Implementation and Evaluation of a High-Efficiency Coupled Data Assimilation System Using Multi-Timescale EnOI-Like Filtering with a Coupled General Circulation Model

Joint ECMWF/OceanPredict workshop on
Advances in Ocean Data Assimilation, Online
17th-20th May 2021

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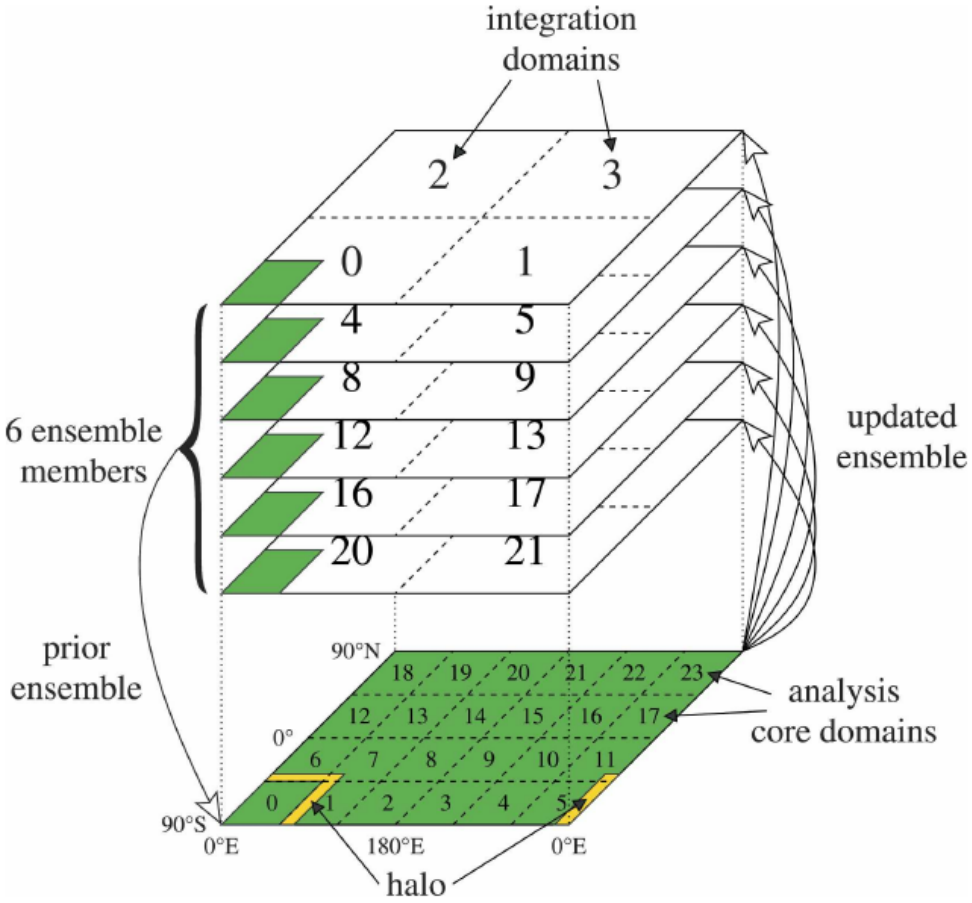
OUTLINE

1. Design of a multi-timescale high-efficiency approximate filter (MSHea-EnKF)
2. Implementation in CM2.1
3. Results of MSHea-EnKF in twin experiments.
4. Results of a long CDA real-obs experiment
5. Summary and discussions

1. Design of a multi-timescale high-efficiency approximate filter (MSHea-EnKF)



EnKF in GFDL CM2.1-ECDA with a so-called superparallel technique (*Zhang et al. 2005*)

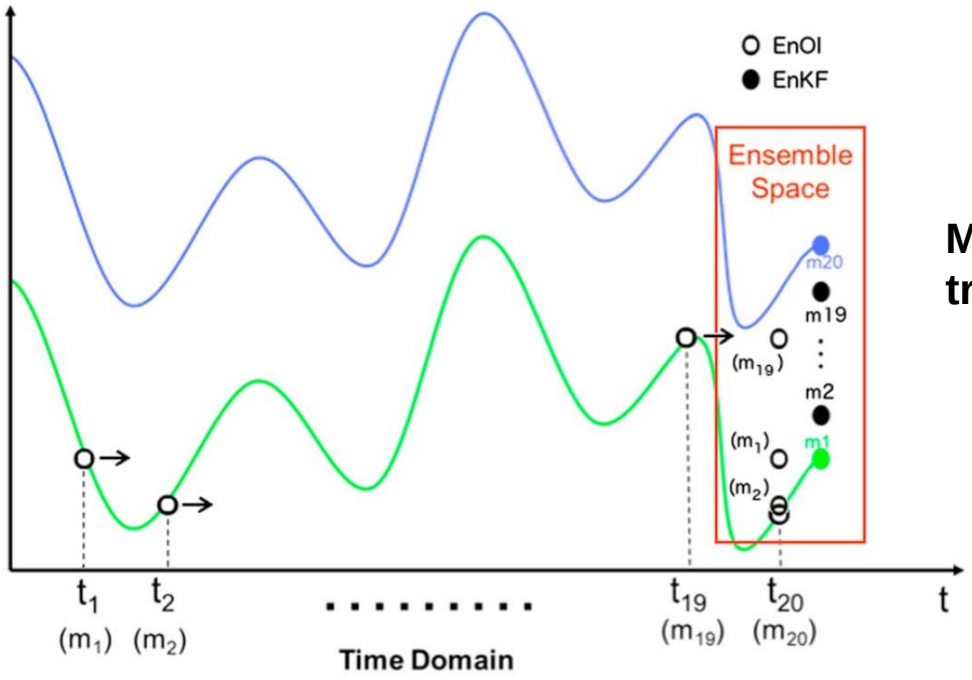
Advantages:

- ✓ Directly implement Bayes Theorem
- ✓ Obtain the optimal combination of dynamic background and observation information.

