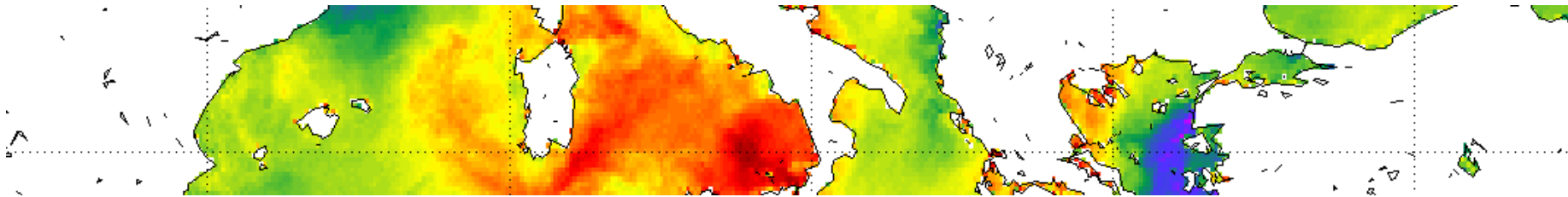# Producing gap-free analyzed sea surface temperature data from L3 products using web-based Data INterpolation Empirical Orthogonal Functions (DINEOF) technique

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GEOHYDRODYNAMICS AND ENVIRONMENT RESEARCH (GHER)
University of Liège, Liège (Belgium)

2014 GHRSST Science Meeting, 02-07. June 2014, Cape Town, South Africa

Outline

- DINEOF
- webDINEOF
  - UI + engine
- Examples
- Future development
- Summary

DINEOF - description

- EOF based technique to fill in missing (satellite) data

- Informations are extraced from spatio-temporal varaiability within the data

- Optimal number of EOFs derived by cross-validation

- Non-parametric, no a priori information (corr. length, cov.)

- Noise reduction due to the trancated EOF series

- Iterative method

- Problem

  - Only repeating structures are retained (no transient features)→ requires longer time series
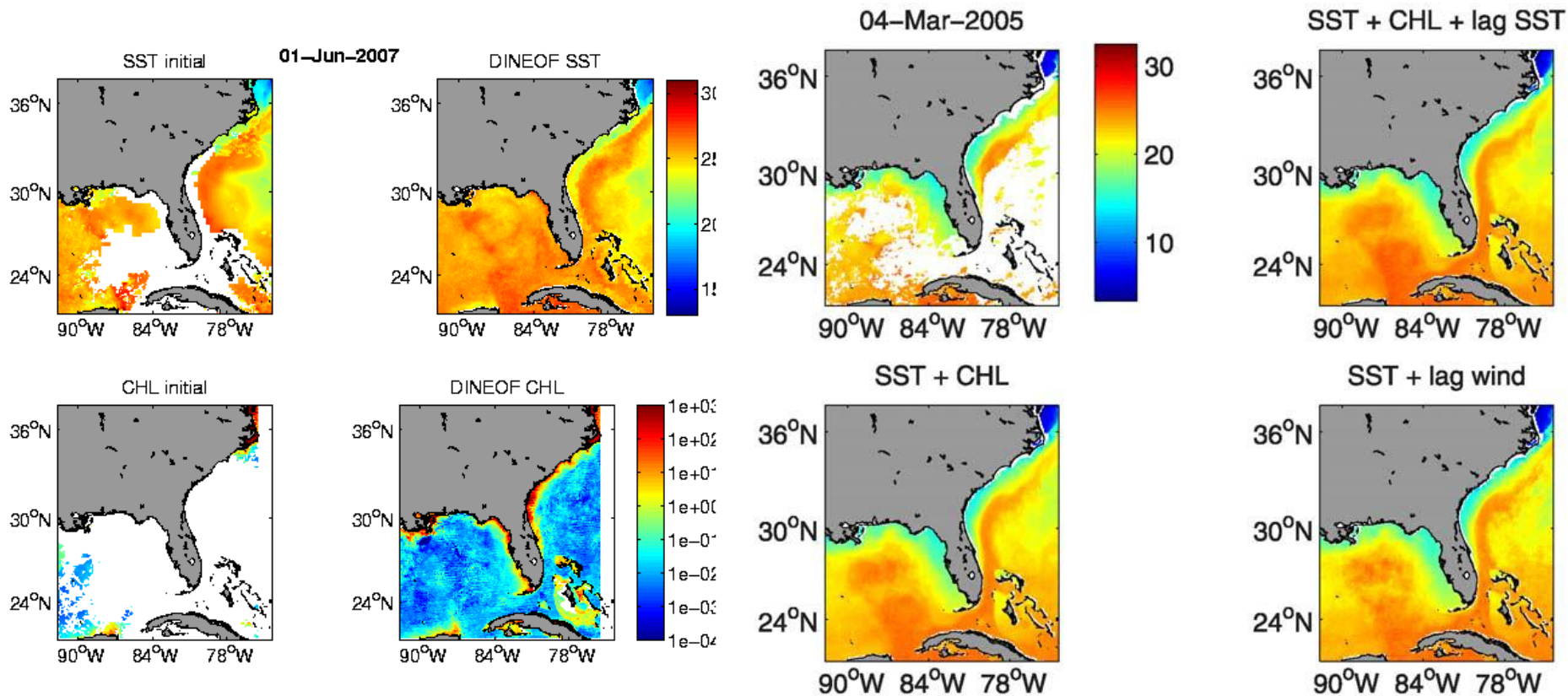
DINEOF – a bit detailed I

- **X –** data matrix $[X_1 \; X_2 \; ...X_N]$
  - data stored as columns
  - N data

- Initial matrix demeaned (working on anomalies)

- Missing data set to zero

- ~3-5% of valid data set for cross-validation (as missing)

DINEOF – a bit detailed II

- $i=1:N_{max\_EOF\_modes}$ {

    Until error with cross validation < THRESH{

    - Perform SVD decomposition ($\mathbf{X=U\Sigma V^T}$)

        – Lanczos solver, Toumazou and Cretaux (2001)

    - Calc missing values using i EOF mode(s)

    - Improve guess with calc. missing values

    - check using cross validation (rms)

        }

    }

- Beckers and Rixen, 2003

- Alvera-Azcárate et al., 2005

DINEOF – multivariate analysis

- Alvera-Azcárate et al. (2007). Multivariate reconstruction of missing data in sea surface temperature, chlorophyll and wind satellite fields. Journal of Geophysical Research, 112:C03008, 2007. doi:10.1029/2006JC003660.

DINEOF – temporal filtering

24-Dec-2003 25-Dec-2003 27-Dec-2003

Reference Reference Reference
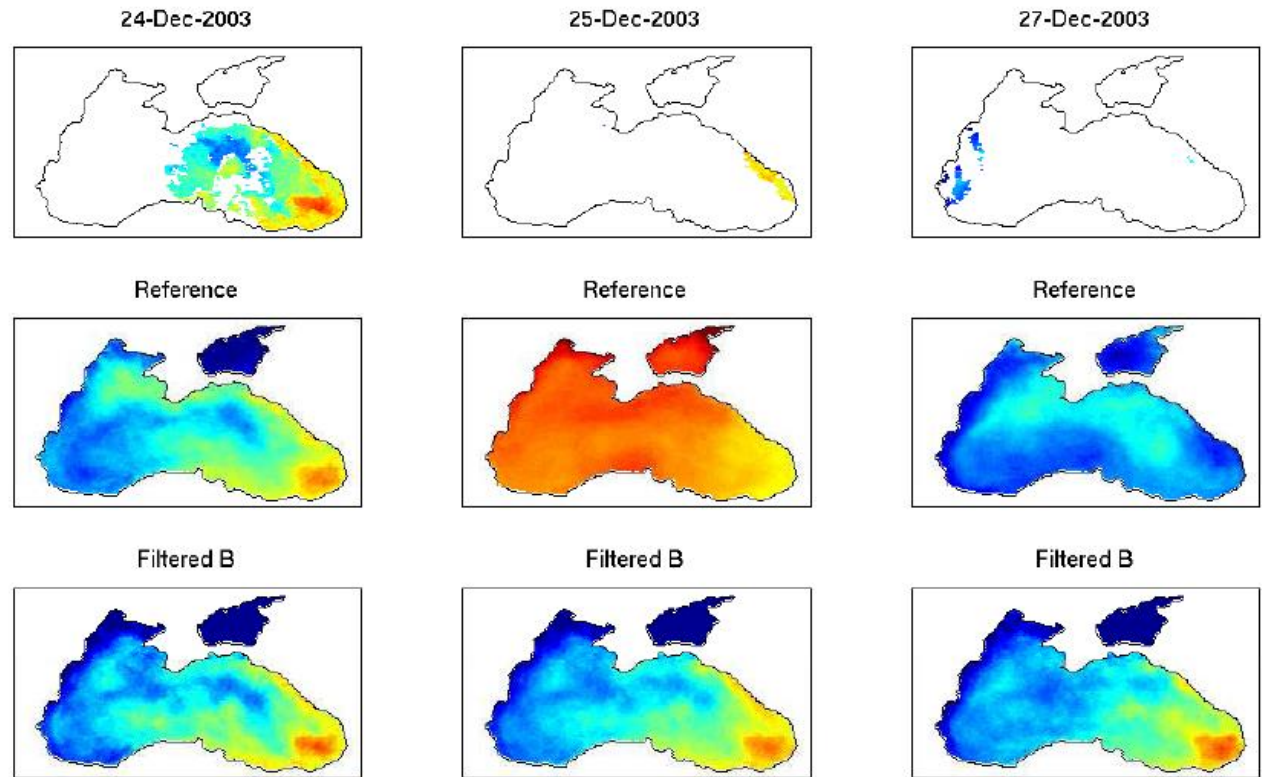
Alvera-Azcárate et al., 2009

