Transmission of Planetary Wave Effects to the Upper Atmosphere by Modulation of Turbulent Mixing

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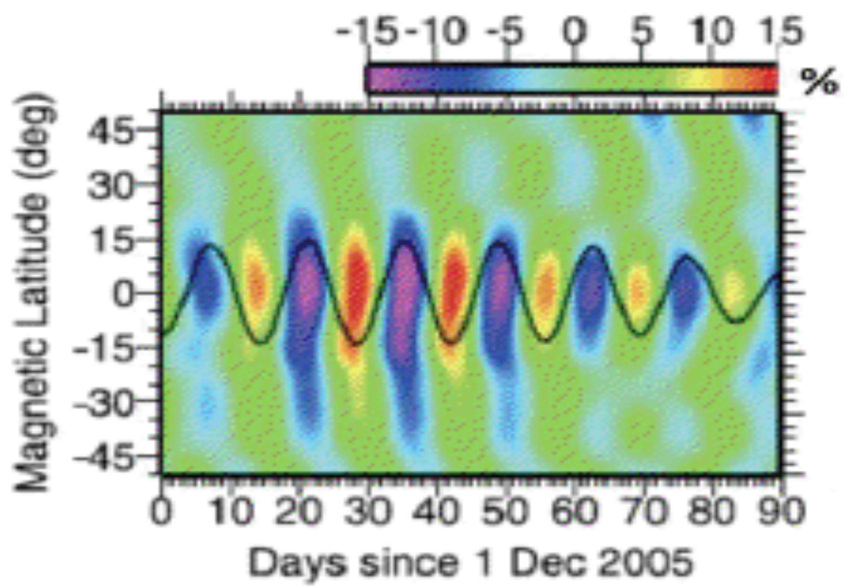
Planetary Waves

- Resonant responses of the atmosphere at multi-day periods (2-day, 10-day, 16-day etc.)
- Seen as global oscillations in wind, temperature, density, etc.
- Forced in the troposphere and stratosphere
- Waves typically dissipate in the MLT (mesosphere-lower thermosphere) but effects still be seen at higher attitudes



16-day planetary wave modulation of ionospheric total electron content at ~350 km and 22:00 local time. Data obtained from the CHAllenging Minisatellite Payload (CHAMP) satellite. Figure adapted from *Pedatella and Forbes, 2009*.

Possible Mechanisms of Planetary Transmission

1. Modulation of upward propagating gravity waves (*Meyer, 1999*) and atmospheric tides through nonlinear interactions (*Forbes, 1996*)
2. Direct propagation: More common for shorter period waves
3. In-situ generation of planetary waves by EUV/Joule heating in the lower thermosphere (*Meyer and Forbes, 1997*)
4. Filtering of gravity waves driving the E-region dynamo
5. **Modification of turbulent mixing in the MLT region (*Forbes, 1996*)**

Modification of Turbulent Mixing

Lower Atmosphere

Planetary waves modulate the amount of vertically propagating gravity waves through wave filtering

