THE POLAR PRECURSOR METHOD FOR SOLAR CYCLE PREDICTION: COMPARISON OF PREDICTORS AND THEIR TEMPORAL RANGE

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Abstract

The polar precursor method is widely considered to be the most robust physics-based method to predict the strengths of an upcoming solar cycle. It uses in form of indicators, the magnetic field concentrated near the poles around sunspot minimum. Here, we present an extensive performance analysis of various such predictors, based on observational data and various existing flux transport dynamo models. We have calculated linear correlation coefficients (r) of the predictors with the next cycle amplitude as a function of time measured from solar cycle maximum and polar field reversal. Setting r = 0.8 as a lower limit for acceptable predictions, we find that observations and models alike indicate that the earliest time when the polar predictors can be safely used is 4 years after polar field reversal and It is typically about 7 years before the predicted maximum. Re-evaluating the predictors at the time of solar minimum increasing the correlation level to $r > 0.9$. We determine the predicted amplitude of Cycle 25 based on the value of the WSO polar field at the official minimum date (December 2019) is 126 ± 3. A forecast based on the value in early 2017, 4 years after polar reversal would have only differed from this final prediction by about 3%.

Introduction

- Sun's variable magnetic field drives the fluctuations of the solar wind and terrestrial space weather, which may have hazardous effects on human activities that depend on the stability of our magnetospheric environment (space missions, satellites, telecommunications, etc.).
- And to assess and prevent those risks, reliable predictions of future solar activity are now very essential.
- The polar precursor method is very well known to predict the upcoming solar cycle.

