UCAR Community Space Weather Initiative

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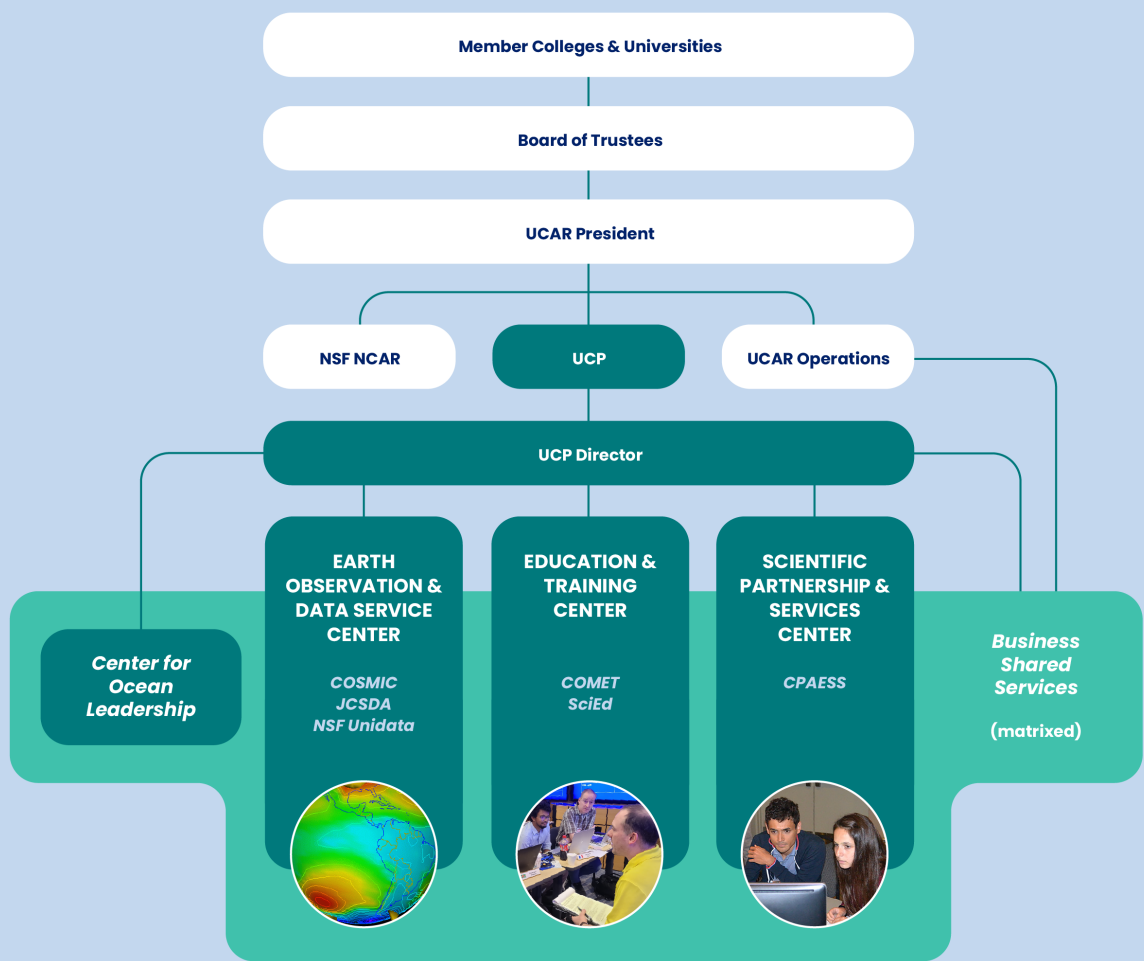[4]*COSMIC Program Office, UCAR*
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NCAR

NSF

10 September 2025
Community Space Weather Modeling and DA Workshop

2024-2028 UCP Strategic Plan

Organizational chart:

- Member Colleges & Universities
- Board of Trustees
- UCAR President
  - NSF NCAR
  - UCP
  - UCAR Operations
    - UCP Director
      - Center for Ocean Leadership
      - EARTH OBSERVATION & DATA SERVICE CENTER — COSMIC, JCSDA, NSF Unidata
      - EDUCATION & TRAINING CENTER — COMET, SciEd
      - SCIENTIFIC PARTNERSHIP & SERVICES CENTER — CPAESS
      - Business Shared Services (matrixed)

Goal 4: Advance Earth system predictability through research and the development of innovative Earth observing, modeling, and data assimilation capabilities

Space Weather was identified as a priority area to advance UCP Strategic Goals, and is a focus of the NSF-NCAR ESPAT initiative

Develop the next generation space weather prediction system; improve whole atmosphere modeling and space weather assimilation capabilities and provide data assimilation analysis outputs and tools for the research and operational communities

What We Will Accomplish:
This initiative will establish new capabilities for space weather data assimilation research, leveraging software and tools used by the operational community to benefit operational agencies.

UCAR's Unique Value and Expertise:
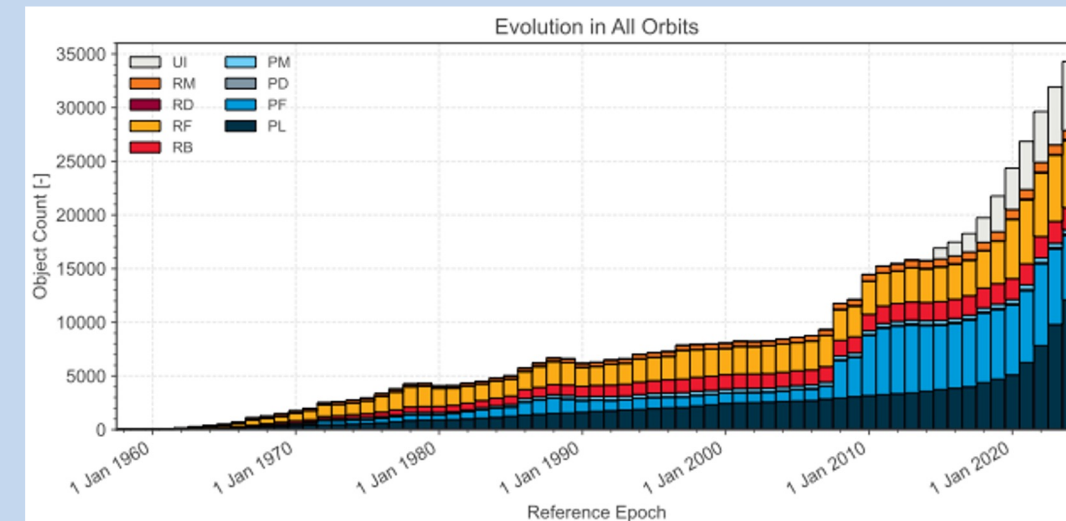UCP/JCSDA: JEDI and implementation of new forward operators.
UCP/COSMIC: expertise related to ionosphere observations for data assimilation
NSF-NCAR HAO & RAL: expertise in whole atmosphere modeling, DA, and post-processing

# Why a Community Space Weather Analysis and Prediction?

There is **currently no community-based Space Weather prediction system** geared towards the research and operations communities.

