Solar EUV effects on the vertical propagation of DE3 from the lower to the middle thermosphere

F. Gasperini[1] (*gasperini@colorado.edu*), J. M. Forbes[1], E. N. Doornbos[2], and S. L. Bruinsma[3]

(1) University of Colorado, Boulder, CO, USA, (2) Delft University of Technology, Delft, The Netherlands, (3) National Center for Space Studies (CNES), Toulouse, France

Abstract

The vertical coupling of waves from the lower to the middle thermosphere is a key process in determining the dynamics and electrodynamics of the upper atmosphere system. In this work, the effect of solar radiation on the vertical propagation of the eastward propagating diurnal tide with zonal wavenumber 3 (DE3) is investigated using Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics - Sounding of the Atmosphere using Broadband Emission Radiometry (TIMED-SABER) temperatures near 110 km and Gravity field and steady-state Ocean Circulation Explorer (GOCE) neutral densities near 260 km. The analysis is performed at low to mid-latitudes during 2010-2012, when reliable and continuous measurements are available. To better characterize vertical coupling, we decompose DE3 into its equatorially symmetric and anti-symmetric components, and convert DE3 temperatures to density perturbations using Hough Mode Extensions (HMEs). Solar effects on the vertical propagation of DE3 are investigated looking at the temporal variability of the ratio of DE3 amplitudes at 260 km to 110 km and S10.7 (EUV index[5]). Significant anticorrelation between S10.7 and DE3 ratios is found, indicating that solar EUV variability plays an important role in modulating the vertical propagation of DE3 from the lower to the middle thermosphere on a day-by-day basis.

