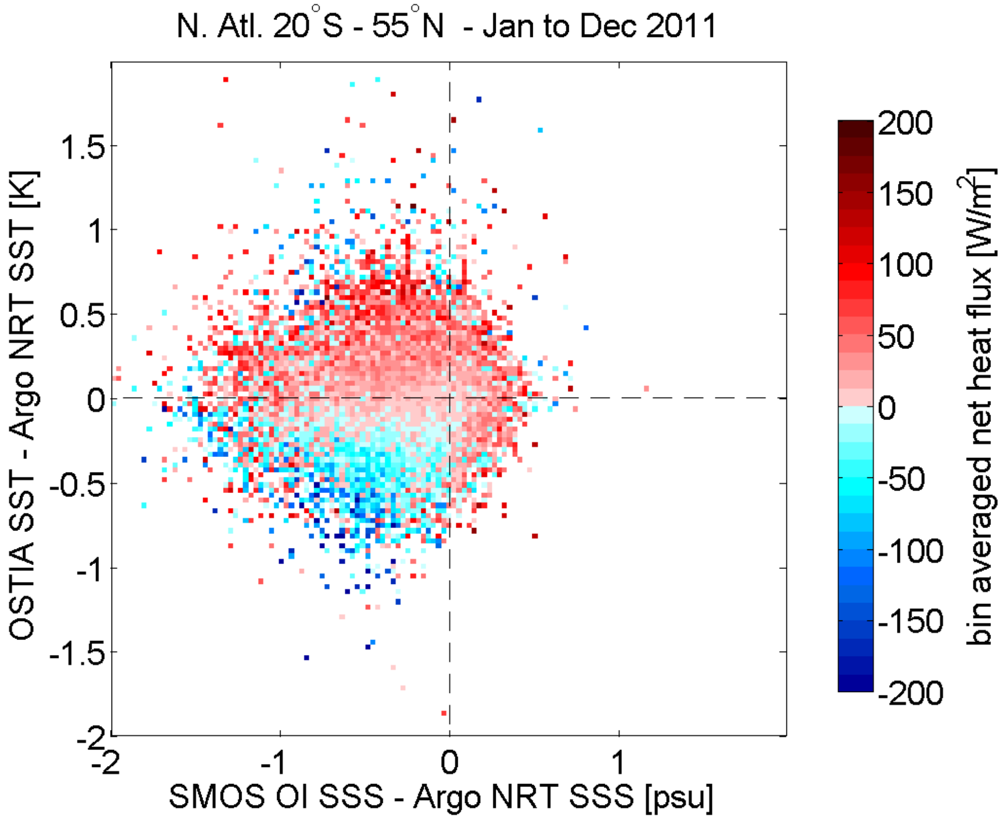






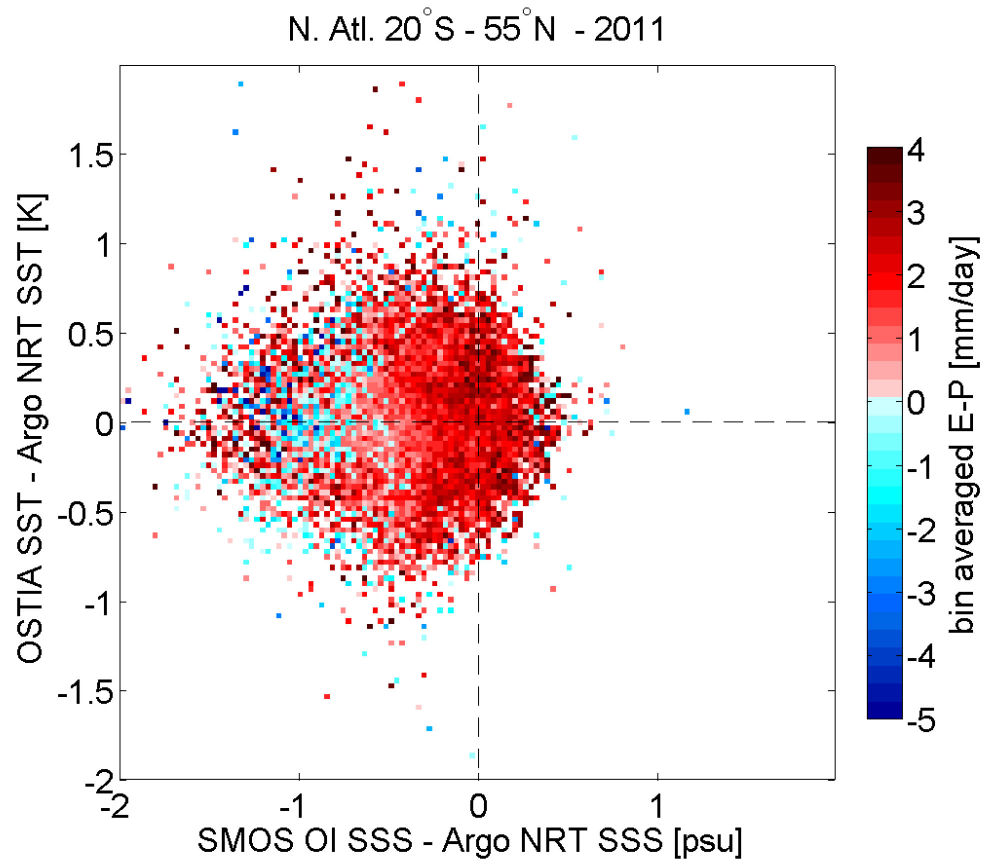
Effect of net heat and freshwater fluxes

