Physical link of the polar field rise rate with the Waldmeier effect enables the scope of early solar cycle prediction

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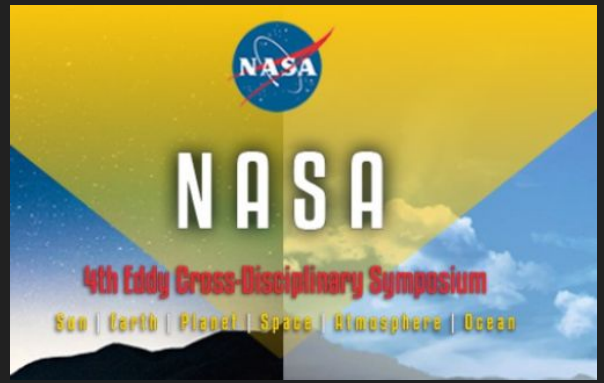
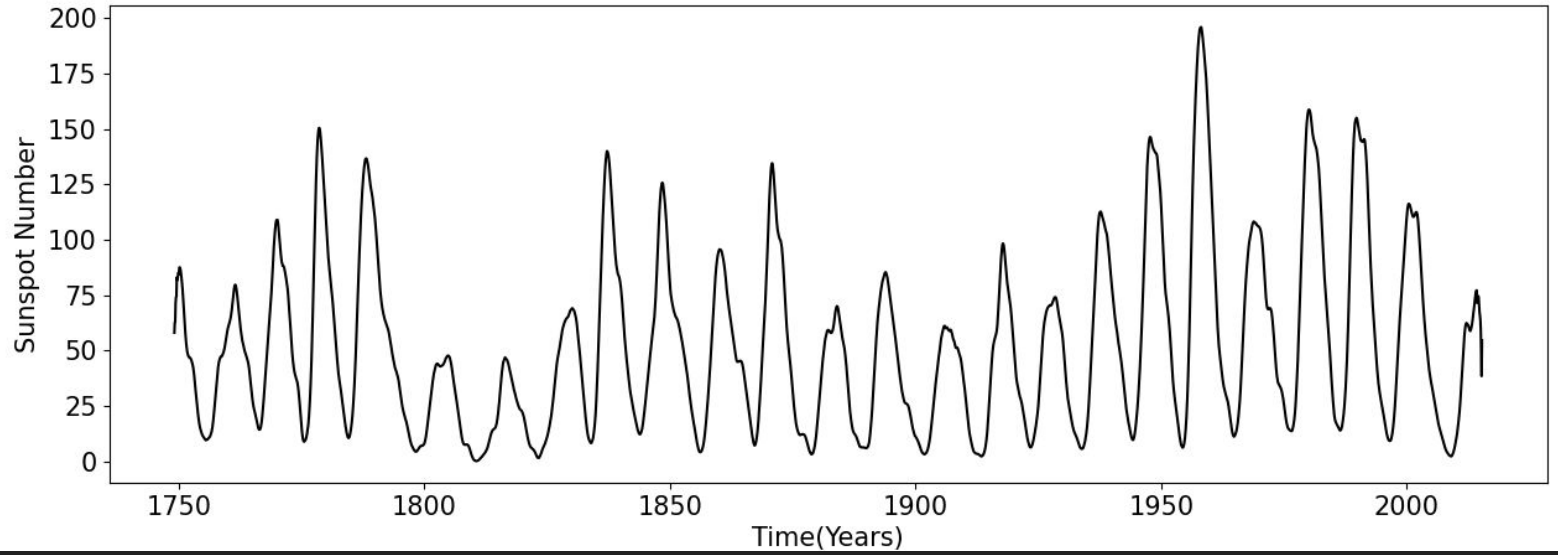
Ref: Pawan Kumar, Akash Biswas and Bidya Binay Karak MNRAS (2022)



Solar Cycle

Cyclic variation of about 11 years. Proxy of the solar magnetic field.



Data source: https://www.sidc.be/SILSO/home

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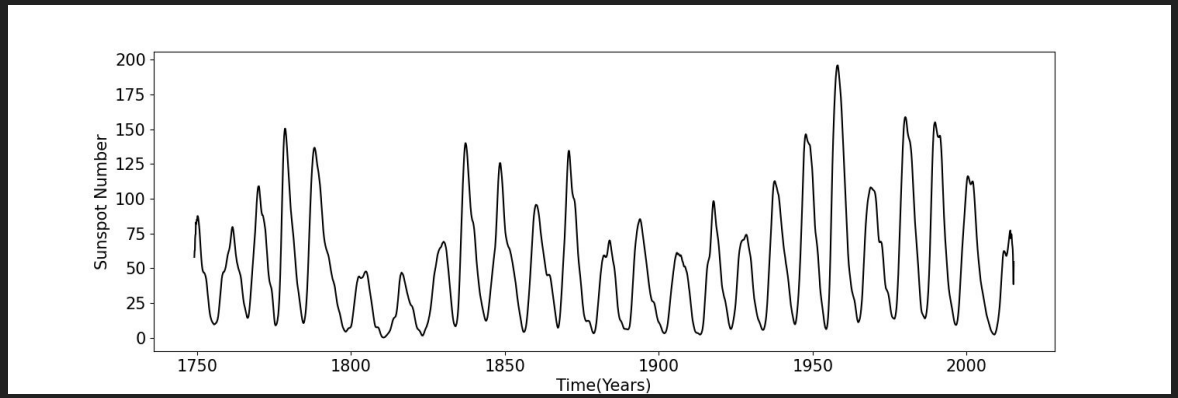
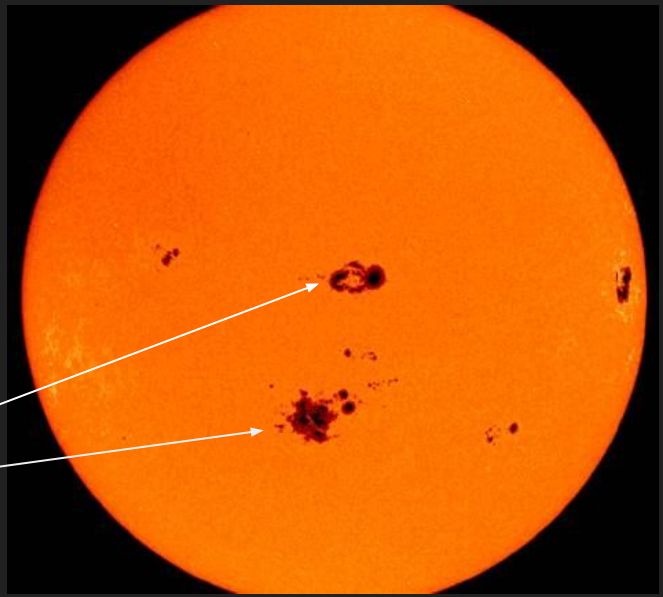


