Eddy saturation & Eddy compensation

Farnetti

Garabato

Hogg

Morrison

Meredith

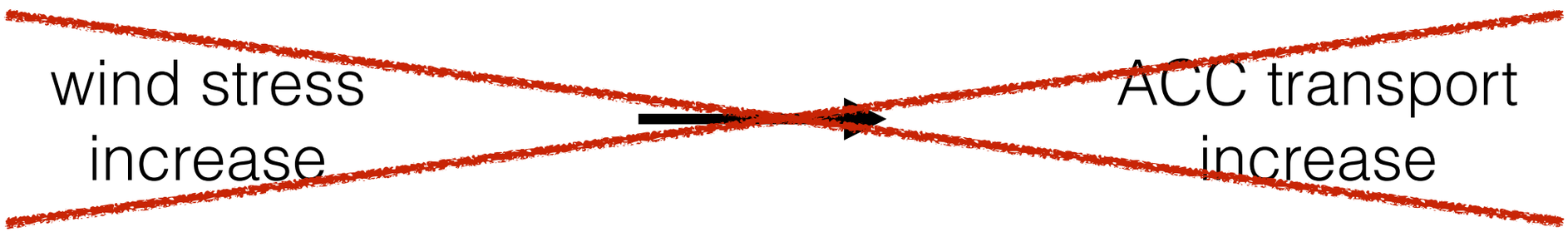
Meredith, et. al. (2012), *J. Climate*, **25(1)**, 99-110

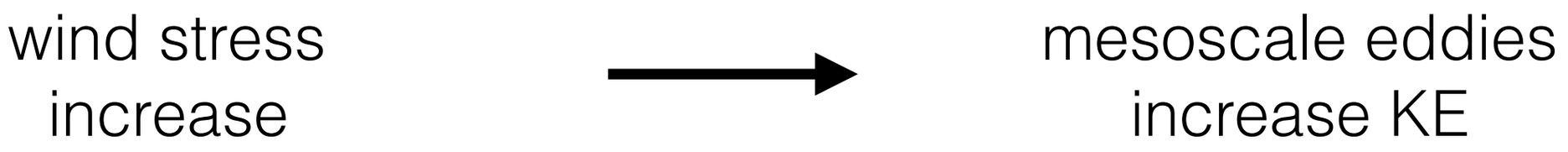
Morrison & Hogg (2013), *J. Phys. Ocean.*, **43(1)**, 140-148

