SeaDataNet

PAN-EUROPEAN INFRASTRUCTURE FOR OCEAN & MARINE DATA MANAGEMENT

WP8 and WP9 developments

Data-Interpolating Variational Analysis (Diva) developments

C. Troupin, A. Barth, M. Ouberdous, A. Alvera-Azcárate & J.-M. Beckers

GHER GeoHydrodynamics and Environment Research

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2nd Plenary Meeting, 26-27 September 2013, Lucca (Italy)

How to install and use the new tools?

Main principles for Diva developments

1. Backward compatibility, portability and independence on proprietary software

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1. Backward compatibility, portability and independence on proprietary software
2. Development & innovation: **user-driven**
3. Strong scientific background

Releases: 4.5.1 – March 2013

New features: from user feedback during Diva workshop 2012 (Roumaillac)

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- Advection constraint with linear decay rate and local sources
- `divadetrend`: change in the detrending order
- Two new error calculations
  - `divacpme`: quick & better than original poor man's error
  - `divaexerr`: almost exact error calculation, much faster than the exact calculation

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- `divadetrend`: change in the detrending order
- Two new error calculations
- Simplified procedure for installation/compilation + tests
- Housekeeping of the code
  (simplifications, error messages, cleaning up of code, further optimisations, elimination of depreciated tools)

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- Advection constraint with linear decay rate and local sources
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- Two new error calculations
- Simplified procedure for installation/compilation + tests
- Housekeeping of the code
- Updated user guide
  (augmented with examples and new tool descriptions)

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- `divadoxml` adapted to new specifications from IFREMER

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- Two additional solvers
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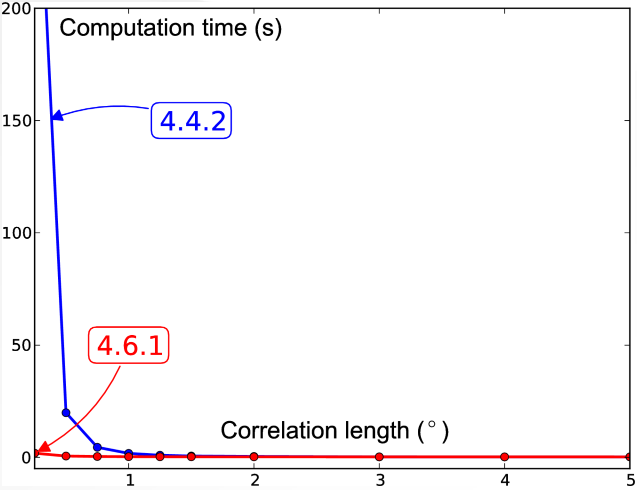
- Two additional solvers
  - parallel version
  - iterative version
- Optimisations for large data sets
- Optimisations of file exchanges for use with ODV
- Highly optimised new version of the grid generator

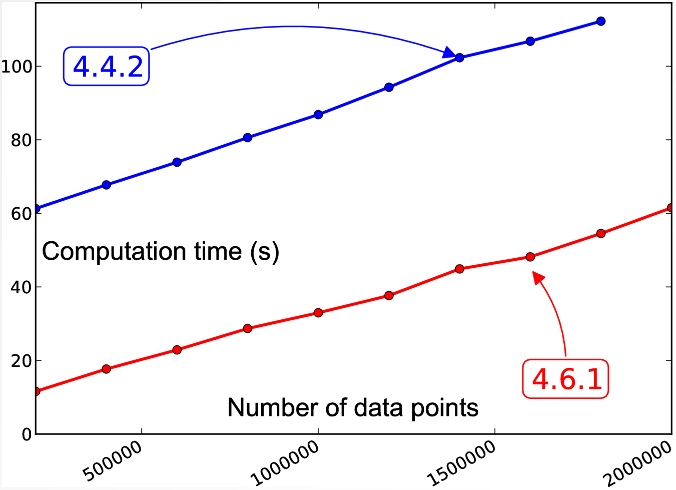
Better, faster, stronger …

Mesh:
very fine
meshes in a
few seconds



Better, faster, stronger …

Analysis:
2 million data
≈ 1 minute



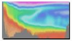
Better, faster, stronger ...

Solvers:

- Direct
- Parallel
- Iterative

Better, faster, stronger . . .

