Perspectives for Surface Current reconstruction combining Altimetry and future Doppler current data : application to the SKIM concept.

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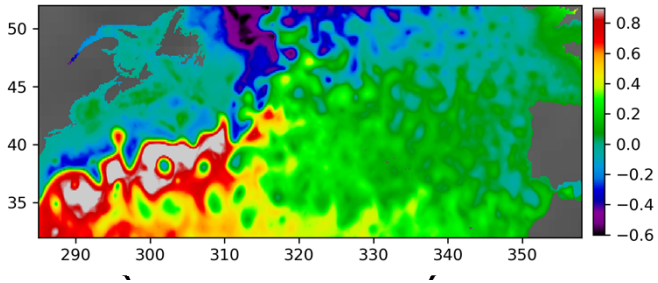
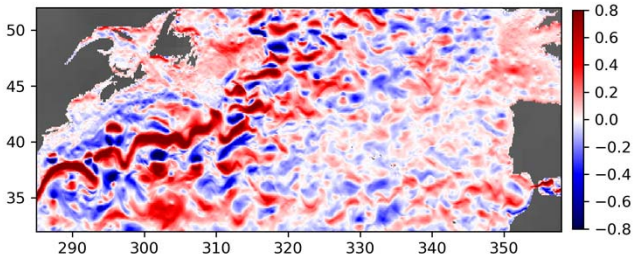
OSTST October 2019

Introduction

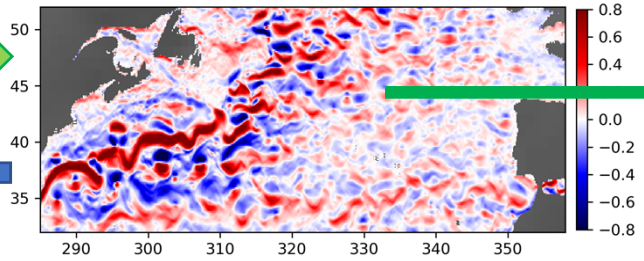
SSH from NEMO NATL60 simulation



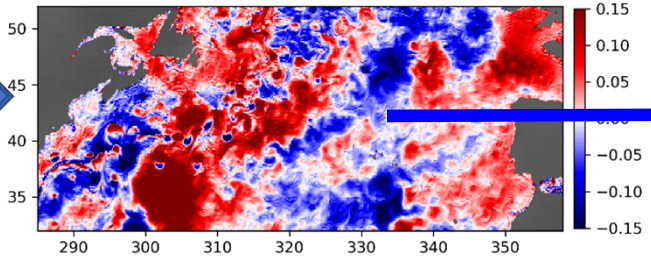
Surface zonal current



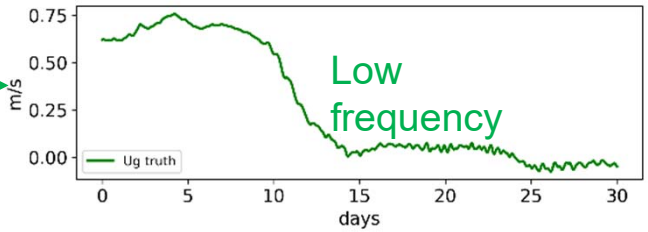
Geostrophic component



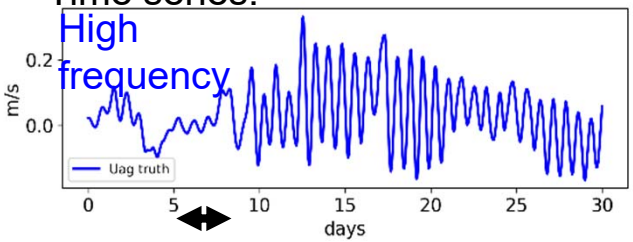
Ageostrophic component



Time series:



Time series:



3-day typical SKIM revisit

⚠ Challenge

With Altimetry + total surface current, we hope to exploit synergy:

→ To get better geostrophy?

→ To get ageostrophy?

How to handle high-frequencies?

Outline

- **The SKIM Doppler mission concept: status**
- **Altimetry and Doppler simulator tools for OSSEs**
- **Basic mapping processing altimetry and surface current separately:**

→ **Features good resolving capabilities but not optimal for ageostrophy**

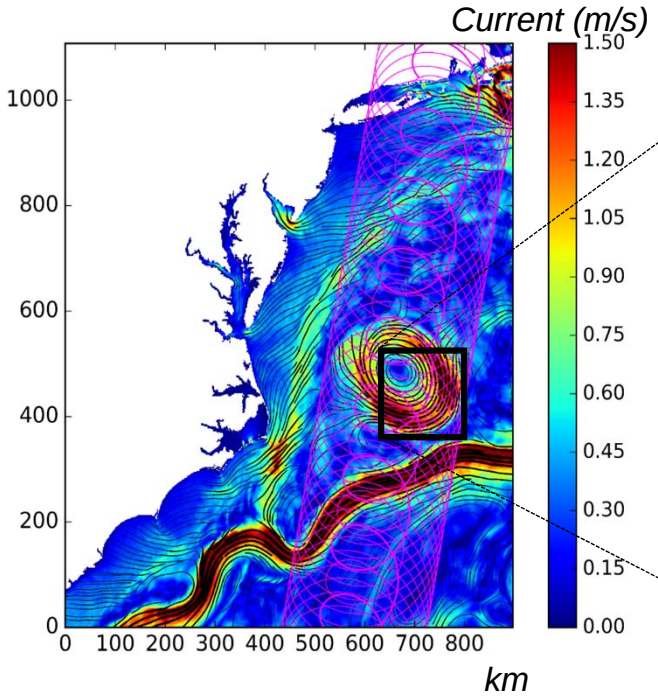
- **Improved mapping accounting for high-frequency motions:**

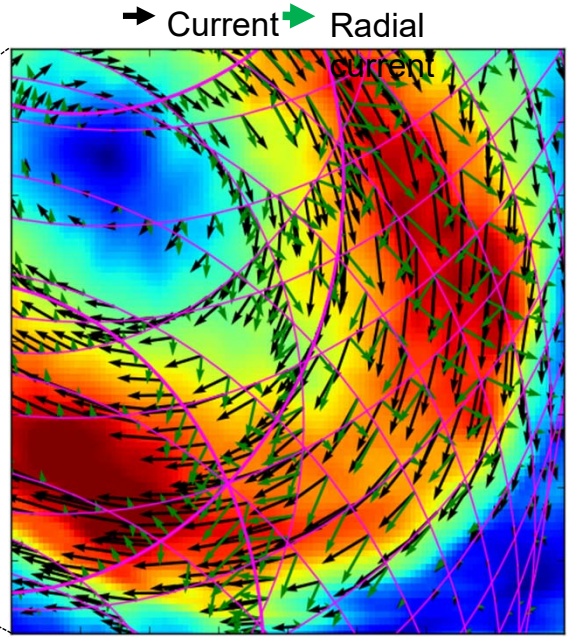
→ **Highlight complementarity for geostrophy and synergy for ageostrophy**

