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*Editorial*

# Editorial for the Special Issue: "Ten Years of Remote Sensing at Barcelona Expert Center"

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Received: 23 July 2020; Accepted: 28 July 2020; Published: 29 July 2020

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**Abstract:** This book celebrates the ten year anniversary of the Barcelona Expert Center by presenting recent contributions related to the topics on which the team has been working during those years. The Barcelona Expert Center's expertise covers a wide variety of remote sensing fields, but the main focus of the research is on the SMOS data processing and its ocean, land, and ice applications. This book contains 14 scientific papers addressing topics that go from the description of the new data processing algorithms that are implemented in the last version of the operational SMOS level 1 processor to scientific applications derived from SMOS: results on the sea-surface salinity assimilation in coastal models, synergies of the sea-surface salinity with temperature and chlorophyll and their impact on the better retrieval of ocean surface currents, quality assessment of SMOS-derived sea ice thickness, sea-surface salinity, and soil moisture products, among others. Moreover, one of the papers verifies the potential of the future Copernicus Imaging Microwave Radiometer (CIMR) mission within the CMEMS sea-surface salinity (SSS) operational production after the SMOS era.

**Keywords:** BEC; SMOS; radiometry; remote sensing; oceanography; soil moisture; cryosphere; processing; sensor calibration; image reconstruction

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## 1. Introduction

The Barcelona Expert Centre (BEC) is a joint initiative between the Spanish Research Council (CSIC) and the Universitat Politècnica de Catalunya (UPC) that was created in 2007. Since its foundation until January 2016, the head of the BEC was professor Jordi Font. The original purpose of the BEC was to provide support to the Spanish activities on the Soil Moisture and Ocean Salinity (SMOS) European mission, professor Font being the co-principal investigator of SMOS and being in charge of the sea salinity part of the mission. SMOS is a European Space Agency (ESA) mission and was the first 2D synthetic aperture interferometric radiometer operating in the microwave L-band ever put in orbit. SMOS was put in orbit on 2 November 2009 and was designed to fulfill two specific goals: to measure sea-surface salinity (SSS) with $1^o$ spatial resolution and monthly temporal resolution and an accuracy of 0.1 PSU over the sea [1], and to measure soil moisture (SM) with 25 km spatial resolution and daily temporal resolution within a maximum uncertainty of 4% [2]. Initially, BEC missions were to provide assessments to the ESA as a level 2 ocean salinity expert support laboratory, to contribute to SMOS radiometric calibration and validation activities, and to develop and validate new algorithms for the generation of added-value products at levels 3 and 4.

Since 2016, Antonio Turiel has been the head of BEC that nowadays consists of four departments, whose areas are SMOS (salinity and land), ocean winds, cryosphere, and ocean currents. The activities developed at BEC has been diversified, as hav its main objectives, which currently are:

- Research and development in Earth observation, with a special focus on microwave remote sensing and more specifically on SMOS and follow-on missions.
- Support to the European Space Agency through expert support laboratory contracts.
- Continuous generation and distribution of high-level remote sensing products.
- Geophysical exploitation of dedicated remote sensing data, with a special interest in scientific applications.
- Fostering the use of BEC remote sensing data among academia, enterprises, and stakeholders.

BEC is now a large team of highly motivated and remote sensing specialist people carrying out the scientific and operational activities in all processing levels of different missions. At the moment we are around 20 people; among us are permanent staff, post-doctoral contracts, visiting scientists, and Ph.D. students working on a wide variety of topics:

- Improvements in calibration, image reconstruction, and stability of radiometric data.
- Synergy of observations from different sensors and data sources.
- Retrieval of geophysical variables: forward modeling and non-linear inversion.
- Validation and quality control.
- Assimilation into atmospheric and ocean models.
- Generation of added-value products at levels 3 and 4.

This book aims to be a tribute to the work done over the last 10 years at the BEC and to the entire team that has made the BEC one of the main remote sensing centers in Spain.

## 2. Overview of Contributions

The contributions reported in this book are structured in three different blocks: contributions to remote sensing data processing; ocean remote sensing applications; and land remote sensing applications,

### *2.1. Remote Sensing Data Processing Algorithms*

The book starts with an analysis of the different methods for reducing the reconstruction error in microwave interferometric radiometers with a large field of view in Corbella et al. [3]. First, the authors propose estimating the reconstruction error contribution through the application of a brightness temperature model outside the fundamental period. Second, they present image reconstruction algorithms implemented on a minimum grid size that allows maximizing the efficiency of numerical processing. Last, they describe a method to reduce Gibbs oscillations based on an improved apodization window over the reconstructed image. The proposed algorithm shows similar performance with respect to the nominal one.