as told by Navid

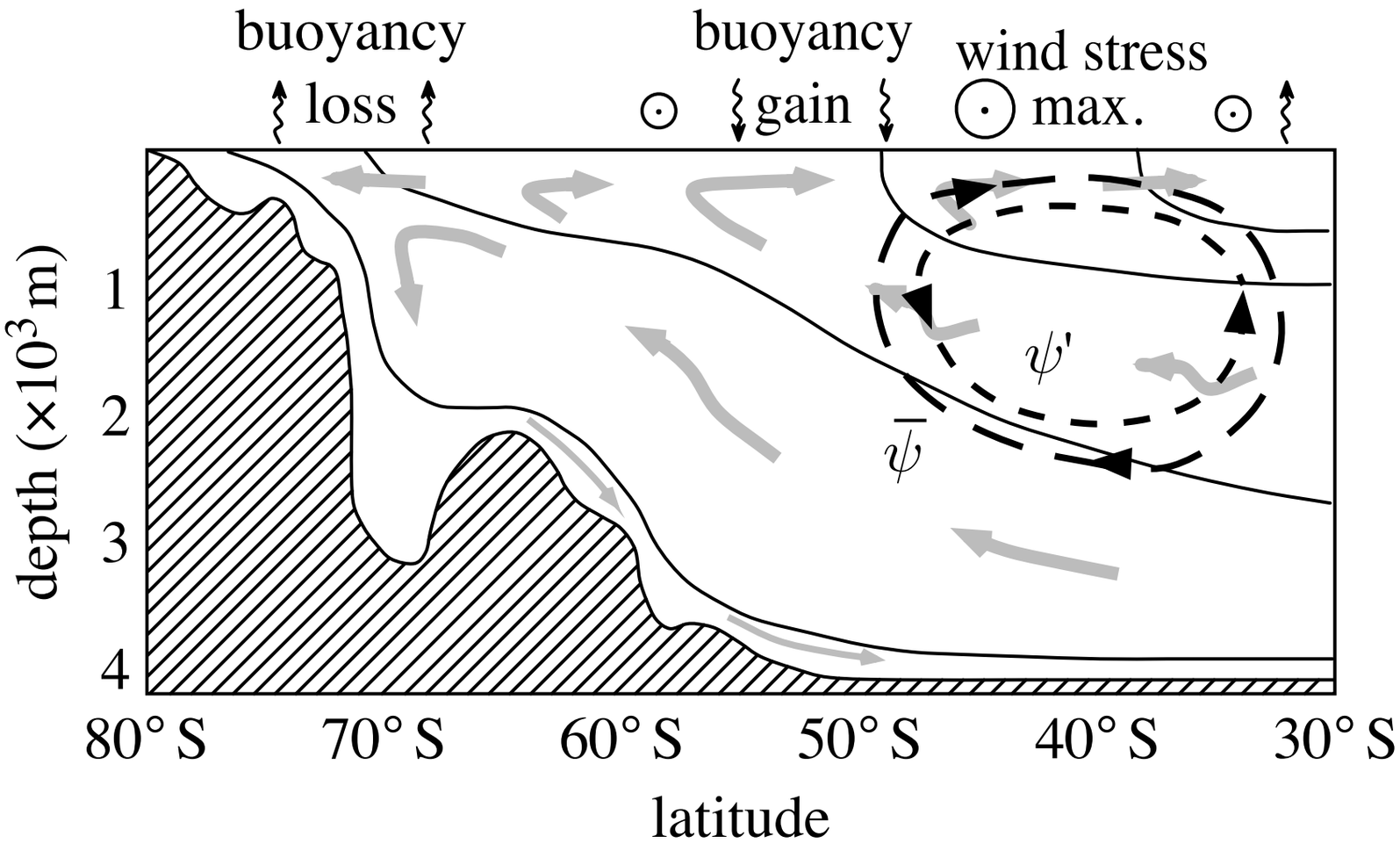
Theory Seminar SIO
Fall 2016

Eddy saturation





Eddy compensation



$$\bar{\psi} \approx -\psi'$$

Eulerian mean circulation

eddy-induced circulation

$$\psi^* = \bar{\psi} + \psi'$$

overturning circulation

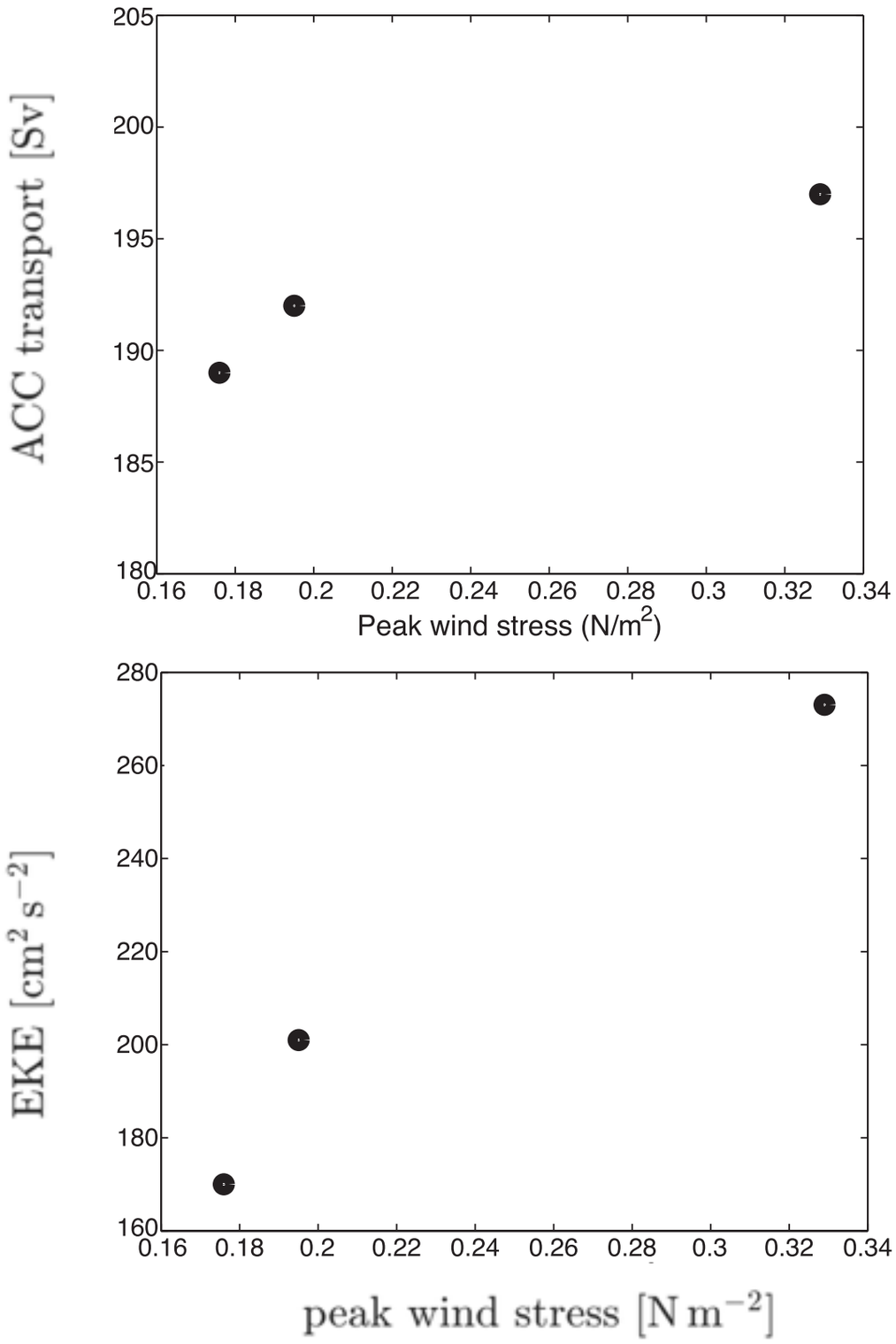
Meredith, et. al. (2012), *J. Climate*, 25(1), 99-110

Question

Does an eddy-saturated ACC imply
a *completely* eddy-compensated meridional overturning circulation?

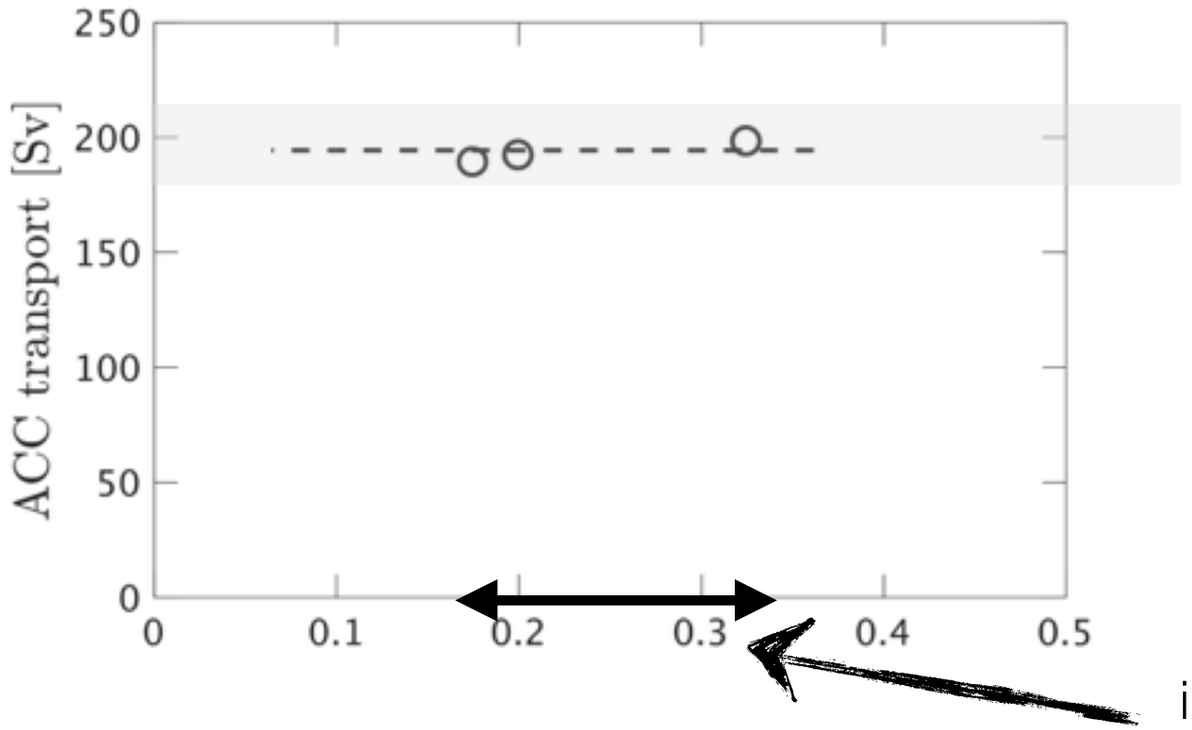
Is ACC saturated?

GFDL CM2.4



Is ACC saturated?

