Intercomparison of *in situ* and remote sensing surface salinity products in the global coastal ocean.

Authors: Sreelekha Jarugula, Severine Fournier, John Reager, Madeleine Pascolini-Campbell
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Background and Motivation

- Coastal sea surface salinity (SSS) at the major river mouths can be used as a metric to interpret the changes in the hydrological cycle and land-sea exchanges.
- Interannual and seasonal variability of coastal SSS is at least 10 times higher than open ocean SSS. *[Fournier et al. 2023]*
- Satellites (SMOS, SMAP) have difficulty in measuring SSS close to coastline due to land contamination, radiofrequency interference.
- Here, we perform an extensive intercomparison analysis of the different satellite SSS products and *in situ* observations in the global coastal ocean.

Data and Methods

We use ~3 million salinity profiles from the World Ocean Database (WOD) during 2010-2022 to compare the satellite SSS from JPL SMAP, REMSS SMAP (40 and 70 km), SMOS, NASA OISSS and EUR CCI. The comparisons are done as a function of distance from the coastline (40-500 km). EOF analysis is performed to understand spatial and temporal variability of SSS at 500 km from coast.

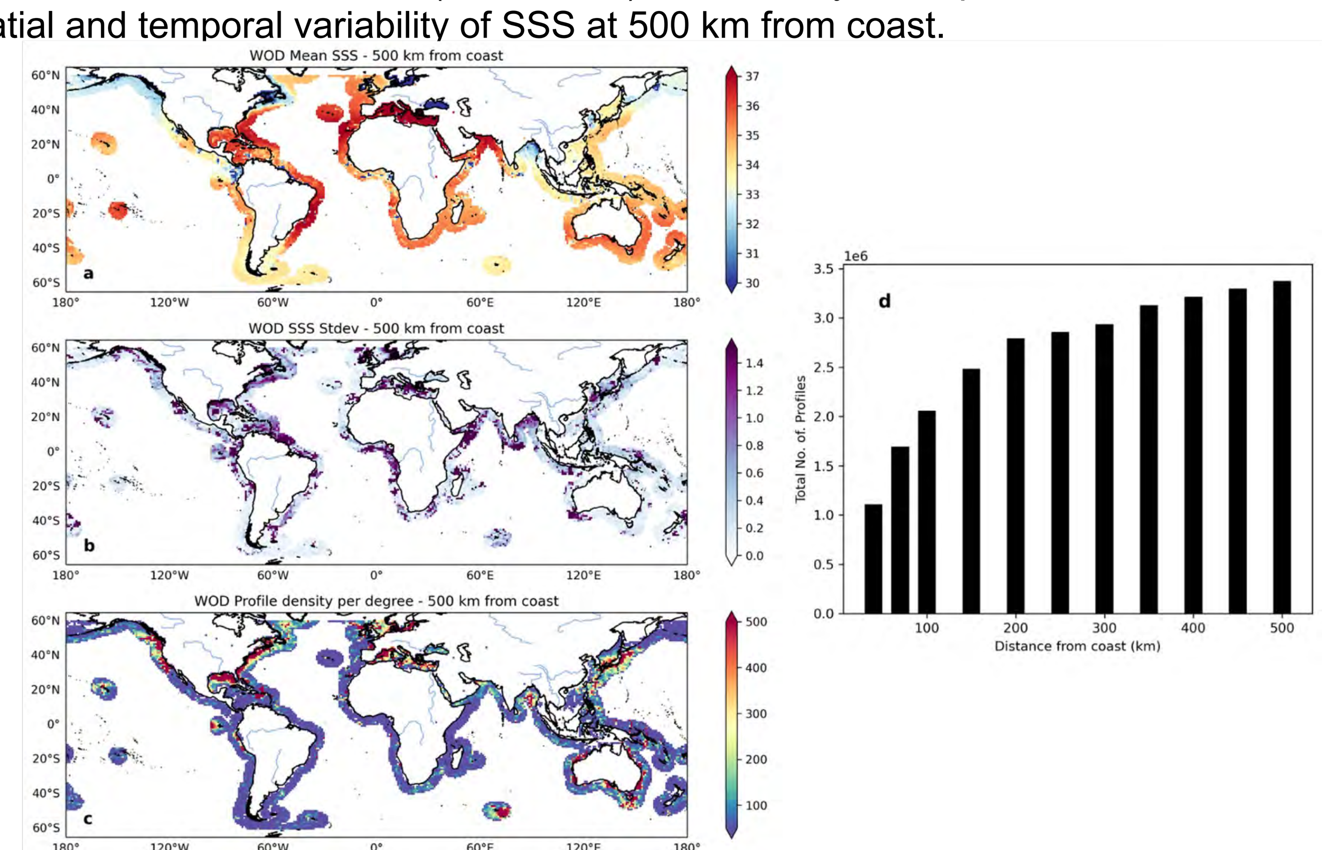


Figure 1: (a) Mean and (b) standard deviation of surface salinity (SSS; pss) 500 km from coastline from the World Ocean Database (WOD) profiles during 2010-2022. (c) Total number of WOD profiles per 1° x 1° spatial box 500 km away from the coastline used to obtain SSS. (d) Total number of WOD profiles available as a function of distance from the coast (km) during 2010-2022.

