Tracking Jupiter's Quasi-Quadrennial Oscillation

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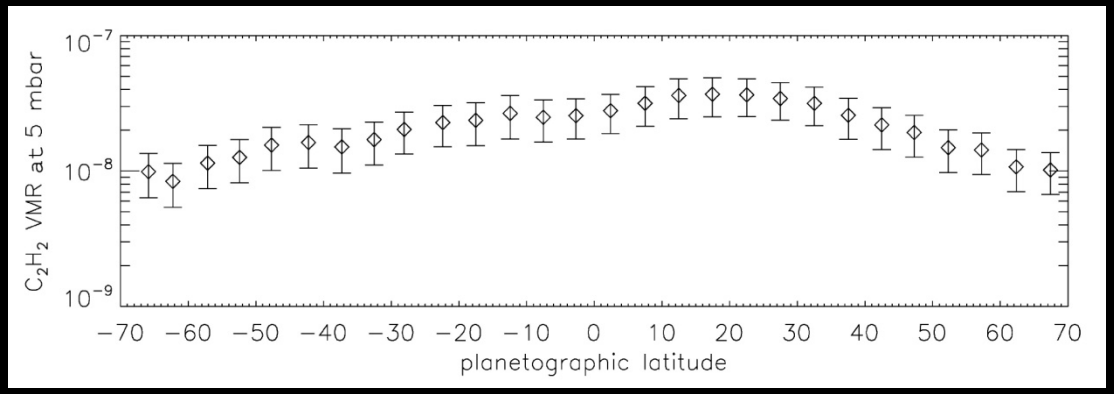
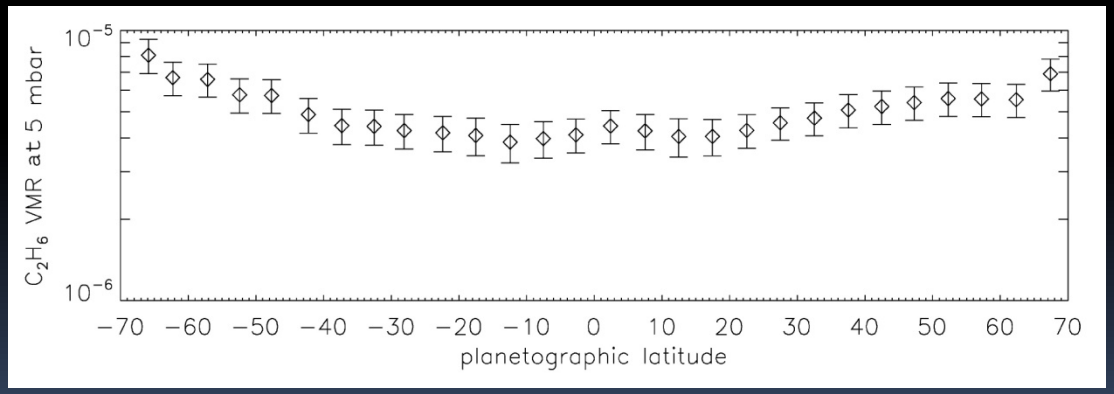
Outline

- Brief history of what led us to this study
- How to track stratospheric dynamics
- Stratospheric wave interactions
  - The Quasi-Quadrennial Oscillation
    - What is it and why does it exists?
    - Importance
    - Our ability to track and characterize it.
- Conclusions
- A Future Study Requiring TMT

