

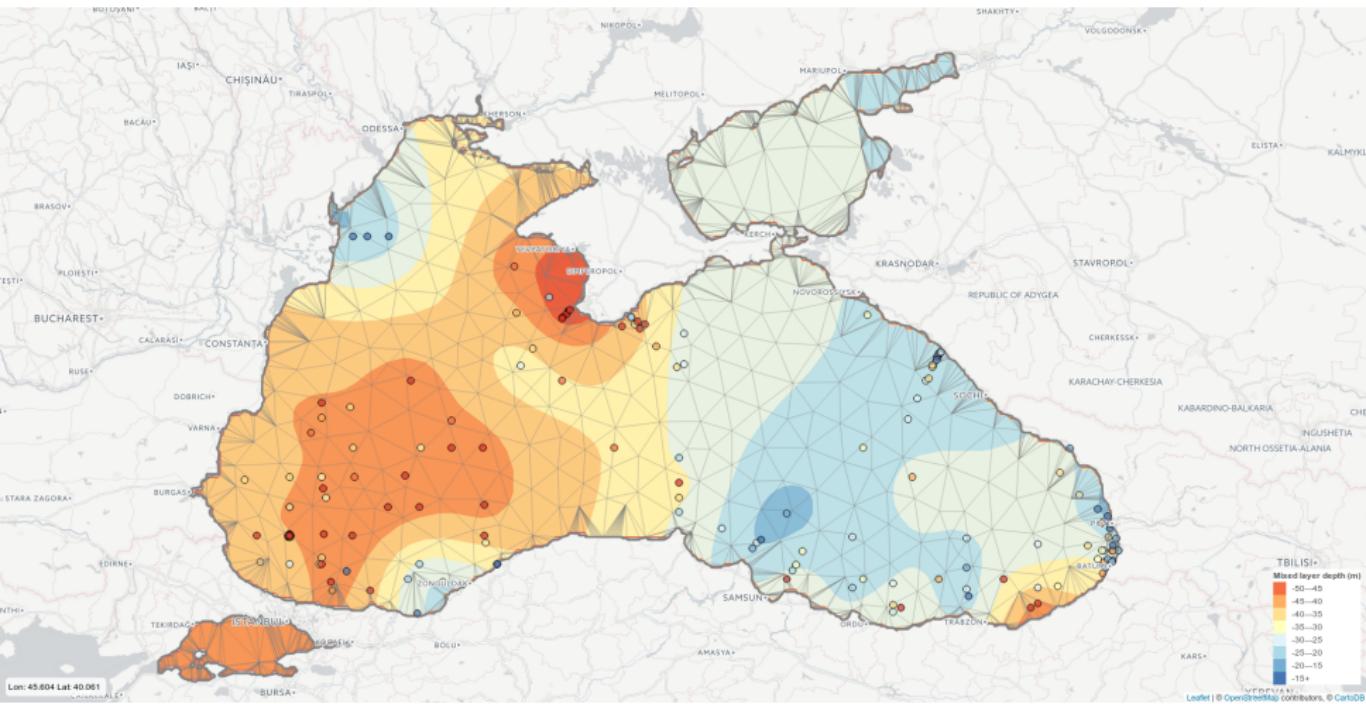
A. Barth, C. Troupin, S. Watelet &
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New *Diva* capabilities for climatologies

Diva: from in situ data to gridded fields



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

DivaND: generalised, n-dimensional interpolation

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

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

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

2013: Octave/MATLAB

2016: Julia

faster, better, stronger

DivaND: generalised, n-dimensional interpolation

- ▶ Variational inverse method
- ▶ Smoothness and other constraints

Differences with Diva (2D)

- ▶ n -dimensional, $n \geq 2$
- ▶ Different formulations, kernels & solvers
- ▶ Programming languages

Fortran vs. Julia

User interfaces:

*Jupyter notebooks
and WPS*

Notebooks: interactive computational environments

Notebooks combine:

- 1 code fragments that can be executed,
- 2 text for the description of the application and
- 3 figures illustrating the data or the results.

```
In [2]: import numpy as np  
import matplotlib.pyplot as plt
```

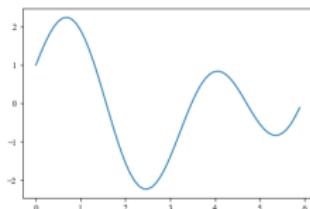
Data

Let's create a simple function.

```
In [6]: x = np.arange(0, 6, .1)  
y = np.cos(x) + 1.5 * np.sin(2 * x)
```

Make a simple plot

```
In [7]: plt.plot(x, y)  
plt.show()
```



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"Digital Playground"

"Data Story Telling"

"Computational Narratives"

Notebooks: interactive computational environments

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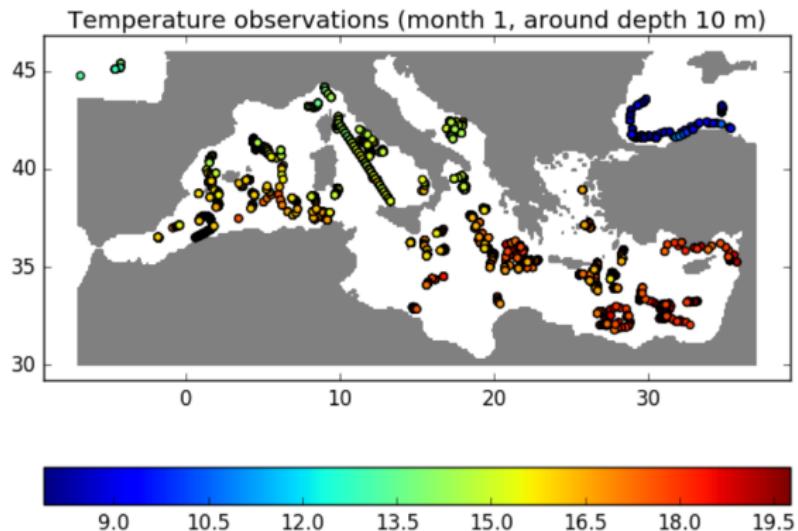
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"Interactive notebooks: Sharing the code", Nature (2014)

[http://www.nature.com/news/
interactive-notebooks-sharing-the-code-1.16261](http://www.nature.com/news/interactive-notebooks-sharing-the-code-1.16261)

divand in a notebook

```
In [36]: # sets the correct aspect ratio  
gca()[:set_aspect](1/cos(mean(latr) * pi/180))
```



Setup the domain using the bathymetry from the file bathname.

Example online

*New climatologies
and products*

Specifications for the new products

Depth levels:

- ▶ Common to all the products allows combined product
 - ▶ Follow IODE levels 33 levels from 0 to 5500 m
 - ▶ Consider World Ocean Atlas 103 levels!

Specifications for the new products

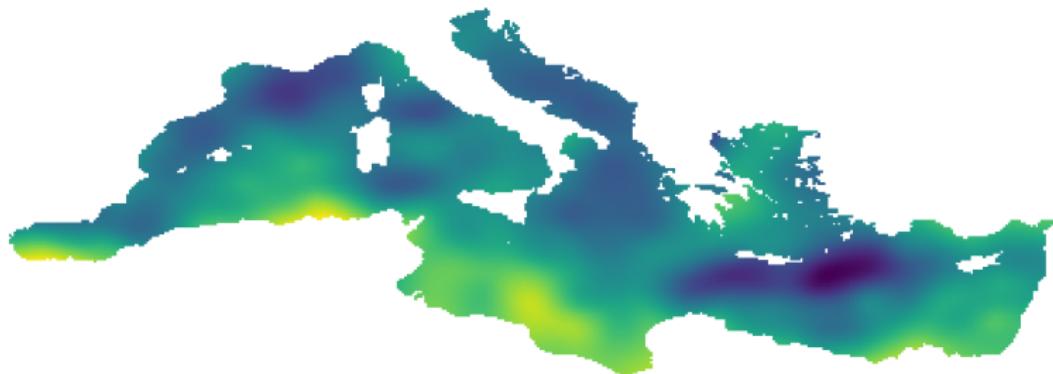
Spatial resolution:

Grid resolution \neq real resolution!!

