Ocean Ensemble Forecasting in the Navy Earth System Prediction Capability
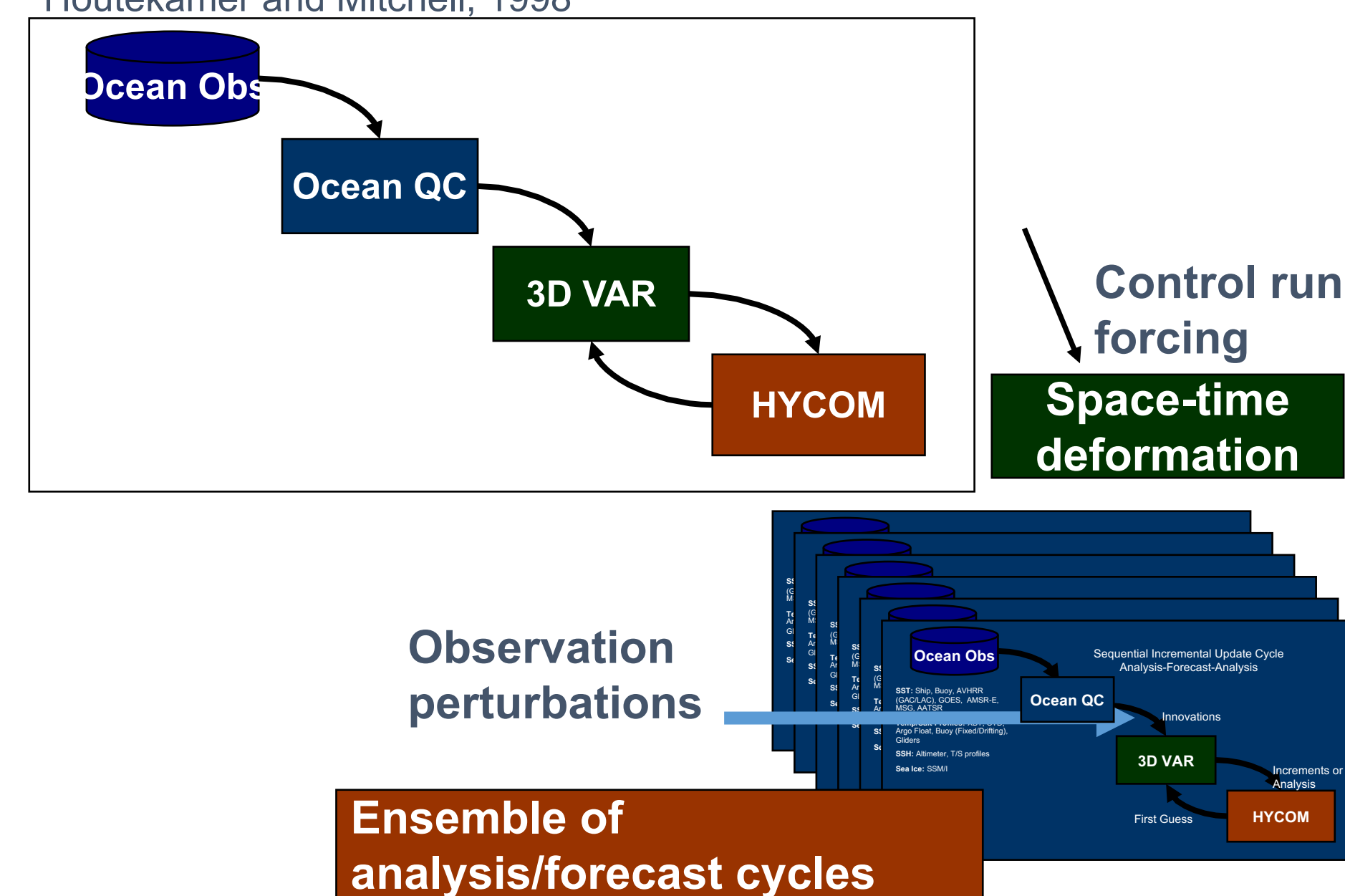
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INTRODUCTION

An extended range ensemble forecast system is being developed in the US Navy Earth System Prediction Capability (ESPC). A global ensemble generation capability to support the coupled ESPC ensemble forecast has being developed, and initial assessments are underway. The air/ocean/ice ensemble is generated with parallel perturbed-observation analyses. The ocean/ice systems use the Navy Coupled Ocean Data Assimilation system (NCODA). The resulting analysis perturbations are used to represent uncertainty in the initial conditions of a global ocean forecast ensemble using the Hybrid Coordinate Ocean Model (HYCOM).

