

Systematic Errors in Correlation Tracking on MDI/HMI Magnetograms

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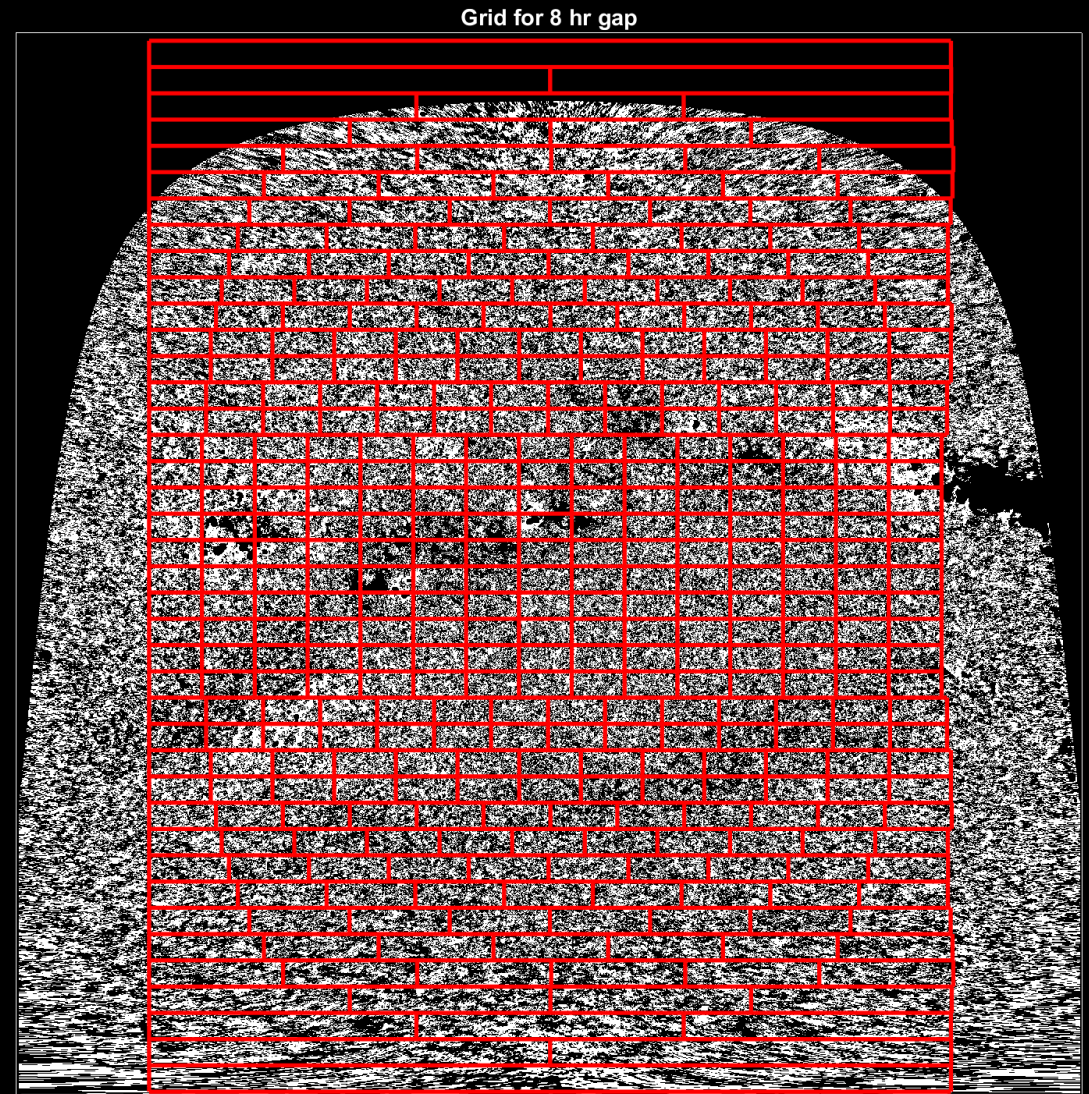


Why am I listening to this?

- We are struggling to find the source of a systematic error in correlation tracking on magnetograms
- This systematic error appears like a flow away from disk center in a sense opposite to the “Shrinking Sun effect” (*Löptien et. al. 2016*)
- We would really appreciate any ideas or feedback from you!

