How Sensitive are Global Coronal Magnetic Fields to Active Regions Emerging in Different Locations?

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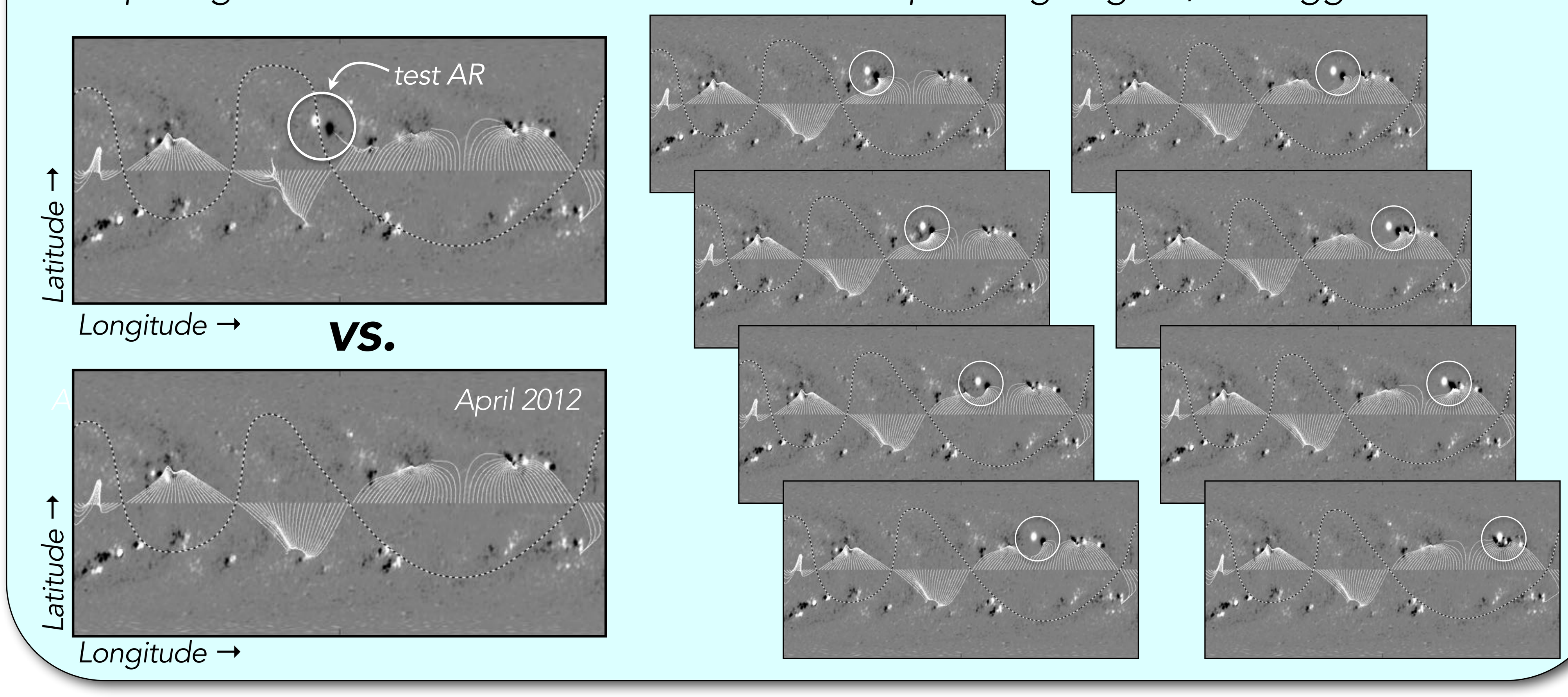
Motivation

Global coronal magnetic field models are used as the basis for modeling the structure and dynamics in the heliosphere, including those associated with forecasting space weather. However, the coronal field models depend (critically, sometimes) on the photospheric magnetic maps used as lower boundary conditions, and the lack of contemporaneous photospheric field observations of all 360° of longitude and the poles represents a significant source of uncertainty. The study presented here examines how often, and by how much, the coronal field models are affected by the emergence of new bipolar active regions, by inserting idealized bipolar active regions into synoptic charts and assessing the resulting changes in potential field models of the coronal field. It is found that active-region flux added at some longitudes causes a greater amount of disruption than at others, and this effect is especially pronounced when the dipole moment of the added active region is out of alignment with the pre-existing large-scale configuration.