Results and Discussion

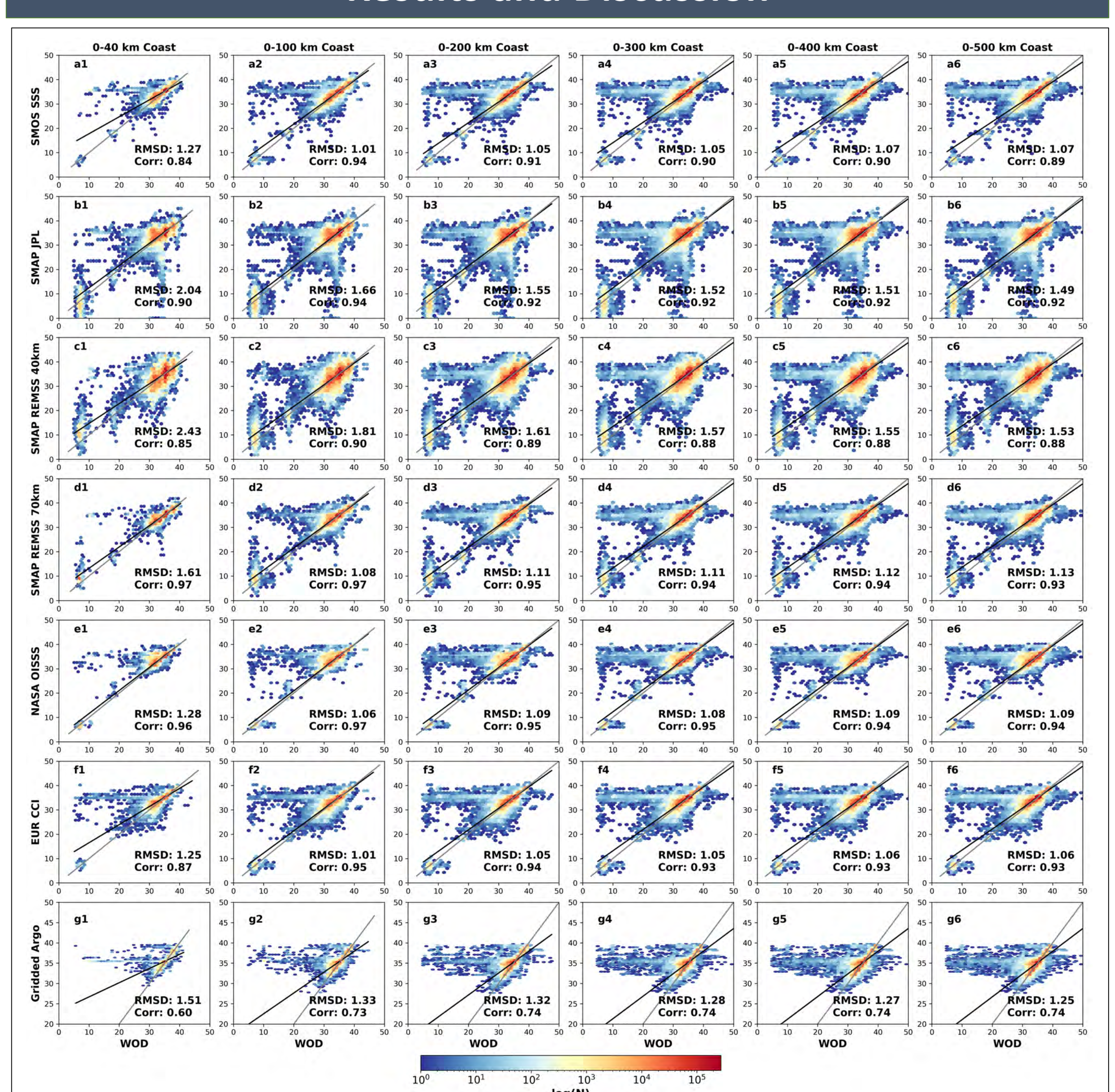