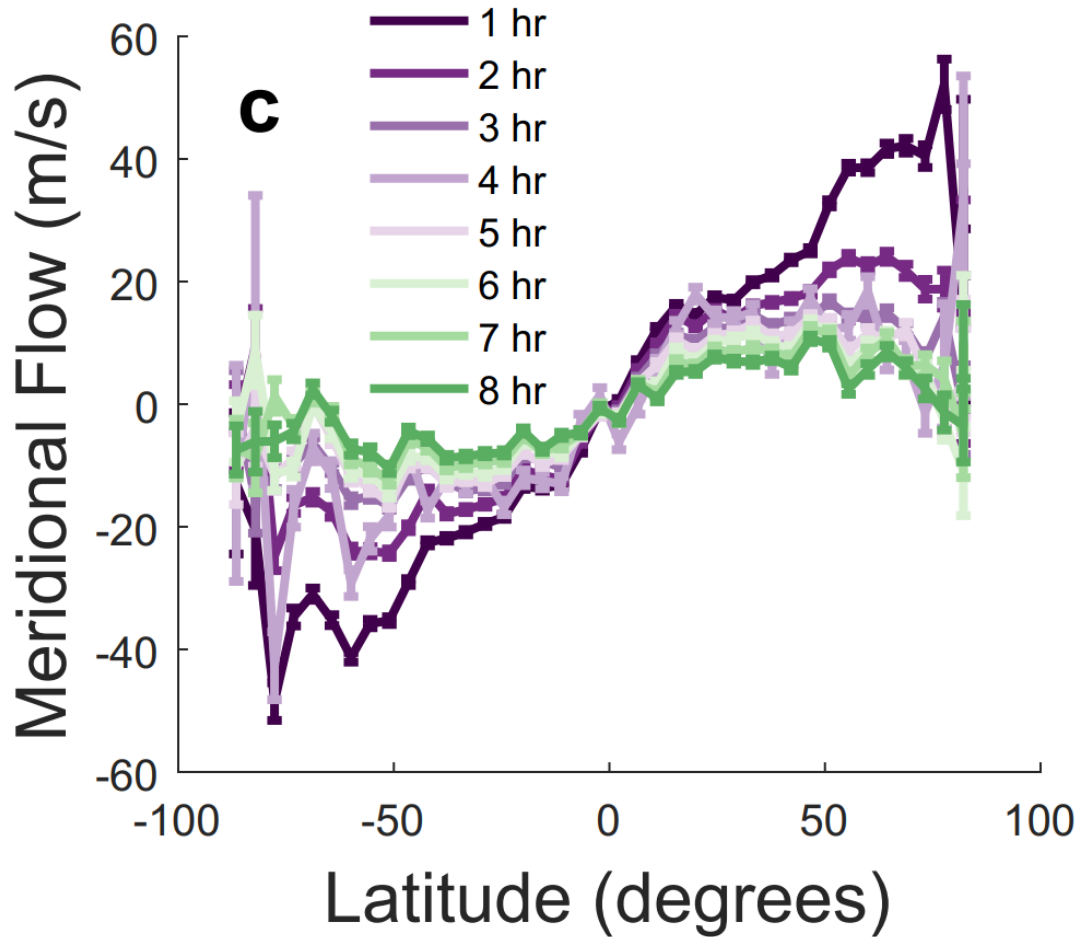
Correlation Tracking on magnetograms

- We project magnetograms (HMI_720s, MDI_96m) on a heliographic grid using an interpolation scheme which works in latitude-longitude coordinates
- Active Regions are masked
- Track each block in the image by comparing with another image a certain **timelag** later using correlation tracking
- We have used timelags of 1, 2, 4 and 8 hrs and find that they give us different results

