Report on the SolarMIP-TOSCA Workshop

The Solar Model Inter-comparison Project (SolarMIP) is a SPARC/SOLARIS initiative to compare the coupled ocean-atmosphere model response to variability in solar irradiance in the CMIP5 (Coupled Model Intercomparison Project phase 5) model simulations. SolarMIP aims at examining the model responses to the 11-year solar cycle variations with special care on (a) the stratospheric response, which is dominated by ozone absorption of incoming UV-radiation and (b) the surface response, which is believed to be a combination of direct heating of the tropical SSTs and indirect effects via the stratosphere. The scope of this international activity falls directly under the aims ofWG4 of the European COST Action TOSCA (ES 1005) regarding the investigation of solar influence on the vertical coupling between atmospheric layers, the role of the ocean influence on the solar impact on the troposphere and the intercomparison of solar cycle effects in climate models simulations.

A focused two-day SolarMIP workshop, co-organized with the TOSCA COST Action was convened at the Aristotle University of Thessaloniki, Greece from 29-30 October, 2013. The workshop aims were to discuss the progresses of analysis of all historical CMIP5 simulations, to present preliminary results and to frame future directions for exploiting the CMIP5 simulations. The workshop was opened by **Kleareti Tourpali** who formally welcomed all participants and presented the agenda. To establish the observation basis, **Lesley Gray** presented an overview of the 11-yr solar cycle signals in the troposphere and stratosphere as seen in 9 different reanalysis products, participating in the SPARC reanalysis Intercomparison Project (S-RIP). She showed that all datasets in solar maxima indicate a similar strong warming in the upper stratosphere and a significant warming in the tropical lower stratosphere. The zonal wind changes in boreal winter time are captured reasonably well in all datasets. **Stergios Misios** listed all models participating to the CMIP5 initiative and described briefly the multiple linear regression model used to extract the solar cycle signals from the historical runs (1850-2005). **Daniel Mitchell** presented the stratospheric response to the solar cycle in selected CMIP5 models with detailed representation of stratospheric dynamics. Focus was given in the annual temperature responses in the tropics (25S-25N) as well as in time evolution of zonal wind anomalies in the boreal winter. A possible downward propagation of the solar cycle signals form the stratosphere down to the troposphere, affecting annular modes was also investigated. Daniel also compared solar signals in 5 models (CanESM2, GFDL-ESM2M, GISS-E2-R, GISS-E2-H, HadGEM2-CC) which have additionally carried our sensitivity simulations forced only with the observed solar cycle variability. Effects of the 11-yr solar cycle on the surface and troposphere in all CMPI5 models were presented by **Stergios Misios**. He showed that consistent to observations the majority of the models indicate a global mean warming of about 0.04 K between solar minimum and maximum. The multi-model mean response of the tropical Pacific Ocean to the solar cycle was found very weak and insignificant but the intra-model spread is high and a strong warming or cooling can be identified in individual ensemble members. The troposphere warms in solar maximum and the simulated warming seems to maximize one year after peaks of solar activity.

The presentation of CMIP5 analysis followed by a discussion section focused on the two main objectives, namely the detection and attribution of the response of the stratosphere and surface to spectral and total solar irradiance variability, respectively. To stimulate discussion, a session of four short talks covering broader outstanding questions was organized. **Lon Hood** presented observational estimates of stratospheric responses to 11-yr solar forcing during October to March to facilitate comparisons to CMIP5 model simulations. Observations indicate a seasonal progression of the solar-induced temperature and ozone responses in the upper stratosphere such that the response maximizes near the summer pole under solstice conditions and near the equator under equinox conditions. Lon pointed out that none of the CMIP5 models simulate strong solar signals near the summer polar stratopause in both hemispheres. **Gabriel Chiodo** presented results from sensitivity simulations with the WACCM model, focusing on the response of the tropical stratosphere to the solar cycle. WACCM produces realistic responses in the tropical stratosphere when compared to observations but Gabriel emphasized that great care must be taken to account possible contamination of solar cycle signals with other factors such as the volcanic eruptions of El Chichón and Pinatubo. **Eugene Rozanov** shifted gears and presented an analysis of the log-term trend in the early part of the 20th century and its possible connection to the secular trend of solar irradiance. He showed that CMIP5 models partially reproduce that early century warming, but trend analysis of observed record is complicated by 1902, 1912 volcanic eruptions and large El-Nino episode in 1941. **Alexei Krivolutsky** gave a talk on solar cycle effects on composition, temperature and dynamics simulated with the ARM and CHARM models. He emphasized that planetary waves play an important role in solar-atmospheric connections.

During the final session of the workshop, outstanding issues of the analysis were discussed, in particular the role of ozone variability with the solar cycle and the way it is treated in the CMIP5 models, as well as the ocean response to the solar cycle and the possible role played by depth of signal penetration into the oceans. Future analysis of CMIP5 simulations will address these issues.

Participants: Kleareti Tourpali, Lesley Gray, Dan Mitchell, Hauke Schmidt, Eugene Rozanov, Lon Hood, Gabriel Chiodo, Alexei Krivolutsky, Stergios Misios, M. Vaskou

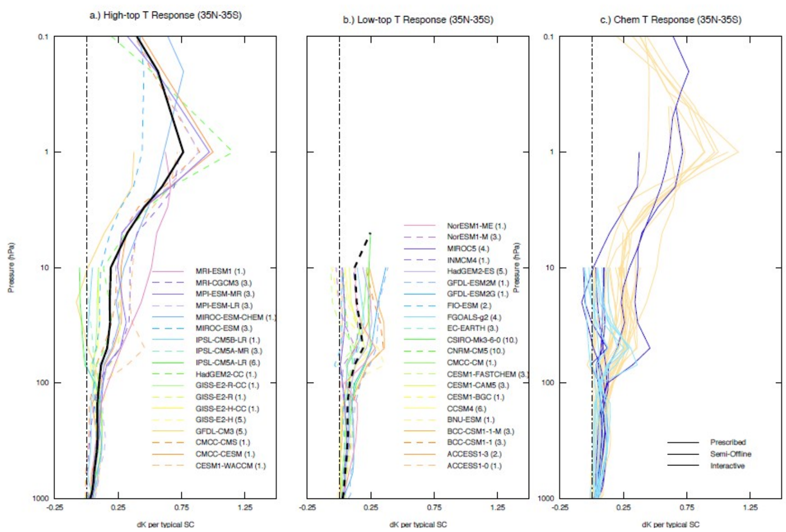

Figure: Profile of temperature response to the 11-year solar cycle in the tropics (35S-35N) from the CMIP5 model simulations, orange: prescribed chemistry, dark blue = interactive, light blue = semi-offline. Figure courtesy of Mitchell, D.M., et al. *The SolarMIP project: Winter and Annual responses*, Journal of Climate, in preparation