

# Identifying the leading patterns of variability in the extratropical circulation

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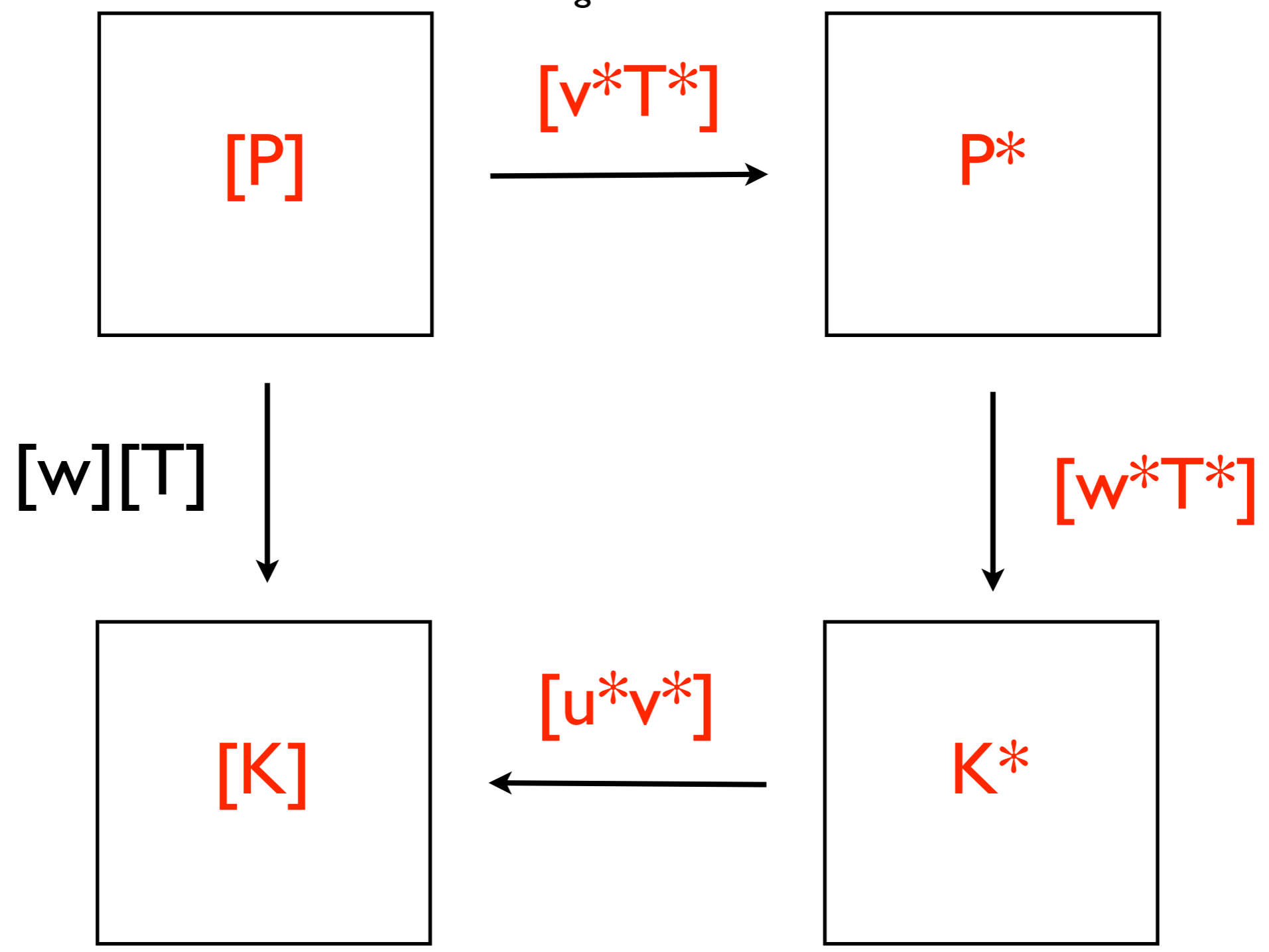
## Motivation (i)

- Widely documented increases in eddy kinetic energy, poleward heat transport, and the latitude of the stormtracks in climate change simulations.
- Not clear if these varied changes reflect the same fundamental phenomenon.

# Motivation (ii):

## Key processes in the midlatitude energy cycle

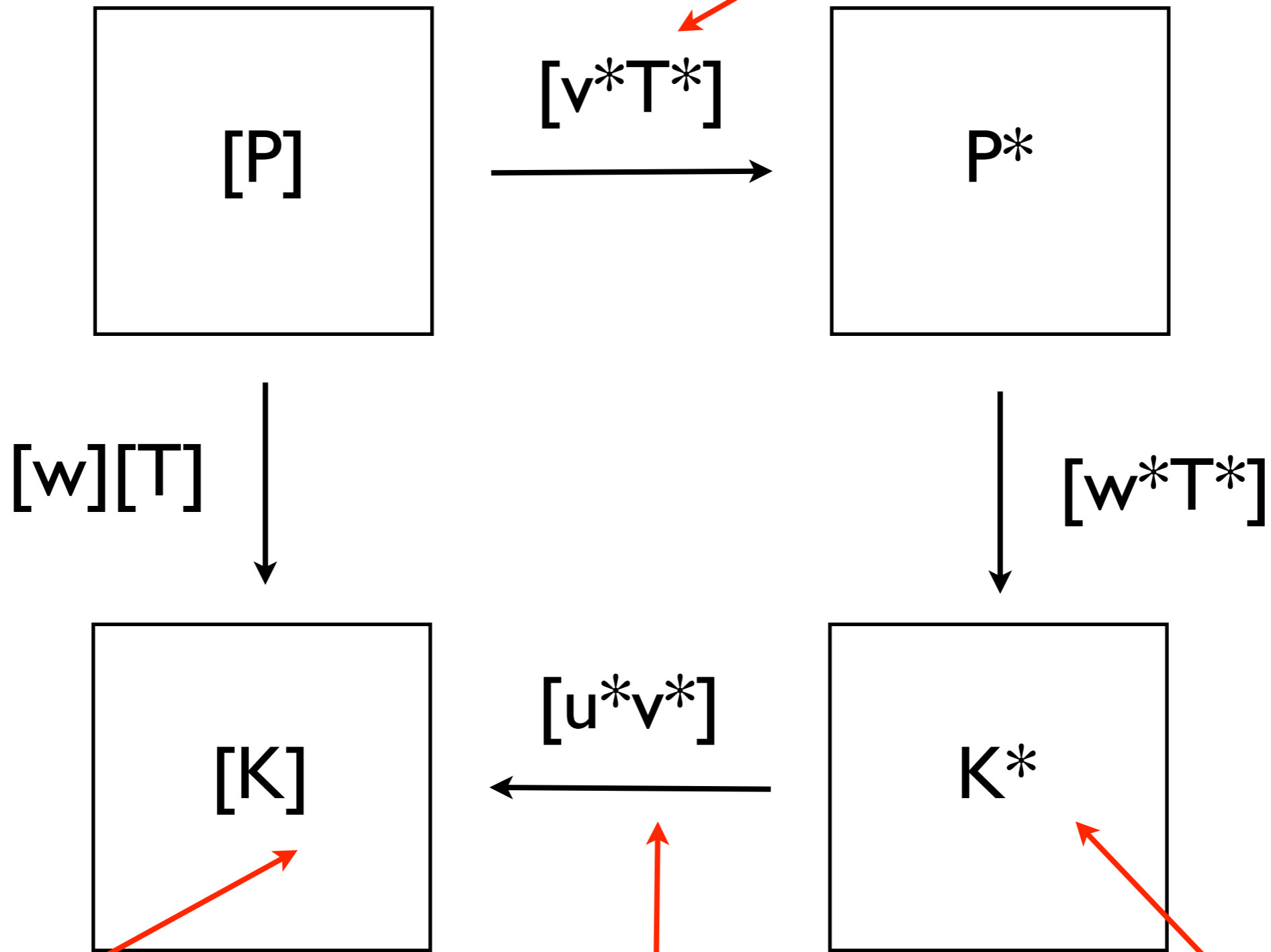
*Gradients in zonal-mean diabatic heating*



*Available potential energy (P)*  
*Kinetic energy (K)*

# Leading patterns of variability in the middle latitude

energy cycle ?

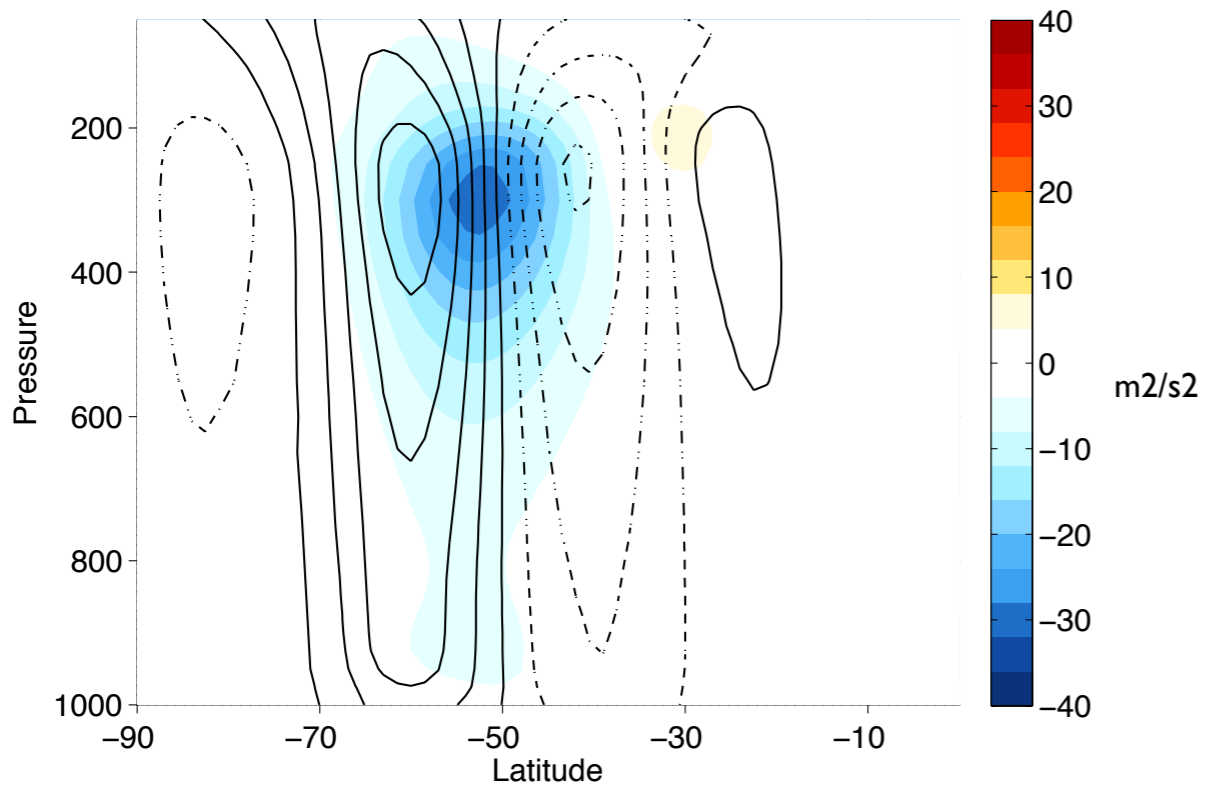


Annular variability

- Examine the leading PCs of zonal mean kinetic energy, eddy kinetic energy, and the conversions between eddy and mean potential and kinetic energy.
- Argue that patterns of variability in the extratropical circulation can be viewed in the context of two *largely independent* classes of structures:
  - 1) those characterized by variations in mean kinetic energy.
  - 2) those characterized by variations in eddy kinetic energy.

