Press-release on the research reported at National Astronomy Meeting 2015 (Landudno)
"Irregular heartbeat of the Sun with Principal Component Analysis and prediction of solar activity"

by Zharkova V.V.[1], Shepherd S.J.[2], Popova E.[3] and Zharkov S.I.[4]

http://nam2015.org/index.php/press-releases/64-irregular-heartbeat-of-the-sun-driven-by-double-dynamo

In this groundbreaking research, we distil the main parameters of dynamo waves from the full disk solar background magnetic field observed in cycles 21-23 by Wilcox Solar Observatory.

Normally, solar magnetic field measured is a combination of many waves, which are very difficult to separate. This is similar to white light emission comprising of many wave lengths, which one can only see after this white light passes through a glass prism and gives a rainbow with distinct wavelengths of each colour. In order separate magnetic waves and to reduce their dimensionality we use the powerful technique of Principal Component Analysis (PCA), producing a number of orthogonal components with decreasing weights describing different processes. The components with the highest weights substitute Principal Components (PCs), which may be ascribed to separate physical processes.

This analysis shown that the magnetic waves in the background field appear in pairs, with the Principal Components pair accounting for some 40% of the whole data variance (Fig. 1) (Zharkova et al, 2012). The magnetic waves travel from the opposite hemisphere to the Northern hemisphere (odd cycles) or to Southern hemisphere (even cycles), with the phase shift between the waves increasing with a cycle number.

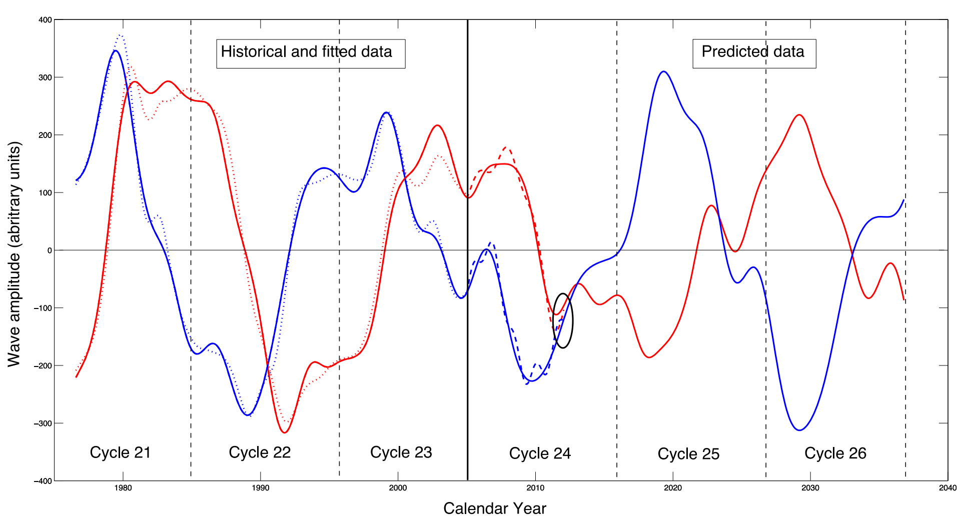

Fig. 1. Principal Components of the solar background magnetic field derived from historic data 9cycles 21-23) and predicted for cycles 24 -26

(Zharkova t al, 2012). The solid curve is calculated from derived formulae, the dotted curve for cycle 24 is the one derived from the full disk magnetic field data measured by WSO.

These two waves arise from the background (poloidal) magnetic field, from which we derived the toroidal magnetic field using a (modified and substantially enhanced) alpha-omega two layer dynamo model with meridional circulation {Popova et al, 2013}. These two components are assumed to originate in two different layers in the solar interior (inner and outer) with close, but not equal, frequencies and a variable phase shift (Popova et al, 2013).

