HMI Local Helioseismology Data: Status and Prospects

Richard Bogart

Stanford University
<table>
<thead>
<tr>
<th>series</th>
<th>module</th>
<th>cadence (sec/rec)</th>
<th>size (MB/rec)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hmi.V_avg120</td>
<td>datavg</td>
<td>396000</td>
<td>60</td>
<td>1/3 rotation averages of Dopplergrams with orbital velocity removed, for detrending</td>
</tr>
<tr>
<td>hmi.rdVtrack_fd05</td>
<td>mtrack</td>
<td>12</td>
<td>18</td>
<td>mosaics of tracked mapped data cubes from data in series hmi.V_45s</td>
</tr>
<tr>
<td>hmi.rdVtrack_fd15</td>
<td>mtrack</td>
<td>340</td>
<td>472</td>
<td>mosaics of the power spectra of the tracked tiles in the series hmi.rdVtrack_fd*, with 1-to-1 mapping of most parameters</td>
</tr>
<tr>
<td>hmi.rdVtrack_fd30</td>
<td>mtrack</td>
<td>2500</td>
<td>1000</td>
<td>mosaics of full-rotation averages of power spectra of tracked tiles in series hmi.rdVpspec_fd*</td>
</tr>
<tr>
<td>hmi.tdVtrack_synopHC</td>
<td>mtrack</td>
<td>993</td>
<td>250</td>
<td>mosaics of travel time fits to the data in series hmi.tdVtrack_synopHC</td>
</tr>
<tr>
<td>hmi.rdVpspec_fd05</td>
<td>pspec3</td>
<td>12</td>
<td>12</td>
<td>mosaics of the &quot;fast&quot; (&quot;dynamics&quot;) fits to the power spectra in series hmi.rdVpspec_fd*</td>
</tr>
<tr>
<td>hmi.rdVpspec_fd15</td>
<td>pspec3</td>
<td>340</td>
<td>324</td>
<td>mosaics of the &quot;slow&quot; (&quot;structure&quot;) fits to the power spectra in series hmi.rdVpspec_fd*</td>
</tr>
<tr>
<td>hmi.rdVpspec_fd30</td>
<td>pspec3</td>
<td>2500</td>
<td>648</td>
<td>mosaics of the &quot;fast&quot; (&quot;dynamics&quot;) fits to the power spectra in series hmi.rdVpspec_fd*</td>
</tr>
<tr>
<td>hmi.tdVtimes_synopHC</td>
<td>travel_times</td>
<td>993</td>
<td>22</td>
<td>mosaics of travel time fits to the data in series hmi.tdVtrack_synopHC</td>
</tr>
<tr>
<td>hmi.rdVflows_fd15_frame</td>
<td>rdvinv</td>
<td>98000</td>
<td>2.25</td>
<td>flow inversions of the fits in all records for a given analysis time in series hmi.rdVfitsf_fd*</td>
</tr>
<tr>
<td>hmi.rdVflows_fd30_frame</td>
<td>rdvinv</td>
<td>196000</td>
<td>0.57</td>
<td>flow and sound-speed inversions of the travel time fits in series hmi.tdVtimes_synopHC</td>
</tr>
<tr>
<td>hmi.tdVinrvt_synopHC</td>
<td>invert_td_hr</td>
<td>248</td>
<td>11</td>
<td>flow and sound-speed inversions of the travel time fits in series hmi.tdVtimes_synopHC</td>
</tr>
</tbody>
</table>
Tracked Doppler data - common input for most local helioseismology analysis

Ring-diagram tiles at three size scales: 32°, 16°, and 5°.12 “squares”

(Uniform apodization to: 30°, 15°, and 5° circles)

Time-distance tiles: 30°.72 “squares”

R-D tile spacings: ~15°, 7°.5, and 2°.5 in arc; T-D tile spacings 24° in latitude and longitude

  R-D Latitude spacing uniform, with tiles centered at 0, ±s, ±2s, ...

