Université de Liège

Université de Liège

SeaDataNet

DIVA

Overview and exercises via web server

Jean-Marie Beckers and GHER-DIVA group Aida Alvera, Alexander Barth, Charles Troupin, Mohamed Ouberdous

MARE INTERFACULTARY CENTER FOR MARINE RESEARCH - LIEGE UNIVERSITY

http://modb.oce.ulg.ac.be/GHER

MARE INTERFACULTARY CENTER FOR MARINE RESEARCH - LIEGE UNIVERSITY

Université de Liège
MARE-GHER Sart-Tilman B5
4000 Liège, Belgique

Université de Liège

Université de Liège

SeaDataNet

Outline

- ODV-DIVA gridding(12:00-12:30)
- Theory (13:30-14:00)
- Implementations (14:00-15:00)
- Diva-on-web (15:30-16:45)
- User feedback (16:45-17:00)

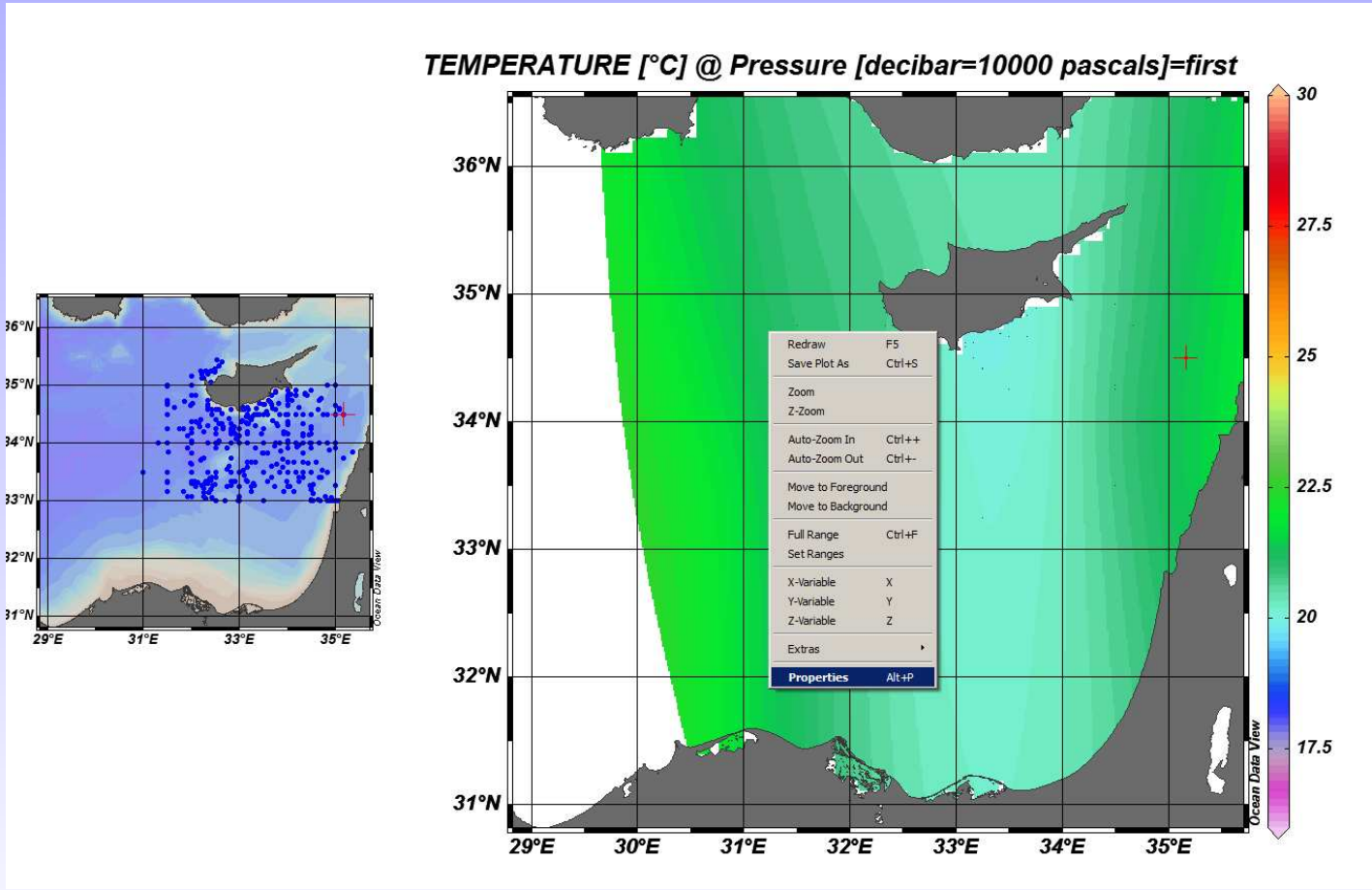
Université de Liège

Université de Liège

- ***ODV-DIVA gridding(12:00-12:30)***
- *Theory (13:30-14:00)*
- *Implementations (14:00-15:00)*
- *Diva-on-web (15:30-16:45)*
- *User feedback (16:45-17:00)*

Until lunch

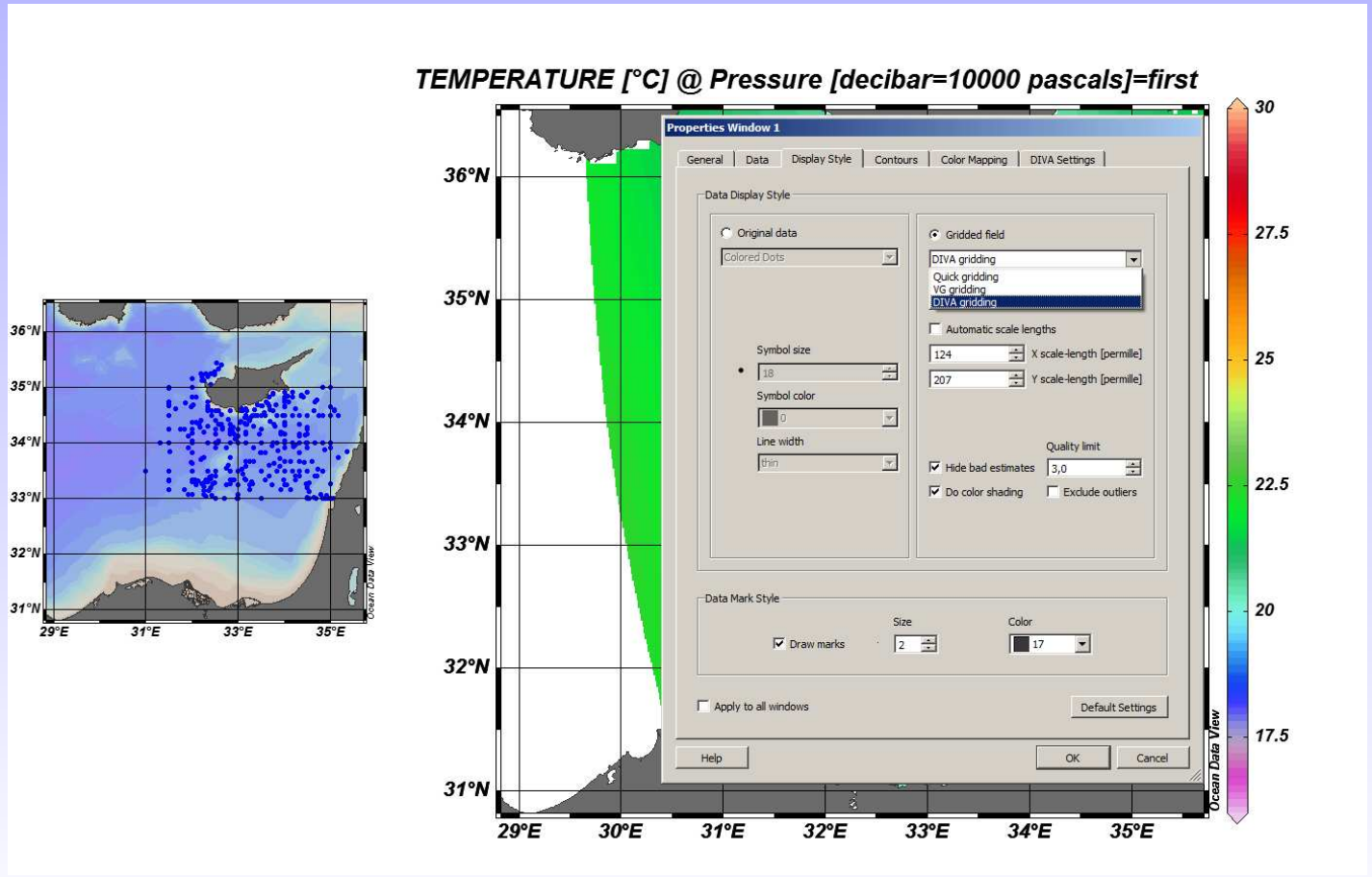
Take the example you worked on when plotting horizontal (or vertical) sections and edit properties (if not available, ask us for the example)



Try parameters of gridding

On `Display Style`

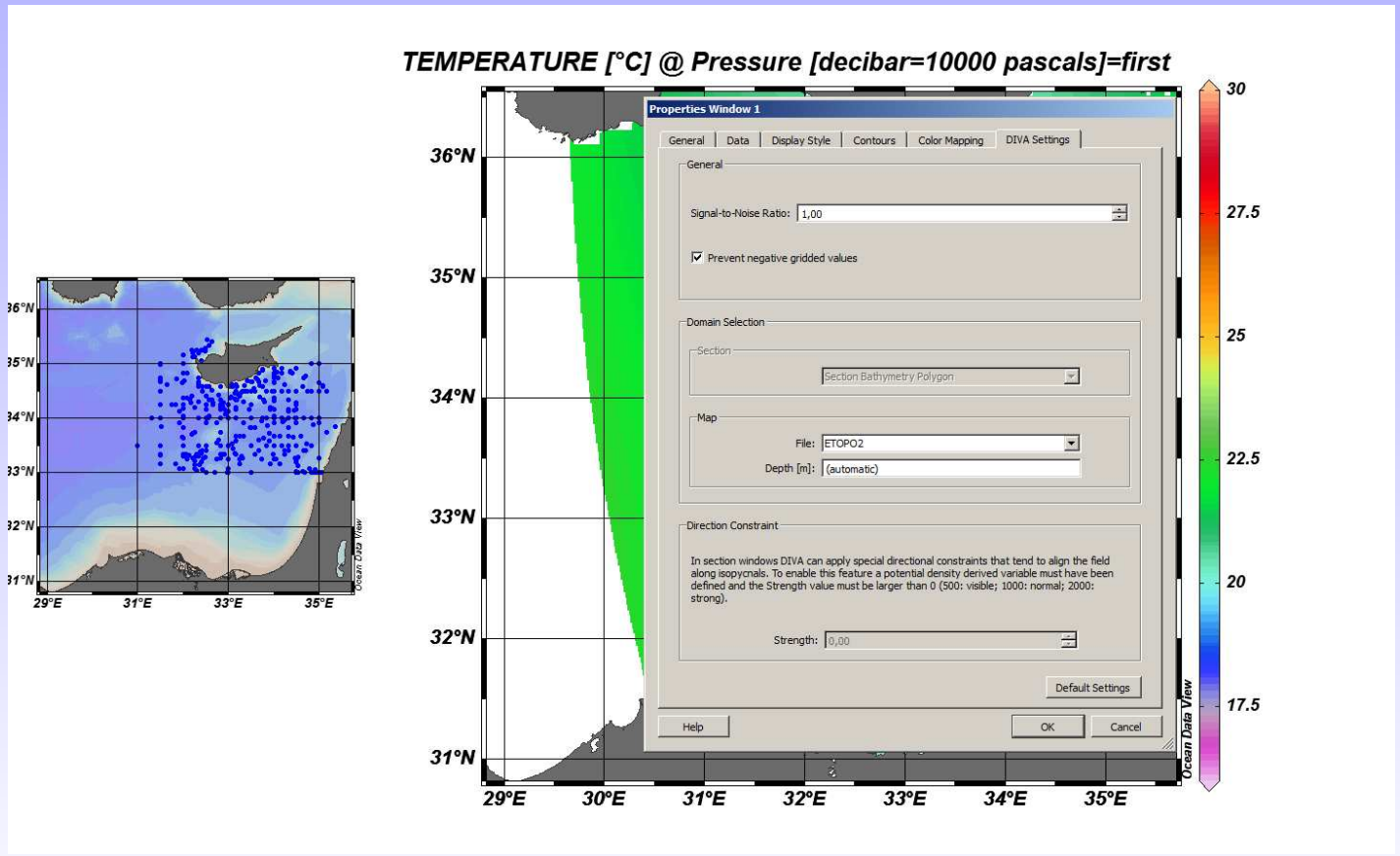
- change analysis method (quick, VG, DIVA)
- change X scale-length and Y scale-length



Try parameters of gridding

On `DIVA Settings`

- Change Signal-to-Noise Ratio
- If available (vertical section), use directional constraint

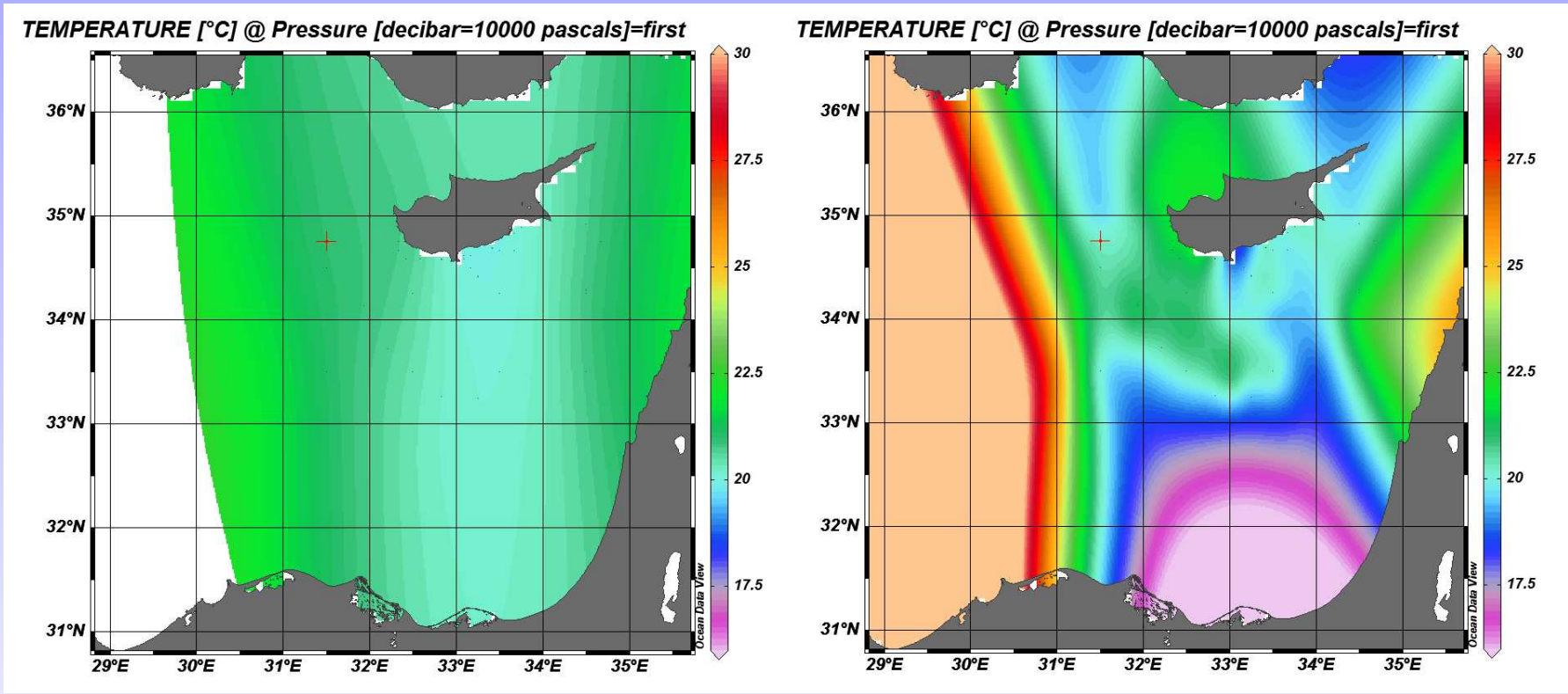


Université de Liège

SeaDataNet

Université de Liège

Observed changes in analyses due to changes in parameters (here signal-to-noise ratio from 1 to 100) will be explained after lunch

