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Study of wave dynamics in the MLT region using the UARS measurements

FINAL REPORT

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Introduction

We have received funding for a three-year effort to develop techniques and models for analysis of UARS wind and temperature observations in the mesosphere and lower thermosphere (MLT) region. The developed methodology and models provide the means to analyze the thermal tides and their influence on the day and nighttime airglow diurnal variations in the MLT region observed by the HRDI and WINDII instruments onboard UARS. Major scientific results from this investigation are outlined in the following.

Major achievements

The global coverage of the UARS winds, temperature, and constituents measurements in the MLT region provide an excellent opportunity to calibrate General Circulation Models (GCM) and mechanistic wave models and to study the global behavior of the diurnal oscillations in the MLT region. However, the determination of the zonal mean and tidal components on monthly time scales from a local-time precessing space platform is currently a subject of active discussion. To study the diurnal variations in the MLT region, asynoptic sampling of the satellite measurements requires collecting data over a month, or several months, to form the necessary local time coverage in the observational database. On these time scales, when asynoptic satellite data are projected onto the local time frame, the day-to-day variations in the mean flow, planetary wave, and tides can be aliased to each other, providing an erroneous determination of the mean flow and waves from the data.

We have developed an original method for fast estimation of the thermal tide amplitude and phases from the HRDI and WINDII wind data based on the combination of linear steady state tidal model and the UARS zonal and meridional wind data. The tidal oscillations in the horizontal and vertical wind components, pressure, density, and temperature fields derived in such a manner are consistent with each other through the model equations. This methodology gives the opportunity to separate the tidal oscillations and the zonal mean fields, when the direct application of least square fits provides erroneous results such as for the daytime HRDI wind and temperature data. Another product of this methodology is the estimation of the effective tidal dissipation, which is needed to obtain the best mechanistic model fit for the diurnal tide amplitude between 40 S and 40 N in the MLT region. Obtaining realistic values of the atmospheric dissipation is an important issue to simulate adequately the dynamical, radiative and chemical coupling in the MLT region. After our first indications for the low values of the vertical tidal damping above 75 km several modeling groups made revisions in the eddy dissipation in their models, which gave allowed them to obtain agreement with the UARS wind measurements. Using the Tuned Mechanistic Tidal Model (TMTM) results, we demonstrated the consistency of the independent wind, temperature, and airglow measurements for daytime and nighttime conditions.

We made the first interpretation for the derived values of the eddy diffusivity from the HRDI/WINDII wind measurements with the help of the GROGRAT gravity wave model. We showed that the annual cycle of the eddy dissipation derived by TMTM is consistent with the annual variabilty of the gravity wave breaking simulated by the GROGRAT model using zonal mean HRDI winds.

Using the 1992-1998 HRDI temperature and wind data, the TMTM technique, and the GROGRAT gravity wave model, we investigated the interannual variability of the diurnal tide and gravity waves in the low-latitude MLT region and their effects green line oxygen emissions.

We developed an extension of the TMTM into the time-dependent framework based on a spectral solver formulation with explicit and semi-implicit numerical schemes. We verified this new model against analytical and numerical steady state model solutions. Using the time-dependent model, the zonal mean wind, and eddy dissipation derived by the steady-state TMTM, derived from the HRDI wind data, we simulated major features of the annual and interannual variability of the diurnal and semidiuranal tides, and the planetary waves. We expect that the time-dependent formulation for the mechanistic wave models will allow us to formulate some new assimilative techniques for derivation of the global wave parameters from UARS data and the data expected from forthcoming satellite missions.

Results for future satellite missions

We hope that insights obtained during our study will be useful for future NASA's satellite missions (e.g., TIMED to be launched on June 2001). In particular, because of the similar technical design and measurements strategy of TIDI on TIMED and HRDI on UARS, during the validation studies of the TIDI

instrument with MF radars, we can expect to see large discrepancies between the TIDI and MF radar winds above 85 km.
The developed Tuned Mechanistic Tidal Model will be able to show the level of consistency between wind, temperature and airglow tidal variations in the low-latitude MLT region, and provide some quasi-assimilative estimates of the diurnal tide amplitudes and phases seen from the TIDI data.

Related Publications and Presentations

1. Yudin V.A., M. Geller, B. Khattatov, D. Ortland, M.Burrage, C. McLandress, G. Shepherd, TMTM simulations of the diurnal and semidiurnal tides: Comparison with the UARS observations of wind temperature and airglow, Geophys Res. Lett., 25, 221-224, 1998.

2. D. R. Marsh, W. R. Skinner, and V. A. Yudin, Tidal influences on atmospheric band dayglow: HRDI observations versus model simulations, Geophys. Res. Lett., 1369-1372, 1999.

3. V.A Yudin., M. A. Geller, L. Wang, and S. D. Eckermann, Interannual variability of the diurnal tide in the low-latitude mesosphere and lower thermosphere during equinoxes: Mechanistic model interpretation of the 1992-96 HRDI measurements, In Press AGU monograph "Atmospheric Science Across the Stratopause", October 15, 2000.

4. V.A. Yudin, M.A. Geller, L. Wang, On the zonal mean temperature and diurnal tide structures derived from the HRDI temperatures in the equatorial MLT region, manuscript in preparation, 2001.

5. V. A Yudin, M. A. Geller, and S. D. Eckermann, Combined model-data analysis of waves and mean flow from the UARS MLT observations of wind, temperature, and airglow, Paper presented at the UARS Science Team Meeting, March 16-18, 1998, Pasadena, California.

6. M.A Geller, V. A. Yudin, and L.Wang, A model study of UARS wind, temperature, and airglow data: interannual variability of tidal effects in the MLT region, Paper presented at the 22nd Assembly of IUGG, Birmingham, July 18-30, UK, 1999.

7. V.A. Yudin M. A. Geller, and L. Wang, A model study of UARS wind, temperature, and airglow data: seasonal variability of tides and gravity waves in the MLT region, Paper presented on the 22-nd Assembly of IUGG, Birmingham, July 18-30, UK, 1999.

8. V.A. Yudin, M. A. Geller, and L. Wang, Annual and interannual variability of tides and their effects in the MLT region: Mechanistic model interpretation of the UARS

wind, temperature and airglow measurements, Paper presented at the Chapman Conference on Atmospheric Science Across the Stratopause, Annapolis, Maryland, April 19-22, 1999.

9. V.A. Yudin, M. A. Geller, and L. Wang, Extension of the Tuned Mechanistic Tidal Model into a time-dependent framework, Paper presented at the AGU Fall Meeting, San Francisco, December, 2000.

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RE: NAG5-7134
"UARS Investigators of Wave-Coupling in the Middle Atmosphere

Dear Ms. Otten:

Please find enclosed the Final Report for the above referenced grant.

Please contact me at (631) 632-4402 if you should have any questions.

Sincerely,

Ivar Strand, Director
Office of Sponsored Programs

IS:rw
Enc.

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