Atmosphere Coupling and Implications for Upper Atmosphere Predictability

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Talk partly based on:

Liu, H.-L., F. Sassi, and R. R. Garcia, Error growth in a whole atmosphere climate model, J. Atmos. Sci., 66, 173-186, 2009.

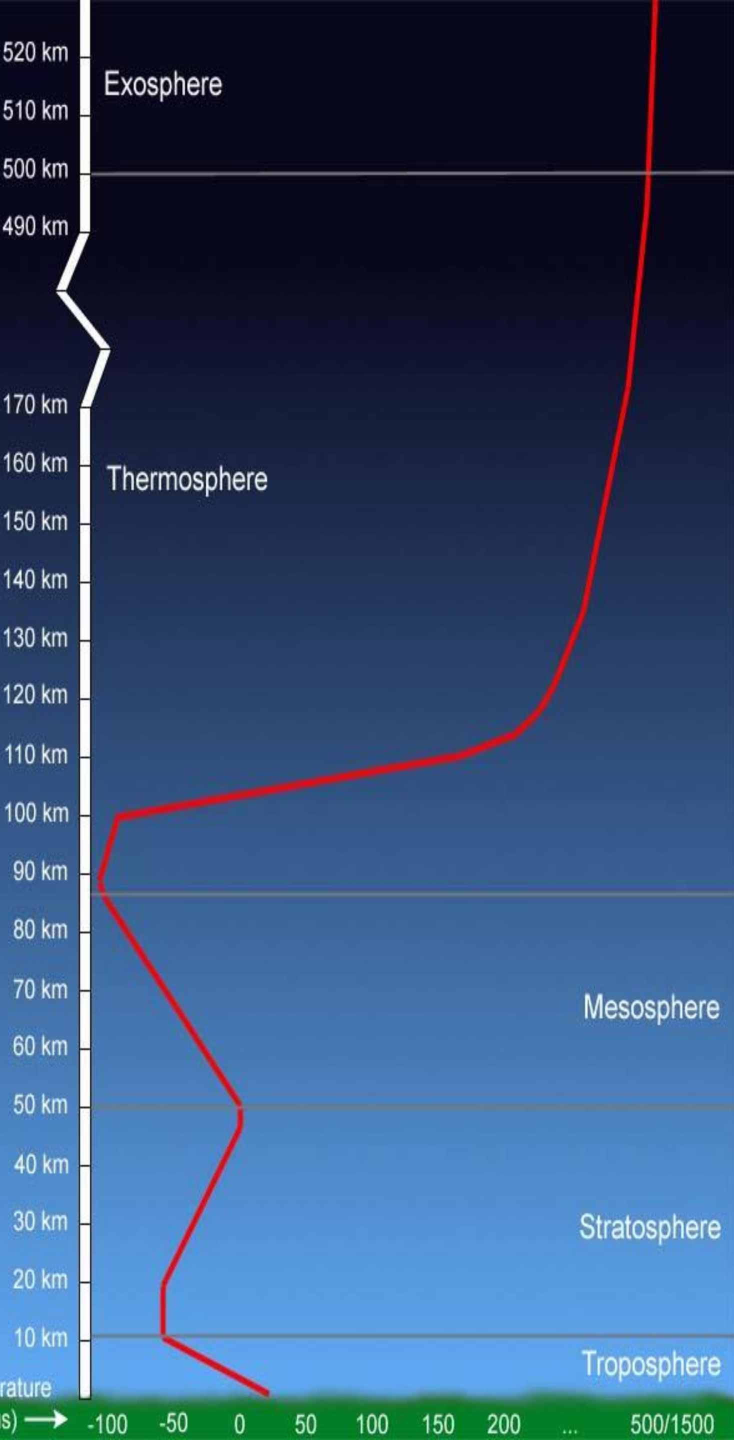
Liu, H.-L. W. Wang, A.D. Richmond, and R.G. Roble, Ionospheric variability due to planetary waves and tides for solar minimum conditions, *J. Geophys. Res., 115,* A00G01, doi:10.1029/2009JA015188, 2010.

