SURFACE WATER & OCEAN TOPOGRAPHY
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SWOT Science Team Meeting and CalVal workshop

17-20 June 2019 | Bordeaux, France

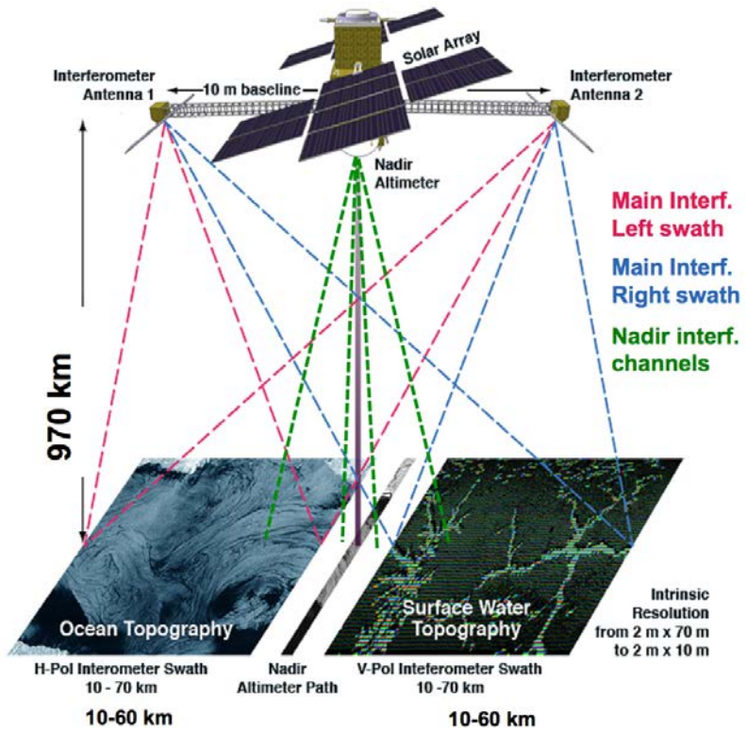
Cross-scale energy exchanges in the North Atlantic : results from NATL60 / eNATL60 simulations

Laurent Brodeau, Julien Le Sommer

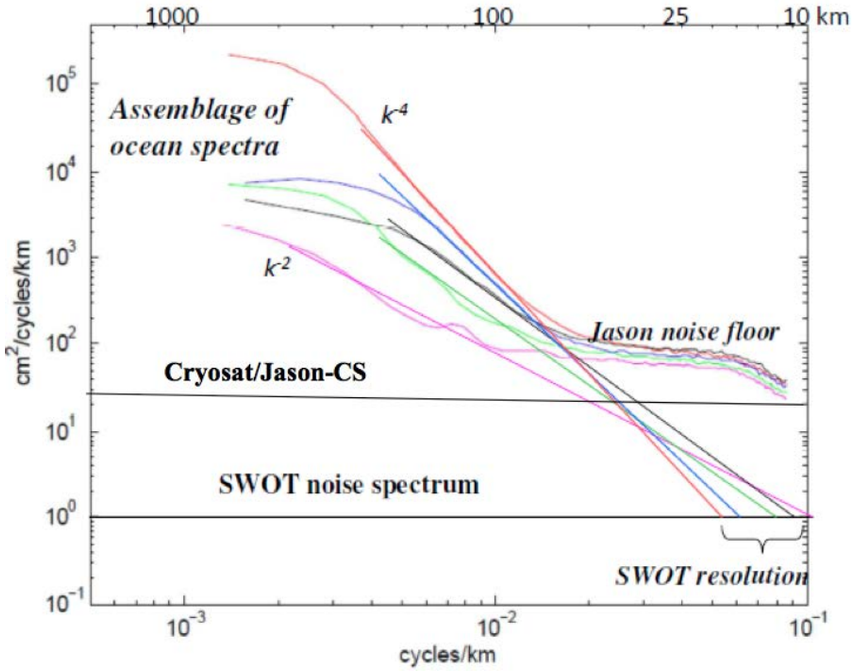
J. Molines, A. Albert, B. Arbic, A. Ajayi, A. Ponte, J. Ansong, F. Lyard, J. Chanut, J. Verron, E. Cosme, B. Barnier, T. Penduff, P. Brasseur

Motivation

- SWOT mission will provide SSH measurements in the range (10km-100km)



Rossby deformation $Rd = NH/f$



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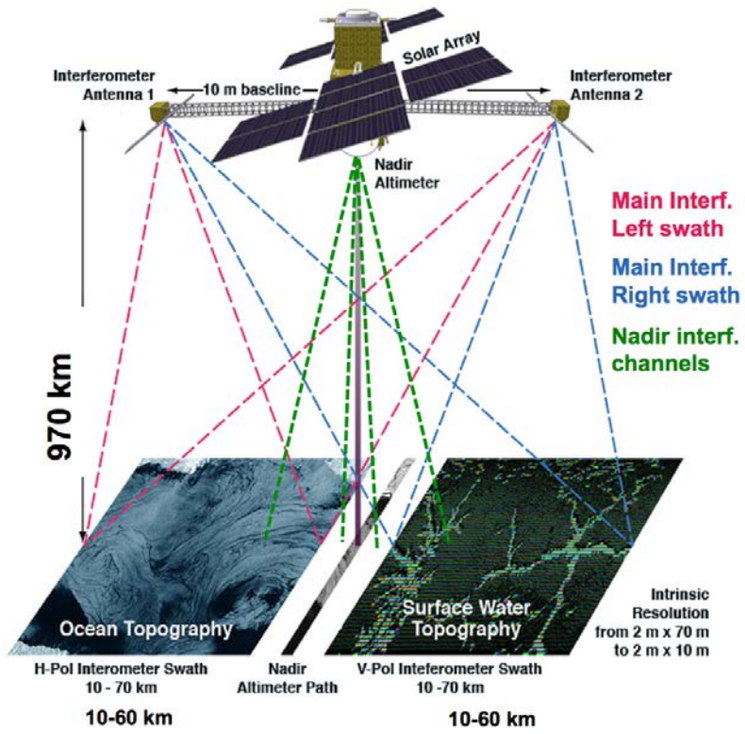

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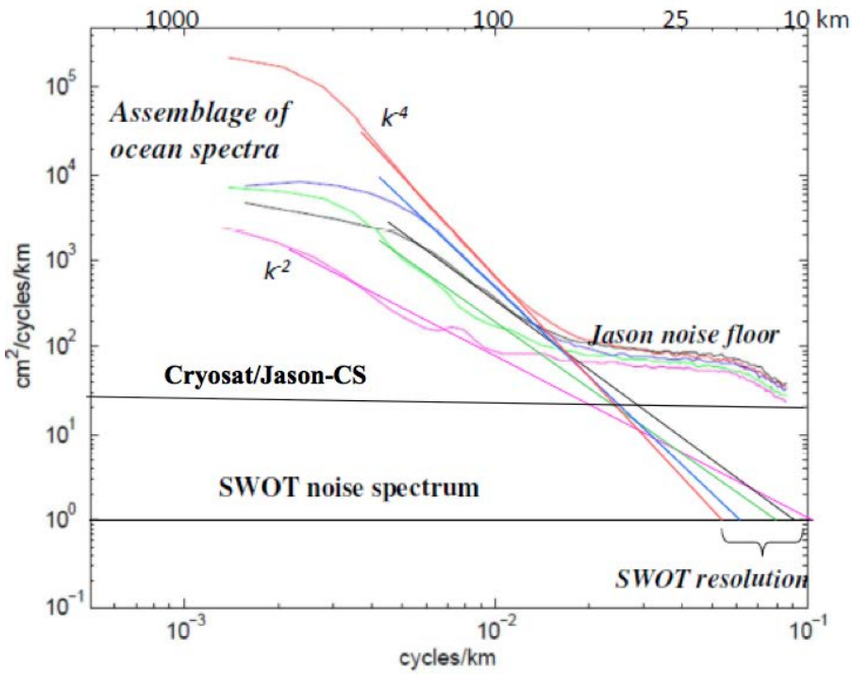

- SWOT mission will help addressing the following questions

1. **Energy exchanges between large and fine scales** (space/time)
2. **Exchanges between the ocean interior and surface** (rate/distribution)
3. **Interactions between IGW / balanced motions** (energy, separation)

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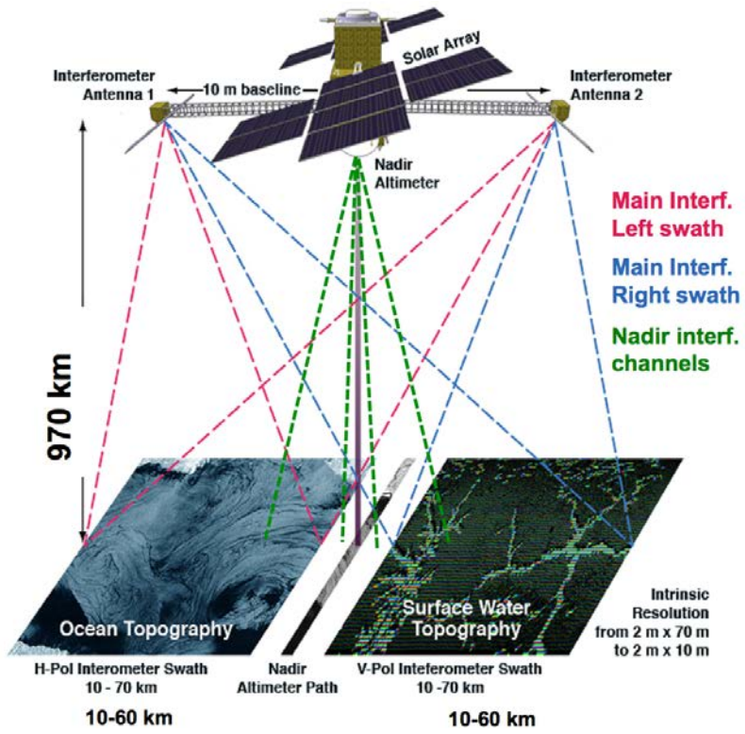

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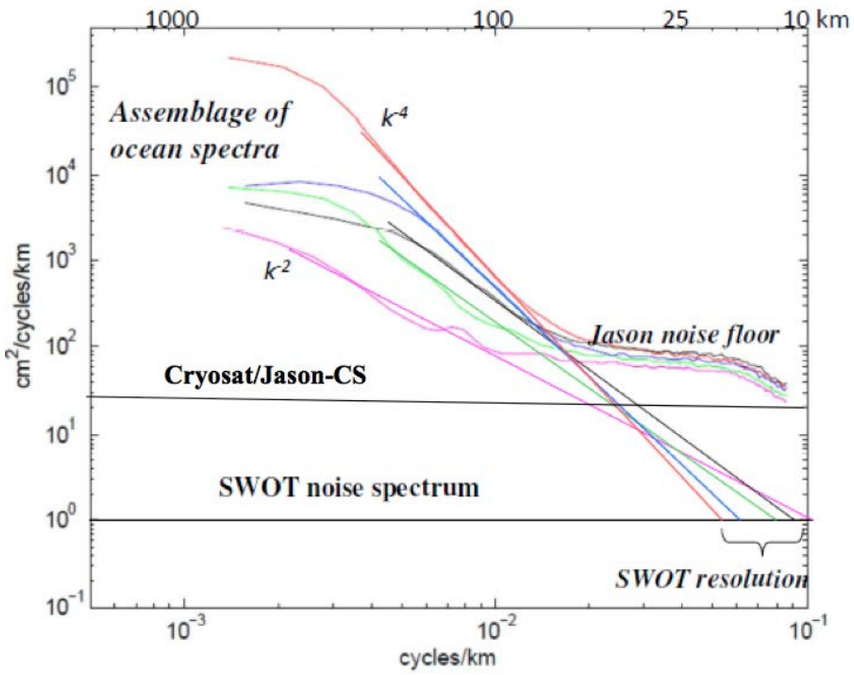

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- Our project intends to leverage hires ocean model simulations in order to document dynamical regimes and prepare inversion techniques for SWOT

Outline

1. Status of NEMO North Atlantic simulations at IGE/Ocean-Next
2. Evaluation of high frequency motions in eNATL60 runs
3. Highlight on recent results on energy exchanges at scales <100km
4. Wrap-up

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North Atlantic simulations in Grenoble

