What does HYCOM tell us about submesoscale processes?

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The big questions,

- Is there another scale of motion between mesoscale and overturning scale?
- Is there an intermediate regime between the 2D and 3D turbulence?
- Can HYCOM catch (part of) these processes?

The small questions,

- How does the submesoscale (SM) form? In our case, the product of ageostrophic baroclinic instabilities in the mixed layer (ML)
- Why are they important? It affects the mixed layer restratification,
- How do we study them? With an high resolution simulation of the Gulf Stream made with HYCOM

How does the submesoscale form?

Submesoscales are the product of the nonlinear interaction of,

Shallow Mixed Layer Instabilities (MLI's)

originate in the ML, L ~ 200m-20km, T ~ 1 day.

Deep Mesoscale Instabilities

originate as instabilities of the main thermocline

L ~ 30km, T ~ 30 days.

How does the submesoscale form?

Classic ML dynamics,

1. Forcings produce horizontal density gradients in the ML,
2. Gravitational sloping leads to a mixed layer in geostrophic balance,

But we can also have,

3. Formation of baroclinic instabilities.

Why are they important?

submesoscale dynamics is involved in the restratification of the mixed layer and could affect the mesoscale too.

Restratification is enhanced by the release of APE (flattering of isopycnals) due to the formation of instabilities in the mixed layer.

How do we study the SM processes?

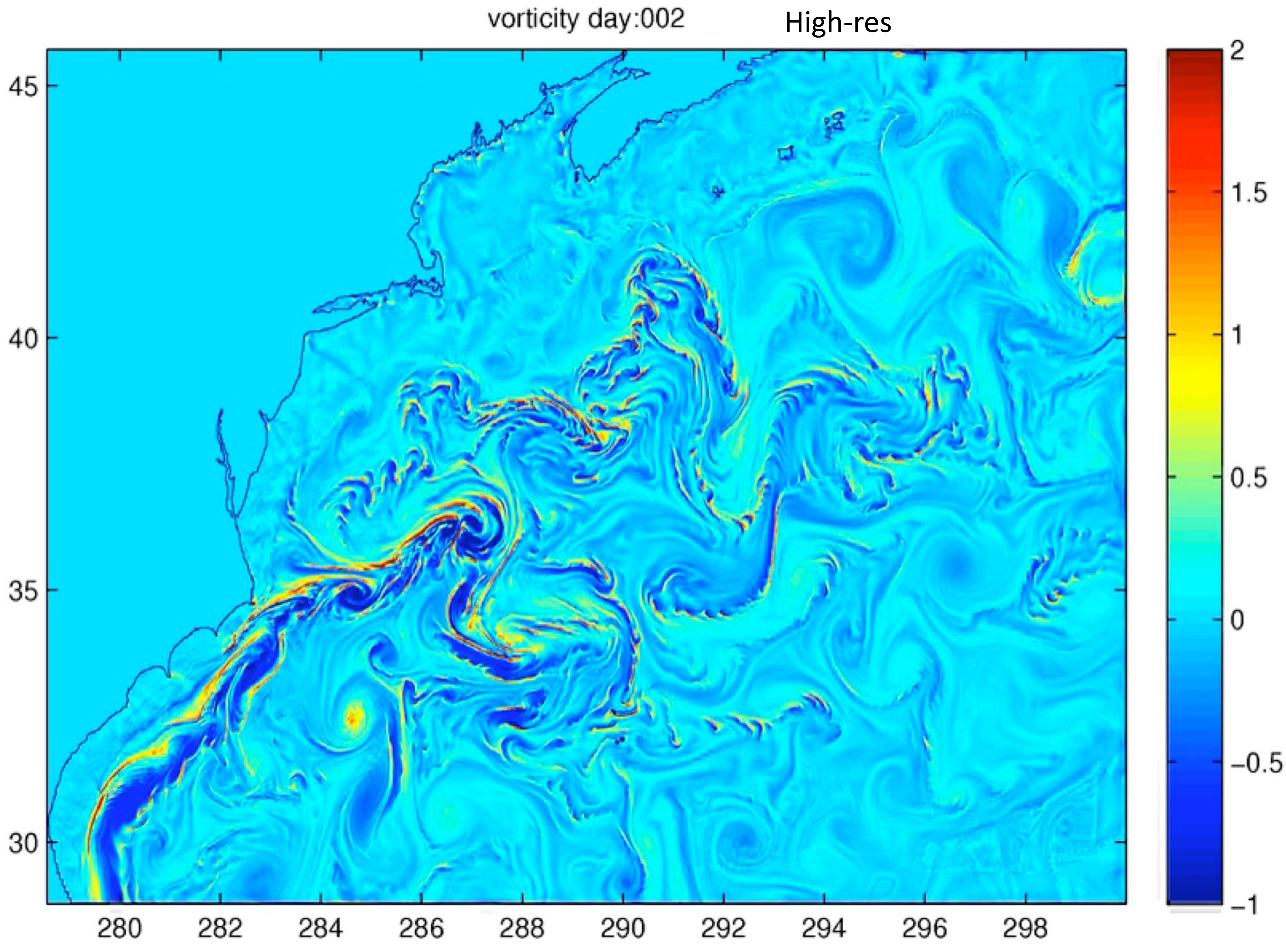
One year simulation HYCOM of the Gulf Stream region.

