Some perspectives for the future high resolution altimetry products: dynamic interpolation

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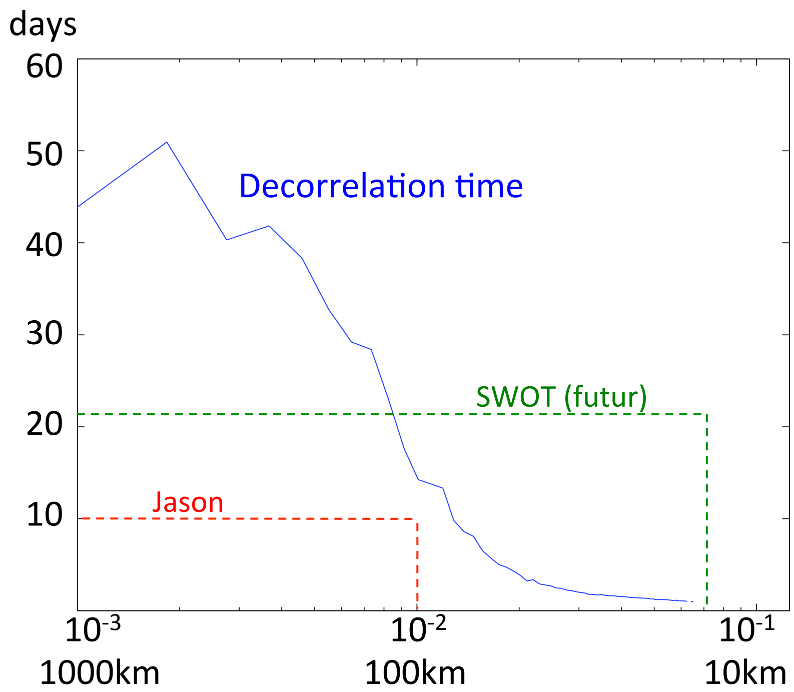
Introduction



→ Present satellites realize a quite continuous time-sampling

→ High resolution altimetry (e.g. SWOT) will not capture the time evolution of short mesoscales

→ **Can we reconstruct SSH missing signal in time? (between satellite revisits)**

Outline

Present altimetry: performances and limitations

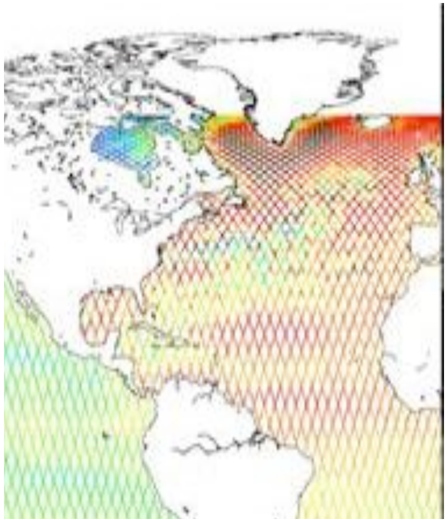
Next generation of altimeters: presentation and challenges

Facing the long time revisits: dynamic interpolation

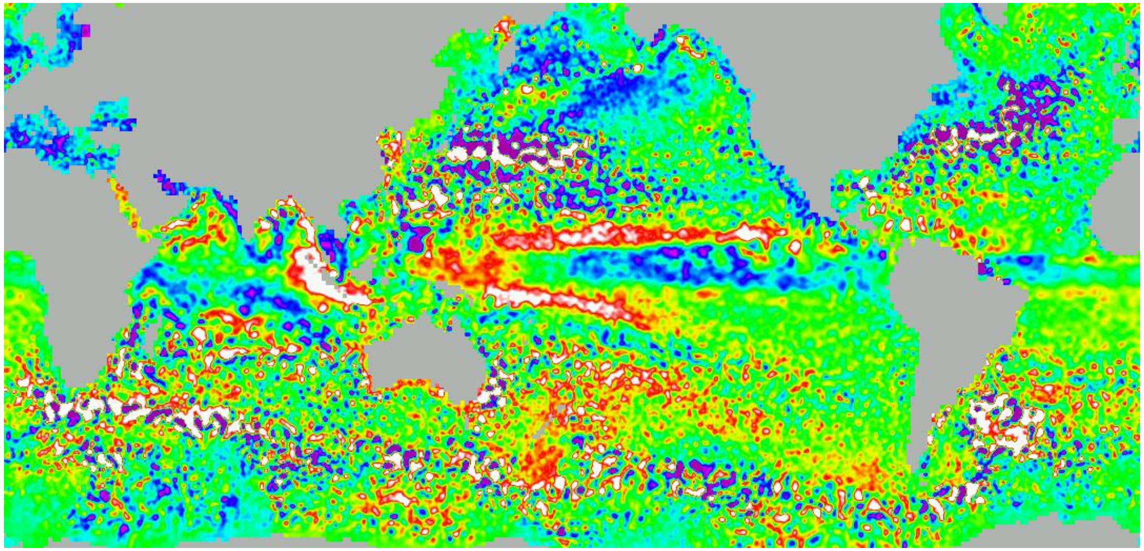
→ First investigation in an idealistic configuration
→ Perspectives to improve the dynamic schemes
→ Implementation to real data?

Conclusions

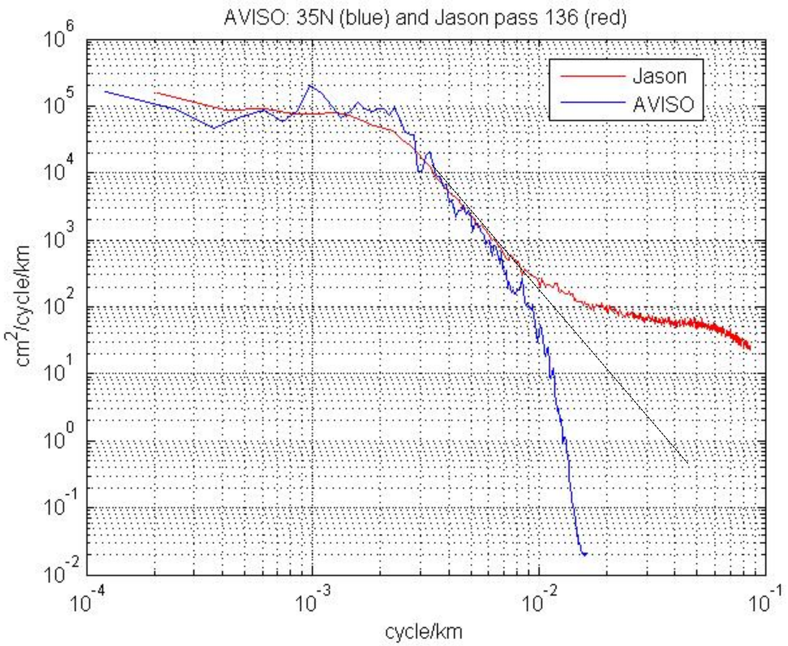
Present altimetry: performances and limitations



10 days of Jason observations



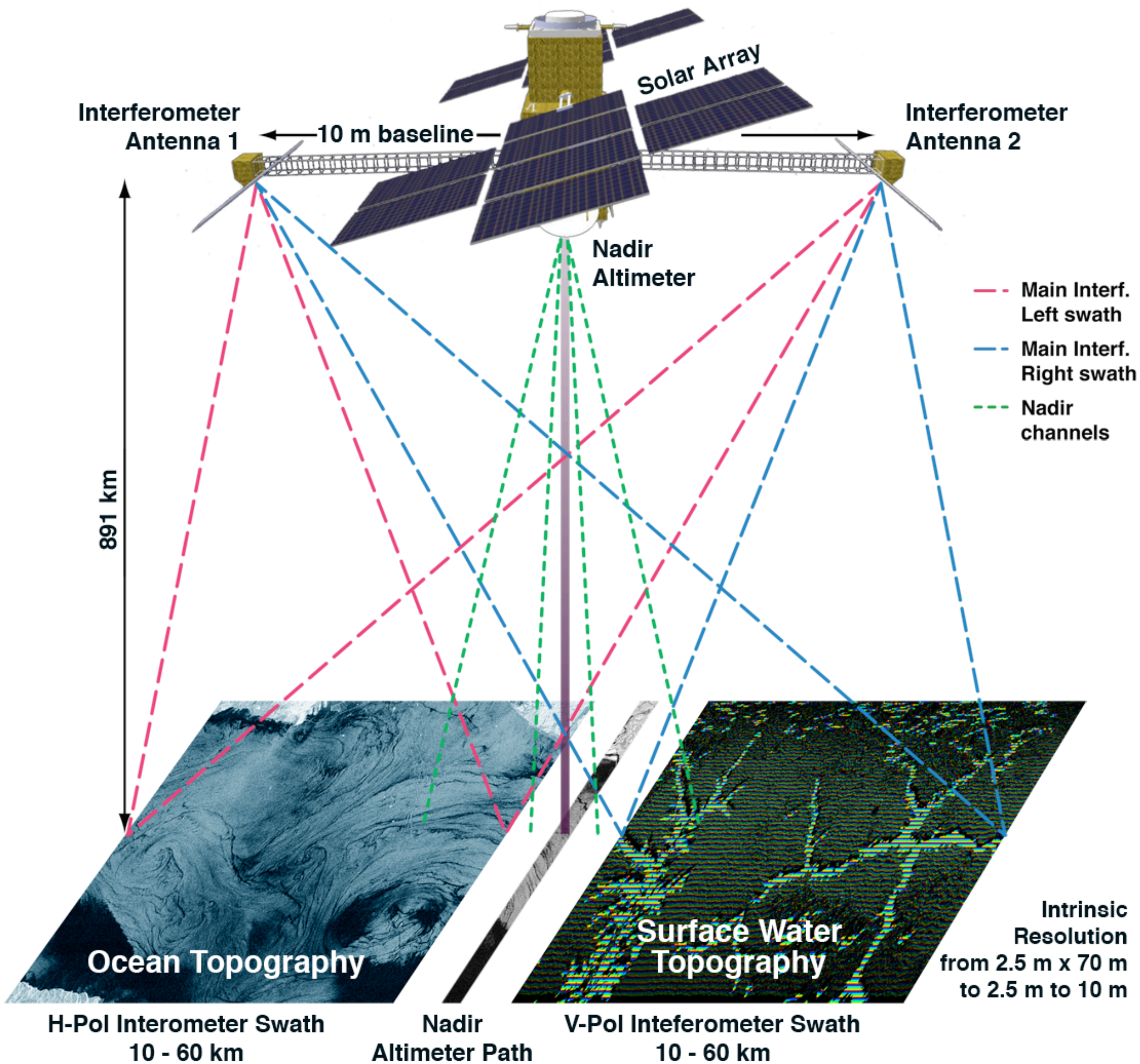
A snapshot of (sea surface height) SSH from Aviso



