OMARSAT 2017, IEAPM, Arraial do Cabo, 3-6 October 2017

Observing System Evaluation Experiments with the REMO ocean data assimilation system (RODAS) and HYCOM in the Atlantic

Clemente A. S. Tanajura[1,2], Davi Mignac[1,3], Alex N. Santana[1,4], Filipe B. Costa[1], Leonardo N. Lima[1,5], Rafael C. Santana[1], Geoff Dorfschafer[1], Vitor Vidal[1], Jiang Zhu[6]

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Content

- What is REMO?
- Data assimilation under REMO (HYCOM+RODAS)
- Observing System Evaluation (OSE) in the Atlantic
- Final considerations

REMO is a research group

Research and technological development in operational oceanography (OO) and physical oceanography with focus on the South Atlantic and regions along the Brazilian coast using assimilative models and observational data. It was formed in 2007.

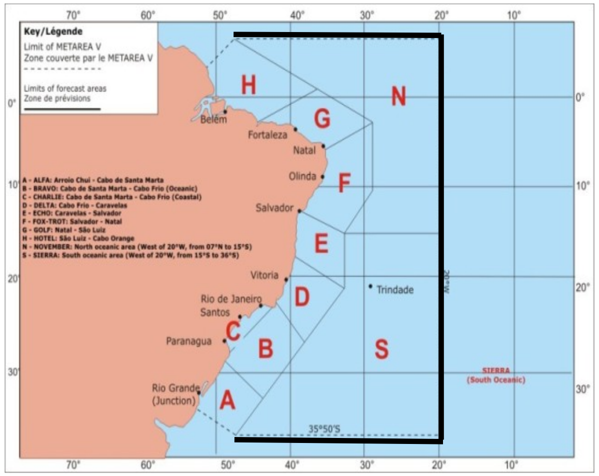
Products:

– Ocean weather forecasts

– Hydrodynamic databases (reanlayses)

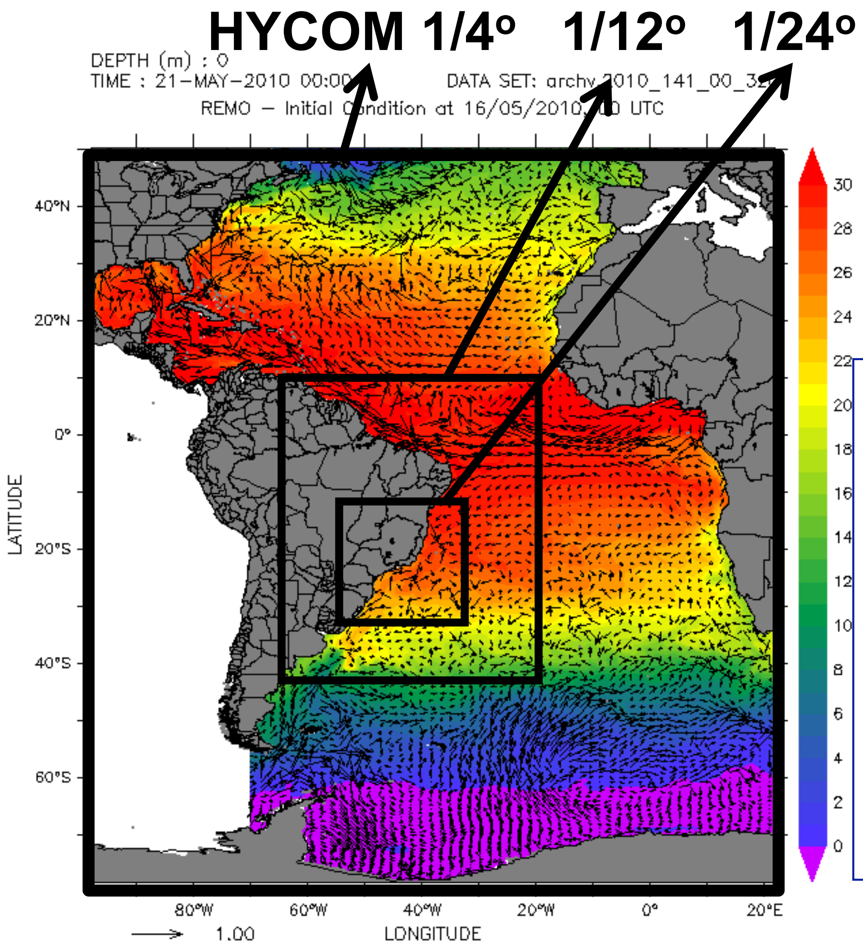
– In situ observational data

www.rederemo.org



Modeling and Data Assimilation in REMO

Large-scale circulation in the Atlantic and downscaling to METAREA V and region along the Brazilian S-SE coast in the Brazilian Navy CHM operational system.



Temperatura e Correntes Superficiais

Brazilian Navy Hydrography Center (CHM) Operational System

- 3-5 day forecasts
- Simplified version of the REMO Ocean Data Assimilation System
- Assimilation of only OSTIA SST and AVISO SLA
- Dissemination by the CHM web page and the REMO web page

Benefits of Data Assimilation

In addition to producing the forecast model initial condition, data assimilation is employed to

- Climate studies / variability studies
- Observing System Evaluation (OSE)
- Observing System Simulation Experiments (OSSE)

Ensemble Optimal Interpolation (EnOI)

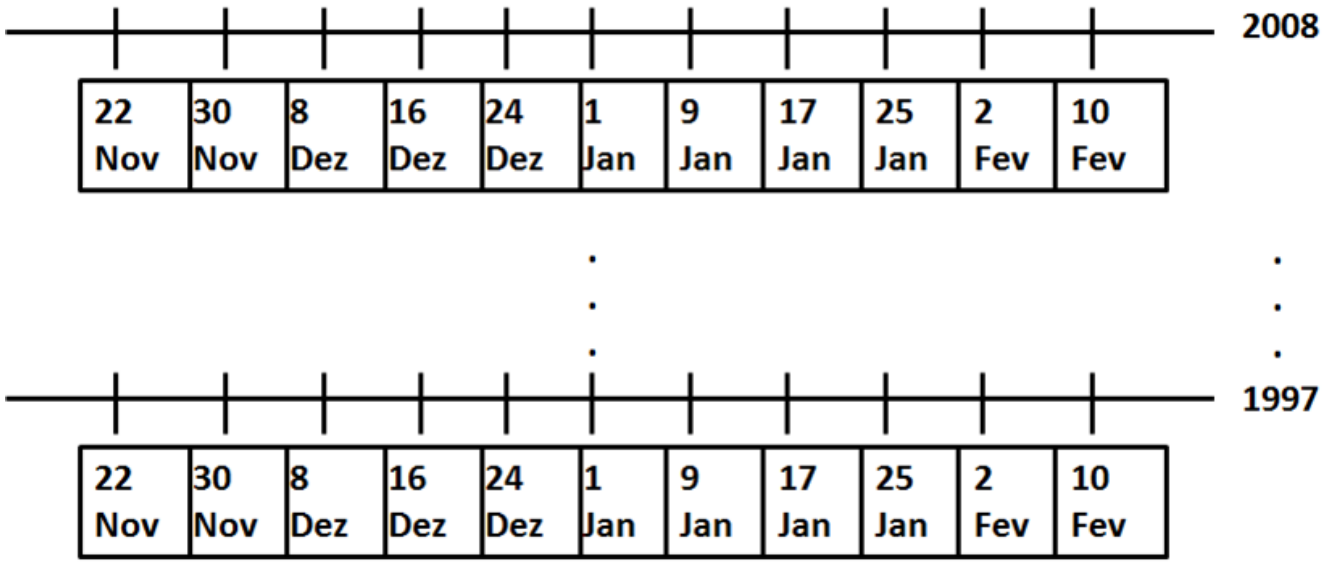
In the EnOI, *B* is estimated with model states from a free run

$$x_a = x_b + K(y - Hx_b)$$

$$K = BH^T(HBH^T + R)^{-1}$$

$$B = \sigma \circ \frac{\alpha}{M-1}\sum_{m\neq 1}^{M}(x_b^m - \langle x_b \rangle)(x_b^m - \langle x_b \rangle)^{\mathrm{T}}$$

Based on the EnOI the **REMO Ocean Data Assimilation System (RODAS) was constructed** but the ensemble members are not static, they depend on the day of the assimilation (*Xie and Zhu 2010, Tanajura et al 2014, Mignac et al 2015)*



A long road to reach RODAS

ELSEVIER

Applied Mathematical Modelling 000 (2001) 000–000

APPLIED MATHEMATICAL MODELLING

www.elsevier.nl/locate/apm

A data assimilation method used with an ocean circulation model and its application to the tropical atlantic

Konstantin P. Belyaev [a], Clemente A.S. Tanajura [a,*], James J. O'Brien [b]

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A long road to reach RODAS

Revista Brasileira de Geofísica
RBGf
Brazilian Journal of Geophysics

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ISSN 0102-261X
www.scielo.br/rbg

ASSIMILATION OF SEA SURFACE HEIGHT ANOMALIES INTO HYCOM WITH AN OPTIMAL INTERPOLATION SCHEME OVER THE ATLANTIC OCEAN METAREA V

Clemente Augusto Souza Tanajura[1,2], Filipe Bitencourt Costa[2], Renato Ramos da Silva[2,3], Giovanni Abdelnur Ruggiero[4] and Victor Bastos Daher[5]

ABSTRACT. Along-track sea surface height anomaly (SSHA) data from the Jaso
1, 2009 until December 31, 2009. A new and simple approach to overcome the bias
differences between the data and the model along each satellite track. An optimal in
to produce a SSHA analysis field and to adjust model layer thicknesses over the A
next assimilation cycle. SSHA data with a 7-day window were assimilated in 3-day
the SSHA analysis. A control run without assimilation was also performed. The
experiment. The modifications of SSHA were compared to the American Navy HY
0.2 m by assimilation. Comparisons were also made with the Argo temperature an
also produced by assimilation. The impact in temperature was in general positive,

Keywords: ocean data assimilation, Jason-1 and Jason-2 satellites, Argo.

Revista Brasileira de Geofísica
RBGf
Brazilian Journal of Geophysics

Revista Brasileira de Geofísica (2013) 31(2): 271-288

ISSN 0102-261X
www.scielo.br/rbg

A STUDY OF THE IMPACT OF ALTIMETRY DATA ASSIMILATION ON SHORT-TERM PREDICTABILITY OF THE HYCOM OCEAN MODEL IN REGIONS OF THE TROPICAL AND SOUTH ATLANTIC OCEAN

Leonardo Nascimento Lima[1] and Clemente Augusto Souza Tanajura[1,2]

ABSTRACT. In this study, assimilation of Jason-1 and Jason-2 along-track sea level anomaly (SLA) data was conducted in a region of the tropical and South Atlantic (7°N-36°S, 20°W up to the Brazilian coast) using an optimal interpolation method and the HYCOM (Hybrid Coordinate Ocean Model). Four 24 h-forecast experiments were performed daily from January 1 until March 31, 2011 considering different SLA assimilation data windows (1 day and 2 days) and different coefficients in the parameterization of the SLA covariance matrix model. The model horizontal resolution was 1/12° and the number of vertical layers was 21. The SLA analyses added to the mean sea surface height were projected to the subsurface with the Cooper & Haines (1996) scheme. The results showed that the experiment with 2-day window of along-track data and with specific parameterizations of the model SLA covariance error for sub-regions of the METAREA V was the most accurate. It completely reconstructed the model sea surface height and important improvements in the circulation were produced. For instance, there was a substantial improvement in the representation of the Brazil Current and North Brazil Undercurrent. However, since no assimilation of vertical profiles of temperature and salinity and of sea surface temperature was performed, the methodology employed here should be considered only as a step towards a high quality analysis for operational forecasting systems.

A long road to reach RODAS

Journal of Operational Oceanography, 2015
http://dx.doi.org/10.1080/1755876X.2015.1014646

Assimilation of sea-level anomalies and Argo data into HYCOM and its impact on the 24 hour forecasts in the western tropical and South Atlantic

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Argo and along-track sea-level anomaly (SLA) data from satellites were assimilated into the Hybrid Coordinate Ocean Model in the western tropical and South Atlantic Ocean. An optimal interpolation method was employed in the assimilation, and the Cooper and Haines scheme projected the altimetry information into the subsurface. The run with assimilation of SLA and Argo data reduced the root mean square deviation of the 24 h forecasts of SLA, sea surface temperature, and subsurface temperature and salinity by 21.4%, 11.5%, 28.1%, and 15.8%, respectively, with respect to the control run without assimilation. Important improvements were also observed in the circulation.