Low res:

1/12th deg, interpolated to 1/48th degree

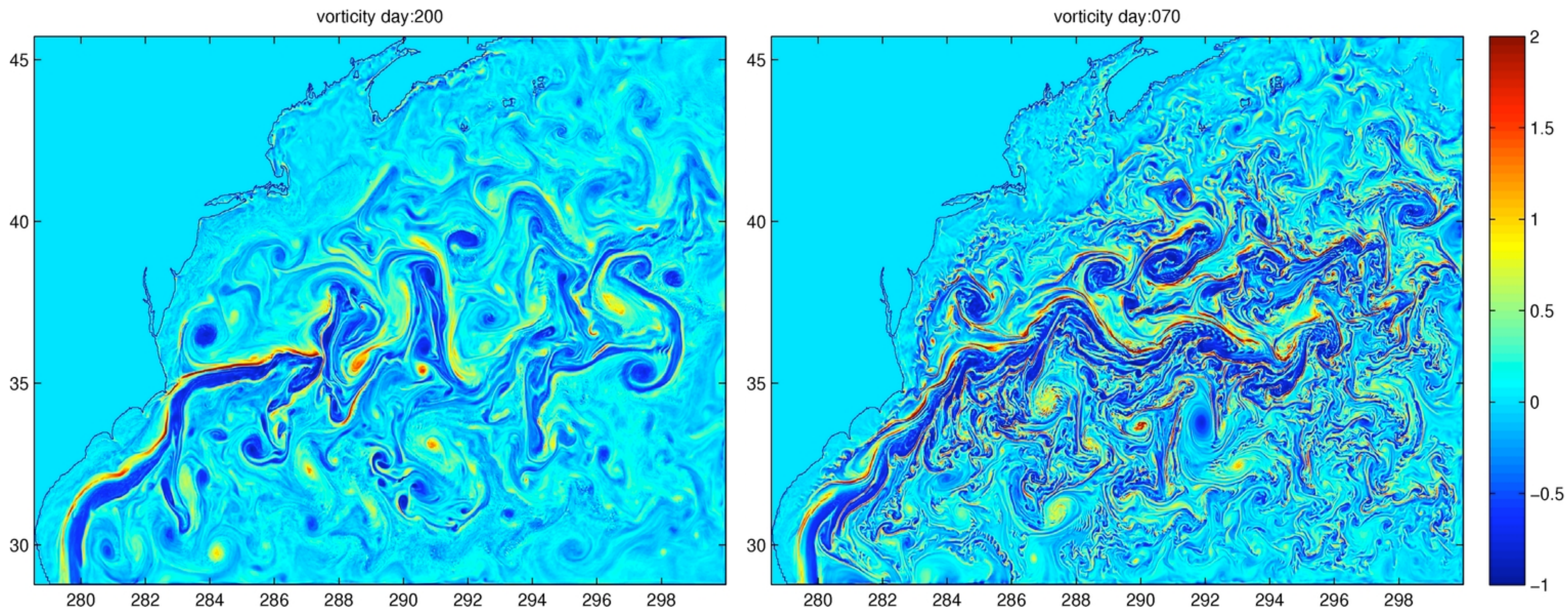
High res (nested in the low res):

