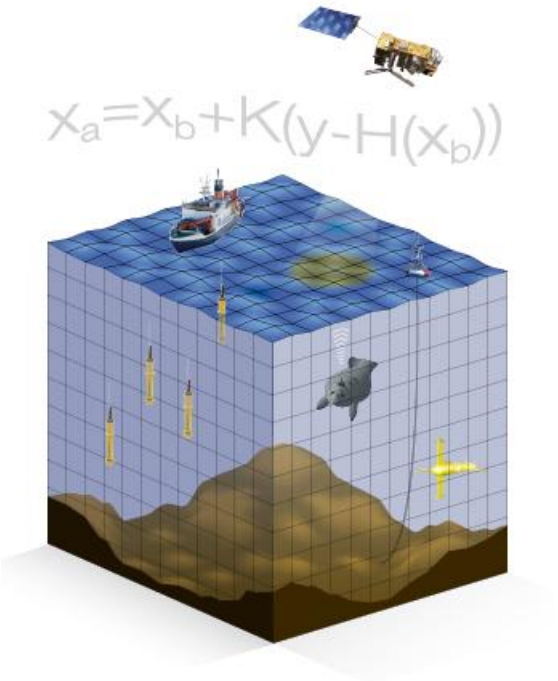
Joint ECMWF/OceanPredict workshop on Advances in Ocean Data Assimilation – 17-20 May 2021

Regional Analysis of Indian OceaN (RAIN)

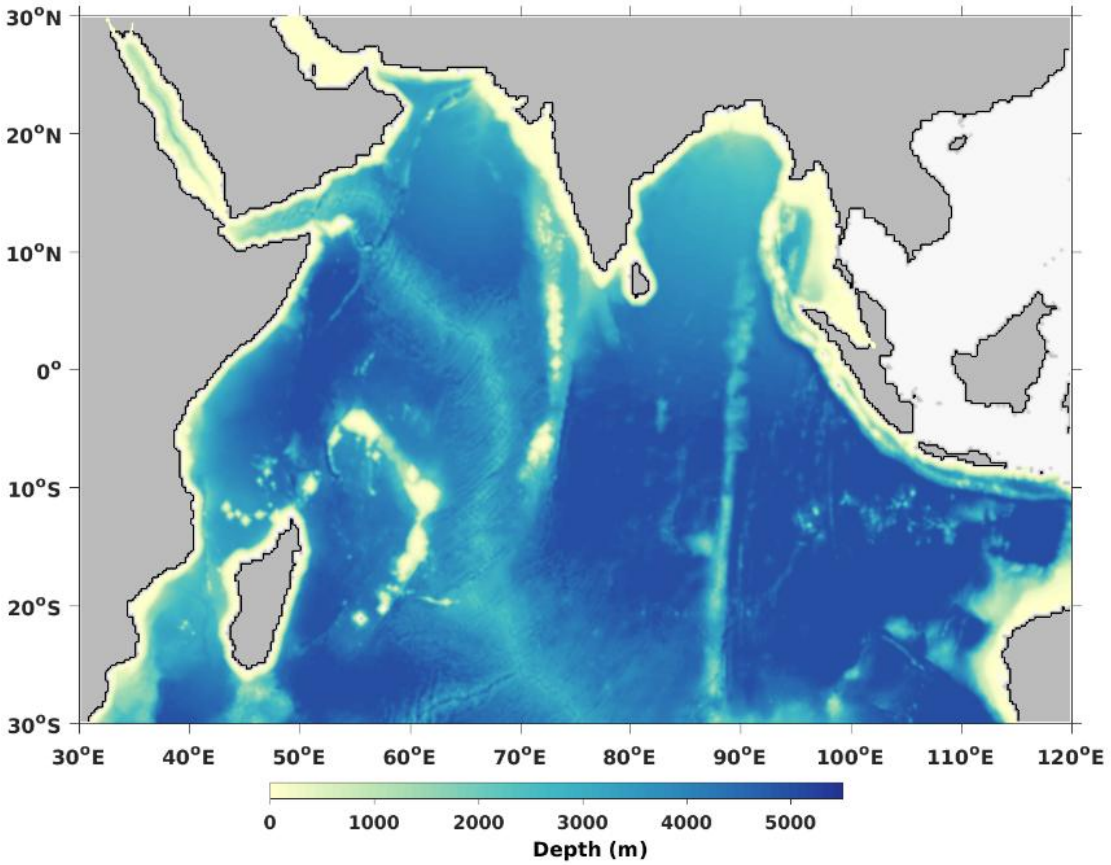
Balaji Baduru
Indian National Centre for Ocean Information Services



Acknowledgements:
Arya Paul, Biswamoy Paul, S. Sivareddy, D.S. Banerjee, P.A. Francis
Eugenia Kalnay, Steve Penny

Specifications

Model Domain



Model :: Regional Ocean Modeling System (ROMS)

DOMAIN:
30ºE to 120ºE ; 30ºS to 30ºN

RESOLUTION:
1/12º (Horizontal)
40 sigma levels (Vertical)

BOUNDARY CONDITIONS:
Derived from INCOIS-GODAS.

ATMOSPHERIC FLUX:
NCMRWF flux from GFS model.

