Solar Activity Forecast for the Next Decade

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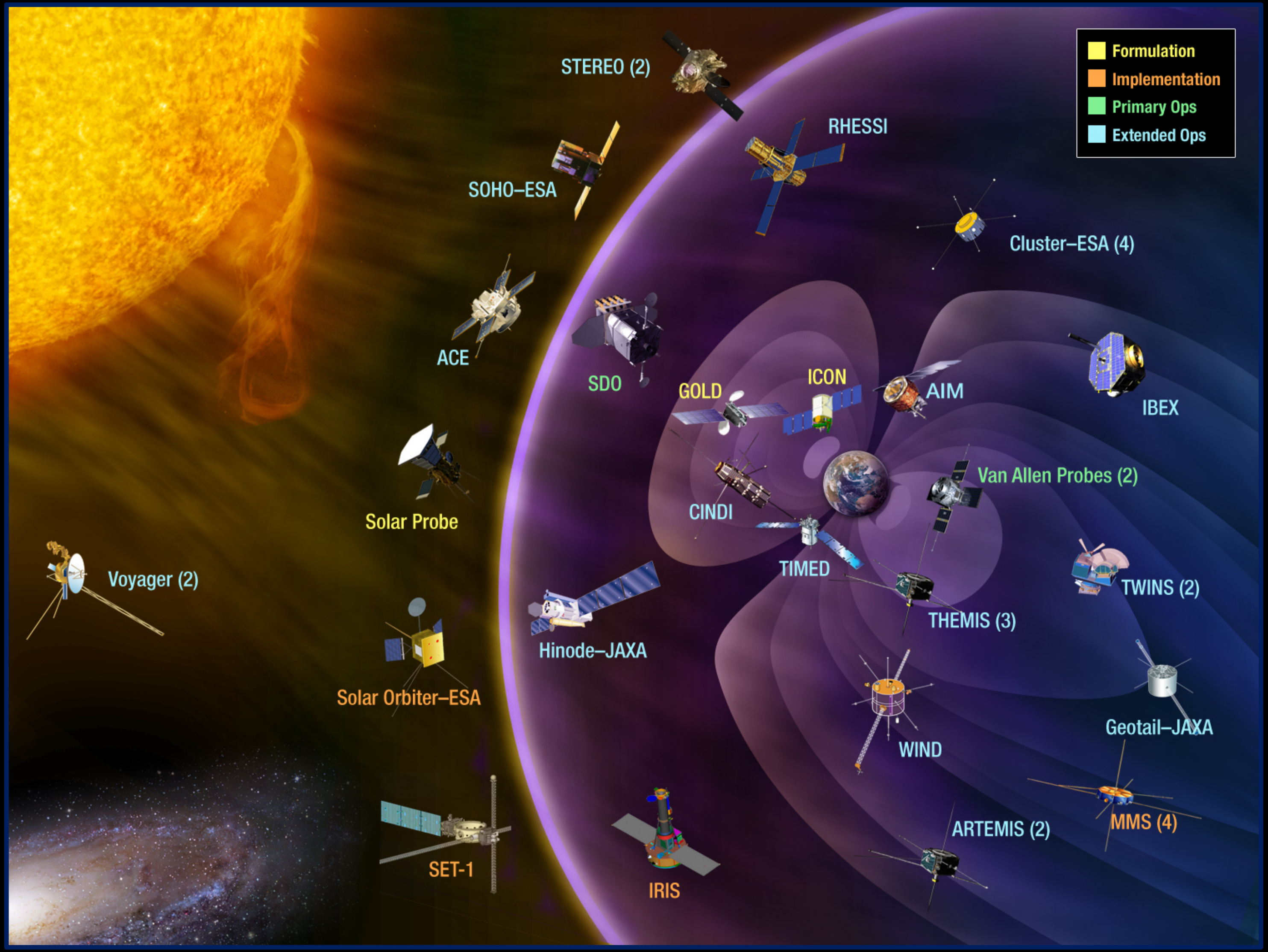
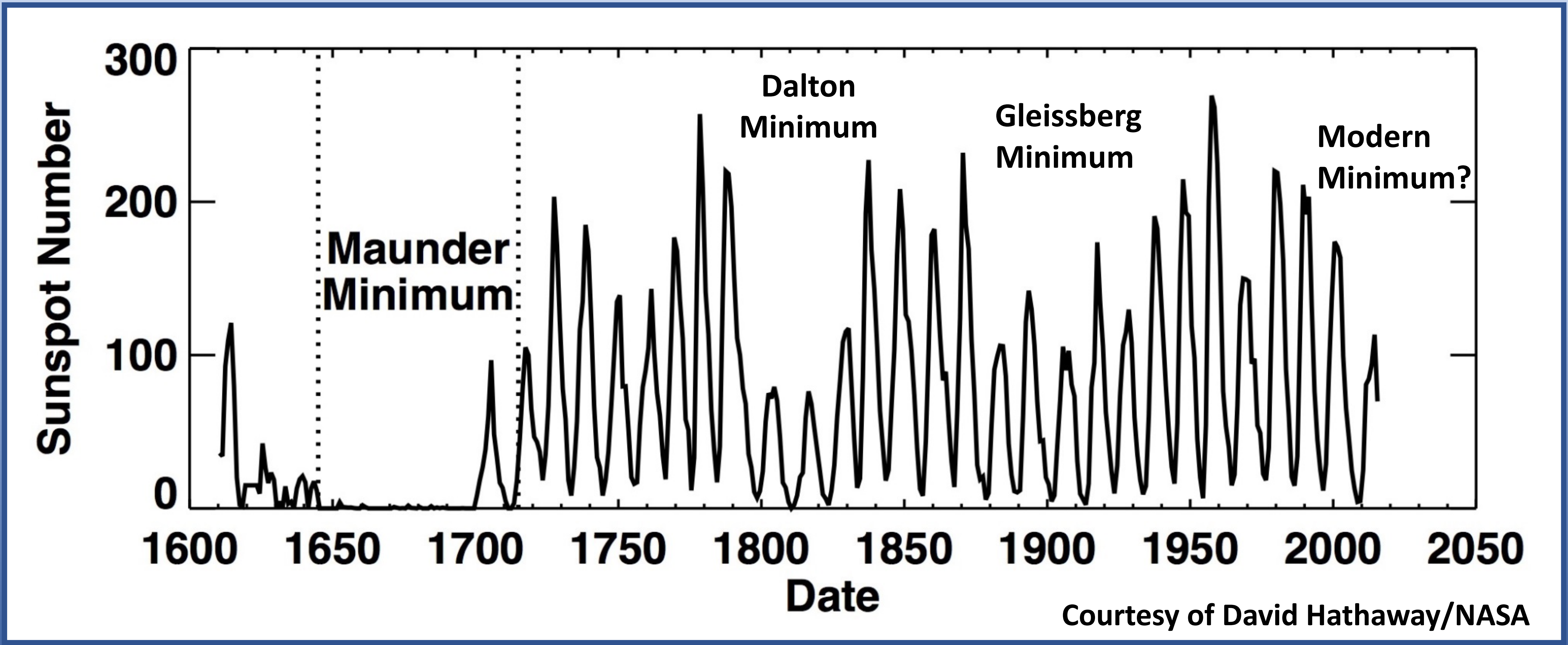
Solar Activity, Space Weather, & Technology

