Global Distribution of Quasi-Two-Day Waves: Results Based on the NOGAPS-ALPHA Reanalysis Model

D. Pancheva , P. Mukhtarov and D. Siskind

NIGGG, BAS, Sofia, Bulgaria

Naval Research Laboratory, Washington, USA

Motivations

- QTDWs are large-amplitude global-scale waves which can induce electric current systems in the ionosphere through a dynamo mechanism and in this way to be very efficient direct dynamic agent in vertical coupling of the atmosphere-ionosphere system.

- QTDWs effectively interact with tides generating new waves in the MLT region and having additional impact on the ionosphere through the secondary waves and modulated tides

- Although significant achievements have been attained in studying the spatial-temporal distribution of the QTDW phenomenon there are still features hidden because of observational limitations.

Used Data

- **Ground-based methods - provide a detailed temporal variability of the QTDW however cannot provide insight into its global distribution**

- **Satellite measurements provides insight in the global spatial distribution however they suffer from aliasing and poor temporal resolution problems.**

- **To overcome the above weak points we employ a version of the NOGAPS-ALPHA reanalysis model that provides output on an hourly basis.**

(Navy Operational Global Atmospheric Prediction System - Advanced Level Physics High Altitude version)

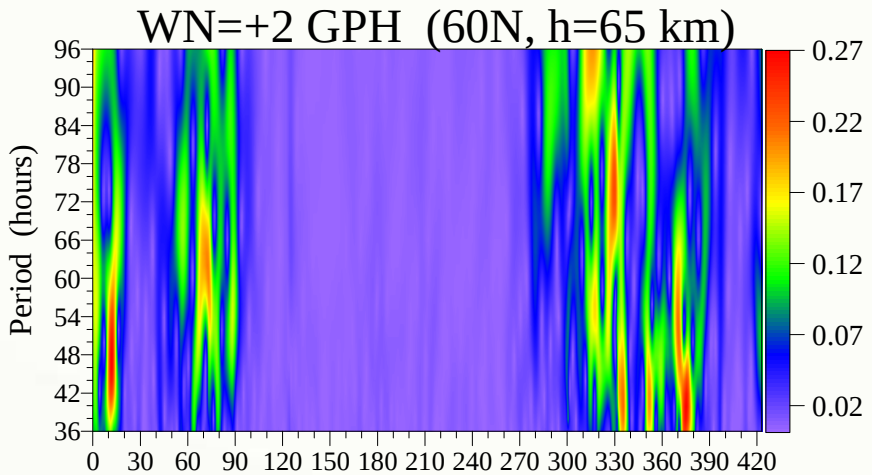
Data Analysis

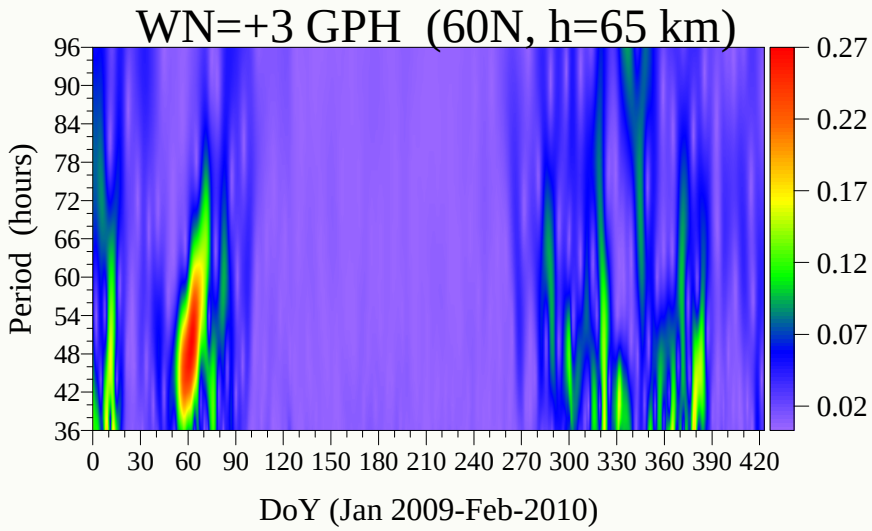
- 14 months: 01 January 2009–28 February 2010
- All meteorological fields: neutral winds, temperature and geopotential height
- Altitudes between ~15 and ~95 km
- Latitudes between ±80°
- 2D Wavelet Analysis
- Decomposition procedure where QTDWS are separated simultaneously with tides and other PWs

