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# Sea Surface Salinity with SMOS

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***Abstract***

*The mission to observe the Sea Surface Salinity (SSS) from the space is not really new because it has been started from long time ago. The first mission was the Skylab which used a 1.4 GHz microwave radiometer in 1970's. But this mission is still not as comprehensive as other missions which observe such as Sea Surface Temperature (SST), Sea Surface Height (SSH), Ocean Color, and so on. Realizing the importance of SSS distribution in the ocean and its influences to the Earth's climate system has motivated the scientists to develop a new technique in observing the SSS from space and lead a mission called the SMOS mission which was launched in November 2, 2011. Besides observing the SSS, this mission observes the Soil Moisture as well. The Soil Moisture and Ocean Salinity (SMOS) mission aims to obtain global and regular measurements on the soil moisture and the ocean salinity. These measurements are essential for climate and hydrological models, among other purposes. SMOS payload is a L band (21 cm, 1.4 GHz) 2D interferometric radiometer on a generic Proteus platform. The mission lifetime is at least 3 years (0.5 for commissioning and 2.5 for normal operation) + 2 years (extended operation) + 10 years for the post-mission processing. Raw physical data, level 1 and level 2 products will be produced by the PDPC (SMOS Payload Data and Processing Centre). It is an ESA center located in Villafranca (Spain) and operated under the responsibility of ESA. The SMOS Ocean Salinity objective is accuracy better than 0.1 psu, with 10 days to monthly grid scale (200 km).*

***Keywords***: *Sea Surface Salinity, SMOS*

***Abstrak***

*Misi untuk mengamati Salinitas Permukaan Laut (SSS) dari satu ruang bukan hal baru. Misi pertama adalah Skylab yang menggunakan microwave radiometer 1,4 GHz di tahun 1970-an. Tapi misi ini masih tidak komprehensif sebagai misi lain yang juga melakukan pengamatan seperti Sea Surface Temperature (SST), Sea Surface Height (SSH), Samudera Warna, dan sebagainya. Menyadari pentingnya distribusi SSS di laut dan pengaruhnya terhadap sistem iklim bumi telah memotivasi para ilmuwan untuk mengembangkan teknik baru dalam mengamati SSS dari ruang dan memimpin misi yang disebut misi SMOS yang diluncurkan pada tanggal 2 November 2011. Selain mengamati SSS, misi ini juga mengamati kelembapan Tanah. Misi kelembapan Tanah dan Samudera Salinitas (SMOS) bertujuan untuk memperoleh pengukuran global dan reguler pada kelembaban tanah dan salinitas laut. Pengukuran ini penting untuk iklim dan sistem model hidrologi. SMOS payload adalah band L (21 cm, 1.4 GHz) 2D interferometric radiometer pada platform Proteus generik. Misi ini dijalankan minimal 3 tahun (0,5 untuk commissioning dan 2,5 untuk operasi normal) + 2 tahun (pengoperasian) + 10 tahun untuk pengolahan pasca-misi. Data fisik mentah, level 1 dan level 2 produk akan diproduksi oleh PDPC (SMOS Muatan Pusat Data dan Pengolahan). Ini adalah pusat ESA terletak di Villafranca (Spanyol) dan dioperasikan di bawah tanggung jawab ESA. Tujuan SMOS Samudra Salinitas adalah akurasi yang lebih baik dari 0,1 psu, dengan 10 hari untuk skala jaringan bulanan (200 km).*

***Kata kunci:*** *Salinitas Permukaan Laut, SMOS*

## 1. Introduction

Besides the temperature, salinity has a large impact in controlling the density of sea water, the colder and saltier the water, and the denser. The difference of the ocean density distribution drives the ocean circulation which is called thermohaline. Particularly, the surface of

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the ocean, the SSS contacts directly influences with the atmosphere and it proved that the SSS plays an important role in climate system. Figure 1 below shows that the global distribution of SSS has distributed very clear that the SSS is relative high at mid latitudes. At mid latitudes the evaporation is higher than precipitation and the opposite at the equator and poles. As water evaporates from the ocean, the salinity increases and the surface layer becomes denser. Nevertheless, the precipitation reduced the ocean density because the fresh water flux gain.