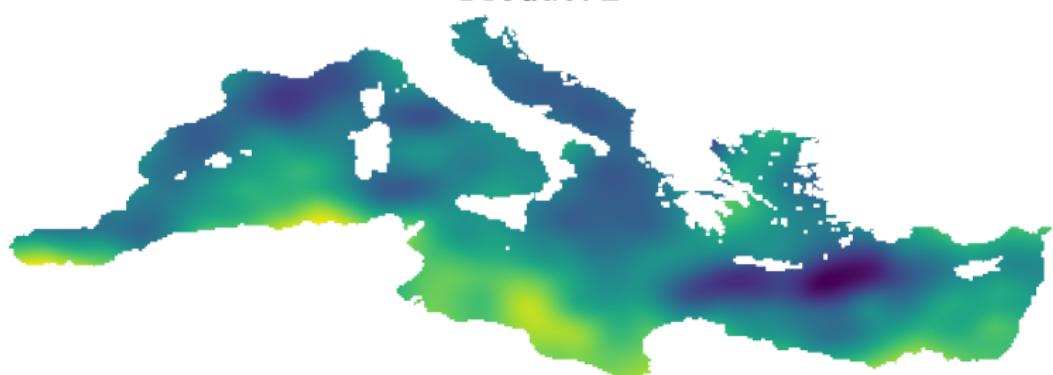
- 1 divand: $1/8^\circ \times 1/8^\circ$ based on data availability
- 2 post-processing: $1/24^\circ \times 1/24^\circ$ match model resolution

Find the differences between Product 1 & Product 2

Product 1



Product 2



Find the differences between Product 1 & Product 2

- 1 Field 1 is 161×426
Field 2 is 641×1701

Find the differences between Product 1 & Product 2

- 1** Field 1 is 161×426
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- 2** File 2 is 30 times larger

Find the differences between Product 1 & Product 2

- 1 Field 1 is 161×426
Field 2 is 641×1701
- 2 File 2 is 30 times larger
- 3 Product 2 would take wayyyyyyyyyyyyyyyyyyy longer
to be created with divand

Re-gridding/re-interpolation: use nco?



nco = netCDF Operators
= set of standalone programs to manipulate netCDF files
→ renaming, averaging, **re-gridding**, binary operations...

<http://nco.sourceforge.net/>

Re-gridding based on Earth System Modeling Framework
(ESMF, <https://www.earthsystemcog.org/projects/esmf/>)

Re-gridding/re-interpolation: use nco?

Usage:

```
ncremap -i data.nc -d grid.nc -o output.nc
```

where:

data.nc = original netCDF containing field

grid.nc = file containing the new (finer) grid

output.nc = new netCDF with field interpolated
onto the new grid

Further ideas on model-climatology comparison

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- 4 Re-interpolate the climatologies at $1/24^\circ$ and use it as a background
Perform analysis with divand by window (larger than correlation length and shorter than domain size)

