The role of eddy- mean flow interaction in shaping midlatitude storm tracks

Weizmann Institute of Science

Talia Tamarin[1] and Yohai Kaspi[1]

[1] Earth and Planetary Sciences, Weizmann Institute of Science, Israel
talia.tamarin@weizmann.ac.il

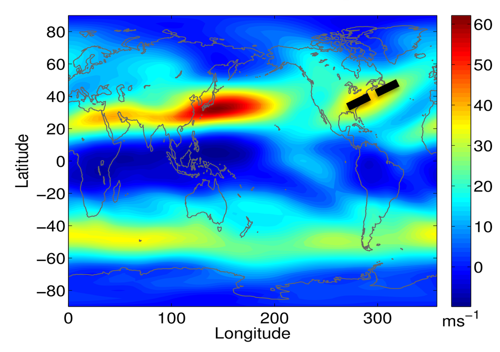
1. Introduction

- Regions of strong jets and enhanced eddy activity such as the Pacific and Atlantic storm tracks are characterized by a downstream poleward tilt that has an important influence on global climate.
- The role of transient eddies in shaping the storm tracks is investigated in observations and by using an idealized aquaplanet General Circulation Model with a localized surface heating.

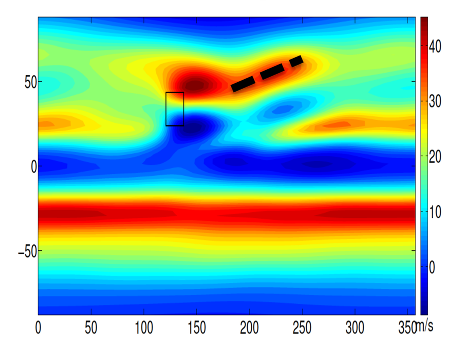
Storm Tracks-

Observations **Vs.** ***Model***

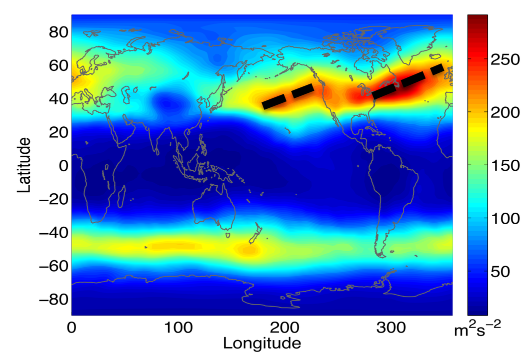
Zonal velocity U (DJF)



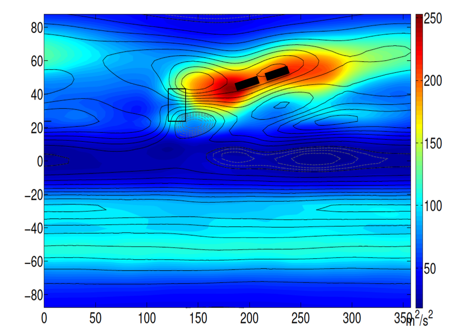
Zonal velocity U (model)



Eddy Kinetic Energy (DJF)



Eddy Kinetic Energy (model)



NCEP reanalysis
data averaged for DJF (1970-2009)

Idealized GCM
FMS GFDL with localized surface heating

The model captures the poleard tilt

2. The eddy mean flow interaction

The momentum equations in steady state (time mean, no friction) in *transformed* form-

$$D\bar{u} - f\bar{v}^* = M_x + N_y$$

$$D\bar{v} + f\bar{u}^* = N_x - M_y$$

Note that in the zonally symmetric case:

$$\frac{\partial \bar{u}}{\partial t} = -(\overline{u'v'})_y$$

Where

$$N = -\overline{u'v'}$$
$$M = \frac{1}{2}(\overline{v'^2} - \overline{u'^2})$$

eddy momentum fluxes

$$\bar{v}^* = \bar{v} - \frac{\partial}{\partial x}(\bar{\phi} + K)$$
$$\bar{u}^* = \bar{u} + \frac{\partial}{\partial y}(\bar{\phi} + K)$$

