Insights on ocean forecasts and ensemble statistics from Large Ensemble Experiments with the Red Sea data assimilation system

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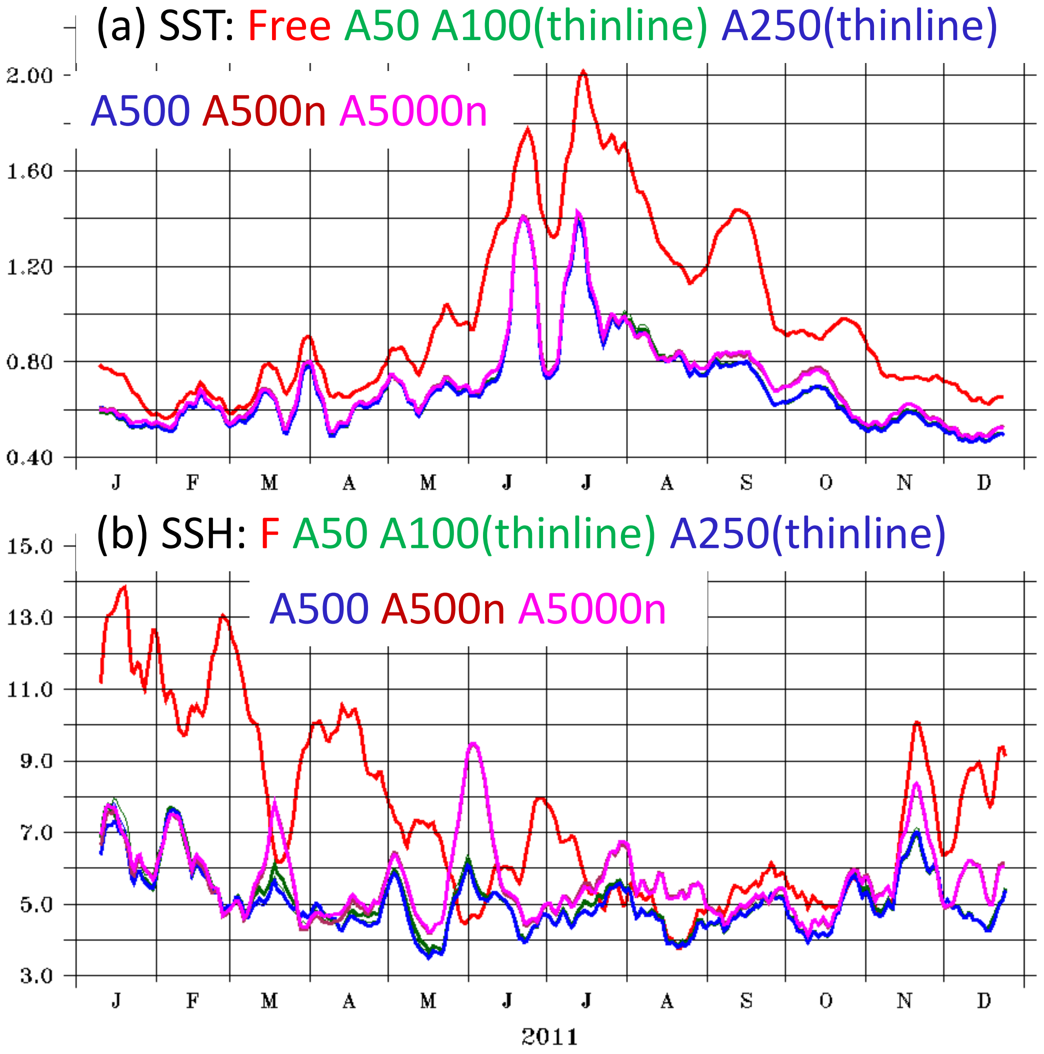
Introduction and Motivation

- Earlier studies based on ocean/atmosphere data assimilation system (Kondo et al., 2016; Toye et al., 2017) have shown that increasing the ensemble size improves sampling errors and devoids the localization at large ensemble size.
- These studies were carried out under simple settings, either using simplified numerical models and simulated observations, or not fully accounting for uncertainties in the inputs (e.g., forcing, physics)
- The present study intends to understand the impact of ensemble size on the quality of ocean state estimation using a realistic ocean ensemble data assimilation system.

