# Small-Scale Salinity Variability from Thermosalinographs: A Global Perspective

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1. How does salinity variability affect satellite validation?

2. Where does salinity drive submesoscale density variability?

# Historical thermosalinograph (TSG) data

LEGOS Sea Surface Salinity Observation Service (Alory et al. 2015)

- Research vessels, voluntary observing ships, sailing ships
- ~$8x10^6$ good measurements: 29 ships, 1000 transects, 1993-2015

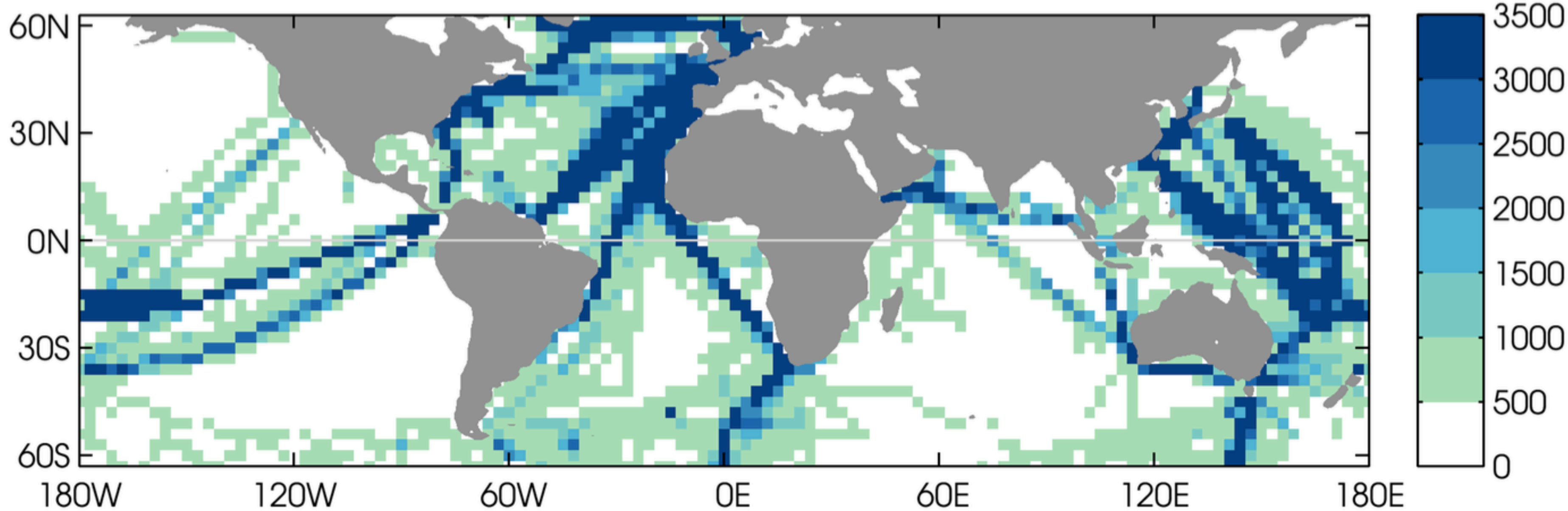
+ data from R/V Polarstern (Alfred Wegener Institut)

