

Is the Brewer-Dobson Circulation driven  
by tropospheric baroclinic waves  
or by high latitude, upper stratospheric planetary waves

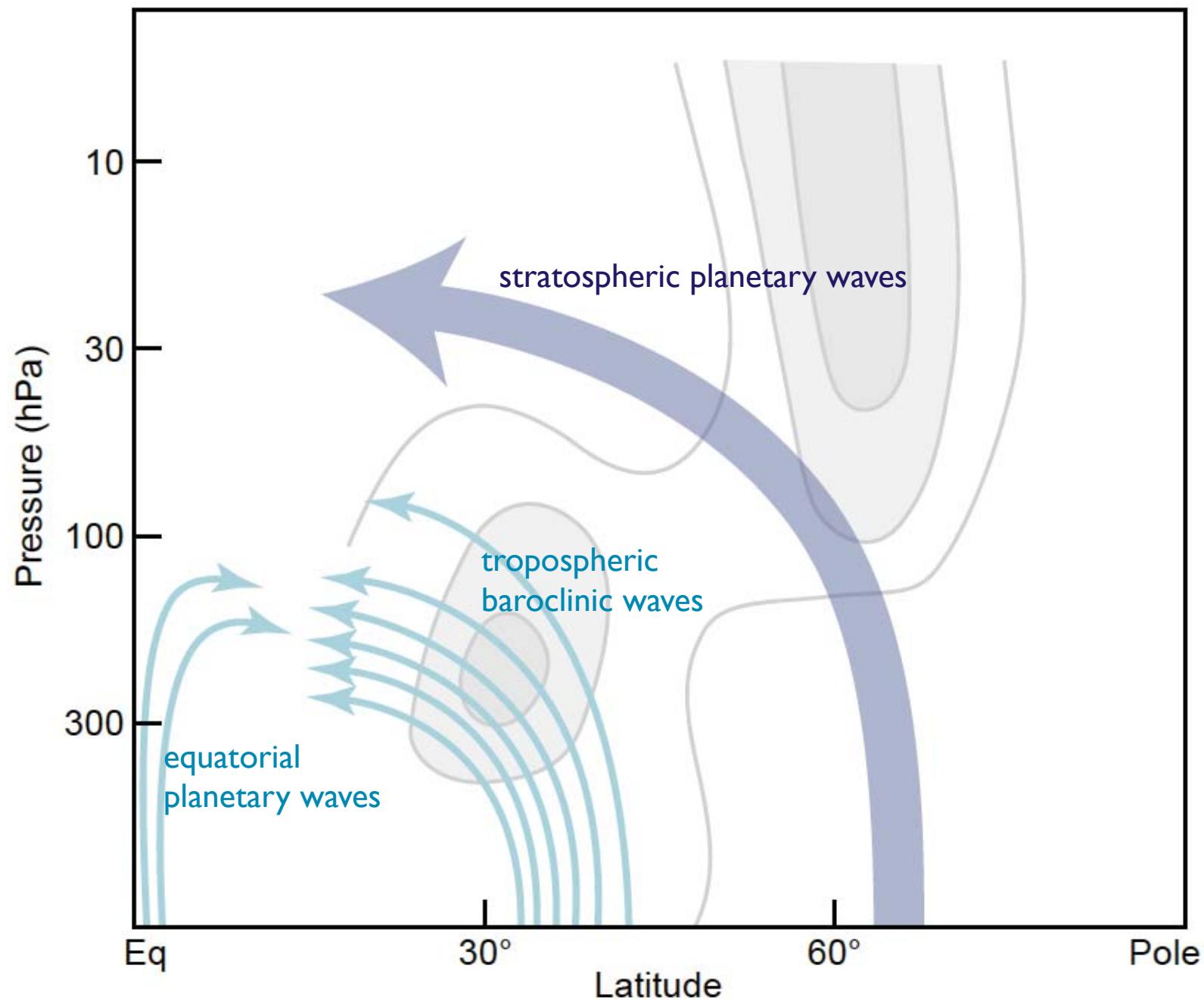
John M. Wallace, Rei Ueyama, Dargan Frierson,  
University of Washington

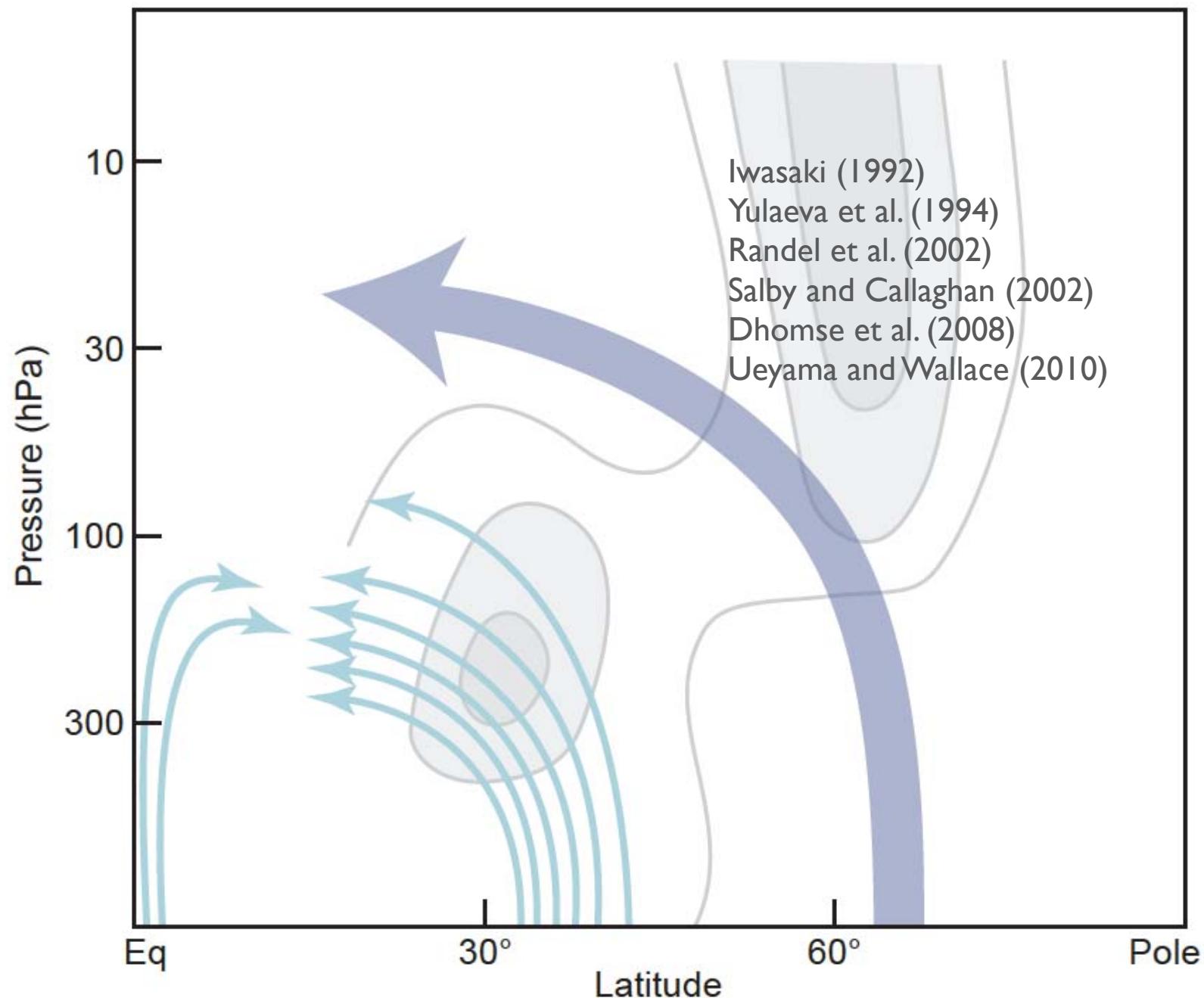
Edwin Gerber  
Courant Institute, New York University

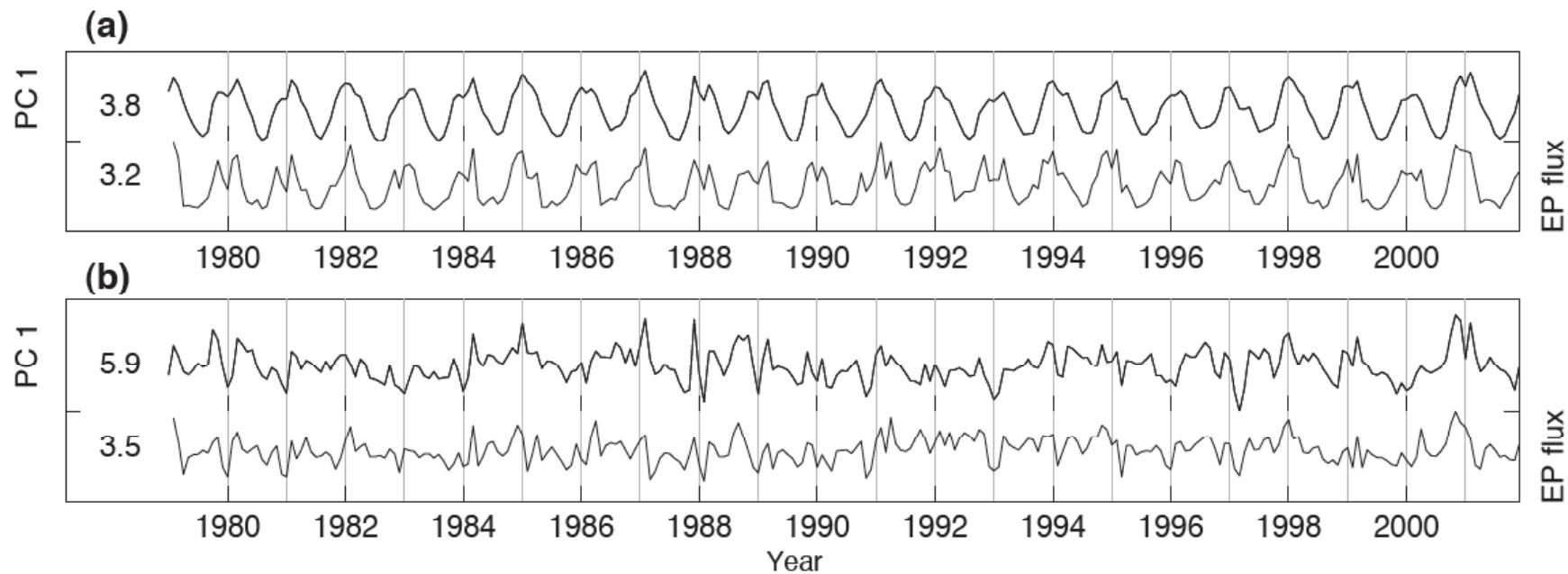
## Background

general agreement that the Brewer-Dobson circulation (BDC) is forced by wave-breaking at stratospheric levels,