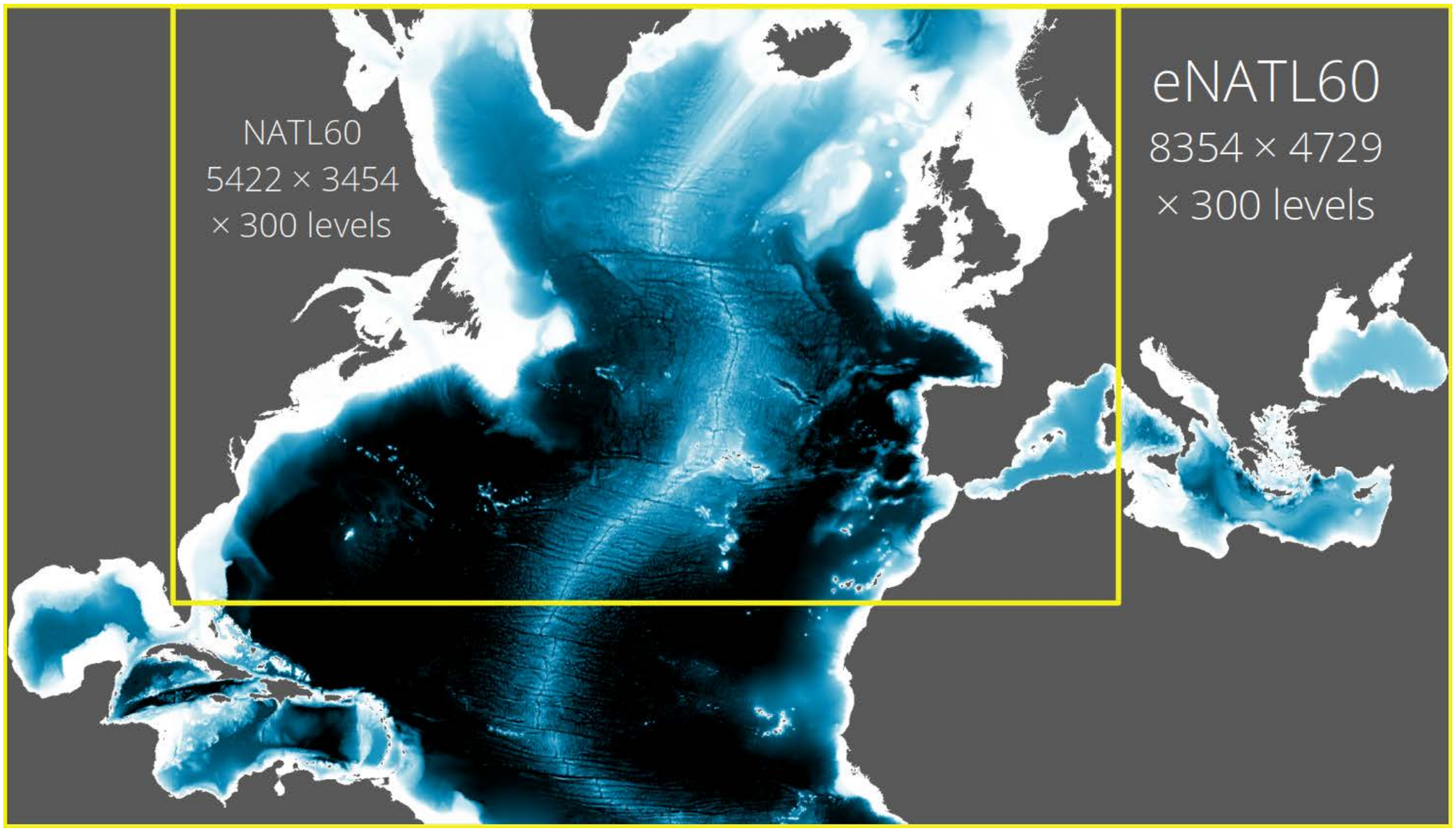
From NATL60 to eNATL60

designed and operated by Ocean Next and the MEOM group @ IGE

in collaboration with : B. Arbic, A. Ponte, F. Lyard, J. Chanut, R. Bourdallé Badie

eNATL60 :

- ✓ - extended domain (6°N + enclosed seas)
- ✓ - with tidal forcing and high freq winds (constituents : K1, O1, S2, M2, N2)
- ✓ - longer spin-up period



North Atlantic simulations in Grenoble

Technical characteristics of eNATL60 experiments

- Numerical code: NEMO 3.6 + xios-2.0
- Horizontal grid: 1/60°, 8354 × 4729 points → 0.8 km < Δx < 1.6 km
- Vertical grid: 300 levels
- # compute points: 6.3 billion
- Required # processors in parallel: 18000
- Tidal motion: potential + LBCs → M2, S2, N2, K1, O1
- Atmospheric forcing: ERA-Interim (ECMWF)
- Daily LBCs U,V, T, S & sea-ice: GLORYS12 v1 (1/12°, Mercator Ocean)
- No-slip condition at the coast
- 40 million cpu-hours burnt (granted by EU/PRACE)

North Atlantic simulations in Grenoble

Twin-experiment

16 months

Explicit Tidal Motion

1-year spinup → 6-month spinup → **Production**

13 months

2008 → 2009 → 2010

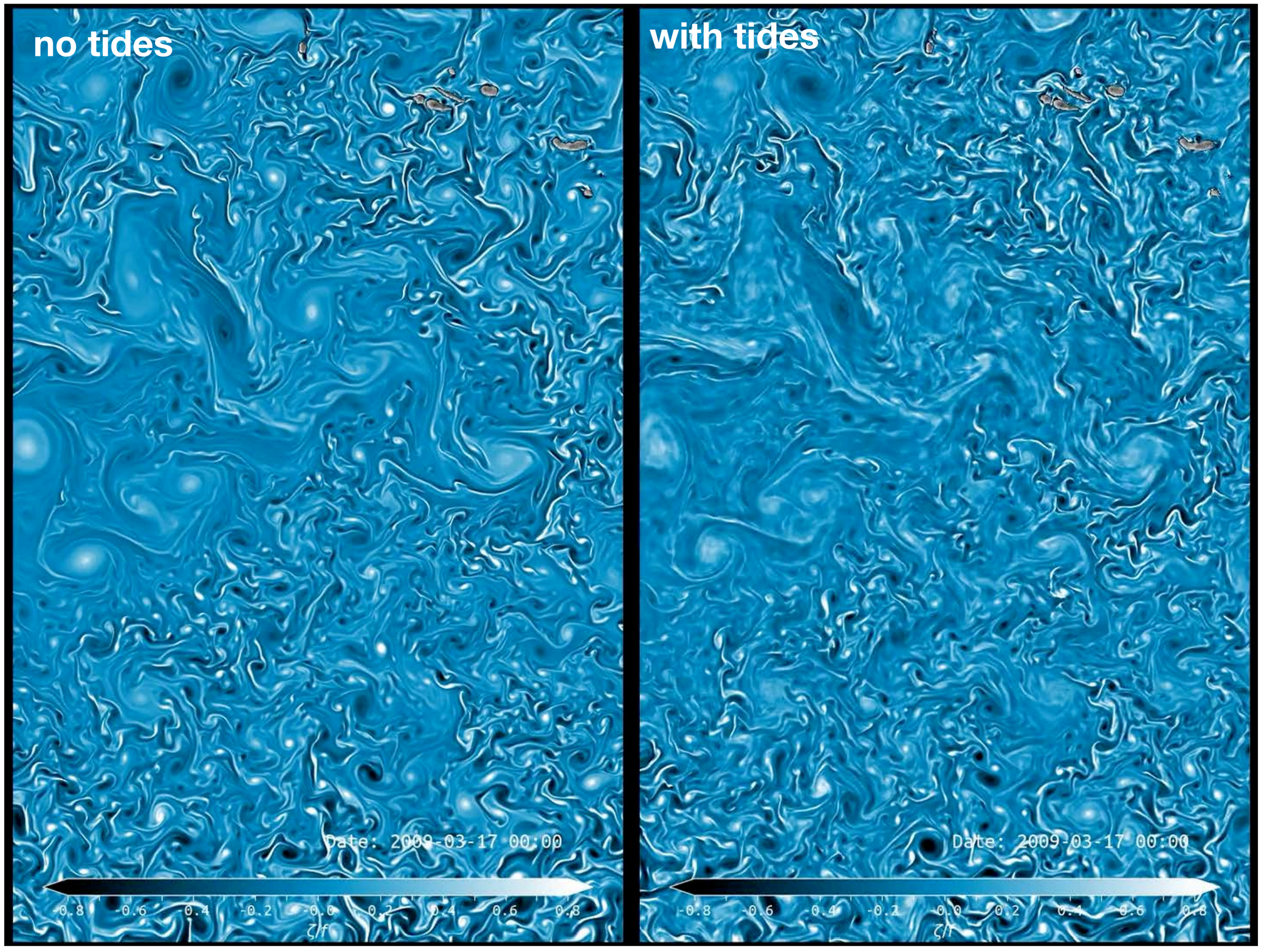
2D fields	1 hour	1 hour	1 hour
3D fields	5 days	1 day	**1 hour!**

→ 1.5 PB of model output have been produced

- surface fields are available on CNES cluster and Pangeo cloud
- the full 3D archive is store on a supercomputer in Montpellier

North Atlantic simulations in Grenoble

surface relative vorticity



North Atlantic simulations in Grenoble

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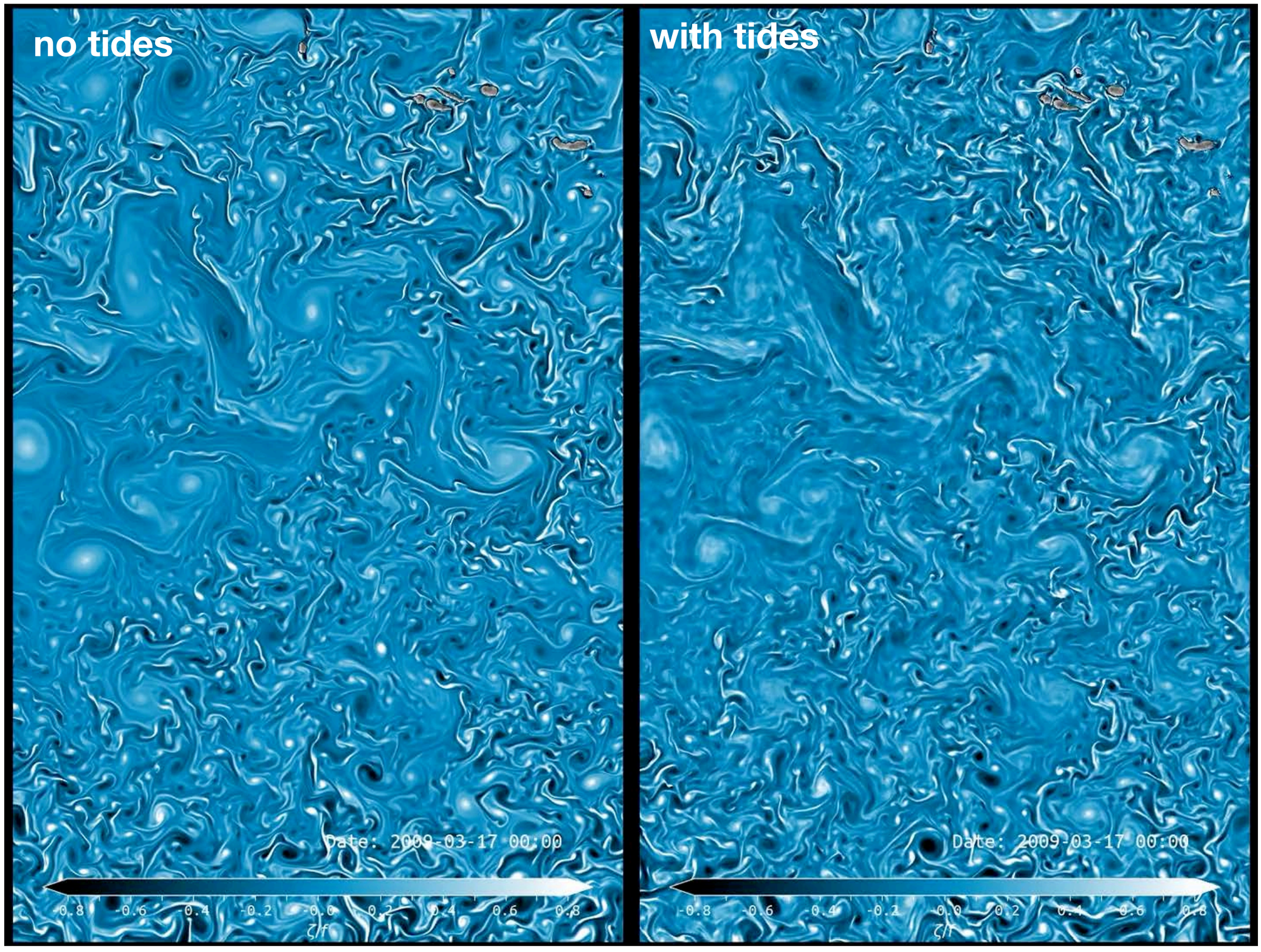

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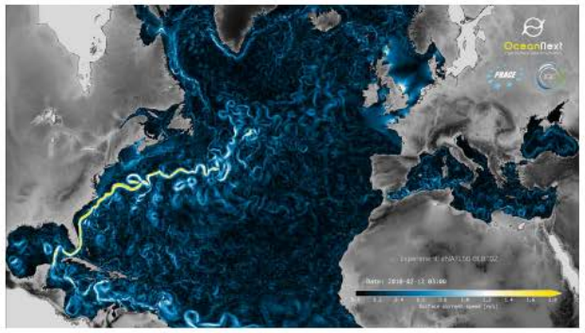
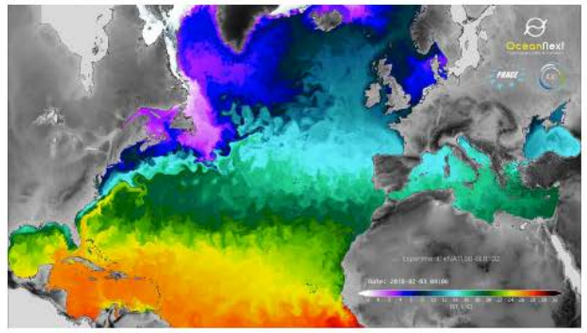
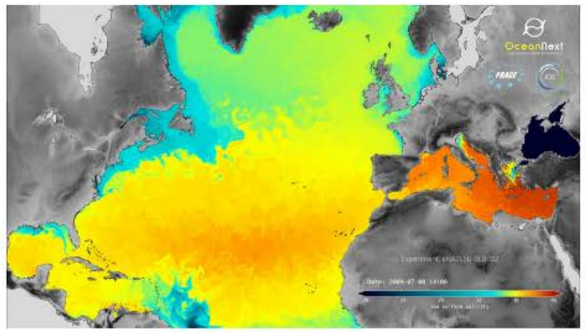