The second chapter, from Oliva et al. [4], is dedicated to describing the improvements gained by the SMOS level 1 operational processor. The authors performed a quality analysis of the enhanced algorithms that included an end-to-end processing of three years. The results confirmed that the new version of the SMOS level 1 operational processor deals with improvements in the SMOS measurements. The new version of the processor is foreseen to be used in the third reprocessing campaign for the SMOS measurements.

In the third chapter, Rubino et al. [5] present a new methodology to derive vertical total electron content (VTEC) maps from the radiometric measurements. The proposed methodology is an alternative approach to the one currently implemented in the SMOS data processor, which has the advantage of being independent of external databases and models. This new approach uses spatiotemporal filtering techniques with optimized filters to be robust against the thermal noise and image reconstruction artifacts present in SMOS images.

The block finishes with a chapter dedicated to analyzing the potential of the Copernicus Imaging Microwave Radiometer (CIMR) mission for the global monitoring of sea-surface salinity (SSS) using level 4 (gap-free) analysis processing, lead by Ciani [6]. Since there are no planned missions to guarantee continuity in the remote SSS measurements after SMOS and SMAP, CIMR could cover that gap, since it will carry an L-band radiometer. The CIMR mission is in a preparatory phase with an expected launch in 2026. In this paper, they study the potential of CIMR within the CMEMS SSS operational production after the SMOS era. They demonstrate that the combined use of in situ and CIMR observations improves the global SSS retrieval compared to a processing wherein only in situ observations are ingested. Therefore, they conclude that CIMR can guarantee continuity for accurate monitoring of the ocean surface salinity from space.

### *2.2. Ocean Remote Sensing Applications*

This section starts with a chapter in which an impact assessment of assimilating SMOS sea-surface salinity data into a coastal ocean model is presented in Phillipson and Toumi [7]. The results of this study show that the assimilation of SSS and SSS combined with SSH consistently provides the best results in the Congo river plume analysis.

The next chapter from Alucino et al. [8] is dedicated to a comparison of the performance of the SMOS SSS maps within the performance of in situ high-resolution glider measurements collected in the framework of the Algerian Basin Circulation Unmanned Survey (ABACUS). The Algerian Basin (located in the Mediterranean Sea) presents complex ocean circulation, wherein the fresh Atlantic water is mixed with the more saline Mediterranean water. The study shows some limitations of the satellite data to describe small spatial structures that are captured by in situ. However, at the spatial scales resolved by the satellite, the SSS in situ and satellite measurements are in a good agreement, providing an averaged difference of −0.11 PSU with a standard deviation of 0.26 PSU.

The following two chapters deal with sea-surface currents. In the first, from Isern-Fontanet et al. [9], the relationship between satellite salinity and temperature data to correct the buoyancy and to retrieve ocean currents by using the SQG approach is explored. The study is focused in the Alboran Sea where the altimetric maps have some limitations for capturing the ocean currents. The results of this study show that the good sampling of infrared radiometers allows at least retrieving the direction of ocean currents in this area. The second paper, from Ciani et al. [10], presents a method for the retrieval of the sea-surface currents in the Mediterranean Sea. They combine the altimeter-derived currents with sea-surface temperature information, to create daily, gap-free, high-resolution maps of sea-surface currents for the period 2012–2016. The quality of the new multi-sensor current maps has been assessed through comparisons to other surface-currents estimates, as drifting buoys trajectories, HF-Radar platforms, and ocean numerical model outputs. The study yielded that the synergetic approach can improve the present-day derivation of the surface currents in the Mediterranean area.

Chapter nine, from Umbert et al. [11], aims at analyzing the similarity of mesoscale and submesoscale features observed in different ocean scalars. This study indicates that they undergo some common non-linear processes. The results show that it is possible to assume a local correspondence of SST and Chl-a multifractal singularities, due to the existence of a common cascade process which makes it possible to use SST data to infer Chl-a concentration where data are lacking. Therefore, the data fusion method was used to improve the coverage of daily Aqua MODIS level 3 chlorophyll maps by using MODIS SST maps as a template. An assessment of the quality of the inference of level 4 Chl-a maps is also performed.

The next chapter deals with tidal fluctuations observed from remote sensing infrared SST, from Gonzalez-Haro et al. [12]. The expected amplitude of fixed-point sea-surface temperature (SST) fluctuations induced by barotropic and baroclinic tidal flows is estimated from tidal current atlases and SST observations. The fluctuations considered are the result of the advection of pre-existing SST fronts by tidal currents. In this study, regional and global estimations of these expected amplitudes are presented. The results show that barotropic tidal motions produce SST fluctuations that may reach amplitudes of 0.3 K, while baroclinic (internal) tides produce SST fluctuations weaker than 0.1 K.

