Solar Impacts on Climate

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Understanding the influence of solar variability on the Earth's climate requires knowledge of solar variability, solar-terrestrial interactions and observations, as well as mechanisms determining the response of the Earth's climate system. A summary of our current understanding from observational and modeling studies will be presented with special focus on the top-down stratospheric UV and the bottom-up air-sea coupling mechanism to discuss the importance of the solar cycle for decadal climate predictions.

Dynamical coupling between the middle atmosphere and lower thermosphere

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This presentation will address recent and ongoing research in coupling between the middle atmosphere and the upper mesosphere - lower thermosphere (MLT). There have been many reports of signatures in the MLT of dynamical perturbations from the lower or middle atmosphere, such as sudden stratospheric warmings and nonmigrating tides forced by latent heat release. The downward coupling is more difficult to verify but a few possible mechanisms have been proposed. The presentation will discuss observations and modeling of coupling as framed by two questions. To what extent is the upper atmosphere "slaved" to the lower atmosphere? Can processes in the thermosphere have an impact on the stratosphere and/or climate?

Constraining gravity wave drag parameterizations using a chemistry climate model nudged to reanalysis data

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The drag exerted by small-scale gravity waves (GWs) plays a fundamental role in the middle atmosphere. Gravity wave drag (GWD) has a first-order effect in the mesosphere where it drives the atmosphere away from radiative equilibrium. GWD is also important in the stratosphere where it drives a significant fraction of the Brewer-Dobson circulation, and, possibly, its future trends in response to global warming. Since the horizontal scales of GWs are generally too small to be resolved by global climate models, their effects must be parameterized. Climate models typically parameterize the effects of two types of waves: zero-phase speed orographic GWs forced by flow over mountains and non-zero phase speed non-orographic GWs forced by convection, shear instability and fronts. The GWD parameterizations are tuned in a somewhat *ad hoc* manner to yield realistic climatologies of zonal wind, temperature and surface pressure.

Here we describe a novel method to quantify the role of GWD on a day-to-day basis using a version of the Canadian Middle Atmosphere Model (CMAM) that is nudged (relaxed) to ERA-Interim horizontal winds and temperatures below 1 hPa. In the mesosphere (i.e., above 1 hPa and up to the model top at ~100 km) the model is freely evolving. The role of GWD is then quantified by comparing the simulated zonal mean winds, temperatures and tracers in the mesosphere to daily observations from the MLS instrument on the AURA satellite. The methodology and results from experiments in which the two types of GWD are selectively turned off are presented in McLandress et al (2013). That study focussed on the extended northern winters of 2006 and 2009 when two large stratospheric sudden warmings occurred. Perhaps the most striking result from that study was the important role of orographic GWD (OGWD) in early winter before the warmings. McLandress et al suggested that this was a validation of the OGWD parameterization. Here, we present results from that study, and extend it to include experiments specifically targeted at validating the OGWD parameterization. We also discuss the common model cold bias in the Southern Hemisphere (SH) winter stratosphere, which is due to insufficient wave drag. Using nudging, the SH winter cold bias in CMAM is manifested in the mesosphere. Experiments in which the GWD is modified in the SH in an attempt to alleviate the bias are discussed.

McLandress, C., J. F. Scinocca, T. G. Shepherd, M. C. Reader, and G. L. Manney, Dynamical control of the mesosphere by orographic and non-orographic gravity wave drag during the extended northern winters of 2006 and 2009. *J. Atmos. Sci*., 2013 (in press).

Satellite Observations of Extreme Events In the Polar Middle Atmosphere

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Stratospheric sudden warmings (SSWs) illustrate clearly the coupling of atmospheric regions from the troposphere through the mesosphere. Six of the strongest, most prolonged SSWs on record have occurred in the past decade, with only two other comparable events in the past 34 years. These recent SSWs, as well as other extreme events in the middle atmosphere, are analyzed using temperature and trace gas data from the Aura Microwave Limb Sounder (MLS) satellite instrument, in conjunction with other satellite measurements, models, and meteorological analyses. Some recent studies highlighting the communication between the upper troposphere, stratosphere and mesosphere will be reviewed, including model-based studies informed by comparisons with satellite observations. Analyses of MLS and other satellite data will be used to show the impact of these extreme events on dynamical fields and trace gas transport from the upper troposphere/lower stratosphere to the mesosphere, especially transport between the stratosphere and mesosphere.

Studies of Stratospheric Gravity Waves Using Superpressure Balloons

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Superpressure balloons (SPB) provide a unique way of studying gravity waves (GW) in the lower stratosphere. Wave motions are measured in a reference frame moving with the mean wind and are therefore determined as a function of the wave intrinsic frequency, unlike GW measurements made from either the ground or space. It is the intrinsic frequency that determines important wave properties. Here we describe GW measurements made during SPB campaigns conducted between September and January 2005/06 and between September and January 2010/11, with a particular focus on the latter (Concordiasi) campaign. In the Concordiasi campaign nineteen 12-m diameter SPB were launched from McMurdo Station (78°S, 166°E). They floated within the Antarctic polar vortex on an isopycnic surface located at a pressure level of 60 hPa, corresponding to an altitude of about 18 km. Measurements of pressure, temperature and GPS-measured vertical and horizontal position were recorded every 30 sec. Some SPB carried dropsondes that were released over both the Antarctic landmass and the Southern Ocean. About 650 vertical profiles of thermodynamic variables were obtained which provide information that complements the SPB results.

Here we discuss the determination of important gravity wave parameters, particularly vertical fluxes of horizontal momentum and energy that define the impact of GW in the middle atmosphere. Computer simulations were made to test the accuracy of the GW retrievals, taking into account the accuracy of the various instruments. It is shown that wave fluxes are retrieved with high accuracy as a function of intrinsic frequency. The strongest fluxes, associated with topographically forced waves, are found near the Antarctic Peninsula. There is a high degree of spatial and temporal intermittency of the fluxes, especially over mountainous regions. It will also be shown that about 30% of the momentum flux is associated with downward propagating waves.