Assimilation Scheme :: **Local Ensemble Transform Kalman Filter (LETKF)**

No. of Ensembles :: 80

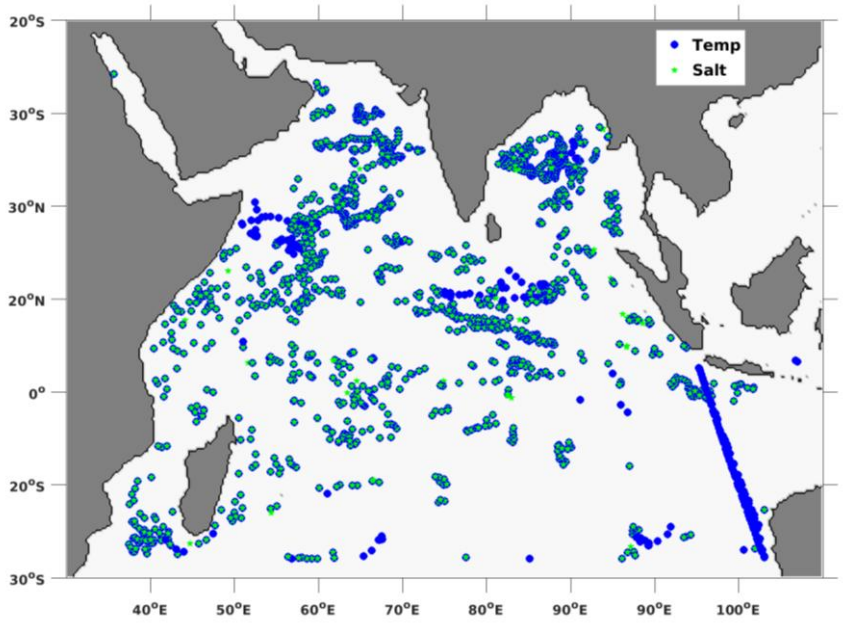
Observations

Assimilated Variables

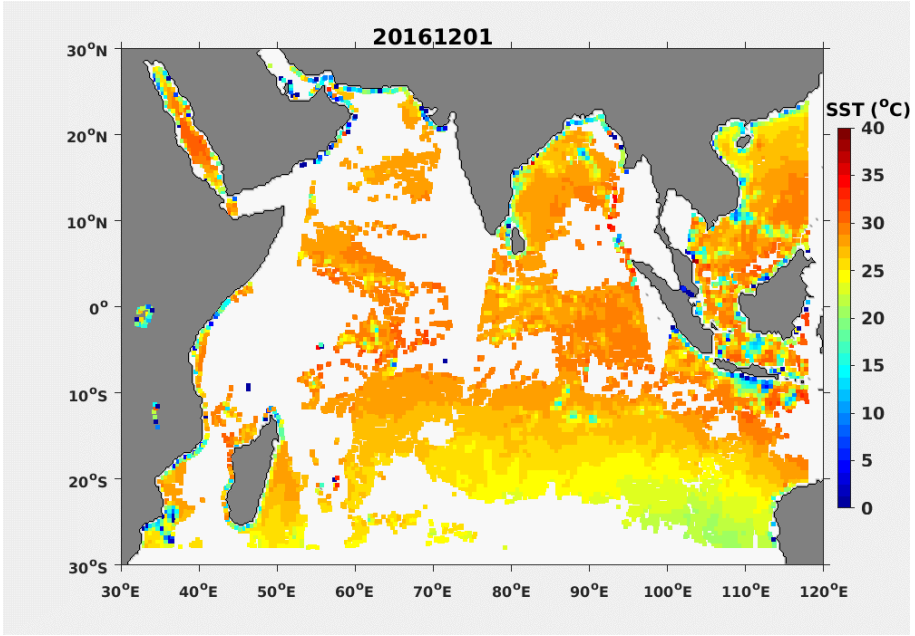
1. In-situ Temperature
2. Salinity Profiles
3. Sea Surface Temperature

Independent Variables

1. Sea Level Anomaly
2. U,V Currents



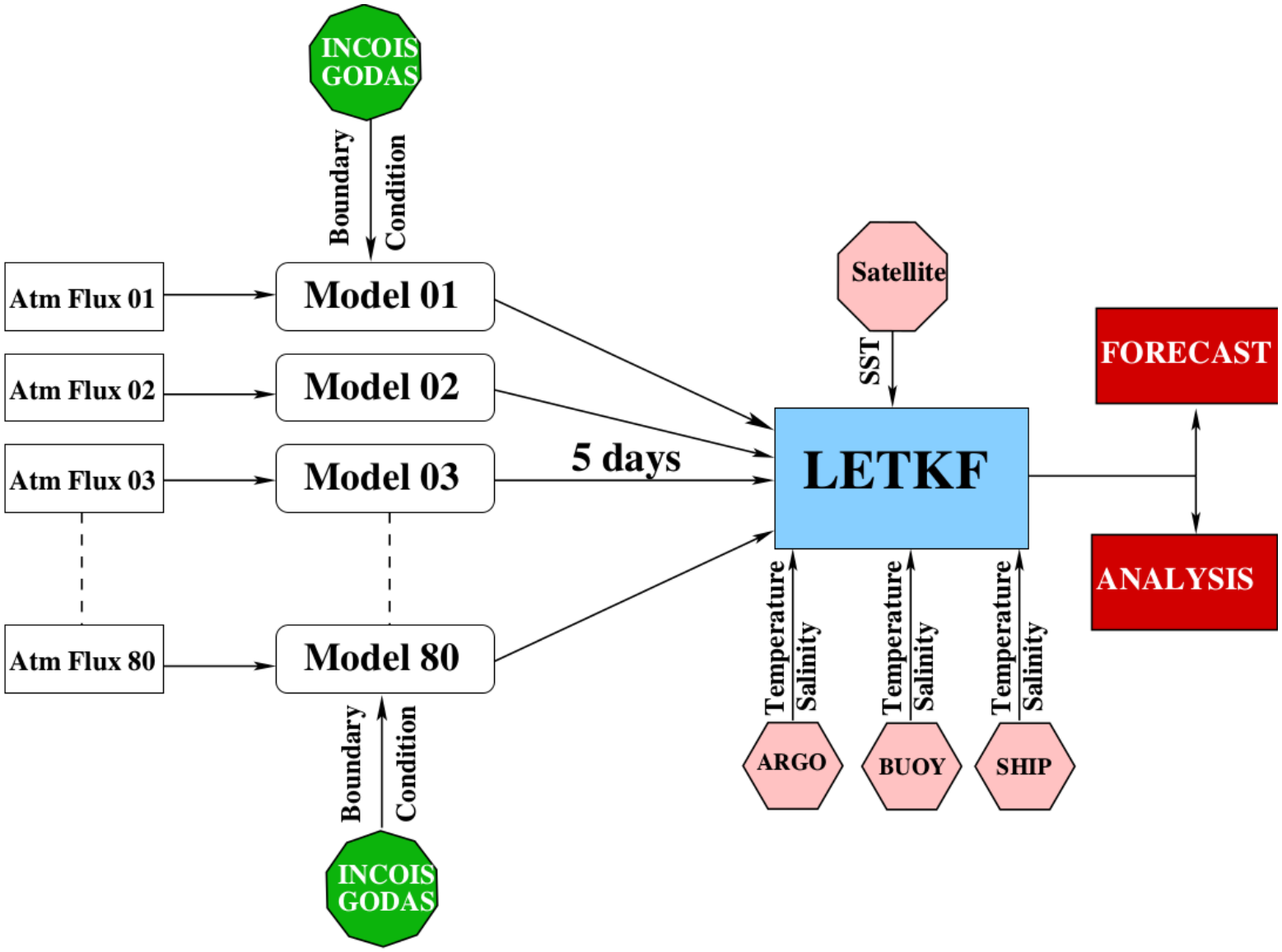
Spatial Distribution of Assimilated Observations (Temp and Salinity) for Aug 2016- Aug 2017



