Meso- to Submesoscale Turbulence in the Ocean

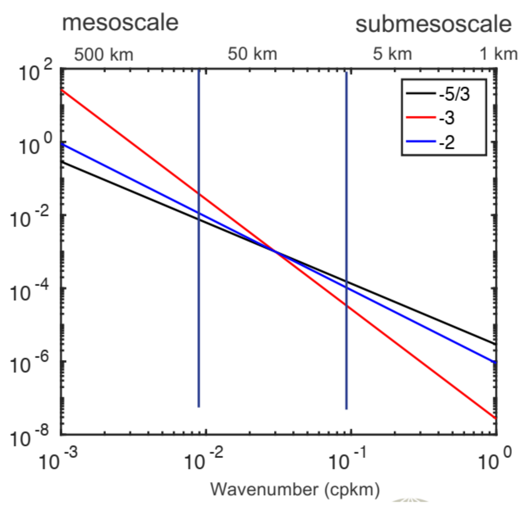
Ilmar Leimann[1], Alexa Grisel[2], Maren Walter[1], Julia Dräger-Dietel[2] and Moritz Epke[2]
[1]MARUM/ IUP, University of Bremen, [2]IfM, University of Hamburg

Objectives

- compare ICON-o Telescope model with observations on meso- to submesoscales, in terms of
  - kinetic energy in spectral space
  - velocity structure functions
- identify inertial ranges in the meso- submesoscale regime
- find direction of energy cascade and processes responsible

Expectations

assume isotropic, statistically homogeneous flow



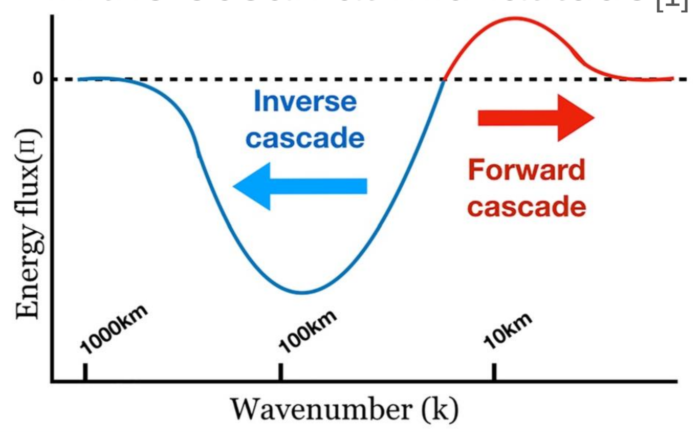
Velocity structure functions

$$\langle \Delta u^2(s)\rangle \approx s^2/2\int_0^{2/s} k^2 E(k)\,dk + 2\int_{2/s}^{\infty} E(k)\,dk$$

Direction of Energy Cascade

$$\langle \Delta u_l^3(s)\rangle \sim -\varepsilon s \begin{cases} \varepsilon > 0, & \text{forward cascade } (d=3) \\ \varepsilon < 0, & \text{inverse cascade } (d=2) \end{cases}$$

