Impact of energetic currents and the wind field on internal waves and diapycnal mixing in the Atlantic

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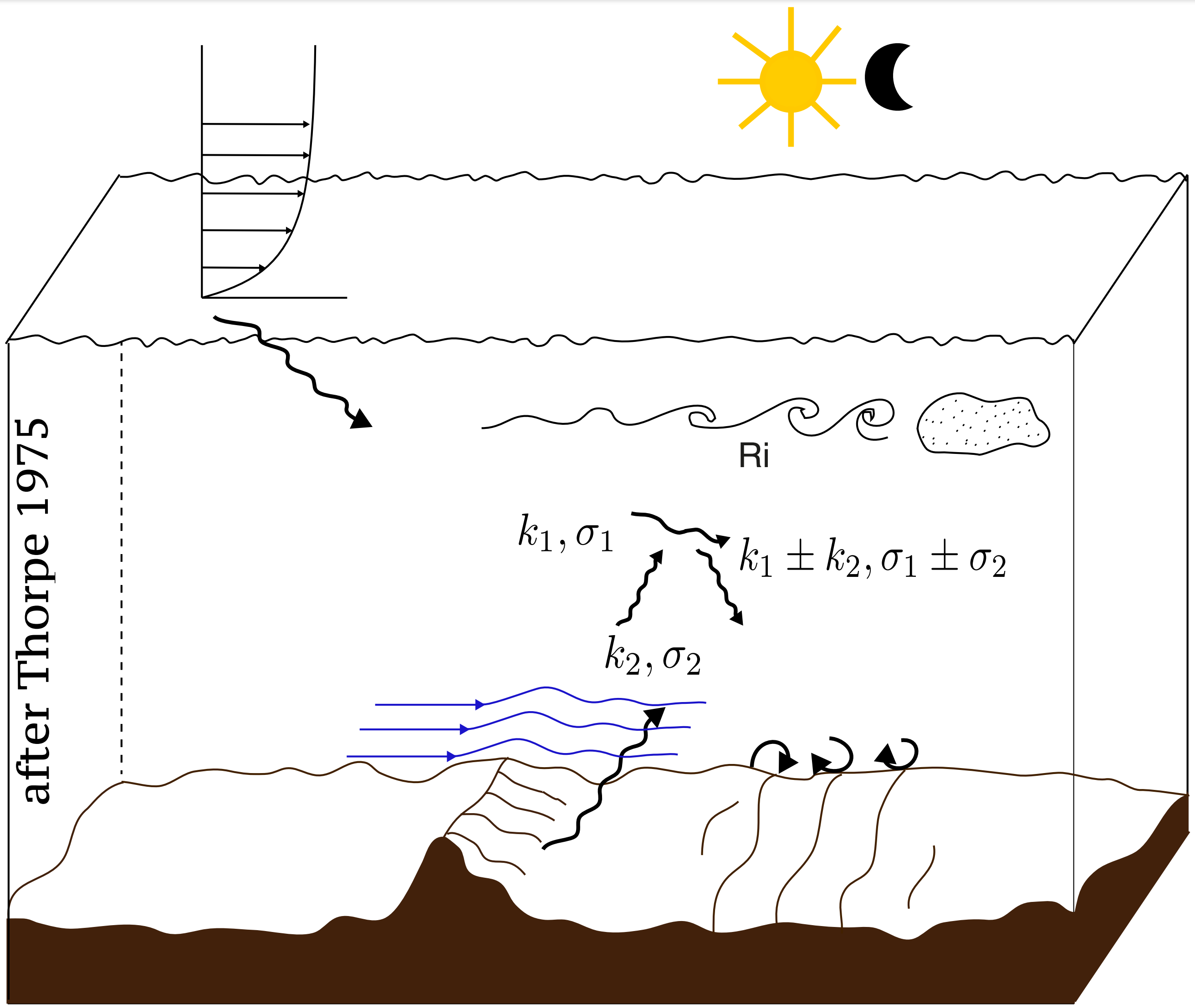
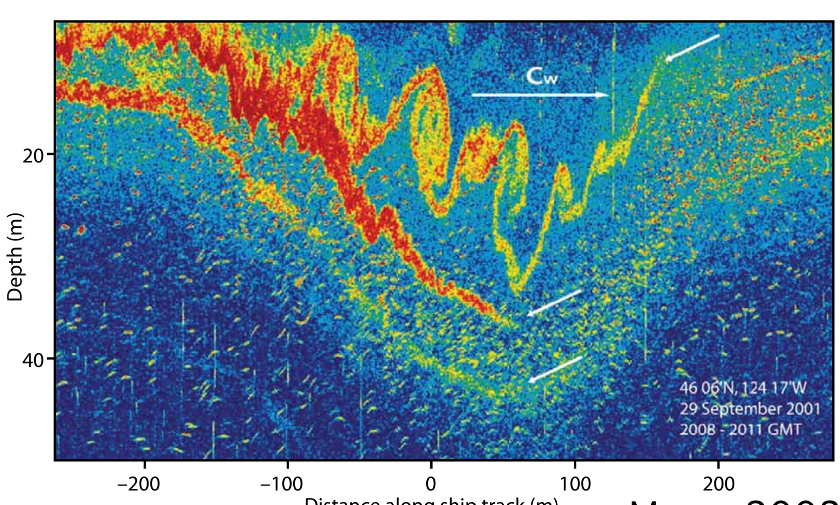
Internal waves and diapycnal mixing





Moum 2003

http://www-frd.fsl.noaa.gov/mab/scatcat/

Energy input into internal wave field

- e.g. wind, tides, flow-topography interactions

Distribution of energy in wavenumber space

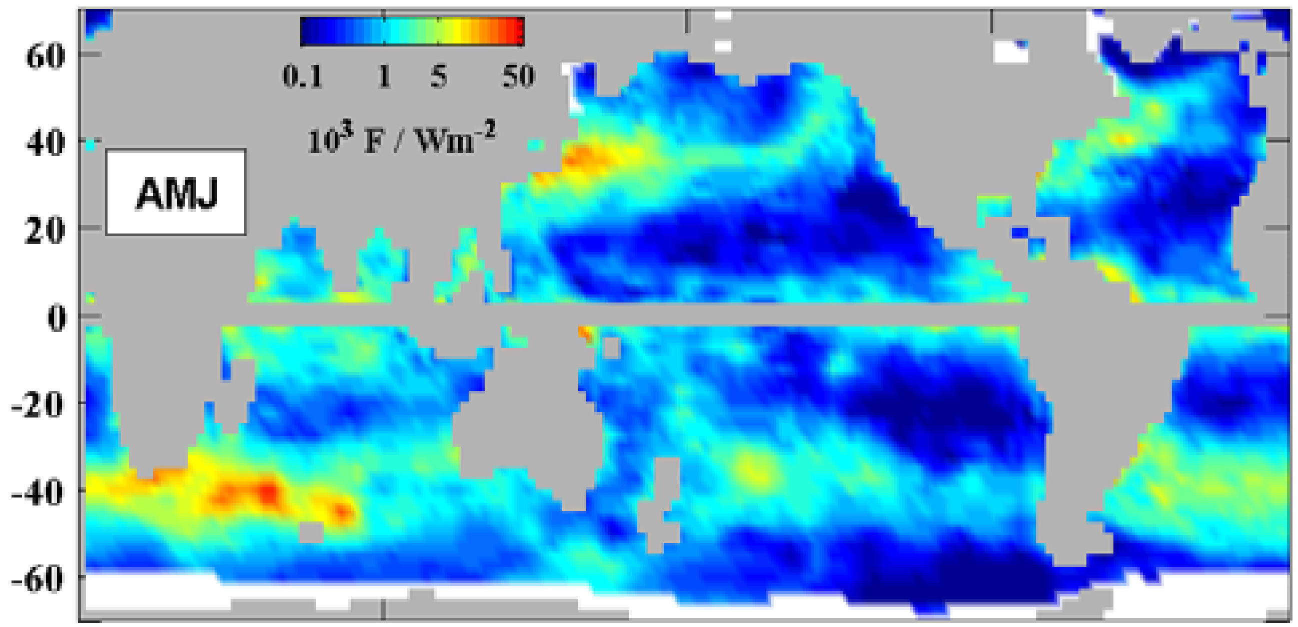
- wave-wave interactions

Internal waves are energy source for diapycnal mixing

- e.g. Kelvin-Helmholtz instabilities
- breaking of internal waves induced by (rough) topography

