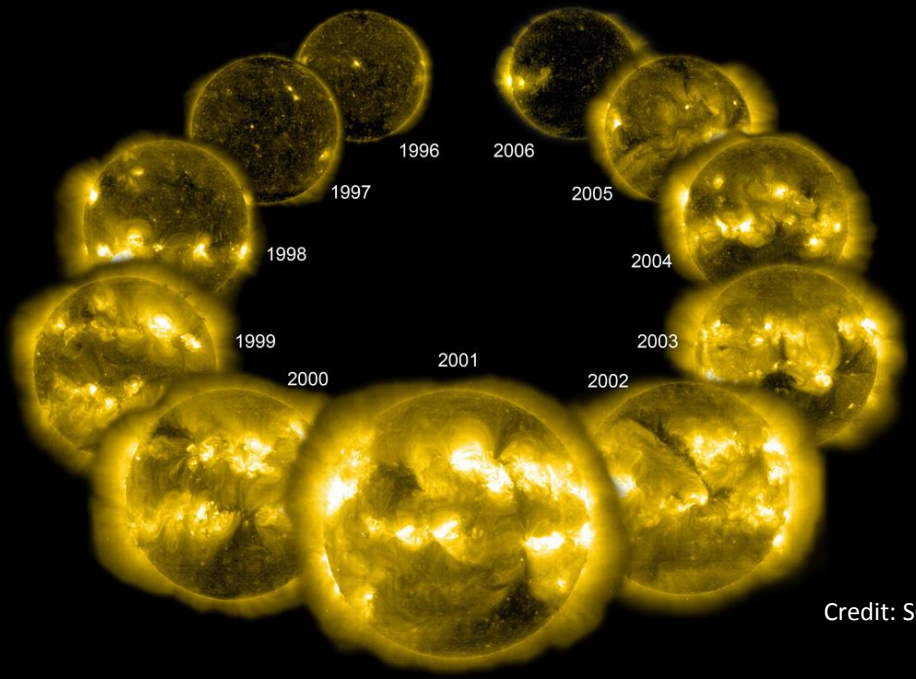
What Makes Each Cycle Special?

A Characterization of Hemispheric Cycles



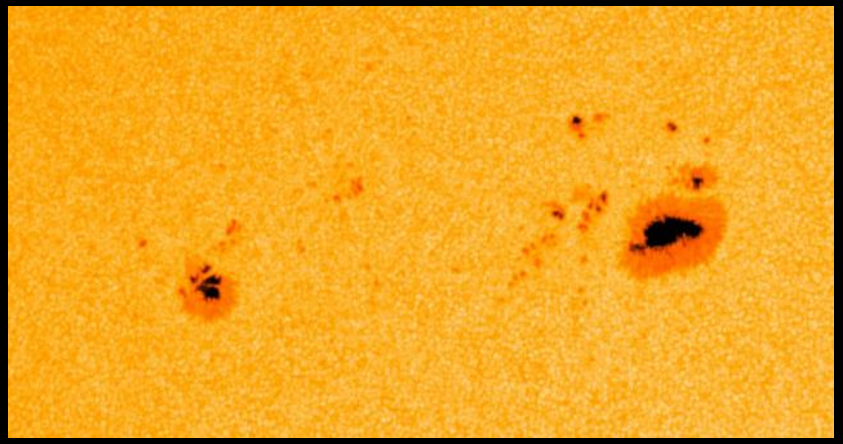
Credit: SOHO/NASA/ESA

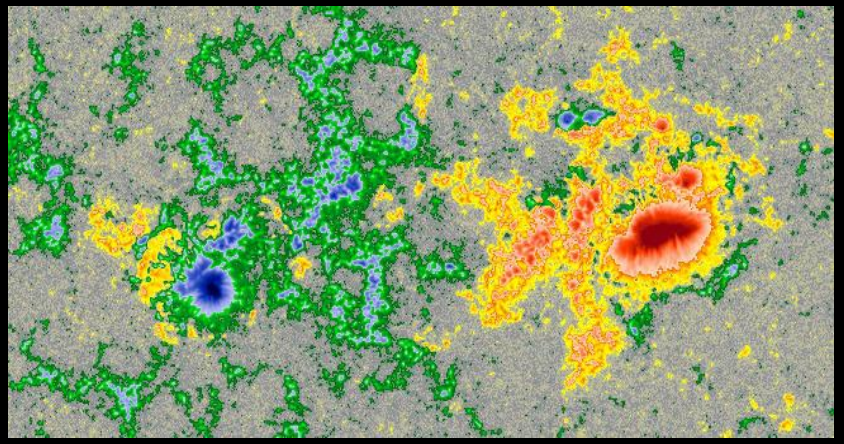
Ryan Senkpeil

Andres Munoz-Jaramillo

Ed DeLuca

Sunspots and Active Regions

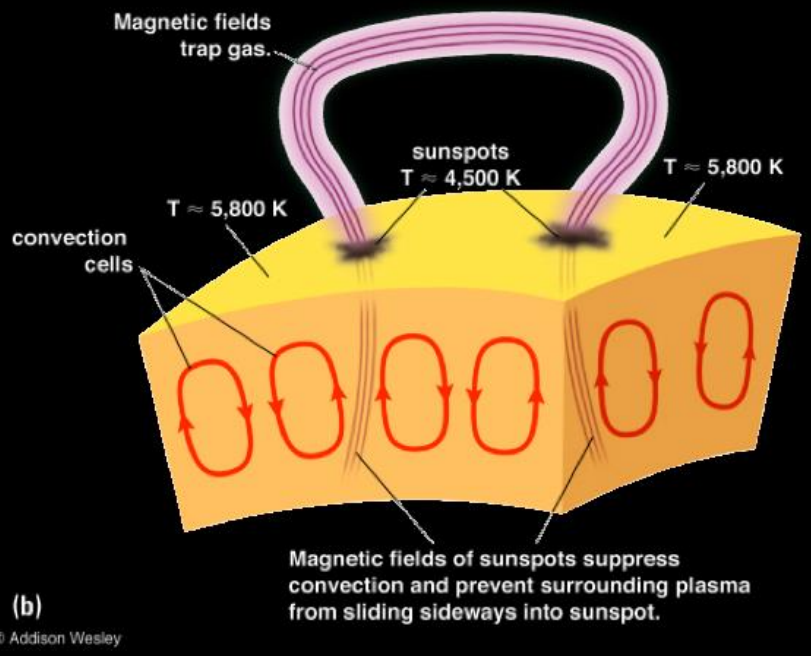




Credit: SDO/HMI

- Regions of very strong magnetic field on the photosphere
- Sunspot pairs are known as active regions

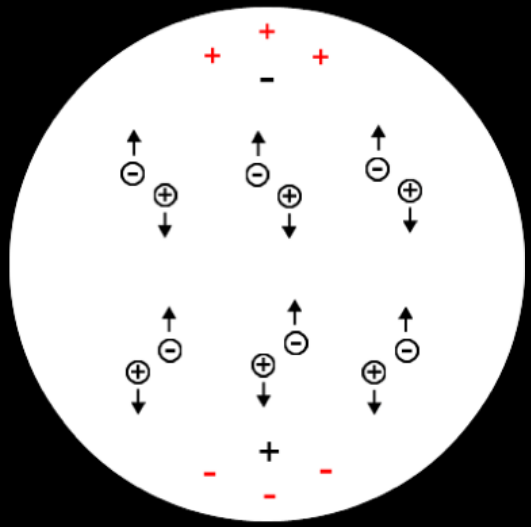
Sunspots and Active Regions

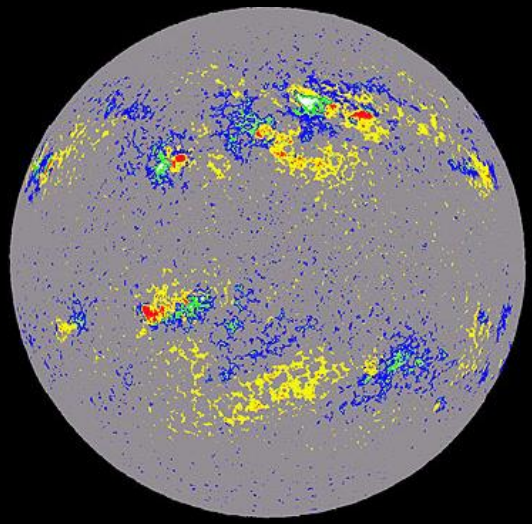


Credit: Addison Wesley

- Active regions originate as rising magnetic flux tubes
- Magnetic fields suppress heat transfer resulting in cooler and darker regions

