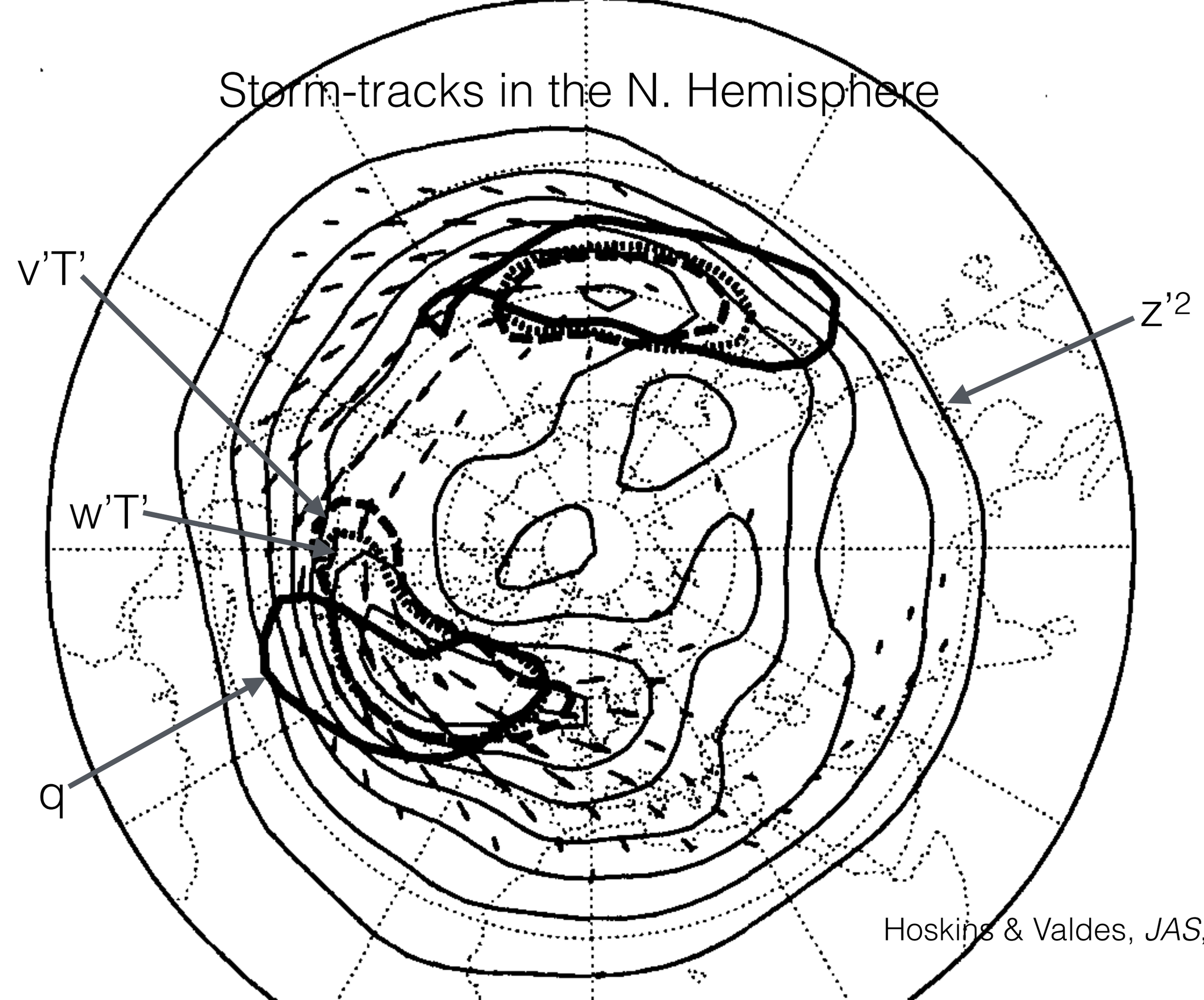
Jet responses to changed friction in idealized GCMs

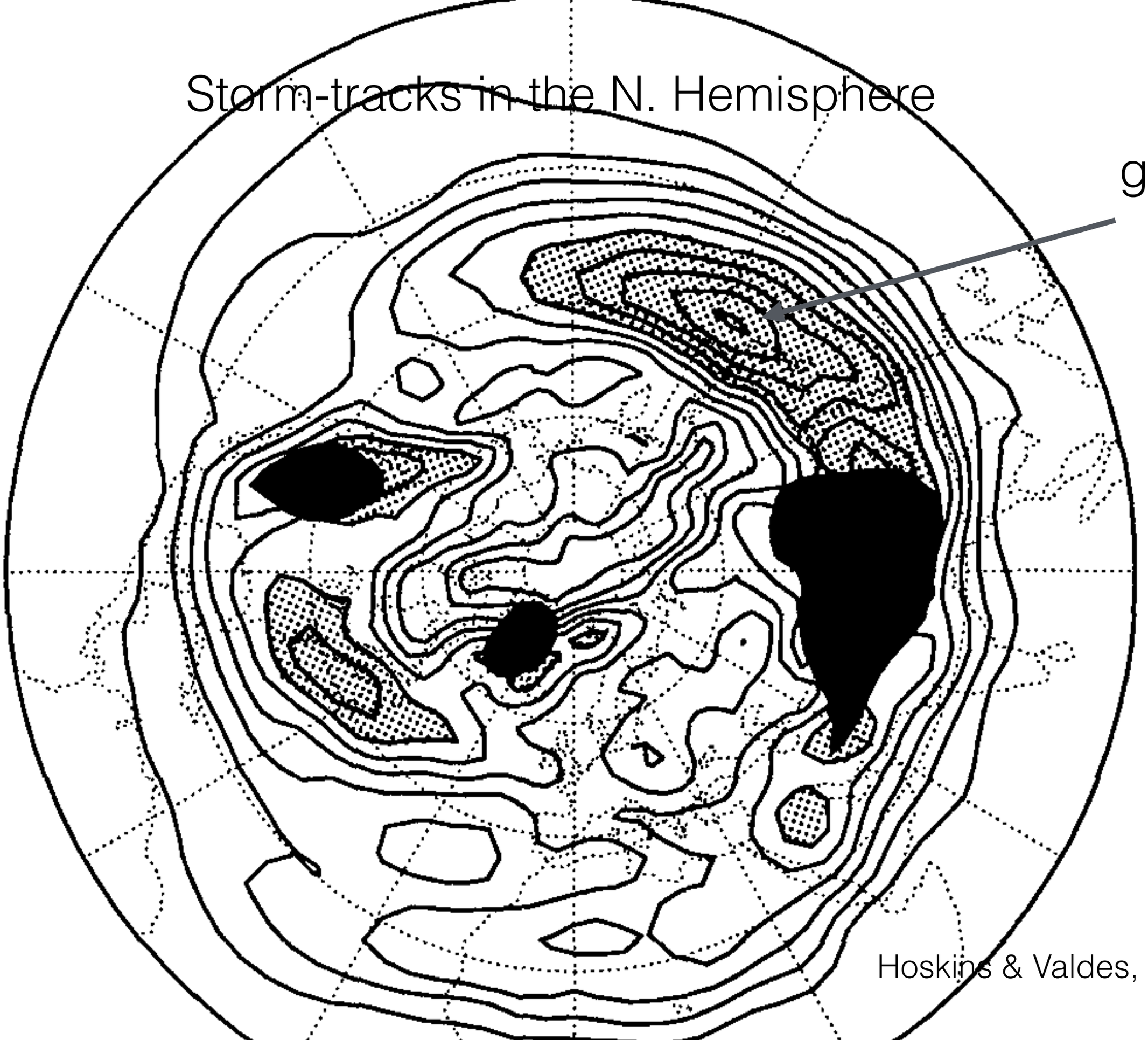
Maarten Ambaum
Lenka Novak
Ben Harvey
University of Reading, UK

