# Gaps in Space Weather Forecasting

**Awareness Gap**: Where is there uncertainty about how the scientific community can contribute to space weather operations?

# Areas With Good Awareness

- All agencies recognize the national need to address space weather research and operations – e.g., SWORM/SWAP – DOC, NASA, NSF, DOD, DOI, DOT, DHS;
- There have been many success where operational capabilities have been significantly enhanced;
- The major user needs for operational forecasts and specifications are well known;
- The need to improve our operational products and services from our research understanding is well known;
- The need for performance metrics is well known.

## Areas With “Poor Awareness”

- Scientists do not know how to predict what we know needs to be predicted (i.e., solar eruptions, IMF at 1 AU, etc.);
- Scientists do not know how quantitatively good or bad our current scientific or operational capabilities are (metrics);
- Specific funding to address topics of operational relevance does not exist (recommended in Decadal Survey, NSF Portfolio Review, SWAP);
- Mechanisms do not exist to enable scientists to use, evaluate, and participate in the improvement of operational models;
- The research environment fosters the advancement of fundamental scientific understanding, not the improvement of operational products.

# Questions to Answer

- How can we identify and direct research effort towards problems that are tractable and operationally valuable?
- How can we develop a shared culture between research and operations and foster the efforts of scientists who wish to improve operational products?
- How can we have scientists actively participating in the use, evaluation, and improvement of operational products?
- If community models are required, how can we establish a path to develop them?

**The overarching goal of the National Space Weather Program is to achieve an active, synergistic, interagency system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts within the next 10 years.**

National Space Weather Program

Strategic Plan

August 1995

**<u>The National Space Weather Program Goals</u>**

**To advance**

- observing capabilities
- fundamental understanding of processes
- numerical modeling
- data processing and analysis
- transition of research into operational techniques and algorithms
- forecasting accuracy and reliability
- space weather products and services
- education on space weather

**To prevent or mitigate**

- under- or over-design of technical systems
- regional blackouts of power utilities
- early demise of multi-million dollar satellites
- disruption of communications via satellite, HF, and VHF radio
- disruption of long-line telecommunications
- errors in navigation systems
- excessive radiation doses dangerous to human health

National Space Weather Program

Strategic Plan

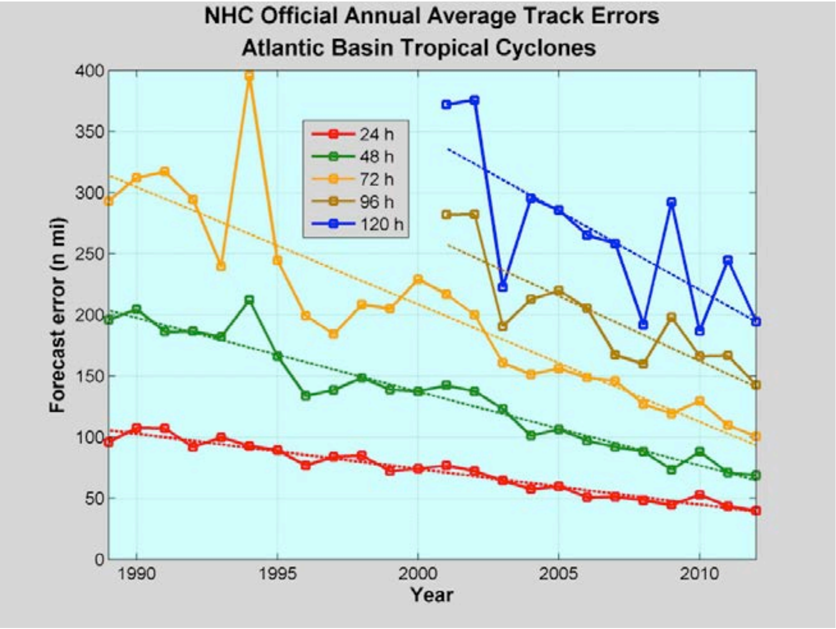
August 1995

**The National Space Weather Program will**

- ⇒ Assess and document the impacts of space weather
- ⇒ Identify customer needs
- ⇒ Set priorities
- ⇒ Determine agency roles
- ⇒ Coordinate interagency efforts and resources
- ⇒ Ensure exchange of information and plans
- ⇒ Encourage and focus research
- ⇒ Facilitate transition of research results into operations
- ⇒ Foster education of customers and the public

