An assessment of the data assimilation (DA) system developed for the SWOT satellite mission
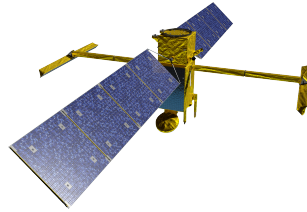
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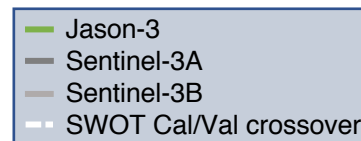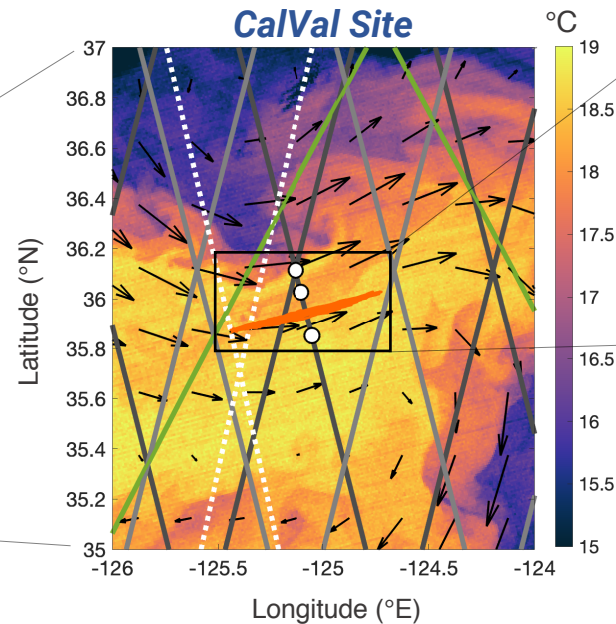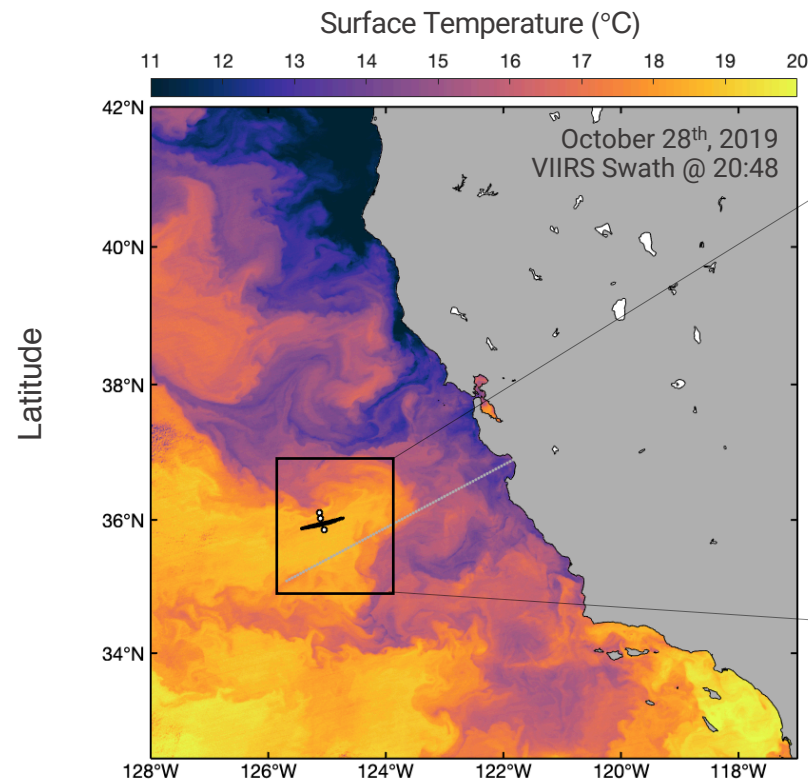
Abstract:

When the Surface Water and Ocean Topography (SWOT) satellite launches in 2022, an in-situ field campaign is planned to reconstruct the ground truth for instrument calibration and validation (CalVal). It is demonstrably difficult to capture the sea surface height (SSH) features that are the focus of SWOT, with both short temporal (< 20 days) and spatial scales (15 – 150 km). Therefore, a critical component of the SWOT CalVal will be a multi-scale data assimilation (DA) system coupled to a primitive equation numerical model that can reconstruct: (1) the 2D sea surface height over the SWOT swaths, and (2) the 3D dynamical (velocity) fields. Here we present a strategic evaluation of the DA system that demonstrates its performance based on independent in-situ observations taken during the 2019-2020 pre-launch field campaign.
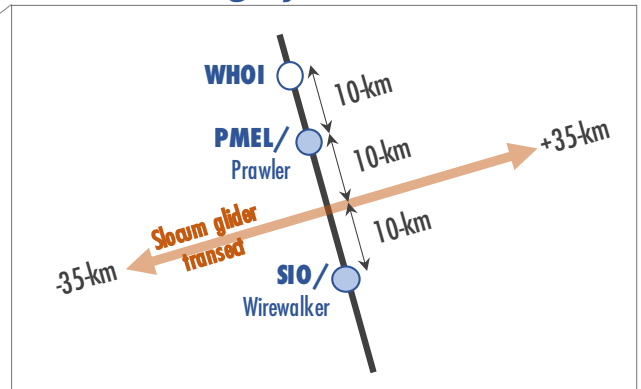
Study Area

We evaluate the DA system using in-situ observations taken during the pre-launch field campaign, which took place between Sep 2019 and Jan 2020 in the same region as the planned post-launch CalVal site. It is located in the California Current system, approximately 300-km offshore Monterey Bay.

