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Timescales of Birkeland currents driven by the IMF

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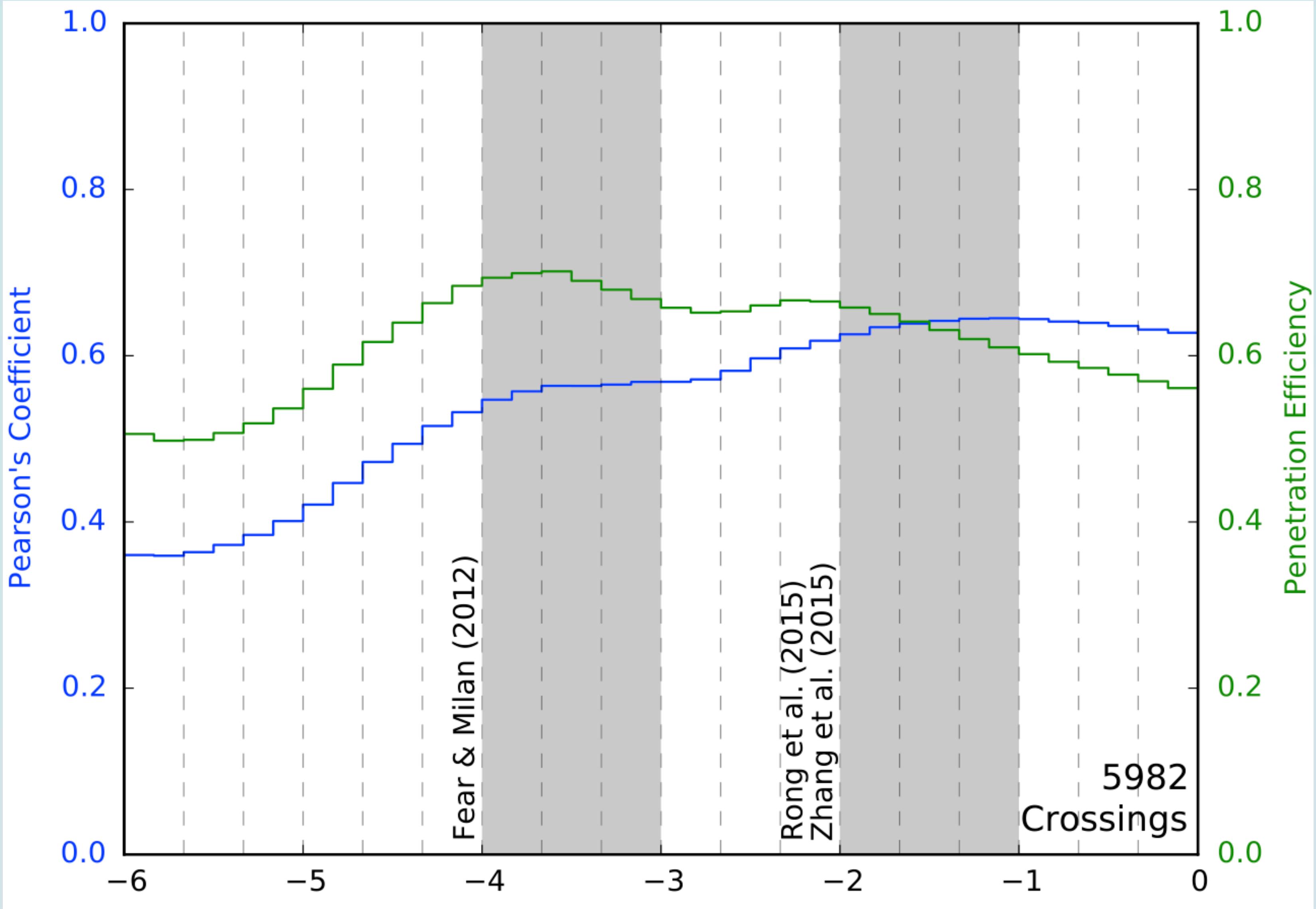
Timescales in the literature

