Argo assimilation in North-West Pacific OGCM Based on POM

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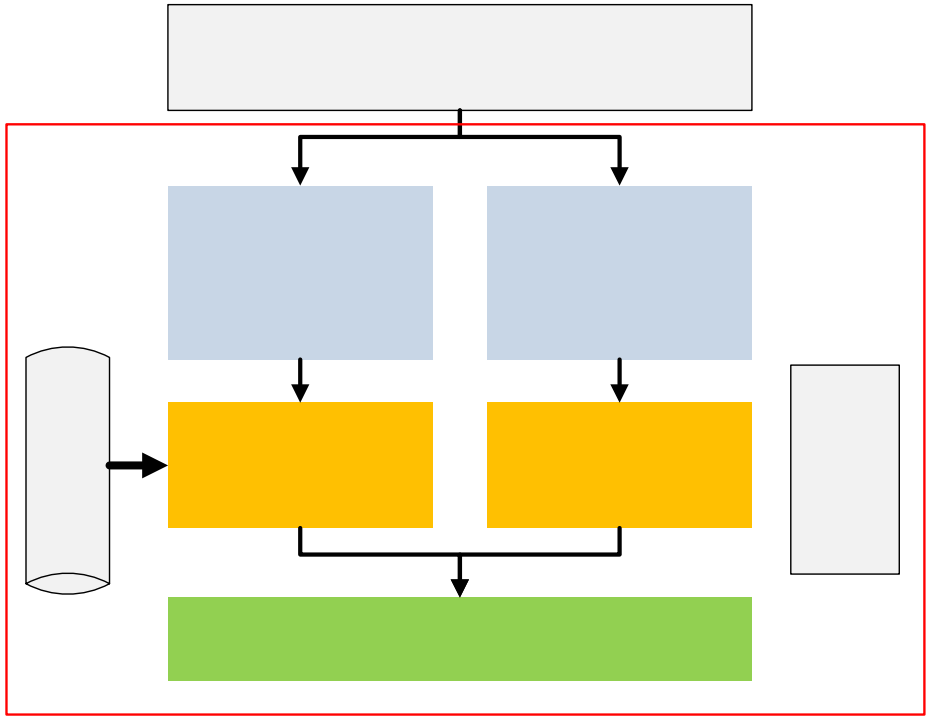
1. Motivation

- Build a data assimilation system for the North West Pacific Ocean for all data available including Argo, GTSPP, Altimetry and etc.
- Produce good oceanic analysis to better understand ocean variability at various time scales.
- Improve the ocean forecast system using the data assimilation system.
- As the first step, Argo profiles are assimilated into NWP OGCM for the past 5-years.

2. Data and Methodology

- **Ensemble Adjustment Kalman Filter (EAKF)**



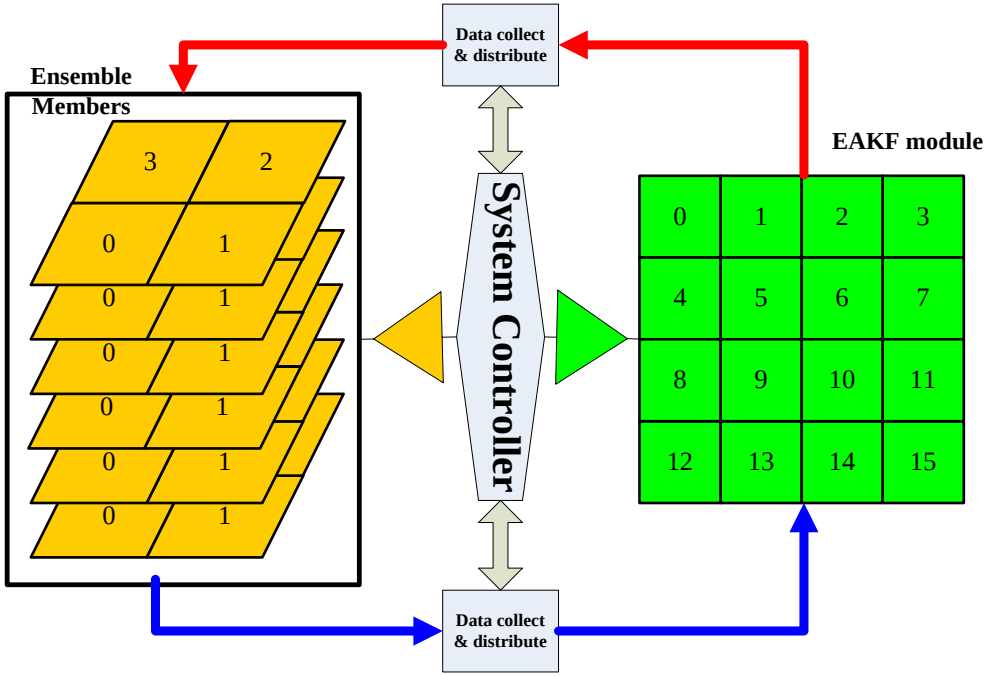
Ensemble Adjustment Kalman Filter (**EAKF**, developed by Anderson 2001, 2003) is used in this study. From an ensemble model integrations, the covariance of model states can be obtained for the adjustment because of the observations.

- Maintains the non-Gaussian information of prior distribution
- The algorithm does not require perturbed observations
- Requires small storage and cheap computational cost (the algorithm can only processes 2x2 matrix)

Ensemble Model Inte

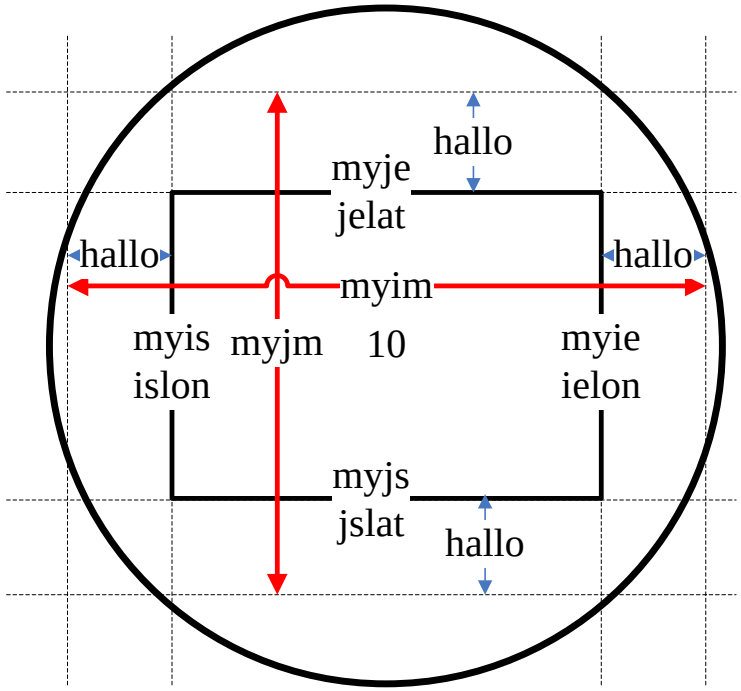
So, the algorithm allows the ensemble filter to be applied to realistic Ocean models

➢ Designing of EAKF assim system



(A)

Structure of parallel EAKF assimilation system



(B)

Parallel Scheme for EAKF

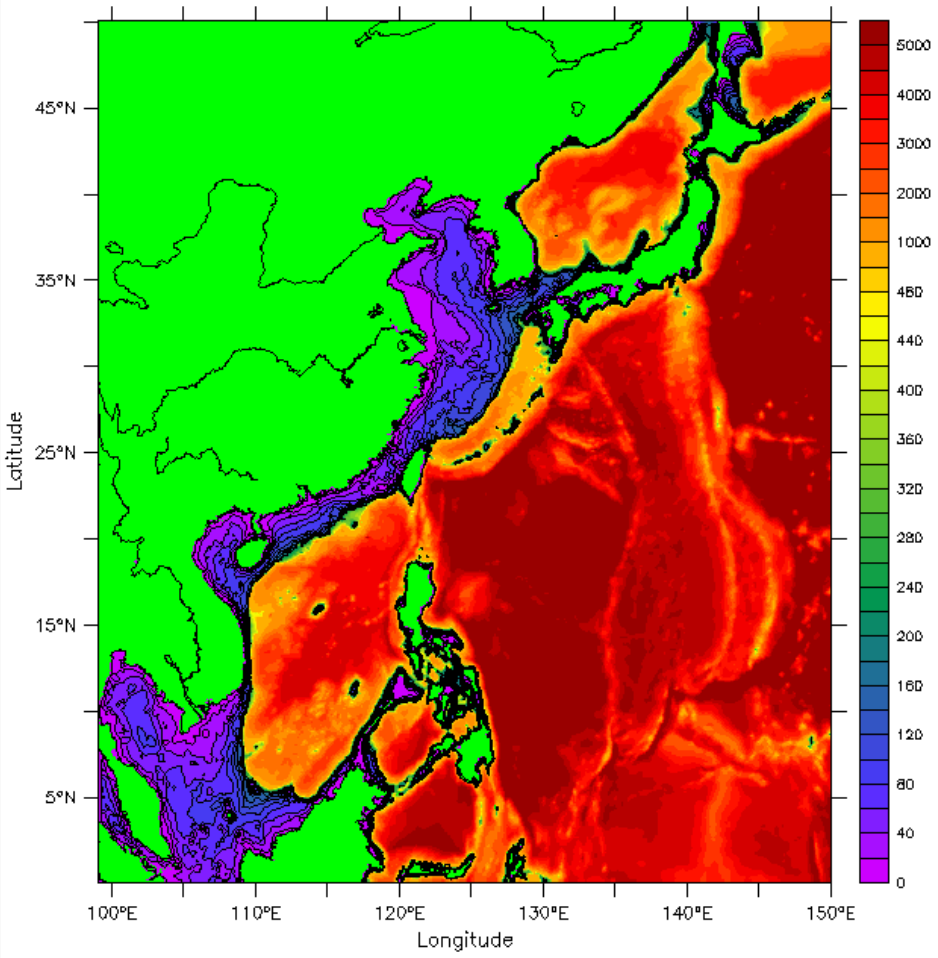
PORTABLE features

The structure of original model is unchanged and each ensemble members kept their own parallel design. The only thing that needs to be changed for ocean model is additional input / output at assimilation time. So this system is easier to be ported to other model systems.