Mesh: $\approx 100 \times$ faster
Analysis: $\approx$ 5-10 $\times$ faster

$\rightarrow$ also quicker in ODV 

Releases: 4.7.1 – expected November 2013

Beta testers …

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Developed features

- Correlated observational errors

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- Correlated observational errors
- Better file structures
  (input and driver better separated from command) in 4D loops

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- Correlated observational errors
- Better file structures
- Automatic selection of solver (parallel, serial, iterative)
  depending on the problem type and size

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- Automatic selection of solver (parallel, serial, iterative)
- Retrieval of topographies from Diva-on-web

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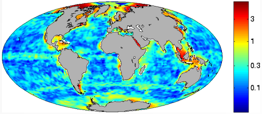
- Automatic selection of solver (parallel, serial, iterative)
- Retrieval of topographies from Diva-on-web
- Improved version of the almost exact error calculation with boundary effects
- Incorporation of metadata
  (EDMO-CDI identifier, space-time location)
  into 4D NetCDF files of climatologies

Scientific developments – innovations

4-dimensional generalisation: `divand`

RMS 3D analysis



- Derivation of the kernel for n dimensions
- Additional constraint
- Algorithms (primal and dual formulations)

Released code version available at:
http://modb.oce.ulg.ac.be/mediawiki/index.php/Divand

Scientific developments – innovations

Spatially correlated observations

Ideally:	observation errors not correlated
Reality:	clusters of observations (cruises, . . .)
Consequence:	observations error covariance matrix is not diagonal

Scientific developments – innovations

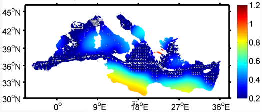
New error computation

Poor man's error: quick, but error underestimation

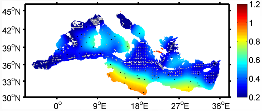
Real covariance: correct error estimation but very slow

Now: two quicker/more accurate methods

Clever poor man's estimate



Almost exact error



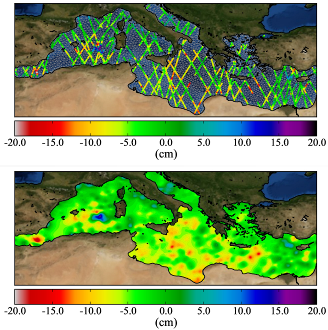
PAN-EUROPEAN INFRASTRUCTURE FOR OCEAN & MARINE DATA MANAGEMENT

SeaDataNet

Scientific developments – innovations

Adaptation to altimetry data

- Particular temporal/spatial coverage
- Input files: NetCDF
- Modified data weights according to time of measurement



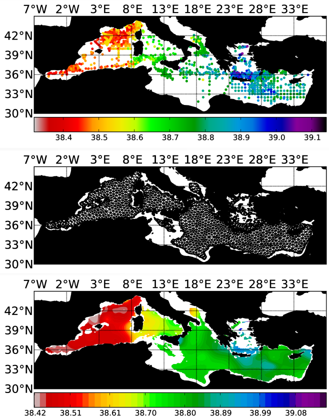
Scientific developments – innovations

Python plotting tools

→ python™

- Free alternative to matlab/octave
- Easily deals with NetCDF
- Publication quality figures with Matplotlib

http://modb.oce.ulg.ac.be/mediawiki/index.php/Diva_python



Publications

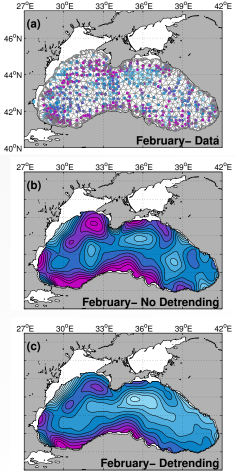
Detrending:

Recognizing temporal trends in spatial interpolation : an application to the Black Sea Cold Intermediate Layer and mixed layer depth

A. Capet, C. Troupin, J. Carstensen, M. Grégoire & J.-M. Beckers

Ocean Dynamics

Under revision

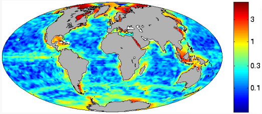


Publications

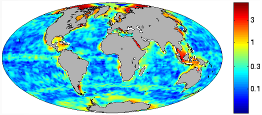
Diva-nd:

divand-1.0: n-dimensional variational data analysis for ocean observations
A. Barth, J.-M. Beckers, C. Troupin,
A. Alvera-Azcárate & L. Vandenbulcke
Geoscientific Model Development
Under revision

