Quantifying the effect of ICME removal and observation age on in-situ solar wind data assimilation

Harriet Turner, Mathew Owens, Matthew Lang, Siegfried Gonzi and Pete Riley

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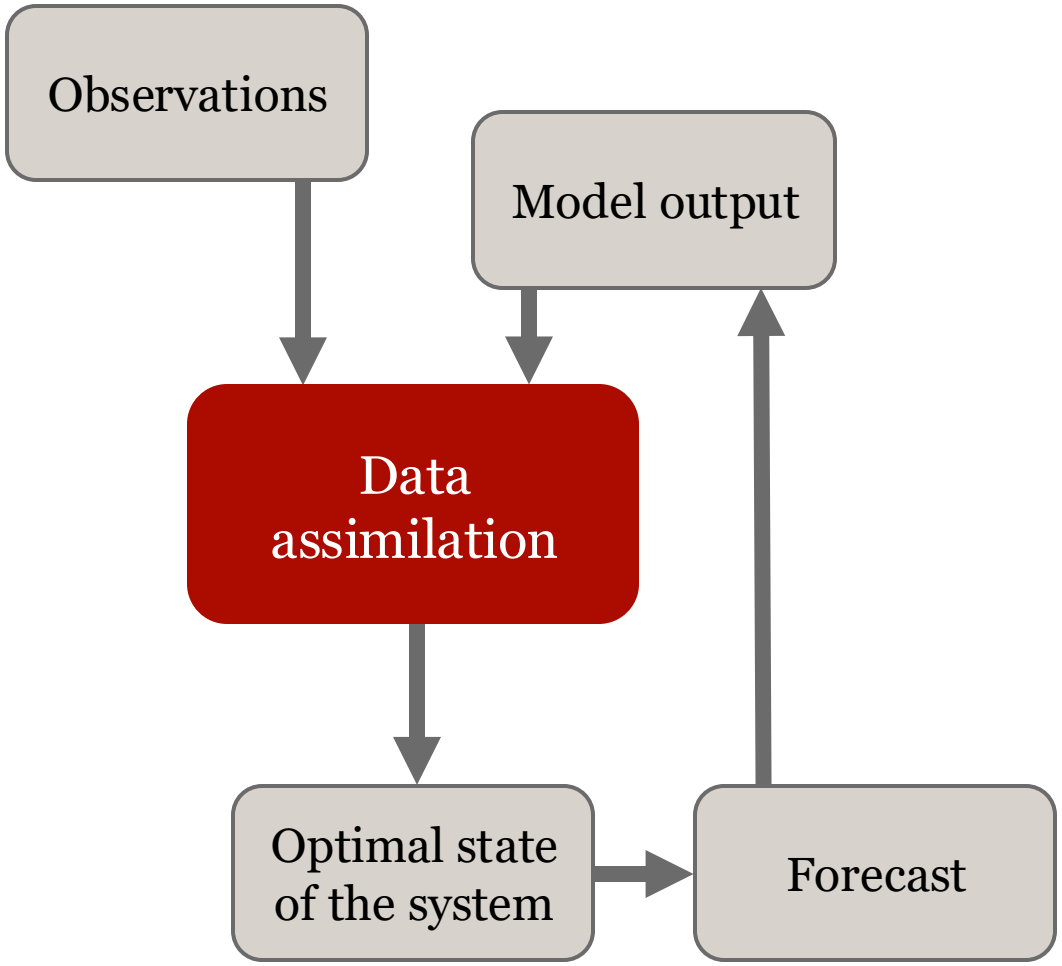
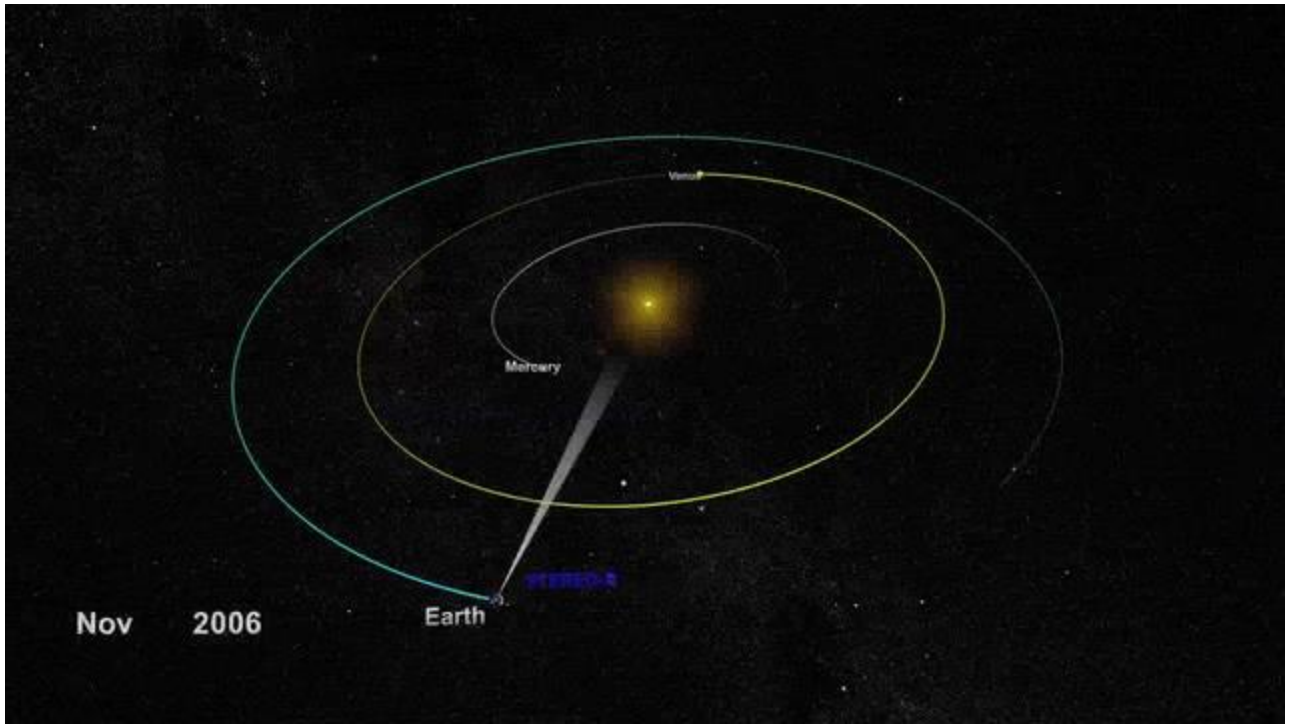
Solar wind and data assimilation