but conflicting interpretations of where the wave-breaking occurs

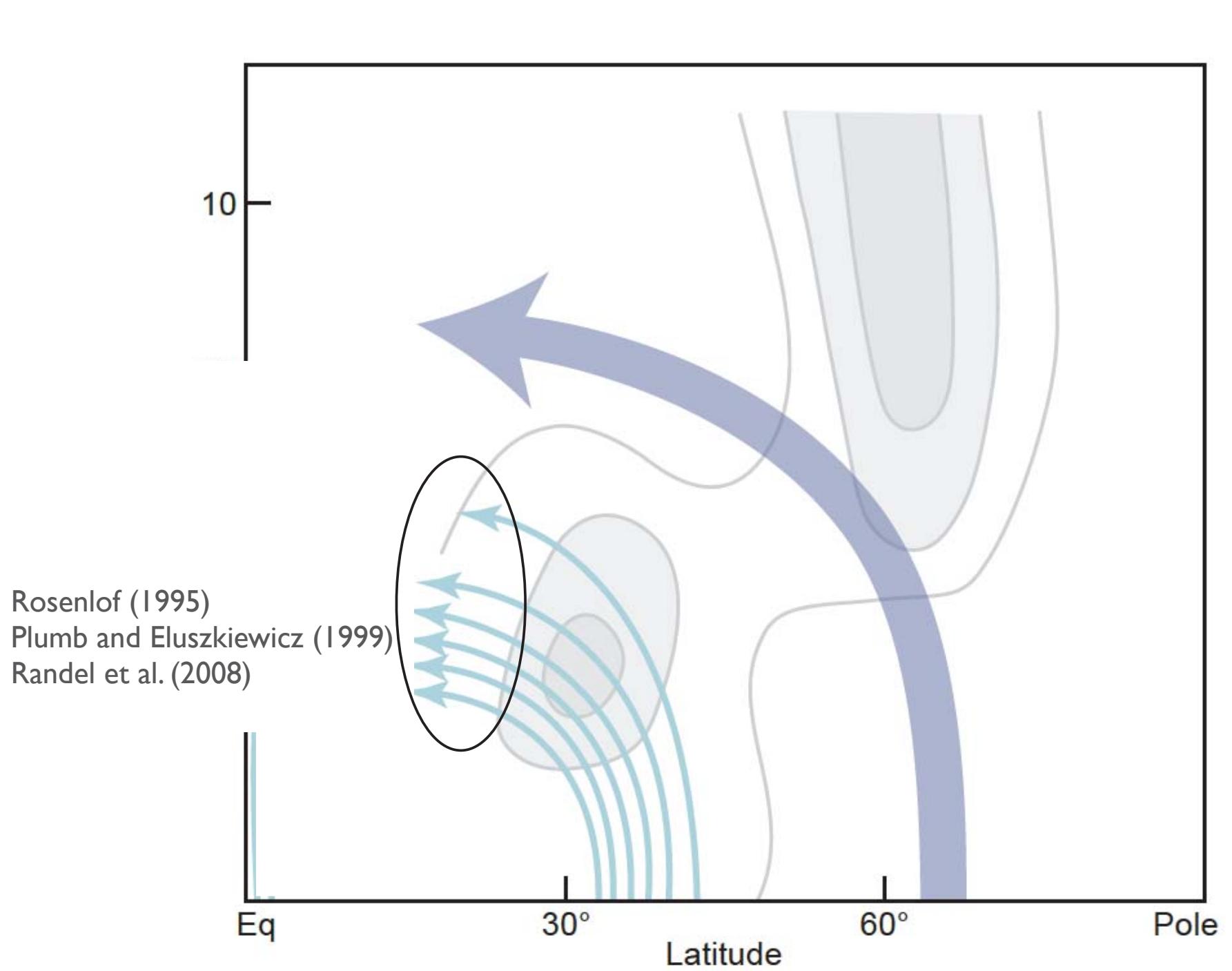


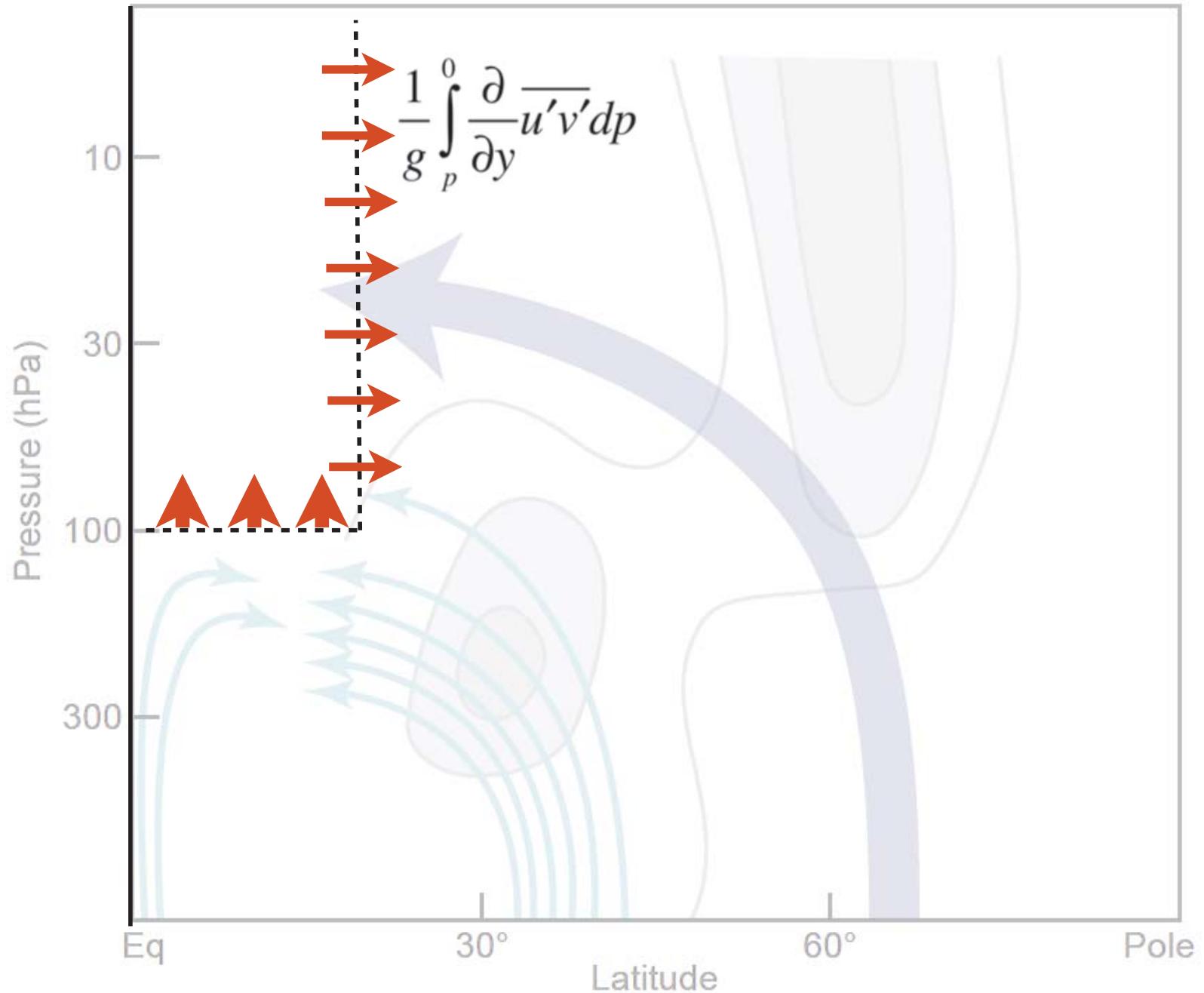


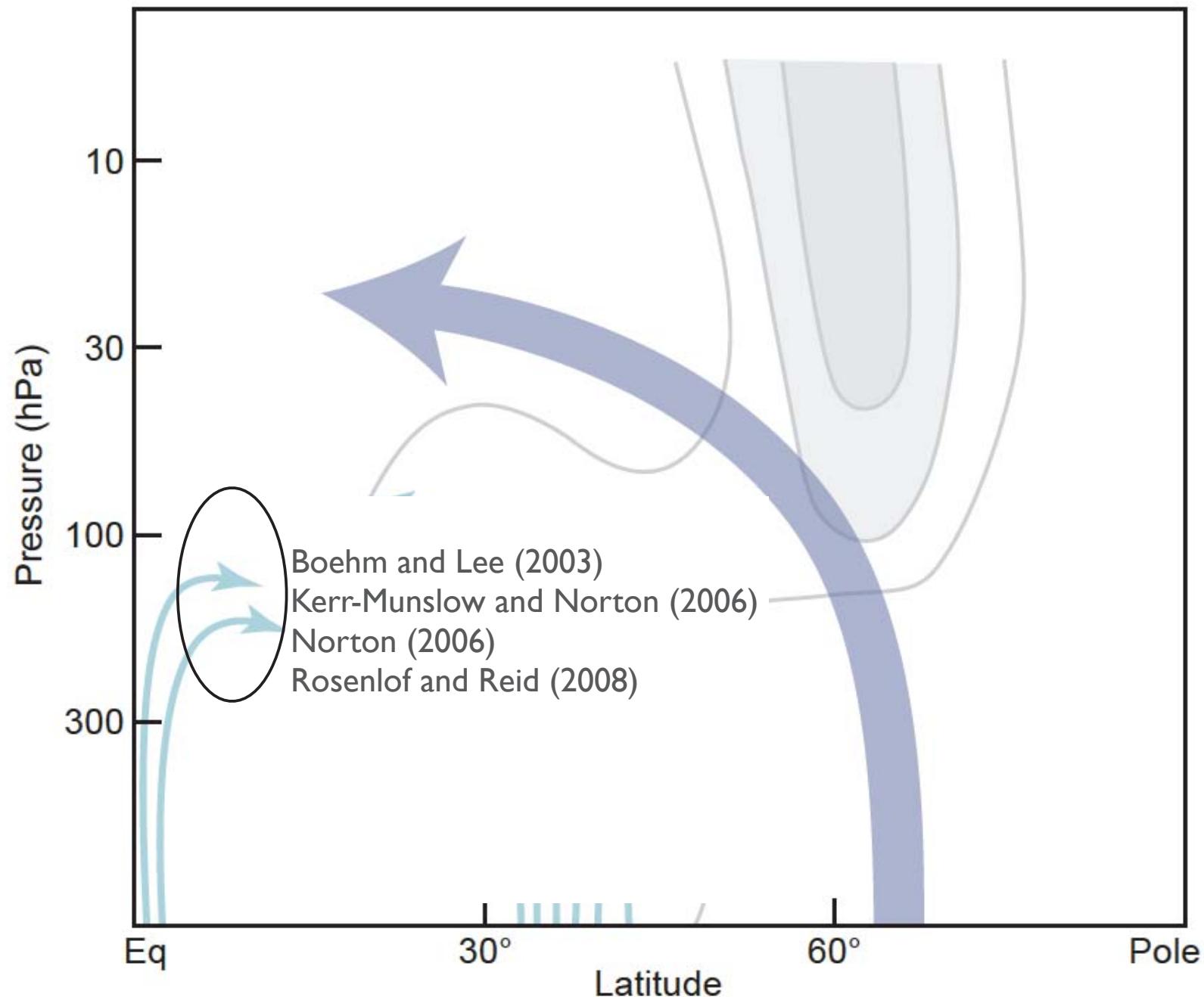


Ueyama and Wallace (2010)

High temporal correlations between high latitude eddy heat fluxes and tropical temperatures (circumstantial evidence)







# Plumb (2002)

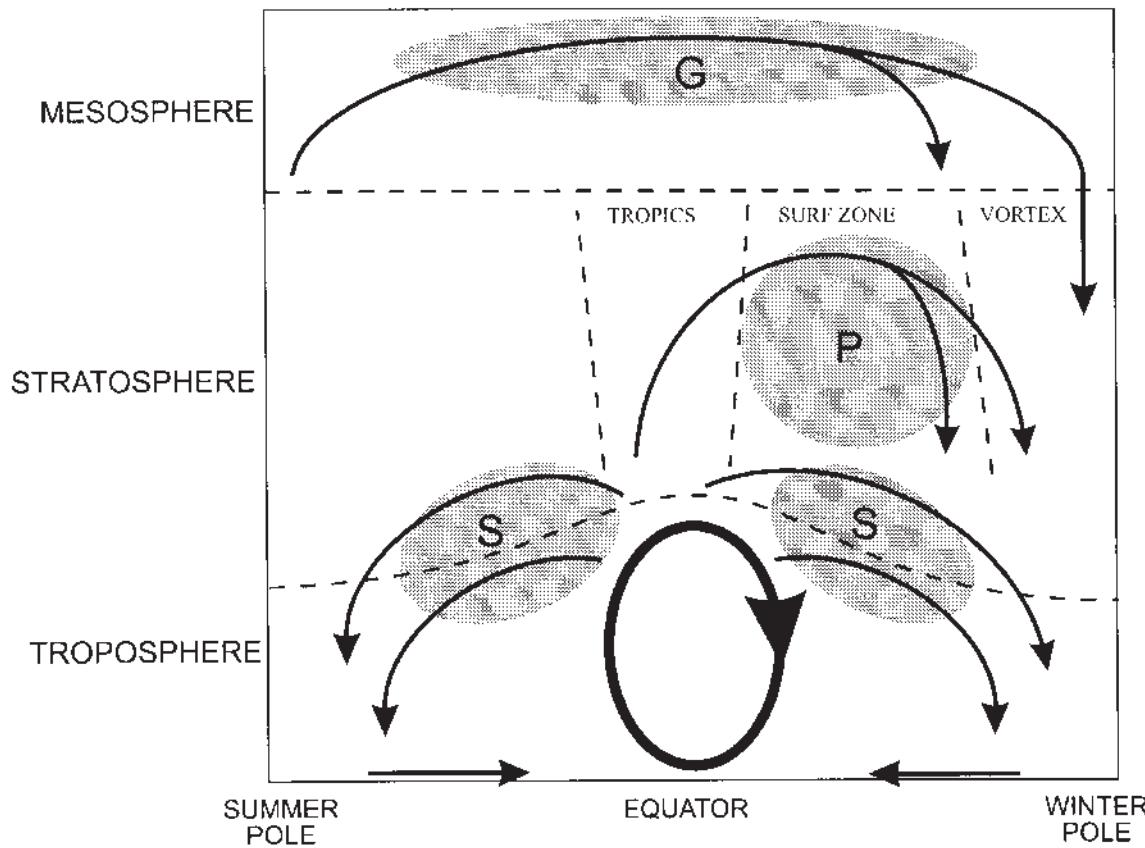


Fig. 2. Schematic of the residual mean meridional circulation in the atmosphere. The heavy ellipse denotes the thermally-driven Hadley circulation of the troposphere. The shaded regions (labelled “S”, “P”, and “G”) denote regions of breaking waves (synoptic- and planetary-scale waves, and gravity waves, respectively), responsible for driving branches of the stratospheric and mesospheric circulation.

## Purpose of this talk

to confirm the existence of lower and middle cells with different sources of wave driving

to show that the breaking of high latitude planetary waves is important for the forcing of the BDC despite the lack of confirmatory evidence based on downward control diagnostics

## Methodology

Side-by-side comparison of regression statistics and downward control diagnostics in the **ERA-40 Reanalysis** and in a **simple dynamical model** that is capable of simulating the sudden warming phenomenon