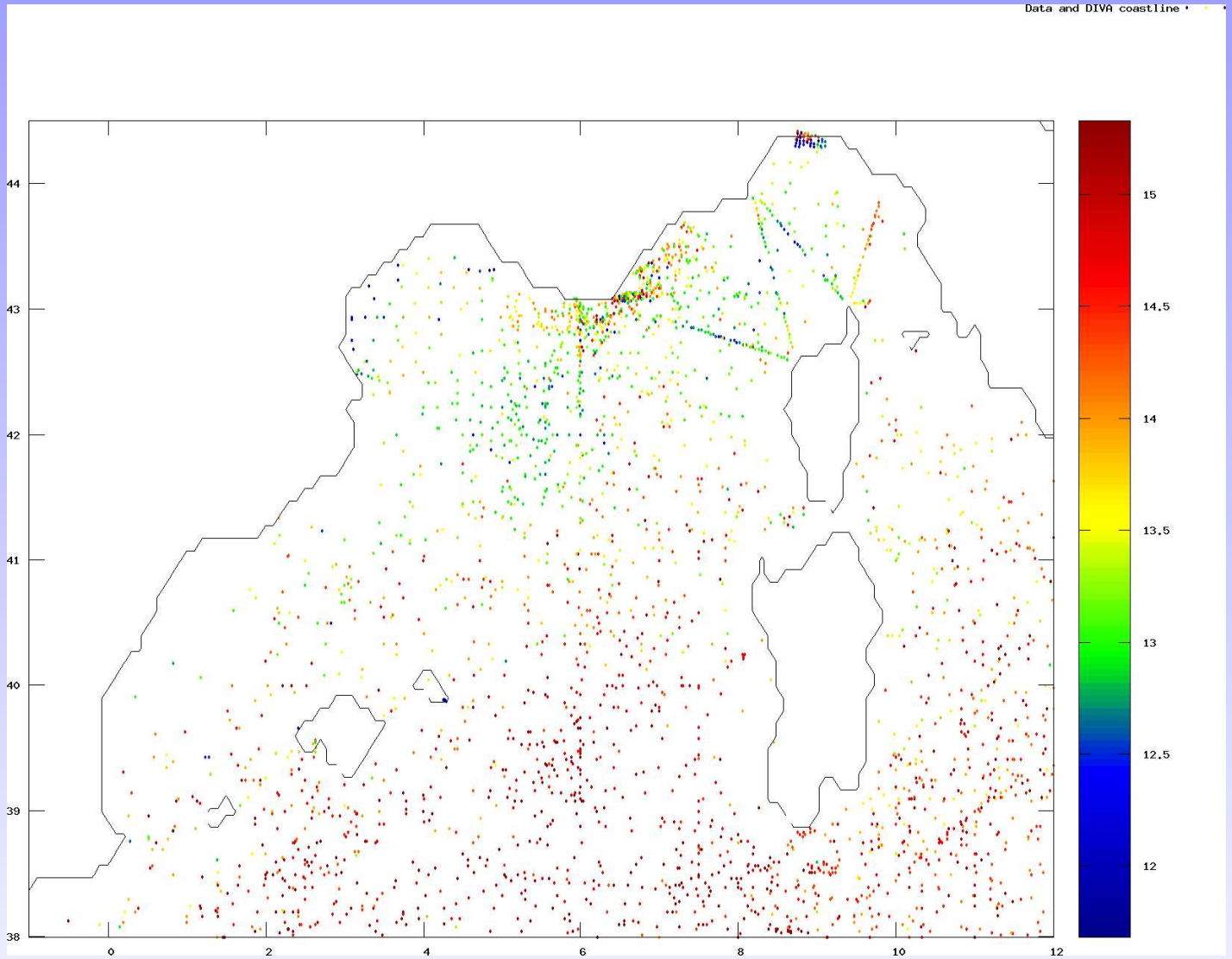


Université de Liège

Université de Liège

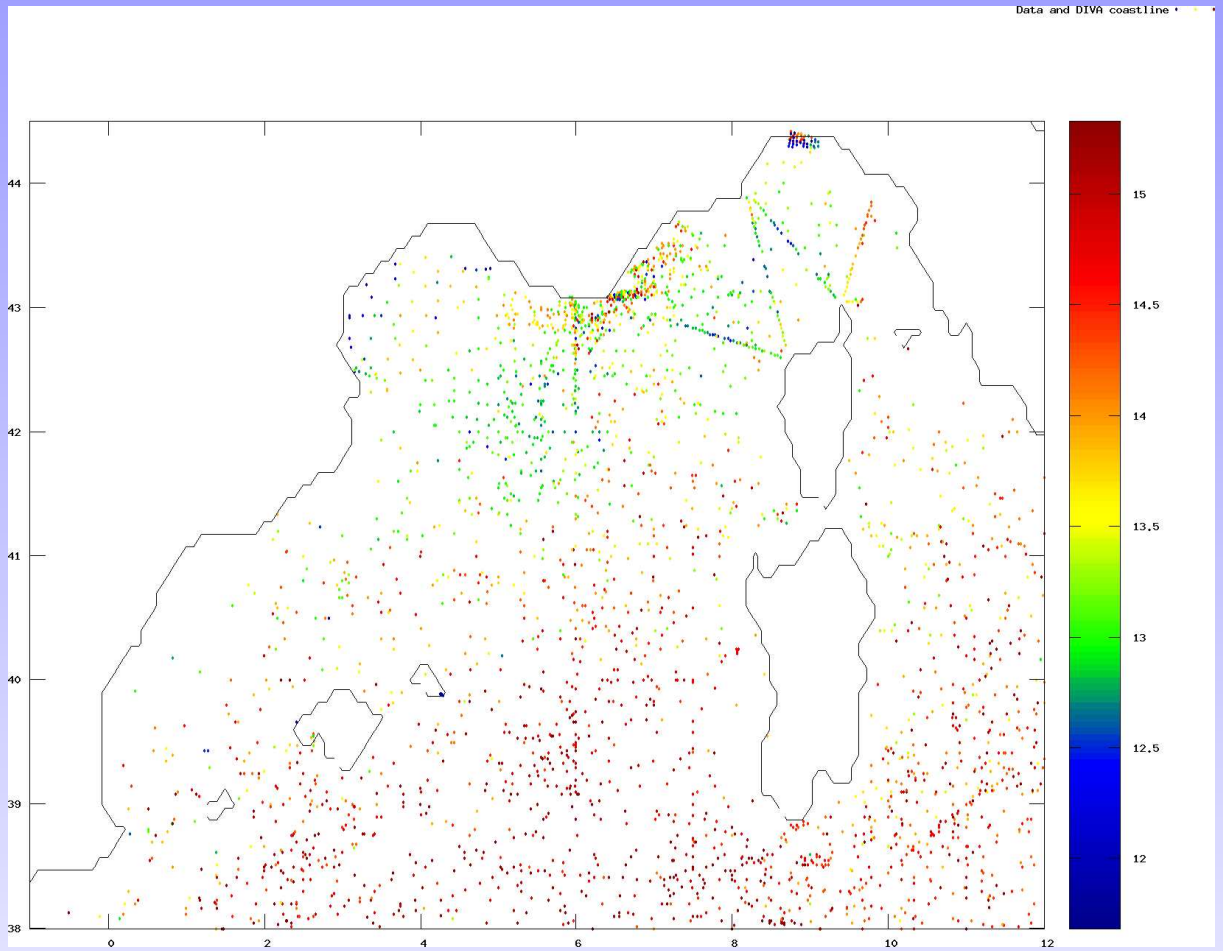
- *ODV-DIVA gridding(12:00-12:30)*
- ***Theory (13:30-14:00)***
- *Implementations (14:00-15:00)*
- *Diva-on-web (15:30-16:45)*
- *User feedback (16:45-17:00)*

Common problem

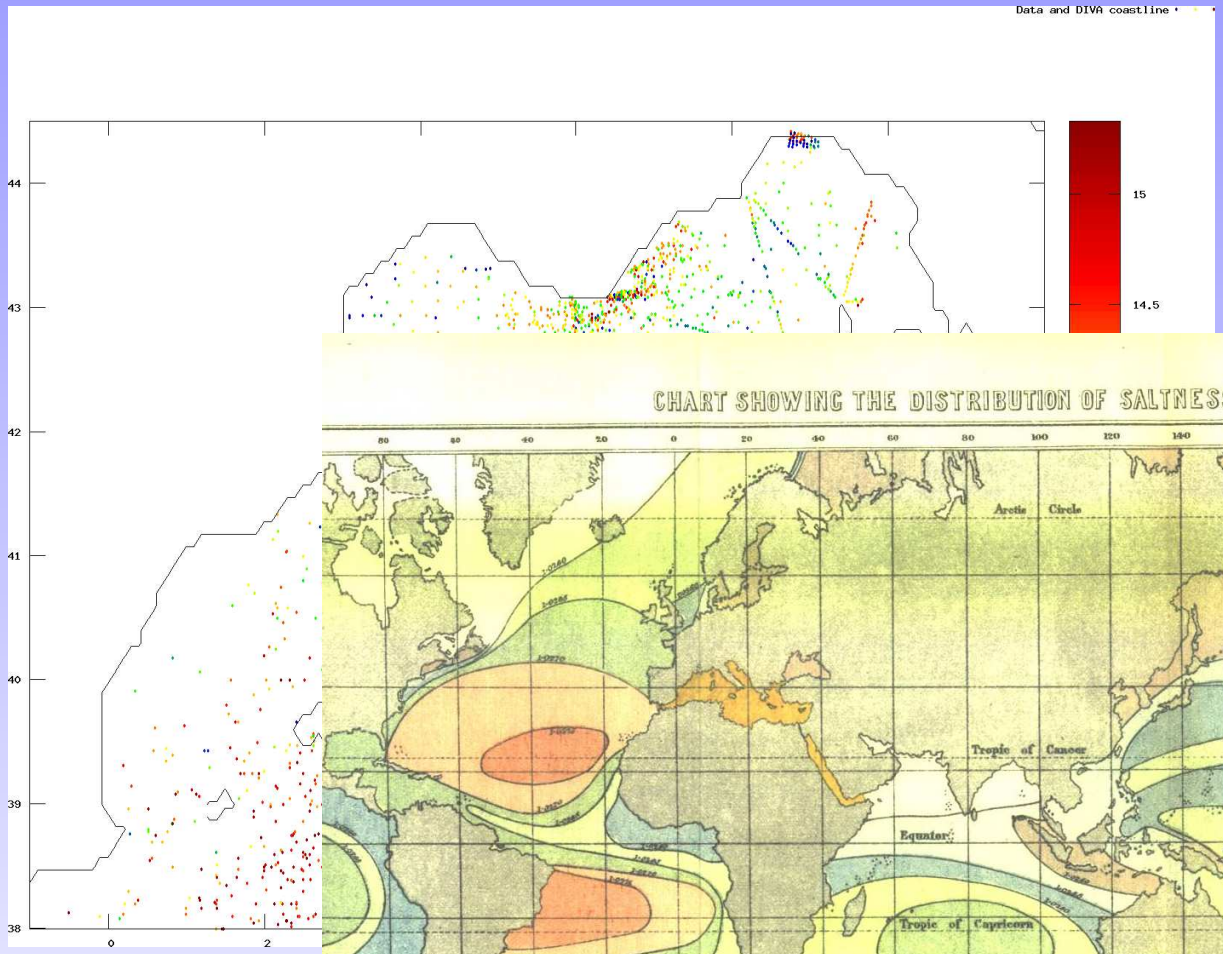


Appears when trying to produce maps, calculate volume averages, prepare initial conditions for models, quality control of data ...

Solutions


Data and DIVA coastline
44
43
42
41
40
39
38
0
2
4
6
8
10
12
15
14.5
14
13.5
13
12.5
12

Solutions


Data and DIVA coastline
15
14.5
44
43
42
41
40
39
38
0
2

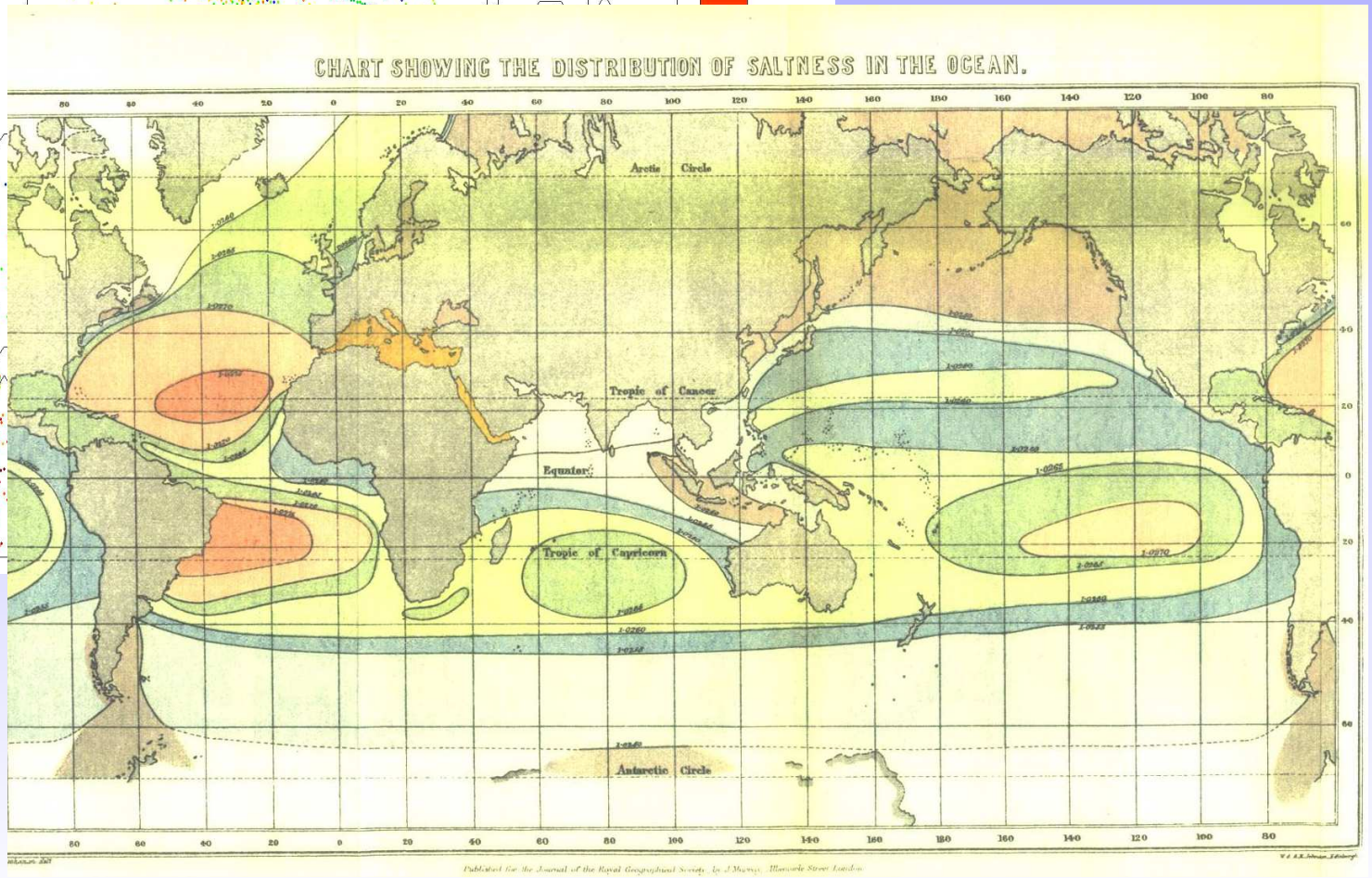
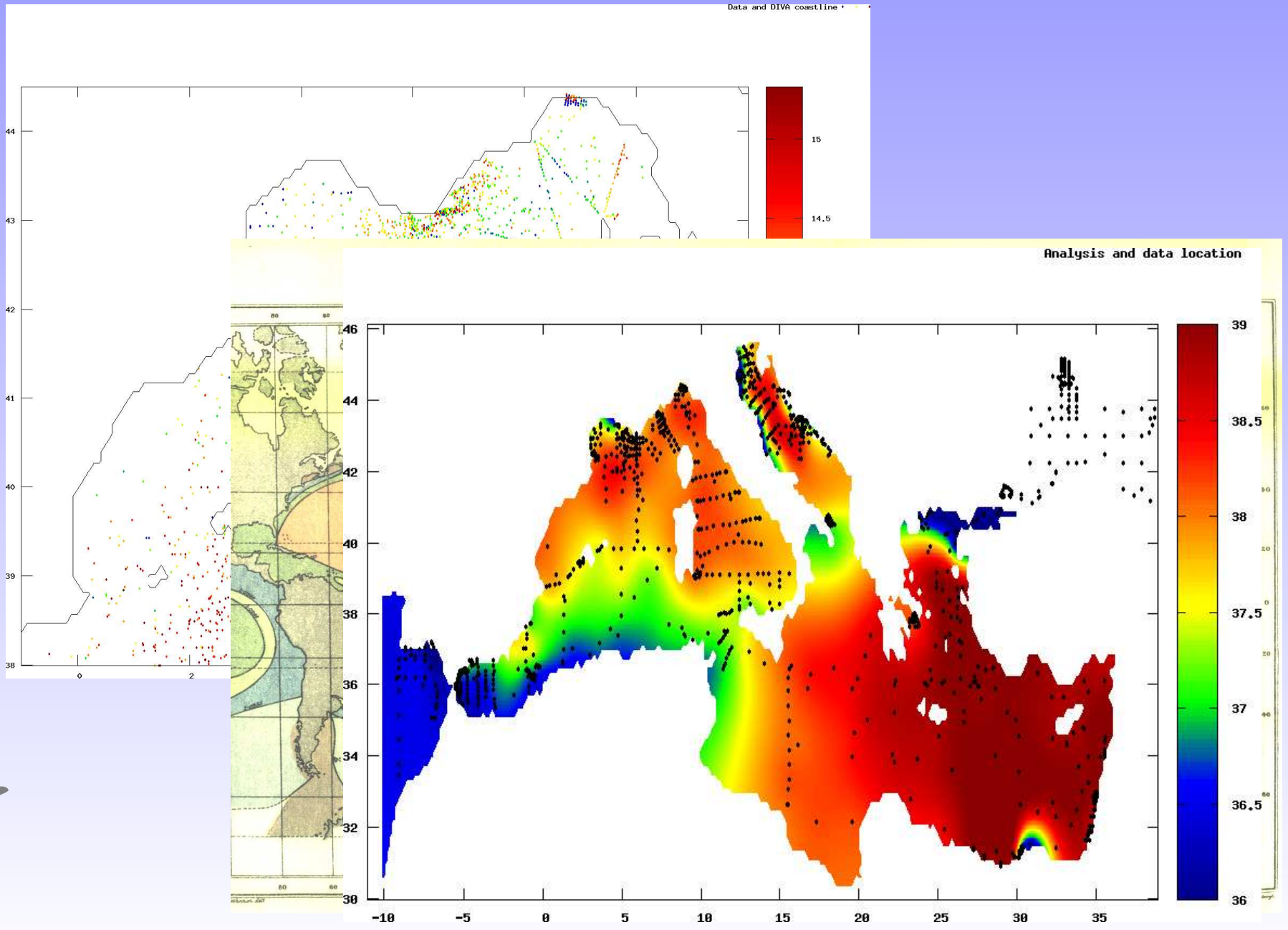


