Agenda of 2021 Workshop: Vertical coupling

Observations and modeling of vertical coupling in the Space-Atmosphere Interaction Region

13-15 MDT June 23rd, 2021 via Zoom

Co-host#1 Yen-Jung Wu; Co-host#2 Nick Pedatella

13:00 - 13:20 (MDT) Komal Kumari, Clemson University

Mechanism Studies of Madden-Julian-Oscillation Coupling into the MLT Tides

Tidal variability on shorter timescales, is much less understood, mainly due to the observational constraints imposed by satellite local sampling. Tidal deconvolution of SABER temperature observations allows one to resolve tidal variability on a 30-90-day timescale that occurs as a response to the recurring Madden-Julian Oscillation (MJO) in tropical convection. We looked into understanding physical causes of tidal intraseasonal variability as a function of various MJO-locations over the Indian and Pacific Ocean. A statistical analysis of SABER observations and SD-WACCMX simulations confirmed previously unverified model predictions of a 10-25% tidal modulation by the MJO in the MLT region. The tides largely respond to the MJO in the tropospheric (from MERRA-2) tidal forcing, while filtering by tropospheric/stratospheric background winds is comparably less important. These findings have broader implications as tides can also couple variability on MJO timescales from the MLT region to the IT region.

13:20 - 13:40 (MDT) Jeffrey M. Forbes, University of Colorado, Boulder

Jeffrey M. Forbes, Xiaoli Zhang, Chihoko Cullens, Christoph R. Englert, John M. Harlander, Brian J. Harding, Kenneth D. Marr, Jonathan J. Makela, and Thomas J. Immel

Vertical coupling by solar semidiurnal tides in the thermosphere from ICON/MIGHTI measurements

In terms of atmospheric dynamics, the region between 100 and 200 km is the least explored in Earth's atmosphere. According to theory and modeling, it is within this region where most vertically-propagating waves dissipate and deposit momentum into the background atmosphere. Molecular dissipation also serves as a filter, removing waves with short vertical scales and enabling larger-scale waves to access the ionospheric F-region. In this research we have utilized wind measurements from the MIGHTI instrument on ICON to delineate the propagation of semidiurnal tides SE2, S0, SW1, SW2, SW3, and SW4 from 100 to 250 km between -9 and +39 degrees latitude during 2020. One caveat is that MIGHTI sampling and utilization of daytime-only data limits the height vs. latitude structures that can be obtained to 60-day means that are centered on select days of year (DOY), and 60-day mean height vs. DOY structures at select latitudes. We focus on presenting and interpreting just a few examples in this presentation.

13:40 - 14:00 (MDT) Federico Gasperini, ASTRA

Federico Gasperini, Irfan Azeem, Geoff Crowley, Michael Perdue, Matthew Depew, Thomas Immel, et al.

Dynamical coupling between the low-latitude lower thermosphere and ionosphere via the non-migrating diurnal tide as revealed by concurrent satellite observations and numerical modeling

The diurnal, eastward propagating tide with zonal wavenumber 3 (DE3) is an important tidal component due to its ability to effectively couple the ionosphere-thermosphere (IT) with the tropical troposphere. In this work, we present the first results of a prominent zonal wavenumber 4 (WN4) structure in the low-latitude ionosphere observed by the Scintillation Observations and Response of The Ionosphere to Electrodynamics (SORTIE) CubeSat mission during May 27 - June 5, 2020. Least-squares analyses of concurrent in-situ ion number density measurements from the SORTIE and the Ionospheric Connection Explorer (ICON) satellites near 420 and 590 km show this pronounced WN4 to be driven by DE3. Thermosphere Ionosphere Mesosphere Energetics Dynamics Sounding of the Atmosphere using Broad band Emission Radiometry (TIMED/SABER) temperatures and Specified-Dynamics Whole Atmosphere Community Climate Model with thermosphere and ionosphere eXtension (SD/WACCM-X) output demonstrate that the ionospheric WN4 structure is driven by DE3 propagating from the lower thermosphere.

14:00 - 14:12 (MDT) Maosheng He, LIAP

Maosheng He, Jorge L. Chau, Jeffrey M. Forbes, Xiaoli Zhang, et al.

Atmospheric quasi-2-day waves as viewed from the ground and space

Quasi-2-day waves (Q2DWs) are the largest dynamical feature of the summertime middle atmosphere. Here, we investigate Q2DWs using horizontal winds observed by multi meteor radars from various longitude sectors and the MIGHTI instrument onboard the ICON satellite. At low-latitude in early 2020, the radar array analyses show that the dominant zonal wavenumbers are s=+2 and +3 at 80—100 km altitude. MIGHTI winds complement the radar results by extending the Q2DW amplitudes to broader latitude and altitude ranges (10°S—40°N and up to 200 km). The Q2DWs exhibit excellent agreement between the radar and MIGHTI amplitudes at their overlapping altitudes (95—100 km). At northern hemispheric mid-latitude, we find the secondary waves of the nonlinear interactions between Q2DWs (s=+3 and +4) and four migrating tidal components occurring in 2019 summer and present the 2012—2019 composite of Q2DWs and the secondary waves. The dominant Q2DWs are associated with s=+3, +4, and -3 occurring in summer, whereas the secondary waves maximize annually during winter.

