Comparing the gravity wave parameterization in WACCM to observations

Anne Smith

working with Rolando Garcia, Doug Kinnison, Sean Santos, Damian Murphy, Francis Vitt

What can we constrain with observations?

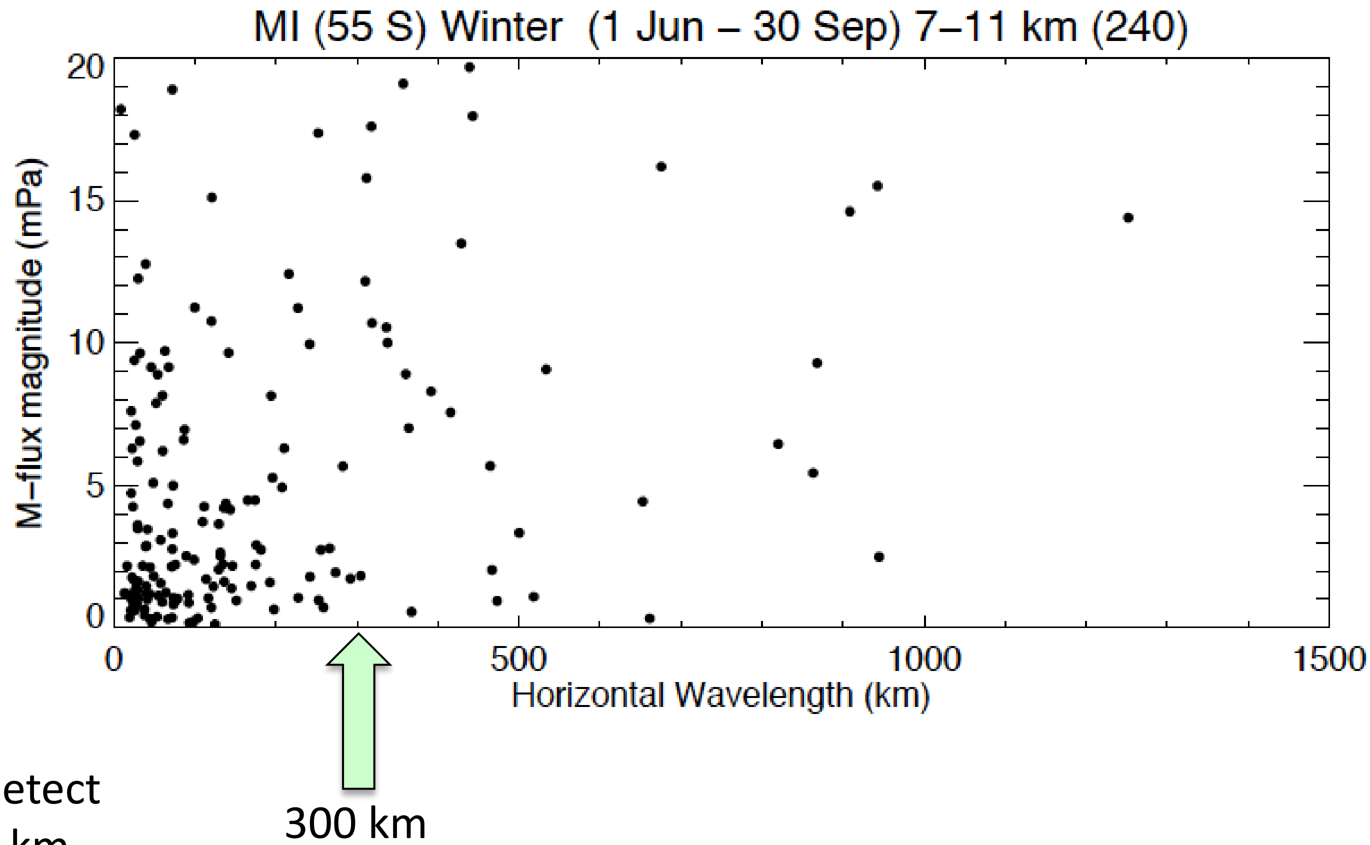
- gravity wave parameters
  - horizontal wavelength
  - range of phase speeds
- gravity wave distribution
  - seasonal variation
  - latitude, longitude where they occur
  - dissipation/breaking level
  - intermittency
- atmospheric response
  - temperature in polar SH lower stratosphere
  - O_3 in polar SH lower stratosphere
  - temperature & winds throughout middle atmosphere
  - planetary waves and sudden warmings

Changes to GW parameterization

- inertia-gravity waves
  - propagation affected by Earth's rotation
  - triggered by same frontal threshold as mesoscale GW
  - horizontal wavelength 300 km
  - narrow spectrum in phase speed centered on wind in lower troposphere (meant to capture speed of storm system)
- orographic gravity waves
  - removed a factor of "landfrac" which does not seem correct in general
  - enhanced momentum flux forcing (x 2) in Southern Hemisphere
- other
  - mesoscale frontal wave unchanged
  - convectively forced waves unchanged

Horizontal wavelength of observed waves (55°S)