CHART SHOWING THE DISTRIBUTION OF SALTNESS IN THE OCEAN.
Arctic Circle
Tropic of Cancer
Equator
Tropic of Capricorn
Antarctic Circle

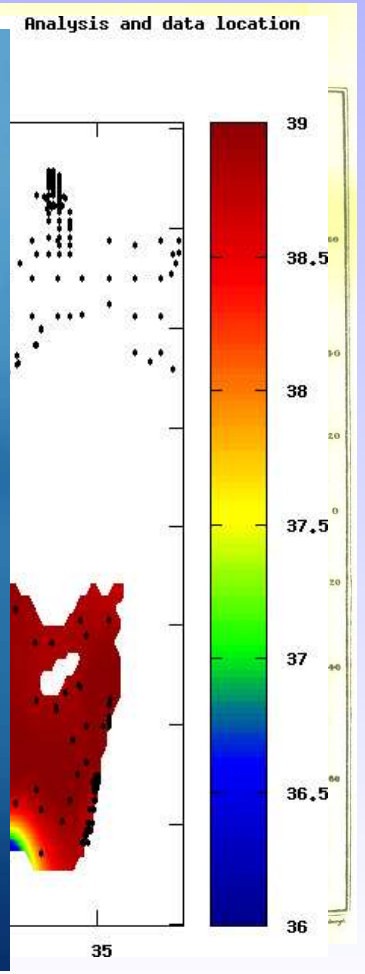
Solutions



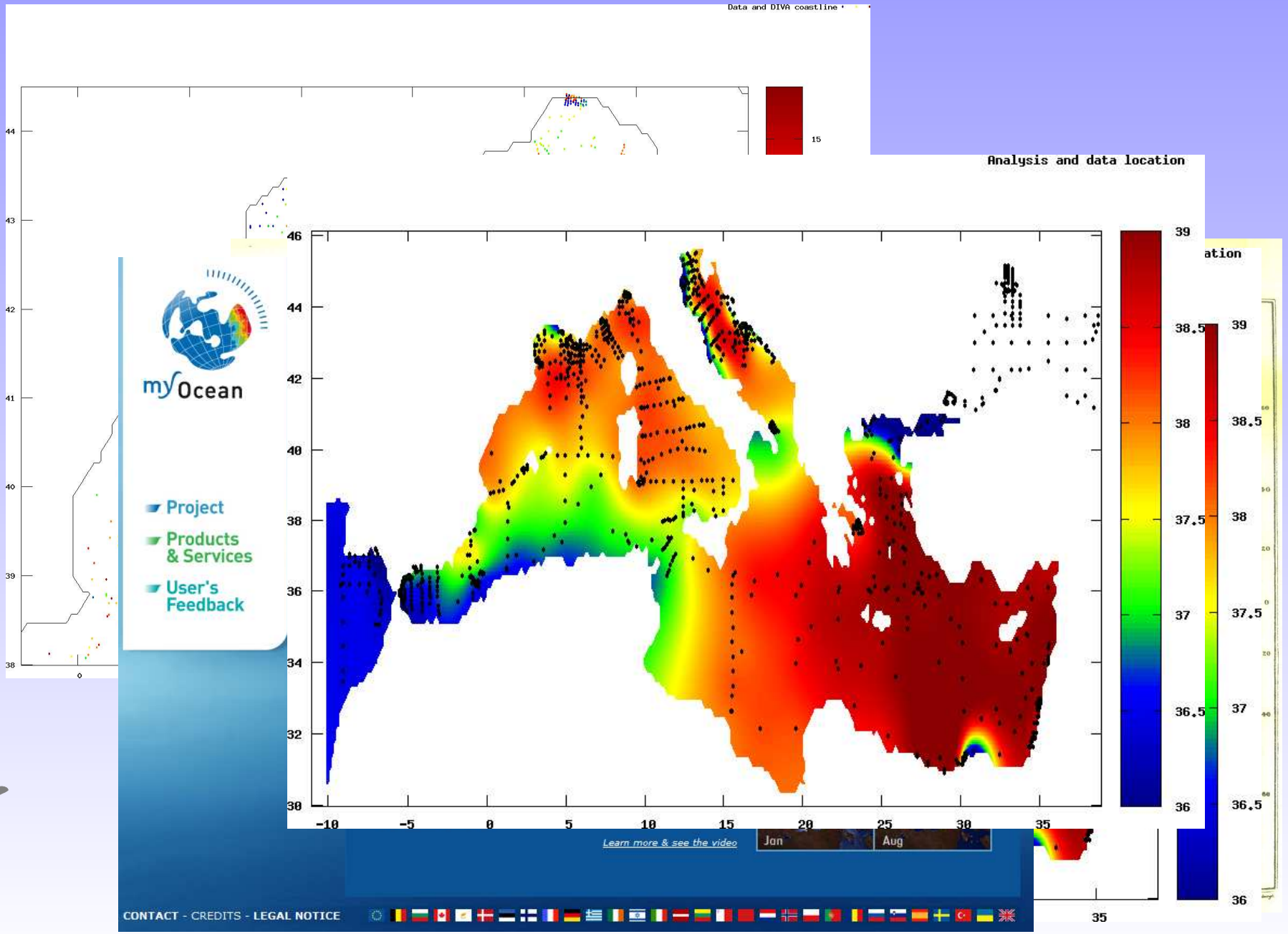
Solutions


Data and DIVA coastline
44
43
42
41
40
39
38
15
14.5

MyOcean
GMES
myOcean
Project
Products & Services
User's Feedback
myOcean
Image of the month:
ARCTIC ICE ON THE MOVE
Ice extent record minima, the opening of the Northeast or Northwest Sea Passages... The Arctic is often in the news these days. Modelling and forecasting its moves as well as its reaction to climate change are important issues.
Learn more & see the video
Jan
Aug
CONTACT - CREDITS - LEGAL NOTICE


Analysis and data location
39
38.5
38
37.5
37
36.5
36
35

Solutions


Data and DIVA coastline
Analysis and data location
myOcean
Project
Products & Services
User's Feedback
Learn more & see the video
Jan
Aug
CONTACT - CREDITS - LEGAL NOTICE

Estimation

- Observer 1: 14°
- Observer 2: 16°

Your best guess ?

Estimation

- Observer 1: 14°
- Observer 2: 16°

Your best guess ?
15°

Estimation

- Observer 1: 14°
- Observer 2: 16°

Your best guess ?

15°

But what if observer 1 uses digital thermometer and observer 2 his finger ?

Estimation

- Observer 1: 14°
- Observer 2: 16°

Your best guess ?

15°

But what if observer 1 uses digital thermometer and observer 2 his finger ?

Best guess probably near 14°.

Estimation

- Observer 1: 14°
- Observer 2: 16°

Your best guess ?

15°

But what if observer 1 uses digital thermometer and observer 2 his finger ?

Best guess probably near 14°.

Exploit knowledge of errors !

Optimal estimate

$$T_1 = T^t + \epsilon_1, \quad \langle \epsilon_1 \rangle = 0, \quad T_2 = T^t + \epsilon_2, \quad \langle \epsilon_2 \rangle = 0 \qquad (1)$$

statistical average, denoted by $\langle \quad \rangle$ with unbiased estimates $\langle \epsilon_* \rangle = 0$
Linear estimate

$$T = w_1 T_1 \; + \; w_2 T_2 \; = \; (w_1 + w_2) T^t \; + \; (w_1 \epsilon_1 + w_2 \epsilon_2) \qquad (2)$$

$$\langle T \rangle = (w_1 + w_2) T^t, \qquad (3)$$

we obtain an unbiased estimate of the true state if we take $w_1 + w_2 = 1$. This leaves one parameter free to chose: w_2

Exploit knowledge on errors to find optimal value of w_2

Choice of weighting ?

$$T^a = (1 - w_2)T_1 + w_2 T_2 \;=\; T_1 + w_2(T_2 - T_1) \tag{4}$$

while in reality there is an error

$$T^a - T^t = (1 - w_2)\epsilon_1 + w_2\epsilon_2, \tag{5}$$

This error is zero on average but its variance is not zero:

$$\left\langle (T^a - T^t)^2 \right\rangle = (1 - w_2)^2 \left\langle \epsilon_1^2 \right\rangle + w_2^2 \left\langle \epsilon_2^2 \right\rangle + 2(1 - w_2) w_2 \left\langle \epsilon_1 \epsilon_2 \right\rangle \tag{6}$$

The actual errors ϵ_1 and ϵ_2 are not known, but the error variance $\left\langle \epsilon_1^2 \right\rangle$ are. Often we can reasonably suppose that the errors ϵ_1 and ϵ_2 are uncorrelated $\left\langle \epsilon_1 \epsilon_2 \right\rangle = 0$. The error variance $\left\langle \epsilon^2 \right\rangle$ of the analysis is

$$\left\langle \epsilon^2 \right\rangle = (1 - w_2)^2 \left\langle \epsilon_1^2 \right\rangle + w_2^2 \left\langle \epsilon_2^2 \right\rangle . \tag{7}$$

So what ?

Minimisation

$$\left\langle \epsilon^2 \right\rangle = (1 - w_2)^2 \left\langle \epsilon_1^2 \right\rangle + w_2^2 \left\langle \epsilon_2^2 \right\rangle . \tag{8}$$

Naturally, the best estimate for T is the one with the lowest expected error variance and we will use w_2, which minimizes the right-hand side:

$$w_2 = \frac{\left\langle \epsilon_1^2 \right\rangle}{\left\langle \epsilon_1^2 \right\rangle + \left\langle \epsilon_2^2 \right\rangle} \tag{9}$$

$$T^a = \frac{\left\langle \epsilon_1^2 \right\rangle \left\langle \epsilon_2^2 \right\rangle}{\left\langle \epsilon_1^2 \right\rangle + \left\langle \epsilon_2^2 \right\rangle} \left(\frac{T_1}{\left\langle \epsilon_1^2 \right\rangle} + \frac{T_2}{\left\langle \epsilon_2^2 \right\rangle} \right) . \tag{10}$$

Best estimate

With (9) we obtain the minimal error variance

$$\left\langle \epsilon^2 \right\rangle = \frac{\left\langle \epsilon_1^2 \right\rangle \left\langle \epsilon_2^2 \right\rangle}{\left\langle \epsilon_1^2 \right\rangle + \left\langle \epsilon_2^2 \right\rangle} = \left(1 - \frac{\left\langle \epsilon_1^2 \right\rangle}{\left\langle \epsilon_1^2 \right\rangle + \left\langle \epsilon_2^2 \right\rangle} \right) \left\langle \epsilon_1^2 \right\rangle , \qquad (11)$$

while the estimate of the temperature itself reads

$$T^a = T_1 \; + \; \left(\frac{\left\langle \epsilon_1^2 \right\rangle}{\left\langle \epsilon_1^2 \right\rangle + \left\langle \epsilon_2^2 \right\rangle} \right) (T_2 - T_1) \, . \qquad (12)$$

Error variance on the combination of T_1 and T_2 is smaller than both $\left\langle \epsilon_1^2 \right\rangle$ and $\left\langle \epsilon_2^2 \right\rangle$.

Optimal Interpolation

Same problem but data distributed in space and $a\ priori$ information on background (with variance σ^2).
Weighting of background (zero value when working with anomalies and σ^2 local variance and covariances between points) information and data points (observed values and observational error variance)

- "Model forecast": Background field.
- Need for covariance of the background field between data points: each element i, j of **B** provides the covariance between points in location i and j. Covariance between a given point and all data points is stored in column vector $\mathbf{c}$ and the local variance at the analysis point is noted σ^2.
- Analysis ϕ of anomaly $\mathbf{y}$ with respect to background leads to spatial analysis at any desired location of covariance between any two points is known.

$$\phi = \mathbf{c}(\mathbf{B} + \mathbf{R})^{-1}\mathbf{y} \qquad (13)$$

Background covariance

Problem, how to specify background covariances (between all data points and between data points and the desired analysis location).

- c_i= covariance between location of the analysis and data location of point i = $C(x, x_i)$
- B_{ij}=covariance between location of data point i and location of point j= $C(x_i, x_j)$

Approaches

- Normally obtained via statistics on data. Seldom possible (noticable exception: satellite images).
- Standard OI: via functions $B_{ij} = f(r/L)$ where r is the distance between points i and j, but still function f needs to be determined. L is the so-called correlation length. Here statistics on all data couples as a function of distance. Example: $f = \sigma^2 \exp(-r^2/L^2)$.
- Via functionals (see Kernel of DIVA later)

Signal to noise ratio

$$\mathbf{B} = \sigma^2 \tilde{\mathbf{B}} \tag{15}$$

$$\mathbf{R} = \epsilon^2 \tilde{\mathbf{R}} \tag{16}$$

$$\mathbf{c} = \sigma^2 \tilde{\mathbf{c}} \tag{17}$$

with non-dimensional correlation matrixes $\tilde{\mathbf{B}}$, $\tilde{\mathbf{R}}$, $\tilde{\mathbf{c}}$

$$\phi = \tilde{\mathbf{c}} \left(\tilde{\mathbf{B}} + \frac{1}{\lambda} \tilde{\mathbf{R}} \right)^{-1} \mathbf{y} \tag{18}$$

with signal-to noise ratio

$$\lambda = \frac{\sigma^2}{\epsilon^2} \tag{19}$$

Also the error field is only depending on the ratio.

DIVA Basics

Variational Inverse Method, (Brasseur $et\ al.$, 1996). Knowing data d_j at location (x_j, y_j), search the field φ which minimizes

$$J[\varphi] = \sum_{j=1}^{Nd} \mu_j [d_j - \varphi(x_j, y_j)]^2 + \|\varphi - \varphi_b\|^2 \qquad (20)$$

$$\|\varphi\| = \int_D (\alpha_2 \nabla\nabla\varphi : \nabla\nabla\varphi + \alpha_1 \nabla\varphi \cdot \nabla\varphi + \alpha_0 \varphi^2) \mathrm{d}D \qquad (21)$$

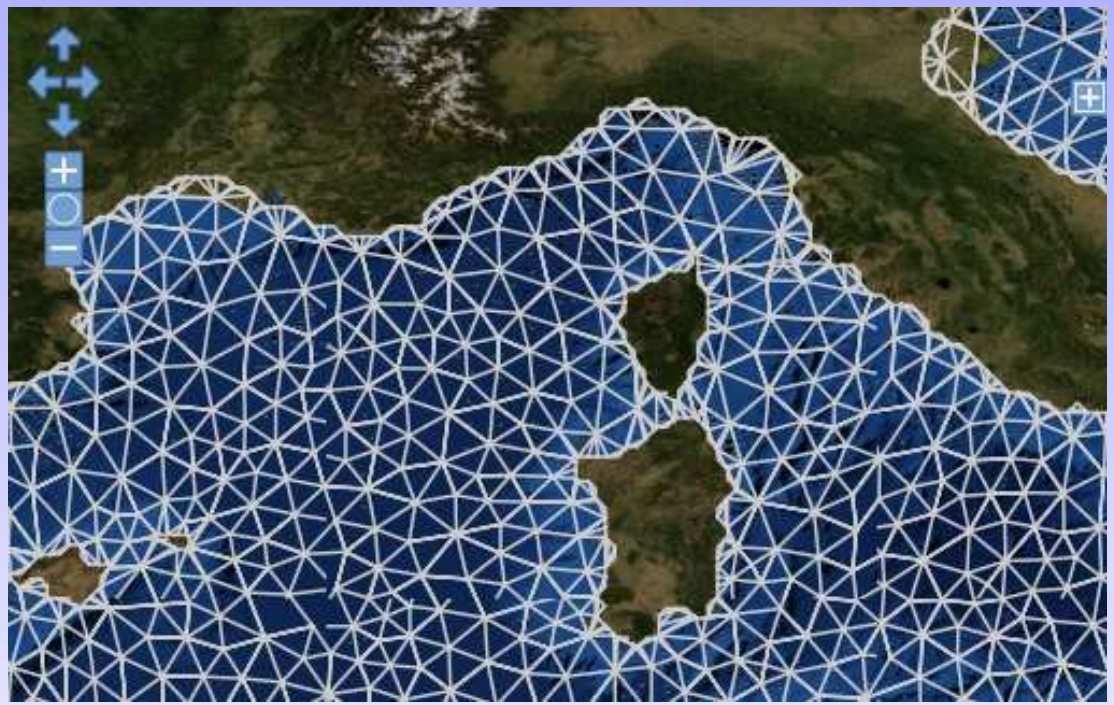
The background field φ_b is typically the data average value.

- α_0 penalizes the field itself (anomalies),
- α_1 penalizes gradients $\nabla\varphi$ (no spatial trends),
- α_2 penalizes variability (regularization of second derivatives $\nabla\nabla\varphi$),
- α_* can be related to a length scale L of the analysis,
- μ_j penalizes data-analysis misfits (objective).

Basics

$$\mu = \frac{\sigma^2}{\epsilon^2}\frac{4\pi}{L^2} \tag{22}$$

where the σ^2/ϵ^2 is known as a signal to noise ratio S/N.



