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TARPs: Tracked Active Region Patches from SOHO/MDI

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Synoptic 2001 M-TARPs (lines mark month boundaries)

Summary

We are developing a new data product for the MDI Resident Archive containing *tracked magnetic features on the scale of solar active regions*, abbreviated MDI-TARPs (MDI Tracked Active Region Patches). This data product, derived from line-of-sight (LOS) magnetograms and continuum intensitygrams, is a companion to the already-released HARP (HMI Active Region Patch) data product from HMI. Together, the two data products cover May 1996 to the present, and should eventually span two solar cycles.

The MDI-TARP data series is intended for:

- Subsetting individual active regions
- Computation of space weather indices for individual active regions
- Facilitating long-term or synoptic statistical studies of active regions

Large spatially-coherent regions are identified within the LOS magnetograms and intensitygrams and tracked from image to image, accounting for merges as regions grow. After the region disappears, the numbered track ("TARP") is placed into a data series by finding the smallest box of constant latitude/longitude extent that encompasses all appearances of the region.

The MDI-TARP data series provides all geometric and heliographic information needed to track active patches in MDI and other solar data sets. For each numbered TARP, the data series defines at each time step a rectangular CCD cut-out, and it provides a mask within the cut-out indicating the active pixels within a regular, smoothly-evolving blob.

Summary keywords such as areas and integrated fluxes are included for each appearance of the region. The data product described here is in draft form, with release as a data series on Stanford University's JSOC expected in June 2014.

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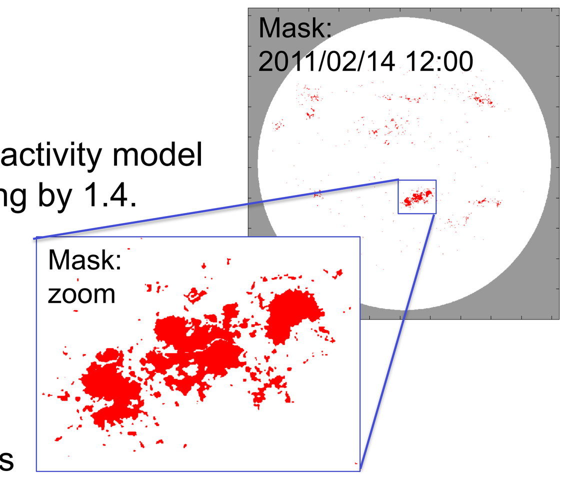
Methodology: Finding Active Regions

- We first compute a full-disk activity mask given input magnetogram and intensity images (Turmon et al. 2002) taking spherical geometry into account (Turmon et al. 2010).
- Bayesian approach trades off pixel-by-pixel agreement of the mask value to the data against spatial coherence of labels (a prior).

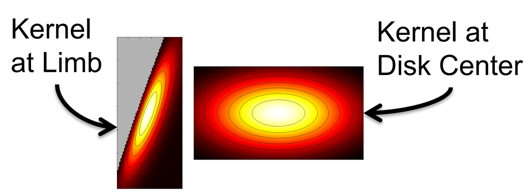
Mask Model and Example

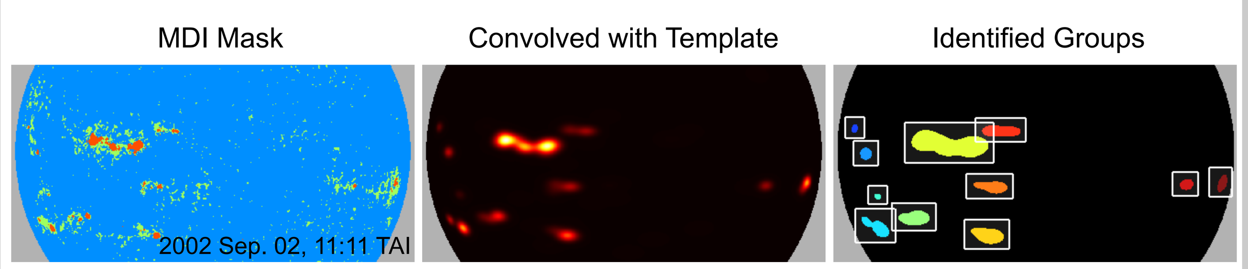
- Following Liu et al. 2012, MDI mask activity model is obtained from HMI model by scaling by 1.4.
- Sample HMI mask (right) shows typical mask appearance.



