Studies Using a Newly Digitized Archive of Global Solar Magnetic Field Patterns

David Webb, Sarah Gibson, Ian Hewins, Robert McFadden, Barbara Emery and William Denig

OUTLINE

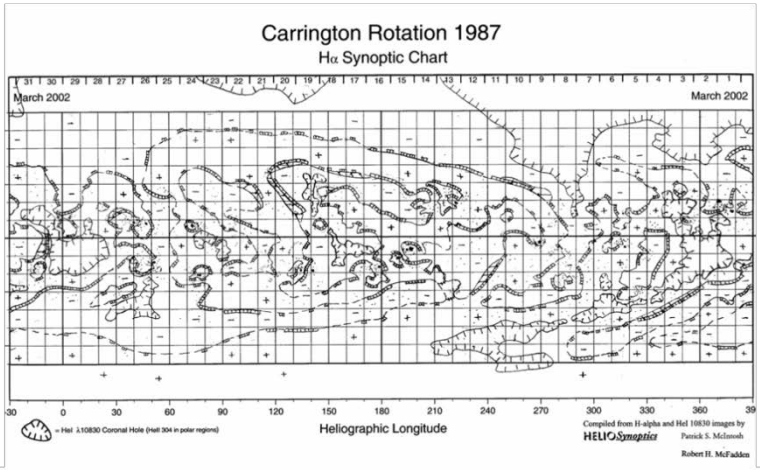
- **History: Pat McIntosh and what the maps are.**
- **Scientific applications and why you should care.**
- **Digitization and archiving process and a progress report**
  - **Bob on map creation**
  - **Ian on map archiving/digitizing**
- **We need feedback on:**
  - **the ideal format(s) of archived data.**
  - **discussion of 1) low-hanging scientific fruit and 2) general studies**

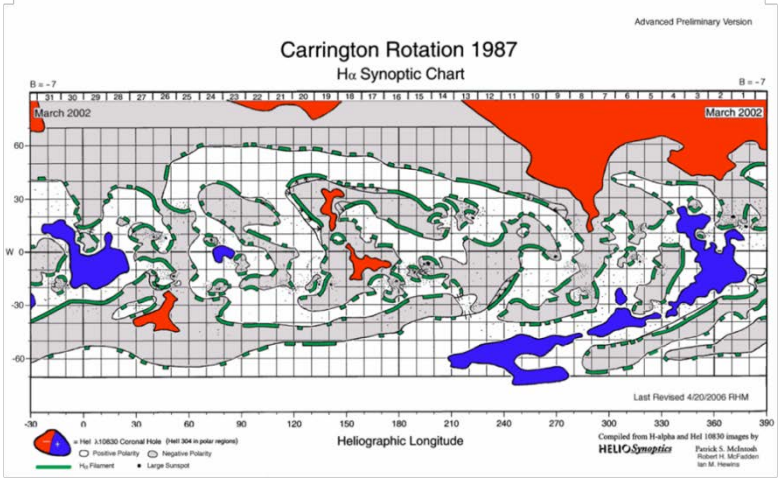
Some History; What the Maps Are

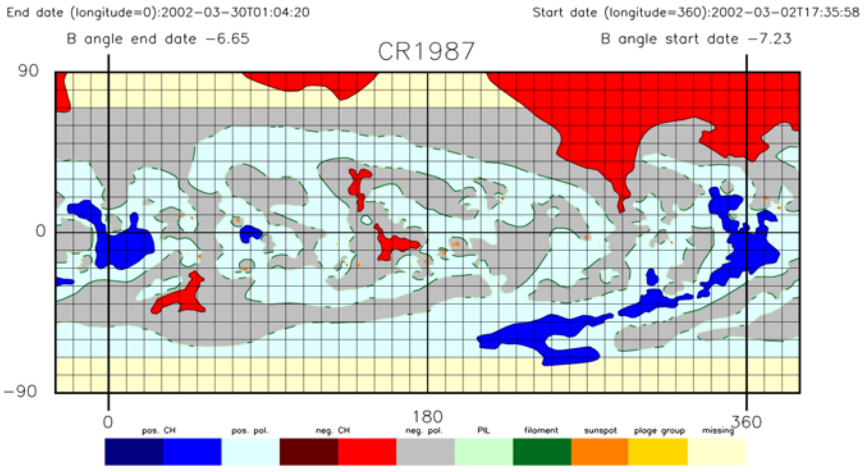
***Above – L to R*: Ian Hewins, Pat McIntosh and Robert McFadden during a mapping session in Pat's Boulder condo.**

