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HIGH RESOLUTION ATMOSPHERIC FORCING FOR THE NORTH ATLANTIC NEMO MESOSCALE EXPERIMENT (1979-2018)

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Sources and Sinks of Ocean Mesoscale Eddy Energy, 12 Mar 2019

Knowing that eddy-resolving ocean model *will* generate a mesoscale motions
even if the atmospheric forcing was coarse,

What is the actual impact of mesoscale information in the atmosphere on the ocean dynamics?

In order to run ocean model we need a long-term mesoscale resolving atmospheric dataset,

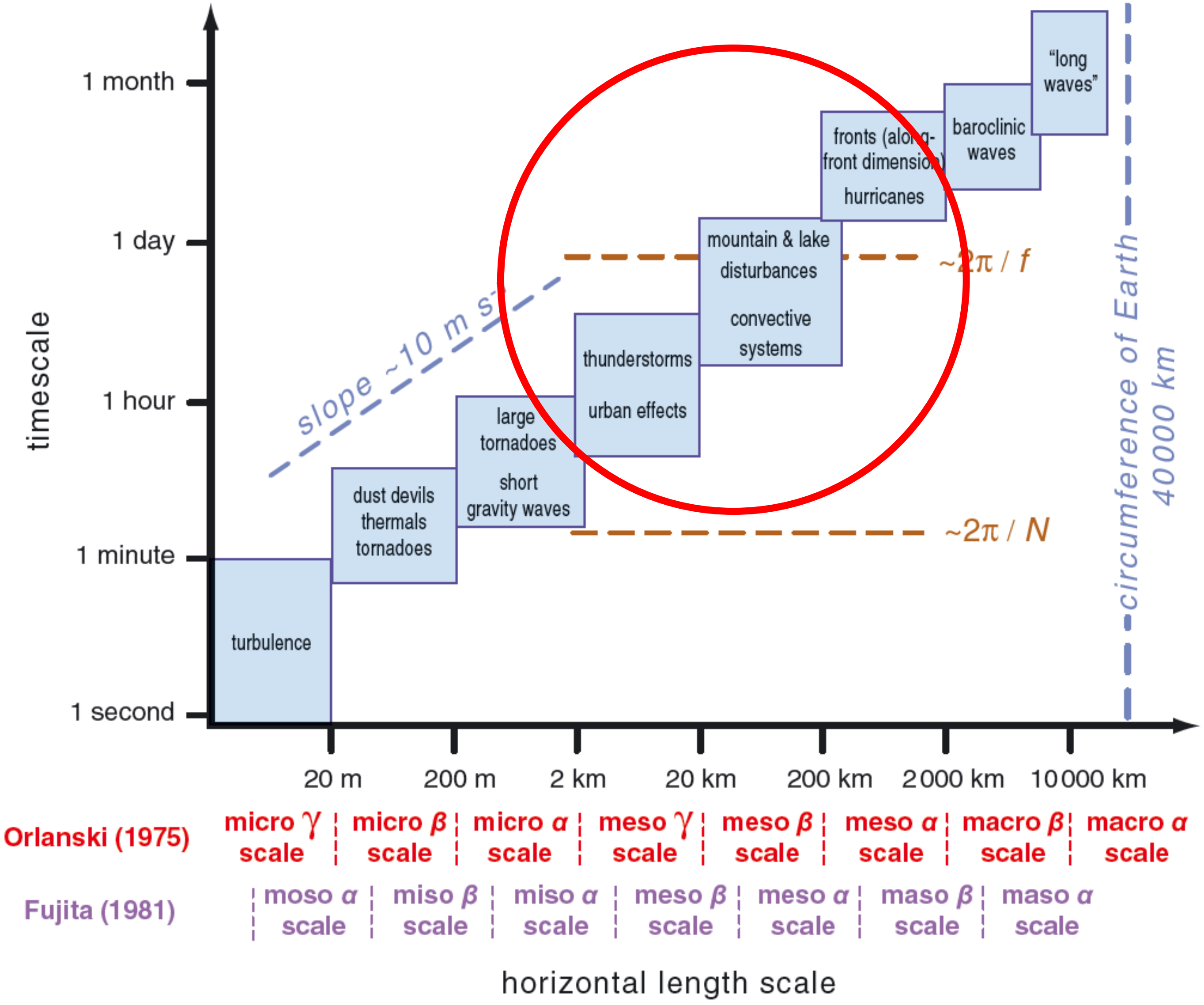
How to get the proper atmospheric data?

To estimate the mesoscale impact we need to filter it out of other scales.
Knowing that there is no solid boundary between synoptic and mesoscale motions,

How to filter the mesoscale circulations out of high resolution data?

WHAT IS MESOSCALE ATMOSPHERIC MOTIONS?

There is no common definition of mesoscale



Mesoscale (by Orlansky)

