Ocean Observing System Simulation Experiments at AOML

What are the optimal observing system designs and strategies that will improve ocean state estimates and forecasts for a broad range of applications?

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Goal and Objectives

The goal is to improve ocean state estimation and ocean forecasts for a suite of applications

Ocean OSSEs will address key observing system questions being considered by NOAA through contributions to observing system evaluation and design, improved utilization of oceanographic data, and identification of cost savings.

Objectives:

- Develop and demonstrate a new ocean OSSE system
  - Incorporate all design criteria and rigorous validation methods developed for atmospheric OSSE systems*
  - Partnership with CIMAS and RSMAS
- Evaluate planned and existing ocean observing systems
- Evaluate and improve ocean data assimilation systems

*Atlas et al., 1997

The New Ocean OSSE System

Nature Run (NR)

- Ocean model: HYbrid Coordinate Ocean Model (HYCOM)
- 2004-2010 simulation of the Gulf of Mexico
- Chosen to represent the true ocean

Forecast system

- Ocean model: HYCOM with with a different configuration from the NR
    - Different vertical coordinate type
    - Different vertical mixing scheme
    - Different horizontal mixing and viscosity coefficients
    - Run at one-half the horizontal resolution
- Coupled to a new ocean data assimilation system
- OSSEs run by assimilating synthetic observations simulated from the NR

The system has been rigorously validated to demonstrate that credible impact assessments are obtained without calibration

Initial Application of the OSSE System

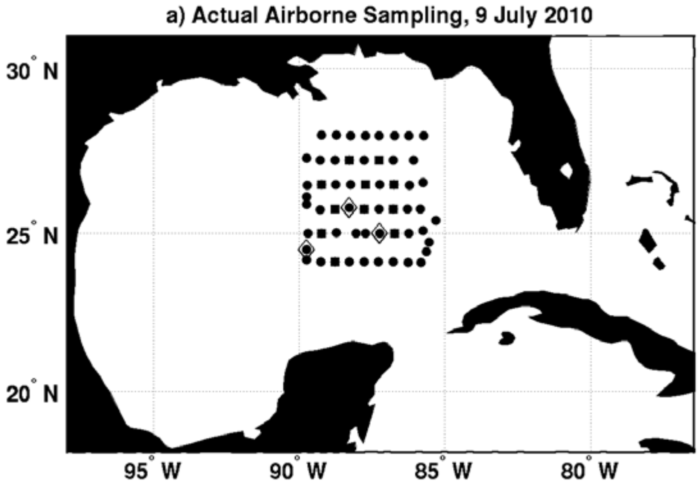
Goal: Improve ocean analyses and forecasts for two applications

- Predict transport and dispersion of oil spills and marine debris
- Improve coupled hurricane intensity forecasts

Objective: Improve experimental design for future rapid-response profiling surveys

Motivation: Rapid-response airborne surveys conducted during 2010

- Minimal time for planning
  - 9 surveys between 8 May and 9 June 2010
  - Irregular separation in time (3 to 14 days)
  - Variable mix of profilers



Key Findings from the 2010 surveys:

1. They significantly reduced errors and biases in ocean analyses
2. OSSEs should be used to increase the positive impact of future survey programs

Approach

Focus on four questions:

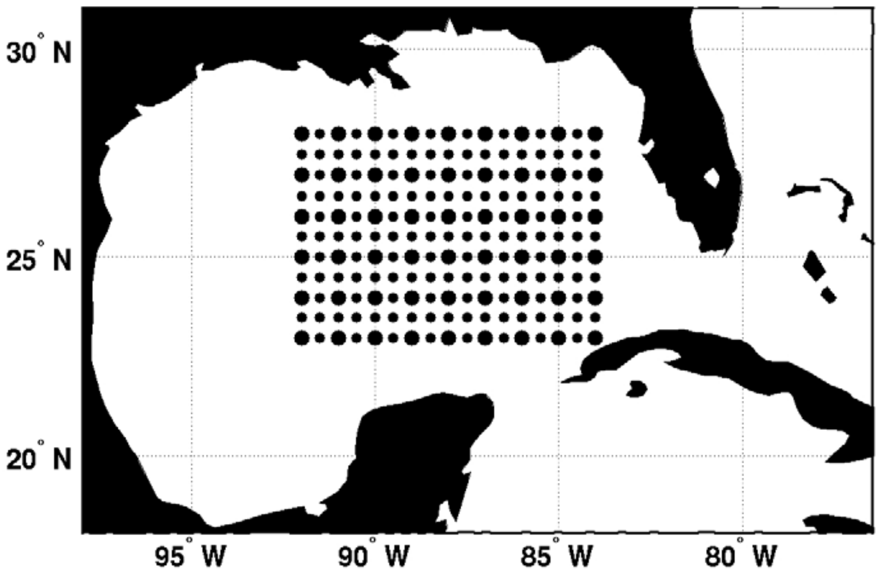
- **Q1** - Overall impact of assimilating profiles
- **Q2** - Impact of horizontal profile resolution
- **Q3** - Impact of probe type
- **Q4** - Impact of time interval between surveys

Control experiment: Assimilates 0.5º profiles of temperature and salinity from synthetic XCTDs to 1000 m over two days prior to each analysis time

- Analyses run every 7 days
- May – October 2010

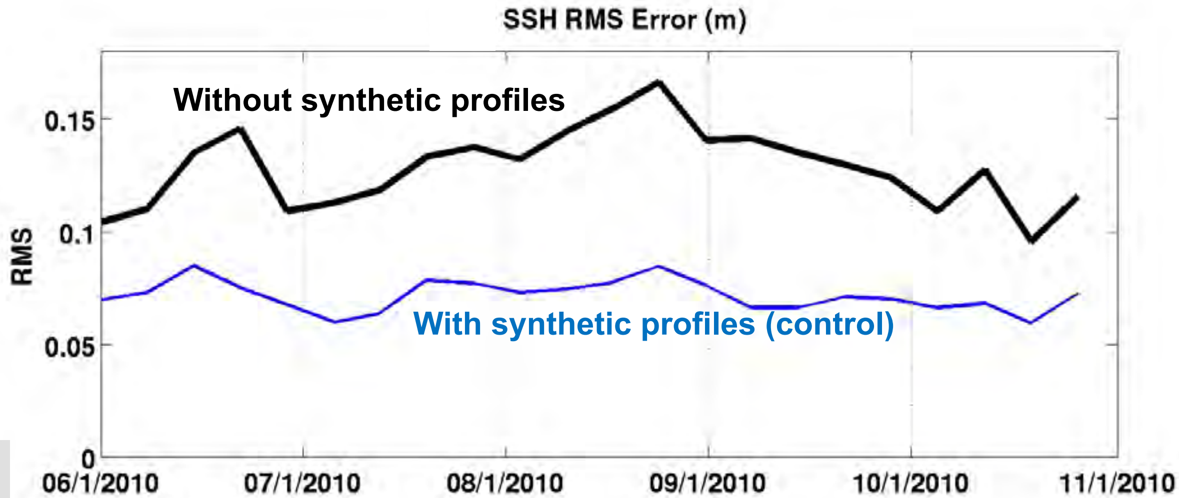
Evaluations are performed by statistically comparing NR and forecast model fields over the profile sampling domain.