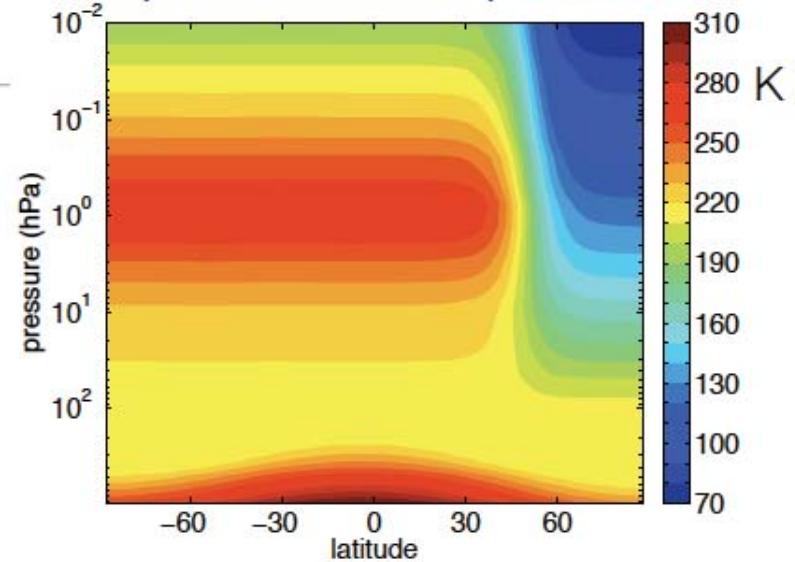
The ERA-40 Model--  
work of Rei Ueyama

The simple dynamical model  
work of Edwin Gerber

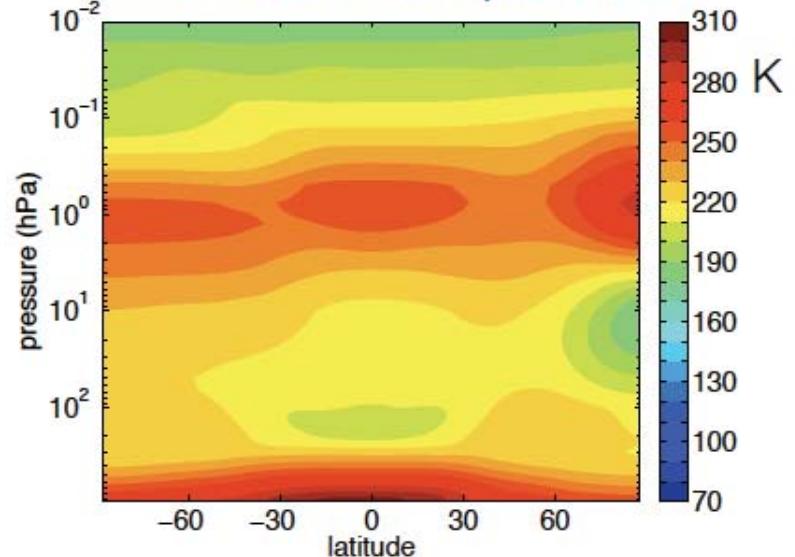
# An idealized Atmospheric GCM

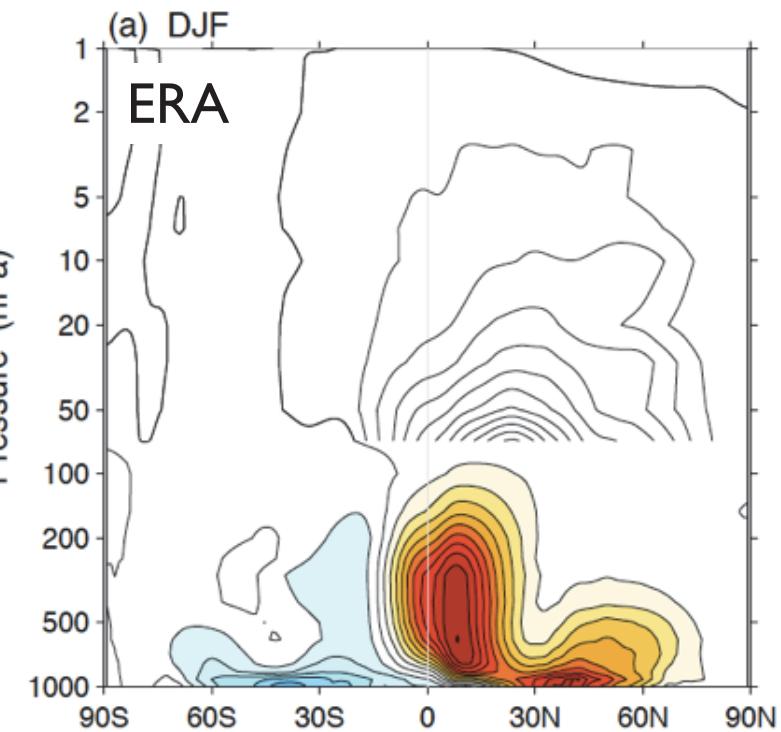
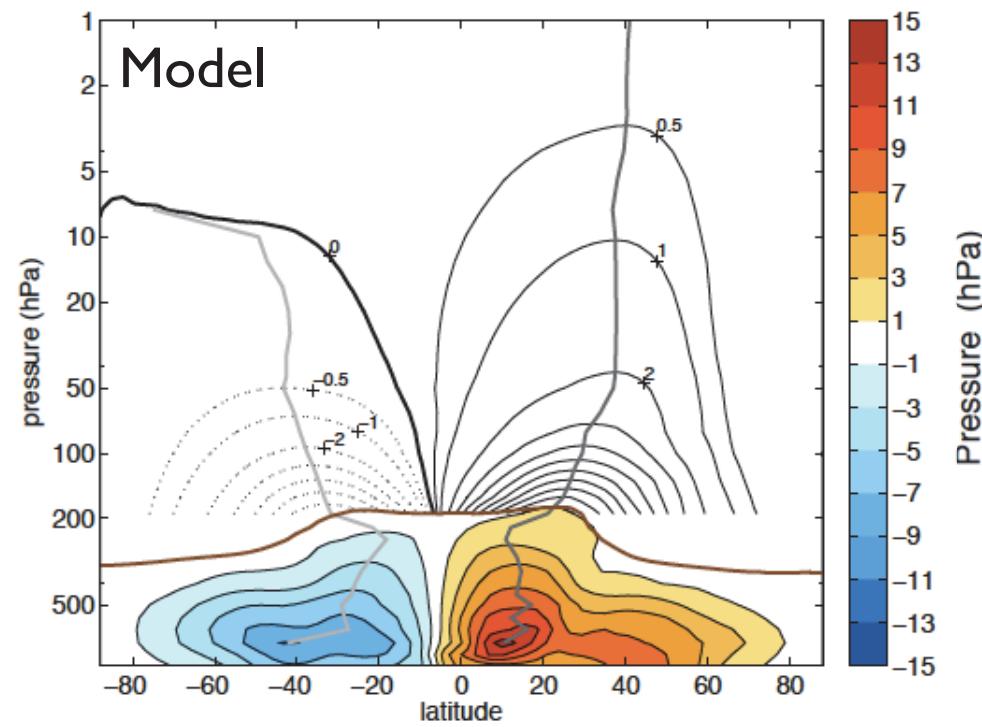
- dry primitive equations on the sphere
- Newtonian relaxation of temperature to radiative-convective equilibrium profile [Polvani and Kushner, 2002]
- Perpetual January-like conditions
- Simple large scale topography [Gerber and Polvani, 2009]
- Rayleigh friction at bottom (surface drag) and top (crude gravity wave parameterization)

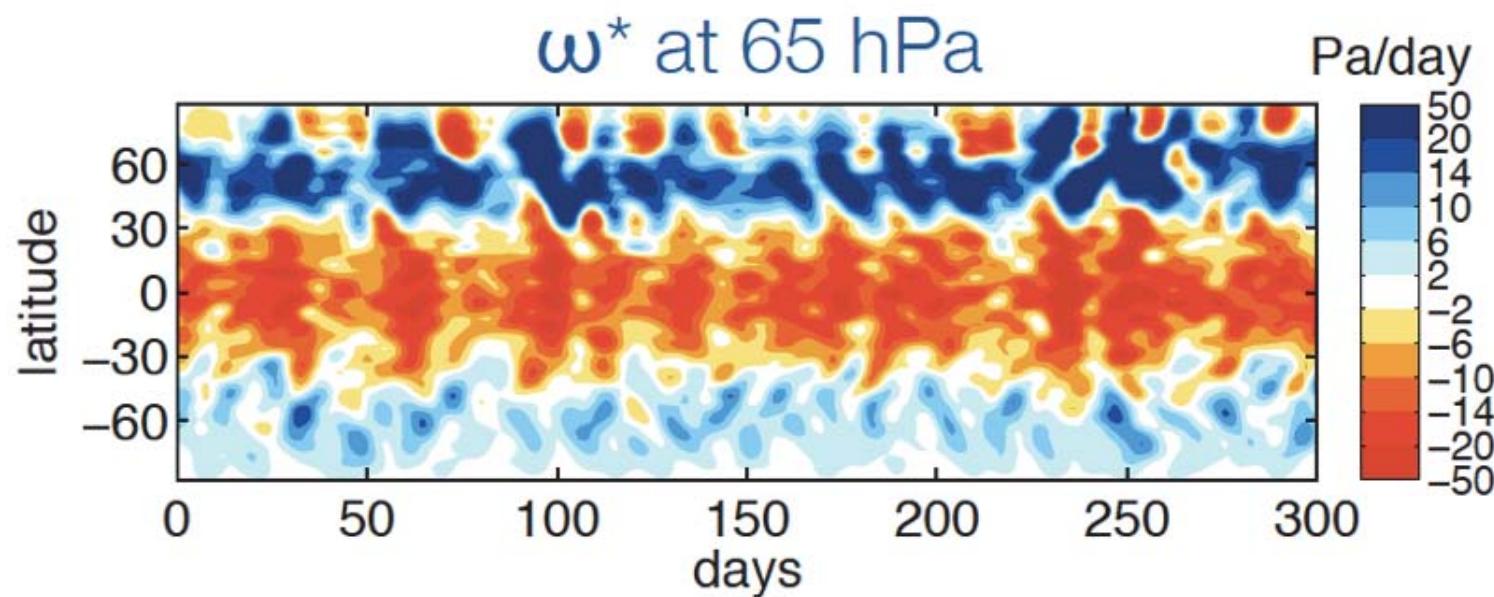
radiative-convective equilibrium temperature

