Toward an Interhemispheric Case Study of Upper Atmospheric Hydrogen Variability for Site Specific Locations: KPNO, PBO, & CTIO

L. T. Ashworth[1], E. J. Mierkiewicz[1], S. M. Nossal[2], L. Qian[4], J. M. McInerney[4], L. M. Haffner[1], & R. C. Woodward[3]

[1]Embry-Riddle Aeronautical University, Daytona Beach, FL; [2]University of Wisconsin-Madison, Madison, WI; [3]University of Wisconsin-Oshkosh, Oshkosh, WI; [4]National Center for Atmospheric Research, Boulder, CO

Abstract

Fabry-Perot spectrometers (FPS) have been surveying the sky in the northern hemisphere since the late 1970s. With the move of WHAM to CTIO in 2009, southern hemisphere observations also became possible. These instruments are capable of collecting high precision, calibrated data sets of the geocoronal hydrogen Balmer series emission, data useful to compare to models using radiative transport codes. Here, INSpIRe and WHAM, the two FPS used to obtain ground-based observations of geocoronal Hα, are described. Bishop's LYAO_RT global resonance radiative transport code is then presented in order to show how modeled Hα intensities are found. WACCM-X hydrogen density profiles are displayed for KPNO and PBO AM/PM equinox and solstice conditions. These profiles will then be extended to higher altitudes via the Chamberlain model and run through the LYAO_RT radiative transport to generate model intensities. Equinox and solstice WACCM-X hydrogen density profiles for CTIO as well as NRLMSISE-00 profiles for similar observing conditions will be added to this preliminary data.

Scientific Motivation

- ⊕ Understanding the relation between geocoronal Hα and excitation mechanisms, effective temperature, and exospheric physics.
- ⊕ Long-term geocoronal Hα observations for the investigation of natural variability, such as seasonal and solar cyclic trends as well as differing latitudes, can be used for model validation of NRLMSISE-00 and WACCM-X.
- ⊕ Observing locations in both the northern and southern hemisphere will provide more data coverage for further model-data comparisons.

Instruments

Fabry-Perot Spectrometers

Fabry-Perot spectrometers (FPS) are well suited for detailed studies of extremely faint/diffuse emissions, including geocoronal Balmer series emission. This is because they can achieve high spectral resolution and throughput. More specifically, high spectral resolution allows for detailed line profiles and is also necessary for the isolation of geocoronal lines from the Galactic (Balmer) background (Haffner et al., 2003). On the other hand, high throughput provides the temporal resolution needed to investigate as well as limit the variations in emission due to changes of various parameters, such as viewing geometry, local time, and atmospheric conditions. Ground-based observations of geocoronal Hα are made throughout the night using the base of the Earth's shadow as a probe for the exosphere's altitude structure. One observation yields one emission intensity measurement per shadow altitude and, therefore, over a given night, many shadow altitudes are probed for Hα emissions. Embry-Riddle Aeronautical University operates two FPS:

INSpIRe

The Investigating Near Space Interaction Regions (INSpIRe) FPS at Pine Bluff Observatory (PBO), 15 miles west of Madison, Wisconsin. INSpIRe began operating from PBO in June 2022.

Figure 1: INSpIRe FPS at Pine Bluff Observatory, Wisconsin.

WHAM

The Wisconsin H-Alpha Mapper (WHAM) FPS at Cerro Tololo Inter-American Observatory (CTIO), Chile. Before 2009, WHAM operated from Kitt Peak National Observatory (KPNO), Arizona.