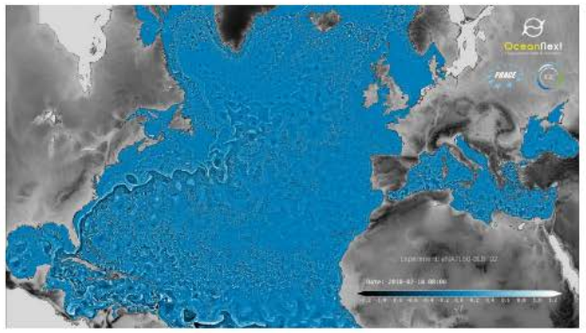
Current speed in eNATL60 simulation with explicit tidal motion.
Ocean Next | 175 plays



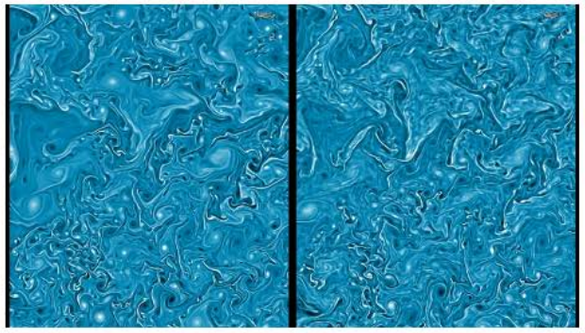
SST + Sea-Ice in eNATL60 simulation with explicit tidal motion.
Ocean Next | 61 plays



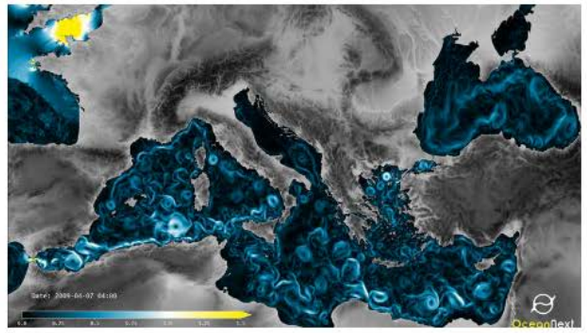
Surface Salinity in eNATL60 simulation with explicit tidal motion.
Ocean Next | five plays



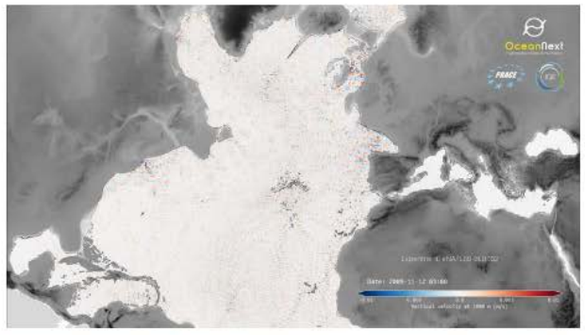
Surface curl/f in eNATL60 simulation with explicit tidal motion.
Ocean Next | 37 plays



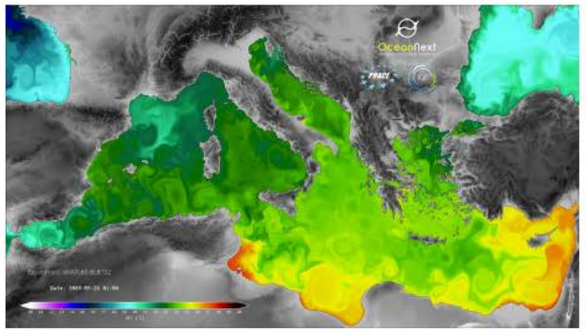
Azores zoom: hourly surface curl/f in eNATL60 spinup without a...
Ocean Next | 141 plays



Med Sea zoom: hourly surface current speed in eNATL60 spinup...
Ocean Next | 106 plays



Vertical velocity (w) at 1000 m in eNATL60 simulation with explici...
Ocean Next | 15 plays



Med Sea zoom: hourly surface temperature in eNATL60 simulati...
Ocean Next | 14 plays

Check Ocean Next's Vimeo channel for more videos about the eNATL60 model experiments:

→ https://vimeo.com/oceannext

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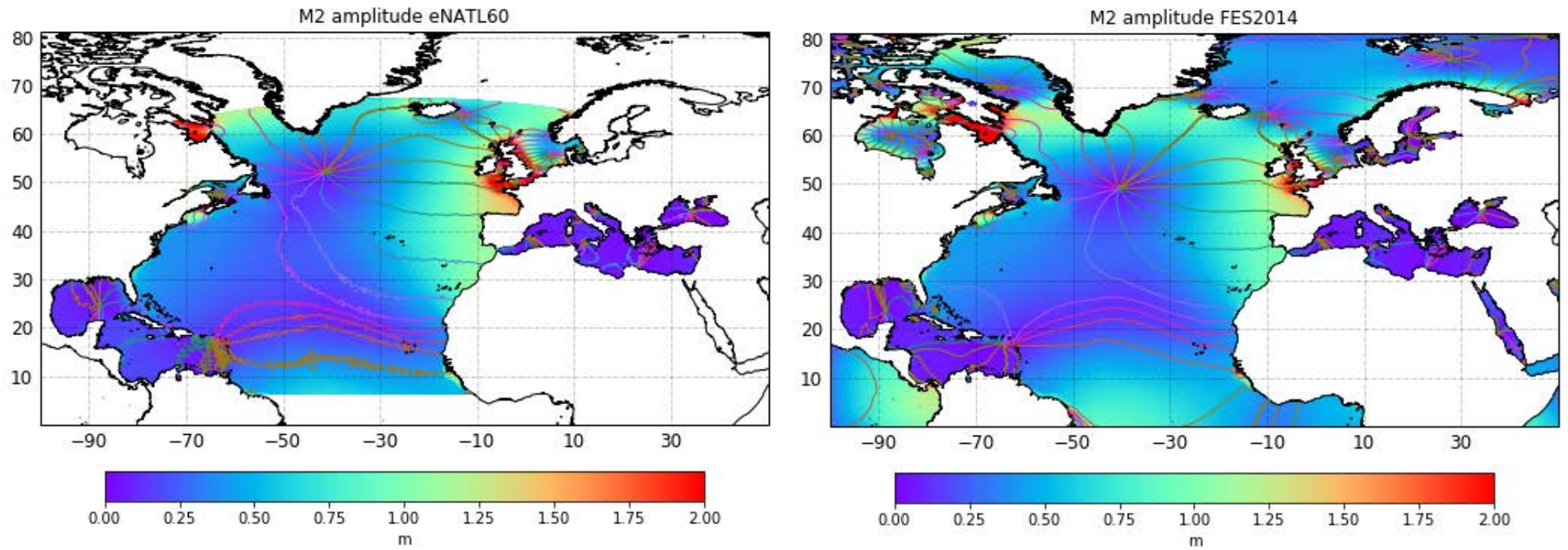
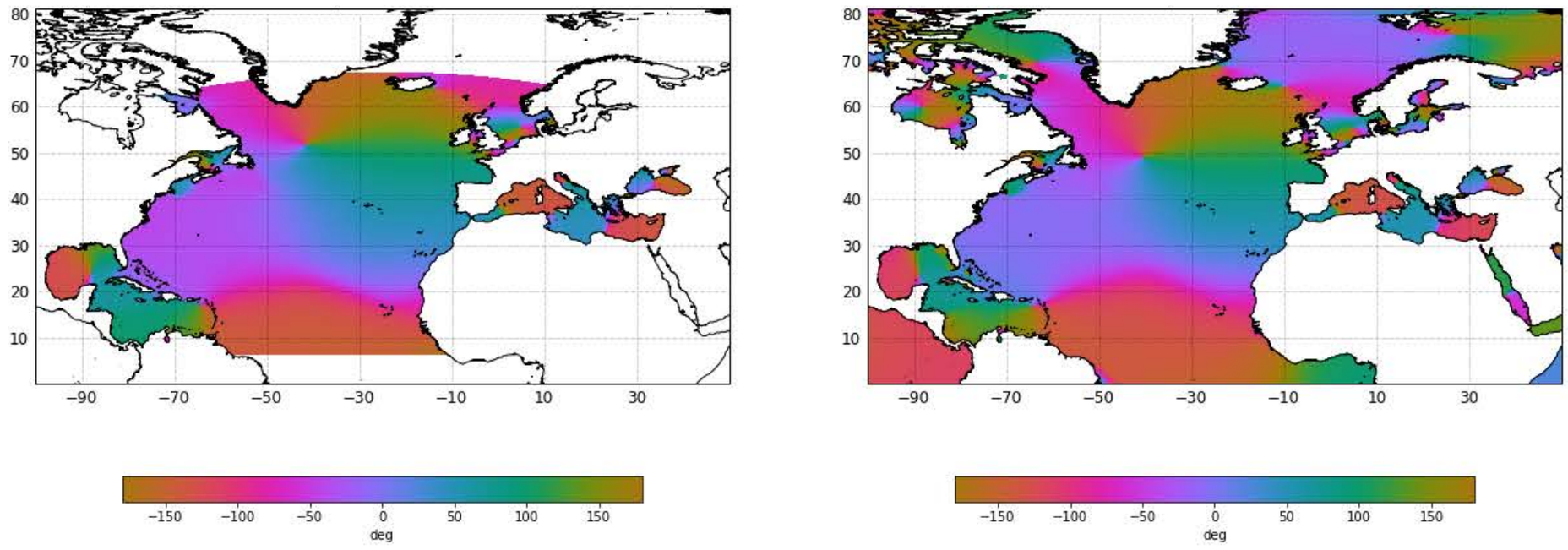
Evaluation of high frequency motions in eNATL60 runs

Evaluation of simulated barotropic tides vs FES2014

M2 amplitude



M2 phase



analyses show a good consistency for all the simulated tidal constituents

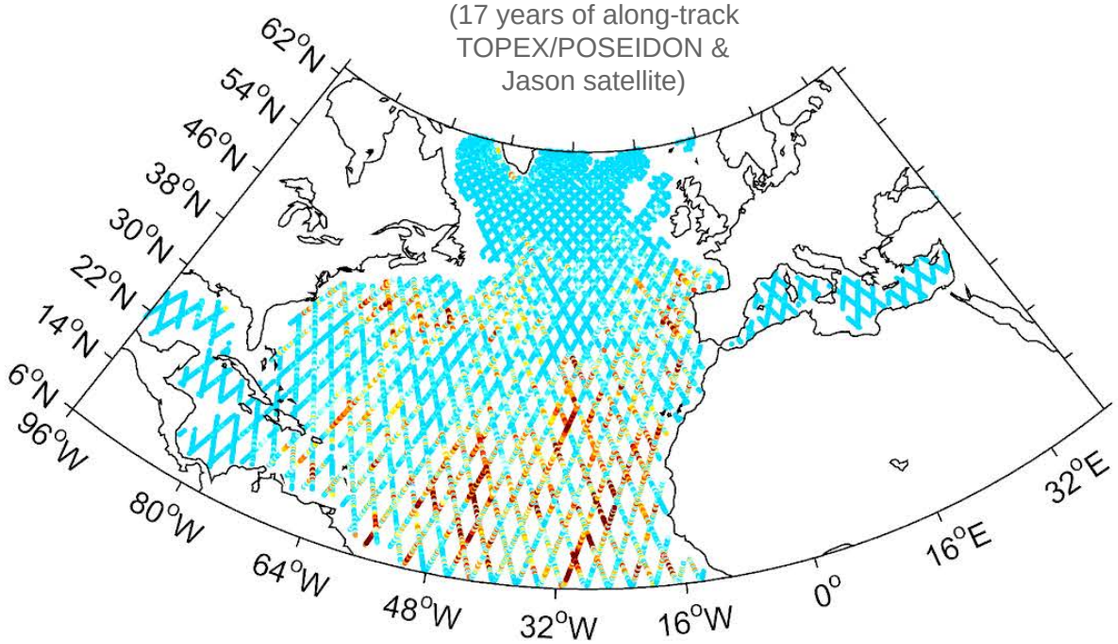
M2, S2, N2, K1, O1

Evaluation of high frequency motions in eNATL60 runs

Evaluation of baroclinic tides vs altimetry

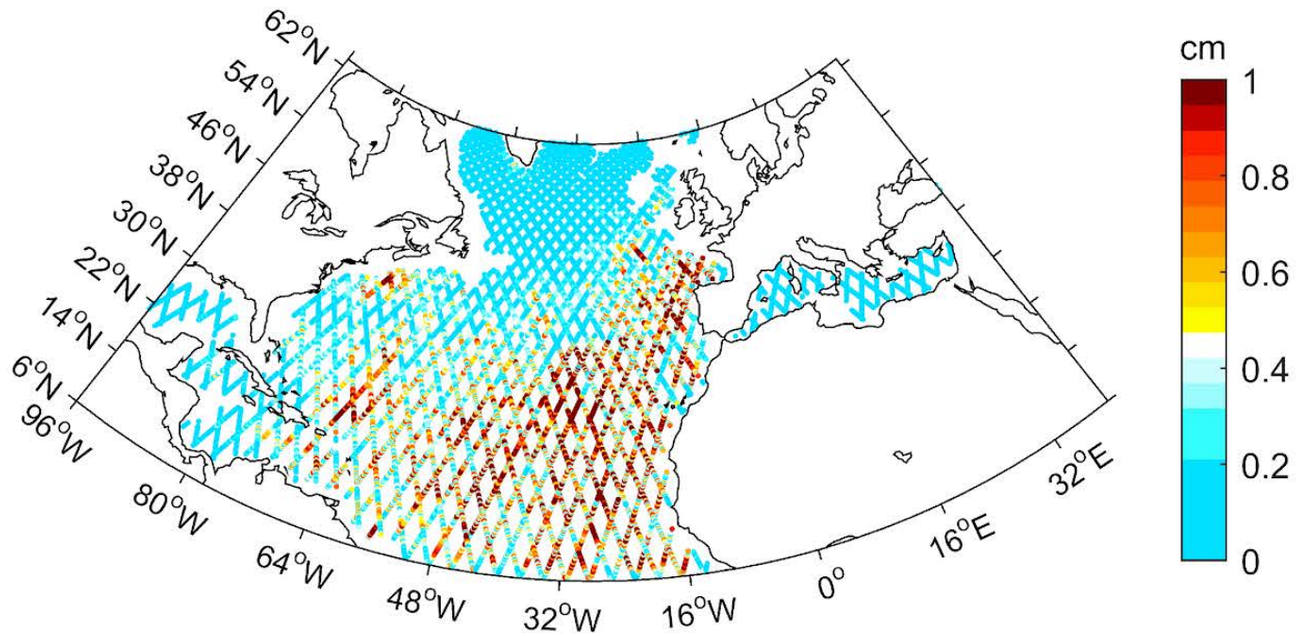
Altimetry

(17 years of along-track TOPEX/POSEIDON & Jason satellite)



RMSA: 0.37 cm

NEMO – eNATL60



RMSA: 0.49 cm

analyses show that eNATL60 slightly overestimates SSH variance as is expected for models without explicit wave drag

Courtesy of Joseph Ansong @ Univesity of Michigan.

