# A “Dressed” Ensemble Kalman Filter for Data Assimilation using Hybrid Coordinate Ocean Model in Pacific

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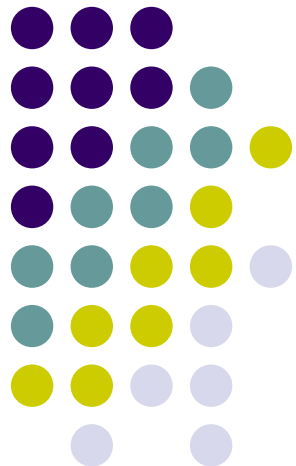


# Outline

- Background
- Dressed Ensemble Kalman Filter
- Experiments: model, data, schemes
- Results
- Summary

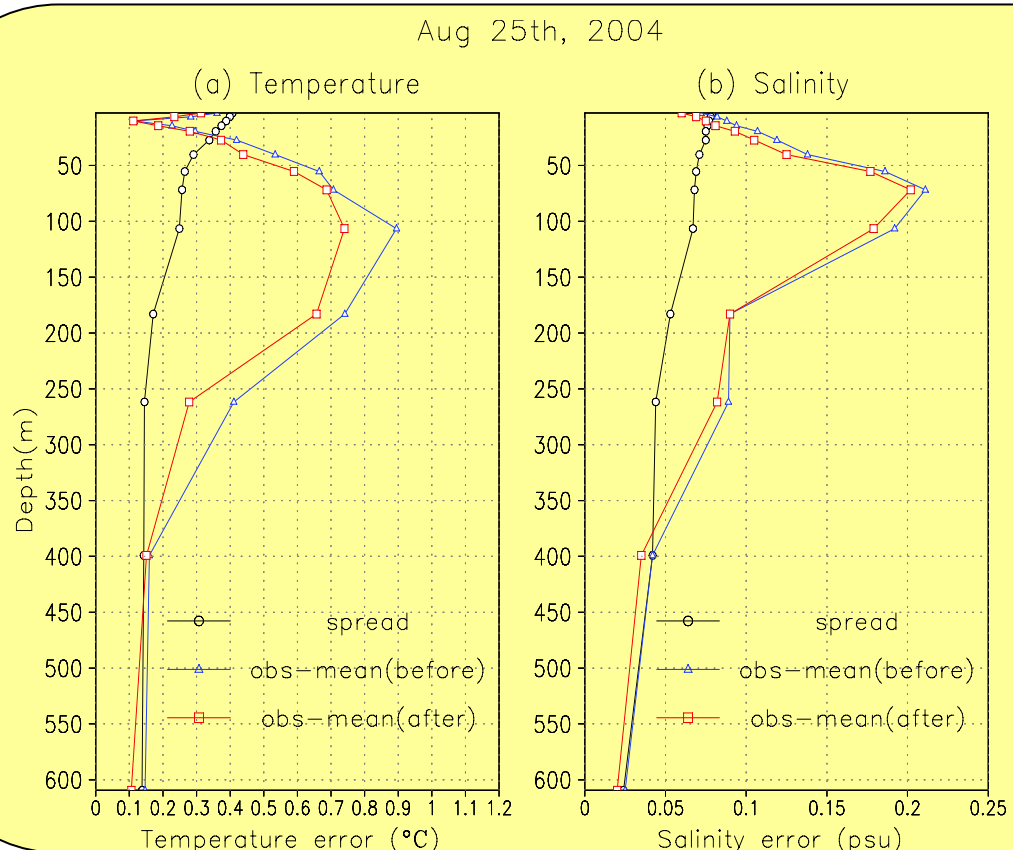
# Background

In EnKF, forecast error background covariance is defined by a set of dynamical ensemble

