Predicting Solar Wind Speed at L1-point based on Convolutional Neural Network and PFSS Magnetogram

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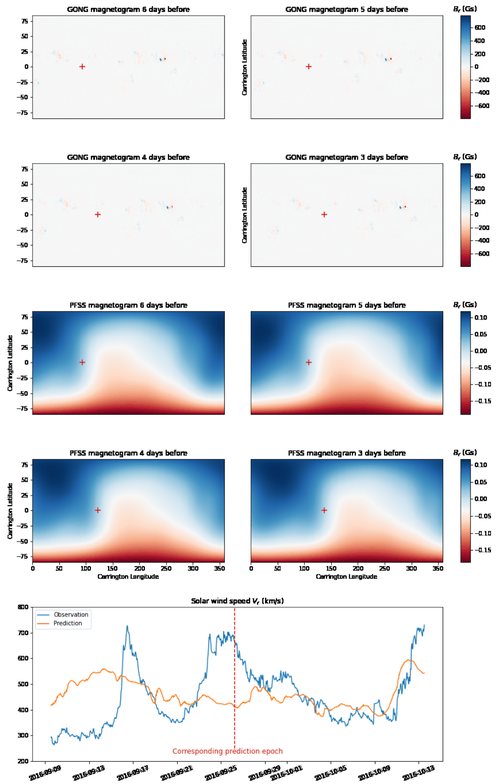
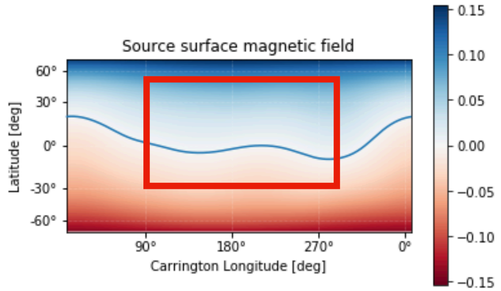
Main Points and Overview

- Motivation: to find a direct mapping from the photospheric magnetic field to the ambient solar wind upstream of the earth.
- Model: Convolutional Neural Network (CNN, fit for extract features from Pictures

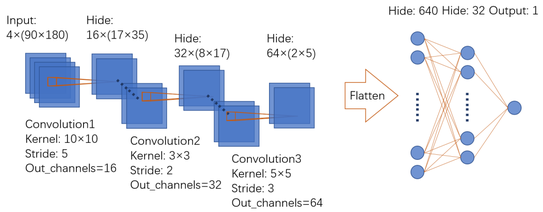


Method and CNN structure

- Source [1st and 2nd rows in 'Overview']: GONG magnetogram synoptic maps at time = [t-6day, t-5day, t-4day, t-3day].
- Input [3rd and 4th rows]: PFSS magnetogram maps at 2.5 Rs, Calculated with Pfsspy, with GOND maps as the boundary condition. We cut the central image (~180deg*90deg) out as the input (marked out with the red rectangle).



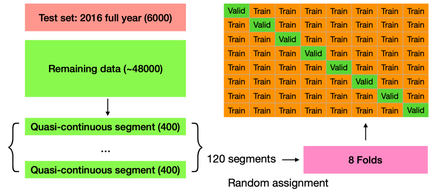
- Output: Solar wind speed at time=t (aiming to match the OMNIWeb data)
- CNN structure:



Model Evaluation: on behalf of Generalization

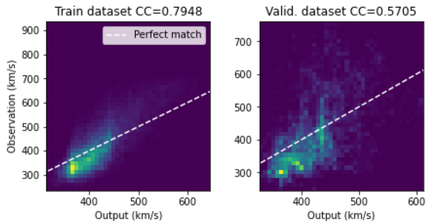
In order to prevent overfitting, a series of techniques are used.

- **L1 regularization**: add penalty in loss function to reduce the summation of the weights.
- **Dropout**: randomly drop out neurons when training.
- **K-fold validation**: this technique guarantees that the dataset partition has reasonable randomness and conserves continuity of time-series data.



Model performances:

Average performance in the training datasets: CC = 0.78, RMSE = 60km/s
Average performance in the validation datasets: CC = 0.55, RMSE = 80km/s
Ensemble performance in the test dataset: CC=0.50, RMSE = 90km/s
Best performance in one validation dataset:



Discussions

ADVANTAGES

The model outperforms WSA and PS27 as benchmarks.
The model covers the whole solar cycle (2009-2020).
The input of our model is simple. Taking the advantage of imaging cutting, the models has the potential to develop an off-elliptic model like WSA (under experiment)

SHORTCOMINGS

The model is conservative, often failing to capture the information of the sudden speed-up of the solar wind, or giving predictions slower than the peak velocity. This may result from

- Fuzzy and inaccurate PFSS coronal magnetic field.
- Model weakness.
- Data distribution (high-speed streams are relatively rare).
- The input information of GONG are not sufficient. Maybe more pictures spaced by < 1day are needed.