CONNECTING OUR STAR AND OUR HOME

High Altitude Observatory
Strategic Plan 2025-2030

Abstract

The High Altitude Observatory (HAO) Strategic Plan outlines an ambitious five-year roadmap to advance solar-terrestrial physics by developing comprehensive, quantitative knowledge of the Sun-Earth connection. This plan emphasizes leadership in observational and modeling facilities, collaborative research, and the education and mentorship of early-career scientists. HAO's core objectives include improving space weather and climate forecasting, maintaining state-of-the-art observational capabilities, and fostering a diverse and inclusive workforce. Through strategic partnerships and community engagement, HAO aims to enhance scientific understanding and public awareness of the Sun's impact on Earth's atmosphere and society.

HAO Staff

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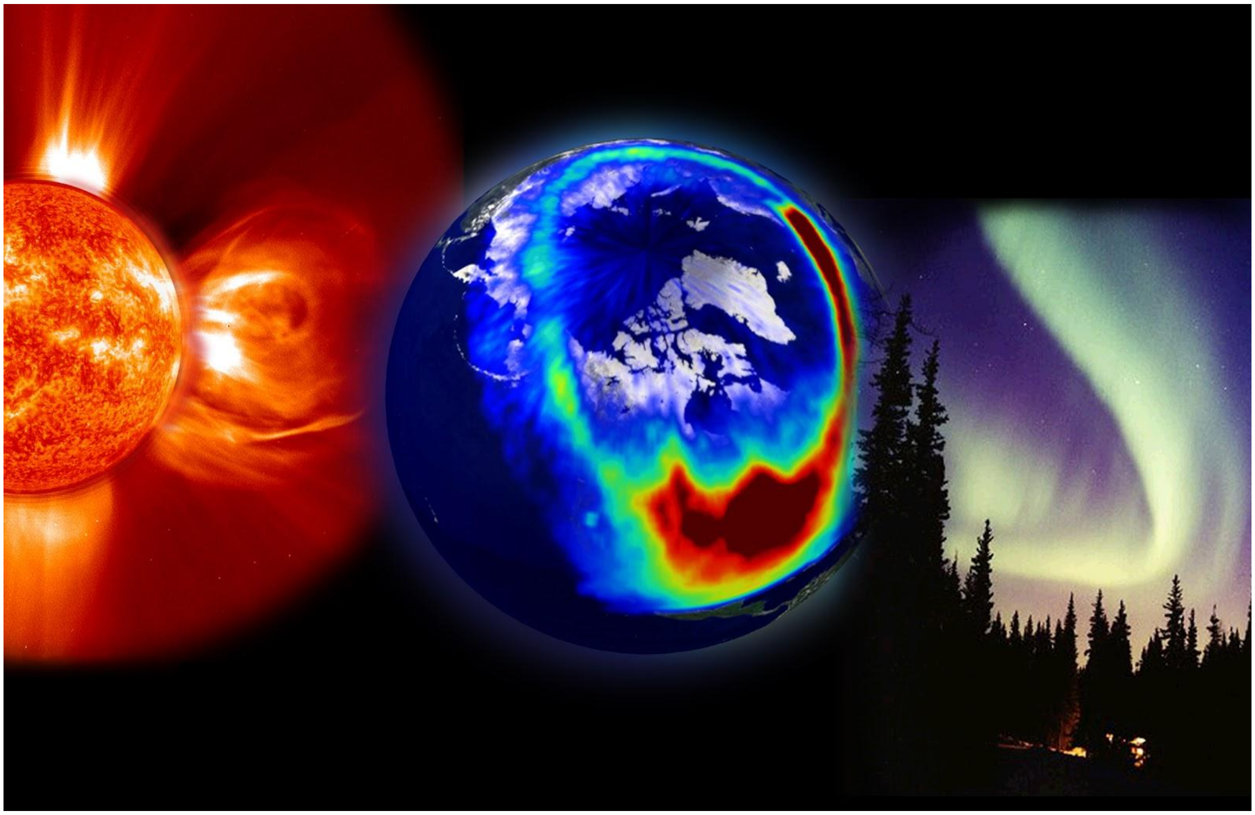


Introduction

The High Altitude Observatory (HAO) is the Solar-Terrestrial Physics Laboratory of the National Center for Atmospheric Research (NCAR). NCAR is a national institution and resource dedicated to the study of the atmosphere, the Earth system, and the Sun. The primary responsibility of HAO and the other NCAR Laboratories is to work toward the achievement of the broad goals and objectives of our sponsor, the U.S. National Science Foundation (NSF). As an NSF Federally Funded Research and Development Center (FFRDC), we share NSF's overarching goals of helping the United States uphold a position of world leadership in science and technology, promoting the transfer of new knowledge to society, and contributing to excellence in science and technology education.

Our plan will steer HAO's direction over the next five years. It outlines the objectives of a research program that is ambitious in looking to build compelling and innovative national capability in the Solar-Terrestrial Physics arena. In support of the broader community, this plan also emphasizes leadership in the development and operation of observational and modeling facilities. Our people—world-class scientists, engineers, and support staff—will achieve the objectives of this plan by continuing to work in close, synergistic relationships with the academic community. This strategic plan and its accompanying implementation plan will guide HAO's priorities, focus energy and resources, and ensure that all stakeholders are working toward common goals consistent with the missions of NCAR and NSF.

