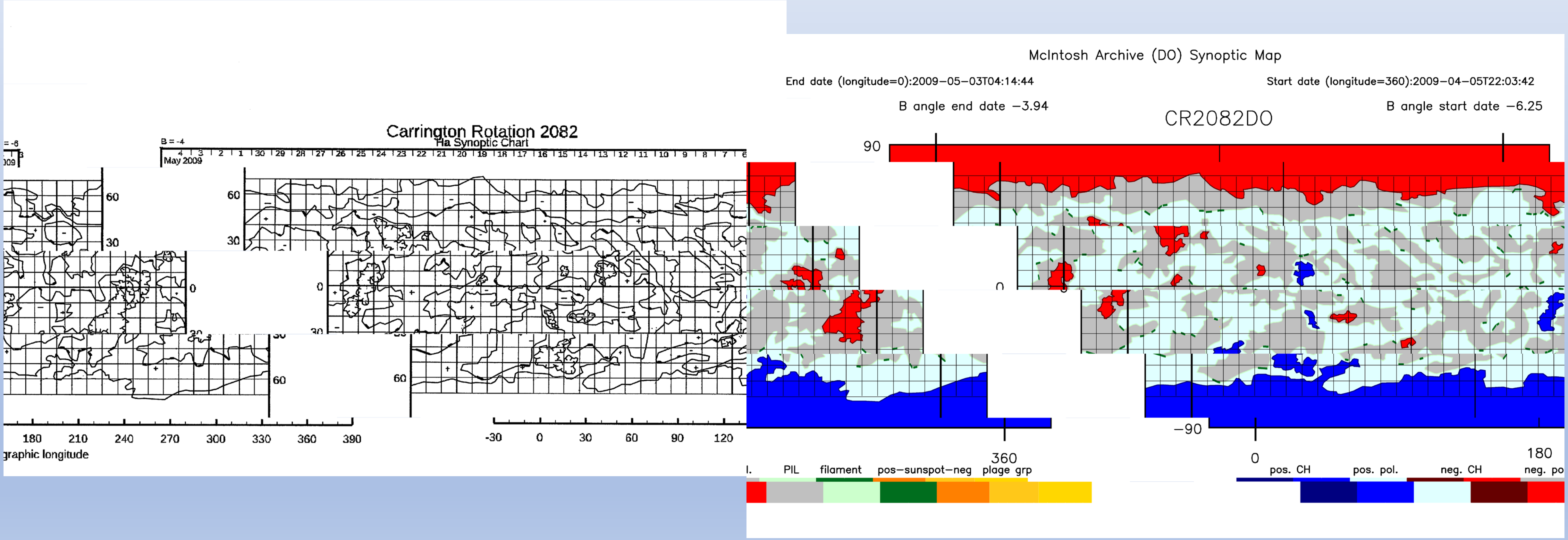
The McIntosh Archive Plus;
Extending a long-term data set into the modern era

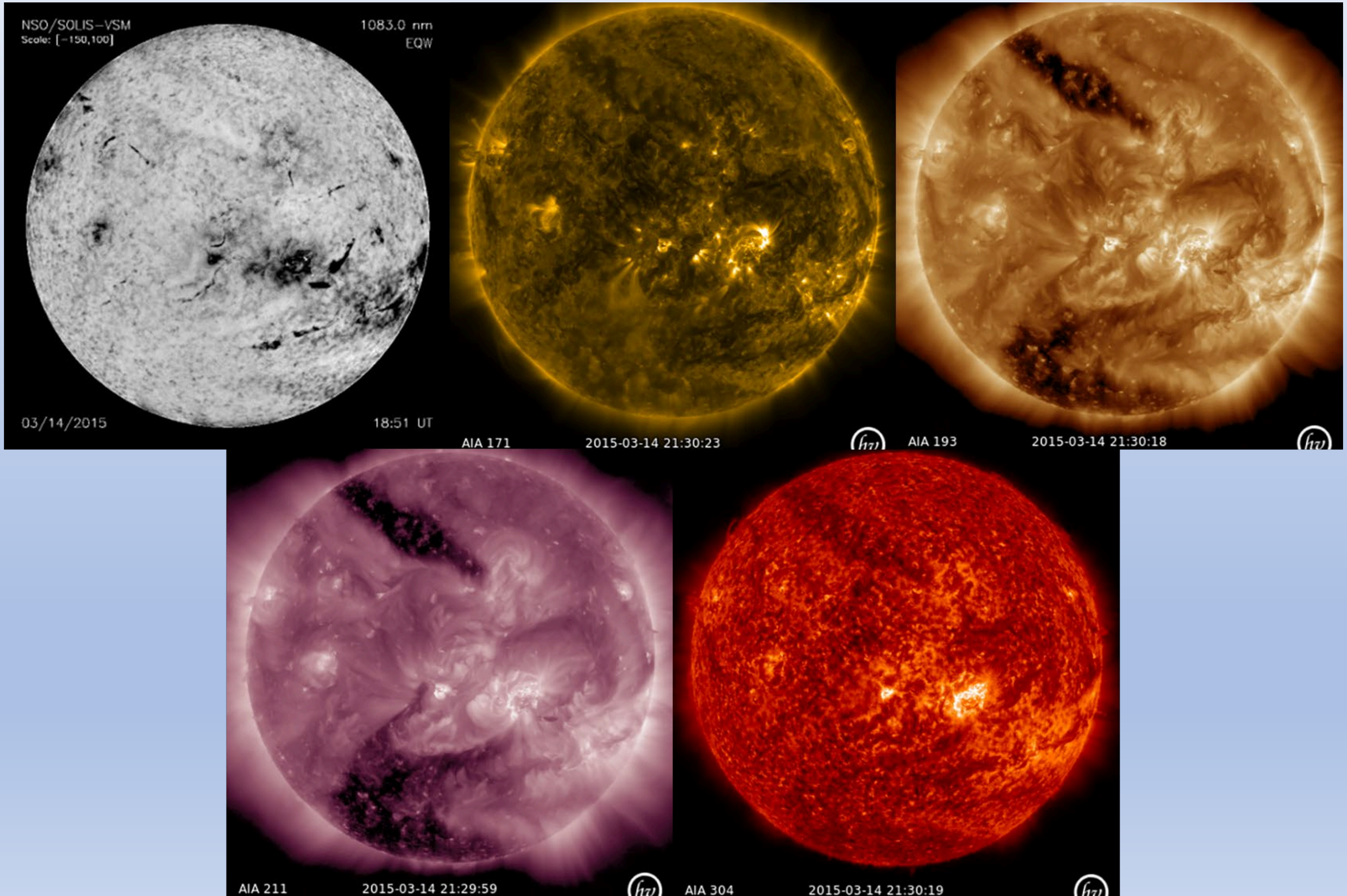
Ian Hewins (1, 2), Robert McFadden (1, 2), Geoff Crowley (1), David Webb (3), Michael Kirk (4), Sarah Gibson (2)

1= Orion Space Solutions, 2= HAO/NCAR, 3= Boston College, 4= NASA

Introduction - The McIntosh Archive is made up of over 4 Solar Cycles (20 – 23) or 45 years (1964 – 2009) of hand made solar synoptic maps made with Hydrogen α, Magnetogram and once available, He 10830 images. Paper, pencils, transparencies and light tables were used to transfer and integrate the features on these separate images into synoptic map format. These original maps were later digitized with Photoshop and IDL codes into a final format available in GIF and FITs formats. They show the size and positions of filaments, polarity inversion lines, sunspots, plage regions and coronal hole boundaries. In order to bring the mapping technique and the maps in the archive themselves into the modern era, we have developed techniques to make the original maps using only Photoshop and IDL and are adding Solar Cycle 24 and using EUV instead of HE 10830 Å data.