Active Region Grouping

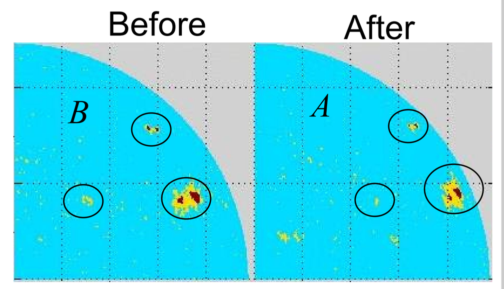
- Group pixel-scale activity from masks into NOAA AR-scale regions
- We used a matched filter approach with an elongated Gaussian kernel of FWHM ~50x25Mm (~40x20 MDI pixels) at disk center.





Methodology: Active Region Tracking

- Chain regions together to make a track: single-link most likely tracker using overlap area
- Compute the overlap area between extrapolated track (using standard latitude-dependent motion relationship) and new region.
- Overlap of patch *a* in *A* and patch *b* in *B* is *D*(*a*,*b*).
- Solve *linear assignment problem* to match *A* up to *B*:



$$\max_P \sum_{a \in A} \sum_{b \in B} P(a,b)\, D(a,b)$$

where *P* is a permutation matrix giving the *B*-to-*A* mapping. Fast, exact solution by linear programming.

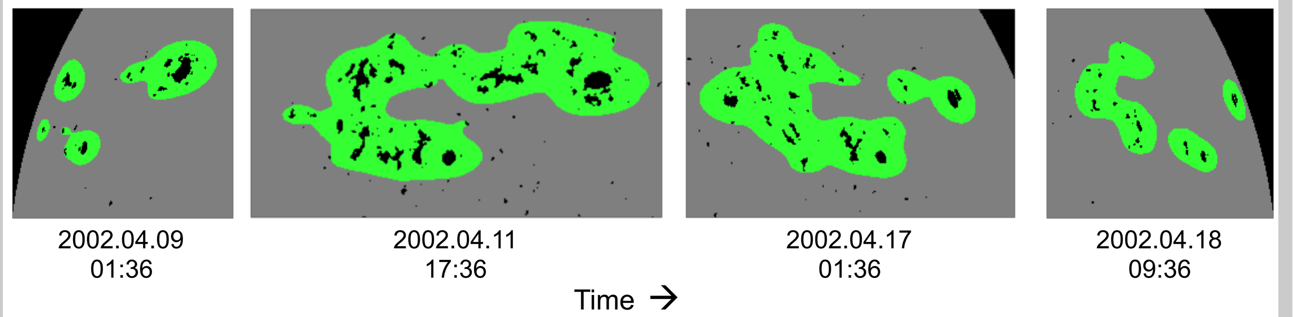
- Chaining this association across many frames yields complete tracks.
- Tracks can be finalized only after they are unseen for a long-enough time.

Merging Tracks and Complex ARs

- Tracks are first identified using past and current data. Thus, growing regions may merge in later appearances.
- Coping with the consequences of merges adds considerable complexity to the implementation. This complexity is hidden in the final data product.
- Care is taken so that regions near the detection threshold are not cut into separate temporal pieces as they exceed and then sink below the threshold.
- The MDI TARP is often not a contiguous region. For shrinking regions, the M-TARP lat/lon bounding box can be much larger than the currently active area. It can even contain other TARPs. Use the bitmap to determine what is part of the TARP.

