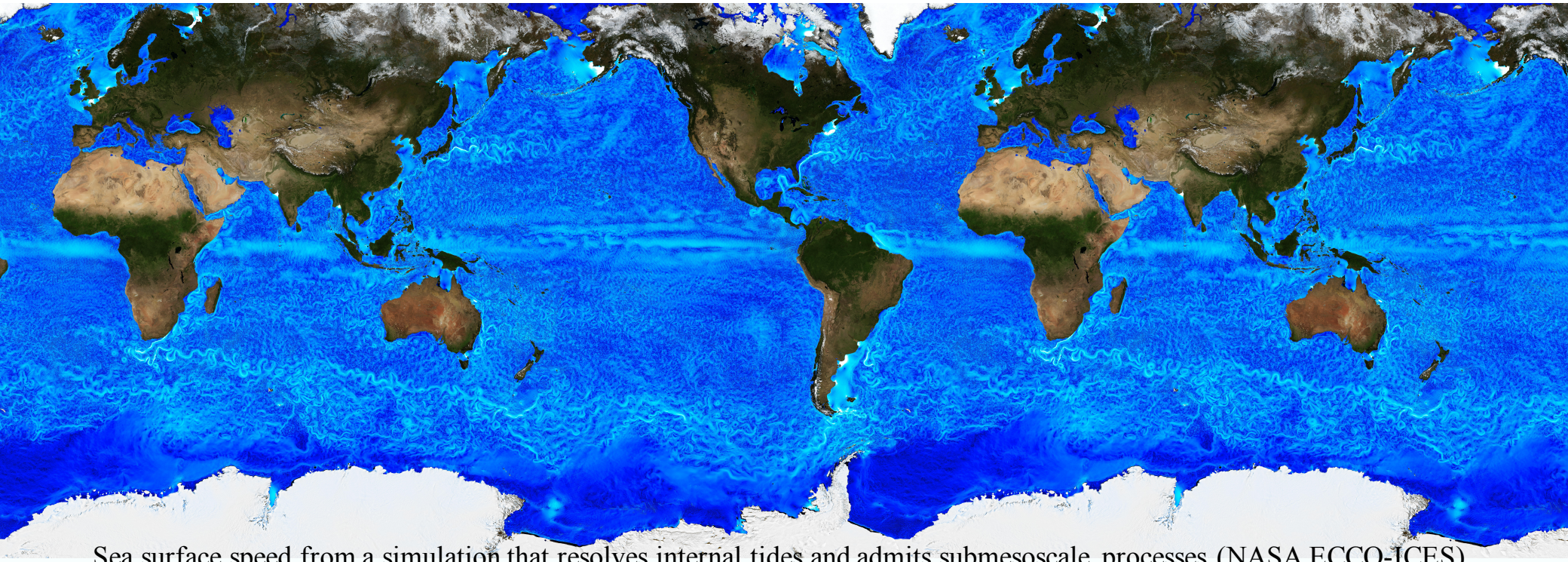
Working Group on

« High Resolution Ocean General Circulation Models »

Patrice Klein[Ifremer/JPL/Caltech] & Brian Arbic [U.M.]



Sea surface speed from a simulation that resolves internal tides and admits submesoscale processes (NASA ECCO-ICES)

SWOT Science Team 13-16 June 2016, Pasadena

Motivation:

Realistic numerical simulations are presently performed **at high resolution** (1 km to 4 km) **within the context of SWOT.**

They use PE models such as:

- **HYCOM** (B. Arbic, E. Chassignet, X. Xu),
- **MITgcm** (D. Menemenlis, C. Hill, R. Ferrari…)
- **ROMS** (UCLA group, J. Gula, J. Molemaker, **...**)
- **NEMO** (J. Le Sommer, **...**)
- **OFES/MRI** (H. Sasaki + MRI)

These simulations have been (are) running either on a **global scale** (MITgcm, HYCOM, OFES) or at a **basin scale** (all models) including Atlantic and Pacific Oceans.

Some of them include **internal tides** (HYCOM, MITgcm, ROMS).

Ongoing **comparisons with experimental data** (in particular mooring and ADCP data) look promising although these models do not involve any assimilation.

