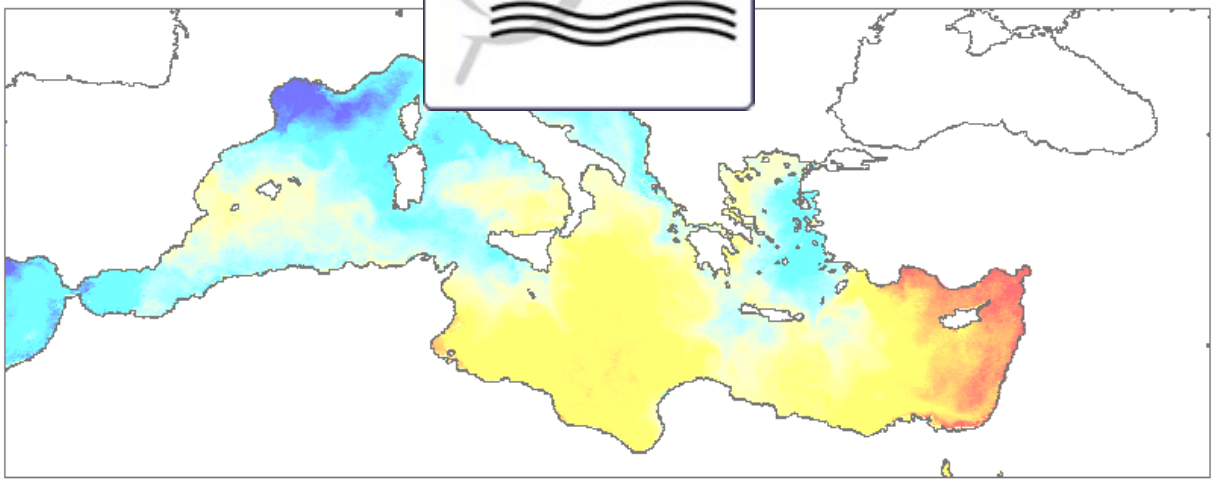
Merging satellite and in situ sea surface temperature data using **DINEOF** (Data Interpolating Empirical Orthogonal Functions)

A. Alvera-Azcárate, A. Barth, J.-M. Beckers

GHER – University of Liège

FNRS – National Fund for the Scientific Research, Belgium



HiSea project (BELSPO SR/12/140, Research programme for earth observation STEREO II)

Introduction

High quality SST data sets needed for various applications, including numerical weather prediction, ocean forecasting and climate research.

Coverage, resolution and precision of individual SST observations not sufficient for these applications

Merging of complementary data sets is needed to increase the coverage and to reduce the final data set error.

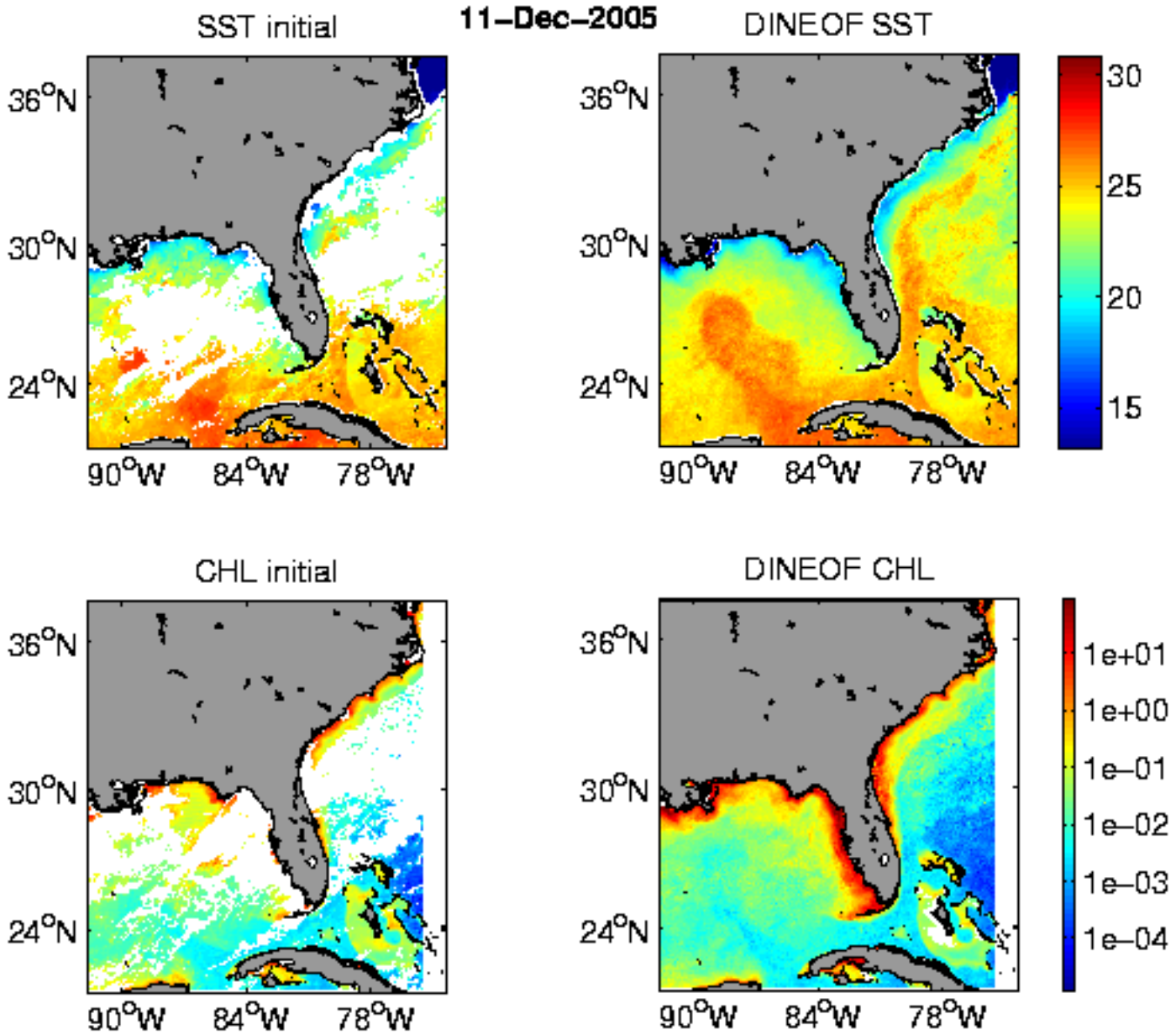
Satellite data and in situ data: different characteristics, depth of measurement, spatial and temporal resolution...