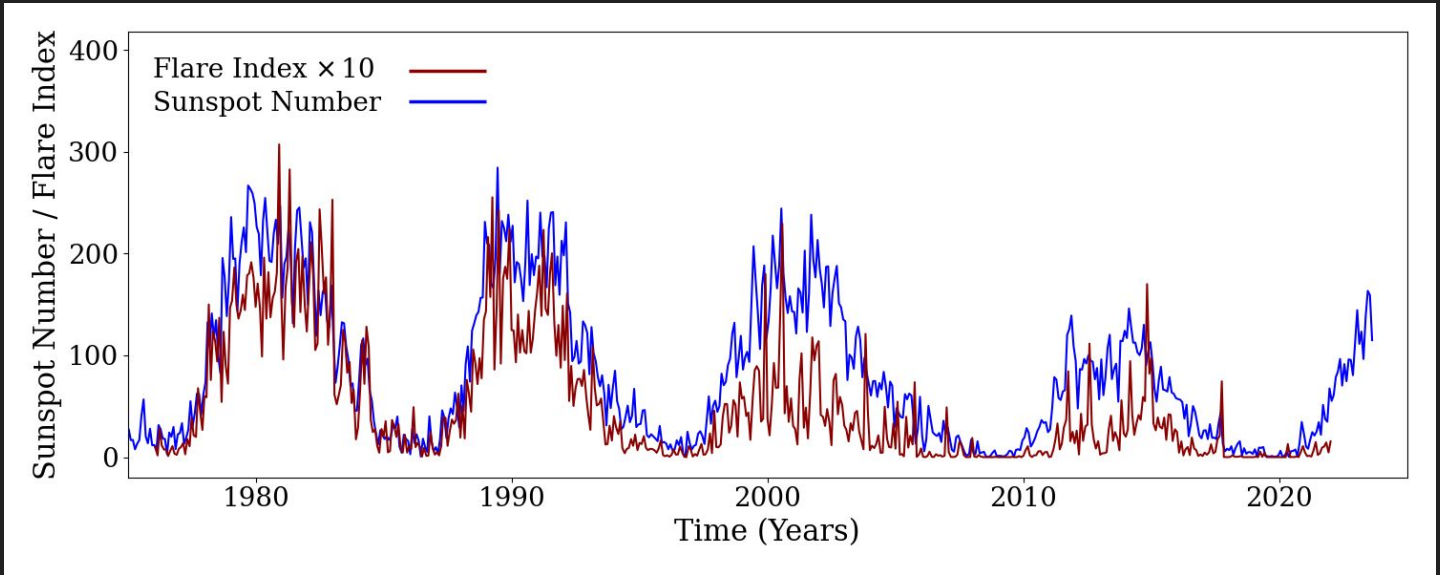


Sunspots

Image credit: NASA/SDO

Sun’s magnetic field induces energetic events

Primarily solar flares, coronal mass ejections (CMEs) and solar wind highly impact the space weather and Earth.



Data source: https:// www.ngdc.noaa.gov/ stp/ space-weather/ solar-data/ solar-features/ solar-flares/ index/