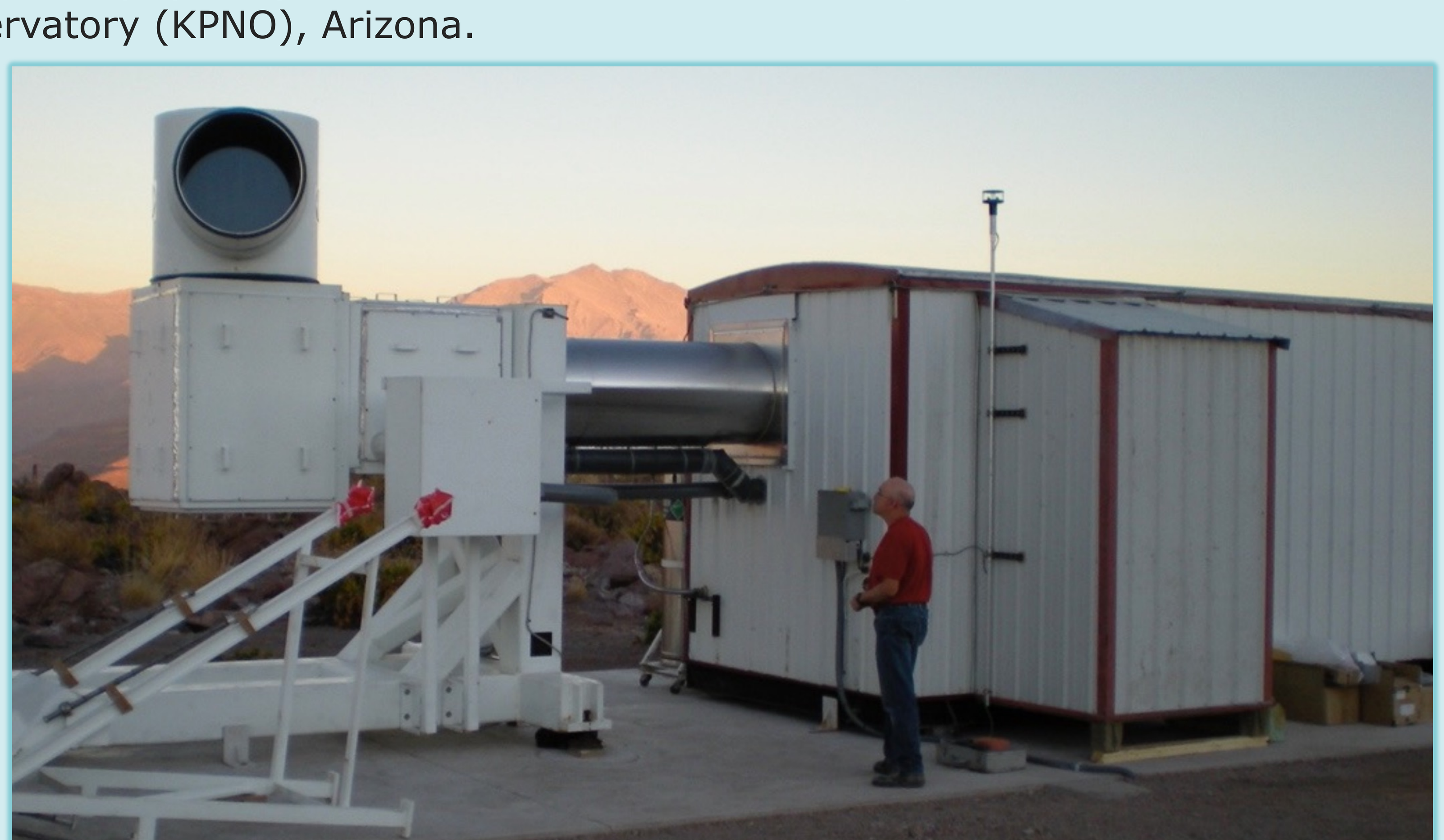

Figure 2: WHAM FPS at Cerro Tololo Inter-American Observatory, Chile.

Forward Modeling

Modeling Hα Intensity Using LYAO_RT

Radiative transport modeling calculates radiative transfer of electromagnetic radiation through the Earth's, or any other planetary, atmosphere. This is executed via the LYAO_RT code of Bishop [1999] using NRLMSISE-00 [O], [O_2], [N_2], and temperature profiles as inputs for the model atmosphere. The neutral atomic hydrogen density, [H], profile is also used as an input and is obtained from NRLMSISE-00 and/or WACCM-X. Next, the LYAO_RT code extends the model atmosphere to higher altitudes, applies radiative transport to solar Lyman-β, and uses given observing conditions to calculate line-of-sight calculations. As a result, these intensity models can be compared to ground-based geocoronal Hα observations.