- 1989-2014: ~$4.5 \times 10^5$ good observations

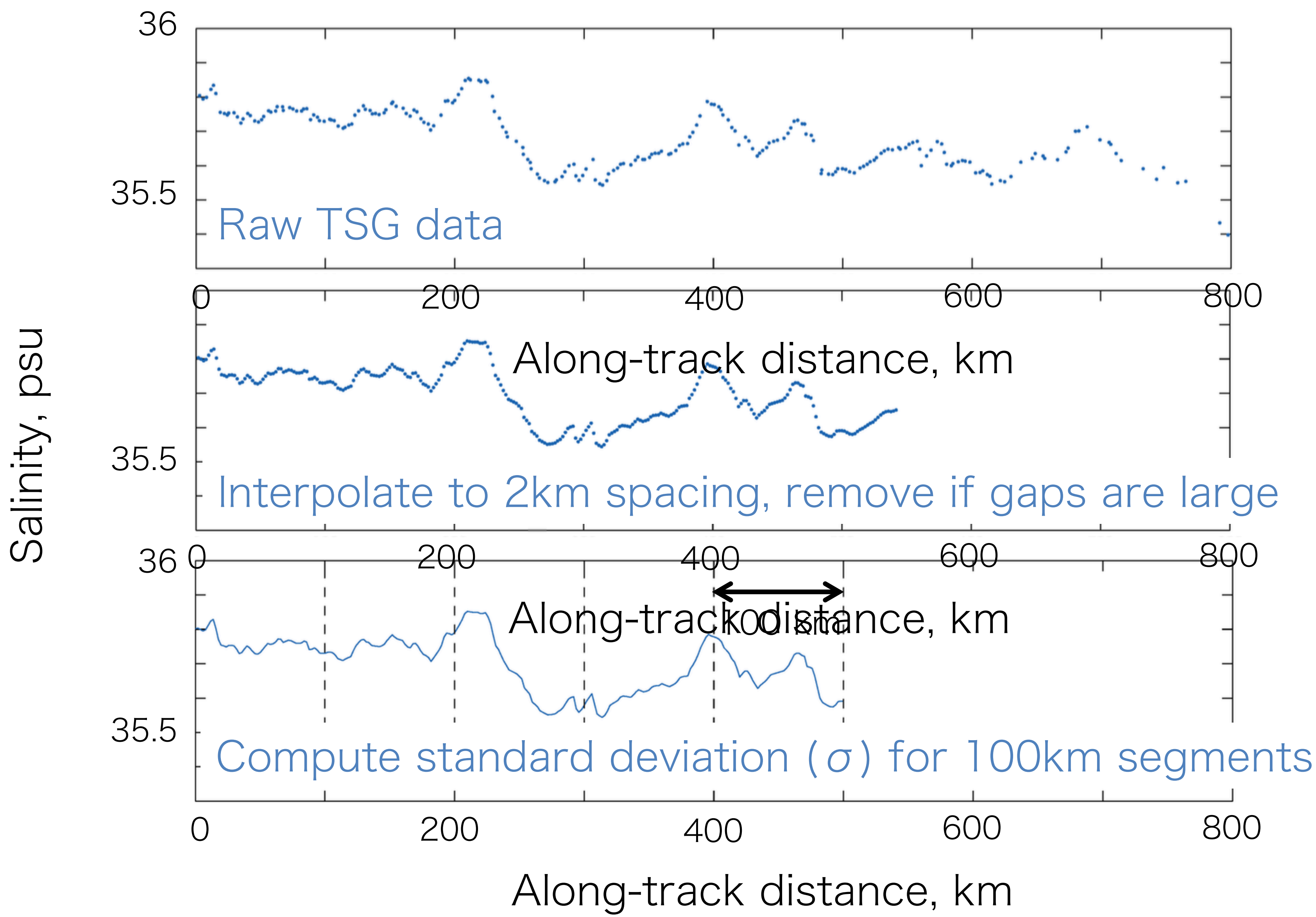
+ data from M/V Oleander (NOAA; quality control by Clifford Hoang)

- 2001-2014: $2x10^6$ good observations

Total number of TSG observations per $3^o x 3^o$ box
(*some have salinity only)