Solution by finite element method. Note decoupling of subbasins. (Each element is in fact compsed by three sub-elements, each one with cubic functions)

Bad news

- No error estimate comes with the method, only an indicator of data-coverage.

Bad news

- No error estimate comes with the method, only an indicator of data-coverage.
- VIM brand already taken:

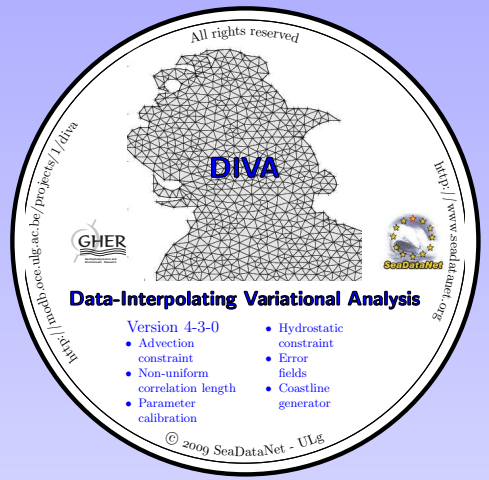
Bad news

- No error estimate comes with the method, only an indicator of data-coverage.
- VIM brand already taken:

- Method is equivalent to well established existing optimal interpolation (OI)

Good news

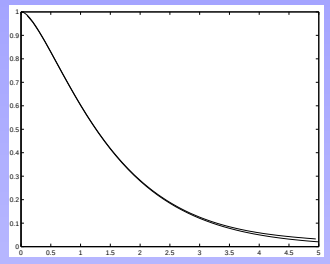
- Name easily changed: DIVA (Data-Interpolating Variational Analysis)



- Optimal interpolation (OI) provides error estimates, so DIVA can also provide it via equivalence
- DIVA has some practical advantages over OI

DIVA as OI

DIVA is identical to the well known Optimal Interpolation



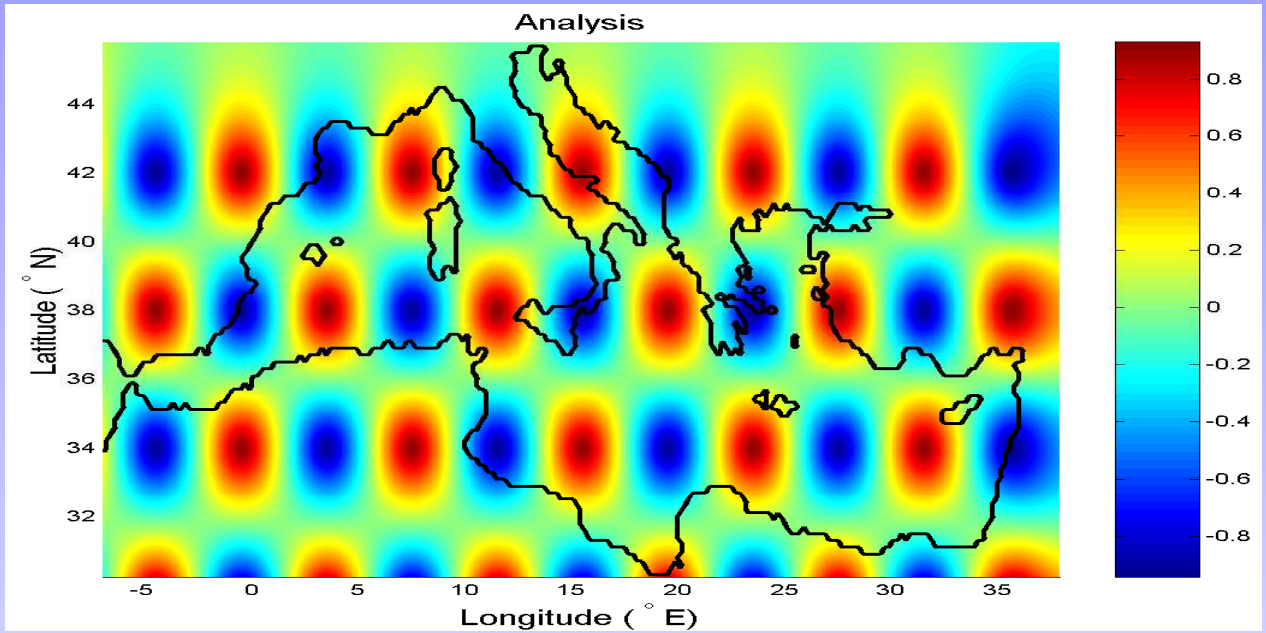
- if so-called reproducing kernel of the norm $=$ covariance function of OI,
- if the noise is random, spatially uncorrelated and the signal/noise ratio parameter is identical with OI.

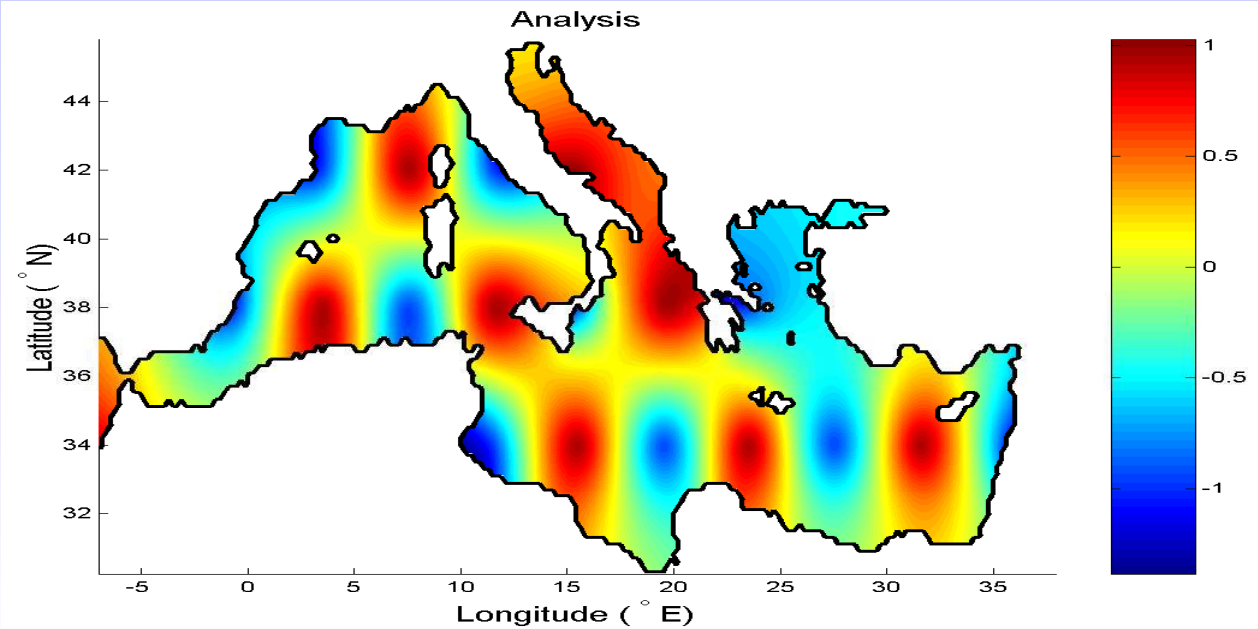
In this case, the OI solution $=$ DIVA solution.

- Advantages of DIVA: regularization, fast finite-element solution, boundary effects taken into account.
- Difficulties: generalizations to 3D and multivariate versions are "hybrid".

Major direct advantage of DIVA: matrix to invert is related to the finite-element mesh, NOT the number of data. Useful for large data sets (Rixen *et al.*, 2000). Equivalence allows to calculate error fields with DIVA even if formulation does not rely on error minimisation.

Illustration of covariance functions





Comparison

Method	$\min(\epsilon^2)$	3D	Multivar	Ops/image	$\epsilon(\boldsymbol{r})$	a priori	C.V.	anisotropy
Cressman		$\star$	$\star$	$N_d N_a$		$w(r/L)$	(L)	$(\star)$
O.I.	$\star$	$\star$	$\star$	$N_d^3 + N_d N_a$	$\star$	$c(r/L)$	$L, \sigma^2/\mu^2$	$(\star)$
DIVA	$\star$	$(\star)$	$(\star)$	$N_e^{5/2}$	$\star$	$K(r/L)$	$L, \sigma^2/\mu^2$	$\star$
DINEOF	$(\star)$	$\star$	$\star$	$N_a^{5/4}$	$(\star)$	stat.	N	$\star$

N_d : number of data points

N_a : number of grid points for analysis

N_e : number of finite elements

N : number of EOFs

L : correlation length

σ^2/ϵ^2 : signal to noise ratio

$\star$: available feature

$(\star)$: available with some adaptations

Université de Liège

Université de Liège

- *ODV-DIVA gridding(12:00-12:30)*
- *Theory (13:30-14:00)*
- ***Implementations (14:00-15:00)***
- *Diva-on-web (15:30-16:45)*
- *User feedback (16:45-17:00)*

Software download

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

Additions to basic tool

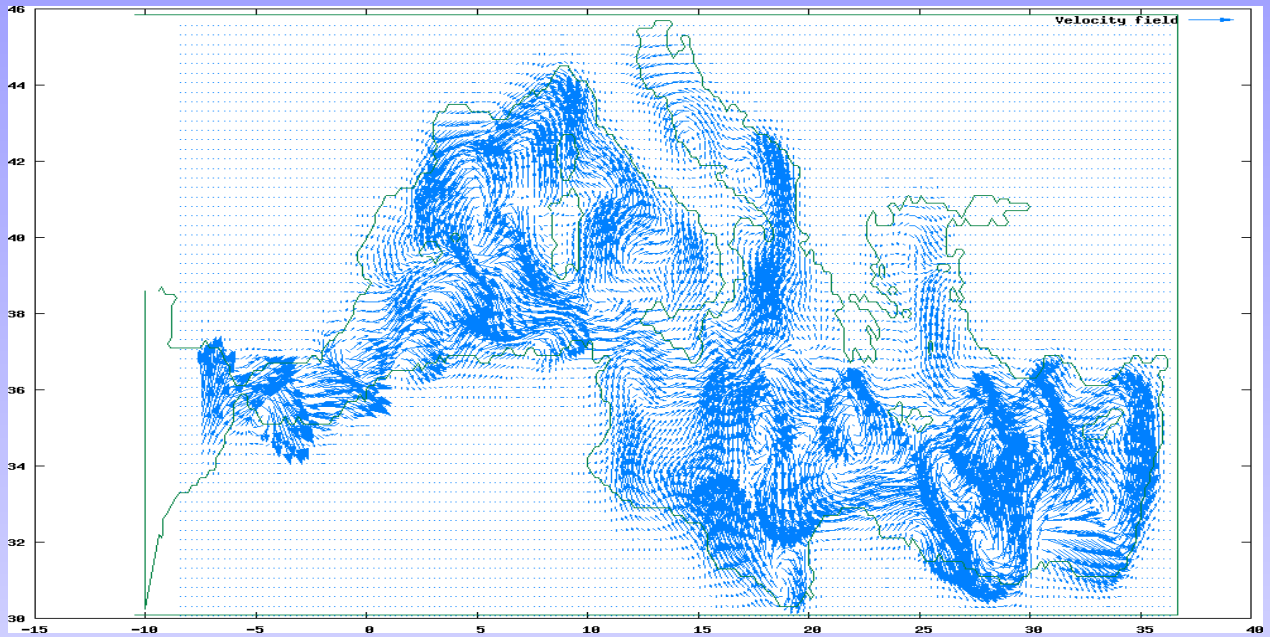
Advection constraint: Augmented cost function to deal with preferred correlation directions, eg, via advection with velocity $\boldsymbol{u}$ and diffusion $\mathcal{A}$

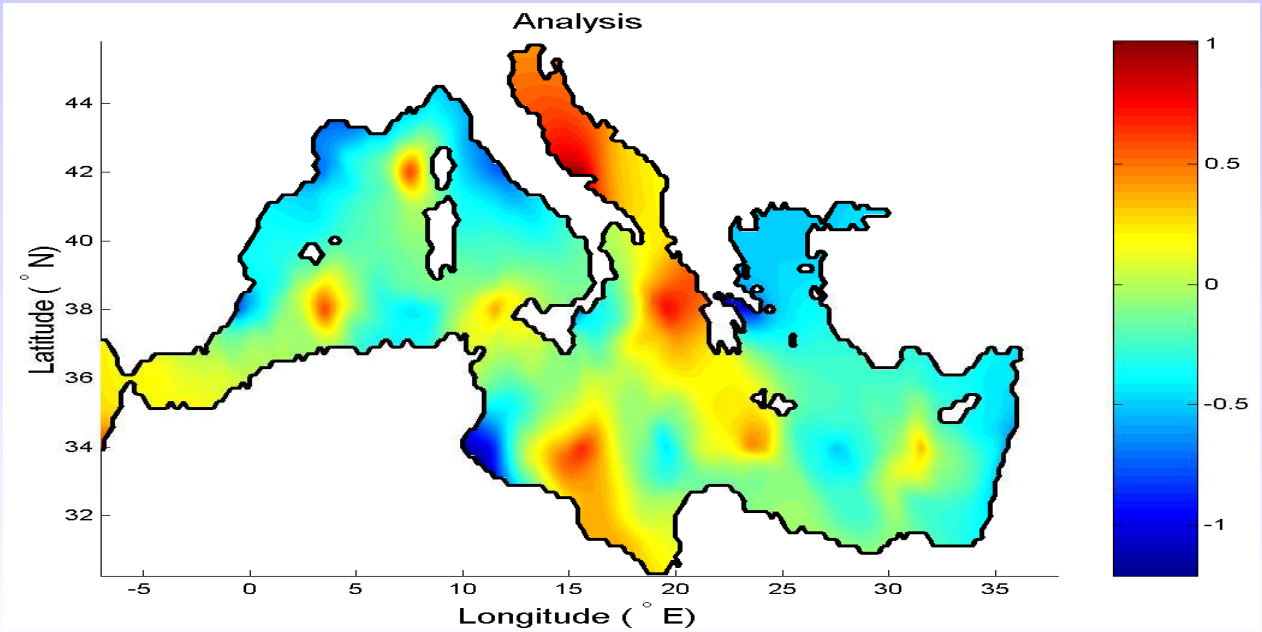
$$J_a = J(\varphi) + \theta \int_D \left[\boldsymbol{u} \cdot \nabla\varphi - \mathcal{A}\nabla\cdot\nabla\varphi\right]^2 \mathrm{d}D \qquad (23)$$

Other features

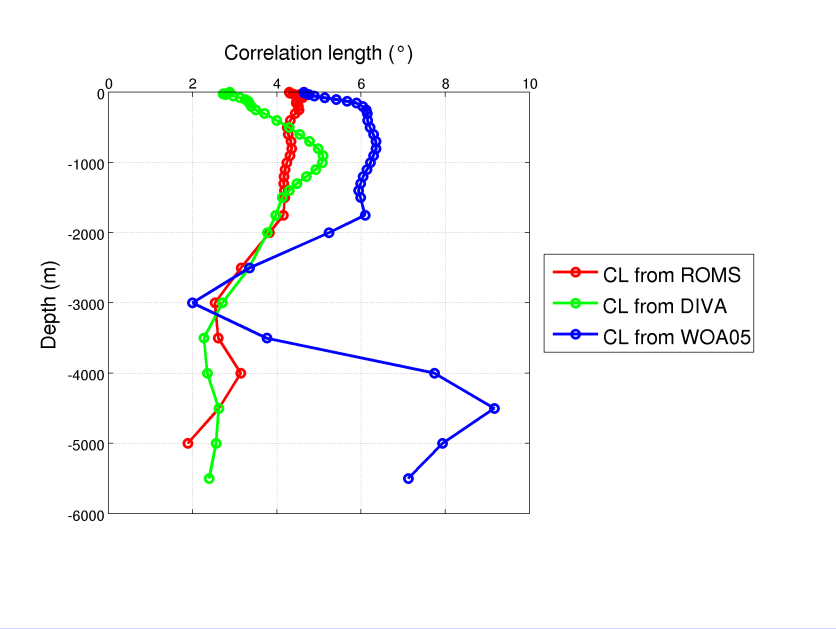
- Error fields taking data distribution into account.
- Toolbox approach allowing to design own versions.
- 3D and 4D modes by looping, hydrostatic constraint in 3D mode.
- Cross validation tools to infer statistical parameters and error estimates.
- Climatology production version with heterogeneous data distributions (detrending) .
- Outlier detection.
- ...