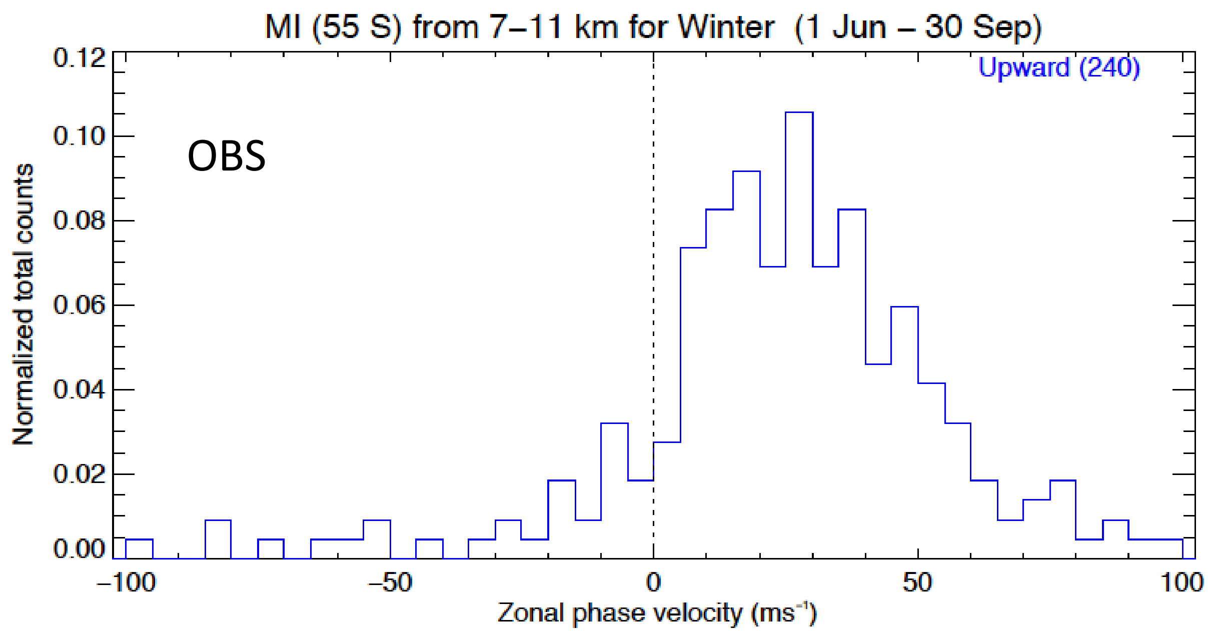
Momentum flux vs horizontal wavelength for upward propagating waves in the upper troposphere at Macquarie Is, winter (analysis from radiosondes)



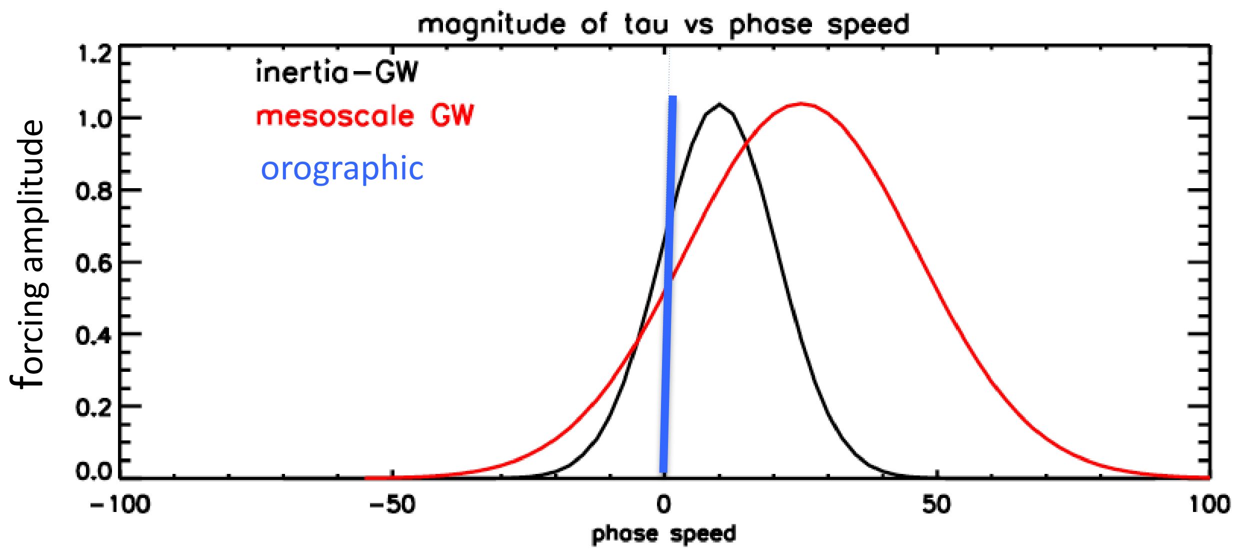
- observations rarely detect waves with $L_h > 1000$ km
- observations of waves with wavelength $L_h < 300$ km is much more frequent

Phase speed relative to ground (55°S, winter)

Phase speed distribution for upward propagating waves in the upper troposphere at Macquarie Is, winter



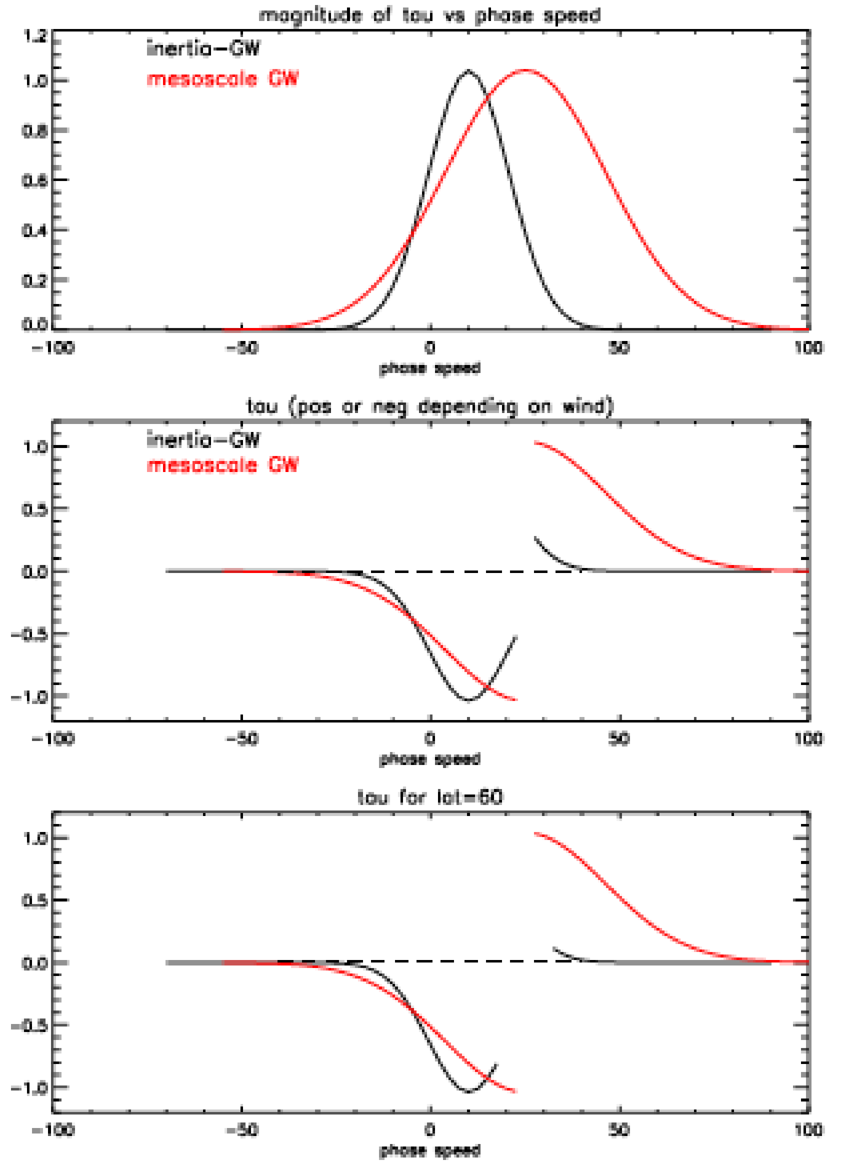
WACCM forcing amplitude vs phase speed (shifted by the mean wind at launch level or wind near surface)