# National Space Weather Program Implementation Plan, July 2000

## Quantitative Metrics:




National Hurricane Center, http://www.nhc.noaa.gov/verification/verify5.shtml

**Table 2-6. Priority Solar and Interplanetary Metrics**

| Category | Parameters | Observing Location | Averaging Interval | Data Source | Criterion | Needed for |
|---|---|---|---|---|---|---|
| Solar EUV | Intensity of strong spectral lines (e.g., 30.4 nm)<br>Integrated EUV flux | L1 | 1 day | SOHO | RMSE | Ionosphere and thermosphere models |
| Solar x-rays | Intensity of 0.1-0.8 nm flux | Earth orbit | 1 hour | GOES | RMSE | Ionosphere models |
| Solar protons | Proton flux | Geosyn-chronous orbit or L1 | 1 hour | Proton detector on GOES spacecraft, ACE or other upstream monitor | Mean absolute error in log | Ionosphere and radiation belt models |
| Solar wind | n, P, $v_X$, $B_X$, $B_Y$, $B_Z$, ram pressure, $E_Y$, $E_Z$, Akasofu ε | L1 solar-wind monitor | 5 minutes | ACE spacecraft | Mean absolute error | Magnetosphere model |
| Disturbance departure times from the Sun | Time when disturbance leaves Sun | Earth's surface | N/A | SOHO, Mauna Lea Solar Obs, and other ground locations | Mean absolute error | Thermosphere, ionosphere, and magnetosphere models |
| Solar wind transit times | Transit time from Sun to Earth | L1 solar-wind monitor | N/A | ACE spacecraft | Mean absolute error | Magnetosphere model |

National Space Weather Program

Implementation Plan

July 2000

Model Inventories:

**Table 3-1. Solar and Solar Wind Research Models**

| ID | Model Name/Acronym | Contact information | Type and Purpose | Status | Funding Source(s) |
|---|---|---|---|---|---|
| S1 | SOLAR2000 | W. Kent Tobiska kent.tobiska@jpl.nasa.gov | Solar irradiance from x-ray to visible wavelengths. | UD | NASA, NSF, NOAA |
| S2 | Evolving PFSS Coronal Model | Janet Luhmann jgluhman@ssl.berkeley.edu | Coronal magnetic field structure derived from observed photospheric field. | UD | NSF, NASA, DOD |
| S3 | 3D MHD Model of the Corona and Solar Wind | Jon Linker and Zoran Mikic linker@iris023.saic.com | 3D MHD simulation of the corona and solar wind using observed photospheric magnetic fields as boundary condition. | UD | |
| S4 | Solar Active Region Evolution and Stability | Stephen Keil skeil@sunspot.noao.edu | 3-D MHD simulation of solar active region evolution. | D | |
| S5 | Magnetic Breakout of the Sun's Atmosphere (MagBrst) | Spiro Antiochos spiro@zeus.nrl.navy.mil | Ejection of solar flux. | UD | DOD |
| S6 | Wang and Sheeley Expansion Factor Model (WS Model) | Yi-Ming Wang ywang@yucca.nrl.navy.mil | Predicting solar wind speed at Earth from magnetic file observations of the photosphere. | M | |
| S7 | 3D Interplanetary Propagation Model (3D IPP) | Victor Pizzo vpizzo@sec.noaa.gov | MHD simulation of global, time-dependent solar wind flow. | UD | NOAA |
| S8 | Shock Time of Arrival/Shock Propagation Model (STOA/ISPM) | Murray Dryer murraydryer@msn.com | Empirical and 2-D MHD interplanetary shock wave. | UD | NOAA |

M = Mature D = In development UD = Useable but under development MD = Mature but undergoing improvements

