A Climatology of Planetary Wave-Driven Mesospheric Inversion Layers in the Extratropical Winter

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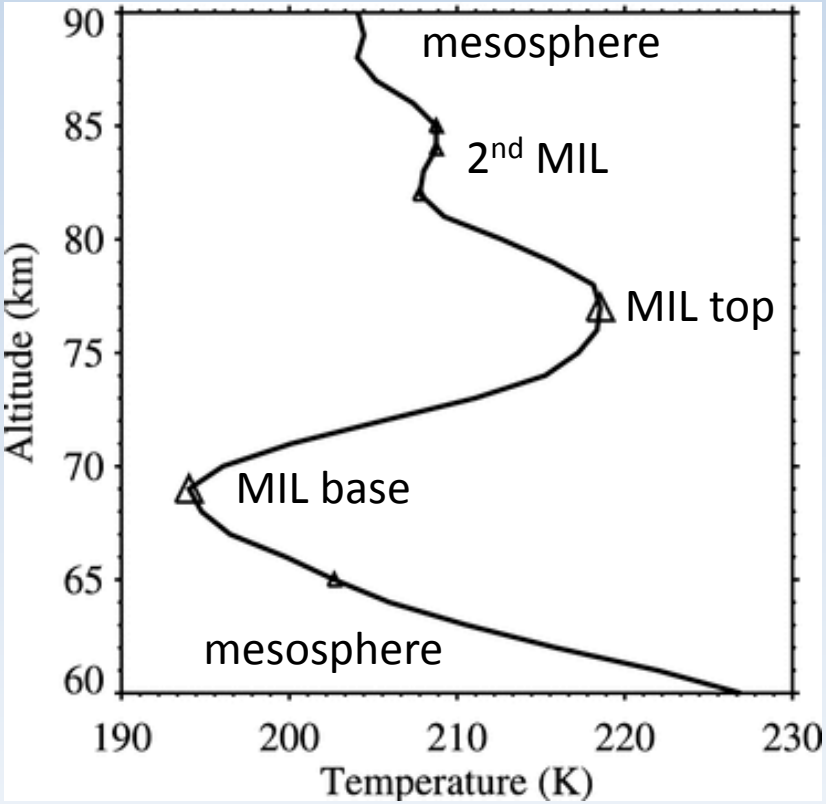
Overview

- Background and motivation
- Data
- Climatology of mid-to-high latitude winter MILs in SABER, MLS, and WACCM
- Roles of planetary waves in the formation of MILs

Mesospheric Inversion Layers (MILs) Diagnostics



Gan et al. [2012]

SABER T

Definitions:

MIL Altitude – altitude of upper large triangle at MIL top

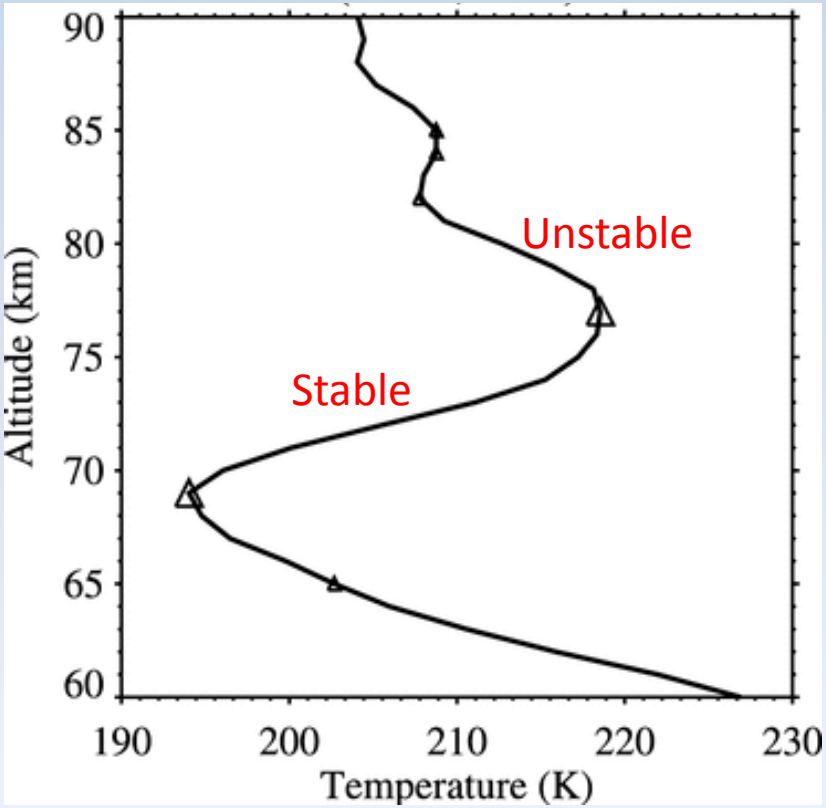
MIL Temperature – Temperature of upper large triangle at MIL top

