Implication of the Sun Transition to High Activity Mode for Climate and Ozone Layer

Egorova T.[1], Shapiro A.V.[2], Shapiro A.I.[2], Arsenovic P.[3] and Rozanov E.[1,4]

(1) Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC), Davos, Switzerland
(2) Max Planck Institute for Solar System Research (MPS), Göttingen, Germany
(3) IAC ETHZ, Zurich, Switzerland,
(4) Saint-Petersburg State University, Saint-Petersburg, Russia

It was recently suggested that the Sun could go through an epoch of high magnetic activity, which would lead to unexpected behaviour of solar irradiance. A noticeable 0.9% drop in the total solar irradiance (TSI) will be accompanied by a large increase in UV irradiance. The response of the terrestrial climate and the ozone layer state is very hard to predict because a multitude of the physical and chemical processes and their nonlinear links will be disturbed by these unusual changes. We simulate climate and ozone layer response with the chemistry-climate model SOCOL-MPIOM to the introduced solar irradiance forcing. We obtained general cooling due to smaller solar energy at the surface and significant increase of the ozone content. We show that the surface climate cooling is only slightly compensated by this ozone increase.

Motivation:

Transition of the Sun to higher magnetic activity state can lead to dramatic and spectrally asymmetric changes of the solar irradiance.

The TSI will noticeably drop (by up to 0.9%) while the UV irradiance will substantially increase. This might lead to a rather unexpected terrestrial response. How atmosphere and climate respond?

Method:

Simulations performed with CCM SOCOLv3-MPIOM (Stenke et al. 2013), T31,top at ~80km, 90-year long runs, preindustrial set-ups, time slice 2000 year:

- Reference run with present-day Sun (TSI=1360.9 W/m^2)
- Experiment run with very active Sun (ΔTSI= - 4.4W/m^2)

Solar forcing

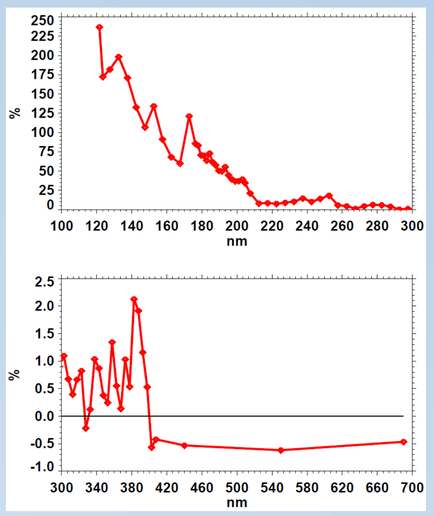


Figure 1. Relative changes (%) related to Sun transition to more active mode (chromospheric activity S=0.25).

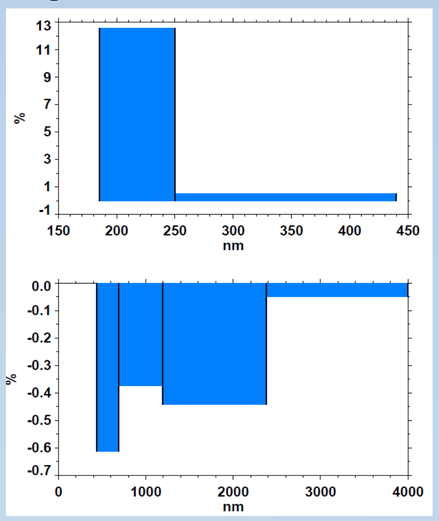
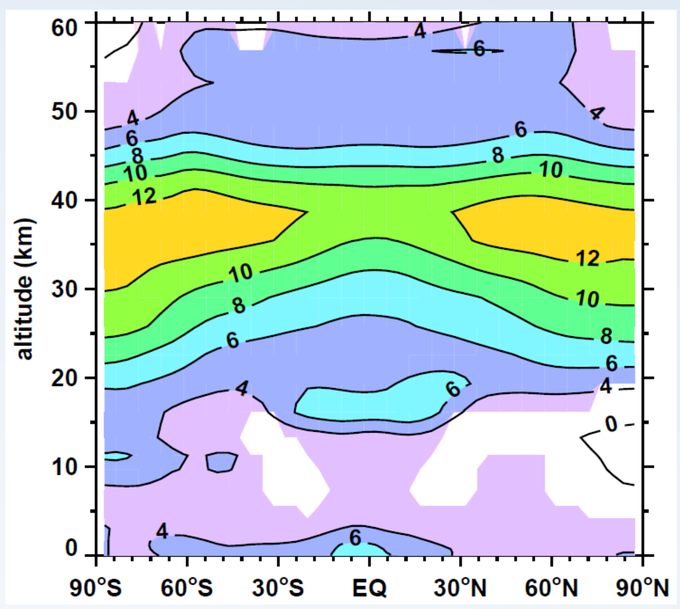


