Comparing the Performance of a Solar Wind Model from the Sun to 1 AU using Real and Synthetic Magnetograms

Kalpa Henadhira Arachchige,[1,2] Ofer Cohen,[1,2] Andres munoz Jaramillo,[3] and Anthony R. Yeates,[4]

[1] Lowell Center for Space Scinece and Technology

[2] Department of Physics & Applied Physics, University of Massachusetts Lowell

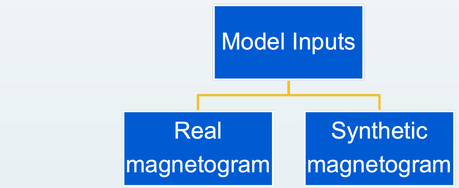
[3] Southwest Research Institute Boulder, Boulder, CO, USA

[4] Department of Mathematical Science, Durham University, Durham, DH1 3LE, UK

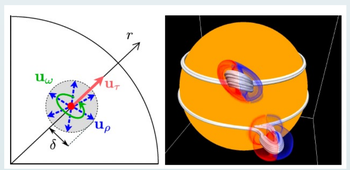
Abstract

The input of the Solar wind models plays a significant role in accurate solar wind predictions at 1 AU. This work introduces a synthetic magnetogram produced from a dynamo model as an input for Magnetohydrodynamics (MHD) simulations. We perform a quantitative study that compares the Space Weather Modeling Framework (SWMF) results for the observed and the synthetic solar magnetogram input. For each case, we compare the results for Extreme Ultra-Violet (EUV) images and extract the simulation data along the earth trajectory to compare with in-situ observations. We initialize SWMF using the real and synthetic magnetogram for a set of Carrington Rotations (CR)s within the solar cycle 23 and 24. Our results help 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.

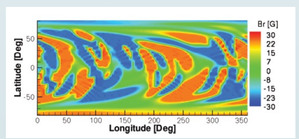
Model Overview



Kd3 Simulation (Synthetic Magnetogram)

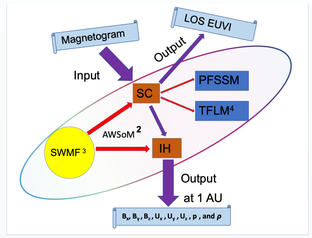


Creating bipolar magnetic regions by imposing a velocity perturbation[1]

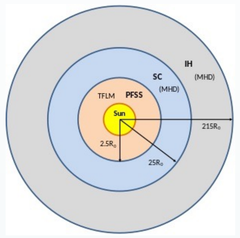


CR1967

Solar Wind Model

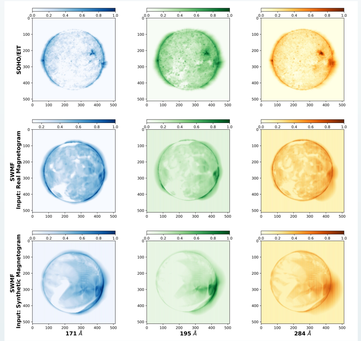


Block diagram of the model (SWMF)



