The need for heliospheric data assimilation

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Introduction

The solar wind has to be modelled for accurate space weather forecasting. This is done by using magnetograms to initialise coronal models, which are then used as the input to heliospheric models. A number of different coronal models are available, but they produce very different outputs as they are based on different equations. This impacts the ambient solar wind state and therefore the dynamics and arrival times of CMEs at Earth.

CME event October 2012

Barnard (2017) studied 4 CME events from 2012, using cone parameters from NOAA SWPC. Here, we present a single case study from October 2012. The CME was observed at 21.5 rS on 2012-10-05 at 0847 with an initial speed of 698 km/s. We use three coronal models as input into the Heliospheric Upwind Extrapolation with time dependence (HUXt) solar wind model.

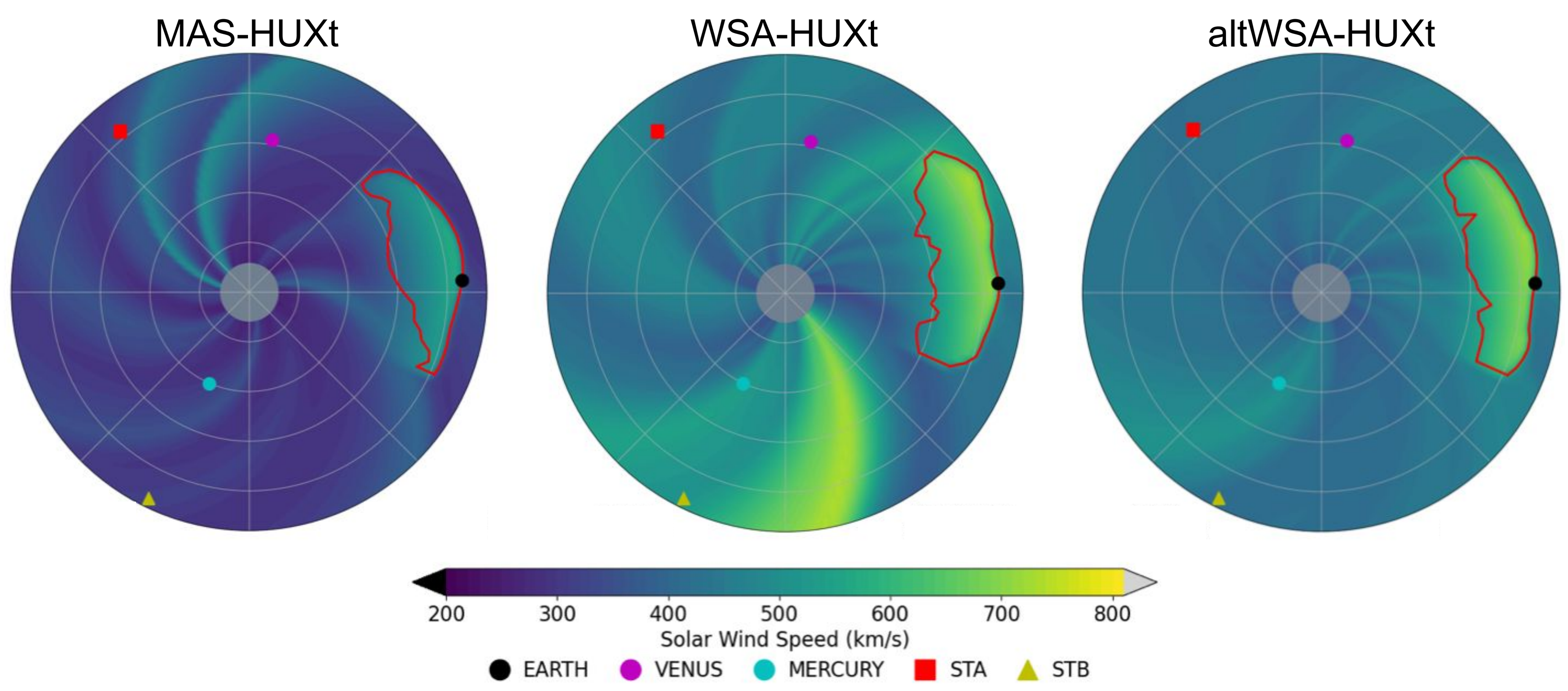

Figure 1. Heliospheric solutions from HUXt using different coronal models as input, with the addition of the case study CME.

Data assimilation (DA)

DA combines model output with observations to form an optimum estimation of reality. It has led to large improvements in terrestrial weather prediction but is underused in space weather forecasting.

