Equatorial Waves from 3 Years of HIRDLS Data

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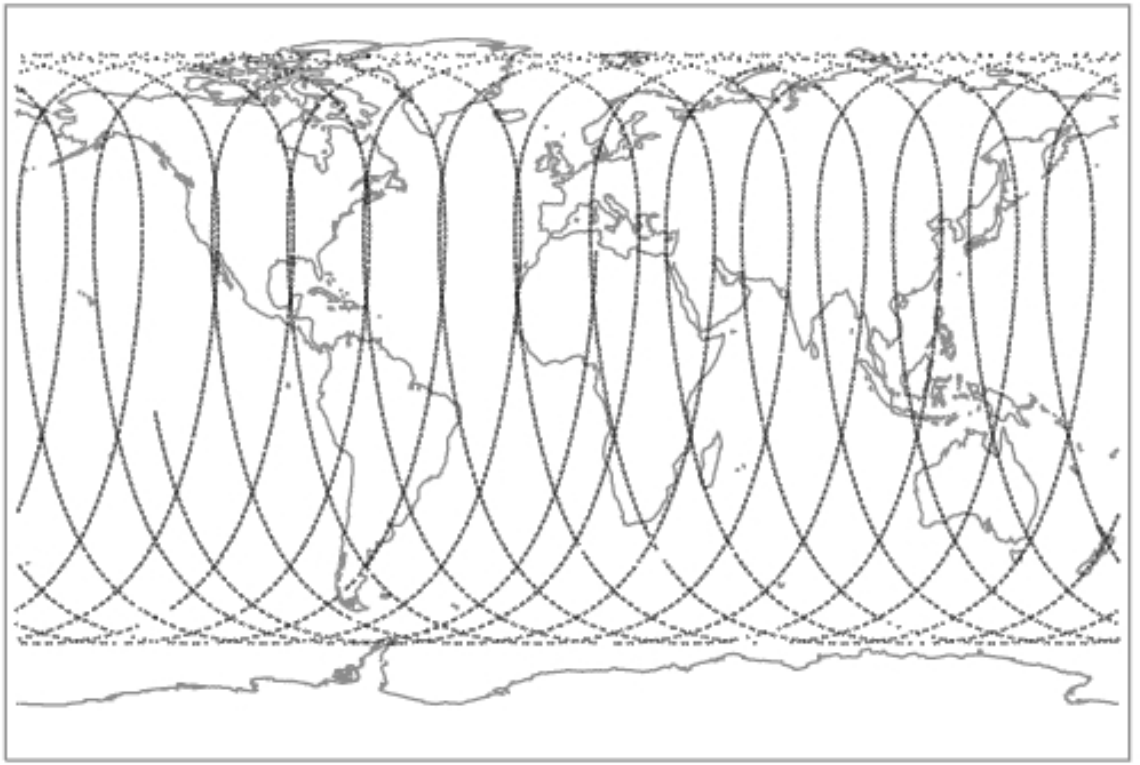
HIRDLS Sampling

Traditional (24°) longitudinal sampling
High Resolution (1°) along-track sampling



- One day of HIRDLS measurements
- Circles show locations of HIRDLS profiles
- Sampling gives equatorial zonal wavenumbers ~ 6-7
- Excellent vertical resolution of 1.2 km

HIRDLS Sampling: Comparison to SABER and GPS

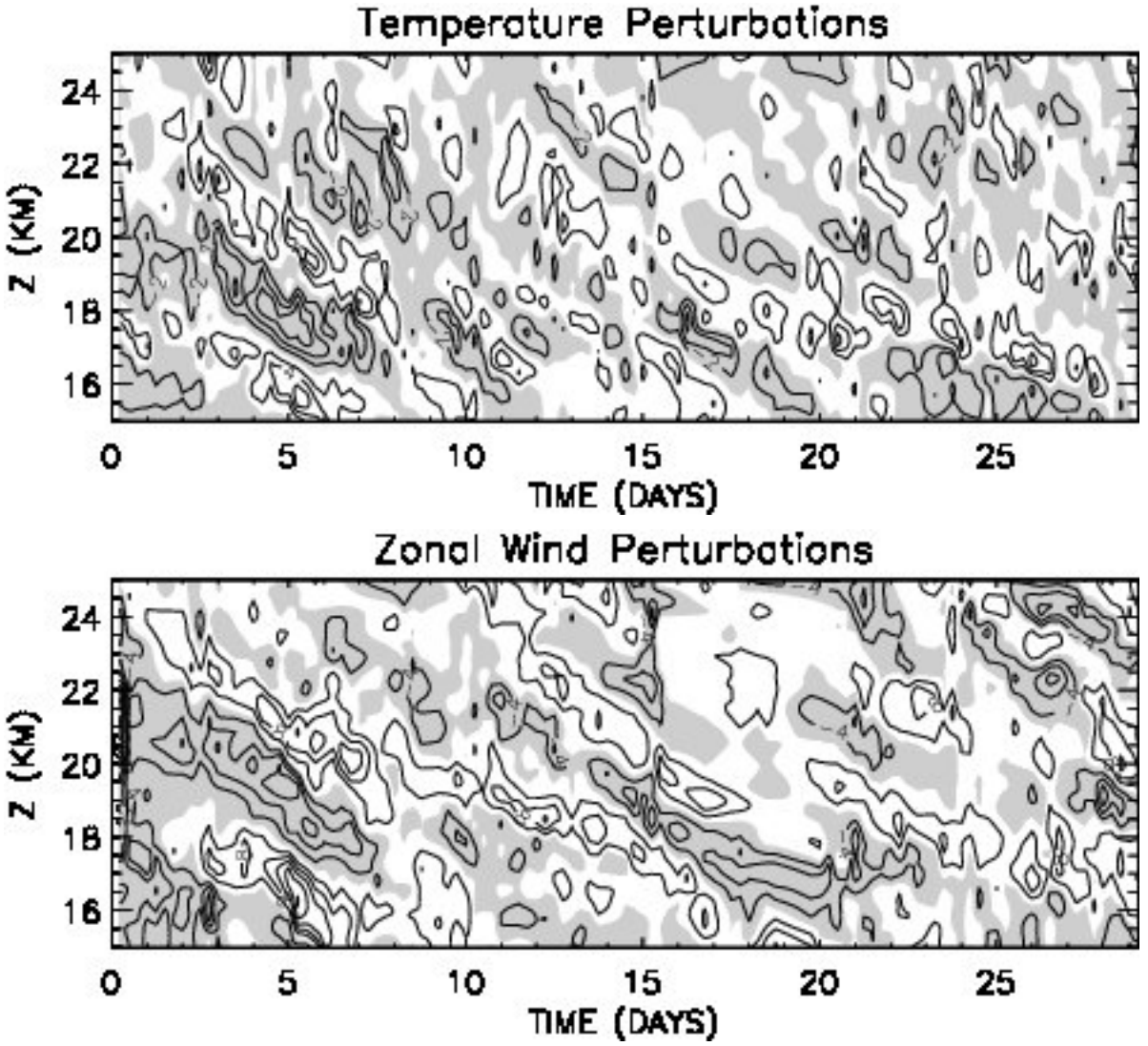
	HIRDLS	SABER	GPS
Vertical Resolution	1.2 km	~2-2.5km	1 km
Zonal resolution	wn < 7	wn < 7	wn<8?
10S-10N profiles/day	~1100	fewer	~200*