PERTURBED OBSERVATION ANALYSIS

Perturbed Observation Ensemble Update
Houtekamer and Mitchell, 1998

NCODA performs a 3DVar analysis of temperature, salinity, geopotential, and vector velocity using remotely-sensed SST, SSH, and sea ice concentration, plus in situ observations of temperature, salinity, and currents from ships, buoys, XBTs, CTDs, profiling floats, and autonomous gliders. Sea surface height is assimilated through synthetic temperature and salinity profiles.

Synthetic profile   **Real profile**

Perturbations to the surface and profile observations use random samples from a normal distribution scaled by the observation error standard deviation, which combines instrument and representation error. Perturbations to synthetic profiles are generated by supplying perturbed surface inputs to the synthetic profile system.

GLOBAL OCEAN ENSEMBLE EXPERIMENTS

A pair of 20-member ensemble experiments with a global HYCOM configuration at 1/12° resolution and 32 layers is used to examine the contribution of the perturbed-observation analysis to the forecast ensemble spread. The ensemble members are initialized with 20 different 01 Jan states from a 20-year reanalysis. Members are cycled with the NCODA data assimilation system for 90 d then integrated over a 90 d forecast with NCEP CSFR forcing.

ENS SSH VAR: 20-member (80.0) day 002
ENS SSH VAR: 20-member (80.0) day 030
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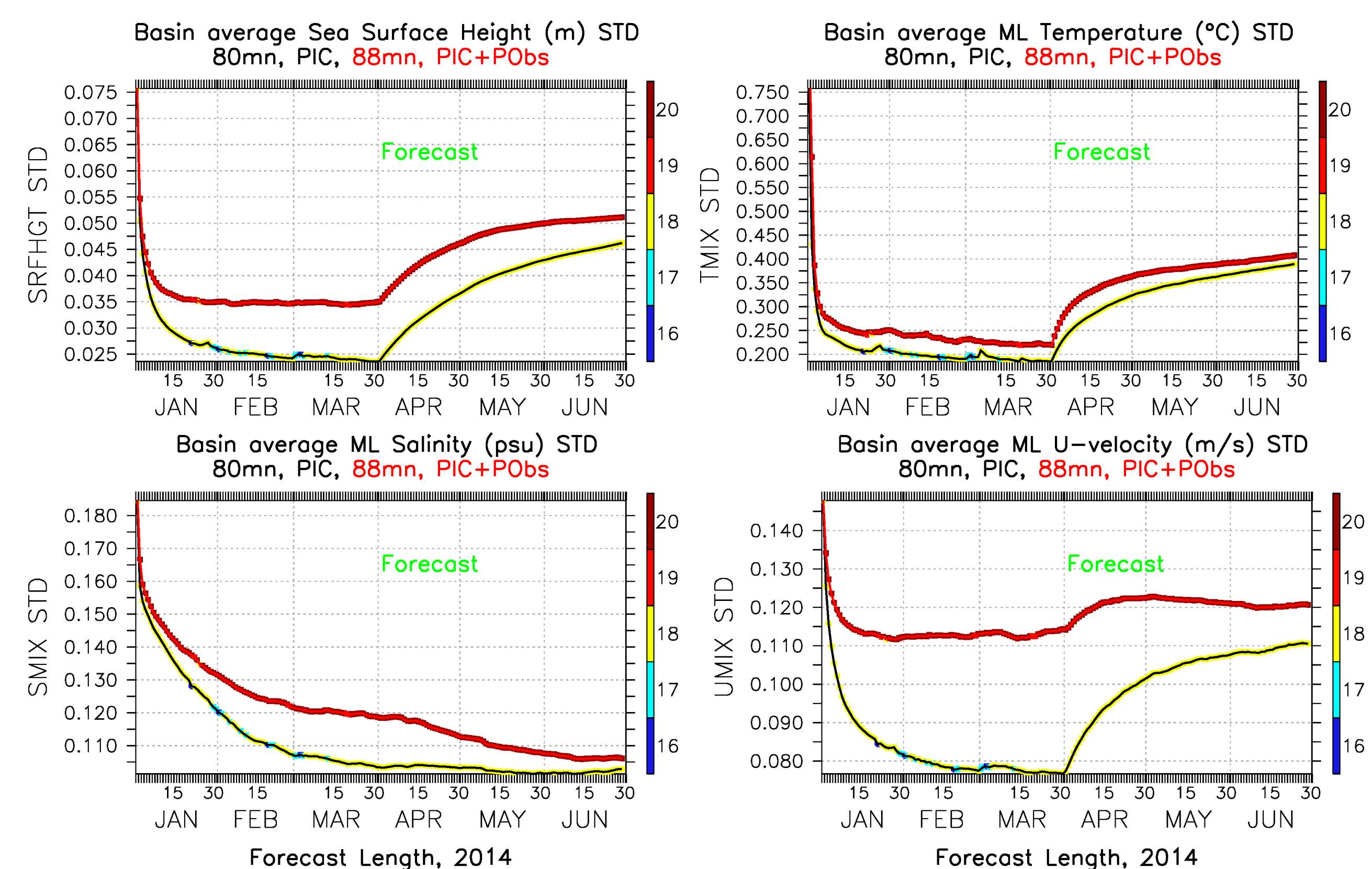ENS SSH VAR: 20-member (80.0) day 180
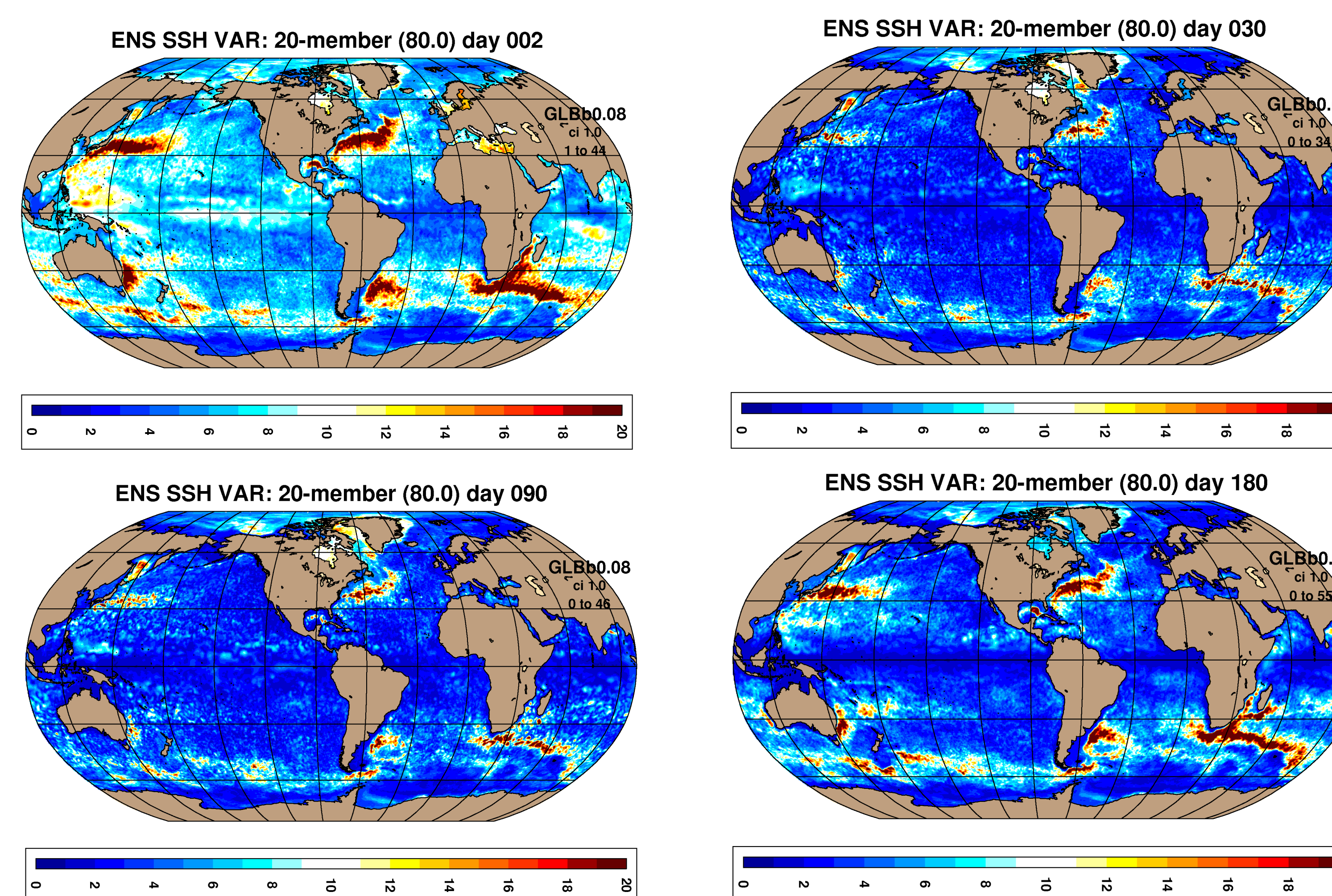
Sea surface height ensemble standard deviation for the initial condition, after 30 d and 90 d of cycling with unperturbed observations, and after 90 d of a free run forecast.

