Metrics for Addressing Space Weather Prediction Center User Needs

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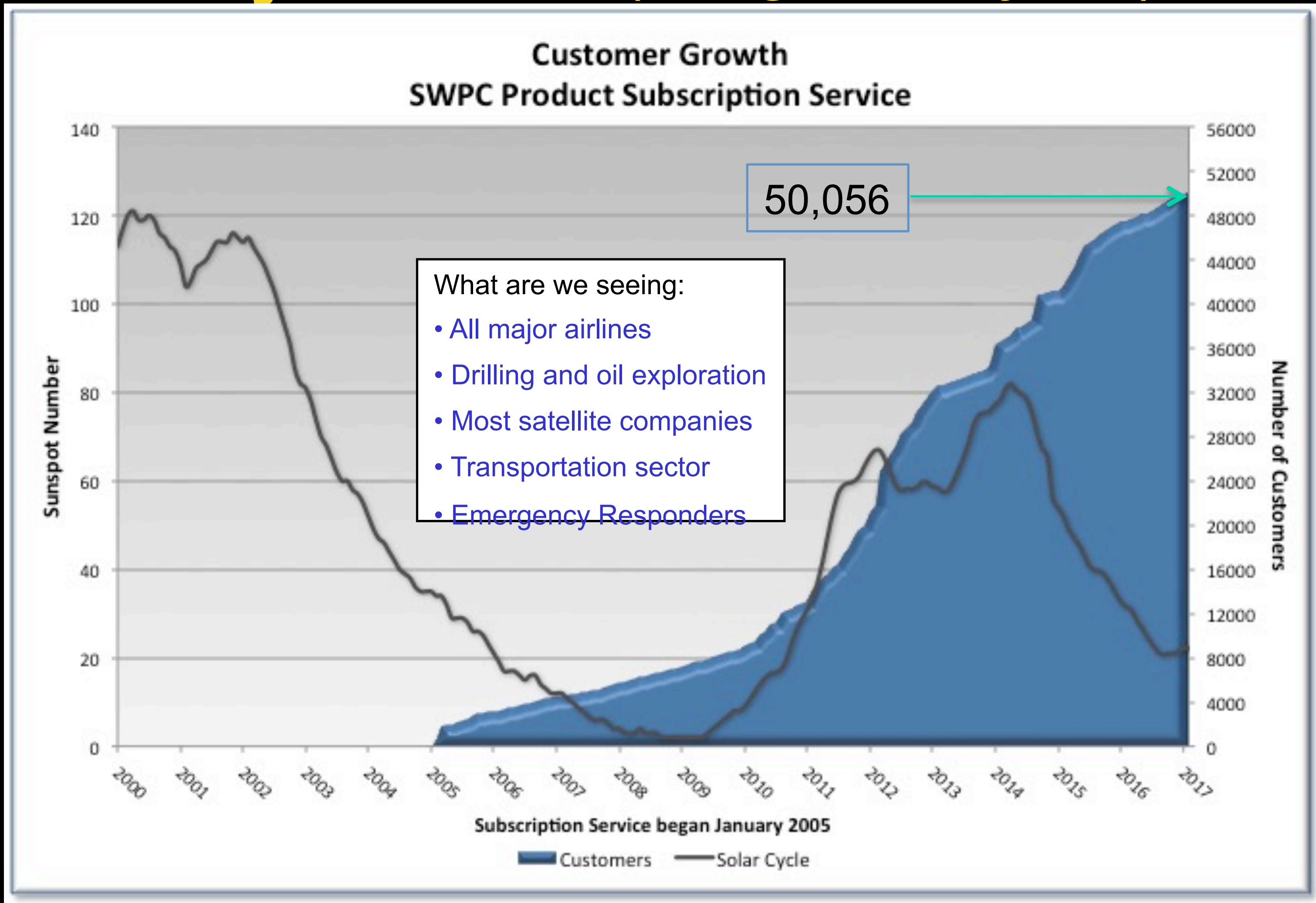
Outline:

- **SWPC Customers and SWPC Mission**
- **Intro to Metrics & Previous Metrics Work**
- **Example: Geospace Model Selection**
- **Using Metrics for Model Performance Verification**
- **SWPC Metrics and Validation Activities**
- **Conclusions and Lessons Learned**

International CCMC-LWS Working Meeting: Assessing Space Weather Understanding and Applications
April 3-7, 2017 Cape Canaveral, Florida

Acknowledgments: Balch, Cash, Murtagh, Onsager, Rutledge, Steenburgh, Viereck

Customer Subscriptions Skyrocket… (through February 2017)



Small solar cycle, but the largest geomagnetic storms on record occurred during smaller than average cycles (e.g. 1859, 1921)

Space Weather Prediction Center

Established 1946 as part of Central Radio Propagation Laboratory

Operations –
Space Weather Forecast Office

Daily forecast since 1965.

