# Comparing the Performance of a Solar Wind model from the Sun to 1 au using Real and Synthetic Magnetograms

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## Abstract

We perform a quantitative study which compares the results of the Alfven Wave Solar Atmosphere Model (AWSOM) within the Space Weather Modeling Framework (SWMF). For selected Carrington Rotations, we drive the model by two different solar magnetogram inputs, the observed magnetogram, and a synthetic magnetogram produced by a dynamo model. We simulate the Solar Corona (SC) and the Inner Heliosphere (IH) domains using these SWMF modules. For each case, we compare the observed and simulated cases (real and synthetic magnetogram) using the model synthesized multi-wavelength EUV images. We also extract the simulation data from the IH domain along the earth trajectory to compare with OMNI observational data at 1 au. We initialize the model using the synoptic magnetogram (real magnetogram) and the surface fields maps produced by the dynamo model (synthetic magnetogram) for a set of Carrington rotations within the solar cycle 23 and 24. Our results help to quantify the ability of dynamo models to be used as input to solar wind models, and thus, provide predictions for the solar wind at 1 au.

## Background

For space weather predictions, the requirement of an accurate physics-based model is vital. However, initializing the model with a better input is essential for precise predictions. The primary information to drive the solar MHD model is the synoptic magnetogram, which estimates the sun's photospheric magnetic field [1]. These maps were taken when the sun completes a full rotation (27.27 days). This work describes the solar corona-inner heliosphere simulation results for solar minimum and maximum conditions within the solar cycle 23 and 24 using the latest version of the AWSoM model within the SWMF[2]. AWSoM uses the Alfven wave turbulence as the primary driving agent for heating and accelerating the solar wind. This model includes detailed thermodynamic effects such as radiative cooling and electron heat conduction which enhances the performance of producing the synthetic EUV images of the solar corona. We introduce the surface field maps produced by the 3D kinematic dynamo model [3] as a new input to the model and perform a quantitative comparison between the model outputs and observations.

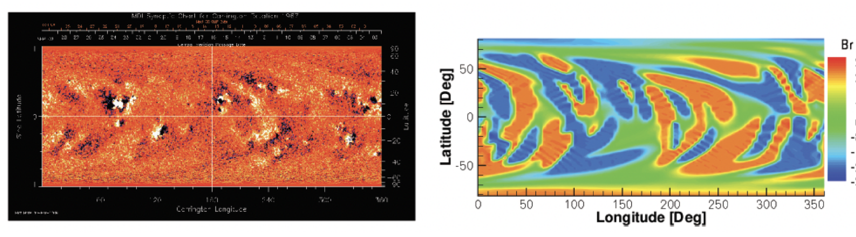
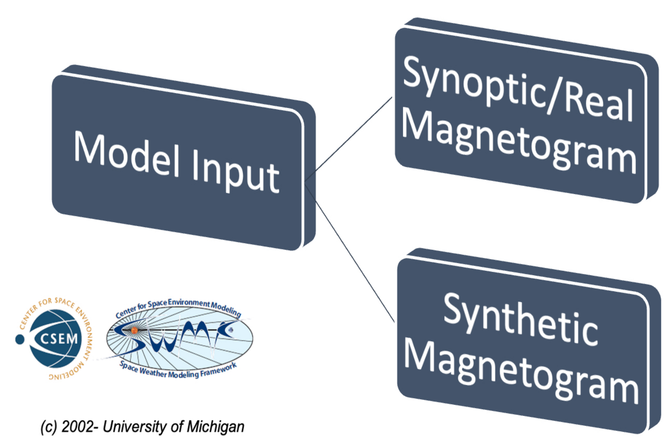



**Figure 1.**(left) SOHO/MDI synoptic chart for carrington rotation 1967. (right) Simulated synoptic chart for the same carrington rotation




## EUV Images (EUVI)

The model simulated electron density and temperature are used to synthesize extreme ultraviolet (EUV) line-of-sight (LOS) images[1].We compared these images with multi-wavelength EUV observations from SOHO/EIT for 171 Å, 195 Å, and 284 Å bands. The observation time for all the rotations coincides with the central meridian times of the real and synthetic maps used for the simulations.