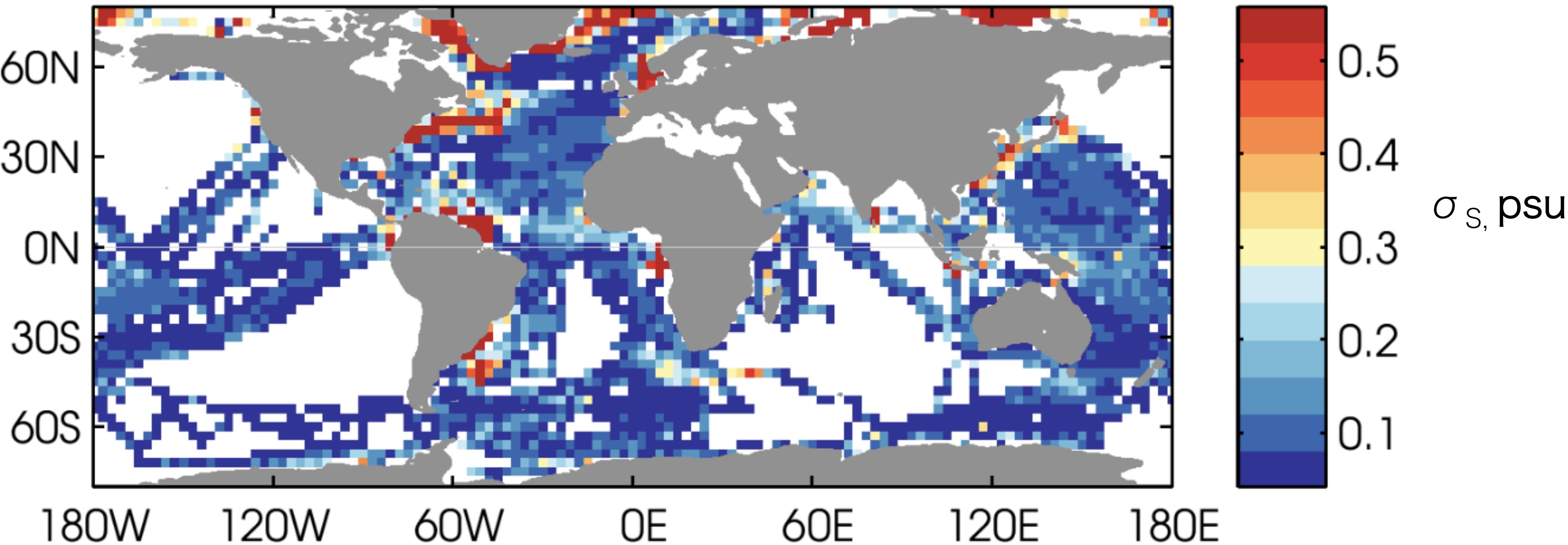


# Quantifying "small-scale" variability



# Small-scale salinity variability ($\sigma_S$)

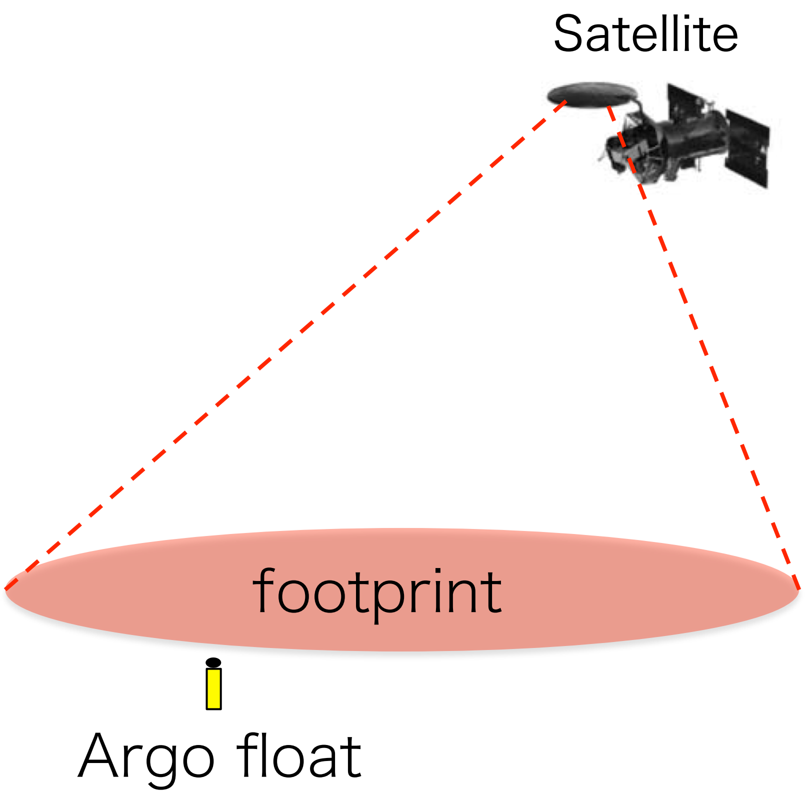
Binned 100-km standard deviation
(95th percentile of values in each bin)




Strongest where large-scale fronts are strong:

- Gulf Stream, Agulhas
- River outflow regions
- Ice-influenced regions

# Part 1. Salinity variability on scales <100 km affects satellite salinity validation

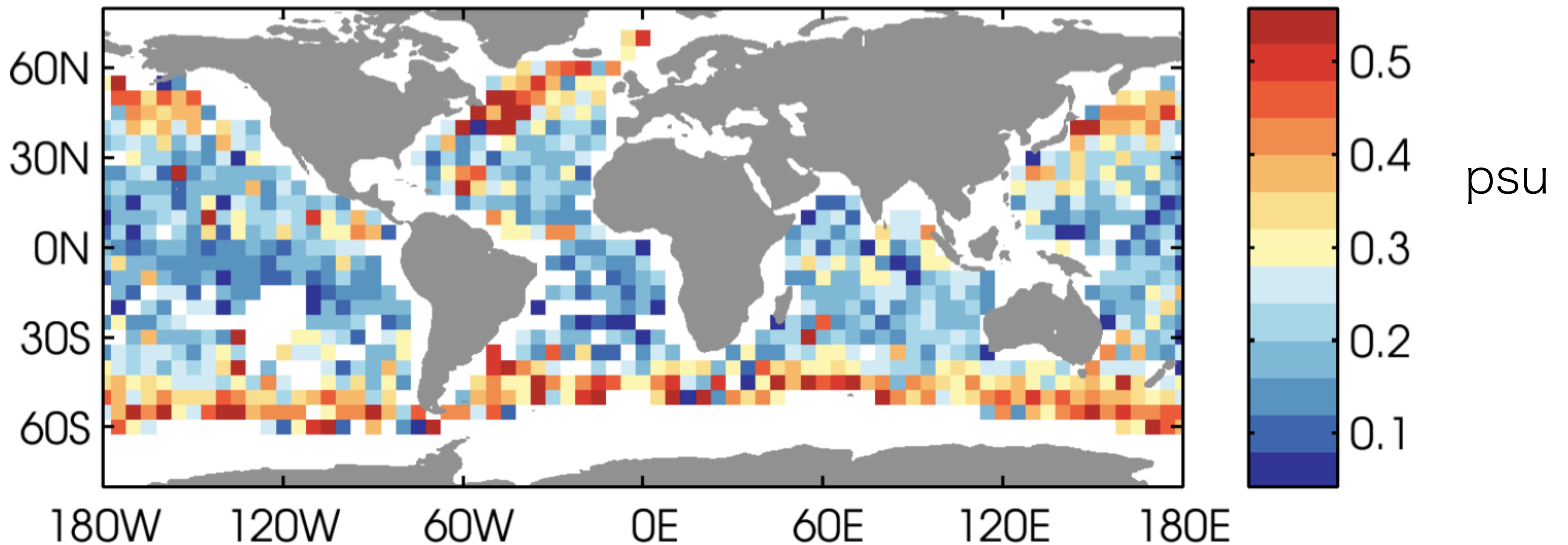



**Question 1:**
Do "subfootprint-scale" salinity variations resemble satellite uncertainties?

Aquarius: 50-100 km footprint
SMOS: ~45 km footprint
SMAP: ~40 km footprint

See Vinogradova & Ponte 2013 for a model-based estimate

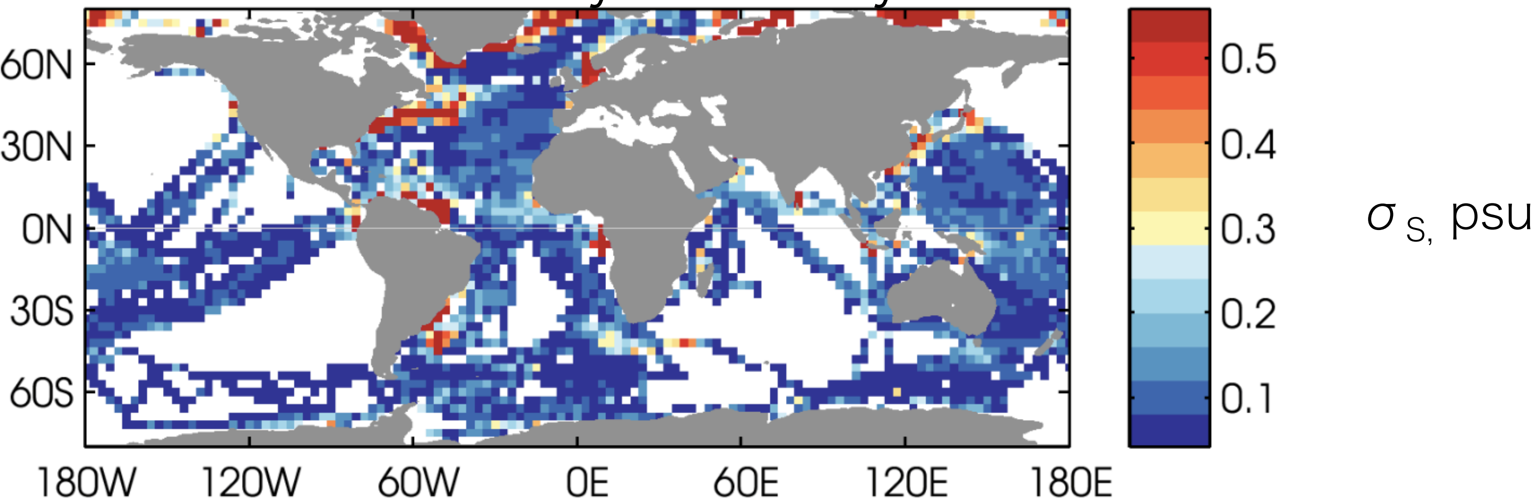
# Aquarius-Argo RMS difference



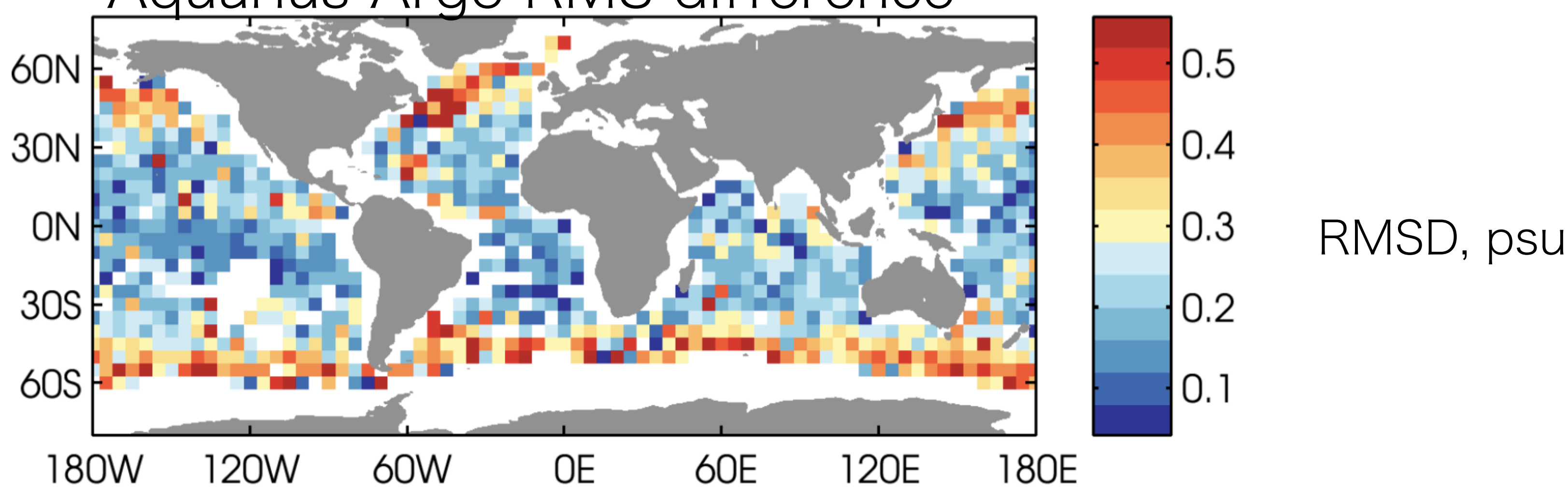

- Aquarius V4 L2 data, 2011-2015
- Matched to Argo profiles shallower than 5m within 50 km & 1 day.
- $2.1\times10^5$ matchups. Mean difference (bias) is removed, then RMSD calculated from matchups in 5°x5° bins