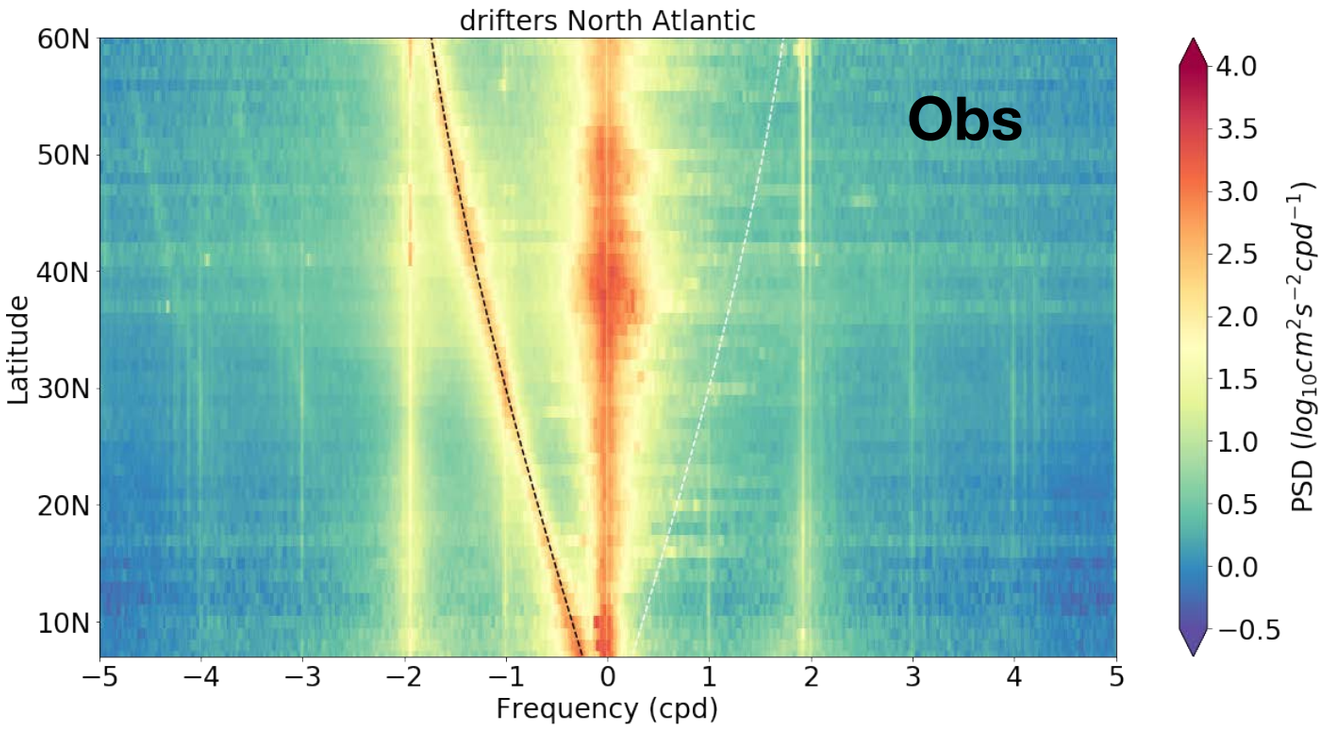
Ansong, J. et al. 2019: *Investigating the fidelity of barotropic and internal tides in global ocean models.* In preparation.

Ansong, J. et al. 2015: *Indirect evidence for substantial damping of low-mode internal tides in the open ocean.* J. Geophys. Res., 120, 9.

Evaluation of high frequency motions in eNATL60 runs

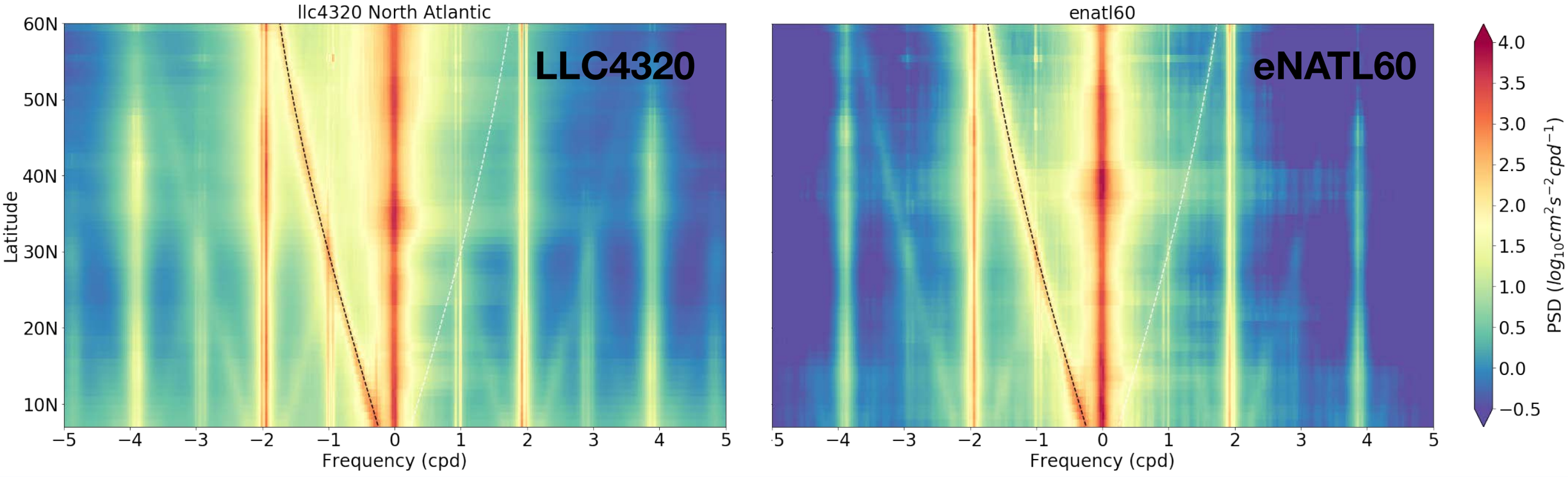
Evaluation wrt GDP drifter data : KE in frequency space

courtesy A. Ponte et X. Yu



analysis shows that the model :

- overestimates semi-diurnal motions
- underestimates inertial motions
- capture adequately diurnal motions



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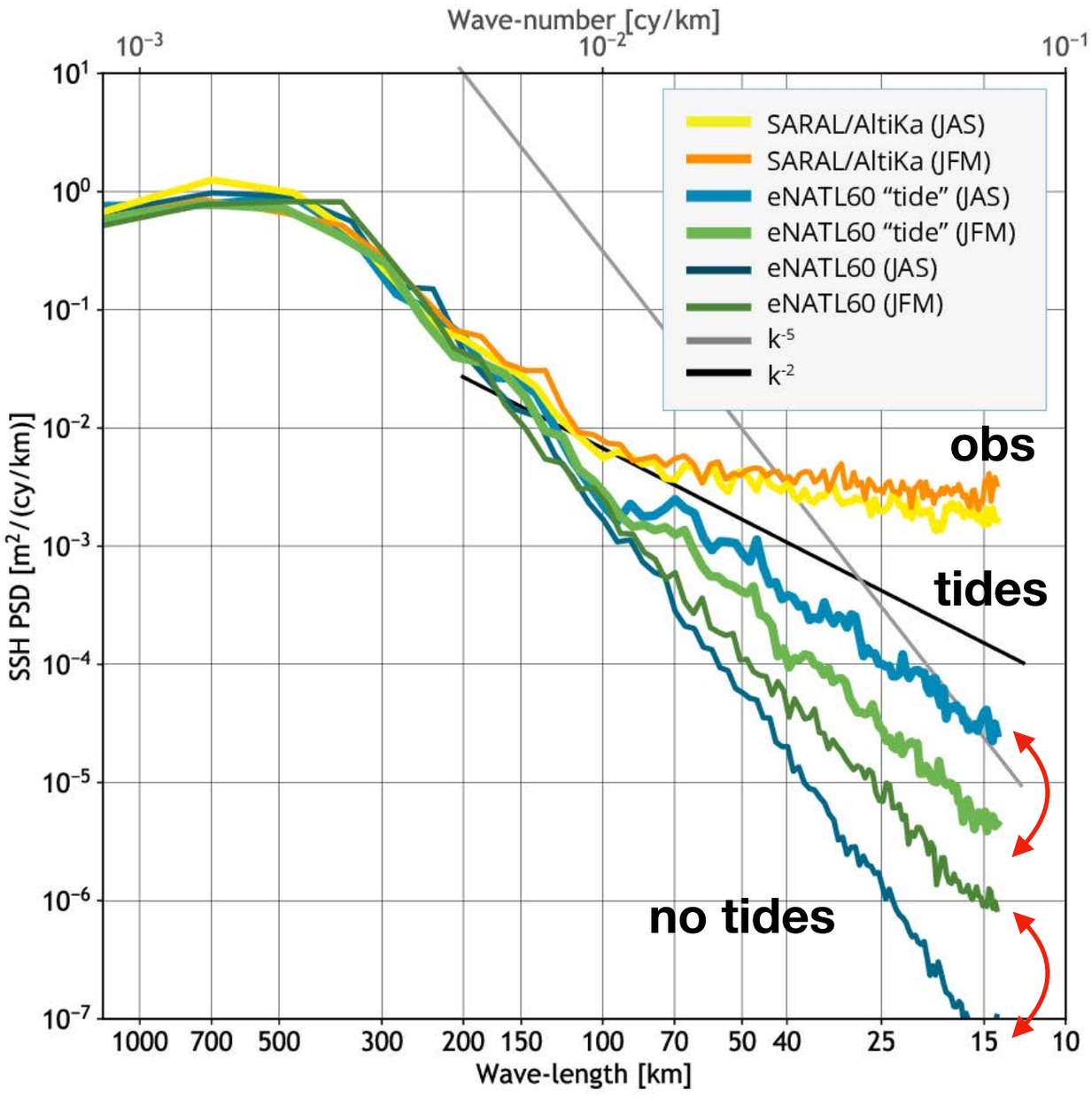
Seasonality of SSH wavenumber spectra with/without tides

Along-track wavenumber spectra around Azores Archipelago



summer **winter**

analysis shows :

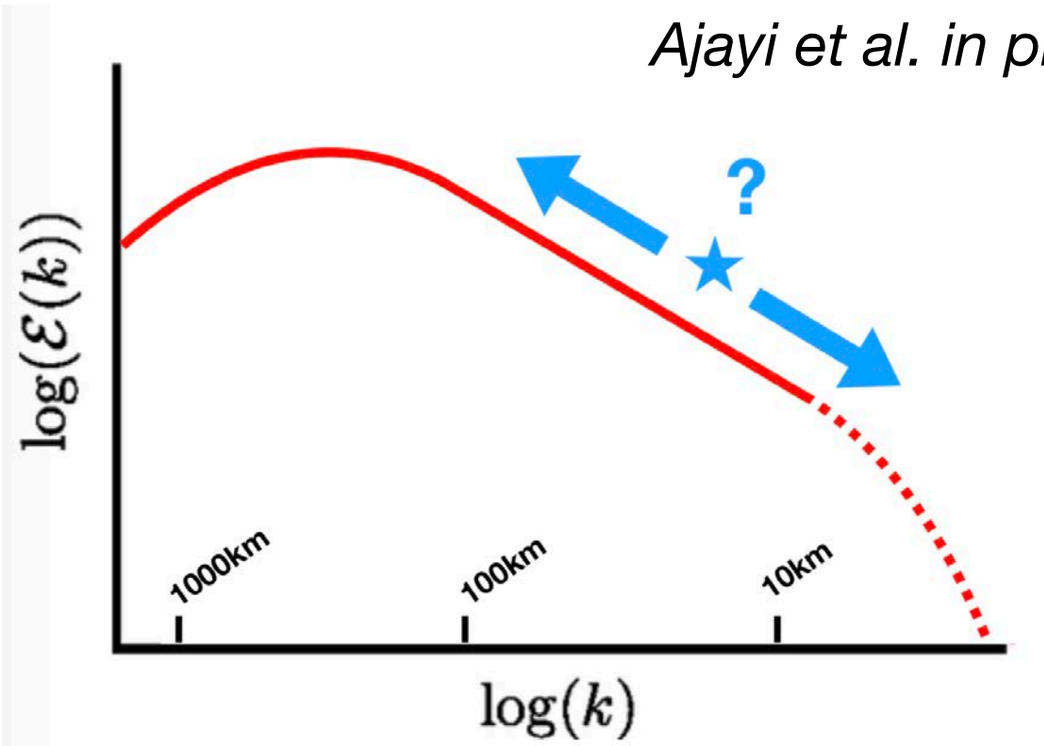
- tidal and non-tidal runs compare well with present day altimeters (AltiKa, S3A)