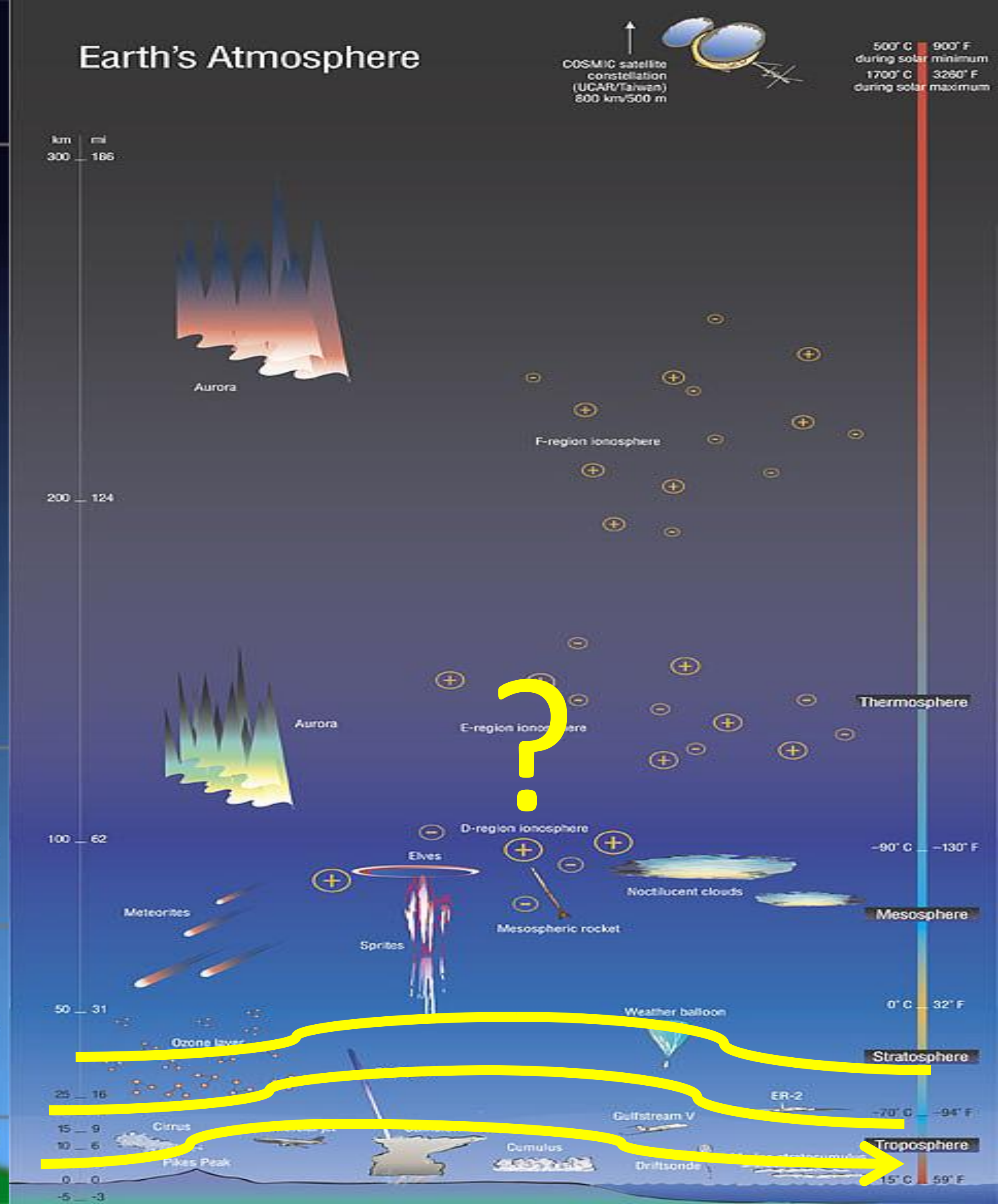
26-29 April, 2011 Space Weather Workshop

NCAR

Overview

- Large-scale impact of lower atmosphere perturbations on the ionosphere/thermosphere
  - Interaction between planetary waves and tides.
- Predictability of the upper atmosphere perturbations.


520 km
510 km
500 km
490 km
170 km
160 km
150 km
140 km
130 km
120 km
110 km
100 km
90 km
80 km
70 km
60 km
50 km
40 km
30 km
20 km
10 km
Exosphere
Thermosphere
Mesosphere
Stratosphere
Troposphere
-100 -50 0 50 100 150 200 ... 500/1500


Earth's Atmosphere
COSMIC satellite constellation (UCAR/Taiwan) 800 km/500 m
500° C 900° F during solar minimum
1700° C 3260° F during solar maximum
km mi
300 186
200 124
100 62
50 31
25 16
15 9
10 6
0 0
-5 -3
Aurora
F-region ionosphere
Aurora
?
D-region ionosphere
Elves
Noctilucent clouds
Meteorites
Sprites
Mesospheric rocket
Weather balloon
Ozone layer
ER-2
Gulfstream V
Cirrus
Cumulus
Pikes Peak
Driftsonde
Thermosphere
-90° C -130° F
Mesosphere
0° C 32° F
Stratosphere
-70° C -94° F
Troposphere
15° C 59° F