# Regressions on SAM (PC1 SH U)

[u\*v\*] (shading) and U (contours)

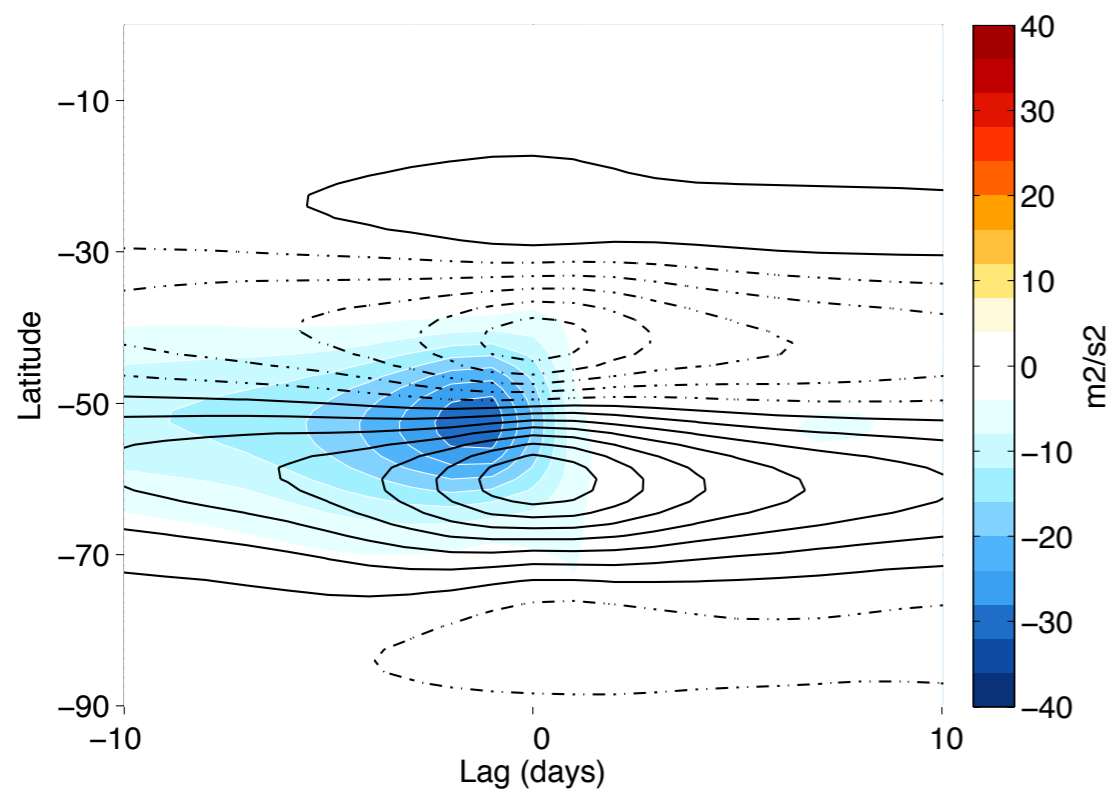


Results based on 6 hrly data from ERA Interim 1979-2010.

(As shown in dozens of papers. Early papers include those by Karoly, Kidson, Trenberth, Hartmann).

# Regressions on SAM (PC1 SH U)

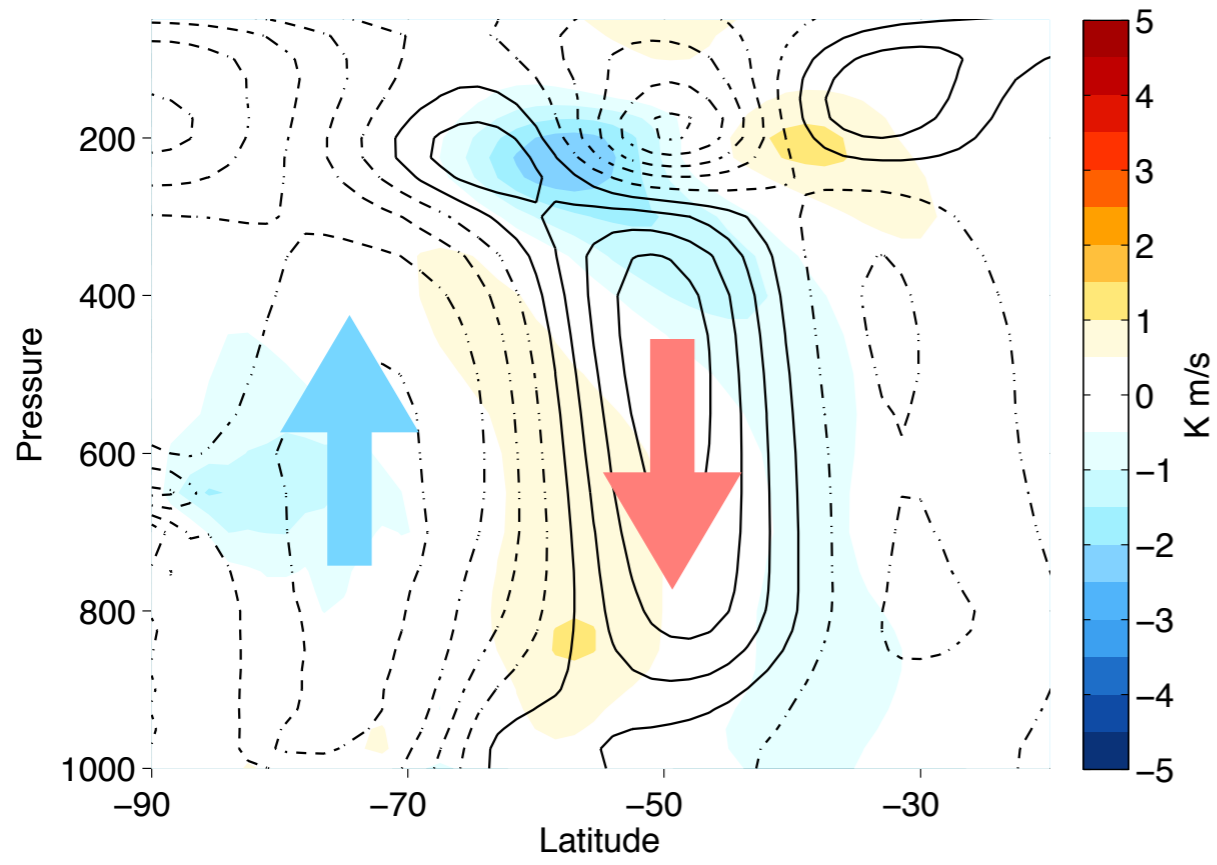
$[u^*v^*]$  (shading) and U (contours) at 300 hPa



(eg Hartmann and Lo 1998; Lorenz and Hartmann 2001)

# Regressions on SAM (PC1 SH U)

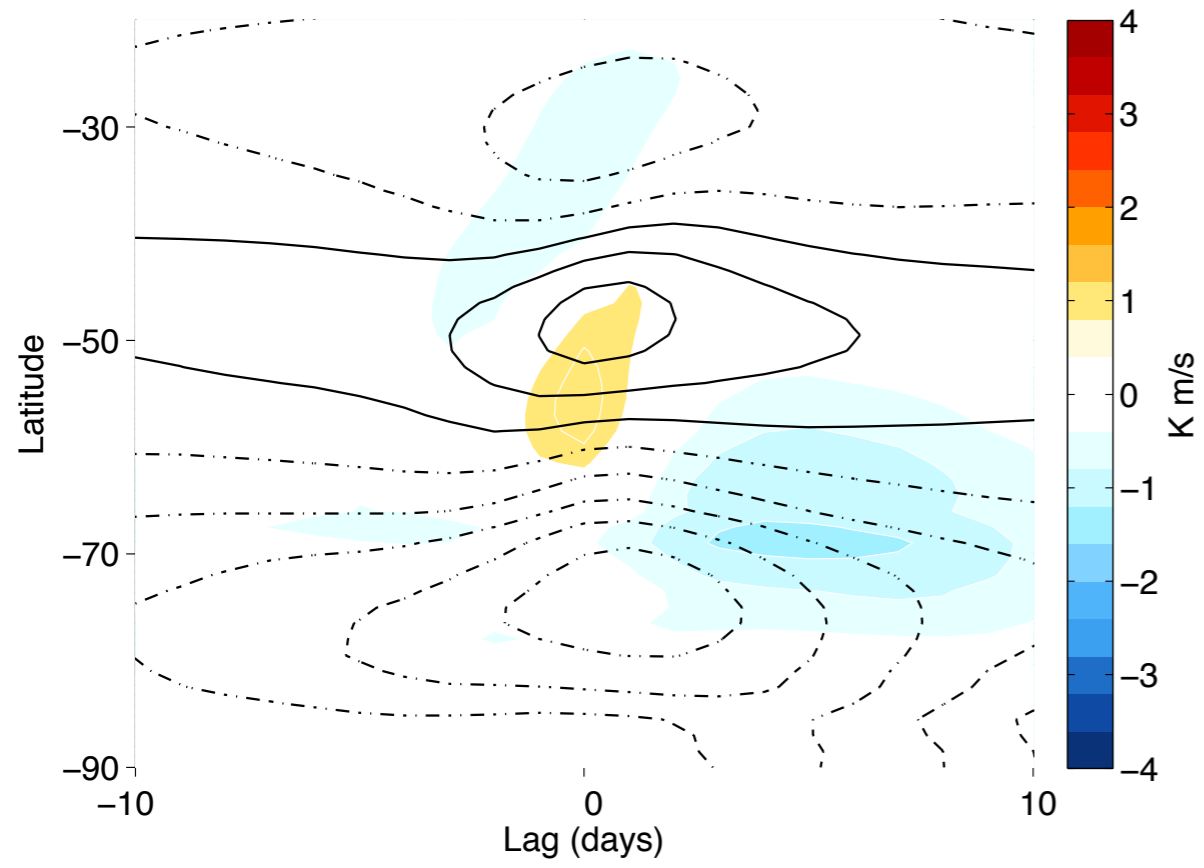
[v\*T\*] (shading) and T (contours)





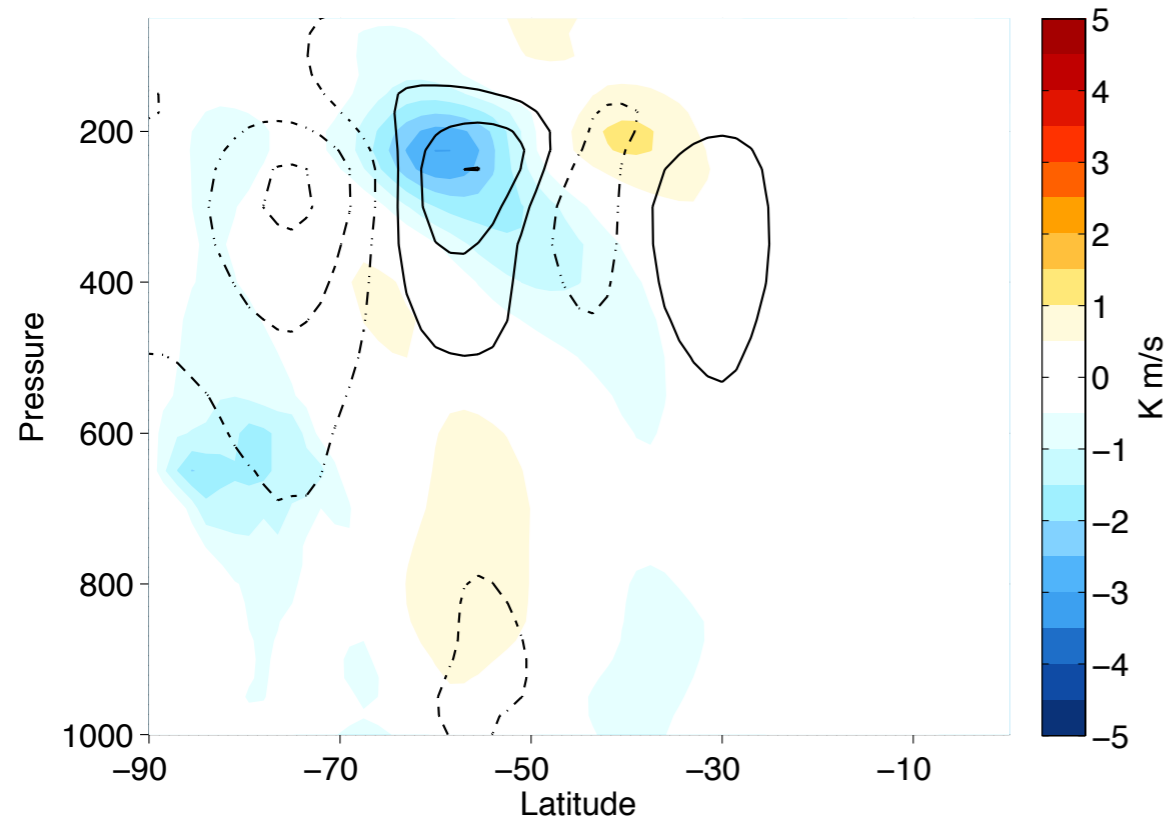
# Regressions on SAM (PC1 SH U)