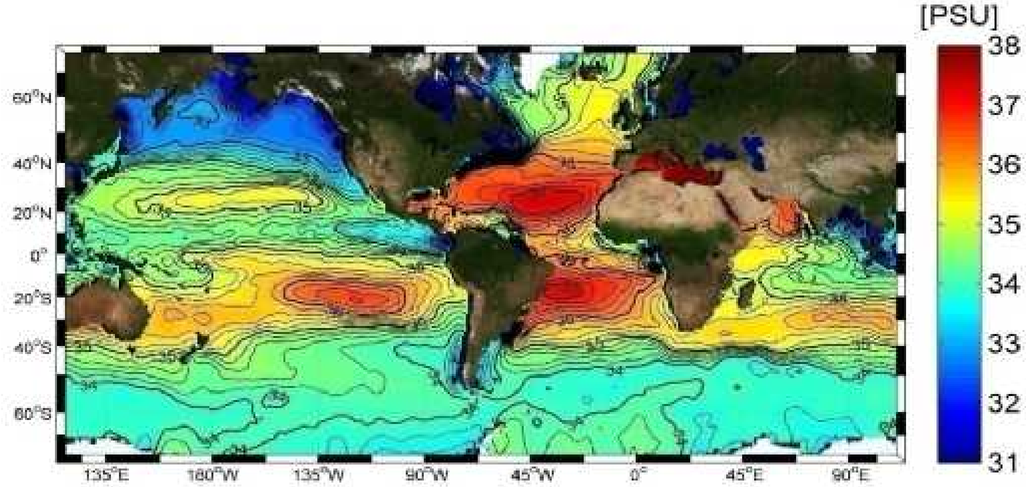


Figure 1: Annual mean of the sea surface salinity distribution and sea surface temperature (World Ocean Atlas, 2005)

This SSS distribution is related strongly affected to the climate system, changed the SSS patterns over time, monitored the relationship between two primary processes in the oceans, evaporated and controlled the loss of water and precipitation which governed the gain of water. The information about SSS distribution is very important, but it was limited knowledge. Thus, it has become the main reason why the mission of SMOS should be carried out.

## 2. Literature Review

### 2.1 The L-band Microwave Imaging Radiometer with Aperture Synthesis (MIRAS)

The microwave imaging radiometer using aperture synthesis (MIRAS) is the single payload of the SMOS. It was a new type of instrument with a radiometer that operates range between 1400 and 1.427 GHz (L-band). This frequency provides the best sensitivity to variate the moisture in the soil and changes the salinity of the ocean, coupled with minimal disturbance from weather, atmosphere and vegetation cover.

Figure 2: Miras (ESA)

In term of MIRAS, there were 69 small antennas, called LICEFs, which interact by simulating a large conventional microwave antenna. The small antennas measure the phase difference of the incident electromagnetic waves by correlating all antenna signals with each other. Cross correlation of observations from all possible combinations of receiver pairs provide a two dimensional image.

**3. How to Measure Sea Surface Salinity?**

The radiation emitted by the sea surface in the L-Band was affected and influenced by SSS. The increasing salinity caused a drop in the brightness temperature of the surface. The SMOS radiometer measured the amount of electromagnetic radiation which emitted by the earth surface (land and ocean surface) in range of frequency of L-band (1.4 GHz or in the wave length of 21 cm). This radiation was measured as brightness temperature. Based on its theory, the energy radiated by an object was its brightness temperature, because the intensity of the radiation was strongly related to the physical temperature of the object at the earth's surface.

$$T_B = e\,T \qquad (1)$$

Based on the above formula, $T_B$ is the brightness temperature, e is the emissivity, and T is the absolute temperature of the object. The black body would absorbs 100% of the incident wave's energy and emits. Therefore, it was called perfect absorber. However, there was no black body in the reality. So, the objects will emit the energy (brightness temperature) as much as they could absorb and depend on the object's emissivity which described the properties of the object.

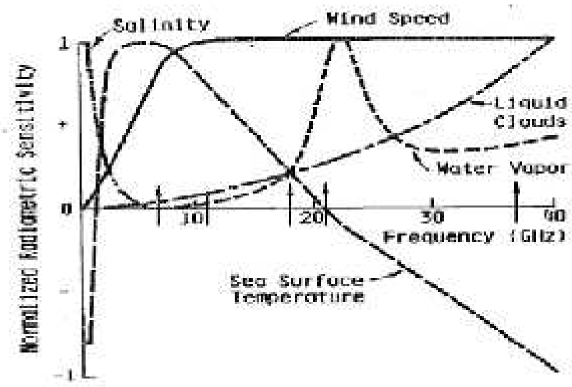


Figure 3: Spectral sensitivity of oceanic parameters (Wilheit et al., 1980)