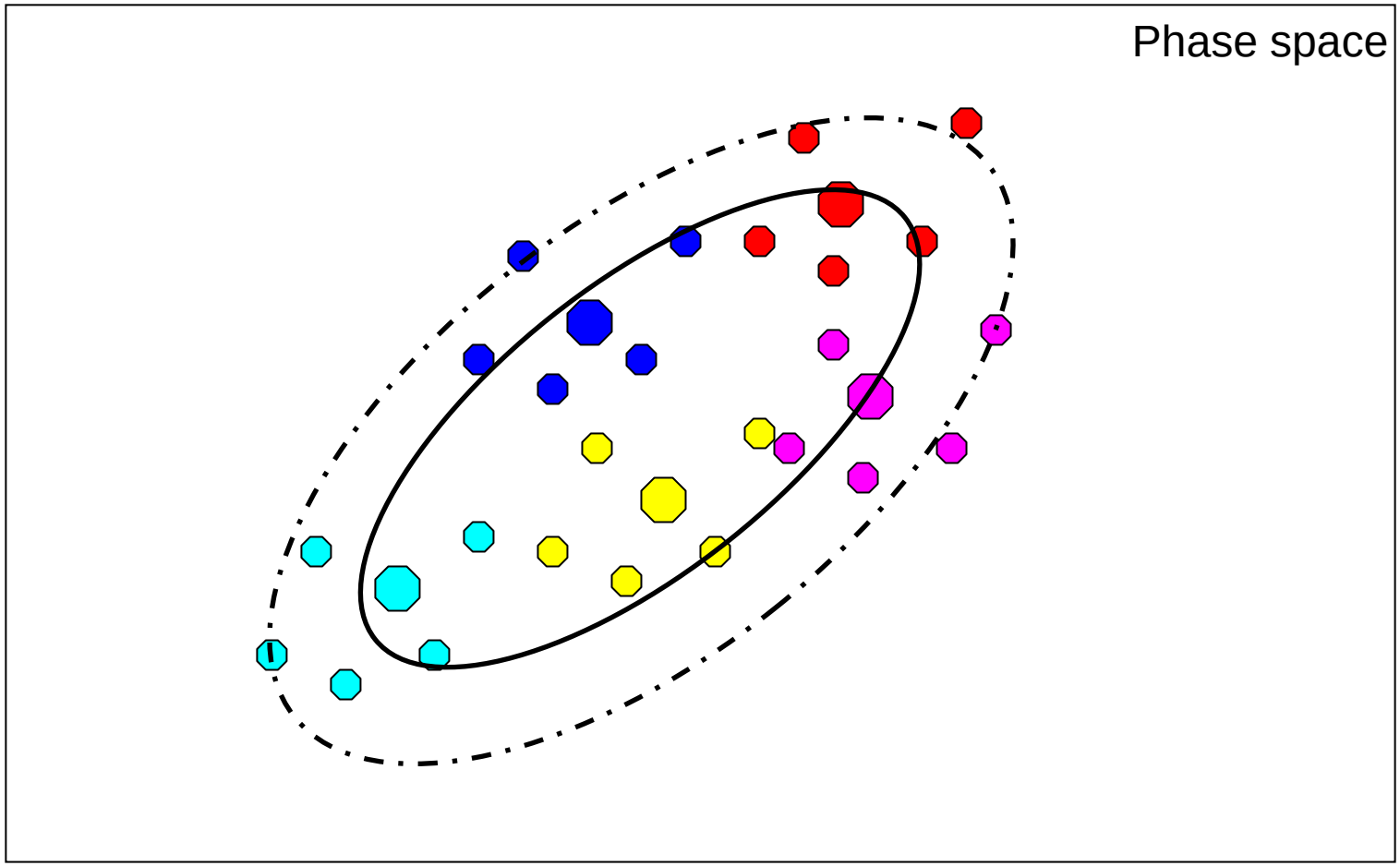
+ flow dependent;
+ nonlinearity of error evolution;
+ …

# Problem

- large computation cost even for “small” size ensemble (e.g., 100);
- error covariance generated confined into a subspace of small dimension.




- **Dynamical ensembles are generated by initial and atmospheric forcing perturbations**
- **Spread is too small at thermocline due unresolved error perturbations in ensembles**

