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Suitability of satellite sea surface salinity data for use in assessing and correcting ocean forecasts

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ABSTRACT

Near-surface salinity data from the Forecasting Ocean Assimilation Model (FOAM) system are used to understand various characteristics of satellite sea surface salinity (SSS) data from SMOS. The errors in the model fields are first estimated by comparing them to near-surface Argo salinity measurements, with RMS errors of less than 0.2 pss over most of the global oceans, except for regions of high variability in SSS such as boundary current regions and areas of large precipitation or river run-off. Regional biases are generally less than 0.05 pss but some regions such as the Antarctic Circumpolar Current and the region to the north of the Gulf Stream extension have larger biases. Various different processing versions of the SMOS data are assessed, including different temporal and spatial averaging, and the daily 1° resolution SMOS differences to FOAM are approximately 3–10 times larger than Argo-FOAM differences. The spatial information in the SMOS data is also assessed by comparing spatial gradients in the satellite SSS data with those calculated from other datasets including satellite sea surface temperature (SST) and satellite altimeter sea surface height (SSH) data, as well as with the model's gradients. The SMOS data contain information about the underlying ocean dynamics in the summer months, in agreement with the SSH data, which are not present in the satellite SST data or in the model's SSS fields. This demonstrates that the data contains useful information which could be used to correct the model through data assimilation.

1. Introduction

Ocean forecasting systems such as the Forecasting Ocean Assimilation Model (FOAM) system (Blockley et al., 2014) aim to produce accurate forecasts of the three-dimensional ocean temperature, salinity and currents, as well as sea-ice variables, for various users including Navies, search and rescue, oil spill, ship routing, oil and gas, and research users. The FOAM system is also now being used in conjunction with the existing Met Office Numerical Weather Prediction (NWP) system to develop short- to medium-range coupled ocean/atmosphere forecasts. For both forced-ocean and coupled ocean/atmosphere forecasting, understanding the errors at the sea surface provides an important method for identifying sources of forecast error, as the impact of the atmospheric forcing on the ocean is then directly observable. We can then more easily distinguish the sources of errors between atmospheric forcing and internal ocean model errors which is difficult if only sparse subsurface observations are available.

Assessment of surface temperature errors has taken place routinely for many years due to the large amount of sea surface temperature (SST) data available, for example through the Group for High Resolution SST (Donlon et al., 2010). The other variable affecting the ocean's density, salinity, has not been observed to anywhere near the same extent as temperature. Argo provides a very useful data-set of salinity since about 2003 (Freeland et al., 2010), but the data are sparse (roughly 3° × 3° horizontal resolution every 10 days) and usually only measure within about 5 m of the surface. The relatively new data-sets provided by the Soil Moisture Ocean Salinity (SMOS; Font et al., 2012) and Aquarius (Lagerloef et al., 2012) satellite missions, launched in 2009 and 2011 respectively, provide a wealth of sea surface salinity (SSS) information which could be exploited through model assessment and assimilation.

SSS is a difficult quantity to measure from space for various reasons. The brightness temperatures measured by satellites in the L-band are related to the SSS through a complicated relationship which includes dependence on SST as well as the sea surface roughness induced by waves and foam (Yin et al., 2012a), Galactic radiation at L-band frequencies are reflected by the sea surface and can contaminate the signal received by the satellites with varying power depending on the time of day (Le Vine and Abraham, 2004). The reflection of solar radiation by

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the sea surface also affects the signal received by the satellite in the L-band and this sun glint needs to be accounted for (Reul et al., 2007). Radio frequency interference (RFI) from sources over land also has significant impacts on the retrieved salinity (Oliva et al., 2012). Calibration and validation of the retrieved surface salinity is also challenging given the different depth sampling and sparse horizontal sampling of the in situ salinity network, as described in Tang et al. (2014).

Despite all these complications in the retrieval of SSS from space, numerous investigations have demonstrated that important ocean processes can be seen in satellite SSS data. Lee et al. (2012) show that Aquarius data can detect Tropical Instability Waves (TIW) in the Pacific; in the frame of SMOS + SOS project (see http://www.smos-sos.org), Yin et al. (2014) demonstrated that SMOS also detects TIW. Grodsky et al. (2012) show the impact of hurricanes on surface salinities in the Amazon/Orinoco river plume and the important relationships between surface salinity and the mixing of heat associated with a hurricane. Gierach et al. (2013) use Aquarius and SMOS data to detect a river flooding event in the Gulf of Mexico. Boutin et al. (2013) investigate the relationship between rain rates and surface ocean freshening in satellite observations. Reul et al. (2014) demonstrate the ability of SMOS data to identify mesoscale structures in the Gulf Stream which are not well-observed by SST data in the summer months, and which correspond to features measured by sea level satellite data.