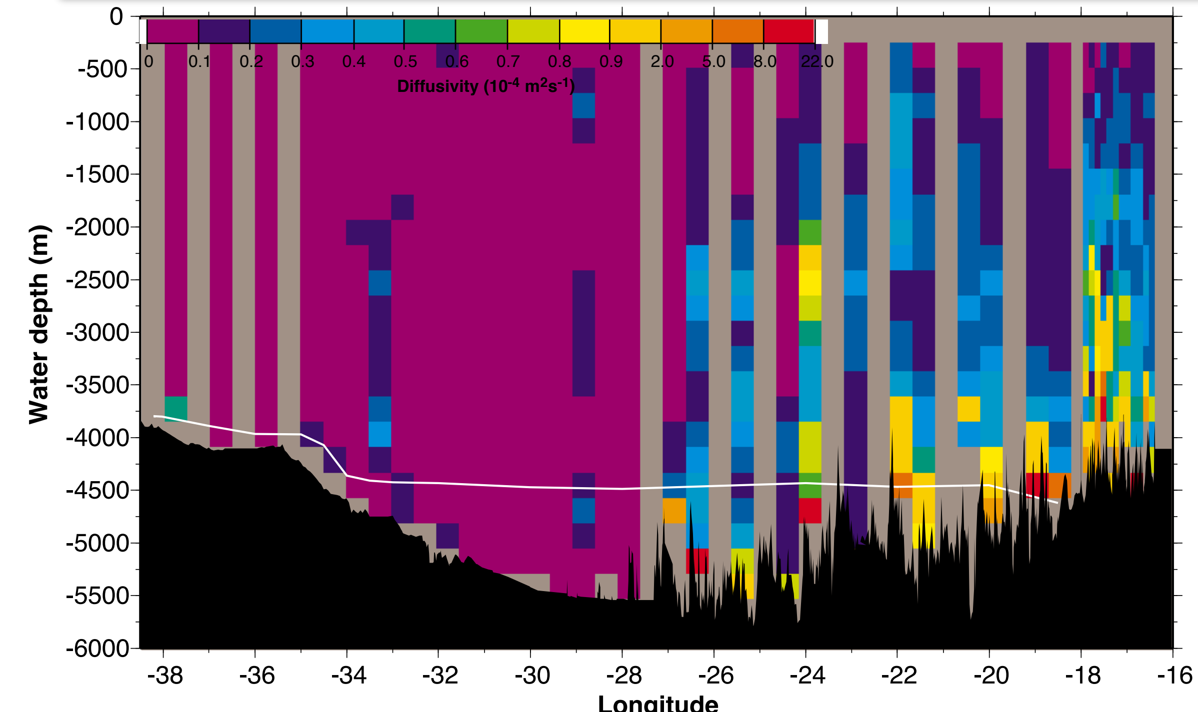
Spatial variability

wind work on near-inertial motions



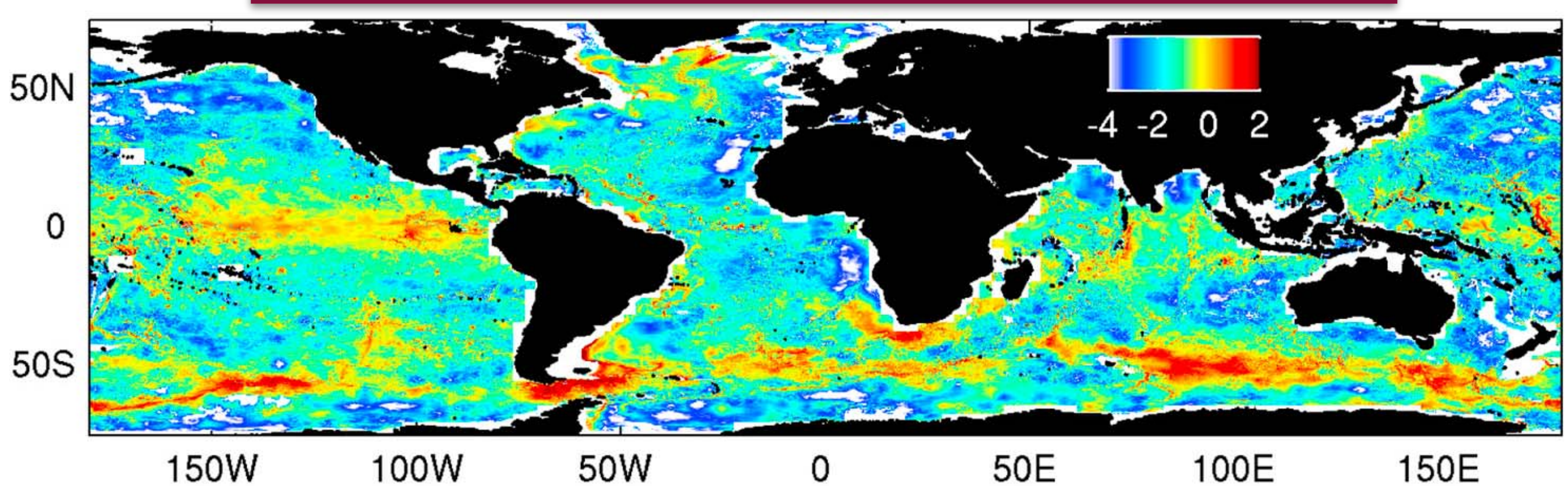
Alford 2003

dissipation over rough topography



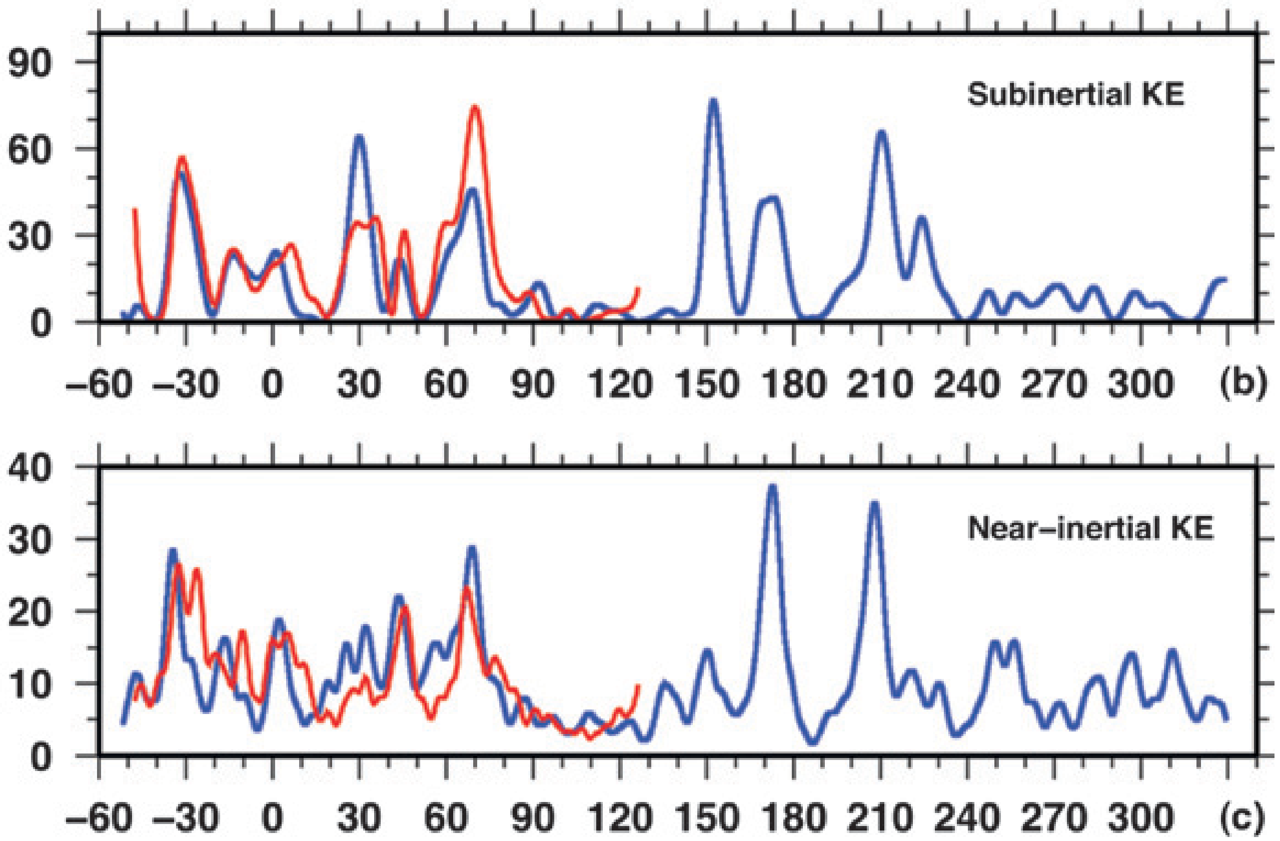
Polzin et al. 2010

energy flux into internal lee waves

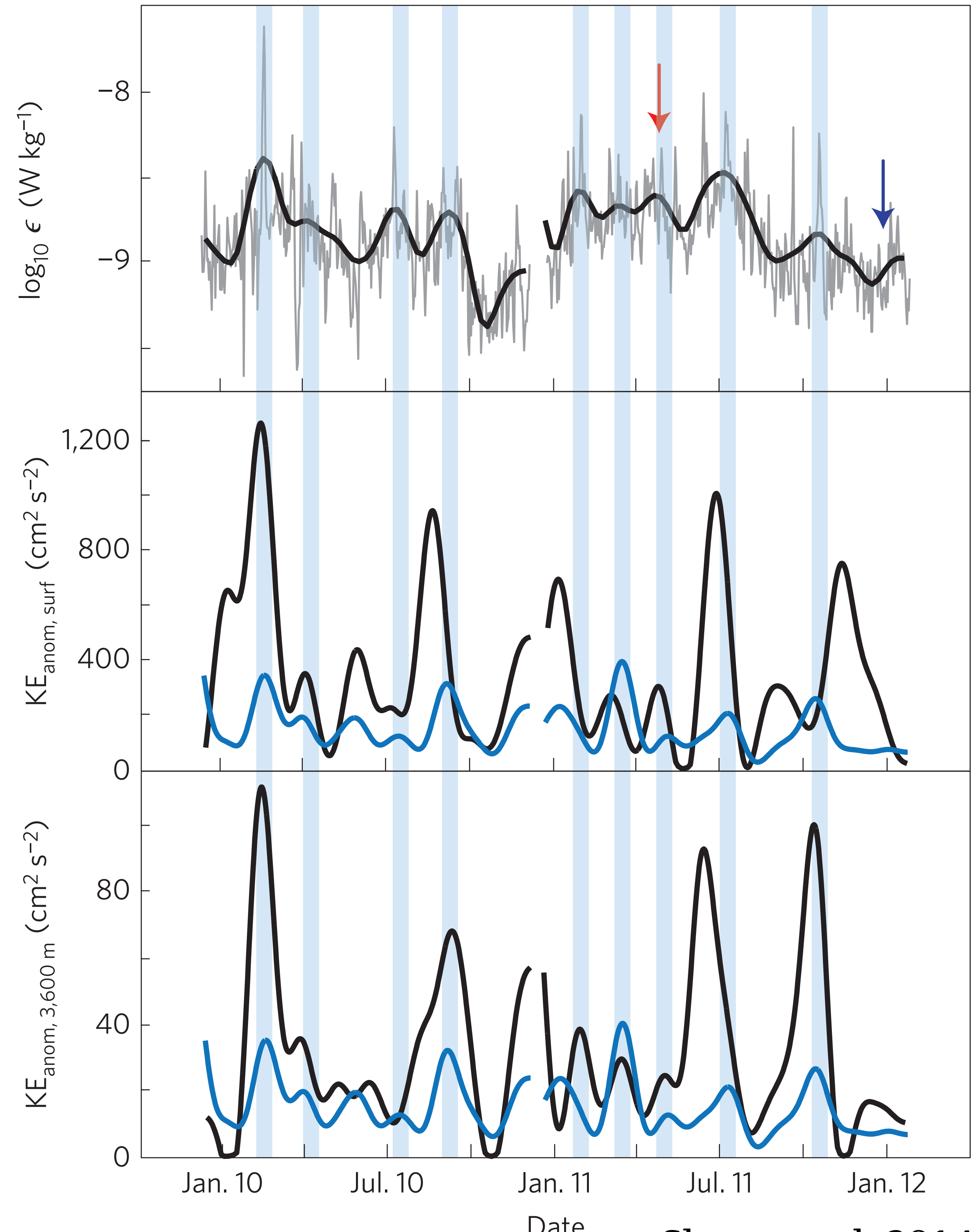


Nikurashin & Ferrari 2011

Temporal variability

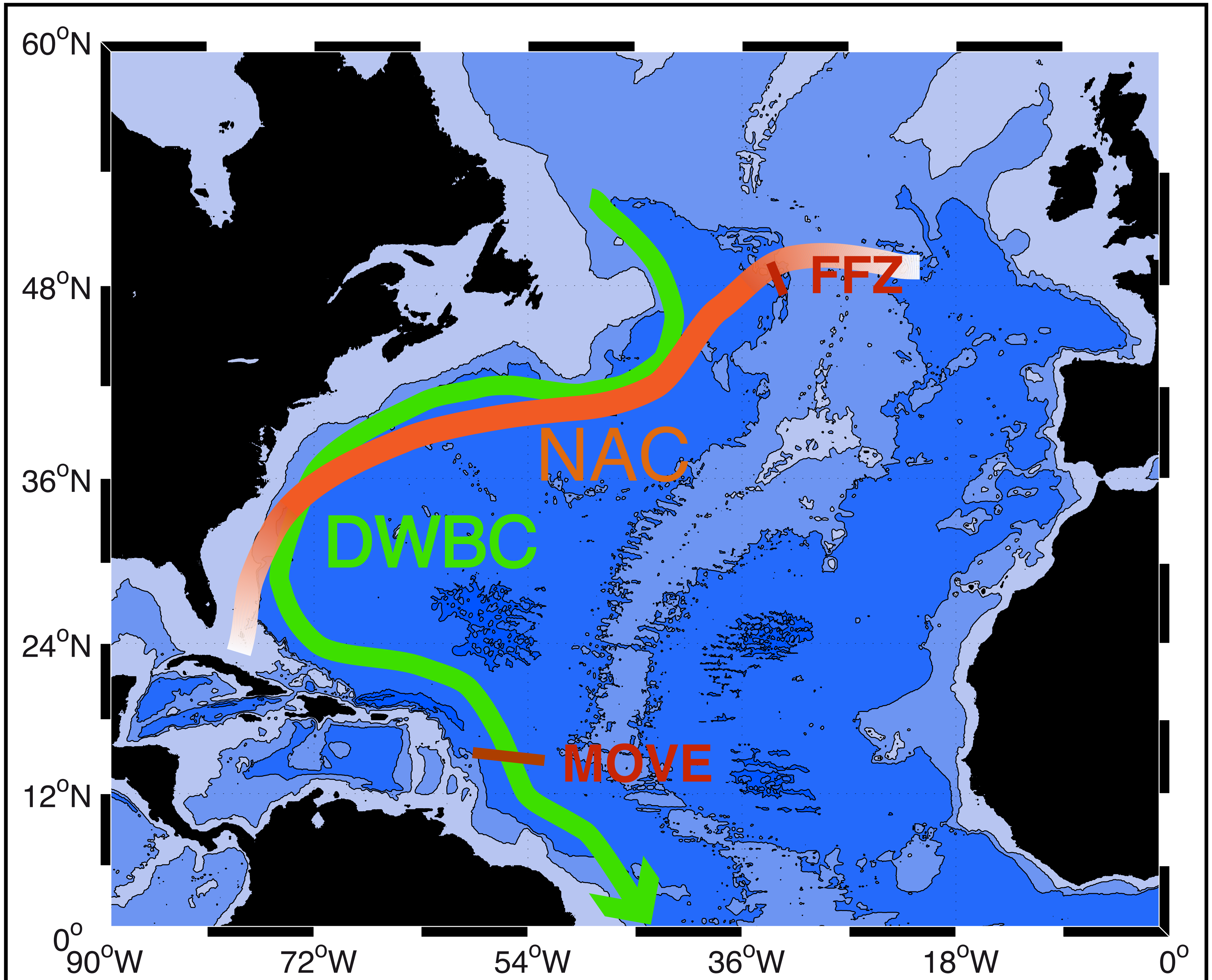


Liang & Thurnherr 2012



Sheen et al. 2014

Sources and magnitude of temporal variability in internal wave energy?