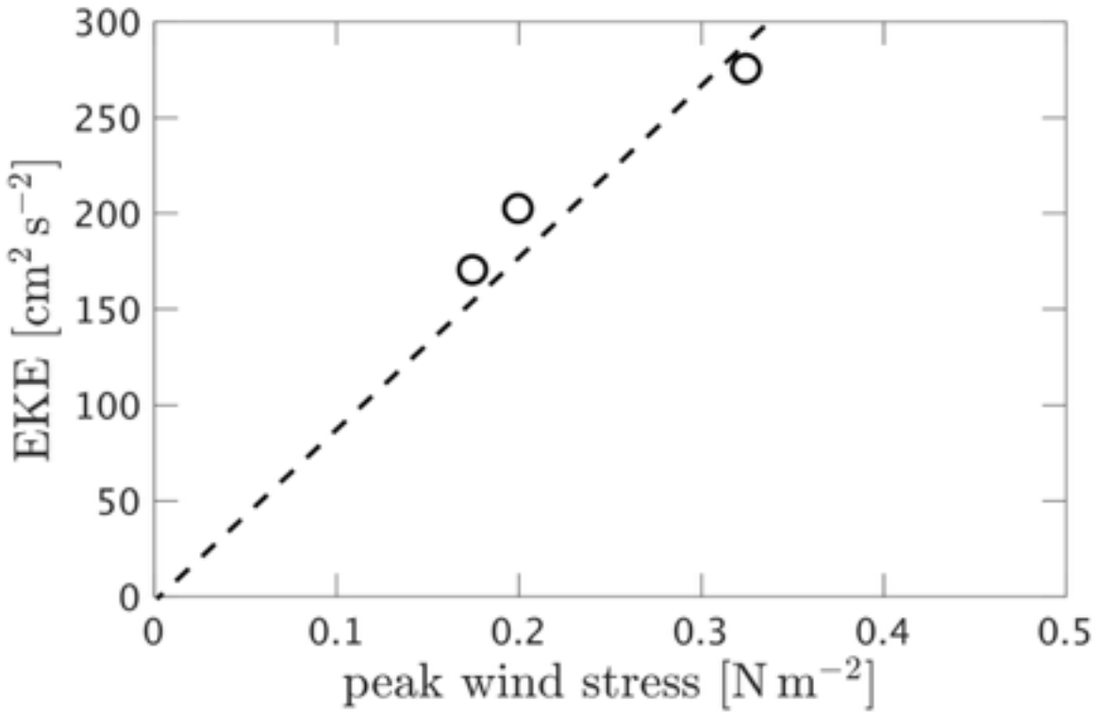
GFDL CM2.4



±5%

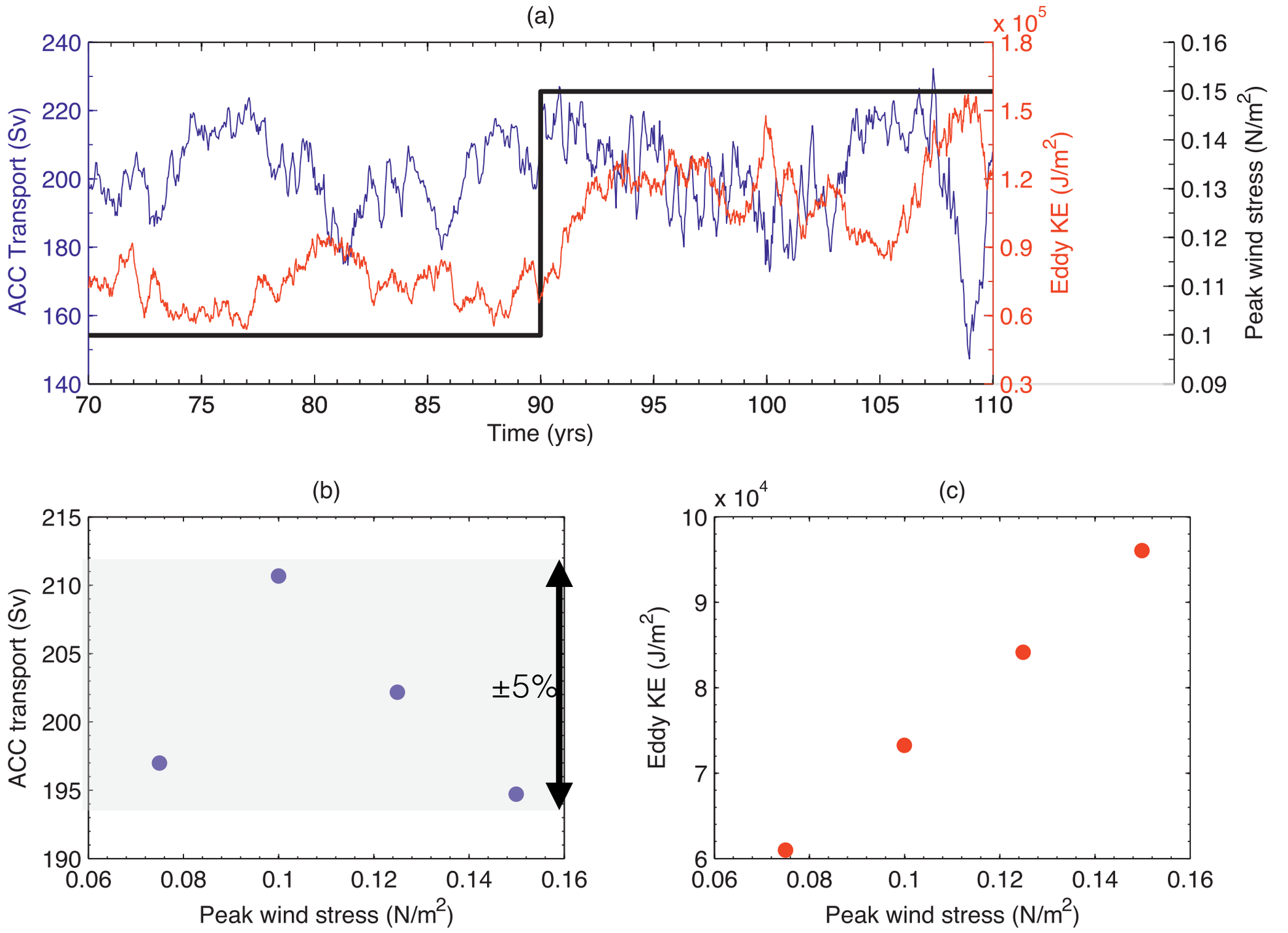
this is ≈doubling
is it enough to conclude?
e.g. how does wind r.m.s. variability compare?

(discuss)



Is ACC saturated?

Q-GCM
3-layer



Is it compensated?

