Solar Impact on Climate through Energetic Particle Precipitation

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Energetic particle precipitation (EPP) is a component of the solar influence on the middle atmosphere, and potentially on climate, that has only begun to be included in whole-atmosphere chemistry-climate models. EPP generates nitrogen and hydrogen oxides (NOx and HOx) and a series of other neutral and ionic trace species in the polar mesosphere-lower thermosphere (MLT). While the broad aspects of its impact on middle atmosphere chemistry is captured by models and supported by satellite observations, its potential feedback on dynamics is still debated. We present some of the challenges in diagnosing and modelling the EPP atmospheric effects.

Some studies found signatures of EPP in re-analyses data, incl. in the troposphere but the statistical robustness and the interpretation of these results is questionable. Over the North Atlantic, the solar signal consists of a modulation of the North Atlantic Oscillation (NAO), with a tendency for a more positive phase lagged by a few years after solar maximum. Nevertheless sensitivity analysis based on different historical reconstructions and climate reanalyses indicates that (i) this solar signal in the NAO variability is non-stationary, appearing mostly after 1960, (ii) when present, the lag is somewhat variable with values ranging from 1 to 4 years depending on the solar proxy and the exact period considered. While the signal originates in the stratosphere and migrates in a top-down fashion, it has been suggested that atmosphere-ocean feedbacks involving wintertime re-emergence of ocean mixed layer temperatures might explain this lagged nature. Alternatively, it has been suggested that the precipitation of Medium Energy-Electrons (MEE), which can penetrate into the mesosphere and which peaks in the declining phase of the solar cycle, could be at the origin of the lag, but there is little modelling evidence yet.

We run decadal ensemble experiments with the coupled NorCPM atmosphere-ocean model in an idealized setting, where the high-top atmospheric model WACCM is coupled to the MICOM ocean model. We combine radiative forcings from the Spectral Solar Irradiance (SSI) varying throughout the 11-year solar cycle to a state-of-the-art MEE forcing (ISSI). We find an enhanced positive NAO signal from increased UV irradiance under solar maximum conditions in winter, but there is no lagged effect. On the other hand, elevated MEE precipitation leads to a more positive NAO lagged with respect to solar maximum, but in the transition from late winter to spring. These results indicate that UV irradiance and MEE precipitation induce weak climate signals over the North Atlantic Ocean, but the signal-to-noise ratio is very small, in line with recent studies indicating that climate models react too weakly to external forcings.