Comparison of 4DVAR and LETKF in Assimilating VIIRS Sea-surface Temperature in the Chesapeake Bay Operational Forecasting System

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Introduction:

- The Chesapeake Bay Operational Forecasting System (CBOFS) is NOAA's operational hydrodynamic model used to provide two days forecasts of several oceanographic products in Chesapeake Bay
- CBOFS forecasts of sea surface temperature (SST) and salinity (SSS) can be improved
- We are evaluating the performance of both the strong constraint 4D-Variational (4D-VAR; Moore et al., 2011) and Local Ensemble Transform Kalman Filter (LETKF; Hunt et al., 2007) data-assimilation systems to assimilate satellite-derived sea surface temperature in order to improve SST forecasts in CBOFS
- We compare the results of assimilating VIIRS SST into CBOFS using 4D-VAR and LETKF.

Model and Data:

Model Description

- Study Domain: Figure 1.
- CBOFS based on ROMS 3.6
- Resolution: 33m in rivers to 4km in coastal area
- Grid size 292 by 332 , vertical 20 S layers
- Time step: 10 s

Data Assimilation:

- IS4DVAR for adjusting initial conditions only
- Decorrelation scales: 17 km (x,y), 3 m (z)
- Archived CBOFS forcing and open boundary conditions
- Randomized normalization coefficient calculation.
- Background error is from standard deviation calculated with yearlong CBOFS results with tidal and annual signals removed
- Assimilation/Forward run window: 6 hours.
- LETKF has 20 ensemble members, adjusts initial/forcing conditions.

Work Performed

- Assimilate VIIRS swath SST dating from 08/06/2014 to 09/06/2014.
- Evaluate model performance with in-situ temperature measurements from Chesapeake Bay Interpretive Buoy System (CBIBS T/S).
- Initial comparison of 4DVAR and LETKF.

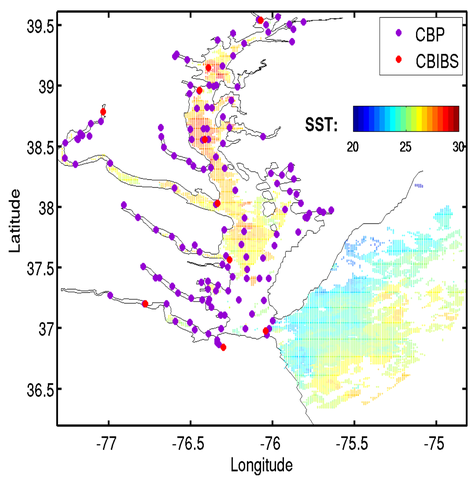


Figure 1. Model domain and stations. CBP = Chesapeake Bay Program CTD casting locations, CBIBS = Chesapeake Bay Interpretive Buoy Systems. Image: daily AVHRR composite for 22 August 2012.