FFZ (Faraday Fracture Zone):

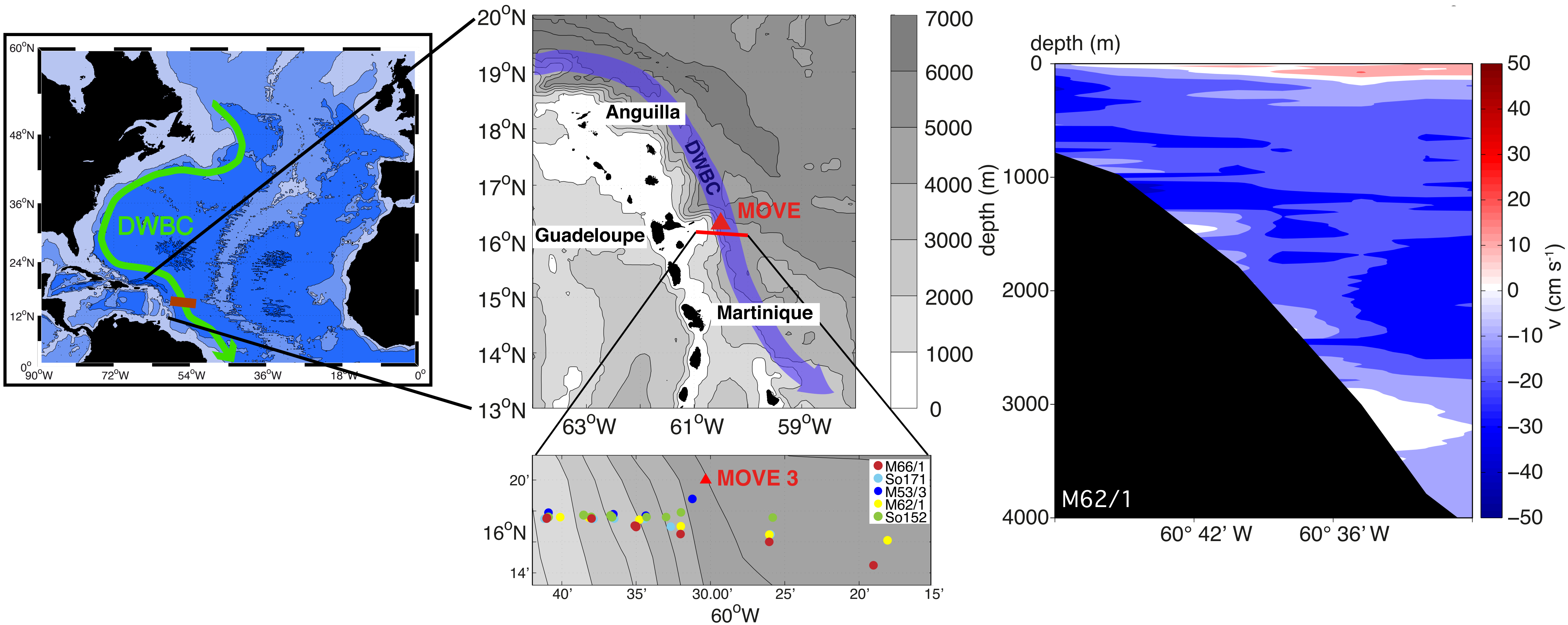
Wind (flow/ stratification)

Move (Meridional Overturning Variability Experiment):

Interaction DWBC - topographie

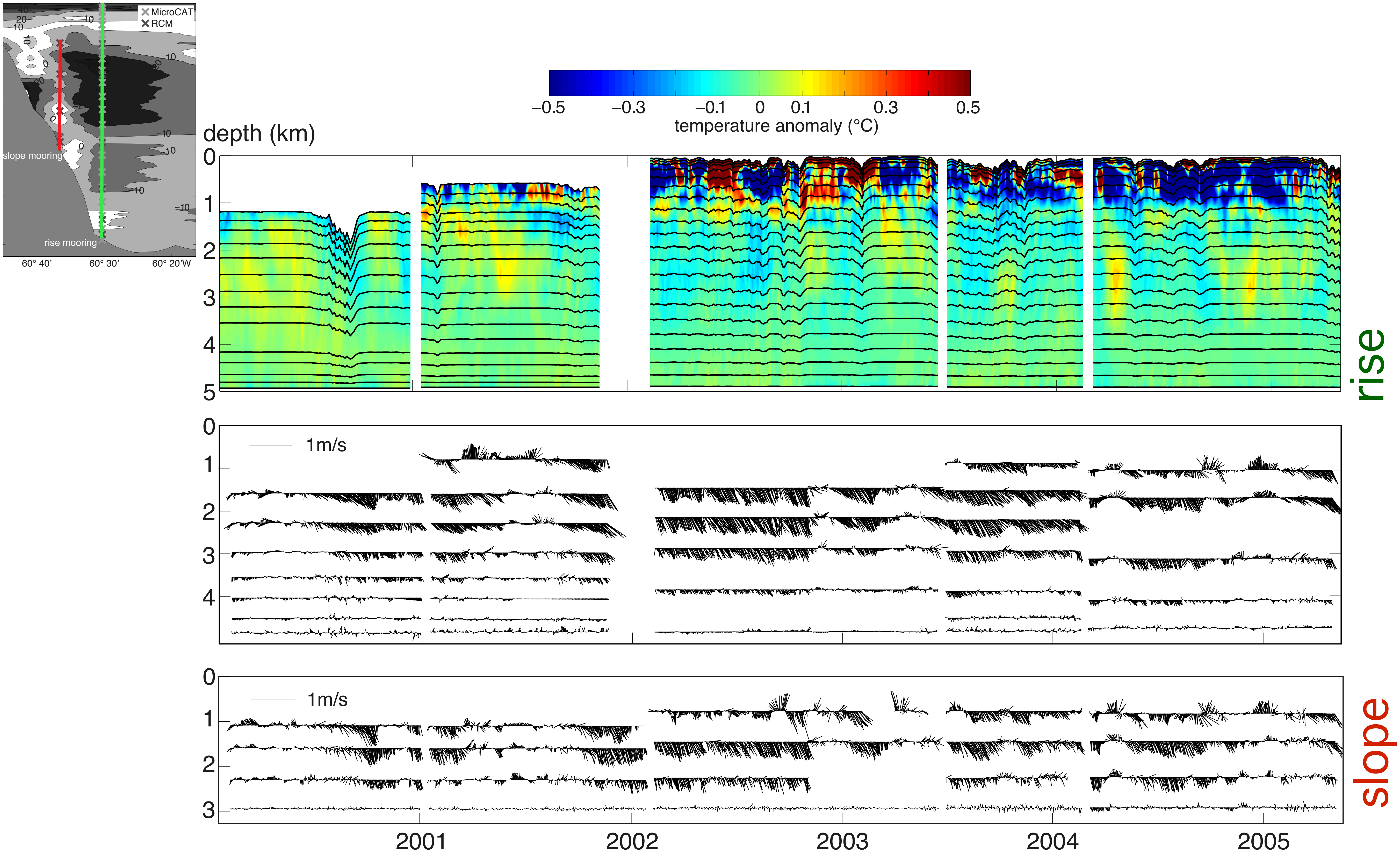
(Köhler et al. 2014 in JPO)

The MOVE array



How does the DWBC influence the internal wave field and subsequently diapycnal mixing rates?

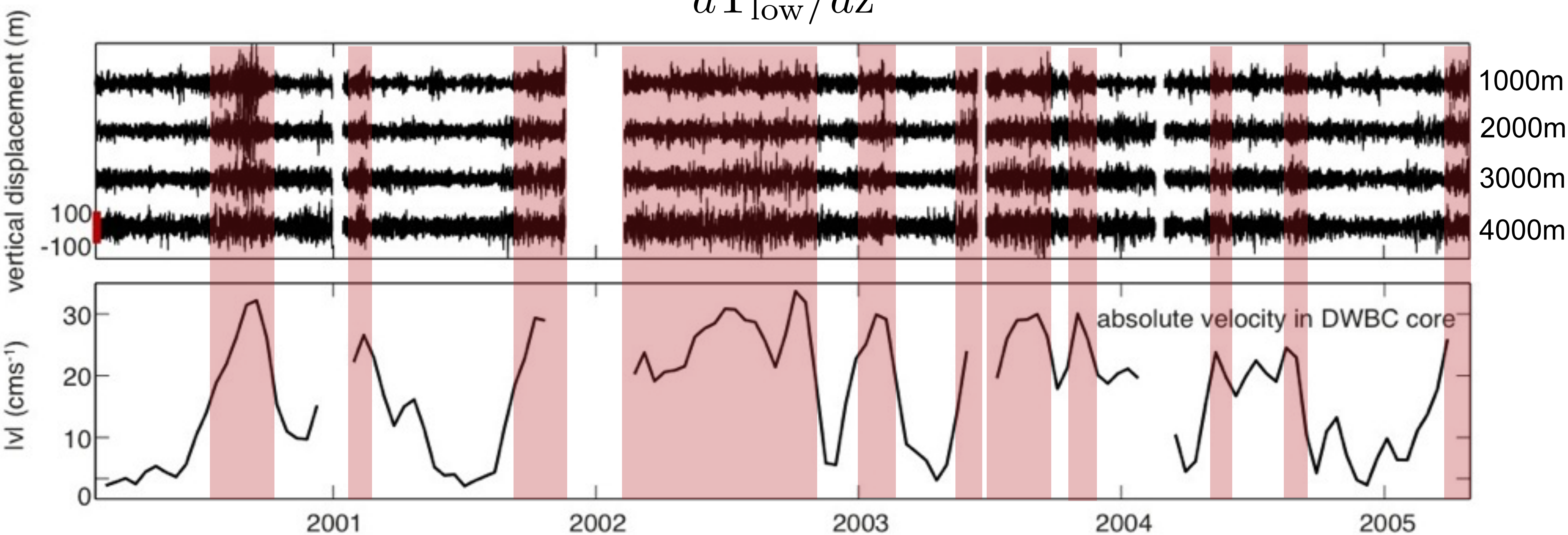
Velocity and temperature timeseries



Vertical displacements

- internal waves vertically displace isopycnals as they propagate
- calculation of vertical displacements ξ from temperature timeseries:

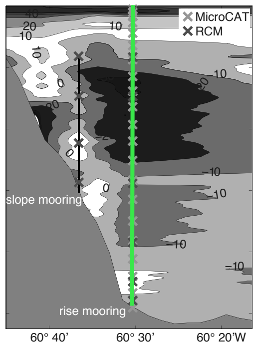
$$\xi = \frac{T - T_{low}}{dT_{low}/dz}$$



- high vertical displacements during strong flow indicate an increase in internal wave energy during these times
- -> used to calculate available potential energy (APE): $\mathrm{APE} = \frac{1}{2}N^2\xi^2$