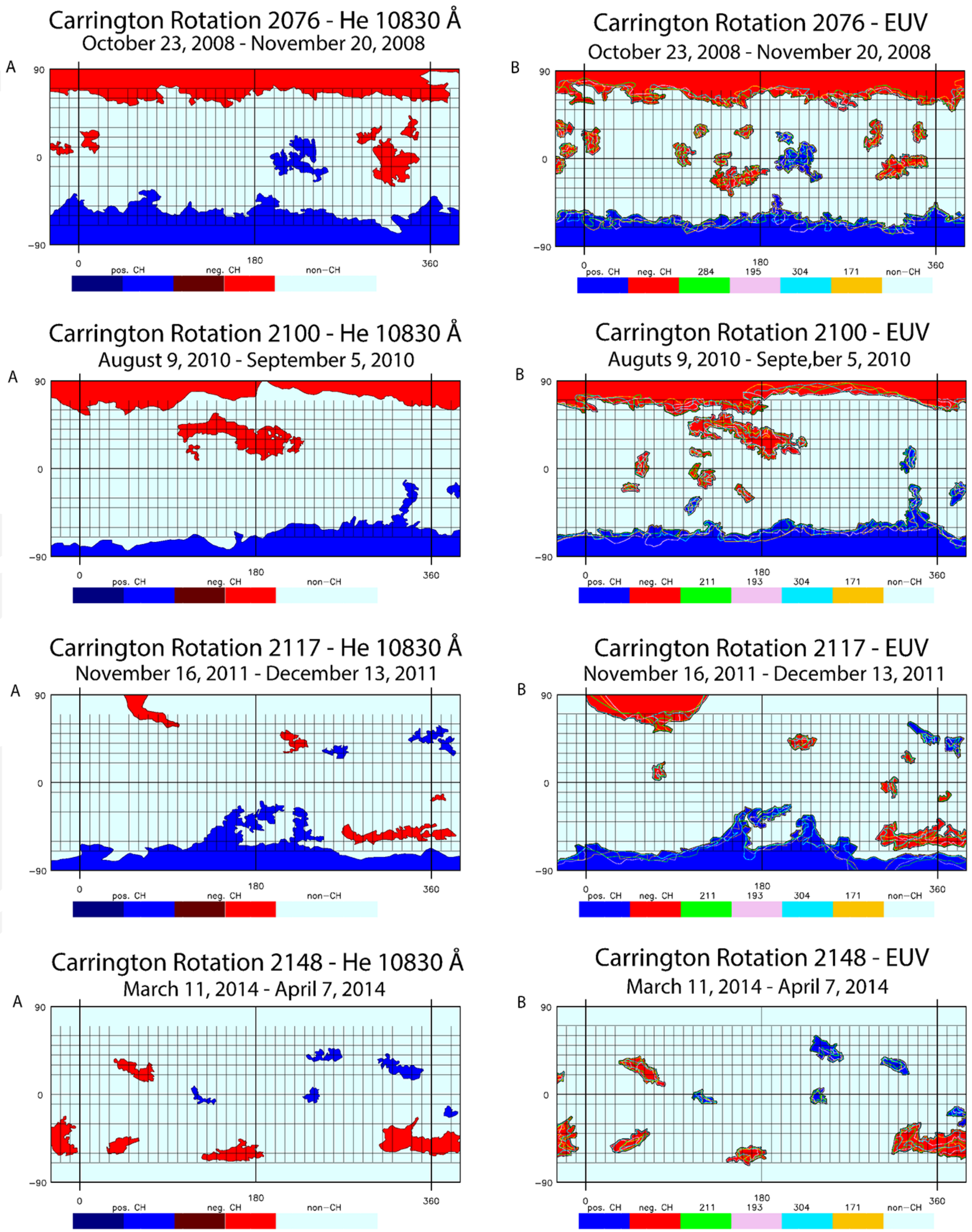


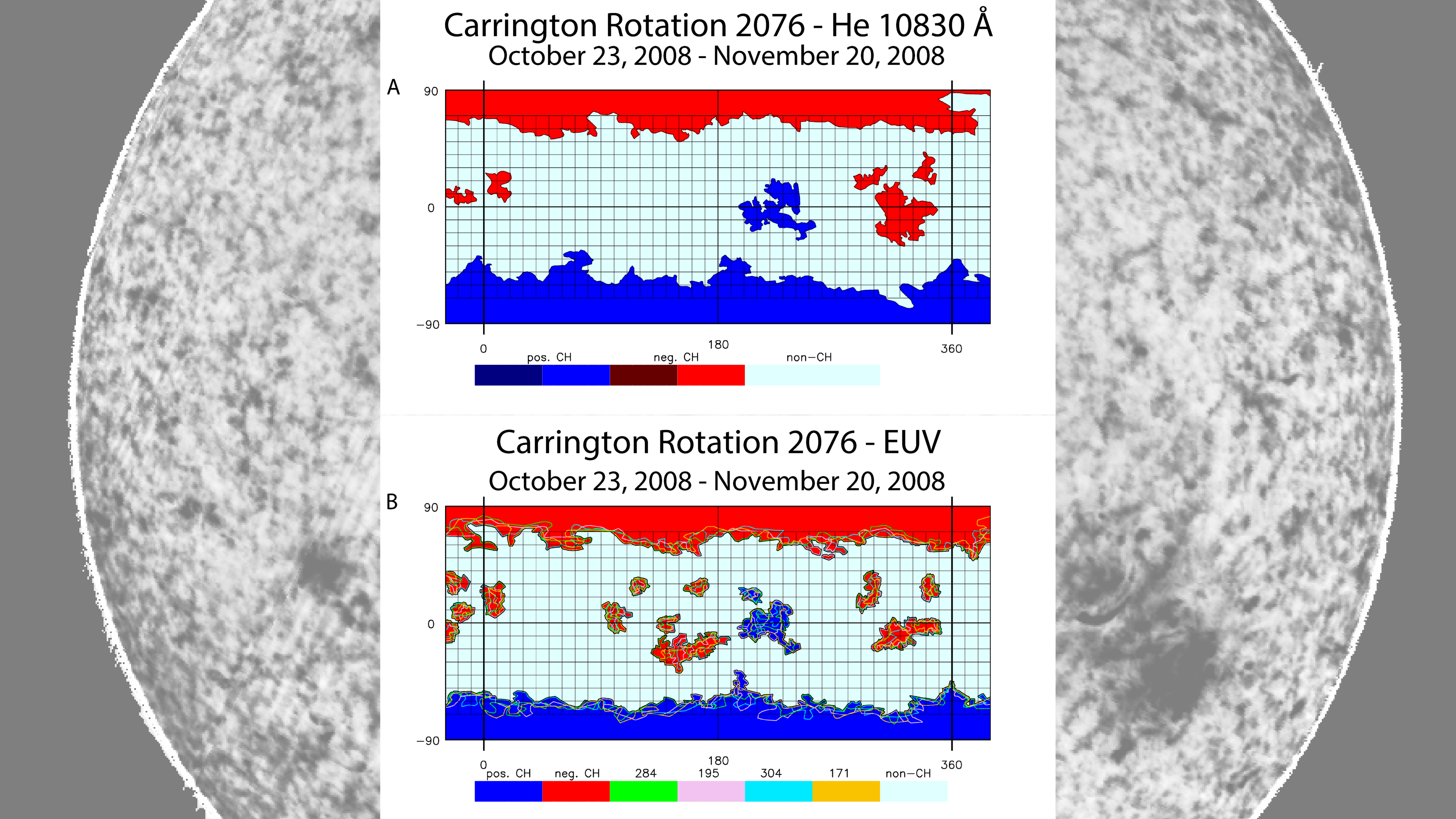
Calibration HE 10830 Å to EUV data - Due to the change in the data used to find coronal hole boundaries (He 10830 Å to EUV) a comparison between the types of data was done. National Solar Observatories discontinued the consistent collection of He 10830 Å in approximately 2014, however this data collection overlaps with the operation of NASA's Solar and Heliospheric Observatory (SOHO) and the first 4 or so years of NASA's Solar Dynamics Observatory (SDO). Examples (left to right and top to bottom) of He 10830 Å (NSO), AIA 171, AIA 193, AIA 211 and AIA 304 images (SDO) from approximately the same day and time.



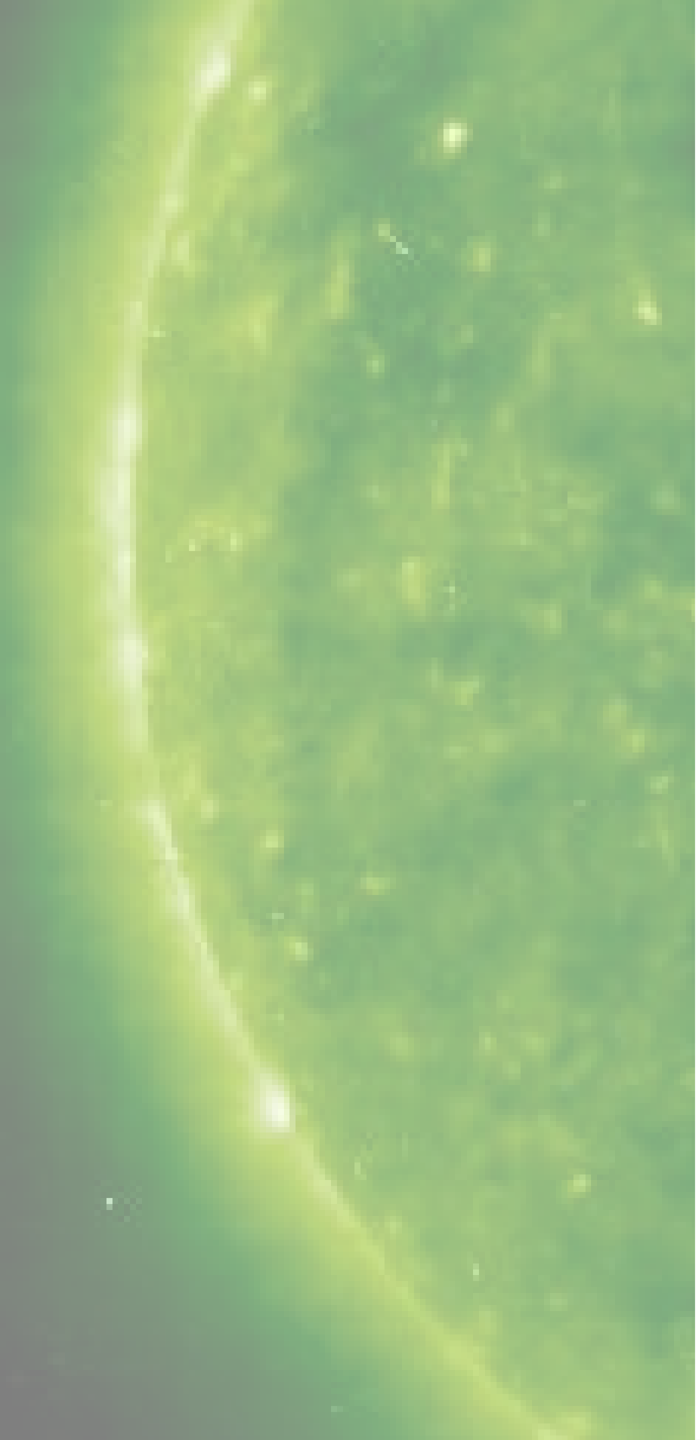
Comparison Maps
HE 10830 Å to EUVE 10830 Å to EUV data

- Comparison maps of four Carrington Rotations. He 10830 Å To EUV data. CR's 2076 and 2100 are closer to solar min and CR2117 and 2148 represent hemispheric solar maximums. Closer to minimum we see more coronal holes in EUV than He 10830 Å. Closer to solar maximum we see greater agreement between them. Top to bottom –
- CR2076 A (left) HE 10830 Å and B (right) SOHO 171 Å, 195 Å, 284 Å and 304 Å.
- - CR2100, CR2117, CR2148 A (left) HE-I 10830 Å and B (right) SDO 171 Å, 193 Å, 211 Å and 304 Å.