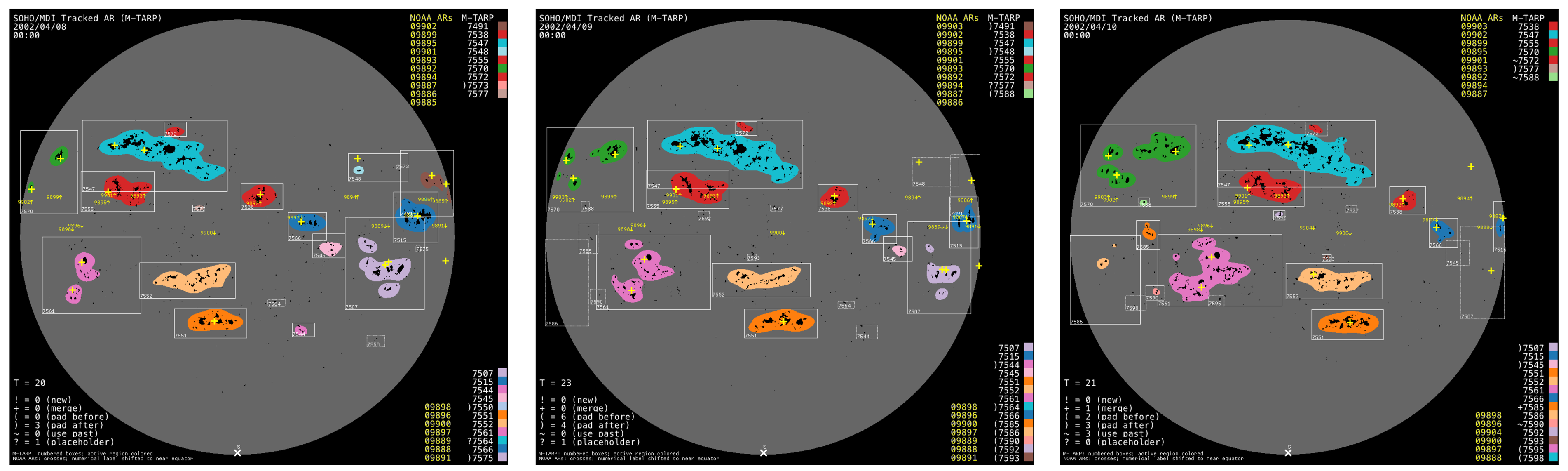
The MDI TARP Data Product

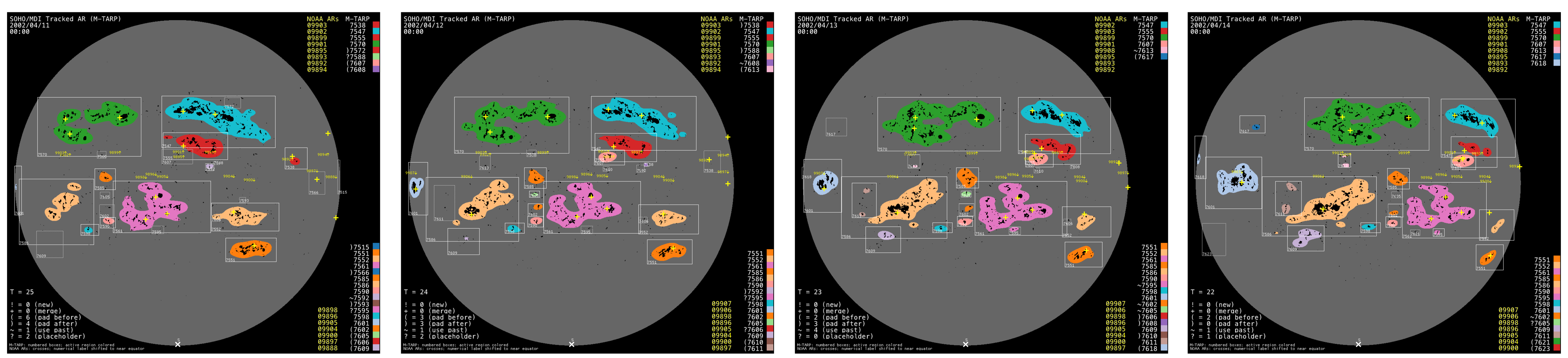
- M-TARPs are indexed by a number called HARPNUM, analogous to NOAA AR number, and time step (`T_REC`).
- For a single M-TARP, the data series is a list of rectangular patches and metadata containing the observed lifespan of the TARP. A 1-day pad is appended on both ends of the TARP. This padding period is seen in the empty, dotted boxes in the tracked frames (e.g., in the next poster panel).
- Each rectangular patch in the list is a cutout from the image plane. A patch can be overlaid on a full-disk image (e.g., the LOS magnetograms) by a simple coordinate shift. Patch WCS are included for other projections.
- The footprint covered by the patch is determined by the the smallest lat/lon bounding box that encompasses all appearances of that TARP. See below.
- The animating idea behind the sizing of the lat/lon bounding box is that the observer is hovering over the AR, staying at a constant latitude and moving at a constant angular rate in longitude.
- Shown below are four patches of the 200 total making up M-TARP 7570. The colored masks below are stored as bitmaps in a suitable integer encoding.