1/48th deg saved in means and snapshot every 12 hours



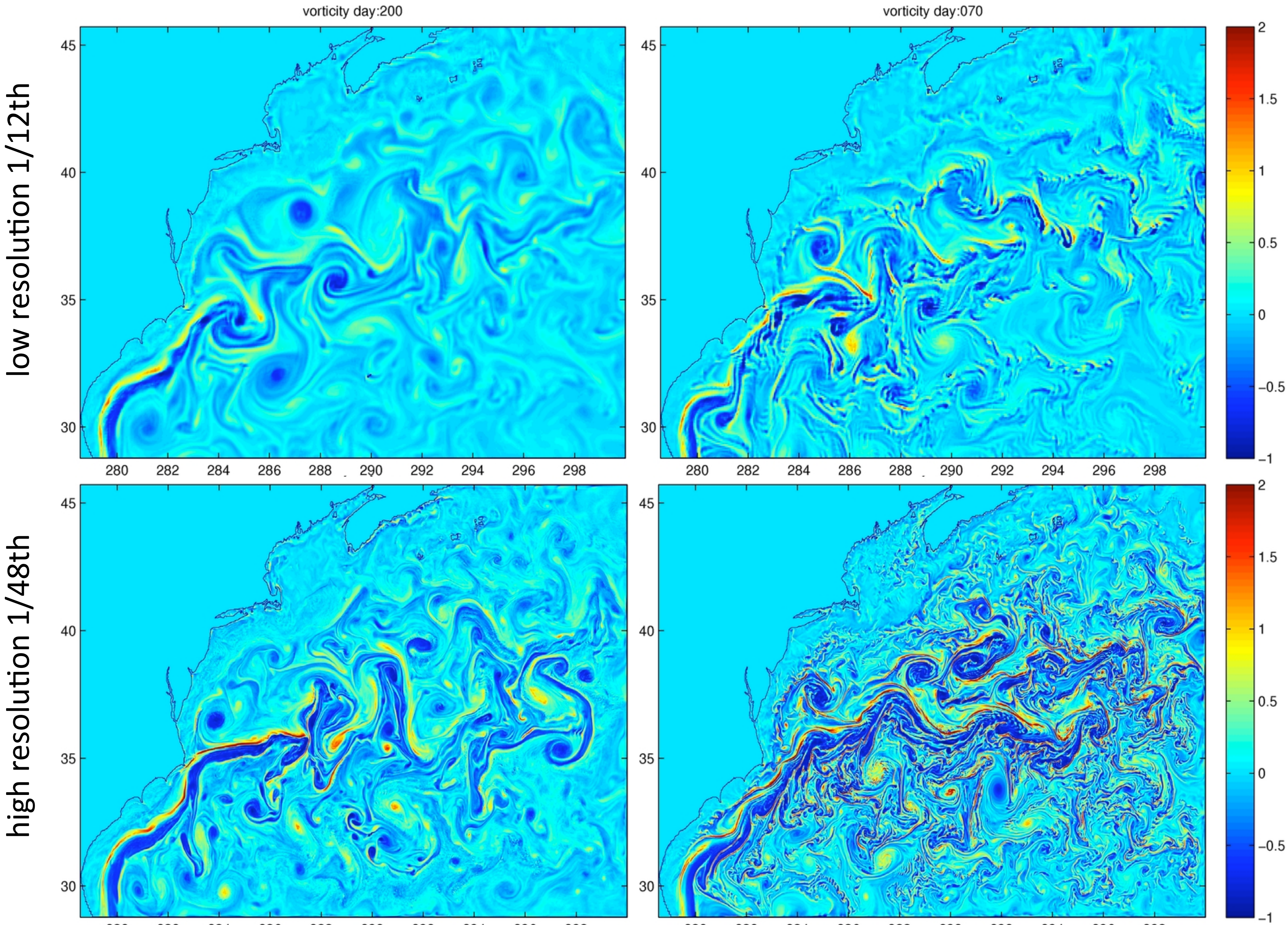
vorticity day:002
High-res
45
40
35
30
280
282
284
286
288
290
292
294
296
298
2
1.5
1
0.5
0
−0.5
−1

