Nonlocal responses of the middle atmosphere to data insertion

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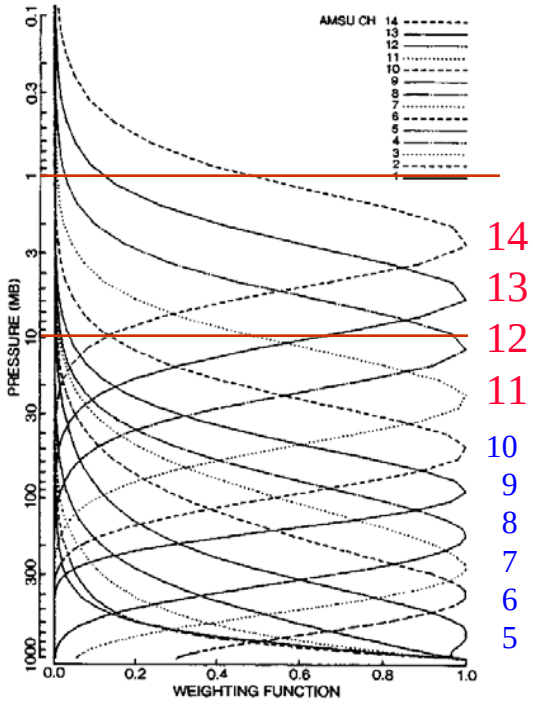
OUTLINE

1. Impact of mesosphere on analysis step
2. The mesospheric response to analysis increments during the forecast step
   a) Vertical coupling through resolved waves
   b) Vertical coupling through unresolved waves
3. Summary

CMAM + 3DVar

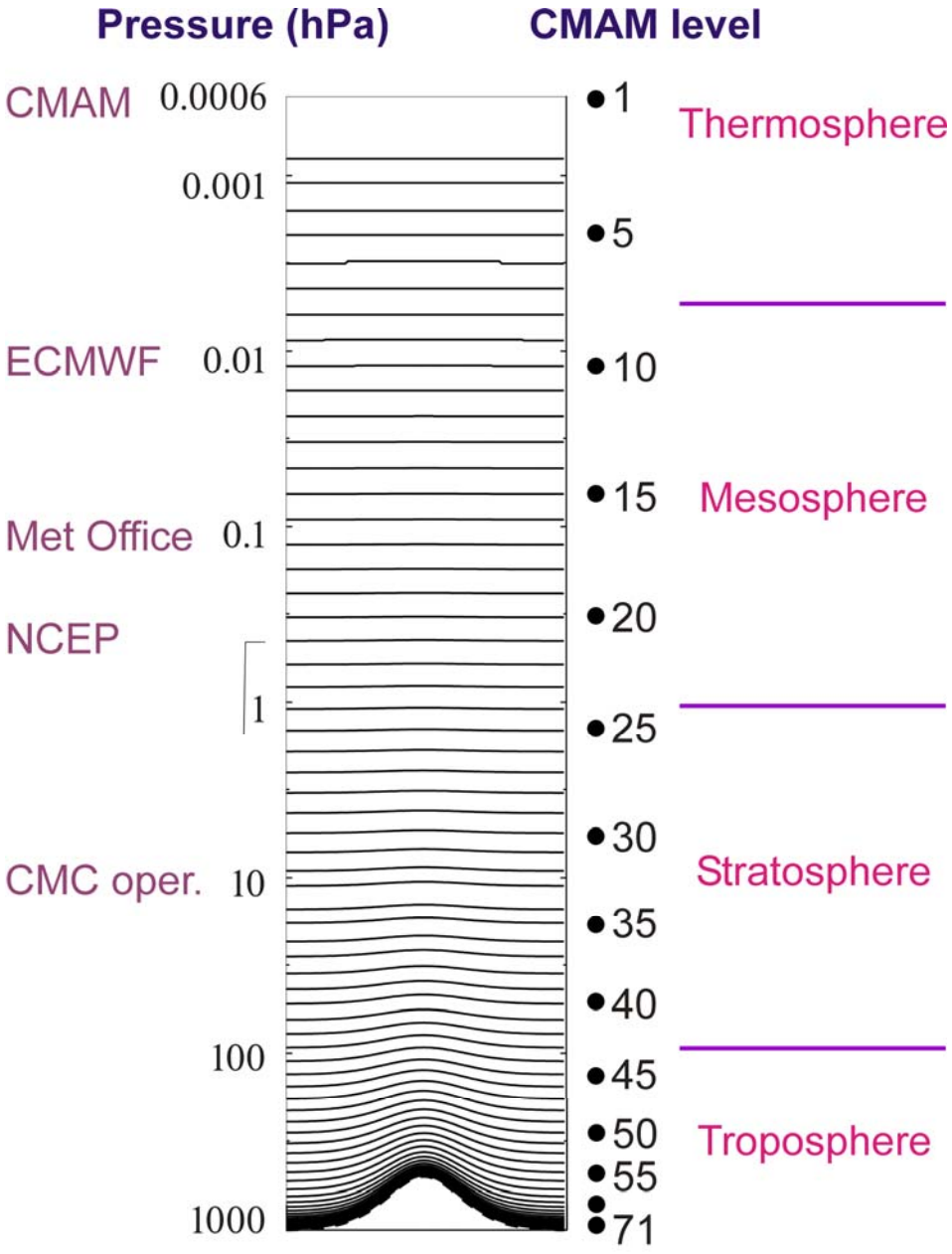
CMAM = Canadian
Middle Atmosphere Model

Normalized AMSU Weighting functions



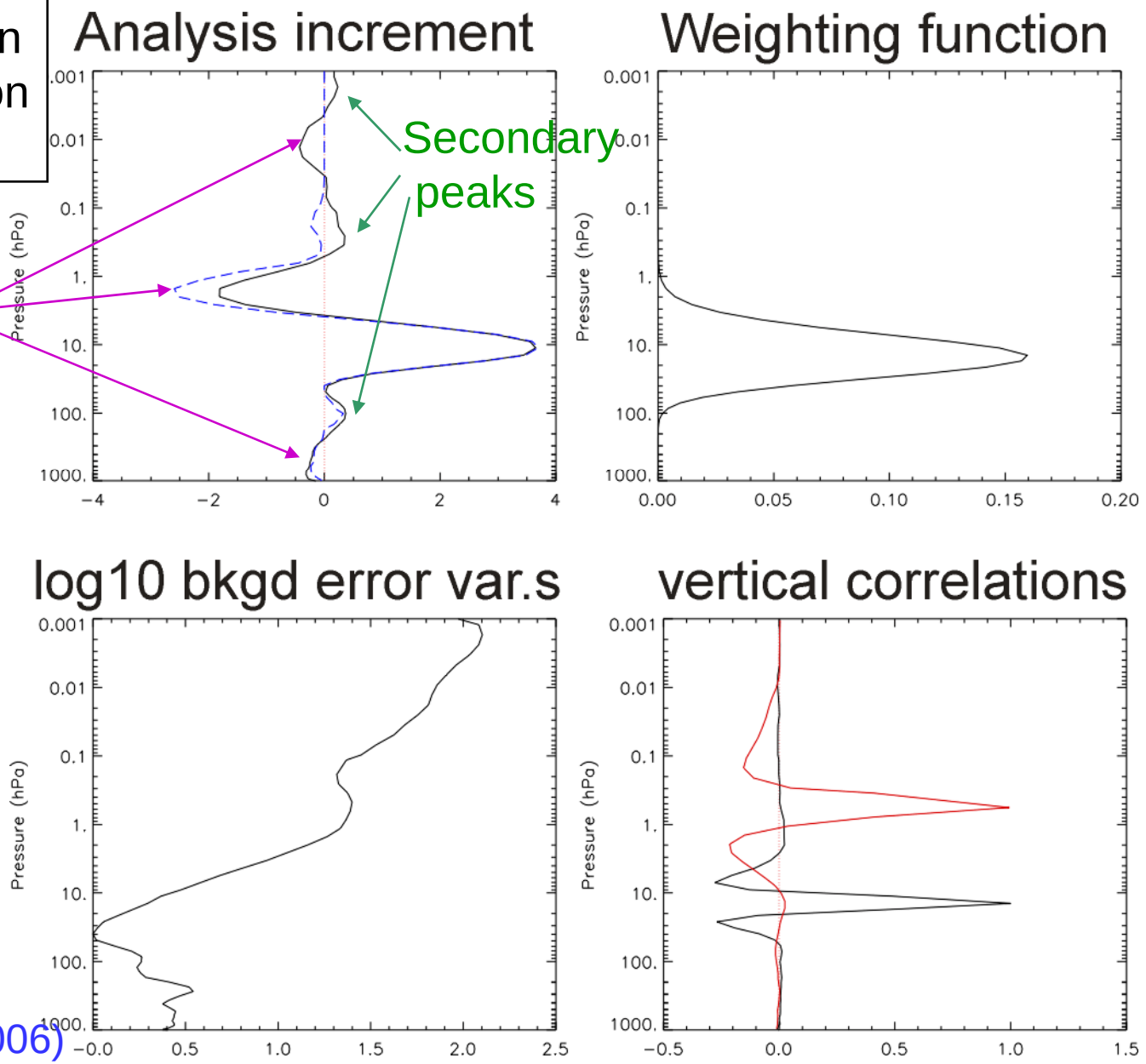
AMSU 10-14

conventional obs + sat.