National Space Weather Program

Implementation Plan

July 2000

# Agency Responsibilities:

**Table 7-1. Agency Participation Matrix**

| | Physical Understanding | Model Development | Observing Systems | Technology Transfer |
|---|---|---|---|---|
| Solar coronal mass ejections | 1,2,3,6 | 1,2,5,6 | 1,2,3,5 | 1,2 |
| Solar activity/flares | 1,2,6 | 2,5,6 | 1,2,5 | 2,7 |
| Solar and galactic energetic particles | 1,2,3,6 | 2,5,6 | 1,2,3,5 | 1,2 |
| Solar UV/EUV/soft x-rays | 1,2,6 | 5,6 | 1,2,5 | 1,2,7 |
| Solar radio noise | 1,6 | 5,6 | 1,2,5 | 1,2 |
| Solar wind | 1,2,3,6 | 1,2,5,6 | 1,2,3,5 | 1,2 |
| Magnetospheric particles and fields | 1,2,3,4,5,6 | 1,2,3,4,5,6 | 1,2,3,5 | 1,2,3 |
| Geomagnetic disturbances | 1,2,3,4,5,6 | 1,2,3,4,5,6 | 2,3,4,5 | 1,2,3 |
| Radiation belts | 1,2,3,5,6 | 1,2,3,5,6 | 1,2,3,5 | 2,3 |
| Aurora | 1,2,3,4,5,6 | 1,2,4,5,6 | 1,2,3,5 | 1,2 |
| Ionospheric properties | 1,2,3,4,5,6 | 1,2,4,5,6 | 2,3,5 | 2,7 |
| Ionospheric electric field | 1,2,4,5,6 | 1,2,4,5,6 | 1,2,3,5 | 2,7 |
| Ionospheric disturbances | 1,2,3,4,5,6 | 1,2,4,5,6 | 2,3,4,5 | 2,7 |
| Ionospheric scintillations | 1,2,5,6 | 1,2,5,6 | 2,5 | 2,7 |
| Neutral atmosphere (thermosphere and mesosphere) | 1,2,5,6 | 1,2,5,6 | 2,5 | 1,2 |

Organization codes: 1=DOC, 2=DOD, 3=DOE, 4=DOI, 5=NASA, 6=NSF, 7=DOT

NASA Living With a Star

Targeted Research and Technology

Science Definition Team Report

November, 2003

**Science Objectives:**

- Predict ionospheric density in the altitude range from 100 to 1000 km
- Quantify the intensity and location of plasma irregularities from 10 to 1000 km
- Determine effects of solar variability on mass density – accuracy better than 5%
- Predict satellite drag variations during geomagnetic storms and the solar cycle
- Forecast induced currents driven by geomagnetic activity
- Develop accurate specification model of Earth’s radiation environment
- Model the acceleration, transport, and loss of radiation belt particles
- Forecast the intensity of CME-shock-driven energetic particles

“Research in Outer Space”
Technical Panel on the Earth Satellite Program
U.S. National Committee for the International Geophysical Year
National Academy of Sciences
1958

“Although there will inevitably be benefits of a very practical nature from such a program [space exploration], **the basic goal of this exploration must be the quest of knowledge** about our solar system and the universe beyond.”

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NASA Heliosphysics Living with a Star
10-Year Vision Beyond 2015

“Deliver the understanding and modeling required for useful prediction of the variable solar particulate and radiative environment at the Earth, Moon, Mars and throughout the solar system.”
…

Standard interpretation: The requirement is not to deliver a predictive capability, but rather to deliver the understanding that would be required if one wanted to predict.

## Collaborative Science Technology, and Applied Research (CSTAR) Program

The CSTAR Program represents a NOAA/NWS effort to create a cost-effective transition from basic and applied research to operations and services through collaborative research between operational forecasters and academic institutions which have expertise in the environmental sciences. These activities engage researchers and students in applied research of interest to the operational meteorological community and improve the accuracy of forecasts and warnings of environmental hazards by applying scientific knowledge and information to operational products and services.

