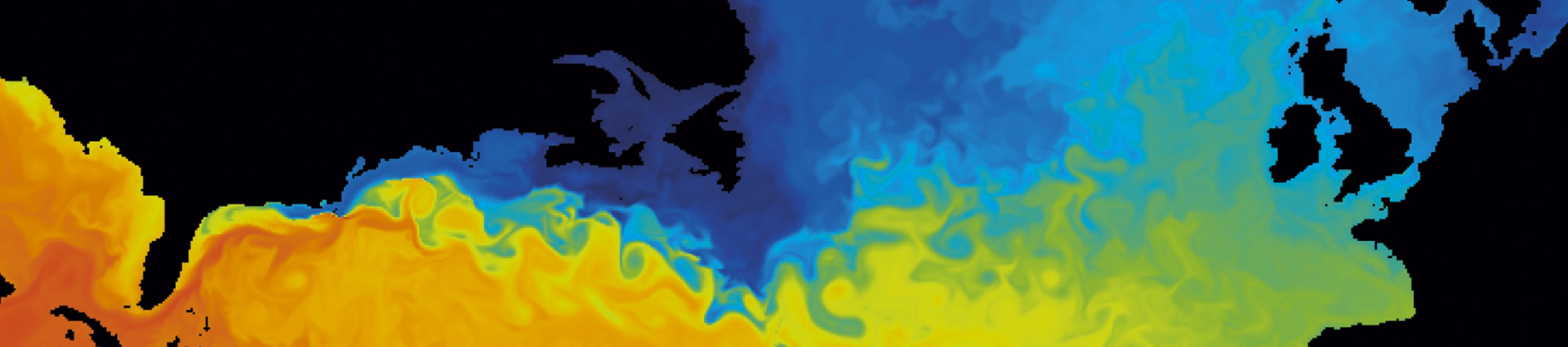


NCOF

The National Centre for Ocean Forecasting

Observation bias correction in altimeter ocean data
assimilation in FOAM comparing two MDTs

Daniel Lea, Keith Haines and Matt Martin



- Altimeter data
- Two MDTs – OSE with different gravity data
- Bias data assimilation method
- Results
- Conclusion

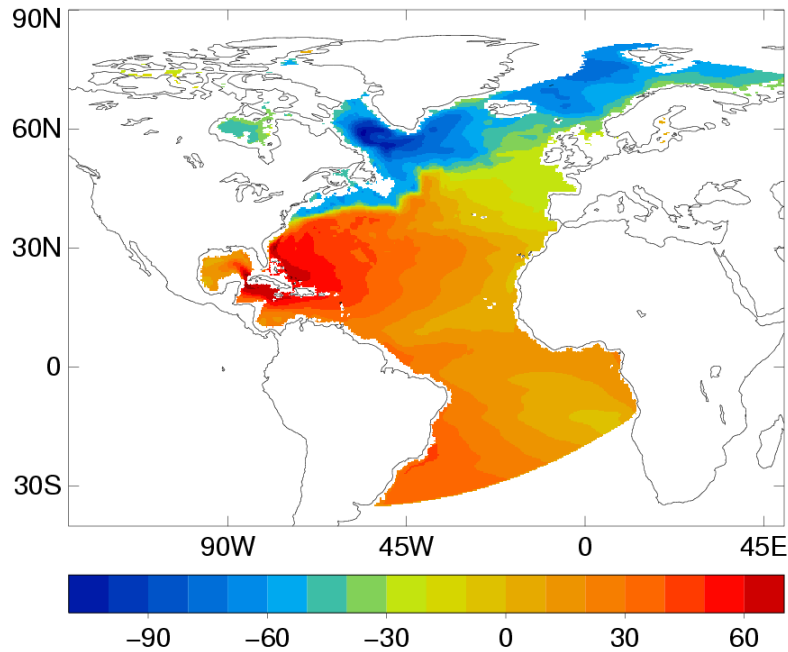
Altimeter data

- Gives direct information about ocean currents with global coverage
- Problem is the unknown gravity field or geoid
- Altimeter data is supplied as anomaly to time mean
- The mean SSH or Mean Dynamic Topography (MDT) is not known
- MDT is estimated from model mean/ gravity obs. - may not be accurate/appropriate

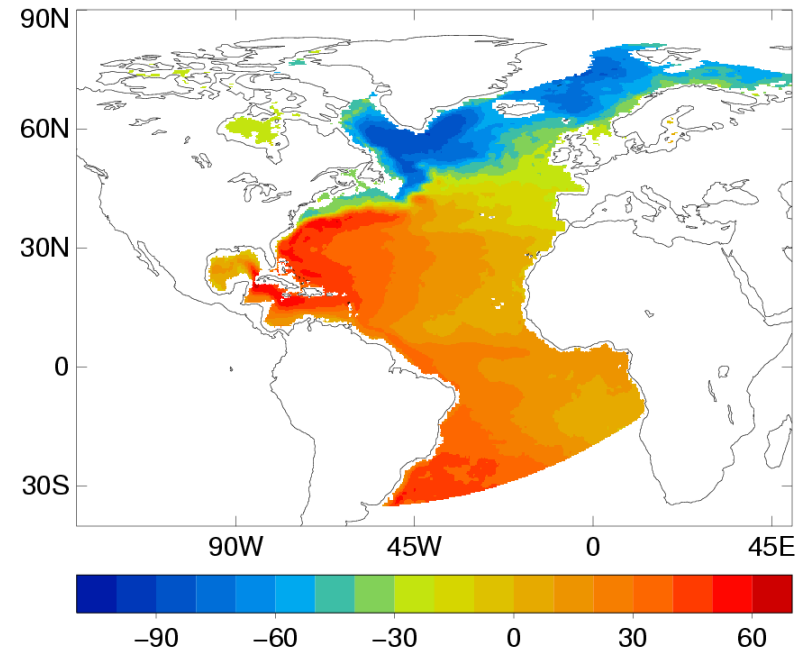
Altimeter assimilation

- Modified Cooper & Haines (1996) [CH96] scheme
- Lifts or lowers T and S levels to fit SSH
- Uses the hydrostatic eqn assuming no bottom pressure change
- Also assimilate T & S

FOAM (+GOCINA) MDT



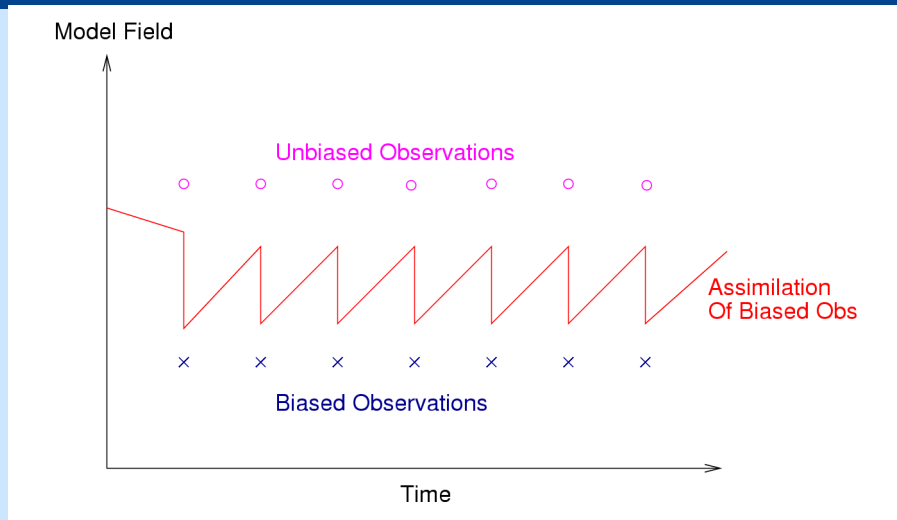
BINGHAM (GRACE/NIILER) MDT¹



¹R. Bingham, POL pers. comm.