- **Conclusions …**

SKIM: a successful phase A at ESA

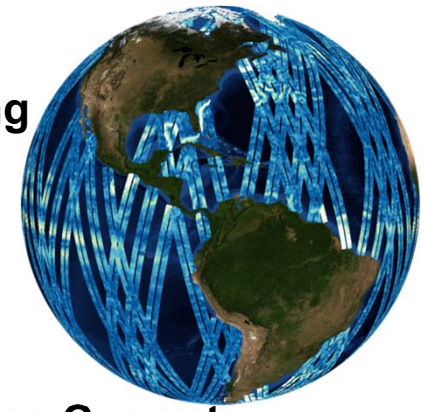
SKIM is designed to measure surface currents, ice drift and waves, using a Doppler Ka-band radar : **https://www.skim-ee9.org/**



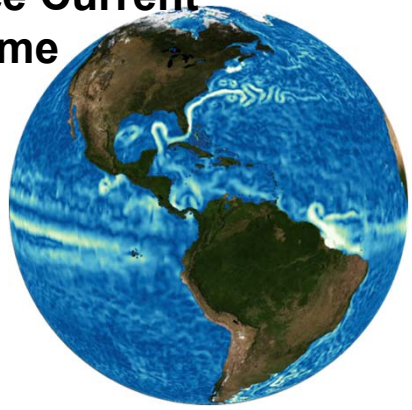


SKIM-L2B simulated observations (radial current)

SKIM-L2C spatial mapping (swath)



Mapping surface Current in space and time while merging with Altimetry?



SKIM: a successful phase A at ESA

so far:

- **2003**: demonstration of **Doppler Centroid** for surface current using Envisat (Chapron et al. JGR 2005), a « cheaper but noisier » alternative to SAR interferometry
- **2015**: Phase 0 at CNES
- **2017**: Proposed for ESA EE9 and pre-selected, together with FORUM : 0 to 12° incidence **Ka Doppler altimeter + conical scan** (Ardhuin et al. Ocean Sci., 2018)
- **2019**: Phase A successfully completed : strong science need + technically feasible. SKIM design gives 3 day revisit (global average), 30 km resolution, 12 cm/s accuracy

Unfortunately, ESA's ACEO selected FORUM for EE9 and recommended that « other ways & means be sought to implement the SKIM mission concept ».

We are thus « seeking other ways and means »: EE11 proposal, demonstration on S3-NG, other

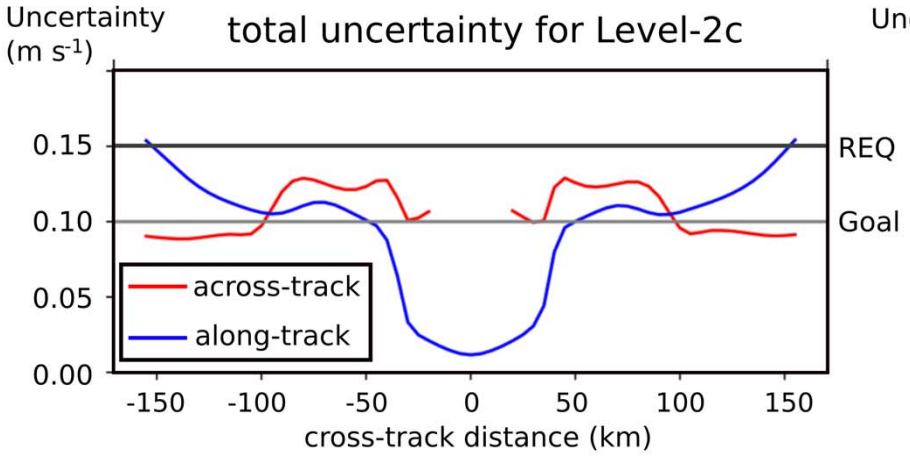
Anyways, it is important to understand the SKIM error budget, and prepare for data use:

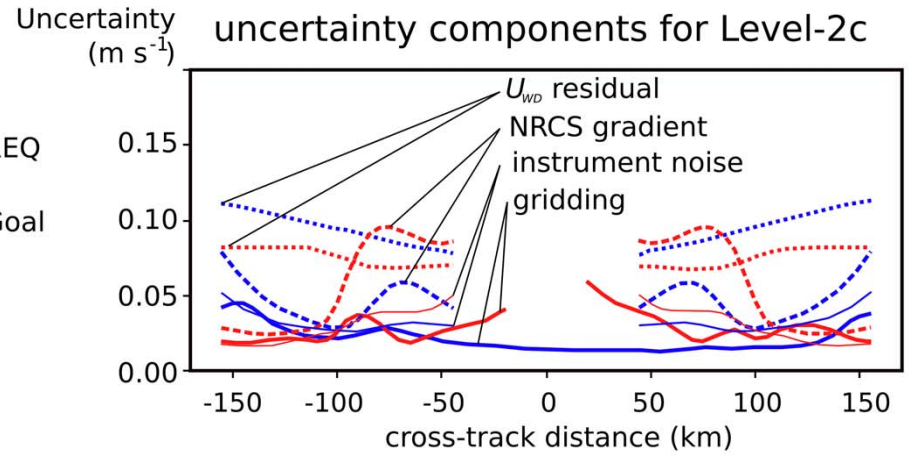
- L2 to L3 mapping (this talk), - assimilation of surface velocities (ESA-funded study) …

SKIM: a successful phase A at ESA

A few elements on SKIM's error budget:

- Different for cross-track (blue) and along-track (red) components
- Instrument noise is lowest (thanks to 12° incidence, see Rodriguez 2019) around 5 cm/s
- near nadir error dominated by NRCS gradients (can be improved with unfocused SAR)
- outer swath error dominated by wave motion correction (to be improved: joint waves & cur. Retrieval)

