NOAA Space Weather Prediction Center

Current Activities Update

Dr. Thomas Berger

Director, NOAA/NWS/NCEP Space Weather Prediction Center

Outline

Budget and Admin

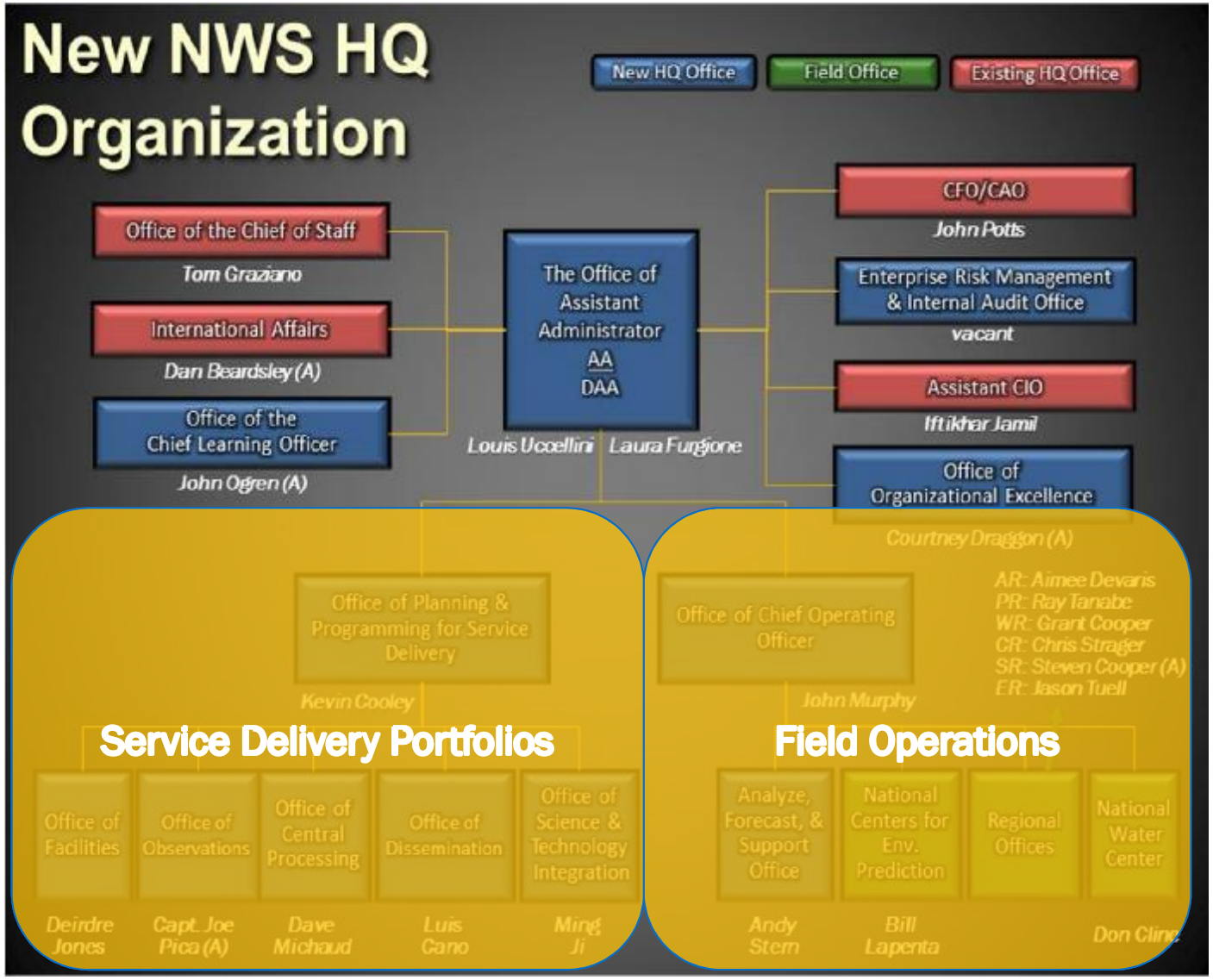
Modeling Developments

Observations Update

Space Weather Action Plan Update

NWS Reorganization

NCEP / SWPC part of "Fully Integrated Field Structure"



