Comparisons of Diurnal Asymmetry in Observed Geocoronal Balmer Series Intensity and Modeled Line-Of-Sight Intensities using NRLMSISE-00 and WACCM-X Model Atmospheres

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Abstract

The LYAO_RT radiative transport code of Bishop [1999] is run using both NRLMSISE-00 and WACCM-X model atmospheres to model line-of-sight emission intensities for geocoronal hydrogen Balmer-alpha excitation, the resulting intensities of which will be compared to ground-based observations of the same emission line. We have obtained geocoronal data from three ground-based geographic locations using high spectral resolution Fabry-Perot Spectrometers, including Wisconsin H-Alpha Mapper (WHAM) observations from Cerro Tololo, Chile and Kitt Peak, Arizona and observations from a similar instrument located at the Pine Bluff Observatory (PBO), Wisconsin [Haffner et al. 2016, Nossal et al. 2004, Mierkiewicz et al. 2012]. This poster will compare model-generated intensities to observational intensities from the Pine Bluff location for both NRLMSISE-00 and WACCM-X model atmospheres. Furthermore, observations of geocoronal hydrogen have been shown to have dusk to dawn asymmetries in Balmer-alpha emission intensity [Mierkiewicz et al. 2012, Tinsley 1970]. The recent work of Gardner et al. [2017] indicates that geocoronal hydrogen Balmer-beta emission intensity similarly shows a dusk to dawn asymmetry. For both emission lines, higher intensities are apparent on the dawn side for shadow altitudes below 2000 km. Intensities modeled using both NRLMSISE-00 and WACCM-X show the same trend towards higher intensities on the dawn side, and the magnitudes of the dusk to dawn asymmetry between the two model atmospheres is to be presented in this poster. This work provides context for the science goals of project INSpIRe (Investigating Near Space Interaction Regions), based at Embry-Riddle Aeronautical University. Designed to be capable of nearly-simultaneous Balmer-alpha and Balmer-beta line profile measurements, INSpIRe is poised to deploy to Arizona in the fall of 2018 to contribute to the growing dataset of high spectral resolution geocoronal hydrogen data. The INSpIRe project is funded through NSFCAREER award AGS135231 and the NASA Planetary Solar System Observations Program. These model-data comparisons were also supported by the NASA Florida Space Grant Consortium.

Scientific Motivation & Objectives

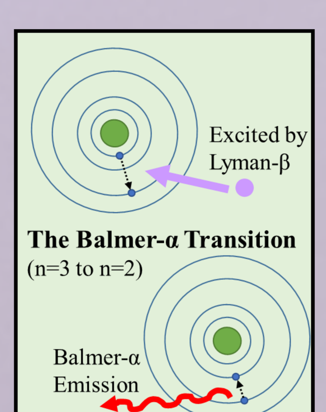
Motivation

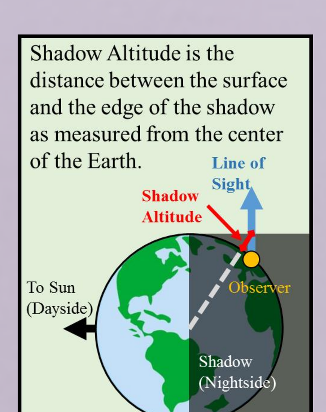
- A lack of direct measurements of neutral atomic hydrogen density leaves gaps in our understanding of the role of hydrogen in the dynamics and chemistry of the exosphere.
- Baseline geocoronal hydrogen observations have been accumulated over large seasonal, solar cyclic, and latitudinal ranges and can be used for preliminary model validation over these time and spatial scales.
- Preliminary data-model comparisons may be useful in planning efficient observing runs for the INSpIRe geocoronal hydrogen observatory.