a) 0.5°, 1.0° Synthetic Airborne Sampling Arrays



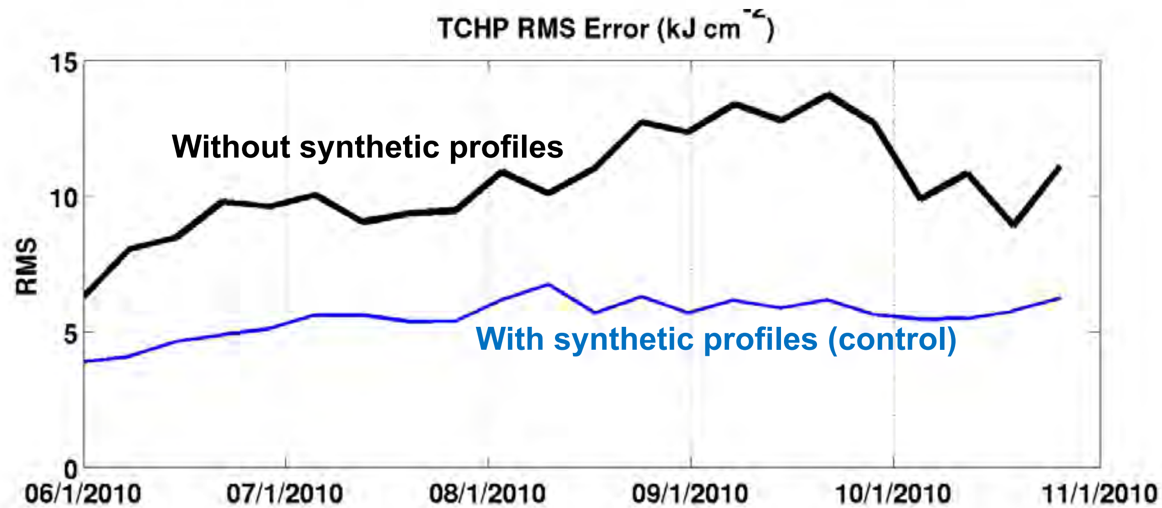
Q1: Impact of Profiles on Analysis RMS Error

Impact on RMS errors are assessed for SSH (top) and Tropical Cyclone Heat Potential (TCHP) relative to the 26ºC isotherm (bottom).



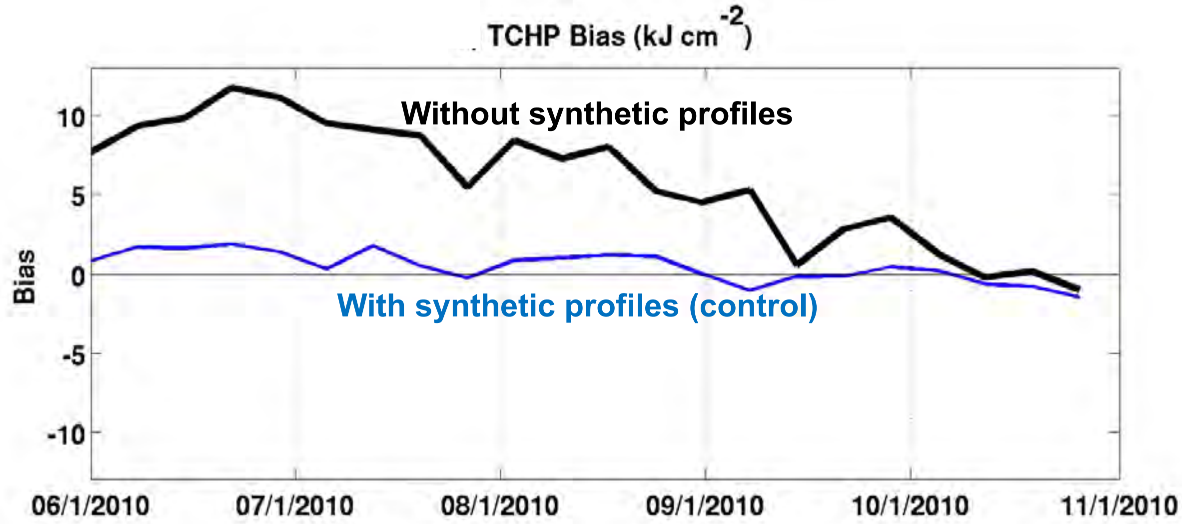
Key Findings:

1. SSH RMS error reduced by 35-50%; associated with improved surface velocities for oil spill and marine debris forecasts
2. TCHP RMS error reduced by 35-60%; important for tropical cyclone intensity forecasts
3. <u>Data Matters</u>



Q1: Impact of Profiles on Analysis Bias

Impact on bias is assessed for TCHP.



