SPA-Aeronomy

SA11A CC: 519 A Monday 0830h

Interpretation and Observation of Mesospheric Gravity Waves From Earth and Space I *(joint with A, P)*

Presiding: **R P Lowe,** University of Western Ontario**; p M Franke,** University of Illinois

SA11A-01 0830h INVITED

Can Satellite Remote Sensors Measure Gravity Wave Momentum Flux?

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The huge impact that satellite data have had on our understanding of synoptic scale dynamics, chemistry and transport processes in the atmosphere raised expectations that new high-resolution instruments could provide similar generational advances in our understanding of global gravity wave (GW) activity and its role in driving the atmospheric circulation. Thirty or more publications, have appeared recently, based on analyzing fluctuations in data acquired by different limb-sounding techniques (infrared and microwave emissions as well as GPS occultation). Enhanced GW variances have been attributed to waves radiating from various tropospheric sources, such as orography and convection. However, since all these studies are based on temperature variances or potential energies they cannot quantify wave momentum fluxes and flux divergences, parameters most relevant to the GW driving of global circulation patterns. In this talk we discuss infared limb-scan temperature data taken by the CRISTA instrument. We consider a case study of mountain waves above South America and discuss the sensitivity of the instrument, vertical-profile analysis and horizontal variation of GW phase. On this basis we introduce a technique to infer temperature amplitudes, vertical and horizontal wavelengths of GWs simultaneously allowing us to infer GW momentum flux (MF) in an operational way. This technique is tentatively applied to the CRISTA data. Despite large uncertainties and the fact that we cannot resolve the direction of the MF owing to insufficient horizontal sampling of the instrument, important results can nonetheless be obtained. Specifically, we find: 1.) Due to large amplitudes and short horizontal wavelengths, GWs excited by distinct sources as deep convection and orography carry large MF. 2.) GW potential energies must not be used as a proxy for GW momentum flux. In particular, even a transfer based on a simple horizontal wavelength distribution (i.e. dependence on Coriolis paprameter) does not result in correct MF values. Encouraged by these results we will finally formulate the requirements for an instrument resolving MF direction at reasonable errors and discuss the prospects of such an instrument.

SA11A-02 0850h INVITED

Linear theory estimates of global distribution of convectively generated gravity waves

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Linear theory can be used to derive relationships between the properties of convectively generated gravity wave spectrum and convection characteristics. Such relationships enable the derivation of global distribution of convectively generated gravity waves using either data or convective scheme output from a General Circulation Model (GCM). These estimates are particularly useful for the high-frequency, short horizontal wavelength gravity waves (waves with periods between 10 and 100 minutes and horizontal wavelengths about 100 km), as these waves can not be measured globally and are not resolved in any global model. In this talk, linear theory of gravity wave excitation mechanisms in convection will be discussed and a method of specifying gravity wave momentum flux above convection will be presented. Subsequently estimated gravity wave momentum flux and spectral characteristics will be shown using global fields from the Whole Atmosphere Community Climate Model (WACCM). Gravity wave properties will be discussed close to their source levels in the troposphere as well as in the stratosphere and mesosphere. Lastly we will discuss how the linear estimates can be combined with observations to reduce the uncertainty in global gravity wave characteristics and magnitude of gravity wave drag in the middle atmosphere.

SA11A-03 0910h

Concurrent Wave Activity in the Polar Mesosphere-Ionosphere Region

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Airglow observations from the winter polar mesosphere and ionosphere over Eureka, Nanavut (80 degrees N, 86 degrees W) through the past solar cycle have shown occasional coupling of mesospheric gravity and tidal waves with the F-region (as seen from [O] 630 nm airglow emissions). In addition to what appear to be tidal harmonics, there are observations of shorter duration gravity waves of 15-30 minute periods. The characteristics of these waves will be illustrated and coupling processes will be discussed.

SA11A-04 0925h INVITED

Application of GPS Radio Occultation Data for the Studies of Atmospheric Waves

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It is well known that gravity waves play a crucial role in driving the general circulation of the middle atmosphere. In any general circulation modeling efforts, GW effects must be considered properly, because effects of the wave-driven pumping can be significant at much lower altitudes, both on tropical upwelling and on polar down-welling. The upward transport and the subsequent deposition of momentum and energy from lower heights form a major part of the dynamical coupling between different parts of the atmosphere. This determines the general circulation and structure of the middle atmosphere. During the past two decades with the advent of VHF radars and lidars, considerable effort has been devoted in characterizing GW. Although these techniques can provide observations with excellent temporal and spatial resolution, the network of these ground-based instruments is coarse and hence the global morphology of GW activity, as acquired with these techniques is poorly known. On other side atmospheric sounding by GPS radio occultation is emerging as a promising tool for numerical weather forecasting and climate change studies due to its high resolution, long-term stability, all weather capability, and global coverage. GPS occultation technique provides profiles of water vapor, temperature and electron density with high accuracy and a very good height resolution superior to other satellite techniques. Using GPS/MET, CHAMP/GPS, and SAC-C data sets, studies related atmospheric waves are carried out. The presentation includes basic concept of GPS occultation measurements, its validation (temperature), Kevin waves observed at equatorial latitudes, global distribution of the stratospheric gravity wave activity, which includes their generation due to convection, topographic forcing, and enhancement over some regions without convection and topography, wave generation associated with stratospheric sudden warming over Antarctica in 2002.

