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
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 "?"

\[
\frac{14.4 + 16.1}{2} = 15.25^\circ C
\]
Can you guess the temperature at the "?"

\[
\frac{14.4 + 16.1}{2} = 15.25°C
\]

??

NOT BAD
6 reasons why spatial interpolation is not so easy
1 Synopticit error

Measurements not collected at the same time
Representativeness error

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
A lot of observations, but not everywhere
4 Need to interpolate at many locations
4 Need to interpolate at many locations
5. Anisotropy

Land acts as a physical barrier
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

\[ J[\varphi] = \sum_{i=1}^{N} \mu_i [d_i - \varphi(x_i, y_i)]^2 + \int_D \left( \nabla \nabla \varphi : \nabla \nabla \varphi + \alpha_1 \nabla \varphi \cdot \nabla \varphi + \alpha_0 \varphi^2 \right) dD, \]

solved by a finite-element technique
Data-Interpolating Variational Analysis

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

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DIVAnd: generalised, n-dimensional interpolation

2013: GNU Octave or MATLAB

2016: Julia faster, better, stronger

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

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https://github.com/gher-ulg/divand.jl
DIVAnd: generalised, n-dimensional interpolation

\[ \begin{align*}
K^{n,m}(r) &= C^{n,m} \left( \frac{2\pi}{2(1 - m)} \right)^{-\frac{n}{2}} r^{\frac{2-n}{2}} \int_0^\infty J_{\frac{n-2}{2}}(kr) k^{\frac{n-2}{2}} \frac{d}{dk} \left( \frac{1}{(1 + k^2)^{m-1}} \right) dk \\
&= C^{n,m} \left( \frac{2\pi}{2(m - 1)} \right) r^{\frac{4-n}{2}} \int_0^\infty J_{\frac{n-4}{2}}(kr) k^{\frac{n-4}{2}} \frac{k}{(1 + k^2)^{m-1}} dk \\
&= \frac{1}{4\pi(m - 1)} C^{n,m} K^{n-2,m-1}(r)
\end{align*} \]

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 \( \nu \)
<table>
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<th>Problem</th>
<th>Solution in DIVA</th>
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<td>1 Synopticity error</td>
<td>Regularity constrain in cost function</td>
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<td>2 Representativeness error</td>
<td>Numerical cost (almost) independent on the number of data points</td>
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<td>3 Many observations</td>
<td>Finite-element solver</td>
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<tr>
<td>4 Interpolate at many locations</td>
<td>Finite-element solver</td>
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<td>5 Anisotropy</td>
<td>Advection included in the cost function</td>
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<td>6 Currents</td>
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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
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
Provide the jupyter-notebooks along with the data product (interpolation)


**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

Authentication

**Inputs:** CDI data and user data

**Results** of the interpolation

**Outputs:** data products, climatologies, gridded fields

MarineID or
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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Specific tools (DIVA, DIVAnd) have been designed for data interpolation.

With a VRE, more users can access more easily SeaDataCloud resources (metadata, data & tools).
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<td>V1.1</td>
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The temperature at the "?"