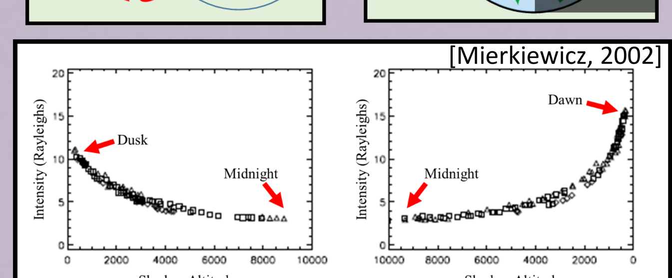
Objectives

1) **Compare predicted and observed diurnal intensity variations over long times scales and at locations of previous observations:** Pine Bluff Observatory, Wisconsin (PBO), Kitt Peak National Observatory, Arizona (KPNO), and Cerro Tololo Inter-American Observatory, Chile (CTIO).
2) **Show that modeled diurnal intensity variation is measurable** using ground-based observations.

Observing and Modeling H-α Intensity





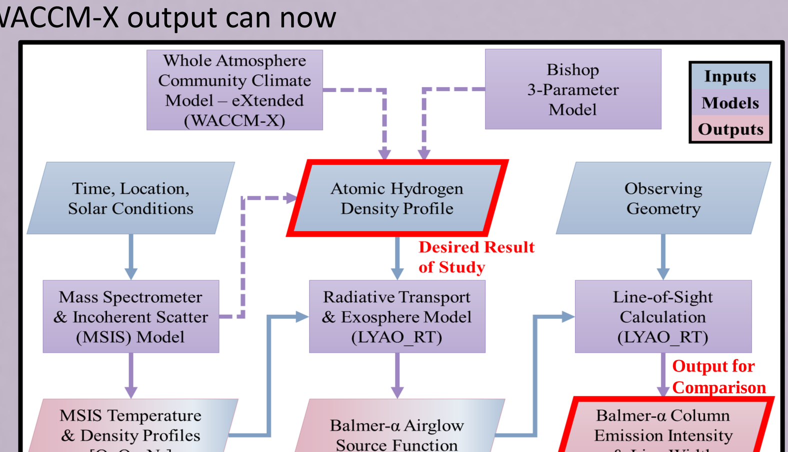


Ground-Based Observations

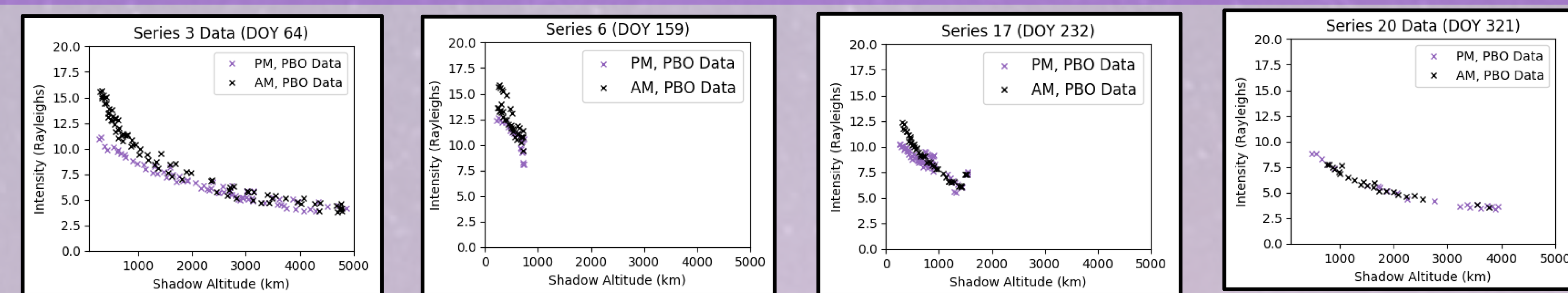
Ground-based observations of the Hydrogen geocorona require careful observation planning. Neutral atomic hydrogen has a 12% chance of fluorescing in the Balmer-α wavelength after interacting with a solar Lyman-β photon in the sunlit atmosphere. One observation yields one emission intensity measurement per shadow altitude. Over a given night, many shadow altitudes may be probed for Balmer- α emissions. Due to viewing geometry, higher emission is expected at dusk and dawn compared to midnight; however, observations have consistently shown that dawn measurements are higher than dusk measurements.