Disadvantages:

- ✓ Need N times computational resource
- ✓ Insufficient representation on statistics of slow-varying flows by a finite ensemble (*Yu et al. 2019*)

1. Design of a multi-timescale high-efficiency approximate filter (MSHea-EnKF)



Yu et al. 2019

MSHea-EnKF idea：

- Using historical data in single model solution to sample different timescales of background flow PDF.

MSHea-EnKF has following advantages to tra-EnKF:

- Single model solution-based; Only a small fraction of tra-EnKF resources
- Applicable to any HR model
- Improving representation of statistics on slow-varying background flows with long time data
- Improving assimilation quality and prediction skills

2. Implementation in CM2.1

CM2.1 coupled model：

- MOM4: 1° ×1° , 50 layers
- AM2.1: 2° lat×2.5° lon, 24 layers
- LM2.1: 2° ×2.5°
- SIS: 1° ×1°

MSHea-EnKF filter implementation:

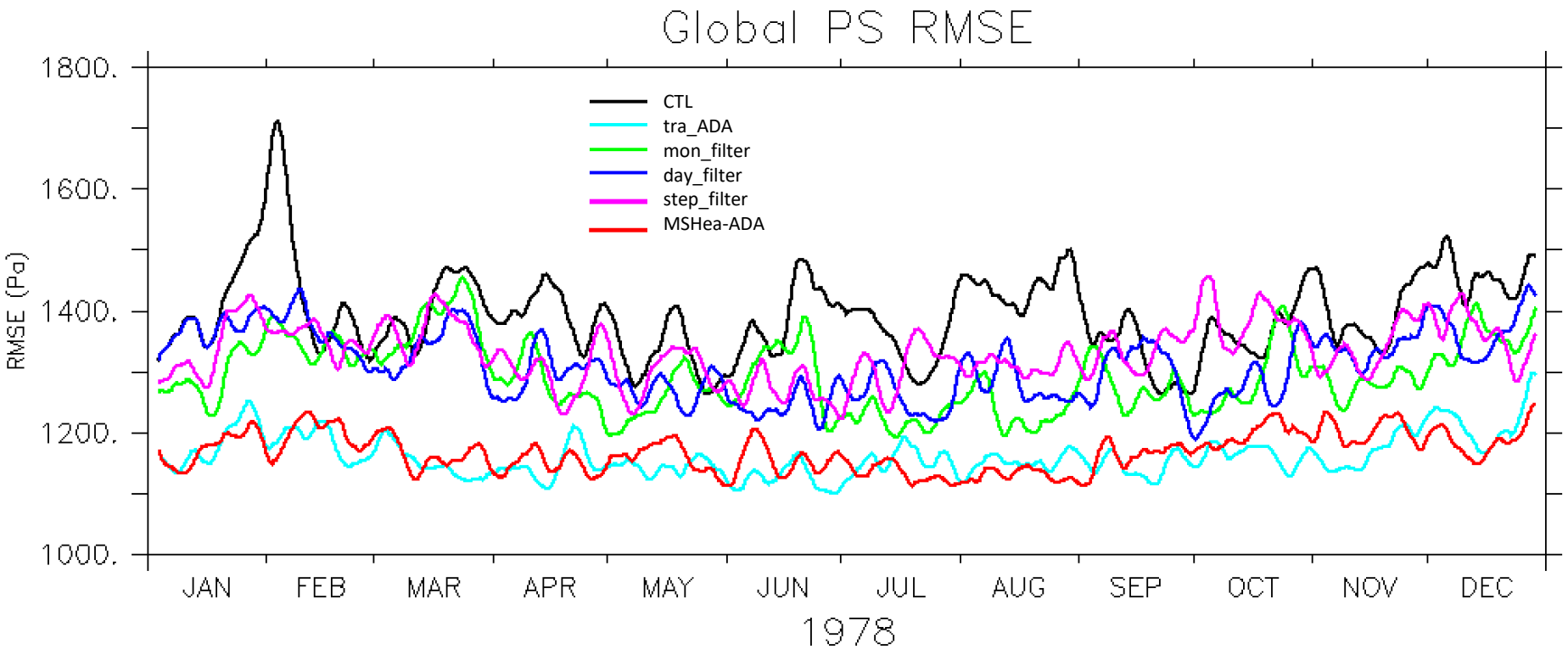
- **ODA**
  - yearly mean (stn_filter)
  - monthly mean (lfq_filter)
  - daily-mean (hfq_filter)
- **ADA**
  - monthly mean (mon_filter)
  - daily mean (day_filter)
  - 20 time steps (step_filter)
- **Historical data with timescale longer than the daily are pre-constructed by a 20-year free model run and updated over time.**