2D Wavelet Spectra

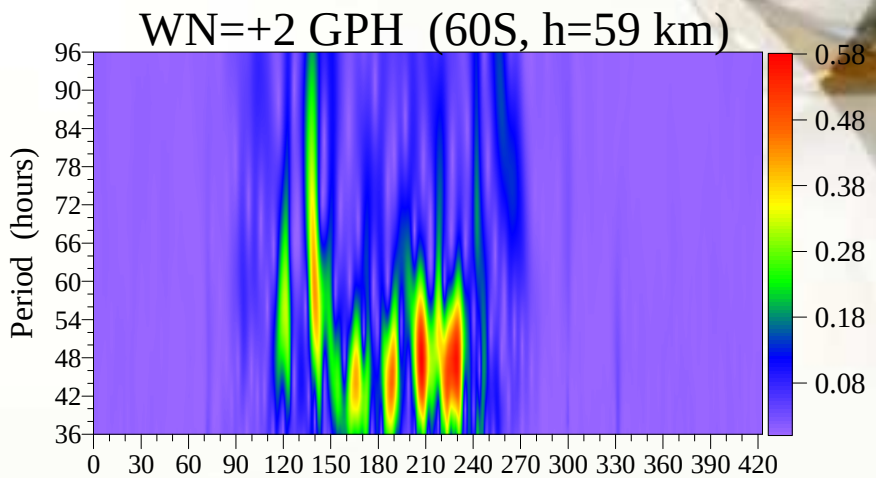
Eastward traveling QTDW

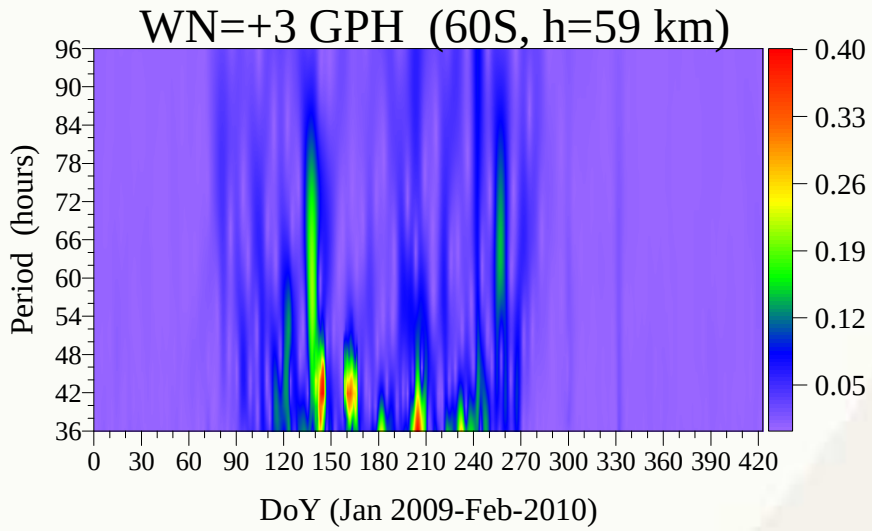
NH





SH

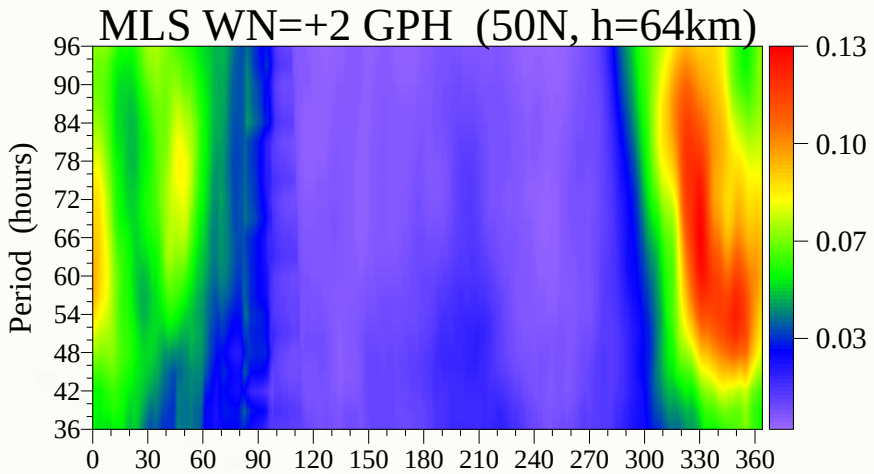


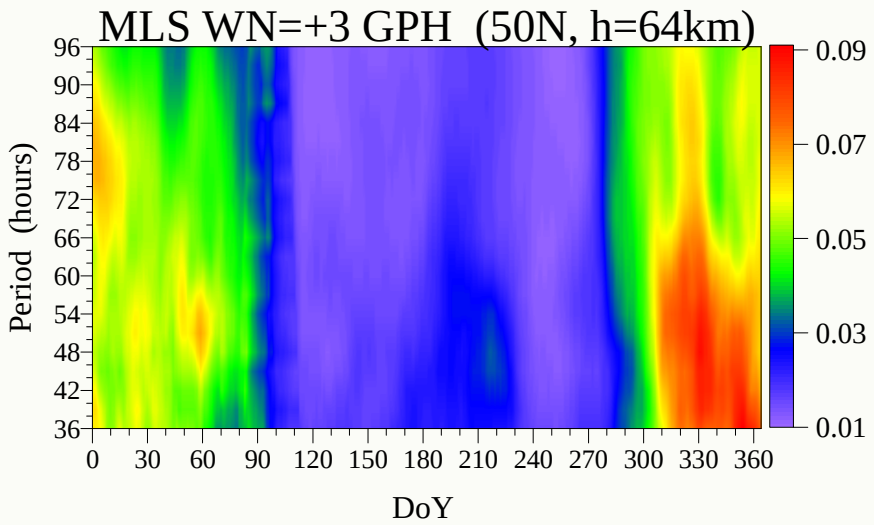


Mean 2D Wavelet Spectra

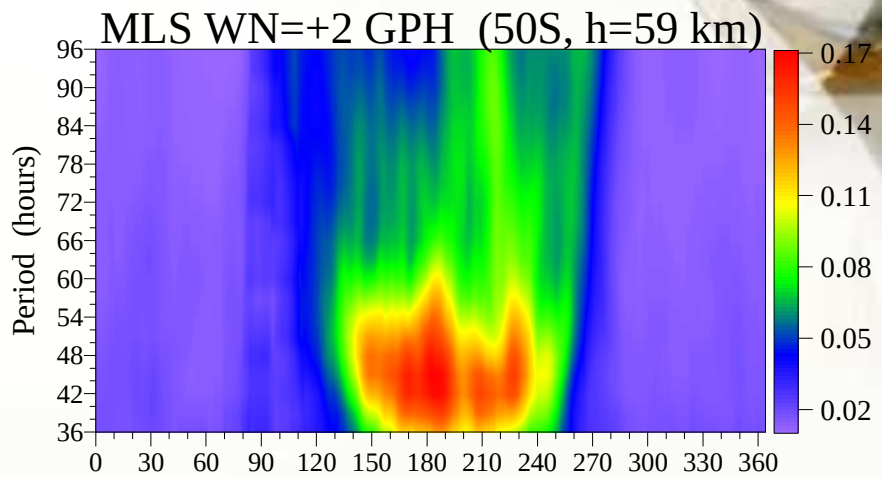
MLS/Aura GPH for 2005-2014

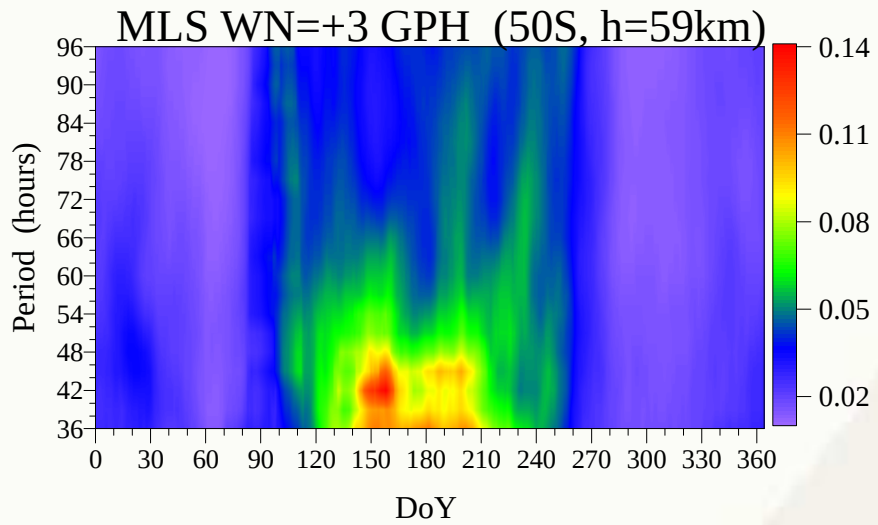
NH





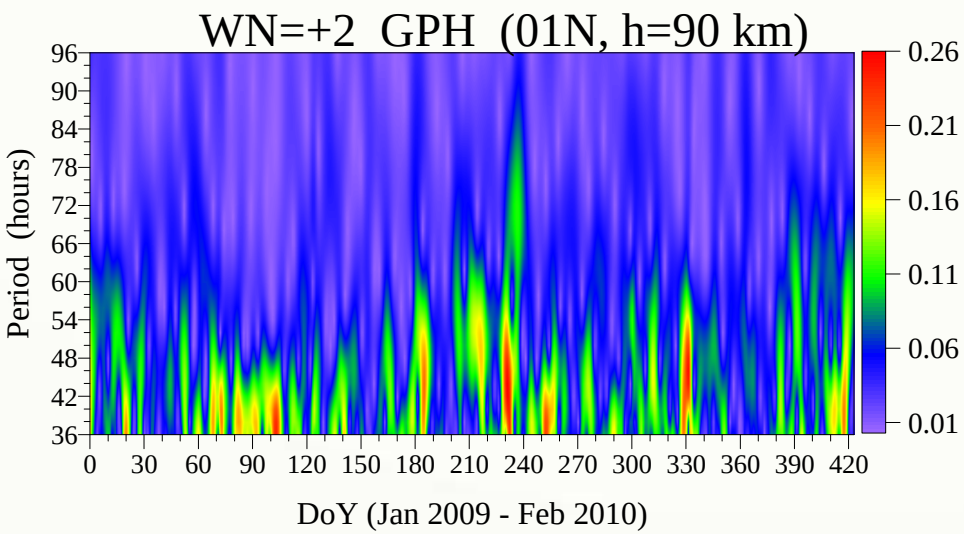
SH

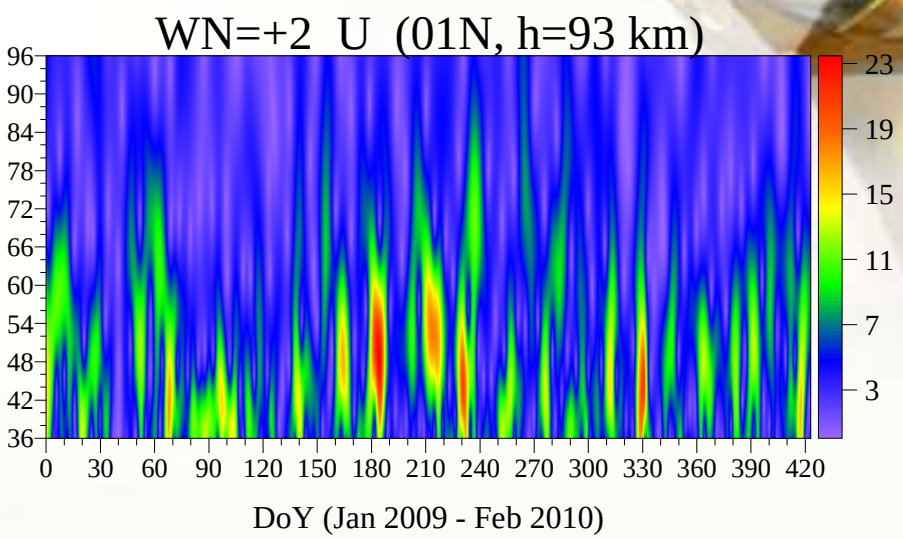


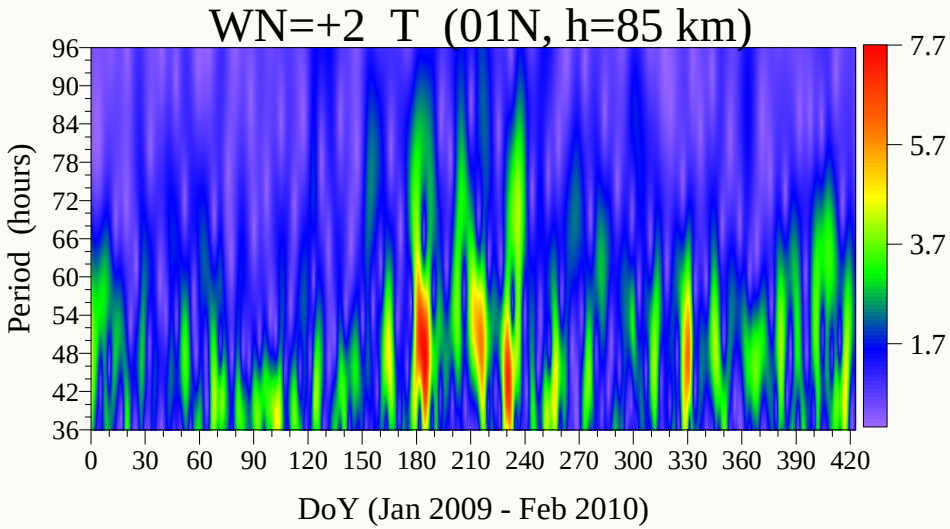


2D Wavelet Spectra over the Equator

GPH, U & T

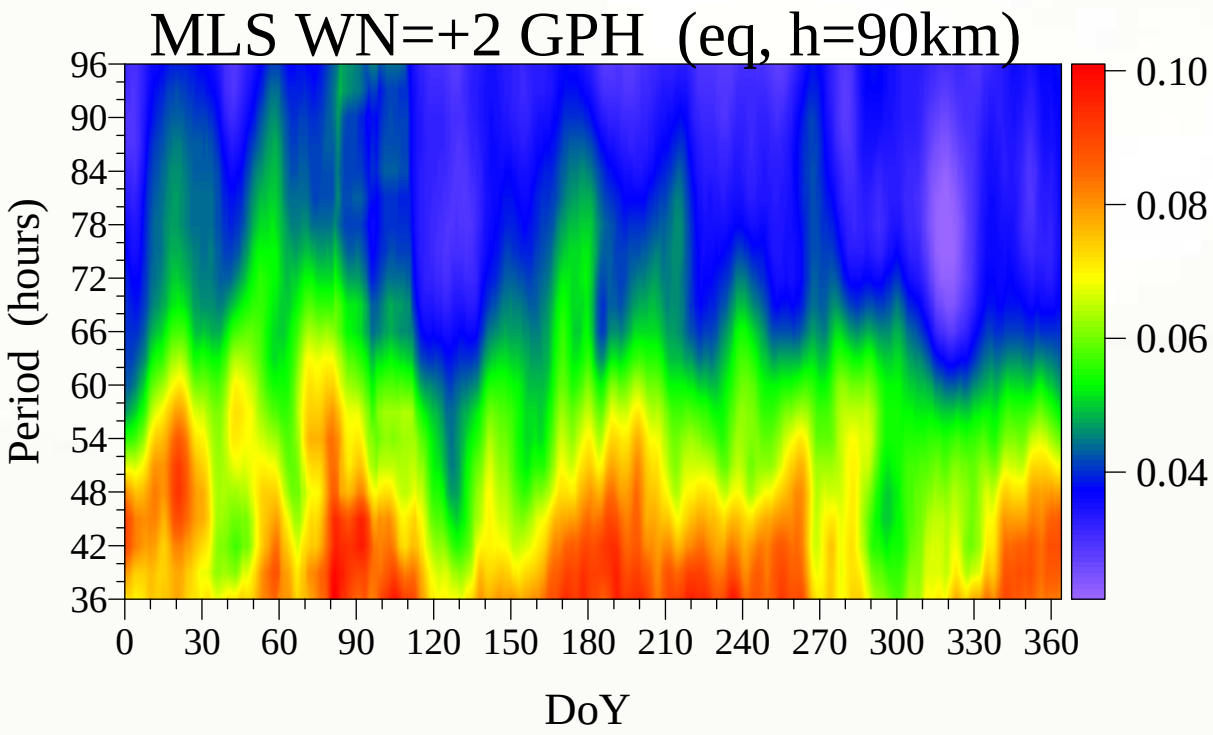




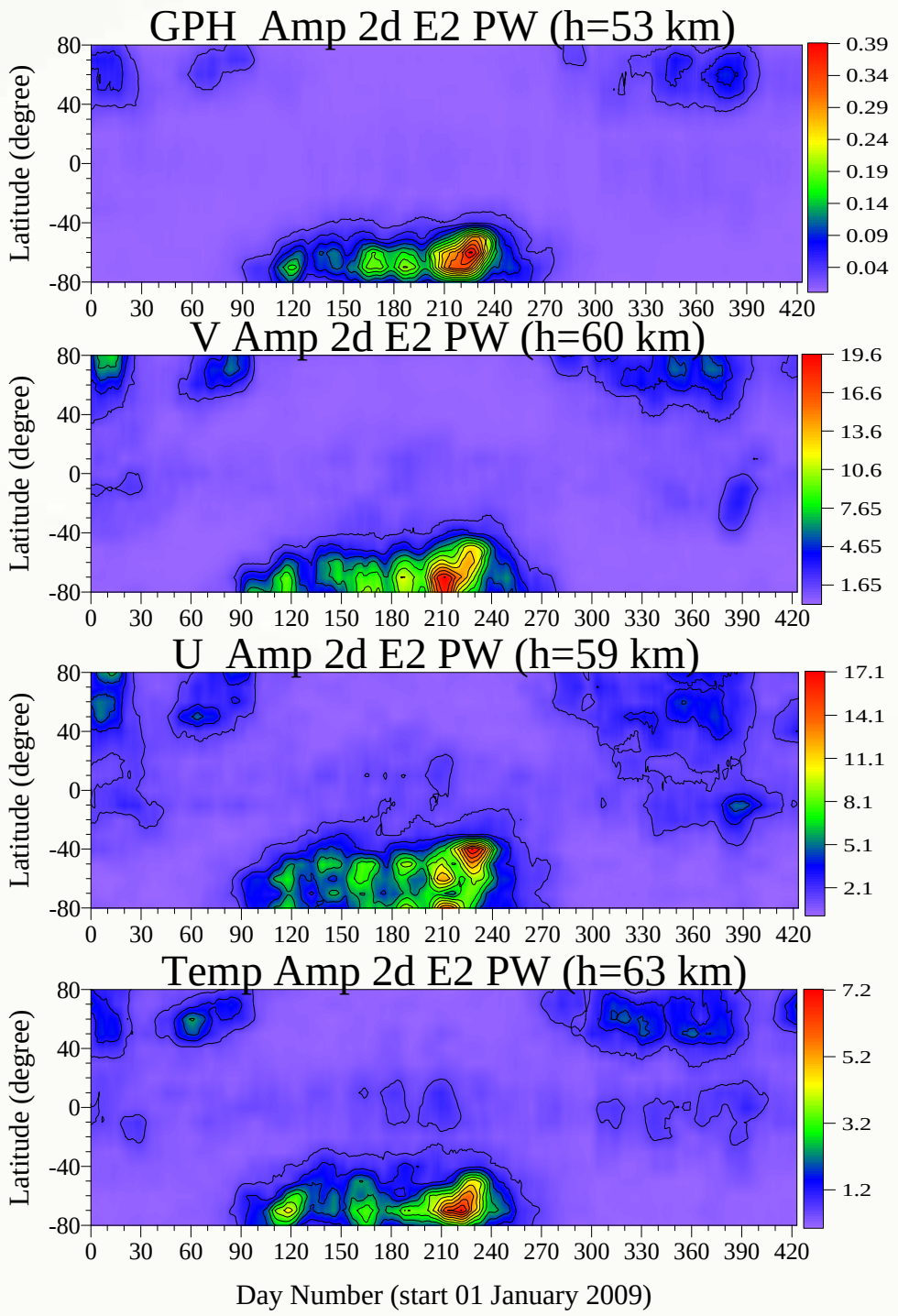


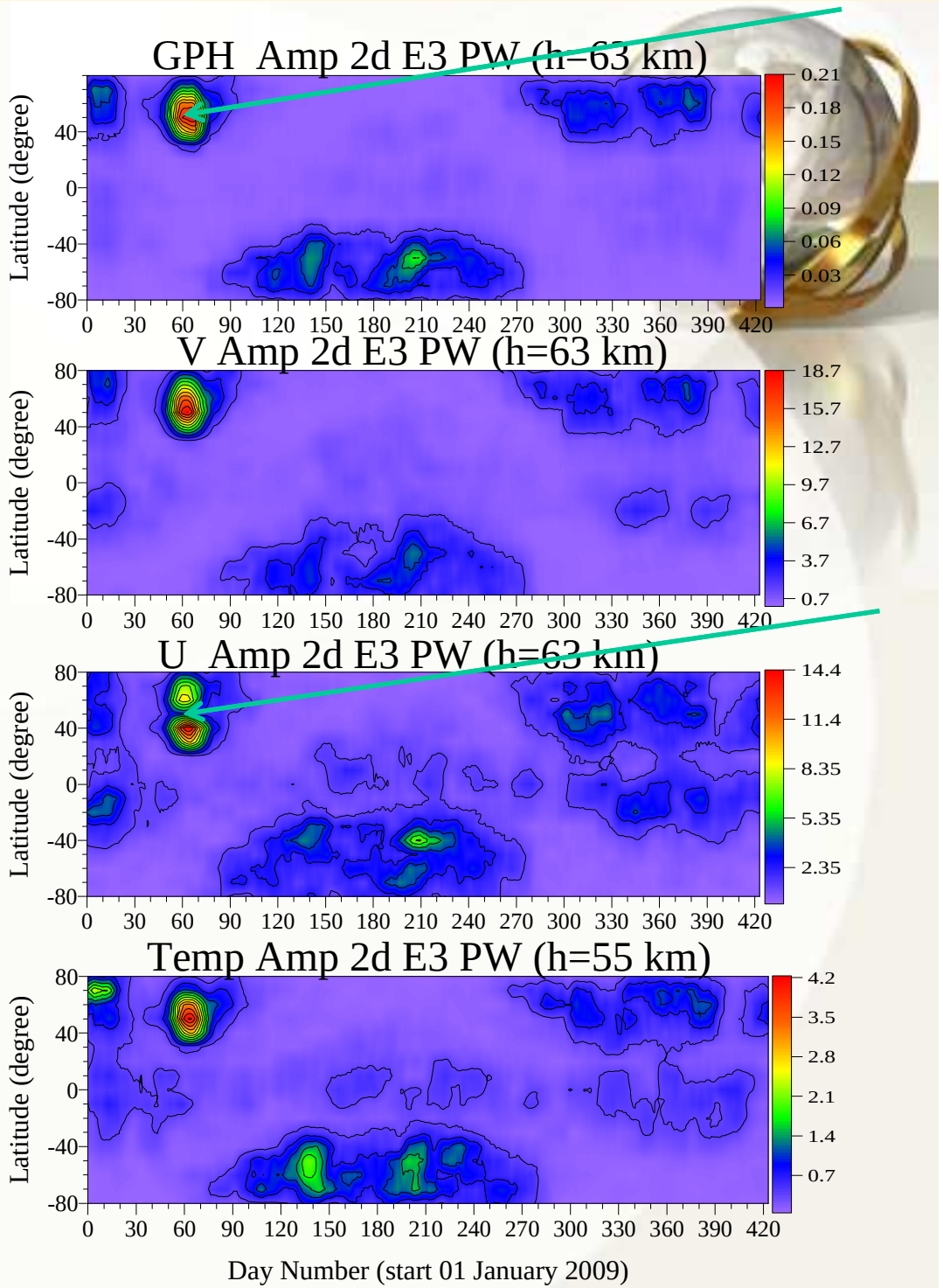
Mean 2D Wavelet Spectra

MLS/Aura GPH for 2005-2014

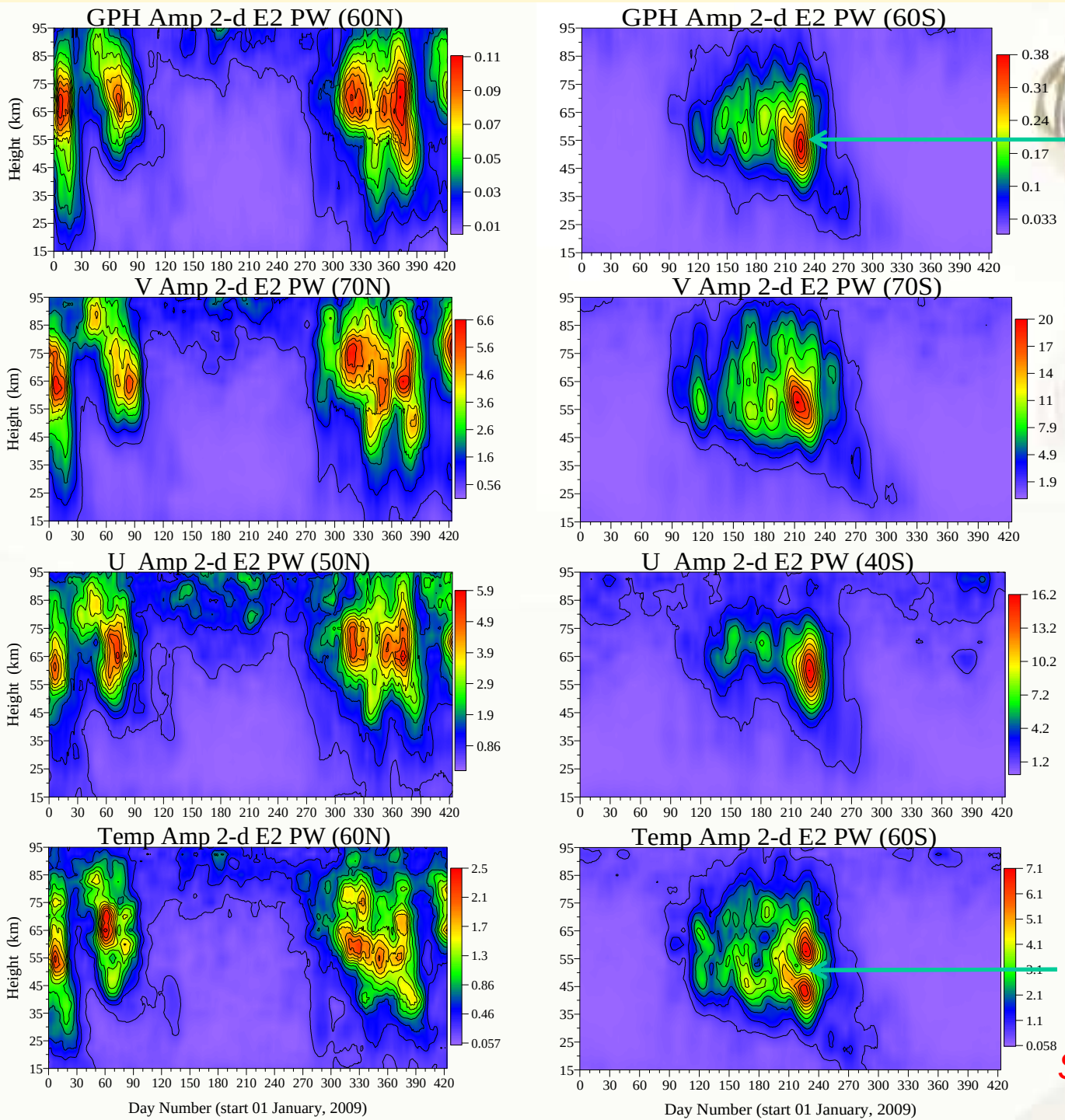


E2 & E3 QTDW - Latitude Structure)





