Multi-temporal monitoring of salinity in Eastern Mediterranean Region using SMOS L2 OS satellite data and in situ measurements.

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Abstract

This study has been motivated to assess, for the first time, the performance of Sea Surface Salinity, *SSS* of the Soil Moisture and Ocean Salinity (SMOS) satellite launched by the European Space Agency (2009), on the Mediterranean Region. The SMOS satellite is a microwave radiometer which records at 1.4 Ghz frequency and at a wavelength l = 21cm, the microwave radiation emitted from the surface of the oceans. The physical properties of the sea water, salinity and temperature are the key factors that need to be constantly monitored. This constant monitoring contributes to a better understanding of the motion of ocean currents. Ocean currents transfer a large amount of heat from the equatorial regions to the poles, sustaining this way the global climate. Until recently the monitoring of salinity and temperature, took place mainly by ship measurements and monitoring stations (Buoys) located in the open ocean, which were sparse, regional and highly costly to maintain. The SMOS mission launched in November 2009, would record for the first time the soil moisture and ocean salinity from space. The mission's objective is the global observation of salinity with a monthly accuracy of 0.1 psu. The data used for the study are L2 OS gridded in bins of 0.5° in latitude and longitude (by Reul, N.) and in-situ data provided by the Hellenic Centre of Marine Research/HCMR and the POSEIDON project. The area of interest is the East part of the Mediterranean (Fig.1) and both the satellite and in-situ data cover a period of three years (2010-2012). Due to the absence of Buoys in the broader area of East Mediterranean, hydro dynamical forecasting models were used provided by the HCMR's Live Access Server/LAS portal for the comparison of the data. The results of the study show very poor quality of SMOS-derived SSS values due to "land contamination" and RFI emissions.

Key Words: Salinity, Mediterranean, SMOS, L2OS,

I. Introduction

The physical properties of the sea water, salinity and temperature, are the key factors that need to be constantly monitored. This constant monitoring contributes to a better understanding of the motion of ocean currents. Ocean currents transfer a large amount of heat from the equatorial regions to the poles, sustaining this way the global climate. Until recently the monitoring of salinity and temperature, took place mainly by ship measurements and monitoring stations (Buoys) located in the open ocean, which were sparse, regional and highly costly to maintain. The SMOS mission launched in November 2009, will record for the first time the soil moisture and ocean salinity from space. The satellite's repeat cycle is 149 days. The main instrument of the satellite is MIRAS (Microwave Imaging Radiometer with Aperture Synthesis), a microwave radiometer using the L-band, that retrieves surface ocean salinity and soil moisture The mission's objective is the global observation of salinity with a monthly accuracy of 0.1 psu (www.esa.int).

As far as the Mediterranean Sea is concerned, salinity holds an important role to the thermohaline circulation within the basin. In the East Mediterranean basin the dense and salty water (LIW) is formed, which exits the Mediterranean through the thermohaline circulation, from the straits of Gibraltar, into the Atlantic Ocean. Because of its density, the Mediterranean water doesn't remain on the surface, but it sinks in intermediate depth and becomes part of the dense Atlantic Water. The significance of the Mediterranean Sea in global circulation is high, but more important is, its complexity as a basin and its variability in circulation (Robinson, A., 2001)

In this study it is examined whether the SMOS L2OS data products could show good results regarding the sea surface salinity of a closed basin like the Mediterranean. The methods used for the validation of the SMOS products, were correlation plots between the satellite data and the daily in-situ measurements from the buoys

(Ratheesh,S.,2012), and the data given by the hydro dynamical models. Visual assessment of SMOS products and the hydro-dynamical models, was performed with the use of BEAM-Visat, ESA's EO toolbox that is developed by www.brockmann-consult.de.