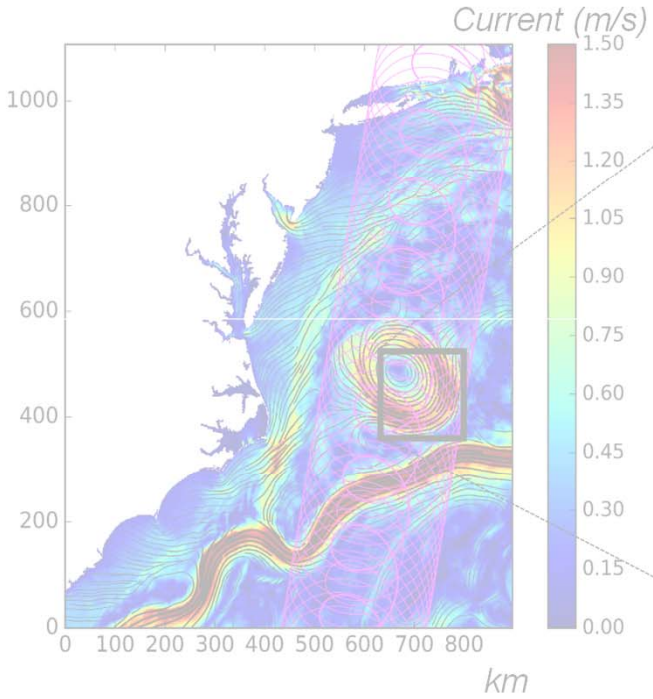


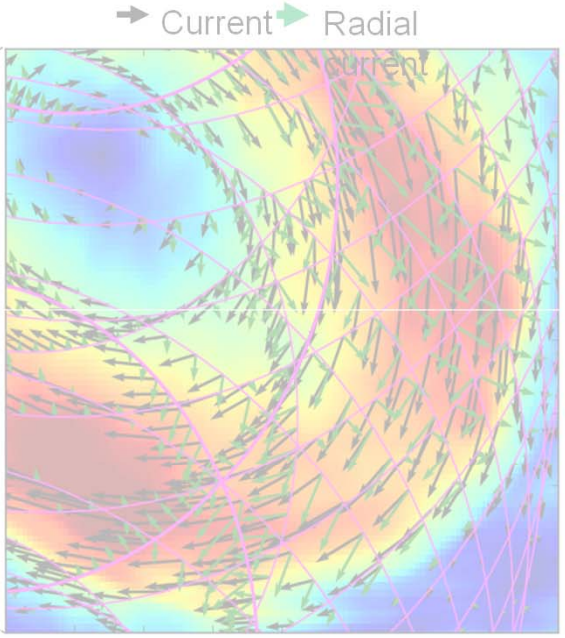


The SKIM mission

- **S**ea surface **KI**nematics **M**ultiscale monitoring (**SKIM**) is a candidate mission for ESA EE9 (PI: F. Ardhuin)

- SKIM is designed to measure surface currents, ice drift and waves, using a Doppler Ka-band radar : https://www.skim-ee9.org/





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SKIM-L2C spatial mapping (swath)

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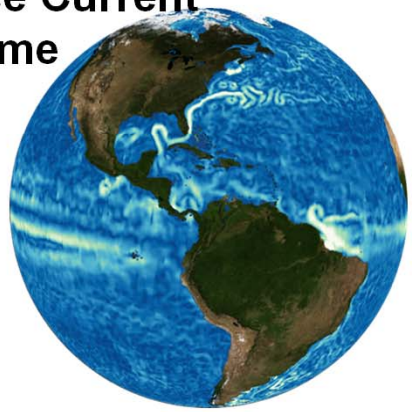
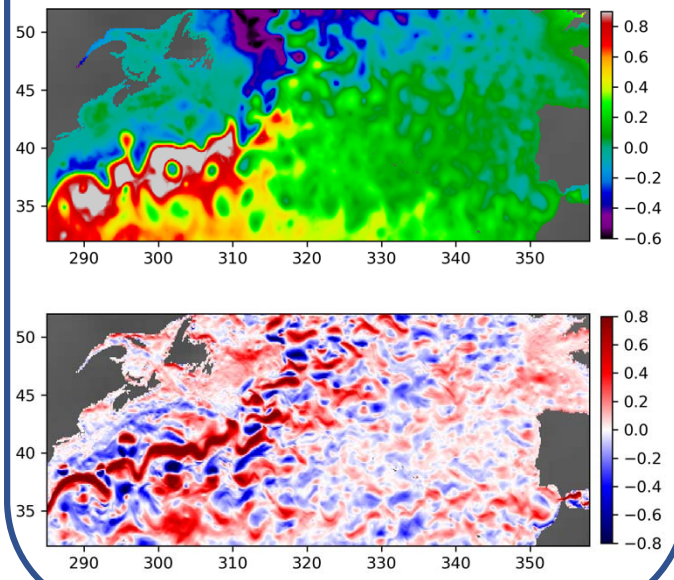


Observing System Simulation Experiments

NATL60 run as 'truth'

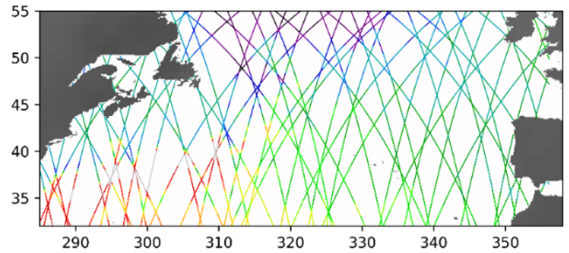
- 1/60deg resolution
- Hourly ERA interim wind forcing
- No tides



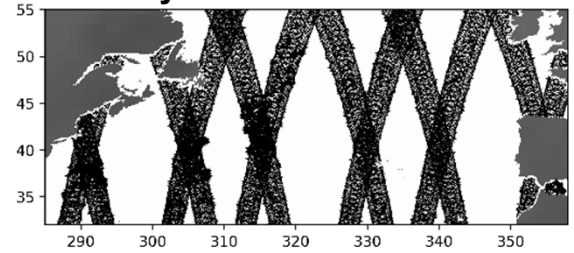
Synthetic observations

Nadir simulator and SKIMulator (sampling+errors)