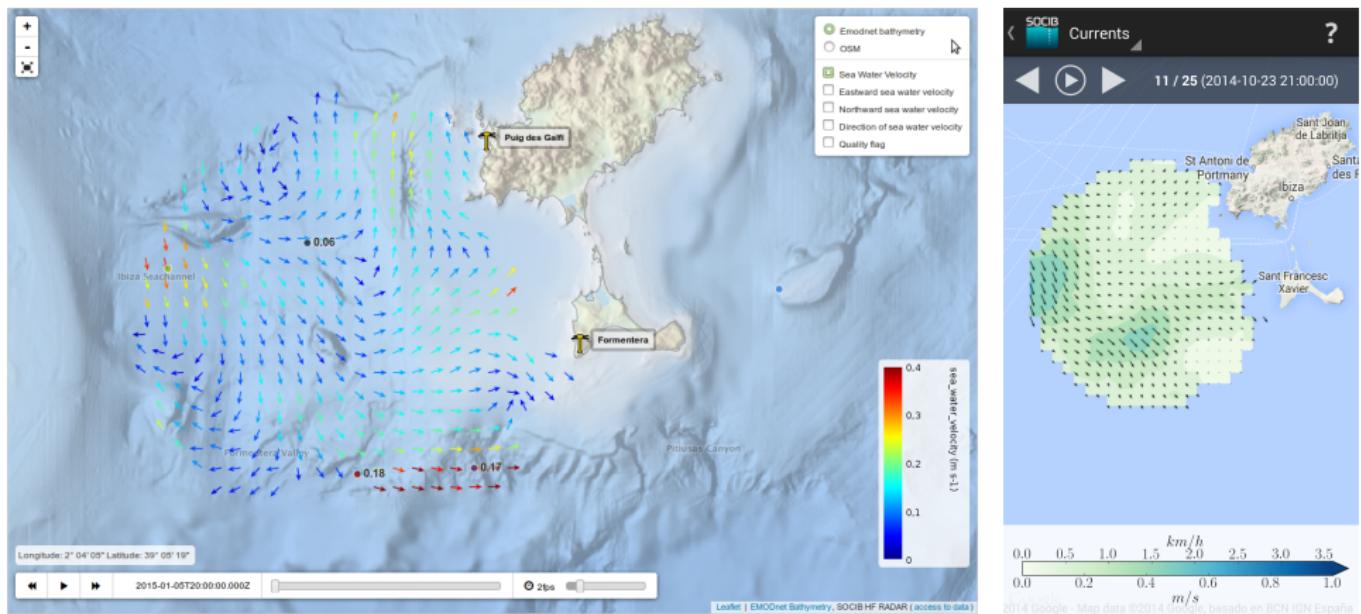
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- 5 Assign lower weight for high-resolution data

(Very) new product

*Velocity field from
HF radar*

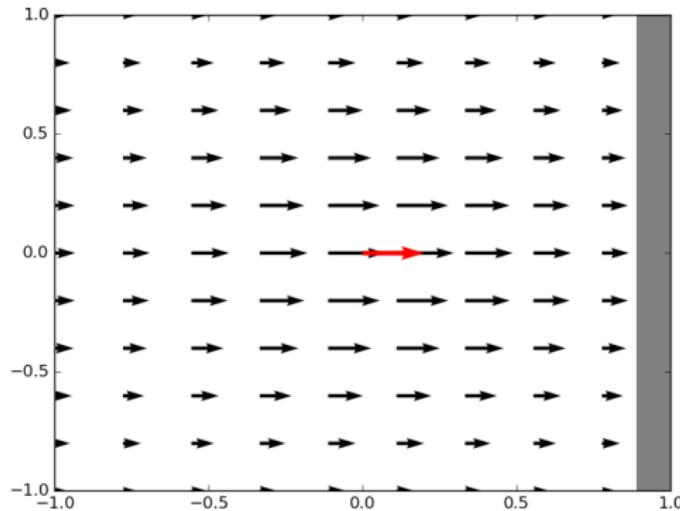
H2020 SeaDataCloud call: emphasis on coastal data



Data: SOCIB HF radar in the Ibiza Channel

New product: currents

- hypothetical measurement
- analyzed field



- ▶ Analysis of radial currents to derive total currents
- ▶ Observation operator links the radial currents of the different radar sites

Formulation: couple velocity components

Norm : $|\varphi|^2 = \int_{\Omega} (\alpha_2 \nabla \nabla \varphi : \nabla \nabla \varphi + \alpha_1 \nabla \varphi \cdot \nabla \varphi + \alpha_0 \varphi^2) d\Omega$