E2 Altitude Structure

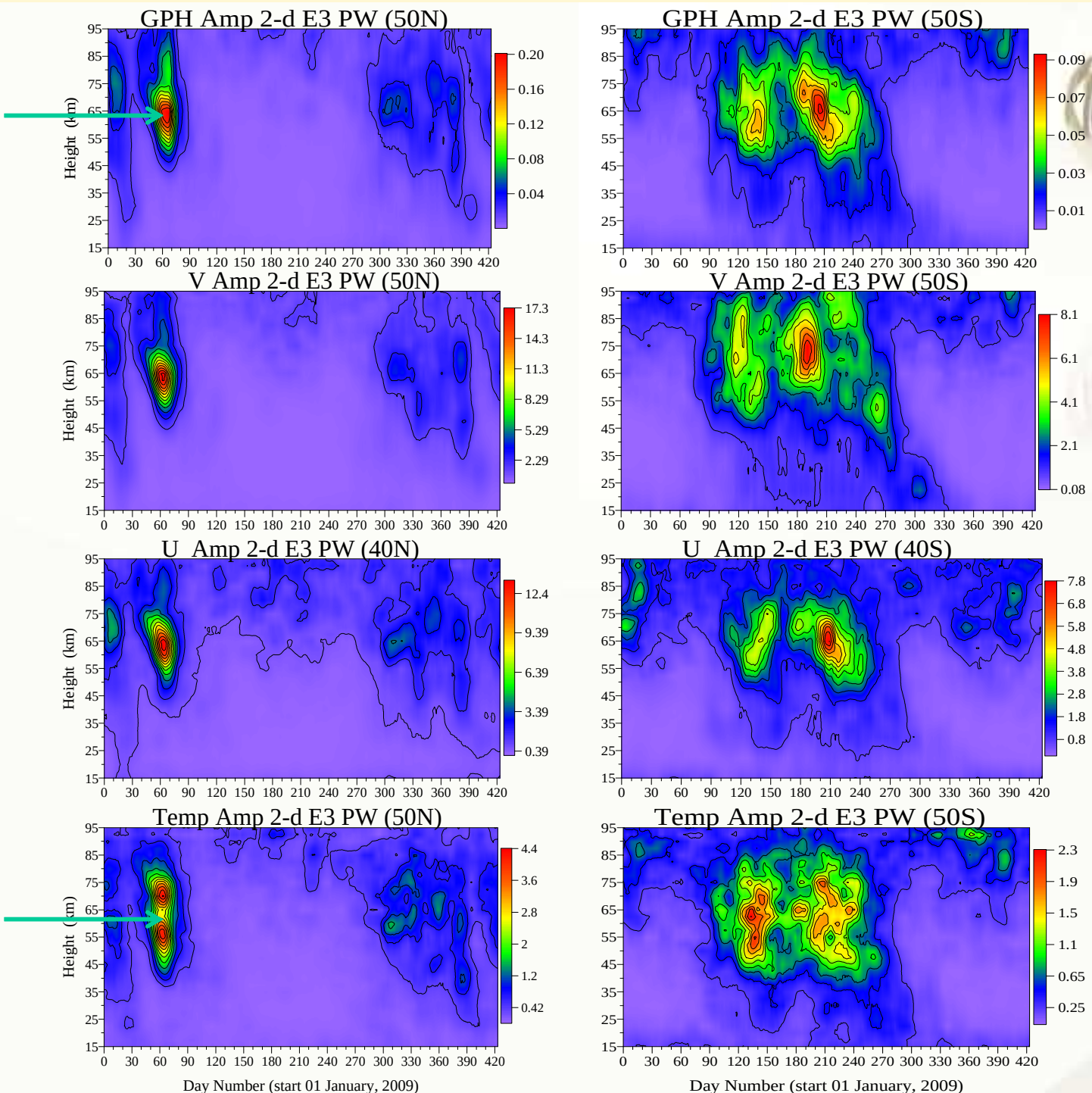


hydrostatic equation

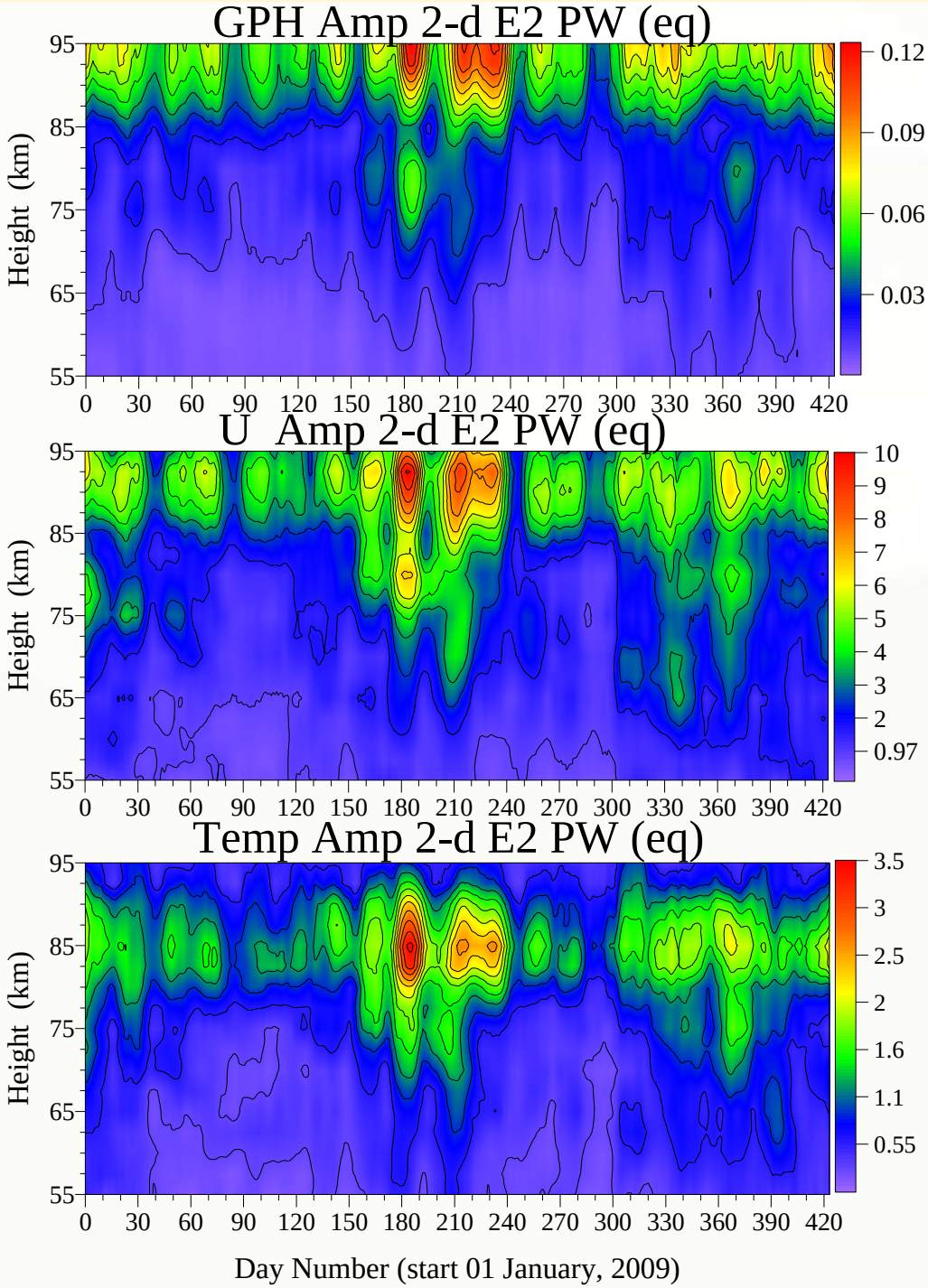
$T=(H/R)\Phi_z$

Sassi et al. (2002)