- → **Maps are based on time-space Optimal Interpolation (OI) methods**
- → **Only mesoscales >200km are mapped**
- → **OI methods work well to generate these large scale maps**

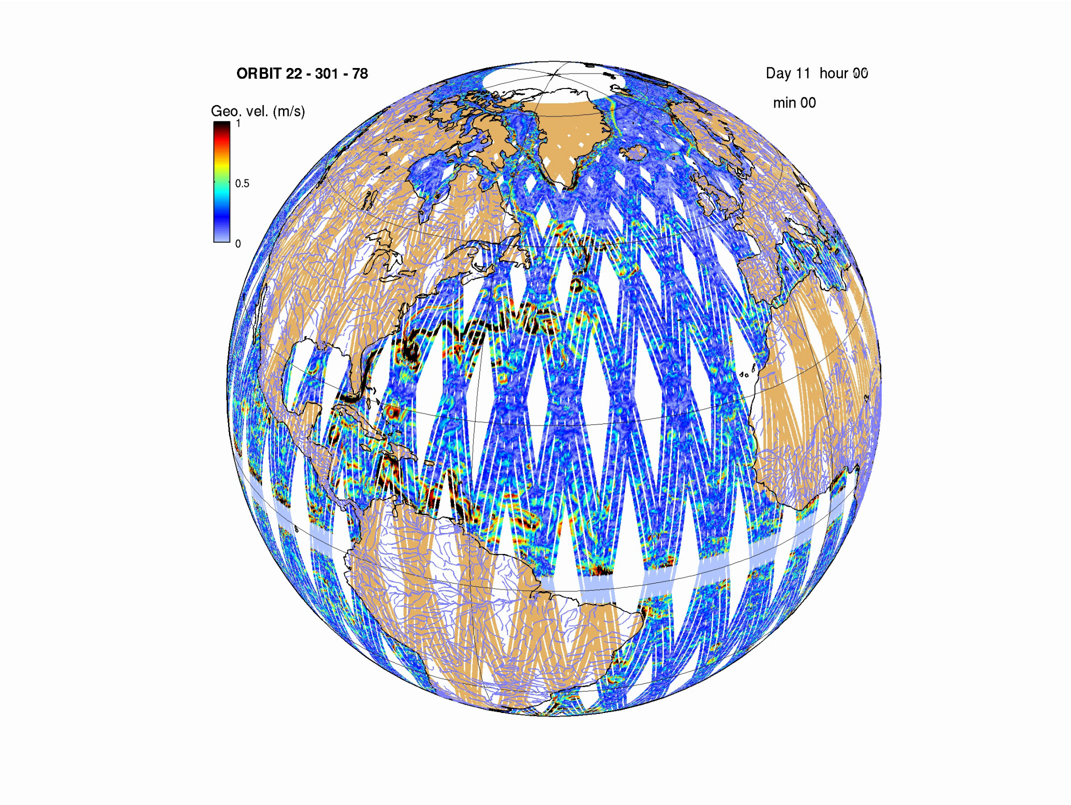
Next generation of altimeters: presentation and challenges

SWOT payload configuration



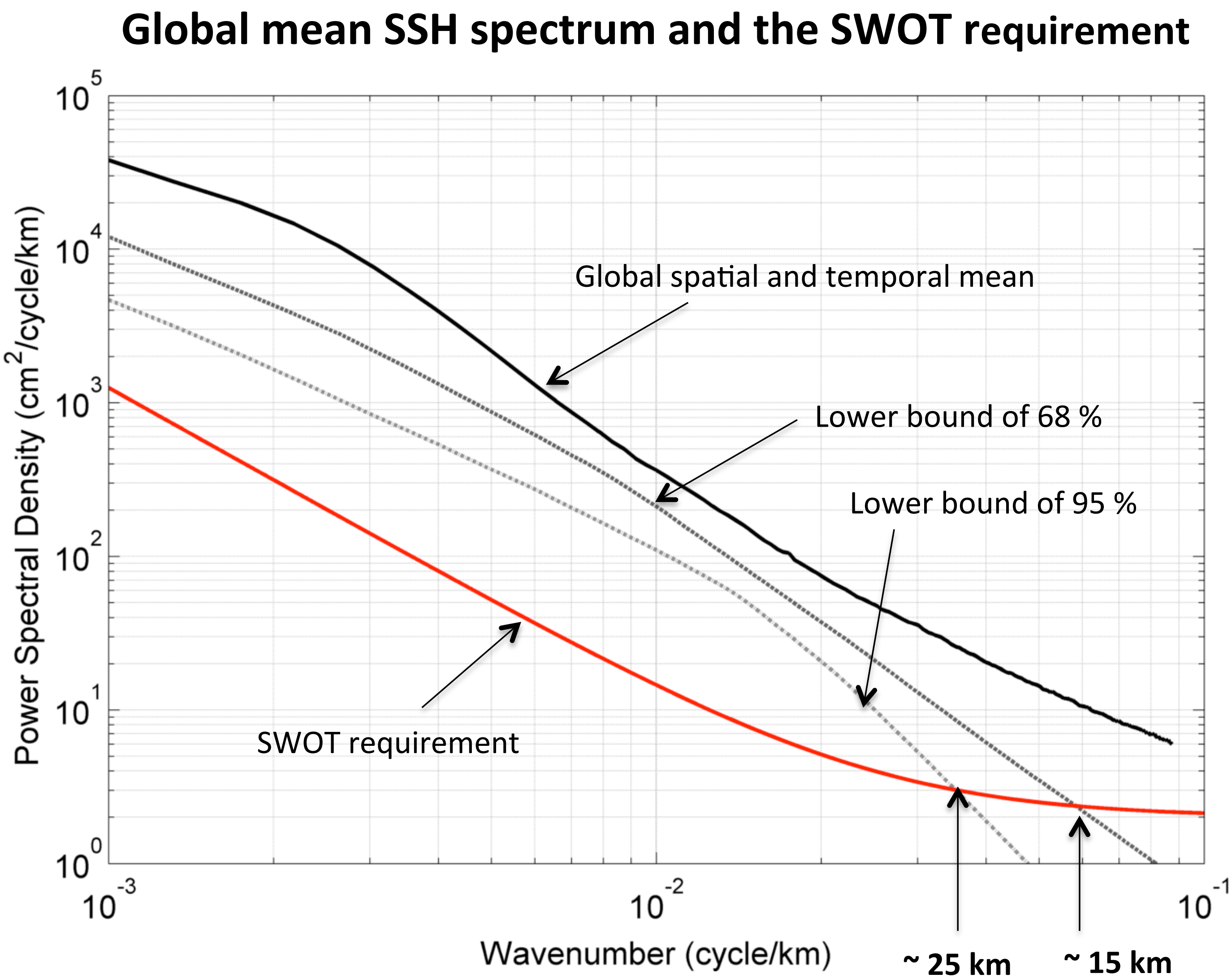
- ***SAR resolution on the order of 10 m***
- ***Average to 1 km to reduce noise***
- ***10km-60km off nadir swath***