➢ NWP OGCM Based on POM: Model setting

Model Setting & Forcing

- Based on POM, Wave-induced mixing is included
- North-West Pacific ocean, $1/8^o \times 1/8^o$， 21-layers
- Climatologic BC from Global model, $1/2^o \times 1/2^o$
- Climatologic heat flux
- Wind forcing
  - (1) QuikSCAT blend wind (2005.01.01-2009.08.01)
  - (2) NCEP/NCAR re-analysis wind (2009.08.01-2010.01.01)
- **Ensemble ICs:** 8 members from different year's restart
- EAKF assimilation for Argo T/S profiles (2005-2009)



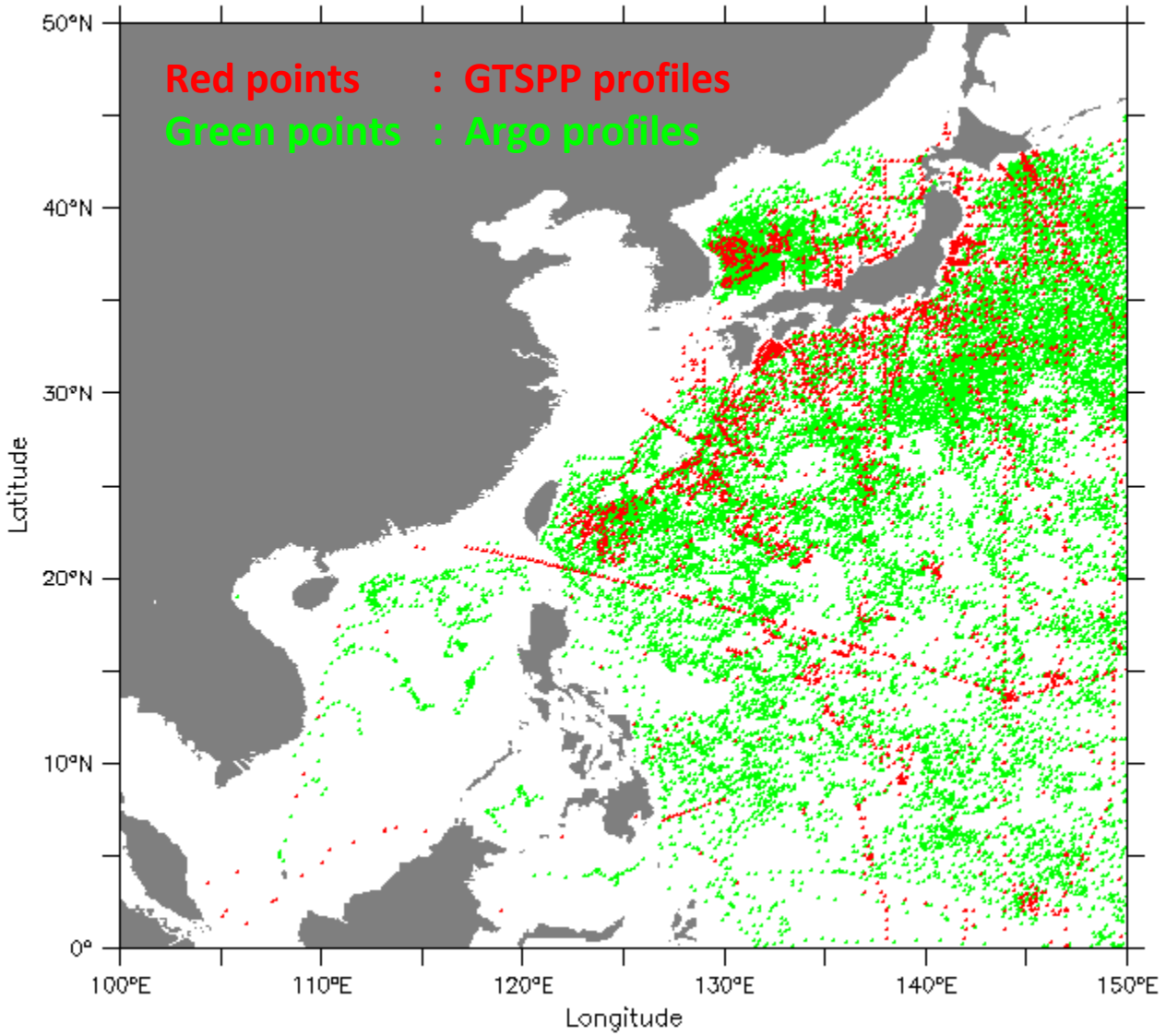
Model Domain & topography

➢ Locations of observation Profiles

Locations of Profile

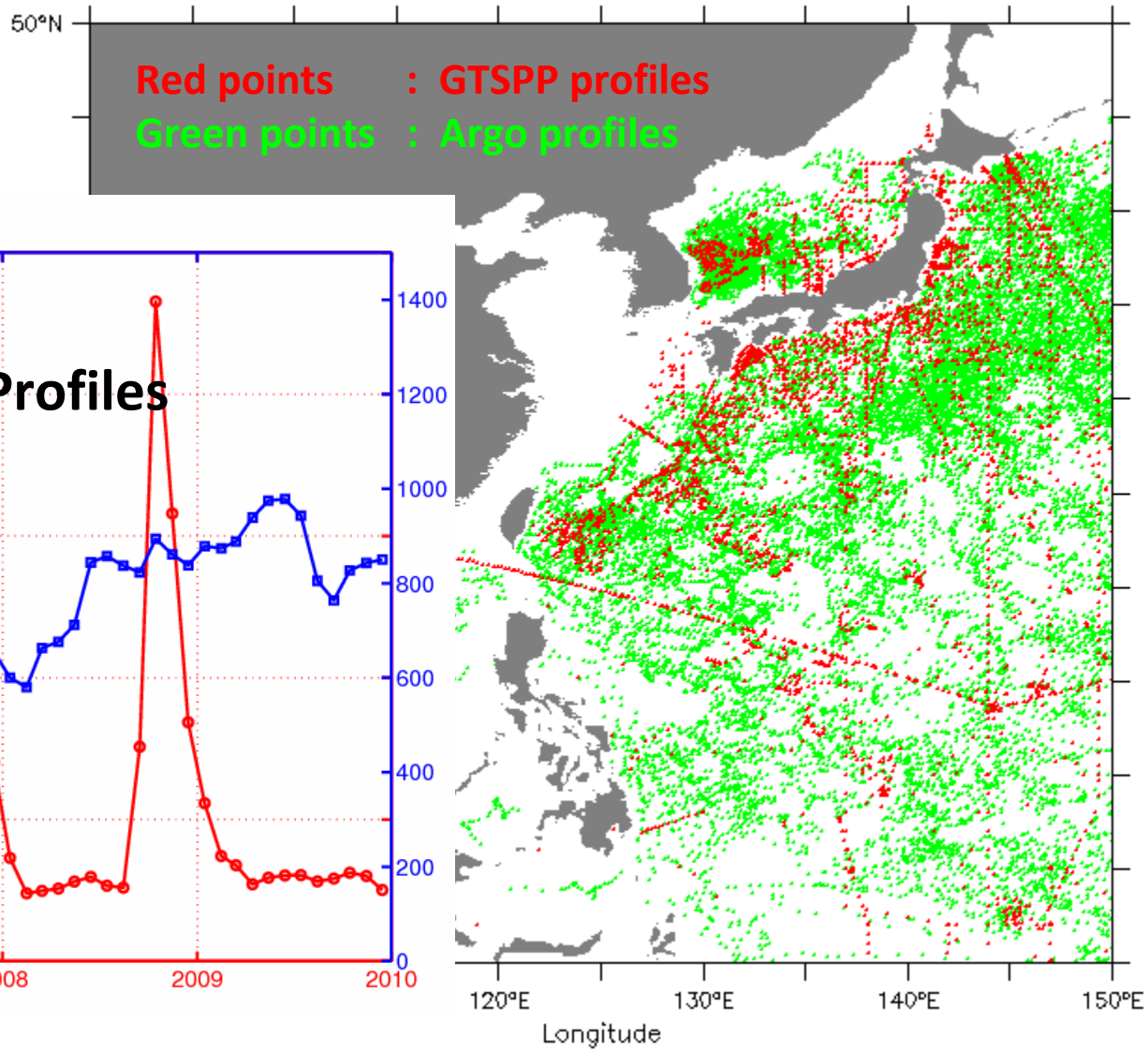
GTSPP: Global Temperature-Salinity Program provided by the U.S. National Oceanographic Data Center (NODC)

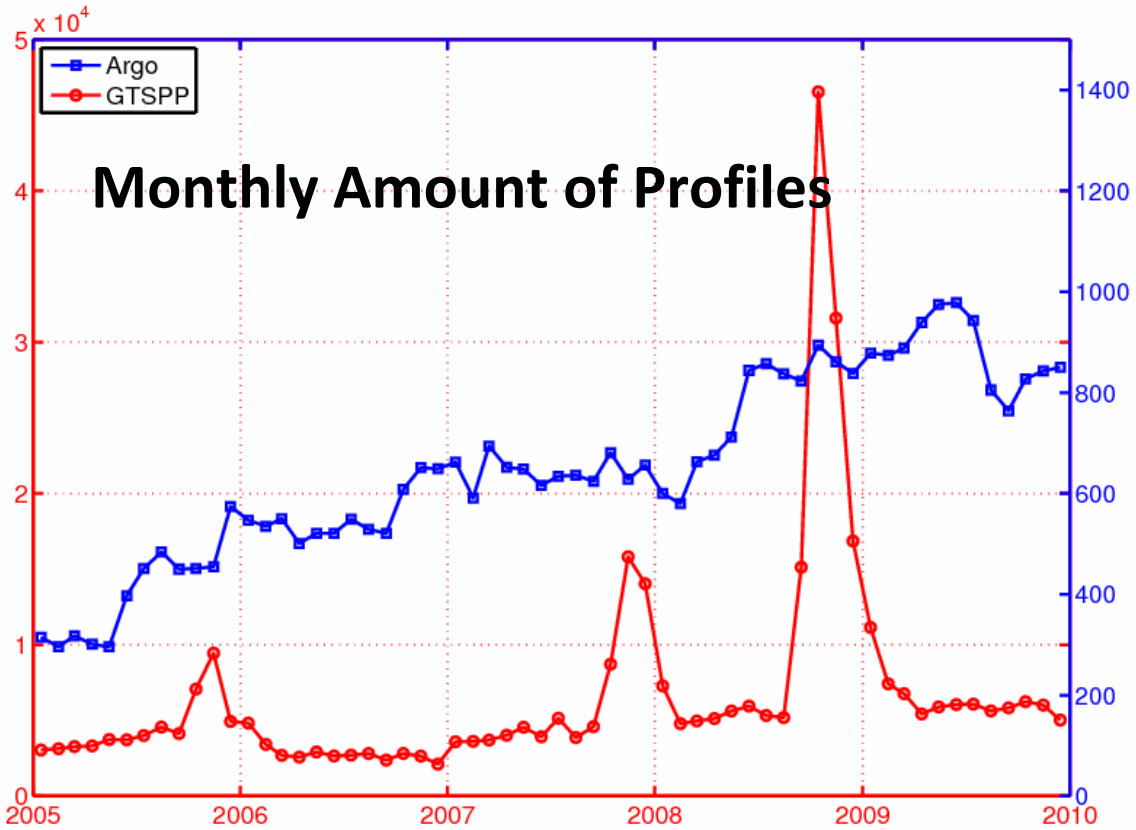
Most of the Argo profiles are contained into GTSPP. Before comparison, Argo profiles are eliminated from GTSPP data set.