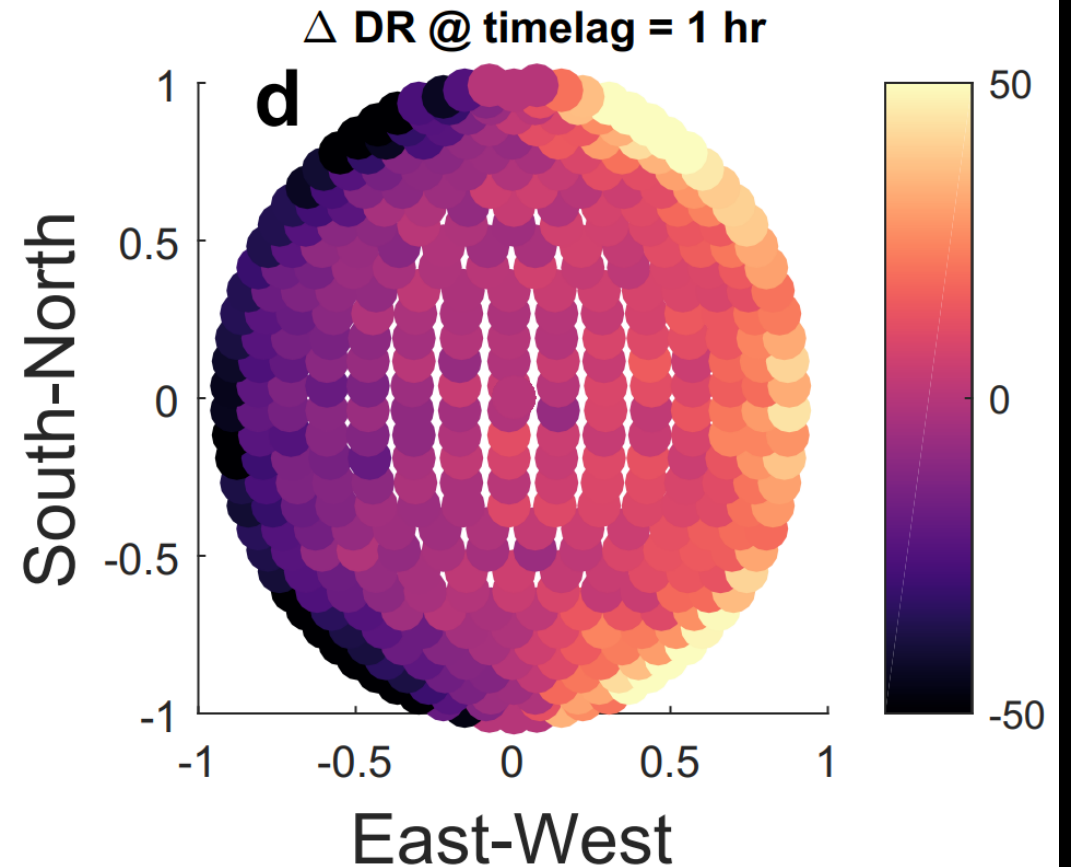


Results show systematic error

MF for different timelags



$V_{\text{rot}} - \langle V_{\text{rot}} \rangle_{\text{latitude}}$ (m/s)