The Burger Radius Variational Data Assimilation (BRaVDA; Lang, 2019) scheme has been shown to improve solar wind forecasts (Turner, 2022; 2023). It is used here to find the optimum inner boundary, taking into account information from solar wind observations and the coronal model solution. This uses observations from the STEREO mission and spacecraft at L1. Using BRaVDA brings the model solutions into closer agreement.

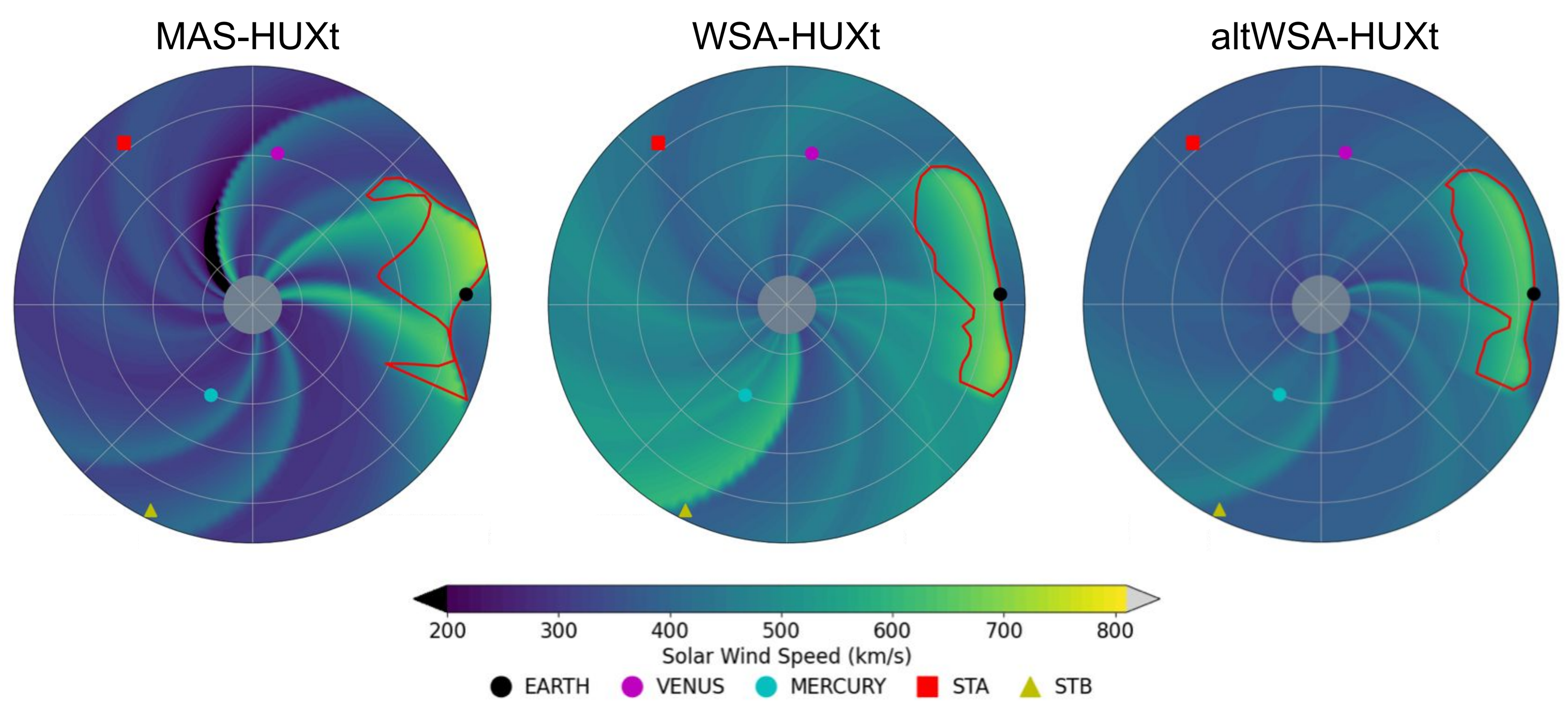

Figure 2. As Figure 1, but using an inner boundary for HUXt that has been updated with BRaVDA.

CME arrival times

Comparing the arrival times shows the effect of the DA.

	Prior arrival time	Difference	Posterior arrival time	Difference
Observed	2012-10-08 0431			
SWPC	2012-10-08 1500	+10h 29		
MAS	2012-10-08 1239	+8h 08	2012-10-08 0250	-1h 41
WSA	2012-10-07 2258	-5h 33	2012-10-08 0224	-2h 07
altWSA	2012-10-07 2343	-4h 58	2012-10-08 0440	+0h 09

Table 1. Arrival times of the CME for different coronal model inputs into HUXt. Here, prior is before DA occurs and posterior is after.

Other CME case studies

The remaining CME case studies have shown more mixed results. DA does not improve arrival time for all CMEs, but there is an overall reduction in RMSE.

