Abstracts

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CubeSats as "Space Weather Balloons"

Abstract:

Space weather seems to have only a small, and little understood, effect on the lower atmosphere below 15km. Meanwhile, the dynamic behaviour of the Sun has an exaggerated effect on the upper atmosphere above 100km. A coronal mass ejection can cause the upper atmospheric temperature to double within a few hours; and the atmosphere expands in tandem, rapidly changing the density at LEO satellite altitudes. As these altitudes become increasingly crowded with satellites and space debris, it becomes urgent to feed models with more frequent and wide-spread observations. Yet the region between 100-300 km altitude has few in-situ measurements because it is too high for balloons, and too low for satellites. Sounding rockets can probe these altitudes, but are too expensive for frequent and global coverage, and provide only a few minutes of observation. In contrast, meteorological weather forecasting relies on frequent observations from a dense network of ground stations measuring winds, temperatures, pressure, humidity and rainfall; alongside satellite images to provide global context and advance warnings as weather systems move into view. Weather balloons are launched twice daily from around 800 locations. They carry instruments to the stratosphere - up to altitudes of 40km. These regular measurements are essential for keeping complex global atmospheric circulation models on track, and as close to reality as possible. The relative cheapness of building and launching cubesats carrying miniaturised sensors has the potential to provide a similar capability for measuring the middle and lower thermosphere regions of the Earth's atmosphere. Remote observation of thermospheric temperatures and densities from Fabry-Perot Interferometers and the EISCAT radars alongside the UCL CMAT2 global circulation model will be presented to illustrate the need for "Space Weather Balloons".

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The H2020 project SWAMI: Development of a Whole Atmosphere Model and Kp Indices

Abstract:

In the framework of the H2020 project SWAMI, which started in January 2018, a new whole atmosphere model (0-1500 km) will be developed that can be used for launch operations, re-entry computations, orbit prediction, as well as aeronomy and space weather studies. Such a model is currently not available in Europe, whereas models in the US and Japan have irreconcilable limits for users.

The model will be constructed by blending two existing models, the Drag Temperature Model (DTM) and the Unified Model (UM). The CNES thermosphere specification model DTM2013, which was developed in the FP7 project ATMOP, will first be improved by assimilating more density data to drive down remaining biases as a function of solar activity and seasons mainly. Secondly, a new high cadence Kp geomagnetic index, which will be developed as part of the project, will be used in order to improve storm-time performance. Compared to the progress made in solar activity proxy research, geomagnetic index development and forecasting is lagging; SWAMI will focus on improving the geomagnetic index as well as its forecast. The Met Office UM will be extended to the lower thermosphere in order to have an overlap with DTM. Then, the average of a multi-year run and the inter-annual variability are computed, representing climatology and weather, respectively. UM and DTM will then be blended in the 120-160 km altitude region to create a whole atmosphere model, which will be made available in a user-friendly package in 2020.

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Comparison of GOCE observations of the thermosphere with WACCM-X simulations

Abstract:

The ESA GOCE mission, which flew between 2009 and 2013, was designed for detailed study of the Earth's gravity field. However, its highly accurate acceleration data, its unusually low orbit and its flight during the rising phase of solar cycle 24, have also proven to be beneficial for the derivation and analysis of in-situ data on the density and wind in the thermosphere. We have compared the GOCE thermosphere density and wind data with the output of WACCM-X 2 simulations. The study considers the period between October 2012 and up to seven hours before GOCE's reentry on November 11, 2013. There was a considerable influence of solar and geomagnetic activity on thermosphere variability during this period, that was measured by GOCE at altitudes between roughly 230-250 km. Data and simulations covering the final days of GOCE, when measurements were made down to 150 km, are considered in additional detail.

S. D. Eckermann (1)*
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Gravity Waves

Abstract:

This talk will focus on aspects of the dynamics, modeling, and parameterization of gravity waves relevant to numerical weather prediction within deep atmospheres.

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An Introduction of Ionospheric Models

Abstract:

It is very important to consider the ionospheric impact on the neutral atmosphere when extending atmospheric models into the thermosphere. Many different ionosphere and plasmasphere models have been established in the US, which are widely used for ionosphere studies such as understanding the impact of neutral dynamics or geomagnetic storms. In this talk, a brief introduction of ionosphere models will be given, including the model structures, the necessary drivers, and physical processes that are solved in these models. Some comparisons among these models at the low-latitude region will be discussed. An overview of the whole atmosphere model (WAM) development at NOAA Space Weather Prediction Center (SWPC) and the selection of ionosphere model used for coupling with WAM will also be presented.