Meridional Distributions of Hydrocarbons

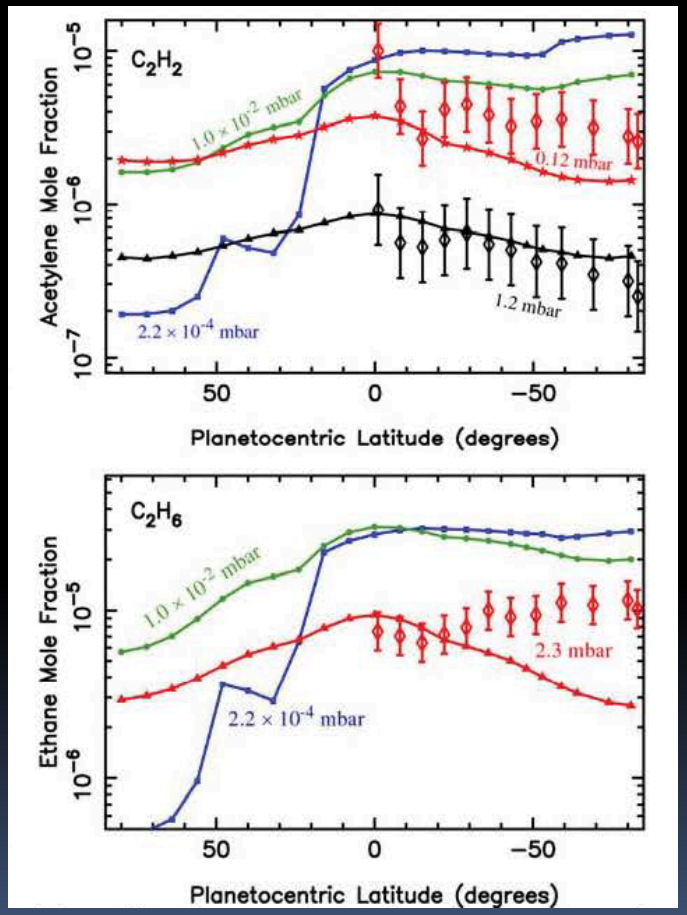
Jupiter





Nixon et al. 2007

Saturn



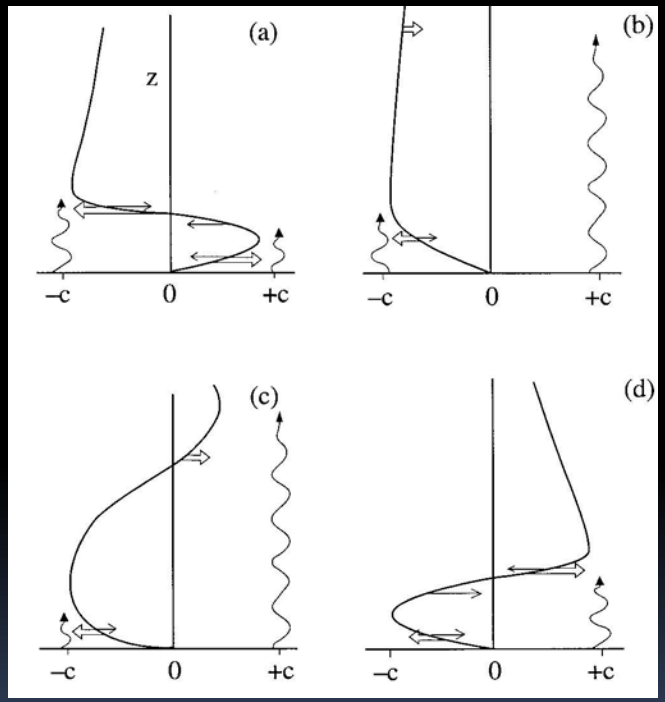
Moses and Greathouse 2005

Tracking Dynamics in the Stratosphere

- Tracers
  - None in visible range
  - Hydrocarbon abundances
    - ~20-30% temporal abundance variation at Saturn (Sinclair et al. *Icarus* **225**, 257-271)
  - Temperatures
- Observational issues
  - Spatial resolution (horizontal and vertical)
  - Integration time vs. Signal to Noise

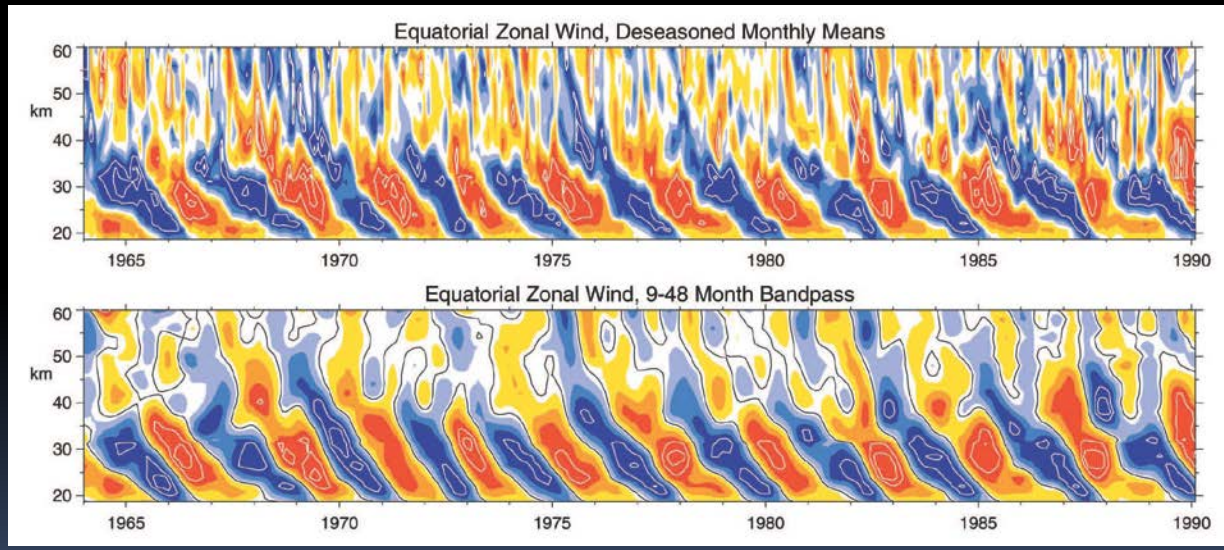
The QQO: a quick primer

The QQO on Jupiter was first described in a Nature paper by Leovy, Friedson, and Orton in 1991.



Baldwin et al. 2001

QQO = Quasi-Quadrennial Oscillation
QBO = Quasi-Biennial Oscillation



Importance of understanding the QQO linked to the importance of Earth's QBO

- The Earth's QBO
  - dominates the variability of the equatorial stratosphere
  - though tropical in nature, the QBO on earth affects the stratospheric flow from pole to pole by modulation of extra-tropical waves
  - affects variability of the mesosphere by selectively filtering vertically propagating waves
  - stratospheric chemical distributions are affected by circulation changes induced by the QBO

Baldwin et al. 2001

Observations

- NASA Infrared Telescope
  - TEXES, the Texas Echelon cross-dispersed Echelle Spectrograph
    - Feb. 2013, Feb. 2014, Mar. 2015, Jan. 2016
    - $R=\lambda/\Delta\lambda\approx80{,}000$
    - CH_4 emission features between 1245-1251 cm^{-1}
    - TEXES is a long slit spectrograph (1.4” by 7”)
    - Scan maps give spatial resolution of ~1.4” (4.5° lat/long)

