The need for heliospheric data assimilation

Harriet Turner, Mathew Owens, Luke Barnard, Matthew Lang

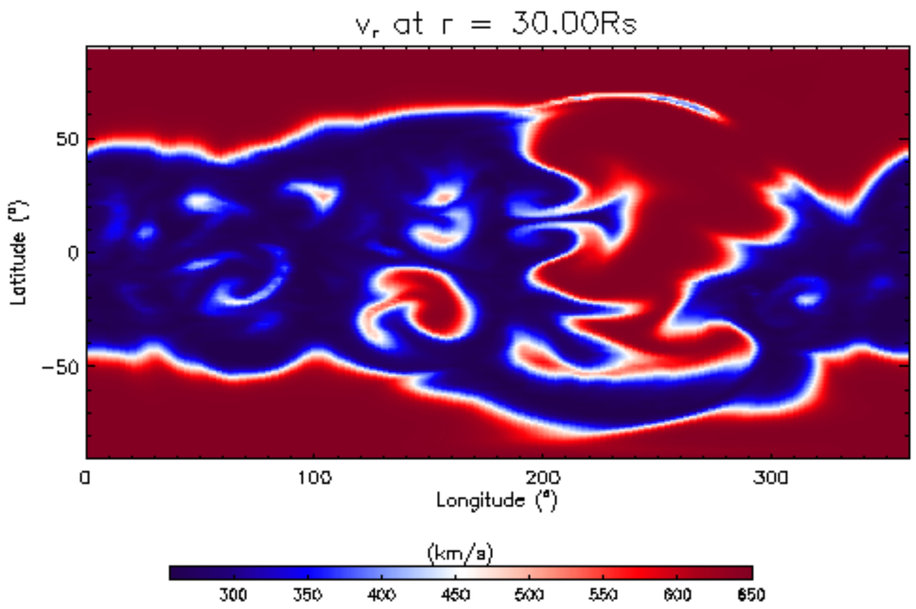
Sandy Park, 11th September 2024

Solar wind model inputs

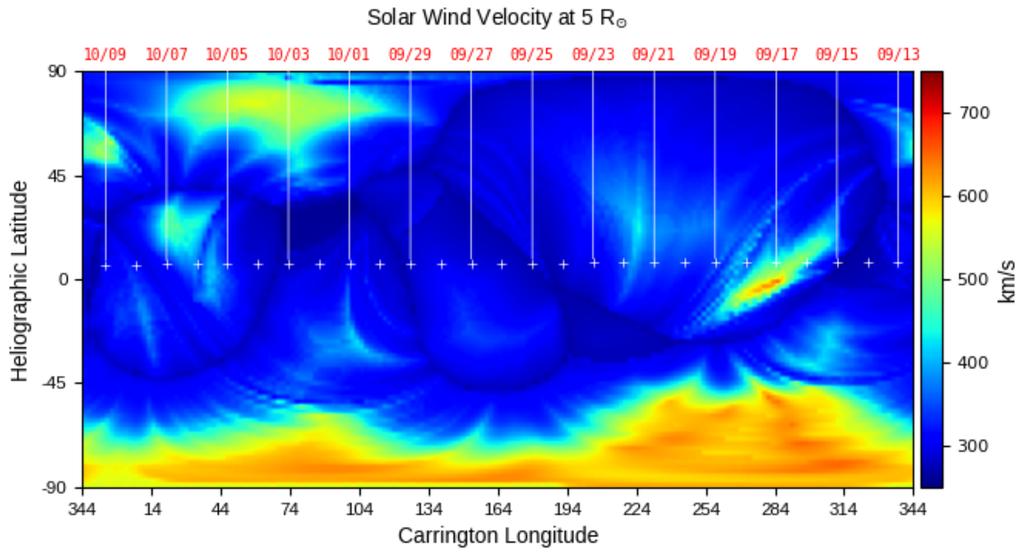
A veritable smorgasbord

- There are numerous different coronal models producing output for use in solar wind models
- They are all valid, but are often very different

