University of Reading

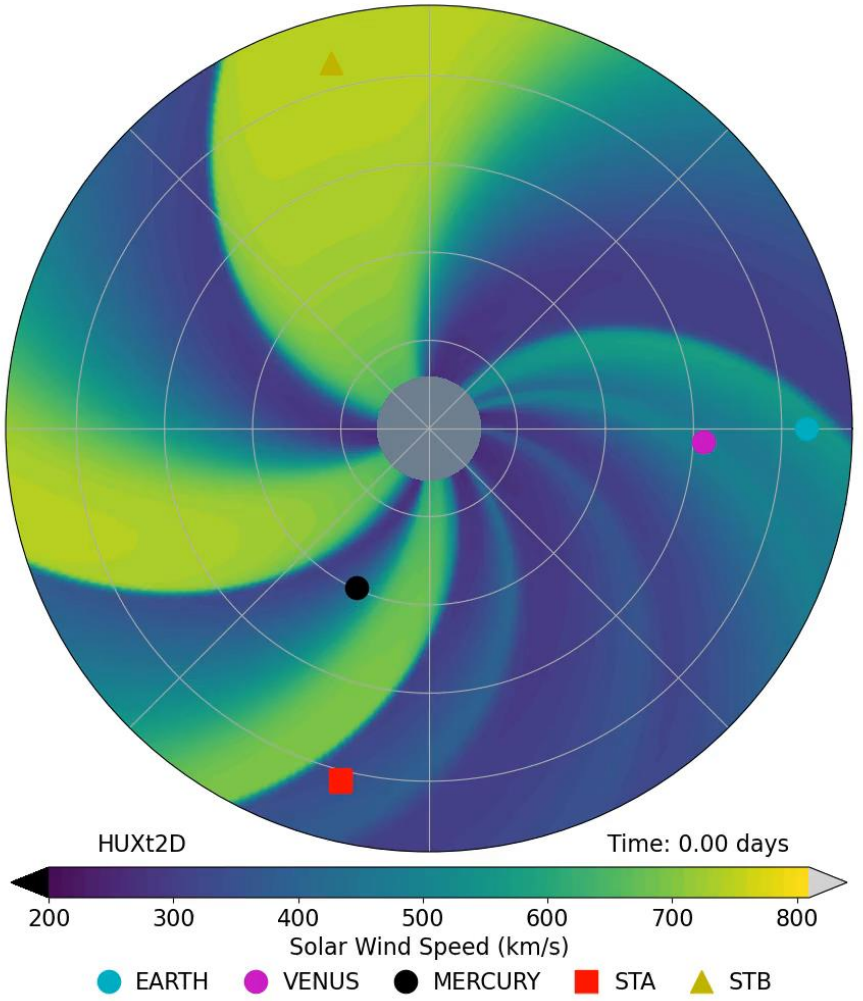
The influence of spacecraft latitudinal offset on the accuracy of corotation forecasts

Harriet Turner, Mathew Owens, Matthew Lang and Siegfried Gonzi

NAM 2021

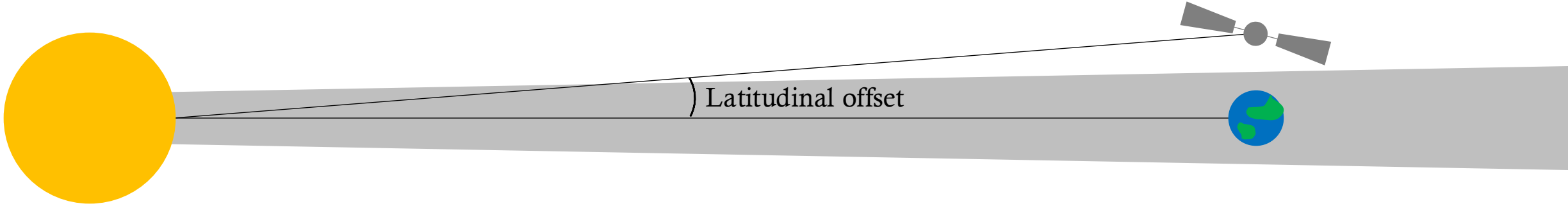
Corotation forecasts

- Assumes steady-state solar wind in the reference frame rotating with the Sun
- Uses observations on the ecliptic plane
- Corotation time determined by longitudinal and radial separation



