Metrics for LWS Strategic Science Areas

- SSA-0, Solar electromagnetic, energetic particle, and plasma outputs driving the solar system environment and inputs to Earth's Atmosphere
- SSA-1, Geomagnetic Variability
- SSA-2, Satellite Drag
- SSA-3, Solar Energetic Particles
- SSA-4, Total Electron Content (TEC)
- SSA-5, Ionospheric Scintillation
- SSA-6, Radiation Environment

Assignment of working team domains into LWS SSAs are highly subjective.

This is not the focus of the discussion today.

Instead, please send your comments to the LWS LPAG who will be rewriting the SSAs!

SSA-0: Solar electromagnetic, energetic particle, and plasma outputs driving the solar system environment and inputs to Earth's Atmosphere *(physics-based understanding enabling forecast capabilities of the variability of solar magnetism)*

(1) Proposed Metrics

Solar Flare Prediction Team:

- Reliability diagrams
- ROC curves (and Gini coefficient)
- SR, HSS, BSS, TSS, Appleman SS (threshold TBD)

Solar Indices and Irradiance Team:

- Quantities to validate: F10.7 and ionospheric variability
- metrics TBD

SSA-0: Solar electromagnetic, energetic particle, and plasma outputs driving the solar system environment and inputs to Earth’s Atmosphere *(physics-based understanding enabling forecast capabilities of the variability of solar magnetism)*

(2) Proposed Metrics for the Coronal and Solar Wind Structure Team

Coronal Structure:

- Metric TBD comparing modeled field lines and synthetic EUV to observed EUV
- Metric TBD comparing coronal hole boundaries
- Metric TBD comparing to coronagraph images
- Possible quantities to validate: IMF polarity and sector boundary crossings at L1

Coronal Hole Boundaries: Comparing different algorithm with metrics TBD

Solar Wind:

- MSE, RMSE, FAR, SR, POD, POFD; Correlation coefficient
- Stream arrival time mean absolute error

SSA-1: Geomagnetic Variability
(1) Proposed Metrics

CME Arrival Time & Impact Team:

- Mean Absolute Arrival Time Error
- Performance diagrams; POD, SR, Bias, CSI (in addition to other contingency table skill scores)
- Ensembles: Reliability diagrams, BSS
- v, n, B, T of arrival: TBD metric

IMF Bz at L1 Team: TBD metric quantifying goodness of modeled **B** at L1

SSA-1: Geomagnetic Variability
(2) Proposed Metrics

Magnetopause Location & Geosynchronous Orbit Crossing Team:

- RMS, Prediction Efficiency, Cross Correlation
- Event-based studies with probability detection
- Database of magnetopause crossings from different missions and Geosync. Orbit crossings
- Possibly developing model/observation comparison tool
- Quantify speed of changing inward and outward motion

Quantities of interest:

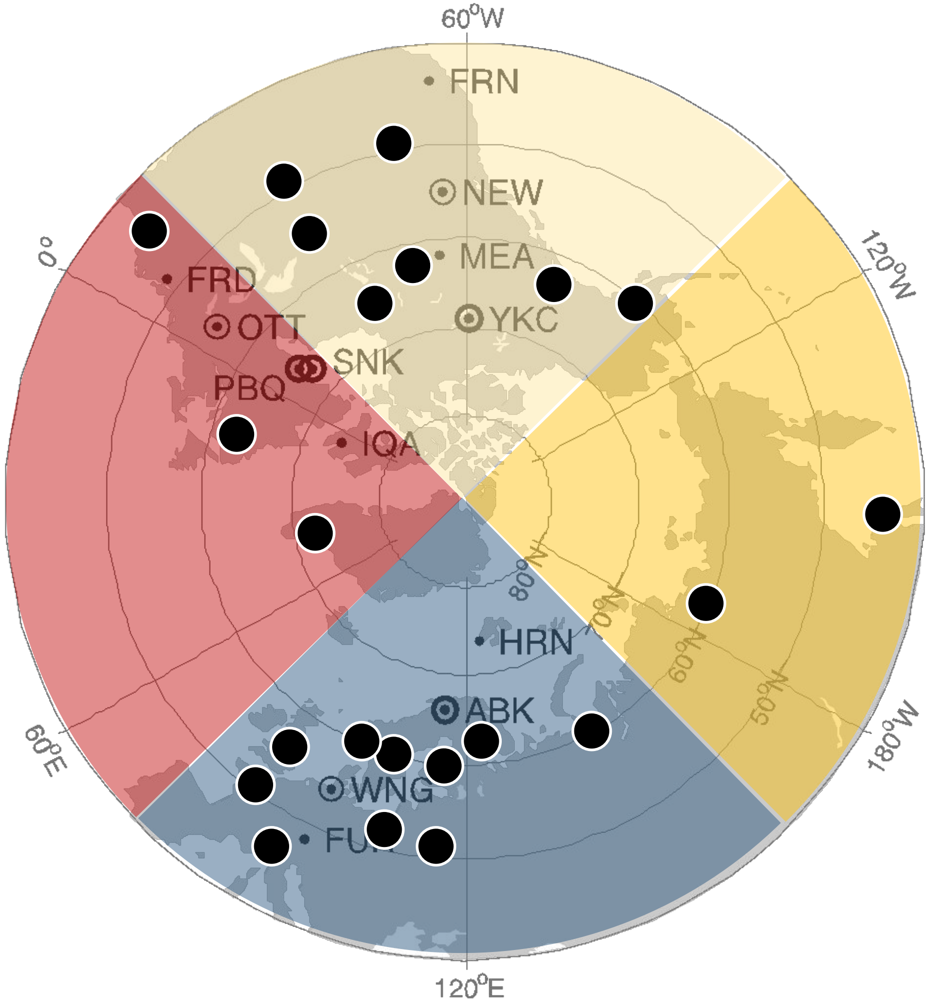
- Modeled standoff positions for the same solar wind conditions.
- Sensitivity of the subsolar and flank magnetopause to changes in model parameters.

SSA-1: Geomagnetic Variability

(3) Proposed Metrics Geomagnetic Indices Team:

- Global indices are both useful and useless
  - Excellent integrators of geospace response
  - Difficult to extract physical meaning from them
  - Our view: good as an overall model test
- The metrics for indices
  - Fit performance: linear fit parameters, Pearson correlation, mean absolute error, root-mean-square error, prediction efficiency
  - Event-detection performance: Heidke Skill Score, Prob. of Detection, and False Alarm Rate vs. threshold, receiver operating characteristic (ROC) curve (POD vs. FAR)
- No time interval is specified as a required test study
  - Selections like this get outdated within a few years
  - Our recommendation: hundreds of value comparisons, thousands is better
- A manuscript is underway

SSA-1: Geomagnetic Variability
(4) Proposed Metrics for dB/dt



- Expand number of magnetometers to *as many as possible* for each event.
- Increase data resolution to 10s.
- Bin by MLT (e.g., midnight, dusk, dawn, noon) and examine strongest dB/dt within a region.
- Bin by activity type (substorm, storm sudden commencement, main phase, etc.)
- Expand event list with preference to extreme dB/dt cases.

Find more information and get involved at ccmc.gsfc.nasa.gov/assessment/topics/geospace-dbdt.php

SSA-2: Satellite Drag
Proposed Metrics for Neutral Density Modeling Validation

- Neutral density in the altitude range 200 ~800 km

- For comparison with accelerometer data:
  - Daily mean
  - Orbit averaged for satellite orbits
  - Model sampled at satellite locations, binned 5° along track
- For comparison with Emmert global mean daily data
  - global-mean daily mean
- Compute ratios of Observed/Modeled

SSA-3: Solar Energetic Particles
Proposed Metrics TBD

Quantities to validate:

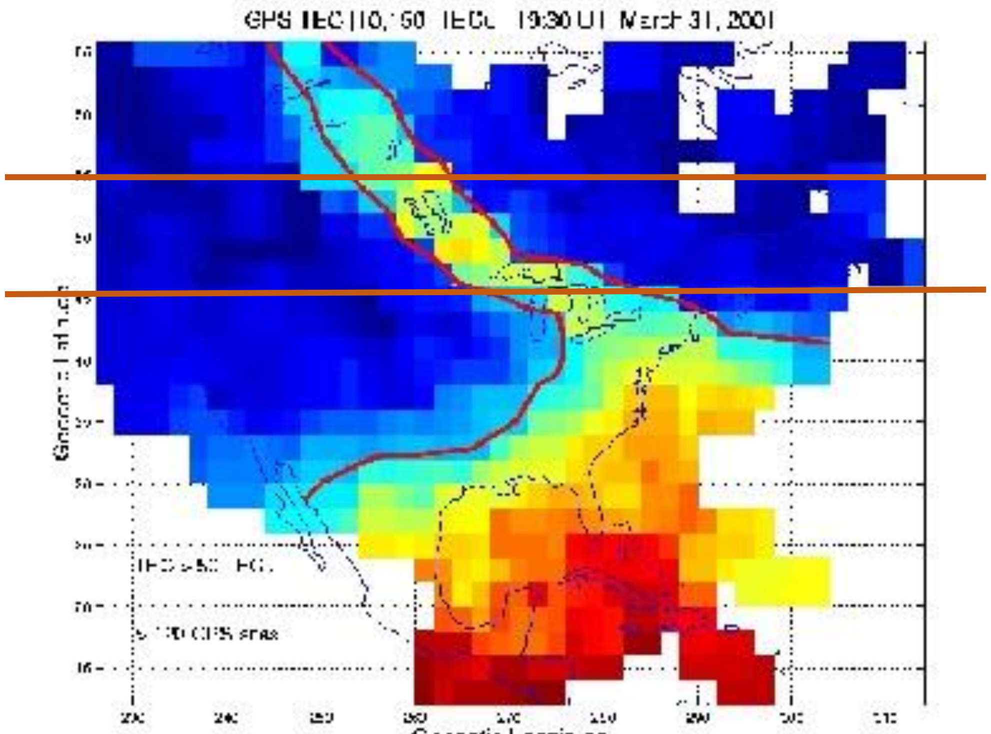
- **Onset time** and **threshold crossing time**
- **Event duration** (above a threshold)
- **Fluence, peak intensity and peak timing** (energy dependent)
- **Flare/CME-SEP prediction** (i.e., when will a flare/CME erupt, and will it be associated with SEPs?).
- **Energy spectrum, anisotropy, profile shape, ESP**
- **All clear** forecasts
- Probabilistic forecasts: to follow flare team metrics.

Overlapping user needs:

- a few **standard energy ranges** relevant to user groups (more than just GOES 10 MeV, 100 MeV protons)
- a few **standard thresholds** (to define SEP event, and duration time) relevant to **user groups**
- Include **heavy ions**
- Make sure a **few key metrics** amongst science metrics are targeting users

SSA-4: Total Electron Content (TEC)
Proposed Metrics for Global TEC Modeling Validation

- **TEC gradient**:
  For example, G45-55 will be calculated as the maximum absolute longitudinal TEC gradient
  in the mid-high latitudes (45˚ < geo. lat. < 55 ˚)
  in North American and European Sectors.



- Normalized percentage change from baseline:

  n_dTEC= [dTEC[%] -ave_dTEC[%]]/std_dTEC[%]

