Uses of DINEOF algorithm for reconstruction and analysis of incomplete satellite databases over the North Sea and the Mediterranean, synthesis from the RECOLOUR project.

Damien Sirjacobs ¹, Aida-Azcárate ¹, Alexander Barth ¹, YoungJe Park ², Bouchra Nechad ², Geneviève Lacroix ², Kevin Ruddick ² and Jean-Marie Beckers ¹

¹ GeoHydrodynamic and Environmental Research, University of Liège, Belgium
² Management Unit of the Mathematical Model of the North Sea, Royal Belgian Institute of Natural Sciences, Belgium

Project RECOLOUR (REconstruction of COLOUR scenes) - SR/00/111
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OUTLINE

1. **DINEOF tool: motivation and principle**

2. **The Southern North Sea and English Channel**
   - Bathymetry and dataset used
   - Reconstruction quality check
   - Outliers detection
   - TSM, CHL and SST monthly climatologies and weekly averages
   - Multivariate analysis of satellite TSM and hydrodynamic fields

3. **Western Mediterranean SST**
   - seen by DINEOF / DIVA / GHER
     - SST outlier detection
     - DINEOF vs GHER3D weekly mean fields for 1998

4. **CONCLUSIONS and PERSPECTIVES**
1. DINEOF tool: motivation

We study:
- highly dynamic environment

We need:
- complete and regular time series of full gridded data

We have:
- gappy satellite ocean data (in space AND time!)

1. DINEOF tool: principle

DINEOF decomposition

field reconstruction

identify dominant spatio-temporal dynamics and correlations

historical satellite data

EOF
decomposition

DINEOF

Spatial Modes

Temporal Modes

(illustrated for MERIS TSM 2003 data on the North Sea)
2. The Southern North Sea and English Channel

Study domain bathymetry (m) and main rivers.
Reconstruction quality check

Original data mg/l

Filled data mg/l

Reconstruction quality under cloud 1 (left) and cloud 2 (right)

$\text{rms} = 0.0965$
$\text{sn} = 1.42$
$r = 0.735$

$\text{rms} = 0.13$
$\text{sn} = 2.65$
$r = 0.949$

MERIS TSM 0.47 < $r$ < 0.95 and 1.0 < $sn$ < 2.65
Reconstruction quality check

Reconstruction quality under cloud 1 (left) and cloud 2 (right)

Meris CHL 16/07/06

Cloud 1

Cloud 2

Original data µg/l

Filled data µg/l

Latitude

Longitude

$\text{r} = 0.43$

$\text{sn} = 1.1$

$\text{rms} = 0.19$

$\text{r} = 0.702$

$\text{sn} = 1.27$

$\text{rms} = 0.21$

$0.12 < r < 0.70$

$0.88 < \text{sn} < 1.27$

Meris CHL $0.12 < r < 0.70$ and $0.88 < \text{sn} < 1.27$
Outliers detection

MERIS TSM 13/4/2003 original data mg/l

MERIS CHL 18/10/2003 original data µg/l

MODIS SST 17/8/2002 original data °C

Outliers field coef.

Filled data mg/l

Filled data µg/l

Filled data °C
Outliers detection

MODIS TSM 16/9/2003 original data mg/l

MODIS SST 16/9/2003 original data °C

outliers field coef.

filled data mg/l

filled data °C
Monthly climatologies of SST, TSM and CHL
Weekly averaged fields

**DINEOF**

- **MERIS CHL weekly average n°: 15; month 4/2003 (µg/l)**
- **MODIS TSM weekly average n°: 9; month 8/2002 (mg/l)**

**Average of existing data**

- **MERIS CHL weekly average (cc) n°: 15; month 4/2003 (µg/l)**
- **MODIS TSM weekly average (cc) n°: 9; month (mg/l)**

Map details:
- West Gabbard
- Scheelde plume
Multivariate Analysis of Satellite TSM and Hydrodynamic fields

**DINEOF MULTIVARIATE EXPLOITATION**  
**principle:** augmented state vectors = hydrodynamic fields + satellite image.

**Interests:**  
- Test for improvements of missing data reconstruction  
- Explore common traits of the dynamics of several parameters.

**DATA**

**REMOTE SENSING DATA**

**MODIS TSM**  
- year 2005  
- 313 images

**C&SNS HYDRODYNAMIC MODEL DATA**

A 3D hydrodynamical model implemented for the English Channel and the Southern North Sea (C&SNS) (Lacroix et al., 2004).