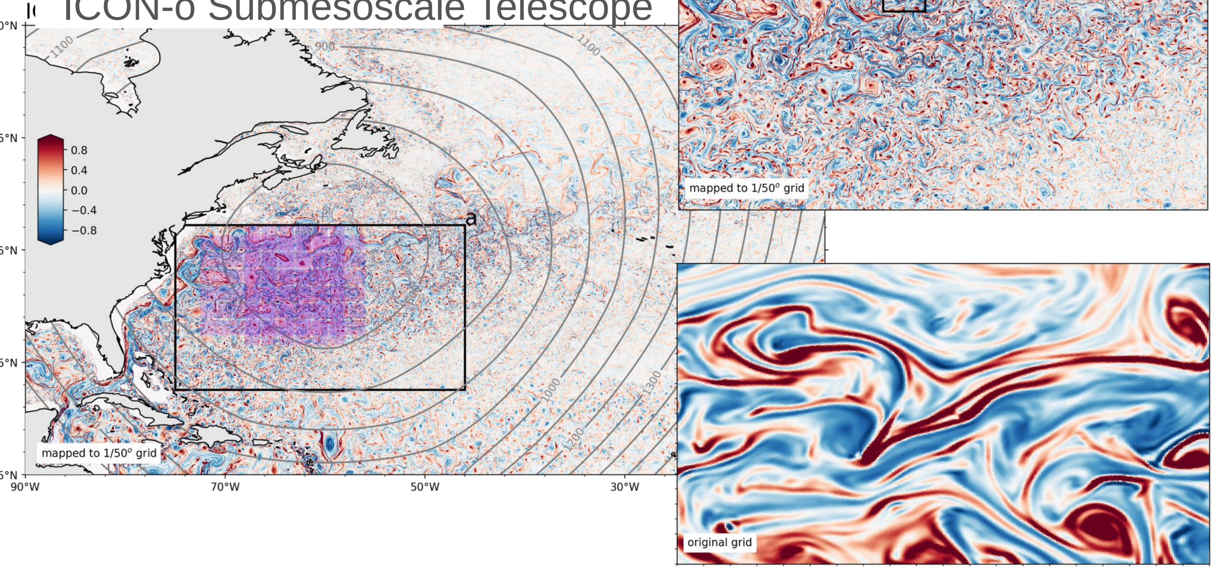
Schematics of kinetic energy spectral flux in the ocean at mid-latitude [1]