* Champ + COSMIC

- SABER has poorer vertical resolution
- GPS (Champ + COSMIC) has fewer equatorial profiles

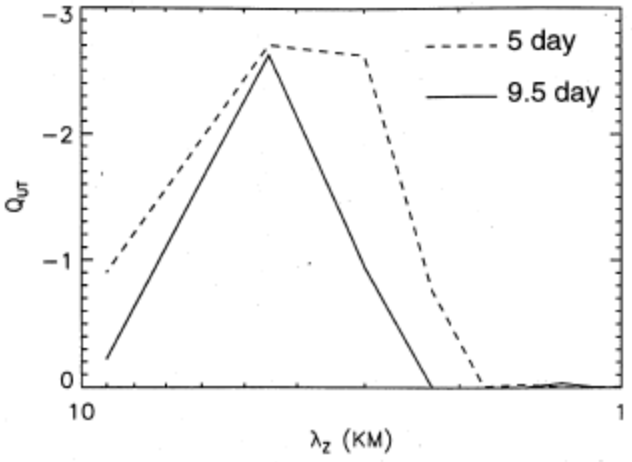
What vertical resolution is needed?

Holton et al. [2001]: Evidence for short vertical wavelength Kelvin waves in the DOE-ARM Nauru 99 radiosonde data

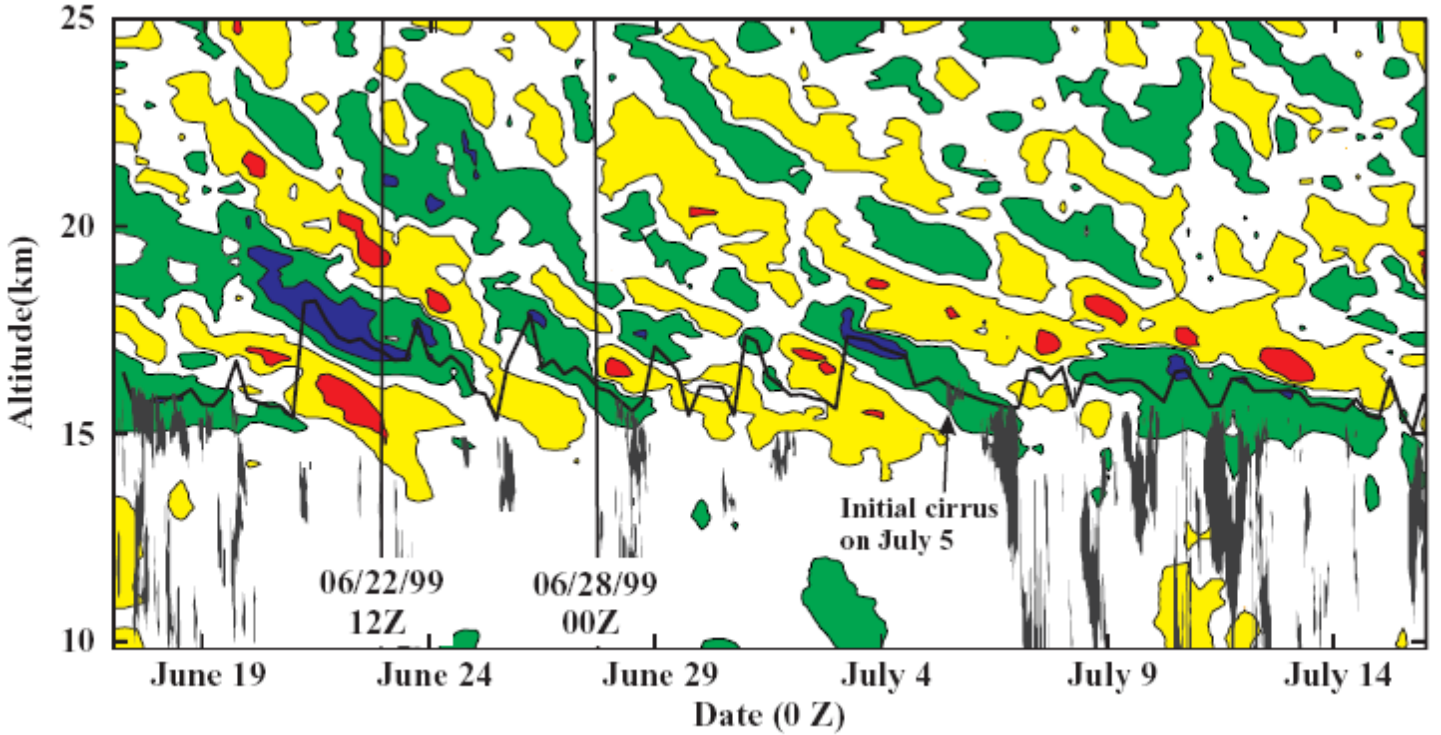


Zonal wind and temperature anomalies revealed properties of Kelvin waves:

- Periods 9.5 and 5 days
- Zonal wns 2 and 4
- Vertical wavelengths 3-4.5km



Wave Effects on Tropical Cirrus

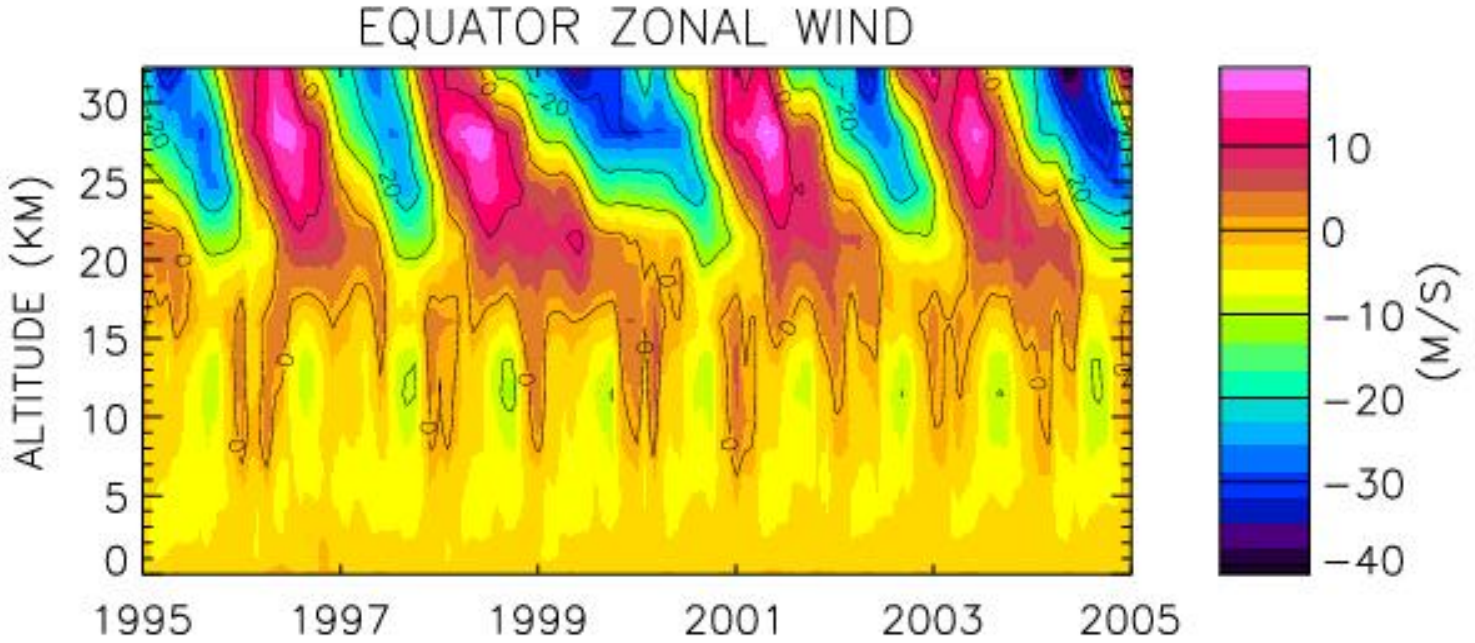


Radiosonde temperatures and cirrus clouds detected by lidar at Nauru (0.9S, 167E) [Boehm & Verlinde 2000]

- Kelvin waves modulate cirrus clouds [Boehm & Verlinde, 2000]
- Equatorial waves in general have a large effect on cirrus occurrence frequencies [Jensen & Pfister, 2004].