Momentum flux vs phase speed

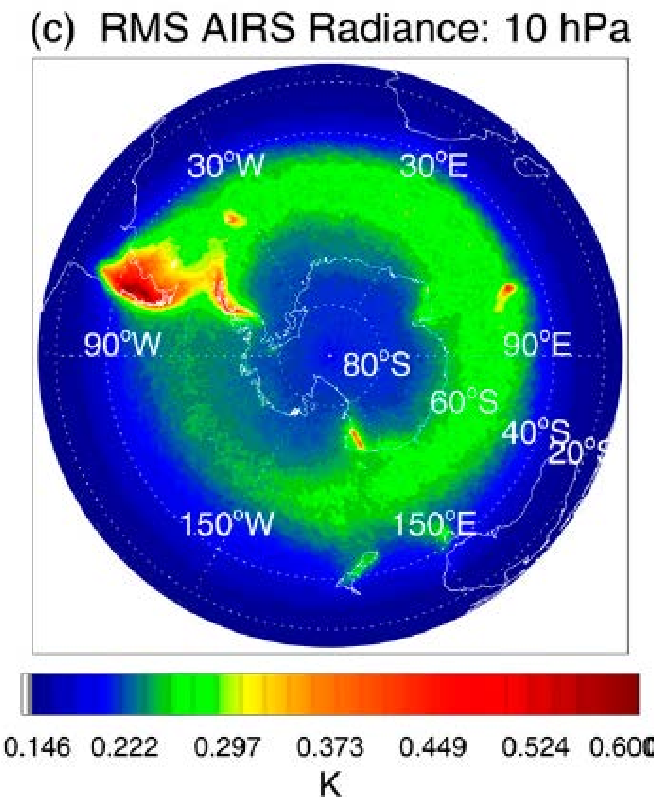
WACCM forcing

- *For inertia-GW, phase speed spectrum is narrow and is centered on speed of storm system*
- *For mesoscale GW, phases speed spectrum is centered on wind speed at the launch level*
- *RESULT: inertia-GW momentum flux is mostly negative but mesoscale flux is evenly split between positive and negative*
- *Recent modeling work (not yet published) supports the prevalence of negative momentum flux (leading to westward forcing)*



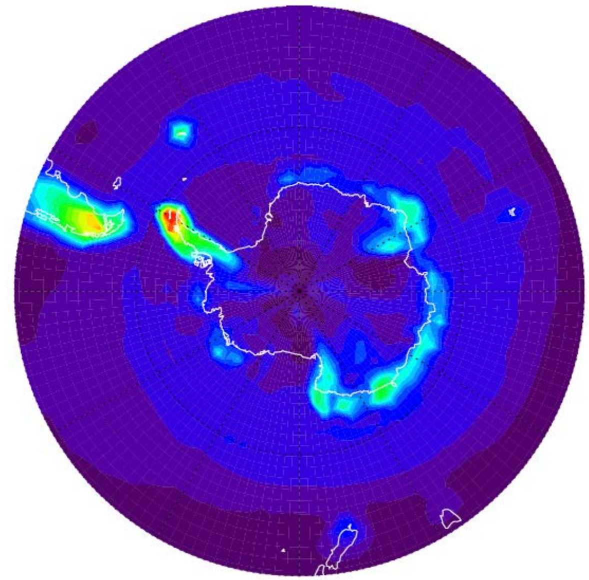
Horizontal distribution of wave activity