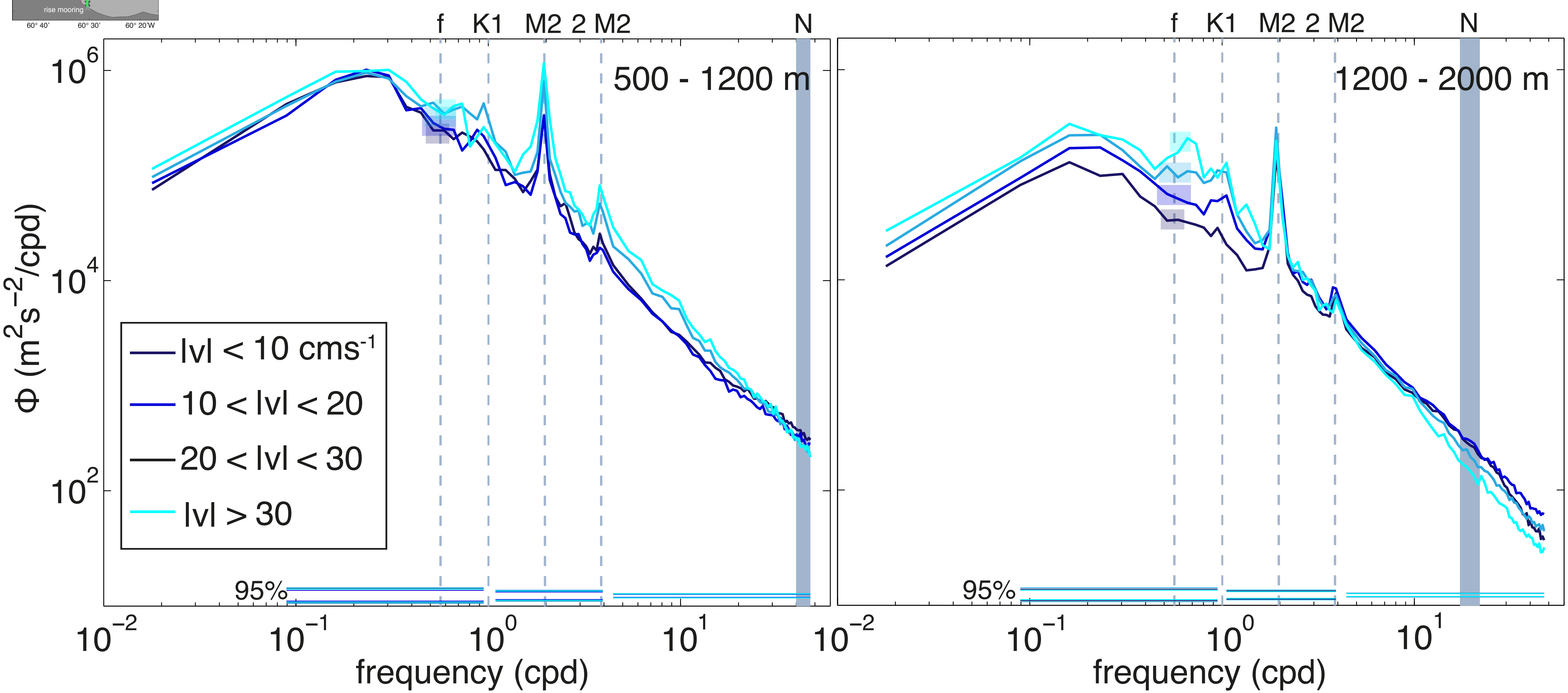
Variability in APE spectra

of half-overlapping 28-day segments



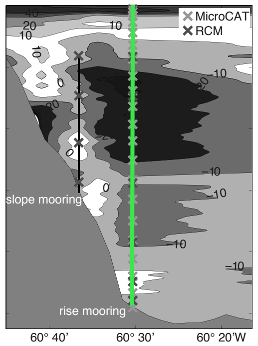
above DWBC

upper part of DWBC



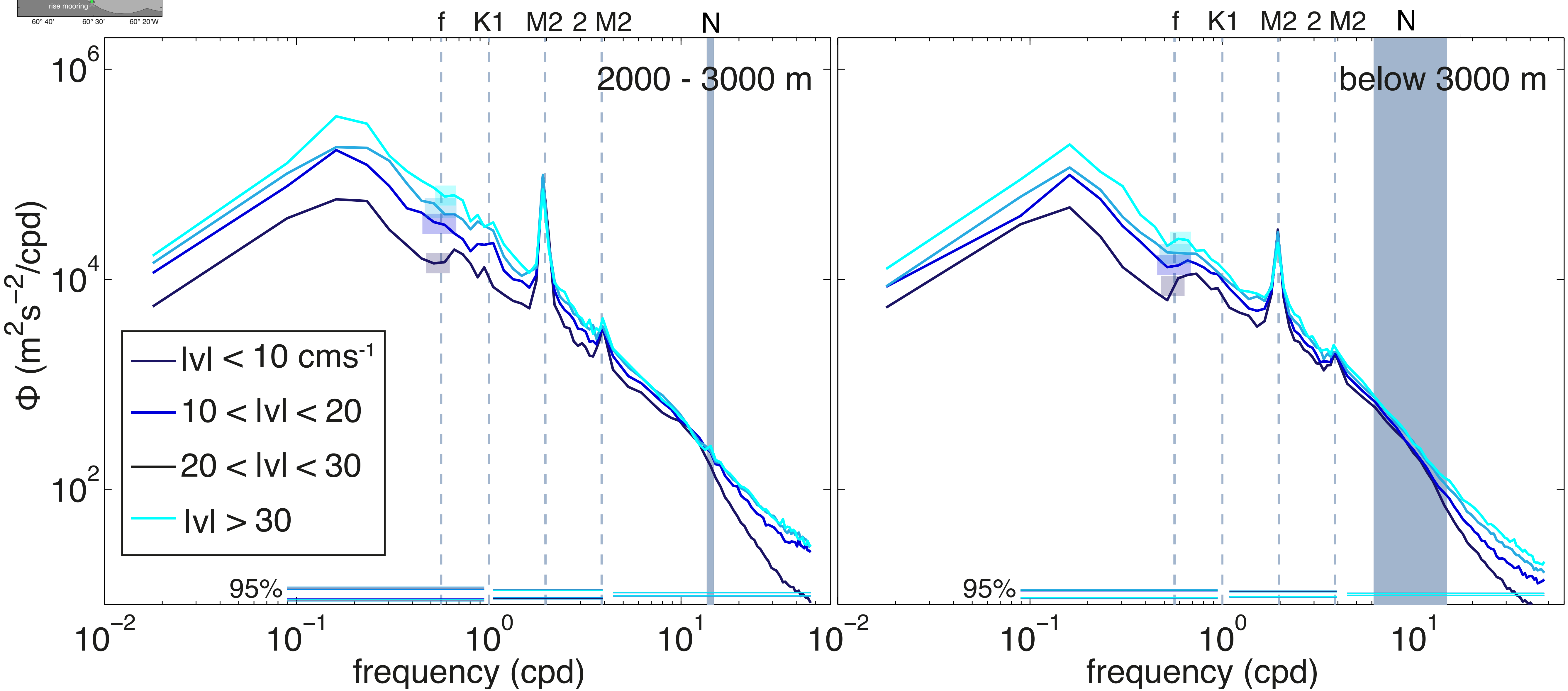
- above DWBC: small, almost constant increase in APE during strong flow
- in DWBC: significant increase in APE particularly in near-inertial frequencies

Variability in APE spectra



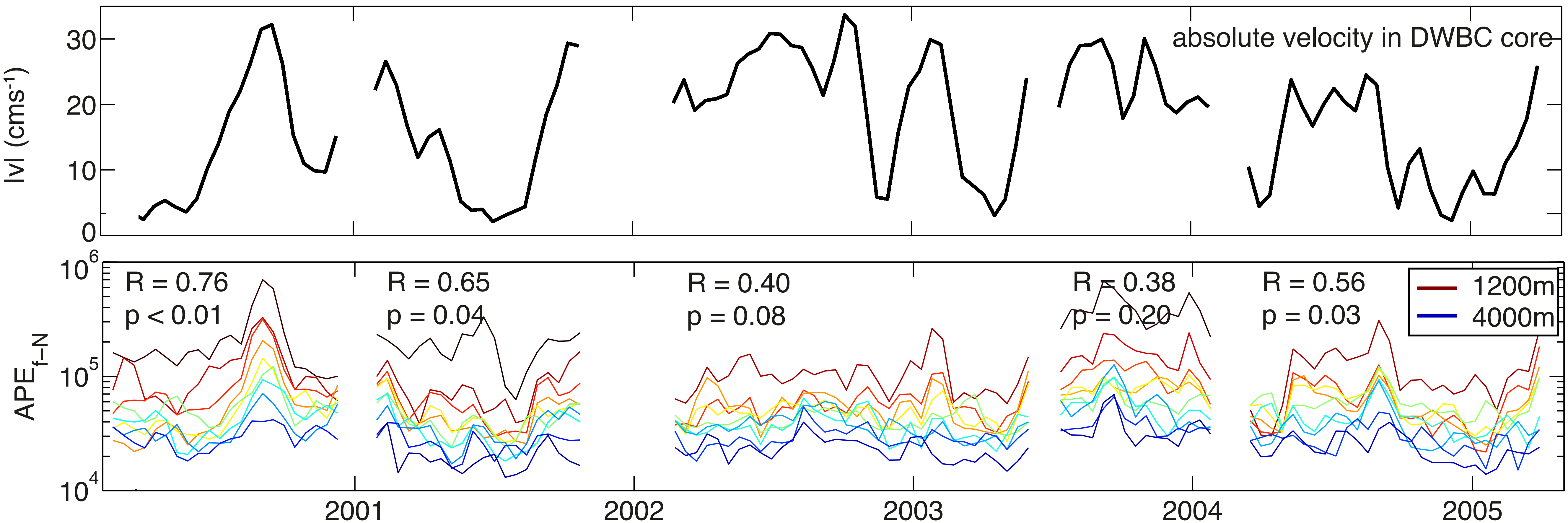
lower part of DWBC

below DWBC



- below DWBC: increase in APE in near-inertial frequencies still visible, but not as pronounced as in DWBC

Timeseries of internal wave APE (f-N)

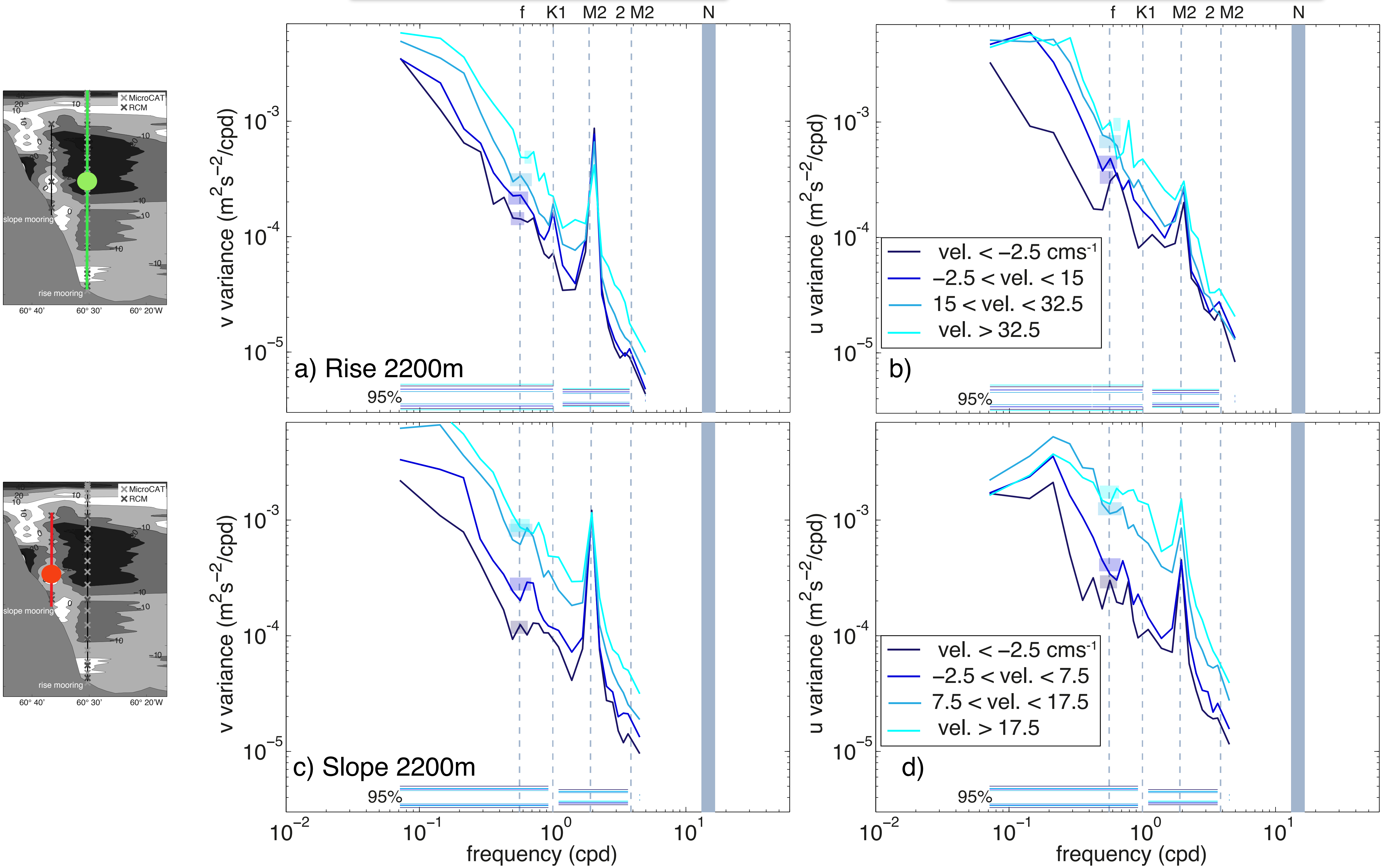


- internal wave APE and flow speed correlate especially during phases of strong changes in DWBC strength
- energy in the internal wave field varies by up to factor of 3