California Current system

Surface Temperature (°C)

October 28th, 2019
VIIRS Swath @ 20:48

CalVal Site

Jason-3
Sentinel-3A
Sentinel-3B
SWOT Cal/Val crossover

Observing system schematic

WHOI
PMEL/ Prawler
SIO/ Wirewalker
10-km
10-km
10-km
+35-km
-35-km
Slocum glider transect

- **PMEL/WHOI mooring** (*hereafter WHOI mooring*)
18 x fixed CTDs
- **PMEL mooring**
0 to 500-m profiling CTD 'Prawler'
- **SIO mooring**
0 to 500-m profiling CTD 'WireWalker'
8 x fixed CTDs
- **Rutgers Slocum glider**
Pumped CTD, 500-m and 1000-m dives

Not used in this study:
2 x Bottom Pressure Recorders (BPRs)
*2 x GPS buoys*

Study Area

This figure shows the ocean circulation evolution during the study period, using CMEMS* absolute dynamic topography (ADT) superimposed with geostrophic current velocity vectors, between 8th Sep and 10th Dec 2019
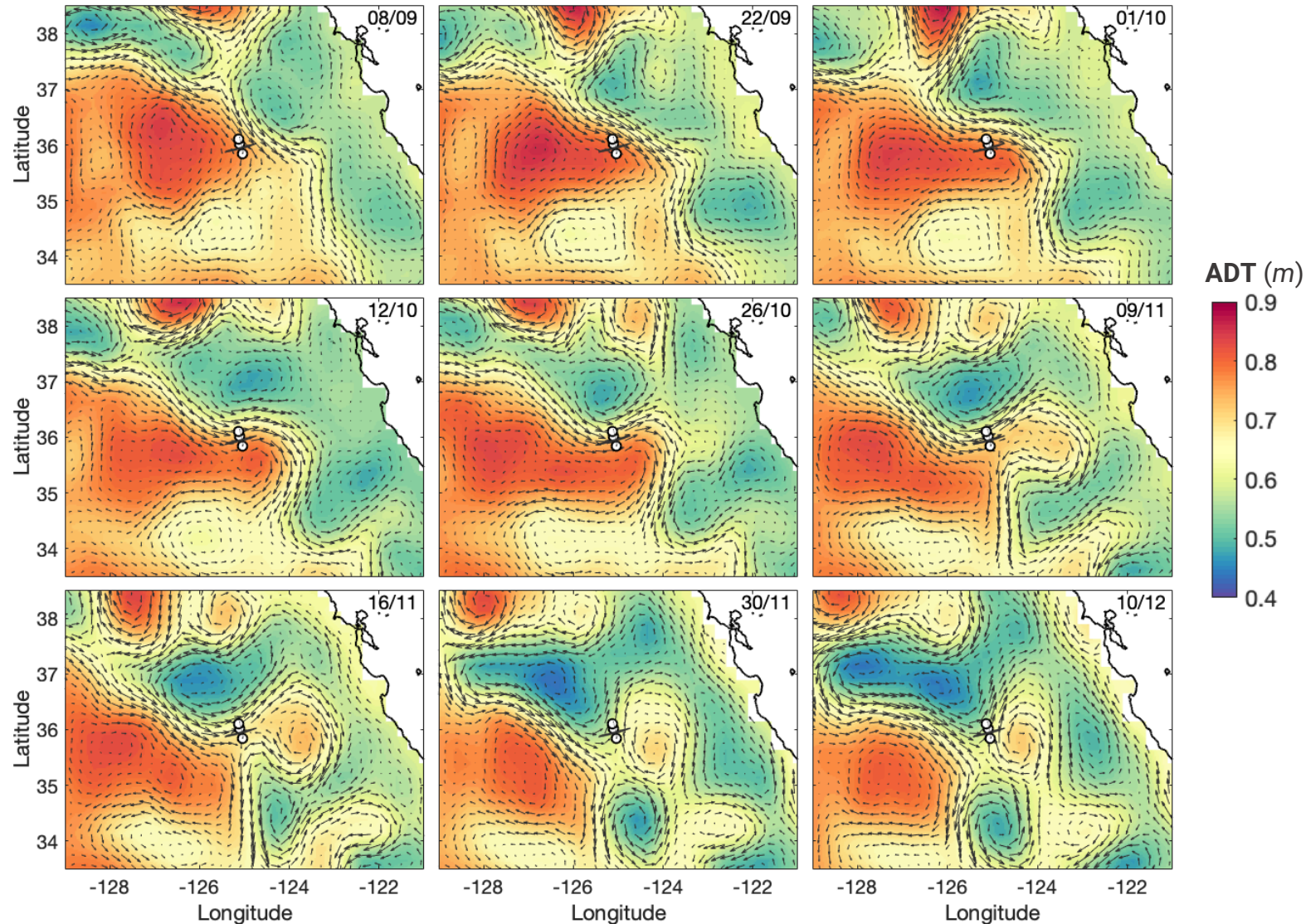
* The SSALTO/DUACS altimeter products were produced and distributed by the Copernicus Marine and Environment Monitoring Service (http://www.marine.copernicus.eu)

Multi-Scale Data Assimilation (MSDA) system

- The SWOT DA system uses a quasi-4D variational formulation (*see Zhijin Li's presentation for details*)

- MS-DA is a novel method to better assimilate the multiple scales of variability from the observations
  e.g. Li et al. (2015, 2019)

- Based on 3-km resolution ROMS with barotropic tidal forcing applied through lateral boundary conditions
  Li et al. (2019)

- **Routine DA** assimilates: gridded and along-track altimetry SSH, microwave SST, vertical profiles of temperature and salinity from Argo and glider, and gridded EN4 product