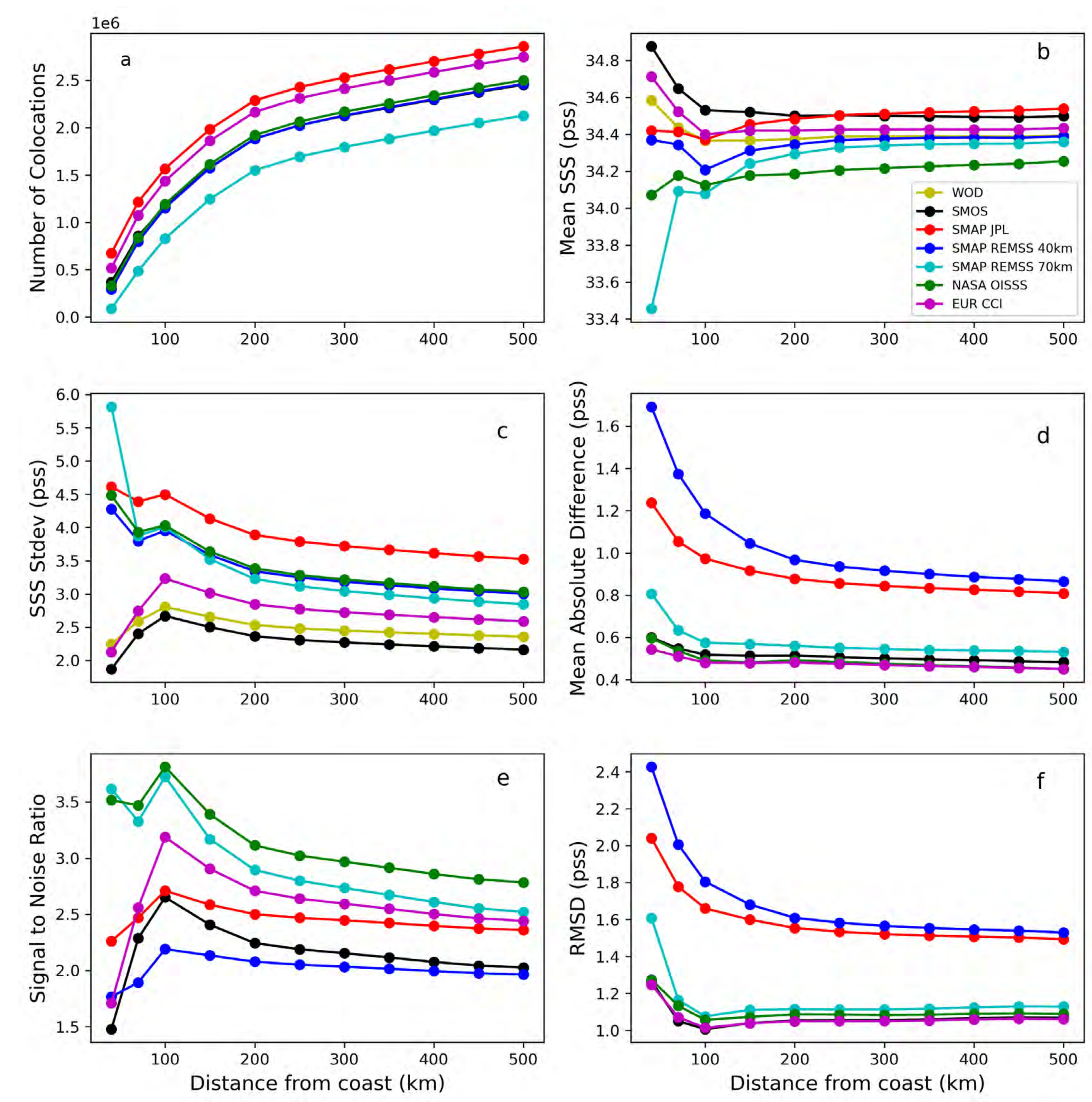