RMS brightness temperature amplitude from AIRS

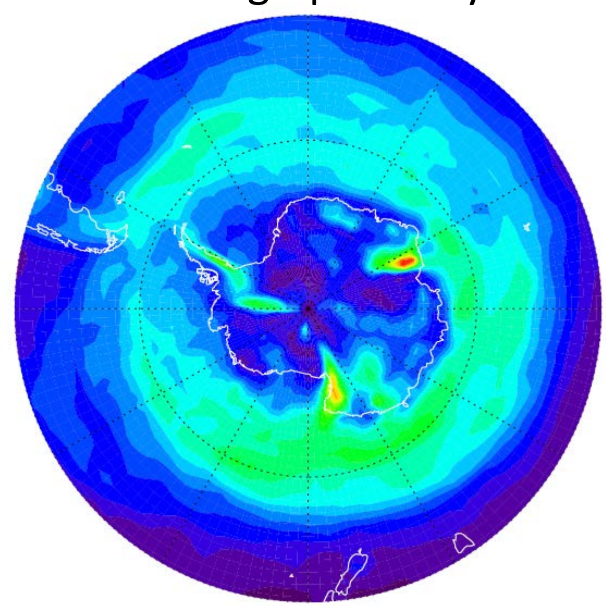


from Hendricks et al., J. Atmos. Sci., 2014

WACCM GW flux (10 hPa, same months)
all waves

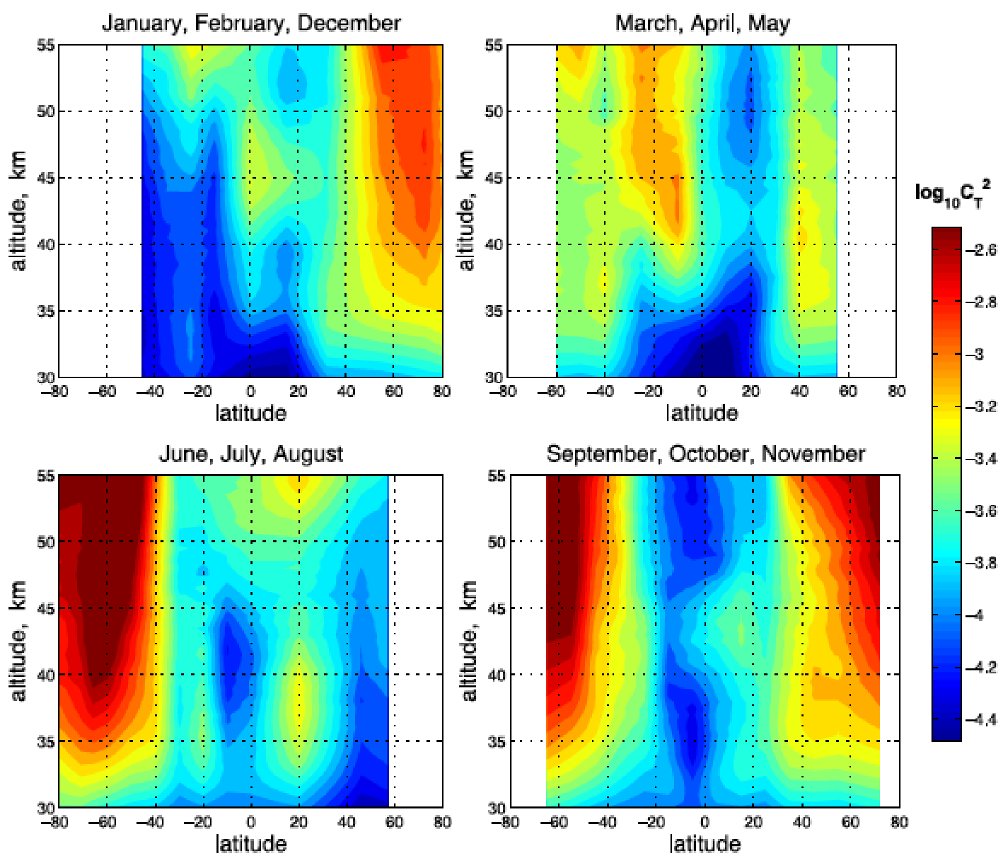


non-orographic only



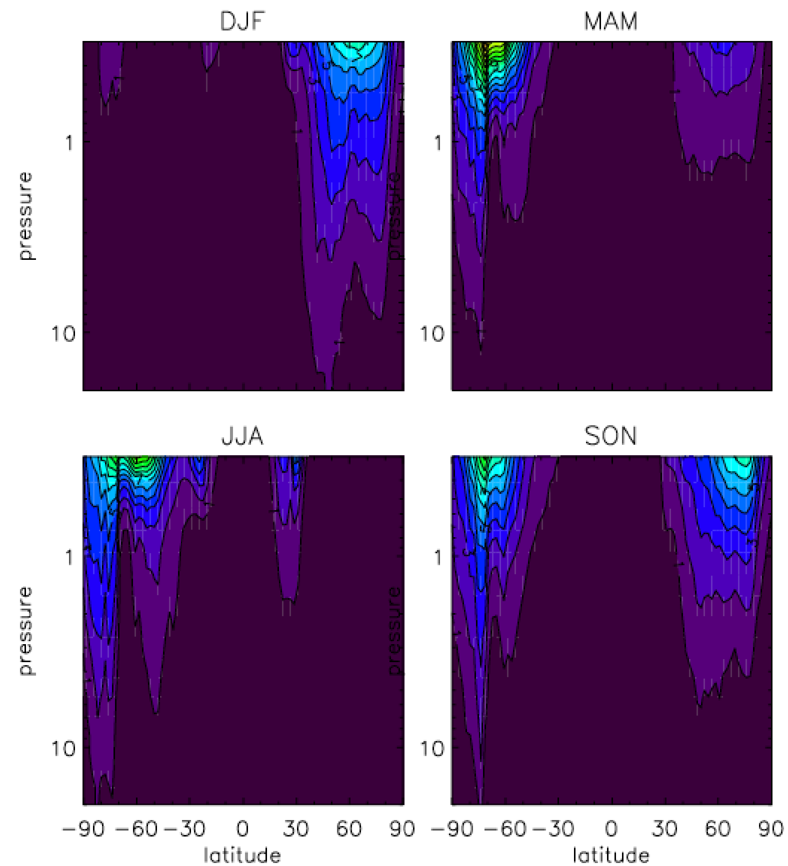
observational support for gw momentum forcing in the SH winter stratosphere

scintillation from stellar occultation
-> a measure of turbulence
-> signal not well correlated with topography