SWPC Org Chart

- Berger, Thomas — SWPC Director
  - Hemmick, Paul — SWPC NOAA Corps Officer
  - Gordon, Brent — SWSB Branch Chief Sup. IT Specialist
    - Hill, Steve — Section Lead DTS Physicist
      - Carpenter, Michael — Computer Scientist
      - Craver II, Robert — IT Specialist (AppSW)
      - England, Marcus — Computer Scientist
      - Husler, Michael — IT Specialist (AppSW)
      - Lauer, Christopher — IT Specialist (AppSW)
      - Newman, Ann — IT Specialist (AppSW)
    - Viereck, Rodney — Section Lead SWPT Physicist
      - Akmaev, Rashid — Physicist
      - Biesecker, Douglas — Physicist
      - Codrescu, Mihail — Physicist
      - Onsager, Terrance — Physicist
      - Pizzo, Victor — Physicist
      - Singer, Howard — Physicist
      - Filled — Space Scientist
    - Rutledge, Robert — Section Lead SWFO Physical Scientist
      - Balch, Christopher — Space Scientist
      - Carr, Charles — Physical Scientist
      - Dahl, Shawn — Physical Scientist
      - Lash, Jonathan — Physical Scientist
      - Marshall, David — Physical Scientist
      - Patterson, Garry — Physical Scientist
      - Steenburgh, Robert — Space Scientist
  - Murtagh, William — Physical Scientist
    - Puga, Lawrence — Physical Scientist
      - Smith, Christopher — Physical Scientist
      - Spencer, Earl — Physical Scientist
      - Stankiewicz, Jeffrey — Physical Scientist
      - Tegnell, Kenneth — Physical Scientist
      - Stockman, Meghan — Physical Scientist
      - Vacant — Physical Scientist
      - Vacant — Physical Scientist
  - Suess, Dianne — Executive Officer Sup. Program/Mgmt.Analyst
    - Stewart, Rhonda — Budget Analyst
    - Vacant — Admin. Support Assistant
    - Vacant — Secretary
  - Feickert, Timothy — ATSB Branch Chief Sup. IT Specialist
    - Crow, Joshua — IT Specialist
    - Finelli, David — IT Specialist (Sys Admin)
    - Ito, David — IT Specialist
    - Masten, Robert — IT Specialist (Network)
    - McKillen, Kathleen — IT Specialist
    - Ortiz, Christopher — IT Specialist (PlcyPlan)
    - Vacant — General Engineer

SWPC March 2016

Total FTE
46
Onboard 41
Vacant 5

SWPC Budget
FY16 Enacted

- NOAA FY16 budget: +5.8% relative to FY15
  - OAR: +8%
  - NESDIS: +5.7%
  - NWS: +3.4%

    OBS: +2.7 CP: -3.8% DIS: +11.5% STI: +12.3% AFS: +2.7%
- Total SWPC Budget FY16: $12.9M (+20%)
- SWPC Budget (non-labor)

