EOF analysis of differences between ascending and descending orbits in SMOS sea surface salinity data: temporal and spatial variability

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In this poster

- Use of DINEOF (Data Interpolating Empirical Orthogonal Functions) to reconstruct missing data in SMOS SSS, detect outliers and reduce noise

- Study of spatial and temporal distribution of the differences between ascending and descending swaths

- Physical signals of Douro and Gironde rivers are detected in the SSS dataset

1. Introduction

SMOS salinity data have been measured since 2010 and provides an unprecedented source of information about the spatial and temporal variability of the oceans' surface salinity.

There are however several problems and shortcomings to be addressed, namely the presence of outliers, noise and missing data. In addition there exist biases and differences between the ascending and descending swaths.

This poster presents our work to reduce these problems, using DINEOF.

2. Materials and Methods

Data used

- Level 2 Ocean Salinity User Data Product (UDP) version 5.50, provided by ESA
- Roughness model #1
- Ascending/descending passes treated separately

Zone: North-East Atlantic Ocean and Mediterranean Sea
Period: January – December 2013

Preprocessing steps

- Quality flags:
- poor geophysical retrieval (Fg ctrl poor geophysical)
- flag for poor retrieval Fg ctrl poor retrieval
- flag for roughness model used (Dg quality SSS1)
- Range check (minimum/maximum salinity)
- Outlier detection (using DINEOF, see below)

Outlier detection

A first DINEOF analysis is performed on the initial data
Three tests are applied to classify pixels as suspect:
- Departure from the DINEOF truncated EOF basis
- Departure from a local median
- Proximity to clouds and land

A weighted sum of these 3 tests allows to determine which pixels will be finally classified as outliers

For this particular configuration:
- Weights: EOF test (1/3), local median (1/3), proximity to missing data/land (1/3)
- Threshold level to classify a pixel as outlier: 1

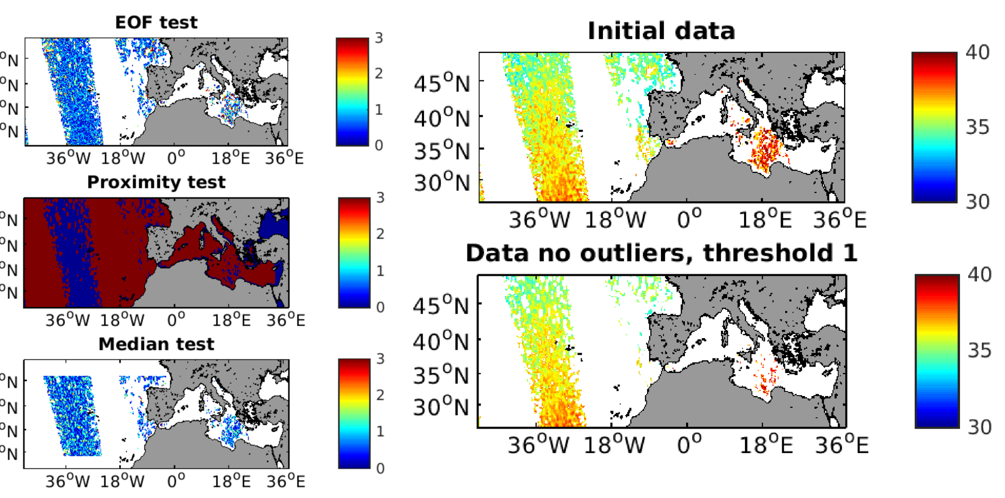


Figure 1: Outliers test example for 7 February 2013

3. DINEOF: Data Interpolating EOFs

- Technique to **fill in missing data** in geophysical data sets
- **Truncated EOF** basis to calculate missing data (iterative method)
- Optimal number of EOFs?: reconstruction error by **cross-validation**
- Uses EOF basis to infer missing data: **non-parametric** in its basic form
- No need of a priori information (correlation length, covariance function...)
- Spatio-temporal coherence exploited to calculate missing values
- EOFs extract main patterns of variability