Proposed orbit sampling



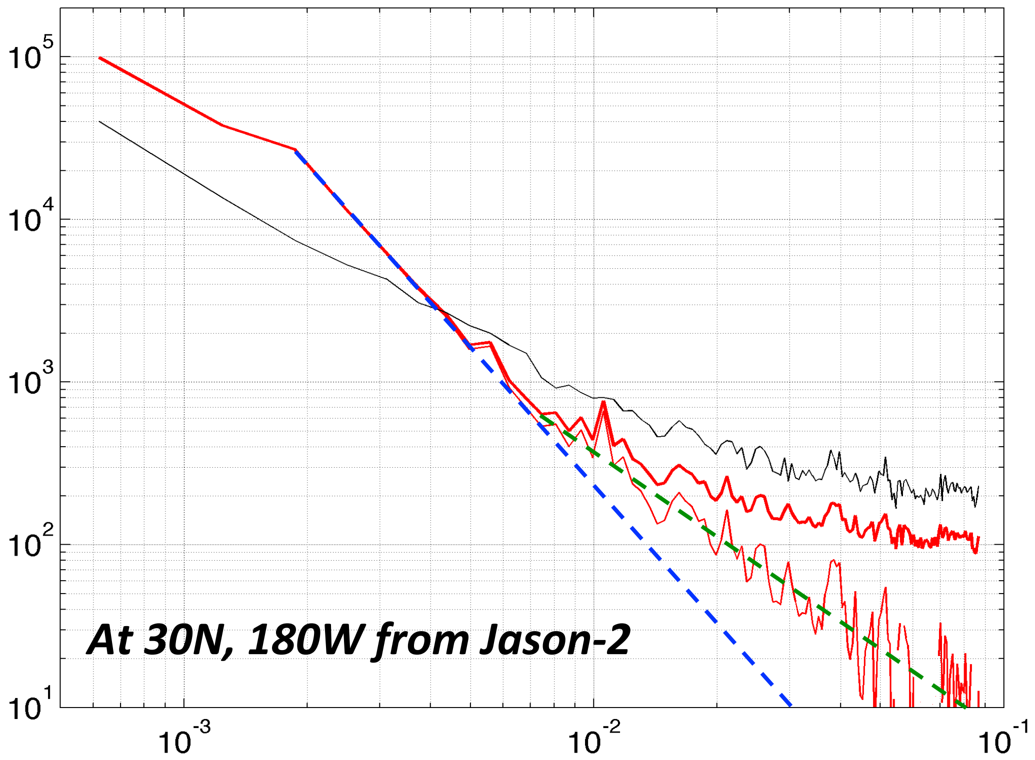
Mapping the globe every 22 days

Expected performances



Observation of very short mesoscale (down to 25km-15km)s is expected

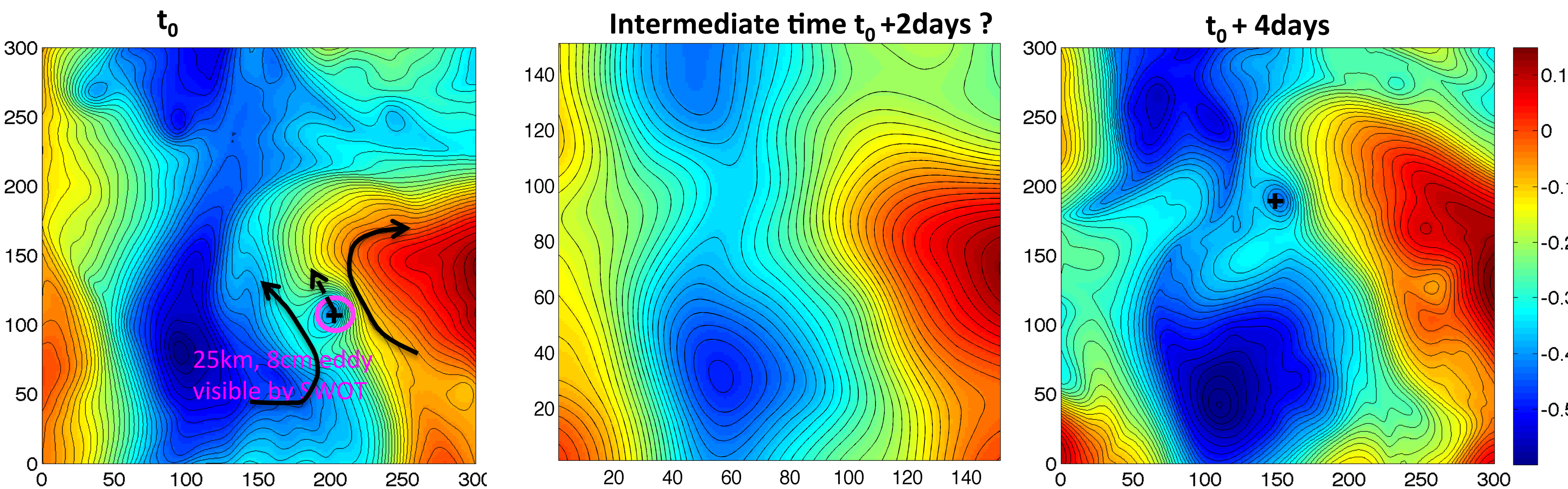
Challenge of the high-frequency SLA variability



In many regions (e.g. eastern part of the basins) the short mesoscales may be dominated by high time-frequency signals …

Challenge of the long time revisits

For short mesoscale variability: 10-20 days between revisits is an issue



For the perspective of 2D continuous gridded products: classical interpolation method would not work for short mesoscales (30-100km)…

→ We certainly need to go beyond optimal interpolation methods…

A first order of SSH motion should be predictable from the SSH itself

Can we make a simple dynamic scheme to propagate the SSH in time? Is there a first-order predictible motion of SSH over a few days?

Facing the long time revisits: dynamic interpolation

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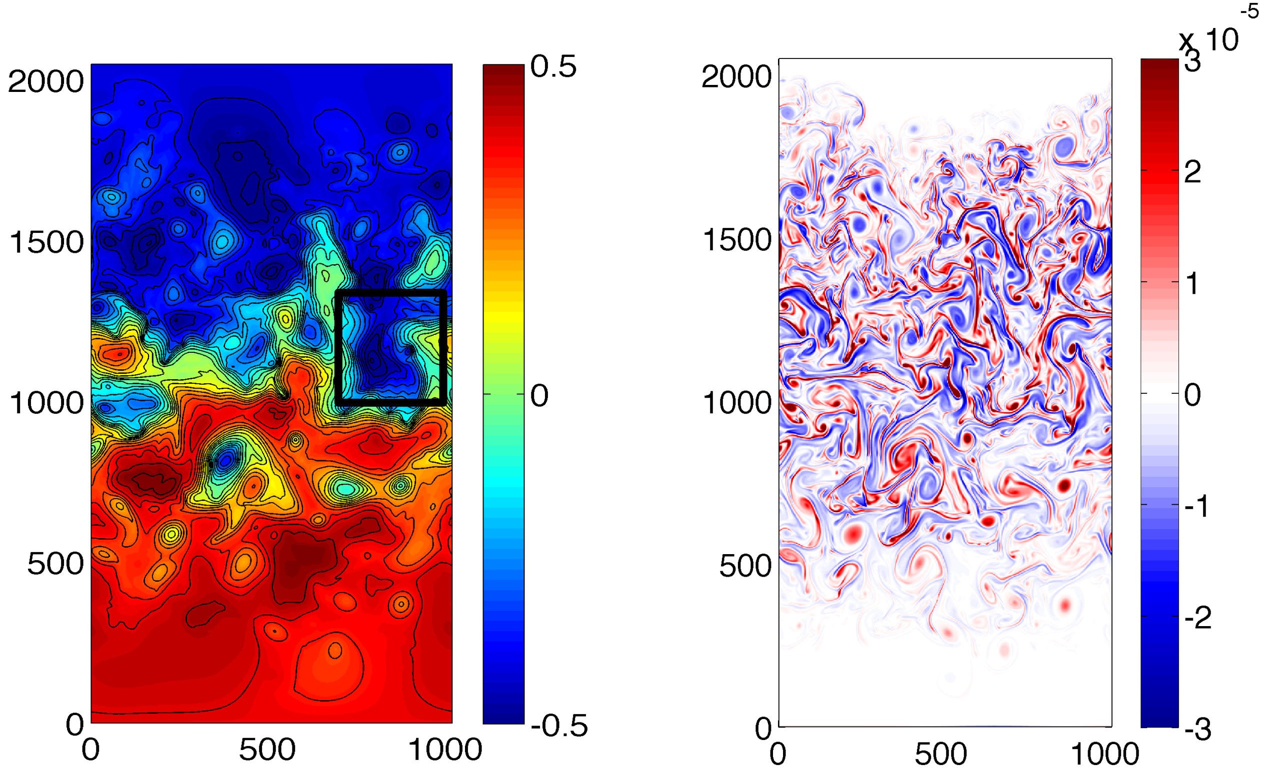
Preliminary tests in an idealistic context

First experimental setup:

Our “truth”: a full 3D model.
100 layers, 2km horizontal resolution



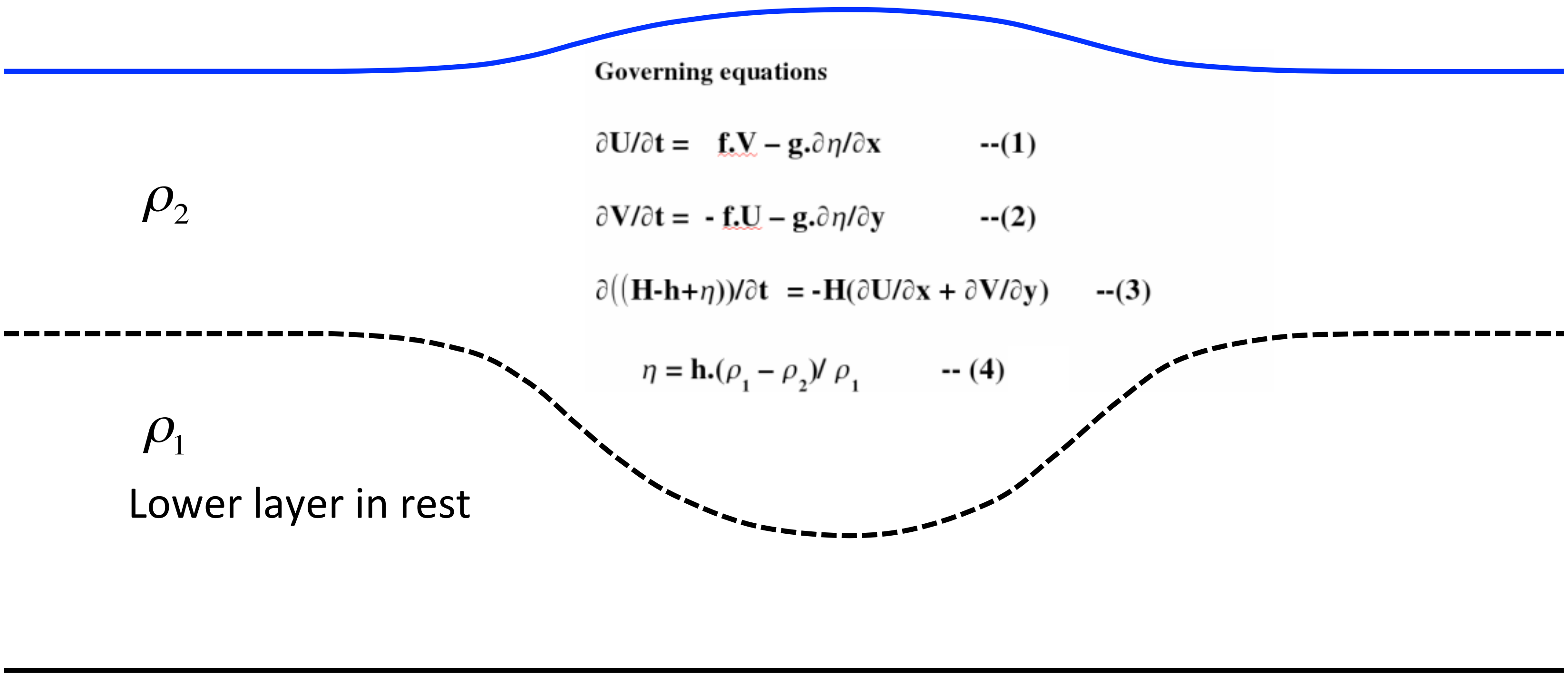
This model contains the 3D dynamic. West boundary current.