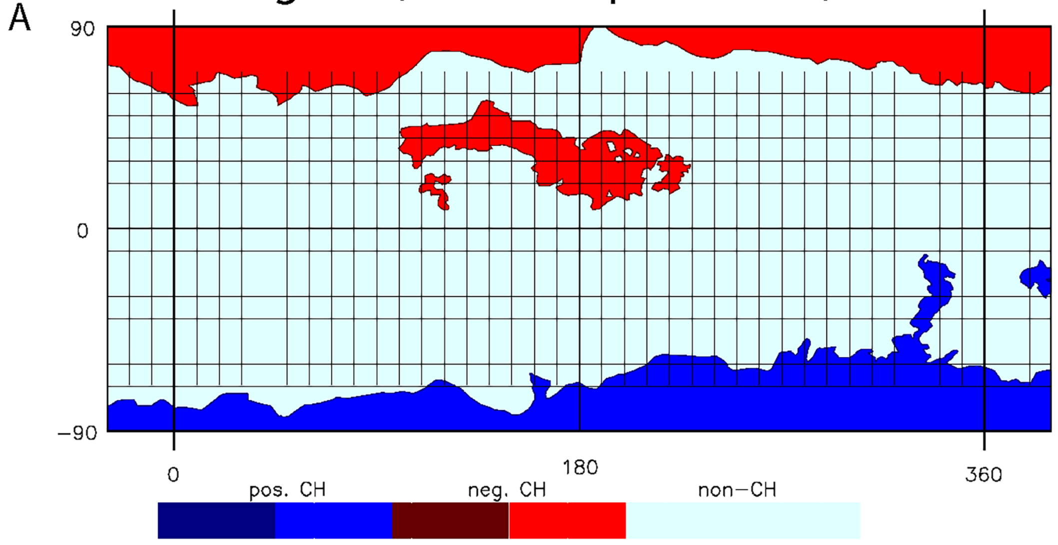


Carrington Rotation 2076 - He 10830 Å
October 23, 2008 - November 20, 2008
A
90
0
−90
0
180
360
pos. CH
neg. CH
non−CH
Carrington Rotation 2076 - EUV
October 23, 2008 - November 20, 2008
B
90
0
−90
0
180
360
pos. CH
neg. CH
284
195
304
171
non−CH