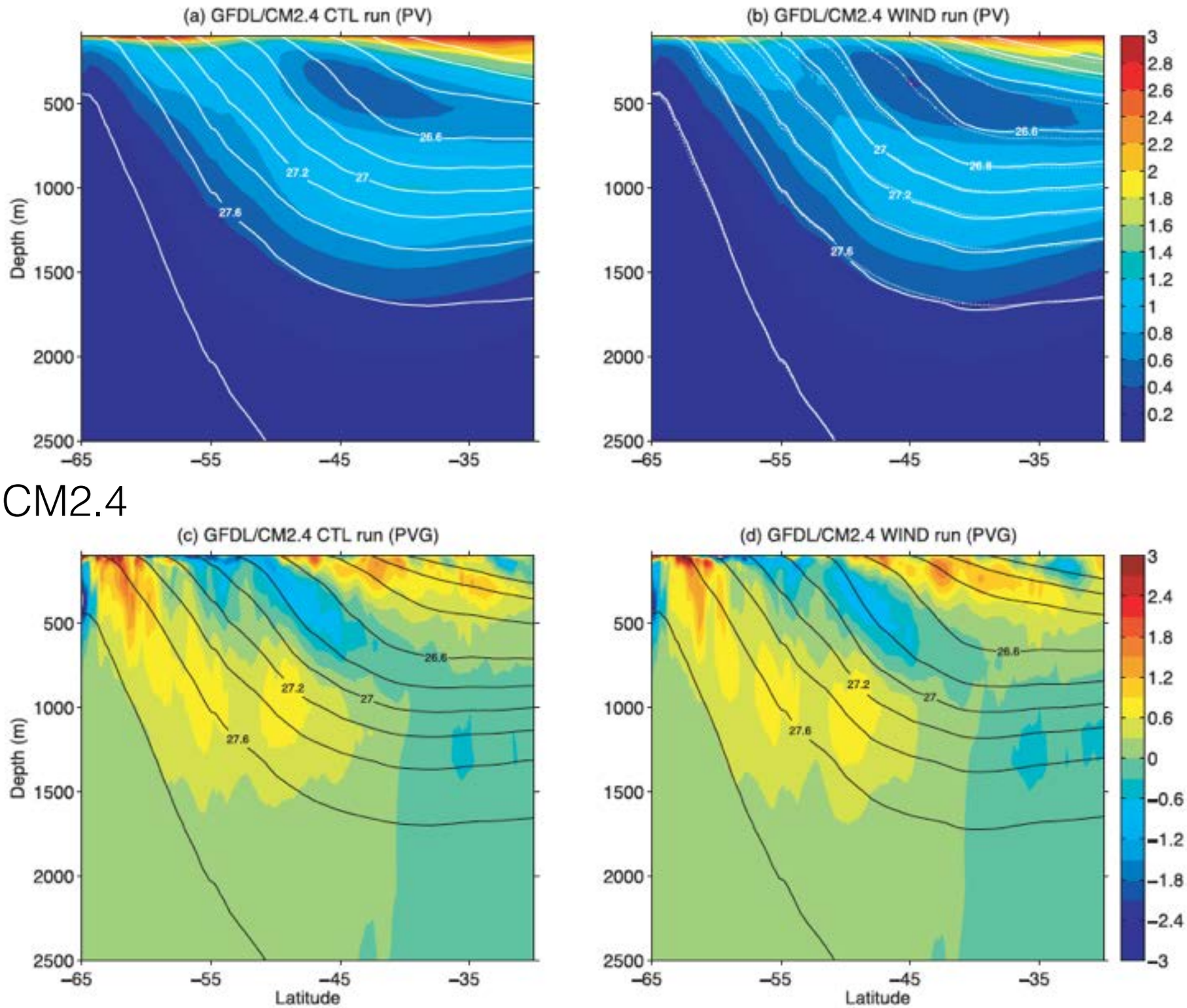
eddy induced meridional streamfunction

$$\Psi_z^* = -\frac{\kappa q_y}{f}$$

they argue that q_y does not change, so

they measure the strength of the overturning with κ

comparison of q_y as wind increases

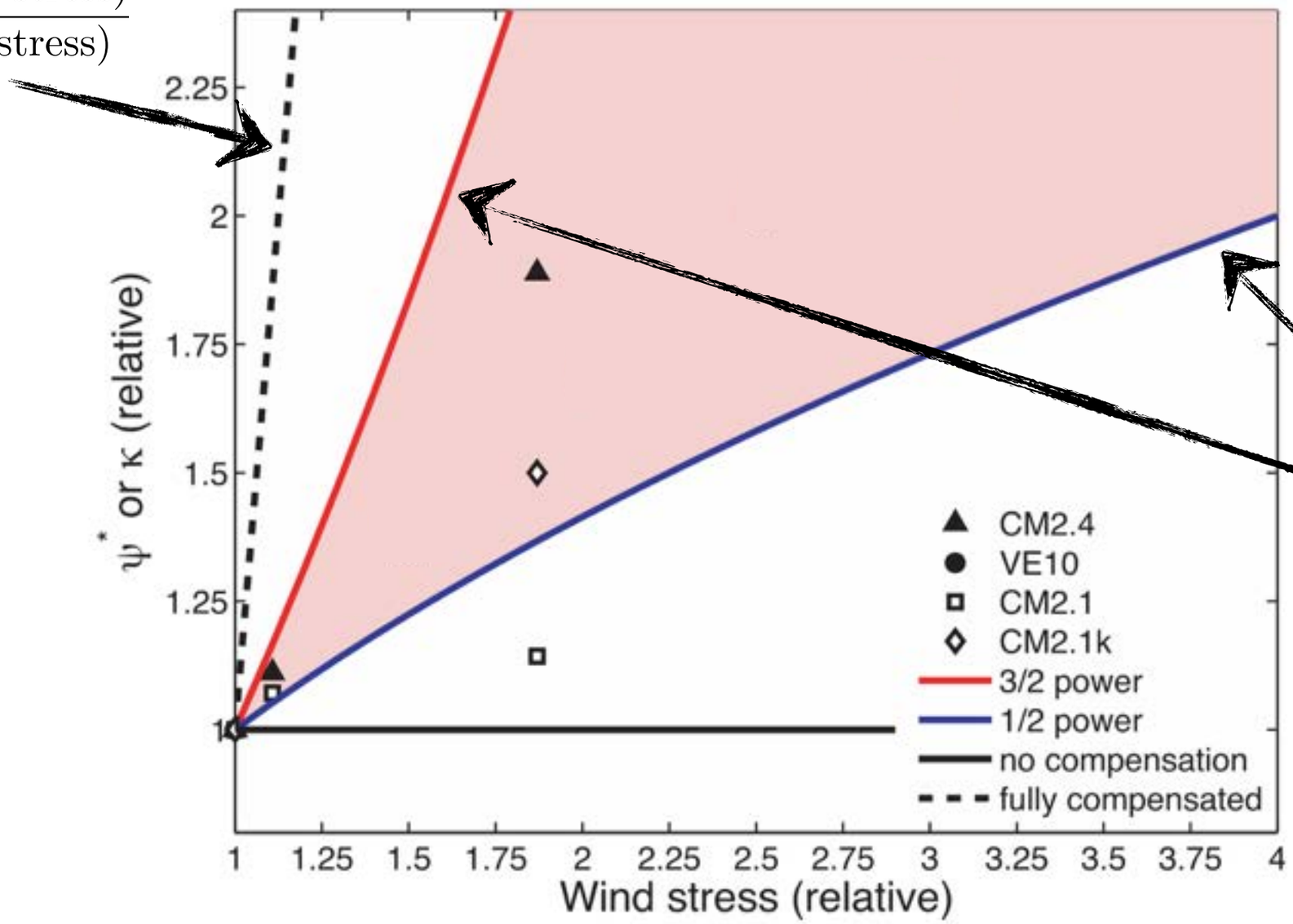


GFDL CM2.4

They find that it's partially compensated…

full compensation
(discuss its derivation)

$$\frac{\delta\kappa}{\kappa} = 8\frac{\delta(\text{wind stress})}{(\text{windstress})}$$



bounds based
on tracer mixing
arguments in the
presence of a jet

(discuss its derivation?)