Increment involves
- Weighting function
- Vertical correlation
- Vertical distribution of variance

AMSU ch. 11



Polavarapu et al. (2006)

Results from Polavarapu et al. (2005)

- Data insertion in troposphere and stratosphere can lead to increments in the mesosphere through nonzero vertical background error correlations
- Because of large mesospheric variances, extreme sensitivity of results to covariance specification
- Small biases can be amplified by incorrect covs

2. Mesospheric coupling and the model response to analysis increments

Zonal wind

contours:
20 m/s (pos)
10 m/s (neg)

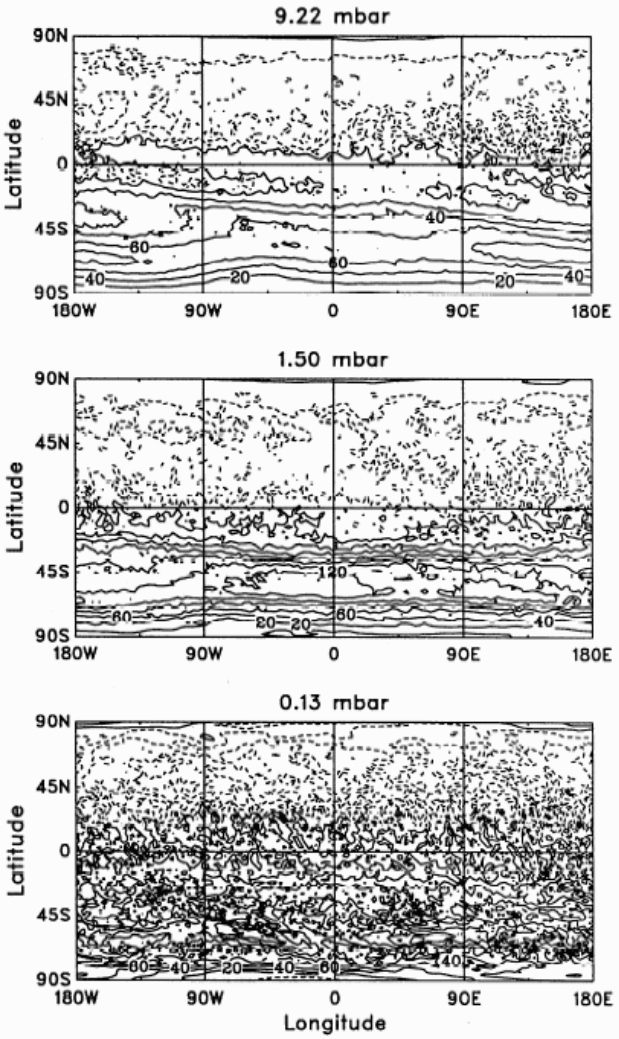


Figure 10. Zonal wind field on three different SKYHI (N90) model levels for a single snapshot in July: 9.22 mbar (top), 1.50 mbar (middle), and 0.13 mbar (bottom). Contour interval = 20 m/s for positive-valued contours and 10 m/s for negative-valued contours.

Koshyk et al. (1999)

Lower stratosphere

stratopause

mesosphere

Gravity waves are important

- Exert a “drag” on mean flow, keeping the middle atm far from radiative equilibrium, driving pole-to-pole meridional circulation
- Warm the winter pole in stratosphere
- Impact on tides
- Help drive QBO

Need to filter analyses

- Analyses not balanced
  - Spurious gravity waves (GWs) are generated
  - dPs/dt, div., prec. forecasts noisy in troposphere
  - Too fast tracer transport in stratosphere
  - Quality control checks obs against 3σ
- After assimilation, a separate filtering or "initialization" step is performed
- In a model with mesosphere, GWs are part of the signal. How do we separate real from spurious GWs?
- Original CMAM-DAS filtered full analysis. Should filter analysis increments only!

