NASA's Geospace Dynamics Constellation: Exploring our Connected Atmosphere

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The US relies on satellites in low earth orbit (LEO) for a wide range of commercial, civil space, and national security purposes. Though LEO was one of the first space environments studied from the dawn of the space age, increased usage of this region has highlighted large gaps in our understanding and predictive capability. For example, following a SpaceX launch of 49 Starlink satellites in February 2022, 38 of those satellites were lost to unexpectedly high atmospheric drag that ultimately caused them to deorbit. In this region, Earth's atmophere extends to form a tenuous envelope of electrically neutral gas called the thermosphere, and its electrically conductive counterpart, the ionosphere. These two layers of the upper atmosphere coexist over the same altitude range, and this has dramatic consequences for the variability of the LEO space environment. The coupled plasma-gas system responds to electrodynamic, dynamical, and chemical/photochemical forcing, at a range of spatial scales from sub-kilometer to global and time scales from seconds to decades.

One of the main aspects of this region that makes it so complex is that it is a crossroads for energy and momentum transmitted from three sources: 1) the direct solar extreme ultraviolet and x-ray radiation that is absorbed at these altitudes, and which can vary dramatically over a solar cycle on yearly to decadal timescales, but also impulsively as active regions evolve on the Sun, on timescales from seconds to days; 2) the lower atmosphere, where weather, seasonal variations, and orography modulate the stratosphere, sending short-scale, medium-scale, and global-scale waves upwards into the LEO region, where they drive strong perturbations in the neutral and ionized gas; and 3) the solar wind / magnetosphere interaction, that drives strong electrical currents through the high latitude / circumpolar regions as well as deluging the upper atmosphere with energized electrons and ions that further ionize and heat the gas and create auroral displays. In addition, the ionosphere/thermosphere system exhibits a number of internal processes that can transmit mass, momentum, and energy vertically, longitudinally, and latitudinally, far from the original energy sources.

Predicting the "weather" in this environment is of high value for satellite operators concerned with orbit propagation and collision avoidance (of satellites and orbital debris), the radiation environment, harmful electrical charging of spacecraft, and modifications or degradations of radio propagation conditions that can affect GPS, radar, and communications systems. In addition, variability in this region directly controls the precise timing and location of uncontrolled reentry of orbiting objects, the radiation environment at aviation altitudes, and the nature and extent of damaging electrical currents induced in power transmission systems and pipelines. While a number of advanced computer models of ionosphere-thermosphere weather have been developed, they share a common challenge: they are not well constrained by direct observations that fully characterize the atmospheric state parameters and the energy sources over the full range of spatiotemporal scales and background seasonal, solar activity, and geomagnetic activity conditions.

NASA plans the Geospace Dynamics Constellation (GDC), a mission within the Heliophysics Living With a Star Program, as a strategic mission that will directly probe the causes of variability in the ionosphere/thermosphere. GDC consists of six identical spacecraft, equipped with instrumentation to measure all aspects of the local space environment, including the properties of the ionosphere and thermosphere and the electric and magnetic fields and energetic charged particles that serve as major energy inputs. GDC's satellites will orbit near 350-400 km altitude, at high inclination, to provide the first-ever comprehensive, global view of the LEO space environment's variability and the casuses of that variability, on all critical spatiotemporal scales. GDC is currently in formulation, with launch anticipated in the first part of the next decade.

In this talk, I will present the science motivation behind GDC, including how it serves as a natural laboratory for understanding fundamental physics of gas-plasma interactions and a baseline for comparative planetology studies. I will show its planned measurement and sampling strategy. I will demonstrate how GDC serves as a "strategic hub" for international scientific investigations to study the near-Earth space environment. Finally, I will show how GDC serves as a key pathfinder for future operational "space weather" monitoring efforts that may be undertaken by DOD and NOAA to provide space situational awareness and forecasting in this key region.

Bio: Doug Rowland has served as NASA's Project Scientist for the Geospace Dynamics Constellation Mission since 2019. From 2018-2023 he served as Chief for NASA Goddard Space Flight Center's Ionosphere, Thermosphere, Mesosphere Physics Laboratory. His research background is in magnetosphere-ionosphere-atmosphere coupling and the nature and impacts of geophysical electric fields that can transfer momentum and energy to the gas as well as accelerate charged particles. He has been part of a team that provided electric field instrumentation to over twenty suborbital rocket investigations of the upper atmosphere. He came to NASA Goddard in 2003 as a National Research Council Postdoctoral Fellow, and joined the federal workforce in 2005. Prior to 2003 he was at the University of Minnesota, where he earned his PhD studying satellite measurements of electric fields during geomagnetic storms. He lives in Rockville, Maryland with his wife, son, and two cats. When he is not working, he enjoys creative writing and karaoke.