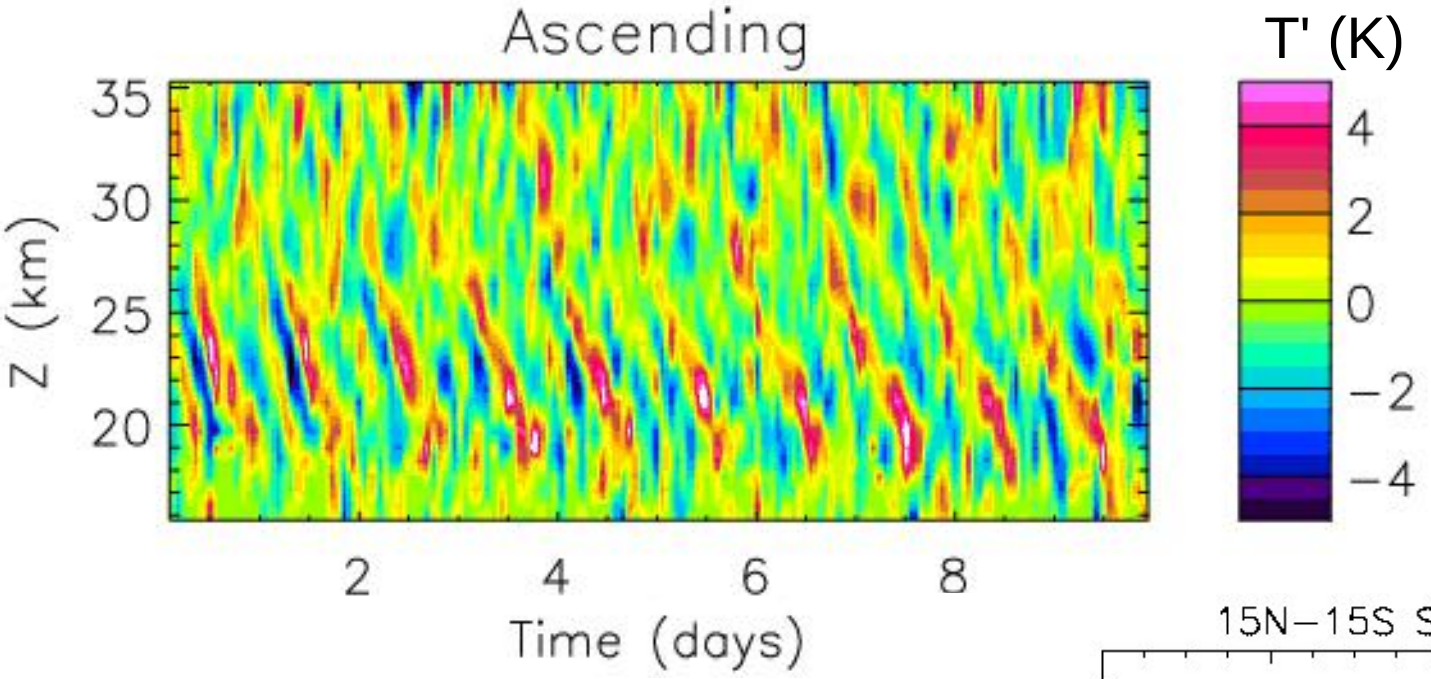
Wave Effects on the Tropical Circulation

- The Quasibiennial Oscillation (QBO) is a wave-driven circulation.
- The mix of waves that drive the QBO is still somewhat uncertain.
- The QBO causes large inter-annual variations in the transport of trace constituents in in the stratosphere like water vapor and CH_4 that affect ozone chemistry.
- Most chemistry-climate models do not include the QBO



- Estimated forcing: -0.2 m/s/day for the easterly phase;
  0.13 m/s/day for the westerly phase [Dunkerton & Delisi, 1985]

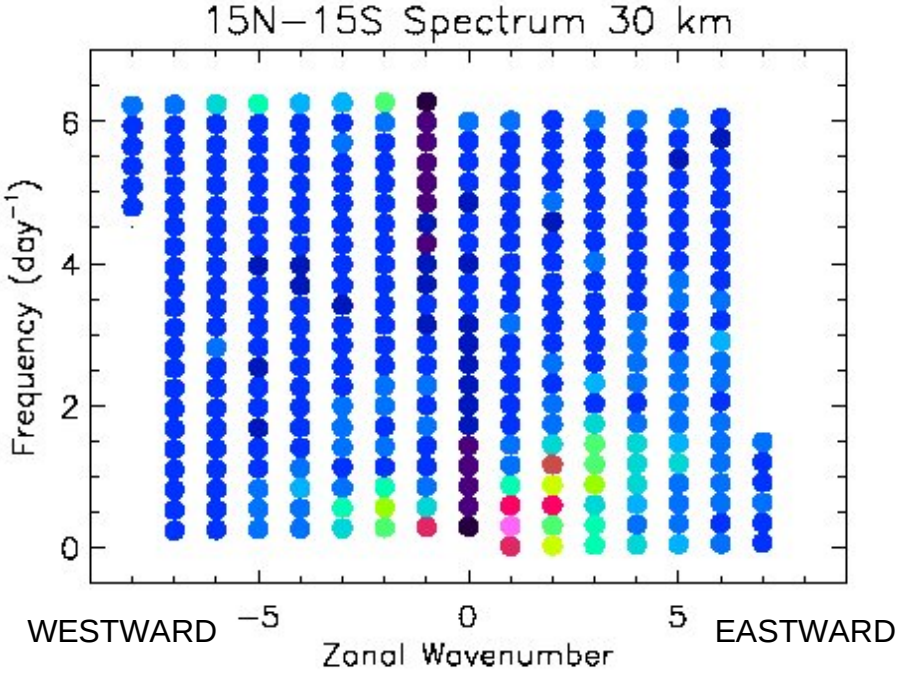
Equatorial Waves in HIRDLS



- Arrange HIRDLS ascending and descending data onto a regular time/height grid.
- $T'=T-T_0$
- Time / Longitude vary along X-axis.

Fourier Analysis of Asynoptically Sampled Data (Salby, 1982)

The resolved wavenumbers and frequencies (30-day sample) show mixed-Rossby-gravity waves, Kelvin waves and equatorial Rossby waves.



