Monitoring and “Understanding” the Solar Cycle Using Synoptic Observations

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Monitoring and “Understanding” the Solar Cycle Using Synoptic Observations

Need Big Picture Science
Provide Observational Insight Into Drivers Of:

- Space Climate (The Sunspot Cycle)
- Space Weather (AR Emergence ➔ Flares/CME production)
  Physically “Link” The Epochs
- Drive Next-Gen. Modeling Efforts

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predictability [prih-dik-tuh-bil-i-tee] noun
1. consistent repetition of a state, course of action, behavior, or the like, making it possible to know in advance what to expect: The predictability of their daily lives was both comforting and boring.

Sometimes we just don’t understand something all that well.....

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“magnetic range of influence”

100-250Mm is consistent with the inferred scale of giant cell convection. NOT something that is readily observable.
EUV Brightpoints are NOT “simple dipole regions” formed at every supergranular vertex - they have a preferred location and spatial scale.

Brightpoints form preferentially around a different kind of magnetic flux vertex - separated in scale by about 100-250Mm. Multiple supergranular scales appear to be contained within each of these vertices.
EUV BPs provide access to the complete cycle modulation PLUS....

EUV BPs show:

Coherent emergence of BPs occurs several years prior to sunspot formation on the SAME equatorward “path”.

The northern activity band does NOT disappear. The disappearance coincides with BP emergence at high latitudes ..... 

There is considerable overlap in solar cycles as visualized via BPs.

The circulatory speed in both hemispheres is approximately the same - they are however offset in time.

Brightpoints (and the spatial scale they are tied to) provide a crucial clue in understanding the phases of the solar activity cycle.
Migration of the active latitudes is critical to understanding what is going on....

There is something more going on than we currently understand.

Critical scale appears at $\pm 55^\circ$ in BOTH hemispheres in 1999.

North migrates immediately!
South starts 2 years later!

Better still, use the preferred scale to monitor migration.

BP branches terminate at the equator!

Progression takes $\sim 19$ years.

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Critical nature of ±55°
L-L Branches (“chevrons”) map onto the “Torsional Oscillation”
“Solar Minimum” - when the high and low latitude bands preclude sunspot emergence in both hemispheres - subsurface cancellation?

Where and when does the next cycle high latitude band appear?

Sunspots erupt in a coherent fashion after the low latitude activity branches cancel each other. Hence the “Waldmeier Effect” of an abrupt sunspot onset. No flux to cancel with in that hemisphere.

As the next cycle high-latitude branch appears it begins to impact the activity in the lower latitude band establishing “the declining phase” of sunspot cycle.
Hemispheric
Max ➔ Max Time = 22 yrs?

Maximum of Northern Hemisphere

Maximum of Southern Hemisphere

"Chevron" Termination

SOHO/SDO Brightpoint progression for solar cycle 22/23/24 (previous) slide.
Hemispheric Max -> Max Time = 22 yrs?

Ulrich (MWSO) Zonal Flow Overplot

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The (entire) atmospheric system seems to be driven by the rotation of the radiative interior.
- STRONG observational evidence in support of giant cell convection.
- VERY strong latitudinal dependence of almost every measurable quantity.
  - ±55° seems to be a critical latitude!

The 11-year sunspot cycle is a consequence of interaction between the (temporally) overlapping activity bands of the 22-year magnetic activity cycle.
- The two hemispheres have to be treated independently.
  - Those activity bands appear at high latitudes (±55°).
- The bands don’t migrate at exactly at the same time in each hemisphere (cycle 23 phase lag).

The evolution of this coupled system can be expressed in terms of four coupled oscillators where the two higher latitude (polar) oscillators have dependable, loosely synchronized, 22-year periods. **Two lower latitude cells experience a significant hysteresis** that can speed them up and slow them down depending on the amount of magnetic field in the cell.
  - Polar cells appear to have robust cycle length (22 ± 1yr)
    - In-phase - Strong/Fast Cycle
    - Slipping-phase - Weak/Slow Cycle - **RIGHT NOW!**

Can, in principal, demonstrate the progression into grand minima and how the Sun recovers.
- Weakening/Slowing causes increase in overlap until the clock can work in our favor.

This rotating system displays shorter-term variability that is very relevant to space weather.
Recalling........

The BPs and “g-nodes” show short-term variability that has hemispheric and latitudinal dependence.
CMEs
Flares
Space Weather

★ Forced quasi-periodic changes in the surface magnetism profoundly impact the radiative, particulate, and impulsive output of our star.

★ Flares and CMEs are not uniformly distributed skewed to the declining phase. They cluster on the herringbone pattern this NOT a surface effect.

★ “Activity band” overlap (and related flux emergence) is most-definitely at play in the development of space weather, we have things that we can monitor in terms of flare/CME rates.

★ Possible predictive capability?

Linking Epochs

★ The Sun is in an energetic decline - possibly symptomatic of a systemic slowdown (decline to deep prolonged minimum?)

★ Both short and long term variability epochs are forced by deeply seeded changes in the convection zone. Predictive capability is a high. The observations presented provide clues on where to look and what to study to capture these evolutionary timescales.

★ Should force a change in modeling philosophy?

A Synoptic Solution?

See Alfred’s talk.
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Next Generation Observing Network
- Link Seismological & “Standard” Observing Modes
- Possibly - Networked Imaging Spectro-Polarimeters
- Single Instrument: Photosphere → “Corona”

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Grand Minima?
Can we naturally explain the progression into, and out of, grand minima?

Representing the progression of solar cycle variation into, and out of, a grand minimum state. The northern hemisphere has a fixed 22-year period while the southern hemisphere has a 22-year period that is randomly perturbed in a ±2 year range to reduce the north-south symmetry. The termination points of the equatorial branches are then stretched out from 20 years using a Gaussian perturbation 30 years wide centered on 75 years.

Impose a 22-year “clock”
Increase Overlap
Low SSN - Longer Cycles
Clock “catches up” driving extra band and gets system back in phase.

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