SST DATA IMPACT IN GLOBAL HYCOM

James A. Cummings

Naval Research Laboratory, Oceanography Division, Monterey, California, USA 93943
Email: cummings@nrlmry.navy.mil

ABSTRACT

An adjoint-based procedure to determine the impact of assimilation of observations on reducing ocean model forecast error has been integrated into the Navy's global HYCOM ocean analysis/forecast system (Cummings and Smedstad, 2013). Adjoint sensitivity gradients and actual model-data differences are used to estimate the impact of each observation assimilated on a measure of model forecast error (Langland and Baker, 2004). It is not necessary for an observation to produce a large change in the model initial conditions to have a large impact on reducing model forecast error. Observations with small model-data differences can have large impacts when the observation influences a dynamically sensitive location. The method provides a feasible all at once approach for determining observation impacts. The procedure is computationally inexpensive and can be used for routine observation monitoring. Data impacts can be partitioned for any subset of the data assimilated: instrument type, observed variable, geographic region, vertical level, or platform with traceability to individual platforms based on call sign. Results presented here show the impact of assimilation of the various SST observing systems on reducing HYCOM 48-hour temperature forecast error.

1. Introduction

Data assimilation corrects the errors of a short-term model forecast with new observations in order to generate improved initial conditions for the next forecast run of the model. It is likely that observations assimilated do not have equal value in terms of correcting model forecast error. The challenge then is to determine which observations are best. Adjoint-based data impact systems provide an objective and quantitative method to determine the value of the data assimilated. It is not necessary to add or remove observations from the assimilation to estimate data impact as is done in data denial experiments. This is advantageous since ocean observing and assimilation/forecast systems are in continuous evolution requiring an efficient procedure that allows the impact of observations to be regularly assessed.

2. Progress

The adjoint of the Navy Coupled Ocean Data Assimilation (NCODA) 3DVAR has been integrated into the Navy global HYCOM analysis/forecast system. HYCOM is executed on a global 1/12° resolution grid and cycles with the 3DVAR every 24 hours. Observation impact requires a forecast error metric which is calculated here as the difference between 72 and 48 hour forecasts valid at the same time. Any difference between the two model trajectories is due entirely to the assimilation of observations and represents the impact of observations assimilated on reducing HYCOM 48 hour forecast errors. HYCOM forecast errors are calculated for full model temperature, salinity, and velocity fields and are assumed to be valid at the model initialization time. Data impacts are calculated for each observation assimilated. A negative value indicates a beneficial impact (forecast errors decreased from assimilation of the observation), while a positive value indicates a non-beneficial impact (forecast errors increased). Non-beneficial data impacts are not expected. If they occur, and are persistent, then it may indicate problems in the data quality control, instrument calibration, error statistics used in the assimilation, or model error. Thus, the adjoint-based data impact system can be used as an effective observing system monitoring tool.

Figure 1 gives an example of a HYCOM forecast error map for SST in the Gulf of Mexico on 24 July 2012. Considerable flow dependence is seen in the forecast errors associated with the loop current and a large eddy in the center of the Gulf. Figure 2 gives a time series of daily impacts of satellite SST observing systems averaged over the HYCOM Atlantic basin during October-November 2012. All sources of satellite SST assimilated reduce HYCOM forecast errors every day. Figure 3 shows the geographic variability of METOP-A and GOES data impacts averaged on the HYCOM grid during the same time period. In general, beneficial impacts are seen almost everywhere. However, some persistent non-beneficial impacts occur with the METOP-A data in the eastern tropical Atlantic likely associated with atmospheric dust, and in the eastern fringe of the GOES data probably due to scan angle dependent errors. Finally, Figure 4 gives rank histograms showing the relative importance of the satellite SST observing systems assimilated by global HYCOM in the Atlantic. METOP-A and NOAA-19 have nearly equivalent data impacts with GOES data the least important source of satellite SST data assimilated on a per observation basis. No discernible difference is found in the impacts of day vs. night and GAC vs. LAC retrieval types for METOP-A in HYCOM, although LAC data types are by far the most frequent.

3. Future Capabilities

In addition to global HYCOM, the NCODA 3DVAR adjoint has been integrated into the Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) adjoint-based observation impact system. Here, atmospheric forecast error metrics (dry energy, moist energy, refractivity) and the adjoint of atmospheric forecast model are used to determine initial condition sensitivity gradients and quantify the impact of SST observations on high-resolution forecasts of atmospheric boundary layers. Thus, the NCODA adjoint-based data impact system can be used to determine the relative importance of the various satellite SST observing systems on both ocean and atmospheric forecast systems. This work is on-going.

4. References

Cummings, J. and O.M. Smedstad (2013). Variational Data Assimilation for the Global Ocean. In, *Data Assimilation for Atmospheric, Oceanic & Hydrologic Applications (Vol. II*). S. Park and L. Xu (eds). Springer, pp. 303-343.

Langland, R. and N. Baker (2004). Estimation of observation impact using the NRL atmospheric variational data assimilation adjoint system. Tellus 56A:189-201.