Storm-tracks in the N. Hemisphere



Hoskins & Valdes, *JAS*, 1990

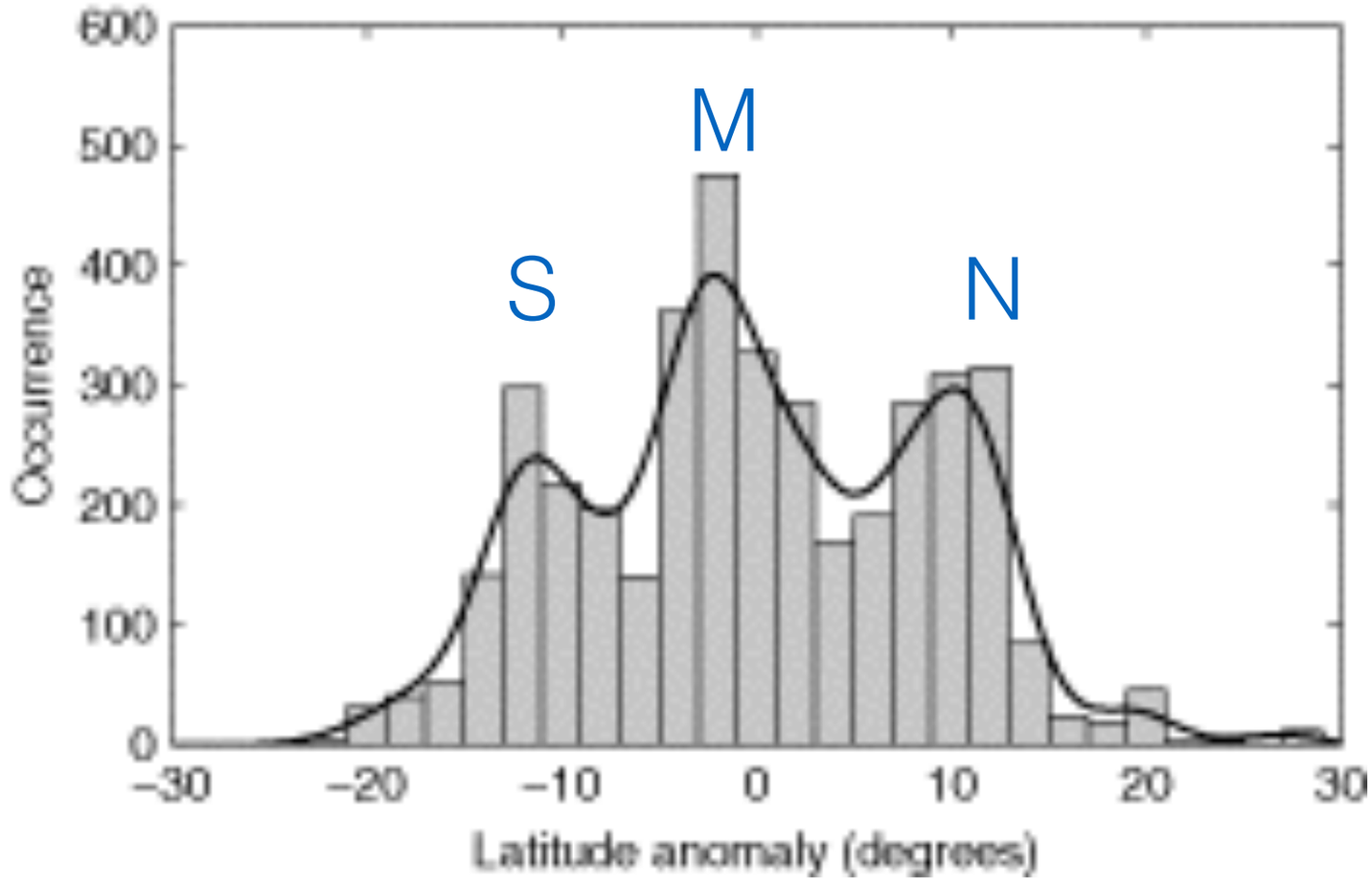
Storm-tracks in the N. Hemisphere



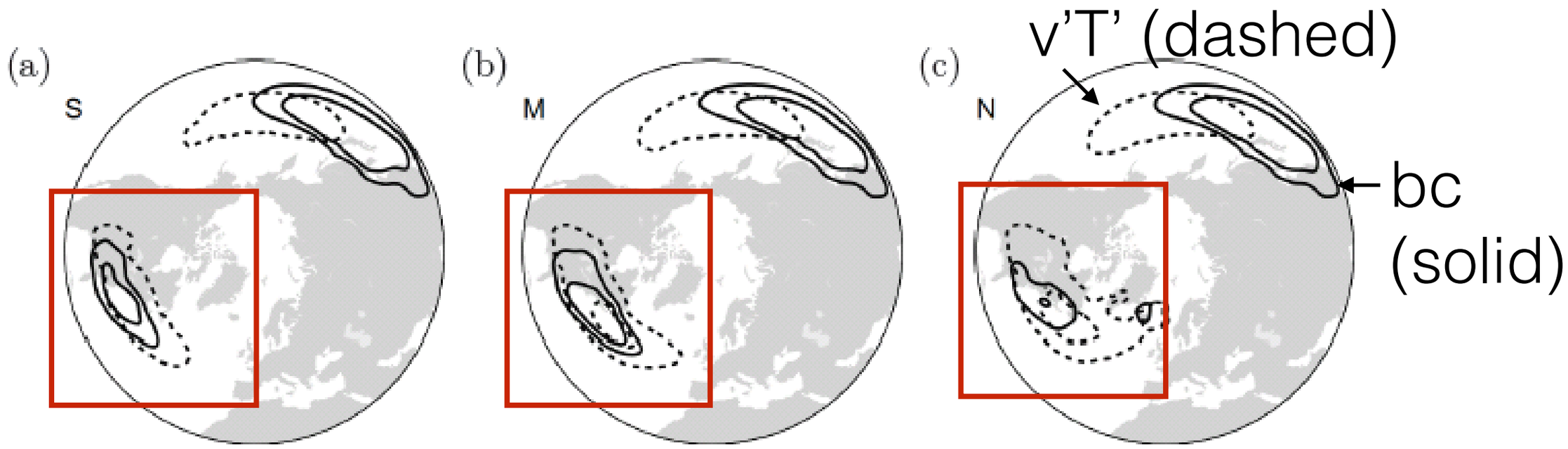
Hoskins & Valdes, *JAS*, 1990

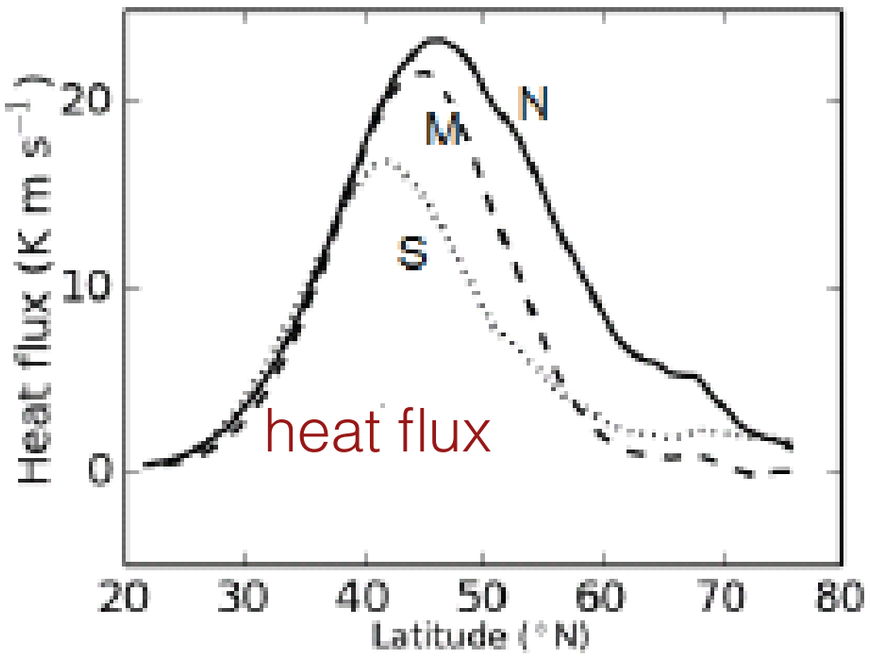
High baroclinicity corresponds to high wave activity (?)

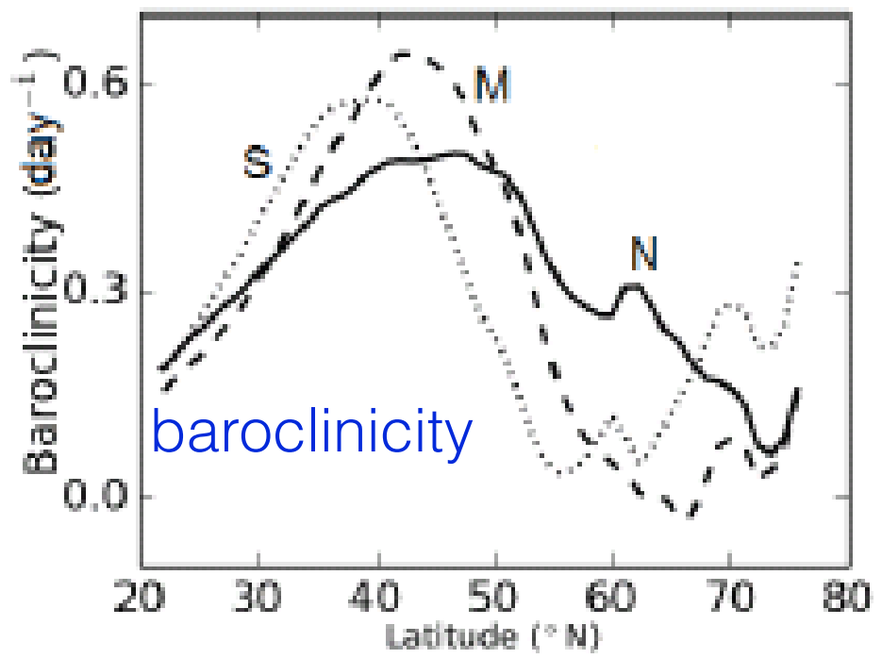
Examined relationship using three-way classification of N Atlantic jet latitude.