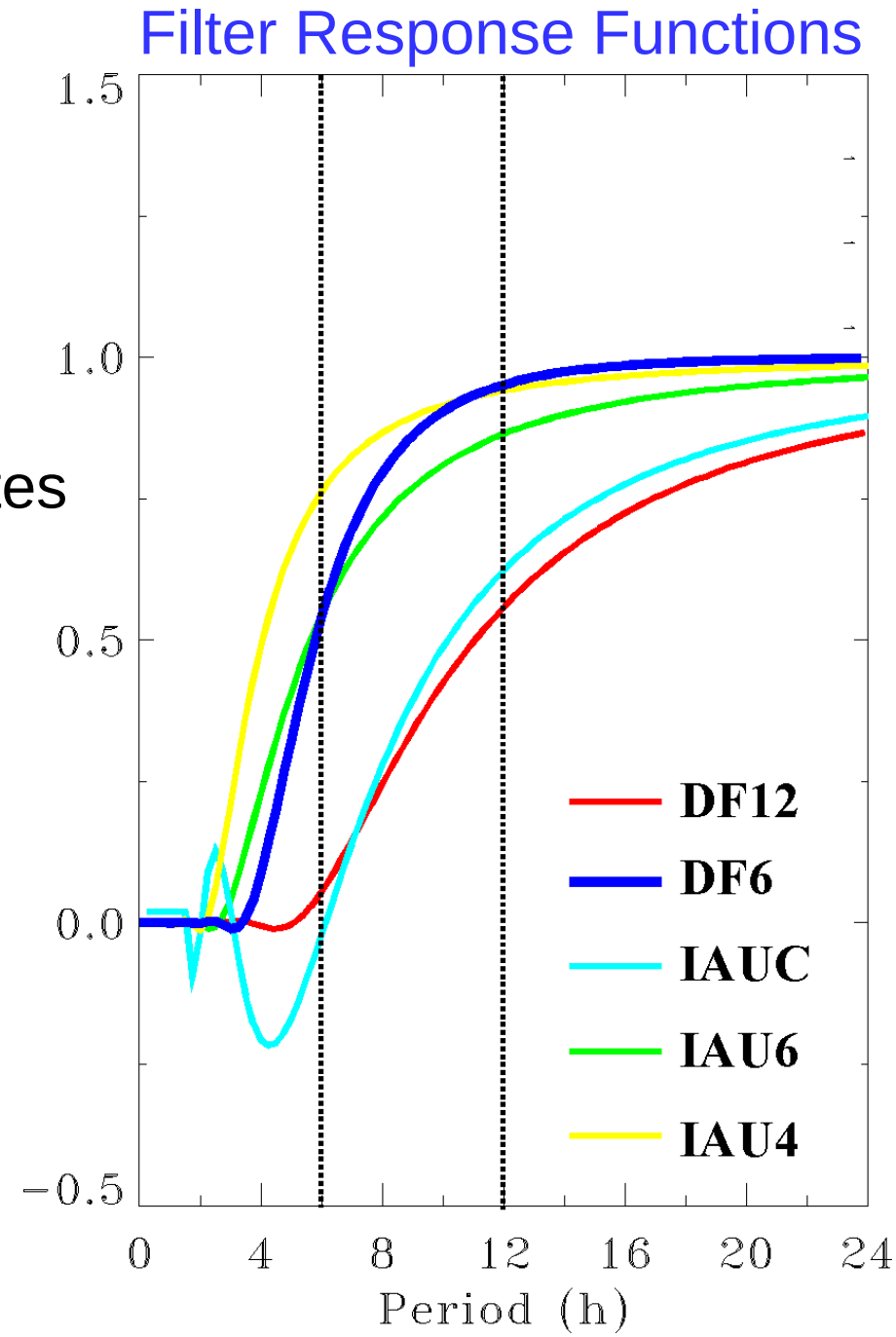
Anal = bkgd + anal incr

DF = Digital Filter

Applied to full analysis

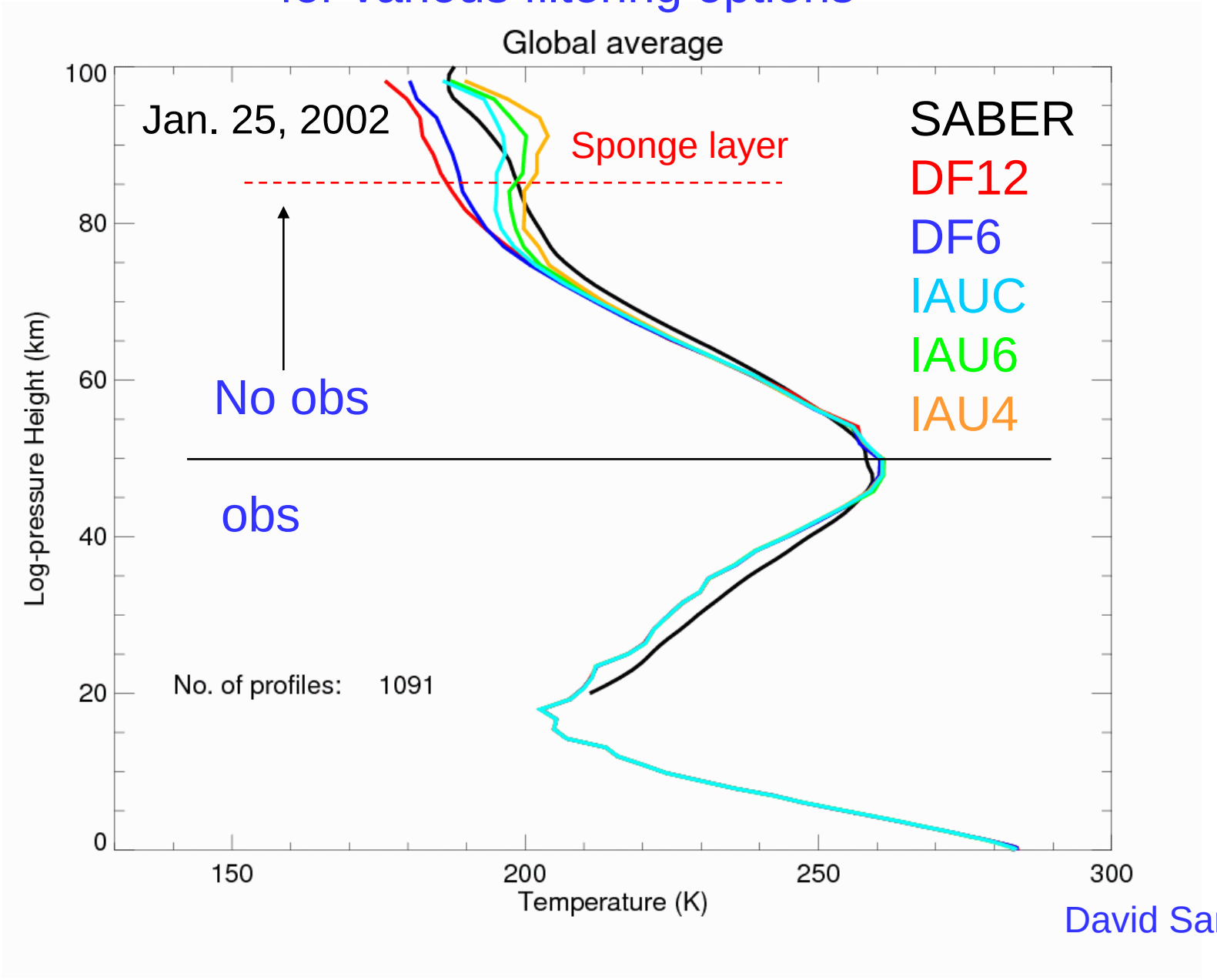
IAU= Incremental Anal Updates

Applies to anal incr only



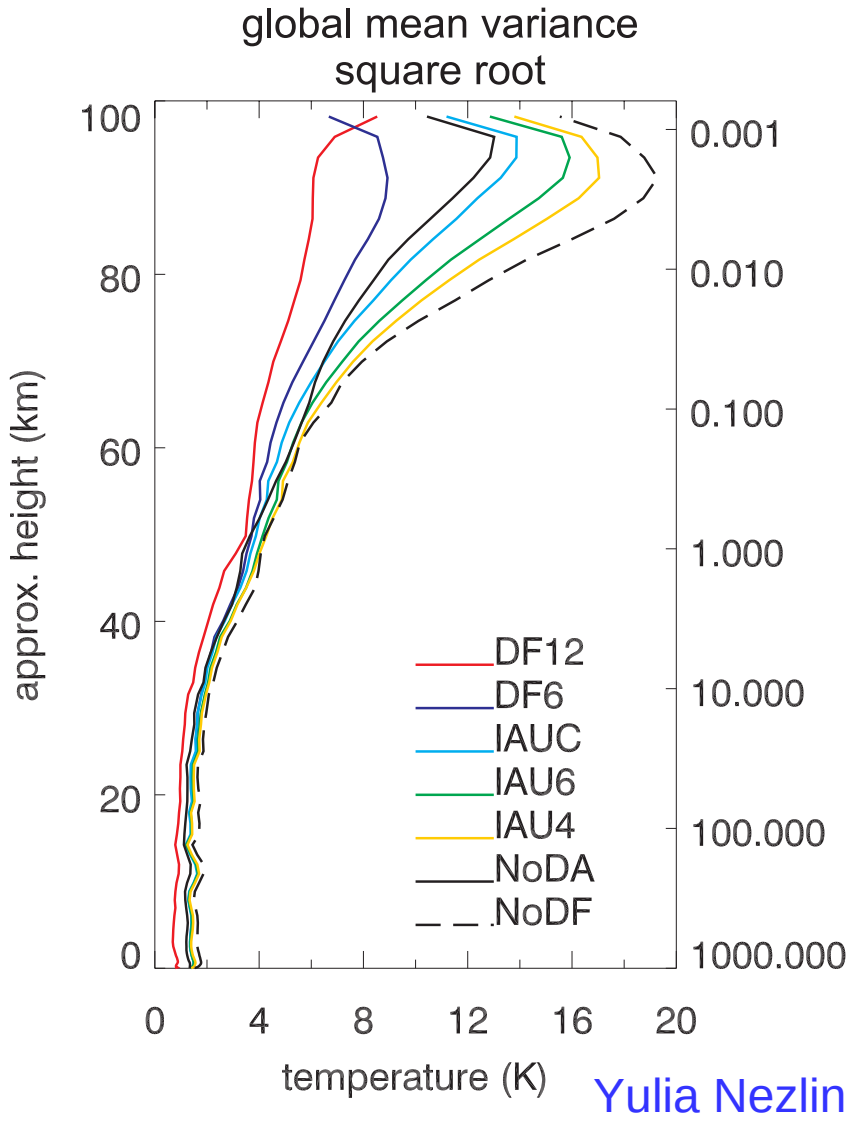
2a. Vertical coupling through resolved waves

Global mean temperature profiles at SABER locations for various filtering options