The amplitudes and the detectability of tidally induced fluctuations of SST are discussed in light of the expected SST fluctuations due to other geophysical processes and instrumental noise.

The remote sensing ocean application block ends with a validation of sea ice thickness (SIT) products from Sánchez-Gámez et al. [13]. In this study, in situ SIT data acquired with upward looking sonar (ULS) instruments on buoys from the Woods Hole Oceanographic Institution (WHOI) were used to validate the thin SIT maps from SMOS and SMAP missions. These buoys acquired data all year round, permitting them to overcome several limitations, thereby improving the characterization of the L-band brightness temperature response to changes in thin SIT. State-of-the-art satellite SIT products and the cumulative freezing degree days (CFDD) model were verified against the ULS ground truth.

### 2.3. Land Remote Sensing Applications

This section starts with a chapter dedicated to a comparison of six operational surface soil moisture (SSM) products derived from SMOS and SMAP in order to diagnose their distinct features, by analyzing their temporal and spatial characteristics, from Partal et al. [14]. The study was focused on the Iberian Peninsula and covers the period from April 2015 to December 2017. A temporal inter-comparison analysis was carried out using in situ SSM data from the Soil Moisture Measurements Station Network of the University of Salamanca (REMEDHUS). Spatial analysis was conducted for the whole Iberian Peninsula with an emphasis on the added-value that the enhanced resolution products provide. They show an overall agreement among time series of the products regardless of their spatial scale when compared to in situ measurements. The largest disparities between these products occur in forested areas, which may be related to the reduced sensitivity of high-resolution active microwave and optical data to soil properties under dense vegetation. Still, higher spatial resolutions would be needed to capture local features, such as small irrigated areas that are not dominant at the 1 km pixel scale.

In the next paper, Pablos et al. [15] presents an evaluation, both temporally and spatially, of six satellite-based root zone soil moisture (RZSM) estimates obtained from SMAP, SMOS, and the Moderate Resolution Imaging Spectroradiometer (MODIS) from March 2015 to December 2016. The RZSM estimates are compared to in situ data from 14 stations of the soil moisture measurements from the University of Salamanca (REMEDHUS), to assess the temporal analysis. Regarding the spatial assessment, the resulting RZSM maps of the Iberian Peninsula were compared between them. All RZSM values followed the temporal evolution of the ground-based measurements well, although SMOS and MODIS showed underestimation while SMAP displayed overestimation. The good results obtained from MODIS are notable, but it should be remarked that it uses optical bands, which are affected by clouds. A very high agreement was found in terms of spatial patterns for the whole Iberian Peninsula except for the extreme north area, which is dominated by high mountains and dense forests.

The last chapter of this book, from Piles et al. [16], aims at investigating the temporal variability of global surface soil moisture acquired with SMOS and two SM products derived from the models: LDAS-Noah and ERA5. The soil moisture time series are decomposed into a linear trend, interannual, seasonal, and high-frequency residual components. The relative distribution of soil moisture variance among its temporal components is illustrated at selected target sites with distinct vegetation type and seasonality. A global assessment of the dominant features and the spatial distribution of soil moisture variability are also provided. Results show that SMOS data provide coherent and reliable variability patterns at both seasonal and interannual scales. The observed linear trends, based upon one strong El Niño event in 2016, are consistent with the known El Niño Southern Oscillation (ENSO) teleconnections. This work can help further our understanding of the terrestrial branch of the water cycle and of global patterns of climate anomalies.

## 3. Conclusions

The contributions reported in this special issue are based on research on remote sensing techniques and its applications to better monitor and understand the changes the oceans, soils, and cryosphere are undergoing on a warming planet. These are the topics on which the BEC team has been working for the last ten years, and they also drive the future lines of research on which the BEC's strategic plan is based. This book is a tribute to the efforts made by all the people that have contributed to building up the BEC and also aims to be an inspiration for the work to be done in the future at the BEC.

**Author Contributions:** The four authors contributed equally to all aspects of this editorial. All authors have read and agreed to the published version of the manuscript.

**Acknowledgments:** The guest editors would like to thank the authors who contributed to this Special Issue and the reviewers who dedicated their time and provided the authors with valuable and constructive recommendations. They would also like to thank the editorial team of Remote Sensing for their support.

**Conflicts of Interest:** The authors declare no conflict of interest.

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