Study Organization

- A short final report is on the web
  - http://rigel.rice.edu/~wolf/swmetrics.html
  - Embedded, modified somewhat, in the 2nd edition of the NSWP Implementation Plan.
- Contributors:

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Why Do We Need Space Weather Metrics?

- A metric is a quantitative measure of ability to predict something.
  - Here "prediction" can be taken in the scientific sense or in the sense of a real forecast made ahead of time.
- Why do we need space weather metrics?
  - Metrics are needed to judge the progress of the National Space Weather Program
- Why set up scientific metrics? Why not use NOAA/USAF user-based metrics?
  - NSF wanted a measure of scientific progress that was as broad as possible.
    - A metric that measured ability to predict equatorial scintillation or outer-belt electrons, for example, might not be the best measures of overall progress of ionospheric and magnetospheric physics.

Definition of a Space Weather Metric

- A "space weather metric" is a quantitative measure of the ability of a scientific algorithm or model to predict or nowcast the value of a physical parameter involved in space weather.
- A specific metric has three elements:
  - A parameter defined at some position and time. Example: *F*-region peak electron density at mid-latitude every hour for the next day.
  - An observable to which a prediction can be compared. Example: density measurement by an incoherent-backscatter radar facility
  - A criterion by which the metric is quantified. Example: RMS difference between prediction and observation.

Scientists in the Three Sub-Fields Reacted Quite Differently to the Idea of Establishing Metrics

- Ionospheric people had already done some systematic work with metrics, particularly rms errors in Nm(F2).
  - Their rms errors tend to be smaller than the average values.
- Except with very limited experience with the MSM, the magnetospheric community had no experience with metrics but tended to be interested and mostly ready to give it a try. The GEM Metrics contest was a spirited, interesting competition.
  - In magnetospheric physics, differences between modeled and observed particle fluxes, electric fields, etc., tend to be about as large as the mean values.
- It was harder to find solar physicists who were much interested in metrics. Most felt that they were still trying to unravel the basic physical processes, and performance metrics seem irrelevant to that activity and perhaps not entirely appropriate.

Challenges for Magnetosphere-Ionosphere Panel

- It takes a lot of parameters to adequately and usefully characterize the state of Earth's magnetosphere:
  - $f_j(\mathbf{v})$, **E**, **B** for all positions
  - f includes e^-, H^+, O^+ for several disparate particle populations:
    - Cold plasma (< 10 eV)
    - Ring-current/plasma-sheet (100 eV-100 keV)
    - Radiation belts, solar particles... (> 100 keV)
    - Distributions aren't Maxwellian, usually aren't even isotropic.
- The scientists wanted a long set of metrics that would be comprehensive and diagnostic, but NSF wanted really wanted us to identify one metric.
  - The report listed key 5 ionosphere-magnetosphere metrics, with one highlighted as most important.

Challenges for the Magnetosphere-Ionosphere Panel

- It is useful to specify the state of the magnetosphere in varying levels of detail
  - Single-number indices (e.g., *Kp*)
  - 1D parameters (e.g., boundary between open and closed field lines)
  - 2D parameters (e.g, magnetopause surface)
  - 3D parameters (e.g., magnetospheric **B**)
- An ideal metric would
  - Cover all crucial elements of Earth's magnetosphere.
  - Interest a large number of scientists.
  - Require only input data that will be uniformly available over the next 10 years.
  - Would be capable of showing major progress over 10 years, if real progress were made.
    - Shouldn't choose parameters that we are already good at predicting (e.g., nowcasts of *AE* or *Dst*).

Major Features of Magnetosphere-Ionosphere Coupled System

Feature	Includes
Magnetic field configuration	Global magnetic structure, including dayside, tail; ground magnetic variations
Electric field configuration	Ionospheric and magnetospheric. Represents effects of solar-wind/magnetosphere coupling, magnetospheric convection
Auroral precipitation	Precipitation from polar cusp, polar cap, main auroral zones and plasma sheet
Trapped energetic particles	Includes ring current and inner and outer radiation belts, from ~ 1 keV to ~ 100 MeV
Cold particles	Plasmasphere, plasmapause, suprathermal ions
Plasma sheet, plasma-sheet boundary layer	Kilovolt electrons and ions that extend into the tail
Magnetopause	Shape and position, reconnection, transfer processes, boundary layers
Waves and small-scale effects	Cause particle loss by pitch-angle scattering, allow magnetic reconnection, accelerate auroral particles

Top-Priority Magnetosphere-Ionosphere Metrics

First priority →

Category	Parameter(s)	Place	Averaging interval	Data	Criterion*
High-latitude ionospheric electric field	Component of **E** along track of polar-orbiting spacecraft above 50Þinvariant latitude	~ 1000 km altitude, from dawn-dusk orbit	100 km along s/c track	Ion drift meter on DSMP spacecraft	Mean absolute error in component of **E** along satellite path
Auroral electron flux	Latitude-integrated energy flux, number flux. Latitudinal centroid of energy flux	~ 1000 km altitude, from nightside auroral zone crossings.	100 km along s/c track	Precipitating electron flux measured by DMSP or NOAA spacecraft	Mean absolute error
Magnetic indices	*AE* (electrojets) *Dst* (ring current) *Kp* (overall activity)	Ground stations	Time resolution of index	Ground magnetometers	Mean absolute error
Magnetospheric electron fluxes	Fluxes of > 10 keV and > 1 MeV electrons	Geosynchronous orbit	15 minutes	LANL and NOAA spacecraft	Mean absolute error in log(flux)

* Mean absolute error is $<|A_{model} - A_{observed}|>$

Summary Comment

- Comments on the rationale for the choice of the high-latitude electric field as the parameter to base the metric on:
  - The high-latitude electric field is an important driver of the ionosphere.
  - Many modelers calculate it (global MHD, statistical models, AMIE).
  - We chose a measure of average error all along a spacecraft track, rather than the total polar cap potential drop, because the latter would have been too easy. There are already pretty good empirical predictors for that.
- Since the magnetospheric-physics community had never done anything like this before, we knew that the initially chosen first-priority metric wouldn’t be ideal.
  - There was no way to know how well it would work until a competition was held and we saw how things came out.
  - At least for the first few competitions, it will be important to save the data and the model predictions, so that it will be possible to adjust the metric and not lose year-to-year normalization.