MOSORA-E
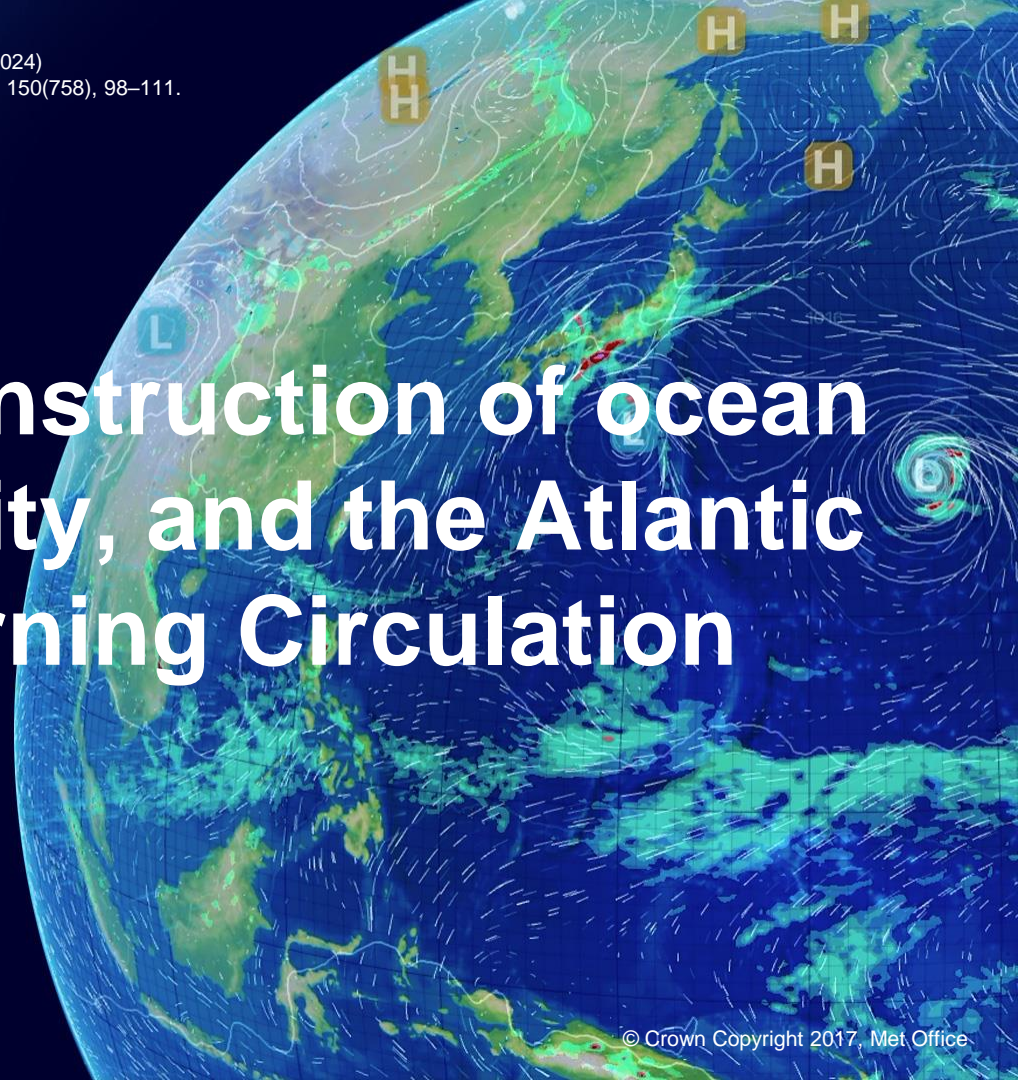# An ensemble reconstruction of ocean temperature, salinity, and the Atlantic Meridional Overturning Circulation 1960–2021