UCAR (UCP & NCAR) has expertise in all aspects needed to develop a Space Weather Analysis and Prediction System, as well as history in community supported modeling and assimilation (e.g., WRFDA)

B B C

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SpaceX loses 40 satellites to geomagnetic storm a day after launch

9 February 2022

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Elements of a Space Weather Prediction System within UCAR

NSF-NCAR: CESM Whole Atmosphere Community Climate Model with thermosphere-ionosphere eXtension (WACCM-X)
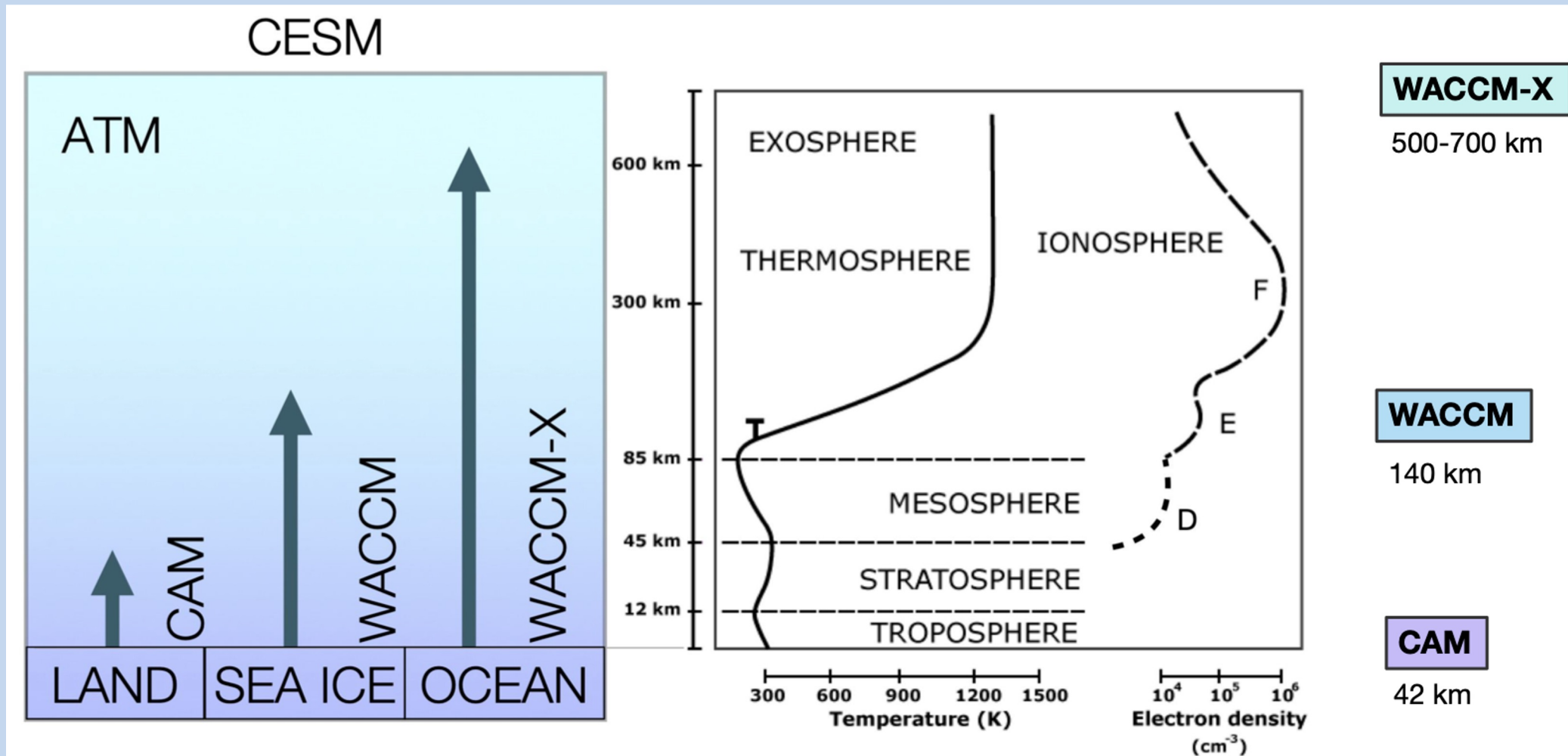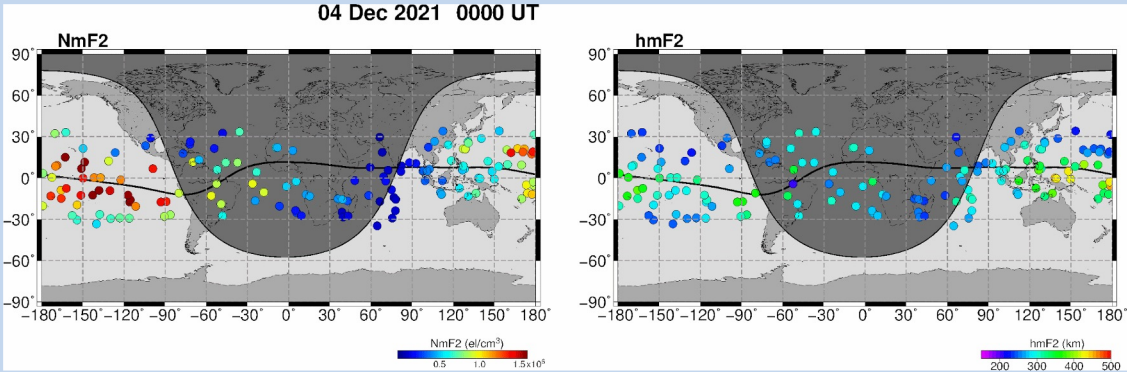
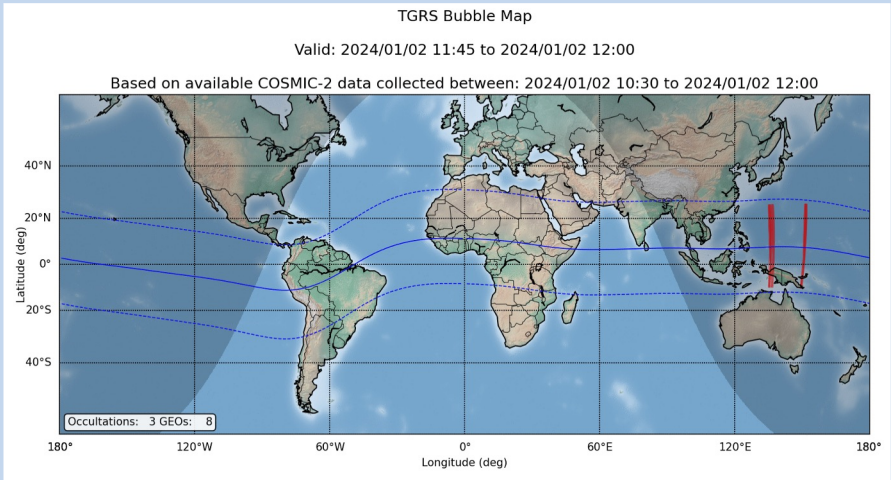# Elements of a Space Weather Prediction System within UCAR