Connected variables

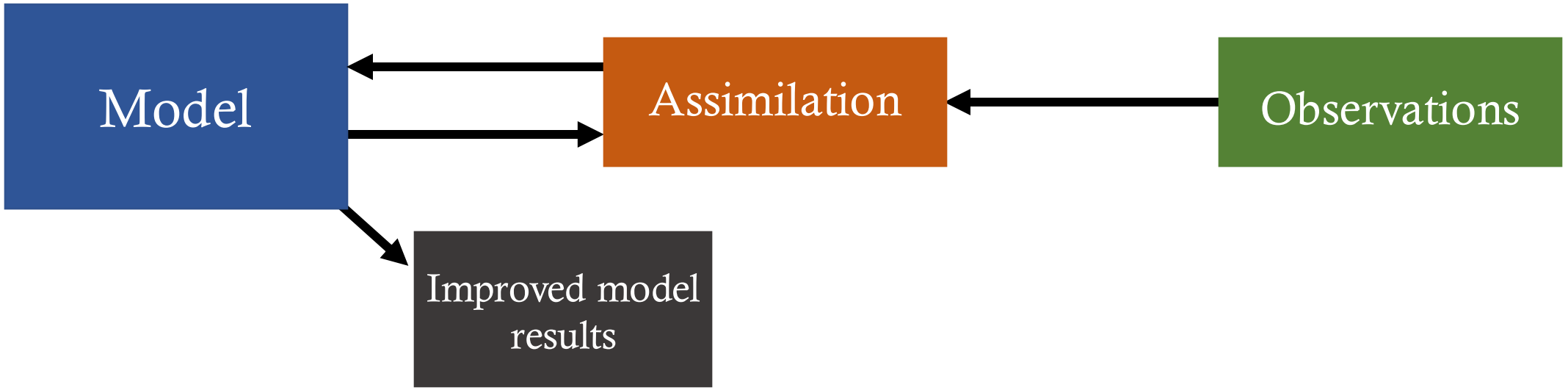
- Corotation time – longer corotation times makes the steady-state assumption less valid
- Solar activity – affects time evolution of the solar wind
- Latitudinal offset – two spacecraft observing different solar wind structures



Motivation – data assimilation

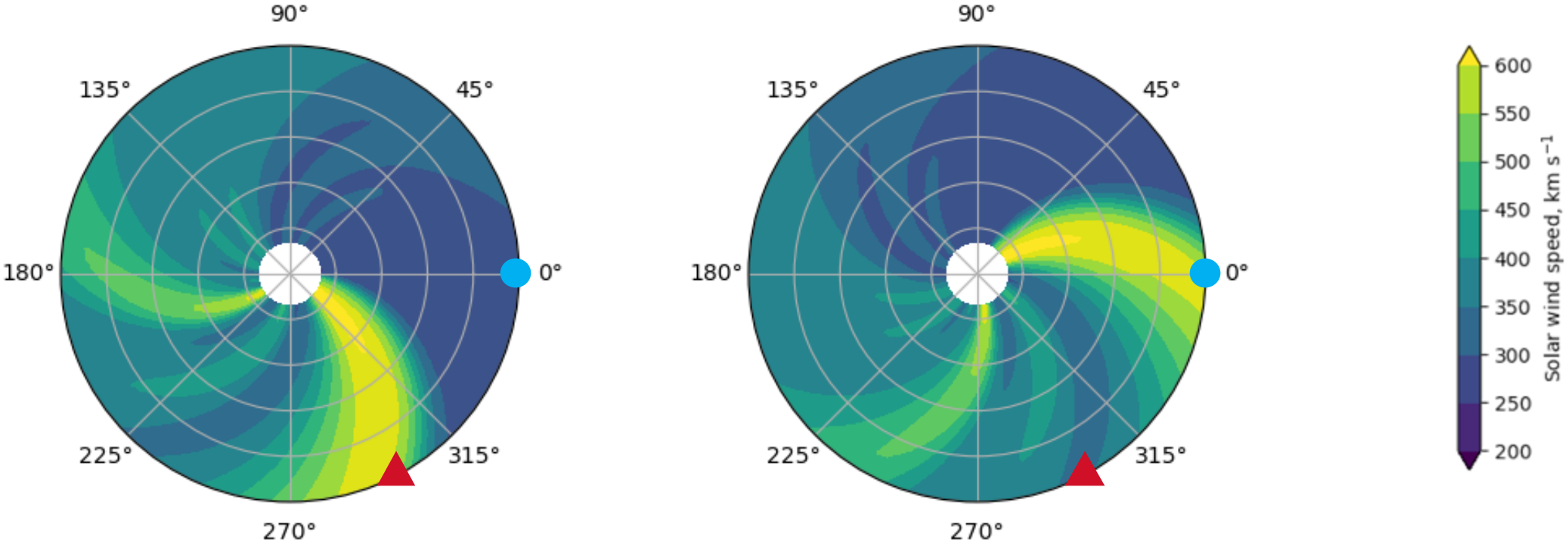
- Data assimilation (DA) combines observations and model output to find an optimum estimation of reality

- Investigate uncertainties through analysis of corotation forecasts



L5 Lagrange point

- Mission due for launch in 2027 to provide a side-on view of Earth-directed CMEs