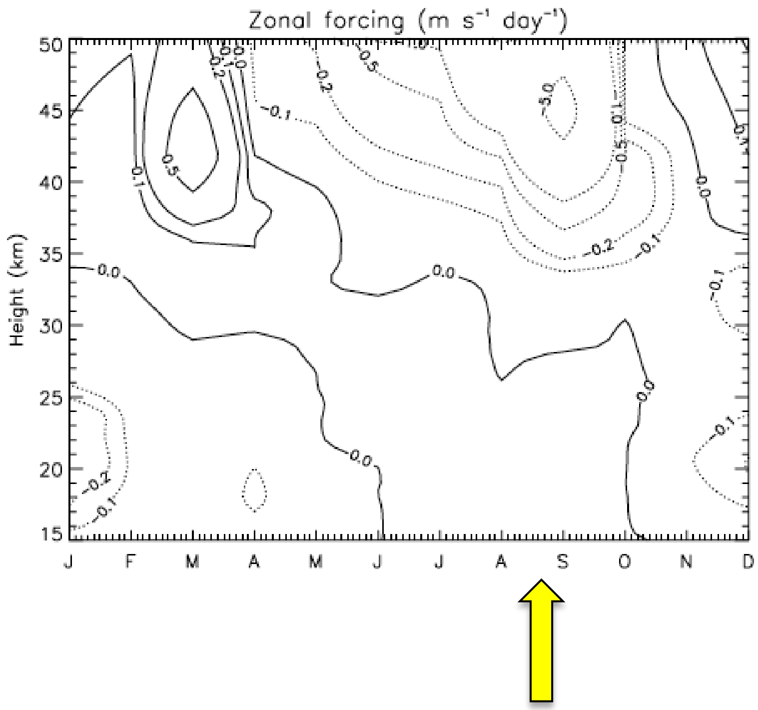
Gurvich et al, GRL, 2007

WACCM magnitude zonal GWD
(all waves)



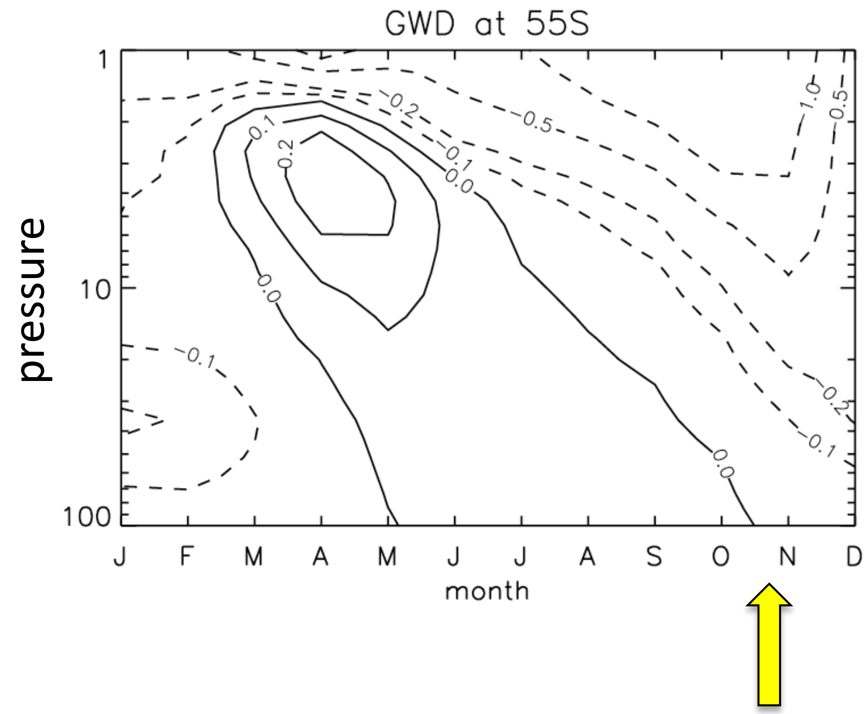
forcing by GW derived from radiosonde obs

