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BACKGROUND

ARGO AND OCEAN OBSERVATIONS

Historical measurements of ocean salinity are very sparse in space and time; The global Argo program has become a major component of the Global Ocean Observing System.

UNDERLYING ISSUES

The salinity sensors are subject to drift over time; Errors in the Argo salinity measurements are found responsible for 40% of the non-closure of the sea level budget since 2016.

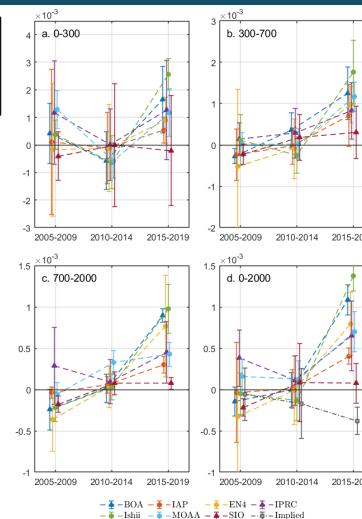
GOALS

Assess the uncertainties of salinity variability from various objective analyses and their spatiotemporal characteristics; Examine if there is a geographical preference of the 'errors' after 2016

A VIEW FROM THE TREND: Large Spread In the Deep

Figure 2. 5-year trends of global mean salinity in vertically averaged layers and their uncertainties ($\pm\sigma$). The implied salinity trend is also given. (Unit: g/kg/year)

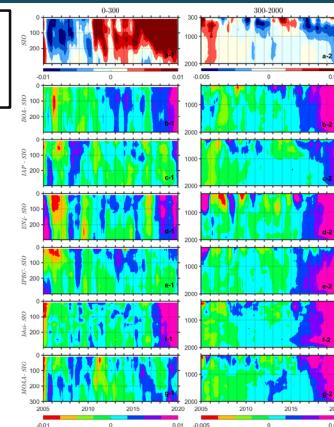
- Globally, the 2010-2014 period has the lowest spread of the estimated 5-year trend between the products;
- The spread substantially increased in the 2015-2019 period, and is at least comparable to 2005-2009, when the spatial coverage of Argo was much lower;
- All examined products show strong positive trends during 2015-2019 when the ocean is supposedly freshening;
- This discrepancy is most apparent between 25-60°S and 700-2000 m (see Figure 3).



SPATIAL DISTRIBUTION: A Common Cause?

Figure 4. a) Mean salinity anomaly over 25-60°S as a function of depth and time over 2005-2019. b-f) Residuals of anomaly after subtracting SIO from the other products. (Unit: g/kg)

- SIO is chosen as a reference for its trend is the closest to the implied salinity change;
- A strong increase in salinity above 300 m, while below 300 m the water has generally freshened;
- Traces of a positive bias are found in the residuals between SIO and other products, particularly below 300 m;
- In the SIO analysis, a strong freshening is evident along the ACC region, yet all other products have large positive residuals.



MEAN SALINITY: Splitting After 2015

- Most products exhibit a rapid increase in the 0-200 m global ocean from 2015 onwards;
- However, such increase is opposite to the implied salinity change from sea level budgets;
- Inconsistency of the timeseries is more evident since 2015, and it is also more apparent in the 700-2000 m layer.

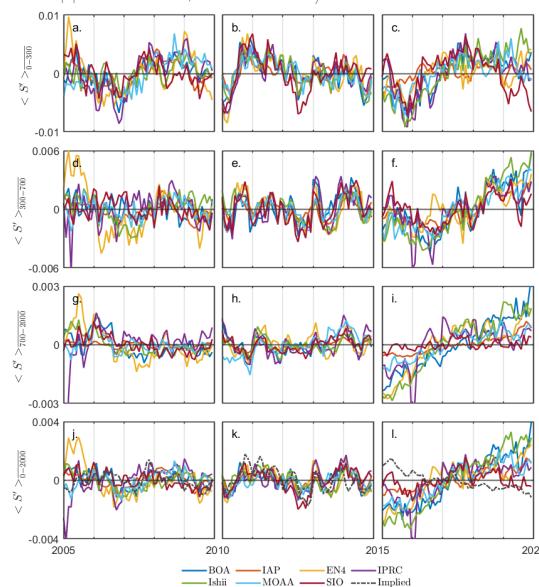


Figure 1. Monthly timeseries of global mean salinity anomaly ($\langle S \rangle$) in vertically averaged layers (0-300m, 300-700m, 700-2000m). The 'implied salinity' anomaly is also given. (Unit: g/kg)

