Project Details

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Project Title:
Solar Forcing Impacts on Middle atmospheric Ozone-controlling HOx and NOx chemistry and the climate

PI Name: Shuhui Wang
PI Email: atn@g.ucla.edu
Affiliation: Jet Propulsion Laboratory
Project Member(s):
- Yung, Yuk L; Co-I; California Institute of Technology
- Froidevaux, Lucien ; Collaborator; Jet Propulsion Laboratory
- Sander, Stanley P; Co-I; Jet Propulsion Laboratory

Summary:
Solar cycles (e.g., 11-year cycle) and the associated UV variability cause quasi-periodic signals in atmospheric temperature and composition, which has to be accurately quantified in order to better understand the complex changes in the O3 layer and climate. However, large discrepancies between observations and models as well as disagreements among various observations remain unresolved. The large uncertainties in solar spectral irradiance (SSI) variabilities adopted by climate models results in different or even contradictory predictions of atmospheric O3 responses to solar forcing, but all models find , "agreement , with observations from certain locations and/or selected parts of the middle atmosphere, making it puzzling to quantify natural O3 variability on decadal scale.

While O3 solar cycle variabilities are complex, involving direct photolysis and many indirect effects, the catalytic HOx (OH and HO2) and NOx (NO and NO2) chemistry that largely controls middle atmospheric O3 loss plays a major factor. Previous work reveals that HOx chemistry variability likely dominate O3 solar cycle responses above ~40 km. However, models significantly underestimate OH variability during the solar 11-year cycle even when using the largest observed SSI variability. At lower altitudes where NOx catalytic cycles take over the role of HOx in controlling O3 loss, surprisingly large discrepancies between models and observations were also reported. Therefore, in addition to SSI, uncertainties in our current understanding of the HOx-NOx-O3 chemical system could be another major source of discrepancy. This is echoed by recent studies on OH responses to solar 27-day cycles: Models underestimate observed OH variability although short-term SSI variability uncertainties are small. Given these puzzles, understanding solar-induced variabilities in O3-controlling HOx and NOx chemistry and quantifying the uncertainties could be the key to help resolve current discrepancies in middle atmospheric responses to solar forcing and to provide insights for the resulting climate impacts.

We propose to use various observations and targeted modeling work to examine the mechanisms that control middle atmospheric variability in the HOx-NOx-O3 system. We will use HOx data from Aura/MLS, long-term ground-based OH measurements, NO2 data from NDACC stations and various satellites, and the ~30 year O3 composite from GOZCARDS. Our modeling work will involve a 1-D chemical-transport model and the 3-D WACCM model. We focus on: (1) Establishing and quantifying the correlations of solar-induced variabilities in the involved key species; (2) Understanding the spatial distribution of variabilities and investigating disagreements among observations and between models and observations; (3) Validating chemical modules by quantifying uncertainties in the involved chemical kinetics and adjusting it within recommended uncertainty ranges to compare with observations; (4) Provide insights for SSI debates and implications for climate models.

By quantifying uncertainties in chemistry and comparing model variability with observational signals over short time scale when SSI uncertainty is small, an optimized state of chemical module will be proposed, which can be used to study longer time scale (11-year cycle) variability when SSI uncertainty is large. This will provide new insights to help explain the unresolved discrepancies of O3 variabilities and important implications for models studying Sun-climate interaction.

Publication References:

no references