Biased twin experiments:

- **“TRUTH”：** CESM1.3 BHISTC5 f19_g16
- **CTL：** CM2.1 free model run
- **ADA (**gridded PS sampled from “TRUTH”)
  - tra_ADA
  - mon_filter
  - day_filter
  - step_filterr
  - MSHea-ADA
- **ODA (**ARGO T/S, SST sampled from “TRUTH”)
  - tra_ODA
  - stn_filter
  - lfq_filter
  - hfq_filter
  - MSHea-ODA
- **CDA**
  - MSHea-CDA

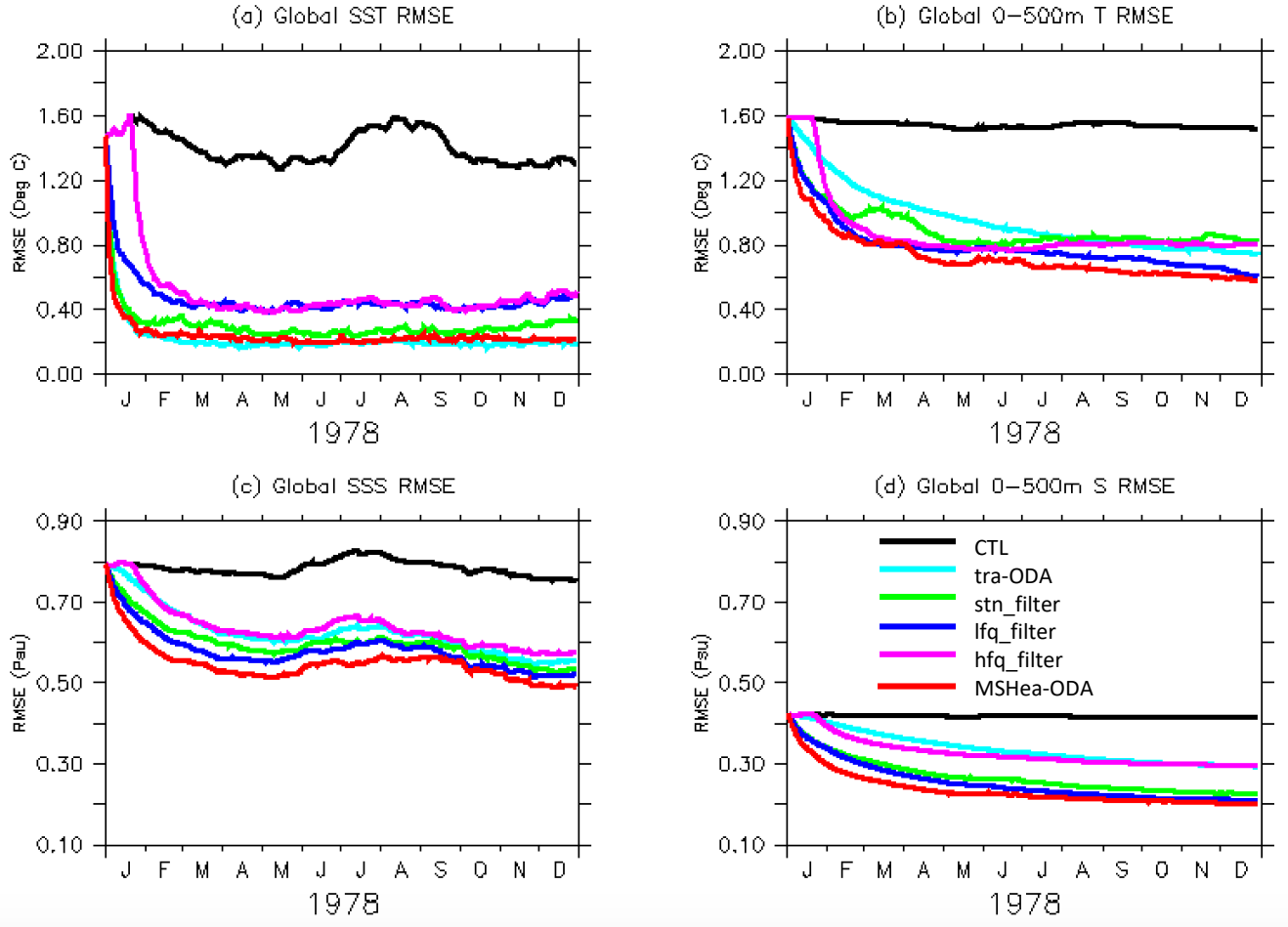
3. Results of MSHea-EnKF in twin experiments: ADA

- MSHea-ADA has almost the same improvement as tra-ADA
- Each individual filter improves against CTL



