EVALUATION OF ASSIMILATIVE SST FORECASTS IN THE OKINAWA TROUGH AND GULF OF MEXICO

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ABSTRACT

Regional ocean models assimilate a variety of sea surface temperature (SST) observations to bring their analyses and forecasts into agreement with measured conditions. We examine the skill of forecasts from the Naval Coastal Ocean Model (NCOM) implemented in the Okinawa Trough and Gulf of Mexico. Each of these is guided by satellite and in situ observations using three–dimensional variational assimilation (3DVAR) through the Navy Coupled Ocean Data Assimilation System (NCODA). The impact including various satellite data streams is evaluated by comparing model analyses and forecasts to unassimilated ship and buoy observations.

1. Introduction

Satellite measurements of sea surface temperature (SST) provide one of the most important data streams supporting real time ocean analyses and forecasts. Before including a new SST data stream within an operational data–assimilating forecast system, it must be demonstrated the inclusion has an overall positive impact. Use of more data does not guarantee improved analyses and forecasts. The impact of observations from a particular platform are a function of measurement accuracy, data distribution and uncertainty relative to other observing systems, timeliness, and representativeness for scales and processes resolved by the assimilative system. These impacts vary by time and location and may be positive or negative. Evaluation of products relative to independent in situ observations provides a basis for assessing the impact of various data sources as well as other errors within the forecast systems.

This article focuses on selected evaluations from two regions, the Okinawa Trough (17–34°N,118–134°E) as a region of interest to our Japanese hosts of the GHRSST XIII meeting and the Gulf of Mexico (18–31°N,79–98°W) as the IOOS regions closest to the workplace of the authors. Assimilation and nowcast analyses employ the Navy Coupled Ocean Data Assimilation System (NCODA; Cummings, 2005); forecasts are generated by systems linking NCODA with regional implementations of the Navy Coastal Ocean Model (NCOM; Barron et al., 2006). The models in both have 3 km horizontal grid spacing, use Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) fluxes on the upper boundary, and receive initial (start of experiment) and boundary conditions from the operational global ocean model GOFS 2.6. The SST level 2 data assimilated in these studies is provided by NAVOCEANO and introduced into NCODA via its OCNQC process. Daytime and nighttime SST are assimilated via 3DVAR in a 24–hour update cycle using a first guess from the prior day's NCOM forecast. Section 1 examines the addition of AMSR–E in the Okinawa Trough, while section 2 considers AVHRR and GOES in the Gulf of Mexico. The conclusion extends consideration of diurnal variations and plans for continuing work.

2. AMSR–E in the Okinawa Trough

Ocean model case studies over 2008–2009 in the Okinawa Trough compared cycling NCOM/NCODA systems assimilating altimetry, in situ profiles, and satellite AVHRR SST. Surface drifter and ship observations were withheld to serve as an independent comparison. The data were assimilated using a first guess at the appropriate time (FGAT) approach to account for temporal variability in the background. The experimental case additionally assimilated SST from AMSR–E while the control did not. Results in Table 1 indicate that inclusion of AMSR–E slightly increased mean bias while slightly reducing RMS error. As AMSR–E is masked near the coast to avoid land contamination of the microwave signal, the statistics in Table 2 are selected using ~330K matchups at least 50 km from land. RMS and bias errors are smaller but continue to show larger bias with smaller RMS error when AMSR–E is assimilated. In both sets of matchups, similarities between analysis and forecast bias and RMS errors show no indications of significant model drift. Work into additional operational bias corrections for the AMSR–E data was suspended when AMSR–E stopped transmitting observations on 10 October 2011.