Filtered B Filtered B Filtered B

- Filtering of covariance matrix (Laplacian)
- Applied iteratively – cut off frequency based on number of iterations

DINEOF - outliers

Alvera-Azcárate et al. (2012). Outlier detection in satellite data using spatial coherence. Remote Sensing of Environment, 119:84–91.

- Local median test

- Proximity test

- EOF basis test:
  difference (analysis – obs)
  larger then statistically
  expected misfit calculated
  during analysis
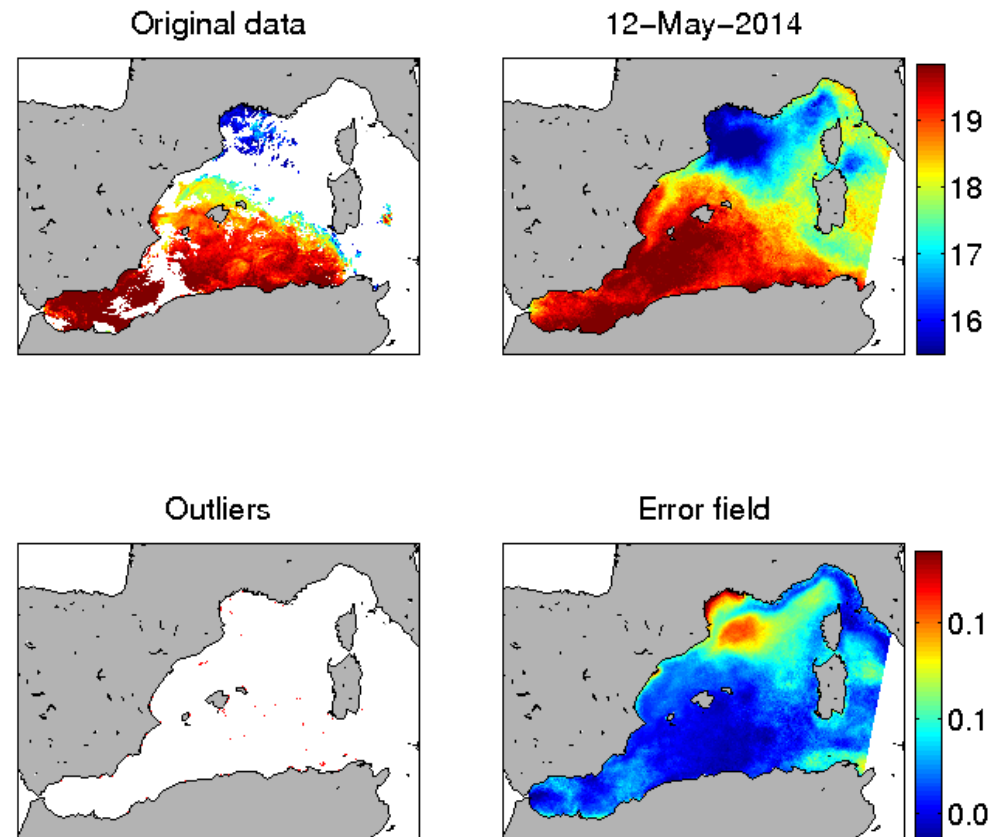
DINEOF + OI

- DINEOF –larger scales
- OI – smaller scales

- http://www.ocean-sci-discuss.net/11/895/2014/osd-11-895-2014.html

- Beckers et al. (2014). Multi-scale optimal interpolation: application to DINEOF analysis spiced with a local optimal interpolation, 11, 895-941, Ocean Science Discussions (under review).

DINEOF + OI
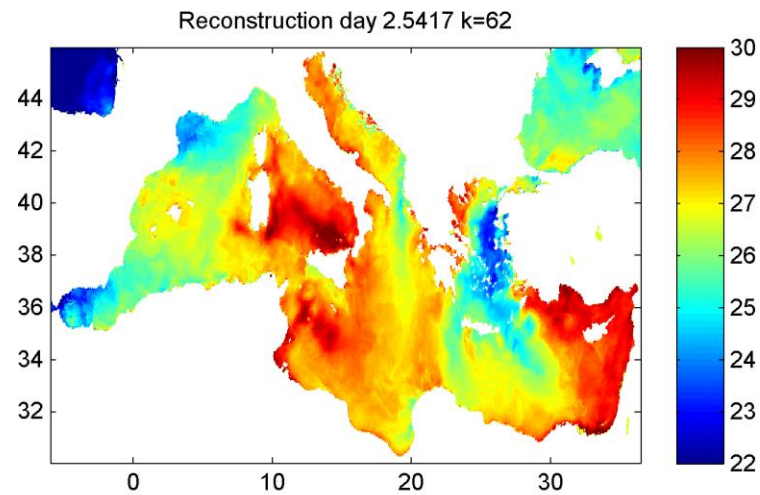
DINEOF
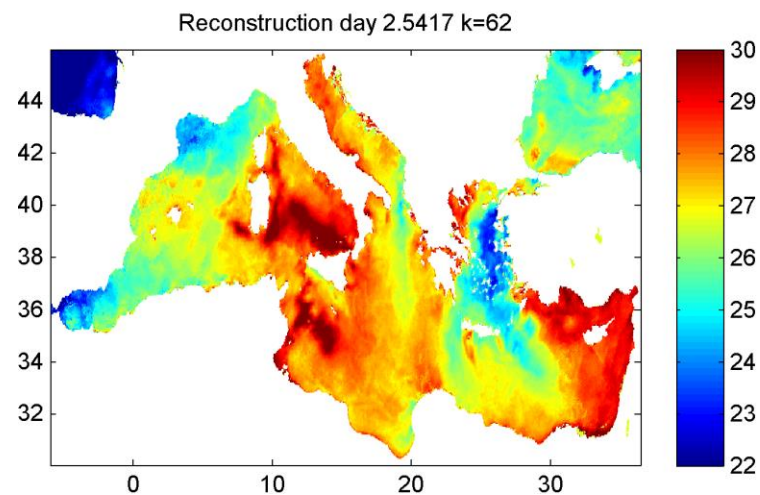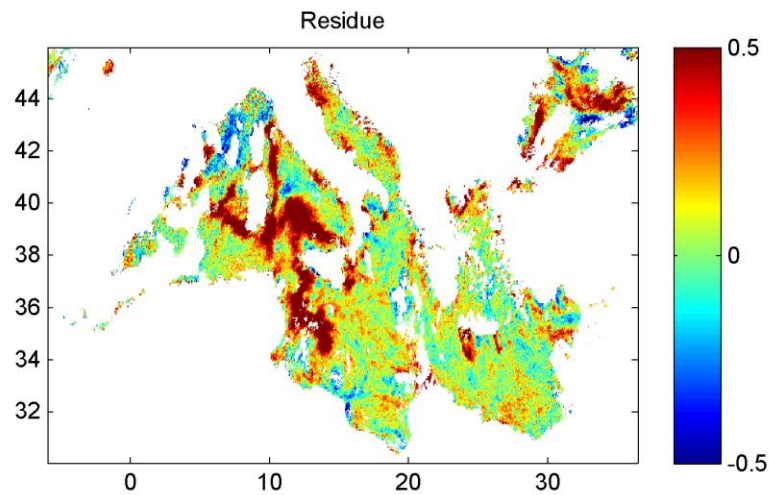
DINEOF+OI
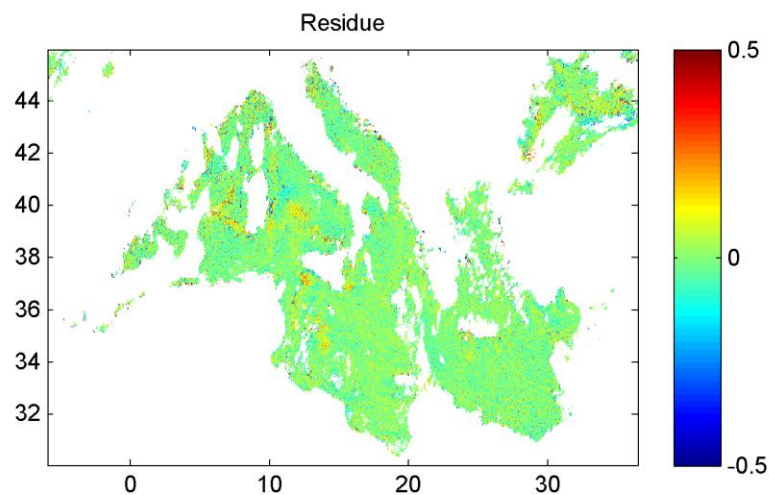
DINEOF + OI