Results – S10.7 effects on DE3 ratios

Background

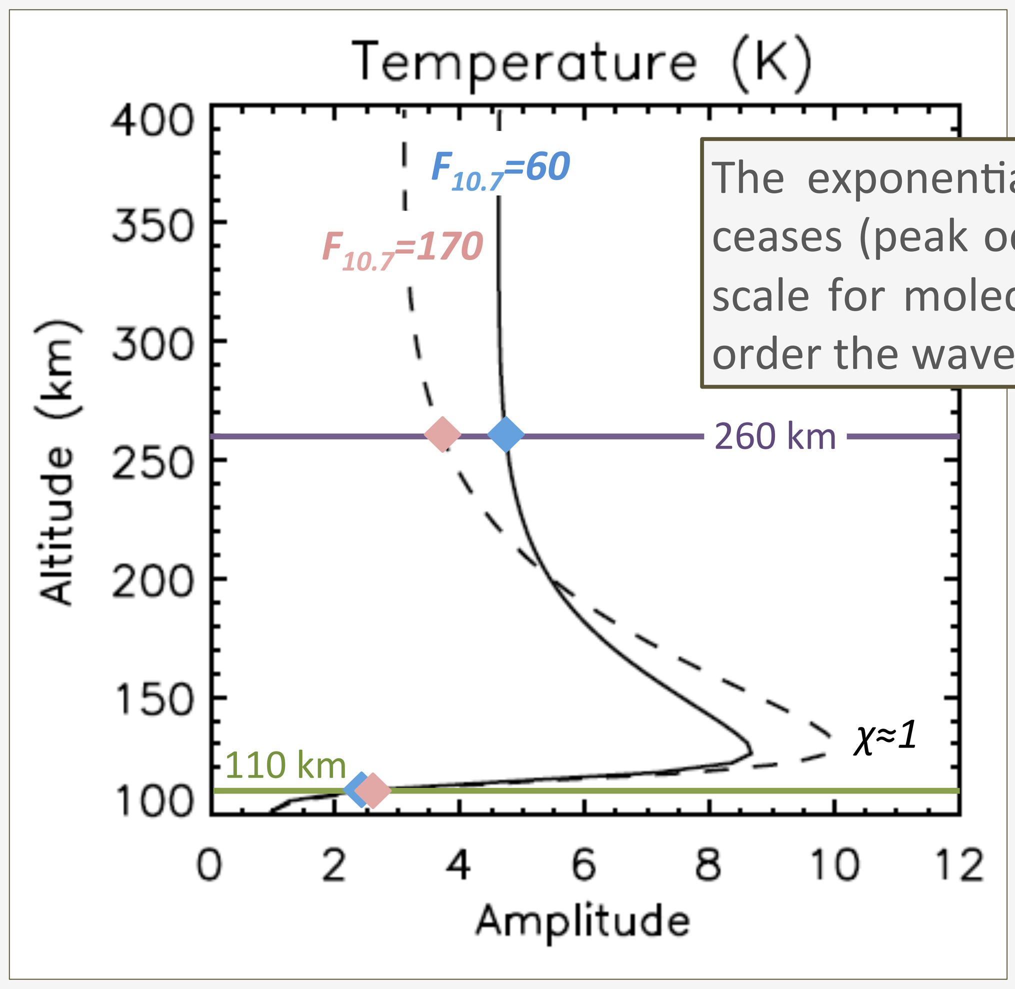

Figure 2 *Vertical profile of DE3 (2,2) amplitudes at solar high (F10.7=170, dashed) and solar low (F10.7=60, solid) from HMEs.*

The exponential growth of a wave ceases (peak occurs) when the time scale for molecular dissipation is of order the wave period T:

$$X = \frac{2\pi}{\lambda_z^2}\frac{\mu_0}{\rho}T \sim 1$$

- ✧ The greater the solar input the larger ρ and the higher the peak altitude (*Fig 2*).
- ✧ The amplitude above the peak depends on the ratio of scale height ($H=RT_0/gM$) to the vertical scale of the wave (λ_z): $\beta=(2\pi H)/\lambda_z$
- ✧ Higher F10.7 results in greater H, thus larger β, meaning that more reflection and less propagation occurs.[3][6]