# Conclusion 1: Aquarius noise is largely consistent with small-scale salinity variability

Small-scale salinity variability




Aquarius-Argo RMS difference



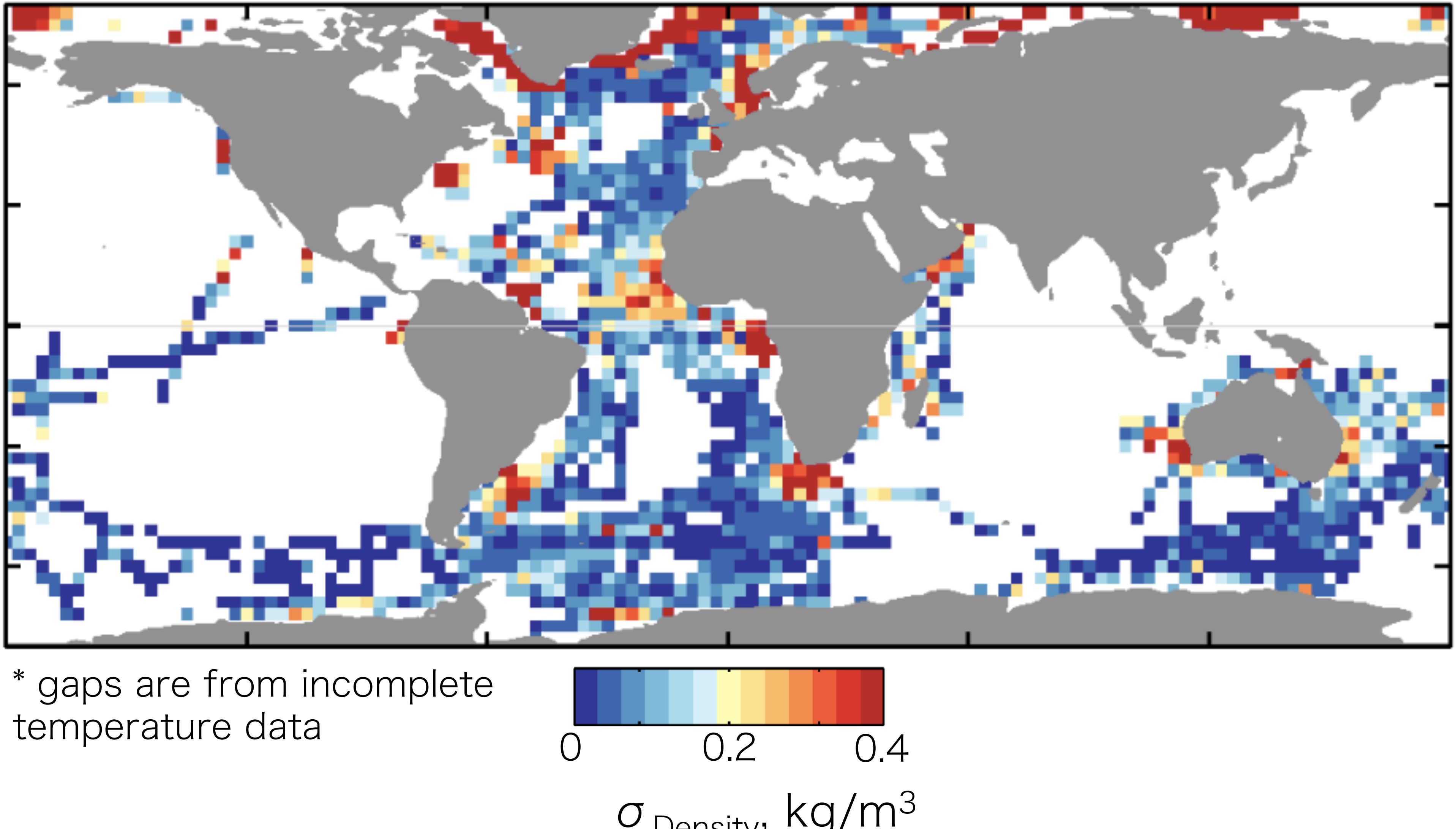
# Part 2. Impacts of small-scale salinity on density

Submesoscale surface density fronts have significant impacts on ocean dynamics.

- Laterally: affect turbulent transfers between scales (e.g. energy cascade from the mesoscale).
- Vertically: are associated with near-surface vertical velocity, transport between surface/mixed layer.