- Data assimilation (DA) combines model output and observations to form an optimum estimation of reality
- Led to large improvements in terrestrial weather forecasting
- Under used in space weather forecasting

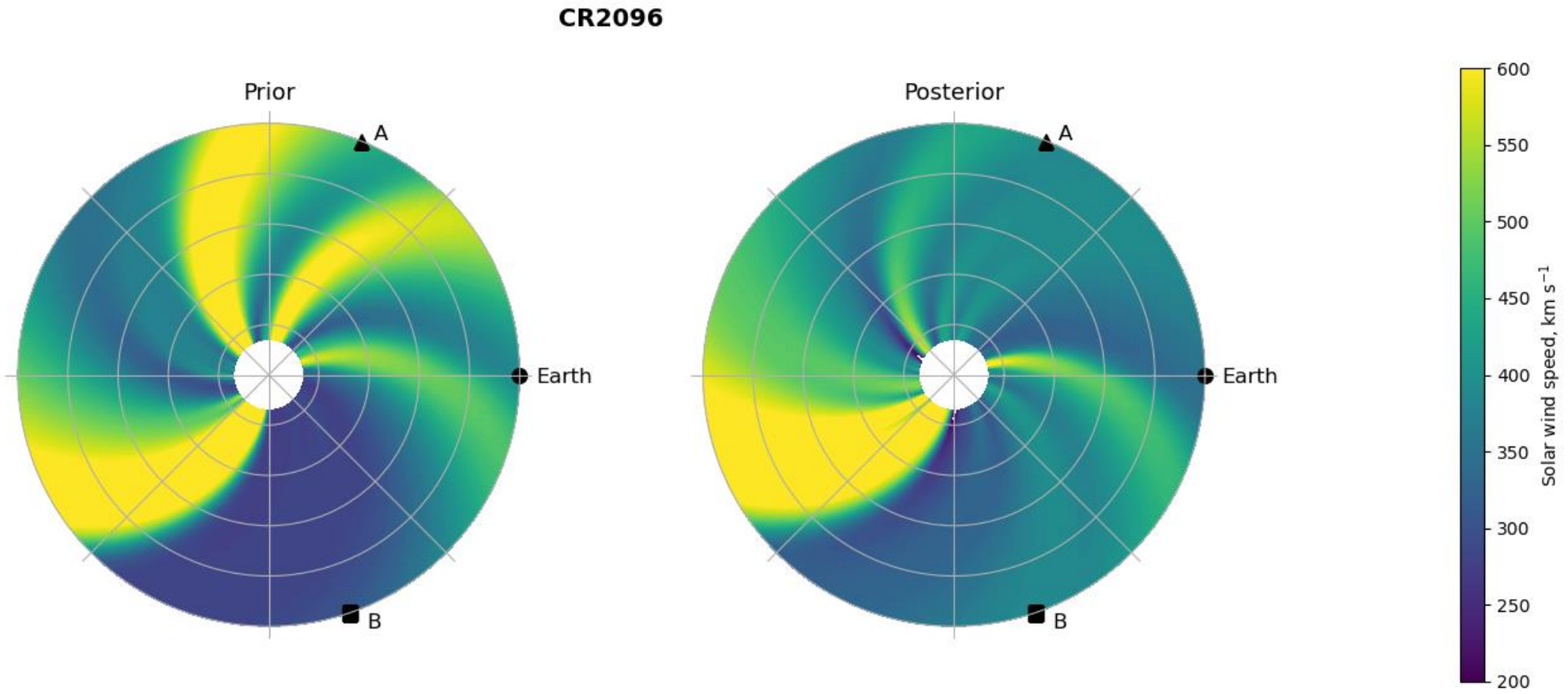


BRaVDA scheme

- Burger Radius Variational Data Assimilation scheme (Lang and Owens, 2019)
- Uses solar wind propagation model and observations from STEREO spacecraft and OMNI dataset
  - 3 sources of observations
  - Spacecraft observations can be assimilated together or individually
- Reconstructs solar wind in 27-day windows from 30 to 215 R_s

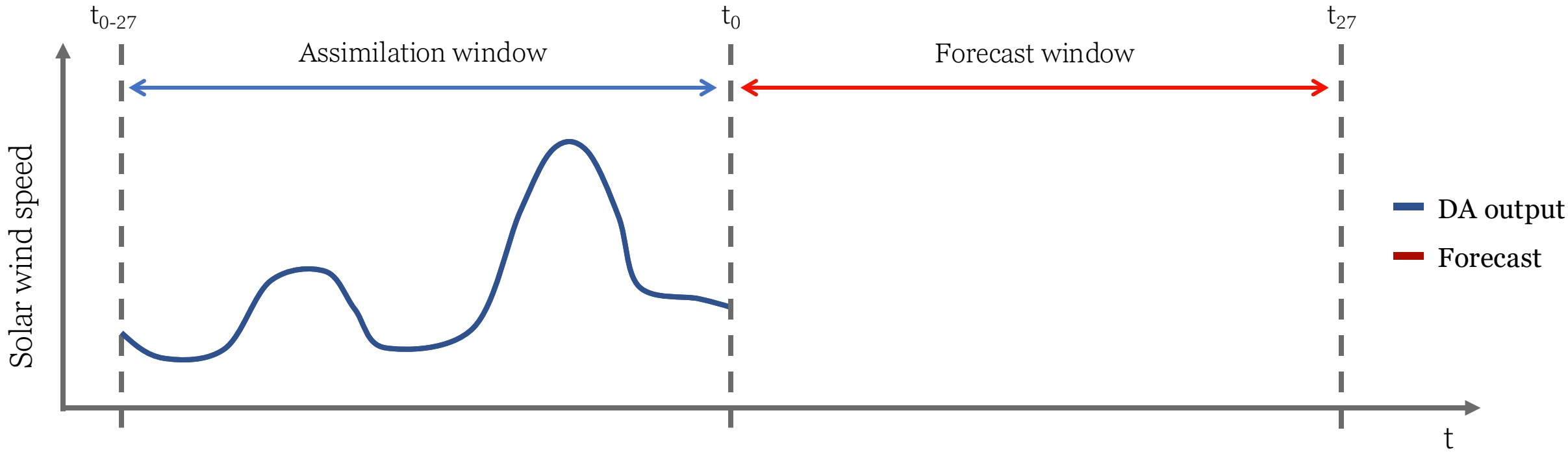


Effect of DA


CR2096
Prior
A
Earth
B
Posterior
A
Earth
B
600
550
500
450
400
350
300
250
200
Solar wind speed, km s^{-1}