u-momentum of an isopycnal layer with outcropping

$$\langle (hu)v \rangle_y - \langle fhv \rangle + \langle h M_x \rangle = \langle \tau \rangle / \rho_0$$

$$\langle h M_x \rangle = \langle h' M_x' \rangle$$

(i) Reynolds stress term negligible

(ii) eddies are close to geostrophic $\quad M_x' = f v'$

$$q = \frac{f+\zeta}{h} \approx \frac{f}{\langle h \rangle}\left(1 - \frac{h'}{\langle h \rangle}\right) \qquad |\zeta| \ll f \,, \quad |h'| \ll \langle h \rangle$$

(iii) assume $\quad \frac{f'}{\langle h \rangle} \ll \frac{\langle fh' \rangle - fh'}{\langle h \rangle^2} \qquad \langle v'q' \rangle = -\frac{\langle fv'h' \rangle}{\langle h \rangle^2}$

(iv) assume $\quad \langle v'q' \rangle = -k\left(-\frac{\beta}{\langle h \rangle} + \frac{f\langle h \rangle_y}{\langle h \rangle^2}\right)$

u-momentum of an isopycnal layer with outcropping

$$\frac{\langle fhv\rangle}{\langle f\rangle} = K\left(-\frac{\beta\langle h\rangle}{f} + \langle h\rangle_y\right) - \frac{\langle\tau\rangle}{\rho_0\langle f\rangle}$$

taking small variations we have

$$-\delta\left(\frac{\langle fhv\rangle}{\langle f\rangle}\right) = \delta K\left(-\frac{\beta\langle h\rangle}{f} + \langle h\rangle_y\right) + K\,\delta\left(-\frac{\beta\langle h\rangle}{f} + \langle h\rangle_y\right) - \frac{\delta\langle\tau\rangle}{\rho_0\langle f\rangle}$$

(v)

$$\delta\left(\frac{\langle fvh\rangle}{\langle f\rangle}\right) \approx 0$$ completely eddy-compensated (the MOC doesn't change)

$$\delta\left(-\beta\frac{\langle h\rangle}{f} + \langle h\rangle_y\right) \approx 0$$ (suggested by the numerics)

$$\frac{\delta K}{K} = 8\,\frac{\delta\langle\tau\rangle}{\langle\tau\rangle}$$

if you put the SO numbers

what to take home?

while ACC seems almost completely *saturated*
it is only partially *compensated*

some (heuristic) arguments suggest that for SO:

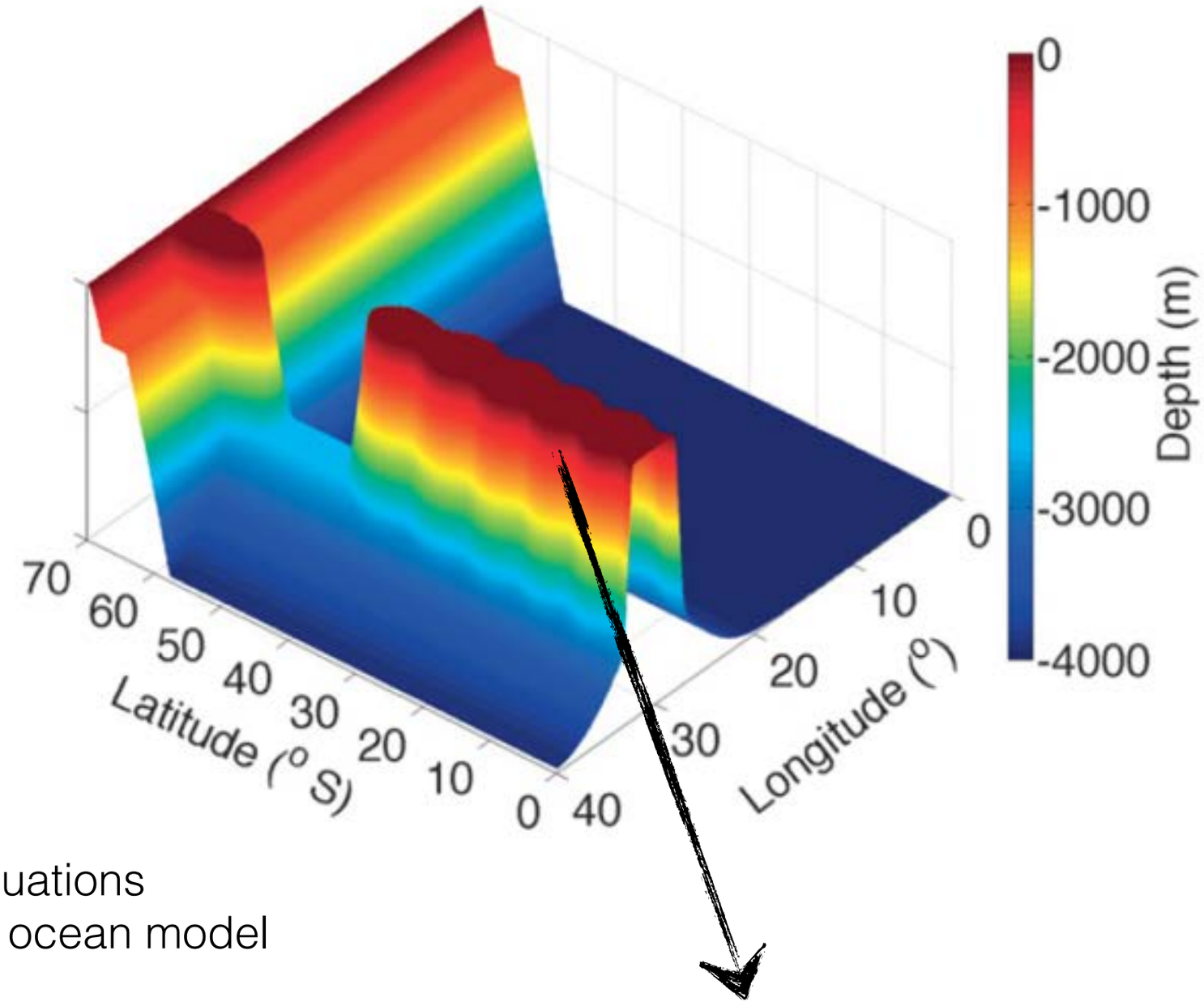
$$\left(\frac{\delta\tau}{\tau}\right)^{1/2} \leq \left(\frac{\delta\Psi^*}{\Psi^*}\right)^{1/2} \leq \left(\frac{\delta\tau}{\tau}\right)^{3/2} \ll 8\left(\frac{\delta\tau}{\tau}\right)$$

Morrison & Hogg (2013), *J. Phys. Ocean.*, 43(1), 140-148

Question

What's the relationship between
ACC transport and residual overturning?