Assimilated satellite track SST over Indian Ocean - 01 Dec 2016

LETKF-ROMS

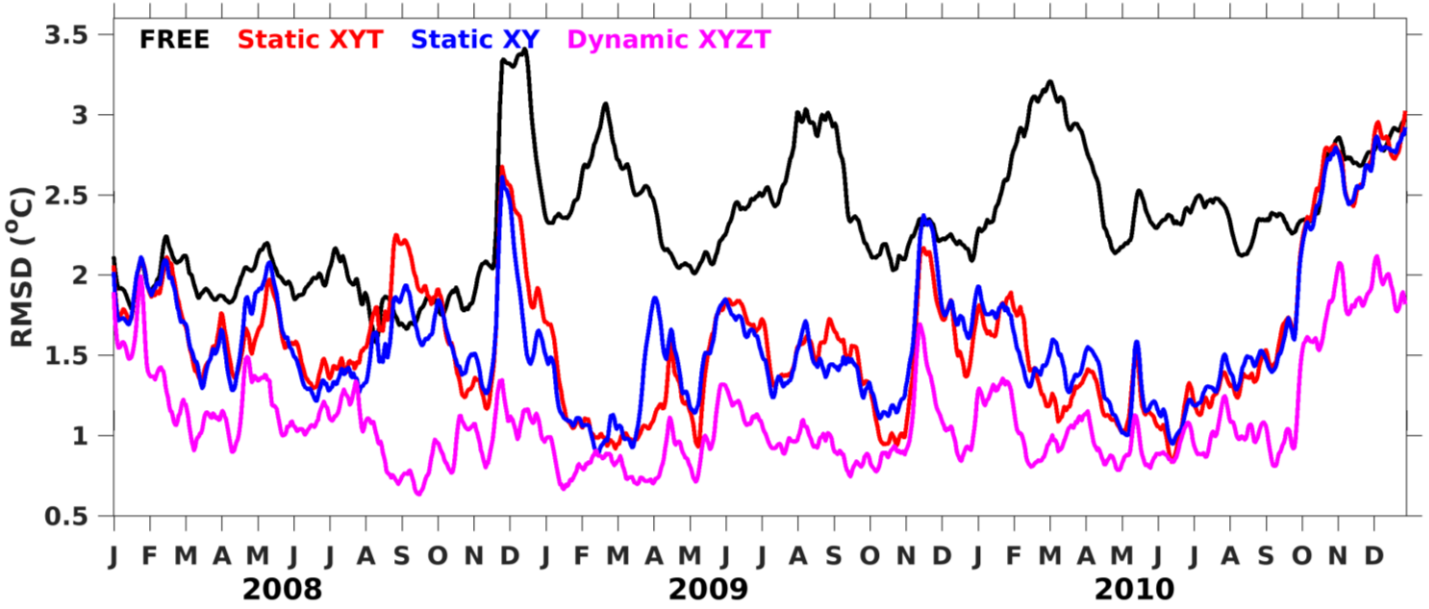
Pictorial Illustration of the system



What's new in this system ?

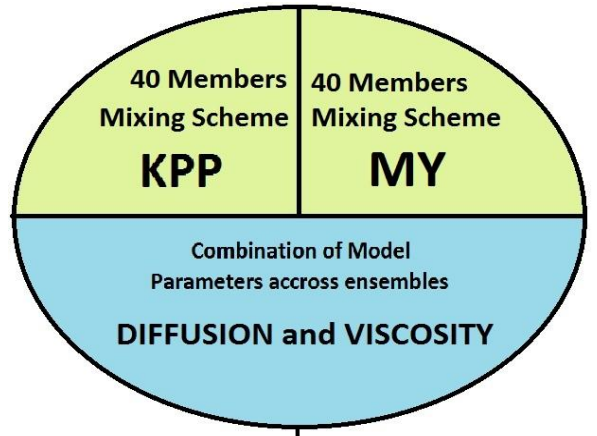
Introduction of spatio-temporal Representational Error

Time Series of RMSD in SST



Impact of dynamical representational errors on an Indian Ocean ensemble data assimilation system, Siva Reddy et al,
Quarterly Journal of Royal Meteorological Society, 2019. DOI: 10.1002/qj.3649

Introduction of two mixing schemes across ensembles

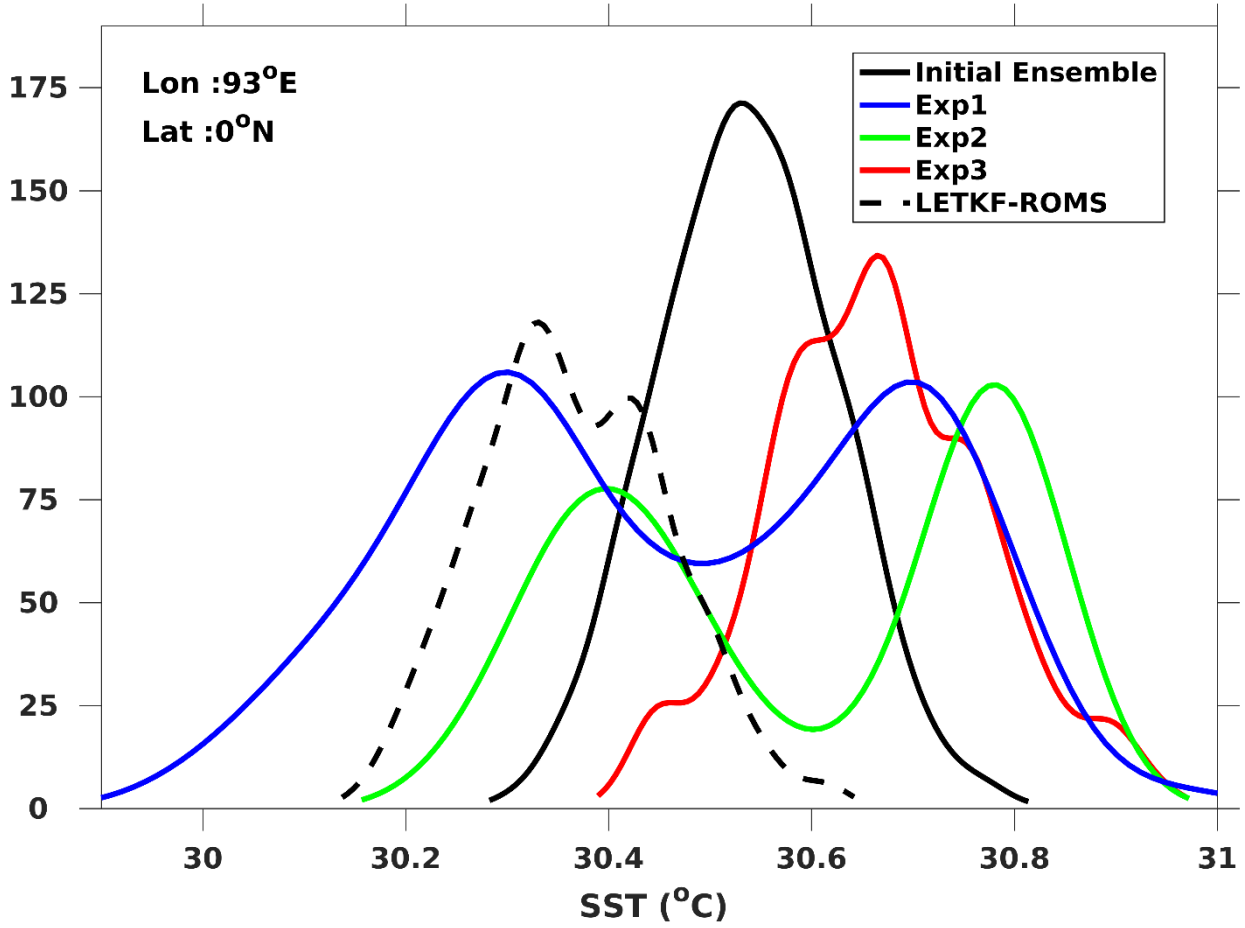


Ensemble combination with use of different mixing schemes and model parameters like diffusion and viscosity coefficients

Ensemble based regional ocean data assimilation system for the Indian Ocean: Implementation and evaluation,
Balaji et al, Ocean Modeling, 2019,
https://doi.org/10.1016/j.ocemod.2019.101470

Disadvantages of two mixing scheme

SST distribution across the ensemble members



Initial ensemble (black) and after 600 days of run of three control experiments (exp1 - blue, exp2 -green and exp3 - red) and LETKF-ROMS (dashed black)