DINEOF
(Data Interpolating Empirical Orthogonal Functions)

- Reconstruction method for gappy data based on an EOF decomposition
- Parameter-free, no need of *a priori* information
- Truncated EOF basis: determines optimal number of EOFs by cross-validation. Error estimation

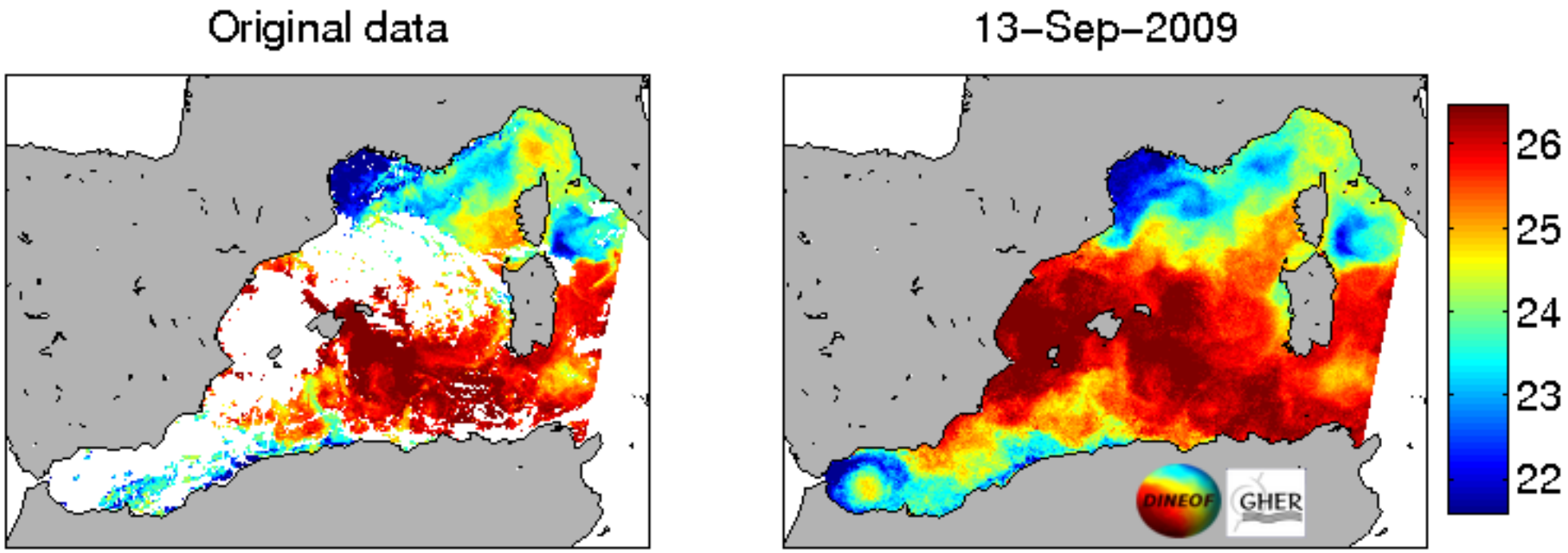
DINEOF examples

SST and chlorophyll in Gulf of Mexico



DINEOF examples

SST in western Mediterranean Sea



Satellite + in situ: data used

Year: 1999 (higher number of in situ data)
Domain: western Mediterranean Sea

SATELLITE DATA

- AVHRR SST data (http://podaac.jpl.nasa.gov)
- ~5 km spatial resolution

IN SITU DATA

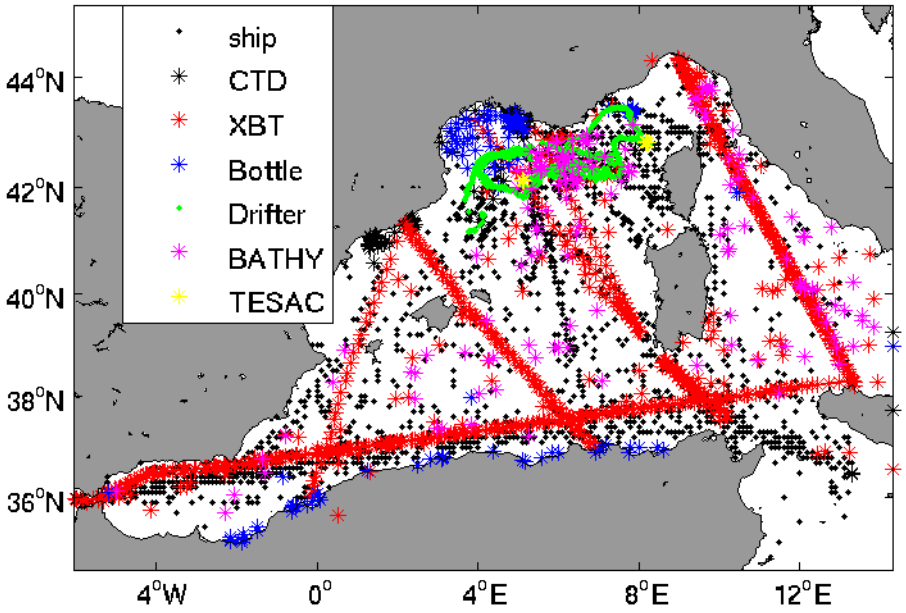
Databases used:

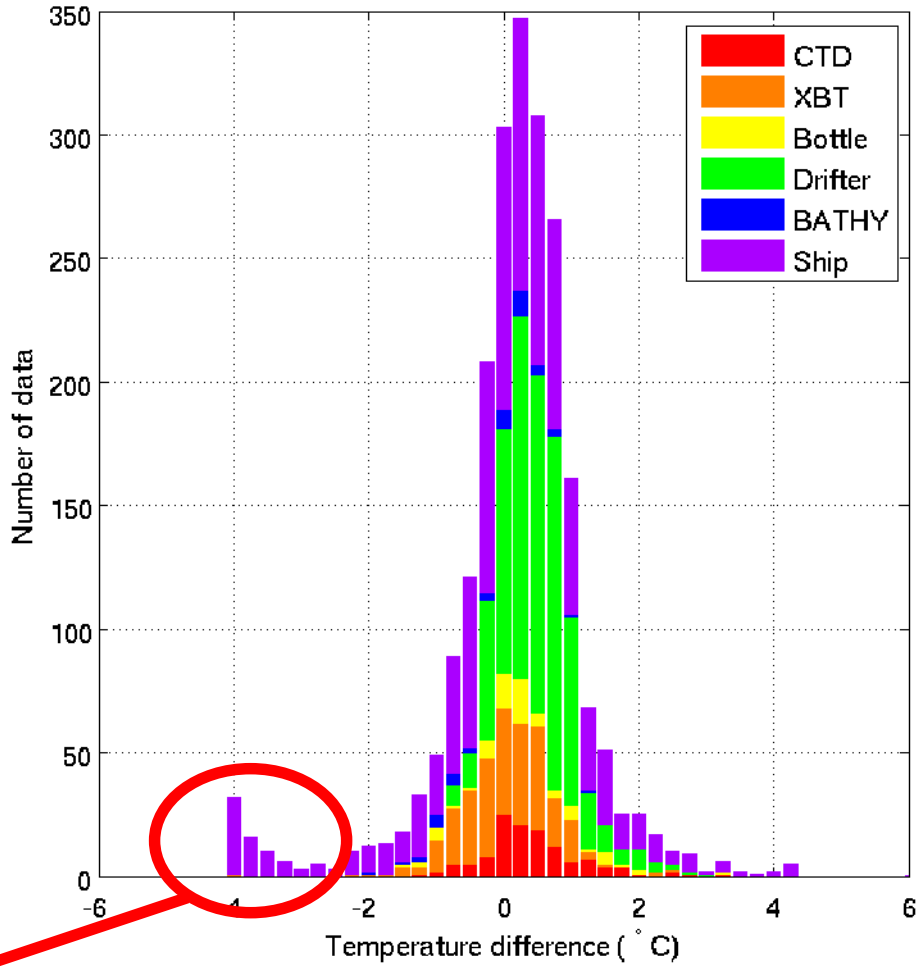
- World Ocean Database 2005 (WOD05, http://www.nodc.noaa.gov/)
- International Comprehensive Ocean-Atmosphere Data Set (ICOADS http://icoads.noaa.gov/).
- MEDAR/MedAtlas (MEDAR-Group (2002), http://www.ifremer.fr/medar/)
- Coriolis Data Center (http://www.coriolis.eu.org/)
- International Council for the Exploration of the Sea (ICES, http://www.ices.dk/).

After check for doubles and depth ≤ 5 m, total number of data: 6636

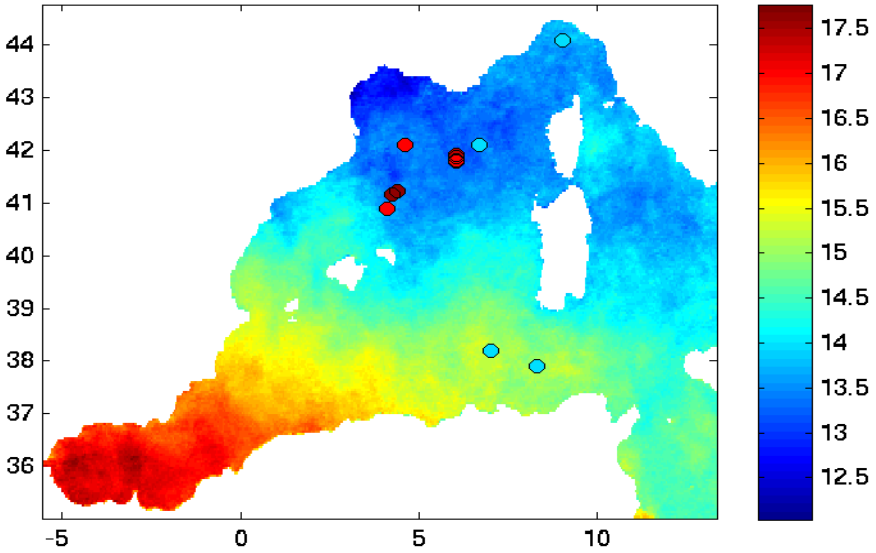
From 6636 in situ data, 4522 satellite match-ups (~50% night-time, ~50% day-time)