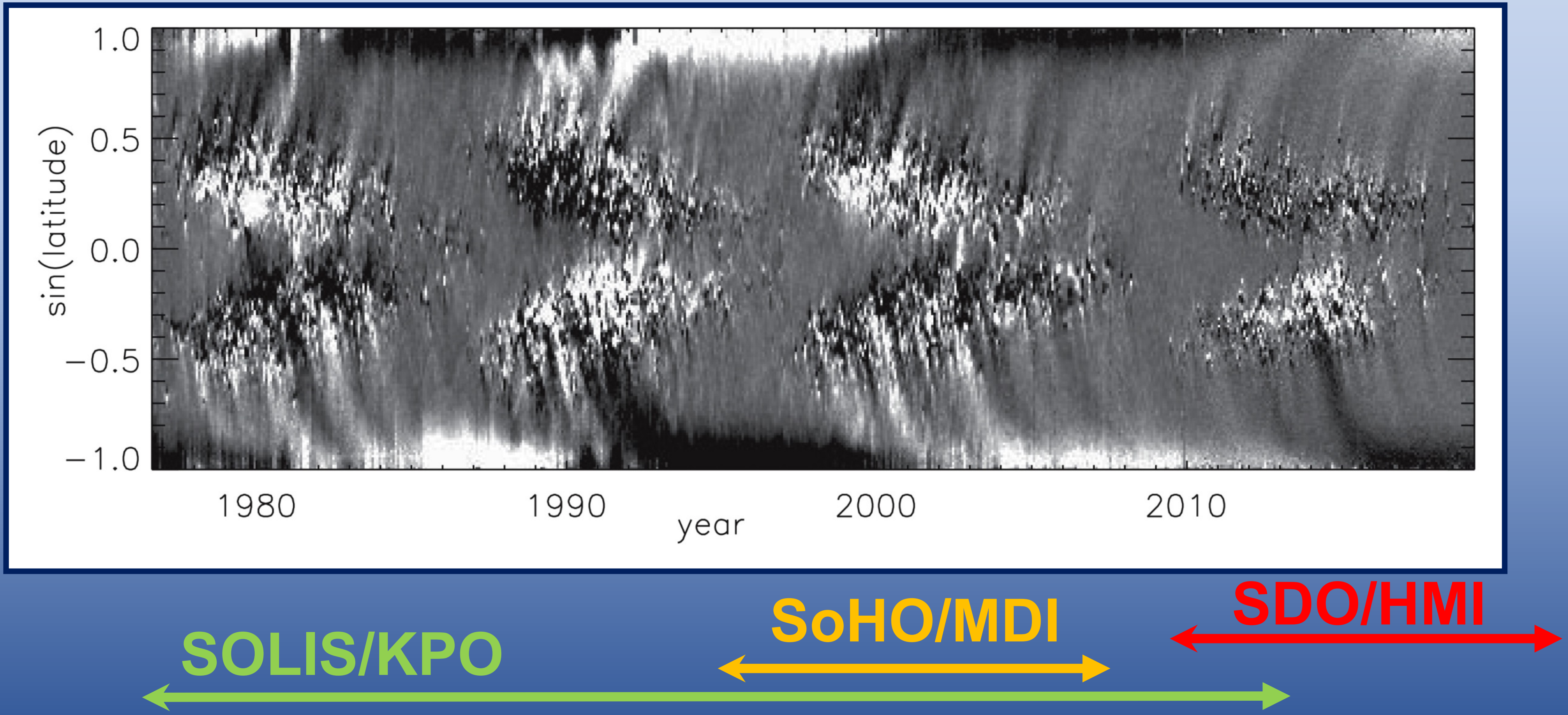


Credit: NASA

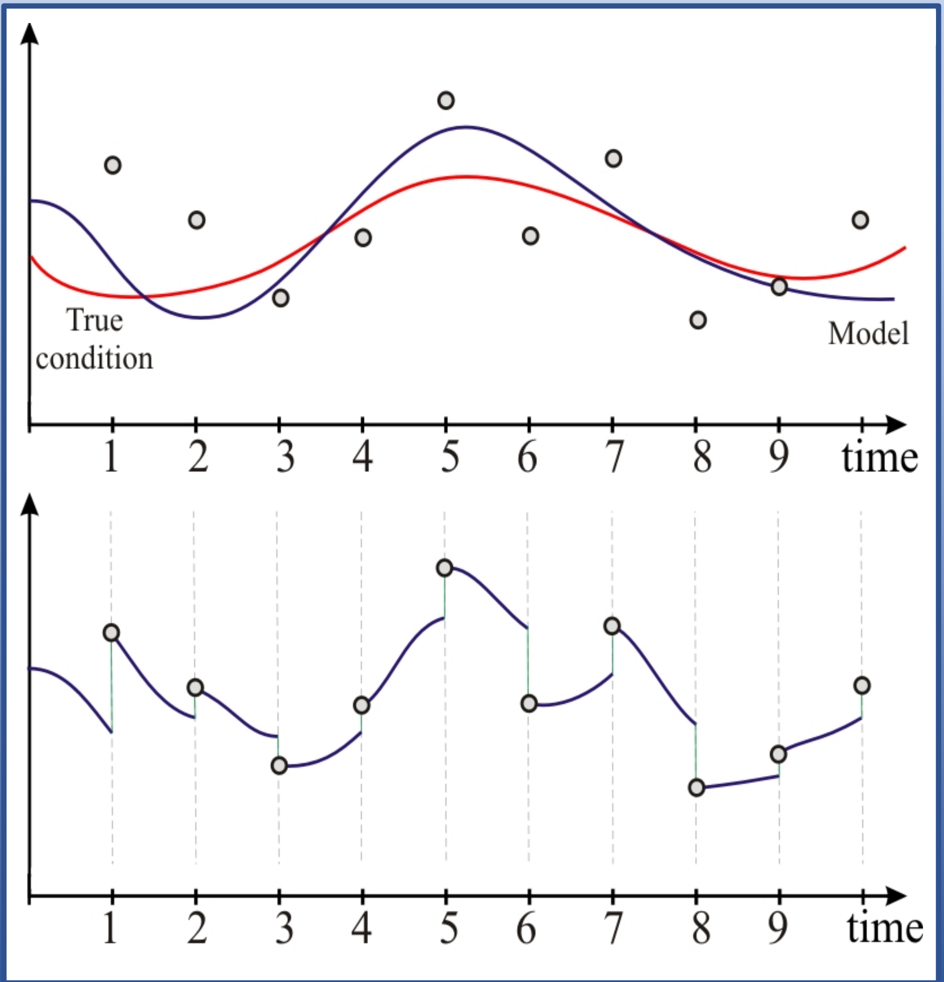
Sunspot Cycles



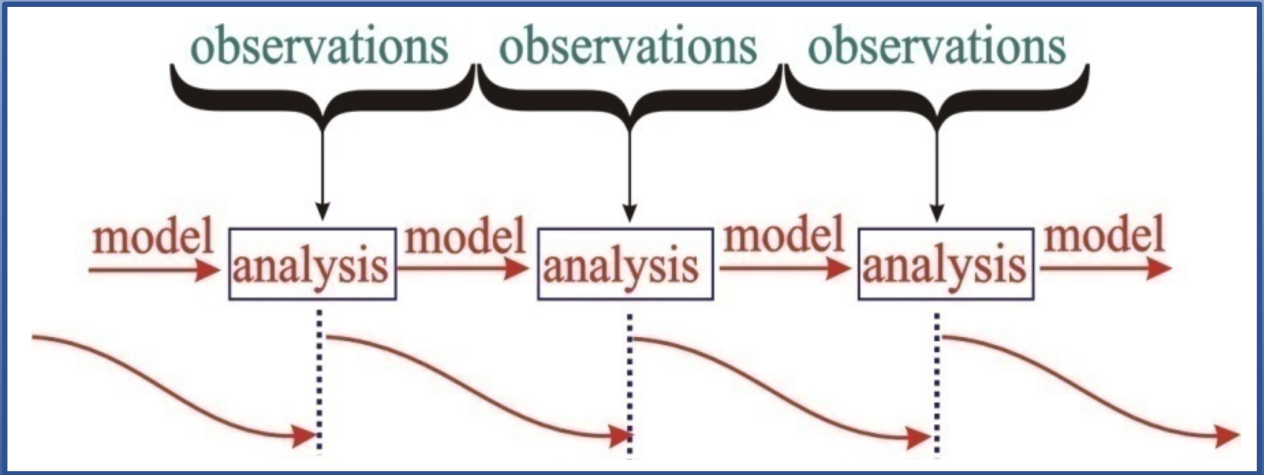
The evolution of global magnetic fields has been observed for four Solar Cycles.



The Data Assimilation Approach allows us to obtain reliable forecasts by taking into account uncertainties in both the data and the dynamo model.

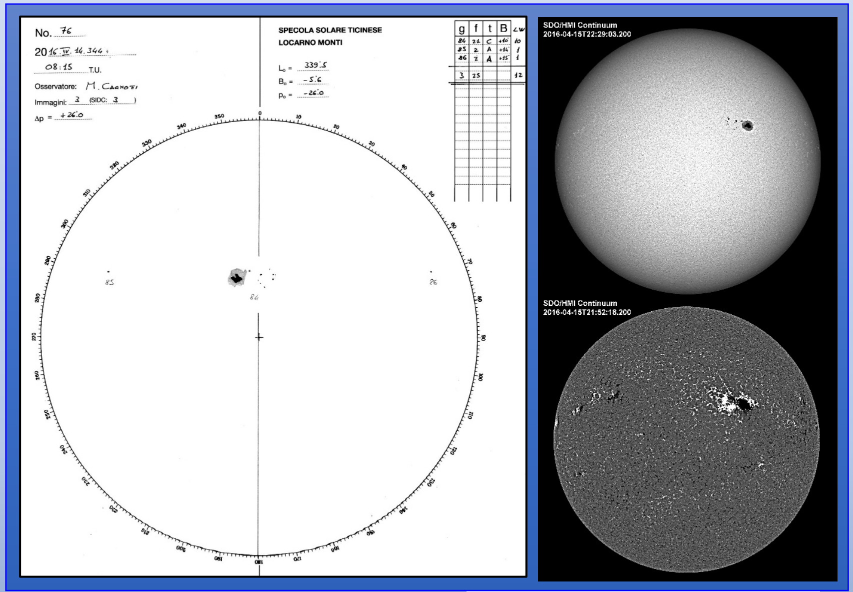


We used the Ensemble Kalman Filter method. It allows prediction of the future state of the Sun by relating observations of the surface to the state of the solar dynamo inside.



Data Assimilation Methodology

Observations



Dynamo model

Parker 1955, Kleeorin & Ruzmaikin, 1982, Kleeorin et al., 1995, Kitiashvili & Kosovichev 2009, 2011

$$\frac{\partial A}{\partial t} = \alpha B + \eta \nabla^2 A \qquad \alpha_k = -(\tau/3)\langle \mathbf{u}(\nabla \times \mathbf{u})\rangle$$

$$\frac{\partial B}{\partial t} = G\frac{\partial A}{\partial z} + \eta \nabla^2 B \qquad \alpha_m = (\tau/12\pi\rho)\langle \mathrm{h}(\nabla \times \mathrm{h})\rangle$$

$$\alpha = \alpha_k + \alpha_m$$

$$\frac{\partial \alpha_m}{\partial t} = \frac{\mu}{4\pi\rho}\left(\mathbf{B}\cdot(\nabla \times \mathbf{B}) - \frac{\alpha \mathbf{B}^2}{\eta}\right) - \frac{\alpha_m}{T_\alpha}$$