Thickness – vertical distance between large triangles (MIL top minus MIL base, km)

Amplitude – temperature difference between large triangles (MIL top minus MIL base, K)

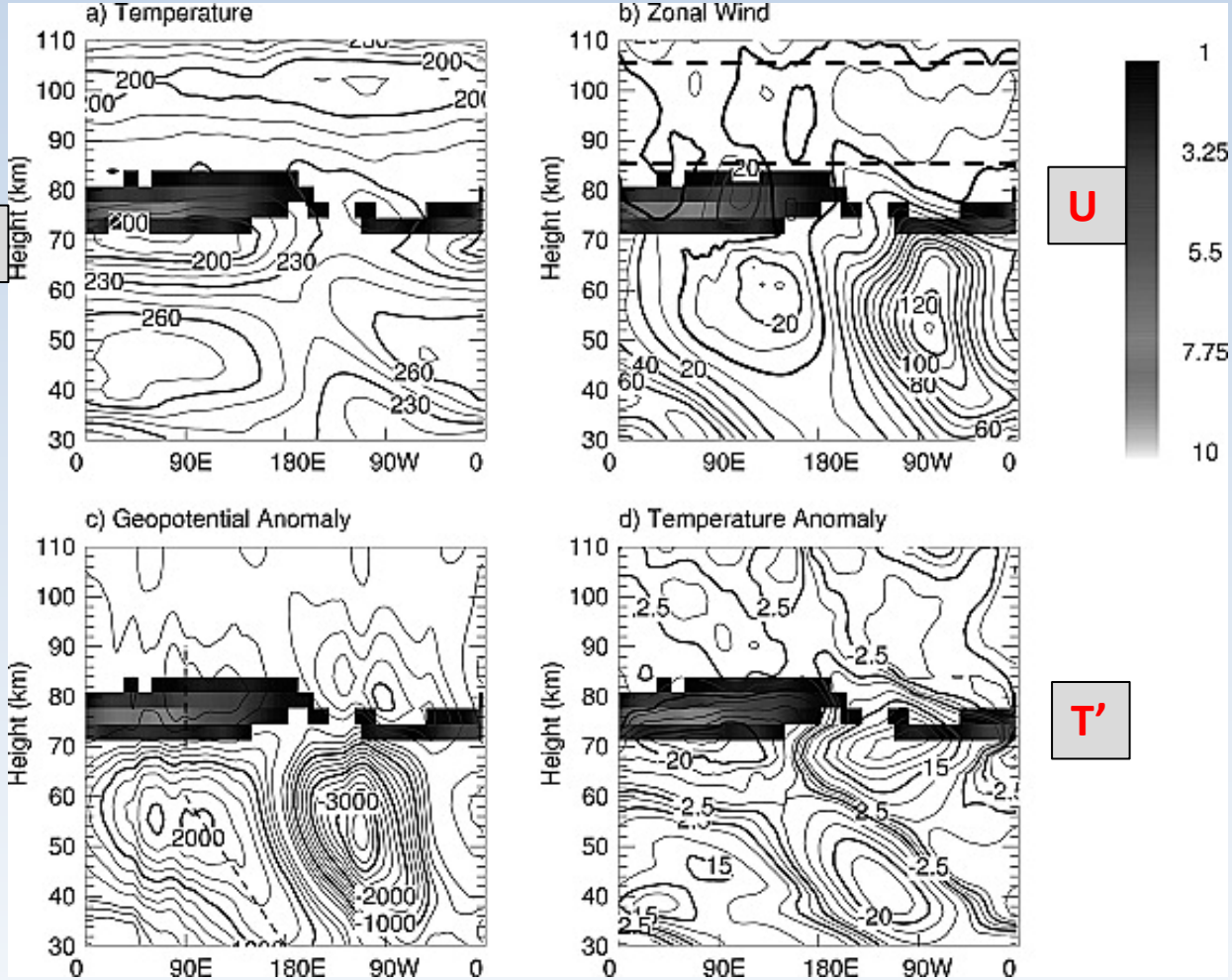
MILs affects atmospheric stability

- Stability
  - Enhanced stability between large triangles
  - Enhanced turbulence and gravity wave breaking above MIL
- Energy Transfer