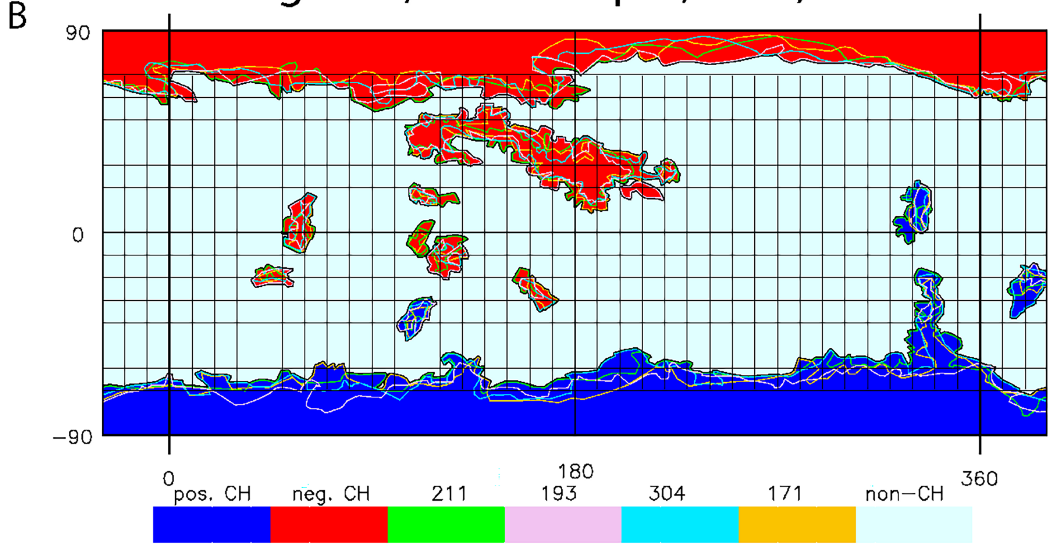
Carrington Rotation 2100 - He 10830 Å

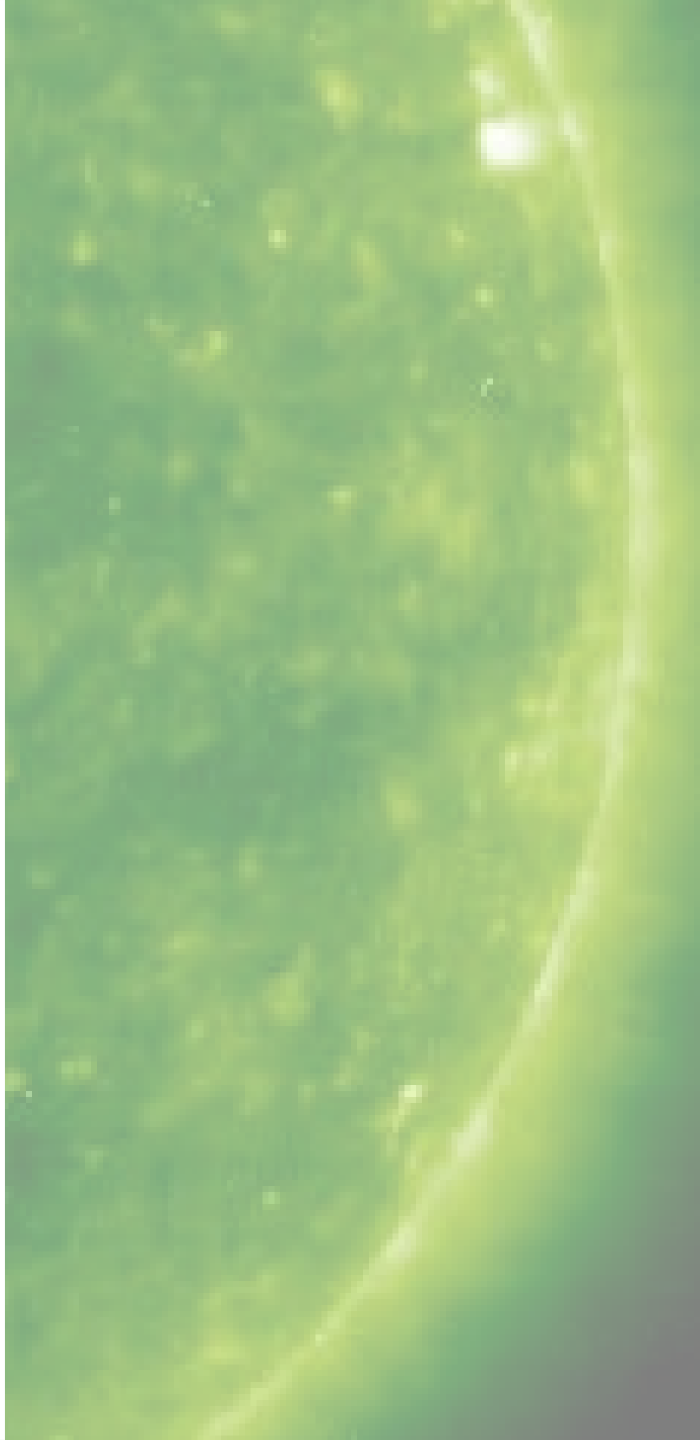
August 9, 2010 - September 5, 2010

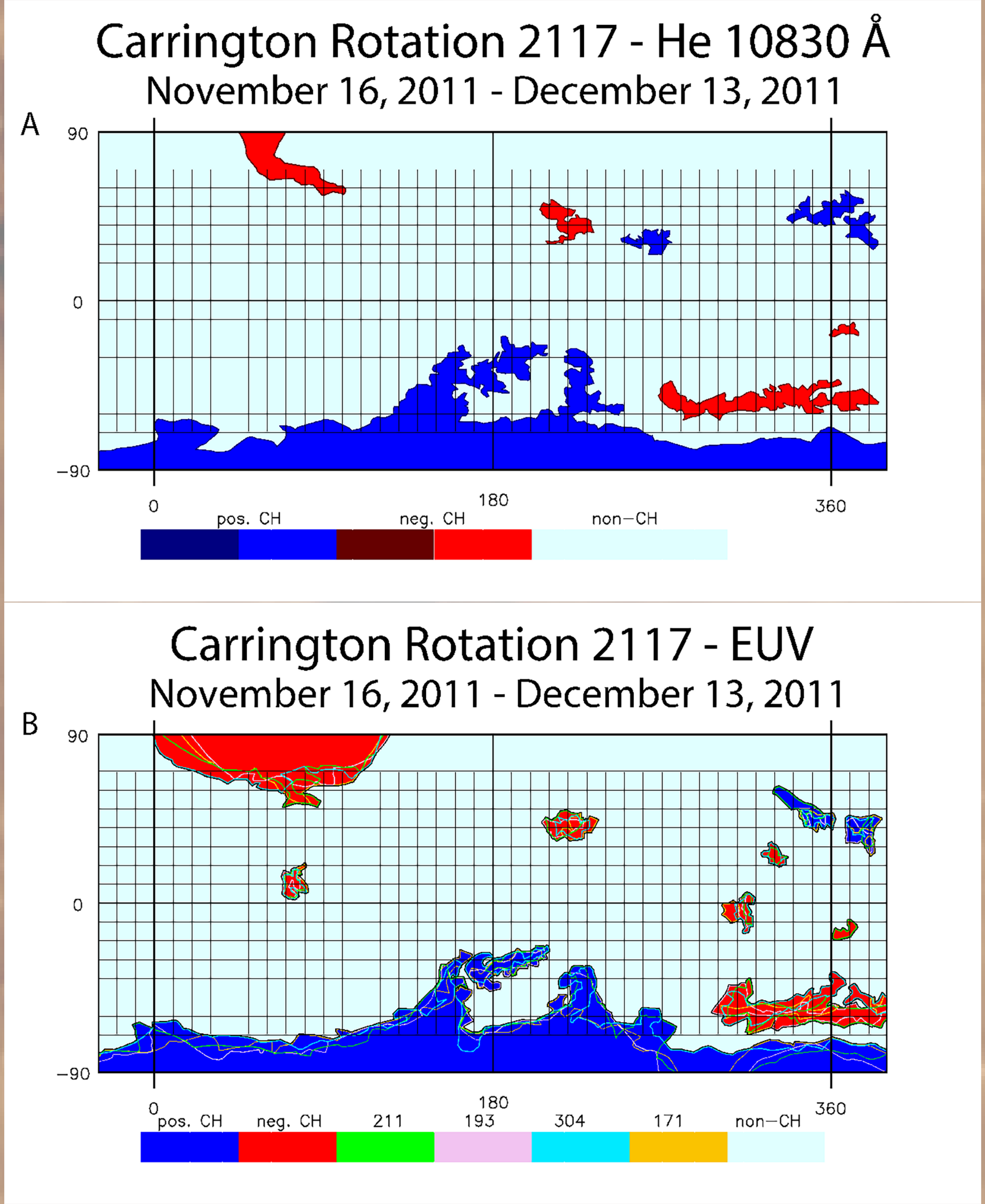


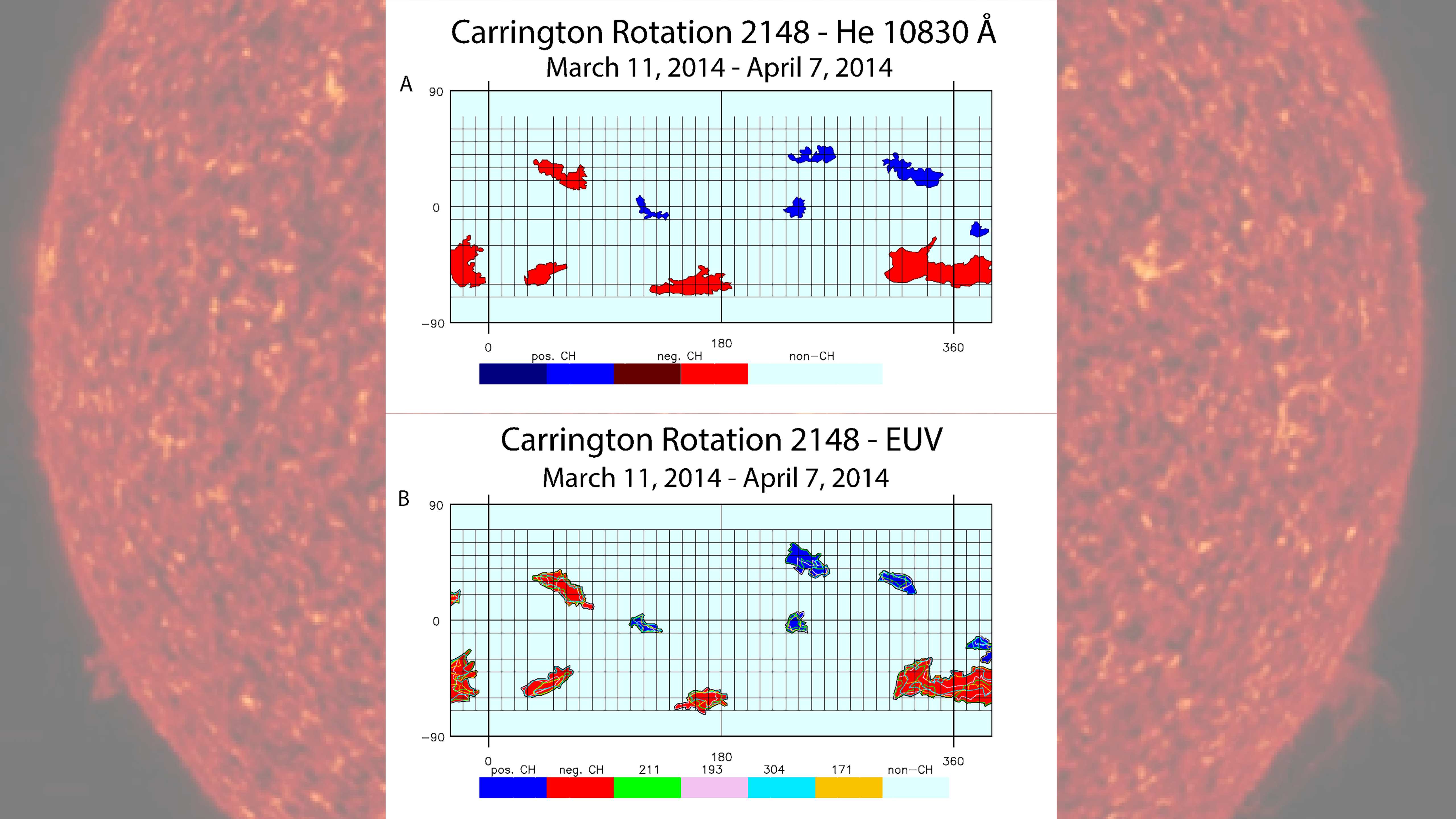
Carrington Rotation 2100 - EUV

Auguts 9, 2010 - Septe,ber 5, 2010






Carrington Rotation 2117 - He 10830 Å
November 16, 2011 - December 13, 2011
A
90
0
−90
0
180
360
pos. CH
neg. CH
non−CH
Carrington Rotation 2117 - EUV
November 16, 2011 - December 13, 2011
B
90
0
−90
0
180
360
pos. CH
neg. CH
211
193
304
171
non−CH



Carrington Rotation 2148 - He 10830 Å
March 11, 2014 - April 7, 2014
A
90
0
−90
0
180
360
pos. CH
neg. CH
non−CH
Carrington Rotation 2148 - EUV
March 11, 2014 - April 7, 2014
B
90
0
−90
0
180
360
pos. CH
neg. CH
211
193
304
171
non−CH

Feature Identification and Digital Mapping.

The digital mapping techniques were designed to imitate as closely as possible the original techniques using paper and pencils. Each of the steps taken in digital mapping imitates what was done with paper and pencil as described below. For further detail on manual mapping see Webb et al., 2018.