$[v^*T^*]$  (shading) and T (contours) at 850 hPa



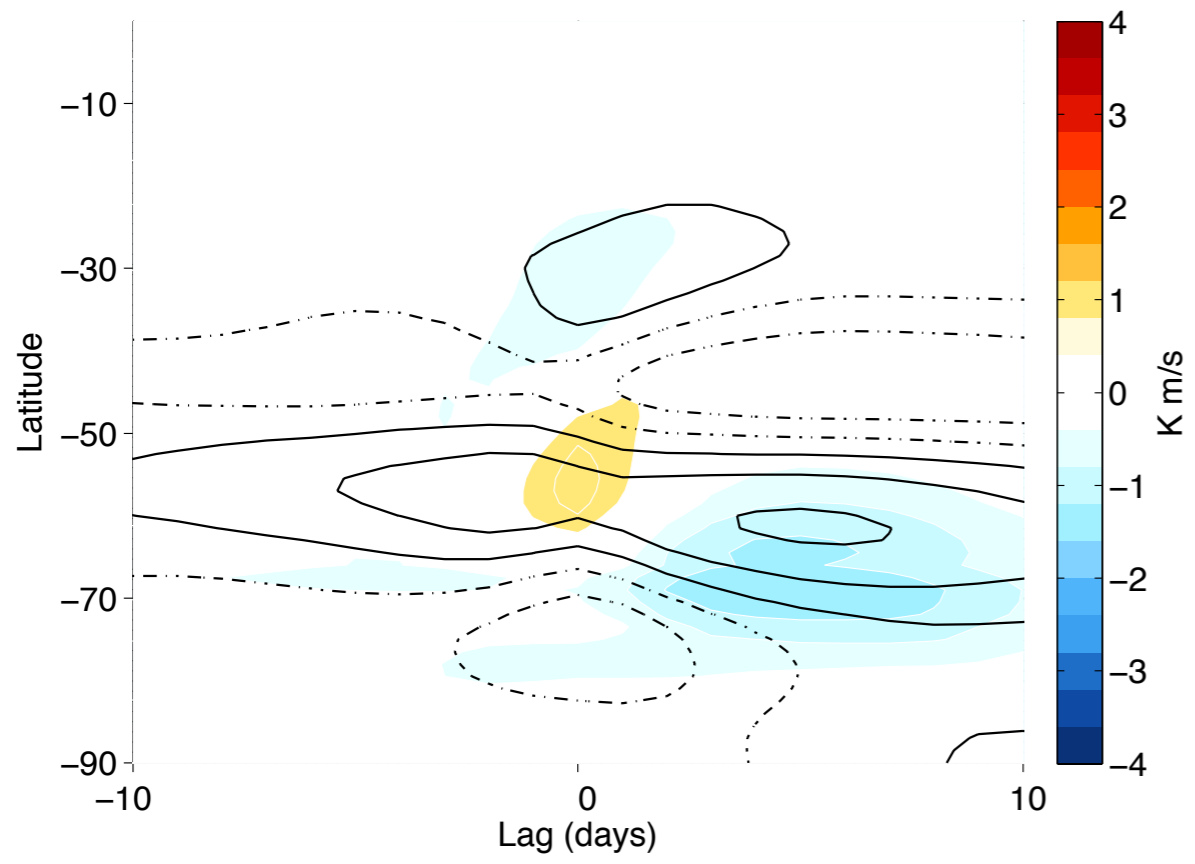
# Regressions on SAM (PC1 SH U)

$[v^*T^*]$  (shading) and eddy kinetic energy (contours)

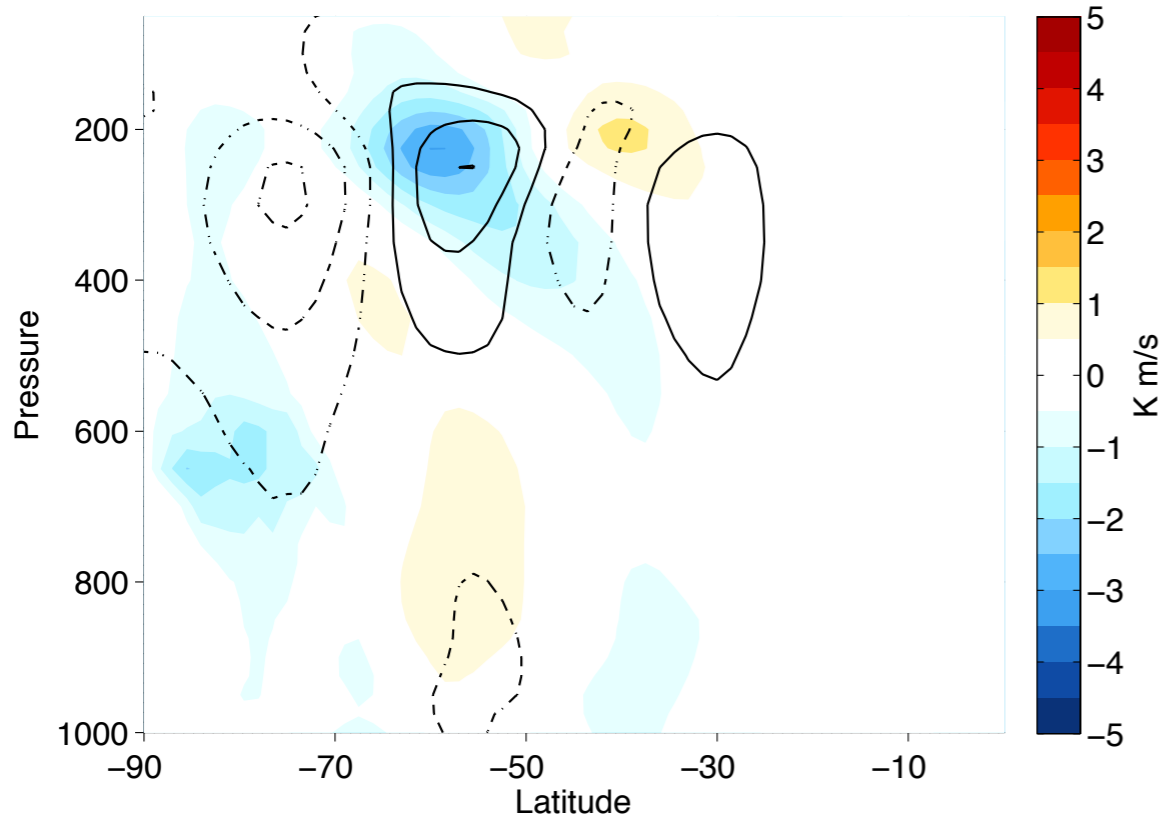


# Regressions on SAM (PC1 SH U)

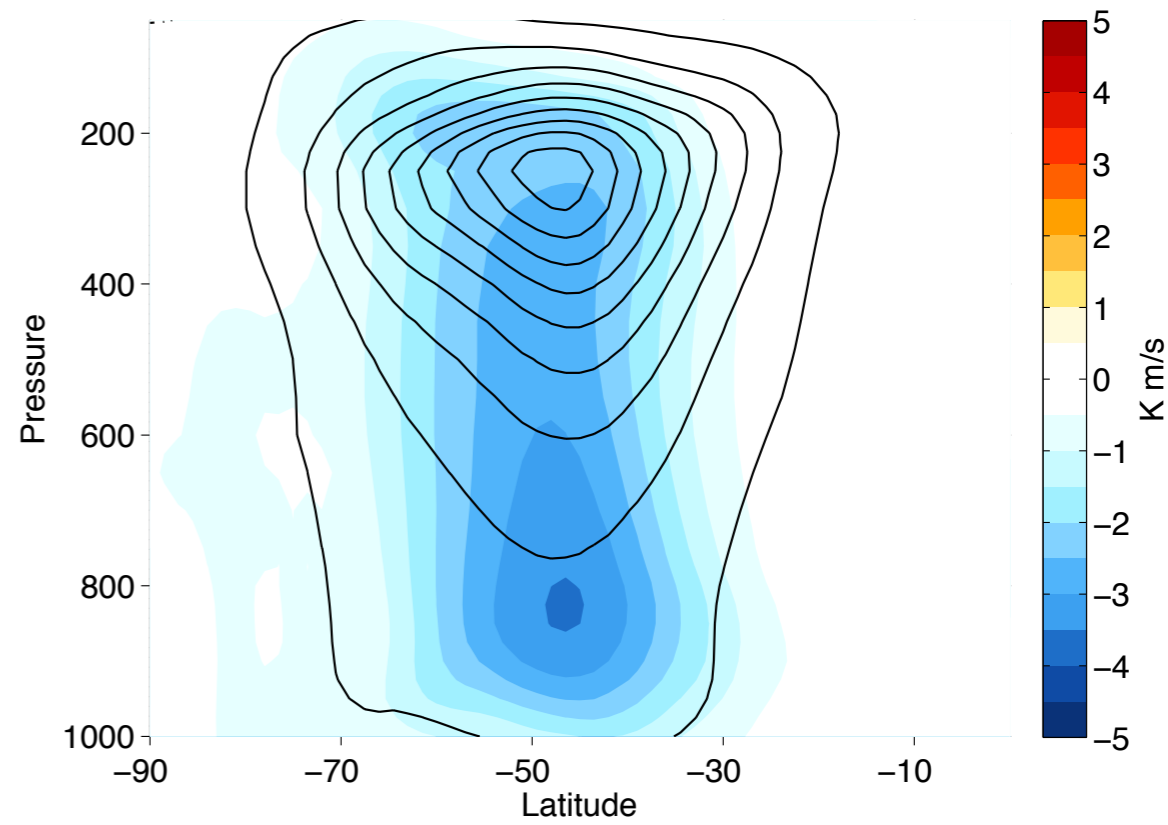
$[v^*T^*]$  (shading) and eddy kinetic energy (contours)



Regressions on SAM (PC1 SH U)

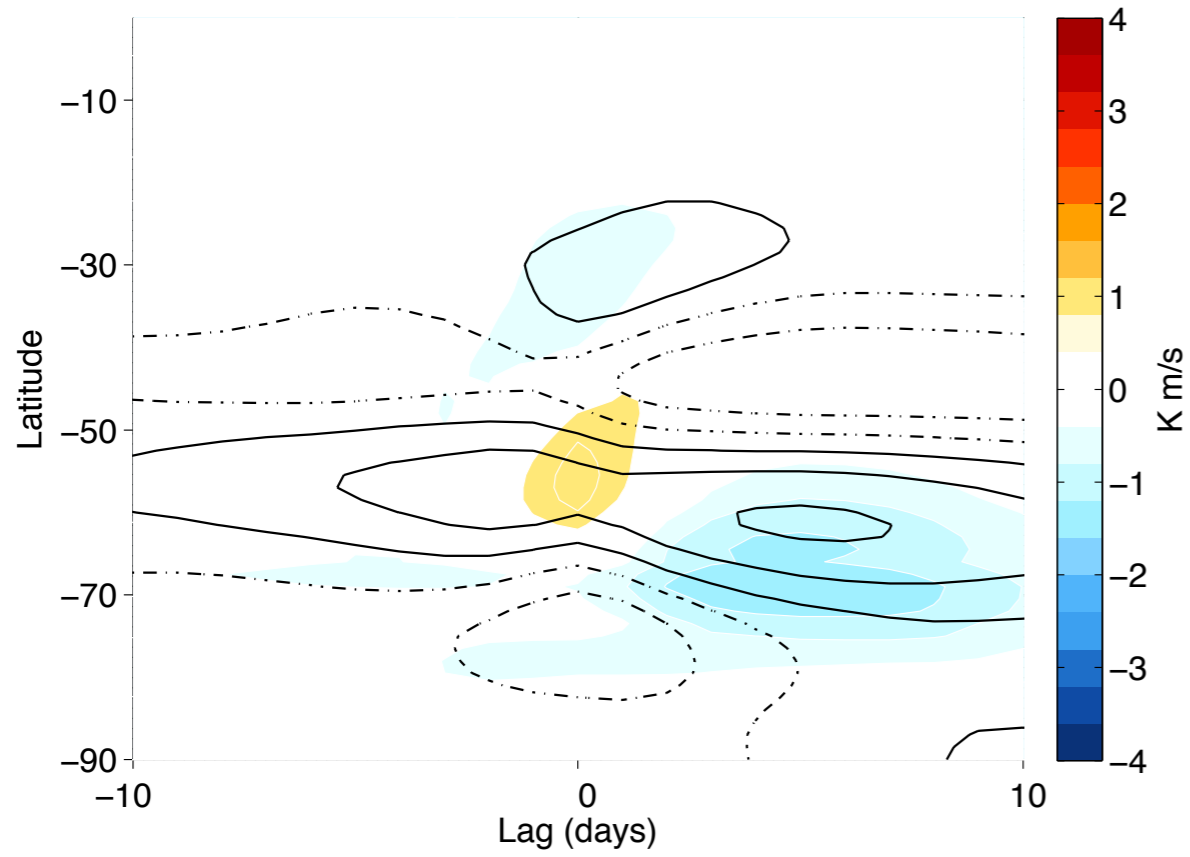


Regressions on E1 (PC1 SH EKE)