***Right Top:* scanned copy of an original synoptic map from March 2002.**
***R Bottom:* processed colorized map, with negative (red) and positive (blue) polarity CHs, filaments (green), PILs (black) and negative (grey) and positive (white) polarity quiet Sun.**

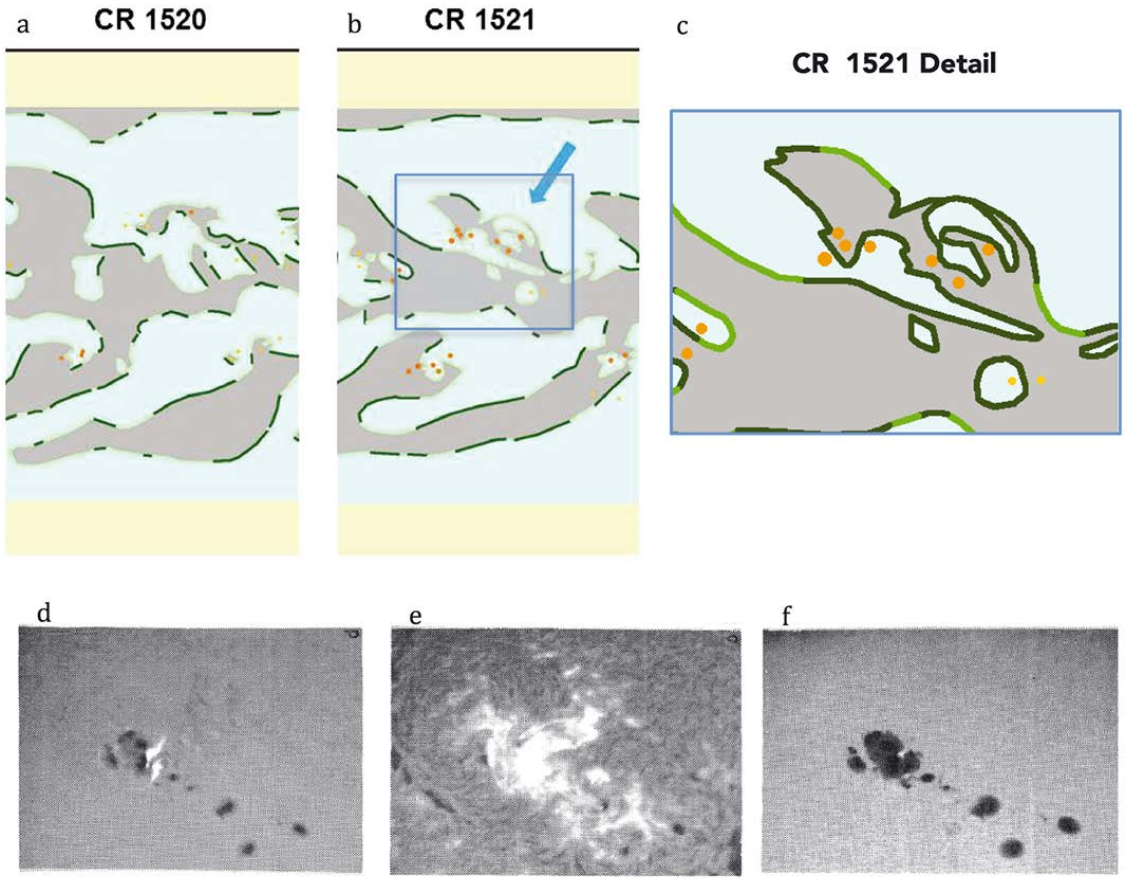
McIntosh collection of maps forms unique & consistent set of global solar field data → evolution of large-scale features over 4 cycles. The existing mapping paperwork and digital files have been brought to HAO. We are working to preserve this unique data set in digitized formats.





