Whole Atmosphere Coupling Embodied by Trace Species Variability during Atmospheric Dynamical Disturbances

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An important source of meteorological variability in the middle atmosphere is a sudden stratospheric warming (SSW) whereby the polar stratosphere can dramatically warm in midwinter. It is known that these SSW events are accompanied by coolings in the mesosphere (mesospheric coolings: MC) and other perturbations even higher in altitude. It has only recently been appreciated that these perturbations in temperature and circulation are accompanied by perturbations in composition. This work characterizes the impacts of SSWs and MCs on the light species distribution (i.e., helium [He], and atomic hydrogen [H]) of the thermosphere using a combined data-modeling approach. Using a set of numerical experiments with a general circulation model whose middle atmospheric dynamical and thermodynamical fields were constrained using a numerical weather prediction system, we simulate the effects of SSWs and MCs on light chemical species, and via comparisons with two data sets taken from the mesosphere and thermosphere, we quantify the associated variability in light species abundances and mass density. Large depletions in the observed and modeled polar H abundance in the mesosphere and lower thermosphere (MLT) occur with MC onset, as opposed to SSW onset. Depletions in all light thermospheric species at high northern latitudes extend up to the exobase in our model simulations during the January 2013 SSW/MC period, with the largest depletions simulated for the lightest species. Observational and modeling evidence in this study demonstrate that SSWs and MCs force these changes in light thermospheric species through an intricate series of processes, set in motion by SSW/MC enhancements in lower and middle atmospheric wave forcing. SSW/MC induced light species variability then gets projected upward into the thermosphere through molecular diffusion. Modeled light species variability during the January 2013 SSW/MC event suggests that SSW/MC signatures could even be present in the topside ionosphere and plasmasphere.