II. Data and Methodology.

The data obtained for this study were SMOS L2 OS swath-based data from ESA's on-line catalogue, EOLI-SA, which can also be found on http://www.argans.co.uk. These data cover a time period of three years (2010-2012). In-situ measurements for the same time period were obtained by HCMR's project, POSEIDON. POSEIDON is a network of observation Buoys that record continuously the physical, chemical and biological parameters of the Greek seas (poseidon.hcmr.gr). From this network of active buoys, only data from one buoy (E1M3A) were suitable for this study, due to its location with coordinates [Lat. 35° 46' 59.40''N, Long. 24° 54' 52.80"E], that matched the L2 SMOS data. Also due to technical problems of the buoy, data from the year 2010 were only retrieved. Although the buoys don't measure physical properties on the sea surface, it is possible to use the shallowest measurement. The shallowest measurement for the POSEIDON buoys is 1 m depth from the surface. Also the data from the buoy, which are in time-series of three hours, were interpolated, so they could be matched, with the respected time of the SMOS L2 data for more accuracy. A correlation plot was used for the year 2010 to compare the data from SMOS and the in-situ data from the buoy.

For the year 2011 data were chosen according to the seasonal cycle of the Mediterranean regarding salinity (**Sorgente,R**.,**2003**). In that case the comparison among data was based on the mean number of salinity of a larger area, where the seasonal behavior can be spotted according to the different tones of grey as it can be seen in Fig.1. The satellite data from SMOS and the responding data from the hydro-dynamical models that were used, had the following dates for years 2010 and 2011 respectively: 25-02, 01-03, 02-03 07-03 for winter months and 28-08, 29-08, 02-09, 03-09, 08-09 for months during summer. Again correlation plots were used to compare the mean values of salinity of the hydro-dynamical forecasting model for each year, with the mean values for the same years of SMOS products.

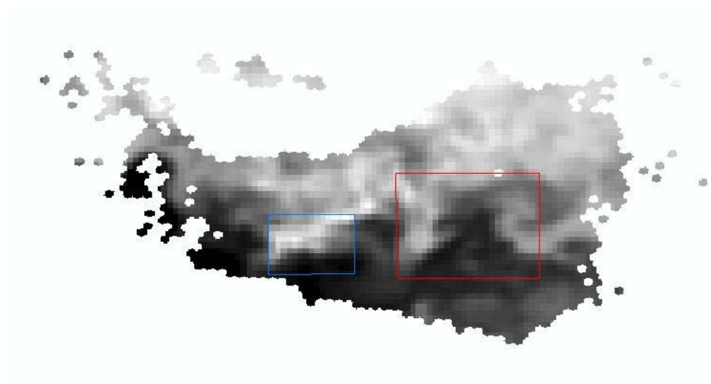

Figure 1 Hydro-dynamical forecasting model of East Mediterranean. The red and blue polygons indicate the areas of sampling where the mean values of salinity were calculated with BEAM-Visat.

For 2010 another approach of 10 day averaged monthly salinity data covering an area of 50x50km in the East Mediterranean, was used (Fig.2). This method is used by SMOS L2 team for the calibration of the SMOS L2 OS data in the open ocean (Font et.al, 2010). An averaged value of salinity for ten days was used for each month for the year 2010, both from SMOS products and the hydro-dynamical forecasting models. Correlation plots were used again to compare the averages.

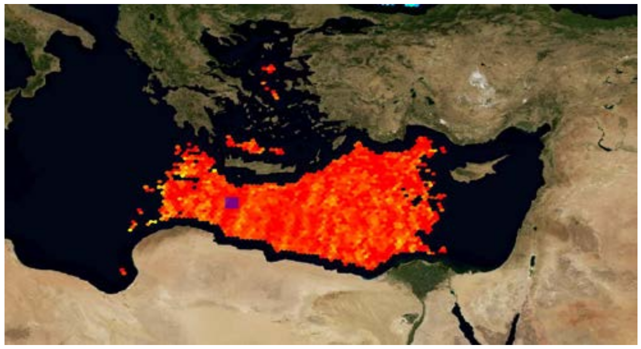

Figure 2 Image exported from BEAM-Visat of the area of study. The purple polygon shows the area of sampling (50x50km)

Finally a different method was employed with the usage of ESA's software, BEAM-Visat, to compare spatially the SMOS L2 OS data and the hydro-dynamical models. With the software's tool "Mask Manager", each file was divided into classes, according to the amplitude of salinity values of the Mediterranean model, which is considered reasonably trustworthy, compared to the amplitude of values given by SMOS SSS1, raging between 32 and 42 psu. The range of values given by the hydro-dynamical model is closer to reality for the area, with the psu values ranging between 38 and 41 psu (Fig.3).