(Woollings, *QJ,* 2010, Frame *et al.*, *QJ*, 2011)

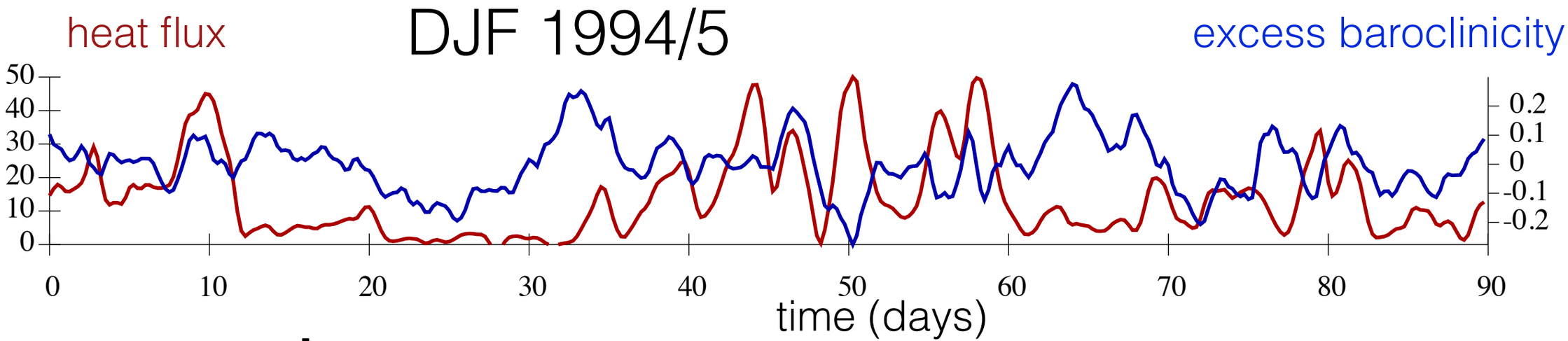




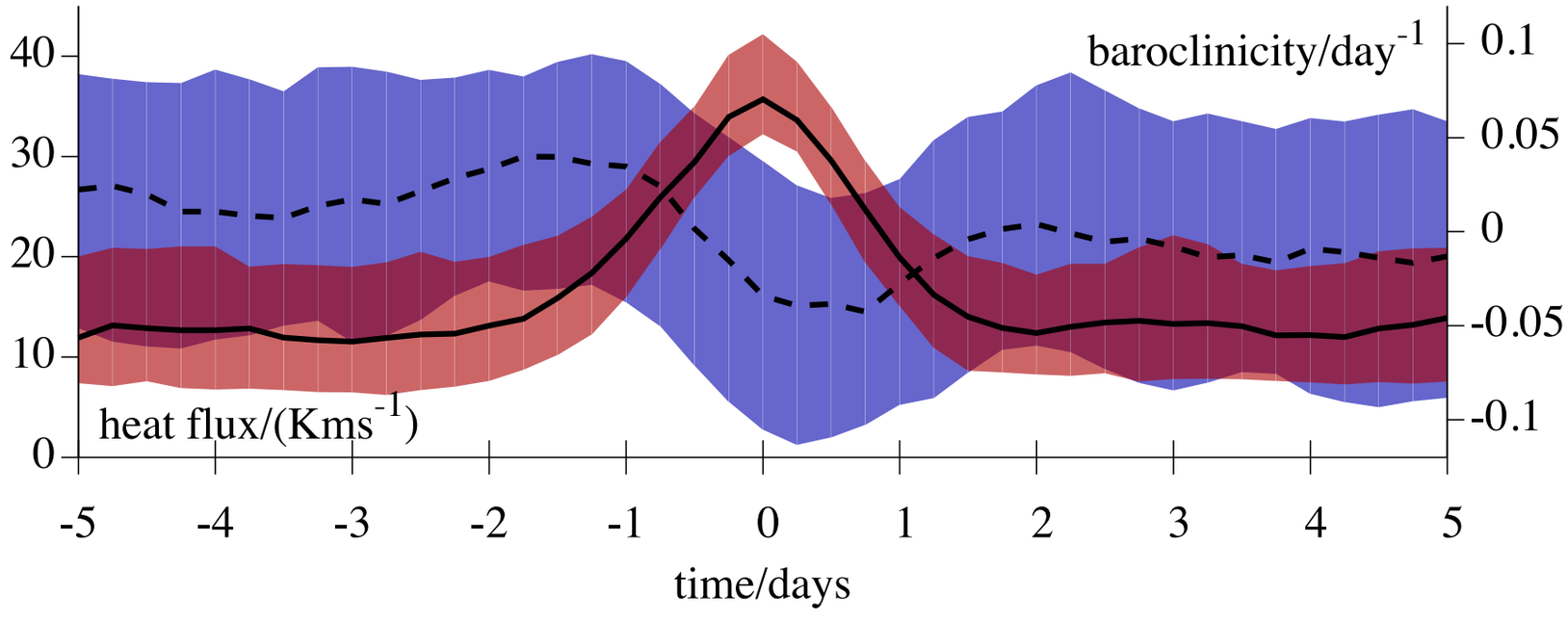


in time, high baroclinicity does **not** correspond to high wave activity

Novak, Ambaum, Tailleux, *JAS*, 2015



Composite



Ambaum & Novak, *QJ*, 2014

What determines the mean flow (thermal wind, zonal mean available potential energy) in the atmosphere?

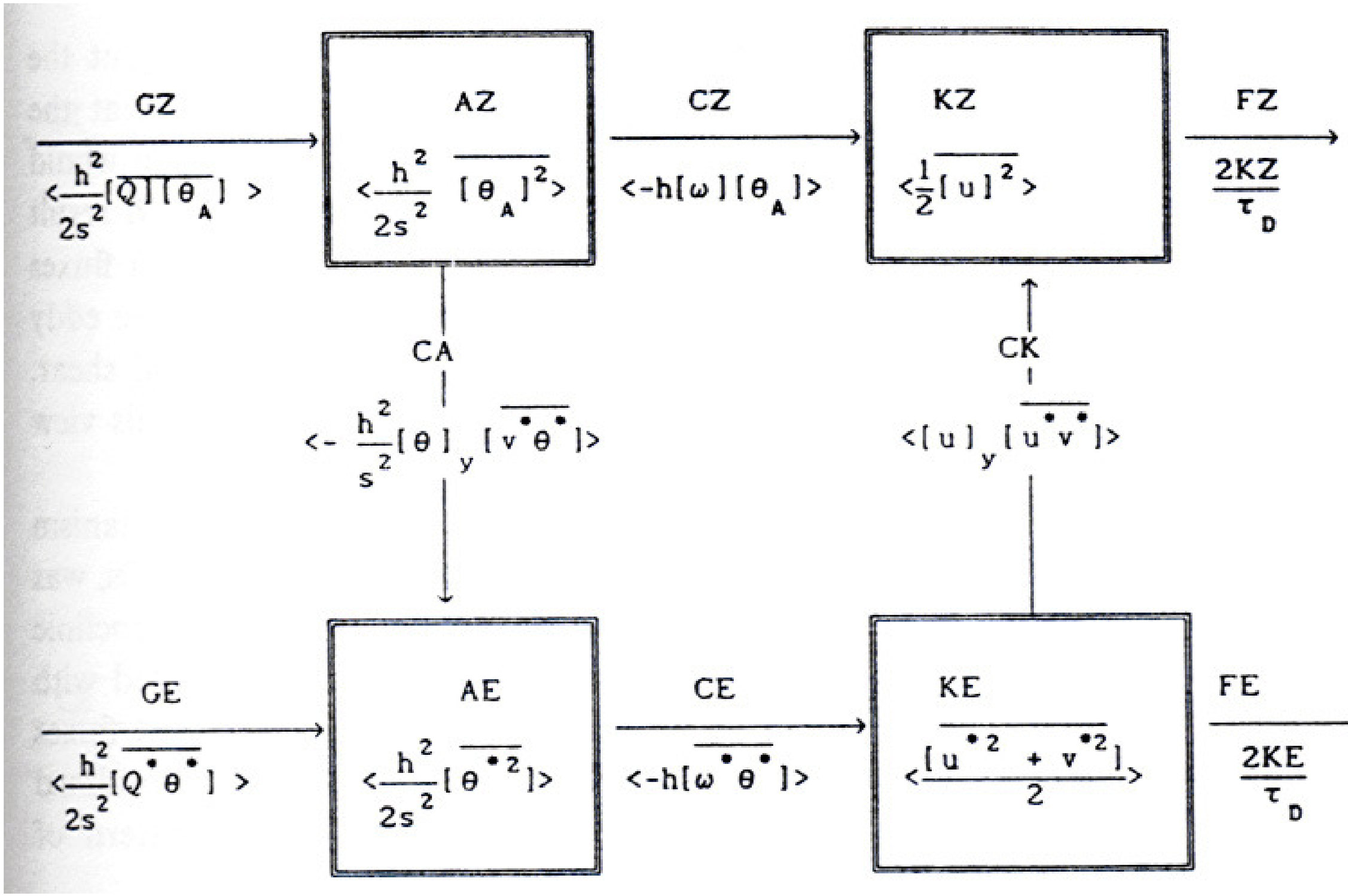
$$\dot{U} = \text{forcing} - \text{friction}$$

?