momentum forcing derived from radiosondes at 55°S



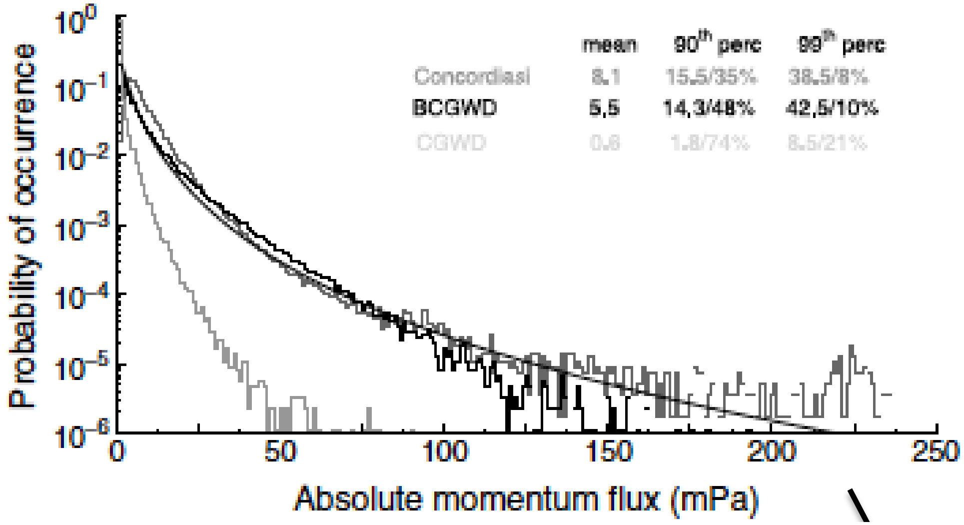
Zink and Vincent, JGR, 2001

WACCM



WACCM magnitude is a bit low but variation is realistic.
Timing is delayed

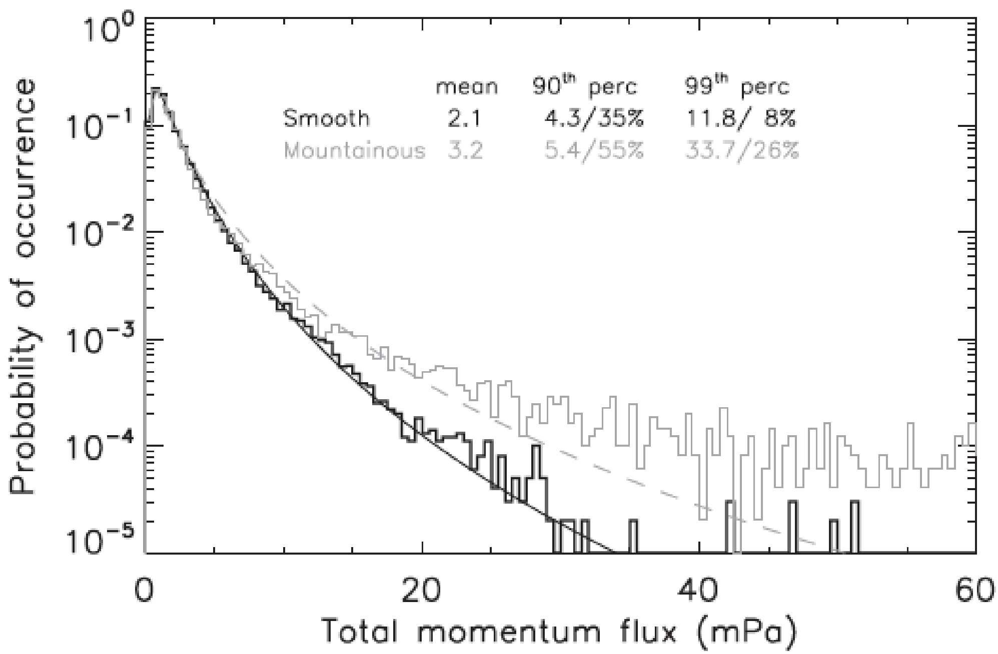
momentum flux from balloon obs



de la Camarra et al., JGR, 2014

Waves with large upward flux occur but are rare.

WACCM: fluxes are ~1-200 mPa and intermittencies are ~1/5 to ~1/500



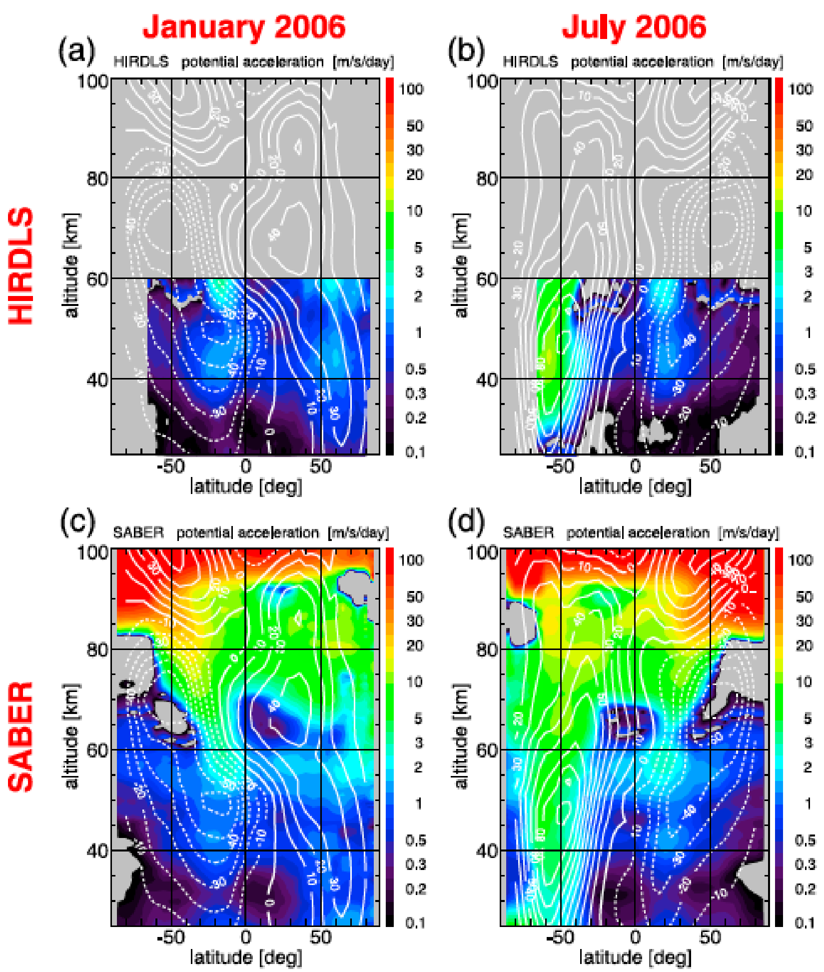
Herzog et al., JAS, 2012

Momentum fluxes higher over mountainous terrain.

WACCM:
orographic fluxes >> non-orographic

what is the principal source of GW SH/NH asymmetry in the winter stratosphere?