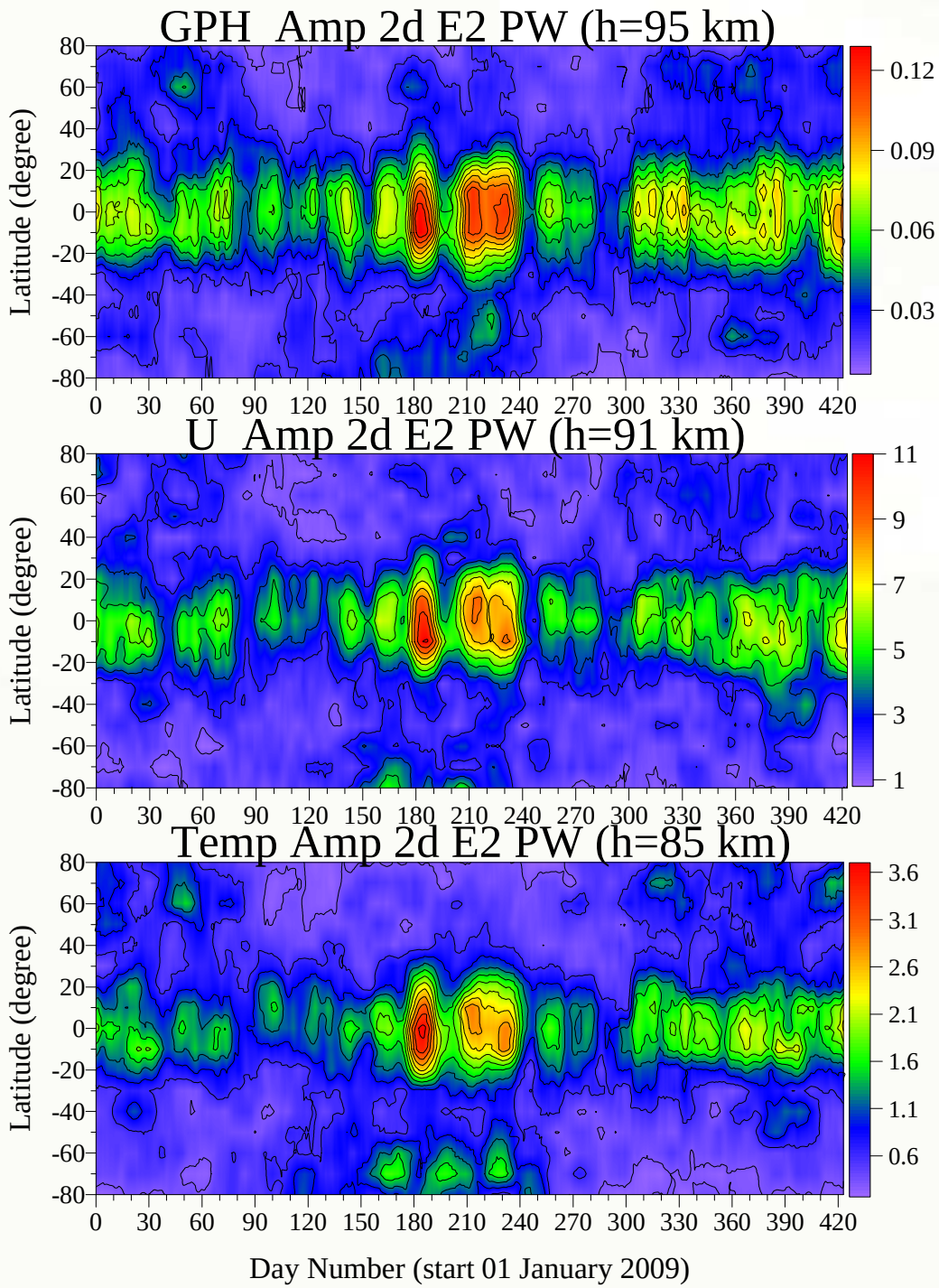
E3 Altitude Structure



E2 over the Equator - Altitude Structure



E2 over the Equator - Latitude Structure



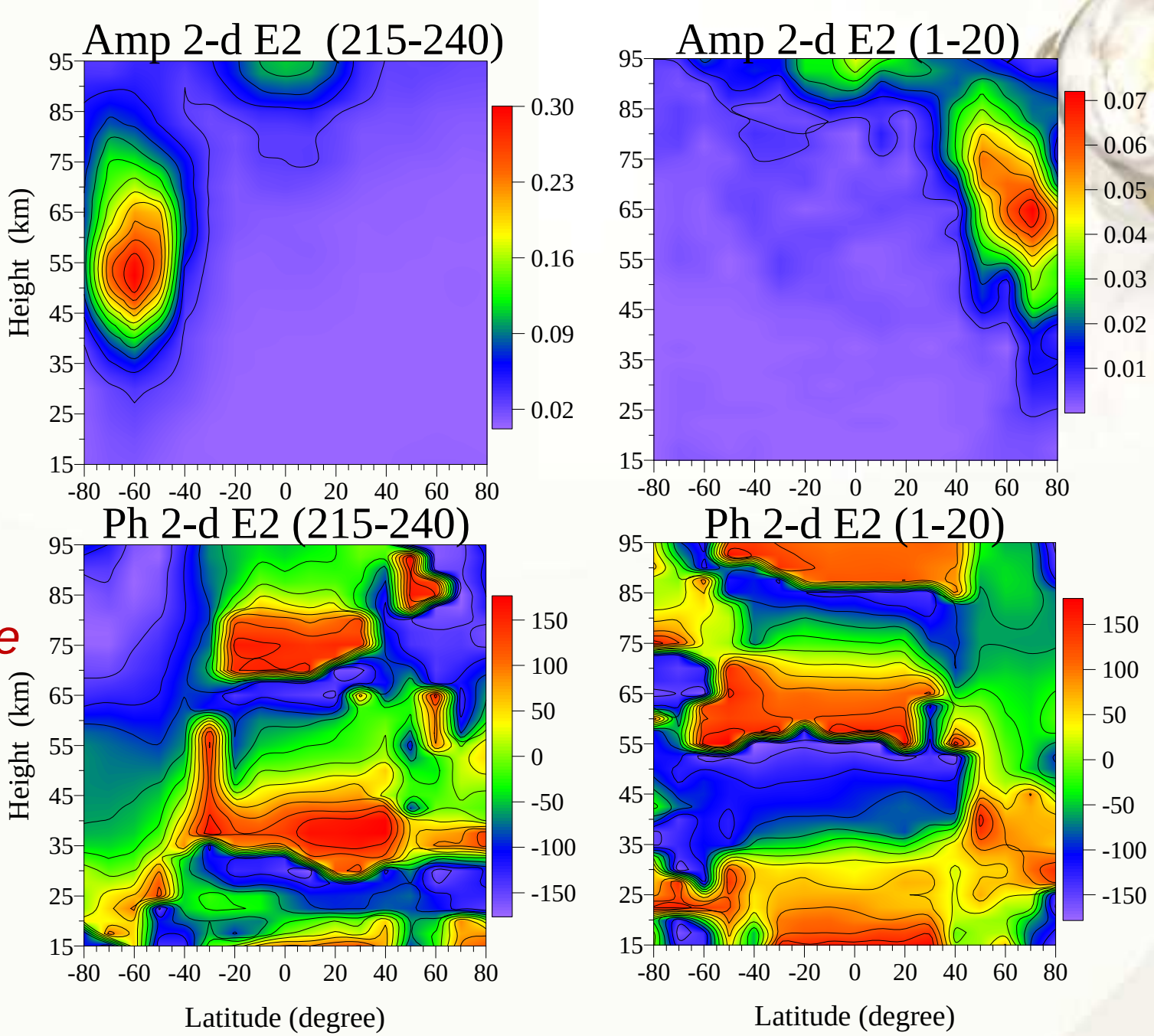
E2 Altitude-Latitude Structure

λ~60 km

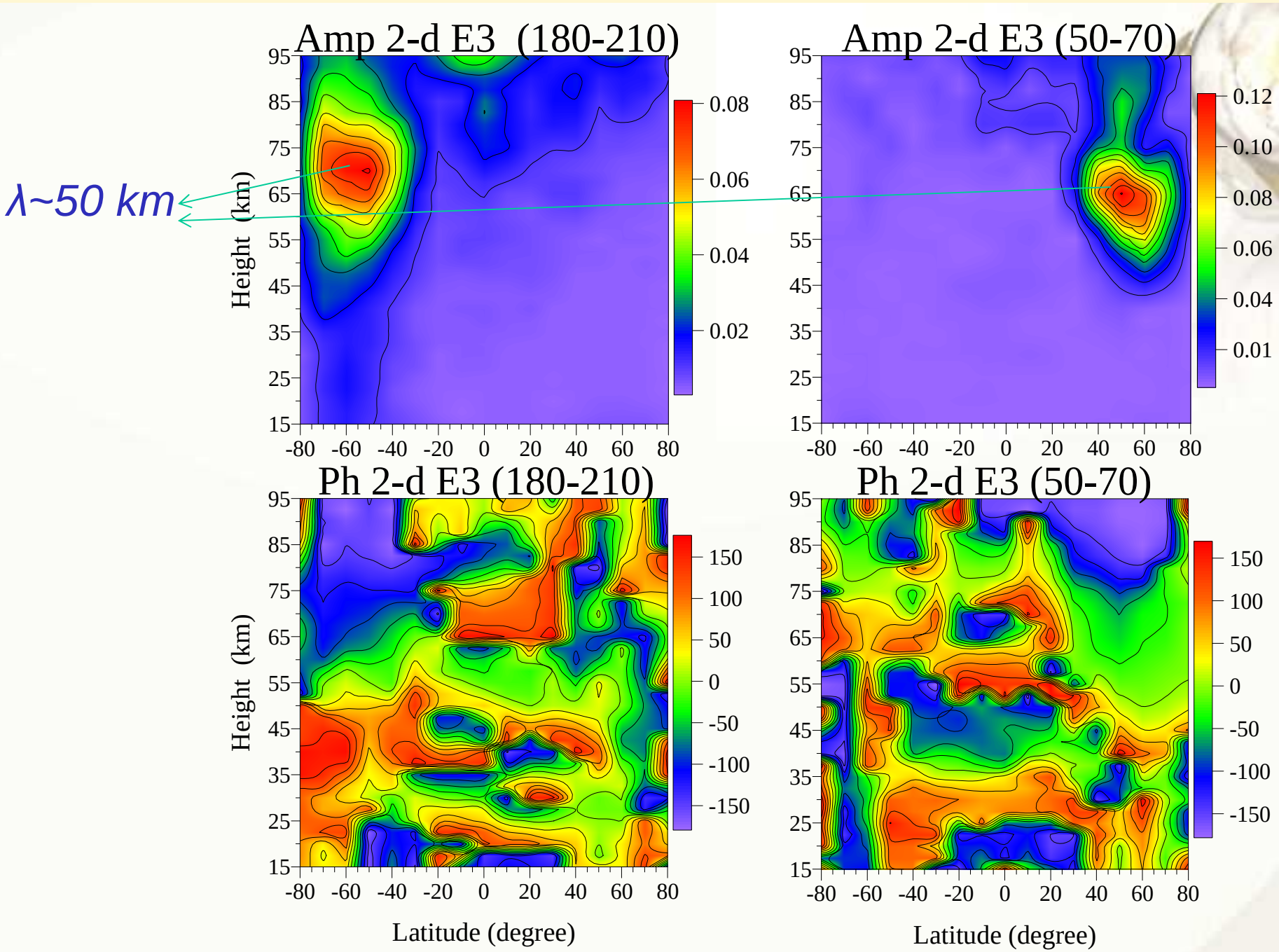
ω=Nk/m
Kelvin wave

↓

λ~30-35 km



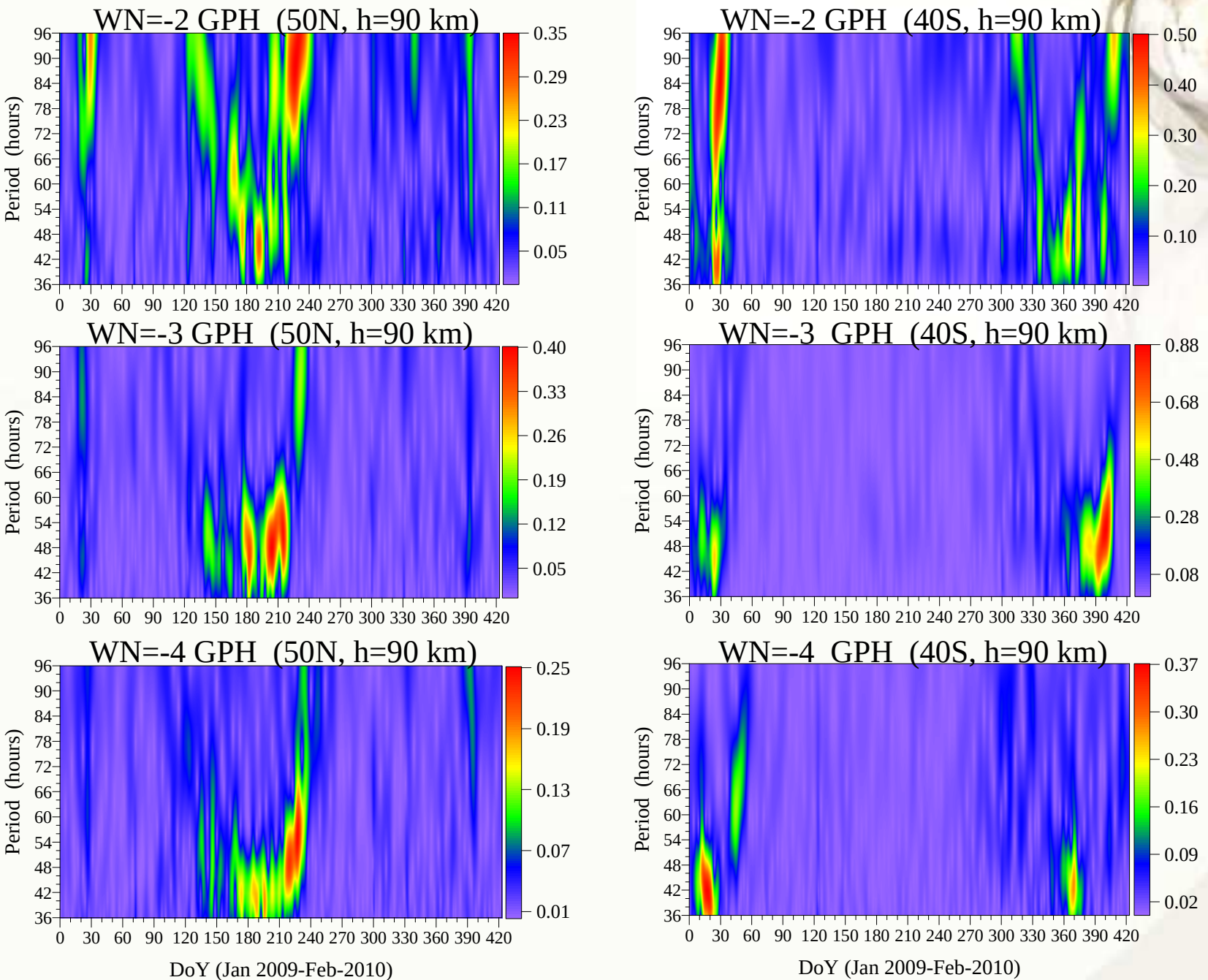
E3 Altitude-Latitude Structure



2D Wavelet Spectra

Westward traveling QTDW

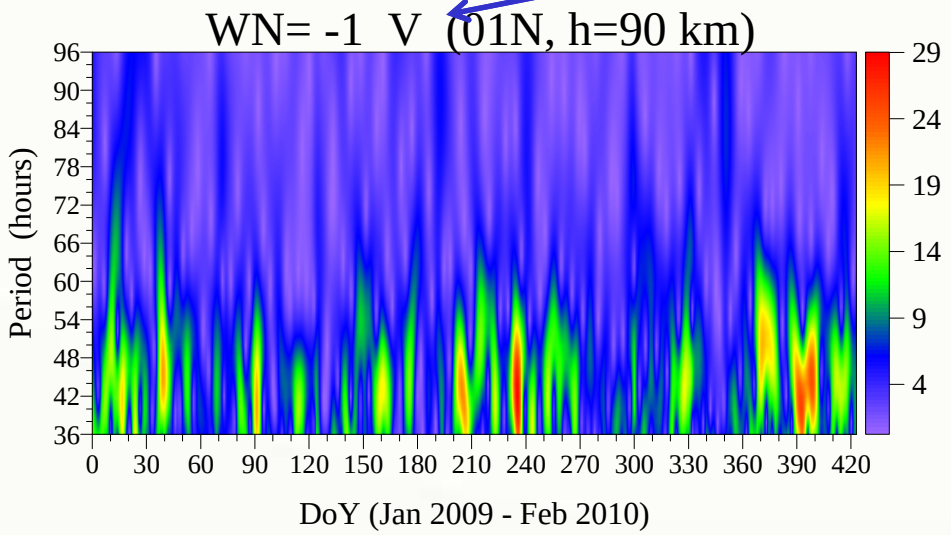
NH **SH**

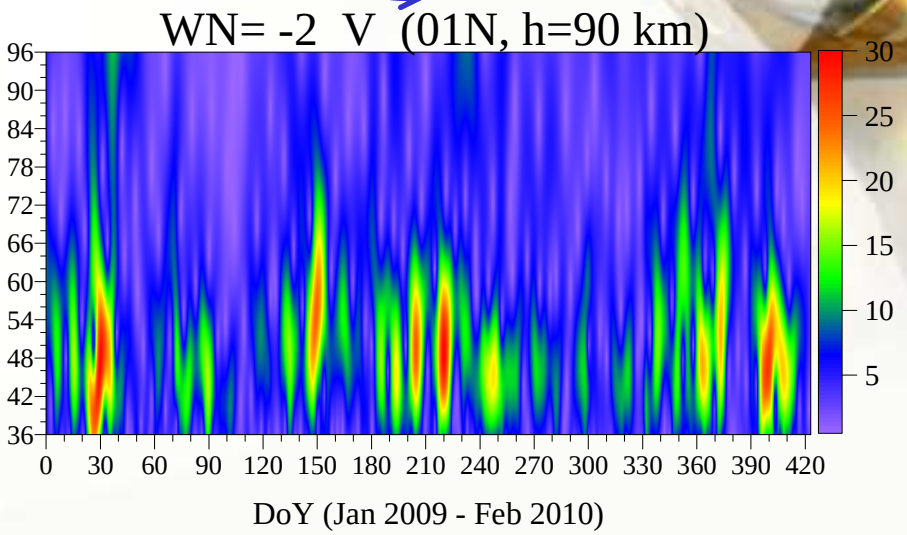


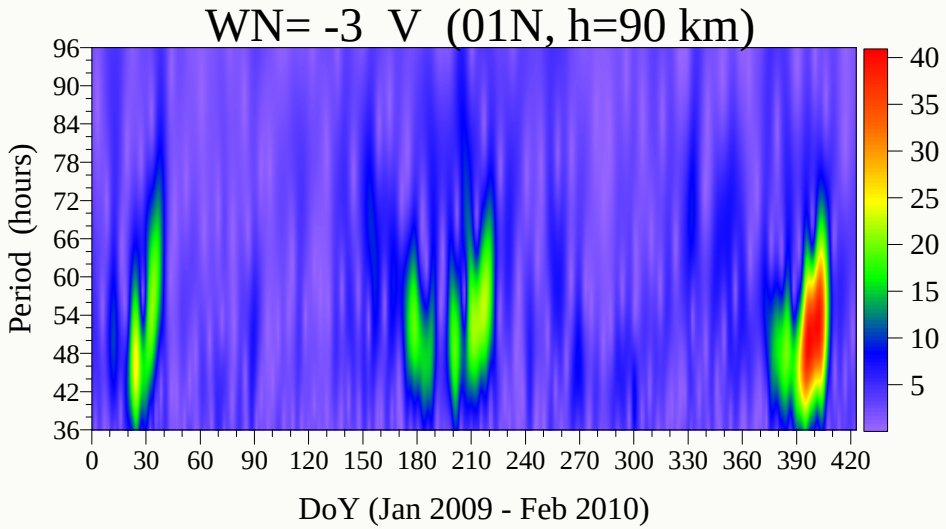
2D Wavelet Spectra over the Equator

Meridional Wind

Pancheva et al., (2006)