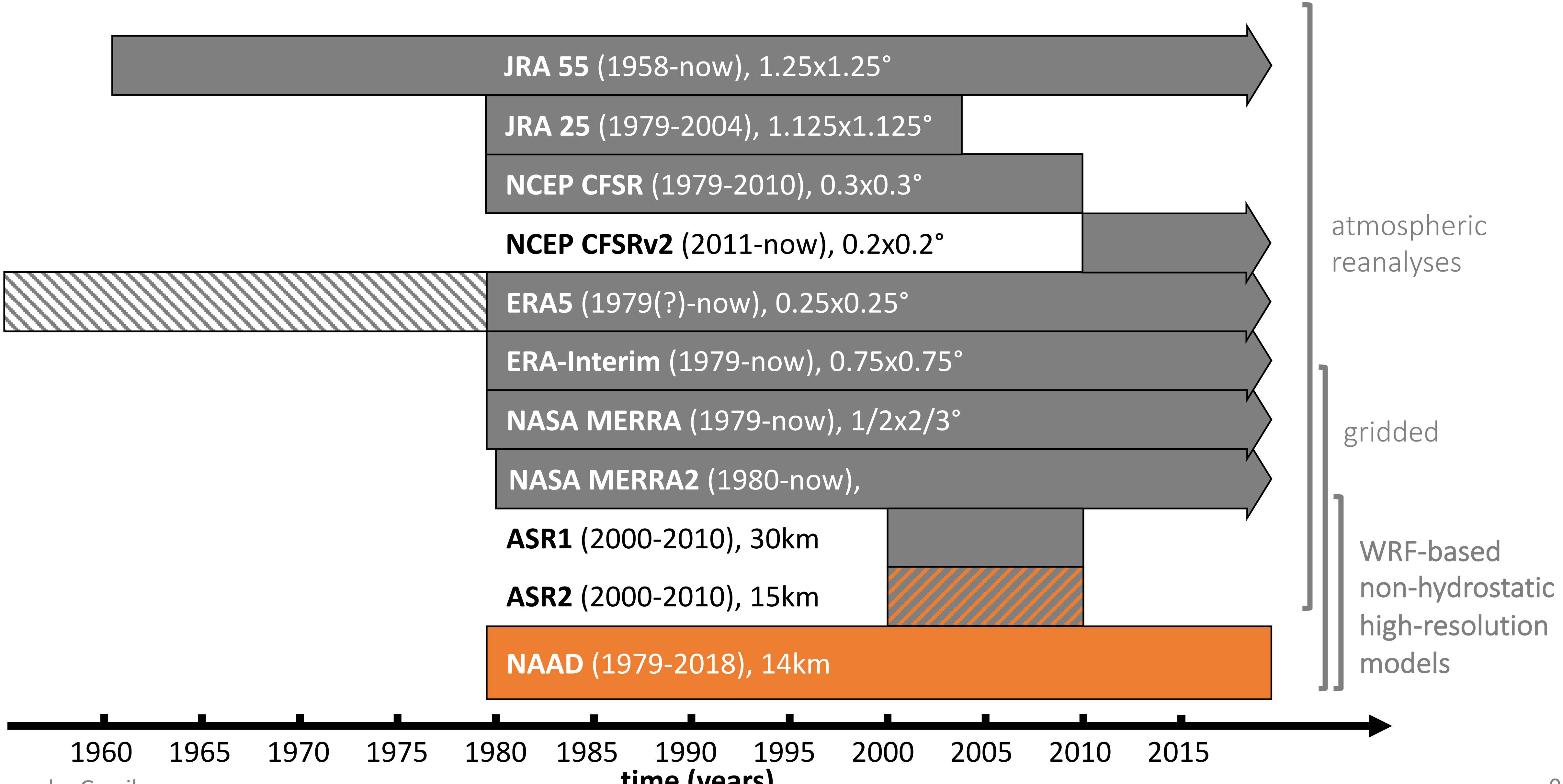
spatial: 2 - 2000 km

temporal: 1 hr - 1 week

(c) Markowski P.M., Richardson Y.P. Mesoscale meteorology in midlatitudes

THE almost-MODERN STATE OF CLIMATE DATA

The **North Atlantic Atmospheric Downscaling** (NAAD) from 1979 up to 2018

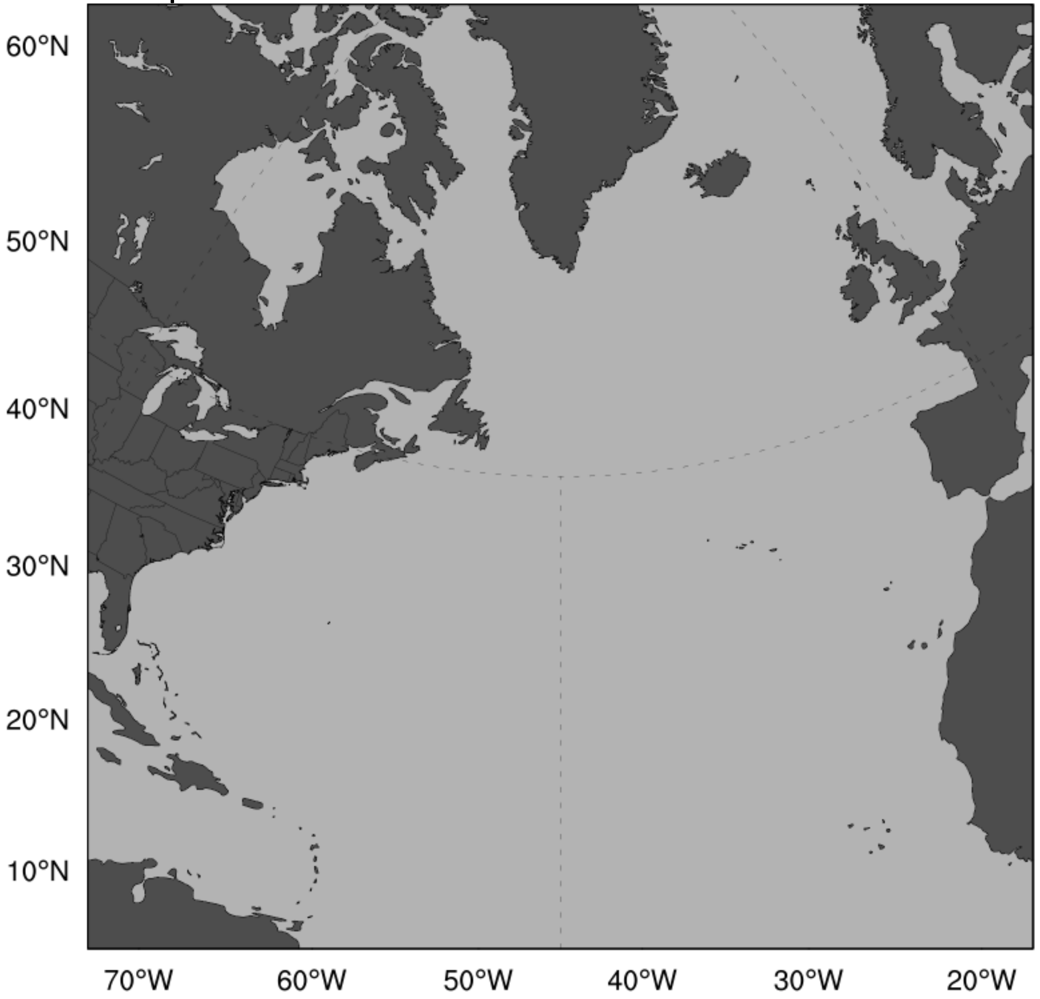


NAAD CONFIGURATION

CONFIGURATION	LoRes	HiRes
Model	WRF-ARW 3.8.1	
Core	hydrostatic	non-hydrostatic
Horizontal resolution	77 km	14 km
Vertical levels	50 (from 10 m to 50 hPa)	
RK3 time step	360 s	30 s
Forcing	ERA-Interim [1] + NUDGING [2]	

PARAMETRISATIONS	LoRes	HiRes
Microphysics scheme	WSM3	WSM6
Radiative transfer	RRTMG (+ features [3])	
Surface layer scheme	new MM5 (with COARE3 for Ch, Cq) + [4]	
PBL	YSU (non-local)	
Cumulus physics	new Kain-Fritsch + features [3]	

Computational domain



