# 2019 Workshop: Polar Workshop

Long title
Polar GeoSPARO for AIM Coupling, Neutral Dynamics, and Cosmic Dust
Conveners
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Description

This workshop aims to bridge the neutral atmosphere communities with the ionosphere and magnetosphere communities, and brings experimentalists, theoreticians, and modelers together to tackle fundamental science questions and make new paths for the future.

1) What are the roles of neutral atmosphere-ionosphere-magnetosphere (AIM) coupling and wave dynamics in shaping the compositions and structures in the space-atmosphere-interaction region and their responses to geomagnetic and solar activities?

2) What new aspects of the source, propagation and dissipation schemes of the atmospheric waves can be revealed by collaborative studies with observations and modeling? What new understandings can be gained on the general circulation?

3) What is the influx magnitude, velocity and mass distribution of the global cosmic dust and how does the cosmic dust impact the Earth’s atmosphere and space environment?

4) What functionality is needed for the polar GeoSpace Physics and Atmospheric Research Observatory (GeoSPARO) to transform sciences in the next 30-50 years?

Recent years several lidar-centered observational campaigns, network of airglow imagers, magnetosphere-ionosphere observational chains, various radar installations, and coordinated campaigns with rockets and ISR have been conducted or are ongoing worldwide including Antarctica and the Arctic. New and exciting data are being provided to the CEDAR science community with unprecedented coverage,

precision and resolution. Combined with modeling efforts, these studies allow for the characterization of the Atmosphere-Ionosphere-Magnetosphere (AIM) electrodynamic and neutral dynamic processes on spatial scales from meters to hundreds of kilometers and temporal scales from seconds to days. Collaborative studies among lidar, airglow imager, rocket, radar, Fabry-Perot interferometer, ionosonde, magnetometer, riometer, etc. and with satellite measurements have provided new potentials for multi-dimensional studies of the global upper atmosphere and space. Numerical models of general circulation, meteoric metal layers, atmospheric waves, turbulence, and AIM couplings as well as the development of empirical geospace models provide good tools for CEDAR community to tackle science questions together.

One of the exceptional examples is the unprecedented datasets collected at Arrival Heights near McMurdo, Antarctica. Profiling of the neutral atmosphere from near the surface up to ~200 km with lidars, along with other optical and radio remote sensing observations, opens a new door to explore the space-atmosphere interactions. The discovery of persistent gravity waves, assisted by theory and modeling, has unraveled a big picture of vertical coupling of Antarctic waves and urged the community to re-evaluate the importance of secondary wave generation to the mean circulation and energy budget of the polar atmosphere. The strong correlation between the thermosphere-ionosphere Fe (TIFe) layer occurrence and solar wind indices hints on the deep coupling from the magnetosphere to the lower thermosphere. The strong diurnal temperature variation in the polar E-region manifests the impacts of ion drag on neutrals and the tight neutral-ion coupling. Therefore, it is fair to state that Arrival Heights is a unique location from scientific point of view as it provides an exceptional window at the edge of polar cap and auroral oval, and is also a gravity-wave hotspot in the Antarctic. However, the current research infrastructure at Arrival Heights is woefully inadequate, placing serious constraints on both the types of instruments that can be deployed and the types of observations that can be accommodated. It is time for the community to push forward a modern spacious research laboratory at Arrival Heights for hosting sophisticated lidar, radar, optical and radio sensing instruments to acquire crucial data such as wind, temperature, electron density, ion composition, and chemical constituent profiles. The data are essential to address key science topics such as 1) space weather research, 2) climate change in the middle and upper atmosphere, and 3) cosmic dust research.

This workshop will provide a platform for the newest observational and modeling results to be discussed, stimulating new science collaborations among experimentalists, theoreticians, and modelers, and seeking new science paths. We would like to invite the input from the community on how to tackle the fundamental science questions and on the desired functionality of the polar GeoSPARO facility and fusing them into a future plan.

