Seasonality of Instability driven Planetary waves in the MLT

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Instability driven Planetary waves in the atmosphere

- Planetary waves in the middle atmosphere are mainly tropospheric in origin, and are mostly quasi-stationary Rossby waves and other waves with periods around 2, 5, 10 and 16 days, which correspond to natural modes of variability of the Earth's atmosphere [see, for example, *Madden*, 2007].
- Planetary scale waves, such as the **zonal wavenumber one (W1) 6.5-day wave**, the **zonal wavenumber three (W3) quasi-two-day wave (QTDW)**, and the **zonal wavenumber four (W4) 1.8-day wave**, are believed to be driven by baroclinic/ barotropic instability of the background atmosphere [*Plumb* 1983, *Meyer and Forbes* 1997, *Liu et al.,* 2004]. IPWs generally occur around the equinoxes and summer solstice.

$$q_y = +\beta + Q_h + Q_v$$

$$\beta = \frac{2\Omega\cos\phi}{a}$$

$$Q_h = -\frac{1}{a^2}\frac{\partial}{\partial\phi}\left[\frac{1}{\cos\phi}\frac{\partial}{\partial\phi}(\bar{u}\cos\phi)\right]$$

$$Q_v = -(2\Omega\sin\phi)^2\rho_o^{-1}\frac{\partial}{\partial z}\left(\rho_o\frac{1}{N^2}\frac{\partial\bar{u}}{\partial z}\right)$$

where

Ω Earth's angular velocity;

a planetary radius;

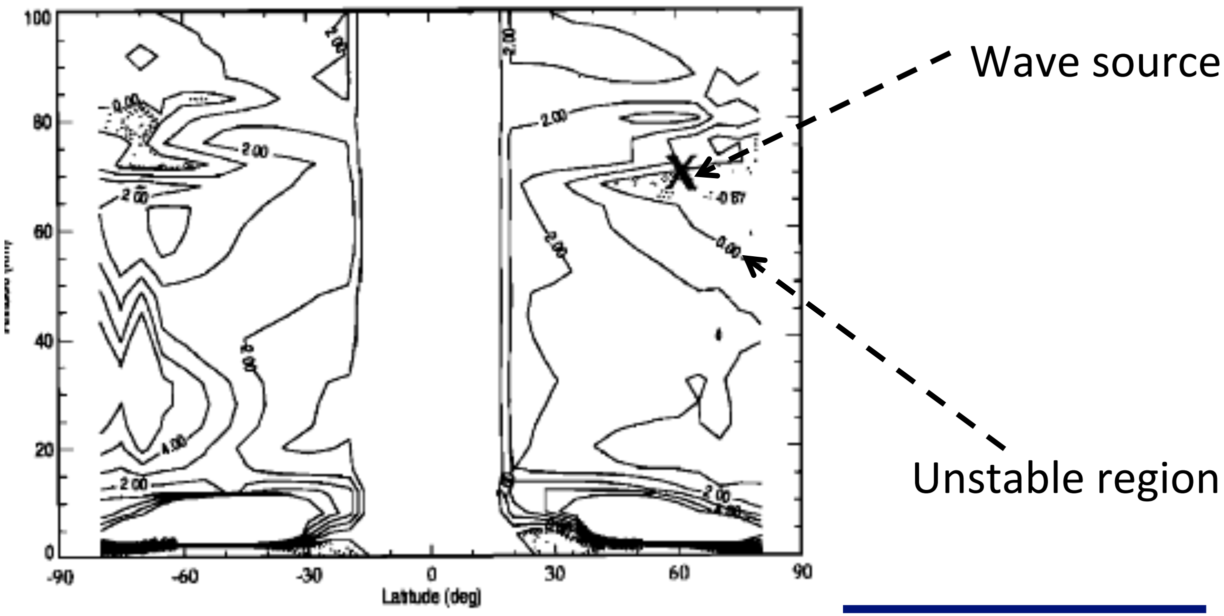
ϕ latitude;

$\bar{u}$ zonal mean wind;

ρ_o density;

N Brunt - Väisla frequency;

Z vertical pressure coordinate.



Ionospheric variabilty due to IPWs ?

