Estimates of lateral mixing in the Southern Ocean

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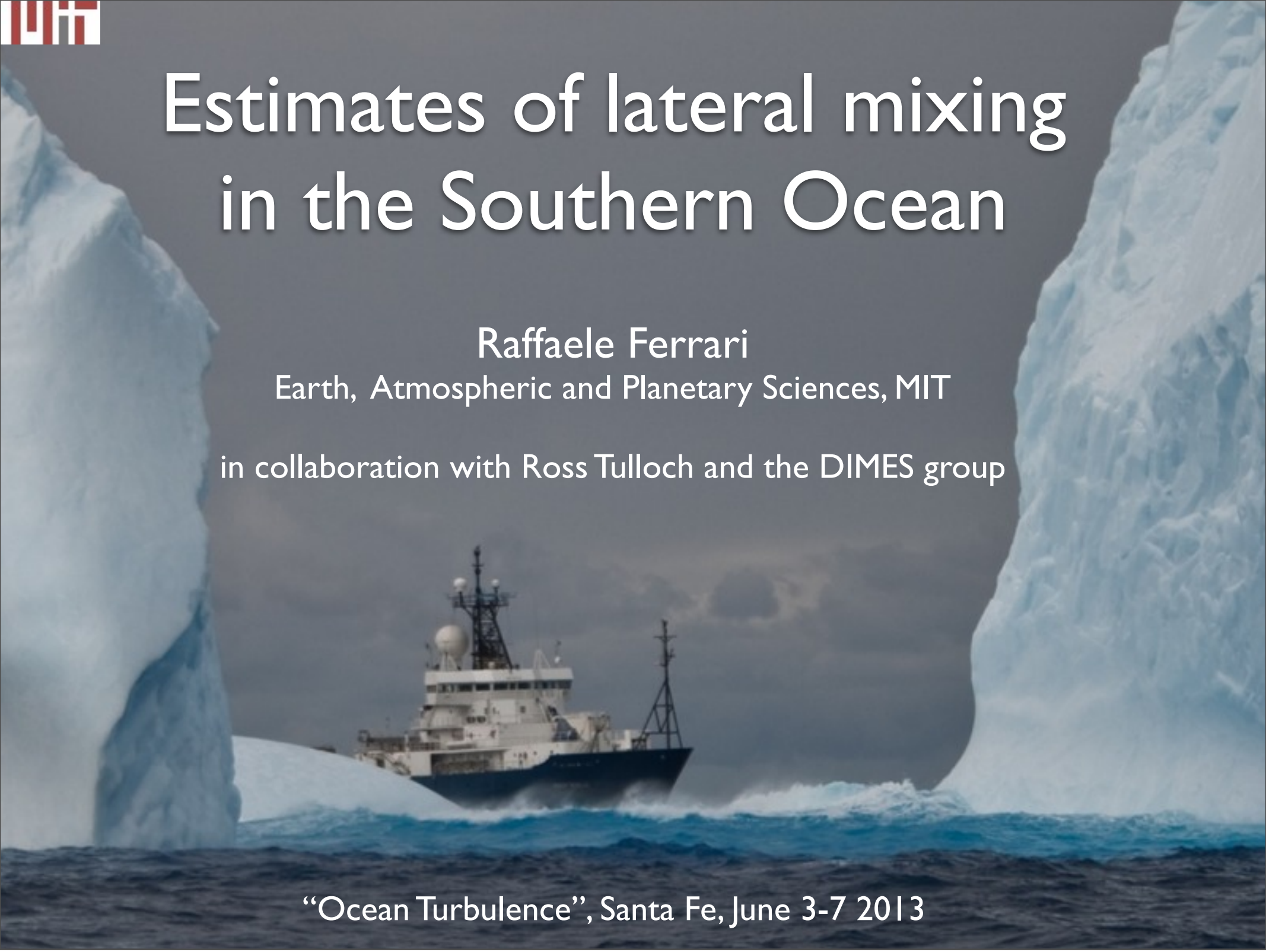
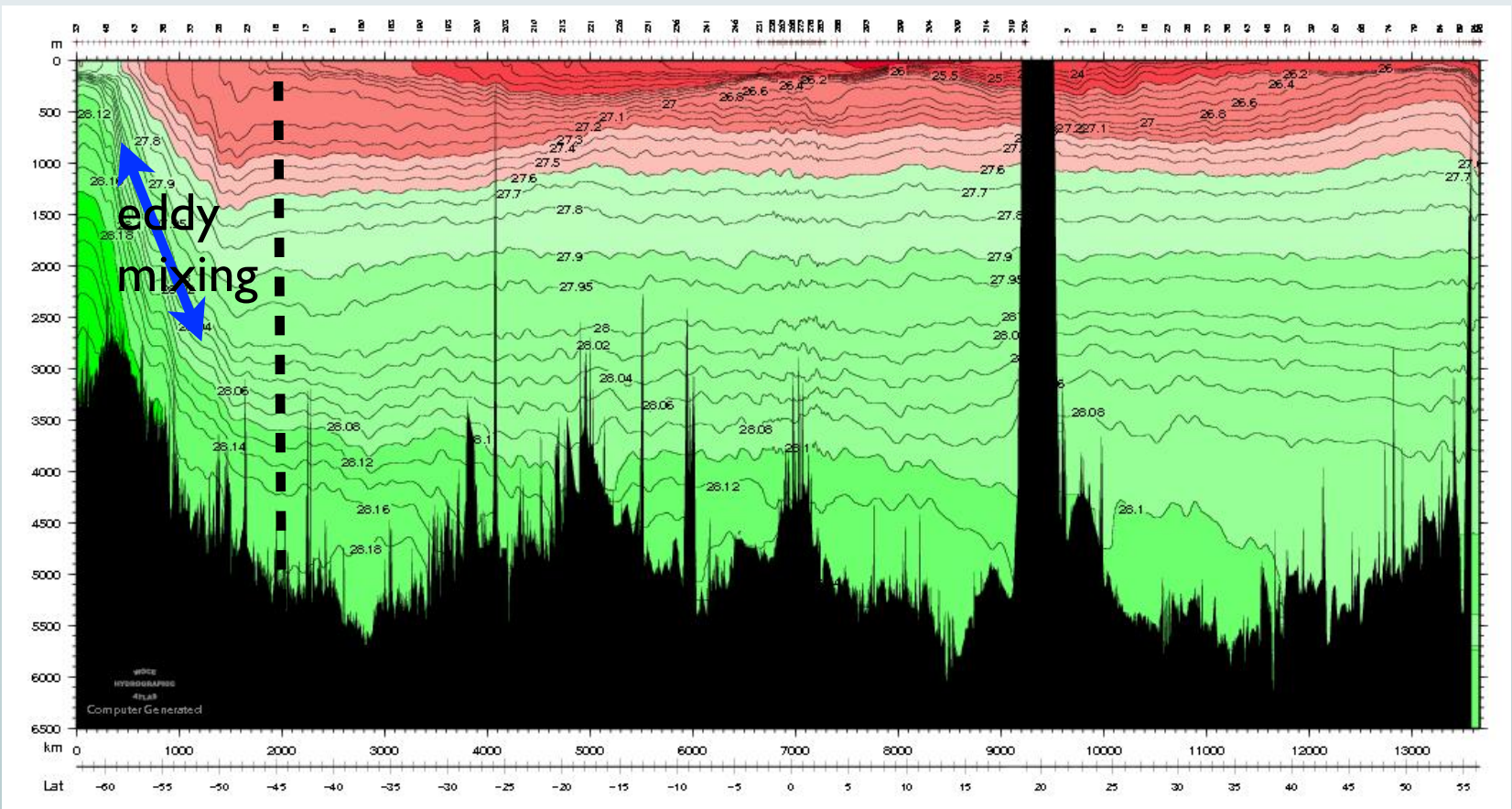
in collaboration with Ross Tulloch and the DIMES group