➢ Locations of observation Profiles

Locations of Profile





3. Assimilation experiments and results

- **Data : ** Argo temperature & salinity profiles
- **Period:** 2005.01.01 ---- 2009.12.31
- **Multi-variable EAKF**

  Temperature profiles (Observation)

  → Temperature adjustments

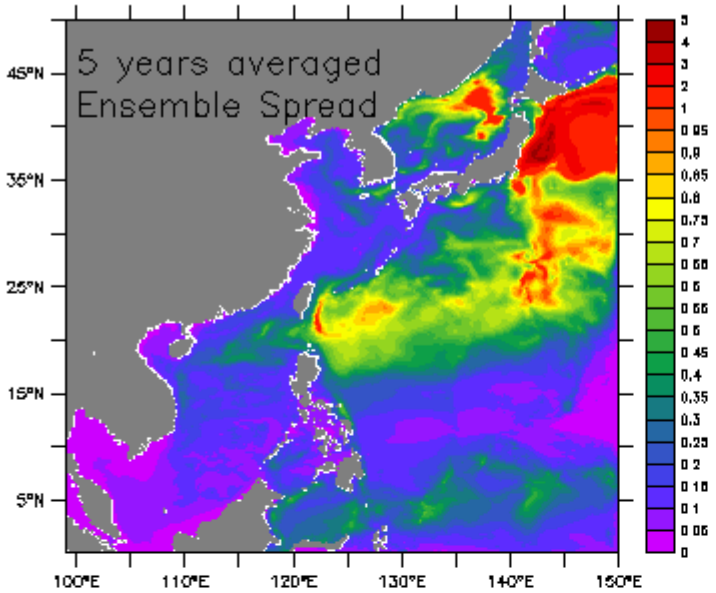
  → Salinity relevant adjustments

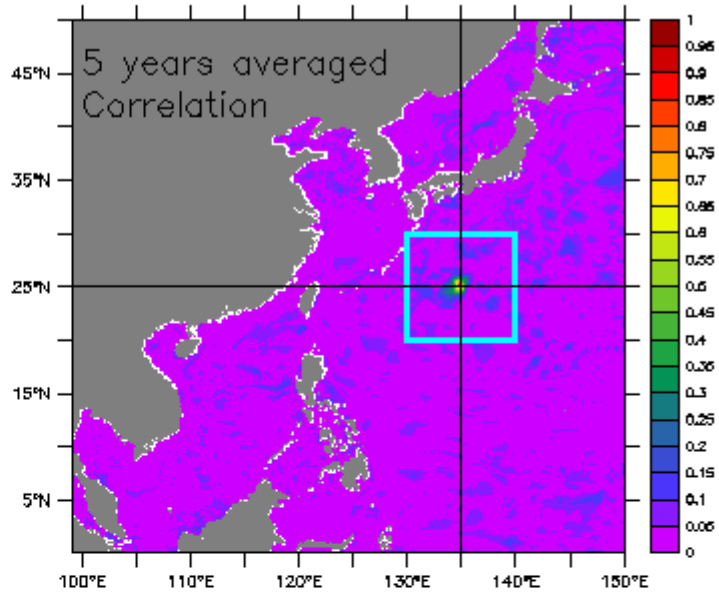
  Salinity profiles (Observation)

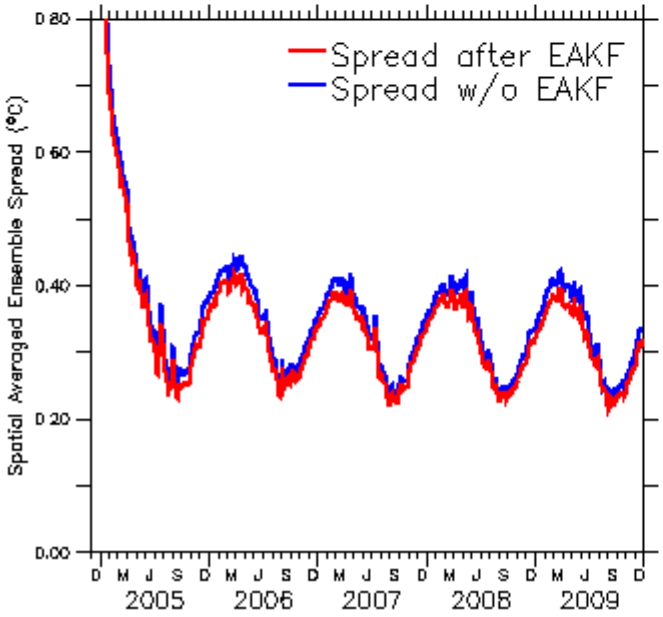
  → Salinity adjustments

  → Temperature relevant adjustments

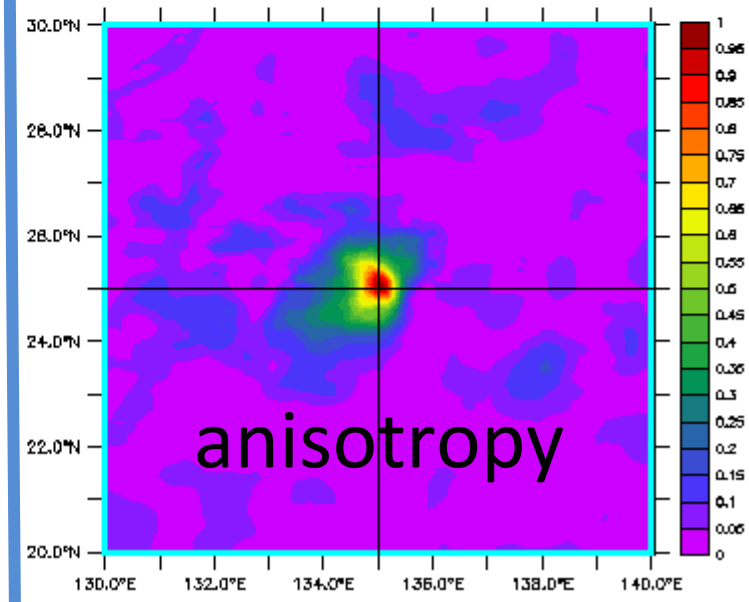
- **Experiments**
  - **CTL(Control run):** Single integration without ODA
  - **EAKF:** Ensemble integrations with Argo assimilation
  - **EnFR:** Ensemble free runs without ODA







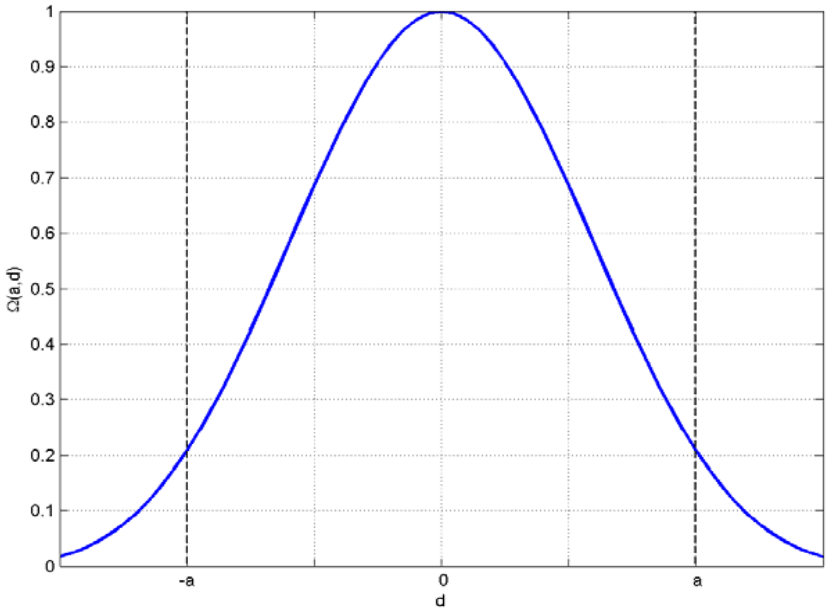
Ensemble Spread

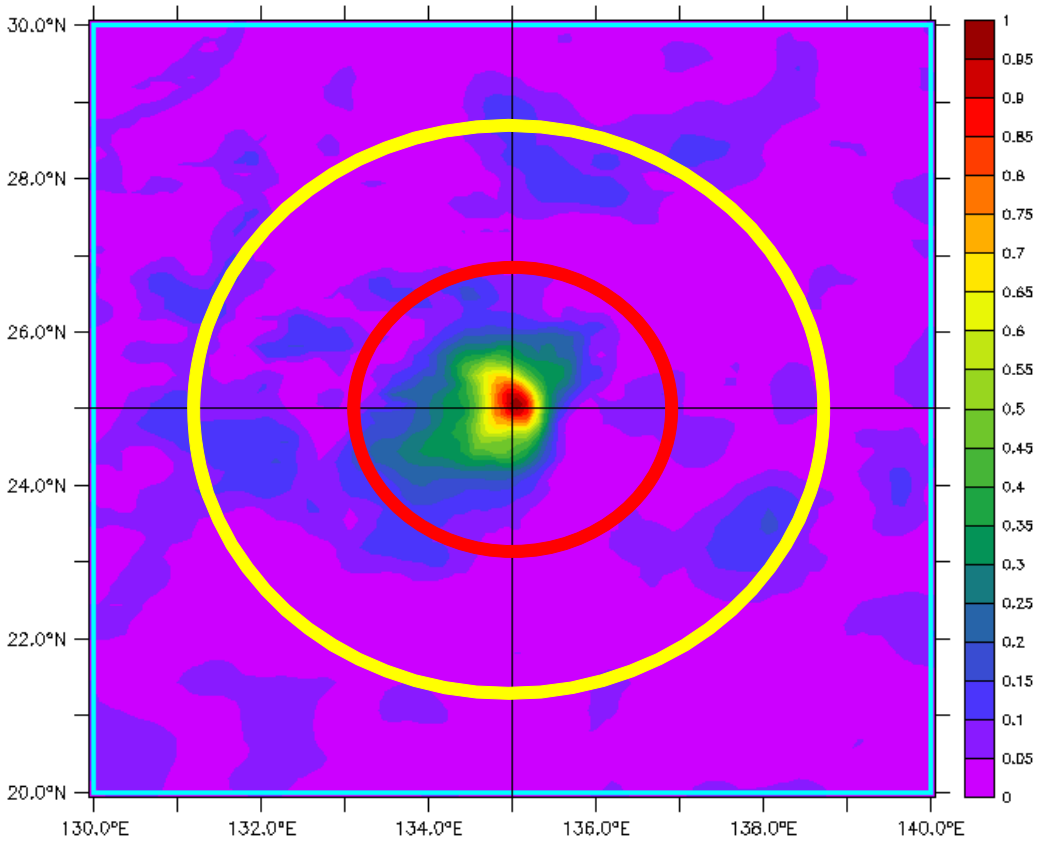


Correlation relative to point (135°E,25°N)

