Coupling and correlation-analysis between the Northern and Southern hemispheres' solar cycle features based on sunspot area data

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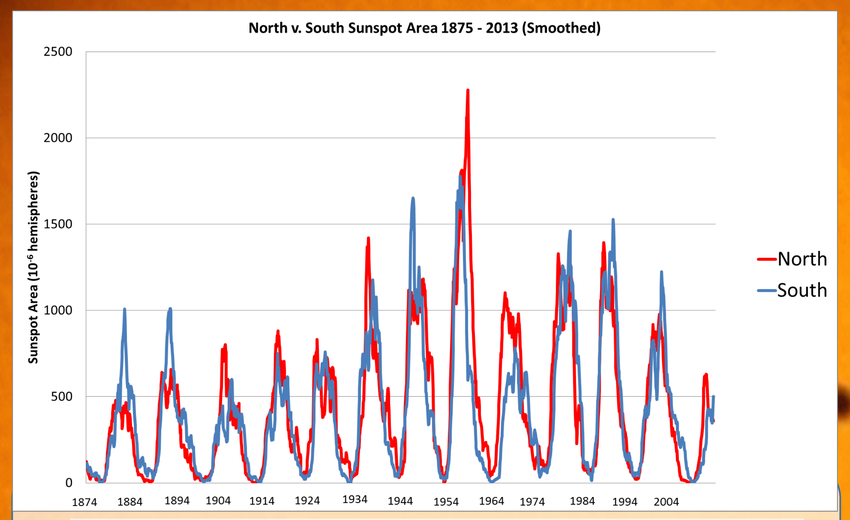
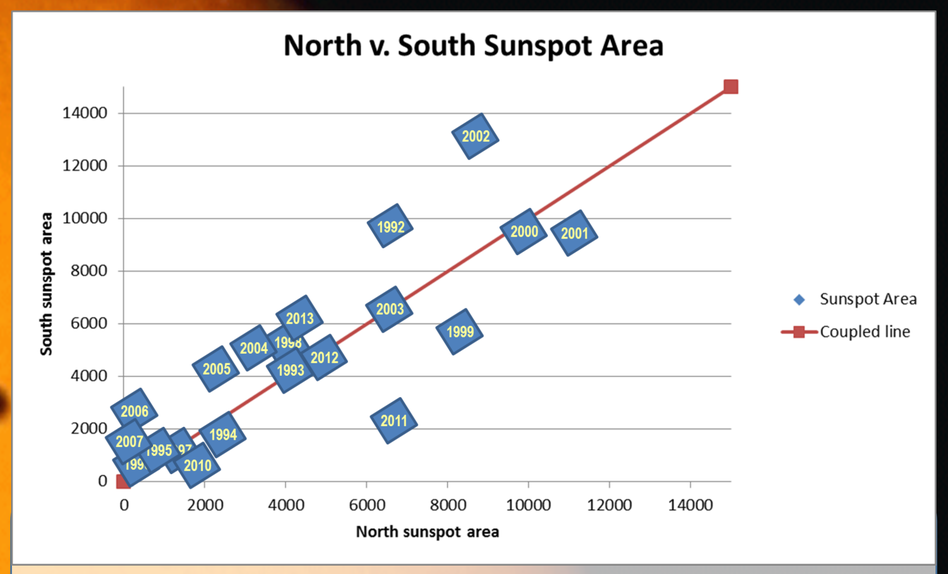
Abstract

Vast literature on Babcock-Leighton flux-transport dynamo models indicate that the sunspot activity cycles in the Northern and Southern hemispheres are primarily decoupled about the equator and are independent of each other. However, we find from the analysis of long-term sunspot area data from 1875 to 2013 that the two hemispheres continuously attempt to couple about the equator. If we define the coupling line as the line where the sunspot area of the two hemispheres is the same on the plot of North versus South spot-area, we find that the two hemispheres' spot-area tend to fall on the coupling line over a very long period of time, despite their short-term traversal away from the coupling line. This indicates that there must be some underlying process inside the Sun's interior which is causing this coupling. Further analysis of the features, such as rise and decay times of solar cycles, minima and peak amplitudes, reveal that the solar cycles normally follow a saw-tooth pattern with a fast rise and slow fall, as noted before. Most interestingly we find that rise-time in one hemisphere correlates with minima-amplitude of the other hemisphere, but anti-correlates with that of the same hemisphere. We speculate that this happens because the fast rise of a cycle can annihilate the opposite-hemisphere's flux faster, leading to a lower minima-amplitude. By contrast, the peak of a cycle does not have much influence on minima-amplitude of the opposite hemisphere. We are investigating the physics behind these features through dynamo simulations.