Now let’s try to reconstruct the some SSH signal between two snapshots

Dynamic scheme

Simple and inexpensive way to propagate SSH:

"One and half layer" shallow water without any forcing



Governing equations

$$\partial U/\partial t = f.V - g.\partial \eta/\partial x \qquad \text{--(1)}$$

$$\partial V/\partial t = - f.U - g.\partial \eta/\partial y \qquad \text{--(2)}$$

$$\partial((H-h+\eta))/\partial t = -H(\partial U/\partial x + \partial V/\partial y) \qquad \text{--(3)}$$

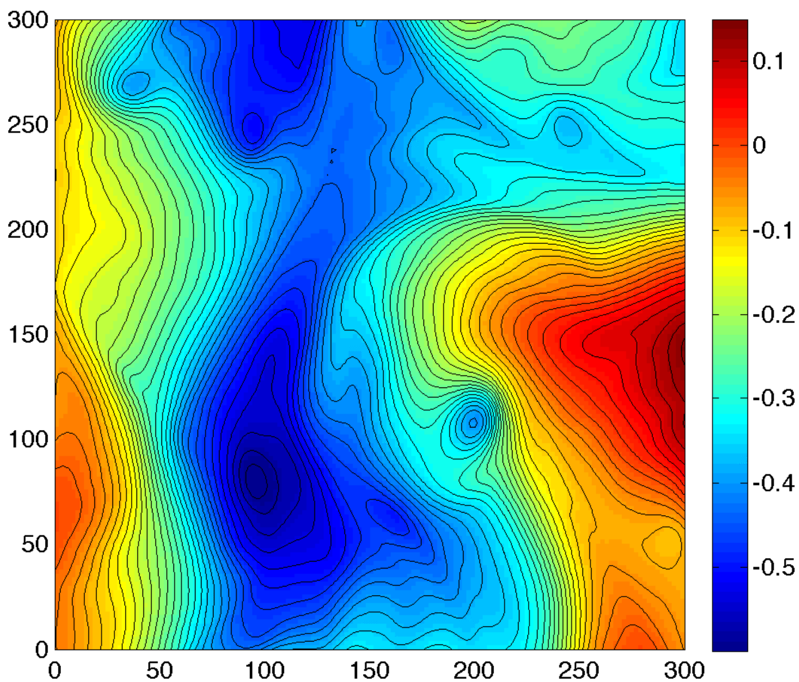
$$\eta = h.(\rho_1 - \rho_2)/\rho_1 \qquad \text{-- (4)}$$

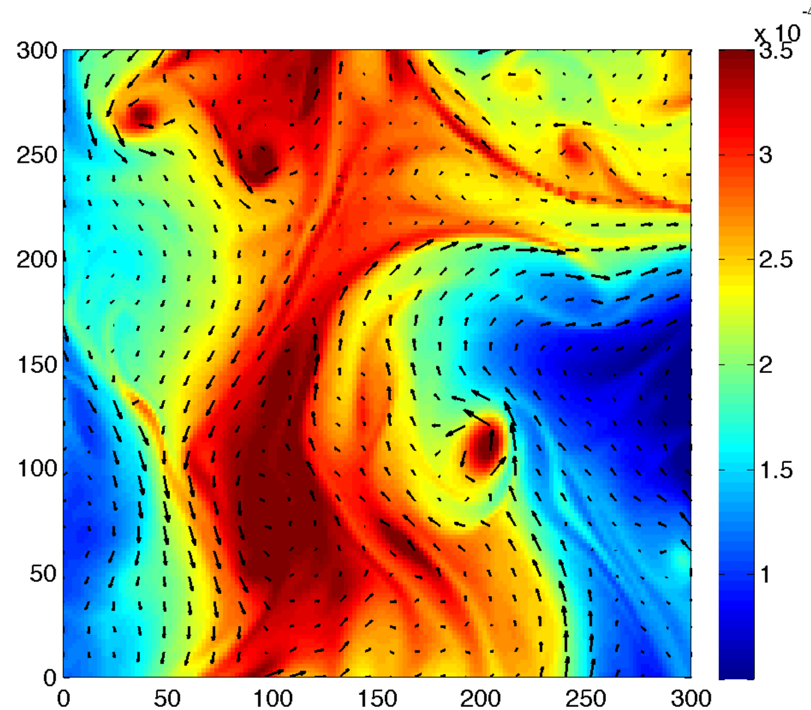
Initialization: with geostrophic velocity and $h = \eta \times \frac{\Delta\rho}{\rho}$

Dynamic scheme – with QG assumption

- q in an equivalent 1 ½ layers shallow-water QG model (SWQG): $q=g/f0(\nabla^2 SSH-1/Lr^2 SSH)$

Single parameter: Lr



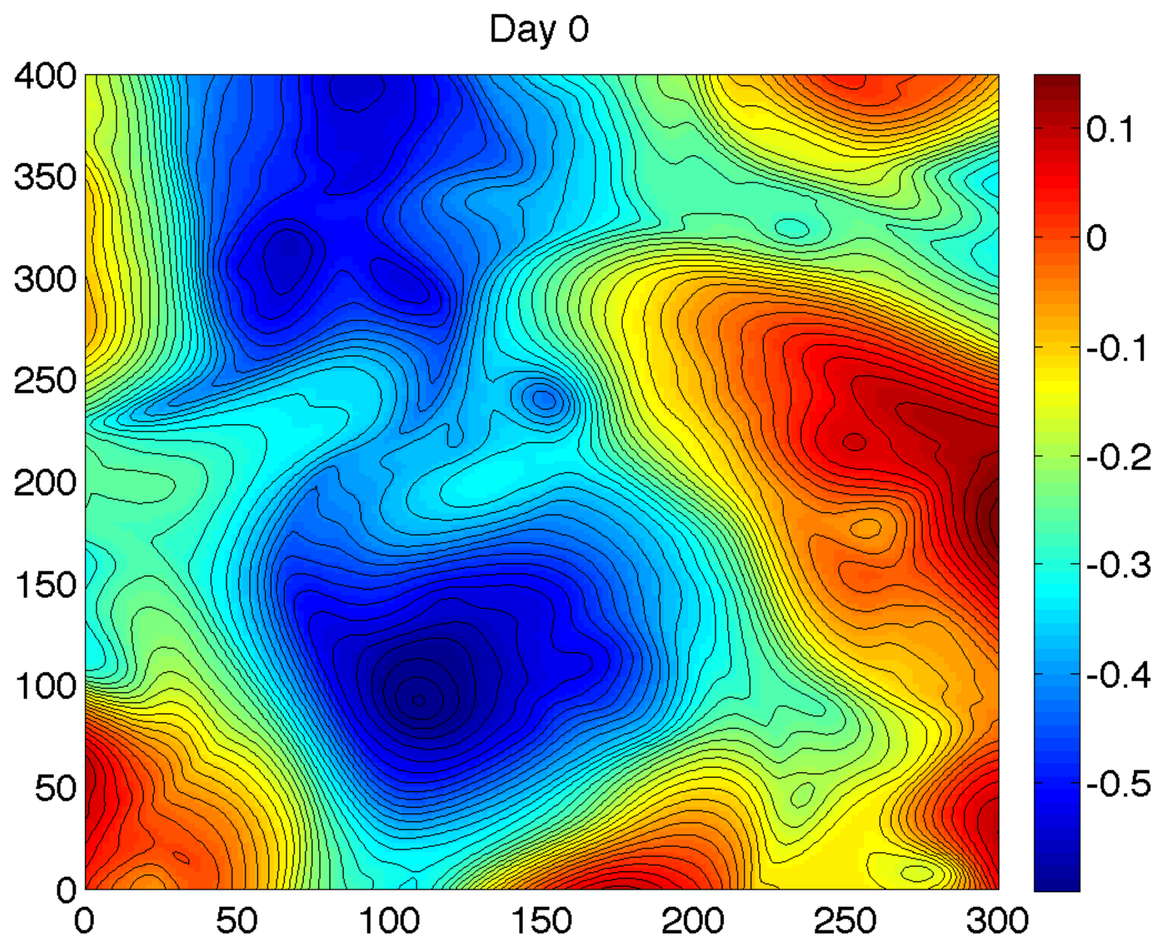


SSH(t) ⟶ Ug(t),Vg(t), q(t)→q(t+1)

SSH(t+1) ⟵ (from q(t+1))

→ Extremely cheap to run, initialized with only SSH + 1 physical parameter only (Rossby radius)

Forward and backward integration

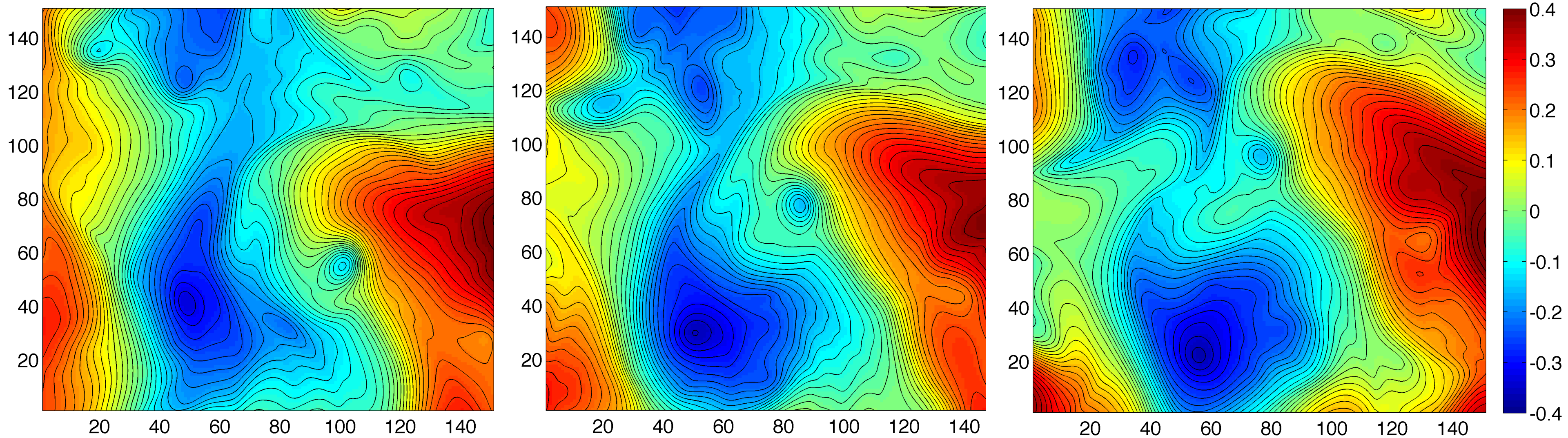


- Provides a deterministic short-term evolution of SSH : we don't create eddies. Just resolve short term predictable displacement(by simple/universal physics)