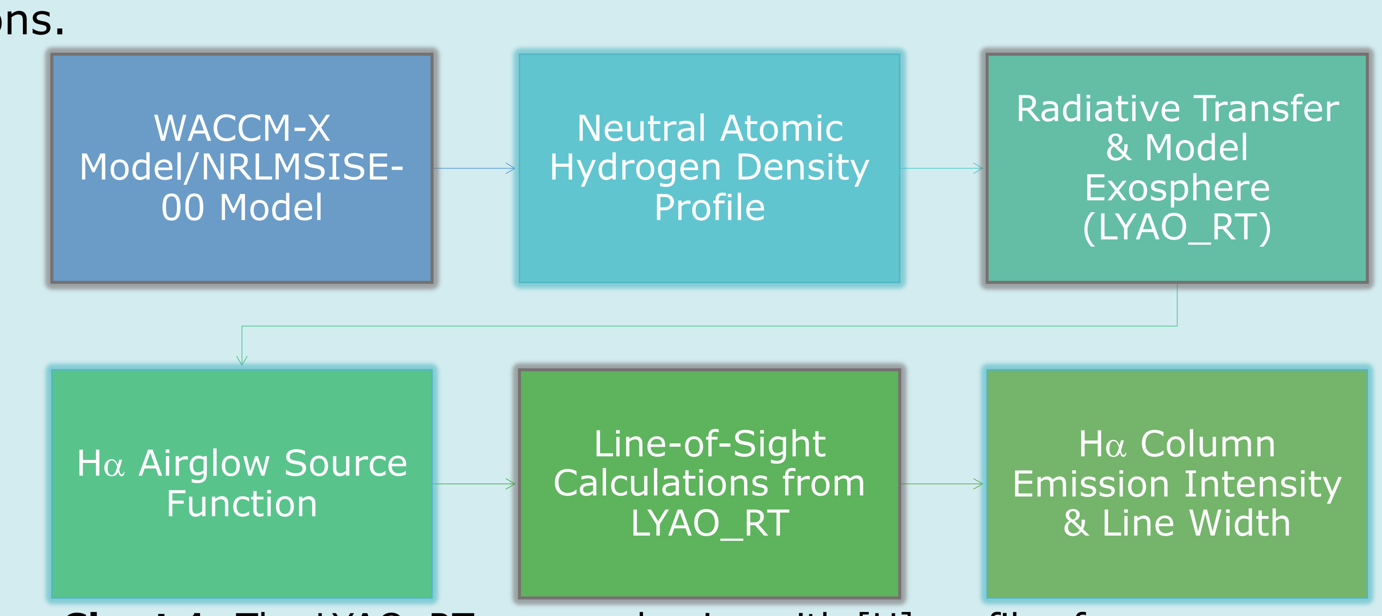

Chart 1: The LYAO_RT process begins with [H] profiles from NRLMSISE-00/WACCM-X resulting in an intensity output for model-data and/or model-model comparison. The tiles outlined in gray represent models.