Specifications; Current conditions
Forecast; Conditions tomorrow
Watches; Conditions are favorable for storm
Warnings; Storm is imminent with high probability
Alerts; observed conditions meeting or exceeding storm thresholds

R & D –
Space Weather Prediction Testbed

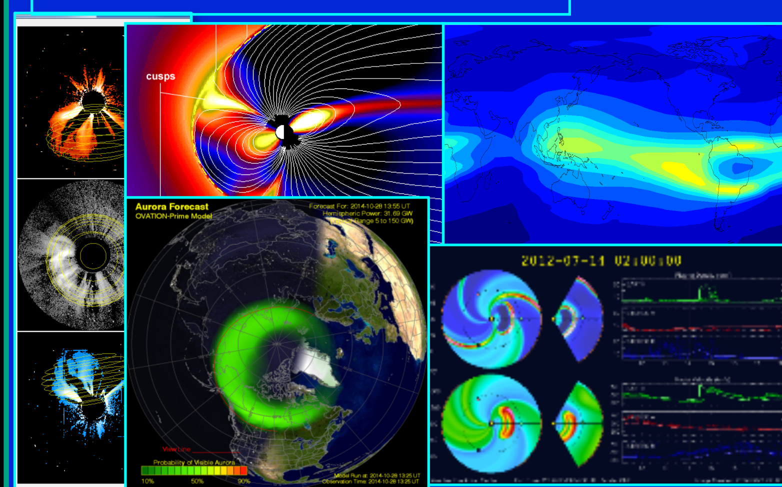
Transitioning models into operations

R2O

Research-to-Operations
- Applied Research
- Model Development
- Model Test/Evaluation
- Model Transition
- Operations Support

Operations-to-Research
- Customer Requirements
- Observation Requirements
- Research Requirements

O2R



A Metrics Definition

“ A METRIC IS A MEASUREMENT, TAKEN OVER TIME, THAT COMMUNICATES VITAL INFORMATION ABOUT A PROCESS OR ACTIVITY, DRIVES APPROPRIATE LEADERSHIP OR MANAGEMENT ACTION, AND IS LINKED TO THE STRATEGIC PLANNING PROCESS.”

From: Performance Measurement And Management - Modern Techniques
by Capt Harry Krukenberg - Air Force Institute of Technology

Metrics Definition

(with Possible Example)

" A METRIC (Geopace model skill predicting dB/dt) IS A MEASUREMENT, TAKEN OVER TIME, THAT COMMUNICATES VITAL INFORMATION (poor comparison of model dB/dt thresholds with nightside observations) ABOUT A PROCESS OR ACTIVITY (substorm activity), DRIVES APPROPRIATE LEADERSHIP OR MANAGEMENT ACTION (support model development that includes ionospheric outflow), AND IS LINKED TO THE STRATEGIC PLANNING PROCESS (e.g. National Space Weather Strategy; Ops Center investment) ."

Prior Community Work on Metrics

ESTABLISHING METRICS FOR THE NATIONAL SPACE WEATHER PROGRAM: A Strategy, Implementation Plan, and Metrics Guidelines (1998)

Identifies both scientific and operational metrics

Steering Committee

E. Szuszczewicz* (Chair): Ionospheric-Thermospheric
E. Hildner*: Solar-Interplanetary (Solar Wind)
R. Wolf*: Magnetospheric-Ionospheric

Subpanels

Solar-Interplanetary	Magnetospheric-Ionospheric	Ionospheric-Thermospheric
T. Bastien	J. Albert	D. Anderson
J. Davils	D.N. Baker	S. Basu
S. Habbal	W. Burke*	W. Denig
J. Harvey	J. L. Horwitz	D. Farley
T. Hocksema	J. Lyon*	B. Fejer*
S. Kahler	T. Onsager	T. Fuller-Rowell*
J. Klimchuk*	J. Raeder	R. Heelis*
J. Lean	J. Rochier	T. Killeen*
J. Linker*	H. Singer*	F. Marcos
D. Neidig*	T. Tascione*	R. Meier
V. Pizzo*	D. Vassiliadis	P. Richards
		R. Schunk

*Initial panel membership responsible for generating strawman specifications for NSWP metrics.