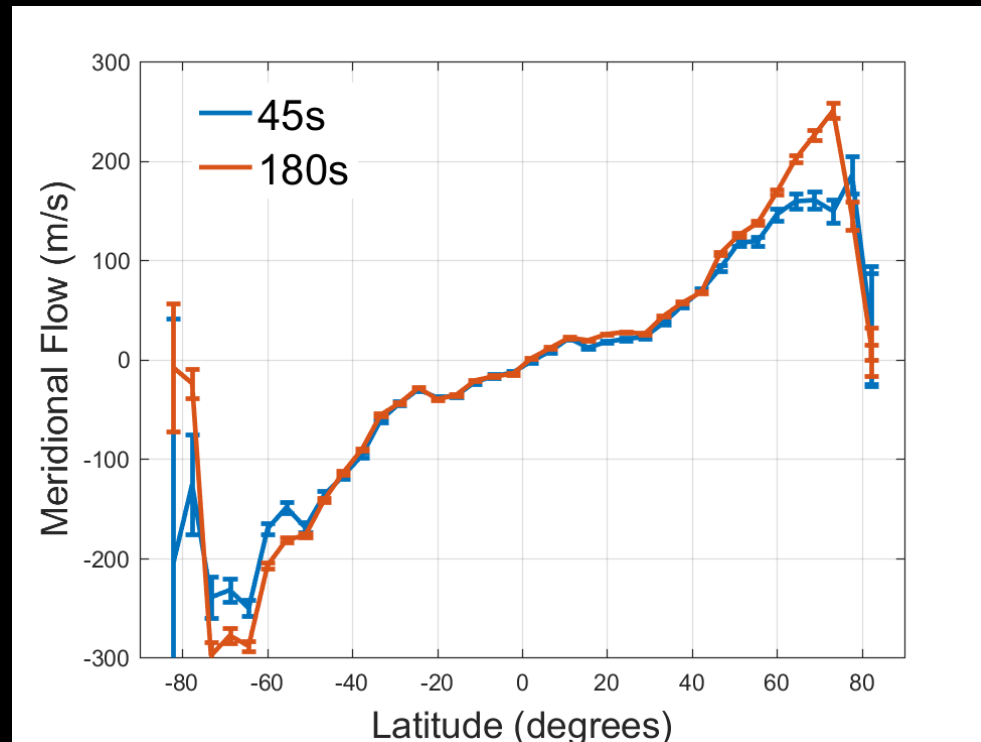


=> MF is faster at high latitudes for smaller timelags

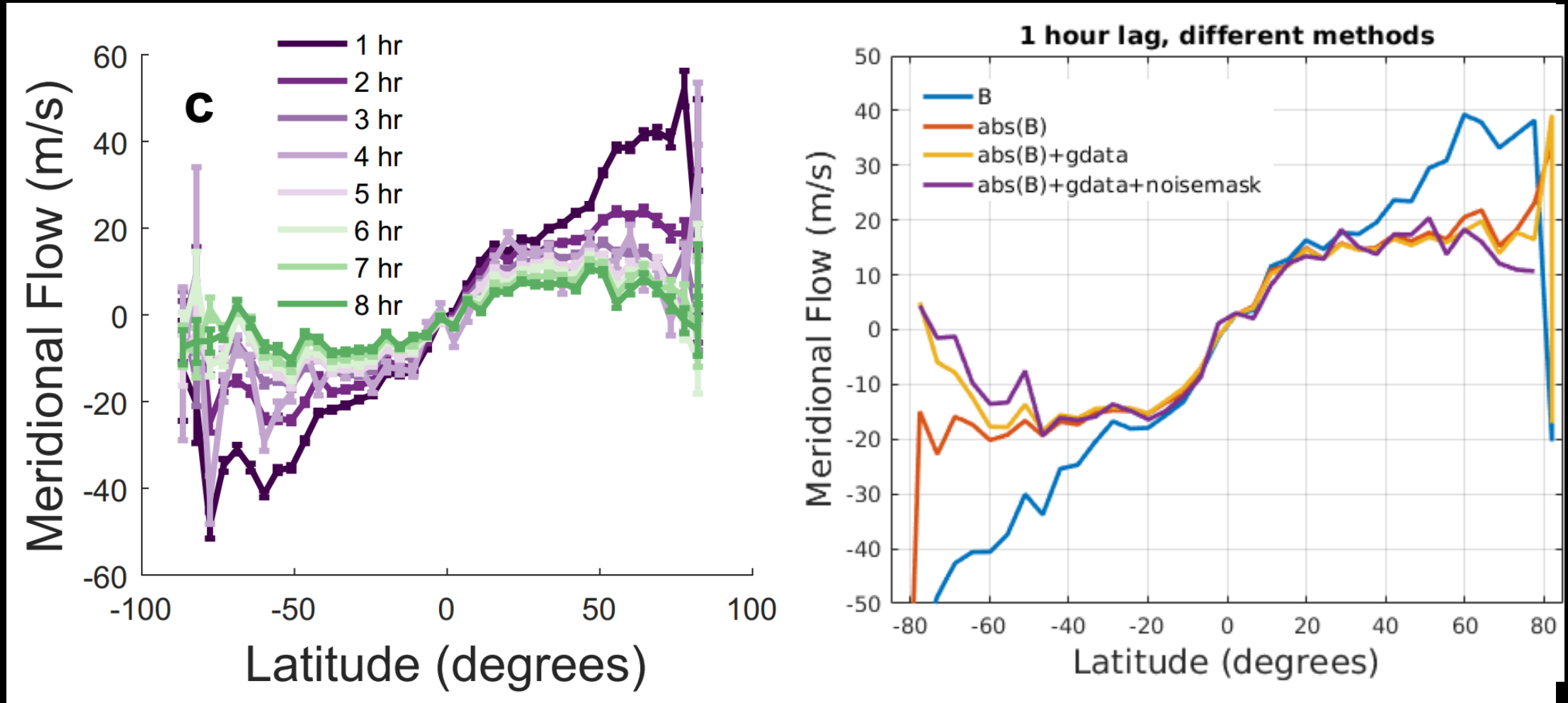
=> Left half of the Sun rotates slower than the right

Tests on HMI 45s magnetograms

- Using a timelag of 45s, the meridional flow measured was again very high ~ 200 m/s
- Increasing the time lag to 180s increases the error
- The systematic error is constant for timelags > 1 hr and is also present in the HMI_dcon series



Systematic Error in MF



gdata = 2D interpolation over a latitude-longitude grid instead of a pixel grid
Noisemask = Mask pixels below the noise level of 10 Gauss

Correction Method

1. Assume that a systematic shift, Δ_s , is the same (in m) for all time-lags
2. Assume that the meridional flow speed, **MF** has a baseline profile, **MF**^{*} (m/s), and time-lag dependent variation, δ *time-lag (m/s² or m/s per hr).