- 2D scatter plot (1-16. 08. 2013)

DINEOF, rms: 0.30783, r:0.96998, S:0, points:700644

DINEOF

K1andK2-10it, rms: 0.22052, r:0.9845, S:0.48681, points:700644

DINEOF+OI

- Google: DINEOF
- Open source
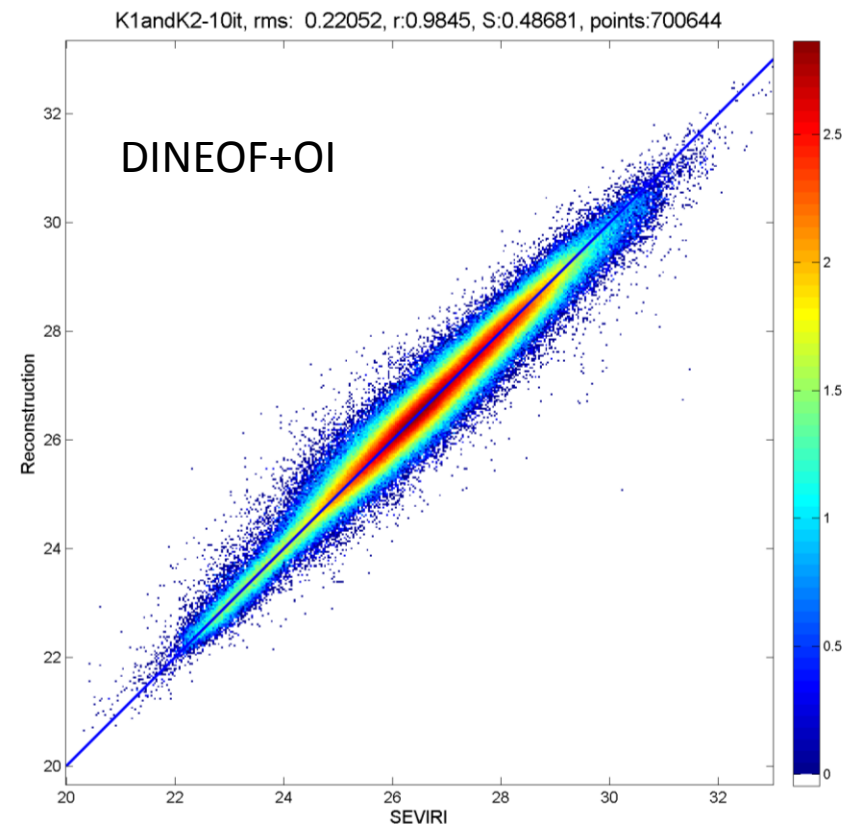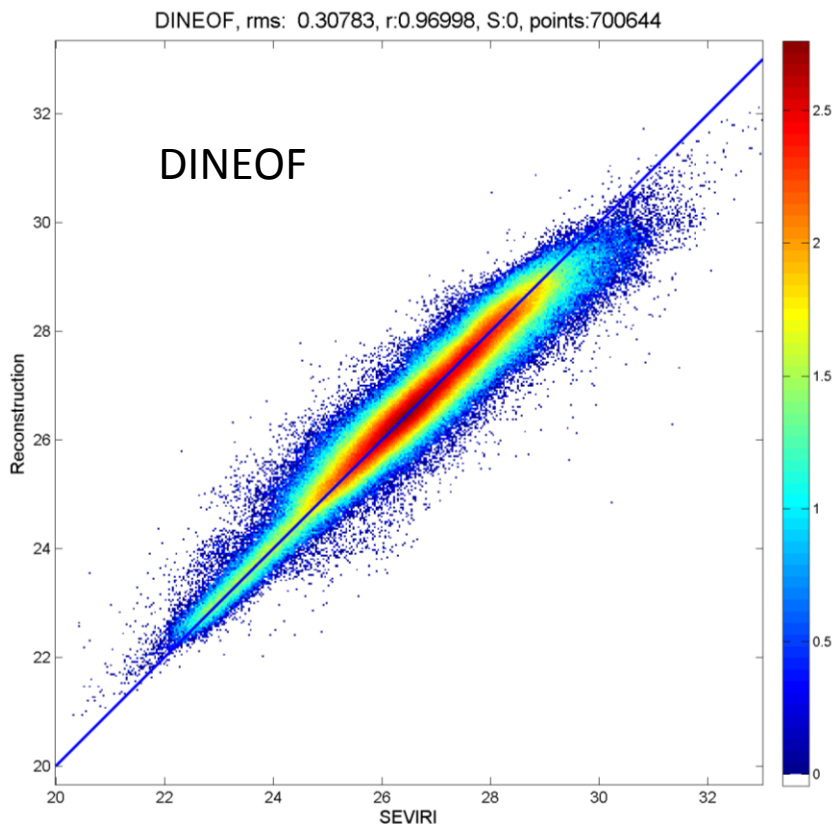
http://modb.oce.ulg.ac.be/mediawiki/index.php/DINEOF

DINEOF - references

- J.-M. Beckers and M Rixen. EOF calculations and data filling from incomplete oceanographic data sets. Journal of Atmospheric and Oceanic Technology, 20(12):1839-1856, 2003.

- A. Alvera-Azcárate, A. Barth, M. Rixen, and J. M. Beckers. Reconstruction of incomplete oceanographic data sets using Empirical Orthogonal Functions. Application to the Adriatic Sea. Ocean Modelling, 9:325-346, 2005.

- J.-M. Beckers, A. Barth, and A. Alvera-Azcárate. DINEOF reconstruction of clouded images including error maps. Application to the Sea Surface Temperature around Corsican Island. Ocean Science, 2(2):183-199, 2006.

- A. Alvera-Azcarate, A. Barth, J. M. Beckers, and R. H. Weisberg. Multivariate reconstruction of missing data in sea surface temperature, chlorophyll and wind satellite fields. Journal of Geophysical Research, 112:C03008, 2007.

- A. Alvera-Azcárate, A. Barth, D. Sirjacobs and J.-M. Beckers. Enhancing temporal correlations in EOF expansions for the reconstruction of missing data using DINEOF. Ocean Science, 5, 475-485, 2009

- A. Alvera-Azcárate, D. Sirjacobs, A. Barth, and J.-M. Beckers. Outlier detection in satellite data using spatial coherence. Remote Sensing of Environment, 119:84-91, 2012.