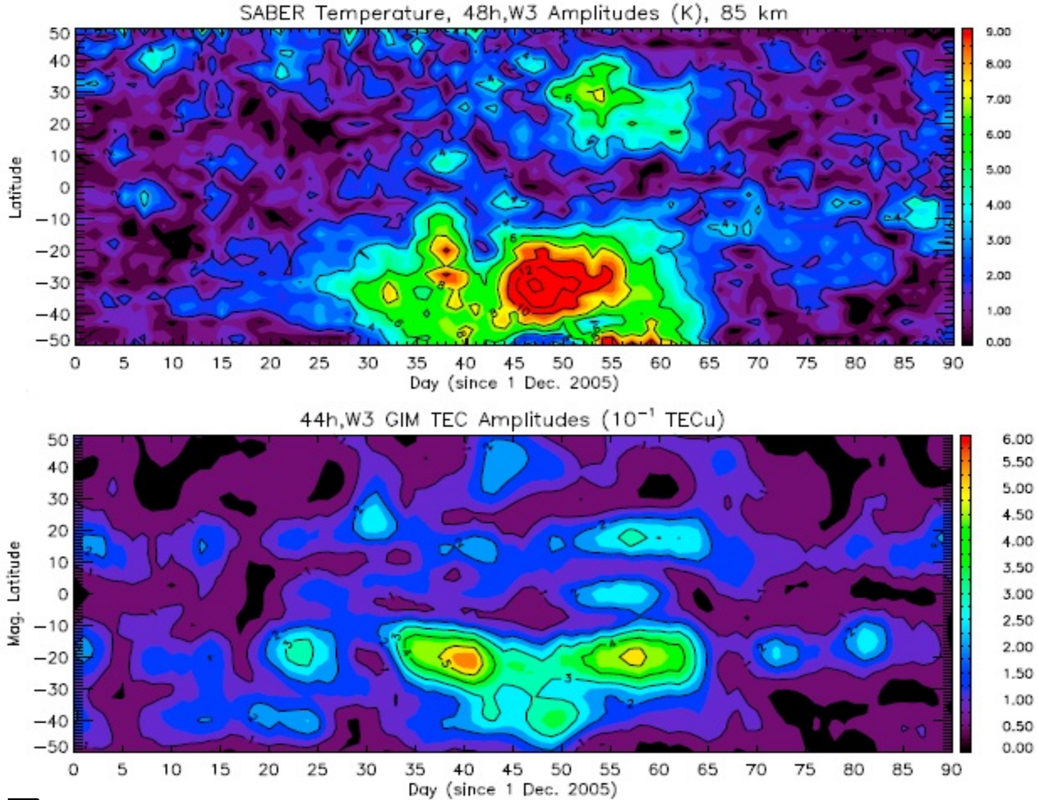
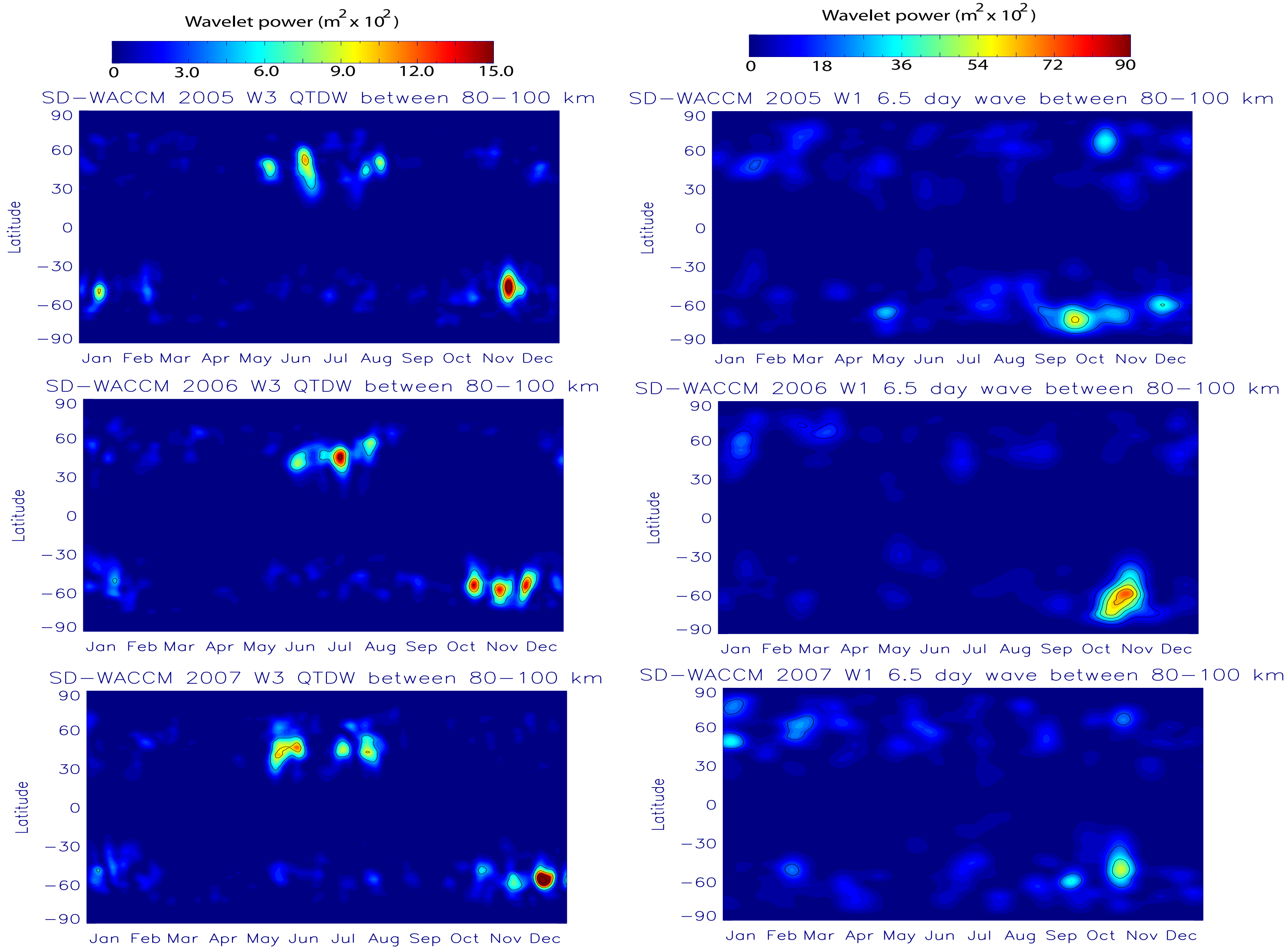