Using the symbolic regression analysis based on Hamiltonian invariance, we managed to derive the fundamental mathematical formulae describing the both waves. We then used these formulae to predict the principal component waves for cycle 24 that, when compared with the observed magnetic field data, showed an accuracy of 97% (Shepherd et al, 2014). The summary curve of these waves is presented in Fig.2 showing that the resulting magnetic wave is clearly decaying from cycle 21 towards cycles 25-26.

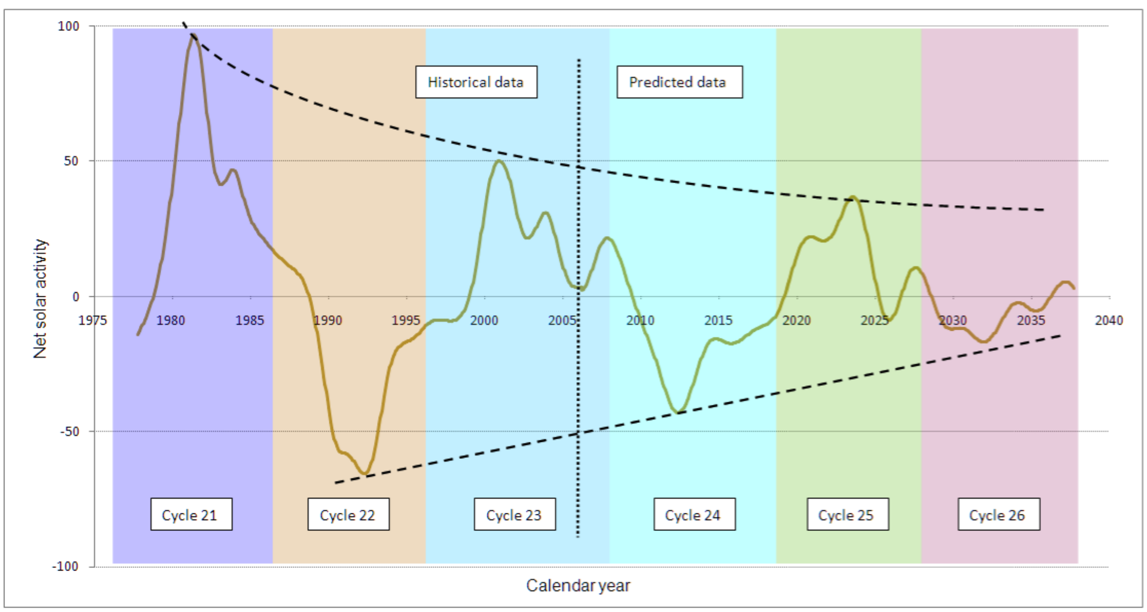

Fig. 2. The summary curve of the two principal components of the solar background (poloidal} magnetic field for the cycles 21-26 shown in Fig. 1.

This summary curve can be compared to the current index of solar activity – averaged sunspot numbers, if on can calculate the modulus (i.e. the absolute value without regard to sign) of the waves (Fig. 3 showing rather close fit to the averaged sunspot numbers.