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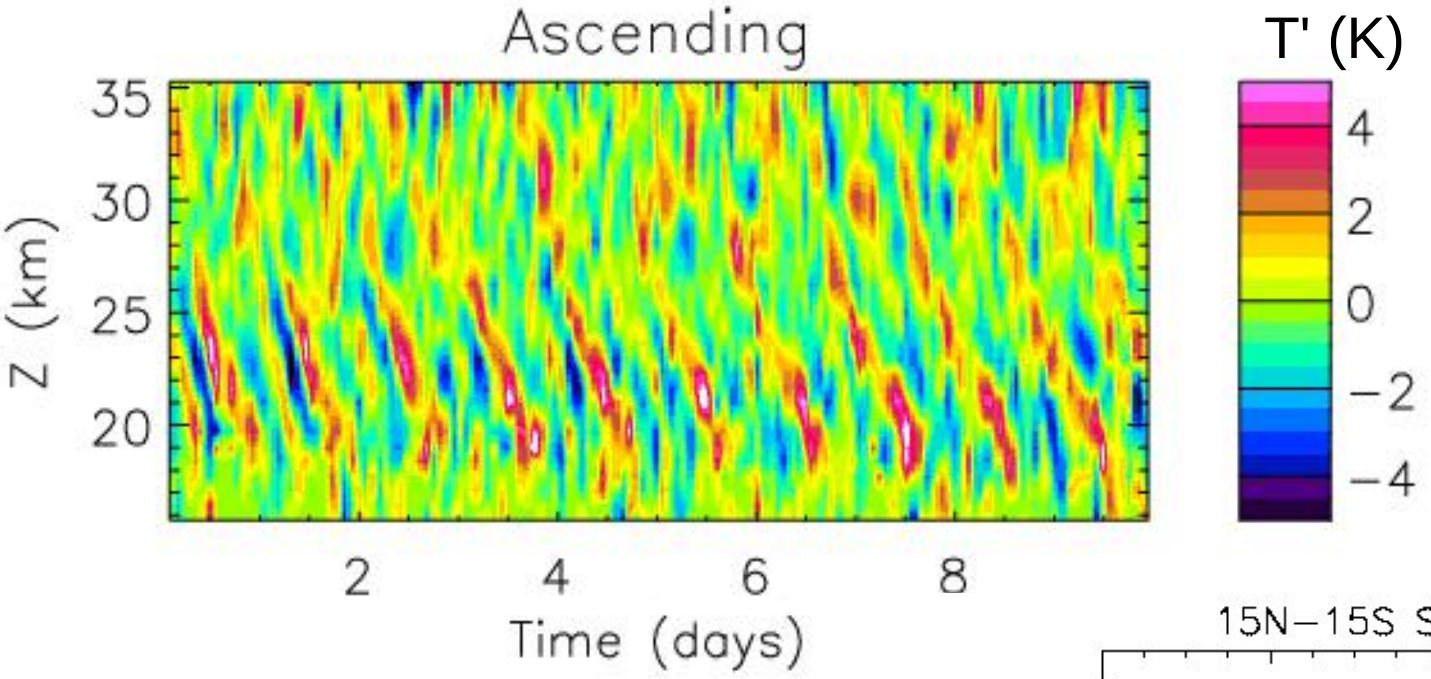

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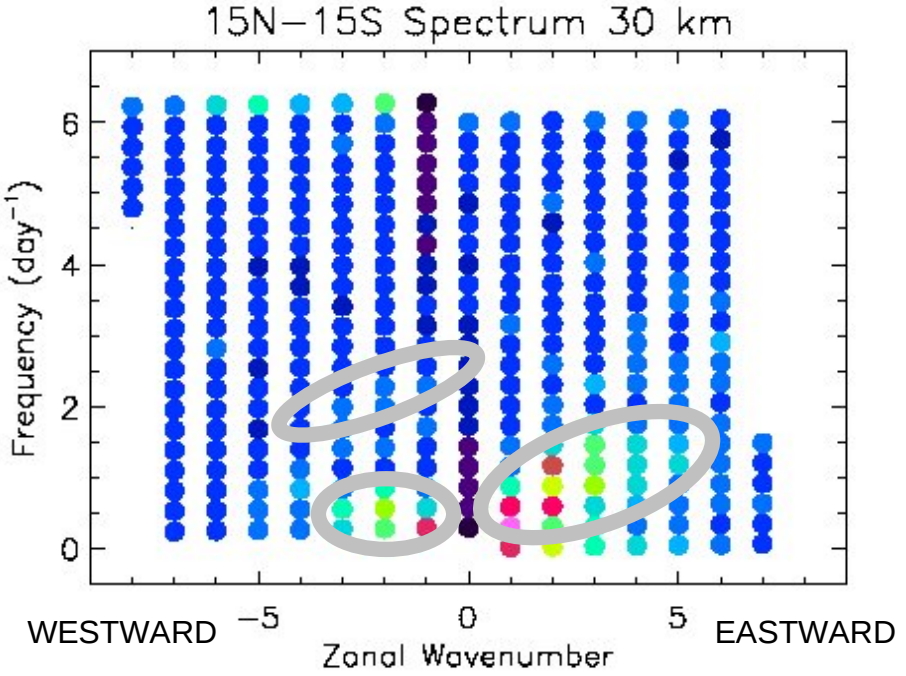
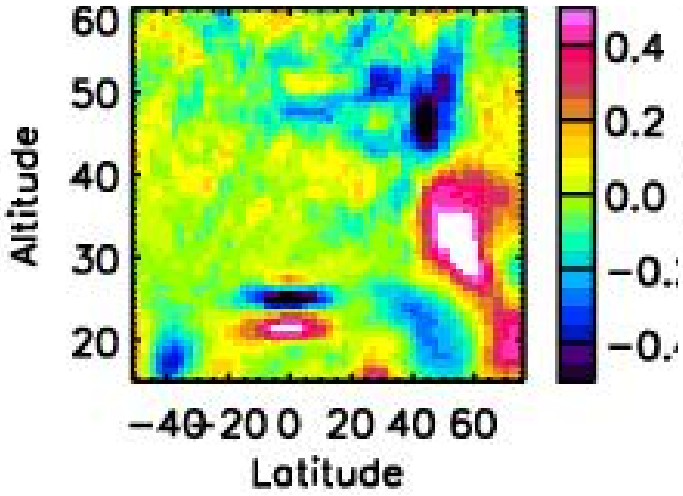