Model domain and bathymetry
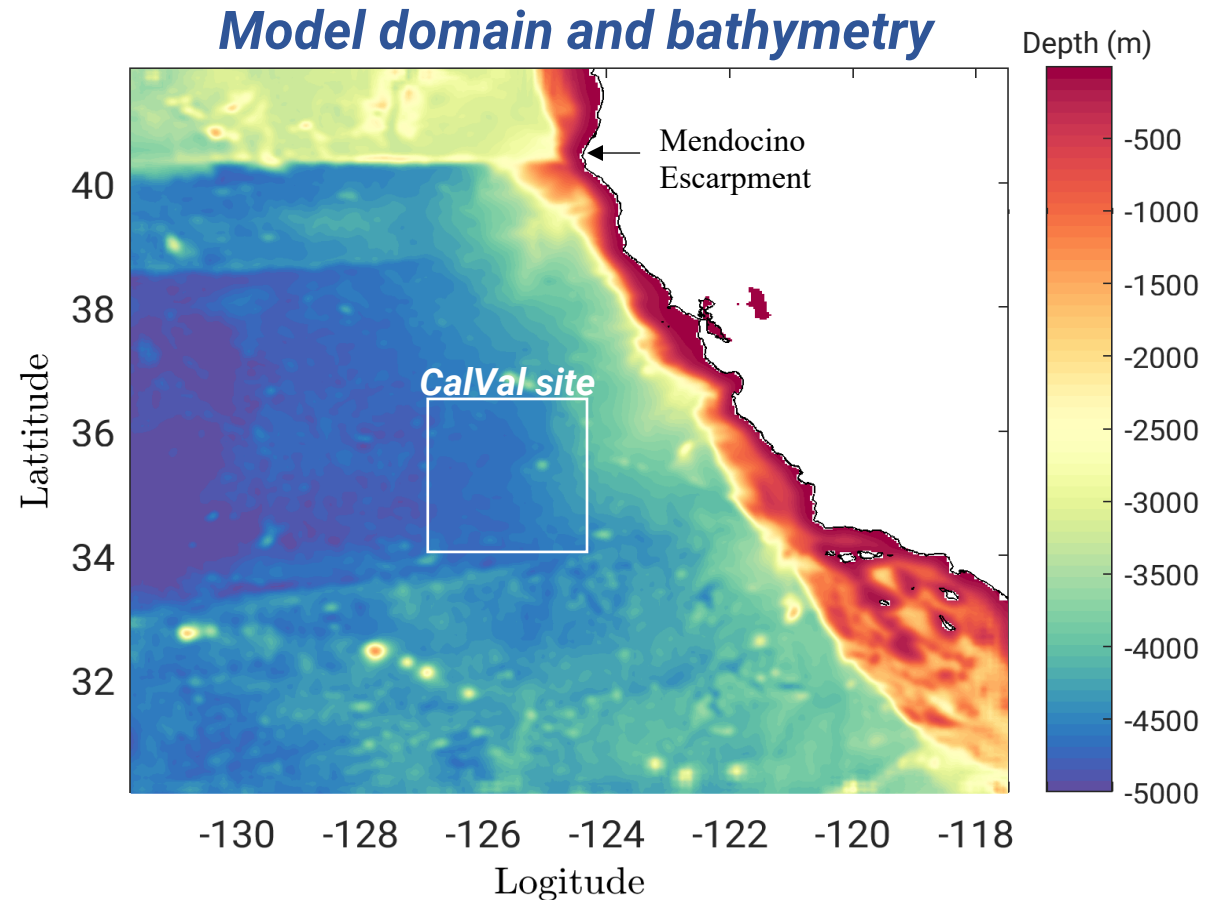
Multi-scale Data Assimilation (MSDA) System

- **Campaign DA** assimilates: all routine observations plus 0 to 500-m T/S profiles at PMEL and SIO moorings (from Prawler and WireWalker) and 500 to 1000-m T/S from fixed CTDs at SIO mooring

Observing system schematic

Model domain and bathymetry
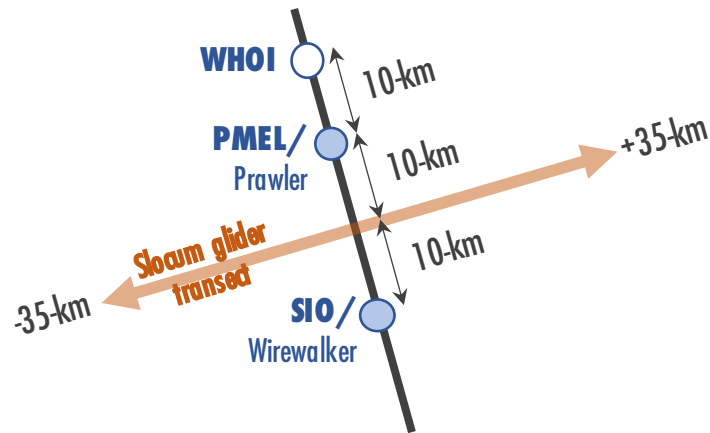
- **Withheld (independent) observations** for performance evaluation: WHOI mooring T/S profiles and Slocum glider T/S measurements
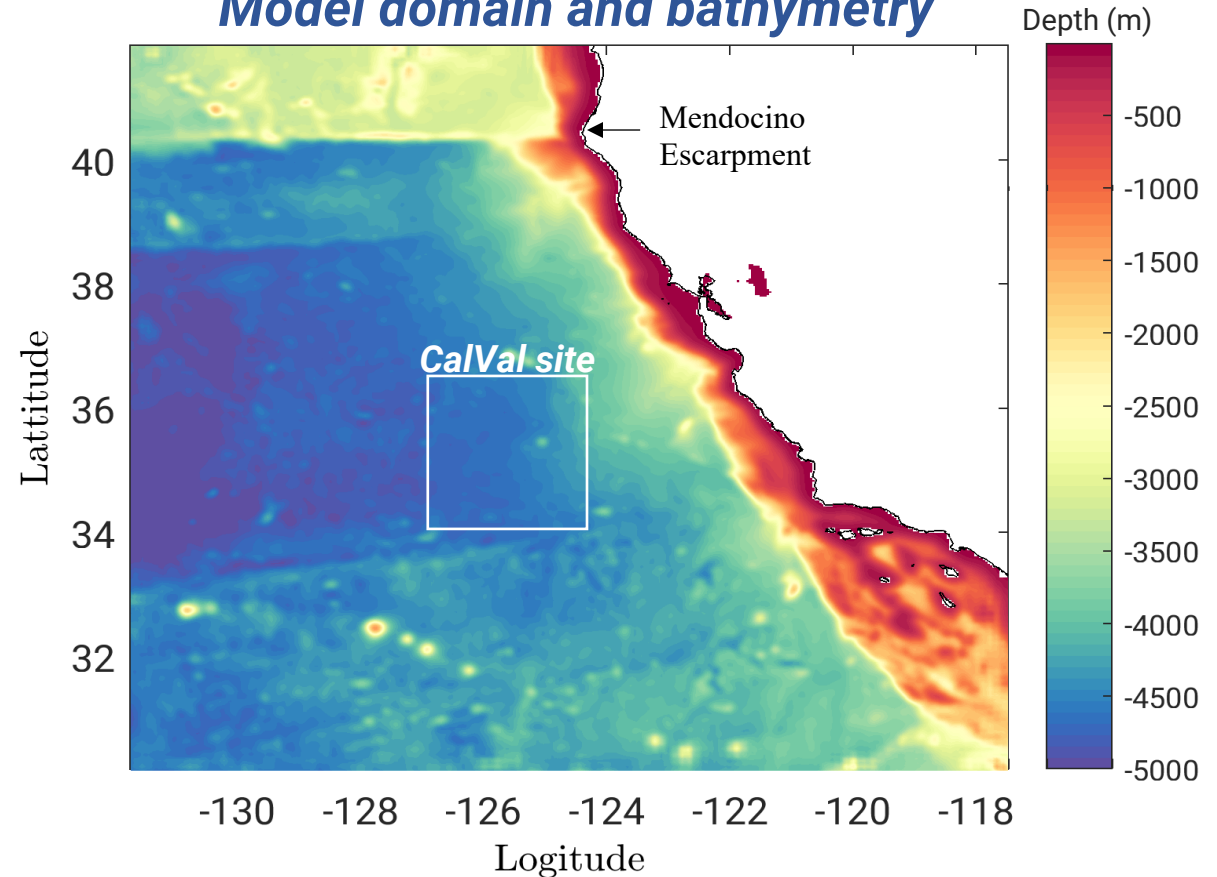
DA daily analysis

