DIVA software and the ☁

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Can you guess the temperature at the "?"

Spatial interpolation: Why is it needed?

Ocean observation is expensive and complex

Credit: www.socib.es

Ocean observation is expensive and complex

"A measurement not made is a measurement lost forever"

"Collect once, use many times"

Can you guess the temperature at the "?"

$$\frac{14.4 + 16.1}{2} = 15.25°\text{C} \qquad ??$$

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6 reasons why

spatial interpolation

is not so easy

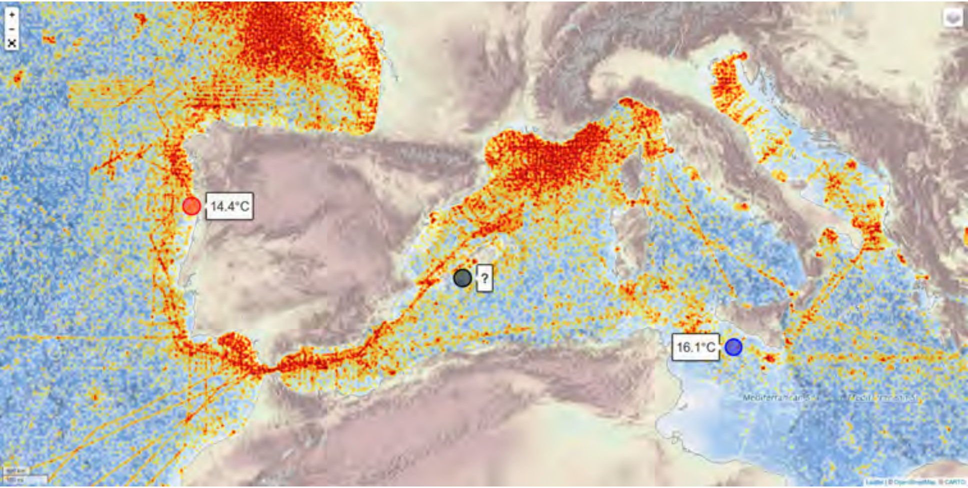
1 Synopticity error

Measurements not collected at the same time

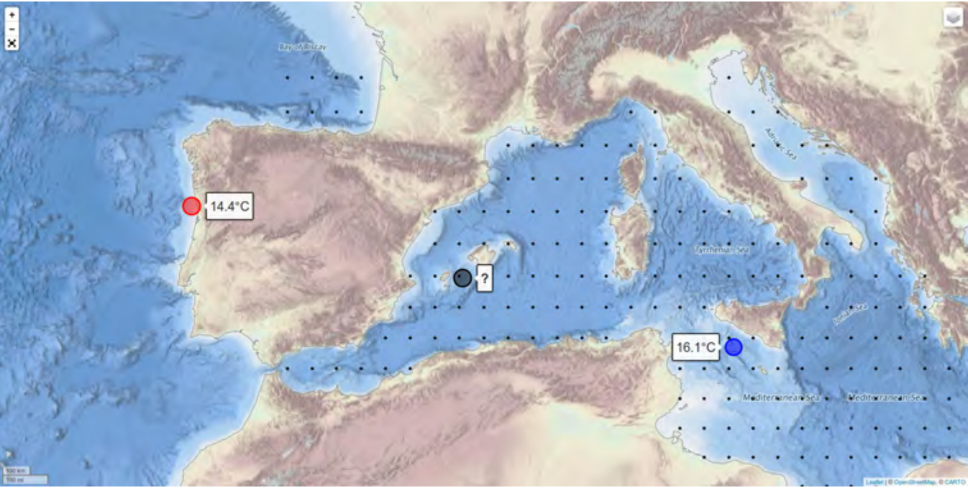
What we measure is not always
what we intend to analyse

Example: I want the mean annual temperature off Porto
but ships are only at sea when the weather is good

