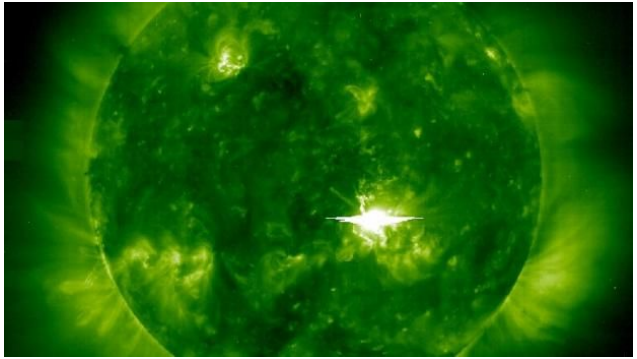
# Research vs Operations

**Research in the Space Weather (SW) context is about how disturbances in a physical system (the Sun, IP space, Geoenvironment, etc.) behave in general.**

**Operations in the same context is about accurately forecasting in NRT how this particular solar event at this particular time is initiated, propagates and evolves through this particular ambient, and arrives near Earth at this particular time with this particular impact.**

# SOLAR ACTIVITY

**Product Focus:** Probabilistic Solar Flare (M, X) Forecasts; Alerts for threshold crossings.



## Supporting Models/Tools

- **Climatology based on McIntosh Classification**
- ****Experiments with ML tools****

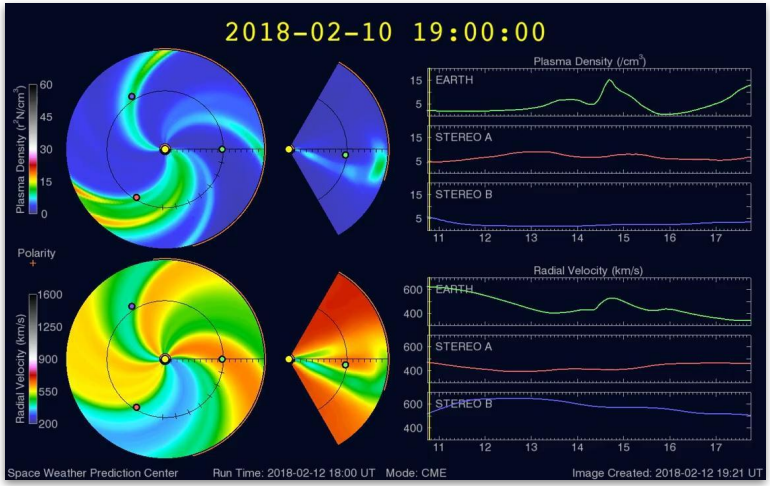
## Operational Data Streams

- USAF SOON reports
- GONG Imagery
- Mt Wilson Sunspot Reports
- GOES XRS and SUVI
- SDO HMI/AIA

# SOLAR WIND

**Product Focus:** Timing & magnitude of Geospace response to solar wind

- Forecast of CME arrival time at Earth
- Transient solar wind stream structures
- Anticipated geomagnetic response




## Supporting Models/Tools

- WSA V5.4
- Enlil V2.9e
  - Single input map mode
  - "Medium" resolution
- SWPC CME Analysis Tool (CAT)

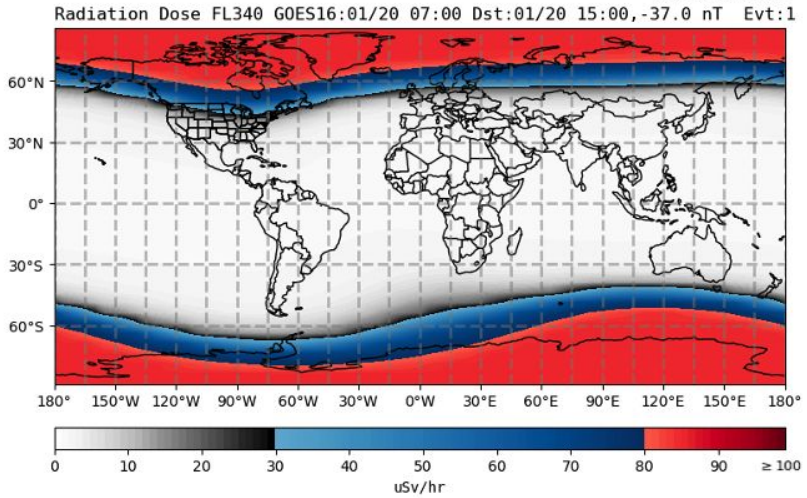
## Operational Data Streams

- GONG synoptic maps (*mrzqs*)
- Coronagraphs: SOHO LASCO, STEREO
- L1 in-situ: DSCOVR, ACE