"Ocean Turbulence", Santa Fe, June 3-7 2013

Southern Ocean and Climate

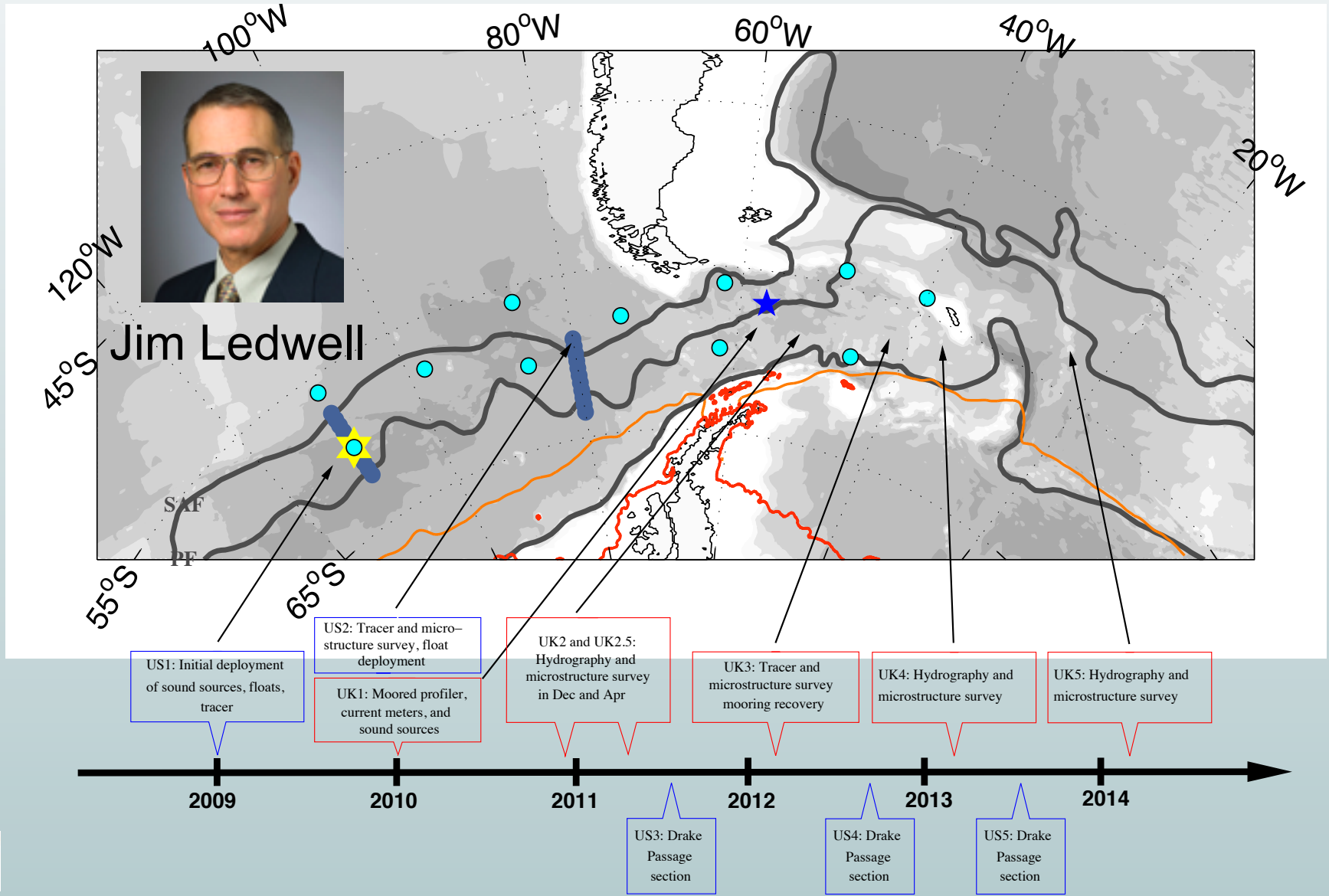
- Deep water masses come to the surface in the Southern Ocean and exchange heat/carbon with atmosphere
- Eddy mixing plays a key role in transporting heat/carbon into the Southern Ocean



Neutral density (kg m^3) section in the Pacific Ocean (WOCE, P16)