3 A lot of observations, but not everywhere



4 Need to interpolate at many locations



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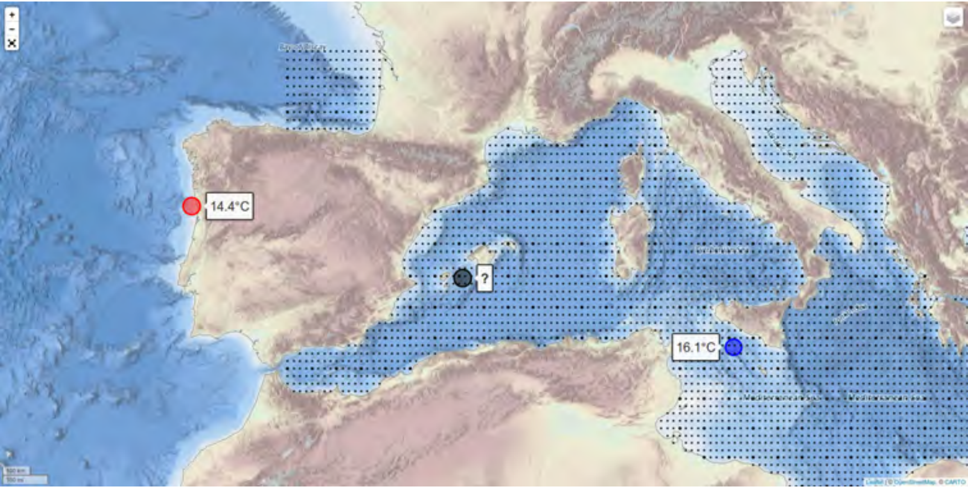
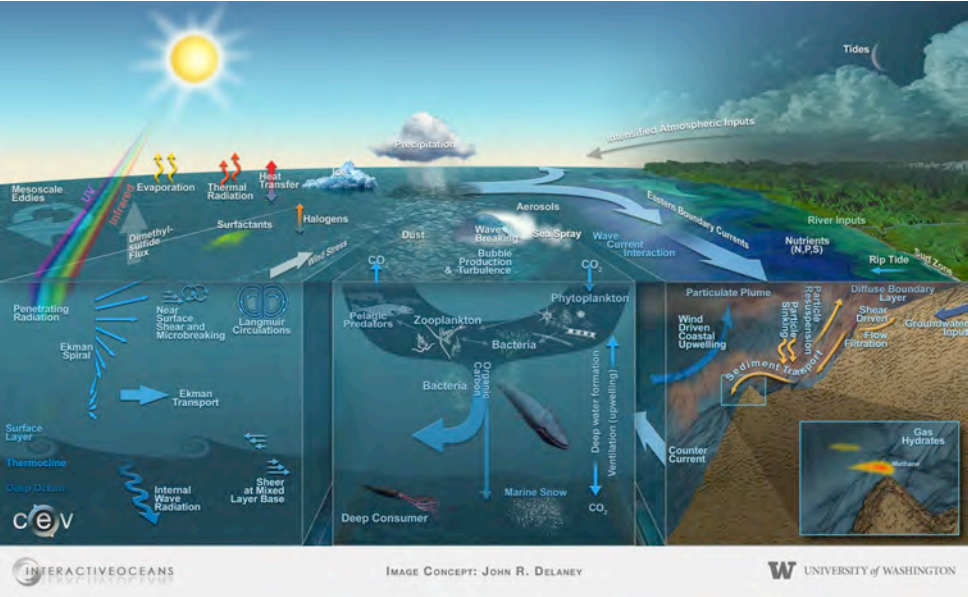


5 Anisotropy

Land acts as a physical barrier

6 A lot of processes taking place...



How do we do it?

Minimisation of a cost function taking into account:

1. Closeness to the observations
2. Regularity/smoothness of the solution

$$
\begin{aligned}
J[\varphi] &= \sum_{i=1}^{N} \mu_i \left[d_i - \varphi(x_i, y_i) \right]^2 \\
&+ \int_D \left(\nabla\nabla\varphi : \nabla\nabla\varphi + \alpha_1 \nabla\varphi \cdot \nabla\varphi + \alpha_0 \varphi^2 \right) \mathrm{d}D,
\end{aligned}
$$