$$\dot{U} = F - \lambda U$$

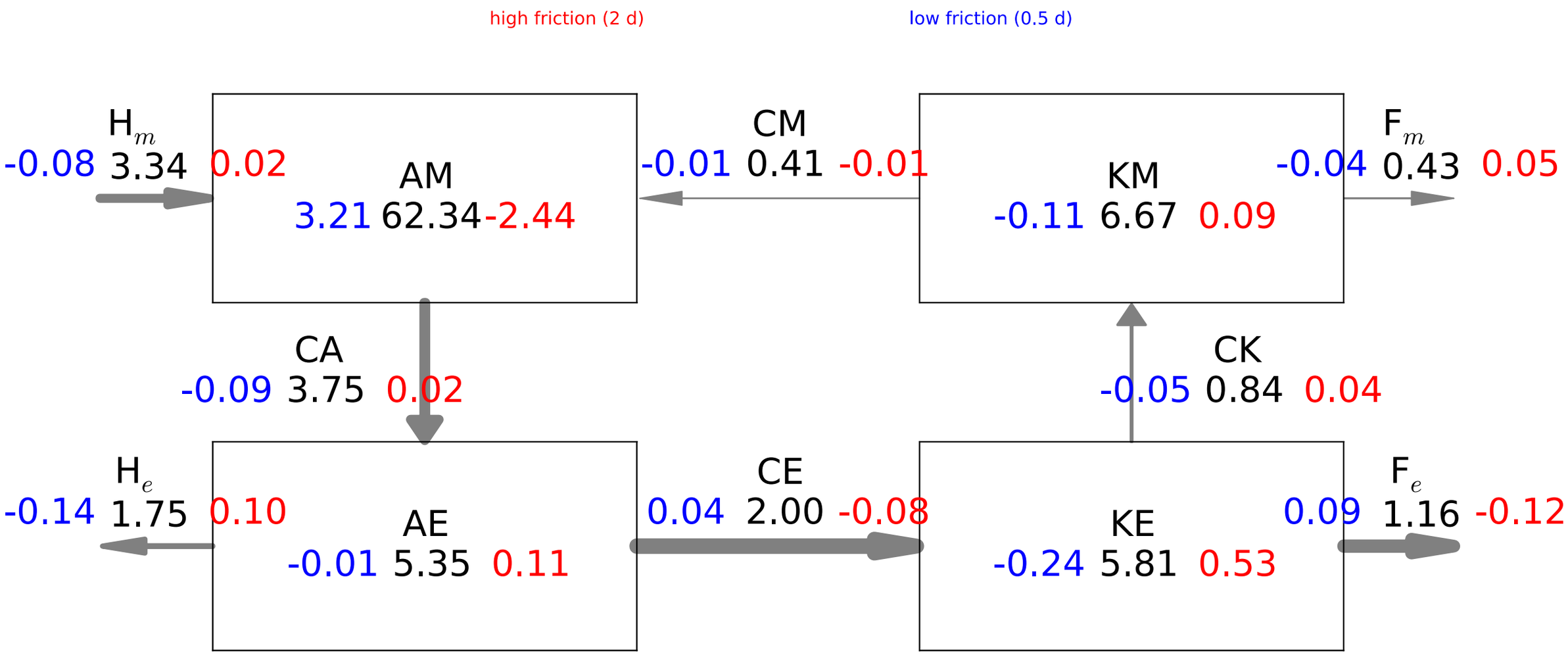
stronger forcing → stronger flow
stronger friction → weaker flow

Lorenz cycle



James, 1990

Lorenz cycle in zonally symmetric dry GCM



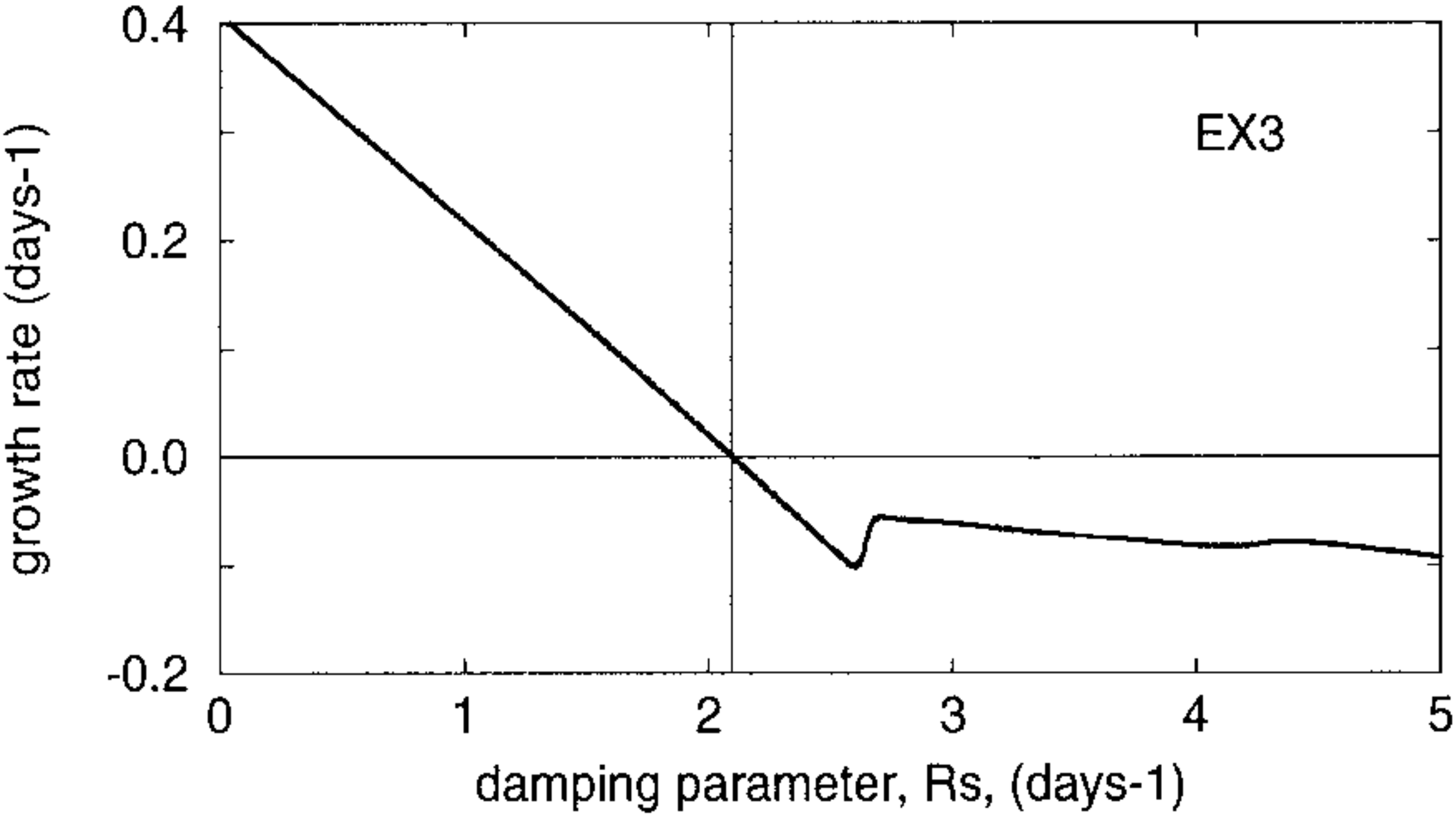
→mean flow gets (mainly) dissipated through eddy processes

What determines the eddy strength in the atmosphere?

$$\dot{f} = \boldsymbol{\sigma} f$$

?

Friction and baroclinic instability



Hall & Sardeshmukh, *JAS*, 1998

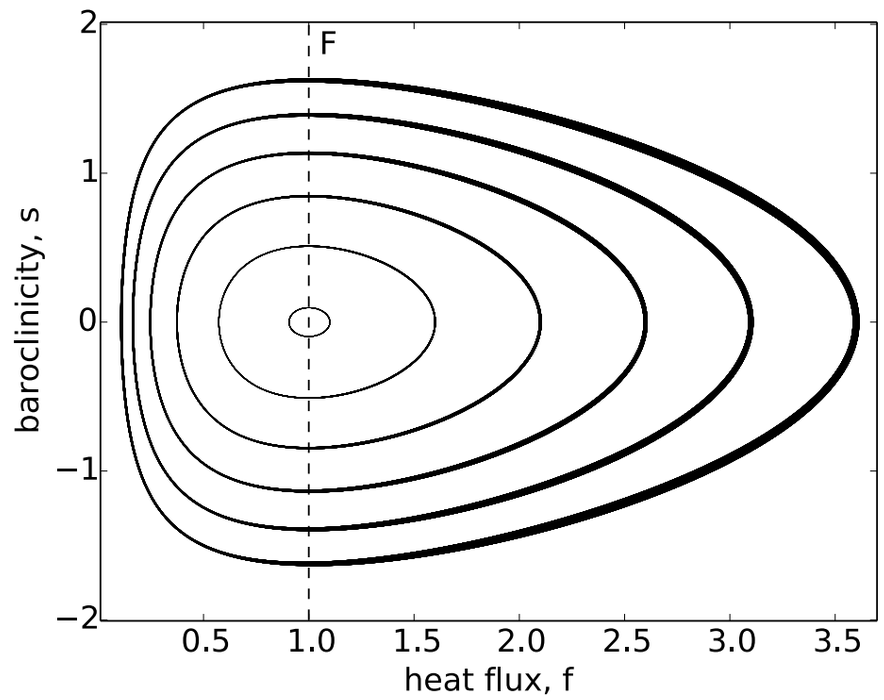
A heuristic model for eddy-mean flow interaction