•Daily images are collected and used from roughly every 4 days. Features are first marked on these images in Photoshop or printed and then marked with pencil for manual mapping (Figure 4A). H α for filaments, sunspots and plage regions, Magnetograms for polarity inversion lines and EUV for coronal hole boundaries.

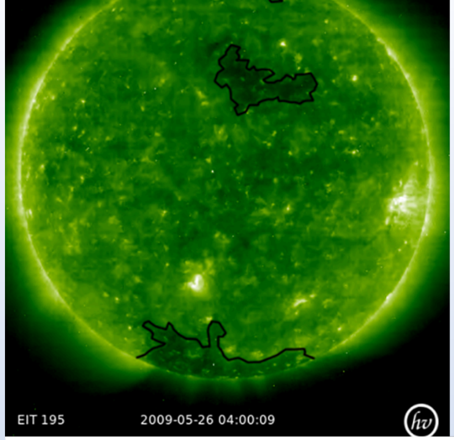
•A Stonyhurst disc is overlayed to adjust for B angle and to create latitude and longitude lines and the central meridian on the image.

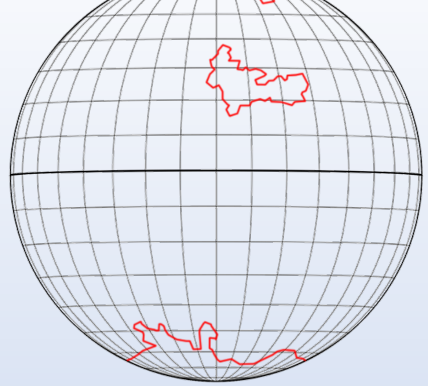
•In manual mapping, after overlaying the Stonyhurst disc, cartographers transfer the data they see onto a "quick look" which would look similar to the IDL output map (Figure 4C).

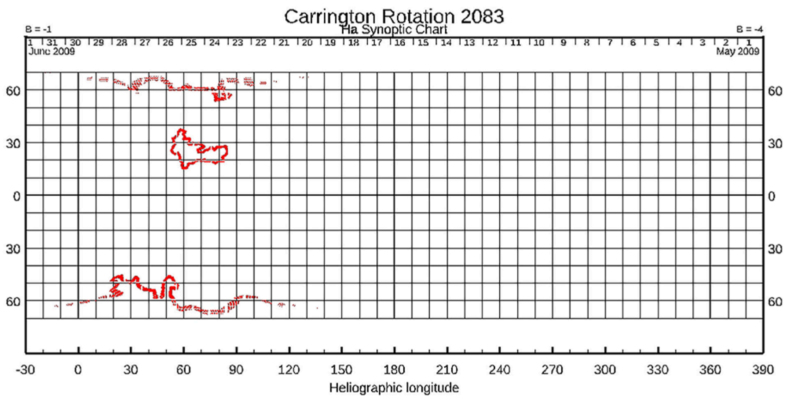
•In digital mapping, features marked on the daily image are traced onto the Stonyhurst disc (Figure 4B). Then, IDL is used to convert the disc coordinates to a synoptic map format (Figure 4C) and place traced features at the appropriate central meridian. Thanks to Thomas Kuchar at BC.

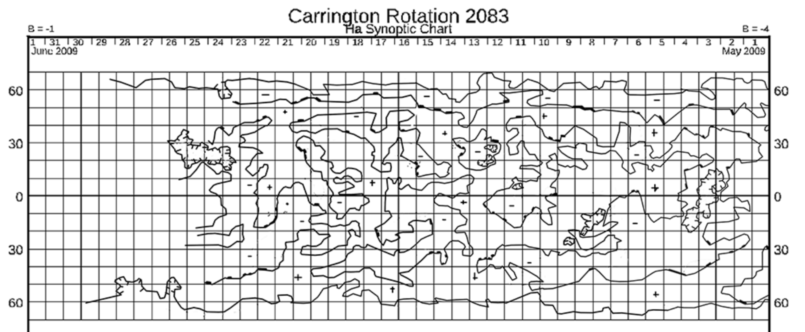
•Features are then traced and integrated with existing data on the map (Figure 4D). This is done with a light table in manual mapping and in Photoshop with digital mapping.