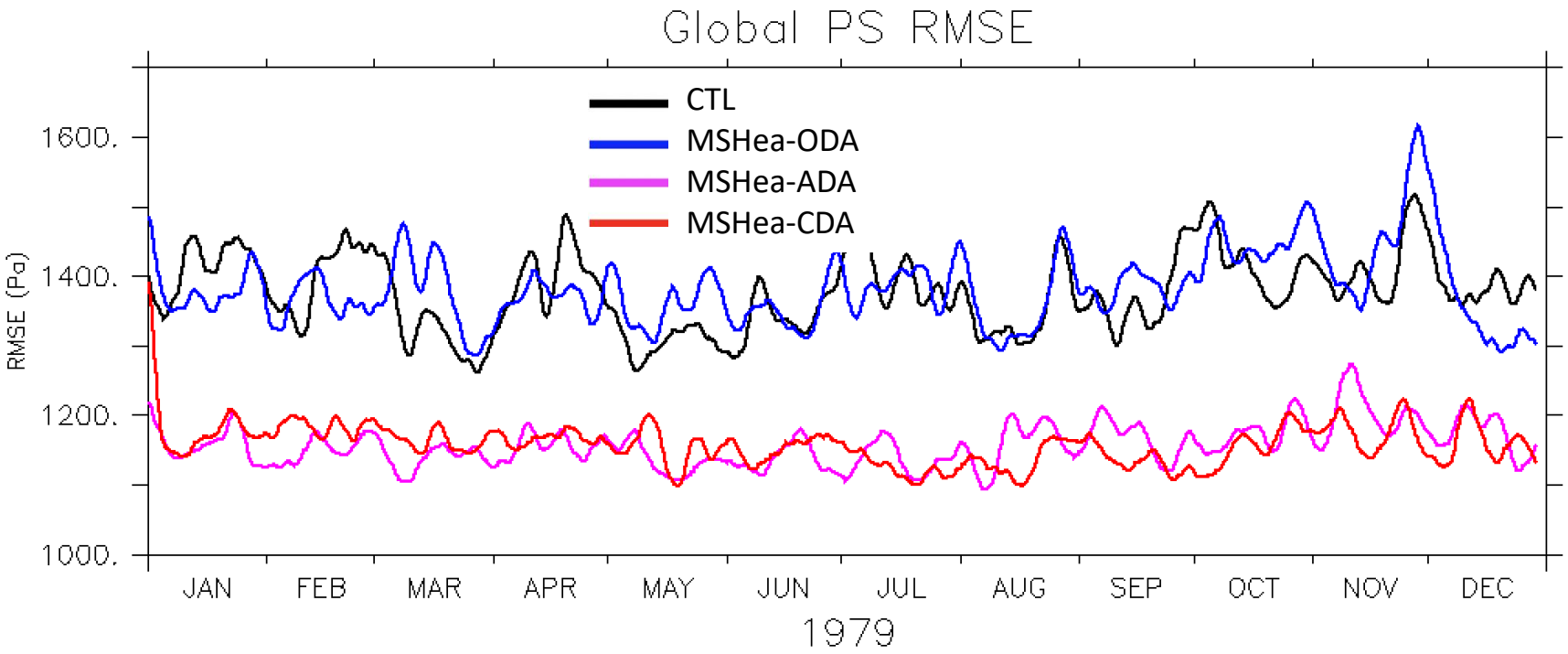
3. Results of MSHea-EnKF in twin experiments: ODA

- MSHea-ODA has better improvements than tra-ODA.
- Even each individual filter is better than tra-ODA.



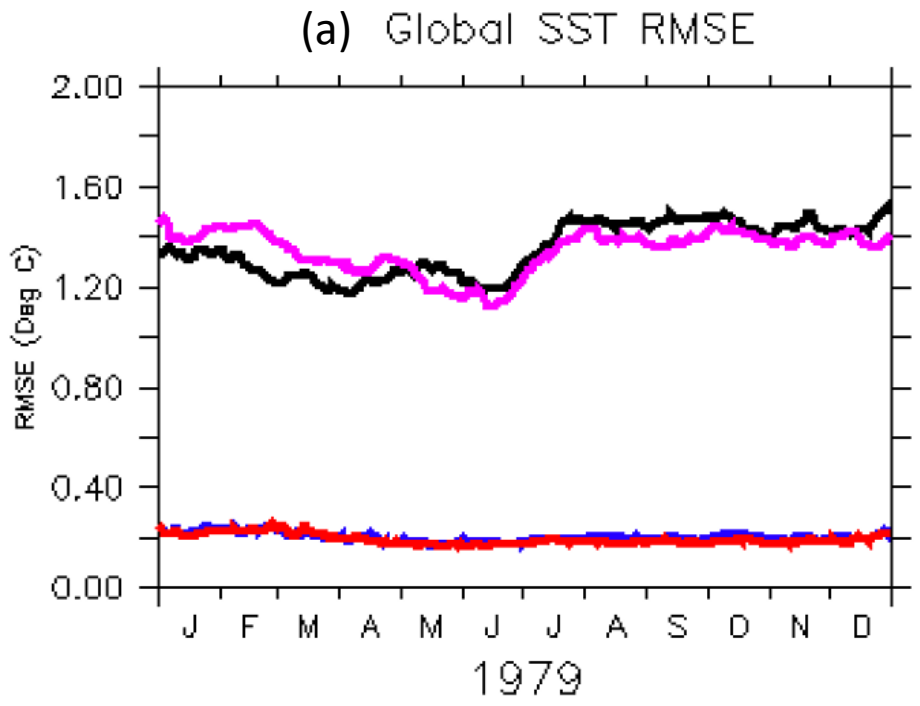
3. Results of MSHea-EnKF in twin experiments: CDA