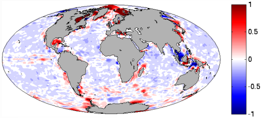
RMS 2D analysis



RMS 3D analysis



RMS(2D) – RMS(3D)



Publications

Error field:

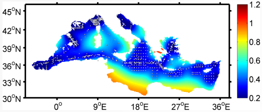
Approximate and efficient methods to assess error fields in spatial gridding with Diva (Data Interpolating Variational Analysis)

J.-M. Beckers, A. Barth, C. Troupin & A. Alvera-Azcárate

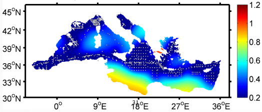
Journal of Atmospheric and Oceanic Technology

Under revision

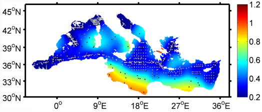
Real covariance



Clever poor man's estimate



Almost exact error



Diva workshop

Where?	STARESO station (ULg), Calvi, FRANCE
When?	Monday 4 (arrival) – Friday 8 (departure) November 2013
Who?	SeaDataNet / EMODnet partners, all levels
What?	Installation, test cases, 2D, 3D, 4D, . . .
✉	ctroupin@ulg.ac.be

More details: http://modb.oce.ulg.ac.be/mediawiki/index.php/Diva_workshop_2013_Stareso

→ Conclusions

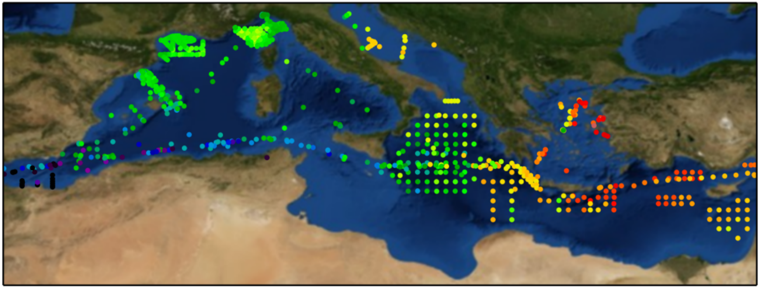
Impact of correlated observation errors

$$\begin{aligned} \text{observation error} &= \text{measurement error} \\ &+ \textit{representativity}\ \text{error} \end{aligned}$$

$$\begin{aligned} \text{field(x,y,t)} &= \text{mean state(x,y)} \\ &+ \text{mesoscale variability(x,y,}\mathbf{t}\text{)} \end{aligned}$$

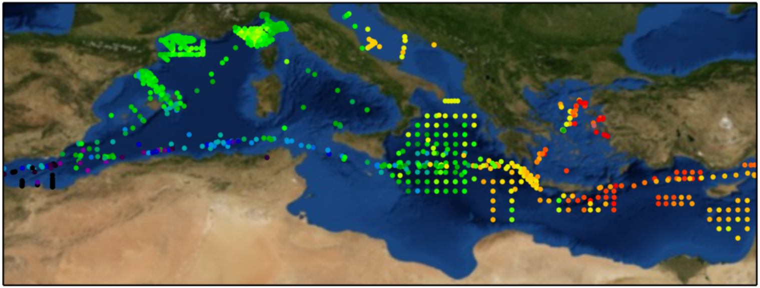
Impact of correlated observation errors

How can we derive the *mean state*,
based on point measurements of a *field*?



Impact of correlated observation errors

Oceanographic data sets are generally *clustered* in space and time (measurement campaigns)



Impact of correlated observation errors

Diva currently does not take into account the correlation of the observation errors

Synthetic experiments

- Generate a random mean field (longitude and latitude)
- Generate a random mean mesoscale field
  (longitude, latitude and **time**)
  given a length-scale (space and time) and variance
- Sum both
- Extract observations

Synthetic experiments

- Try to determine the mean field based on observations using:
  1. correct observations error covariance $\mathbf{R}$ — non-diagonal R
  2. only the diagonal part $\mathbf{R}$ — diagonal R
  3. bin all close-by observations together within the correlation length-scale and use corresponding diagonal $\mathbf{R}$ — binning
  4. use all observations, but inflate error variance of observations in cluster — inflation
  5. use all observations, but inflate error variance of observations by the product $\mathbf{R}\vec{v}$ ($\vec{v} = 1\ 1\ 1 \ldots 1\ 1$) — inflation 2

Synthetic experiments

- Mean state, mesoscale field and observation locations randomly chosen.
  Experiments are repeated 100 times and average are shown.
- Location of 100 observations is controlled by the number of clusters and the *width* of each cluster.