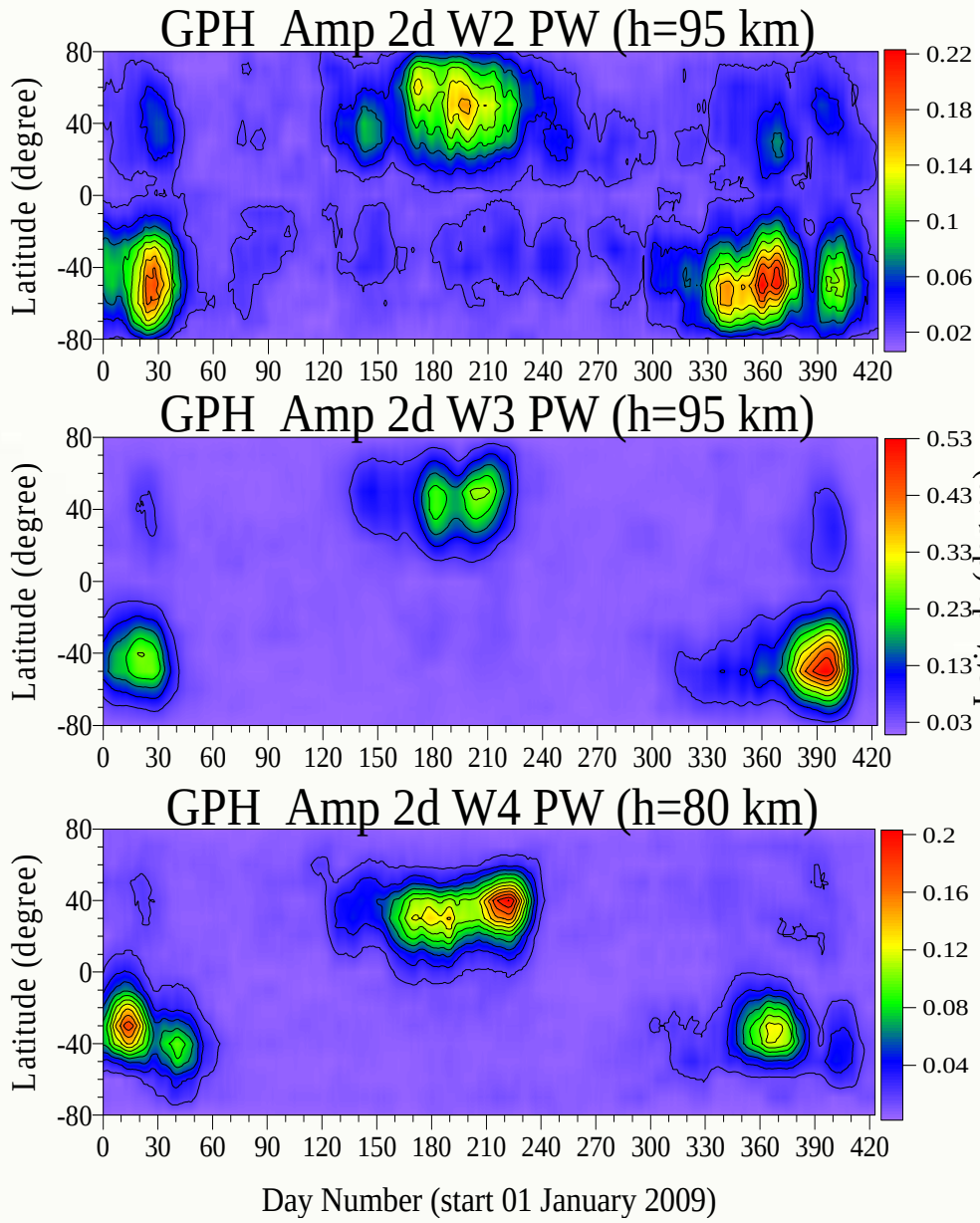




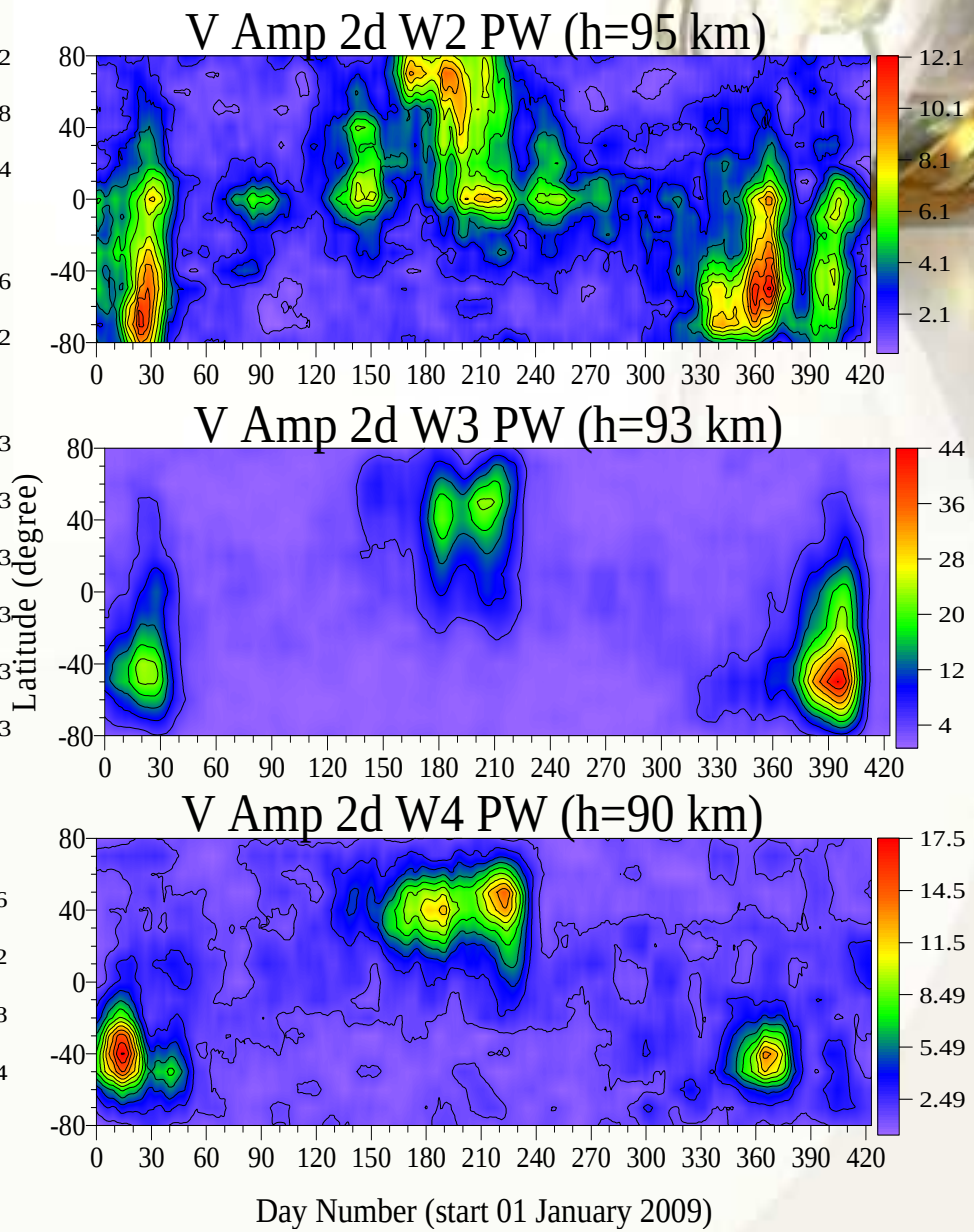


W2, W3 & W4 QTDW - Latitude Structure)