$$\dot{\sigma} = F - f$$

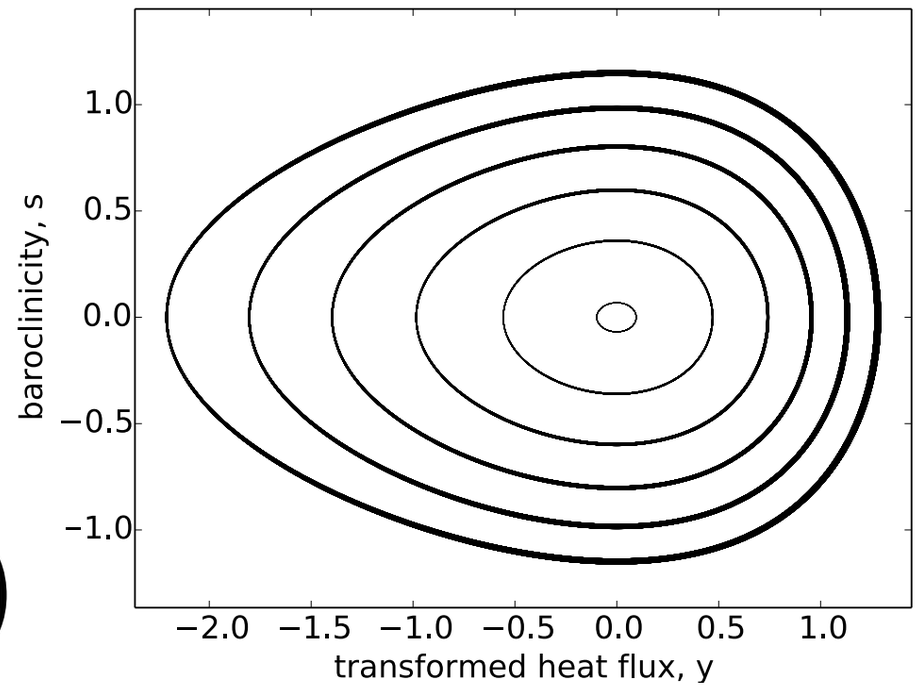
$$\dot{f} = \sigma f - D f$$

$$y = \log(f/F)$$

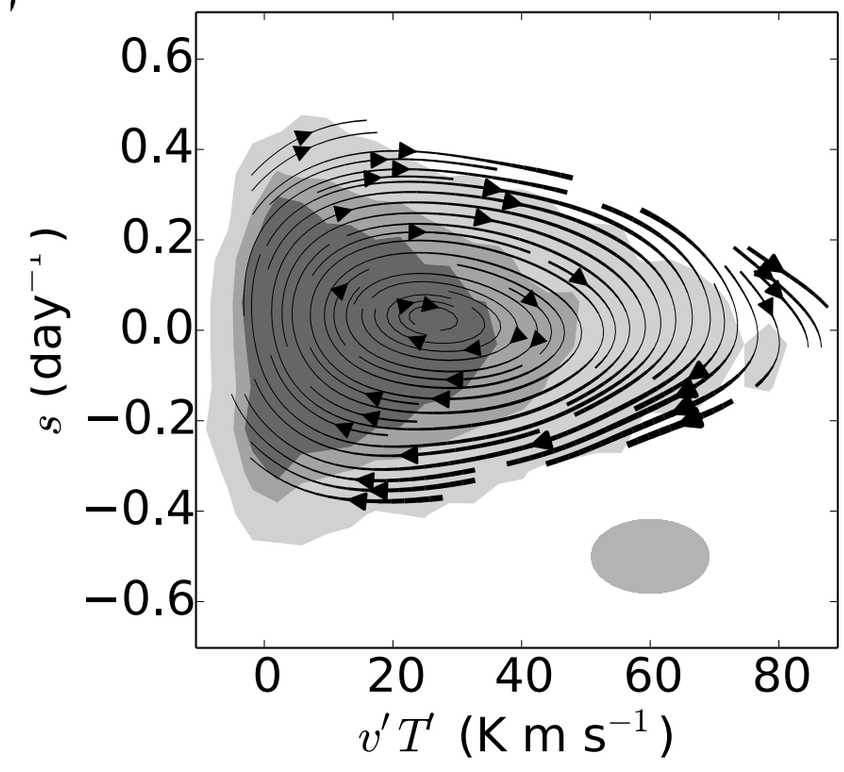
(a)



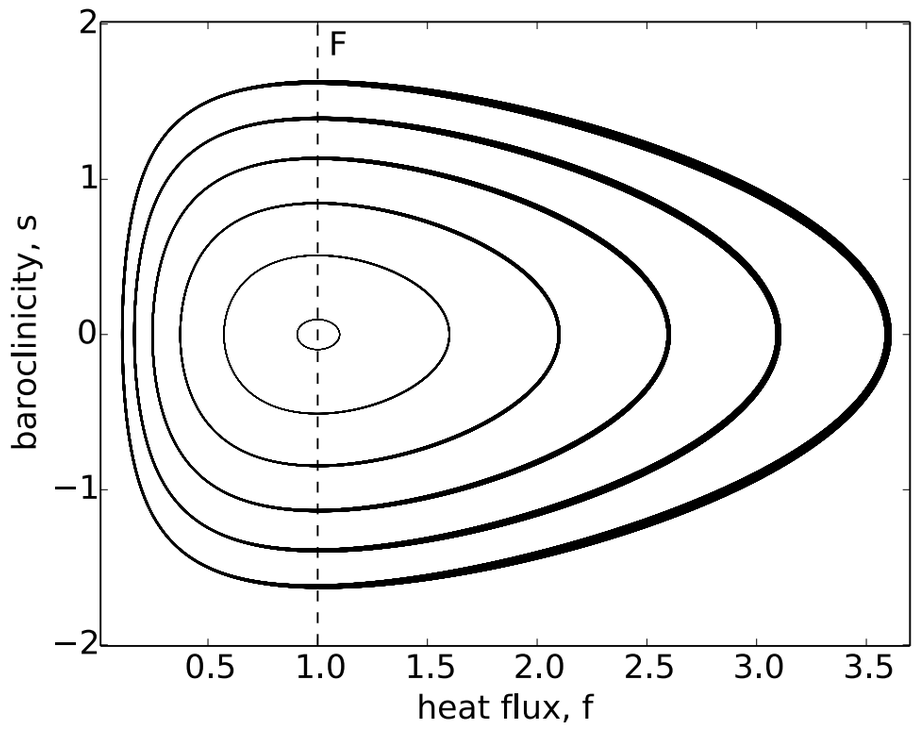
(b)



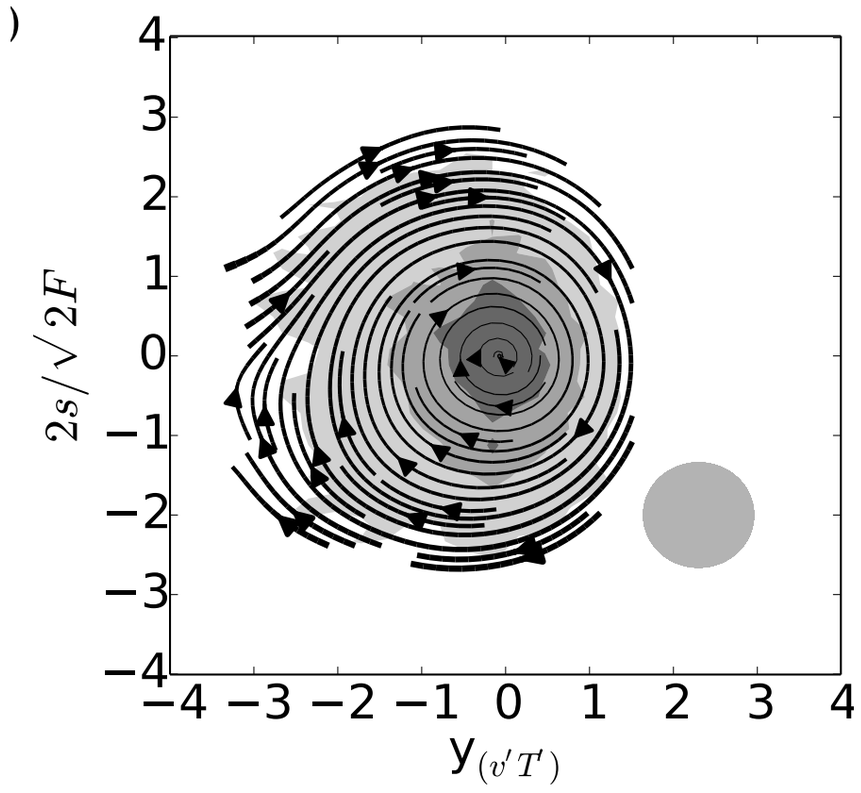
)


0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
s (day^{-1})
0
20
40
60
80
$v'T'$ (K m s^{-1})

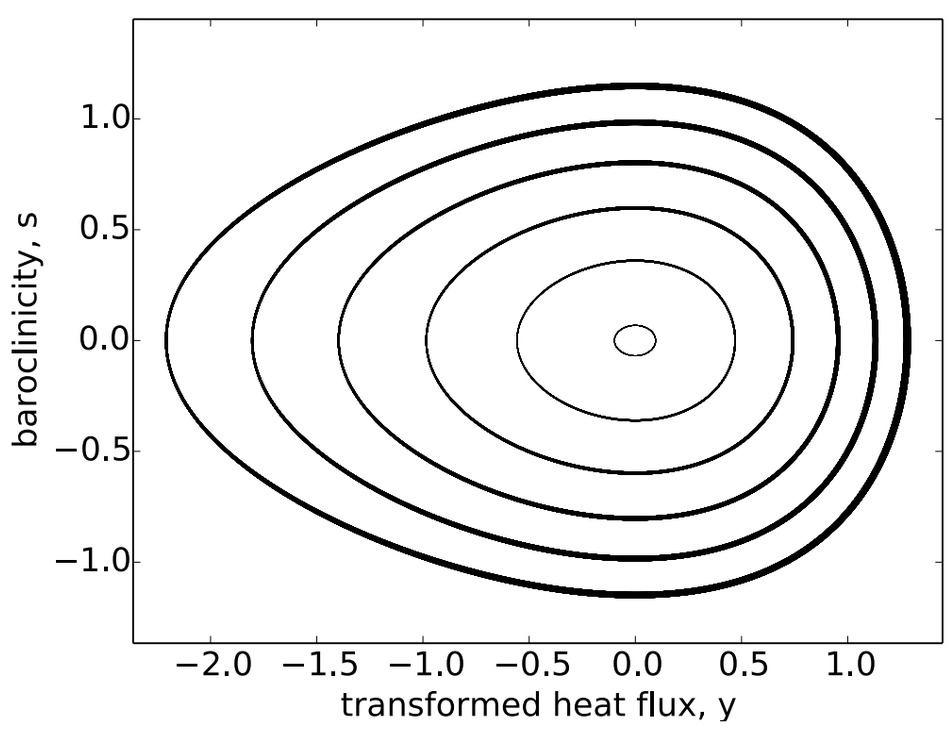
(a)