UCAR/UCP/COSMIC: Providing higher level Space Weather products for operational and science use

Product	Status
Abs total electron content	Operational
Electron density profiles	Operational
Line of sight scintillation amplitude and phase indices	Operational
Scintillation geolocation	Operational
Scintillation bubble map	Operational
Scintillation all-clear	Operational
Limb-to-disk	Future
In situ plasma density, composition, temperature	Operational

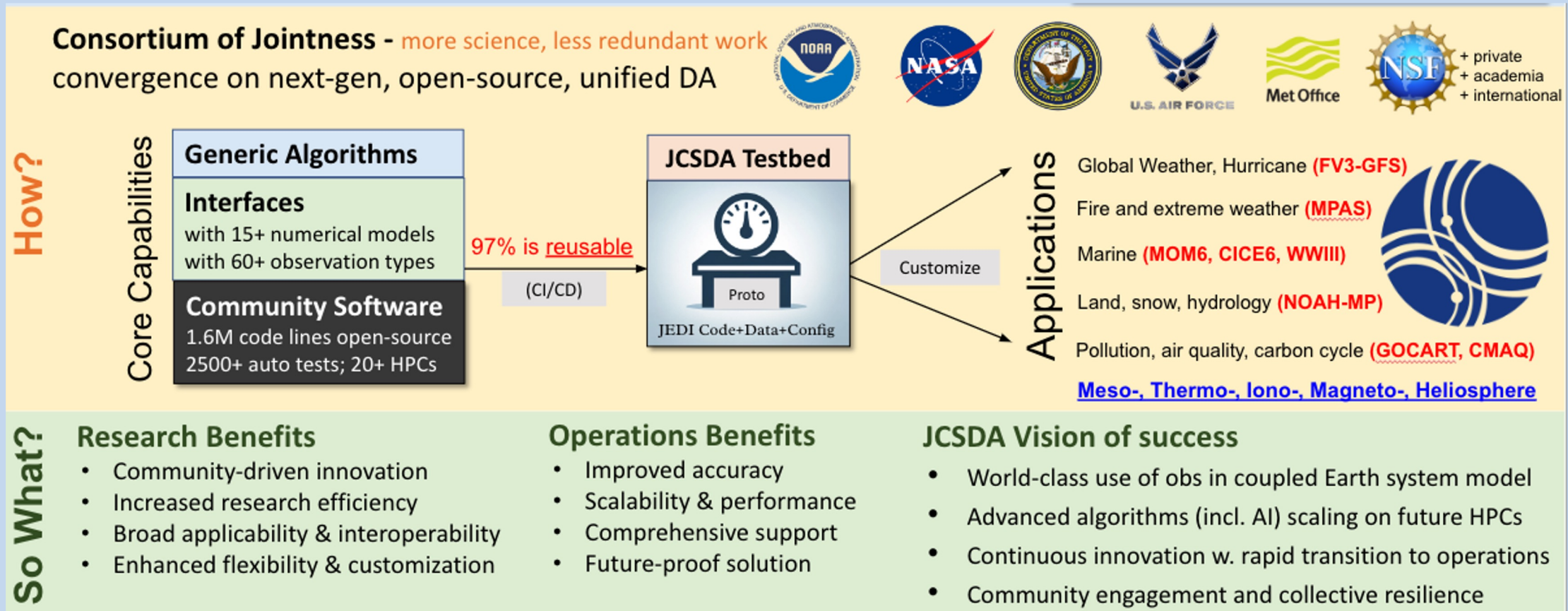Ionospheric peak density and height from COSMIC-2 Radio Occultation profiles (~5K daily, ~200/hr)

COSMIC-2 Bubble Map

Elements of a Space Weather Prediction System within UCAR

UCAR/UCP/JCSDA: Joint Effort for Data assimilation Integration (JEDI)
Unified Data Assimilation for NWP, Climate, Ocean, Sea Ice, Land, and Space Weather

Consortium of Jointness – more science, less redundant work
convergence on next-gen, open-source, unified DA

NOAA · NASA · DEPARTMENT OF THE NAVY · U.S. AIR FORCE · Met Office · NSF
+ private + academia + international

How?

Core Capabilities

Generic Algorithms

Interfaces
with 15+ numerical models
with 60+ observation types

97% is reusable
(CI/CD)

Community Software
1.6M code lines open-source
2500+ auto tests; 20+ HPCs

JCSDA Testbed
Proto
JEDI Code+Data+Config

Customize

Applications
Global Weather, Hurricane (FV3-GFS)
Fire and extreme weather (MPAS)
Marine (MOM6, CICE6, WWIII)
Land, snow, hydrology (NOAH-MP)
Pollution, air quality, carbon cycle (GOCART, CMAQ)
Meso-, Thermo-, Iono-, Magneto-, Heliosphere

So What?