estimated GWD magnitude for resolved waves

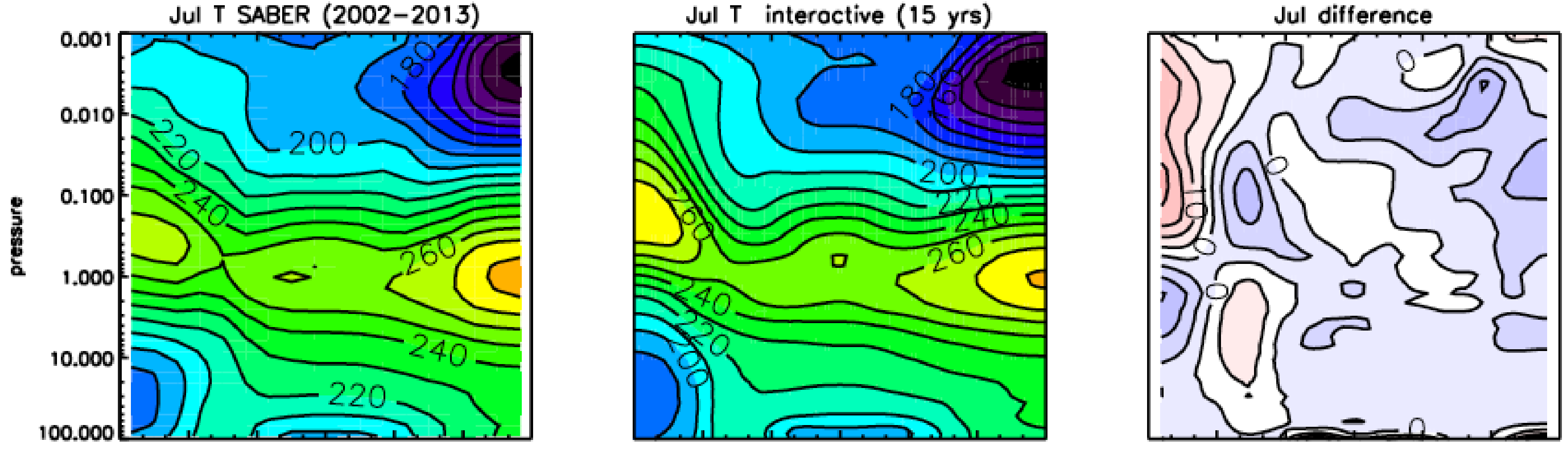


Ern et al., JGR, 2011

- There are many observations that indicate enhanced GW fluxes and/or GW drag in the SH winter stratosphere compared to the NH.
- Some obs. show strongest relation to topography; others to storm tracks.
- Current WACCM parameterization does not find the same hemispheric asymmetry in either orographic or frontal GW sources.
- What sources are missing and/or not well represented?
- Possibilities:
  - relative strength of baroclinic storms not right (not captured in the WACCM trigger)
  - orographic forcing underestimated because of orientation of ridges & winds
  - orographic GW with non-zero phase speed neglected

monthly T: WACCM vs SABER

July



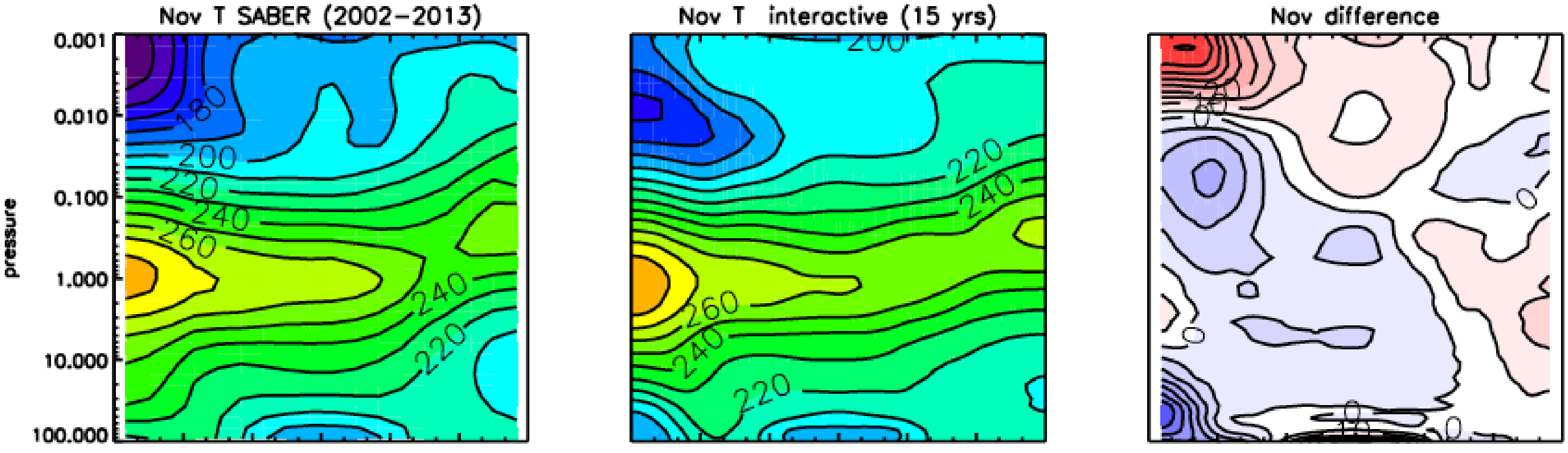
(WACCM-SABER)