This figures shows a visual comparison between the DA daily analysis from the campaign run and the AVISO (CMEMS) ADT and geostrophic velocity field. It provides a sanity check, showing that the daily analysis field is able to accurately capture the mesoscale flow and its evolution.
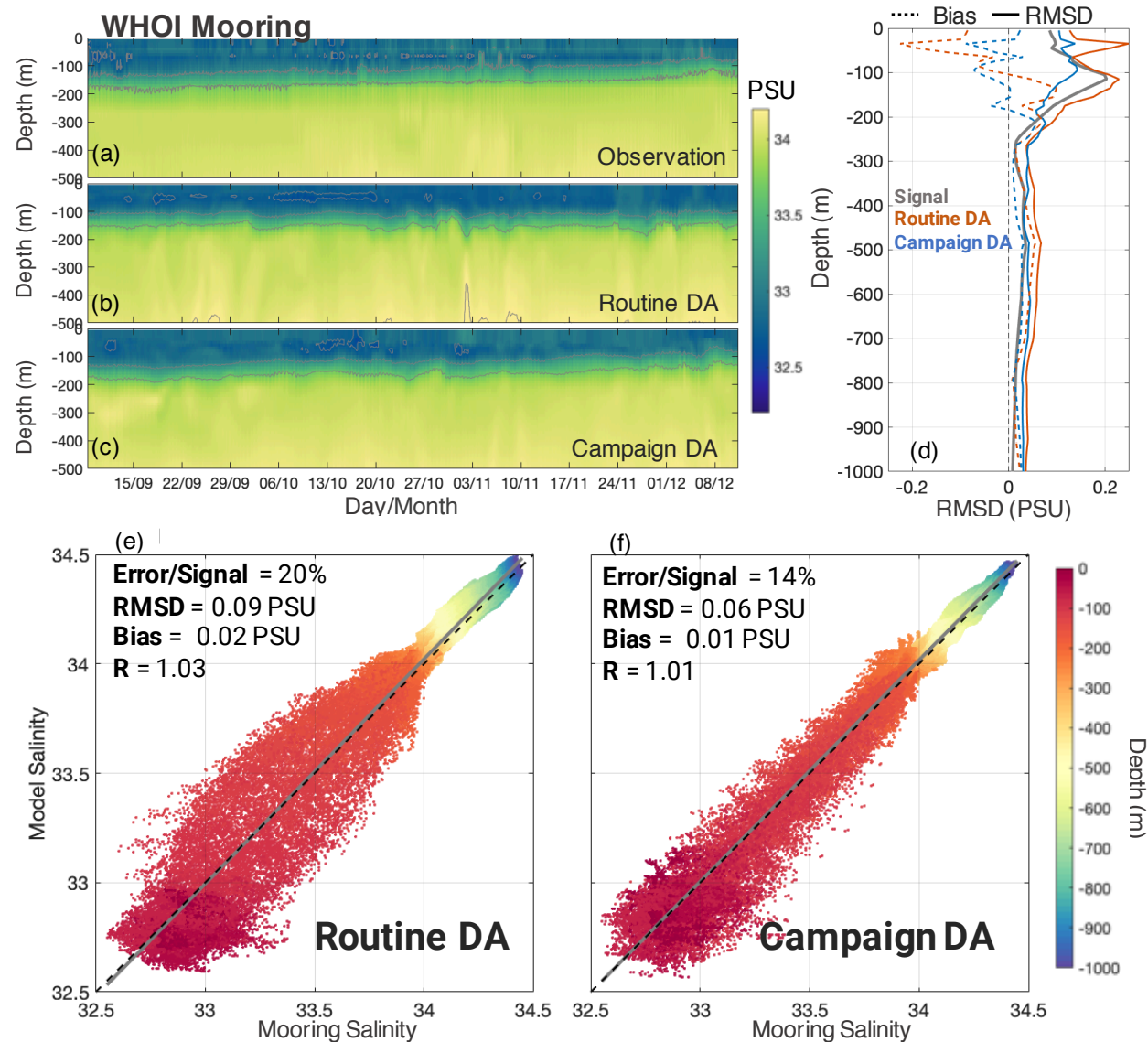
All following slides will present 7 to 30-hour DA