

The 11-year solar cycle - mechanisms for surface impact

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Abstract

The 11-year period solar cycle in the sun's output impacts the winter surface climate of Northern Europe and the Atlantic. This occurs through a chain of dynamical processes, illustrated below, that we are only just starting to understand. Using the HadGEM model to conduct a series of sensitivity experiments, I aim to improve this understanding, and perhaps the predictability of N.Europe winters.

Upper stratosphere

- Variation of UV radiation over the solar cycle is greater than that of visible radiation¹
- Ozone absorption of UV heats the upper stratosphere
- This yields a $\sim 2\text{K}$ response² to the solar cycle over the equator, shown in Figure 1, leading to 2 main dynamical responses

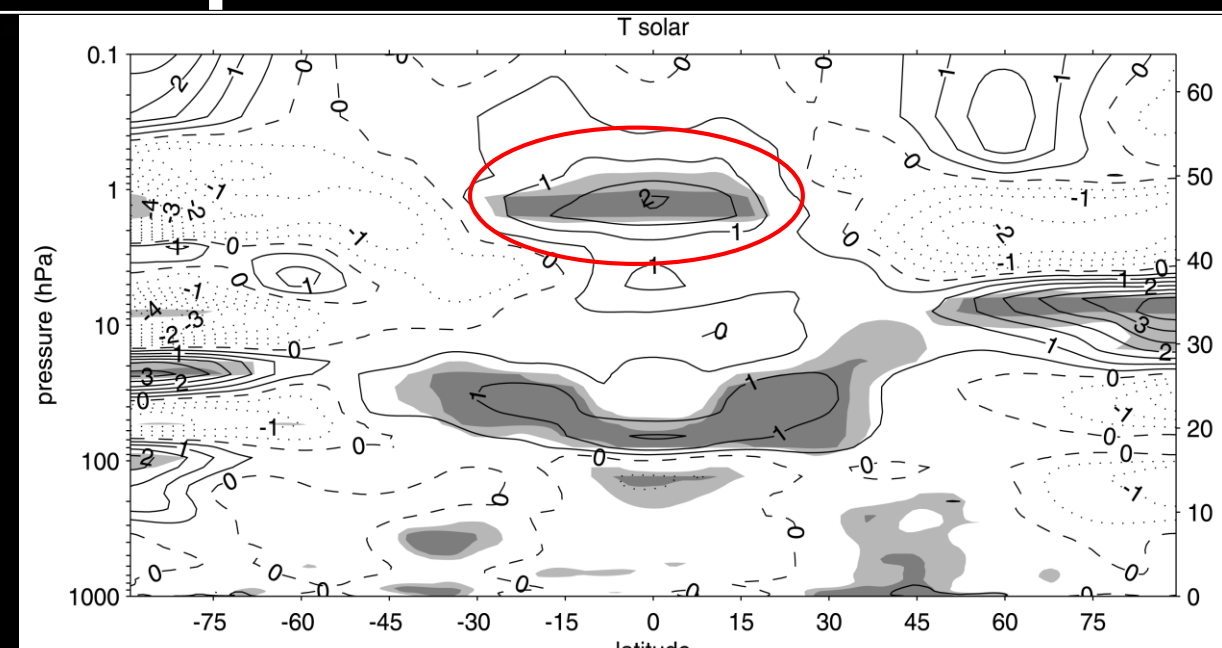


Fig 1: Zonal average temperature response to the solar cycle calculated using multi-linear regression (MLR) of ERA-Interim reanalysis data. Upper stratosphere anomaly circled.¹

Lower stratosphere

- The upper temperature anomaly creates a zonal wind anomaly that affects circulation in the stratosphere³, reducing upwelling at the equator
- Less adiabatic cooling and accumulation of ozone then lead to a $\sim 1\text{K}$ temperature (T) response to the solar cycle here, Fig 1

Polar vortex

- The polar vortex is a strong westerly jet that forms around the winter pole
- It strengthens at solar max through:
- Less downwelling and less adiabatic heating over the winter pole
- Refraction of planetary waves, which can weaken the vortex, away from the pole⁴