Our overarching objective is to develop comprehensive, quantitative knowledge of the processes that connect the Sun and Earth, which is critical for the NCAR mission to understand the Earth's atmosphere, near space environment, and the impacts of their evolving state on society. The scope and breadth of our activities require fundamental and applied research extending from the solar photosphere to Earth's upper atmosphere, using a combination of observational, theoretical, and numerical methods. As a national center, we support and extend the capabilities of the broader research community and will continue to strengthen collaborative activities with the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center (SWPC), the NSF's National Solar Observatory (NSO) and NASA's Goddard Space Flight Center.

HAO Mission

It is our mission to understand and quantify the impact of Solar variability on Earth's atmosphere across temporal scales. By fostering the transfer of knowledge and technology we will lead, support, enhance, and extend the capabilities of the university and broader scientific communities nationally and internationally.

HAO Vision

We will provide scientific leadership, observations, and interpretative capabilities to serve the university and broader community. In doing so we will support the engagement, education, and training of early-career scientists and provide advocacy for solar-terrestrial physics to the rest of NCAR, NSF, the university community, and the general public.

HAO Values

To achieve our objectives, it is imperative that collaborative, community-based approaches be employed. An open environment of scientific cooperation is essential to effectively develop and disseminate observational and analytical tools. We will maintain a strong visitor program and promote interactions with universities to pursue common research objectives and to train future generations of scientists. HAO will serve the community with facilities, models, workshops, leadership, education, and advocacy for solar-terrestrial physics.

HAO Culture

The asset of highest value at HAO is its staff; as such, to be part of the HAO team a high degree of excellence and professionalism is expected. HAO values high performance from its staff. This includes excellence in one's personal output as well as the expectation to perform as part of a team within HAO and its broader community, including active participation within NCAR and the University Corporation for Atmospheric Research (UCAR) when necessary.

HAO leaders do not discern value from position title or level. All staff are given the opportunity to be leaders in HAO, NCAR, and the community. HAO leaders foster a sense of belonging where all staff work hard, and all staff are valued for what they contribute to our mission. With a history spanning more than 80 years, HAO has a unique culture with a strong familial rapport between staff and welcoming environment for visitors.

HAO embodies the following shared values:

- We value a working environment that requires excellence and promotes transparency, flexibility, academic freedom, and the virtues of a healthy work-life balance.
- We value open and honest communication among our staff within a framework of respect and professional decorum. We strive to make organizational decisions that are consensus-driven.
- We value teamwork and the demonstration of mutual respect within an atmosphere of collegiality.
- We value creativity that broadens our opportunities for success, fun that enriches our time at work, and humor that enlivens our workplace.

HAO expects the following traits and behaviors of its staff:

- To conduct themselves in a manner that is supportive of each other, respectful, tolerant of differences, and responsive to both individual and collective needs.
- To carry out the responsibilities of their roles with a commitment to excellence and dedication to organizational goals and commitments.
- To maintain honesty, integrity, and openness in workplace interactions.

HAO Role within NCAR

HAO is an integral part of NCAR. HAO's role as the Solar-Terrestrial Physics Laboratory of NCAR is to look outward from the Earth, studying the coupled Sun-Earth system from the Earth's upper atmosphere through the heliosphere and solar corona down to the Sun's photosphere.

HAO needs and strives for strong ties to the remote sensing, supercomputing, and scientific laboratories of NCAR. To develop the comprehensive understanding of the coupled Sun-Earth system that is required to meet NCAR's mission, the seven laboratories of NCAR must work together. HAO's mission and vision are well aligned with those of NCAR as a whole. Indeed, there is a very close match between the strategic goals that we identify below and those articulated in the NCAR Strategic Plan:

1. Budling national resilience;
2. Understanding Earth system science;
3. Empowering the scientific community;
4. Inspiring our scientific future.

This coherent program of activities across NCAR creates multiple pathways for HAO's staff to both benefit from the experience of other NCAR staff with the result that we will grow stronger together. Such cross-lab activities are critical when trying to understand the potential impact of solar variability on our climate or how complex observational datasets can be brought to bear, "nudging" terrestrial weather models to a more accurate forecast.

HAO staff members serve on numerous NCAR committees and work in close partnership with the various education and outreach activities around the center. Notwithstanding these existing links, HAO is committed to finding further opportunities to communicate its science and vision to the rest of NCAR and to foster additional collaborations and interactions that advance NCAR's mission and benefit the wider community.

HAO Role within Solar-Terrestrial Research Community

HAO interacts closely with the broad solar-terrestrial community to carry out its mission and follow its vision. Because the scientific problems are so complex, it is imperative that collaborative, community-based approaches are employed. HAO provides a variety of services and facilities to researchers throughout the world, augmenting the capabilities of a broad array of scientific disciplines.