MAS



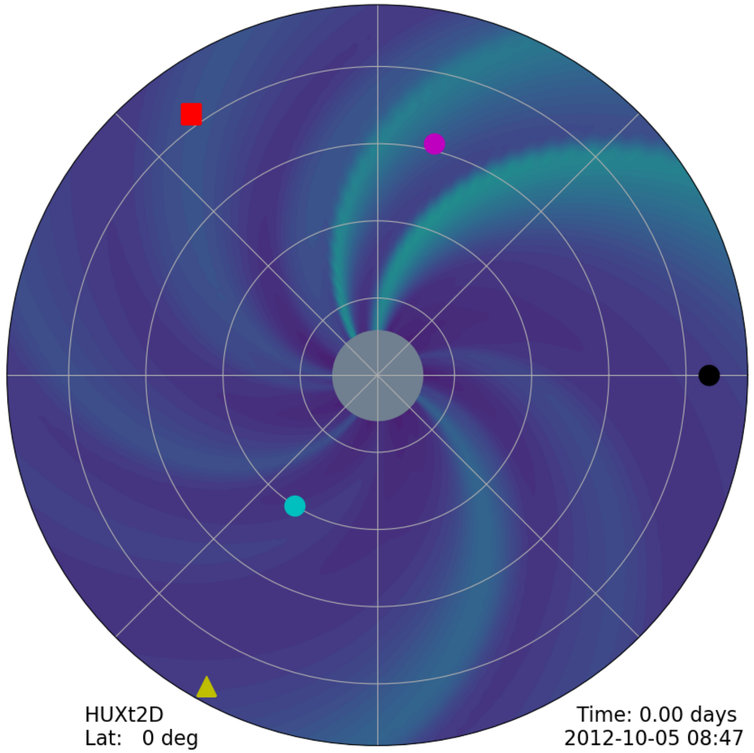
WSA



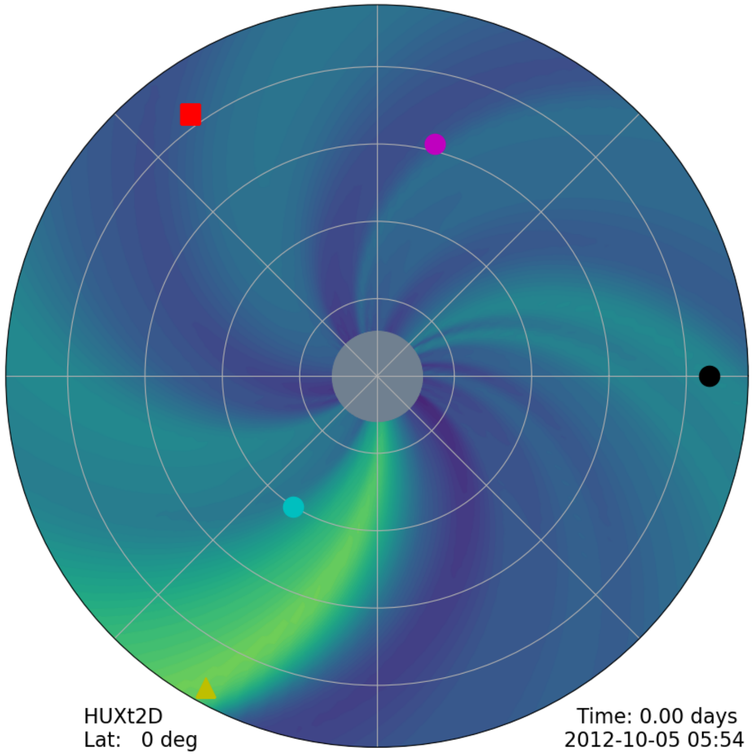
Heliosphere

Ambient solar wind in HUXt

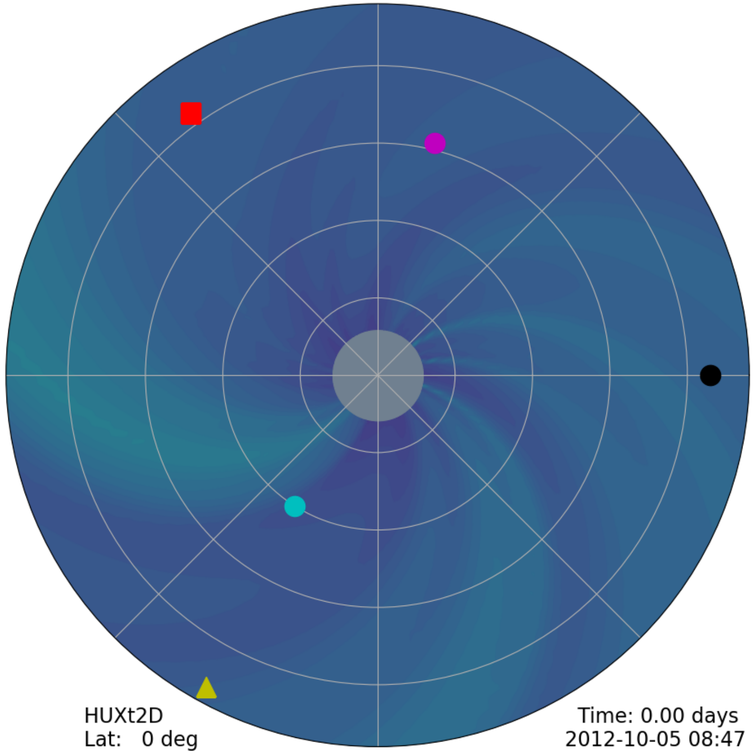
MAS

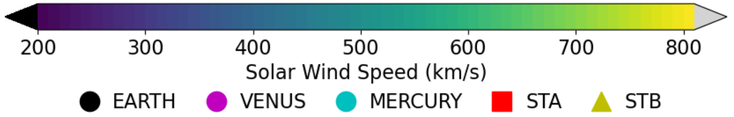


WSA



altWSA

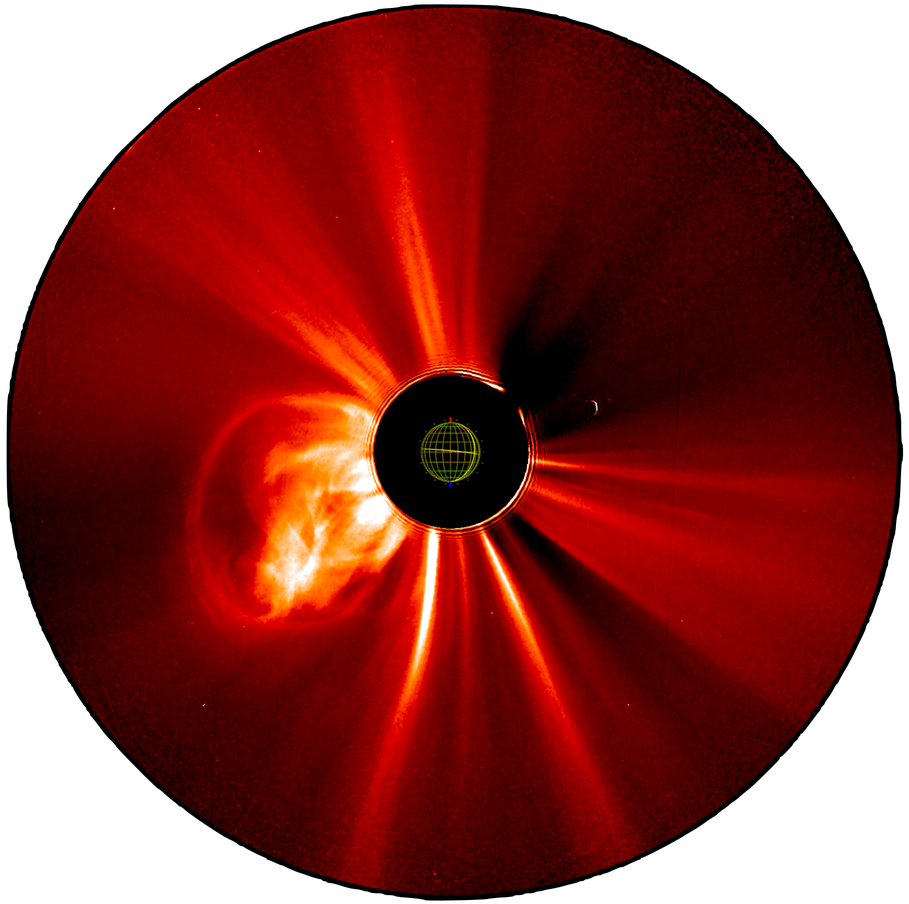




CME event

October 2012

Time at 21.5 rS	2012-10-05 0847
Longitude	9
Latitude	-24
Width	84
Speed	698
SWPC arrival	2012-10-08 1500
Observed arrival	2012-10-08 0431