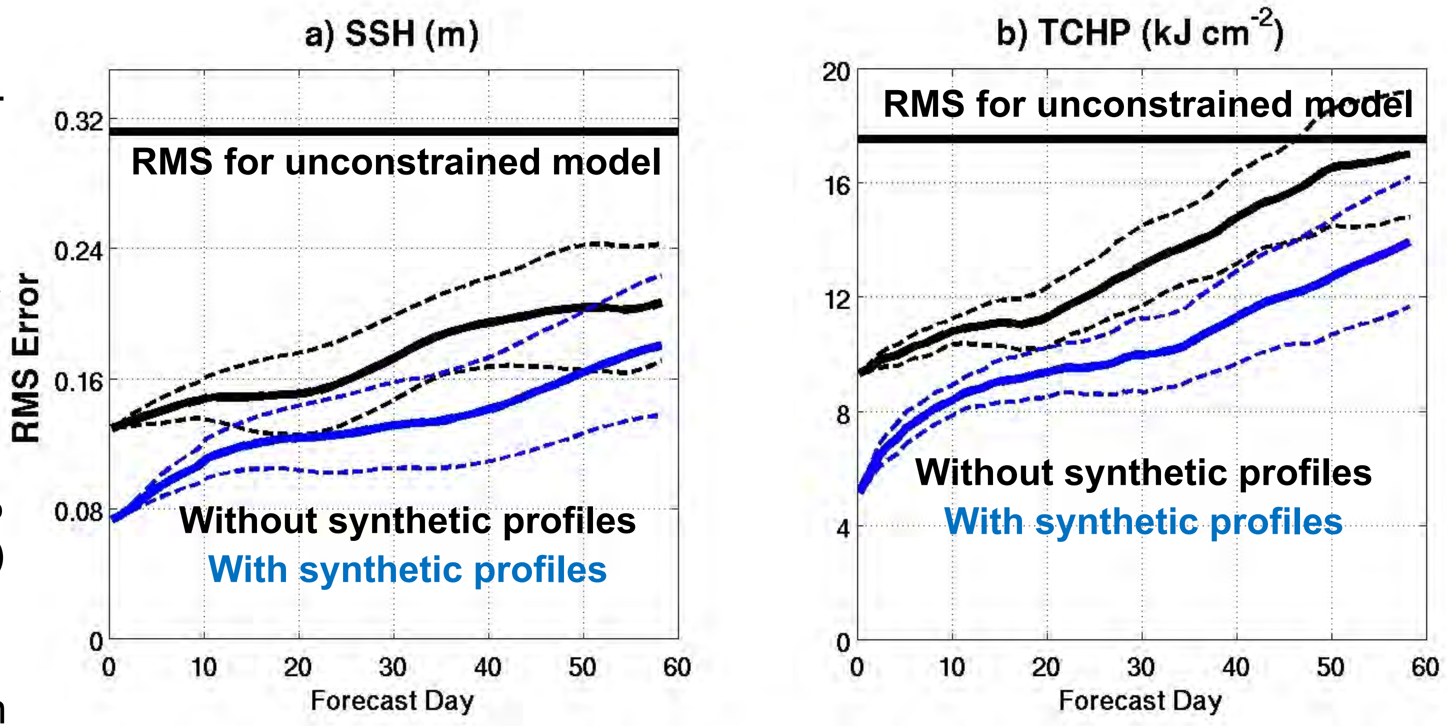
Key Findings:

1. TCHP mean bias in the NR is reduced to near zero. This correction is important for coupled hurricane forecast models to generate unbiased surface enthalpy fluxes beneath storms.
2. <u>Data matters</u>

Q1: Impact of Profiles on Forecast RMS Error

Ensemble of 15 60-day forecasts initialized at 7-day intervals during spring and summer of 2010

RMS error evolution (with 95% confidence interval) for SSH and TCHP is compared between cases with and without profile assimilation



Key Findings:

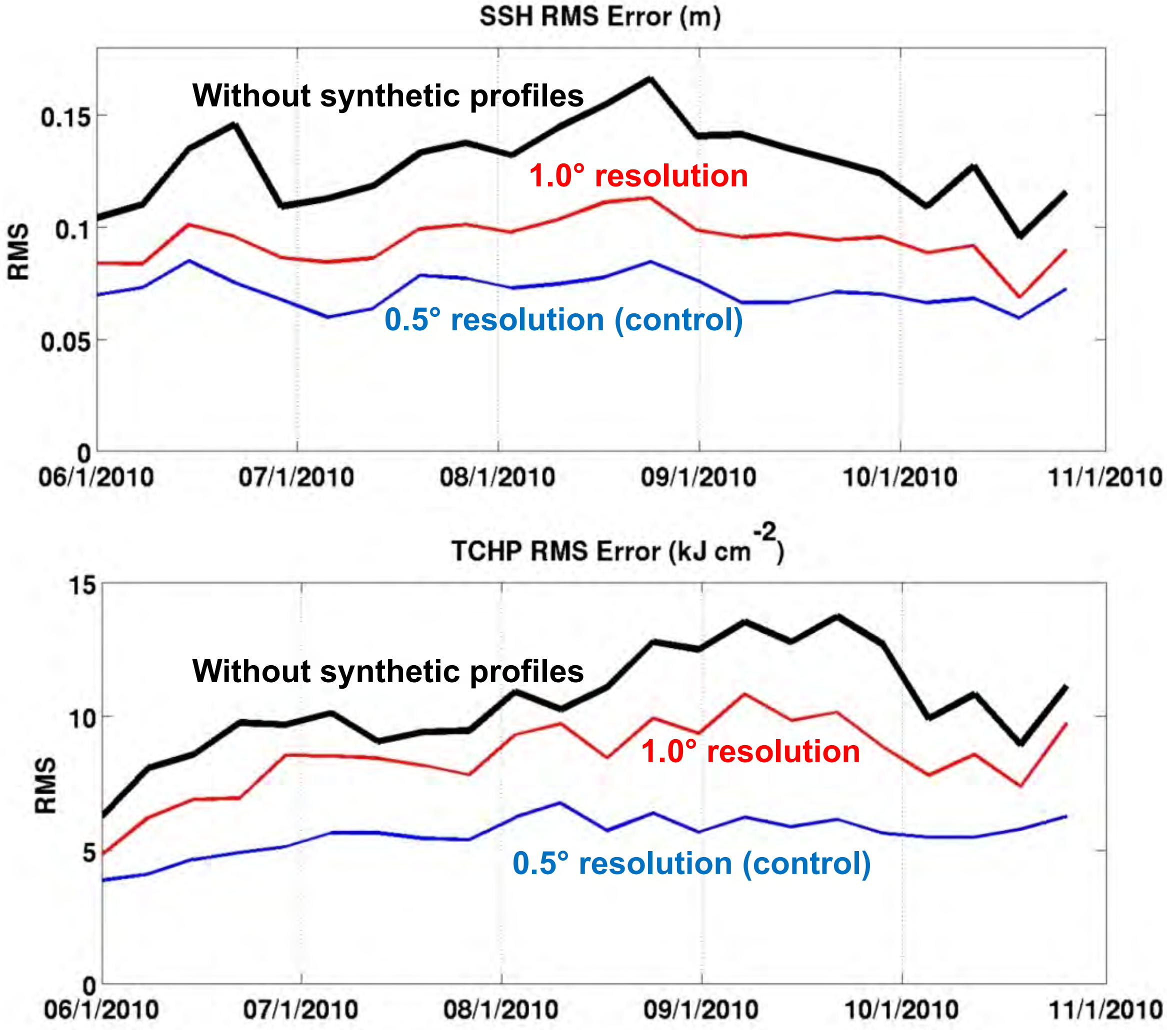
1. SSH and TCHP forecasts both improved when initialized with analyses that assimilated profiles.
2. Improvement persists through 60 forecast days, but becomes marginally significant for SSH after 12 days, and for TCHP after 17 days.
3. <u>Data matters</u>

Q2: Impact of Horizontal Resolution on RMS Analysis Error

Impact of horizontal profile resolution on RMS error is assessed for SSH (top) and TCHP (bottom).