Generating Modeled Intensity using LYAO_RT

Radiative transport modeling is accomplished via the LYAO_RT tool [Bishop, 1999] using MSIS-00 [O], [O_2], [N_2], and temperature profiles as inputs for the model atmosphere. The neutral atomic hydrogen model is handled separately and can come from MSIS-00 or elsewhere: thanks to recent efforts (see Poster MDIT-03), WACCM-X output can now be used as the model for atomic hydrogen. The LYAO_RT tool extends the model atmosphere to higher altitudes, applies radiative transport for solar Lyman-β, and uses the given observing conditions to calculate a line-of-sight intensity model. These intensity models can be directly compared to ground-based geocoronal hydrogen observations.



Diurnal Variation in One Year of PBO Observations



Spring Summer Autumn Winter

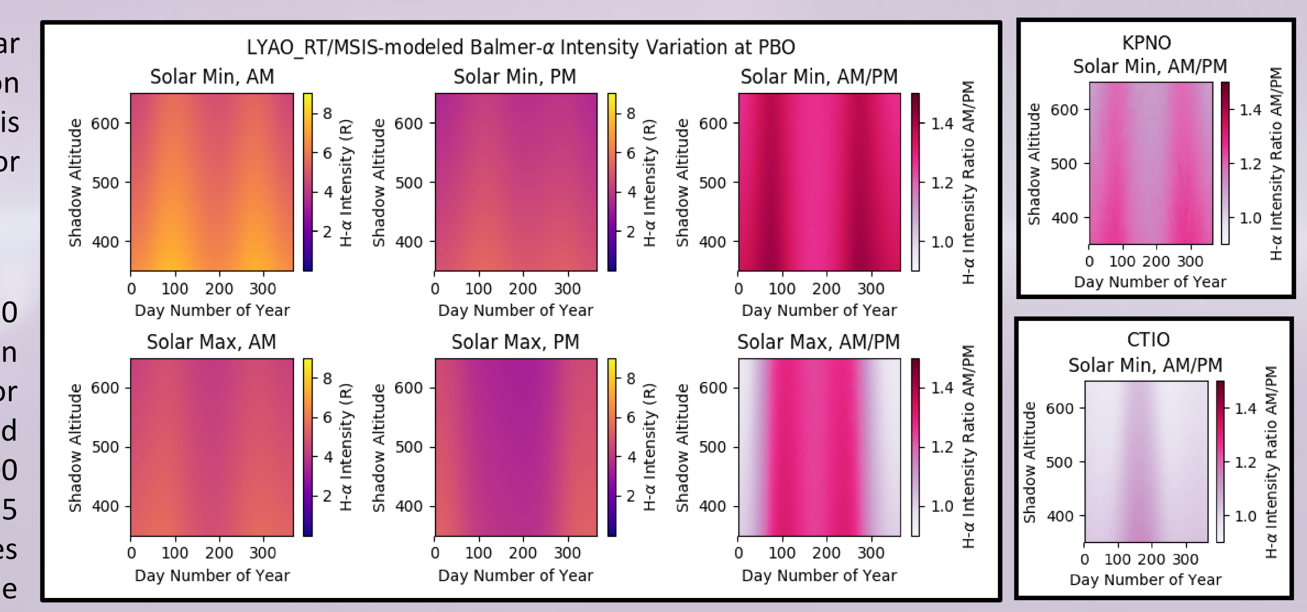
High spectral resolution Balmer-α data taken during solar max at the Pine Bluff Observatory in Wisconsin [Mierkiewicz, 2012] shows diurnal variation in column emission intensity. Variation was as high as 5 R and as low as <1 R at low shadow altitudes.