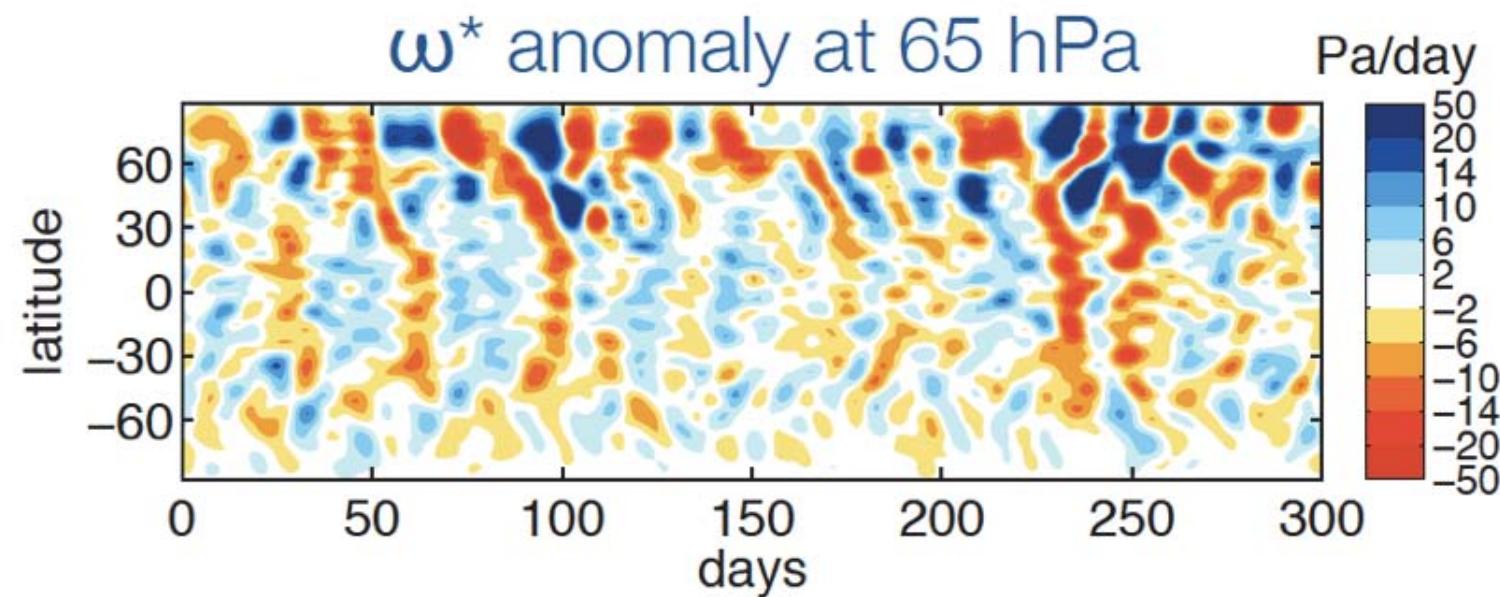


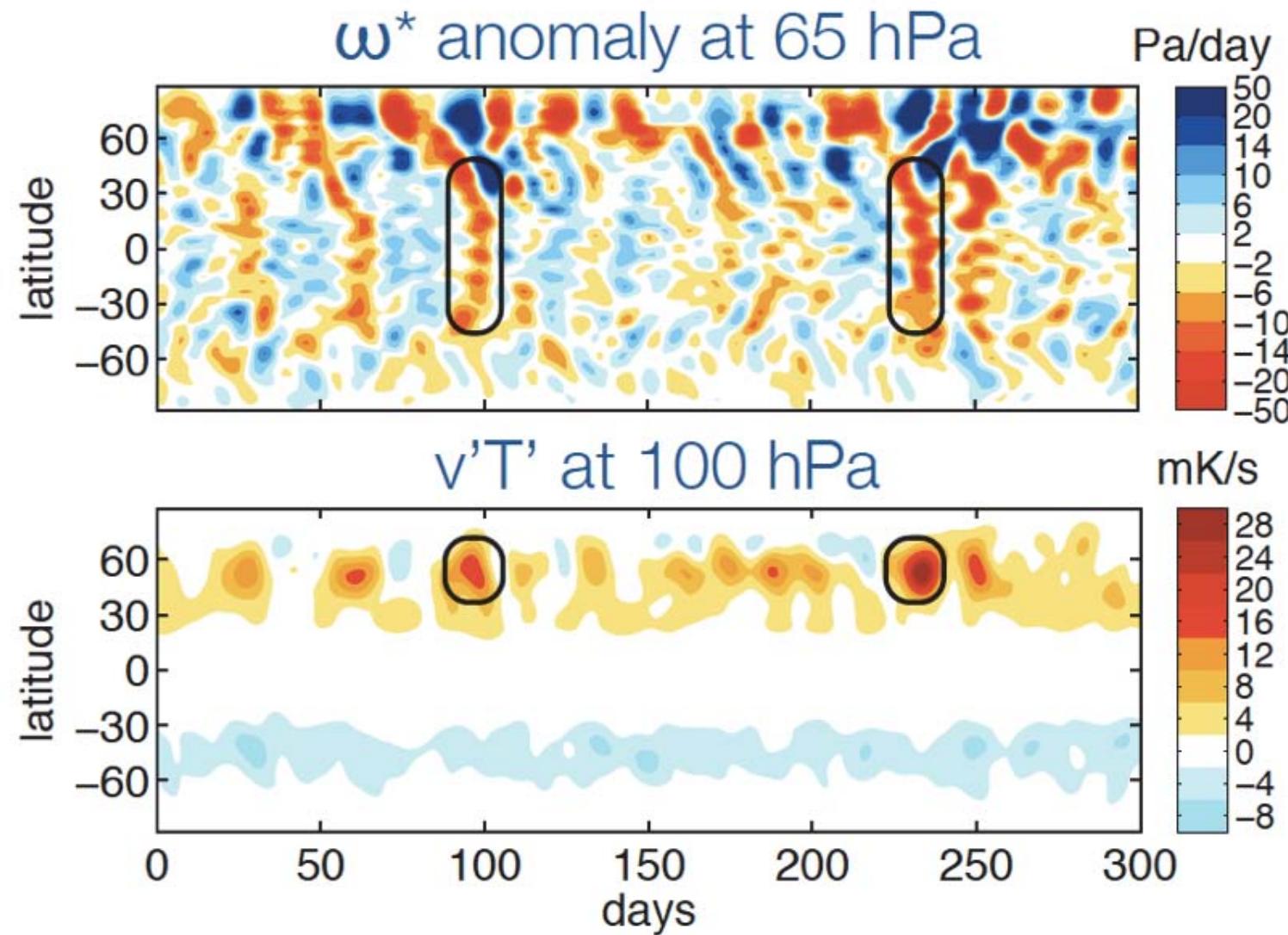
time mean temperature

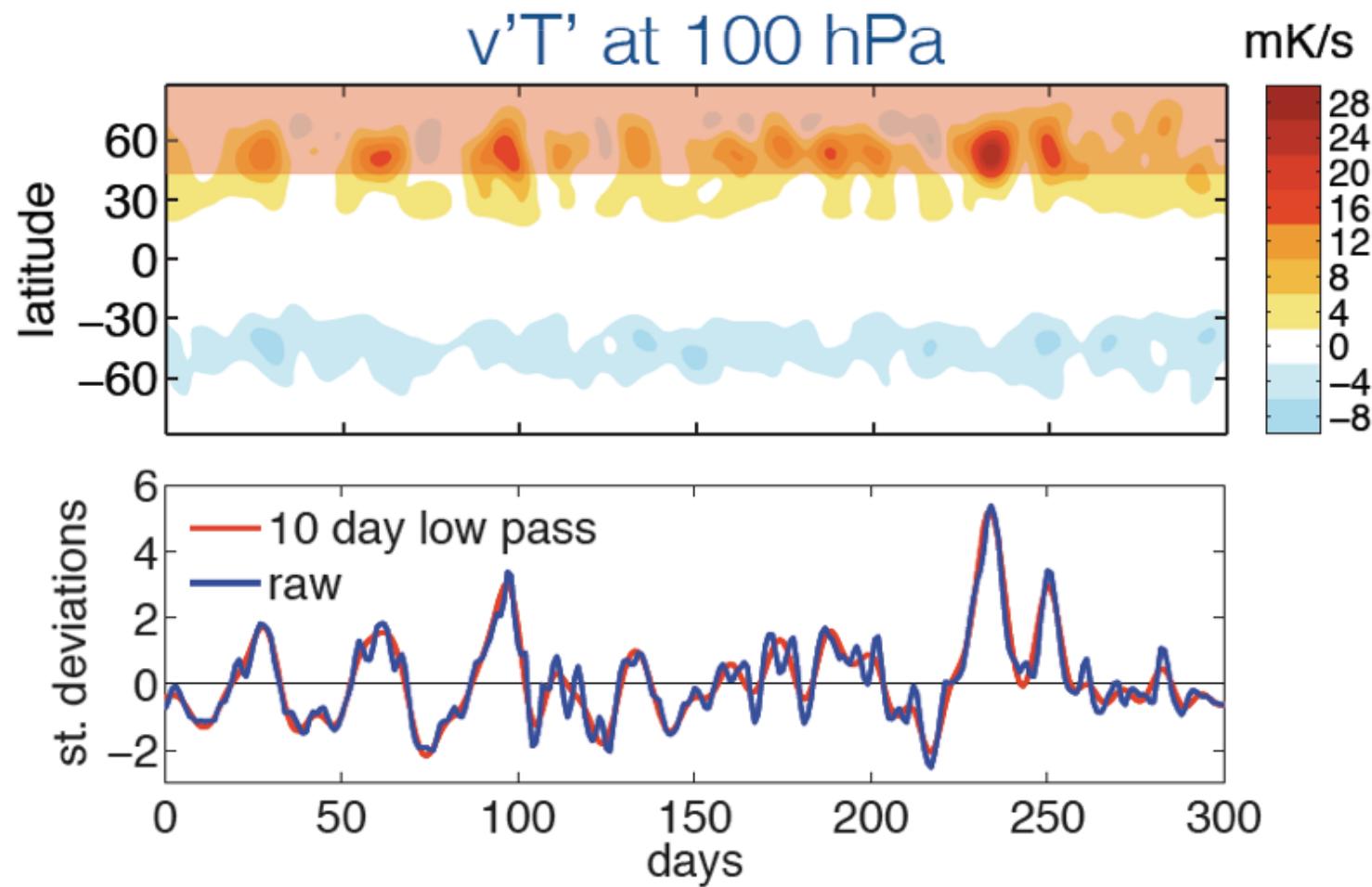










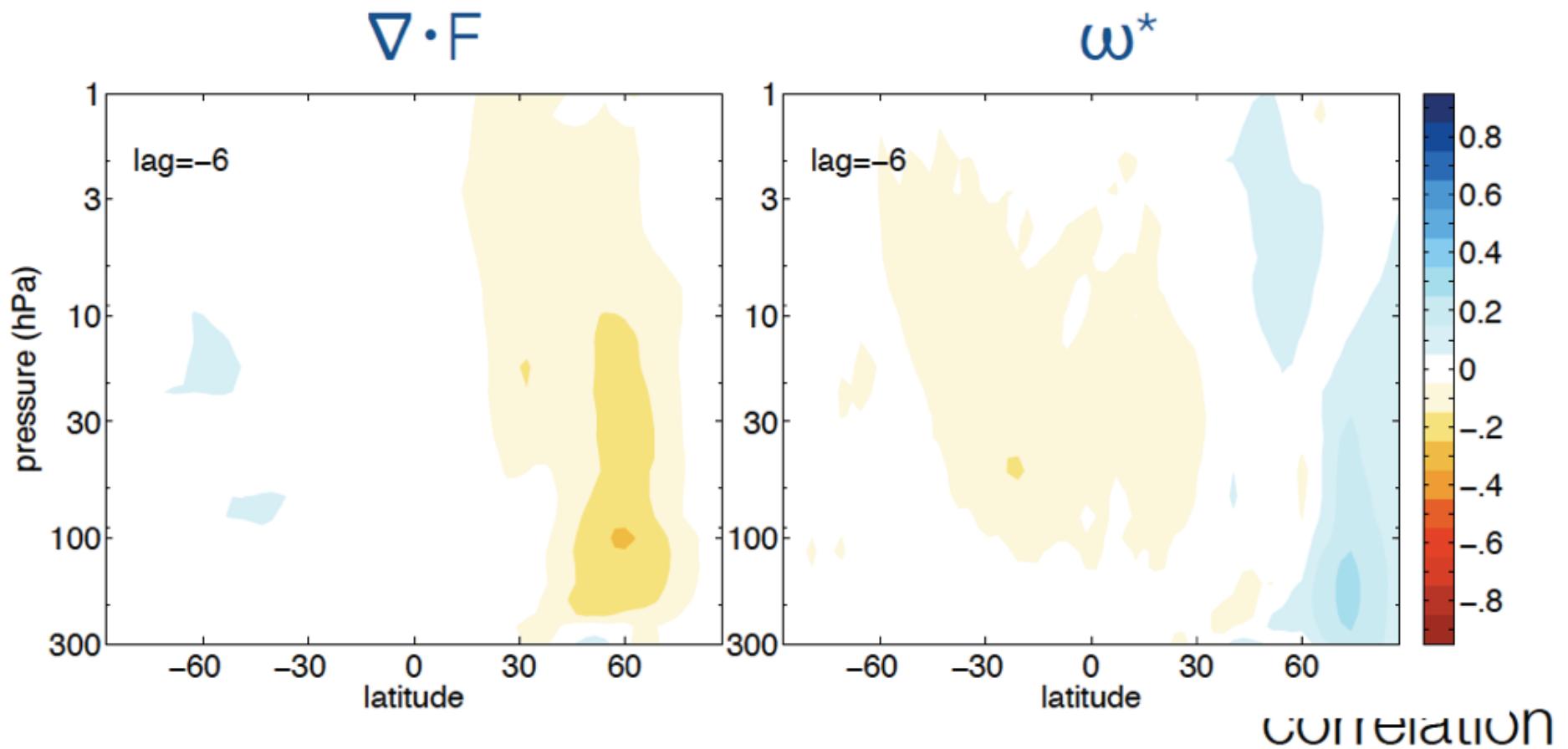


$$v'T' \text{ index} \propto \text{int}_{45^{\circ}}^{90^{\circ}} v'T'$$

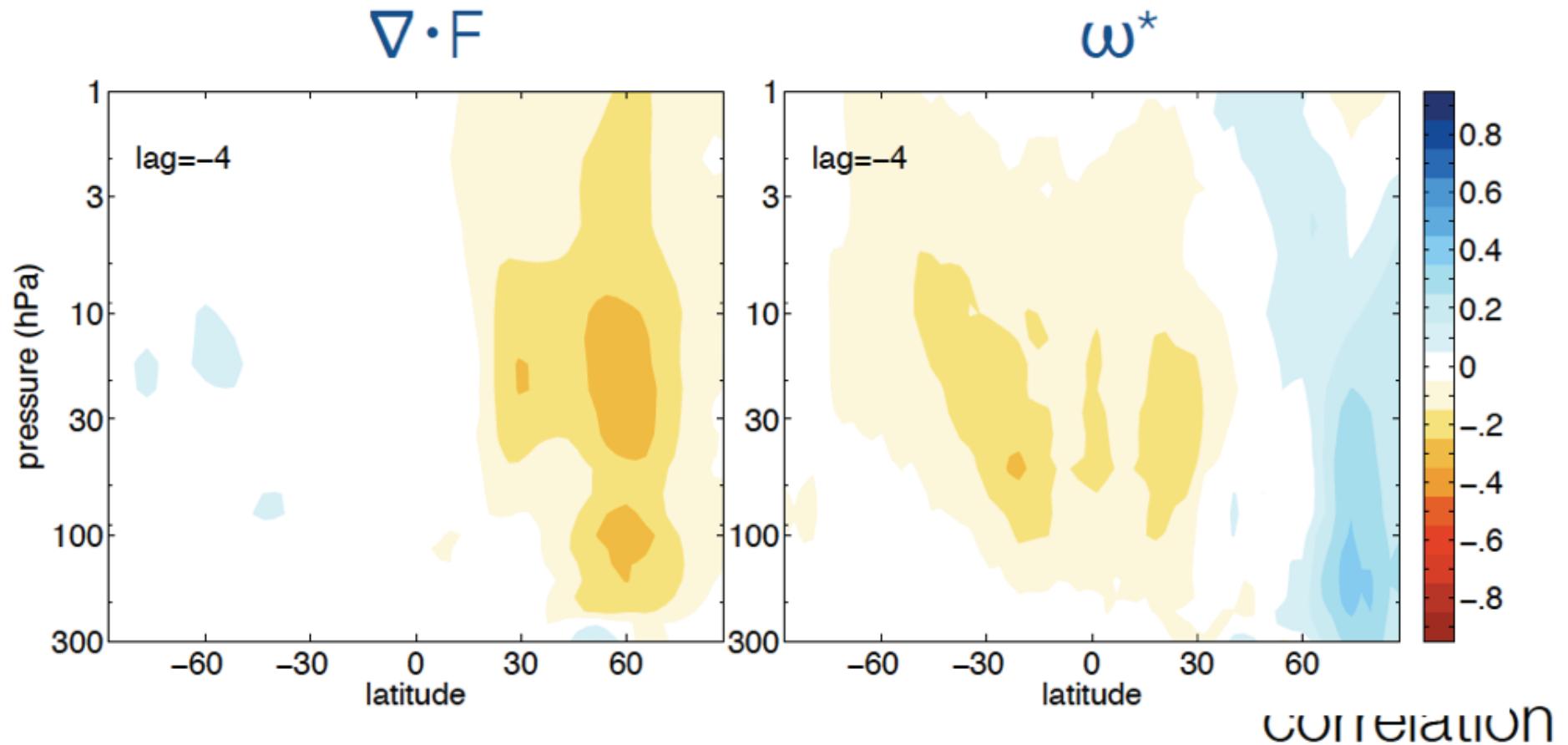
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# Correlation of E-P flux divergence and $\omega^*$ with extratropical v'T' index

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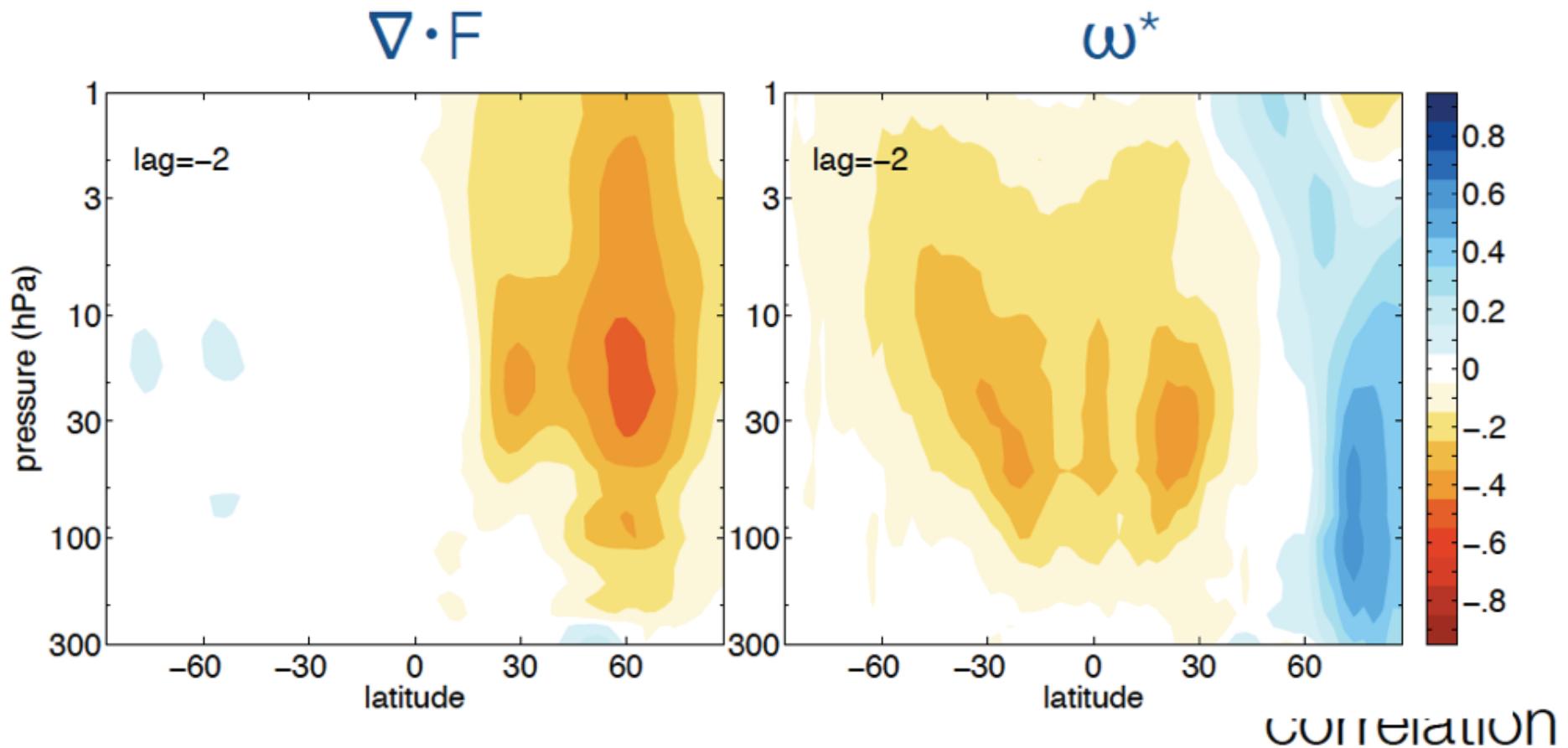