Figure 2: Binned scatter plots with 0.5 pss bin size and data density (color) between WOD SSS and satellite SSS from (a1-a6) LOCEAN SMOS, (b1-b6) JPL SMAP, (c1-c6) REMSS SMAP 40 km, (d1-d6) REMSS SMAP 70 km, (e1-e6) NASA OISSS, (f1-f6) ESA CCI and (g1-g6) gridded Argo. The six panels in each row from left to right indicate the distance from the coast: 40 km, 100 km, 200 km, 300 km, 400 km and 500 km respectively. The Root-Mean-Square Difference (RMSD), correlation coefficients, linear regression line (black) and line with slope=1 (gray) are shown in each panel. The range of salinity values on each axis is constant for all panels except for g1-g6. The color bar represents the number of profiles on a log scale.

- We observe high correlation coefficients (range 0.84 - 0.97) between satellite SSS and WOD SSS for all the satellite products. Highest correlation for each satellite product is observed at 100 km distance from the coast.
- Overestimation of fresh salinity values in the gridded Argo product as compared to the WOD point measurements indicate that the representation differences play an important role in the discrepancies: Gridded products tend to smooth out the low coastal salinity signals.

Intercomparison of satellite SSS with *in situ* observations



$$RMSD = \sqrt{\frac{\sum(Satellite\ SSS - WOD\ SSS)^2}{N}}$$

, N is the total number of observations available for collocation. The collocations are *in situ* data centric and have a space-time cutoff of ± 25 km and ± 3 days.

Signal to noise ratio (SNR) is defined as the ratio between the standard deviation in the satellite SSS and RMSD

- Number of collocations increase as a function of distance from coast.
- Mean Bias and root-mean-squared difference (RMSD) decrease as a function of distance from the coast.
- SNR for all satellite SSS products is highest at 100 km from the coast and generally high for merged products (OISSS and CCI) and REMSS 70 km SMAP.
- REMSS 40 km and JPL SMAP have high RMSD (1.6-2.4 pss) as compared to other products (1-1.6 pss).

Figure 3: Intercomparison of statistical relationships between the global sea surface salinity (SSS; pss) from WOD and different satellite SSS products as a function of distance from the coast (km): (a) Number of collocations with in situ available for each satellite product and gridded Argo, (b) mean SSS (pss), and (c) standard deviation (pss) of each satellite and in situ data product, (d) mean absolute difference between gridded Argo, satellite and WOD (pss), (e) signal-to-noise ratio and (f) Root-mean-square Difference between gridded Argo, satellite and WOD (RMSD; pss). The different colored lines indicate SSS from the different products, labels shown in panel b.