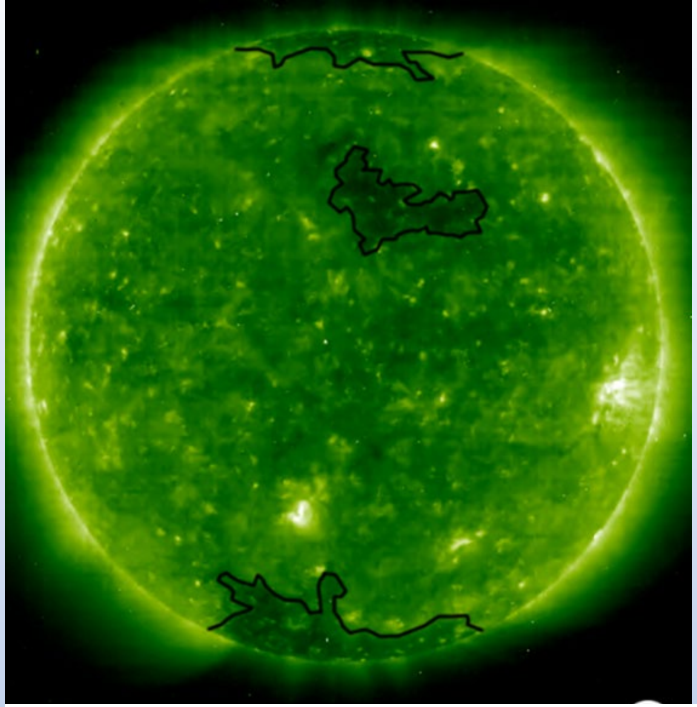
•The original black and white map is then colorized and digitized in the identical way the original hand made maps were digitized. The example below is a SOHO EIT 195 image used for the first 20 Carrington Rotations of SC24.