Cost function: $J(\vec{u}) = |u|^2 + |v|^2 + \sum_{i=1}^N \frac{(\vec{u}_i \cdot \vec{p}_i - u_{ri})^2}{\epsilon_i^2}$

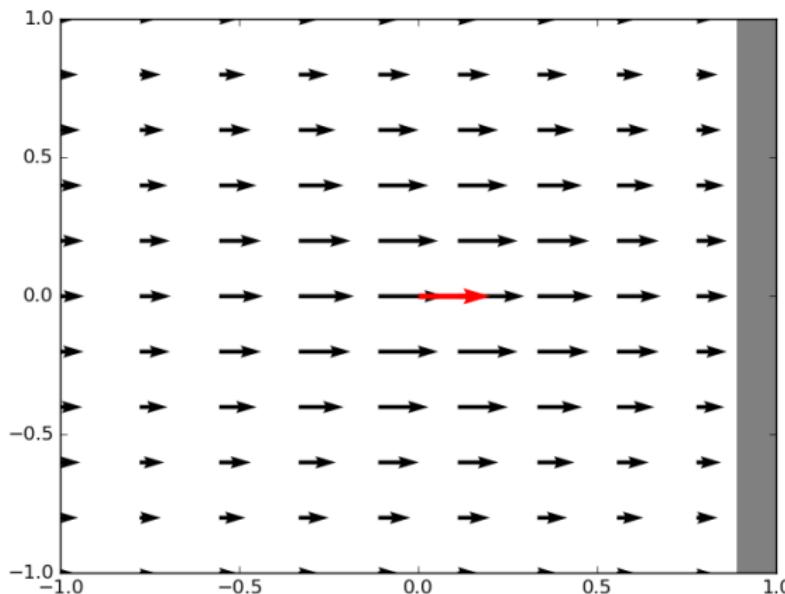
$$\vec{u} = (u, v)$$

\vec{p}_i = normalized vector pointing toward the correspond HF radar site of the i -th radial observation u_{ri}

Coastline as a boundary condition ($\vec{u} \cdot \vec{n} = 0$)

Cost function (OFF)

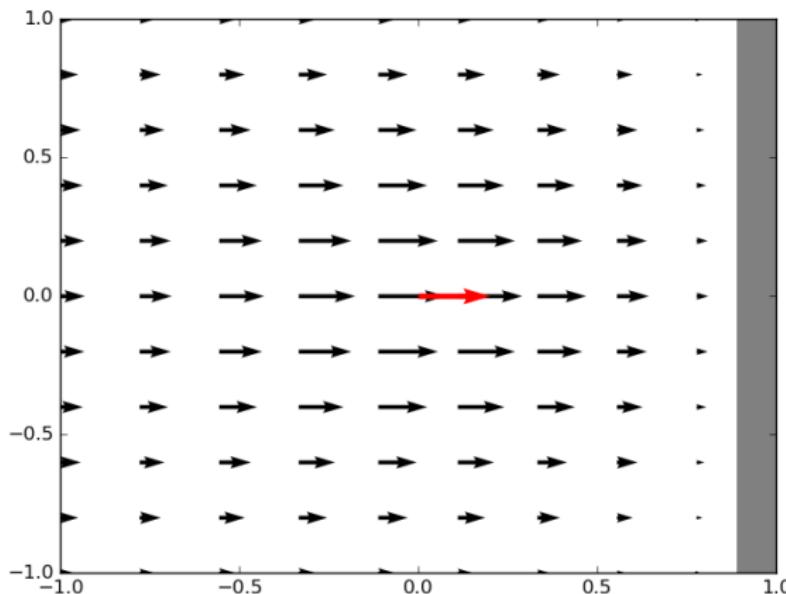
$$J_{bc}(\vec{u}) = \frac{1}{\epsilon_{bc}^2} \int_{\partial\Omega} (\vec{u} \cdot \vec{n})^2 ds$$