- Timescales of Earth's reaction to southward IMF are relatively well understood:
  - ~60 minutes before first substorm (Milan et al., 2009)
  - ~2.5 hour periodicity in substorms thereafter (Freeman & Morley, 2004)
- Some controversy over timescales of reaction to B_Y effects:
  - Browett et al. (2017) argue for timescales with peak at 90 minutes for southward IMF or 180 minutes for northward IMF, based on field line propagation argument
  - Tenfjord et al. (2015) argue for timescales of 10–20 minutes, based on Alfvén wave argument

IMF *By* timescales – Browett et al. (2017)



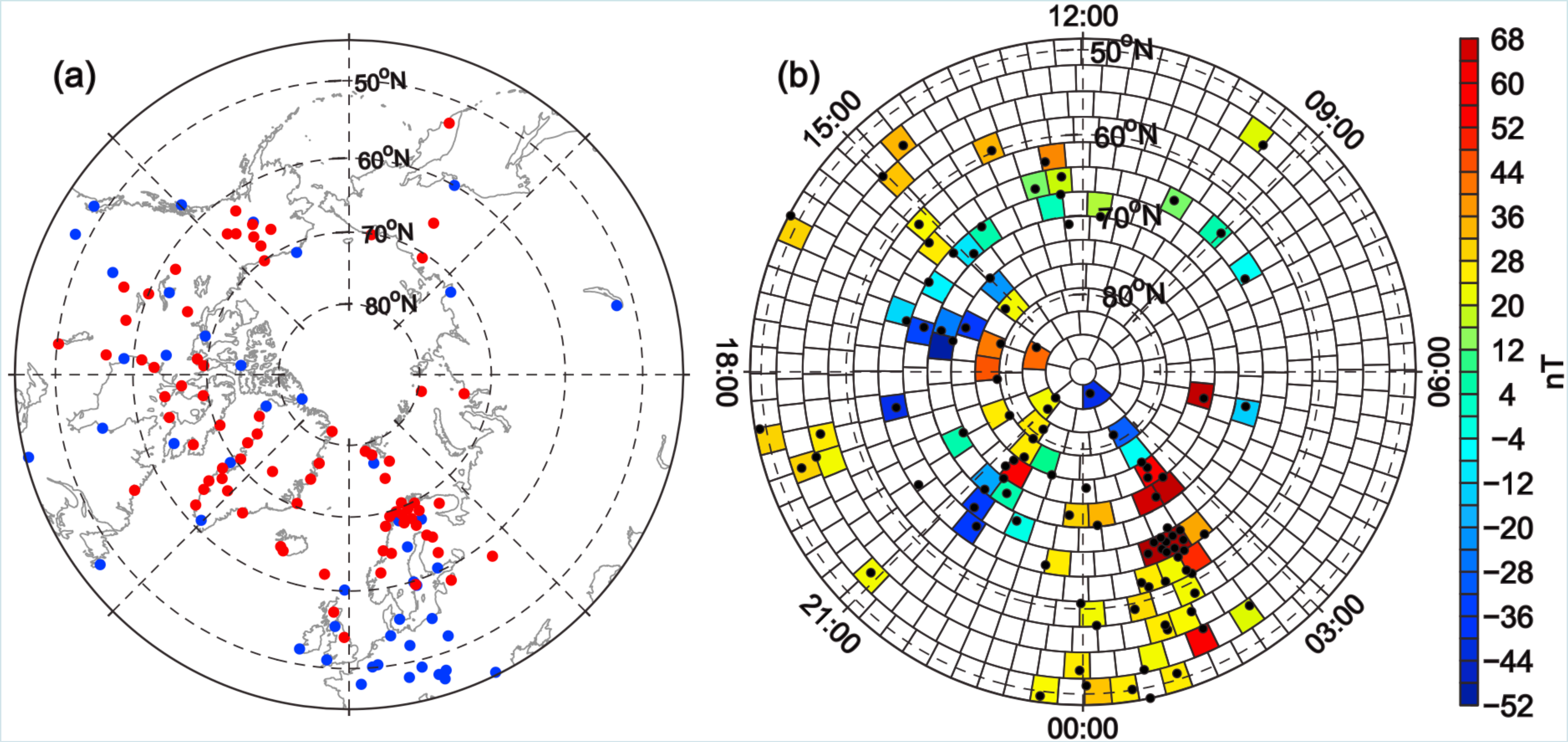
Browett et al. (2017)

