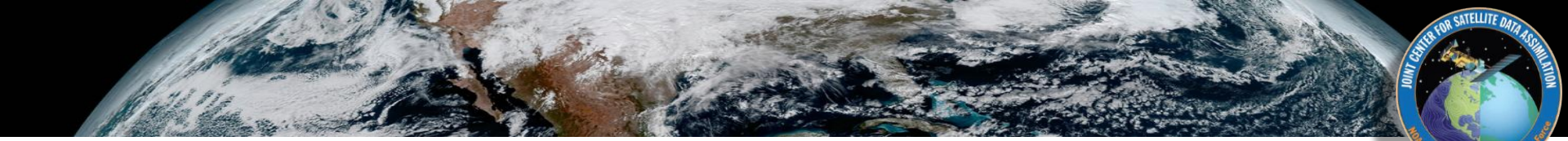


2024 JEDI Space Weather Workshop

2025 Community Space Weather Modeling and Data Assimilation Workshop

Hui Shao

Joint Center for Satellite Data Assimilation (JCSDA)

UCAR/UCP

Boulder, CO, US, 10-11 September, 2025

2024 JEDI Space Weather Workshop

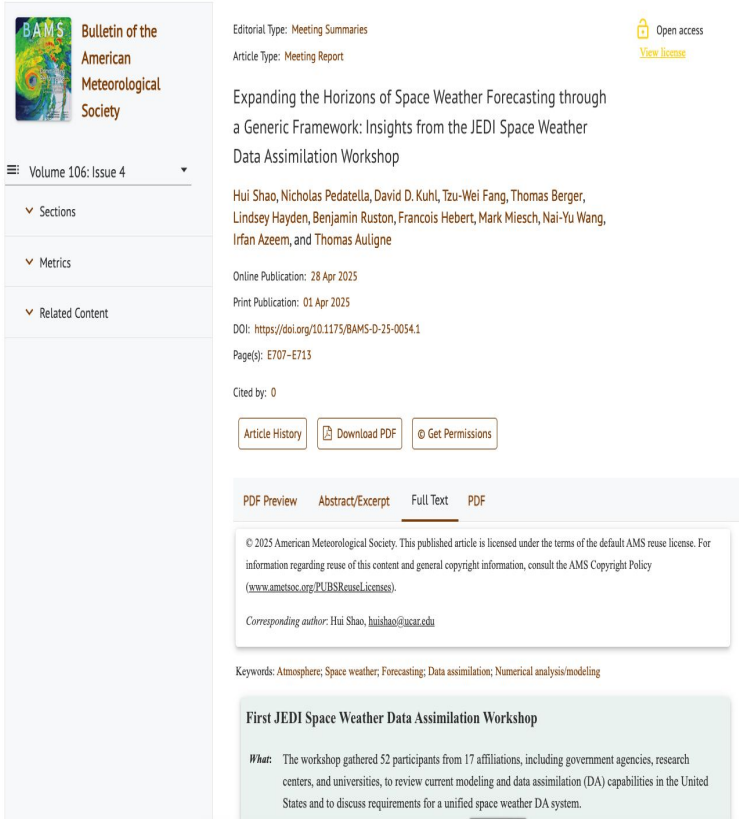
Space Weather JEDI Workshop

- Hosted by JCSDA & Univ. of Colorado/SWORD
- Boulder, CO | Aug 28–29 | *invited-only*

Participation: 53 participants, 18 presentations, 3 discussion sessions

Attendees: NRL, AFRL, NASA, NOAA, UCAR, NSF NCAR, Univ. of Colorado, Aerospace Corp, Space Force

https://doi.org/10.1175/BAMS-D-25-0054.1



Bulletin of the American Meteorological Society

Volume 106: Issue 4

Sections

Metrics

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Editorial Type: Meeting Summaries

Article Type: Meeting Report

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Expanding the Horizons of Space Weather Forecasting through a Generic Framework: Insights from the JEDI Space Weather Data Assimilation Workshop

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Online Publication: 28 Apr 2025

Print Publication: 01 Apr 2025

DOI: https://doi.org/10.1175/BAMS-D-25-0054.1

Page(s): E707–E713

Cited by: 0

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Keywords: Atmosphere; Space weather; Forecasting; Data assimilation; Numerical analysis/modeling

First JEDI Space Weather Data Assimilation Workshop

What: The workshop gathered 52 participants from 17 affiliations, including government agencies, research centers, and universities, to review current modeling and data assimilation (DA) capabilities in the United States and to discuss requirements for a unified space weather DA system.

Models Highlighted

Model (affiliation)	Brief description
Geospace model (University of Michigan)	Physics-based magnetosphere model driven by solar wind, operational at NOAA since 2016
GITM (University of Michigan)	Simulates Earth's thermosphere–ionosphere system, solving for key neutral and ion species while incorporating Geospace coupling and solar-terrestrial inputs
WAM-IPE (NOAA)	Extends GFS to 600 km, forecasting neutral winds, ion densities, and temperatures with ionospheric electrodynamics
NRLSAMI (NRL)	3D ionospheric model simulating plasma and chemical evolution for seven ion species with 21 chemical reactions
NAVGEM-HA (NRL)	500-km global atmospheric model capturing space weather conditions, integrating internal models of ionospheric and neutral species states
NEPTUNE-HA (NRL)	Next generation of NAVGEM-HA that can be global or limited area is nonhydrostatic and has a vertical finite-difference scheme
TIEGCM (NSF NCAR)	Simulates neutral and ionized species dynamics in the thermosphere and ionosphere for space weather applications
WACCM-X (NSF NCAR)	Whole-atmosphere climate model spanning the surface to ~500 km, coupling neutral atmosphere, ionosphere, and thermosphere
GEOS-MLT (NASA Goddard)	Developmental model extending to 150 km with a mesospheric–lower thermosphere DA system
IRI (International Community)	Empirical model of global electron density, ion composition, and temperature using ground and satellite observations
PyIRI (NRL)	Python-based version of IRI, computationally efficient for initializing and constraining ionospheric models
GloTEC (NOAA SWPC)	Uses IRI with real-time GNSS and COSMIC-2 data for global electron density and TEC nowcasting