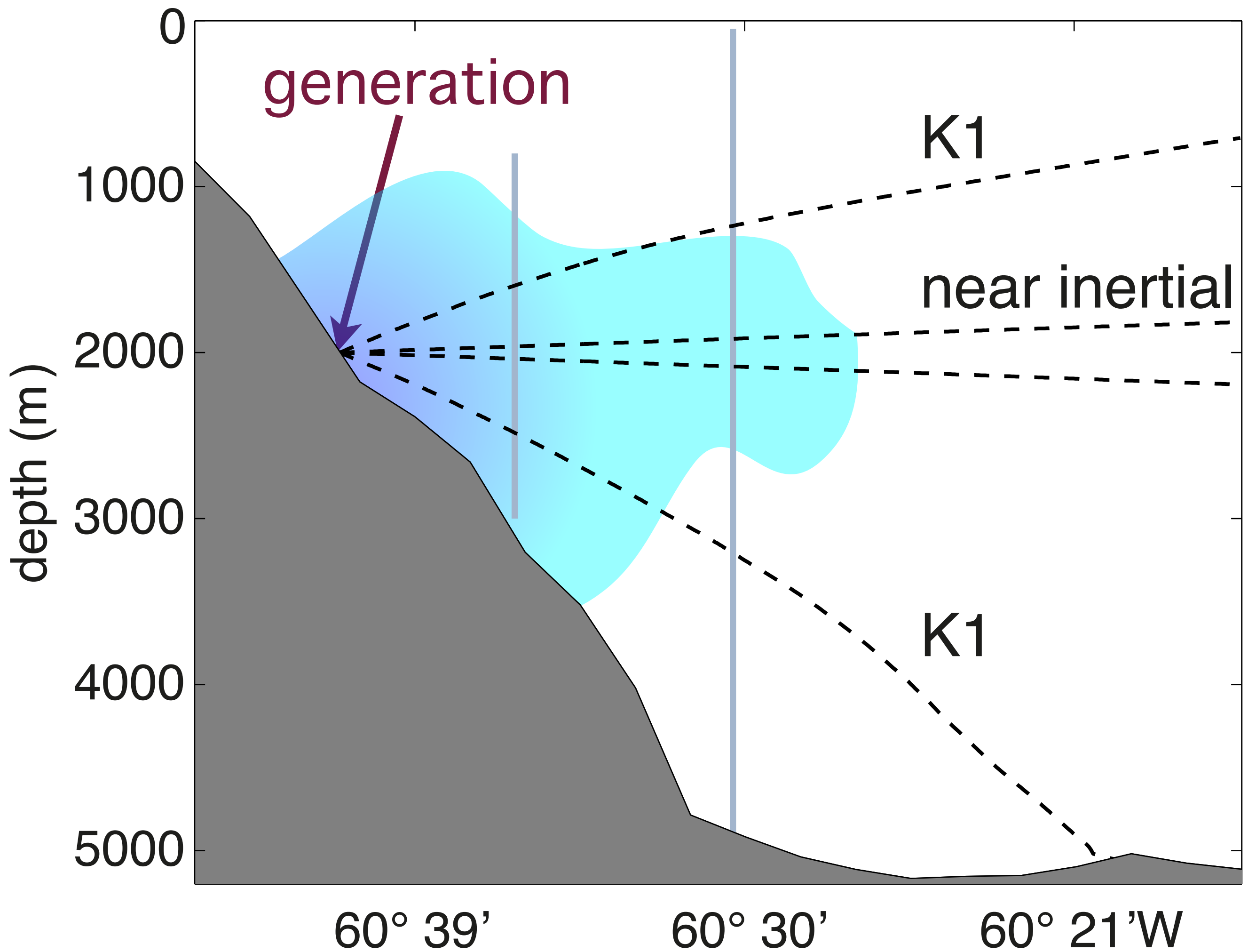
Variability in kinetic energy spectra

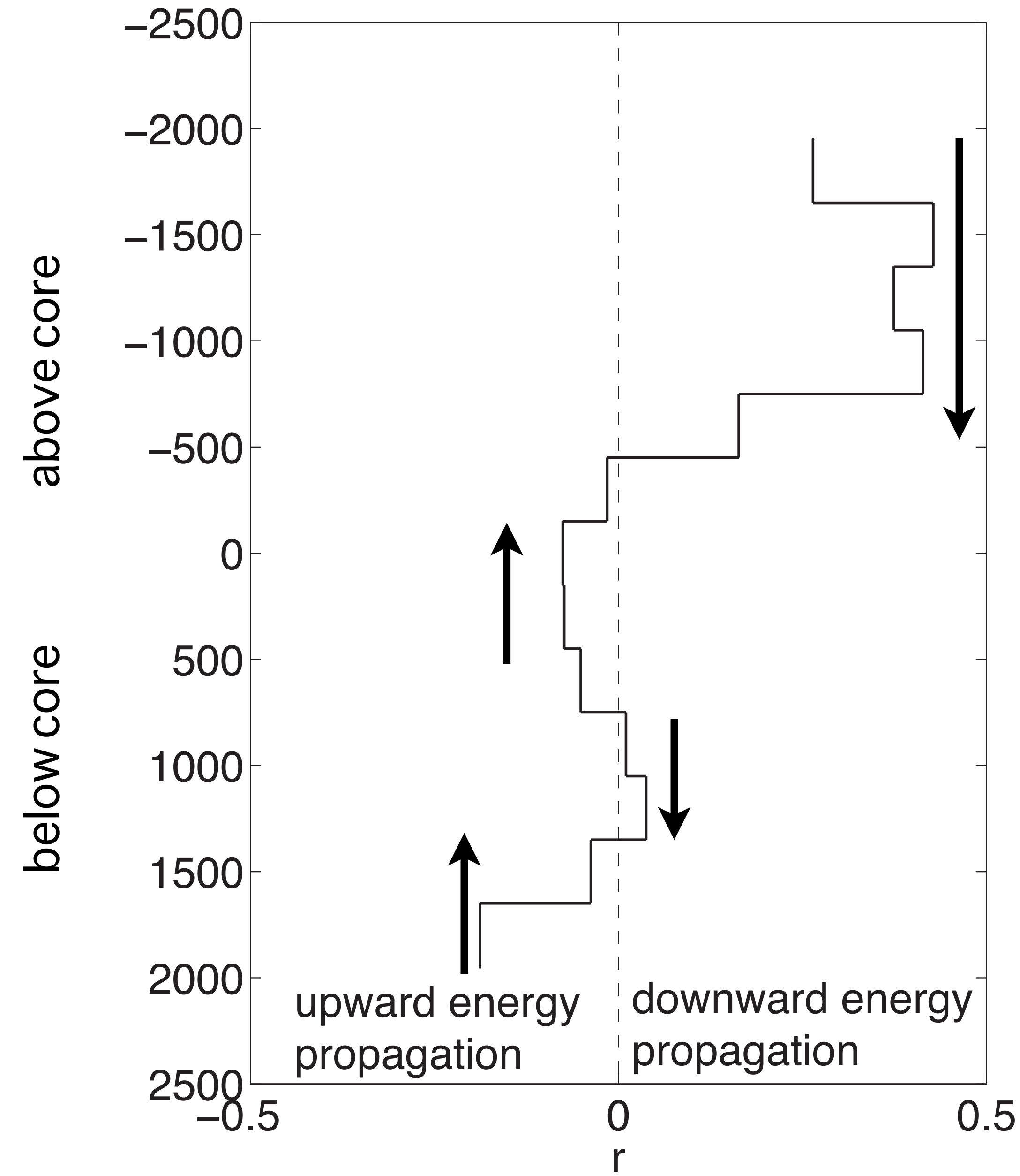
along slope vel.

cross slope vel.