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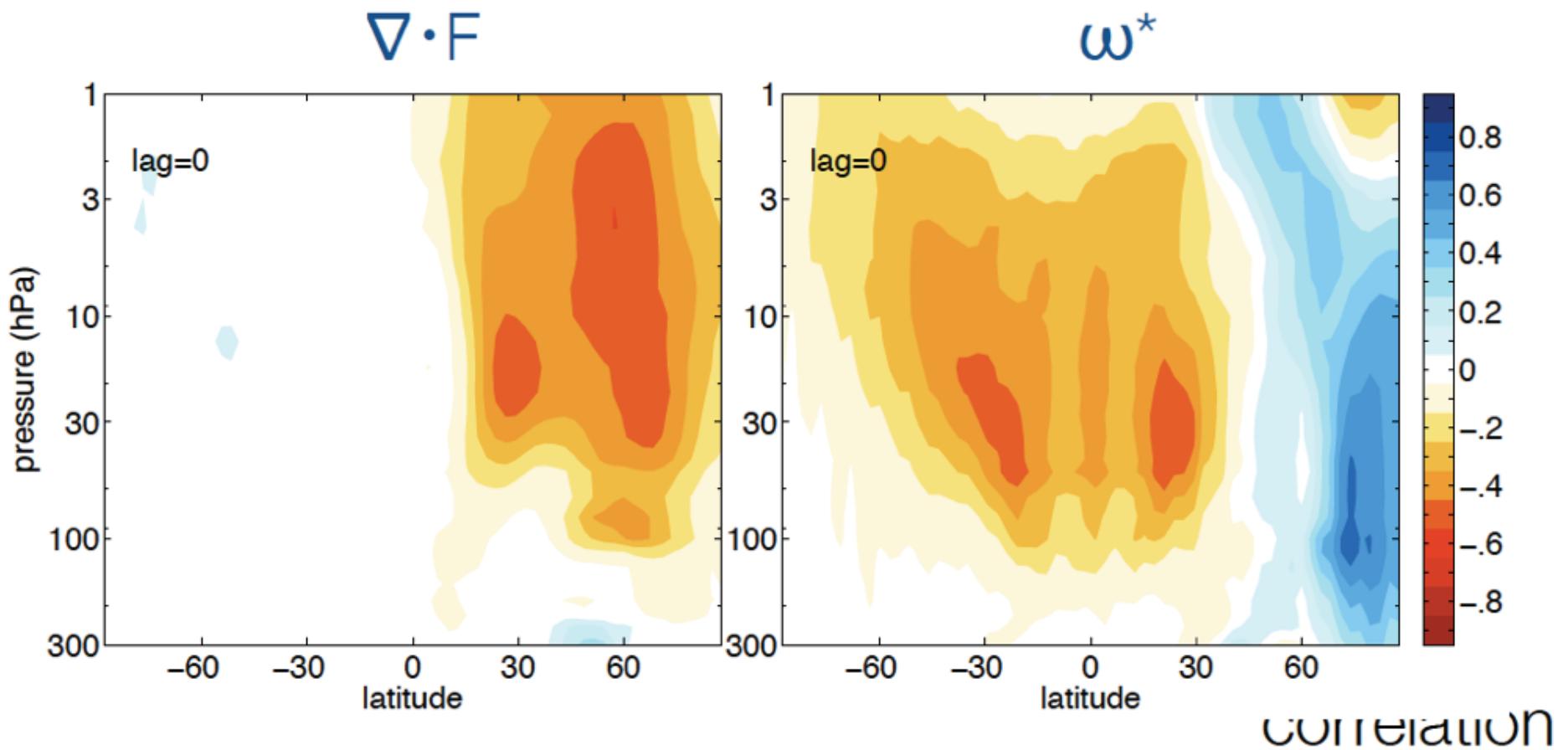
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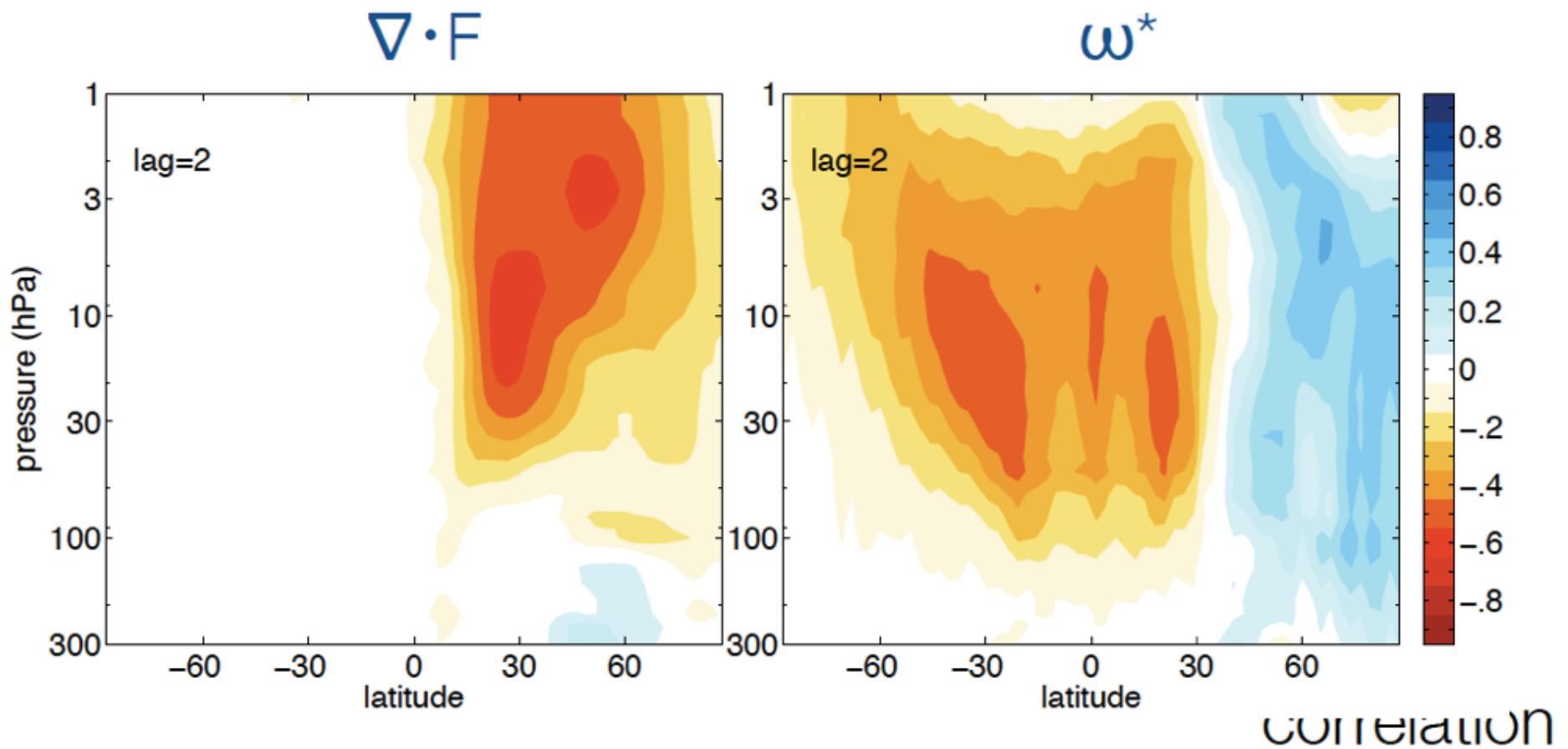
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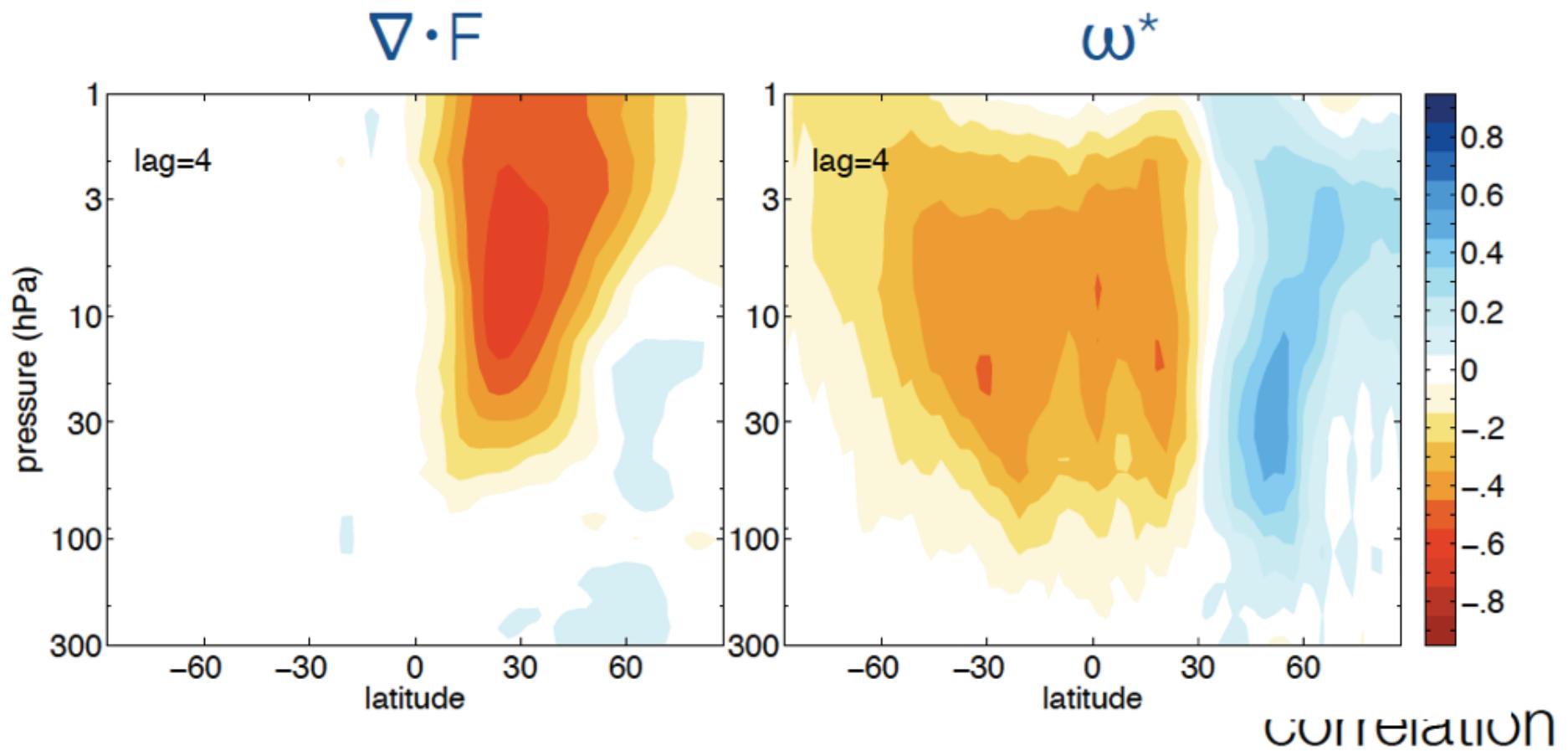
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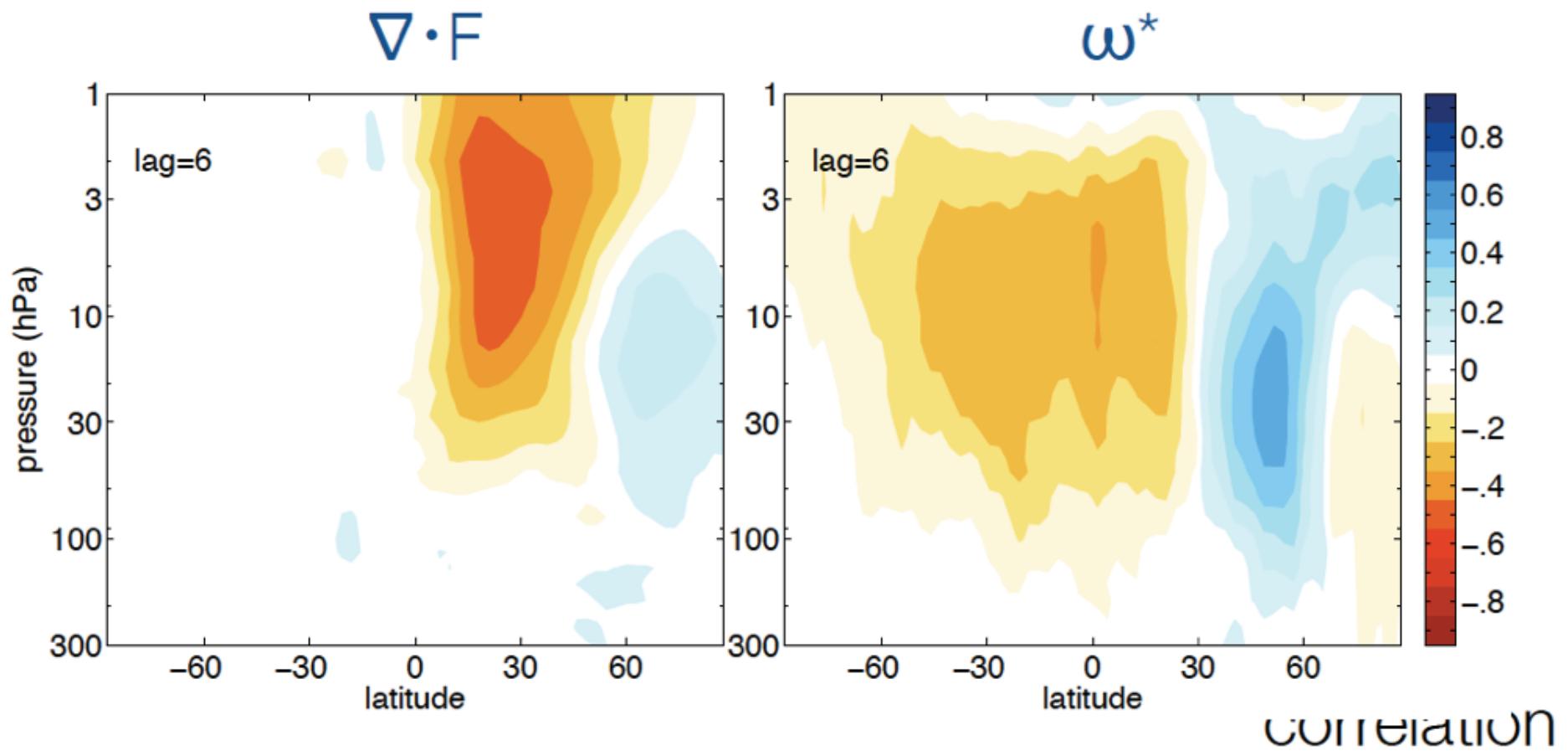
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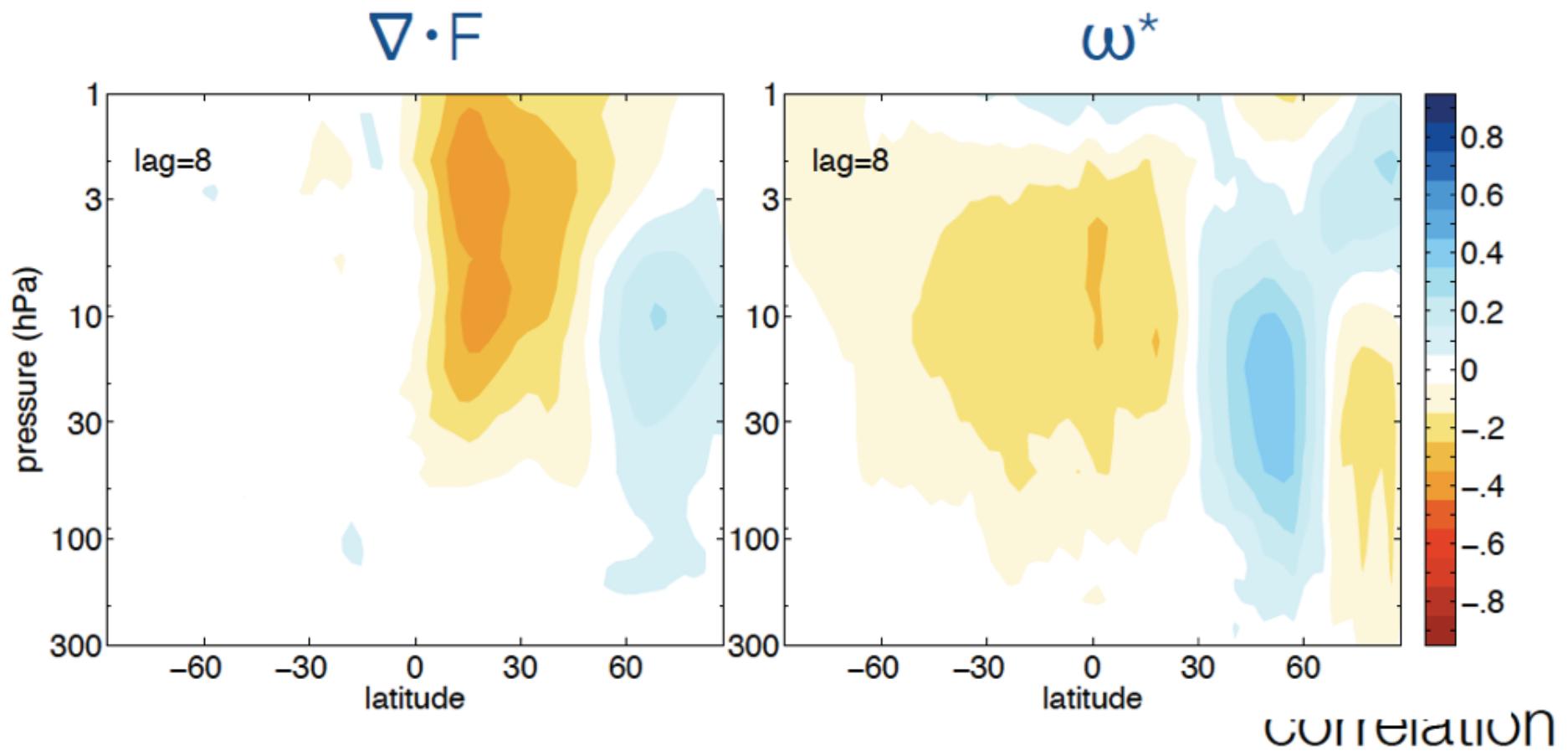
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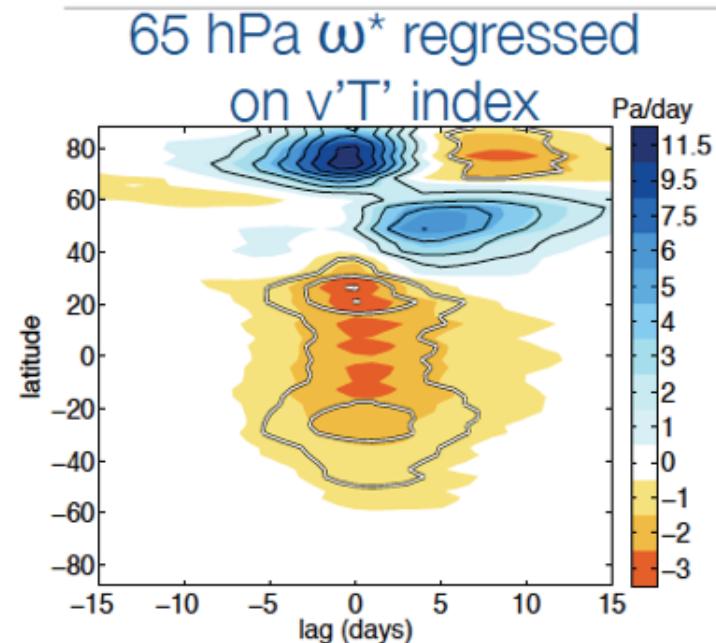
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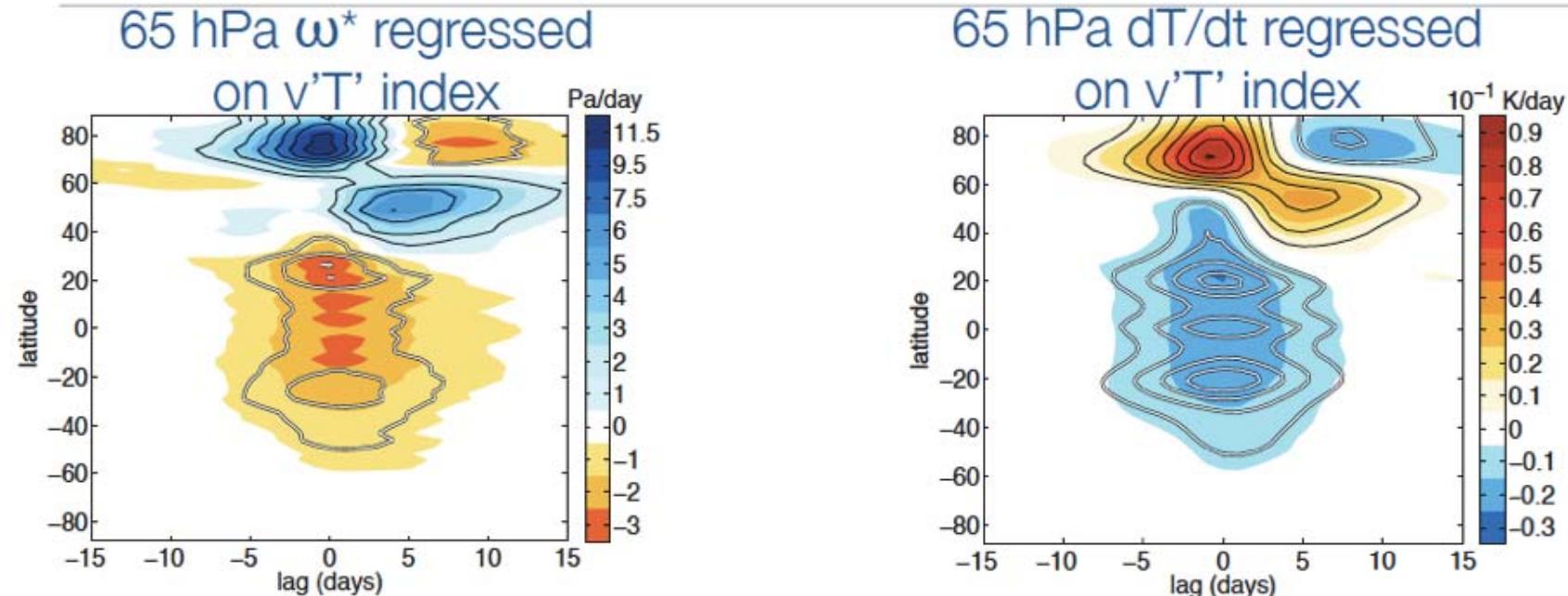