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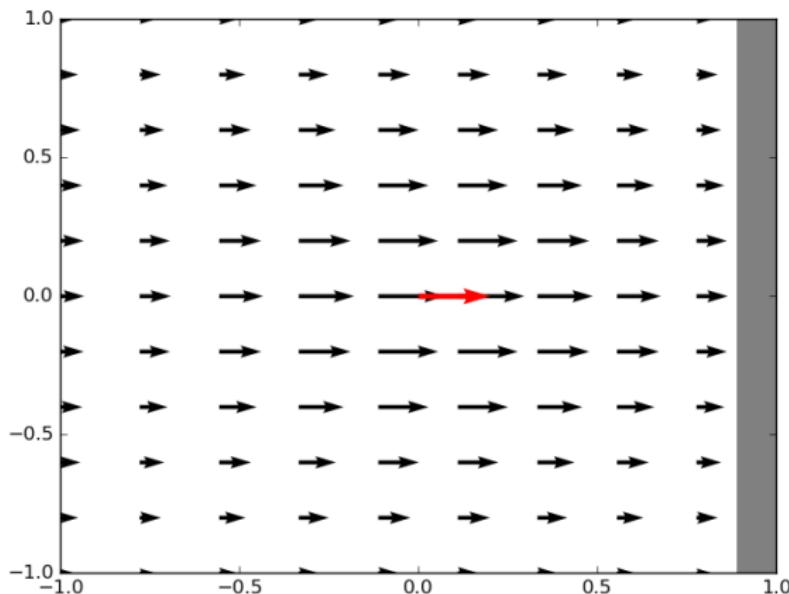
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Low horizontal divergence of currents ($\nabla \cdot \vec{n} = 0$)

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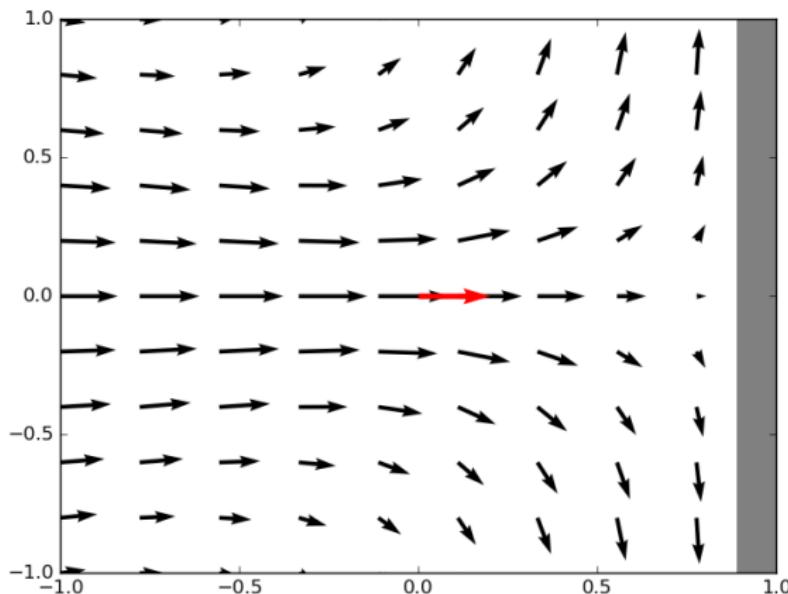
$$J_{\text{div}}(\vec{u}) = \frac{1}{\epsilon_{\text{div}}^2} \int_{\Omega} (\vec{\nabla} \cdot \vec{u})^2 dx$$



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3D analysis: longitude, latitude and time

- ▶ Include the data the hour before and after
- ▶ Temporal correlation length
- ▶ Coriolis force