The vorticity field shows a strong seasonality in the submesoscale activity



Day 200 Year 8, Summer

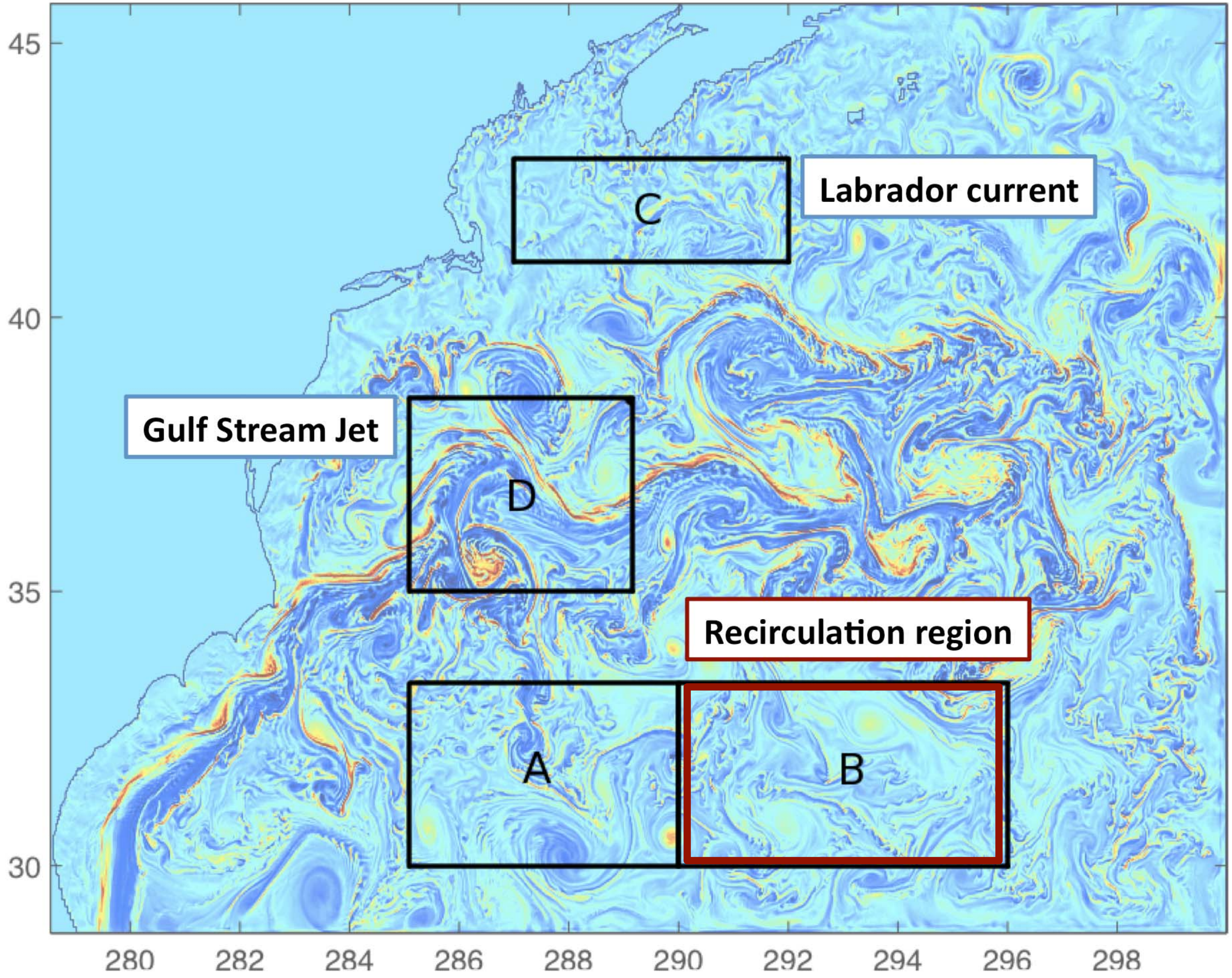
Day 70 Year 9, Winter



Day 200 Year 8, Summer

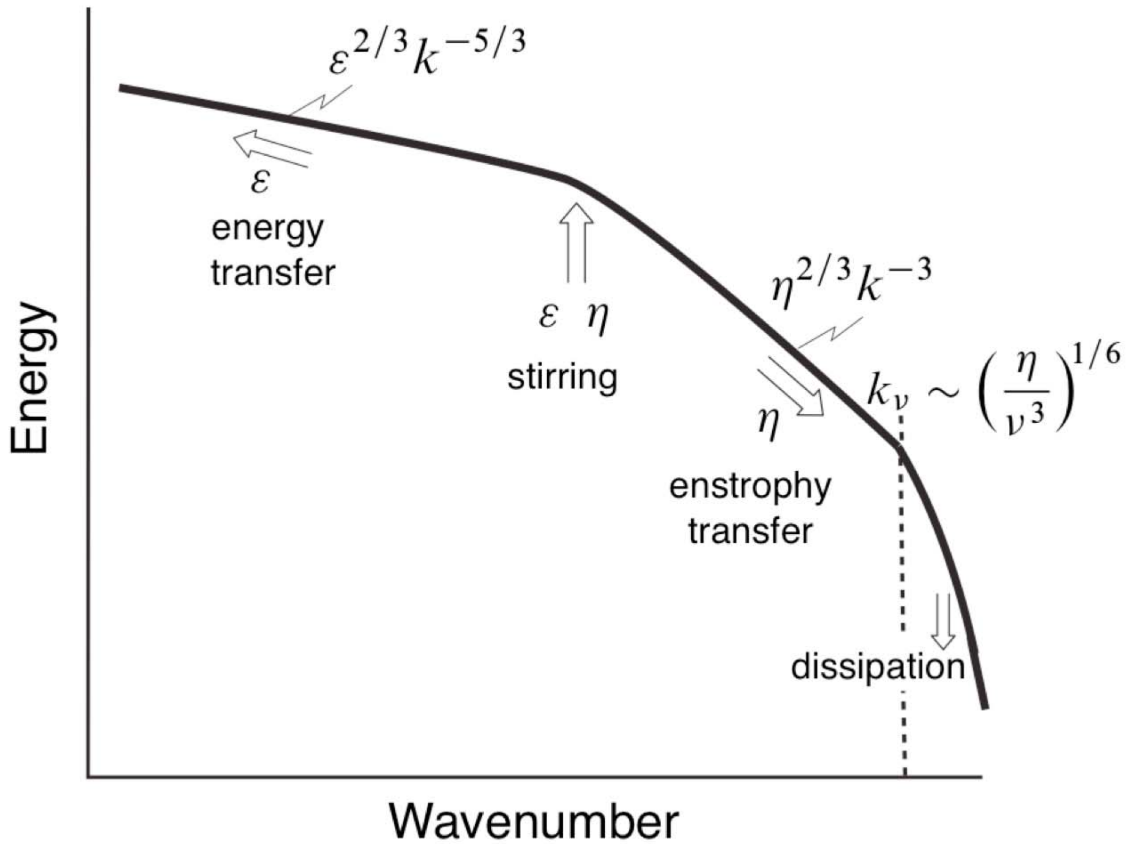
Day 70 Year 9, Winter

4 Regions of Interest



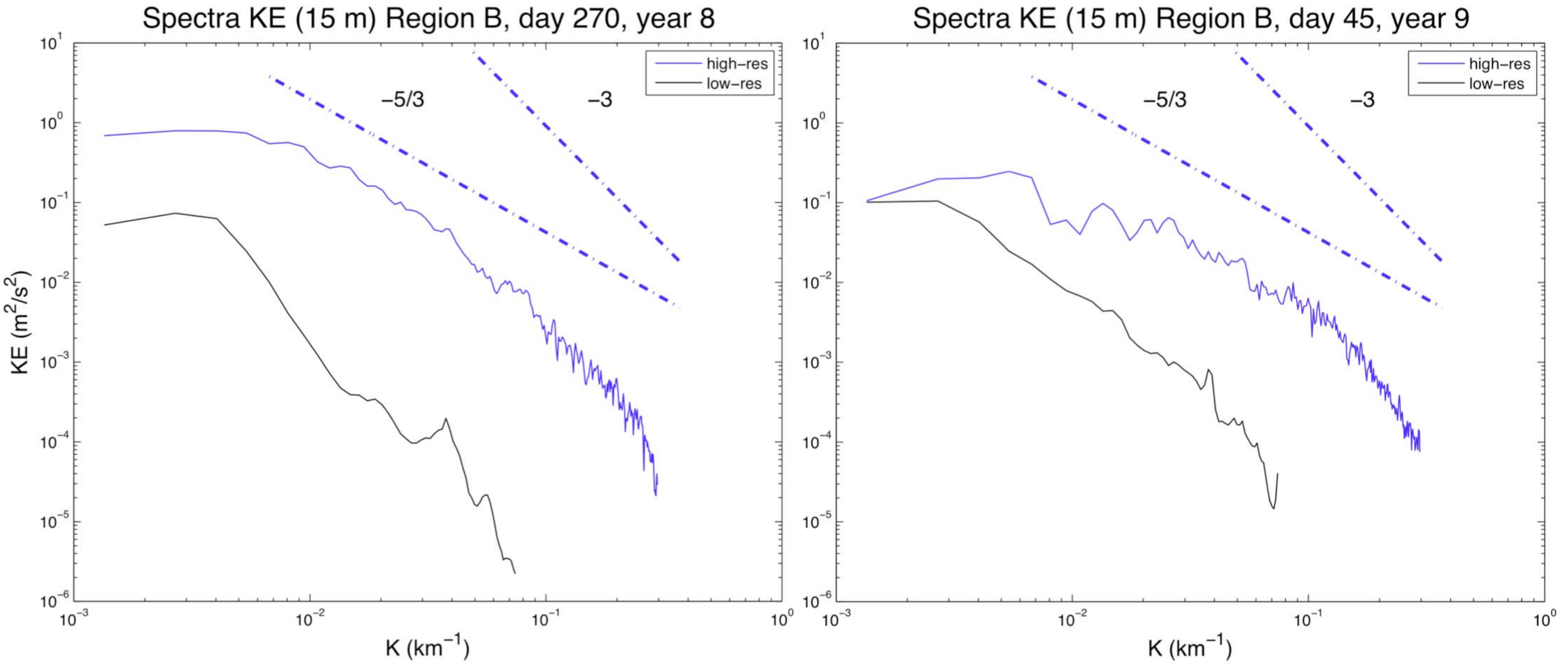
We computed spectra of KE to have a quantitative idea of the processes involved...

ε rate of energy cascade
η rate of ensotrophy cascade
K wave number
k_ν Kolmogorov scale
ν viscosity coefficient



K. Vallis. Atmospheric and oceanic fluid dynamics: fundamentals and large-scale circulation. (2006) pp. 745

We computed spectra of KE to have a quantitative idea of the processes involved...