GPH



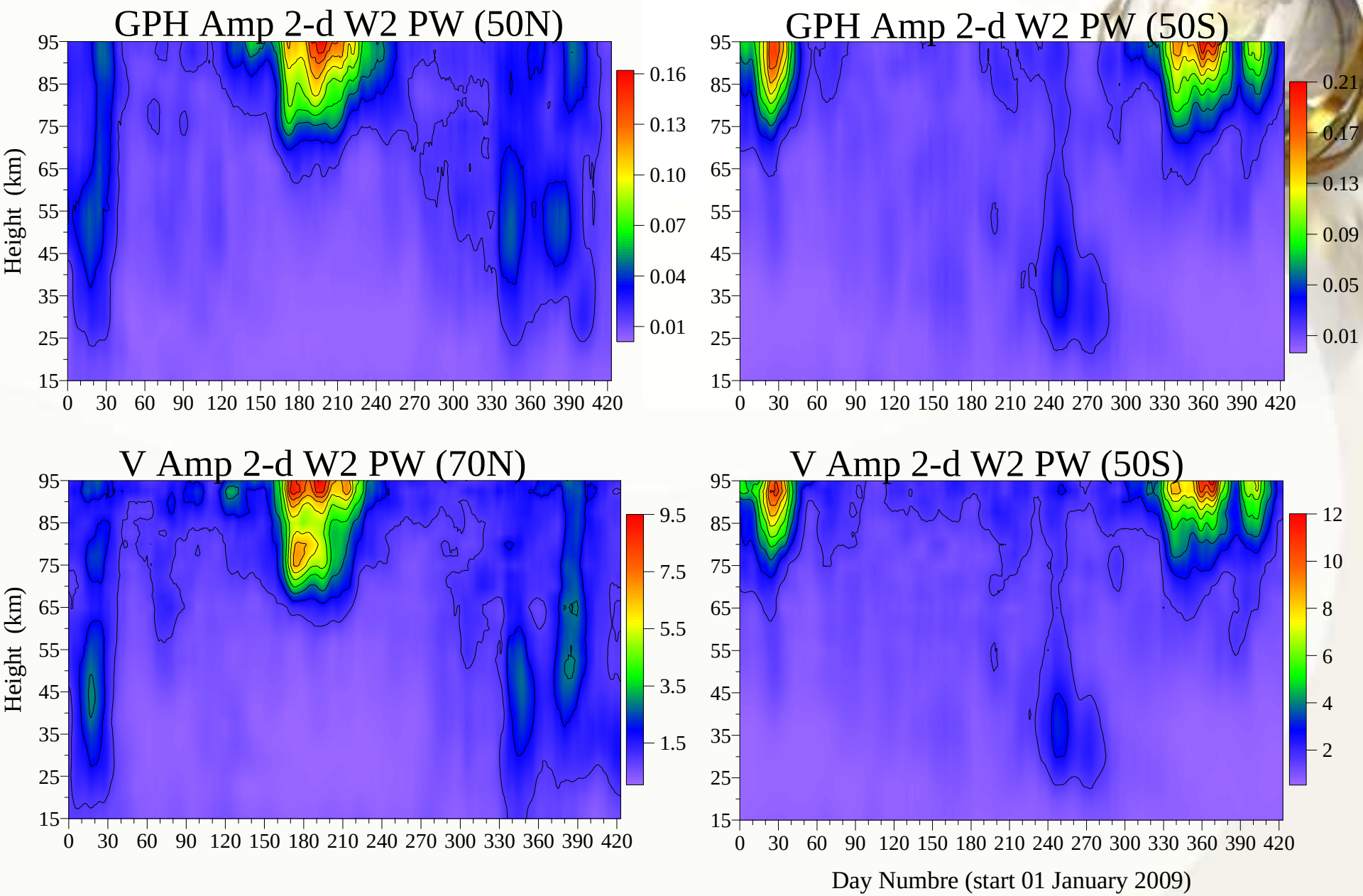
V



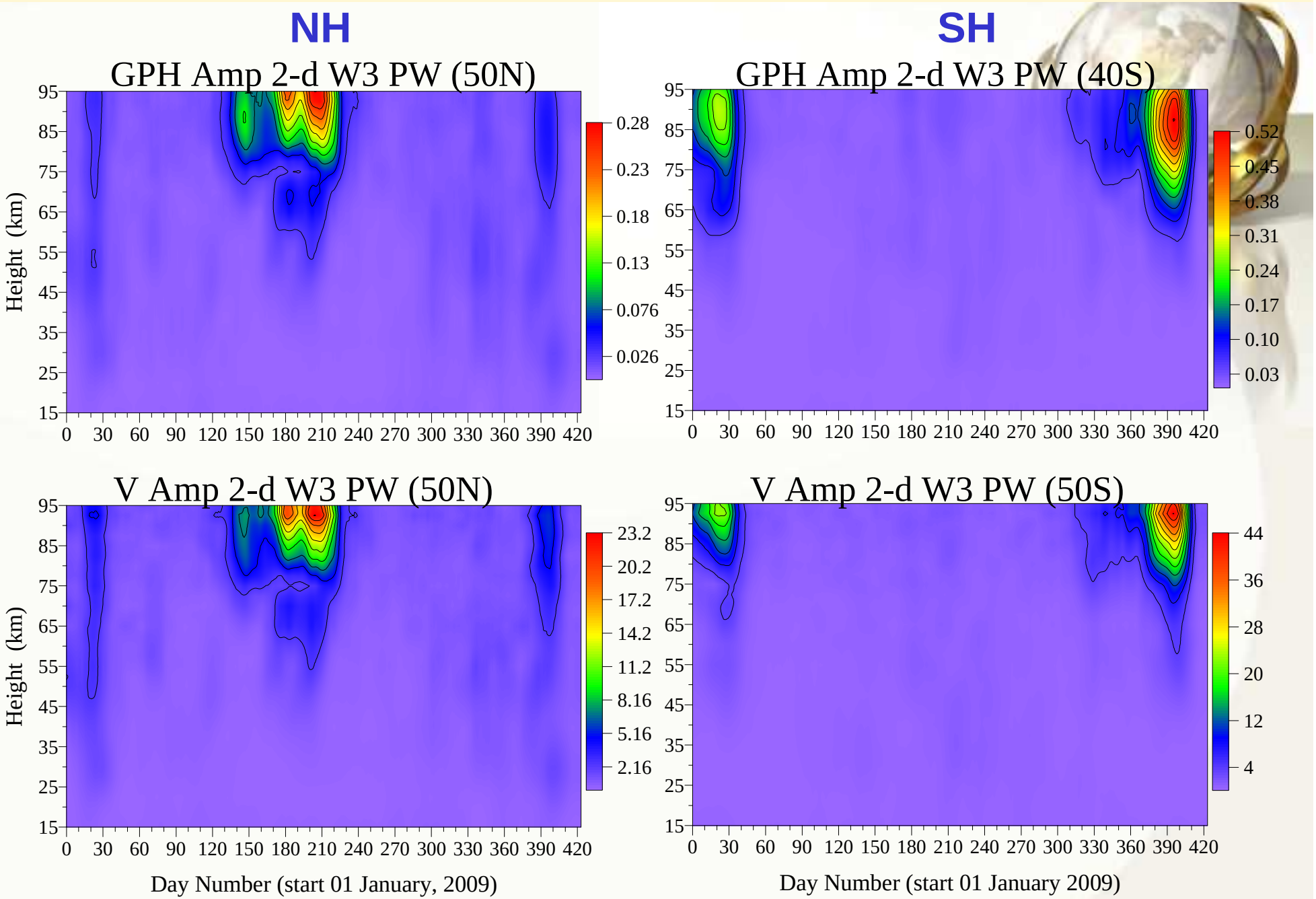
W2 Altitude Structure

NH

SH

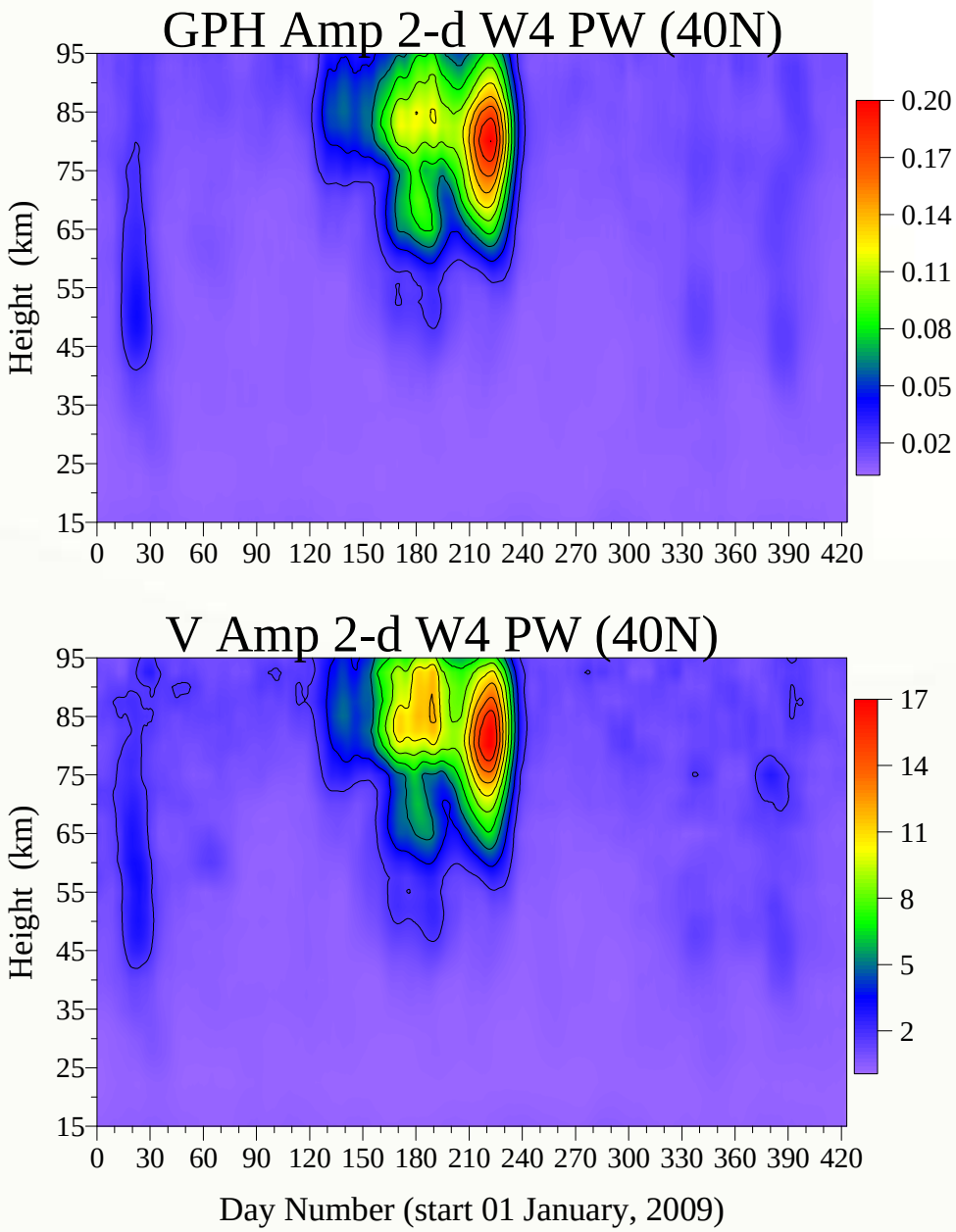


W3 Altitude Structure

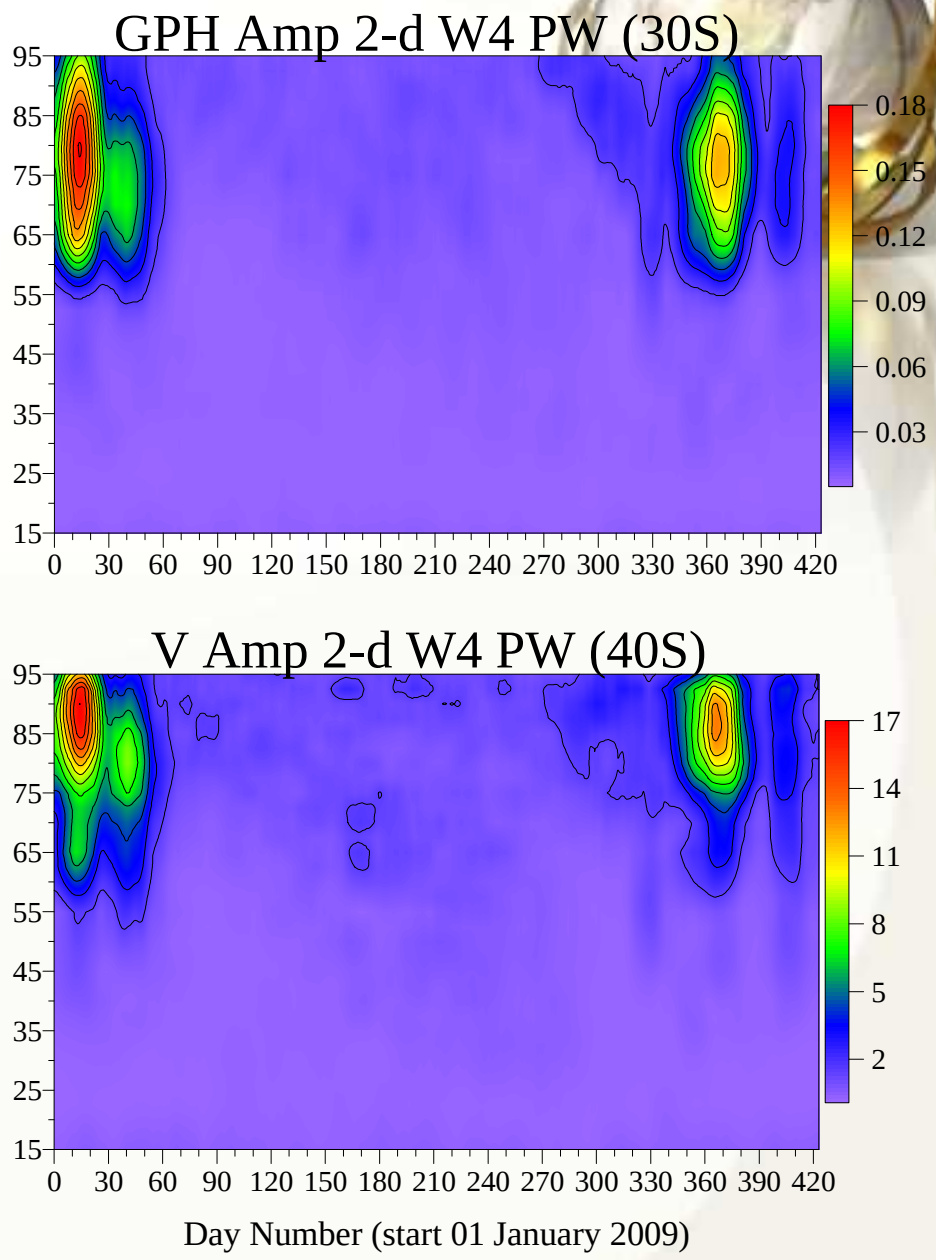


W4 Altitude Structure

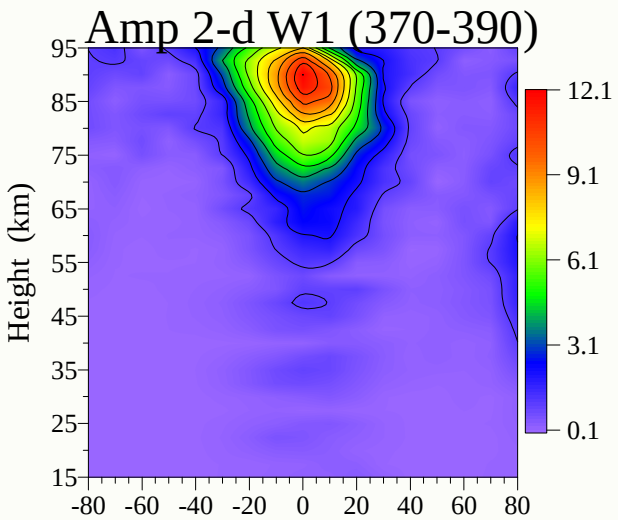
NH

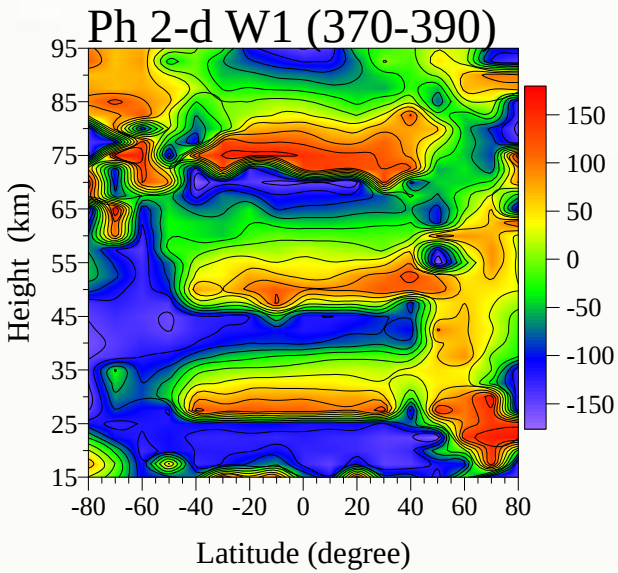


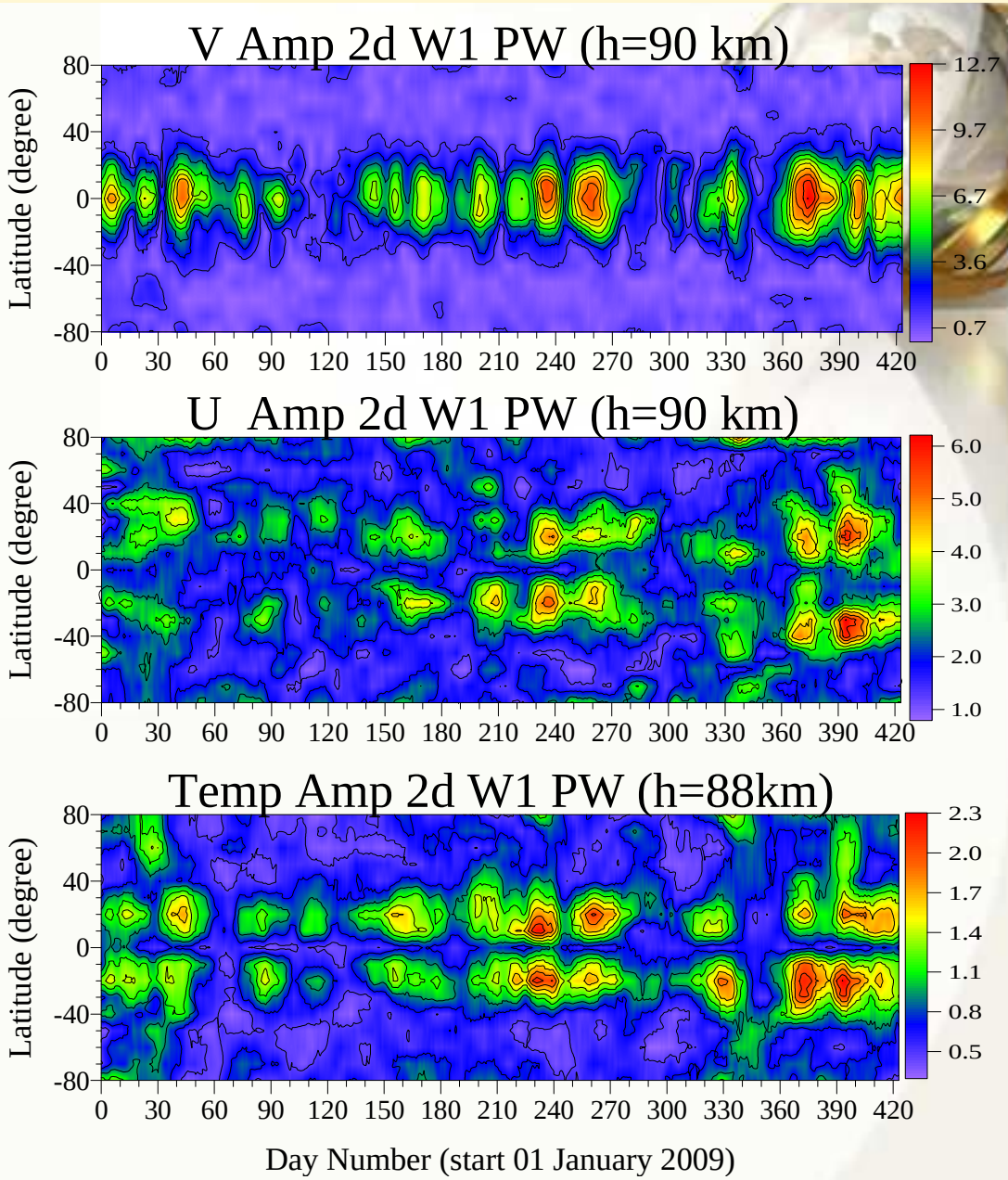
SH



W1 over Equator (V)







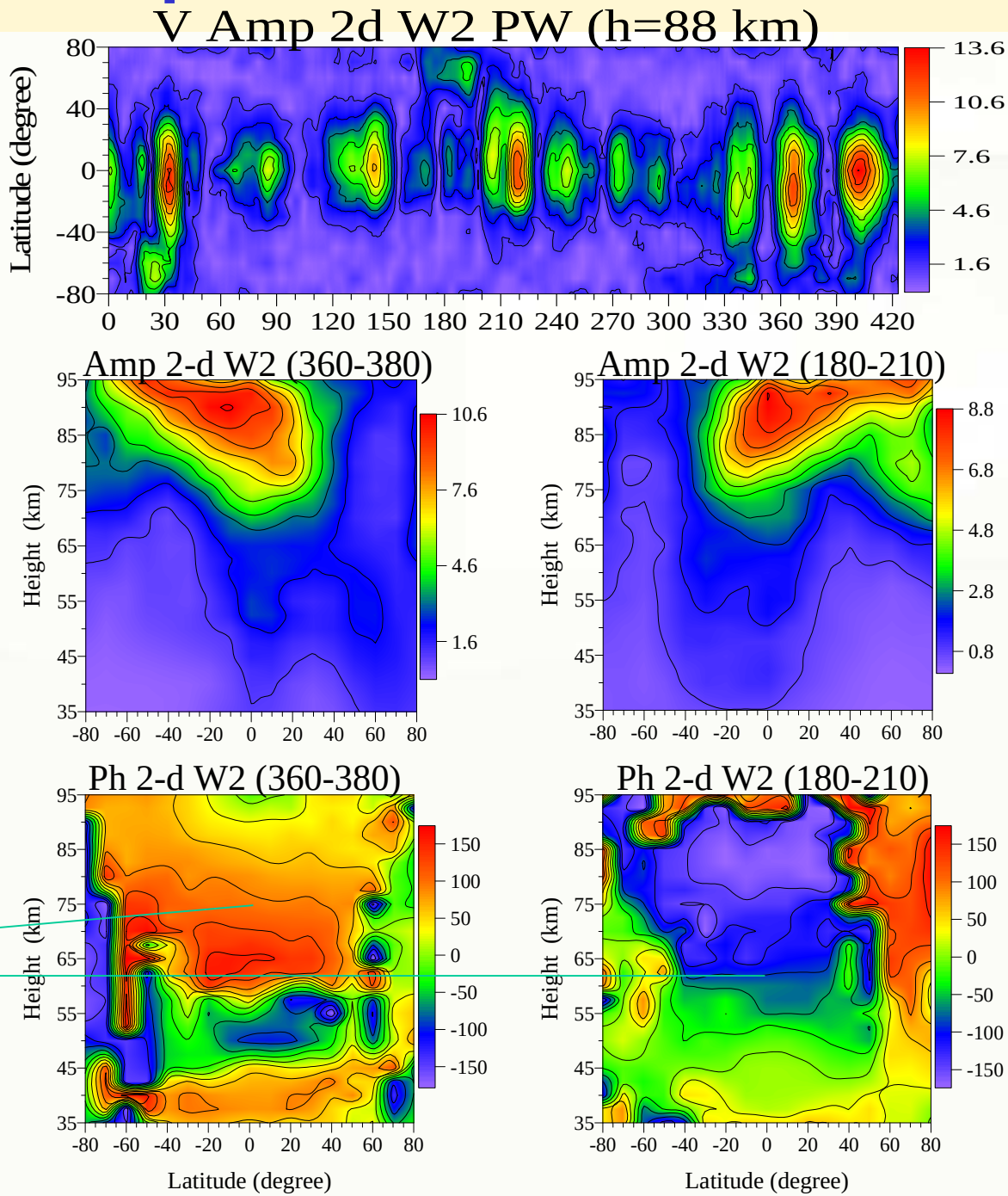
Rossby-gravity wave

λ~25 km

W2 over Equator & Middle Latitudes (V)