A long road to reach RODAS

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www.ocean-sci.net/11/195/2015/
doi:10.5194/os-11-195-2015

Ocean Science
Open Access

Argo data assimilation into HYCOM with an EnOI method in the Atlantic Ocean

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A long road to reach RODAS

ATMOSPHERIC AND OCEANIC SCIENCE LETTERS, 2014, VOL. 7, NO. 5, 464–470

The REMO Ocean Data Assimilation System into HYCOM (RODAS_H): General Description and Preliminary Results

Clemente Augusto Souza TANAJURA[1,2,3], Alex Novaes SANTANA[2], Davi MIGNAC[2,4], Leonardo Nascimento LIMA[2], Konstantin BELYAEV[2,5], and XIE Ji-Ping[6]

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Received 11 February 2014; revised 1 March 2014; accepted 10 March 2014; published 16 September 2014

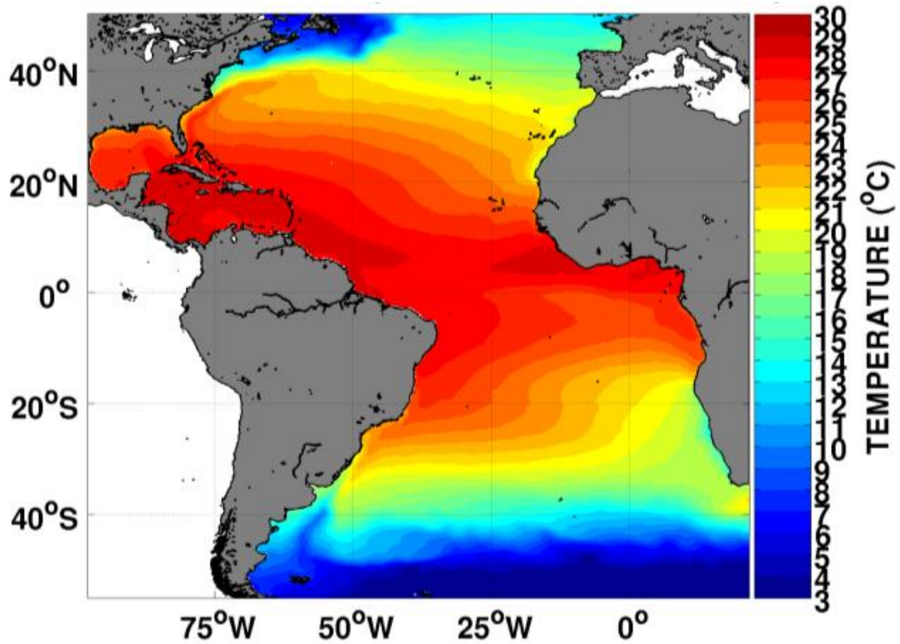
RODAS assimilates UK MetOfffice OSTIA SST

Gridded data with 0.25° resolution

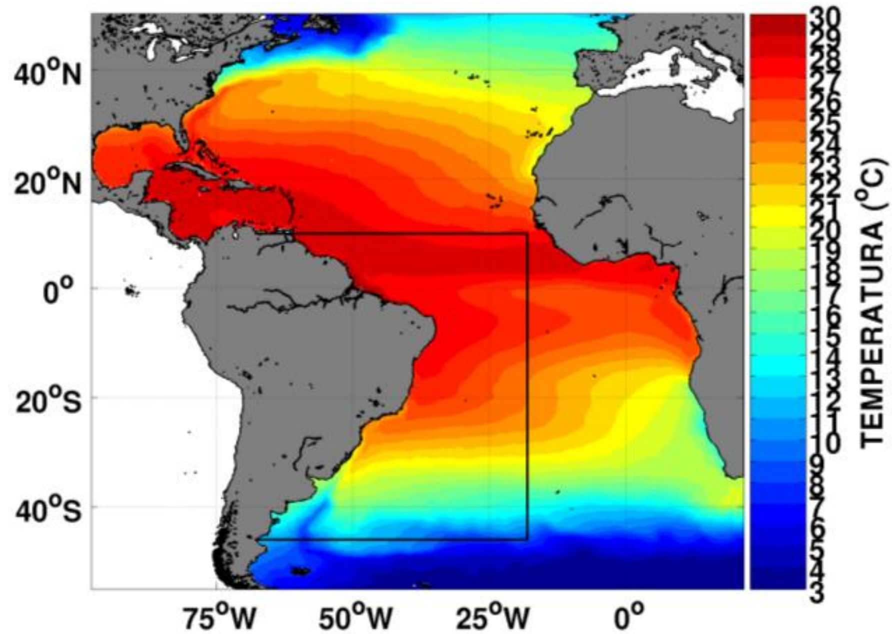
1600 x 2600 ~ 4 M data → superob

Mean SST (°C)
2010-2013

OSTIA

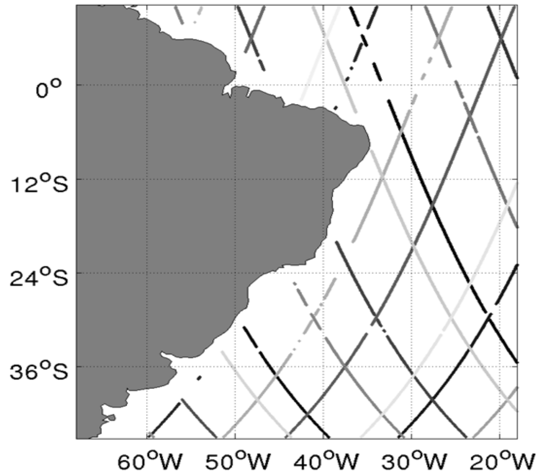


RODAS

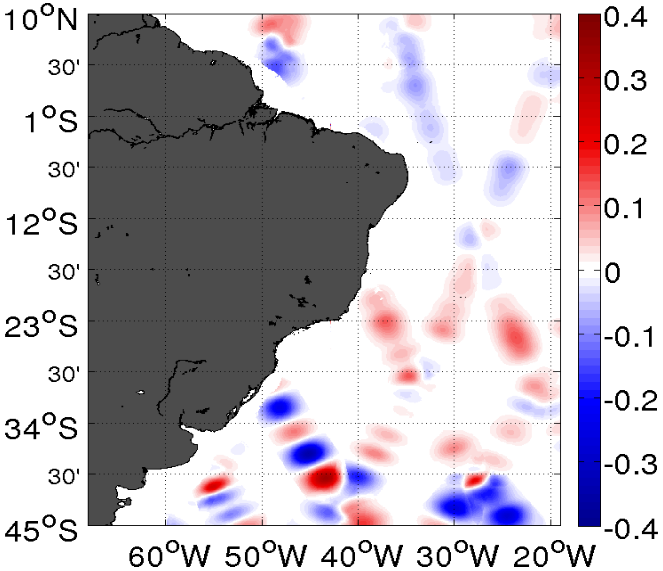


RODAS assimilates sea level anomalies (SLA)

Along-track SLA data (m)

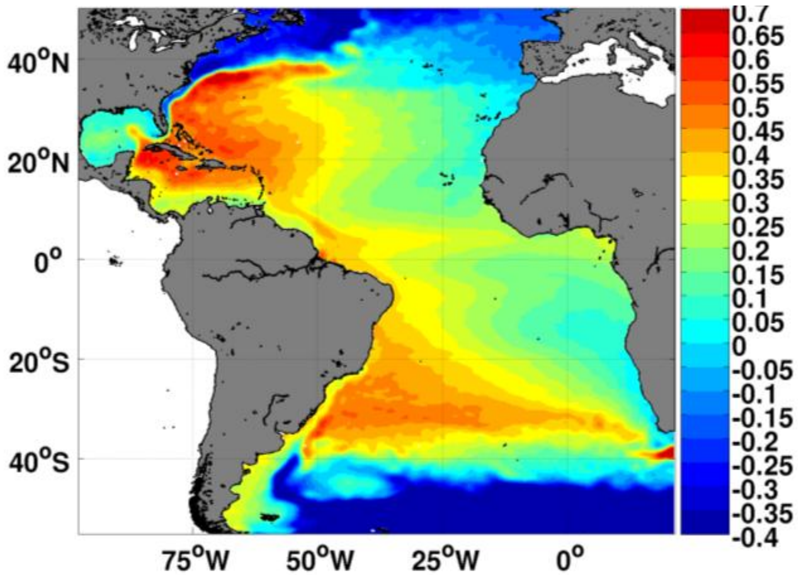


(b) 31/12/2010 e 01/01/2011

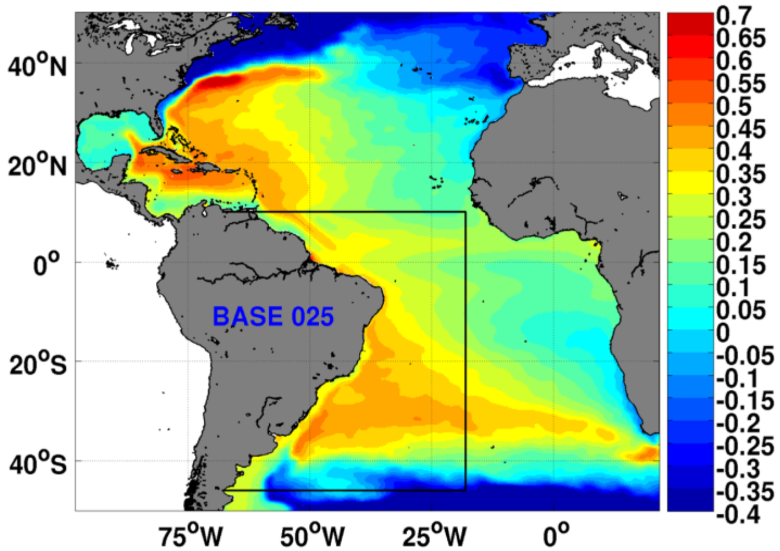


Gridded SLA data

AVISO



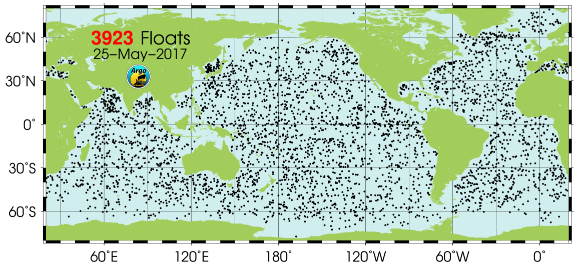
RODAS

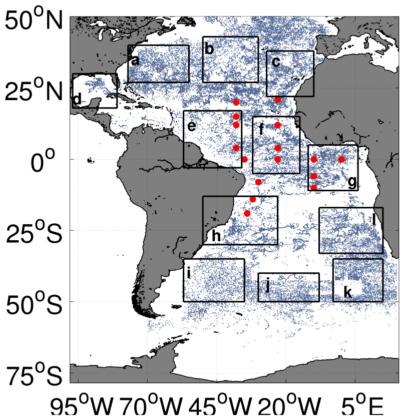


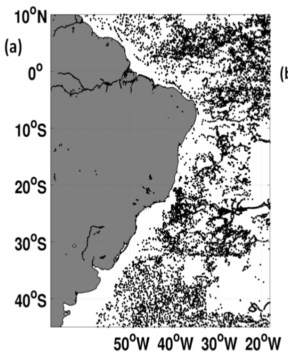
RODAS assimilates Argo T/S profiles

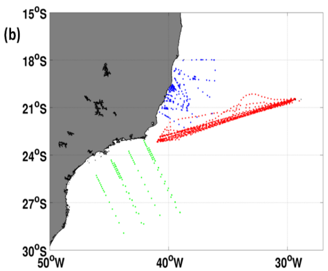
Thacker and Esenkov (2002); Xie and Zhu (2010); Mignac et al. (2015)

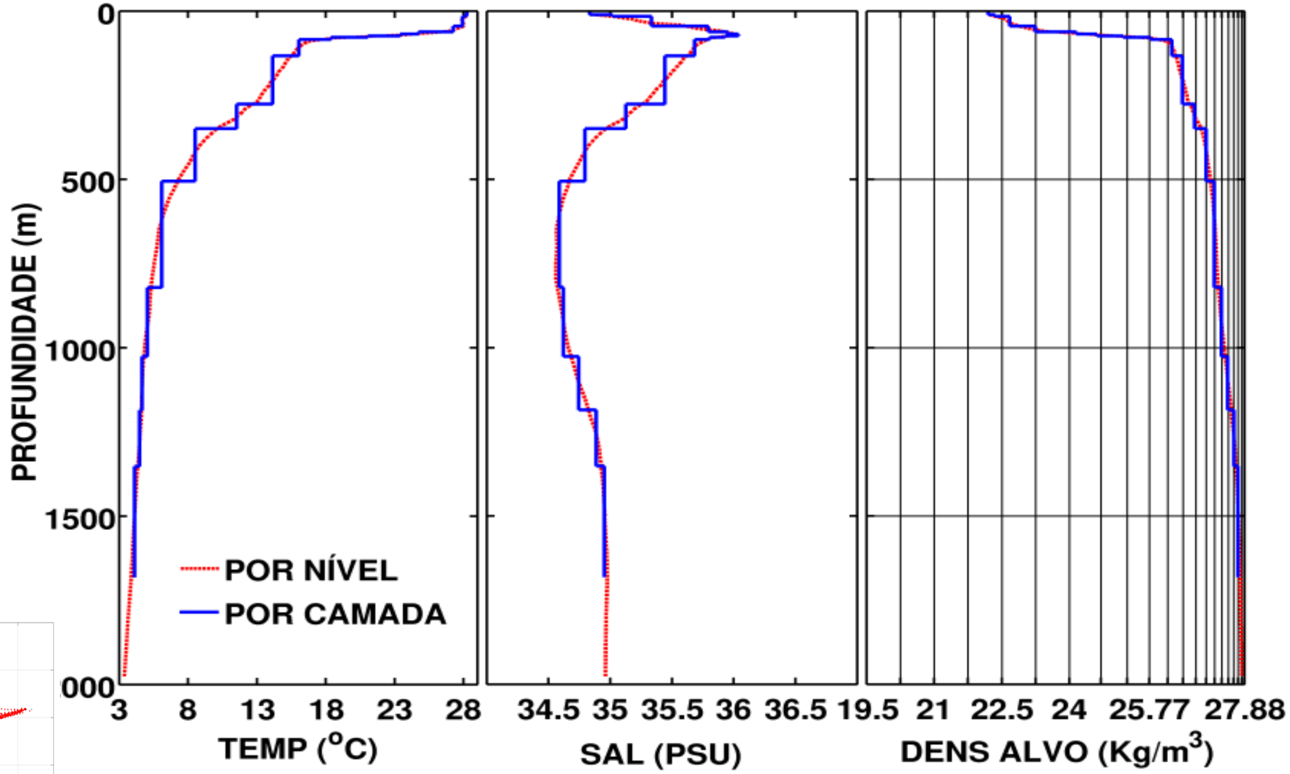
Assimilates pseudo-observations of model layer thickness







