Investigation of Thermosphere Mass Density Perturbations Ascribed by CHAMP Observations

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Motivation

• CHAMP accelerometer has provided a decade’s worth of drag acceleration data, yet in-track wind influences on acceleration are often neglected
• A new ascending-descending accelerometer (ADA) technique has been developed and demonstrated that the in-track wind perturbations can be extracted and analyzed

This poster applies the ADA technique to CHAMP accelerometer data in the high-latitude region to reveal potential in-track wind contributions

General Accelerometer

• Highly sensitive accelerometers, such as STAR on the CHAMP mission, have been used to extract thermosphere properties such as mass density and cross-track winds by relating the acceleration due to drag to density and wind [1] as shown below

\[ a_d = -\frac{\rho}{2m} C_d |v|^2 \rho \]  

where \( a_d \) is the drag acceleration, \( C_d \) is the drag coefficient, \( v \) is the reference area, \( \rho \) is the molecular mass, \( \rho \) is the thermosphere mass density, \( v \) is the relative velocity of the atmosphere with respect to the satellite, \( v_r \) is the spacecraft velocity, \( v_{ref} \) is the co-rotating atmospheric wind, and \( \rho_{ref} \) is the thermospheric wind density.

• An ambiguity between mass density and winds makes it difficult to distinguish mass density and wind perturbations
• This is typically resolved by either neglecting winds or modeling the winds and absorbing the wind effect as a contributing error

Ascending-Descending Accelerometry (ADA)

ADA splits satellite orbits into ascending and descending passes to take advantage of the fact that while mass density is scalar, winds have a directionality with respect to the relative satellite motion, making it possible to discern whether acceleration perturbations are due to mass density or wind changes. See Buynovskiy et al. (2024) for a detailed procedure.

- Conditions
  1. Satellite must ascend and descend through the same local time with similar space environment conditions
  2. Orbit must be near polar to mitigate in-track contributions from large co-rotating atmospheric and zonal winds
  3. Target region should be a persistent, recurring phenomenon

- Interpretation
  a) Density-dominated: acceleration perturbations due to density are much greater than those due to winds
    • Wind perturbations are considered small, so ascending and descending orbits yield similar acceleration perturbations
    • The threshold to determine density dominance is shown in Eq. 2a accompanied by density perturbation contributions in Eq. 2b
  b) Wind-dominated: acceleration perturbations due to winds are much greater than those due to density
    • Density is considered constant, so the wind perturbations yield an inverse behavior between ascending and descending orbits
    • The threshold to determine wind dominance is shown in Eq. 3a accompanied by wind perturbation contributions in Eq. 3b

Results

- Figure 2: Averaged ascending relative acceleration data in the north pole organized in mlat and MLT
- Figure 3: Averaged descending relative acceleration data in the north pole organized in mlat and MLT
- Figure 4: Percent contribution of wind and density perturbations in the north pole organized in mlat and MLT
- Figure 5: Averaged derived in-track wind perturbations (positive = equatorward, negative = poleward)

Data Description

- CHAMP in-track accelerometer data from 2003-2006 is used
- The in-track drag accelerometer data is normalized to a constant attitude and put into a relative acceleration format
- The relative accelerations are split into ascending (Fig. 1a) and descending (Fig. 1b) passes, for a total of 8 ADA datasets
- CHAMP’s precession rate allows the satellite to ascend a local time and descend the same local time approximately a year later
- To remove in-track contributions from co-rotating and zonal winds at high latitudes, data with the meridional component <95% are not considered
- Data where Kp > 3 is removed
- Relative accelerations are organized into 1-hour magnetic local time (MLT) and 2° magnetic latitude (mlat) bins

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