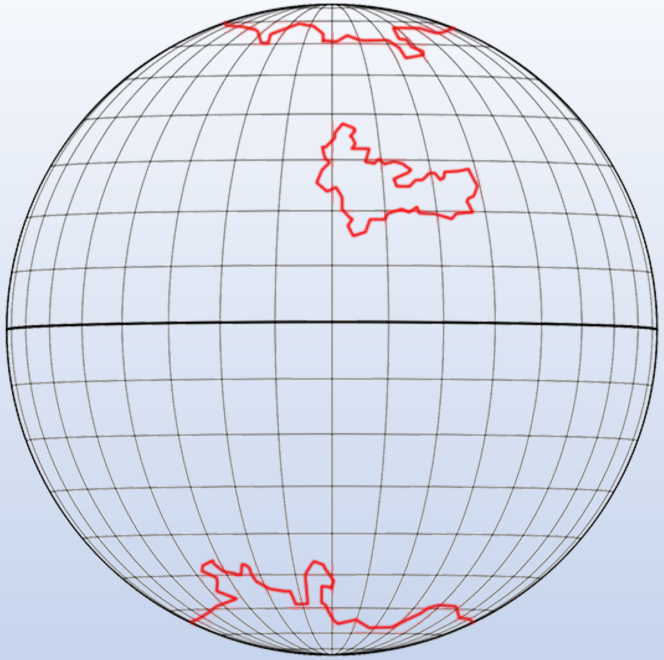


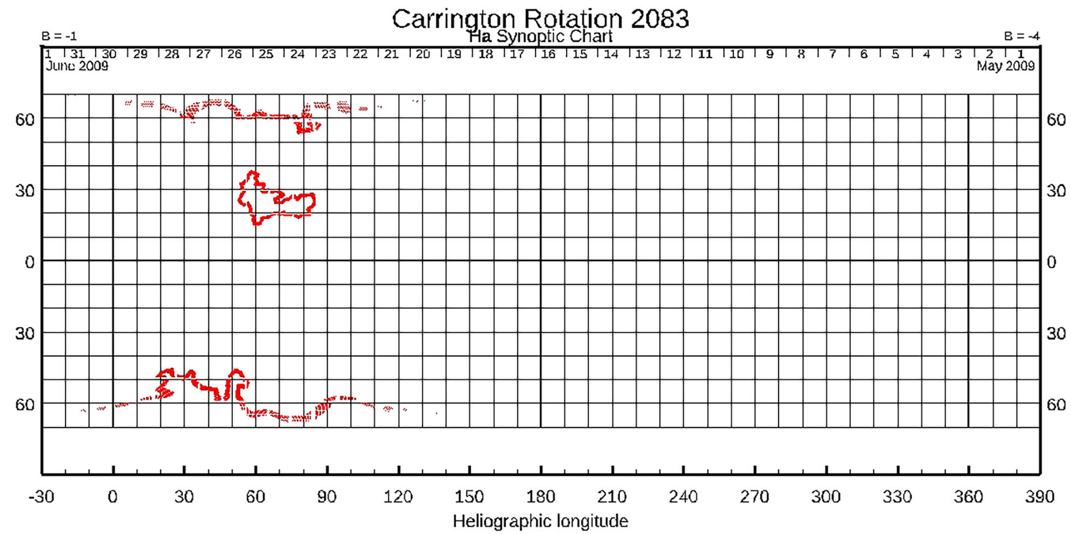


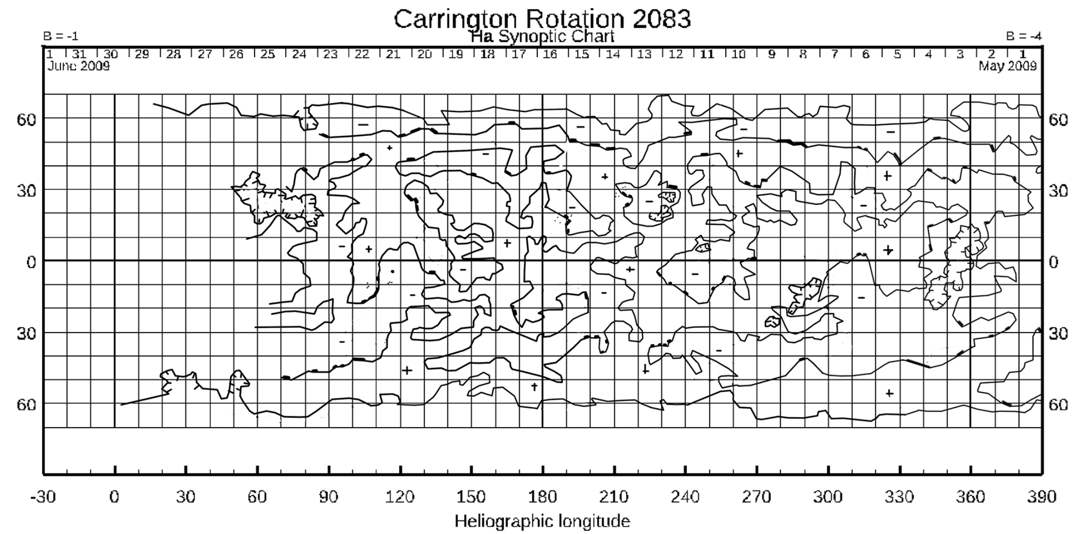




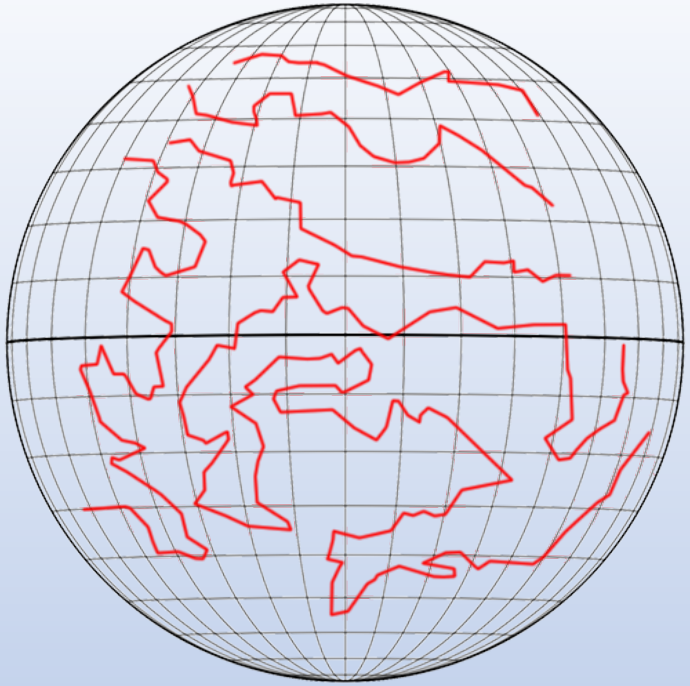


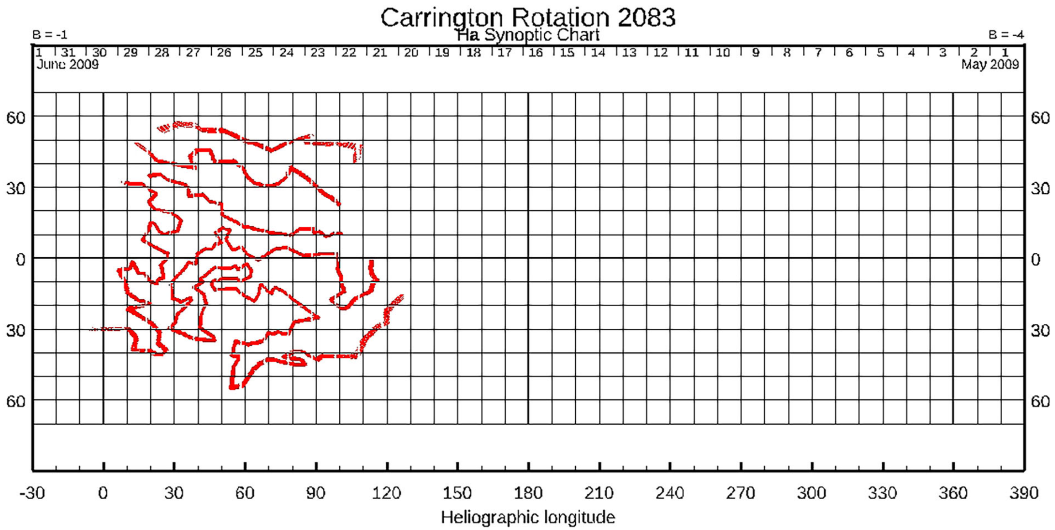



Carrington Rotation 2083
Hα Synoptic Chart
B = -1
B = -4
June 2009
May 2009
-30 0 30 60 90 120 150 180 210 240 270 300 330 360 390
Heliographic longitude

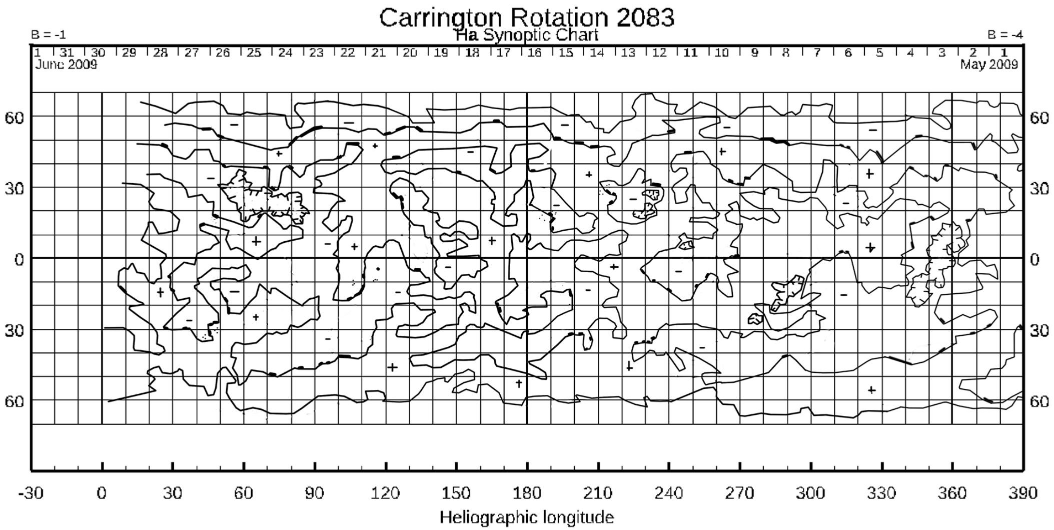

Carrington Rotation 2083
Hα Synoptic Chart
B = -1
B = -4
June 2009
May 2009
-30 0 30 60 90 120 150 180 210 240 270 300 330 360 390
Heliographic longitude

Integrated Synoptic Program (NISP)
Big Bear, CA USA
10-Minute Averaged Magnetogram (Zero Point Corrected)
NISP





Carrington Rotation 2083
Hα Synoptic Chart
B = -1
B = -4
1 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
June 2009
May 2009
60
30
0
30
60
-30 0 30 60 90 120 150 180 210 240 270 300 330 360 390
Heliographic longitude



Carrington Rotation 2083
Hα Synoptic Chart
B = -1
B = -4
1 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
June 2009
May 2009
60
30
0
30
60
-30 0 30 60 90 120 150 180 210 240 270 300 330 360 390
Heliographic longitude

Conclusions

Consistent long term data sets are essential to understanding the cycles and patterns we see in the sun over time. However, improving instrumentation as well as techniques of data collection and integration provide new insights and greater accuracy in our research. The challenge we face is to integrate what has been done in the past with what we do today and will do tomorrow.

With the McIntosh Archive and mapping techniques, we have tried to hold onto the essential approach and techniques while utilizing modern tools that improve accuracy and reproducibility. Due to the loss of He 10830 Å we have adapted to the newer EUV data sources and attempted to calibrate what was used in the past with what is available today. Although EUV data is arguably easier to interpret than He 10830 Å, the fact that features are not visible in a consistent manner throughout the solar cycle in both data types means that we have a significant challenge in interpretation of current data as compared to what is available from previous solar cycles.

As human observers we face some of the same challenges faced with machine learning and automated feature identification. There are few absolutes in data interpretation. A change in contrast and brightness in an image can change our ability to interpret data in a consistent manner. Different data types and sources do not show features in an identical manner. Two different cartographers or algorithms can interpret the same data differently. However, without consistent long term data sets, without an ability to utilize what has been done by those that come before us, we miss opportunities to discover patterns and regularity of recurrences. Our goal is to ensure that what was done in the past can be utilized in conjunction with what is done today and tomorrow while recognizing that consistency and calibration are essential.