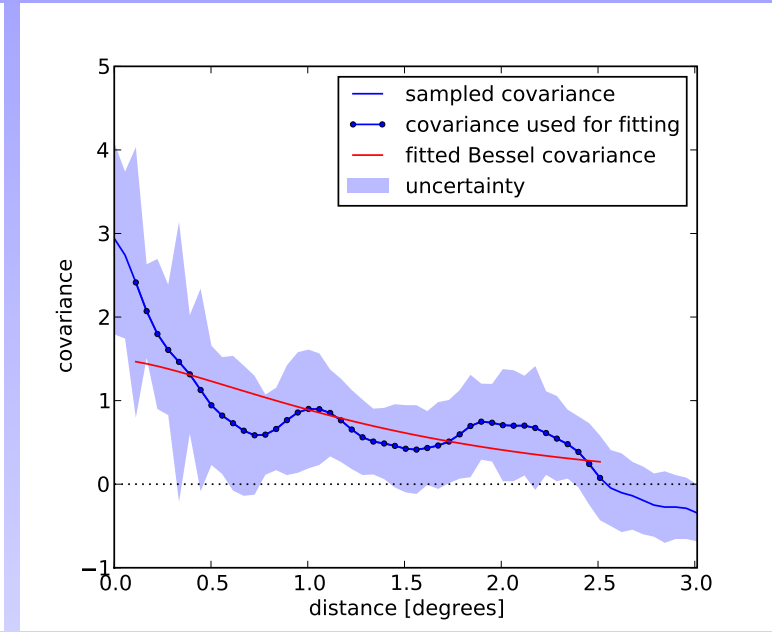
Covariances with advection





Parameter calibration

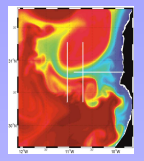




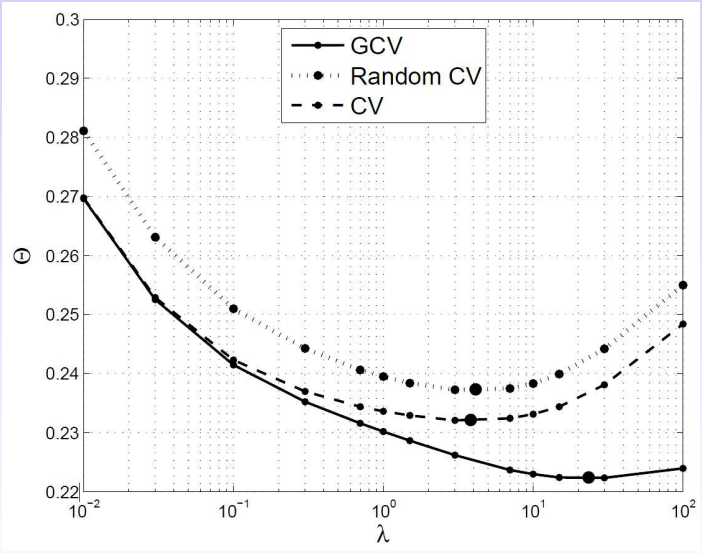
Spatial coherence of parameters: here correlation length obtained with covariance fitting (Troupin *et al.*, 2010).

Signal to noise ratio

The most elusive parameter.

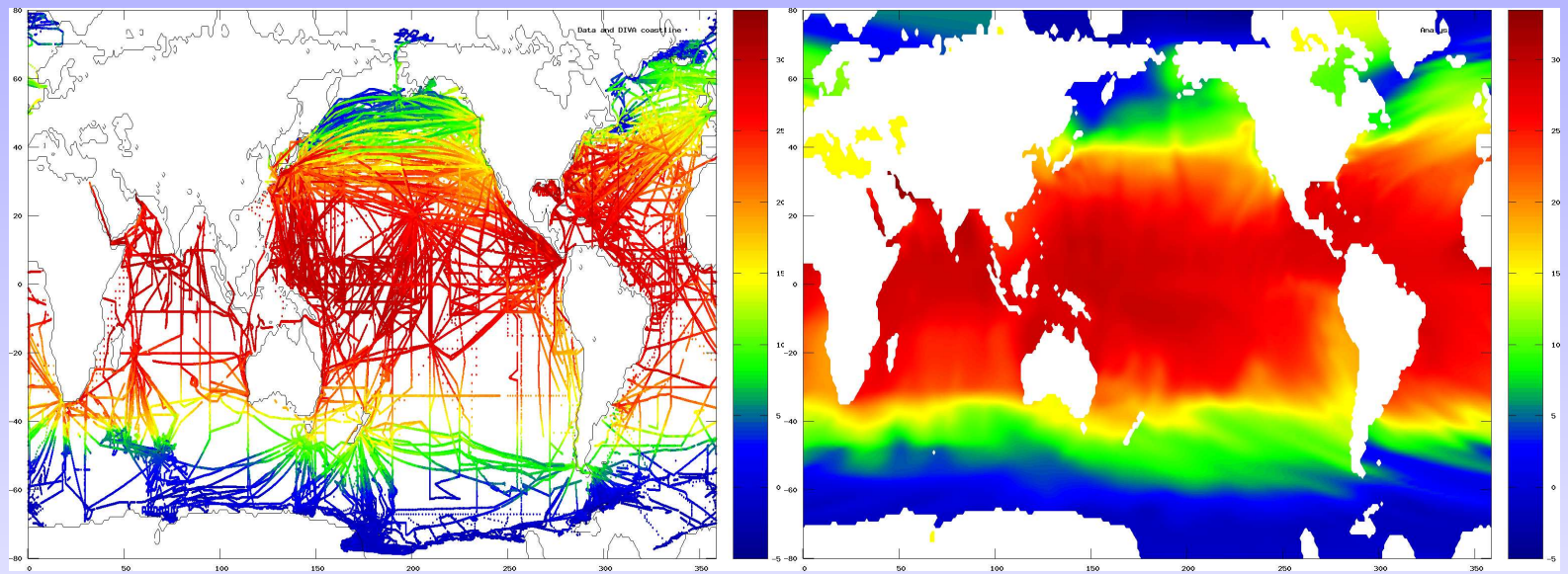
- Noise is not only instrumental error: 
- Very hard problem to decide on value with dependent data (cross-validation approaches fail).

A series of estimation tools are provided with DIVA, but here the experience of oceanographers is critical. A posteriori analysis of residuals allows to verify coherence. With reasonable amount of data, parameter not critical for analysis but for error estimates.

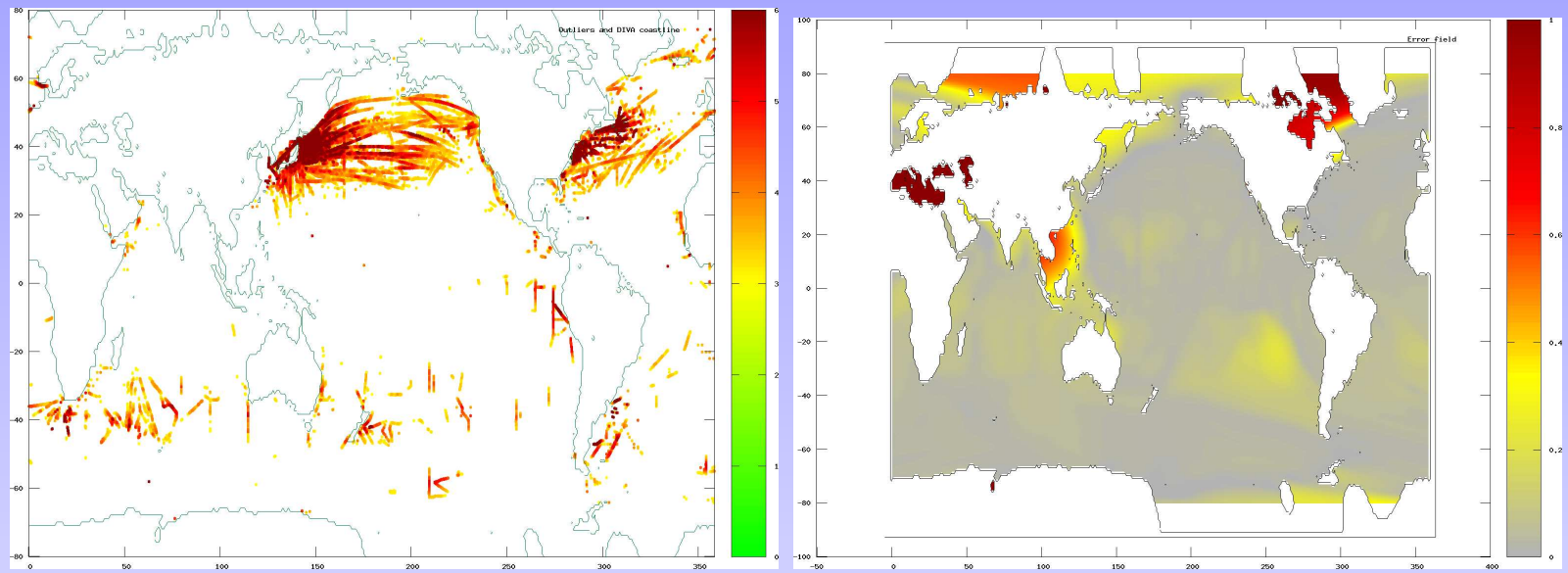


Huge problems

LDEO data base with 4.5 10^6 measurements (Takahashi $et\ al.$, 2009). Running on a laptop within a few minutes. Shown here, temperature fields.



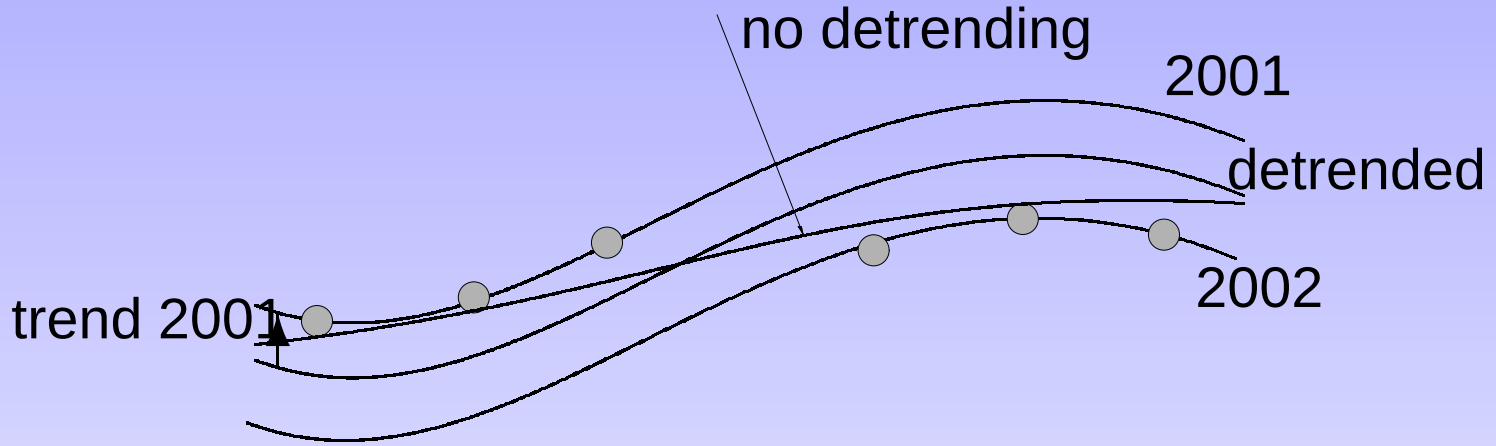
Huge problems, outliers and relative error field



Outliers detected via comparison of statistically expected residuals (value provided by the DIVA analysis) and actual residuals.

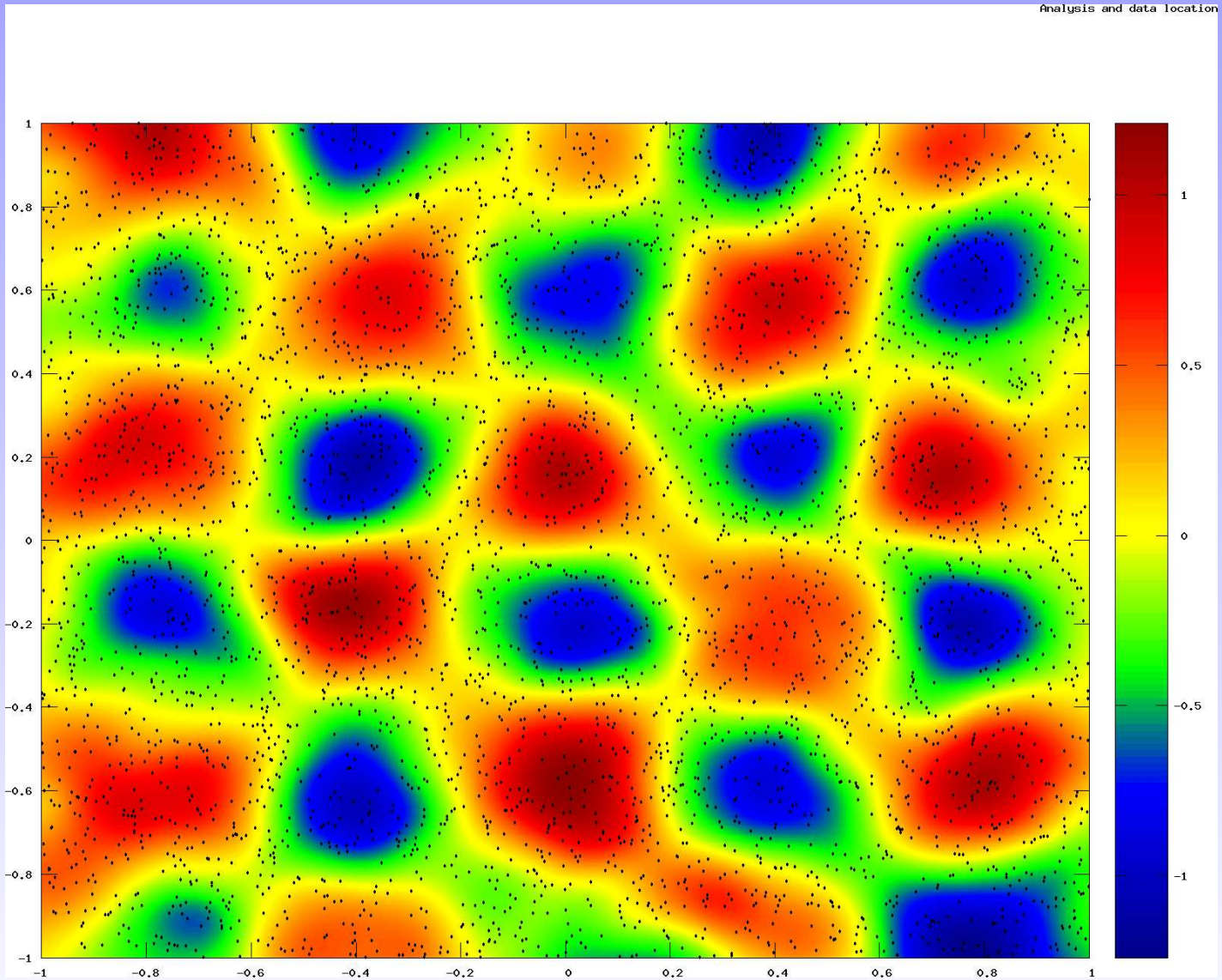
Detrending

Heterogeneous data distribution:



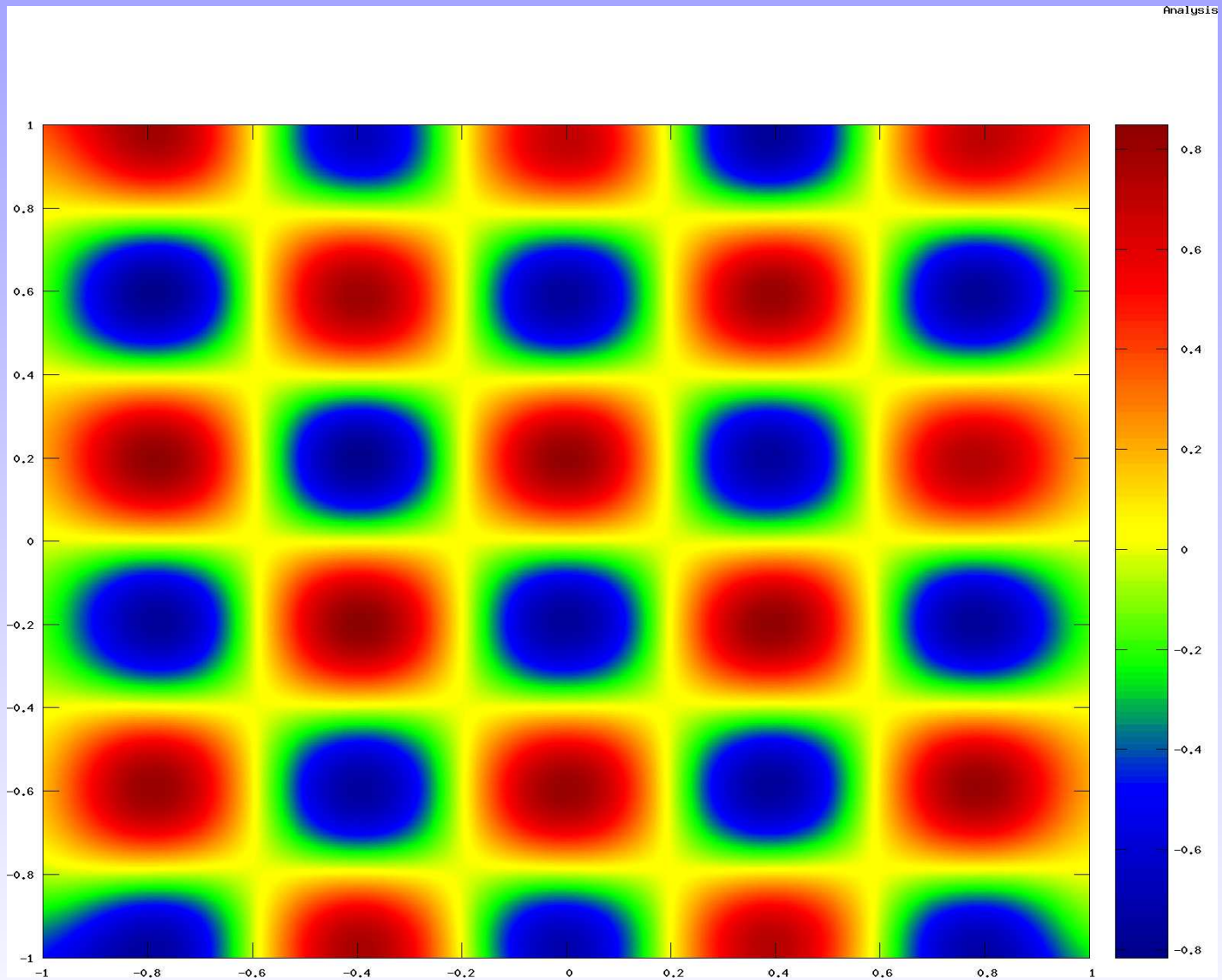
First analysis show a biais for each year's data with respect to first analysis. Subtract the biais estimate and redo the analysis, accumulating the biais. After convergence, detrended analysis+biais of the year.