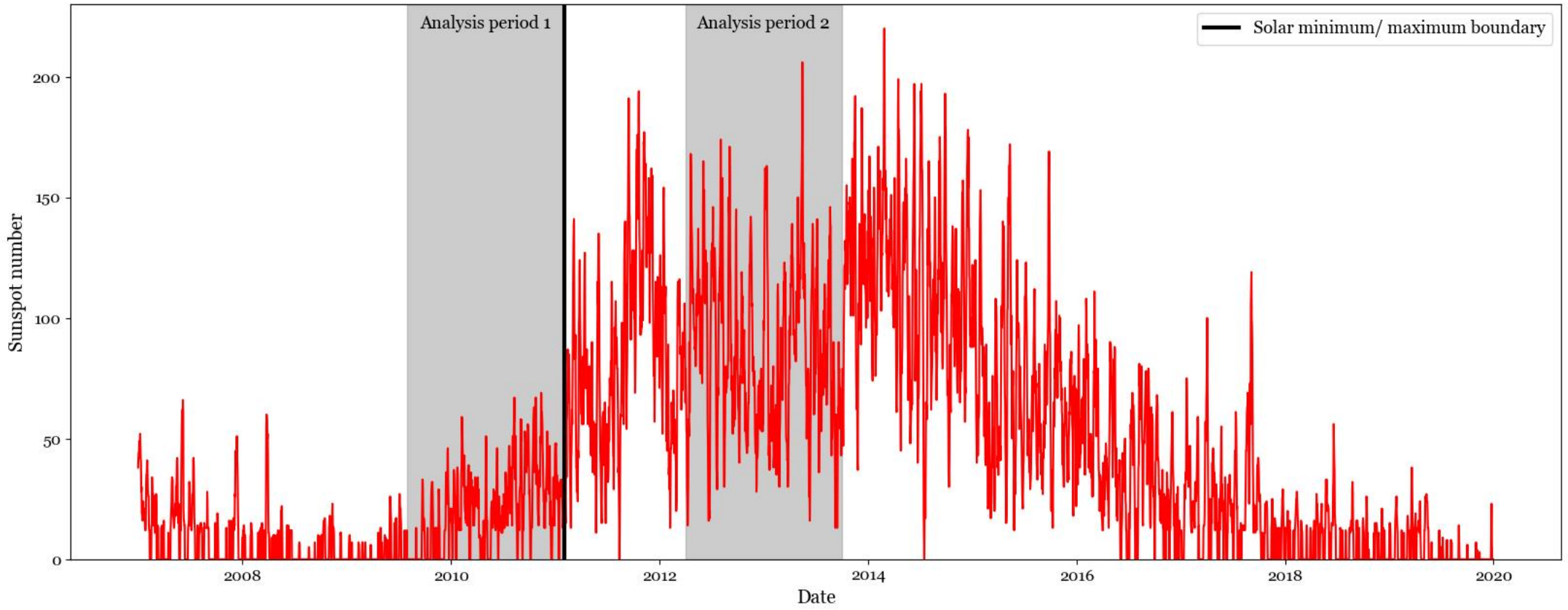
Solar wind forecasts from BRaVDA

- Using the 27-day reconstruction, this can be used to forecast the next 27 days
- Forecasts for Earth, STEREO-A and STEREO-B