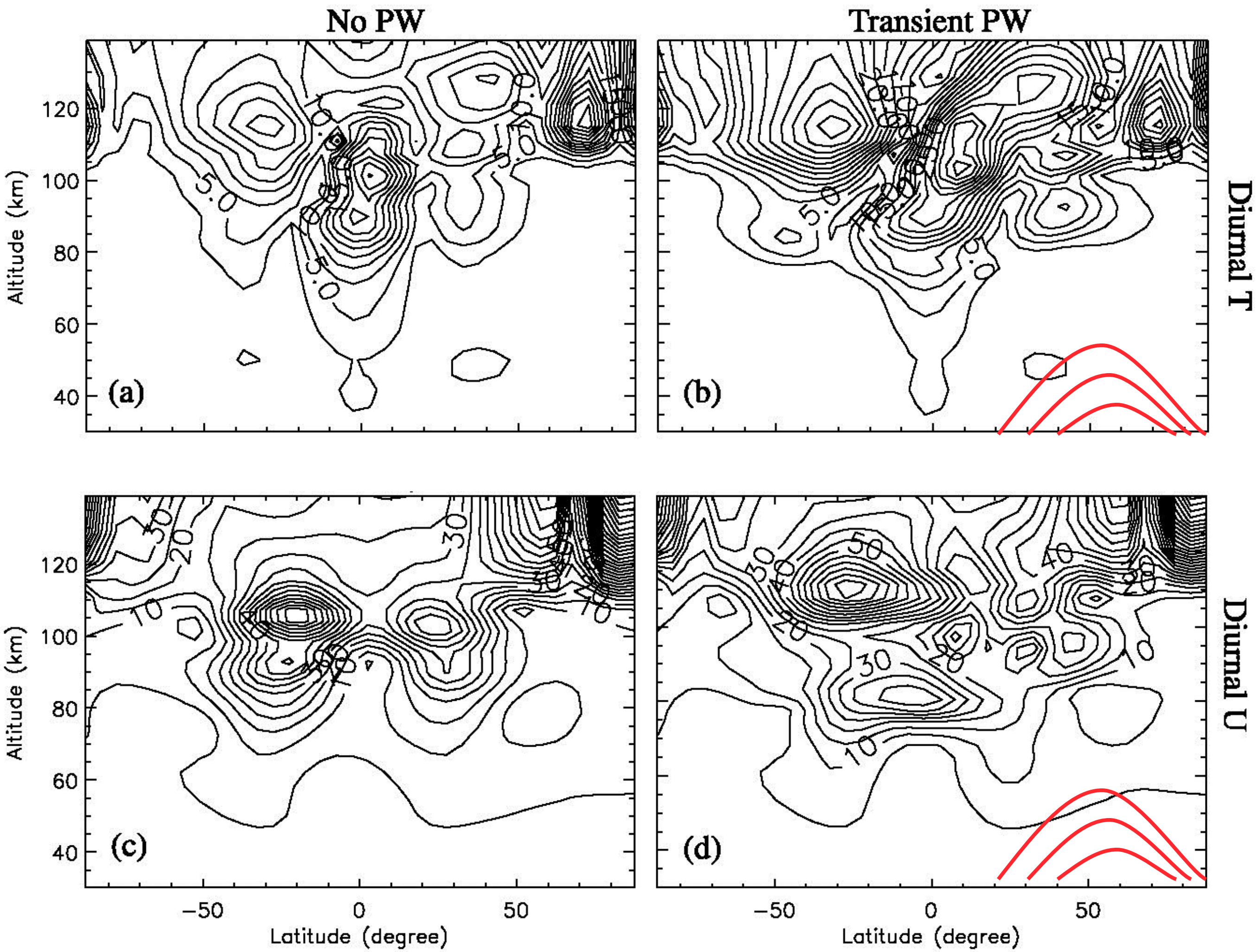
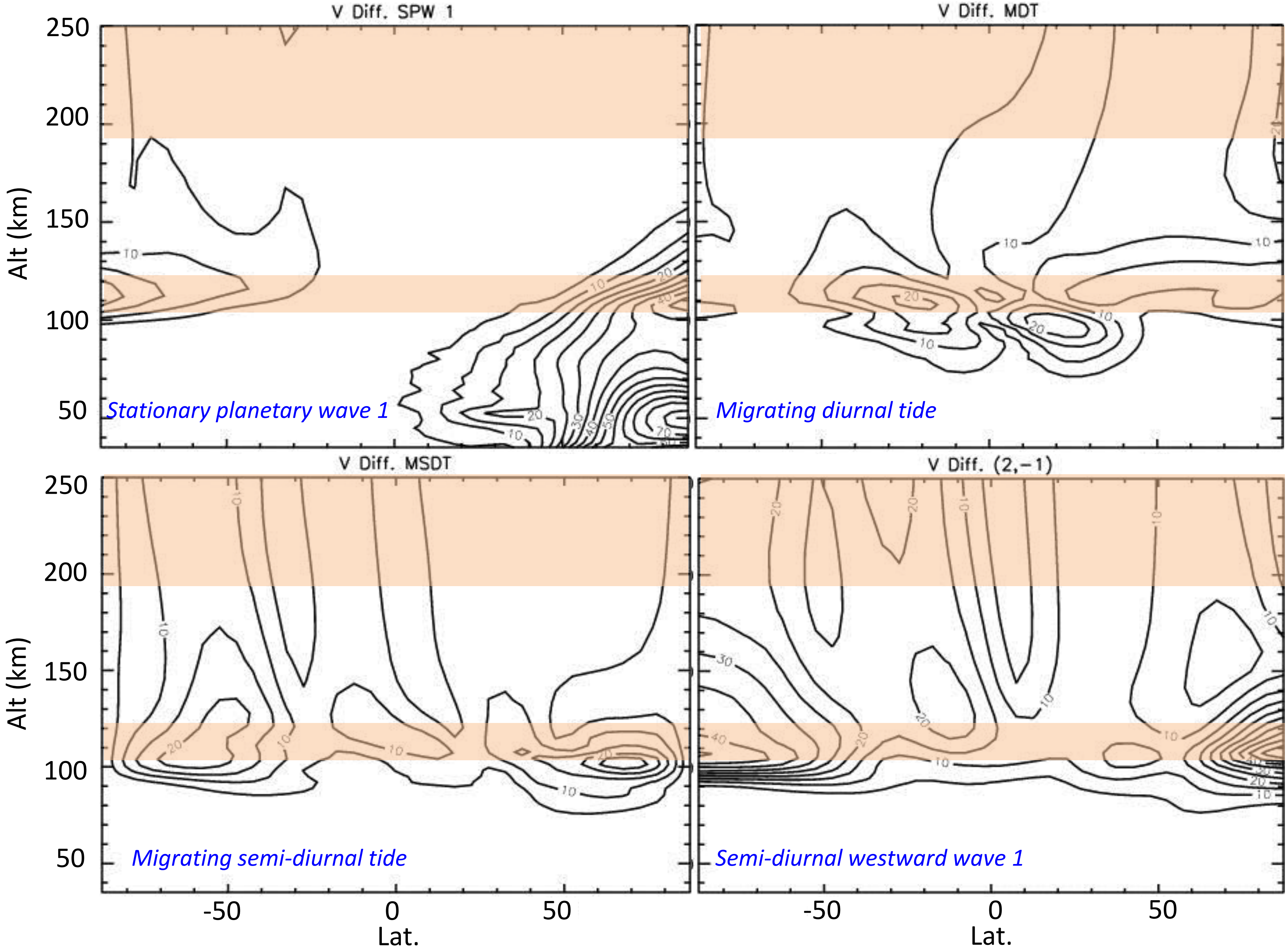


Figure 5. (a and b) Total diurnal temperature and (c and d) zonal wind amplitudes from base case (Figures 5a and 5c) and control case (Figures 5b and 5d) TIME-GCM simulations on day 267. The contour intervals for Figures 5a and 5b are 2.5 K. The contour intervals for Figures 5c and 5d are 5 m s^{-1}.