Figure from *Chang et al. 2011* showing the SABER zonal wave number 3 QTDW SABER temperature perturbations and GPS TEC perturbations

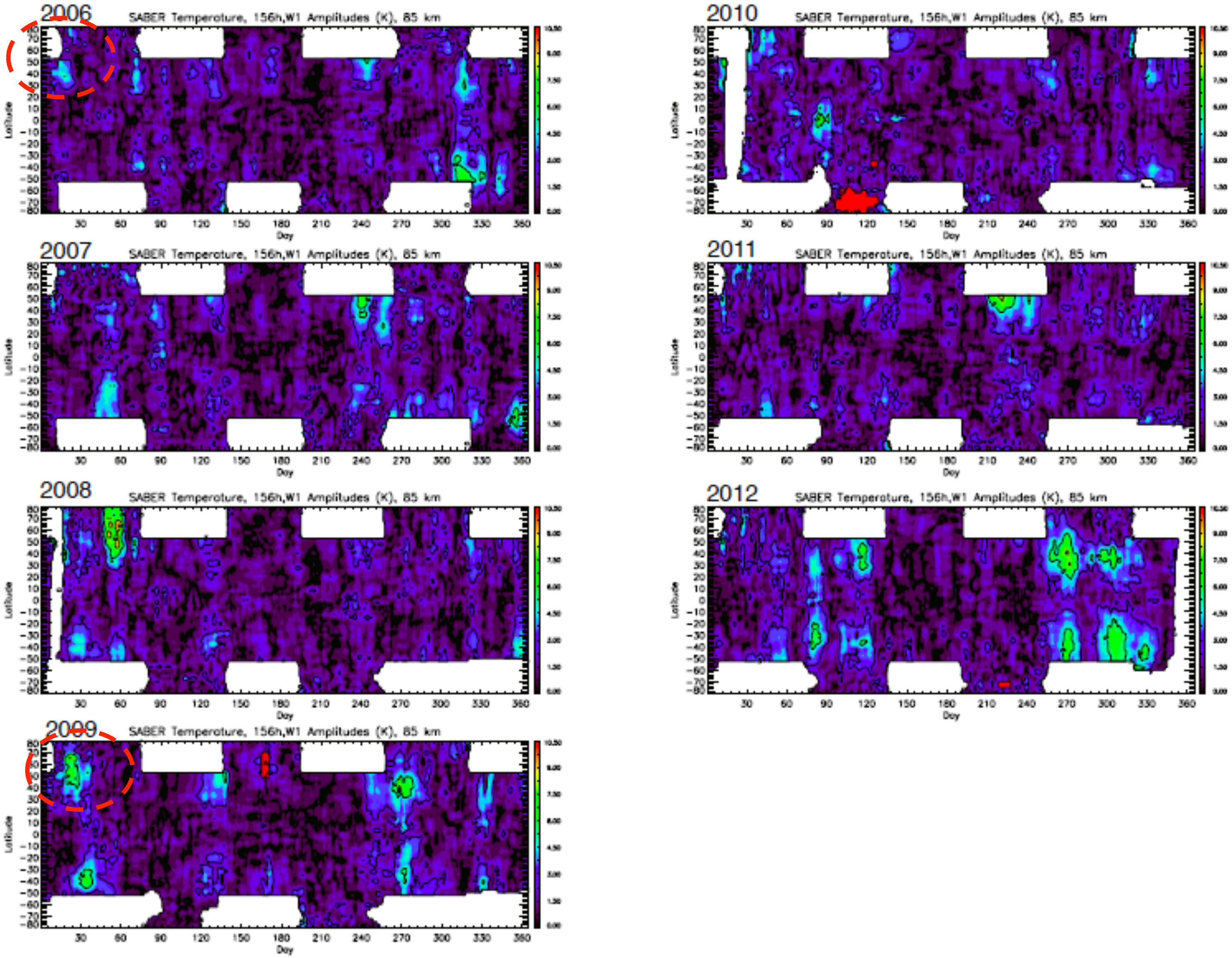
- ❑ These IPW, which have their origin in the mesosphere, propagate into the thermosphere and can potentially impact the ionosphere by affecting the Thermospheric winds through the wind dynamo effect.

- ❑ SSWs have been shown to excite secondary planetary waves in the MLT. Are secondary planetary waves associated with SSW events similar to IPW occurring around the equinoxes and summer solstice?

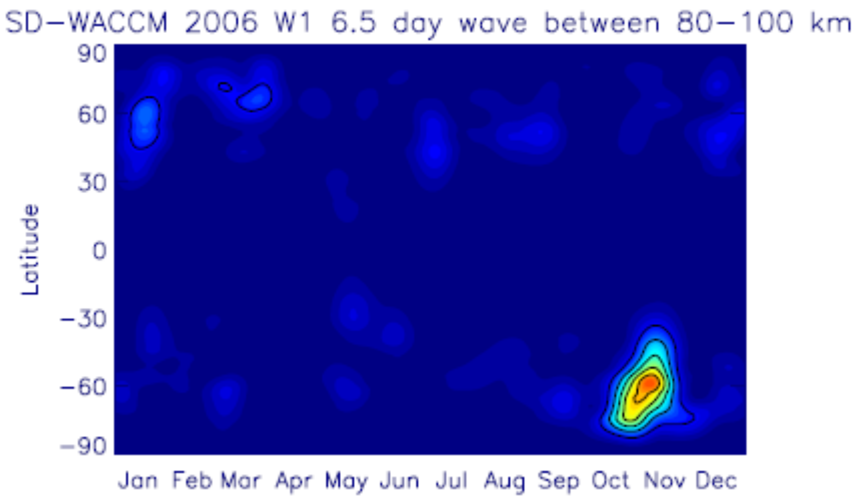
Seasonality of the QTDW and 6.5 day from SD WACCM