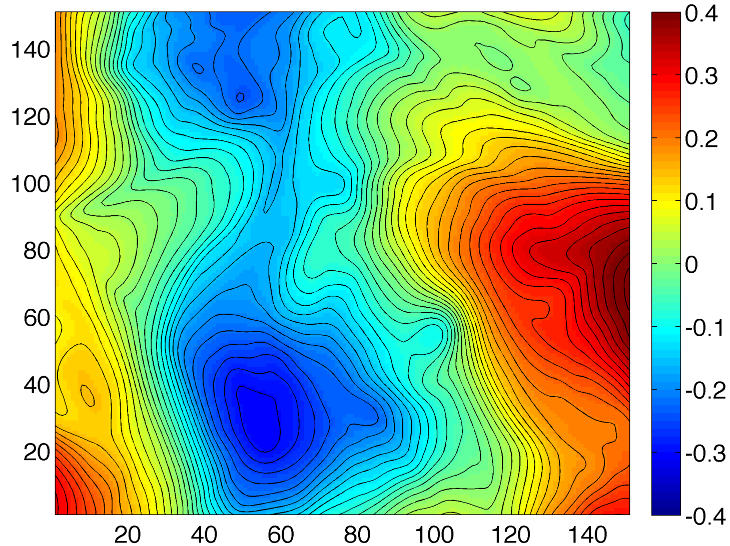
- Can be run forward and backward in time (quasi reversible over a few days)
  → Allowing a ''dynamic'' time interpolation

Results: reconstruction of SSH at intermediate time

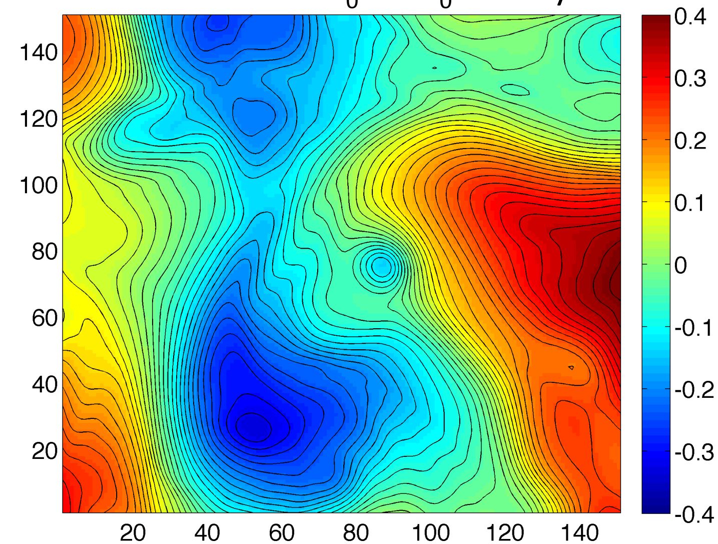
Truth at t_0 | Truth at t_0+ 2day | Truth at t_0 + 4 days



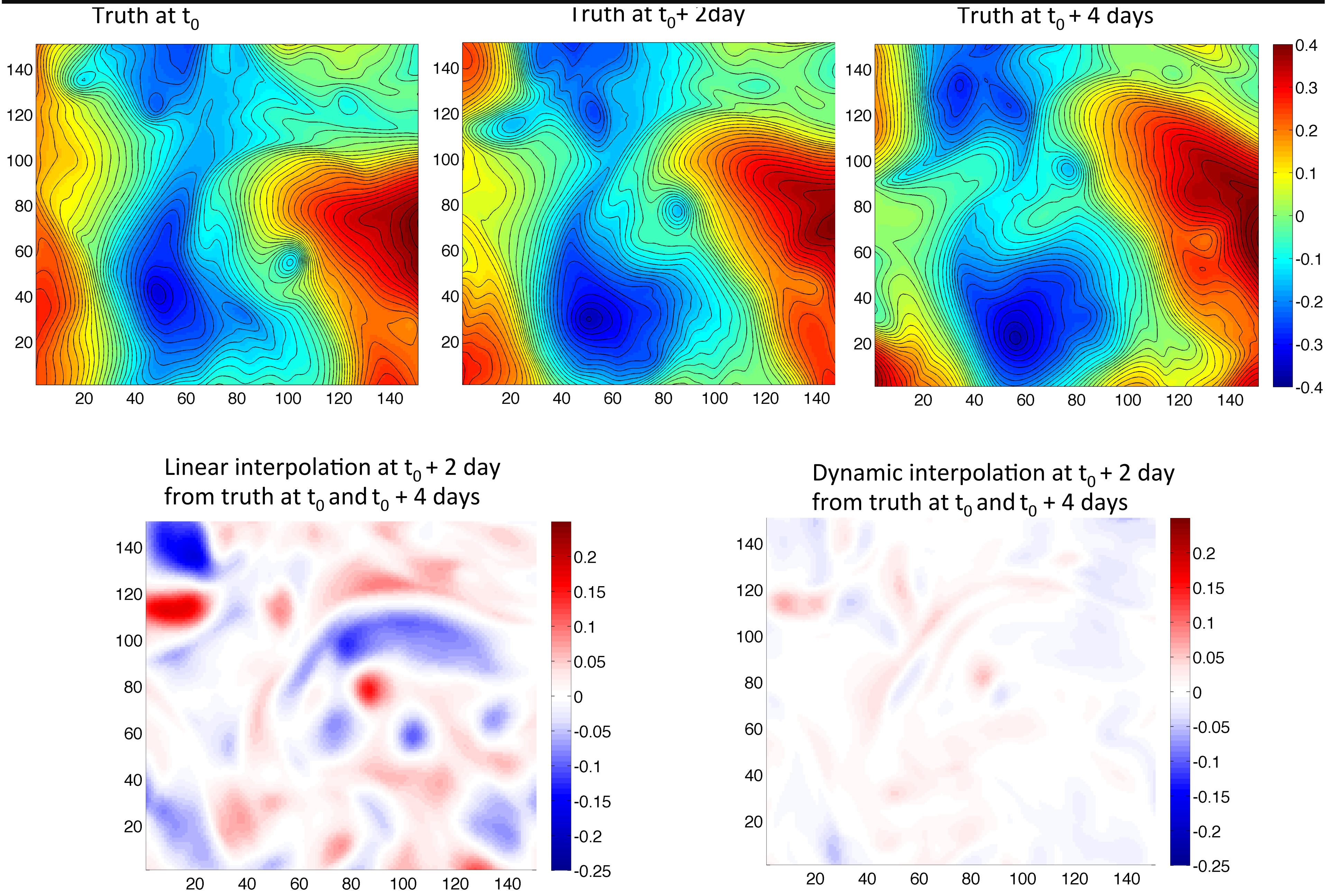
Linear interpolation at t_0 + 2 day from truth at t_0 and t_0 + 4 days



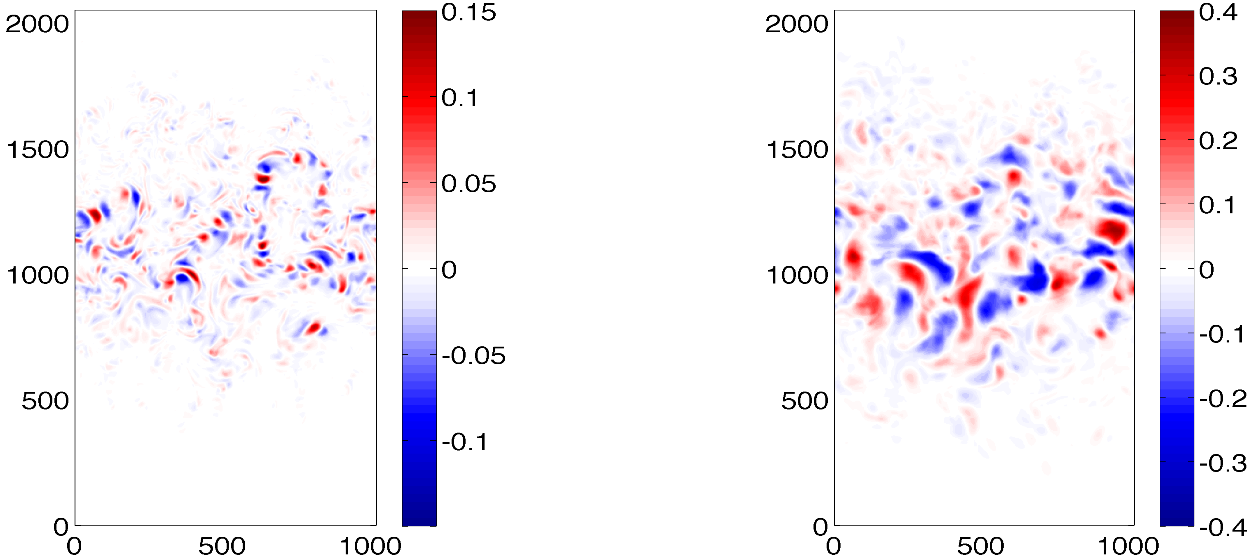
Dynamic interpolation at t_0 + 2 day from truth at t_0 and t_0 + 4 days



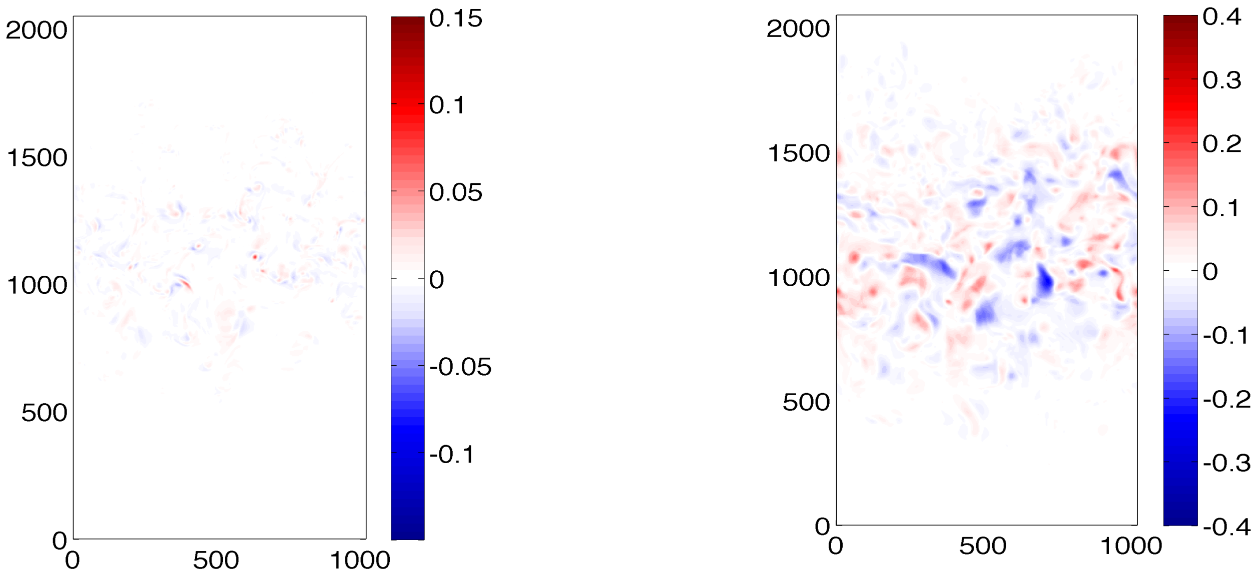
Results: reconstruction of SSH at intermediate time