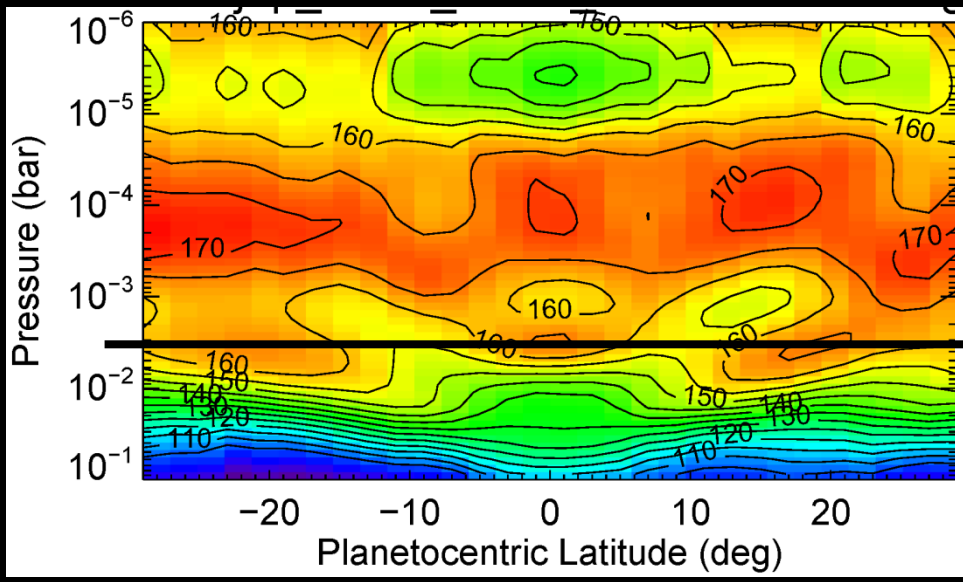
Temperature Retrieval

- Use an automated line-by-line radiative transfer code {optimal estimation approach Rodgers (2000)}
- Assume CH_4 is homogenous in latitude and longitude and follows the vertical profile from Moses et al. (2005).
- Plane Parallel, 95 layers separated equally in log pressure space
- LTE assumed throughout

