Space Weather

Whole Atmosphere Community Climate Model–Extended: Modeling earth’s atmosphere from surface to space with WACCM-X

Spring 2015

I. Description

Everyday weather in the upper reaches of our atmosphere is highly variable and strongly affected by solar and geomagnetic activity from above, and due to weather in the troposphere below. During space weather events, Earth’s near-space region (which begins about 20 km or 66,000 feet above the surface) can experience periods of strong solar activity, resulting in increased amounts of radiation or concentration of ions in the upper atmosphere. These effects can radiate downward influencing, for example, the ozone layer and possibly tropospheric climate. Similarly, atmospheric waves occurring in Earth’s lower regions, originating from jet streams and hurricanes, can spiral upward, affecting different regions of the upper atmosphere and ionosphere. These waves range from large scale (planetary waves) to being very small (gravity waves).

Understanding the atmosphere’s cascading effects is critical to correctly predicting (geo-)space weather. Depending on the strength and extent of a perturbation, satellite (including GPS) communications and the Earth’s electrical grid may be adversely affected, while increased radiation emissions caused by space weather may affect the wellbeing of air passengers flying over the Earth’s polar regions and astronauts in space. Threats to human health and safety are driving a need to improve our ability to predict the atmosphere’s behavior. NCAR’s Whole Atmosphere Community Climate Model (WACCM) with thermosphere-ionosphere extension (WACCM-X) offers new insights on the coupling of atmospheric layers from the Earth’s surface to geospace.

II. Stage of Research

WACCM-X merges the capabilities of three models developed at NCAR. One is a climate model that captures atmospheric behavior from the Earth’s surface to about 100,000 feet, a second covers the middle (100,000 feet) to the uppermost parts of the atmosphere (310 miles), while the third models the atmosphere’s chemistry from surface to upper limits. The combined model – WACCM-X – provides a picture of the Earth’s
entire atmosphere, from surface to the top of the thermosphere, including a comprehensive representation of the atmosphere’s chemistry and dynamics. WACCM-X is nearing the final stages of development. Already, it does a good job of modeling the composition, chemistry, and electrodynamics of the geospace environment. It is capable of simulating the long-term variability of geospace, including the response to solar variations and climate change. Run at very high resolution, for the first time, WACCM-X allows researchers to identify and generate realistic patterns of variability at a variety of scales.

III. Advantages

• WACCM-X provides a better understanding and quantification of the energetics, dynamics, composition, chemistry, radiative transfer, and electrodynamics occurring throughout the Earth’s atmosphere; these influence the variability of weather and climate scales across all atmospheric regions of the planet.
• Atmospheric variability – e.g., due to perturbations in the upper atmosphere caused by geomagnetic storms and solar flares – can affect GPS transmission and communications signals, and satellite orbits. Atmospheric mixing and effects propagating upward and downward can also affect ozone, greenhouse gas, or other chemical concentrations in the atmosphere, and affect regional and long-term climate dynamics. Understanding and better predicting these effects is critical to minimizing or adapting to predicted changes.
• Building on the framework of NCAR’s Community Earth System model allows a large degree of flexibility in model configuration, permitting self-consistent simulations to be carried out across a range of temporal and spatial scales.

IV. Applications

• WACCM-X offers the first whole atmosphere model that can resolve down to mesoscales. This is an important step to better understand and predict irregularities in upper atmosphere behavior that could change or adversely affect GPS and other communications satellite signals.
• WACCM-X is capable of modeling the thermosphere and ionosphere’s response to forcing from above (solar and geomagnetic) and below (tropospheric weather) in a self-consistent manner.
• WACCM-X could provide a base from which to develop operational models for space weather.

V. Funding and IP Status

Primary: National Science Foundation (core funding). NASA Living With a Star Strategic Capability (the last Fiscal Year of the support).

Seeking funding to support: New collaborations and a new scientist for the WACCM-X team.

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