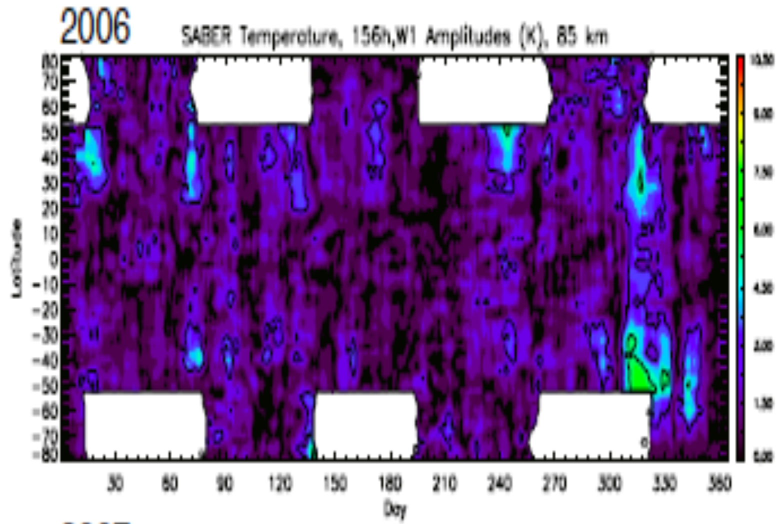


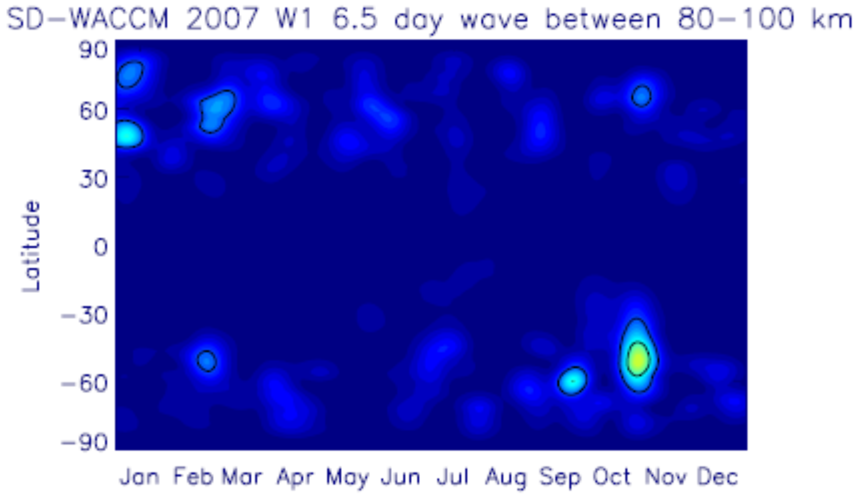
Seasonality of the 6.5 day from SD WACCM from SABER