Gan et al. [2012]

High latitude MILs atop anticylones in WACCM



Temp

U

Z'

T'

MIL location occurs preferentially above the positive geopotential anomalies.

***Sassi et al.* [2002]**

Goals of this Work

- What is the climatological geographical distribution of MILs in the context of the polar winter vortex and anticyclones?
- What is the role of planetary waves in generating climatological mid-latitude winter MILs as discussed by *Salby et al*. [2001] and *Sassi et al.* [2002]?
- How well does WACCM reproduce the observed geographical distribution of MILs?

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MLS and SABER

	Temperature Retrieval	Vertical Resolution	Profiles per Day	Date Range
MLS (v3)	O_2 emissions at 118 GHz and 190 GHz	6 km	~3500	Aug 2004 - present
SABER (v2)	from 15 μm and 4.3 μm bands of CO_2	3 km	~2200	Jan 2002 - present

SABER has better vertical resolution but limited coverage

- Community Earth System Model 1.0.3 WACCM4
- 40-year free running simulation, year 2000 time slice
- Finite-volume dynamical core [*Lin*, 2004]
- Non-orographic gravity wave parameterization for deep convection and frontal systems [*Richter et al.*, 2010]
- 1.9° latitude by 2.5° longitude
- 3.5 km vertical resolution above 65 km [*Garcia et al.,* 2007]