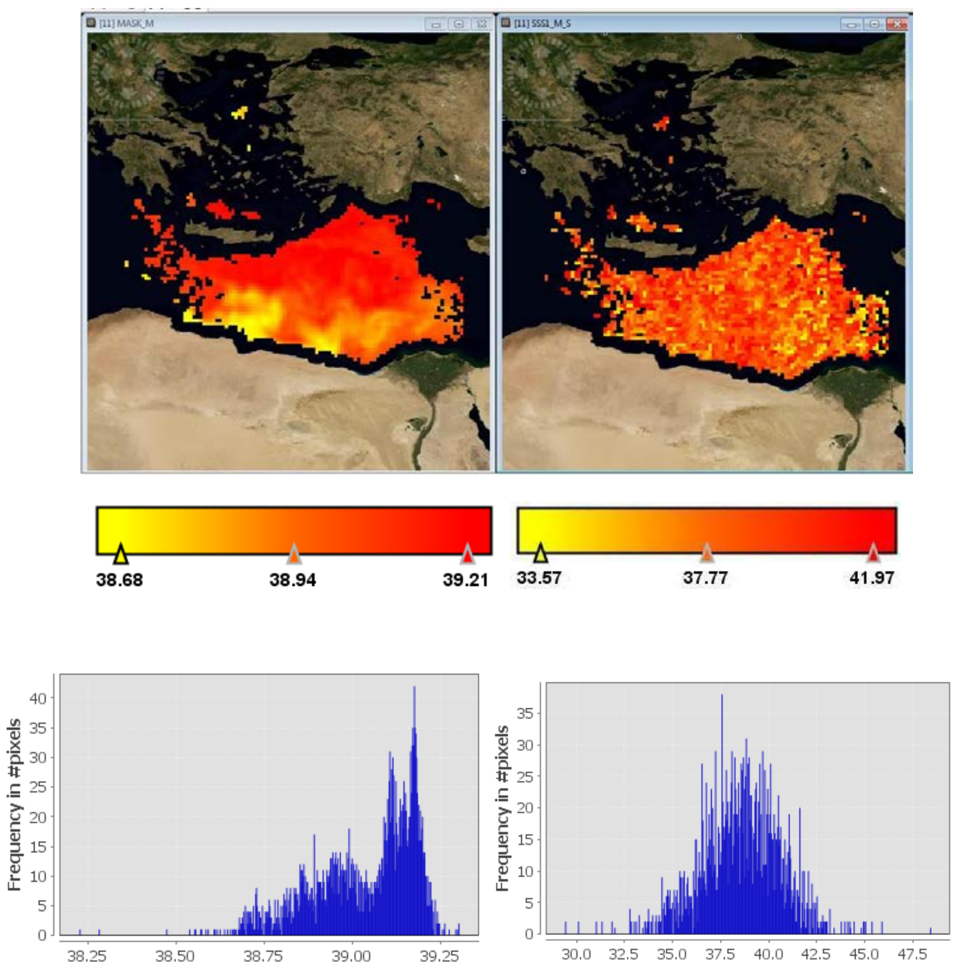

Figure 3 Images of the same area from BEAM-Visat showing the salinity of East Mediterranean. On the left is salinity as shown from the hydro-dynamical model and on the right is the salinity as shown from SMOS. (Below) Their histograms respectively.

The tool “Mask Manager” from BEAM-Visat allows the users to create classified images between ranges of pixel values. For this study and specifically for the SMOS LS OS product with date 20-01-2010 and the hydro-dynamical model with the same date, 6 classes were created with 0.2 psu value range. The results of the classification can be seen in Fig.4.