Leon Hermanson,
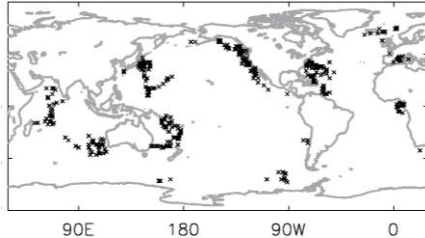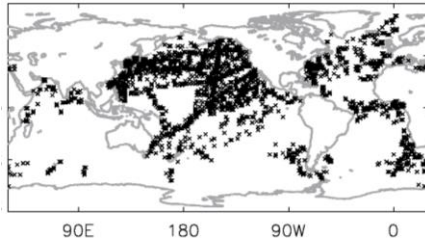
Doug Smith, Rosie Eade, Nick Dunstone

Met Office Statistical Ocean Reanalysis (MOSORA)
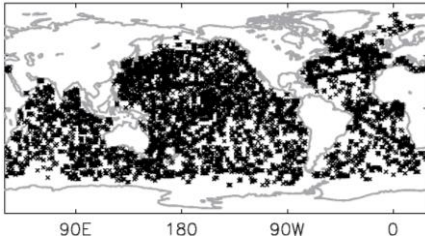
Sparse ocean data: need to fill the gaps
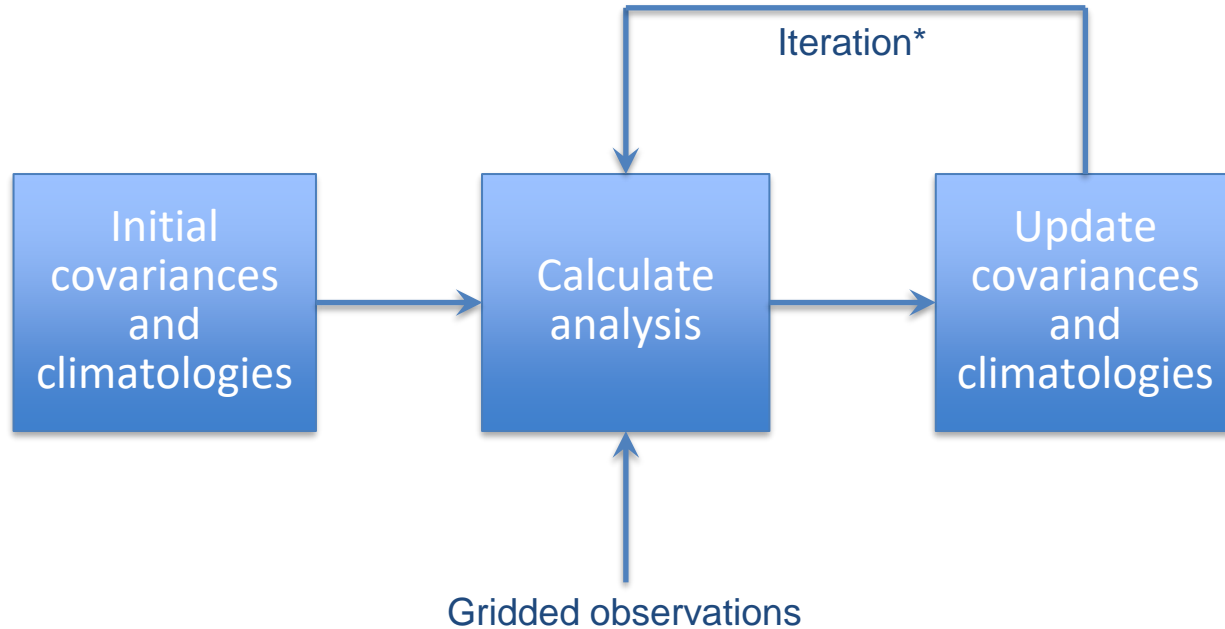
1960

1980

2007

- 3-D potential temperature and salinity analysis

- Starting 1950, monthly means up to present

- Nudged into assimilation run (together with ERA in atmosphere) to initialize decadal forecasts

- Based on a lat-lon ocean grid:

  - 1.25˚ x 1.25˚

  - 20 levels

- Uses profile observations (EN4) and SST (HadISST1.1 from 1982, HadSST2 before)

- Global covariance optimal interpolation (Smith & Murphy, 2007)

- Initial covariances are taken from an ensemble of model historical runs (smoothed to 1.25 degrees)

- The first-guess analysis then provides the covariances for subsequent analyses (2 iterations)