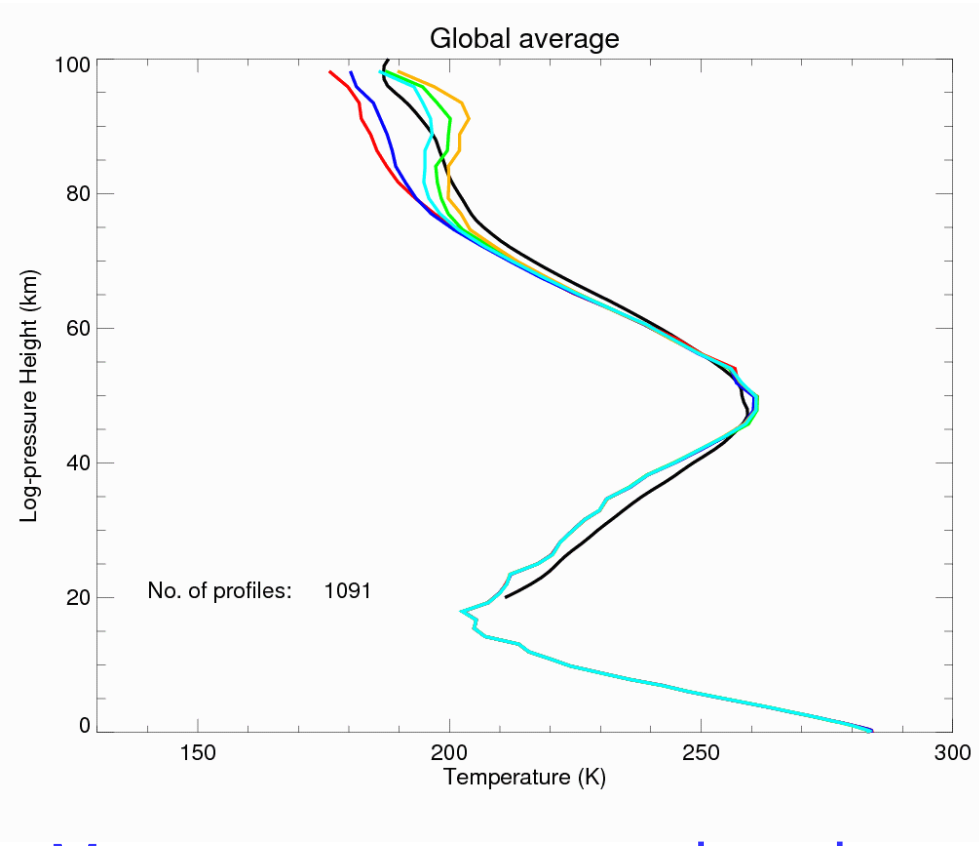


David Sankey

There are more resolved waves in the upper mesosphere with less filtering

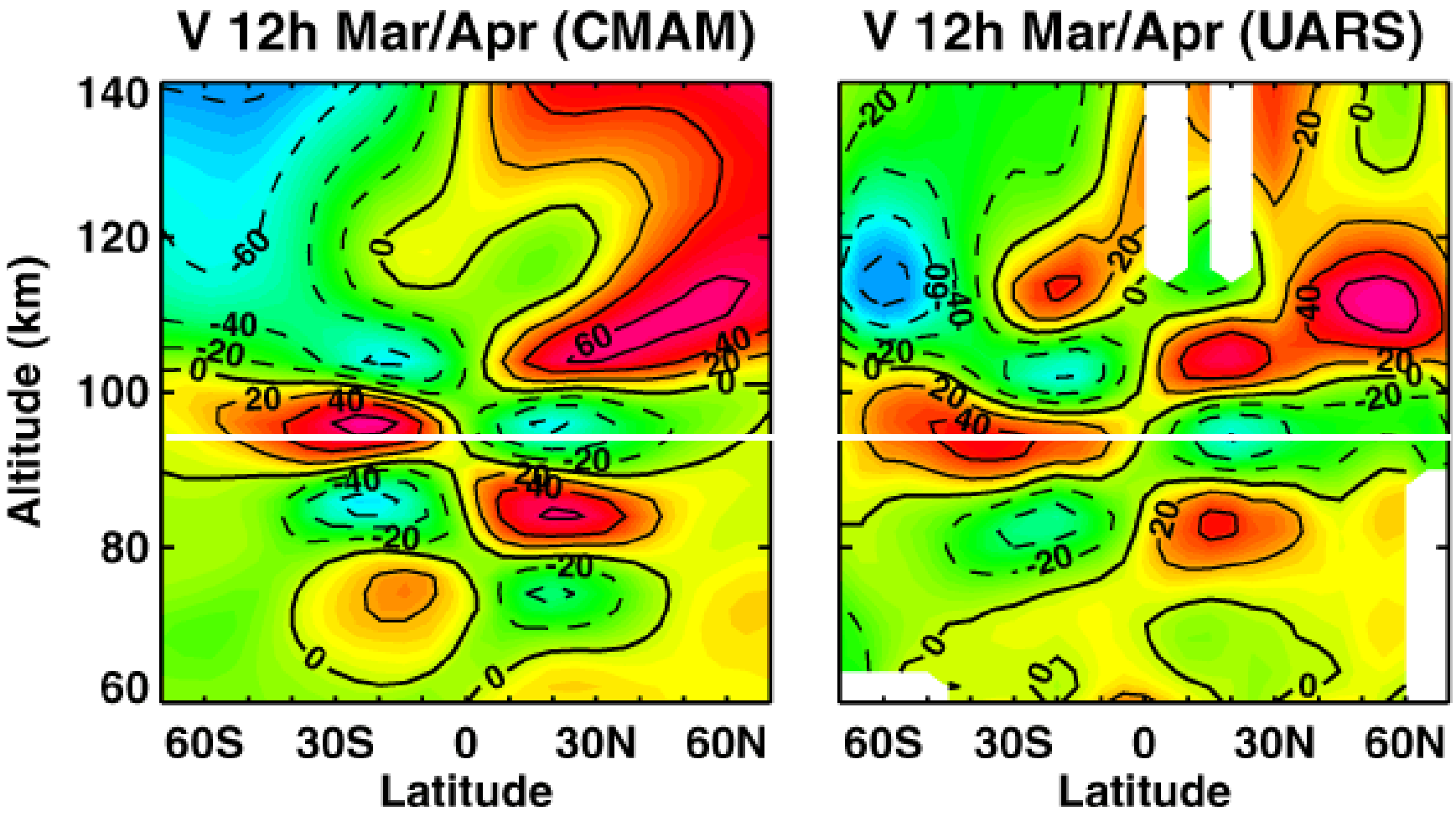


Yulia Nezlin



More waves --> more damping --> more heating

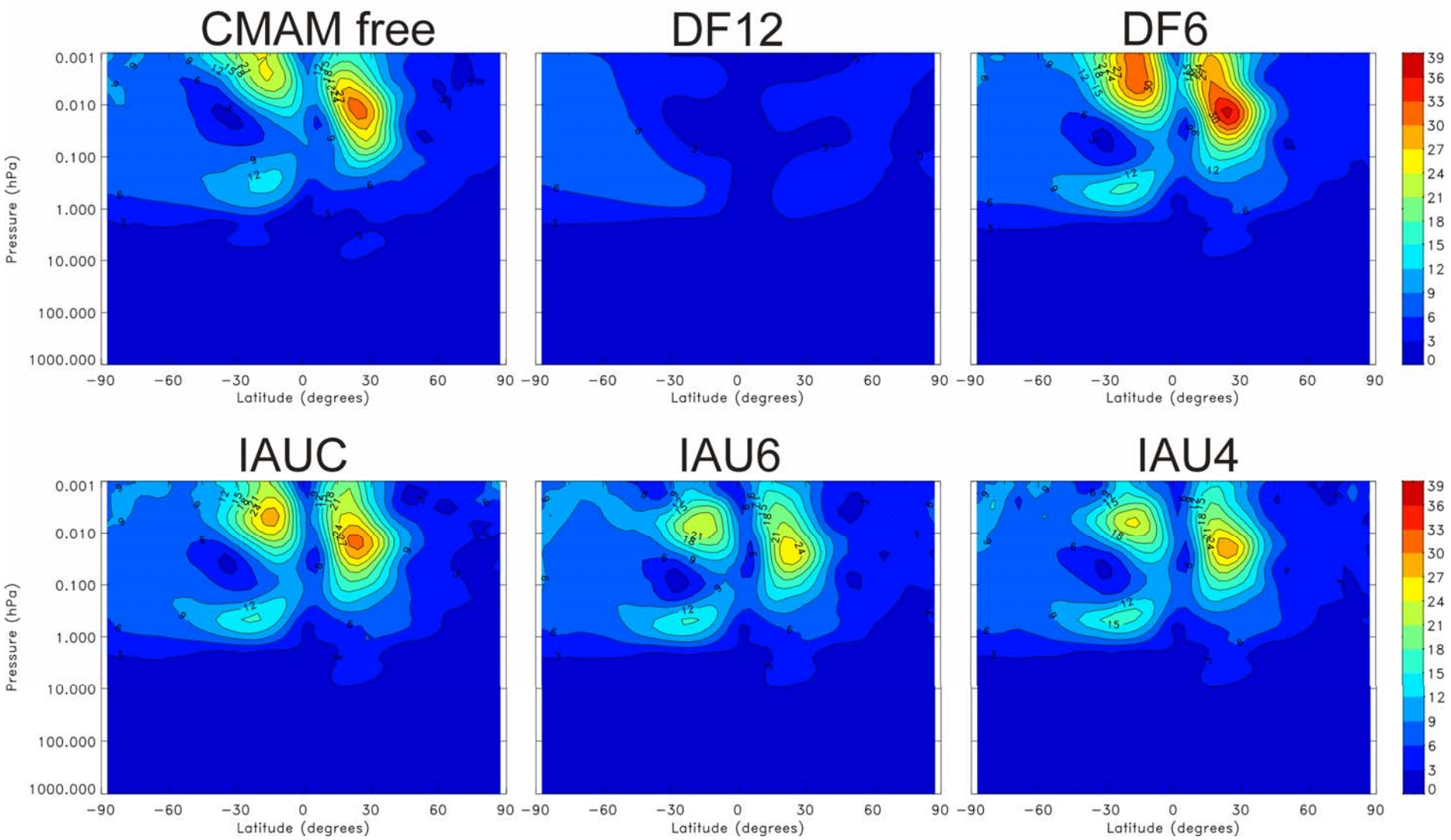
Propagating diurnal thermal tide



Beagley *et al.* (GRL 2000)