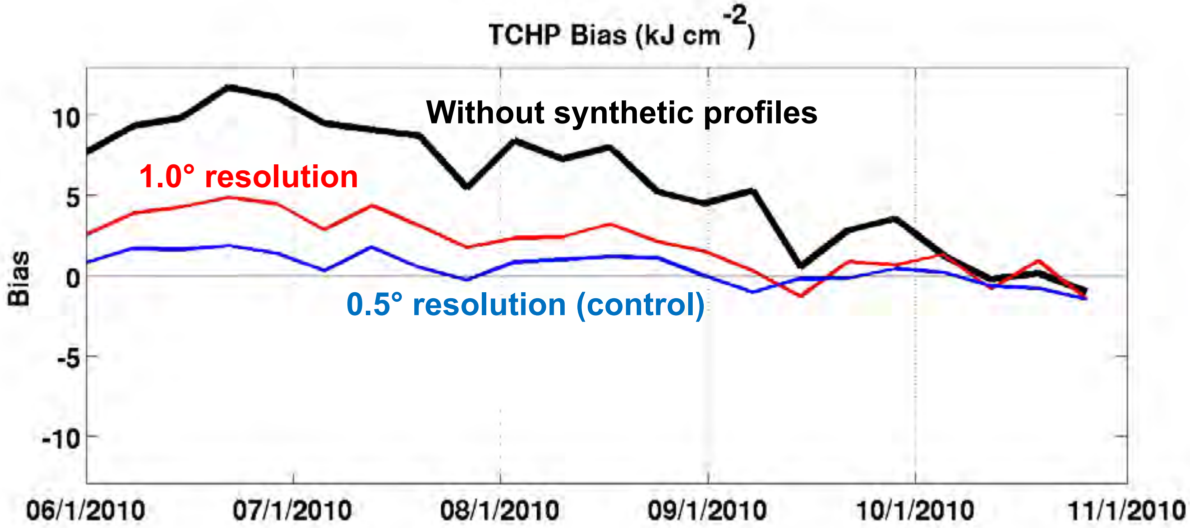
Key Findings:

1. Decreasing horizontal resolution has a large impact on RMS errors of both SSH and TCHP.
2. Higher profile resolution corrects the structure and location of fronts and associated current jets, along with smaller-scale eddies, that are poorly constrained by satellite altimetry.



Q2: Impact of Horizontal Resolution on Analysis Bias

Impact of horizontal profile resolution on mean bias over the survey region is assessed for TCHP.



Key Finding:

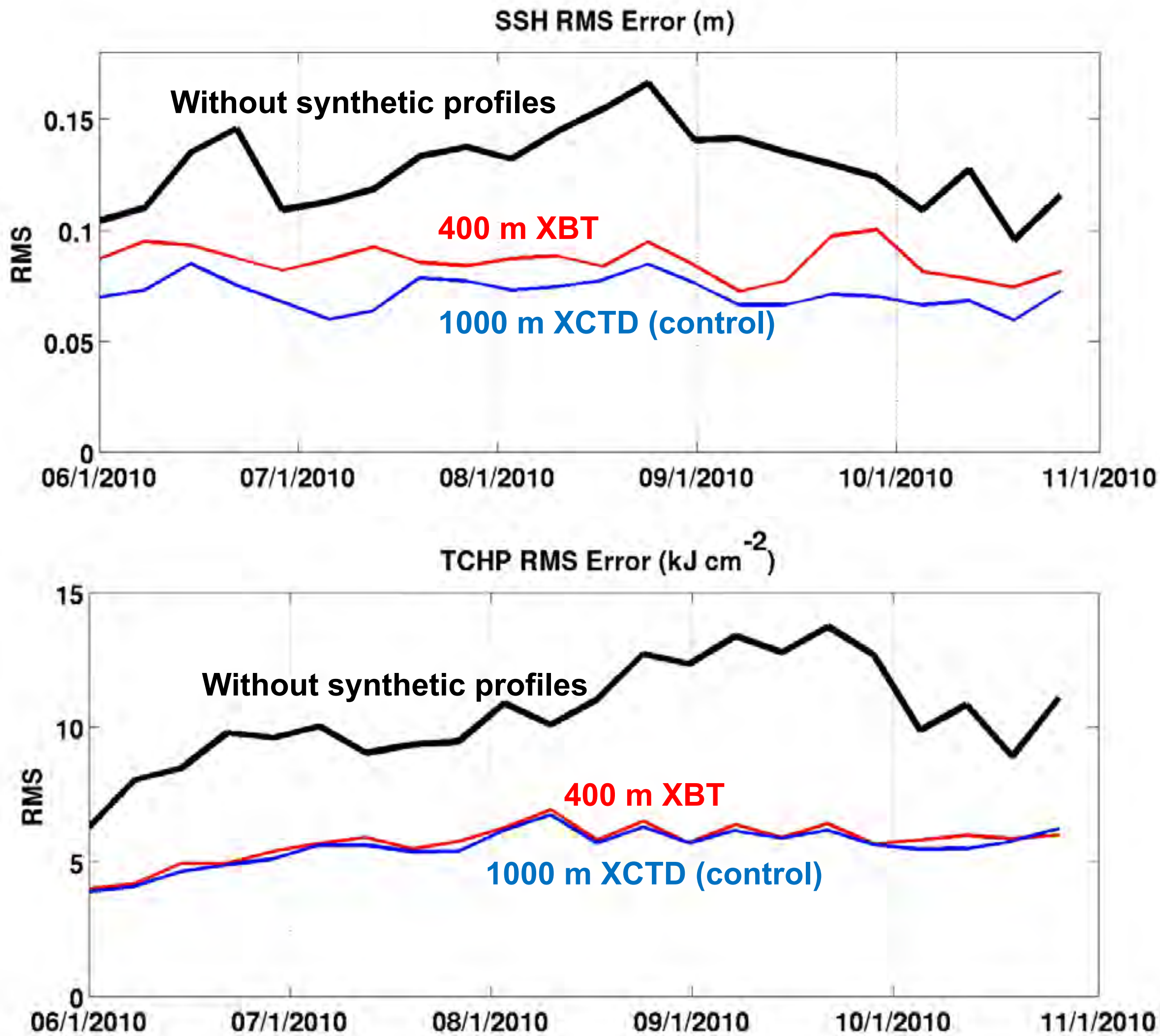
Improved representation of smaller-scale fronts and eddies results in reduced TCHP bias across the analysis domain.

Q3: Impact of Probe Type on RMS Analysis Error

Impact of probe type on RMS error over the survey region is assessed for SSH (top) and TCHP (bottom).

Key Findings:

1. Assimilating shallow (400 m) XBTs instead of deep (1000 m) XCTDs results in a modest increase in SSH errors, but no increase in TCHP errors.
2. Assimilation of both temperature and salinity profiles to 1000 m provides additional correction to the structure of ocean dynamical features.



Q4: Impact of Survey Time Separation on RMS Analysis Error

Daily analyses are run assimilating 1000 m XCTDs at times separated between 1 and 16 days.

Run for May-October 2010.

Time interval between surveys	SSH RMS Error (m)	TCHP RMS Error (kJ cm^{-2})
1 day	0.066	6.78
2 days	0.074	7.09
4 days	0.087	8.05
8 days	0.100	8.97
16 days	0.110	9.72
Without profiles	0.122	10.94

Key Findings:

1. Surveys run every 16 days still produce a 10-12% reduction in RMS error for both SSH and TCHP.
2. Shorter time intervals lead to substantially larger error reduction as expected, but rapid-response surveys remain an effective approach to improving ocean analyses even when no more than 2 to 4 are performed every month.

Conclusions and Future Directions

The new ocean OSSE system produces credible observing system impact assessments.

The system is capable of providing guidance for designing future rapid-response ocean profiling surveys

Future directions:

- Further expand the OSSE system to different ocean regions
- Evaluate existing observing systems, including alternate deployment strategies for these systems
- Design and evaluate of new observing systems

Thank you very much

Questions?



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Key Stakeholders

NOAA (including AOML) ocean observing programs

National and international ocean observing programs (e.g. GOOS, IOOS)

Operational ocean forecast centers (e.g. NOAA/EMC, Naval Research Laboratory, international ocean forecast centers)

Emergency response agencies (e.g. NOAA Office of Response and Restoration, U. S. Coast Guard)