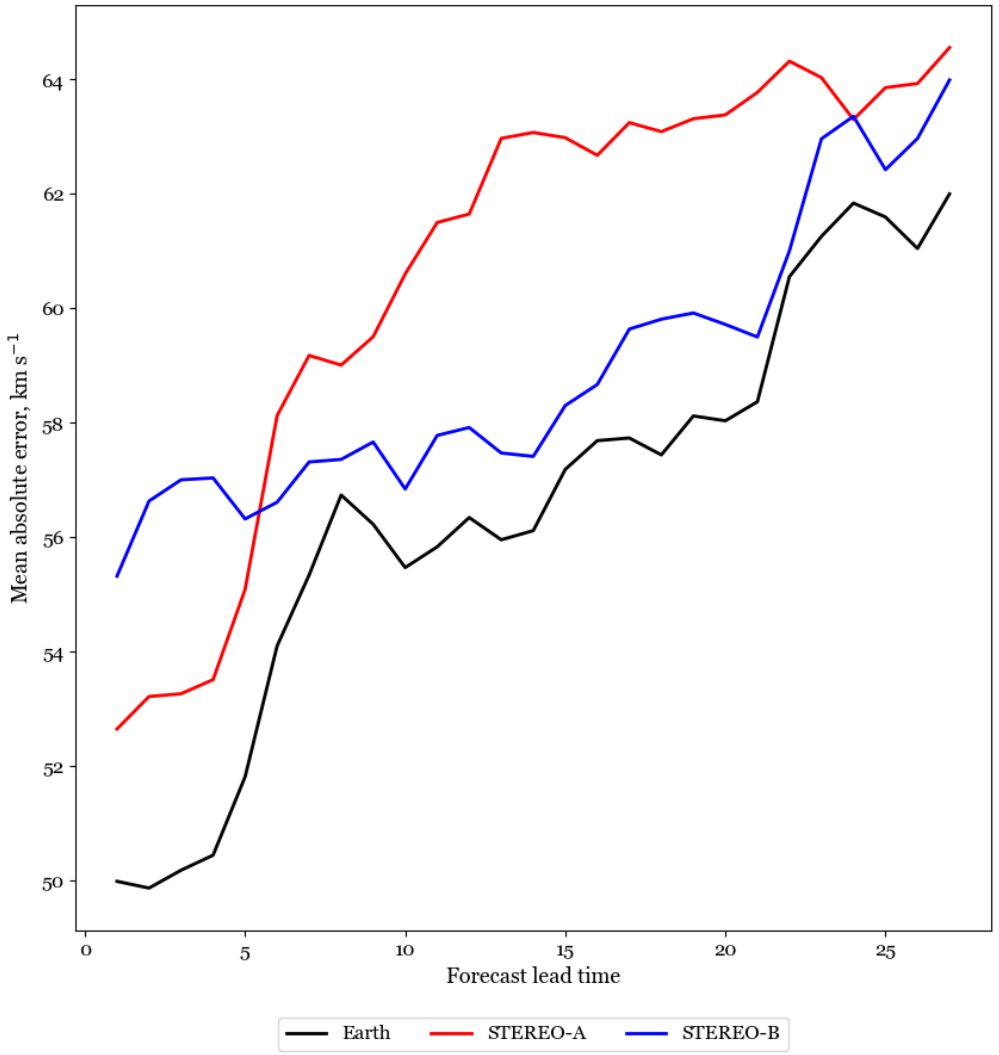
Analysis periods

- Two analysis periods – solar minimum and solar maximum



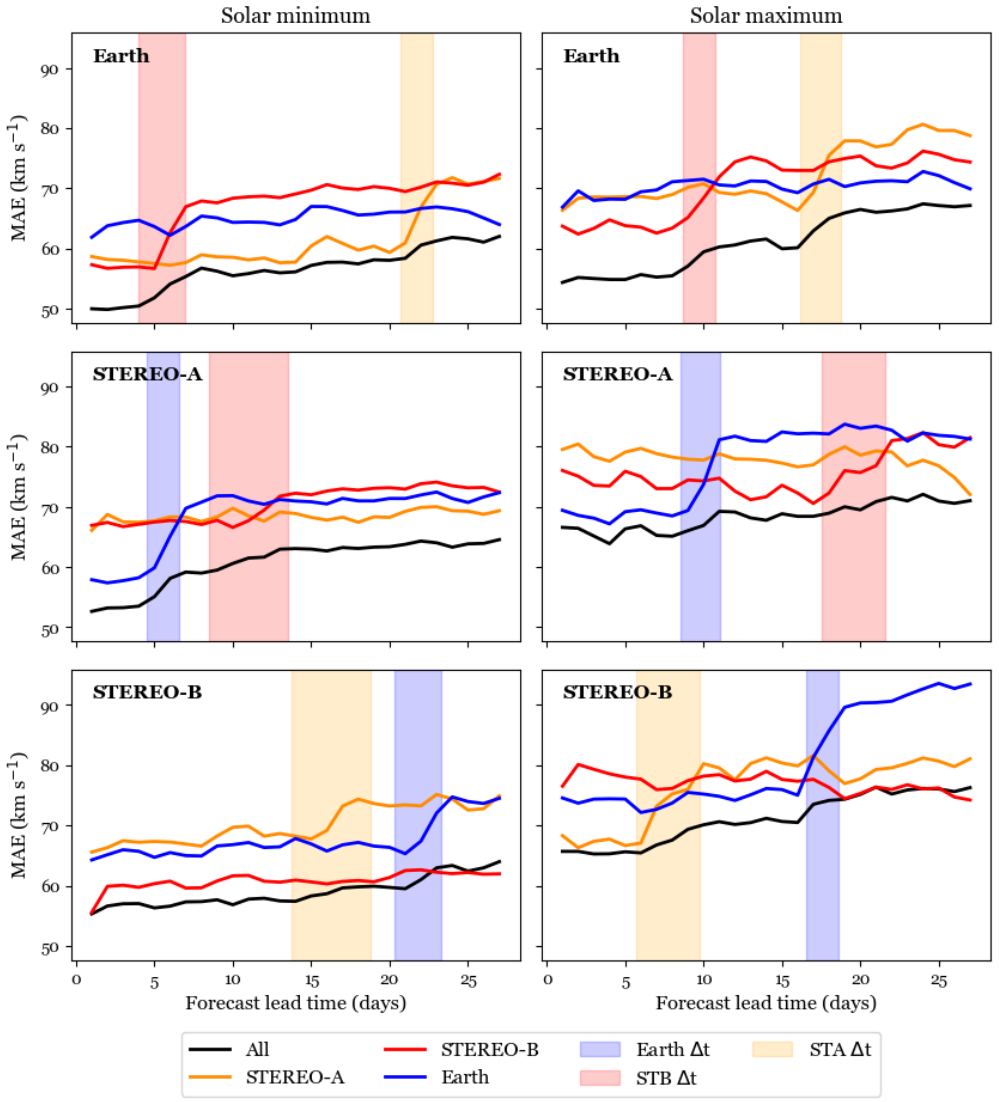
Forecast error against lead time

- Error generally increases with lead time
- Longer lead time forecasts are worse, which would be expected