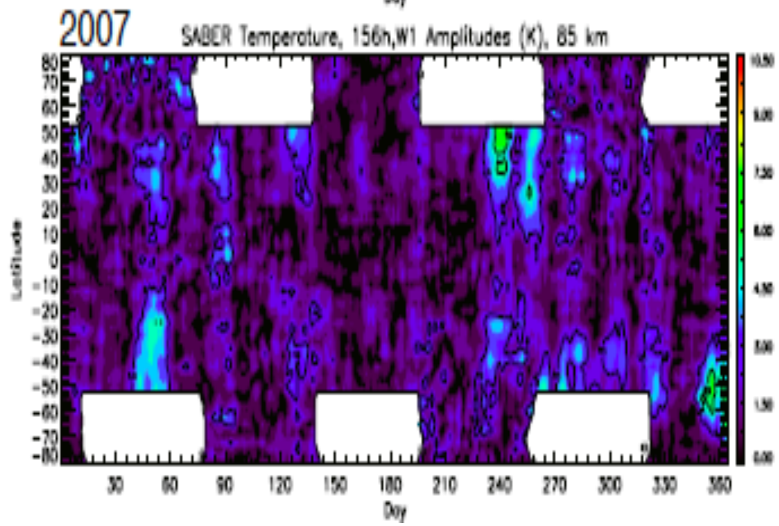


Comparison of SABER seasonality of the 6.5 day with SD WACCM

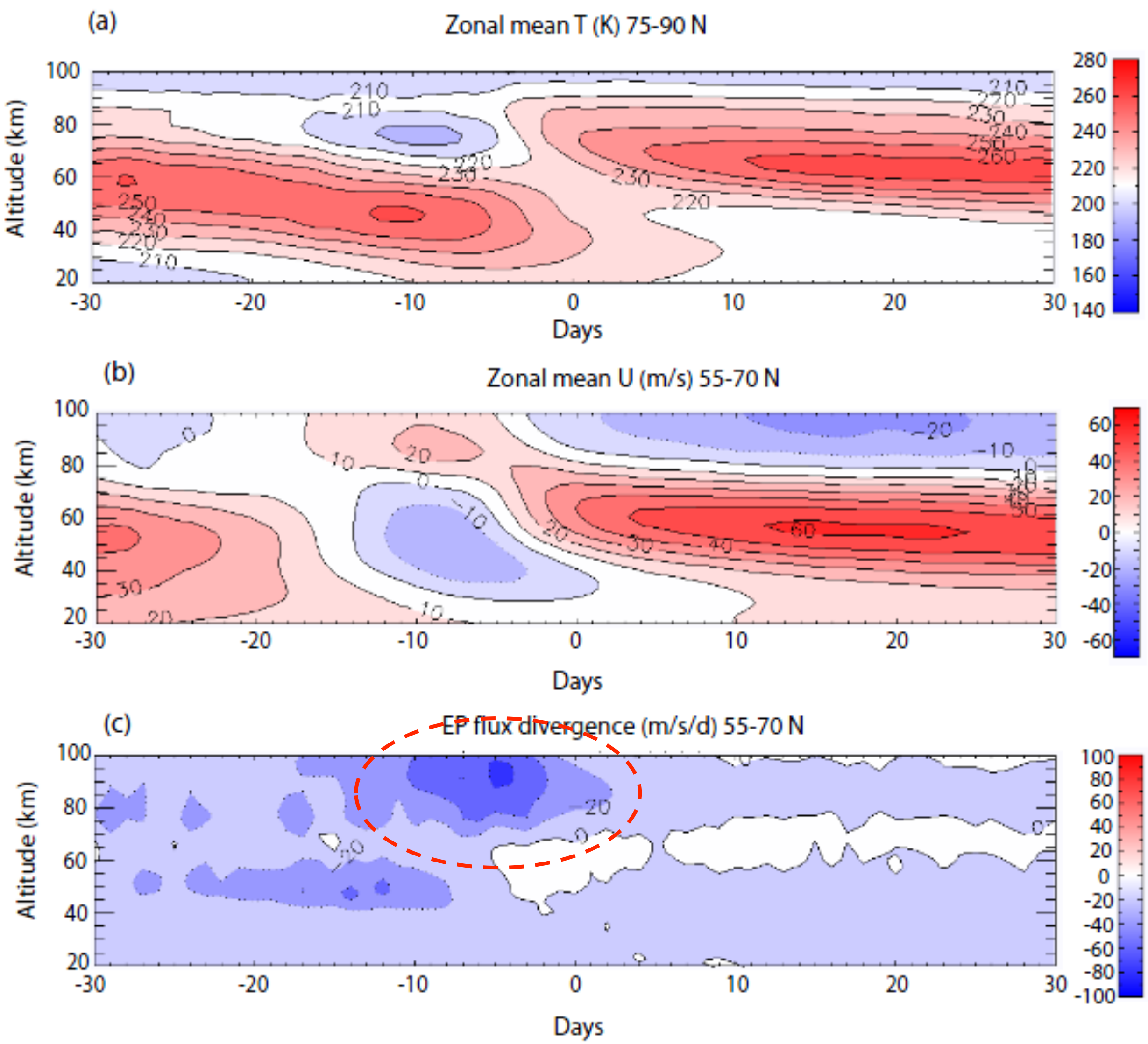








Secondary EP flux convergence in MLT following SSW



Composite of 68 elevated stratopause winters in four 53 year WACCM simulations.

[Chandran et al. 2013a]