**Question 2:**
Where does salinity drive surface density variability on *O*(1)-*O*(10) km scales?

# Small-scale density variability from TSG data
(standard deviation over 100 km segments)




* gaps are from incomplete temperature data

# Two considerations regarding drivers of surface density variability:

1. Density fluctuations are related to salinity & temperature fluctuations:

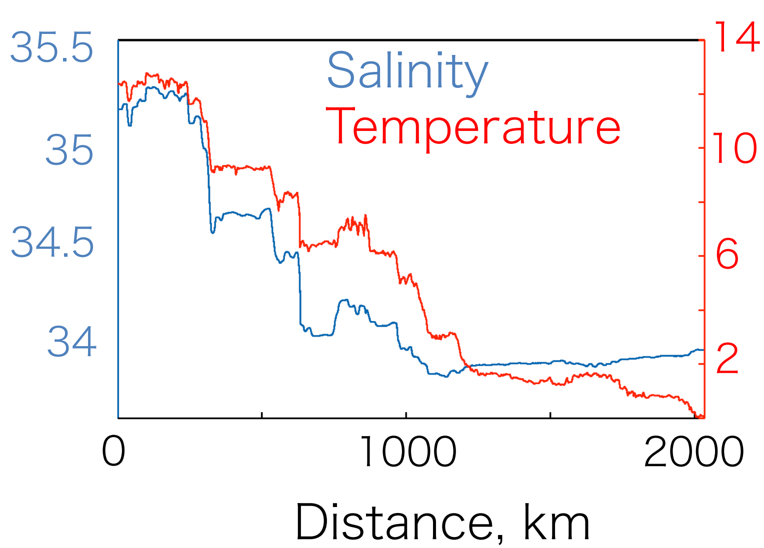
$$\frac{\Delta\rho}{\rho_0} = \beta\Delta S - \alpha\Delta\theta$$

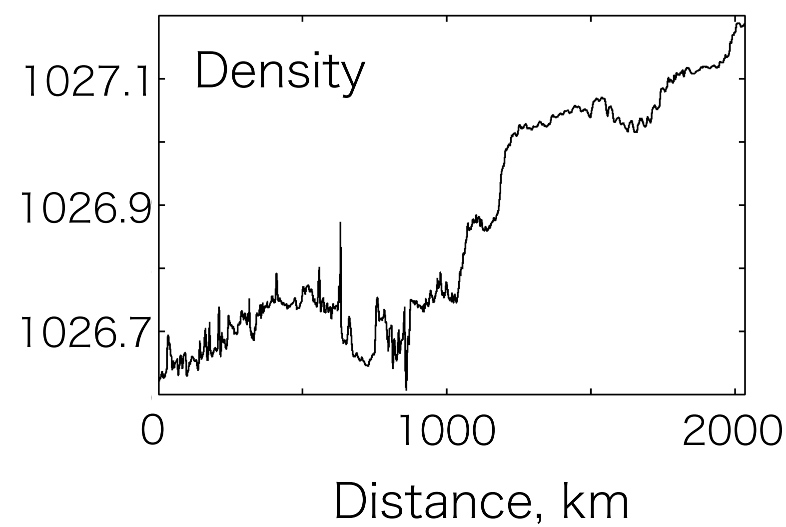
$\beta$: Haline contraction coefficient

$\alpha$: Thermal expansion coefficient

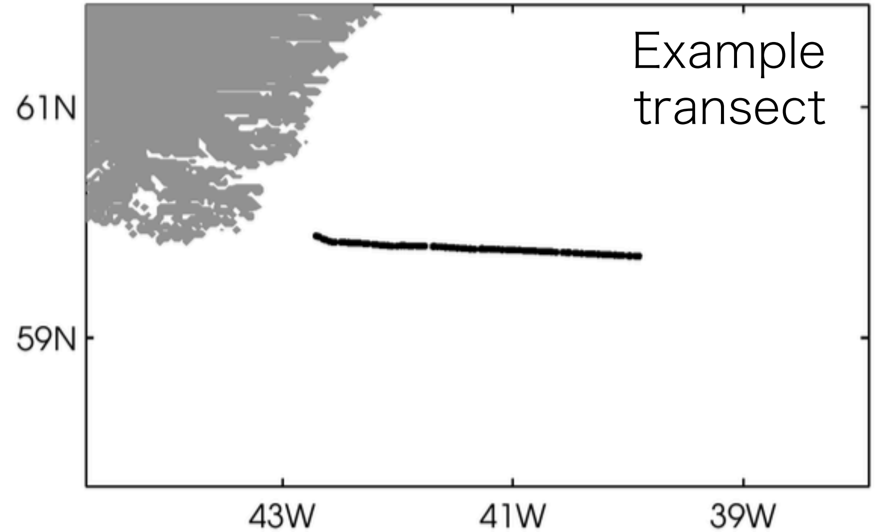
$\alpha$ and $\beta$ vary relative to each other
- tropics $\beta \sim 2\alpha$
- high latitudes $\beta >> \alpha$