Coriolis force and geostrophically balanced mean flow

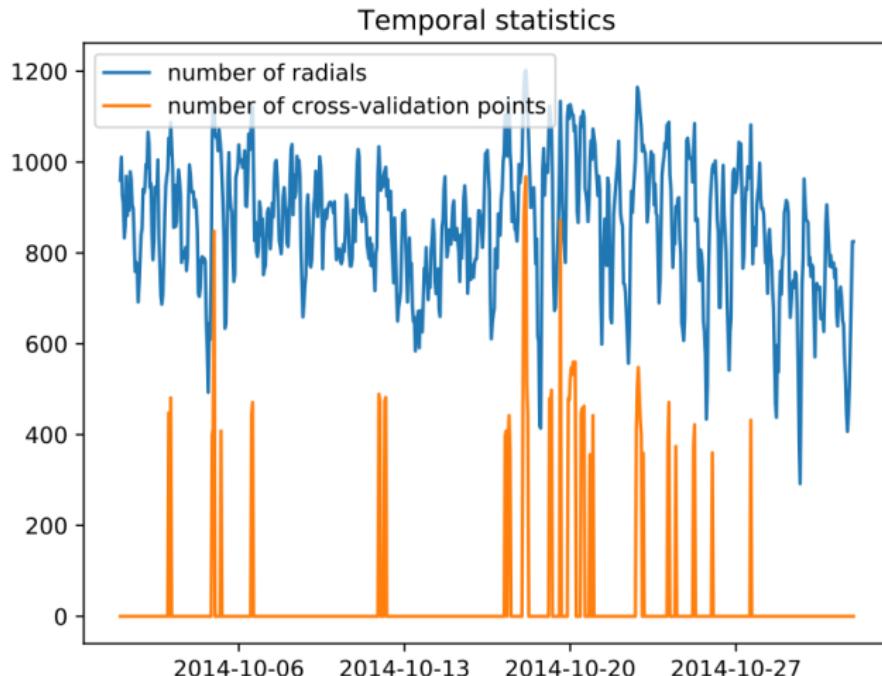
$$\begin{aligned}\frac{\partial u}{\partial t} &= fv - g \frac{\partial \eta}{\partial x} \\ \frac{\partial v}{\partial t} &= -fu - g \frac{\partial \eta}{\partial y}\end{aligned}$$

f = Coriolis frequency

η = sea surface elevation

Cross validation

In 30 current maps with the best coverage,
some data points are marked as missing (for both sites)



Test cases: more constraints (physics) in the interpolation

Case	Description
2D	classical 2D-analysis (longitude, latitude)
2D_bc	as 2D, but with boundary conditions
2D_iv	as 2D, but imposing small horizontal divergence
3D	3D-analysis (longitude, latitude, time)
3D_Coriolis	3D-analysis with the Coriolis force
3D_Coriolis_geo	3D-analysis with the Coriolis force and the surface pressure gradient

Skill score

$$S(\text{Case}) = 1 - \frac{\text{MSE}(\text{Case})}{\text{MSE}(2D)}$$

- ▶ The 2D case is the base-line for computing the relative improvement
- ▶ $\text{MSE}(C)$ is the mean square error (relative to the cross-validation dataset)
- ▶ If $S = 0$: reconstruction as "good/bad" as the base-line
- ▶ If $S = 1$: reconstruction matches perfectly the validation dataset.

Comparison: increased skill with more constrains

Case	RMS	Skill score	Optimal parameter(s)
2D	0.0652	0.000	$\epsilon^2 = 0.0001161$
2D_bc	0.0652	0.000	$\epsilon^2 = 0.0001, \epsilon_{bc}^2 = 10$
2D_div	0.0650	0.005	$\epsilon^2 = 9.799e-05, \epsilon_{div}^2 = 2.778e+08$
3D	0.0606	0.134	$\epsilon^2 = 0.1219, \text{lent} = 6904$
3D_Coriolis	0.0547	0.295	$\epsilon^2 = 5.673e-05, \epsilon_{Cor}^2 = 9.207e-05$
3D_Coriolis_geo	0.0485	0.447	$\epsilon^2 = 5.37e-05, \epsilon_{Cor}^2 = 5.65e-05, \text{ratio} = 26.46$

Conclusions

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- 5 Additional dynamical information imrpoves the skill score.
- 6 Dynamical information appears to be highly beneficial when analyzing surface currents.