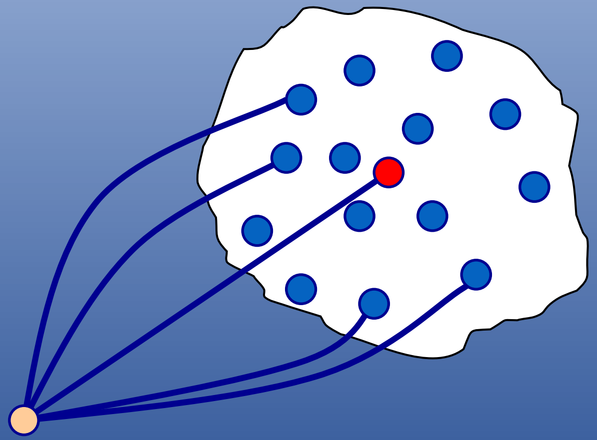
$$d_j = \psi^t + \varepsilon_j \qquad j = 1,\ldots,N \qquad d\psi = G(\psi)dt + h(\psi)dq$$

$$K_e = \frac{\left(C^e_{\psi\psi}\right)^f M^T}{M\left(C^e_{\psi\psi}\right)^f M^T + C^e_{\varepsilon\varepsilon}}$$

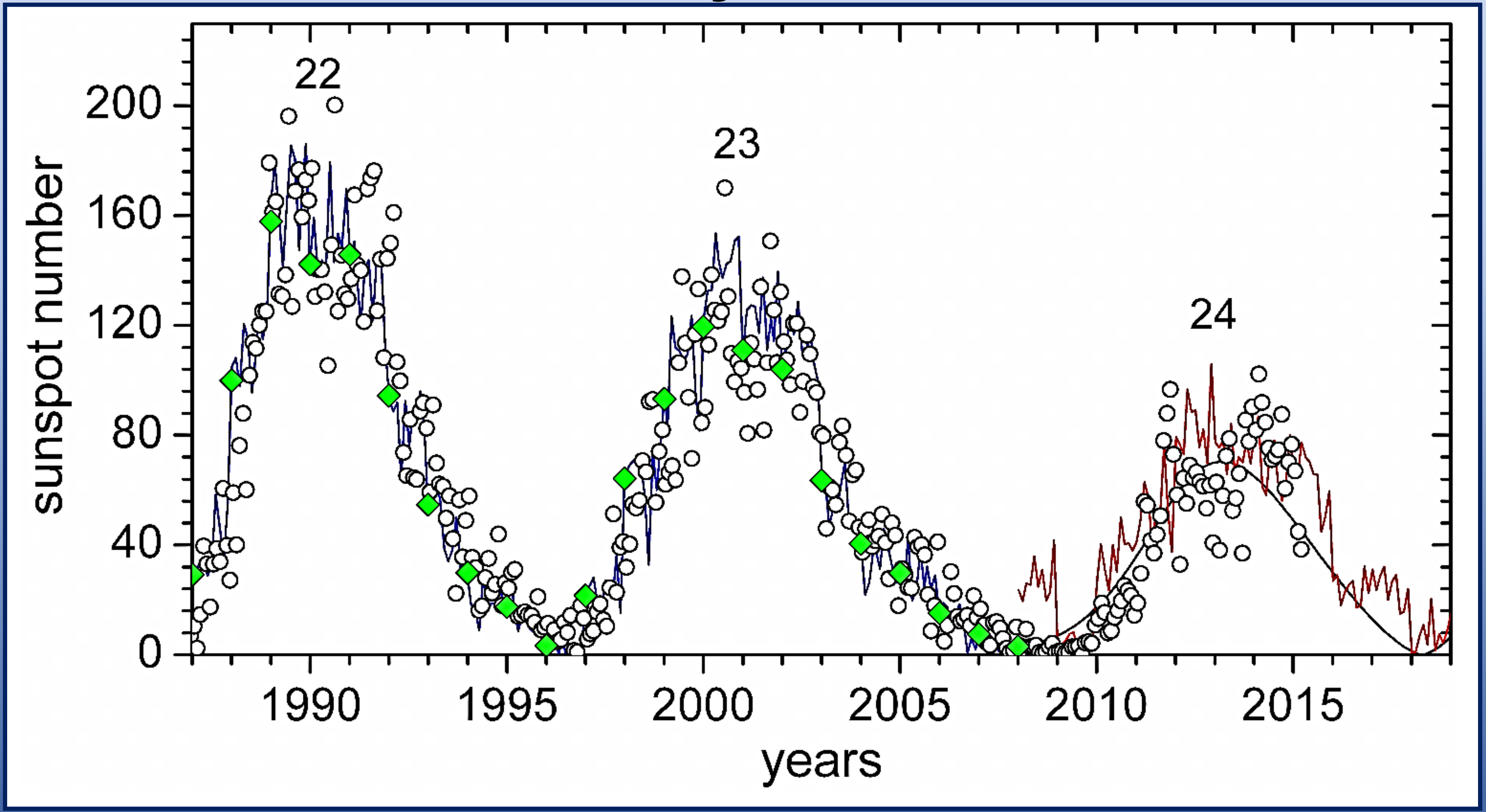
Kalman gain

$$\psi^a_j = \psi^f_j + K_e\left(d_j - M\psi^f_j\right) \qquad \overline{\psi^a} = \overline{\psi^f} + K_e\left(\overline{d} - M\overline{\psi^f}\right)$$

$$\left(C^e_{\psi\psi}\right)^a = \overline{\left(\psi^a_j - \overline{\psi^a}\right)\left(\psi^a_j - \overline{\psi^a}\right)^T} = (I - K_e M)\left(C^e_{\psi\psi}\right)^f$$



This method worked well for prediction of the current Solar Cycle, no. 24. The prediction below was made in 2008 before the start of cycle 24.