Forward Modeling using NRLMSISE-00 and WACCM-X

LYAO_RT/MSIS-00

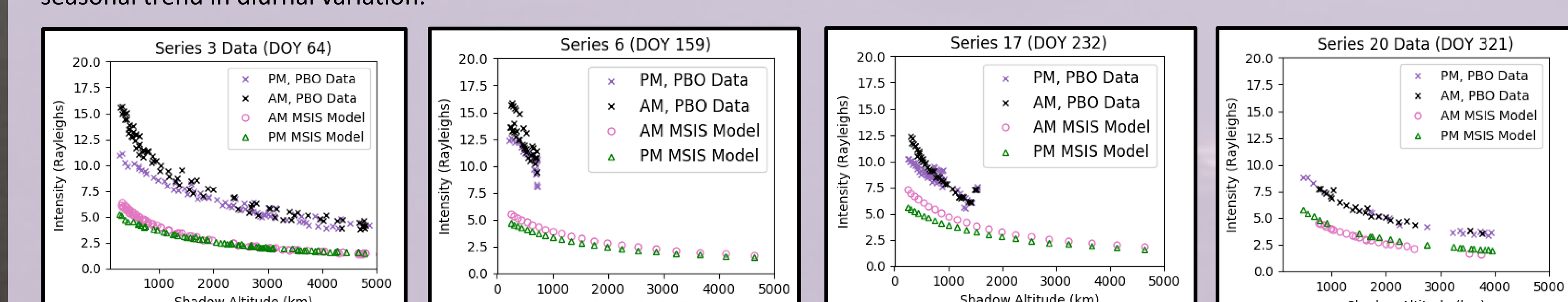
Predictions

LYAO_RT/MSIS-00 predicts a seasonal, solar cyclic, and latitudinal dependence on diurnal H-α intensity variation. Variation is especially large during solar minimum for high latitude.



Data-Model Comparison

PBO data from Series 3, 6, 17, and 20 exemplify the range of diurnal variation observed. LYAO_RT/MSIS-00 runs for similar observing conditions are plotted alongside the observed data. MSIS-00 predicts intensities between 3 and 1.5 times lower than observed, but does appear to have successfully predicted the seasonal trend in diurnal variation.