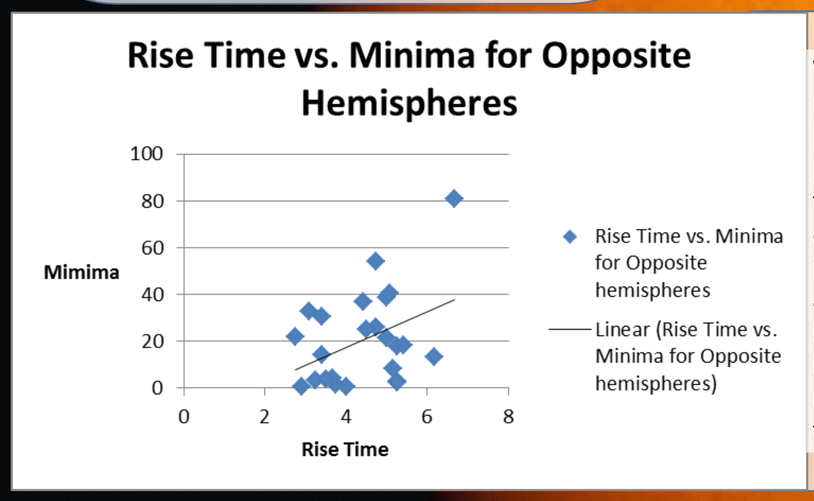


Monthly sunspot area in millionths of a hemisphere in the northern hemisphere vs. southern hemisphere using 1875 to 2013 sunspot area data from NASA MSFC smoothed for 12 months. There are a lot of variations in the timing and amplitude of the solar maxima and solar minima between the two hemispheres.



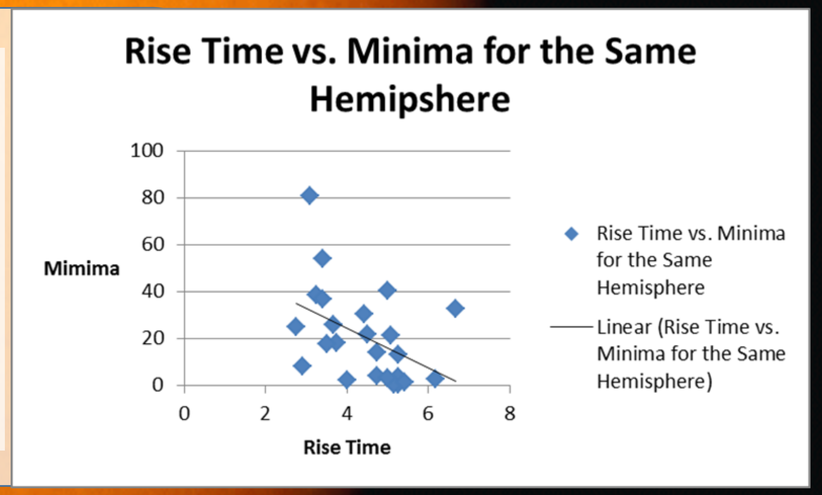
A comparison of the yearly average sunspot area between the north and the south from 1992 to 2013 with a coupling line in the middle. The coupling line indicates that if a dot representing the sunspot area for the north and the south were to fall on that line, the two hemispheres would be perfectly coupled. Over a long period of time, the sunspot area between the two hemispheres generally tends to fall on this line.