Sunspots and Active Regions

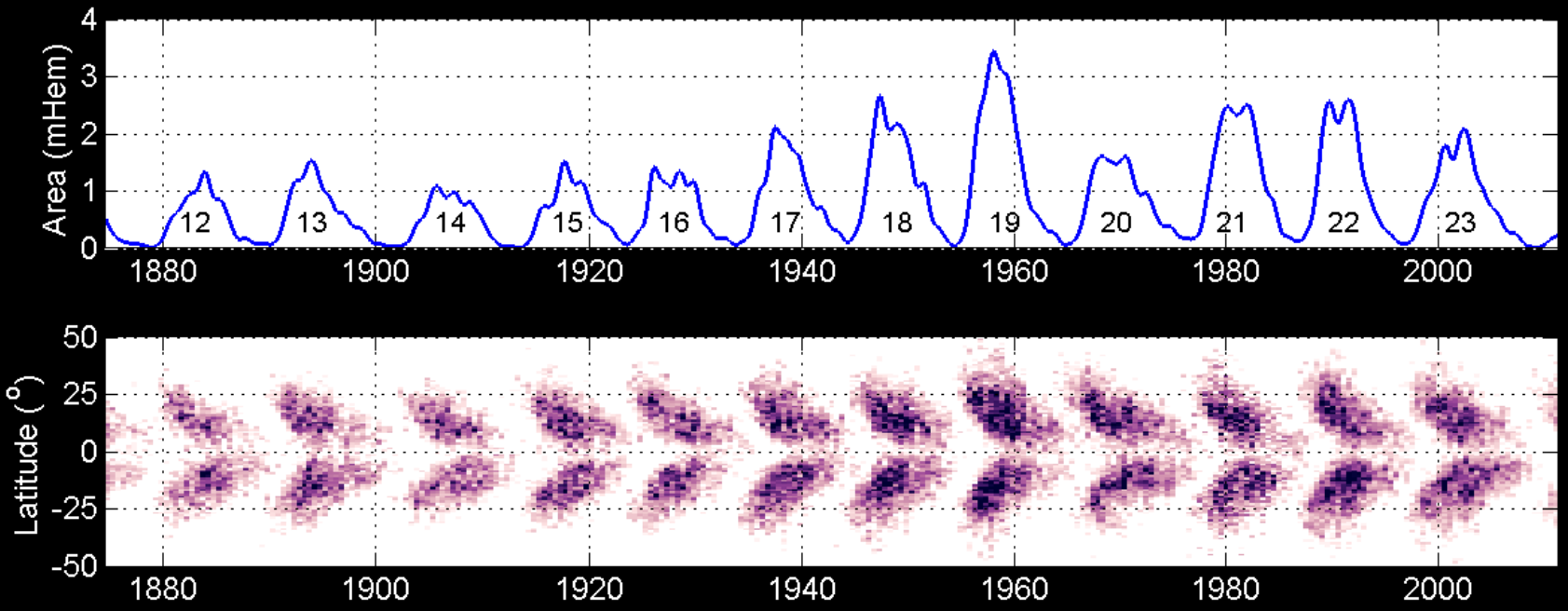




Credit: NSO/NOAO

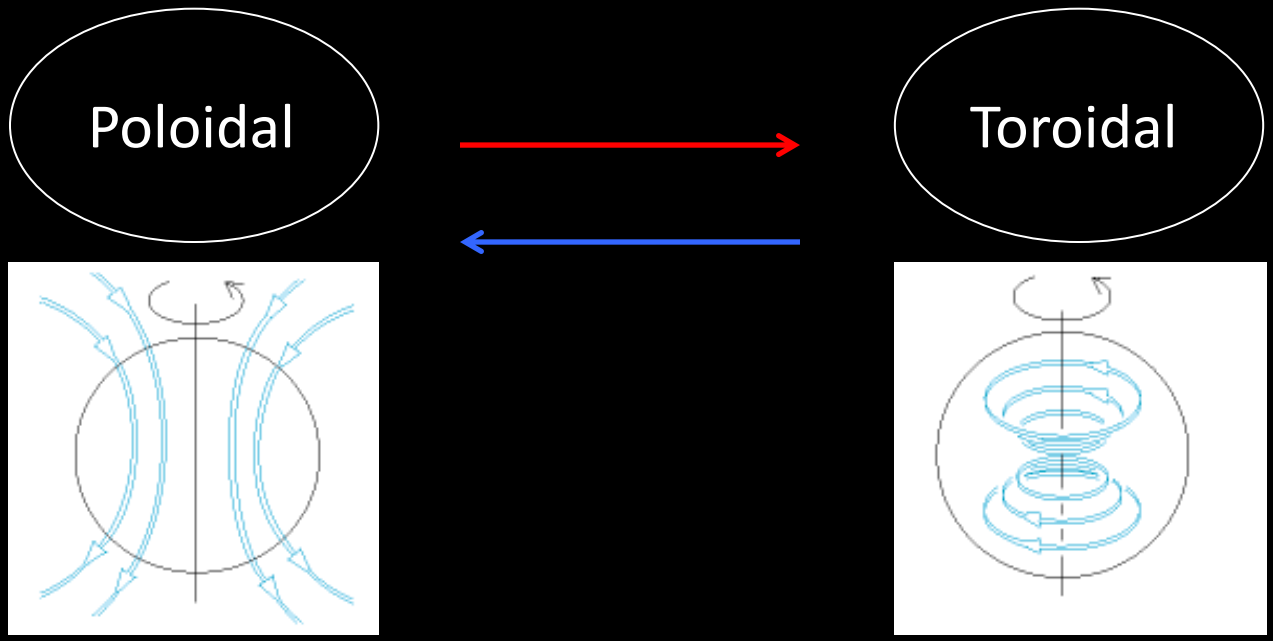
- Active regions have tilt based on latitude
- Leading polarity of active regions is opposite in each hemisphere

What is the Solar Cycle?



- The periodic change in solar activity characterized by the number of active regions
- Minimum to minimum of 11 years on average
- Variation in strength and duration between cycles
- Flip in polarity after each cycle

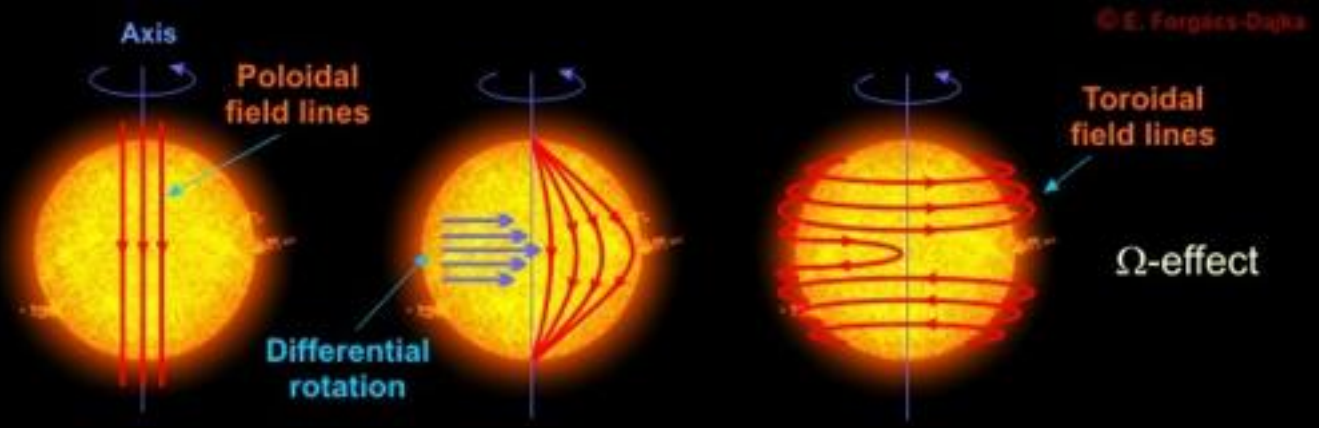
What Causes the Solar Cycle?