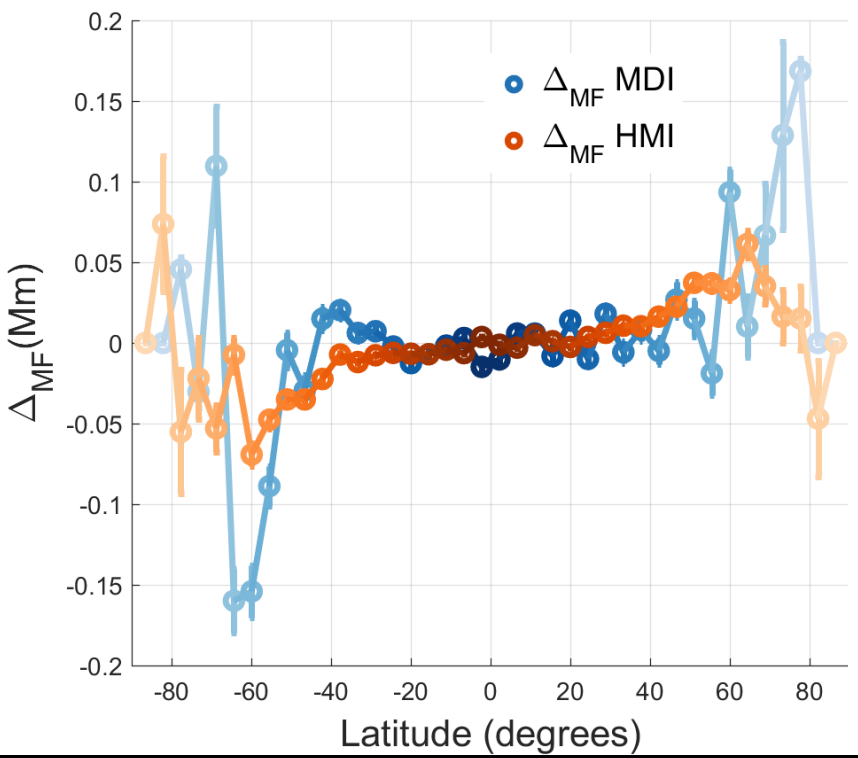
Then:

$$\text{shift @1}^h \Delta_1 = (\mathbf{MF}^* + 1\delta) * 1^h + \Delta_s$$

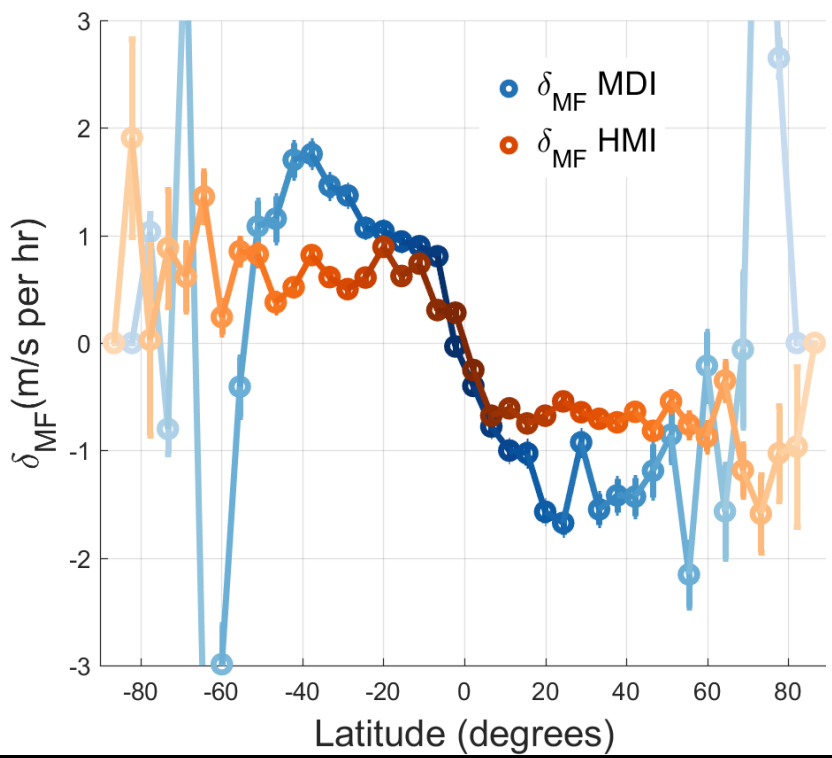
$$\text{shift @2}^h \Delta_2 = (\mathbf{MF}^* + 2\delta) * 2^h + \Delta_s$$