- J.-M. Beckers, A. Barth, I. Tomazic, and A. Alvera-Azcárate, (2014). Multi-scale optimal interpolation: application to DINEOF analysis spiced with a local optimal interpolation, 11, 895-941, Ocean Science Discussions (under review).
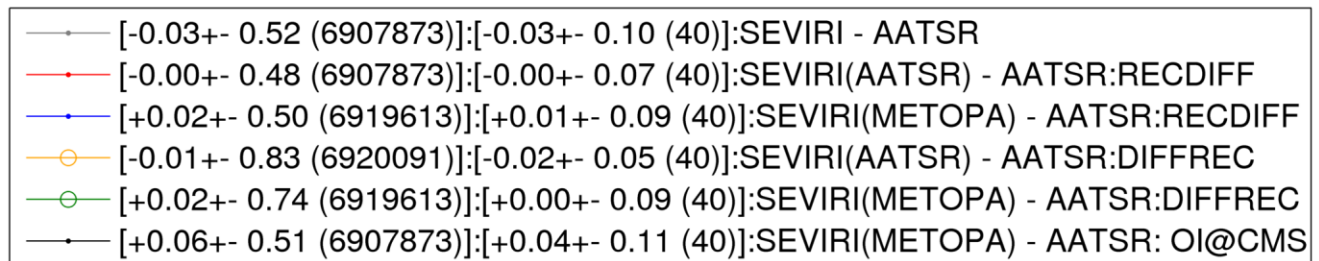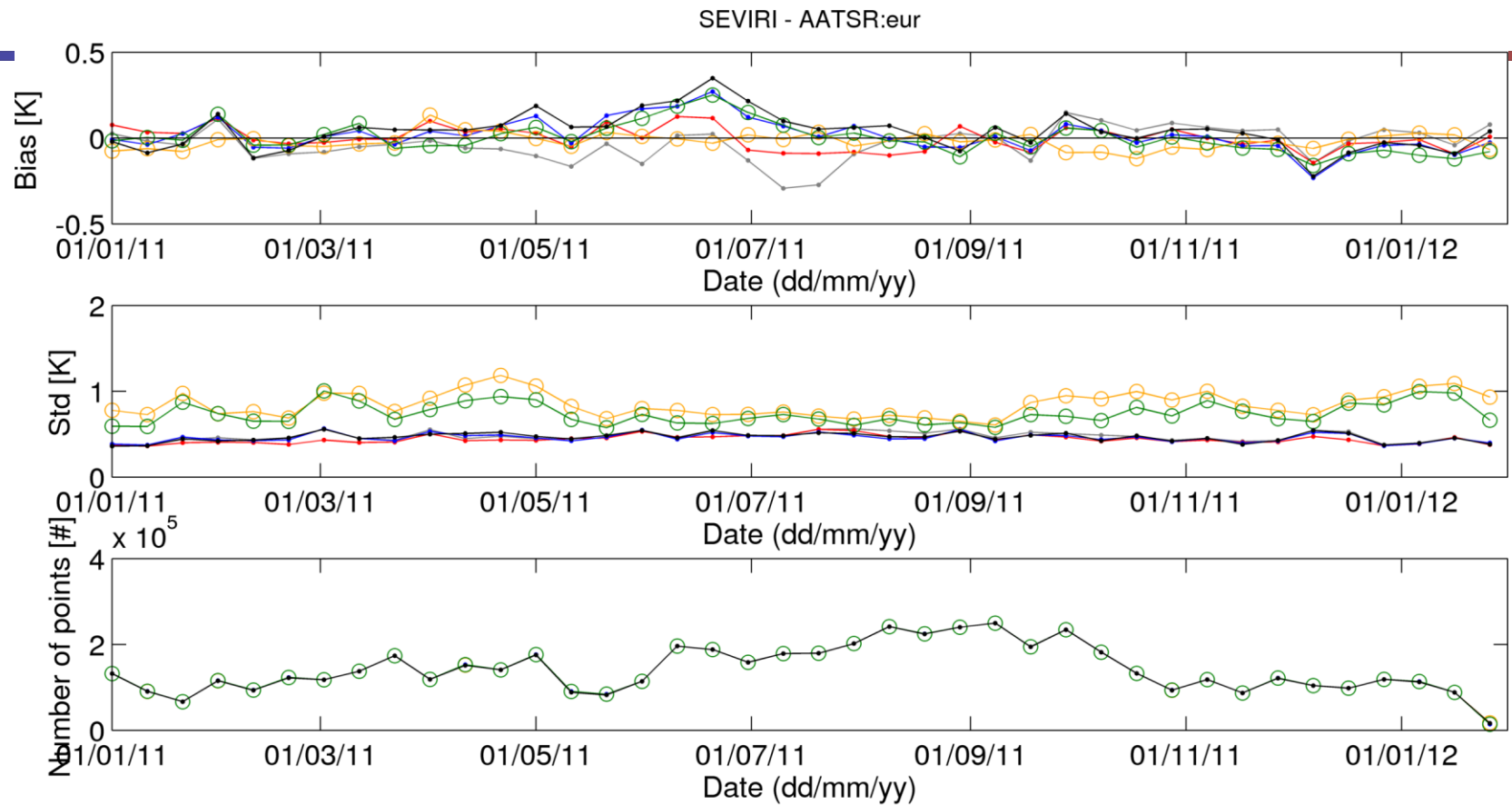
DINEOF implementations

- B. Nechad, A. Alvera-Azcárate, K. Ruddick, and N. Greenwood. Reconstruction of MODIS total suspended matter time series maps by DINEOF and validation with autonomous platform data. Ocean Dynamics, 61(8):1205–1214, 2011. doi:10.1007/s10236-011-0425-4.
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- N.P. Nezlin, K. Kamer, J. Hyde, E.D. Stein, ED. Dissolved oxygen dynamics in a eutrophic estuary, Upper Newport Bay, California. Estuarine, Coastal and Shelf Science, 82 (1): 139-151 MAR 20 2009.
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- U. Ganzedo, A. Alvera-Azcárate, G. Esnaola, A. Ezcurra, and J. Saénz. Reconstruction of Sea Surface Temperature by means of DINEOF. A case study during the fishing season in the Bay of Biscay. International Journal of Remote Sensing, 32 (4):933-950, 2011.
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- E. Mauri, P.M. Poulain, G. Notarstefano. Spatial and temporal variability of the sea surface temperature in the Gulf of Trieste between January 2000 and December 2006. Journal of Geophysical Research. Vol. 113, No. C10, C10012. 2008.
- E. Mauri, P.M. Poulain, Z. Južnič-Zonta. MODIS chlorophyll variability in the northern Adriatic Sea and relationship with forcing parameters. Journal of Geophysical Research, vol 112, C03S11, 2007.
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- filling of ocean color and sea surface temperature remote sensing products over the Southern North Sea by the
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- U. Ganzedo, A. Alvera-Azcárate, G. Esnaola, A. Ezcurra, and J. Sáenz. Reconstruction of Sea Surface
- Temperature by means of DINEOF. A case study during the fishing season in the Bay of Biscay. International
- Journal of Remote Sensing, 32 (4):933-950, 2011.
- B. Nechad, A. Alvera-Azcárate, K. Ruddick, and N. Greenwood. Reconstruction of MODIS total suspended
- matter time series maps by DINEOF and validation with autonomous platform data. Ocean Dynamics,
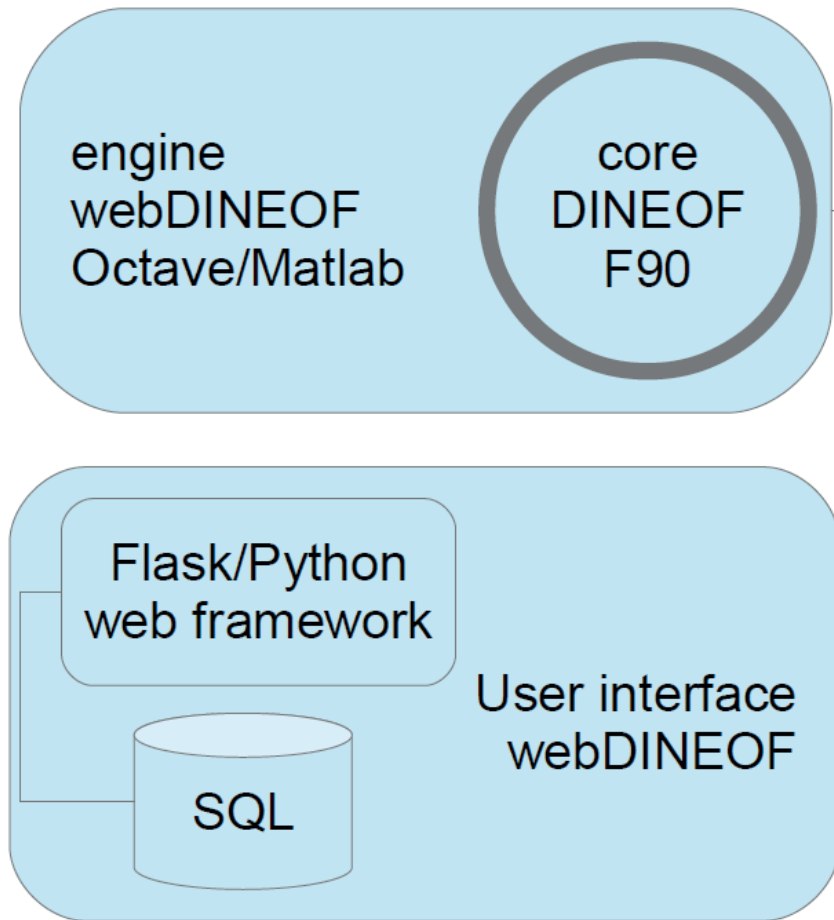- 61(8):1205-1214, 2011.