Configuration of Red Sea Data Assimilation System

- Model description:
  - OGCM: 4km-MITgcm, with 50 vertical levels, setup for 30E-50E & 10N-30N
  - Deterministic OBCS: Daily averaged 25km-resolution GLORYS ocean reanalysis
  - Stochastic Atmosphere: Sampled from 50-member ECMWF ensemble available at 50km resolution
  - Stochastic Physics: Randomly (across ensemble) varying horizontal advection and vertical mixing schemes, and diffusion and viscosity parameters
  - Stochastic IC: Hindcasts around 1st Jan with the mean recentered onto 1st Jan,2011
- Assimilation: DART with EAKF
- Assimilated Observations:
  - Satellite Level-4 Reynolds SST
  - Satellite Level-3 altimeter SLA (merged)
  - In situ T & S profiles from EN4 dataset (fully QC'd)
- Assimilation cycle: 3 days

RMSDs between model forecasts and satellite based observations

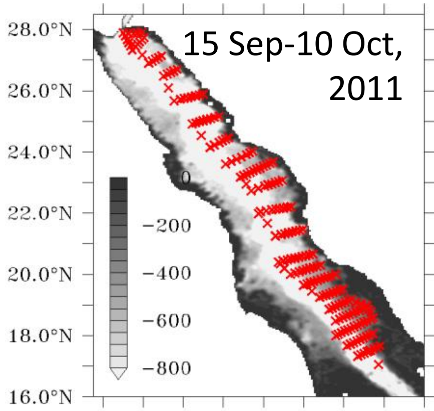


Marginal improvements in SST and SSH with the increase of ensemble size when localization is used.

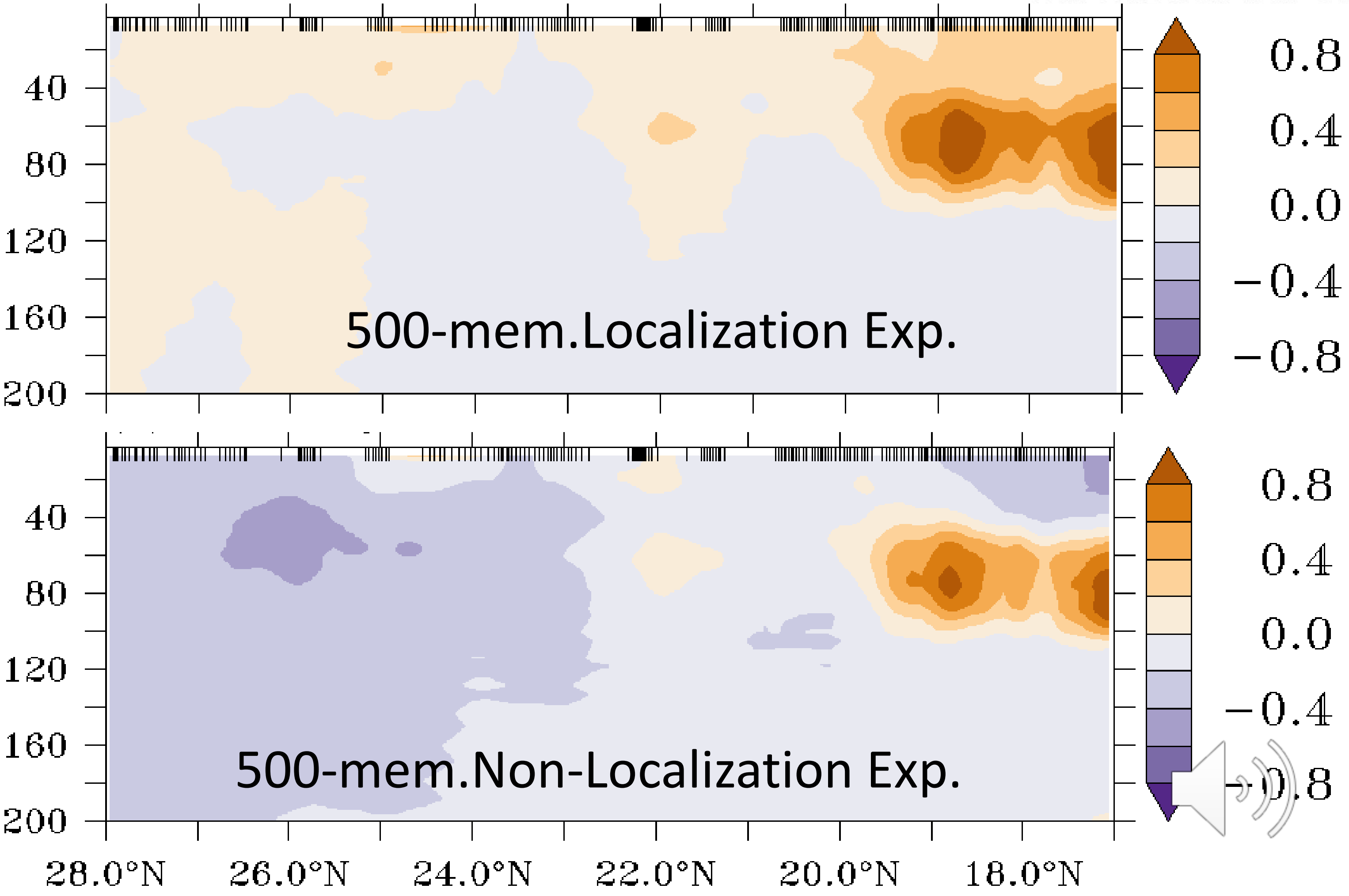
Assimilation improvements saturated well below 500 members.