Impact of filters on migrating diurnal tide

21-30 January 2002



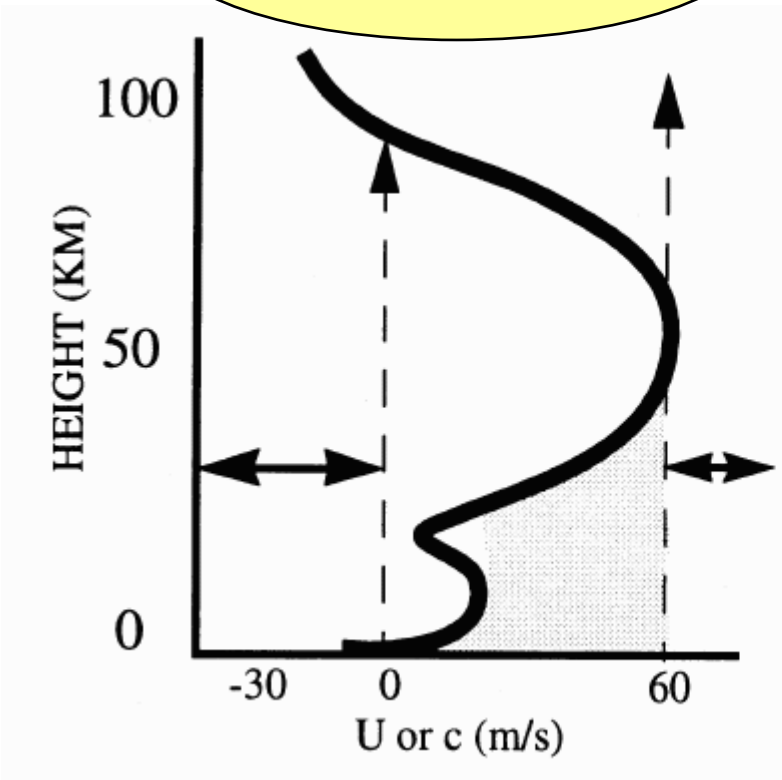
Sankey, Polavarapu, McLandress

2b. Vertical coupling through unresolved GWs

Critical level filtering of gravity waves by background mean winds

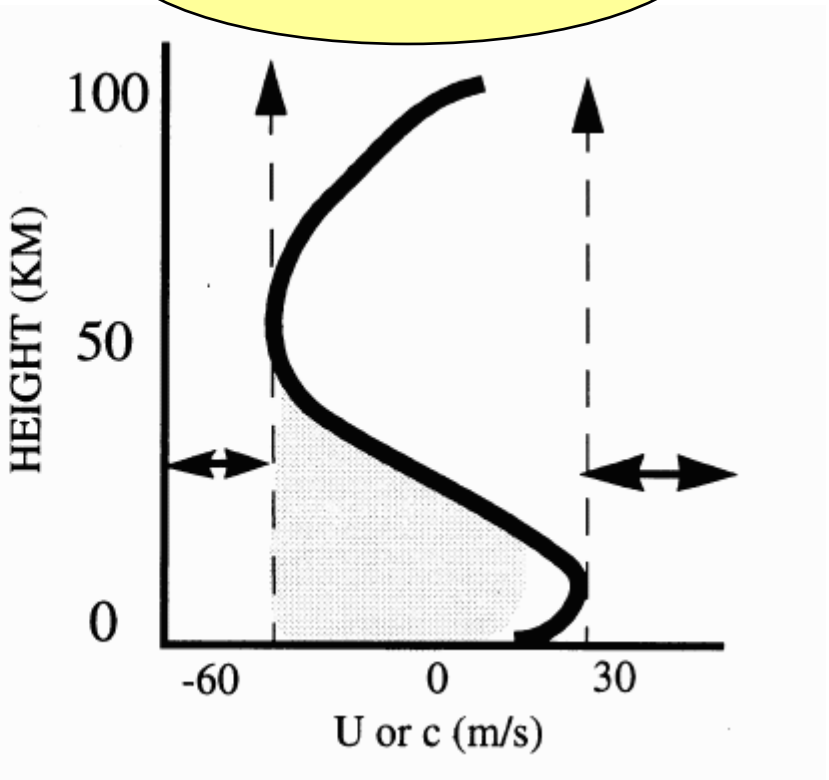
WINTER

GWs c<0 break, drag reduces westerlies



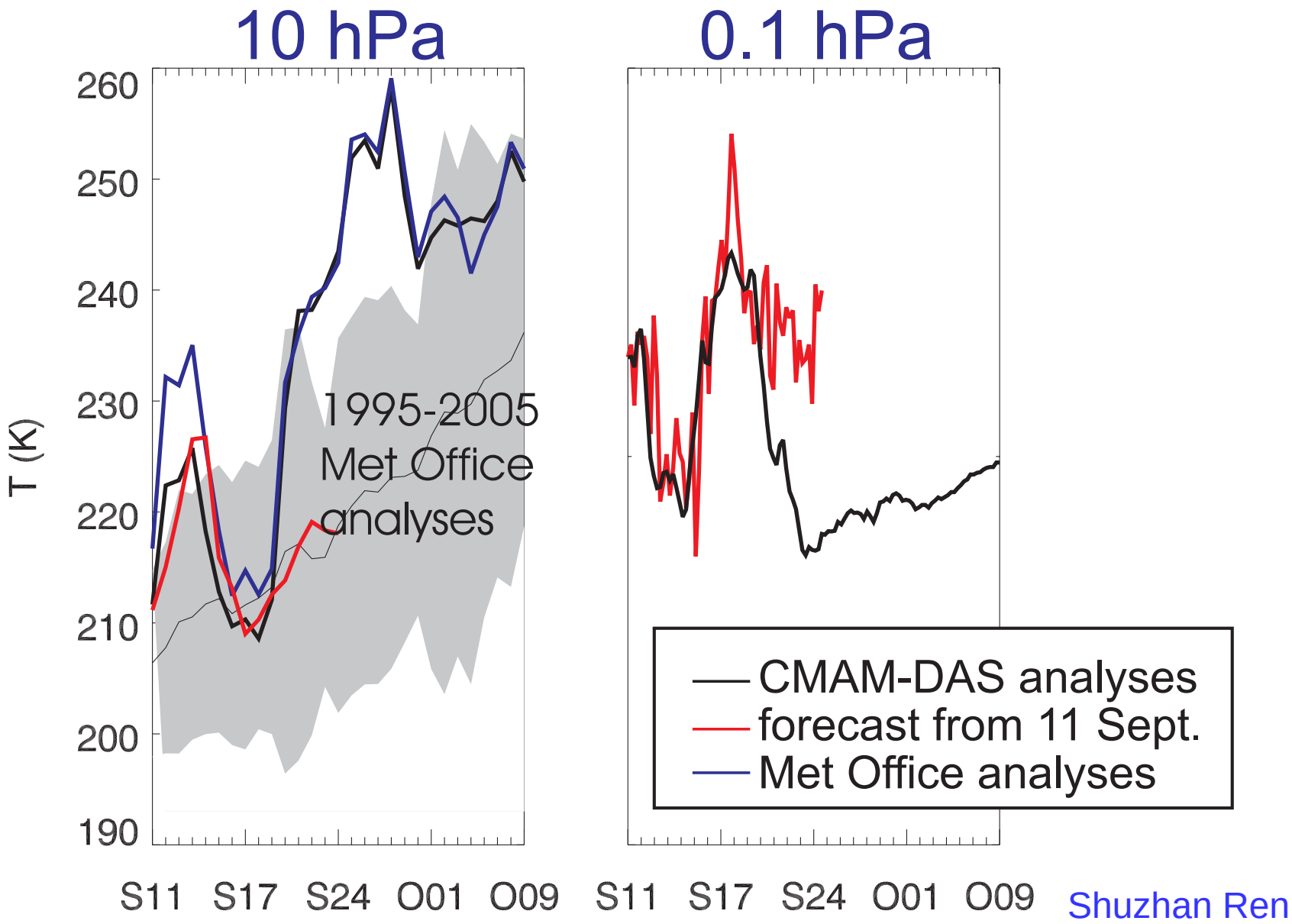
SUMMER

GWs c>0 break, drag reduces easterlies



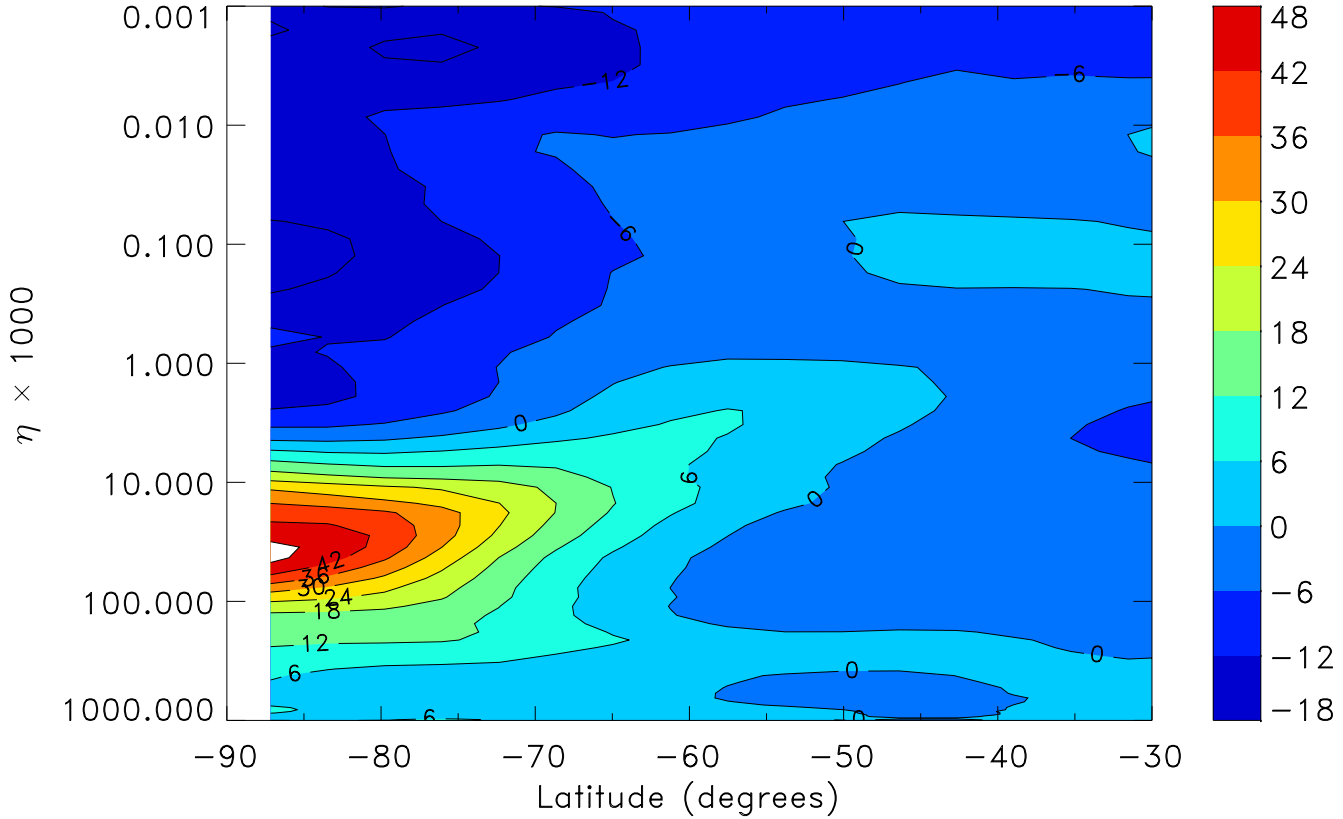
McLandress (1998)