$$\text{shift @4}^h \Delta_4 = (\mathbf{MF}^* + 4\delta) * 4^h + \Delta_s$$

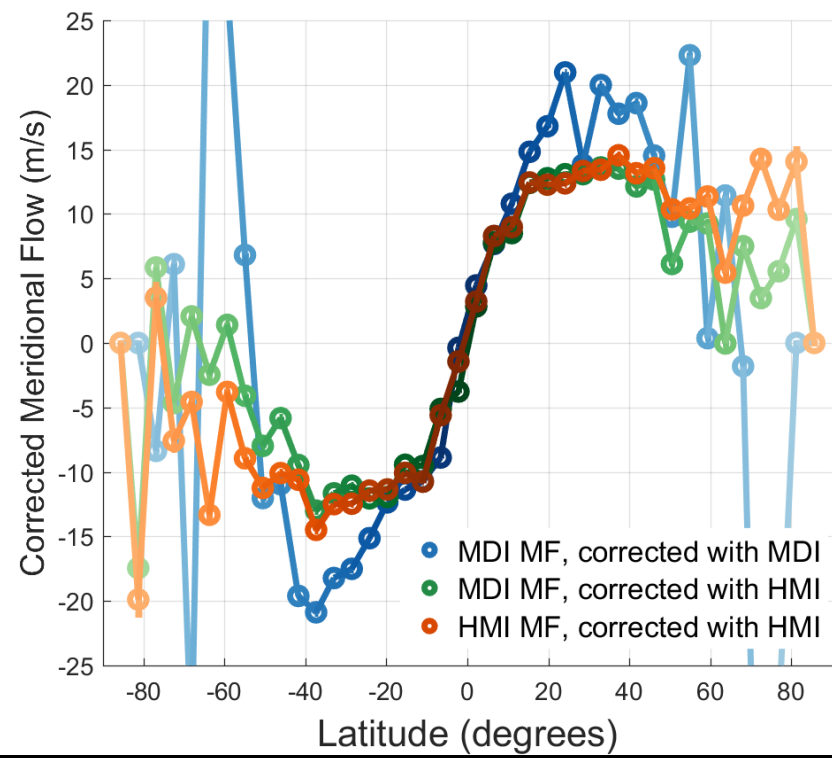
MF and Systematic error



Systematic Error

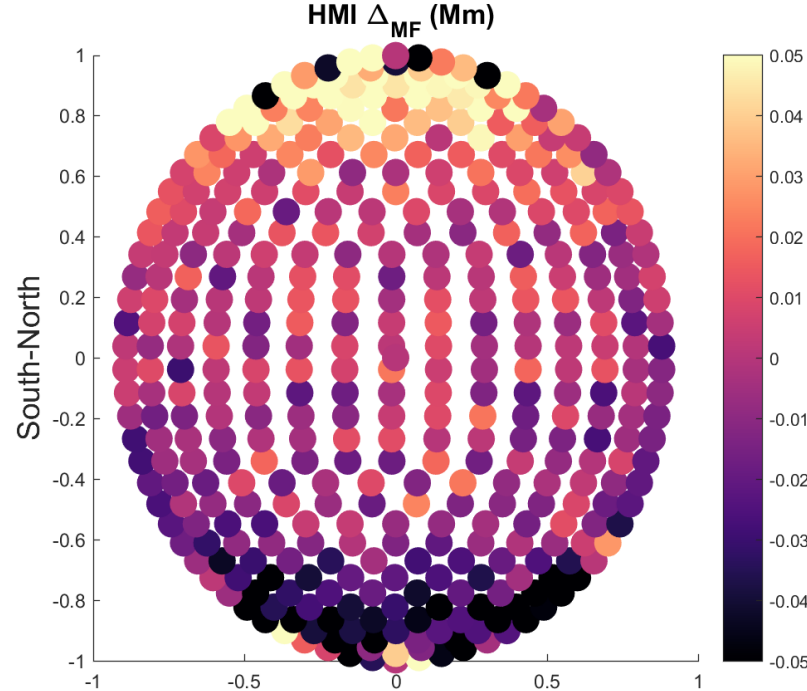
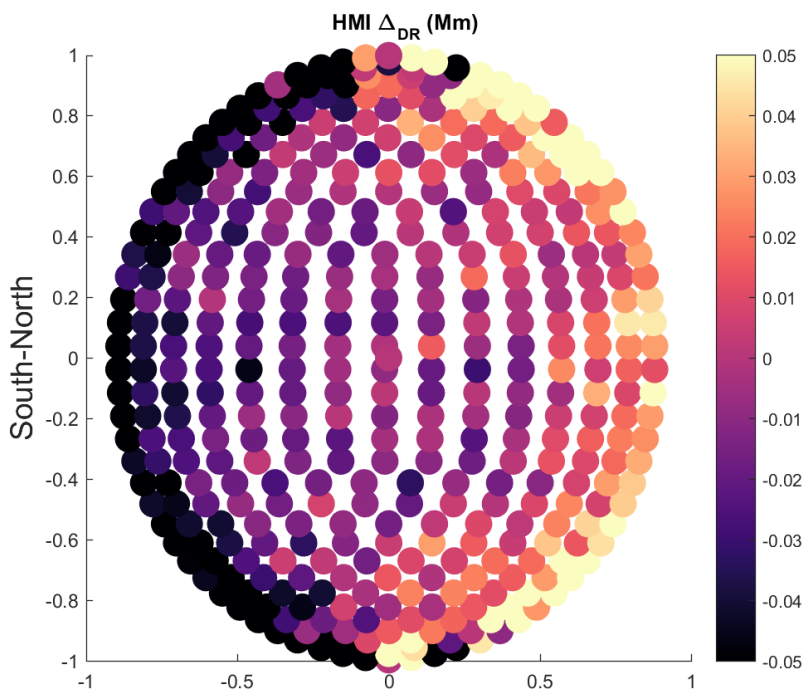