Localization

$$\Omega(a,d)=\begin{cases}-\frac{1}{4}(\frac{d}{a})^5+\frac{1}{2}(\frac{d}{a})^4+\frac{5}{8}(\frac{d}{a})^3-\frac{5}{3}(\frac{d}{a})^2+1, & 0\le d\le 2a\\ \frac{1}{12}(\frac{d}{a})^5-\frac{1}{2}(\frac{d}{a})^4+\frac{5}{8}(\frac{d}{a})^3+\frac{5}{3}(\frac{d}{a})^2-5(\frac{d}{a})+4-\frac{2}{3}(\frac{d}{a})^{-1}, & a<d\le 2a\\ 0, & d>2a\end{cases}$$





Parameter a

Horizontal : 2º

Vertical : 30 m

Temporal : 5 days

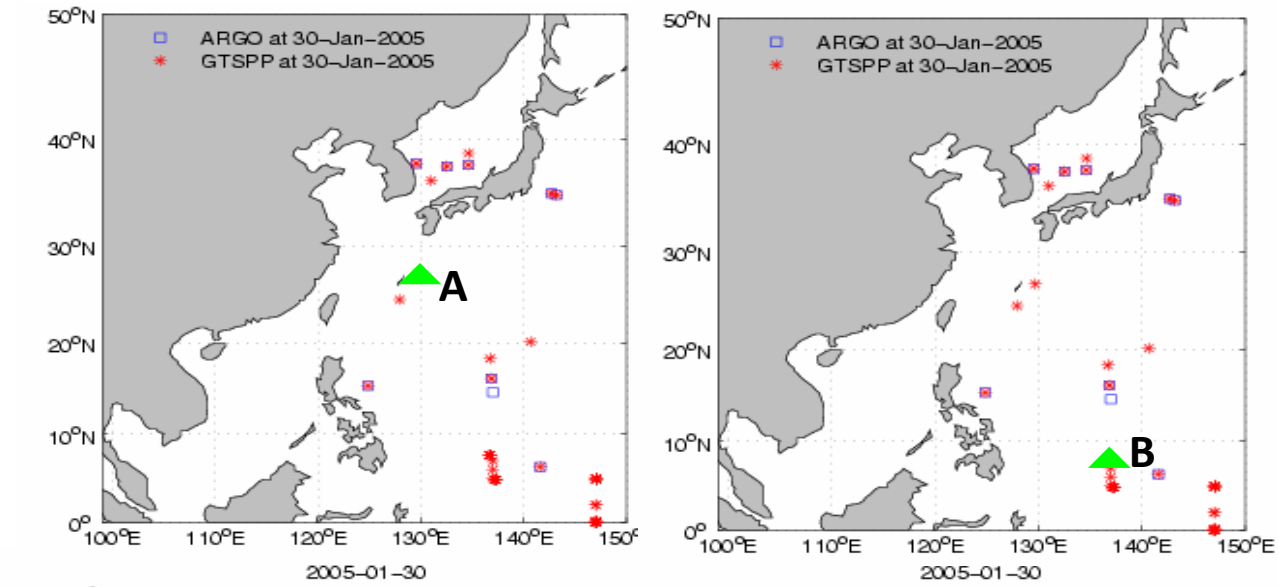
The yellow circle is covered the whole region where the variables will be adjusted given observation at its center.

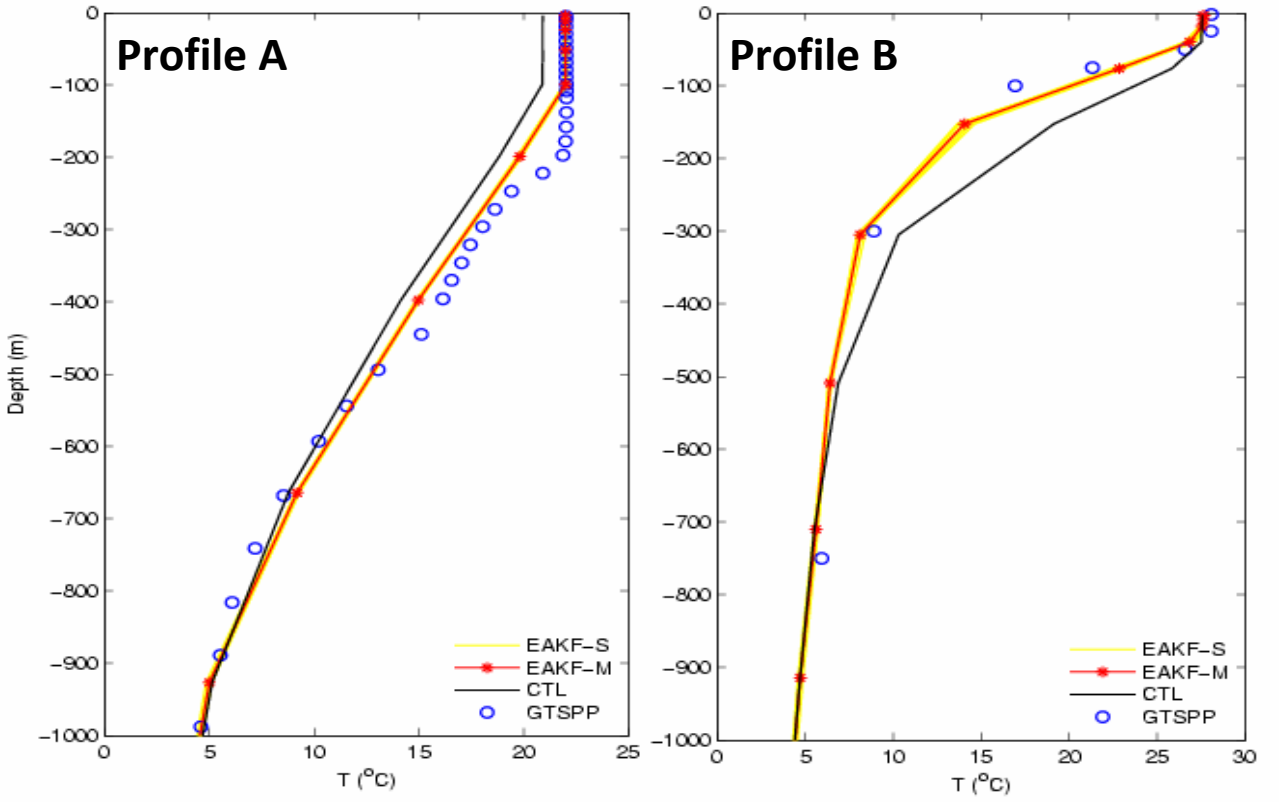
Inside the red circle, the adjustment will be intensive.

Comparison with GTSPP

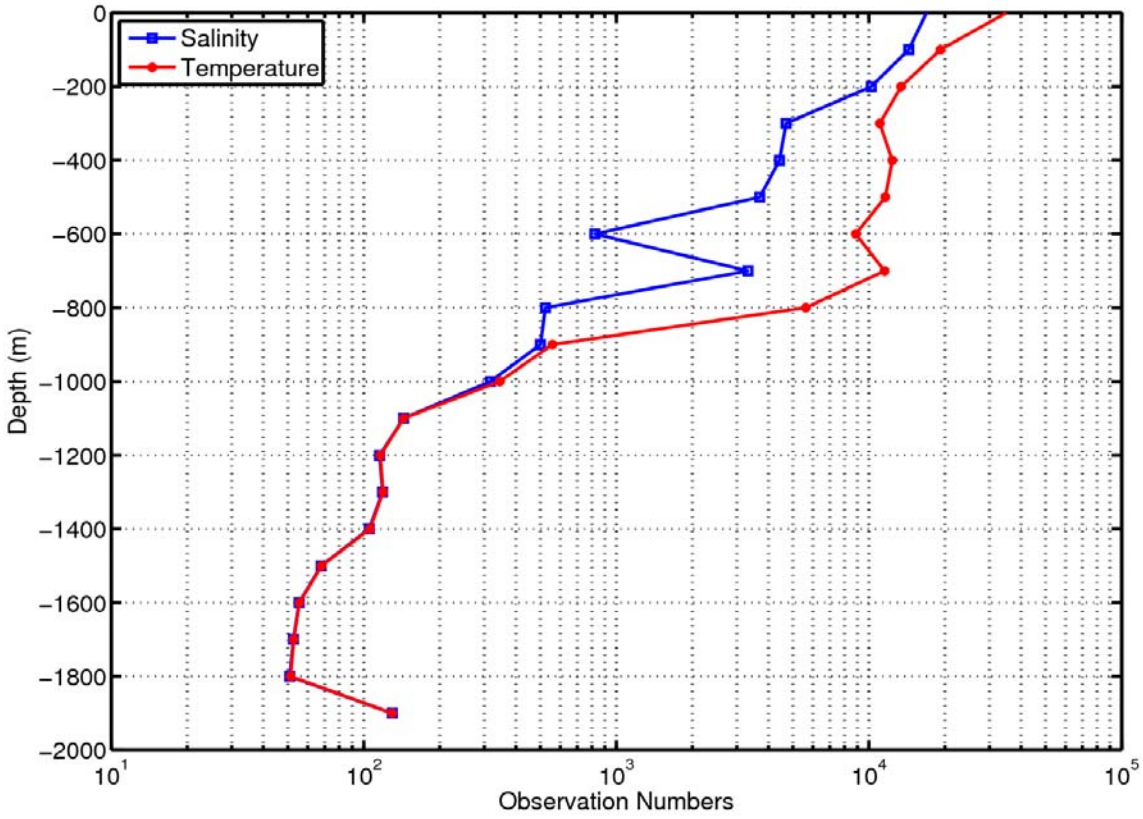
Green triangle with A / B represent the location of GTSPP profile