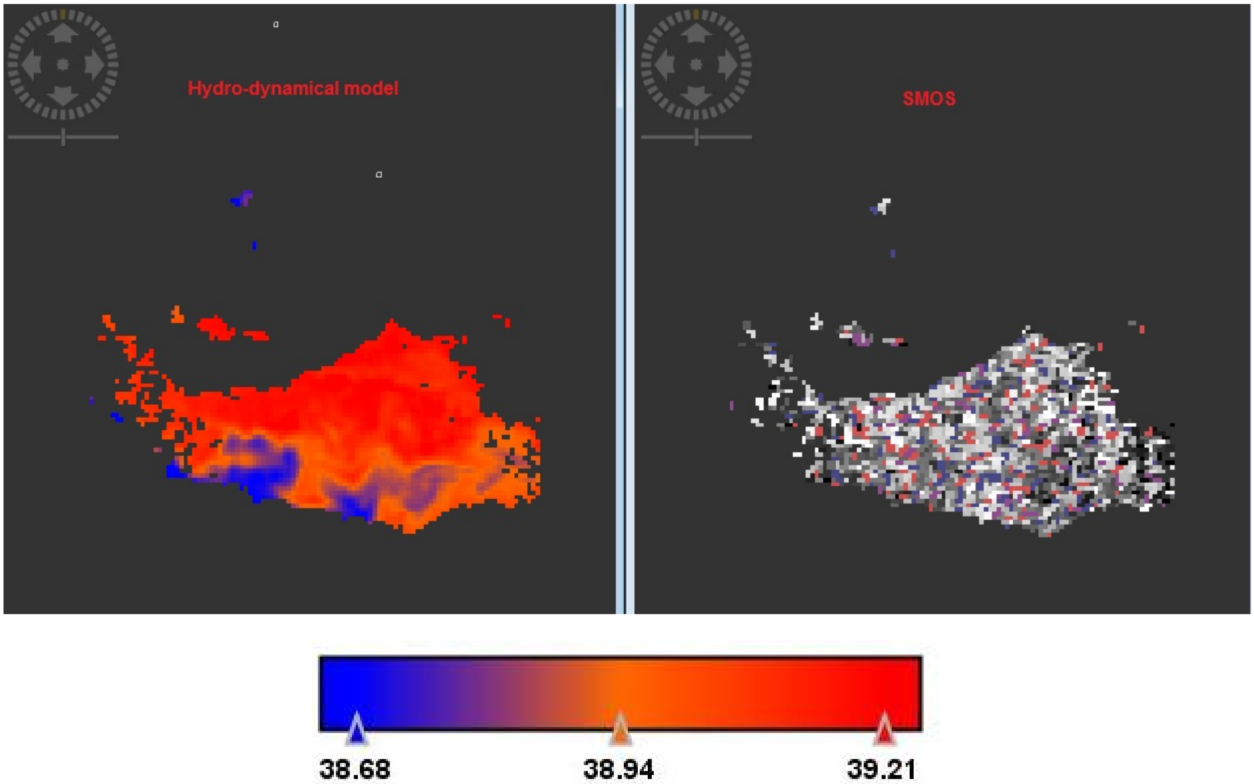

Figure 4 Images of SMOS (right) and of the hydro-dynamical model (left) after the classification with “Mask Manager” with software BEAM-Visat.

The classification produces two very different results for the same area. Even before the classification into 6 different classes with the same value range, in Fig.3 the differences between the two images can be easily observed.

III. Results

The first correlation plot between SMOS L2 OS data and data from the buoy E1M3A for the year 2010 can be seen in Fig.5. The match between the two sets is not good for the Coefficient of correlation R is 0.0007. Also it is easily noticed on the axes x and y the different range value that SMOS and E1M3A have for the same area. That shows that SMOS has failed completely to record the surface salinity in the area. The position of the buoy also is not helping because it is surrounded by masses of land (island of Crete,Fig.6) that cause “land contamination” to the satellite’s retrievals.

