NATIONAL ACADEMIES Sciences Engineering Medicine

# Committee on Solar and Space Physics

## Report to Space Studies Board, 6 June 2024

*J. Clemmons for the CSSP, Co-Chair*

*University of New Hampshire*


NOVEMBER 2022 UPDATE

# CSSP Committee membership

James Clemmons, Co-Chair
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Laila Andersson
*University of Colorado*

Roman G. Gomez
*Southwest Research Institute*

Hantao Ji
*Princeton University*

KD Leka
*NorthWest Research Associates, Nagoya U. / ISEE*

Wayne A. Scales
*Virginia Tech University*

**TBD**, Co-Chair

Mahboubeh Asgari-Targhi
*Harvard-Smithsonian Center for Astrophysics*

Larisa P. Goncharenko
*MIT Haystack Observatory*

David M. Klumpar
*Montana State University*

Nicholas M. Pedatella
*NSF National Center for Atmospheric Research*

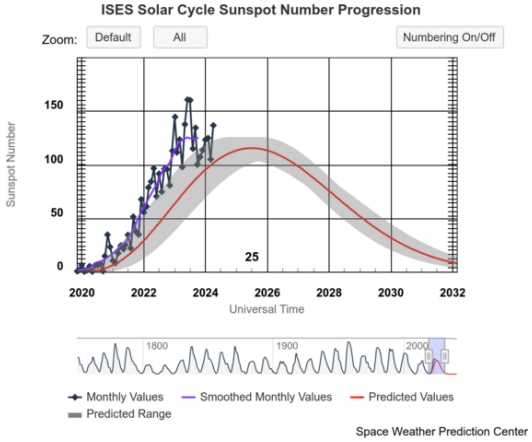
Phyllis L. Whittlesey
*University of California, Berkeley*

**NASEM Staff**

Abigail Sheffer
*Study Director*

# An Exceptional Year for Solar and Space Physics

- The last year has been eventful for solar and space physics
- Two solar eclipses in US
- Solar maximum is approaching
- NASA's Parker Solar Probe headed toward closest approach to Sun
- The "Heliophysics Big Year" is living up to its billing!


# Observing the effects of the solar eclipse April 8, 2024


Scientists setting up all sky camera at UTA at the center of the football field (50 yd line)

New high-rate real-time GNSS receivers installed for the eclipse experiment in numerous locations from Texas to Vermont – in farm fields, backyards, and football fields

New HF transmitters and receivers installed in MA and on a rooftop at UNH

Three Black Brant IX sounding rockets were launched from NASA's Wallops Flight Facility in Virginia April 8, 2024, during the solar eclipse. The Atmospheric Perturbations around Eclipse Path (APEP) mission made measurements of disturbances in the ionosphere created when the Moon eclipsed the Sun.

*NASA/Garon Clark*

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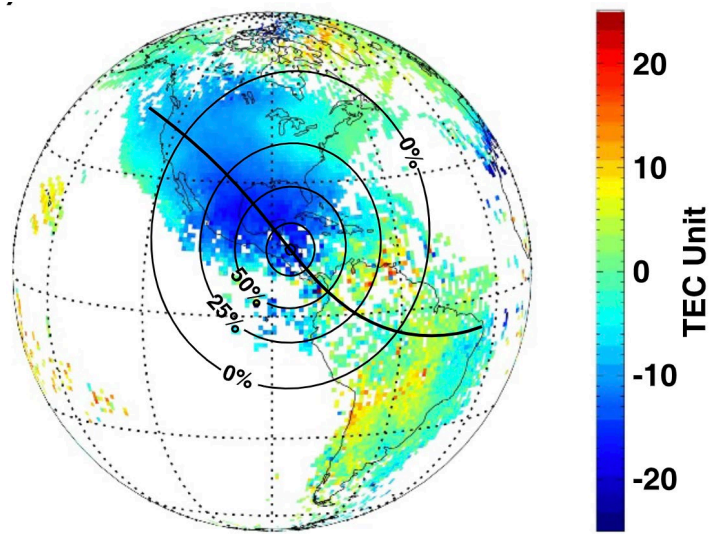
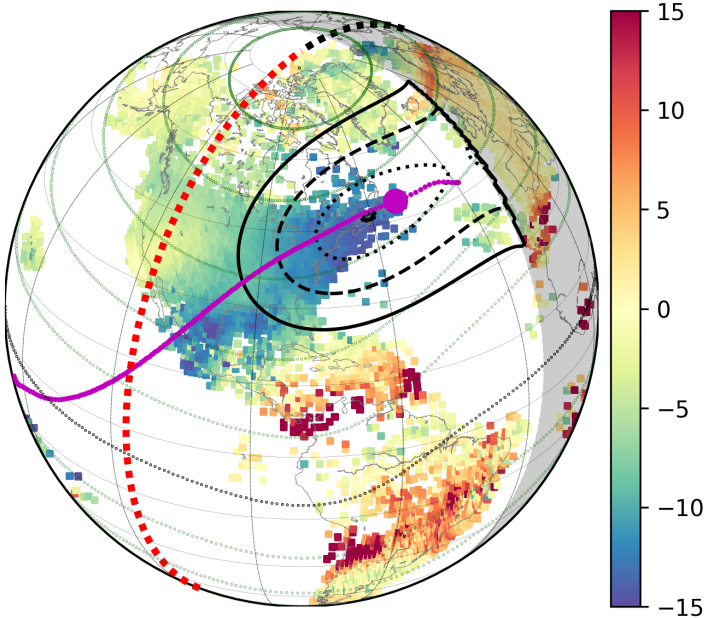
# Ionospheric responses to the solar eclipses