A few studies to date have investigated the suitability of SMOS and Aquarius data to be used for ocean model assessment and assimilation. Vinogradova et al. (2014) carry out a model-data comparison exercise for both SMOS/Aquarius satellite and in situ surface salinity measurements to understand the relative errors in each estimate, with the aim of using those error estimates in future assimilation studies. The model used is in that study is part of the ECCO system (Wunsch and Heimbach, 2013), with the model data coming from a model-only (no data assimilation) run of the MITgcm and comparisons carried out for

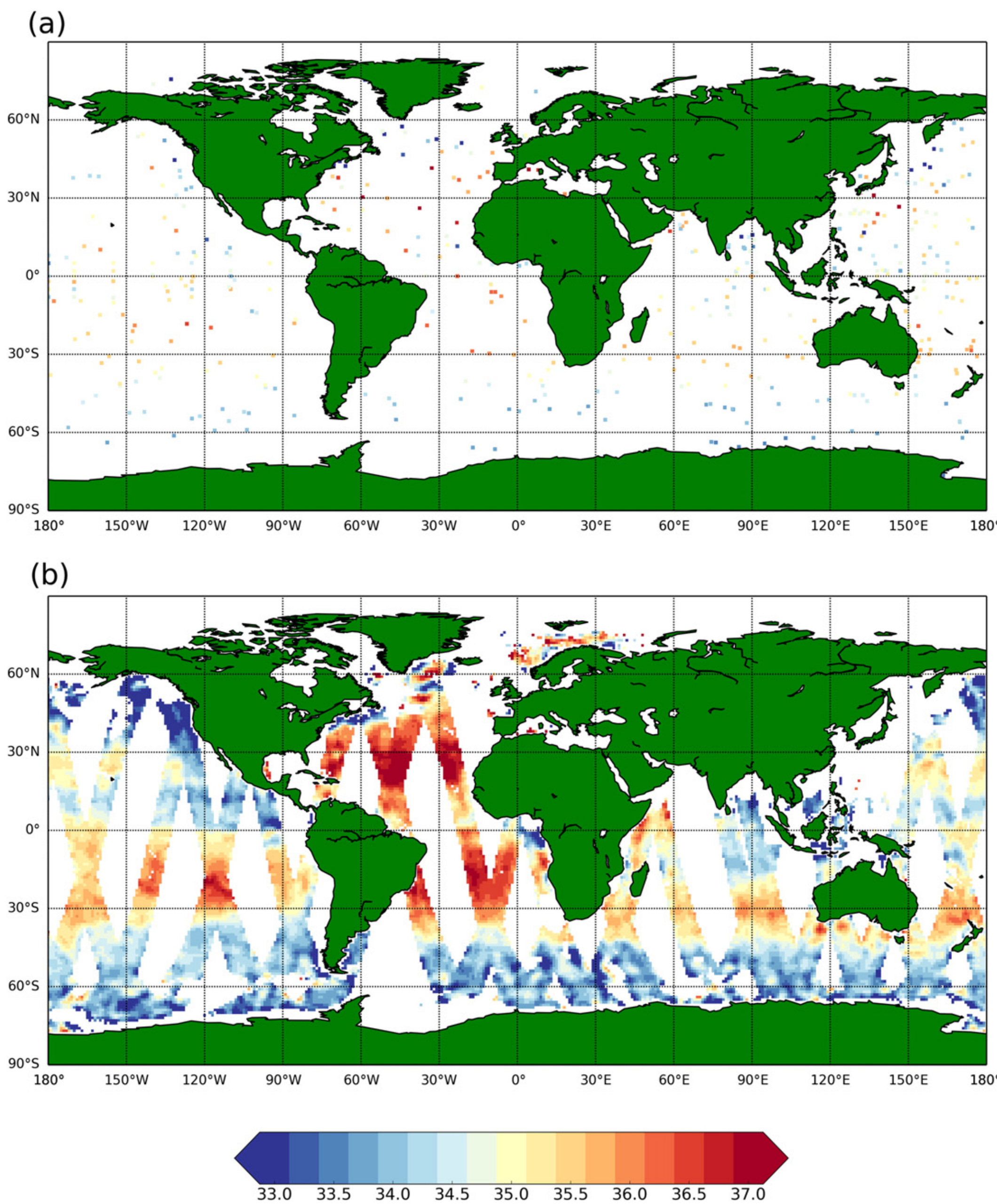

Fig. 1. Example observation coverage for one day (1st Feb 2012) for (a) Argo, (b) SMOS (1°, daily product from Ifremer). The values are sea surface salinity (pss).