Age of observations

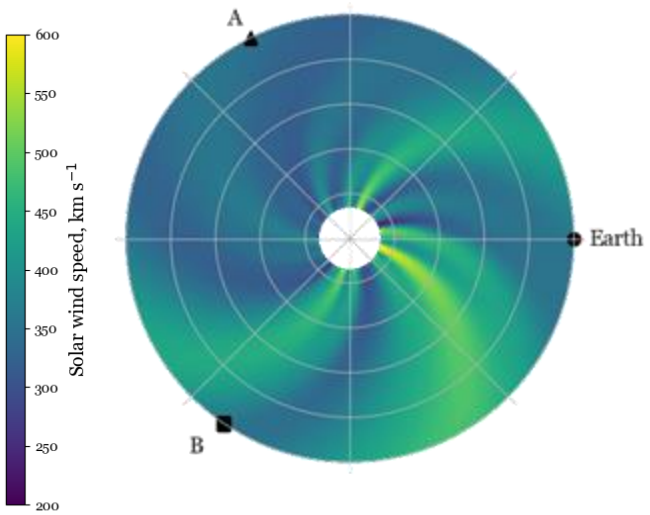
- Increase in error when forecast lead time exceeds corotation time
  - Assimilation of individual spacecraft
- Due to age of observations
- Almost always, better to assimilate multiple spacecraft than single spacecraft