For different time intervals:

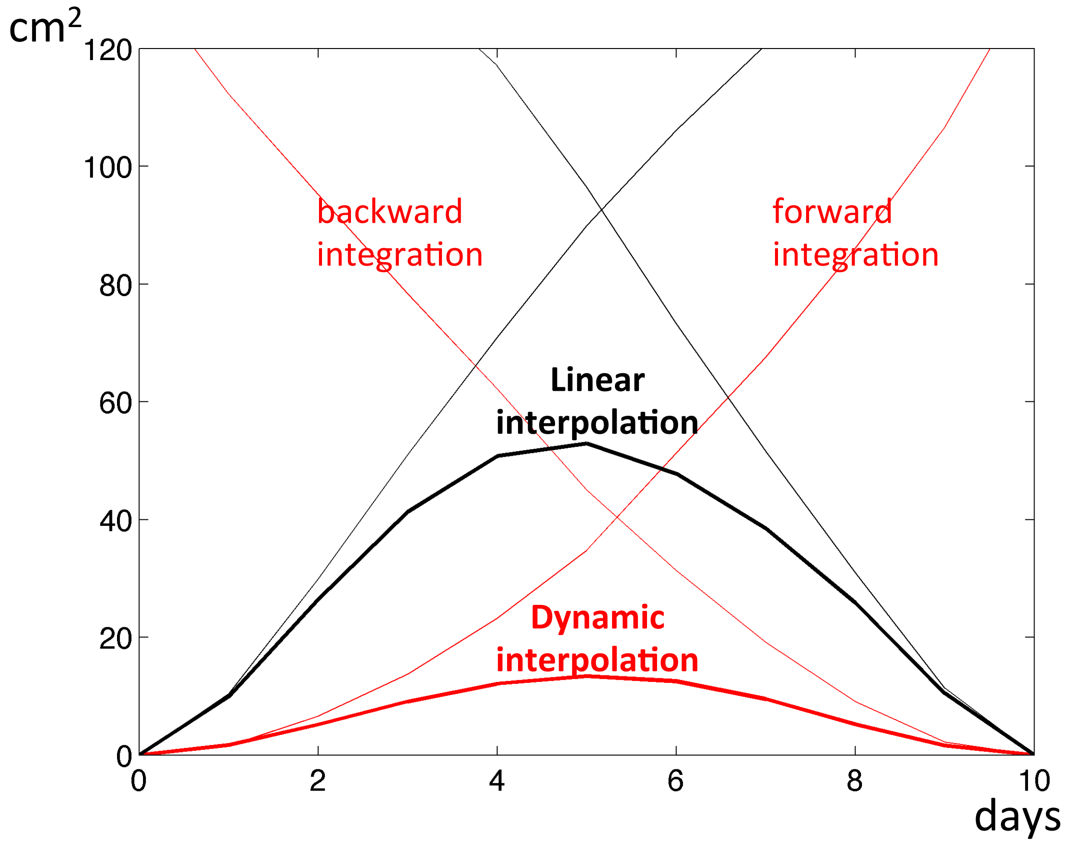


Residual error of linear interpolation in a 3 days period (1) and 10 days period (2)



Residual error of dynamic interpolation in a 3 days period (1) and 10 days period (2)

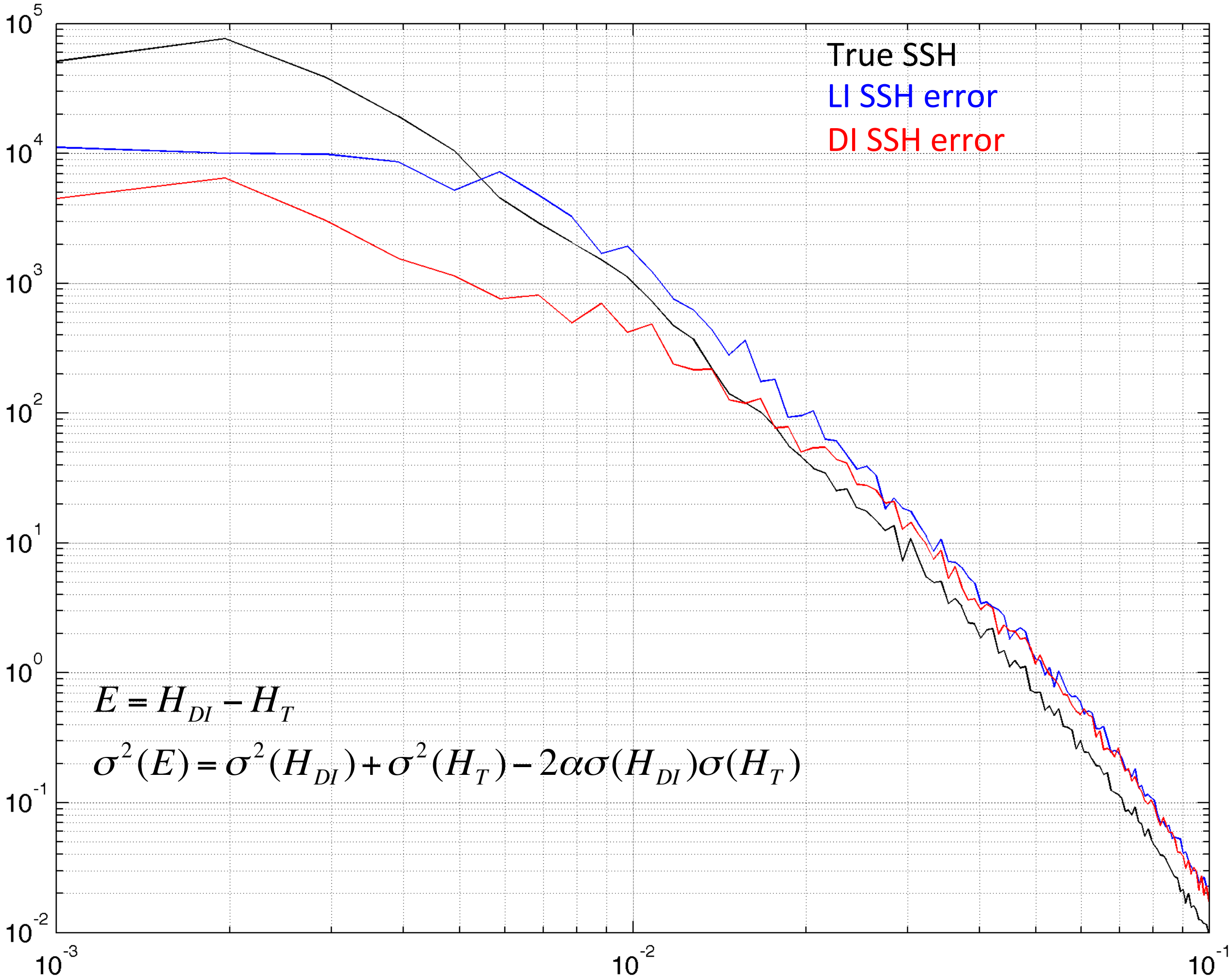
Error growth



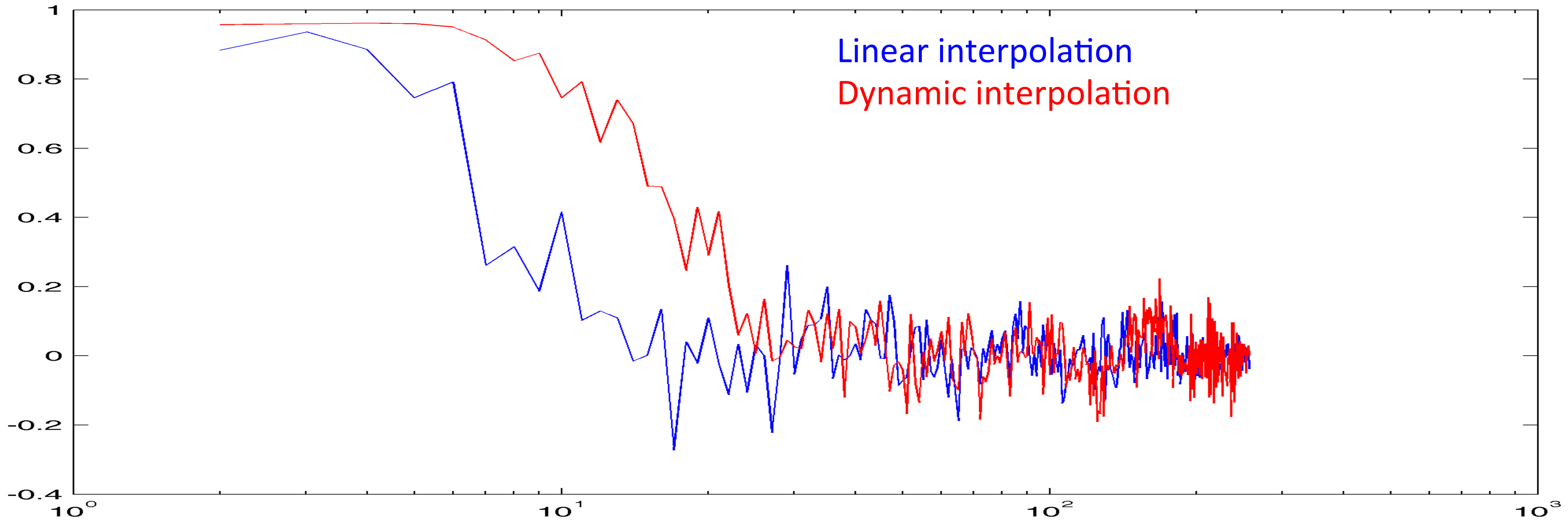
- Strong error reduction by combining the forward and backward solution.