Example without detrending



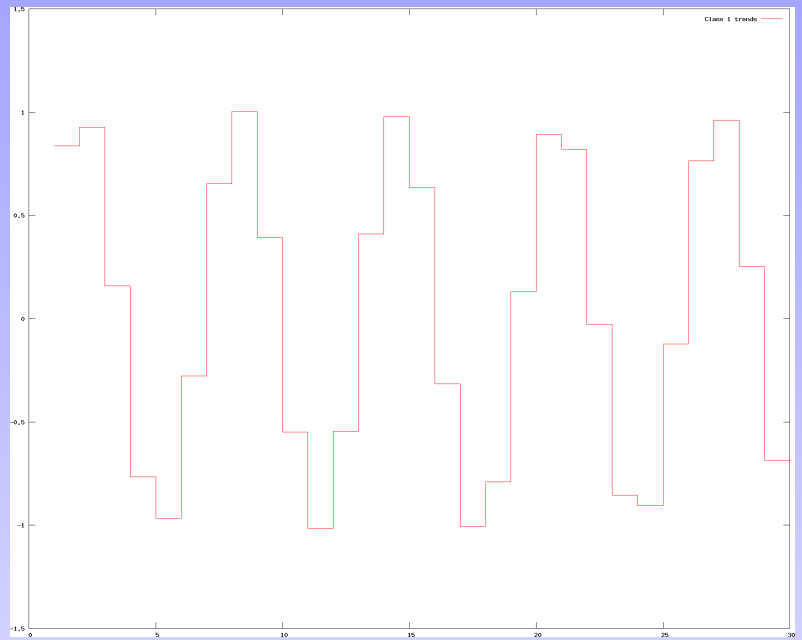
DIVA analysis of sin-cosine spatial structure with superimposed decadal, seasonal and daily cycles and noise.

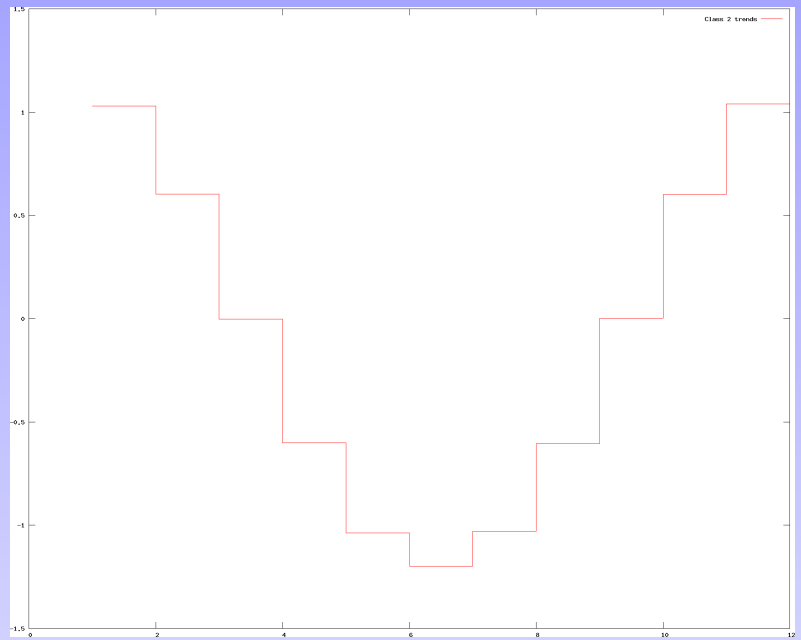
Example with detrending

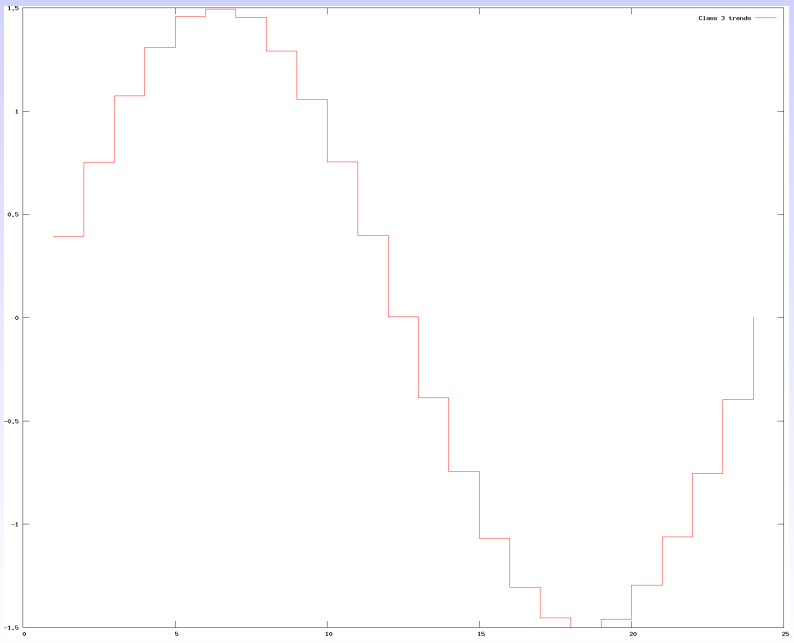


DIVA analysis of sin-cosine spatial structure with superimposed decadal, seasonal and daily cycles and noise.

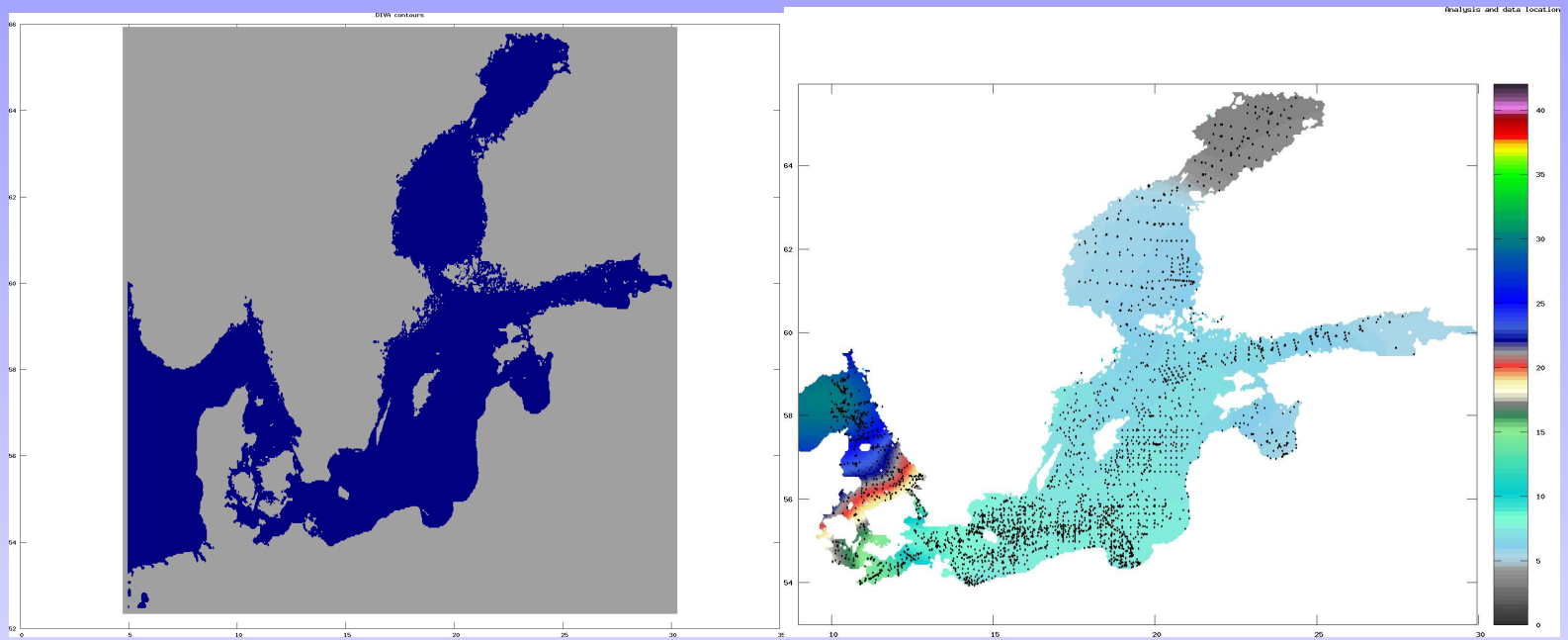
Trends can also be retrieved







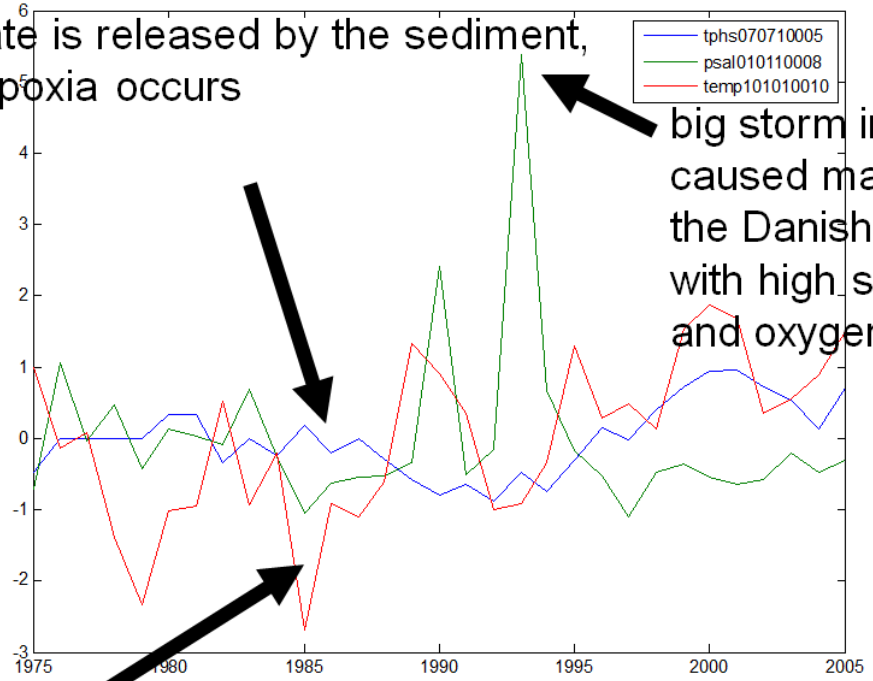
Heterogeneous case



Baltic Salinity Climatology (Bassompierre *et al.*, 2010)

Heterogeneous case, trends

X= nutrient & climatic trends from Kattegat to Bothnian Bay (SDN products)



phosphate is released by the sediment, when hypoxia occurs

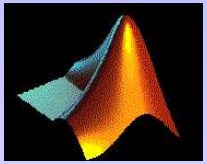
big storm in January 1993, caused massive water through the Danish straits inflows with high salinity and oxygenated the Baltic

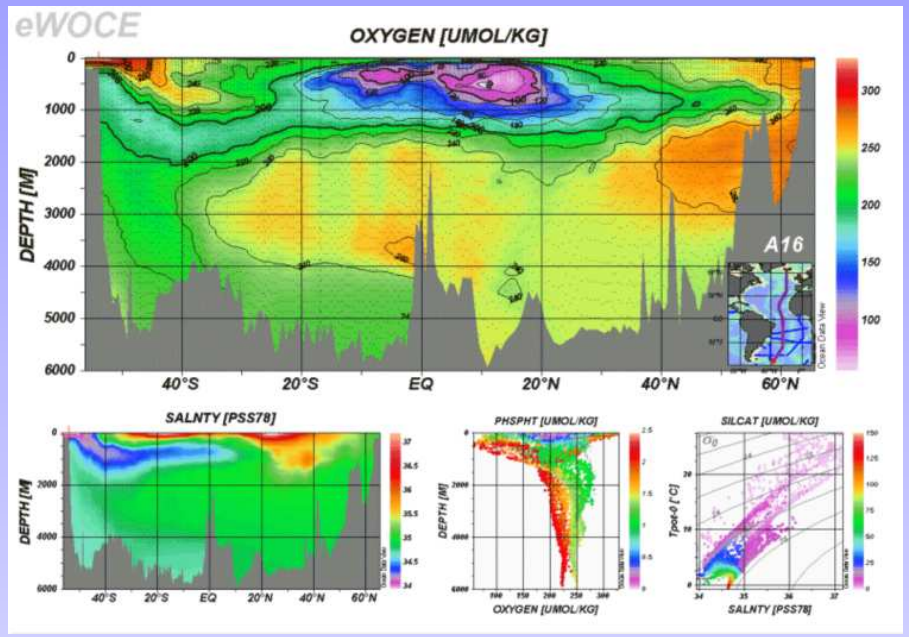
increased temperature increases risk of hypoxia

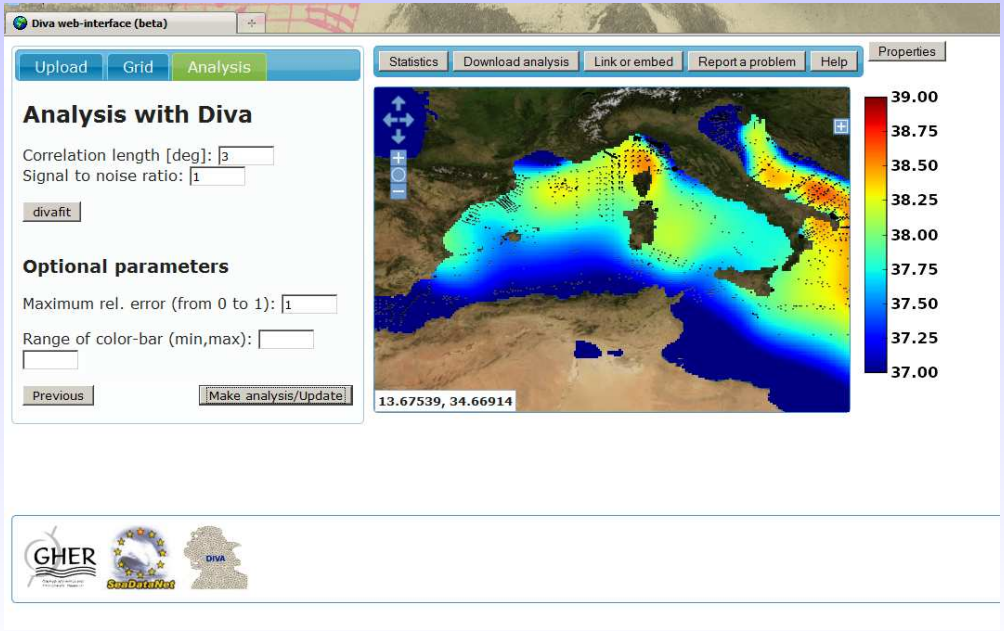
tphs0707005= total phosphate July -100 m
psal 0101108=salinity January level -40 m
temp101010010=temperature October -20 m

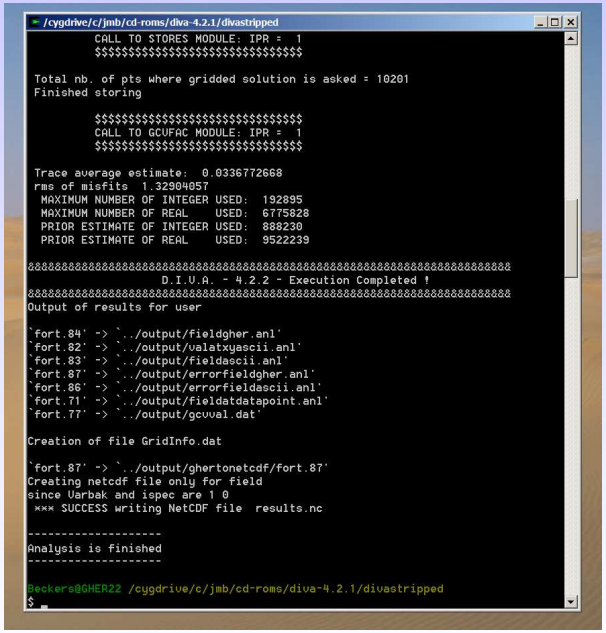
(Bassompierre *et al.*, 2010)

How to use DIVA?