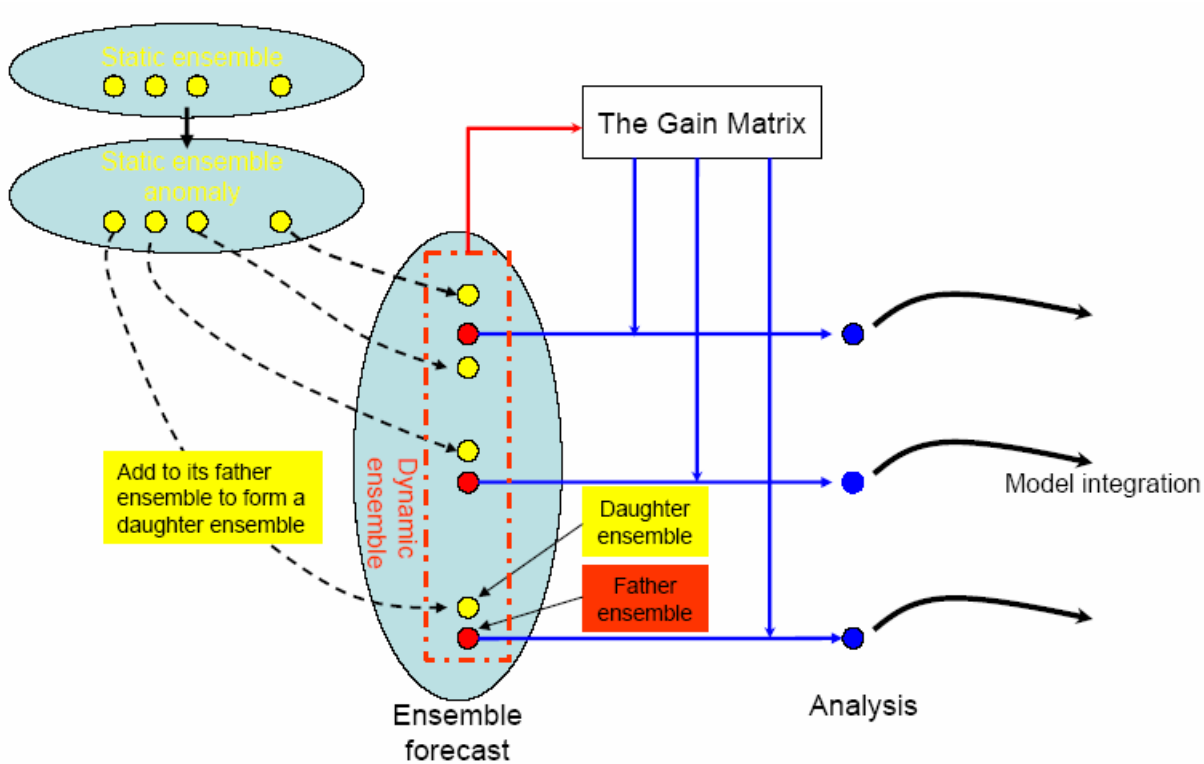



Idea of dressed dynamical ensemble with stationary ensemble by Roulston and Smith (2003).

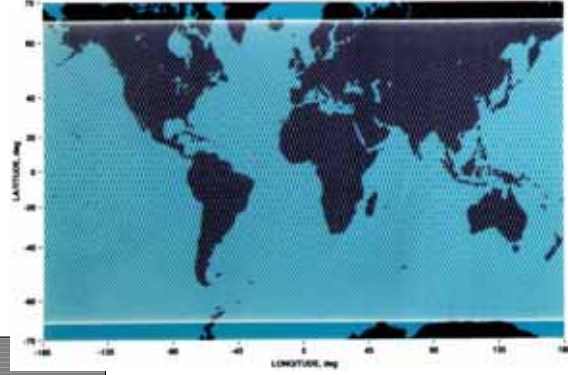
# Dressed EnKF

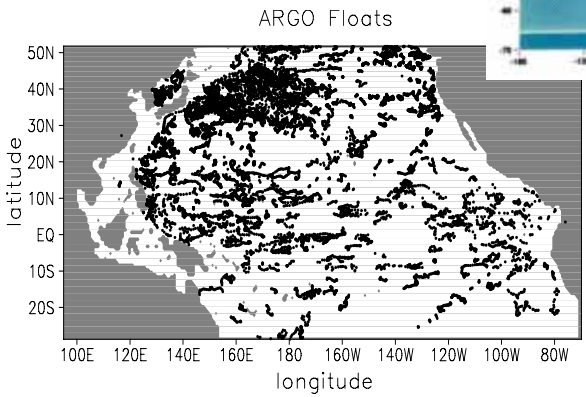
Small size (e.g., 10) dynamical ensembles dressed by large size (e.g.,100) stationary ensembles.

- to reduce computation cost dramatically (1 vs 10);
- to compensate for unresolved error perturbations in dynamical ensembles.



