Investigating Climate Change from the Stratosphere to Space

8th Workshop on Long-Term Changes and Trends in the Atmosphere; Cambridge, United Kingdom, 28–31 July 2014

Laser beams of the ground-based lidar instruments at the Leibniz Institute of Atmospheric Physics in Kühlungsborn, Germany, slice through to an altitude of about 120 kilometers, collecting data in atmospheric regions along the way. Credit: © IAP, Kühlungsborn

By John. T. Emmert, Daniel R. Marsh, and Ingrid Cnossen 11 February 2015

Multidecadal changes to Earth's upper atmosphere (~15–500 kilometers altitude) are becoming increasingly relevant to the future of our world. Societal impacts of upper atmospheric climate change derive from our technological reliance on this region, through which satellites orbit and electromagnetic signals propagate, and from the boundary conditions it imposes on the troposphere. It is therefore critical that we quantify and understand changes occurring at all levels within the coupled atmospheric system.

Increasing concentrations of greenhouse gases (which exert a cooling influence in the upper atmosphere), stratospheric ozone depletion, varying solar and geomagnetic activity, and secular change of Earth's magnetic field are some of the drivers of changes in the stratosphere (~15–50 kilometers), mesosphere (~50–90 kilometers), thermosphere (~90–500 kilometers), and ionosphere (embedded in the mesosphere and thermosphere). At a July 2014 workshop, 49 participants from nine countries discussed the latest research on multi-decadal changes in these atmospheric regions.

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One challenge of studying upper atmospheric climate is that available data sets are typically sparse or short compared to tropospheric data. Accordingly, a major workshop focus was the selection of statistical tools to characterize climate and to detect and attribute long-term changes. The participants identified and examined appropriate techniques for rigorous uncertainty assessment.

Several presenters used coupled climate models to investigate the tropospheric climate response to changes in the stratosphere. These included geoengineering via solar radiation management through stratospheric aerosols and the reduction in stratospheric temperatures that might occur should the Sun enter a prolonged grand solar minimum. The regional response in surface climate to such forcing strongly depends on how the stratosphere is perturbed.

In the stratosphere, mesosphere, and lower thermosphere, significant progress has been made in measurement and modeling of the carbon dioxide (CO_2) concentration trend, which is the expected dominant driver of thermal changes in this region. Extended satellite observations of temperature, heating rates, noctilucent clouds, and composition are now available to investigate the response to natural and anthropogenic forcing. Simulations reveal strong heterogeneity among the responses of different metal species (e.g., sodium, potassium) to temperature and composition changes.

In the upper thermosphere, anthropogenic cooling trends and mass density decreases estimated from sophisticated models are in good agreement with satellite drag observations. Orbital debris simulations indicate that prolonged reduction of thermospheric density may induce a dramatic increase in space debris (atmospheric drag is currently the only mechanism for debris removal).

Discussion of ionospheric changes included novel techniques for exploiting archived radio wave propagation data, changes in neutral composition, and the relative effects of geomagnetic field evolution versus CO_2 increases. For example, centennial simulations indicate that the change in magnetic field can produce larger local changes in electron density than those related to increasing CO_2.

More information about the workshop can be found at http://bit.ly/upperatmo (http://bit.ly/upperatmo). A joint special section of *Journal of Geophysical Research: Atmospheres* and *Journal of Geophysical Research: Space Physics* will detail the presented results. The workshop was sponsored by the British Antarctic Survey, the International Association of Geomagnetism and Aeronomy, the Scientific Committee on Solar-Terrestrial Physics, and the Royal Astronomical Society. The next workshop in this biennial series will be held in 2016 in Kühlungsborn, Germany.

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