- shallowing of SSH slopes at scale <70km in the tidal run

- out-of-phase seasonality of the tidal and non-tidal run in this region

Kinetic energy cascade in the mesoscale range

Ajayi et al. in prep



- SWOT will help mapping KE exchange across mesoscales
- regimes of KE cascade and spectral slopes are related
- over the mesoscale inertial range, slopes are consistent with QG predictions
- results reproduced with HYCOM50 and NATL60

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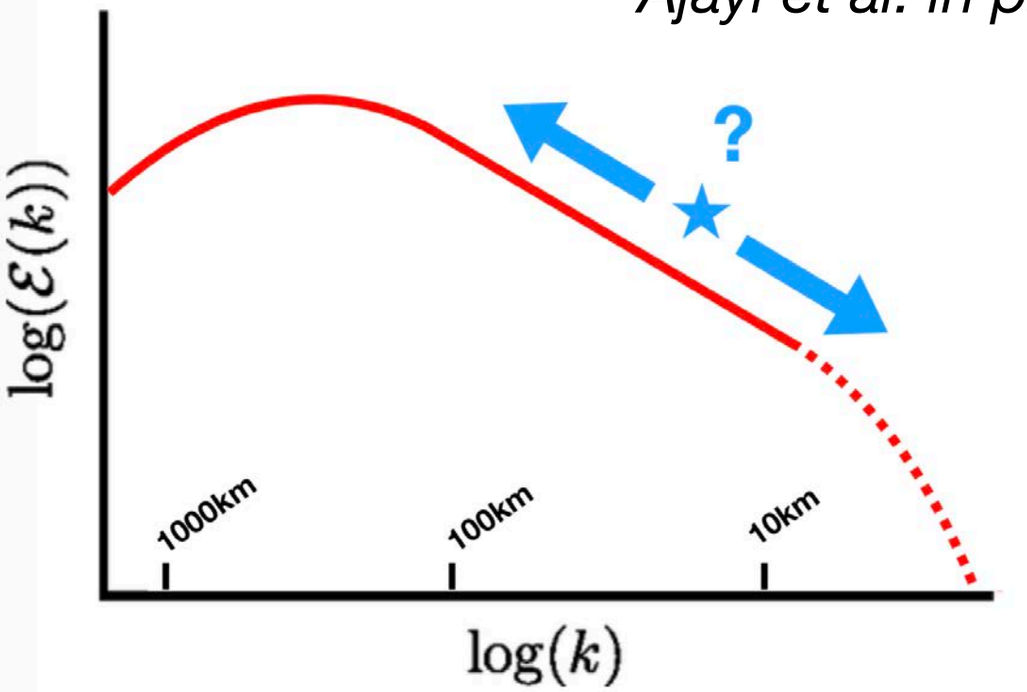

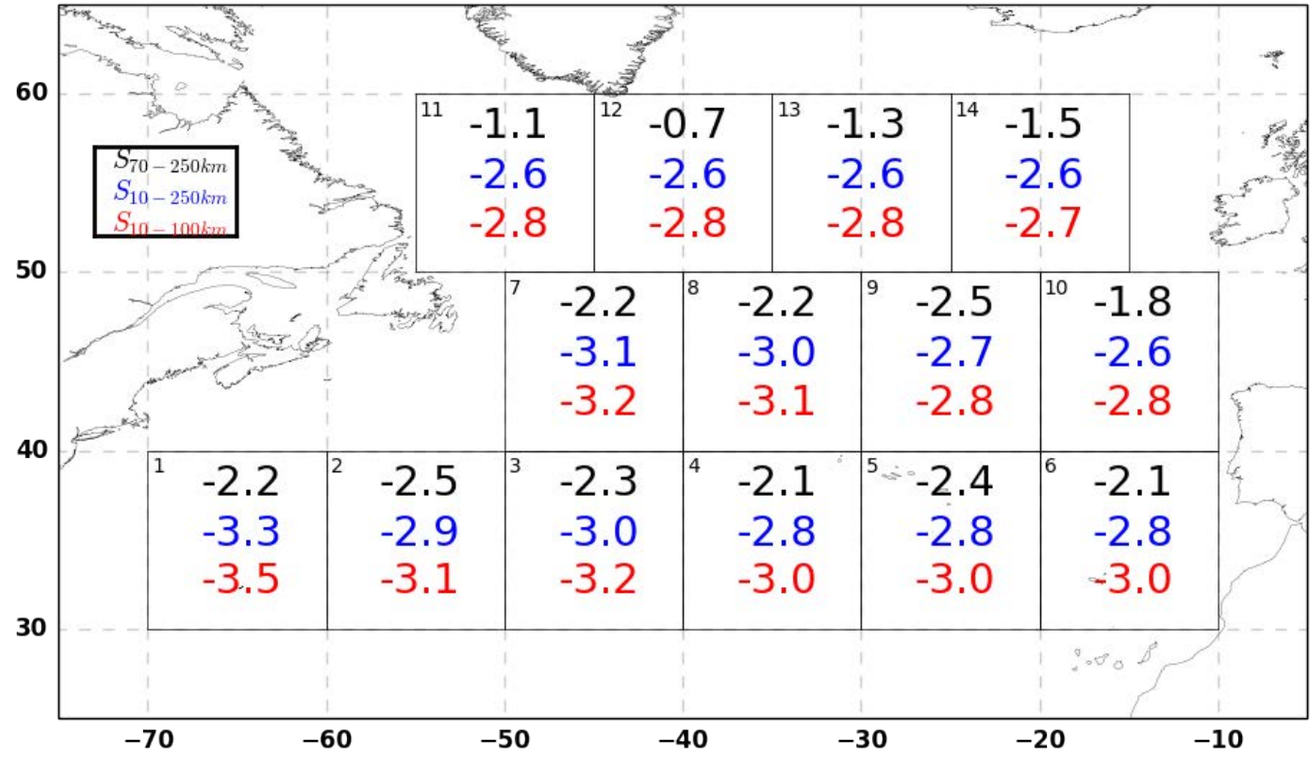

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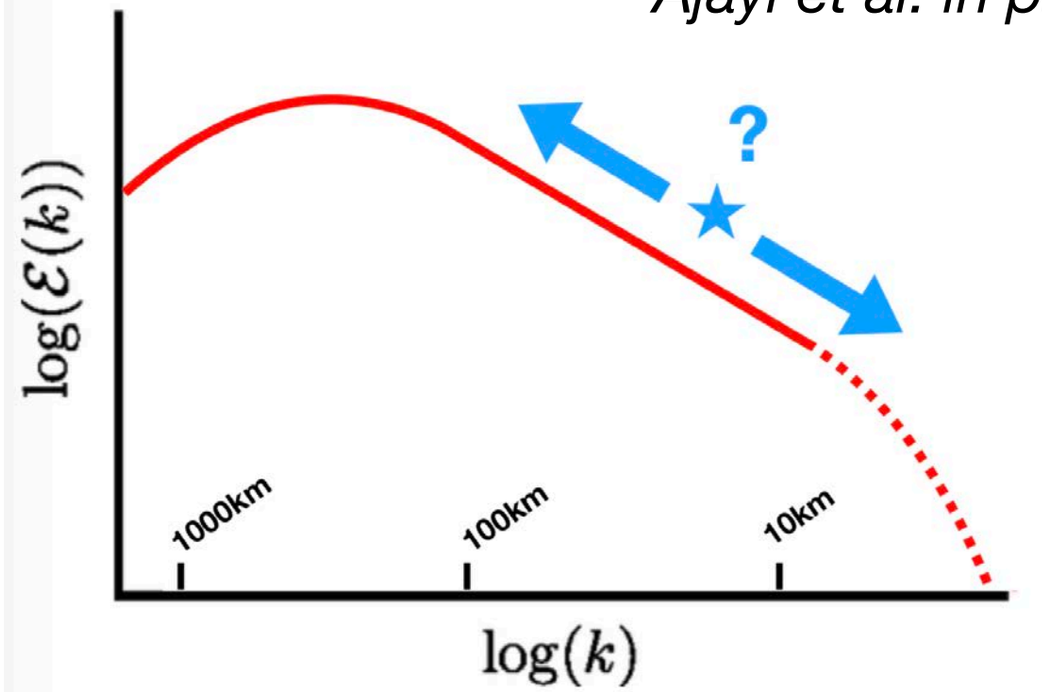

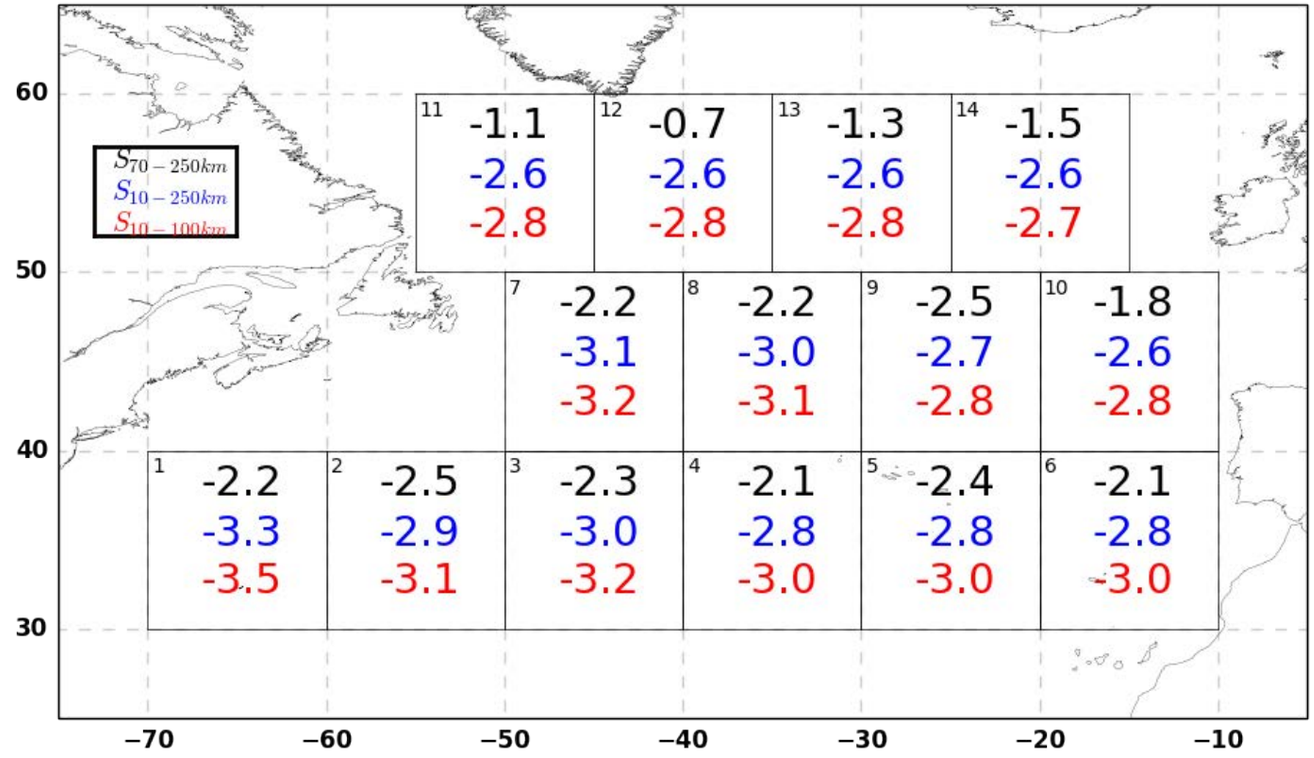

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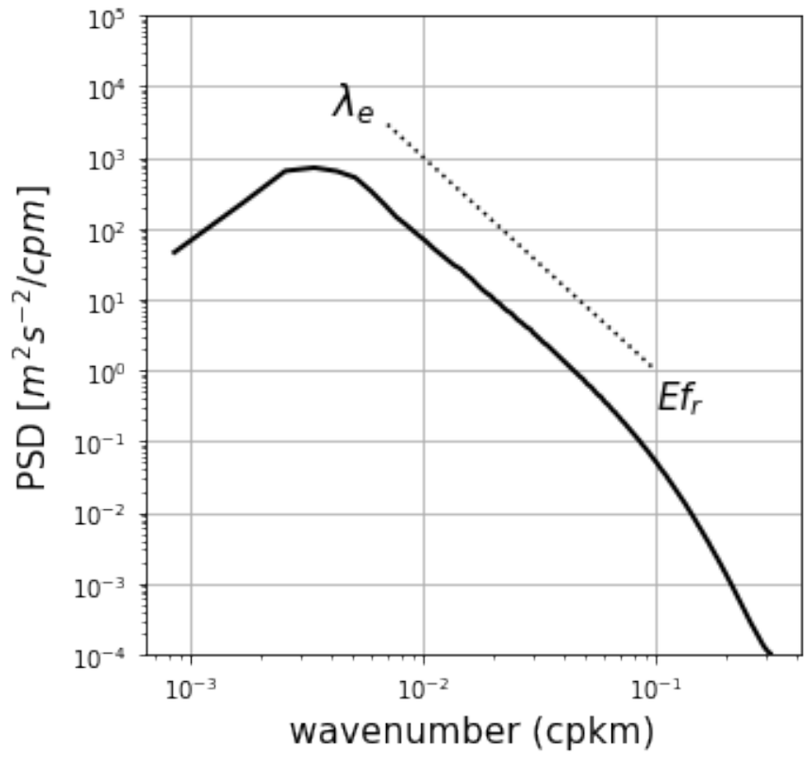