Profiles A and B are far from Argo



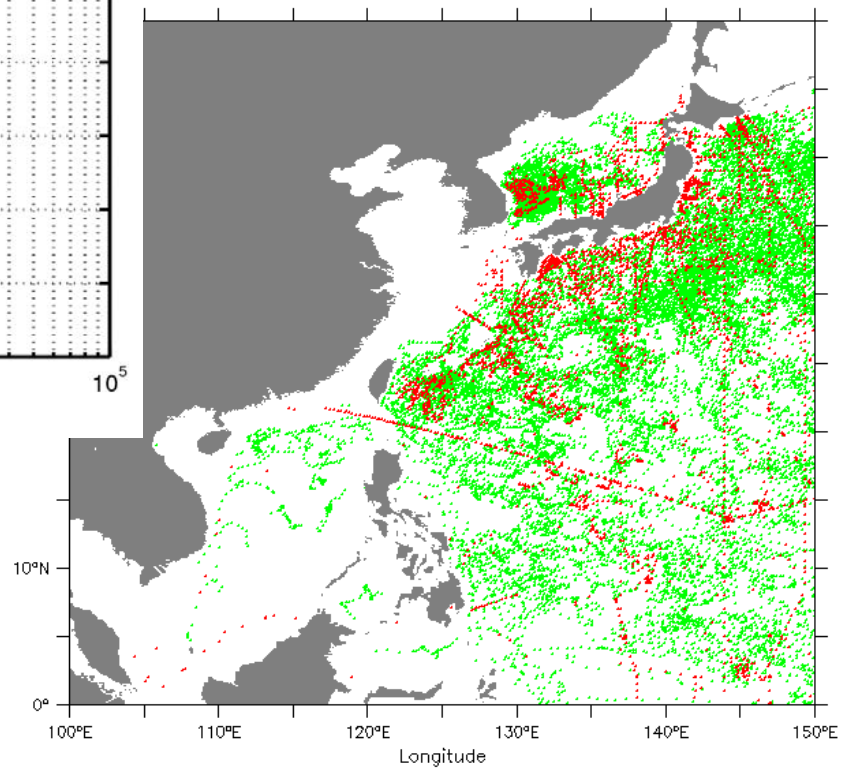


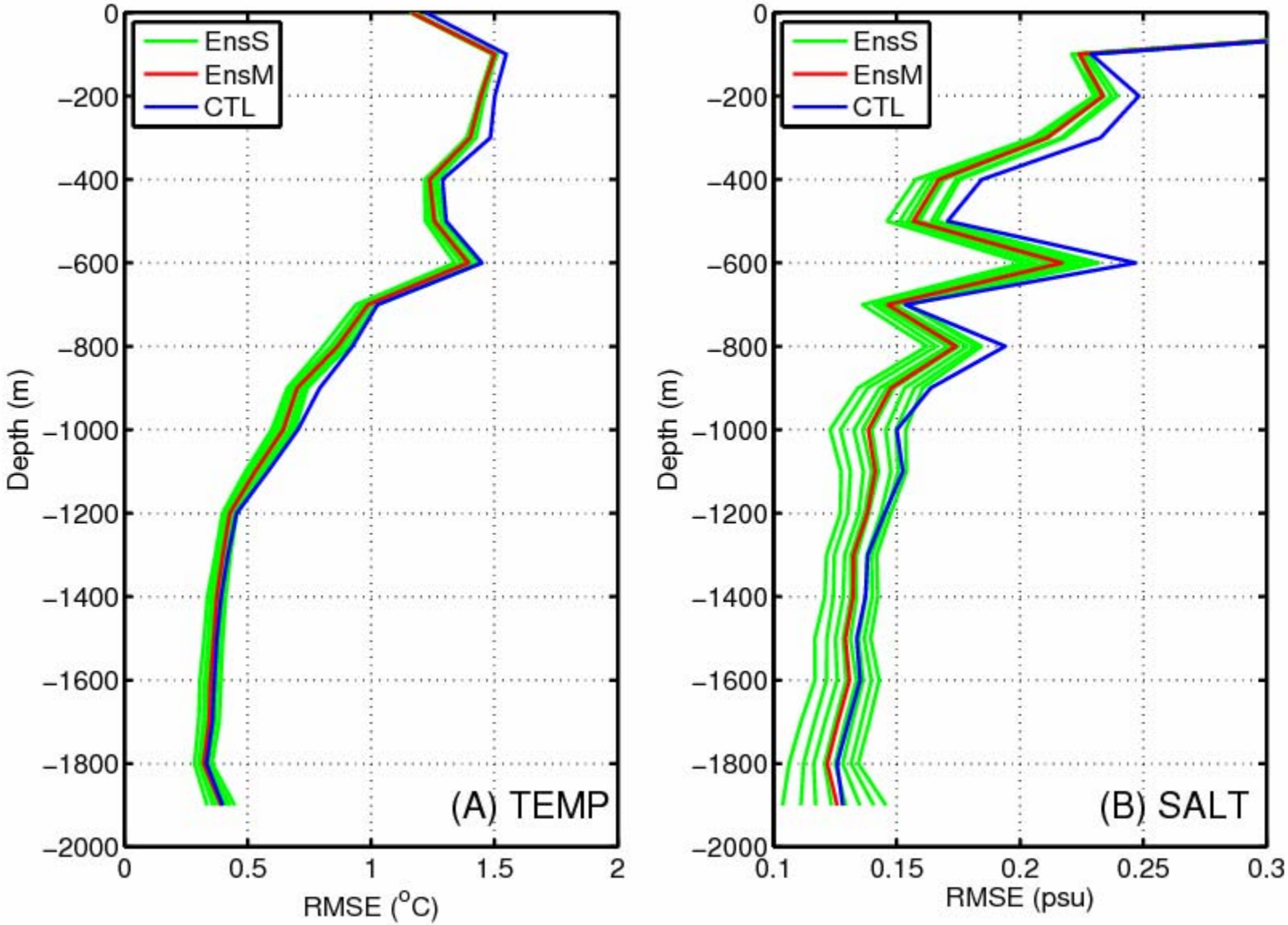
Comparison with GTSPP



GTSPP profiles numbers temp & salt

GTSPP Locations

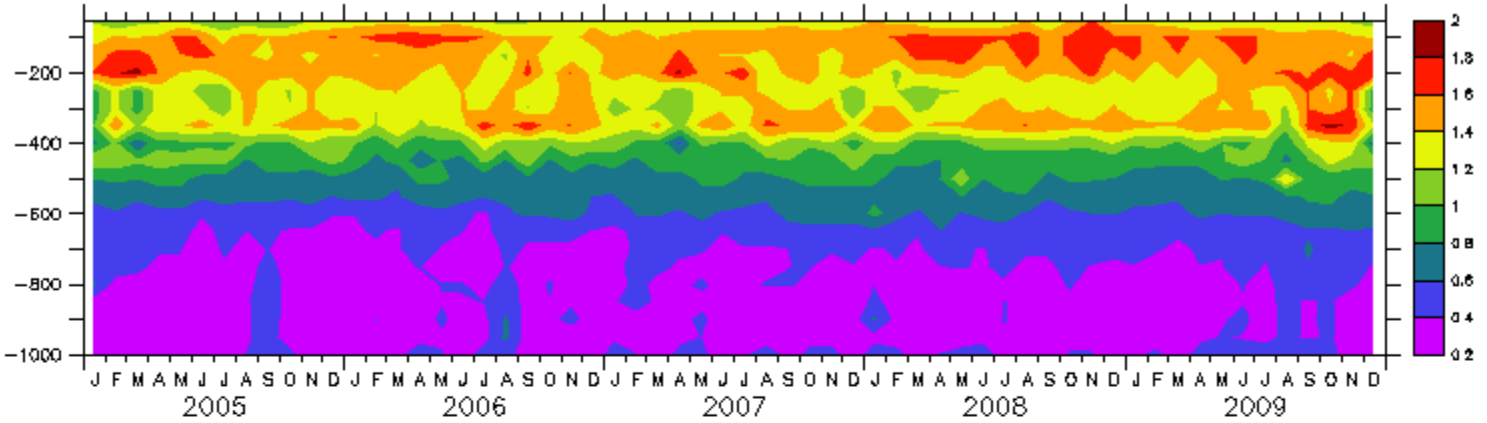



EnsS
EnsM
CTL
(A) TEMP
Depth (m)
RMSE (°C)
0
−200
−400
−600
−800
−1000
−1200
−1400
−1600
−1800
−2000
0
0.5
1
1.5
2
(B) SALT
RMSE (psu)
0.1
0.15
0.2
0.25
0.3