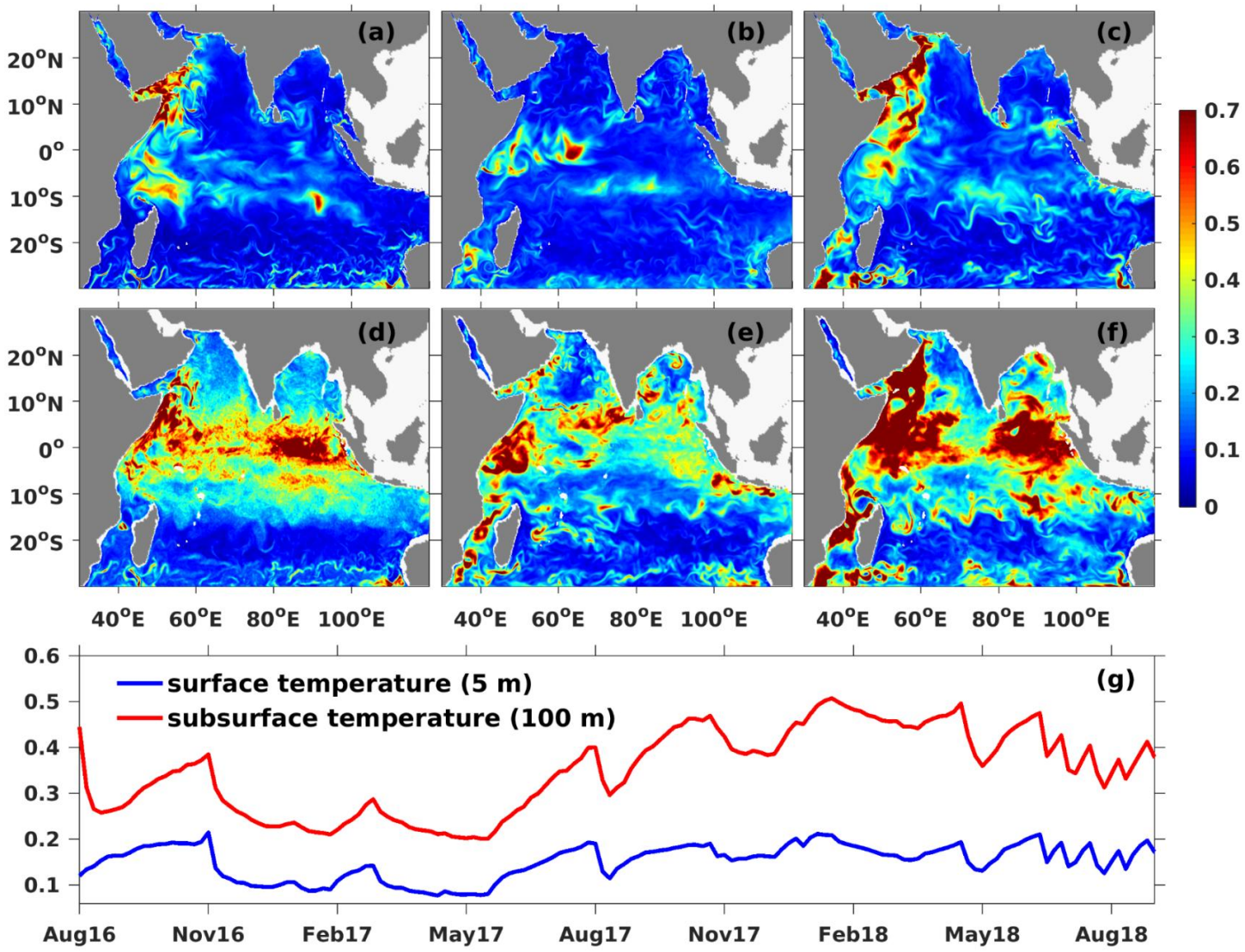
LETKF-ROMS : 80 ens members driven by 80 fluxes; KPP in 40 members & MY in 40.

Exp 1: Same as LETKF-ROMS (no assm); ensemble flux

Exp 2: Same as LETKF-ROMS (no assm); identical flux

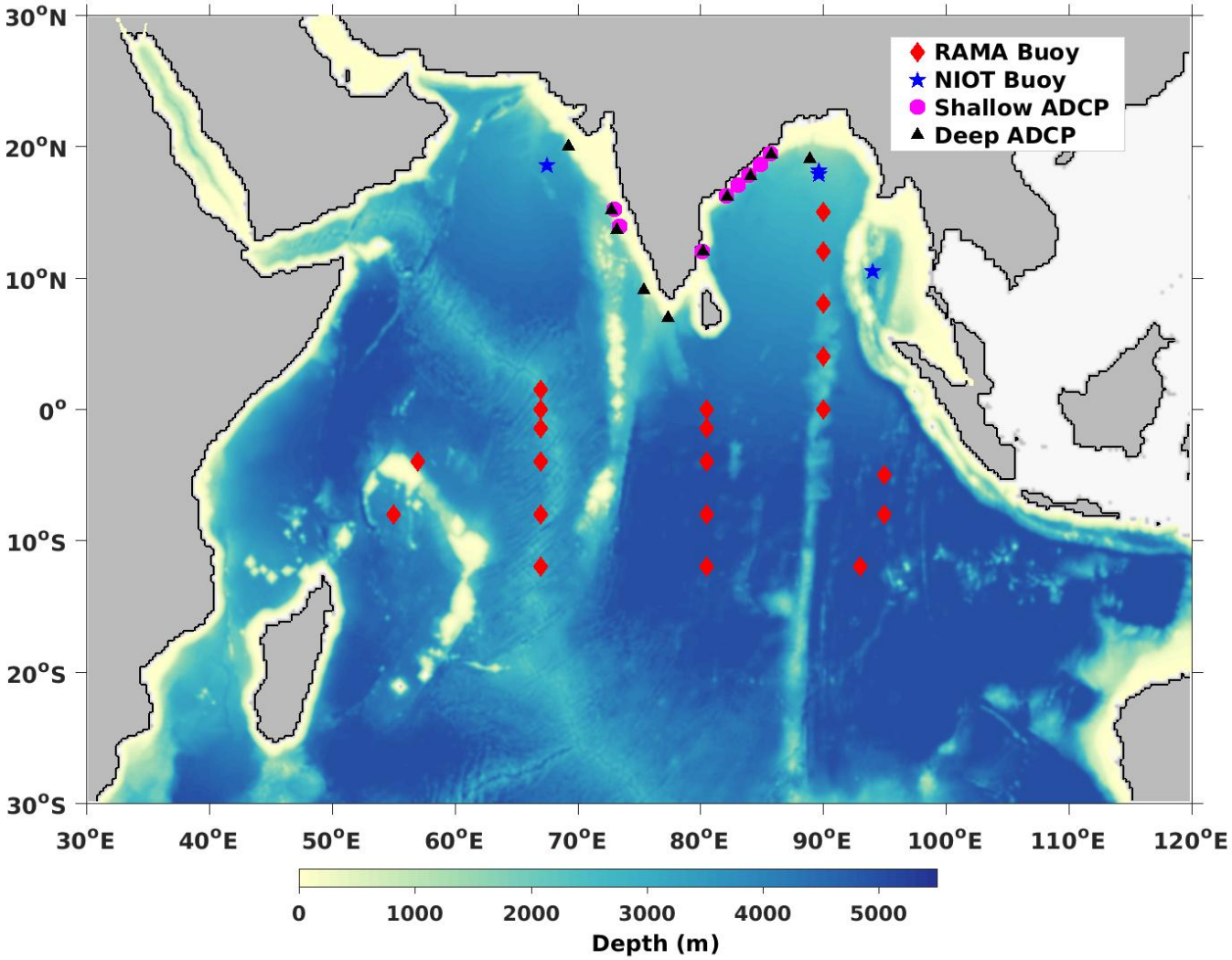
Exp 3: Same as exp 1; all ensemble members respond to KPP