Pronounced deteriorations when localization is not used, especially for SSH

Latitude-wise salinity profile differences between model forecasts and *insitu* observations

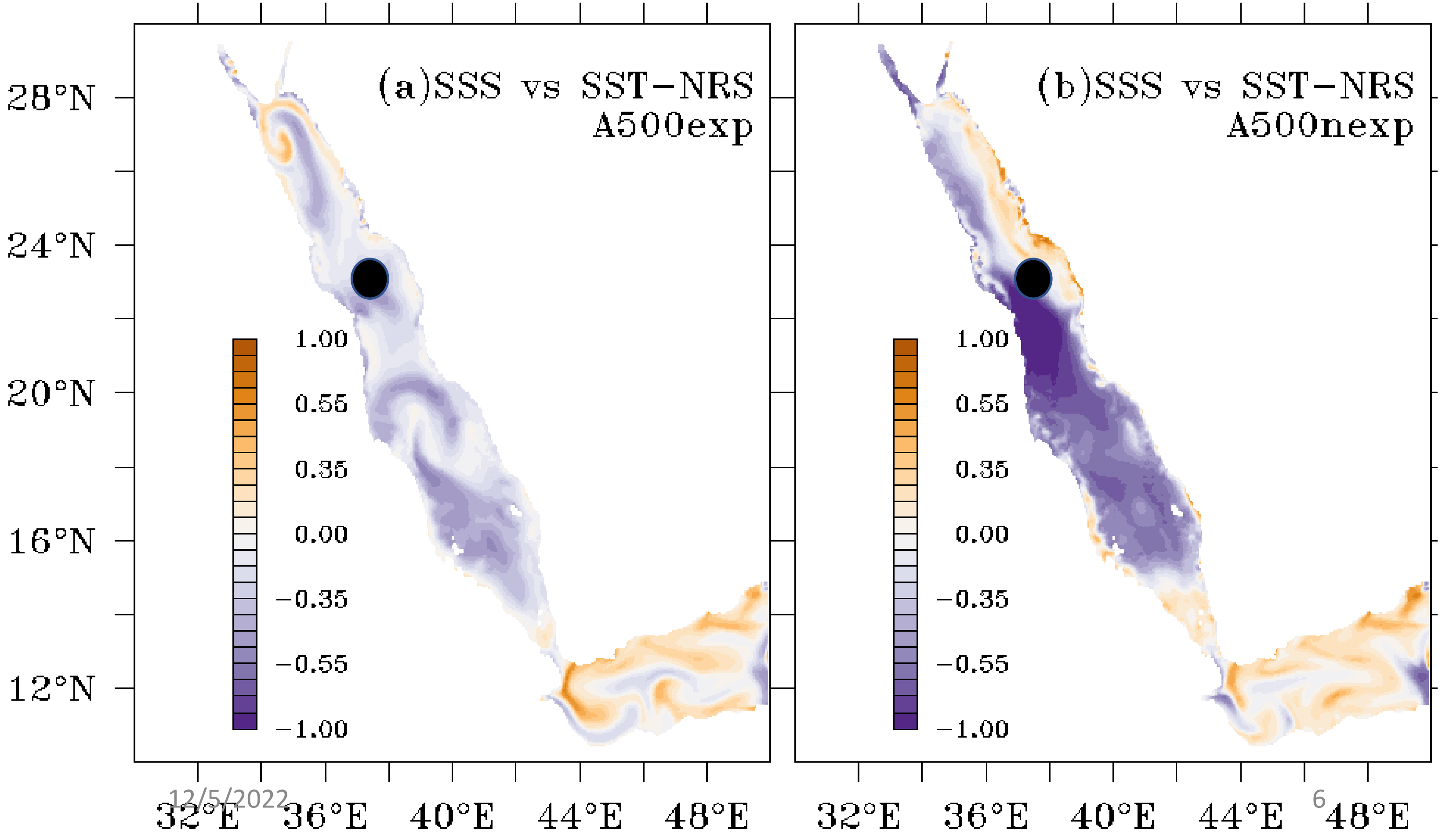


Removing localization causes pronounced degradations in the subsurface too



Cross-Correlations between SSS Vs SST-at-NRS on 1st Oct, 2011

Localization Exp. Non-Localization Exp.