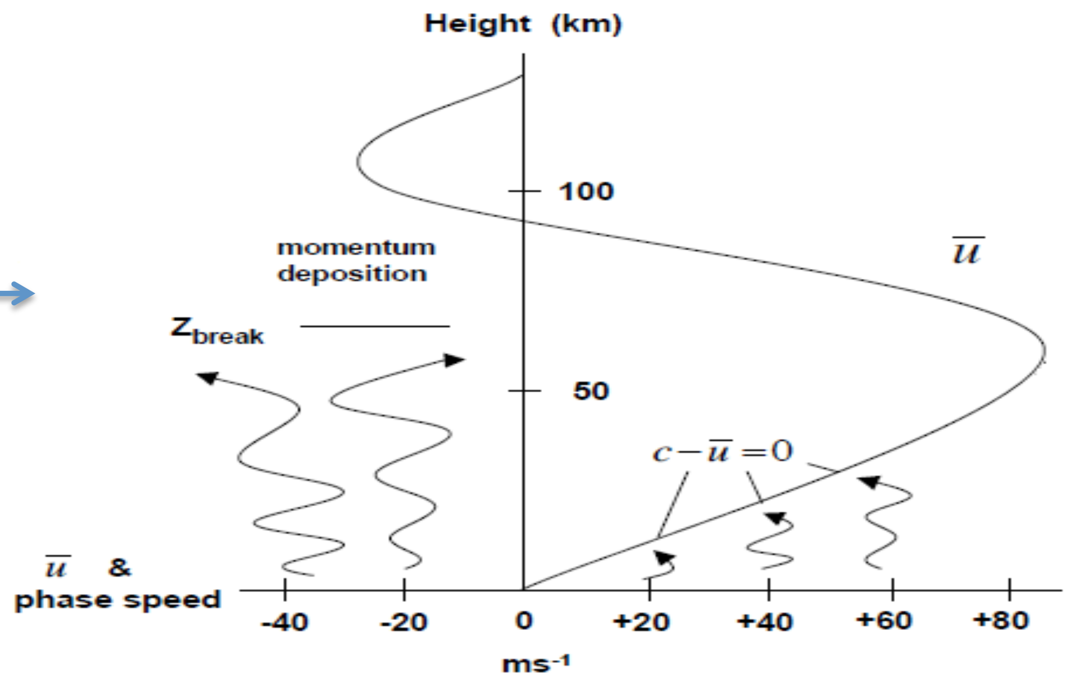
MLT

Gravity wave/tidal breaking determines the amount turbulent (eddy) mixing in the MLT region

Upper Atmosphere

Turbulent (eddy) mixing causes different neutral species to follow mean molecular scale height

Gravity Wave Filtering



Research Objective and Procedure

Research Objective

- Understand how the modulation of eddy diffusion at planetary wave periods can affect upper atmospheric density
- Quantify the effects on the upper atmospheric density at different modulation periods