Synthetic experiments

number of clusters: 1, 3, 5, 7, 9, 20, 40, 60, 80, 100

cluster width (relative to the domain size) =
0.031623, 0.046416, 0.068129, 0.1, 0.146780,
0.215443, 0.316228, 0.464159, 0.681292, 1

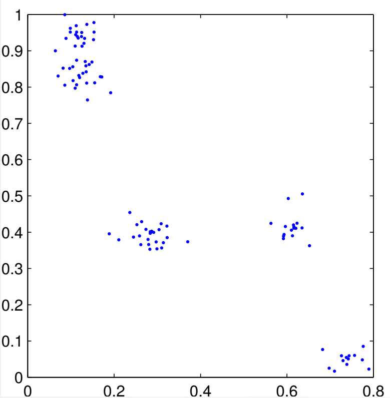
variance of background = 1

variance of observation = 2

domain: $100 \times 100 \times 100$ grid points
$[0, 1] \times [0, 1] \times [0, 1]$

correlation lengths (space and time) = 10

Distribution of data points



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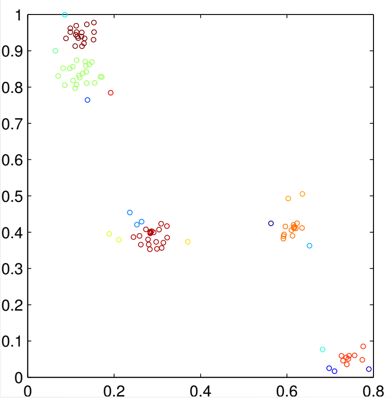


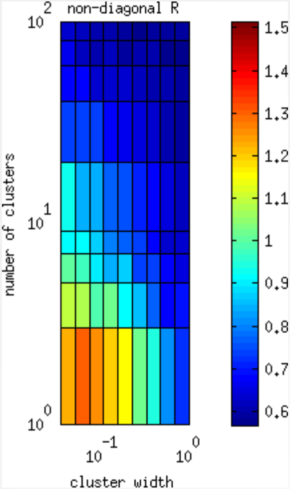
Observations ’close-by’

Cluster analysis: determine highly-correlated observations.

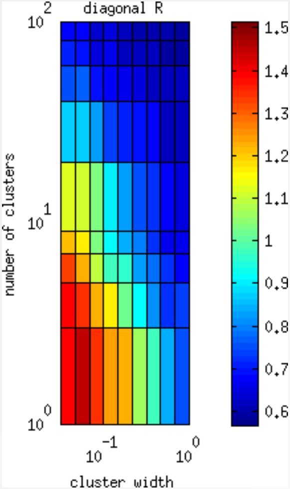
Observation error correlation length < cluster size (typically).

Such observation clusters used for binning and covariance inflation.

RMS between the true and reconstructed fields



RMS between the true and reconstructed fields



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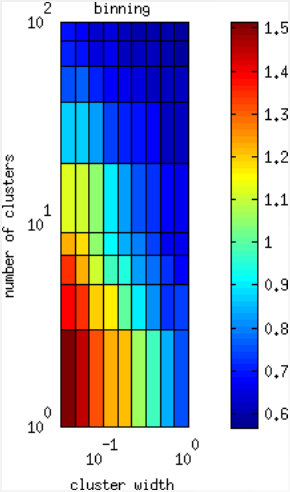

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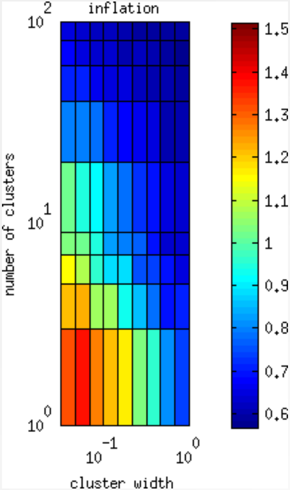

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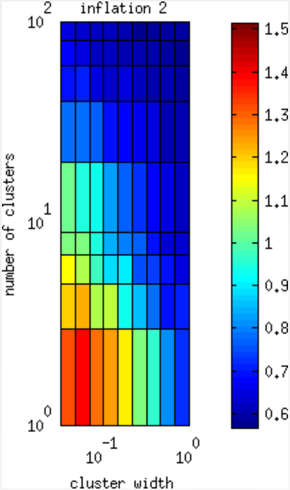

