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LT and solar cycle variation of H escape flux

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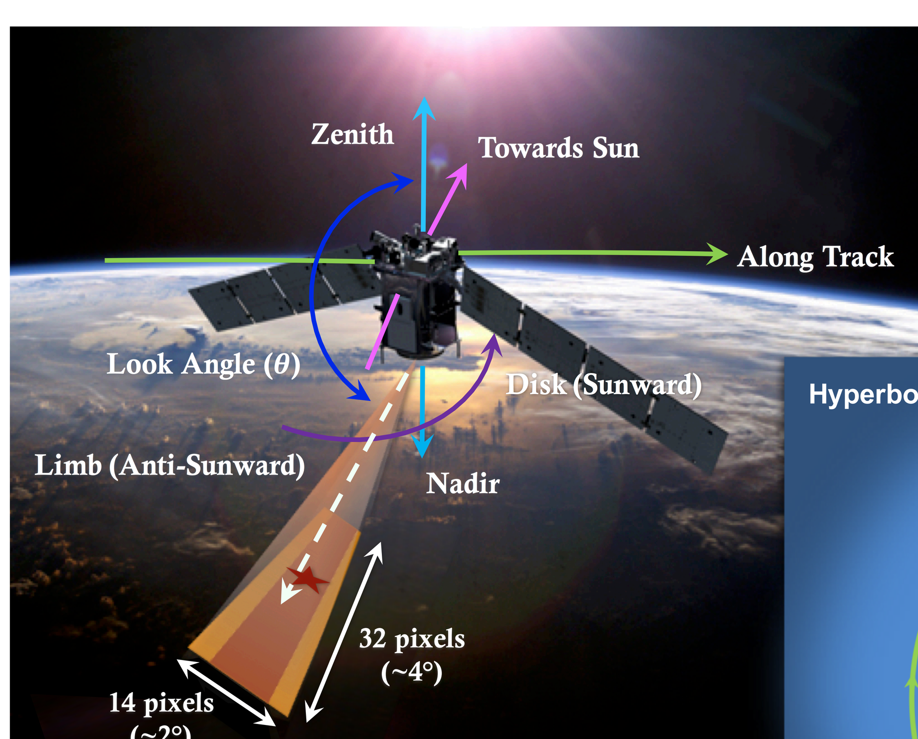
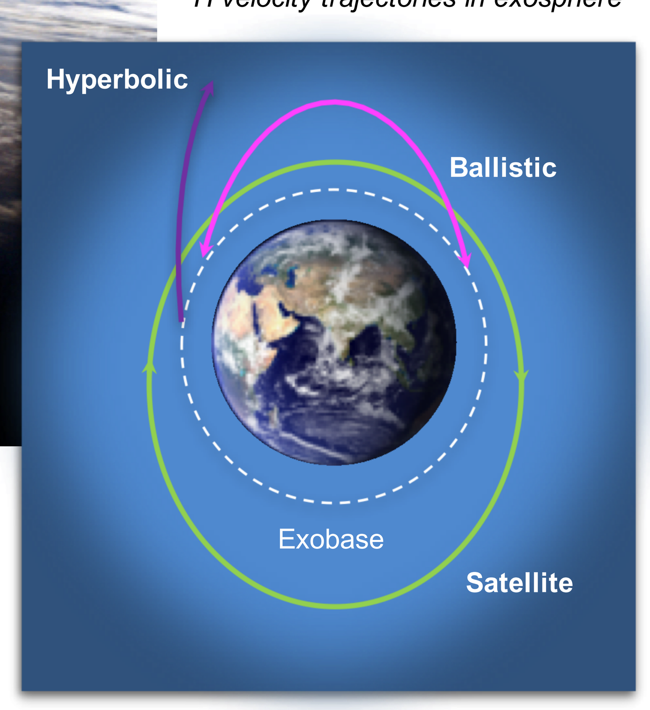
Background & Motivation