The second and third correlation plots (Fig.8,Fig.9) were used to compare the mean values of salinity of the hydro-dynamical forecasting model for years 2010 and 2011 with the mean values of large areas (Fig.1) for the same years of SMOS data, during the time that seasonal changes occur in the Mediterranean. For 2010 and 2011 the match between the sets is also not good with the coefficient of correlation, R to be 0.0021 and 0.0988 respectively. That shows that even in the area of East Mediterranean the “land contamination” caused by the land masses is also very high.

Finally the last correlation plot (Fig.9) with the ten-day-average for the year 2010 and for an area of 50x50km in the East Mediterranean (Fig.2), shows also not a good match between the two sets of data with the correlation coefficient, R to be 0.1268. Another diagram (Fig.10) shows the salinity variation during the year 2010 given the data of SMOS and the hydro-dynamical forecasting model for the specific area. The variation shown by SMOS is very different from the variation shown by the hydro-dynamical forecasting model. The model shows a very smooth seasonal change of salinity within a range of 0.5 to 0.6 psu through the year but on the other hand SMOS gives a changing range of almost 1.2 psu throughout the year 2010. Of course this cannot be in agreement with any realistic measurement regarding the Mediterranean regime.

The results of the classification also produce two very different images of the same area. The value range of the hydro-dynamical model, which is considered to be more accurate in this study, doesn’t match at all with the value range of SMOS’s L2OS products of the Mediterranean. In an attempt to classify SMOS’s products according the ‘correct’ value range of salinity, the image produced, verifies the huge divergence of SMOS’s measurements of salinity in the Mediterranean.