Tracked Frames

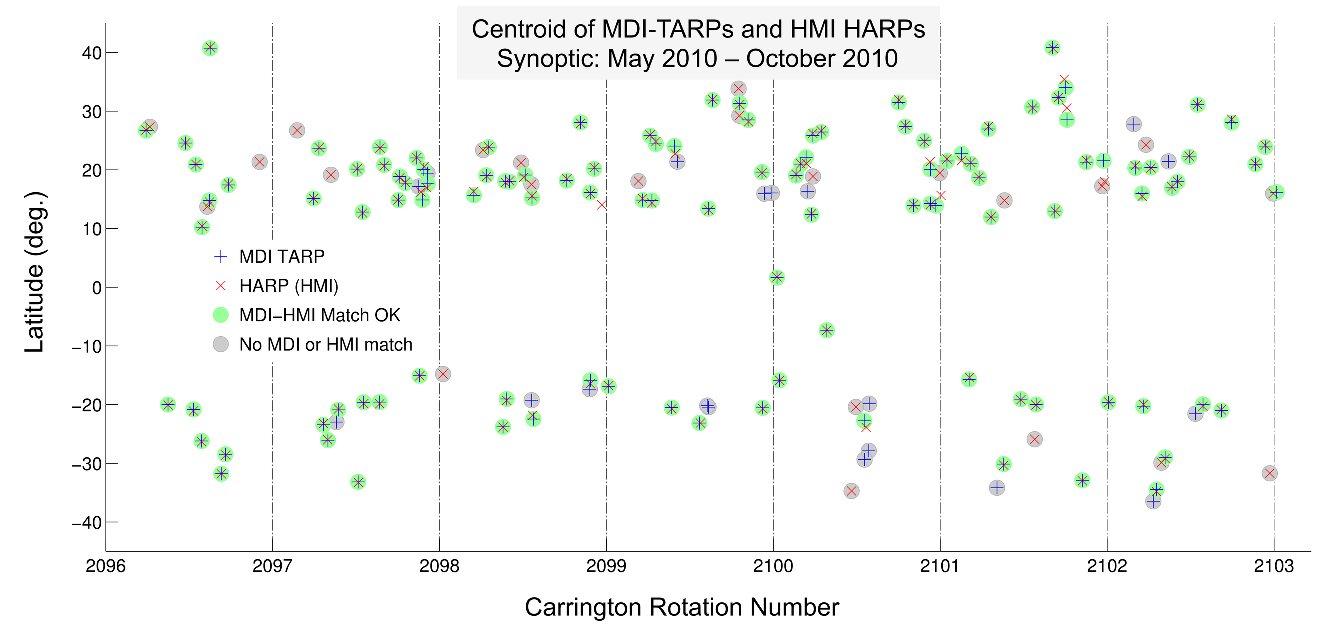
- The quick-looks here are sampled 1/day from the 96m (15/day) full series.
- M-TARPs are colored blobs. NOAA ARs are yellow crosses.
- The M-TARP/NOAA correspondence is found and coded in keywords.
- Example TARP merges: green (7570), pink (7561). Expired: violet (7507), red (7538), etc. New: tan (7586), etc.





