Predicting solar wind using reservoir computing

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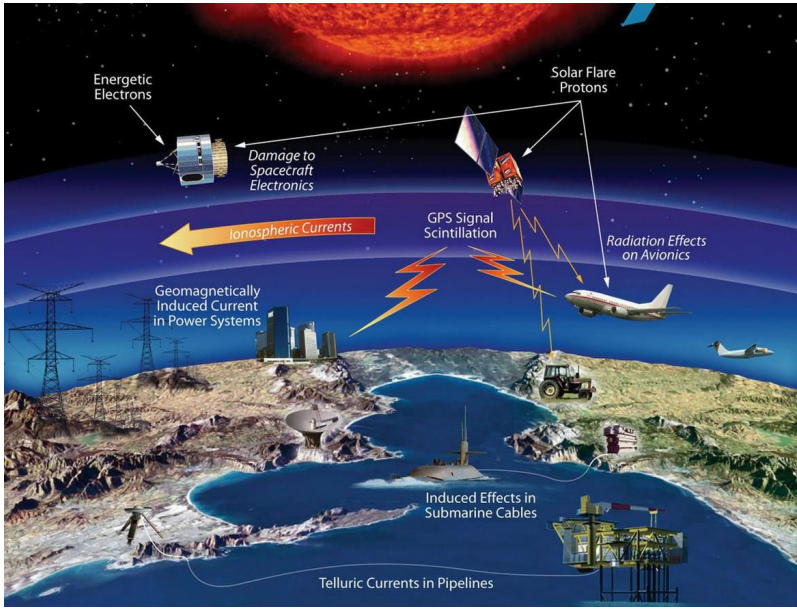
Space Weather

Space weather is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modeling, at understanding and predicting the state of the Sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them, and also at forecasting and nowcasting the potential impacts on biological and technological systems.



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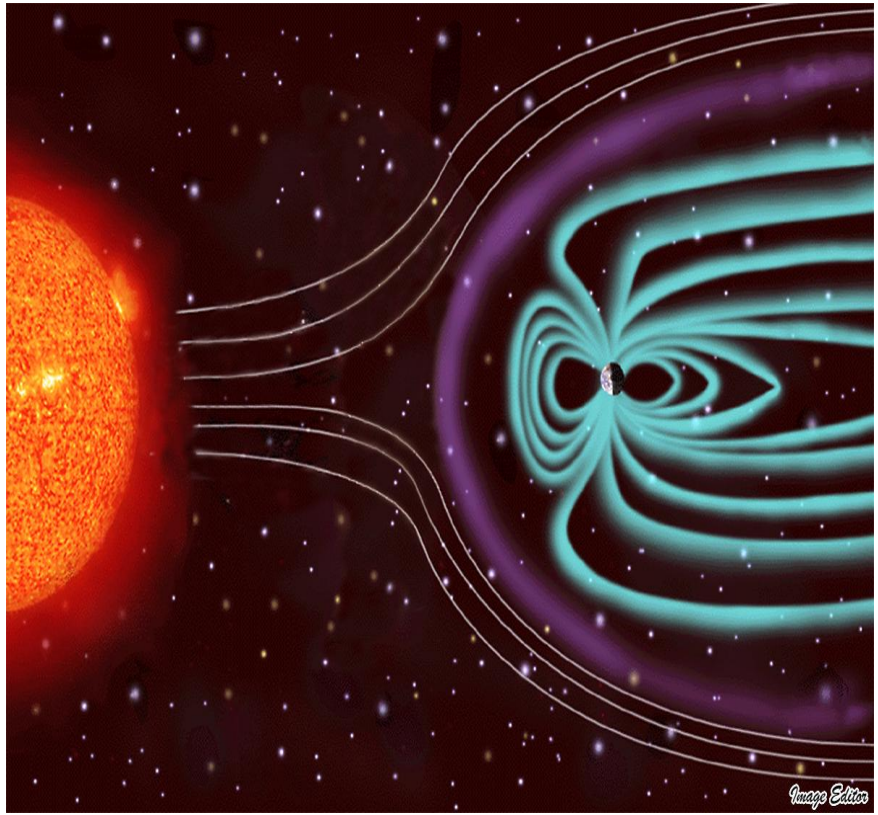
Solar Wind

Solar wind is a magnetised plasma emanating from the Sun's corona whose interaction with the magnetosphere has space weather consequence like solar flares and geomagnetic storms which could adversely affect our technological systems.