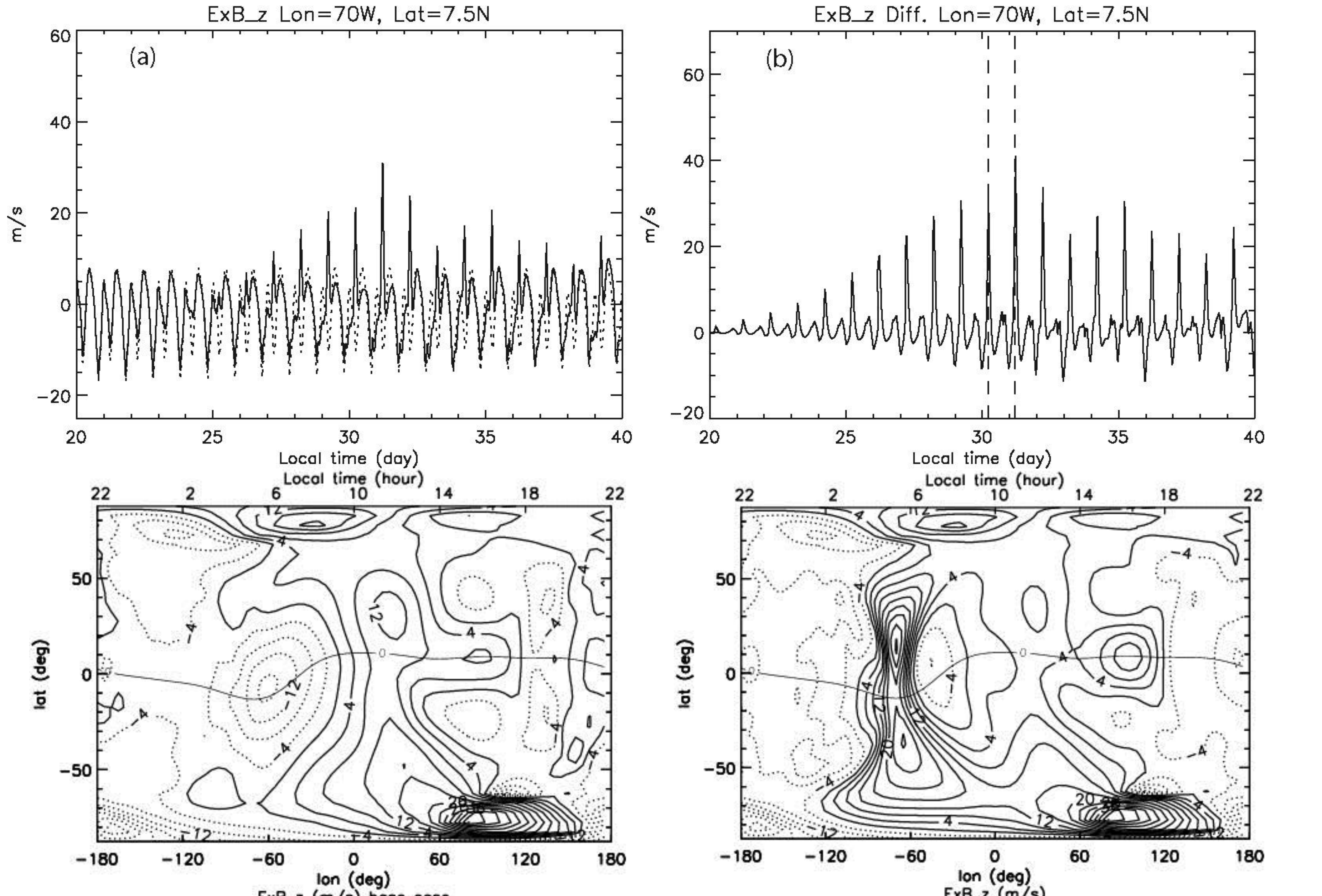
Liu et al (2007)