MDI TARP vs. HMI HARP Correspondence

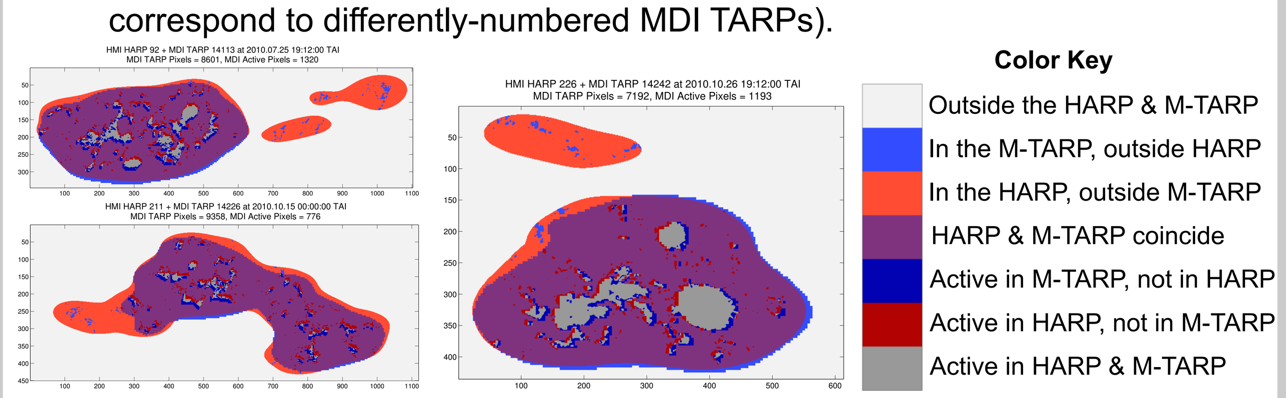
We checked for correspondence between MDI TARPs and HMI HARPs using the ~140 ARs in the May–October 2010 overlap period.
By checking location and shape, we determined matching regions (in green) and misses (in gray). We find 130 matches and 11 misses of each type (TARP present but no HARP, and vice versa).