forecasts at hourly resolution.
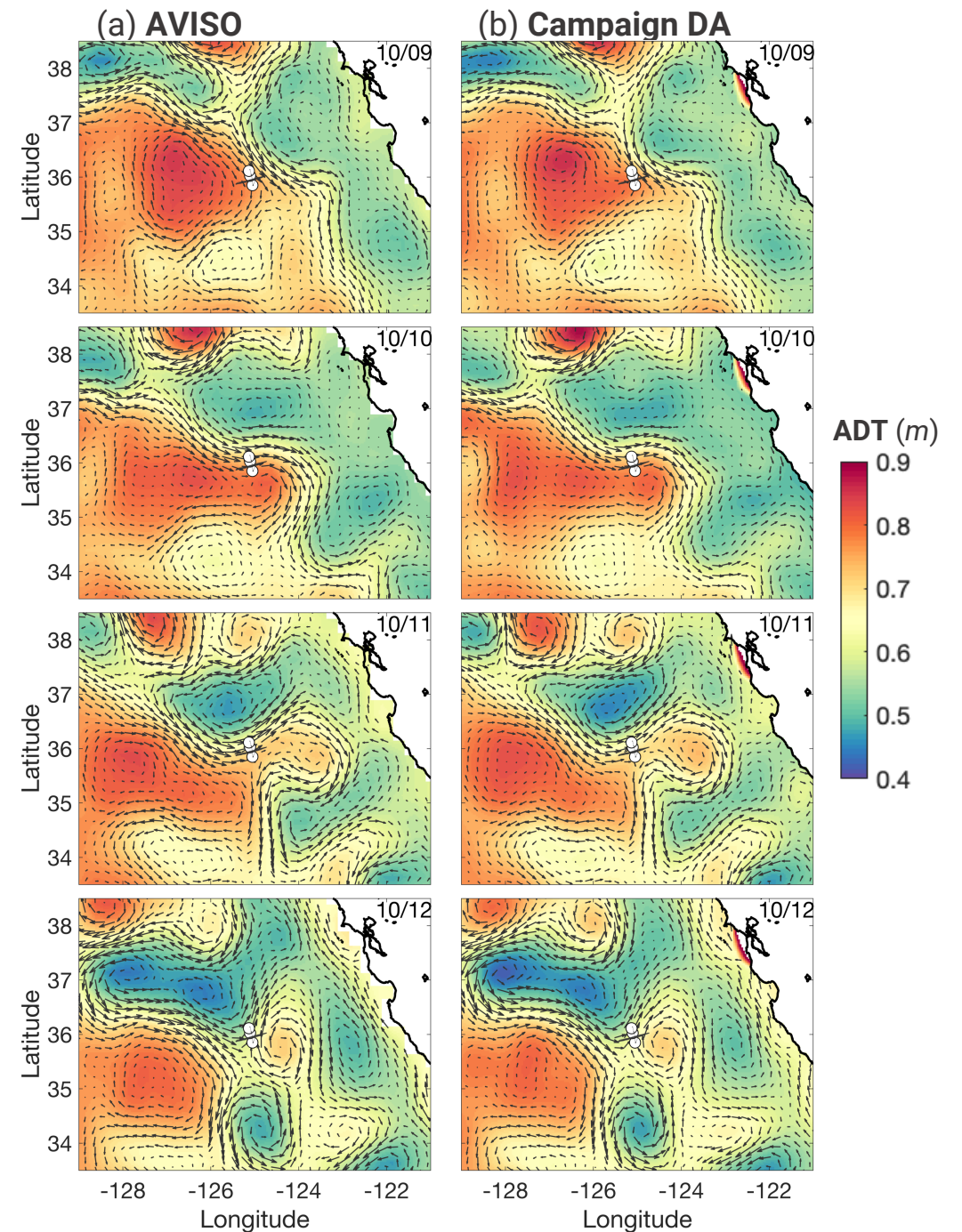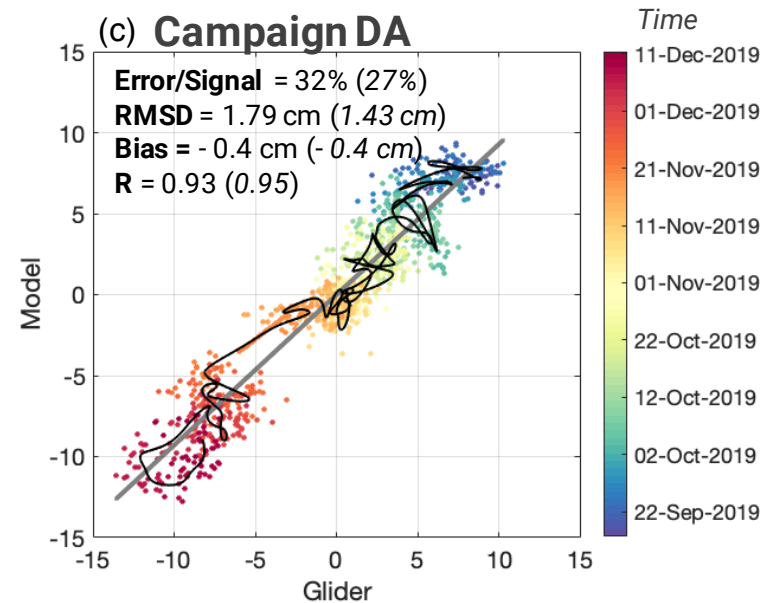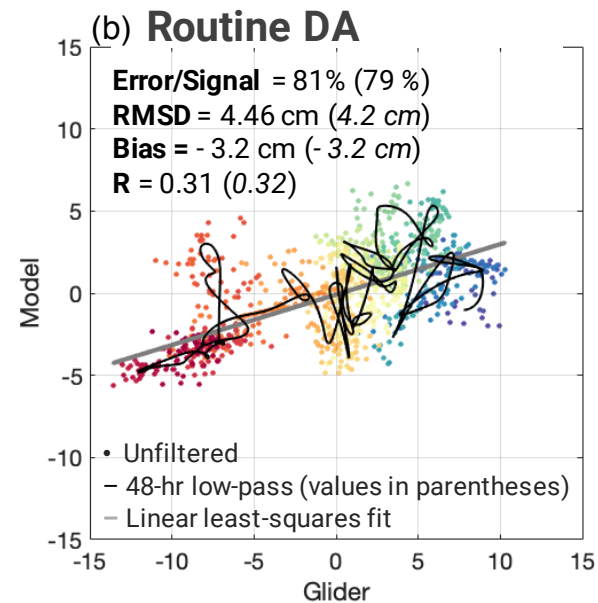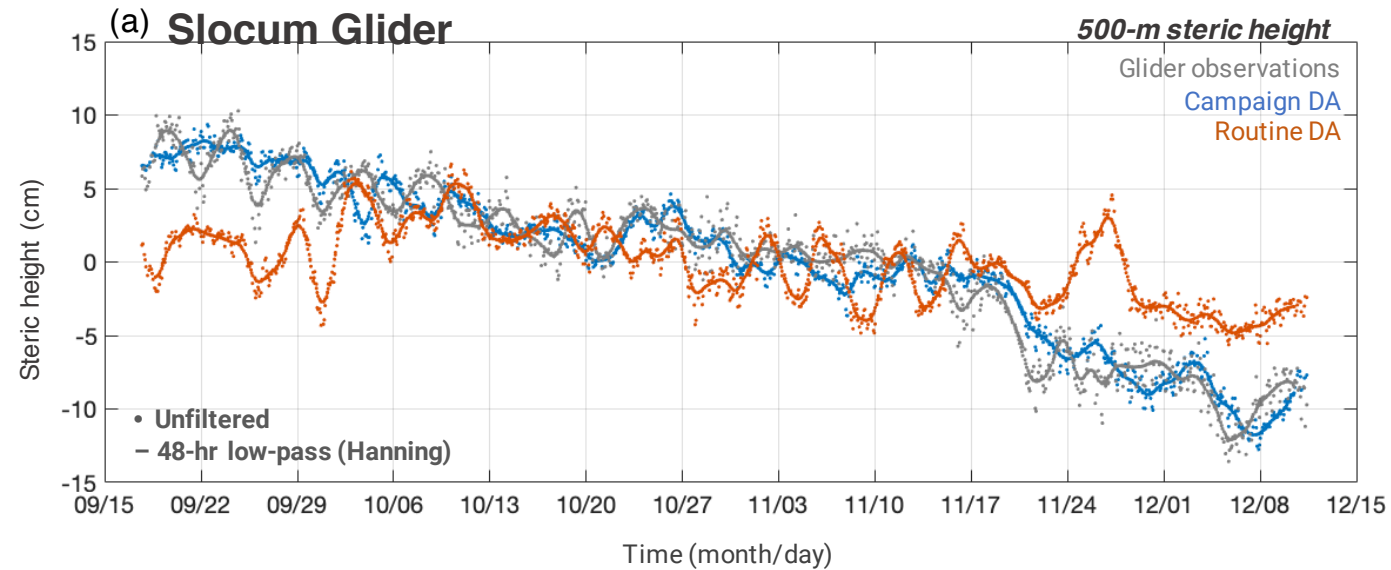