Prior Community Work on Metrics

Center for Integrated Space Weather Modeling Metrics Plan and Initial Model Validation Results

H. Spence et al. / Journal of Atmospheric and Solar-Terrestrial Physics 66 (2004) 1499–1507

				Baseline Models	Skill Score Data Sets	Physics Models
	Operational SW Community					
Operational Metrics	1		*Shocks and CMEs at L1*		ACE	MAS+ENLIL
		a	Speed	Augmented Vrsnack-Gopalswamy[a]	"	
		b	Arrival time	"	"	
		c	Bz	"	"	
		d	Duration	"	"	
	2		*SEP Properties*		GOES	UCB
		a	Event/No Event	PROTONS[b]	"	
		b	Rise Time	"	"	
		c	Peak Flux	"	"	
		d	Duration	"	"	
		e	Cutoff	Shea-Smart[c]	POES	
	3		*Magnetic Indices*			
		a	Dst	Temerin-Li[d]	NGDC	LFM+RCM
		b	Ap/K	ARX-McPherron	"	
	4		*Regional Ground dB/dt*	Weigel-Baker[e]	IMAGE (mag)	LFM+TING
	5		*Radiation Belt EP fluxes*			
		a	GEO	Li[f]	LANL	RBM
		b	MEO and LEO	Vassiliadis[g]	SAMPEX	"
	6		*Ionosphere/Neutral Atmosphere*			
		a	"State" of ionosphere	IRI[h]	Digisondes	TING
	Scientific SW Community					
Science Metrics	1		Solar/Coronal			
		a	Coronal Hole Index	PFSS/Wang-Sheeley[i]	SOHO UV maps	MAS+ENLIL
		b	White-light Streamer Belt Index	PFSS/Yi-Ming Wang[j]	SOHO LASCO	"
	2		*Solar Wind/IMF at L1*			
		a	Density	WSA[k] + nv = constant	ACE	MAS+ENLIL
		b	Velocity	WSA	"	"
		c	IMF - vector	WSA + IBI	"	"
	3		*GEO/MEO Environment*			
		a	Magnetic field	Tsyganenko[l]	GOES	LFM+RCM
		b	Particle fluxes (ring current/rad belt)	MSM[m], CRRESELE[n]	GOES/LANL	LFM+RCM,RBM
		c	M'pause crossing	Shue[o]	"	LFM+RCM
	4		*MI Coupling*			
		a	Polar Cap Potential	Weimer[p]	DMSP	LFM+TING
		b	Polar Cap Boundary	Weimer	"	"
		c	Field Aligned Currents (2D)	Weimer	"	LFM+TING+MIC
		d	Particle precipitation	AURORA[q]	"	MIC
	5		*Ionospheric Plasma*			
		a	E-, F-region Heights	IRI	Digisondes +	TING
		b	E-, F-region Peak Densities	"	ISRs	"

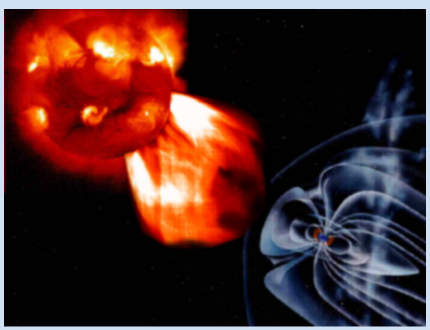
Geospace Models: Transition to Operations

- **Goal:** Evaluate Geospace models (MHD and empirical) to determine which model(s) are ready for transition to operations
- **Focus:** Regional K and dB/dt (important to electric utilities)
- **Partnership:** Evaluation at NASA/Goddard CCMC working with SWPC, modelers and science community

Select Models and Events → Establish Metrics → Model-Data Comparisons → CCMC Reports to SWPC

SWPC Selection FY 14: U. Of Michigan (MHD), VT (Weimer Empirical)

based on CCMC reports, internal and external advice, and following considerations:



Solar Influences on Geospace Predicted with Geospace Models using Solar Wind Input