In situ data: location and type



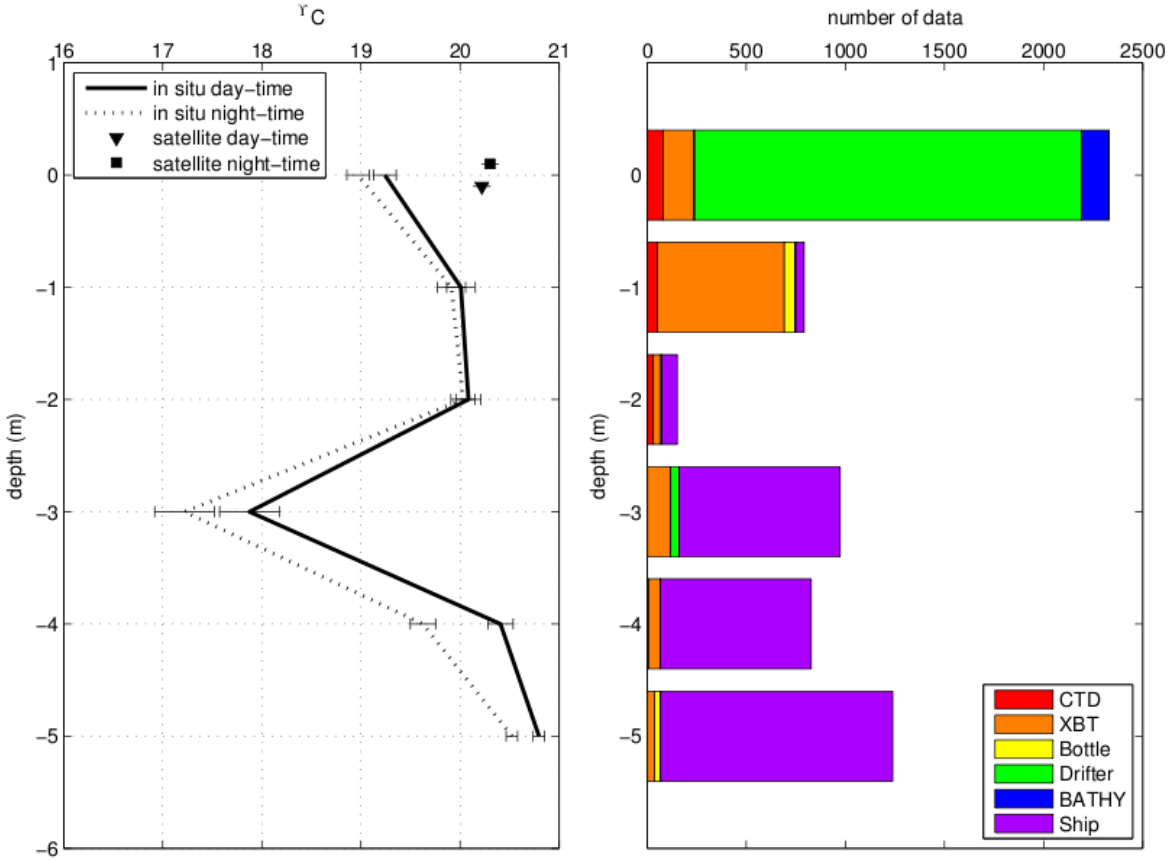


20 March 1999

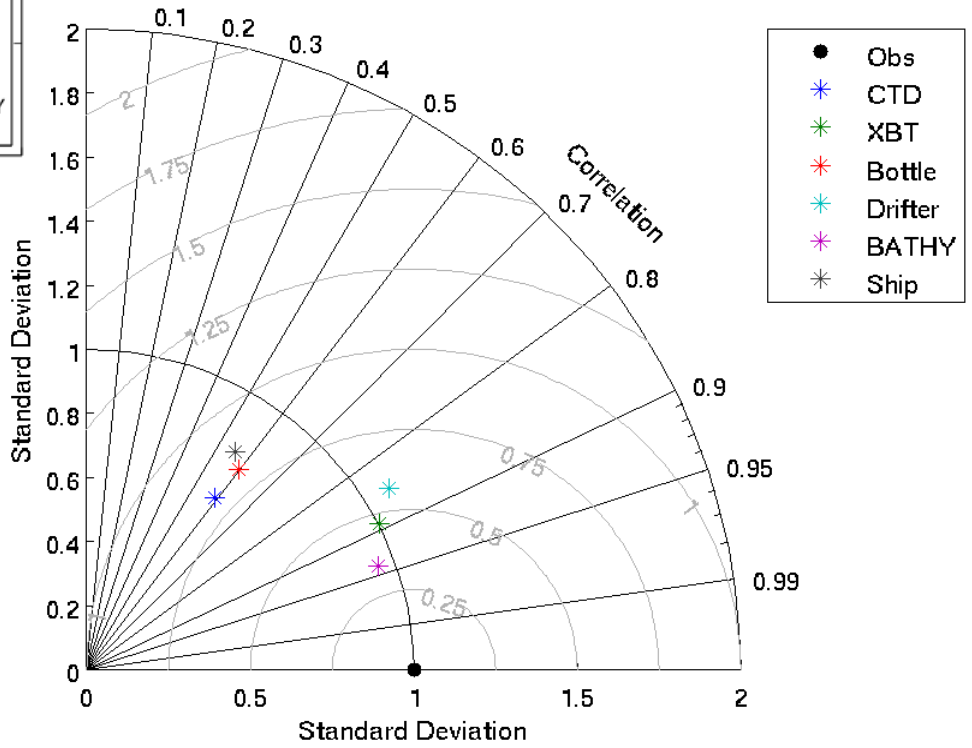


Temperature difference between satellite and in situ data

In situ-satellite data comparison



Day-time satellite data vs. in situ data



	Bias(ºC)	RMS(ºC)	Anom. Corr.
Day-time	0.16	1.12	0.7
Night-time	-0.12	1.23	0.7

Detailed comparison in Alvera-Azcárate et al, Oc. Dyn. 2011

Day-time satellite data reconstruction

1 year satellite data, 65.5 % missing data

3% of cross-validation data (valid satellite data), in the form of clouds

11 EOFs retained

99.6 % total variance explained

0.5ºC cross-validation error

DINEOF + OI

Two-step process:

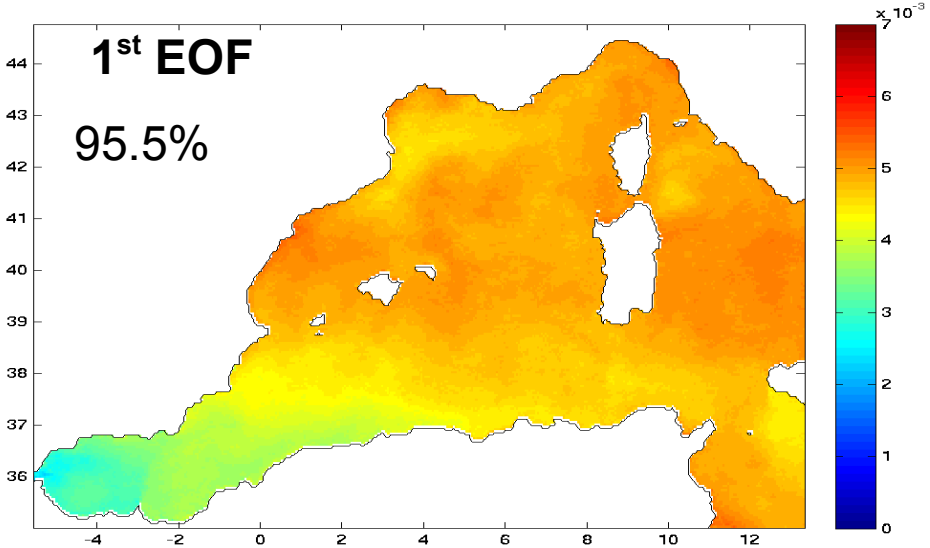
- DINEOF on satellite data
- Optimal Interpolation to merge in situ and satellite data

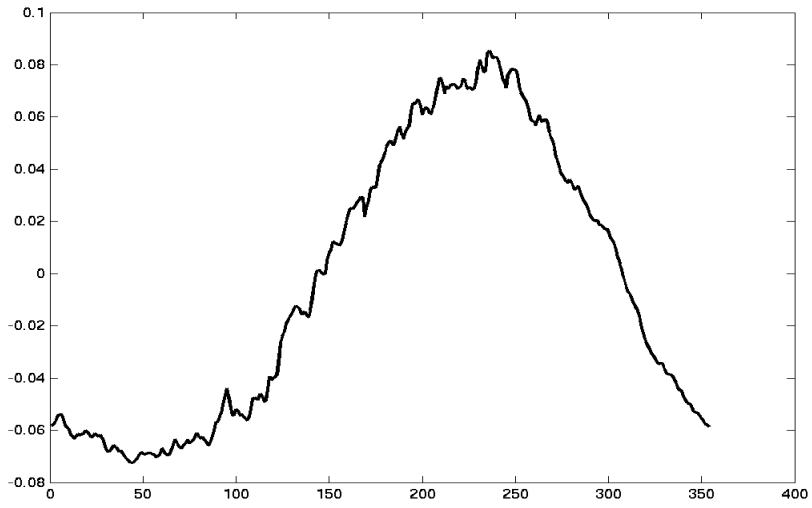
Truncated EOF basis given by DINEOF used as covariance matrix (**P**).

Error variance (**R**) fixed for in situ data (0.25ºC) and satellite data (0.5ºC)

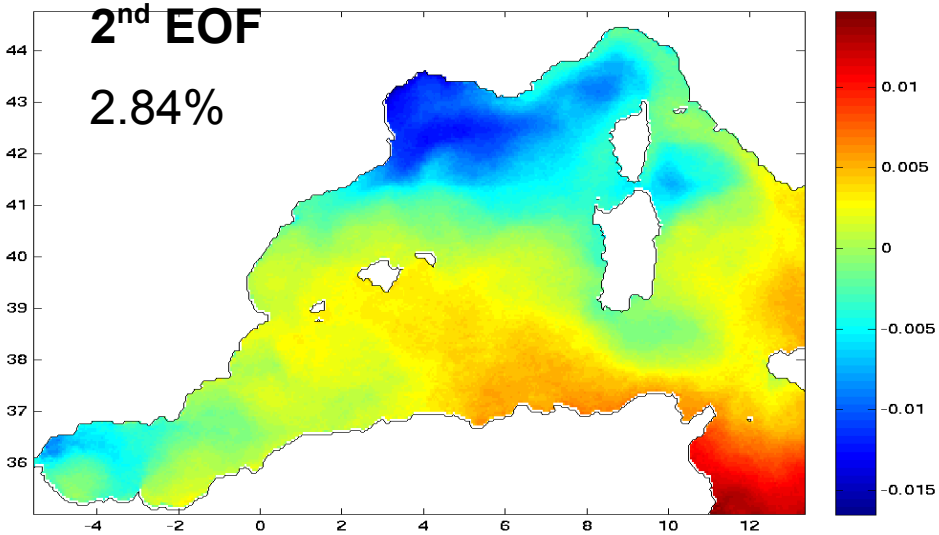
$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{P}\,\mathbf{H}^T (\mathbf{H}\,\mathbf{P}\,\mathbf{H}^T + \mathbf{R})^{-1} (\mathbf{y}_o - \mathbf{H}\,\mathbf{x}_b)$$