Observation Priority List

Region	Near-real-time instruments/ observations (highest priority)	Research instruments/observations (watch list)
Ionosphere	Ionosonde: vertical electron density distribution, critical plasma frequency, ionospheric layer characteristics (E and F2 layers) GNSS-RO and ground-based GNSS: electron density along signal paths, slant TEC (sTEC), vertical TEC (vTEC) Over-the-Horizon Radar (OTHR): TEC variations, ionospheric scintillations	Madrigal GNSS network: TEC Jicamarca radio observatory and Super Dual Auroral Radar Network (SuperDARN): plasma drift measurements Vertical Incidence Pulsed Ionospheric Radar (VIPIR)/dynamic ionosonde (Dynasonde): drift data Ham Radio Science Citizen Investigation (HamSCI) radio and HF-related data Active Magnetosphere and Planetary Electrodynamics Response Experiment (AMPERE): field-aligned currents
Thermosphere	Neutral density via orbital decay analysis Neutral density derived from GNSS precise orbit determination (POD) observations	Midlatitude All-Sky Network of Optical Stations (Mango) Fabry–Perot Interferometer (FPI) networks: neutral winds and temperature at ~250 km Ionospheric Connection Explorer (ICON): neutral wind data Global-Scale Observations of the Limb and Disk (GOLD): (temperature, O/N_2 ratio) Starlink: thermospheric density, RO potential Sounding of the Atmosphere using Broadband Emission Radiometry (SABER): temperature ICON/Special Sensor Ultraviolet Limb Imager (SSULI)/Global Ultraviolet Imager (GUVI) Far Ultraviolet (FUV) spectrometer: FUV-based thermospheric density profiles Accelerometer-based density from Satellite mission by the European Space Agency (SWARM) and GRACE–Follow-On (GRACE-FO)
Mesosphere	SSMIS–upper-atmospheric sounding (UAS): temperature and humidity Aura/MLS: temperature, ozone, water vapor, and other trace gases	Meteor radar: winds between 85 and 105 km SABER: mesospheric/lower thermosphere composition and temperature up to 110 km

Guidelines for developing a generic model interface

Unified DA Framework: JEDI core reusable; interface development requires in-depth study on operational/research needs and future extensibility

Key Challenges: diverse layers, mixed grid structures (lat–lon vs. geomagnetic), varied variables

Priorities:

- Thermosphere: can align with existing NWP extensions (e.g., GFS → WAM, NAVGEM → NAVGEM-HA)
- Ionosphere: grid diversity requires specialized interfaces (regular grids vs. geomagnetic grids)
- Separate JEDI interface needed for geomagnetic grids

Model Interfaces: thermosphere aligns with NWP; ionosphere needs specialized geomagnetic interface

Guidelines for developing a unified DA framework

Unified DA Framework: Avoids fragmentation of independent systems; Common foundation for diverse observations, model physics, and advanced DA/ML; Streamlines research-to-operations transition; Standardizes data formats and evaluation metrics for cross-comparison

Key Challenges:

- Handling observations integrated over time;
- Reconciling different time scales (thermosphere vs. ionosphere);
- Defining assimilation windows and balancing regional vs. global DA

Model Uncertainty: ensemble-based error characterization, storm resilience, potential use of seasonal climatology

Validation: curated cases for performance assessment; standardized DA processes across models and datasets

Strategies & Next Steps: improve forcing/parameter estimation, use variable transformations, geomagnetic grid localization, account for extreme events, plan for DA + ML integration

2025 Community Space Weather Modeling and Data Assimilation Workshop

Supported by UCP Strategic Plan and NSF NCAR President's Strategic Initiative Fund

Objectives:

- Exchange technical knowledge and details on ongoing space weather modeling and data assimilation efforts
- Bring together key stakeholders developing community-based and advanced data assimilation systems within the JEDI framework to support space weather forecasting across the ionosphere, thermosphere, mesosphere, and magnetosphere
- Collect operational needs for developing community space weather modeling and data assimilation systems, along with community input on barriers and potential solutions for implementing operational space weather data assimilation
- Assess the roles and contributions of each participant and explore how resources can be effectively shared to achieve common objectives

About This Workshop

Participants: 56 (in person), 67 (remote), 29 oral presentations

Five Sessions: Program overview, Observations and processing, Model, Post-processing and AI/ML, Data Assimilation

Two Discussion Sessions: Wednesday 3:50-5:00pm (US Mountain); Thursday 3:40-5:00pm (US Mountain)

Optional Gathering: Avanti Food Hall, 1401 Pearl Street, Boulder