Vertical and Latitudinal Structure

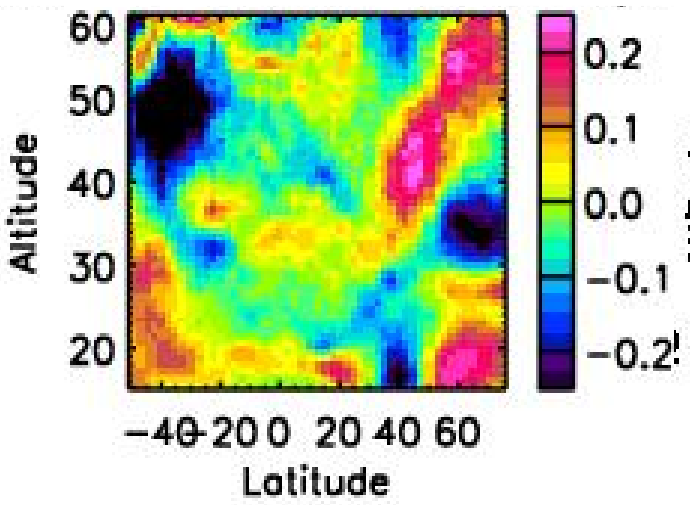
Kelvin Wave

WN = 2 Period = 14 days



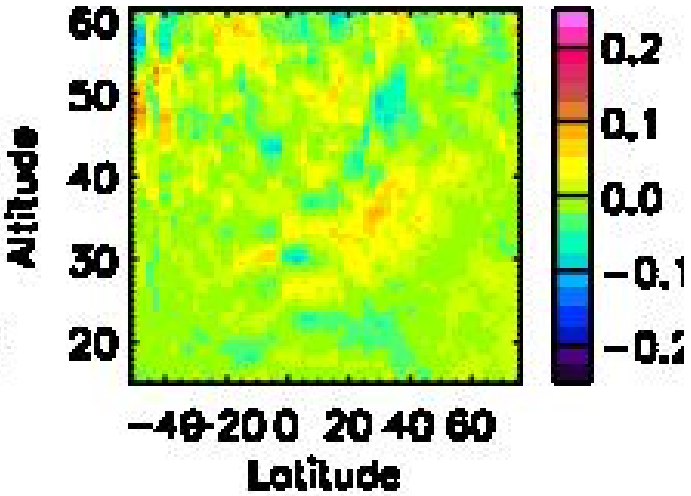
Equatorial Rossby Wave

WN = -1 Period = 30 day



Mixed Rossby-Gravity Wave

WN = -4 Period = 4.4 days



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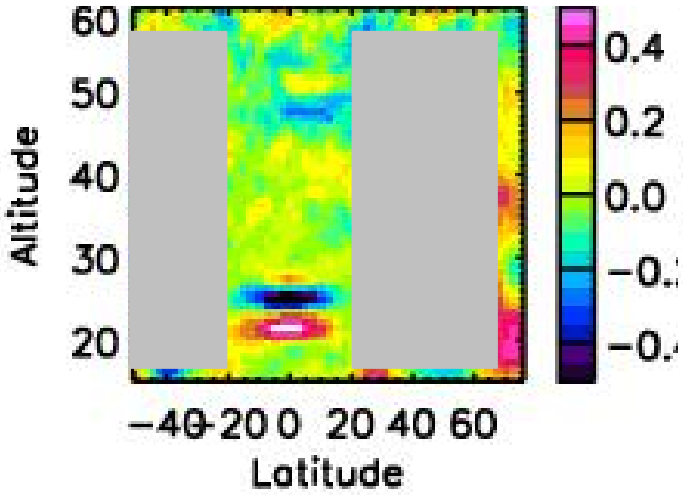

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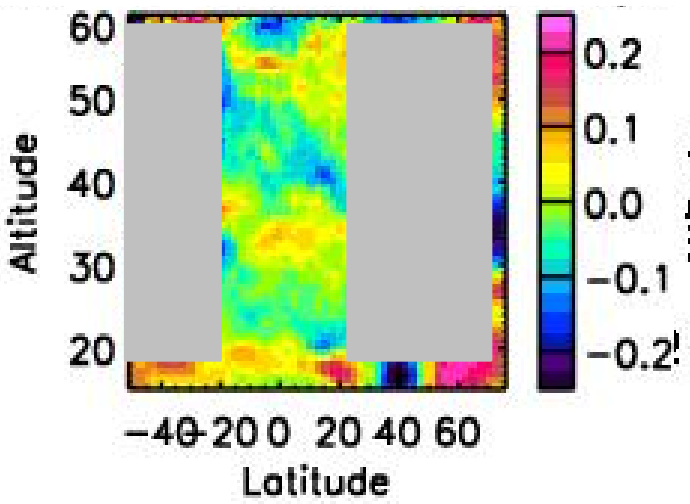