14 October 2023



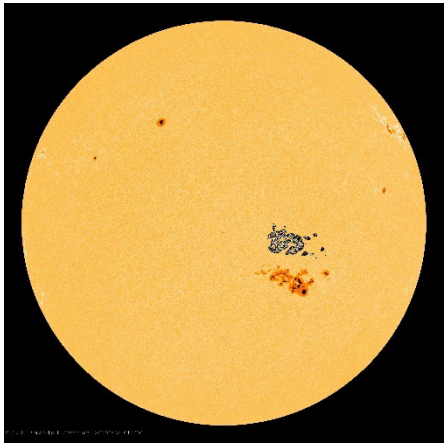

8 April 2024




- Ionospheric responses to the annual solar eclipse (left) and the total solar eclipse (right).
- These eclipses caused electron density (total electron content) reduction by up to 30-40% - lower than during Aug 2017 eclipse.

# The May, 2024 geomagnetic superstorm

- Large, complex sunspot group appeared in early May
- Numerous coronal mass ejections and X-class flares were observed
- A superstorm-class geomagnetic disturbance was registered at Earth
- Aurora was observed at very low altitudes

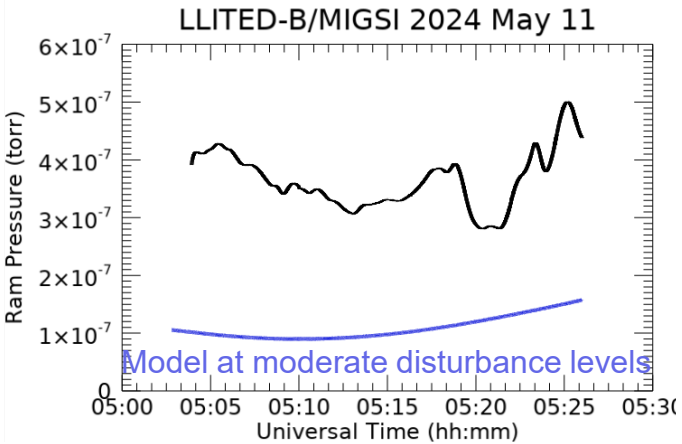




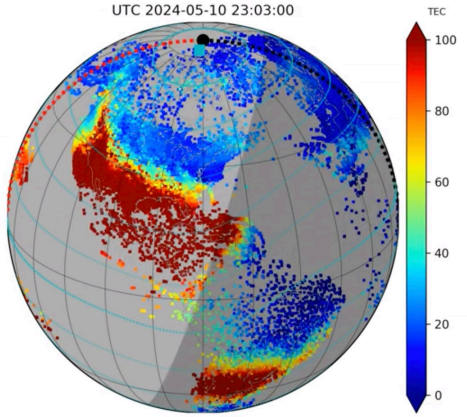
MOUNT MITCHELL, UNITED STATES - MAY 10: Unusual sun activity created a G5 Geostorm on Earth sparks northern lights (Aurora Borealis) in Mount Mitchell, North Carolina, United States on May 10, 2024.
(Peter Zay/Anadolu via Getty Images)