DINEOF projects

- BELSPO: BESST – Inter-sensor Bias Estimation in Sea Surface Temperature
  - Partner: Meteo-France/CMS (MyOcean)

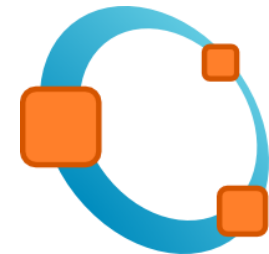- myOcean: OCEANCOLOUR_BS_CHL_L4_NRT_OBSERVATIONS_009_045
- ARCLAKE

BESST

SEVIRI - AATSR:eur

[-0.03+- 0.52 (6907873)]:[-0.03+- 0.10 (40)]:SEVIRI - AATSR
[-0.00+- 0.48 (6907873)]:[-0.00+- 0.07 (40)]:SEVIRI(AATSR) - AATSR:RECDIFF
[+0.02+- 0.50 (6919613)]:[+0.01+- 0.09 (40)]:SEVIRI(METOPA) - AATSR:RECDIFF
[-0.01+- 0.83 (6920091)]:[-0.02+- 0.05 (40)]:SEVIRI(AATSR) - AATSR:DIFFREC
[+0.02+- 0.74 (6919613)]:[+0.00+- 0.09 (40)]:SEVIRI(METOPA) - AATSR:DIFFREC
[+0.06+- 0.51 (6907873)]:[+0.04+- 0.11 (40)]:SEVIRI(METOPA) - AATSR: OI@CMS

webDINEOF – User Interface+engine

BELSPO

webDINEOF – engine (Octave)

- Octave/command line

- Open source

- For advanced users

  - Defining dataset/variable

  - Define time range

  - Defining DINEOF parameters

  - Define area/grid size

  - Define filtering/correcting criteria

```
CTE_RUN.DATASET='PATHFINDER_DAILY_NIGHT_V52';
CTE_RUN.VARNAME='sea_surface_temperature';
CTE_RUN.VARNAME_SHORT='sst';
CTE_RUN.DATE_START=datenum('2010-01-01','yyyy-mm-dd');
CTE_RUN.DATE_END=datenum('2012-01-01','yyyy-mm-dd');
CTE_RUN.GRID_SIZE_NEW=[0.0417*1];% degrees
CTE_RUN.EXPID={  {'nev' 30} {'ncv' 40} {'alpha' 0.01} ...
                        {'min_clear' 3} {'nitemax' 100}...
                    };

CTE_RUN.FILTER_ARR={ { {'pathfinder_quality_level'}  'pql' [0 5] '>=,&,<=' '' ''} ...
                    };
%                   { {'wind_speed'}      'w'   4        '<'      '' ''} ...
%                   { {'quality_level'}  'ql' [0 4] '>=,&,<=' '' ''} ...
CTE_RUN.CORRECTION_ARR={{{'sea_surface_temperature'} 'k2c' 'k2c'}};

CTE_RUN.AREA_CALC.name='adri'; %Mediterranean2
CTE_RUN.AREA_CALC.llmm_arr=mapGetLLMM_os(CTE_RUN.AREA_CALC.name);

CTE=webDineofCONSTANTS;
CTE.CALC_ERRORS=true;
CTE.CALC_OUTLIERS=true;
CTE.VERBOSE=true;
CTE.UPDATE_ALL=false;
CTE_RUN.NDAYS=CTE_RUN.DATE_END-CTE_RUN.DATE_START;
CTE.UPDATE_PICS=false;
CTE.UPDATE_GRID=false;
CTE.PLOT_RECONSTRUCTION=true;
CTE.PLOT_COMPARISON=true;
CTE.PLOT_OUTLIERS=true;
CTE.PLOT_ERRORS=true;
CTE.PLOT_SCATTERS=true;
CTE.PLOT_EOFS=true;
CTE.PLOT_RESULTS=true;
CTE.PLOT.mapping='m_map';
CTE.PLOT.projection='mercator';
CTE.PLOT_DATA_RANGE=[10 28];
```

webDINEOF – products definition

```
% DATASET constants
prodid=PATHFINDER_DAILY_NIGHT_V52
prodid_type=AVHRR
area_name=globe
area_llmm=[]
dir_structure=*
dir_type=yearly
fn_pattern=*-NODC-L3C_GHRSST-SSTskin-AVHRR_Pathfinder-PFV5.2_*_night-v02.0-fv01.0.nc
root_dir=/satellite/pathfinder/V52/PATHFINDER_DAILY
save_dir=/satellite/pathfinder
convertfilename2date=@(fn)datenum(fn(1:14),'yyyymmddHHMMSS');
grid_name=glb_00417_8640x4320
grid_size=0.0417
```

```
% DATASET constants for L3C SEVIRI dataset from MYOCEAN
prodid=SEVIRI_MYOCEAN_L3C_EUR
prodid_type=SEVIRI
area_name=eur
area_llmm=[]
dir_structure=*
dir_type=yearly
fn_pattern=METEOFRANCE-EUR-SST_L3MONOSENSOR_NRT-OBS_SEVIRI_1_1H_SST-EUR-MYOCEAN_*.nc.gz
root_dir=/satellite/SEVIRI/MyOcean/METEOFRANCE-EUR-SST_L3MONOSENSOR_NRT-OBS_SEVIRI_1_1H_SST-EUR-MYOCEA
save_dir=/satellite/SEVIRI
convertfilename2date=@(fn)myoceanGetFileInfo(fn)
grid_name=eur_005_1900x1000_svri60
grid_size=0.05
```

webDINEOF - UI

- Access over UI/ for standard users

- Extra functionality for verifying inputs

- Select dataset/variable

- Select area/gridsize

- Select filtering criteria

- Select date range

- DINEOF parameters
  - Advanced mode (all available parameters)
  - Standard mode (only the most important)

webDINEOF – UI (test version)

webDINEOF - output

- NetCDF (GDS 2.0?)