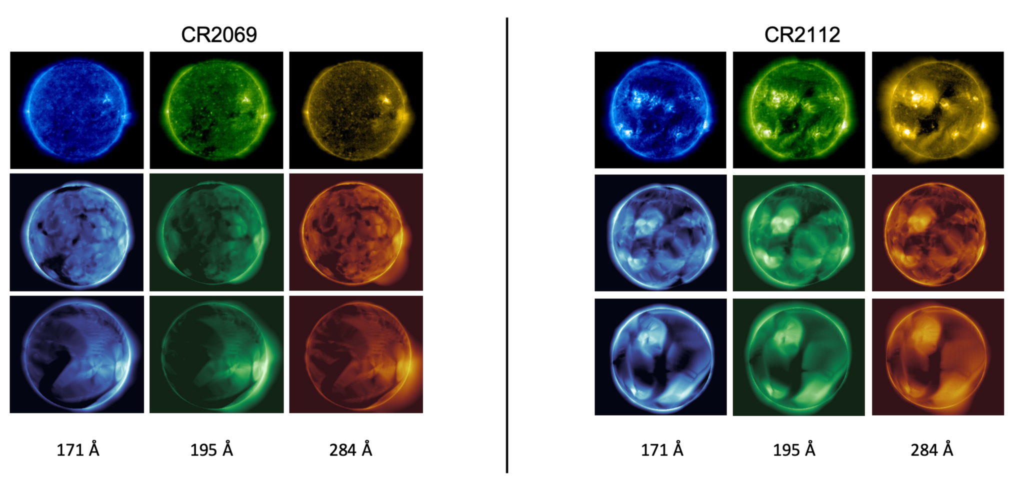



**Figure 2.** Comparison of synthesized EUV images of the model with SOHO/EIT EUV images. The columns are from left to right for 171 Å, 195 Å, and 284 Å. Top panels: observational SOHO/EIT images. Middle panels: synthesized EUV images of the model driven by real magnetogram. Bottom panels: synthesized EUV images of the model driven by synthetic magnetogram. The images are generated for CR2069 (left), and for CR2112 (right)

## Comparisons with OMNI data

Figure 3 and Figure 4 show the comparisons of simulation results at 1 au for the Carrington rotations 2069 and 2112 with the hourly averaged OMNI data. These observations set of data for the solar wind properties at 1 au are from the Advanced Composition Explorer (ACE) satellite orbiting around L1 (Lagrange point). These images also show the comparison of the magnetic field strength (B), proton temperature (T), proton number density ($N_p$), and the radial flow speed ($U_r$) from OMNI data (black) with the model predicted results initialized from the real magnetogram data (red) and initialized from the synthetic magnetogram data (blue) at the end of the solar corona-inner heliosphere simulations.