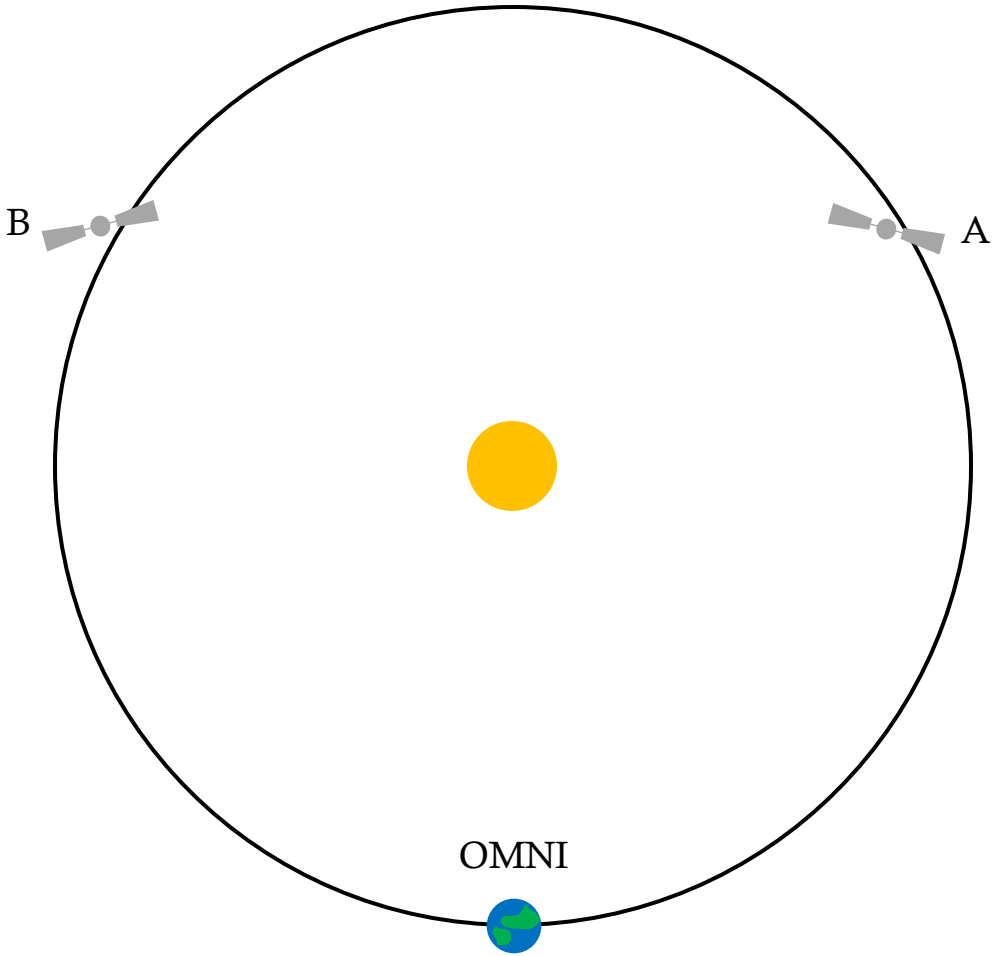


time = t

time = t + 4.5 days

Data

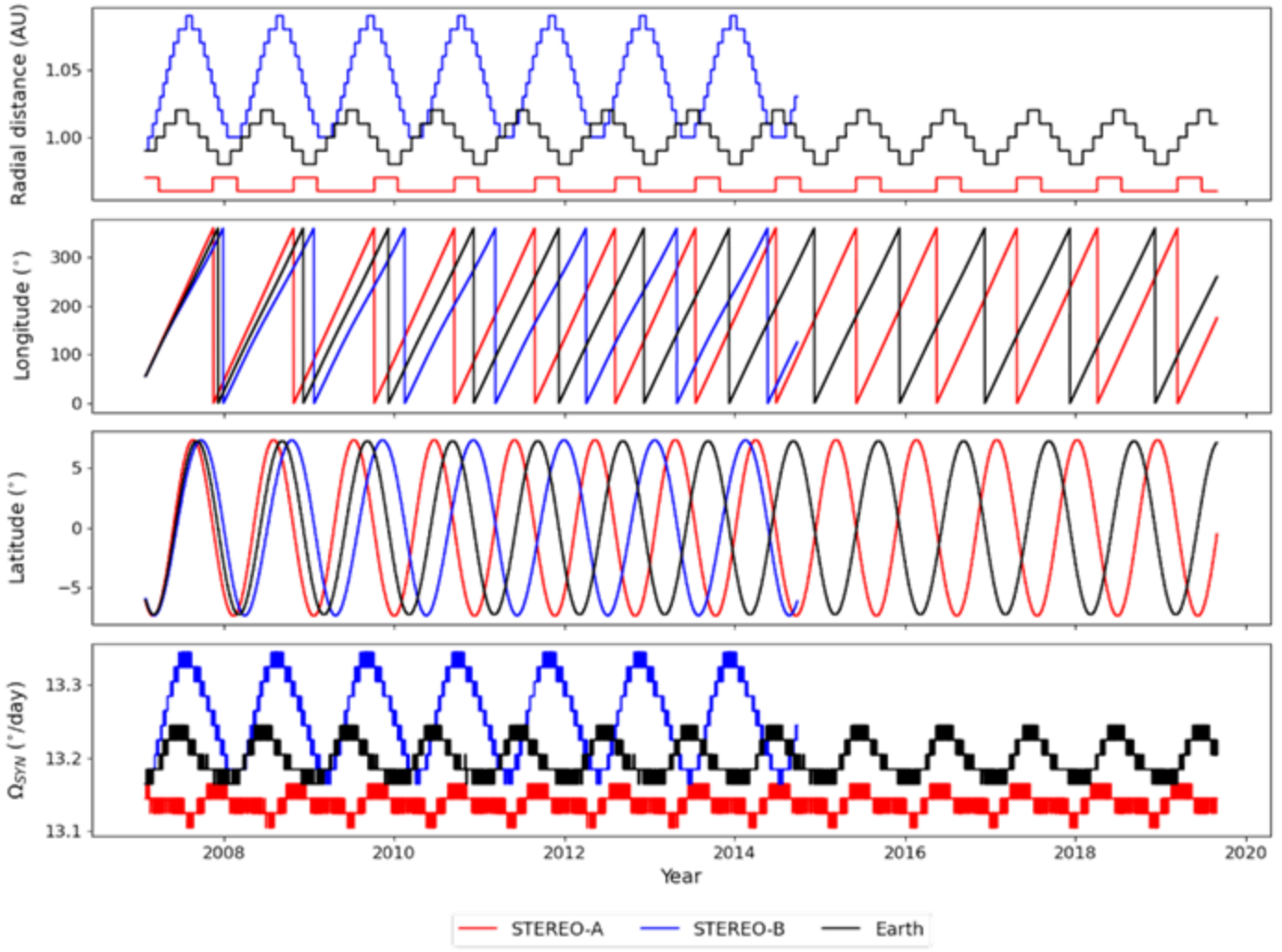
- Using STEREO mission and OMNI data set
- 6 possible corotation combinations
- Majority of analysis for 2007 – 2014