All these simulations **explicitly resolve**, both, the large scale and small scale part of the **mesoscale turbulence** (10 km – 400 km) that should be sampled by SWOT

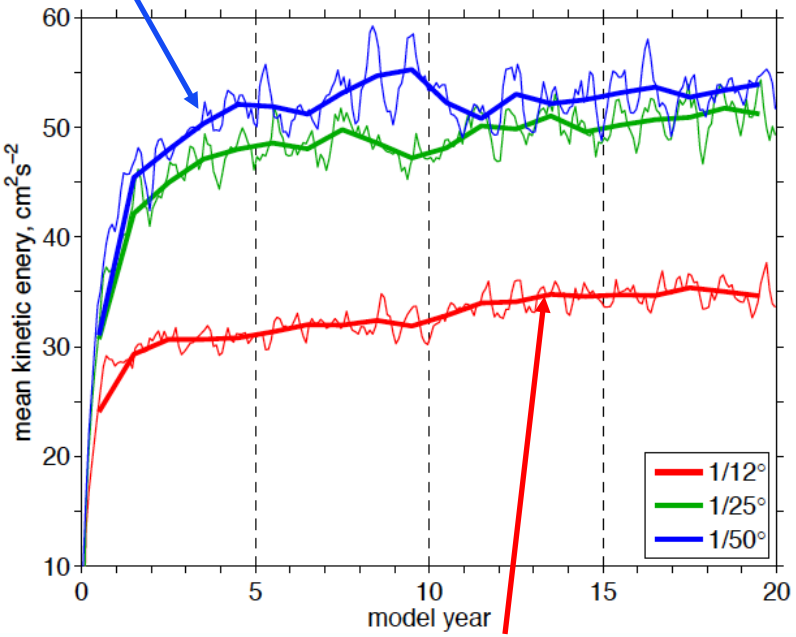
This international effort has allowed **in the last 3 years** to **unveil some new** (sometimes unexpected) **impacts** of small scales (10 km - 50 km) on larger scales [*see conclusions of the Brest Workshop, March 2016*].

They include:

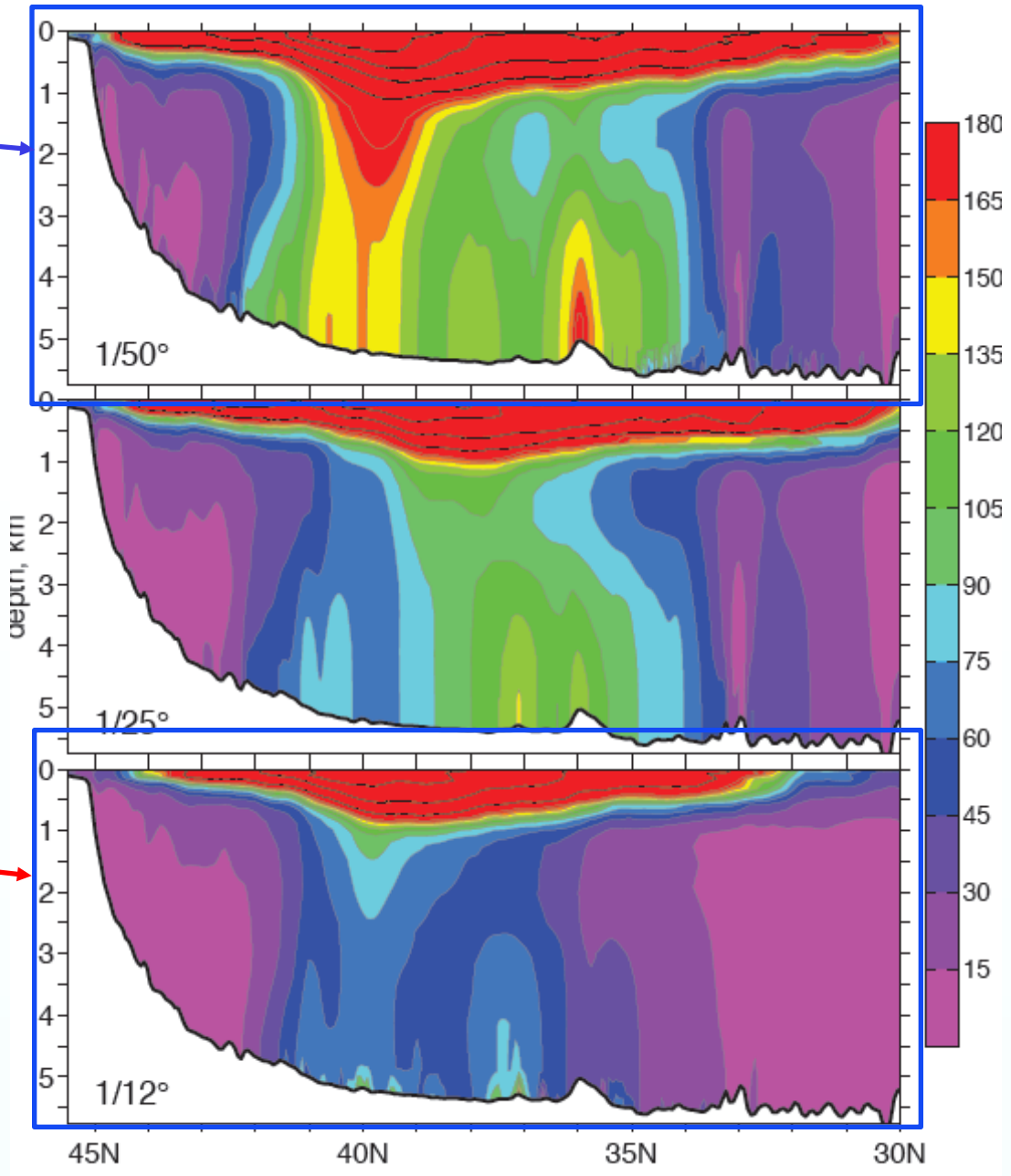
- A **significant KE increase** (factor 1.5 – 2) at surface and depth: [Chassignet & Xu'16, Sasaki et al.'16, Menememlis et al.'16];
- A **significant seasonality of scales smaller than 50 km** (MLIs in winter) with a strong regional character !
- An efficient **energy route** linking small scales to larger scales leading to a seasonality of the mesoscale turbulence EKE (50 km – 400 km);
- An **unexpected magnitude** of the impacts of small-scale internal waves on, both, the KE and SSH spectrum up to scales of 50 km (even 100 km).
- Surface motions are in nonlinear geostrophic (cyclostrophic) balance
- Significant impact of submesoscale on mixing near rough topography.