Allows variation of meridional flow as a function of timelag probably because longer lasting features are rooted deeper inside the Sun

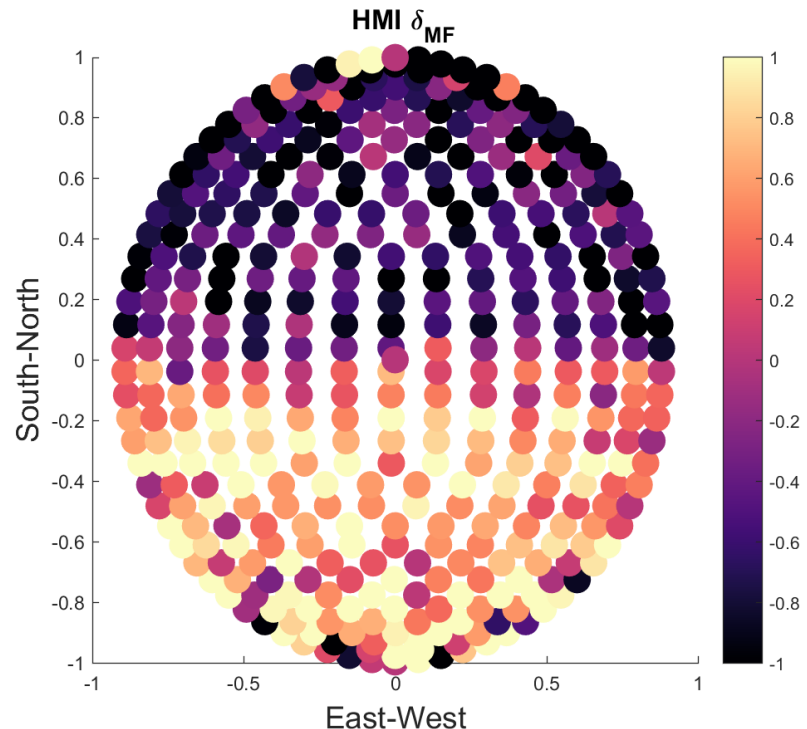
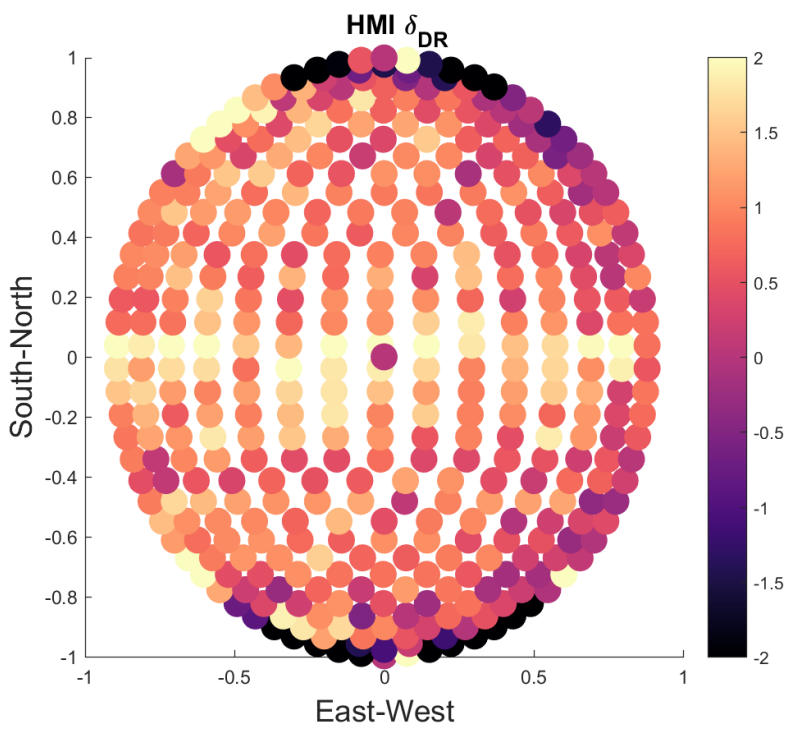