Ensemble spread

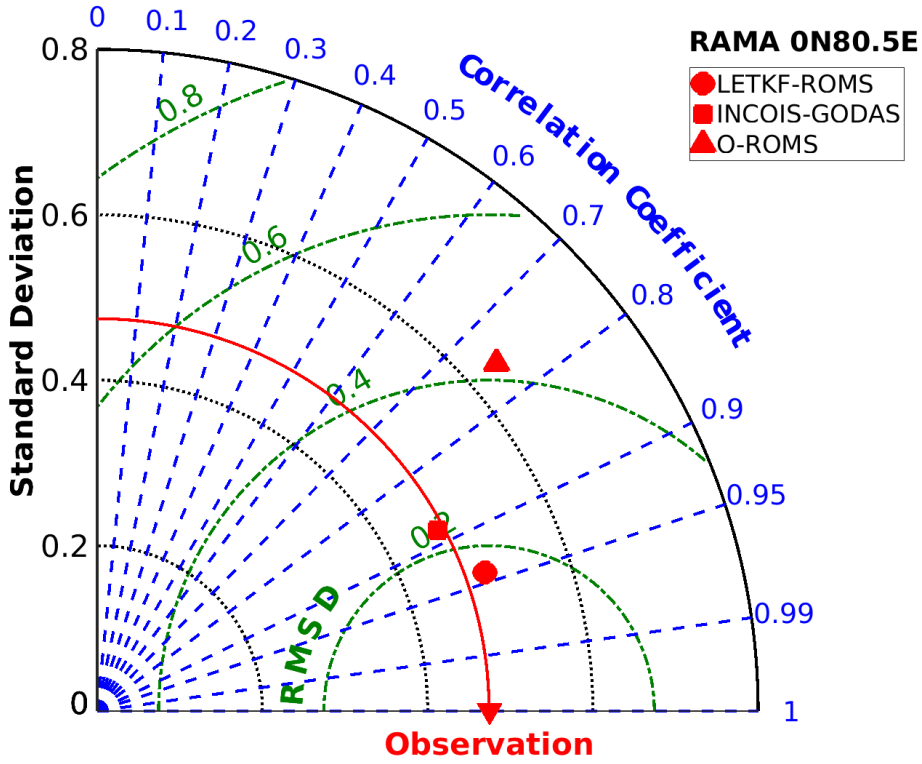


Spatial ensemble spread on 1st September 2016, 1st March 2017 and 1st September 2017 of the surface (5 m) temperature ((a), (b) and (c) respectively) and subsurface (100 m) temperature ((d), (e) and (f) respectively). (g) Domain-averaged time series of spread in temperature at 5 m (blue) and 100 m (red) depth.

Analyses



Location of in-situ observations (RAMA, NIOT, ADCP) used for comparison and validation of the analysis

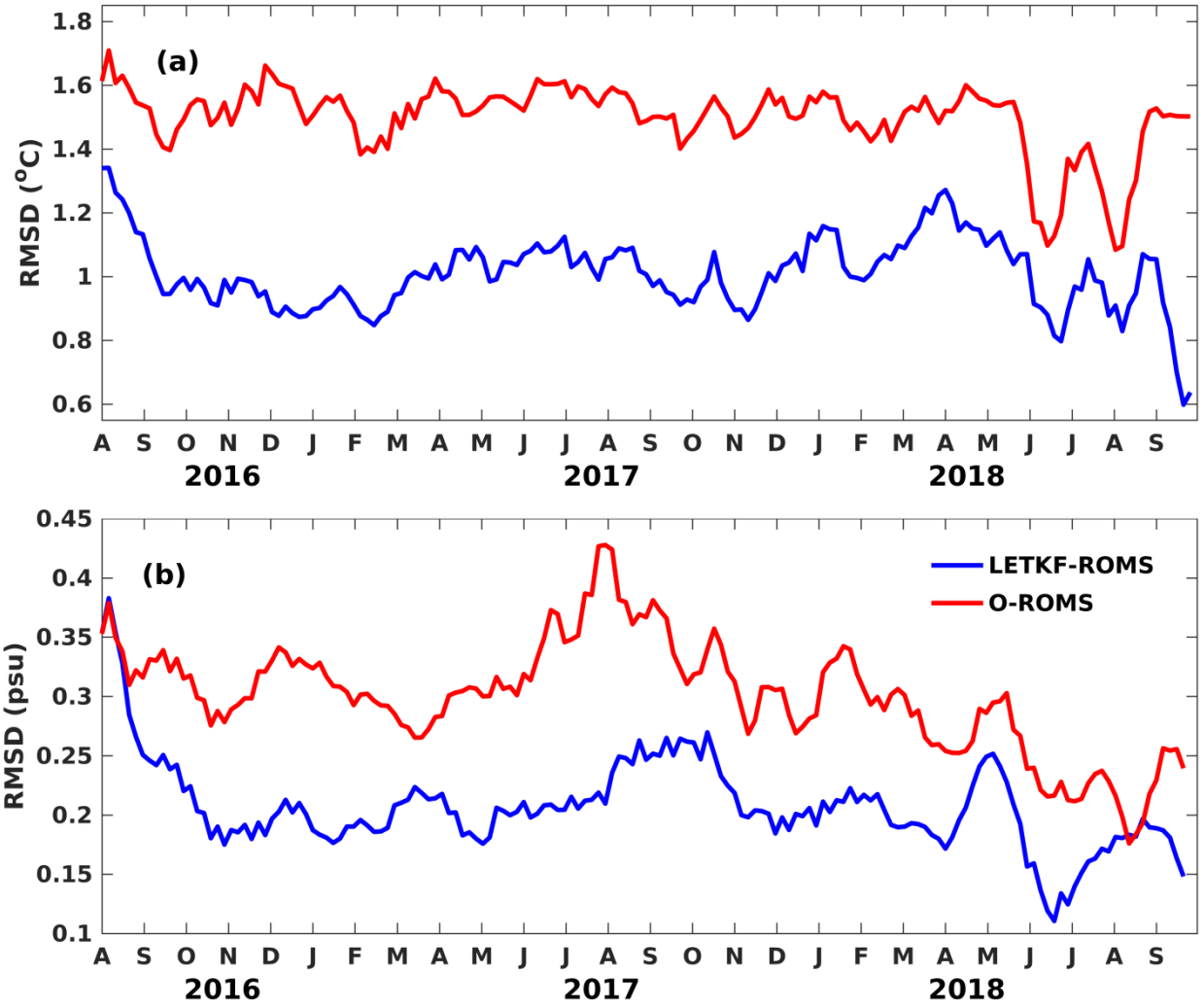


Taylor Diagram of SST from LETKF-ROMS, INCOIS-GODAS and O-ROMS with respect to RAMA