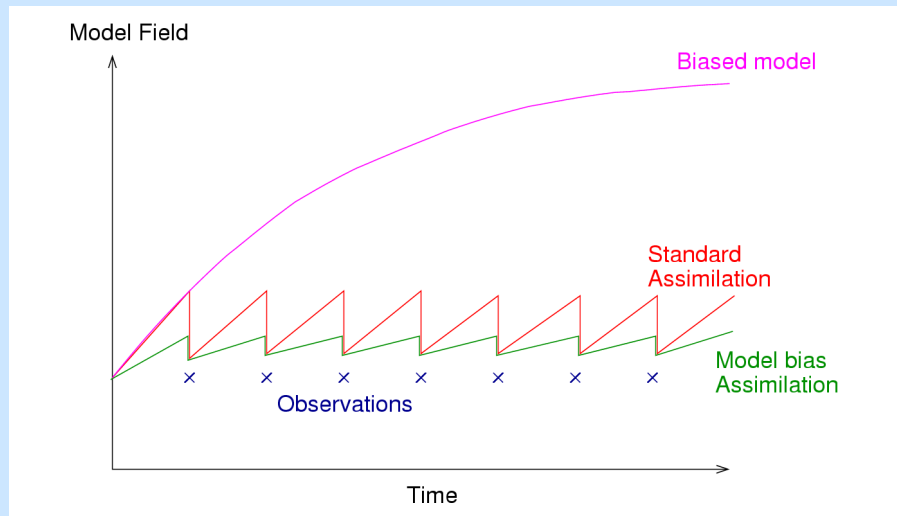
Schematic of assimilation in the presence of bias

Observation
bias
b - cm



Obs bias can be found only if the model moves to the unbiased state

Model bias
c - cm/day



Model bias and Obs bias have a similar effect – separate with covariances/ bias models

Method: 3D-Var cost function

$$\begin{aligned} J = & (\mathbf{y} - \mathbf{H}(\mathbf{x} + \mathbf{b}))^T \mathbf{R}^{-1} (\mathbf{y} - \mathbf{H}(\mathbf{x} + \mathbf{b})) && \text{Model data misfit} \\ & + (\mathbf{x} - \mathbf{x}^f + \mathbf{c})^T \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x}^f + \mathbf{c}) && \text{Background constraint} \\ & + (\mathbf{b}^o - \mathbf{b})^T \mathbf{T}^{-1} (\mathbf{b}^o - \mathbf{b})^T && \text{Obs bias constraint} \\ & + (\mathbf{b} - \mathbf{b}^f)^T \mathbf{O}^{-1} (\mathbf{b} - \mathbf{b}^f) && \text{Obs bias forecast constraint} \\ & + (\mathbf{c} - \mathbf{c}^f)^T \mathbf{P}^{-1} (\mathbf{c} - \mathbf{c}^f) && \text{Model bias forecast constraint} \end{aligned}$$

\mathbf{x} – model state

\mathbf{y} – observation

\mathbf{R} – observation error covariance

\mathbf{B} – background error covariance

\mathbf{H} – observation operator

\mathbf{b} – observation bias

\mathbf{c} – model bias

\mathbf{T} – observation bias error covariance

\mathbf{O} – obs bias forecast error covariance

\mathbf{P} – model bias forecast error covariance

Method: Analysis equations

$$\mathbf{x}^a = (\mathbf{x}^f - \mathbf{c}^f) + \mathbf{K}_1 \{ \mathbf{y} - \mathbf{H}(\mathbf{L}\mathbf{b}^o + (\mathbf{I} - \mathbf{L})\mathbf{b}^f) - \mathbf{H}(\mathbf{x}^f - \mathbf{c}^f) \} \quad ..$$

$$\mathbf{K}_1 = (\mathbf{B} + \mathbf{P})\mathbf{H}^T \{ \mathbf{H}(\mathbf{B} + \mathbf{P} + \mathbf{L}\mathbf{T})\mathbf{H}^T + \mathbf{R} \}^{-1} \quad \dots \quad \text{State analysis}$$

$$\mathbf{b}^a = \mathbf{b}^f + \mathbf{F} \{ .. \}$$

$$\mathbf{F} = \mathbf{O}\mathbf{H}^T \{ \dots \}$$

Observation bias analysis

$$\mathbf{c}^a = \mathbf{c}^f - \mathbf{G} \{ .. \}$$

$$\mathbf{G} = \mathbf{P}\mathbf{H}^T \{ \dots \}$$

Model bias analysis

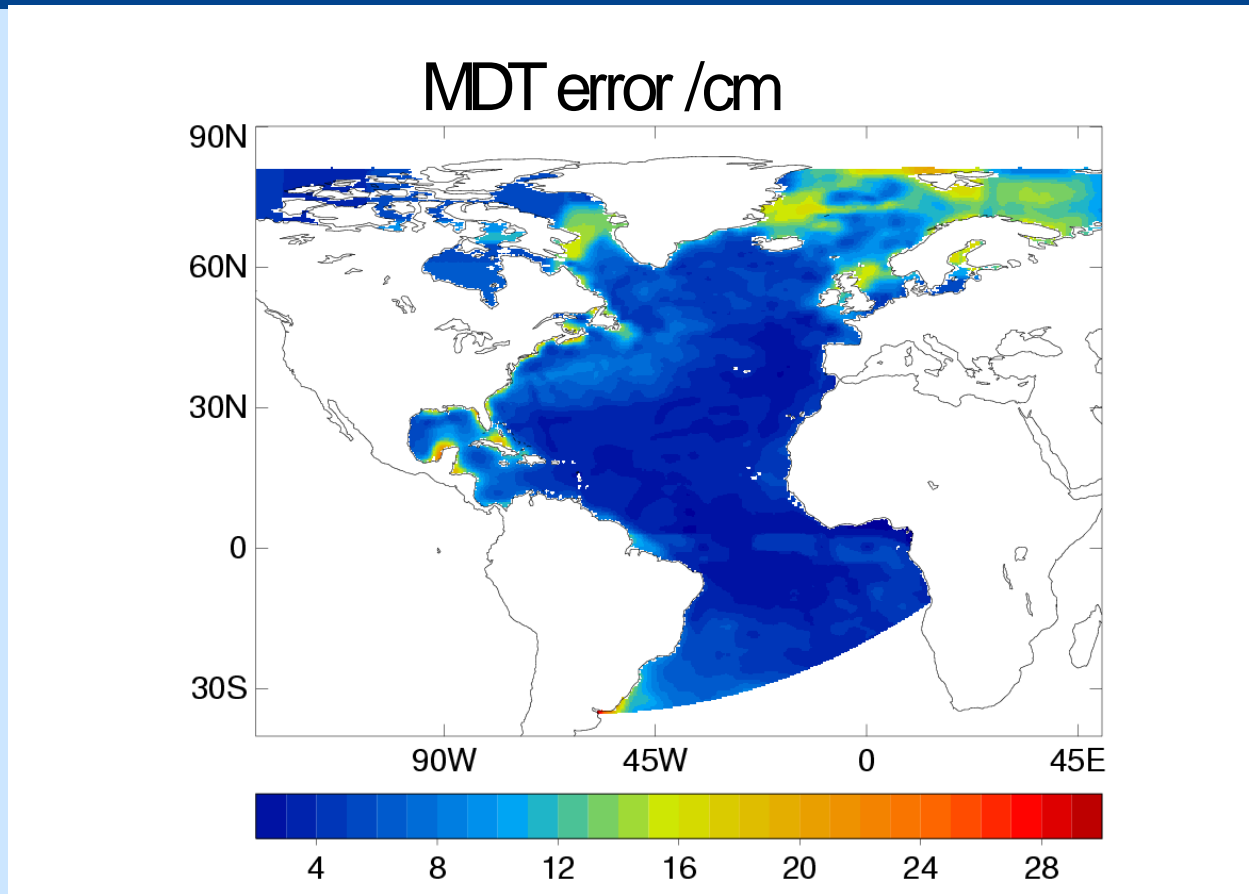
Method: Five covariances

- R** – observation error covariance
- B** – background error covariance
- T** – observation bias error covariance
- O** – obs bias forecast error covariance
- P** – model bias forecast error covariance