Rossby-gravity

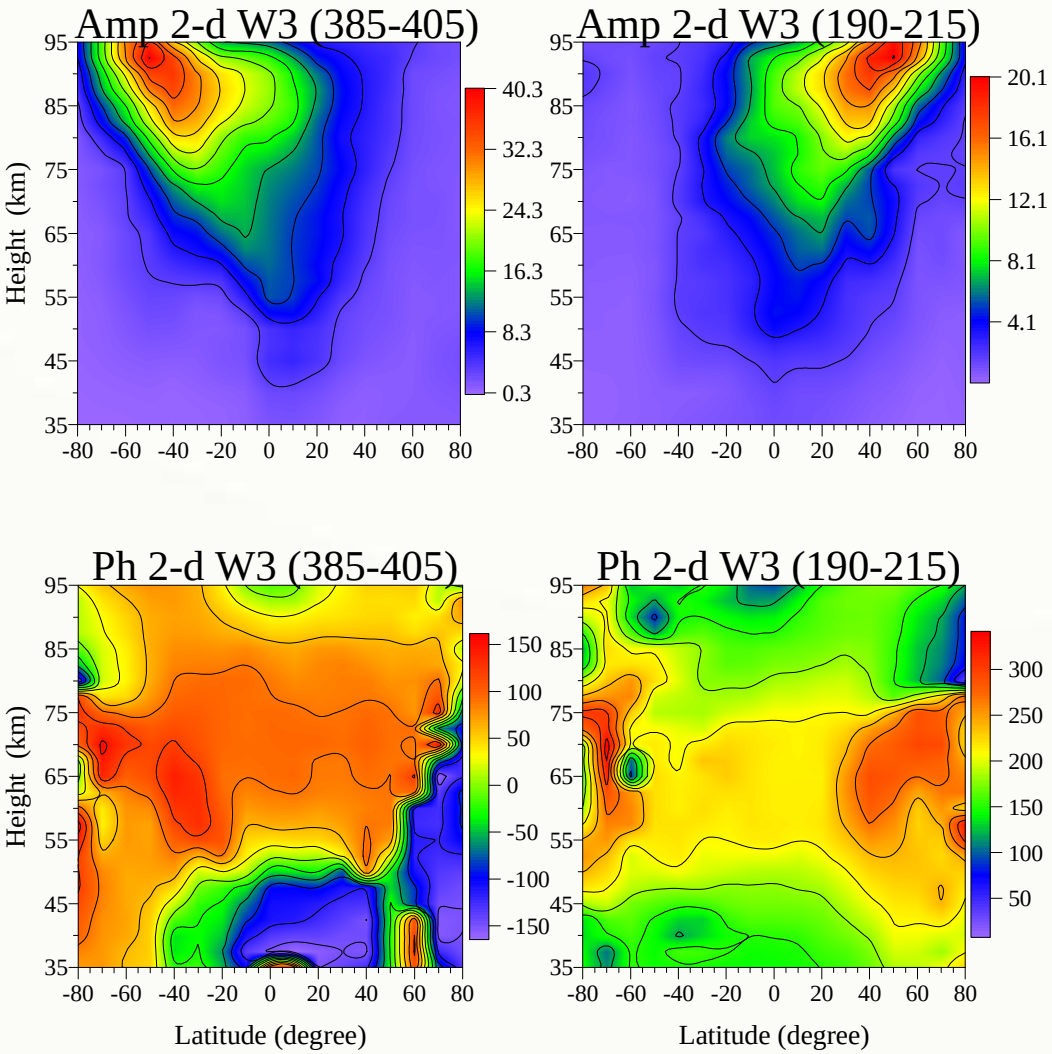
λ~65-70 km

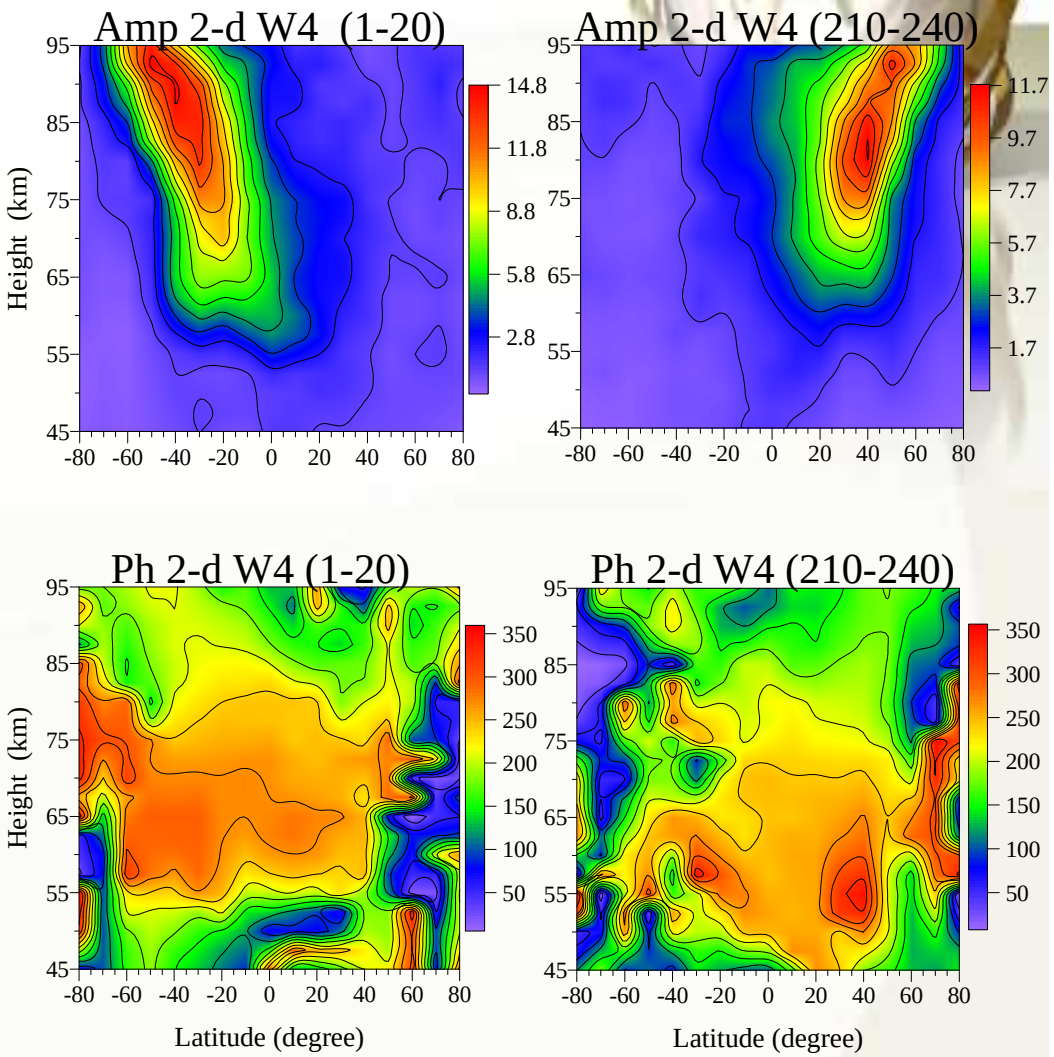


W3 & W4 Latitude-Altitude Structure (V)

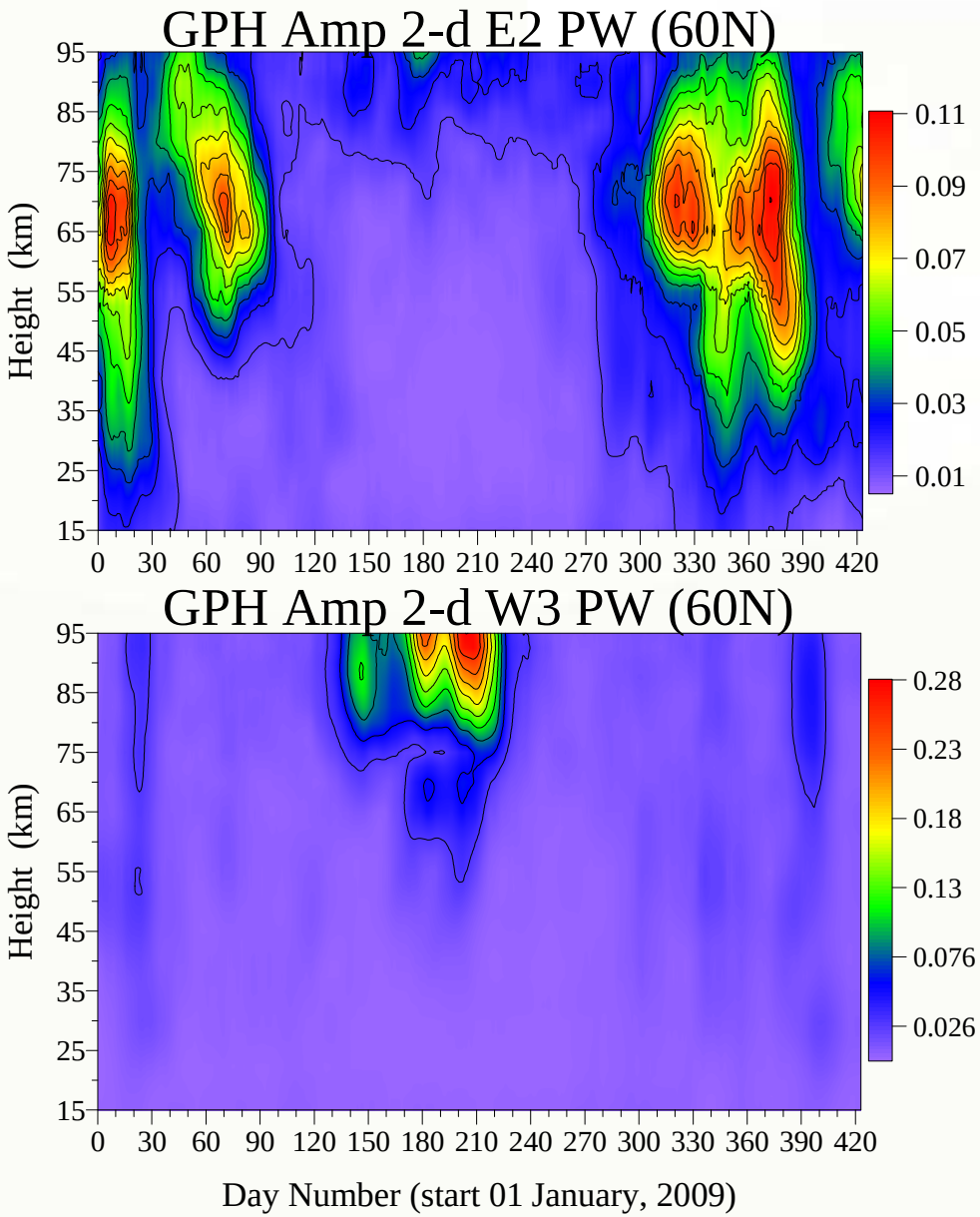
W3

W4





~2-d E2 & W3 waves in GPH



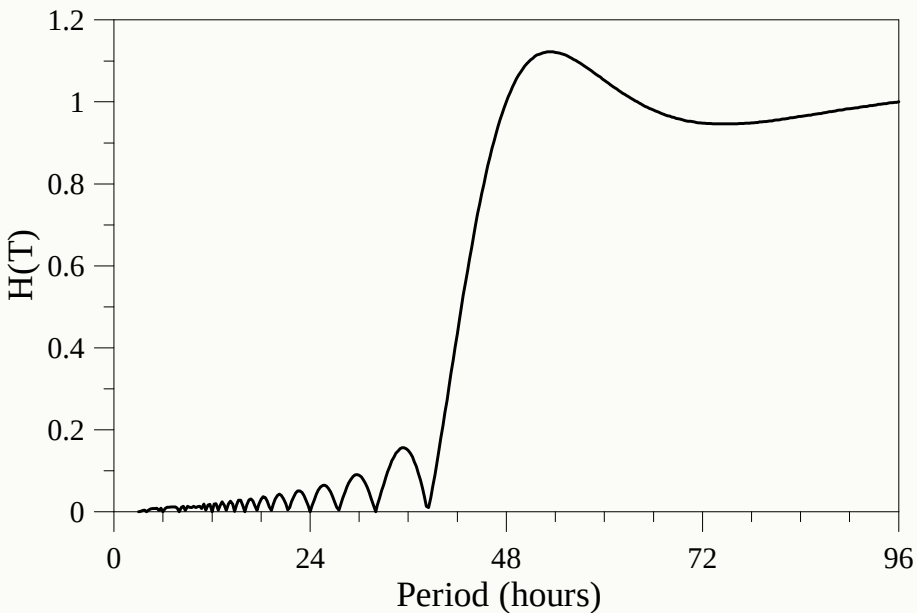
New Approach for Searching Traveling PWs

- A low-pass filter from the 4th degree with a boundary period of T_0 of 48 hours described as:

$$y(t)=\frac{1}{T}\int_{t-\frac{T_0}{2}}^{t+\frac{T_0}{2}} f(\tau)d\tau+\frac{2}{T}\sum_{k=1}^{n}\int_{t-\frac{T_0}{2}}^{t+\frac{T_0}{2}} f(\tau)\cos\left(\frac{2k\pi}{T}(t-\tau)\right)d\tau$$

with frequency characteristic:

$$H(T)=\sum_{k=-n}^{n}\frac{\sin\left(\pi\left(k-\frac{T_0}{T}\right)\right)}{\pi\left(k-\frac{T_0}{T}\right)}$$