internal tides

1/50°



1/12°



Mean kinetic energy at 55°W

1/50° is close to Richardson'85

[Chassignet & Xu, OS 2016]

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- A **significant KE increase** (factor 1.5 – 2) at surface and depth;
- A **significant seasonality of scales smaller than 50 km** with strong regional character (!) …

  … associated with an efficient **energy route leading to a KE transfer from small to larger scales** (50 km – 400 km) [Mensa et al.'13, Sasaki et al.'14, Qiu et al.'14, Su, Wang et al'16, Rocha et al.'16, Le Sommer et al.'16]
- An **unexpected magnitude** of the impacts of small-scale internal waves on, both, the KE and SSH spectrum up to scales of 50 km (even 100 km).
- Surface motions are in nonlinear geostrophic (cyclostrophic) balance
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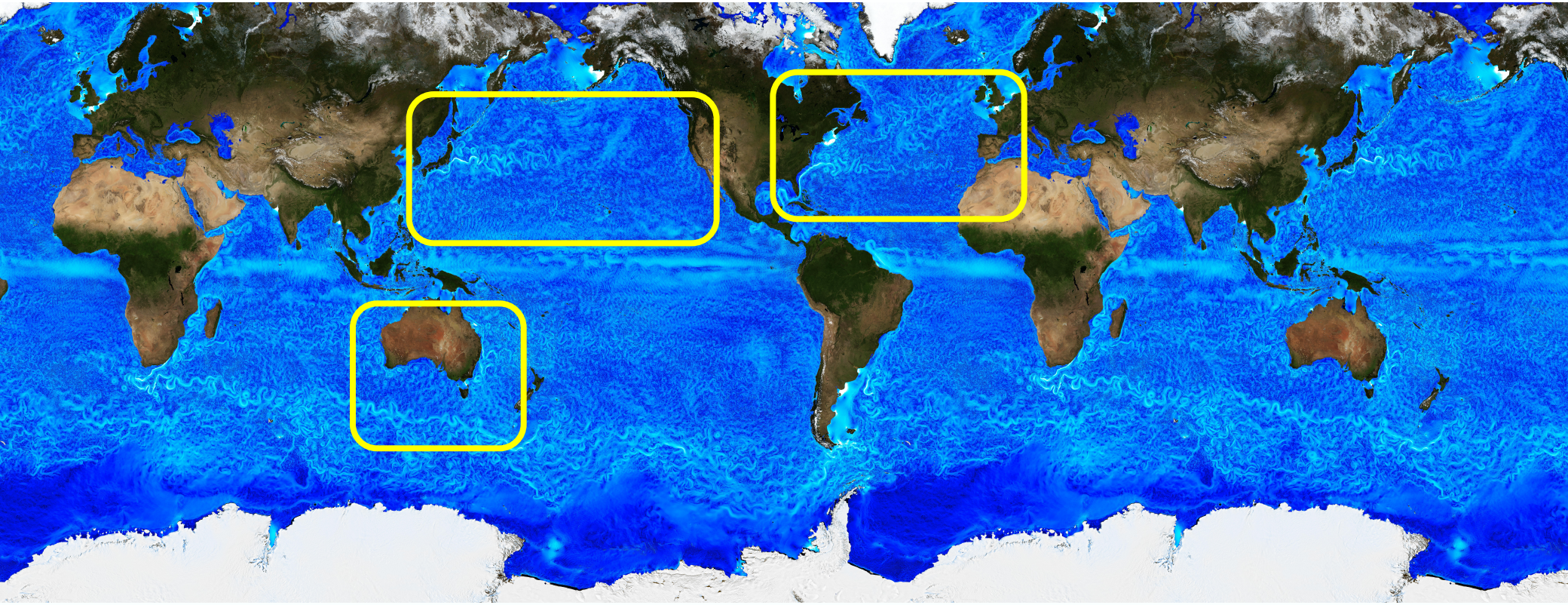
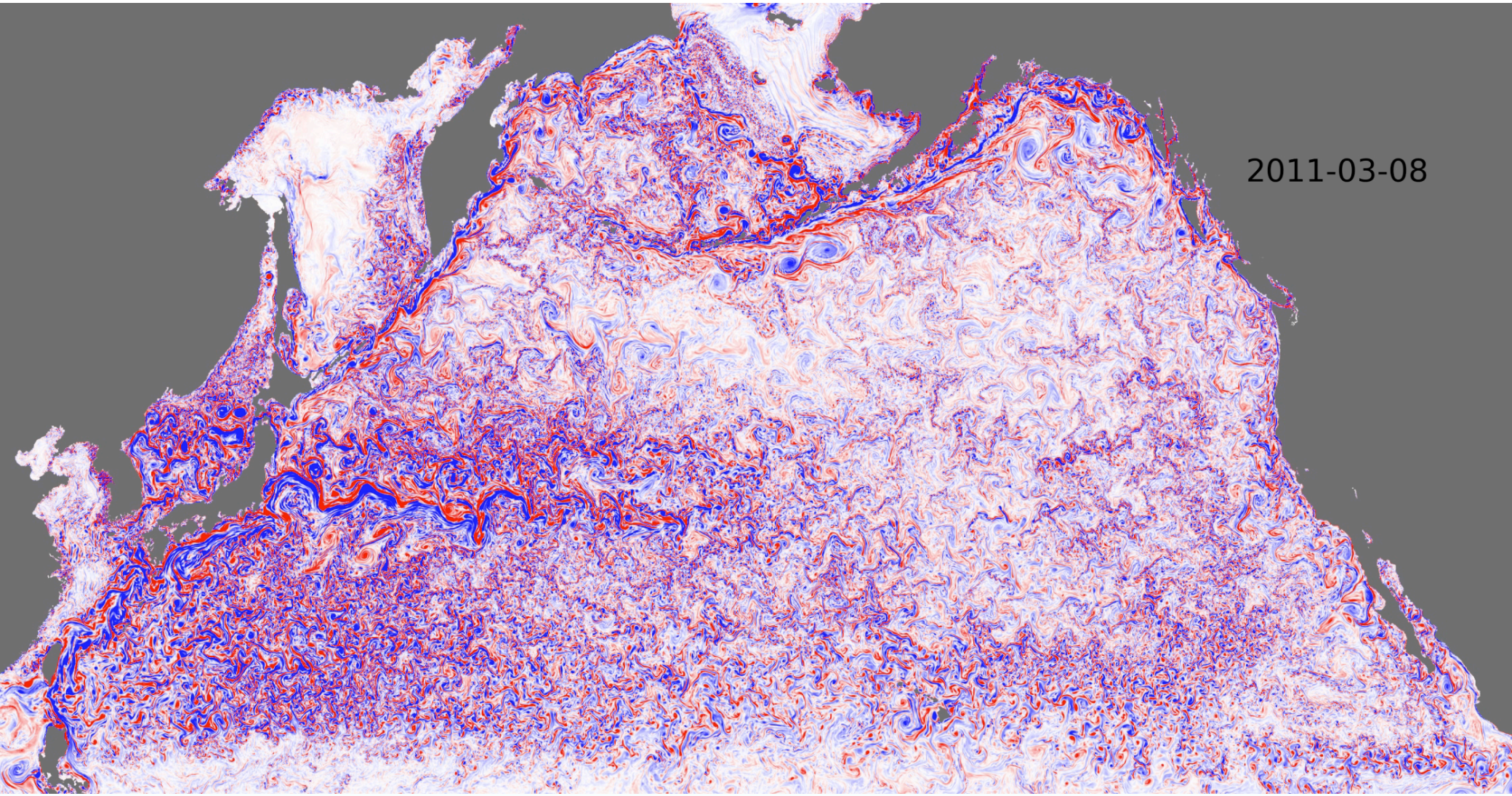
internal tides