- Processing log

- DINEOF output log

- OpenDAP

webDINEOF – processing log

DINEOF log

webDINEOF – OPeNDAP access

Examples

- Pathfinder SST
  - South Africa
  - Pathfinder ql 6,7
  - 2011/01/01-2011/04/01

Spatial: mod 1 (98.00%)

Temporal: mod 1 (98.00%)
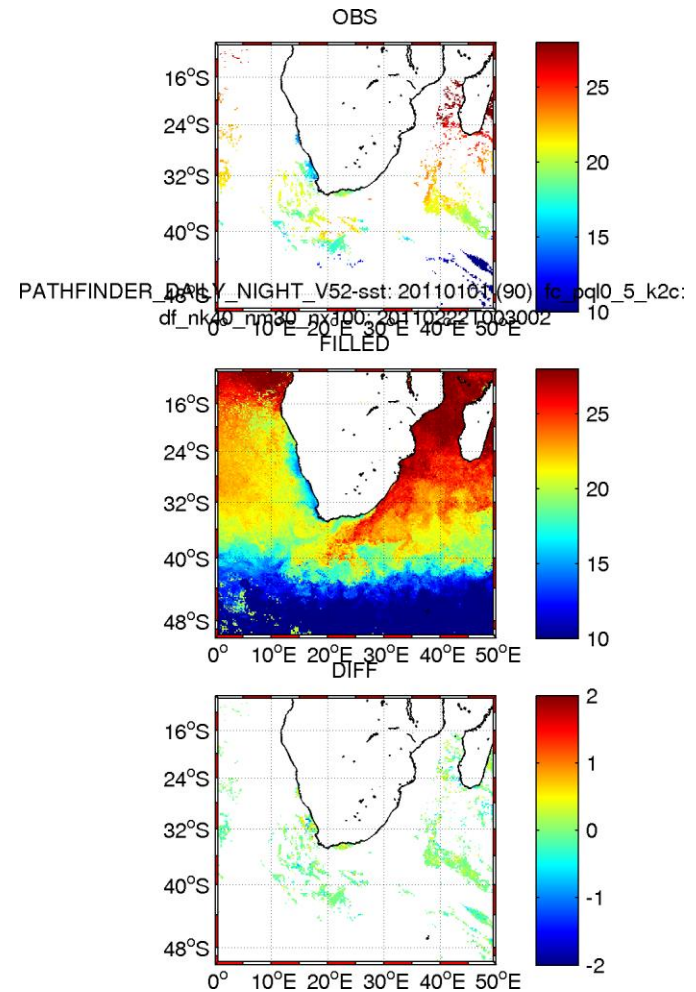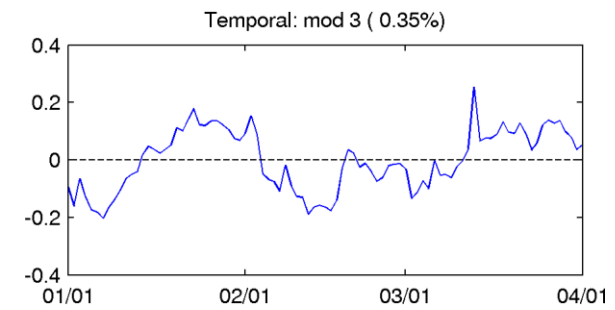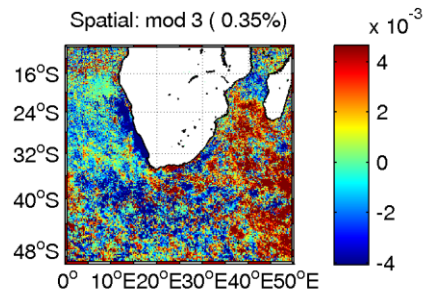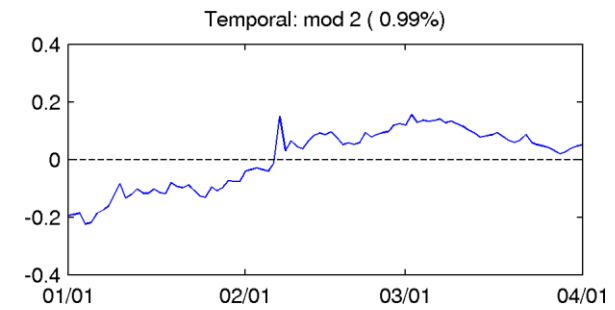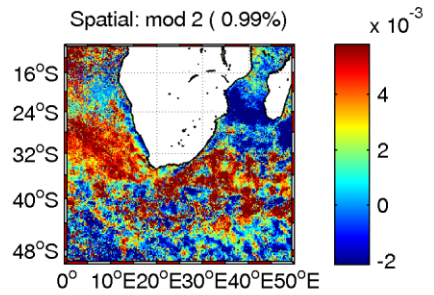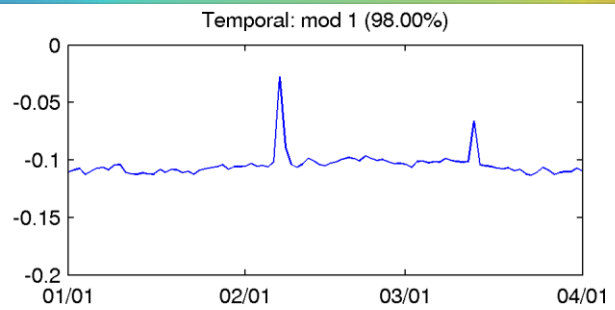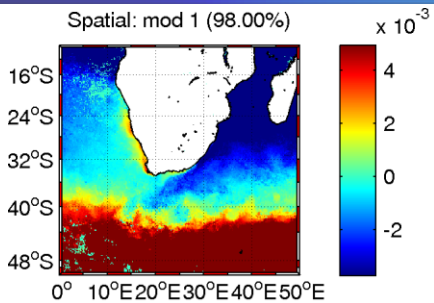
PATHFINDER_DAILY_NIGHT_V52-sst
20110101 (90)
fc_pql0_5_k2c: df_nk40_nm30_nx100
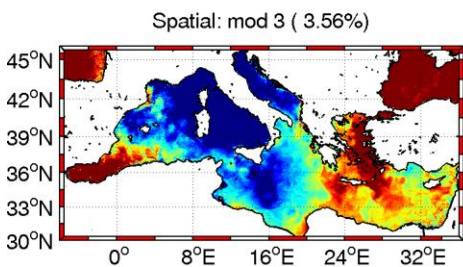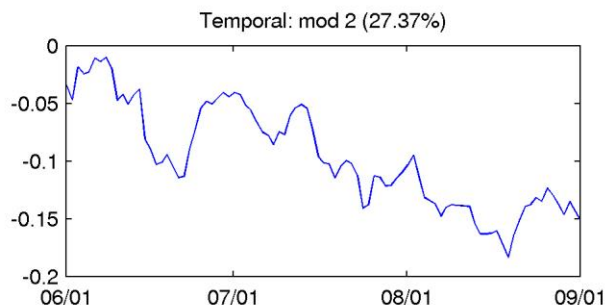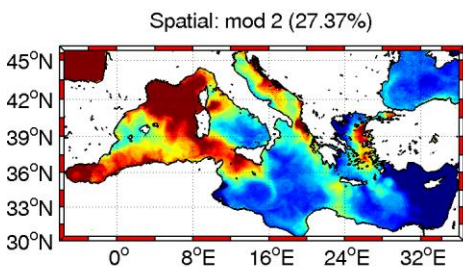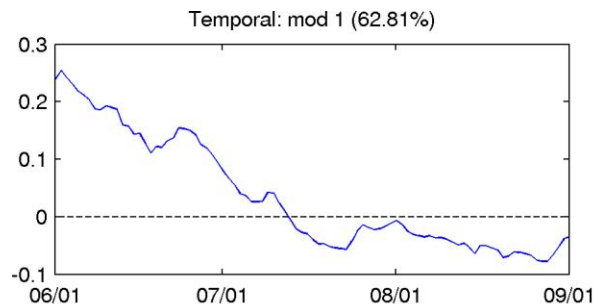bs:-0.01 std: 0.23 rms: 0.23 (30983/30983)
Scatter clouds corr:0.9993

Spatial: mod 2 (0.99%)

Temporal: mod 2 (0.99%)

Spatial: mod 3 (0.35%)

Temporal: mod 3 (0.35%)
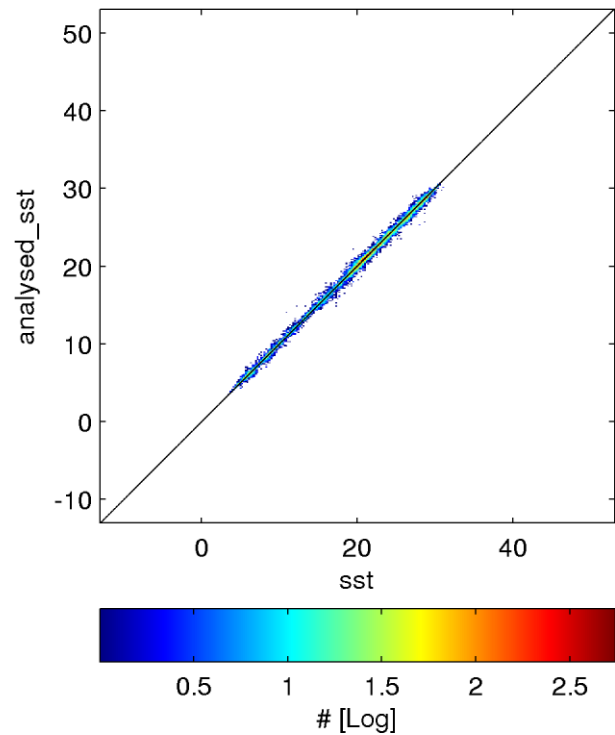
PATHFINDER_DAILY_NIGHT_V52-sst: 20110101 (90): fc_pql0_5_k2c:
df_nk40_nm30_nx100: MODES: 01 - 03