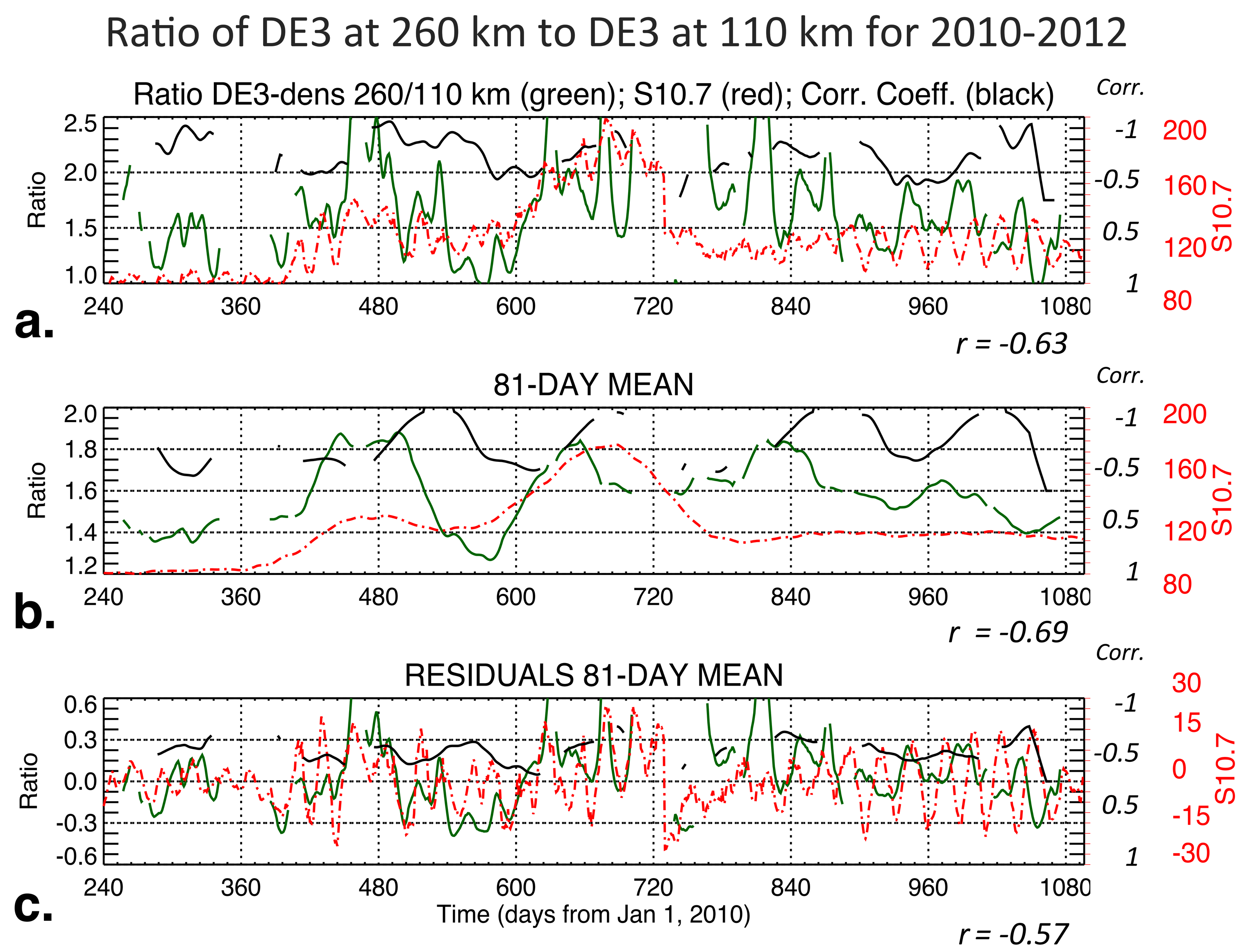

Figure 3 *(a) Ratios between DE3 density at 260 km and 110 km (green line), S10.7 (red line), moving correlation coefficient (black line); (b) 81-day means; (c) residuals from 81-day means.*

- Significant anticorrelation (r=-0.63) is found between DE3 ratios (260 km/110 km) and S10.7 for 2010-2012 (*Fig 3*).
- Increasing solar EUV causes higher reflection (greater β) and thus less propagation, explaining the inverse relationship between S10.7 and the ratios found in SABER and GOCE data.

Data and Methodology

- Daily DE3 amplitudes for 2010-2012 are derived from SABER temperatures at 110 km and GOCE densities at 260 km by least-squares fitting wave-4 to differences between values at the ascending and descending nodes[2] in 5-day moving windows.
- To properly characterize the vertical propagation, we decompose DE3 into its equatorially symmetric and anti-symmetric components, and convert DE3 temperatures to DE3 densities using Hough Mode Extensions (HMEs) [1][4], global solutions to the linearized dynamical equations that are internally self-consistent.
- Significant correlation between the temporal variability of DE3 at both heights (*Fig 1*, r>0.7) and lack of correlation with S10.7 suggests that the majority of DE3 at 260 km is due to vertical propagation from 110 km (the not exact agreement is likely due to the influence of wave-wave interactions, zonal mean winds, dissipation, and inherent transience).