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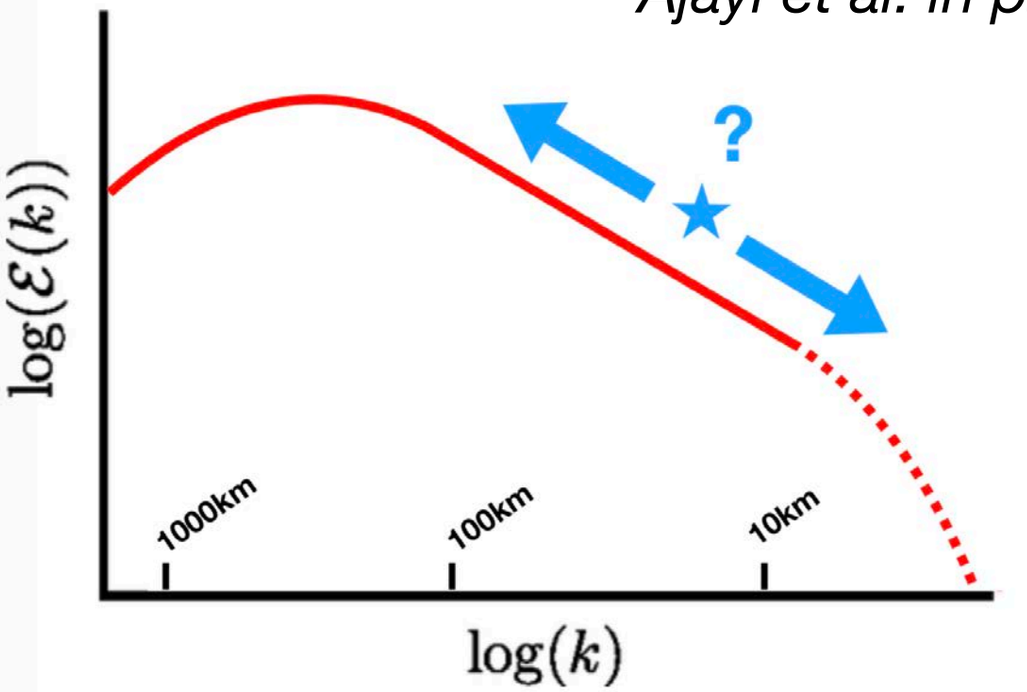

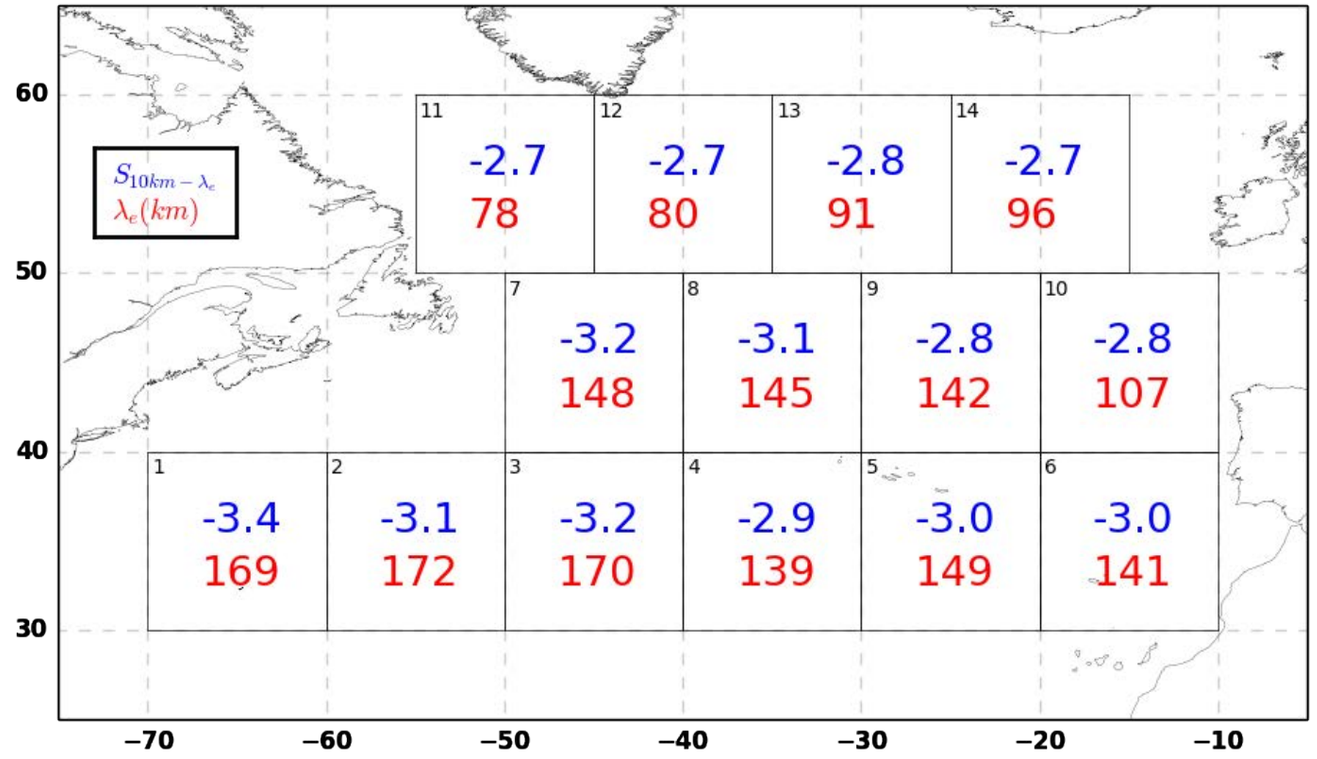

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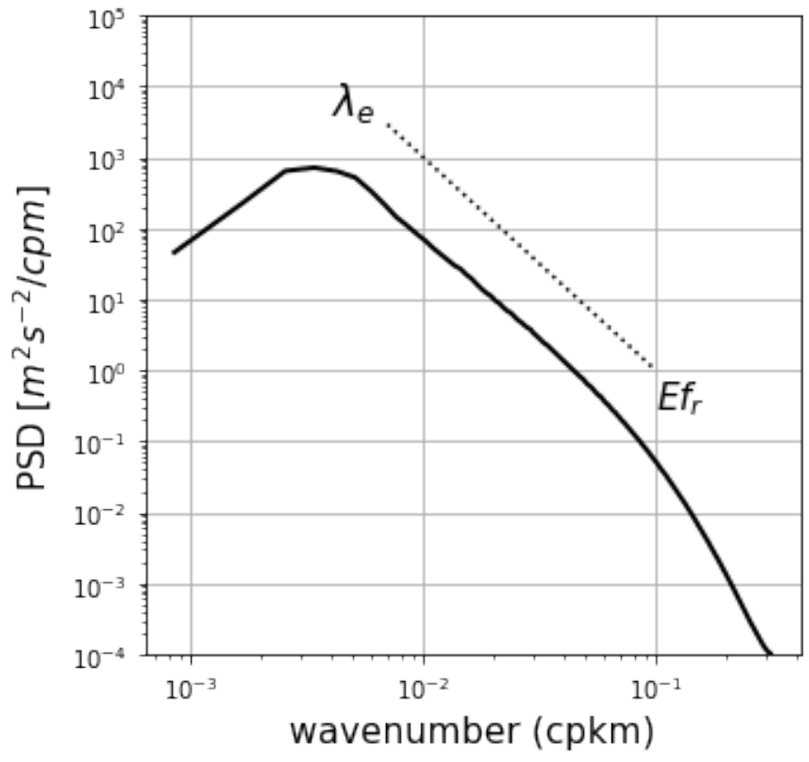
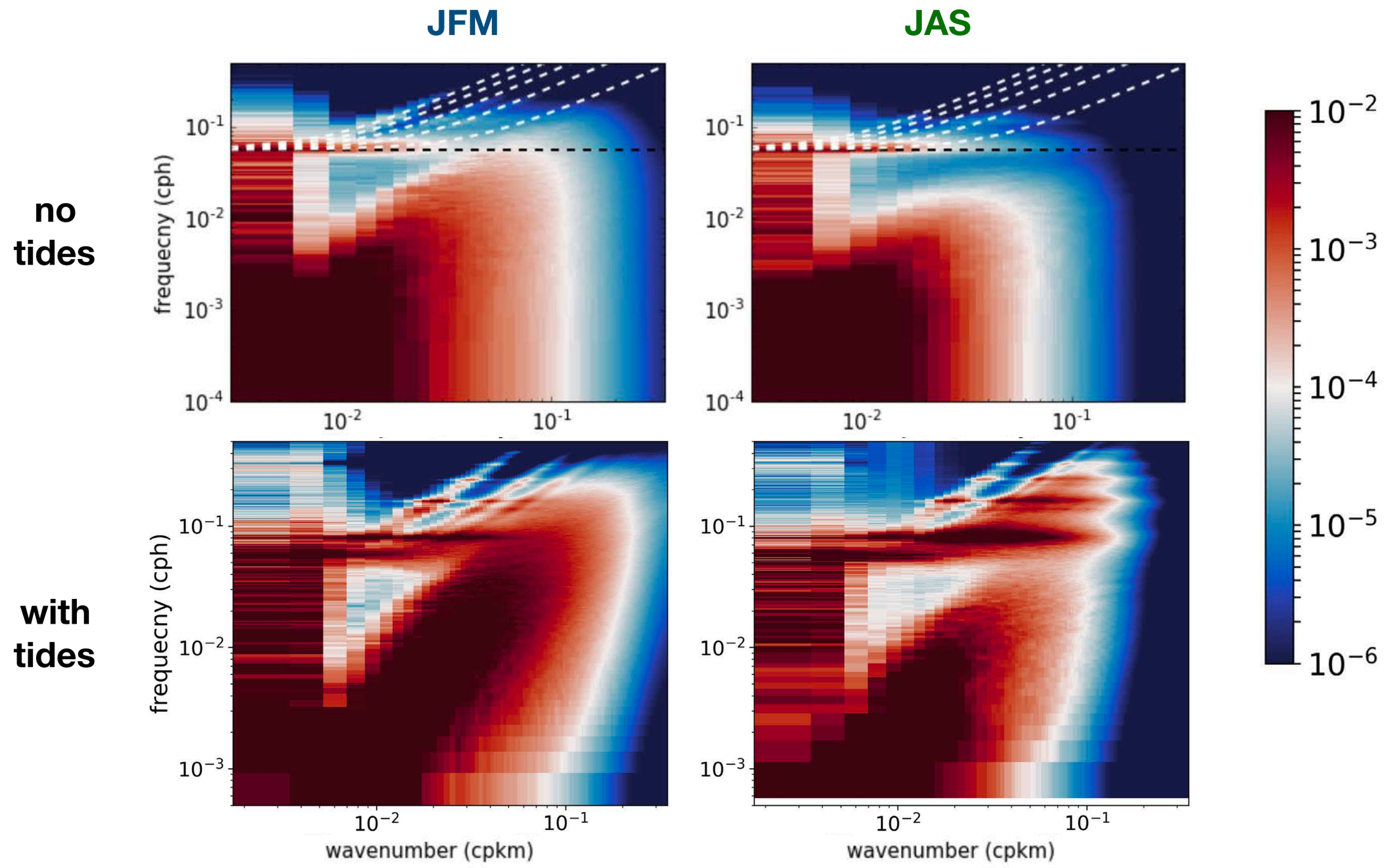