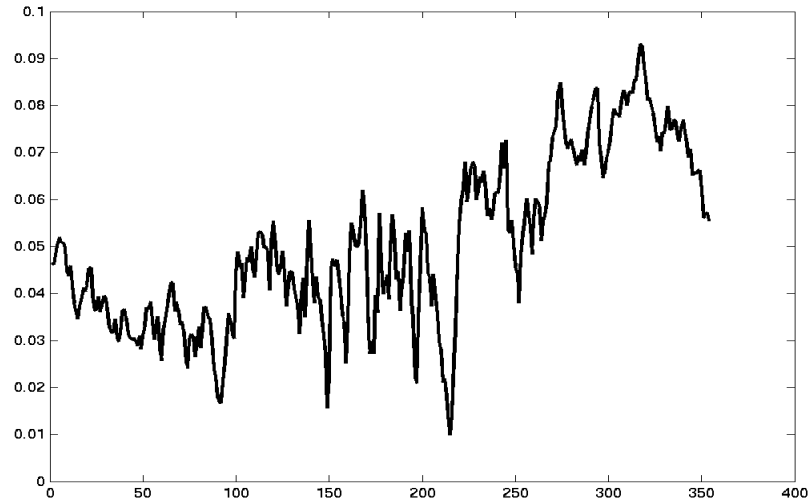
EOFs



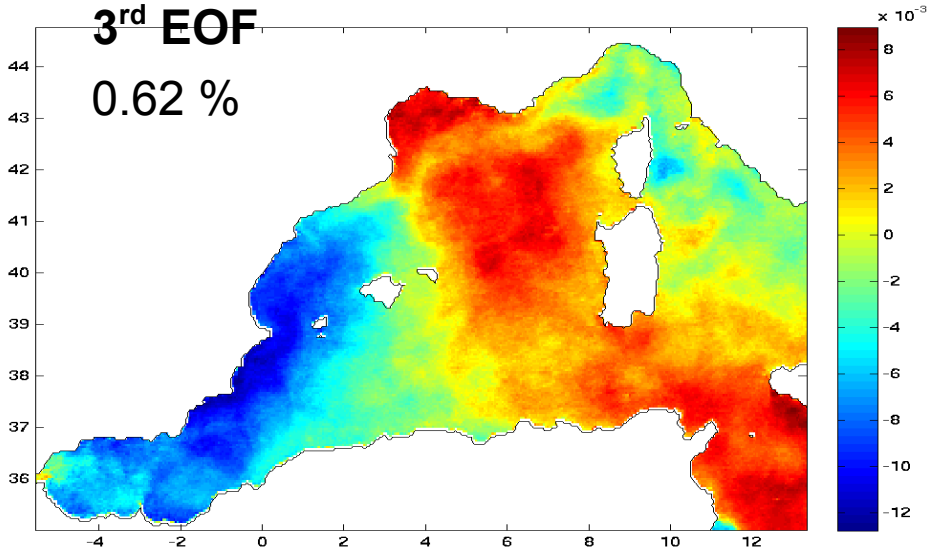


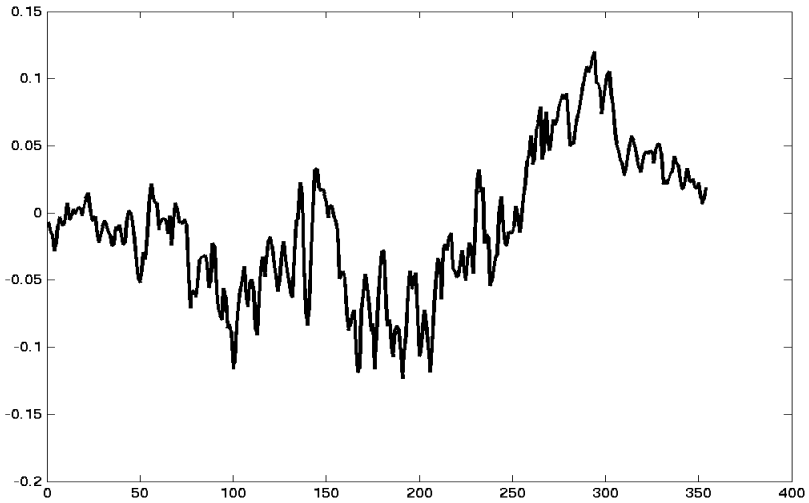
Seasonal cycle





EOFs



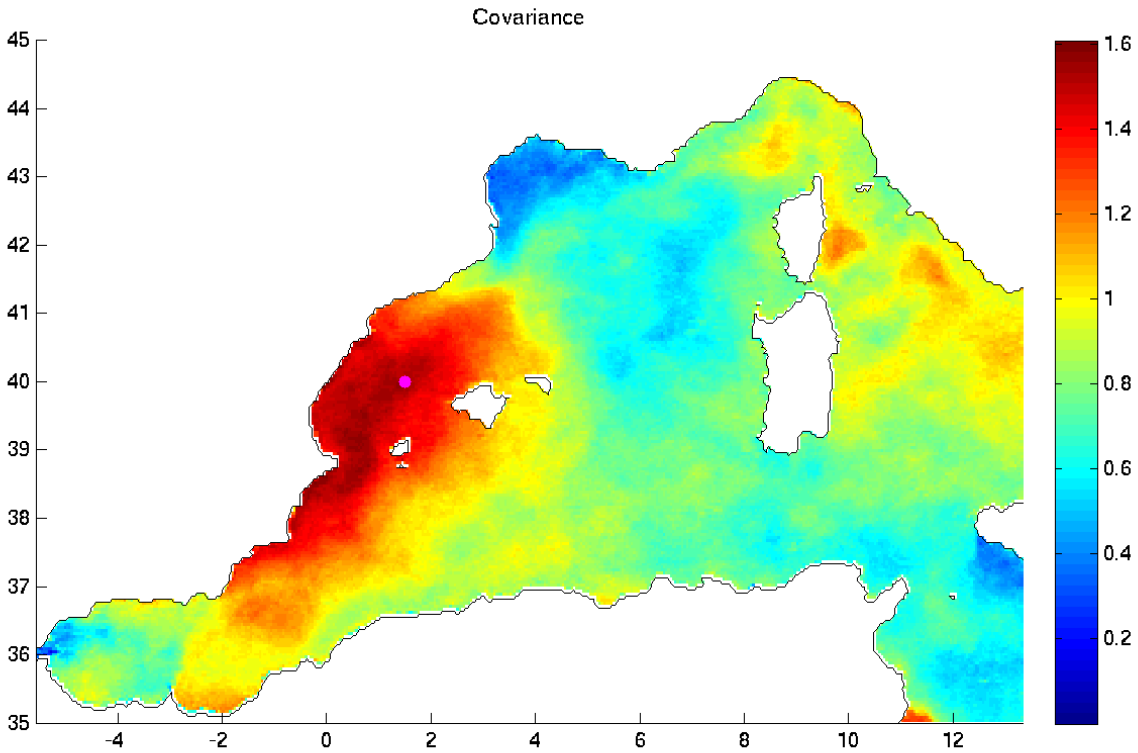


First EOF dominates

Small scales not well represented?