F
2
1
0
−1
−2
baroclinicity, s
0.5
1.0
1.5
2.0
2.5
3.0
3.5
heat flux, f

)


4
3
2
1
0
−1
−2
−3
−4
$2s/\sqrt{2F}$
−4 −3 −2 −1 0 1 2 3 4
$y_{(v'T')}$

(b)


1.0
0.5
0.0
−0.5
−1.0
baroclinicity, s
−2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0
transformed heat flux, y

A heuristic model for eddy-mean flow interaction

$$\dot{\sigma} = F - f$$

$$\dot{f} = \sigma f - D f$$

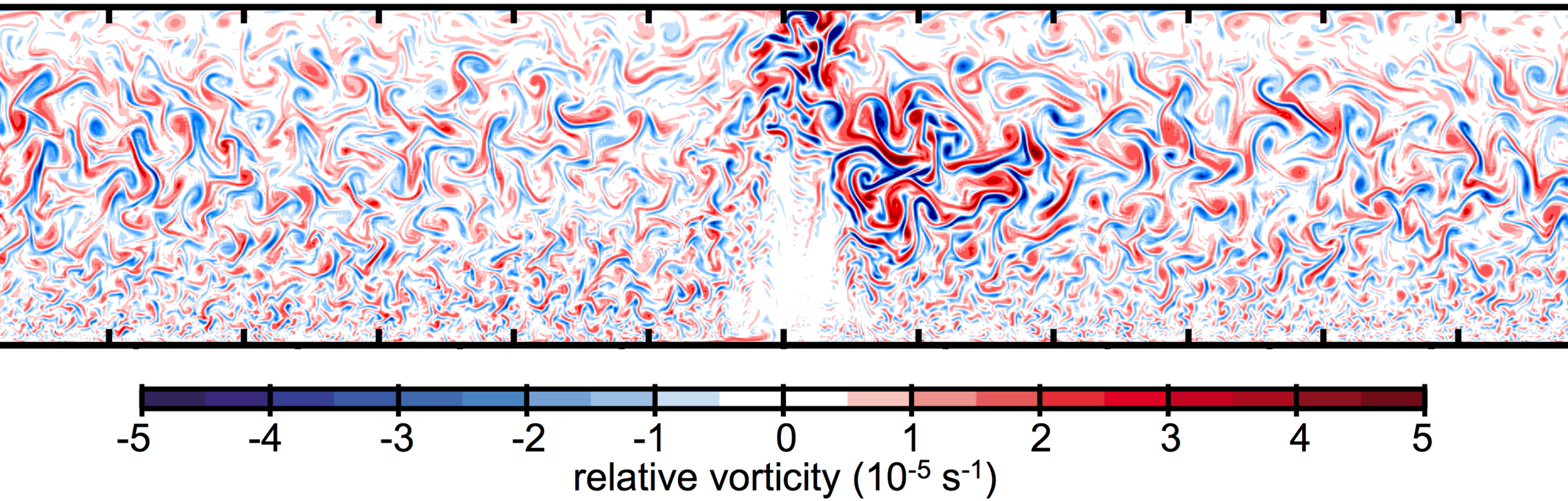
"eddy saturation"

Corollary:

$f_0 = F$ (eddy strength = mean source)

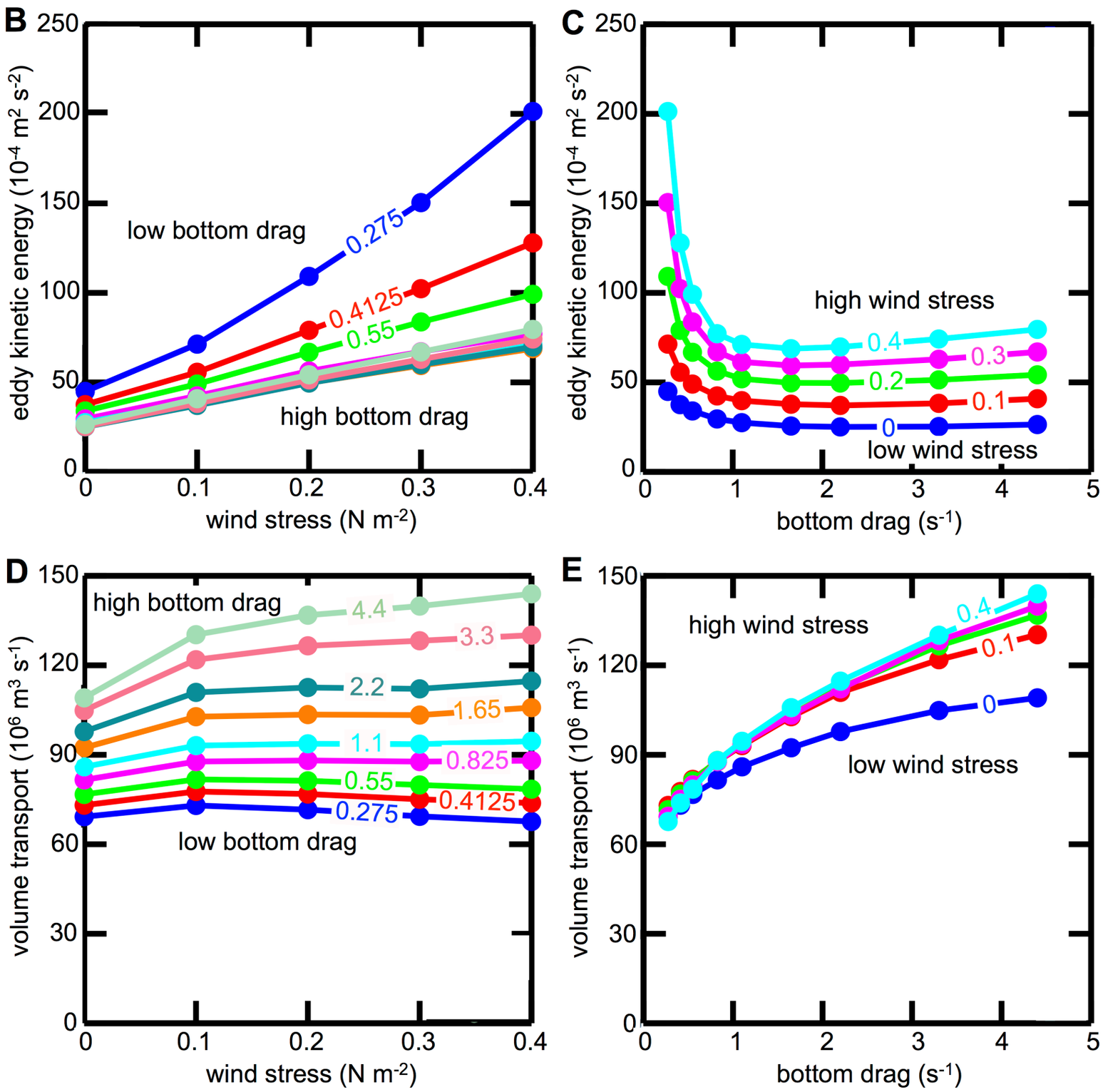
$\sigma_0 = D$ (mean flow is marginally stable)