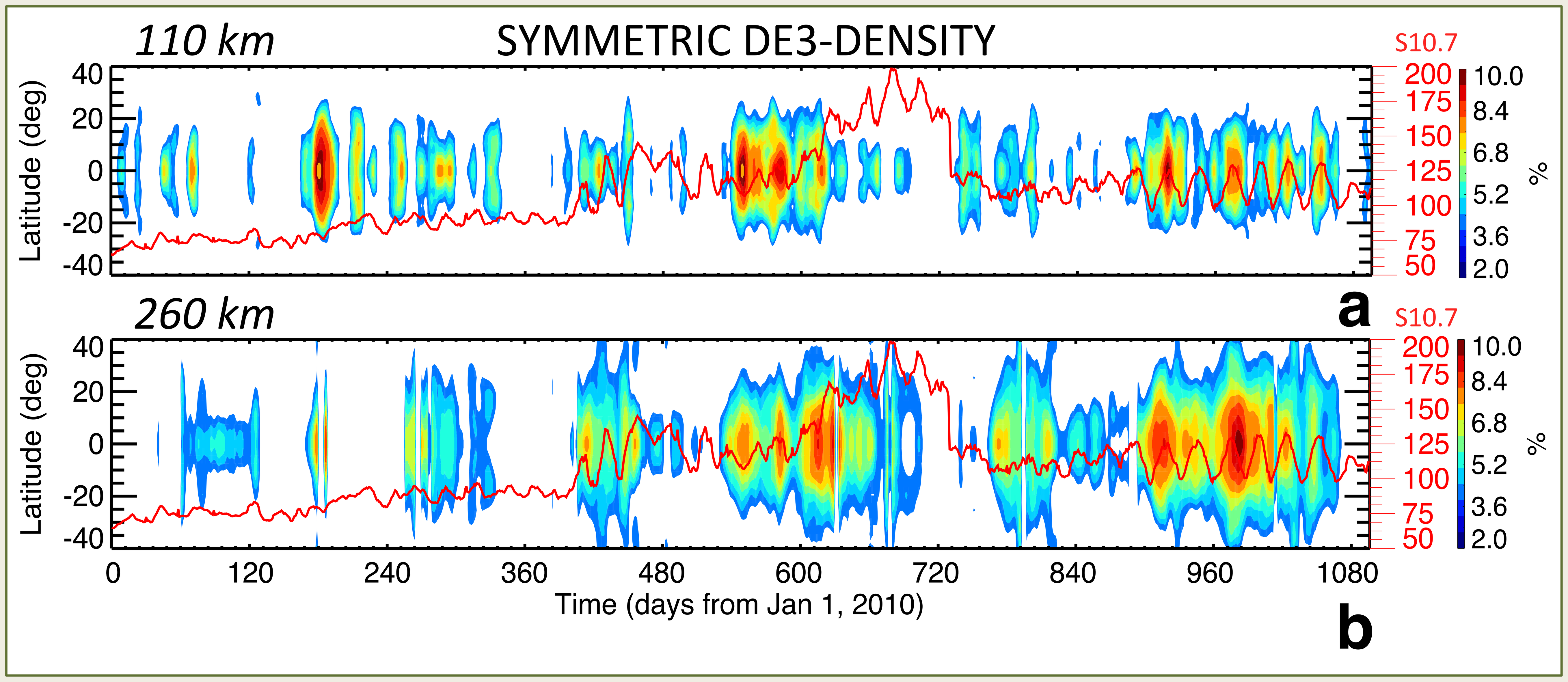

Figure 1 *Comparison of DE3 symmetric density latitude-time structures at 110 km and 260 km during 2010-2012. The superposed red line represents the solar EUV index S10.7. DE3 temperatures at 110 km are converted to DE3 densities using HMEs.*

Summary and Conclusions

- The day-to-day variability of the symmetric component of DE3 density perturbations at 110 km and 260 km is analyzed in connection with solar EUV variability.
- Significant correlation (r>0.7) is found between the temporal-latitudinal variability of DE3 symmetric at 110 km and at 260 km, suggesting that the majority of DE3 at 260 km is due to the vertical extension from 110 km.
- The ratio of DE3 at 260 km to DE3 at 110 km and S10.7 are found to be anticorrelated (r=-0.63), in line with the theory that increased solar input is responsible for higher reflection (reduced vertical propagation) due to larger scale height (and thus β).
- The effect of solar EUV variability on vertical propagation will be further analyzed, closing the gap between 260 km and 110 km, using National Center for Atmospheric Research (NCAR) thermosphere-ionosphere-mesosphere-electrodynamics general circulation model (TIME-GCM) simulations, with MERRA (Modern-Era Retrospective Analysis for Research and Application) reanalysis data at the lower boundary.

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Acknowledgements

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