# RADIATION/ENERGETIC PARTICLES

**Product Focus:** Onset and Energy/Intensity of radiation in space or atmosphere

- **Effective dose rates aviation flight levels**
- **Warnings and Alerts for >10 MeV and >100 MeV protons**
- **3 day probabilistic S1 forecasts**




## Supporting Models/Tools

- **FAA CARI-7 Radiation Model (aviation customers)**
- **SWPC Proton Prediction Model (satellite industry, human space exploration)**

## Operational Data Streams

- **GOES X-rays and protons, Dst, type II and IV radio burst information**

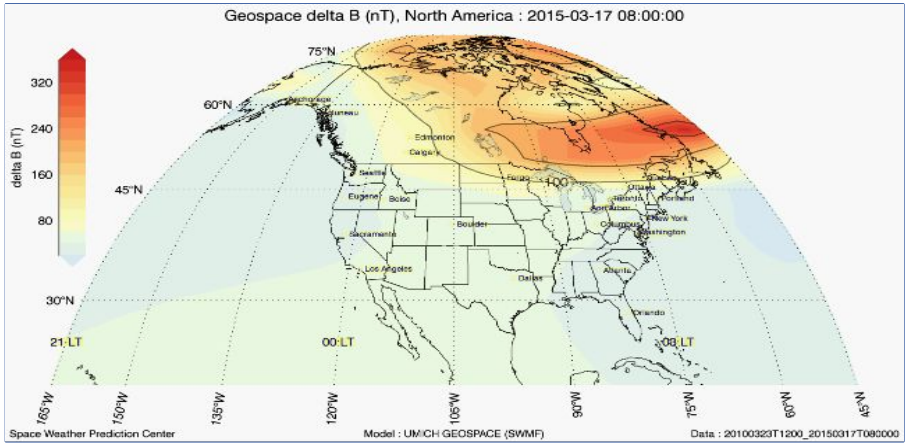
# GEOSPACE

## Product Focus: regional magnetic variations at Earth's surface

- db/dt, magnetic variations
- Driving predictive Geoelectric
- Geomagnetic indices: e.g. Kp, Dst..
- E-field for driving other models

## Supporting Models/Tools

- Michigan's Space Weather Modeling Framework (SWMF) including: Ridley Ionosphere Model, Rice Convection Model, BATS-R-US magnetosphere



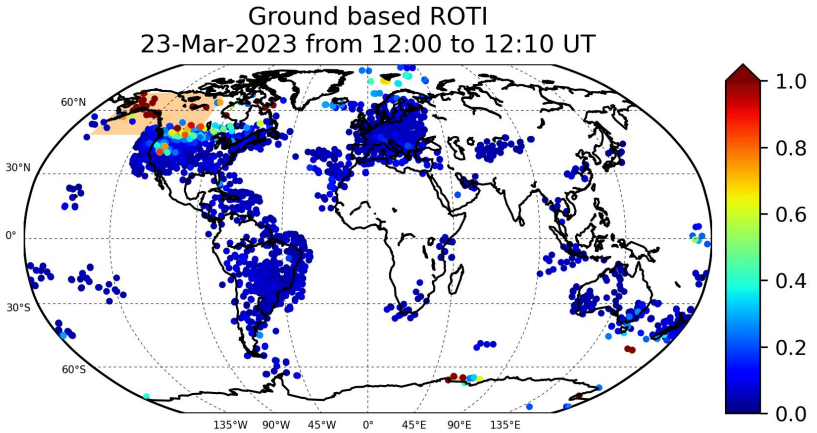

## Operational Data Streams

- Solar Wind velocity, density, temperature, and magnetic field observed at L1 by DSCOVR and ACE
- F10.7 (solar EUV proxy)

# IONOSPHERIC SCINTILLATION

**Product Focus:** Timing and location of moderate/severe phase/amplitude scintillation

- Global coverage
- Nowcast
- Forecast




## Supporting Models/Tools

- ROTI
- Ground-based and space-based observation
- Large gradient based on WAM-IPE