Credit: J.J. Love

- Magnetic field from poloidal to toroidal, and toroidal to poloidal
- Solar maximum when mainly toroidal, minimum when mainly poloidal

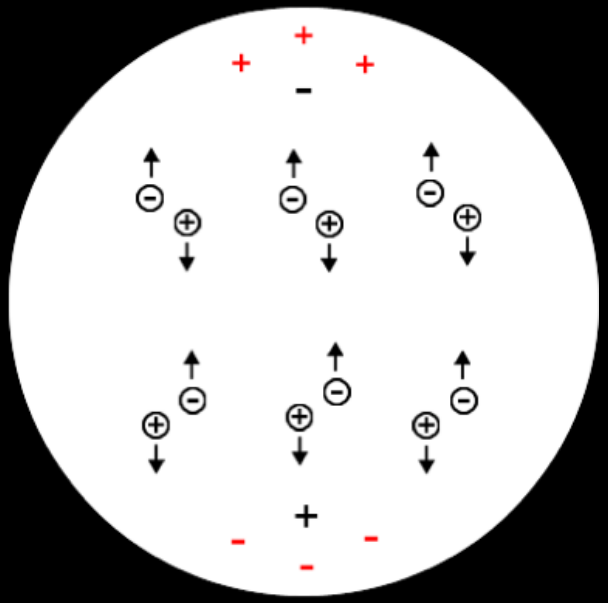
What Causes the Solar Cycle?



Credit: Konkoly Observatory

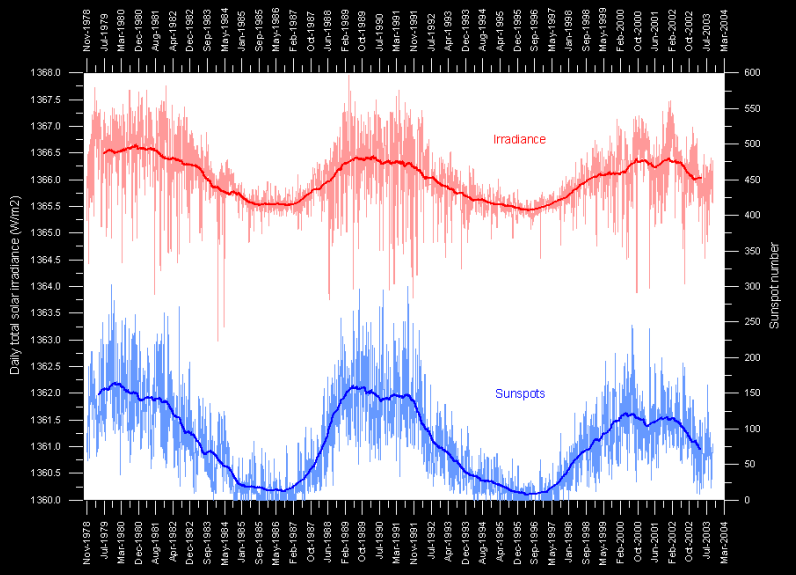
- Poloidal to toroidal magnetic field via differential rotation

What Causes the Solar Cycle?

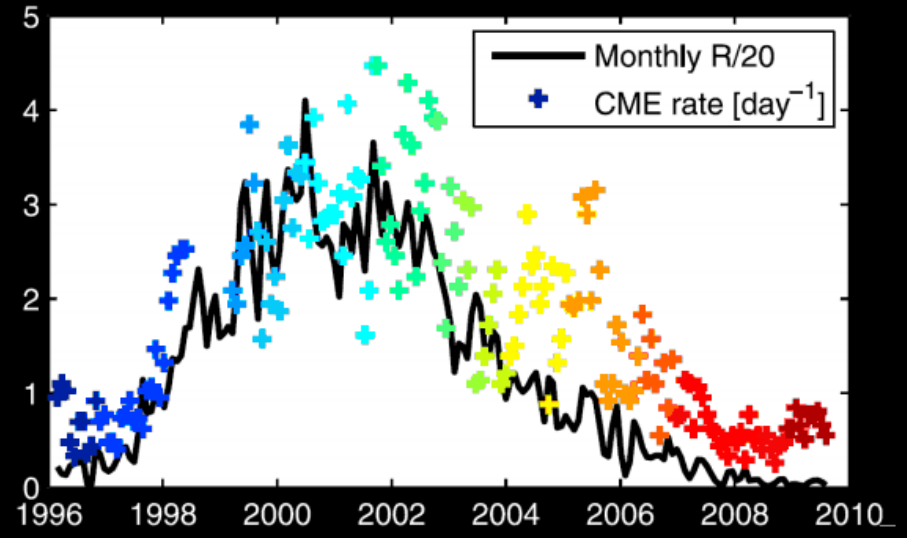


- Toroidal to Poloidal magnetic field via tilted active region emergence and decay

Why do we want to make predictions?