Example of DINEOF reconstruction

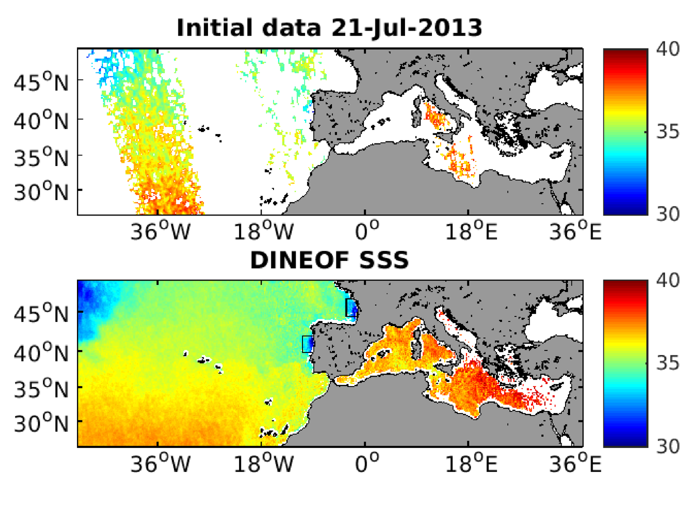


Figure 2: example of reconstruction of SSS using DINEOF

In figure 2 we can observe:

- the meandering Gulf Stream
- An east-west gradient in the Mediterranean Sea
- Fresh signals at the Douro and Gironde river plumes

4. Rivers in the DINEOF SSS dataset

- The signal of the Douro and Gironde rivers can be observed in the DINEOF SSS reconstruction results.
- It is difficult to assess quantitatively the accuracy of the SMOS data at these river plumes
- The qualitative description of these signals can be helpful to analyse the extent of the plumes and their seasonal variability.

Gironde river: Following Jalón-Rojas et al.(Hydrology and Earth System Sciences 19, 28052819, 2015), a flood event occurred in the Gironde estuary in June 2013, which explains the low salinity values observed in the DINEOF reconstruction (figure 3)

Douro river: visible in SSS and chlorophyll-a concentration data (figure 4). The zone of the lowest SSS near the mouth of the river is associated with a higher chlorophyll-a concentration, and that the plume has a spatial signature that reaches a longitude of ~11ºW.

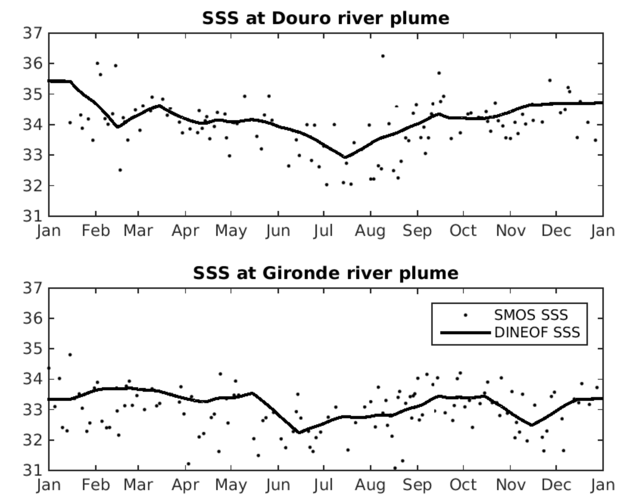


Figure 3: Time series of SSS at the Douro (top panel) and the Gironde (bottom panel) river plumes. The boxes delimiting these two zones are shown in figure 2.