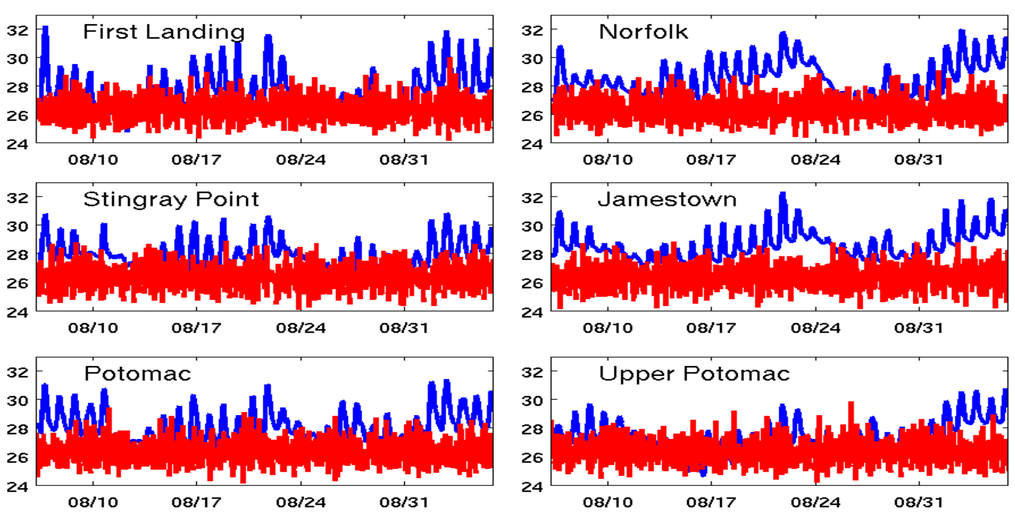


Figure 2. Comparison of the surface temperature between the forward run model results and the observations. Red lines represents observations on CBIBS stations, blue lines are model simulated. Persistent model warm bias about 2-3 degrees can be seen in the whole model domain except a few river area.

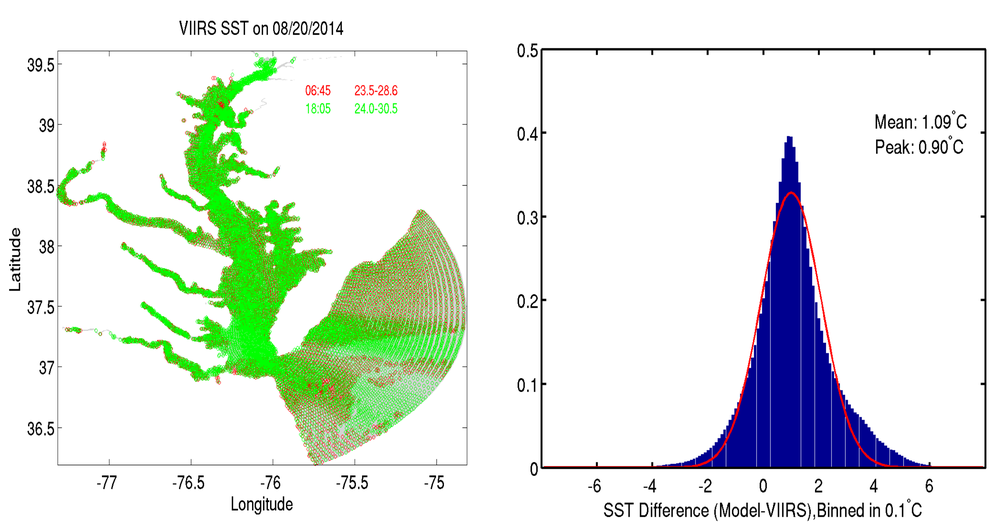


Figure 3. SNPP passes over Chesapeake Bay area two times per day, mainly near the mid night and early afternoon. The global Advanced Clear Sky Processor for Oceans (ACSPO) of NOAA VIIRS SST L2 products are used for this data assimilation. The SST product has a resolution of 750m. Cloud removal and quality control have been applied to the data. Left panel shows SST pixel locations on 08/12/2014. Right figure shows the histogram of VIIRS SST and CBOFS SST from 05/2014-10/2014.

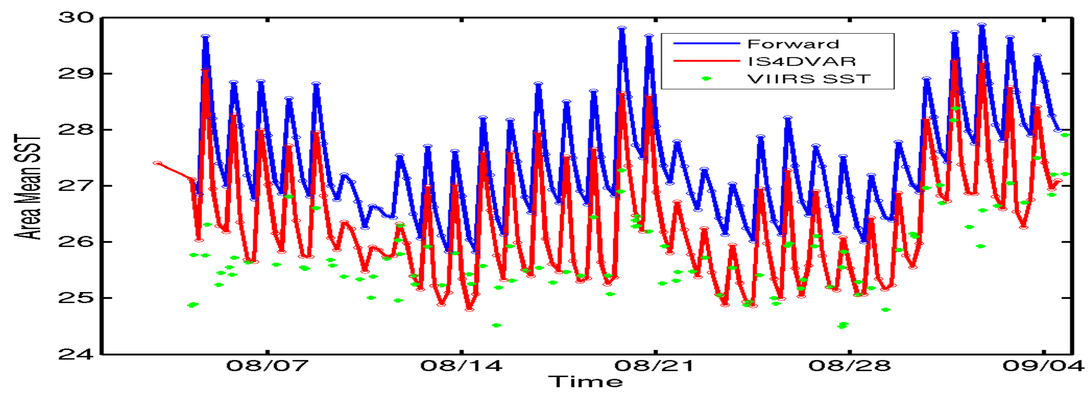


Figure 4: Time series of SST (model domain averaged) every 6 hours with 4DVAR data assimilation.