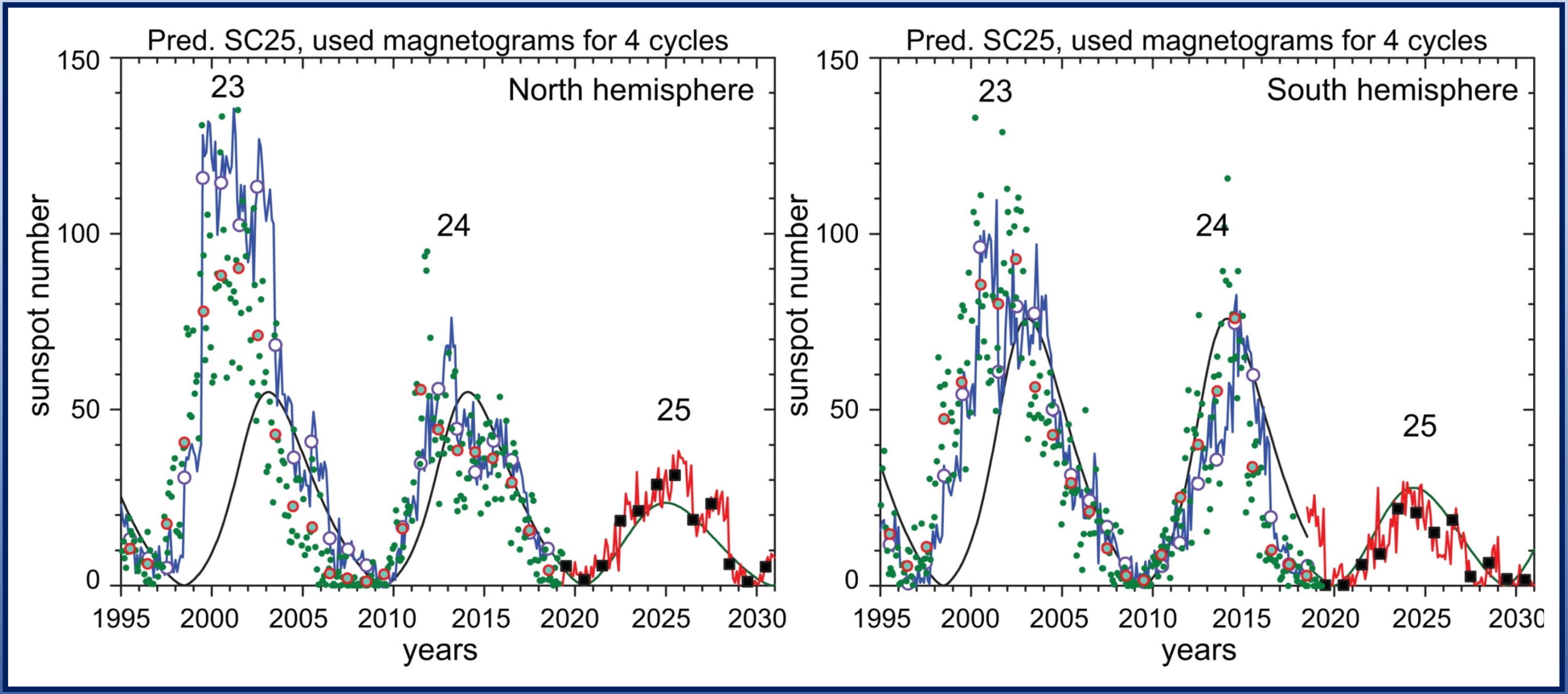


Kitiashvili & Kosovichev, 2008

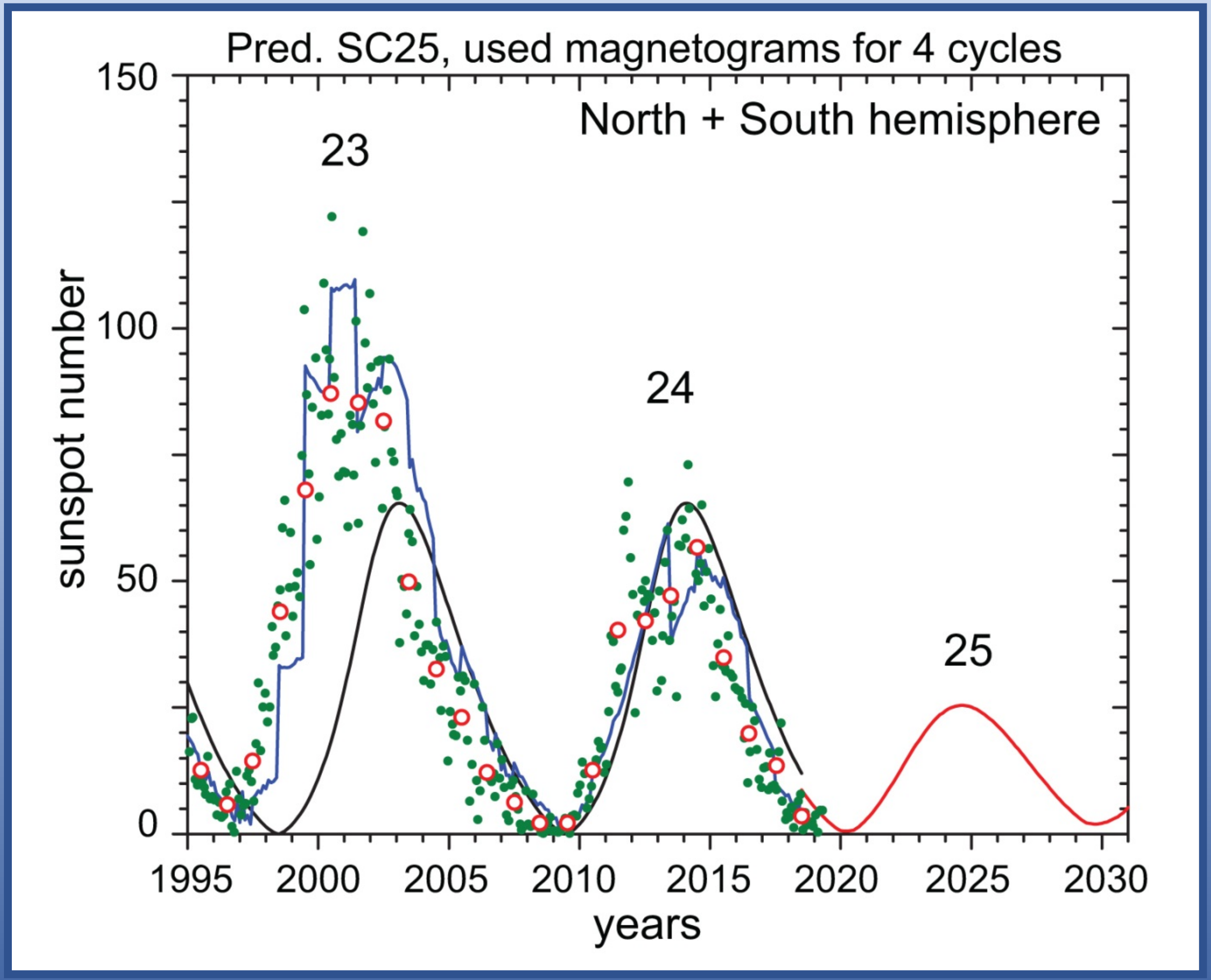
♦ **Annual sunspot data, used for assimilation into the physical dynamo model**

○ Monthly sunspot data

The method has now been applied to predict the upcoming Solar Cycle, no. 25.