# Ionosphere-thermosphere effects of superstorm

- Large response in high-latitude thermosphere at 400 km
  - Observed factor of 4 increase in atmospheric density over moderately-disturbed conditions
  - Large-amplitude waves and perturbations were generated

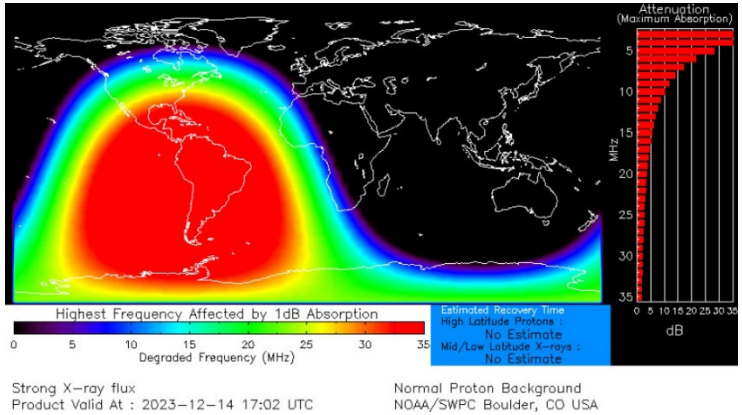



- Large response in ionosphere
  - Large subauroral storm-enhanced density plume
  - Connected to the tongue of ionization and plasma patches in the polar cap region



# Challenge 1: Space weather and its effects

- The complex Sun-Earth system produces difficult-to-predict space weather
- Technological effects are considerable for a spectrum of stakeholders

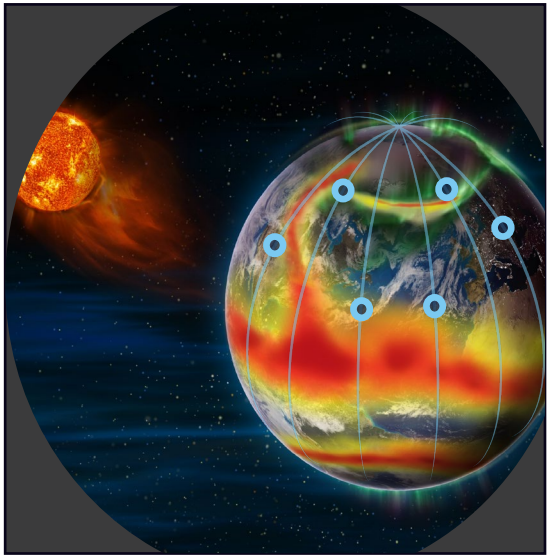



- Approach: Improving space weather prediction capabilities
  - The predictions associated with the recent superstorm were quite good
  - Much more development is needed to improve accuracy of predictions
- Approach:  Improving recognition of the effects of space weather on systems and operations
  - In conjunction with the superstorm, SWPC held a telemedia conference attended by over 1300 reporters
  - Over 150 individual broadcast or radio interviews were given including national and international media outlets

# Challenge 2: Improving and maintaining needed assets for research and operational purposes

- Advances in solar and space physics are predicated on improving and maintaining community capabilities
- Missions are needed in space
- Facilities are needed on the ground

- Approach: The Geospace Dynamics Observatory (GDC)
  - GDC will make the next big step in understanding heliophysics
  - Its multi-parameter, multi-point measurements will provide a comprehensive view of the ionosphere-thermosphere system
  - Unfortunately, development of GDC is “on pause”
- Approach: Awaiting Decadal Survey release
  - We eagerly await release of the Decadal Survey to show the path forward for a tractable and transformative research and operations program fo solar and space physics



# Conclusions

- **Solar and space physics is in the midst of an already-eventful year for science**
- Much new understanding will result as we observe the dynamics of the system under active conditions
- Revolutionary insights into the solar upper atmosphere are expected from the Parker Solar Probe measurements

- **The challenges presented by the science and the needs for infrastructure are significant**
- Space weather prediction has made great strides, but improved accuracy is required
- New measurements are needed in space and on the ground, and we eagerly anticipate the release of the Decadal Survey this summer