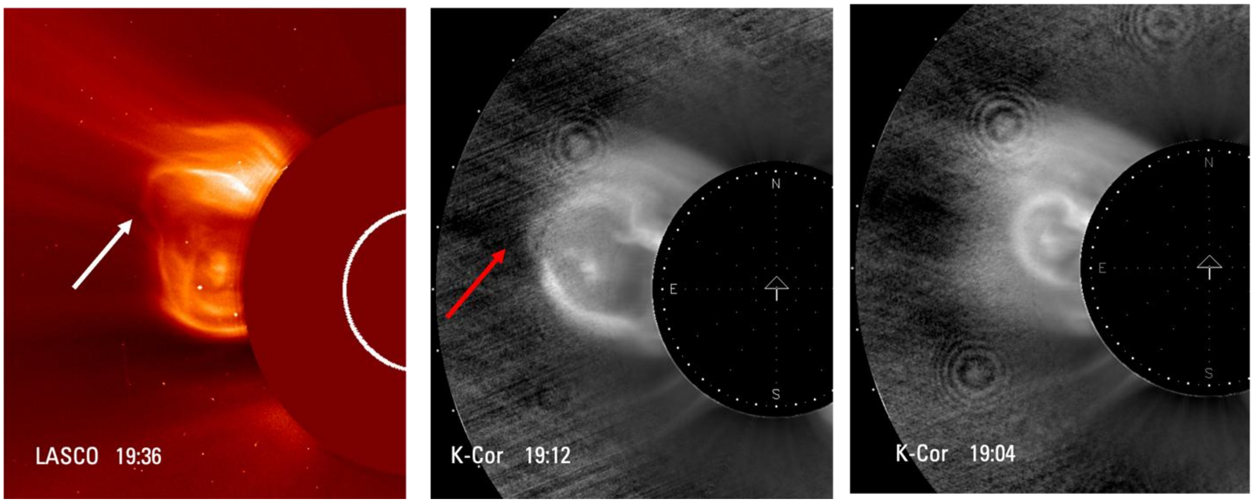
HAO supports the Heliophysics research communities by developing and maintaining community observing facilities, instruments, databases, and models. HAO's visitor program fosters essential scientific interaction, collaboration, and exchange. The scope and breadth of these activities enable the Observatory to effectively bridge gaps between diverse scientific disciplines that make up heliophysics including solar and geospace.

HAO's interactions with the national community are enhanced through the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR); Geospace Environment Modeling (GEM); Solar, Heliosphere, and INterplanetary Environment (SHINE); and Space Weather programs. We also play an active role in NASA-funded activities, such as NASA's Living With a Star (LWS) program.

HAO Role within the General Public

HAO has a vast array of stakeholders beyond NCAR and the worldwide solar-terrestrial physics community. Federal budgets are tight but there is increasing reliance on ground- and space-based technology to drive society's power, communication, and fiscal needs among others. Such technology is critically susceptible to climatic and episodic changes in solar output. However, due to the day in, day out reliability of the Sun to rise in the East and set in the West without causing any significant direct harm on us, we as a society are very complacent about our star and its undoubted capability to wreak havoc on us. It is therefore incumbent on HAO to establish itself as a national center for the communication of weather and climatological impacts of our star on our planet and its extended atmosphere to the general public in addition to the decision and policy makers.

Section 2 – HAO Opportunities and Objectives



Overarching themes of space weather and climate

HAO will focus research effort on aspects of solar variability and geospace dynamics that impact the Earth's upper atmosphere under the following cross-disciplinary themes:

- To improve understanding and forecast capability of space weather hazards and their impacts on the Earth, people, and technology.
- To characterize and evaluate the impact of solar variability on the coupled terrestrial and space climate.

By adopting these overarching themes in our strategy, it is our desire to gain better understanding of the key physical processes that can both improve and inform next-generation forecasts of *space weather*, associated hazards, and *space climate*. It is implied that the implementation plan necessary to make progress with these themes will span the disciplines of solar, heliospheric, magnetospheric, ionospheric, and atmospheric physics. Further, to advance these themes, we must maintain a state-of-the-art observationally focused program that supports concerted activities in theoretical analysis and numerical simulation.