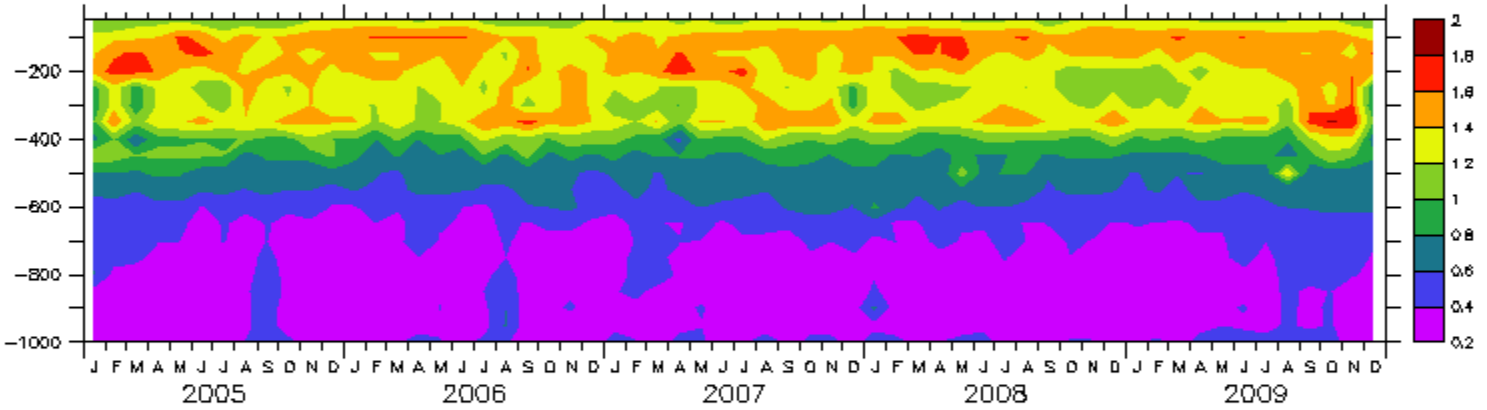
Compare with GTSPP: Temperature

Detailed Error Structure in Depth-Time plan

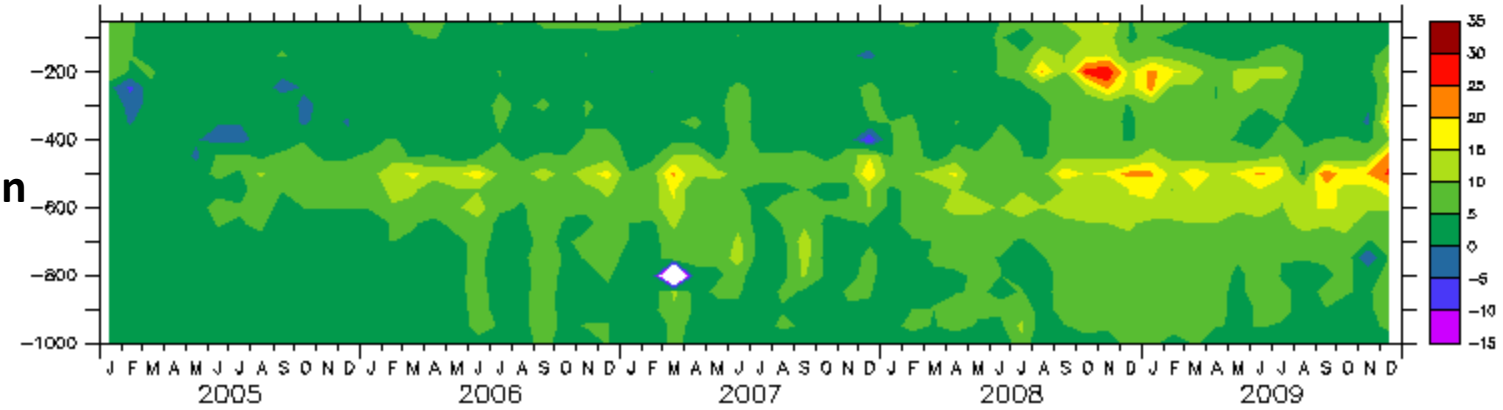
RMS error for CTL

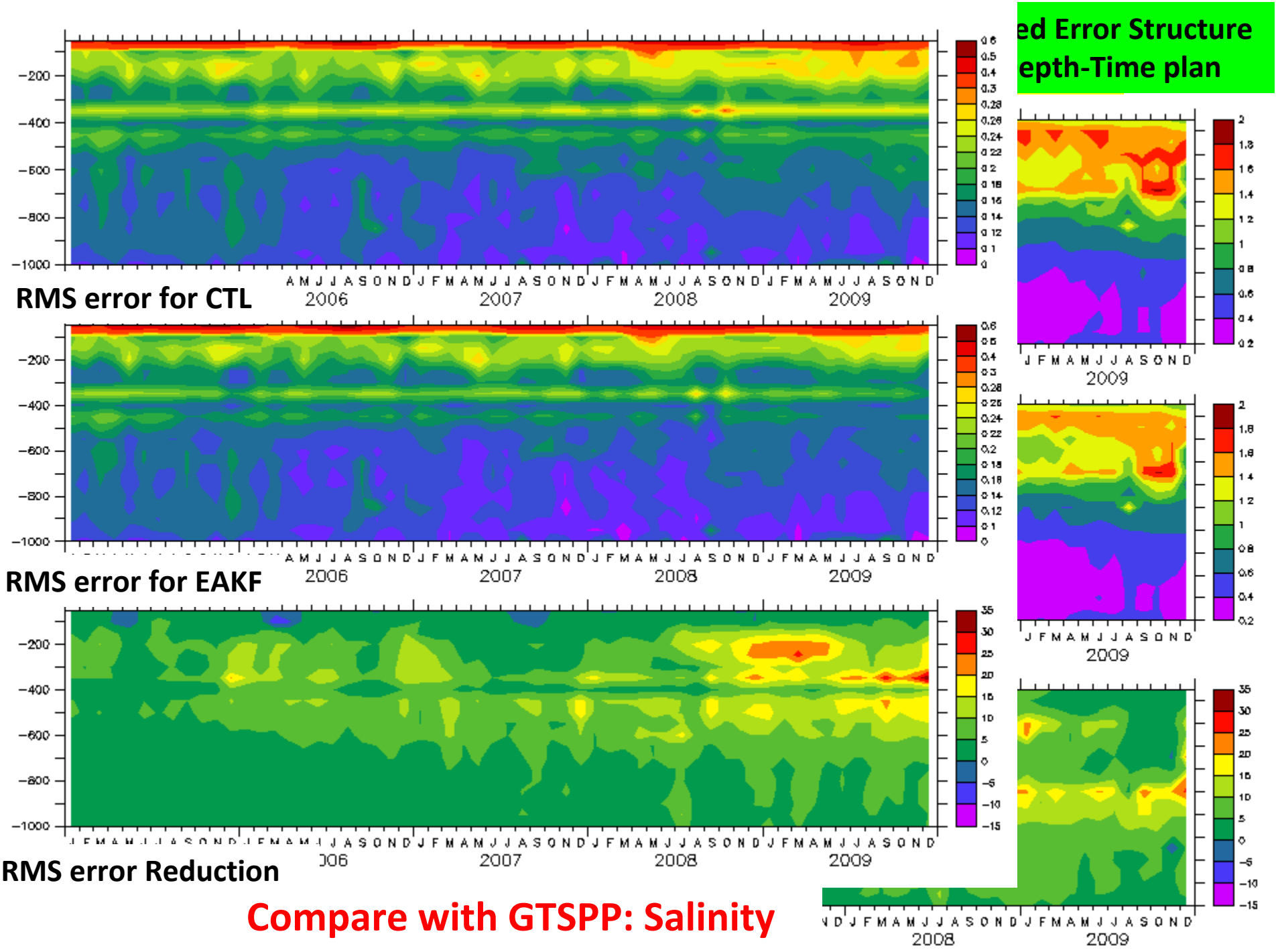


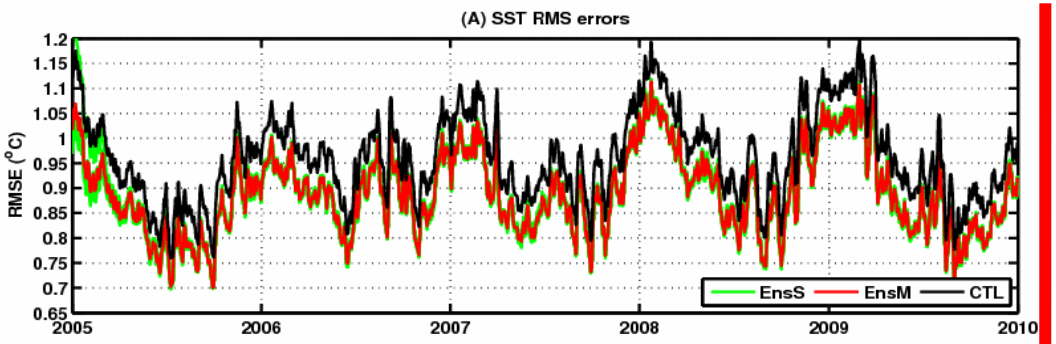
RMS error for EAKF

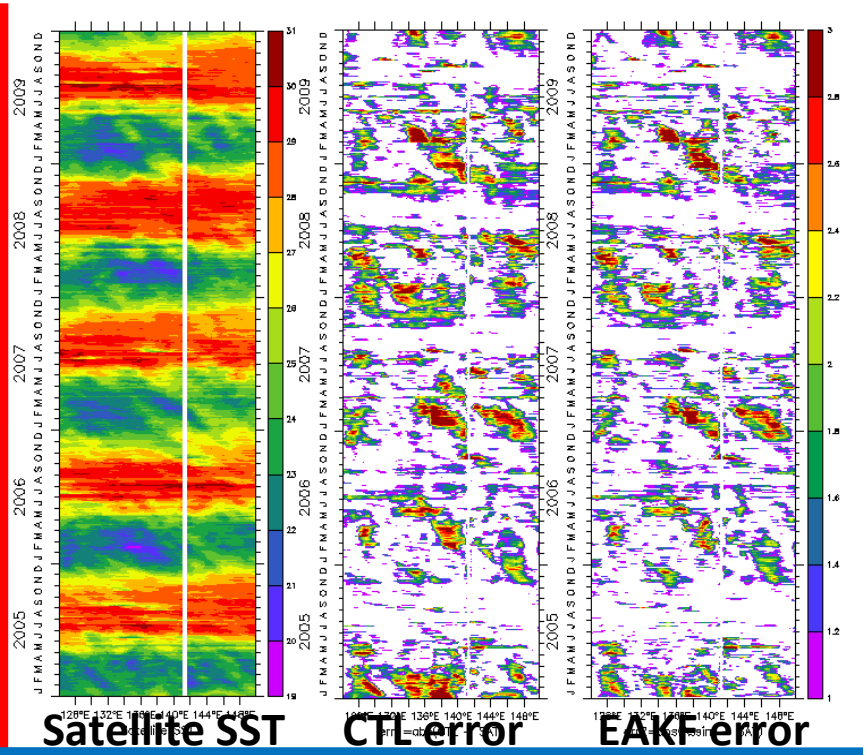


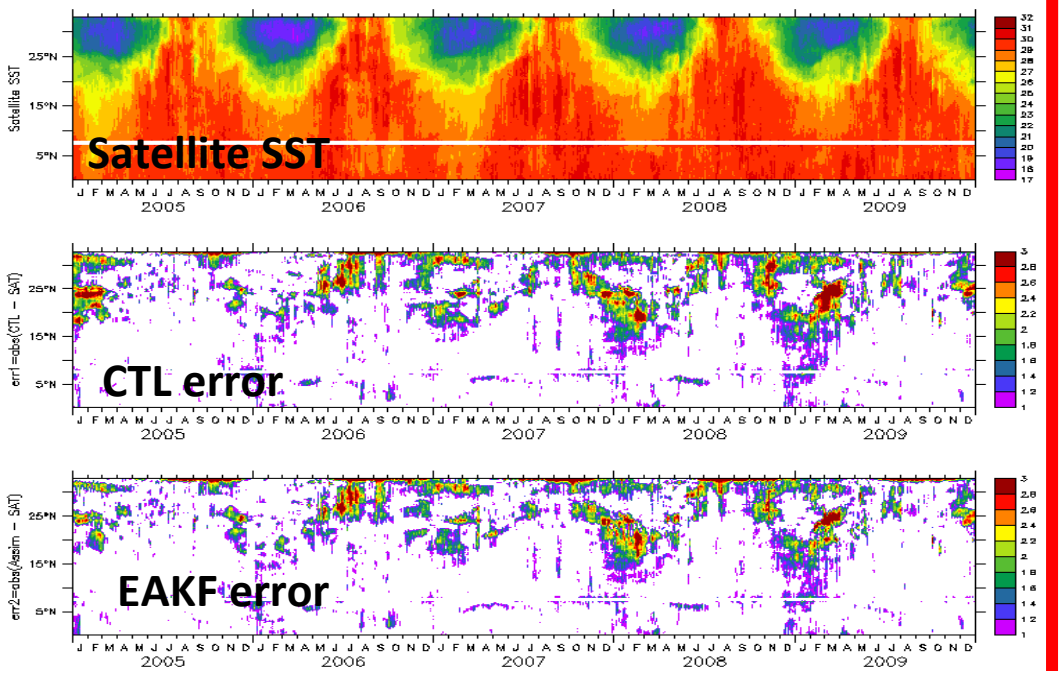
RMS error reduction

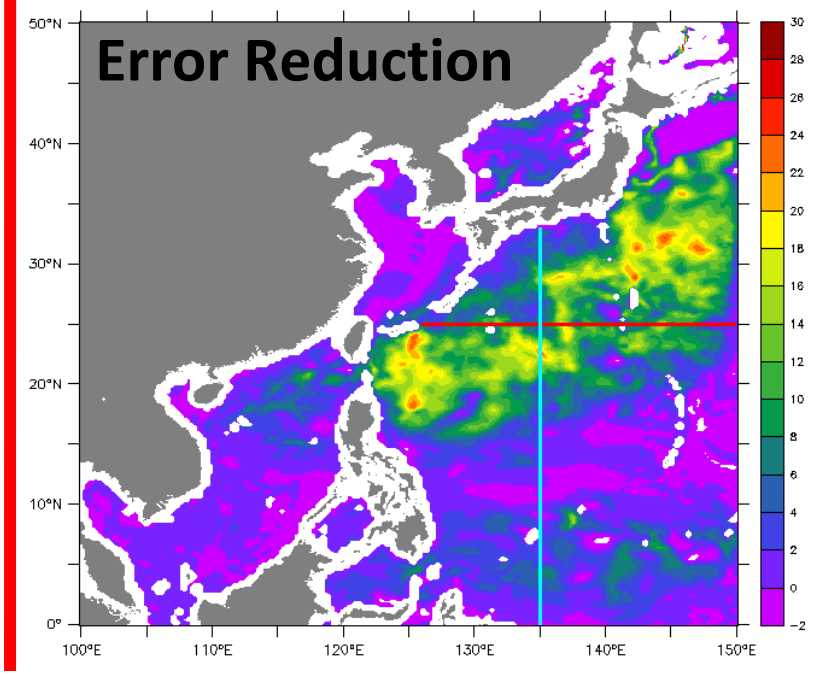



ed Error Structure
epth-Time plan
RMS error for CTL
RMS error for EAKF
RMS error Reduction
Compare with GTSPP: Salinity
2006
2007
2008
2009


(A) SST RMS errors
RMSE (°C)
EnsS
EnsM
CTL
(B) SST RMS error reductions
RMSE Reduction (%)
EnsS
EnsM


Satellite SST
CTL error
EAKF error


Satellite SST
CTL error
EAKF error


Error Reduction

Conclusions

- An EAKF module is designed to assimilate Argo temperature and salinity profiles into NWP OGCM. Experiments are carried out for the period of 2005-2009 and the results are compared with GTSPP and satellite SST.