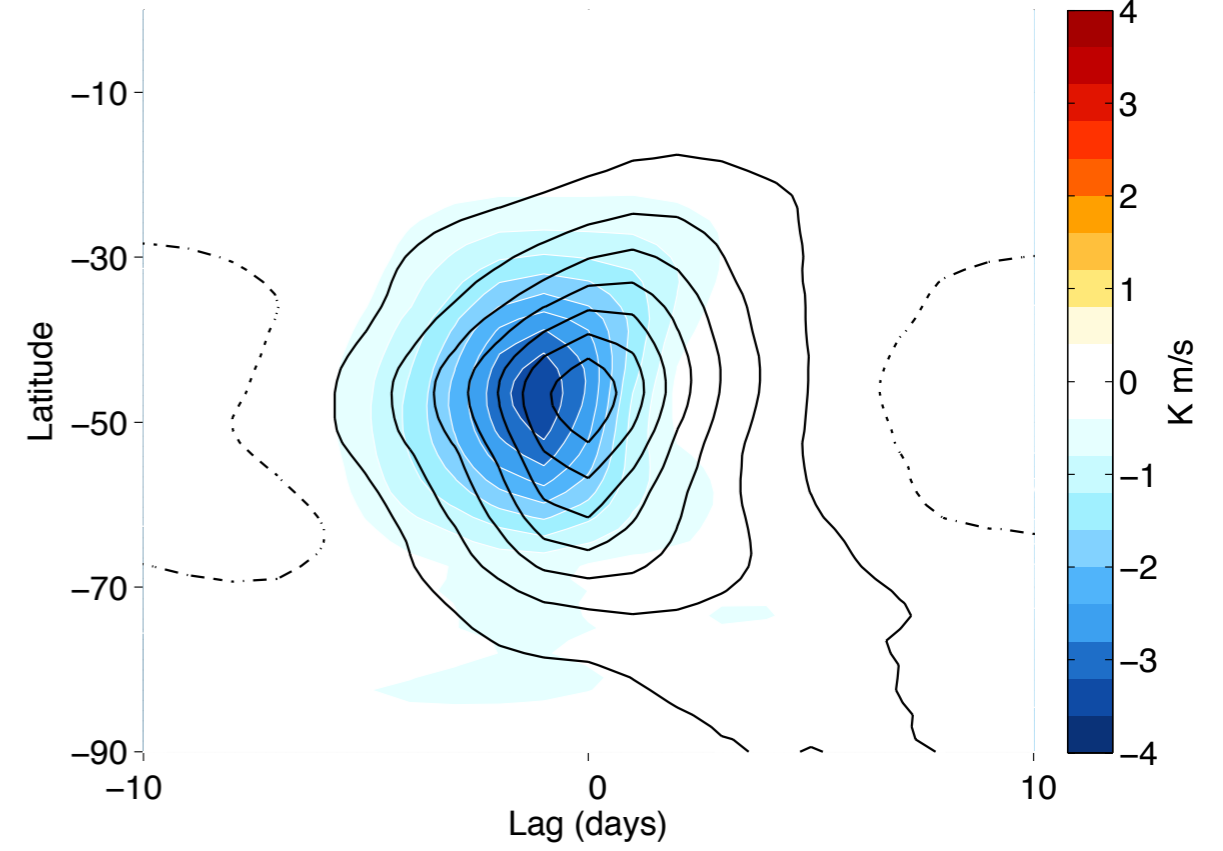


# Regressions on SAM (PC1 SH U)

[v\*T\*] (shading) and eddy kinetic energy (contours)

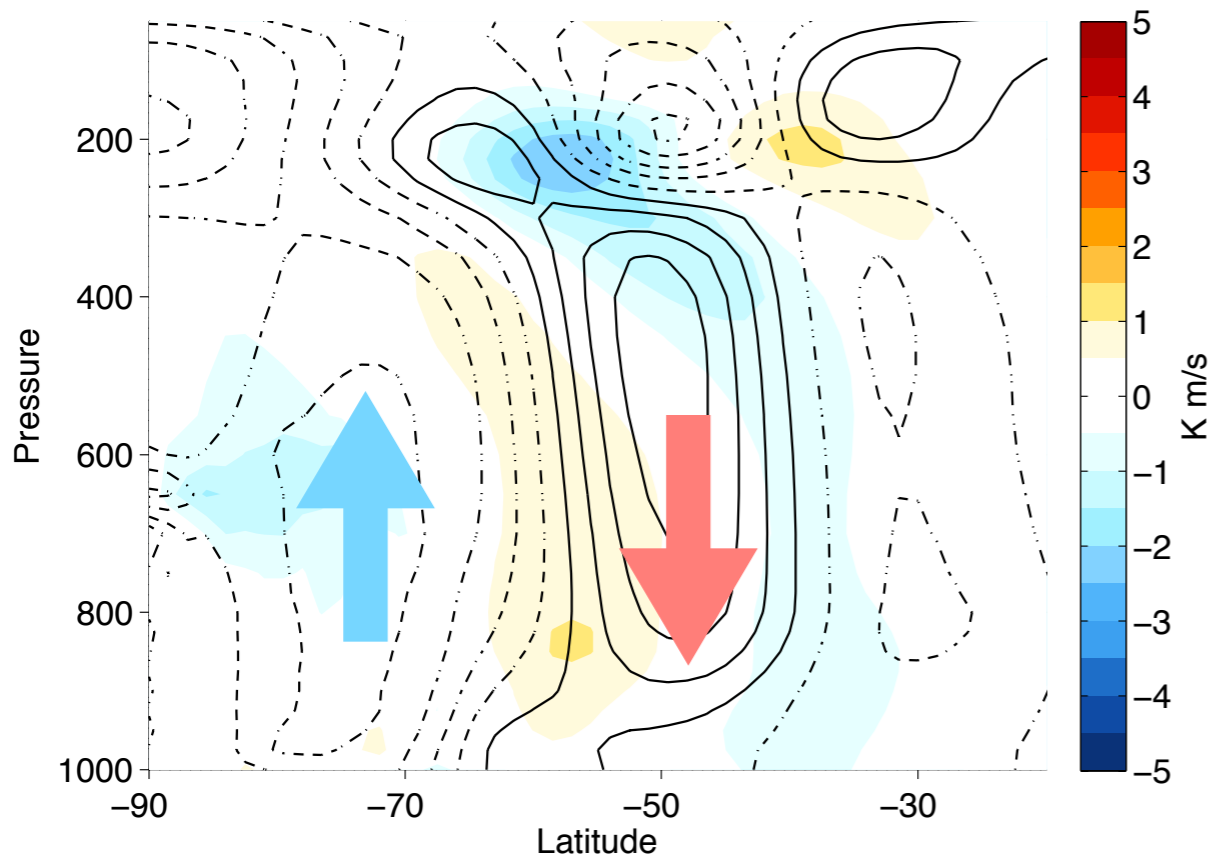


# Regressions on E1 (PC1 SH EKE)

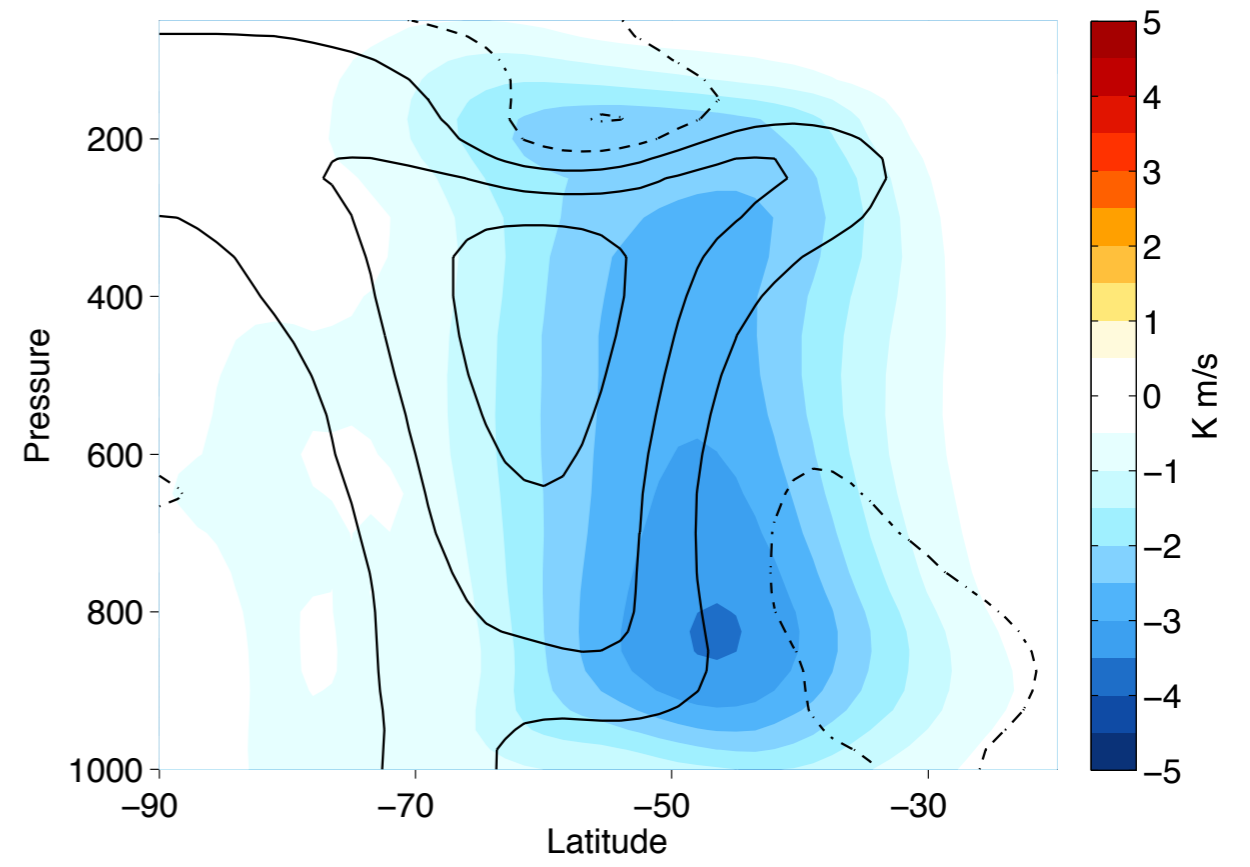


Regressions on SAM (PC1 SH U)

[v\*T\*] (shading) and T (contours)

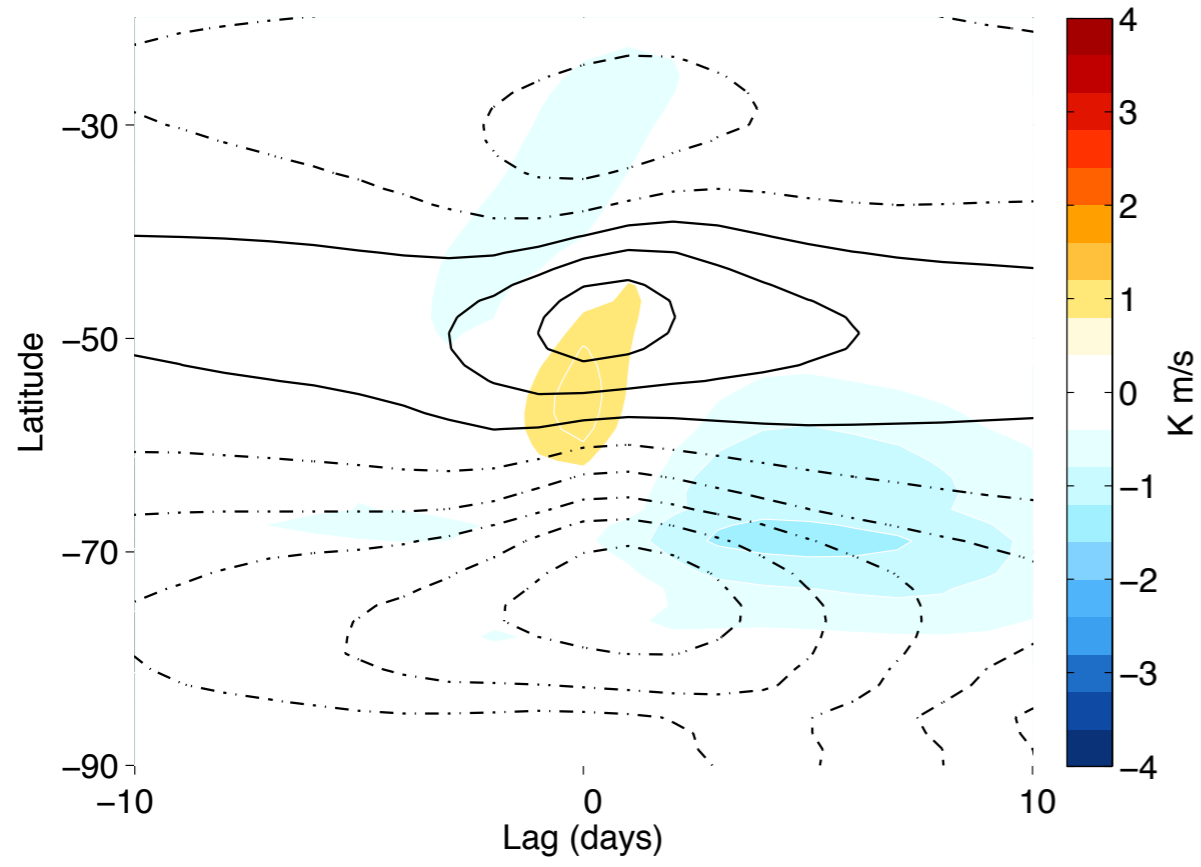


Regressions on E1 (PC1 SH EKE)