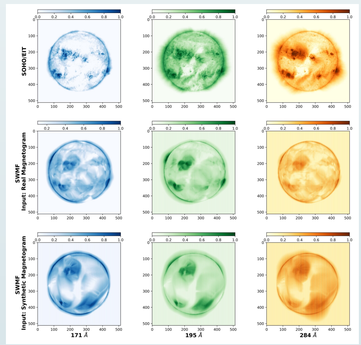
Simulation domains

Comparisons with SOHO/EIT Images



CR2069

Centered on 04.29.2008



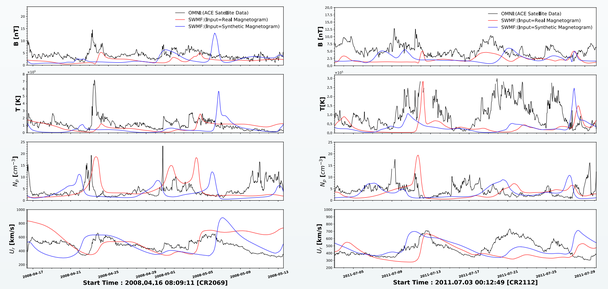
CR2112

Centered on 16.07.2011

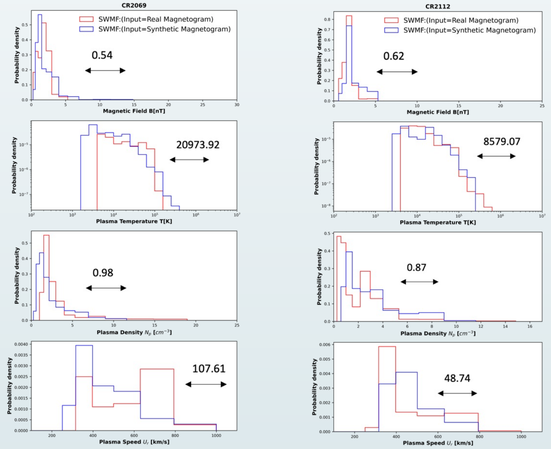
RMSE Calculations for EUVI

CR	Wavelength	Root Mean Square Error (RMSE)		
		SOHO/EIT - SWMF (Input :Real magnetogram)	SOHO/EIT - SWMF (Input :Synthetic magnetogram)	SWMF (Input :Real magnetogram) SWMF (Input :Synthetic magnetogram)
2069	171	0.2143	0.1831	0.1377
	195	0.1343	0.1649	0.1010
	284	0.1463	0.1588	0.0802
2112	171	0.2215	0.2457	0.1628
	195	0.1595	0.1996	0.1321
	284	0.1651	0.1932	0.1318

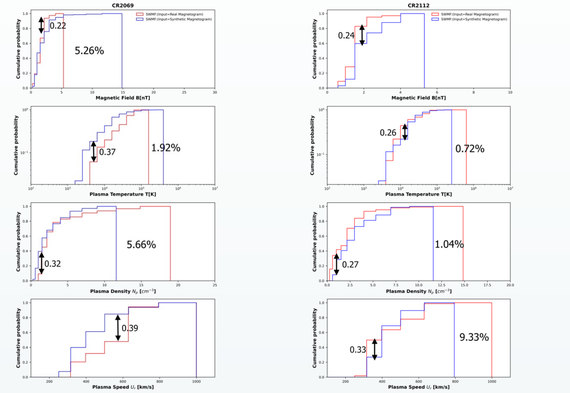
Comparisons with OMNI Observations



Earth Movers' Distance Calculations



Kolmogorov-Smirnov Test



Conclusion

The comprehensive study and analysis conclude that synthetic magnetograms could initialize solar wind models for future space weather predictions as an alternative to the observed magnetograms in reproducing realistic solar wind conditions at 1 AU. We conclude that the synthetic magnetogram performs better in reproducing 1 AU results when a certain number of active regions are present on the solar surface or in a solar maximum.

Acknowledgements

This work is supported by NASA LWS grant 80NSSC18K0930. Simulation results were obtained using the (open source) Space Weather Modeling Framework, developed by the Center for Space Environment Modeling, at the University of Michigan with funding support from NASA ESS, NASA ESTO-CT, NSF KDI, and DoD MURI. The simulations were performed on the Massachusetts Green High-Performance Computing Center (MGHPCC) cluster supercomputer.

References

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

[2] B. van der Holst, I. V. Sokolov, X. Meng, M. Jin, IV Manchester, W. B., G. Toth, and T. I.Gombosi. Alfven Wave Solar Model (AWSoM): Coronal Heating. , 782(2):81, February 2014.

[3] 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, Ken-neth 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, February2012.

[4] Igor V. Sokolov, Bart van der Holst, Ward B. Manchester, Doga Can Su Ozturk, Judit Szente,Aleksandre Taktakishvili, Gabor Toth, Meng Jin, and Tamas I. Gombosi. Threaded-field-line Model for the Low Solar Corona Powered by the Alfv´en Wave Turbulence. , 908(2):172, February2021.

Contact author : kalpa_henadhiraarachchige@student.uml.edu