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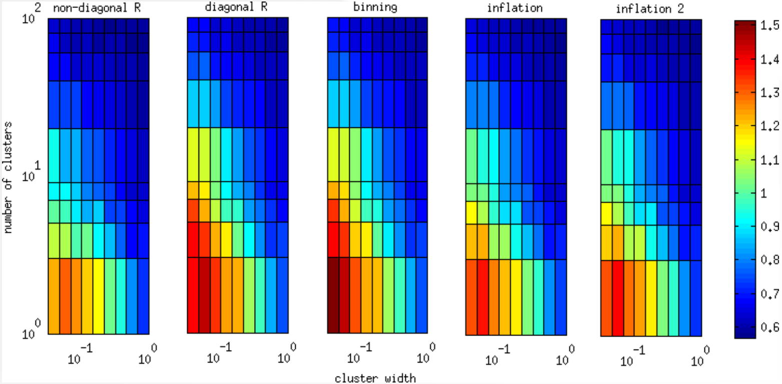
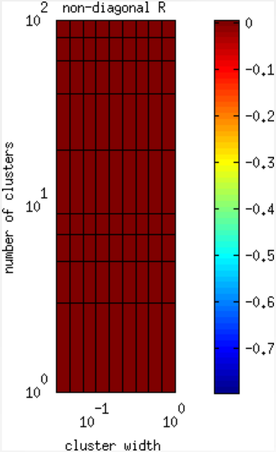


- Data is more clustered → reconstruction degrades
- More severe degradation with diagonal R and binning

Degradation relative to non-diagonal R



- Skill score using non-diagonal R approach
  as reference.
- Skill score is negative since all other approaches are approximations.

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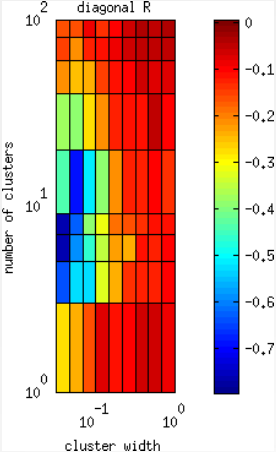

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- Degradation is quite large for 10 clusters and 0.05 cluster width using the diagonal R and binning approaches.

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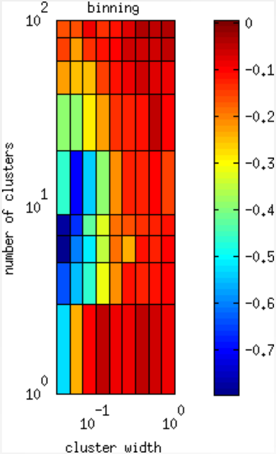

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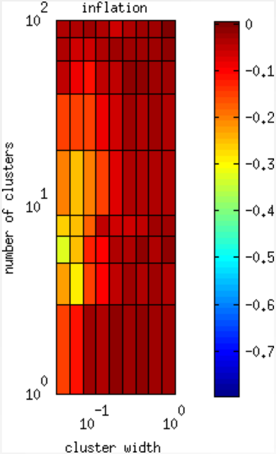

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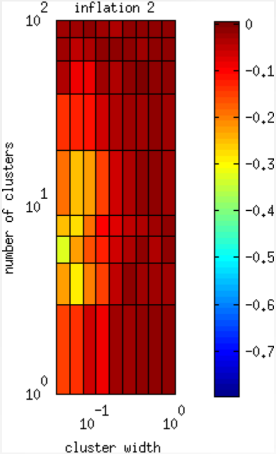

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Impact on error variance of the analysis

- Using a diagonal observation error covariance also affects the expected error variance of the analysis
- 5 clusters with a width of 0.05
- RMS of error variance relative to non-diagonal R

Experiment	RMS of error variance
diagonal R	0.144947
binning	0.126911
inflation	0.134404
inflation 2	0.128268

Summary

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  (based on the sum of all elements of $\mathbf{R}$ in a given row)
- In comparison the binning approach leads to a large degradation,
  but to a relatively smaller degradation of the error estimate.
- In practice, the question remains: *how to estimate the correlation length of the observation error covariance?*

Conclusions

- Improved documentation, installation, log files, . . .
- Enhanced mesh generation, solver (direct, parallel, iterative) and error computation
- Cutting-edge developments in spatial interpolation theory
- Adapted version of OceanBrowser

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Thanks to all
for your attention

Thanks to Giuseppe & his team
for everything