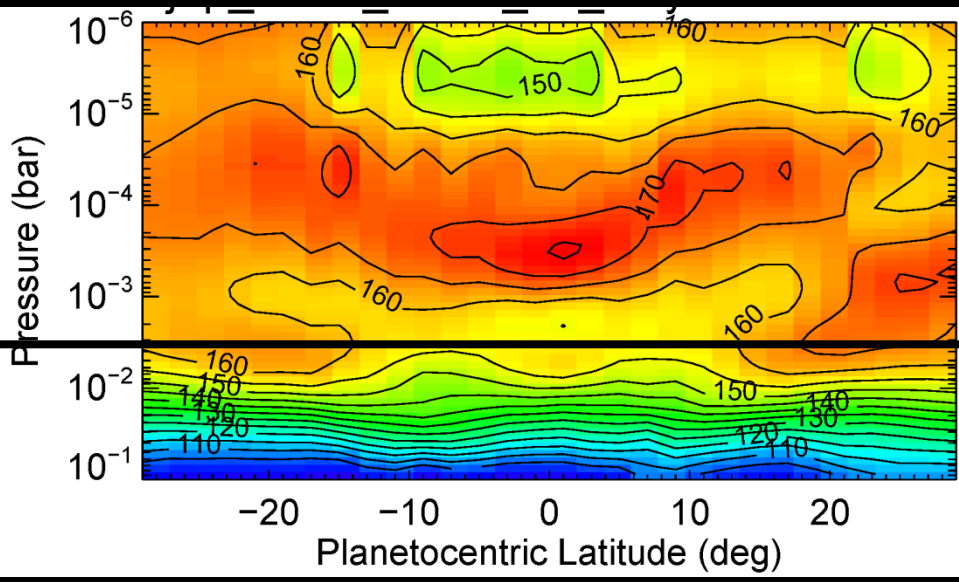
Greathouse et al. 2011

Zonal Averaged Temperatures

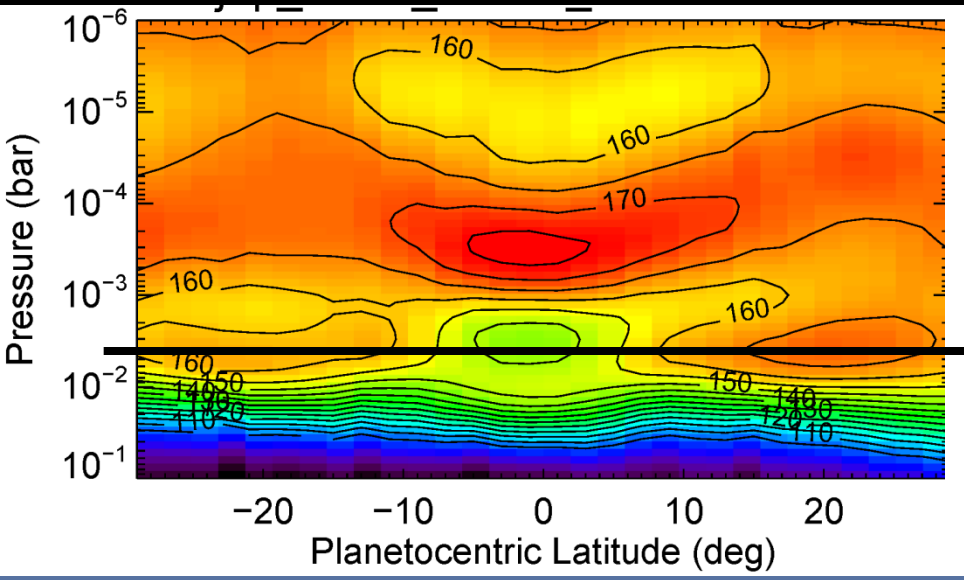
February 2013



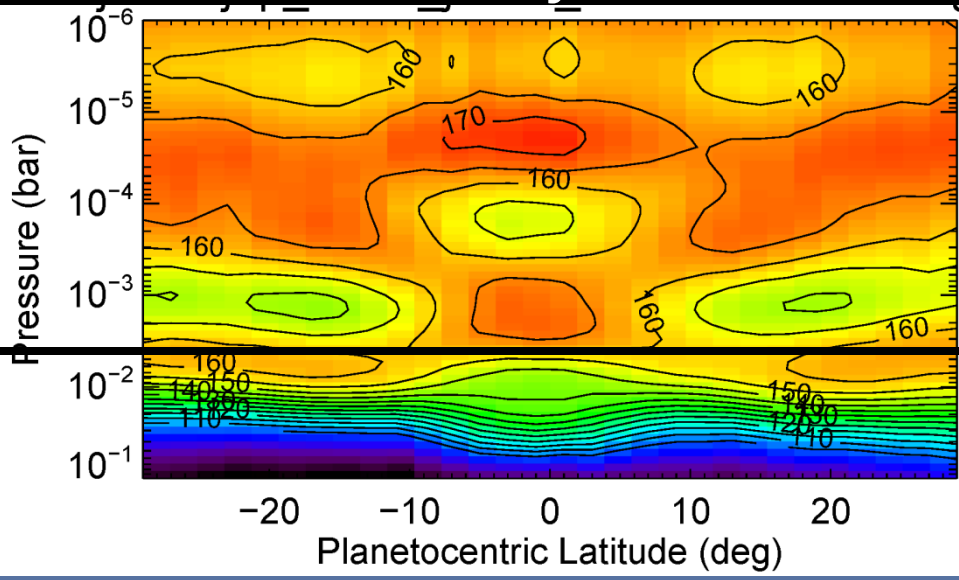
February 2014



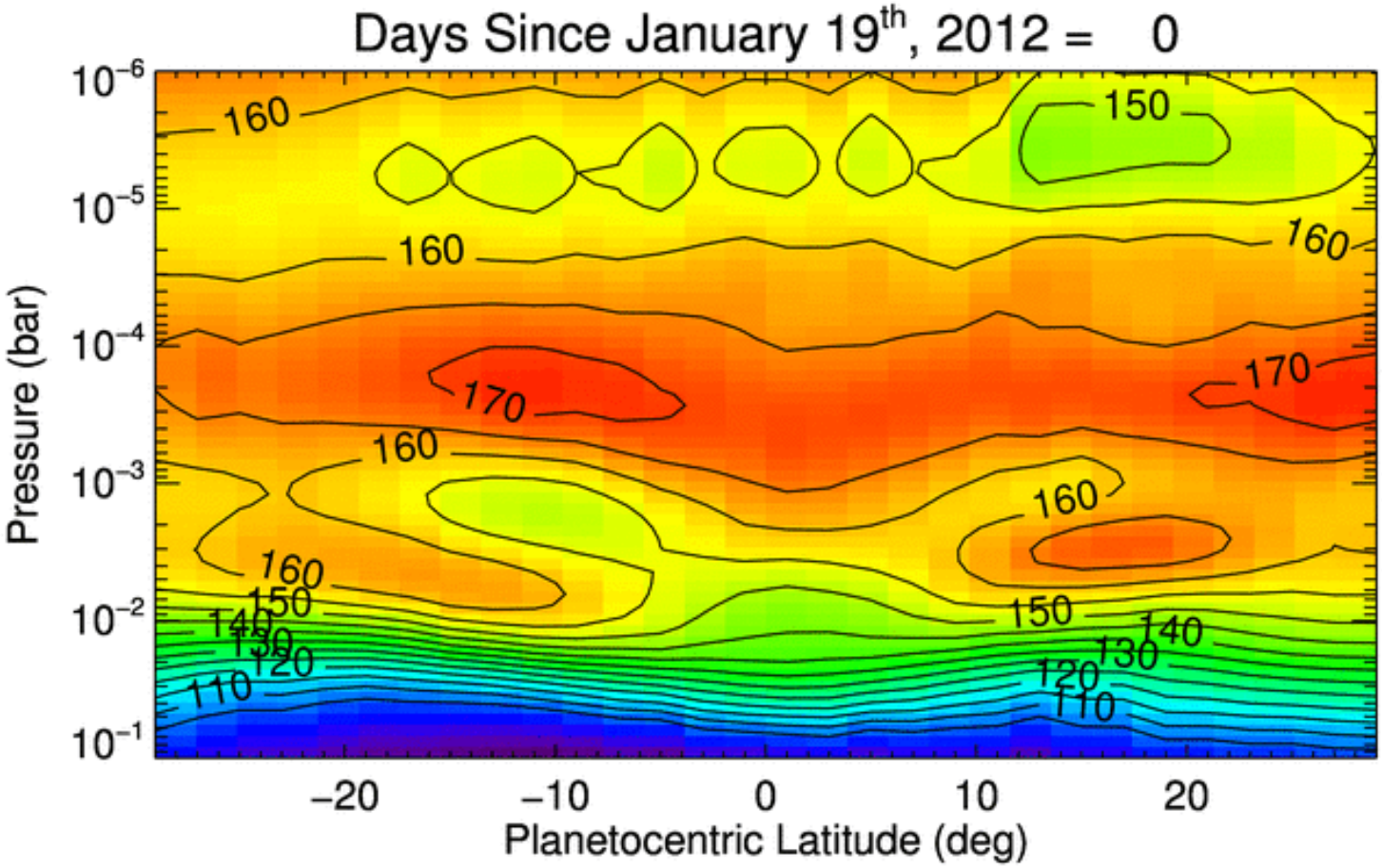
March 2015



January 2016

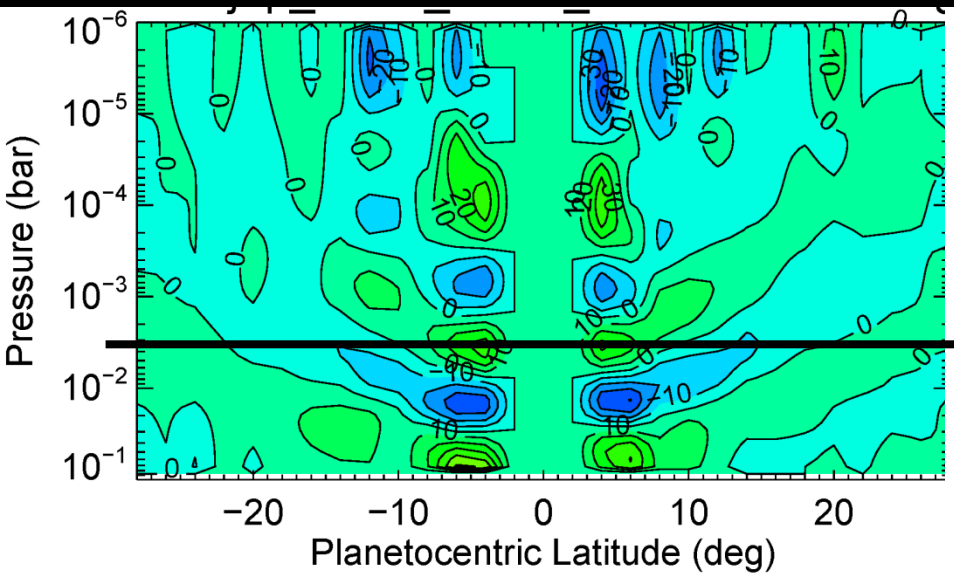