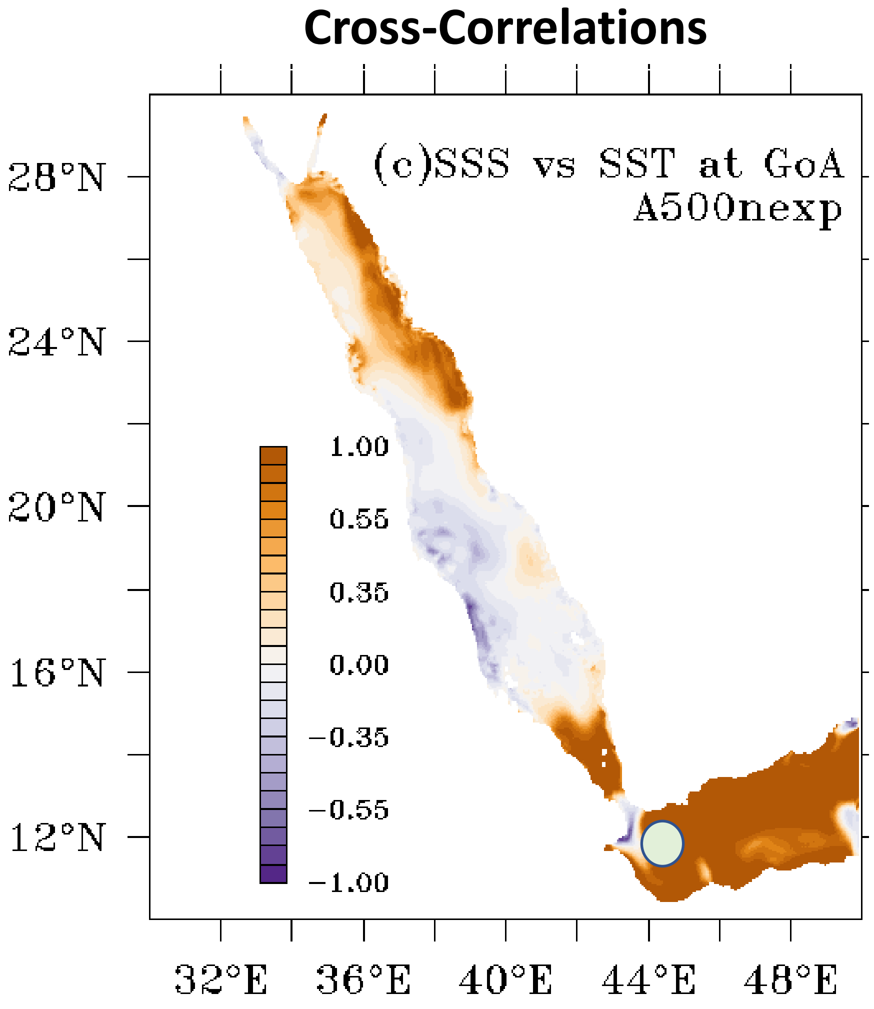


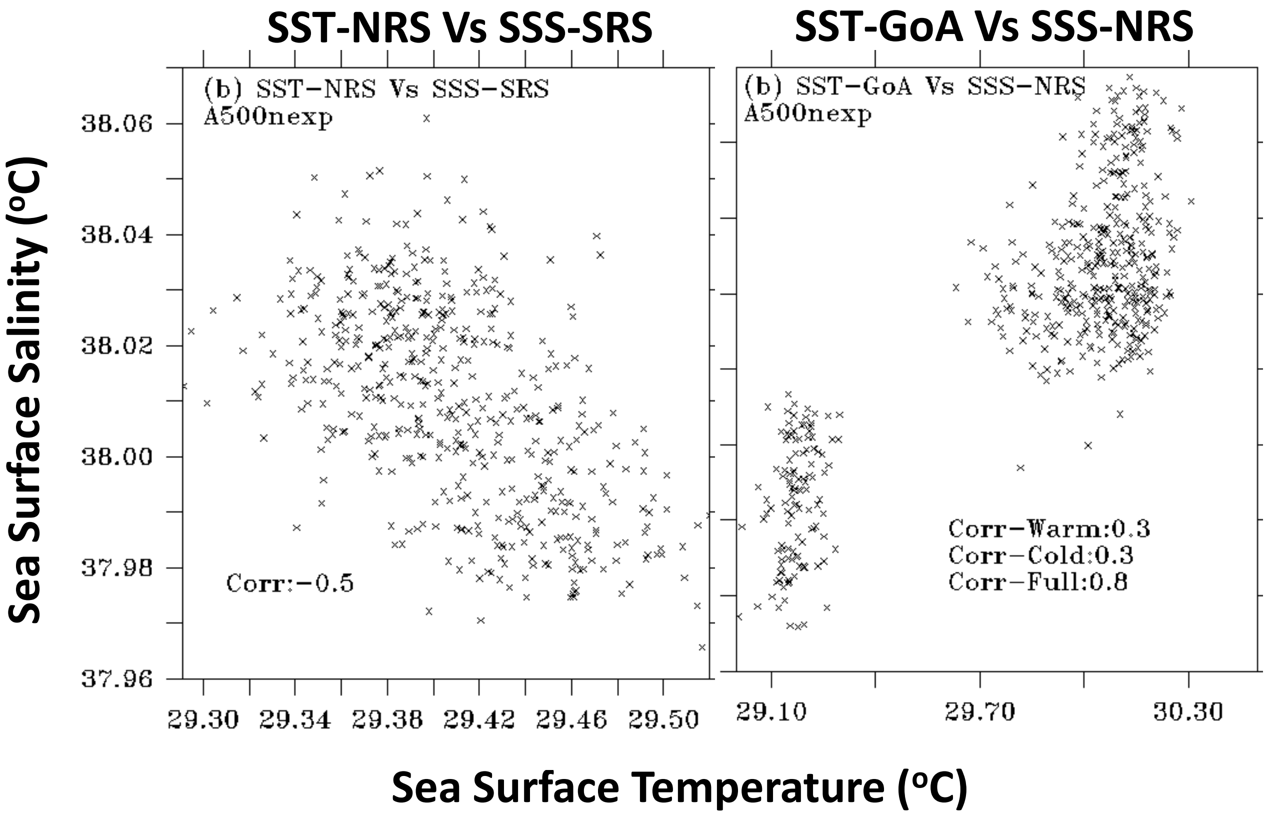
Ensemble correlations in Localization and non-Localization turnedout to be independent from each other, despite driven from the same atmosphere and stochastic physics.