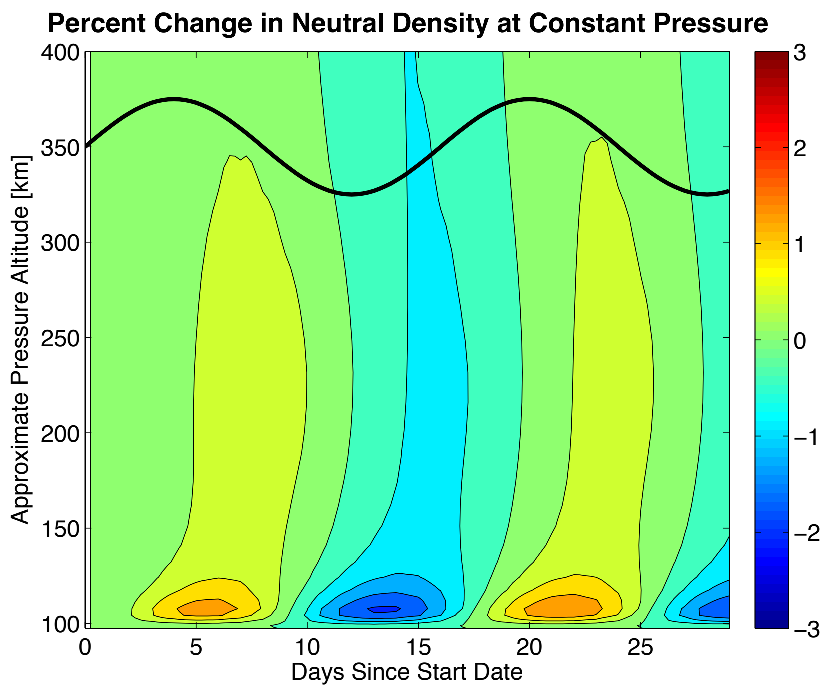
Procedure

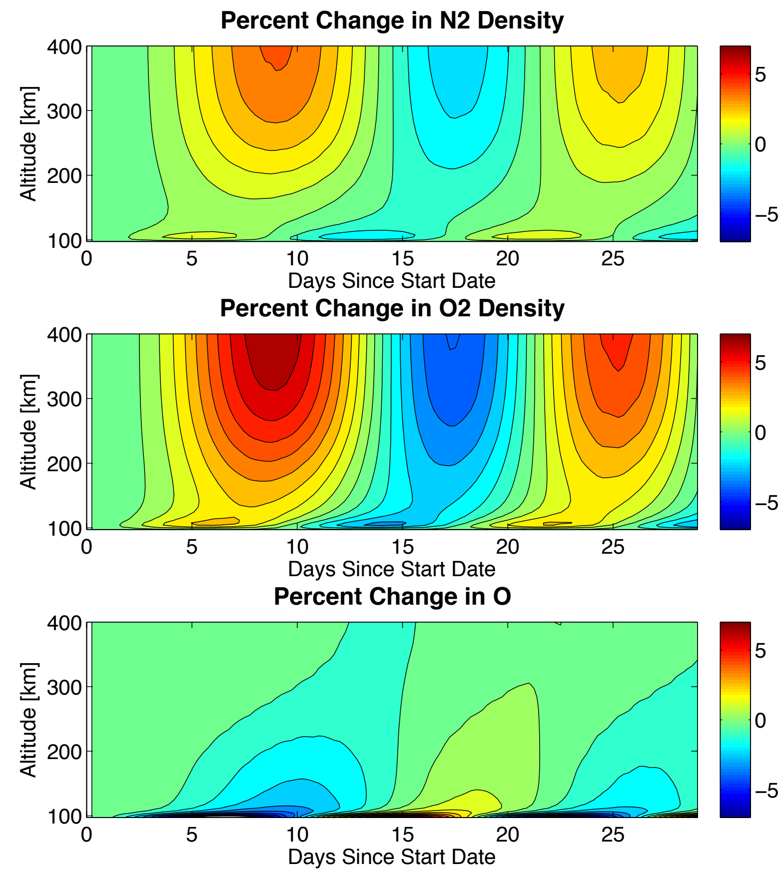
- Use the **N**ational **C**enter for **A**tmospheric **R**esearch (NCAR) **T**hermosphere-**I**onosphere-**E**lectrodynamics **G**eneral **C**irculation **M**odel (TIE-GCM)
- Modulate the eddy diffusion coefficient (20% of the mean value) at a specified period at the model lower boundary (~97 km).
- Compute globally averaged quantities and percent change from the control run
- Repeat for different modulation periods (4-day, 8-day, 16-day, 32-day)

Neutral Density at Constant Pressure Level

- Black line shows relative eddy diffusion value over the model run
- Percent change in neutral density at ***constant pressure level*** is ***directly proportional*** to the eddy diffusion coefficient

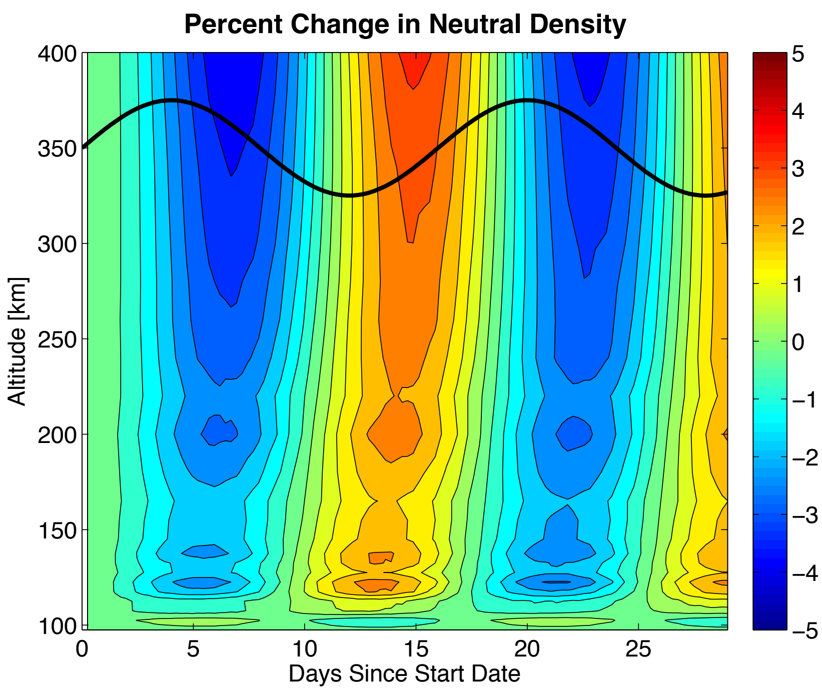
- Neutral density response is determined by the diffusion of minor species