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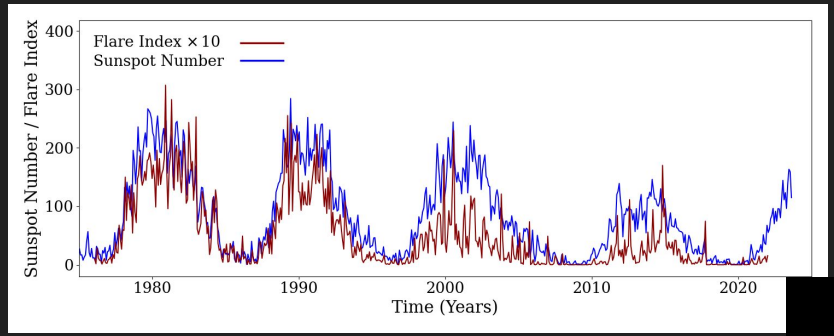
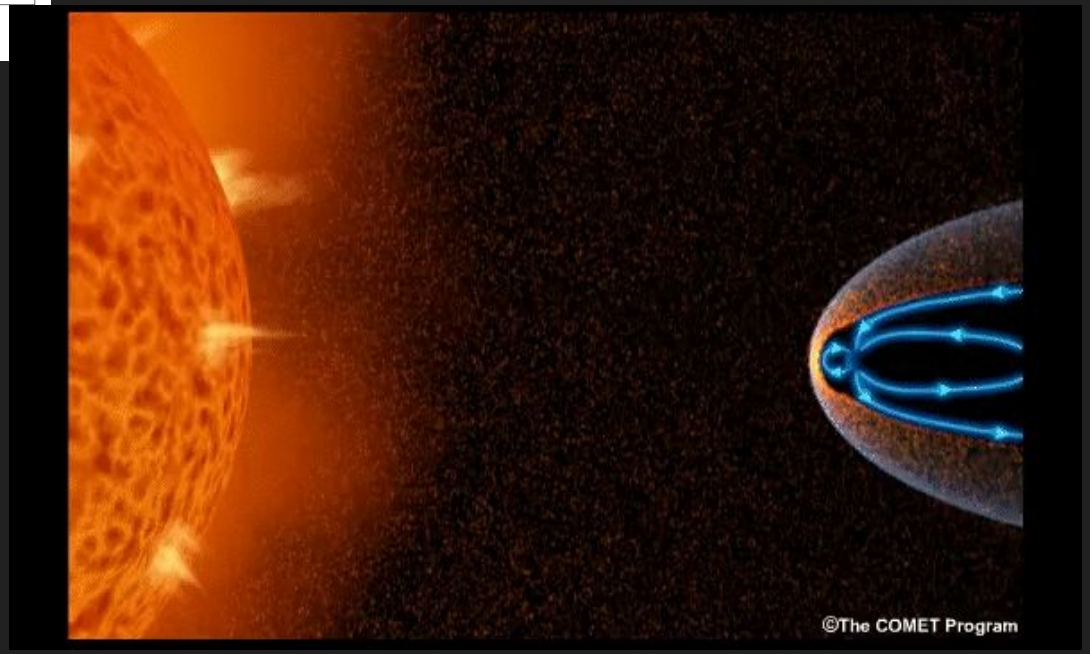


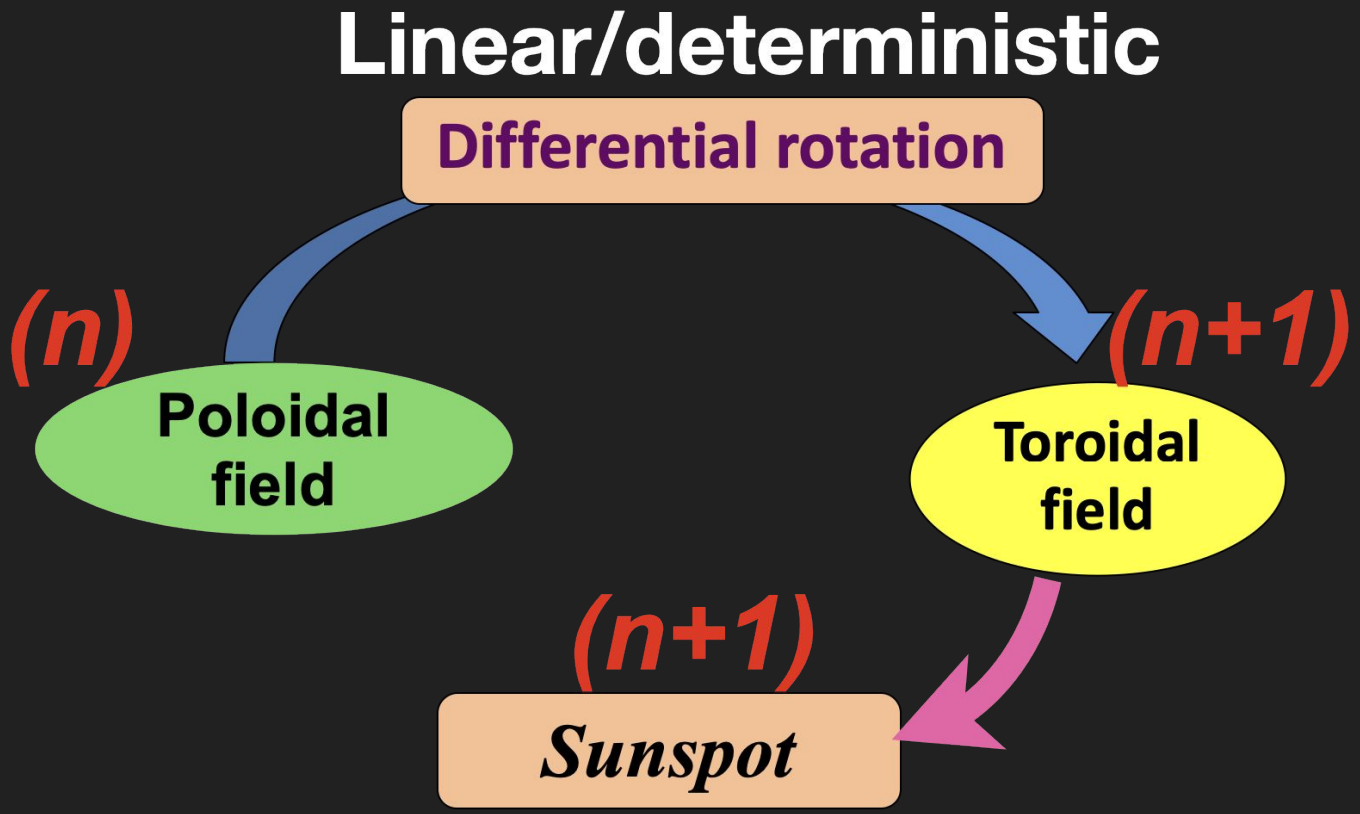
Credit: https://scied.ucar.edu/learning-zone