LLC4320 simulation (MITgcm) integrated for 12 months
[1/48° resolution + 90 vertical levels; **include tides**]

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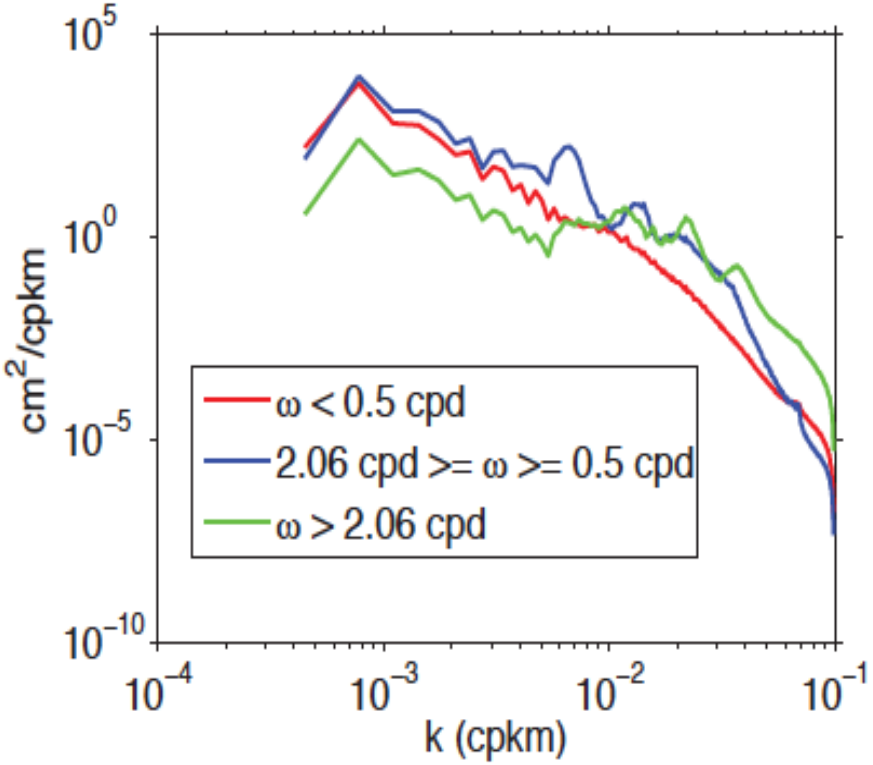
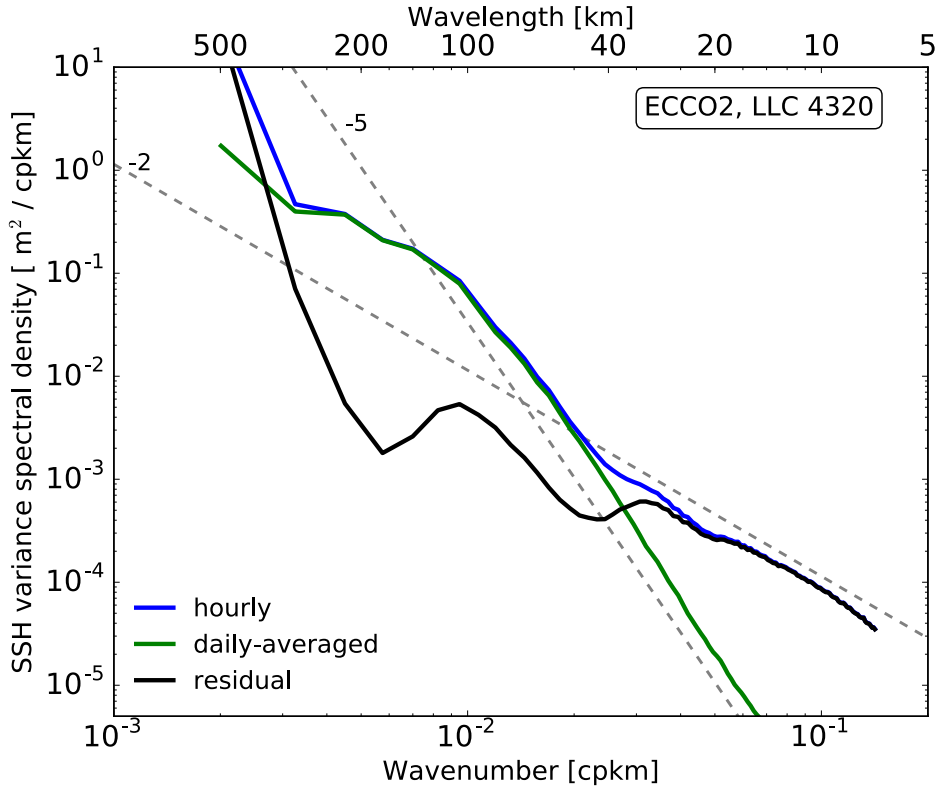
- An efficient **energy route** linking small scales to larger scales leading to a seasonality of the mesoscale turbulence EKE (50 km – 400 km);
- An **unexpected magnitude** of the impacts of small-scale internal waves on, both, the KE and SSH spectrum up to scales of 50 km (even up to 100 km)… much larger than anticipated by Richman et al.'12.
  [Ubelmann et al.'15, Rocha et al.'16, Ansong et al.'16, Savage et al.'16, Morrow et al.'16] *=> detailed in several talks during this ST meeting …*
- Surface motions are in nonlinear geostrophic (cyclostrophic) balance
- Significant impact of submesoscale on mixing near rough topography.