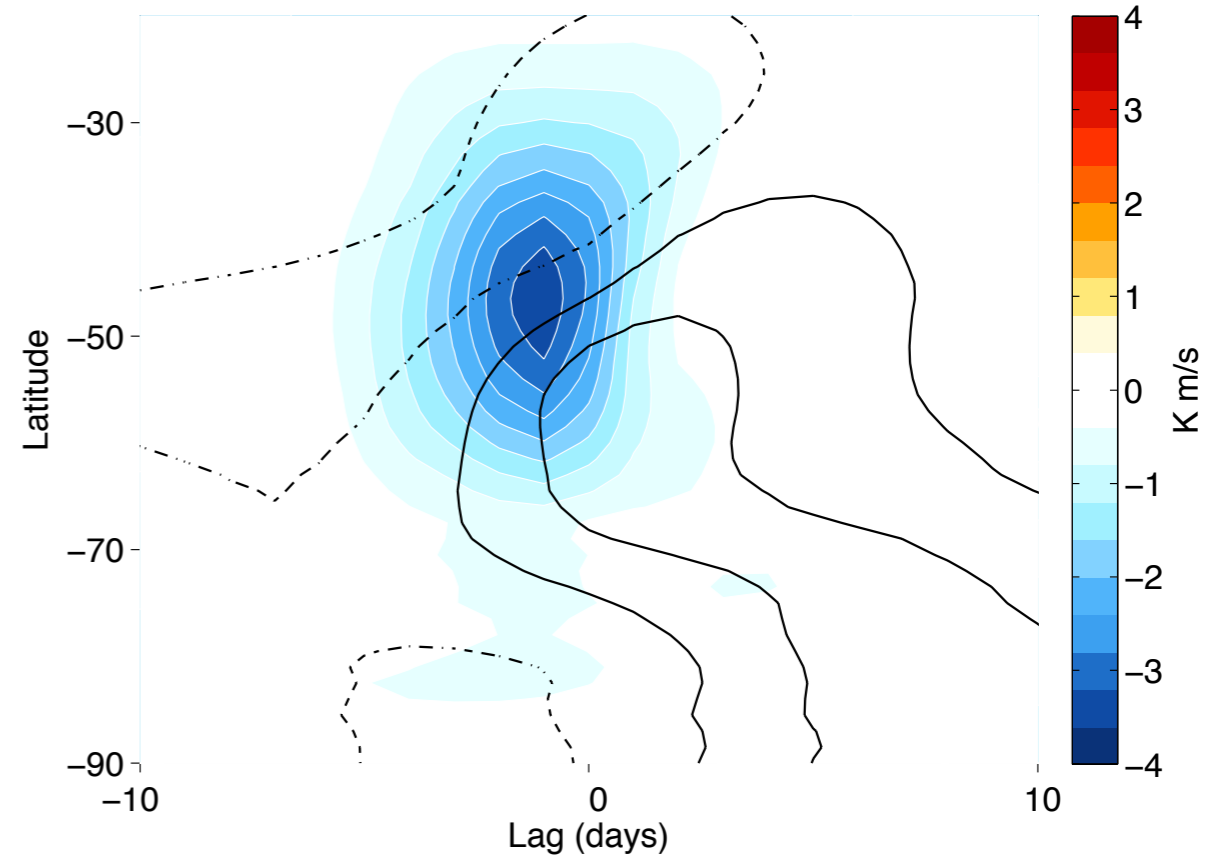


Regressions on SAM (PC1 SH U)

$[v^*T^*]$  (shading) and T (contours) at 850 hPa

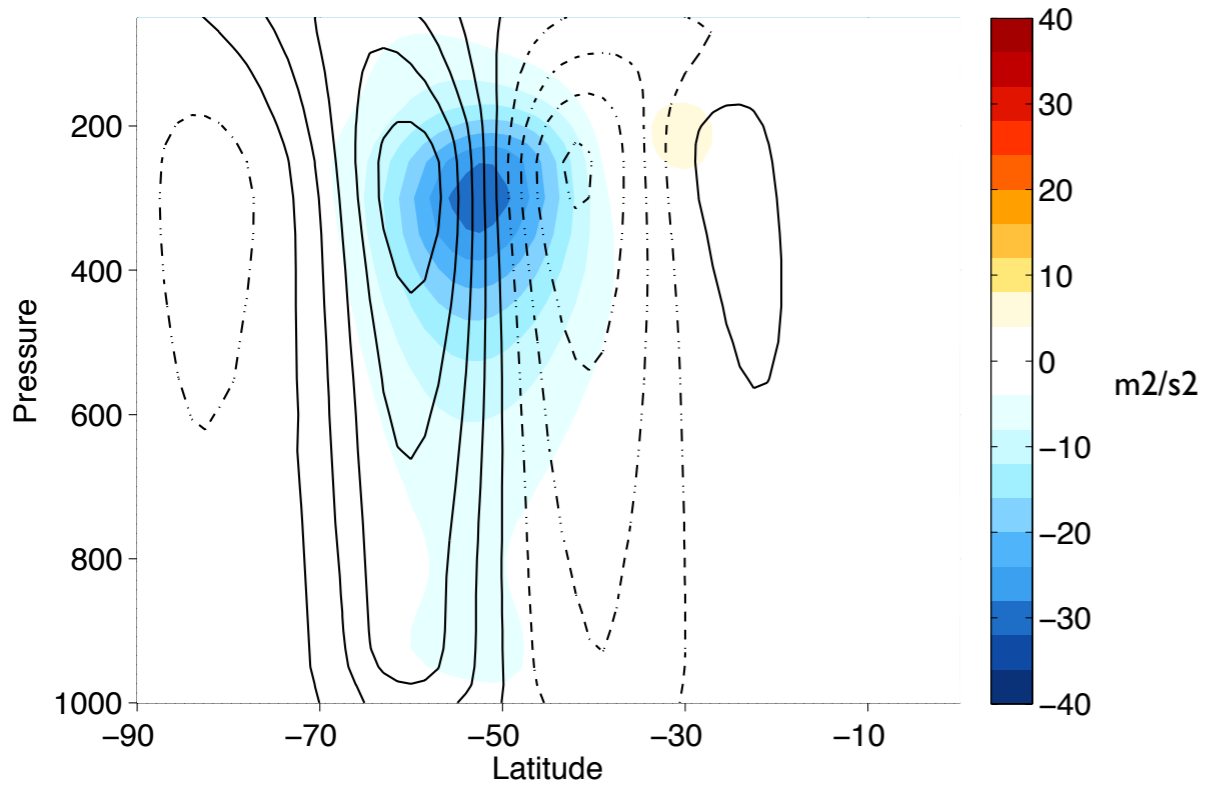


Regressions on E1 (PC1 SH EKE)

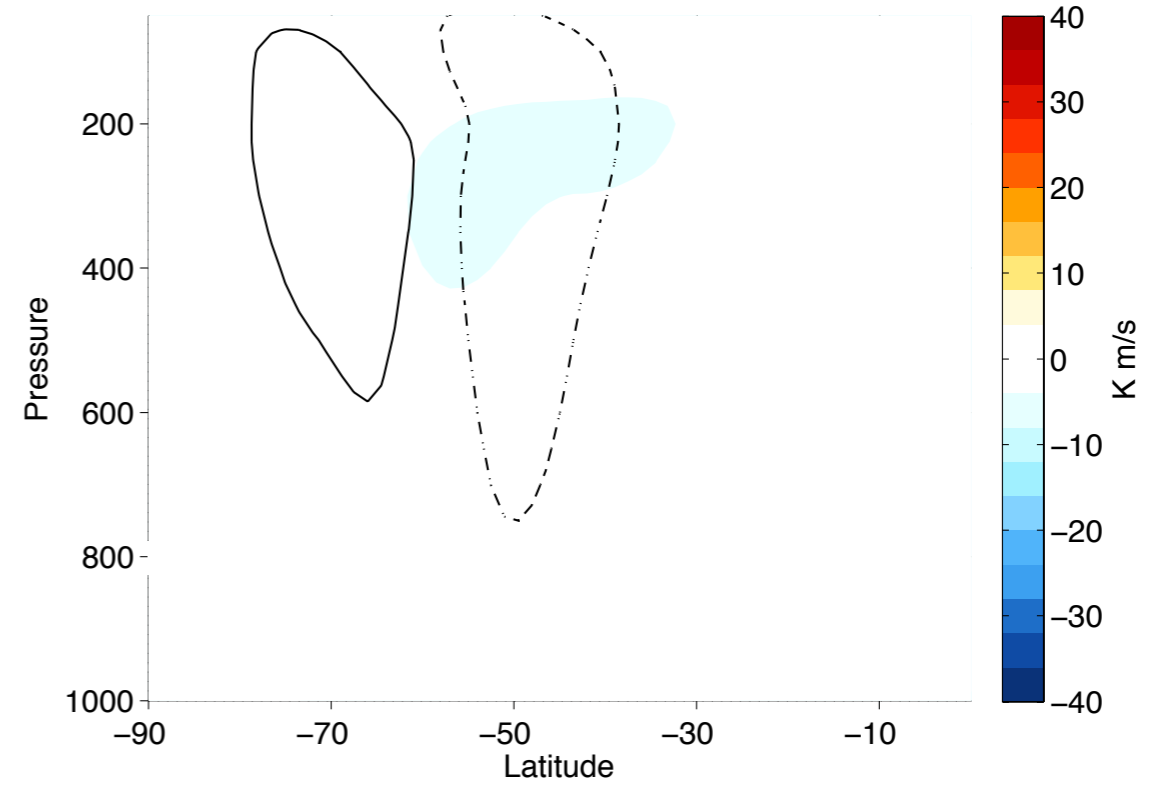


# Regressions on SAM (PC1 SH U)

[u\*v\*] (shading) and U (contours)



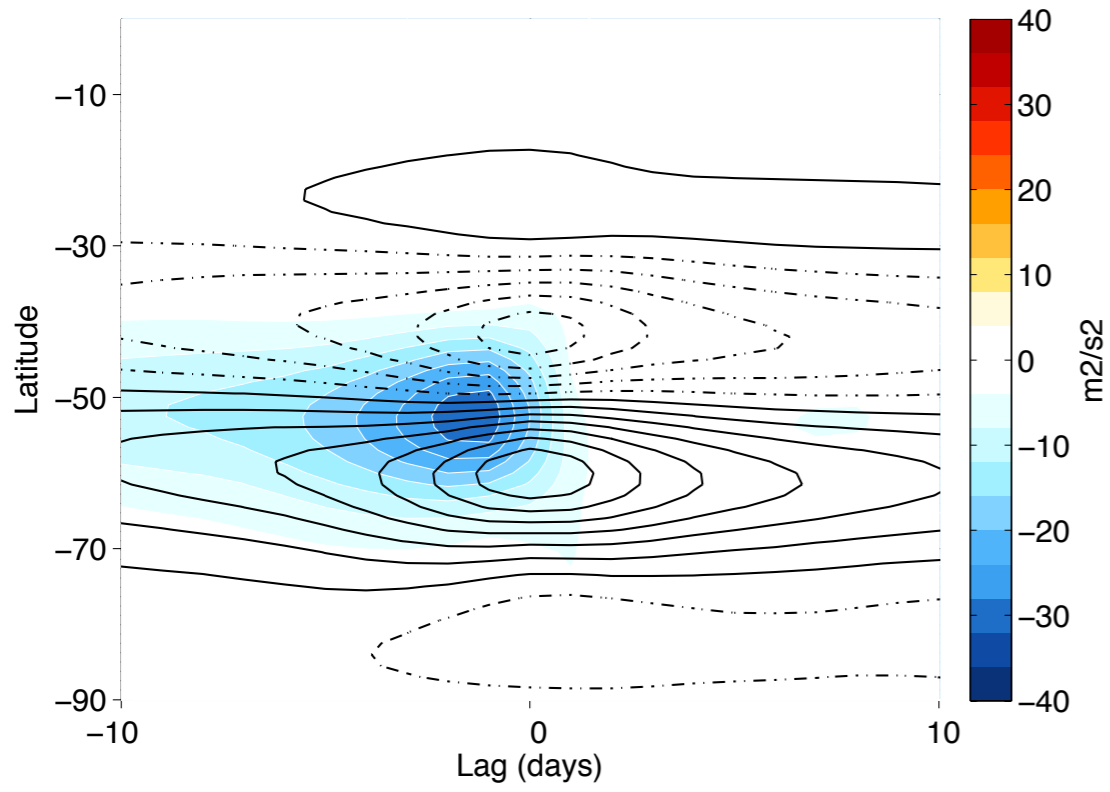
# Regressions on E1 (PC1 SH EKE)