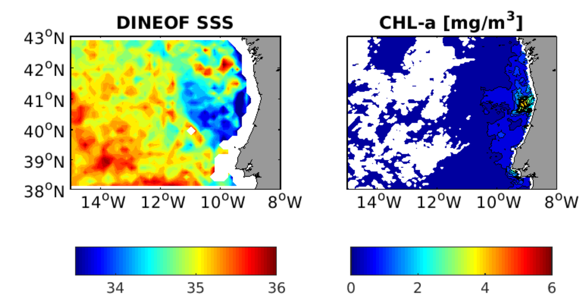


Figure 4: Example of the signal of the Douro river plume in SSS (left panel) and chlorophyll-a concentration (right panel) averaged over the period 26 February to 5 March 2013

5. Analysis of differences in ascending/descending swaths

A DINEOF analysis has been applied separately for ascending and descending swaths. A filter has been applied to the covariance matrix, with a length of ~14 days (best in validation, see Alvera-Azcárate et al 2015).

The spatially averaged time series (figure 5) shows that the largest differences between ascending and descending swaths occur during summer, with ascending swaths 0.2 to 0.4 fresher than the descending swaths. The DINEOF full fields are used to compute ascending-descending differences, and EOFs are calculated on these (figure 6).

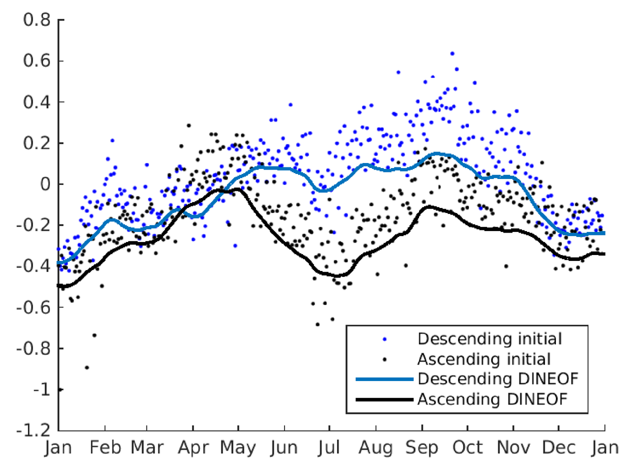
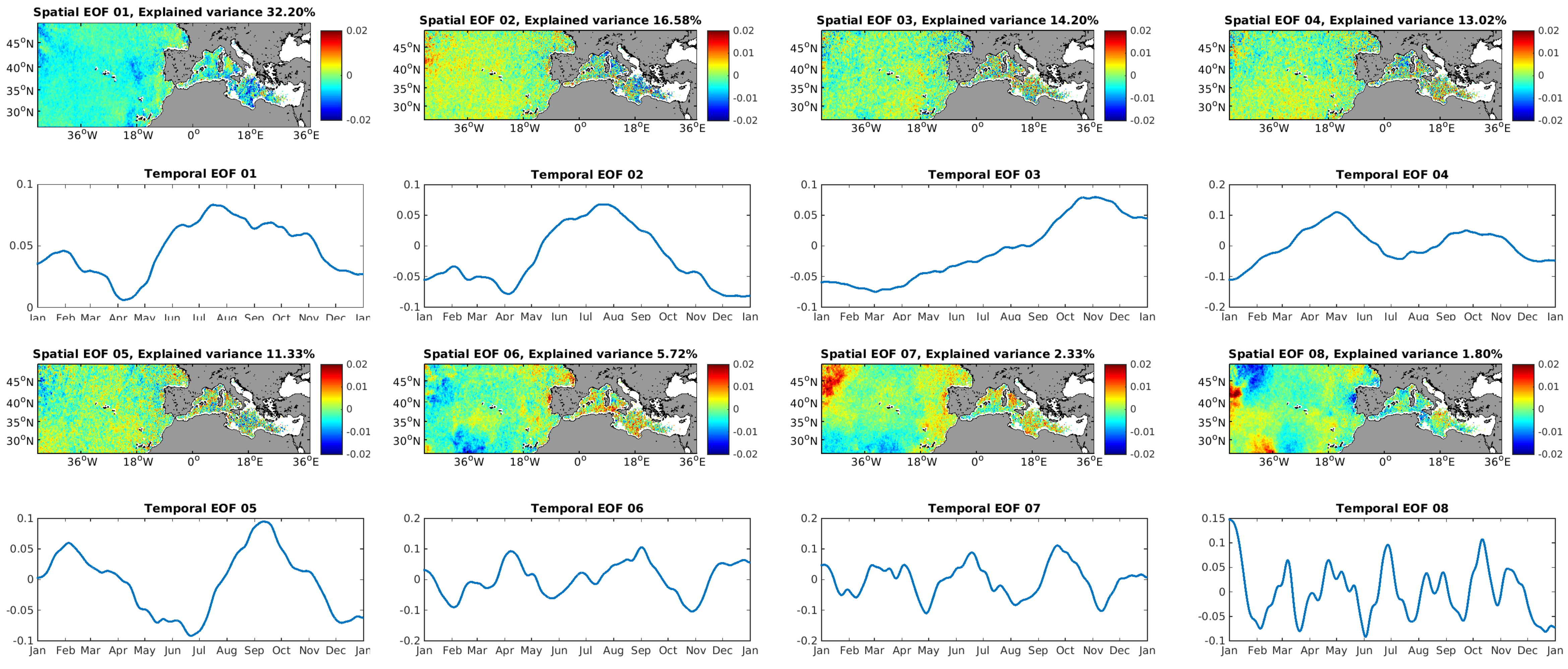