WACCM-X [H] Profiles

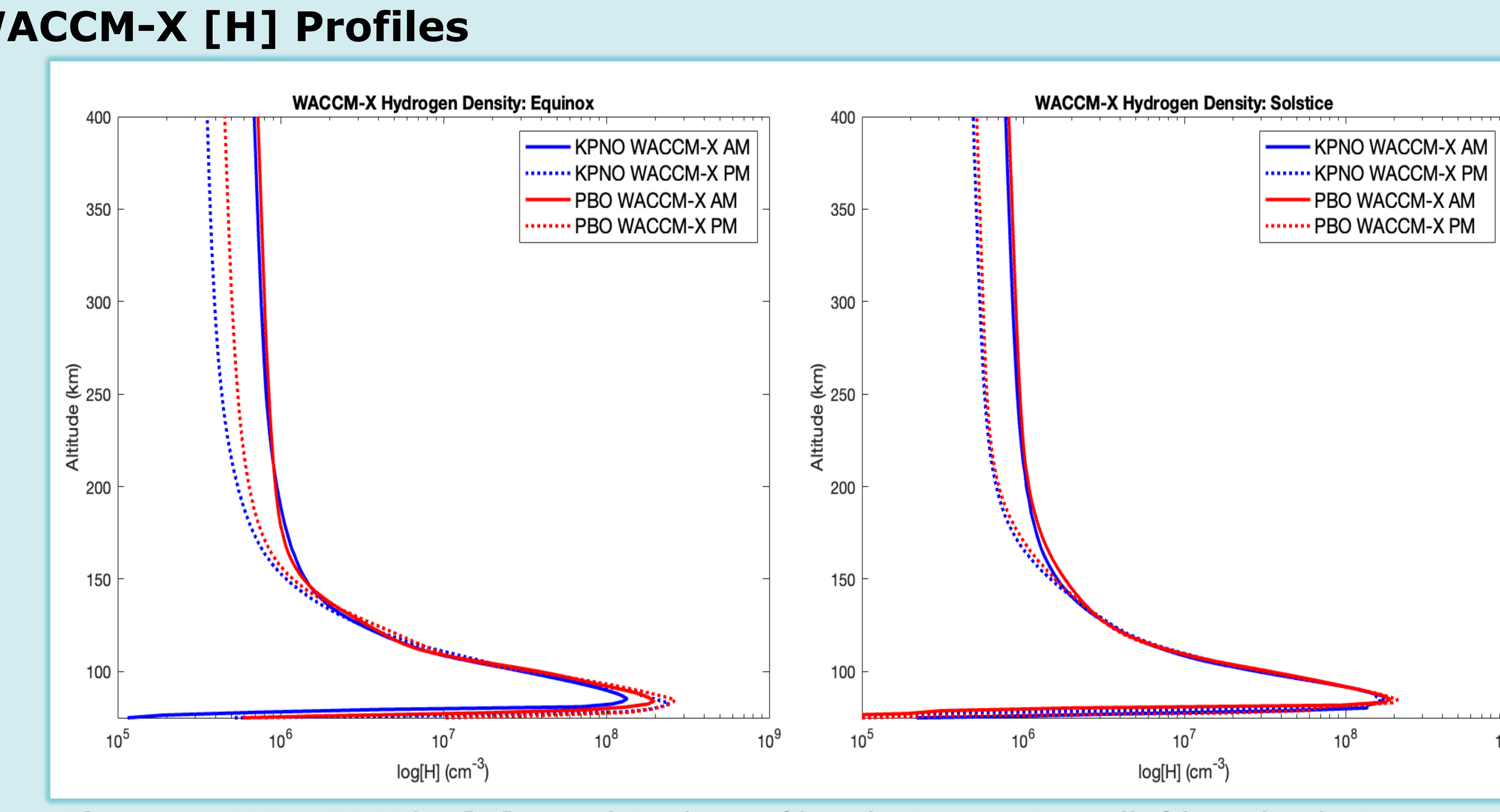

Figure 3: WACCM-X log[H] vs. altitude profiles during equinox (left) and solstice (right) conditions at 5 AM and 10 PM for KPNO and PBO.