# Experiments

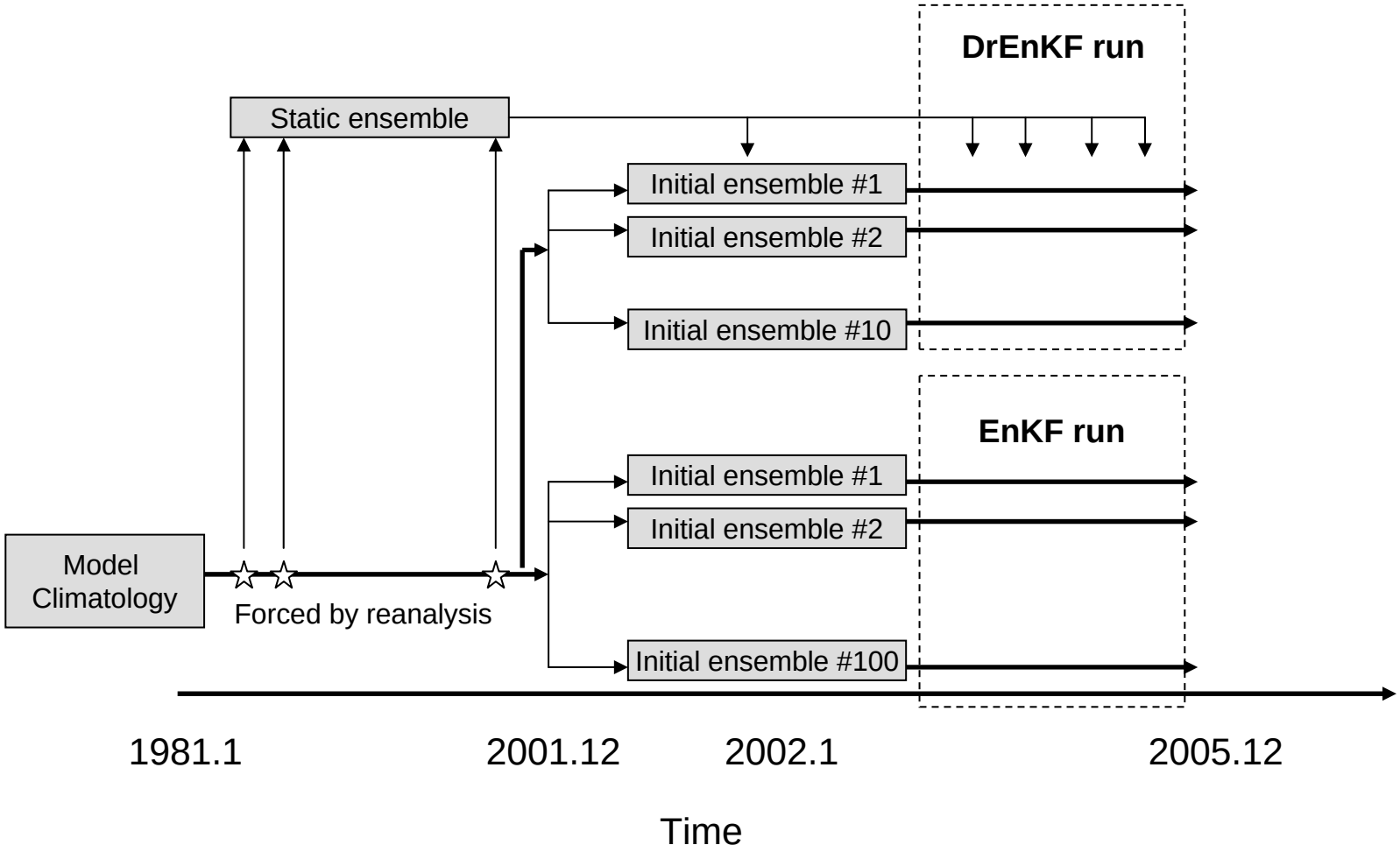




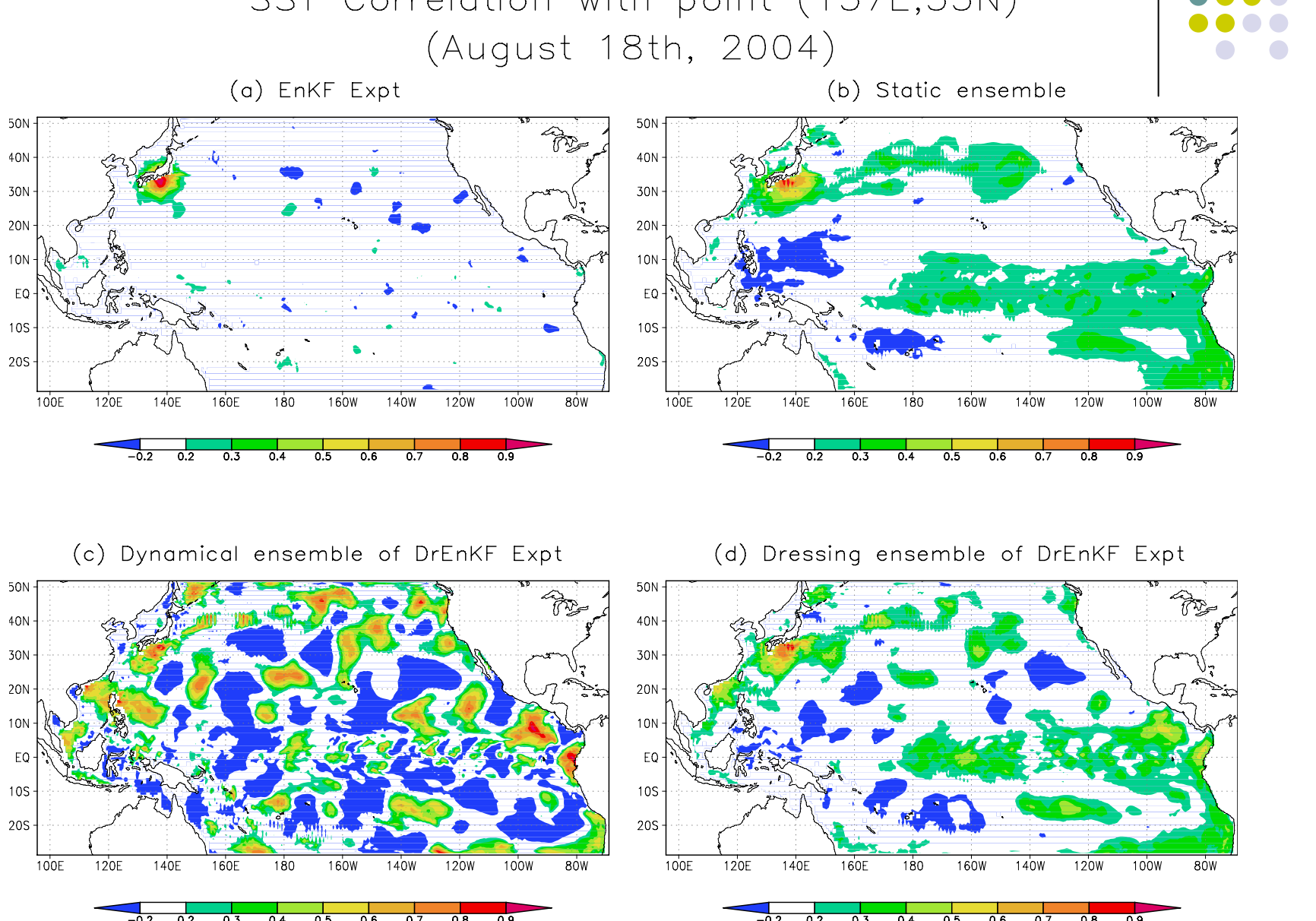

| | |
|---|---|
| **Model** | HYCOM |
| **Domain** | Pacific |
| **H-Resolution** | 0.5ºX 0.5º |
| **Forcing** | ECMWF high frequency (6 hourly) |
| | COADS climatology |
| **Assimilation** | EnKF (dynamical ensemble size 100) |
