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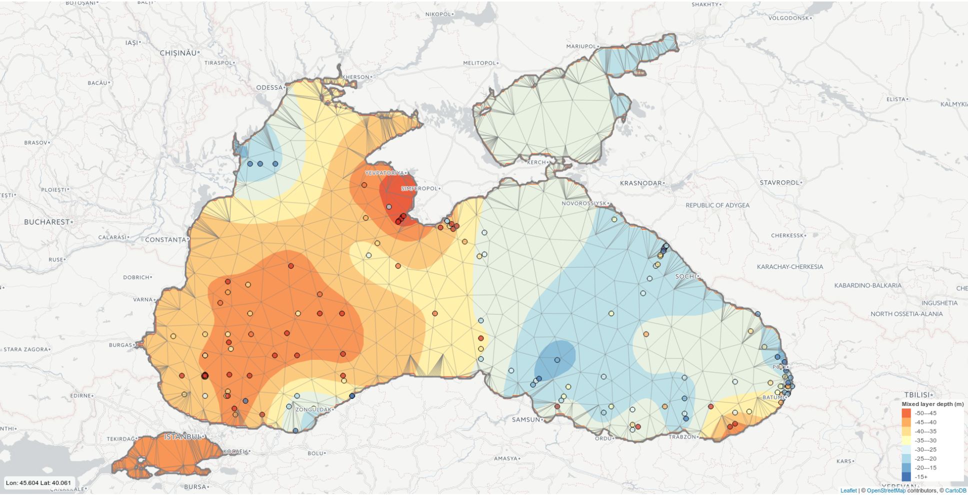
New Diva capabilities for climatologies

SeaDataCloud – Product Meeting

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
```

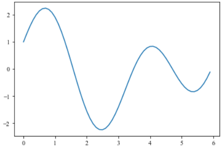
Data

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"

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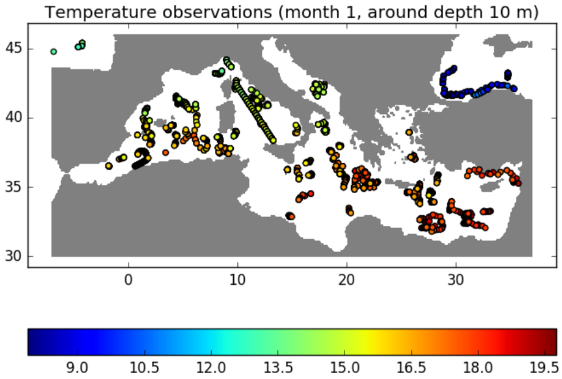
"Interactive notebooks: Sharing the code", Nature (2014)
http://www.nature.com/news/interactive-notebooks-sharing-the-code-1.16261

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 — more than 100 levels!

Specifications for the new products

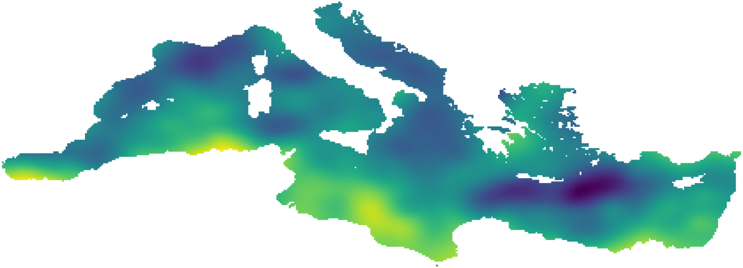
Spatial resolution:

Grid resolution $\neq$ real resolution!!