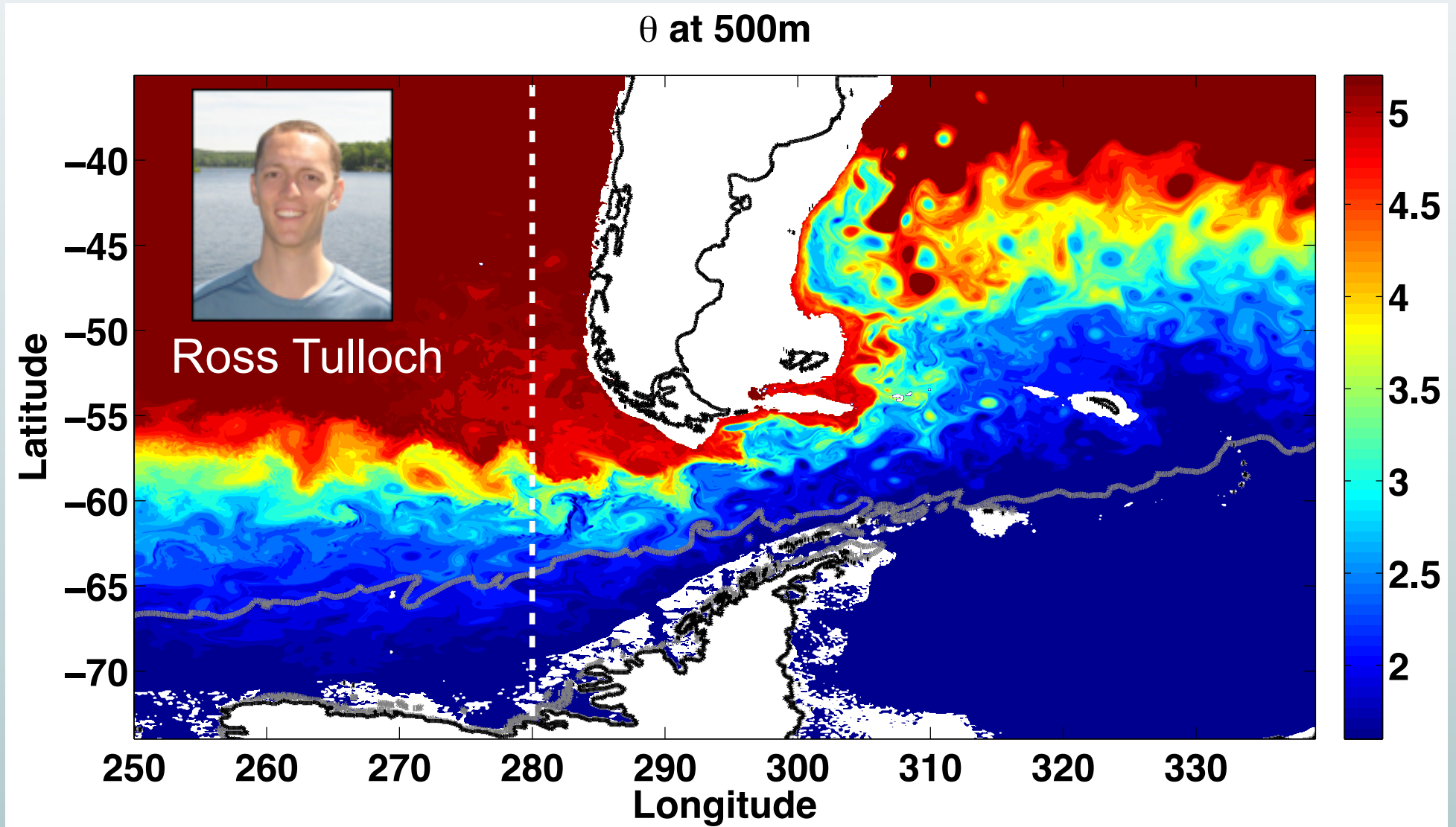
DIMES Experiment

- DIMES = Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean



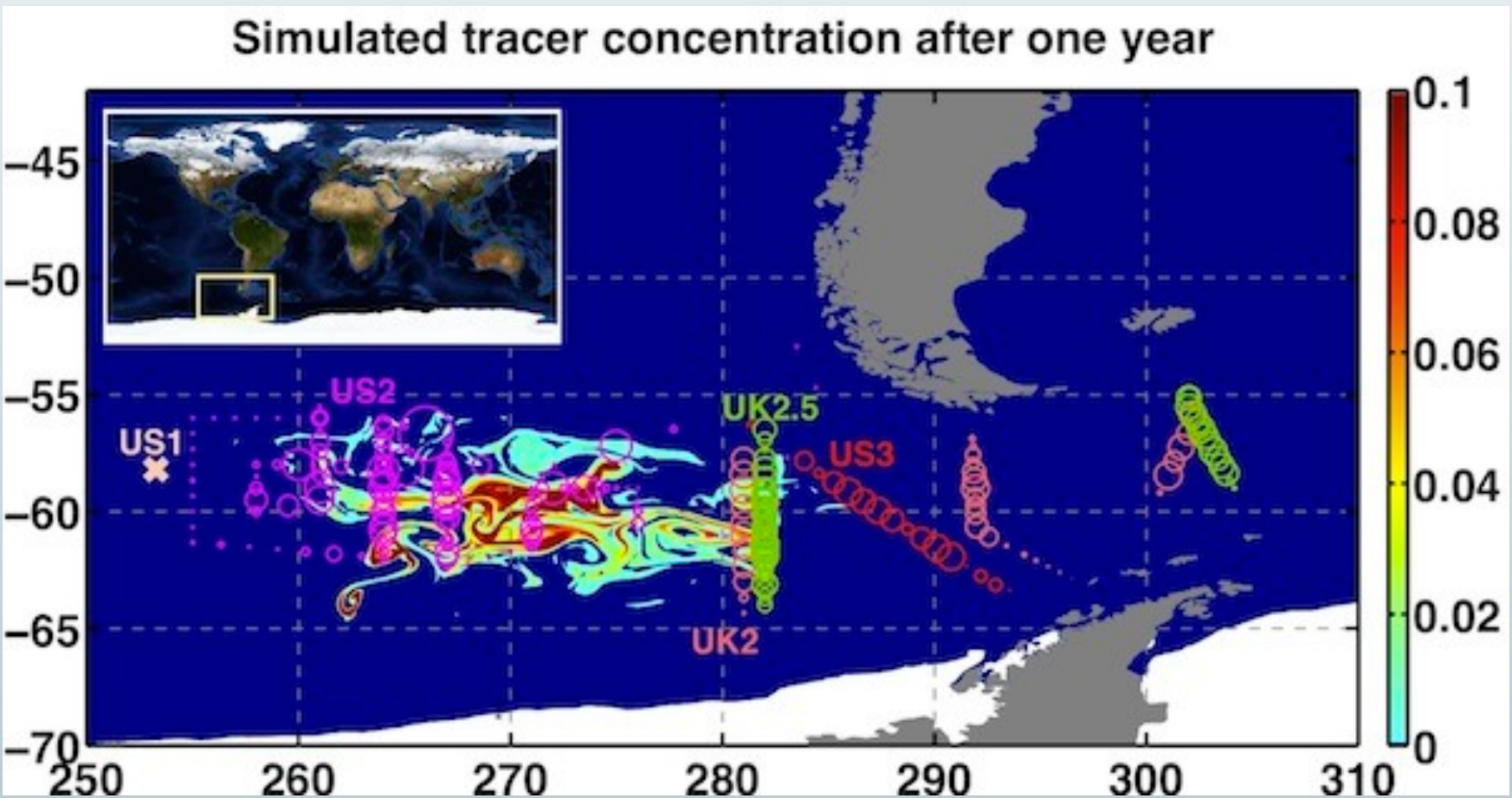
High resolution model

- MIT General Circulation Model, 3 km horizontal resolution, 100 vertical levels
- Forced with reanalysis surface fluxes and state estimate at lateral boundaries



Tracer sampling

- Tracer released (107°W, 58°S) on ρ=27.9 kg/m^3 (1500m) in Feb 2009