The spectral sensitivity of radiation detector was the ratio of the quantity characterizing the level of the detector's response. The energy flux of the monochromatic radiation caused and raised the response. The picture above shows that the highest sensitivity $T_B$ to SSS was stand at low frequency, around 1.4 GHz. This is one of the reasons why SMOS uses this frequency. In addition, the frequency was reserved by international conventions (Recommendations from the International Telecommunications Unit, ITU_R) for Telecomunications, ITU-R) radioastronomy, operations, as it contains the spectral line of neutral hydrogen, HI (1420.406 MHz).

The sensitivity of $T_B$ to SSS was influenced by the Sea Surface Temperature (SST). The picture below showed that the sensitivity of $T_B$ to SSS decreases as the SST gets cooler. This realita made the salinity retrieval in cold ocean areas even more challenging given. The decreasing of frequency til 1.4 GHz, it increased $T_B$ sensitivity to SSS and decreased the Attenuation. For instance, at nadir, the sensitivity was 0.5K/psu for SST of 20 oC and it decreased to 0.25K/psu for SST of 0 oC. The examples showed that SMOS requires the high performance instrument to achieve its goals. The precision of a snapshot by the radiometer on the brightness temperature data should be increase higher than 2 K (approximately 1.5-1.7 K) and these **snapshots** were averaged in order to be able to attain the required accuracy of 0.1 psu in 10-30 days.

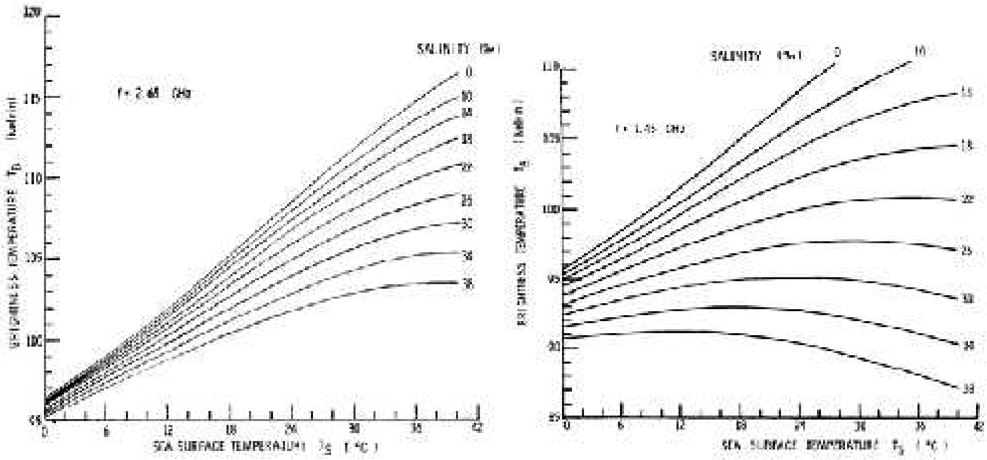

Figure 4: Temperature brightness at nadir view [4]

## 4. Calibration

To ensure that the data from the SMOS mission were exactly converted into salinity estimates, all the variables which influence the $T_B$ signal such as SST, Sea surface roughness, Ionospheric effect, solar system and cosmic radiations should be properly assessing. It needed to know all this variables (in order to extract all noises) are caused by those factors. The other errors such as the time being contaminated by the land or sea ice emission, radio frequency interference (RFI), sun and moon glint, or heavy rain attenuation.

In case to extract and remove the errors mentioned above, some calibration have been conducted by measuring the data at the some points and using the other data resources such as ECMWF, etc. By implementing the ECMWF data, the average of SMOS L2 products over 30 days and 22 boxes would generate an SSS L3 product with an error of 0.22 pss. This could accomplished the study requirements.