Opportunities on the horizon

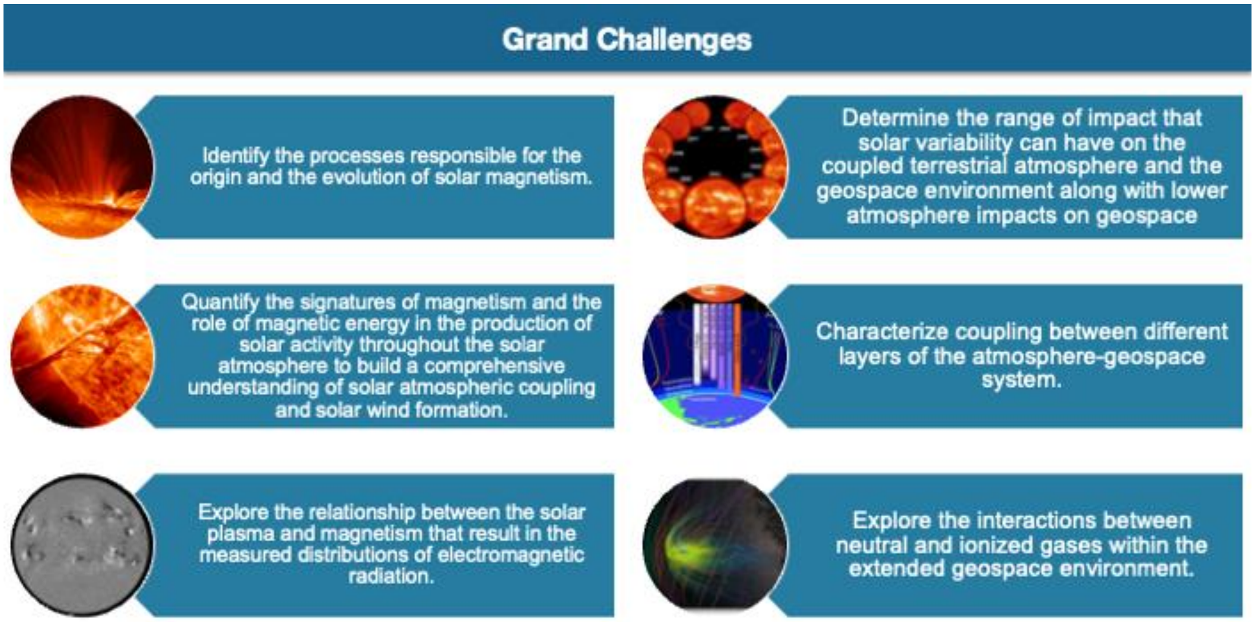
Over the five years of operation covered by this plan there will be significant opportunities to advance the standing of solar-terrestrial physics and the relentless connection between our star and our home.

The completion of the Coronal and Solar Magnetism Observatory (COSMO) concept as a next-generation solar observing facility for the geosciences will strengthen HAO's collaborations with NSO and SWPC. The novel observations made by COSMO and assimilative techniques currently under development for solar observations at HAO can be brought to bear on advancing our understanding of instabilities in solar magnetism and/or the origins of the solar wind—either of which would yield significant progress in the space weather forecast enterprise.

Leadership in space-based mission opportunities are becoming a higher priority in HAO's portfolio and new partnerships with industry, academia, and government agencies play a large role in facilitating our presence in space. We have a unique position of enhancing the synergies between ground-based and space-based solar observatories. Current collaborations include two NASA Heliophysics Small Explorer (SMEX) missions: PUNCH (launched fall 2025) and CMEx (led by HAO), selected for Phase A in 2023), the WindCube cubesat (led by HAO, selected for launch 2026), STRUVE cubesat (led by HAO selected summer 2025 and several coronagraph opportunities. Future opportunities include instrumentation on NASA MIDEX and Decadal missions as well as smaller Mission of Opportunity (MoO) missions.

The National Solar Observatory (NSO) in Boulder significantly strengthens our local community. It also presents an opportunity to push forward on collaborative activities around the Daniel K. Inouye Solar Telescope (DKIST). HAO's synoptic observing program is highly complementary to that of DKIST and NSO. We will continue to foster strong connections through the DKIST facility instrument, the Visible Spectropolarimeter (ViSP) and through the Community Spectro-Polarimetric Analysis Center (CSAC). CSAC was conceived to facilitate understanding of the complex magnetic field measurements made by HAO facility instrumentation—such instrumentation forms the basis of DKIST operations. These activities will provide opportunity to foster strong collaborations on the interpretation of multi-scale observations critical to understanding how the outer solar atmosphere is constructed and populated.

The 2023 installation of the Atmospheric Waves Experiment (AWE) on the International Space Station as well as the ongoing Global-scale Observations of the Limb and Disk (GOLD) mission continue to augment the current and future capabilities of U.S./Taiwan Constellation Observing System for Meteorology Ionosphere and Climate-2 (COSMIC-2) constellation of satellite measurements and present significant opportunities to improve our understanding of the upper atmospheric nexus of tropospheric and space weather. Development and distribution of the next-generation Whole Atmosphere Community Climate Model – eXtended (WACCM-X) to the community enables a broader understanding of ionospheric and thermospheric variability across temporal and spatial scales in concert with the observations of COSMIC, GOLD, and AWE in addition to those of potential future missions such as the Geospace Dynamics Constellation (GDC) and Dynamic Neutral Atmosphere-Ionosphere Coupling (DYNAMIC).



Grand Challenges

To improve our understanding of space weather and space climate over the next five years and beyond, we have identified the following five grand challenges that guide our strategy. Our forward-looking program will be built on the foundation of HAO's historical core strengths in spectropolarimetry, solar magnetism, and upper atmospheric numerical modeling and actively encourage participation from the national and international solar terrestrial physics communities and the other laboratories of NCAR, with an emphasis on maintaining fundamental research and developing early-career scientists.