Necessity of solar cycle strength prediction

- ★ **Planning and preparation of any space mission takes several years and the space organizations need to know the level of solar activity well advance.**
- ★ **Prediction of the solar cycle strength will give a estimate of the frequency of occurrence of the energetic events.**
- ★ **It will help to protect our space and technology dependent assets.**

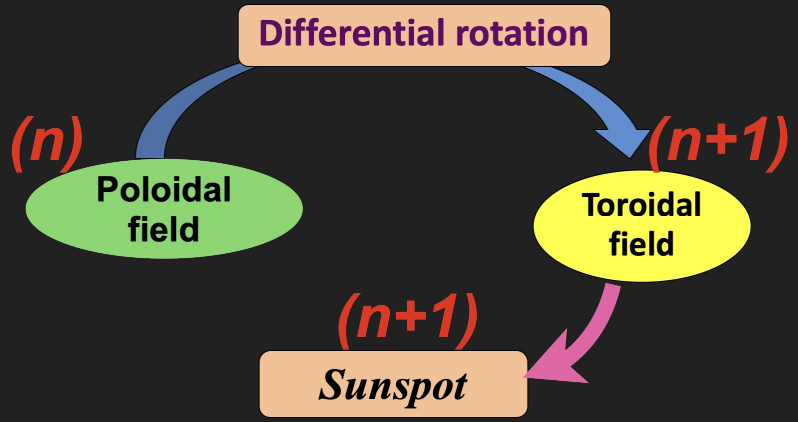


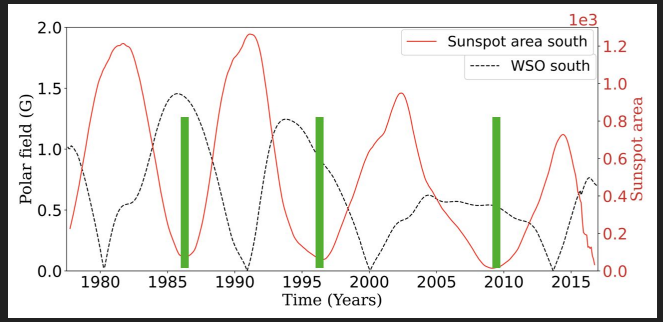
Prediction of solar cycle under the Babcock—Leighton framework