SA11A-05 0945h

Observations of a large-scale thermospheric gravity wave using ISR, TEC, and airglow data and its effect on the mesosphere

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On October 1-2, 2002, a moderate geomagnetic storm took place with the 3-hour K_p index reaching 5- for 24 hours and 7+ twice. Evidence from ISR, TEC, airglow, and ionosonde data indicate that a series of large-scale thermospheric atmospheric gravity waves were launched from the auroral zone, modulating the mid-latitude ionosphere over Arecibo by over 150 km and driving mid-latitude and indirectly equatorial spread-F. A unique method is presented to "image" the TIDs using TEC perturbations, which can be interpreted as the effect of the F-layer modulation due to neutral wind perturbations on the plasma pressure (plasmaspheric flux). These TIDs, while inherently thermospheric, also effected the mesosphere. We show 630.0-nm and 557.7-nm airglow measurements from Hawaii and Arecibo that show a change in the emission levels of several hundred Rayleighs, most of which was due to the F-layer fluctuations. However, the TID also caused an enhancment in the mesospheric portion of the 557.7-nm emission. Via a modeling study of the two emissions using standard techniques, we find that an atomic oxygen fluctuation of about 15% is required to explain the observed intensities. These variations may be associated with changes in the eddy diffusion parameters associated with the gravity wave passage.

SA12A CC: 519 A Monday 1030h

Interpretation and Observation of Mesospheric Gravity Waves From Earth and Space II *(joint with A, P)*

Presiding: **R P Lowe,** University of Western Ontario**; p M Franke,** University of Illinois

SA12A-01 1030h

Gravity Wave Observations From Space - What can we Expect to see and Learn?

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A number of missions have been proposed to image gravity wave signatures from a space-born platform. Most are based on well-proven ground-based techniques which utilize the naturally occurring airglow emissions to investigate gravity wave signatures as they propagate (and break) in the upper reaches of the mesosphere and lower thermosphere (MLT) region (altitude 80-100 km). There are several important advantages of satellite-borne observations: (1) they will provide the first global measure of wave occurrence, spatial characteristics, directionality, seasonal and geographic variability, (2) they can make measurements over regions that are not readily accessible by ground-based instrumentation (e.g. deserts, oceans, ice shelfs etc), and (c) they will be able to measure the near and far field signatures of the propagating wave patterns generated

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by various sources. Indeed, a key goal of such a mission would be to utilize these data to investigate the global source distribution and associated impact (via momentum deposition) of gravity waves on the MLT region. Existing ground-based observations of short-period (<1 hour) gravity waves can be used to help estimate the types of data to be expected on such a mission. These waves are an essential component of the gravity wave spectrum as they are known to transport large amounts of momentum from tropospheric sources into the MLT region where they can saturate and break. This talk will focus on the use of ground-based all-sky image measurements of small-scale waves using data obtained a low-, mid- and high-latitudes to illustrate the expected characteristics of the wave data (scale-sizes, amplitudes, morphology), and to discuss the advantages and limitations of satellite-born observations.

SA12A-02 1045h

Gravity Waves Generated by Convection during the Darwin Area Wave Experiment (DAWEX)

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We describe a model study of gravity wave generation by convection near Darwin during the Darwin Area Wave Experiment (DAWEX). We focus on an 7-hour period on 17 November 2001 for our study, which included a major Hector event over the Tiwi Islands followed by a continental convective outbreak that included a squall line to the southeast of Darwin. Our model is a dry version of a 3-dimensional (3D) mesoscale cloud resolving model with horizontally uniform background wind and stability fields. The model is forced with a spatially and temporally varying heating field representative of the convective latent heating in the area. We derive this heating field from 3D volumetric reflectivity from the precipitation radar located just north of Darwin at Gunn Point during DAWEX. The conversion from radar reflectivity to a 3D latent heating field requires numerous assumptions that do notallow a quantitative heating estimate, but which do provide a very realistic measure of the spatial morphology and temporal variations of the latent heating. Gravity waves generated by convective heating are known to be very sensitive to these characteristics of the heating, so our resulting wave field is likely to be the most realistic possible description of the waves emitted from convection in the Darwin area. Uncertainty in the wave amplitudes is large both because the input forcing (heating) is uncertain and because the use of heating as the sole proxy for wave forcing leads to additional wave amplitude errors. We therefore compare the results of the model to other DAWEX measurements and previous modeling studies both to validate the waves in our model and to calibrate the wave amplitudes. Our study in turn aids in the interpretation of the other gravity wave measurements as from airglow imagers during DAWEX.