Specified Dynamics WACCM simulation of January 2012

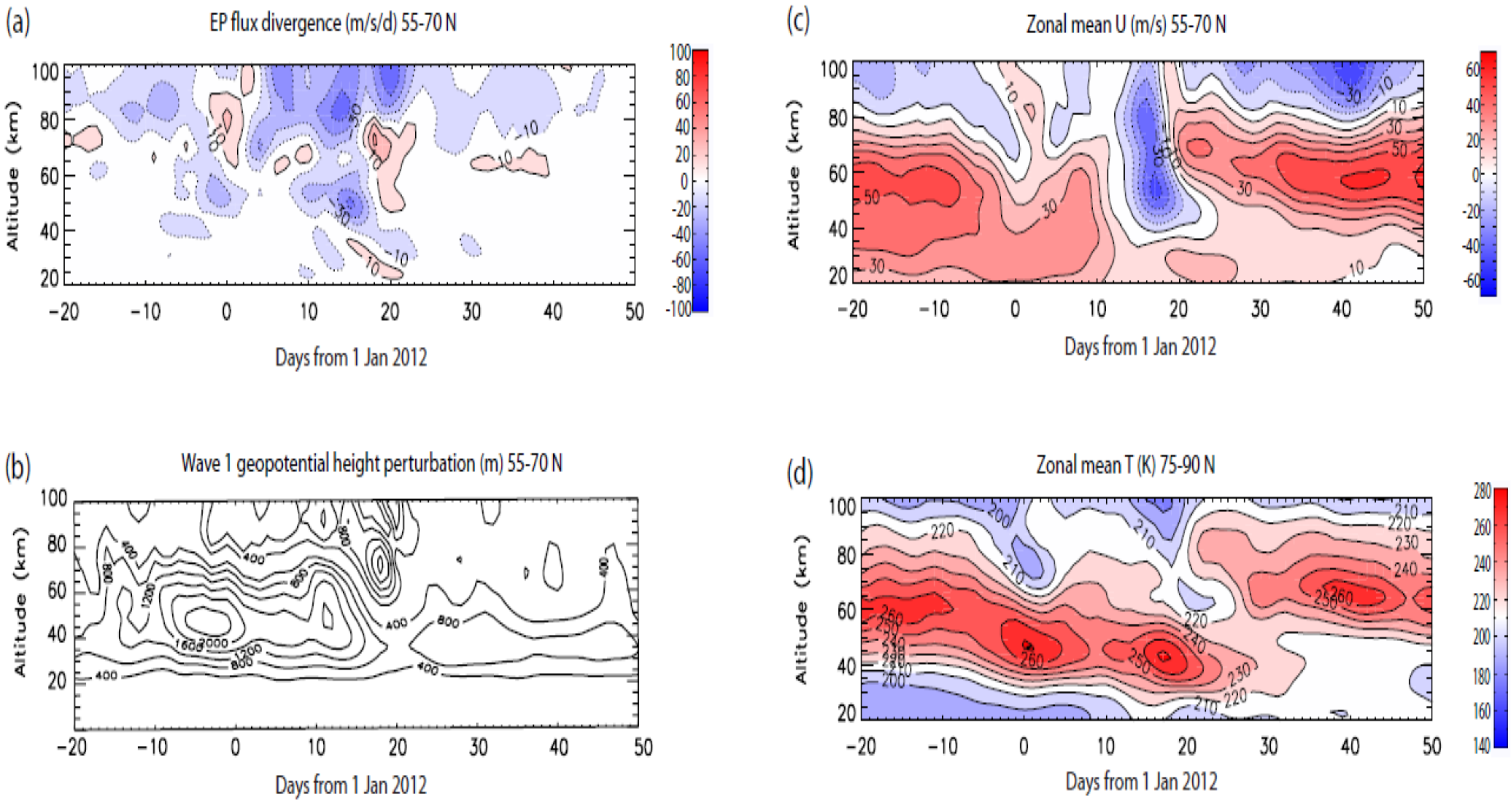
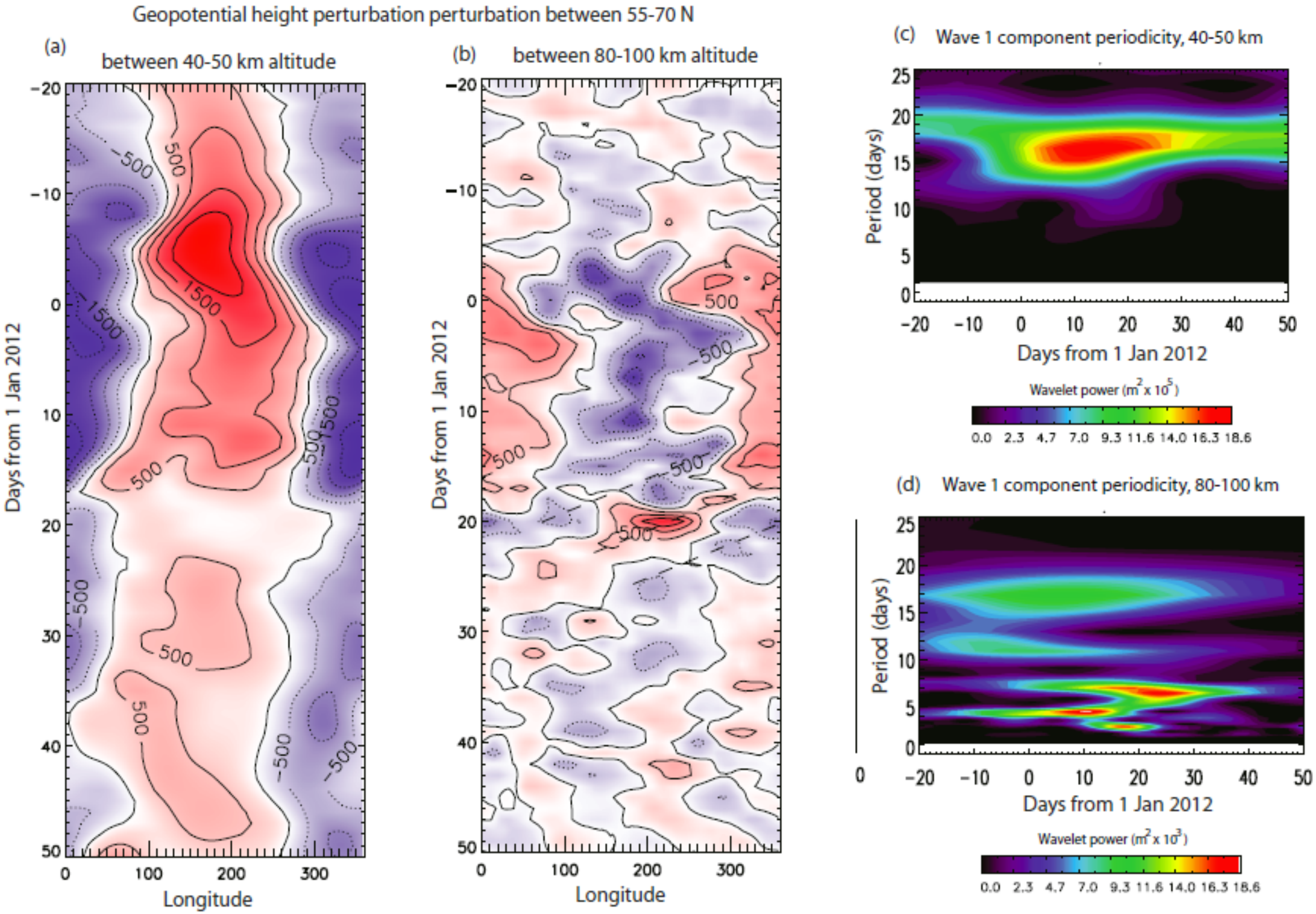