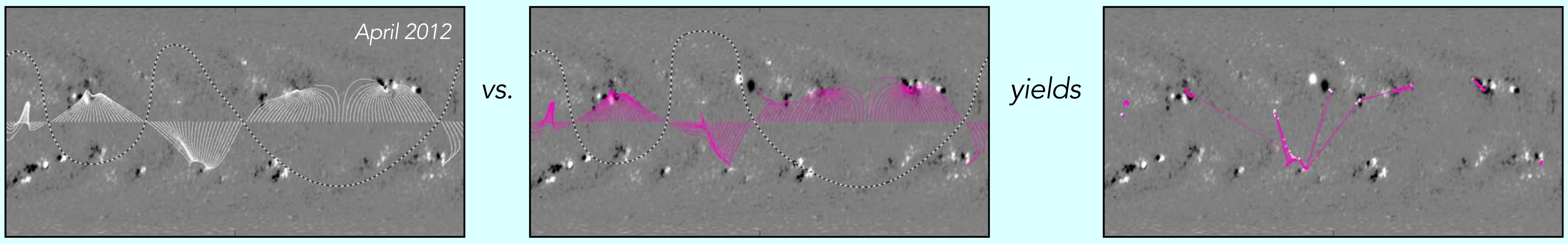
Methodology

The same test active region (AR) is placed at various longitudes in synoptic charts from the current sunspot cycle. Using the potential field source surface model, fieldlines are integrated from the equatorial plane down toward the photosphere in each of the models. The distance by which the photospheric endpoints of these fieldlines shift, when comparing models with the added AR to the corresponding original, are logged.



