SMOS Satellite Sea-surface Salinity Data: Impact on Upper-ocean Modelling

Bin Li[1], Avichal Mehra[2], and Eric Bayler[3]
[1]IMSG at NOAA/NWS/NCEP/EMC, [2]NOAA/NWS/NCEP/EMC, [3]NOAA/NESDIS/STAR
Bin.Li@noaa.gov

Satellite sea-surface salinity (SSS) observations provide a new means for constraining an important state parameter in numerical ocean models. The benefits of assimilating satellite SSS observations include improved model surface density, near-surface convection, and thermohaline circulation. NOAA's Real-Time Ocean Forecast System (RTOFS)-Global [1] employs an eddy-resolving 1/12th-degree (approximately 9 km horizontal resolution) Hybrid Coordinate Ocean Model (HYCOM) [2]. In the current operational configuration, the RTOFS-Global sea-surface salinity is relaxed to Polar Science Center Hydrographic Climatology version 3.0 (PHC3) SSS fields [3]. Experiments that separately use satellite SSS data and the PHC3 SSS climatology have been conducted to assess the impact of satellite surface salinity measurements on simulated upper-ocean salinity, temperature, and sea-surface height fields.

The first phase of these experiments employs a lower-resolution (1/4th-degree horizontal resolution) HYCOM model. Nine experiments have been performed (Table 1). In the control run, sea-surface salinity is relaxed to an annual cycle of climatological monthly-mean values of SSS (PHC3 climatology). Two sets of cases are then used to explore the model's sensitivity to constraining SSS to satellite measurements, both in terms of relaxation strength and satellite data update interval using monthly-mean and nine-day-mean satellite SSS data from the European Space Agency's Soil Moisture – Ocean Salinity (SMOS) mission [4]. Relaxation strength is modified by changing the e-folding time ($30 \times H_m/H_s$ days), where H_m is the mixed-layer depth and H_s is a reference depth. Greater H_s leads to a shorter e-folding time scale, increasing the constraint on surface salinity by more quickly relaxing surface salinity to the specified SSS reference field.

Table 1. List of experiments

Case	Relaxation Reference SSS	H_s (relaxation strength)
PHC_CL (control)	PHC monthly-mean climatology	15 m
SMOS_MN_15M	SMOS monthly-mean	15 m
SMOS_MN_45M	SMOS monthly-mean	45 m
SMOS_MN_75M	SMOS monthly mean	75 m
SMOS_MN_105M	SMOS monthly mean	105 m
SMOS_9D_15M	9-day mean SMOS	15 m
SMOS_9D_45M	9-day mean SMOS	45 m
SMOS_9D_75M	9-day mean SMOS	75 m
SMOS_9D_105M	9-day mean SMOS	105 m

The results show that the use of satellite SSS data reduces the root-mean-square error (RMSE) of modelled SSS, referenced to SMOS observations (Figs.1a-d). The improvement of SSS is more significant when model SSS is more tightly constrained to observations. On the other hand, increasing data update frequency by using the 9-day-mean SMOS data slightly increases the RMSE of SSS generally everywhere. For the equatorial band 5°S - 5°N, more tightly constraining SSS produces clear and more intense heating along the thermocline in each of the ocean basins (most notably in the Pacific) with the exception of the far western Atlantic, which experiences stronger cooling. The additional signal from increasing the SSS update rate intensifies the monthly-update heating signal along the thermocline, except in the Atlantic, where the additional signal is the opposite of the monthly signal, cooling along most of the thermocline. With more tightly constrained model SSS, salinity is generally fresher everywhere within the 5°S - 5°N equatorial band, except for the eastern Pacific, not including the core of the cold tongue. Intense freshening occurs in the western Pacific, with narrow bands of comparably intense freshening in the Pacific cold tongue and far western Atlantic regions. The freshening seen in the western Atlantic is potentially associated with better representation of freshwater influx from major South American rivers. Increasing the SSS update rate increases salinity relatively uniformly nearly everywhere in the equatorial band, with some narrow intensification in the far eastern and far western portions of each basin. In general, incorporating satellite SSS data improves modeled sea surface height anomalies in the mid-latitude North Atlantic and North Pacific regions.