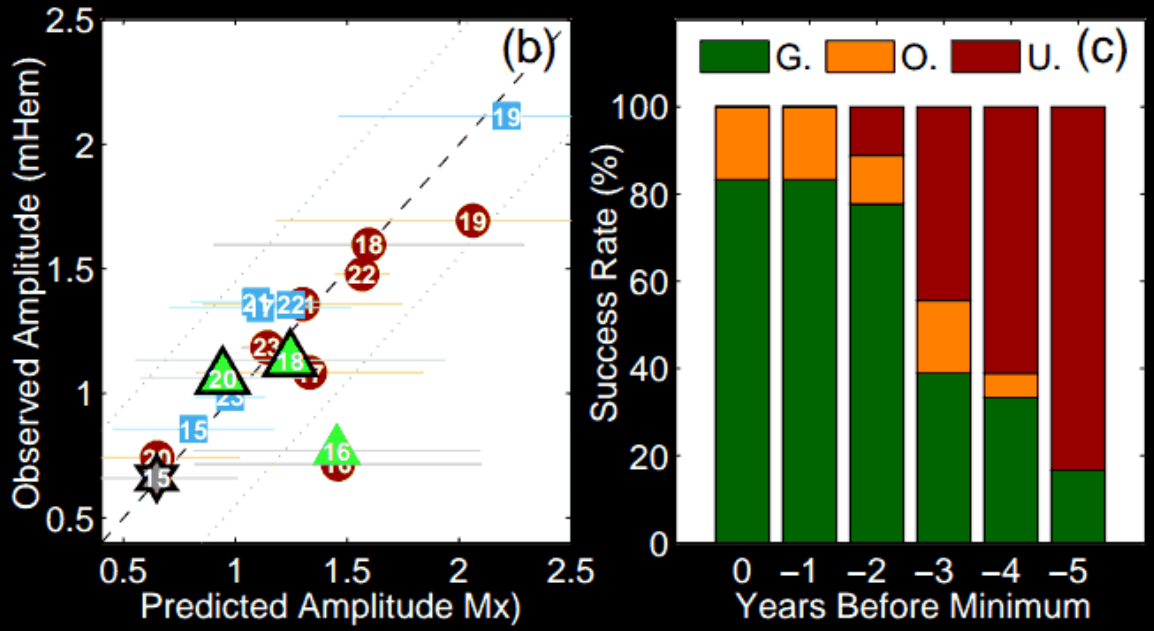
Credit: NOAA NGDC



Owens & Lockwood 2012

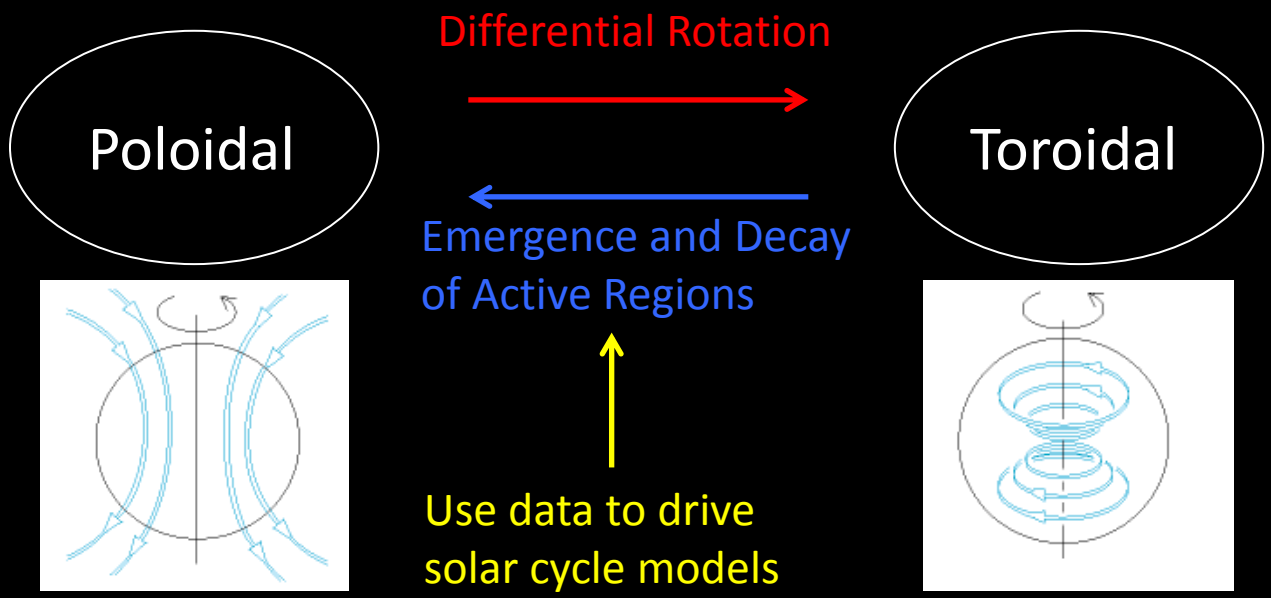
- Strength of solar cycles are the main contributor to solar events and changes in the heliospheric environment
- Long term solar cycle trends may effect climate change

How is the Cycle Predicted?



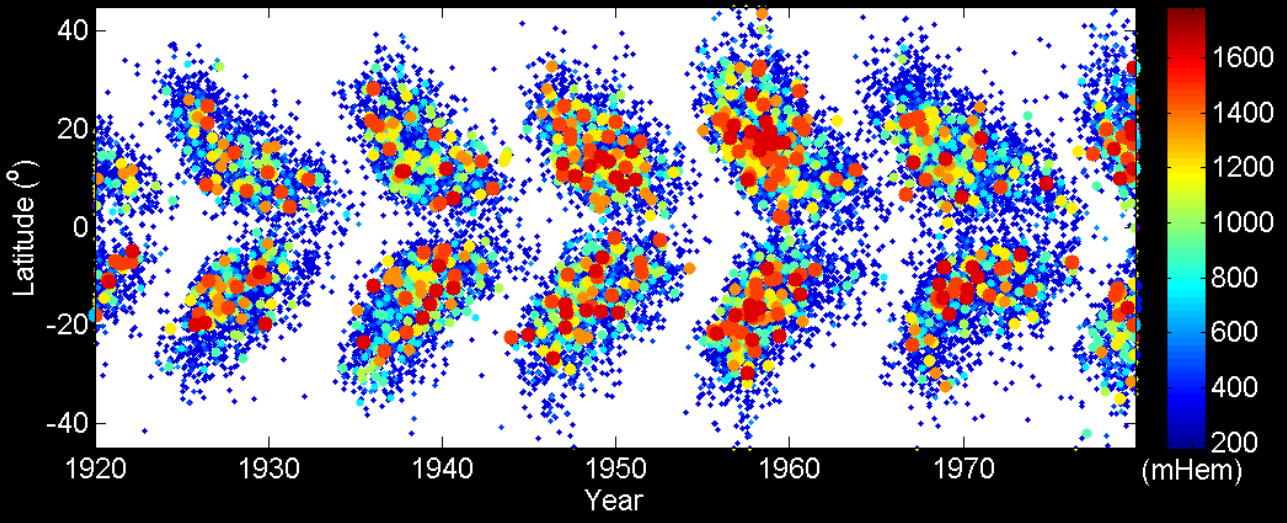
- Given the conditions at minimum of a cycle, we can predict the maximum amplitude of the following cycle
- Currently no means of predicting solar minimum conditions

Future of Solar Cycle Predictions



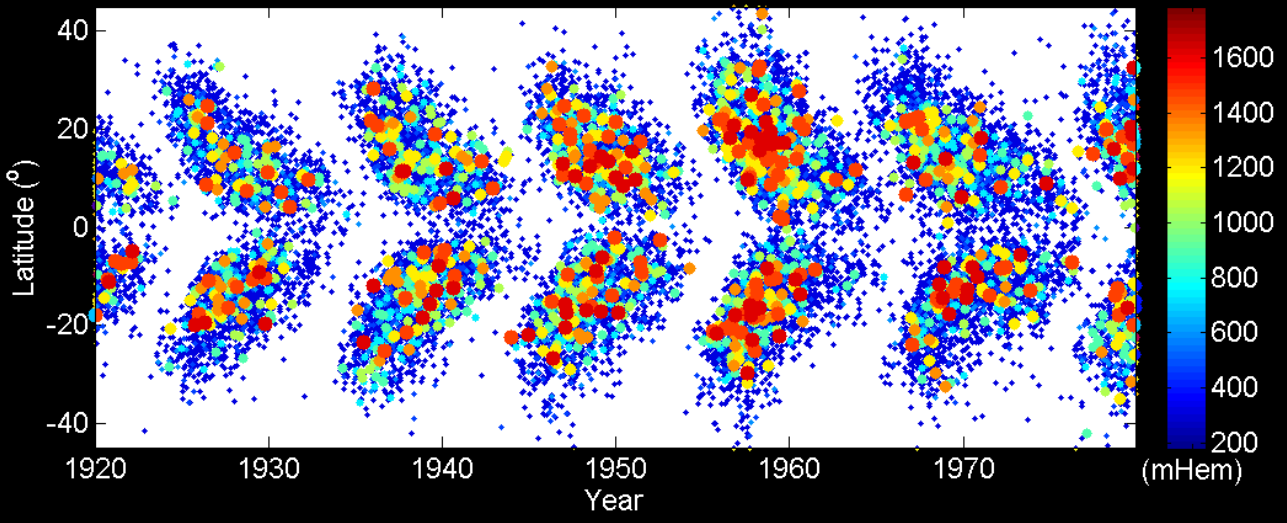
- Model based predictions to estimate conditions at solar minimum
- Use estimated conditions to predict maximum amplitude earlier

Characterization of Solar Cycles



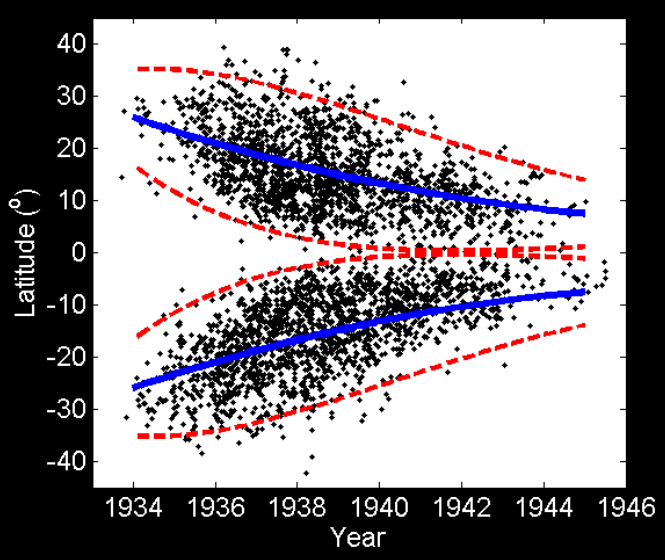
- Synthesize solar cycle data using only predictable values
- Use synthetic cycles to help determine conditions at solar minima
- Based on the work of Jiang et al. (2011)