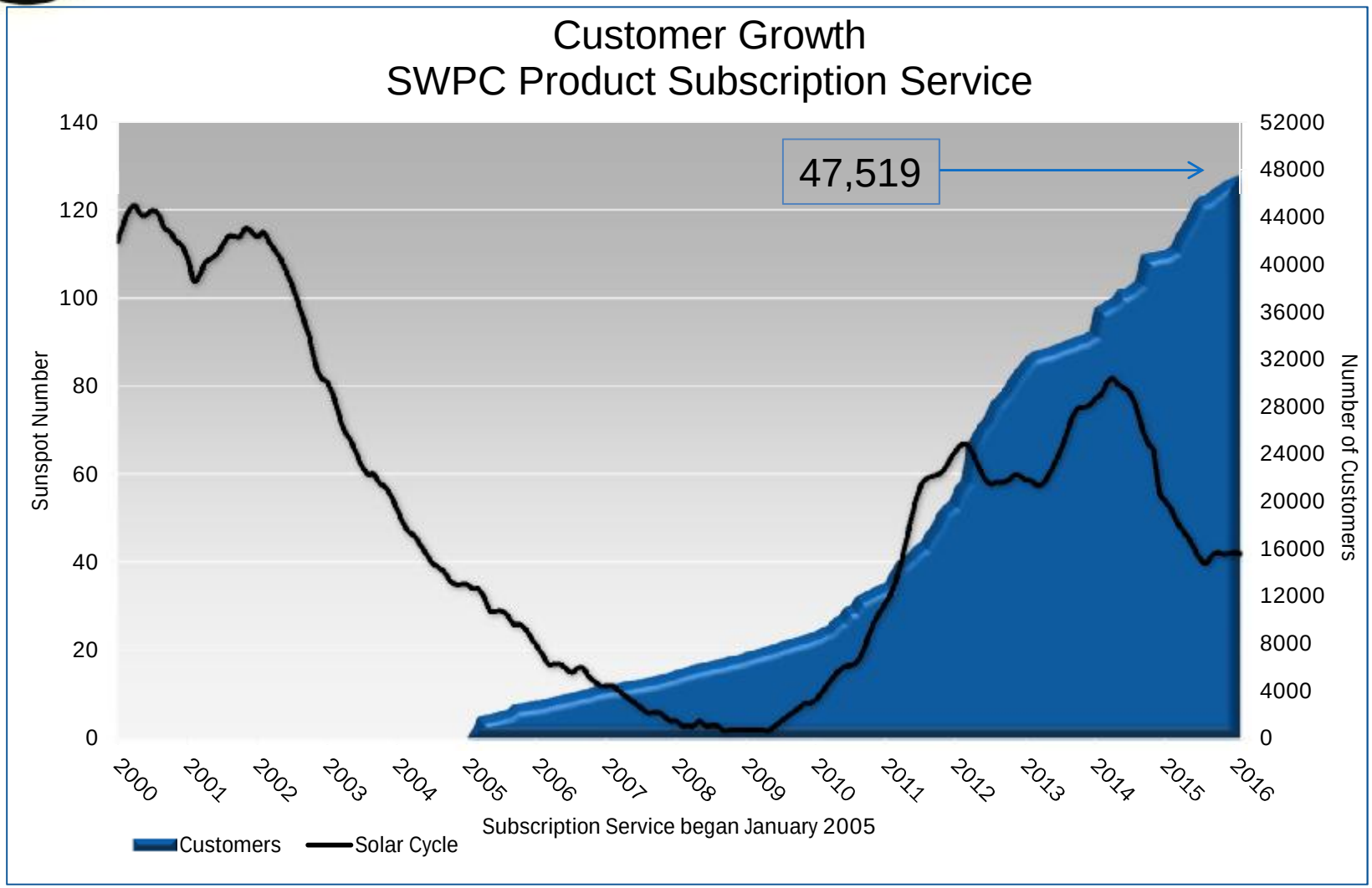
Portfolio	FY15	FY16 request	FY16 enact
AFS	$1.39M	$1.37M	$1.37M
CP	$759K	$856K	$856K
OBS	$400K	$400K	$1.4M [a]
STI	$1.82M	$1.82M	$3.32M [b]

a. $1M Presidential budget plus-up for operationalizing the GONG network.
b. $1.5M Presidential budget plus-up for modeling and O2R development.

SWPC Budget
FY17 Request

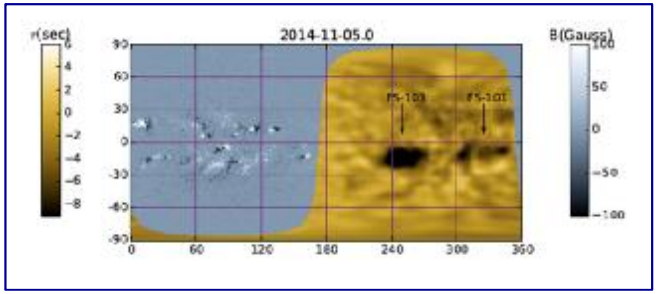
- NOAA FY17 budget request
  - Overall NWS Operations, Research, Facilities: -1.6% relative to FY16
  - Total SWPC Budget FY17: projected $12.9M (flat)
  - NESDIS Space Weather Follow-On: $2.5M for continued studies.
    - Mission start in 2018, launch in 2022, with total cost of $757M.
- Research & Development:
  - NOAA Research Transitions Acceleration Program: $10M
    - Administered by NOAA Chief Scientist Office.
    - Designed to provide direct grants to NOAA organizations seeking to transition research from internal, academic, or private sector sources into operational products and services.
    - SWPC will aggressively pursue RTAP funding to be used for contract work in R2O transition of space weather models.

SWPC Customer Growth
Through February 2016

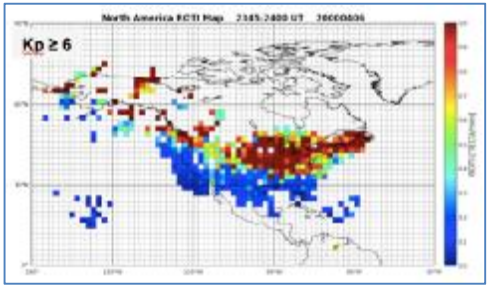


SBIR updates
2015 and 2016 milestones

- Far-side helioseismology product (NWRA, NSO, Stanford, JPL) underwent Phase-1 review on 11-March.