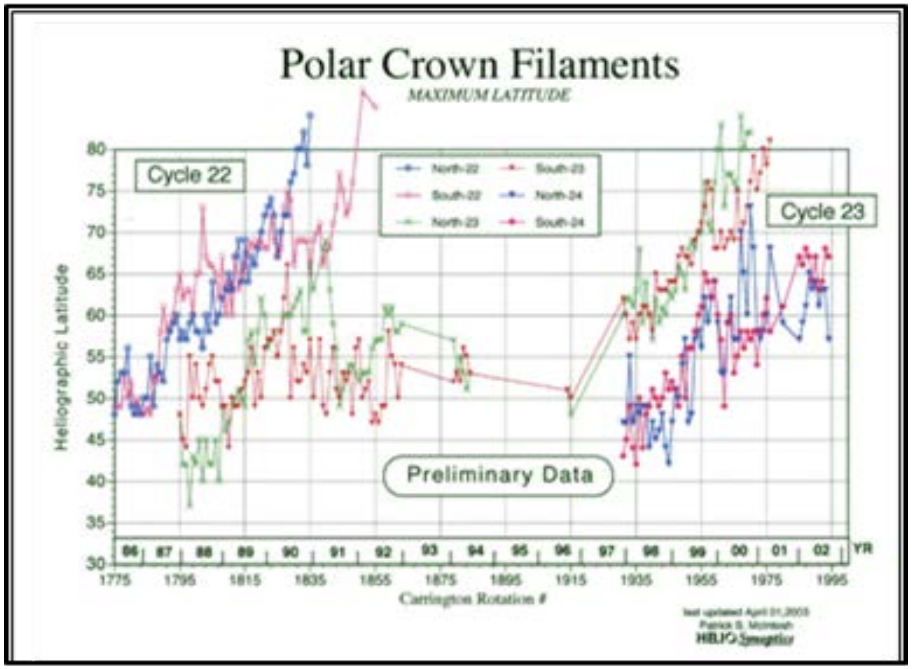


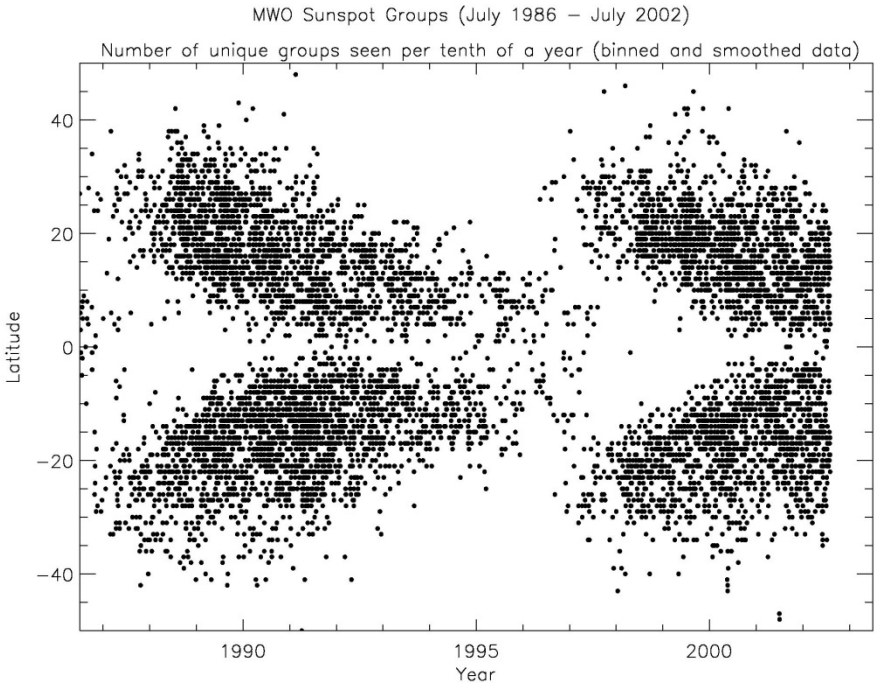
Example of New Scientific Use of Historical Data