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Thermosphere - Ionosphere dynamics of the 20 November 2003 superstorm modelled by CTIPe

Abstract:

The 20t November 2003 storm was one of the most intense events of the past solar cycle. The storm produced significant perturbations in the ionosphere-thermosphere (IT) system, with remarkable consequences in communication and positioning over Europe. This study analyses the IT response to this storm using the Coupled Thermosphere Ionosphere Plasmasphere electrodynamics model (CTIPe) in combination with ionosonde, Global Navigation Satellite System (GNSS) and CHAMP satellite measurements. The CTIPe simulation shows global changes in neutral winds, temperature, and composition which are reflected in the global electron density structure. The consistency between simulation and measurements allows the interpretation of the physical mechanisms behind the ionosphere perturbations and the dramatic changes in neutral composition during this event.

*Tim Fuller-Rowell(1)**

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Why Forecast Space Weather with Whole Atmosphere Models?

Abstract:

We have known for a long time that waves from the lower atmosphere are a source of variability in the thermosphere and ionosphere, but it has been hard to quantify the impact and understand the physical processes. With the advent of whole atmosphere models we are able to probe the connection, begin to understand the physical processes, quantify the impact, and potentially be able to forecast the consequences on operational systems. When there is a geomagnetic storm, and a coronal mass ejection strikes Earth, it dominates space weather in the near-Earth environment. But space weather doesn't just occur during big geomagnetic storms. When whole atmosphere models are coupled to the ionospheric plasma domain, on a typical day it can be shown that the three drivers – solar radiation, geomagnetic activity, and the lower atmosphere – all contribute significantly to space weather in the upper atmosphere. Whole atmosphere models can explore the day-to-day variability and the longitude dependence of lower atmosphere wave sources driving the sporadic ionospheric space weather. For instance, tides driven in the lower atmosphere create longitude ionospheric structure, sudden stratospheric warmings can increase total electron content by 50%, and variability in the neutral atmosphere can trigger ionospheric irregularities on any day, disrupting satellite navigation and communication. In addition, HF radio wave propagation by operational systems for communication and geo-location is impacted by all the "bumps and wiggles" in the ionosphere that diffract, bend, delay, or fade radio signals. Anyone observing the ionosphere will see these bumps and wiggles everywhere all the time. There is also the potential for whole atmosphere models to not only follow, but also forecast, the day-to-day variability and the longitude dependence of lower atmosphere wave driving the sporadic ionospheric space weather.

Daniel Joe Griffin (1) and John Thuburn (1)*

(1) The University of Exeter, UK.

Extension of the Met Office Unified Model dynamical core, ENDGame, into the thermosphere

Abstract:

The Met Office Unified Model (UM) dynamical core ENDGame is in the process of being developed to include an implicit treatment of vertical molecular viscosity and diffusion fully coupled to the dynamics. This new version of ENDGame should allow stable integrations with the upper boundary significantly higher (up to approximately 480km) compared with the current limit of around 120km, which is a crucial step towards a whole atmosphere version of the UM. Here, I will present the progress that has been made towards this end and further work that needs to be done.

By using ray tracing techniques, it was found that molecular viscosity and diffusion may prevent the excessive growth of waves in the thermosphere, which could improve ENDGame's stability as it is extended into a whole atmosphere model (Griffin and Thuburn 2017).

A 1D column version of ENDGame that simulates vertical wave propagation was developed to test the hypothesis that molecular viscosity and diffusion would improve the model's stability as it is extended into the thermosphere. The short timescale of molecular viscosity and diffusion in the thermosphere demanded an implicit treatment, coupled with the semi-implicit treatement of the dynamics. This required the development of a novel numerical solver to solve the coupled system effectively. Realistic molecular viscosity and diffusion and a modest amount of artificial damping are sufficient to stabilise the 1D version of ENDGame up to altitudes of 600km (Griffin and Thuburn 2017).

In 3D, further development to this numerical solver is required. We will discuss these developments, and will present preliminary results of stability tests of this new scheme.