Smith and Murphy 2007; Smith et al 2015; Hermanson et al 2023

Iteration procedure for MOSORA


```
                    ┌──────── Iteration* ────────┐
                    ↓                            │
┌──────────────┐   ┌──────────────┐   ┌──────────────┐
│   Initial    │   │              │   │   Update     │
│ covariances  │ → │  Calculate   │ → │ covariances  │
│     and      │   │   analysis   │   │     and      │
│ climatologies│   │              │   │ climatologies│
└──────────────┘   └──────────────┘   └──────────────┘
                          ↑
                   Gridded observations
```

*Usually two iterations are done

- There is a clear improvement in RMSE between the initial and first iteration
- The second iteration generally has larger anomalies, but no better RMSE

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The effect of iteration on uncertainties at 995m. (a) ensemble standard deviation for iteration 2 potential temperature (units K) over annual means of the re-analysis (1960 to 2016) and (b) the difference to the first guess analysis. (c) and (d) the same as (a) and (b) but for salinity (practical salinity units, PSU). The crosses in (d) show points used in later Figures.
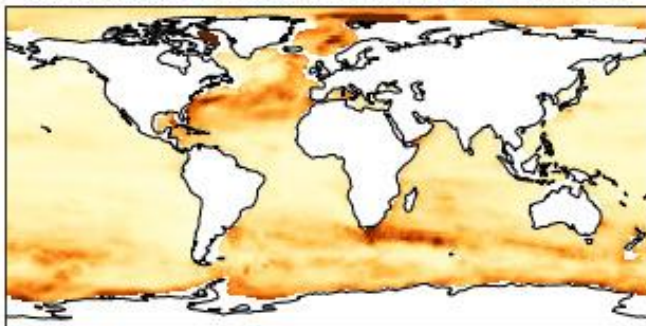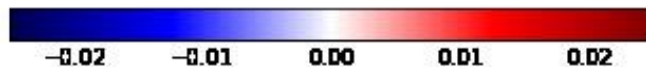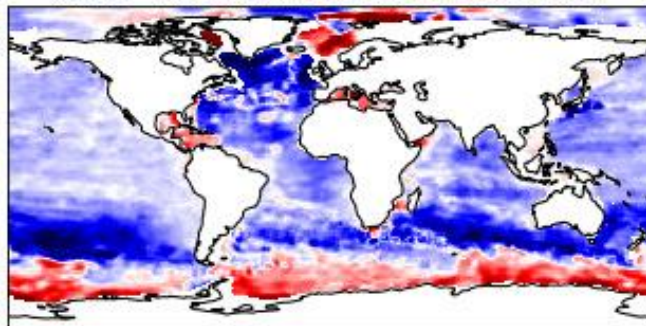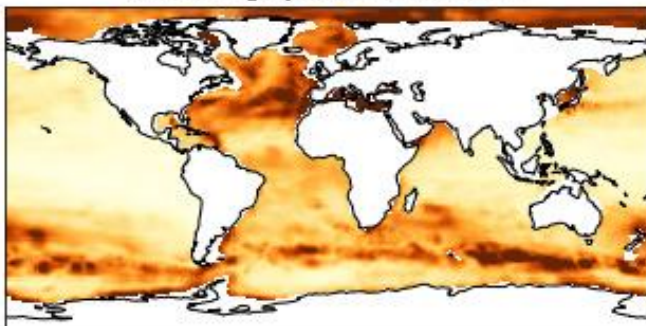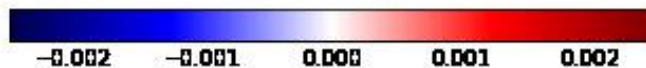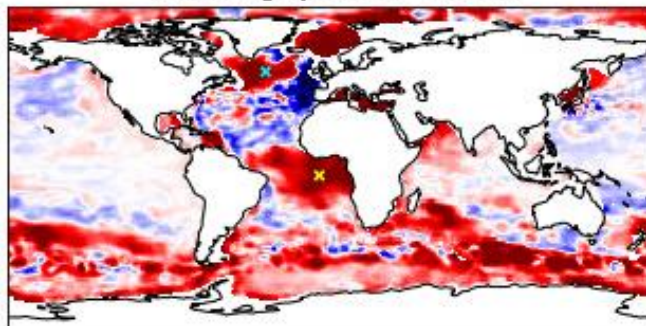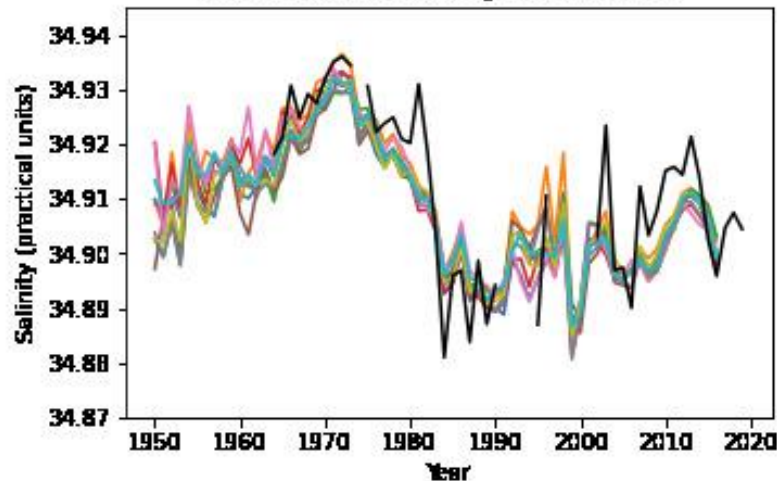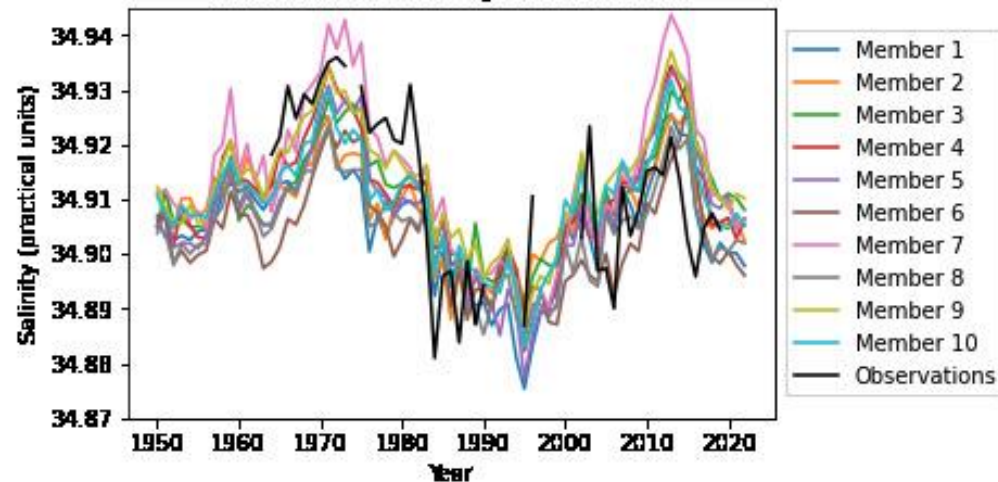
(a) Model Covariance Salinity at 53°N 36°W
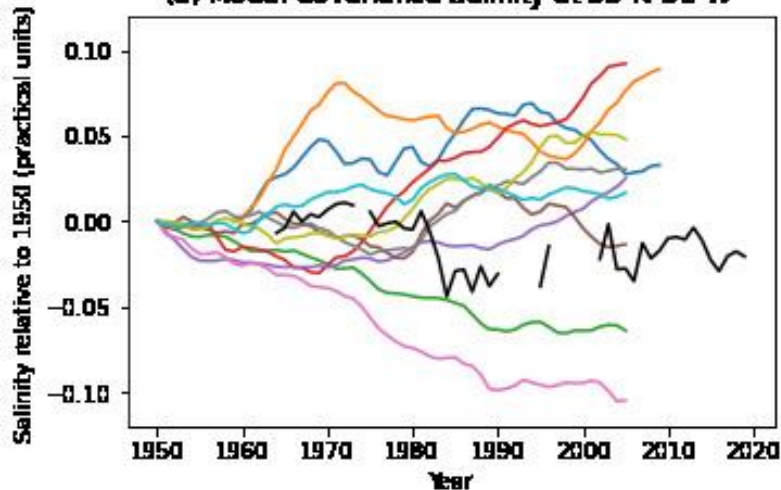
(b) First Guess Salinity at 53°N 36°W