Few additional features for long-term simulations:

(1) sst updates every 6hr (ERA-Interim)	*(2) calculating skin temp based on Zeng and Beljaars (2005)*
(3) Nudging above PBL; wavelength>1100km; against u,v,p,t; with default G coefficient eq. 10^{-3} (1hr relaxation)	
(4) CAM aerosol climatology, ozone account and sub-grid cloud effect to the optical depth account in RRTMG scheme	

MESOSCALE FILTRATION: DYNAMICAL METHOD

Based on the GEOSTROPHIC BALANCE approach

The vector difference between the real (or observed) wind and the geostrophic wind is the ageostrophic part:

$$\overrightarrow{\boldsymbol{U}} = \overrightarrow{\boldsymbol{U}_g} + \overrightarrow{\boldsymbol{U}_a}$$

Model output

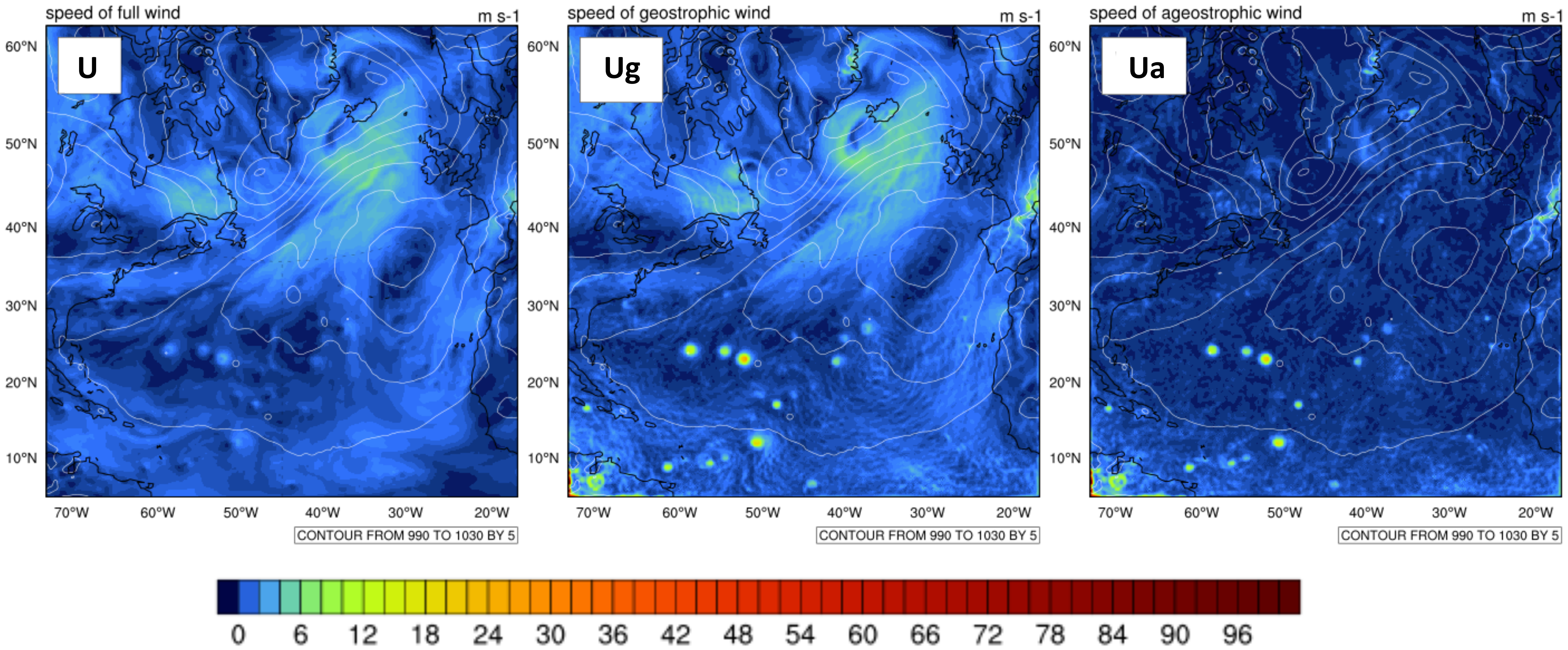
The geostrophic part (planetary and synoptic-scale systems)