Assume

$$\begin{aligned} \mathbf{O} &= \mathbf{b} \mathbf{T} & \mathbf{b} &= 0.01 & & (\mathbf{b} \text{ units cm}) \\ \mathbf{P} &= \mathbf{c} \mathbf{B} & \mathbf{c} &= 10^{-3} & & (\mathbf{c} \text{ units cm/day}) \end{aligned}$$

Mean Dynamic Topography



Rio (2005) MDT error (times 5) – use for **T** (**O** = 0.01 **T**)

- Four experiments:
 - STD FOAM MDT – 5 year altimeter assimilation using the standard FOAM MDT
 - OBS FOAM MDT – as above but with observation bias correction
 - STD BING MDT – 5 year altimeter assimilation using Rory Bingham's MDT
 - OBS BING MDT – as above but with observation bias correction

Results: Innovations

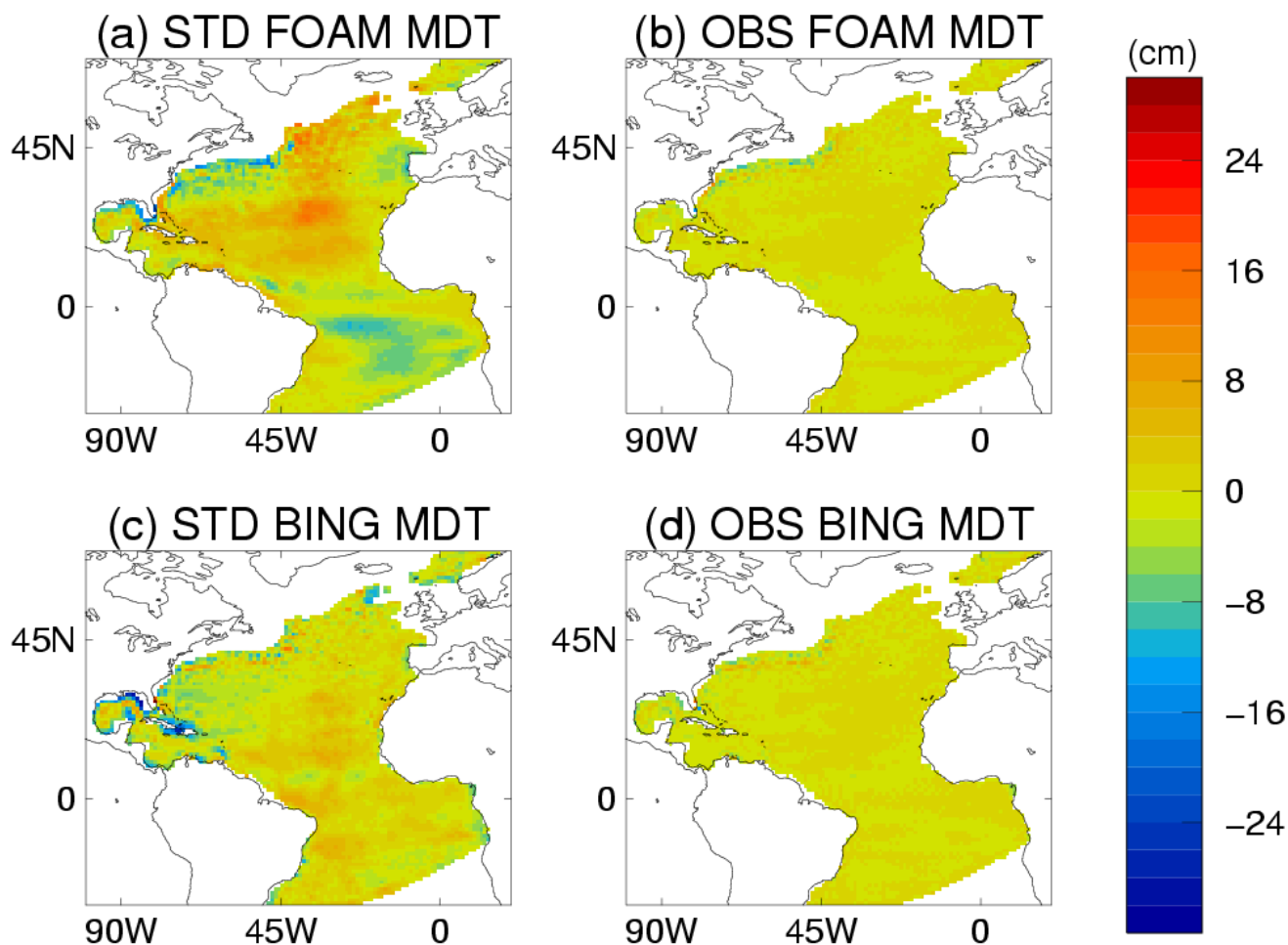
- Results that follow are mainly assessed by innovations (give info about bias in results) which are bias corr obs minus model 1 day forecast

$$\mathbf{y}_k - \mathbf{H}\mathbf{b}_k^f - \mathbf{H}\mathbf{x}_k^f$$

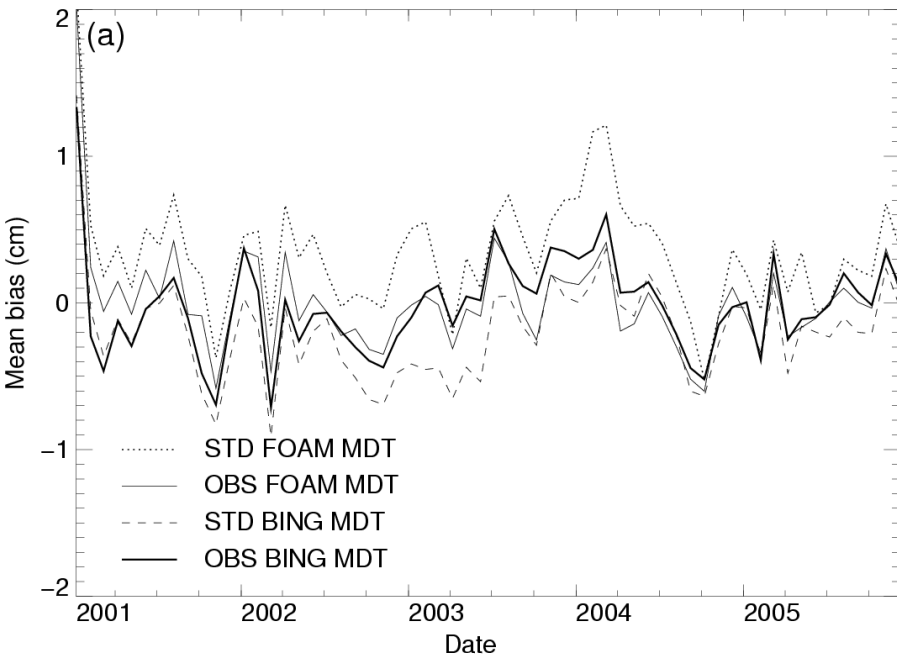
Time & domain space average innovations

	Mean /cm	Standard deviation /cm
STD FOAM MDT	0.317	9.56
OBS FOAM MDT	-0.014	8.15
STD BING MDT	-0.211	8.86
OBS BING MDT	-0.024	8.13