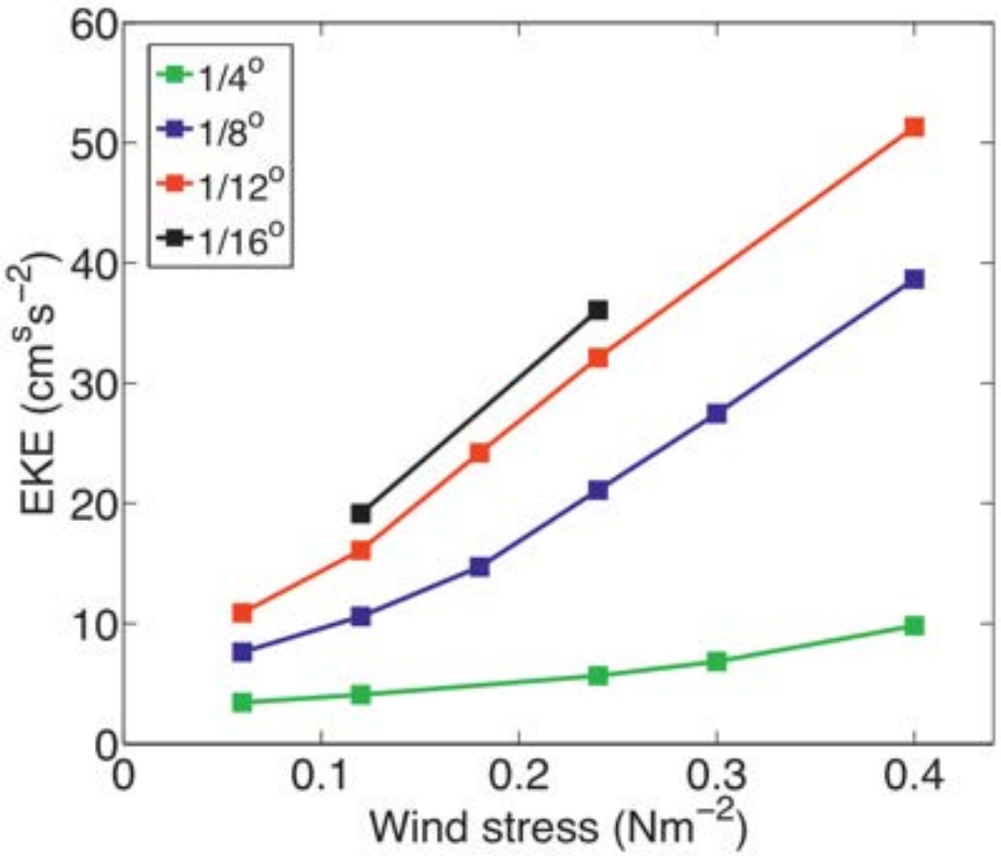
flow setting



primitive equations
isopycnal layered ocean model

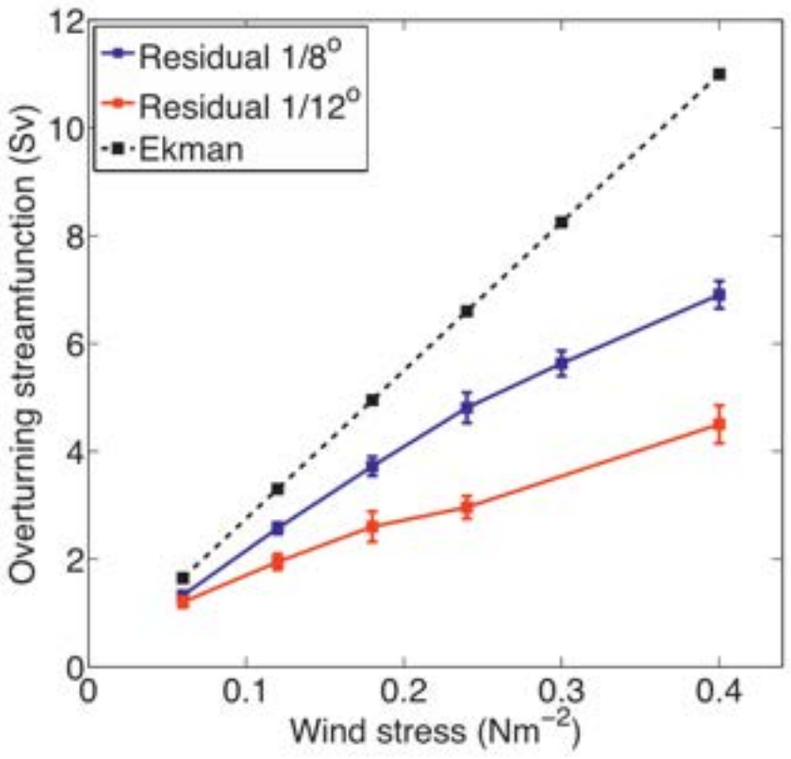
what are these side-bumps?

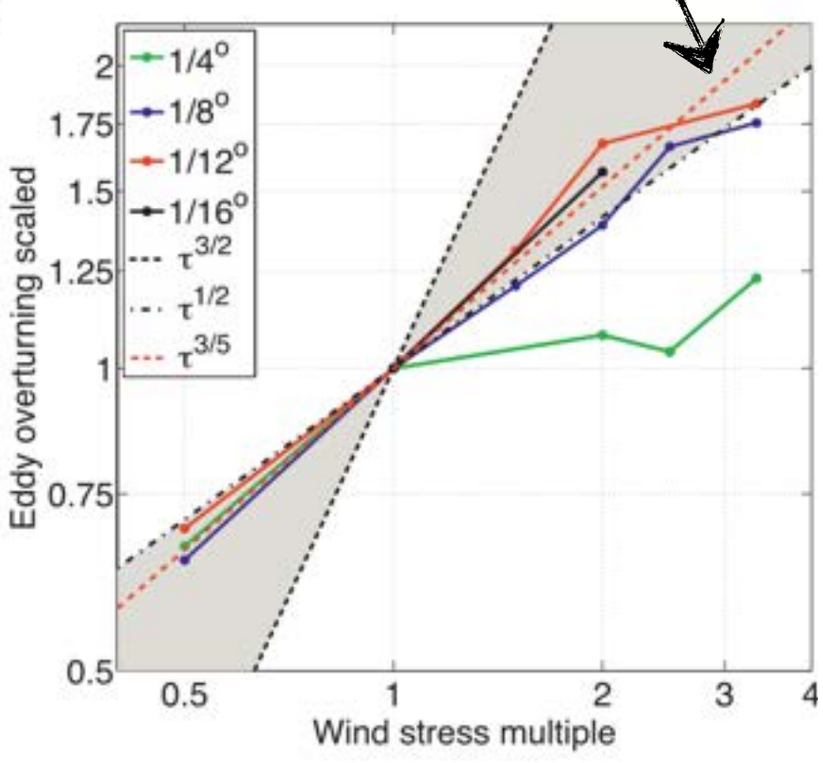
EKE depends linearly on wind stress — ACC saturated