solved by a finite-element technique

Data-Interpolating Variational Analysis

https://github.com/gher-ulg/DIVA

DOI 10.5281/zenodo.836727

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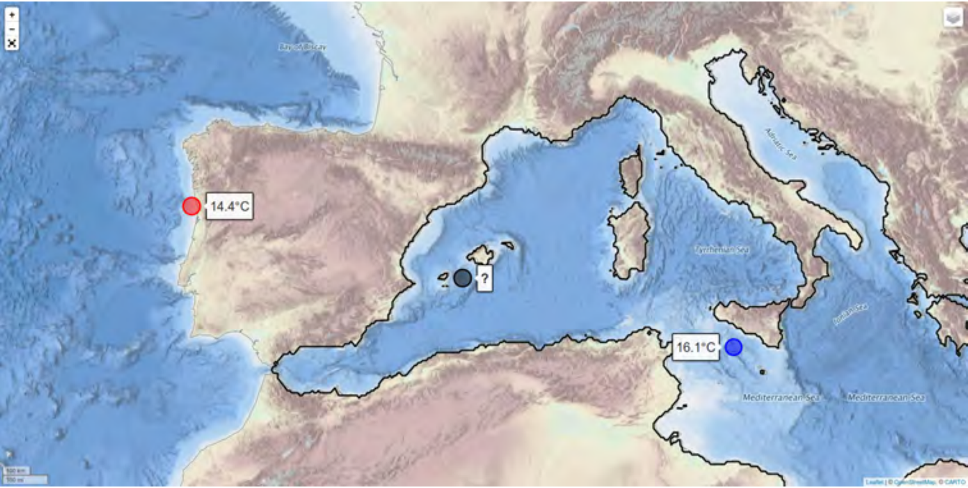

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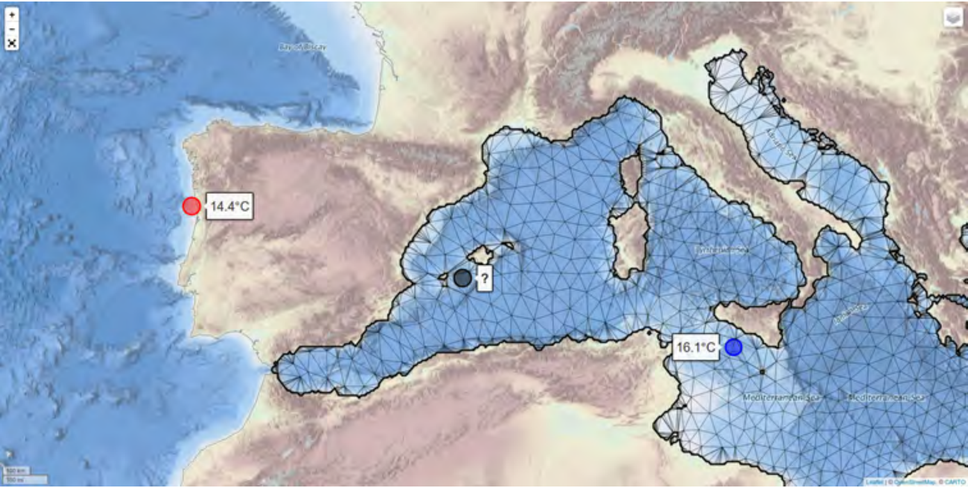

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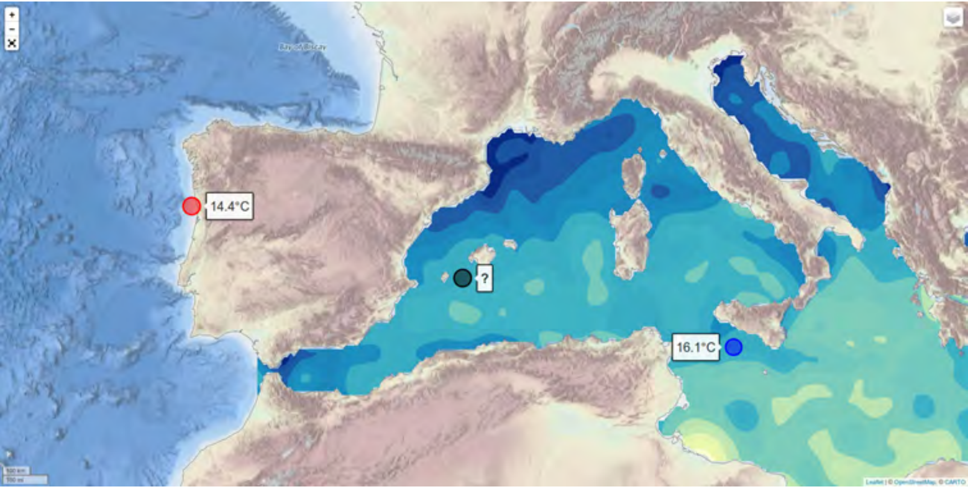