(c) Iteration 2 Salinity at 53°N 36°W

Member 1
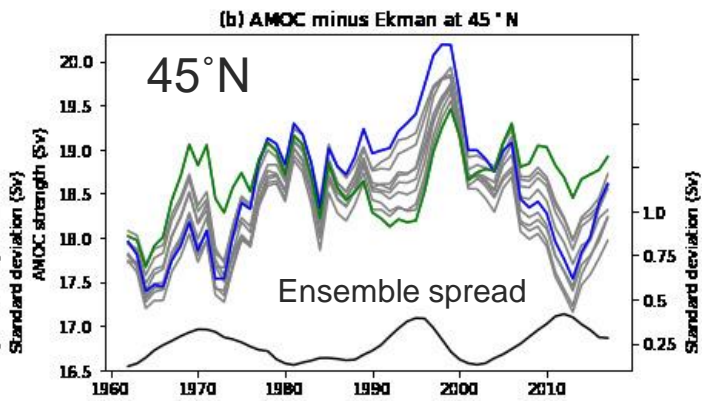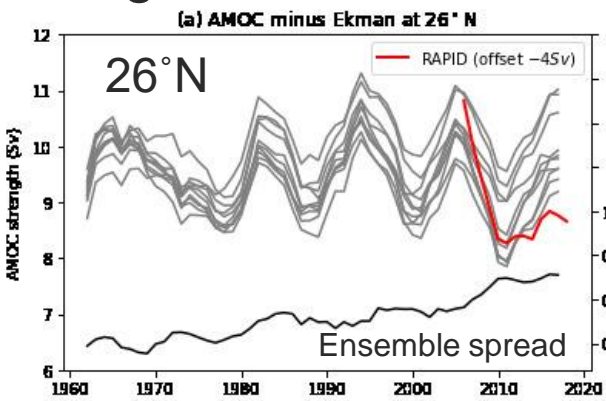Member 2
Member 3
Member 4
Member 5
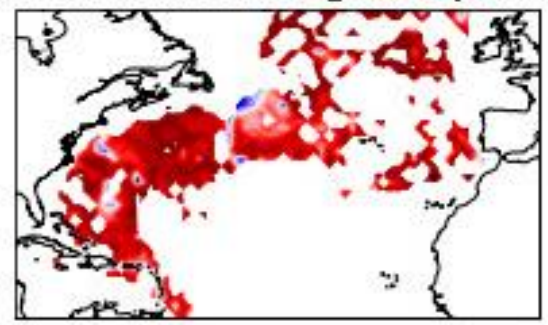Member 6
Member 7
Member 8
Member 9
Member 10
Observations

Annual mean salinity at a point (53°N 36°W) at 995m for the (a) initial model covariances, (b) first guess analysis, and (c) iteration 2. Ensemble members are in colour and observations in black. Observations are not continuous at this location and some values may be biased due to missing months in the annual mean. In (a) the salinity values are relative to the value in 1950 to emphasize the trends.
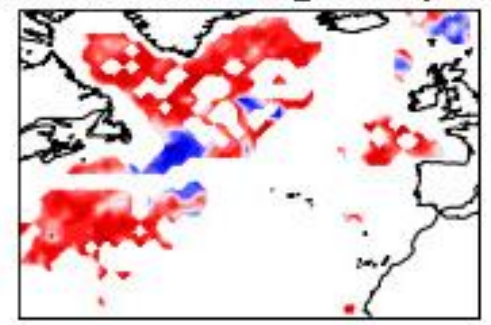
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- Assimilation ensemble shows spread of AMOC changing with time

- When observations are added for regions with uncertain covariances spread increases

- A better characterisation of the covariances would lead to a more constrained AMOC