2. Compensated fronts have no density anomaly



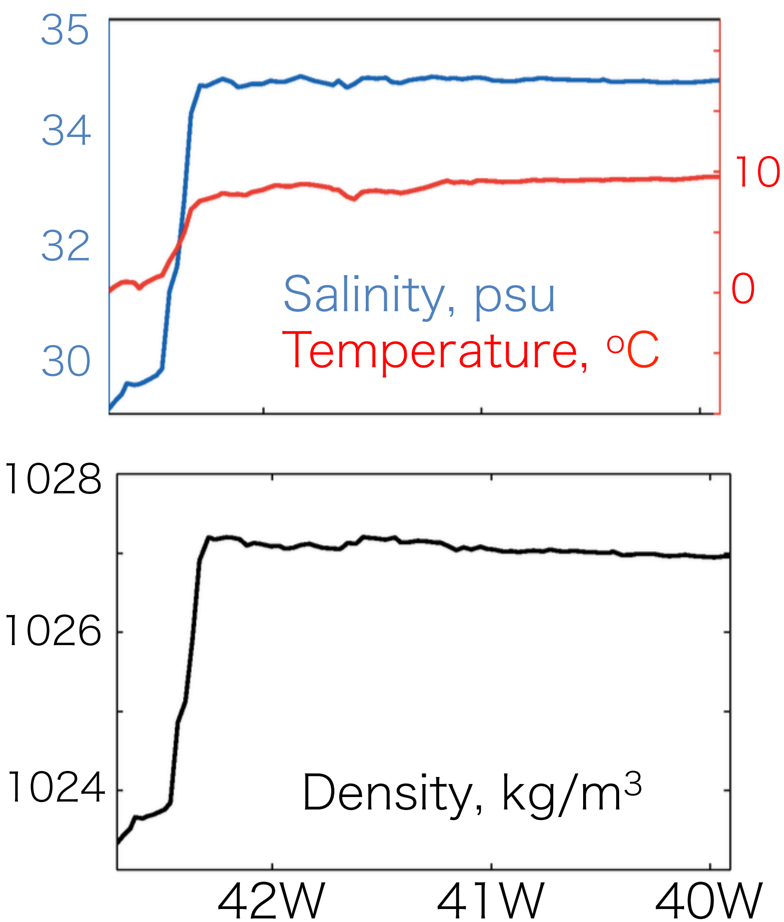
# Example: Greenland



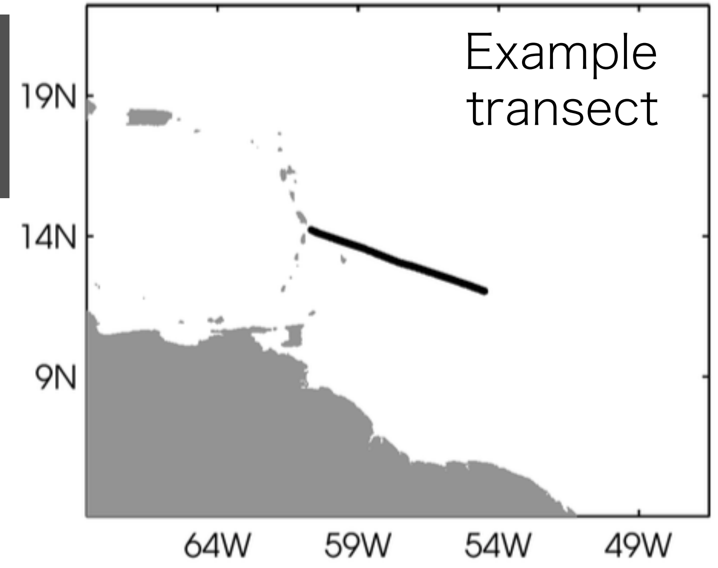

Ice melt drives strong variations in both *T* and *S*

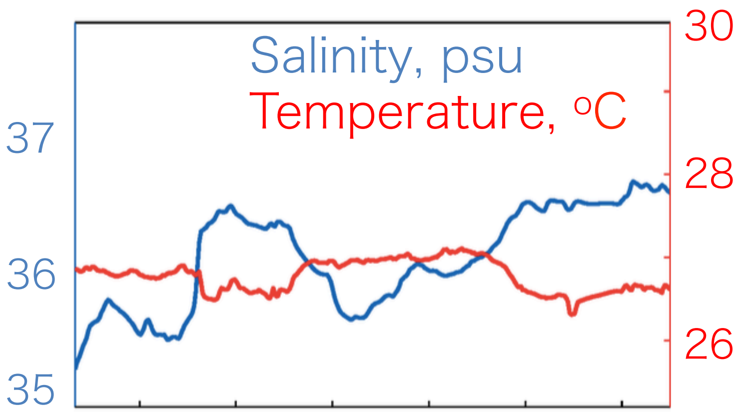
Density is somewhat compensated –

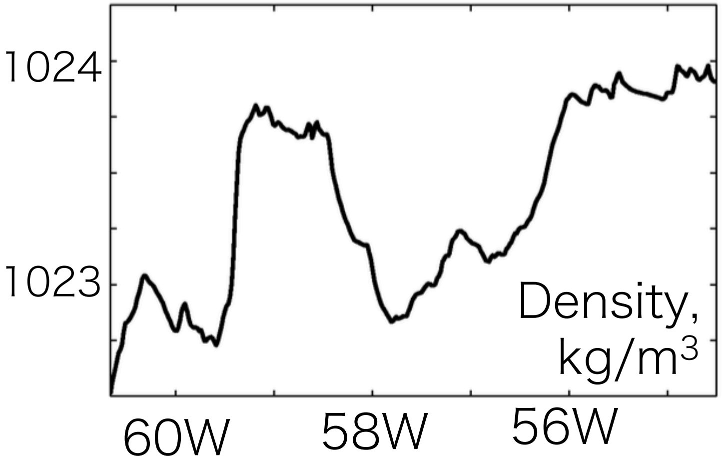
But $\beta >> \alpha$ , so salinity anomalies dominate density