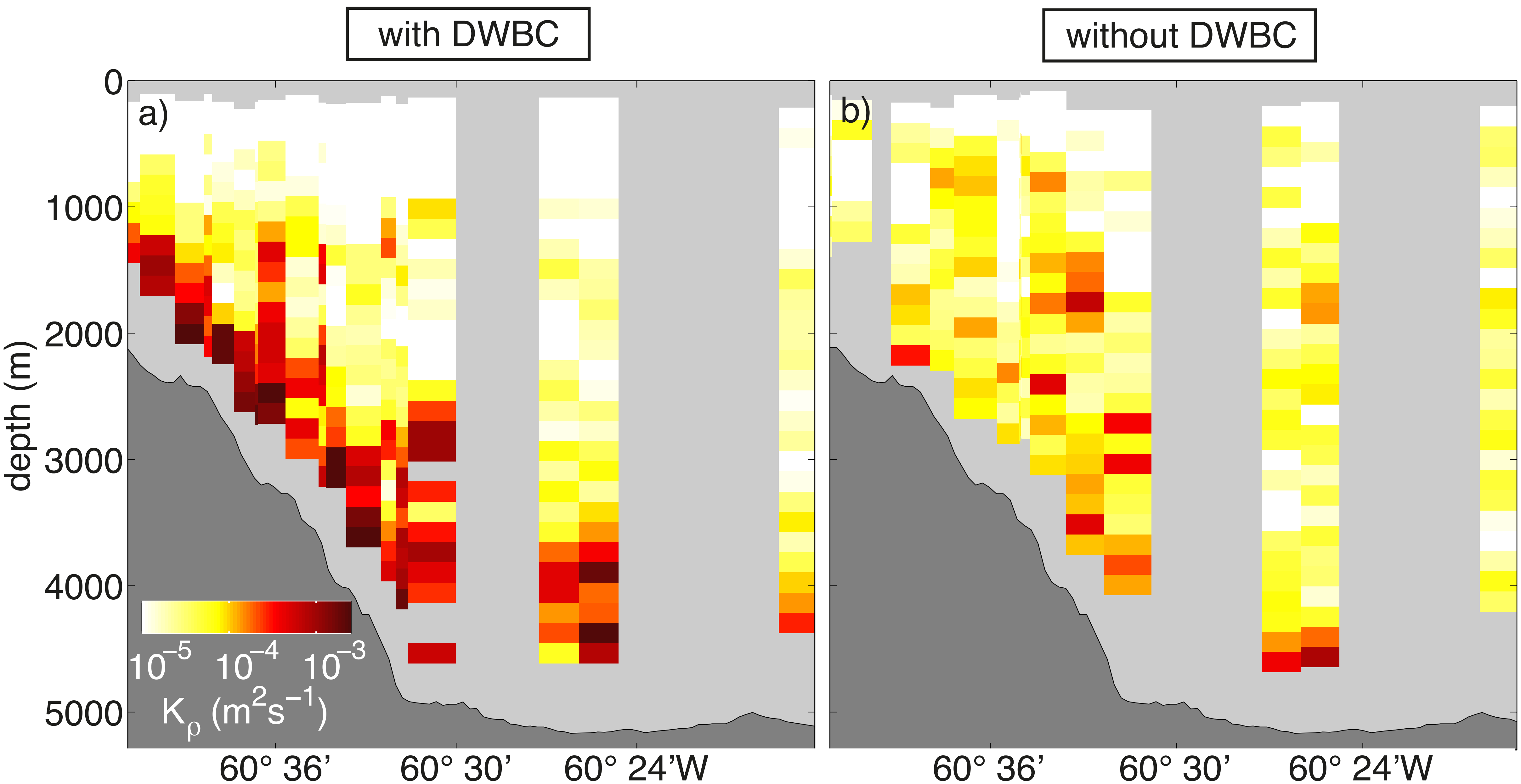
Generation of near-inertial waves





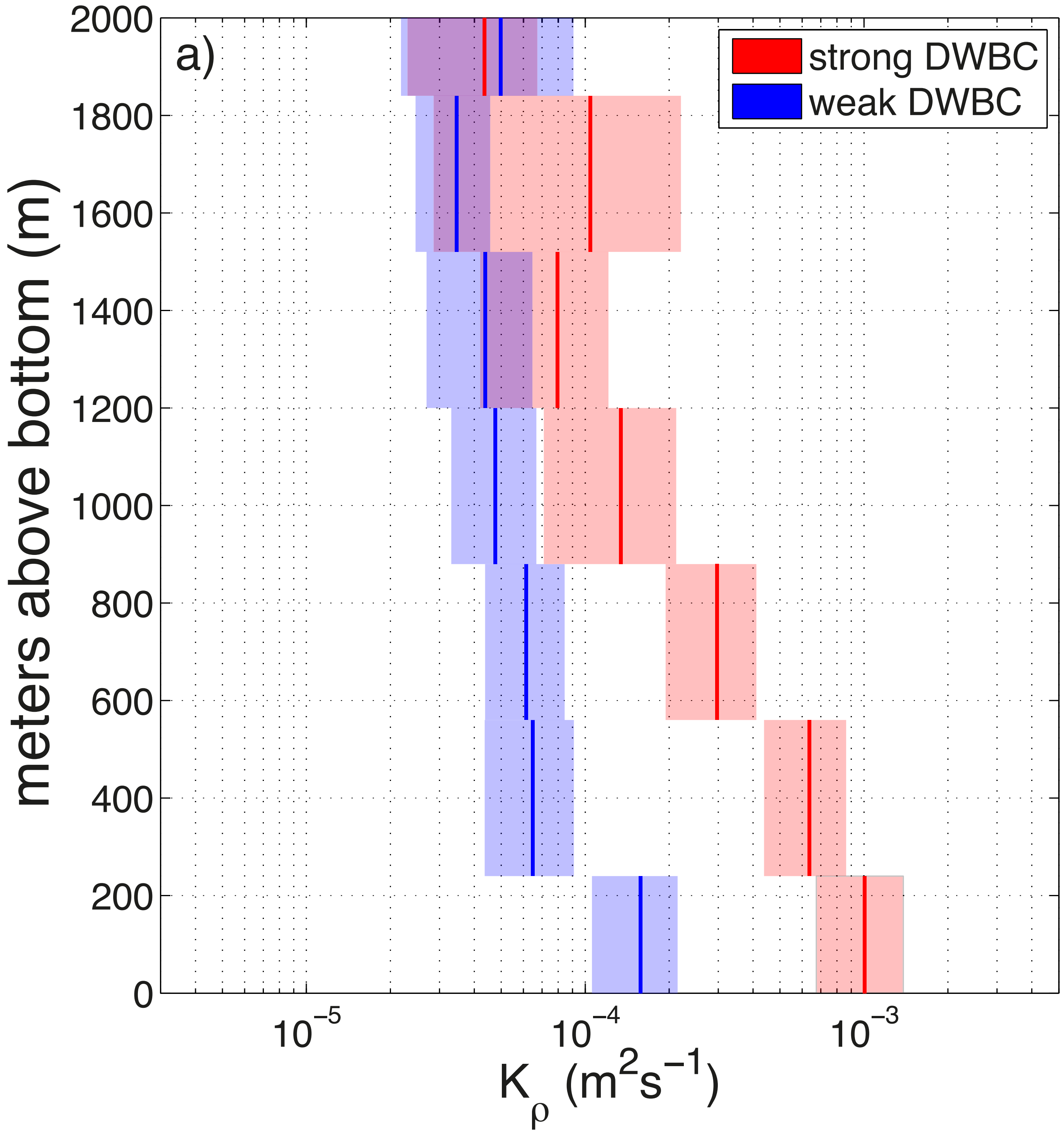
- generation of near-inertial waves by interaction of strong current with bottom topography (Nikurashin and Ferrari 2010)
- vertical energy propagation estimated from spectral analyses of shipboard velocity measurements
- good agreement with generation at DWBC core depth

Diapycnal diffusivities K_ρ from finescale parameterization



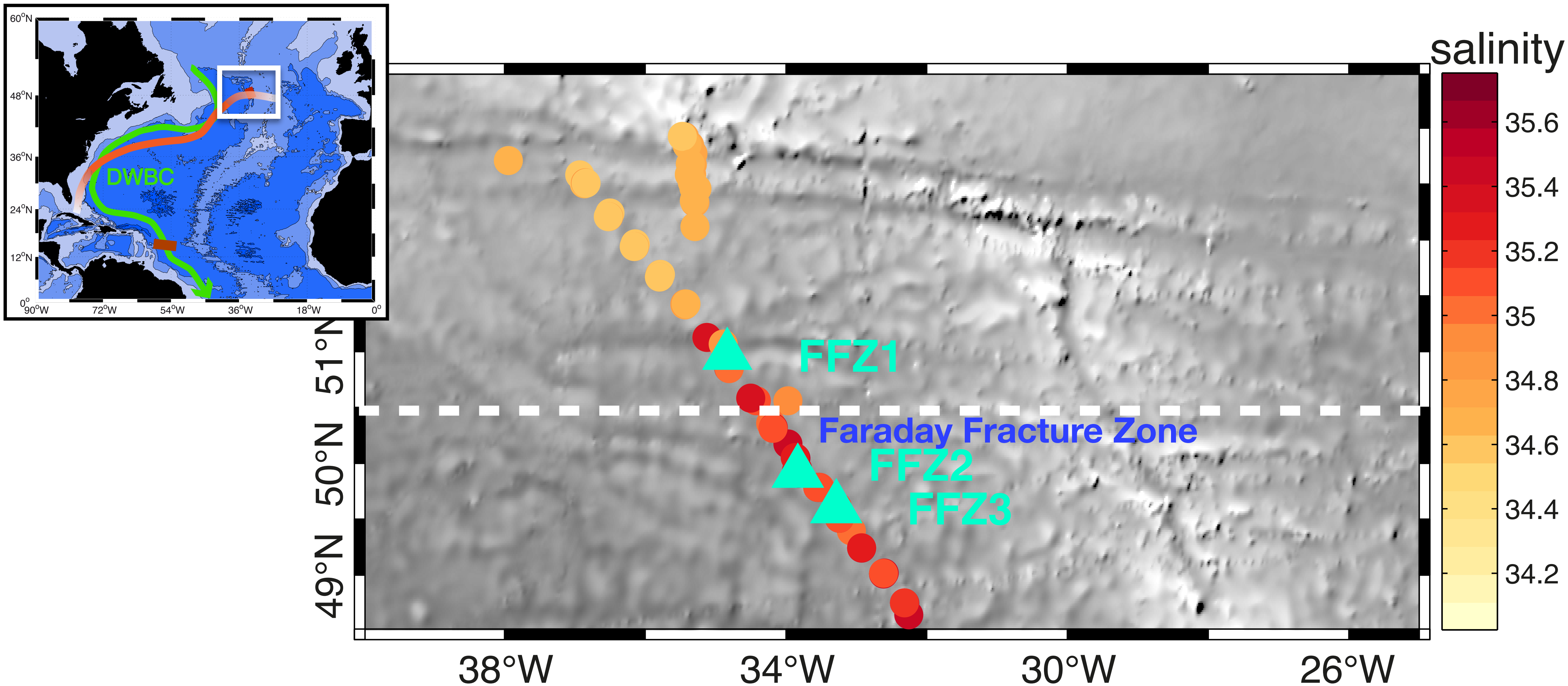
- diapycnal mixing is significantly elevated during phases of a strong DWBC

Diapycnal diffusivities K_ϱ



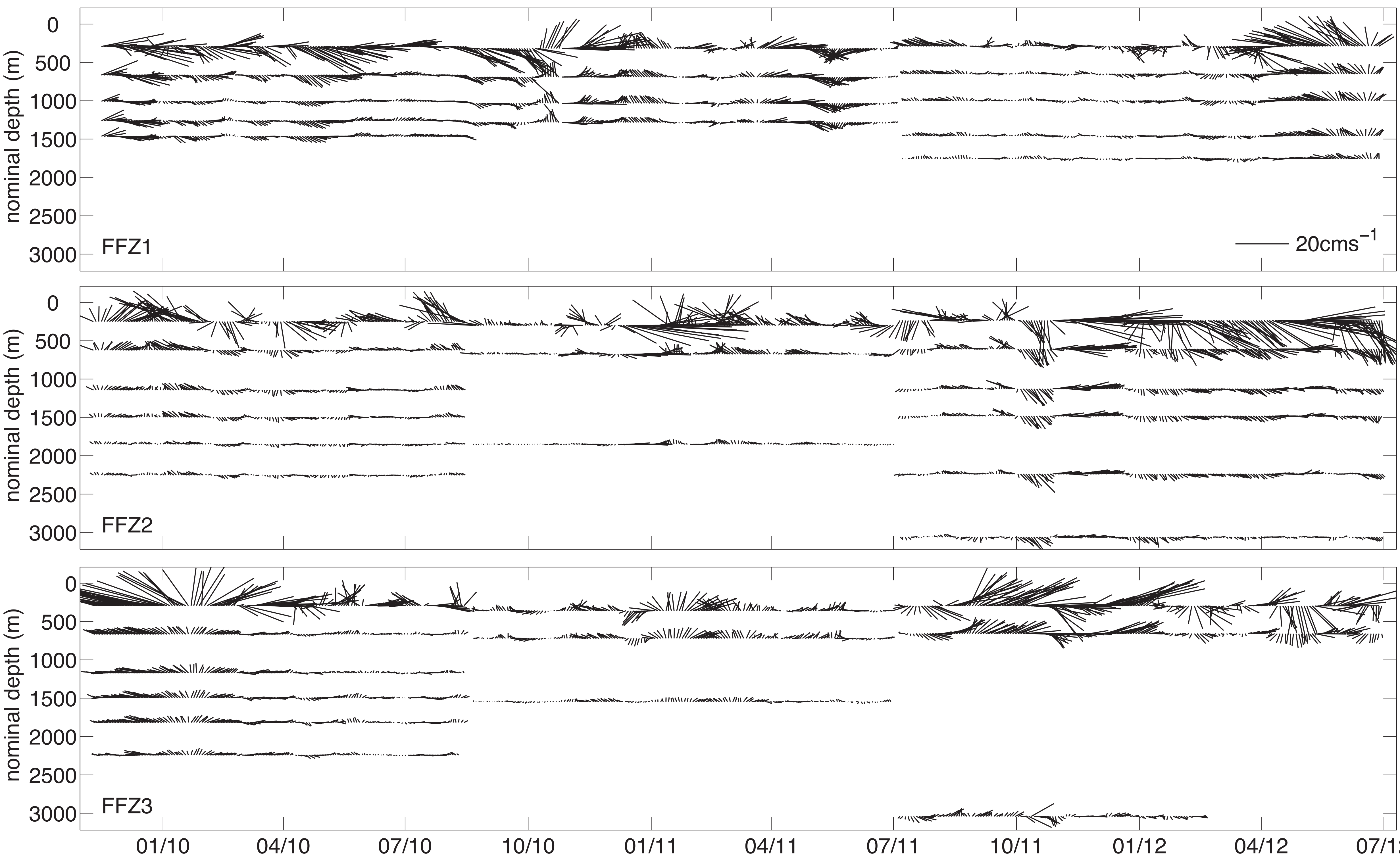
- mean diapycnal diffusivities during strong DWBC phases are elevated more than 1000m above bottom
- increase by a factor of 10
- local dissipation of internal wave energy