None is free from long-range correlations

NRS: Northern Red Sea

SSS and SST relations in 500-member-NoLoc.exp. on 1st Oct, 2011





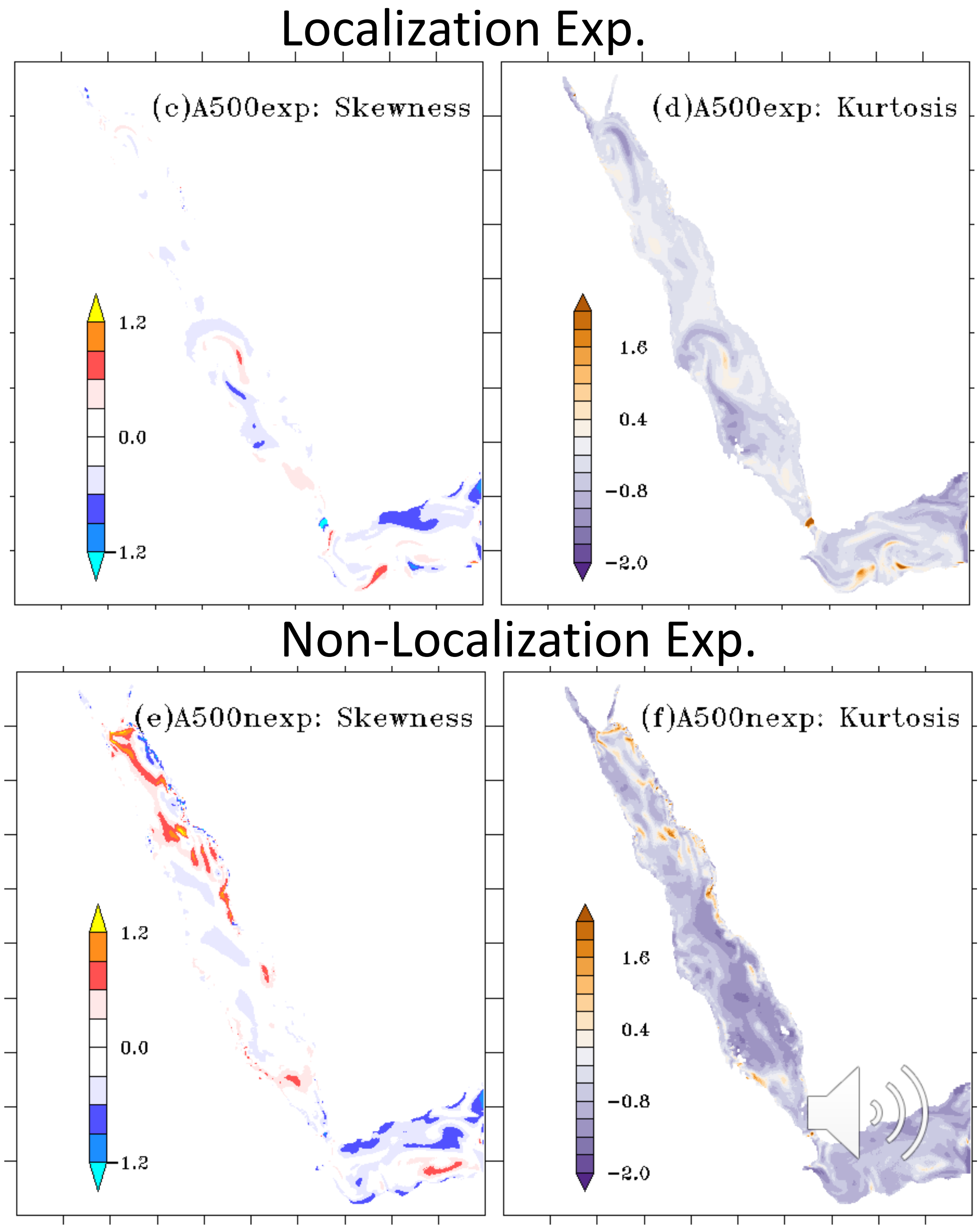
Bimodalities exists in both SST and SSS ensembles.
Some of the correlations are affected by bimodality.