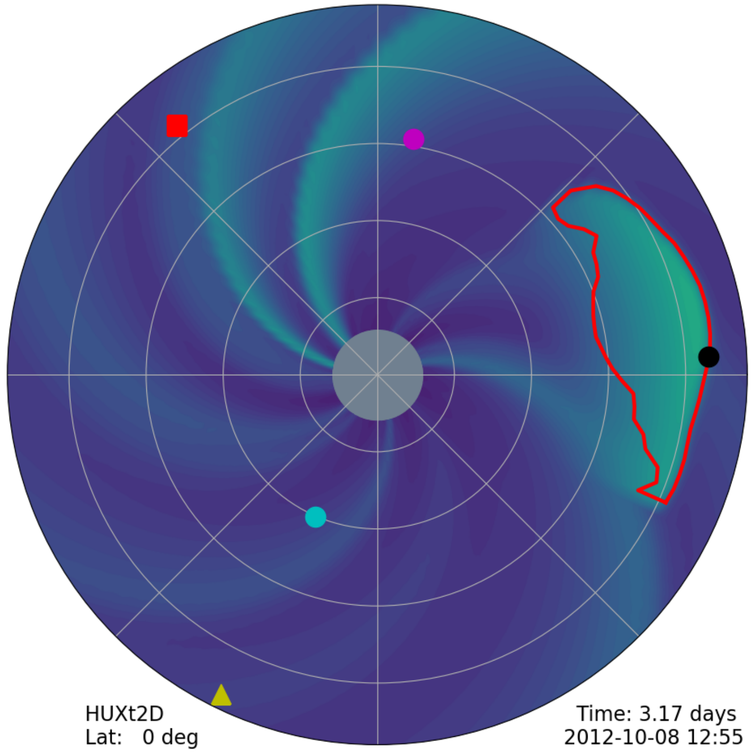


Cone parameter from events studied in Barnard, 2017. DOI: 10.1002/2017SW001609

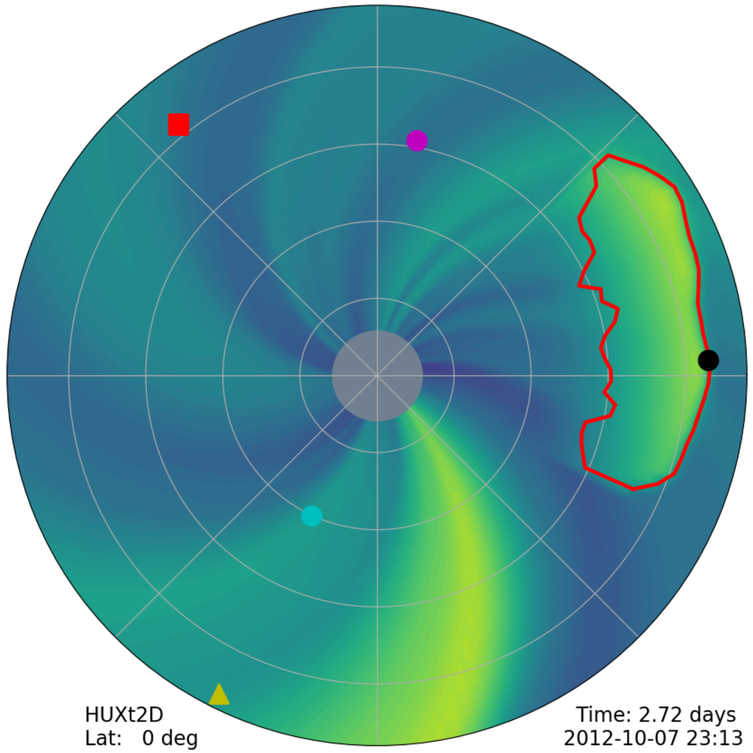
Heliosphere

Modelling the CME in HUXt

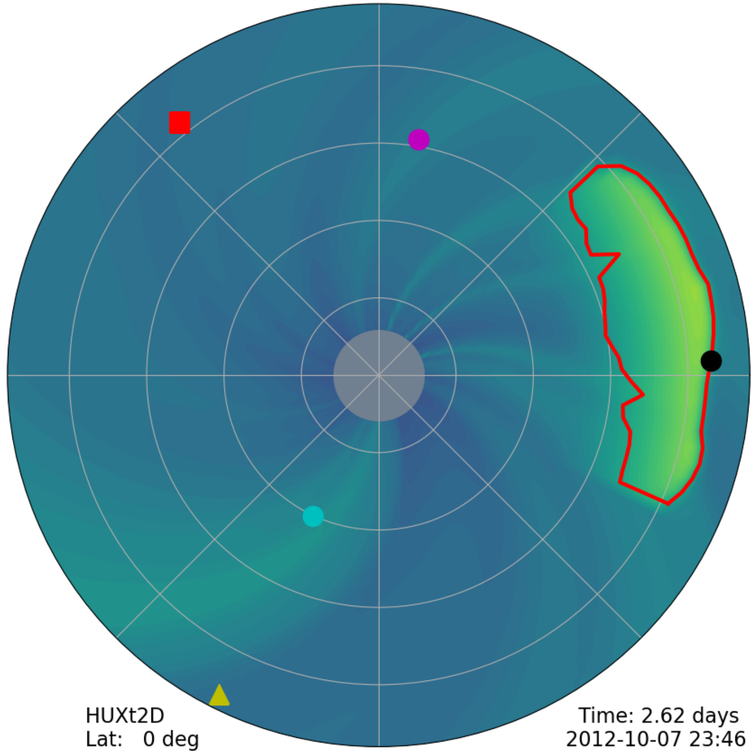
MAS

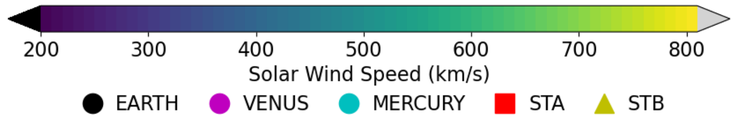


WSA



altWSA





CME arrival times

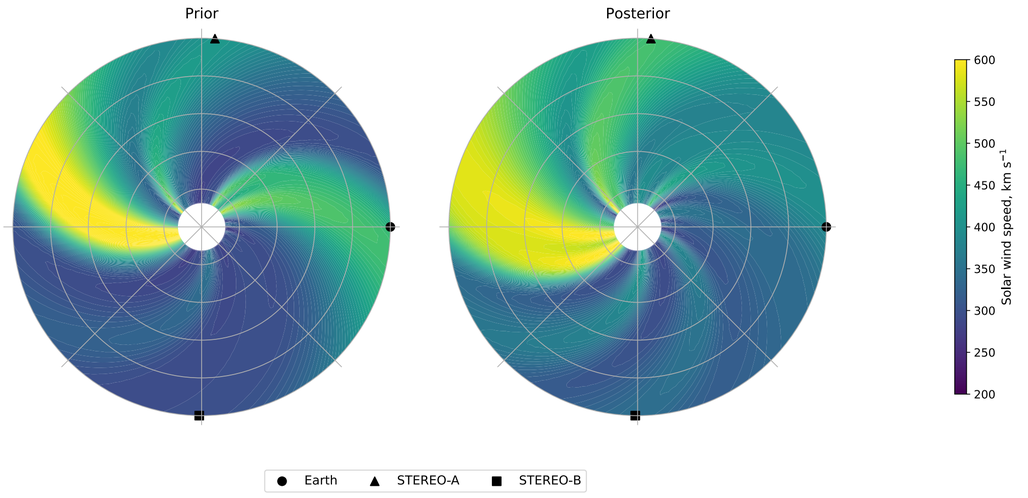
Comparison of input

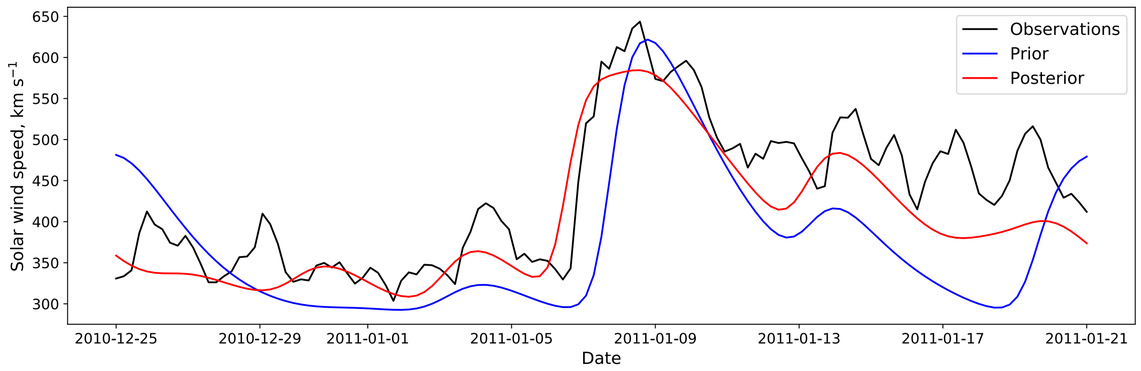
	Arrival time	Difference
Observed	2012-10-08 0431	
SWPC	2012-10-08 1500	+10h 29
MAS	2012-10-08 1239	+8h 08
WSA	2012-10-07 2258	-5h 33
altWSA	2012-10-07 2343	-4h 58

Data assimilation

Application to the solar wind

- DA combines model output and observations to form an improved estimation of reality
- Extensively used in NWP, leading to large forecast improvements
- Applied to the solar wind, forecasts improved (my PhD)