The ageostrophic part (mesoscale?)

$$\overrightarrow{\boldsymbol{U}_g} \begin{cases} u_g = -\dfrac{1}{\rho f}\dfrac{\partial p}{\partial y} \\ v_g = \quad \dfrac{1}{\rho f}\dfrac{\partial p}{\partial x} \end{cases}$$

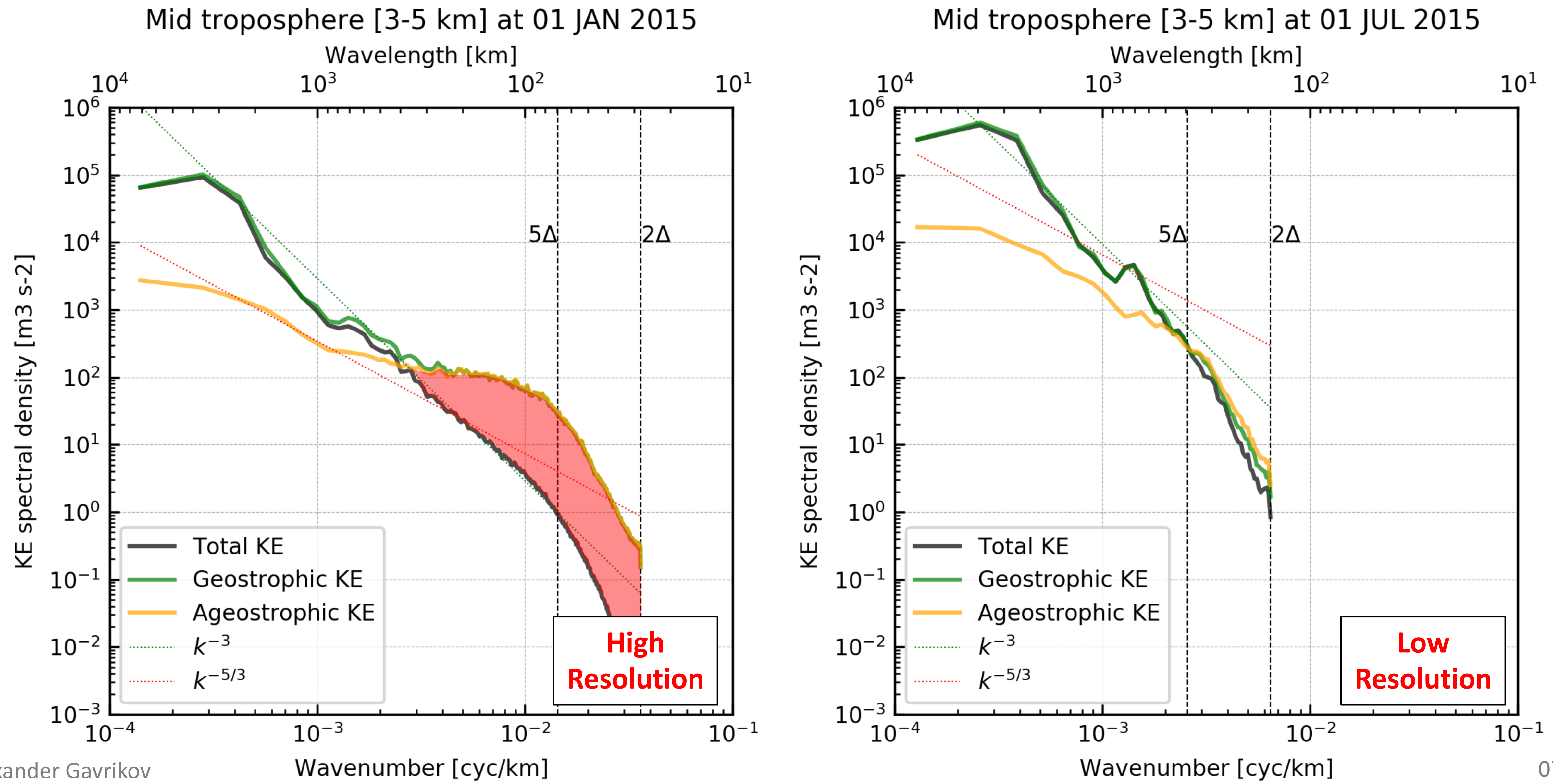
MESOSCALE FILTRATION: DYNAMICAL METHOD

Wind speed at 1 km [1979-09-24 06:00:00]