2-day worth of 5-altimeter constellation

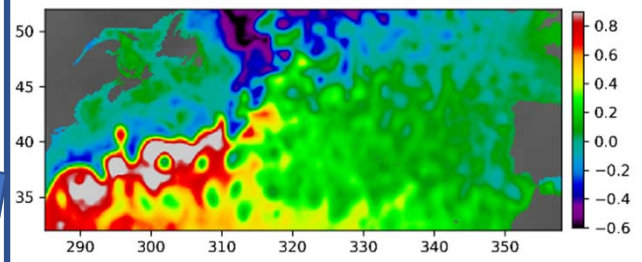


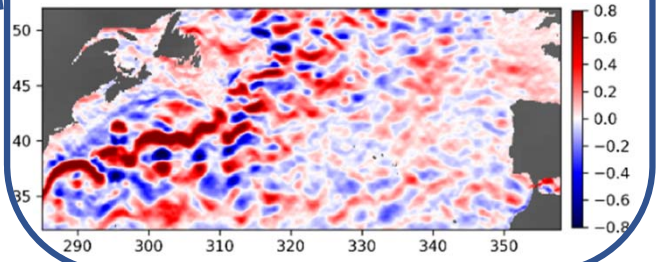
2-day worth of SKIM



Reconstructions

Basic mapping, improved mappings, …

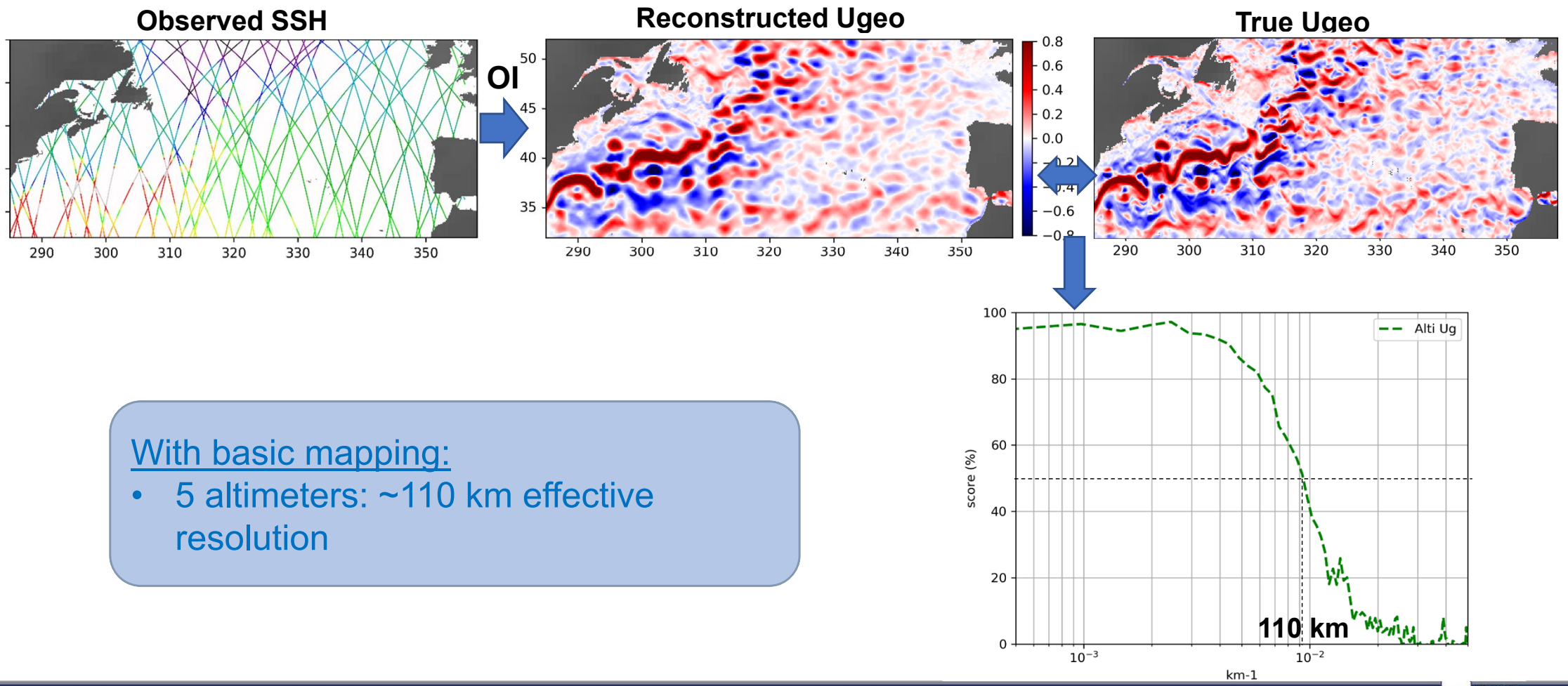




Comparison with truth

Basic mapping of altimetry (geostrophy)

Mapping similar to SLTAC-CMEMS (basic OI)

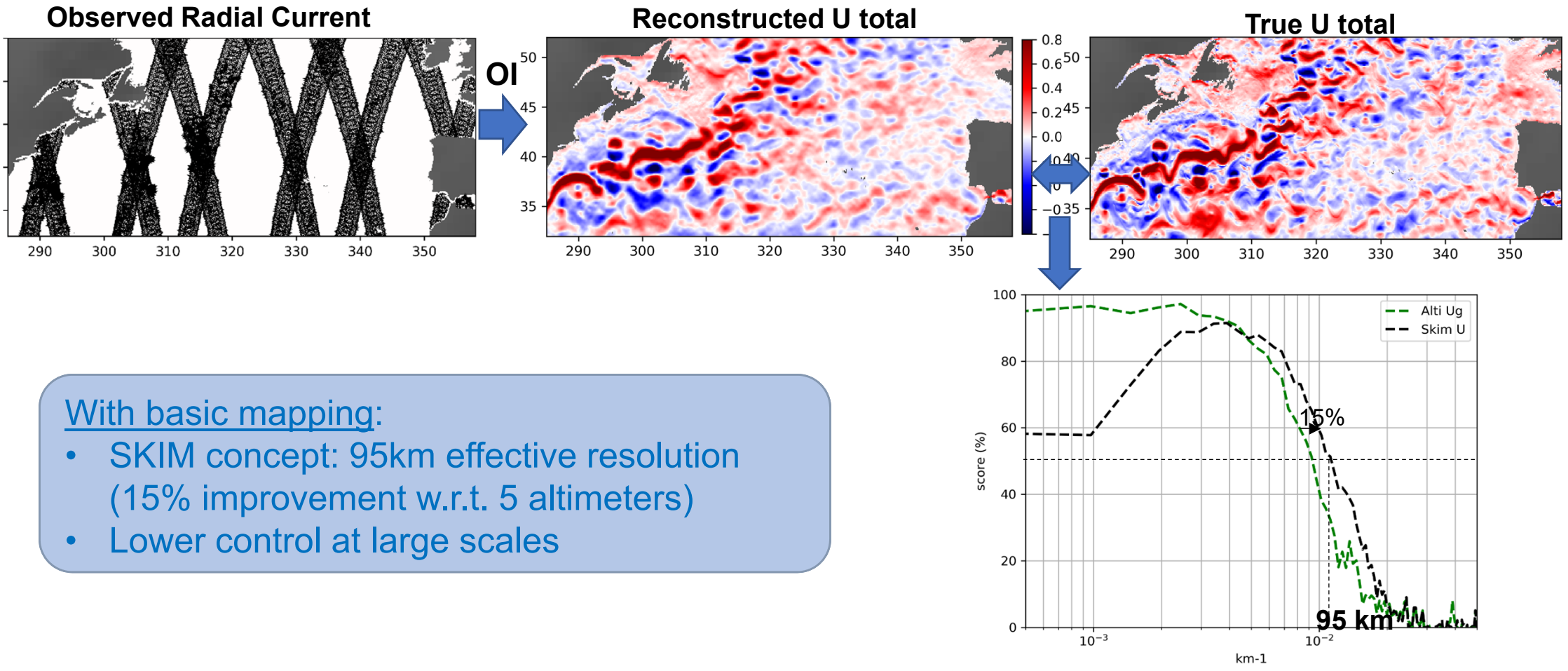


With basic mapping:

- 5 altimeters: ~110 km effective resolution

Basic mapping of total current

Bivariate mapping of U,V from radial current with basic OI

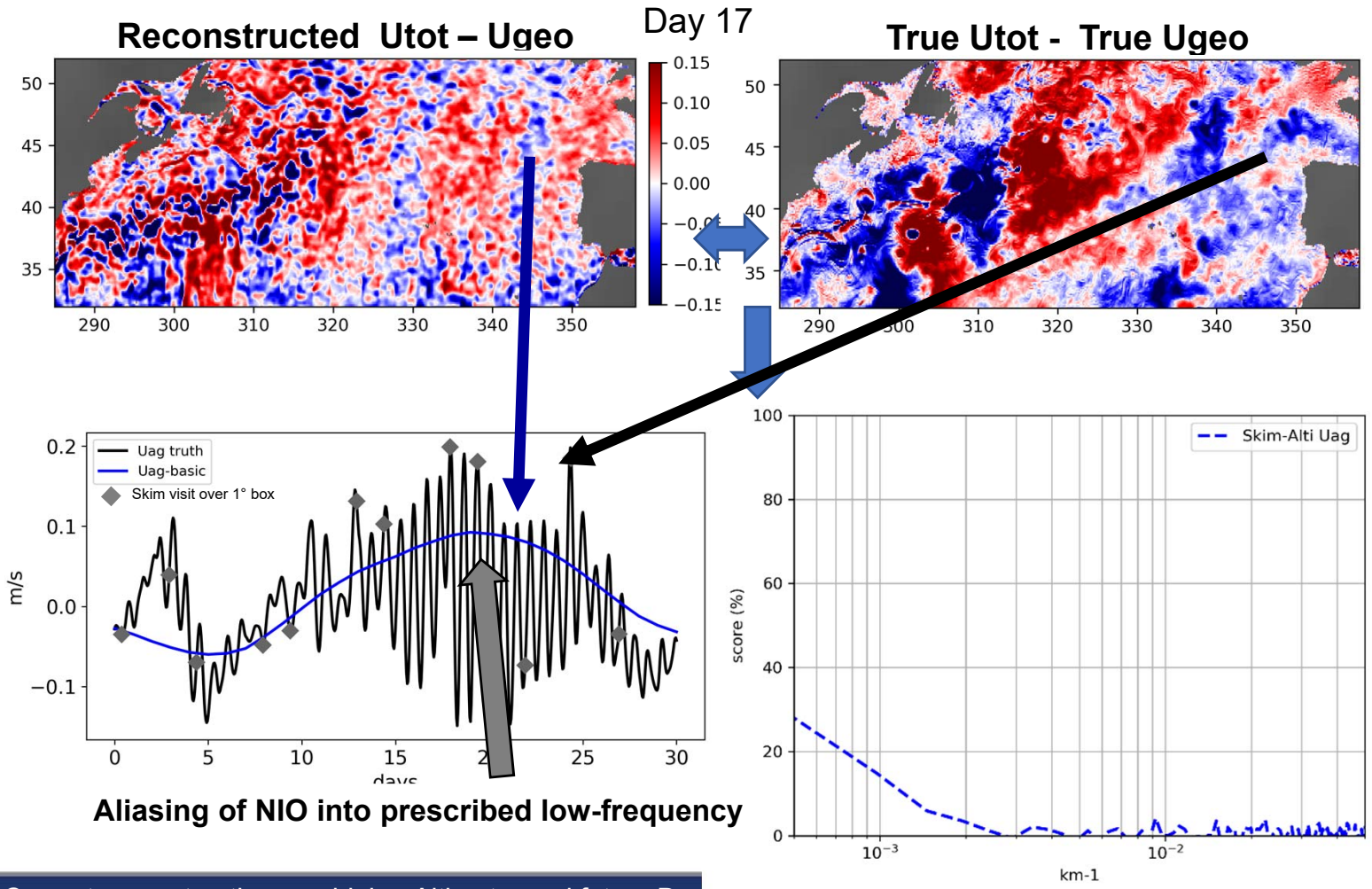


With basic mapping:

- SKIM concept: 95km effective resolution (15% improvement w.r.t. 5 altimeters)
- Lower control at large scales

Uskim – Alti : ageostrophy?

Difference :



With basic mapping:

- Low-frequency only (limited to SKIM sampling…)
- **Suffering from aliasing of HF content**

So far ...

- **SKIM concept itself features interesting resolving capabilities at short scales w.r.t. 5 nadir altimeters (good space-time sampling for mesoscales)**

- **The ageostrophic field is poorly reconstructed with this method (strong aliasing affecting large scales)**

→ Should we explore better parameterizations to handle both total surface current and altimetry?

Improved mapping to handle multiple dynamics

$$\mathbf{x_a} = \mathbf{BH^T(HBH^T + R)^{-1}y}$$

Estimate · State vector · State to obs operator · (obs,obs) error cov · obs

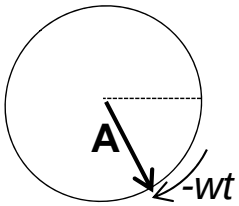
One can extend **B** for multiple dynamics and for SSH/current simultaneously:

Covariance models for B and R matrices		Physical components: State vector					Error matrix	
		Geostrophy	**Barotropic HF (low-wavenumber)**	**Internal tides**	**Large scale ageostrophy (Ekman…)**	**Inertial Oscillations**	**The trash: under-sampled dynamics**	**Obsrvation errors**
Variable nature:	**SSH**	Standard model used in Aviso	low-pass in space, high-pass in time cov. functions	Local plane wave cov.	0	0	HF/HW Cov functions	Instrument Noise
	Current ([ψ,ξ] decomposition)	Derived standard model (**ψ** only)	*Not implemented yet (weak in open Ocean)*	Mom. and cont. eq., e.g. Zaron et al.	low-pass in space, high-pass in time cov.	$Ae^{(-iwt)}$ cov. Functions	HF/HW Cov functions	Instrument Noise.
	Cross SSH/ Current	Partially derived model (**ψ** only)	*Not implemented yet (weak in open Ocean)*	Mom. and cont. eq.,	0	0	0	0