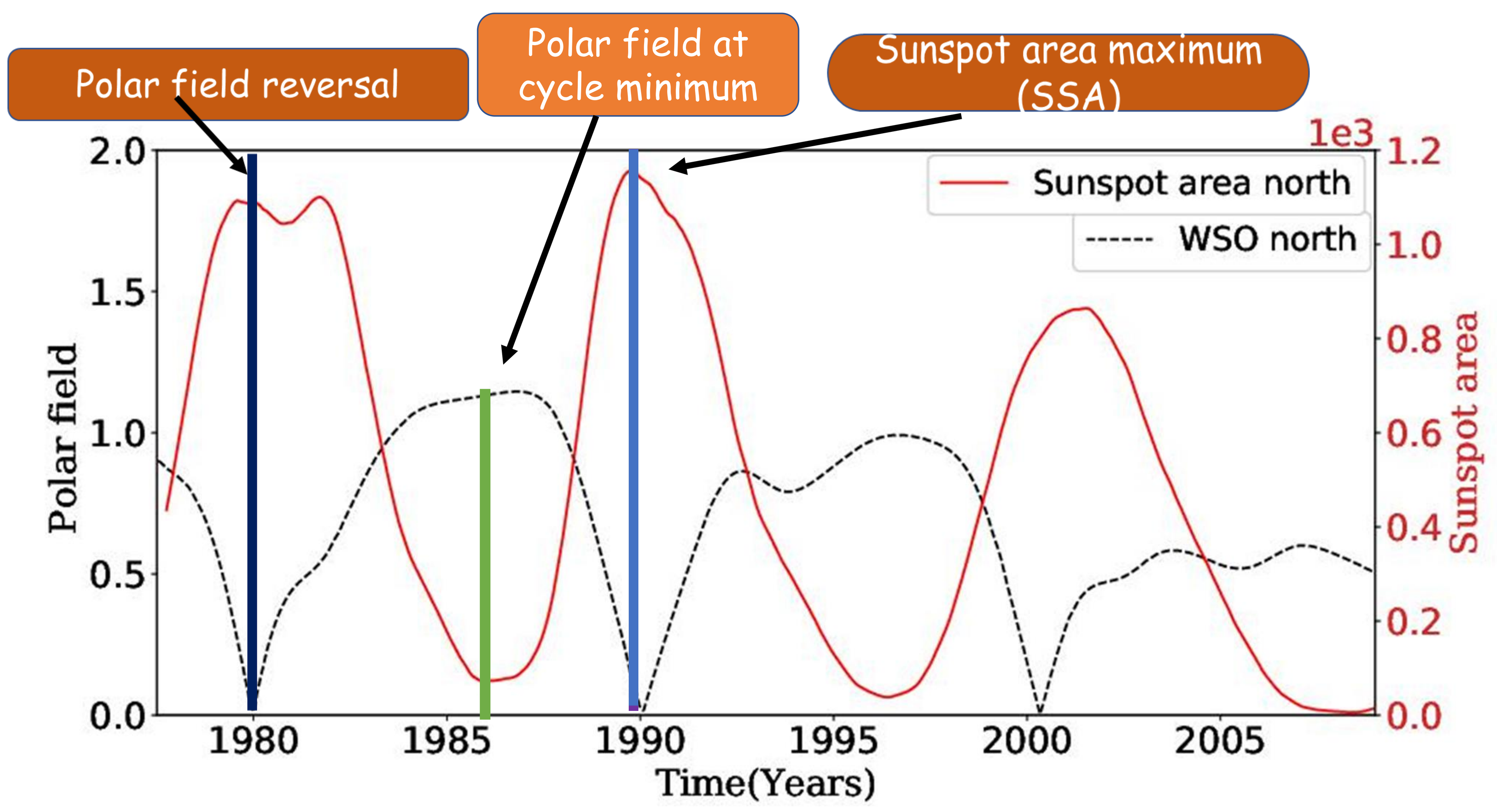


Figure 1. Variation of sunspot area (SSA) and polar field with time. Vertical lines shows times of SSA maximum (blue) and polar field reversal (black) respectively.

Questions to be answered

- Is it the polar field at the time of its peak value that best determines the strength of the next cycle, or is it at a different time?
- Is there an acceptable window over which we can use the polar field data to make a prediction?
- Do we need to wait until the activity minimum to make a reliable prediction of the next cycle?

Method and analysis

We have calculated linear correlation coefficients (r) of the polar field with the next cycle amplitude as a function of time measured back from sunspot area maximum and forward from polar field reversal (fig. 1) and showed the results of linear correlation coefficient (r) with the function of time in fig. (a) and (b) respectively for figure 2, 3, 4 and 5.

Conclusions

- Using the polar precursor method we find a prediction range using observational data as well as models.
- These results indicate that the temporal range of the polar precursor method is longer than it is generally thought and that reliable predictions based on this method can be made 4 years after polar reversal, which is, on average, nearly 3 years earlier than cycle minimum and 7 years before the predicted maximum.
- The results of next cycle 25 Predicted using WSO polar field data shown in the table below.

Time	N (SSA)	S (SSA)	Total (SSA)	Sunspot number
4 yr. after polar field Reversal (2017)	(399.45 ± 105.05) MHem	(744.38 ± 137.31) MHem	(553.29 ± 166.63) MHem	120±25
At cycle min. (2019)	(663.71 ± 91.62) MHem	(523.94 ± 82.27) MHem	(589.11 ± 21.84) MHem	126 ± 3

Results

Fig. 2 (a) and (b) for Observational data.