- ROTI product (PRA, JPL) applying for Phase-3 funding. Product transition to SWPC forecast office starts in FY16.



- New Grant: Satellite Environment SWx Products
  - Evaluate satellite industry needs
  - Utilize available data and models
  - Develop products and solicit feedback

  Five proposals received and evaluated: awaiting decision on Phase 1 funding

Space Weather Overview
Current Models and Observations

Sun:
Models
- ADAPT
- WSA
- NRL-EUV

Space Observations
- STEREO
- LASCO (SOHO)
- EUV Irradiance (GOES)
- X-Ray Imaging (GOES)

Ground Observations
- GONG Solar Magnetograms
- SOON/RSTN

Solar Wind:
- Enlil
- 3DMHD
- ACE (at L-1)
- DSCOVR

Energetic Particles:
- ACE (at L-1)
- GOES

Ionosphere:
- GAIM-USU
- GAIM-JPL
- GPSII
- SAMI3
- IDA4D
- SSUSI/SSULI /SSIES (DMSP)
- TIP /RB (COSMIC I)
- GPSRO (COSMIC II)
- IVM/RB (COSMIC II)
- GOLD
- ICON
- TEC/Ground GPS Data
- SCINDA
- Ground Based Imagers

Radiation Belts:

Aurora:
- OVATION
- 30 min & 3 Day Forecast

Magnetosphere:
- U. Michigan SWMF
- GOES Magnetopause Model
- LFM
- GOES
- DMSP
- USGS Magnetometer Network

Thermosphere:
- HI-TIDES
- WAM
- CTIPe
- HASDM
- NRL-MSIS/HWM
- COSMIC

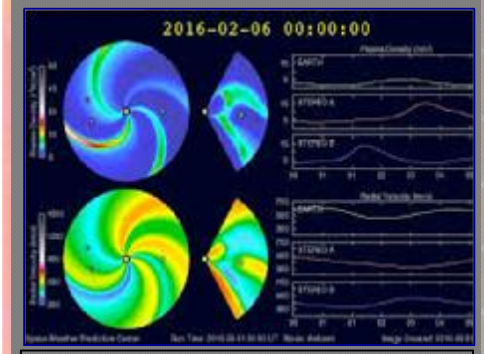
Ground Effects:
- E-field GIC nowcast
- Aircraft Radiation
- Radar Clutter
- Scintillation
- GPS Error
- HF/UHF Comms

Defense R&D

Civilian R&D

SWPC Operational Model Suite

Tracking solar storms from "Sun to Mud"



GMU/AFRL WSA/Enlil

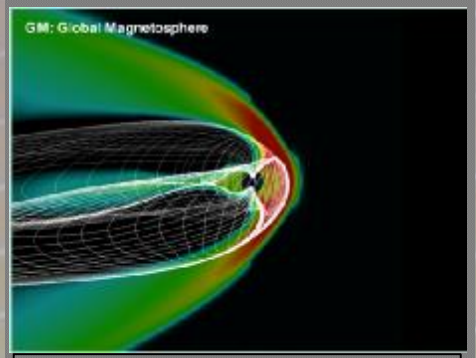
Inputs:

1. GONG solar magnetic field data
2. SOHO/LASCO coronagraph CME images from L1

Validation:

1. DSCOVR solar wind character at L1
2. GOES magnetometer shock arrival

Operational



U. Michigan Geospace

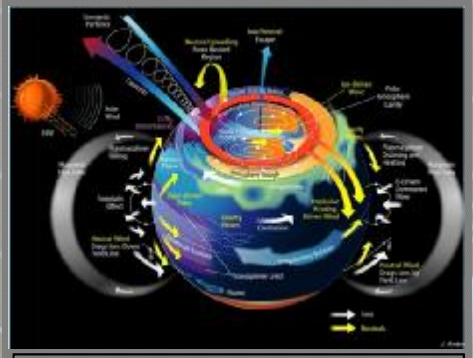
Inputs:

1. DSCOVR solar wind density, temp, speed, mag field at L1
2. Solar F10.7 radio flux measurements

Validation:

1. GOES vector magnetic field
2. USGS magnetometer network

Operational FY16



NOAA/CIRES WAM-IPE

Inputs:

1. GFS Tropospheric weather model inputs
2. GOES Solar EUV flux
3. COSMIC-2 RO electron density
4. Geomagnetic storm data from Geospace

Validation:

1. GPS receiver network TEC measurements

Operational FY17-19

USGS/NOAA E-field

Inputs:

1. USGS lithospheric conductivity model
2. USGS magnetometer network

Validation:

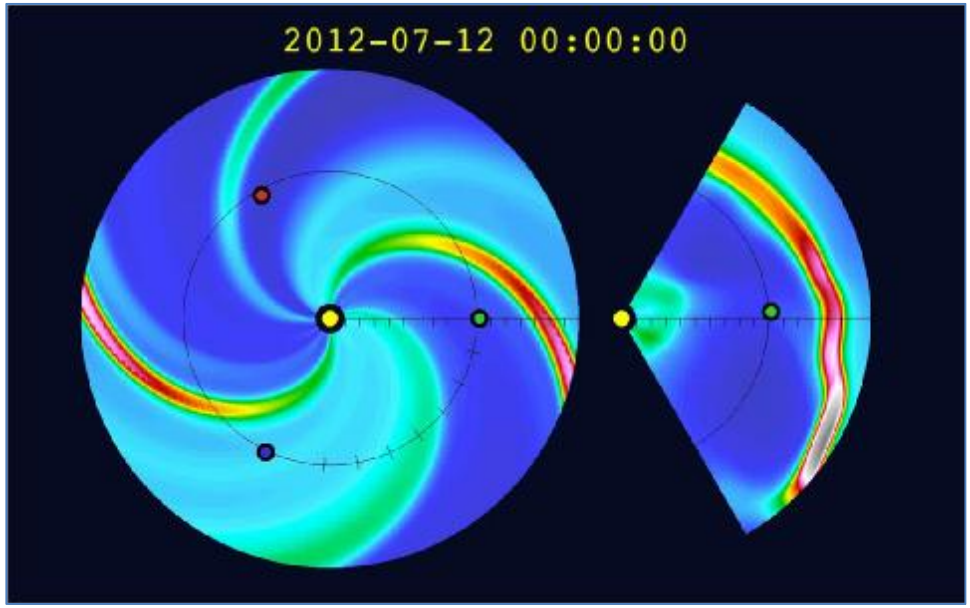
1. USGS geoelectric field measurements.

Operational FY16-17

Note: all models developed with NASA and/or NSF funding at some level.