Browett et al. (2017) argued for a bimodal distribution with peaks at ~90 and ~180 minutes, consistent with previous studies

AMPERE timescales

- AMPERE yields current density *j* on maps of 50° (co)latitude and 1 hour of MLT (1200 coordinates in total)
- Current density is given in a ten minute long sliding window evaluated every two minutes
- If we treat the 1200 coordinates each as a separate time series, we can correlate each with some solar wind stimulus (e.g. IMF)
- Lagging one with respect to the other allows us to find the lag at which the best correlation is achieved, which we interpret as the timescale on which the solar wind stimulus drives the Birkeland current
- This technique was pioneered with SuperMAG (Shore et al., in review)

SuperMAG – Shore et al. (2017)

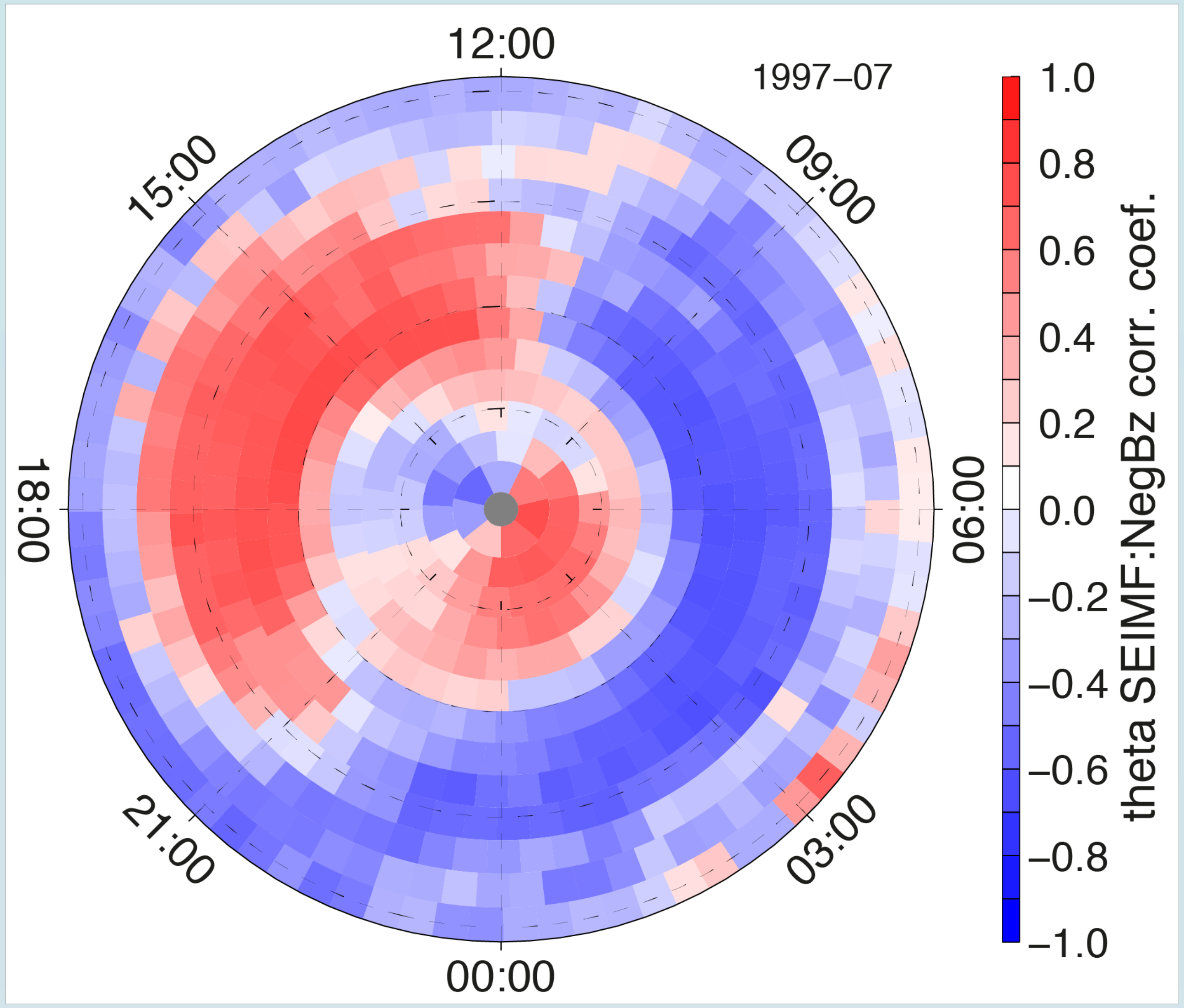


Shore et al. (2017)

125 magnetometers reporting data on 1 February 2001

155 equal-area bins defined in Quasi-Dipole latitude and MLT

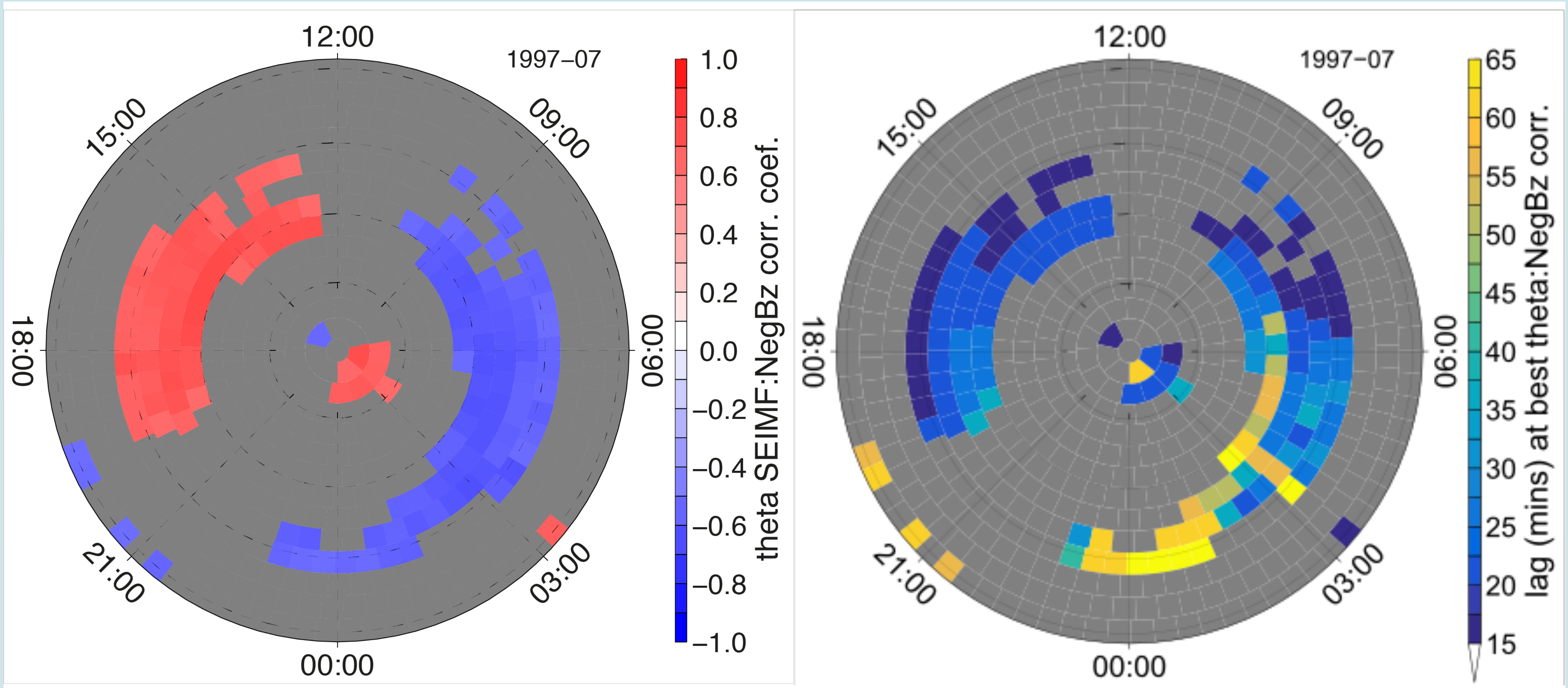
This method with SuperMAG



Shore (private communication)