Methodology

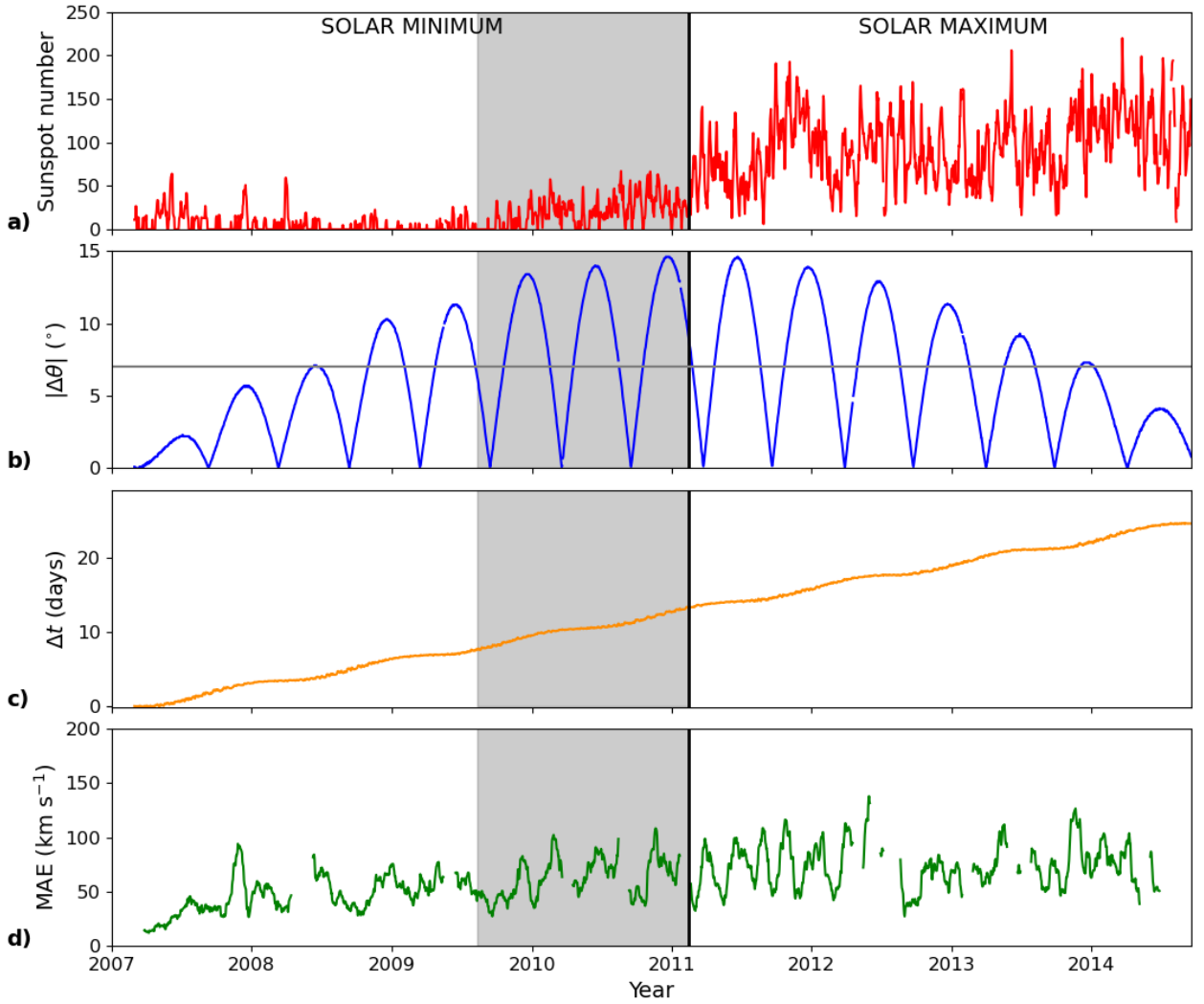
University of Reading

- Previous methods used only longitudinal and radial separation
- Included variation in spacecraft orbital angular speed in the inertial reference frame