Prediction of solar cycle under the Babcock—Leighton framework

Linear/deterministic

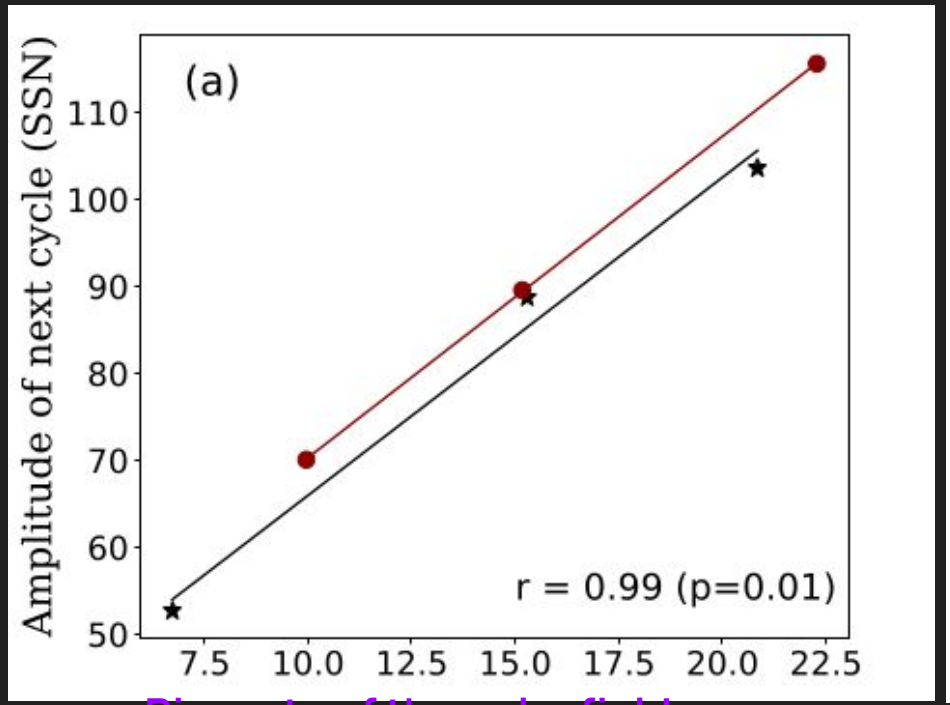




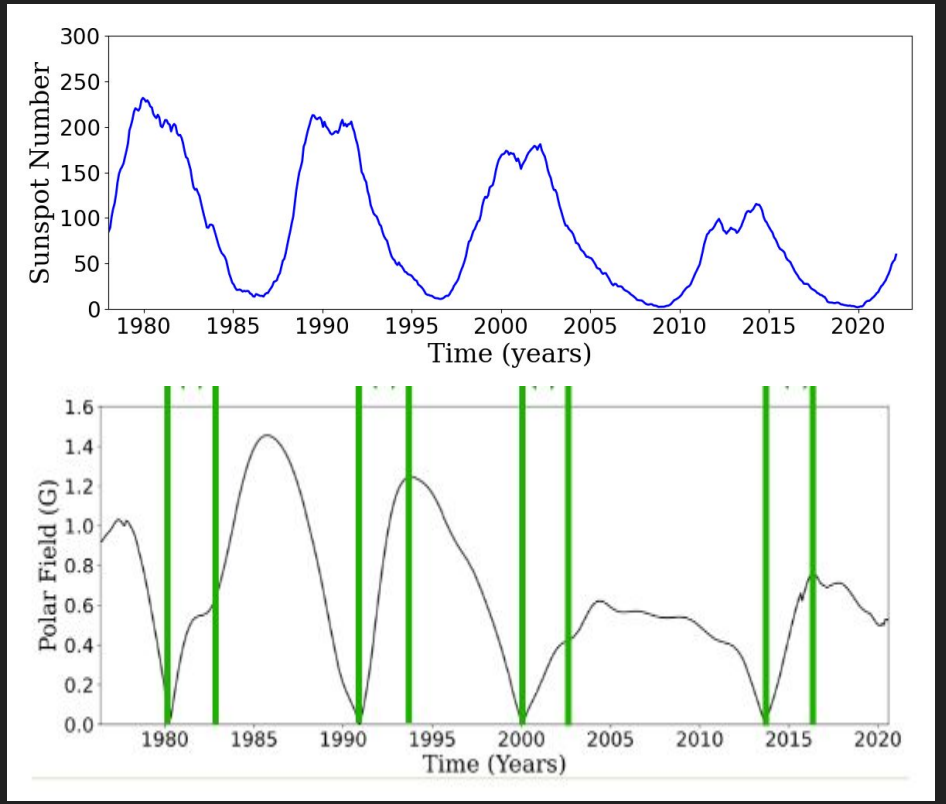
Usually cycle strength is predicted using the polar field at solar minimum (Schatten et al. 1978; Choudhuri et al. 2007) Svalgaard et al. 2005; Dikpati et al.2006

- ★ **The current methods can reliably predict the amplitude of the next cycle about 4-5 years, i.e., during solar minimum.**
- ★ **Can we extend this period?**

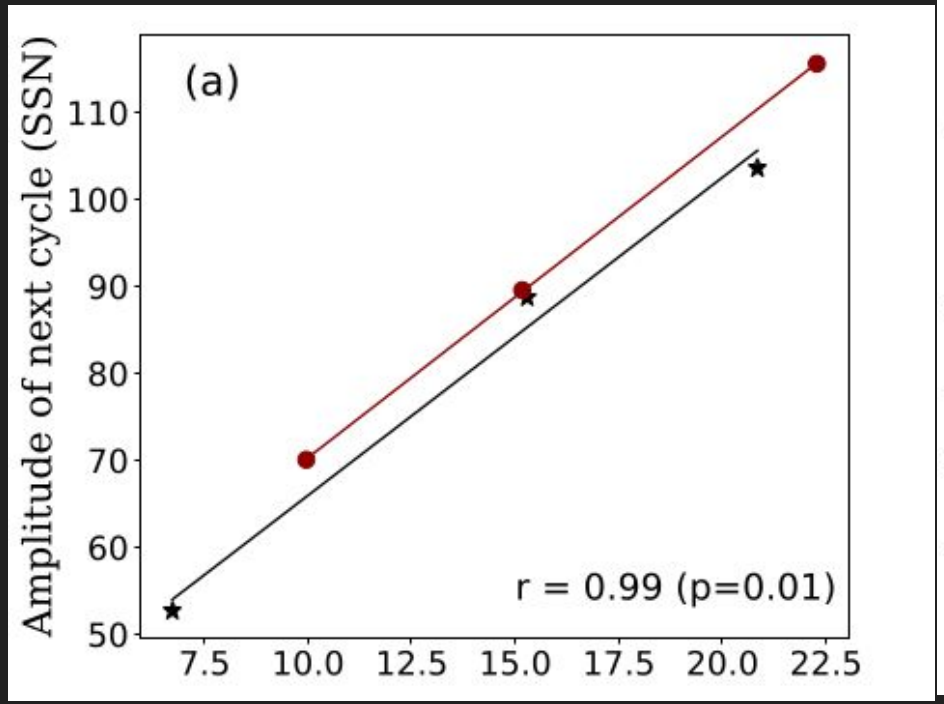
Polar field buildup rate can give the amplitude of the next cycle