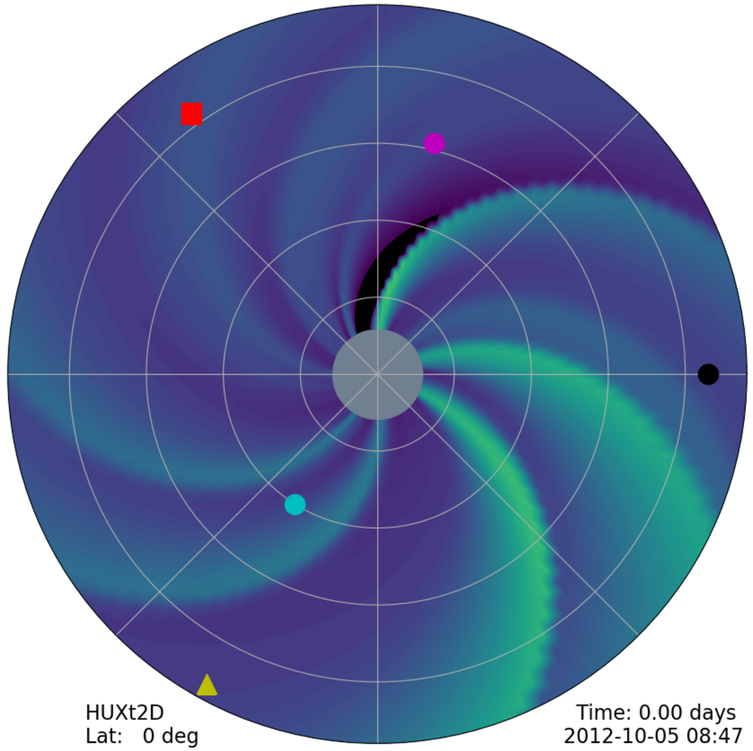


Prior = before DA, posterior = after DA

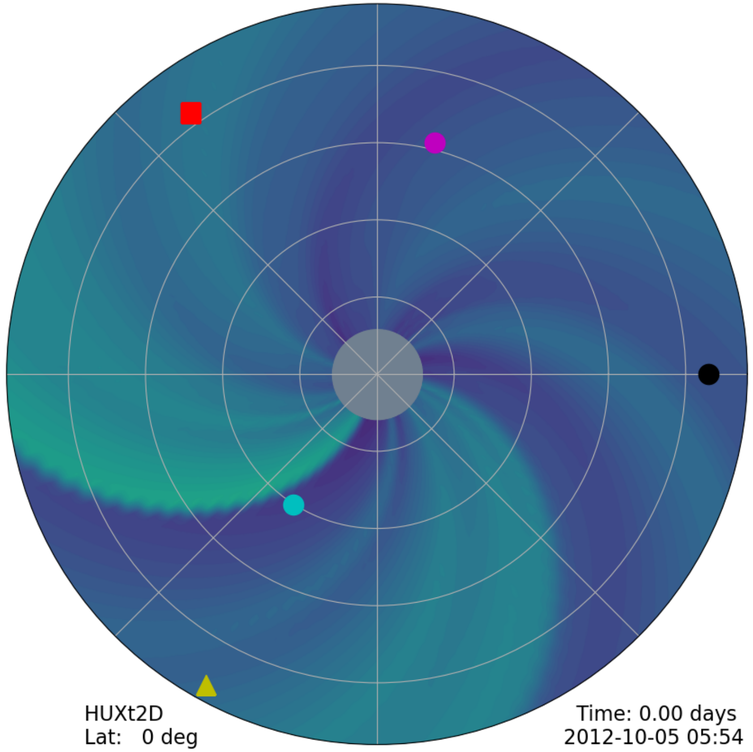
Heliosphere

Ambient solar wind in HUXt with DA

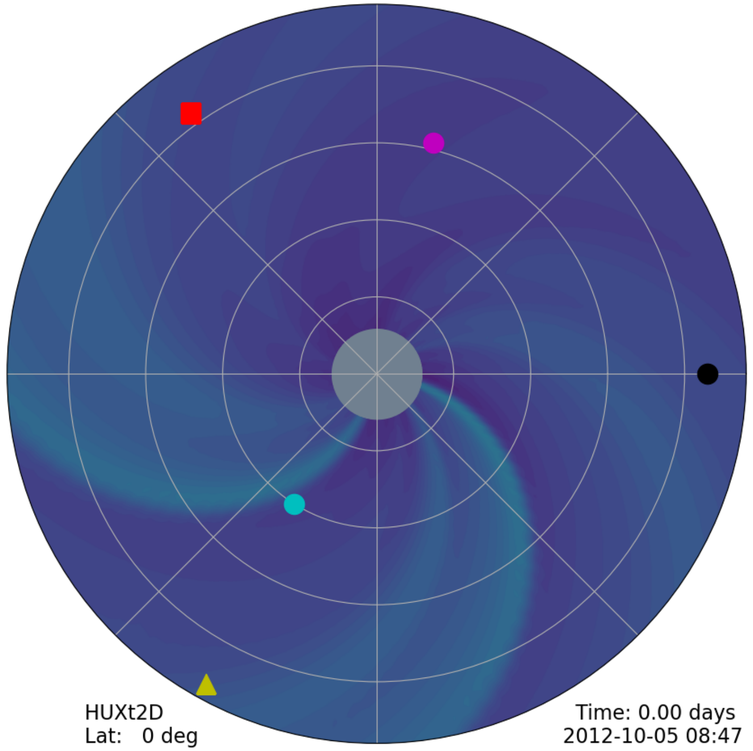
MAS

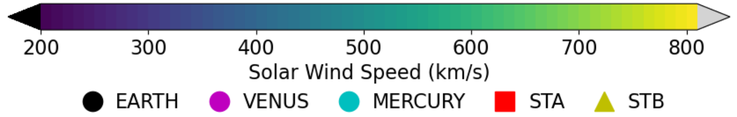


WSA



altWSA

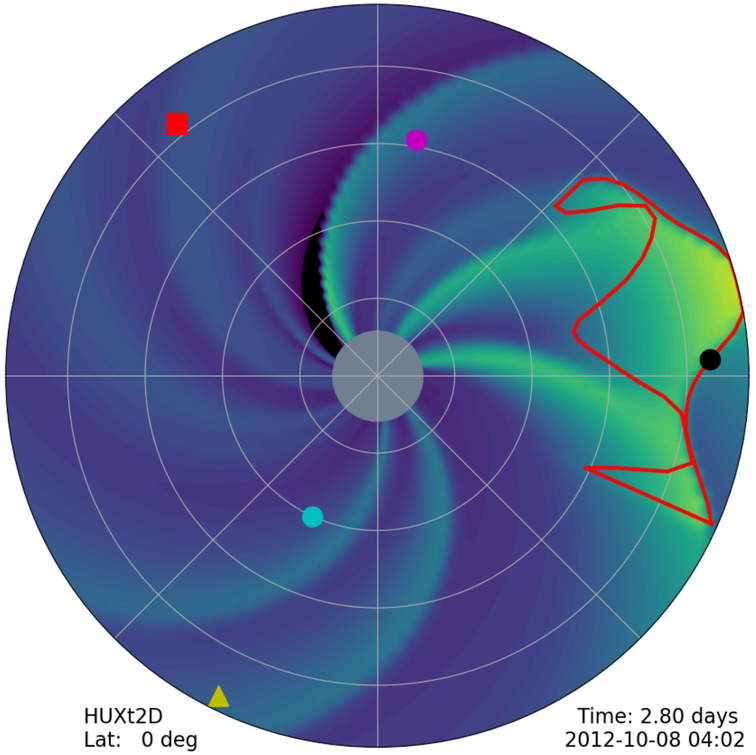




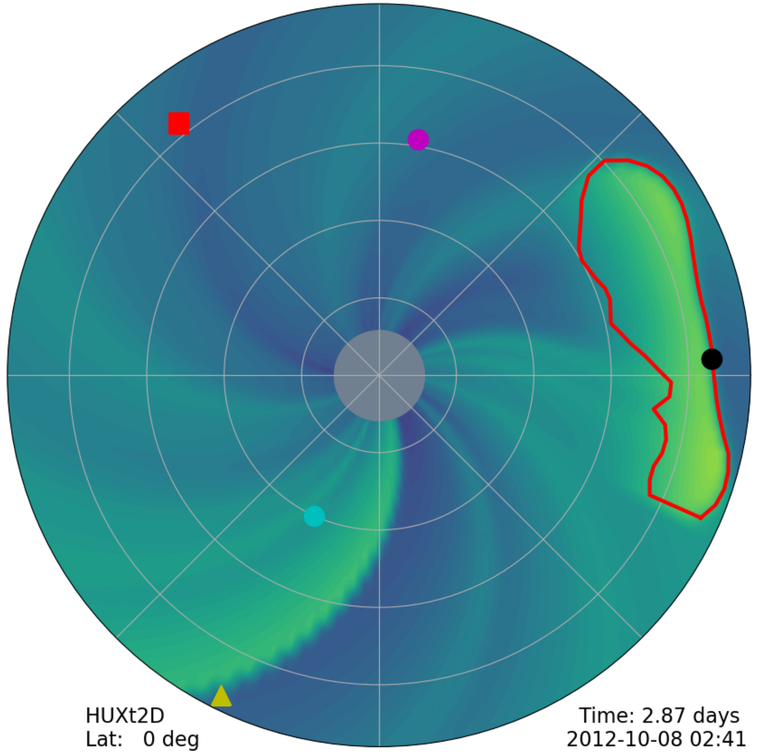
Heliosphere