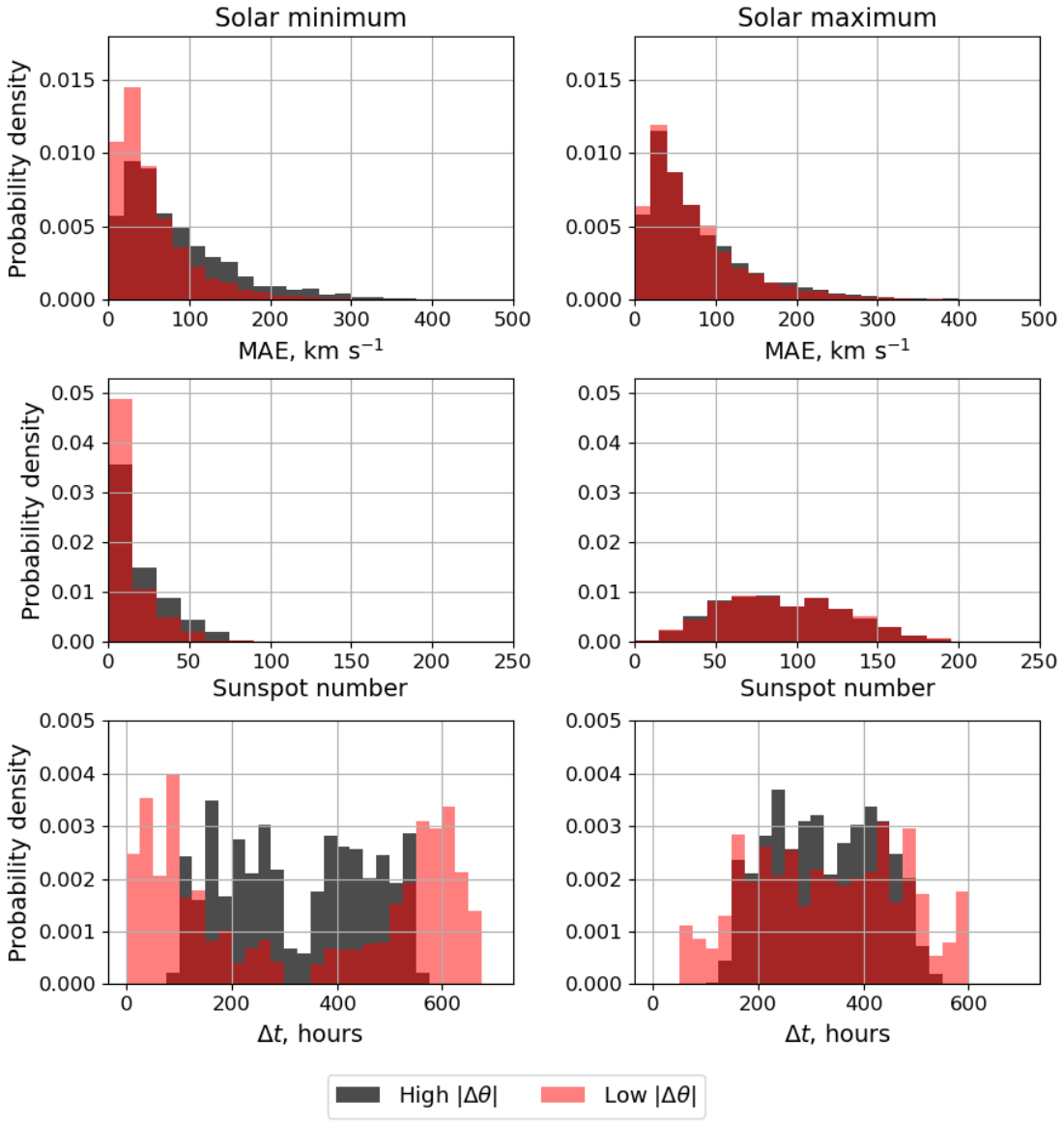
Results

- Complications due to variable aliasing (misidentification of a signal)
- Low latitudinal offset at times of low corotation time and sunspot number
- Difficult to ascribe changes in mean absolute error (MAE) to one variable



STEREO-B to STEREO-A corotation
$|\Delta\theta|$ = latitudinal offset, Δt = corotation time