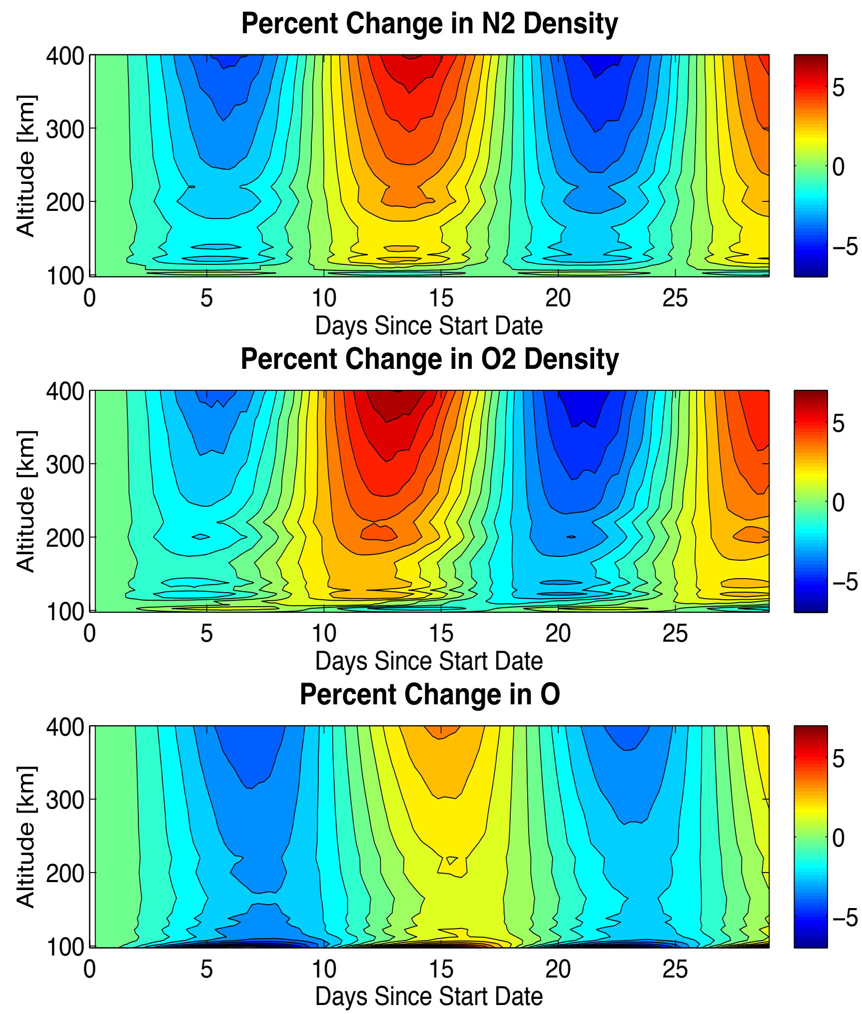




Neutral Density at Constant Altitude

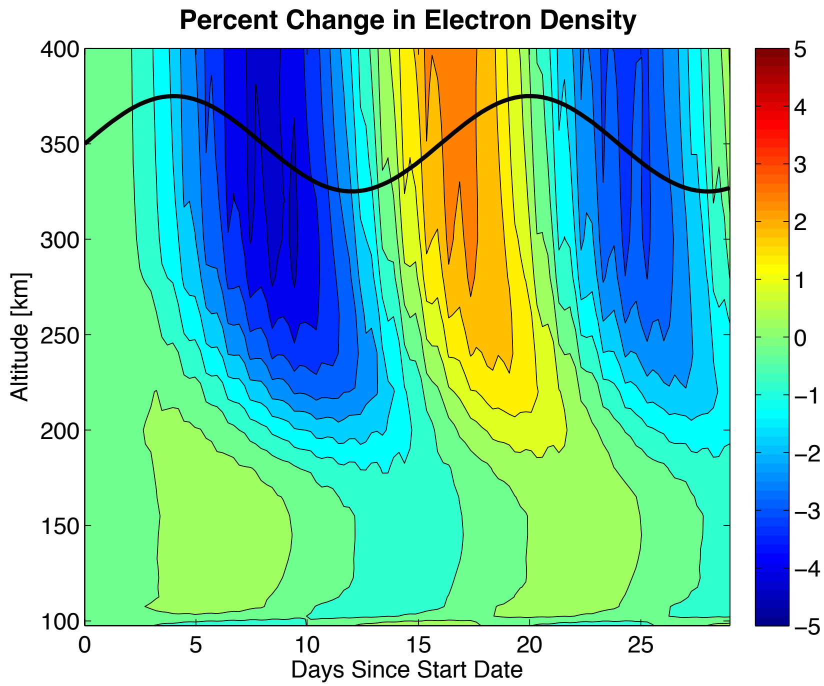
- Increase/decrease in mean molecular mass at constant pressure level causes decrease/increase in atmospheric scale height
- As a result, percent change in neutral density at ***constant altitude* is *inversely proportional*** to the eddy diffusion coefficient