Summer

Winter

…while we used Okubo Weiss for a more quantitative approach.

$$Q = S^2 - \Omega^2$$

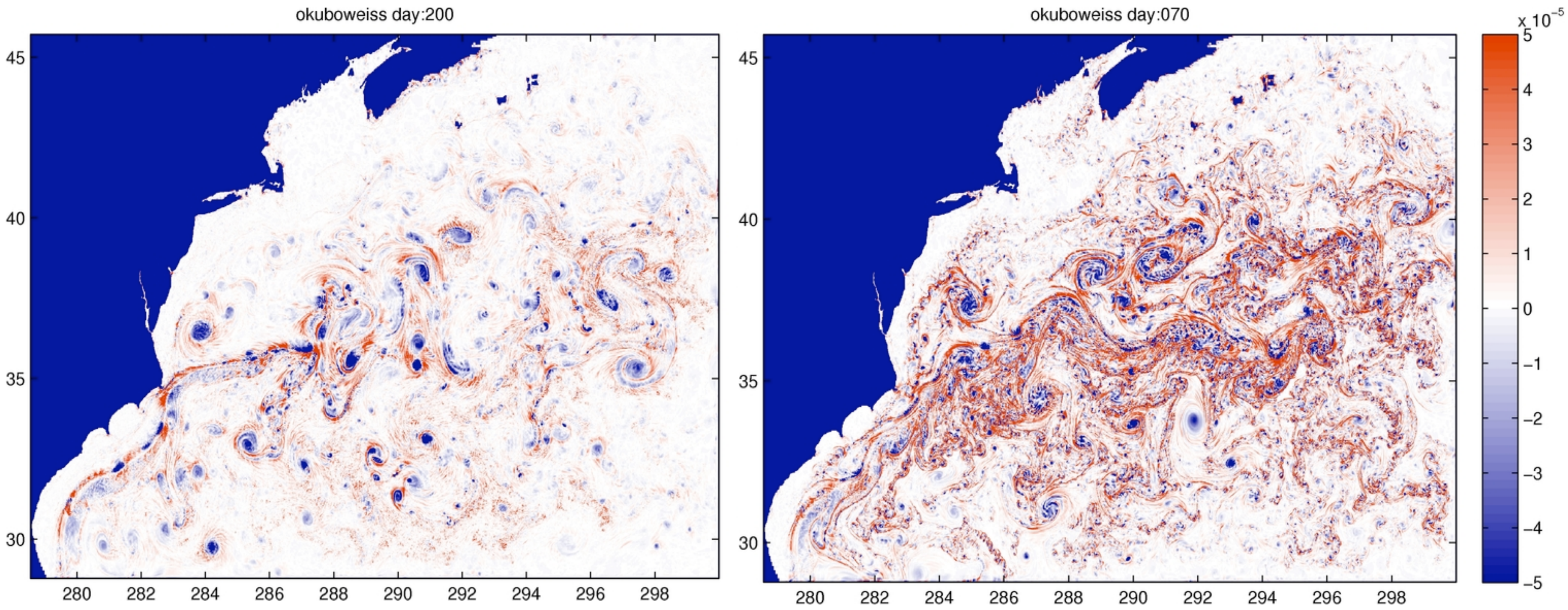
Where S is the strain rate (horizontal, shear + stretching) and Ω is the relative vorticity.

Q > 0, strain rate dominates: e.g. beside an eddy.
Q < 0, vorticity dominates: e.g. within an eddy.

…Okubo Weiss display a stronger seasonality in its positive part.

Q > 0, strain rate dominates: e.g. beside an eddy.

Q < 0, vorticity dominates: e.g. within an eddy.