Figure 1: Specified Dynamics WACCM simulations of midlatitude (55 - 70 N) (a) EP flux divergence, (b) wave 1 geopotential height perturbation (contour lines every 400 m), (c) mean zonal wind, and (d) polar cap (75 - 90 N) temperature for the winter of 2011-2012.

[Chandran et al. 2013b]

Specified Dynamics WACCM simulation of January 2012



Specified Dynamics WACCM simulation of January 2012

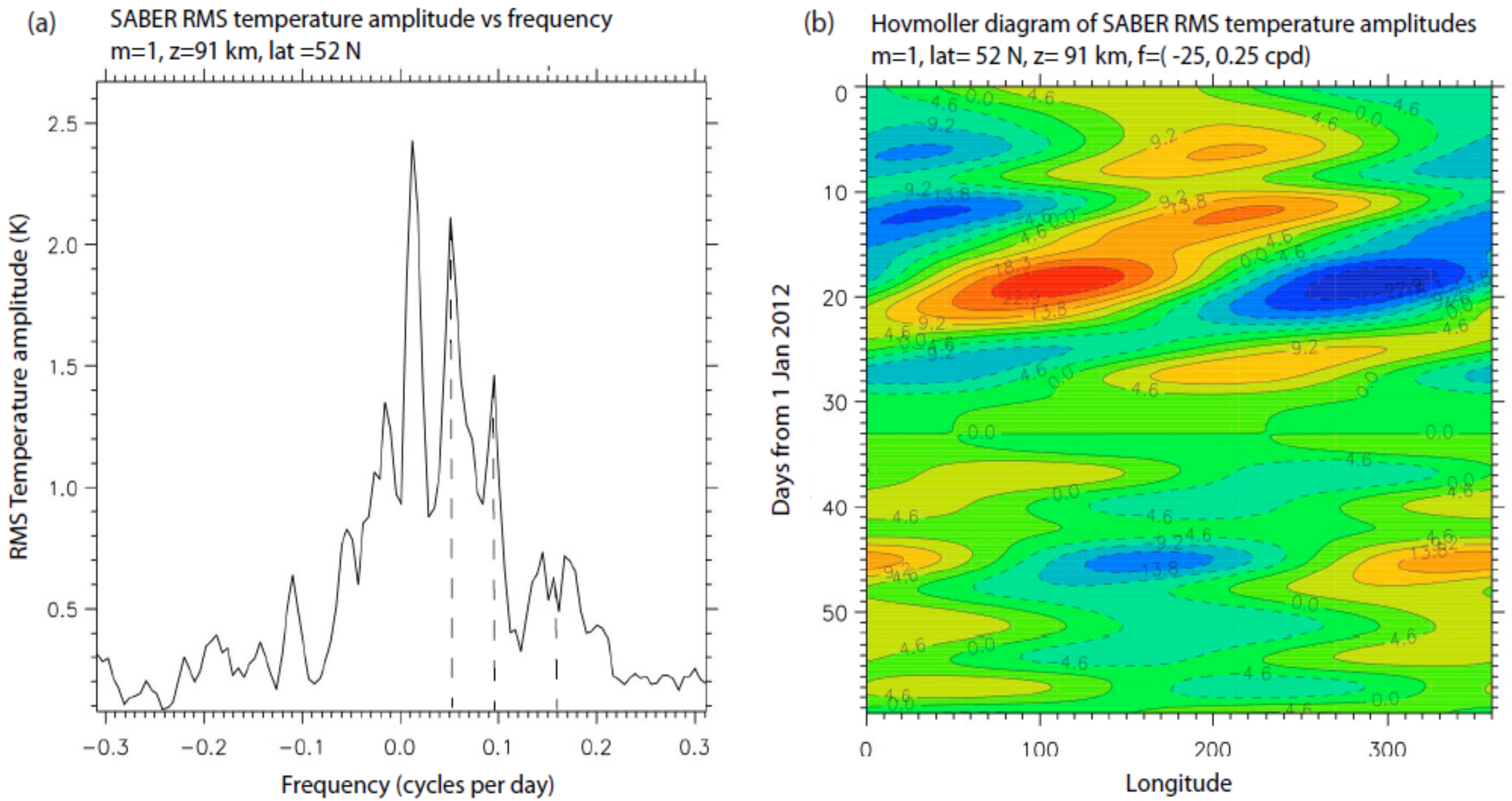


Figure 3: (a) SABER wavenumber 1 frequency spectrum for the period November 2011 to April 2012 at 52 N and ~ 91 km; (b) Hövmoller diagram of SABER wavenumber 1 temperature amplitudes at 52 N and ~ 90 km in the frequency range (-25, 0.25 cpd) for the first 60 days of 2012.