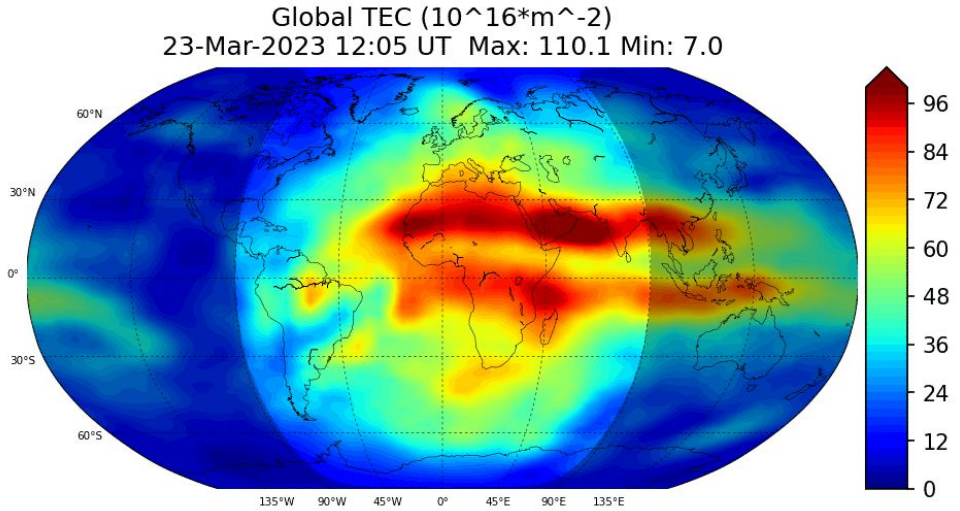
## Operational Data Streams

- Ground-based GNSS receiver data
- COSMIC-2 scintillation products
- Commercial RO data
- In-situ density measurement

# IONOSPHERIC DENSITY

**Product Focus:** Ionosphere changes associated with geomagnetic storm

- Global TEC nowcast/forecast
- TEC anomaly and gradient




## Supporting Models/Tools

- CTIPe
- WAM-IPE
- GloTEC

## Operational Data Streams

- Real-time solar wind parameters and forecast F10.7/Kp
- Ground- and space-based observations

# HF COMMUNICATION

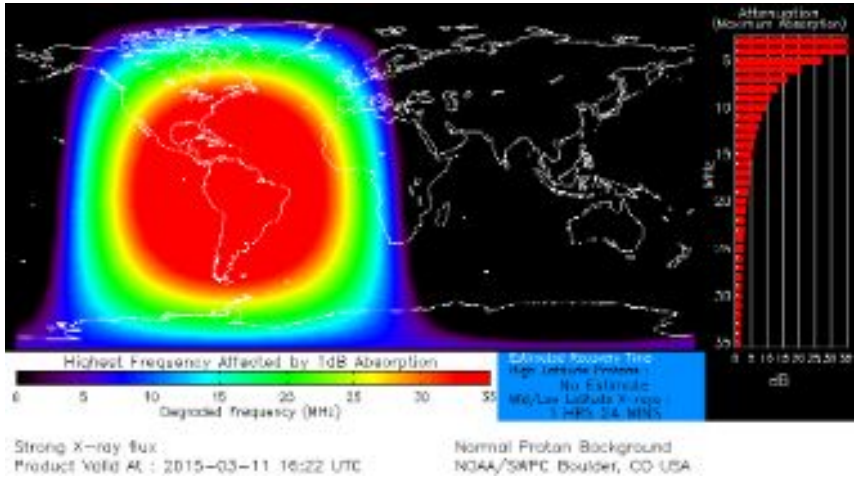
## Product Focus:

D-region plasma density changes

- **Shortwave Fadeout (Flare)**
- **Polar-Cap Absorption**
- **Auroral Absorption**

E-region and bottom-side F-region density changes

- **Maximum usable frequency depression**




## Supporting Models/Tools

- **D-RAP**
- **OVATION model**
- **WAM-IPE**

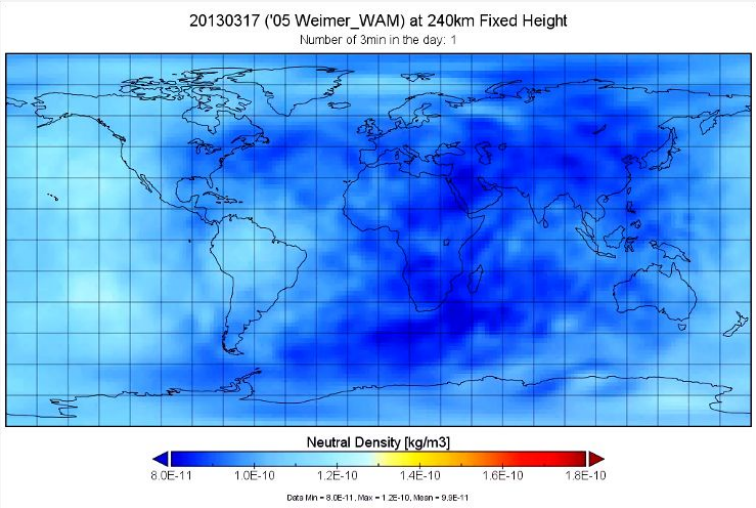
## Operational Data Streams

- **GOES X-ray flux data**
- **GOES proton flux data**
- **Real-time solar wind parameters and forecast F10.7/Kp**