  R-D Longitude spacing depends on latitude, same as latitude spacing at equator, and subject to
  constraint of integer divisor of 360°

  4 additional T-D tiles at 20° spacings from edges on equator and meridian

Mapping with Postel’s projection at scale of 0°.04 / pxl (5° and 15° tiles), 0°.08 / pxl (30° tiles), and 0°.06 / pxl (T-D tiles)

R-D regions tracked while within 80° of disc center

  Three different sets, depending on heliographic latitude of SDO

R-D regions tracked at Carrington rate

  Maximum photospheric zonal velocity 260 m/s at 50°
  Maximum photospheric drift rate 4°.34 / day at poles

T-D regions tracked at nominal photospheric Doppler rate at center of region
Distribution of Ring-diagram Target Regions
Tracked Doppler data cubes, centred at 2152:210 (2014.07.09_08:45)

5° @ 12.5W07.5S

30° @ 15.0W00.0N
15° power spectrum, 2151:240 (2014.06.09_21:36), 00.0W00.0N

2.5 mHz

3.5 mHz

5.0 mHz
15° power spectrum, 2151:240 (2014.06.09_21:36), 00.0W00.0N

2.5 mHz

3.5 mHz

5.0 mHz
15° power spectra cuts @ 2.5 mHz around disc
for ring-diagram fits to power spectra, 2151:240, 00.0W00.0N

\[ l, v \text{ for ring-diagram fits to power spectra, 2151:240, 00.0W00.0N} \]
Sample flow inversions over the disc at different depths, 2101:240
Time-Distance Sound-Speed Inversions

Target Depth [Mm]

Fitting Method
- Gabor Wavelet
- Gizon-Birch

Inversion Method
- Born Approx
- Ray Path

Date: 2014.07.09_12:00
Time-Distance Sound-Speed Inversions
2014.07.09_12:00

Fitting Method
- Gabor Wavelet
- Gizon-Birch

Inversion Method
- Born Approx
- Ray Path

Target Depth [Mm]
0.5
Local Helioseismology Data Recovery

During 57 rotations, 2096:250 – 2153:255 (2010.05.01 – 2014.08.02):

<table>
<thead>
<tr>
<th>series</th>
<th>window</th>
<th>opportunities</th>
<th>threshold</th>
<th>missed</th>
<th>recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>5º ring diagrams</td>
<td>9:36</td>
<td>4104</td>
<td>0.7</td>
<td>51</td>
<td>0.988</td>
</tr>
<tr>
<td>15º ring diagrams</td>
<td>28:48</td>
<td>1368</td>
<td>0.7</td>
<td>4</td>
<td>0.997</td>
</tr>
<tr>
<td>30º ring diagrams</td>
<td>57:36</td>
<td>684</td>
<td>0.7</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>time distance</td>
<td>8:00</td>
<td>4572</td>
<td>0.5</td>
<td>36</td>
<td>0.992</td>
</tr>
</tbody>
</table>

Principal causes of lost 5º ring diagram data

- EVE cal: 22%
- EVE+AIA/HMI cal: 14%
- AIA/HMI cal: 45%
- S/C roll: 2%
- Op Error: 4%
- Inst Failure: 4%
- S/C offpoint: 4%
- GT cal: 2%
- Lunar transit: 2%
Ring-diagram Data Products

Delay between Observation and Completion of Processing
Time-distance Data Products

Delay between Observation and Completion of Processing
Prospects

More of Same
   Identical analysis (almost) applied to MDI, GONG, and Mt Wilson data sets

Ring-Diagrams
   Addition of multi-ridge fit code to pipeline
   Full-disc fitc fits for 15° tiles
   Improved fitting procedures to account for spatial variations

Time-Distance

???
Spatial Distribution of Averaged mode-fit Parameters

\( n = 1–3, 0.9875 < r_T < 0.9975 \)

4-year mean 5° \( rdfitc \)
CR 2096:250–2149:050
(2010.05.01_02:12–2014.04.30_19:59)

(25 m/s contours)

last 2 yrs minus first 2 yrs 5° \( rdfitc \)
CR 2123:330–2149:050 -
CR 2096:250–2123:335

(2.5 m/s contours)
Comparing Ring-Diagram and Time-Distance Zonal Flow Anomalies
(Depth 3–6 Mm)
HMI, MDI, & GONG Coverage during Comparison Interval

2096:240 – 2098:015 (2010 05.01–07.12)
Differences in 4-year means of $rdfitf$ and $rdfitc$ flow parameters

$U_x$  
(2.5 m/s contours)  
$U_y$

Differences in 2.5-month means of $rdfitm$ and $rdfitc$ flow parameters  
(MDI data, 2096:150–2098:030)

(5 m/s contours)
But...
Differences in 1-rotation means of 15° and 4-yr means of 5°

And...
Differences in 2.5-month means of MDI 15° and 4-yr means of HMI 5°