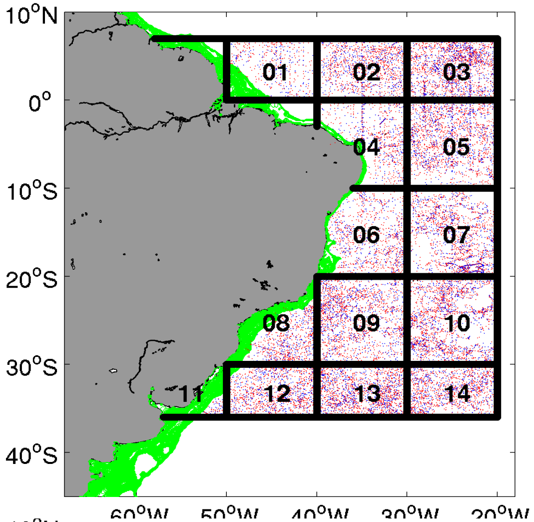


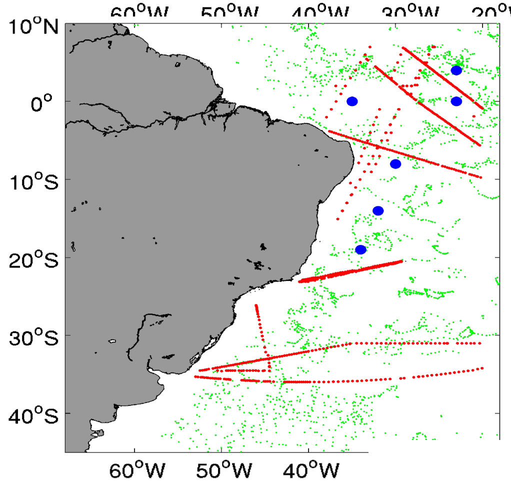


Recently RODAS assimilated XBT and PIRATA data

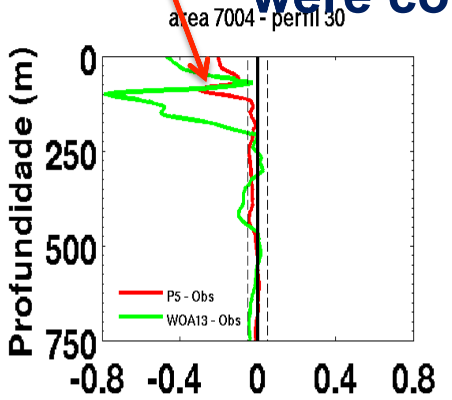
To assimilate T profiles RODAS needs an estimate of Salinity

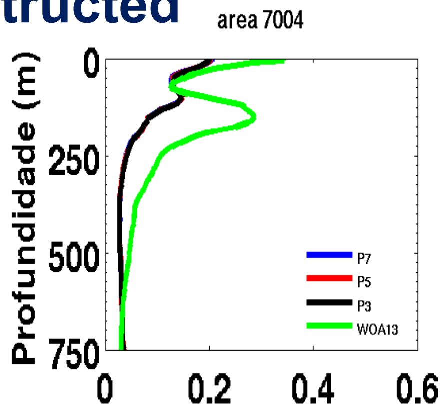
PIRATA and XBT Temperture data → Synthetic S

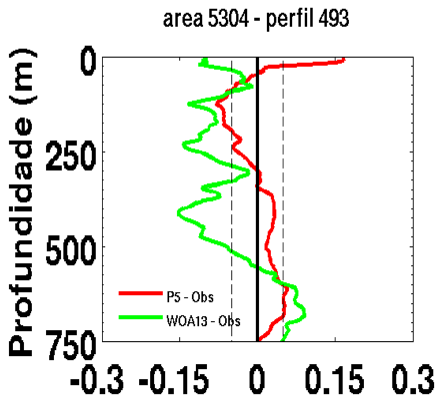


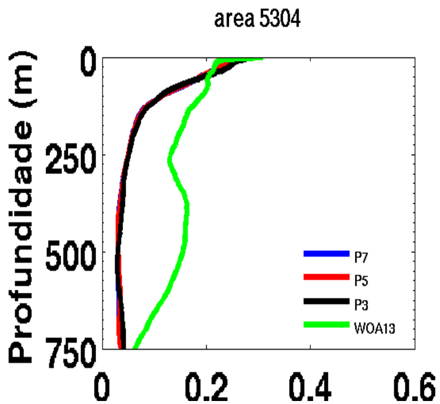


3rd, 5th and 7th order polynoms S(T) were constructed









S difference Poly 5 – Obs **RMSD (psu)**

HYCOM 1/4+RODAS

- **Assimilation is performed every 3 days**

	A_SST	A_IN_SITU	A_SLA
Observational window	-	72h	72h
Covariance length scales	150 km	150 km	150 km
Superobs (grid cells)	2x2	-	2x2
State vector	ALL	DP, U,V, T, S	ALL

- **126 ensemble members**
  - 21 members per year
  - 60-day window centered in the corresponding assimilation day
  - 6 years to capture the variability spread

- **Separate steps to assimilate SST, Argo T/S and SLA**

1. 00 UTC ⇨ Assimilation of SST from UK MetOffice **OSTIA**
2. 03 UTC ⇨ Assimilation of **T/S Argo** data
3. 06 UTC ⇨ Assimilation of **along-track SLA** from all altimeters

OSE with HYCOM 1/4+RODAS

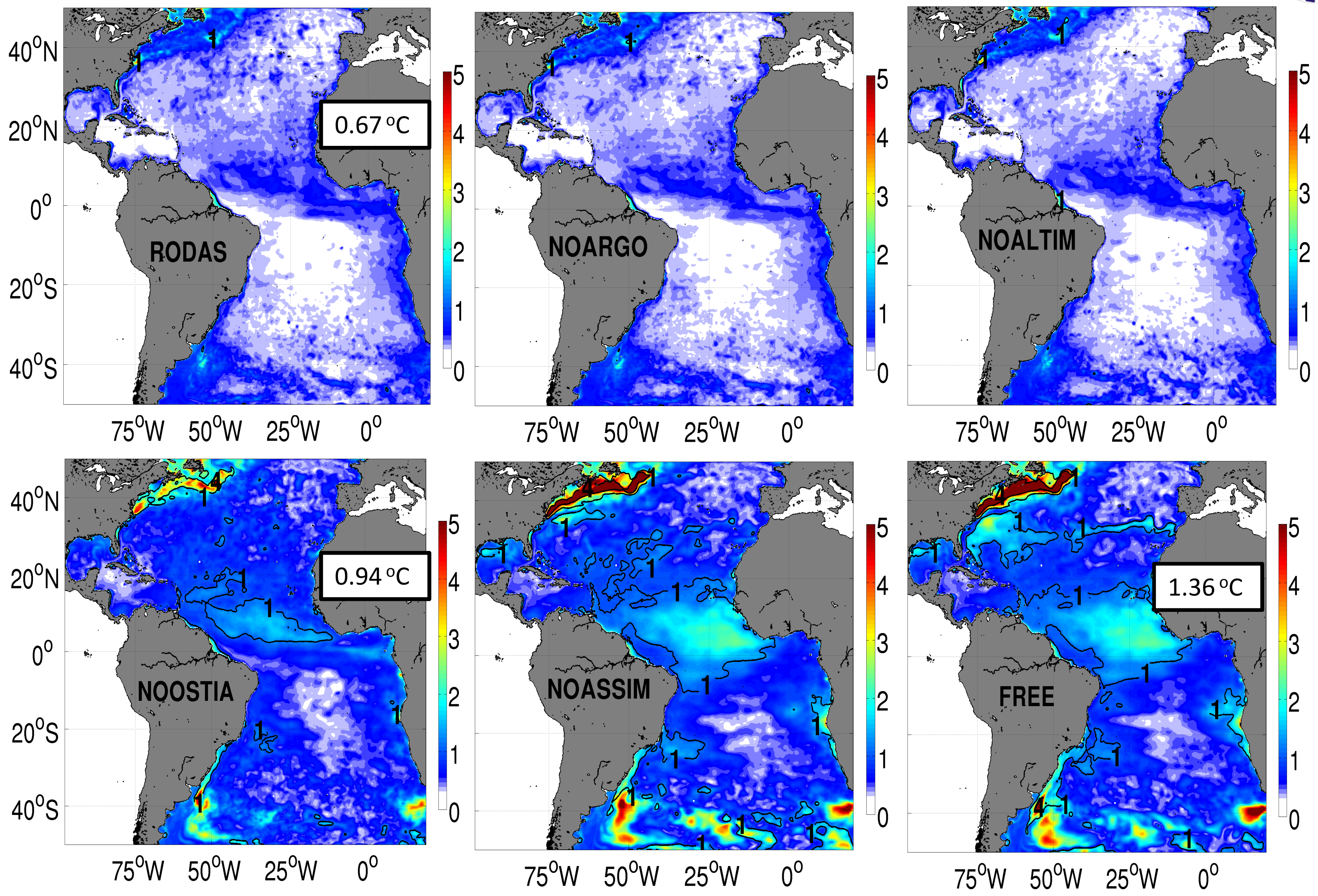
1 JAN 2010 – 31 DEC 2012

RODAS	Assimilation of SLA, SST and Argo
NOARGO	Withholding only Argo
NOALTIM	Withholding only altimeters
NOOSTIA	Withholding only OSTIA
NOASSIM	Withholding all observation types and turning off DA
FREE	Free run

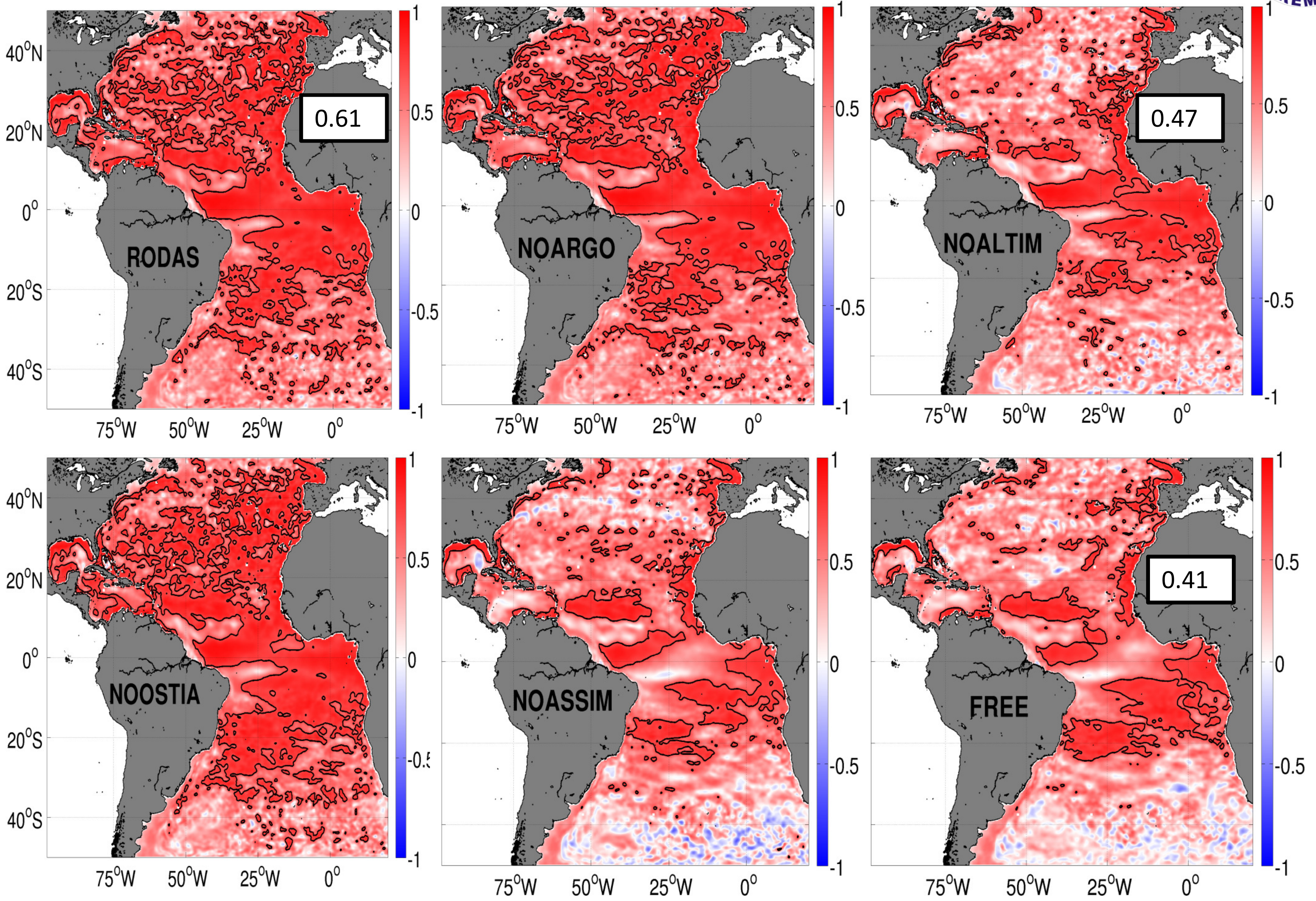
Same model configurations for all the runs