14:12 - 14:24 (MDT) Jia Yue, GSFC

Quasi-two-day wave modulation of carbon dioxide in the mesosphere and lower thermosphere

In this paper, for the first time we report the quasi-two-day wave (QTDW) in daytime only SABER CO2 in January 2003. The QTDW in CO2 of ~7 ppmv or 3-4% shows double peak structures at mid and low latitudes of both hemispheres. We compare the SABER measured QTDW disturbance in CO2 and temperature to those in the eCMAM (the extended Canadian Middle Atmosphere Model). Good agreement of QTDW CO2 spatial and temporal variations is seen, especially at southern mid latitudes. eCMAM outputs are further analyzed to show that the QTDW in CO2 mixing ratio is mainly driven by both vertical and meridional advection. Because waves in vertical advection can be derived by temperature disturbance via a so-called adiabatic displacement approach, we can estimate the QTDW in CO2 mixing ratio from the SABER QTDW in temperature assuming meridional advection is weak at low and mid latitudes.

14:24 - 14:36 (MDT) Larisa Goncharenko, MIT

Goncharenko, L. P., V. L. Harvey, K. R. Greer, S.-R. Zhang, A. J. Coster, L. J. Paxton

Impact of September 2019 Antarctic Sudden Stratospheric Warming on Mid-Latitude Ionosphere and Thermosphere over North America and Europe

During the last decade, numerous studies showed that Arctic SSWs cause large anomalies in the low-latitude ionosphere, and few studies pointed out especially large disturbances at middle latitudes in the southern hemisphere ionosphere. However, it is not known if similar mid-latitude ionospheric anomalies on the other side of the globe are produced by Antarctic SSWs, mostly because Antarctic SSWs occur less often than Arctic ones. In this study we analyze ionospheric and thermospheric observations in September 2019, when very strong SSW developed over Antarctica. We found both positive and negative disturbances in the thermospheric O/N2 ratio and total electron content over North America and over Europe. Surprisingly, these disturbances are limited to narrow (20-40 degree) longitude ranges, differ between North America and Europe, and persist for a long time. We discuss the reasons why these anomalies occur only at specific longitudes and suggest that differences in magnetic declination angle play an important role as they affect how SSW-modified thermospheric wind influences ionospheric electron density.

14:36 - 14:48 (MDT) Gary Swenson, UIUC

Inter-Annual variations of Kzz from SABER and SCIAMACHY atomic oxygen climatologies as well as insights into the two mixing zones in the MLT

Sixteen years of SABER and ten years of SCIAMACHY measurements have been analyzed to describe the inter-annual variation (IAV) of both vertical transport (Kzz) and O densities (80-96 km). The results will be presented with a few surprises regarding expectations of O loss associated with the annual and semi-annual (AO and SAO), the two major oscillations observed. A vertical penetration of the AO from a vertical extent near 87 km, briefly surges to 96 km for 3-4 weeks prior to summer solstice, in both hemispheres. A second 'zone' between 96 and >105 km is separate, with separate KHI (Kelvin-Helmholtz Instability) forcing. New data from the Andes Lidar Observatory (ALO) will be presented, providing support to the early study by Larsen (2002) describing large wind shears in this region.

14:48 - 15:00 (MDT) Justin Tyska, University of Texas, Austin

Justin J. Tyska, Cissi Y. Lin, Yue Deng, and Shunrong Zhang

Volcano-generated Ionospheric Disturbances: Comparison of GITM-R simulations with GNSS observations

Geophysical events such as earthquakes, tsunamis, and volcanic eruptions can create disturbances in the ionosphere-thermosphere (IT) system by propagation of the developed acoustic-gravity waves (AGWs). These disturbances can be observed by ground based and spaceborne Global Navigation Satellite Systems (GNSS) and used to analyze various properties of the initial perturbation such as localization [1], wavelength [2], and total energy content [3]. The focus of this study is to simulate ionospheric Total Electron Content (TEC) variations induced by volcanic eruption using a global circulation model and to subsequently compare the simulated results to GNSS data. Unlike tsunamis and earthquakes, volcanic eruption is more or less like a point source at a fixed geographic location causing relatively localized perturbation. Simulations using the Global Ionosphere-Thermosphere Model with local mesh refinement (GITM-R) are performed to capture mesoscale subtleties in the regions near the volcano [4]. GITM’s lower boundary is at ~100 km altitude, thus an analytical AGW propagation model is used in conjunction with a volcanic source model to specify GITM’s lower boundary. The simulated TEC variations are compared to GNSS data to demonstrate GITM’s ability to resolve mesoscale acoustic-gravity waves signals induced by volcanic eruptions as well as attempts to link TEC waveform characteristics to volcanic source parameters.