  - max. of n_dTEC
  - (max. of n_dTEC + max. of |n_dTEC|)/2

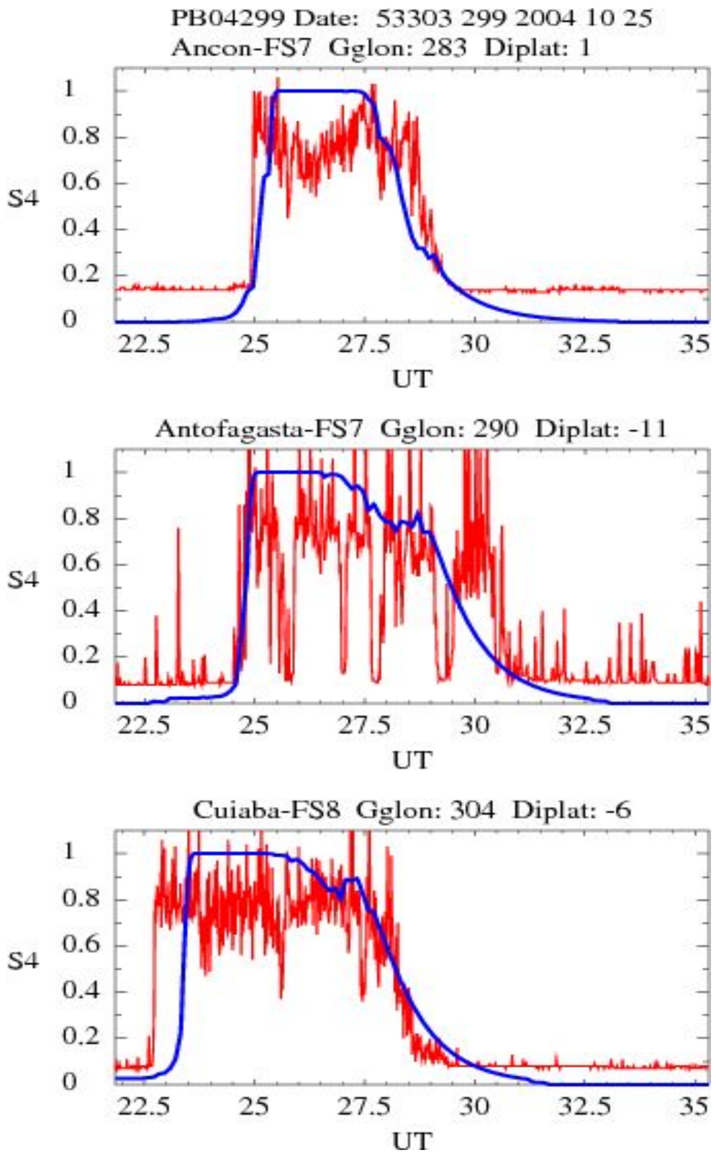
- TEC difference/average among several stations (~12) strategically selected

SSA-5: Ionospheric Scintillation

(1) Proposed Metrics for Ionospheric Scintillation Modeling Validation

- S4 index
- ROTI (Rate of TEC index:

  STD of the ratio of change of TEC)
- Onset time at a particular level
- Peak value
- Duration above a certain level
- Average value
- Time integral



SSA-5: Ionospheric Scintillation
(2) Proposed Metrics for Plasma Density Modeling Validation

- foF2/NmF2, hmF2, vTEC, MUF
- In different latitude and local time sectors
- Complementary analysis of a set of metrics, including RMSE, MAE, and Correlation Coefficient
- For each physical quantity, the metrics will be calculated to measure ability to model
    - Climatological variations
    - Day-to-day variability
    - Storm impact (deviation from climatological estimates over storm events)

SSA-6: Radiation Environment

SSA-3: Solar Energetic Particles

Proposed metrics using log ratio

- Two new metrics using log ratio (Morley et al., 2018) satisfying the four attributes (see below)

The median symmetric accuracy

$$\varsigma = 100(\exp(M\ (|log_e(Q_i)|)\ ) - 1)$$

where $Q_i = \frac{y_i}{x_i}$: ratio of predicted versus observed, y_i: model, x_i: observation
M: median value

The Symmetric Signed Percentage Bias (SSPB):

$$\text{SSPB} = 100\ sgn\left(M\left(log_e(Q_i)\right)\right)(\exp(\left|M(log_e(Q_i))\right|) - 1)$$

Sgn: signum function;
M: median value

(1) The metrics must be meaningful for data that cover orders of magnitude,
(2) underprediction and overprediction by the same factor should be penalized equally,
(3) the metrics should be easy to interpret, and
(4) the metrics should be robust to the presence of outliers and bad data.