Evaluation will be based on the 24h, 48h and 72h after assimilation with observations that are not yet assimilated

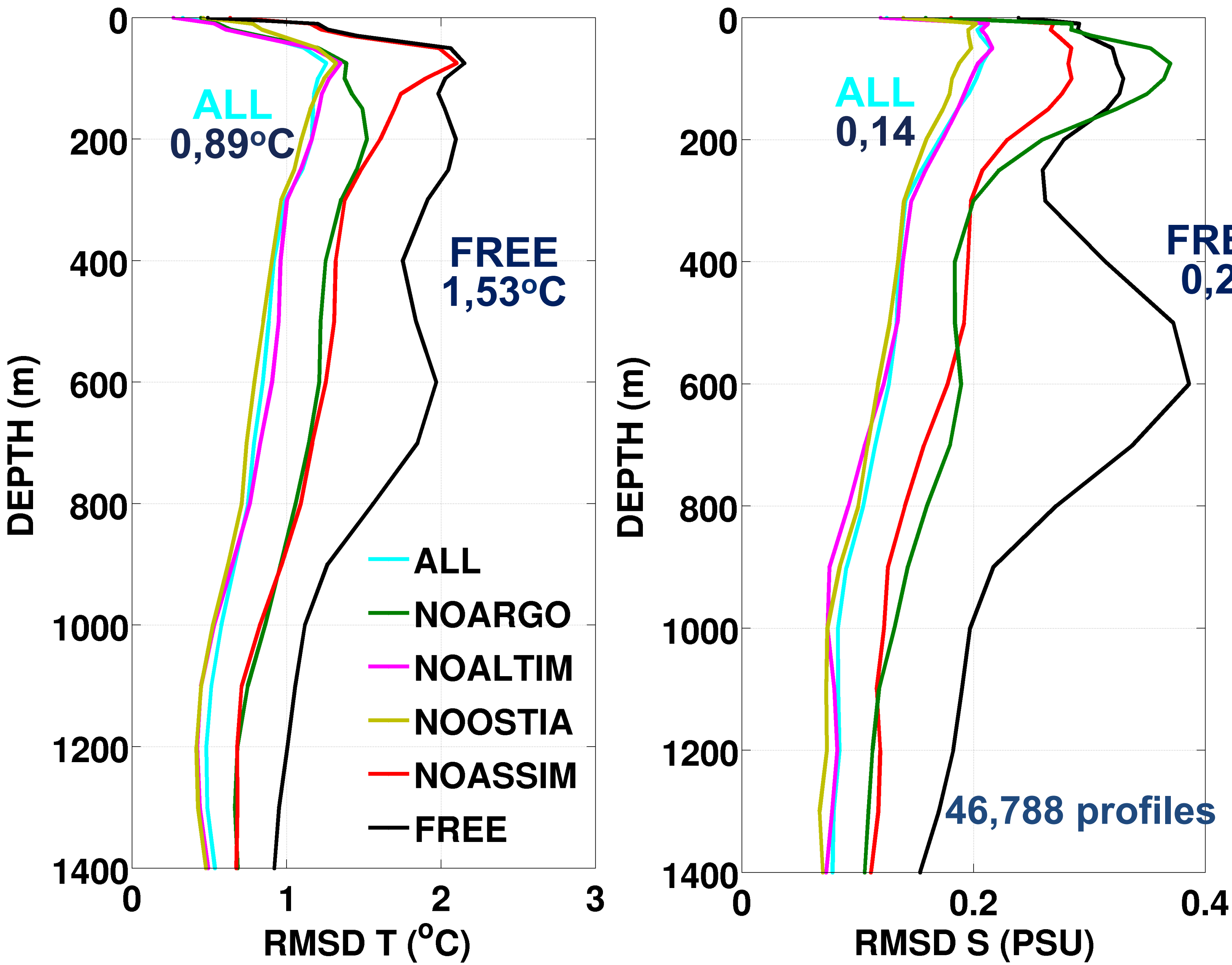
OSE: RSMD OSTIA (ºC)



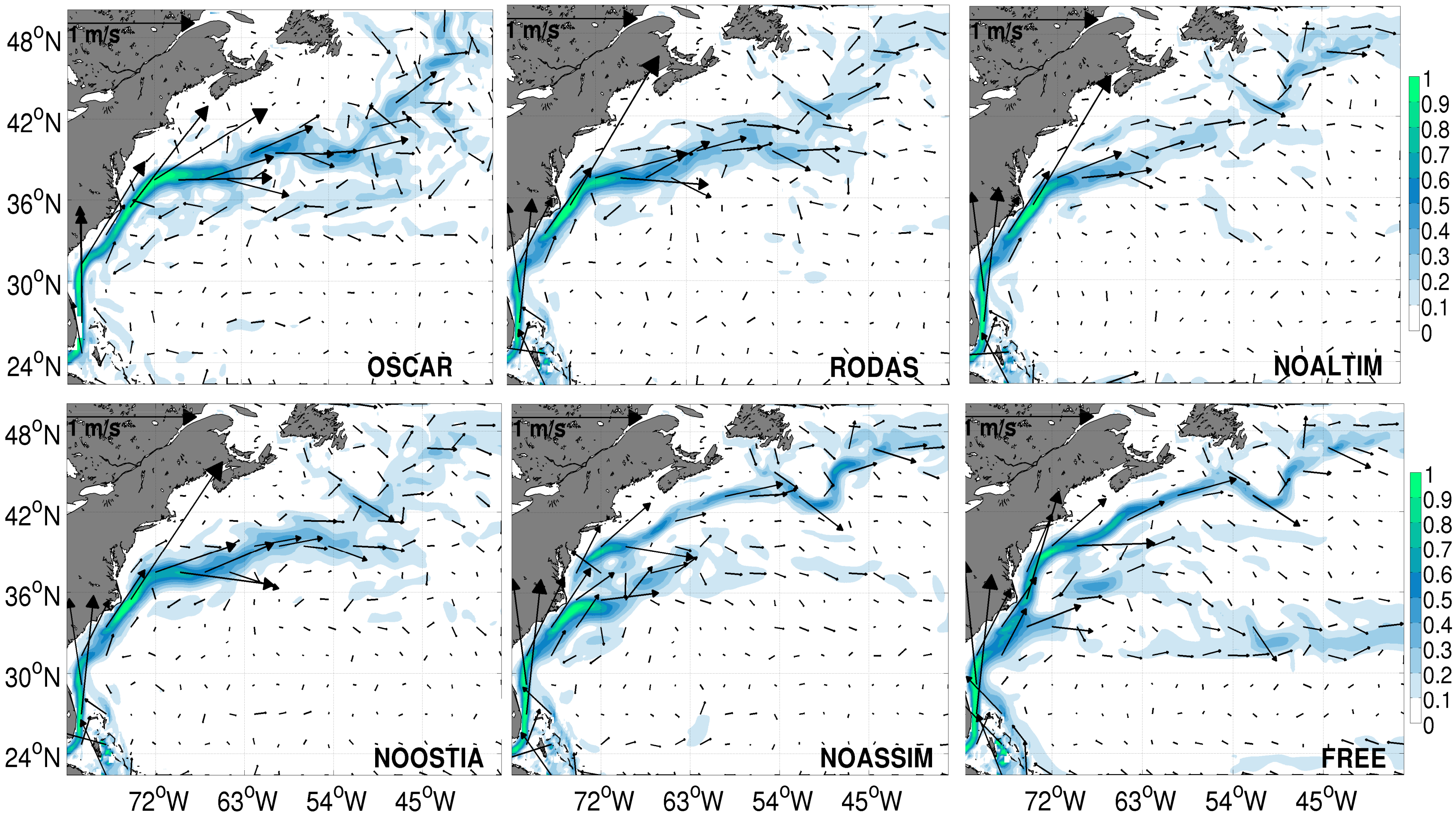
OSE: Correlation Gridded SLA



OSE: RSMD w.r.t Argo T/S



OSE: Comparison with OSCAR (m/s)



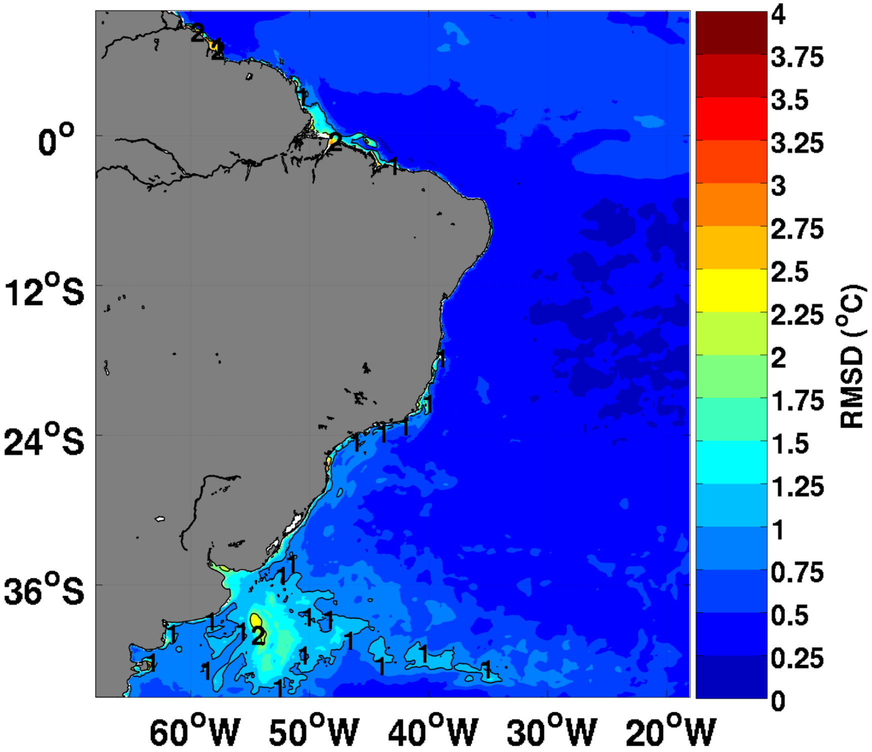
OSE w/without PIRATA HYCOM 1/12+RODAS

Assimilation of SST, Argo T/S, SLA and PIRATA Jan-Dec 2012

SST RMSD (°C)

With PIRATA

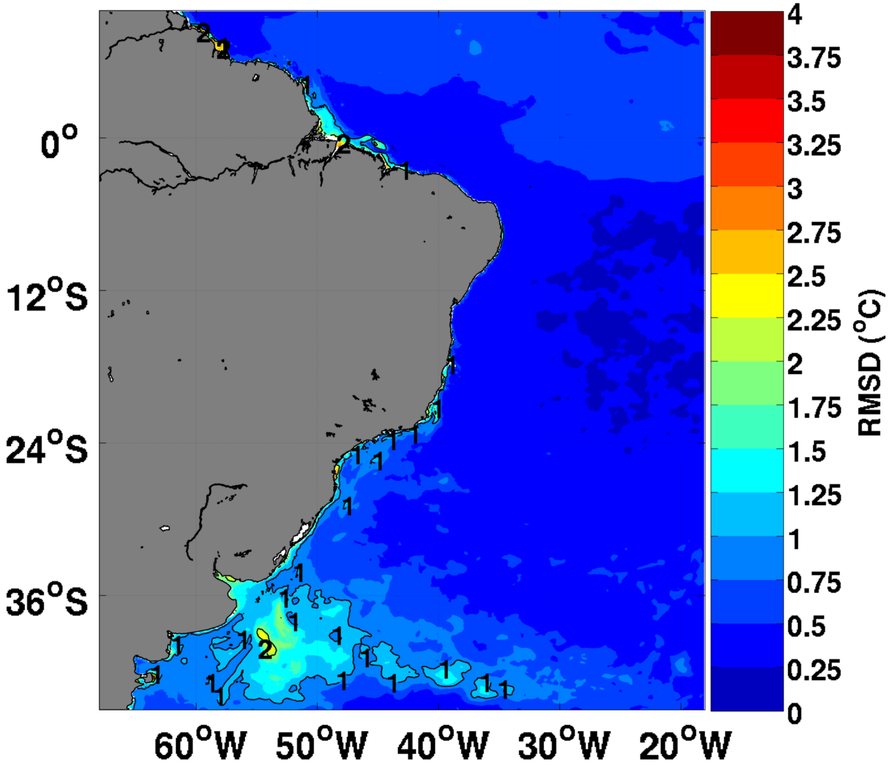
RODAS+PIRATA RMSD W.R.T. OSTIA (01/01/2012-31/12/2012)



0..49°C

Without PIRATA

RODAS RMSD W.R.T. OSTIA (01/01/2012-31/12/2012)