NRS: Northern Red Sea; SRS: Southern Red Sea; GoA: Gulf-of-Aden

Skewness and Kurtosis in 500 member-SSS-Forecast ensemble on 1stOct, 2011

The PDF is said to be non-Gaussian when $|skewness| > 0.3$ or $|kurtosis| > 0.6$

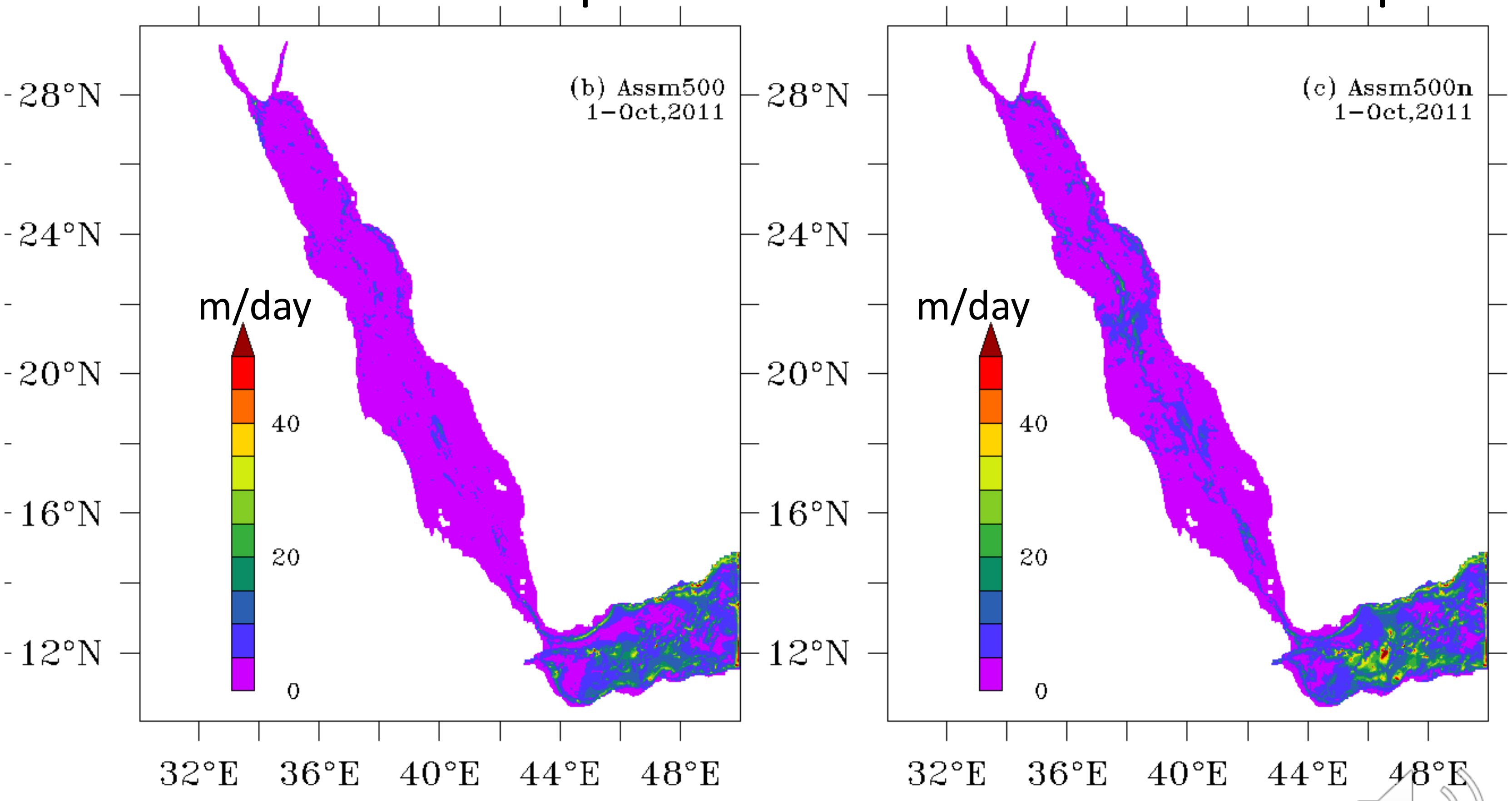
Removing localization causes significant increase of non-Gaussianity in the model forecast ensemble.



Max. Vertical velocity (Wmax) in 500 member experiments: 1st Oct, 2011

Wmax increases in the non-localization experiment, indicating pronounced dynamical imbalances in the system.

Localization Exp. Non-Localization Exp.



Summary and Conclusions

- Large ensemble experiments are conducted using high resolution real ocean data assimilation system implemented with an OGCM with perturbed internal physics and forcings.
- Increasing the ensemble size obtains only marginal improvements, and improvements saturate well below 500 members.
- Removing localization causes significant degradations
- Spurious long-range correlations exists, and some of these correlations are affected by the bimodality.
- Non-Gaussianity become prevelent when localization is removed, associated with increased dynamical imbalances.
- Gaussian mixure schemes are needed in real ocean assimilation systems to take full advantage of the observations information.