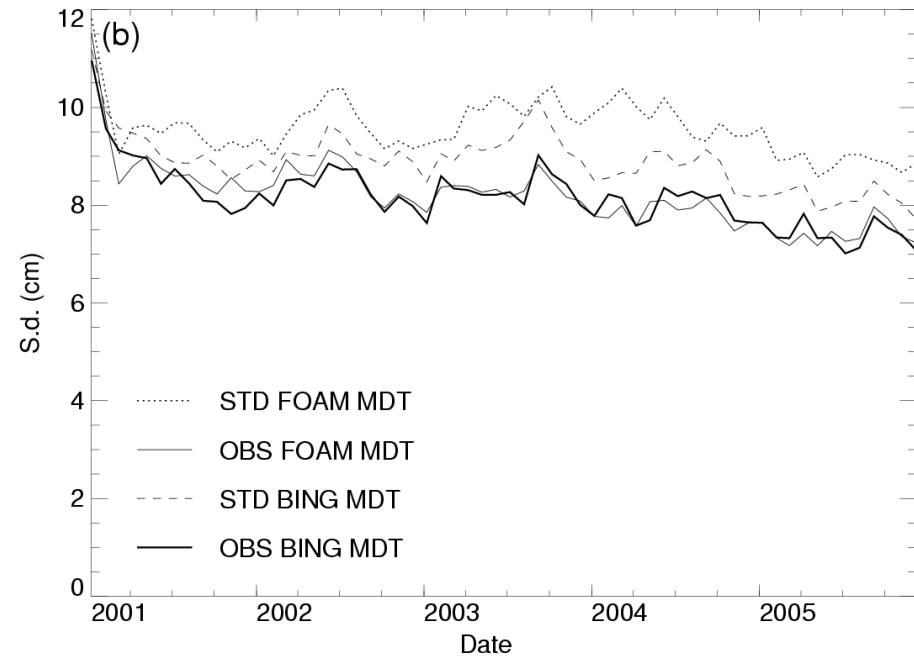
Results: mean innovations



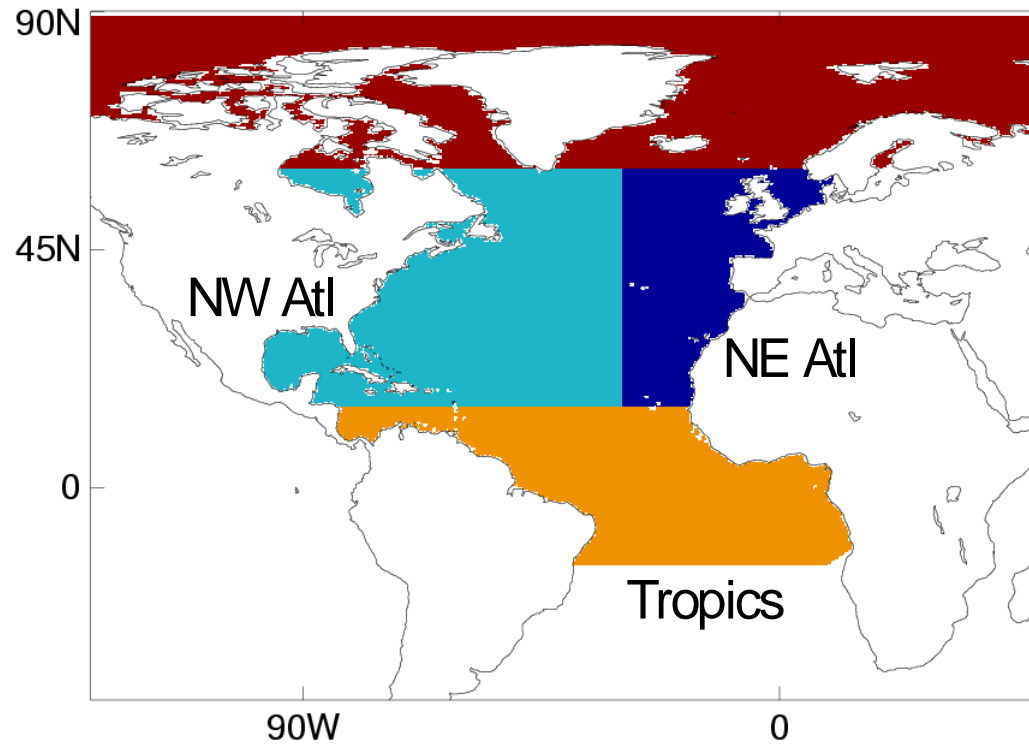
Mean innovations



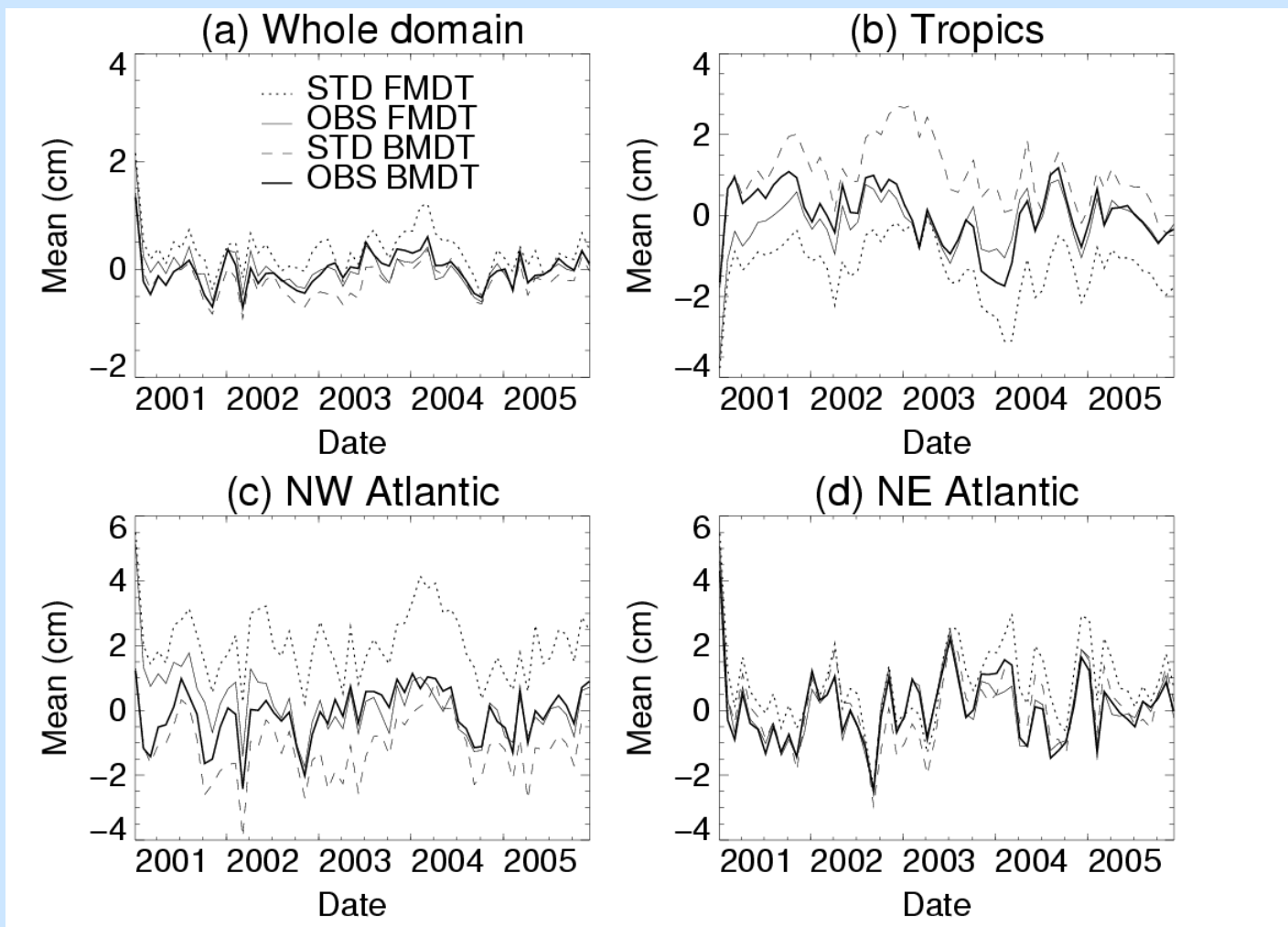
s.d. innovations



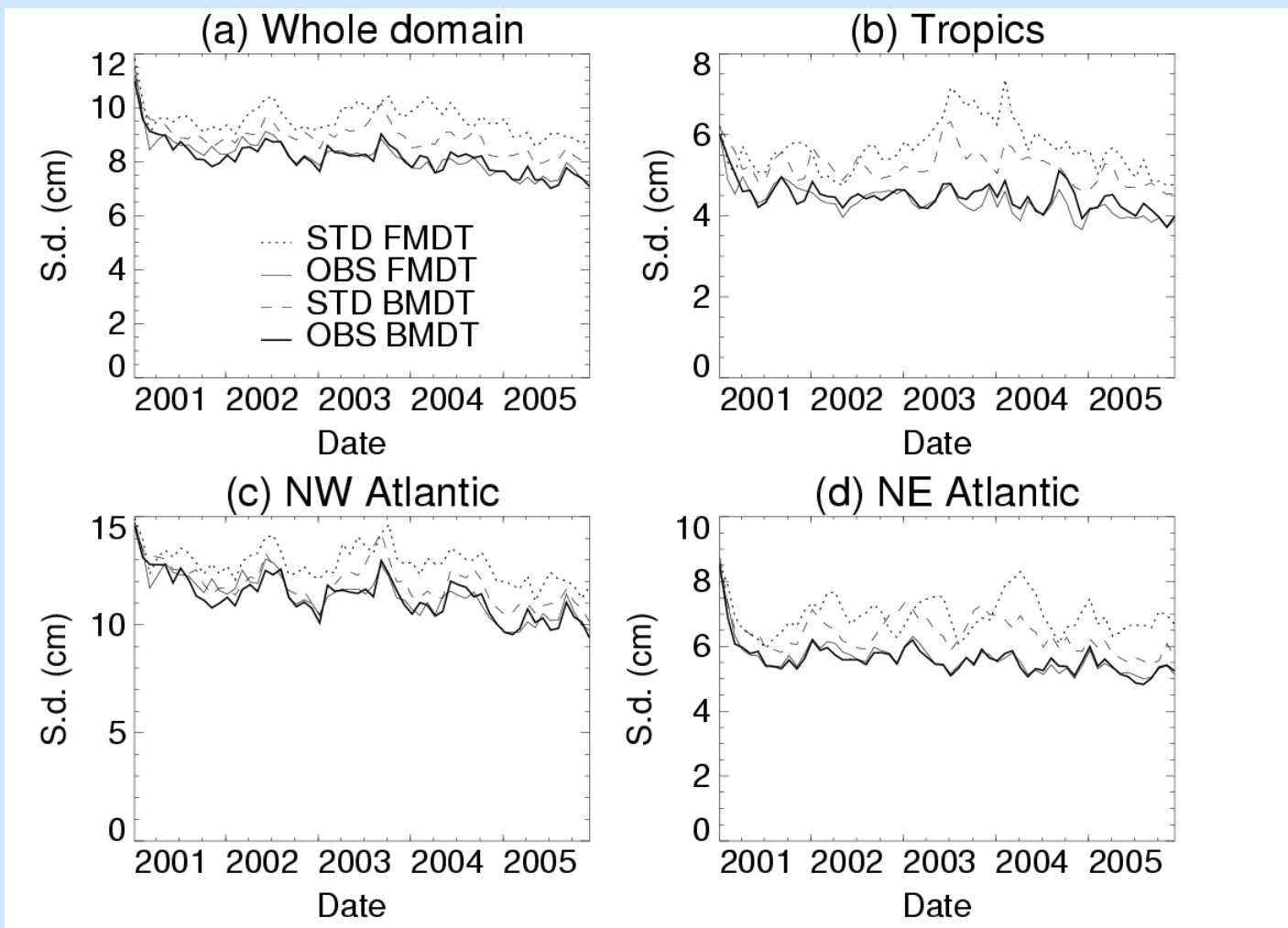