- Surface and external induced magnetic field (SEIMF)
- Calculated by determining principal modes of variation of SuperMAG data and infilling based on those modes (Shore et al., 2017 a, b, in review)
- The peak correlation of the SEIMF and negative Bz from the IMF for July 1997

This method with SuperMAG



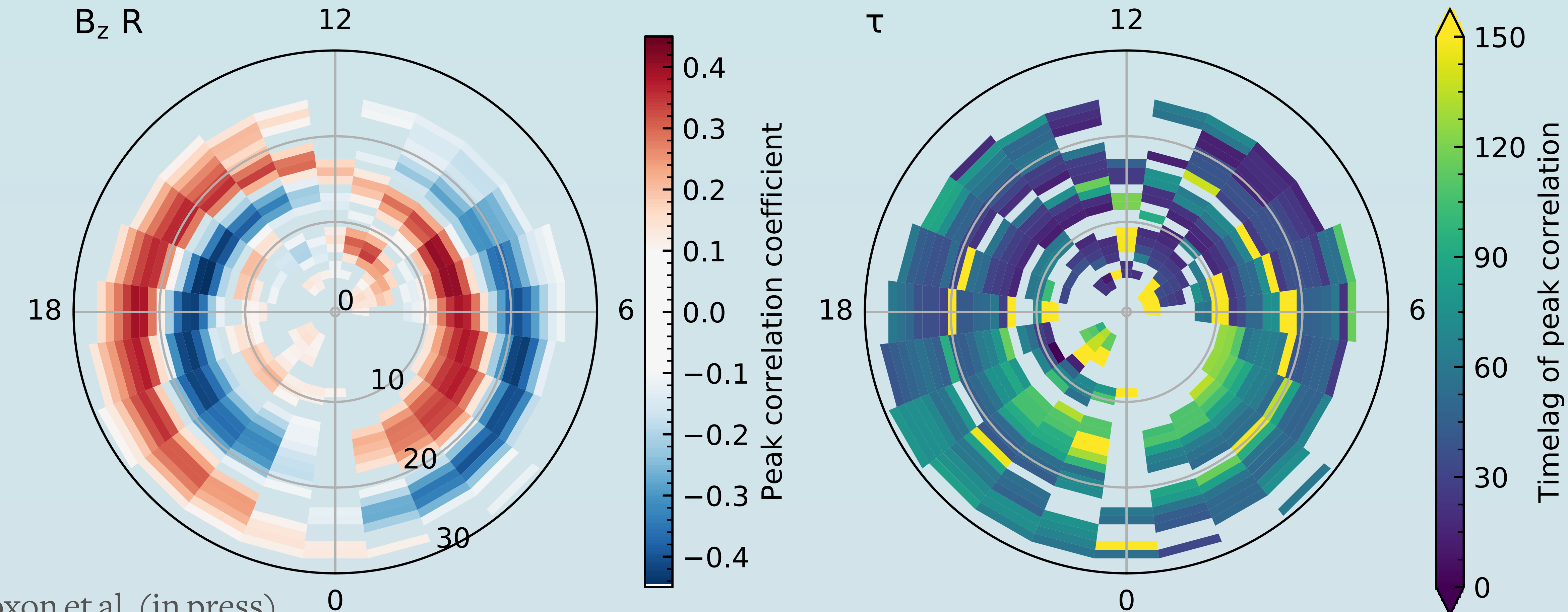
Shore (private communication)