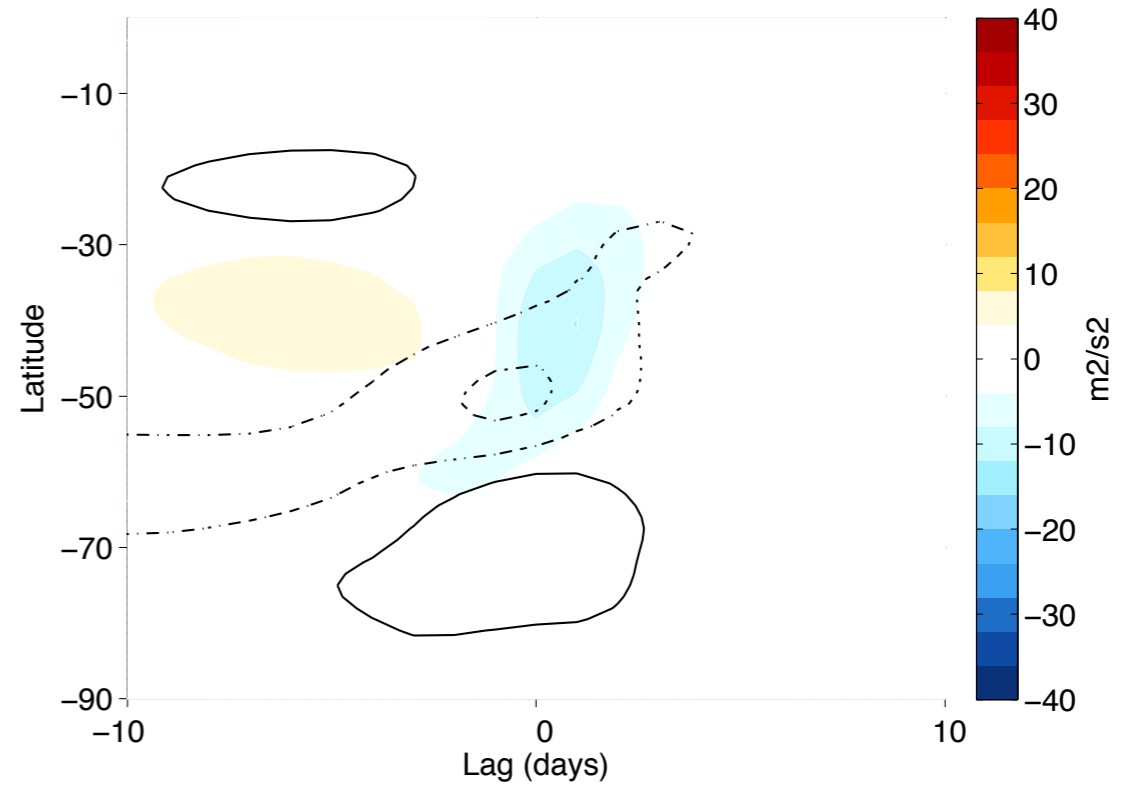


### Regressions on SAM (PC1 SH U)

[u\*v\*] (shading) and U (contours) at 300 hPa

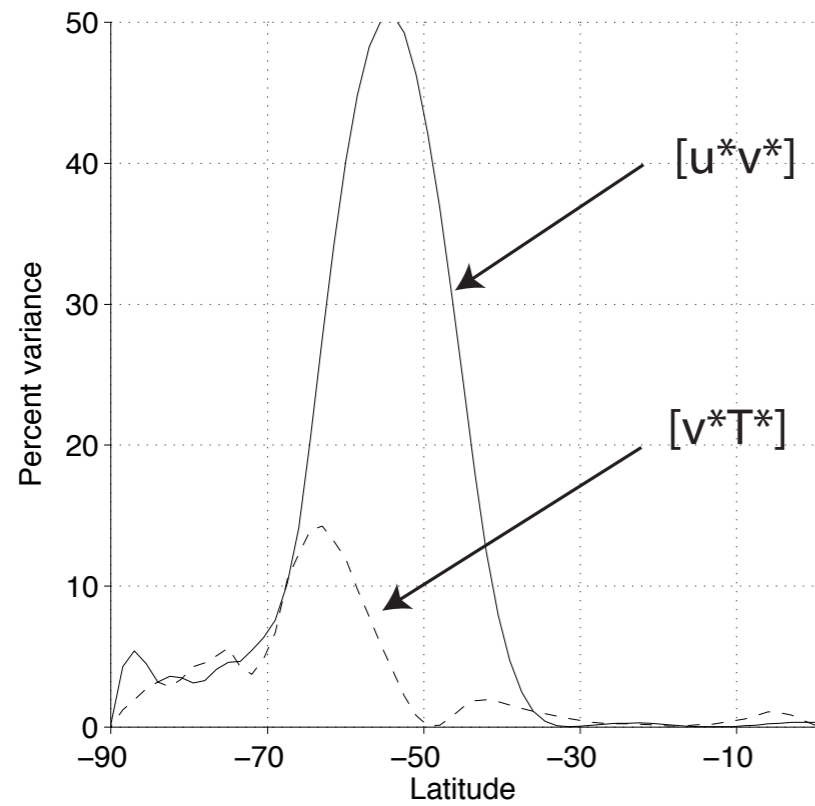


### Regressions on E1 (PC1 SH EKE)

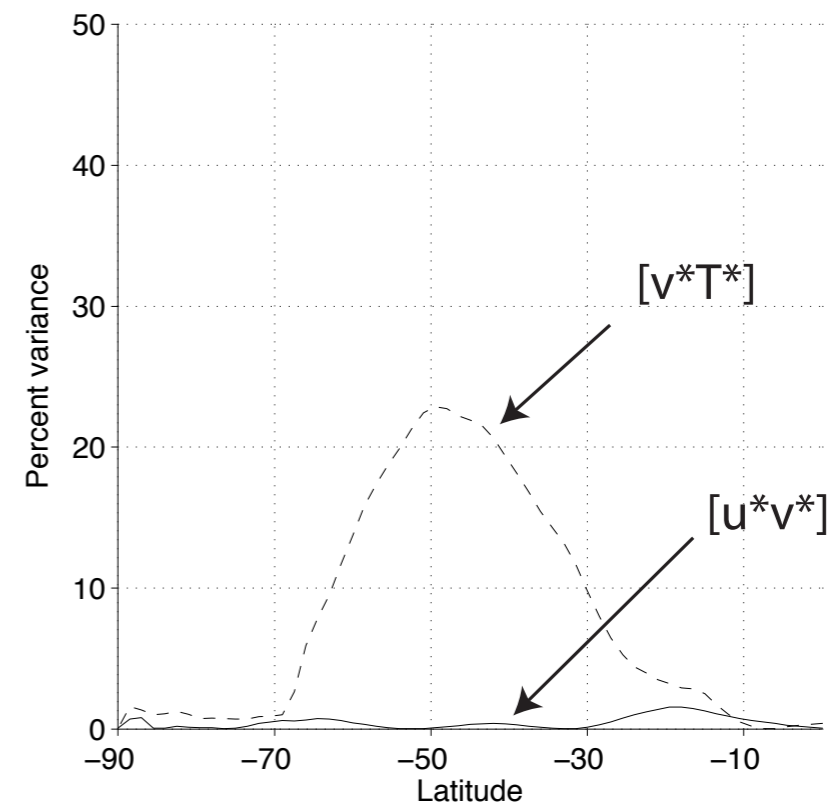


# Variations explained in the monthly-mean eddy fluxes of heat and momentum

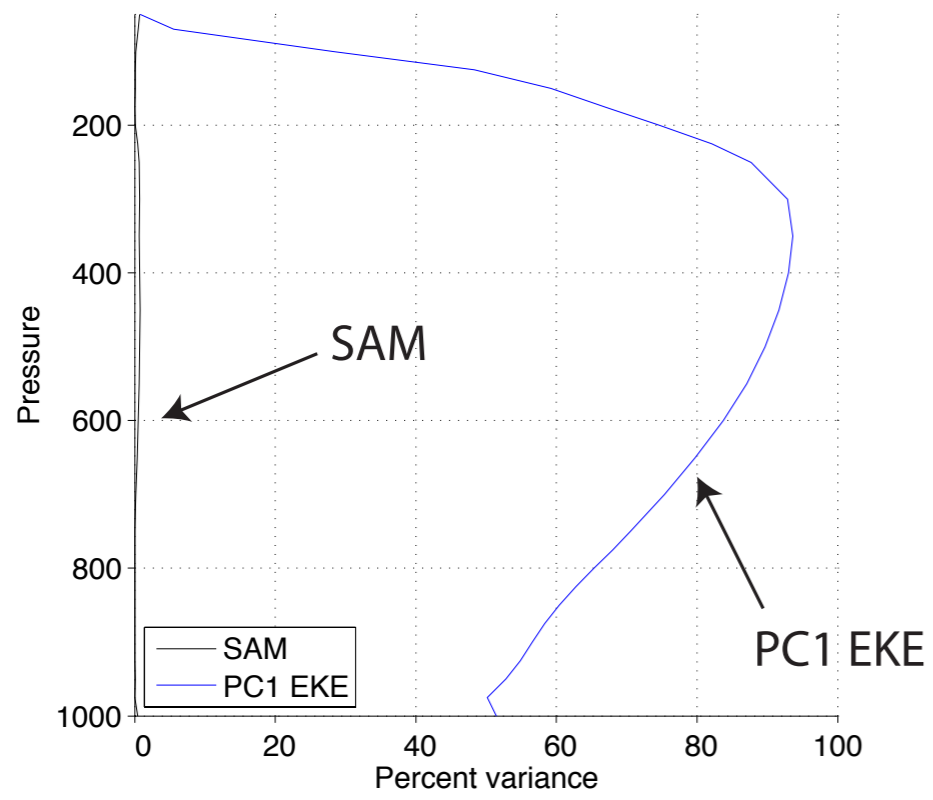
## SAM (PC1 SH U)



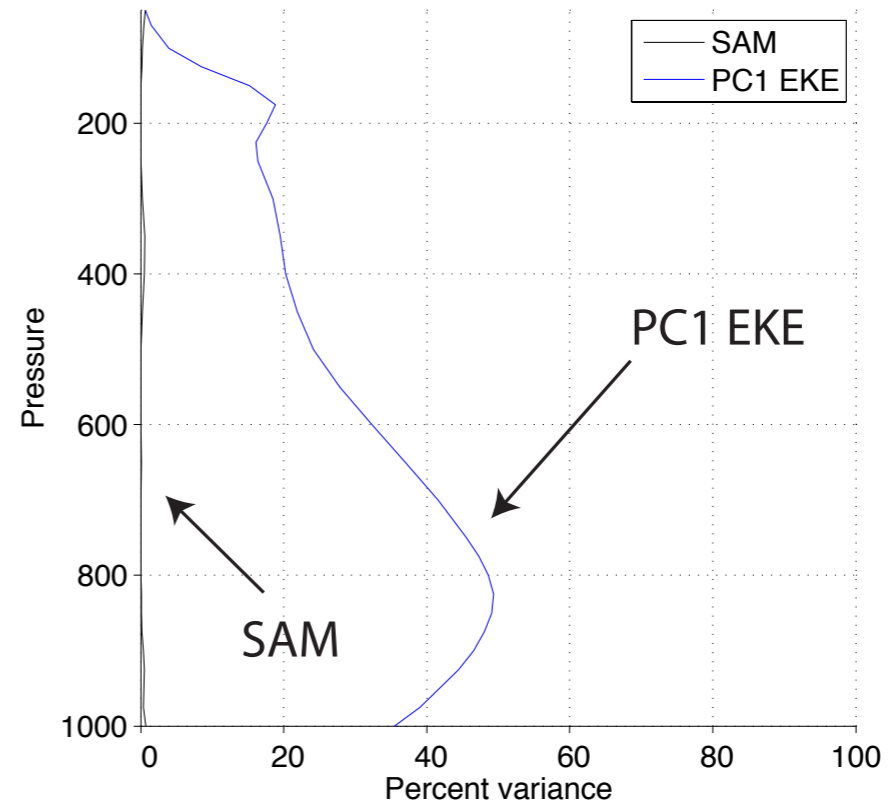
## E1 (PC1 SH EKE)



c) Variances explained in SH EKE



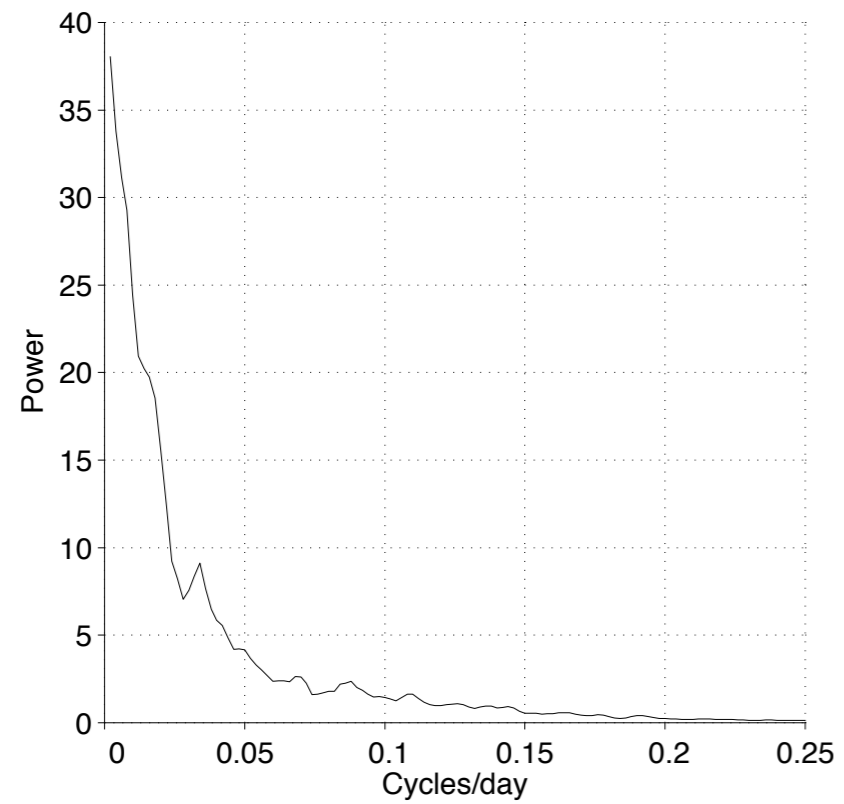
d) Variances explained in SH [ $v^*T^*$ ]