Performances as a function of length scale

Method: comparison of the residuall error with the truth in the spectral domain allows to compute a correlation coefficient as a function of wavenumber



Performances as a function of length scale

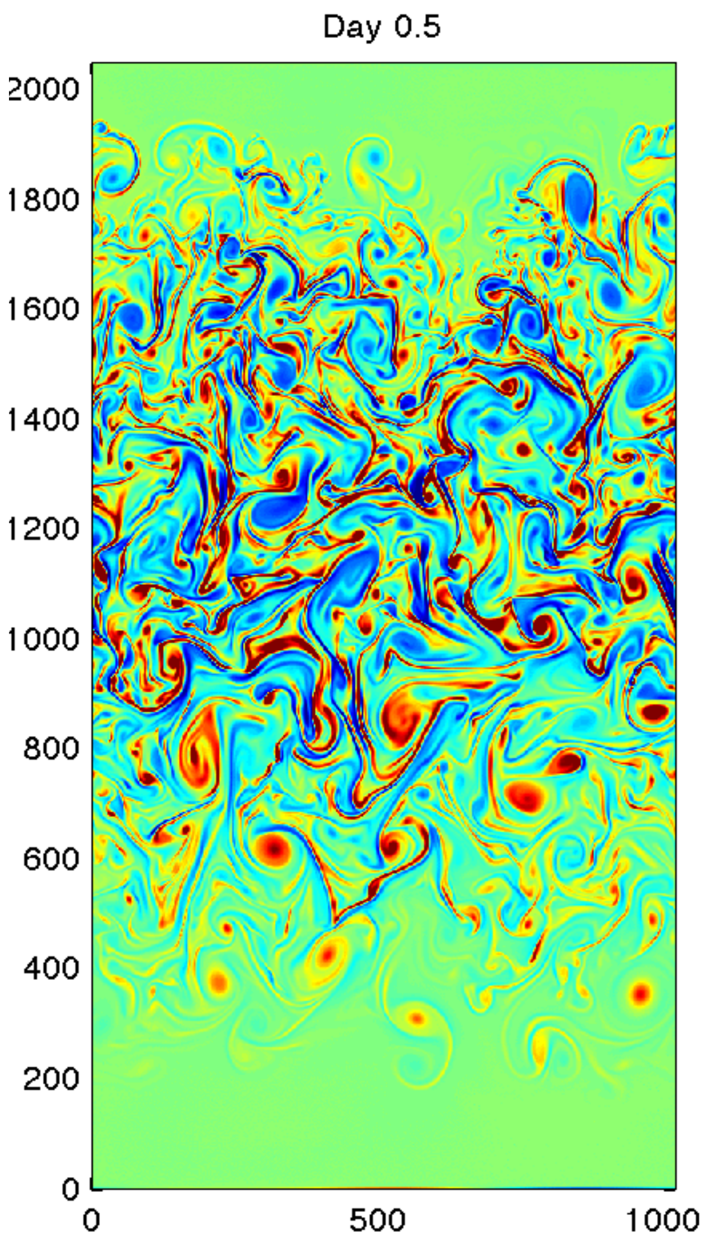


Correlation as a function of wavenumber

Over the typical 10 days time gaps of SWOT, DI could reconstruct eddies as short as 50-100km while OI would be limited to ~200km

Perspectives to improve the dynamic schemes

Limitations of the 1-layer QG



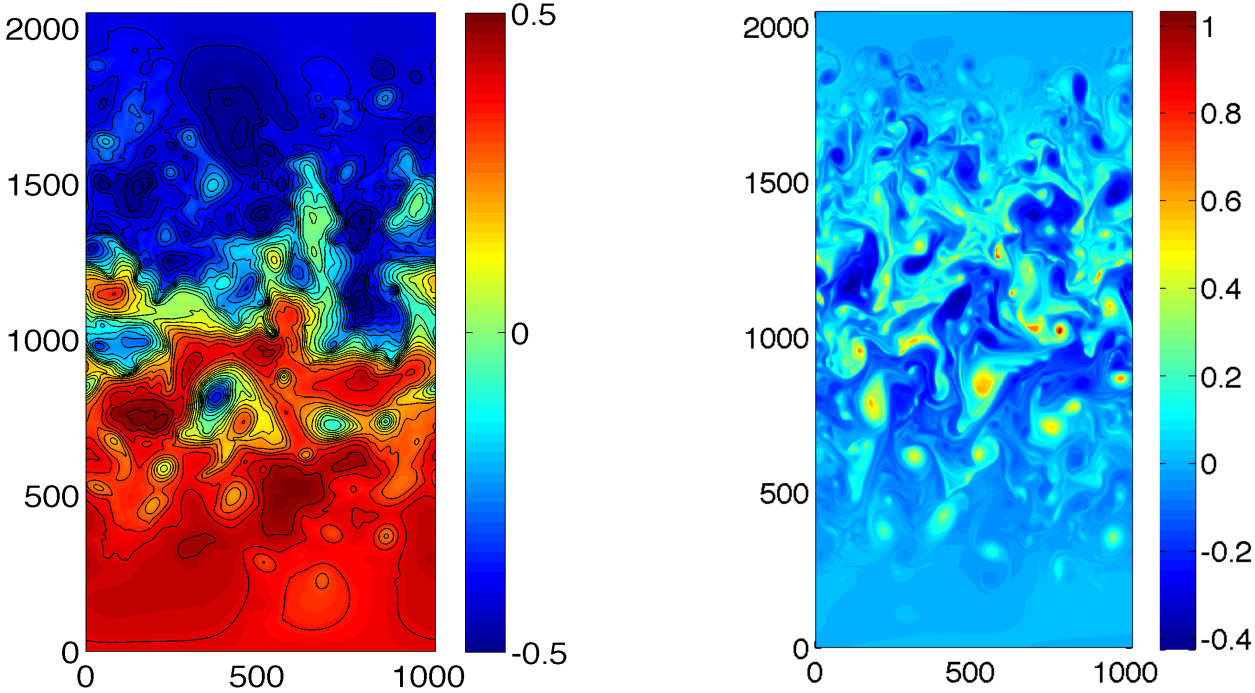
→ Strong inverse cascade, probably too much

→ In the backward integration, we therefore represent a forward cascade (irrealistic)

- but we don’t want to ‘create’ eddies neighter (chaotic/unpredictible)

Anything more realistic w/o generating unstabilities ?

The SQG approach



With SQG: Some differences with the 1-layer QG case
Under investigation…

+ possibility of combining SST measurements

Conclusions of these first tests:

- Dynamic interpolation is possible between two high resolutionSSH images: At the first order, over a few days, very simple universal physics drive SSH evolution before chaotic/unstable processes (unpredictable) dominate.

- Over the typical 10 days time gaps of SWOT, DI could reconstruct eddies as short as 50-100km while OI would limit to ~250km

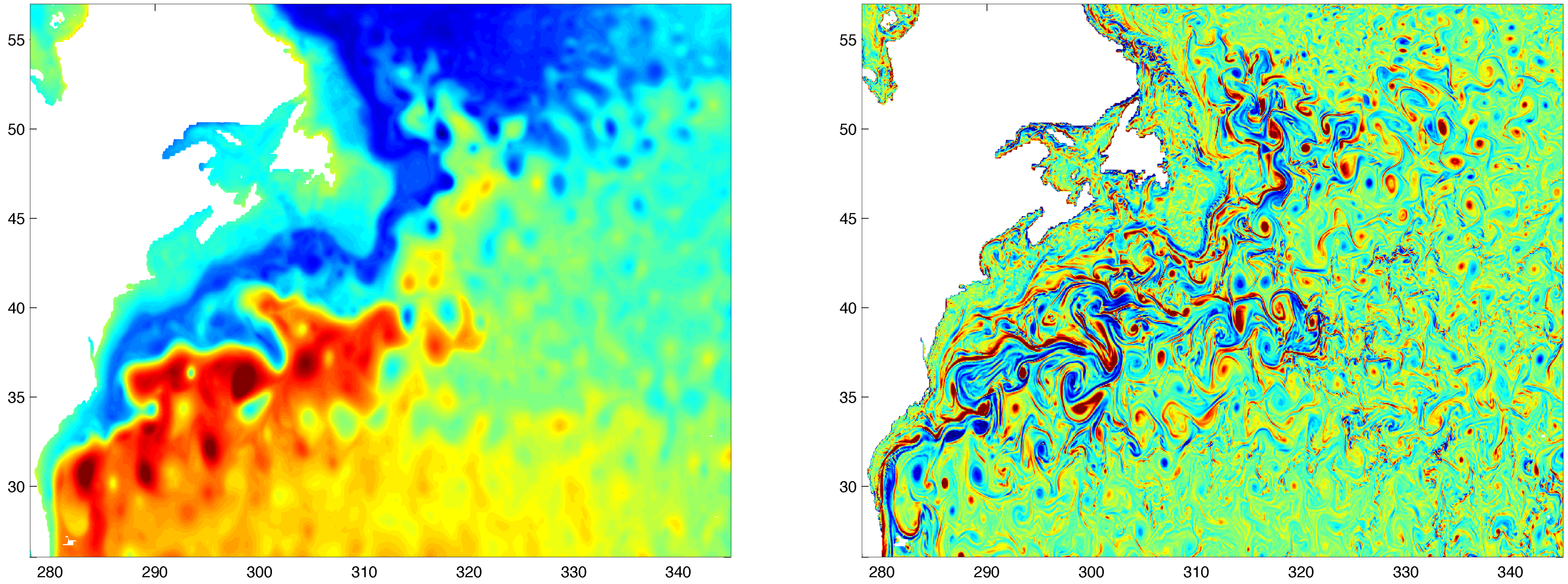
- Perspectives to explore different dynamic schemes (e.g. SQG) as a function of regions/dynamic regimes and/or do parameter adjustment