Control of ACC transport in eddy resolving model



Marshall *et al*, 2016

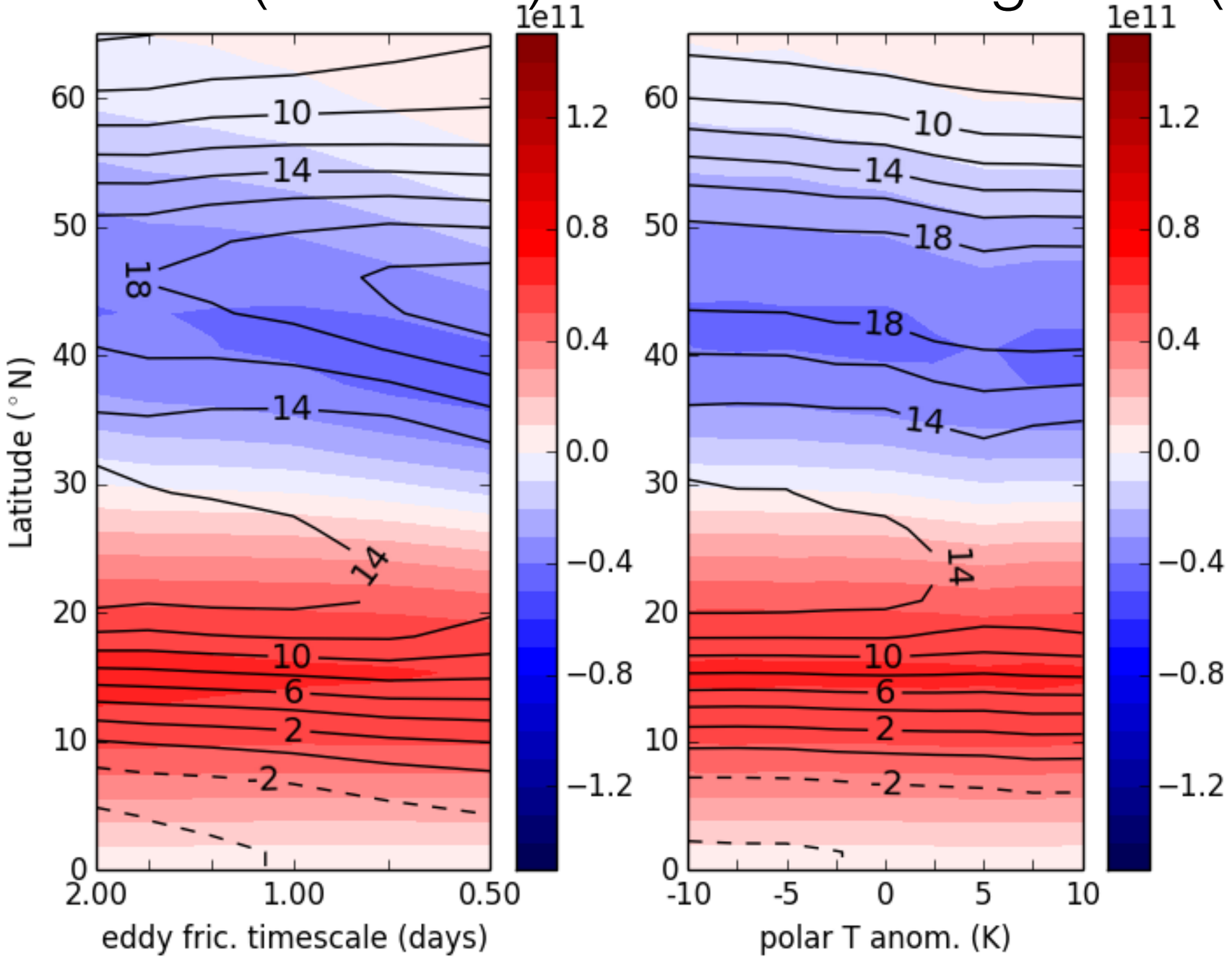
Control of ACC transport in eddy resolving model



Marshall *et al*, 2016

Control of mean flow in dry atmosphere GCM

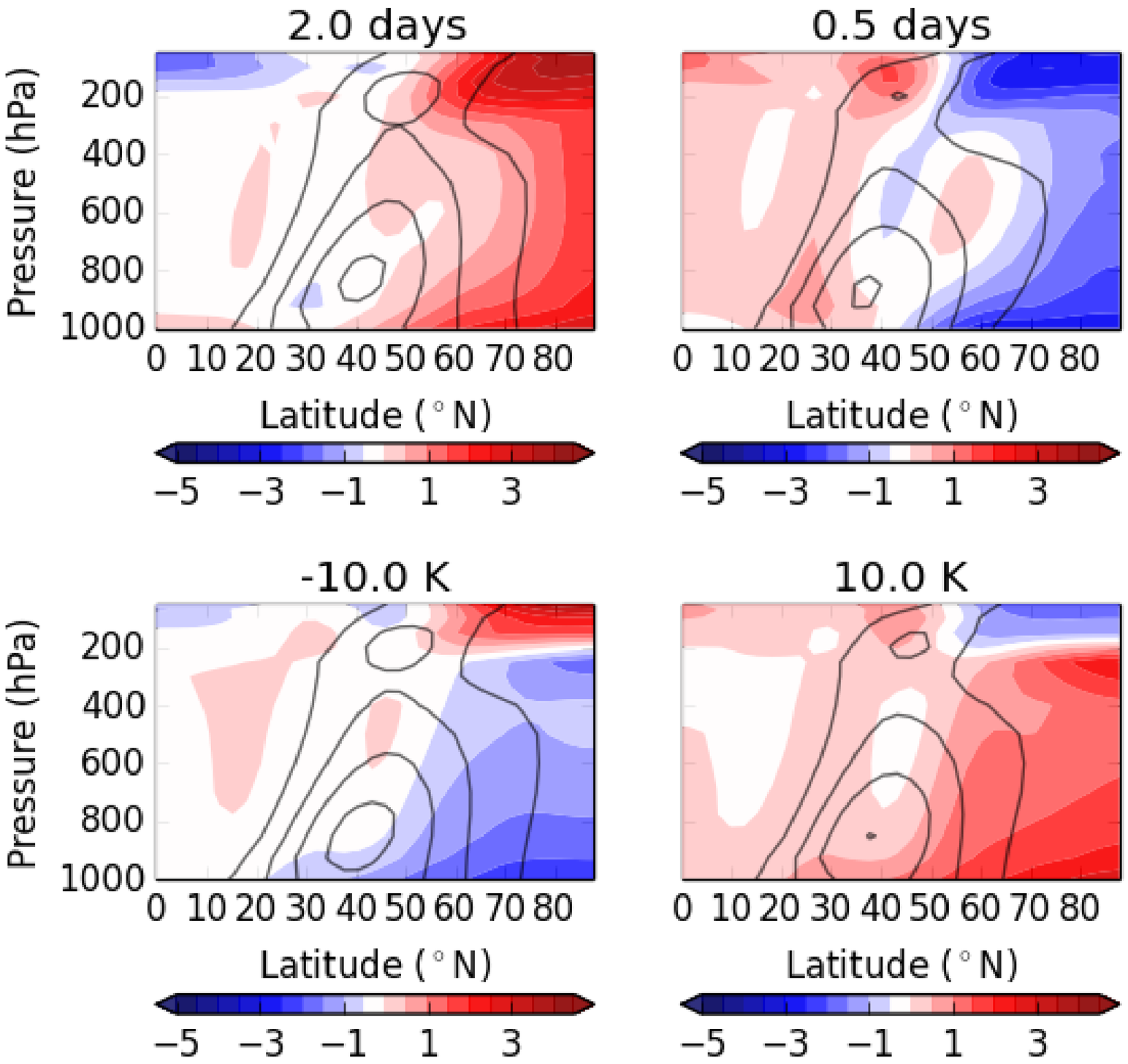
Thermal wind (contours) and overturning str.fn (colours)



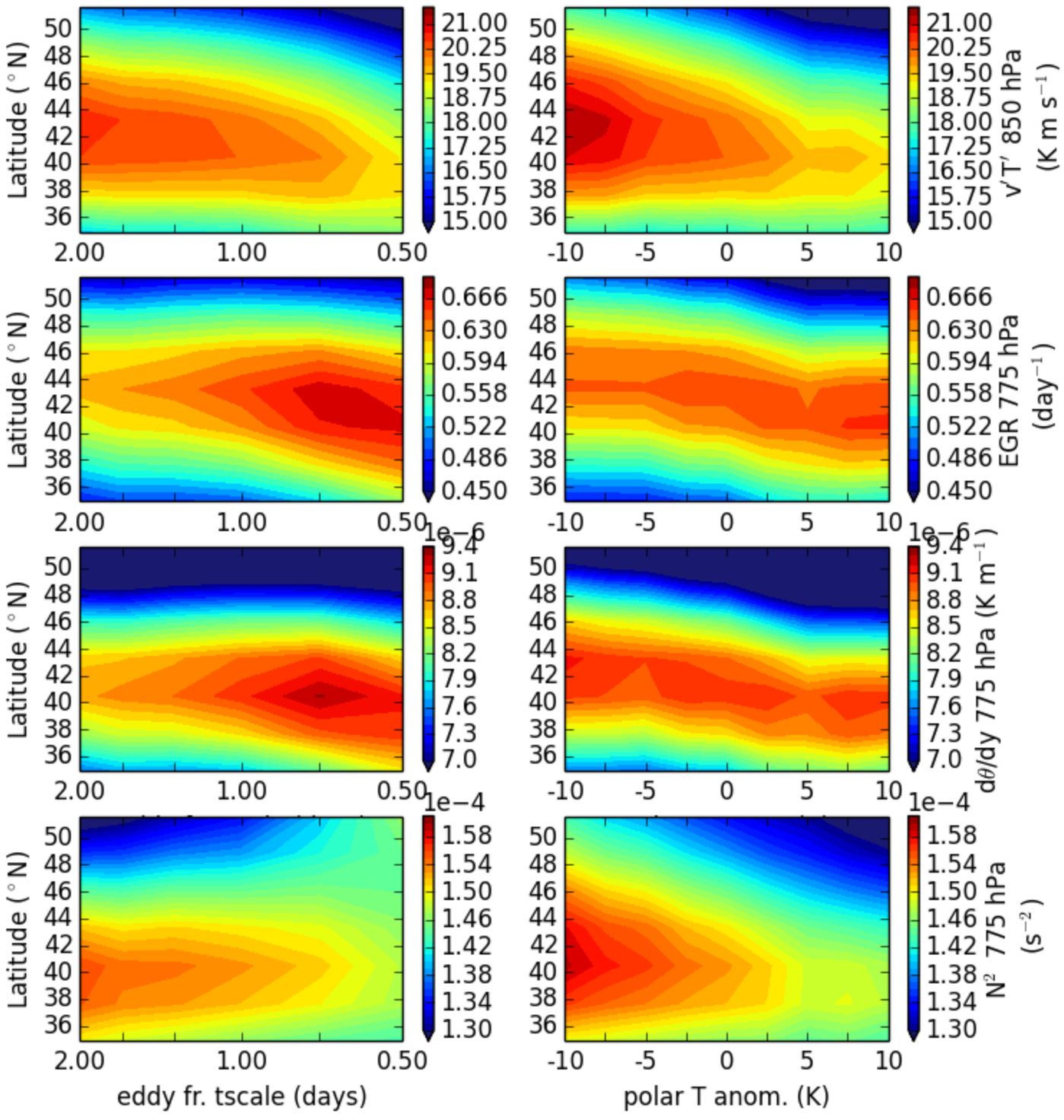
(Note: all adjustments are made outside the tropics only)