Winter hemisphere waves drive upwelling deep into summer hemisphere



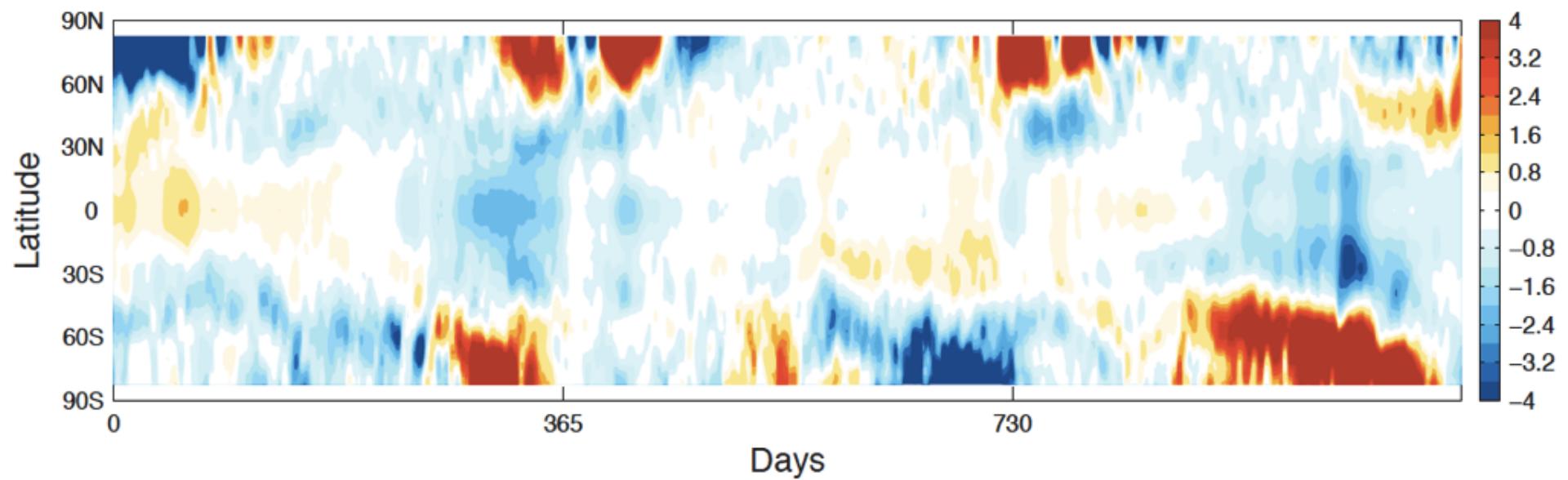
When waves enter extratropical stratosphere,  
tropical upwelling begins almost instantaneously,  
spreading deep into the summer hemisphere.