## 5. Results

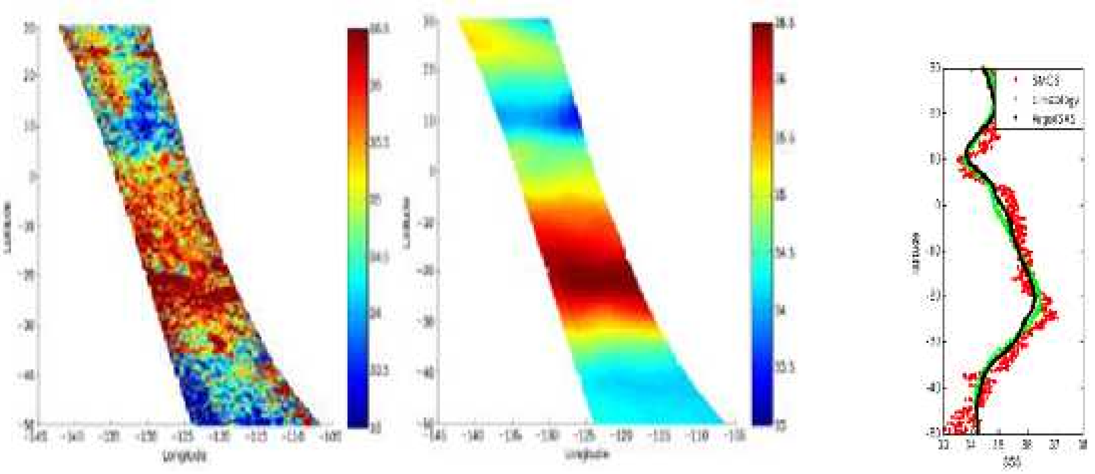

Figure 5: Retrieved SSS along an orbit in the east Pacific Ocean on 11th of December 2009 (left), the corresponding monthly averaged SSS of December from WOA05 (middle), and North-South SSS profile in the eastern Pacific Ocean, comparing SMOS, ISAS and WOA05 SSS (Yin et al., 2010).

On December 2009 was first processed with preliminary calibration algorithms in L1OP processor, and used to retrieve SSS using all measurements in FOV. The picture above (left) showed that the retrieved SSS could identified the SSS distribution and agreed with the WOA05 data (middle) although it was still noisy because of the prior time averaging. The comparison of three SSS datas (SMOS, ISAS and WOA05) could be seen on the right picture which presented a strong agreement. The three curves were distributed separate in the same way, over 0.1 degree in latitude and acrossed the SMOS swath.

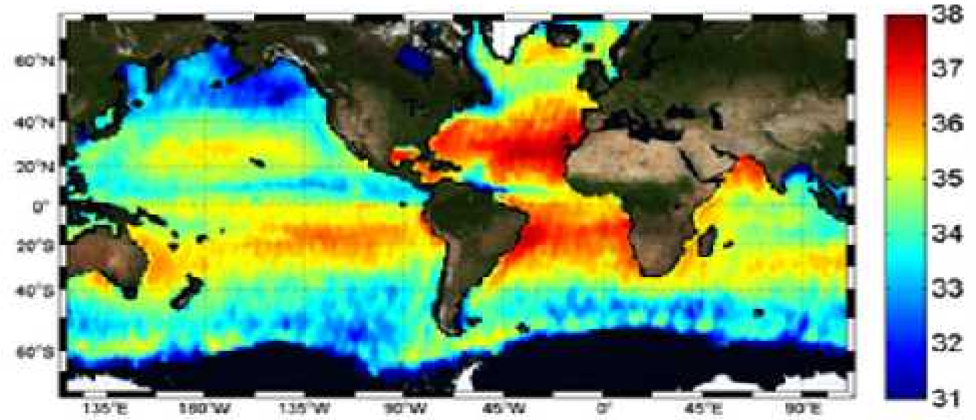

Figure 6: August 2010 SMOS SSS data 1ox1o [psu] (CERSAT)

The centre of ERS d'Archivage et de Traitement (CERSAT) noted that since May, the L1 processor, the SMOS calibration and our Level 3 processing algorithms have been significantly improved based on the following map for the month of August 2010. This temporary had changed in the patterns associated with the Amazon and Orrinoco river plumes, the improved land-contamination and RFI problems filtering (by combining and filtering ascending and descending passes). Compared with the situ measurements for the month of August 2010 had revealed a global standard deviation error of ~0.4 psu.

## 6. Conclussion

It was important to point out that SMOS cannot measure absolutely $T_B$ directly to an accuracy of 0.05 K. It needed an external calibration and an analyzing process of SMOS retrieved and SSS requires further its improvements both in model and also in calibration to achieve the SSS accuracy 0.1 psu.

In spite of SMOS answering some fundamental scientific questions, it does not fulfill all existing needs, and the ways forward must being sought to address these needed. Over all, the important priority was in term of probably improvement of the spatial resolution [3].

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