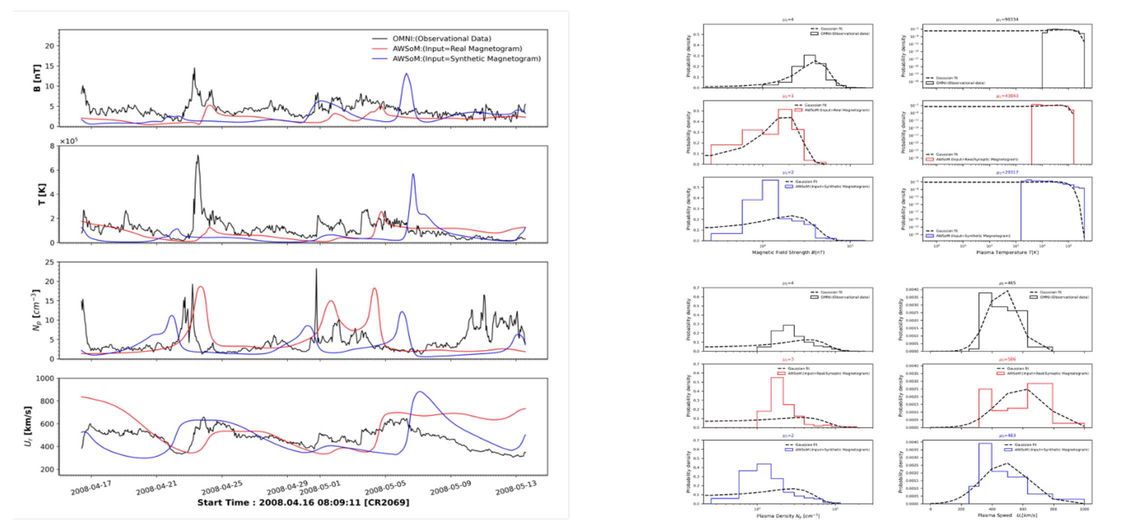


**Figure 3.**OMNI data (black) and AWSoM simulated solar wind parameters driven by synoptic magnetogram data (red) and from synthetic magnetogram data (blue) for Carrington rotation, 2069 (left) and density distribution of the solar wind parameters (right) for CR2069

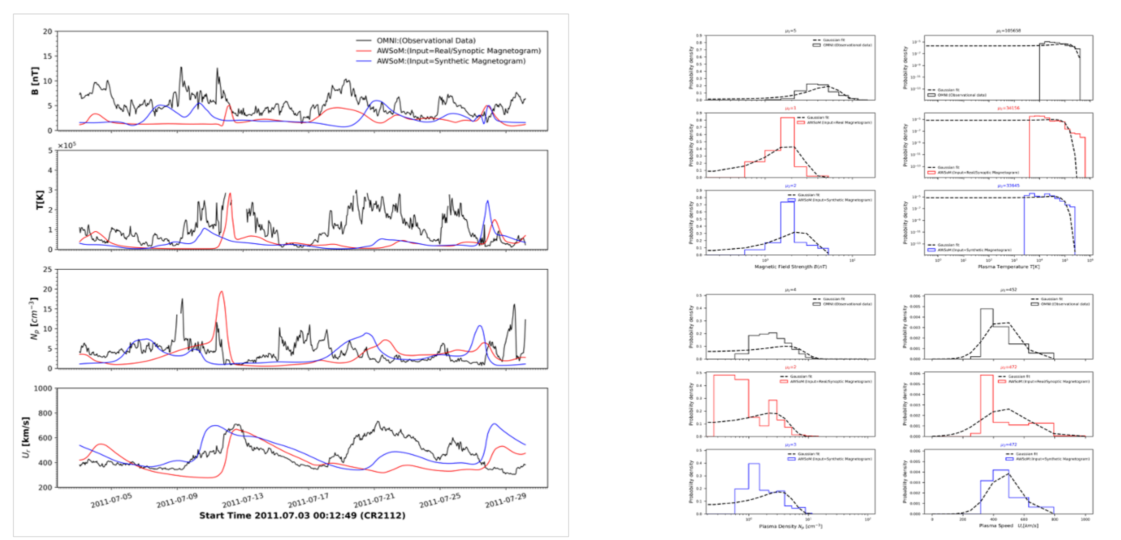


**Figure 4.**OMNI data (black) and AWSoM simulated solar wind parameters driven by synoptic magnetogram data (red) and from synthetic magnetogram data (blue) for Carrington rotation, 2112 (left) and density distribution of the solar wind parameters (right) for CR2112

## References

[1] Nishtha Sachdeva, Bart van der Holst, Ward B. Manchester, Gabor Tóth, Yuxi Chen, Diego G. Lloveras, Alberto M. Vásquez, Philippe Lamy, Julien Wojak, Bernard V. Jackson, Hsiu-Shan Yu, and Carl J. Henney. Validation of the Alfvén Wave Solar Atmosphere Model (AWSoM) with Observations from the Low Corona to 1 au. , 887(1):83, December 2019.

[2] Gábor Tóth, Bart van der Holst, Igor V. Sokolov, Darren L. De Zeeuw, Tamas I. Gombosi, Fang Fang, Ward B. Manchester, Xing Meng, Dalal Najib, Kenneth G. Powell, Quentin F. Stout, Alex Glocer, Ying-Juan Ma, and Merav Opher. Adaptive numerical algorithms in space weather modeling. *Journal of Computational Physics*, 231(3):870–903, February 2012.

[3] A. R. Yeates and A. Muñoz-Jaramillo. Kinematic active region formation in a three-dimensional solar dynamo model. , 436(4):3366–3379, December 2013.