- Time variability and RMS reduced by bias correction
- Obs bias correction most effective in reducing RMS



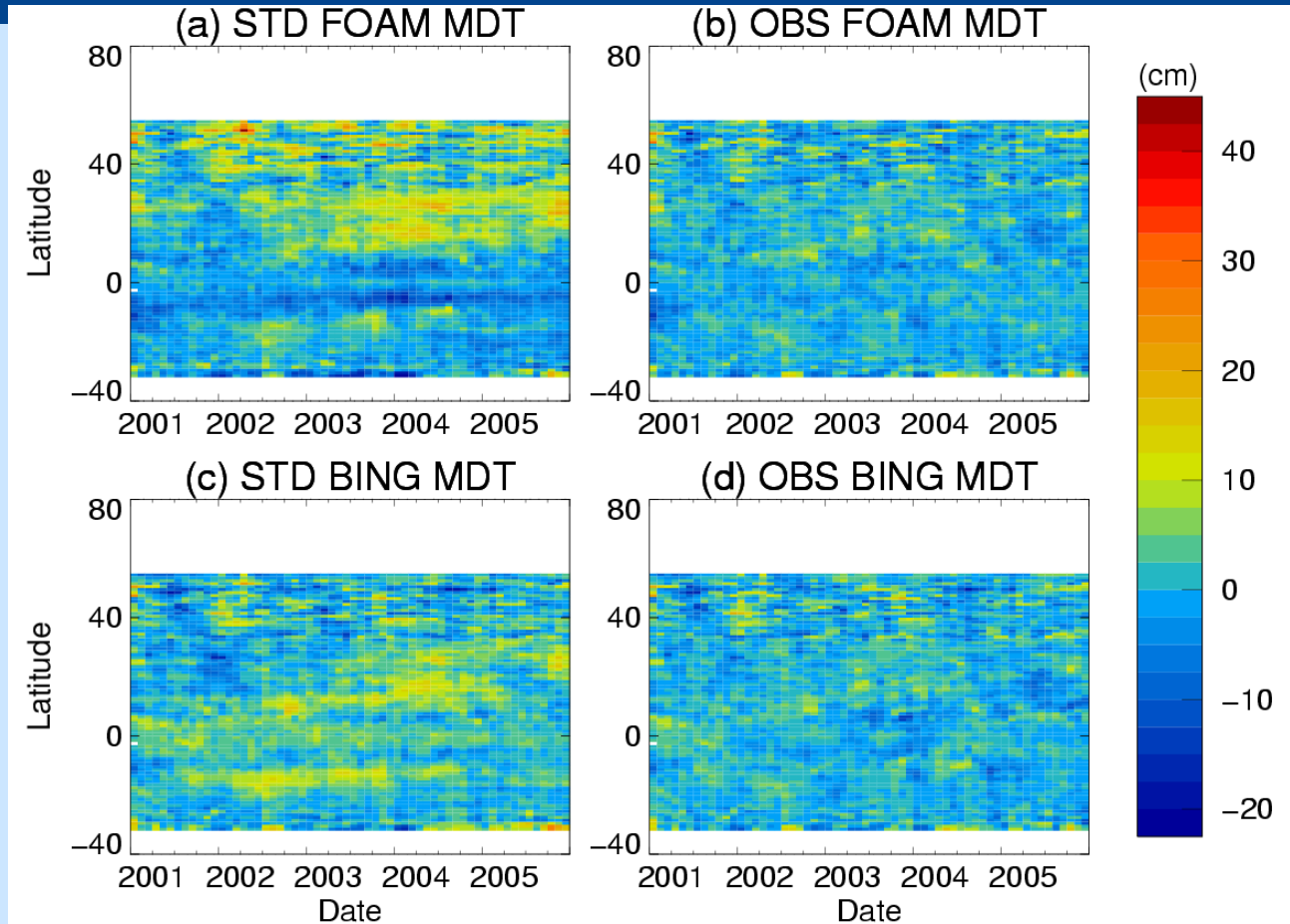
Mean Innovations in areas



Std dev of innovations in areas



Time variability of innovations (30°W)