Covariances

Non-parametric, based on satellite data

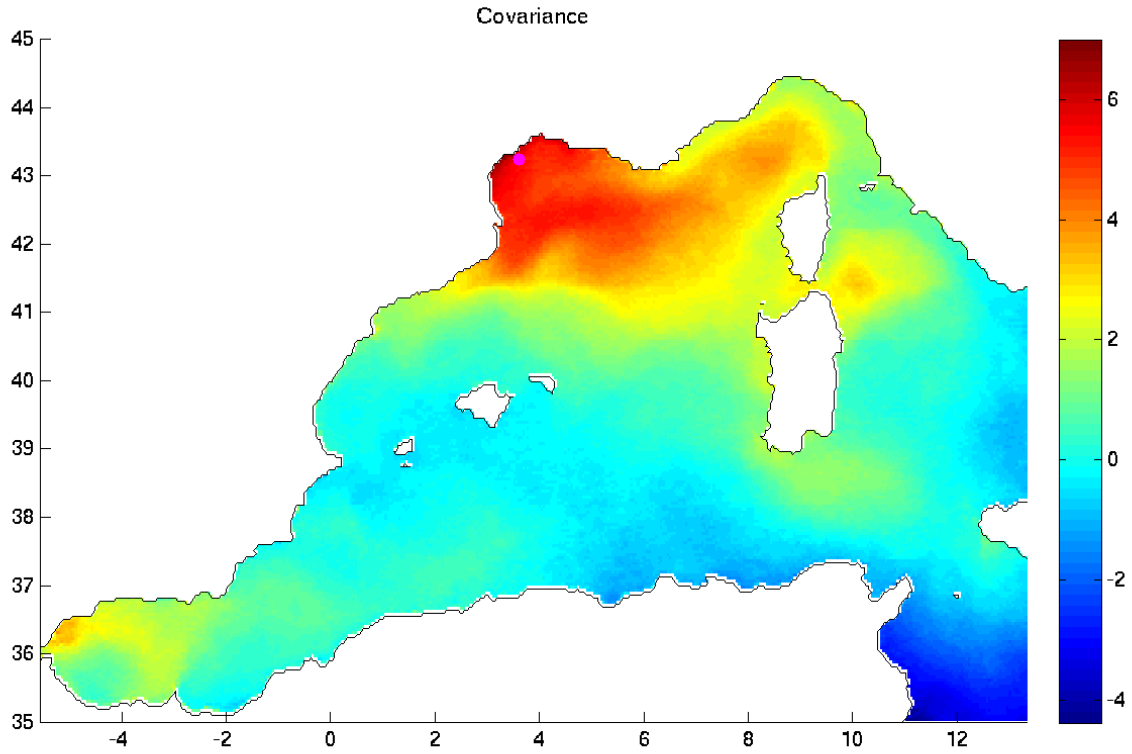


Balearic Sea

Northern current signature along Spanish coast

Spurious long distance correlations

Covariances



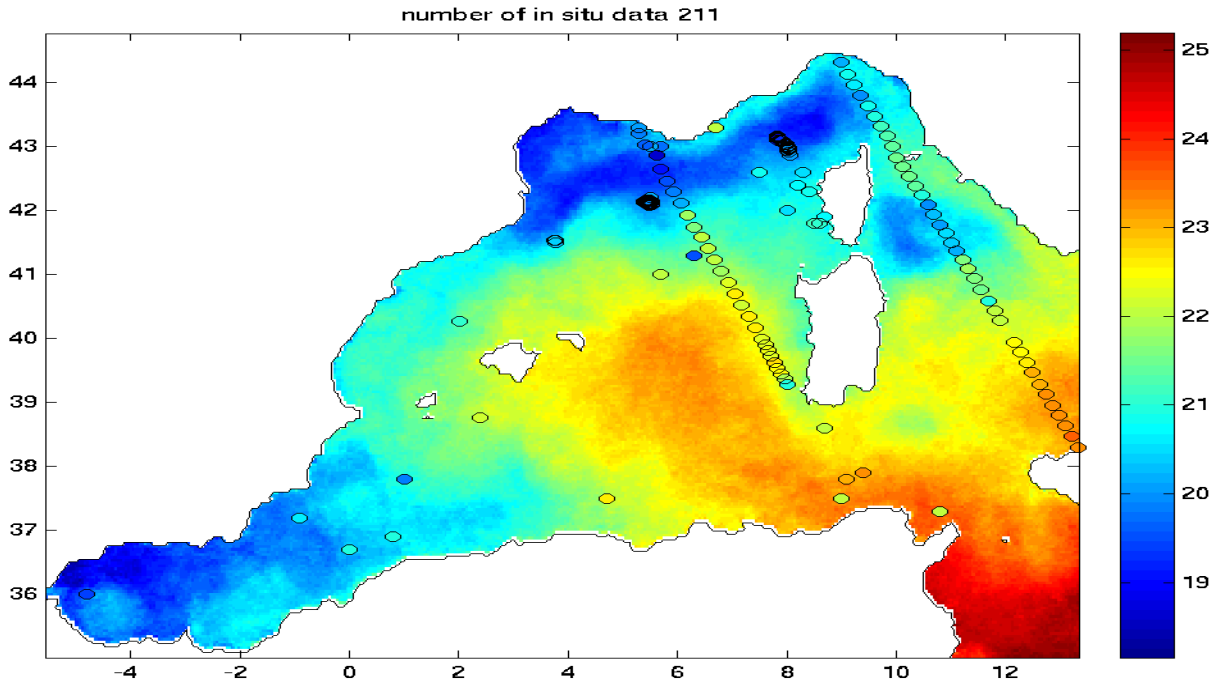
Gulf of Lions

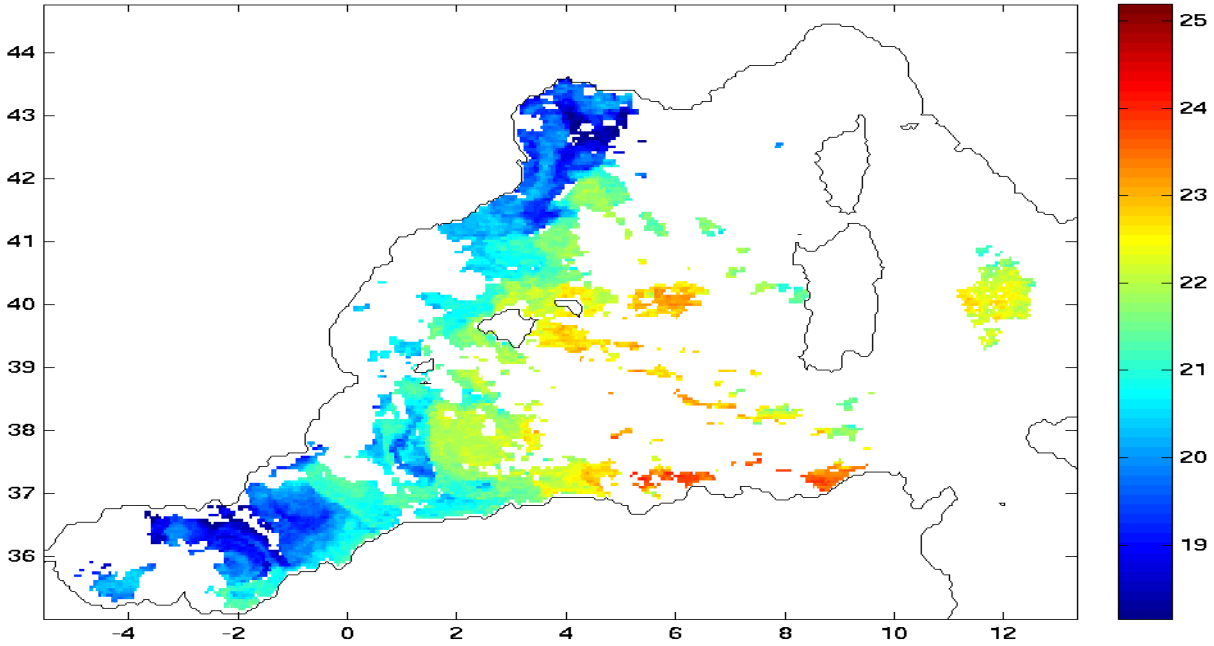
Strong correlation over the entire Gulf of Lions/Ligurian Sea domain

Signature of the Northern Current

Small correlation with Alboran Sea, probably only specific for the time period considered

Example of DINEOF-OI analysis, 16 October 1999





Cross-validation test

10% of in situ data set aside for validation of DINEOF-OI method

Random locations

	all	CV data
DINEOF	1.12	1.07
DINEOF-OI with all insitu data	1.08	1.04
DINEOF-OI without CV insitu data	1.08	1.06

DINEOF-OI improves over DINEOF alone (only satellite data)

Conclusions

- DINEOF + OI step (EOF basis is covariance matrix) to merge satellite with in situ data
- Cross-validation shows improvement of DINEOF-OI over DINEOF alone
- Few EOFs retained: small scales not well represented
- Covariances realistic, although spurious correlations at long distances appear
- Future work

  Removal of seasonal cycle
  Longer time series
  Embedding OI step into DINEOF analysis might also improve small scales

  Also: satellite + satellite data merging using EOFs