Net heat flux



Mainly affects dSST

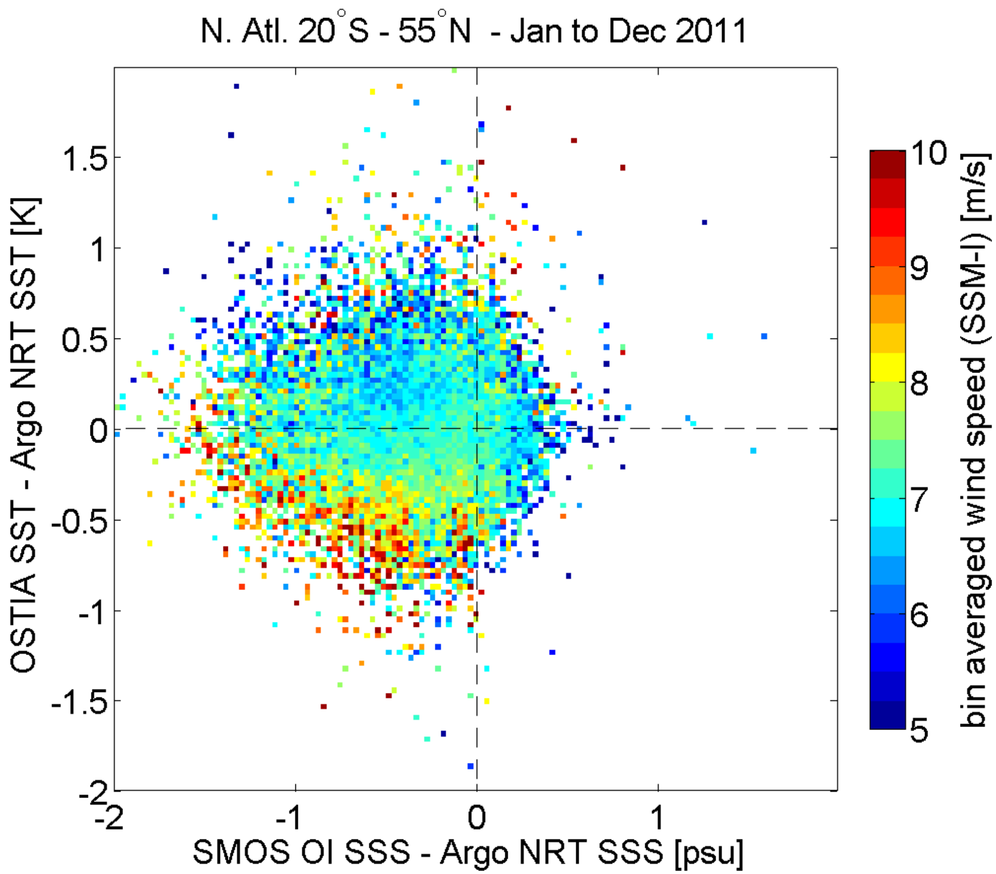
Net freshwater flux



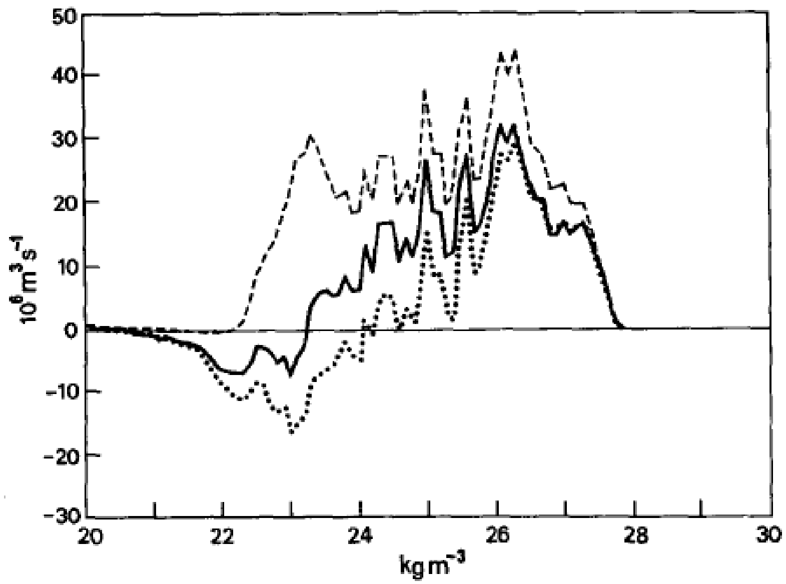