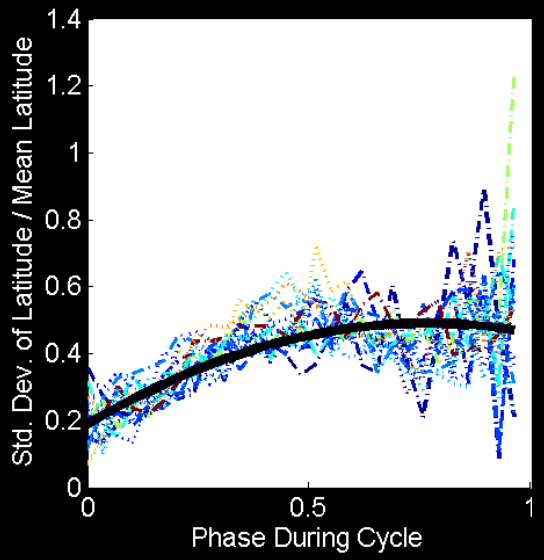
Characterization of Solar Cycles

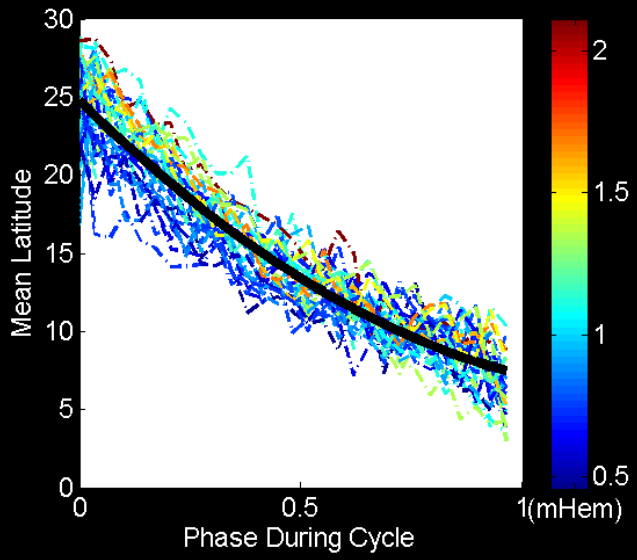


- Need to characterize the following active region properties:
  - Distribution of latitude and time of emergence
  - Tilt
  - Distribution of size (total magnetic flux)

Characterization of Active Latitudes

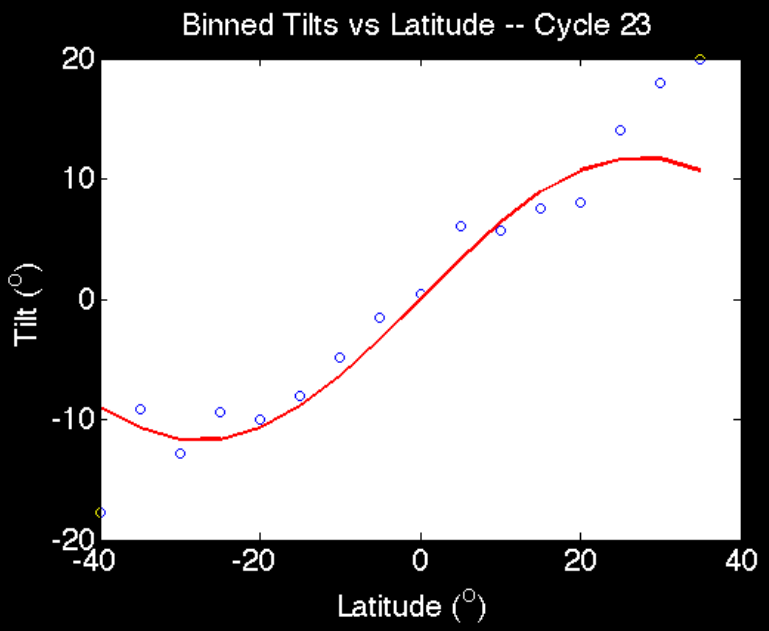


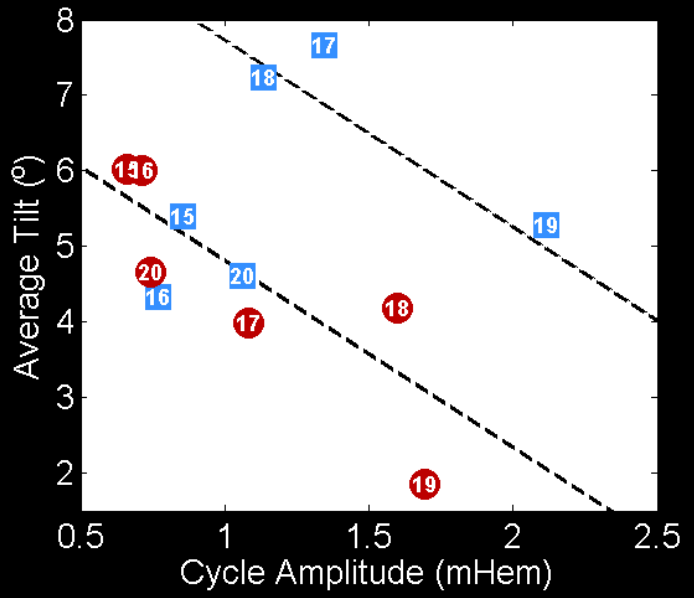




- Latitude and spread of active region emergence as a function of cycle phase

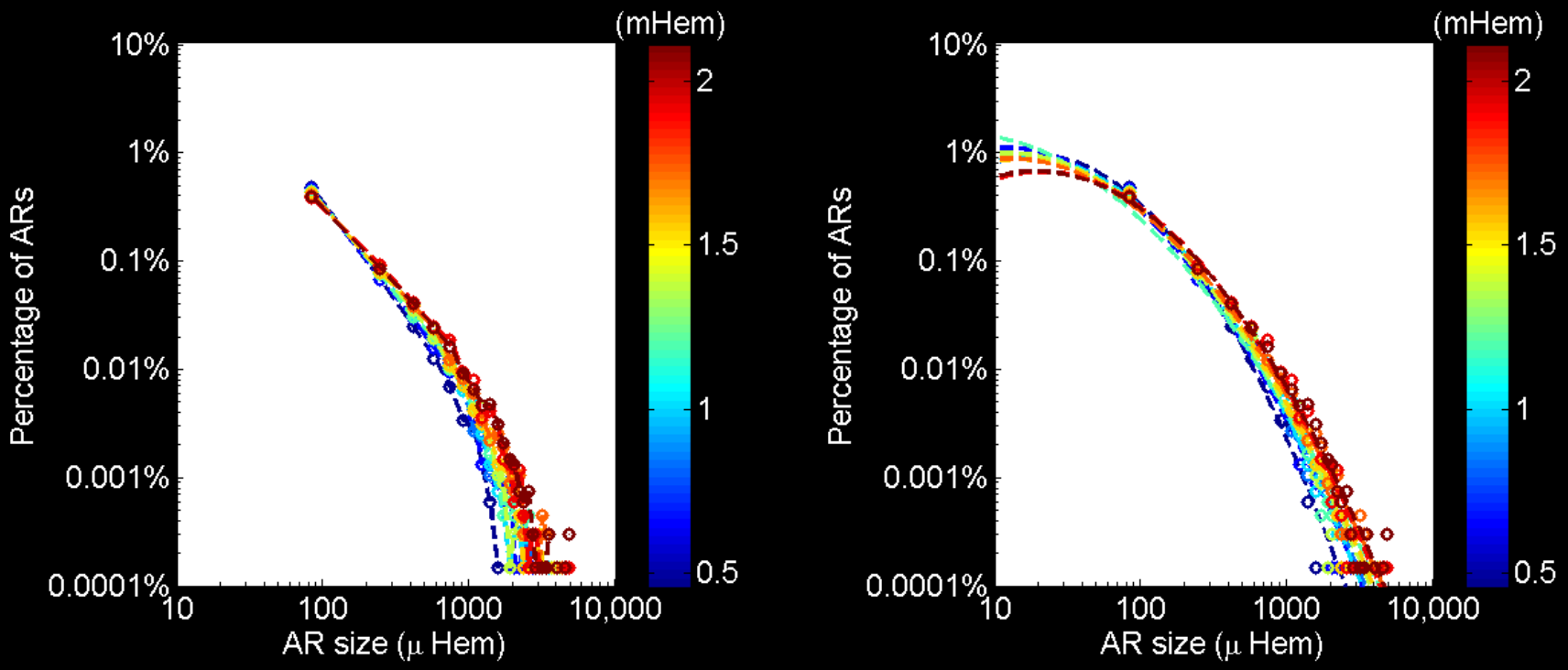
Generating Active Region Tilt





- Tilt of emerging sunspots as a function of latitude (Joy's Law)