Six grand challenges:

1. Identify the processes responsible for the origin and the evolution of solar magnetism.
2. Quantify the signatures of magnetism and the role of magnetic energy in the production of solar activity throughout the solar atmosphere to build a comprehensive understanding of solar atmospheric coupling and solar wind formation.
3. Explore the relationship between the solar plasma and magnetism that result in the measured distributions of electromagnetic radiation.
4. Determine the range of impact that solar variability can have on the coupled terrestrial atmosphere and the geospace environment along with lower atmosphere impacts on geospace.
5. Characterize coupling between different layers of the atmosphere-geospace system.
6. Explore the interactions between neutral and ionized gases within the extended geospace environment.

Goals

HAO's staff collectively considered our scientific program and set themselves the following seven goals, which all involve collaboration with the broader community:

I. Solve critical problems of solar-terrestrial physics.
II. Improve capabilities to assess space weather and space climate hazards.
III. Develop, deploy, and maintain state-of-the-art observational facilities and science data services.
IV. Advance and support sophisticated models of the Sun-Earth system.
V. Identify, develop, and transfer critical knowledge of the Sun-Earth system to the community, the public, and other stakeholders.
VI. Educate and mentor a talented group of undergraduate and graduate students.
VII. Educate and mentor a talented group of postdocs and early-career solar-terrestrial scientists.

Goal I - Solve critical problems of solar-terrestrial physics

HAO will focus on those aspects of the solar variability and geospace dynamics that impact Earth's upper atmosphere and drive space weather and space climate. To address HAO's Grand Challenges, we will explore the drivers of space weather by understanding the physical processes of magnetic flux emergence, active region evolution, and the initiation of solar eruptions such as flares and coronal mass ejections (CMEs). We will explore the solar and terrestrial drivers of space climate, including solar cycle variability and anthropogenic effects on the upper atmosphere. We will analyze the interconnections between the lower and upper atmosphere, the atmosphere and ionosphere, the magnetosphere, and solar drivers.

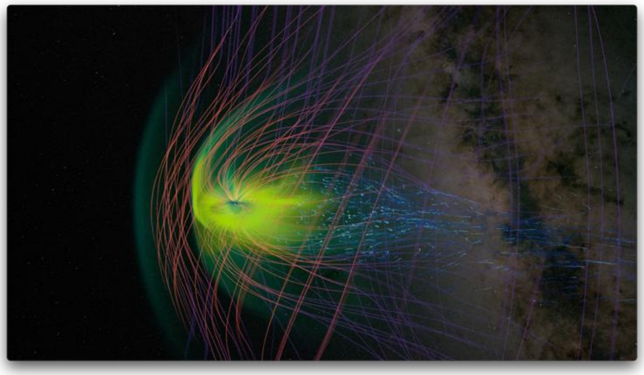
This goal will be accomplished

- in collaboration with the broader community
- by providing support and a focus for fundamental research
- to advance knowledge of the coupled Sun-Earth system

The specific objectives of this goal are:

- Investigate the physics of the solar cycle by carrying out semi-empirical parameterized 3D mean field modeling including 3D tachocline dynamics, the role of Rossby waves, and the impact on space weather.
- Advance the theory and modeling of polarized radiative transfer in the solar atmosphere for the diagnosis of magnetic and electric fields in highly dynamic plasmas via spectro-polarimetric observations (COSMO and DKIST), with a focus on inversion code/techniques and Hanle-RT (e.g., as applied to the CLASPII rocket).
- Combine observations (in particular the magnetic field diagnostics from DKIST, and the COSMO) and models, such as MHD, to understand the evolution of solar magnetism across spatial and temporal scales, including in the chromosphere. Determine the magnetic field structure and dynamics of realistic CMEs and coronal jets, providing the inner boundary conditions for heliospheric modeling of space weather.
- Advance understanding of the plasma structure in the corona.
- Advance a physical and chemical modeling infrastructure capable of addressing the connections in the globally interconnected geospace system to quantify the relative roles of forcing from the lower atmosphere and from the magnetosphere, and the Sun on the upper atmosphere.
- Combine observations with radiative MHD simulations to determine the solar spectral irradiance (SSI) variability. Use the developed insight into the SSI to quantify impacts on the coupled Sun-Earth system and compare these with the range of impacts produced by anthropogenic forcing. Use this insight to explore the climatology of the upper atmosphere and geospace environment.

Goal II - Improve capabilities to assess space weather and space climate hazards



Predicting the Sun's influence on the Earth and its atmosphere to protect our ever-evolving technological society from space weather and climate hazards is central to our role as a national science center. We will work with our colleagues throughout NCAR to adapt models in data-assimilation frameworks, so that we can build capability for timely forecast and climatological study of typical and extreme space weather scenarios. Through strategic visits and collaborations, we will connect HAO efforts with community end-to-end space weather modeling efforts. We will develop and apply HAO's novel capabilities in instrumentation, observations, models and data assimilation to space weather applications, and develop and transfer space-weather operational products to external partners and institutions. We will strive to do all these things in a manner that is based on a strong physical foundation.