Left: The upper quintile of correlations in July 1997

Right: The lags which yield those correlations

Correlation of B_Z with j

2010-03-01 to 2010-04-01 in the Northern Hemisphere



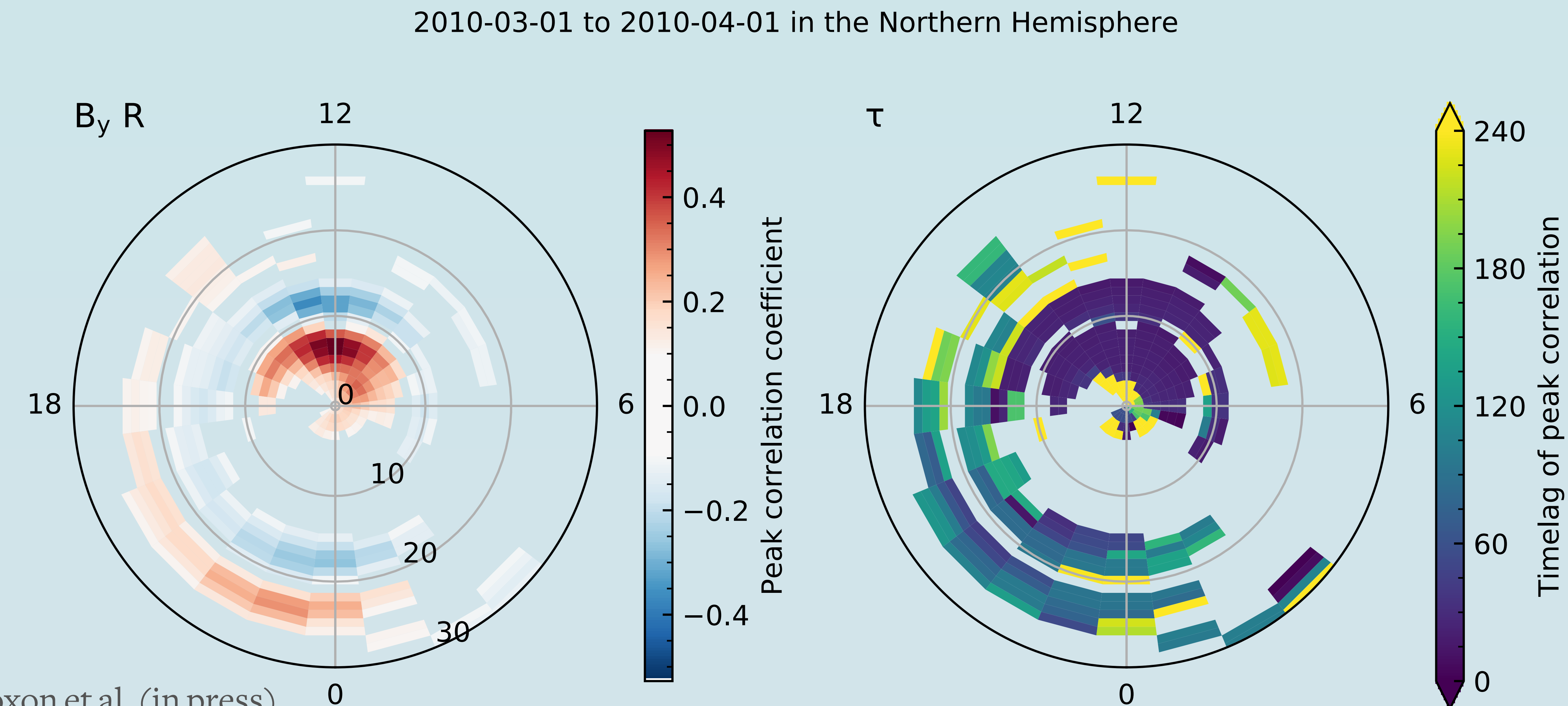
Coxon et al. (in press)

The R1/R2 current system is clearly visible (left)