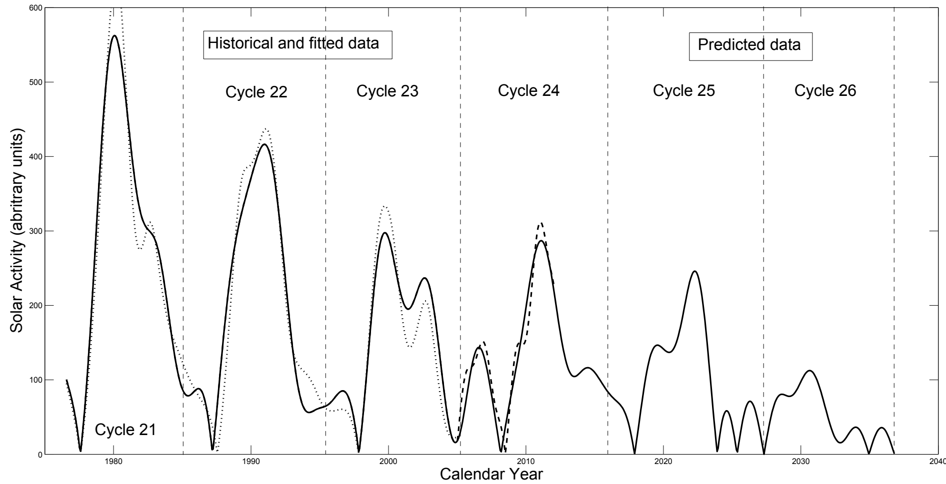

Fig. 3. The modulus summary curve of the principal components of solar background (poloidal) magnetic field, which fits the averaged sunspot numbers (measured for cycles 21-23) and predicted for cycle 24-26) (Shepherd et al, 2014).

Then by using the derived formulae we extrapolated the model further to predict the waves for solar cycles 25-26 (the right parts of Figs. 1-3). The prediction revealed increasing phase separation in cycle 25 and 11 year phase between these waves in cycle 26, ,e.g. these two waves become separated into the opposite hemispheres. We predict (Fig. 3) that this will lead to a significant reduction (more than 60%) in solar activity in cycle 26 compared to current cycle 24. These cycle s 25-26 will have the properties of a “Maunder minimum”.

The first Maunder minimum was reported in 17th century and lasted for about 6 solar cycles (1645-1700) when the solar activity was reduced to a very small number (50-70) of sunspots per year versus normal numbers of tens of thousands (see Fig. 4.5 below).

The restoration of the solar irradiance during the last 400 year shows its strong decrease during the period of the Maunder Minimum by a magnitude of about 3 W/m^2 (see Fig. 5). This amount of the solar radiance reduction was converted into reduction of the average temperature of the Earth. In particularly, in England the average temperature in 17 century dropped to ~8.5C versus 10.5C in 20th century (Fig. 6).

This drop of temperature led to freezing rivers and lakes in England, and all over the Europe. Given the fact that the upcoming Maunder minimum is upon us in 15 -20 years, we all will witness if this will have the similar consequences for the Earth as measured in the 17th century or it will be reduced by the human-made greenhouse gasses. Either way it looks like the Sun gives us the second chance to sort out human induced emission while it is in the minimum of activity before any worse case scenarios can come to play.

Our results have clear and profound relevance to the current debate on climate change and open a new era in long-term solar physics research.