SH lower stratosphere temperature looks OK

NH temperature looks OK

monthly T: WACCM vs SABER

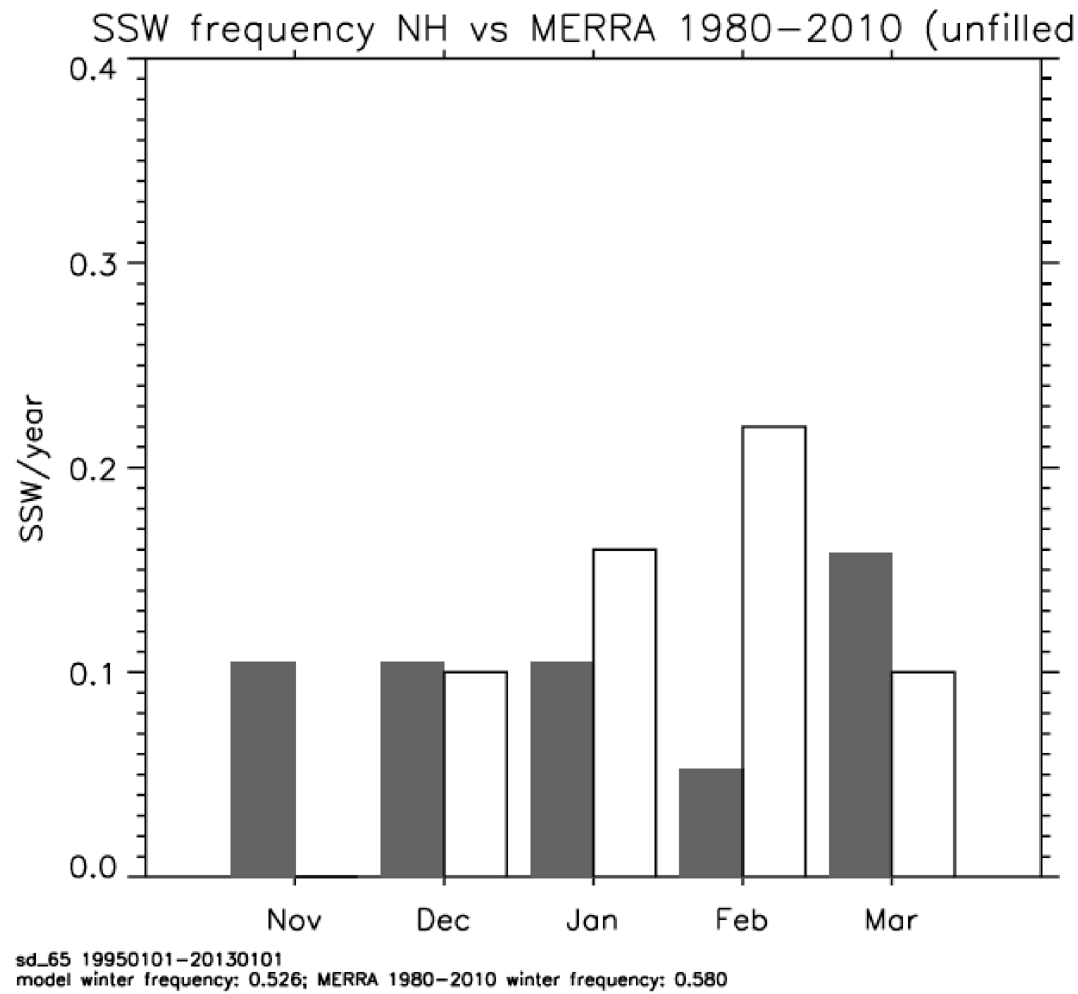
November



SH lower too cold

“summer” mesopause has not developed

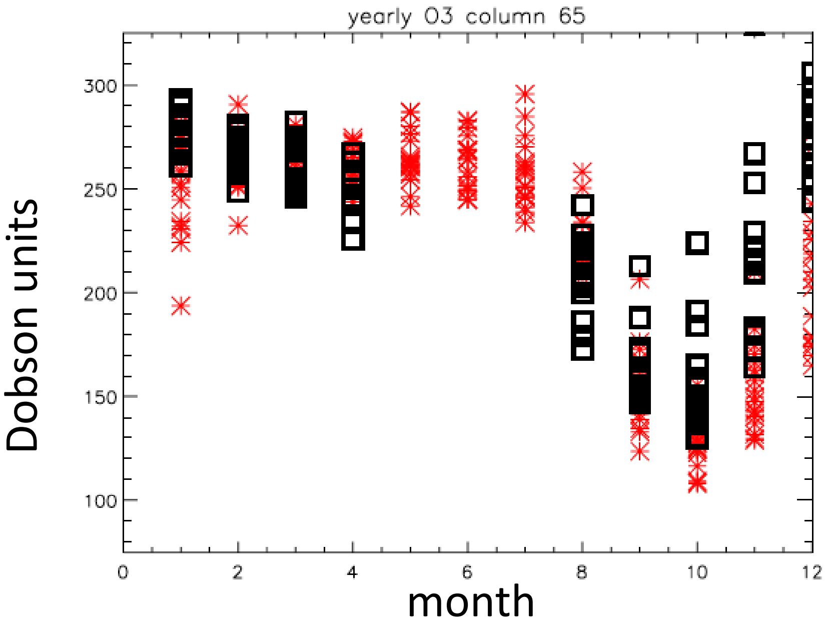
NH sudden warming climatology

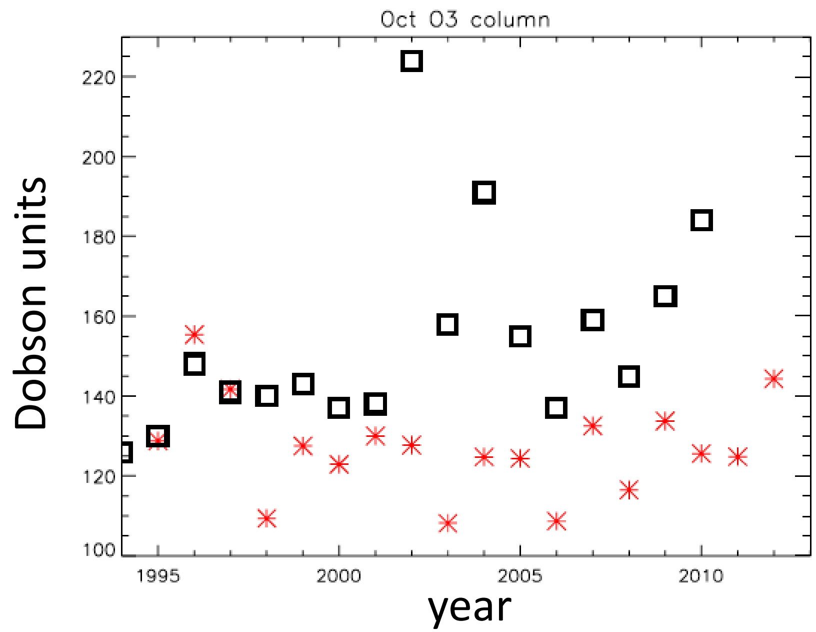


monthly column ozone: WACCM vs Halley Bay

annual cycle 1995-2012

black: obs
red: WACCM





Remaining issues:
- October variability weaker than observed
- Oct-Dec ozone too low

conclusions

- Changes to WACCM GW parameterization
  - added an additional spectrum of inertia-gravity waves (longer wavelength, larger amplitude) launched by frontal trigger
  - change (correction?) to orographic gravity waves that increases their impact, especially in SH
- The horizontal wavelength of IGW (300 km) and range of phase speeds (centered on the background wind near the surface) are compatible with waves observed at Macquarie Island.
- The longitude x latitude distribution of parameterized waves agrees reasonably with stratospheric observations.
- SH forcing is still too weak and too late but, so far, changes in parameters that increase it are detrimental to the NH simulation.
- Some difference between the NH and SH gravity wave sources is still missing and or misrepresented.