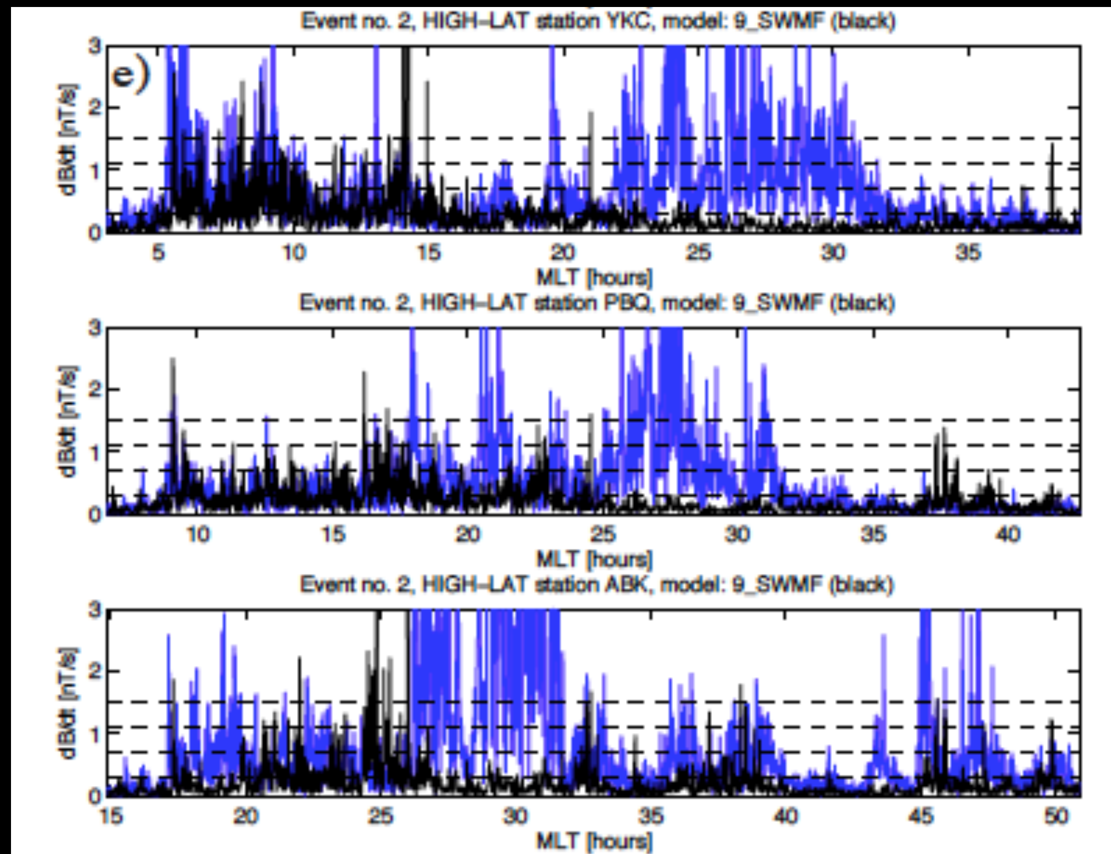
- Strategic Importance
- Operational Significance
- Implementation Readiness
- Cost to Operate, Maintain, and Improve

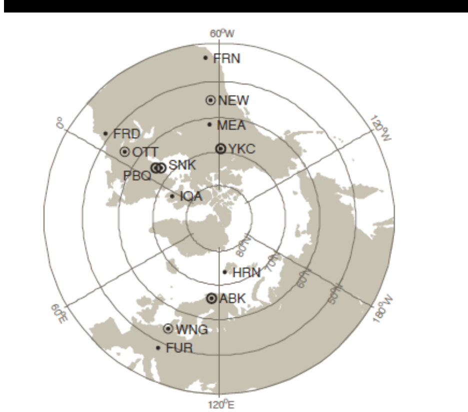
U. Of Michigan Geospace Model Operational Oct 16

Geospace Model Selection Threshold Metric
dB/dt Model Data Comparisons at High Latitudes

Contingency tables can be created from model/ observation values crossing thresholds at different dB/dt levels.

Pulkkinen et al.: Geospace Model Validation/Transition, Space Weather Journal, 2013.