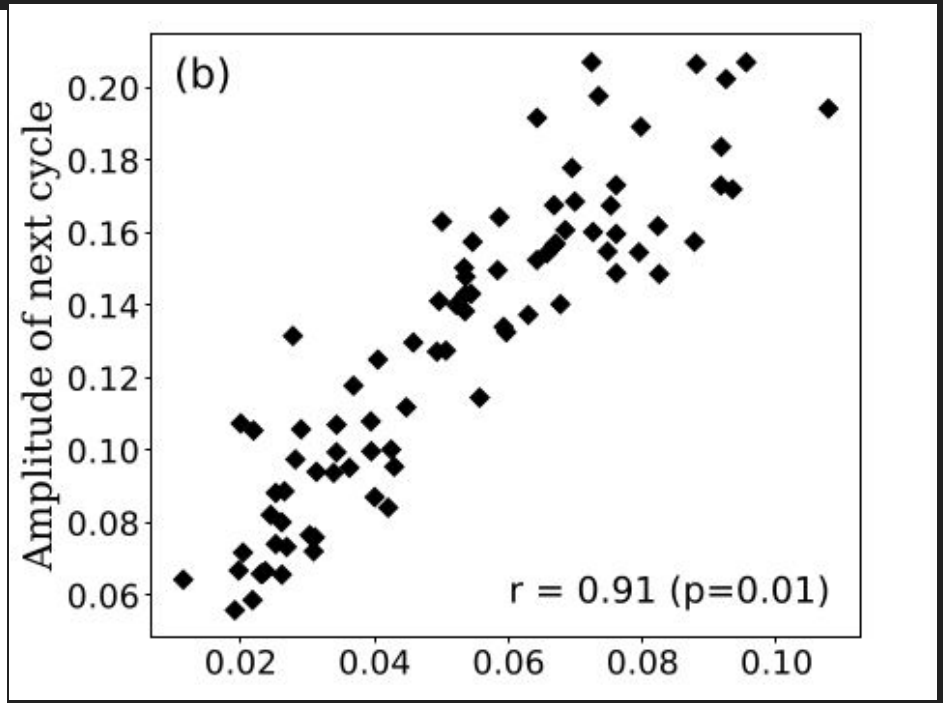


Rise rate of the polar field



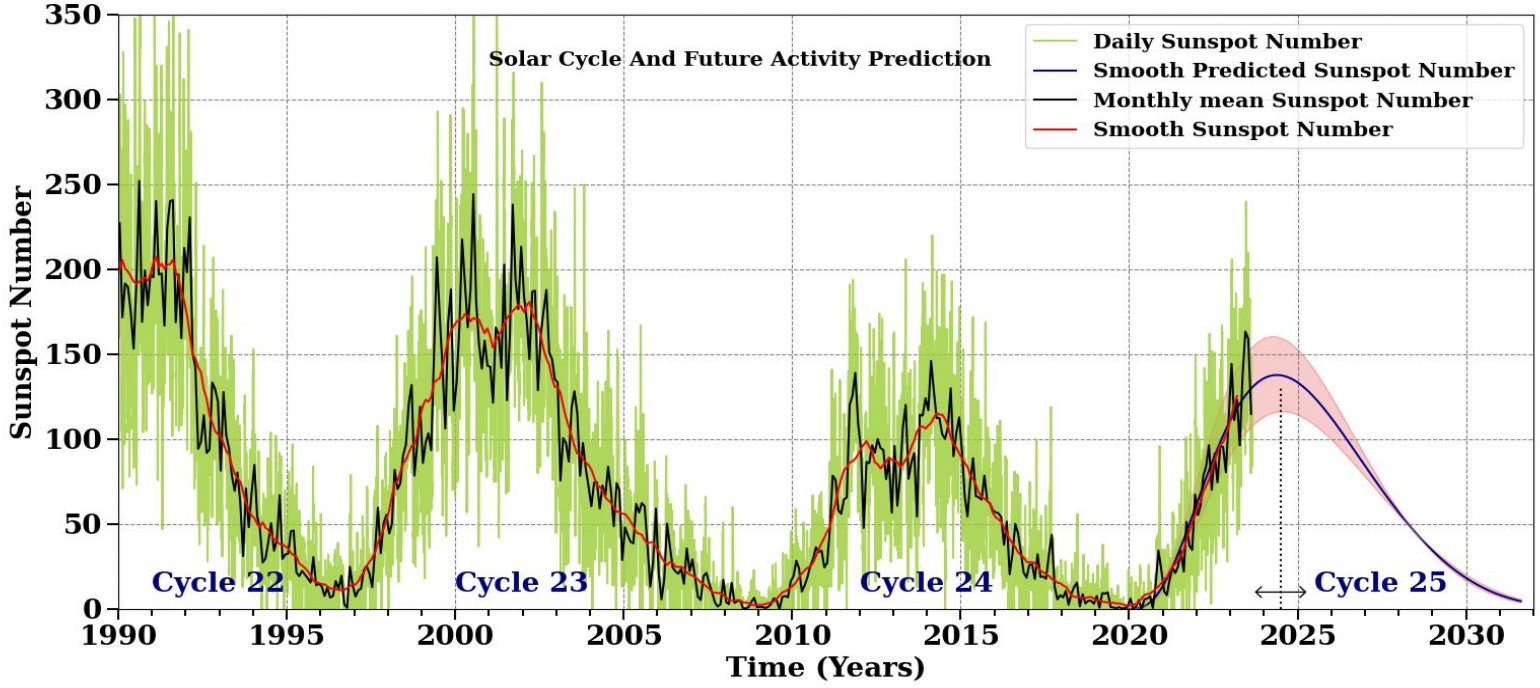
Polar field buildup rate can give the amplitude of the next cycle