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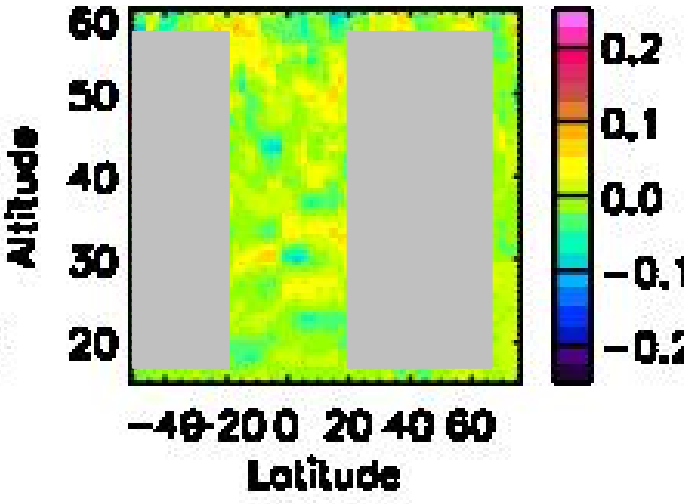
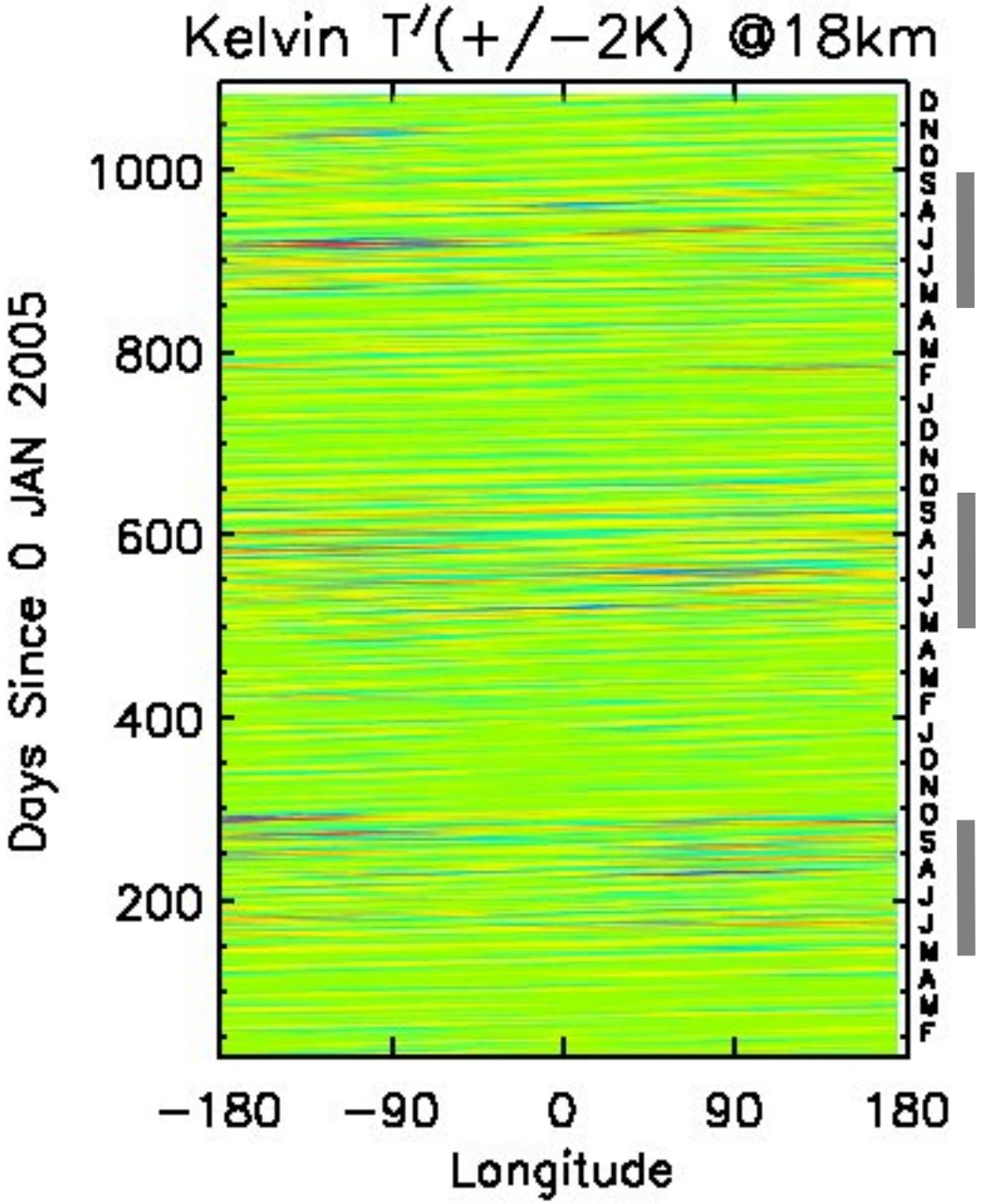
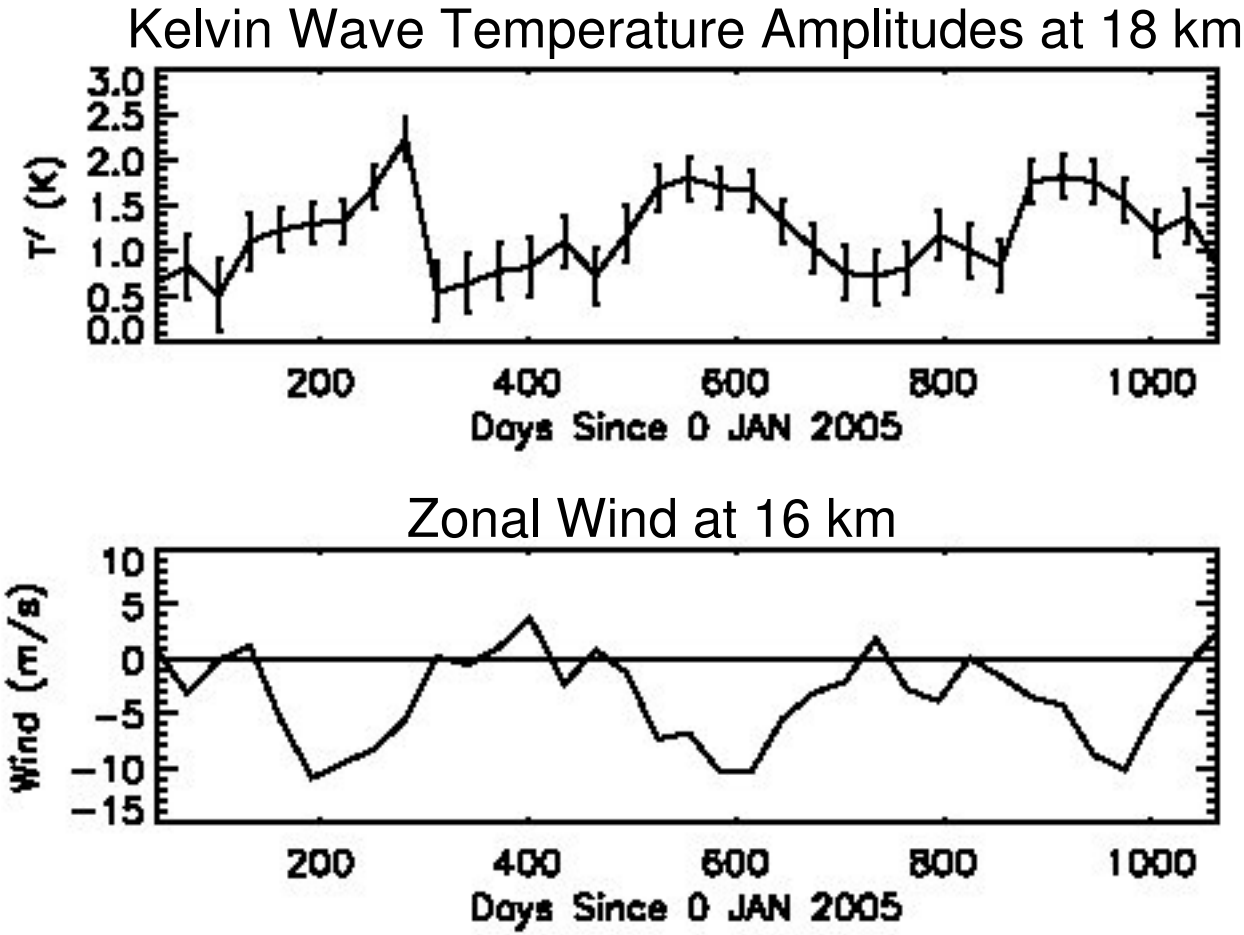


3-Year Time Sequence: Kelvin Waves



- Clear Annual Cycle observed below 20 km
- Maxima ~May-Sep

3-Year Time Sequence: Kelvin Waves



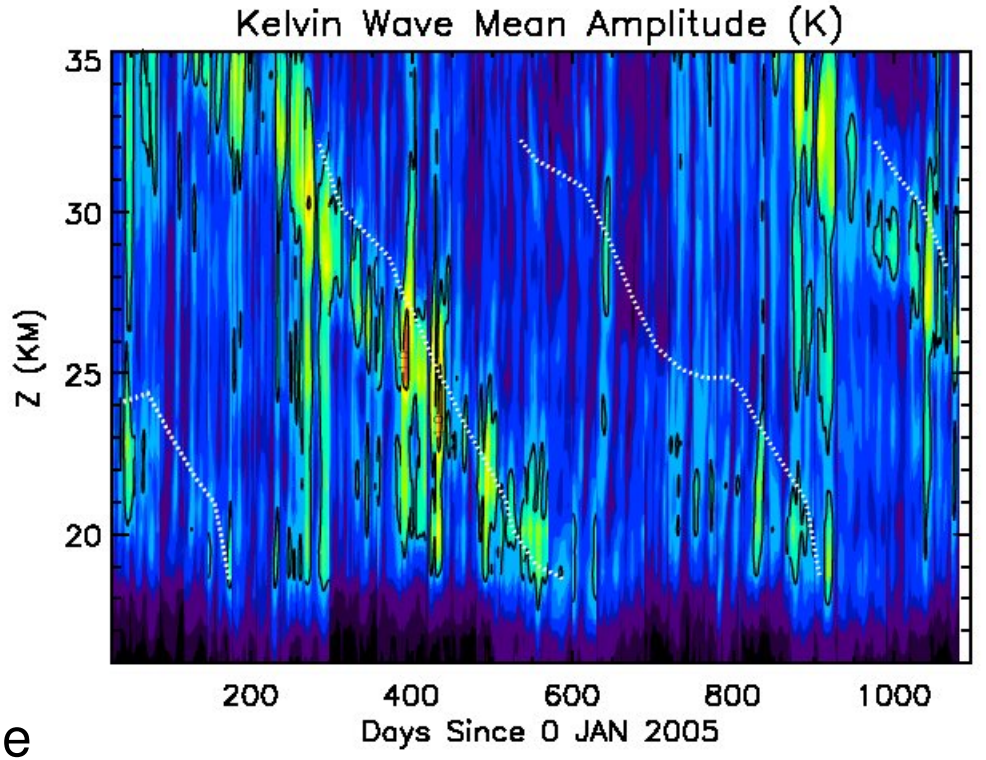
- The annual cycle goes with the strength of westward winds near the tropopause.