# THERMOSPHERIC DENSITY

**Product Focus:** Neutral density specification and forecast

- LEO orbits and reentry
- Uncertainty quantification
- Tools developed for operators
- Day-to-day and storm conditions




## Supporting Models/Tools

- Whole Atmosphere Model (WAM) for nowcast and 2-day forecast

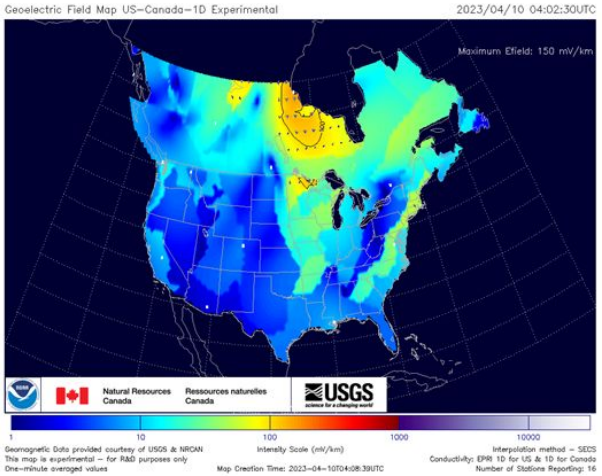
## Operational Data Streams

- Possible near real-time orbit averaged density from COSMIC-2 and Starlink

# GEOELECTRIC

## Product Focus:

- Provide Electric Power Industry a better space weather indicator than a global index
- The geoelectric field provides a local measure of system impact




## Supporting Models/Tools

- Geomagnetic Field interpolation model (SECS)
- Descriptions for electrical conductivity of the Earth (geology)
- Power grid systems models

## Operational Data Streams

- Input: operational magnetometers
- Outputs: Efield (mV/km) as graphical maps, geojson gridded data files, ascii gridded data files, netcdf daily archive

# NOAA Research to Operations Funnel

# NOAA Readiness Levels

**RL 1: Basic research:** *Systematic study directed toward understanding of the fundamental aspects of phenomena without any targeted applications specified. Basic research, however, may include activities with broad applications in mind.*

**RL 2: Applied research:** *Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met; invention and concept formulation. Investigation directed primarily towards a specific, practical aim or objective. Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives.*

**RL 3: Proof-of-concept for capability (system, process, product, service or tool):** *This can be considered an early phase of development. Beginning at RL 3, an increasing involvement of the deploying unit, receiving unit, or end user is anticipated in order to assist in guiding the research toward a mission application. The earliest version of a concept of operations (CONOPS) should be developed no later than RL 3.*

# NOAA Readiness Levels

**RL 4: Validation of capability in development (laboratory/experimental) environment:** *This can be considered an intermediate phase of development. Projects should not be resourced beyond RL 4 without a transition plan in place and having been developed in close coordination with the intended deploying unit. Such transition plans are expected to describe a viable path extending beyond a project's established RL through a successful operational implementation (RL 9).*

**RL 5: Validation of capability in an operations-relevant environment through testing and prototyping:** *This can be considered the final stage of development before demonstration begins. At RL 5, validation should be done on a prototype of at least medium fidelity in a Proving Grounds test environment, to rigorously confirm the attainment of pre-defined, quantitative performance expectations resulting from previous RL 4 validation efforts. This should include the integration with realistic supporting elements such that the system can be tested in a simulated end-use environment.*

**RL 6: Demonstration of prototype capability in a testbed environment (potential demonstrated).** *RL 6 is a level where it becomes necessary to engage with a testbed. At this stage, a high-fidelity implementation of the capability is demonstrated in a testbed environment which includes all critical components of the end-use environment. At this stage, the capability functions as intended under real world operational constraints, provides acceptable lead times relevant to forecasting efforts, and meets established performance requirements.*

# NOAA Readiness Levels

**RL 7: Demonstration of prototype capability in an operational environment (functionality demonstrated in near-real world environment; subsystem components fully integrated into system).** *Capability shown to execute robustly (effective error handling and monitoring in place) within an operational environment using available real-time data streams. CONOPS fully implemented and successfully demonstrated.*

**RL 8: Finalized capability tested and shown to operate, or function, as expected within the user's environment; user training and documentation completed; operator or user approval given.** *Execution in production parallel "staging" environment. This is the final stage of testing aiming to confirm the expected execution performance, robustness to the operational environment, and failure response.*

**RL 9: Capability deployed and used routinely.** *Once the capability is fully deployed, it has completed the process transition of R&D. However, the originating research unit may continue to be involved in support of continued refinements or incremental improvements throughout the total life cycle of the capability (O2R). An RL 9 designation means that the project has transitioned to operations and the research entity is not responsible for operating the system.*