Dec 14, 2006 12 UT
Dec 16, 2006 00 UT

Black – Model
Blue - Observation

Geospace Model Selection

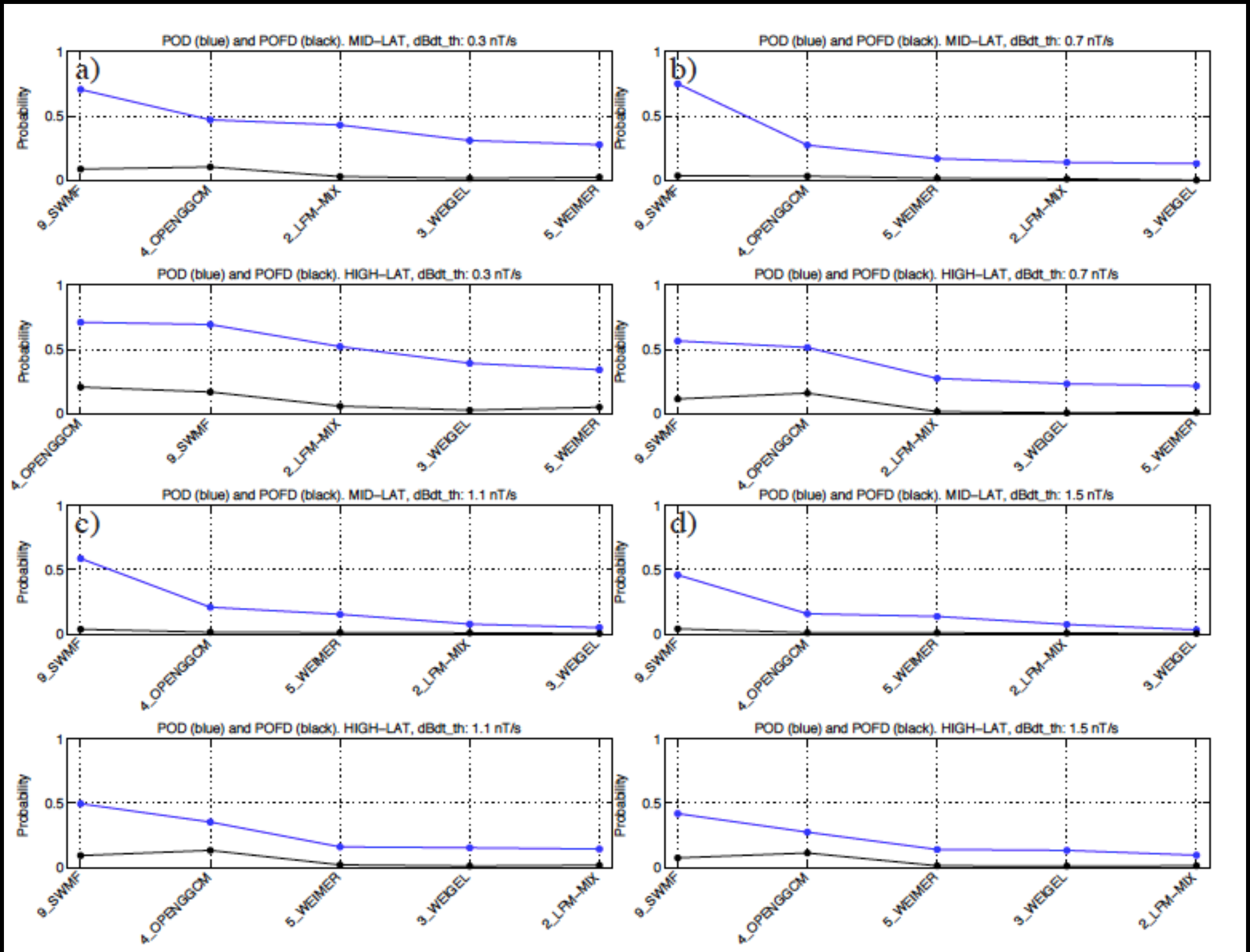
Model Data Comparisons

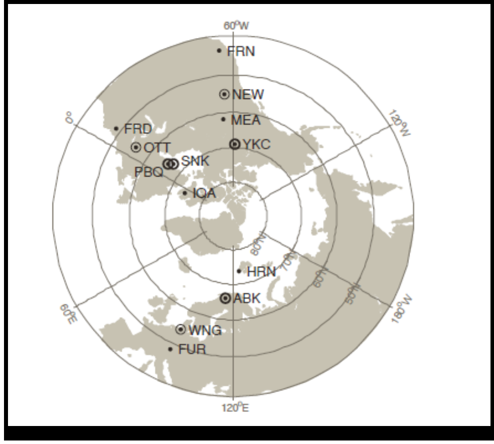
POD and POFD for different dB/dt Thresholds integrated over high and mid-latitude stations

Pulkkinen et al.: Geospace Model Validation/Transition, Space Weather Journal, 2013.