| **Schemes** | DrEnKF (10 dynamical ensemble, 100 stationary ensemble) |
| **Obs assimilated** | Altimetry (CLS product, 1/3º, every 7 days) |
| **Obs validation** | ARGO *T* and *S* profiles, OISST |
| **Assimilation period** | 2002.1-2005.12 |

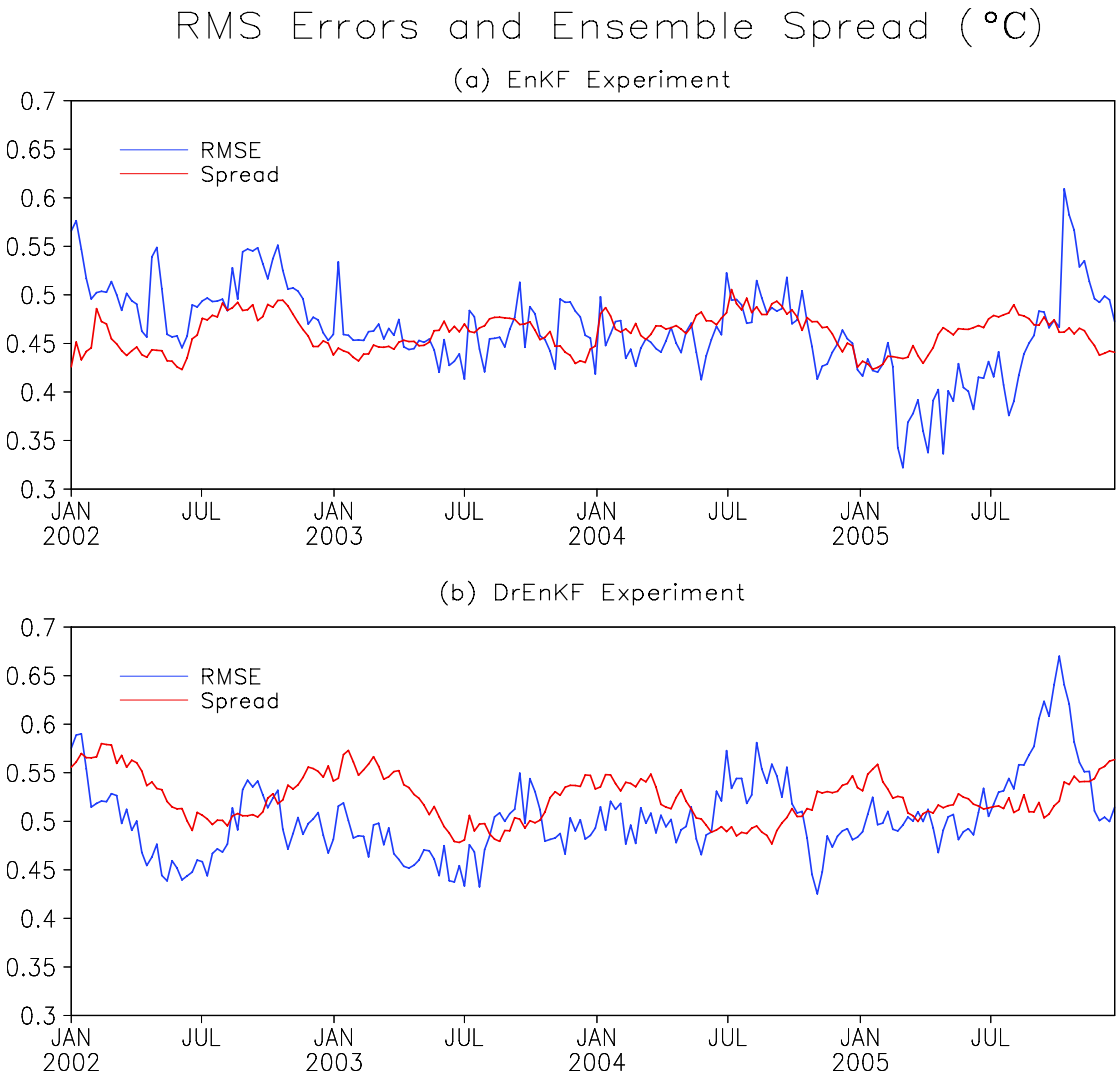
EnKF: perturbations on initial state and atmospheric forcing;