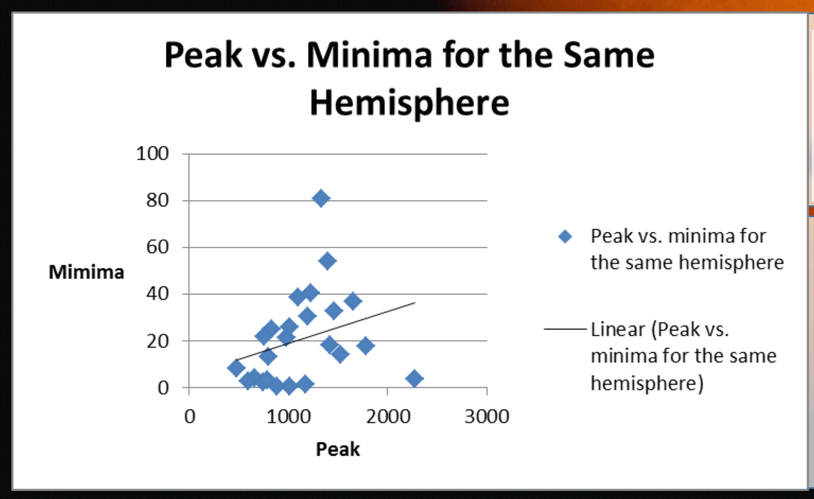
Results



When comparing the rise time of one hemisphere and the minimum amplitude in the other, we get a correlation of **0.406**. This indicates that if we have a faster rise time in one hemisphere, we will most likely have a smaller minimum amplitude in the other, on average.

When plotting rise time and minimum amplitude for the same hemispheres (North vs. North and South vs. South), there is an anti-correlation of **-0.446**. This indicates that a faster rise time will likely lead to a larger minima in the same hemisphere compared to the other hemisphere.

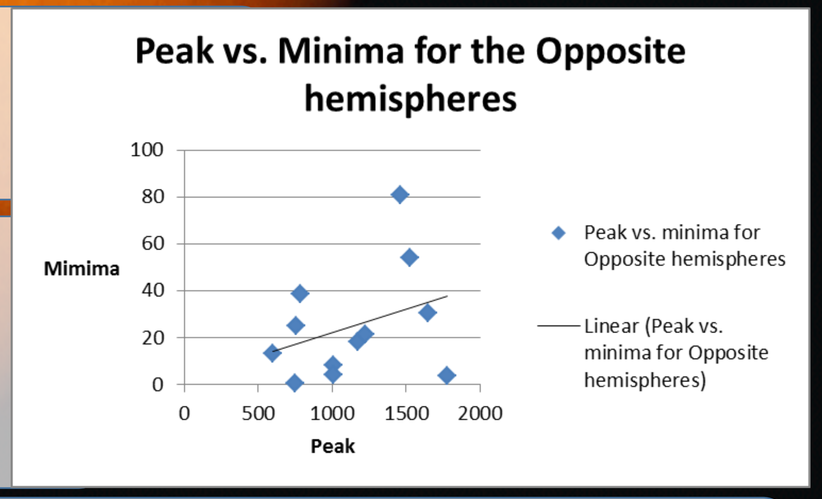




Peak amplitude vs. minimum amplitude for the same hemispheres has a correlation of **0.289**; it is small

Peak amplitude vs. minimum amplitude for the opposite hemispheres gives us a correlation of **0.237**; this is also small.

We can infer from both of theses correlations that the peak amplitude is correlated to the minimum amplitude in the same hemisphere to a small extent, but does not have very much influence on the minimum of the opposite hemisphere.



References

1. M. Dikpati, P. A. Gilman, G. De Toma and S. S. Ghosh, 2007, Sol. Phys., 245, 1
2. R. P. Kane, 2005, Journal of Atmos. Solar-terrestrial Phys., 67, 429
3. M. Temmer, A. Veronig, and A. Hanslmeier, 2002, Astron. Astrophys., 390, 707

Concluding Remarks

- Our results indicate that the two hemispheres tend to couple about the equator
- Correlation between rise time in one hemisphere and the minima in the other hemisphere is physically understandable because of annihilation of flux by opposite hemispheres' flux crossing the equator
- Peak amplitude does not have much influence on the minima of opposite hemisphere; This is counterintuitive

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