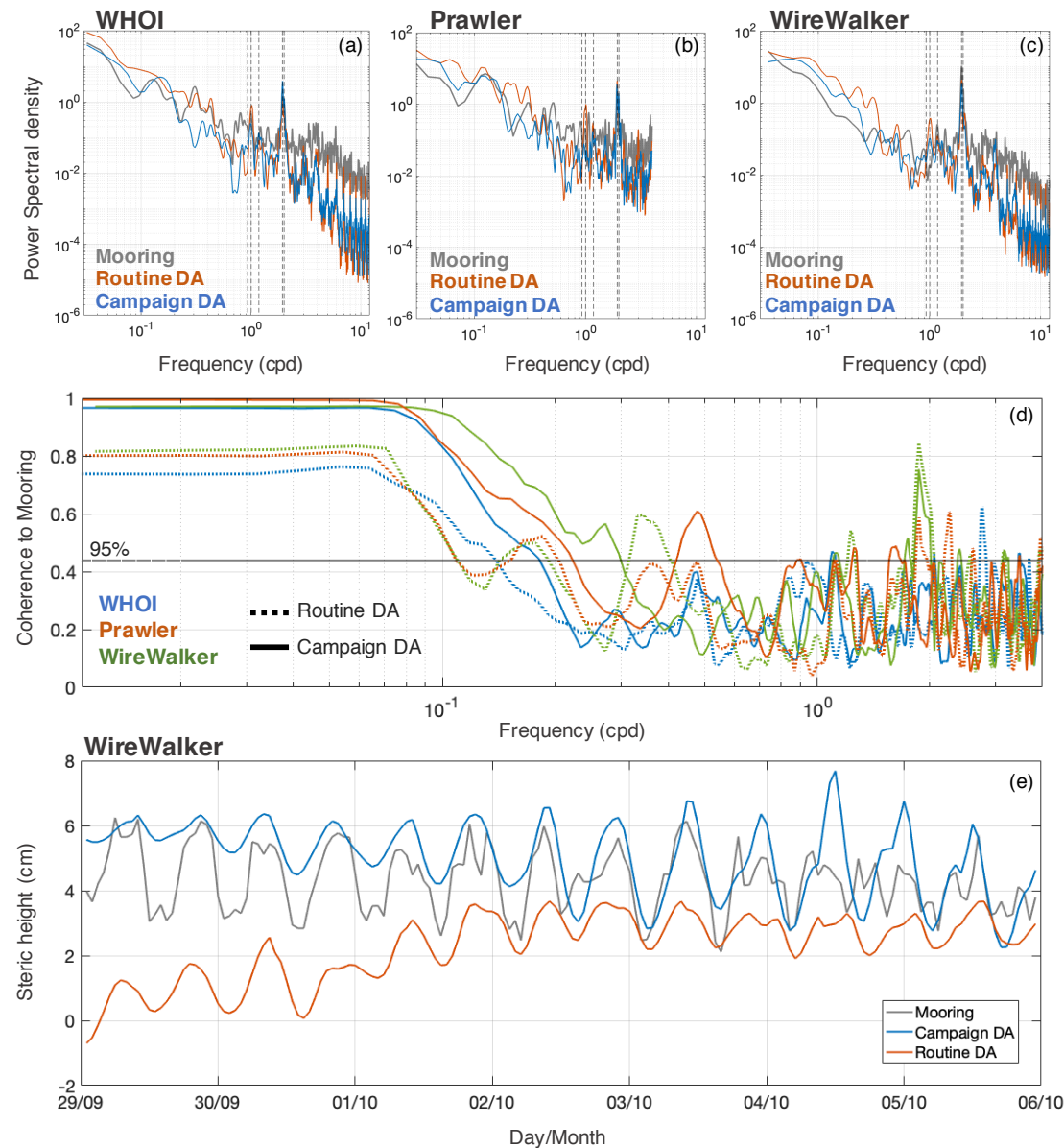# **Evaluation of:** potential temperature at WHOI mooring
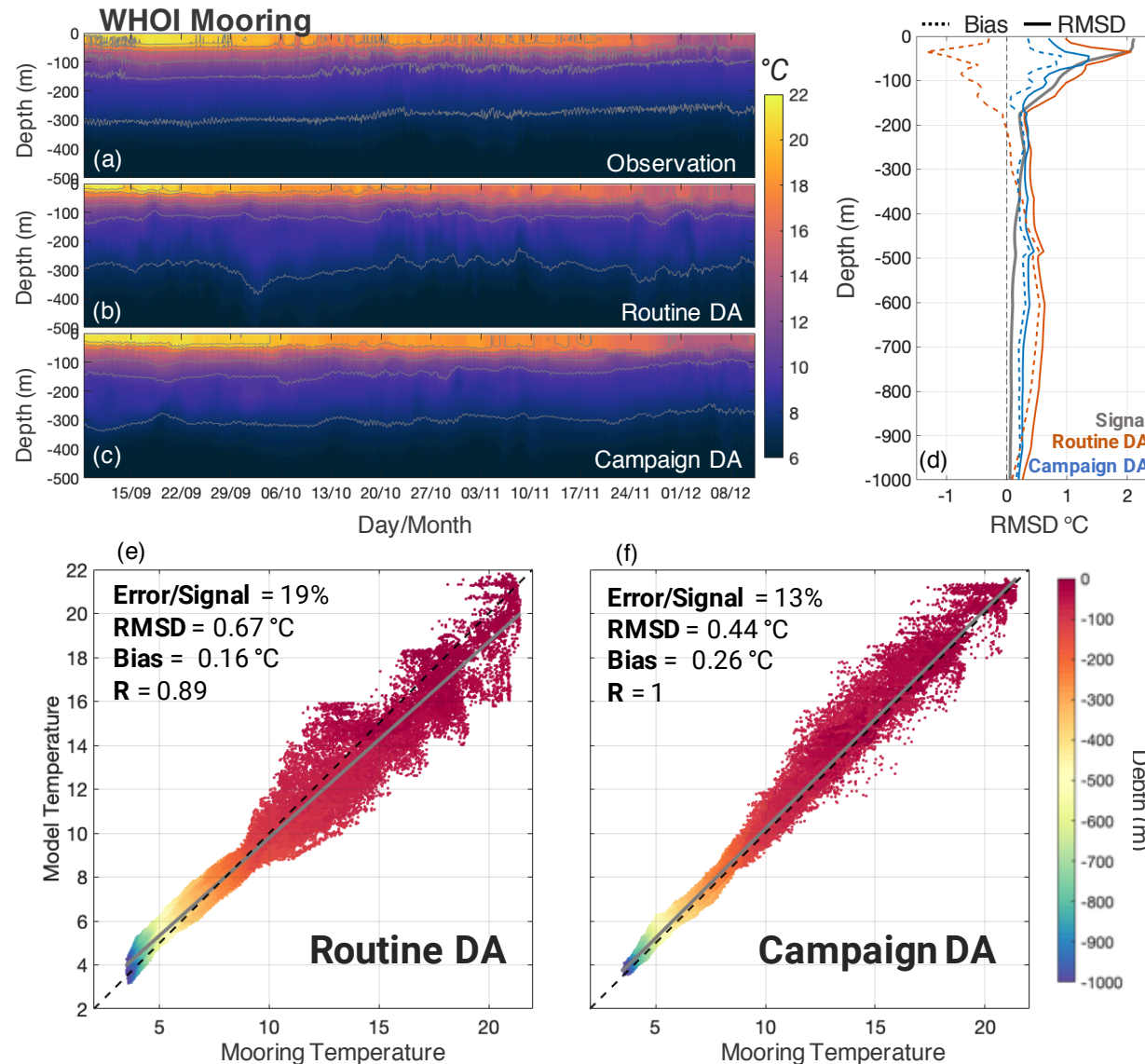
Evaluation of: salinity at WHOI mooring