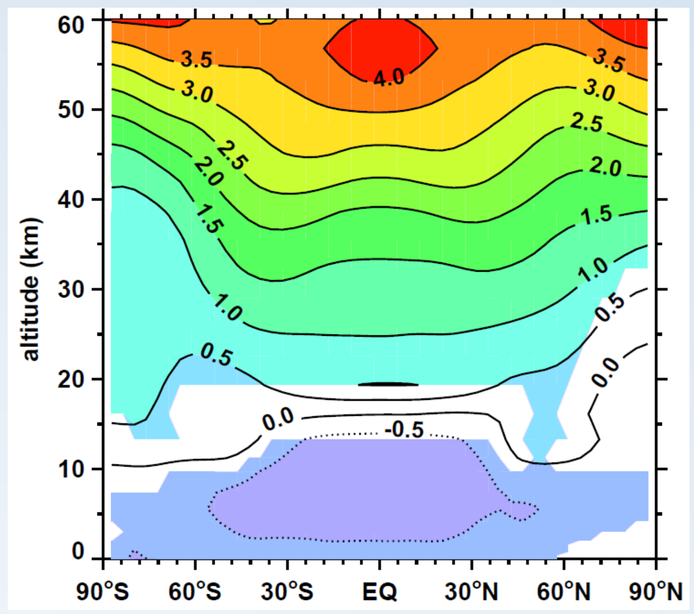
Figure 2. Changes (%) of the SSI for the six spectral intervals used in the model for heating rate and radiation flux calculations.

Changes of atmospheric quantities caused by the transition of the Sun to the high activity mode

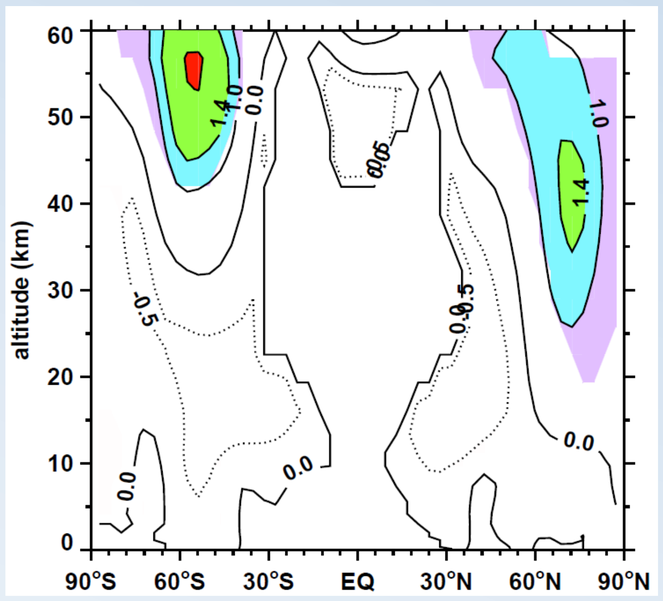
Ozone (%)