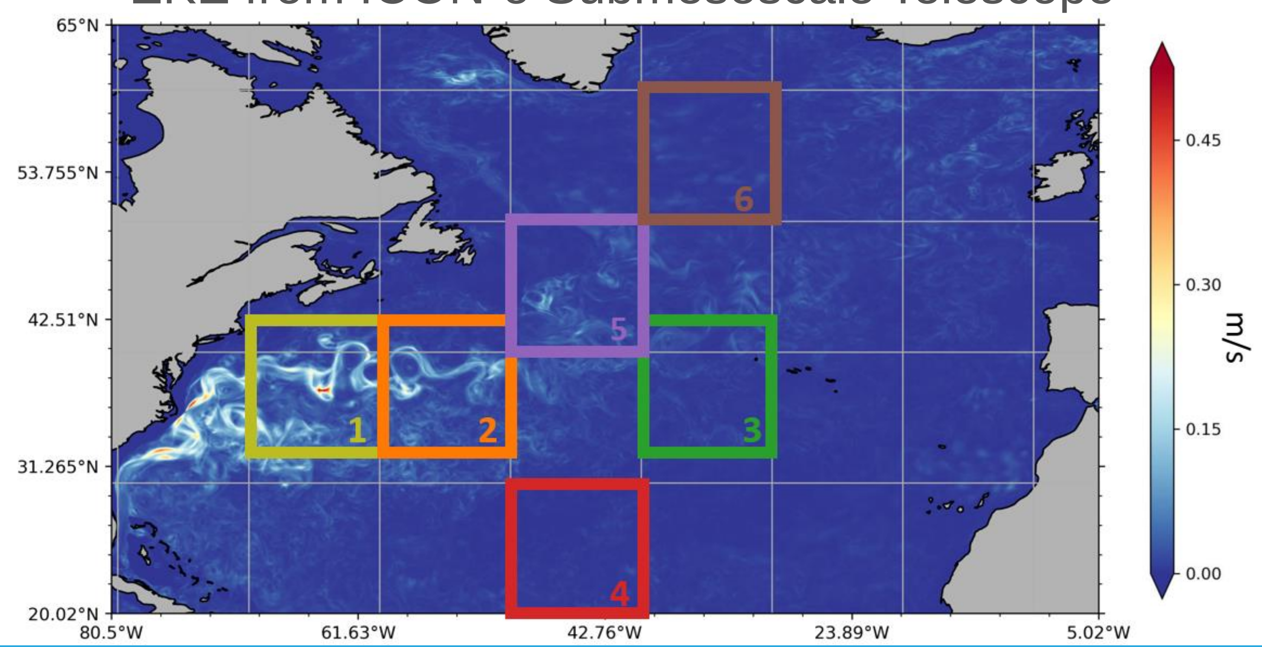
ICON-o Submesoscale Telescope model

- refined grid up to 540m resolution over a large region in the North Atlantic
- more realistic variability on small and large scales

Vorticity
ICON-o Submesoscale Telescope



EKE from ICON-o Submesoscale Telescope



Different regions in North Atlantic

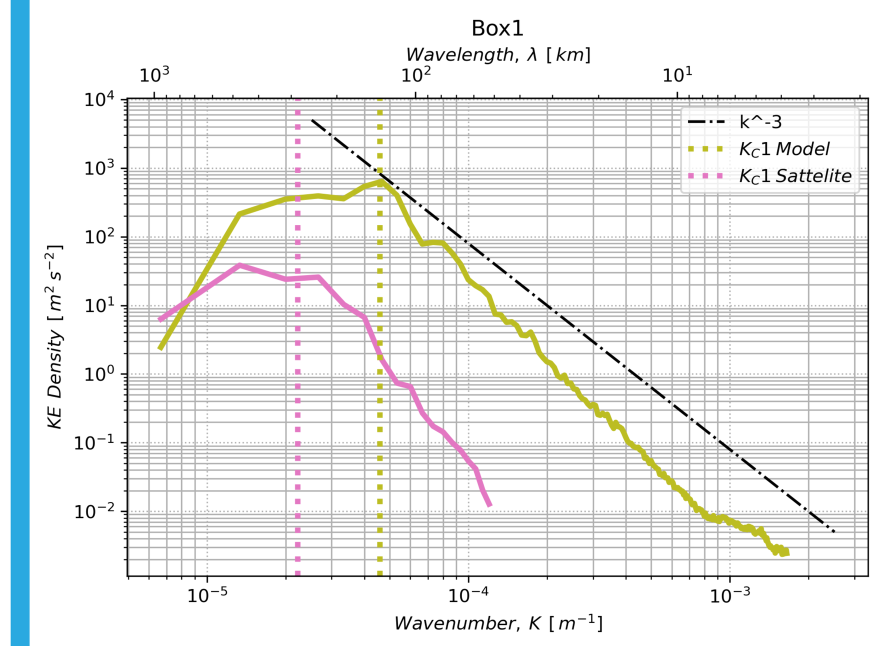
- six boxes in size of 10° x 10°
- aim to capture different turbulent regimes

Data

- ICON-o Submesoscale Telescope model, 9 Mar 2010 to 22 Mar 2010
- Satellite: Global Ocean Gridded L 4 Sea Surface Heights And Derived Variables Reprocessed Copernicus Climate Service, 0.25° × 0.25°, 1 Jan 1993 to 31 Dec 2020