Modelling the CME in HUXt with DA

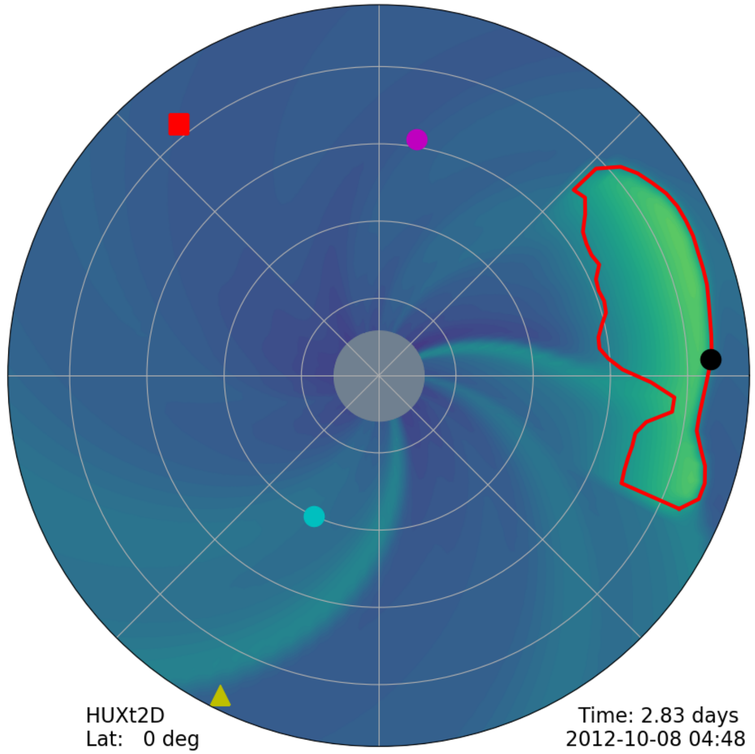
MAS

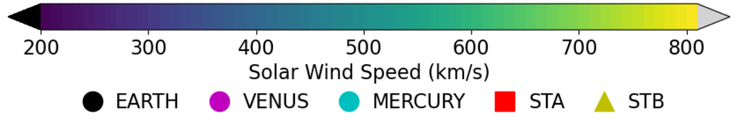


WSA



altWSA





CME arrival times

Comparison of input

	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

Could DA be the pathway to making the models agree?

Maybe

Not quite as clear cut

- Other case studies show mixed results