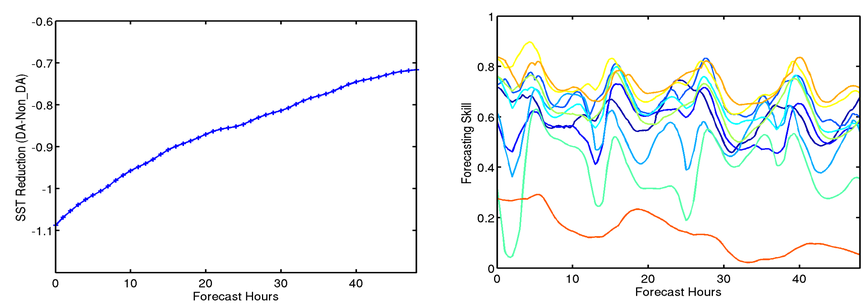
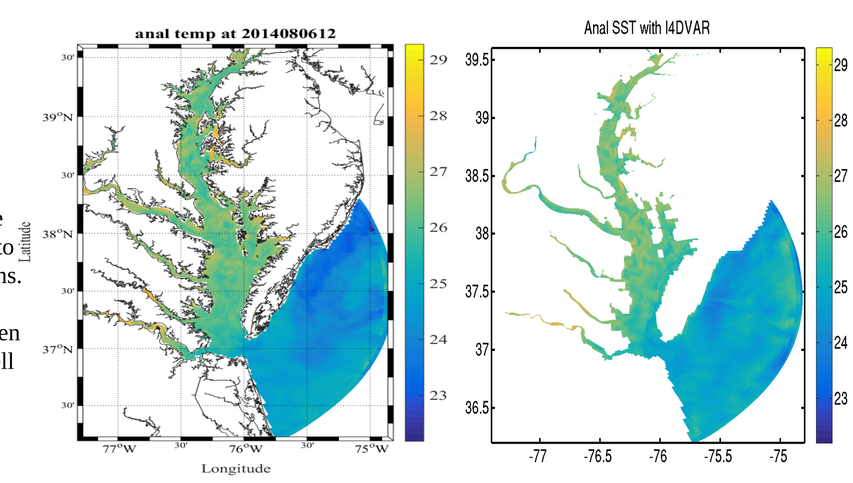


Figure 5: Model forecast SST bias reduction (compared to no DA) (left) and model forecasting skills(right) in 48 hours at 10 CBIBS stations. The forecasting skill f is calculated as

$$f = 1 - \sum(F_da - Obs)^2 / \sum(F_noda - Obs)^2$$

Figure 6: Initial Analysis using VIIRS SST on 08/06/2014 12:00 with LETKF and 4DVAR, respectively, shows that both DA methods produce similar results, very close to the VIIRS SST observations. In this case, LETKF also adjusts surface forcing, open boundary conditions as well as river forcing.



Results:

- One month (08/06/2014-09/06/2014) sequential 4DVAR data assimilation run using VIIRS Advanced Clear Sky Processor for Oceans (ACSPO) SST (Fig. 4) has successfully reduced the CBOFS model bias. The application of data assimilation has reduced the area mean SST from 27.4 ºC to 26.3 ºC, very close to mean VIIRS SST value of 25.8 ºC in that one month period.
- The correction of initial condition can have influence on the forecast for a couple of days. The model bias changes from -1.1 ºC to about -0.7 ºC in a two-days period. With 4DVAR, the CBOFS system has forecasting skills more than 0.6 for most CBIBS stations .
- 4DVAR and LETKF is comparable each other in performance (Fig. 6). Initial tests show LETKF can take less computational times, which depends on the ensemble number selected.

Ongoing Work:

- Daily composite AVHRR SST from NOAA coastal watch are being using with 4DVAR and can significantly reduce the model bias and standard deviations.
- Complete comparison between LETKF and 4DVAR with CBOFS in terms of performance and computational cost are being carried on.

References:

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