Wind Changes Due to A Quasi-Stationary Planetary Wave

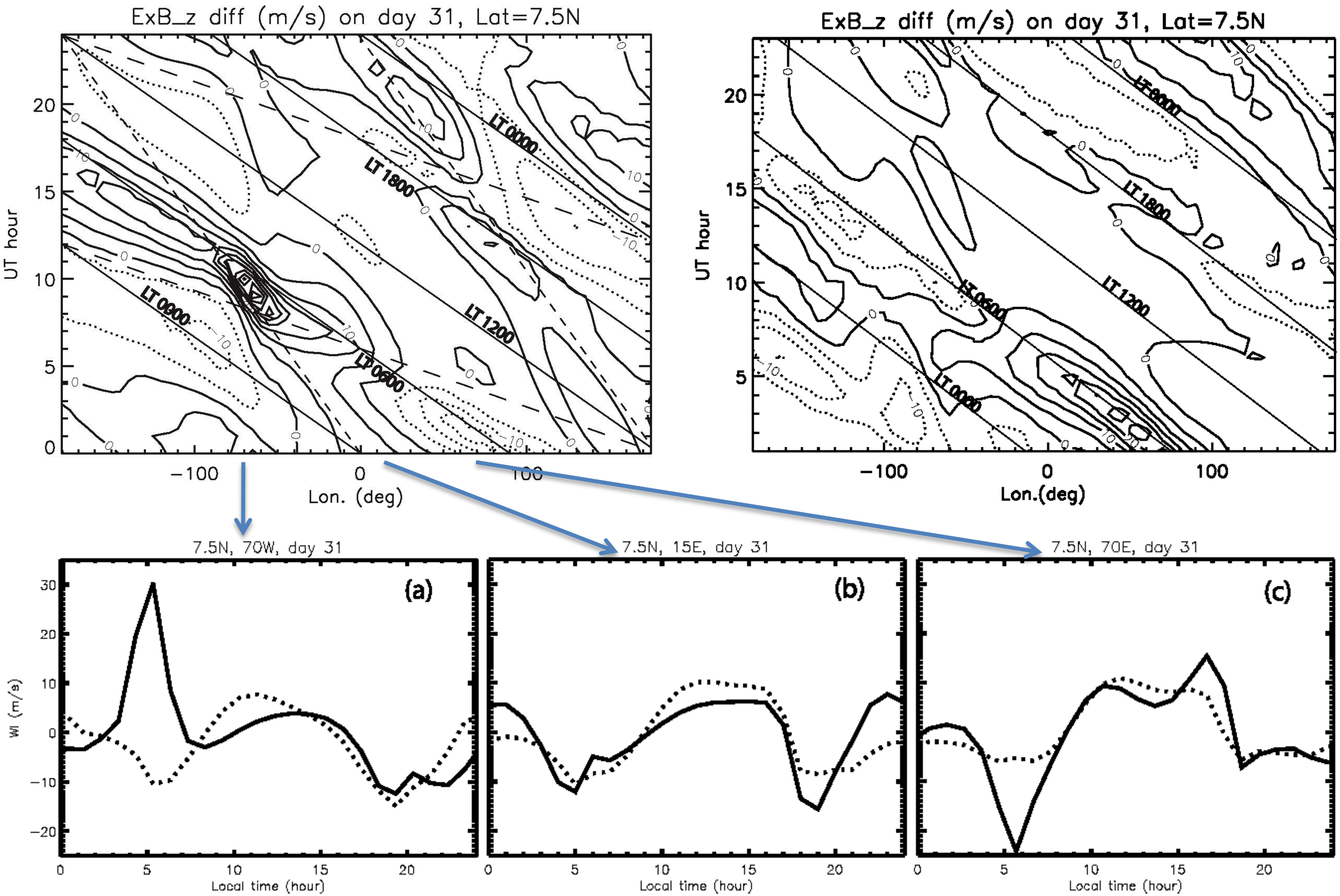


Liu et al., 2010

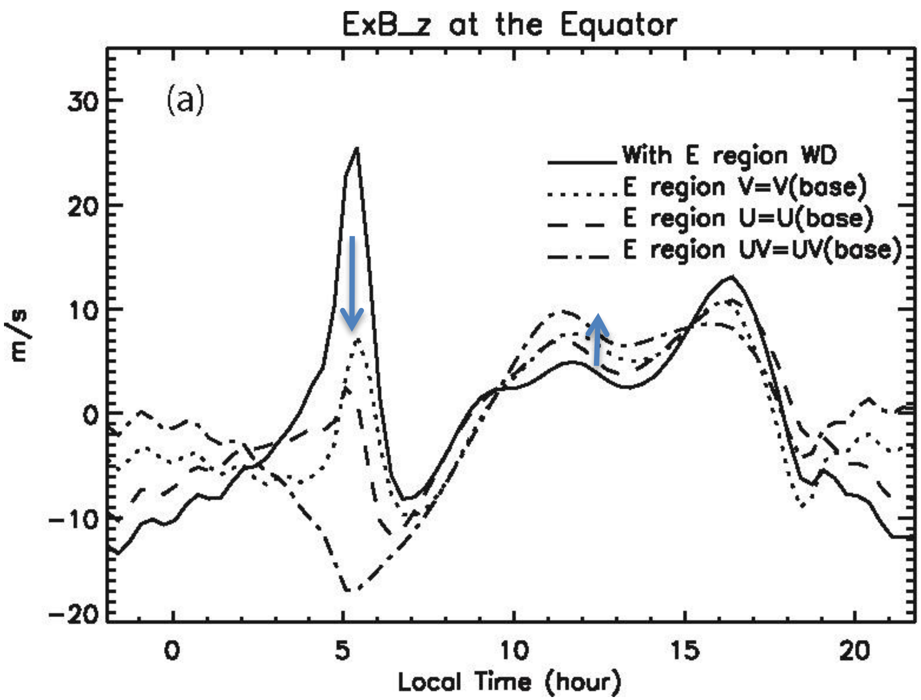
Comparing Vertical Ion Drift (Solar Min)