Mainly affects dSSS

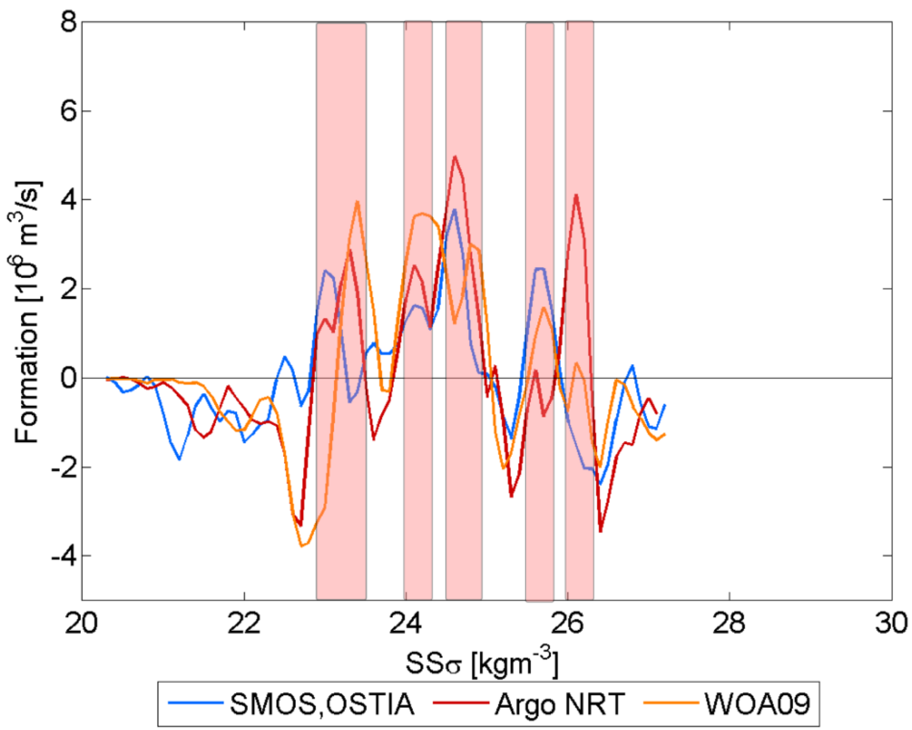
Effect of wind speed

SSM/I



Trans- to Formation





Speer & Tzipermann (1992)