Blue – POD

Black – POFD

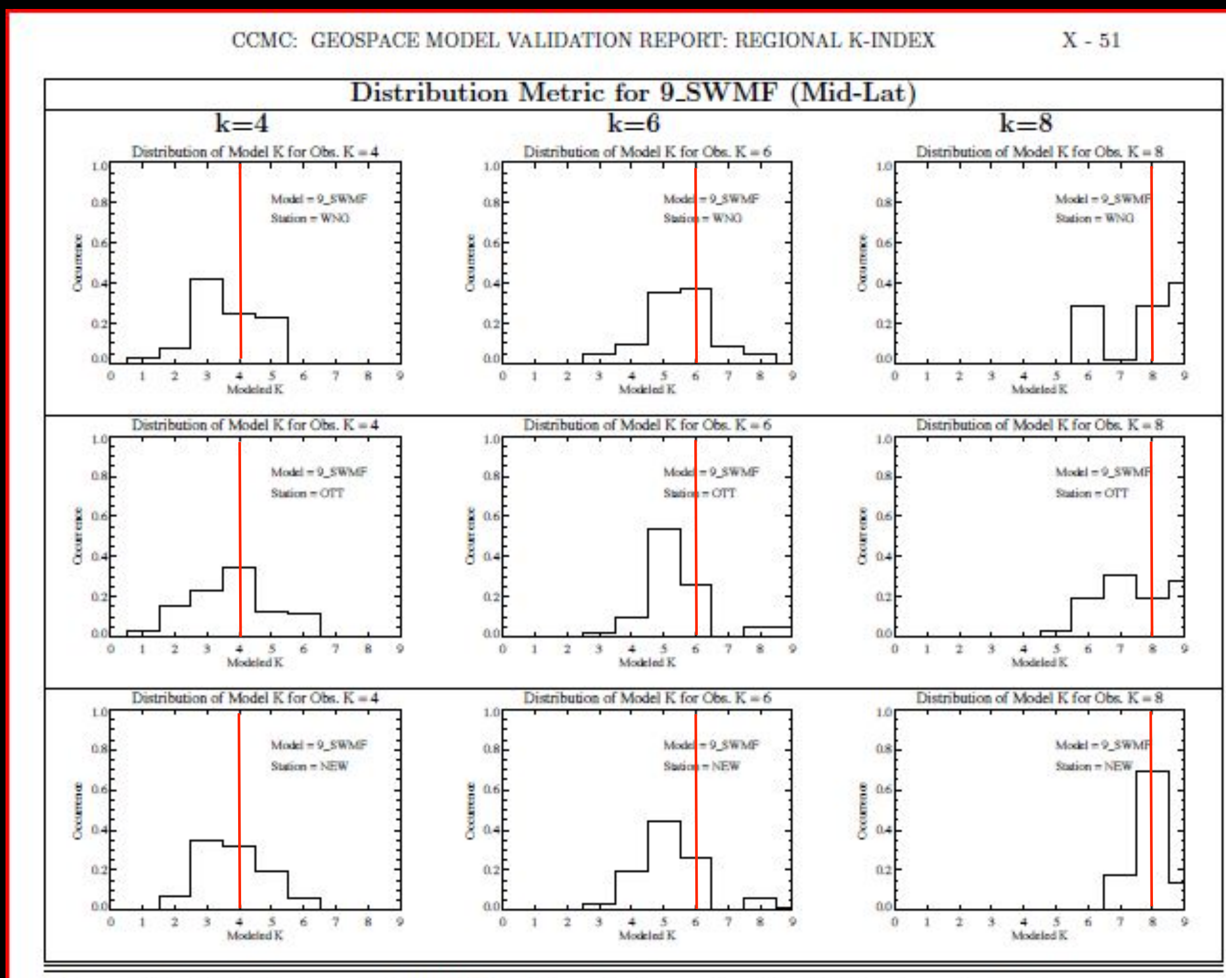




Geospace Model Selection

Distribution Metric

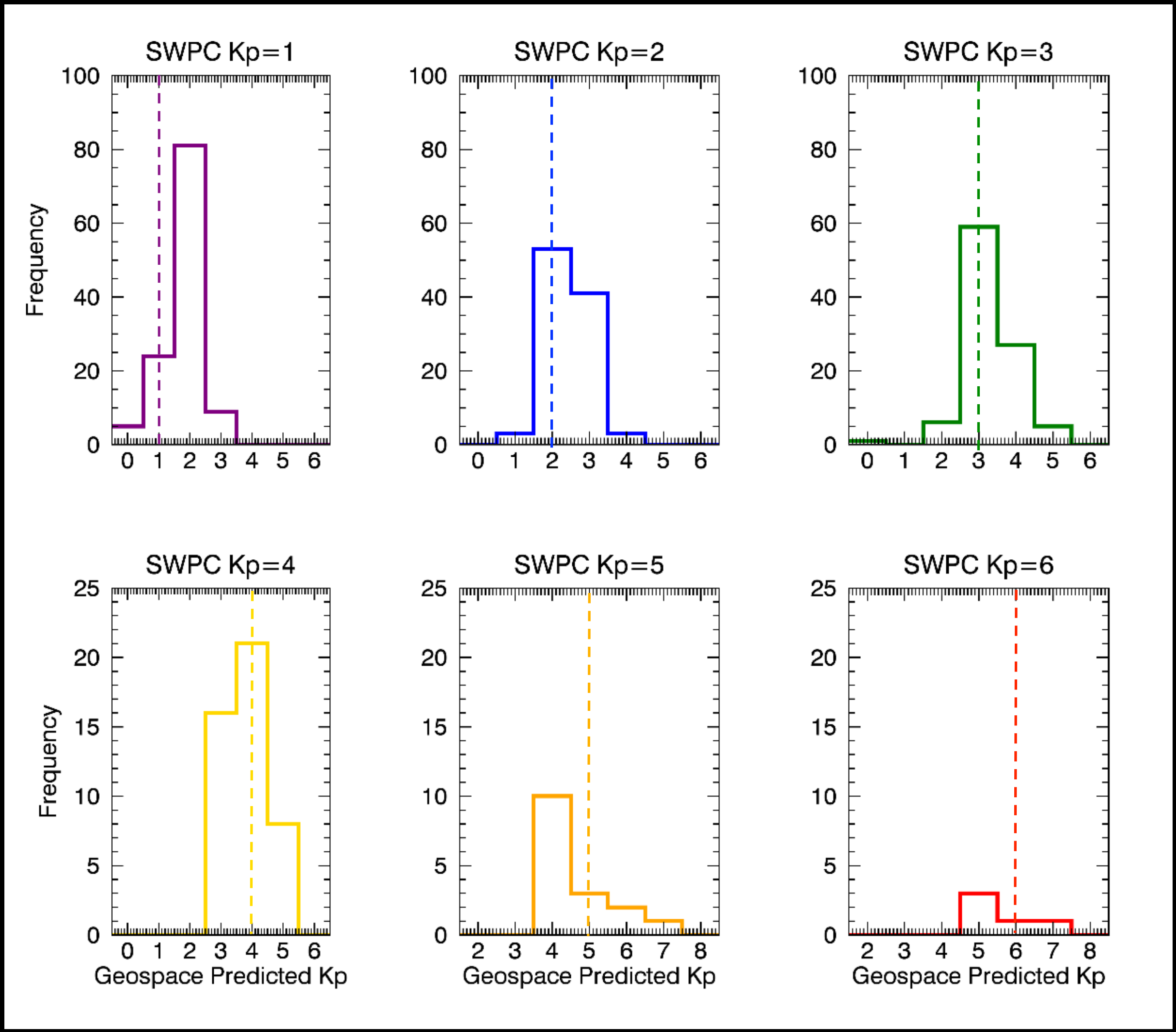
Distribution of model K for Observed K=4, 5, and 6 at mid-latitude stations