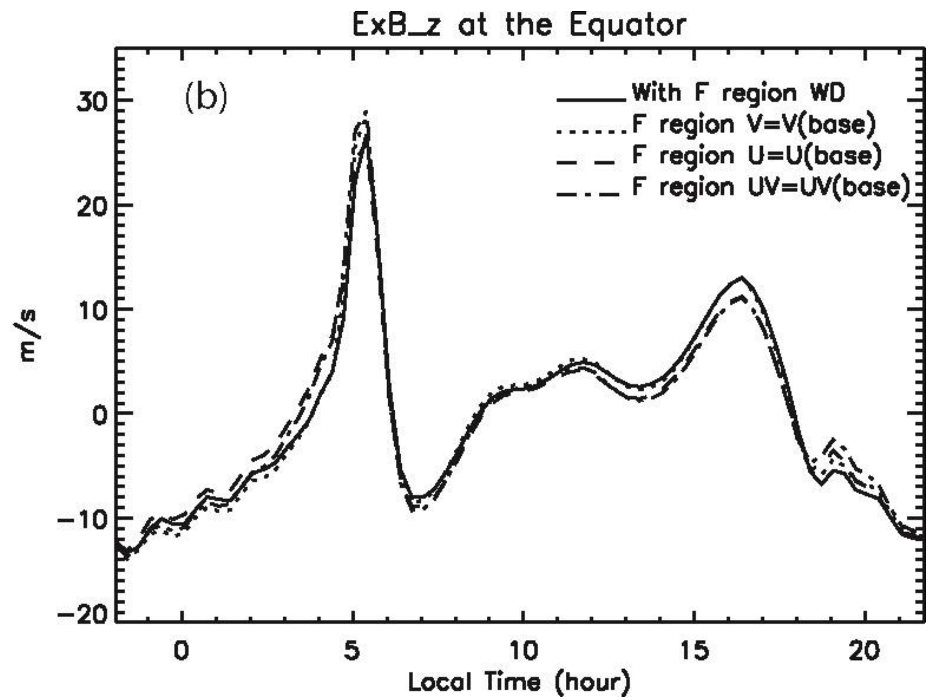


Temporal-Spatial Variability



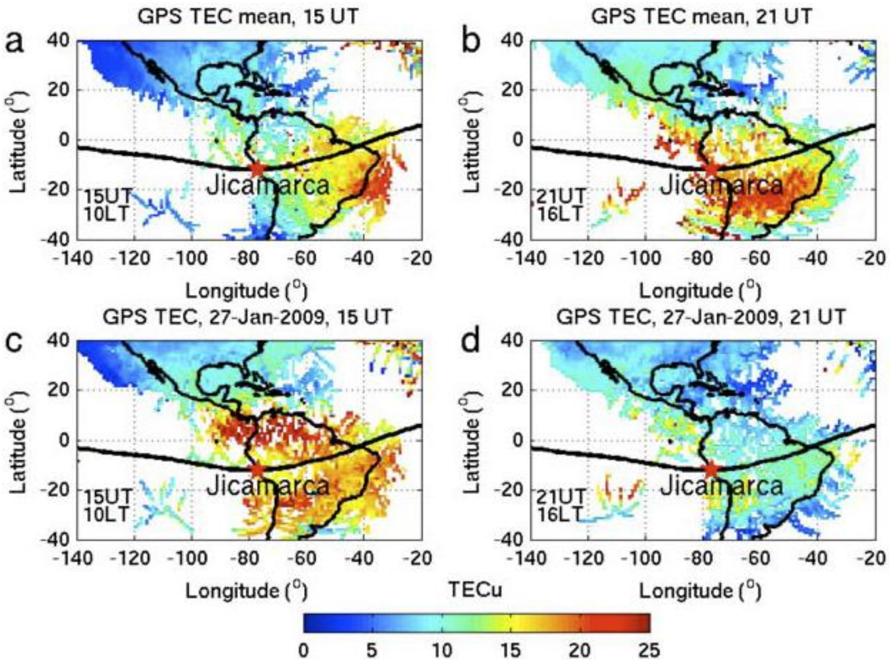
E and F Region Dynamo

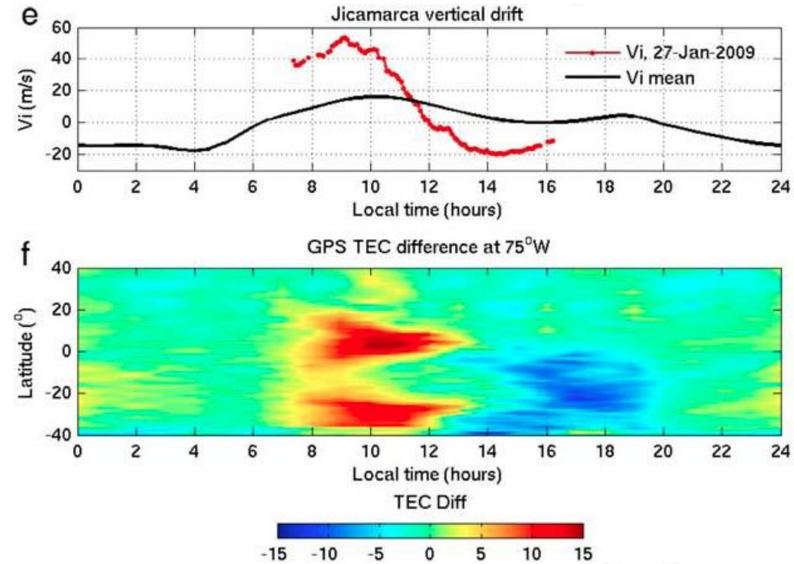


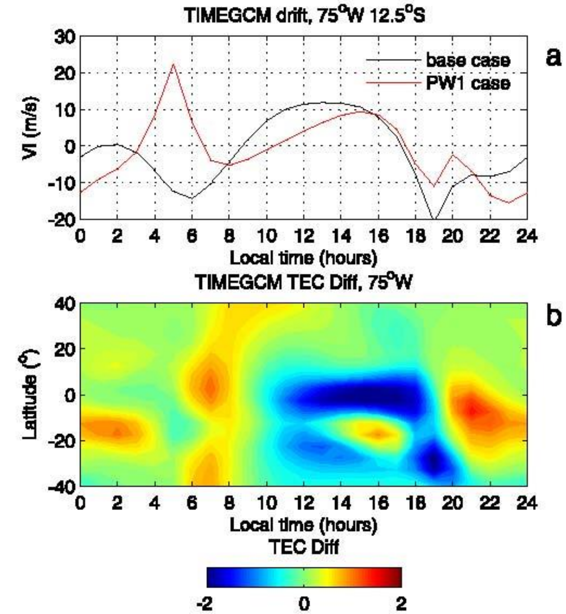


Observational Evidence of Ionospheric Response During SSW

Goncharenko et al, 2010



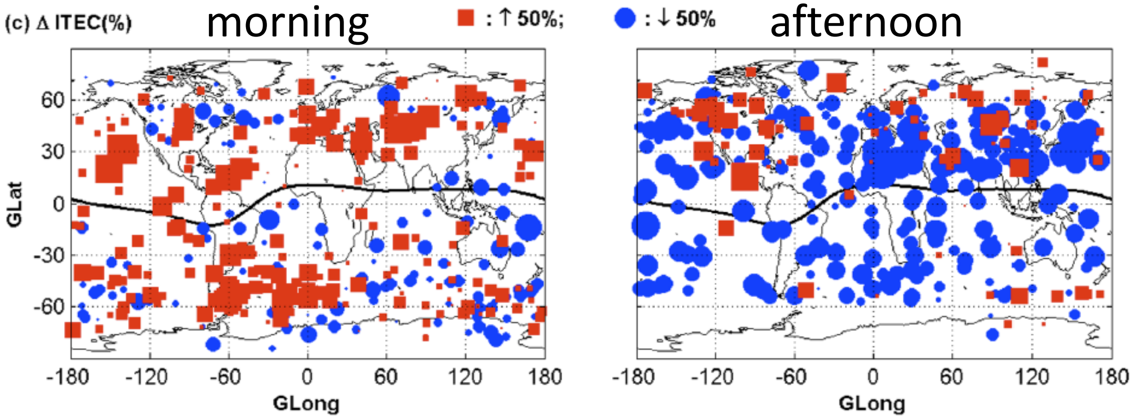




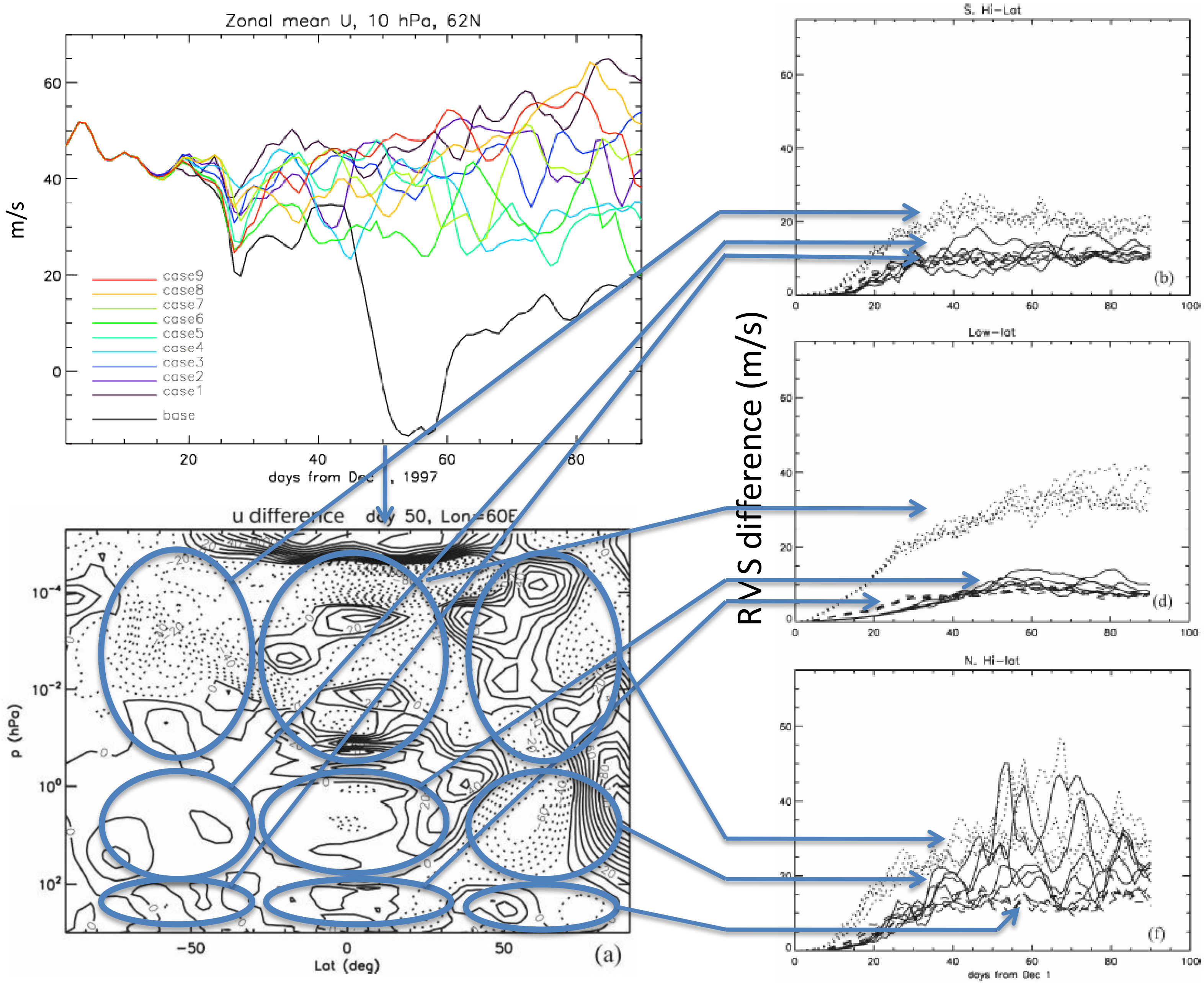
Yue et al, 2010

morning

afternoon



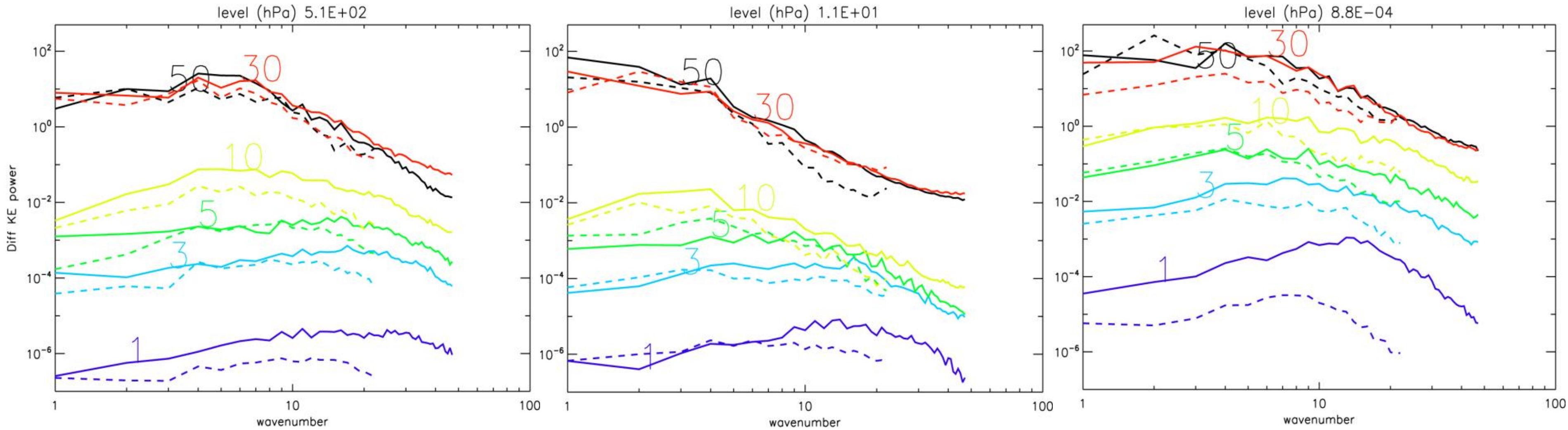
Error Growth of WACCM



Solid: Stratosphere
Dashed: troposphere