WACCM-X & NRLMSISE-00 Model Intensities

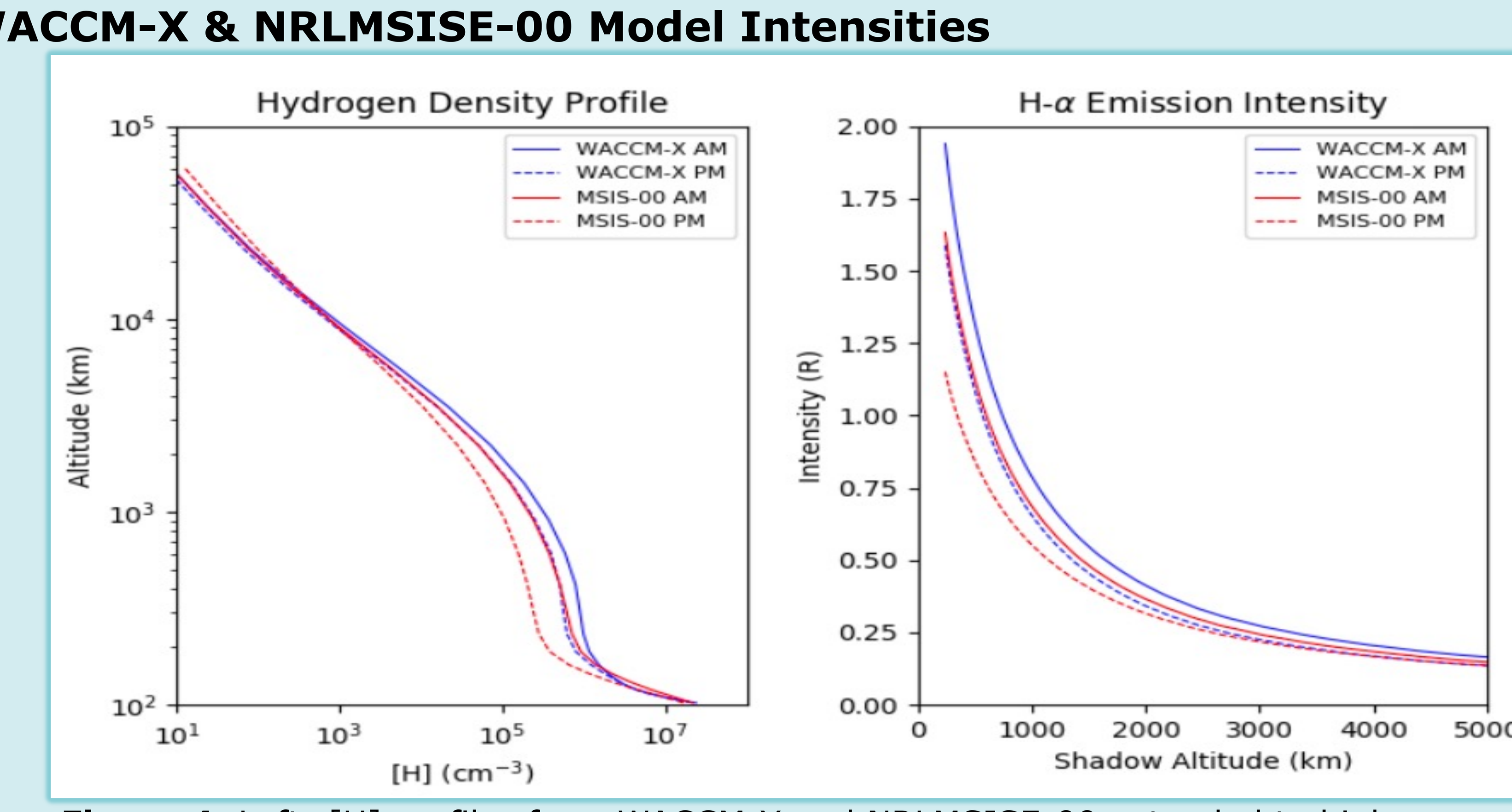

Figure 4: Left: [H] profiles from WACCM-X and NRLMSISE-00 extended to higher altitudes using the Chamberlain model. Right: Model intensities for WACCM-X and NRLMSISE-00. Intensity axis not to scale (Gallant, 2018).

Future Work

- ⊕ Extend equinox and solstice [H] profiles (Figure 3) to higher altitudes using the Chamberlain model.
- ⊕ Apply LYAO_RT radiative transport to extended profiles to generate model intensities.
- ⊕ Obtain model intensities from ground-based site-specific locations: KPNO, PBO, & CTIO.

References

Gallant, M. A. (2018). Comparisons of Diurnal Asymmetry in Observed Geocoronal Balmer Series Intensity and Modeled Line-Of-Sight Intensities using NRLMSISE-00 and WACCM-X Model Atmospheres [Poster presentation]. CEDAR.

Gallant, M. A. (2018). A Ground Based Observatory for Geocoronal Hydrogen Emissions. NASA Florida Space Grant Consortium.

Gallant, M. A., Mierkiewicz, E. J., Nossal, S. M., Qian, L., Burns, A. G., Zacharias, A. R., & Roesler, F. L. (2019). Signatures of Thermospheric-Exospheric Coupling of Hydrogen in Observed Seasonal Trends of H α Intensity. Journal of Geophysical Research. Space Physics, 124(6), 4525–4538. doi:10.1029/2018JA026426.

Haffner, L. M., Reynolds, R. J., Tufte, S. L., Madsen, G. J., Jaehnig, K. P., & Percival, J. W. (2003). The Wisconsin Hα Mapper Northern Sky Survey. The Astrophysical Journal. Supplement Series, 149(2), 405–422. doi:10.1086/378850.

Acknowledgements

This work is partially supported by NSF award 2050077 and is a collaborative effort between ERAU, UW-Madison, UW-Oshkosh, and NCAR.