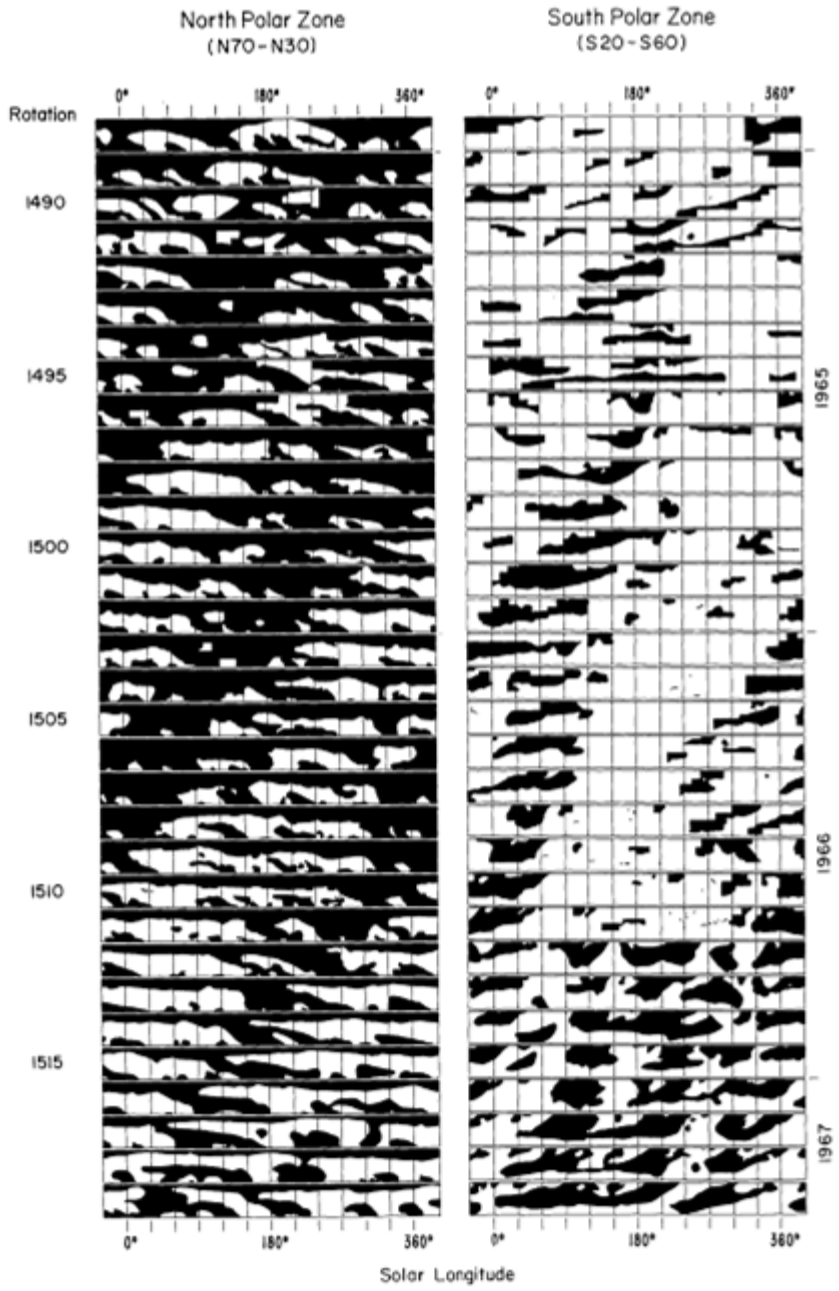
- **Newly digitized maps from SC 20 zooming in on evolution of "one of the greatest activity complexes of SC 20" (Pat M). Region (center - arrow) produced a great white-light, proton flare on 23 May 1967 that had serious space weather implications.**
- **The May 1967 great storm and radio disruption event: Extreme space weather and extraordinary responses; see Knipp et al. (SWxJ, 2016)**
- **1967 dates centered on these maps: 24 April (CR 1520), 20 May (CR 1521), 16 June (CR 1522).**