DrEnKF: dynamical ensembles same as EnKF



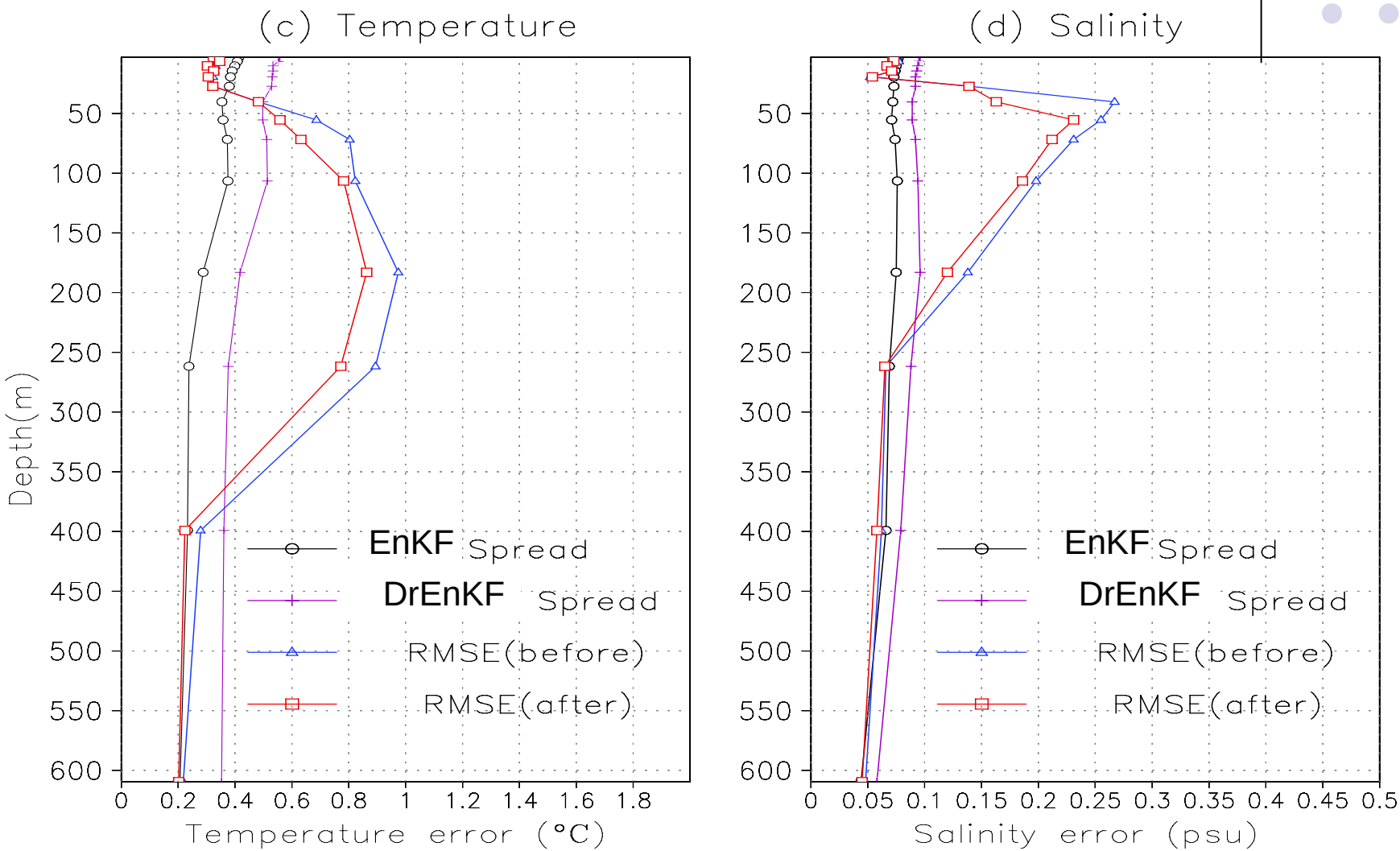
# Results

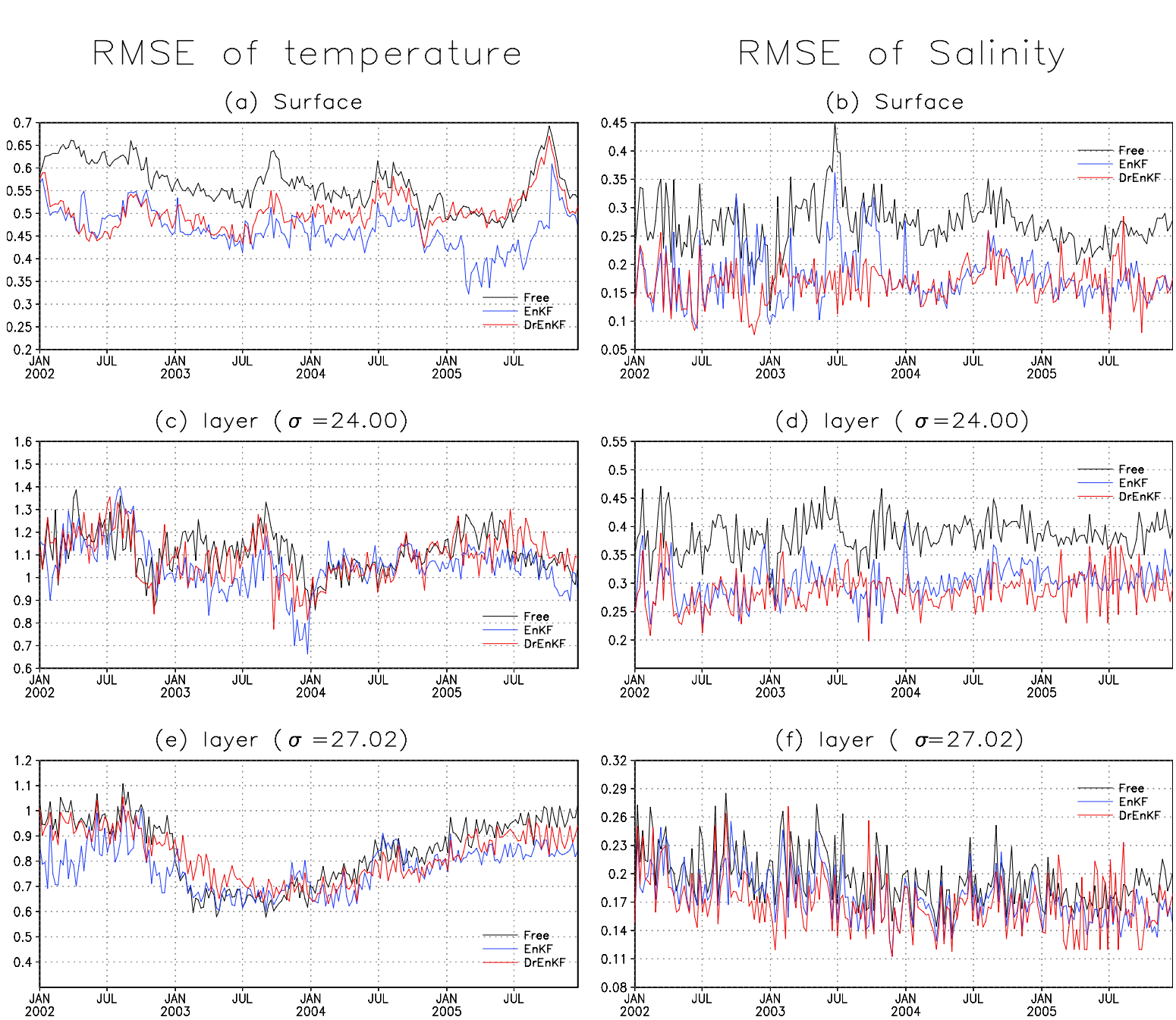

SST Correlation with point (137E,33N)
(August 18th, 2004)
(a) EnKF Expt
(b) Static ensemble
(c) Dynamical ensemble of DrEnKF Expt
(d) Dressing ensemble of DrEnKF Expt
50N
40N
30N
20N
10N
EQ
10S
20S
100E
120E
140E
160E
180
160W
140W
120W
100W
80W
−0.2
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9




RMS errors against OISST.

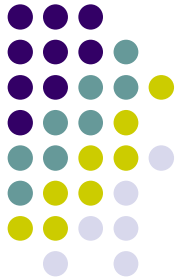
# RMSE of ensemble mean vs spread of DrEnKF