Operational Model Updates
WSA/Enlil

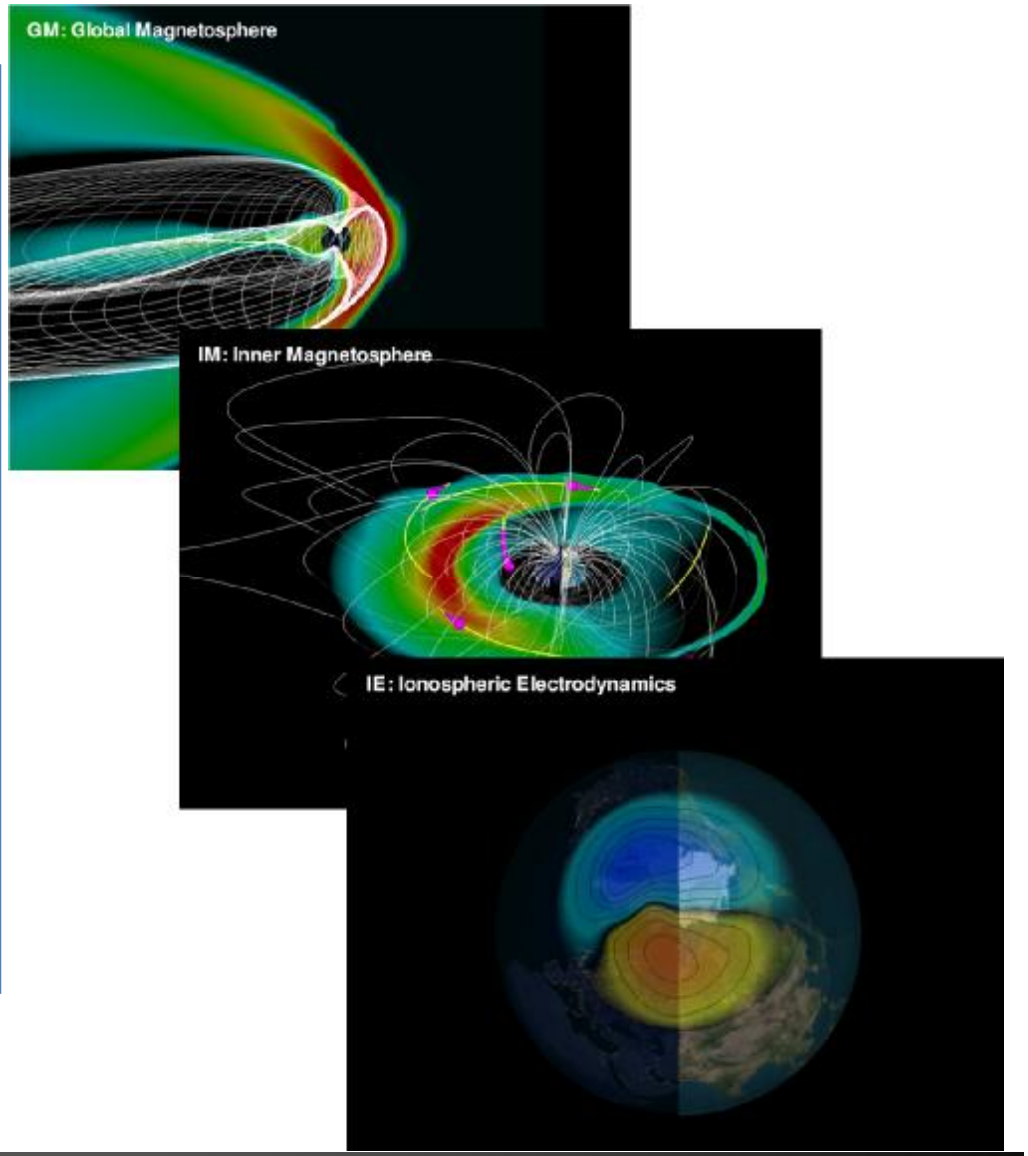
- New CIRES hire: Dr. Eric Adamson
- Update operational Enlil to v2.8 in 2016—2017.
- Implement AFRL ADAPT code for improved WSA input in 2017.
- Time-dependent Enlil: validation study required



Operational Model Updates

U. Michigan Geospace

- 30-day operational trial run underway on WCOSS supercomputer system.
  - Started on 15-March
  - Restarted automatically after loss of data stream due to power outage.
- Accurately re-forecast the St. Patrick's Day 2015 storm to show regional k=9 values in Alaska
- Products for forecast office and web under development with release in Q4 FY16.