Residual velocities

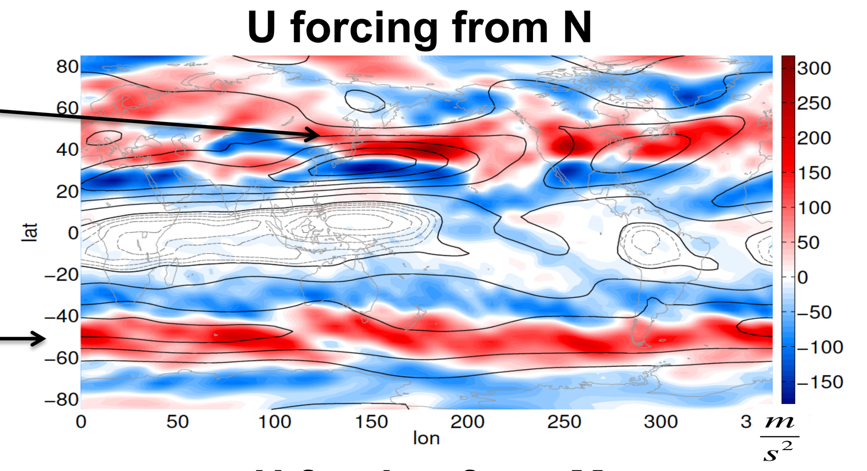
$$D = \bar{u}\frac{\partial}{\partial x} + \bar{v}\frac{\partial}{\partial y}$$
$$K = \frac{1}{2}(\overline{u'^2} + \overline{v'^2})$$

$\phi = geopotential$

Similar to Hoskins et al. (1983), Trenberth (1986)

Zonal mean flow forcing- *separate contributions from M,N*

U forcing from N

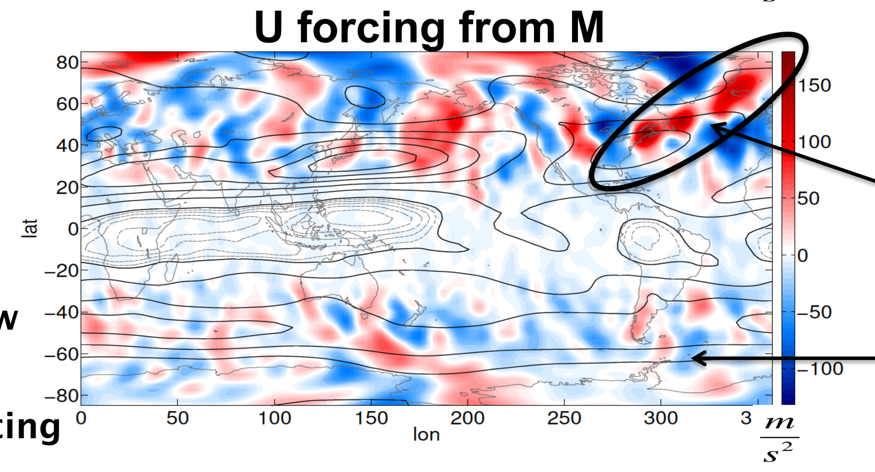


Strengthen the jet on the poleward flank

Momentum fluxes ***strengthen*** the jet in its maximum position

$$D\bar{u} - f\bar{v}^* = (M_x) + N_y$$

U forcing from M



A localized contribution, related to the *tilt*

Almost *zero* in the zonal mean

Black/ grey contours= Positive/ negative mean flow

Red/ blue colors= Positive/Negative eddy forcing

3. Vorticity framework

Taking curl on the momentum equations-

$$D(f+\bar{\xi}) - (f+\bar{\xi})\frac{\partial w}{\partial z} = N_{yy} - N_{xx} - 2M_{xy}$$