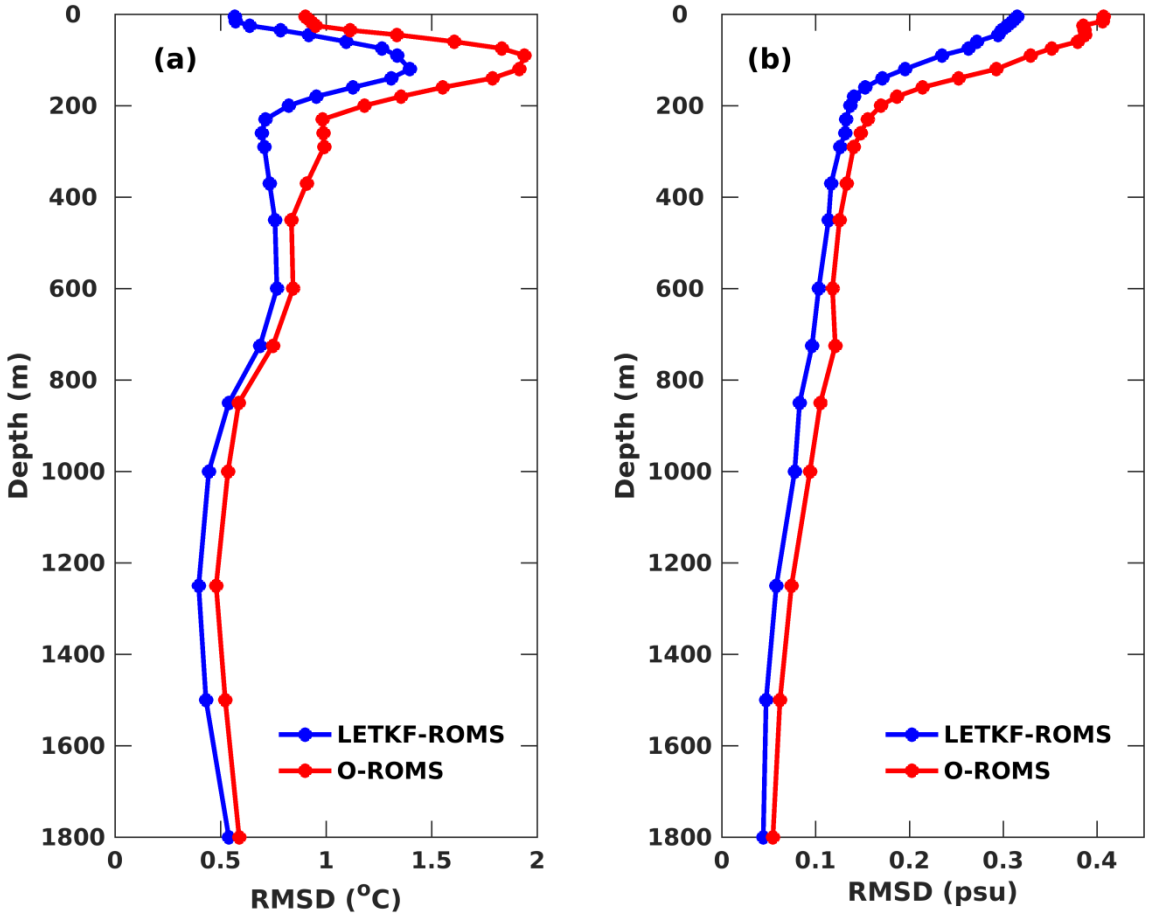
Comparisons at all locations is available in Technical Report. (Balaji et al., 2018)
http://www.incois.gov.in/documents/TechnicalReports/ESSO-INCOIS-MDG-TR-03 (2018).pdf

Temperature and Salinity Analysis

RMSD time series of (a) temperature and (b) salinity



RMSD Vertical profile of (a) temperature and (b) salinity

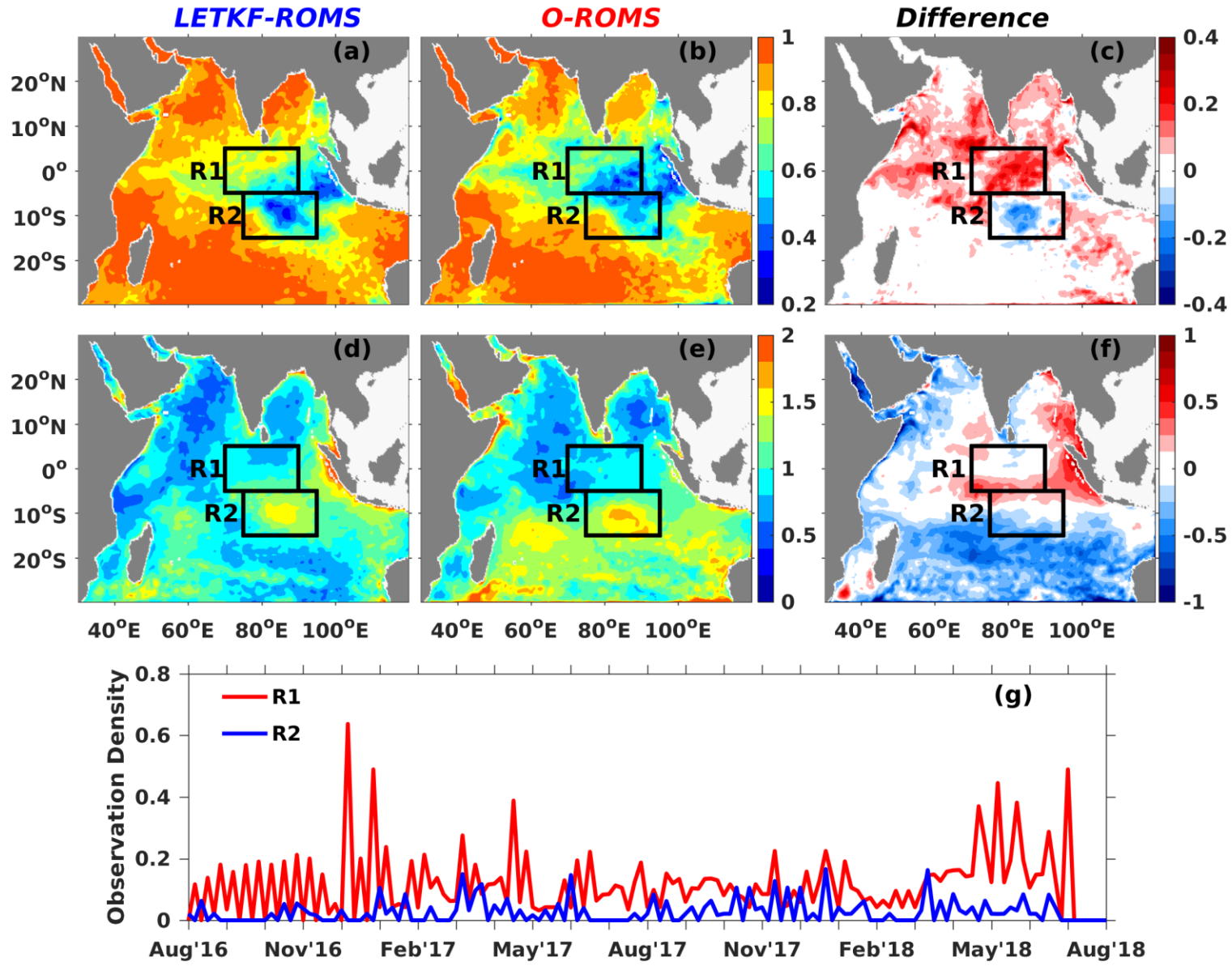


(Balaji et al., Ocean Modeling 2019)