M. Griffith (1); C. Budd (1); N. Mitchell (1); D. Jackson (2); J. Thuburn (3)*

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(3) *University of Exeter, UK*

Raising the Roof: Using the Unified Model to simulate the lower thermosphere. Results and validation.

Abstract:

Forecasting weather in the lower thermosphere (85 – 120 km) is of particular interest due to its impact on spacecraft re-entry and radio communications. To this end, we aim to extend the current 85 km upper boundary on the Met Office's Unified Model (UM) to a height of around 120 km. Thus, we shall raise the roof on current numerical weather prediction and pave the way for the development of a whole atmosphere model.

This region, however, has proven to cause particular difficulties for the UM. Thus, extended UM simulations were performed to assess the model anomalies directly. With these model runs, the radiation scheme was discovered to be a significant contributing factor causing the model to crash. In particular the lack of consideration of non-Local Thermodynamic Equilibrium (LTE) effects in the thermosphere leads to anomalous shortwave radiative heating.

The inclusion of non-LTE effects is still a work in progress. Thus, in order to circumvent this problem, we shall replace the radiation scheme by nudging towards a climatological temperature structure above 70 km. With this in place, we look to validate the model's accuracy in the lower thermosphere by comparison to data.

In particular, we shall focus on accurately depicting the reversal of the zonal jets, forced by gravity waves (GWs). In order to do this, tuning of the GW forcing schemes is required. We can then make a comparison with available radar and satellite data for the GW profile. We present and explain this data, and describe how it will be used to validate and enforce accuracy on the extended model

A. Grocott (1) and M.-T. Walach (1)*

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Data driven ionospheric electric field models

Abstract:

The Earth's ionosphere plays a key role in controlling global atmospheric dynamics, coupling the magnetic environment of geospace above to the neutral atmosphere below. Electric fields, produced by the solar wind interaction with the magnetosphere, drive the convection of plasma in the ionosphere. Ion-neutral collisions within the thermosphere transfer plasma kinetic energy to the neutral atmosphere, modifying the neutral winds and causing heating. The associated temperature and density changes can also launch gravity waves that further couple this energy through the different atmospheric layers. At the same time, the neutral winds themselves produce a dynamo effect in the ionosphere, modifying the electric field and thus also providing a time-dependent feedback to the electrodynamics. Magnetospheric electric fields dominate at high-latitudes with the mid- and low-latitude electric fields being driven by the neutral dynamo, although during geomagnetic active times, such as geomagnetic storms, the high-latitude electric fields become enhanced and expand equatorward. Any attempt to model this complex electrodynamic interaction is inherently difficult. One requirement is a reliable model of the electric field that is driven by the solar wind-magnetosphere-ionosphere interaction. A number of empirical models of the ionospheric electric field, or the associated plasma convection, have been derived from spacecraft measurements and ground-based radar observations. Typically, these models are parameterised by the conditions in the solar wind and interplanetary magnetic field, which control the ionospheric electric field to first-order. However, they lack any information on the time-dependence of the magnetospheric electrodynamics that also plays a significant role. In this presentation we will review some of the commonly used models, discuss their deficiencies and consider future directions in the field.

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SWAMI – a project to develop a European whole atmosphere model for improved satellite operations

Abstract:

'Space Weather Atmosphere Model and Indices' (SWAMI) is a new European project which aims to enhance the understanding of space weather processes and their impact on atmospheric density. A chief objective is to develop a unique new whole atmosphere model, by extending and blending the physics-based Unified Model (UM), and the semi-empirical Drag Temperature Model (DTM), which are leading models of their kind in the field. Together with improved nowcasts and forecasts of geomagnetic index, the whole atmosphere model shall be the basis of enhanced user-focused tools for satellite orbital prediction, launch and re-entry operations.

The presentation shall summarise SWAMI objectives, and will then focus on the development of the extended UM. The UM currently spans the 0-85 km altitude range, and is used for weather forecasts and climate studies at the Met Office but its dynamical setup makes it potentially very well suited to the thermosphere, too. Within SWAMI the goal is to raise the UM upper boundary to around 150-170 km. Much work shall focus on radiative transfer. This includes implementation of a non local thermosphere equilibrium scheme for more accurate heating rates above 70 km in altitude, and development of ultraviolet and extreme ultraviolet radiation schemes. The latter will provide photolysis rates which will be input into a new thermospheric chemistry scheme. Associated work includes assessing and developing the UM dynamics to make it more robust in the thermosphere, and verification of the UM against observations and other models.