No obs perturbation   **With obs perturbations**
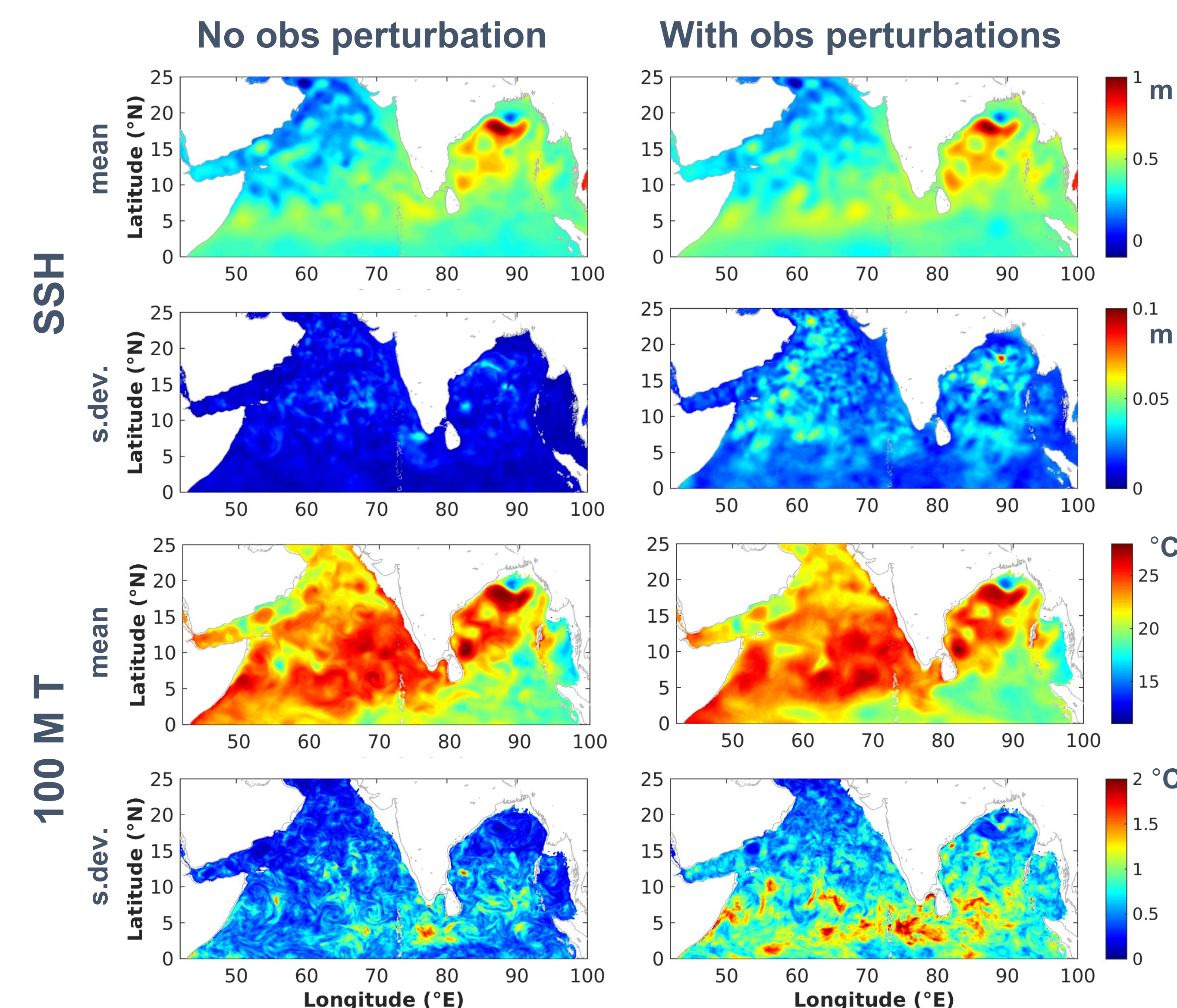
North Indian Ocean sea surface height and 100 m temperature ensemble mean and standard deviation after 90 d of cycling with the NCODA data assimilation system with unperturbed (left) and perturbed observations (right).