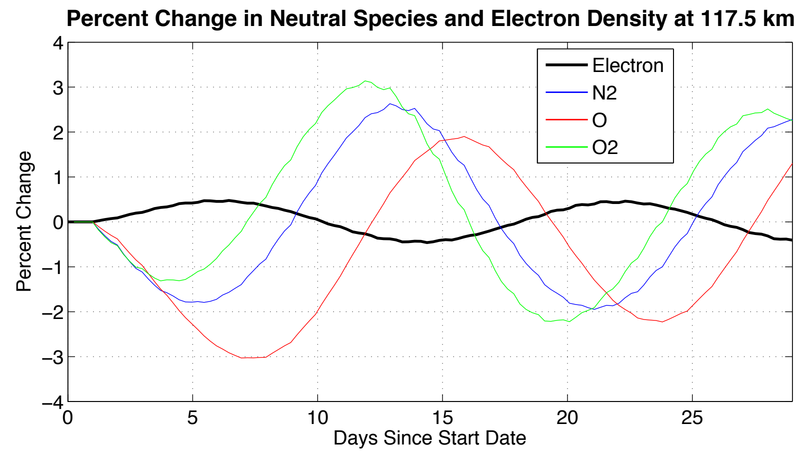


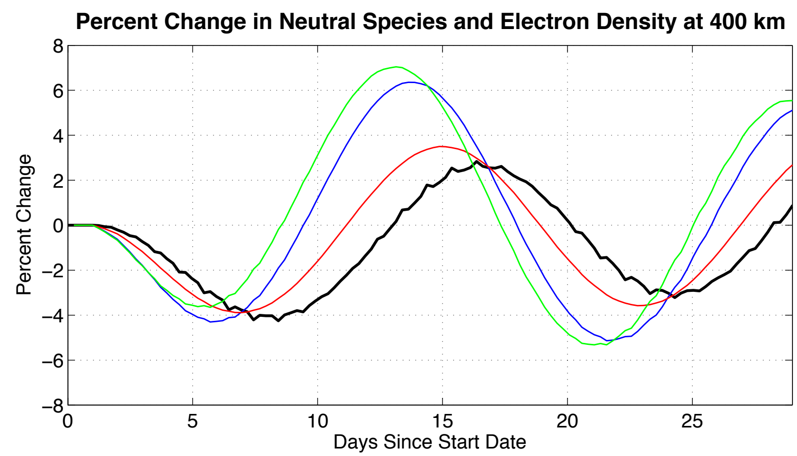


Electron Density at Constant Altitude

- Electron density change follows the change in neutral species composition
- Different drivers are present in different altitude regimes
  - Below 180 km: Electron density is primarily driven by change in N_2 and O_2
  - Above 180 km: Electron density is driven by change in O