- The H velocity distribution in the Earth's exosphere is not Maxwellian-distributed and partitioned into – ballistic, satellite (bound) and hyperbolic (escaping) trajectories
- Atomic H can escape gaseous atmospheres through thermal evaporation (Jeans escape) or through collisional (charge exchange) energization [Hunten, 1973]
- Quantification of the escape flux and its thermal and non-thermal drivers is crucial to assess and predict atmospheric evolution on Earth and other planets
- NASA/TIMED GUVI observations of resonantly scattered Lyα (121.6 nm) emission along the earth's limb are used here to constrain its density distribution through the thermosphere and lower exosphere in terms of parameters which include satellite density and vertical flux.
- Accurate interpretation of optically thick Lyα observations by GUVI requires sophisticated radiative transfer modeling and parameter inversion [Qin and Waldrop, 2016]



GUVI limb scanning viewing geometry

H velocity trajectories in exosphere



Derivation of Jeans Escape

$$F_J = \frac{n_c}{2}\sqrt{\frac{2kT_c}{m\pi}}(1+\lambda_c)e^{-\lambda_c}$$

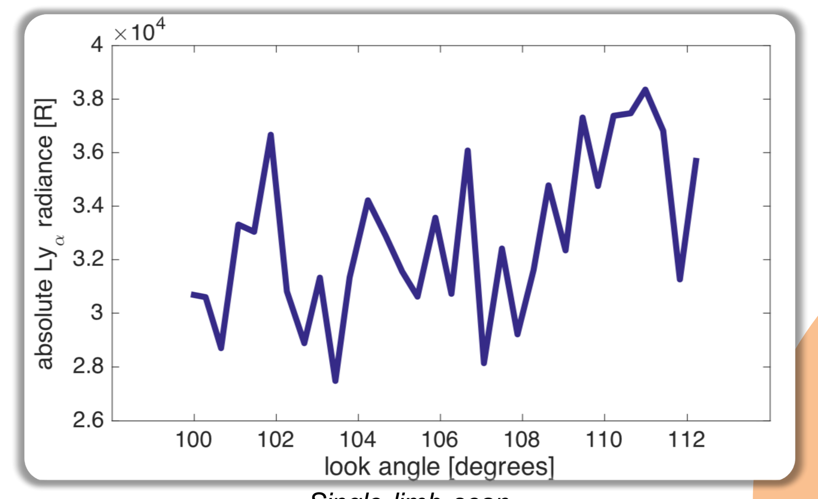
F_J : Jeans or Thermal Escape

n_c : Escaping [H] density at exobase

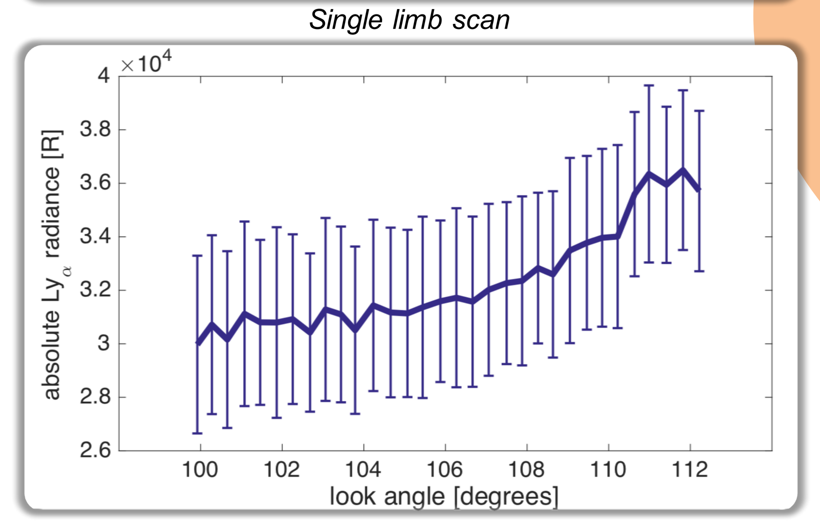
T_c : Exobase Temperature

$\lambda_c = E_{esc}/kT_c$: Exobase Parameter

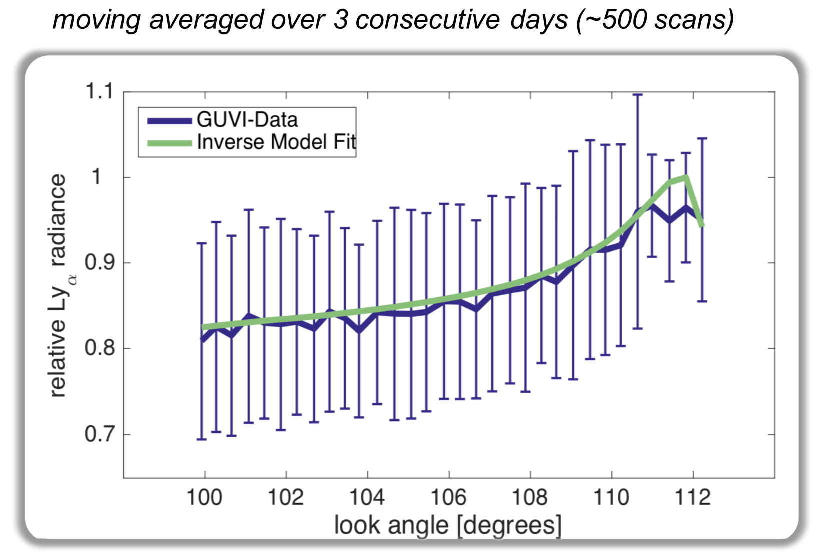
$E_{esc} = \frac{1}{2}mv_{esc}^2 = 0.61[eV]$: Total Energy



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)

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Radiative Transfer (RT) Model

Use normalized radiance profiles to constrain the RT model in terms of best-fit parameters describing the [H] distribution [Waldrop, 2013]