- Tracer was sampled on a grid after 1 year (US2 cruise) and along a few transects after 2 years (UK2), 2.5 years (UK2.5) and 3 years (US3)
- Similar tracer releases are repeated with the numerical model



Estimating K from tracer

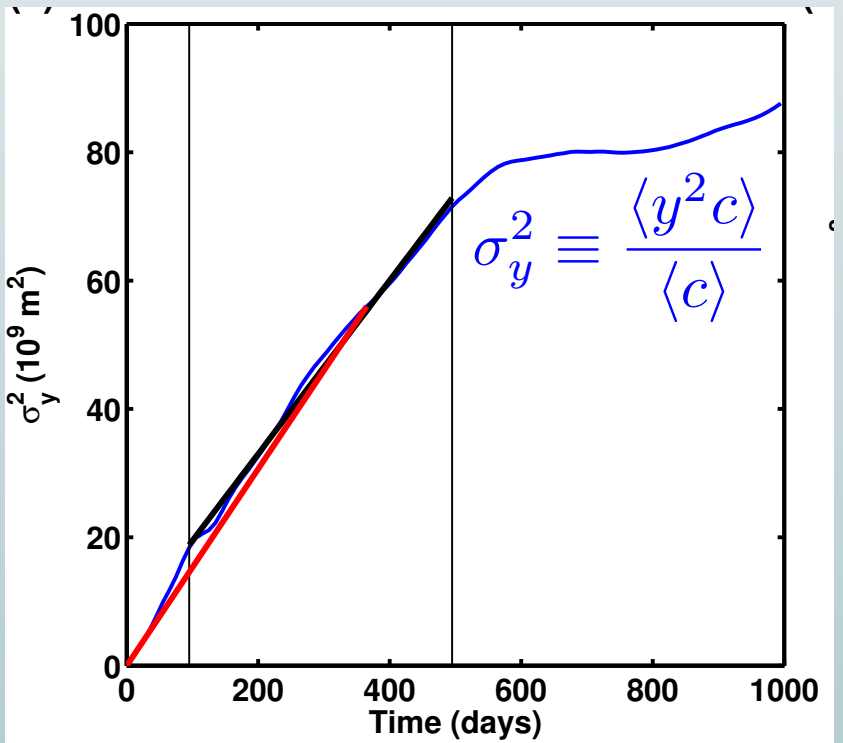
- Eddy diffusivity K describes the rate at which turbulence spreads tracer

model (black line)

$$K \equiv \frac{d}{dt}\left(\frac{\langle y^2 c\rangle}{\langle c\rangle}\right)$$