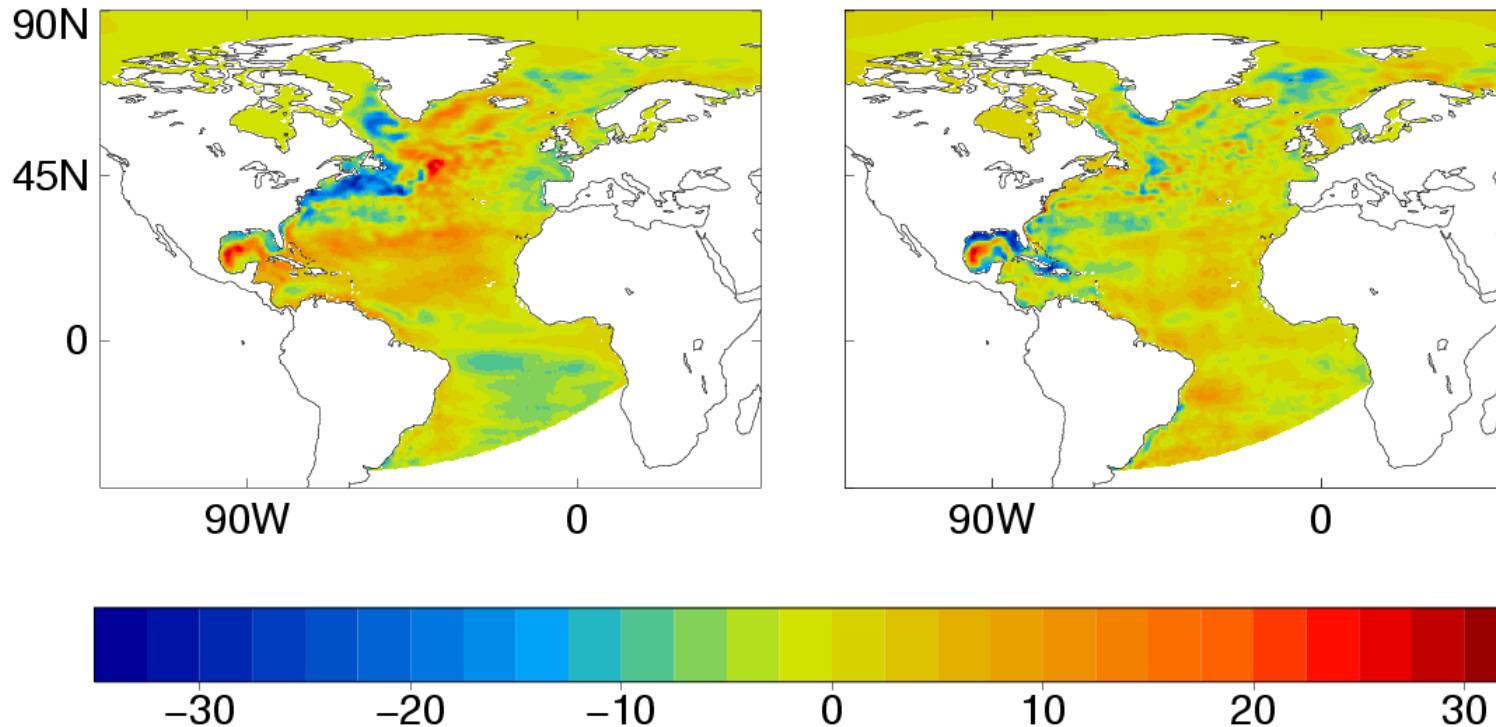


- Time average bias and seasonal bias removed by bias assim
- Still some variability in the vicinity of the Gulf Stream

Mean obs bias field (b field)

(a) FOAM MDT

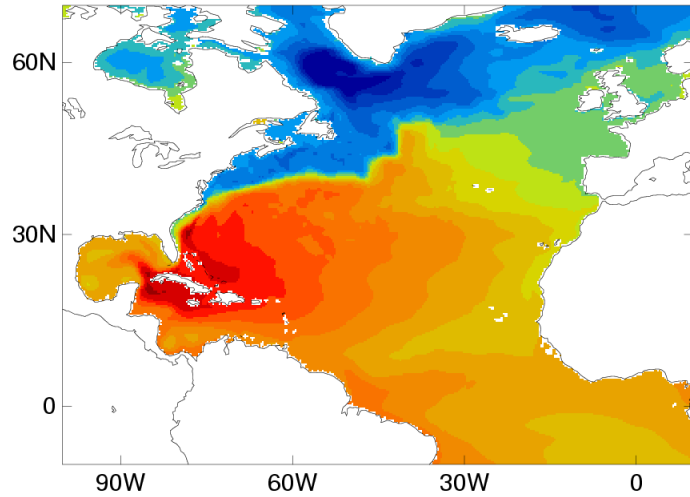
(b) Bing. MDT



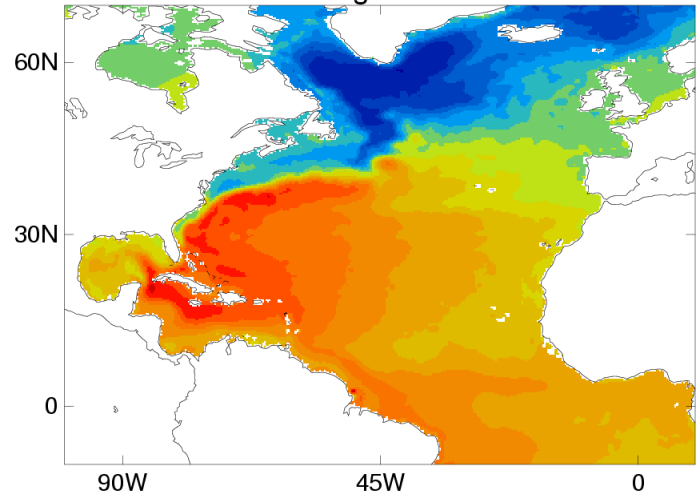
- (a) MDT raised north of Gulf Stream, lowered in sub-tropical gyre
- May be picking up on model error – E.g. Gulf of Mexico lacks in situ data

Change in MDT

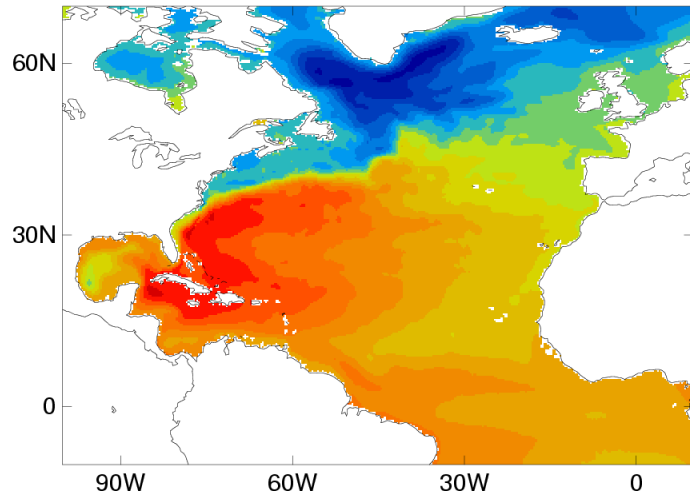
FOAM MDT



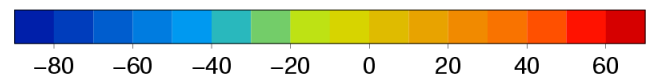
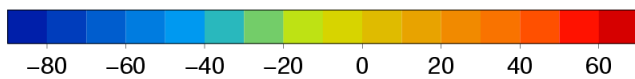
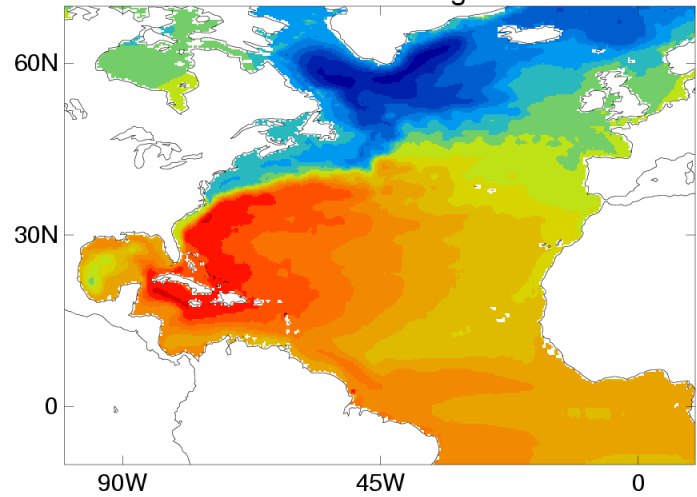
Bing. MDT