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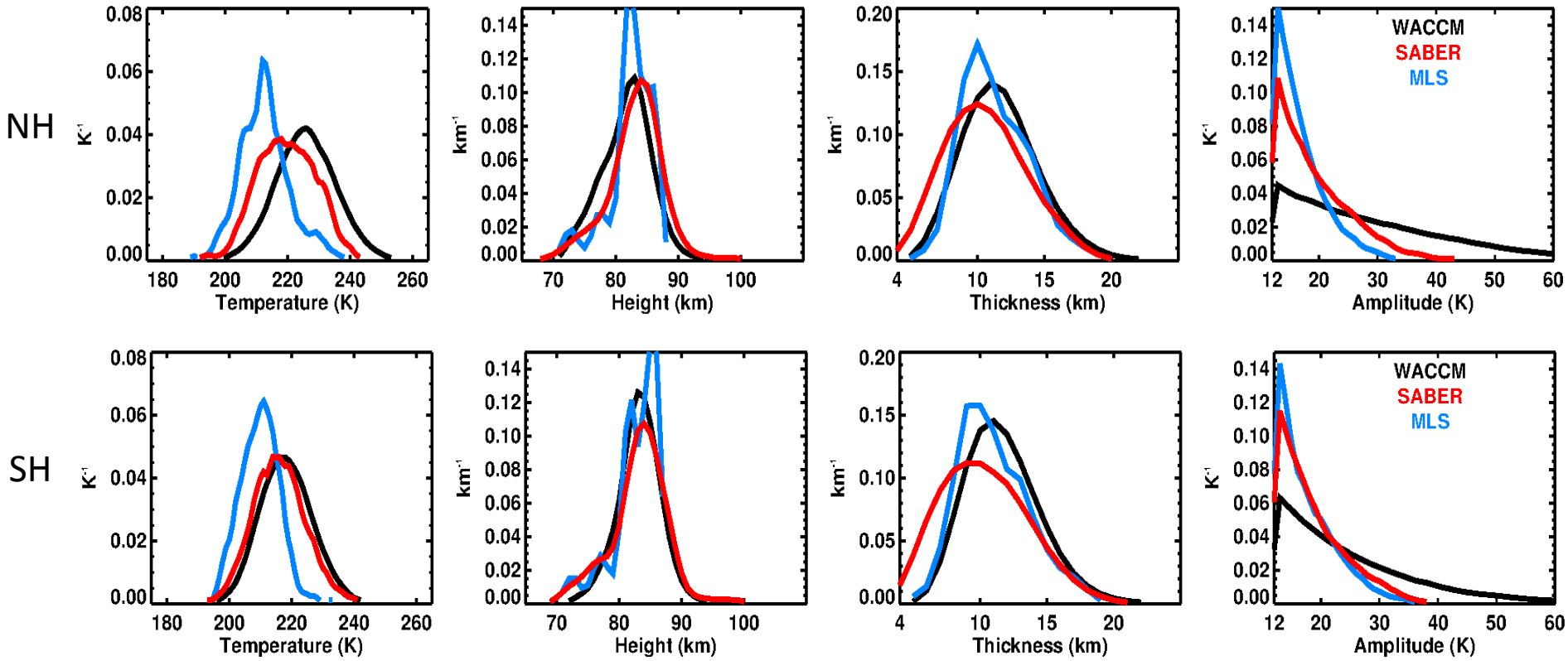
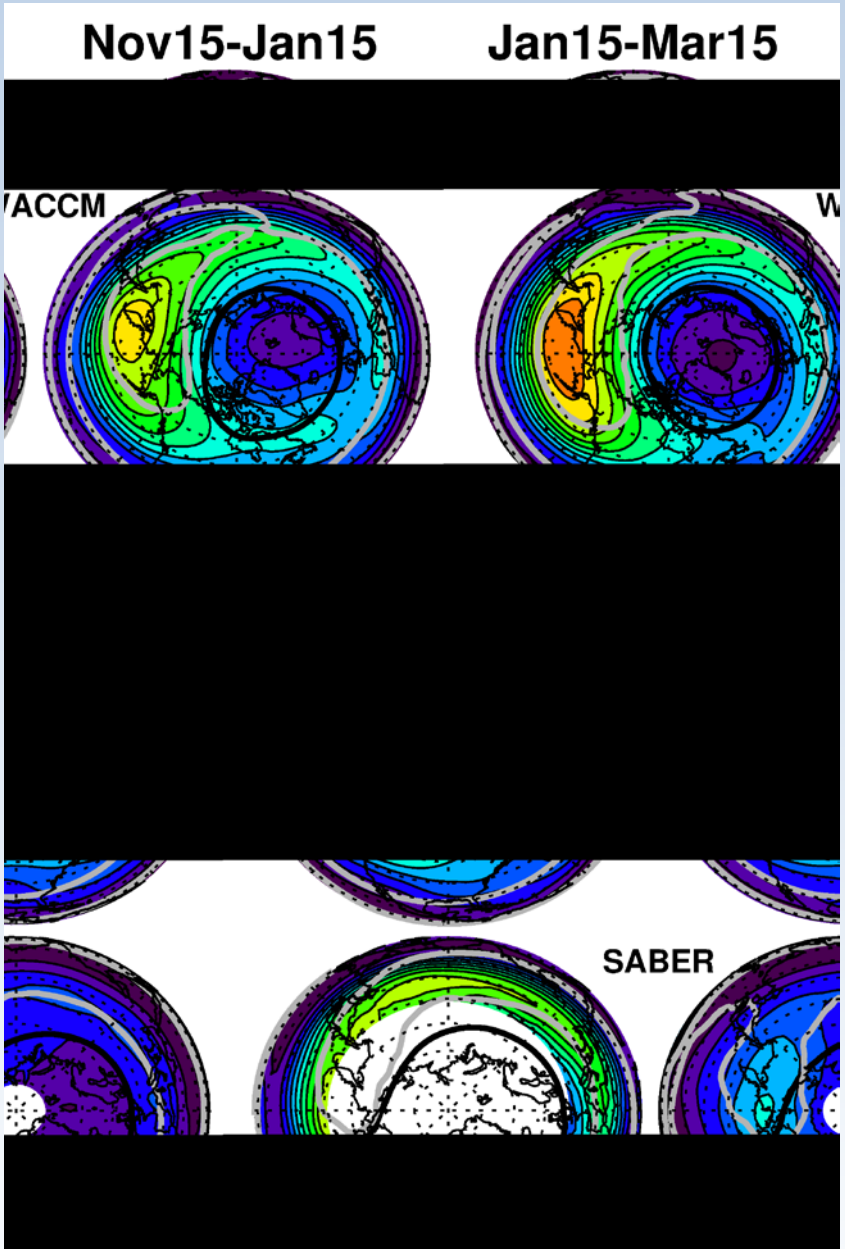
WACCM MIL statistics are in good agreement with MLS and SABER