EOF Analysis of global coastal SSS from satellites and gridded Argo

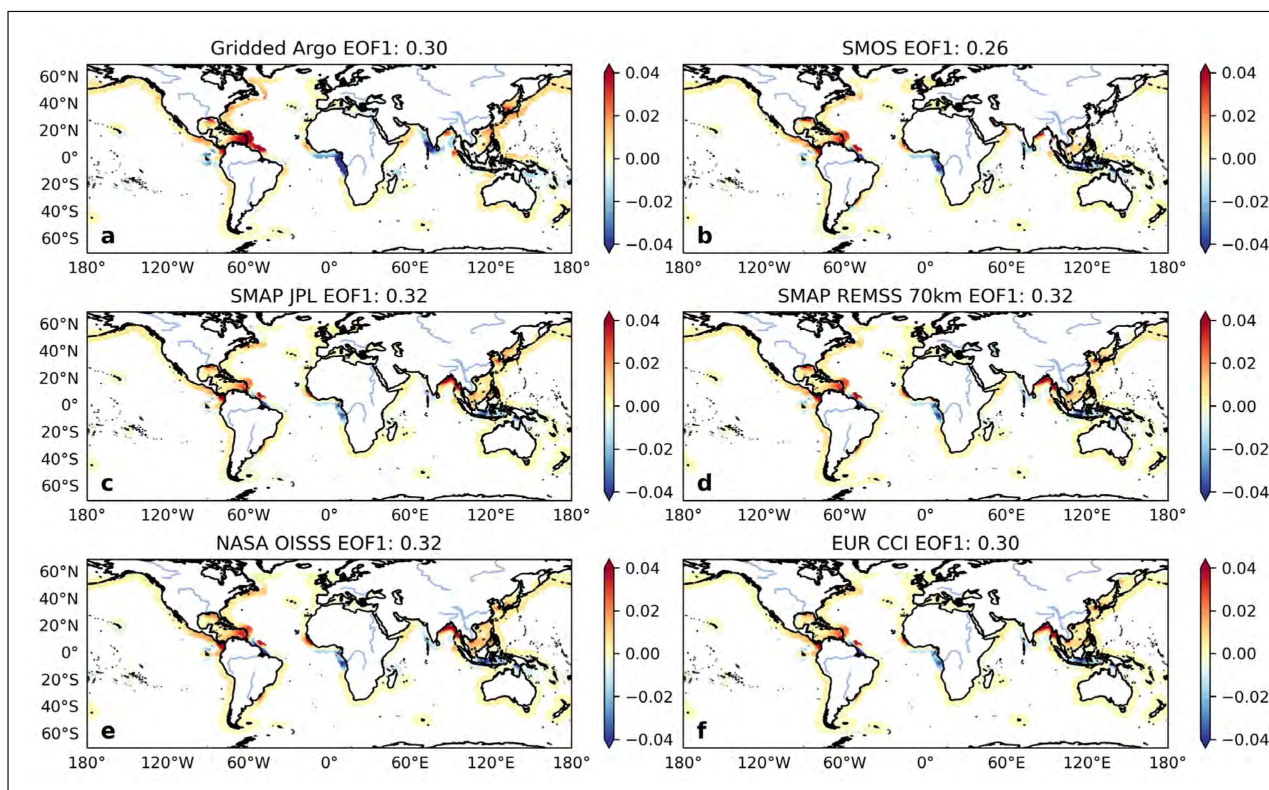


Fig 4: Spatial maps of mode EOF-1 for gridded Argo and satellite SSS at 500 km from the coast.

- Gridded Argo and satellite SSS products show comparable fraction of variance in EOF 1-3 modes.
- EOFs 1-2 are associated with seasonal cycle of SSS at major river mouths in the northern and southern hemispheres.