SA12A-03 1100h

Observational Implications of a New Model of Mesospheric Bores

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We examine the observational implications of a new numerical model of the generation and propagation of mesospheric bores. The bores develop as long-wave excitations in mesospheric wave ducts, formed by the temperature and wind structure, in much the same way as they do in the tropospheric boundary-layer duct. However, while the boundary-layer duct has a clamped ground boundary (zero vertical displacement), the embedded mesospheric duct has two free boundaries, which results in some differences in behavior. With a separability assumption valid in the long-wave limit, the fluid equations separate into a product of solutions of the Taylor-Goldstein equation describing the vertical dependence of the mode function and of the Benjamin-Davis-Ono (BDO) equation describing the horizontal and time behavior. We compare results of the numerical model with the analytic model of Dewan and Picard (1998) that is based on Lighthill's channel-bore solutions. The numerical model leads to predictions of new and/or as-yet-unobserved phenomena, including (1) the possible existence of bores in Doppler ducts, (2) the existence of a fast sinuous-mode bore with no channel-bore analogue having phase speeds of 150-180 m/s, and (3) the possibility of foaming or turbulent (non-undular) bores. Following Christie (1989), we model the turbulent dissipation processes in the latter case by including a Burgers-type term in the BDO equation. We also compare model predictions with recent bore observations accompanied by simultaneous lidar data [Smith et al., 2001; She et al., 2004].

SA12A-04 1115h

Gravity wave propagation, tidal interaction, and instabilities in the mesosphere and lower thermosphere during the winter 2003 MaCWAVE rocket campaign

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The winter MaCWAVE rocket campaign took place in January 2003 at Esrange, Sweden and the ALOMAR observatory in Andenes, Norway. The campaign combined balloon, lidar, and rocket measurements to produce full temperature and wind profiles from the ground to 105km. This presentation will investigate gravity wave propagation in the mesosphere and lower thermosphere using data from the Weber sodium lidar and the RMR lidar at ALOMAR and rocket-launched falling spheres on 27-28 January 2003. From 50 to 70 km, several smaller-scale waves were dominant, and propagated upward into a very large semidiurnal tide above 70km that had an amplitude growing to 90 m/s at 100 km. The superposition of the gravity waves and tide caused small regions of possible convective or shear instabilities to form along the downward progressing phase fronts of the tide. We will present the characteristics of the gravity waves, their interaction with the tide, and the resulting unstable regions.

SA12A-05 1130h

Observed and Modeled Stratospheric Gravity Waves above Hurricane Humberto

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A three-dimensional model can be a very powerful tool to the study of various properties of hurricanes including areas of deep convection as possible sources of internal gravity waves. Data collected by aircraft, although extremely useful, does not give a full picture of the dynamics of the system because only a few slices through the storm can be sampled within the limitations of the campaign. A validated model can help to fill in the gaps where the sampled data cannot. In this study, a three-dimensional MM5 model is used to study the characteristics of Hurricane Humberto, a category 2 hurricane observed in September 2001 during the the fourth field campaign in the Convection and Moisture Experiment series (CAMEX4). Of particular interest to this study are internal gravity waves induced by the convective activity within the rain bands of the hurricane. Further understanding of the sources for these waves and their effects on the large-scale circulation is an ongoing topic of research. Vertical velocity perturbations and potential temperature contours are used to pinpoint vertically propagating gravity waves in the stratosphere. Possible correlations between areas of deep convection as gravity wave sources within the storm and observed vertically propagating gravity waves are presented. Comparison of model results to data collected during the CAMEX4 on board the high-altitude NASA ER-2 aircraft with the ER-2 Doppler Radar (EDOP) and Microwave Temperature Profiler (MTP) will also be presented.

SA12A-06 1145h

Airglow Imaging Systems for Gravity Wave Observations in the Martian Atmosphere

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Airglow imaging has proven to be a useful technique for measuring gravity wave activity, allowing retrieval of parameters such as the wave amplitude, horizontal wavelength, direction of propagation, phase velocity, and wave period. Mars atmosphere is composed mainly of CO2, with small amounts of N2 and Ar. There is considerable evidence of vertically propagating gravity waves. Although the current radiative-convective and general circulation models reproduce the general features of the thermal structures in the lower Martian atmosphere, the observed thermospheric temperatures are lower than model forecasts. Model studies have shown that the introduction of gravity wave drag can reconcile the model results with observations. For example, inclusion of results suggest that gravity wave drag can account for the cold thermospheric temperatures by adiabatically warming the atmosphere via dynamical induced circulation. In this paper we present two systems we are developing to monitor the wave activity in the Martian atmosphere through measurement of the contrast in the image of selected airglow features: a zenith-sky imaging system (MARES) that will operate from the ground, and an orbiter-based imaging system that will operate from space (GWIM-Mares). Since the airglow on Mars is poorly known, an airglow model has been built to estimate the airglow response to gravity waves and thus to determine the target emissions for the instruments.