Prediction time 4 year after polar reversal

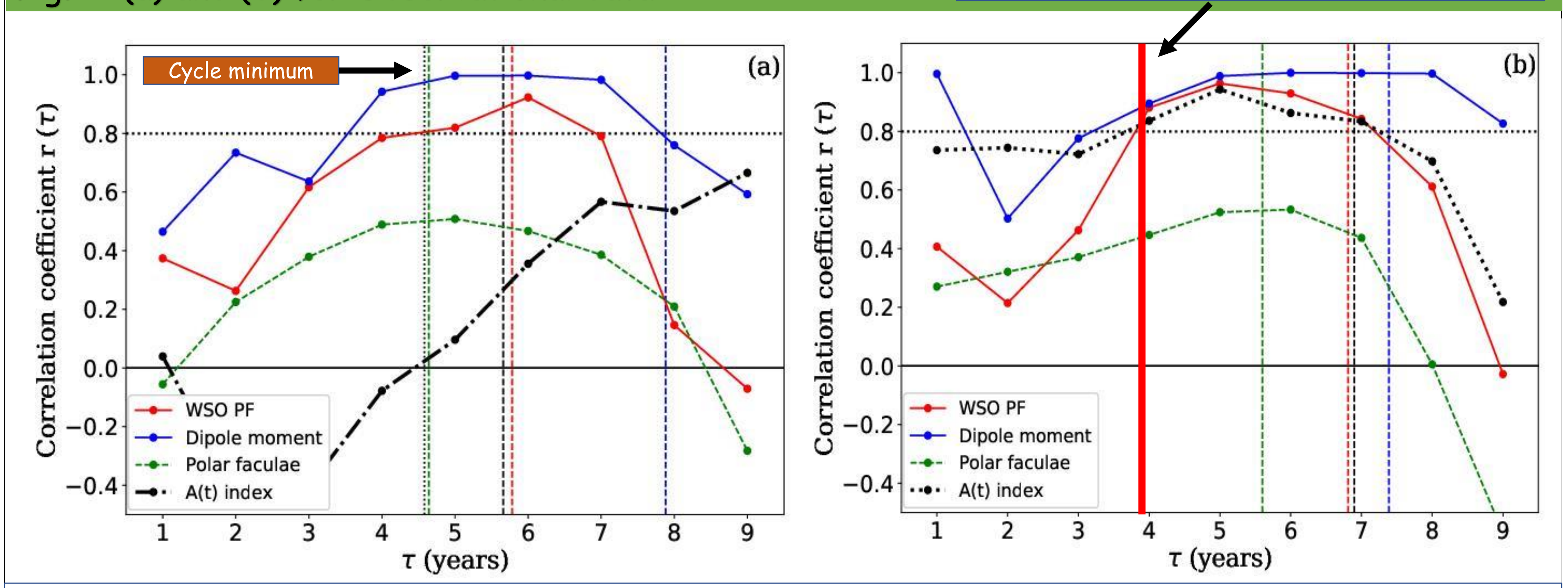


Figure 2. Pearson's correlation coefficient, between the peak sunspot area T at the maximum of the next cycle and polar field measures P(t) as a function of time (a) measured backward from the cycle maximum: t = tmax − τ (b) measured forward from the reversal of polar field : trev + τ. Vertical lines indicate the average positions of other cycle landmarks in the given plot, with the same color coding as the associated curves. (a) Black dots: cycle minimum. Dashed lines: time shift from the time of the maximum of polar field to next cycle maximum.

Dynamo Models

Fig. 3 (a) and (b) shows results of Surya dynamo model (Axisymmetric)

