# 2021 Workshop: Vertical coupling

Long title
Observations and modeling of vertical coupling in the Space-Atmosphere Interaction Region
Conveners
Yen-Jung Wu
Nick Pedatella
Mack Jones
Chihoko Cullens
Colin Triplett
Description

Waves play a vital role in the dynamics in the upper atmosphere, and carry energy and momentum from the lower atmosphere to the upper atmosphere. Whole atmosphere models driven by robust physics understanding fill the observation gaps in measurements. Satellite platforms such as ICON, GOLD and COSMIC-2 along with ground-based instruments provide cross-platform and multi-field measurements in the near-Earth atmosphere and ionosphere. With three ionosphere-thermosphere missions running currently in their major mission phase, the cross-comparison between space- and ground-based observations can benefit from the validation of vertical coupling in model simulations. This workshop aims to address the challenges of simulating multi-parameter data in the vertical coupling processes. Presentations to be included as part of this workshop will focus on: 1) vertical coupling of the waves coming from the lower atmosphere, 2) in-situ wave-wave interactions, 3) ion-neutral coupling, and 4) wave structures in the F-region and their connection to the neutral atmosphere.

Agenda

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.

Jeffrey M. Forbes, University of Colorado, Boulder

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

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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 $CO_2$ spatial and temporal variations is seen, especially at southern mid latitudes. eCMAM outputs are further analyzed to show that the QTDW in $CO_2$ 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 $CO_2$ mixing ratio from the SABER QTDW in temperature assuming meridional advection is weak at low and mid latitudes.

Federico Gasperini, ASTRA

**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.

Maosheng He, LIAP

**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.

Larisa Goncharenko, MIT

**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.

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.

Justin Tyska, University of Texas, Austin

**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.

Justification

One of the challenges stated in CEDAR: The New Dimension is “Comprehensive observational campaigns, providing much needed multi-scale and multi-parameter data, will be a challenge for the CEDAR modeling community to simulate/predict and

to account for all of the coupling processes in the SAIR, which at this time are far from being integrated”. The energy and momentum transported through vertical coupling modulate multiple atmospheric variables including composition, electrodynamics, temperature and winds. In order to understand these coupling processes and interactions, observational data of multiple fields are in needed by the modeling community. Strategic thrust # 6 “Manage, Mine and Manipulate Geoscience Data and Models”, emphasizes the importance of cross-dataset integration and the fusion of models and observations. This workshop will provide a platform for new results on vertical coupling in the Space-Atmosphere Interaction Region (SAIR) to show what is currently available and what is needed from both the observational and modeling perspective.

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