Research Benefits
- Community-driven innovation
- Increased research efficiency
- Broad applicability & interoperability
- Enhanced flexibility & customization

Operations Benefits
- Improved accuracy
- Scalability & performance
- Comprehensive support
- Future-proof solution

JCSDA Vision of success
- World-class use of obs in coupled Earth system model
- Advanced algorithms (incl. AI) scaling on future HPCs
- Continuous innovation w. rapid transition to operations
- Community engagement and collective resilience

Critical components (background model, data assimilation system, and observations) and relevant expertise of a Space Weather prediction system all exist within UCAR

NSF | NCAR
Operated by UCAR

Elements of a Space Weather Prediction System within UCAR

NSF-NCAR: RAL post-processing techniques to improve NWP forecasts

We are evaluating the application of the Analog Ensemble (AnEn) system, a proven method for surface variables, to improve predictive accuracy for Space Weather.
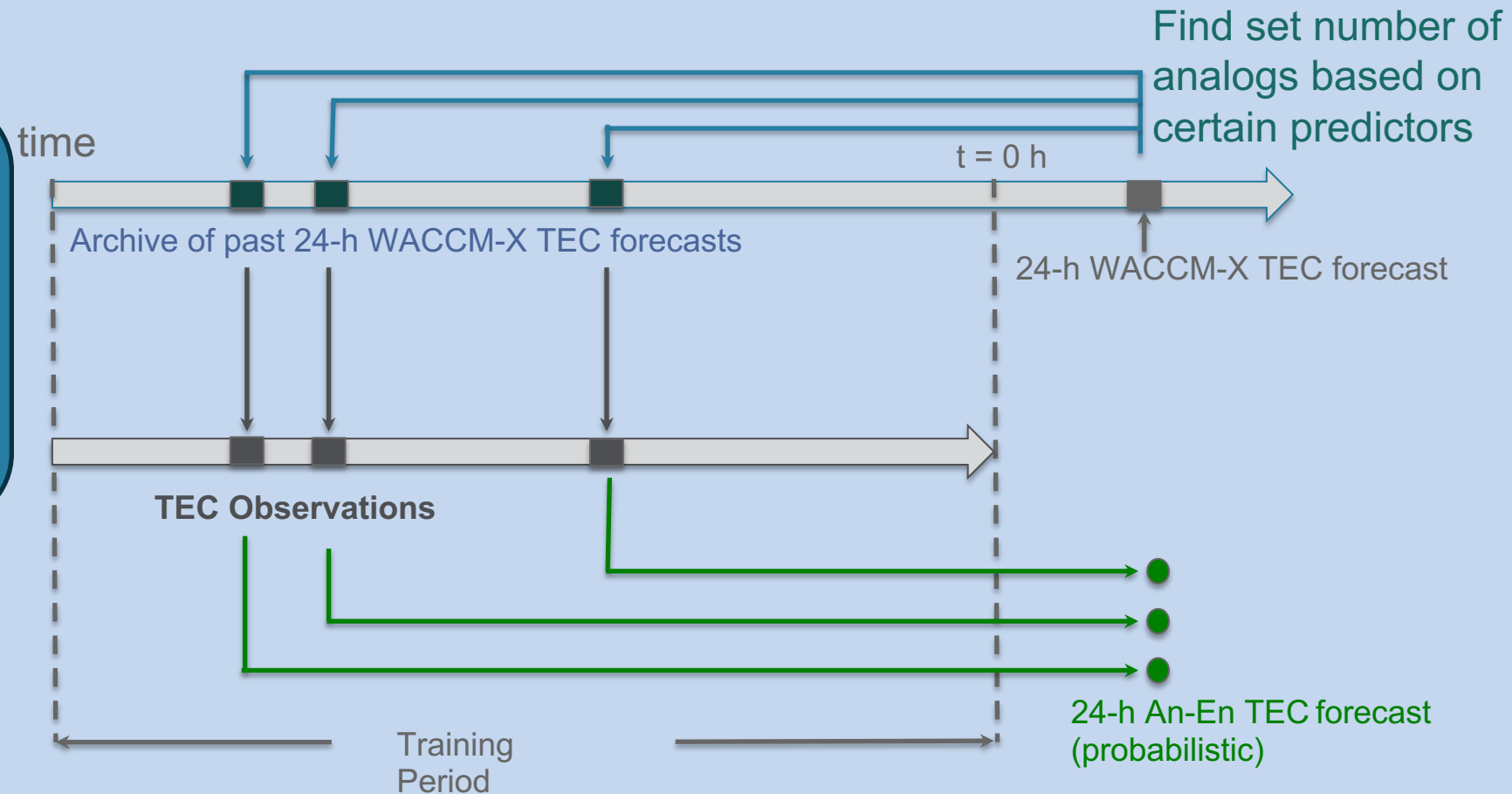
Find set number of analogs based on certain predictors