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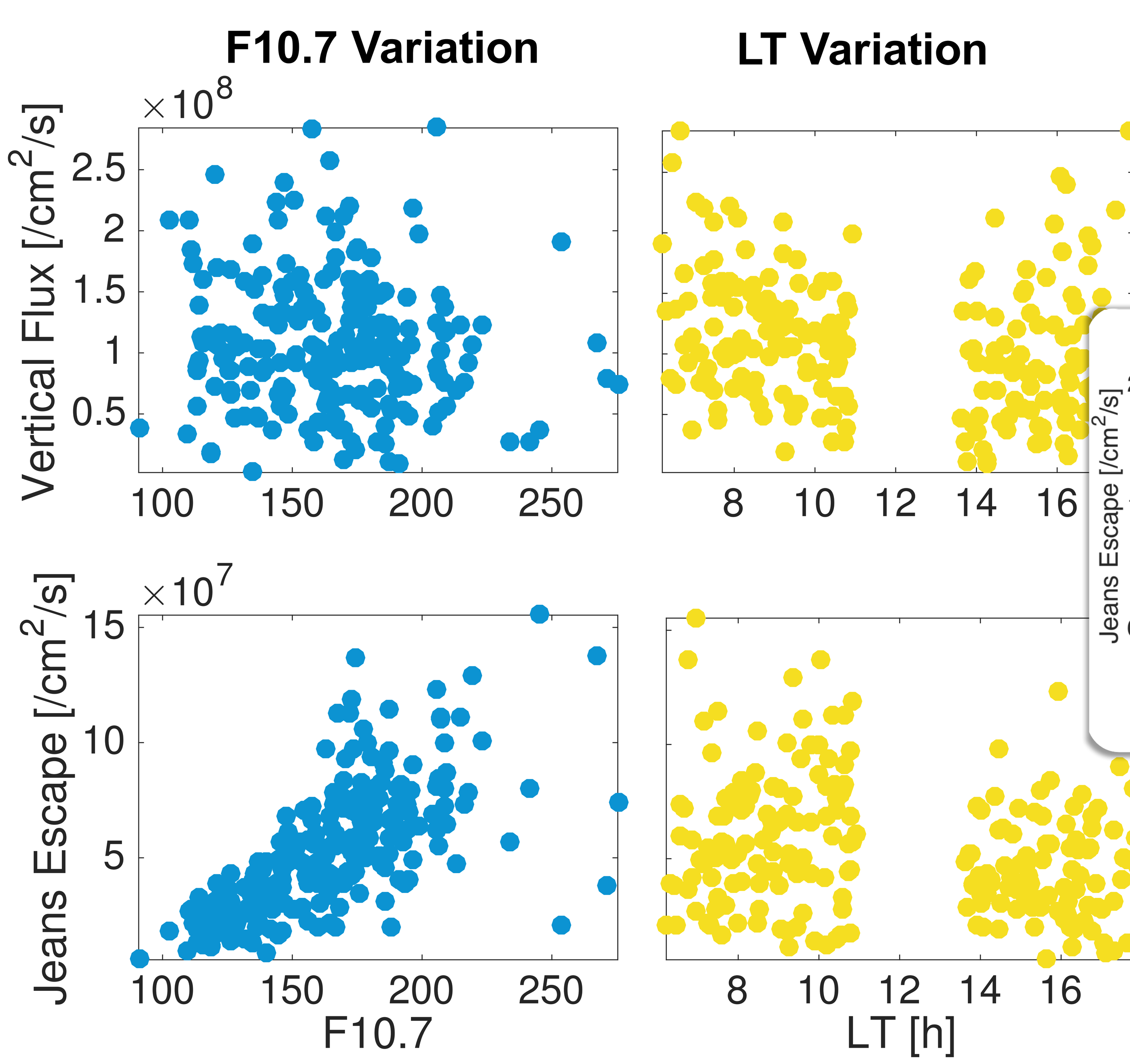
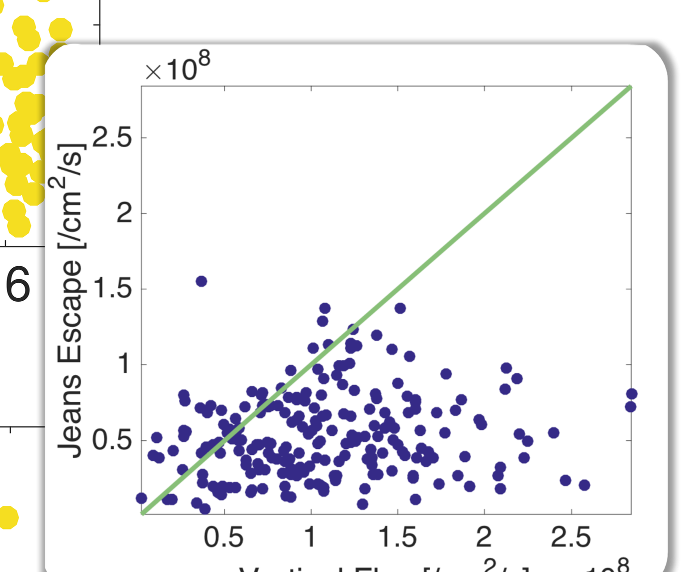
Satellite Temperature
Satellite [H]
Vertical H Flux
Exobase [H]