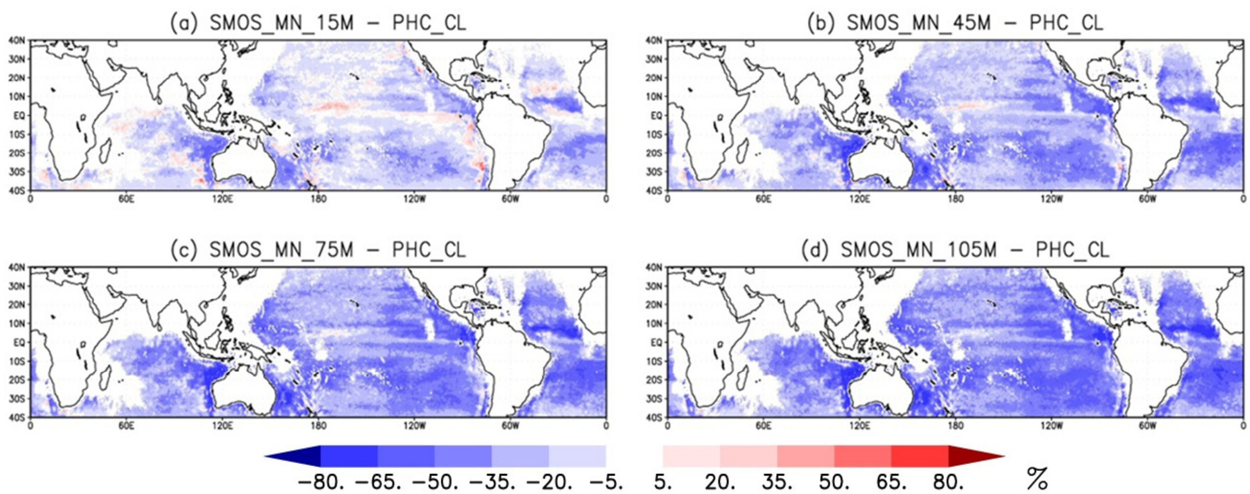

Figure 1. Root mean square error (RMSE) change – SMOS monthly-mean SSS data cases versus control case using PHC SSS climatology, referenced to SMOS observations, with increasing constraint to observed SSS: H_s = a) 15m, b) 45m, c) 75m, and d) 105m.

In terms of constraining models, models have long had a good initial temperature state but not a good initial salinity state. While satellite SSS observations improve the situation, the number of in situ subsurface observations remains inadequate. Modeling needs a mechanism for constraining subsurface salinity values; consequently, research needs to explore not only the use of satellite SSS to constrain modeled surface values but also how to extract/project meaningful values for the upper-ocean.

References:

[1] Mehra A., I. Rivin, H.L. Tolman, T. Spindler and B. Balasubramaniyan, 2011: A Real Time Operational Global Ocean Forecast System. Presented at US GODAE Ocean View Workshop on Observing System Evaluation and Inter-comparisons, Univ. of California Santa Cruz, CA, USA, 13-17 June 2011.
[2] Bleck, R., 2002: An oceanic general circulation model framed in hybrid isopycnic-cartesian coordinates, Ocean Modeling, 4, 55-88.
[3] Steele, M., R. Morley, and W. Ermold, 2001: PHC: A global ocean hydrography with a high quality Arctic Ocean, J. Climate, 14, 2079-2087.
[4] SMOS-BEC Team, 2015: SMOS-BEC Ocean and Land Products Description, BEC-SMOS-0001-PD.pdf version 1.4 dated 18 Jun 2015, http://www.smos-bec.icm.csic.es.