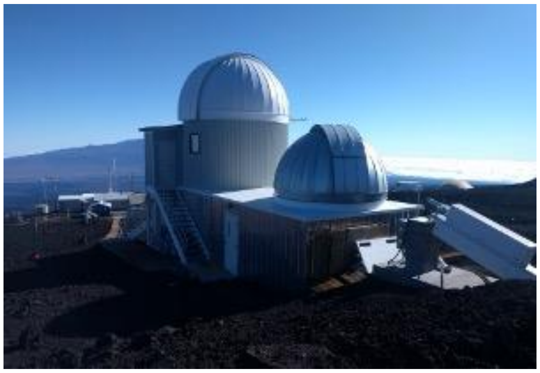
This goal will be accomplished

- in collaboration with, and for ultimate transfer to, the operational community
- by characterizing the physical state and isolating essential processes using observations, models and data assimilation
- to improve forecasting of space weather and climate hazards

The specific objectives of this goal are:

- Increase the capability of operational space-weather forecasts in collaboration with external partners.
- Utilize HAO instrumentation and observations to develop space weather forecast applications such as MLSO near real-time CME alerts and application to SEP forecasting.
- Combine HAO and community data assimilation efforts to fully utilize the potential of the Whole Geospace model/MAGE and tachocline models for space-weather prediction.
- Advance HAO's role in community end-to-end space weather modeling and generate heliospheric inputs for space and terrestrial climate models.
- Develop data-optimized coronal and chromosphere magnetic field model with explicit treatment of uncertainties, based on multiwavelength observations and validated by synthetic model testbeds.

Goal III - Develop, deploy, and maintain state-of-the-art observational facilities and science data services.



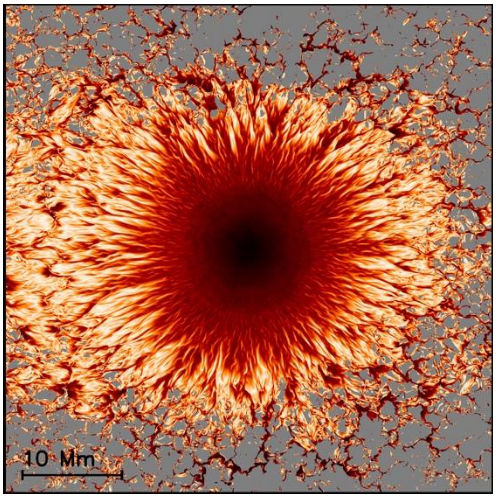
The scientific research done at HAO is fundamentally rooted in the observation of the coupled Sun-Earth system, as well as in the inference and modeling of its physical properties, for the purpose of understanding, and ultimately predicting, the short- and long-term evolution of Earth-impacting phenomena of solar origin.

For this reason, HAO is committed to the development, support, and operation of new and existing observational facilities (e.g. the Mauna Loa Solar Observatory), both ground-based and space-borne, to provide the Geospace and Solar Physics communities with state-of-the-art observations that can help unveil the physical processes that drive the evolution of the coupled Sun-Earth system. The challenges posed by the interpretation and modeling of such observations demand a parallel effort in the development and maintenance of science data analysis and interpretation tools which enable inference of physical quantities required by community models. Finally, it is necessary to effectively manage and disseminate these data products to the solar-terrestrial physics community. These needs place a requirement on HAO to retain a level of excellence in instrument development as well as data calibration, analysis and interpretation.

This goal will be accomplished
- in support of the geospace and solar physics communities
- through both internal programs and external collaborations
- to provide solid observational and interpretational bases for the understanding of the coupled Sun-Earth system

The specific objectives of this goal are:
- Strengthen the HAO instrumentation program, especially with regard to synoptic observations of the coupled Sun-Earth system, and new space-based instrumentation.
- Develop the next generation of instrumentation needed to advance the scientific frontiers of the heliophysics community.
- Ensure timely provision of calibrated data to the community.
- Develop user-friendly data analysis and interpretation tools that can tackle the complexity of state-of-the-art observations.
- Foster current collaborations, as well as develop new partnerships, to enable development and transfer of both cutting-edge ground-based and space-borne instrumentation.

Goal IV - Advance and support sophisticated models of the Sun-Earth system

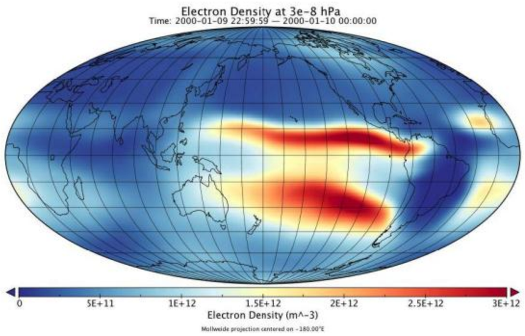


Given the complex nature of the solar and terrestrial system, advanced numerical models are essential for discovery and forecast in studying the coupled system. HAO is a world leader in the development of advanced Sun-Earth system models and has worked closely with the solar-terrestrial community in their development and their usage.