Figure 5: time series of the spatially averaged SSS anomalies (with respect to an in situ climatology) over the whole domain of study for the initial ascending and descending passes, and their DINEOF reconstruction.



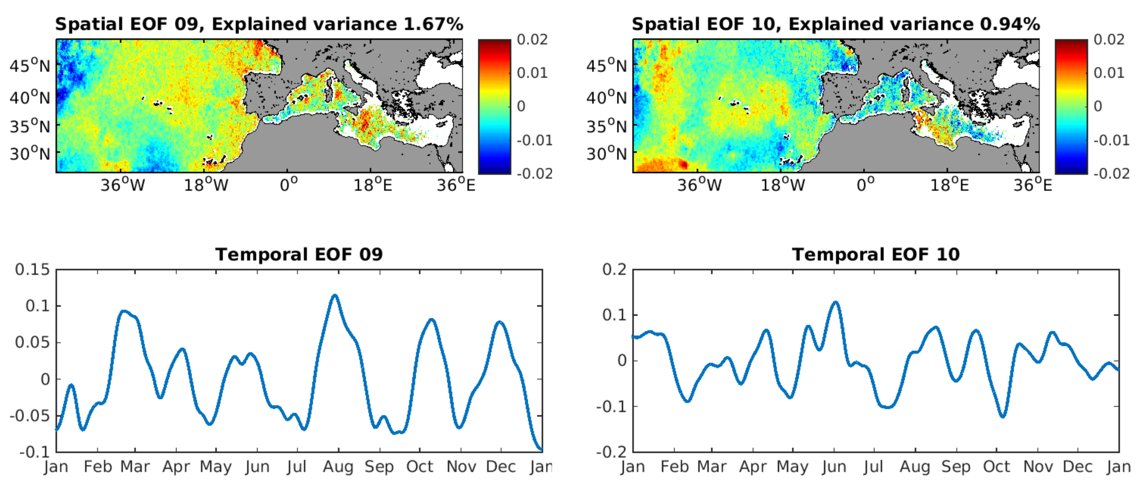


Figure 6: Spatial and temporal EOF modes of the ascending – descending daily differences (swaths previously reconstructed by DINEOF). While EOFs 2 to 5 do not show large-scale patterns in the differences between ascending ans ascending swaths, EOFs 6 to 10 do present about 10% of variability in zones like the Gulf Stream, the subtropical salinity maximum, and zones near land. The first EOF shows the consistent fresher difference of the ascending swaths, which account for 32% of the variability.