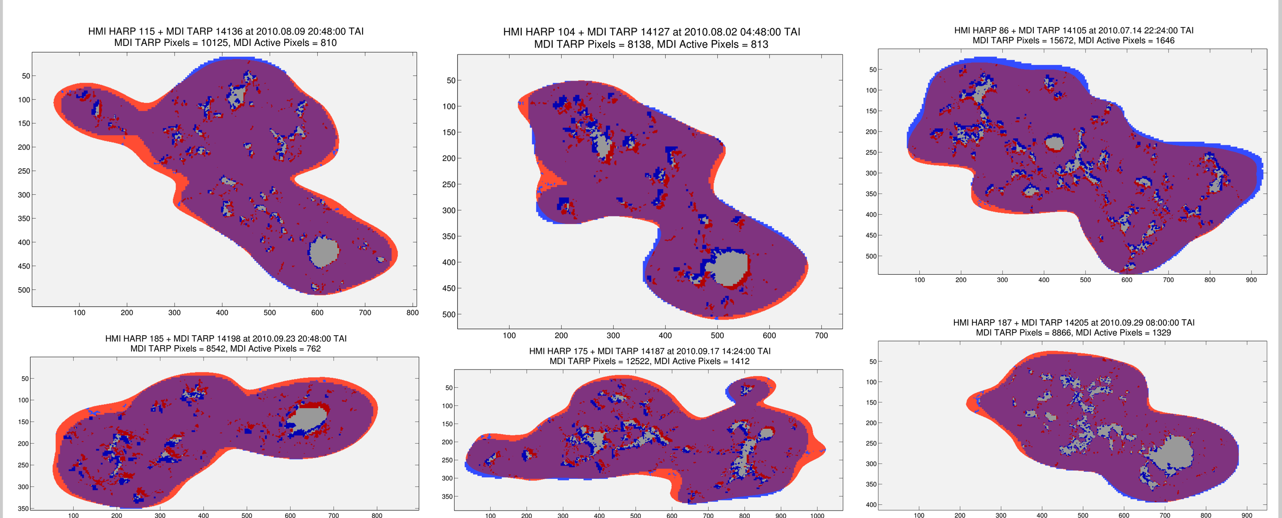
Some extra HARPs are found due to enhanced spatial/temporal resolution of HMI. With current settings, some extra M-TARPs are found due to grouping (next panel). These results are consistent with the good MDI/HMI agreement found by Liu et al. (2012), especially for relatively high fields.

MDI TARP vs. HMI HARP Region Boundaries

- For the 2010 overlap, we overlaid the nine largest MDI TARPs over the HMI HARPs, projecting the MDI TARPs into the HMI coordinates by image WCS.
- Some HMI HARPs enclose more activity within one HARP (blue blobs below correspond to differently-numbered MDI TARPs).

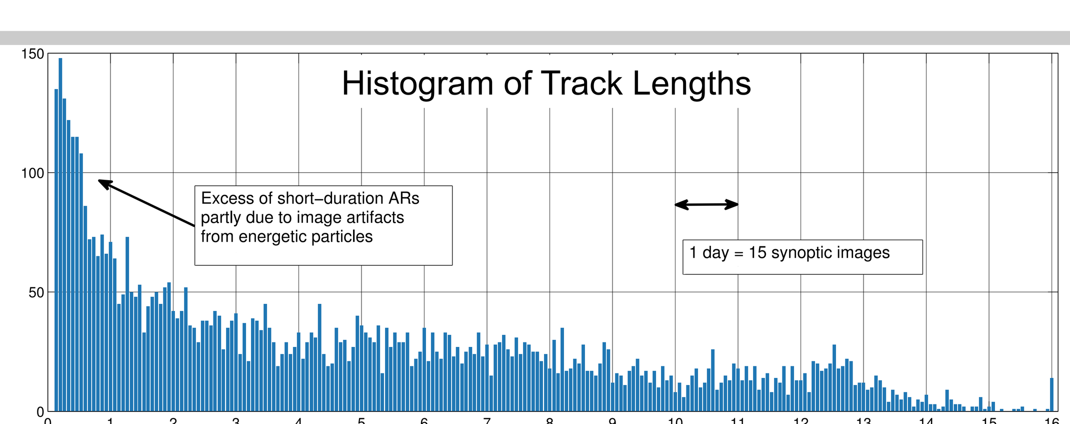


- More typically, as below, the HARP and the M-TARP coincide well.



MDI TARP Data Characteristics

- Tracks cover April 1996 – October 2010 (all usable MDI)
- 15 years, 72100 masks, 6170 M-TARPs.
- Median M-TARP length = 4.1 days = 61 frames
  459 are ≥ 12 days (180 frames)
- The ease of computing per-AR quantities should enable new studies that would have been prohibitive.



Status and Plans

The draft data product here will be improved before an expected June 2014 release:

- Better suppression of extraneous patches due to energetic particles.
- Improved correspondence of MDI TARPs to HMI HARPs.
- We hope to identify sunspots within the activity mask.

References

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