Day 200 Year 8, Summer

Day 70 Year 9, Winter

We define OW+ and OW- as

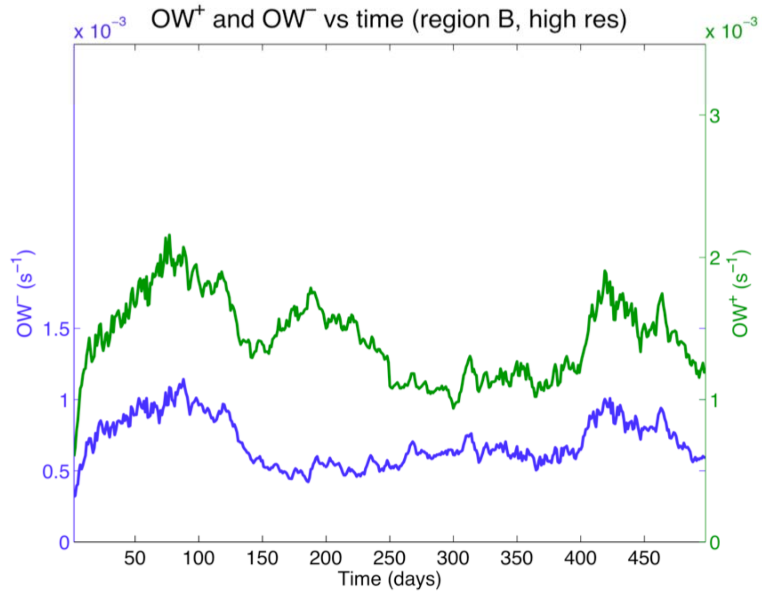
[Poje et al, 2010],

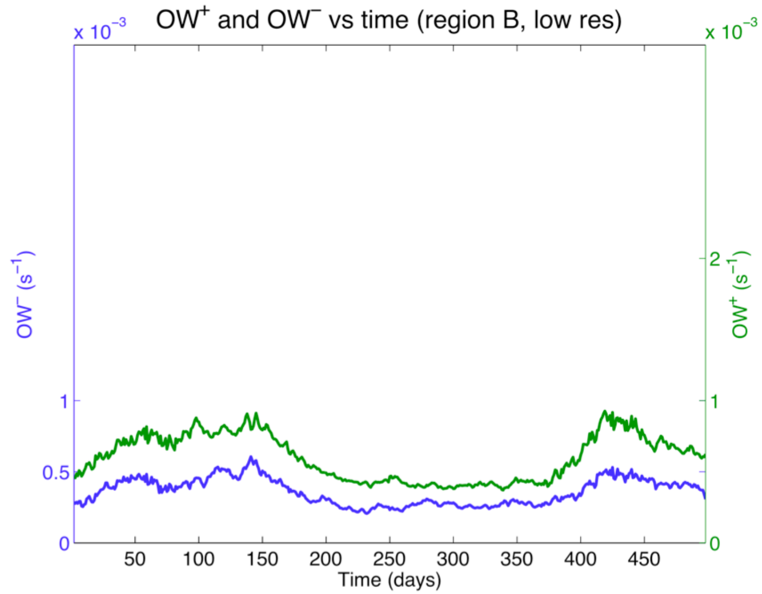
$$OW^{+} = A^{-1}\int \sqrt{Q}dA, Q > 0$$