- 5 km spatial resolution; 15 minutes temporal resolution

**Parameters:**

1) Wind-U [m/s];  
2) Wind-V [m/s];  
3) mean depth U-velocity [m/s];  
4) mean depth V-velocity [m/s];  
5) surface elevation [m];  
6) Bottom stress maximum [m²/s²], between 8hpm previous day-9am satellite image day.

*Fig. Background field obtained for MODIS TSM data, year 2005.*
# RESULTS

## Multivariate Analysis of Satellite TSM and Hydrodynamic fields

<table>
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<th>run</th>
<th>parameters</th>
<th>Neof</th>
<th>Sumvarex</th>
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<td>b</td>
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<td>14</td>
<td>97,93</td>
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<td>c</td>
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<td>98,87</td>
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<td>17</td>
<td>98,87</td>
<td>17,66</td>
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</table>
Original Data 29/08/05

Univariate R.

Multivariate R.

Cloud 1

Cloud 2

Cloud 2

Cloud 1
3. Western Mediterranean SST seen by DINEOF / DIVA / GHER

DINEOF: Data Interpolation by Empirical Orthogonal Functions Satellite databases

DIVA: Data Interpolating Variational Analysis in-situ scattered data

AVHRR Pathfinder SST \(\downarrow\) EOF decomposition

Spatial Modes

Temporal Modes

daily field reconstructions & multitemporal averages

Mean monthly SST field for 1985-1995 i.e. September

Optimisation of correlation length and signal/noise ratio

T (°C)
SST outliers detection

Pathfinder SST 20/10/1998 original data °C

outliers field coef.

filled data °C
DINEOF vs GHER3D Weekly mean fields for 1998

- Good agreement between DINEOF reconstructions and GHER modeled SST products from March to October 1998 (-0.085 °C)

  - Larger discrepancies in winter (higher cloud cover introduces bias in DINEOF?; some phenomena underestimated by the GHER model?)

  Global average DINEOF-GHER SST difference of – 0.4 °C probably due to the skin temperature effects of night-time AVHRR images.
• Generally good correlation between the DINEOF and GHER SST fields (60-90 %), indicating well captured general dynamics, ...

• ...But not for weeks of may and some weeks in july, why? we’re searching ...
4. CONCLUSIONS

- Successful applications of the parameter free DINEOF method to satellite optical data
  
  4 years of MERIS TSM data → 18 EOFs; varex = 97.2%
  4 years of MERIS CHL data → 8 EOFs; varex = 93.5%
  4.5 years of MODIS TSM data → 14 EOFs; varex = 97.5%
  (4.5 years of MODIS SST data → 13 EOFs; varex = 98.0%)
  → “less biased” multitemporal averages and climatologies

- Outliers maps successful in pointing haze, cloud edges, contrails, cloud shadows, unusual events, both on optical and SST data, both regions
  → improve data quality
  → provides efficient insight into large databases

- Multivariate analysis of TSM with hydrodynamic model data can improve reconstruction.
  → best improvements with mean depth current components
  → less filtration of smaller structures

- Validation of Hydrodynamical model SST simulations, 20 y trends analysis
4. PERSPECTIVES

- **Occasionnal spikes in EOFs, unconsistent reconstructions:**
  - Elimination of unconsistent projections based on conditioning number of the problem
  - Use a second DINEOF reconstruction cycle based on the data cleaned from outliers by a first DINEOF analysis
  - Filtration of covariance matrix to eliminate high frequency variations of temporal EOFs modes

- **Comparison of DINEOF products with DIVA and various “O.I.” methods**

- **Excessive spatial filtering?**

  Combine DINEOF and DIVA to target reconstruction of smaller scale and higher frequency dynamics, and increase distinction noise - small scale processes
Thanks for attention!

Acknowledgments:

To the GHER and MUMM teams for their teaching and support

RECOLOUR project was funded by the Belgian Science Policy (BELSPO)

MERIS DATA was provided by ESA

Links:

GHER-ULG: http://modb.oce.ulg.ac.be/projects/2
MUMM - RBINS: http://www.mumm.ac.be/BELCOLOUR
DINEOF: http://groups.google.com/group/group/dineof
Thanks for attention!

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