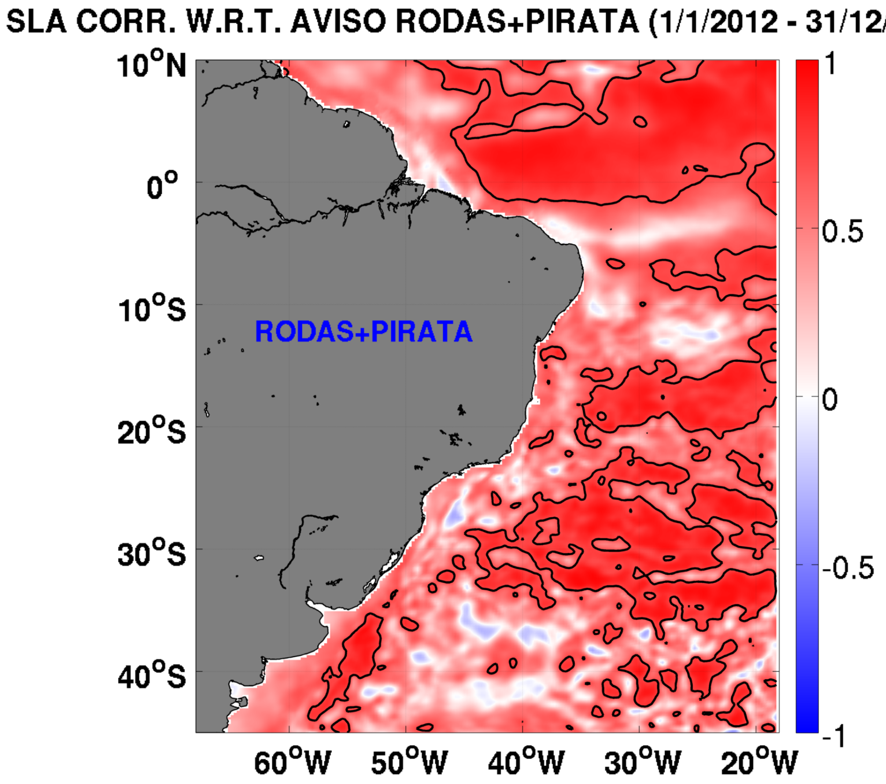
0.49°C

OSE w/without PIRATA HYCOM 1/12+RODAS

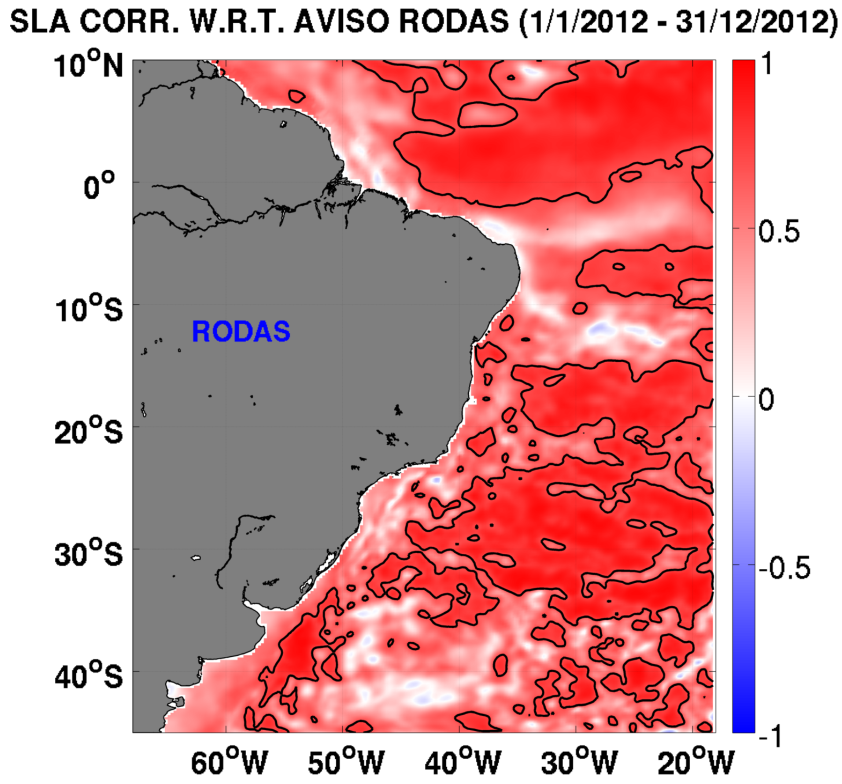
Assimilation of SST, Argo T/S, SLA and PIRATA Jan--Dec 2012

SLA Correlation

With PIRATA | **Without PIRATA**



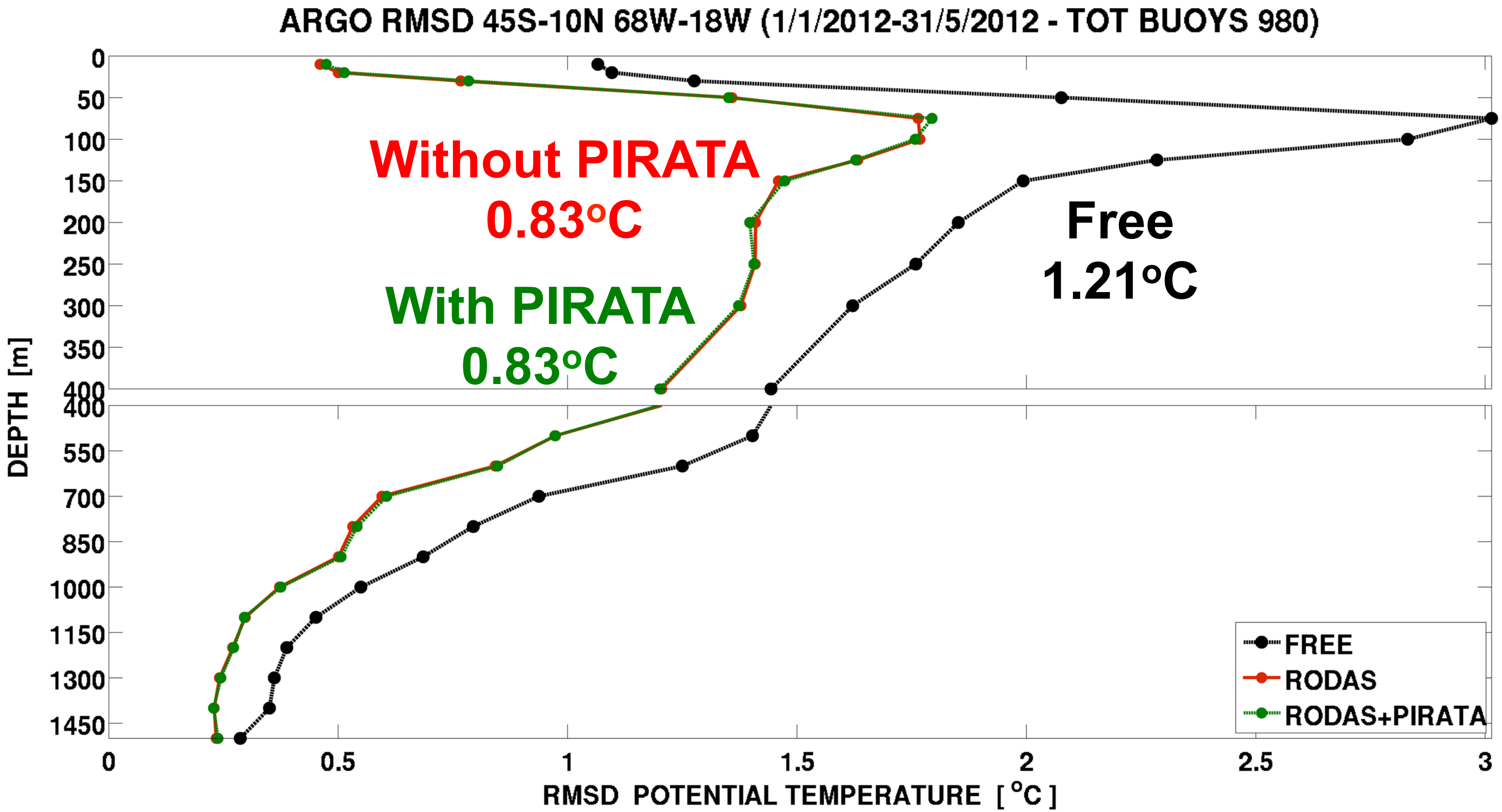
< 0.70



0.70

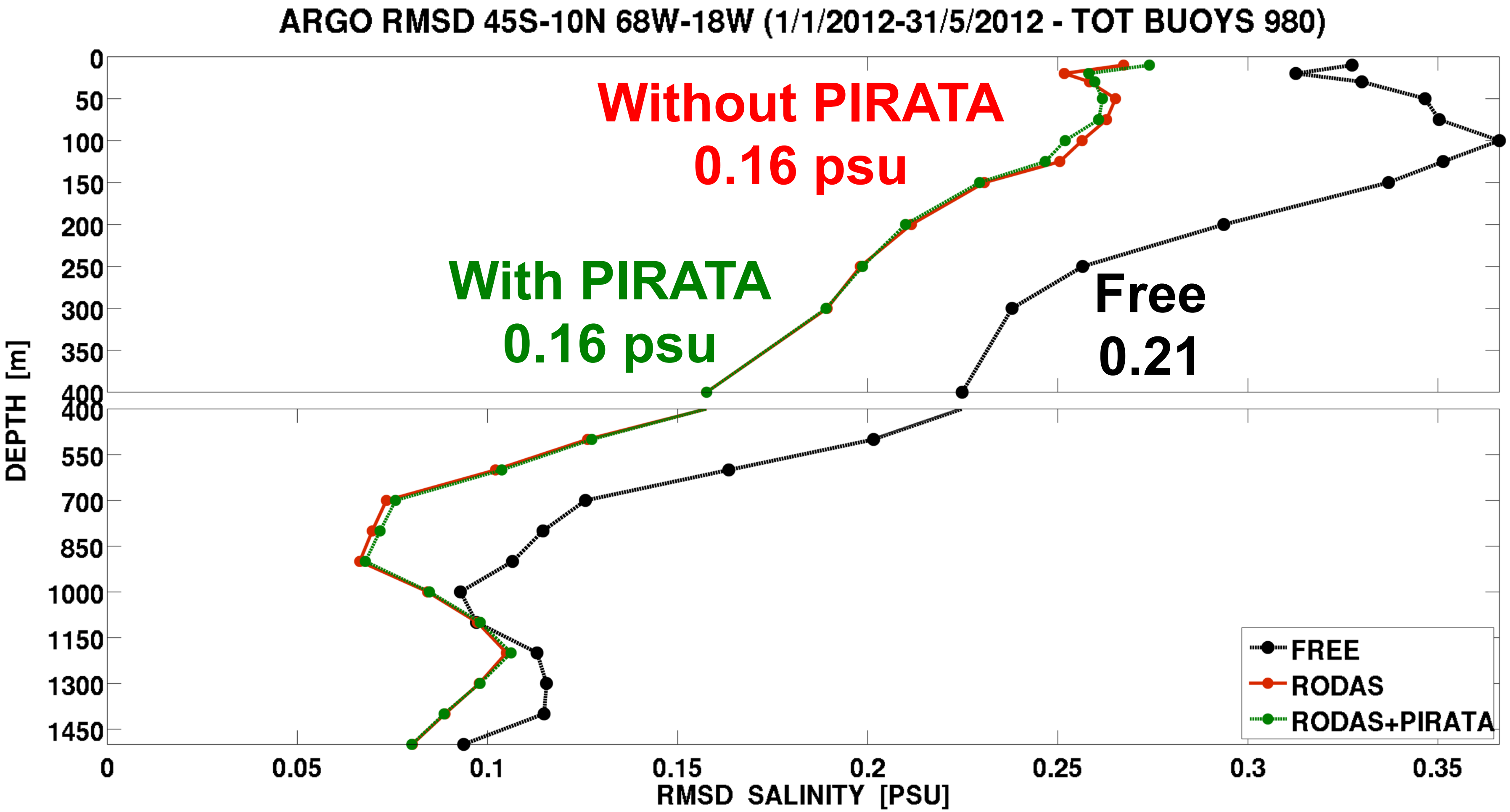
OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD T (°C) wrt Argo data Jan-May 2012