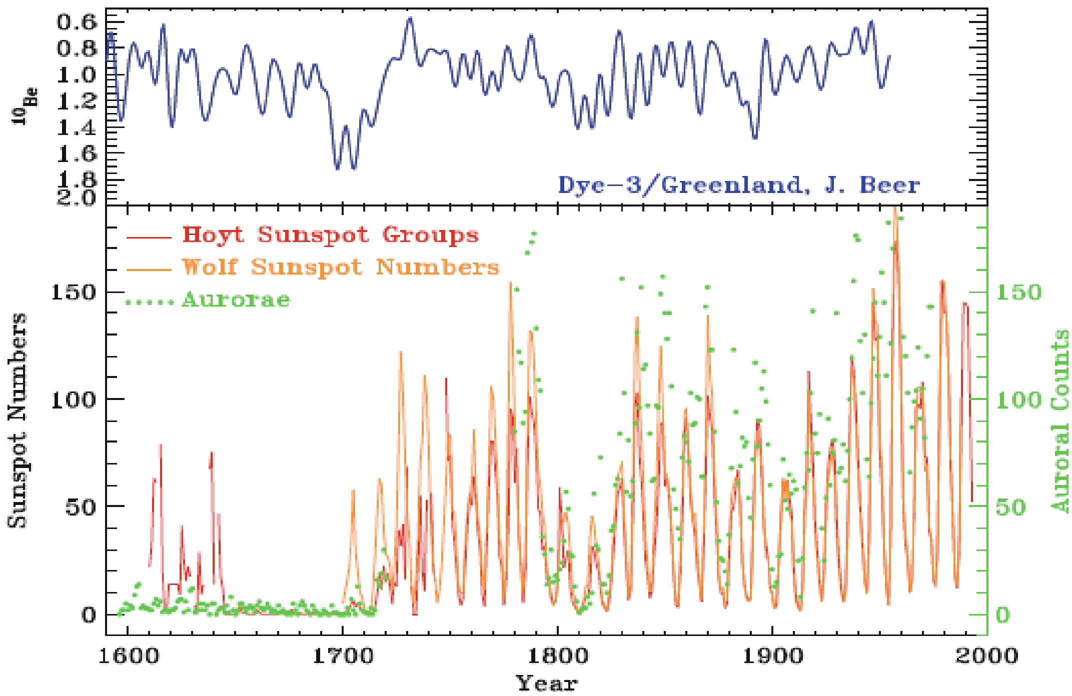

Fig. 4.5 The Maunder minimum, as seen through cosmogenic radioisotopes (*top panel*) and sunspot and auroral counts (*bottom panel*). The *thick red line* is the so-called Group Sunspot Number, a reconstruction similar to Wolf's (*thin orange line*) but deemed more reliable in the 18th century because it relies exclusively on the more easily observable sunspot groups. Beryllium 10 data courtesy of J. Beer, EAWAG/Zürich.

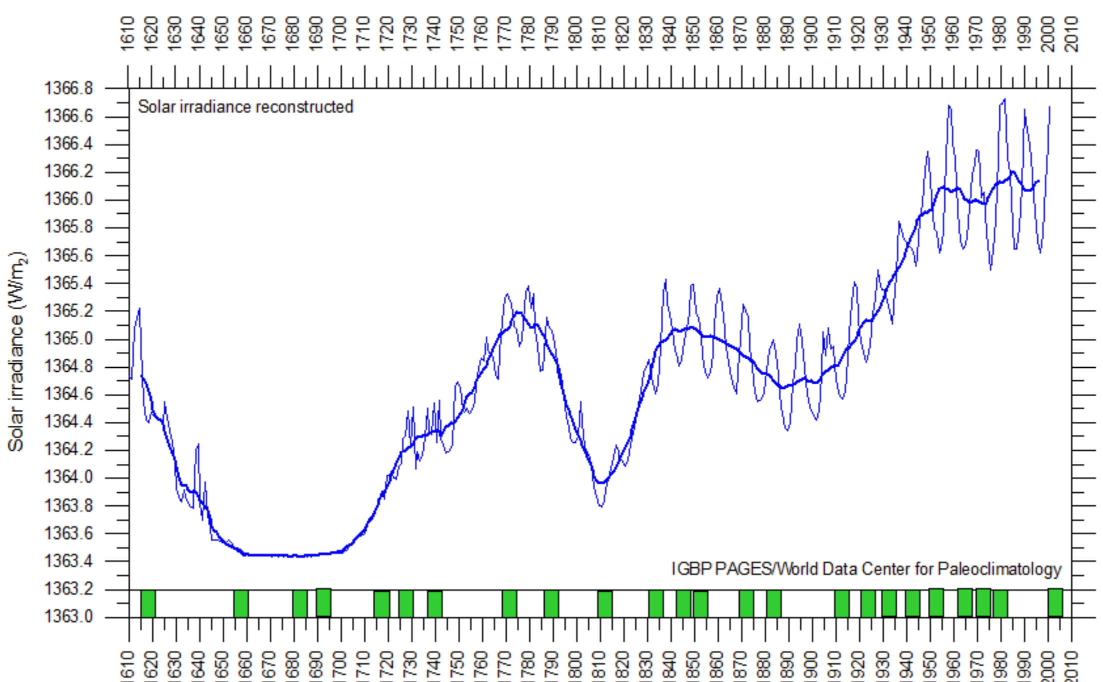

Fig. 5. *Solar irradiance since 1610 as reconstructed by Lean et al (1995) and Lean (2000). The thin line indicates the annual reconstructed solar irradiance, while the thick line shows the running 11 average.*