Evaluation of: 0 to 500-m steric height (glider)

Evaluation of: 0 to 500-m steric height (at 3 moorings)

Evaluation of: 0 to 500-m steric height in space

Error in steric height as a function of distance to assimilated moorings (km). The glider spatial mean has been removed, and all data are low-passed filtered with a 48-hr Hanning window.

(a) Error as an RMSD between observation and routine/campaign DA estimates (red/blue circles). The signal standard deviation (STD) within each distance bin is shown as gray circles. The lines represent a robust linear best-fit to the data. The crosses represent the WHOI mooring location, which was excluded in the linear fitting because it lies perpendicular to all other observations. The comparison to assimilated Prawler and WireWalker is shown at 0-km.

(b) Error normalized by the signal STD. For data points above the 1-1 line, the error is larger than the signal.
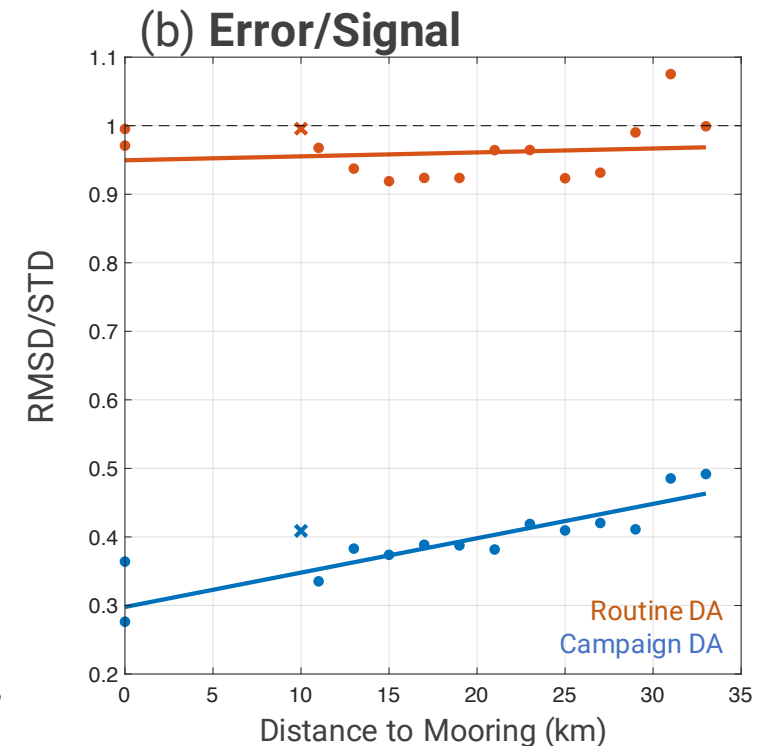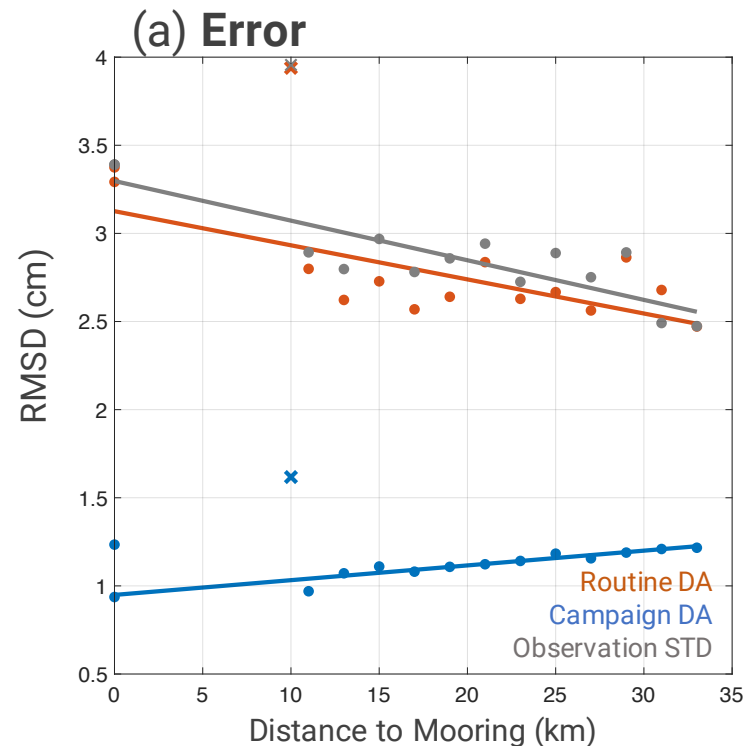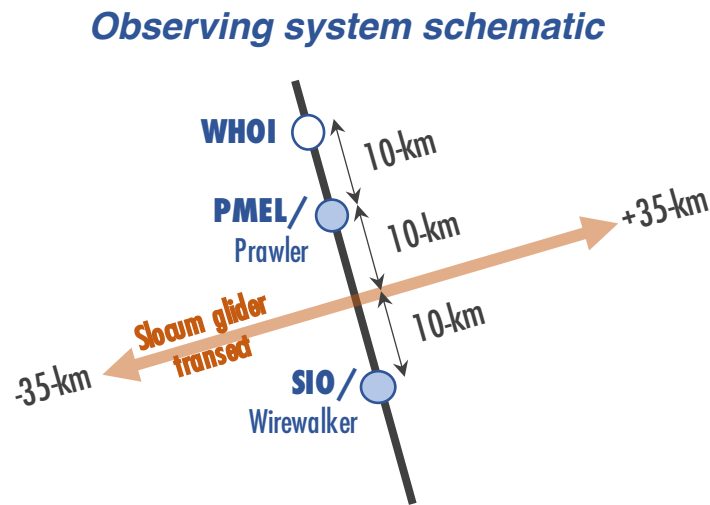
Summary

- Assimilating in-situ T/S profiles from two moorings at the CalVal site ('campaign DA') significantly improves the DA forecast than using only routinely available observations ('routine DA')

    Error/signal ratio reduces from 20% to ~10% in temperature and salinity, and 80% to 30% in steric height

- Comparison with the glider reveals a spatial pattern in performance: error decreases almost linearly with distance to assimilated data

    From 1.25-cm (~45%) at 34-km distance to below 1-cm (~30%) at 0-km

- For temperature and salinity, the largest errors in vertical are due to a displaced mixed layer base

    The routine DA is too shallow leading to a cold, fresh bias in the top 100-m. In contrast, the campaign DA can largely correct for this and therefore has significantly smaller mean bias and RMSD

- For steric height, the campaign DA is strongly coherent with observations at periods longer than 10 days, significantly coherent ≥ 5 days, and not significantly coherent <5 days

    An exception to this is the semi-diurnal frequency at the SIO mooring – here the signal was significantly larger and more coherent; we are investigating this further.

Ongoing Work

(1) We are running observing system simulation experiments (OSSEs) to optimize the design of the post-launch field campaign that will provide observations to assimilate into the DA system

(2) We are continuing analysis of the pre-launch field campaign datasets to examine space-time ocean variability at the CalVal site

Thank you for reading!

Questions?

Please email: `archer@jpl.nasa.gov`