	Regional NCODA/NCOM (Okinawa Trough), All SST						
	Simulation	AMSR SST Assimilated			AMSR SST Not–Assimilated		
		R	Bias (°C)	RMS (°C)	R	Bias (°C)	RMS (°C)
2008	NCODA Analysis	0.95	0.16	0.99 ●	0.95	0.05 ●	1.00
	NCOM 24 Hr Fcst	0.94	0.13	1.01 ●	0.94	0.04 ●	1.04
	NCOM 48 Hr Fcst	0.94	0.08	1.04 ●	0.94	–0.01 ●	1.07
2009	NCODA Analysis	0.96	0.09	0.93 ●	0.96	0.00 ●	0.96
	NCOM 24 Hr Fcst	0.95	0.10	0.99 ●	0.95	0.01 ●	1.02
	NCOM 48 Hr Fcst	0.95	0.06	1.02 ●	0.95	–0.02 ●	1.05

Table 1: Statistics associated with ~400K matchups between independent analyses and forecasts in the Okinawa Trough and independent in situ observations (OCNQC ship/buoy). Green circles indicate the case with smaller errors.

	Regional NCODA/NCOM (Okinawa Trough), SST > 50 km from Land						
	Simulation	AMSR SST Assimilated			AMSR SST Not–Assimilated		
		R	Bias (°C)	RMS (°C)	R	Bias (°C)	RMS (°C)
2008	NCODA Analysis	0.94	0.16	0.94 ●	0.94	0.04 ●	0.96
	NCOM 24 Hr Fcst	0.94	0.13	0.97 ●	0.94	0.02 ●	0.99
	NCOM 48 Hr Fcst	0.94	0.08	0.99 ●	0.93	–0.03 ●	1.02
2009	NCODA Analysis	0.96	0.09	0.89 ●	0.96	–0.02 ●	0.92

Regional NCODA/NCOM (Okinawa Trough), SST > 50 km from Land						
Simulation	AMSR SST Assimilated			AMSR SST Not–Assimilated		
	R	Bias (°C)	RMS (°C)	R	Bias (°C)	RMS (°C)
NCOM 24 Hr Fcst	0.95	0.08	0.94 ●	0.95	–0.02 ●	0.98
NCOM 48 Hr Fcst	0.95	0.04 ●	0.98 ●	0.95	–0.05	1.01

Table 2: Statistics associated with matchups between independent analyses and forecasts in the Okinawa Trough and independent in situ observations (OCNQC ship/buoy). Green circles indicate the case with smaller errors. Matchups are restricted to at least 50 km from land.

3. GOES in the Gulf of Mexico

Two sources of SST observations are considered in the Gulf of Mexico study: polar–orbiting NOAA AVHRR SST in both its global (GAC) and local (LAC) area coverage, and geostationary GOES SST. The spatial representativeness of these GAC, LAC and GOES measurements is nominally 2.2, 8.8 and 4 km, respectively, as shown in the examples of figure 1. The 30–minute sampling frequency of the GOES observations enables much better coverage than is available from the nominally 12–hour interval between ascending and descending AVHRR swaths.

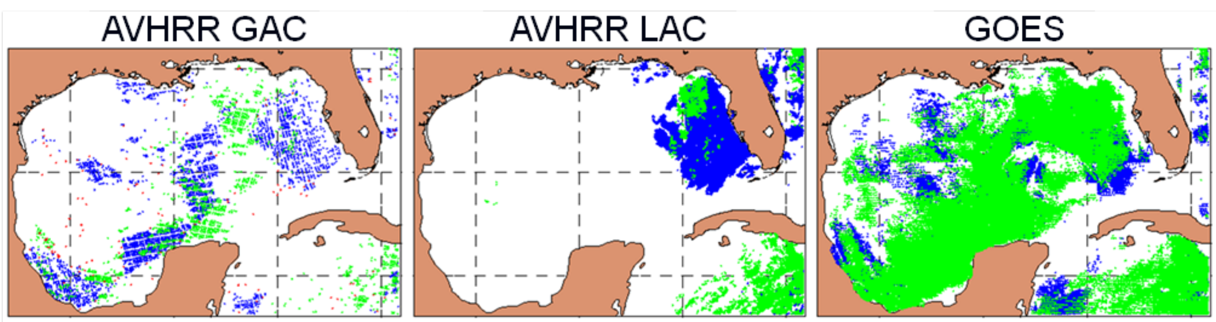

Figure 1: GAC, LAC, and GOES coverage in the Gulf of Mexico on 15 January 2010. Green and blue points indicate day–time and night–time measurements, respectively.