1/12.5° Hycom simulation (Savage et al.'16)



1/48° MITgcm simulation (Rocha et al, JPO'16)

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- Significant impact of submesoscale on mixing near rough topography. [Gula et al.'15, Molemaker et al.'15]
- Surface motions are in nonlinear geostrophic (cyclostrophic) balance

internal tides

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Two recommendations:

1 - **revisit** existing satellite and in-situ data to confirm the new results from these high-resolution simulations, for example:

@ Seasonality of the impact of submesoscale [Callies et al., NC'15; Dufau et al.'16; Rocha et al (AVISO & alongtrack altimeter data, person. com.)]
@ Impact of internal waves on the KE and SSH spectrum [Callies et al. JPO'13, Rocha et al., JPO'16; Muller et al.'15]
@ …

Such strategy based on HR realistic simulations should help to better define the analysis of SWOT data when they become available.

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Two recommendations:

2 – Continue to push i**ncreasing the resolution in these realistic simulations**

Differences between 1/10° and 1/50° have highlighted new dynamical regimes in the oceans. Going to higher resolution should …

- allow a better representation of small scales (non-hydrostatic mechanisms).
- further explore the impact of small scales on the larger ones in terms of mixing versus KE source (direct/inverse KE cascade)
- better infer the impact of small scales on SSH

⇒ Computer resources is an issue (although we should be able to have access to Petascale machines (K-machine, Sequoia, …)) + data availability to and access by the SWOT community
but NOT so more important as the physics in the existing models that need to be improved *[see conclusions of the Brest workshop, March 2016]* …

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Improving the physics in ocean models *[conclusions of the Brest workshop, March 2016]* :

