LT and solar cycle variation of atomic H density [H] in the terrestrial upper atmosphere

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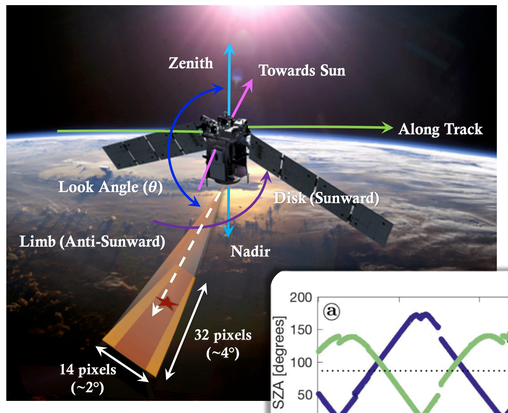
Summary

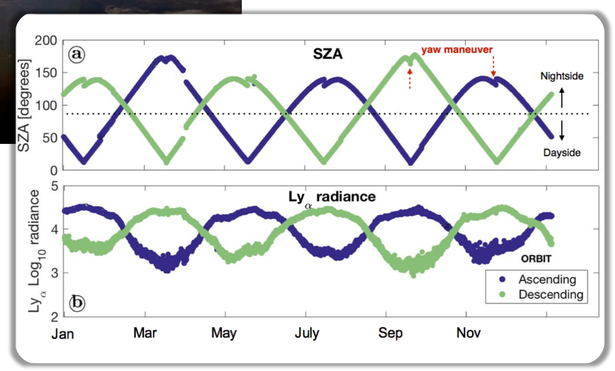
- Reliable specification of atomic H density [H] distribution in thermospheric and lower exospheric regions remains sparse, with implications for variability with solar cycle [Waldrop, 2013]
- Our study has been motivated by this lack of knowledge of the abundance and spatial distribution of [H]
- The goal of this work is to quantify local time (LT) variation and solar cycle dependence of [H], in order to advance numerical models and physical understanding
- We use GUVI observations of geocoronal Ly_α emission (121.6 nm) along the earth's limb to yield an unprecedented climatological analysis of [H] between 250 km-1Re on the dayside
- Our analysis reveals strong solar cycle dependence and evidence for a spherically asymmetric [H] distribution that highlights the need for continued model development of the geocoronal [H] distribution

Background

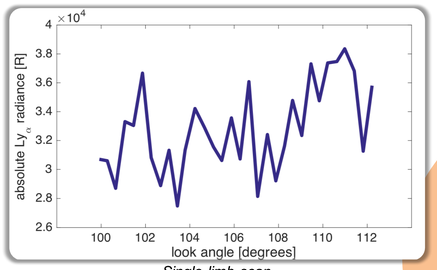


GUVI limb scanning viewing geometry

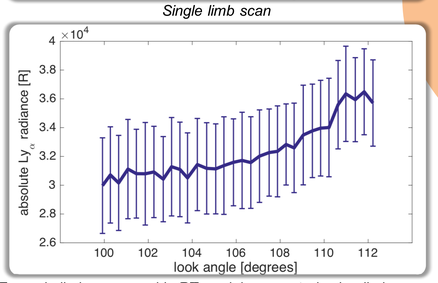
LT coverage of the central pixel of GUVI Limb Scan Image (highlighted as ★)
(a) Solar Zenith Angle(SZA)
(b) Corresponding Ly_α variation



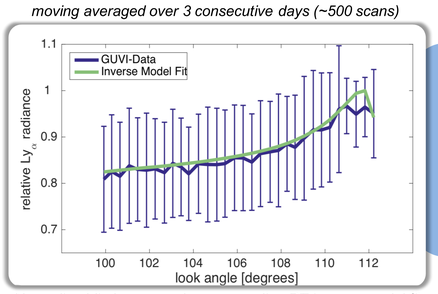
- Resonantly scattered Ly_α (121.6 nm) is the most intense UV resonance line in the outer atmosphere of planets and provides an important probe for studying the distribution and properties of [H]
- With TIMED-GUVI, the geocoronal Ly_α emission is more densely sampled in both space and time than ever before
- GUVI is a far-ultraviolet imaging spectrograph with 11.78 degrees FOV (115-128 nm) [Christensen, 1994] and has unprecedented coverage through different LT, except around noon due to yaw maneuver of TIMED
- Accurate interpretation of optically thick Ly_α observations requires computationally intensive radiative transfer modeling featuring spherical symmetric [H] distribution, asymmetric solar illumination, and a non-isothermal thermosphere. Here, we use a Radiative Transfer (RT) model initially developed by Bishop [2001] and modified by Qin and Waldrop [2016]



Single limb scan



Example limb scan used in RT model, generated using limb scans moving averaged over 3 consecutive days (~500 scans)



Normalized limb scan and corresponding RT inverse model fit

Methodology

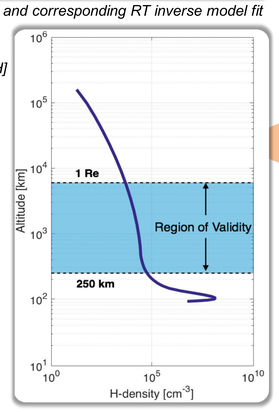
Data Averaging Scheme

- Average 6 central along-track pixels to generate a single limb scan
- θ_{GSE} < 5° (limit to geocentric solar ecliptic latitudes 5°N-S)
- A_p < 20 (exclude storm events)
- Average over 3 consecutive days (~500 scans) to generate a single invertible limb scan (tagged to central pixel of limb scan image)