The surface and ocean

- Both the lower anomaly and polar vortex (Fig 2) affect winter jet stream strength and surface pressure patterns over N.Europe¹
- The resulting T anomaly may be 'stored' beneath the ocean mixed layer and amplify the surface anomaly in later years⁵
- This creates a surface response that *lags* the solar cycle⁶ (Fig 3)

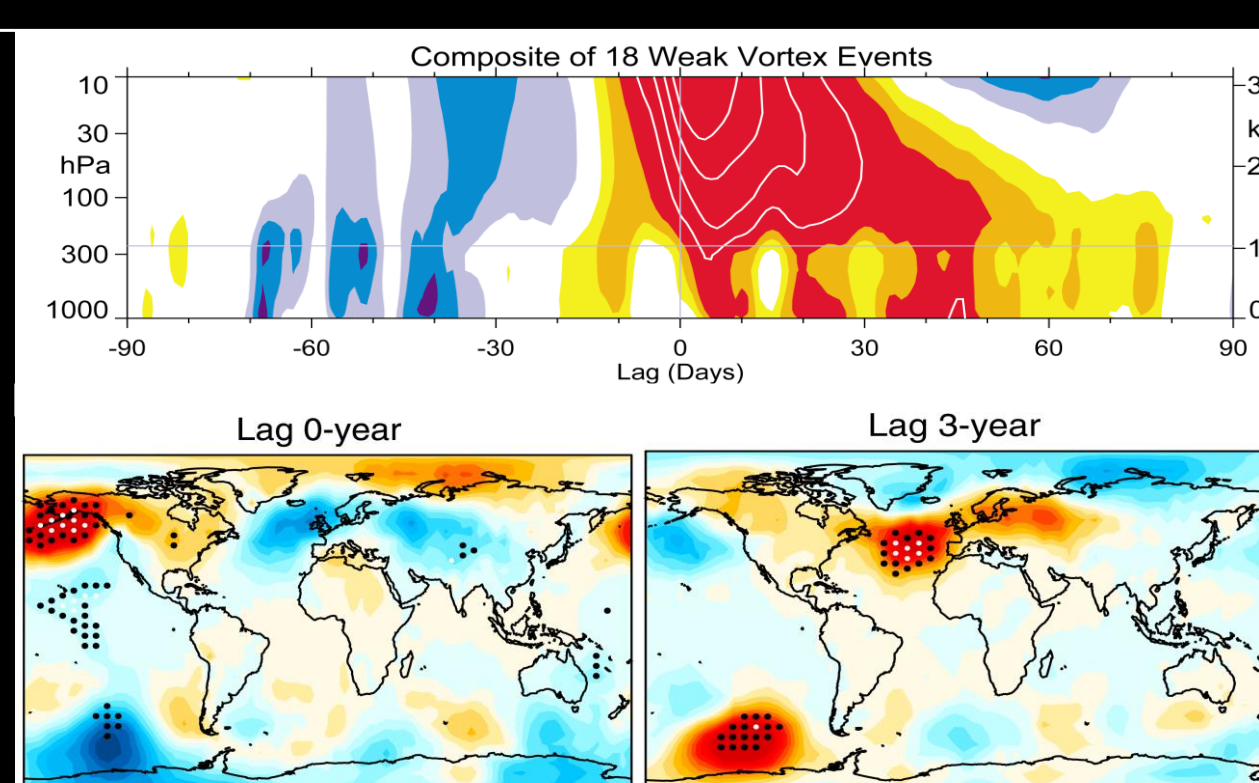


Fig 2 (top): Time-height plot showing the average evolution of weak polar vortex events⁷
Fig 3 (bottom): Surface pressure response to the solar cycle from multi-linear regression of HadSLP data which lags the cycle by 0 (left) and 3 (right) years⁶

Key Question: What are the relative roles of the lower anomaly, polar vortex and ocean in producing the surface response?