- Pathfinder SST:
  - Mediterranean Sea
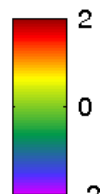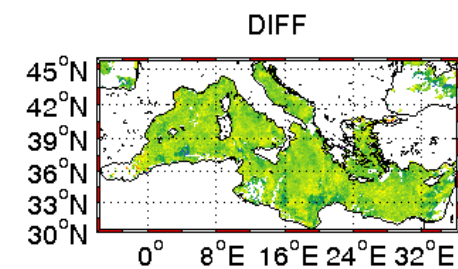 - Pathfinder ql 6,7
  - 2010/06/01-2010/09/01

Spatial: mod 1 (62.81%)

Temporal: mod 1 (62.81%)
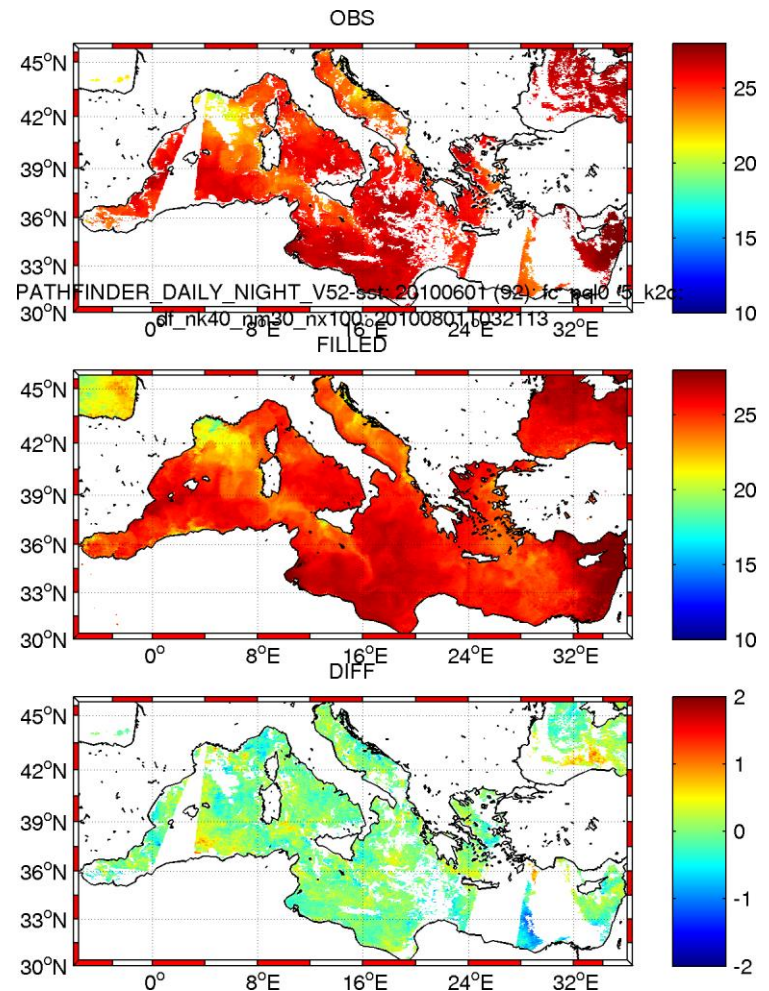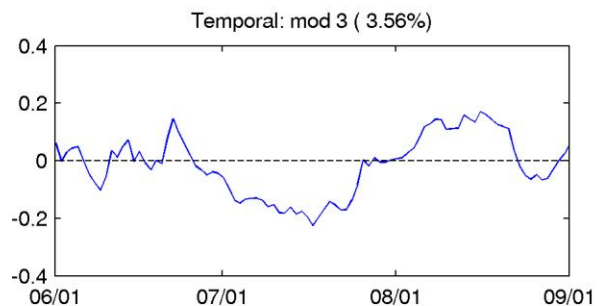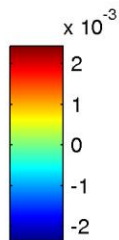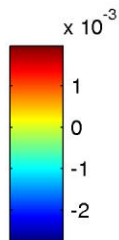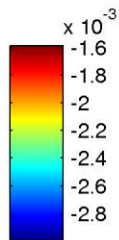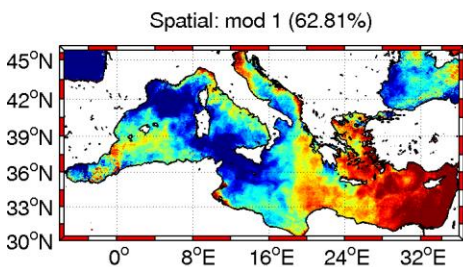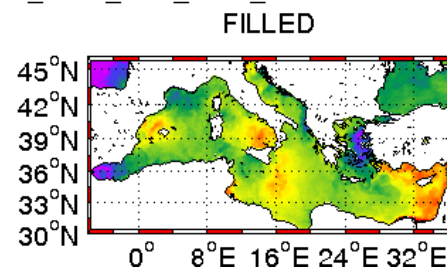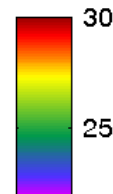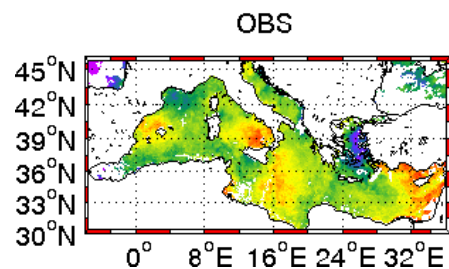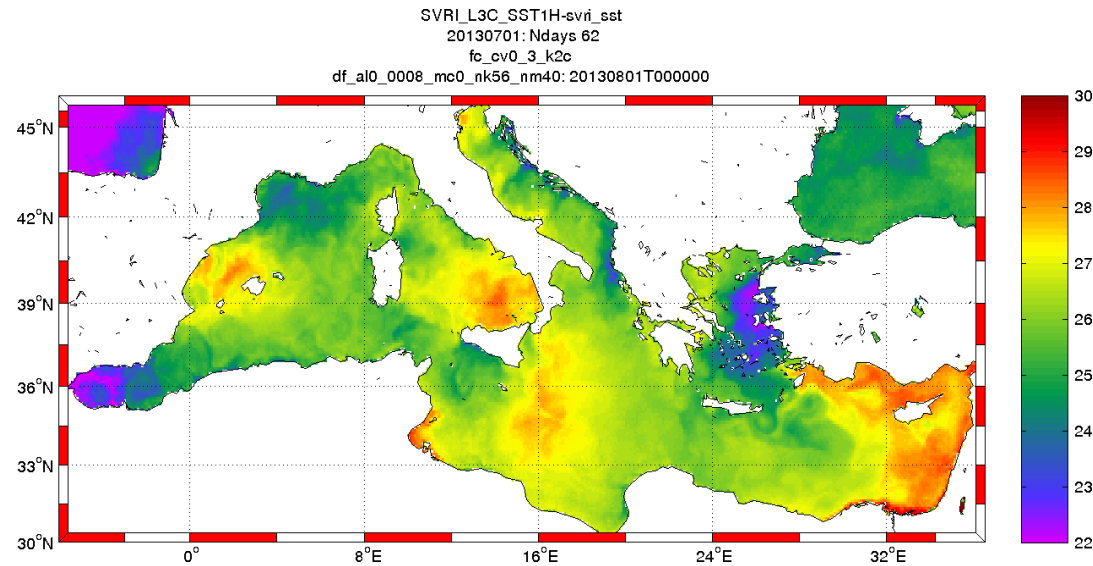
PATHFINDER_DAILY_NIGHT_V52-sst
20100601 (92)
fc_pql0_5_k2c: df_nk40_nm30_nx100
bs: 0.00 std: 0.32 rms: 0.32 (7612214/15827539)
Scatter ALL corr:0.99184