South Pole Temperature in 2002



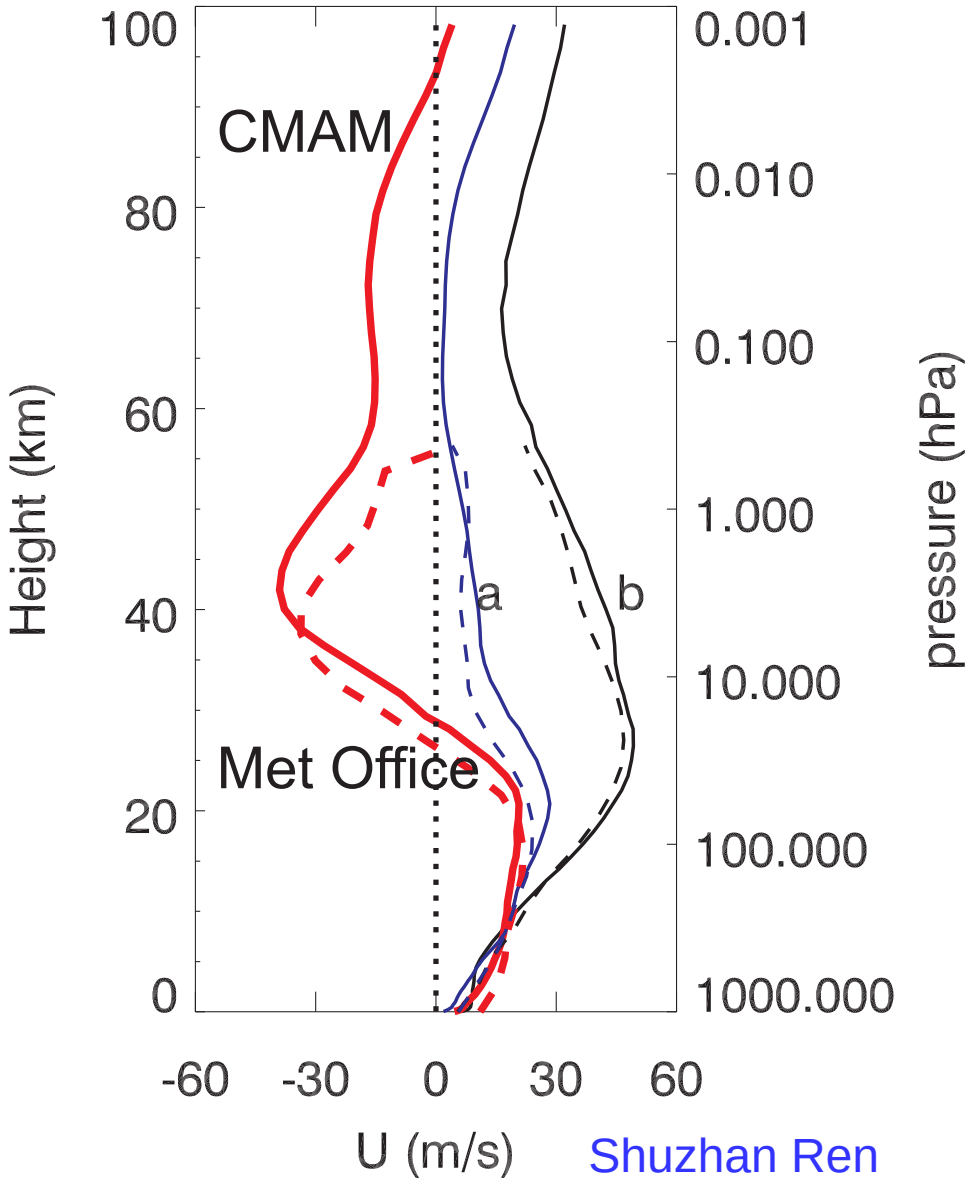
Shuzhan Ren

Analysis minus 15-day forecast
15 Sept. 2002
Zonal mean temperature diff

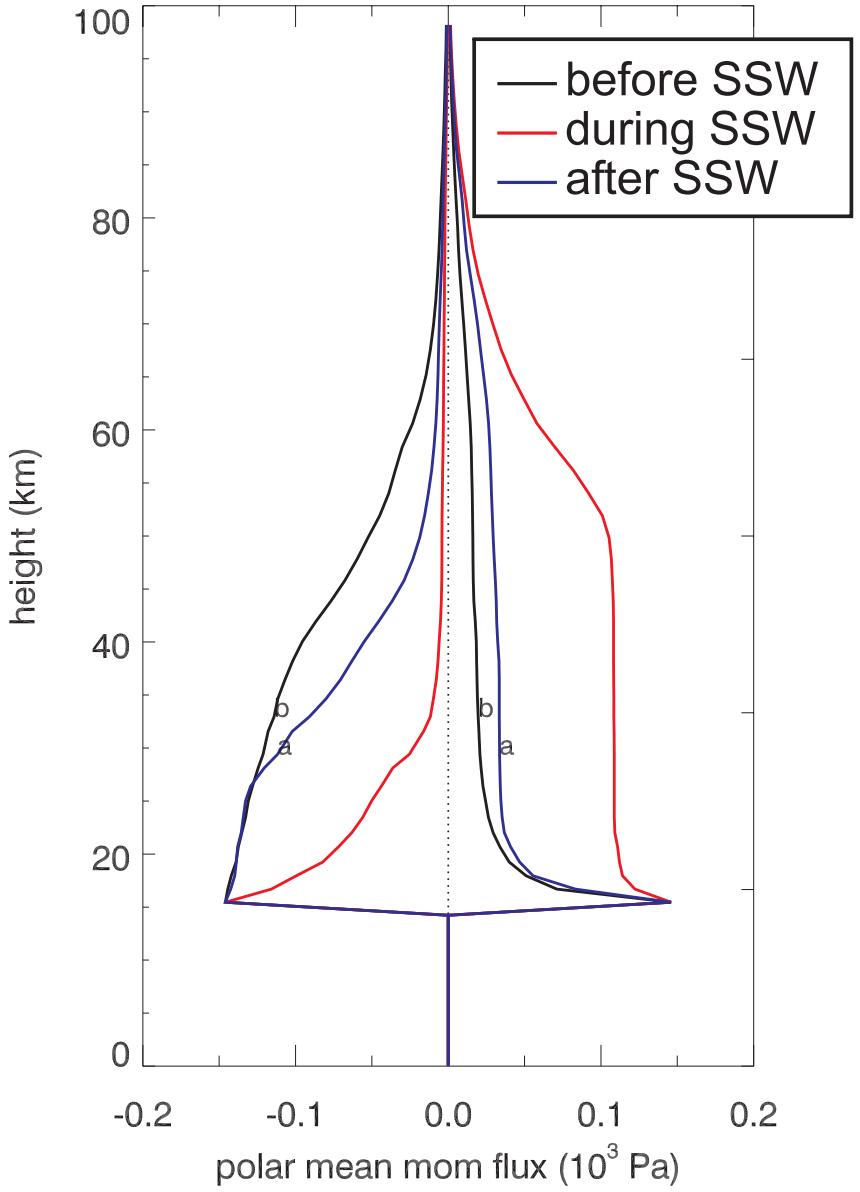


Shuzhan Ren

Zonal mean zonal wind at 60°S

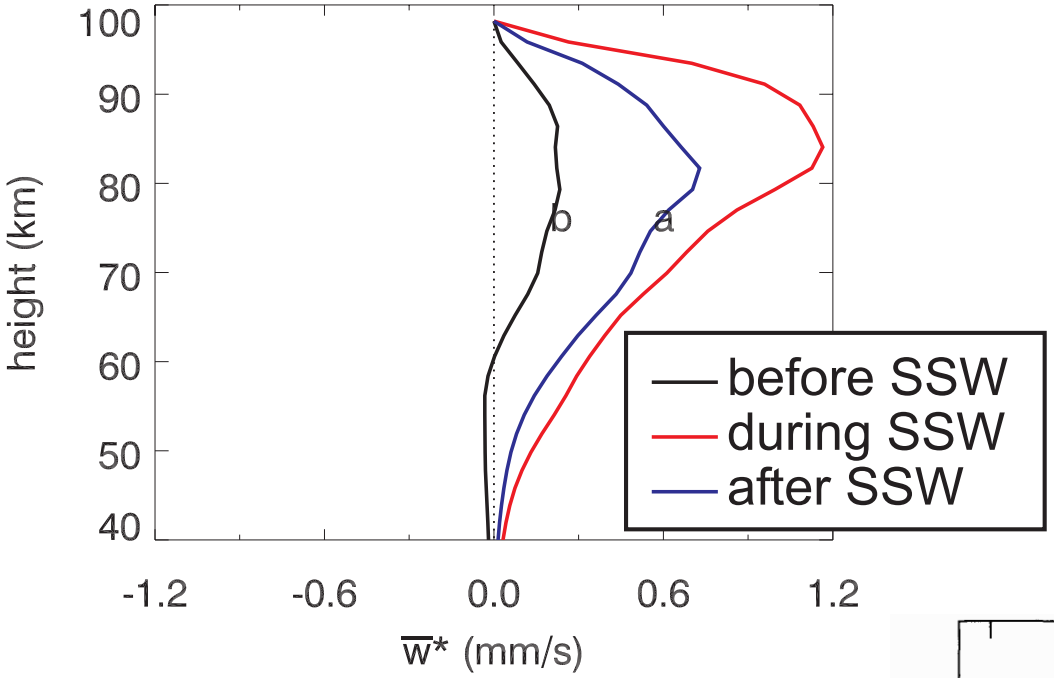


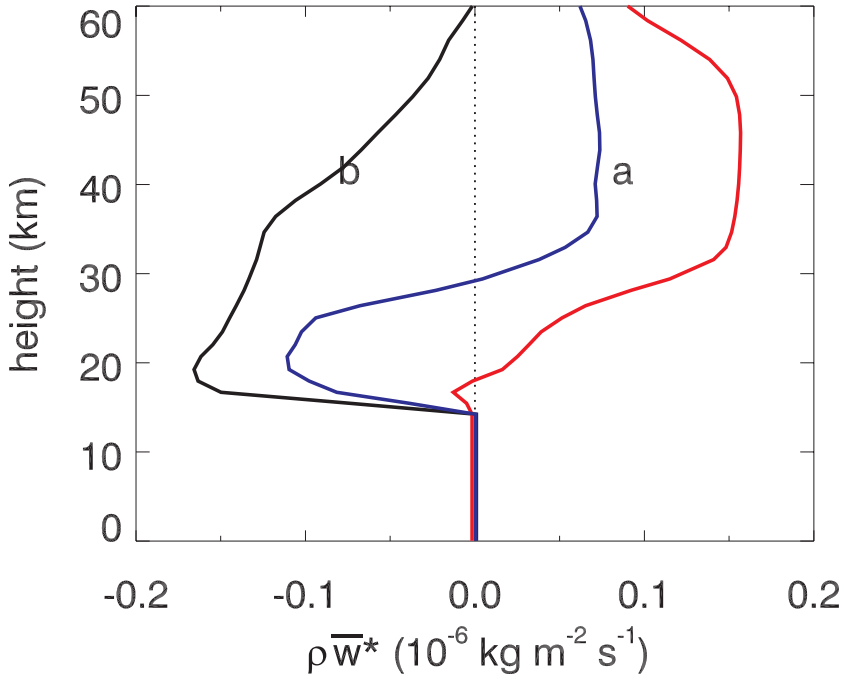
Mom flux due to GWs avg over polar cap

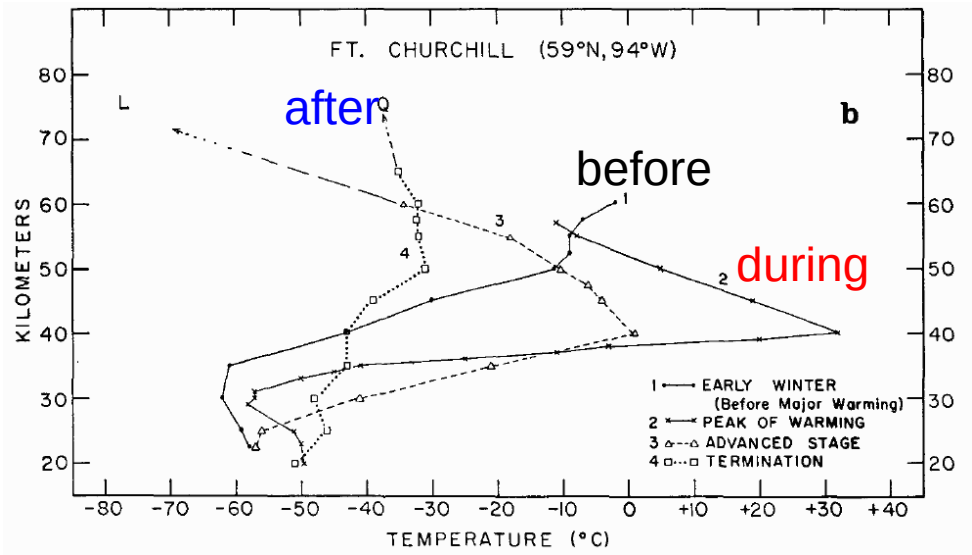


Shuzhan Ren

Impact of waves on mean flow changes the residual circulation







Labitzke (1972)

Conclusions

- Vertical propagation of resolved waves from data region into the mesosphere :
  - creates heat when the GWs are damped. Filtering methods can have big impact on mesosphere.
  - can affect the diurnal tide. Because of nonlinear wave interactions, increased damping does not necessarily lead to increased tidal amplitudes
- Vertical propagation of information through unresolved (GW) waves affects mesosphere
  - Clear impact of obs on mesosphere thru model response. Confirm Holton filtering mechanism.
  - Can we use mesospheric obs to constrain GWD parameters, e.g. sources?