RMSE of temperature
RMSE of Salinity
(a) Surface
(b) Surface
(c) layer ( σ =24.00)
(d) layer ( σ=24.00)
(e) layer ( σ =27.02)
(f) layer ( σ=27.02)
Free
EnKF
DrEnKF
JAN 2002
JUL
JAN 2003
JUL
JAN 2004
JUL
JAN 2005
JUL

| Layer | Free-running | EnKF | | DrEnKF | |
|---|---|---|---|---|---|
| | T (℃) | T (℃) | Improvement percent (%) | T (℃) | Improvement percent (%) |
| 1 | 0.564 | 0.484 | 14.2 | 0.506 | 10.3 |
| 2 | 0.982 | 0.930 | 5.3 | 0.935 | 4.8 |
| 3 | 0.987 | 0.936 | 5.2 | 0.936 | 5.2 |
| 4 | 1.001 | 0.946 | 5.5 | 0.948 | 5.3 |
| 5 | 1.011 | 0.967 | 4.4 | 0.969 | 4.2 |
| 6 | 1.046 | 1.009 | 3.5 | 1.008 | 3.6 |
| 7 | 1.124 | 1.088 | 3.2 | 1.100 | 2.2 |
| 8 | 1.172 | 1.141 | 2.7 | 1.161 | 0.9 |
| 9 | 1.173 | 1.170 | 0.3 | 1.172 | 0.1 |
| 10 | 1.215 | 1.205 | 0.8 | 1.209 | 0.5 |
| 11 | 1.194 | 1.181 | 1.1 | 1.182 | 1.0 |
| 12 | 1.419 | 1.412 | 0.5 | 1.416 | 0.2 |
| 13 | 1.341 | 1.271 | 5.2 | 1.287 | 4.0 |
| 14 | 0.725 | 0.674 | 7.0 | 0.694 | 4.3 |

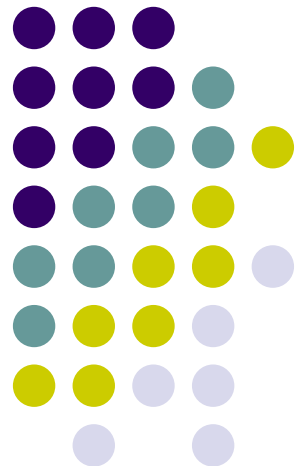
| Layer | Free-running | EnKF | | DrEnKF | |
|---|---|---|---|---|---|
| | S (psu) | S (psu) | Improvement percent (%) | S (psu) | Improvement percent (%) |
| 1 | 0.270 | 0.179 | 33.7 | 0.176 | 34.8 |
| 2 | 0.439 | 0.391 | 10.9 | 0.393 | 10.5 |
| 3 | 0.437 | 0.391 | 10.5 | 0.393 | 10.1 |
| 4 | 0.439 | 0.391 | 10.9 | 0.394 | 10.3 |
| 5 | 0.439 | 0.393 | 10.5 | 0.394 | 10.3 |
| 6 | 0.441 | 0.408 | 7.5 | 0.408 | 7.5 |
| 7 | 0.456 | 0.433 | 5.0 | 0.437 | 4.2 |
| 8 | 0.460 | 0.443 | 3.7 | 0.440 | 4.3 |
| 9 | 0.433 | 0.414 | 4.4 | 0.417 | 3.7 |
| 10 | 0.360 | 0.321 | 10.8 | 0.318 | 11.7 |
| 11 | 0.412 | 0.369 | 10.4 | 0.376 | 8.7 |
| 12 | 0.348 | 0.287 | 17.5 | 0.296 | 14.9 |
| 13 | 0.248 | 0.218 | 12.1 | 0.208 | 16.1 |
| 14 | 0.190 | 0.176 | 7.4 | 0.179 | 5.8 |



# Summary

- The idea of a “Dressed” ensemble is the combination of a dynamical ensemble with a small size (here 10 members) and a static ensemble.
- DrEnKF avoids the underestimation of errors as expected with a dynamical ensemble of small size.
- HYCOM data assimilation experiments show that the DrEnKF can dramatically reduce computation while maintain the performance.

# Thank you for your attention!



# Parameters in assimilation experiments

| Parameters | Description | Value |
|---|---|---|
| N | Number of static ensemble members in DrEnKF Experiment | 100 |
| | Number of dynamical members in EnKF Experiment | 100 |
| M | Number of dynamical members in DrEnKF Experiment | 10 |
| m | Maximum number of local observations | 49 |
| $r_0$ | Observations radius of influence | 700 km |
| $\sigma_e$ | Observations error standard deviation | 0.05 m |
| $r_e$ | Observations error decorrelation length | 200 km |
| $r_h$ | Initial error Decorrelation length | 1000 km |
| $\sigma_d$ | Layer thickness logarithmic standard deviation | 10 % |
| $\sigma_T$ | Temperature logarithmic standard deviation in Mixed Layer | 5 % |
| $r_{vd}$ | Vertical correlation coefficient of layer thickness | 2.0 |
| $r_{vT}$ | Vertical correlation coefficient of temperature | 3.0 |
| $r_\beta$ | Decorrelation length of random forcing | 10 grid cells |
| $\sigma_T$ | Atmospheric temperature standard deviation | 3 K |
| $\sigma_\Gamma$ | Atmospheric wind stress standard deviation | 0.03 N/m2 |
| $\sigma_w$ | Wind speed standard deviation | 1.6 m/s |
| $\sigma_r$ | Radiative flux standard deviation | 0.2 W/m2 |
| T | Time correlation scale | 3 days |