Spatial: mod 2 (27.37%)

Temporal: mod 2 (27.37%)

Spatial: mod 3 (3.56%)

Temporal: mod 3 (3.56%)

[Log]
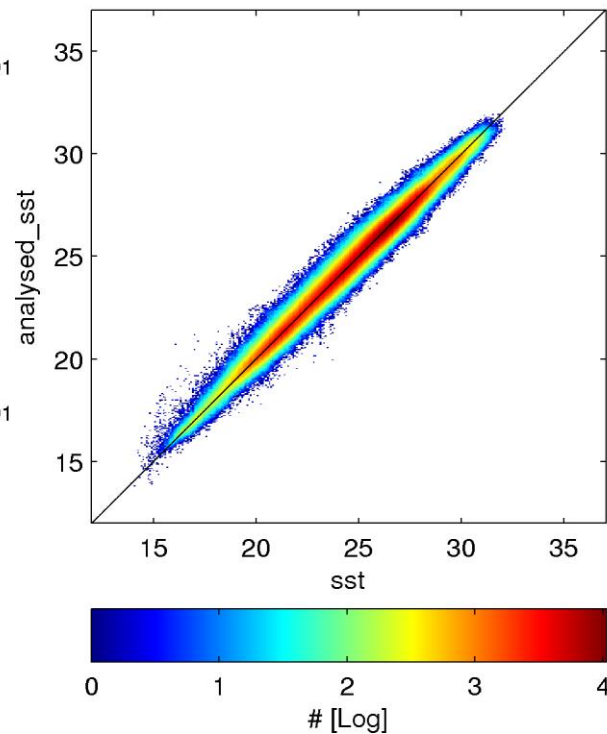
PATHFINDER_DAILY_NIGHT_V52-sst: 20100601 (92): fc_pql0_5_k2c:
df_nk40_nm30_nx100: MODES: 01 - 03

- ## SEVIRI hourly
  - Mediterannean
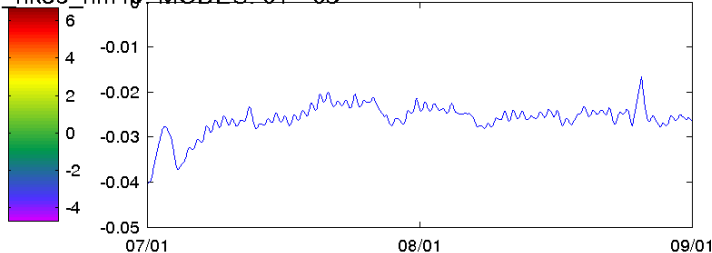 - Qual 4,5
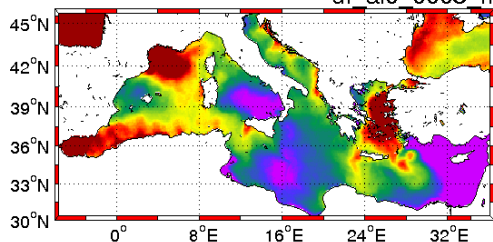 - Start:2013/07/01
  - End: 2013/09/01

SVRI_L3C_SST1H-svri_sst
20130701: Ndays 62
fc_cv0_3_k2c
df_al0_0008_mc0_nk56_nm40: 20130801T000000

OBS

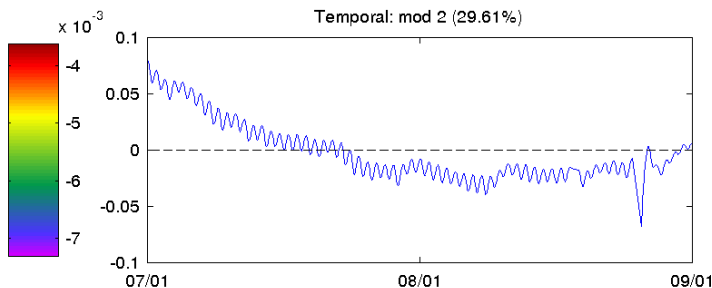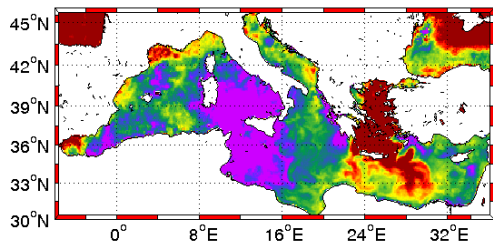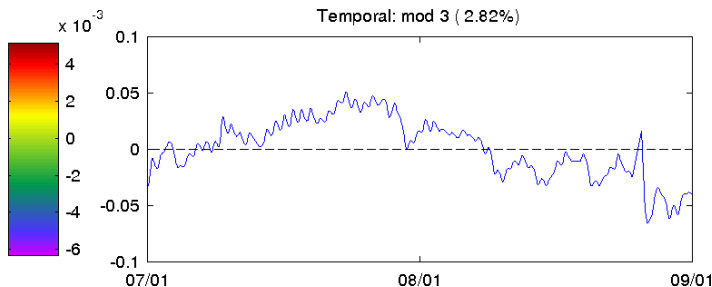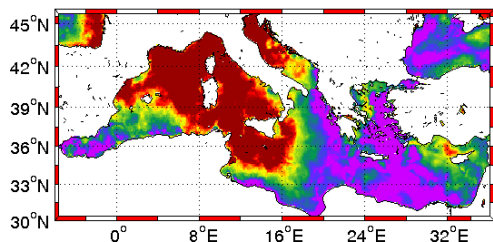

FILLED

DIFF
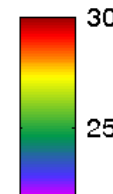
SVRI_L3C_SST1H-svri_sst
20130701: Ndays 62
fc_cv0_3_k2c
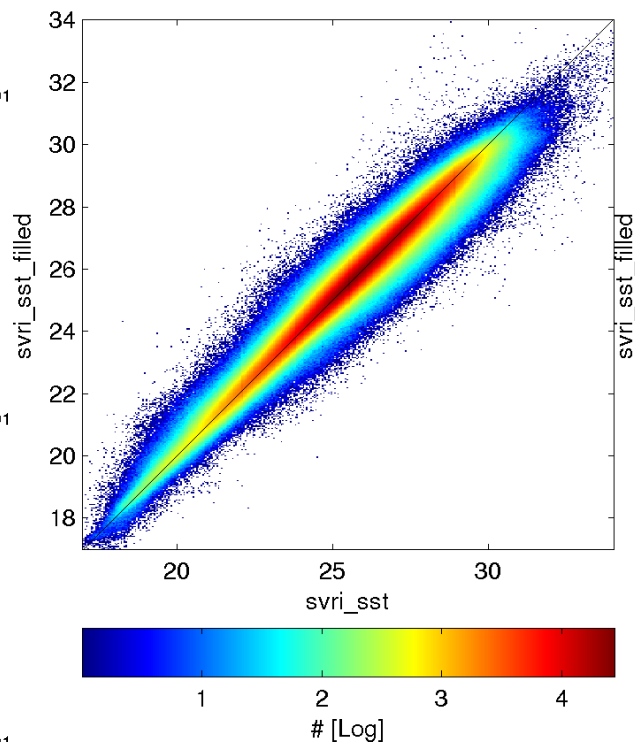df_al0_0008_mc0_nk56_nm40: MODES: 01 - 03

SVRI_L3C_SST1H-svri_sst
20130701: Ndays 62
fc_cv0_3_k2c
df_al0_0008_mc0_nk56_nm40
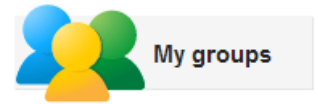bs:-0.00 std: 0.31 rms: 0.31 (31618264/43986558)
Scatter ALL corr:0.98472

Future development

- Multivariate analysis

- DINEOF + OI

- felyx

  - access to data

- Simple visualisation of the analysis

webDINEOF

- Google: DINEOF
- http://modb.oce.ulg.ac.be/DINEOF
- join DINEOF group
- http://groups.google.com/group/dineof
- e-mail:
  - **a.alvera@ulg.ac.be**; **i.tomazic@ulg.ac.be**
- webDINEOF engine: open source
- Beta release webDINEOF (v4): June/July 2014

THANK YOU!