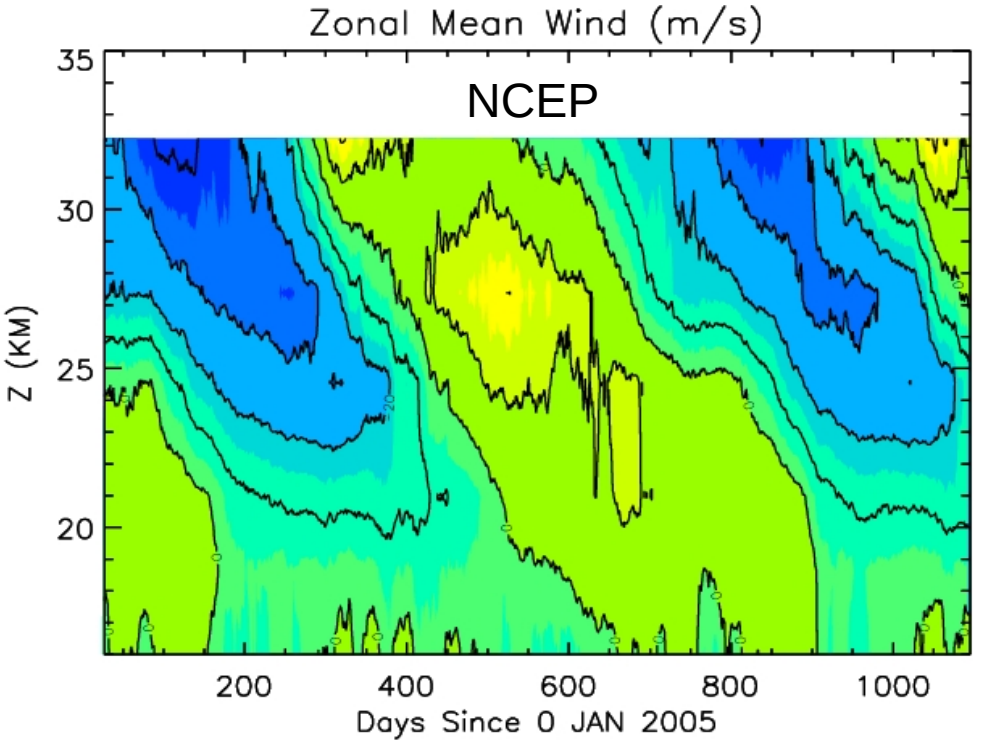
Time-Height Sequence of Kelvin Wave Amplitudes:

wn=1-5, periods=4-20 day
at the equator

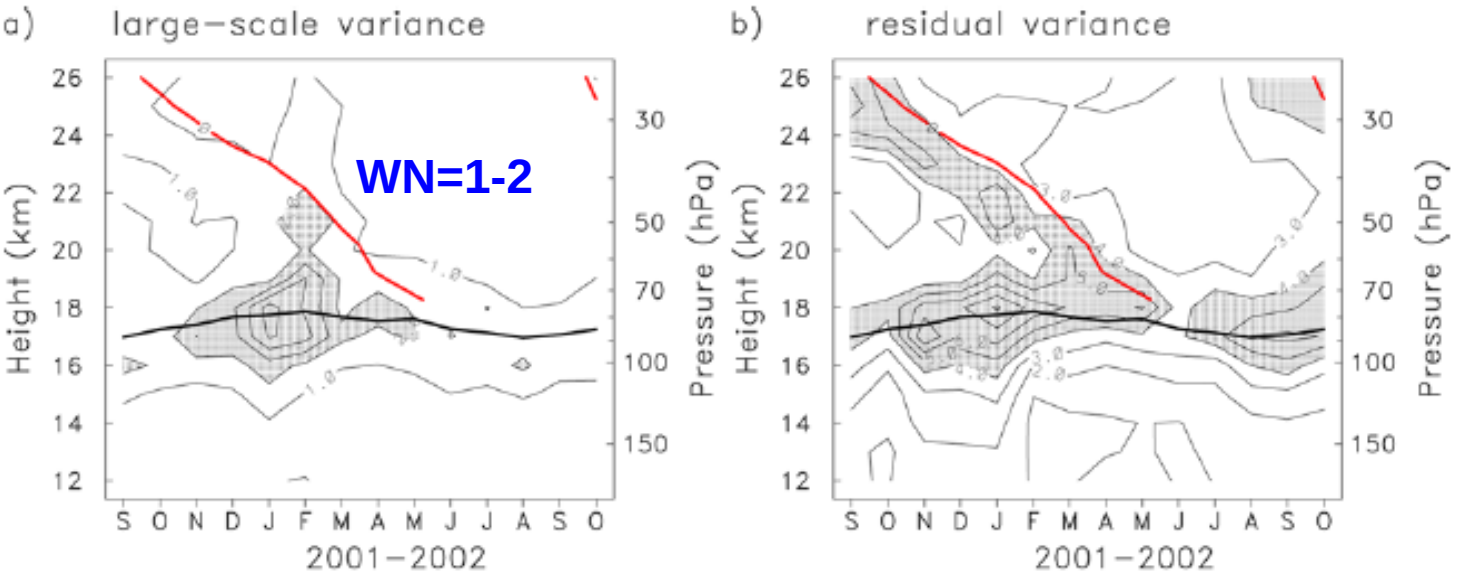
Interannual Variation
at Altitudes > 20 km

A clear interannual variation follows the QBO westerly phase descent of the zero wind line.