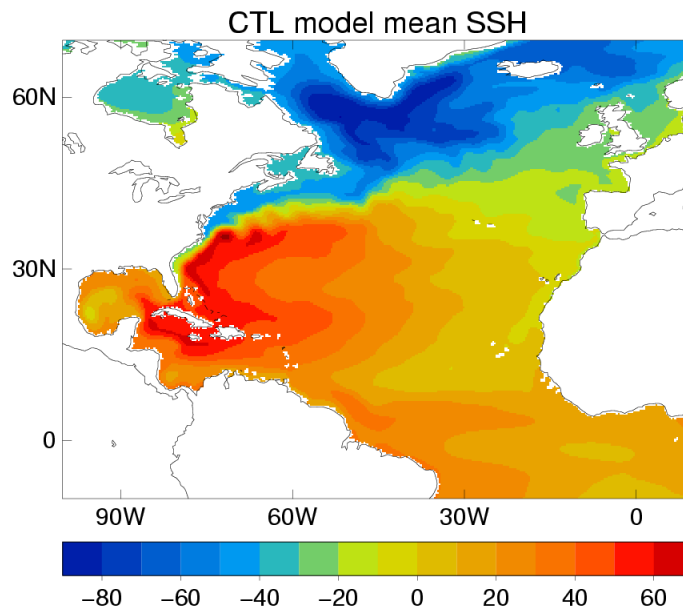
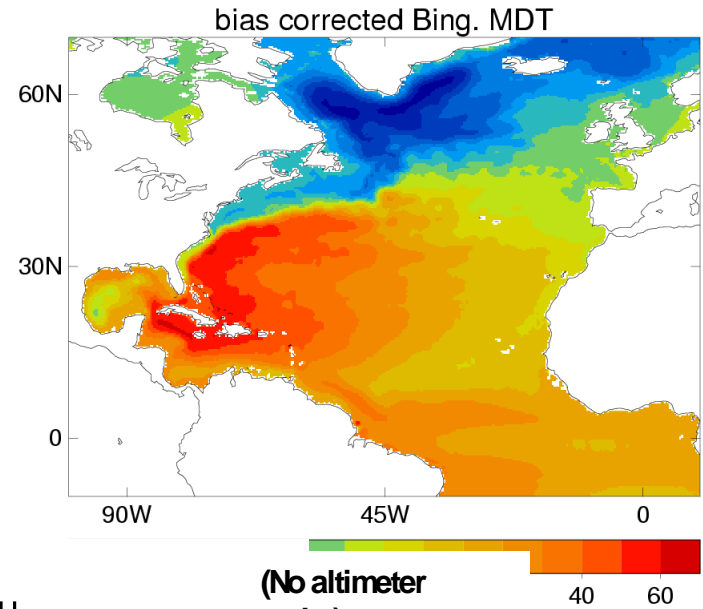
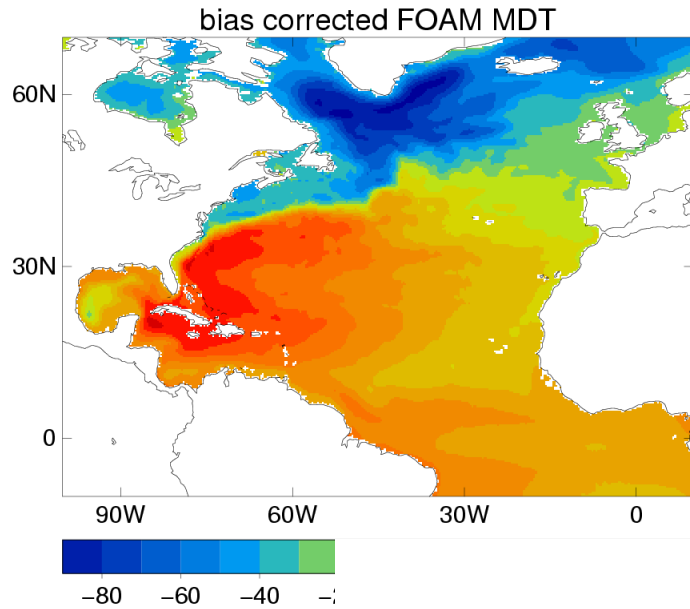
bias corrected FOAM MDT



bias corrected Bing. MDT



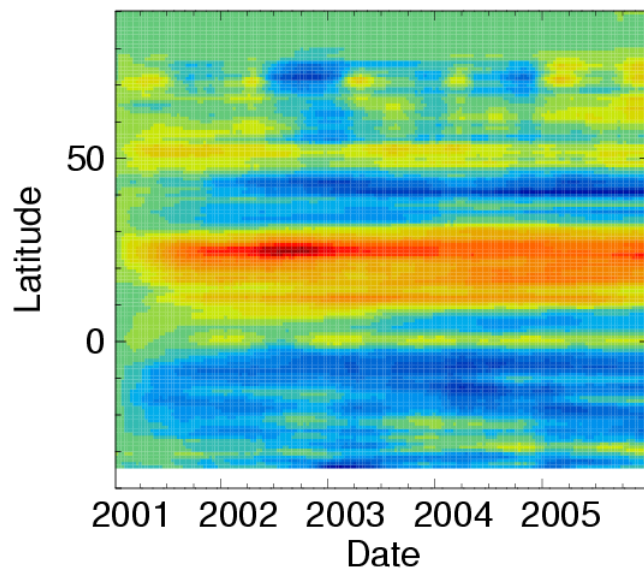
Comparing new MDTs to model mean without Altimeter assim



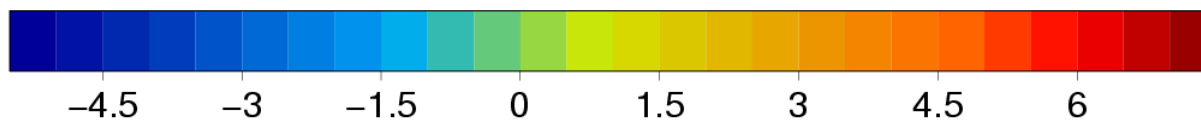
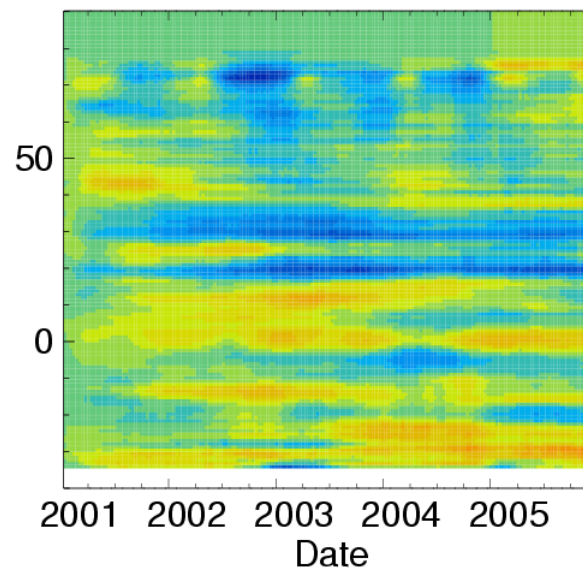
(No altimeter assim)

Hovmuller of obs bias b (zonal avg)