- DA doesn't improve CME arrival time for all the case studies
- Overall reduction in RMSE for forecasts, but this could be solar cycle dependent
- Unsure on what conditions are favourable for DA, and why it performs worse in some areas

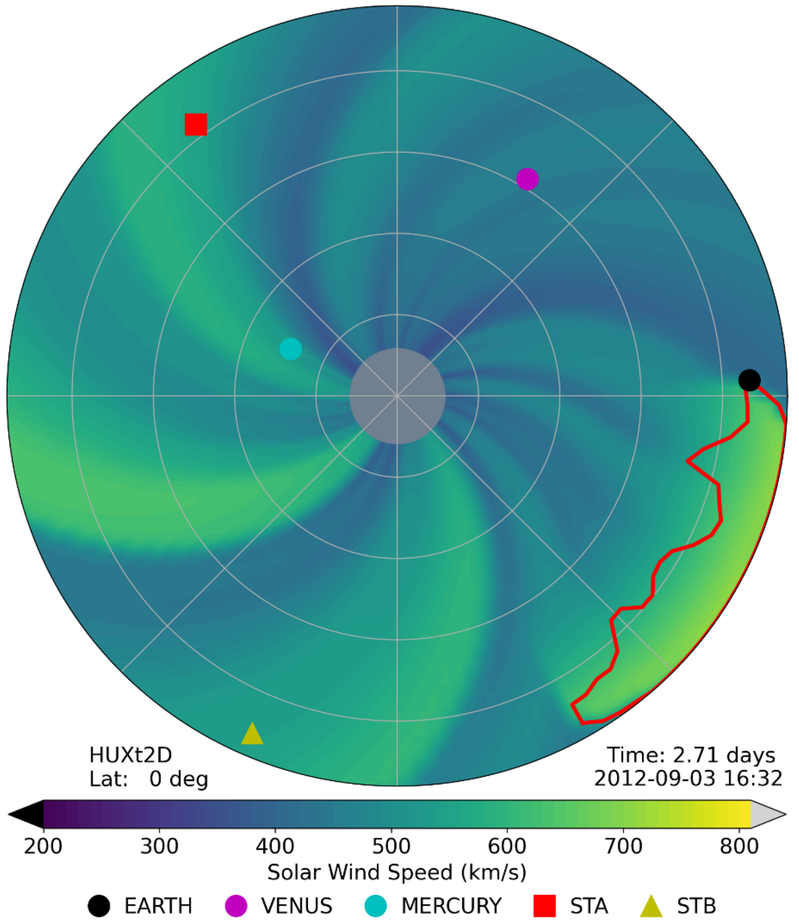
	Ambient solar wind [km/s]	Ambient solar wind + CMEs [km/s]
Prior RMSE	89.3	152.9
Posterior RMSE	79.4	137.6

