Project Details

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Program Element: Focused Science Topic

Topic: Atmosphere-Ionosphere Coupling During Stratospheric Sudden Warmings

Project Title:
The Dynamical Effects of Sudden Stratospheric Warming Events on the Thermosphere

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Summary:
The dynamically active stratosphere during Northern Hemisphere winter sometimes undergoes dramatic changes, called stratospheric sudden warmings (SSW). During a SSW event, temperatures can increase dramatically over a period of days and the normally strong polar westerly winds may reverse to easterlies. These events also have impacts both above and below, causing dramatic cooling in the mesosphere of up to 20 K with associated transport and chemistry changes, and foretelling statistical shifts in surface weather patterns with enhanced skill at intraseasonal timescales. Recent modeling and observational evidence also suggests that SSW events can have an impact within the thermosphere. Our research will examine the dynamical connections that are in force during SSW events. These connections include anomalous mean meridional circulations set up by nonlinear interactions between waves and the mean flow, the filtering and refraction of various waves by anomalous flow conditions during an SSW, and the nonlinear interaction between tides and planetary waves that give rise to tide variability during the rapidly changing conditions when an SSW is under way.

We will specifically focus on the following goals:

1) Quantify how gravity wave filtering and forcing drives the evolution of the atmosphere up into the thermosphere during SSW;

2) Characterize nonmigrating tide variability arising from all sources and isolate the source due to interaction between the large migrating tides and planetary wave amplification.

Our study will employ a global mechanistic model that extends from the surface to 300 km. This model directly simulates all large scale wave dynamics, including tides, planetary waves and tropical waves, and it includes small-scale gravity waves via parameterization. All the wave-wave and wave mean flow interactions needed to describe the connections between the different layers of the atmosphere are present in our simulated SSW events. The model will be further constrained to various degrees by wind and temperature fields from the NASA reanalysis data, MERRA, up into the mid-stratosphere, but will be allowed to evolve freely above, up to the model top. We will also examine simulations of the Whole Atmosphere Community Climate Model (WACCM) run freely and in specified dynamics mode. Both model results will be validated by comparing the evolution during an SSW to the real atmosphere as observed in TIMED-SABER and AURA-MLS temperature measurements in the mesosphere and thermosphere.

Nature has provided a nice set of SSW experiments for our study in the last seven years of these data, with major warmings in 2006, 2009, and 2010. There is also a minor SSW in early 2012 that shows unusually dramatic effects at mesospheric heights apparently more similar to conditions during a major SSW. Since the evolution of an SSW in the upper atmosphere is quite sensitive to the gravity waves in the model, our goal will be to use these comparisons to constrain the gravity wave source spectra used as input to the gravity wave parameterization. We will also derive the short term variability of tides from the temperature data, and use the model simulations to determine the source of this variability. Through collaboration with NCAR, the results of this study will lead to improvements in the parameterized gravity waves in the WACCM.

Publication References:

Summary: no summary

Reference: Wu, Q.; Ortland, D. A.; Foster, B.; Roble, R. G.; (2012), Simulation of nonmigrating tide influences on the thermosphere and ionosphere with a TIMED data driven TIEGCM, Journal of Atmospheric and Solar-Terrestrial Physics, Volume 90, p. 61-67, doi: 10.1016/j.jastp.2012.02.009

Summary: no summary

Reference: Yamazaki, Yosuke; Richmond, Arthur D.; Maute, Astrid; Wu, Qian; Ortland, David A.; Yoshikawa, Akimasa; Adimula, Isaac Abiodun; Rabiu, Babatunde; Kunitake, Manabu; Tsugawa, Takuya; (2014), Ground magnetic effects of the equatorial electrojet simulated by the TIE-GCM driven by TIMED satellite data, Journal of Geophysical Research: Space Physics, Volume 119, Issue 4, pp. 3150-3161, doi: 10.1002/2013JA019487