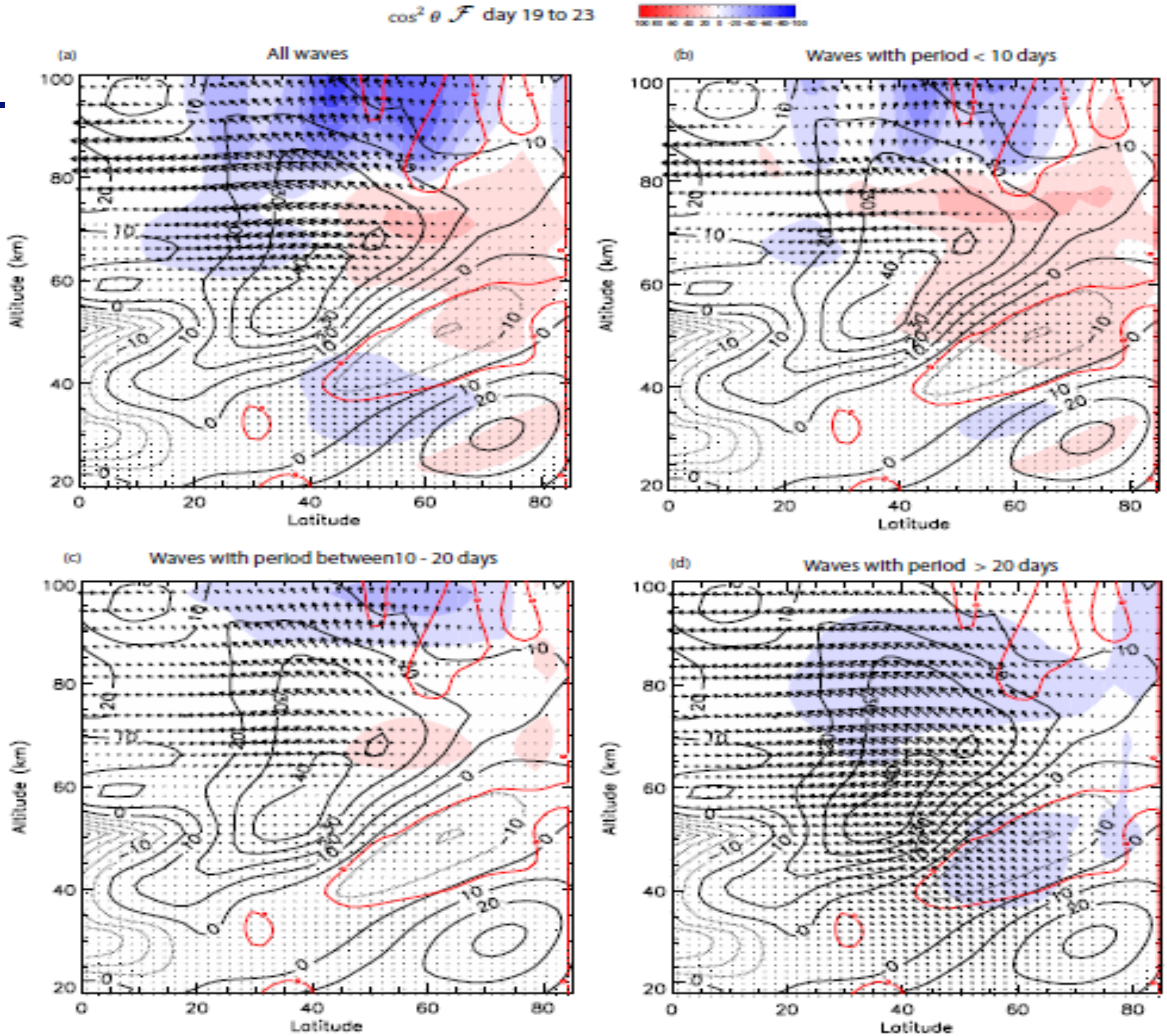


Figure 4: Latitude-Height cross-sections of of the quantity $\cos^2\theta$ F averaged between days19 and 23 for (a) all waves (b) short period waves (c) medium period waves (d) long period waves. F is proportional to the EP flux divergence; see text for details. The red contours enclose regions where the necessary condition for baroclinic/barotropic instability is fulfilled. The zonal-mean zonal wind distribution ($m\,s^{-1}$) is indicated by the black contours.

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Summary & Conclusions

- Both model and SABER observations show significant inter-annual variability in the occurrence of the 6.5-day wave
- The QTDW in SD-WACCM maximizes in summer in both hemispheres.
- Both the QTDW and the 6.5-day wave show stronger amplitudes in the Southern hemisphere in SD-WACCM. (Could be due to the stronger SH zonal mean winds and associated larger shears in WACCM.)

- In SD WACCM simulations of 2012 event a near 15 day westward propagating wave is seen in the stratosphere which causes the SSW, while a near 6.5 day wave with zonal Wave number 1 is seen in the MLT region immediately after the SSW with its source in the upper stratosphere and lower mesosphere.
- The QGPV gradient becomes negative due to the stratospheric wind reversals which result in baroclinic/barotropic unstable regions which acts as a source region for the secondary planetary waves.

- ***Does Ionospheric variability (TEC, temperature disturbances etc) after SSW show a 6-7 day periodicity ?***