- Very idealistic truth so far …

Toward implementation to real altimetry data

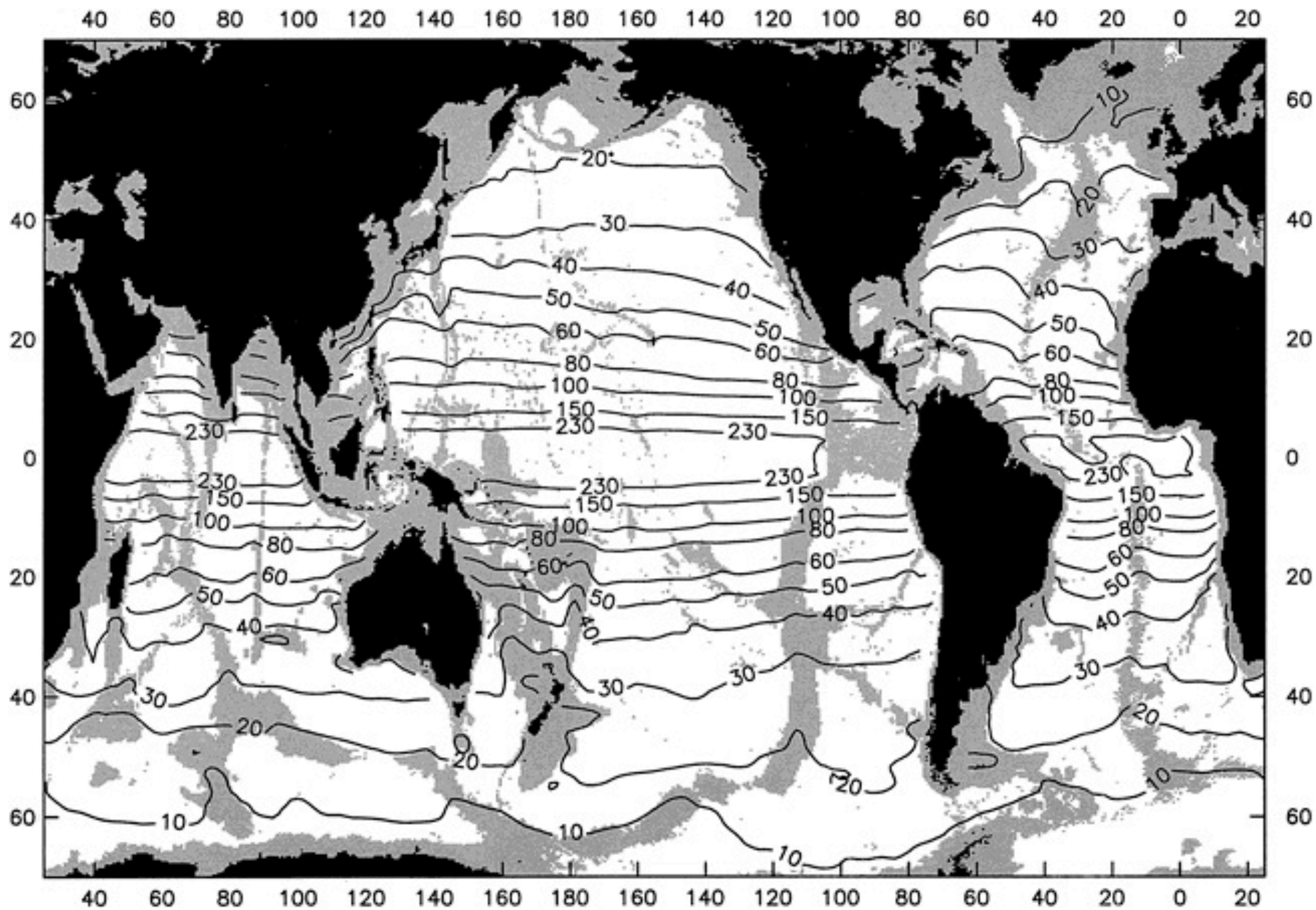
→ **Future SWOT data**
→ **Along-track altimetry?**

Twin experiments with high resolution OGCMs



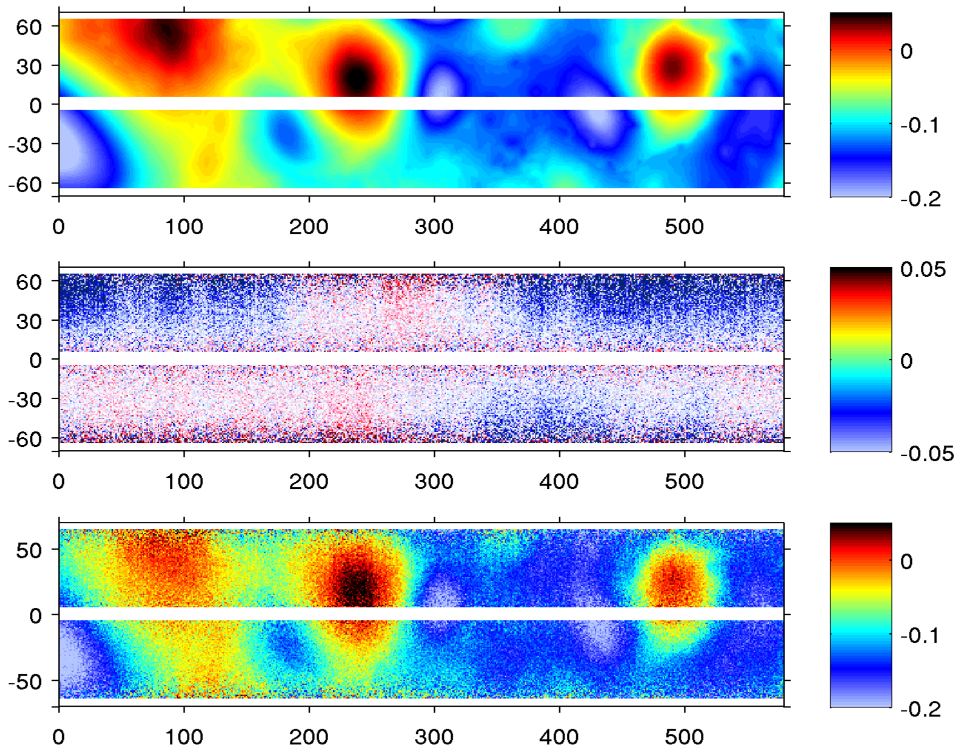
Twin experiments with high resolution OGCMs

Using a climatology for the radius of deformation.



Chelton et al., 98

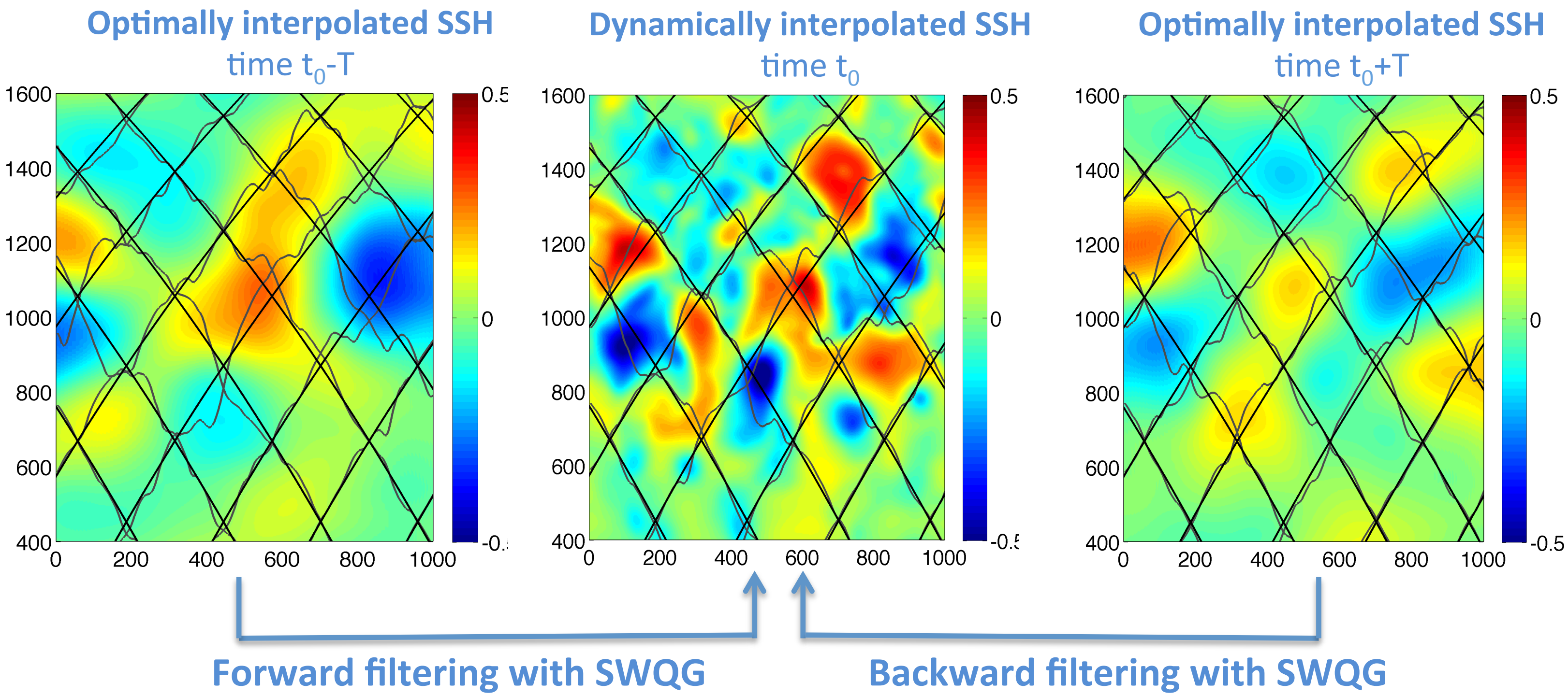
Implementation with future SWOT data



- SWOT image: finite swath + noise →he dynamic model cannot be directly initialized from SWOT image→ need to introduce data assimilation techniques

Implementation to existing along-track data?

Adding the time-dynamical constraint to the optimal interpolation…



- Along track resolution ~80km wavelength while inter-track distances currently limit to 250km wavelength…

- Cryosat: high resolution, quiasi-synoptic image, 30-day subcycle → good case

- OSSEs experiment

Conclusions

- In the future high resolution altimetry, time between revisits is an issue. Mismatch time vs space resolution
- Need to go beyond OI methods
- Why not full OGCM systems? → involve other obs, 3D state and assumptions: not self consistent product
- "Dynamic" interpolation: only rely on simple universal physics
- Perspectives with SQG framework
- Still far from real implementation, data assimilation needed
- Possible applications to along-track altimetry as well?