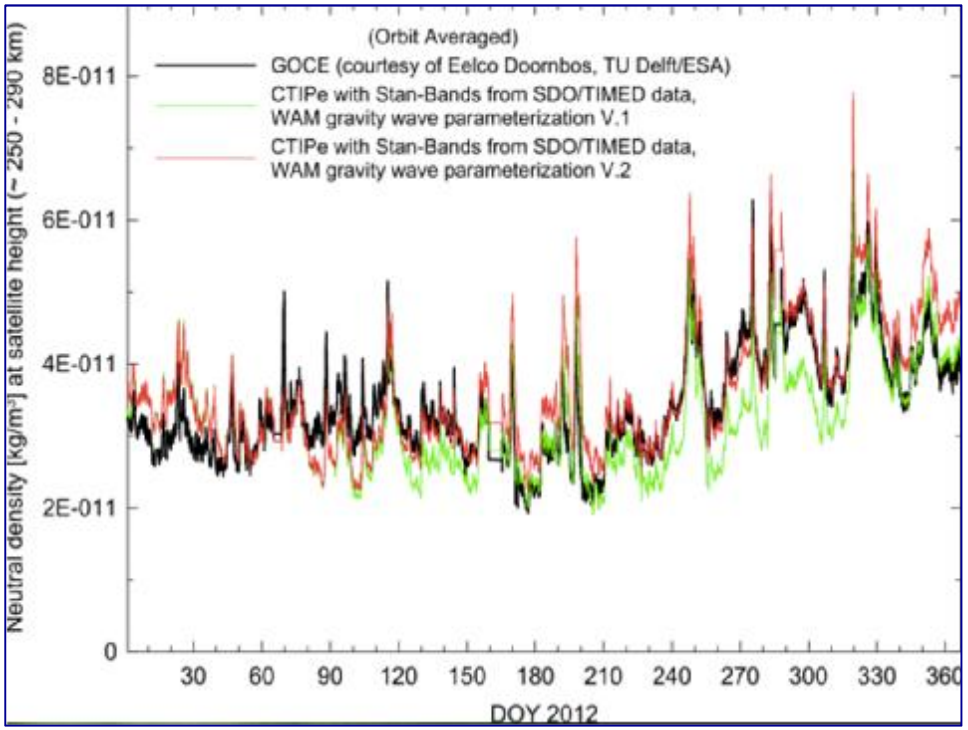
St. Patrick's Day G4 Storm

Reforecast Analysis: ~30 minutes lead time

Operational Model Updates

NOAA/CIRES WAM-IPE

- WAM = Whole Atmosphere Model
  - Neutral atmosphere operational GFS model extended to 600 km.
- IPE = Ionosphere Plasmasphere Electrodynamics
  - Magnetic field gridded model of ionized atmosphere
- WAM + IPE = IDEA!
  - Integrated Dynamics of Earth's Atmosphere
- Also required: WAM Data Assimilation System (WDAS)
  - Extension of GFS DAS to 100 km
- One-way coupled model operational on WCOSS in FY17



Improved atmospheric density calculations using new WAM gravity wave parameterization.

NWS R2O grant 2015—2016, Yudin and Fuller-Rowell.

E-field Model Update

Nowcast and Forecast Capabilities

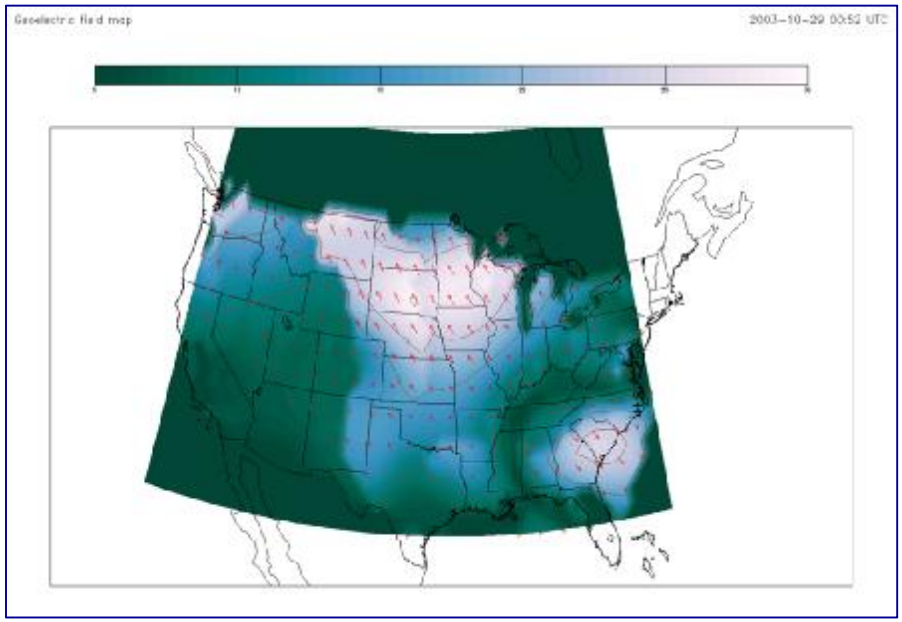
Long Term Goal:
Nowcast and Forecast the local geoelectric field (V/km)

Nowcast development steps

- Use real-time magnetometer data as the input
- Interpolate geomagnetic field variations between observatories
- Calculate Electric field 'locally' using appropriate conductivity models
- Apply electric field to a power grid model to calculate geomagnetically induced currents
- User assesses system stability and transformer vulnerability

Forecast development steps

- Use Geospace model to predict real-time magnetic field variations.
- Calculate the corresponding geo-electric field at each point.



Nowcast model operational in 2016.
Forecasting capability 2017.

DSCOVR Update

The Moon Photo-Bombs the Earth

DSCOVR Update
March 8, 2016 Solar Eclipse

DSCOVR Update
Operational Status

"The DSCOVR satellite was launched on February 11, 2015. Since its launch, the satellite has had more anomalies than anticipated, which requires additional engineering support from the spacecraft and instrument vendors."