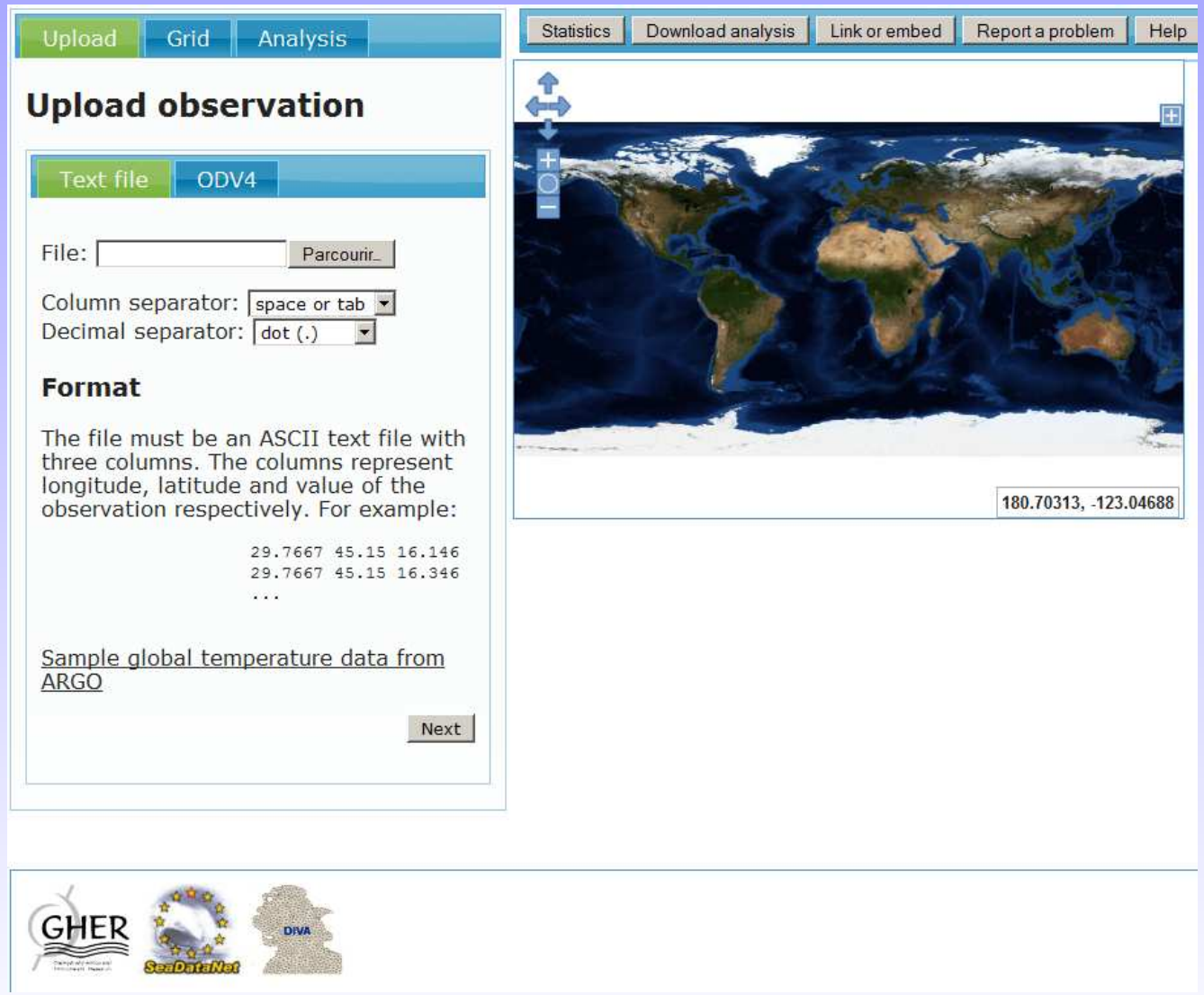
Université de Liège

Université de Liège

- *ODV-DIVA gridding(12:00-12:30)*
- *Theory (13:30-14:00)*
- *Implementations (14:00-15:00)*
- ***Diva-on-web (15:30-16:45)***
- *User feedback (16:45-17:00)*

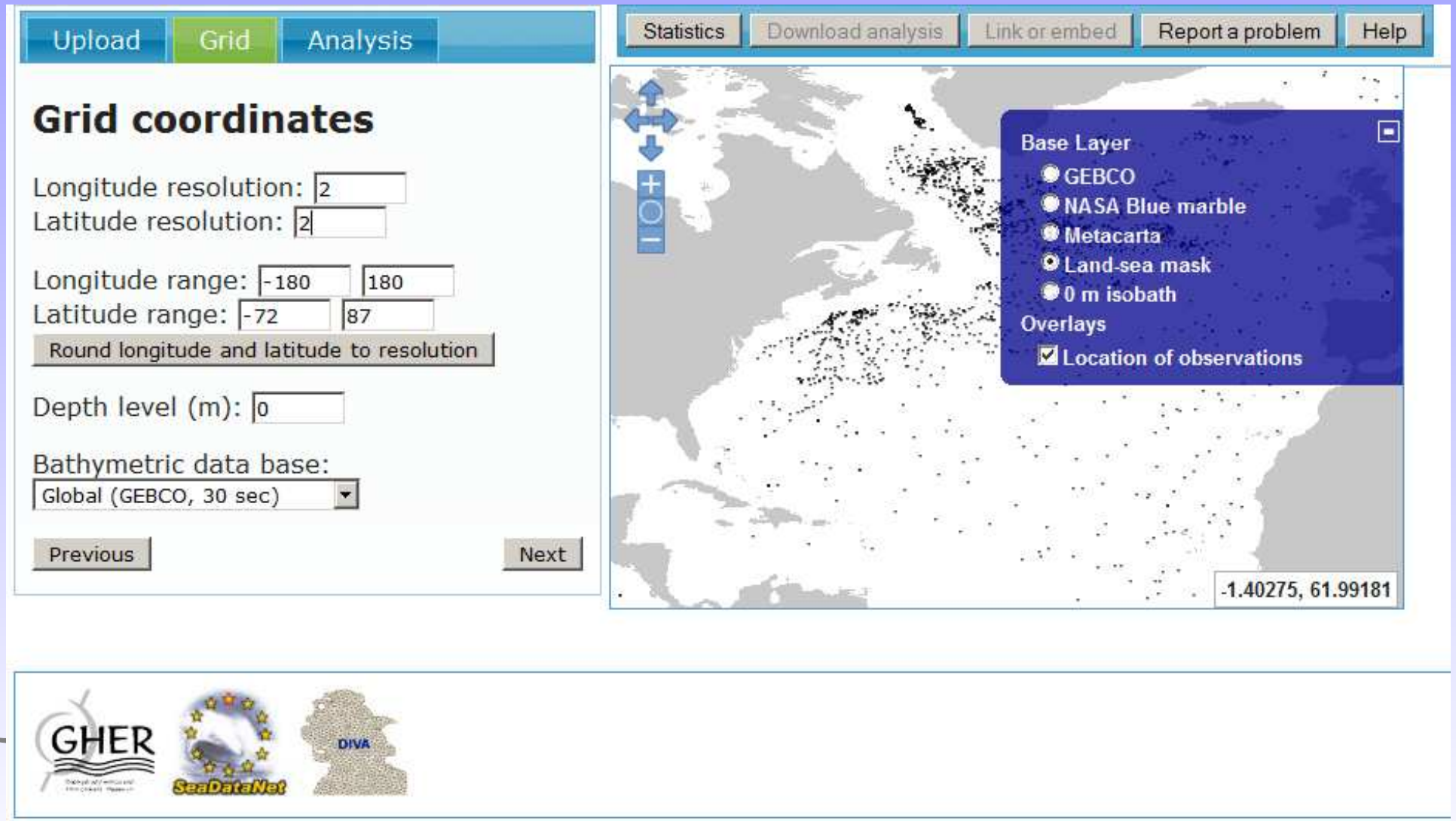
Diva-on-web

http://gher-diva.phys.ulg.ac.be/web-vis/diva.html



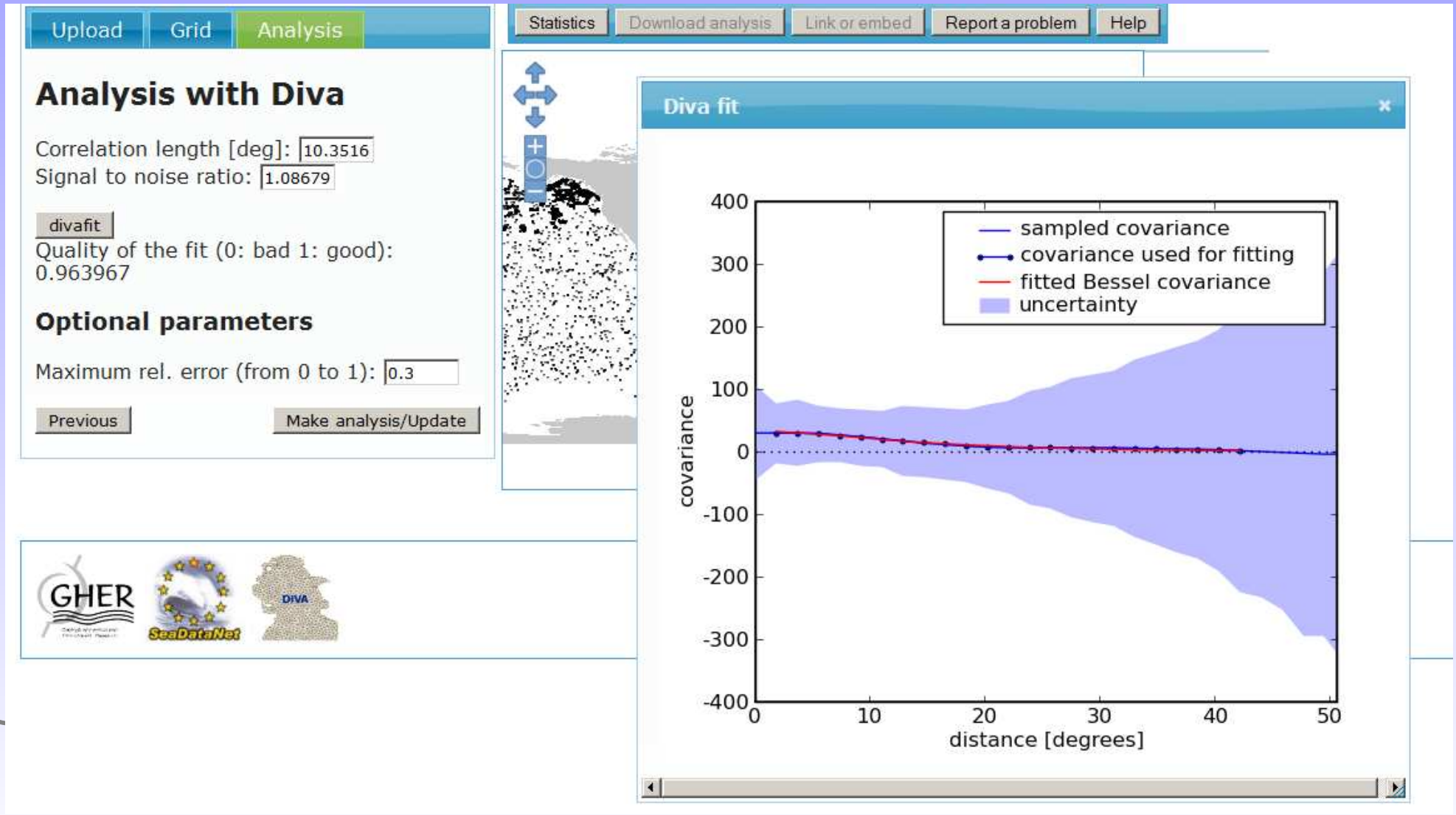
Diva-on-web

Data upload (3 column ascii file or ODV4) and output grid definition



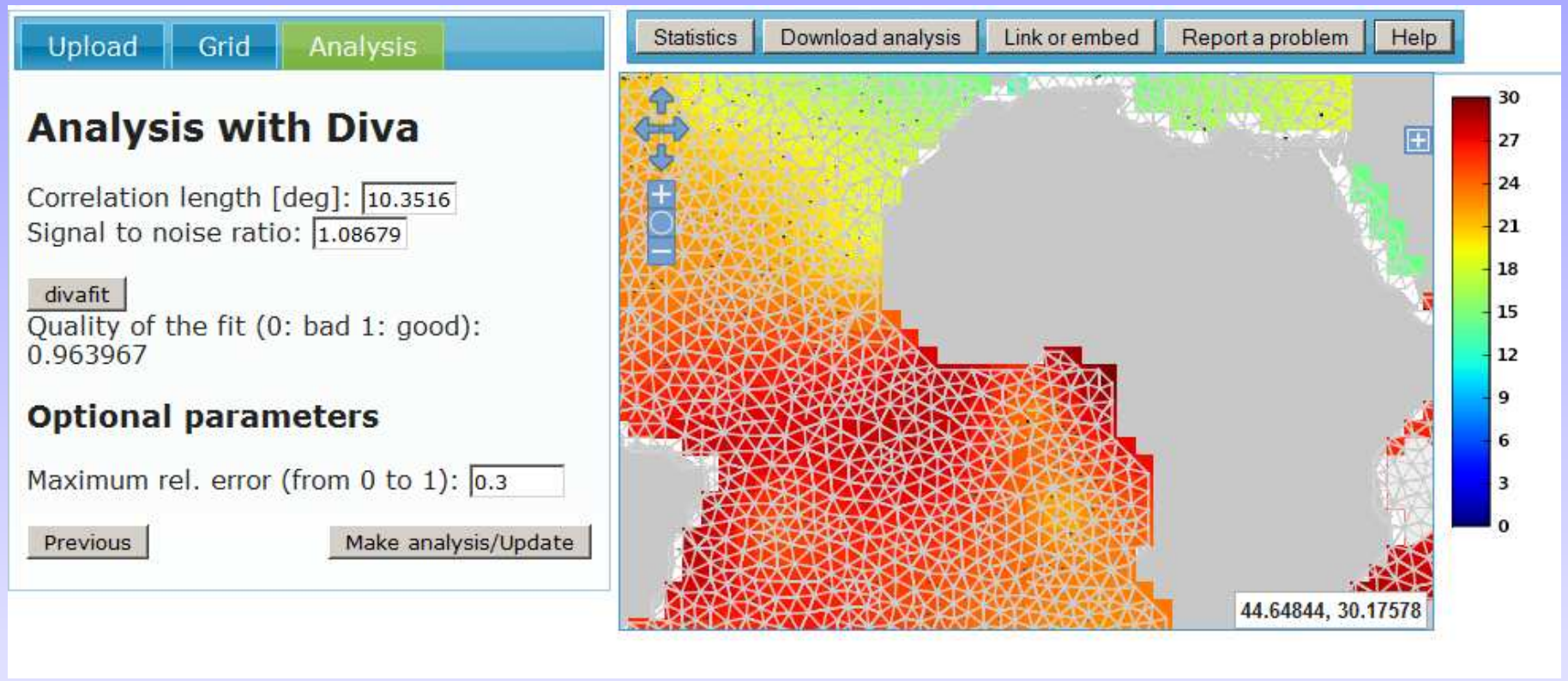
Diva-on-web

Analysis parameter definition (or fit)



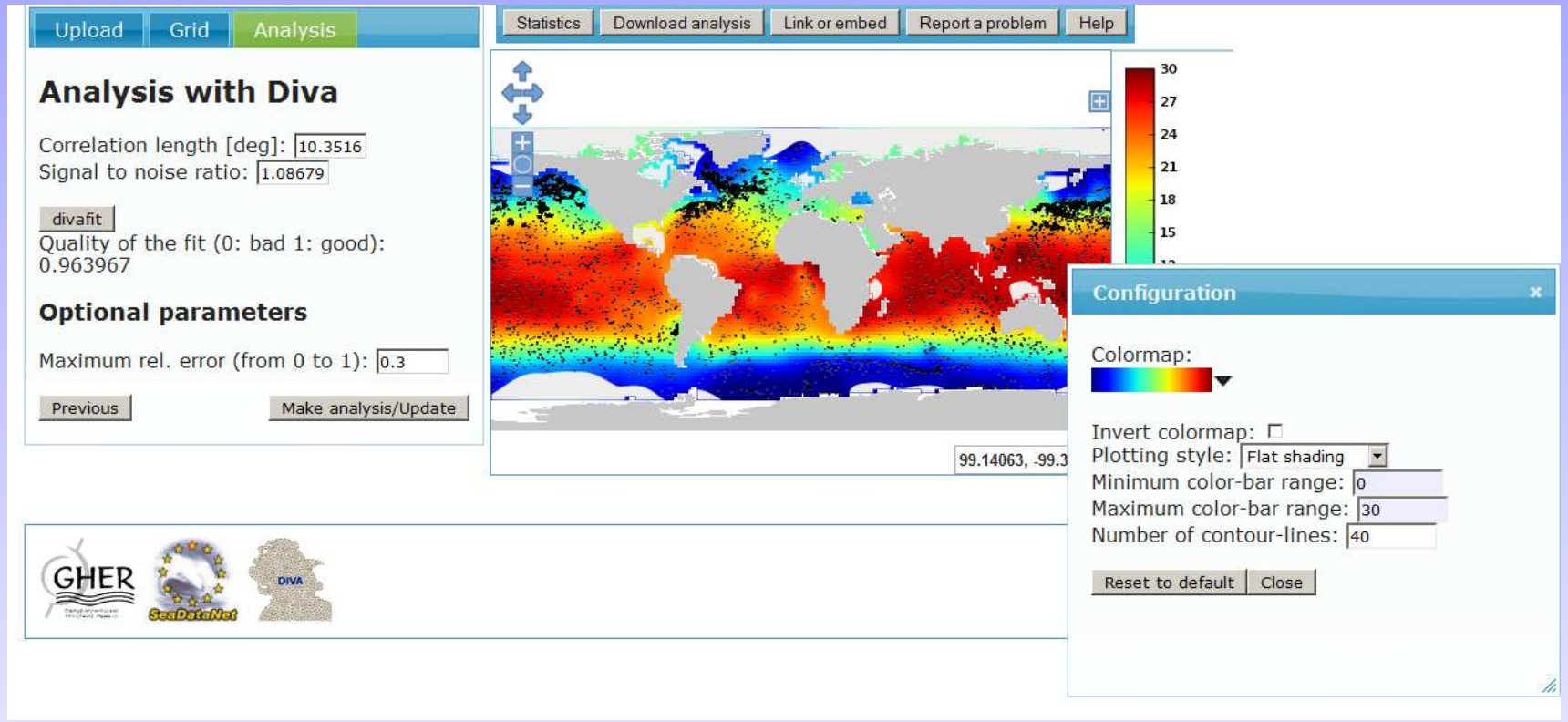
Diva-on-web

Analysis (and numerical grid)