Time progression of stratospheric temperatures

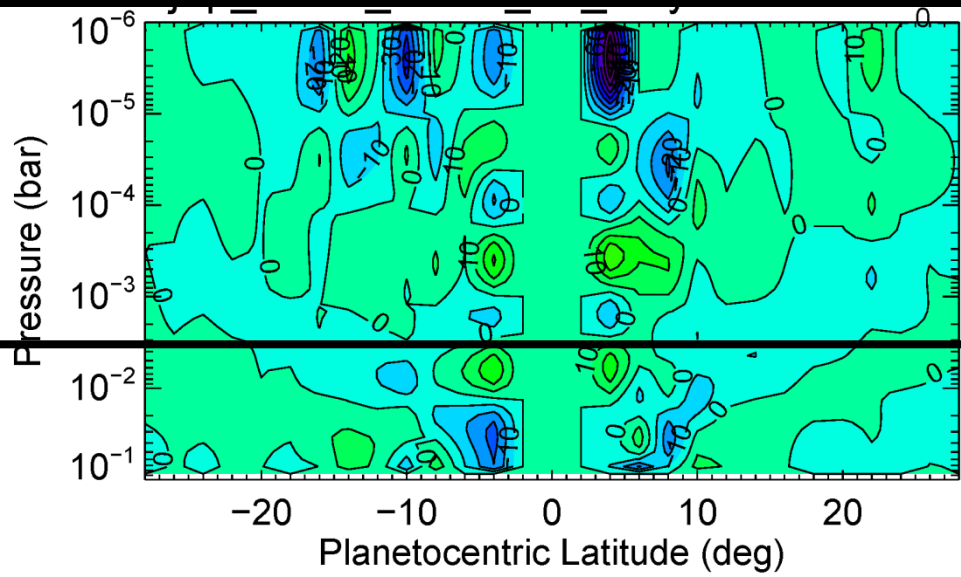


Stratospheric Zonal Winds

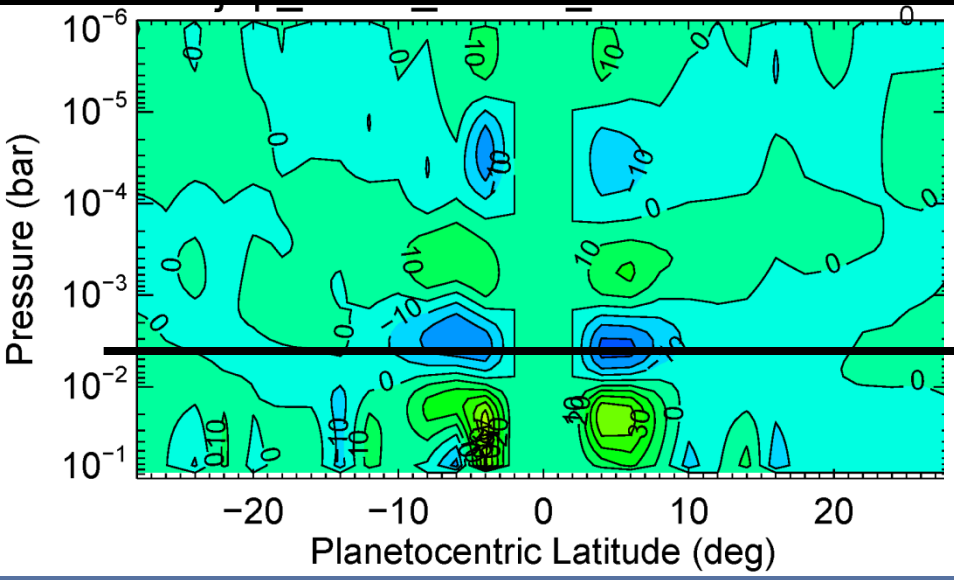
February 2013



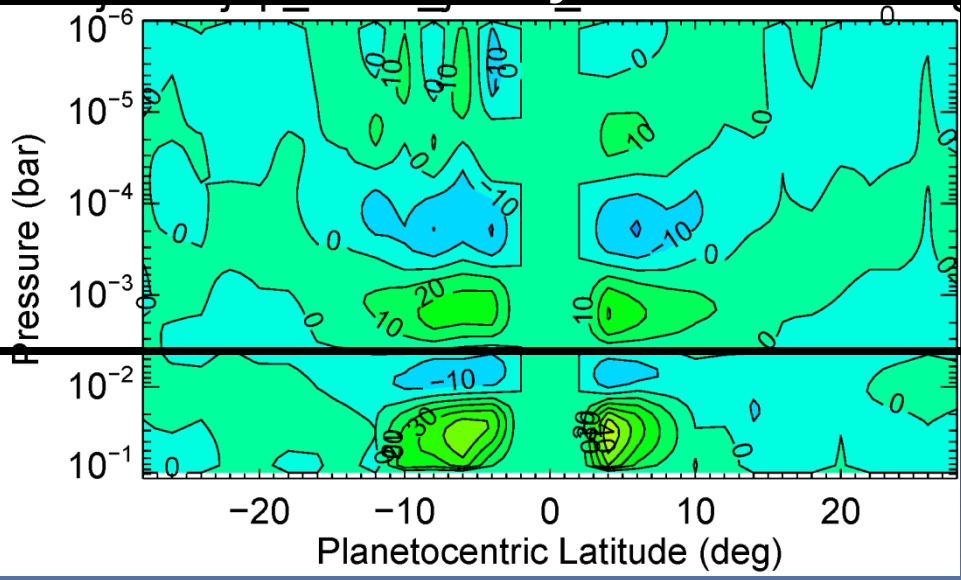
February 2014



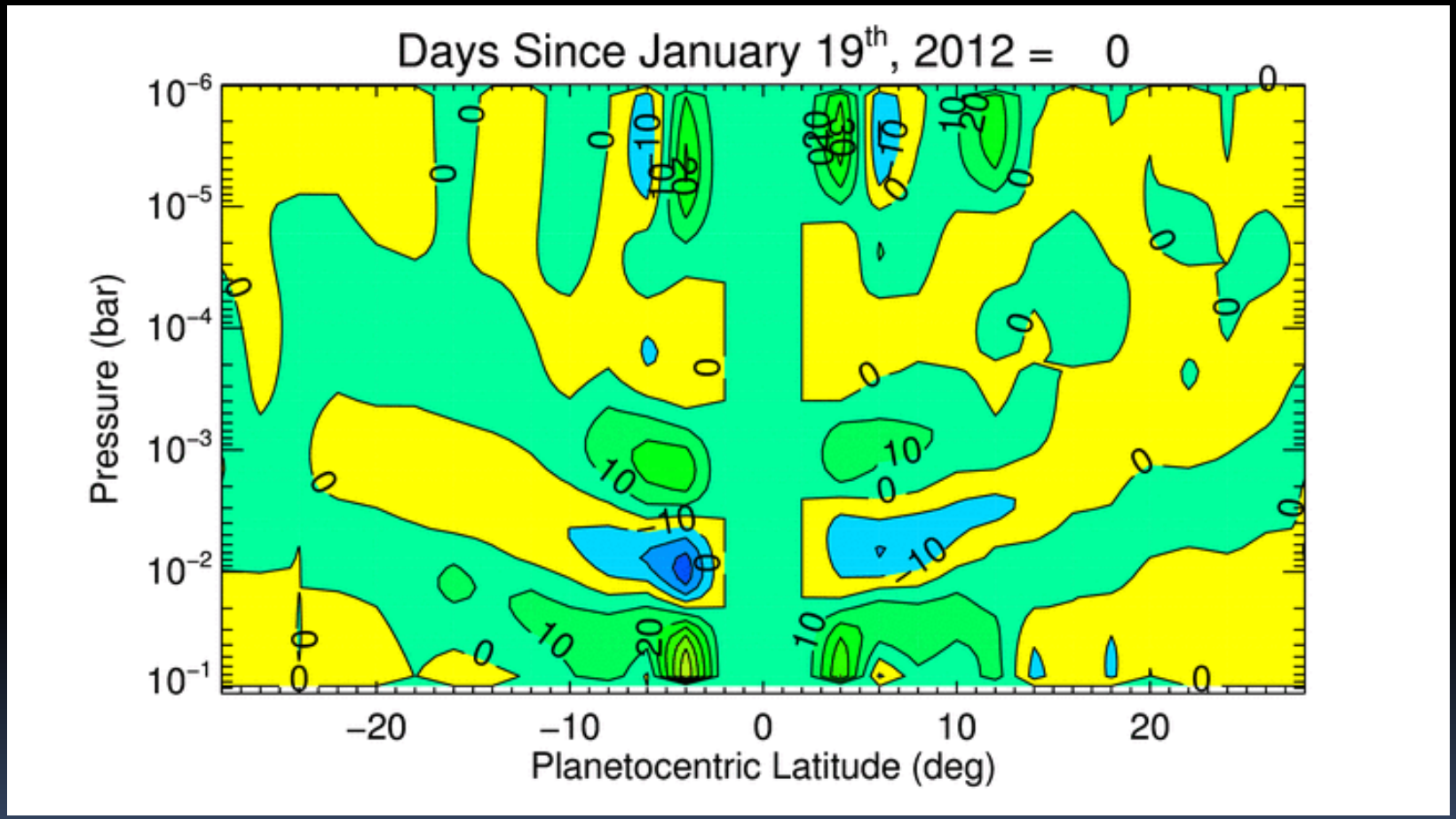
March 2015



January 2016

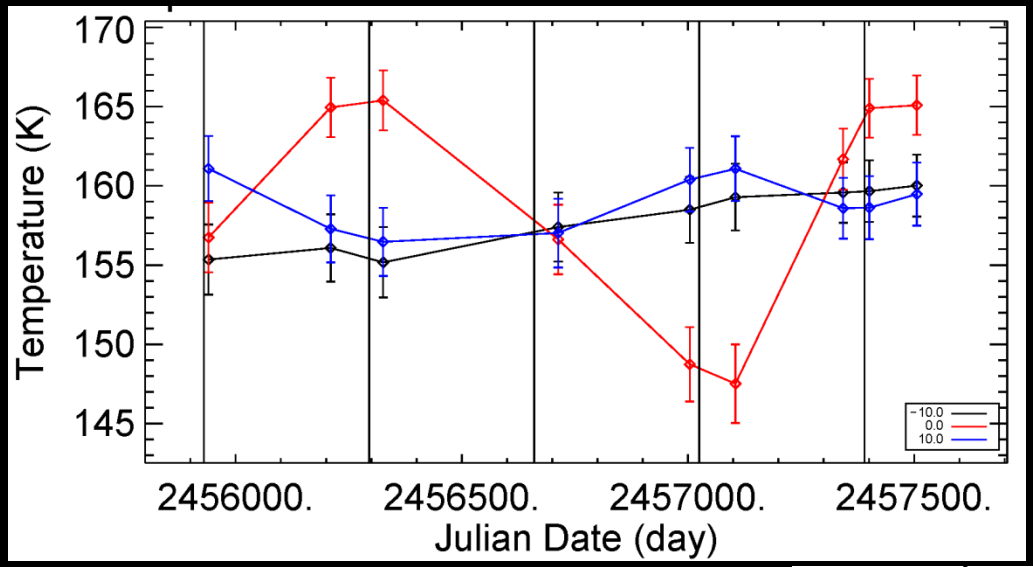


