2021 Workshop: AIM Coupling at High Latitudes

Long title
AIM Coupling Studies at High Latitudes Inspired with Lidar Observations
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Description

The 10 years of McMurdo lidar observations in Antarctica since December 2010 have led to many eye-opening discoveries in the space-atmosphere sciences. Besides the thermosphere-ionosphere metal (TIMt) layers and persistent gravity waves, a recent surprising finding is the large downwelling vertical winds below 90 km during the middle of Antarctic winter. The mean vertical winds on the order of m/s are about 1-2 order of magnitudes larger than traditionally expected by general circulation models. However, the highly elevated temperatures, enhanced Na and Fe layer densities, downward shifted Na and Fe layer peak altitudes, and clear gravity wave signatures with full spectrum as well as the measured heat and Na fluxes are self-consistent with the observed downwelling winds. Therefore, the lidar observational results pose significant challenges to our current understandings of the residual/general circulation, wave drag and sources, and plasma-neutral coupling as well as the ionospheric, magnetospheric, and solar wind drivers to the mesosphere and lower thermosphere (MLT) region. Furthermore, an interesting question is whether such large downwelling vertical winds do not take place in the Arctic, which is possibly related to inter-hemispheric differences.

This workshop solicits presentations focusing on the high-latitude general circulation, neutral dynamics, and electrodynamics that may help interpret the abnormally large vertical winds, persistent gravity waves, and TIMt layers. We welcome numerical modeling that can help understand the observations, especially on the aspects of general circulation, multi-step wave coupling, and AIM coupling along with the underlying physics. We also welcome data showing driving forces from above and from below, including neutral winds, temperatures, and wave fluxes

as well as ionospheric and solar wind observations (such as current systems, ion convection, aurora, etc.). Presentations on inter-hemispheric differences are encouraged.

Agenda

1. (Invited) Transport of NOx into the top of polar vortex (Lynn Harvey -- 10+2 min)

2. Vertical fluxes and transport velocities of heat, Na, energy, and enthalpy at McMurdo (Xinzhao/Chet -- 10+2 min)

3. Gravity wave activity in the southern winter hemisphere as simulated with the nudged HIAMCM (Erich Becker -- 10+2 min)

4. Implementing a new method of photon-noise bias elimination for lidar data (Jackson Jandreau -- 10+2 min)

5. MJO modulation of wind and GWs in the NH polar region, and does it propagate to the E-region? (Jintai Li -- 10+2 min)

6. Using machine Learning to Understand Weather of the Middle and Upper Atmosphere (Rich Collins -- 8+1 min)

7. A machine learning convection climatology based on SuperDARN observations (Bill Bristow -- 10+2 min)

8. Multi-Resolution Data Assimilation Model (Lattice Kriging) for High-Latitude Aurora and Electric Field (Haonan Wu -- 10+2 min)

9. An update on simulating the strong neutral responses during 2015 St. Patrick’s Day Storm using electric field assimilation (Xian Lu – 5+1 min)

10. 10 years of PMC observations at McMurdo, Antarctica (Arunima Prakash -- 8+1 min)

11. Investigating interhemispheric asymmetries with geomagnetic field response in high latitude regions (Zhonghua Xu -- 10+2 min)

12. Measurements of the meridional advective acceleration and the modified Coriolis parameter in the E-region during different geomagnetic activity (Rafael Mesquita -- 10+2 min)

Justification

This workshop aims to bring experimentalists, modelers, and theoreticians together to reveal gaps in our current understanding of some key issues in the field, and to bridge the neutral atmosphere communities with the ionosphere and magnetosphere communities to tackle these gaps and some fundamental science questions.

Challenges:

1) How to understand the abnormally large vertical winds observed at McMurdo? What new understandings can be gained on the residual/general circulation by collaborative studies of such discovering observations with high-resolution modeling?

2) What are the wave contributions to the constituent, heat, and momentum transport? What new aspects of wave drag and sources do persistent gravity waves reveal?

3) What are the roles of AIM coupling in shaping the compositions and structures in the space-atmosphere-interaction region and their responses to geomagnetic and solar activities?

4) Besides the known differences in polar vortex, are there other inter-hemispheric differences in the middle and upper atmosphere between the Arctic and the Antarctic? Are the larger-than-expected downwelling vertical winds something special in Antarctica?

Significance and fit with the decadal survey and strategic plan:

The high-latitude space environment is tightly coupled to the magnetosphere, and continuously perturbed by the lower-atmosphere waves. The coupling between the magnetosphere, ionosphere plasma, and neutral thermosphere, and the wave coupling among different atmosphere/space regions makes it challenging to fully describe and understand its behavior. Two major roadblocks are the starvation of sufficient observations that measure the neutral gas and plasma properties in large ranges with adequate accuracy, resolution and overlap, and the lack of coordinated studies of observations with various instruments, data analyses and numerical modeling. Lidar measurements provide new insights and opportunity to refine our traditional understanding. This joint CEDAR workshop will encourage the community

to help tackle these issues by which to advance our understanding of the AIM coupling at high latitudes.

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

The Workshop helps address two of the four key scientific goals articulated in the NRC report. They are:

Key Science Goal 2. Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.

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.

How the questions will be addressed? • Cutting-edge observatories • Observations and data analyses with unprecedented capabilities • Coordinated observations with multiple instruments • Coordinated studies of numerical simulations and data analyses • Technology innovations to push the detection limits

What resources exist, are planned, or are needed Recent years several lidar-centered observational campaigns, magnetosphere-ionosphere observational chains, and lidar- and radar-involved multi-instrument observational campaigns have been conducted or are ongoing worldwide. Excellent data have emerged or are emerging. Numerical models and empirical models are being developed with promising results produced. New technologies are being actively pursued and more ideas are emerging.

Progress will be measured by: • Analyzing the existing and new observational data creatively, in collaboration with advanced numerical modeling • Publishing new science findings and understandings into journal papers • Sharing new ideas of technologies and producing new observational capabilities • Planning observing campaigns and developing new strategies to advance this area of research

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