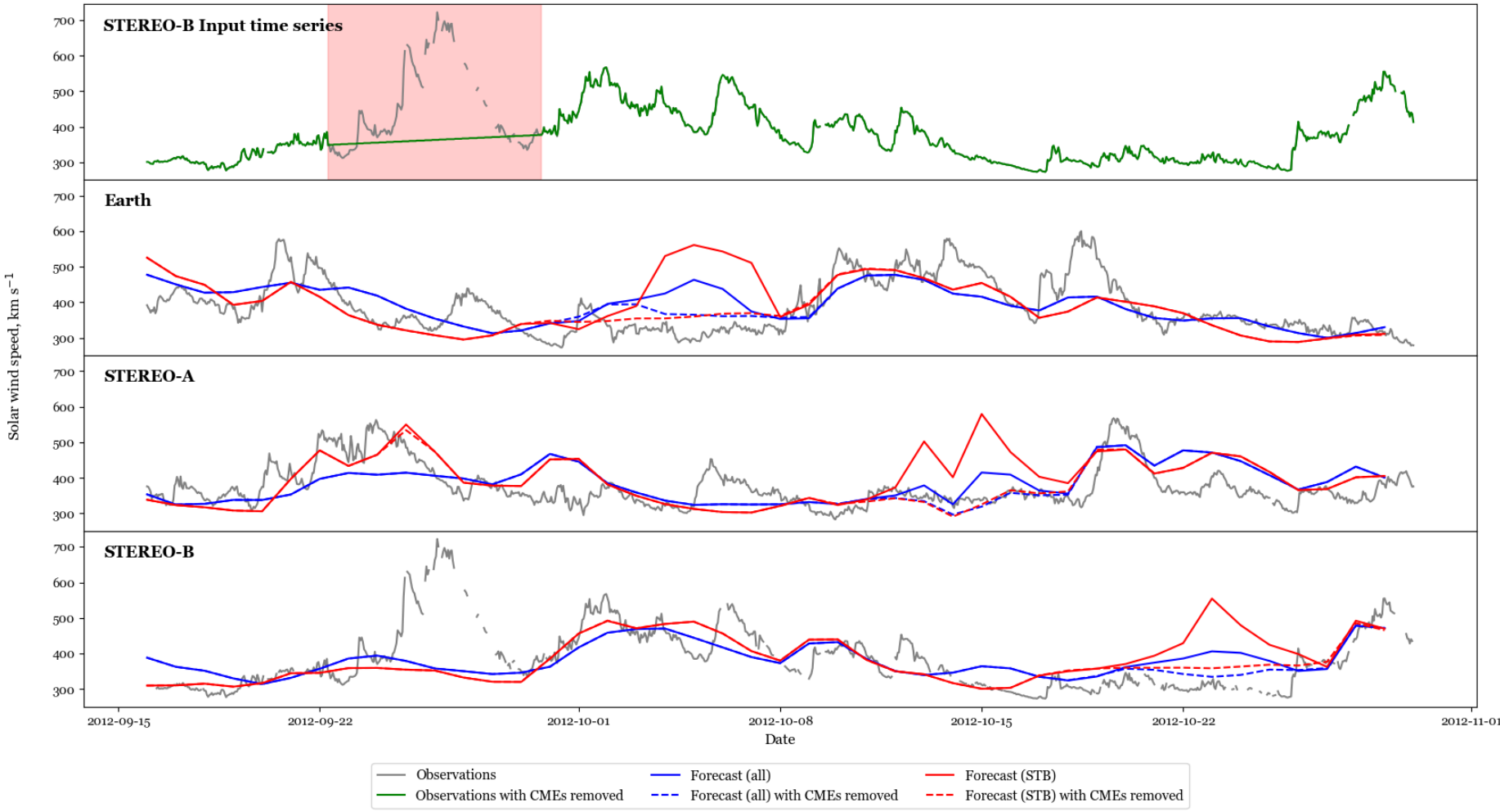


ICME removal

- BRaVDA has no knowledge of ICMEs, so observations are treated as the steady-state solar wind
- ICMEs could produce false streams in the solar wind reconstruction or false alarms in the forecast
- Removed from the DA input time series and linearly interpolated over