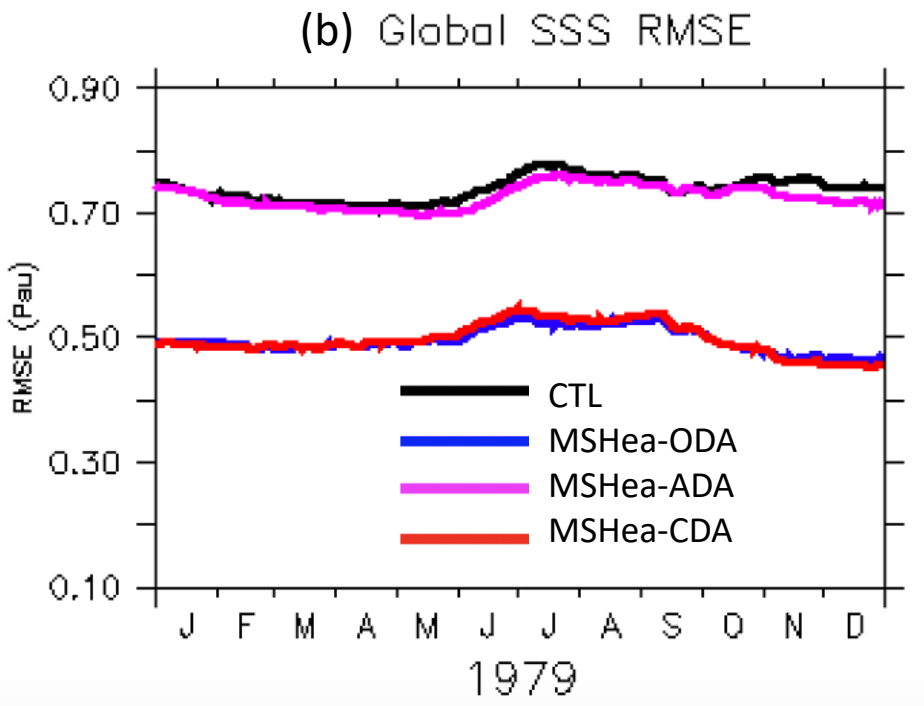
- The PS improvements in MSHea-ODA is also marginal.



3. Results of MSHea-EnKF in twin experiments: CDA

- The T/S improvements in MSHea-ADA is marginal.





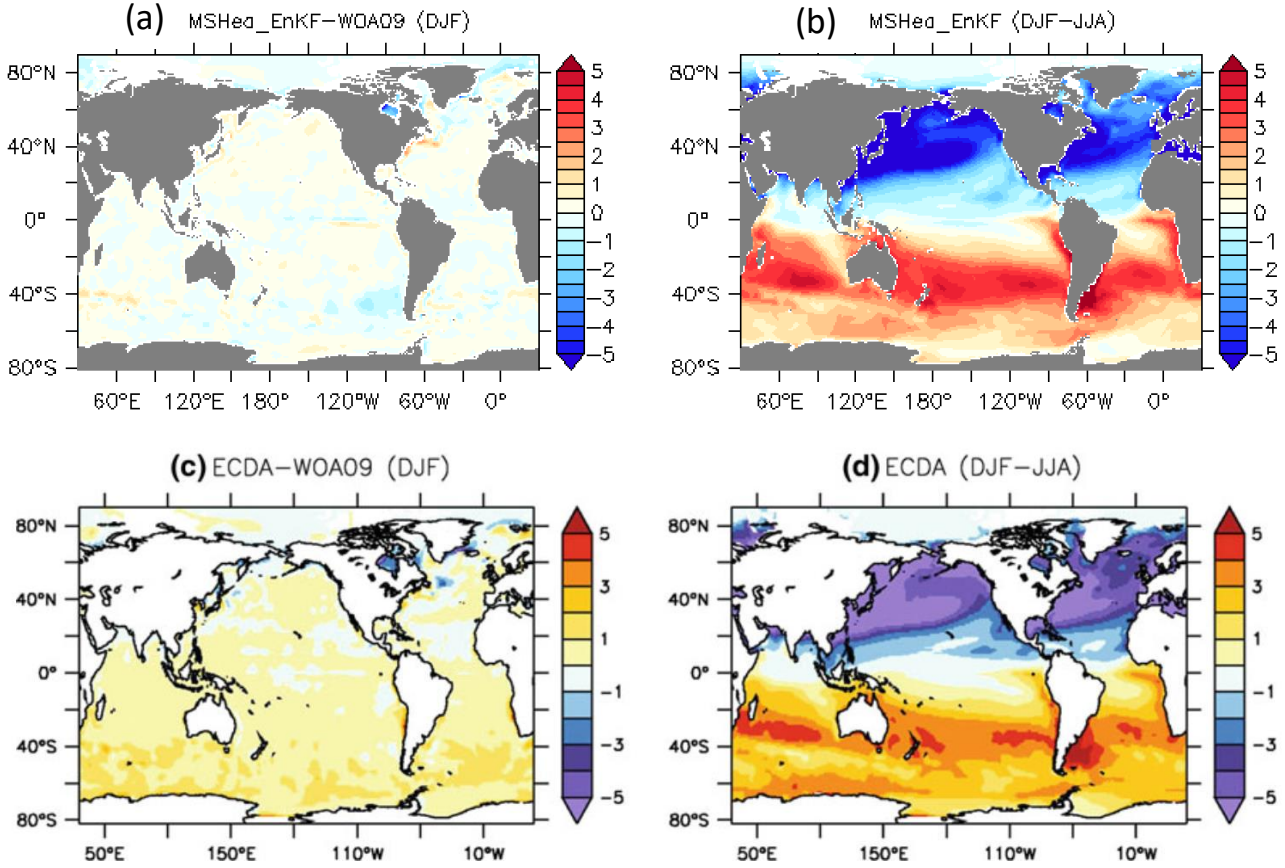
4. Results of a long CDA real-obs experiment: SST

Assimilating data:

- Atmosphere： 6hourly ERA-Interim PS；
- Ocean： TS profiles, OISST with daily frequency.