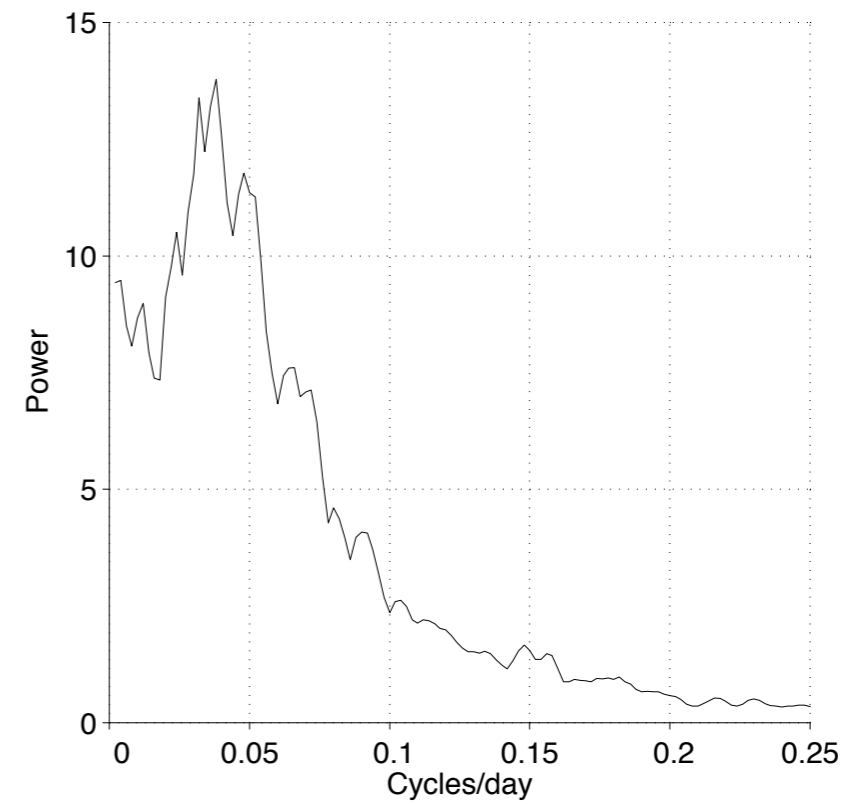
# Some other interesting differences

Power spectra

SAM (PC1 SH U)



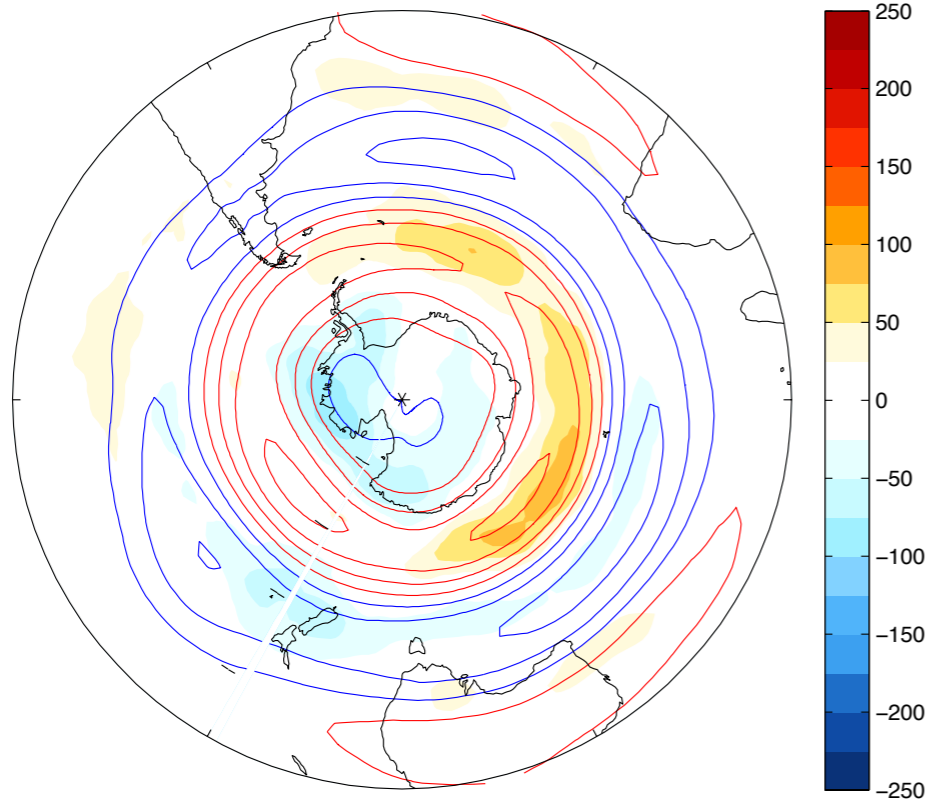
E1 (PC1 SH EKE)