Some Ideas for Scientific Applications of the Maps: 1) Butterfly-type Plots





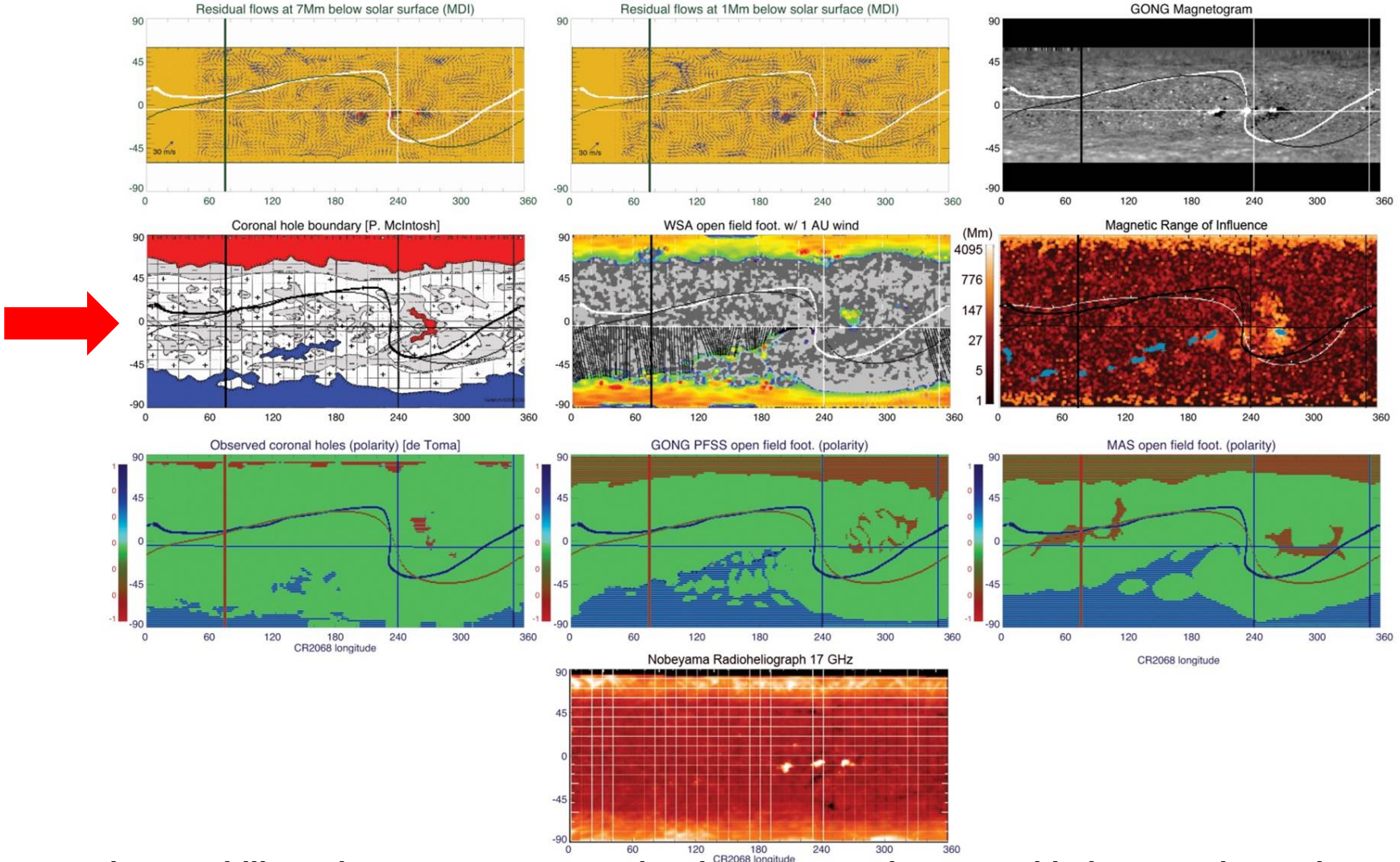
- ***Left:*** **Location of the maximum latitudes of PCFs during SCs 22 and 23 as tracked on McIntosh synoptic maps.**
- **PCFs and their PILs form the final boundary between old-cycle polarity which will reverse at maximum and new-cycle polarity which replaces it. During the period before reversal this high-latitude PIL nearly encircles the Sun.**
- **Overall, these motions give clues about the Sun's fluid dynamics and its dynamo processes over solar-cycle time scales. It is evident that similar plots of other features such as CH boundaries or active region centers and large sunspots *(right)* are also possible.**