C. W. Kelly* (1), M. P. Chipperfield (1), J. M. C. Plane (1), W. Feng (1), P. E. Sheese (2), K. A. Walker (2,3), and C. D. Boone (3)

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Nitrous oxide in the atmosphere: Chemistry-climate model simulations of a mesospheric-lower thermospheric source

Abstract:

Nitrous oxide (N_2O) is the major precursor of odd nitrogen (NO_x) production in the middle atmosphere and hence plays a significant role in the depletion of stratospheric ozone. It was previously assumed to only be produced at the Earth's surface. However, a mesospheric-lower thermospheric source has recently been identified by satellite measurements from the Atmospheric Chemistry Experiment - Fourier Transform Spectrometer (ACE-FTS). One likely production mechanism, first postulated by Zipf and Prasad (1982) based on laboratory experiments, is that secondary electron impact from energetic electron precipitation (EEP) promotes N_2 to the excited triplet state, which is then followed by a reaction with O_2 to produce N_2O above 90 km [$N_2(A^3\Sigma_u^+) + O_2 \rightarrow N_2O + O$]. We report chemistry-climate model simulations including this new source of N_2O using the NCAR Whole Atmosphere Community Climate Model (WACCM) with external forcing from the NCAR Global Airglow (GLOW) model. We compare our simulations to the ACE-FTS satellite measurements in order to establish a plausible mechanism for the source of the observed N_2O. With reasonable assumptions about both photoelectrons and the EEP source; the model reproduces the vertical, latitudinal, and seasonal N_2O variations observed by ACE-FTS. Model sensitivity results indicate that continuous N_2O production occurs via a reaction route involving the secondary electrons from EEP at high latitudes, and photoelectrons at all latitudes.

H.-L. Liu (1) and WACCM-X Team (1)*

(1) National Center for Atmospheric Research

Whole Atmosphere Community Climate Model with Thermosphere and Ionosphere Extension (WACCM-X): Model Requirements, Structure, Capabilities and Validation

Abstract:

The NCAR Whole Atmosphere Community Climate Model with Thermosphere and Ionosphere Extension (WACCM-X 2.0) has been developed to study the solar impact on the Earth system, to understand and quantify couplings between atmospheric layers through chemical, physical and dynamical processes, and to investigate the implications of the couplings to climate (downward coupling) and to space environment (upward coupling). The model extends from the Earth surface to the exobase, encompassing ~29 scale heights (13 order of magnitude change in pressure and density), and including both well-mixed and diffusively separated regions, and neutral and partially ionized constituents. In this talk, we will discuss the whole atmosphere model requirements to represent the dynamics, chemistry, energetics, transport, and ionospheric electrodynamics processes, and we will describe the structure of WACCM-X 2.0. We will also discuss new capabilities of WACCM-X 2.0, in particular the newly implemented modules of ionospheric electrodynamics, O+ transport and plasma temperatures, as well as modification of model dynamical core for the thermosphere, where mean molecular mass and specific heats are variables. With the interactive ionosphere modules and the improved dynamics core, we have made extensive simulations to validate the thermosphere and ionosphere results. The thermospheric compositional structures are in good agreement with climatology. Atmospheric tides, which are important in controlling the dynamics, transport and electrodynamics in the upper atmosphere but were underestimated in earlier versions of WACCM-X, are now well resolved and are in good agreement with observations. Ionospheric plasma densities and ExB drifts, as well as their seasonal and short-term variability, are found to be in general agreement with observations. Model uncertainties and constraining of the uncertainties using observations will also be discussed.

M. López-Puertas

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Non-LTE IR energy budget of the middle and upper atmosphere: Status and implementations in GCMs

Abstract:

In this talk I will present a review of the major components of the radiative heating and cooling terms of the energy budget with emphasis on the middle and upper atmosphere where non-local thermodynamic equilibrium processes are at work. A brief introduction to non-LTE will be given, followed by the description of the major IR heating and cooling terms. The most recent observations, taken mainly by the SABER and MIPAS instruments will be presented. An overview of the current parameterizations of those heating/cooling in planetary atmospheres will be discussed. Finally, the major problems, uncertainties and current lacks in their modeling in the context of future climate projections will be discussed.