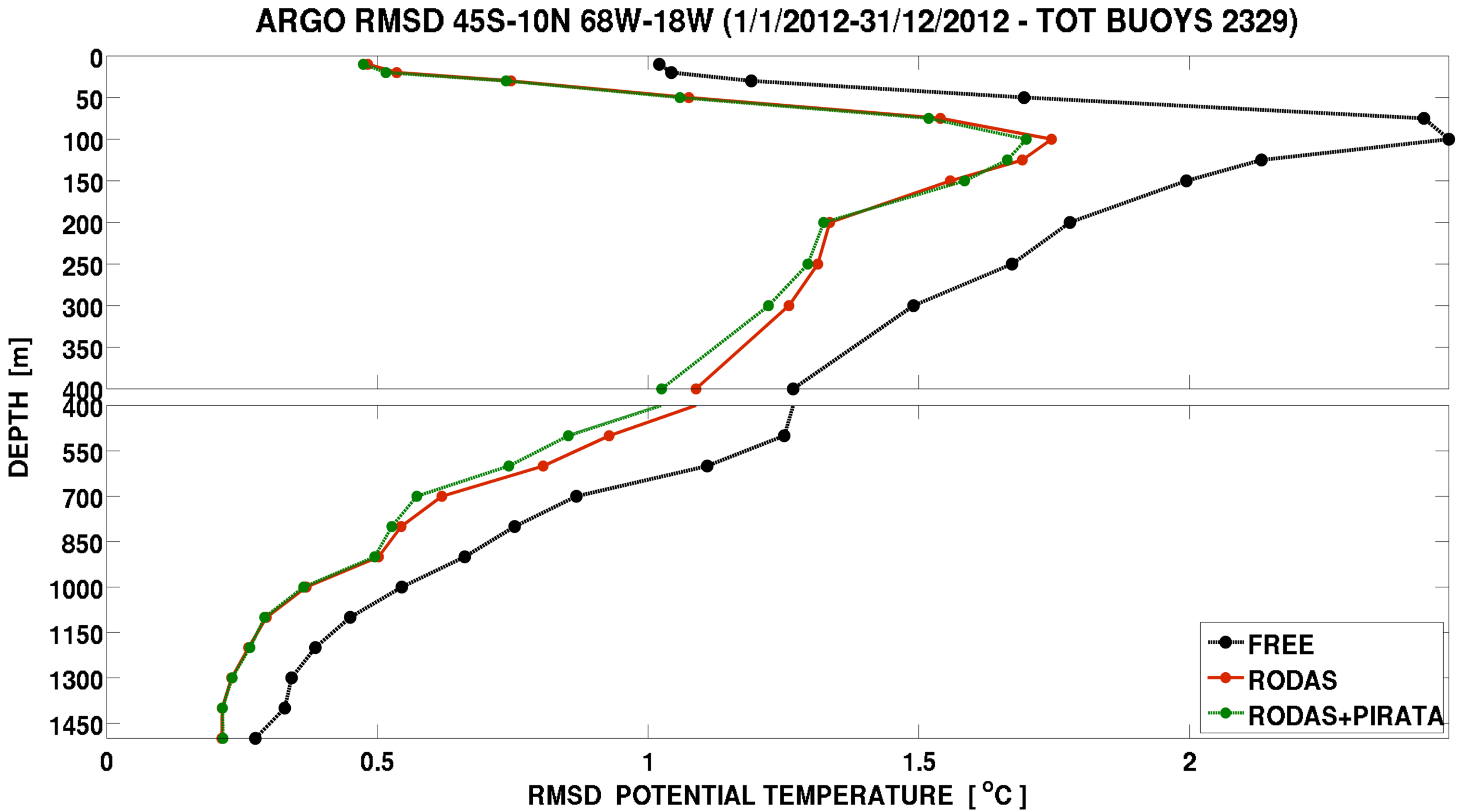
OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD S (psu) wrt Argo data Jan-May 2012



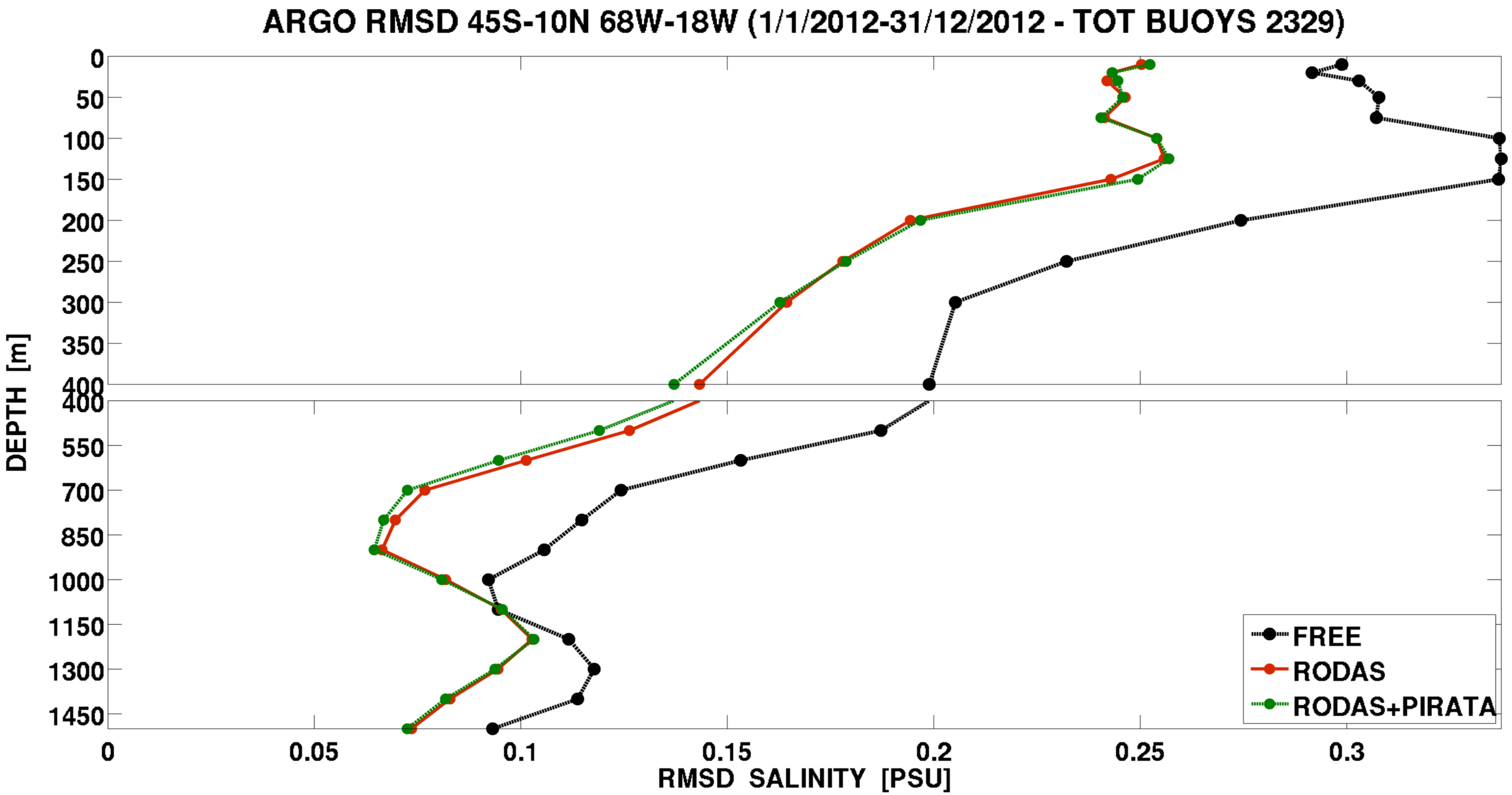
OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD T (°C) wrt Argo data Jan-Dec 2012



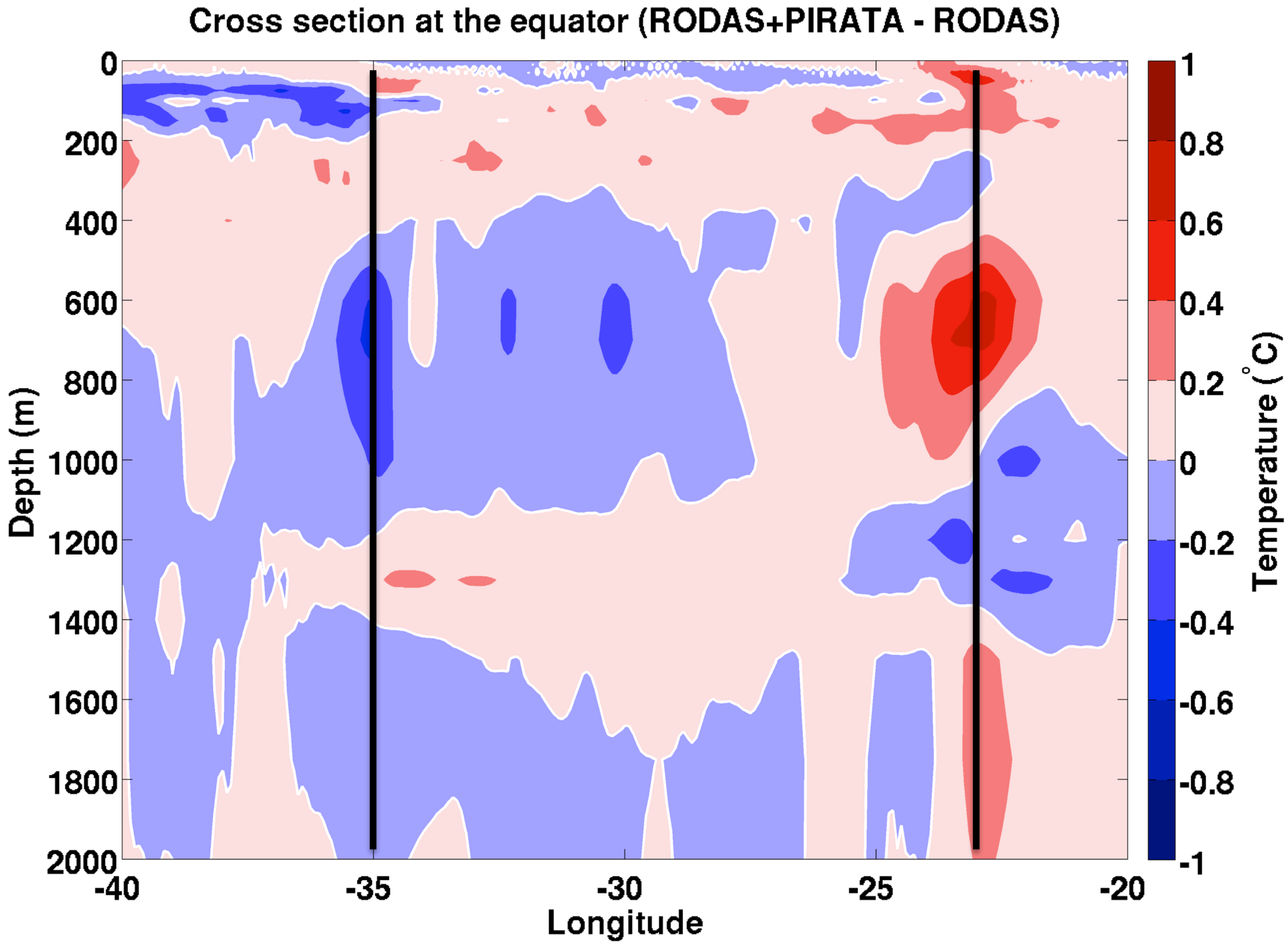
OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD S (psu) wrt Argo data Jan-Dec 2012