Implied Salinity Calculated from the sea level budget by subtracting *Gravity Recovery and Climate Experiment* and *thermsteric Argo contributions* from *altimetry observations*

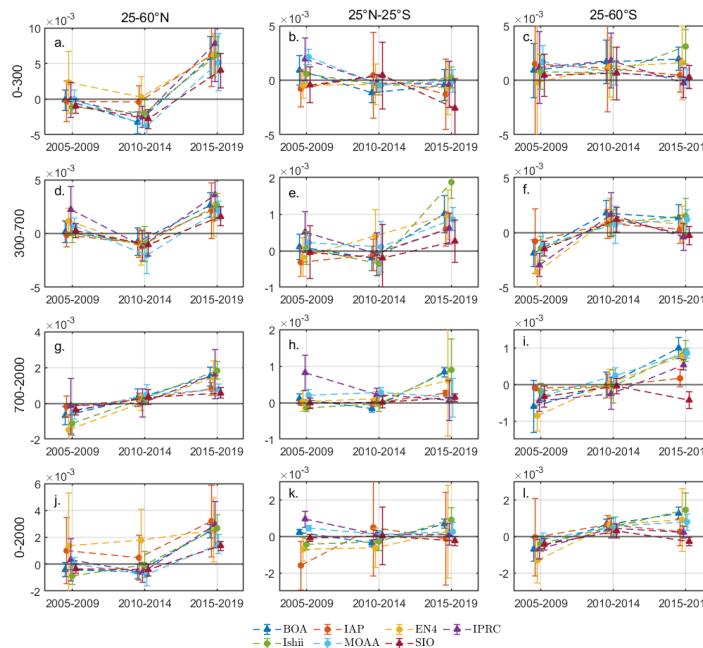


Figure 3. 5-year zonally averaged salinity trends in vertically averaged layers. (Unit: g/kg/year)

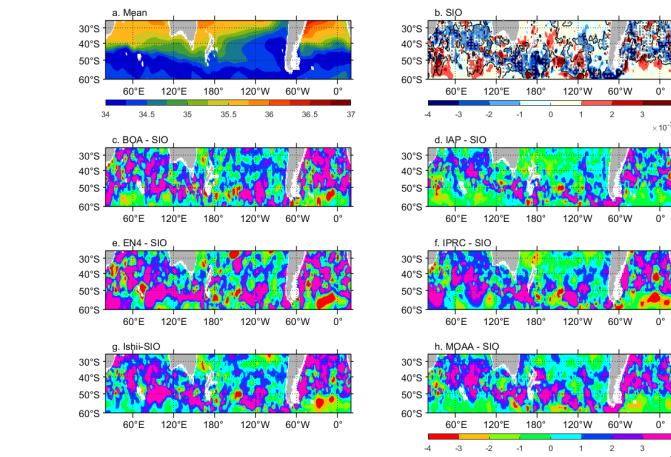


Figure 5. Mean salinity, 5-year trend, and residuals of the trend over 25-60°S between 700-2000 m over 2015-2019. (Unit: g/kg & g/kg/yr for the left and right columns, respectively.)

CONCLUSIONS

- Spreads on both the anomaly timeseries and the trends have substantially increased after 2015 between various objective analyses;
- A consistent increase of salinity is observed in most products after 2015. However, it is likely not real for being inconsistent with other measurement;
- Most objective analyses show a strong positive bias against the implied salinity change after 2015, which could result from sensor drifts.