Dotted: MLT

Liu et al., 2009

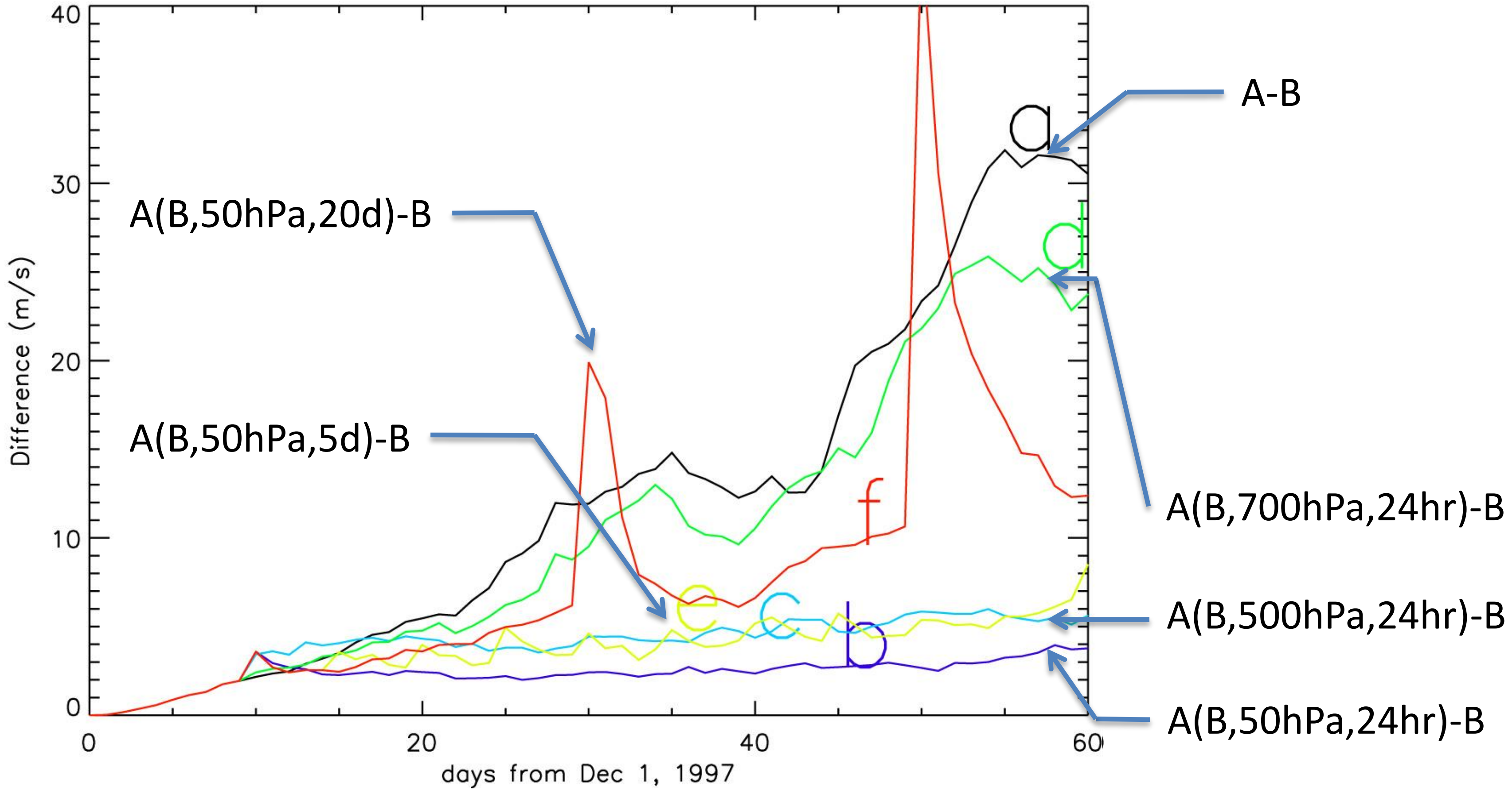
Scale Dependence of Error Growth



Control of Error Growth

- Error growth in the upper atmosphere is likely closely tied to decreasing skills in forecasting atmospheric waves.
- We should be able to control error growth in the upper atmosphere if we have good knowledge of the wave sources.
- WACCM Experiments:
  - "B" case: Base case ("truth")
  - "A" case: Error in initial condition
  - "A(B,p_s,ΔT)" case: A corrected with perfect knowledge of B at level p_s every ΔT time.

Control of Error Growth in the Upper Atmosphere



Liu et al., 2009.

Summary

- Two related reasons why we should get the lower atmosphere waves right:
  - Planetary waves/tides from the lower atmosphere can affect the ionospheric variability.
  - The loss of forecasting skills of these waves is a major cause of error growth in the middle and upper atmosphere (in the absence of magnetic storms).
- Accurate specification of the lower atmosphere state helps control the error growth of the middle and upper atmosphere.