Control of mean flow in dry atmosphere GCM

Heat flux (contours) & T anomaly (colours)



Control of mean flow in dry atmosphere GCM



Heat flux

Eady growth rate

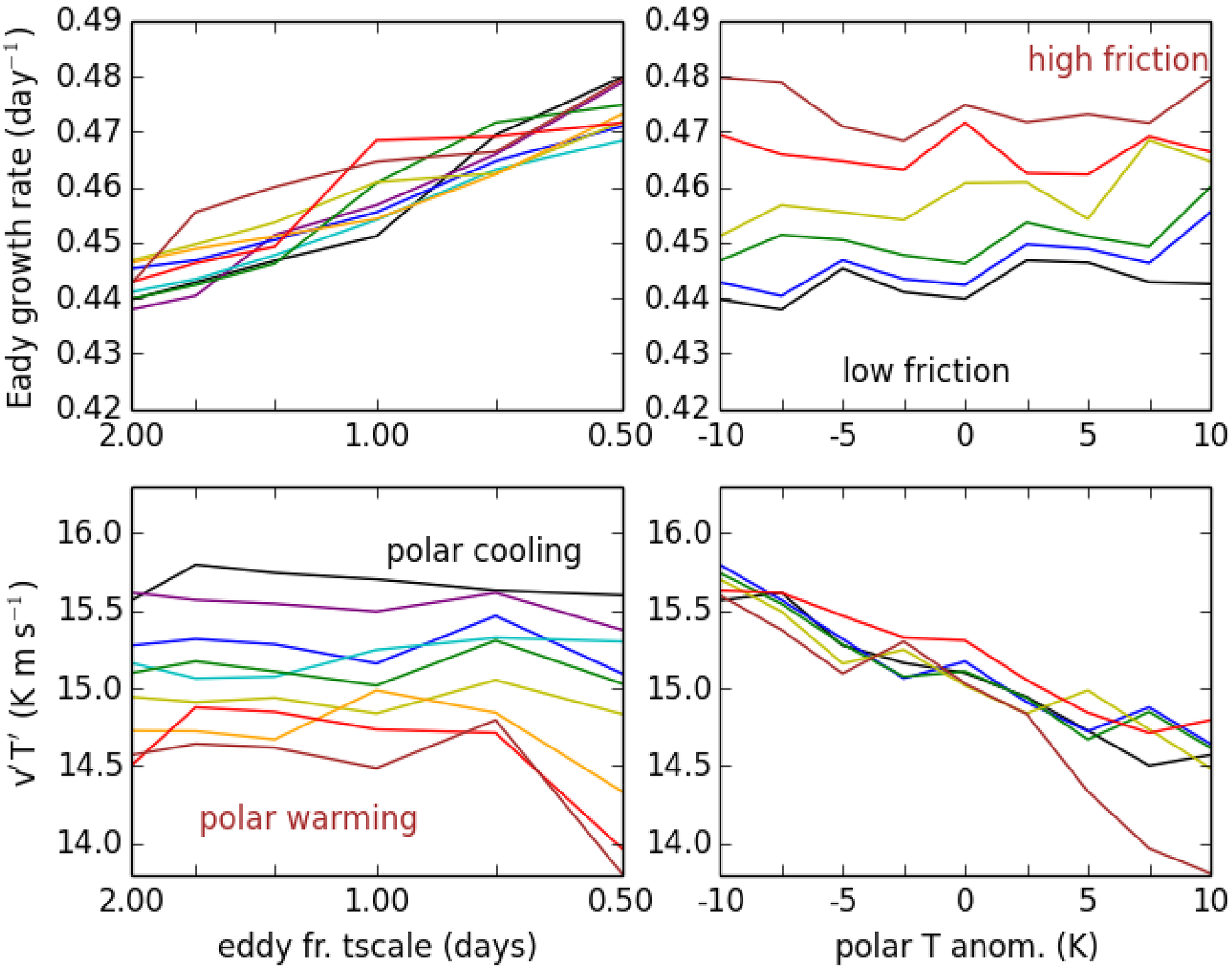
dT/dy

static stability

friction

forcing

Control of mean flow in dry atmosphere GCM



Summary

- NH Storm Tracks appear to satisfy a simple two way exchange between eddies and mean flow.

- Hadley cell response can be isolated/excluded by changing only extratropical parameters (in simplified agcm)

- Eddy saturation hypothesis and “frictional control” hypothesis confirmed in simplified eddy-resolving ocean model and in AGCM

- Extratropical eddy drag increase should correspond to jet increases and no response in eddies.

Related publications

- Ambaum, M. H. P., and L. Novak, 2014: A nonlinear oscillator describing storm track variability. *Quart. J. Roy. Meteor. Soc.*, **140**, 2680-2684. doi:10.1002/qj.2352

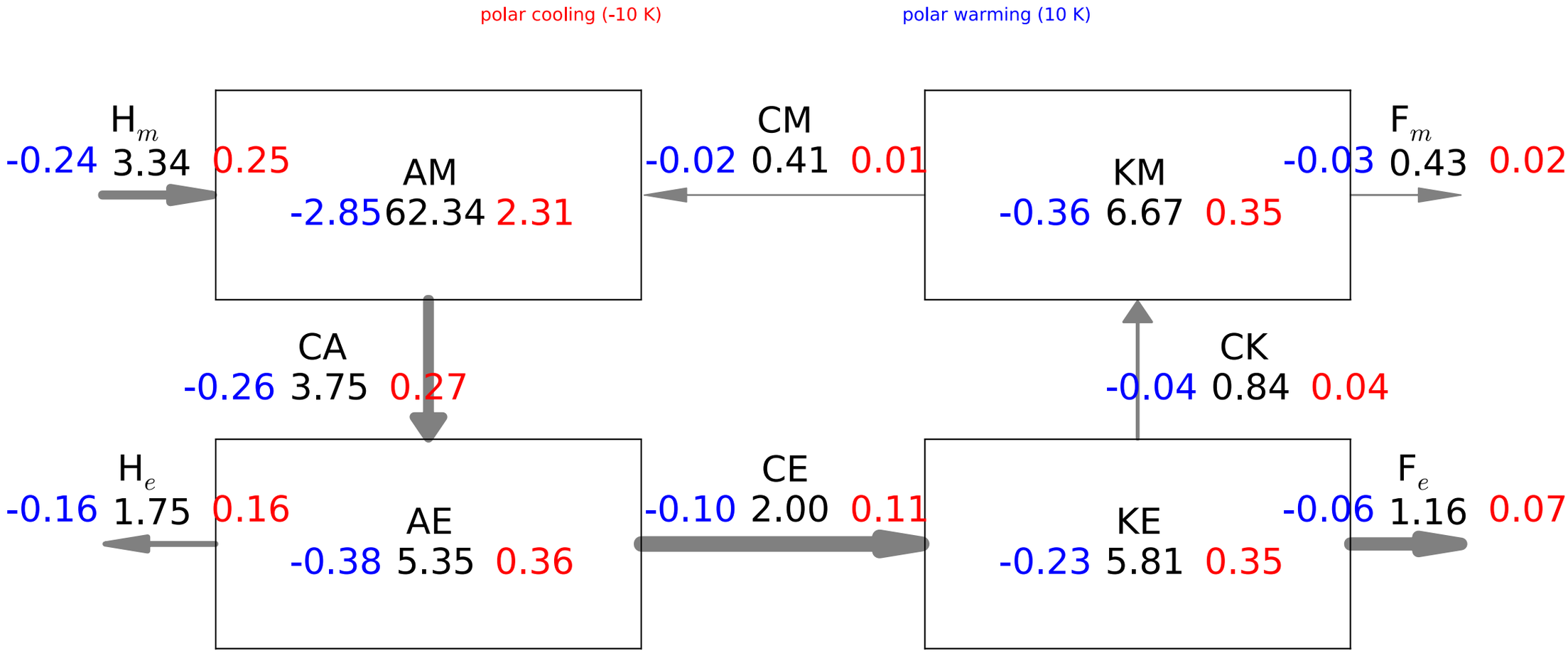
- Novak, L., M. H. P. Ambaum, and R. Tailleux, 2015: The lifecycle of the North Atlantic storm track. *J. Atmos. Sci.*, **72**, 821-833. doi:10.1175/JAS-D-14-0082.1

- D. P. Marshall, M. H. P. Ambaum, J. R. Maddison, D. R. Munday, L. Novak, 2016: Understanding ocean eddy saturation and its surprising consequences. *Science*, Under review

- Novak, L., M. H. P. Ambaum, and R. Tailleux, 2016: Marginal Stability and Predator-Prey Behaviour within Storm Tracks. *Quart. J. Roy. Met. Soc.*, Under review.

- Novak, L., M. H. P. Ambaum, and B. J. Harvey, 2016: Steady state behaviour of storm tracks. In preparation.

Lorenz cycle in zonally symmetric dry GCM



Lorenz cycle in zonally symmetric dry GCM