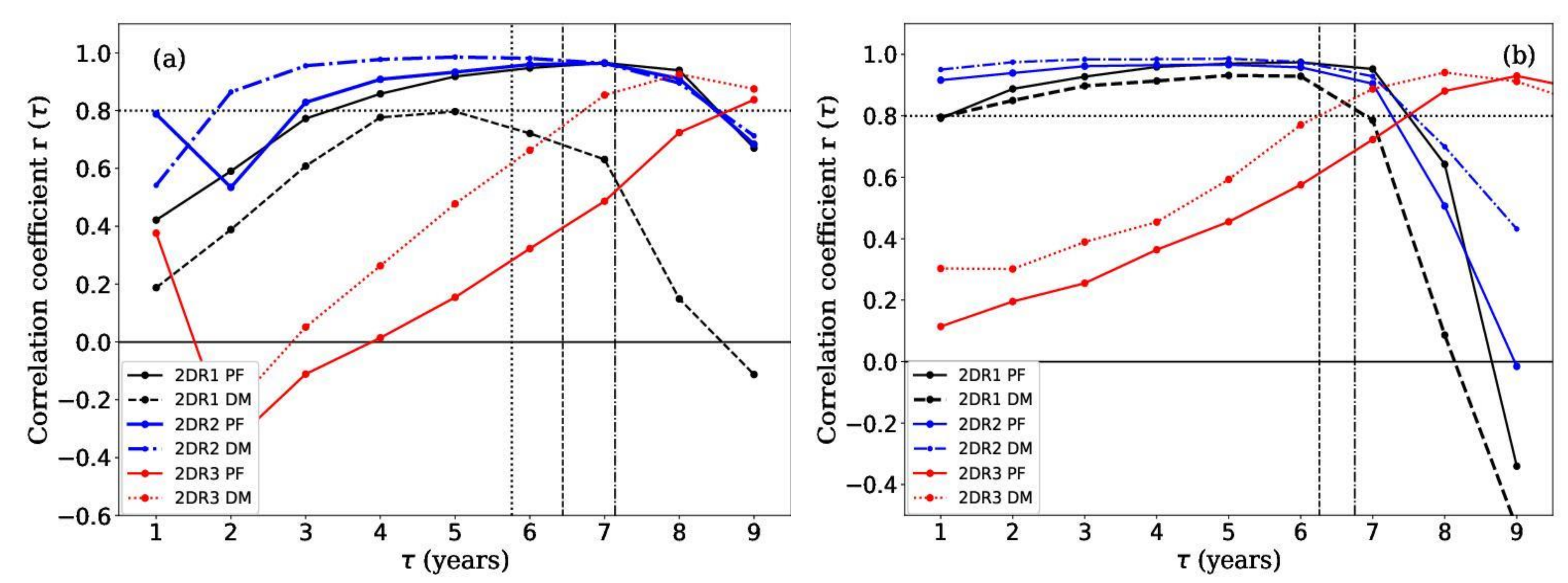


Figure 3 ,4 and 5 Same as Fig. 2. For different parameterizations of the Surya dynamo model, STABLE dynamo model and 2 x2D dynamo model respectively. Black dots: Cycle minimum. Dashed lines : Dipole moment peak and Dot dashed : Polar field peak.