Lags are ~10 minutes on the dayside, with banding from ECPC timescales

Lags are up to 150 minutes on the nightside

Correlation of B_Y with j

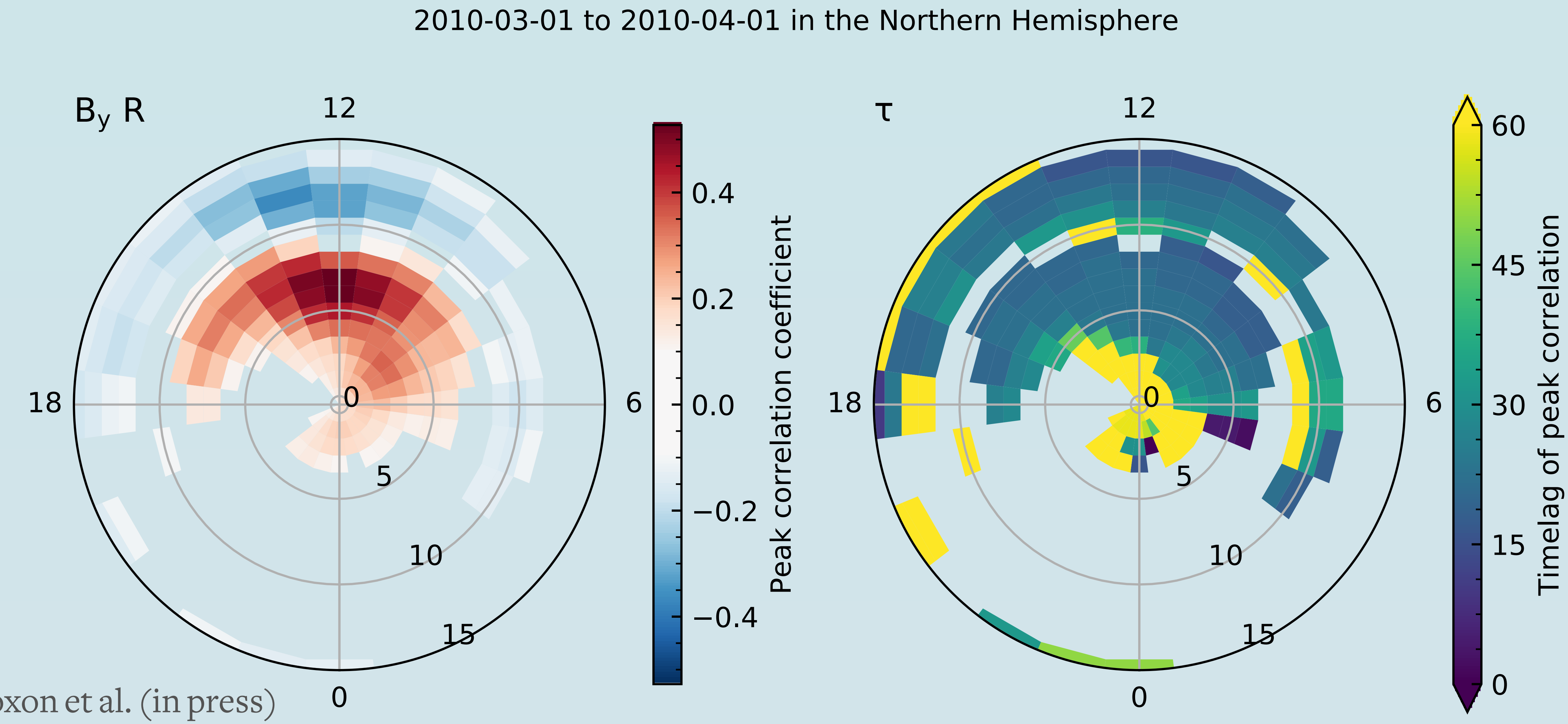


Coxon et al. (in press)

Pattern looks like the average current configuration for negative IMF B_Y (e.g. Weimer et al., 2001)

Timescales outside the high-latitude dayside are 60–240 minutes

Correlation of B_Y with j



Coxon et al. (in press)

Zooming in on the area 15° from the pole

Timescales are 15–30 minutes in the high-latitude dayside

Interpreted as cusp current mechanism (Saunders et al., 1989)

Conclusions

- B_Z timescales are 10–20 minutes on the poleward edge of the current ovals, and 60–90 minutes on the equatorward edge – this is the timescale for expansion of the polar cap
- Nightside timescales are 120–150 minutes, consistent with substorm recurrence timescales
- Timescales on the dayside in B_Y are ~15–30 minutes, indicative of direct driving from the solar wind
- B_Y timescales are up to 240 minutes elsewhere, consistent with Browett et al. (2017) timescales