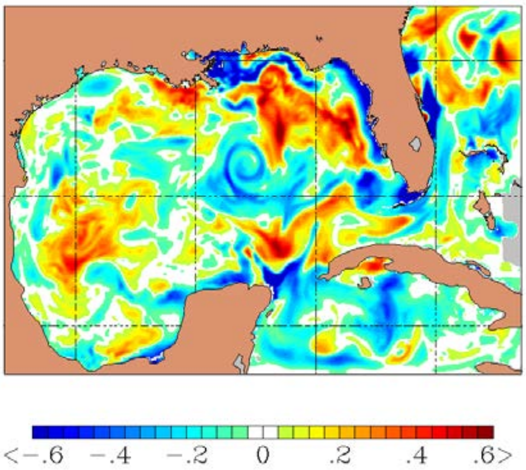

Figure 1. HYCOM SST forecast errors in Gulf of Mexico 24 July 2012. Negative values indicate forecast error reduction; positive value indicates forecast errors increase.

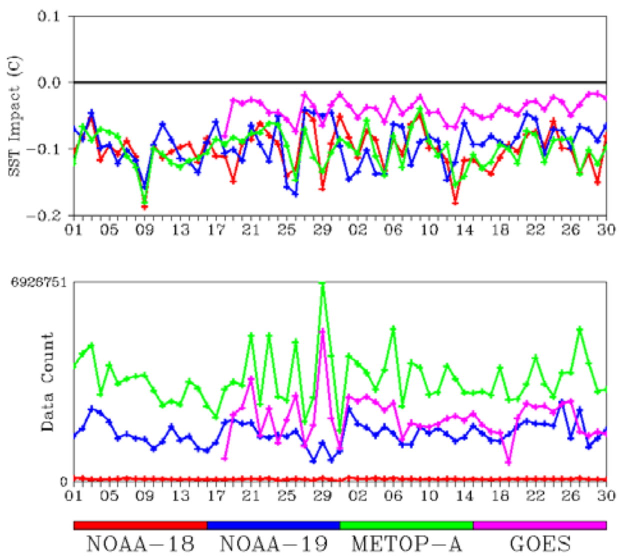

Figure 2. Daily satellite SST data impacts for HYCOM Atlantic basin: October-November 2012. Negative values indicate beneficial impacts.

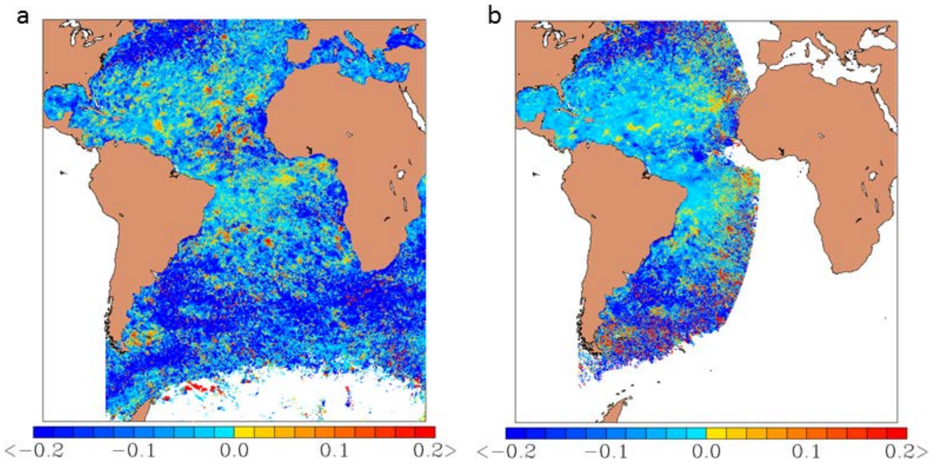

Figure 3. Geographic distribution of SST data impacts averaged on the 1/12° HYCOM Atlantic basin model grid for October-November 2012. (a) METOP-A, (b) GOES. Negative values (cool colors) indicate beneficial impacts.

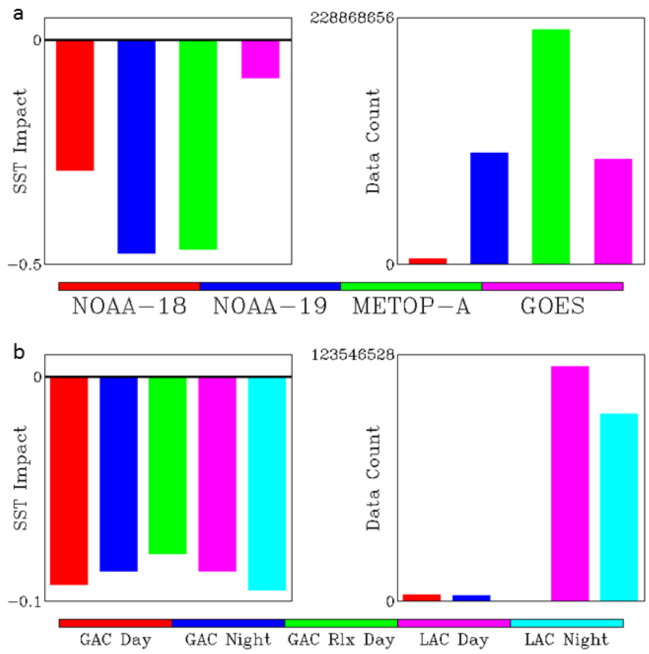

Figure 4. Rank order histograms of HYCOM Atlantic basin satellite SST data impacts and observation data counts for October-November 2012. (a) Satellite SST observing system data impacts; (b) METOP-A retrieval type data impacts. Negative values indicate beneficial impacts.