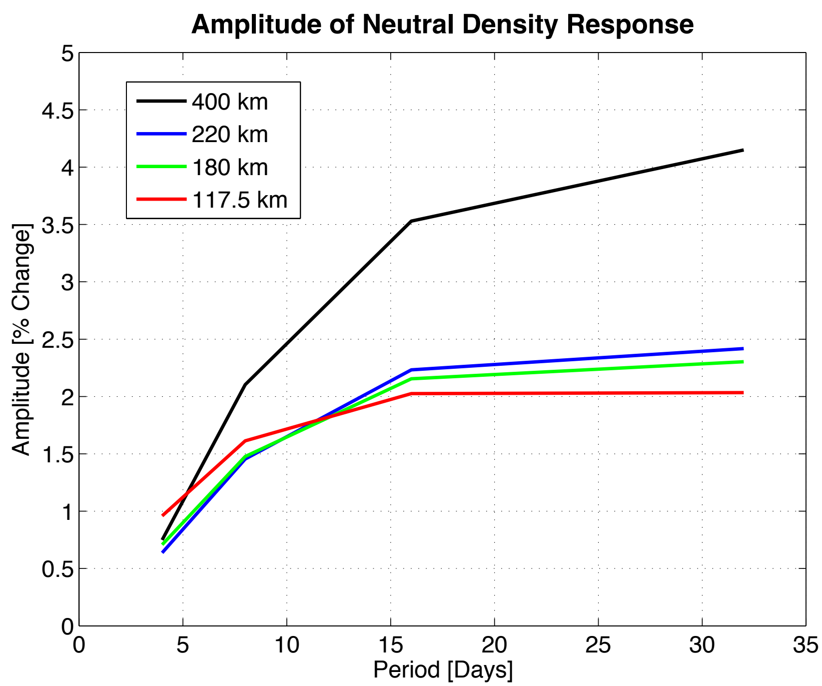


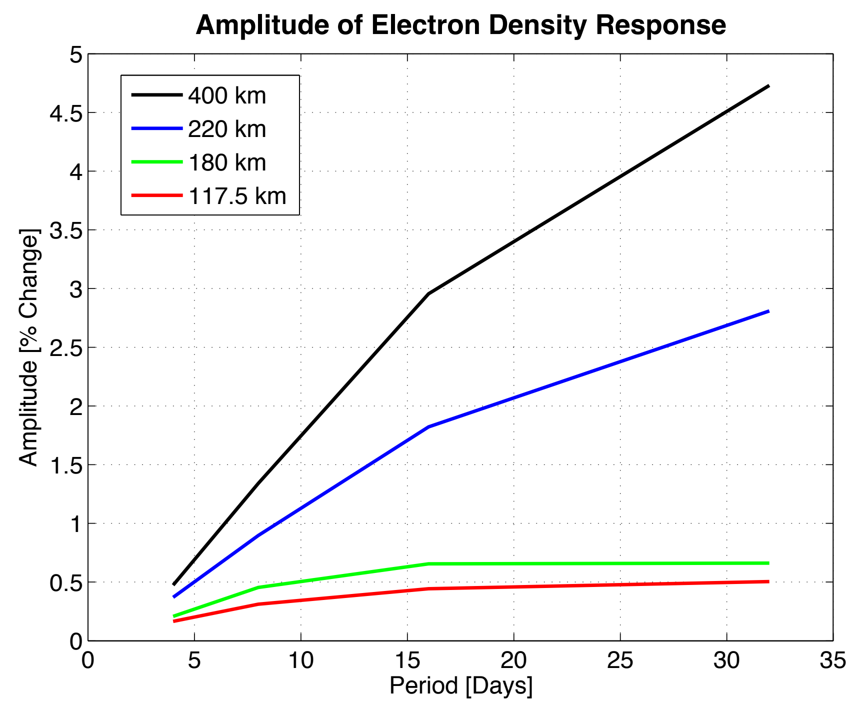




Electron Density at Constant Altitude

- Experiment is repeated for different modulation periods (4-days, 8-day, 32-day) to compare amplitude response
- Results show that the atmosphere acts like a low pass filter for this mechanism
  - The amplitude of the response is larger for longer eddy diffusion modulation periods
- Cutoff period is determined by the lag of the response
  - More response lag will result in a larger cutoff period





Conclusions/Future Work

- **Conclusions**
  - Varying the eddy diffusion coefficient in the MLT has the potential to induce planetary wave oscillations in the upper atmosphere
    - A 20% change in eddy diffusion causes a ~5% change in neutral and electron density at 400 km
  - Results show this mechanism is more efficient for longer period waves
- **Future Questions**
  - How does gravity wave filtering by planetary waves actually modulate the eddy diffusion in the MLT region?
  - How does this mechanism compare to other mechanisms for planetary transmission in the upper atmosphere?

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