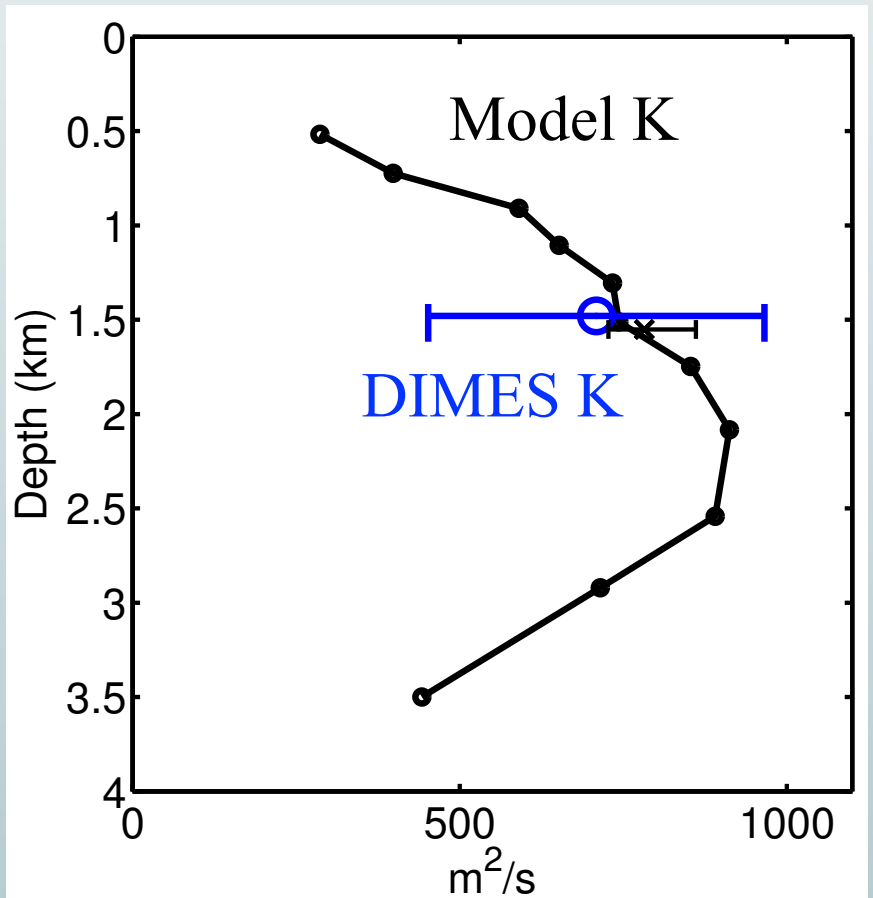
data (red line)

$$K \equiv \frac{d}{dt}\left(\frac{\langle y^2 c\rangle}{\langle c\rangle}\right) \approx \frac{1}{1\,year}\left[\frac{\langle y^2 c_{1year}\rangle}{\langle c_{1year}\rangle} - \frac{\langle y^2 c_0\rangle}{\langle c_0\rangle}\right]$$