This goal will be accomplished
- in collaboration with and service to the solar-terrestrial physics community
- through community development of innovative numerical methods and open-access algorithms
- to provide tools for understanding the components and connections of the Sun-Earth system

The specific objectives of this goal are:
- Continue development and advancement of a radiative solar MHD modeling suite that extends from the solar interior (upper convective zone) to the chromosphere and lower corona (MURaM). The model is coupled to a coronal MHD model (MFE), in order to study the initiation of coronal mass ejection and to provide surface magnetic flux condition for heliospheric models.
- Develop tachocline and Rossby wave models to support fundamental research and enable forecast of solar cycles.
- Continue development and advancement of the Whole Atmosphere Community Climate Model - eXtended (WACCM-X), with a fully coupled ionosphere-plasmasphere model that is capable of assimilating both lower and upper atmosphere observations and that can resolve down to mesoscales.
- In collaboration with the Center for Geospace Storms support the development of a whole geospace model via contributions to the Multiscale Atmosphere Geospace Environment (MAGE) model including ionosphere, thermosphere, magnetosphere, electrodynamics, and ionospheric outflow capabilities.

Goal V - Identify, develop, and transfer critical knowledge of the Sun-Earth system to the community, the public, and other stakeholders



Sharing our science with the world is part of our job as a national science center. Through public outreach and scientific advocacy, we can promote a broad appreciation of the societal relevance and scientific excitement of heliophysics. Through education, we can deepen understanding of the physical processes at play in the coupled Sun-Earth system and inspire a new generation of researchers to the field. To do this effectively requires us to rise to the challenge of communicating our science in a manner that is simultaneously clear, compelling, and accurate.

This goal will be accomplished

- for the benefit for society
- by advocacy and communication
- to convey the excitement and relevance of heliophysics

The specific objectives of this goal are:

- Increase the visibility of heliophysics science and capabilities.
- Support and enhance NCAR outreach efforts (e.g., Mesa Lab exhibits, Industry Day).
- Actively engage in education effort (e.g., UCAR university programs and K-12 outreach).
- Define and work toward an optimal level of HAO staff involvement in education/outreach/advocacy activities.

Goal VI - Educate and mentor a diverse and talented group of undergraduate and graduate students

As a laboratory of a national center, HAO is in the unique position of being able to promote heliophysics among the geosciences and entrain a capable and diverse pool of students and early-career professionals into the field. Over the course of its 75-year history, HAO has welcomed a multitude of students, post-doctoral research fellows, and visiting scientists. HAO alumni have gone on to promising careers in helio-geophysics and other Science, Technology, Engineering, and Mathematics (STEM) fields. It is imperative for HAO to foster an active and engaging environment for early- career scientists within the laboratory where they can begin to forge their career paths.

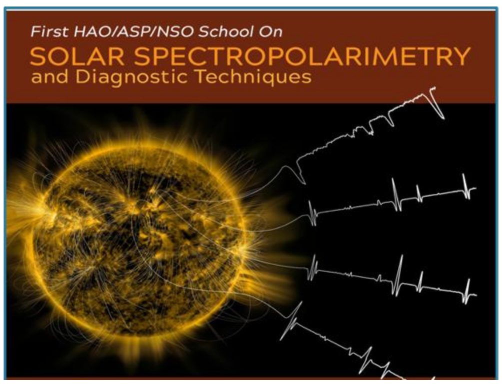
This goal will be accomplished

- in the disciplines of solar-terrestrial physics
- through undergraduate and graduate programs
- for the vitality of the broader solar-terrestrial physics community

The specific objectives for this goal are:

- Advertise and promote opportunities across the wider NCAR and heliogeophysics communities that are available for students, such as lectures and networking functions. Identify opportunities for external outreach to attract visitors and students.
- Provide opportunities for career development, training, and education for visiting students.
- Foster an engaging atmosphere for students by providing a range of opportunities for interacting with other scientists and discussing research and career topics.

Goal VII - Educate and mentor a diverse and talented group of postdocs and early-career solar-terrestrial scientists



The goal to educate and mentor a diverse and talented group of postdocs and early-career solar-terrestrial scientists is central to the High Altitude Observatory's (HAO) mission. HAO's Postdoctoral Fellowship Program offers an exceptional opportunity for recent Ph.D. graduates to engage in cutting-edge research under the guidance of experienced scientists. This program is designed to foster intellectual growth and professional development through hands-on research and active participation in scientific discourse. Additionally, HAO collaborates with the National Center for Atmospheric Research's (NCAR) Advanced Study Program (ASP) to provide a robust platform for interdisciplinary collaboration, skill enhancement, and networking. This partnership amplifies the resources and support available to emerging scientists, helping them to thrive in their early careers and contribute significantly to the field of solar-terrestrial science.

This goal will be accomplished

- in the disciplines of solar-terrestrial physics
- through the visitor program and postdoctoral programs
- for the vitality of the broader solar-terrestrial physics community

The specific objectives for this goal are:

- Identify our community by understanding the people that benefit from our scientific work.
- Gather data on alumni to identify where they are post-HAO, what they are working on, etc.