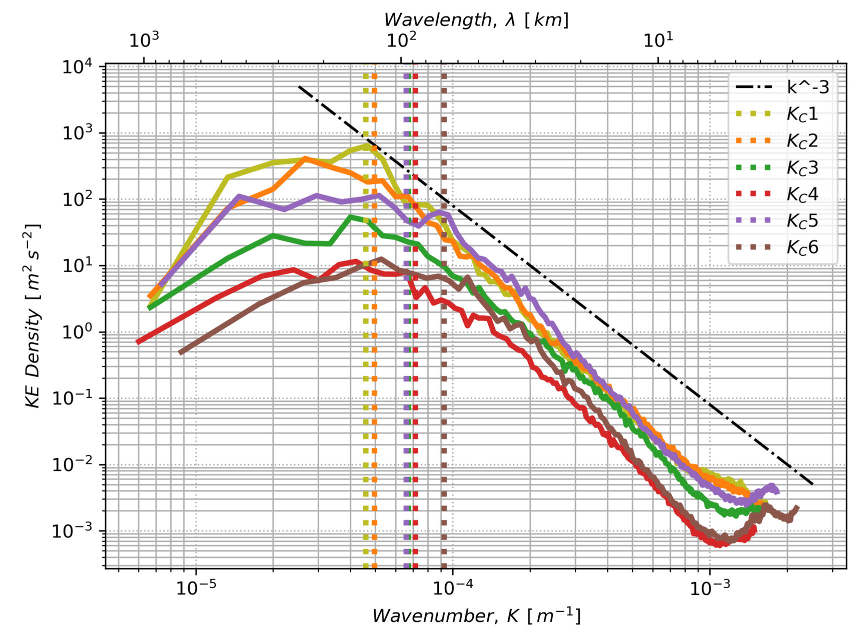
Results

Model vs. Satellite



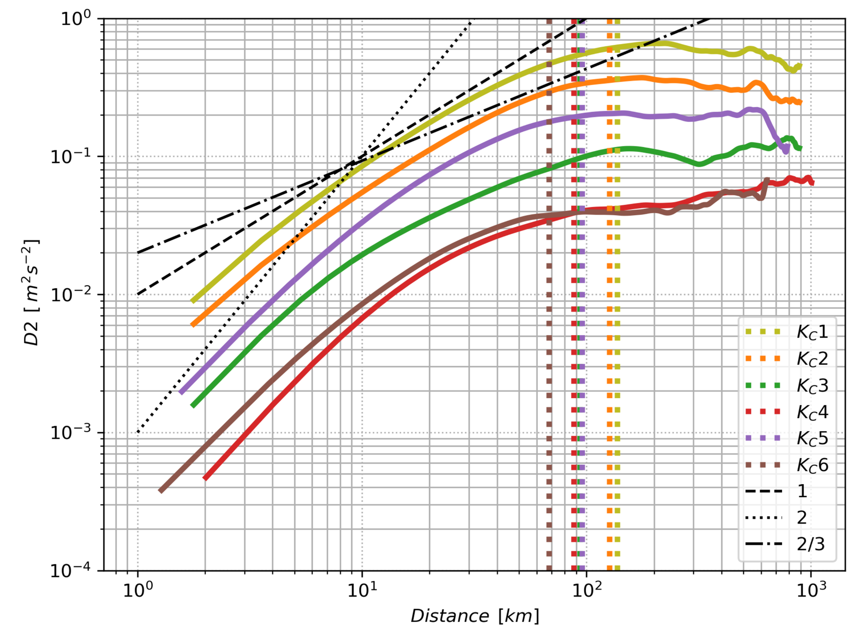
- model - higher KE density & higher wavenumber of K_c