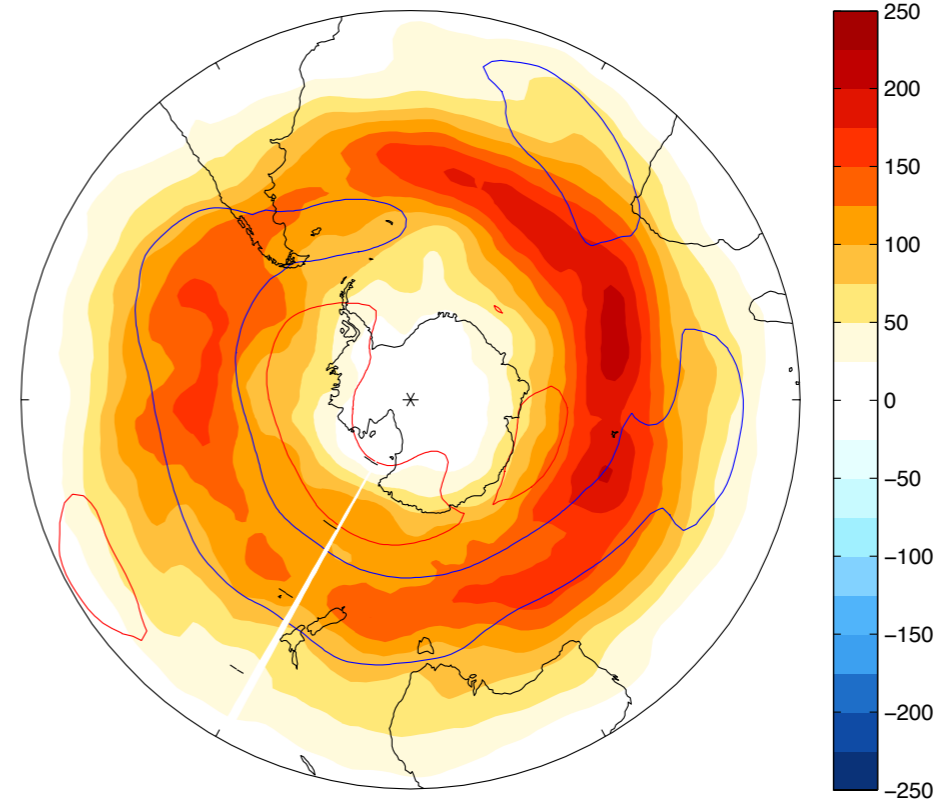
# Some other interesting differences

## Differences in eddy kinetic energy

High-low polarity of PC1 Uwnd



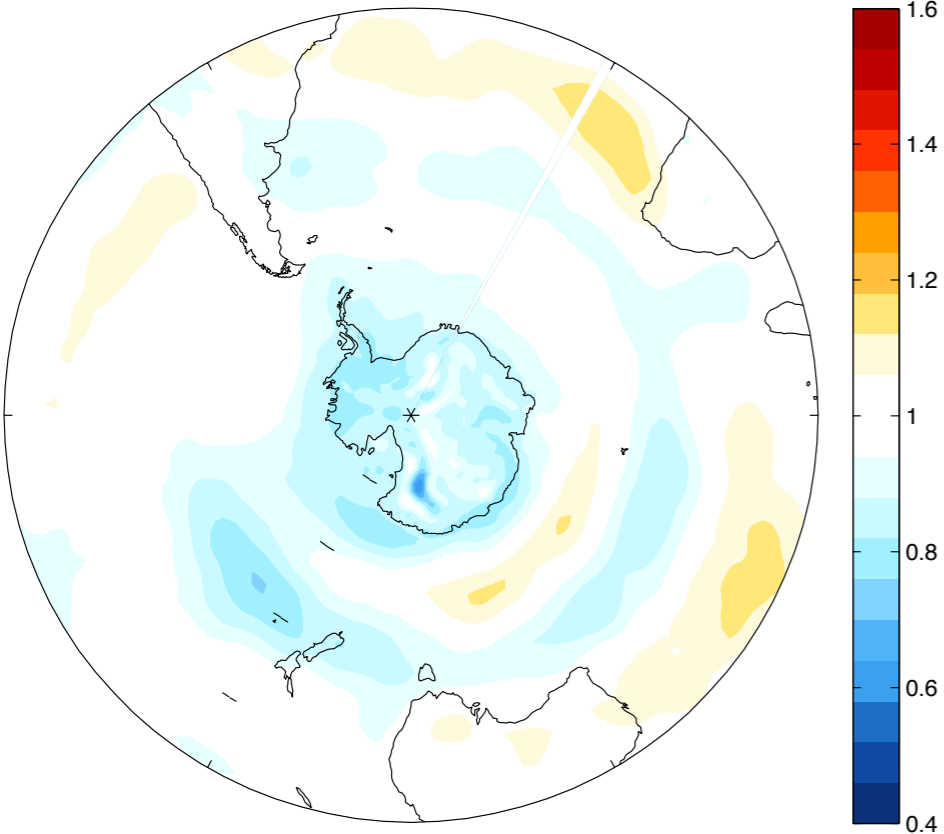
High-low polarity of PC1 EKE



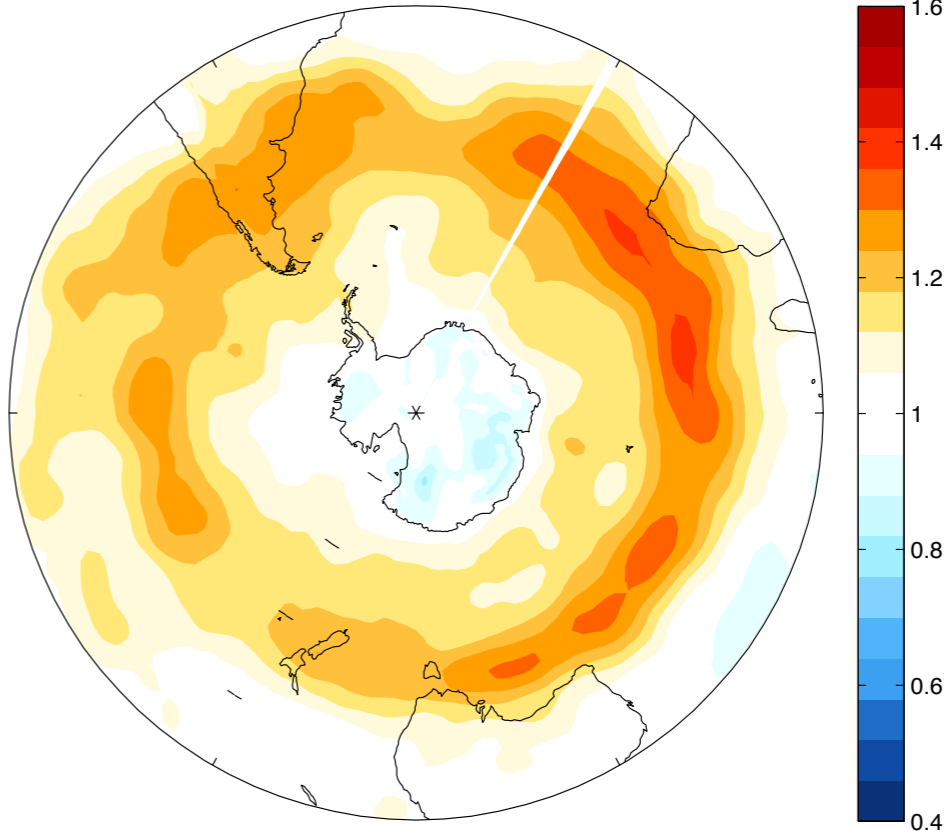
# Some other interesting differences

Ratios of variance in lower tropospheric temperatures

High/low polarity of PC1 Uwnd



High/low polarity of PC1 EKE

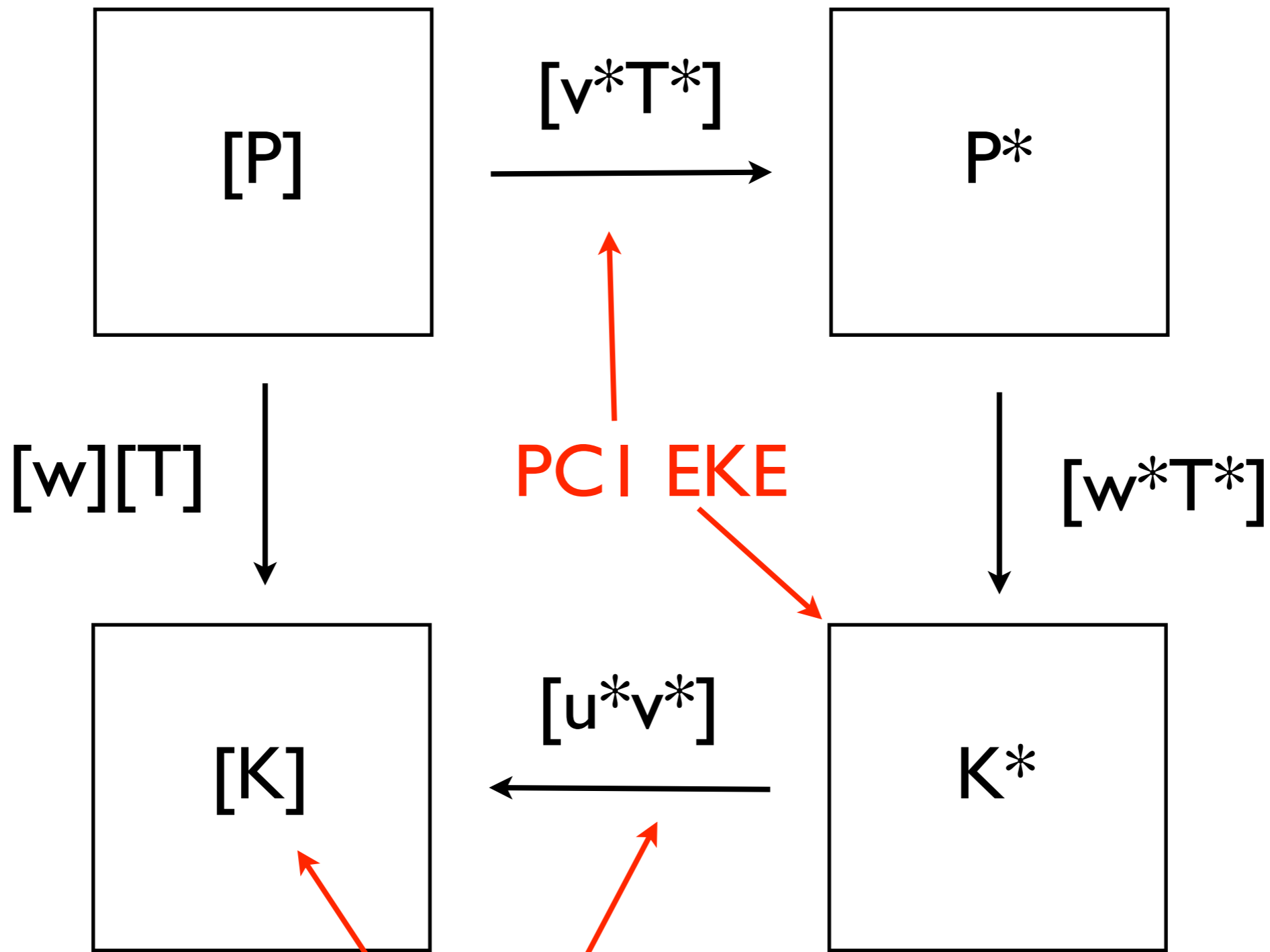


Variability in the zonal-mean SH circulation is characterized by two largely independent structures:

1) one that converts eddy to mean kinetic energy and dominates the zonal mean kinetic energy field (the SAM).

2) one that converts mean to eddy potential energy and dominates the eddy kinetic energy field (PCI EKE).

# Leading patterns of variability in middle latitude energy cycle



Annular variability

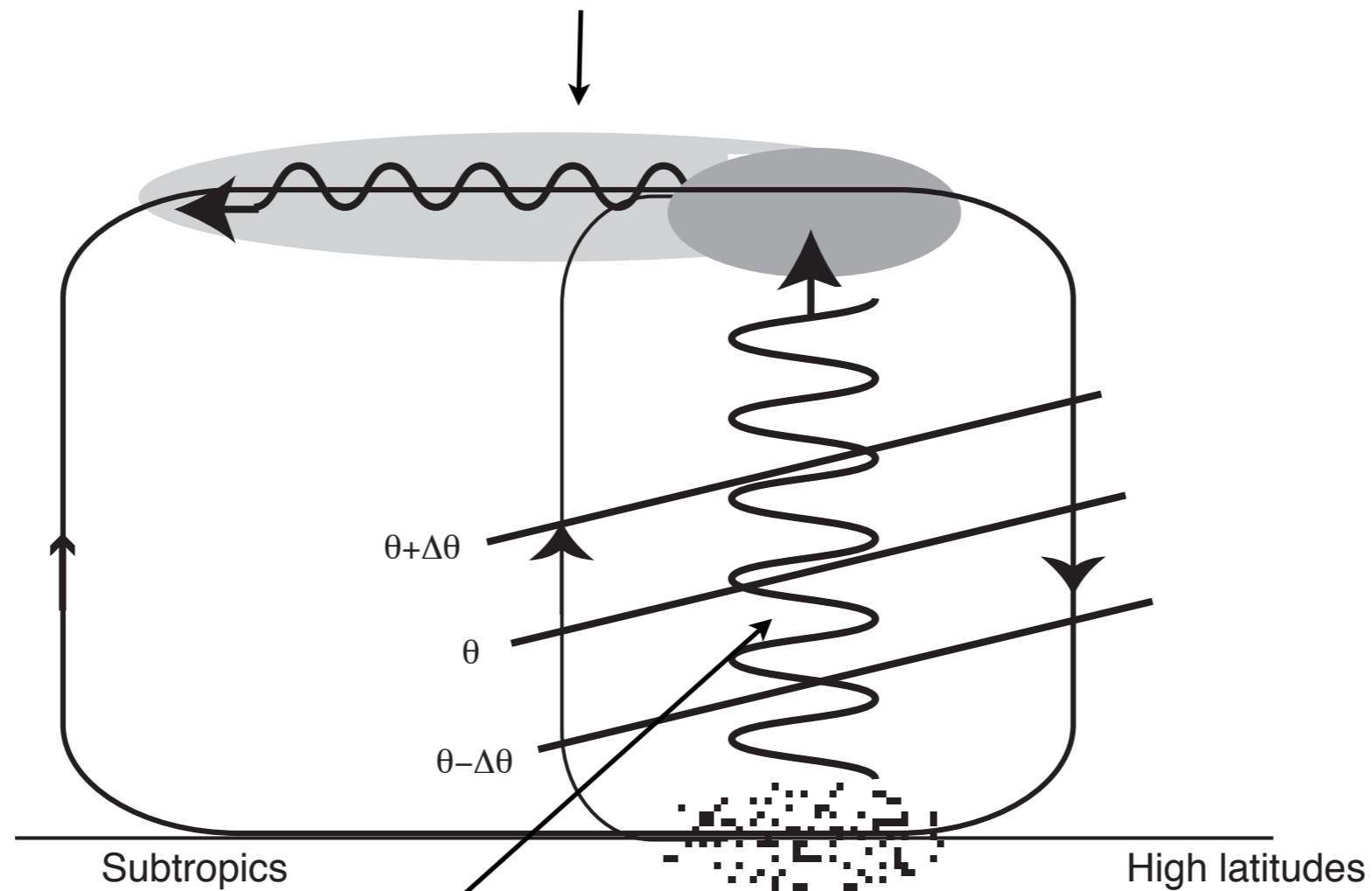
(reminiscent of Lau 1988)



# Questions

- Why does EKE (and  $v^*T^*$ ) exhibit such pronounced quasi-periodicity?
- Is similar behavior evident in the NH (yes).
- Does PCI of EKE account for much of the predicted increases in EKE and  $v^*T^*$  in climate change simulations? (The SAM accounts for the increases in ZKE and  $u^*v^*$ ).
- How does PCI of EKE relate to common indices of stormtrack variability (e.g., Lau 1988)?

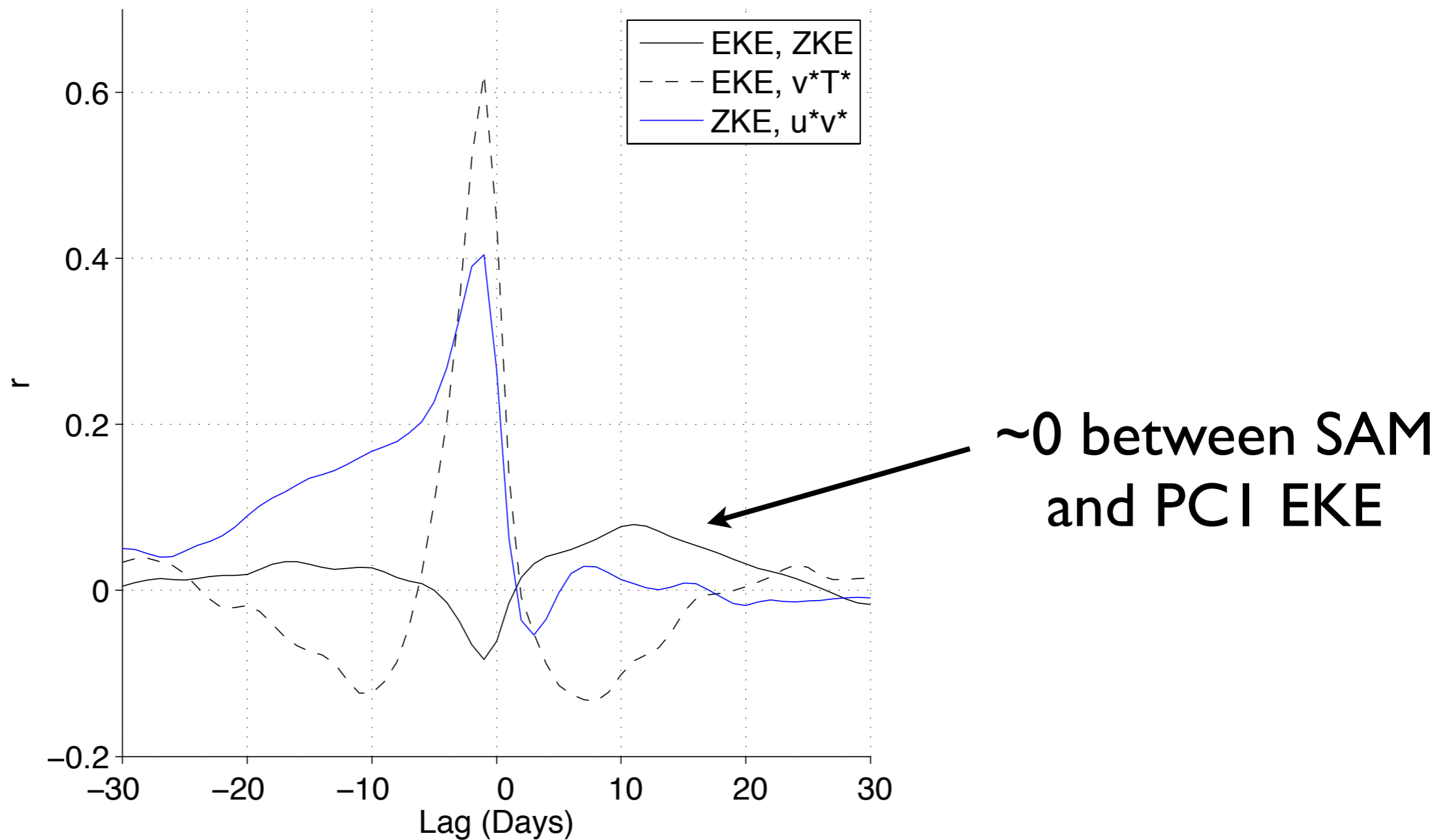
meridional wave fluxes (momentum fluxes)  
lag vertical wave fluxes (heat fluxes) by ~several days



vertical wave fluxes (heat fluxes) in regions of large isentropic slope

*Heat and momentum fluxes are both key components of the lifecycle of baroclinic waves (eg, Simmons and Hoskins 1978). But they are not strongly correlated.*

### c) Correlations between leading PCs



**PCI EKE is not linked to any significant EOF of the zonal wind field.**