Time progression of stratospheric winds

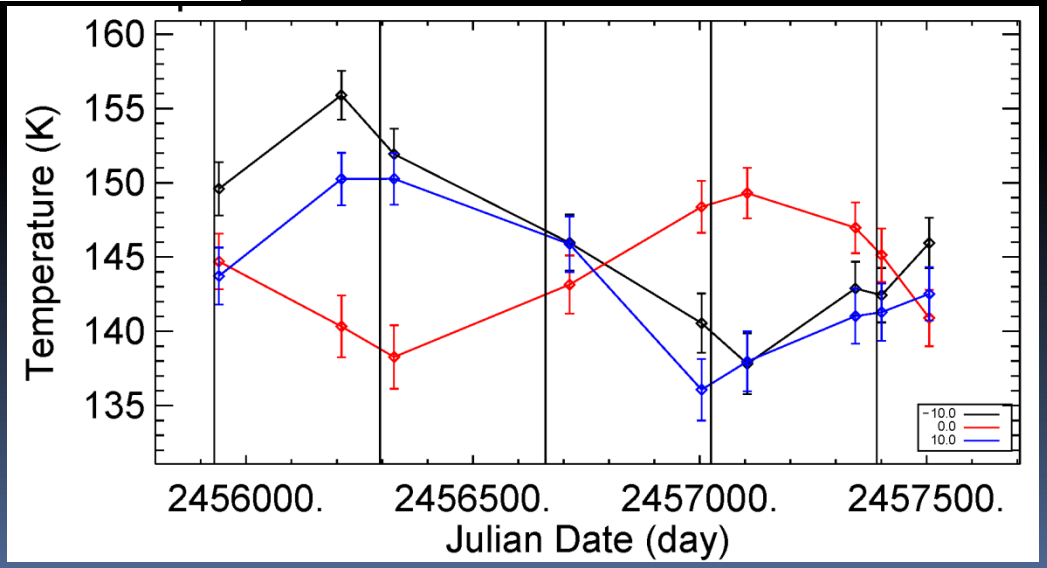


QQO in the time domain

3.0 mbar



13.5 mbar

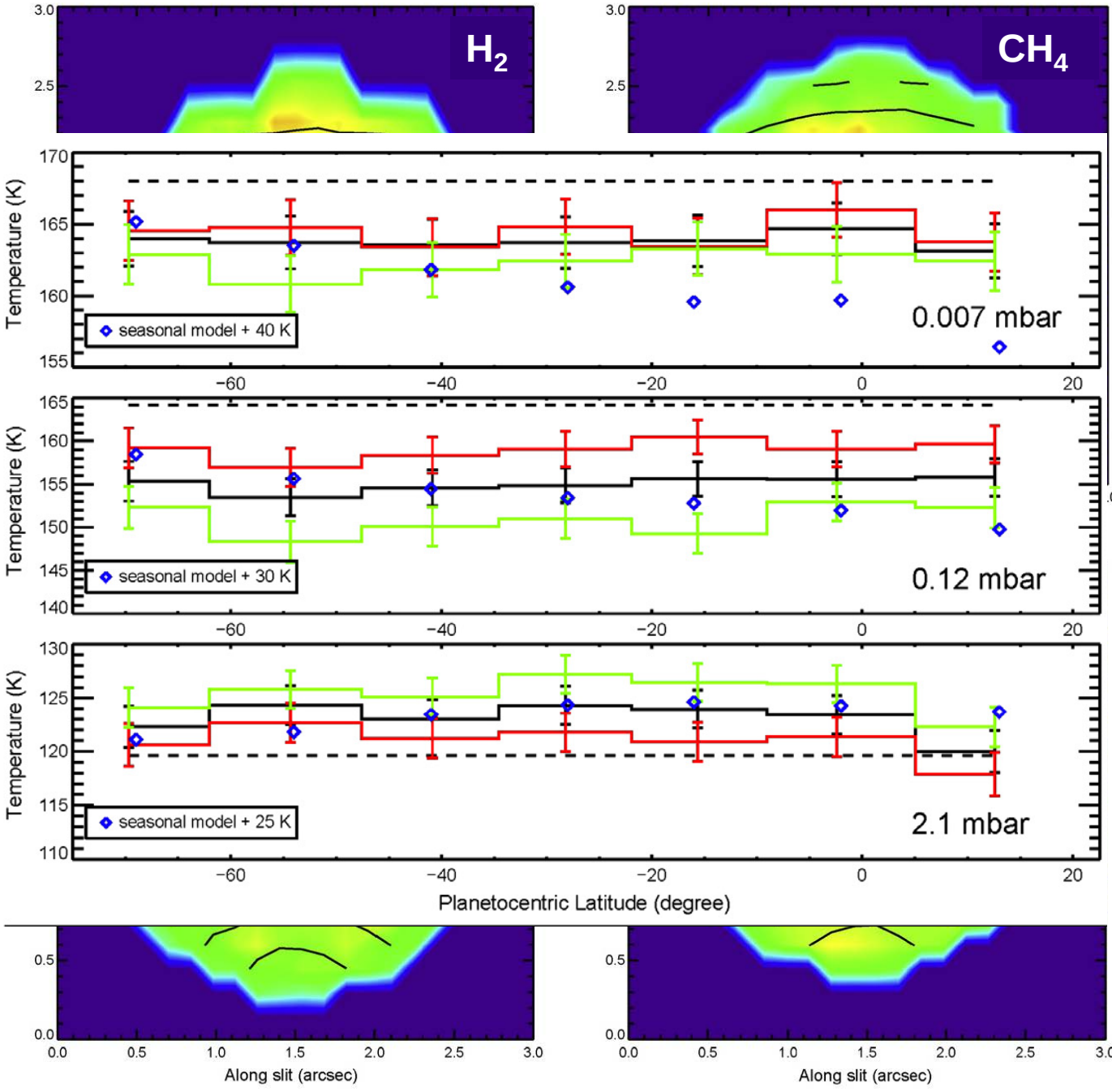


Conclusions

- Clear detection of QQO at the equator at 3 mbar.
- QQO at 13.5 mbar is completely out of phase with the 3 mbar variations.
- QQO at 13.5 mbar forces the opposite circulation at ±10° planetocentric latitude.
- QQO is well named as the period is close to 4 Earth years.
- Like the QBO on Earth, the QQO forces variations of the background wind velocities as much as -20 to +40 m/s

Neptune

- Gemini North/ TEXES
- Measured Strat Temp 25-40 K higher than seasonal model predictions
- TMT needed



TMT/MICHI Requirements for Neptune Study

- Non-Sidereal tracking
- Achromatic Optics throughout, or pre-calibrated focus versus wavelength numbers
- Efficient scan mapping capability
- Extended blackbody calibration source
- Optimization of slit length
- R=100,000 in the N-band
- Q-band is useful (H_2 S(1) emission feature), but not required.