Kinetic energy exchanges involving wave motions

Kinetic Energy in frequency-space domain

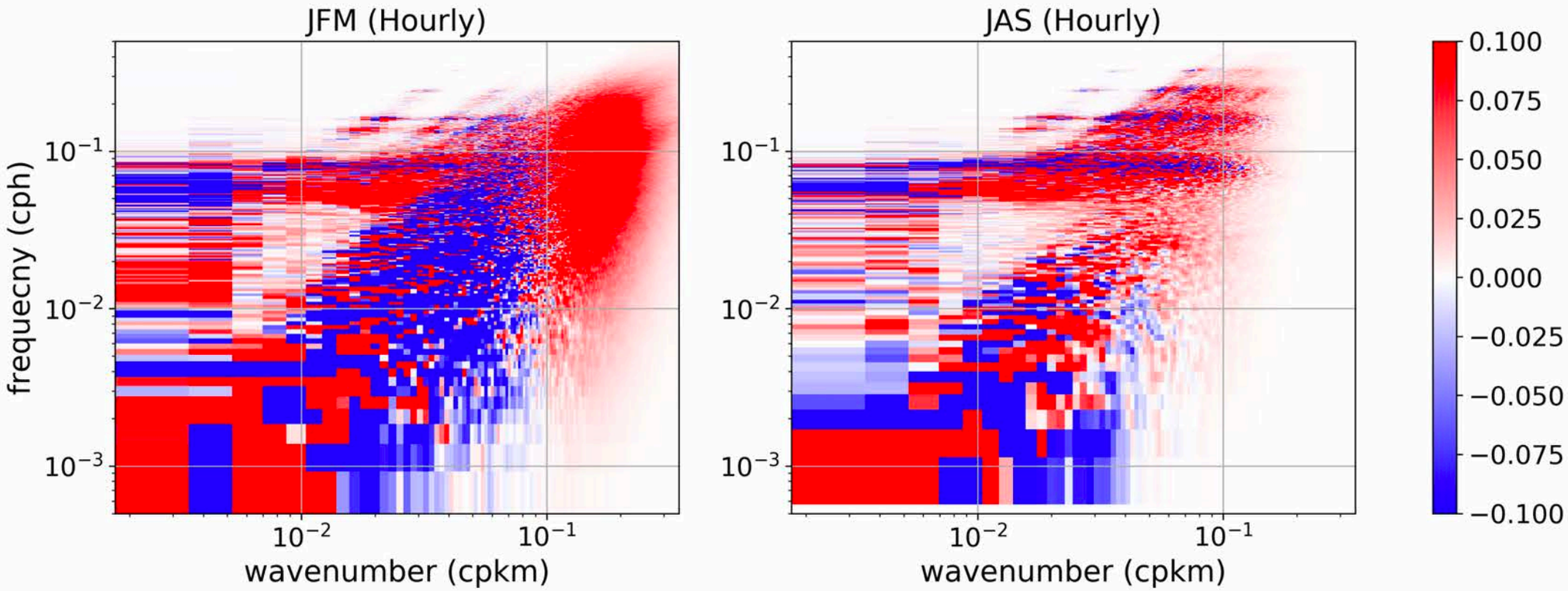
Central North Atlantic

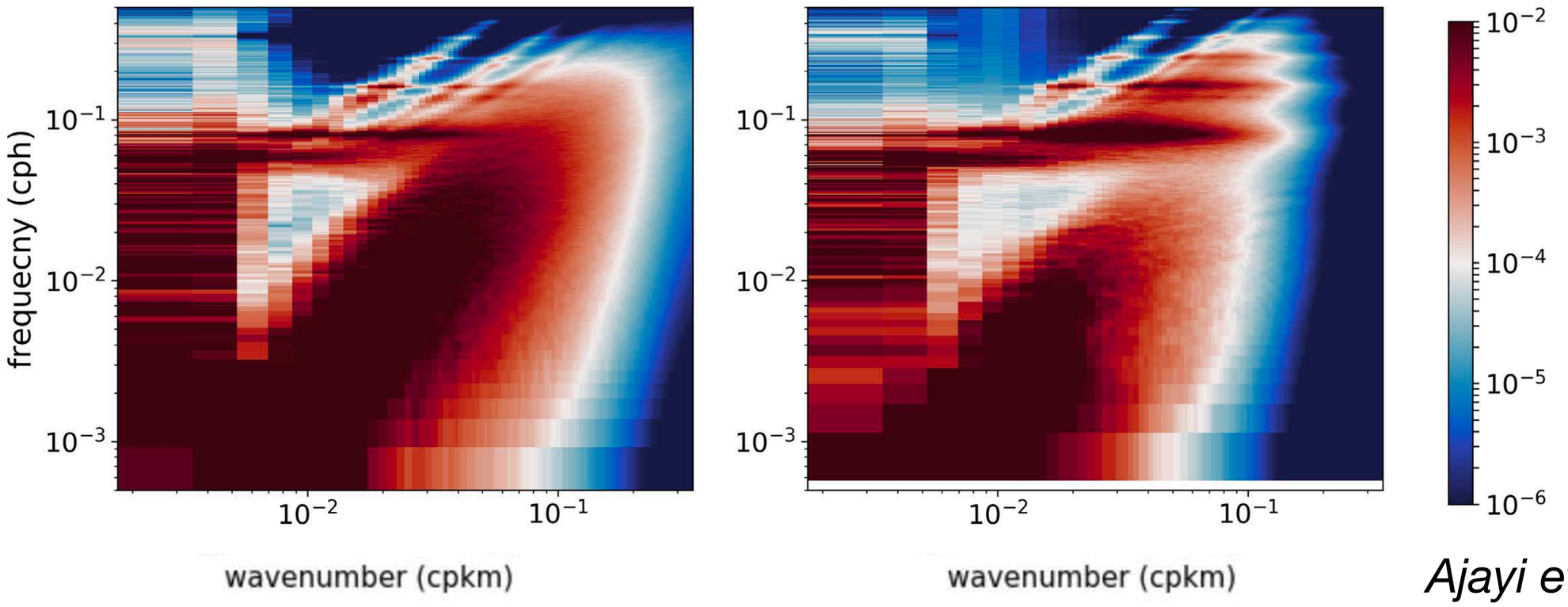


Ajayi et al. in prep

Kinetic energy exchanges involving wave motions

Kinetic Energy transfers in frequency-space domain





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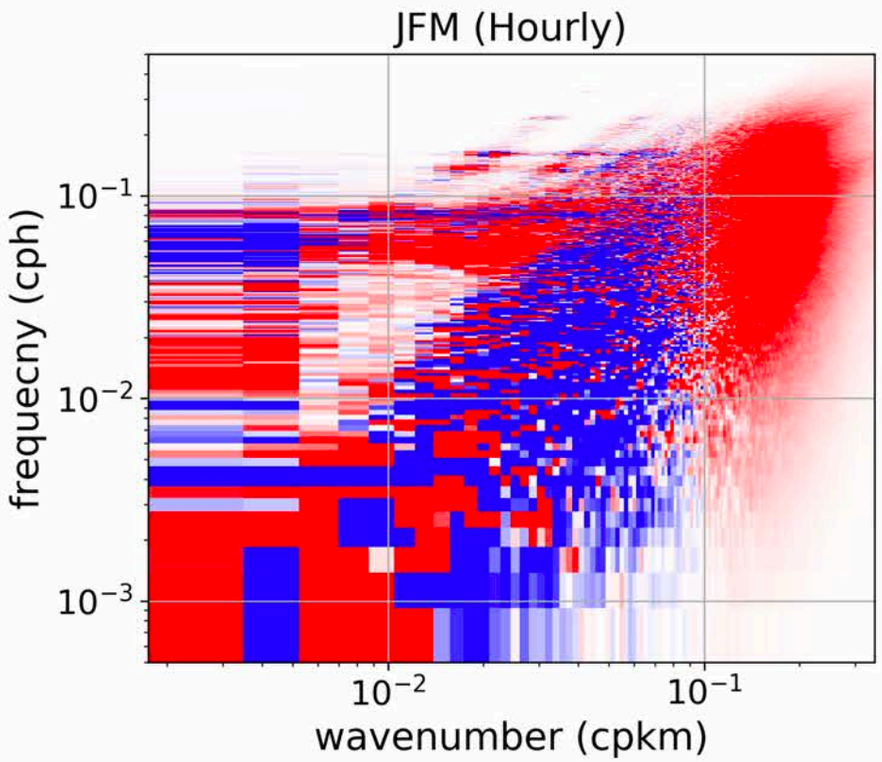
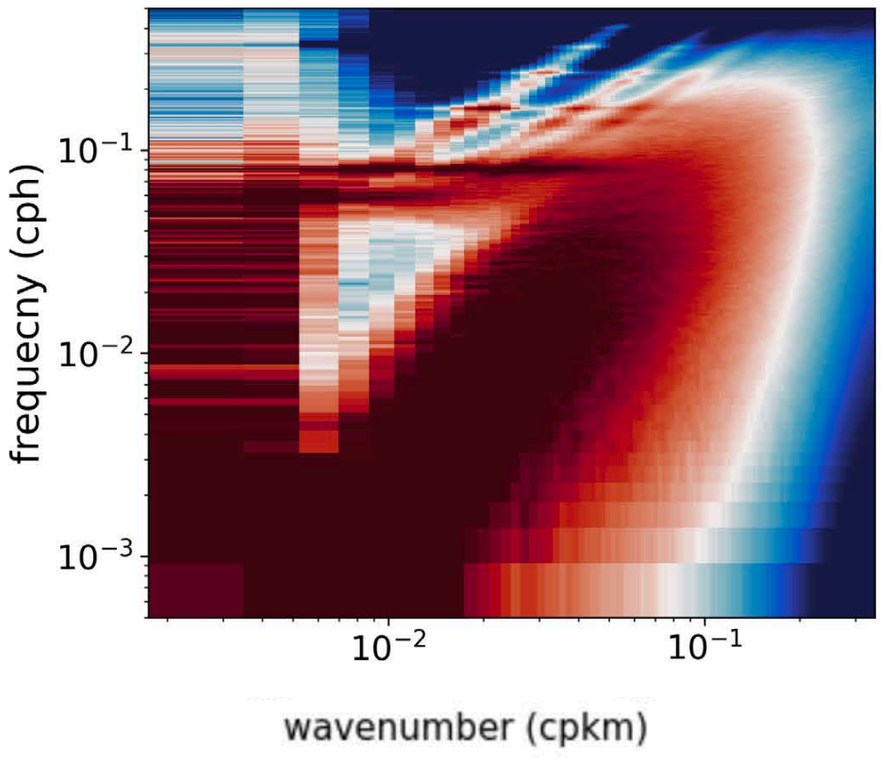
Kinetic Energy transfers in frequency-space domain



Winter conditions favour a direct energy cascade from scales >10km to scales <10km



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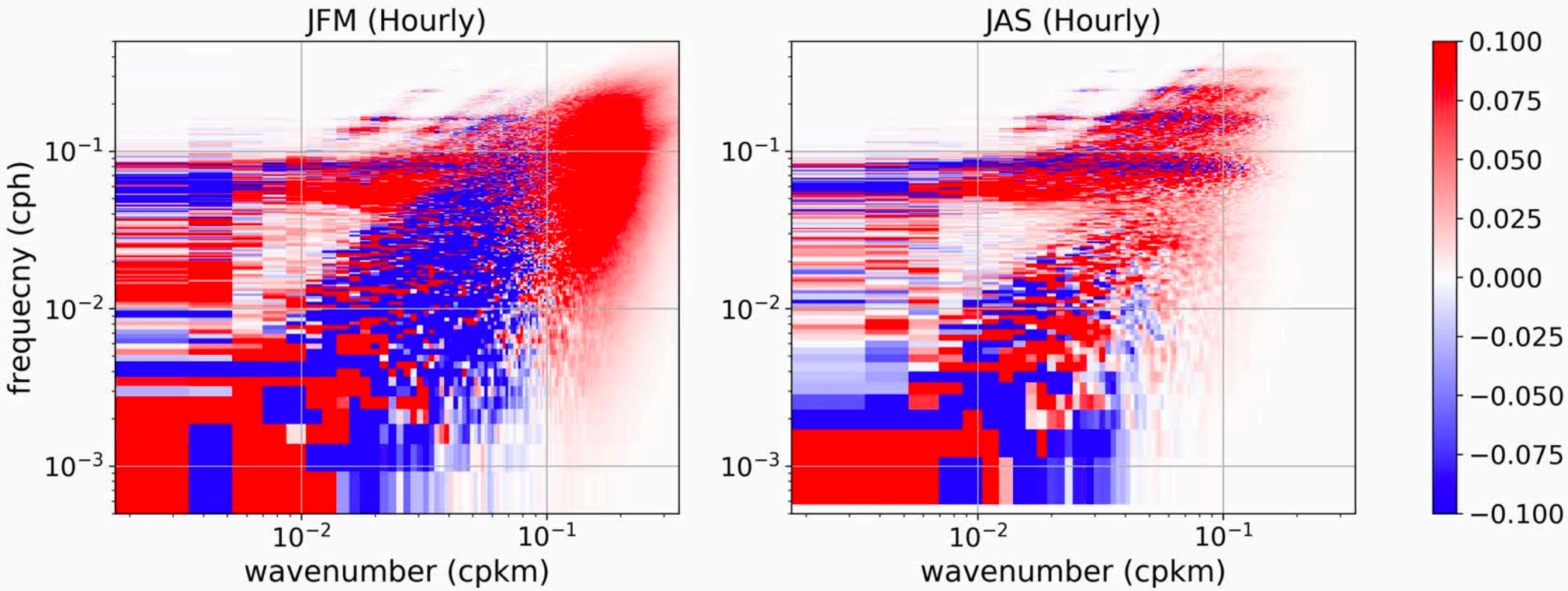
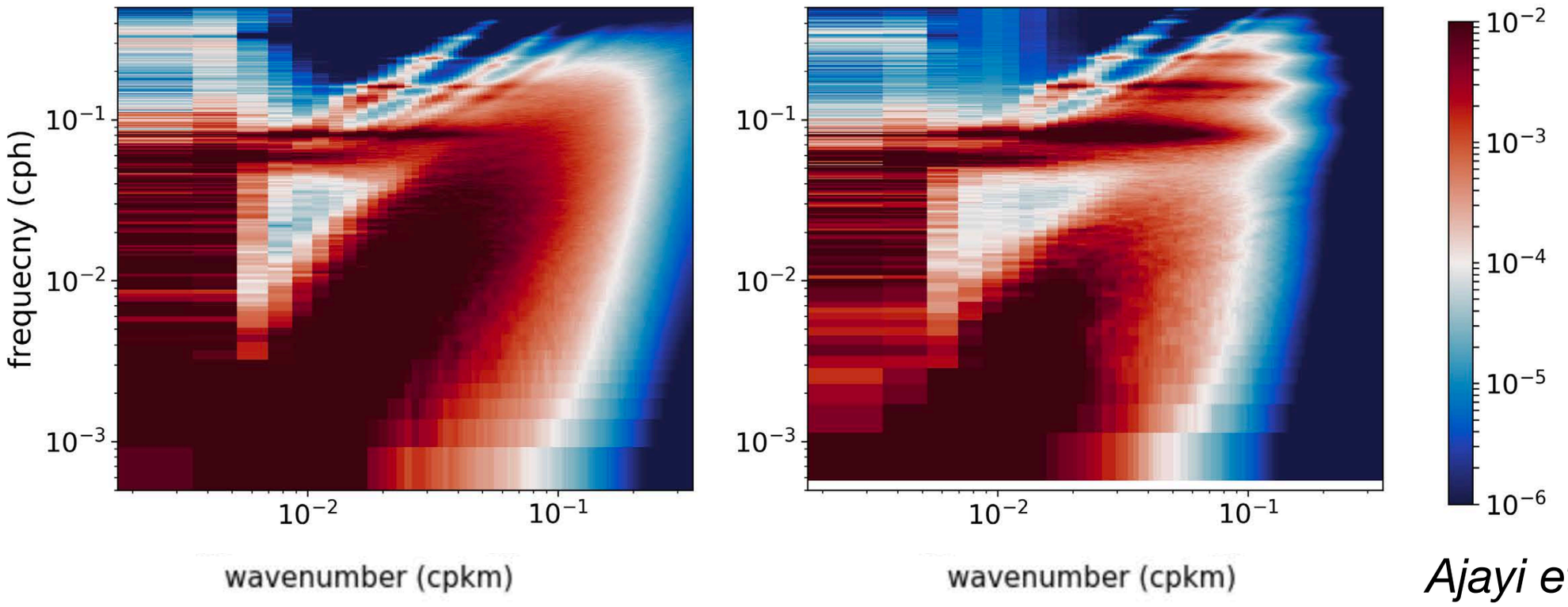