IW energy at the subpolar front

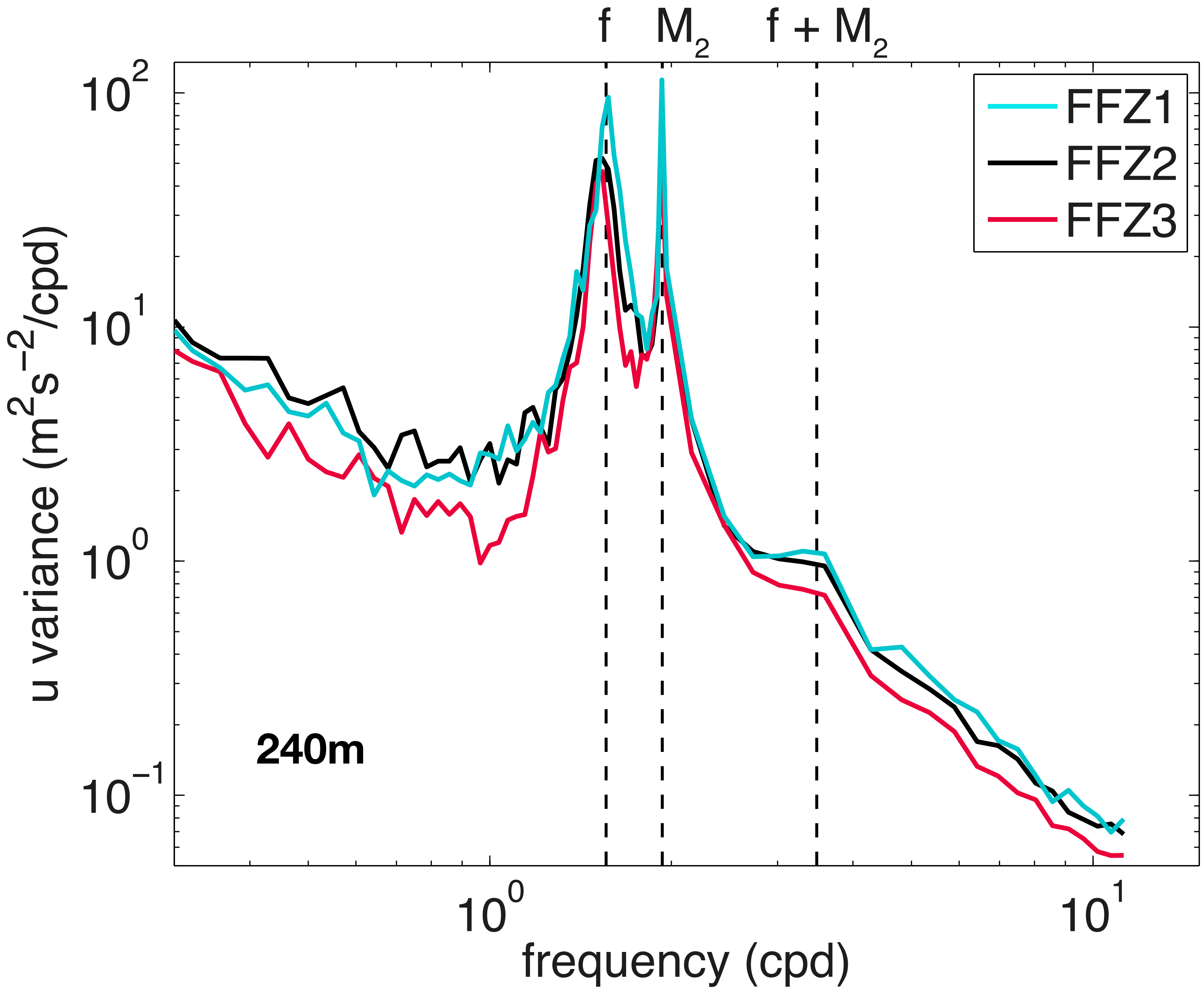


- 3 moorings close to the Faraday Fracture Zone (FFZ) since 2009
- 3 to 6 RCMs per mooring
- CTD/LADCP profiles

Velocity timeseries



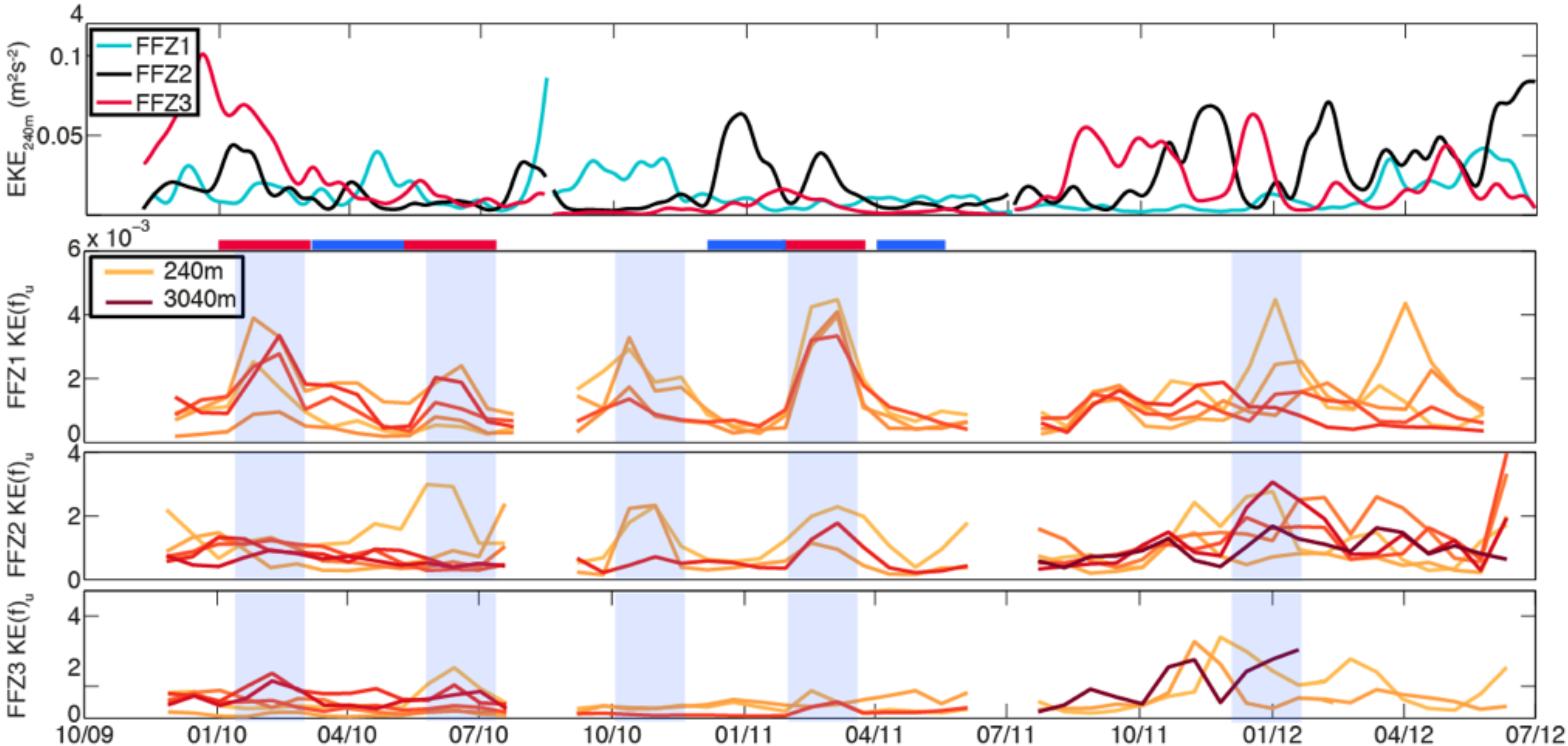
Mean velocity spectra



- dominant peaks at inertial and M_2 tidal frequency
- energy decreases from North to South
- integration of individual spectra $f \pm 0.3$