Data: 1982-2008. (ongoing)

SST difference with WOA09



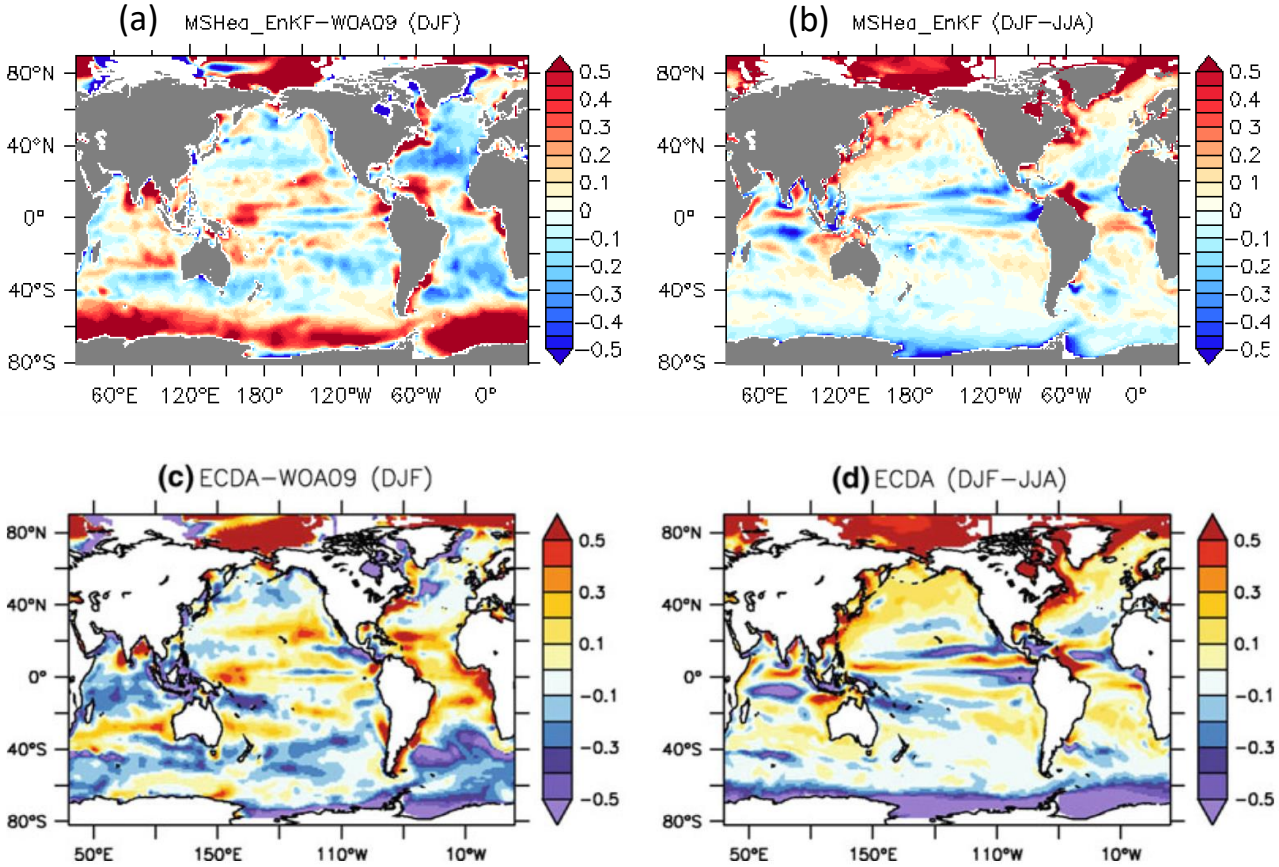
- While the ECDA shows a warm bias in Southern Ocean, the MSHea-EnKF shows cold bias in most areas in Southern Ocean.