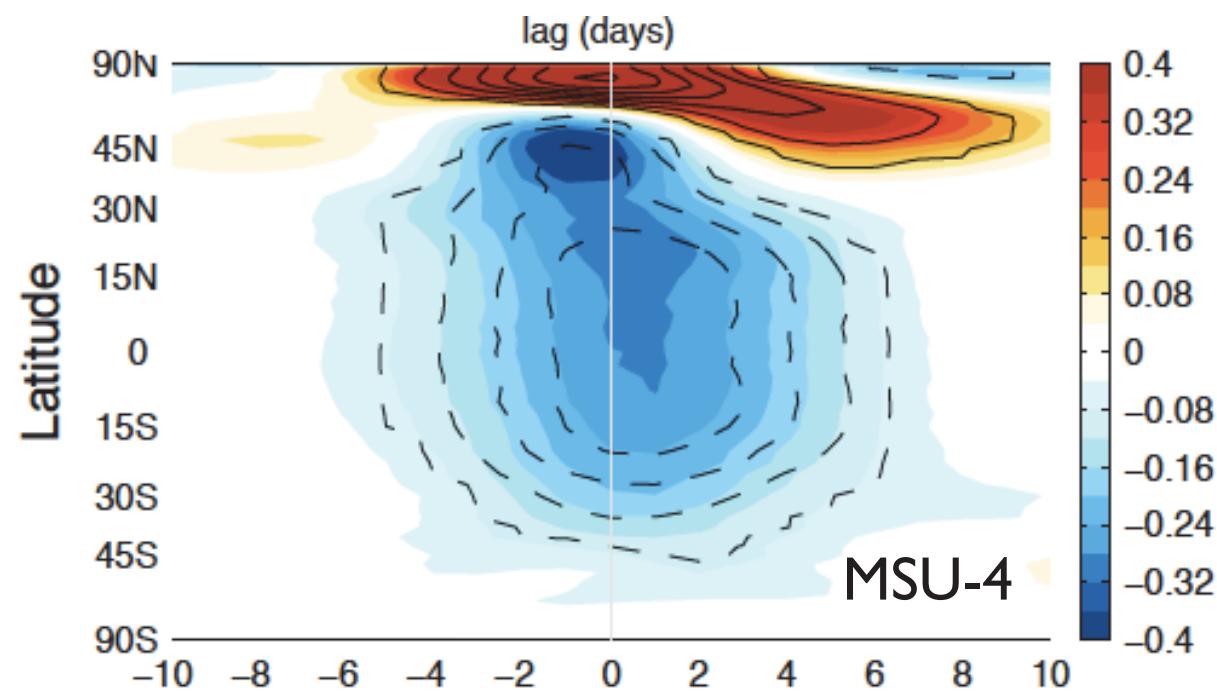
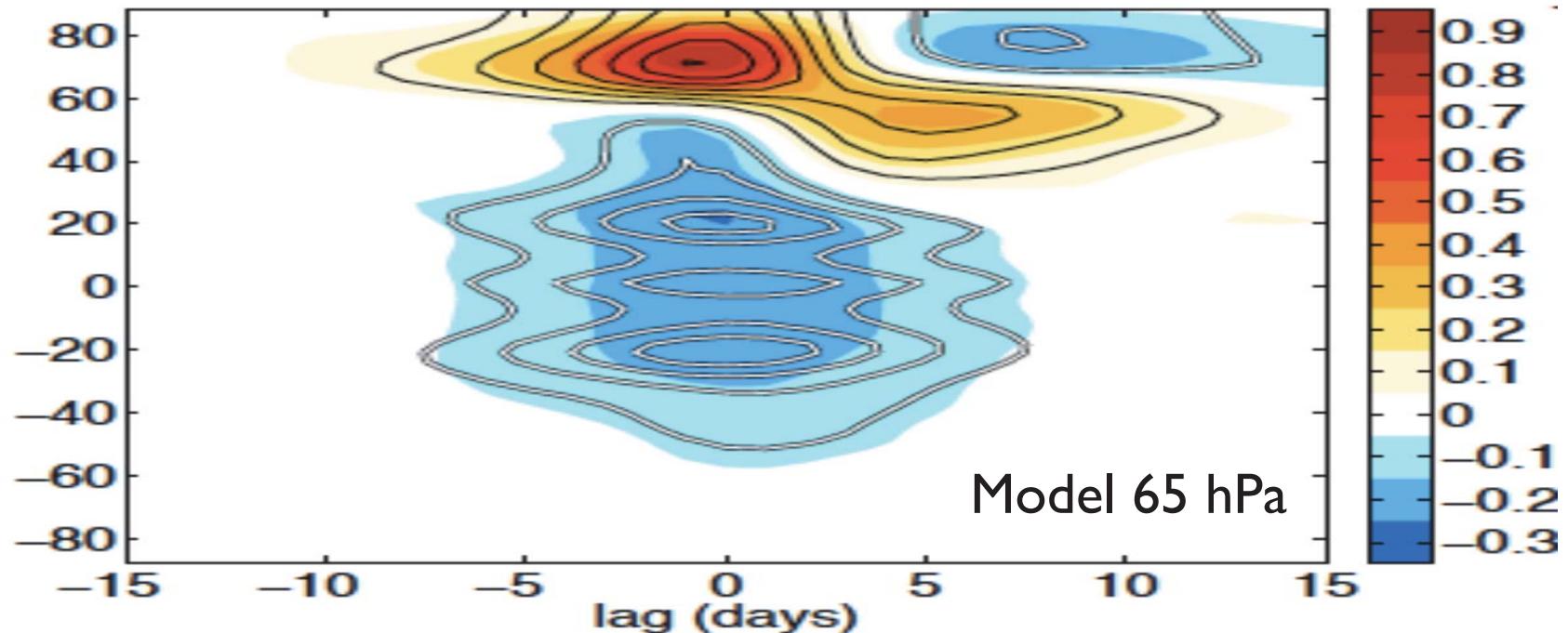
Winter hemisphere waves drive upwelling deep into summer hemisphere, cooling the tropics!



Upwelling induces low latitude cooling in both hemispheres

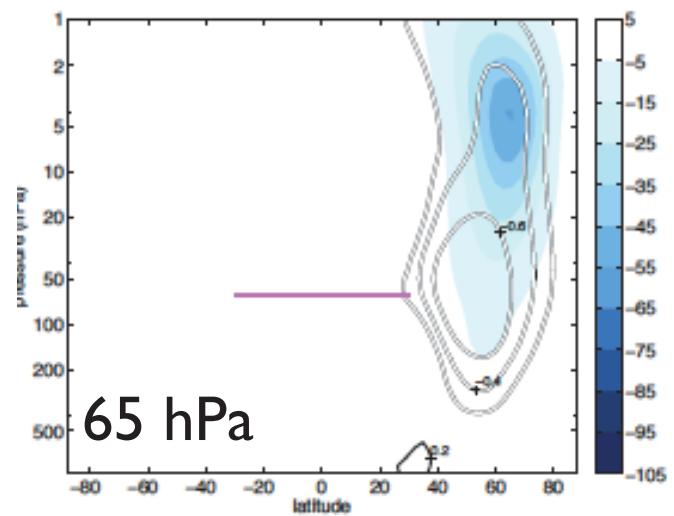
## MSU-4 2000-2004





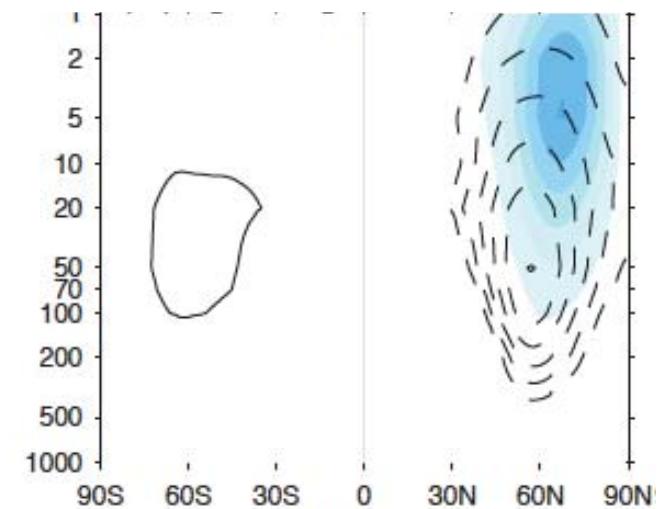
2-day  $\frac{\partial T}{\partial t}$   
regressed on  
 $\overline{v'T'}_{45-90^\circ N}^{100 \text{ hPa}}$

Model



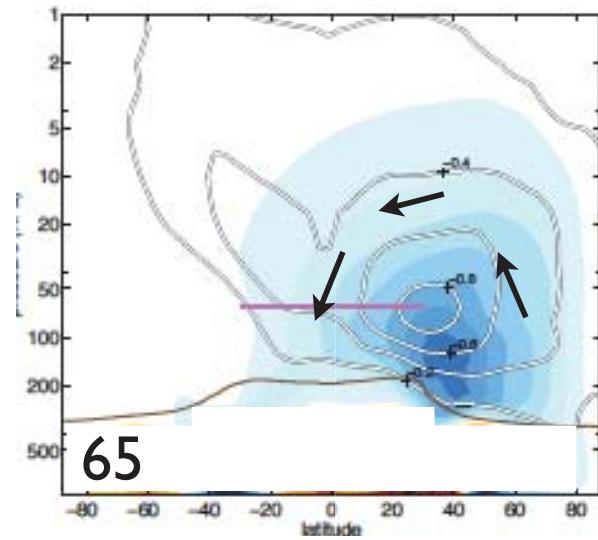
65 hPa

ERA on MSU-4

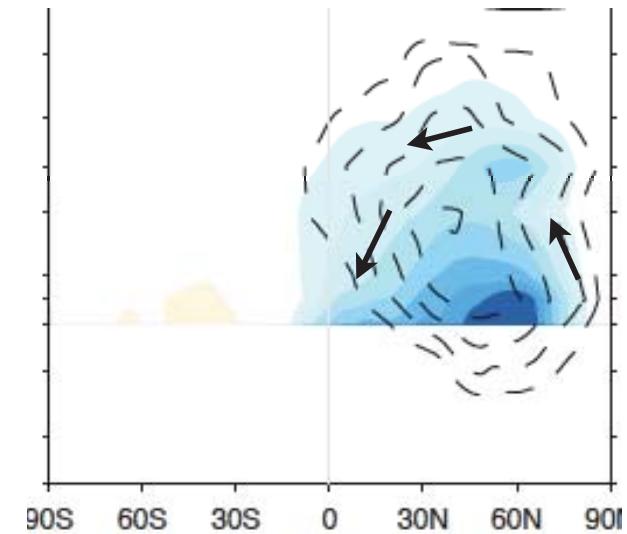


$$\overline{v'T'} \text{ upon daily } \frac{dT}{dt}_{30^\circ\text{S} - 30^\circ\text{N}}$$

Model

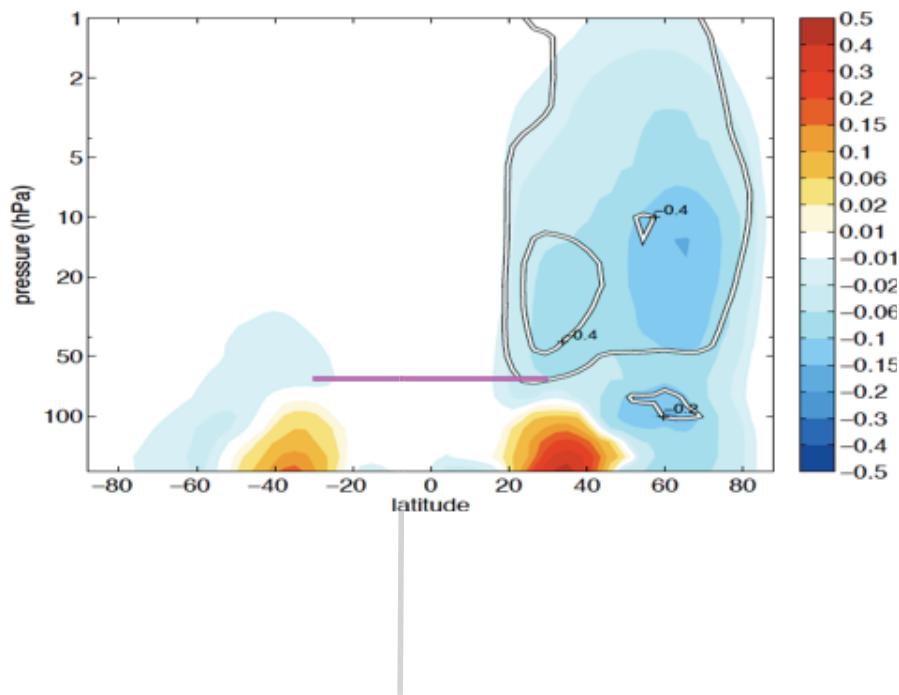


MSU / ERA

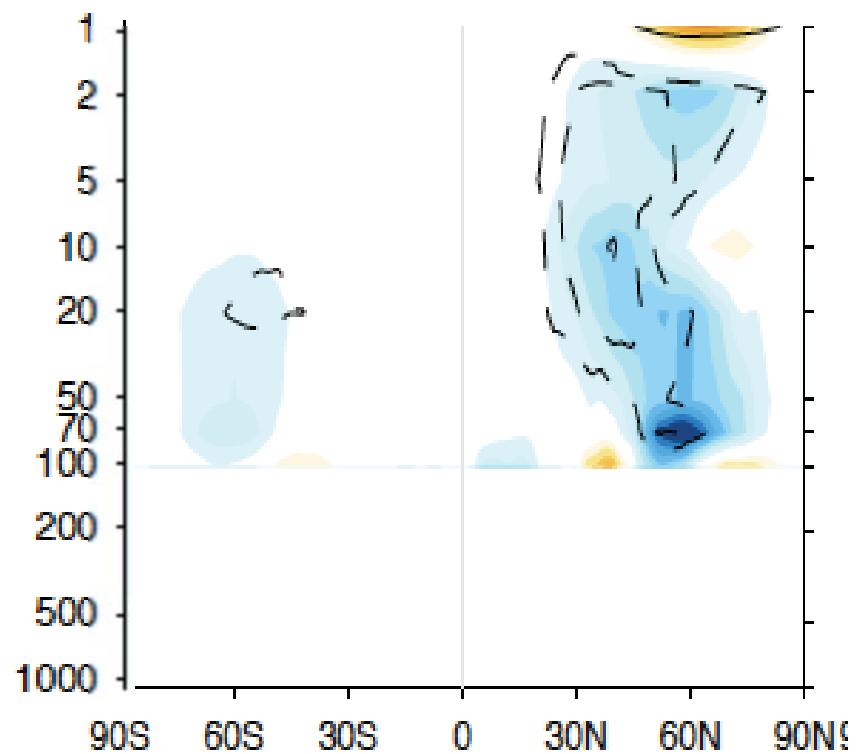


$$\psi_{\text{TEM}} \text{ upon daily } \frac{dT}{dt}_{30^\circ\text{S} - 30^\circ\text{N}}$$