Frequency Characteristics of Filter

Expansion in Fourier series as a function of longitude:

$$Y(lon,t) \approx Y_0(t) + \sum_{s=1}^{S} Y_s(t)\cos(slon - \varphi_s(t)) \qquad (1)$$

Angular frequency is defined as the derivative of the phase:

$$\omega(t)t = \varphi(t)$$

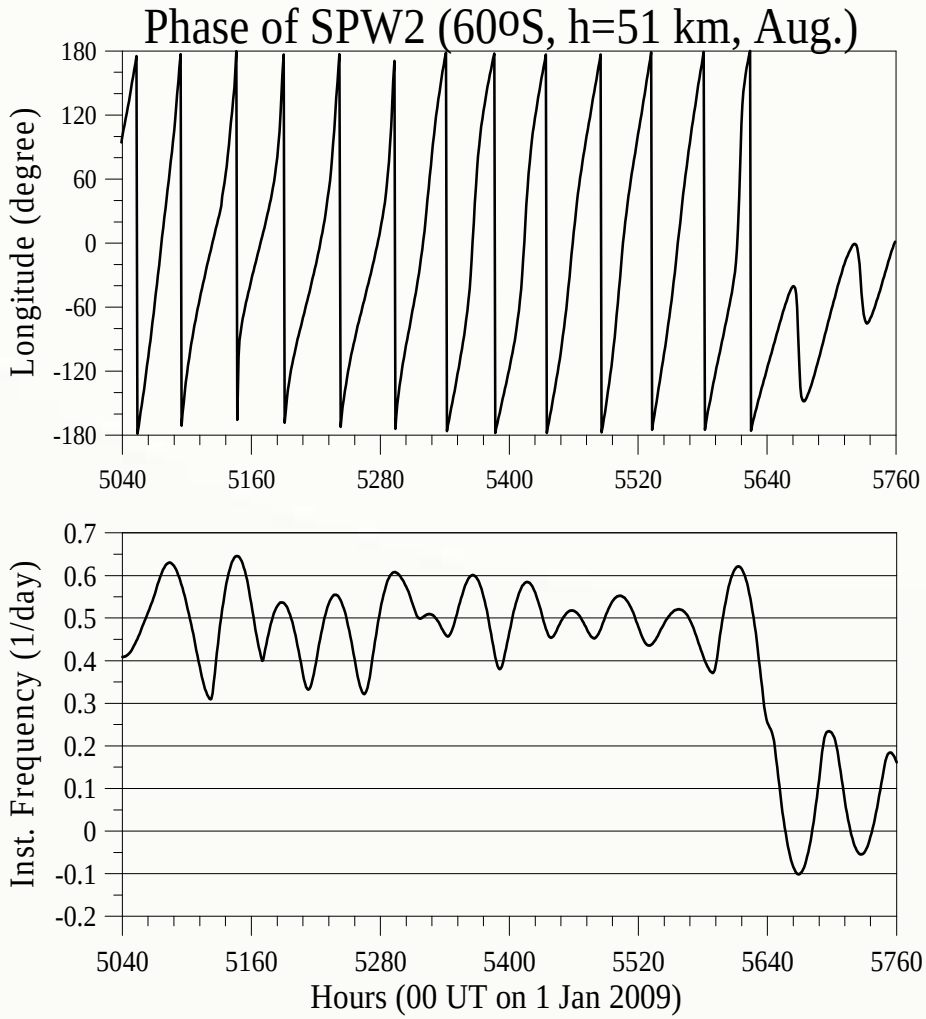
$$\frac{d\omega(t)}{dt}t + \omega(t) = \frac{d\varphi(t)}{dt} \qquad \omega(t) = \frac{d\varphi(t)}{dt} \qquad (2)$$

Having in mind (2) then (1) becomes:

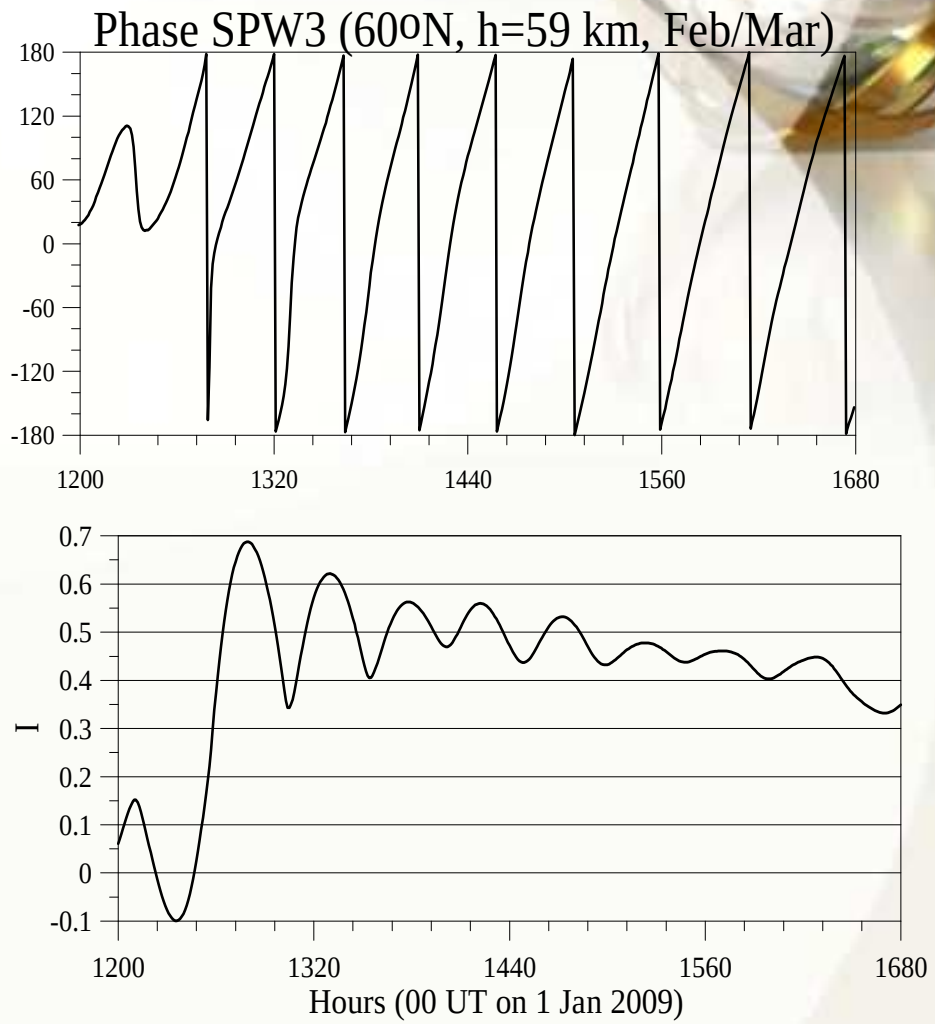
$$Y(lon,t) \approx Y_0(t) + \sum_{s=1}^{S} Y_s(t)\cos(\omega_s(t)t - slon)$$

Examples

GPH 2-d E2 wave (SH)

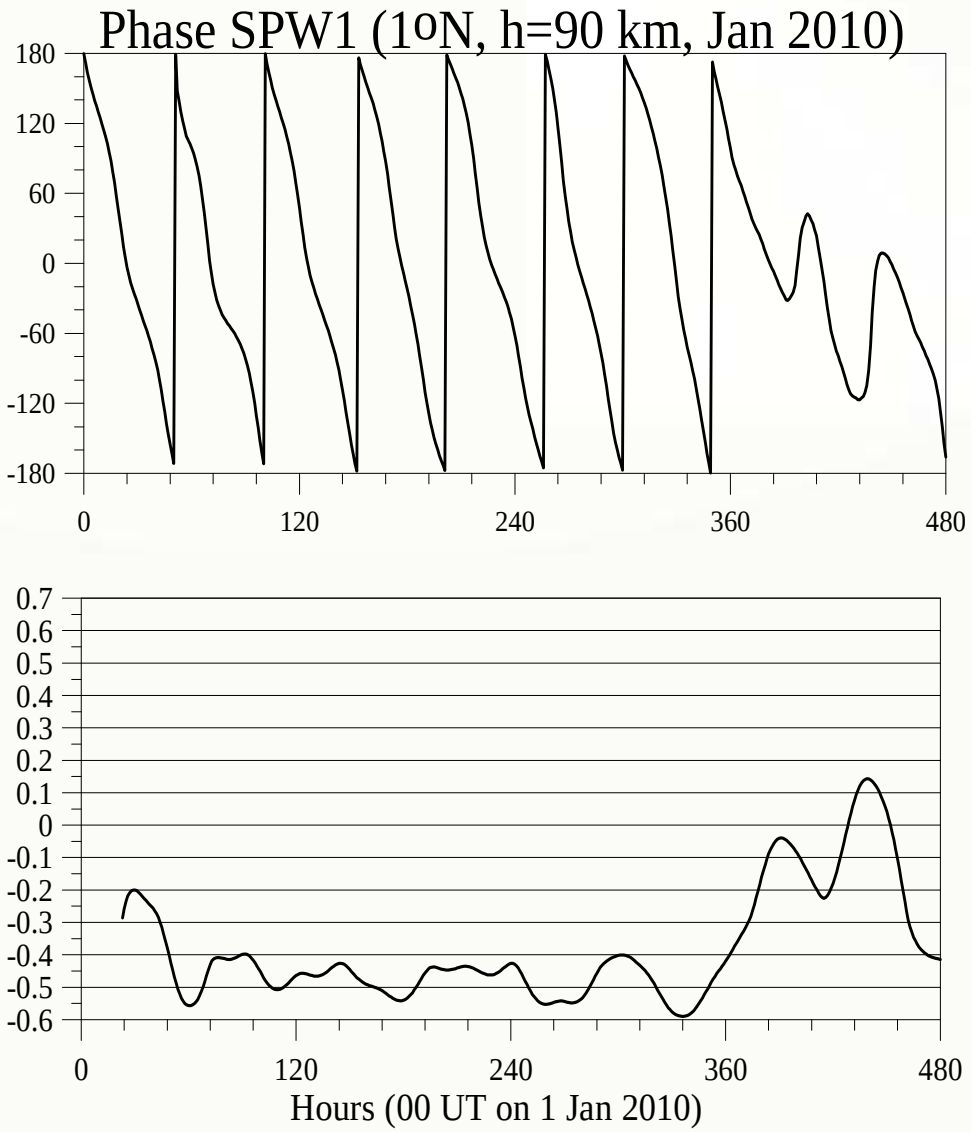


GPH 2-d E3 wave (NH)

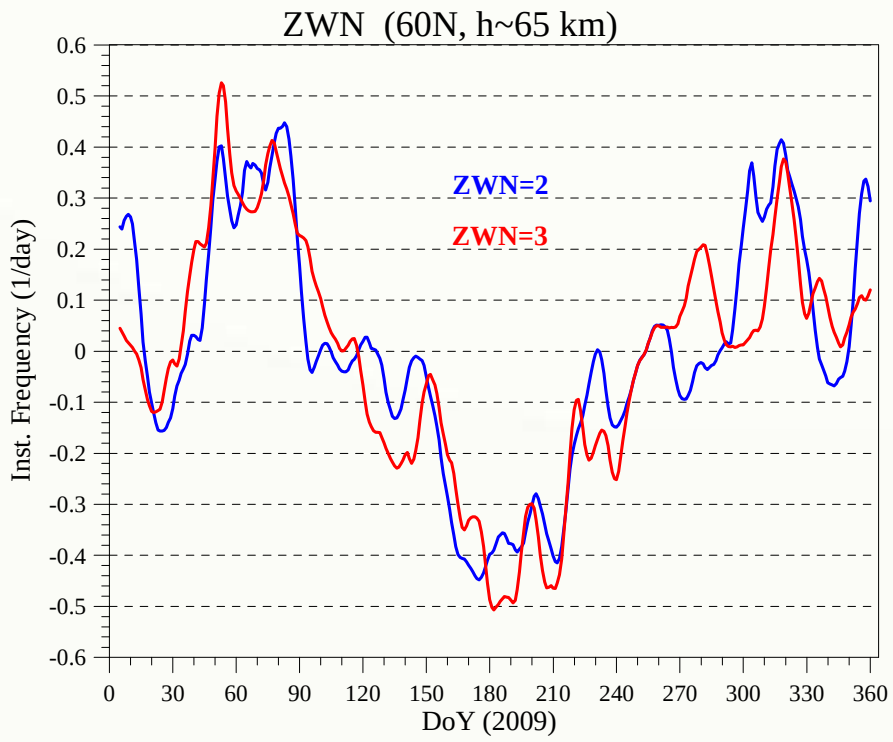


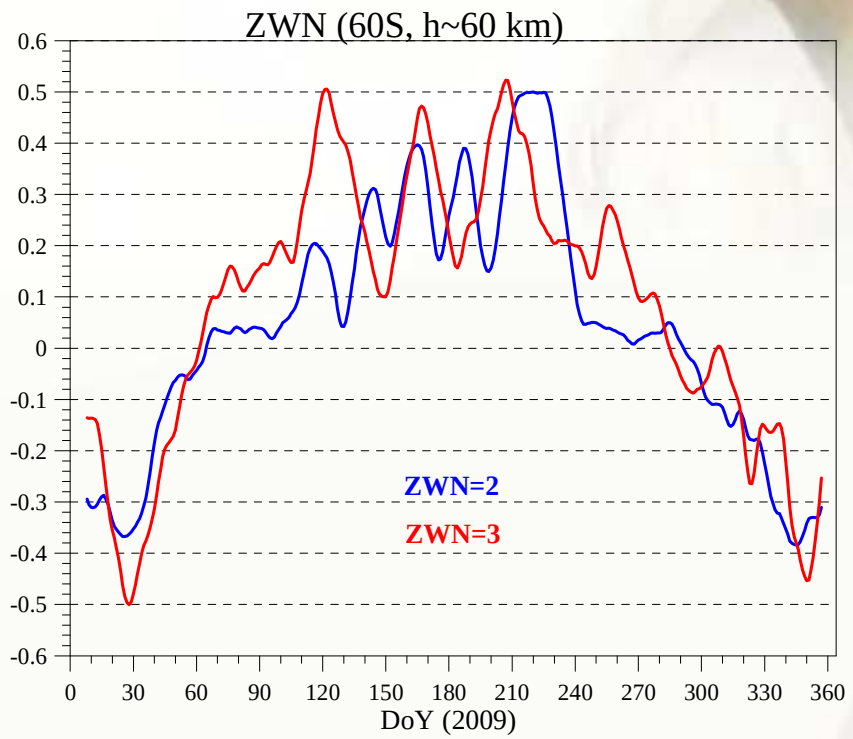
Example V over Equator

V 2-d W1 wave (eq)



Instantaneous Frequency





Summary (new 2-d waves)

- Two different types of eastward-traveling waves are identified: (i) E2 & E3 waves at middle and high latitudes, observed in the winters, and (ii) E2 wave observed over the equator with not well defined seasonal variability but with some enhancement between June and August; most probably it is a Kelvin wave.

- 2-d E2 wave is a primary wave, i.e. it is not generated by coupling between DW1 and 2-d W3 wave

- W1 & W2 waves Rossby-gravity waves observed in the meridional wind at low latitudes

THANK YOU