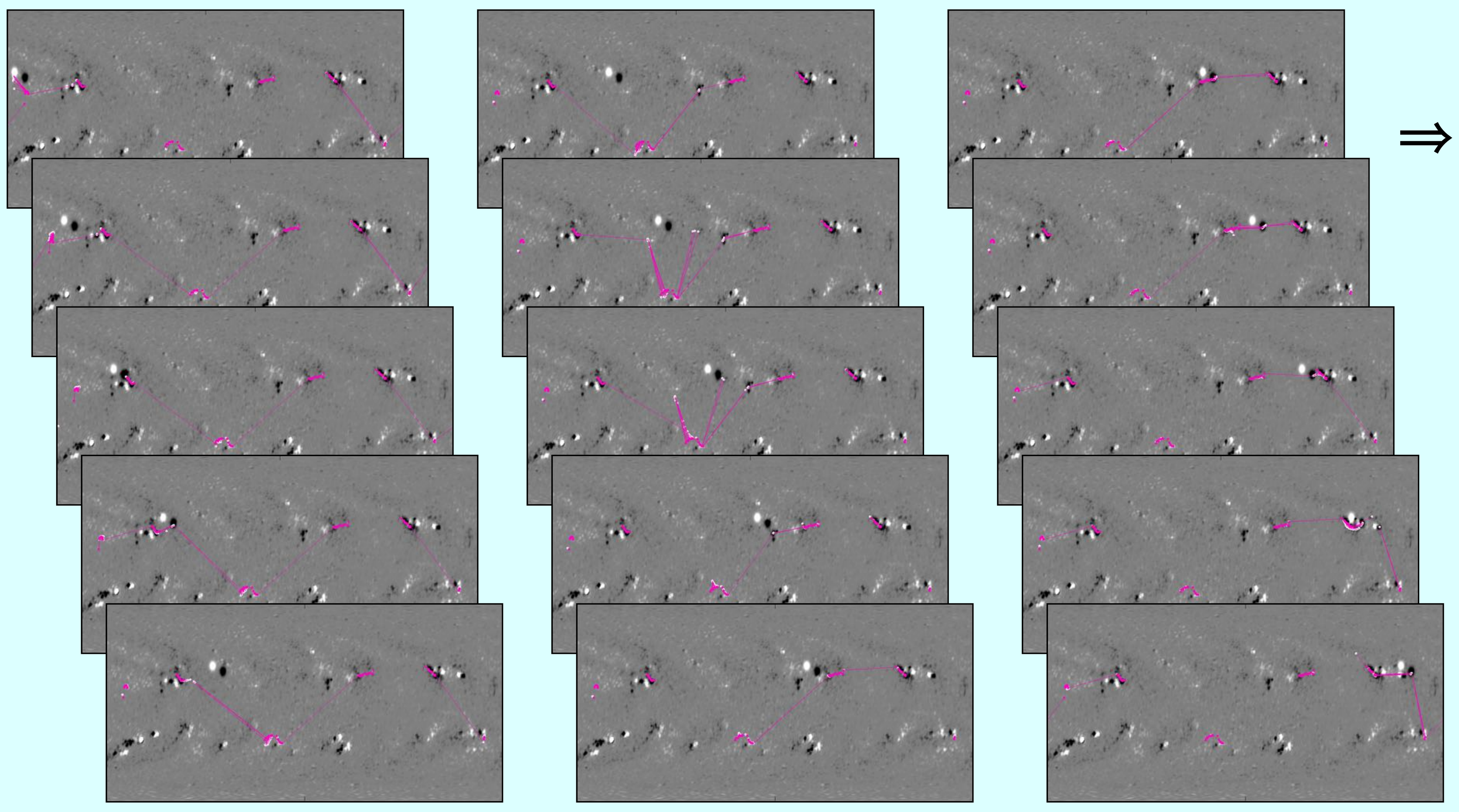
Quantifying Endpoint Shifts

First consider a single pair of maps (i.e., with and without the test AR), plot 360 fieldlines from the equatorial plane, and calculate statistics about the shifts:

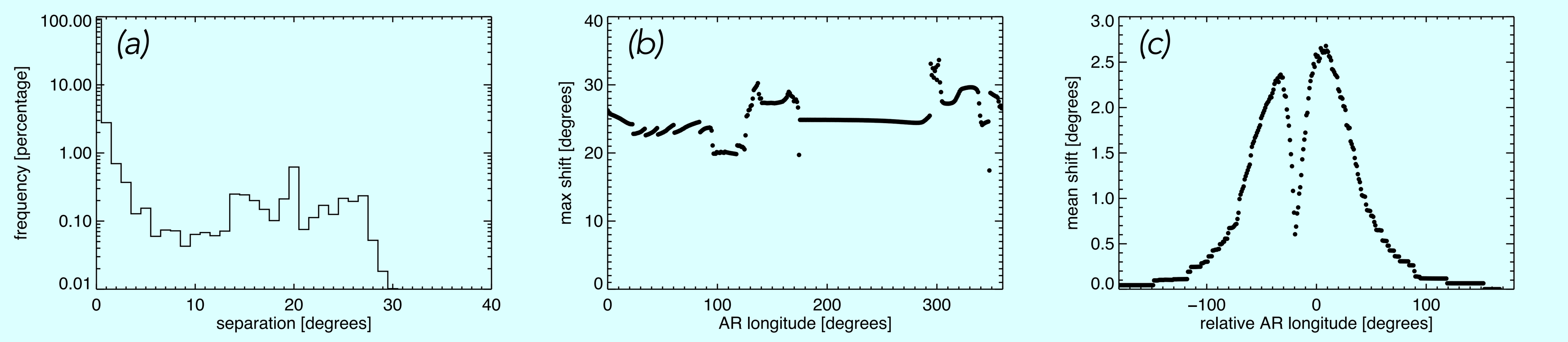


⇒ 27.9° max shift (mean=1.3°)

Next, compile statistics of the endpoint shifts based on the insertion of the test AR at different longitudes into the same original synoptic map:



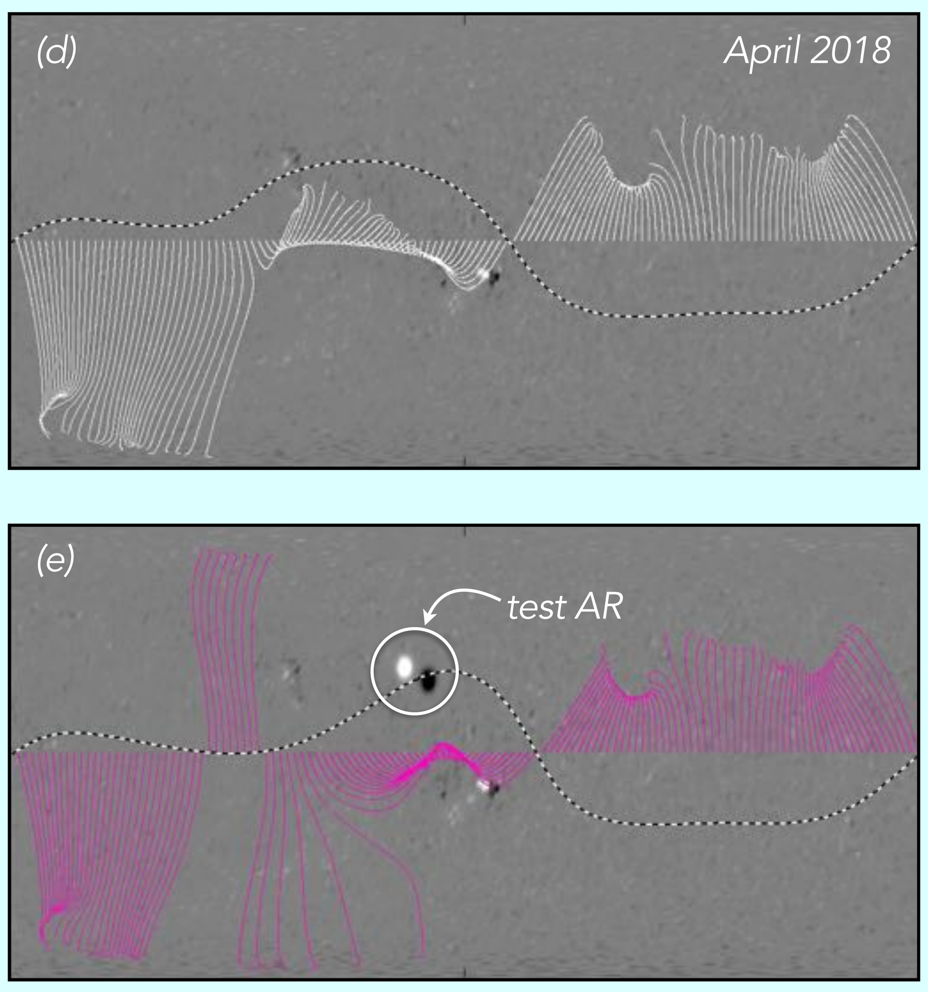
⇒

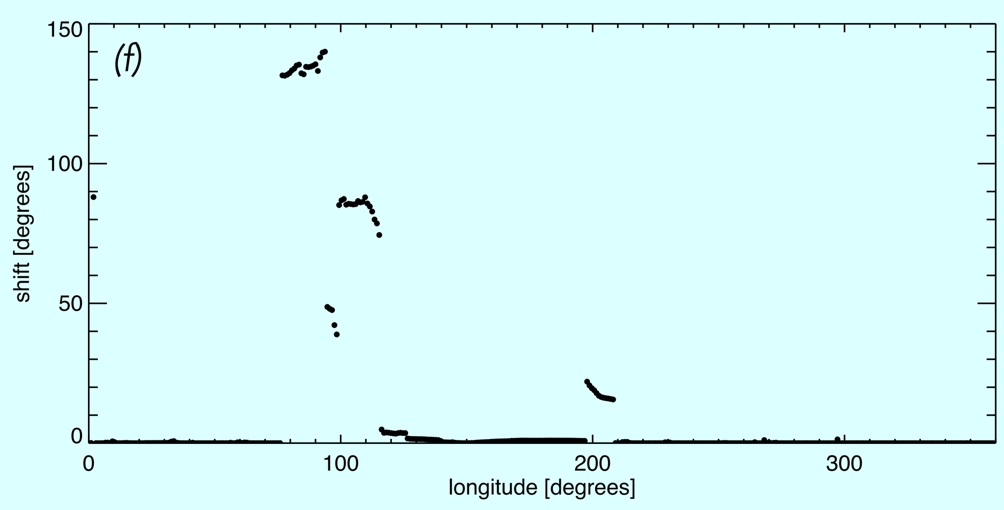


From this synoptic map (April 2012), adding ARs at different longitudes results in an average fieldline endpoint separation of approximately 1° [see ***panel (a)*** *above]. Indeed, 95% of all endpoint shifts are at or below 1°, however an endpoint shift by at least 20° is found 1% of the time. Regardless of where the AR is added, some fieldlines are shifted by at least 15° and usually 20° or more [see* ***panel (b)*** *above], and for those longitudes near where the AR is added, the mean endpoint shift is between 2° and 3° [see panel (c) above]. The asymmetry in the plot shown in* ***panel (c)*** *is a result of the tilt angle of the added AR.*

Endpoint Shifts at Minimum

During solar minimum when the large-scale magnetic field is fairly close to an axial dipole, many fieldlines that intersect the upper boundary of the model at the equator map back to the photosphere at one of the polar regions [see ***panel (d)*** *at right]. However, small perturbations in the photospheric magnetic field due to a newly emergent AR often perturb the global structure in such a way to result in fieldline endpoints shifting from one pole to the other, leading to shifts greater than 120° [compare* ***panels (d) and (e)*** *at right]. These pole-to-pole shifts may occur for equatorial fieldlines as far away as 90° in longitude from the new AR [see* ***panels (e) and (f)*** *at right].*