2) Time series zonal "stackplots"

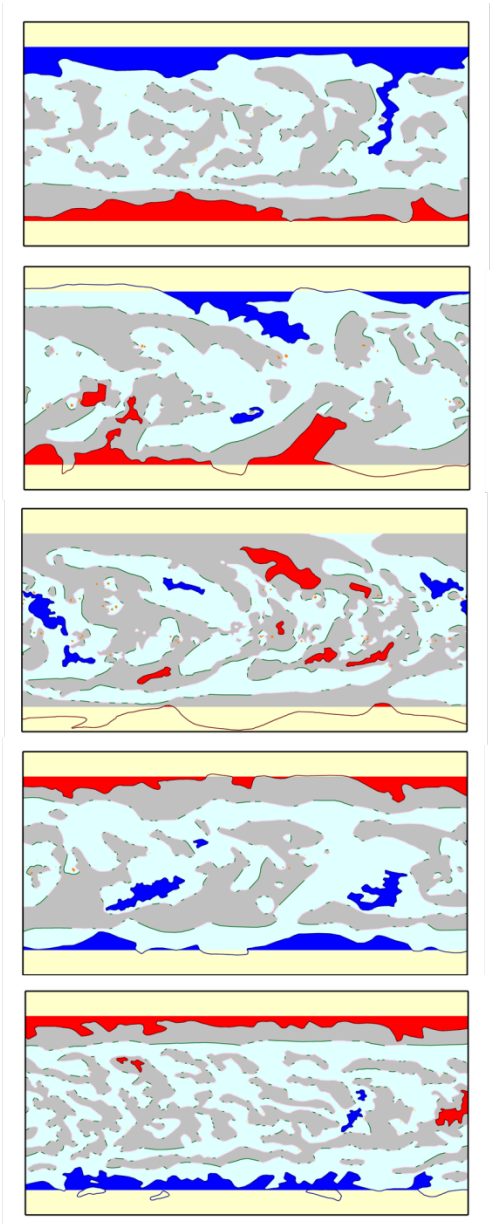
- ***Left:*** **Time series of zonal plots of Hα synoptic maps for mid solar latitudes for 1964-1967 comparing northern (left) and southern (right) hemispheres. Barber-poll patterns denote the varying rotation rates of the large-scale patterns.**
- **The time series stacking should be adjustable from a few consecutive maps to maps covering a solar cycle or so in time.**
- **An atlas of stackplots of the Hα synoptic charts covering two full solar cycles, from 1966-1987, was published by NOAA (McIntosh et al., 1991).**
- **Decadal stackplots have demonstrated the evolution of the Polar Crown and Gaps, polarity reversals and longitudinal pattern drifts that circle the Sun over a cycle. Their analysis led to the development of a model of flux emergence and surface evolution (e.g., Wilson and McIntosh).**

3) Comparisons with synoptic maps at other wavelengths



- **Desire capability to intercompare or overlay the Hα synoptic maps with those made at other wavelengths or for other purposes. Overlays done by keying on coord. of large sunspots, at fixed latitude and longitude locations, or over same fixed areas.**
- ***Above:* Solar Carrington maps comparing polarity boundary map (arrow) with subsurface, magnetograph, radio, magnetic range of influence, and solar wind footpoint data (from WHI in 2008).**