SST Analysis

Correlation →

RMSD →

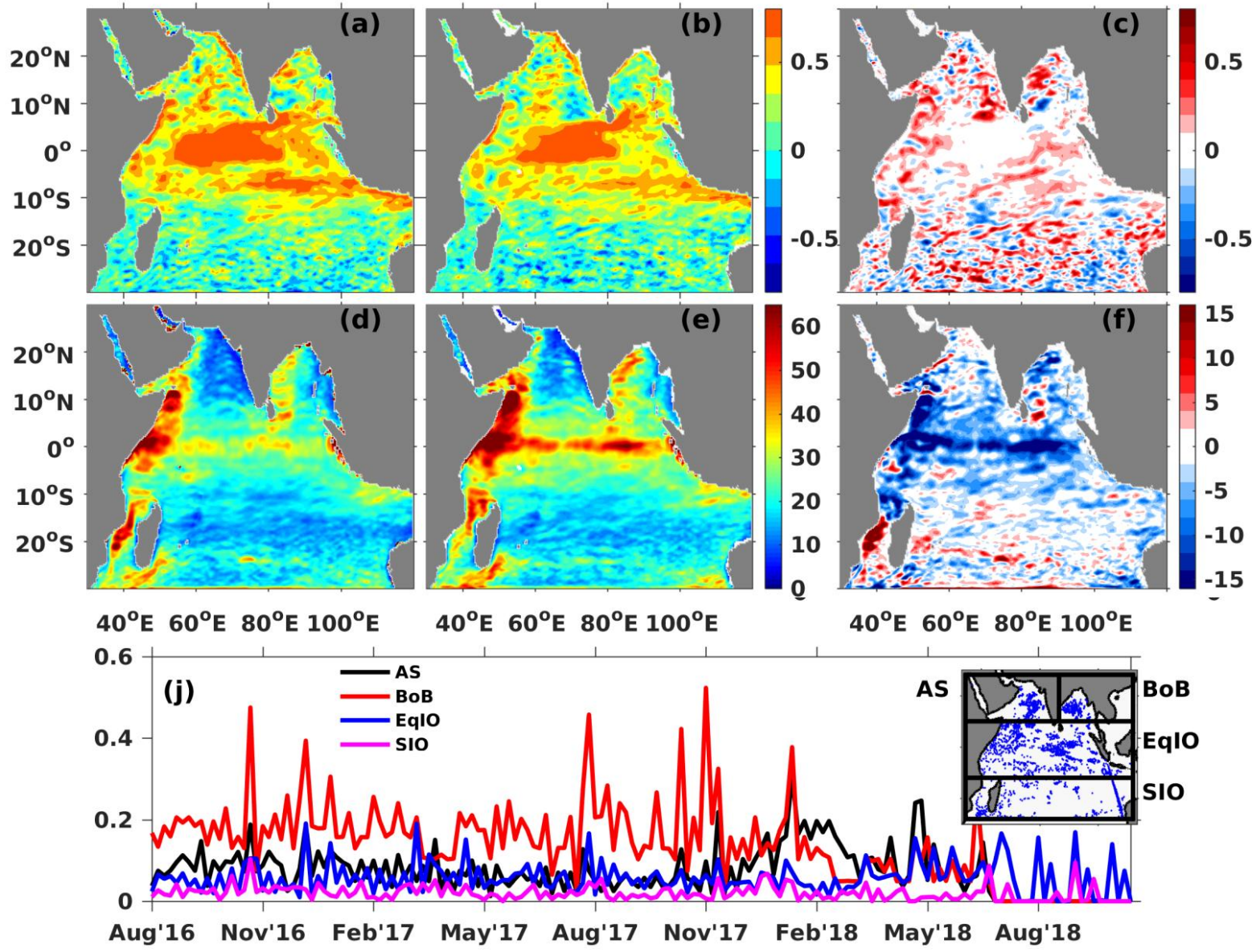


Spatial Correlation and RMSD of SST against AVHRR

Zonal Current Analysis

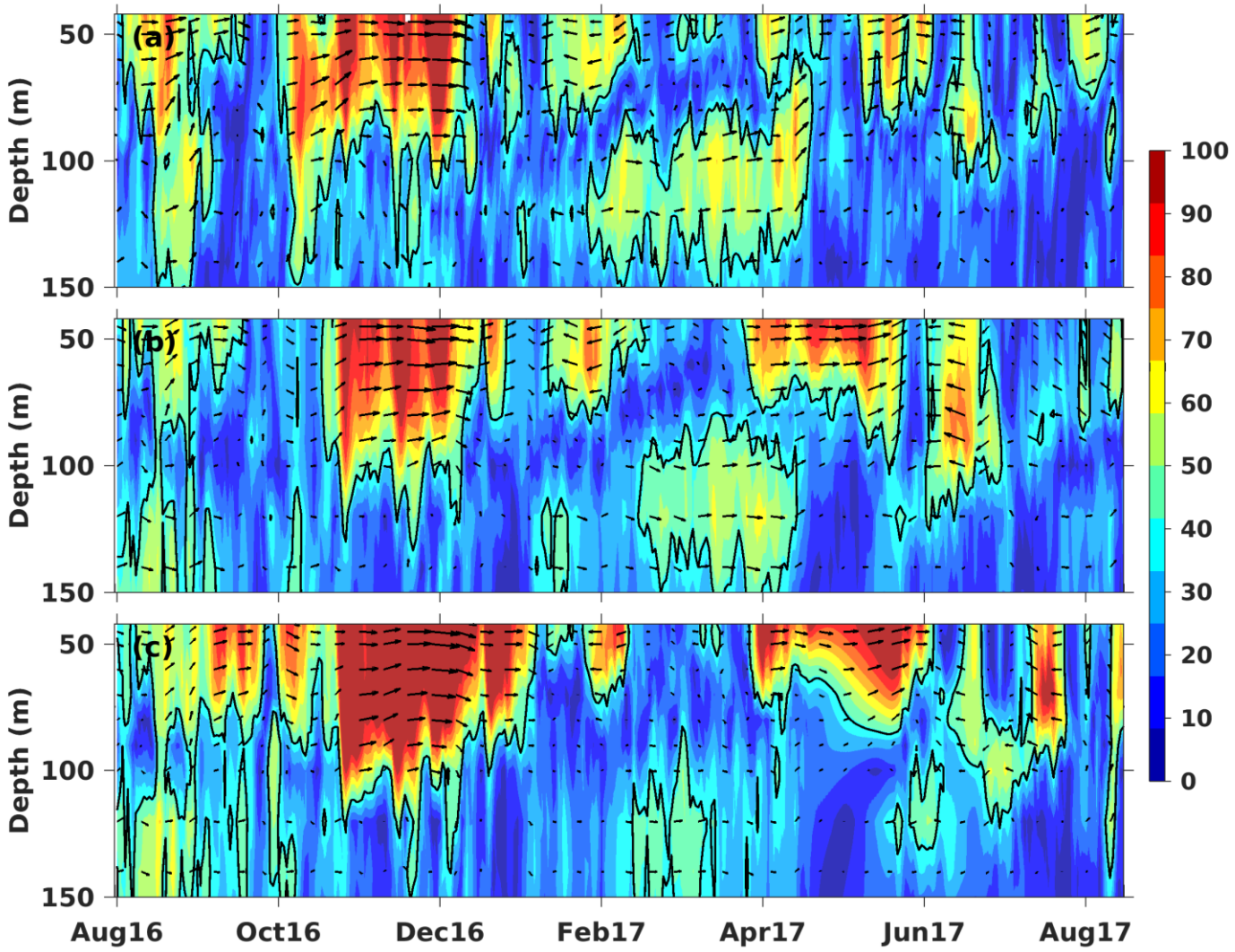
Correlation →

RMSD →

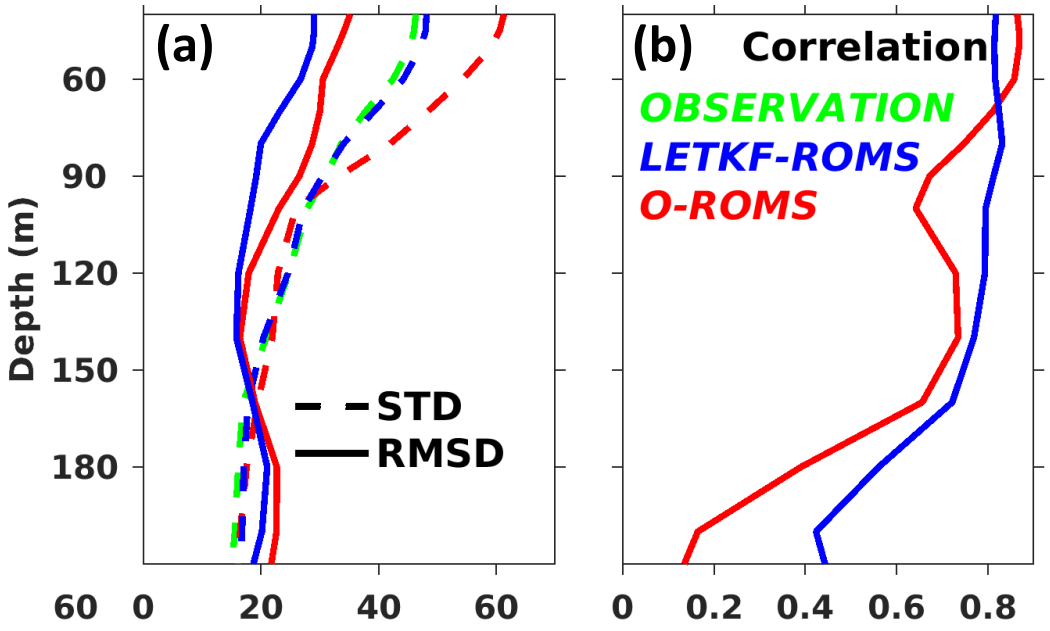


Spatial Correlation, RMSD of Zonal Current against OSCAR

Zonal Current Analysis

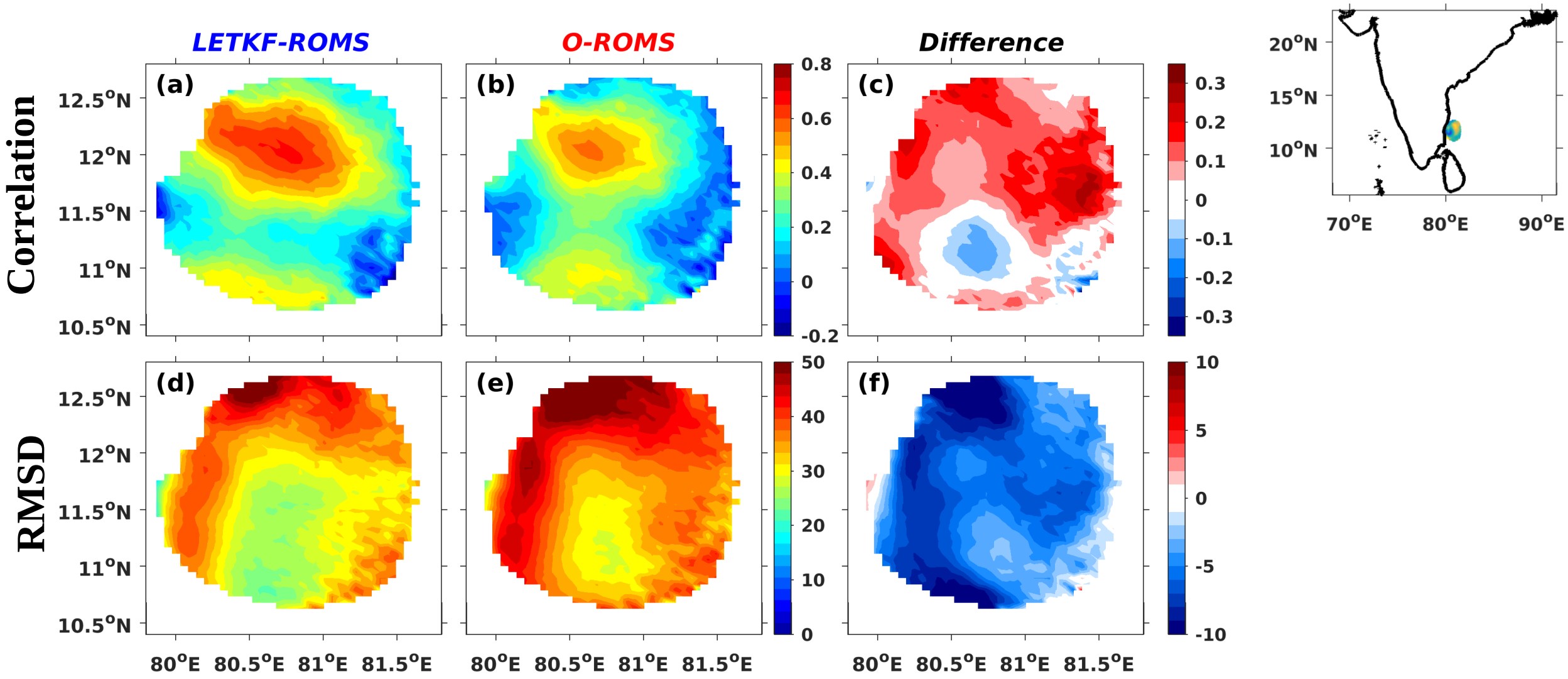


Time-depth evolution of currents at Equator, 80.5 ^{O} E from (a) ADCP, (b) LETKF-ROMS and (c) O-ROMS.



(a) RMSD and standard deviation of LETKF-ROMS and O-ROMS. (b) Correlation of zonal current of LETKF-ROMS and O-ROMS.

Current Analysis



Spatial Correlation and RMSD of Meridional Currents against HF Radar observations on East Coast of India

Summary

- An ensemble kalman filter based data assimilation is implemented using LETKF for 1/12º X 1/12º ROMS.
- This system comprises of 80 ensemble members
- It assimilates in-situ temperature and salinity profiles and satellite track SST.
- The ensemble members are tweaked to maintain healthy spread.
- The assimilation showed significant improvement in estimation of tracers as well as independent variables.
- The most profound improvements were seen in currents whose observations were not assimilated.