Agenda

**Thursday Morning (10am-12pm) @ Zia/Eldorado, chaired by Dr. Zhonghua Xu**

1) **Xinzhao Chu** (15 min), PRIC's Na Doppler lidar at Zhongshan Station in Antarctica / Arrival Heights GeoSPARO / Neutral metal layers in the Antarctic E-F regions

2) **Bill Bristow** (7), Observations of small-scale convection features in the central polar caps

3) **Zhonghua Xu** (14), Multi-instrument studies of a TIFe layer case: Implications for impacts from magnetosphere-ionosphere coupling

4) **Sharon Vadas** (15), Tertiary gravity waves in the wintertime mesosphere and thermosphere over McMurdo Station

5) **Haonan Wu** (14), A mechanism study of large temperature enhancement and inversion layers in the E-region during geomagnetic storm

6) **Astrid Maute** (14), Electrodynamics and current at low, middle and high latitudes

7) **Boyi Wang** / Toshi (14), Dynamics of electron precipitation and the ionospheric responses obtained by ground-based measurements

8) **Kshitija Deshpande** (12), Investigating the Ionospheric Irregularities during Substorms observed over Antarctic Plateau

9) **Jiaen Ren** / Shasha Zou (5), Multi-scale Observations of High-Latitude Ionosphere Plasma Transport During Oct. 12, 2016 Geomagnetic Storm

10) **Zihan Wang** /Shasha Zou (5), Storm-Enhanced Density (SED) Formation and Structuring During the September 7, 2017 Geomagnetic Storm

11) **Andy Gerrard** (5), Antarctic Science Horizon Scan

**Thursday Afternoon (4-6pm) @ Zia/Eldorado, chaired by Dr. Xian Lu**

1) **Qian Wu** (15 min), NCAR FPIs in the Antarctic and Arctic Regions

2) **Mike Taylor** (15), Antarctic Gravity Wave Instrument Network (ANGWIN) overview and highlights

3) **Larisa Goncharenko** (10), Observations of pole-to-pole, stratosphere to ionosphere connection

4) **Yucheng Zhao** (14), Initial Fe lidar and AMTM mesospheric temperature comparison from McMurdo

5) **Zhuoying Chen** (6), Possible link of gravity wave potential energy density (Epm) at McMurdo to QBO

6) **Xian Lu** (12), Quasi-biennial oscillation (QBO) and solar cycle variations of polar gravity waves and barotropic/baroclinic planetary waves

7) **Ken Zia** (14), Multiple “frontal” events over Alaska

8) **Liying Qian** (10), WACCM-X simulation on long-term trend and solar cycle

9) **Maosheng He** (14), Wavenumber diagnosis of mesospheric global-scale waves over arctic with a dual-radar configuration

10) **Erich Becker** (10), Quick updates on High-resolution KMCM

Justification

**Challenges:**

1) What are the fundamental processes that shape the Earth’s geospace and atmospheric environment and govern its evolution, enabling the Earth to support and harbor life in the last 3.5 billion years?

2) How do these processes affect space weather, terrestrial weather, and climate on Earth?

3) How do they shape the atmospheres of Earth-like planets throughout the Galaxy?

4) How does cosmic dust impact the Earth’s atmosphere and space environment?

**Significance and fit with the decadal survey and strategic plan:**

The coupling between the magnetosphere and ionosphere plasma and neutral thermosphere and mesosphere gas, and the wave coupling among different atmosphere/space regions lead to very complicated processes that govern the space-atmosphere-interaction region (SAIR). These processes and the states of SAIR are far from being sufficiently described and understood, but they are critical to fully understanding the whole atmosphere and to improving space weather and climate models. 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 of neutral atmosphere winds, temperatures and species in the thermosphere, mesosphere and stratosphere are critically needed, but very challenging, to complement radar observations of the plasma. This joint CEDAR workshop will encourage the community to tackle these issues through building world-class observatories, making unprecedented measurements, and conducting multi-dimension studies.

**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 and modern facilities

• 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.

Key measurements such as three-dimension neutral winds and temperatures in the region of 100-200 km and the simultaneous monitoring of plasmas in critical regions (such as transition zone of AIM coupling and gravity-wave hotspot) are needed. New observatories and modernized facilities that provide such observational capabilities should therefore be planned. The first-principle numerical models and empirical models should be planned to incorporate new observations and understanding to push for the next-generation suite of models.

**Progress will be measured by:**

• Soliciting community’s input on the desired functionality of the polar GeoSPARO facility and fusing them into a future plan

• 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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