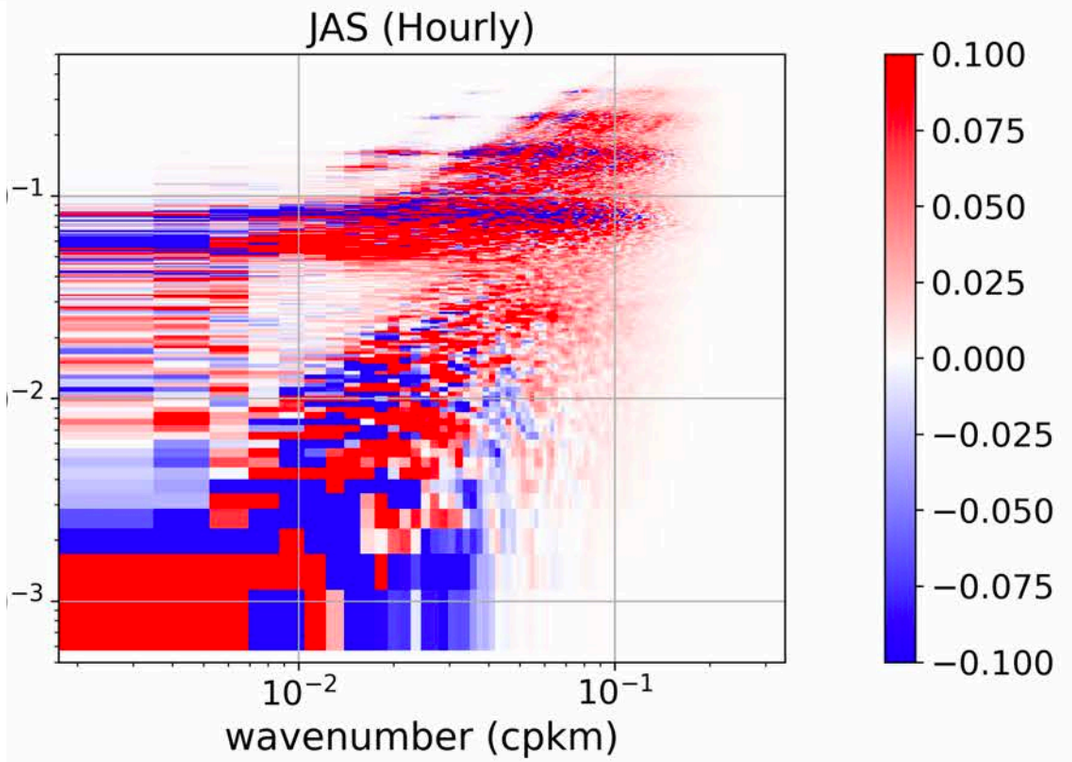


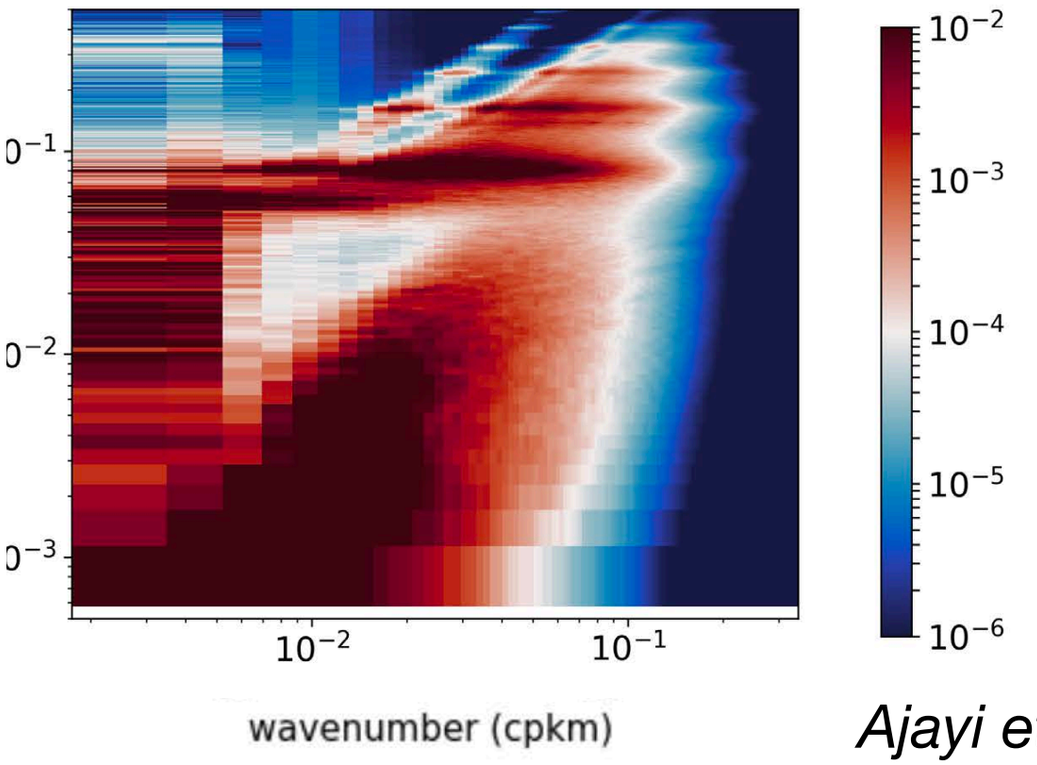
Ajayi et al. in prep

Kinetic energy exchanges involving wave motions

Kinetic Energy transfers in frequency-space domain

Summer conditions are prone to the build up of GM spectra with a direct extraction of KE from tidal frequencies





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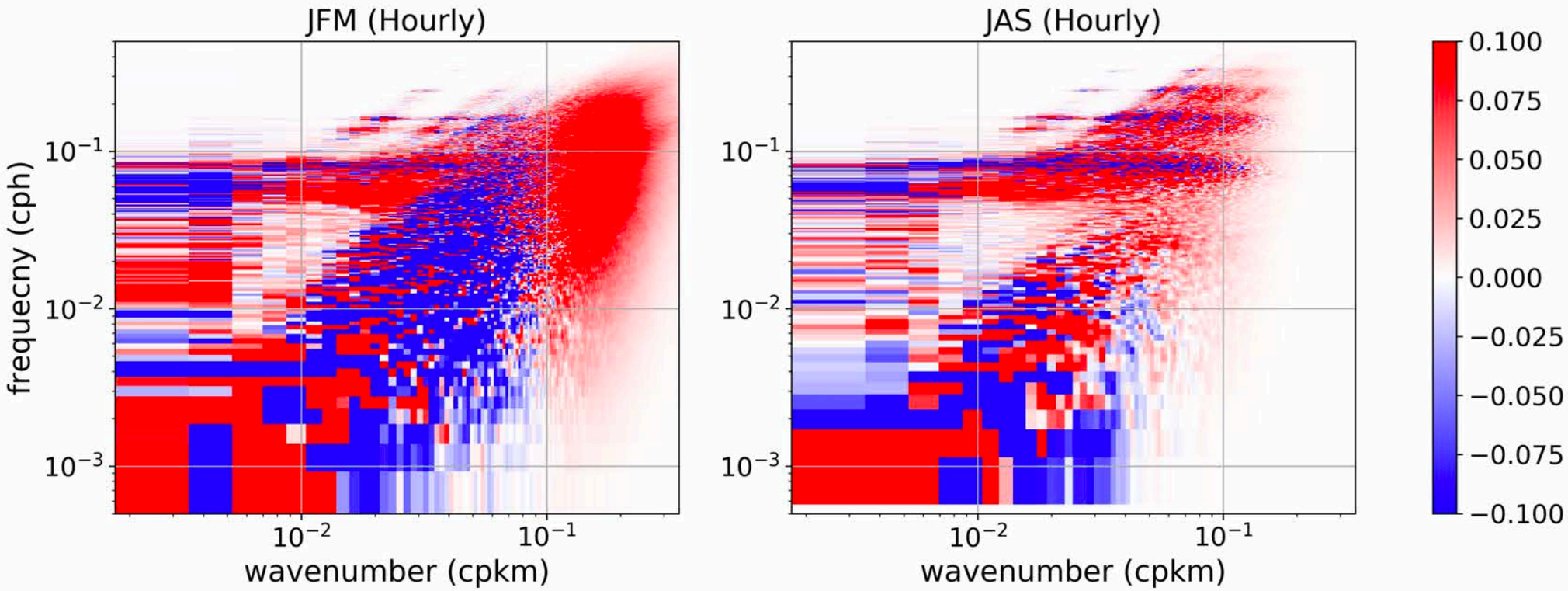

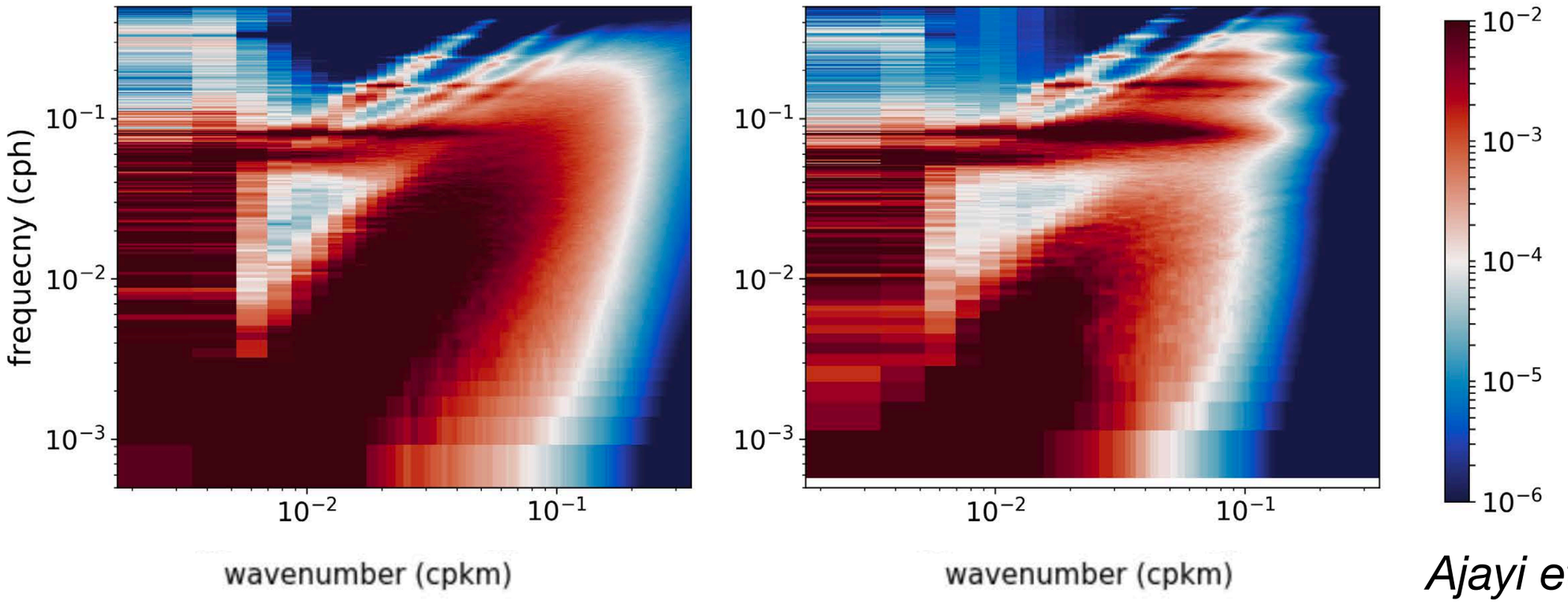

Ajayi et al. in prep

Wrap-up and conclusions

Wrap-up and conclusions

A new generation of North Atlantic simulations

- a series of simulations has been produced through a PRACE HPC resources allocation
- the new generation eNATL60 uses a larger domain and la onger spin-up
- eNATL60 simulations includes a run with tidal forcing (K1, O1, S2, M2, N2)
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Kinetic energy cascades in the North Atlantic Ocean

- over the *inertial range*, model KE spectral slopes agree with QG prediction (k^{-3})
- at scales <Rd, transfers in (k, ω) domain show a forward cascade in wintertime
- at scale <Rd, transfers in (k, ω) domain show the building of GM spectrum