Northern Hemisphere MILs: zonal asymmetries

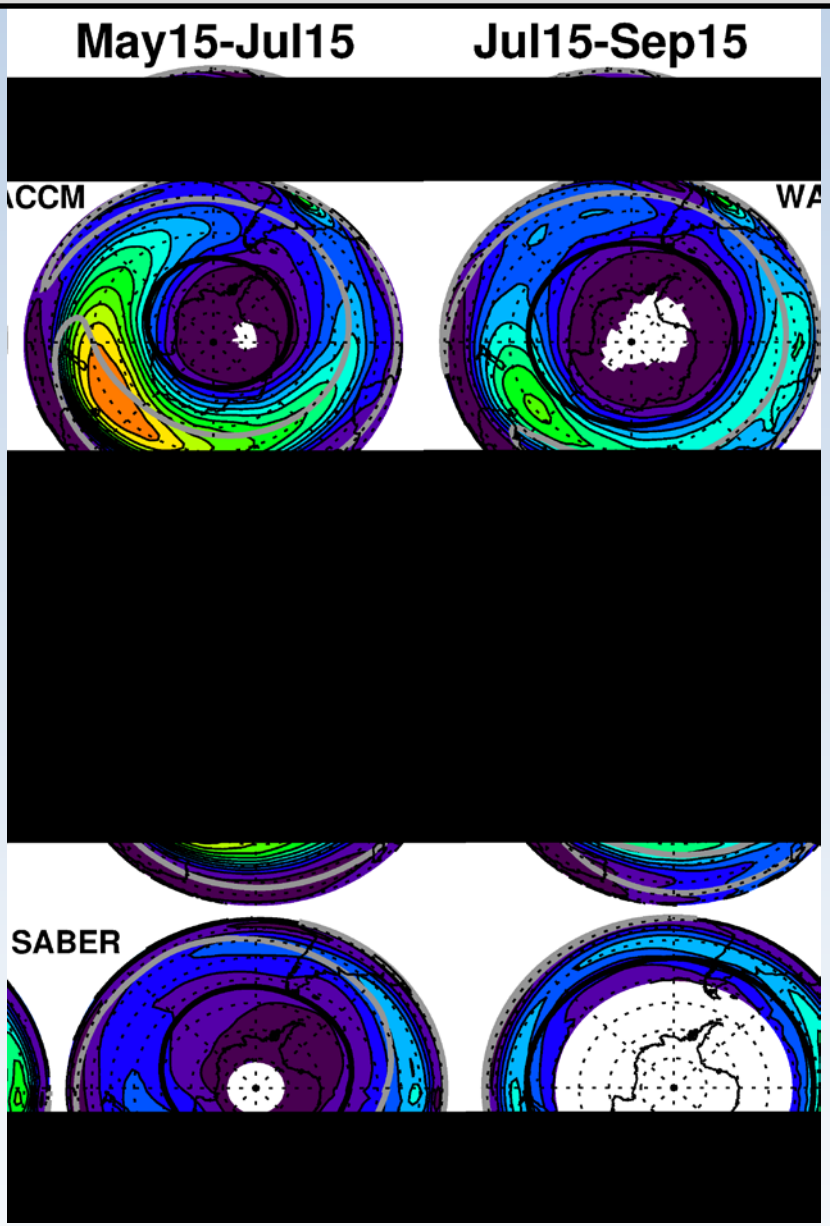
- Max MIL frequencies above the Aleutian High
- Few MILs above the vortex