ENSEMBLE METRICS

Basin average Sea Surface Height (m) STD
80mn, PIC, 88mn, PIC+PObs

Basin average ML Temperature (°C) STD
80mn, PIC, 88mn, PIC+PObs

Basin average ML Salinity (psu) STD
80mn, PIC, 88mn, PIC+PObs

Basin average ML U-velocity (m/s) STD
80mn, PIC, 88mn, PIC+PObs

Time series of the global ensemble basin average standard deviation from the unperturbed observation (black) and perturbed observation (red) experiments for the 90 d data assimilation period and the 90 d forecast period.

Rank Histogram, Temperature (°C), 80/81
Rank Histogram, Temperature (°C), 88/89
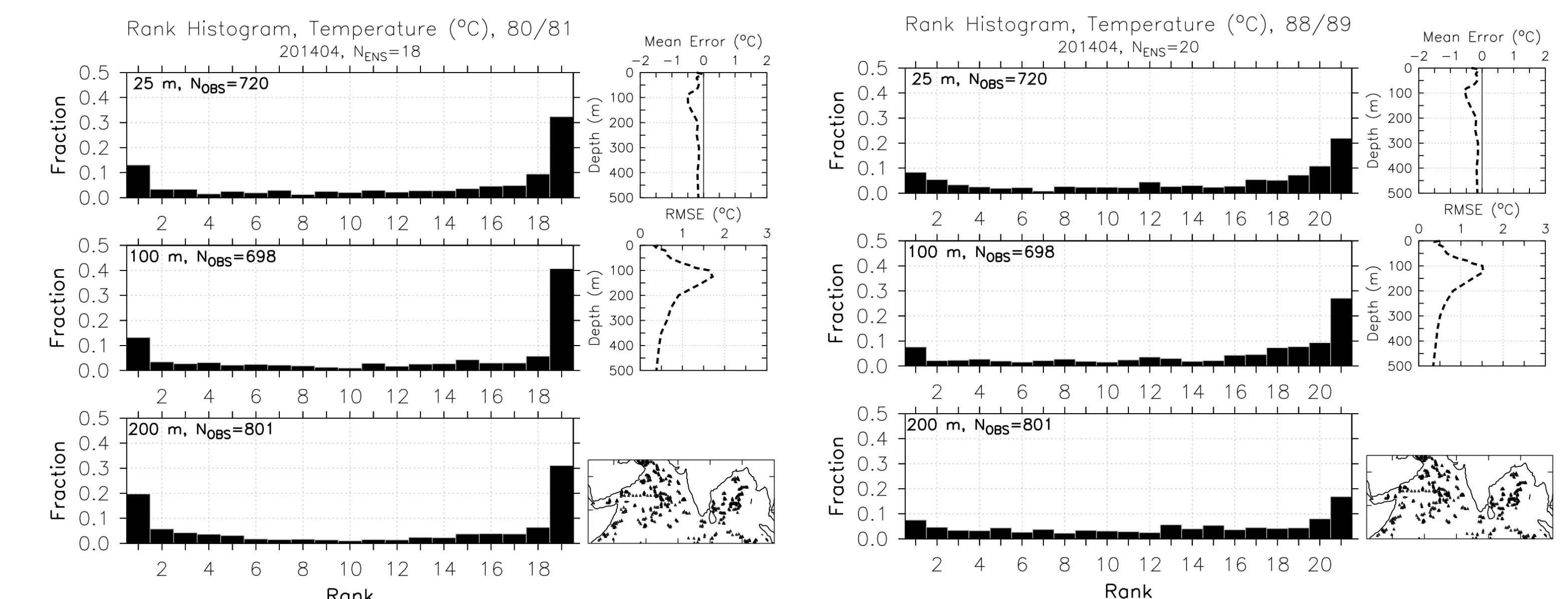
Ensemble rank histograms at three depths and area-average ensemble bias and RMS error for profile temperature observations in the North Indian Ocean for the first month of the forecast period for the ensemble experiments with unperturbed (left) and perturbed (right) observation analyses.
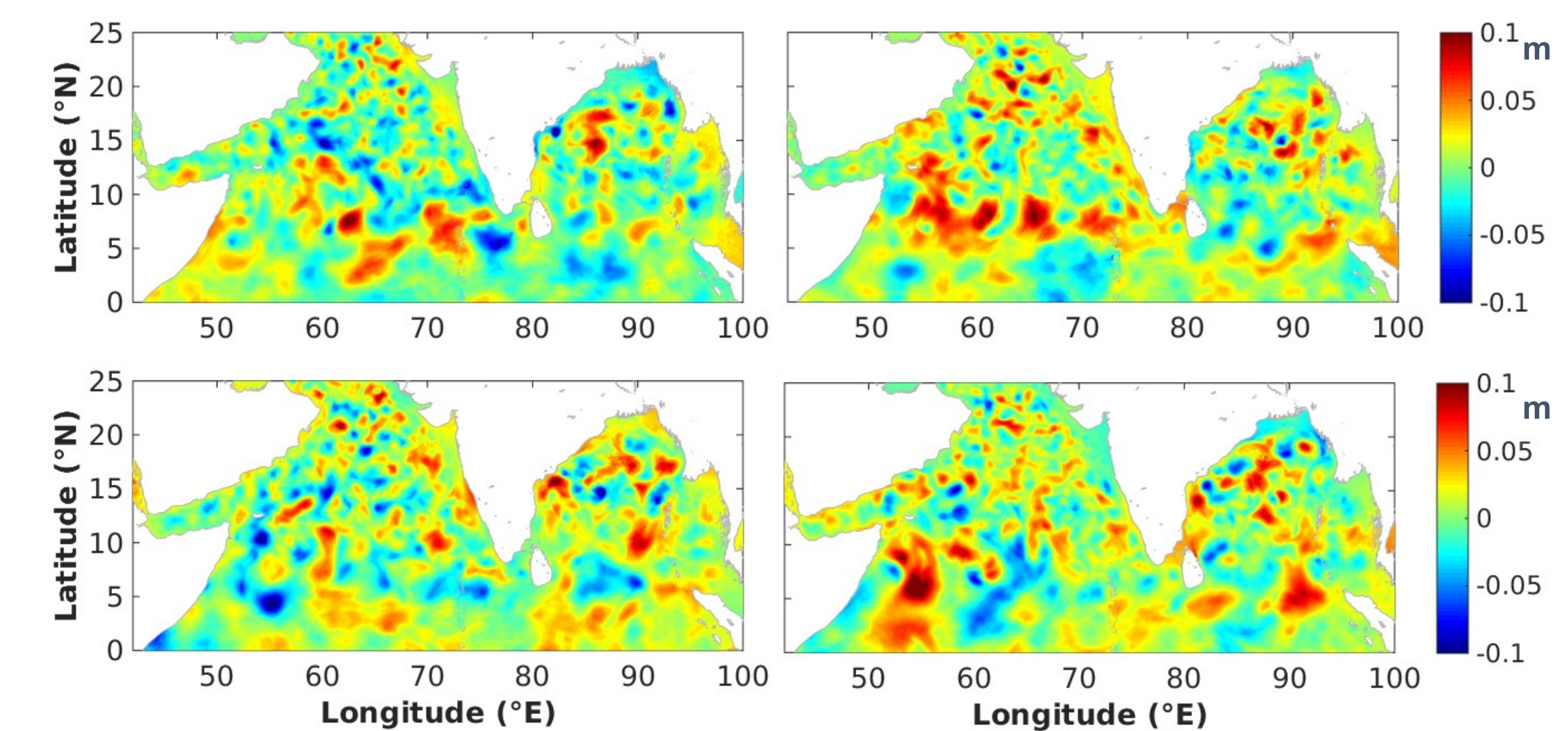
North Indian Ocean sea surface height perturbations (deviations from ensemble mean) for members 1-4 of the perturbed-observation ensemble after 90 d of cycling with the data assimilation system.