Chang et al. 2013

4. Results of a long CDA real-obs experiment: SSS

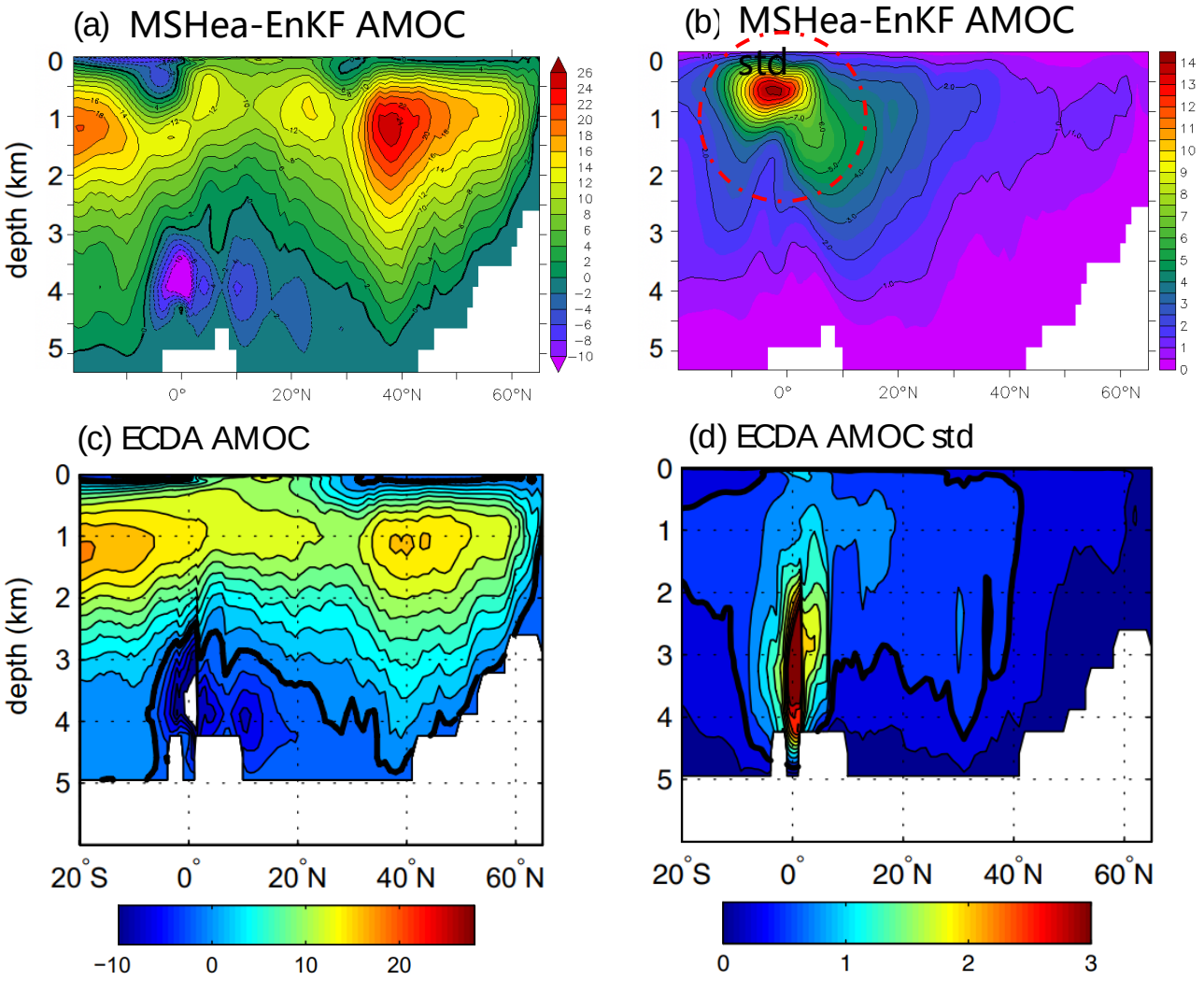
- MSHea-EnKF shows similar distribution as ECDA except for large salty bias in Southern Ocean

Climatology of SSS difference with WOA09



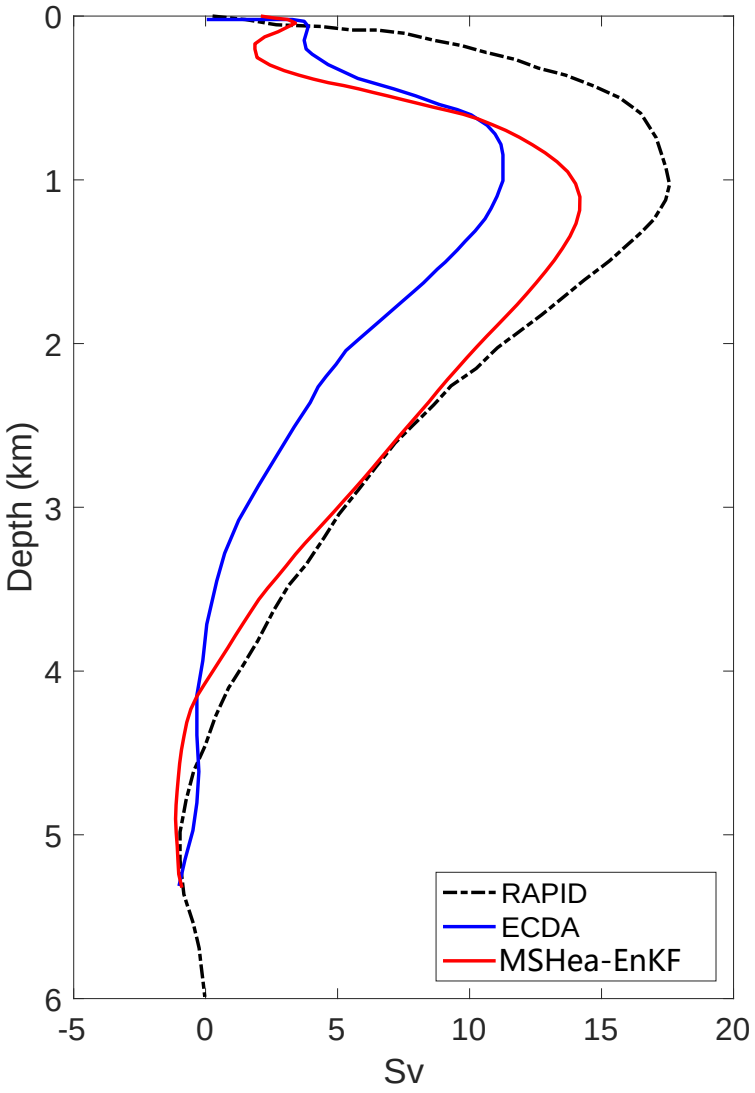
(c) and (d) are from Chang et al. 2013.