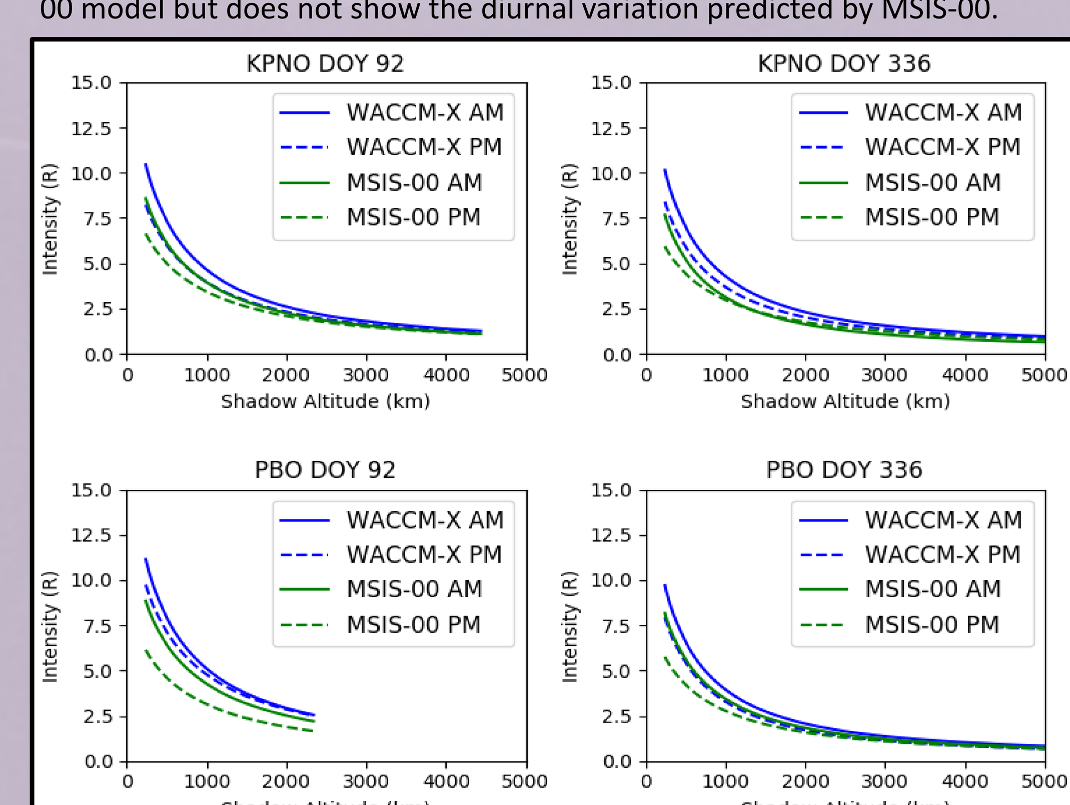


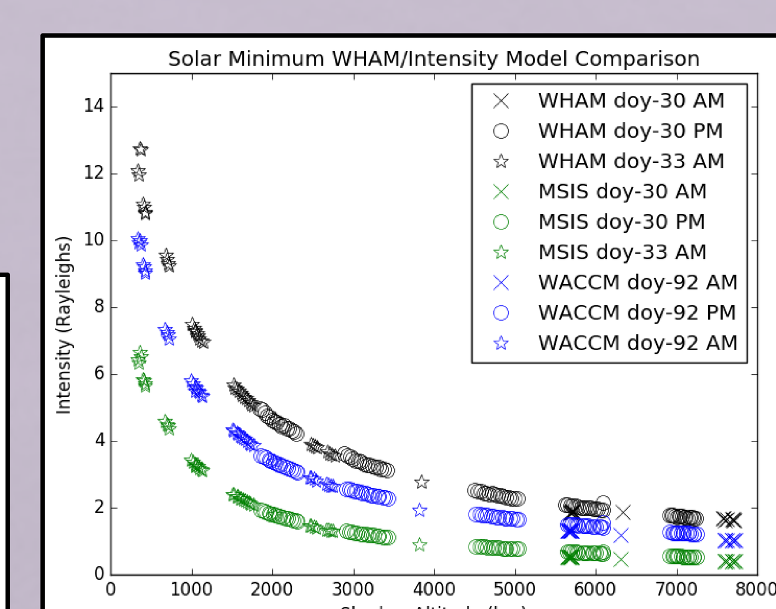
Spring Summer Autumn Winter

LYAO_RT/WACCM-X

Model-Model Comparison

WACCM-X model runs for solar minimum conditions were obtained from NCAR collaborator Liying Qian. LYAO_RT radiative transport is applied to the WACCM-X hydrogen profiles for KPNO and PBO locations on DOY 92 and 336. H-α intensity models were also generated using MSIS-00 and identical observing conditions. The WACCM-X intensity model is higher than the MSIS-00 model but does not show the diurnal variation predicted by MSIS-00.





Data-Model Comparison

Solar minimum observations from the Wisconsin H-alpha Mapper (WHAM) taken at KPNO on DOY 30/33 are plotted against WACCM-X KPNO DOY 92 and MSIS-00 KPNO DOY 30/33 modeled intensities. The PM observations do not cover enough of the lower shadow altitudes to draw any conclusions about diurnal variation from this comparison, but it appears that WACCM-X may generate a closer fit to observed data than MSIS-00.