For all 4 Barnard, 2017 CMEs plus one extra from a similar time

Other problems

CME parameters

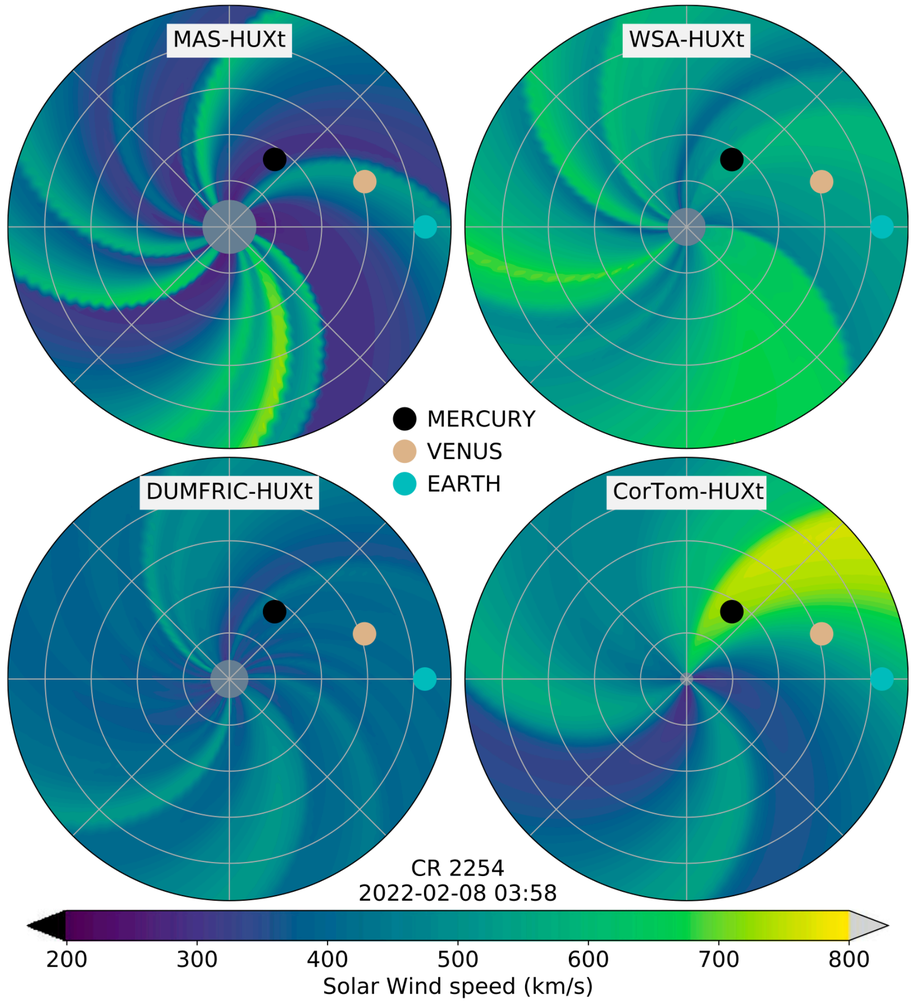
- Large uncertainties on CME cone parameters
- One case study does not give an arrival time at Earth, yet SWPC gets an arrival time with the same parameters
- The CME is observed at Earth
- Difficult to quantify improvement from solar wind if CME parameters are wrong



What next

Future work

- Investigate the impact of the different coronal model inputs - multi-model study
  - Use Gong and HMI magnetograms as input for WSA (alt) and MAS
  - Potentially use other coronal models such as CorTom
- Try to untangle the conditions that DA works best in and why it seems to perform worse elsewhere



Barnard & Owens, 2022. DOI: 10.3389/fphy.2022.1005621

Conclusions

Nearly finished

- Large disagreement between photospheric observatories and coronal models, leading to different solar wind states
- DA brings these closer in agreement
- The ambient solar wind is improved, which should lead to an improvement in CME arrival times
- Lacking confidence in CME parameters - makes a large-scale statistical study difficult without a reliable verification data set

“All models are wrong, DA should be less wrong”

A ~~wise~~ jaded supervisor, 2024