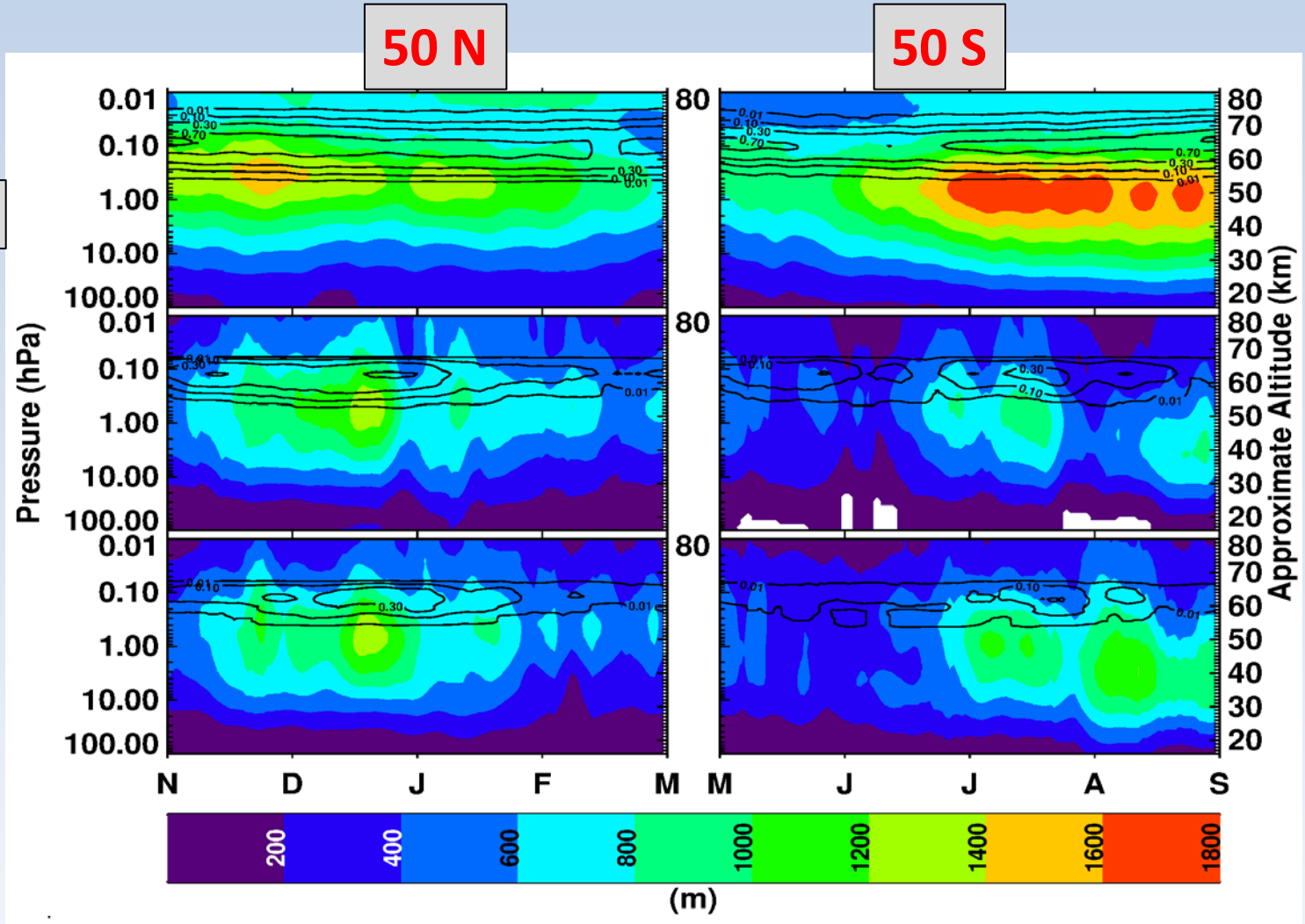
Southern Hemisphere MILs: zonal asymmetries

- Early winter MILs confined to lower latitudes in the data.
- Why are MIL frequencies so high in WACCM?

-> Differences in PWs.



MILs + Planetary wave amplitudes



MILs occur when PWs are large

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Mathematical Formulation: Role of planetary waves in MIL formation