- **Illustrates biases**
- **Insight into skill scores in contingency tables**
- **Identifies systematic and random errors**

Glocer et al.: Geospace Model Validation/Transition, SWJ, 2016.

Validation and Metrics Applied to Operational Michigan Geospace Model



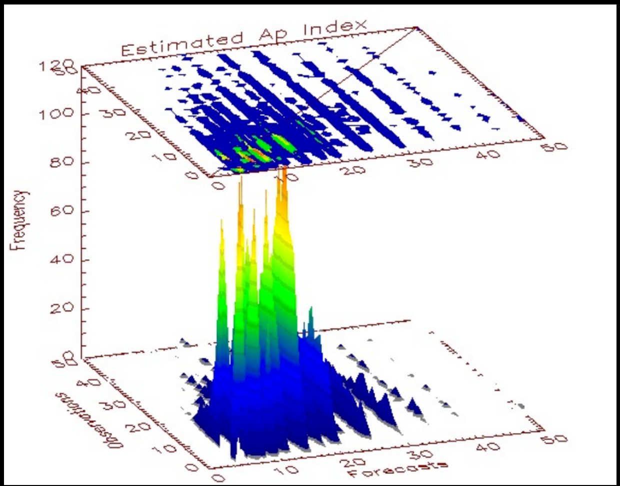
Kp Distribution of Predicted Kp Values for Observed Kp Values (1-6)