- The ensemble spread showed that the ensemble integrations can maintain a certain magnitude to ensure the EAKF analysis. The horizontal distribution of correlation indicated the necessary of localization.
- The comparison with GTSPP indicated that the data assimilation reduced the simulated error in temperature and salinity. The comparison against satellite SST showed a continues improvement because of the Argo assimilation.
- This system is potentially capable of reconstructing oceanic data sets which are of high quality, and temporally and spatially continuous. In the future, more observations including GTSPP profiles, satellite SST, and etc. should be introduced into this assimilation system.

Thanks for your attention!

Questions?

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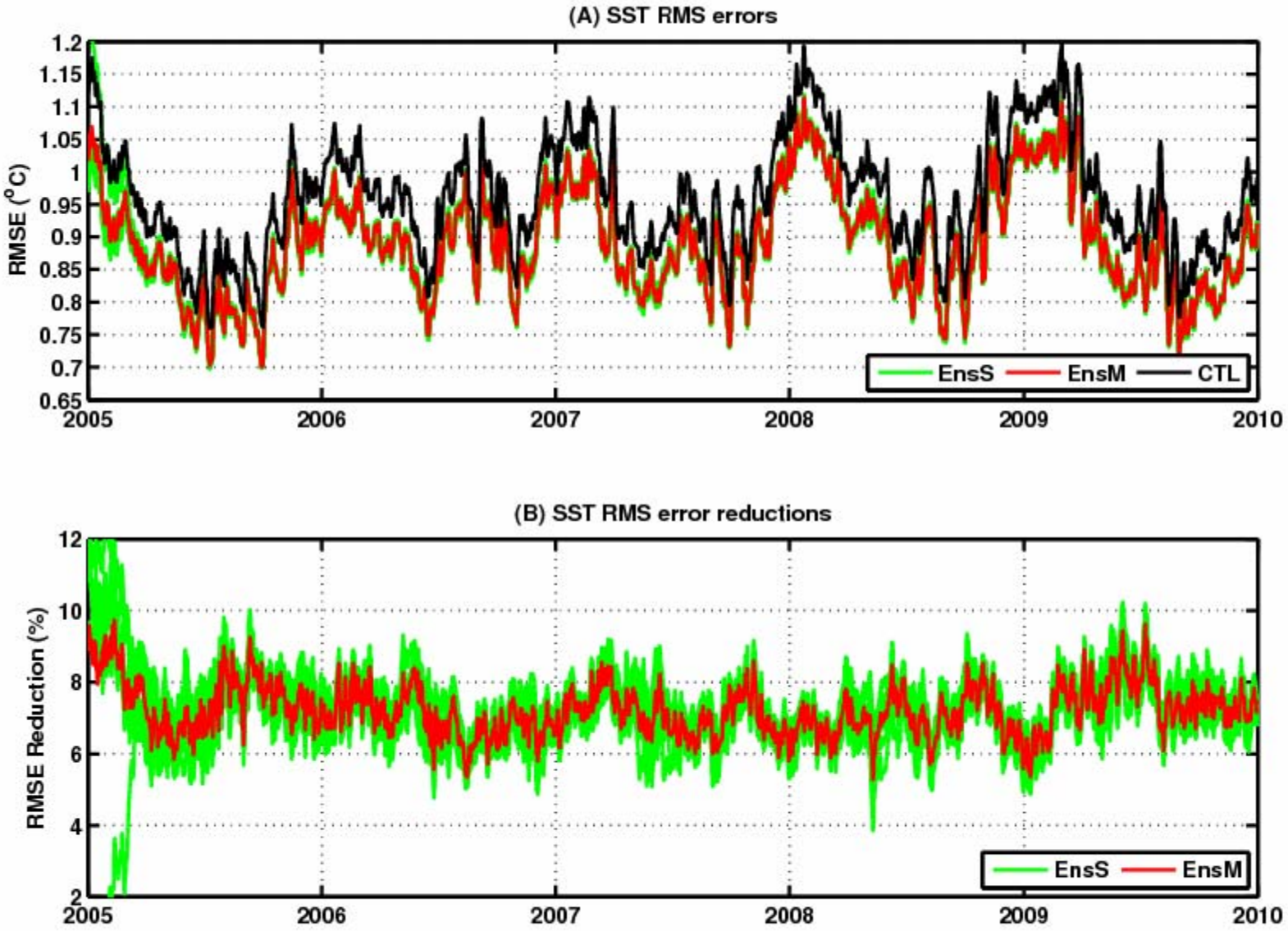
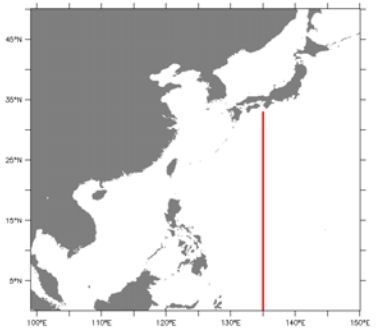
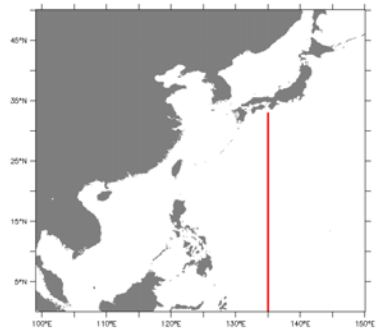

(A) SST RMS errors
RMSE (°C)
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
2005
2006
2007
2008
2009
2010
EnsS
EnsM
CTL
(B) SST RMS error reductions
RMSE Reduction (%)
12
10
8
6
4
2
2005
2006
2007
2008
2009
2010
EnsS
EnsM