Three NCOM simulations are used to evaluate introduction of GOES into the standard AVHRR–centric input stream of satellite observations. The control case assimilates NOAA AVHRR SST (GAC and LAC), a second case replaces the AVHRR stream with GOES, and a third case assimilates both AVHRR and GOES. All cases additionally assimilate altimeter and in situ profiles but reserve the surface ship and buoy observations for independent validation. FGAT was not used in the Gulf of Mexico cases. The three simulations are initiated from a common 01 December 2009 initial condition regridded from GOFS 2.6. Annual statistics over 2011 (Table 3) show SST bias is <0.1°C warm with RMS error <0.9°C. The differences in bias are mixed, but the RMS errors indicate a preference for the combined data streams. More notable than the differences among the cases is the degradation over the forecast, with the forecast bias about 0.25°C colder than the slightly warm analysis bias. RMS error increases by 0.1°C.

Table heading	AVHRR only	GOES only	GOES + AVHRR
Bias °C (model – observation)			
nowcast	0.07	0.05	0.07
forecast	–0.20	–0.23	–0.21
RMS error °C			
nowcast	0.84	0.88	0.83
forecast	0.96	0.99	0.95

Table 3: Statistics associated with 364336 matchups between Gulf of Mexico SST NCODA analyses, 72–hour NCOM forecasts, and independent surface observations.

4. Conclusion

A seasonal breakdown of the matchups by local time of day provides additional insight into the forecast cold bias. Winter 2010–2011 (Figure 2) and summer 2011 (Figure 3) errors are largest in magnitude during midday to late afternoon. Bias is coolest in late afternoon, suggesting an underestimation of diurnal warming. In addition, biases are near zero in winter but 0.2–0.8°C cool in summer. A possible source of these discrepancies is a low bias in the incoming solar radiation. A 6–hour update cycle or FGAT approach using GOES observations might reduce analysis errors but would be unable to address the forecast bias; 3DVAR assimilation addresses errors in the initial state. A 4DVAR approach that jointly mitigates errors in the initial state and boundary conditions holds more promise in these cases. Alternatively, other methods have been developed to calibrate or adjust surface forcing according to satellite measurements of the terms in the bulk heat flux formulation. Work at NRL is progressing along these avenues in addition to continuing work on incorporating the GHRSST data streams into the Navy ocean forecast systems.