Corrected MF

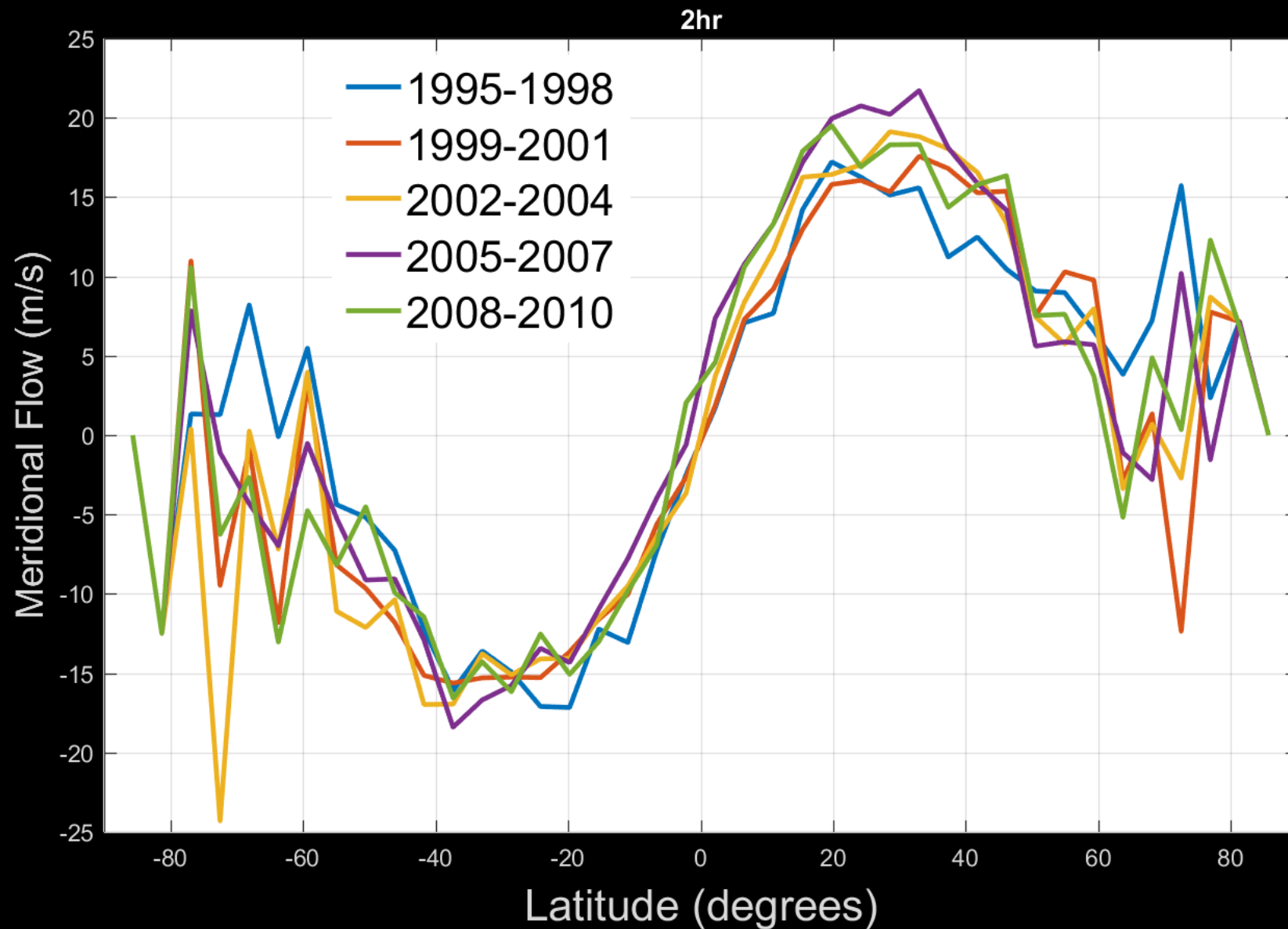
Unphysical →



Probably Physical →



Long-term corrected MF from MDI



Search for possible sources

- Testing our algorithm with synthetic data shows no such systematic error
- The absolute value of B is less susceptible to the error
- Could Doppler signal of the Sun's rotation leak into magnetograms?
- Can dependence of line-profile on height in the atmosphere cause such apparent anti-symmetric rotation?
- Is the effect of Faraday rotation accounted for in magnetograms?

Summary

Δ :

- Something is causing a systematic error (Δ) which builds up in a few minutes and then stays constant with time
- This error (Δ) makes Sun's rotation asymmetric across longitudes and speeds up poleward flow
- Using $\text{abs}(B)$ for tracking reduces the error by 50%
- The error is very similar between MDI and HMI
- The systematic error is easier to measure in HMI due to its higher resolution
- Correcting MDI measurements with systematic error obtained from HMI works best

δ :

- δ is probably not a systematic error and allows the meridional flow profile to vary as a function of timelag

Thank You