Spectral analysis



- higher KE density values in regions where high EKE occur

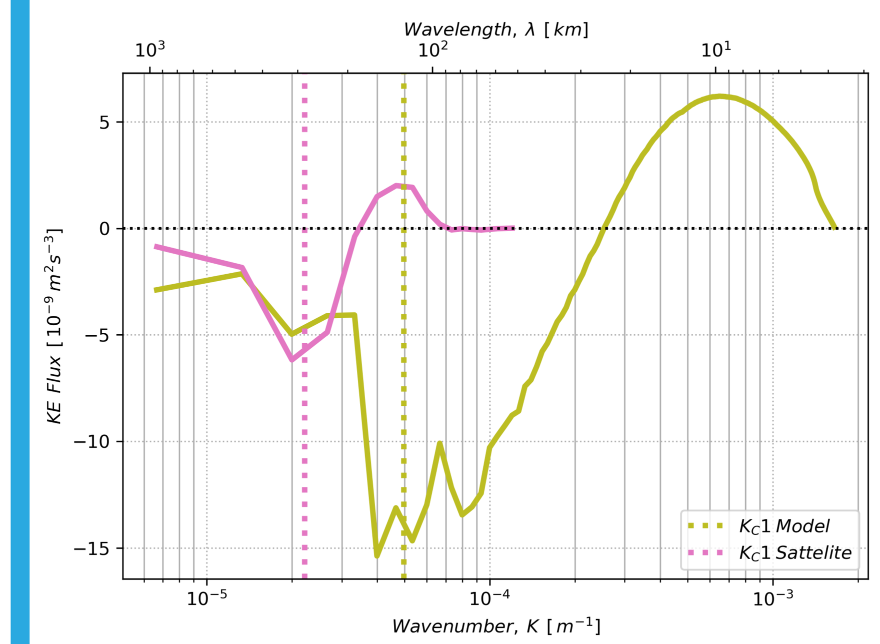
Velocity structure functions



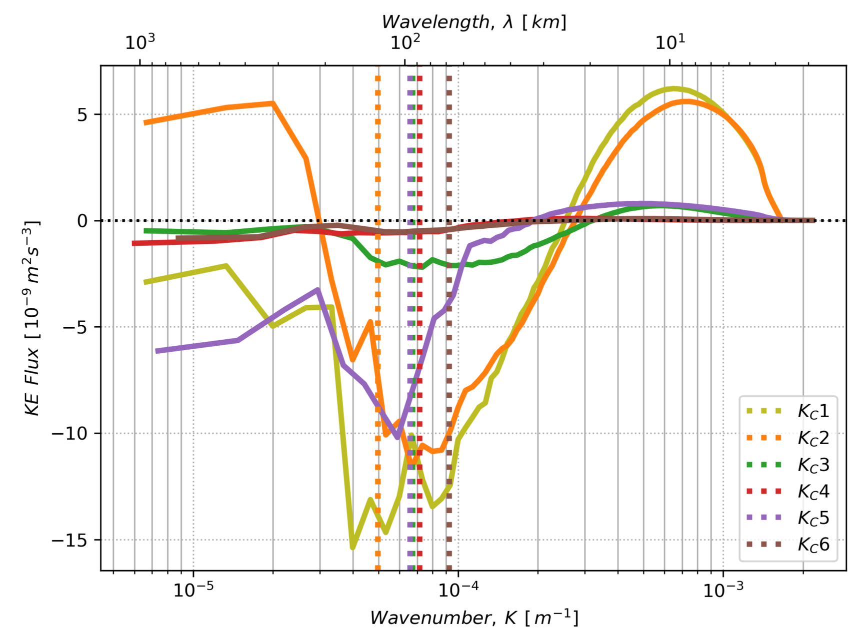
- energy gets saturated near K_c

Kc – energy-containing scale, which represents the scale of the most energetic eddy structure.

$$K_c = \frac{\int K\varepsilon\, dK}{\int \varepsilon\, dk}$$



- both exhibit inverse & forward energy cascade
- model provides insight into submesoscale flux



- higher amplitude of inverse cascade occurs in regions with high EKE
- maximum inverse cascade coincides with K_c

Preliminary results:

spectral and velocity structure functions are consistent with QC turbulence theory

Outlook

- Consistency of spectral fluxes and structure functions
- Global Drifter Program data as high resolutions observational reference
- Tracking of Lagrangian Particles within the Model

References

[1] Ajayi, A., Le Sommer, J., Chassignet, E. P., Molines, J.-M., Xu, X., Albert, A., & Dewar, W. (2021). Diagnosing cross-scale kinetic energy exchanges from two submesoscale permitting ocean models. *Journal of Advances in Modeling Earth Systems*, 13, e2019MS001923. https://doi.org/10.1029/2019MS001923

Universität Bremen
marum