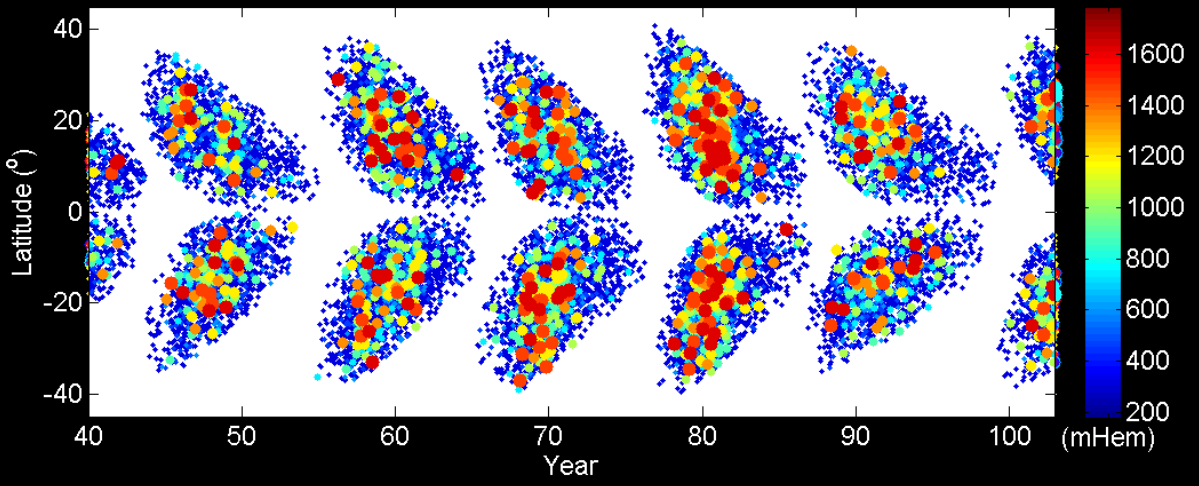
Defining Magnetic Flux of Active Regions



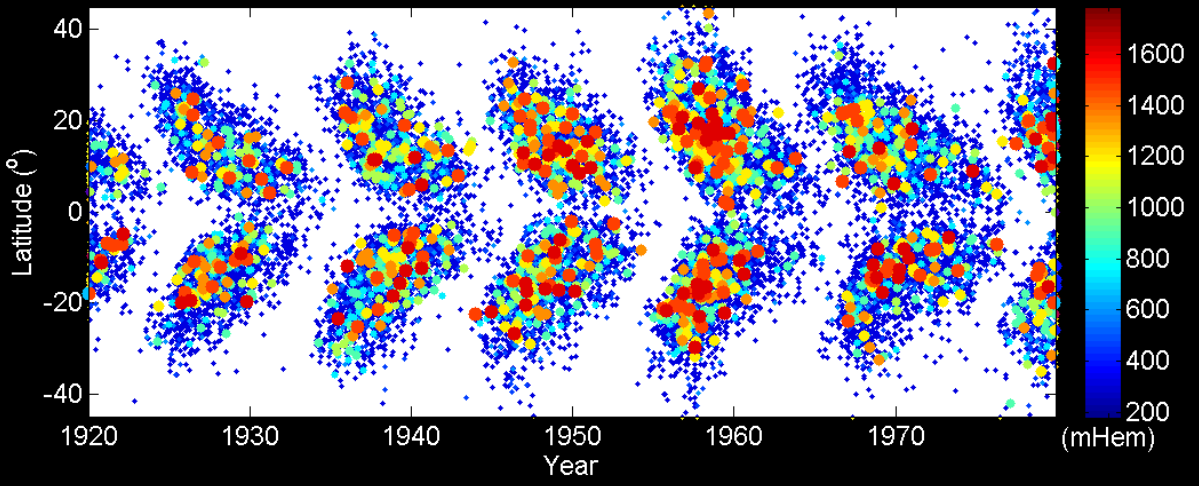
- Distribution of flux of emerging sunspots as a function of cycle strength

Our Synthetic Cycles

Synthetic

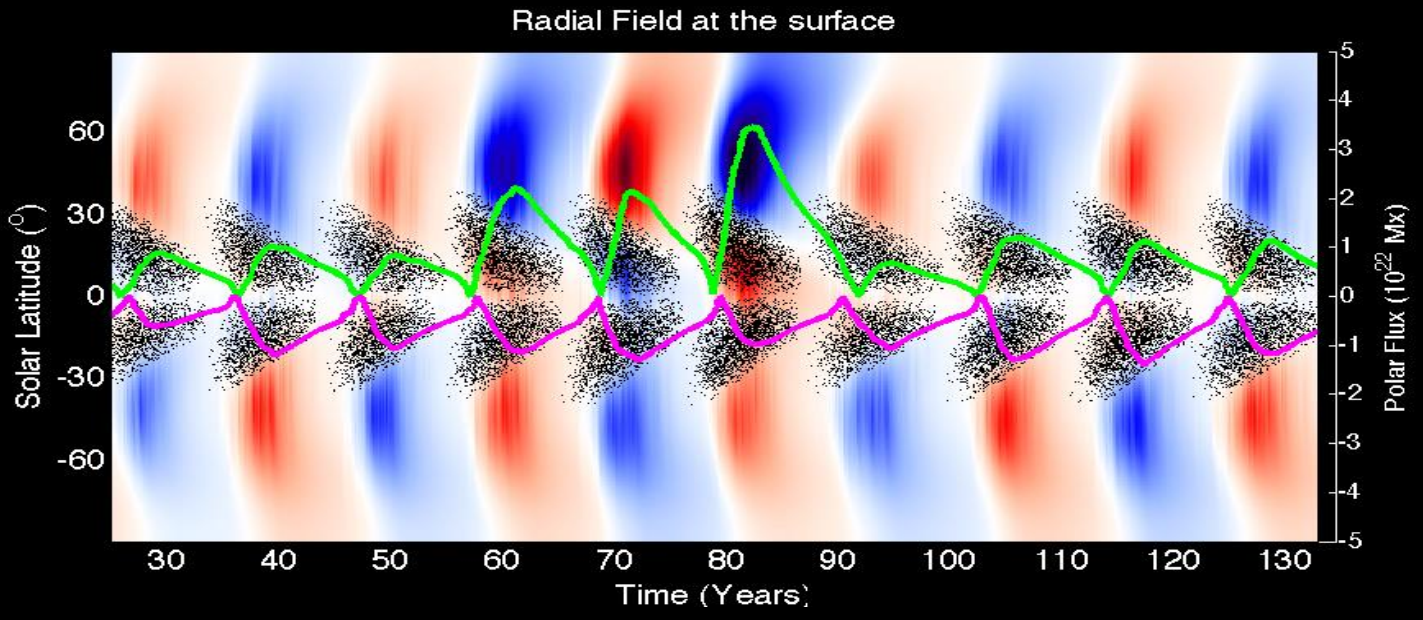


Observed

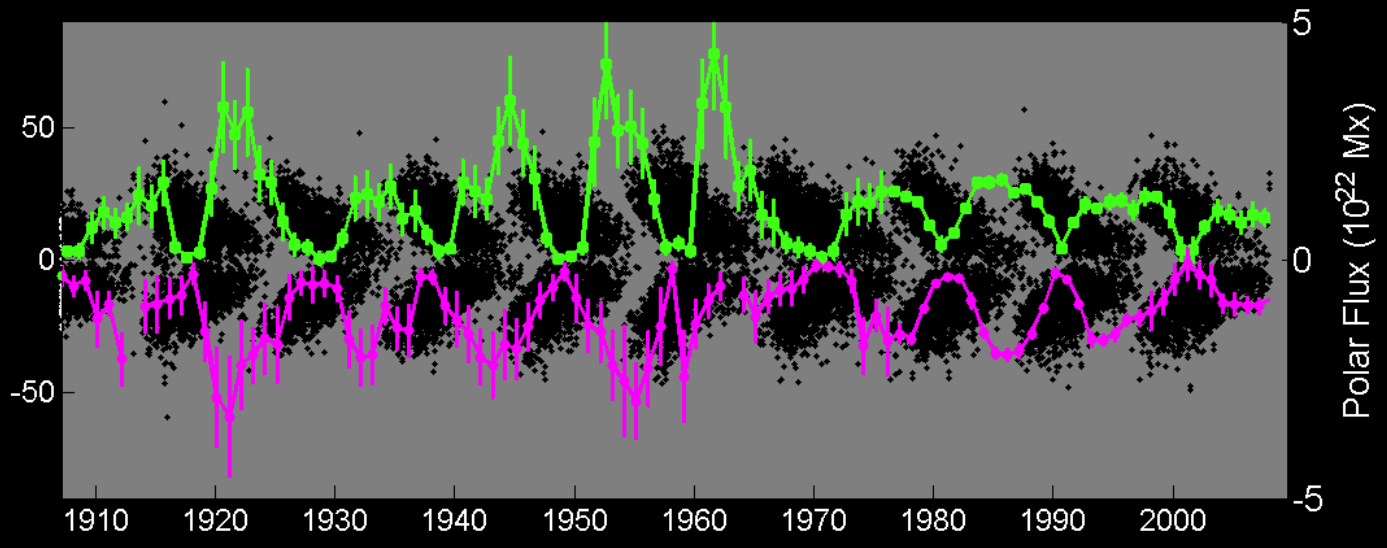


Synthetic vs Observed Simulations

Synthetic



Observed



Achievements

- Characterized solar cycle hemispherically
  - Characterization of distribution of AR sizes (dependent on cycle strength and latitude)
- Built infrastructure for creation of synthetic cycles and used them to drive simulations
- Improved solar cycle forecasting using data driven simulations