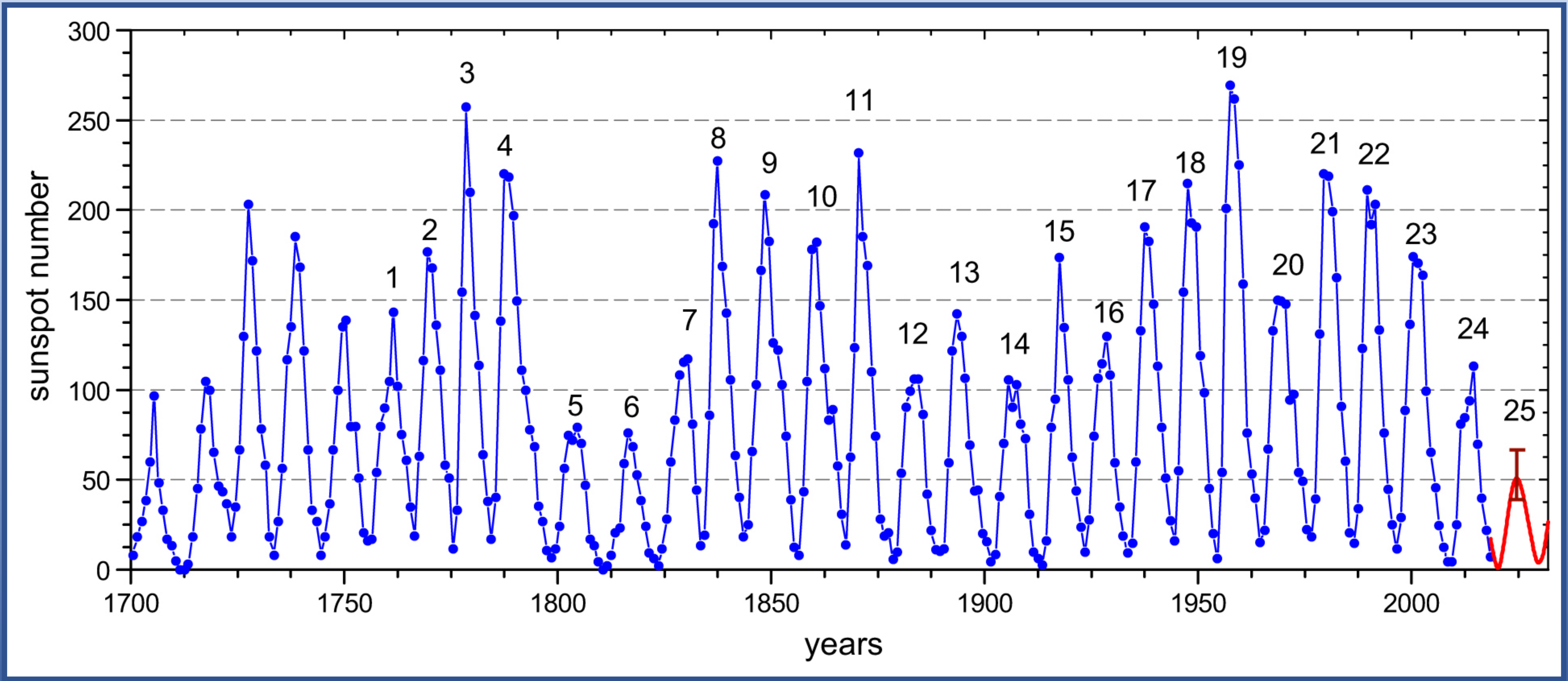


The results show that the next Solar Cycle will start in 2020 and reach a maximum in 2025.



Cycle 25 is expected to be even weaker than the current solar cycle.

According to this forecast, upcoming solar activity will be the weakest in the last 200 years.



Source sunspot number series: WDC-SILSO, Royal Observatory of Belgium, Brussels

Conclusions

- Prediction of solar cycles requires linking dynamo processes inside the Sun to the observed sunspots. This is very difficult due to our incomplete understanding of the physical mechanisms of the solar dynamo and also due to observational limitations that result in significant uncertainties in the initial conditions and model parameters. Using the data assimilation technique, we have made a successful prediction of the current Solar Cycle 24 before it started. That prediction was made by using sunspot number data as a proxy for the solar magnetic field.
- The new approach takes advantage of synoptic observations of magnetic fields emerging on the surface of the Sun to produce a more advanced and reliable forecasting method. For this work we combined observations from NASA's space missions SOHO and SDO with ground-based data from the National Solar Observatory.
- Using the currently available observational data, predictions and prediction uncertainties have been calculated for Solar Cycle 25. The results, based on both the sunspot number series and observed magnetic fields, indicate that the upcoming Solar Maximum (Solar Cycle 25) is expected to be significantly weaker than that of the current cycle (which near its end). The model results show that a deep extended solar activity minimum is expected in about 2019-2021, the maximum will occur in 2024 - 2025, and the sunspot number at the maximum will be about 50 (for the v2.0 sunspot number series) with an error estimate of ~15-30%. The maximum will likely have a double peak or show extended high activity over 2 – 2.5-years.
- For more information on how NASA will protect astronauts on deep space mission go to NASA webpage: https://www.nasa.gov/feature/scientists-and-engineers-evaluate-orion-radiation-protection-plan

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