Accurately predicting the solar wind through measurements of the spatiotemporally evolving conditions in the solar atmosphere is important but remains an unsolved problem in heliophysics and space weather research



Data & Method

Data

Solar wind data at 5 minutes interval was obtained from OMNIWeb.

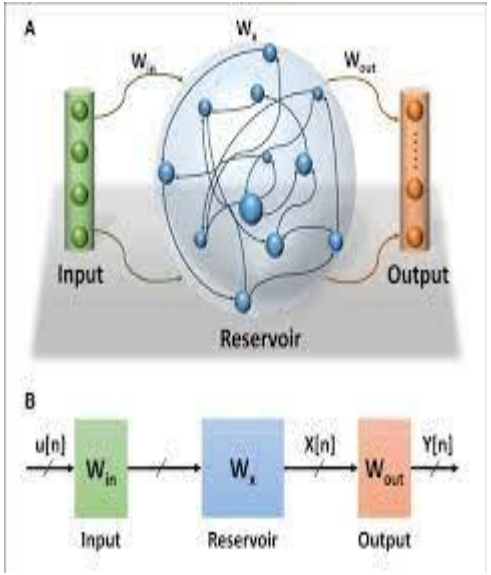
http://omniweb.gsfc.nasa.gov/

Daily averages were estimated for analysis.

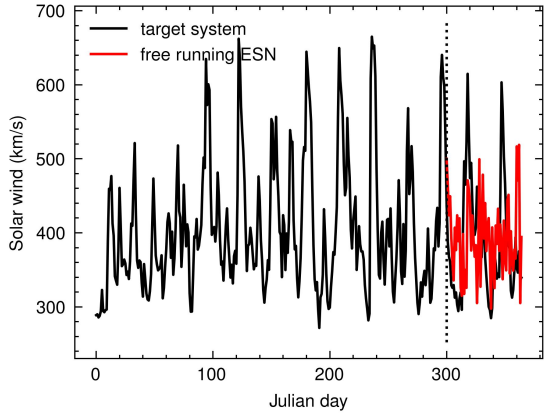
Echo State Network

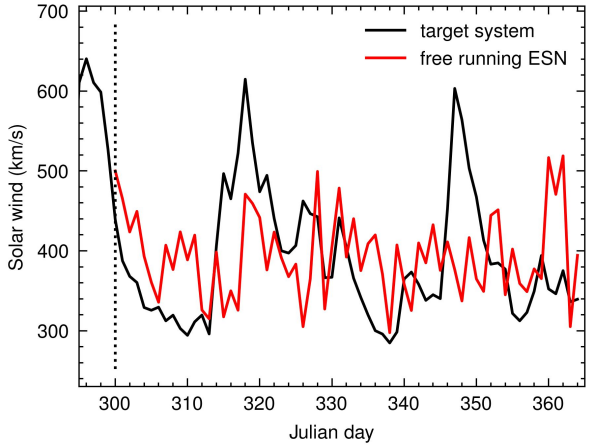
It is a recurrent neural network with sparsely connected hidden layer.