Acknowledgements

- Drs. Ed DeLuca and Andres Munoz-Jaramillo
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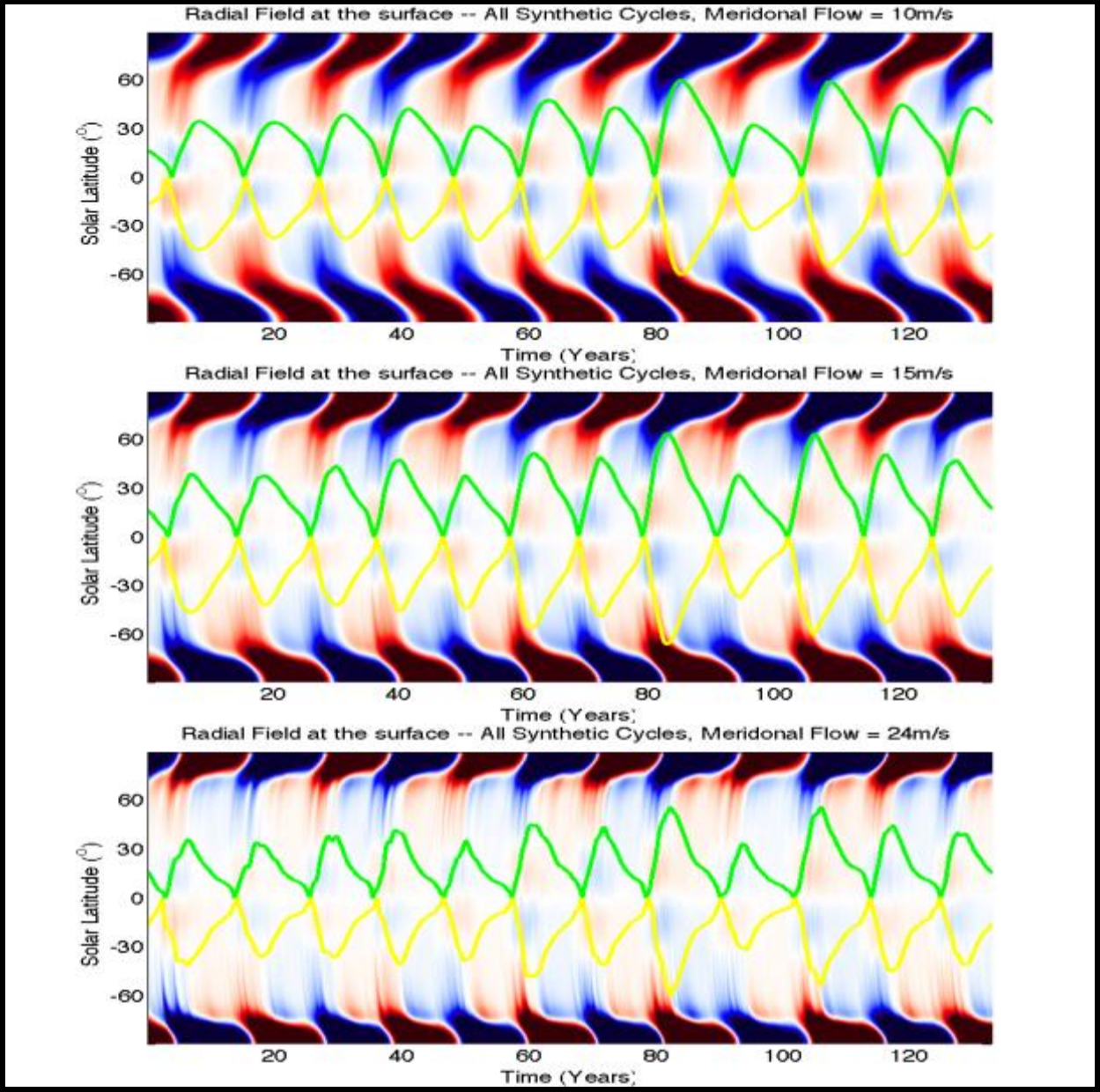
- NSF (grant number AGS-1263241)
- SSXG and Admins
- Solar and Astro REU students

Supplemental Plots



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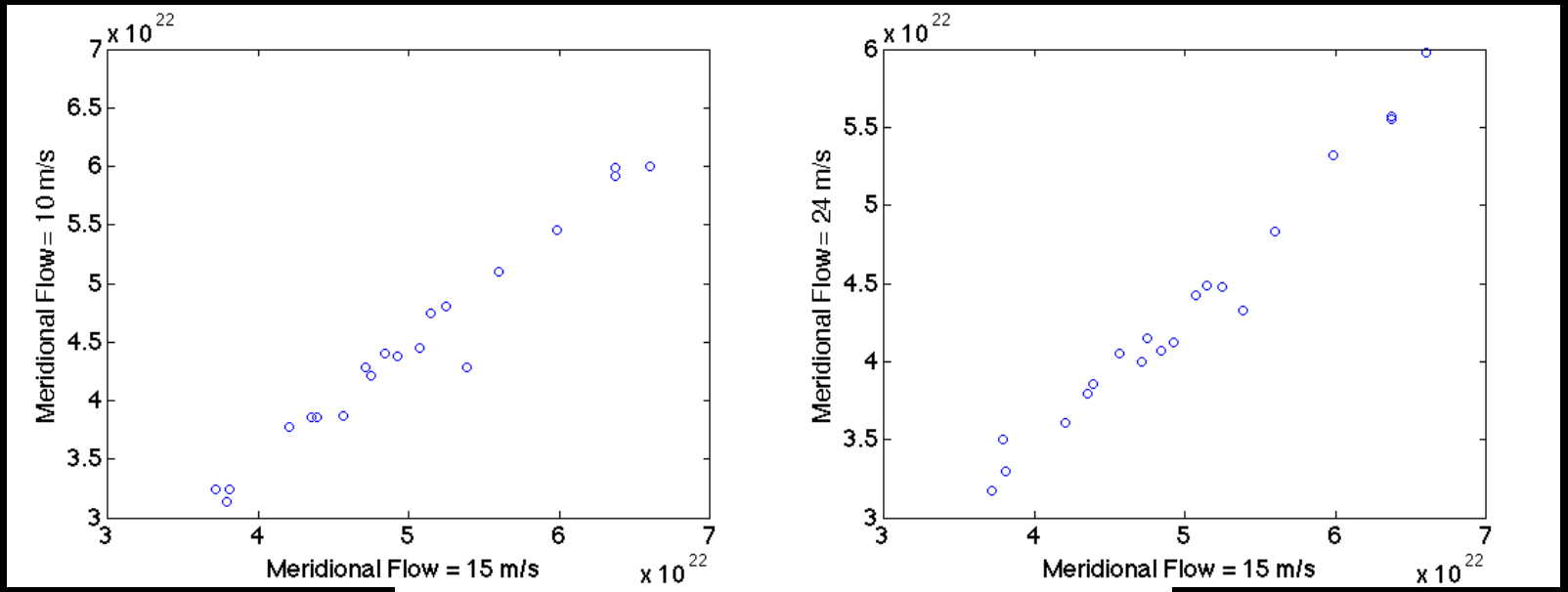