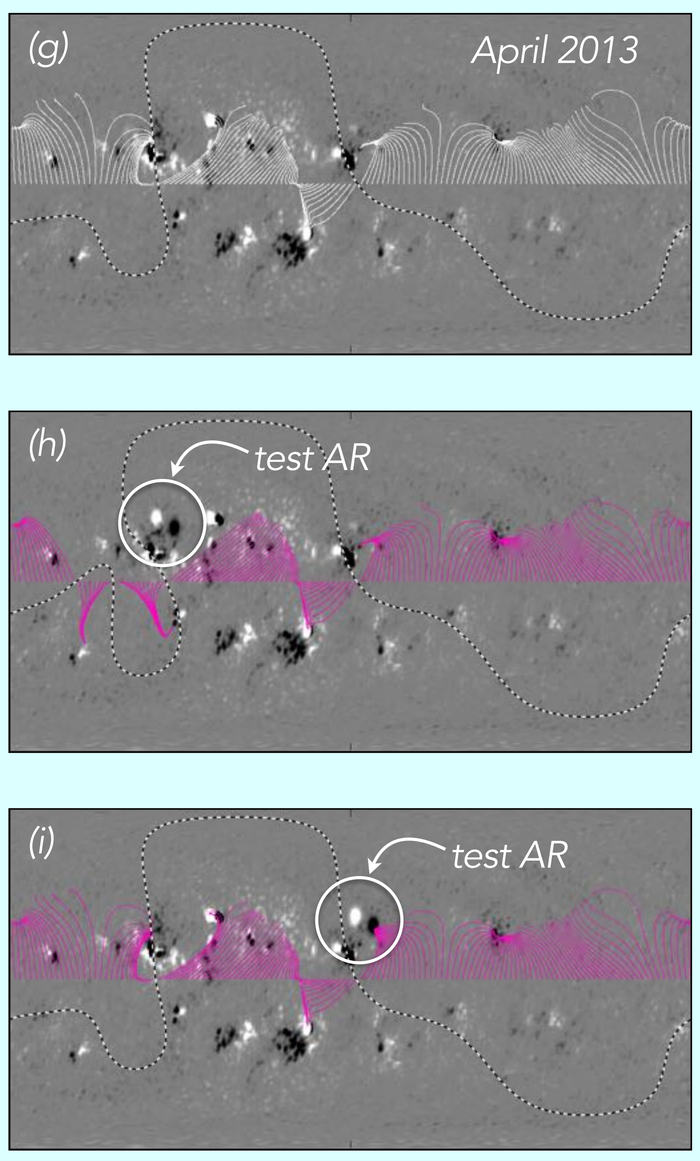


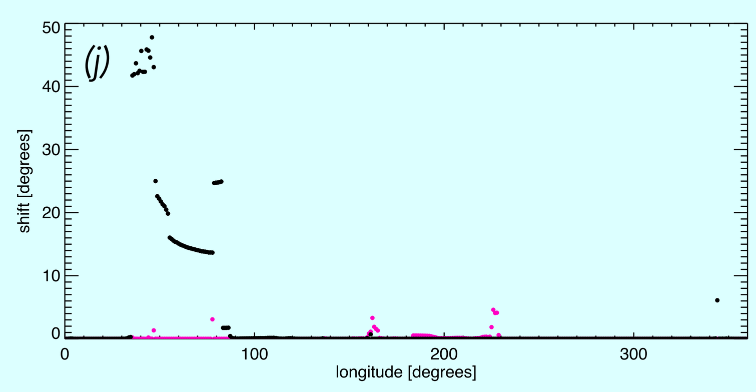


Importance of Alignment

Large fieldline endpoint shifts also tend to occur when the dipole axis of the added AR is misaligned with the pre-existing coronal magnetic field, as in the case shown in ***panel (h)*** *at right (April 2013). Here the added AR causes a set of fieldlines to switch to the opposite polarity and connect to the other side of the equator, resulting in shifts of between 40° and 50° [black dots in* ***panel (j)****].*

In contrast, in the case shown in ***panel (i)*** *at right the added AR causes little change in the positions of the fieldline endpoints, due to the fact that the dipole axis of the added AR is aligned with pre-existing global magnetic field. None of the fieldline endpoints shift more than 10° [magenta dots in* ***panel (j)****].*





IAU General Assembly ~ Vienna ~ August 2018