# Example: Amazon



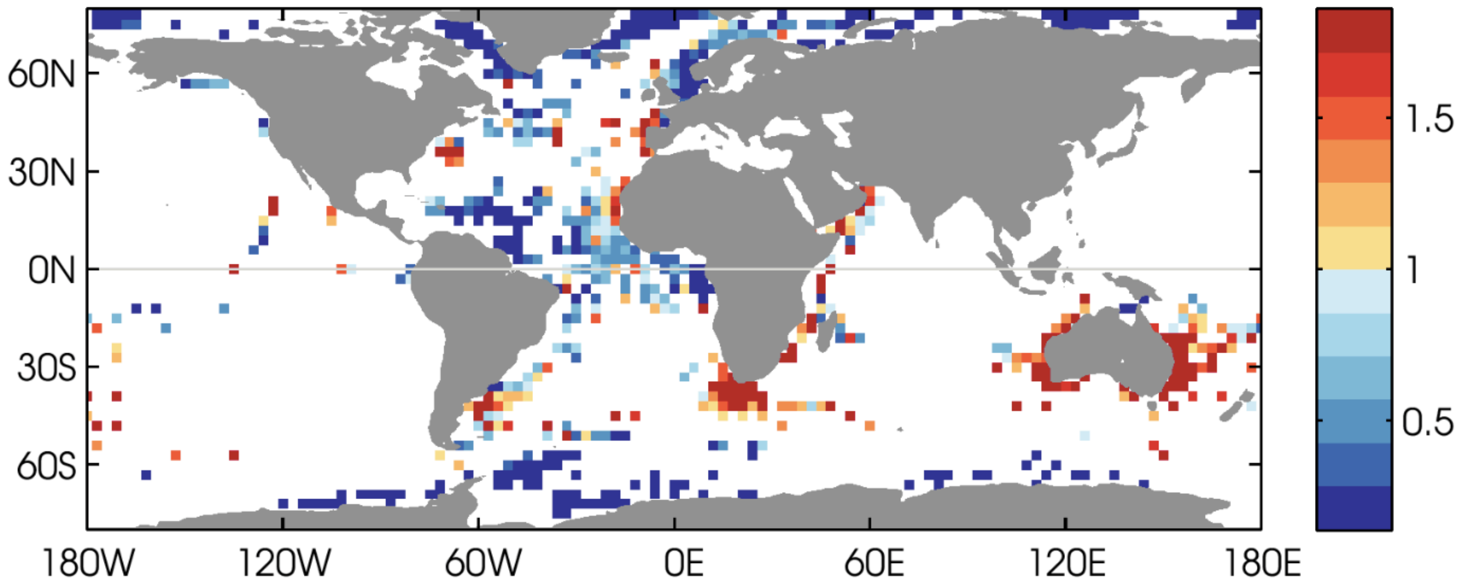

*T* and *S* act together – strong density variability

# Temperature and salinity both drive small-scale surface density

"Density variability ratio "

$$\frac{\alpha \cdot \sigma_T}{\beta \cdot \sigma_S}$$

* Only regions with strong density variability




Where large-scale SST gradient is strong

**Temperature** variability dominates

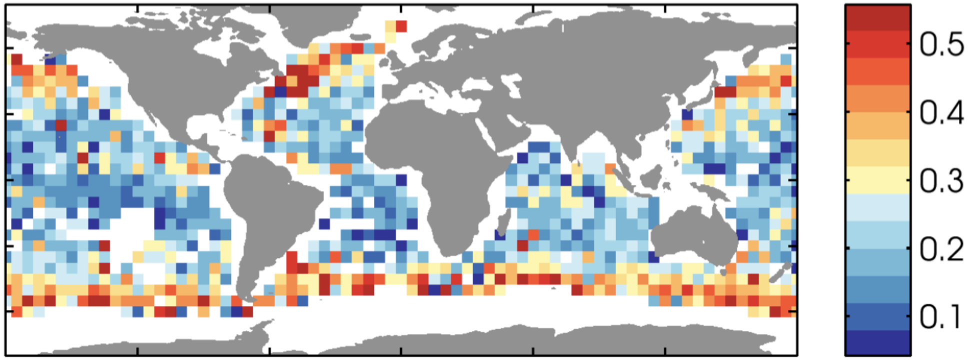
**Salinity** variability dominates

high latitudes, river outflow regions

# Summary

1. Aquarius-Argo noise can be explained by salinity variability smaller than the satellite footprint

Aquarius-Argo RMSD




2. Strong small-scale density variations are controlled by:
   - salinity (at high latitudes, near river outflows)
   - temperature (Gulf Stream, Agulhas, around Australia)

"Density variability ratio"