MESOSCALE FILTRATION: DYNAMICAL METHOD

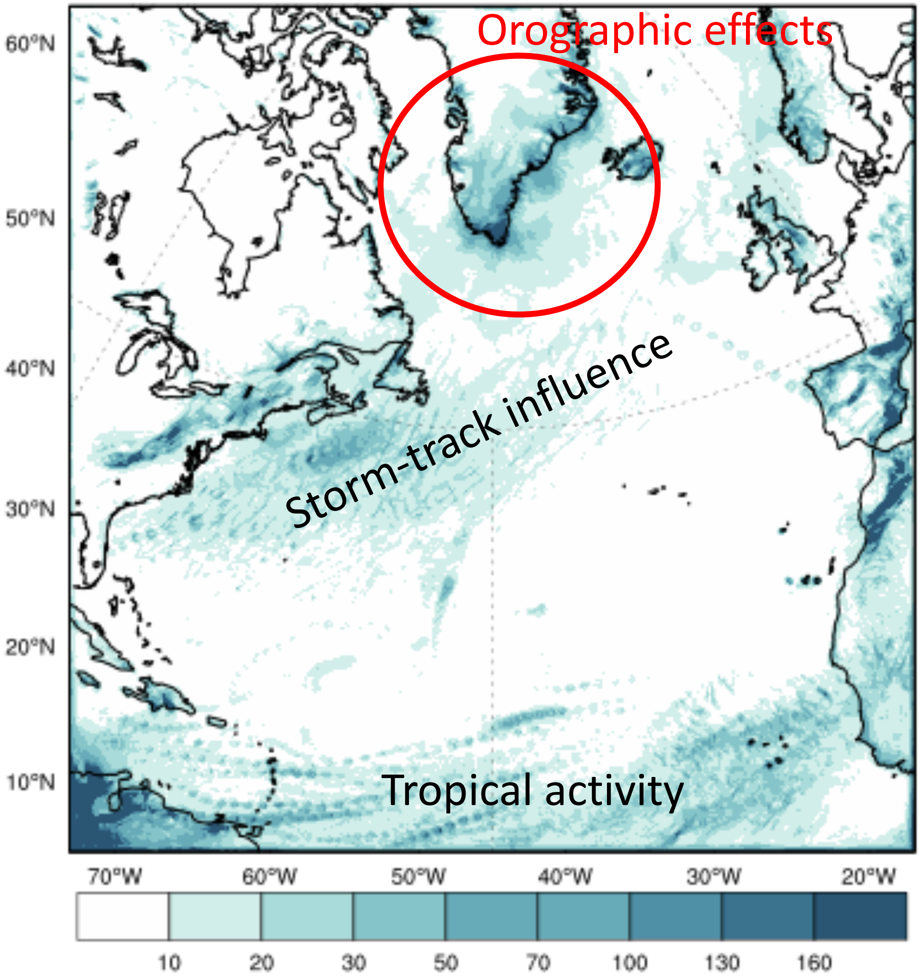
Case study 01 JUL 2015: Spectra in HiRes (left) and LoRes (right) data for Mid Troposphere