J. Manners (1)*

(1) *Met Office*

MLT radiation scheme developments in the UM

Abstract:

The Met Office Unified Model currently runs operationally to a height of 85km using the Socrates radiation scheme (a two-stream correlated-k code) to determine radiative heating rates. In order to extend this model to the lower thermosphere a number of developments are required to the treatment of radiative transfer, two of which will be the focus of this talk. Recent work has introduced a treatment of the pseudo-spherical approximation for the direct flux allowing radiative transfer in twilight regions. Plans will also be presented for an extension of wavelength coverage into the far and extreme ultraviolet in order to provide photolysis rates for the upper atmosphere.

D.R. Marsh (1) and WACCM(-X) team (1)

(1) *National Center for Atmospheric Research, USA*

The Community Earth System Model: A platform for atmospheric prediction from the surface to geospace

Abstract:

Understanding the response of geospace to changes in solar irradiance and energetic particle fluxes on timescales from minutes to several decades remains a significant challenge. It is becoming increasingly apparent that this response is driven not only by forcing of solar origin but also forcing from the lower atmosphere, and so necessitating a 'whole atmosphere' view. In this talk, I will describe efforts at NCAR to represent how changes in solar output affect Earth's energetics, composition, and dynamics within the Community Earth System Model (CESM). CESM is a community-developed, global chemistry-climate model capable of simulating Earth's past, present, and future climate states. CESM can be run with full coupling between components that represent the atmosphere, land, ocean, land and sea ice. The model's vertical domain is flexible through the selection of the atmospheric component, which depends on the chosen application. Currently there are two 'high-top' options, the Whole Atmosphere Community Climate Model (WACCM), with a model lid around 140 km, and WACCM-X, with the lid extended to approximately 700 km. Since CESM spans the whole atmosphere it simulates the coupling between atmospheric layers, such as the ionospheric effects of gravity waves, tides and planetary waves that have their origin in the troposphere. As a climate model, it is also capable of simulating the effects of anthropogenic global change through the entire atmosphere, including changes in the thermospheric density and temperature. Here we describe and give examples of the current capability of CESM in its high-top configurations, the CESM modeling infrastructure, future development plans and potential areas of collaborative development

O. Martynenko (1), V. Fomichev (1), W. Ward (2) and Yongsheng Chen (2)*

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(2) *University of New Brunswick, Canada*

The Canadian Ionosphere and Atmosphere Model: its description and ability

Abstract:

The Canadian Ionosphere and Atmosphere Model (C-IAM) is a first principles global three-dimensional model extending from the Earth's surface to the inner magnetosphere, which incorporates all known major physical and chemical processes of importance within its domain. The model is able to calculate in a self-consistent manner the atmospheric composition (including neutral species, ions and electrons), temperature (neutral, ion, electron), motion (wind and electromagnetic drift of charged components) and the electric field of both magnetospheric and dynamo origin. A two-way coupling between the ionosphere and neutral atmosphere is implemented that allows for the reproduction of both the impact of the lower atmosphere on the ionospheric plasma and the impact of the ionosphere on the neutral atmosphere (including the impact of geomagnetic storms on the thermosphere).

Special attention in the presentation will be given to the description of the open modular structure of the C-IAM. This structure allows to easily upgrade the modelling system by replacing the current components with newer more advanced models for either atmosphere or ionosphere or both. It also provides ability to integrate into the modelling system additional schemes of different atmospheric processes or use real observation data as the model input. In addition to the first principles modelling blocks, the C-IAM includes as an alternative option the empirical models (e.g., MSISE) which can be used for specific studies for switching on and off different processes and feedbacks to study their role in the atmosphere. Also in order to reproduce the response to specific space weather events, the model has an option to accommodate the real (observed by SuperDARN) high-latitudinal electric field distribution.

To demonstrate the model ability some results are to be presented, including modelling of night-time and day-time ionospheric emissions and atmospheric density along the satellite path.