- Need more sustained observations

(a) AMOC minus Ekman at 26°N

26°N

RAPID (offset −4Sv)

Ensemble spread

(b) AMOC minus Ekman at 45°N

45°N

Ensemble spread

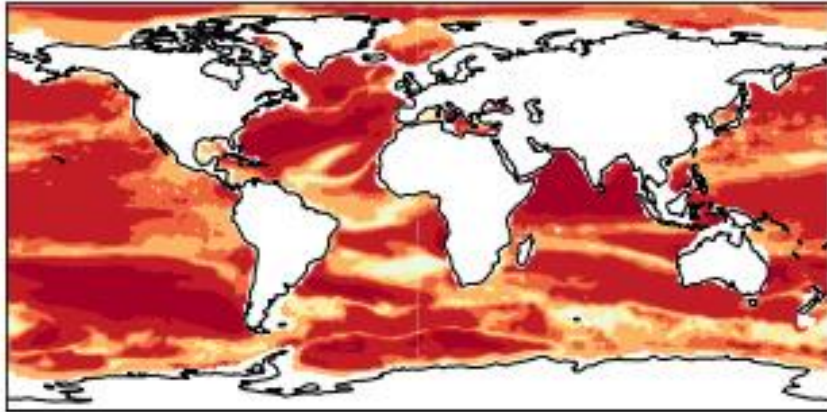(c) #observations against spread

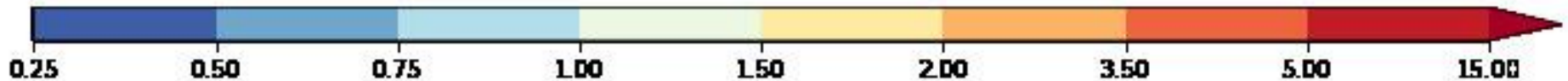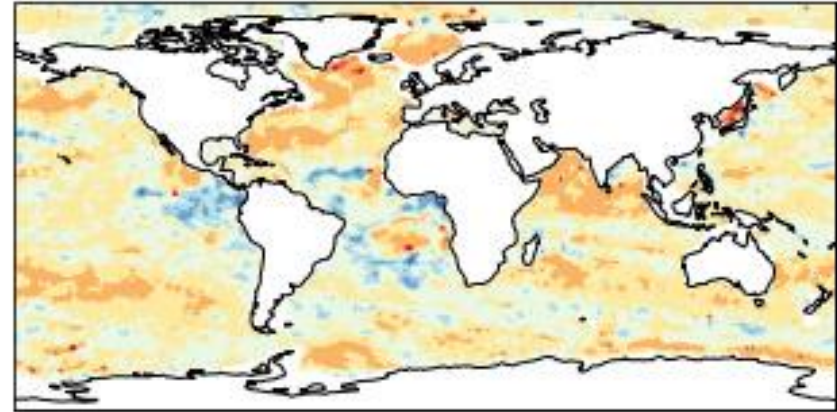(f) #observations against spread

Thank you!

Questions?

Ratio Actual to Expected Error Variance

iteration 0 | iteration 2

0.25 0.50 0.75 1.00 1.50 2.00 3.50 5.00 15.00

**Ratio of actual to expected error variance** for salinity at 995m for (a) first guess covariances and (b) iteration 2. Note that the colour scale is nonlinear.