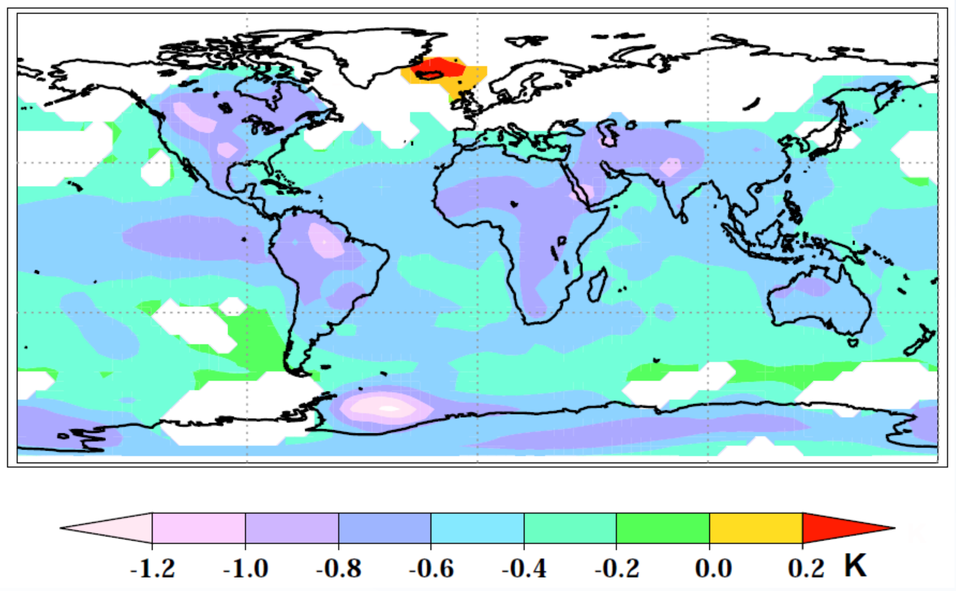
Temperature, K



Zonal wind, m/s



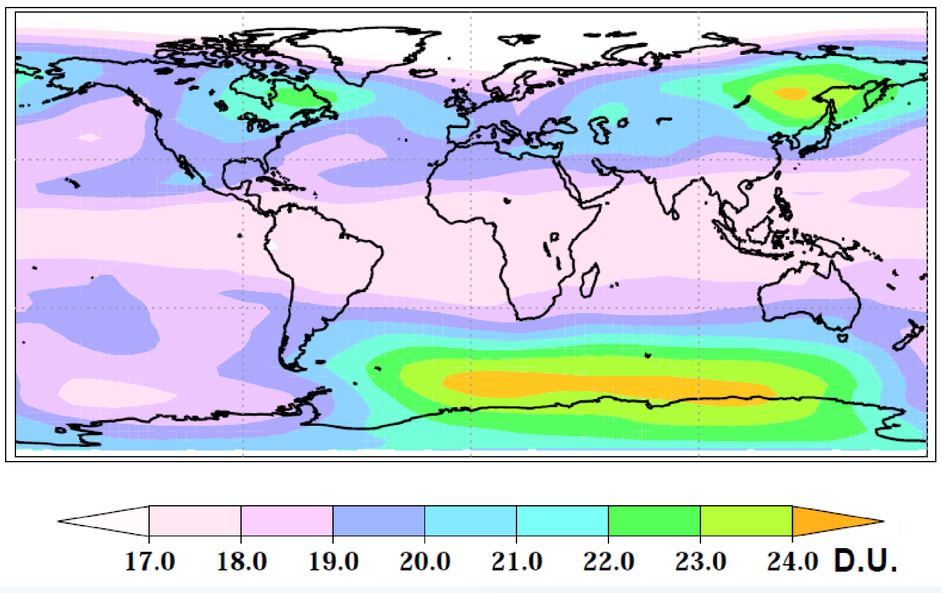
Surface air temperature, K



Conclusions

- All shown here annual mean results (tropospheric cooling, ozone increase, stratospheric warming) are theoretically expected.
- A possible switch of the Sun to a more active state can lead to a slightly cooler climate and some decrease in the surface UV. However, these changes cannot be considered as catastrophic.

Total column ozone, D.U.



References:
Egorova et al., 2023 , J. Atm.Sol.-Terr.Phys., 106020. https://doi.org/10.1016/j.jastp.2023.106020
Isik, E., et al., 2020. Astrophys. J. Lett., 901, 1. https://doi.org/10.3847/2041-8213/abb409
Shapiro, A.I., et al., 2020, A&A, 633, A32. https://doi.org/10.1051/0004-6361/201936018
Stenke, A., et al., 2013, Geosci. Model Dev., 6, 1407–1427, https://doi.org/10.5194/gmd-6-1407-2013

pmod wrc