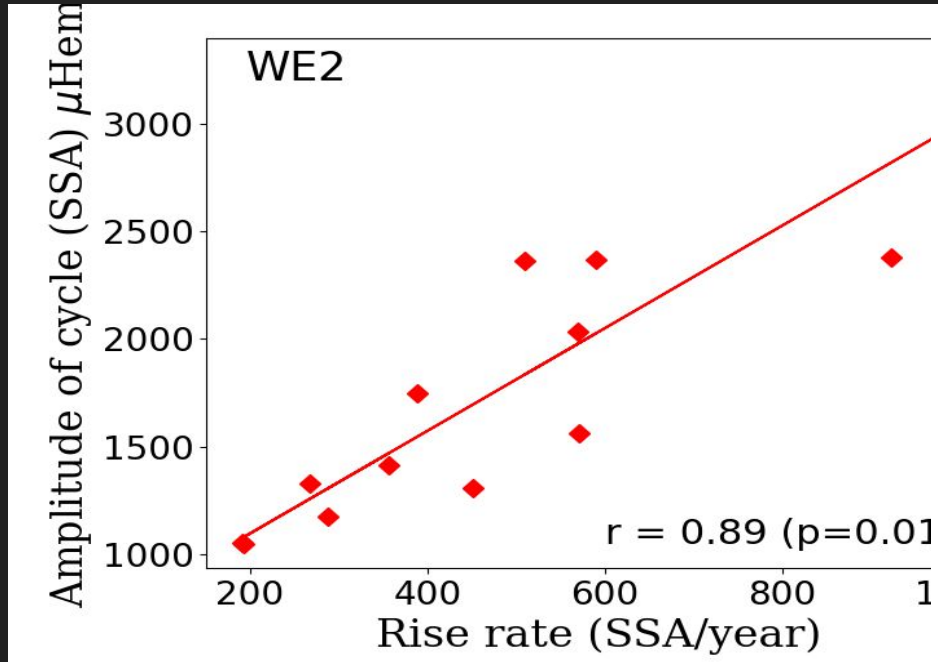
Biswas et al. (2023) also found this relation in Surface Flux Transport (SFT) model.

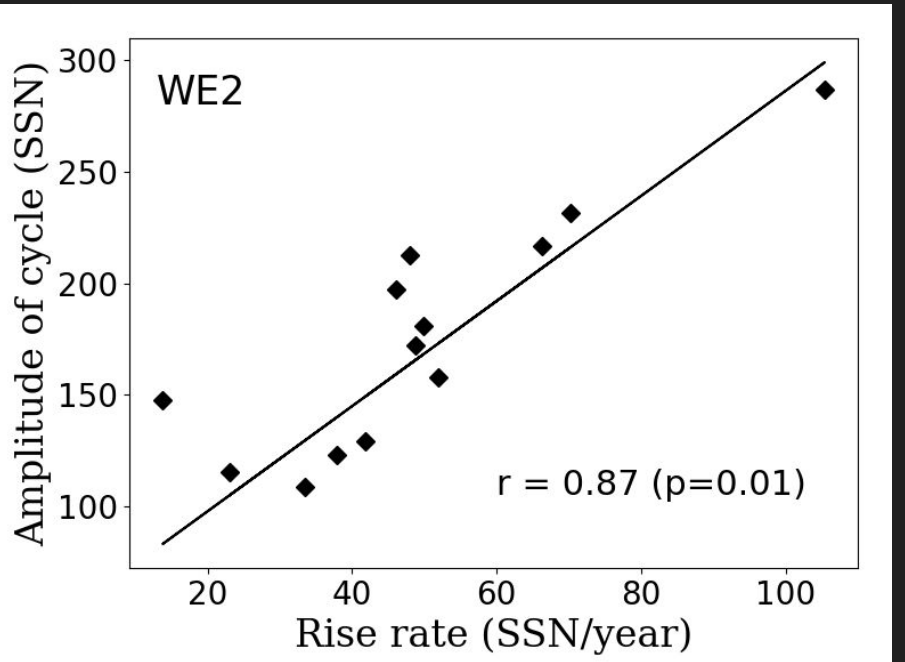
Cycle 25 prediction range based on polar field rise rate: 137+/- 23



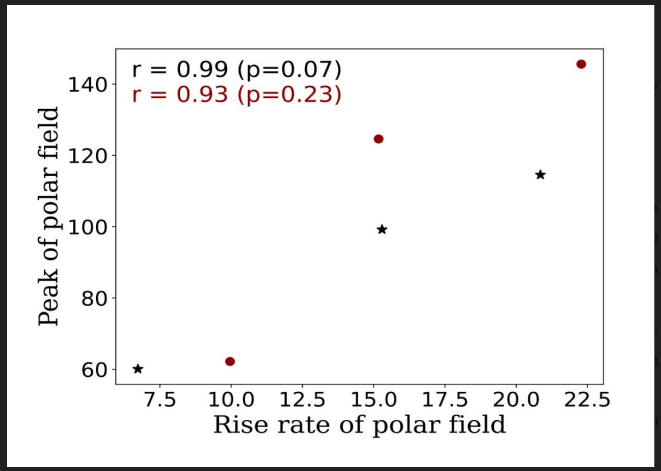
Waldmeier effect

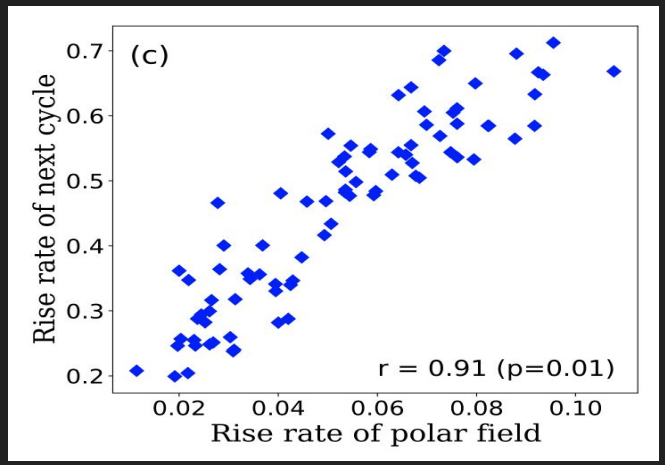
- ★ **Waldmeier effect** tells that weaker cycle rise slowly and takes longer time than stronger cycle and vice versa.
- ★ That means using **Waldmeier effect** we can predict the cycle strength.