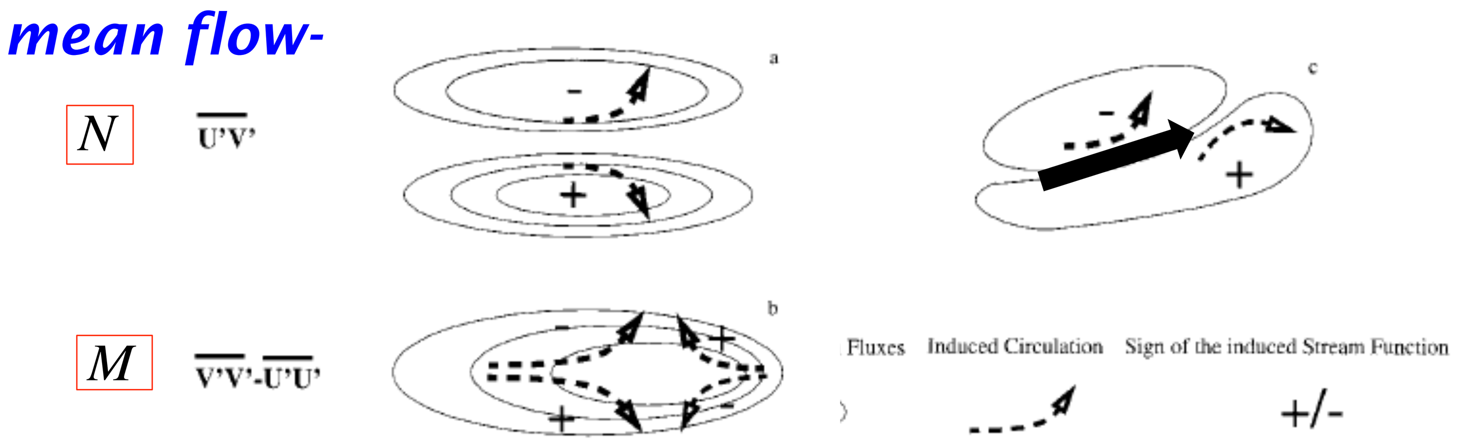
The time mean vorticity equation

Vertically integrating →

$$\langle D(f+\bar{\xi})\rangle = \langle N_{yy} - N_{xx} - M_{xy}\rangle$$

Observational analysis show that momentum fluxes force a tilted mean flow-

Orlanski (1997)



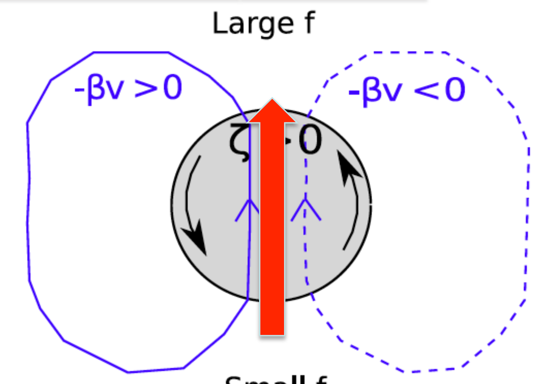
The streamfunction tendency from eddy momentum fluxes

However, does not give information about cause and effect!

4. A dynamical mechanism for poleward drift

The 'beta- drift'

- *stronger cyclones* will have a larger poleward drift
- Cyclones created at *lower latitudes* will have a larger poleward drift



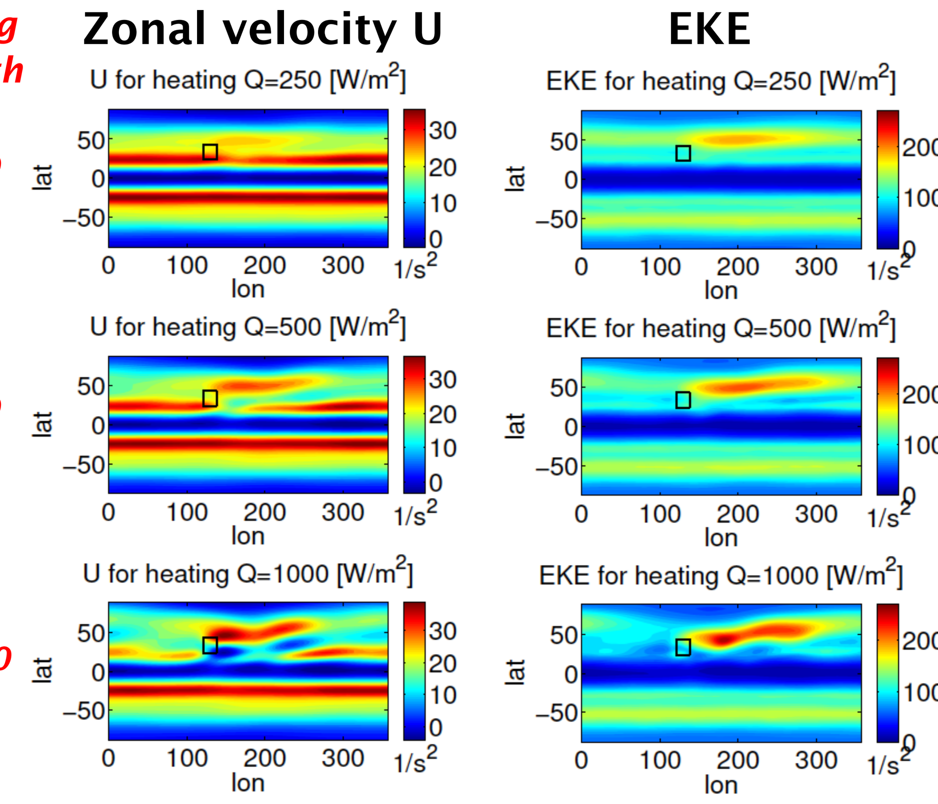
Riviere et al (2012), *Oruba et al* (2013)