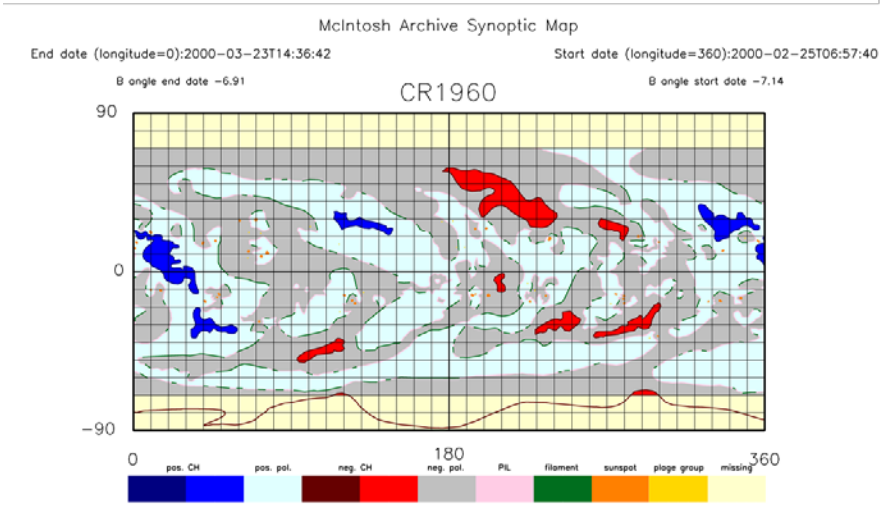
Our Digitization and Archiving Methodology & Progress