- RMSE in currents is reduced by 5 cm/s over entire domain and 15cm/s in Equatorial IO and East Coast of Africa.
- LETKF has shown better predictability of surface and subsurface currents.

Things to worry about:

- LETKF-ROMS is computationally expensive compared with FREE-ROMS.
- LETKF-ROMS requires periodic checks as the Ensemble system ideally works for Gaussian distributed ensemble members

References

- Balaji, B., Deepsankar, B., Paul, B., Sanikommu Sivareddy, P.A. Francis, Abhisek Chatterjee, and Arya Paul (2018). LETKF-ROMS: An improved predictability system for the Indian Ocean. Technical Report, ESSO-INCOIS-MDG-TR- 03, available at http://moeseprints.incois.gov.in/id/eprint/4572.

- Balaji, B., Biswamoy Paul, Deep Sankar, B., Sivareddy, S., Arya Paul. 2019. Ensemble based Regional ocean data assimilation system for the Indian Ocean: Implementation and Evaluation. Ocean Modelling.

- Sivareddy, S., Deep Sankar, B., Balaji, B., Biswamoy Paul, Arya Paul, Kunal Chakraborty, Ibrahim Hoteit. 2019. Impact of Dynamical Representational Errors on an Indian Ocean Ensemble Data Assimilation System. Quarterly Journal of the Royal Meteorological Society.

THANK YOU