DIVAnd: generalised, n-dimensional interpolation

2013: GNU Octave or MATLAB

2016: julia

faster, better, stronger

divand-1.0: *n*-dimensional variational data analysis for ocean observations

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https://www.geosci-model-dev.net/7/225/2014/gmd-7-225-2014.pdf

https://github.com/gher-ulg/divand.jl

DIVAnd: generalised, n-dimensional interpolation

$$
\begin{aligned}
& K^{n,m}(r) \\
= \quad & c^{n,m}\frac{(2\pi)^{-\frac{n}{2}}}{2(1-m)} r^{\frac{2-n}{2}} \int_0^\infty \mathrm{J}_{\frac{n-2}{2}}(kr) k^{\frac{n-2}{2}} \frac{d}{dk}\left(\frac{1}{(1+k^2)^{m-1}}\right) dk \\
= \quad & c^{n,m}\frac{(2\pi)^{-\frac{n}{2}}}{2(m-1)} r^{\frac{4-n}{2}} \int_0^\infty \mathrm{J}_{\frac{n-4}{2}}(kr) k^{\frac{n-4}{2}} \frac{k}{(1+k^2)^{m-1}} dk \\
= \quad & \frac{1}{4\pi(m-1)} \frac{c^{n,m}}{c^{n-2,m-1}} K^{n-2,m-1}(r)
\end{aligned}
$$

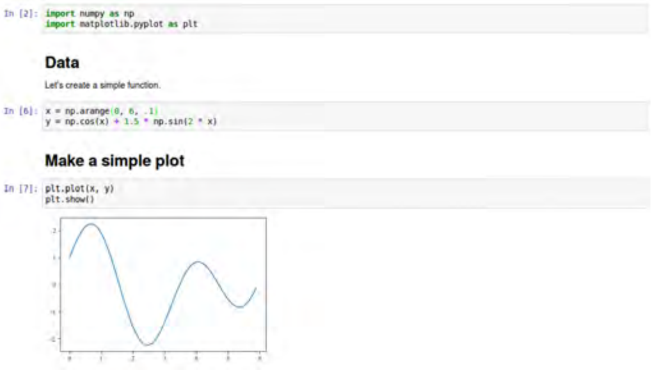
where

- n is the dimension
- m is the highest derivative
- $K^{n,m}$ is the Kernel
- $J_\nu(r)$ is the Bessel function of first kind or order ν

Problem	Solution in DIVA
1 Synopticity error 2 Representativeness error	Regularity constrain in cost function
3 Many observations	Numerical cost (almost) independent on the number of data points
4 Interpolate at many locations	Finite-element solver
5 Anisotropy	Finite-element solver
6 Currents	Advection included in the cost function

Notebooks: user-interface

1. Documentation, including equations and export to pdf
2. Code fragments for different steps of the interpolation
3. Figures illustrating the data or intermediate results



Notebooks: workflow description

NATURE | TOOLBOX

Interactive notebooks: Sharing the code

The free IPython notebook makes data analysis easier to record, understand and reproduce.

Helen Shen

05 November 2014

http://www.nature.com/news/interactive-notebooks-sharing-the-code-1.16261

Notebooks: workflow description

Provide the jupyter-notebooks
along with the data product (interpolation)

Easy to share: `http://nbviewer.jupyter.org/`,
`http://github.com/`

Make easier the **reproducibility** and peer-review

Why do we need Virtual Research Environments?

Computational resources

Storage and inversion of huge matrices

Typical case:

Horizontal grid: 500×500

Vertical levels: 50 depth levels

Time periods: 20

Better access to SeaDataCloud data and tools

People connect, access the data, and work!

Installed/deployed once, used many times

Installing is sometimes much harder than running the code...

DIVAnd in the VRE with jupyterhub

Management of multiple instances
of the single-user Jupyter notebook server

https://github.com/jupyterhub/jupyterhub
Demo available at https://hub-test.oceanbrowser.net/
(deployed at CINECA via Docker)

I/O

MarineID or

Authentication

Inputs: CDI data and user data

Results of the interpolation

Outputs: data products, climatologies, gridded fields

Summary

✓ Spatial interpolation is a **frequent** but **not trivial** operation in ocean sciences

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✓ **Specific** tools (DIVA, DIVAnd) have been designed for data interpolation

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but **not trivial** operation in ocean sciences

✓ **Specific** tools (DIVA, DIVAnd)
have been designed for data interpolation

✓ With a VRE, **more** users can access
more easily SeaDataCloud resources
(metadata, data & tools)

Thanks for your attention

Tools	Leaflet DIVA DIVAnd
Map layers	EMODnet Bathymetry Earth At Night 2012
MedSea observations	Temperature and salinity observation collection V1.1

The temperature at the "?"