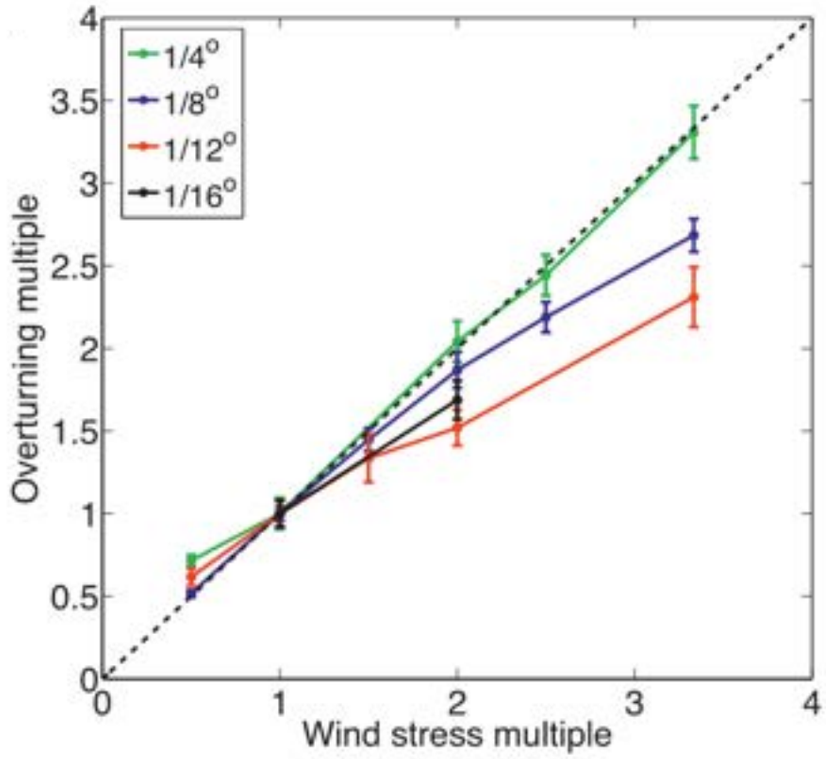


6-fold increase

results



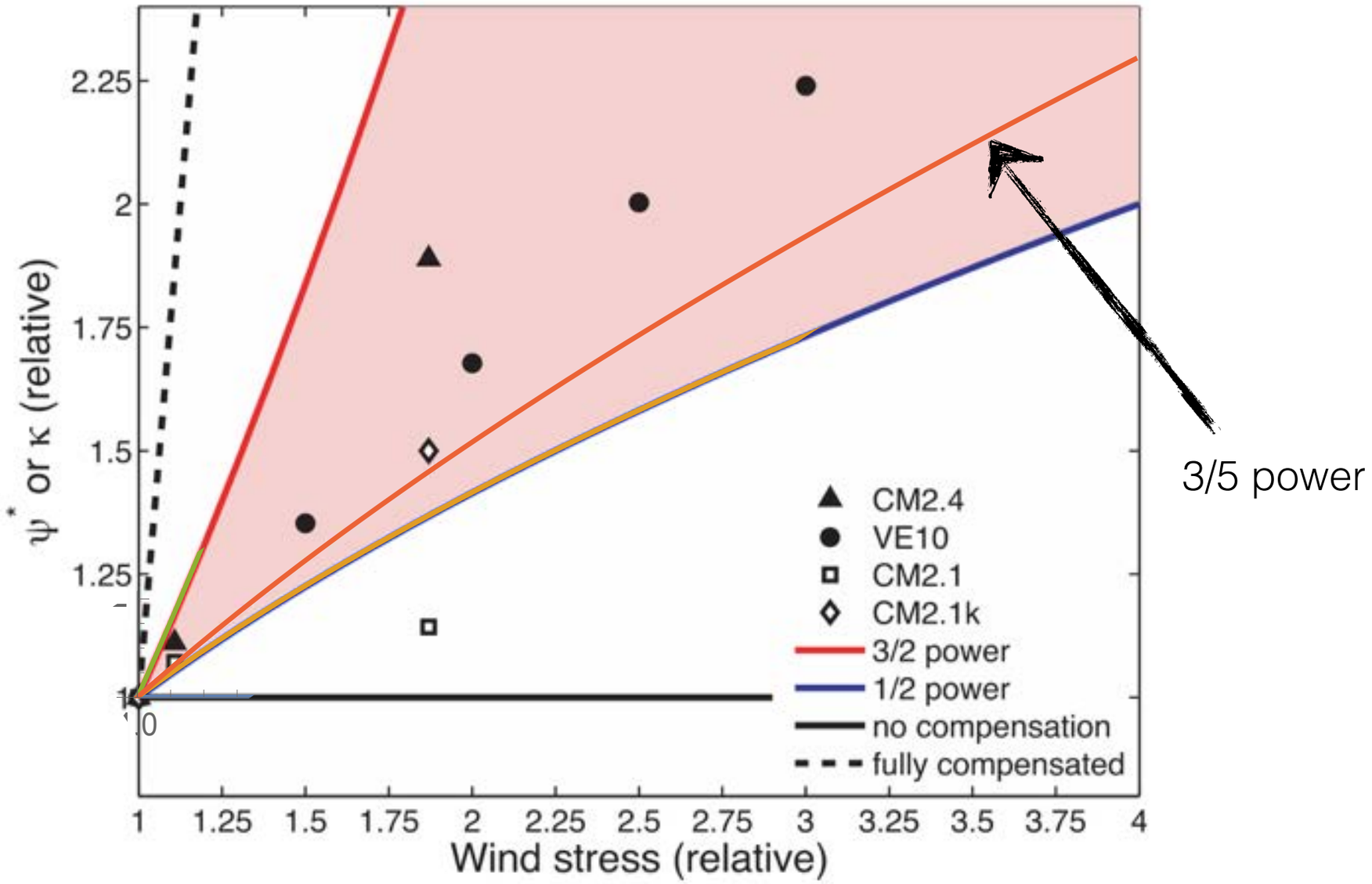




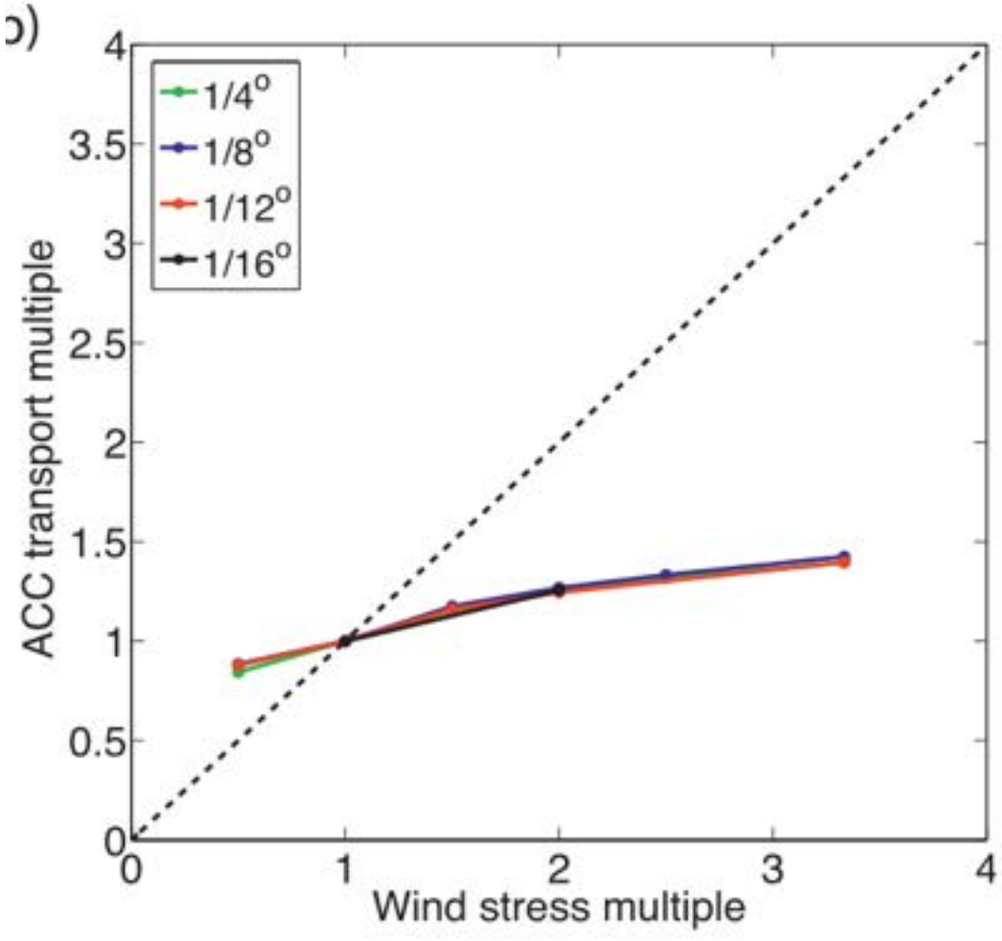
increased resolution
increases compensation

are these non-monotonic
with increased resolution?
(discuss)

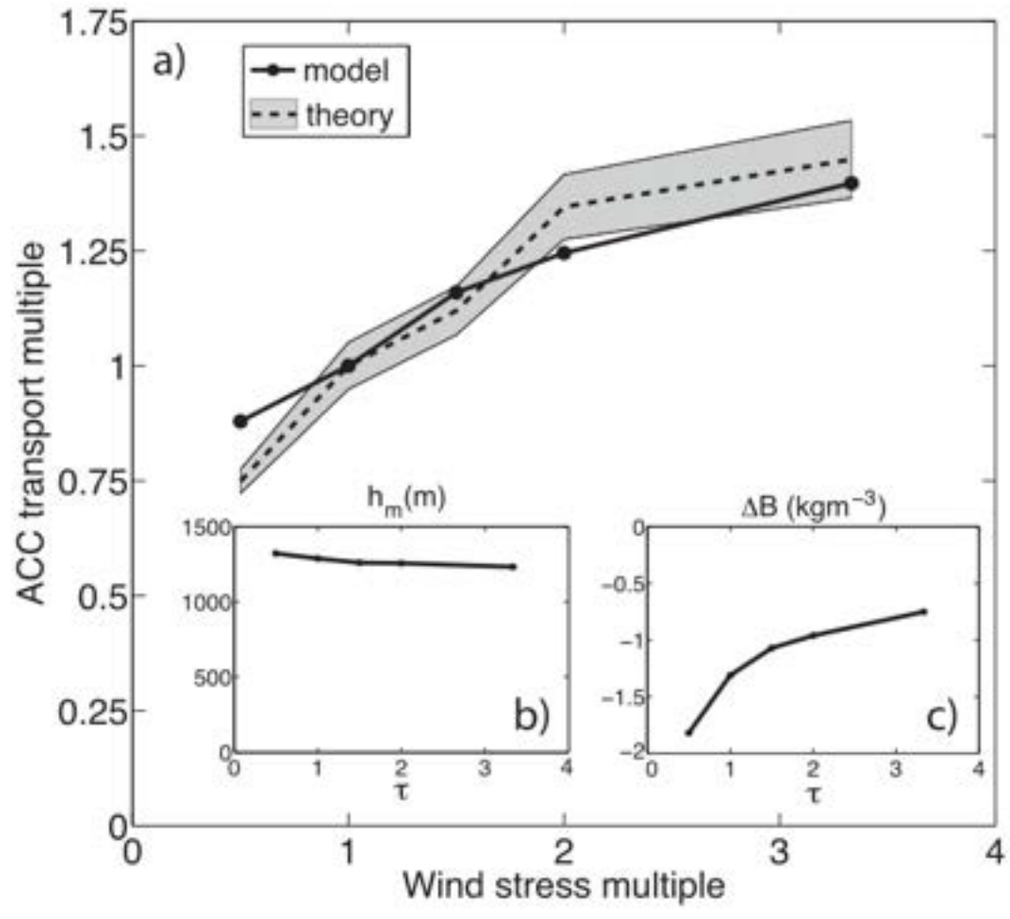
how does 3/5 compares with Meredith et. al. results?



results



using the 3/5 scaling they predict ACC transport



$$T_{\mathrm{ACC}} \sim \frac{-g\,\Delta B\,h_m}{K f^2}(\tau + \Psi_{\mathrm{res}})$$

what to take home?

there is *not* a one-on-one relationship between
eddy saturation *&* eddy compensation

eddy compensation is sensitive to the cancelation between the
Ekman and eddy-induced transports near the surface

eddy saturation refers to the depth integrated transport and
depends on stratification changes throughout the whole depth

hypothesis:

this causes compensation to be resolution dependent
and saturation to be (relatively) independent