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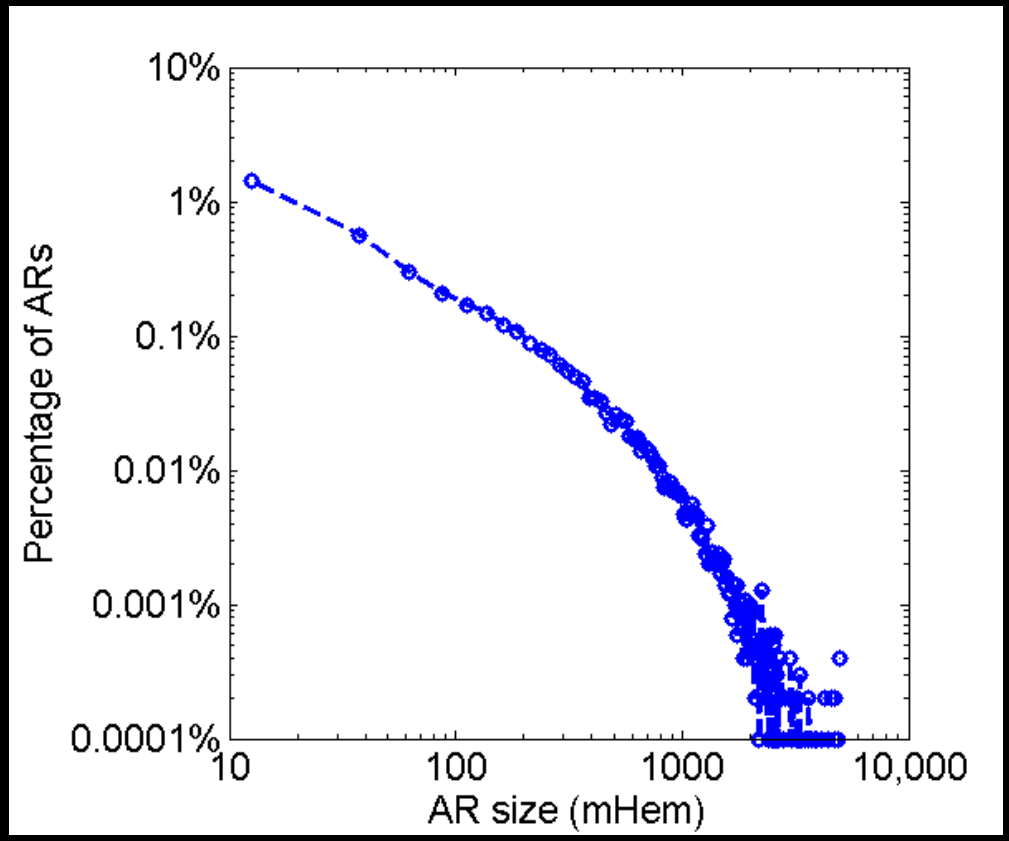
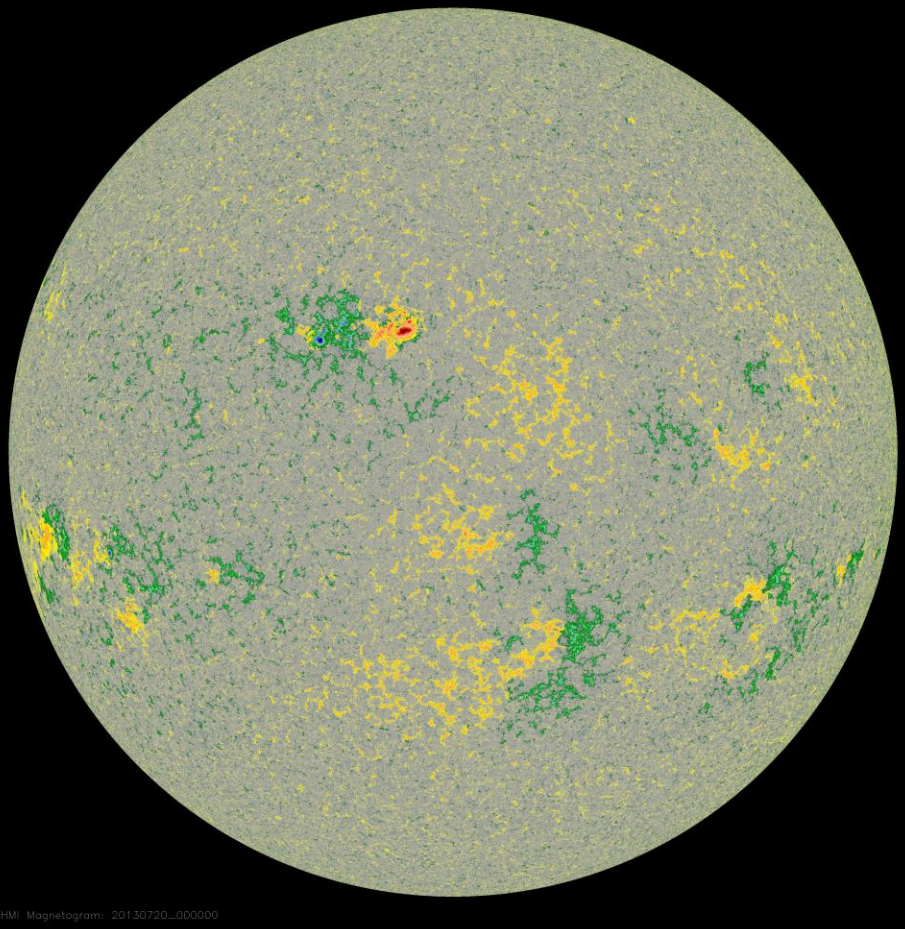


Supplemental Images



- SOHO/HMI, July 20th 00:00

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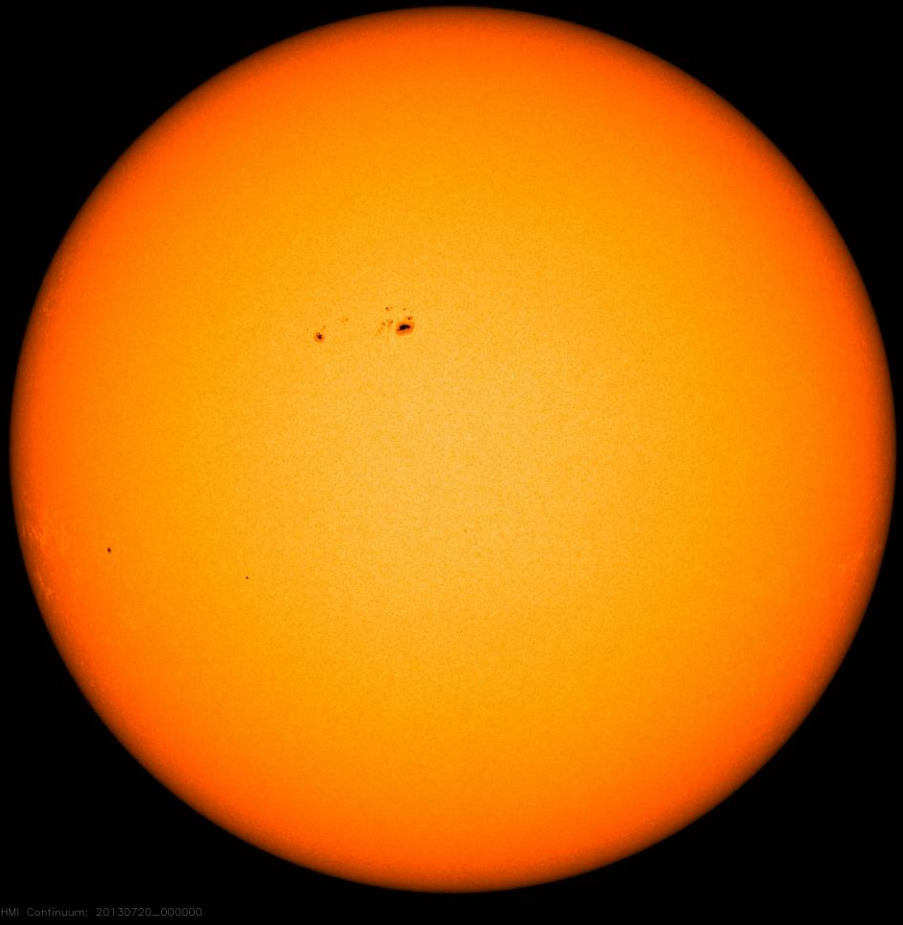

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