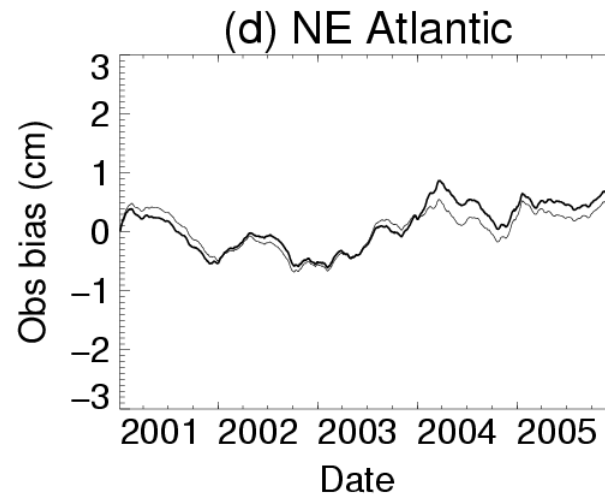
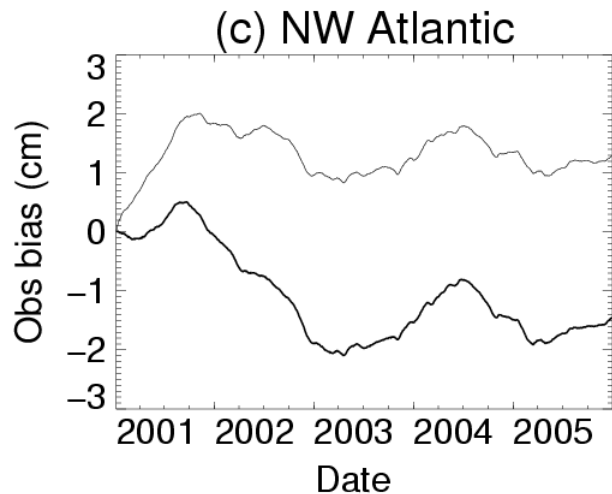
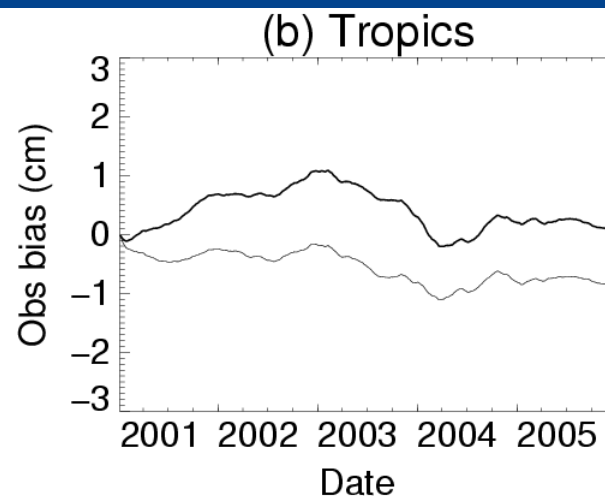
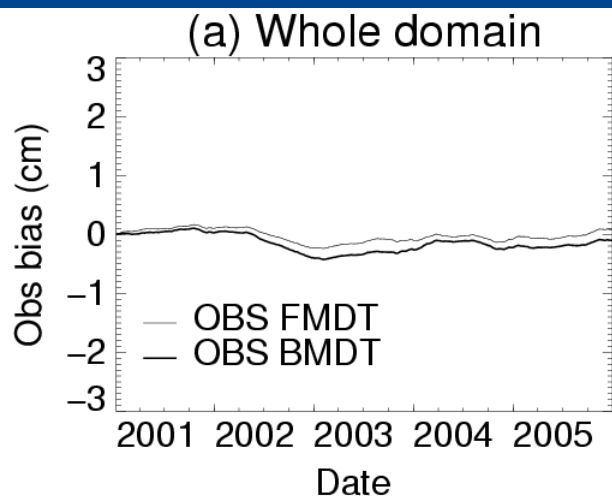
(a) FOAM MDT



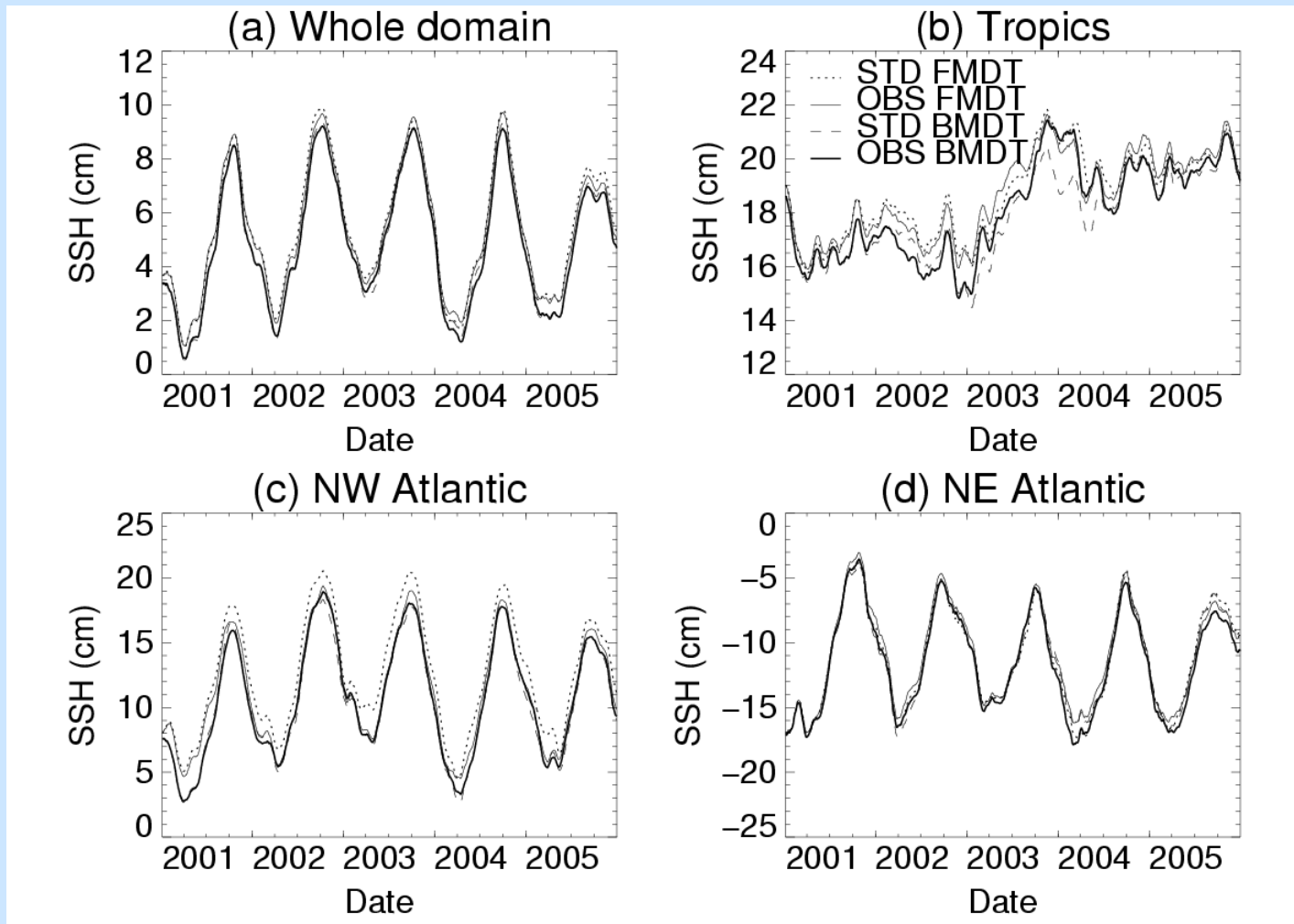
(b) Bing. MDT



Obs bias in areas



SSH fields in areas



Conclusions

- Effectively doing an OSE with different gravity data, I.e. the FOAM and Bingham MDTs
- Bingham MDT gives reduced mean and standard deviation innovations compared to the FOAM MDT (same anomaly data, but different gravity 'data')
- Is it more realistic, or just better for this particular model?
- Would be useful to look at the results with the Rio05 MDT.
- Performing obs bias correction with initial MDTs shows they both converge to similar optimal MDT (for this model)
- Future plan to use error and MDT from GOCE
- Also investigate different models (NEMO) and different resolutions