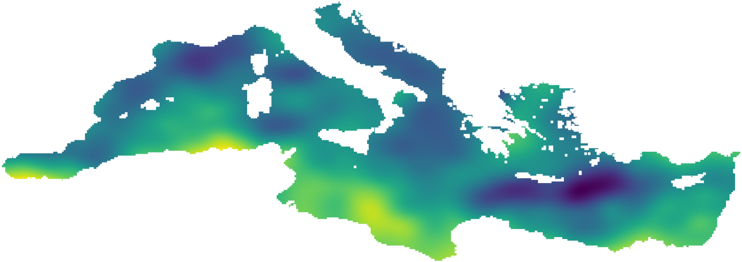
1. divand: $1/8° \times 1/8°$ based on data availability
2. post-processing: $1/24° \times 1/24°$ match model resolution

Find the differences between Product 1 & Product 2

Product 1



Product 2



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   Field 2 is 641×1701

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1. Field 1 is 161×426
   Field 2 is 641×1701
2. File 2 is 30 times larger
3. Product 2 would take wayyyyyyyyyyyyyyyyy 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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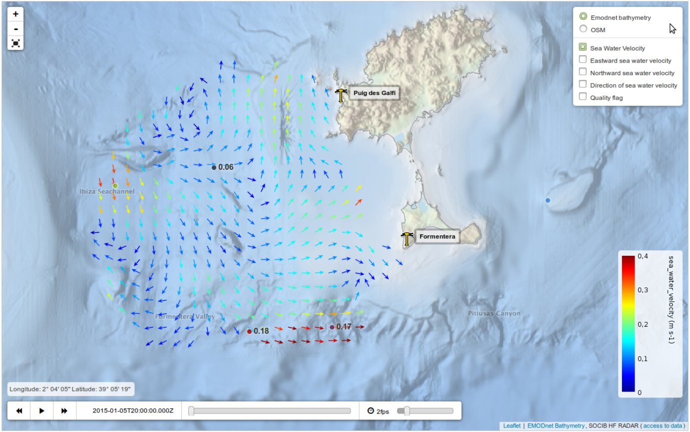
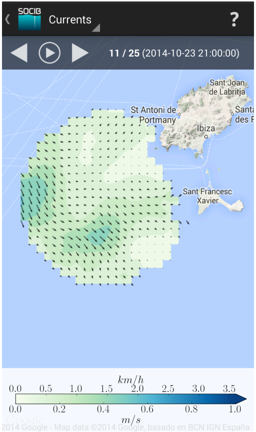
5. Assign lower weight for high-resolution data

(Very) new product

Velocity field from HF radar

H2020 SeaDataCloud call: emphasis on coastal data



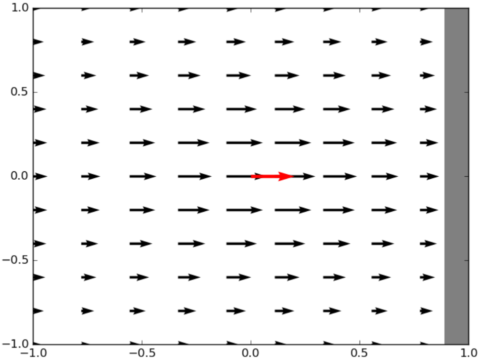


Data: SOCIB HF radar in the Ibiza Channel

New product: currents

$\rightarrow$ hypothetical measurement

$\rightarrow$ 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

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

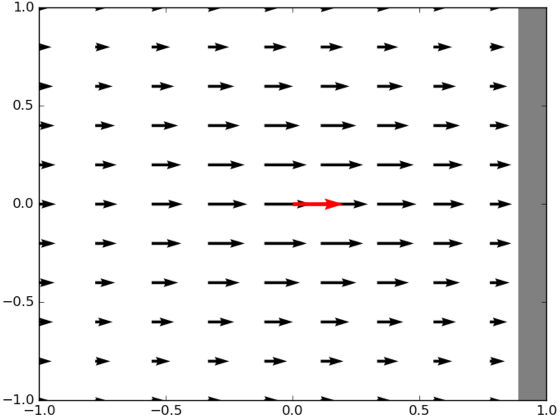
$$\text{Cost function:} \quad J(\vec{u}) = |u|^2 + |v|^2 + \sum_{\imath=1}^{N} \frac{(\vec{u}_\imath \cdot \vec{p}_\imath - u_{r\imath})^2}{\epsilon_\imath^2}$$

$\vec{u} = (u, v)$
$\vec{p}_\imath =$ normalized vector pointing toward the correspond HF radar site of the $\imath$-th radial observation $u_{r\imath}$

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

Cost function (OFF)