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Vertical coupling processes simulated by a whole atmosphere-ionosphere coupled model GAIA

Abstract:

It has been recognized that upward propagating atmospheric waves from the lower atmosphere play an important role in the general circulation in the thermosphere-ionosphere. Whole atmospheric models are useful tools for studying the vertical coupling processes between the lower and upper atmospheres. As one of whole atmospheric models, we have developed a whole atmosphere-ionosphere model called GAIA. GAIA consists of three different models: a general circulation model of the neutral atmosphere, an ionosphere model and an electrodynamics model. In this presentation, we introduce GAIA, and show some results concerning the vertical coupling processes. In particular, we show behaviors of upward propagating tides and gravity waves from the lower atmosphere to the upper atmosphere, and their impacts on the momentum budget in the thermosphere. Moreover, we show variability of the ionosphere caused by these upward propagating waves through the interaction processes between the plasma and the neutrals. Finally, we discuss future development of GAIA.

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Ionospheric and cosmic ray variations coupled with stratospheric modes in middle latitudes

Abstract:

The study is based on the analysis of atmospheric and space weather parameters in the midlatitude region (Iberian Peninsula). The principal component analysis was applied to sets of air temperature and geopotential height measurements at different pressure levels from a near-ground level to the stratosphere. The analysis of extracted modes shows couplings between atmospheric and medium-term variations (from weeks to months) of space weather parameters.

The first mode of the atmospheric variability is related to the atmospheric dynamic processes that are common for the extratropical Northern Hemisphere. Extracted temperature and pressure variations are located in the upper troposphere-lower stratosphere region and positively correlated with the ozone content. Regarding the space weather parameters, this atmospheric mode shows a statistically significant negative correlation with the ground-measured cosmic ray flux measured by the Castilla-La Mancha neutron monitor (Spain) and weaker or no correlation with geomagnetic parameters.

The second mode, located in the low and middle stratosphere, is positively correlated with middle-stratospheric ozone content. Among locally measured space weather parameters, this atmospheric mode negatively correlates with the ground-measured horizontal geomagnetic field component and the ionospheric total electron content. The stratospheric-ionospheric coupling was tested both with correlation and regression analyses, as well as with the convergent cross mapping analysis allowing estimation of the causal relations between the parameters.

*O.O. Odeyemi *(1)*

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Investigation on Slab-Thickness and B0 over an Equatorial Station in Africa and Comparison with IRI Model

Abstract:

The present study investigates the simultaneous morphologies of slab-thickness (τ) and thickness parameter (Bo) over Ilorin (8.50N, 4.68E; dip lat. 2.95) an equatorial station at low solar activity (2010). The τ is deduced from global positioning system total electron content (GPS-TEC) and F2 peak electron density (NmF2) from digisonde portable sounder (DPS). The use of measured TEC for this type of investigation takes care of the inclusion of plasmaspheric electron content (PEC). The PEC distribution on the topside and bottomside electron density (Ne) profile add considerably to the genuine signatures of τ and Bo. Therefore, the dynamic contributions of the PEC need to be emphasized for the accurate prediction of the ionospheric models. Apart from daytime signatures of the τ and Bo that are not primarily influenced by PEC, we found that between two to three hours of pre-sunrise and dusk periods are mainly controlled by PEC that evolved as huge peaks in the τ and Bo. Also, our investigation reveals that the Bo profile is thicker than the τ profile during the pre-sunrise in June which may indicates partial flow or halt of PEC. The result revealed approximately the same values of τ and Bo around the sunrise period that may be due to the absence or small PEC contributions. Our investigation also showed that there is maximum and minimum of the thickness in Bo and τ during the December solstice and June solstice, respectively. We also observed a moderate sunrise enhancement in τ that is not conspicuous in the Bo signature. On the relationship between the τ and Bo, we found a significant association between τ and Bo with the highest coefficient value observed during the June seasons that indicates the possible prediction of τ in the absence of Bo or otherwise, especially during the June season that revealed the most significant relationships in τ and Bo. The validation of International Reference Ionosphere (IRI) model with observed τ and Bo revealed appreciable discrepancies between the model and observed values, particularly between the IRI-τ and observed τ values that indicates a higher percentage of changed difference in all hours of the months. Our result in November and December revealed the underestimation of IRI-τ with respect to observed τ value as reported in the validation of IRI-τ in all regions.