Enhances understanding of model performance

Enables establishment of confidence levels and error bars

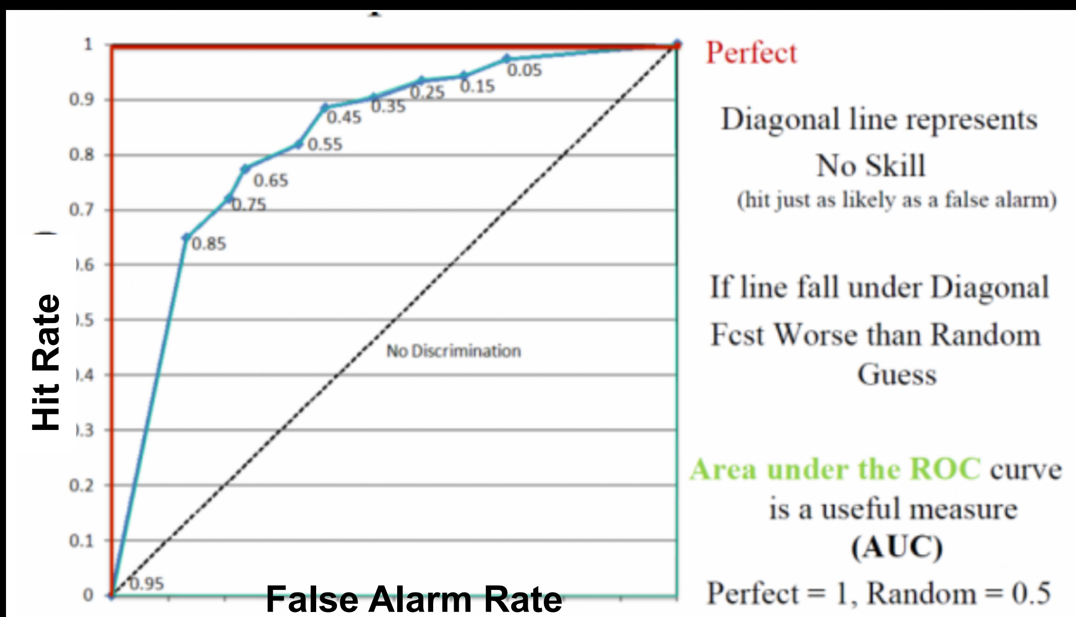
SWPC Metrics and Validation

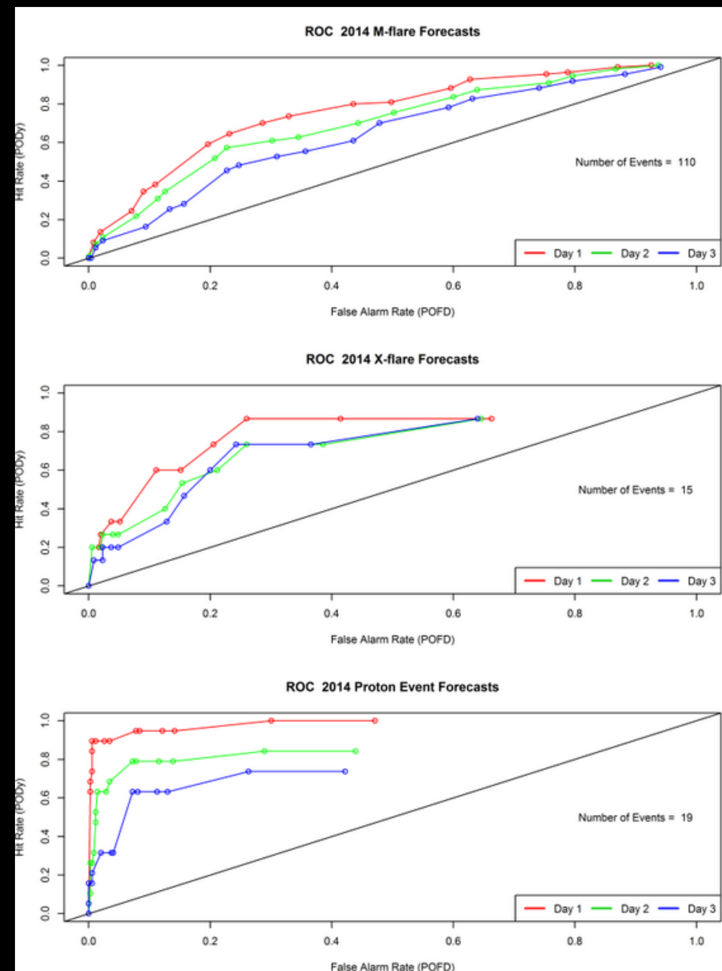
- www.swpc.gov (under Products and Data, Reports, Forecast Verification)
- Topics include:
  - Geomagnetic Activity Forecasts
  - Solar Activity Forecasts
  - Flare Receiver Operating Characteristics (ROC) Curves
  - Bibliography, Tutorials, Verification Glossary



Receiver Operation Characteristic Curves Applied to Flares and SPE

		Observed		
		Yes	No	Total
Forecast	Yes	a	b	a+b
	No	c	d	c+d
	Total	a+c	b+d	n





See SWPC http://www.swpc.noaa.gov/content/roc-receiver-operating-characteristic-curves

Metrics: Selected Lessons Learned and Conclusions

- Metrics for model performance are different from metrics for operational forecasts (forecasters provide forecasts; models provide guidance)
- The same product (model prediction) may need different metrics applied for different users
  - E.g. power grid (Kp 5) vs pigeon racer (Kp 4)
- Operational metrics can be different than scientific metrics
  - dB/dt on ground vs cross-polar cap potential
- Sometimes operations can benefit by using scientific rather than operational metrics
  - Bz accuracy is a scientific metric, but clear that many operational products can benefit from Bz accuracy

Metrics: Selected Lessons Learned and Conclusions

- Operational metrics can be established by customers and forecasters, but iteration between customers and model developers leads to appropriate choices
- One model may not always be “best” at all metrics
- Metrics are important for understanding model limitations and credibility
- Evaluations for operations (rather than science) provides valuable feedback to science (O2R)
- Models depend on data for input, assimilation, and validation