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Evolution of salinity anomalies at 995m with iteration for all available observations (left) and for observations typical of 1967 (right). All anomalies are relative to the climatology of the final iteration (iteration 2) for 1951-2016. (a) locations and grid box mean amplitude of gridded observed salinity anomalies in May 2013. (b) The May 2013 observations subsampled to resemble the observational density of May 1967. (c) and (d) analysis of salinity anomalies with first guess covariances using the observations above. (e) and (f) analysis of salinity anomalies for iteration 2. In brackets in the title of (d) and (f) are the spatial correlations of these fields with (c) and (e), respectively.
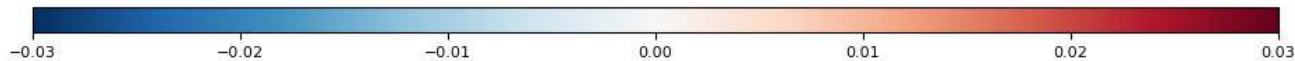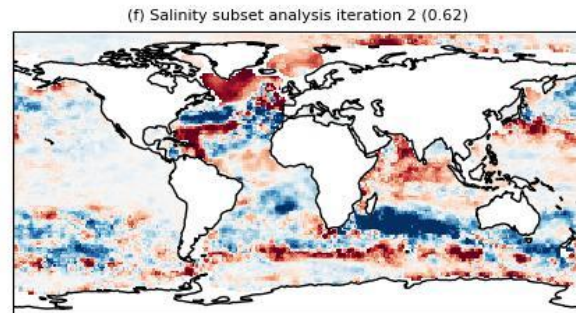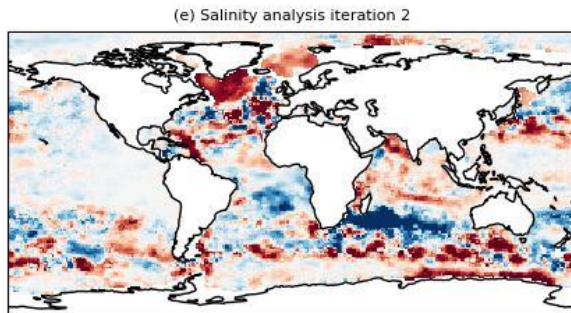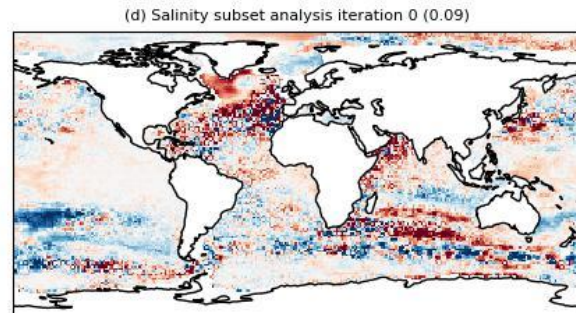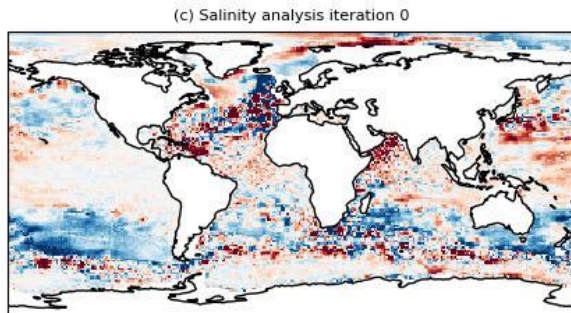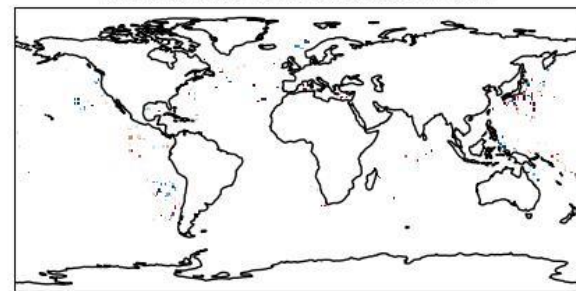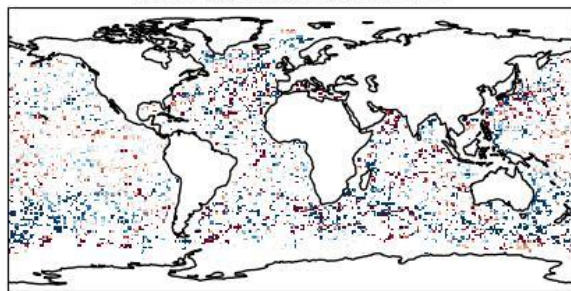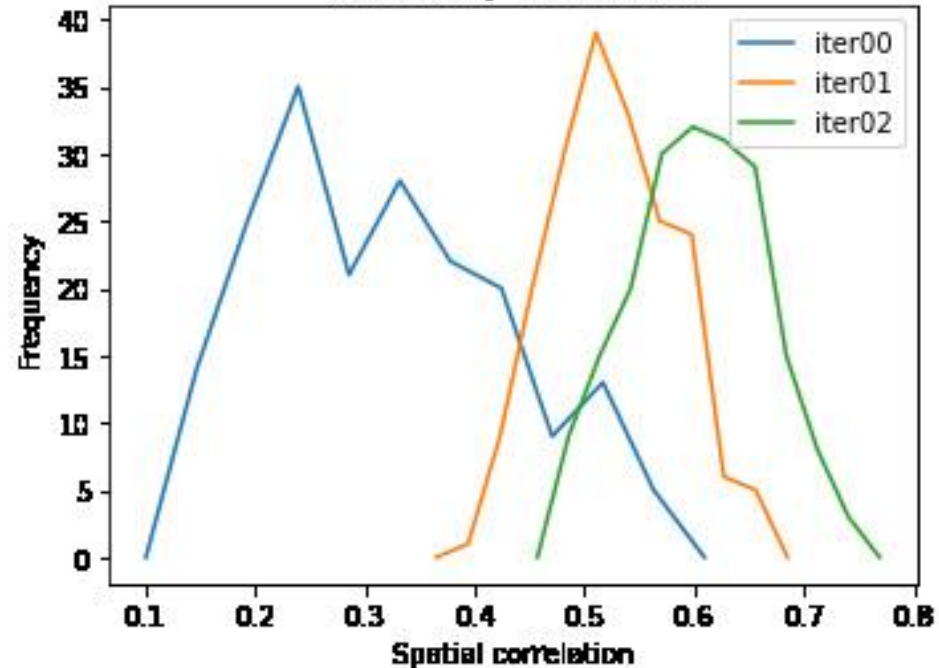
Spatial correlations between full and subset analysis
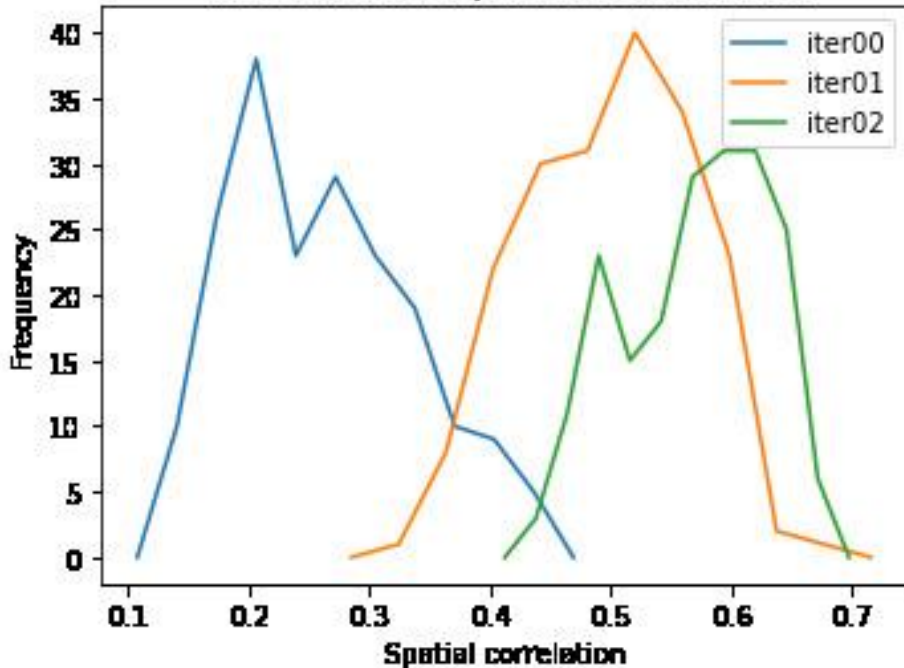
Frequency polygons of spatial correlations between the analysis with all observations and the analysis with withheld observations for potential temperature (left) and salinity (right). All months between 2010-2013 and four levels (447m, 666m, 995m, 1500m) are used to create the histograms. Each iteration is shown with a different colour.