We can express the lapse rate in terms of the geopotential:

$$\Gamma = -\frac{\partial T}{\partial z}$$

$$\frac{\partial \Phi}{\partial z} = \frac{RT}{H}$$

$$\Gamma = -\frac{H}{R}\frac{\partial^2 \Phi}{\partial z^2}$$

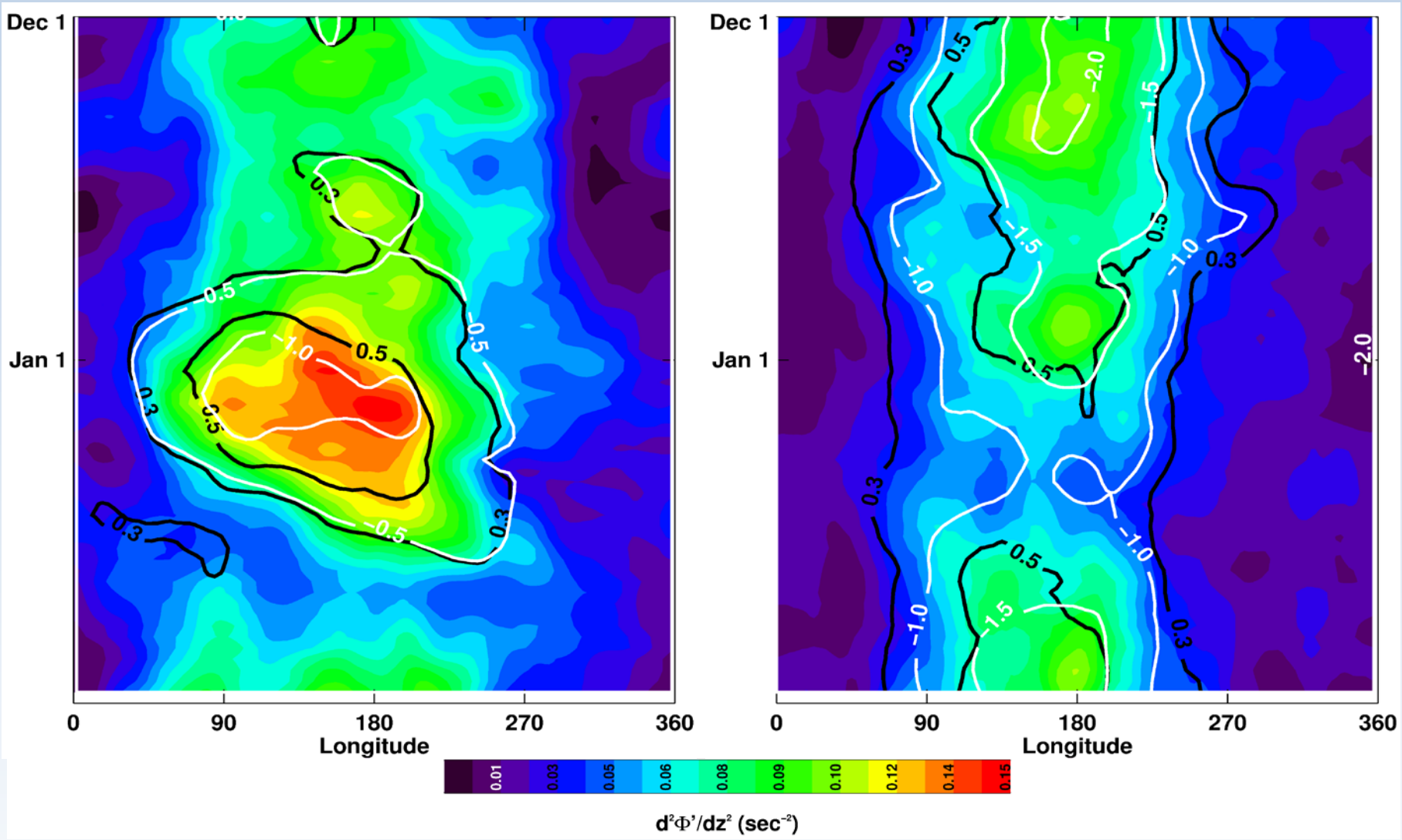
Breaking the lapse rate into a zonal mean and wave component:

$$\Gamma = \bar{\Gamma} + \Gamma'$$

$$\Gamma' = -\frac{H}{R}\frac{\partial^2 \Phi'}{\partial z^2}$$

From *Salby et al.* [2001]

Positive curvature is well correlated with MIL formation



In both MLS and WACCM, MILs occur in regions of large curvature

Conclusions

- MILs are driven by the decay of vertically propagating planetary waves in the mesospheric surf zone
- MILs occur climatologically atop the stratospheric anticyclones
- MILs in WACCM occur in the same geographical regions as in observations, though it generally overestimates PW amplitudes and MIL frequencies

Thanks!