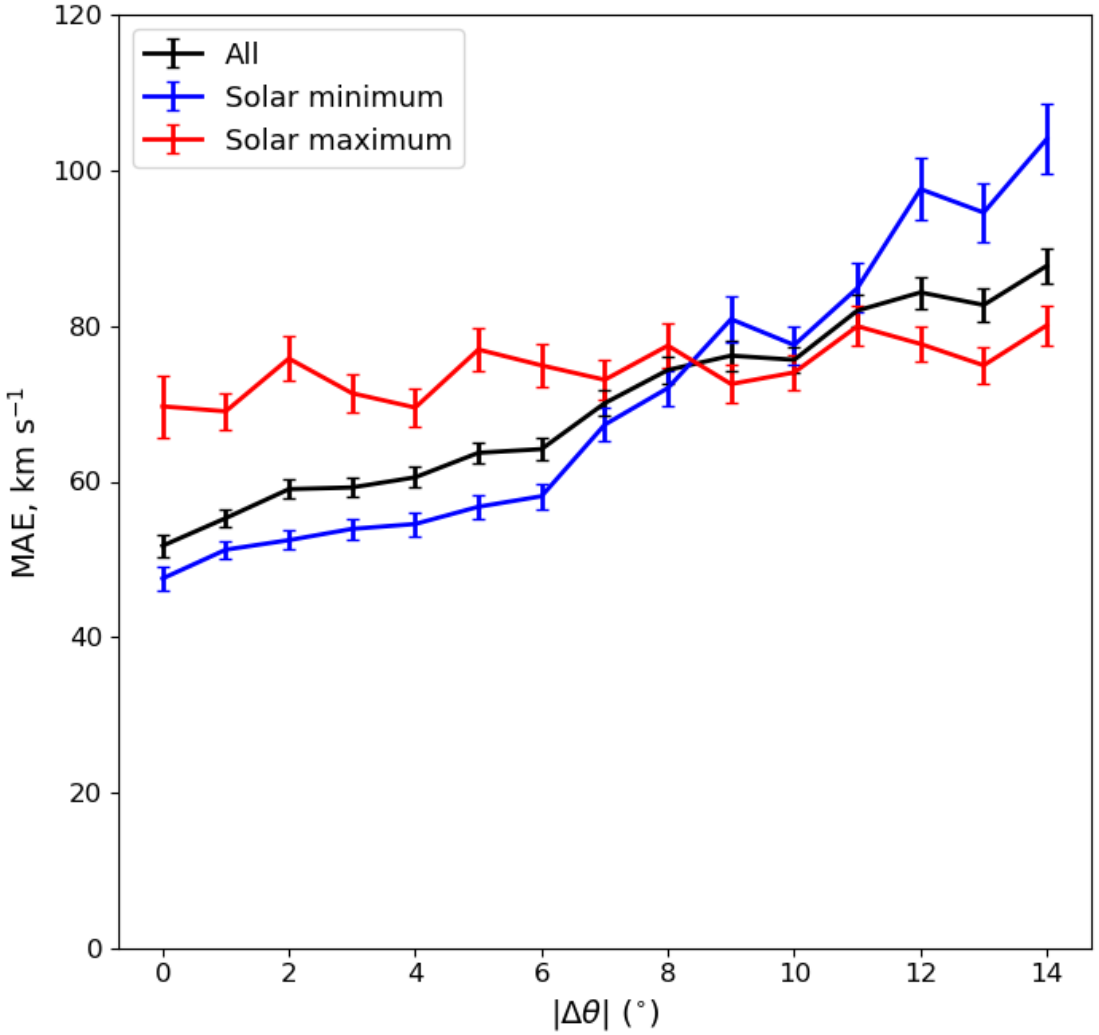
Variable aliasing



All corotations

High: $|\Delta\theta| \geq 7°$
Low: $|\Delta\theta| < 7°$

Latitudinal offset with MAE



All corotations

Restricted period

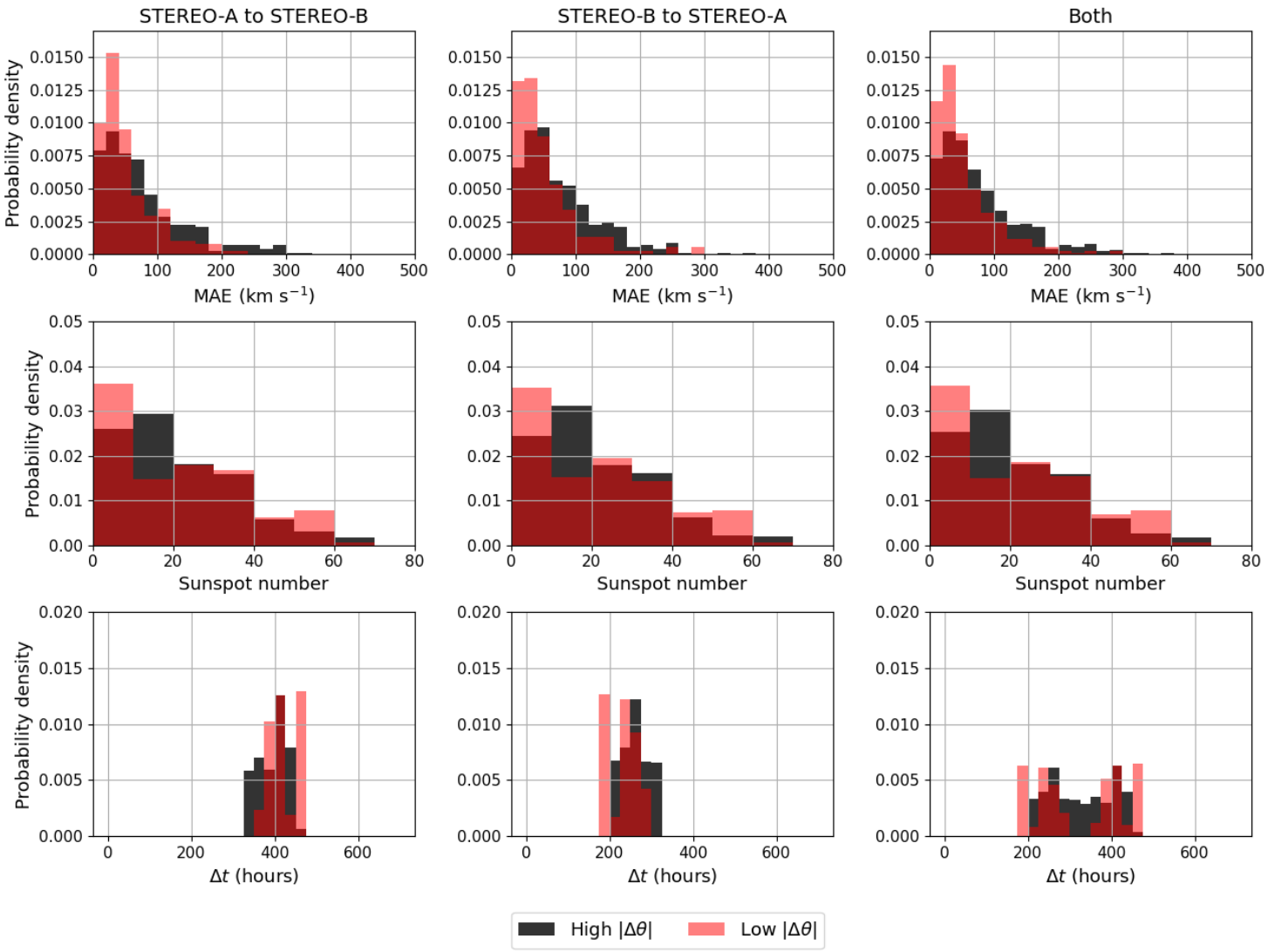
University of Reading

- To limit aliasing, a period of approximately constant sunspot number and even sampling of latitudinal offset at all corotation times was required
- Used period from 08/2009 to 02/2011 – time up to the transition from solar minimum to maximum
- Isolate latitudinal effect