Fig. 4 (a) and (b) shows the results of STABLE (3D) dynamo model

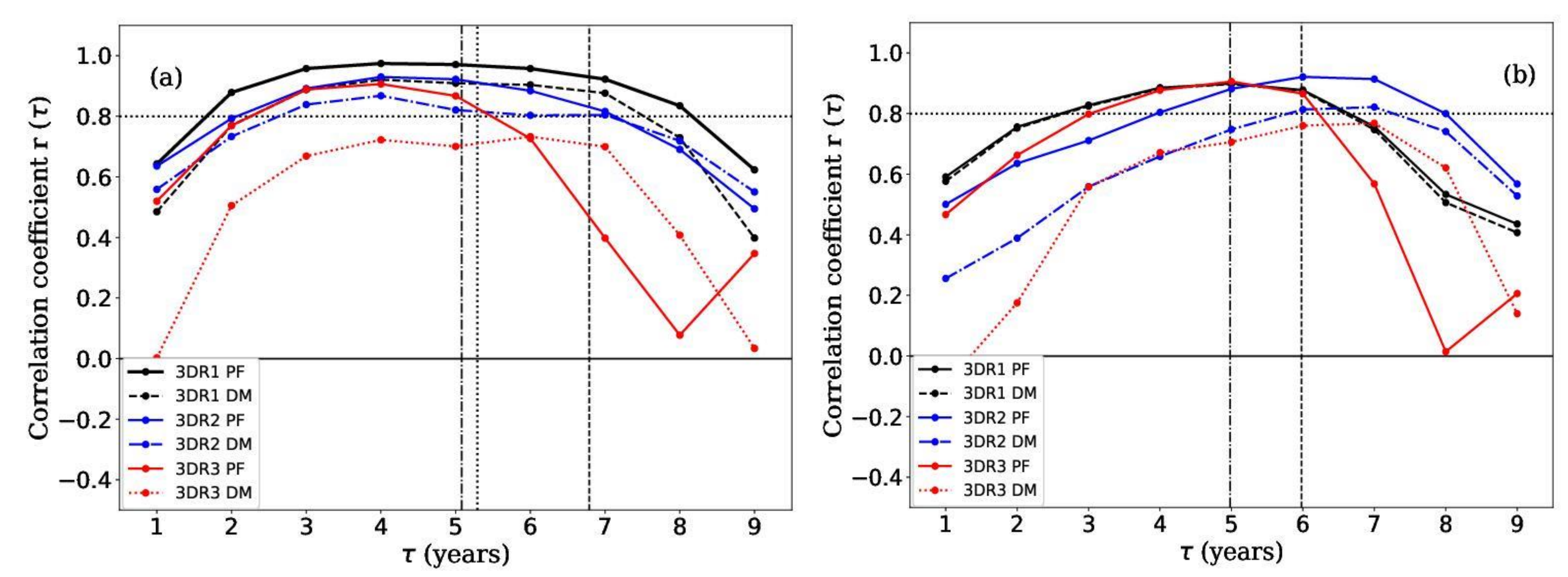
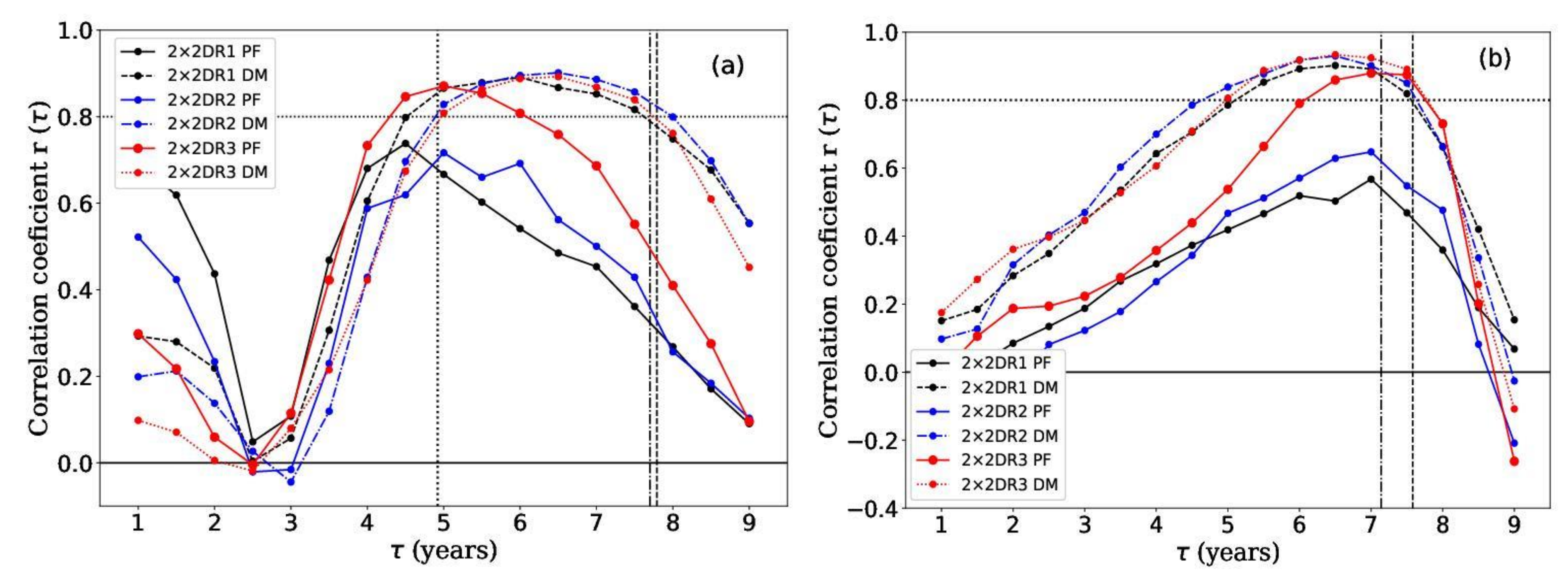


Fig. 5 (a) and (b) shows the results of 2 x 2D dynamo model.



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