Model

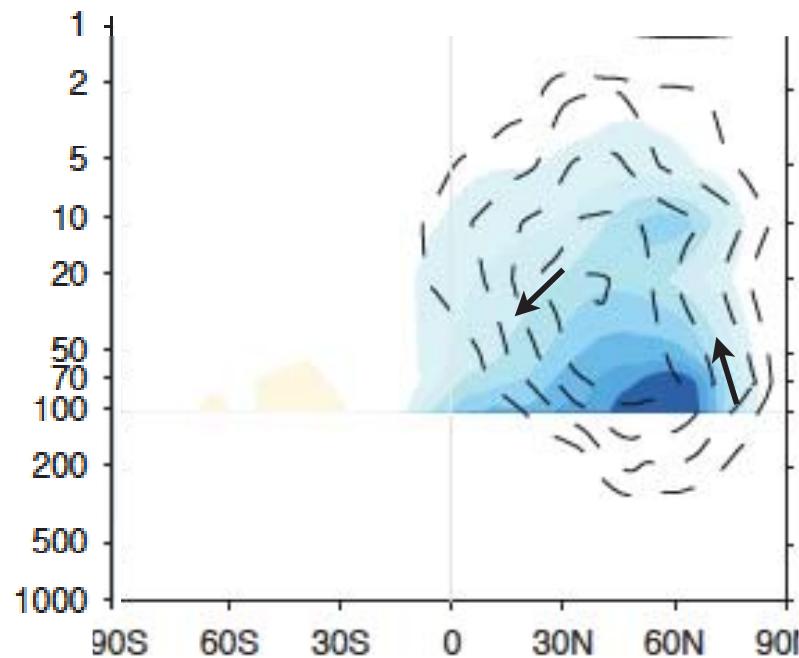


MSU / ERA

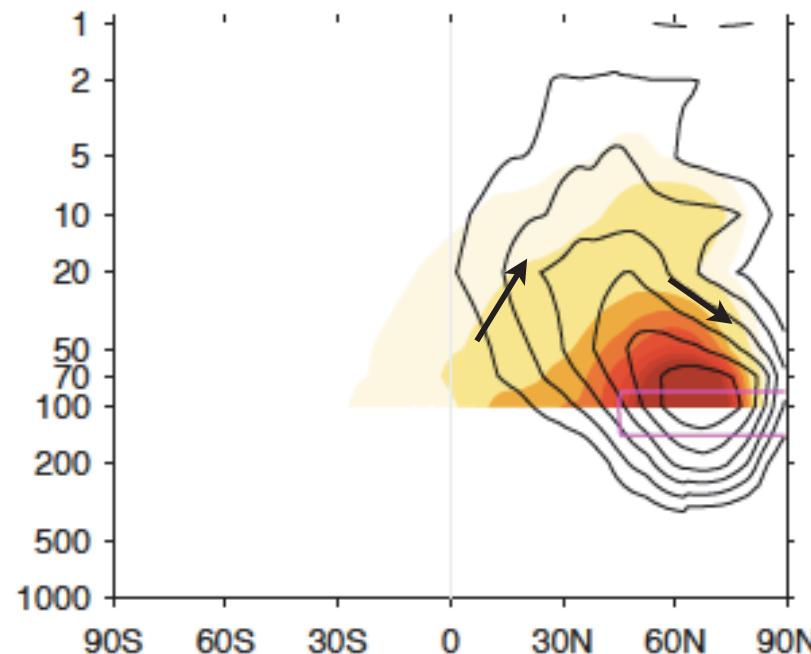


$$\nabla \cdot \vec{F} \text{ upon daily } \frac{dT}{dt}_{30^\circ\text{S}-30^\circ\text{N}}$$

$\psi$ <sub>TEM</sub> ERA

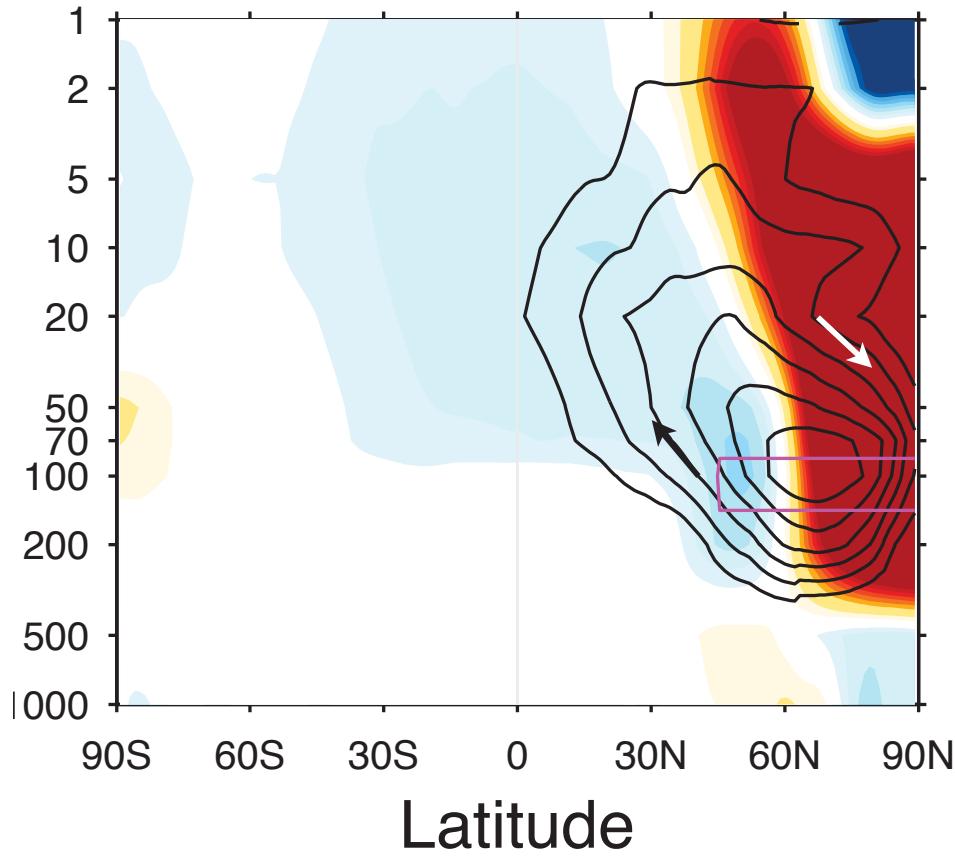


upon daily  $\frac{dT}{dt}$ <sup>MSU-4</sup>  
 $_{30^{\circ}\text{S}-30^{\circ}\text{N}}$

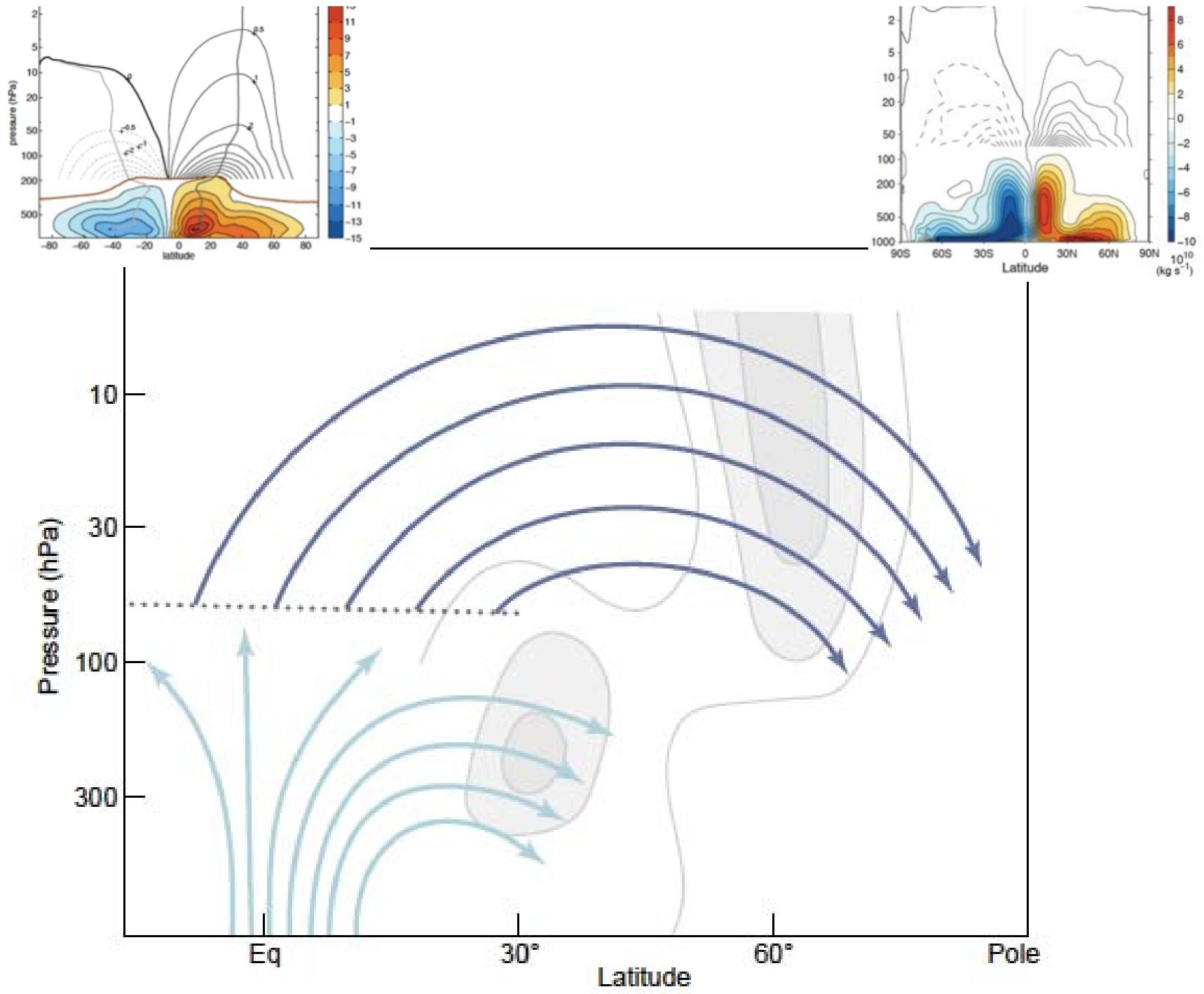


upon  $\overline{v'T'}^{100 \text{ hPa}}_{45^{\circ}-90^{\circ}\text{N}}$

ERA



regressed on  $\overline{v' T'}_{45^{\circ}\text{S}-90^{\circ}\text{N}}$  100 hPa



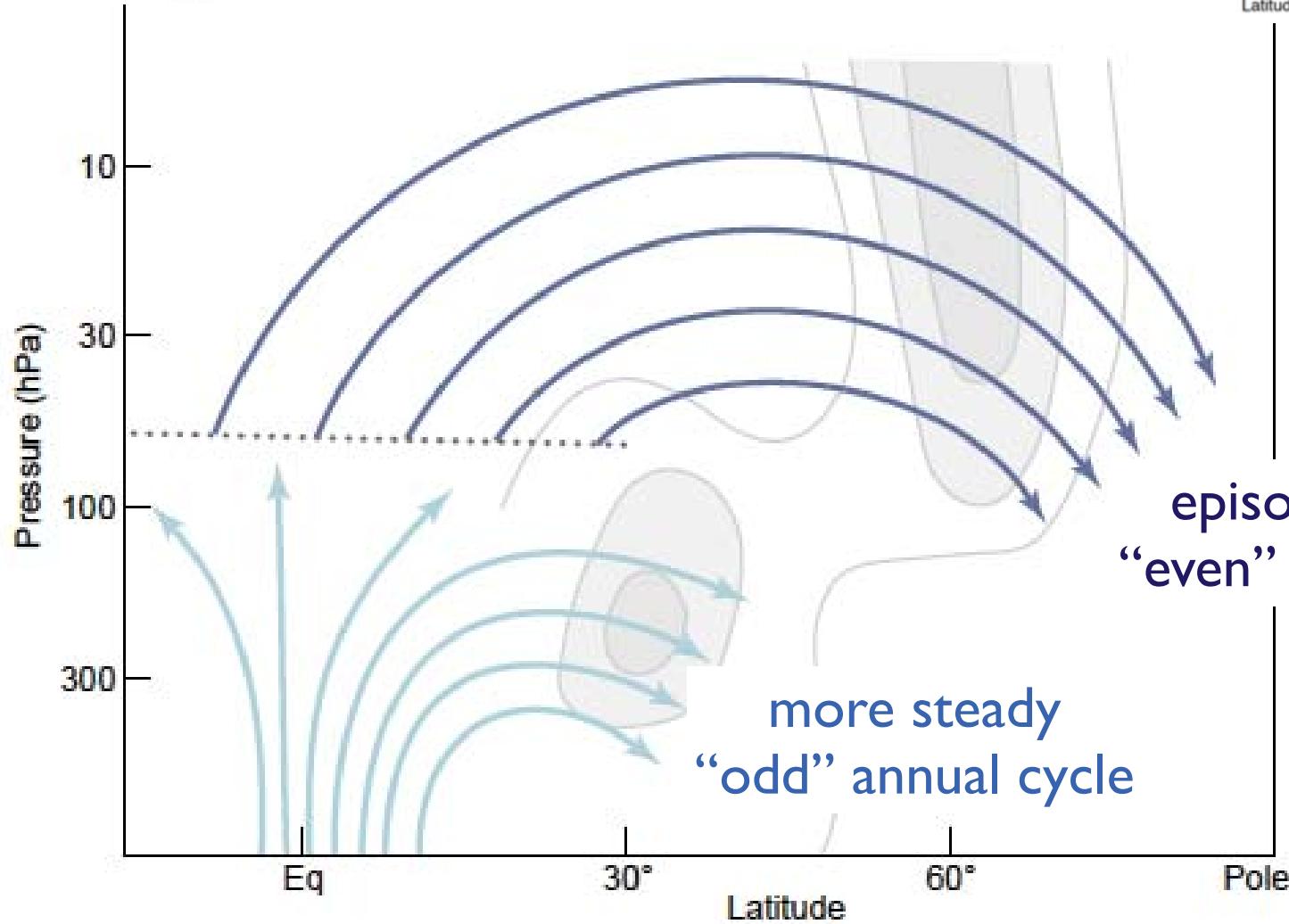
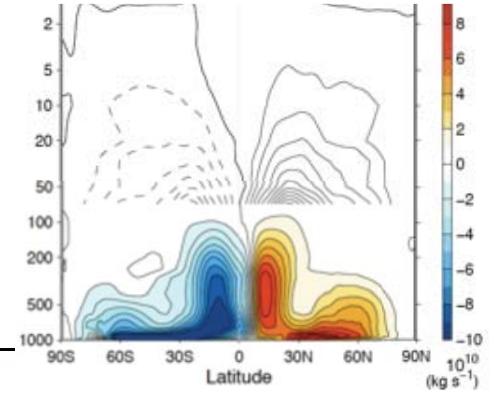
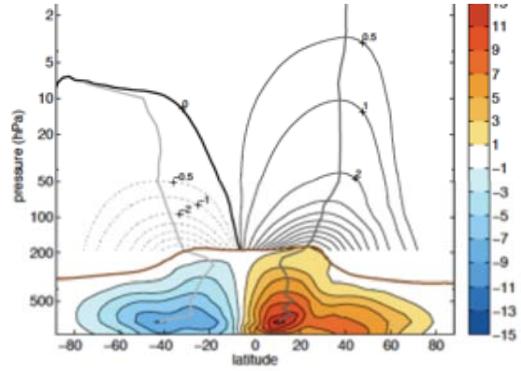
## Conclusions

Tropospheric forcing is predominant at the cold point (100 hPa)

Stratospheric forcing predominant above 70 hPa

MSU-4 mainly samples the upper branch.

Cold point temperature mainly influenced by lower branch



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Forcing field is planetary in scale