	Ambient solar wind [km/s]	Ambient solar wind + CMEs [km/s]
Prior RMSE	89.3	152.9
Posterior RMSE	79.4	137.6

Table 2. RMSE of prior and posterior solar wind forecasts for all case studies.

Future work

- Investigate the impact of the different coronal model inputs through a multi-model study.
- Use both GONG and HMI magnetograms as input, as coronal models are sensitive to their input.
- Establish the conditions where DA is most effective.
- Develop DA to improve forecasts outside of optimal conditions.

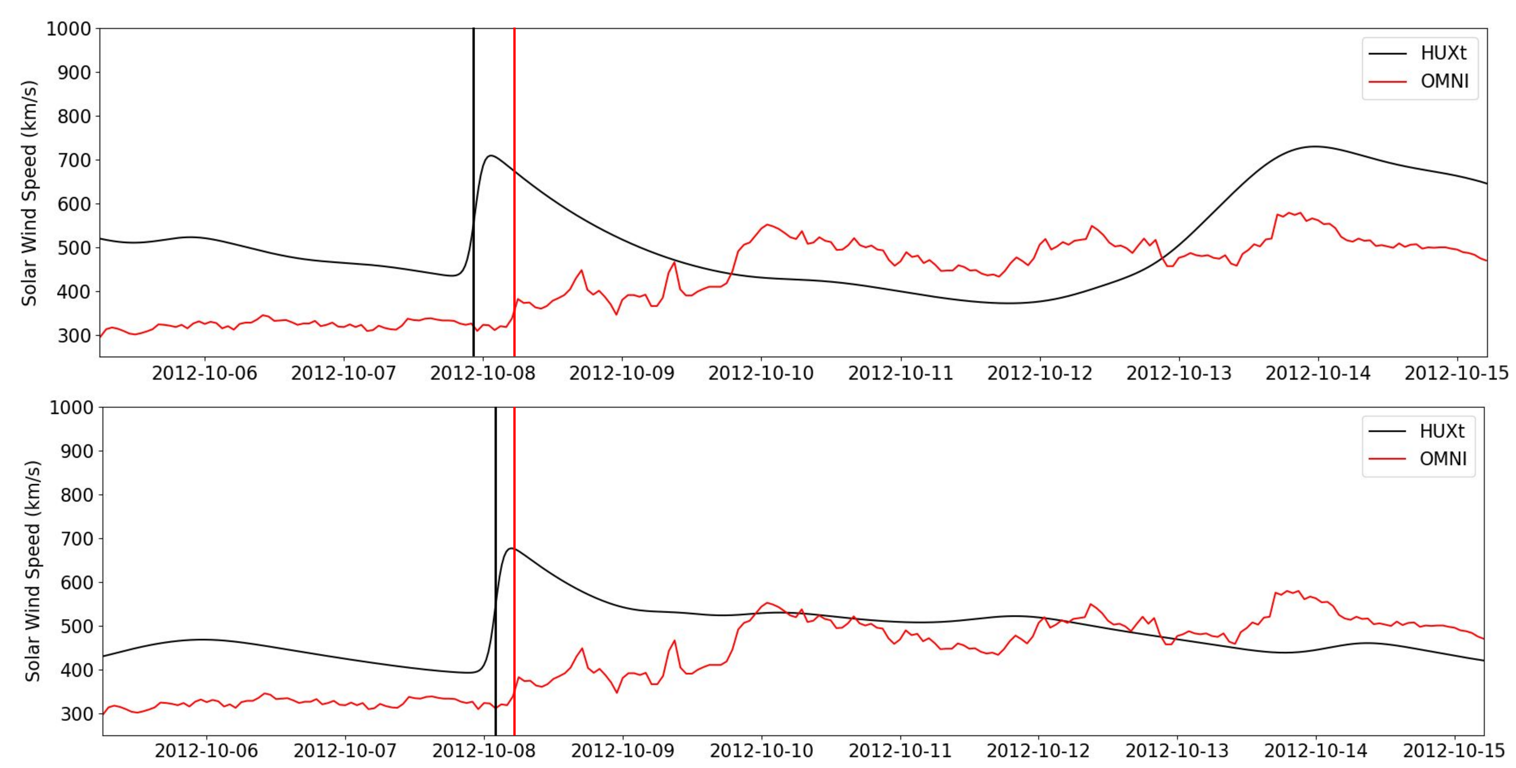

Figure 3. Solar wind time series for the WSA prior (top) and posterior (bottom). The black vertical line shows the modelled CME arrival time and the red vertical line shows the observed arrival time. The DA increases the agreement between the model and observations and improves CME arrival time.

References

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