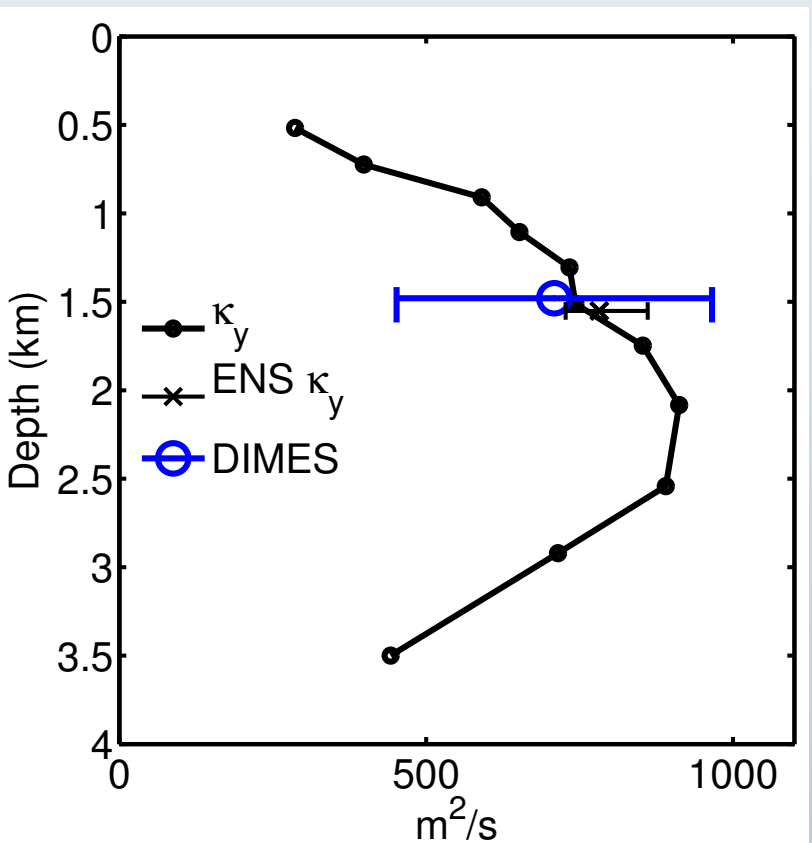
Estimates of K

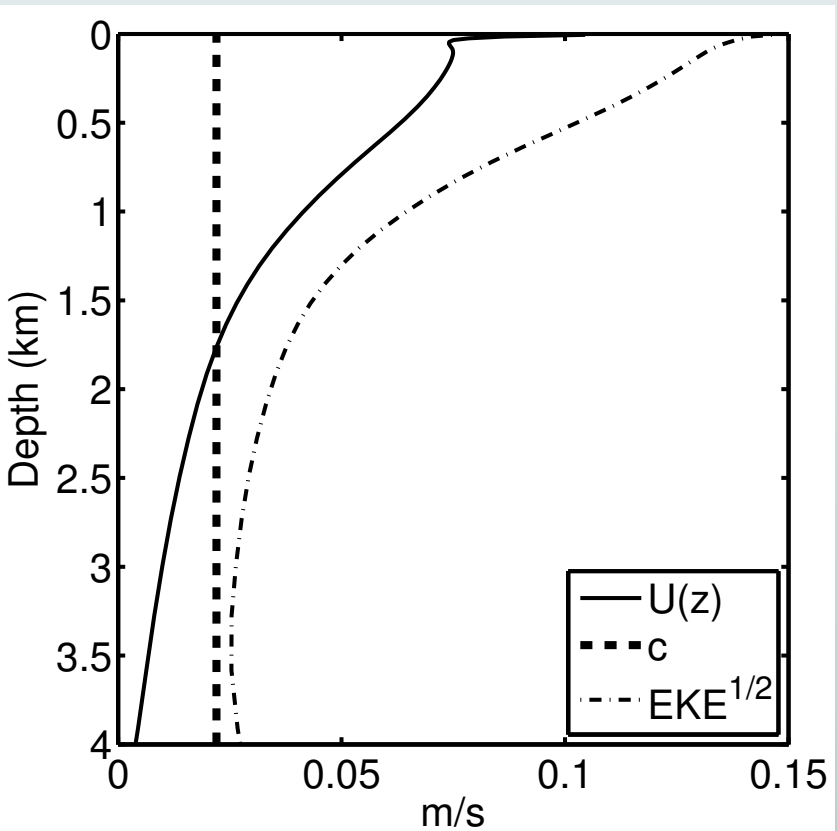
- The DIMES tracer indicate that at 1500m, K=710±260 m^2/s
- The model tracers indicate that K is less than 500 m^2/s in the upper kilometer and reaches 900 m^2/s at 2000 m



Vertical structure of K

- Eddy mixing is suppressed in the upper kilometer and enhanced at steering levels where $U=c$
- The vertical structure of K is well described by linear theory (Bretherton, 1966; Green, 1970; Ferrari and Nikurashin, 2010)





Tulloch, Ferrari et many al., submitted

Conclusions

- First direct measurements of eddy mixing in the Southern Ocean at 1500 meters: $K \simeq 710 \pm 260 \quad m^2/s$

- Eddy mixing is suppressed in the upper kilometer
  - K drops to less than 500 m^2/s