time

t = 0 h

Archive of past 24-h WACCM-X TEC forecasts

24-h WACCM-X TEC forecast

TEC Observations

24-h An-En TEC forecast (probabilistic)

Training Period

Figure adapted from Delle Monache et al. (2013)

What We Will Accomplish

- We will develop a space weather prediction system leveraging important existing capabilities within NCAR and UCP
- This will bring together NCAR strengths in whole atmosphere modeling (WACCM-X) and post-processing and UCP strengths in data assimilation (JCSDA) and GNSS observations (COSMIC)
- WACCM-X/JEDI based Space Weather prediction system would be advantageous in multiple ways

- Currently no whole atmosphere data assimilation system in existence that makes use of operational data assimilation software
- NASA and NRL are beginning to pursue JEDI-based whole atmosphere data assimilation but NASA lacks a whole atmosphere model and NRL system is not publicly available

Observations (COSMIC)

Community SWx Prediction and DA system

Modeling and post processing (HAO/RAL)

Data Assimilation (JCSDA)
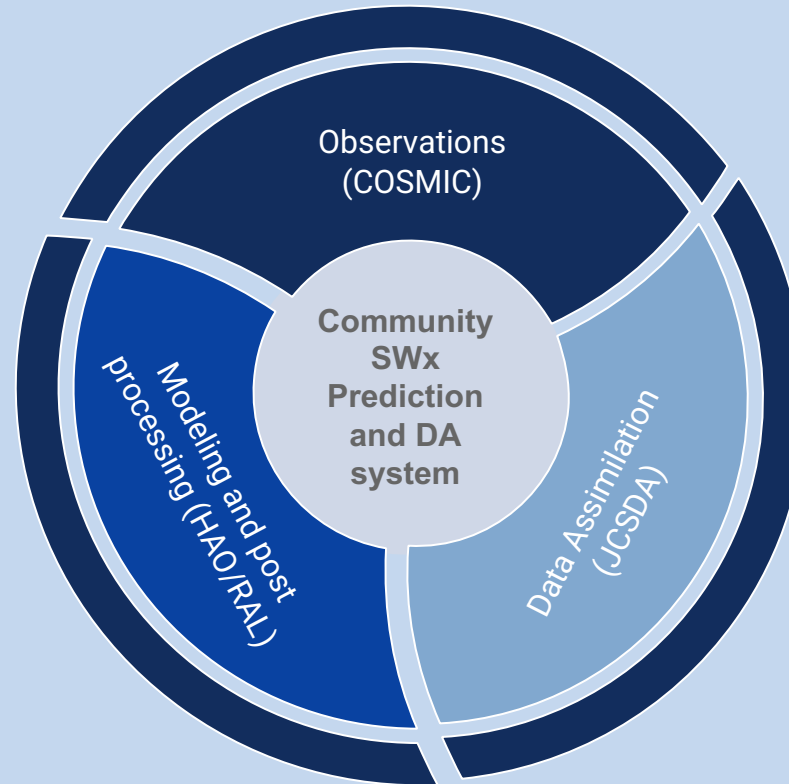
- Inherently coupled treatment of thermosphere-ionosphere
- Modern computing language and agile development
- Generic interfaced with multiple models
- Holistic view of atmosphere
- Potential (generic algorithm, reusable code) to interface with next-gen space weather forecast models