- Survey the experiences of past and present early-career professionals within the laboratory to assess strengths and shortcomings and make current early-career professionals aware of the exciting career tracks of HAO alumni.
- Advertise and promote opportunities across the wider NCAR and heliophysics communities that are available for early-career professionals, such as lectures and networking functions. Identify opportunities for external outreach to attract visitors and students.
- Provide opportunities for career development, training, and education for early-career scientists.
- Foster an engaging atmosphere for early-career professionals by providing a range of opportunities for interacting with other scientists and discussing research and career topics.
- Incorporate methods for capturing data on who, what, and why people are using our data resources. Use this data to better serve our community-at-large with useful tools and resources for understanding our science and our work.

Connections to the research community

HAO's Mauna Loa Solar Observatory (MLSO) makes daily observations of the outer solar atmosphere that are rapidly distributed to researchers via the Internet to provide a picture of the physical condition of the solar atmosphere. Our data users receive a high level of data-processing and technical support from HAO staff on the calibration, analysis, and interpretation of spectropolarimetric measurements.

HAO has collaborated with George Mason University, the Harvard-Smithsonian Observatory, the University of Hawaii, and University of Michigan to develop the COSMO as an upgraded replacement for our current MLSO capability and is a three-instrument suite to capture the three-dimensional magneto-thermal environment of the inner heliosphere. The measurements made by COSMO will be an observational driver for the next generation of space-weather models and possibly provide a strong "Research to Operations" pathways between HAO and SWPC.

HAO also designs, builds, and operates several optical instruments for the measurement of upper atmospheric neutral winds that are distributed all over the world in addition to balloon-based platforms and a cubesat. The data from this world-wide network of upper atmospheric observatories are gathered and distributed via the internet to the community. HAO has built instruments that are widely used in the community, such as the Advanced Stokes Polarimeter (ASP), Spectro-Polarimeter for the Infrared and Optical Regions (SPINOR), and the Hinode Solar Optical Telescope Stokes Polarimeter (SP). Built on the heritage of these facility instruments, HAO provided the Visible Spectro-Polarimeter (ViSP) for the Daniel K. Inouye Solar Telescope (DKIST) operated by the National Solar Observatory (NSO). The measurements made by ViSP permit inferences of the complex vector magnetic field in the lower solar atmosphere at unprecedented spatial resolution.

Finally, HAO develops large-scale, computational community models that support community research in upper atmospheric, ionospheric, and magnetospheric physics. These include the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) and WACCM-X, the aforementioned upper atmospheric extension of NCAR/CESM WACCM. The development of WACCM-X and its extension to a whole model will couple the physics and chemistry of the magnetosphere and plasmasphere with those (of lower atmosphere) provided by WACCM-X following the Common Infrastructure for Modeling the Earth (CIME) framework that is being adopted across NCAR's other laboratories. HAO is a core member of the Center for Geospace Storms and is contributing ionosphere, thermosphere, and magnetosphere simulation expertise and code to the Multiscale Atmosphere Geospace Environment (MAGE) model.

Summary

The High Altitude Observatory (HAO) at the National Center for Atmospheric Research (NCAR) plays a pivotal role in advancing solar-terrestrial physics, aligning with the goals of its primary sponsor, the U.S. National Science Foundation (NSF). Over the next five years, HAO aims to achieve a deeper understanding of the Sun-Earth connection, enhance observational and modeling facilities, and foster robust collaborations with the academic community, NOAA, NSF's National Solar Observatory (NSO), and NASA's Goddard Space Flight Center. The strategic plan emphasizes HAO's mission to quantify the impact of solar variability on Earth's atmosphere, support educational initiatives, and advocate for the field of solar-terrestrial physics.

HAO's vision is centered on providing scientific leadership, conducting critical observations, and offering interpretative capabilities to the broader community. This includes engaging and training early-career scientists and promoting career development within its workforce. The observatory's culture values high performance, teamwork, and an open, safe working environment. These values guide HAO's commitment to maintaining a collaborative and supportive atmosphere, crucial for its success and the advancement of solar-terrestrial research.

Strategically, HAO focuses on understanding and forecasting space weather hazards and the impact of solar variability on Earth's climate. Key opportunities include the development of the Coronal and Solar Magnetism Observatory (COSMO), participation in NASA missions, and leveraging new collaborations with the NSO. HAO's research agenda addresses six grand challenges, such as elucidating the origins of solar magnetism, understanding solar atmospheric coupling, and characterizing the interactions between different atmospheric layers.

To meet its objectives, HAO has set seven goals, including solving critical problems in solar-terrestrial physics, improving space weather hazard assessment, developing observational facilities, advancing sophisticated models, and sharing knowledge with the community and public. Additionally, HAO is dedicated to educating and mentoring students and early-career scientists, fostering the next generation of experts in solar-terrestrial science.

HAO maintains strong connections with NCAR's laboratories and the broader research community. Collaborative efforts include developing the Whole Atmosphere Community Climate Model (WACCM-X) and engaging in observational campaigns through facilities like the Mauna Loa Solar Observatory. HAO's partnerships extend to various universities and research institutions, enhancing its capacity to contribute to significant advancements in understanding and forecasting solar-terrestrial phenomena. Through these initiatives, HAO aims to solidify its role as a leader in solar-terrestrial research and support the scientific community in addressing the challenges posed by solar variability and space weather.

Appendix