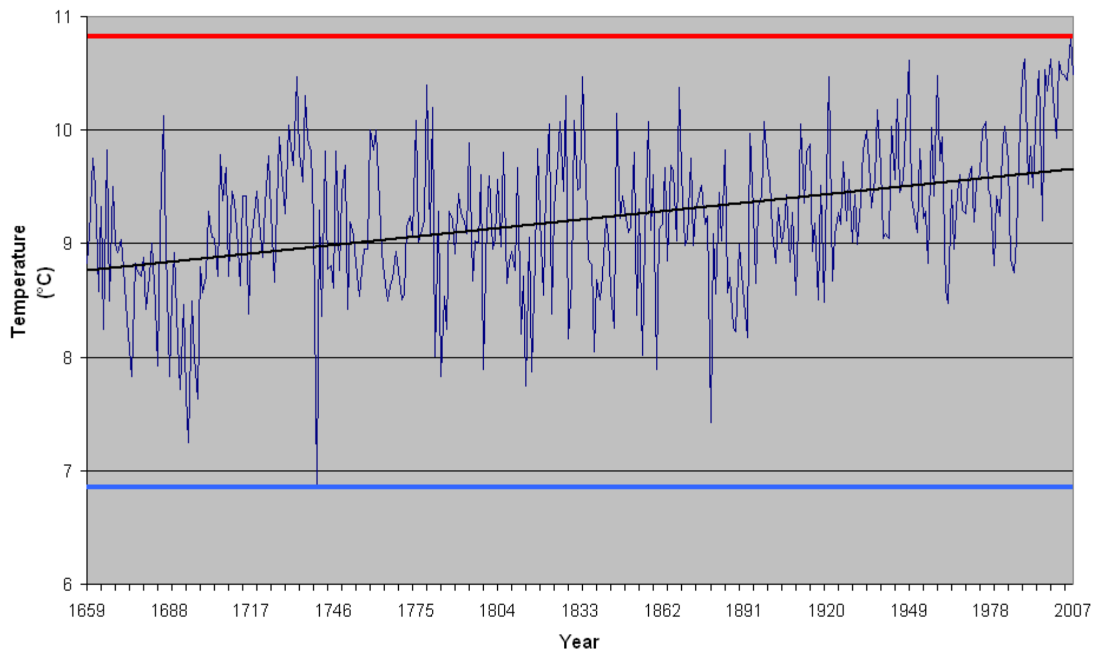

Fig. 6. The average temperature variations in England from 17 to 21 centuries.

References

1. Zharkov S., Gavryuseva E. and Zharkova V. The Observed Long- and Short-Term Phase Relation between the Toroidal and Poloidal Magnetic Fields in Cycle 23, 2008, Solar Physics, Volume 248, Issue 2, pp.339-358 http://adsabs.harvard.edu/abs/2008SoPh..248..339Z

2. Zharkova V.V., Shepperd S.J. and Zharkov S.I., Principal Component Analysis of Background and Sunspot Magnetic Field Variations During Solar Cycles 21-23, 2012, Monthly Notices of Royal Astronomical Society, Volume 424, Issue 4, pp. 2943-2953, http://adsabs.harvard.edu/abs/2012MNRAS.424.2943Z

3. Popova E., Zharkova V. and Zharkov S., Probing latitudinal variations of the solar magnetic field in cycles 21-23 by Parker's two-layer dynamo model with meridional circulation, 2013, Ann. Geophys., 31, 2023-2038 http://www.ann-geophys.net/31/2023/2013/angeo-31-2023-2013.html

4. Shepherd S.J., Zharkov S.I. and Zharkova V.V., Prediction of solar activity from solar background magnetic field variations in cycles 21–23, Astrophysical Journal, 2014, 795, 46 http://computing.unn.ac.uk/staff/slmv5/kinetics/shepherd_etal_apj14_795_1_46.pdf