2014 Workshop: Coupling and Transport Processes

Long title
Grand Challenge: Coupling and Transport Processes from the Upper Mesosphere through the Middle Thermosphere (80-200 km)
Grand Challenge
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Description

The workshop is being proposed as a Grand Challenge Workshop and the description of the workshop is articulated in that section.

Justification

Challenges:

What is the role of the neutral gas in coupling with the plasma to establish the predominant state of the Earth's upper atmosphere and ionosphere between 80 and 200 km?

How do wave-induced transport and turbulence influence the structure, composition and circulation of Earth's upper atmosphere between 80 and 200 km?

Significance

The natural upward extension of the Earth's atmosphere ultimately leads to its interaction with space above 50 km altitude, where atmospheric neutral gasses become entwined with the dynamic plasma of space. This space-atmosphere-interaction region (SAIR) is common to all planetary systems, yet its properties, and the processes that govern them, are not sufficiently described to fully understand its role in an atmosphere's development and evolution. The least understood and sparsely observed are the properties of the thermosphere neutral gas between 100 and 200 km. This middle thermosphere region is a controlling factor in many important processes of the upper atmosphere. Unfortunately, there is no set of observations that adequately captures the neutral gas properties in this region, however, whole atmosphere model simulations have begun to illustrate the importance of understanding this region. This Grand Challenge Workshop will focus on establishing the measurements, theory, and modeling of the neutral gas needed to address a broad class of processes in the 80-200 km region. To provide focus, the Workshop will concentrate on two processes that have profound effects on planetary atmospheres everywhere and, in particular, on Earth; 1) Plasma-neutral atmospheric coupling and 2) wave-induced transport and turbulence.

The principal scientific goals of this Workshop are consistent with the goals and recommendations of recent community scientific surveys and strategic plans.

National Research Council 2013-2022 Decadal Strategy for Solar and Space Physics; A Science for a Technological Society

The Workshop addresses primarily Key Science Goal #2 in the NRC report: Key Science Goal 2. Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.

However, two of the other three goals are relatable: Key Science Goal 1. Determine the origins of the Sun's activity and predict the variations of the space environment. Key Science Goal 4. Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe.

In addition, the Workshop goals are consistent with four of the scientific goals identified by the NRC Panel on Atmosphere-Ionosphere-Magnetosphere Interactions (AIMI). They are:

AIMI Science Goal 1. Global Behavior of the Ionosphere-Thermosphere: How does the IT system respond to, and regulate magnetospheric forcing over global, regional and local scales?

AIMI Science Goal 2. Meteorological Driving of the IT System: How does lower atmosphere variability affect geospace?

AIMI Science Goal 3. Ionosphere-Thermosphere-Magnetosphere Coupling: How do high-latitude electromagnetic energy and particle flows impact the geospace system? What are the origins of plasma and neutral populations within geospace?

AIMI Science Goal 4. Plasma Neutral Coupling in a Magnetic Field: How do neutrals and plasma interact to produce multiscale structures in the AIM system?

CEDAR: The New Dimension, Strategic Vision for the NSF Program on Coupling, Energetics and Dynamics of Atmospheric Regions [May 2011]

The Workshop is highly relevant to the NSF Coupling Energetics and Dynamics of Atmospheric Regions (CEDAR) program. The new CEDAR strategic vision, released in 2011, focused on the science of the space-atmosphere-interaction region and advocated the development of a systems perspective to study this region. The Workshop contributes directly to the first four of the CEDAR Strategic Thrusts.

Strategic Thrust 1. Encourage and undertake a systems perspective of geospace to understand global connectivities and causal relationships involving the SAIR and to determine their influences on the interaction region and the whole Earth system.

Strategic Thrust 2. Explore exchange processes at boundaries and transitions in geospace to understand the transformation and exchange of mass, momentum and energy at transitions within the ITM and through boundaries that connect with the lower atmosphere and the magnetosphere.

Strategic Thrust 3. Explore processes related to geospace evolution to understand and predict evolutionary change in the geospace system and the implications for Earth and other planetary systems.

Strategic Thrust 4. Develop observational and instrumentation strategies for geospace system studies capable of measuring system properties necessary to examine the coupling mechanisms and complexity within the SAIR.

Because the Workshop will include upper atmospheric dynamicists and chemists, and planetary aeronomers who will employ both observations and other correlative datasets and models to address the key scientific questions, the Workshop also contributes indirectly to the two remaining strategic thrusts.

Strategic Thrust 5. Fuse the knowledge base across disciplines to promote collaborations. Strategic Thrust 6. Manage, mine and manipulate geospace data and models to tap the vast resources of burgeoning geospace data.

(1) How will questions be addressed

o Theory o Whole Atmosphere Simulation o Observations

(2) What resources exist, are planned, or are needed

Presently whole atmosphere models are simulating the behavior of the middle thermosphere including lower atmosphere influences. These simulations will serve to guide the discussions of requirements.

Observations of plasma phenomena in this region will help establish the plasma structure that possibly relate to neutral gas behavior. Often radar measurements of plasma are used to infer neutral properties.

Observations of middle thermosphere neutral gas properties are desperately needed. Presently limited capability exists through airglow measurements.

(3) How progress is to be measured

Progress will be measured by: o establishing a set of science goals that are most pressing for middle thermosphere research – the first of its kind. o developing a traceability matrix that aligns the science requirements with the measurement expectations (existing and planned) o planning observing campaigns and develop new strategies to advance this area of research.

It has long been recognized that plasma-neutral coupling and wave- and turbulence-induced transport play major roles in establishing the structure, composition and circulation of the upper atmosphere. However, the lack of observational data of middle thermosphere neutral gas properties has severely limited progress in understanding and characterizing the impact of these processes, which in turn, has inhibited the advancement or verification of global circulation models of the upper atmosphere. Because of the relative inaccessibility of the near-space environment, the interaction of the upper atmosphere with space is not well-described, nor are its influences on the lower atmosphere understood well enough to incorporate them in weather and climate models. This Grand Challenge Workshop will help focus efforts of the community to acquire the necessary observations and improve existing models by characterizing these processes and their effects in the Earth’s upper atmosphere. Observations of the middle thermosphere neutral gas properties are critical and need advancement beyond inferences and single altitude estimates. Science issues that require further investigation of the middle thermosphere neutral properties include: thermosphere mixing of composition, vertical shear in horizontal winds, gravity wave propagation and dissipation, sporadic E-layer formation, plasma instabilities, heat conduction, and Joule heating, to name a few.

Recent observations by metal lidars at several sites have demonstrated the potential for measuring neutral winds and temperatures well into the middle thermosphere. By making similar lidar observations at incoherent scatter radar sites, simultaneous measurements of the dynamical and thermal properties of both the plasma and neutrals are possible. This capability would enable empirical studies of plasma-neutral coupling to be conducted for the first time. Similarly, radars have been used to characterize wave transport of horizontal momentum by measuring gravity wave momentum fluxes, while lidars have measured gravity wave momentum, heat and constituent fluxes. More powerful, high-resolution lidars are potentially capable of also measuring eddy, heat and constituent fluxes. All of these transport processes have profound effects on the structure, composition and circulation of the upper atmosphere. This Grand Challenge Workshop will identify the key scientific questions and the critical observations and instruments needed to address them. This will require several years to properly organize and prioritize the science goals, develop the required measurements, and execute the necessary observations and interpret the results.

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