$$OW^{-} = A^{-1}\int \sqrt{|Q|}dA, Q < 0$$

we compute this quantity over each region,

We find that,



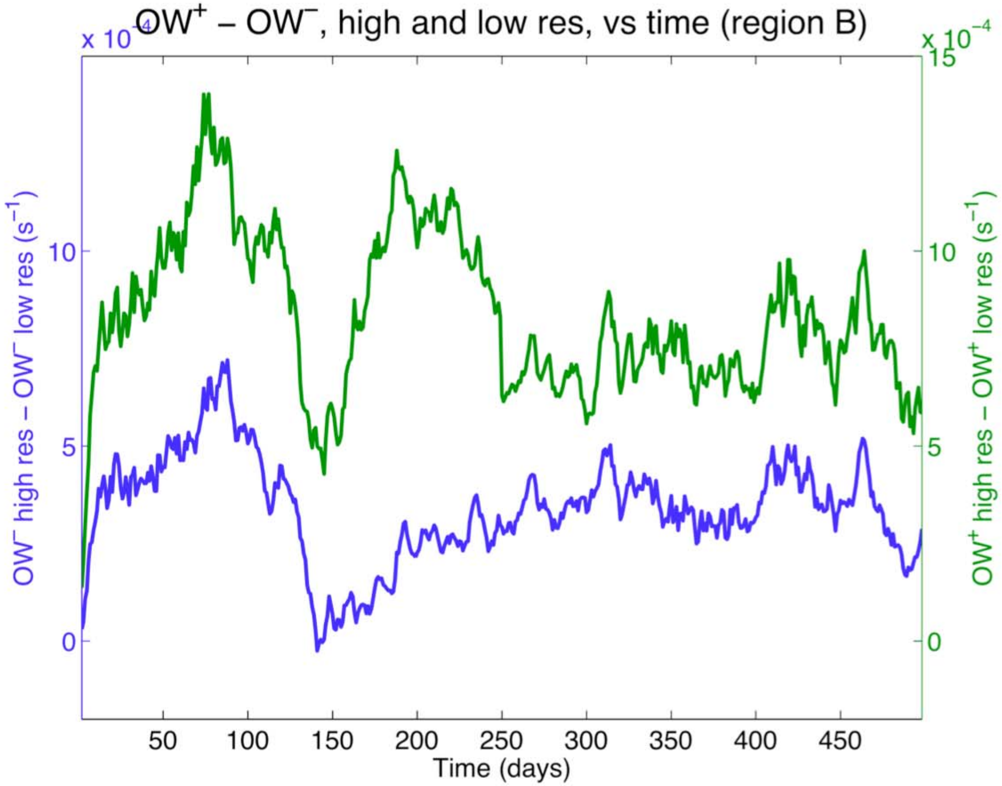


$OW^+ > OW^-$

hyperbolicity

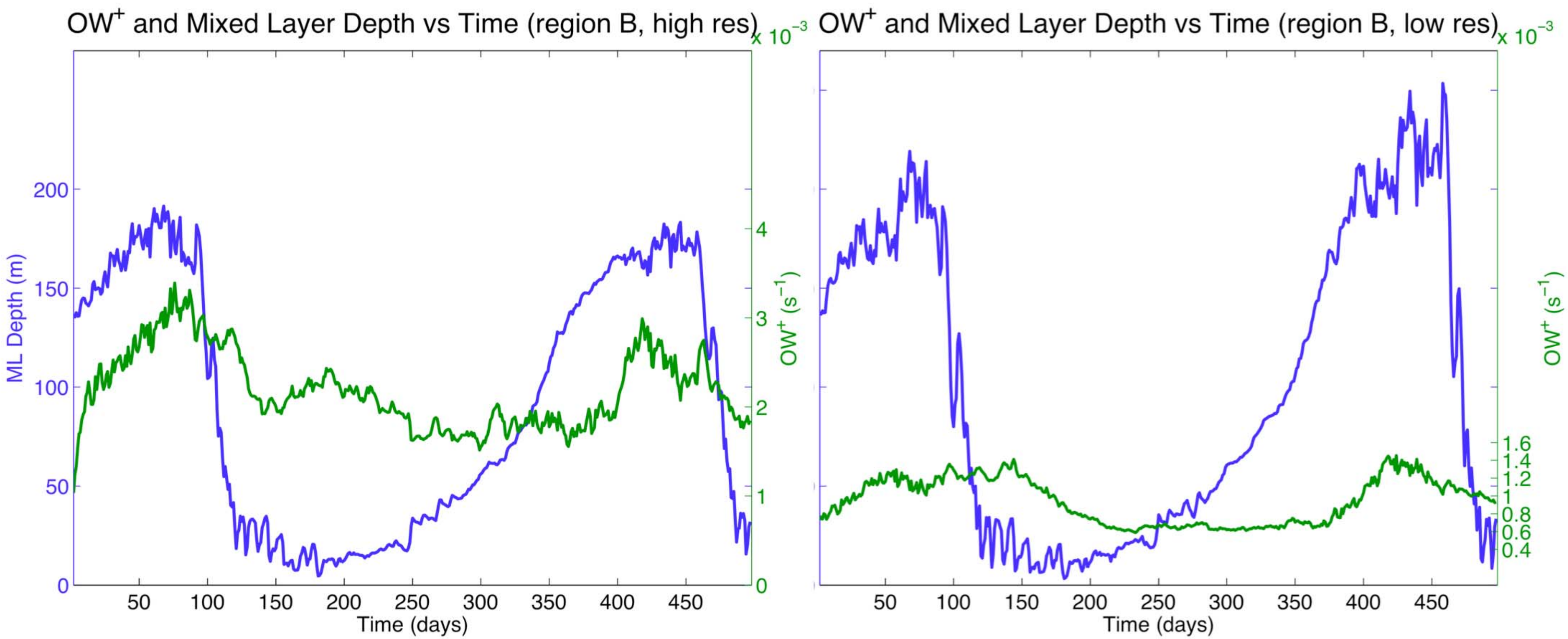
$OW^+_h > OW^+_l$

Indicator of SM



We use OW⁺ as a metric of the SM activity…

…and ML Depth as a metric of restratification.



Conclusions

1. Submesoscale activity in the Gulf Stream displays a strong seasonal cycle,
2. The model resolves part of the SM, as seen from the spectra,
3. the SM is mostly hyperbolic,
4. SM affects the restratification process.

References

- *Boccaletti et al. Mixed layer instabilities and restratification. J. Phys. Oceanogr (2007) vol. 37 (9) pp. 2228-2250*
- *Poje et al. Resolution dependent relative dispersion statistics in a hierarchy of ocean models. Ocean Modelling (2010) vol. 31 (1-2) pp. 36-50*
- *Lapeyre, G., Klein, P., & Hua, B. L. (2006). Oceanic Restratification Forced by Surface Frontogenesis. Journal of Physical Oceanography, 36(8), 1577. doi: 10.1175/JPO2923.1.*