CSTAR Program basics:

- **One to three-year projects--maximum funding level $150K/year**
- **Applied research and education projects involve collaboration between operational forecasters and university scientists.**
- **Proposals must address NWS science needs and priorities that have the potential to be applied nationally through the Operational Proving Ground (OPG).**
- **A CSTAR Funding Opportunity is open until 01/04/17**

- Collaborative between operational forecasters and academic institutions
- Applied research of interest to operational meteorology community
- Improve the accuracy of forecasts and warnings
- Apply scientific knowledge to operational products and services

# Collaborative Science Technology, and Applied Research (CSTAR) Program

| Program ▲▼ | Subject Area ▲▼ | Project Title ▲▼ | Principal Inverstigator(s) ▲▼ | PI Affiliation ▲▼ | Project Start ▲▼ | Project End ▲▼ | Total Budget ▲▼ |
|---|---|---|---|---|---|---|---|
| CSTAR | Ensembles, Data Assimilation | A Partnership to Develop, Conduct, and Evaluate Real-time Advanced Data Assimilation and High-Resolution Ensemble and Deterministic Forecasts for Convective-Scale Hazardous Weather | Ming Xue and Fanyou Kong | University of Oklahoma | 7/1/2013 | 6/30/2016 | $375,000 |
| CSTAR | Ensembles | An Evaluation and Application of Multi-Model Ensembles in Operations for High Impact Weather over the Eastern U.S. | Brian Colle | SUNY Stony Brook | 10/1/2013 | 9/30/2017 | $337,722 |
| CSTAR | Synoptic Weather | Advancing Analysis, Forecast, and Warning Decision Support Capabilities for High-Impact Weather | James Steenburgh and John Horel | University of Utah | 9/1/2013 | 8/31/2017 | $250,000 |
| CSTAR | Synoptic Weather | Collaborative Research with the National Weather Service on the Occurrence and Prediction of High-Impact Precipitation Events in the Northeastern U.S. | Kristen Corbosiero and Ryan Torn | SUNY Albany | 9/1/2013 | 8/31/2017 | $375,000 |
| CSTAR | Tropical Weather | Improved Forecasting of Extreme Rainfall Events Associated with Tropical Cyclones | Henry Fuelberg | Florida State University | 9/1/2013 | 8/31/2017 | $299,307 |
| CSTAR | Data Assimilation, Ensembles | Application of Dense Surface Observations for High-Resolution Ensemble-Based Analysis and Prediction | Clifford Mass | University of Washington | 9/1/2013 | 8/31/2017 | $372,287 |
| CSTAR | Hydrology, Ensembles | Understanding and Improving the Full Hydrometeorological Forecasting Chain Using Multimodel Ensembles | Alfonso Mejia | Penn State University | 5/1/2014 | 4/30/2017 | $291,189 |
| CSTAR | Atmospheric Physics | Improving Understanding and Prediction of High Impact Weather Associated with Low-Topped Severe Convection in the Southeastern U.S. | Matthew Parker, Joanna Jones, Gary Lackmann | North Carolina State University | 5/1/2014 | 4/30/2017 | $375,000 |

# The Recognized Need for Outcome-Based Research

## Solar and Space Physics Decadal Survey, 2012:

Top Level Decadal Survey Applications Recommendations:

2.5: Develop and maintain distinct programs for space physics research and space weather specification and forecasting

# The Recognized Need for Outcome-Based Research

NSF Portfolio Review, February, 2016:

**Recommendation 6.16** The PRC recommends the establishment of **a distinct funding line** for basic space weather research that supports improved capabilities in **space weather specification and forecasting**, and sustain a robust space weather and climatology program that invests in "**predictive space weather science**" and activities that "**optimize the use of research to address national needs**."

# The Recognized Need for Outcome-Based Research

National Space Weather Action Plan, 2015:

5.5.3 NASA, DOC, and DOD will identify and support research opportunities that seek to address targeted operational space-weather needs.

Deliverable: Announce and provide awards that enhance research in focused areas

Timeline: Within 1 year and sustained thereafter

R

o

R solar-Terrestrial Physics

R Space Weather

O

L

# Areas With Good Awareness

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