

UTILIZING REAL TIME UV AIR GLOW MEASUREMENTS TO DEVELOP A PREDICTIVE MODEL FOR SATELLITE DRAG

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LONG-TERM GOAL

Develop detailed models of the thermosphere that are compatible with historical and contemporary drag measurements and real time UV air glow data. These models will be used to improve estimates of day to day variability in the thermosphere, which is critical for maintaining a catalog of thousand of Earth satellites and for accurately predicting orbital decay of satellites.

SCIENTIFIC OBJECTIVES

Thermospheric empirical models such as Jacchia (1971) are being updated with data obtained over the last 26 years from the thermosphere and exosphere. Differential correction programs are being developed which utilize both drag, UV air glow, and other in situ data to improve estimates of the response of the atmosphere to solar and geomagnetic activity, variations in altitude, local solar time, latitude and season, the semi-annual variation and unexplained variations. Long term drifts in the upper atmosphere are being explored. Methods will be developed to identify possible biases between drag and UV air glow data and possible biases between different UV air glow data sets. Ultimately the properties of the changing thermosphere will be used in real time to update the catalog of Earth satellites.

APPROACH

A comparison is made of a number of existing thermospheric models to establish which, if any, is a good starting point for the development of an empirical thermospheric model for catalog maintenance. Satellite drag data derived from the satellite catalog over the years is used along with other data, to test the accuracy of various models. Then a differential correction program will be incorporated using the recent satellite drag and other data to improve these models. The differential correction procedures will be compatible with the vertical structure of individual species (N_2 , O, etc.) as measured by the air glow technique. Since, on any day, the air glow measurements will be made at specific local solar times, the drag data will be used to estimate the diurnal variation at other local solar times.

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WORK COMPLETED

Identified constellation of hundreds of satellites sensitive to drag effects which could be compared with future air glow measurements of number density in real time. Investigated daily values for 35 satellite-years of data. These data were used to compare present day atmospheric condition with historic models.

Compared recent drag measurements from a number of satellites with a number of empirical thermospheric models, including Jacchia (1971), MSIS, and Jacchia (1977). It was found that the Jacchia (1971) model correlated best with the recent drag data.

The J71 model was chosen as the model to modify as the initial step toward developing a model for application to the recent drag data and future UV air glow data. The J71 model has now been modified to be more flexible and to generate analytic solutions using the Bates' temperature profile.

A differential correction scheme was developed to improve empirical model parameters based on present day densities derived from 9 satellites. In the initial tests, 8 of the parameters were improved using satellite data from 1991. In the future, the analysis will be expanded to cover variations over the 11 year solar cycle.

RESULTS

Analysis of historic drag data gave evidence of decreasing density of the atmosphere for the 1996 solar minimum compared to the earlier solar minima. Many satellite-years of data were used in this initial analysis of whether there is a long term drift in the thermosphere. The density decreases may be due to the increased thermospheric CO₂ cooling as tropospheric CO₂ increases.

An investigation was made on the simultaneous response of 8 satellites to various geomagnetic disturbances. It was found that in many cases the corresponding atmospheric disturbance began *before* ground based Ap and Kp indices indicated a disturbance.

Studies were performed comparing the J71 (derived from drag) and MSIS (derived from neutral mass spectrometer and incoherent scatter data) models with recent data obtained at altitudes near the top of the thermosphere. Neutral and ion spectrometer data was obtained in 1995-96 on the DOD Midcourse Science Experiment (MSX) satellite. It was discovered that near the summer pole the major drag effect came from *atomic oxygen ions* rather than neutral atomic oxygen or helium as previously assumed. Near the winter pole, helium was the major species (winter helium bulge) and was in accord with both empirical models. At the summer pole the discrepancy between the J71 and MSIS models was explained in terms of strong O⁺ drag.

IMPACT/APPLICATION

The long and short term trends identified above have significant impacts on our understanding of the thermosphere and its natural variability. The apparent thermospheric cooling over a number of solar cycles could be an early indication of global tropospheric warming due to CO₂ loading and such long term changes must be taken into account when adjusting models such as J71 for present day conditions. The appearance of thermospheric response prior to surface measurements of geomagnetic activity suggest that traditional surrogate indices are not adequate for real time prediction and that a space based solar wind index may be required. Finally, the resolution of the long standing discrepancy between drag and mass spectrometer measurements has been resolved

with the discovery that O^+ is a major contributor to upper thermosphere satellite drag at the summer pole.

TRANSITIONS

The differential correction methods developed under this grant have been utilized in a complementary program with the Naval Space Command at Dahlgren, VA. The emphasis there was utilizing short sequences of orbital decay data to adjust local atmospheric parameters to improve prediction. The results were very encouraging and will be explored for application in the NSC operation software.

RELATED PROJECTS

The above increases in our understanding of the thermosphere are being incorporated into improved atmospheric models that will be evaluated under a Naval Space Command task to utilize atmospheric models to improve satellite catalog maintenance.

REFERENCES

Hicks, J.R., 1997. "An Adaptive Thermospheric Model to Improve the Prediction of Satellite Orbits," George Washington University MS Thesis.

Wilkin, P.G., 1997. "Methods to Improve the Maintenance of the Earth Catalog of Satellites During Severe Solar Storms," George Washington University MS Thesis.

Leary, J.C., 1997. "MSX In Situ Atmospheric Measurements near the Exobase," George Washington University MS Thesis.

Keating, G.M., Leary, J.C., Tolson, R.H., Uy, O.M., Benson, R.C., Erlandson, R.E., Boies, M.T. and Lesho, J.C., 1997. "Amplitude of the Winter Helium Bulge near the Exobase," *Advances in the Astronautical Sciences*.

Keating, G.M., Leary, J.C., et al., 1997. "Neutral and Ion Drag Effects Near the Exobase: MSX Satellite Measurements of He and O^+ , AAS 97-634," Proceedings of *AAS/AIAA Astrodynamics Specialist Conference*, Sun Valley, Idaho.

Benson, R.C., Phillitp, T.E., Boies, M.T., Uy, O.M. and Keating, G.M., 1997. "Atmosphere Helium Density Measurements at 900 km from the Neutral Mass Spectrometer on MSX," *EOS*, 78, #17, S230.

Keating, G.M., Leary, J.C., et al., 1997. "Atmospheric Composition Near 900 km from MSX and Drag Measurements," *EOS*, 78, #17, S230.

Leary, J.C., Keating, G.M., Tolson, R.H., Uy, O.M. and Benson, R.C., 1997. "Future MSX In Situ Measurements Near the Exobase," *EOS*, 78, #17, S234.