5. Results from idealized GCM

GCM results for increased heating and different latitudinal locations are consistent with the 'beta- drift' mechanism

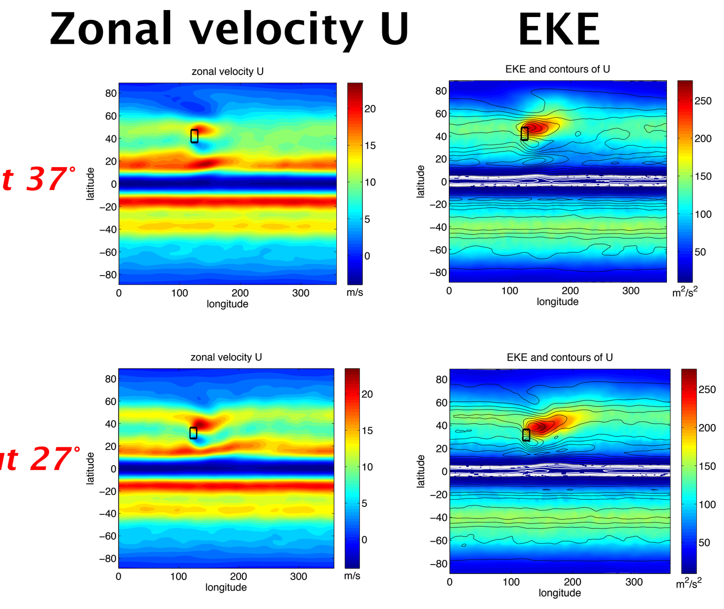
Heating strength

Zonal velocity U **EKE**



Heating latitude

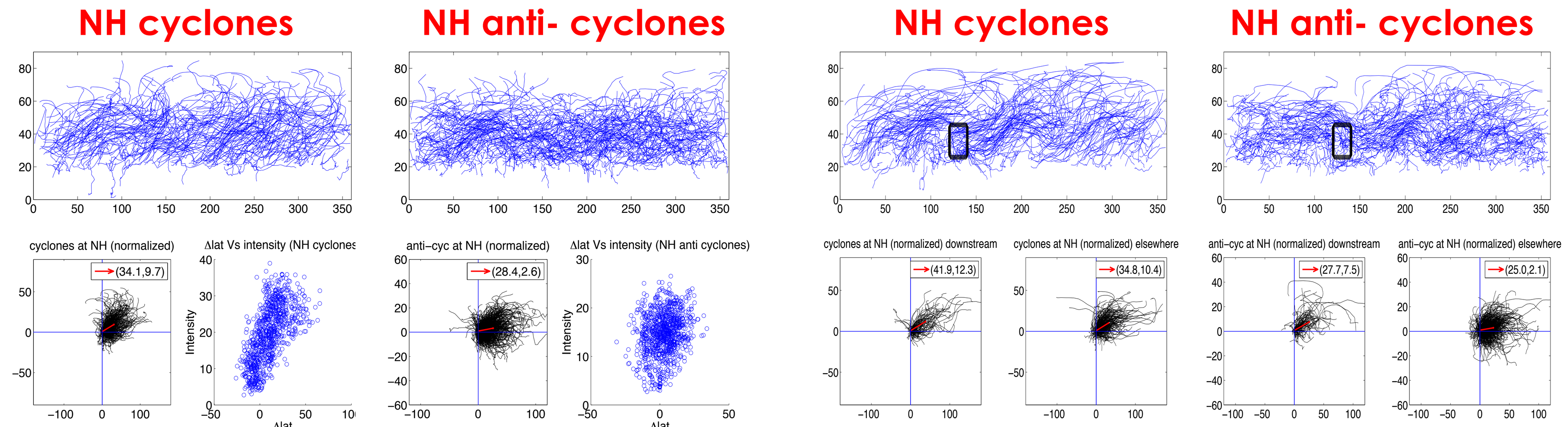
Zonal velocity U **EKE**



- As heating is increased, the storm track becomes *more tilted*
- At lower latitudes, the storm track are *more tilted*

Poleward drift analysis- storm tracking algorithm *(TRACK, Kevin Hodges)*

Runs with no heating **Runs with heating**



- Cyclones propagate poleward more than anti-cyclones
- Downstream of heating, poleward propagation is enhanced