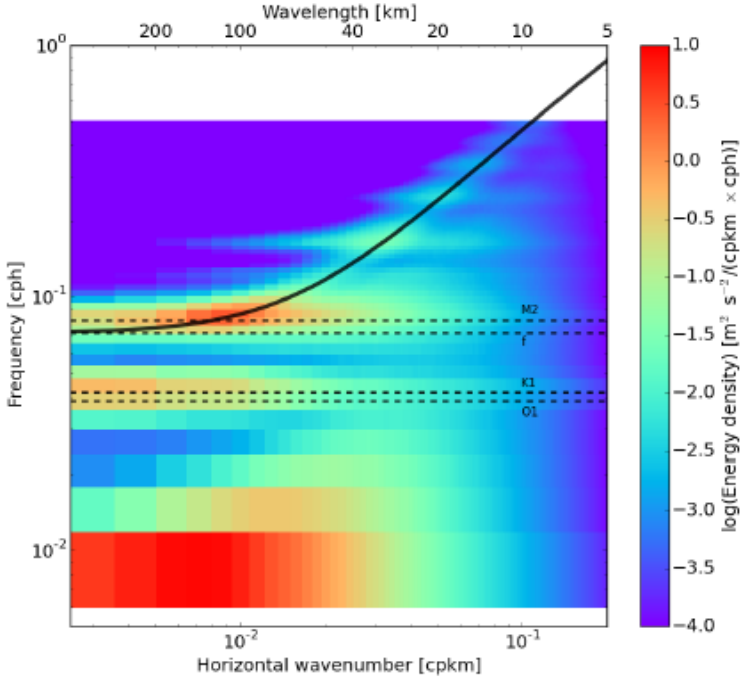
- Representation of topographic roughness
- Numerical schemes
- Damping of low mode internal tides
- Impact of vertical/horizontal resolution
- Nondydrostatic effects
- Mixed-layer parameterization
- Atmospheric forcings (intermittency): long term project
- Better representation of the internal wave spectrum
- Surface gravity waves
- ….

We have learnt a lot these last 3 years from these high-resolution realistic simulations.

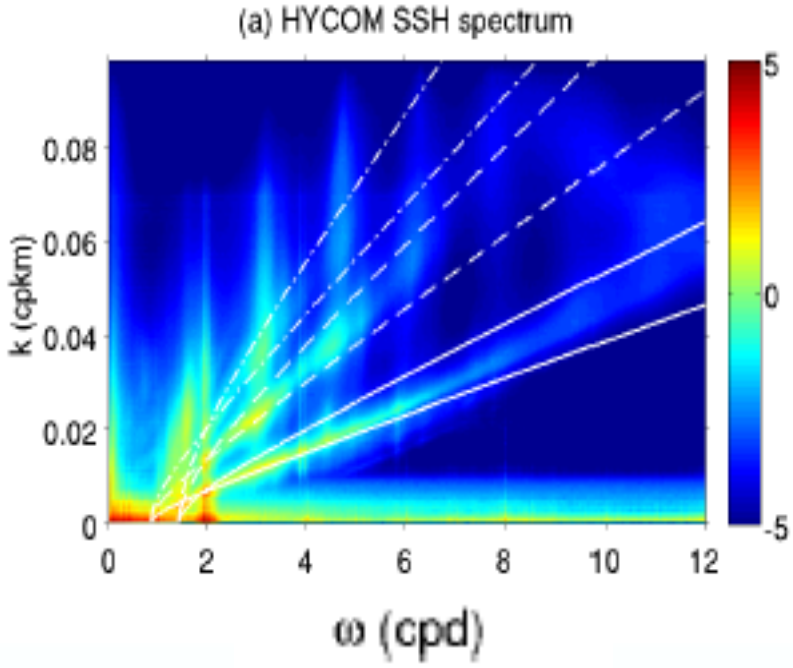
- Within the context of SWOT we need first to confirm these results obtained these numerical simulations through the analysis of existing data but using different approaches

- We need to move forward and increase the resolution in these models

- ***Everybody in the SWOT ST is welcome to join the working group***
- ***First meeting may be during the OSTST 2016 in La Rochelle (Fra) (Oct. 31st- Nov. 3rd)?***



1/48° MITgcm simulation
(Rocha et al, JPO'16)



1/12.5° Hycom simulation
(Savage et al.'16)