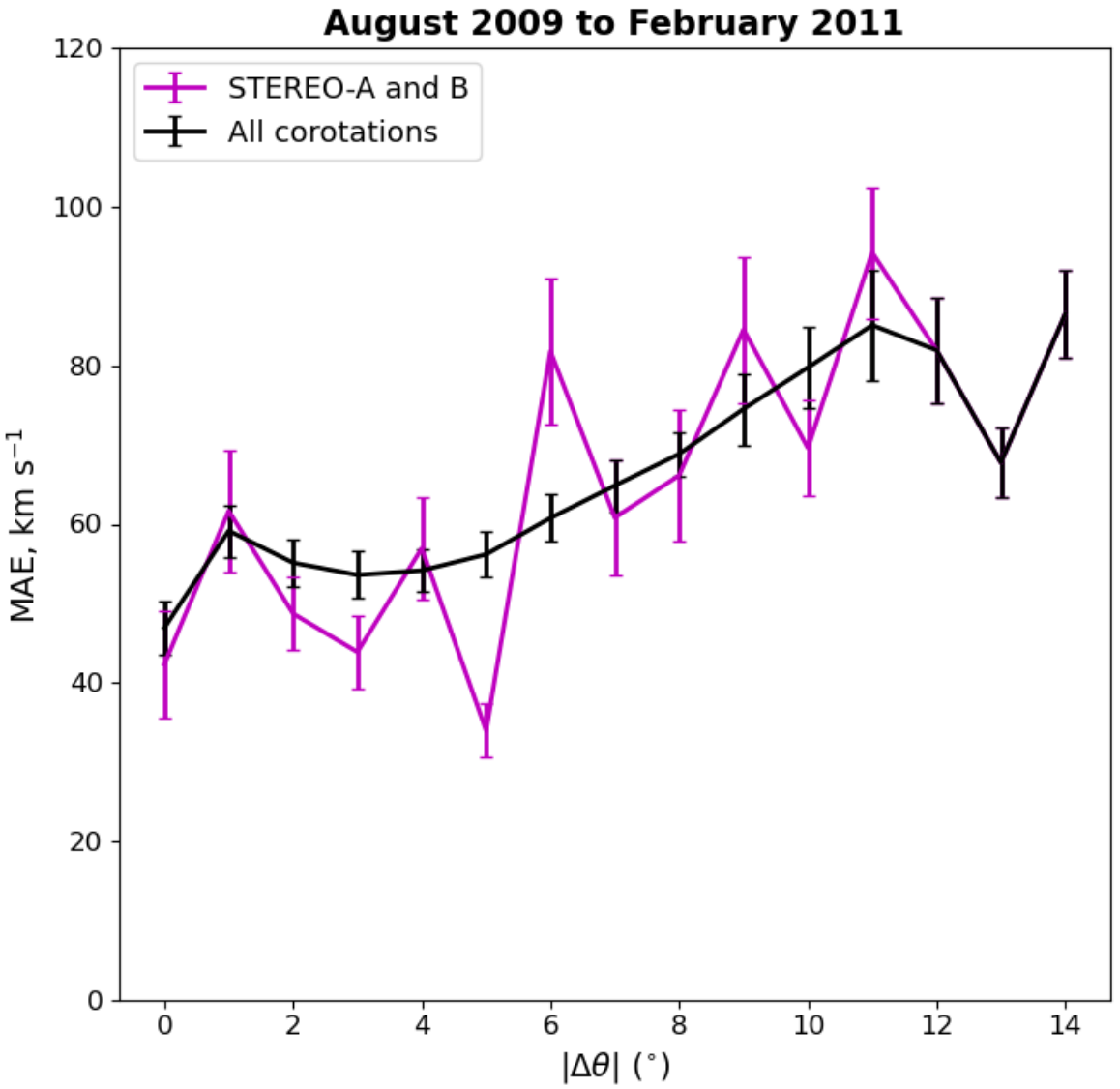
Restricted period

University of Reading

- MAE:
  - High $|\Delta\theta| = 77.7 \pm 2.4$ km s^{-1}
  - Low $|\Delta\theta| = 53.3 \pm 2.4$ km s^{-1}
- Sunspot number:
  - High $|\Delta\theta| = 20.2 \pm 0.6$
  - Low $|\Delta\theta| = 19.9 \pm 0.9$
- Corotation time:
  - High $|\Delta\theta| = 327.8 \pm 2.8$ hrs
  - Low $|\Delta\theta| = 327.1 \pm 5.0$ hrs



Latitudinal offset with MAE



Impact from latitudinal offset

University of Reading

- Approximately constant error up to 6° separation
- Increasing dependence for > 6°

	Correlation coefficient	**p-value**
$\lvert\Delta\theta\rvert < 6$	0.40	0.44
$\lvert\Delta\theta\rvert \geq 6$	0.75	0.02

Future work

University of Reading

- Implement results into the DA scheme
- Validate the changes
- Look at CME propagation through the improved ambient solar wind

Conclusions

University of Reading

- Used STEREO spacecraft and OMNI data set for corotation forecasts
- Approximately constant error contribution from latitudinal offset up to 6 degrees, increasing dependency above this
- Latitudinal offset should have little effect on L5 corotation
- Will be used to improve data assimilation

Work is available pre-print at https://www.essoar.org/doi/abs/10.1002/essoar.10507131.1

University of Reading

Thank you!

I am happy to answer any questions

h.turner3@pgr.reading.ac.uk

NAM 2021