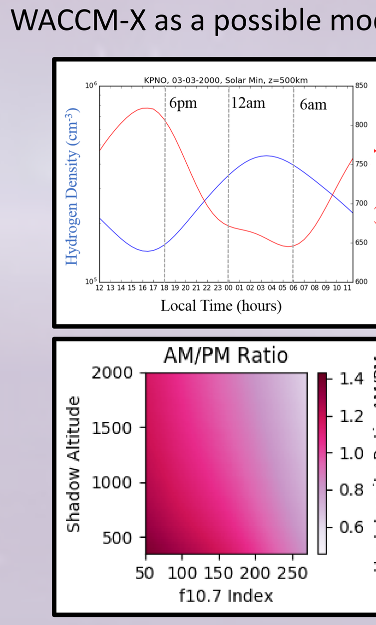
Discussion of Results

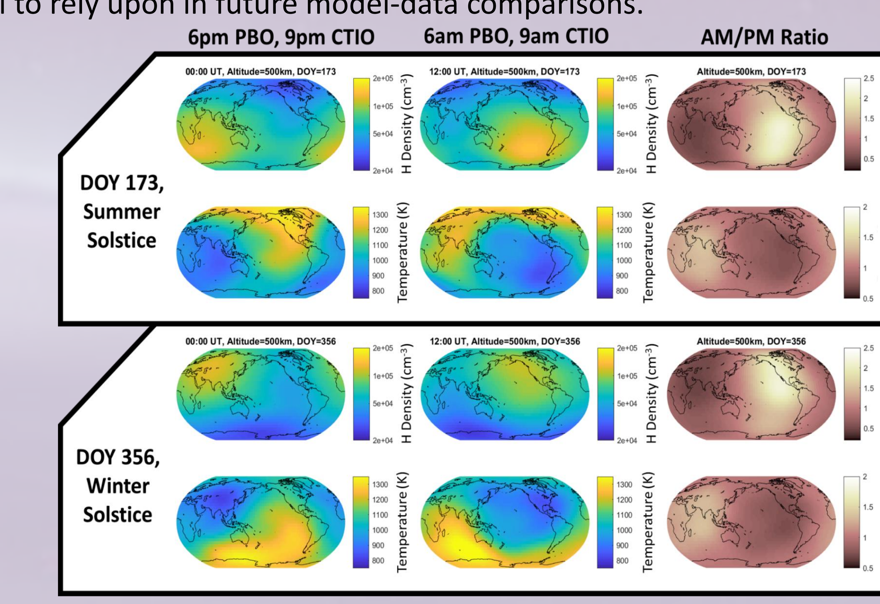
Diurnal Intensity Variation and Temperature

On a diurnal time-scale at a given altitude, MSIS-00 predicts that hydrogen number density follows the opposite trend of temperature. The same correlation is seen in model runs that explore latitudinal and solar cyclic variation. The northern hemisphere summer and southern hemisphere summer, when temperatures are higher, see lower hydrogen density, and vice versa. Solar activity also plays a role; modeling indicates that low f10.7 correlates to higher H-a intensity and lower exospheric temperature, and vice versa. When temperature at lower altitude decreases, collisions between atomic hydrogen and heavier molecules are less likely, allowing the hydrogen to remain in a diffusive state. This is likely the case for solar cyclical variation; however, it is unclear whether vertical winds play a role in diurnal, seasonal, and/or latitudinal variations.

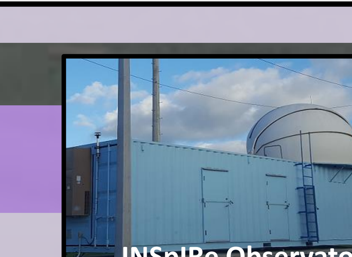
What This Means for Future Observations & Modeling

The seasonal trend predicted by MSIS-00 has been validated in observations for a sampling of day numbers. The intensity difference predicted by MSIS-00 is 3 R at the highest and <1 R at the lowest, values that are measurable by the PBO ground-based spectrometer, which has since moved to the new INSpIRe observatory at ERAU to continue observations. The modeling work completed so far has shown that more data coverage is needed throughout the year at low shadow altitudes, and that having two observing locations, one each in the northern and southern hemispheres, may be beneficial to further studies. Additionally, initial studies with WACCM-X simulated hydrogen have shown higher absolute intensities than MSIS-00, and this may point to WACCM-X as a possible model to rely upon in future model-data comparisons.





Future Work



Hydrogen Modeling

- WACCM-X preliminary integrations into the LYAO_RT tool show promise for future data-model comparisons. Data over longer time scales will need to be acquired to complete comparisons.

INSpIRe Observatory

- The observatory will be moved Fall 2018 to its remote site in the southwest, where northern hemisphere studies can ensue using the same instrument as the PBO data [Mierkiewicz, 2012].
- Low shadow altitude (<2000km) observations are needed on long time scales (i.e. year, solar cycle).

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