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



Cost function (ON)

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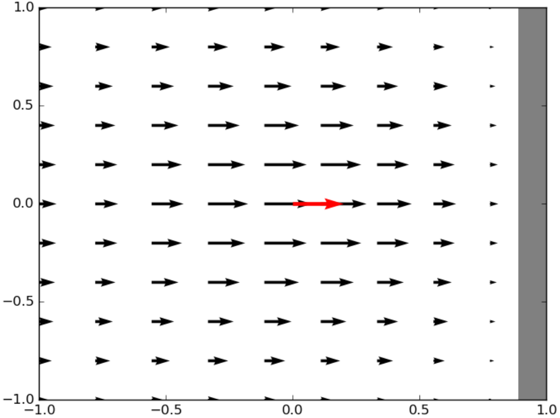
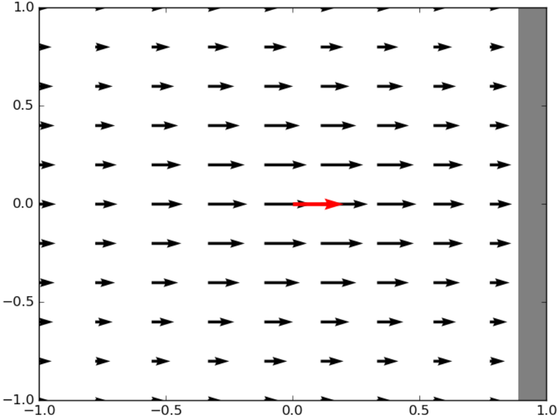


Low horizontal divergence of currents ($\nabla \cdot \vec{n} = 0$)

Cost function (OFF)

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



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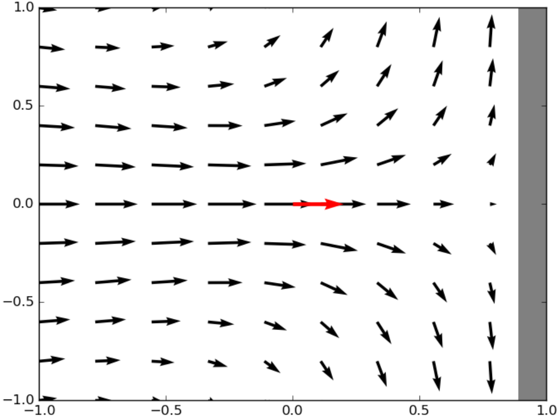


3D analysis: longitude, latitude and time

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

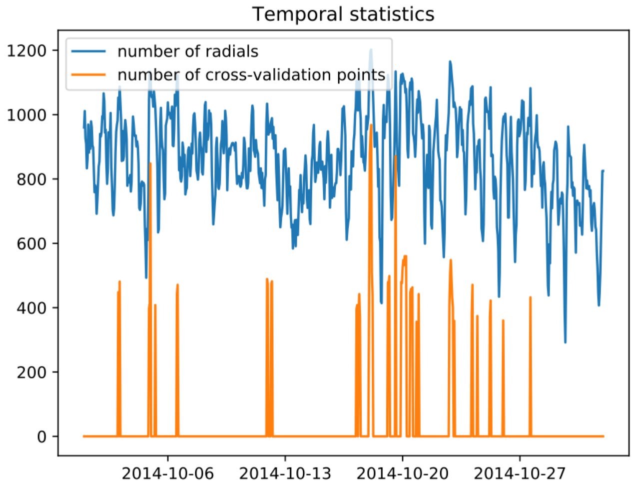
Coriolis force and geostrophically balanced mean flow

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

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 constrains (physics) in the interpolat

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

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

- 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 $\text{S} = 0$: reconstruction as "good/bad" as the base-line
- If $\text{S} = 1$: reconstruction matches perfectly the validation dataset.

Comparison: increased skill with more constrains

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

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4. Taking for every time instance the previous and the following radial maps into account (i.e. a 3D analysis) improves the skill score .
5. Additional dynamical information improves the skill score.
6. Dynamical information appears to be highly beneficial when analyzing surface currents.