Example of DINEOF reconstruction and effect in the differences analysis:

- The initial SSS anomaly fields and DINEOF reconstructions are shown for 5 July 2013
- The initial fields do not allow to study the spatial distribution of differences

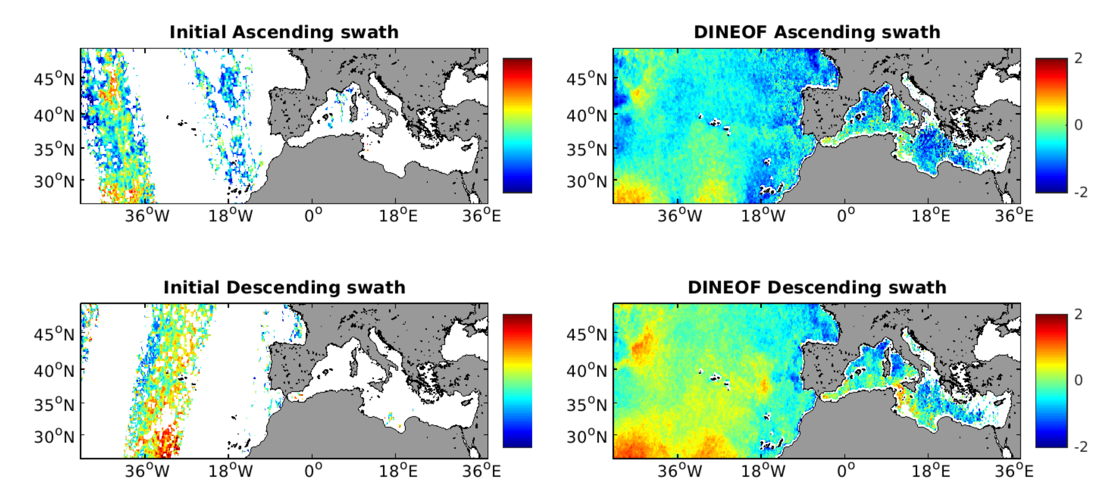


Figure 7: initial ascending and descending swaths for 5 July 2013, and their DINEOF reconstruction

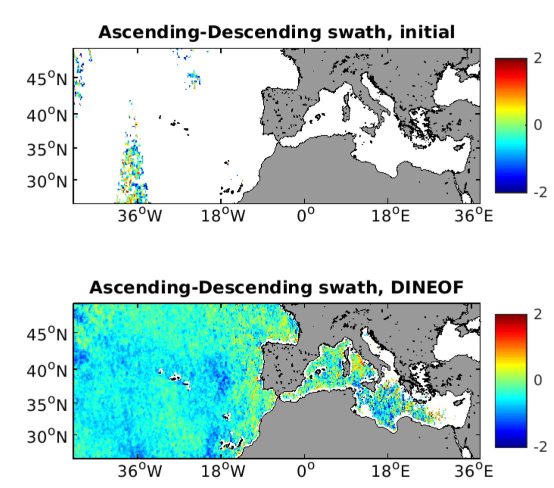


Figure 8: difference field for 5 July 2013 calculated using initial swaths (top) and the DINEOF reconstructed datasets (bottom)

6. Conclusions

- The difference between ascending and descending swaths presents a temporal and spatial variability
- Maximum differences in time are found during summer months
- Maximum differences in space are found in the Gulf Stream, the subtropical SSS maximum and near land
- A temporal covariance matrix filter is applied, which influences the EOF modes (specially the temporal modes). Therefore, long-term changes in the differences fields are shown here.
- The DINEOF SSS fields show the signal of the Douro and Gironde rivers

Acknowledgements
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In situ salinity data were obtained from the Coriolis database (http://www.coriolis.eu.org) and World Ocean Database (http://www.nodc.noaa.gov/)

More information: http://www.gher.ulg.ac.be/WP/
http://modb.oce.ulg.ac.be/DINEOF

Some DINEOF references:

Development of DINEOF:
-Beckers and Rixen, 2003
JAOT, 20(12):1839-1856.
- Alvera-Azcarate et al, 2005
Ocean Model. 9:325-346.

Multivariate application:
Alvera-Azcarate et al, 2007
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Alvera-Azcarate et al, 2009.
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Remote Sens. Environ. 119:84–91

DINEOF and SMOS:
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RSE, under review