The wavelet basis for Inertial Oscillation component

NIOs can be locally expressed as :

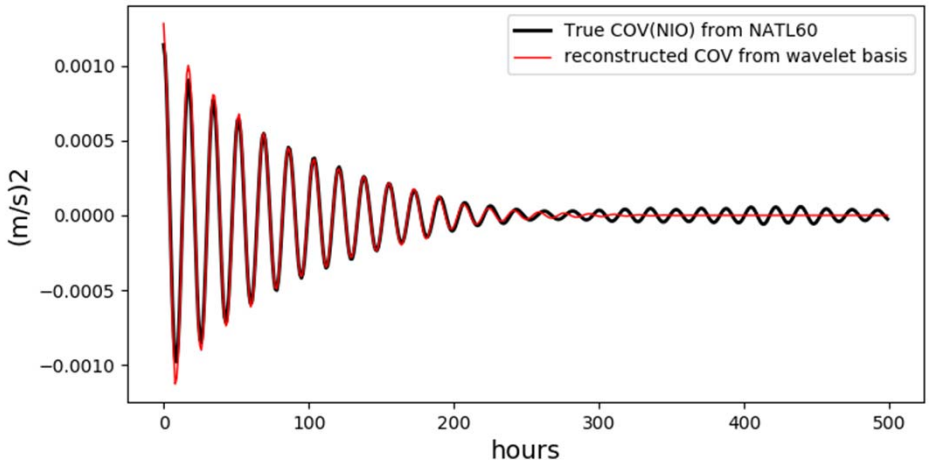
$$V_{IO}(t) = Ae^{-iwt+\varphi}$$



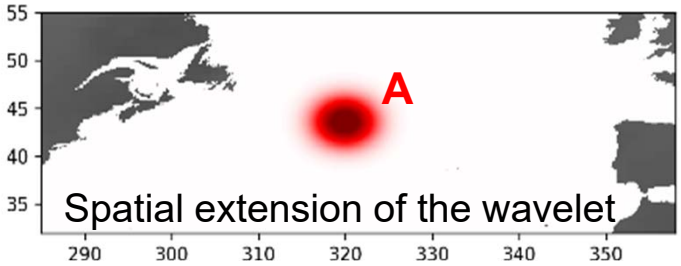
$$w = f\,c + \xi \quad , \xi << fc$$

B adjusted to fit observed NIO covariances:

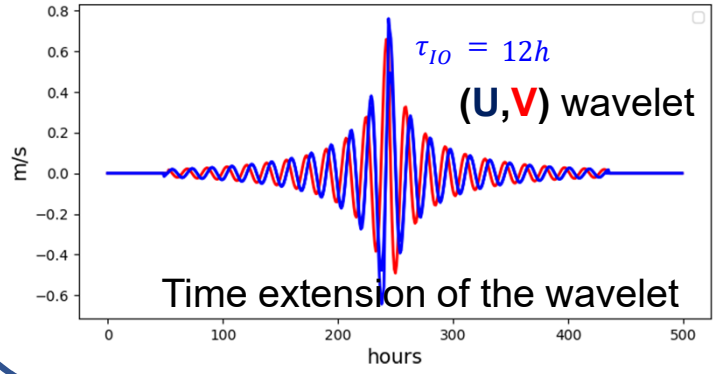
$$\mathbf{HBH^T}$$



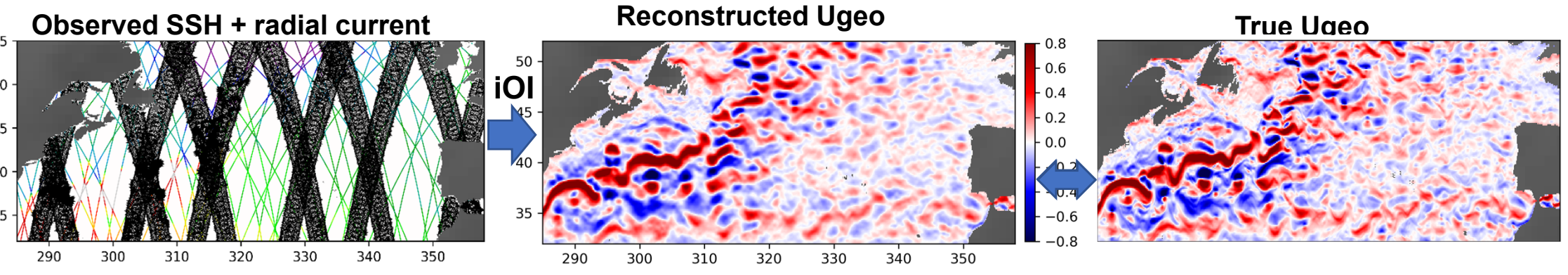
Construction of a wavelet basis : (here a single element H[:,N])

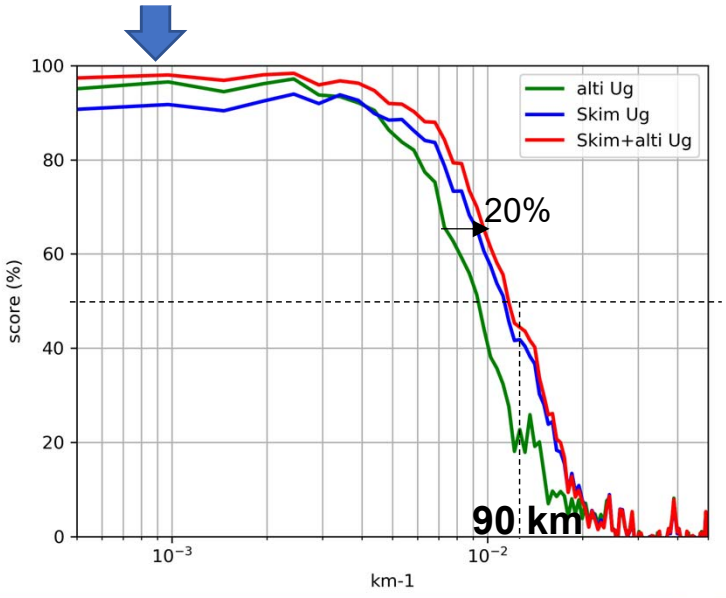


$$U + iV = Ae^{-iw\delta t}e^{-\delta t^2/\tau_{IO}^2}$$



Improved mapping : geostrophy





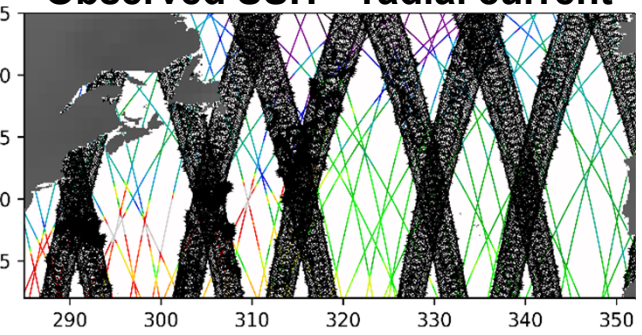
Thanks to the improved mapping:

- The simultaneous Alti/Current inversion brings 20% improvement in spatial resolution

→ **SKIM is complementary for geostrophy, acting as a gap filler**

Improved mapping : ageostrophy

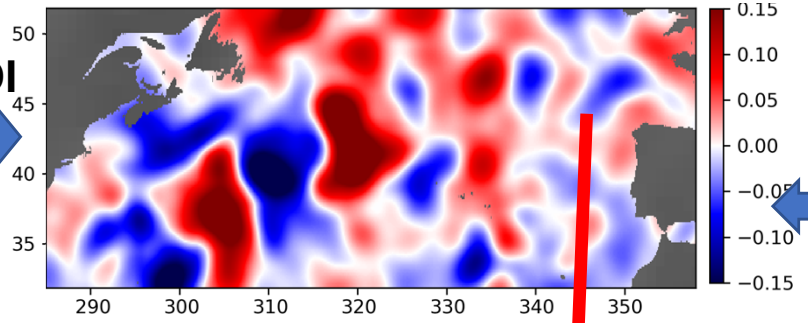
Observed SSH + radial current



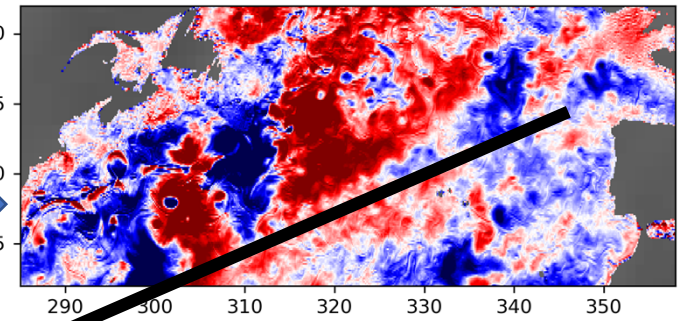
iOI

Reconstructed Uageo

Day 17



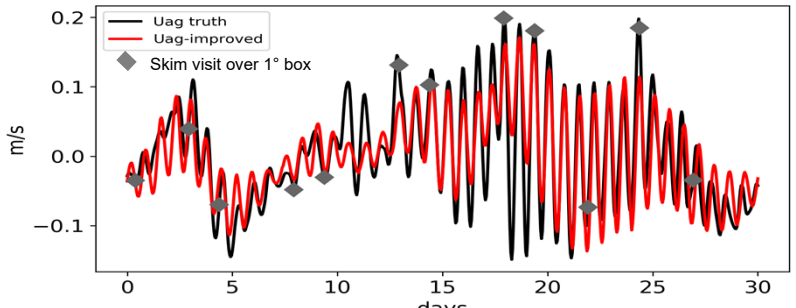
True Utot - True Ugeo



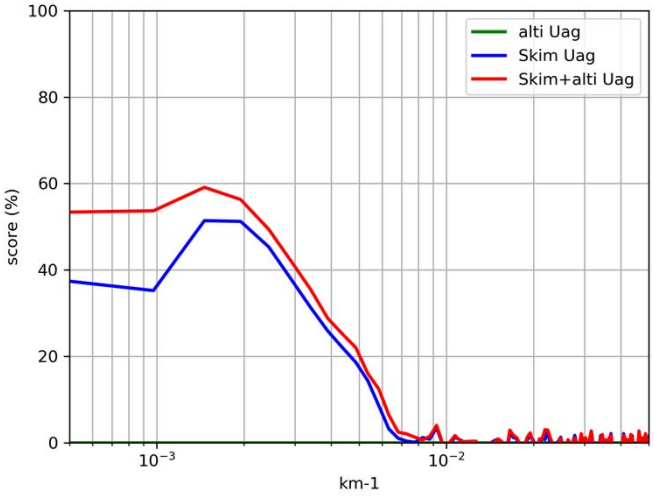
Thanks to improved mapping:

- HF ageostrophy is now partly resolved: **50% variance of NIO captured**
- Less w/o altimetry

→ **Altimetry acts in synergy to solve HF ageostrophy**



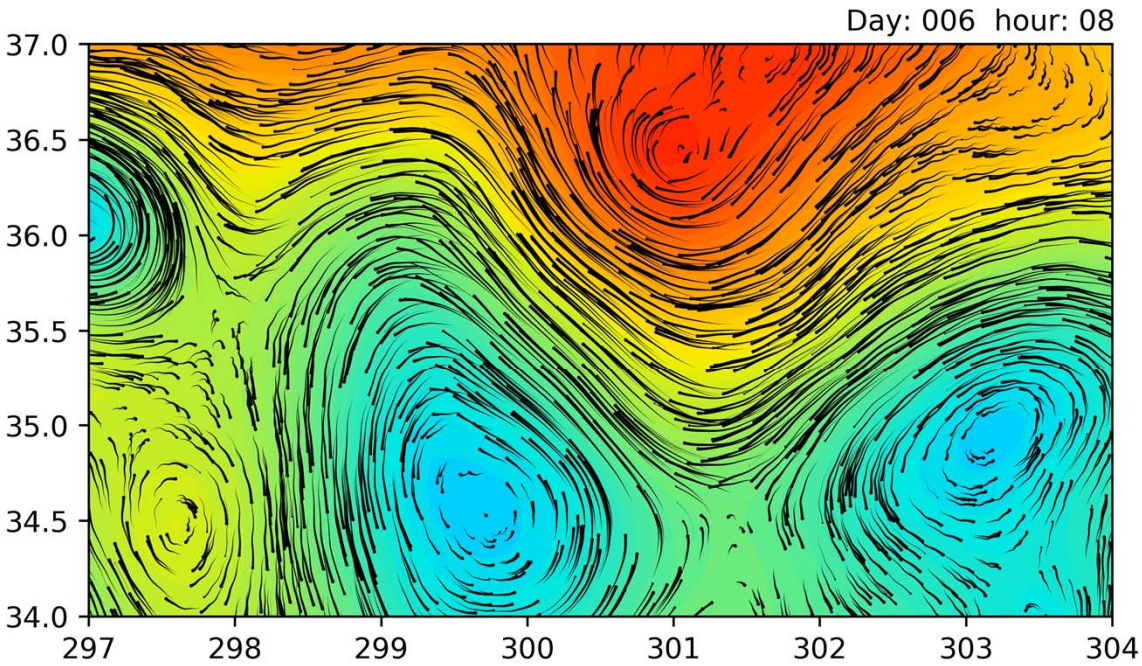
(compare with slide 7)