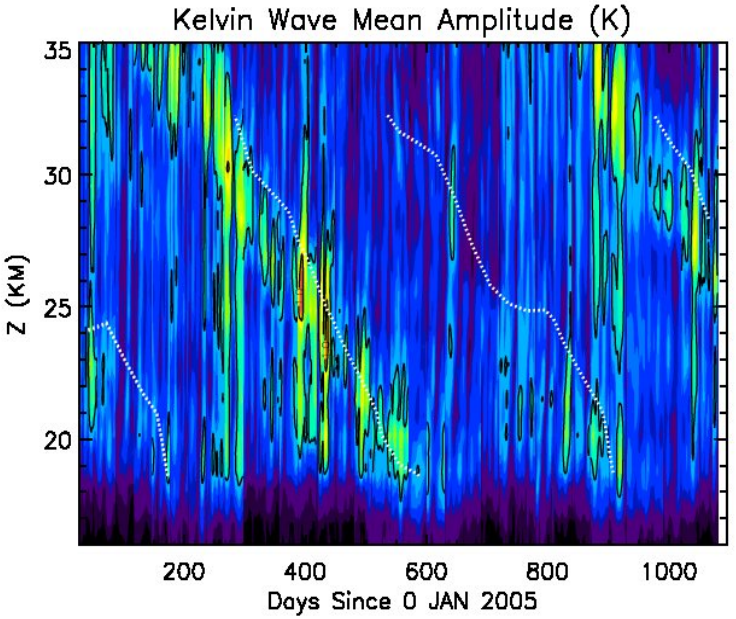




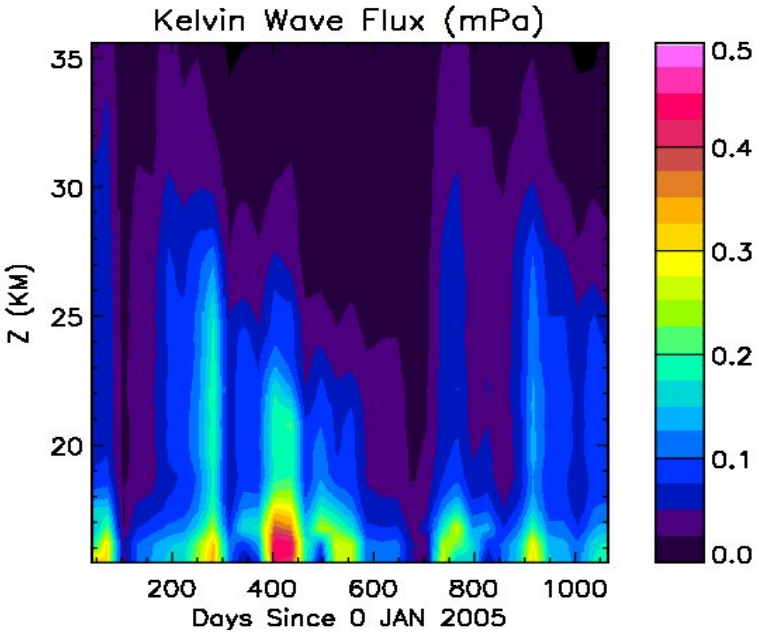
GPS Temperature Variance (K^2): Randel and Wu [2005]



HIRDLS Kelvin Waves:



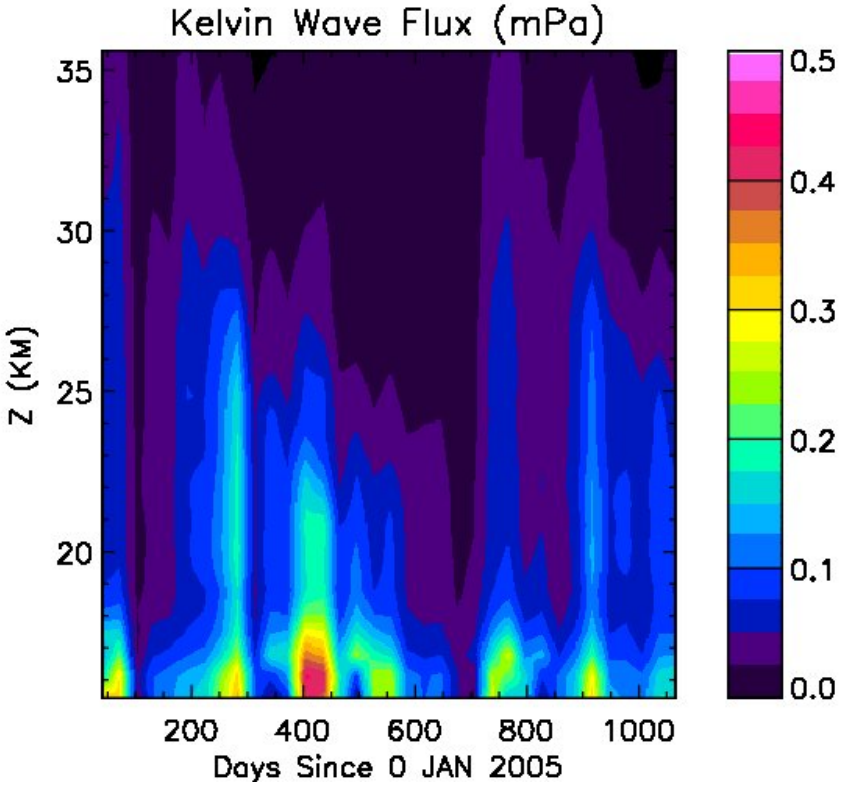
WN=1-5

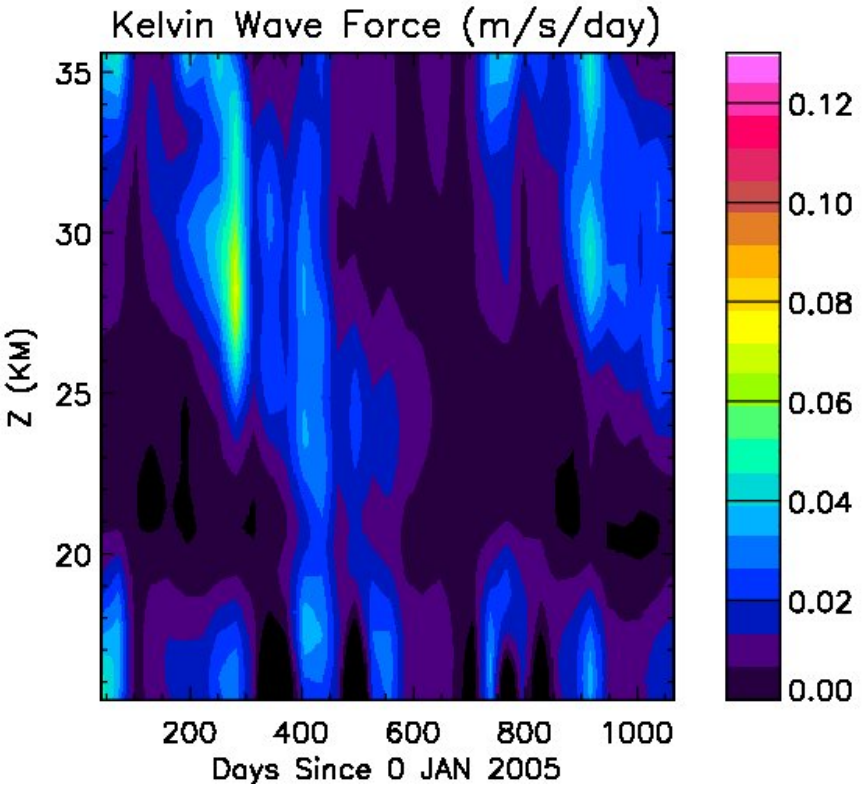


Kelvin Wave Driving of the QBO

Compute the Mean-Flow Force at the Equator:

Force = ρ^{-1} d/dz(Flux)





Kelvin wave force up to 0.08 m/s/day
Total eastward force ~ 0.13 m/s/day

Summary

- HIRDLS has sufficient vertical resolution and sampling to resolve equatorial waves in the stratosphere throughout the QBO wind cycle.

- Kelvin waves in HIRDLS data show an annual cycle in T' below 20 km that is correlated with westward winds near the tropopause.

- Above 20 km, Kelvin wave T' show an interannual cycle with maxima that follow the zero wind line during the descent of QBO westerlies.

- We have evaluated the Kelvin wave force on the mean flow and find values ranging 0.04 - 0.08 m/s/day, up to 2/3 of the total force needed to drive the westerly phase of the QBO.