## Statistical Analysis

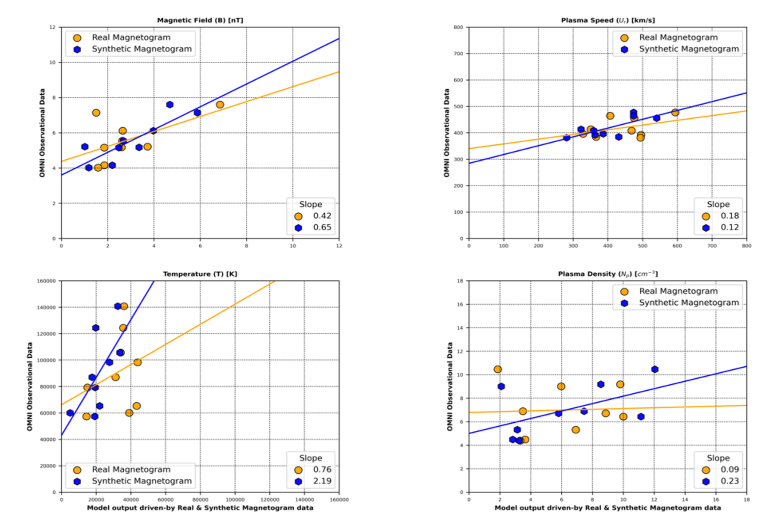


**Figure 5.**Correlation between OMNI observations and model results at 1 au for the mean values of each solar wind parameter for Carrington rotations 1925, 1957, 1989, 2021, 2069, 2086, 2112, 2151, and 2164.

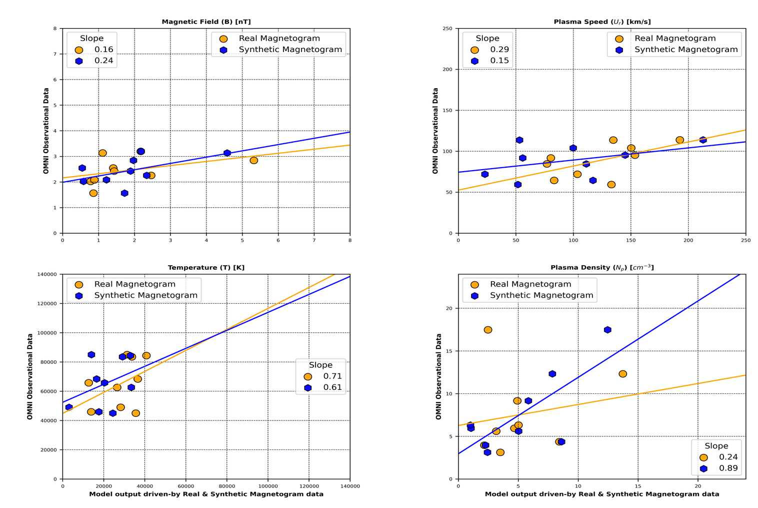


**Figure 6.**Correlation between OMNI observations and model results at 1 au for the standard deviations of each solar wind parameter for Carrington rotations 1925, 1957, 1989, 2021, 2069, 2086, 2112, 2151, and 2164.

## Summary and Conclusion

In EUV image comparison, we find that the bright features and the coronal hole locations are well captured for the real and synthetic magnetogram-driven simulations. Here, both model results show good agreement with SOHO/EIT observations. For comparisons at 1 au, we find that the model results initialized from the real and synthetic magnetogram show a similar variation within the period of a Carrington rotation for solar minimum (CR2069) and maximum (CR2112). However, the model result initialized from the synthetic magnetogram shows a time lag with OMNI observations. The synthetic magnetogram did a better job than the real magnetogram input in reproducing the corotating interaction regions and found peaks in density and temperature are well-matched with observations. We do not see a strong correlation between the model simulated solar wind parameters with OMNI observations. However, the correlation between the real and the synthetic magnetogram results for the mean and standard deviation is reasonable. So, from the results, we conclude that synthetic magnetograms can be used to initialize the model for future space weather predictions as an alternative to real magnetogram input.

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