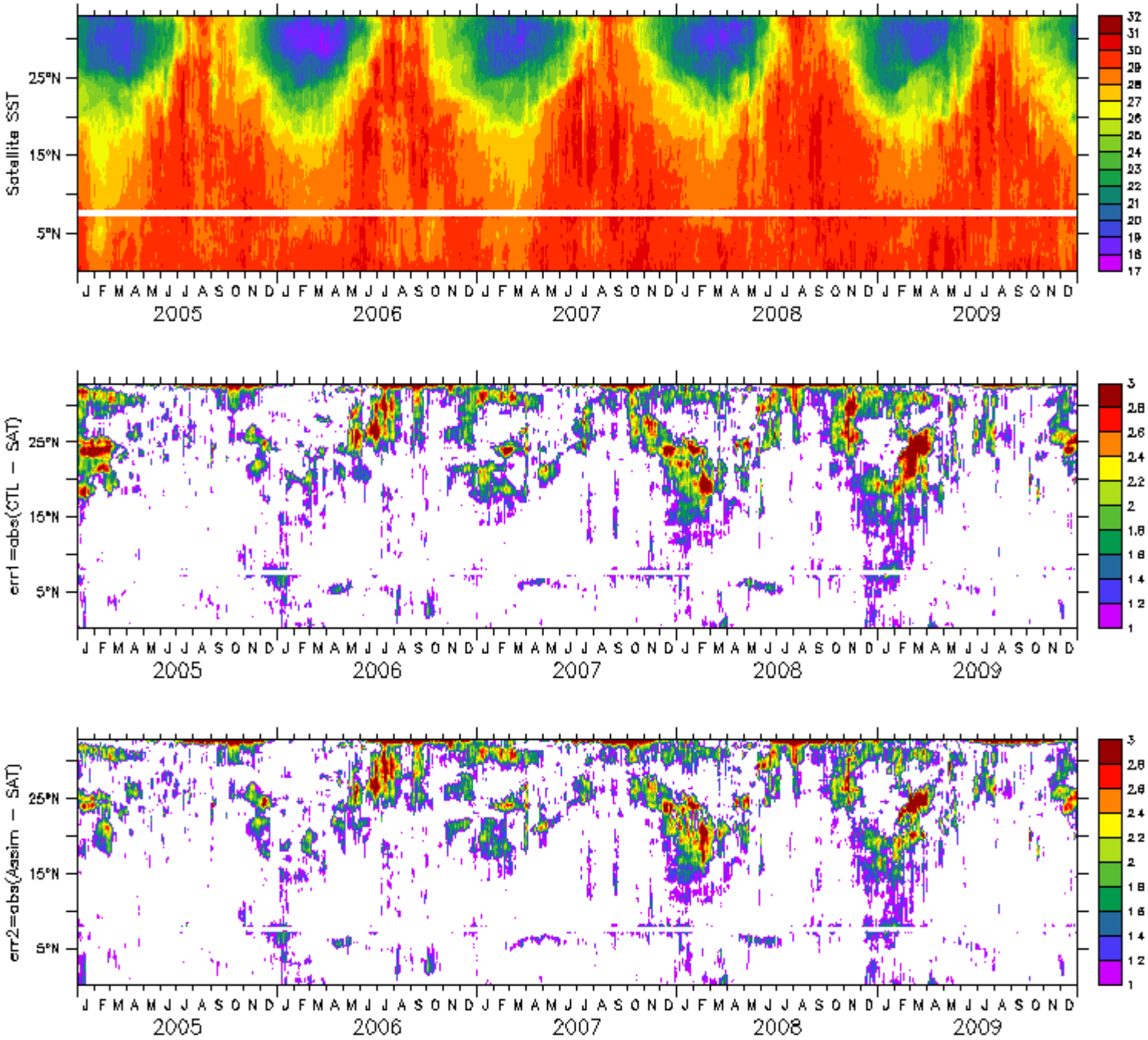
SST along 135°E

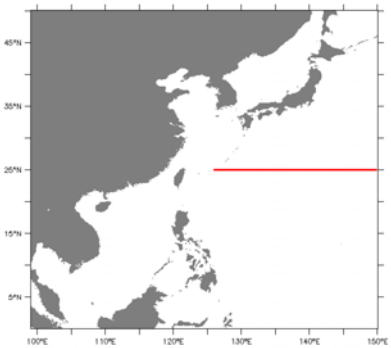


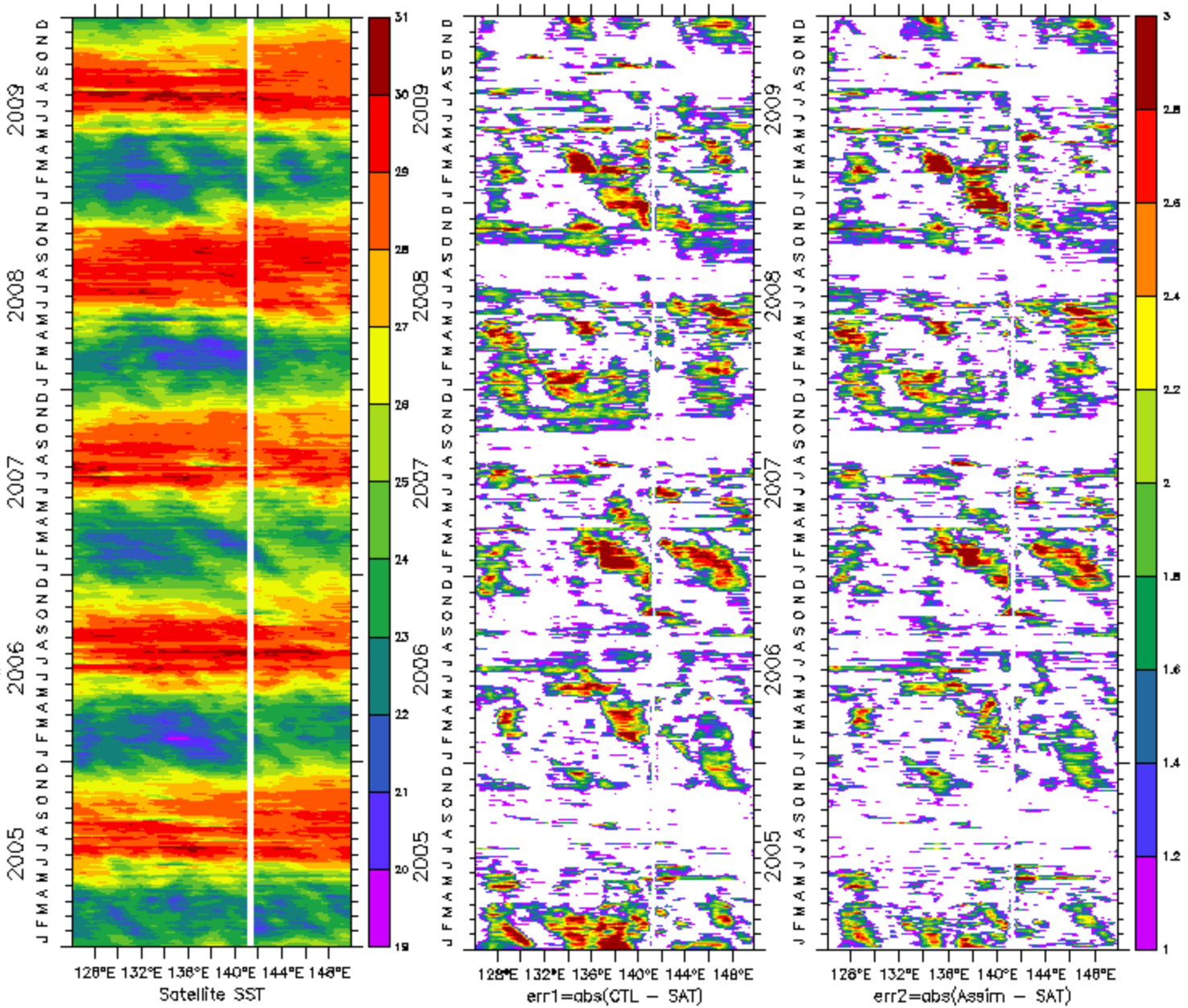
Error along 135°E (CTL)



Error along 135°E (Asim)



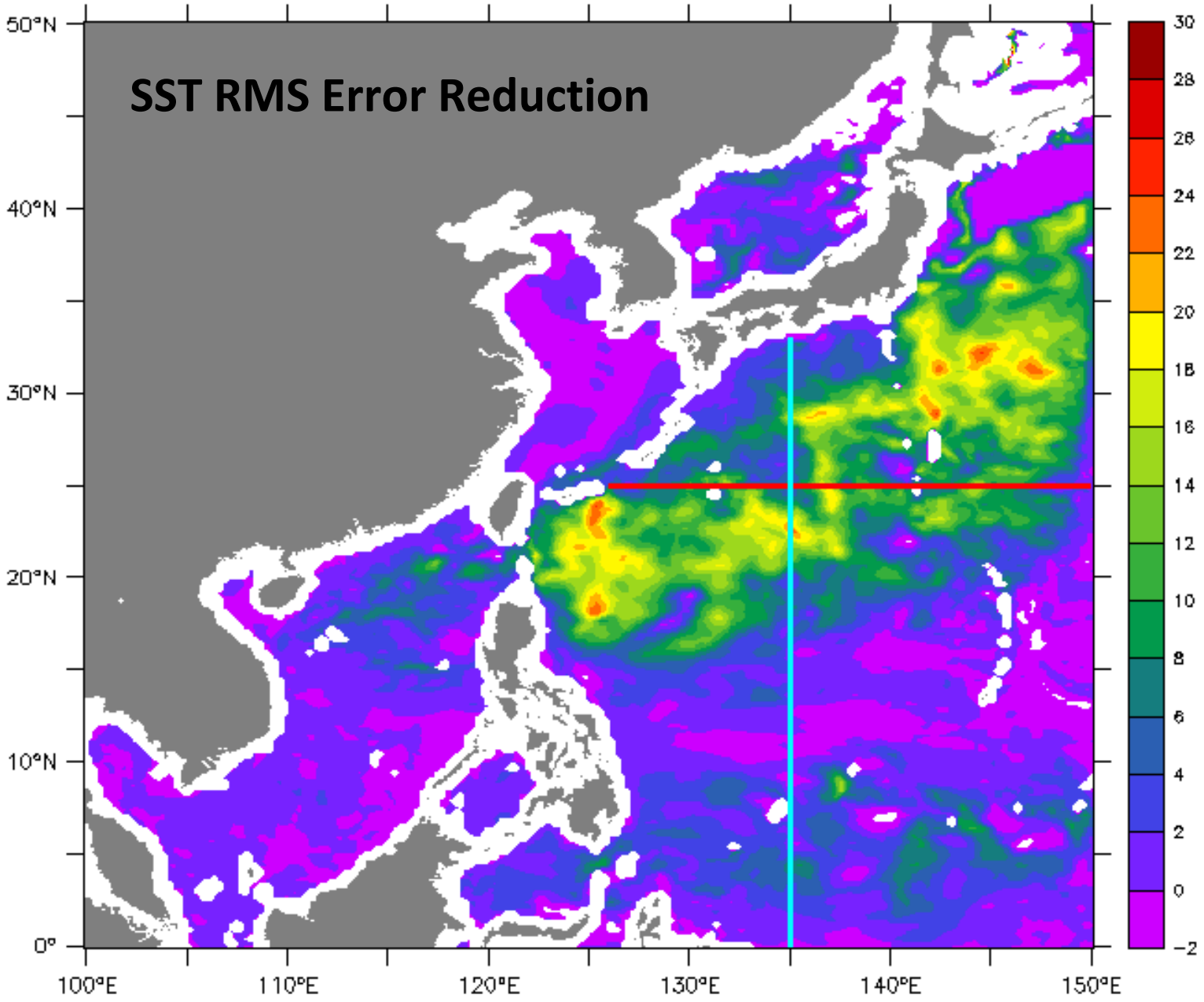




SST along 25°N Satellite

Error along 25°N (CTL)

Error along 25°N (Asim)


SST RMS Error Reduction
50°N
40°N
30°N
20°N
10°N
0°
100°E
110°E
120°E
130°E
140°E
150°E
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
−2