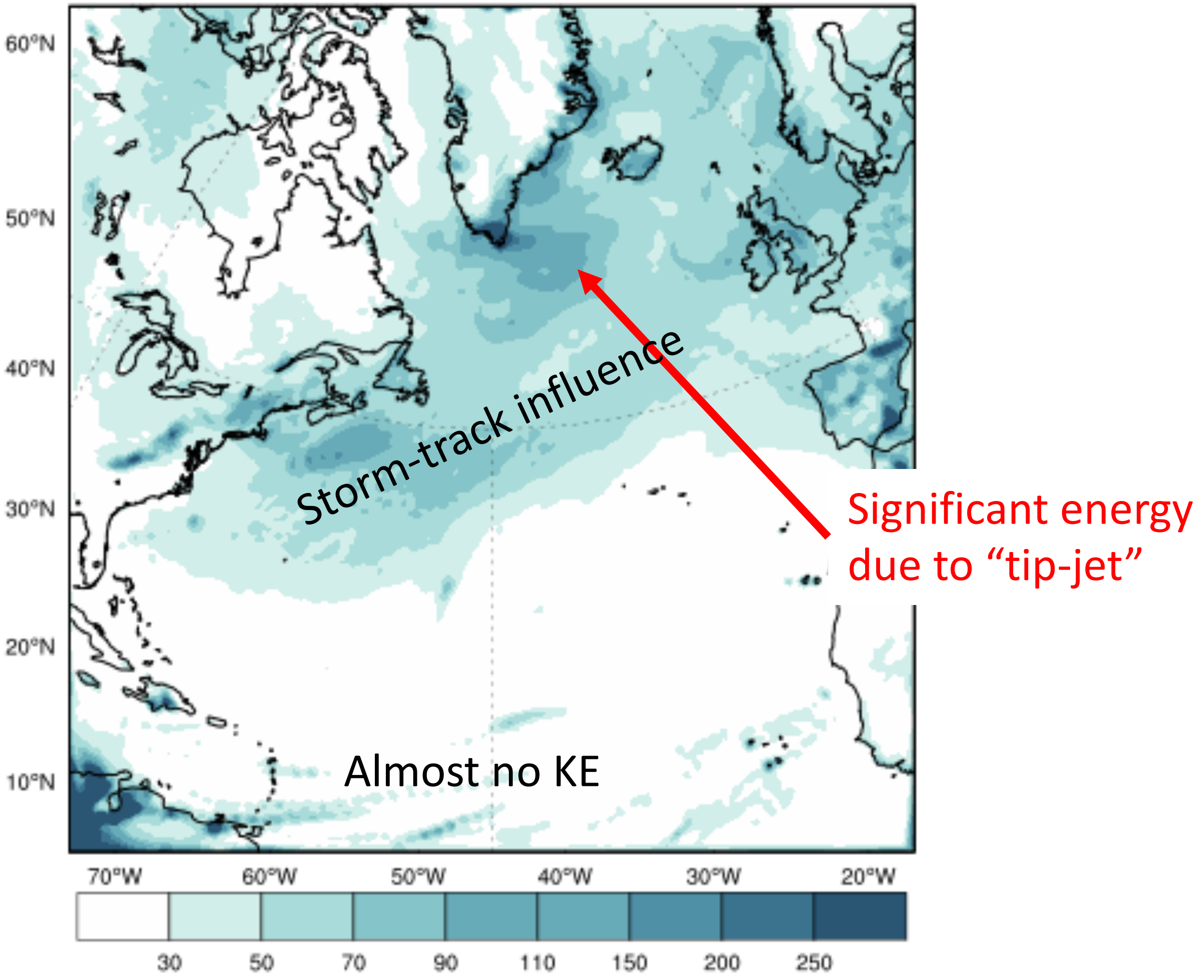
MESOSCALE FILTRATION: DYNAMICAL METHOD

Spatial characteristics for JAN 2015

Ageostrophic wind variance at 1 km for JAN 2015



Geostrophic wind variance at 1 km for JAN 2015



The limitations of the dynamical method

1. Formally cannot be applied in Ekman's layer (approx. 1 km above the surface)
2. In order to gain the mesoscale impact we need to compare ageostrophic variance with total wind variance. To do that all components of equation below has to be linearly independent. **But they do not!**

$$\mathrm{Var}(V) = \mathrm{Var}(V_g) + \mathrm{Var}(V_a) + 2 \cdot \underbrace{\mathrm{Cov}(V_g, V_a)}_{50\% \text{ of } Var(V_a)}$$

MESOSCALE FILTRATION: TOPOLOGICAL METHOD

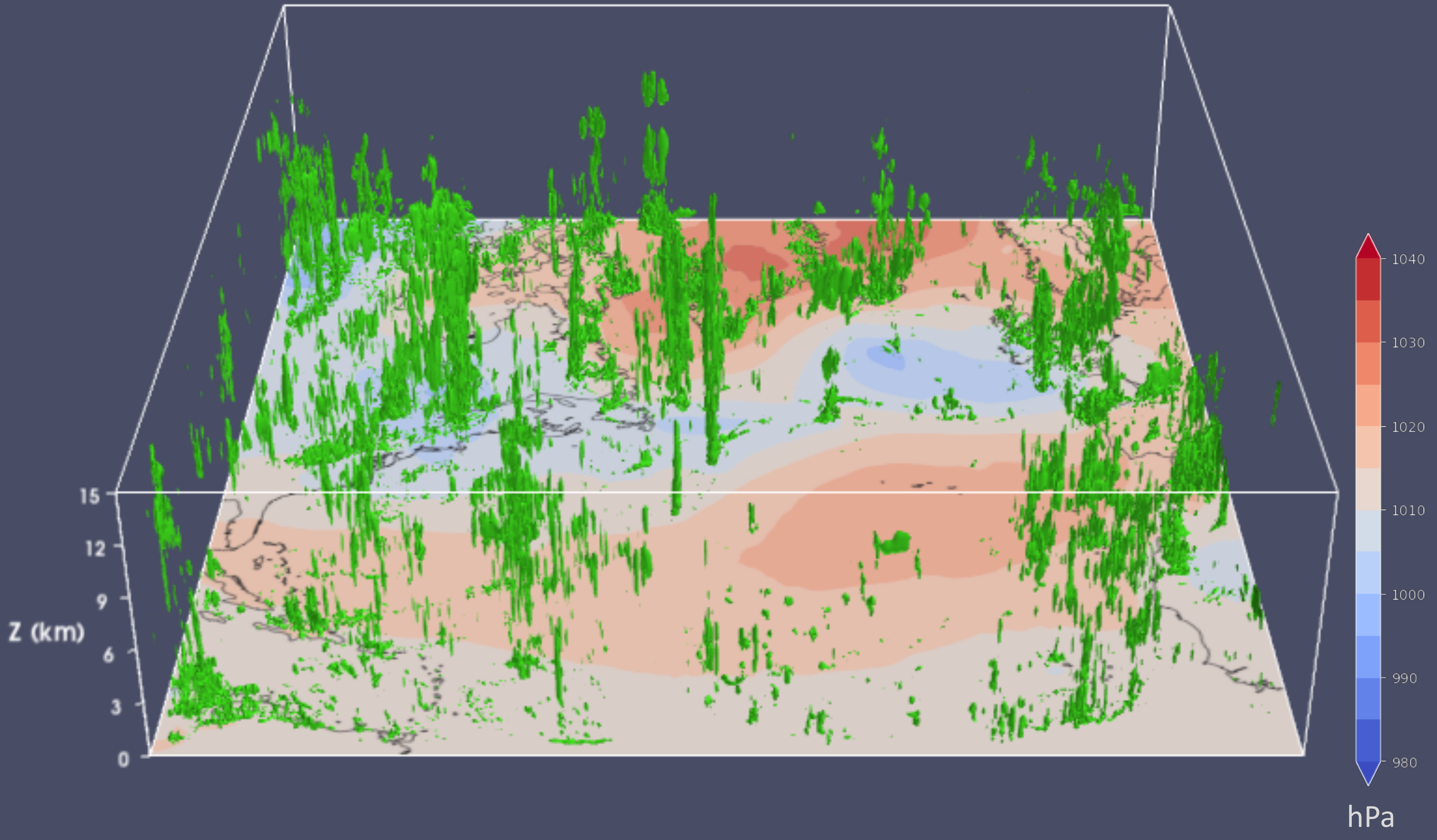
Vortex identification as a coherent structure. A coherent structure is an idea that singles out areas in the fluid where there is less mixing or movement than would be otherwise expected considering the velocity field, that means that a section of the fluid remains roughly together (coherent) while moving in the fluid.