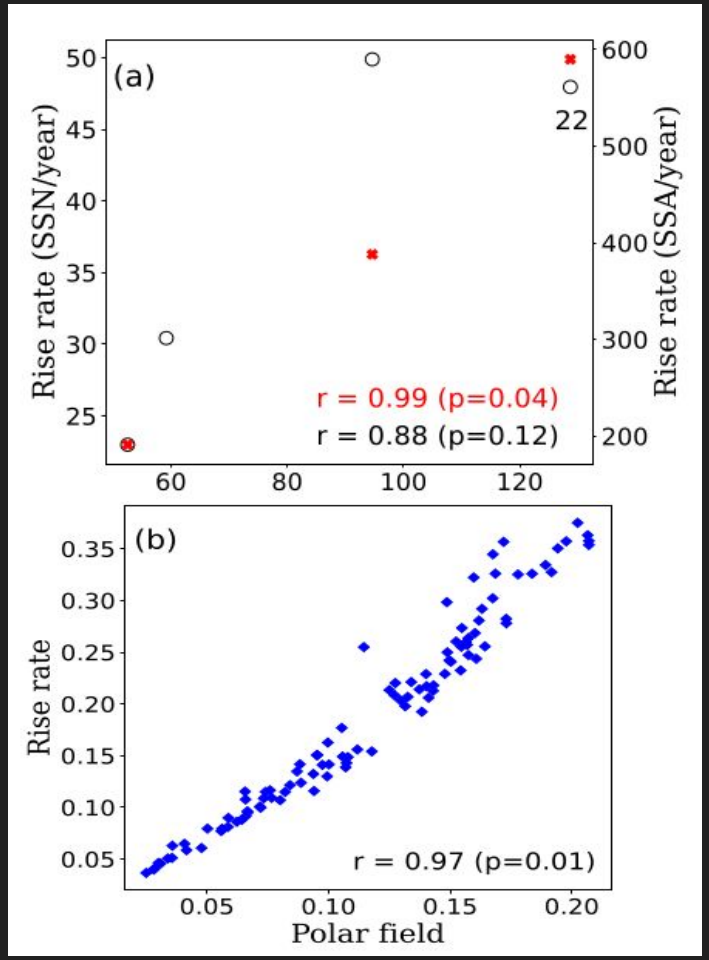




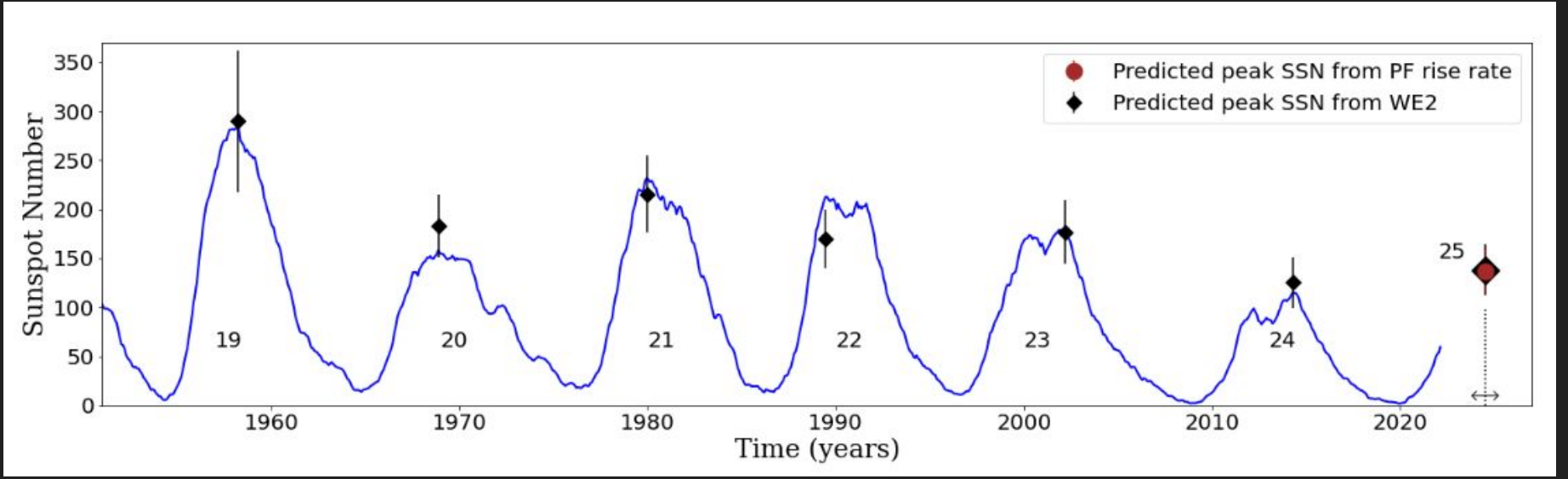
Connecting the polar field rise rate with Waldmeier effect







Results from polar field rise rate and Waldmeier effect



Conclusions

- ★ Solar Cycle rise rate and amplitude depends on the previous cycle polar field rise rate i.e., there is a physical link between polar field rise rate and the Waldmeier effect.
- ★ We can predict the next cycle strength reliably before ~ 8 to 9 year from solar maximum.

Thank you for your attention!