N. M. Pedatella (1), H.-L. Liu (1), D. Marsh (1,2), J. Liu (1), K. Raeder (3), and J. Anderson (3)*

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Whole Atmosphere Data Assimilation in WACCMX+DART

Abstract:

The recently developed Whole Atmosphere Community Climate Model eXtended version (WACCMX) extends from the surface to the upper thermosphere (~500 km), including a fully coupled ionosphere with self-consistent electrodynamics. We have implemented the capability to perform data assimilation in WACCMX using the Data Assimilation Research Testbed (DART) ensemble Kaman filter. This enables the seamless assimilation of observations from the troposphere to the thermosphere in order to specify, and forecast, the state of the whole atmosphere-ionosphere system. This presentation will provide an overview of WACCMX+DART, with a focus on initial results that demonstrate the capability of WACCMX+DART to specify and forecast the middle and upper atmosphere variability during the 2009 sudden stratospheric warming, as well as the relative impacts of lower-middle atmosphere (0-100 km) and ionosphere (100-500 km) observations on upper atmosphere specification. The challenges in developing a whole atmosphere-ionosphere data assimilation system will also be discussed.

J. M. C. Plane (1), W. Feng (1,2), D. R. Marsh (1,3), C. S. Gardner (4)*

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(4) *) University of Illinois, USA*

Developments in MLT Chemistry

Abstract:

This presentation will discuss a number of key chemical constituents in the MLT which provide important constraints for vertical transport in whole atmosphere chemistry-climate models, a major consideration in the context of space weather. Four chemical "families" will be discussed: the meteoric metal layers, atomic O and O_3, NO, and CO/CO_2. Layers of metal atoms – Na, Fe etc. – occur between 80 and 105 km as a result of the ablation of cosmic dust particles. The metal layers therefore sit at the boundary between the atmosphere and geospace. Since many of the relevant chemical reactions of these metals have now been studied in the laboratory, capturing the metal layer peak heights and top and bottom scale heights – which are measured precisely by the lidar technique - is a constraining challenge for a model. Furthermore, the vertical fluxes of Na and Fe atoms have recently been measured for the first time, and there have also been advances in determining the injection rates of the metals from meteoric ablation. This mean that the rate of vertical transport in these models – through eddy diffusion and wave-induced chemical/dynamical transport – can also be tested, and appears to be substantially underestimated, perhaps by a factor of 5. Vertical transport also affects species such as O and NO which are mainly produced in the lower thermosphere by photochemistry and energetic electrons – these species play a very important role in the radiative balance of the MLT either directly, or through chemiluminescent reactions contributing to the airglow. Finally, observations of the vertical profiles of relatively heavy CO_2 and its photochemical fragment CO provide another very useful test case of vertical transport in the MLT.

F. Sassi*(1), S.E. McDonald(1), J.P. McCormack(1), J.T. Emmert(1)

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NRL's ground-to-space atmosphere-ionosphere prototype for R&D

Abstract:

We introduce the Navy-Highly Integrated Thermosphere Ionosphere Demonstration System (Navy-HITIDES) developed at the Naval Research Laboratory (NRL) as a prototype of next generation whole atmosphere-ionosphere coupling for US Navy applications. Navy-HITIDES interfaces a state-of-the-art 3-dimensional, physics-based ionospheric model (the NRL Sami is Another Model of the Ionosphere) to a whole atmosphere model to study the effects of the atmospheric weather on the ionosphere. Navy-HITIDES uses the Earth System Modeling Framework (ESMF) for efficient regridding between the atmosphere and the ionosphere, and implements an NRL-developed algorithm to extend neutral atmosphere fields to the whole ionosphere above the exobase. We illustrate some applications of Navy-HITIDES in which the effects of the day-to-day meteorology are provided by atmospheric specifications (0-90 km) generated by the prototype High Altitude Navy Global Environmental Model (HA-NAVGEM), which are used to constrain a whole atmosphere model to the weather of the day. We discuss the role of winds and composition in determining the day-to-day variability of the ionosphere, and the extent to which dynamical and physical drivers influence the variability of the upper atmosphere from days to seasonal scales. Future directions in whole atmosphere modeling at NRL will also be presented.

