Past and Future Climate of Thermospheric Density: Solar and Anthropogenic Influences

John T. Emmert[1] *[john.emmert@nrl.navy.mil], J. L. Lean*[1]*, and H. G. Lewis*[2]

[1] *Space Science Division, Naval Research Laboratory (NRL), Washington, DC, USA*

[2] *Astronautics Research Group, Faculty of Engineering and the Environment, University of Southampton, UK*

In this presentation, we review thermospheric climate and its dependence on solar irradiance, geomagnetic activity, and atmospheric greenhouse gases. The thermosphere is heated primarily via absorption of solar far (100–200 nm) and extreme (10–100 nm) ultraviolet irradiance and energy input associated with geomagnetic activity, and cooled mainly via infrared emission by CO_2 and NO. Changes in the balance of heating and cooling cause the thermosphere to expand (more heating or less cooling) or contract (less heating or more cooling), so that density at a given altitude increases or decreases, respectively. Variation in solar UV irradiance is the dominant influence on thermospheric density, which at 400 km altitude typically increases by an order of magnitude from solar minimum to solar maximum. There is strong evidence that the thermosphere is contracting in response to anthropogenic increases in CO_2; this effect is relatively small but monotonic. We also examine the record-low thermospheric density that occurred during the Cycle 23/24 minimum, and discuss its attribution (and uncertainty thereof) to forcing by solar irradiance, geomagnetic activity, and CO_2 increases. Finally, we project thermospheric climate 200 years into the future, using solar activity scenarios built from past behavior and representative concentration pathways of atmospheric CO_2. The future behavior of the thermosphere will affect the evolution of the increasing orbital debris population, because atmospheric drag is currently the only mechanism by which debris are removed from orbit. We briefly discuss how the range of possible future thermospheric states may affect debris mitigation and remediation strategies.