Timeseries of near inertial energy

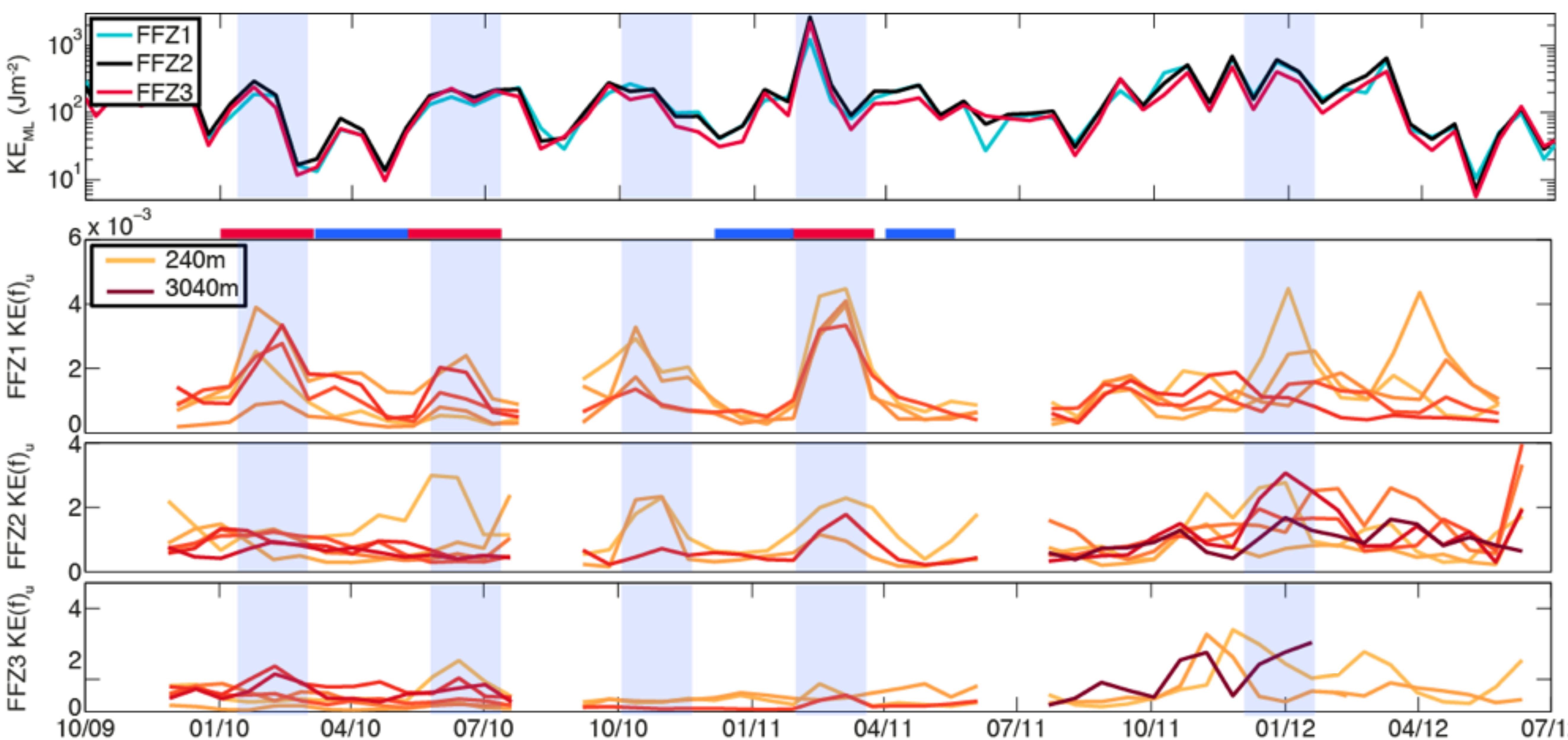
Eddy kinetic energy



Energy in near inertial waves

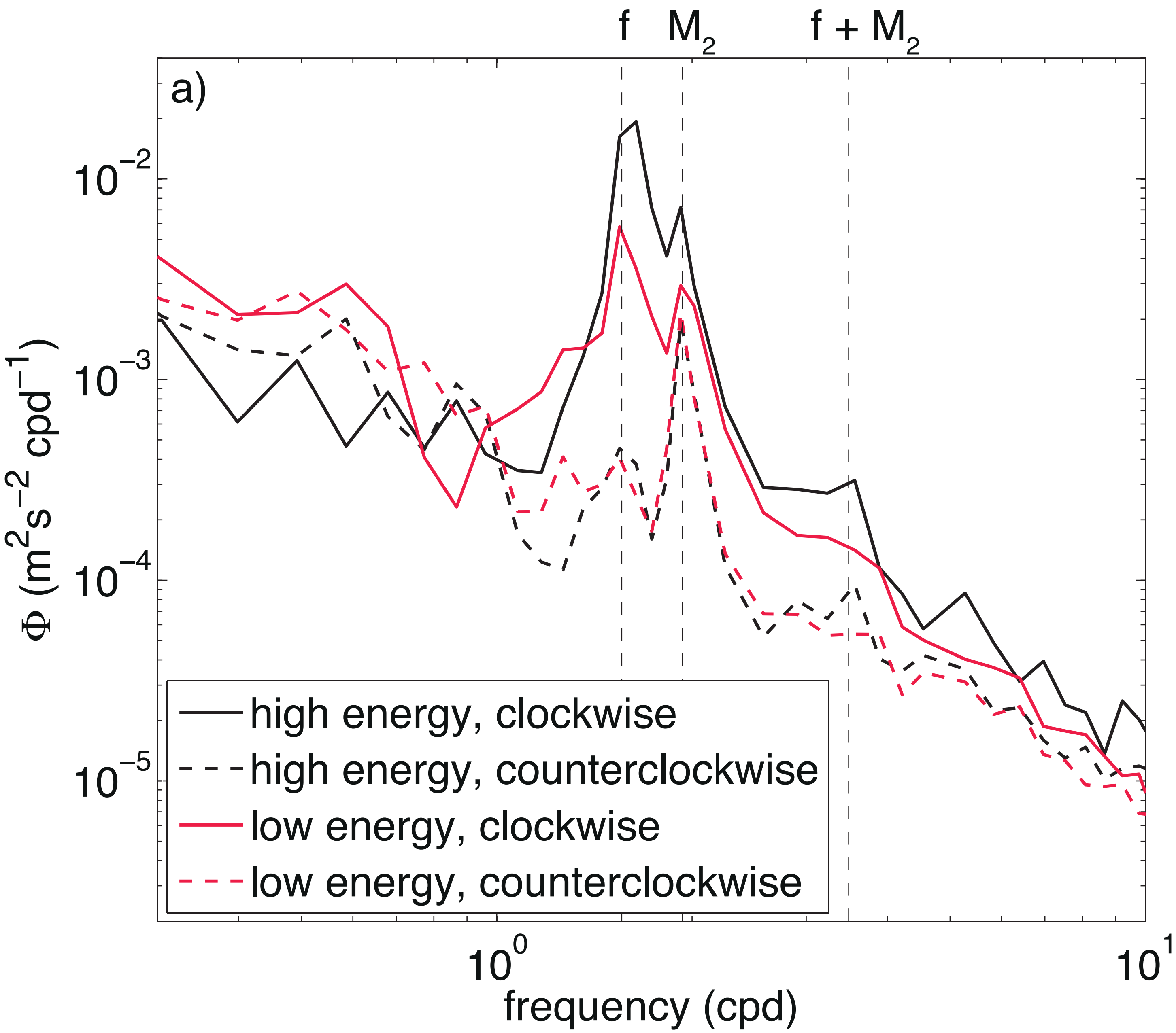
Timeseries of near inertial energy

Wind energy input



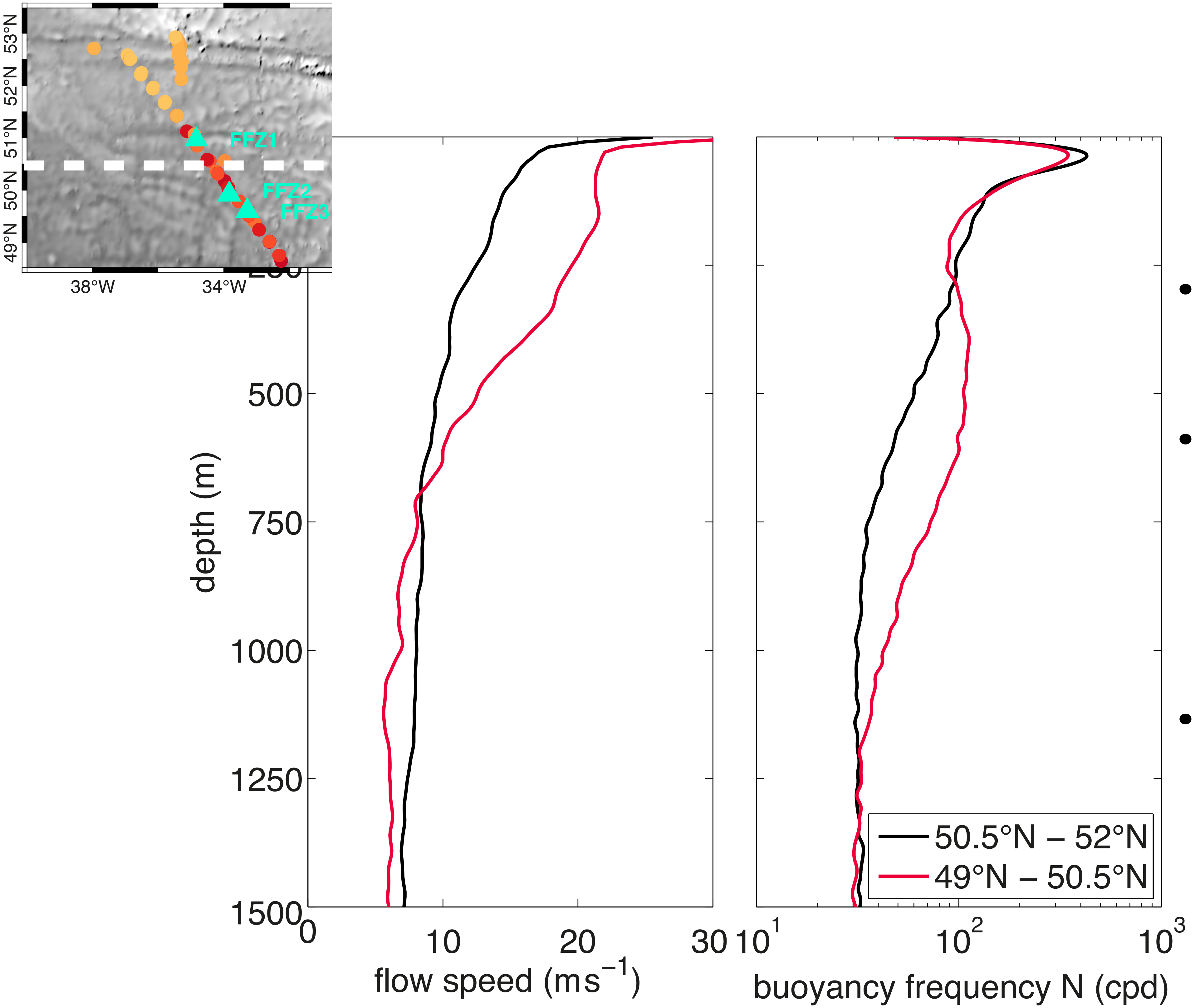
Energy in near inertial waves

Rotary spectra



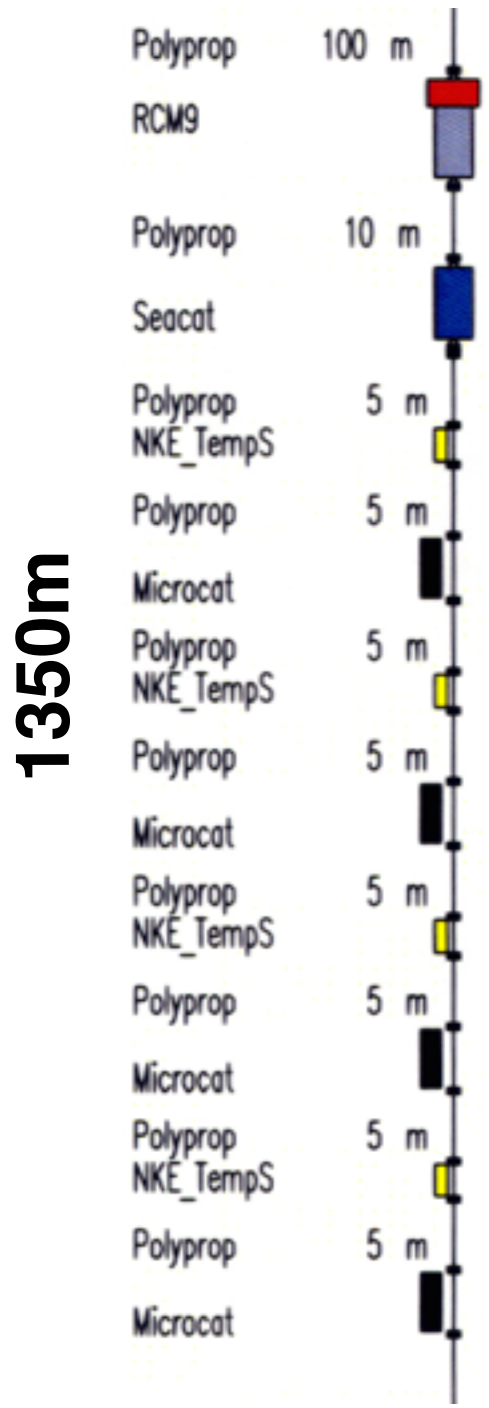
- increase in clockwise component during high energy phases
- counterclockwise component stays constant

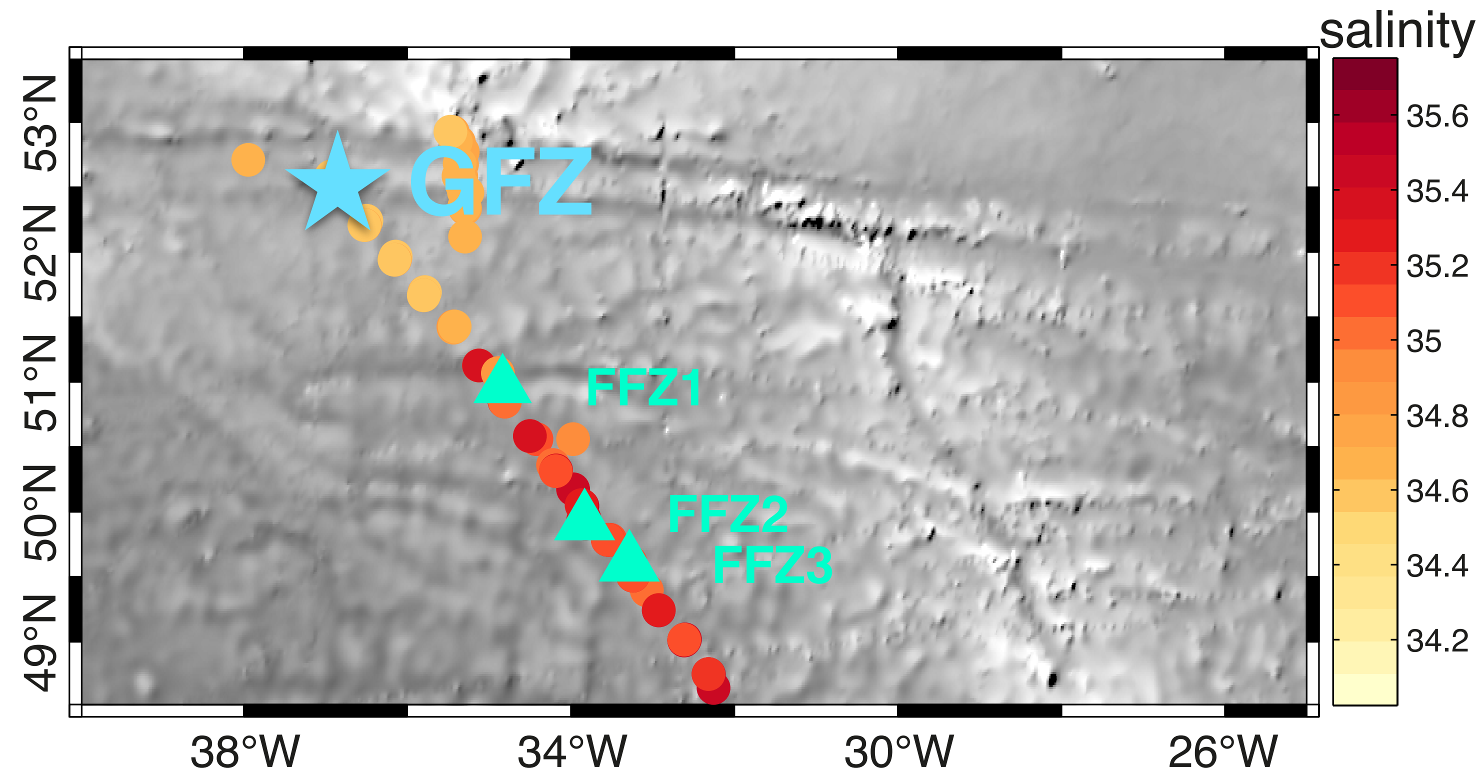
Differences in background conditions



- stronger mean flow in the South
- but also stronger stratification-> slower downward propagation
- breaking/ reflection of internal waves?

Outlook: Local vs. remote energy dissipation at depth





- Closely spaced T/p-measurements at GFZ (north of FFZ)
- will be recovered this June
- timeseries of mixing rates from Thorpe scales in relation to IW energy

Summary and Conclusions

Flow-topographie interaction in DWBC

- flow-topography interaction transfers energy to near-inertial waves
- energy in the internal wave field varies by up to factor of 3
- considerable temporal variability of diapycnal mixing rates by at least an order of magnitude

Wind induced variability in the NAC

- energy in the internal wave field varies by up to factor of 6
- near inertial energy variability dominated by changes in wind
- IW energy decreases within the NAC
- breaking of waves generated at mixed layer base?

Open Questions

- What proportion of the generated internal wave energy is dissipated locally and how much is radiated away from the source region?
- What are the energy pathways from sources to sinks?
- What is the role of the continental slope in generating, reflecting, and dissipating internal tides?