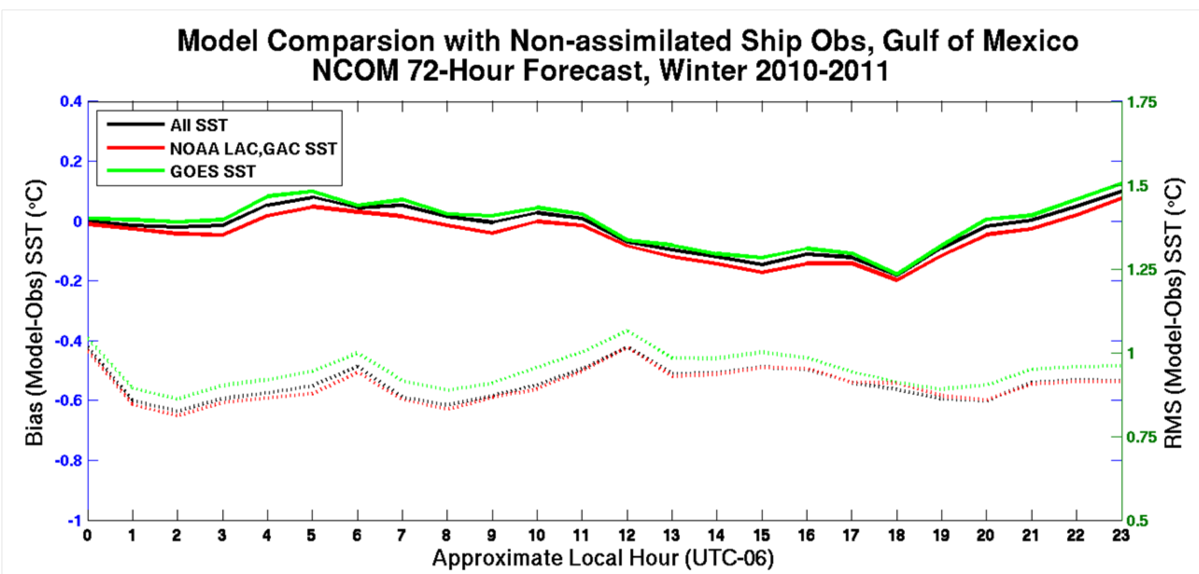

Figure 2: Winter (2010–2011) matchups binned by hour between observations and tau 48–72 forecasts. Bias (RMS error) is shown by solid (dashed) lines with the scale on the left (right).

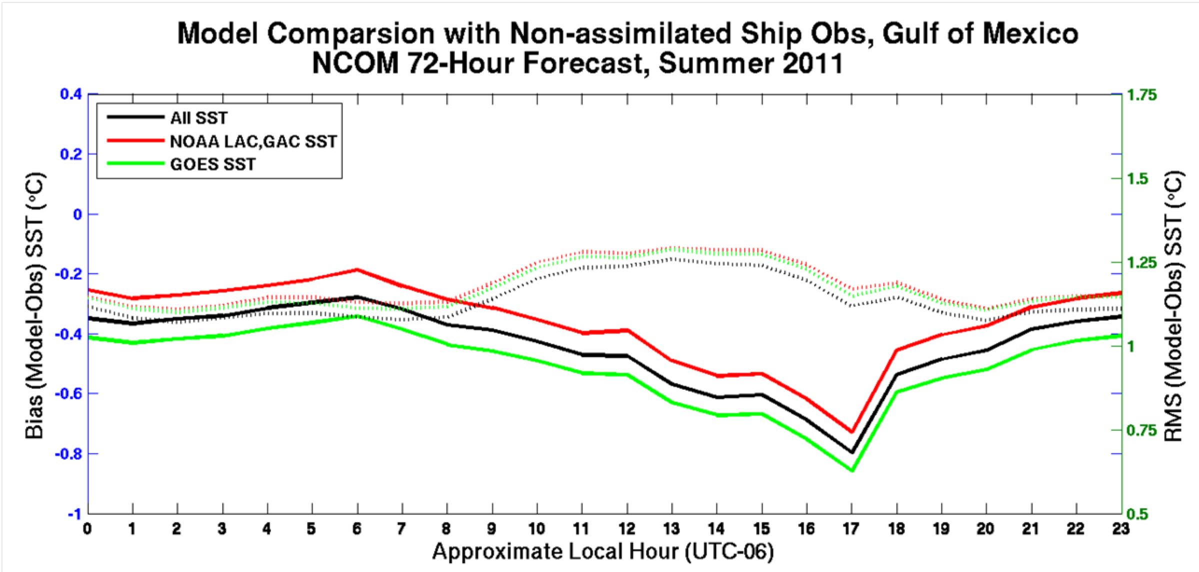

Figure 3: As in figure 2 for summer 2011.

5. References

Barron, C. N., A. B. Kara, P. J. Martin, R. C. Rhodes, and L. F. Smedstad, Formulation, implementation and examination of vertical coordinate choices in the global Navy Coastal Ocean Model (NCOM), Ocean Model., **11**(3–4), 347–375, doi:10.1016/j.ocemod.2005.01.004, 2006.

Cummings, J. A., Operational multivariate ocean data assimilation, *Quart. J. Roy. Met. Soc.* **131**, 3583–3604, 2005.