Climatology Results

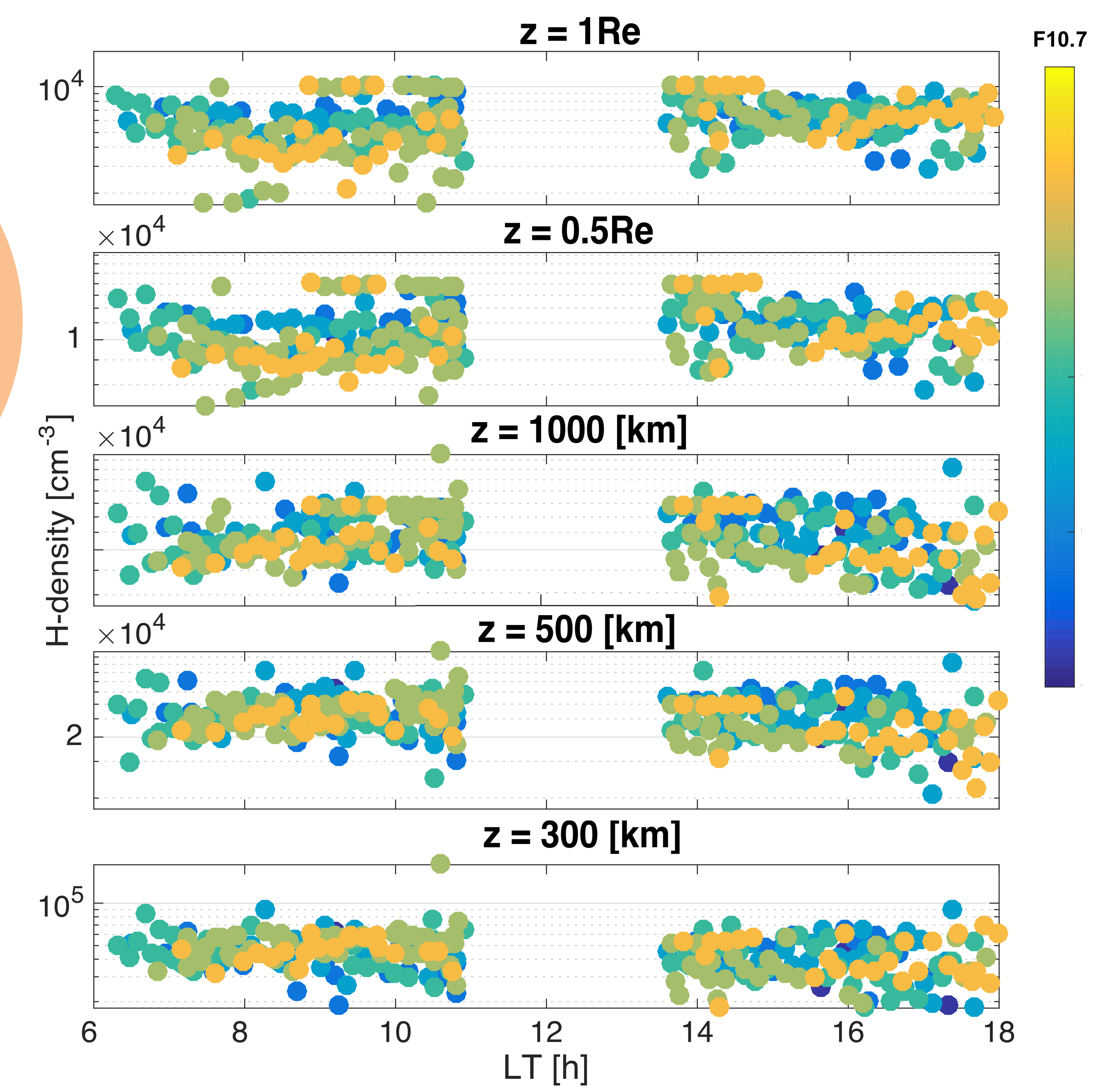


LT and F10.7 Variation of Jeans Escape and Vertical Flux



Jeans Escape vs Vertical Flux

Climatology Results



LT and F10.7 Variation of Derived [H] for various altitudes

Findings

- The estimated vertical flux exhibits an insignificant dependence on solar activity and LT
- The calculated Jeans escape flux significantly increases with increasing solar activity but does not exceed the estimated vertical flux on average
- Non-thermal escape likely accounts for the difference between the vertical flux and thermal evaporation (Jeans escape) at solar minimum

Acknowledgements

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References

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Hunten, D. M. (1973). The escape of light gases from planetary atmospheres. Journal of the Atmospheric Sciences, 30(8), 1481-1494.

Qin, J., & Waldrop, L. (2016). Non-thermal hydrogen atoms in the terrestrial upper thermosphere. *Nature Communications*, *7*.