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Current Status

- Internal UCAR PSIF funding for 1-year to support NCAR/UCP collaboration on Community Space Weather Prediction System

- Initial WACCM-X/JEDI interface nearing completion (NASA SWORD Space Weather Center of Excellence)

- Offline H(x) testing for both ionosondes and radiosondes with WACCM-X fields

- Initial WACCM-X forecasts for testing Analog Ensemble post-processing for improved space weather forecasting
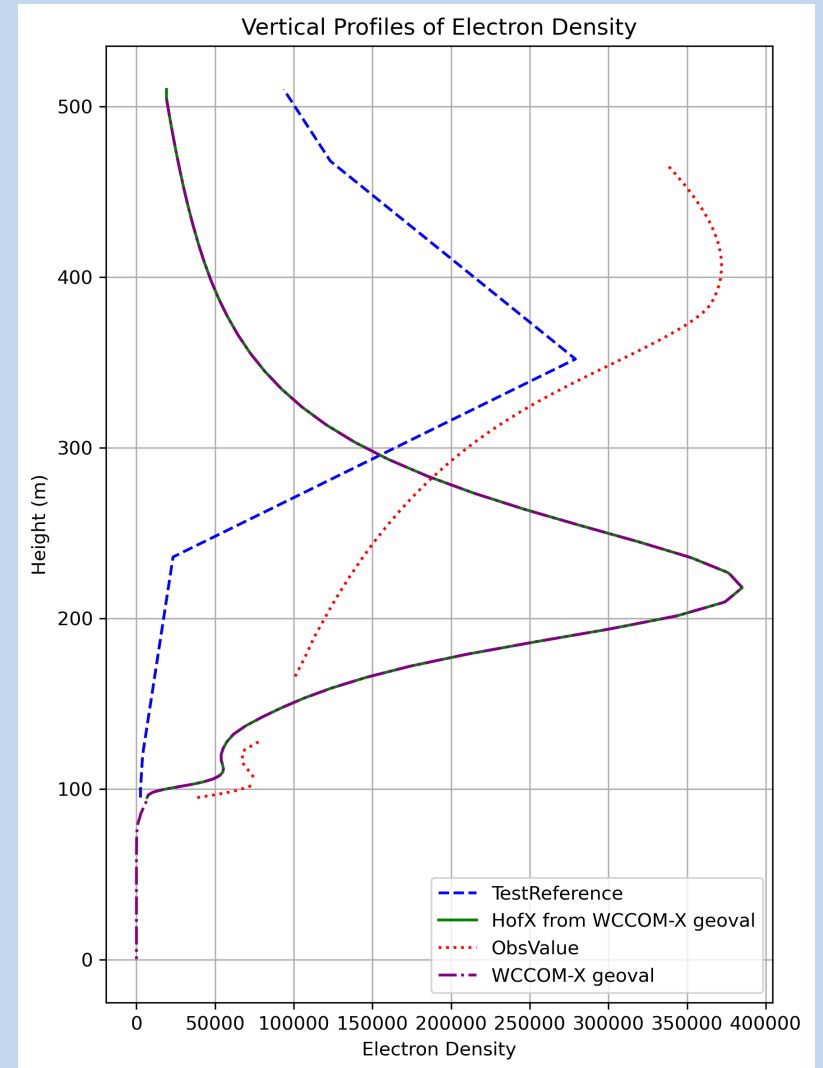
Next Steps

- We would like to gather community inputs on the development goals and plans for a UCAR Space Weather Analysis and Prediction System

- Aim is to develop something that is useful for _both_ the operational and research communities

- We welcome collaborations targeting future developments and applications

- Open questions:

    What observations should be prioritized?

    How can a community DA system best support research into DA techniques for advancing space weather predictions?