The most popular are velocity gradient tensor criteria. Where velocity gradient tensor can be decomposed into a symmetric and a skew-symmetric part:

$$\nabla v = \underbrace{\frac{1}{2}[\nabla v + (\nabla v)^T]}_{\textit{rate-of-strain tensor}} + \underbrace{\frac{1}{2}[\nabla v - (\nabla v)^T]}_{\textit{the vorticity tensor}} = S + \Omega,$$

Q-criterion	**Δ-criterion**	**λ_2-criterion**
$Q = \frac{1}{2}(\lvert\Omega\rvert^2 - \lvert S\rvert^2) > 0$	$\Delta = \left(\frac{Q}{3}\right)^3 + \left(\frac{\det(\nabla v)}{2}\right)^2 > 0$	$S^2 + \Omega^2 = -\frac{1}{\rho}P_{ij}$ $\lambda_2 < 0$
Norm of the vorticity tensor exceeds the rate-of-strain tensor norm	defines vortices as regions in which the eigenvalues of ∇v are complex and the streamline pattern is spiralling or closed	The λ2-criterion looks for a pressure minimum (2 eigenvalues of Hessian has to be < 0) but removes the effects from unsteady straining and viscosity by discarding these terms
[Hunt et al., 1988]	[Chong et al., 1990]	[Jeong and Hussian, 1994]

Isosurfaces of the **Δ-criterion>1e-25** (3D representation) for **JUL 2008**



Applications of NAAD

Currently we're working on estimation the impact of mesoscale-resolving boundary conditions in models of wave and ocean dynamics

NAAD output

U10, V10

U10, V10, T2, Q2,
RADIATION (short/longwave daily means),
PRECIPITATION (liquid + show daily means)

NOAA WAVEWATCH III® model

Numerical spectral wave model

Configuration of WW3:
Spatial resolution: 1/0.2 degrees (0-82N/20-80N) - 2-way nesting, spectral resolution: 25 frequencies, 24 directions, ST6 physics package (with modified CDFAC=1.15), DIA for non-linear wave interactions, Ocean surface currents from ECMWF ORAS5 reanalysis (0.25 degree, daily)

NEMO

Nucleus for European Modelling of the Ocean

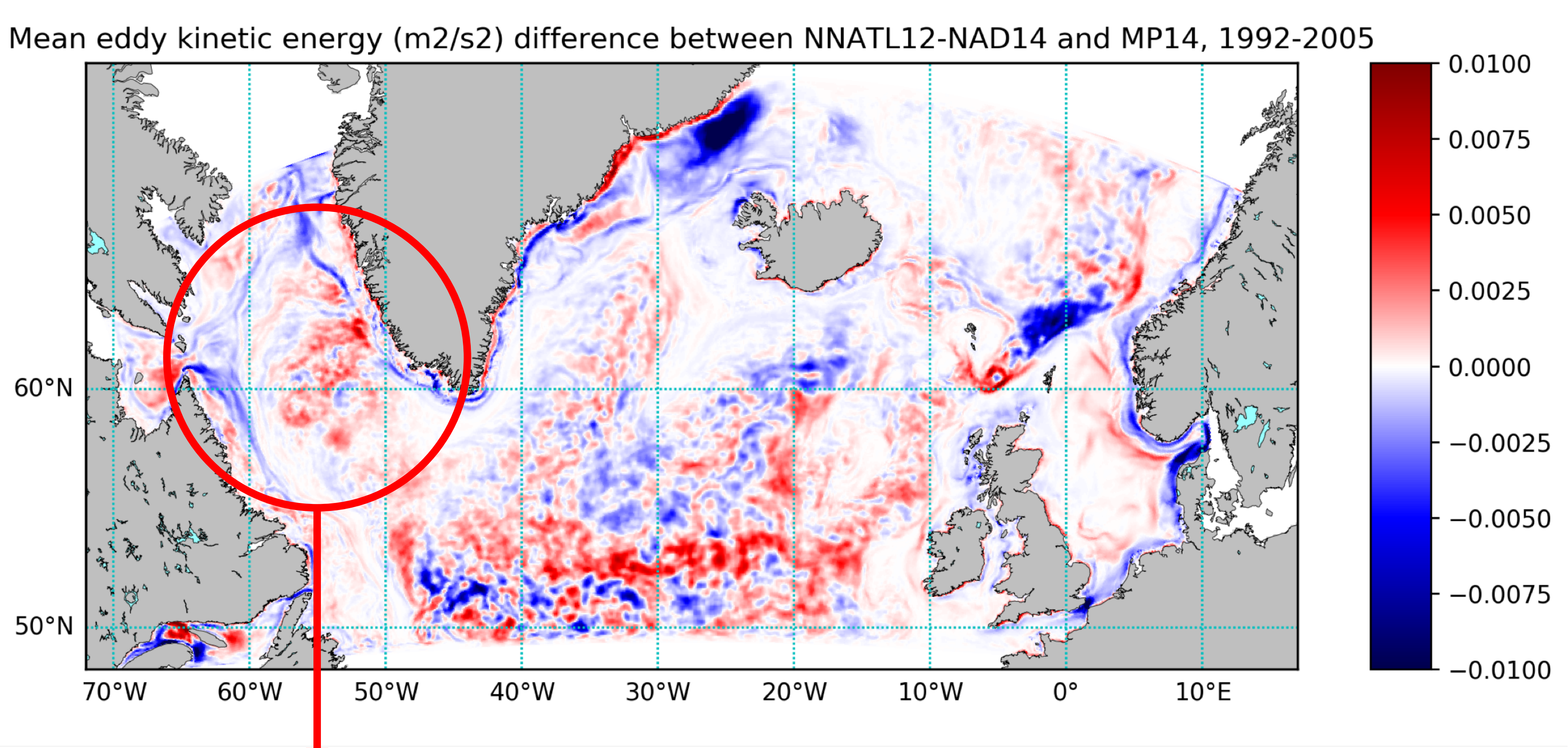
Configuration of NEMO (NNATL12-MP4):
Spatial resolution: 1/12°, 75 vertical levels, Initialization: T, S and Ice (GLORYS2v4), self-diffusive UBS-scheme for momentum and tracer advection, no-slip lateral momentum boundary condition

by Polina Verezemskaya (verezem@sail.msk.ru)