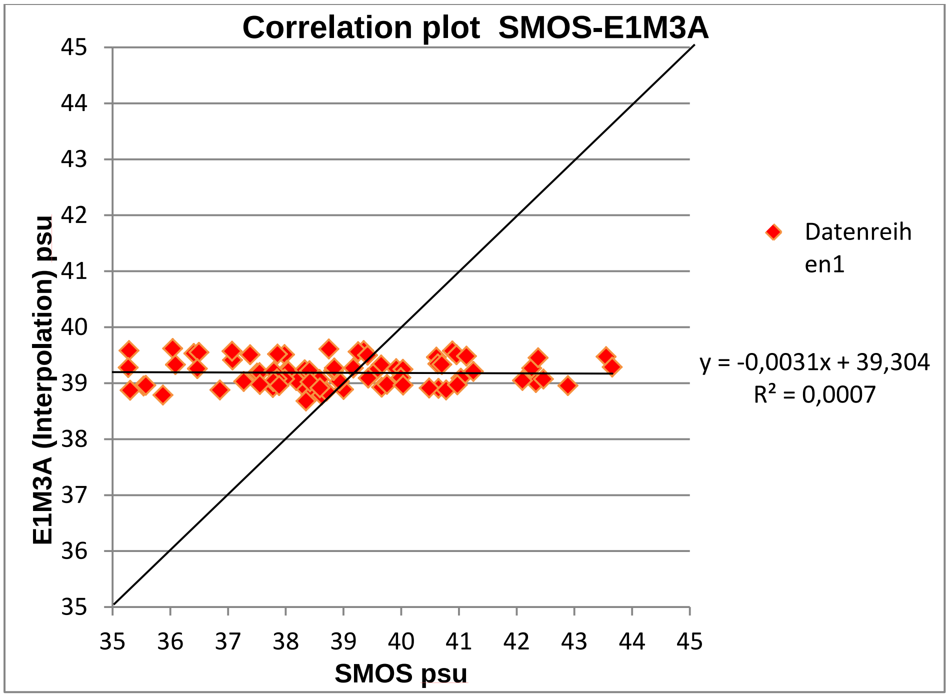

Figure 5 Correlation plot SMOS and E1M3A

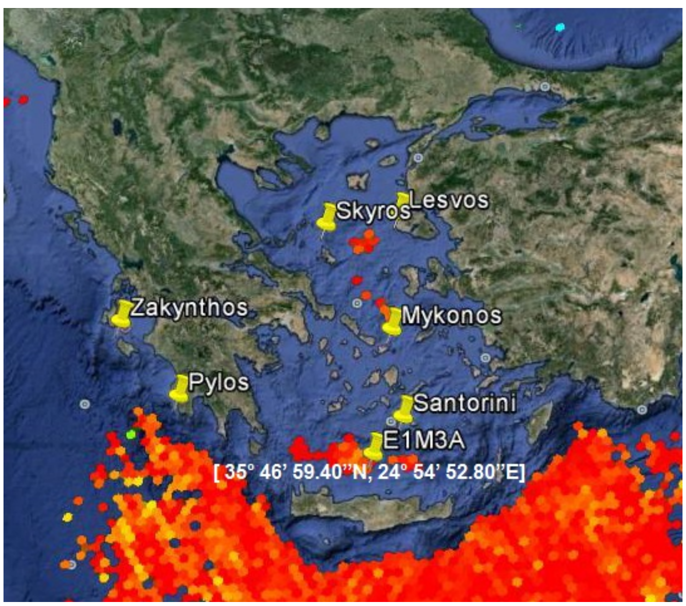

Figure 6 Google Earth: Position of E1M3A

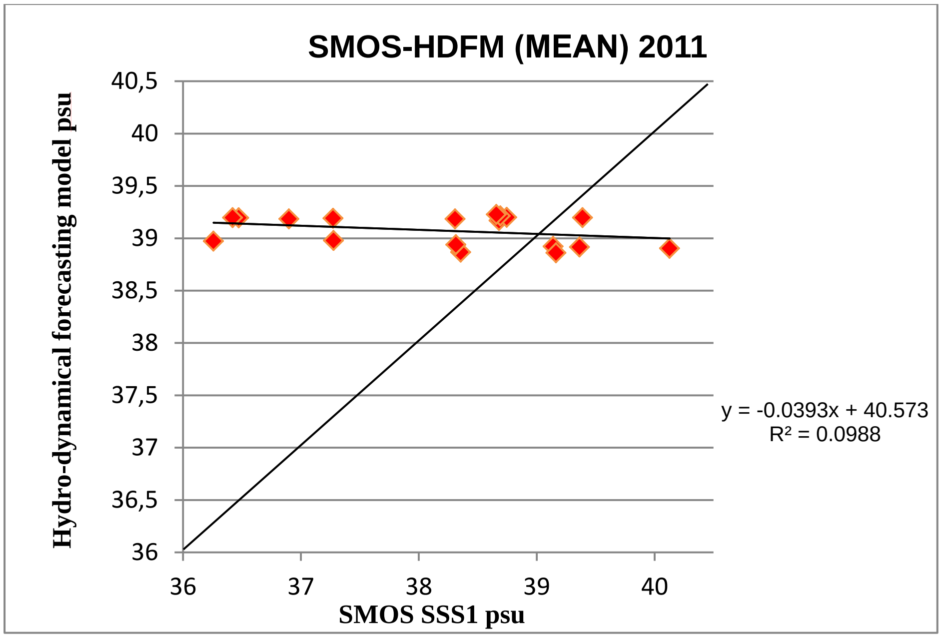

Figure 7 Correlation plot SMOS, Hydro-dynamical forecasting model

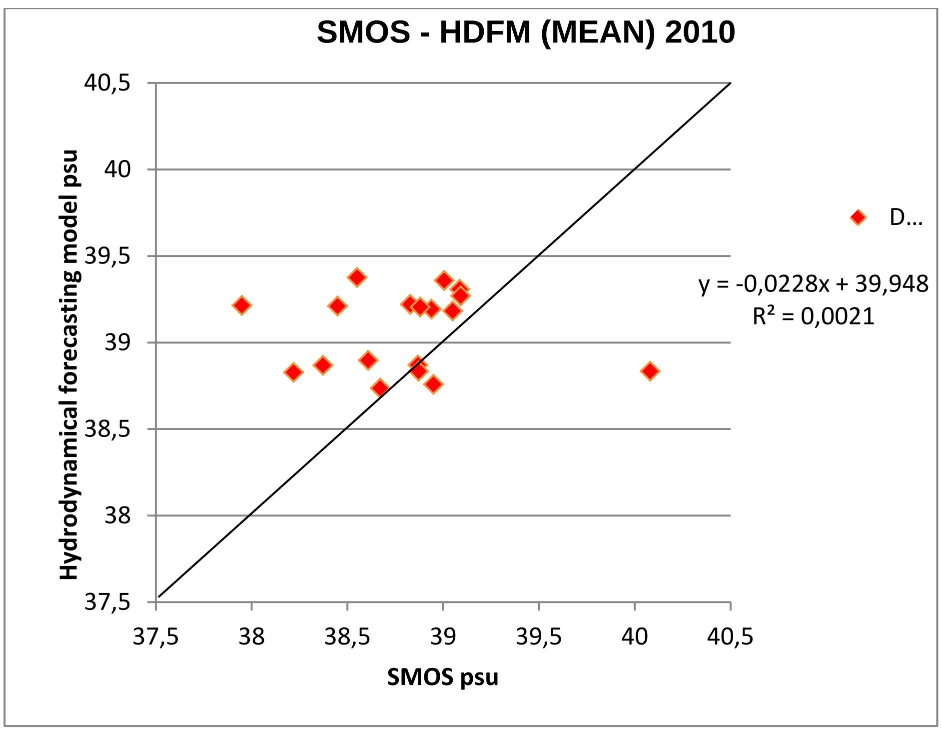

Figure 8 Correlation plot SMOS, Hydro-dynamical forecasting model

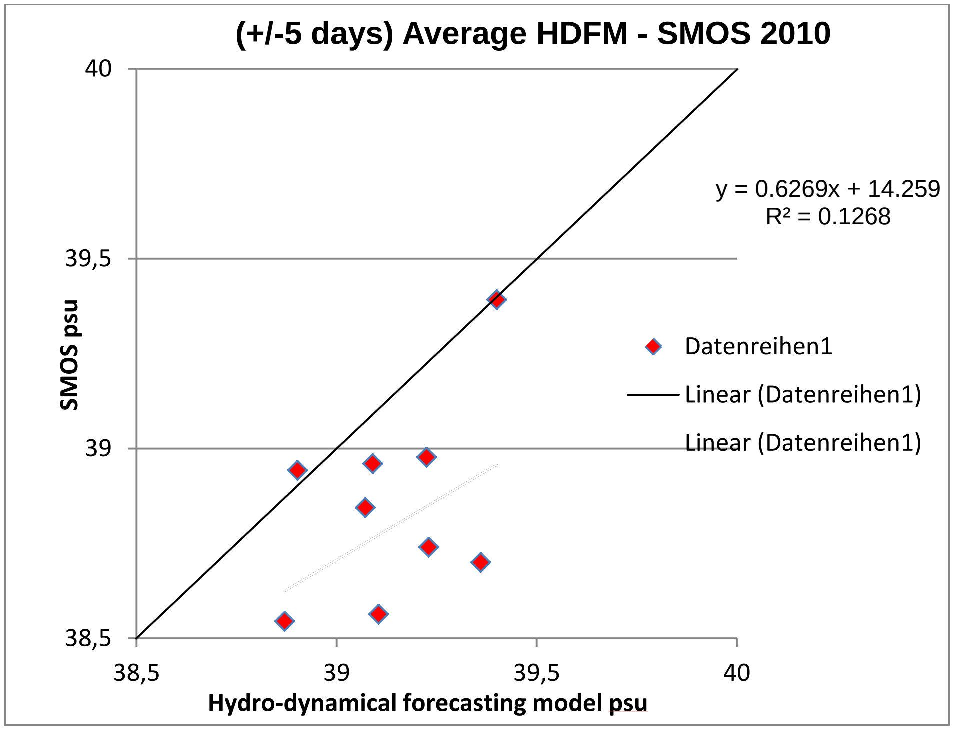

Figure 9 Correlation plot (+/-5 day) Average

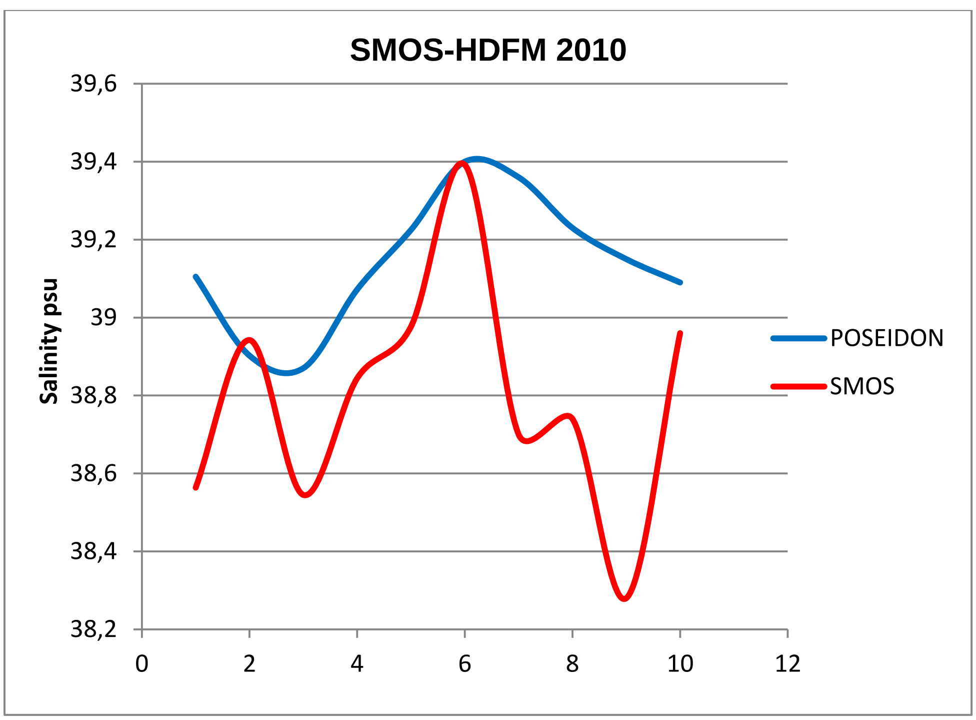

Figure 10

IV. Conclusions

The objective of this study is to validate the SMOS L2 OS products for the East Mediterranean region. The study has been done using in-situ as well as model data sets. The comparison between the data from the buoy and also the data from the forecasting models for the East Mediterranean