4. Results of a long CDA real-obs experiment: AMOC



- MSHea-EnKF has similar AMOC mean structure as ECDA, but different standard deviation distribution which seems more reasonable.

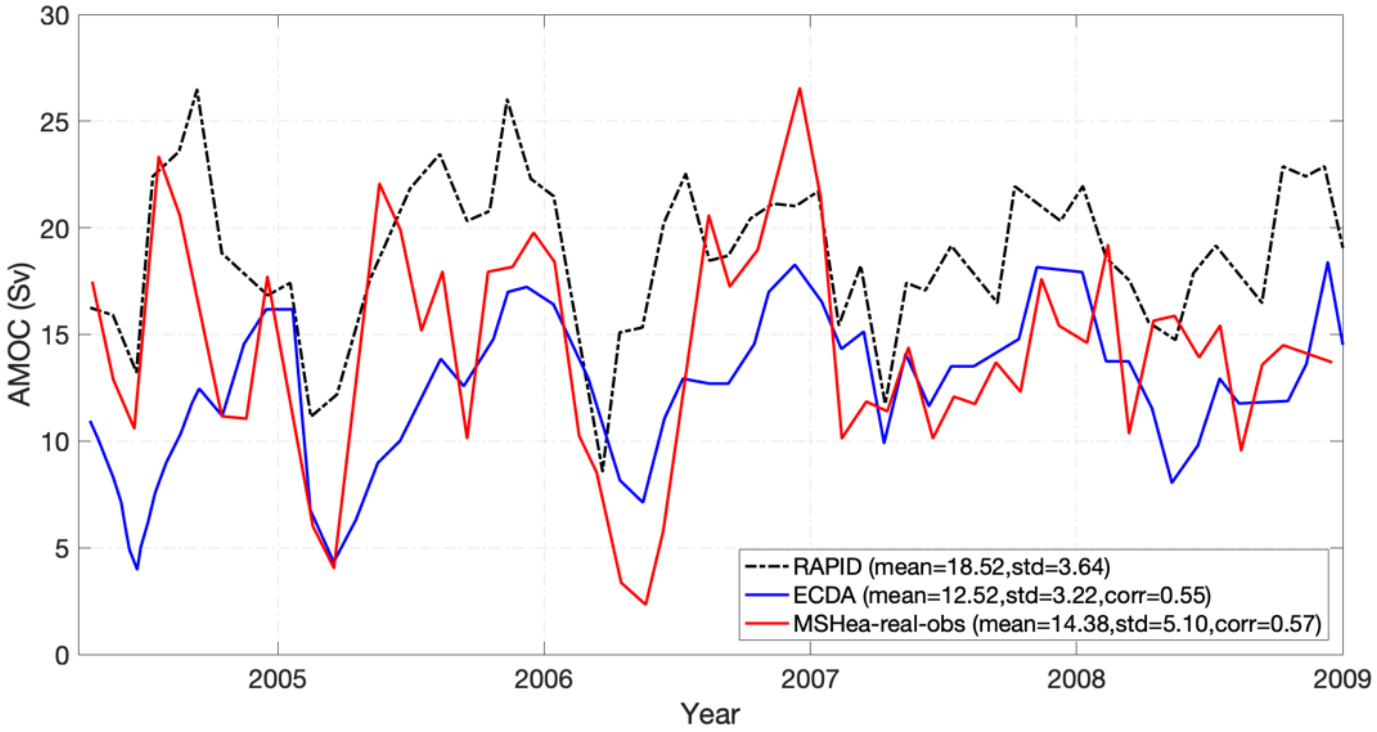
4. Results of a long CDA real-obs experiment: AMOC



- MSHea-EnKF is closer to Rapid observation below 2000m for AMOC at 26.5N.

4. Results of a long CDA real-obs experiment: AMOC

- The mean value of AMOC timeseries at 26.5N in MSHea-EnKF is closer to Rapid than that in ECDA.



5. Summary and discussions

Summary

1. A multi-timescale high-efficiency approximate filter (MSHea-EnKF) has been implemented in a fully coupled GCM (CM2.1), dramatically reducing the computational resource demanding.
2. Biased twin experiment results show the same or better improvements relative to tra-EnKF.
3. Preliminary real-obs CDA experiment results show better representation of AMOC in the deep ocean.

Discussions

1. The MSHea-EnKF is applicable to any HR model since it needs only single model computing cores.
2. It still face challenges like：
   - Constructing statistics of different time scales.
   - Huge memory commands for 3-filter statistics and their online update over time.
   - Although it takes only one-model computing cores, 3 filters need do assimilation for 3 times, may taking too much time for HR models.

References

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Thank you !

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