Applications: ocean modelling (NEMO)

HighRes atmospheric forcing vs LowRes forcing: NEMO run for 1992 – 2005

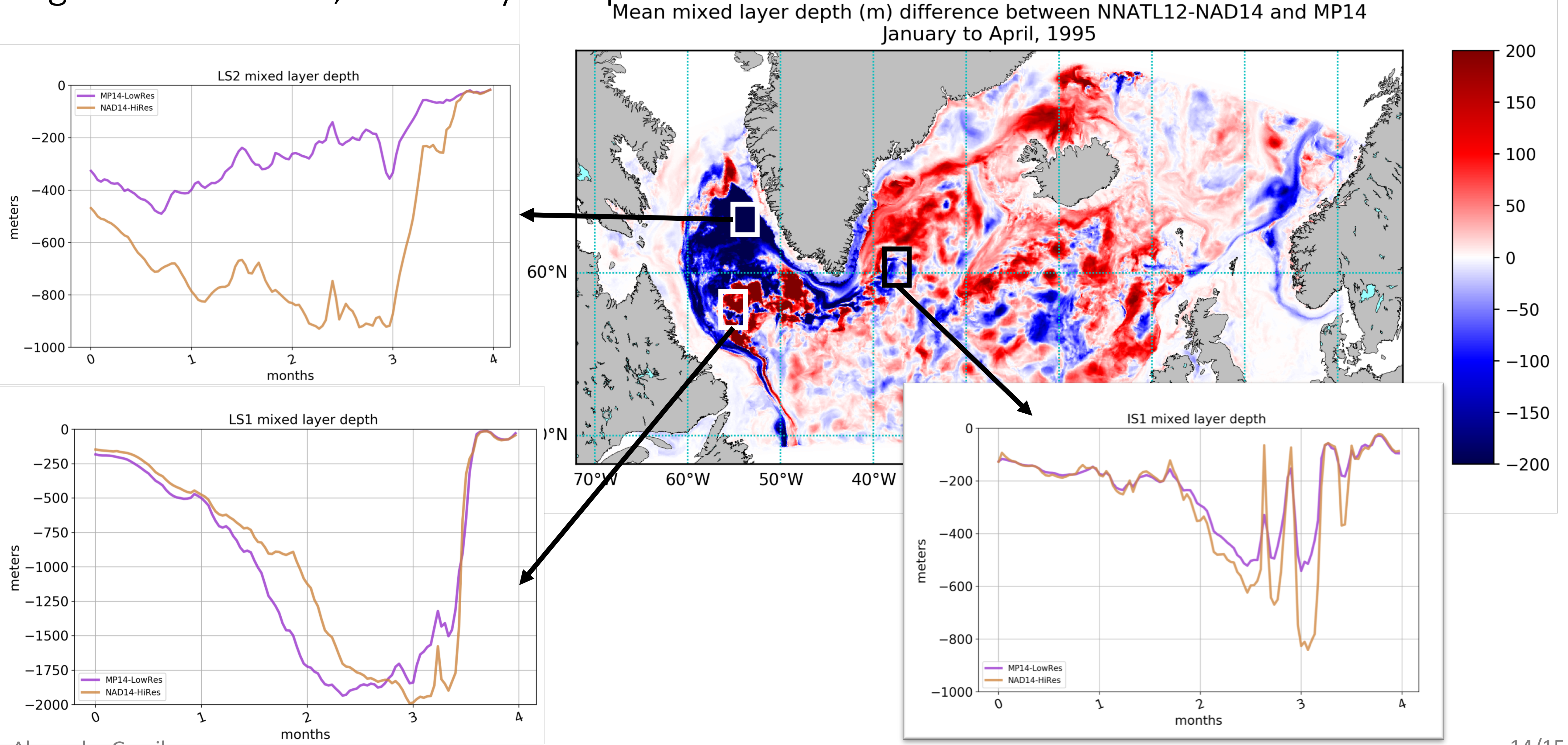
Mean eddy kinetic energy difference



More or stronger ocean eddies help to develop the convection

Applications: ocean modelling (NEMO)

HighRes vs LowRes, Mixed layer depth



Summary

What's been done

1. **We've developed the long-term (1979-2018) mesoscale resolving dataset over the North Atlantic region (NAAD)**

   for further study of mesoscale processes in the atmosphere and their impact on the wave and ocean dynamics
2. **Implemented dynamical (geostrophic balance) and topological (Eurlean) methods for filtration mesoscale structures out of high-resolution data**
3. **The impact of mesoscale boundary conditions on waves characteristics has been investigated using WW3 model**

   Sea waves are sensible to the mesoscale boundary conditions only in the regions of significant mesoscale activity (e.g. the Irminger sea)
4. **The eddy-resolving NEMO experiment with "mesoscaled" forcing showed significant impact on the mixed layer and better agreement with observations**

Nearest future

1. Make NAAD dataset available online
2. Implement more topological methods (Lagrangian?) for coherent structures identification (using NAAD)
3. Building atmospheric mesoscale climatology for North Atlantic (using NAAD)
4. Developing the long-term mesoscale dataset of ocean dynamics in the North Atlantic (using NEMO)

Спасибо