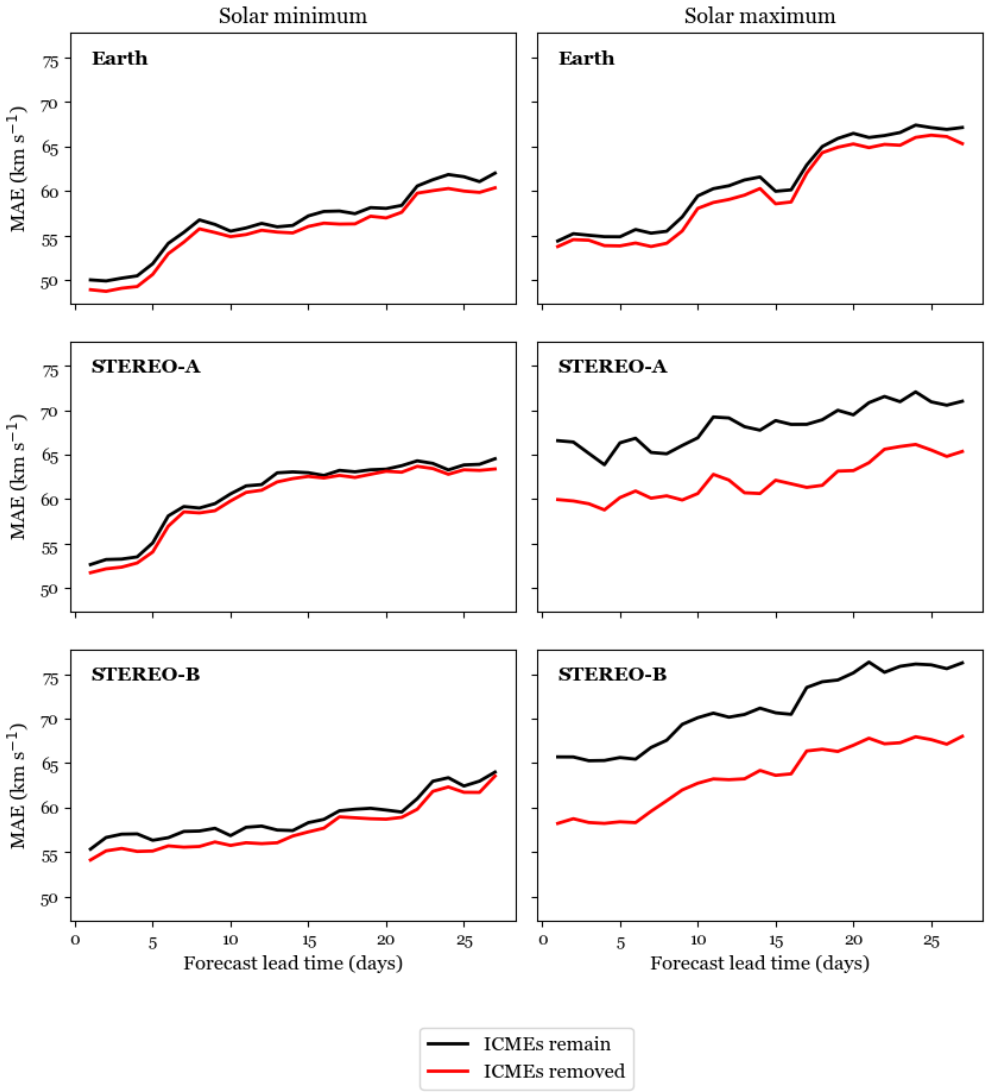
ICME removal





ICME removal

- Applying removal over the analysis periods
- Larger improvement in solar maximum
- More fast ICMEs at STEREO A and B



Future work

- All experiments have been with science-level data
- Testing the performance of BRaVDA with real-time data
  - Required for operational deployment
  - Initial results are showing that the real-time data does not have much of an impact

Conclusions

- Data assimilation is in early development stages for space weather forecasting
  - Our implementation has improved solar wind forecasts
- Looking at 3 years of forecasts:
  - Large impact from observation age
  - Removing ICMEs improves forecast accuracy
- Better to assimilate multiple spacecraft observations rather than single spacecraft observations
- Moving towards using real-time data

Thank you

h.turner3@pgr.reading.ac.uk

References

ESA, 2022. https://www.esa.int/ESA_Multimedia/Images/2018/01/Space_weather_effects

Lang, M. & Owens, M. J. (2019). A Variational Approach to Data Assimilation in the Solar Wind. *Space Weather, 17*(1), 59 – 83. DOI: 10.1029/2018SW001857

NASA, 2022. https://www.nasa.gov/mission_pages/sunearth/news/News070712-X1.1flare.html

Owens, M., Lang, M., Barnard, L., Riley, P., Ben-Nun, M., Scott, C. J. & Gonzi, S. (2020). A Computationally Efficient, Time-Dependent Model of the Solar Wind for Use as a Surrogate to Three-Dimensional Numerical Magnetohydrodynamic Simulations. *Solar Physics, 295*(3). DOI: 10.1007/s11207-020-01605-3

WDC-SILSO, Royal Observatory of Belgium, Brussels. https://wwwbis.sidc.be/silso/home