region showed that the SMOS data sets are not in agreement with the in-situ and the model data. The correlation coefficient had very low values in each case which means that there is no good match among the different data sets. Considering the land masses that surround the Mediterranean as well as the strategic significance of its Eastern part, it is inevitable not to consider the anthropogenic factor that causes the Radio Frequency Interference (RFI). The L band is used by the military for air-traffic control and surveillance (http://www.radartutorial.eu), which is the same band that SMOS uses. This might be the most important factor that causes high RFI emissions in East Mediterranean while at the same time this problem is not detected in the open ocean. Still it is hard to say which factor affects more the performance of SMOS L2 OS products. In general a major problem observed in SMOS mission was the “contamination” of the ocean pixels as soon as land masses enter the satellite’s field of view. It was a problem expected by the SMOS team, while designing the L2 OS processor, but not in that extent. The anomalous salinities appear in large bands around the continental masses up to 1500 km (Gabarro,C., 2012). This is caused because of the radiometer’s high sensitivity and the higher emission of brightness temperature over land (2-4K, 7-10K) in comparison with the emission of the sea surface (0.8K) (Font,et.al,2010).So it is highly possible that the poor quality of the SMOS-derived SSS data is caused by both “land contamination” and high RFI emissions in the area.

V. Acknowledgements

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