- Principal component timeseries corresponding to EOFs 1-3 show satellite SSS and Argo agree well on seasonal timescales.
- Distinct differences found between Argo and satellite SSS products in resolving the non-seasonal variability (mode EOF-3)

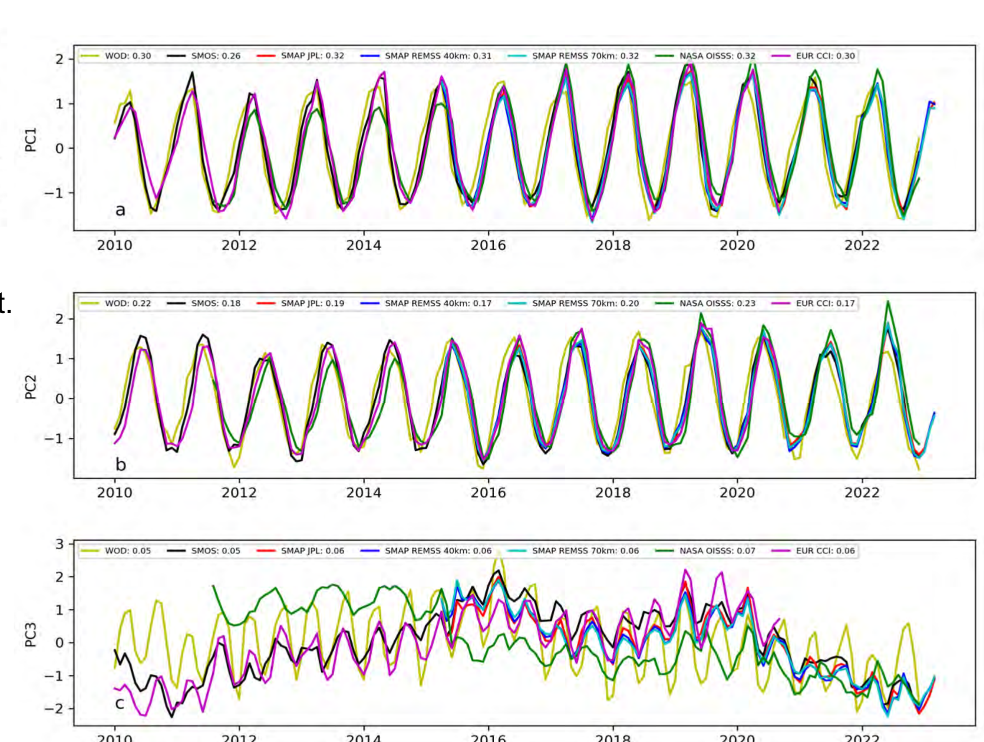


Figure 5: The principal component time series corresponding to the modes (a) EOF1 (b) EOF2 and (c) EOF3.

Summary

- High RMSD values in satellite SSS products close to the coastline are mainly attributed to issues such as radio frequency interference, land contamination in the retrieved signals and sampling differences between the satellite and *in situ* data.
- EOF analysis shows both gridded Argo and satellite products capture the seasonal variability in the coastal SSS well but have significant differences in capturing the non-seasonal variability.
- There is a need for improvement in the spatiotemporal coverage, sampling resolution of near-surface coastal salinity measurements to monitor the impacts of changing hydrological cycle and land-sea exchanges on coastal ocean processes and better prediction of extreme events.
- It is important to maintain an improved and sustained network of ocean observations in the coastal regions to help validate the available satellite observations.

References:

Fournier, S., Reager, J. T., Chandanpurkar, H. A., Pascolini-Campbell, M., & Jarugula, S. (2023). The salinity of coastal waters as a bellwether for global water cycle changes. *Geophysical Research Letters*, 50, e2023GL106684.

Jarugula S., Fournier S., Reager J. T. and Pascolini-Campbell (2024). Intercomparison of in situ and remote sensing surface salinity products in the global coastal ocean. *Manuscript in Review in JTech.*

Author Contact Information: sreelekha.jarugula@jpl.nasa.gov