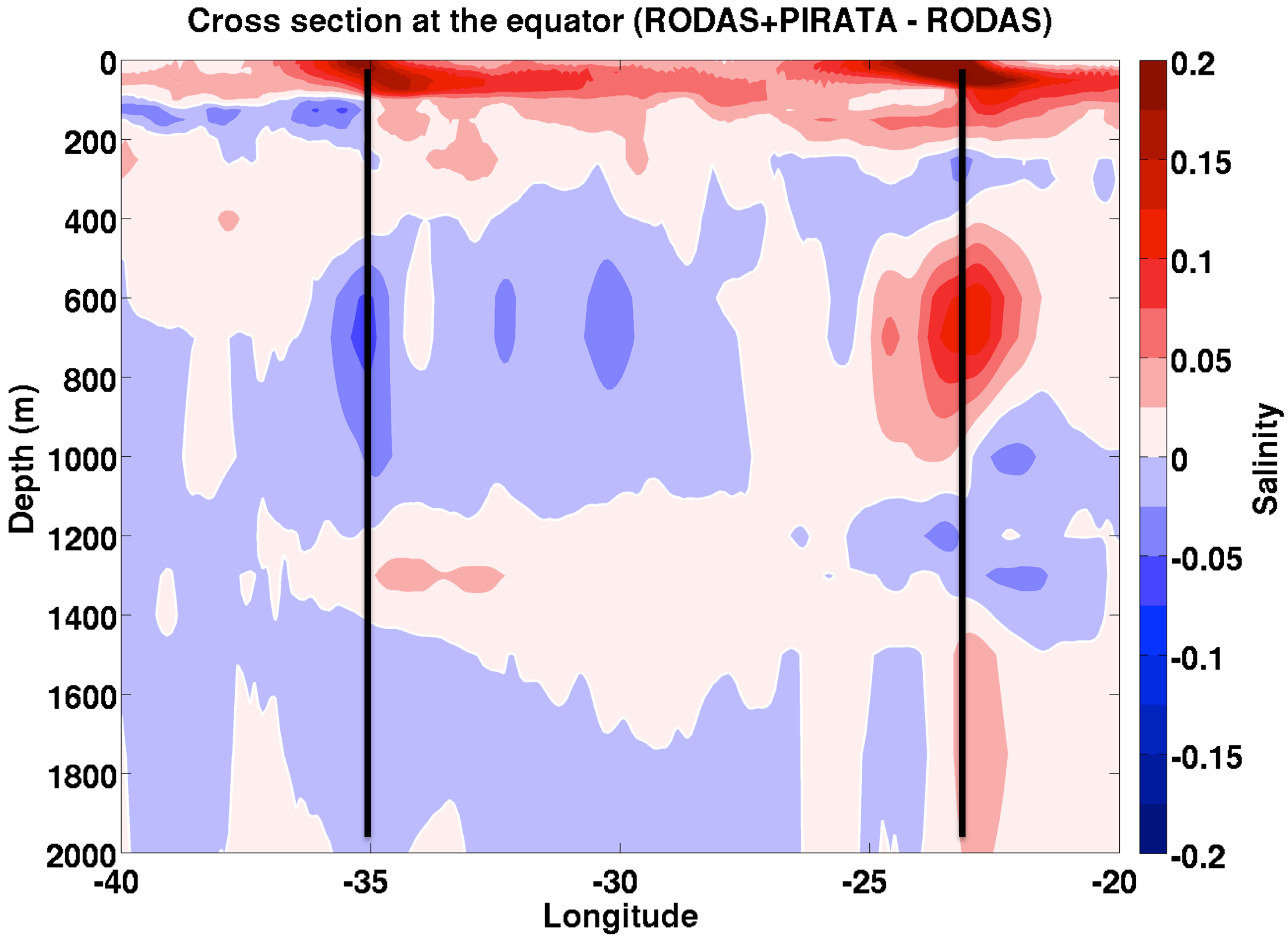
OSE w/without PIRATA HYCOM 1/12+RODAS

T(°C) Difference With – Without PIRATA Jan-May 2012



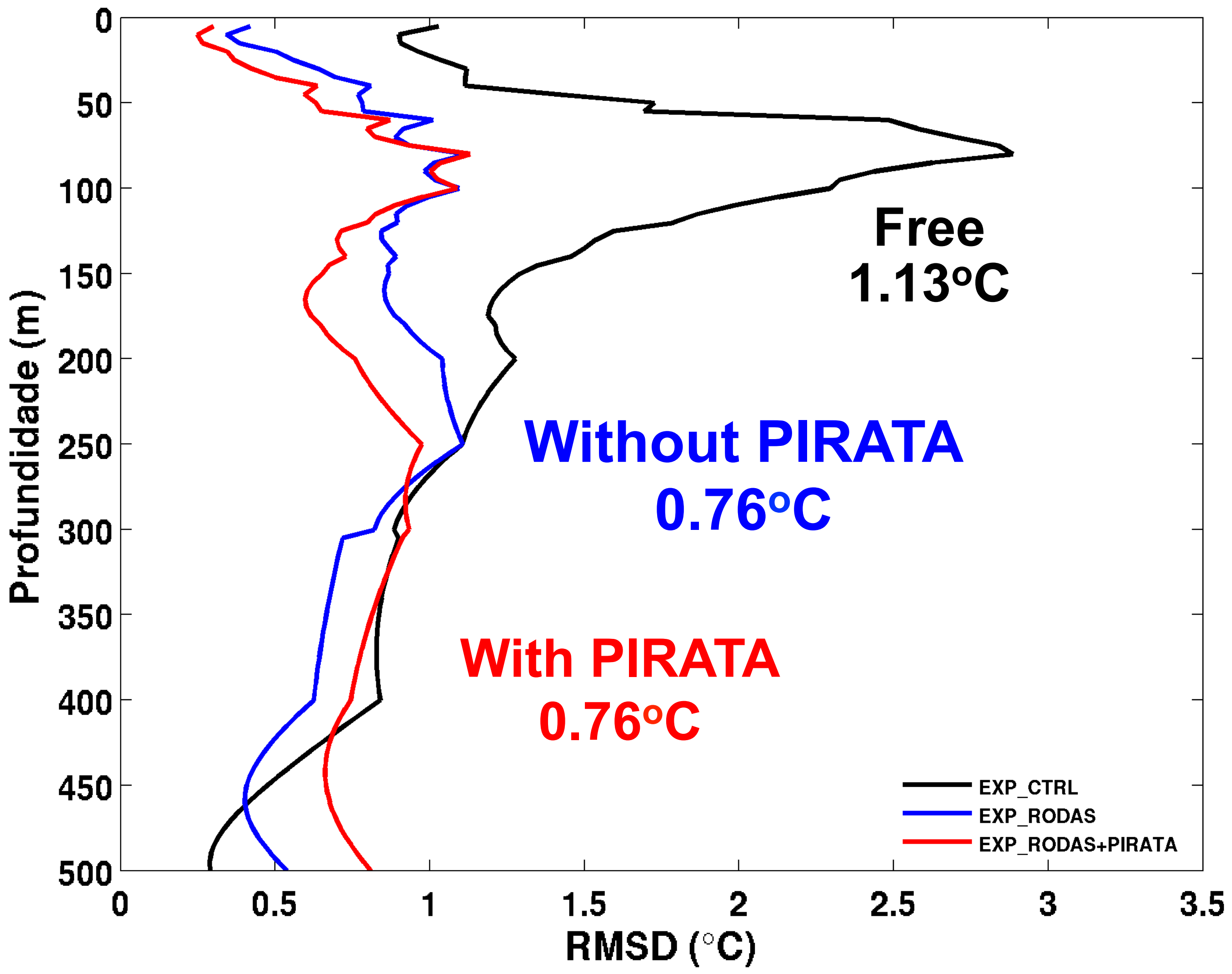
OSE w/without PIRATA HYCOM 1/12+RODAS

S (psu) Difference With – Without PIRATA Jan-May 2012



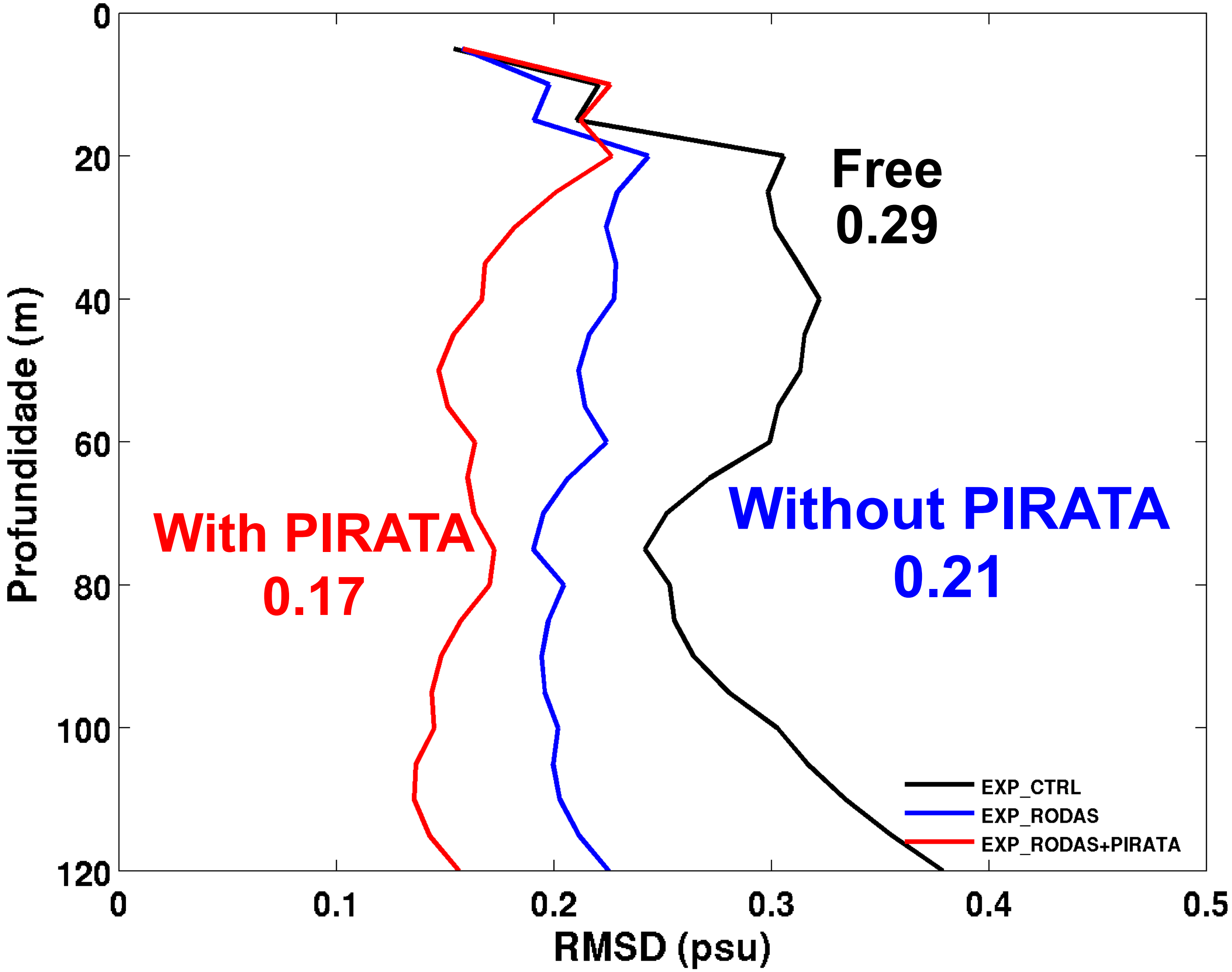
OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD T (°C) wrt PIRATA data (5 buoys) Jan-May 2012