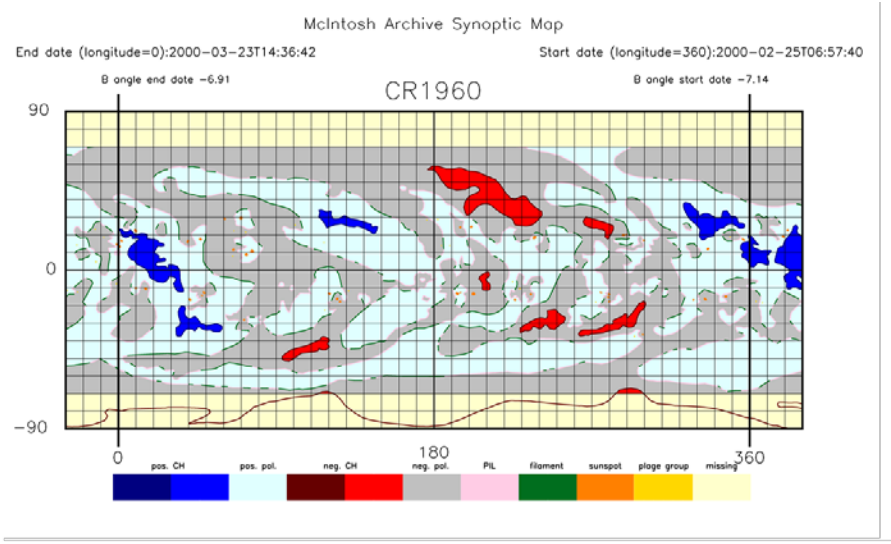


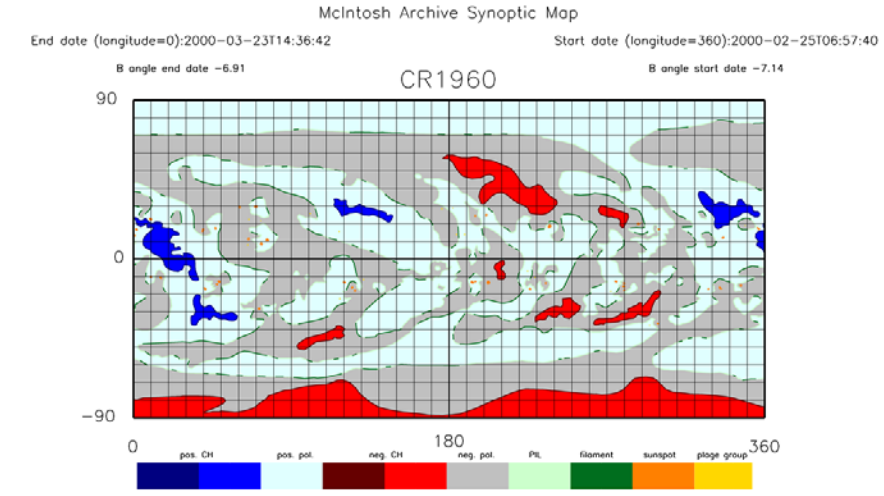
- The maps show filaments, PILs, CHs, sunspot/plage and missing data (> 70° latitude) regions for each CR. Original maps are scanned with an HAO scanner. Processing consists of using Adobe Photoshop and IDL to convert maps to a standard size based on no. of pixels in width (heliolongitude) and height (heliolatitude), to remove any unnecessary notes, marks, or symbols, and to colorize the maps.
- Next → output processed maps as arrays of numbers which reproduce color-coded solar features for each rotation.
- Processing of the initial electronic maps has begun with the most recent data, for SC 23. Will then work backwards in time and SC number, as funding permits.
- In the process of writing computer codes to permit efficient searches of the map arrays and to organize the information for scientific purposes.
- Finally, digital files for each CR map created in each process step will be stored at NOAA NCEI → William Denig.

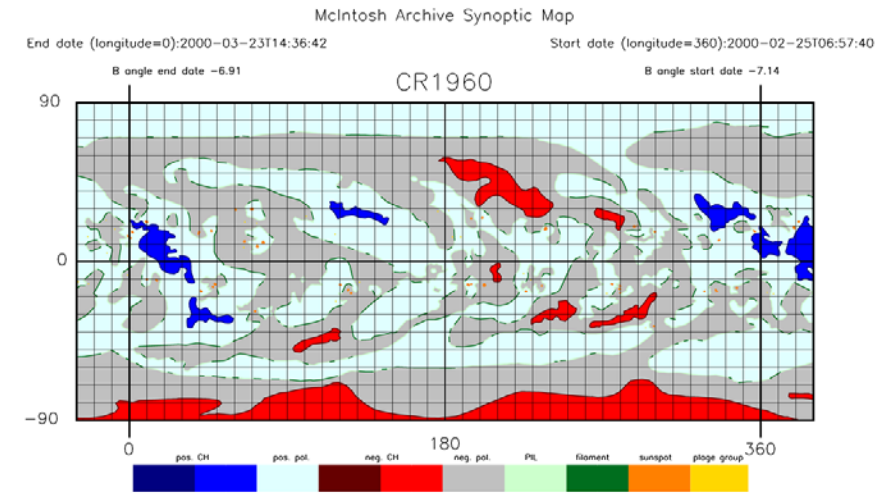
Left: **Sample of maps illustrating evolution of magnetic field polarity boundaries and CHs over SC 23.**

Top to bottom: **CR maps from cycle 22/23 min. in 1996, rise in 1998, max in 2000, declining phase in 2007, and cycle 23/24 min. in 2008-09.**









Four additional annotated map products are shown for the max. at CR 1960:

Left:	**0° – 360° map with grid and with and without missing data,**
Right:	**360° ± 30° map with grid and with and without missing data.**
Top:	**Maps with CH boundaries drawn into the > 70° latitude areas.**
Bottom:	**Maps show CH boundaries filled with the appropriate CH color.**

Can Run any Format as a Movie!

General Discussion - Feedback

- **In the maps each feature is denoted by a single number corresponding to a unique (RGB) color (see color-key bar). Thus, in the digital file for a given CR, a given feature can be located by finding all those pixels that have that color number as a function of latitude and longitude.**

- **Since all the final CR maps will have the same color system and known scaling, features can be intercompared over many CRs, with time and solar cycles.**

- **We are working on developing codes to access these data:**
  - **Would like your comments/feedback on how the maps can be used for scientific purposes.**
  - **What are the best format(s) for the archived data (e.g., image files, FITS, 16 possible formats)?**