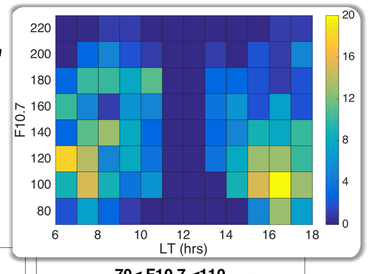
Radiative Transfer (RT) Model
Use normalized radiance profiles to constrain the RT model in terms of best-fit parameters describing the [H] distribution

Estimated [H]
(250 km - 1Re)

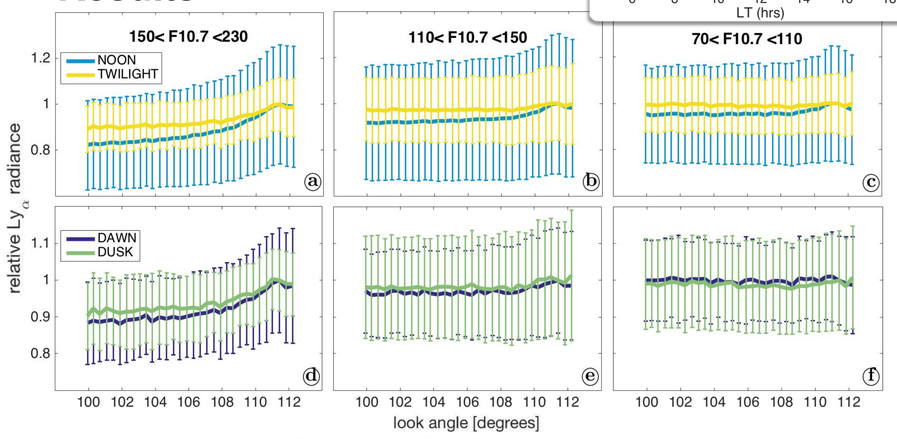
Derived [H]



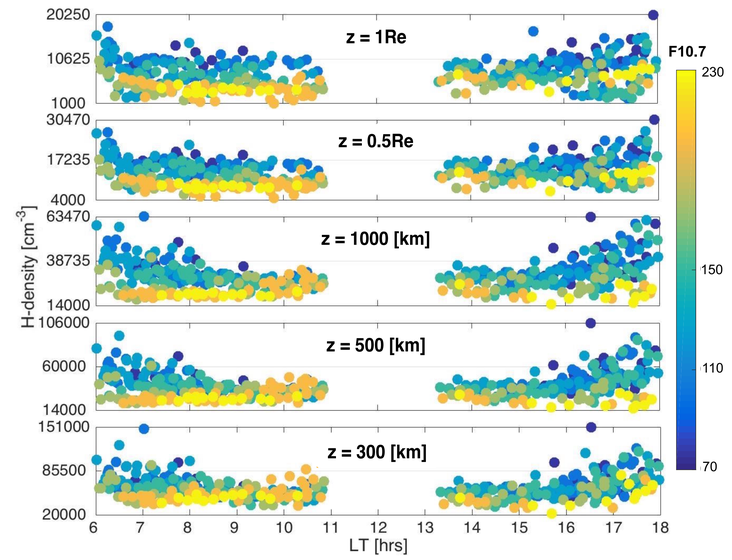
Histogram of data



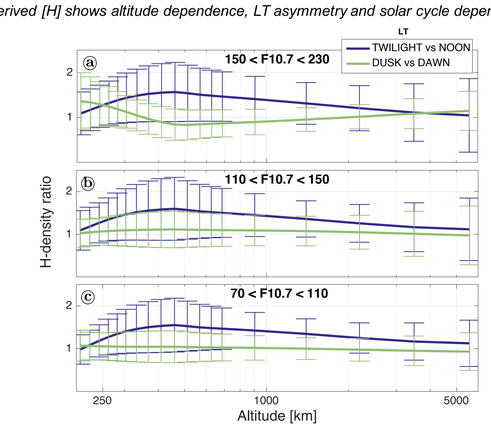
Results



Measured radiances exhibit significant differences particularly at solar maximum
(a)-(c) Twilight-Noon – LT dependence is significant irrespective of solar activity, with lower density (expected) at noon relative to twilight at lower altitudes
(d)-(f) Dusk-Dawn – LT dependence is insignificant except at solar maximum



Derived [H] shows altitude dependence, LT asymmetry and solar cycle dependence



LT asymmetry between Twilight-Noon is stronger relative to Dusk-Dawn and is dominant at lower altitudes

Conclusions

- LT [H] structure exhibits a minimum near noon relative to twilight
- [H] is inversely proportional to solar activity
- LT asymmetry of [H] is most pronounced in thermosphere and lower exosphere
- Evidence for spherically asymmetric [H] distribution that requires revisiting of the current empirical or assimilative [H] models and datasets
- Future work includes extending the climatological analysis to MLT altitudes and higher latitudes

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