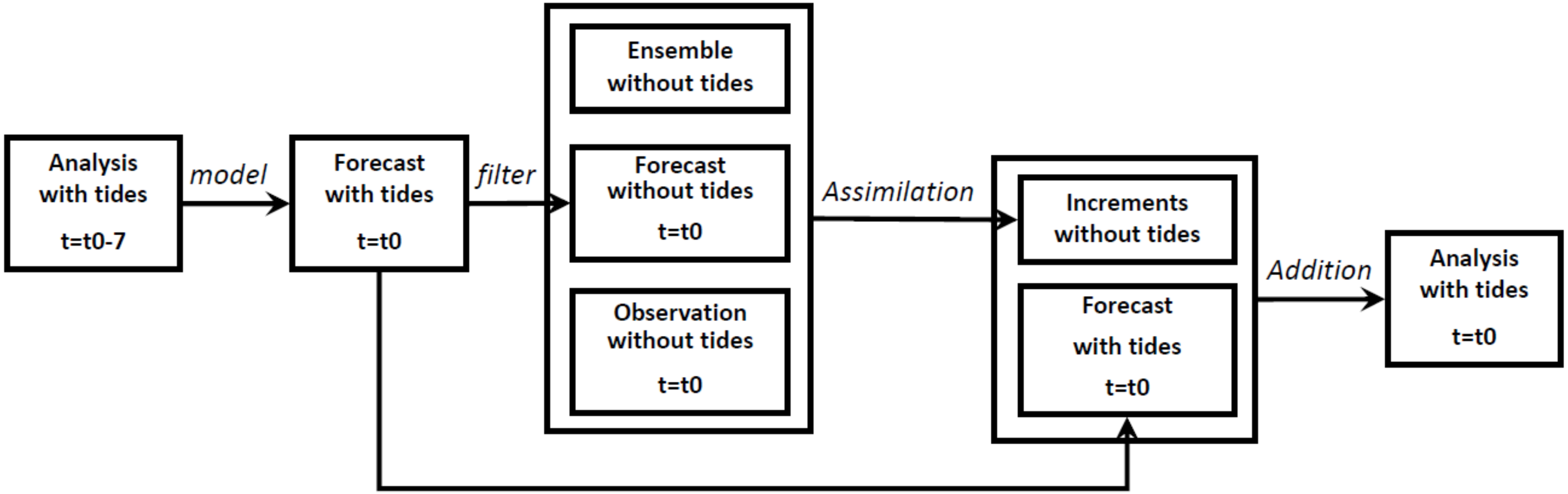


OSE w/without PIRATA HYCOM 1/12+RODAS

RMSD S (psu) wrt PIRATA data (5 buoys) Jan-May 2012

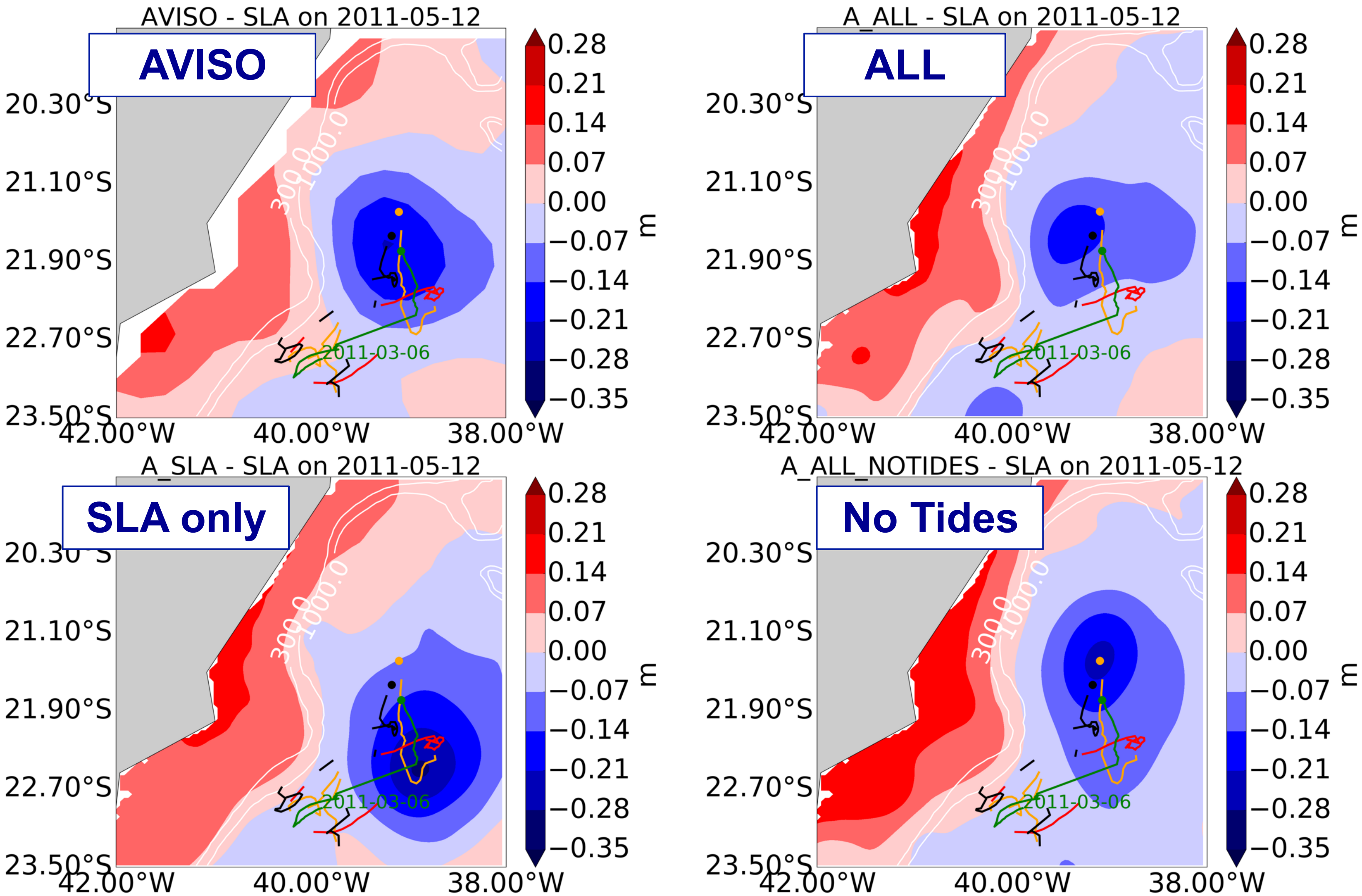


RODAS: Assimilation into HYCOM with tides



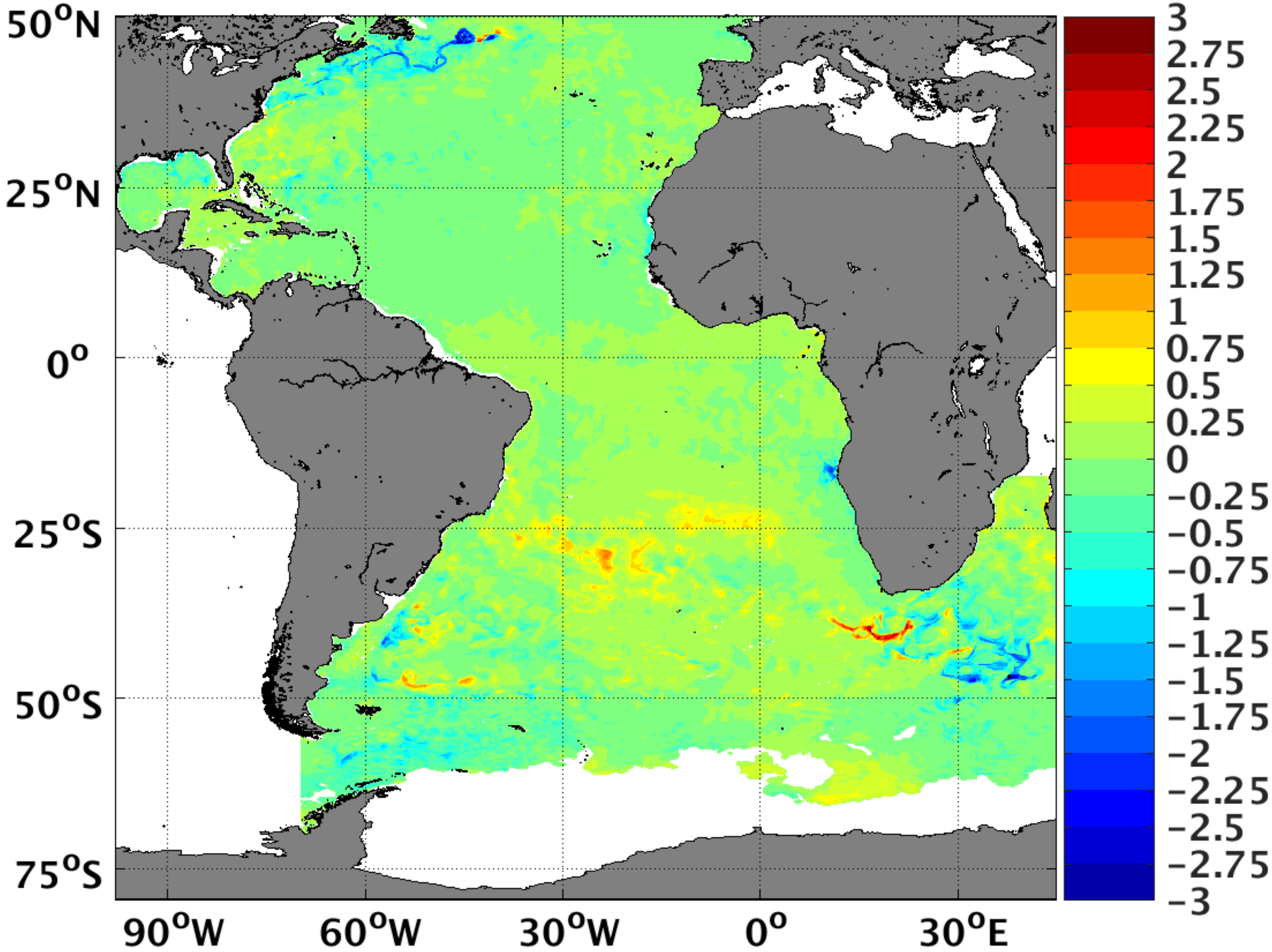
RODAS: Assimilation into HYCOM with tides

HYCOM 1/24 Assimilation of SST and SLA – 2008



New HYCOM grid: 1/12^o and 32 layers

First SST (^{o}C) analysis Increment in the new grid (1 Jan 2003)

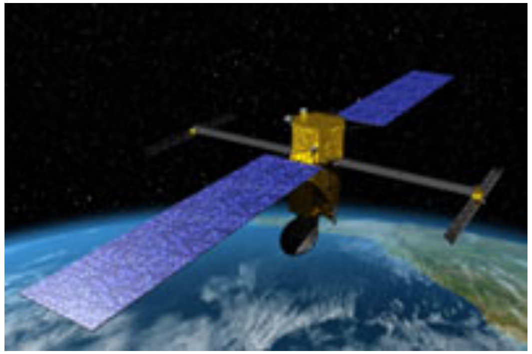


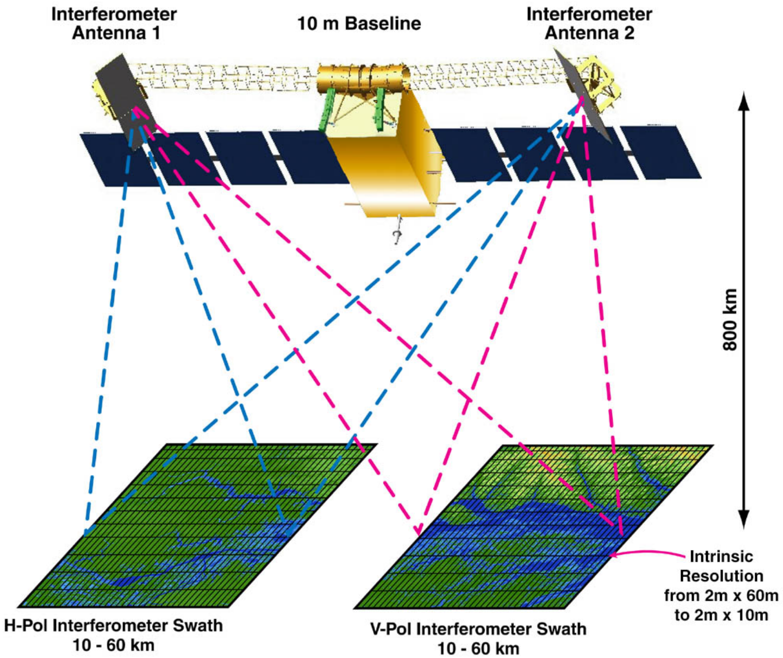
Challenges in DA: SWOT

Surface Water and Ocean Topography

Hydrology
Water level inland

Oceanography
SLA in a 120 km band along the satellite track
There will be 10 km gap in the center
2 km x 2 km resolution and **8 mm accurate**





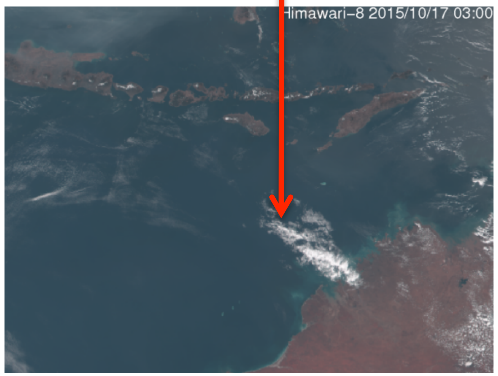
Aplications
- **Hydrology:** floods, droughts, reservoirs, trade, insurance

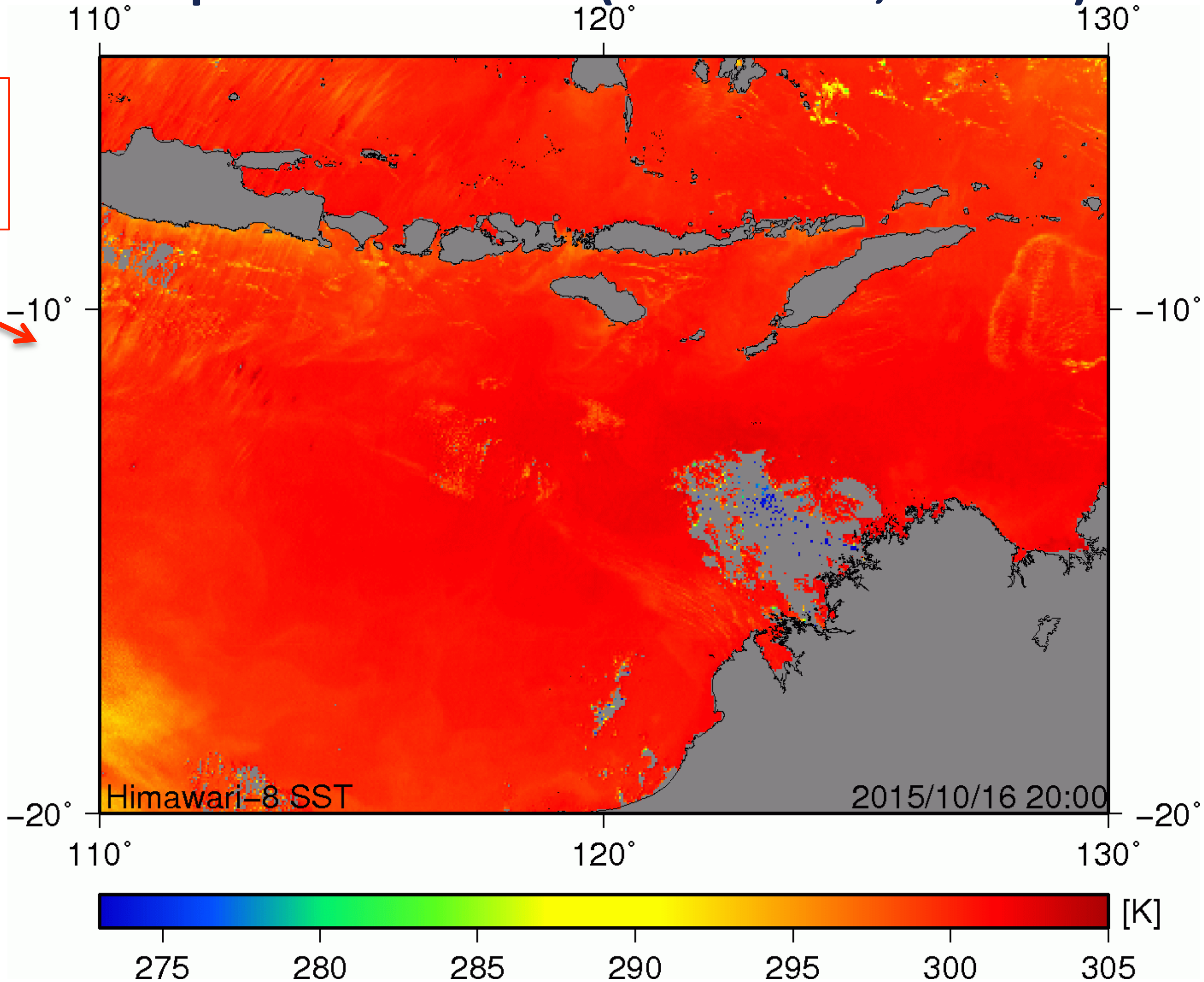
- **Oceanografia:** operational oceanography, weather, climate, fisheries, maritime operations, and more....

New generation of sensors: Himawari-8

High spatial and temporal resolution (300-500 m, 10 min)

Zoom-in





Yukio Kurihara (JAXA)

Given by Gary Corlet (GHRSST)

Final Considerations

- HYCOM+RODAS tool was developed. It assimilates SST, SLA, Argo T/S, XBT and PIRATA data.
- SST data strongly impacts on SST and mixed layer T.
- T/S profiles impacts on subsurface T/S, especially S, but also influences in the circulation.
- SLA data strongly impacts on SLA and surface circulation.
- OSE with PIRATA needs longer assimilation run to better show the impact of PIRATA data, but preliminary results show that locally the impact is substantial.
- All data complement each other and improvements towards assimilation of SMOS, gliders, hi-res SST and SWOT data are necessary.