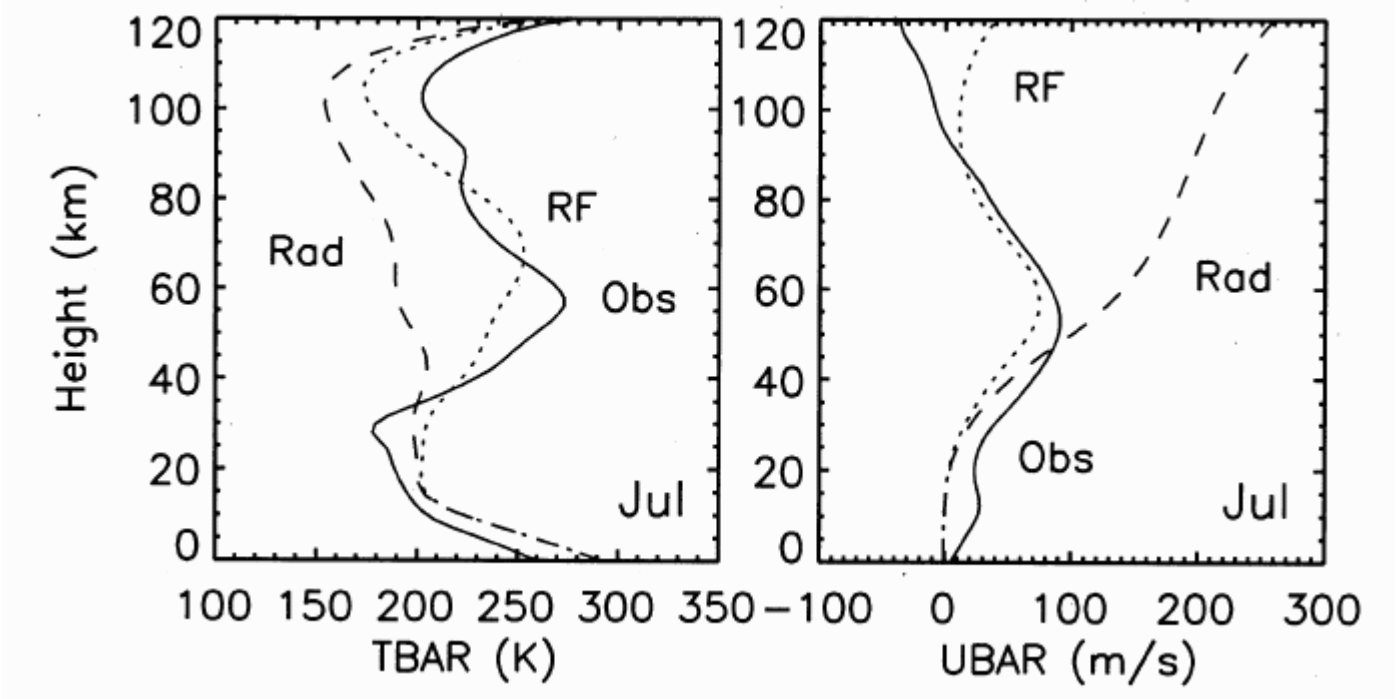
The End

The middle atmosphere is far from radiative equilibrium

Southern hemisphere winter

zonal mean fields

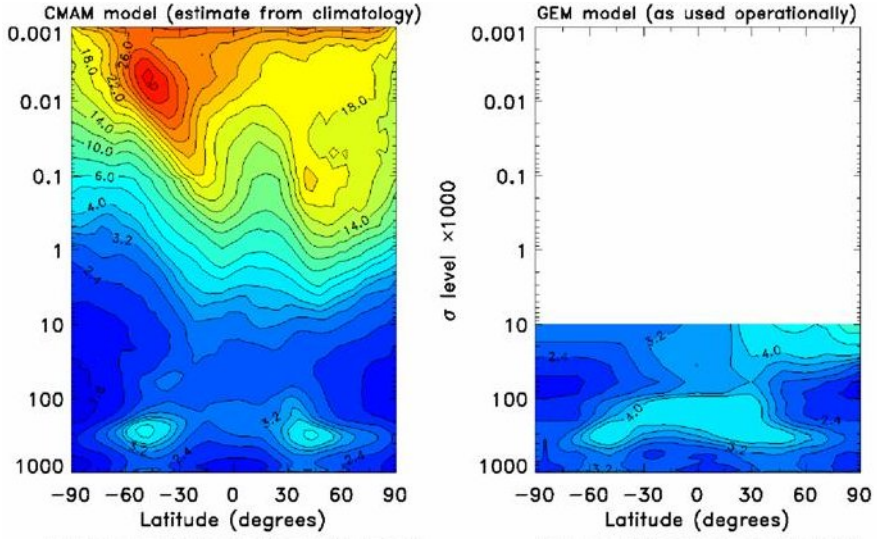
Temperature at 90°S Zonal wind at 40°S



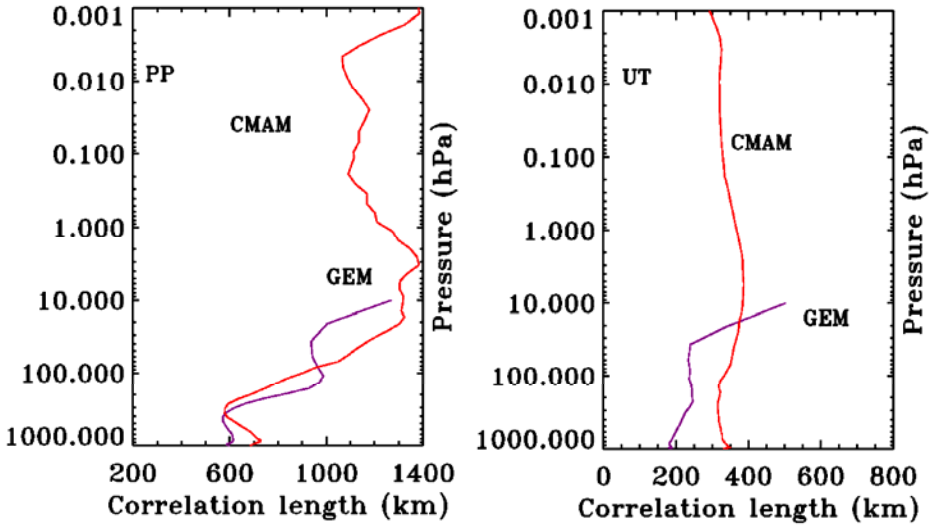
McLandress (1998)

CMAM Background Error Statistics

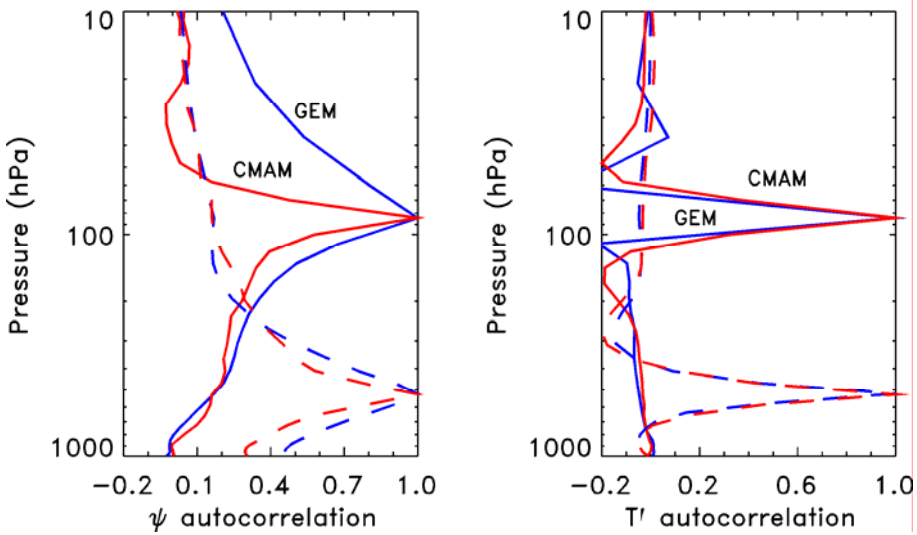
Zonal wind std dev



Horizontal correlation length scales



Vertical correlations at 84 and 520 hPa



Yves Rochon