Conclusion

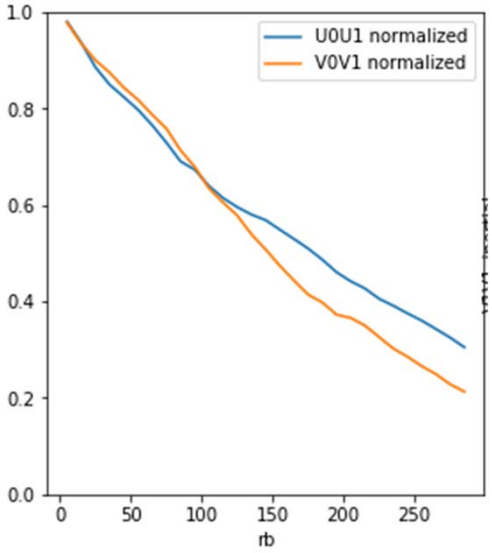
- The high-frequency challenge can be addressed thanks to coherency* in time and space
- With a joint altimetry+Doppler-current, one can **improve geostrophy** (‘gap-filler’ complementarity w/ alti) and **solve some rapid ageostrophy** (synergy w/ alti)
- Soon: simulated SWOT and SKIM SSH nadir beam
  - Include tides in reference
- Perspectives for data assimilation: we may need large 4D time-space windows for disentenglement

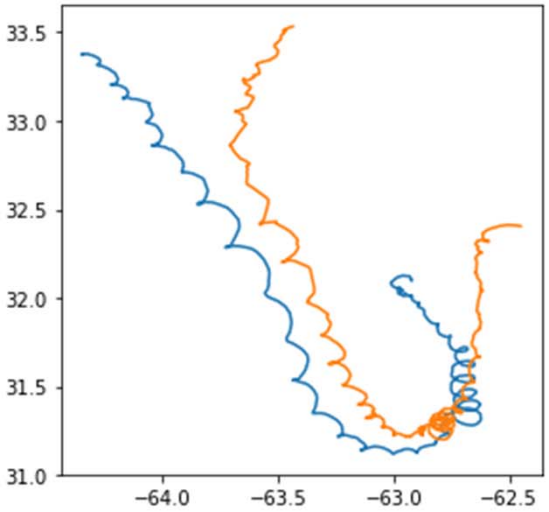
**Coherency also supported from drifter observations (Ponte et al., in prep. see next slide)*

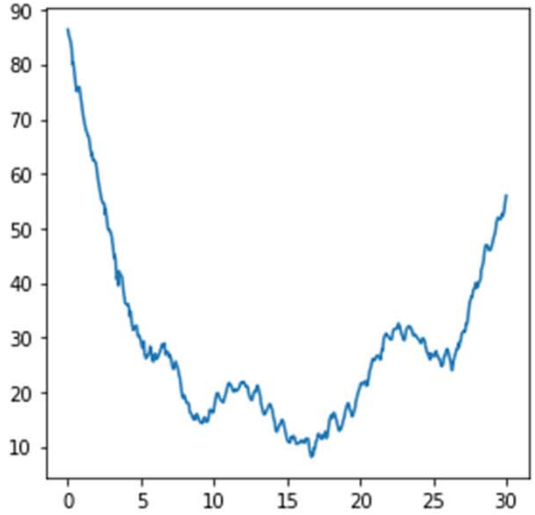


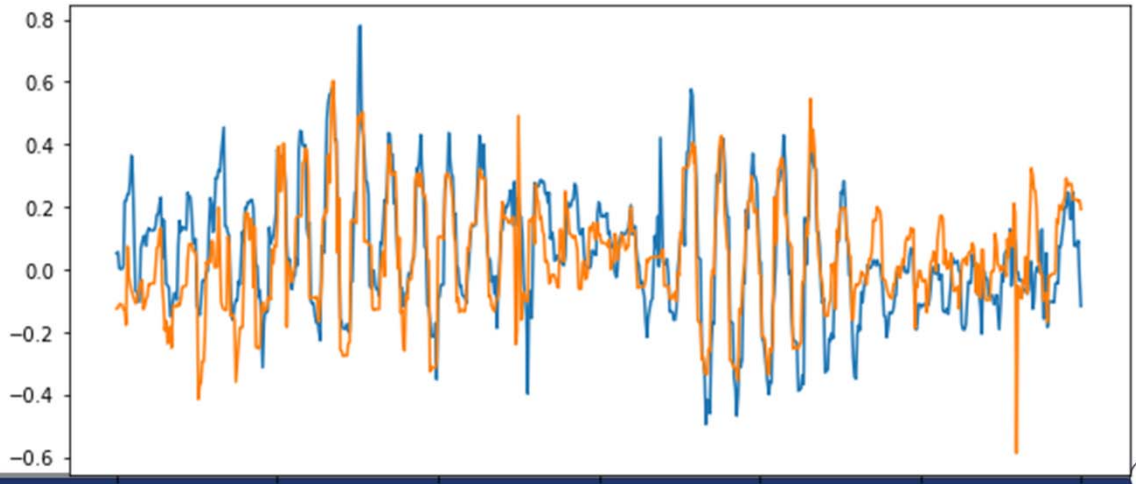
Surface current mapped from simulated 5 altimeters + SKIM

Observational support for favorable space and time coherency of NIOs









Drifters also support spatial and time cohérence of the NIOs

Backup

Conclusion

- The proposed SKIM mission would bring direct observations of the total surface current.
- Mapping in space and time is challenging
- **But joint use of altimetry and appropriate filters (accounting for Near Inertial Currents) would disentangle and reconstruct current components**
- **Higher temporal resisit would be appreciated to go beyond 50%**

Surface current mapped from simulated 5 altimeters + SKIM

- **What matters is not the time scale (few hours) but the coherency time (few days)**
  → Even sub-weakly synoptic current observations could substentially help the control of surface dynamics