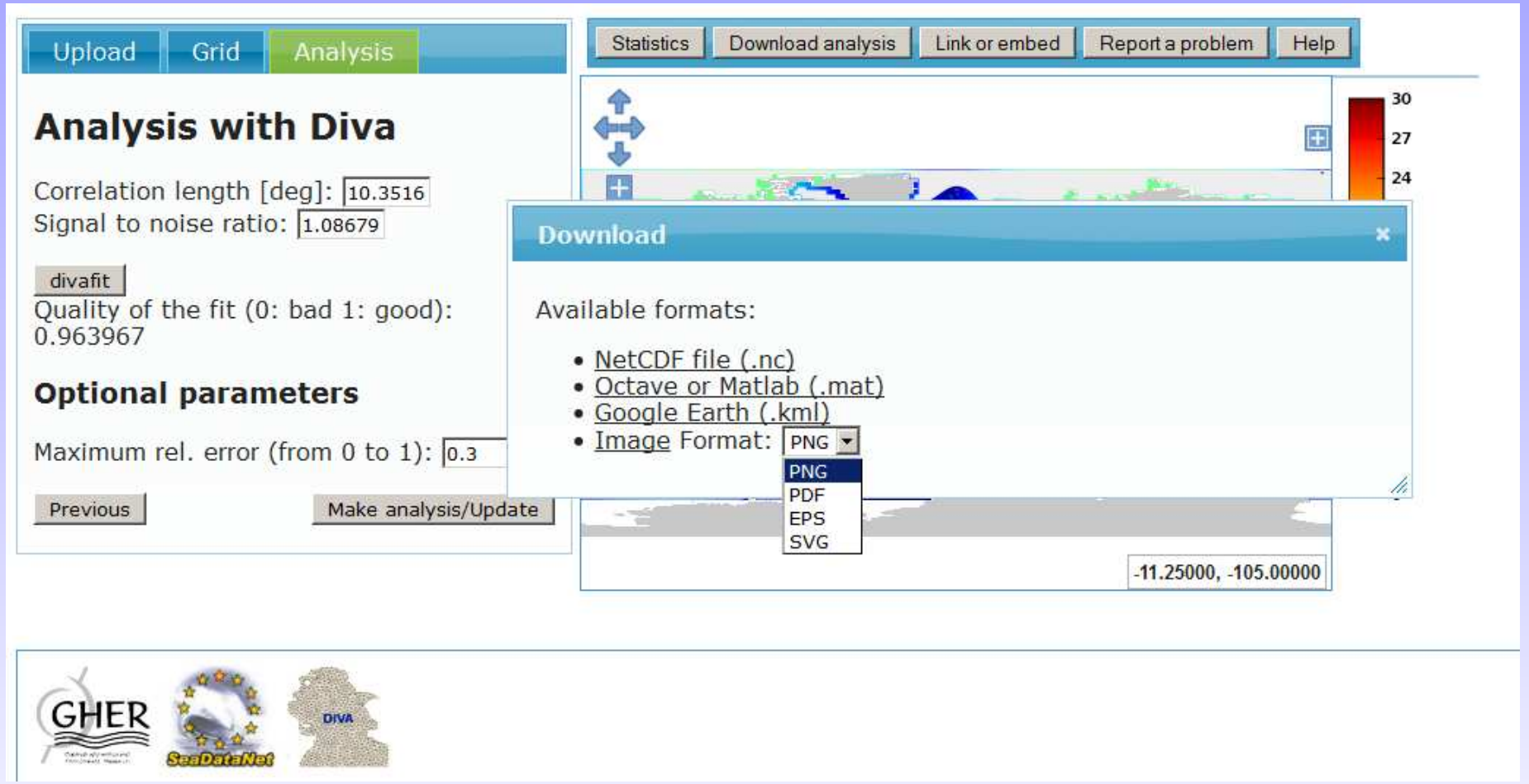
Diva-on-web

Plotting options



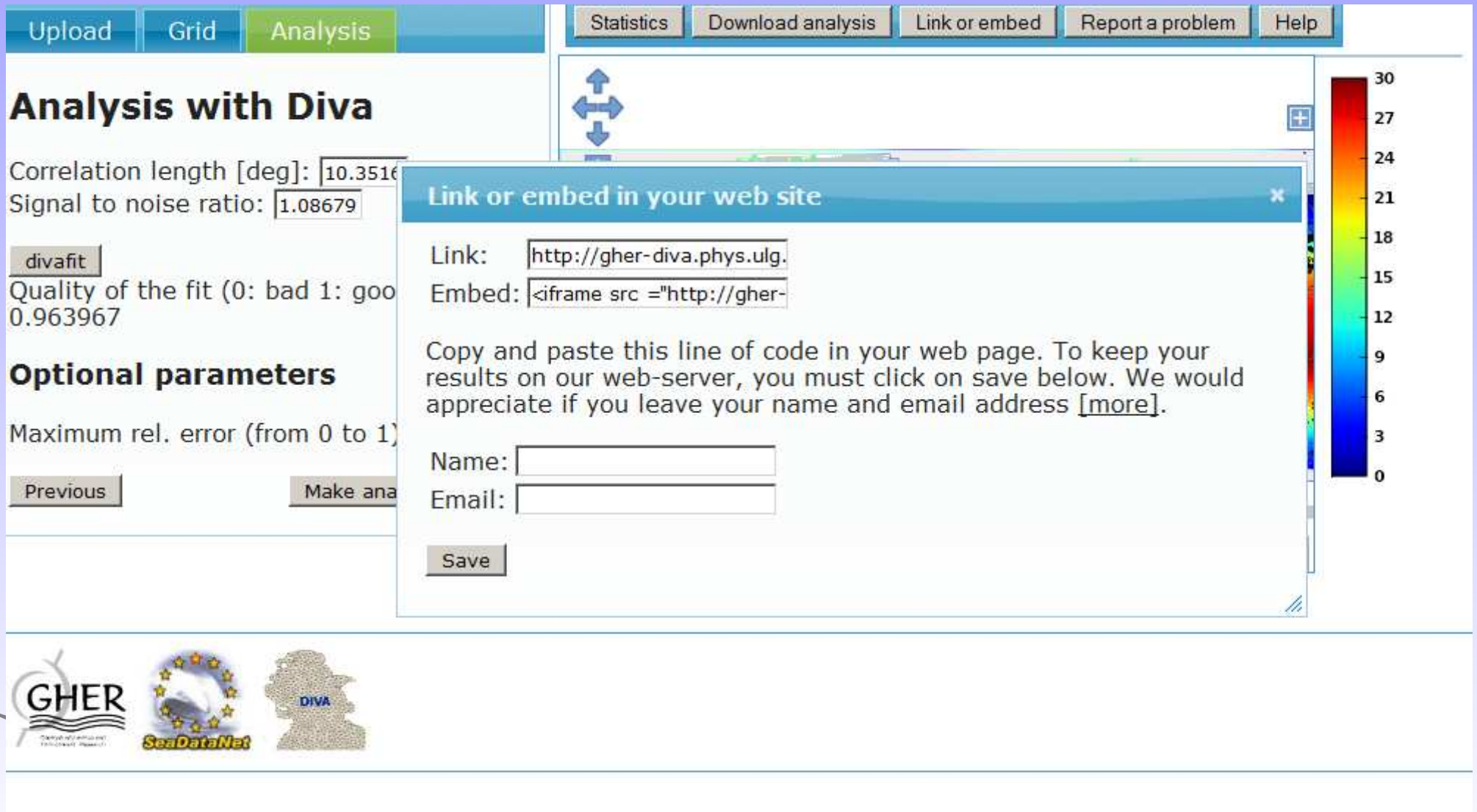
Diva-on-web

Download options



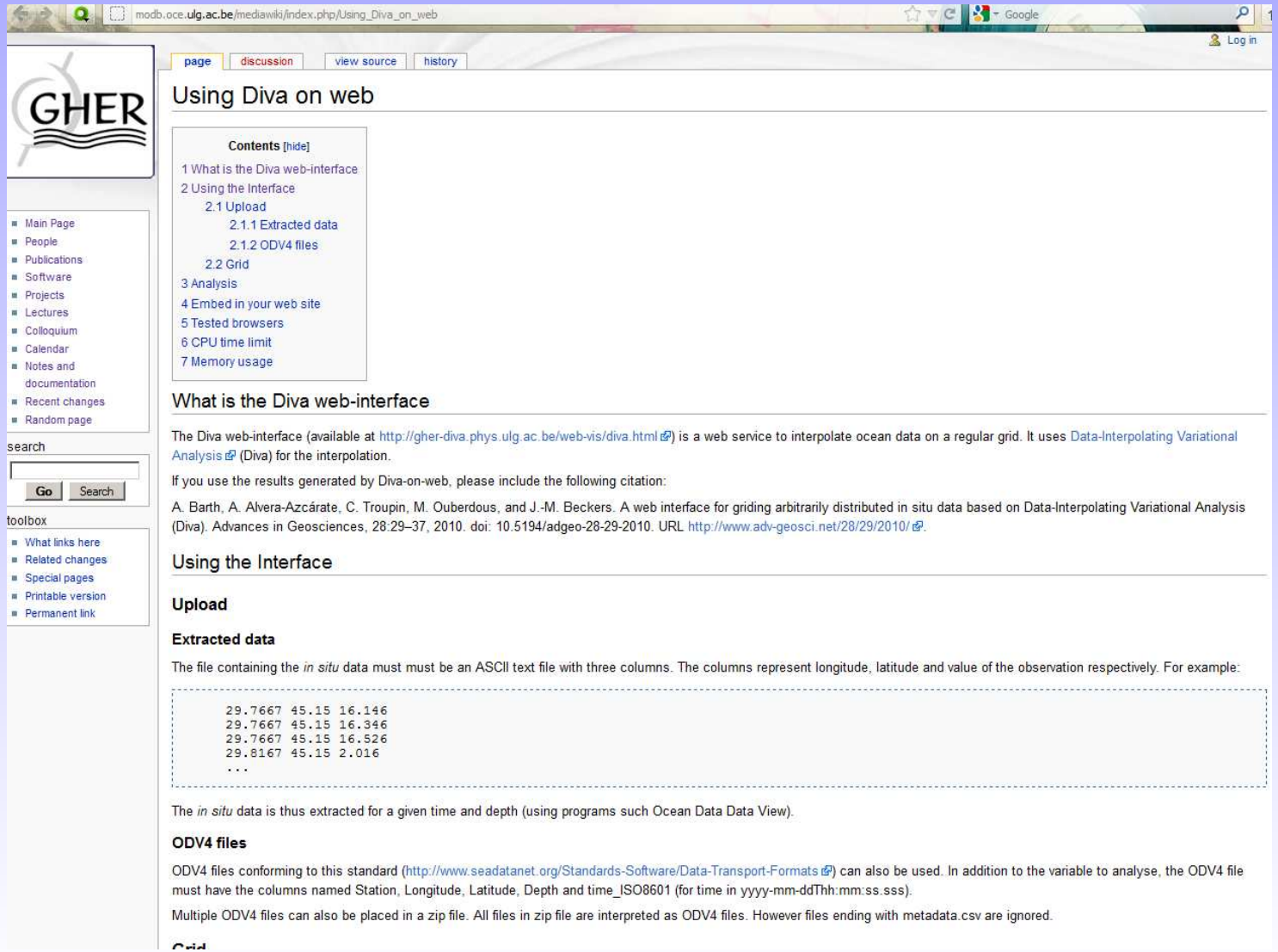
Diva-on-web

Exploitation of WMS-OGC layering techniques



Help

More information
http://modb.oce.ulg.ac.be/mediawiki/index.php/Using_Diva_on_web



modb.oce.ulg.ac.be/mediawiki/index.php/Using_Diva_on_web

page | discussion | view source | history

Log in

GHER

- Main Page
- People
- Publications
- Software
- Projects
- Lectures
- Colloquium
- Calendar
- Notes and documentation
- Recent changes
- Random page

search

Go | Search

toolbox

- What links here
- Related changes
- Special pages
- Printable version
- Permanent link

Using Diva on web

Contents [hide]

What is the Diva web-interface

The Diva web-interface (available at http://gher-diva.phys.ulg.ac.be/web-vis/diva.html) is a web service to interpolate ocean data on a regular grid. It uses Data-Interpolating Variational Analysis (Diva) for the interpolation.

If you use the results generated by Diva-on-web, please include the following citation:

A. Barth, A. Alvera-Azcárate, C. Troupin, M. Ouberdous, and J.-M. Beckers. A web interface for griding arbitrarily distributed in situ data based on Data-Interpolating Variational Analysis (Diva). Advances in Geosciences, 28:29–37, 2010. doi: 10.5194/adgeo-28-29-2010. URL http://www.adv-geosci.net/28/29/2010/.

Using the Interface

Upload

Extracted data

The file containing the *in situ* data must must be an ASCII text file with three columns. The columns represent longitude, latitude and value of the observation respectively. For example:

```
29.7667 45.15 16.146
29.7667 45.15 16.346
29.7667 45.15 16.526
29.8167 45.15 2.016
...
```

The *in situ* data is thus extracted for a given time and depth (using programs such Ocean Data Data View).

ODV4 files

ODV4 files conforming to this standard (http://www.seadatanet.org/Standards-Software/Data-Transport-Formats) can also be used. In addition to the variable to analyse, the ODV4 file must have the columns named Station, Longitude, Latitude, Depth and time_ISO8601 (for time in yyyy-mm-ddThh:mm:ss.sss).

Multiple ODV4 files can also be placed in a zip file. All files in zip file are interpreted as ODV4 files. However files ending with metadata.csv are ignored.

Grid

Université de Liège

Université de Liège

SeaDataNet

- *ODV-DIVA gridding(12:00-12:30)*
- *Theory (13:30-14:00)*
- *Implementations (14:00-15:00)*
- *Diva-on-web (15:30-16:45)*
- ***User feedback (16:45-17:00)***

Feedback

- Report non-standard ODV4 files retrieved from SDN interface to SDN-TTT
- Report diva runtime errors (be it in ODV or WWW or stand-alone) to `M.Ouberdous@ulg.ac.be`
- For installation of GODIVA (4D batch mode), contact us
- When reporting problems in batch-mode version, try to pinpoint errors and minimal example which reproduces error (please do not come with "It does not work")
- For bugs on diva-on-web, use web interface for reporting
- Do not hesitate to add things to a wishlist
- Strong interactions during DIVA workshops
  `http://modb.oce.ulg.ac.be/mediawiki/index.php/Diva_workshop_2012`

- P. Brasseur, J.-M. Beckers, J.-M. Brankart, and R. Schoenauen. Seasonal temperature and salinity fields in the Mediterranean Sea: Climatological analyses of a historical data set. *Deep Sea Research*, 43:159–192, 1996. http://orbi.ulg.ac.be/handle/2268/4788
- Ch. Troupin, F. Machin, M. Ouberdous, D. Sirjacobs, A. Barth, J.-M. Beckers. High-resolution Climatology of the North-East Atlantic using Data-Interpolating Variational Analysis (Diva). *Journal of Geophysical Research*, **114**, 2010. http://orbi.ulg.ac.be/handle/2268/68400
- M. Rixen, J.-M. Beckers, J.-M. Brankart, and P. Brasseur. A numerically efficient data analysis method with error map generation. *Ocean Modelling*, 2:45–60, 2000. http://orbi.ulg.ac.be/handle/2268/40371
- A. Karafistan, J.-M. Martin, M. Rixen, and J.-M. Beckers. Space and time distributions of phosphates in the Mediterranean Sea. *Deep Sea Research*, 49:67–82, 2002. http://orbi.ulg.ac.be/handle/2268/4289
- Tyberghein, L., Verbruggen, H., Klaas, P., Troupin, C., Mineur, F., De Clerck, O., 2011. ORACLE: a global environmental dataset for marine species distribution modeling. *Global Ecology and Biogeography.* http://orbi.ulg.ac.be/handle/2268/112937
- Barth, A., Alvera-Azcárate, A., Troupin, C., Ouberdous, M., Beckers, J.M., 2010. A web interface for griding arbitrarily distributed in situ data based on Data-Interpolating Variational Analysis (DIVA). *Adv. Geosci.* 28, 29-37. http://orbi.ulg.ac.be/handle/2268/81401

M. Rixen, J.-M. Beckers, S. Levitus, J. Antonov, T. Boyer, C. Maillard, M. Fichaut, E. Balopoulos, S. Iona, H. Dooley, M.-J. Garcia, B. Manca, A. Giorgetti, G. Manzella, N. Mikhailov, N. Pinardi, M. Zavatarelli, and the Medar Consortium. The Western Mediterranean Deep Water: a proxy for global climate change. *Geophysical Research Letters*, 32, 2005. `http://orbi.ulg.ac.be/handle/2268/4299`

C. Troupin, A. Barth, D. Sirjacobs, M. Ouberdous, J.-M. Brankart, P. Brasseur, M. Rixen, A. Alvera-Azcárate, M. Belounis, A. Capet, F. Lenartz, M.-E. Toussaint, J.-M. Beckers. Generation of analysis and consistent error fields using the Data Interpolating Variational Analysis (DIVA). *Ocean Modelling*, **52**, 90-101, 2012. `http://orbi.ulg.ac.be/handle/2268/125731`