Echo State Network



Result and discussion



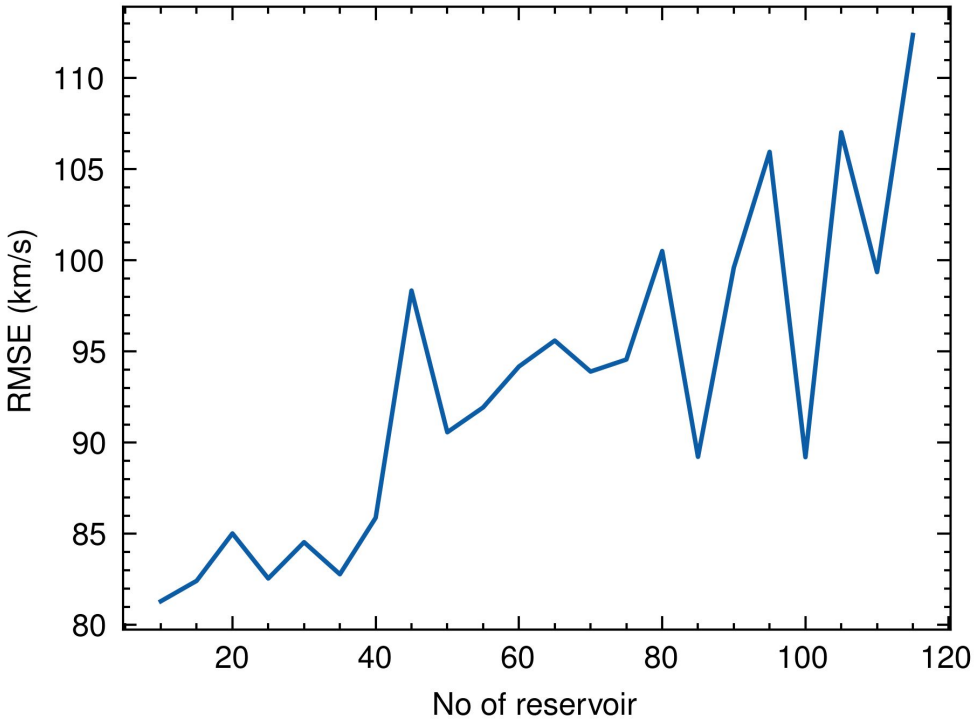


Echo State Network with 100 reservoirs was found to perform very well with an RMSE value of 89.21 km/s.

Echo state network largely captured the trend and peaks in solar wind within 20 days.

Reservoir

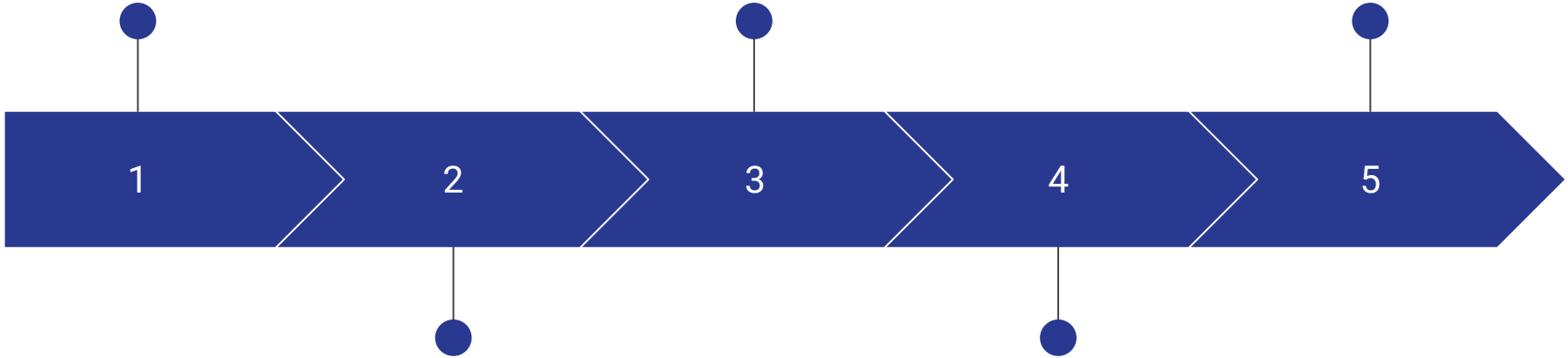
Less than 40 reservoirs give RMSE values in the range 80 - 85. Above this, the RMSE values increases. Values of 25, 35, 50, 85, 100, and 110 give lower RMSE values compared to other values.



We attempted to predict solar wind using echo state network

Using 100 reservoirs, an RMSE value of 89 km/s was observed

ESN was able to predict solar with 20 days ahead.



Daily data during 2010 was considered.

RMSE increased from 81 km/s for a reservoir of 10 to 110 with 120 reservoirs.

References

1. Weimer, D. and T. Edwards (2021), Testing the electrodynamic method to derive height integrated ionospheric conductances, Ann. Geophys., 39, 31-51, https://doi.org/10.5194/angeo-39-31-2021

2. Nakano, S. and R. Kataoka (2022), Echo state network model for analyzing solar-wind effects on the AU and AL indices, Ann. Geophys., 40, 11-22, https://doi.org/10.5194/angeo-40-11- 2022