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Characterising and understanding temporal variability in ionospheric flows using SuperDARN data

Abstract:

The ionosphere links the atmosphere to the Earth's magnetosphere and the interplanetary medium. Measurements of ionospheric flows can be used to infer the electric fields and can have varying drivers, ranging from external drivers, such as the solar wind, to internal drivers, such as substorms in the magnetosphere. The Super Dual Aurora Radar Network (SuperDARN) have been observing ionospheric flows at Earth near the geomagnetic poles for decades. Doppler-shifted signals provide us with line-of-sight measurements of ionospheric velocities from the high frequency radar network. To produce global maps of ionospheric flows the SuperDARN line-of-sight measurements are gridded and have spherical harmonic functions fitted to them. A baseline model, categorised by grouping the data by the interplanetary magnetic field (IMF) conditions, is used to fit to patchy data to obtain global maps of convection. As the solar wind is highly variable and due to the dynamics in the Magnetospheric Ionospheric and Thermospheric system, the ionospheric flows can also vary significantly with respect to the convection models. Thus, it is important to isolate and study the variability in the flows to be able to produce improved convection maps. In this work, we look at the temporal variability in the SuperDARN line-of-sight velocities, to be able to build our understanding of what controls temporal variability of the ionosphere system and how we can minimise variability in future models. By studying data intervals of varying interval length and solar wind conditions, we find that the temporal variability can vary by almost 1 km/s, even when IMF conditions stay constant and models would predict the ionospheric convection only to vary marginally. We use statistical methods to try to start building a better understanding of what drives the variability on small temporal scales.

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Modeling the Magnetosphere-Ionosphere System for WAM Applications: Challenges and Opportunities

Abstract :

First-principles-based numerical modeling of the magnetosphere-ionosphere system has proven to be a reliable and powerful way to understand the nonlinear M-I system. At the forefront of this field are 3D magnetohydrodynamic (MHD) models coupled to height-integrated ionospheric electrodynamic codes. The MHD approach has yielded innumerable new insights into the M-I system and is now employed in space weather operations. MHD simulations of the magnetosphere-ionosphere system can provide valuable inputs to Whole Atmosphere Models (WAMs), including ionospheric electric potentials, field-aligned currents, and more. The advantage of using these models is that they are capable of producing dynamic ionospheric conditions that are self-consistent with the solar wind-magnetosphere interaction.

This presentation reviews the current state-of-the-art of MHD modeling of the M-I system with a focus on providing inputs to WAMs. The strengths and weaknesses of this approach are reviewed, including challenges and shortcomings when MHD output is used for WAMs. Techniques for improving ionospheric parameters, such as precipitation and electric field, will also be reviewed. Focus will be placed on the University of Michigan's Space Weather Modeling Framework (SWMF) and ongoing efforts to couple to NOAA's Whole Atmosphere Model coupled to the Ionosphere-Plasmasphere-Electrodynamics model (WAM-IPE).

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Quasi-6 day wave effects on the equatorial ionosphere

Abstract :

The equatorial ionosphere is subject to large day-to-day variability but the source of the variability is not well understood. We examine the day-to-day variability of the equatorial electrojet derived from the magnetic measurements by the Swarm and CHAMP satellites. We find that there are occasionally times when the intensity of the equatorial electrojet shows an oscillatory variation with a period of approximately six days. The spatial and temporal variability of the equatorial electrojet intensity during these events reveals characteristics of a westward-propagating wave with zonal wavenumber 1, which can be explained as the effect of the quasi-6 day planetary wave. The observed modulation of the equatorial electrojet is greater than what is previously predicted by a model simulation.

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Tidal Variability in the Whole Atmosphere Models

Abstract:

The paper presents analysis of tidal variability as simulated by two whole atmosphere models, WAM and WACCM-X. To perform the model-data comparisons for given day (month) of the year, simulations were constrained by the meteorological analyses of NASA/GMAO in the lower atmosphere. Both models reproduce the main features of the day-to-day, annual and year-to-year variability of diurnal and semidiurnal tides, as deduced from the multi-year (2009-present) space-borne observations. In the Mesosphere and Lower Thermosphere (MLT), sensitivity of the mean flow and tidal dynamics to the model gravity wave physics are examined. Sensitivity of model results highlights needs for space-borne wind observations to perform adequate evaluation and tune-up of gravity wave model physics and carry out wind data assimilation studies in the middle atmosphere. The role of current satellite temperature observations (MLS and SABER) to constrain WAM tidal predictions are evaluated in the assimilation case studies. The influence of the mid-winter Sudden Stratospheric Warming (SSW) on the MLT tides and planetary waves will be discussed and compared with the observed variability of wave dynamics in the MLT after the onsets of recent SSW events.