- Eddy mixing is enhanced at deep steering levels
  - K reaches 900 m^2/s at 2000 m
  - enhancement at interface between upper and lower MOC cells in ACC

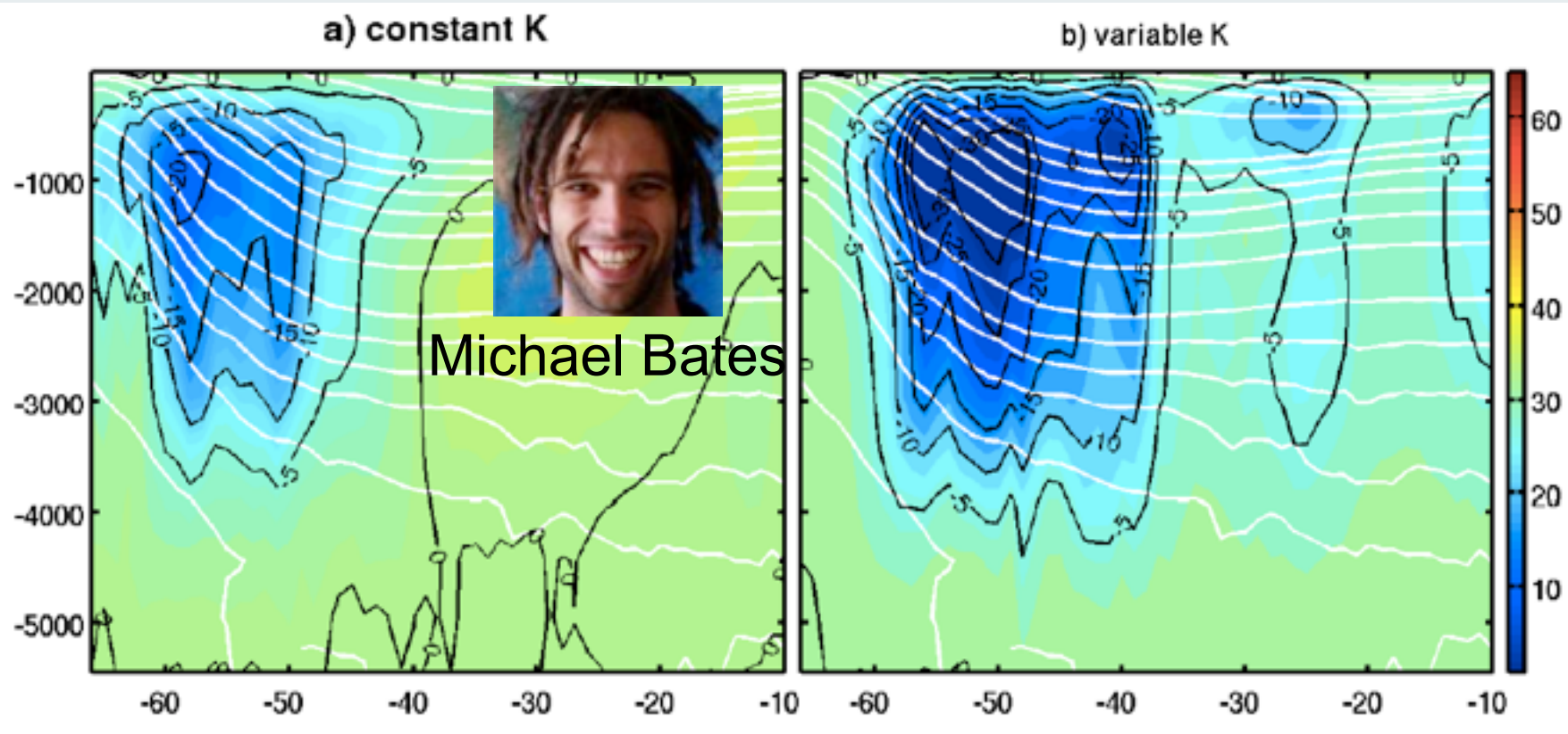
- New eddy parameterizations are developed to capture variations of K with depth (Bates, Marshall, Ferrari, JPO)

- This work is about the Redi diffusivity. Gent-McWilliams diffusivity can be reconstructed from Redi one, but it has different vertical structure

New eddy parameterization

$$K = constant$$

$$K \propto EKE^{1/2} \ell_{eddy} \Big/ \left(1 + 8\frac{(U-c)^2}{EKE}\right)$$



Bates, Marshall and Ferrari, submitted