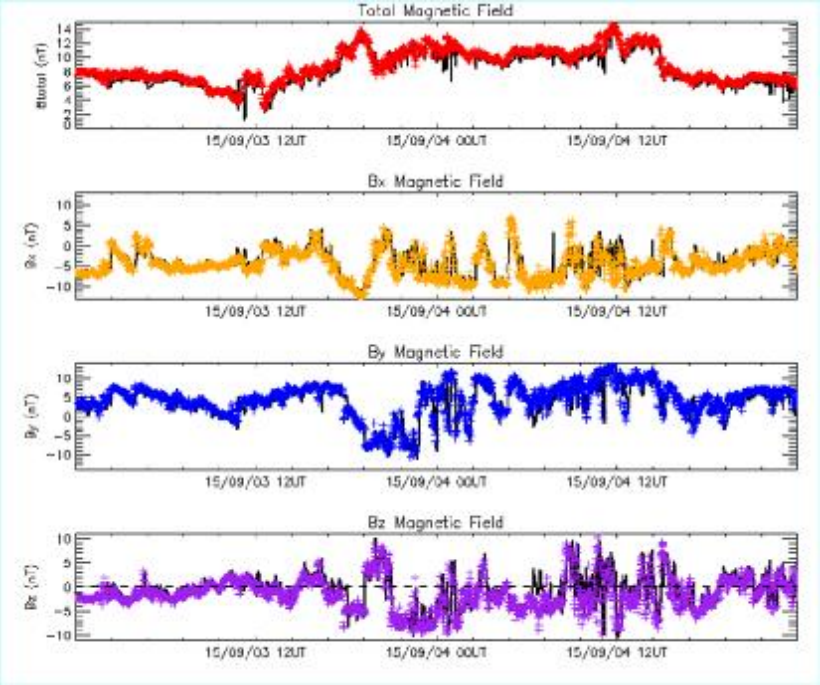
Anomalies include Comp-Hub reboot issue and Faraday Cup low density readout noise.

- Operational hand-off of satellite operations to NOAA: October 27, 2015.
- Operational data service: dependent on new Faraday Cup calibration and read-out algorithm testing in low-density (HSS) conditions. Target is April 2016.

DSCOVR Update

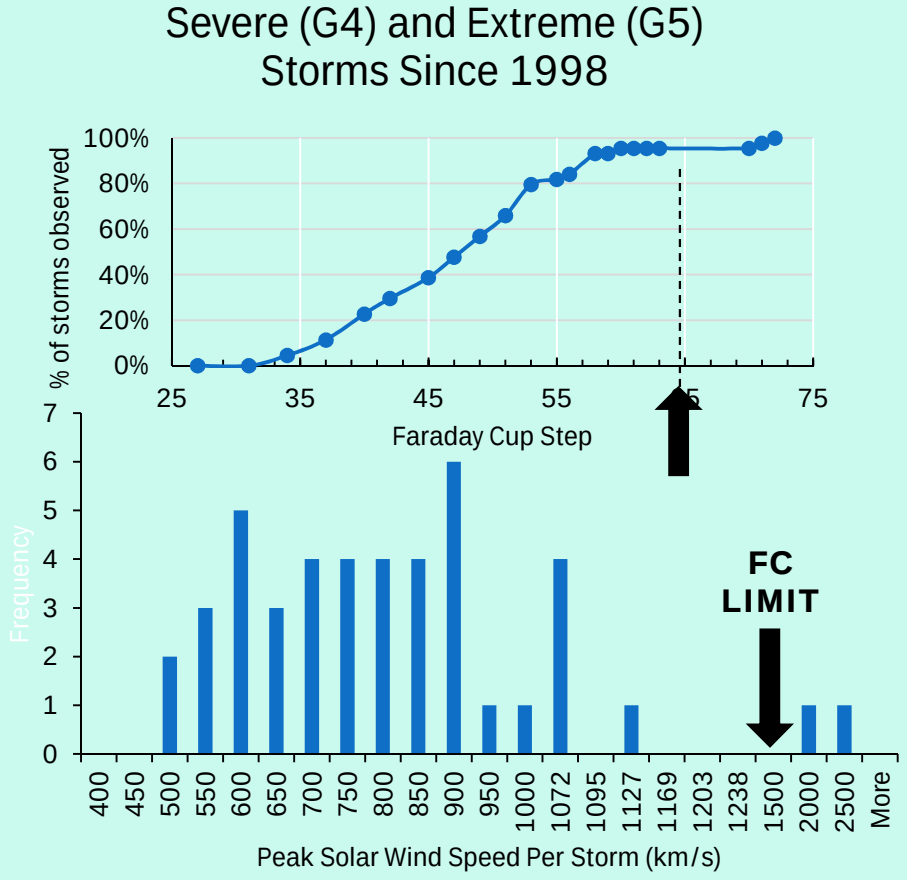
Magnetometer comparison with ACE

Extremely close match

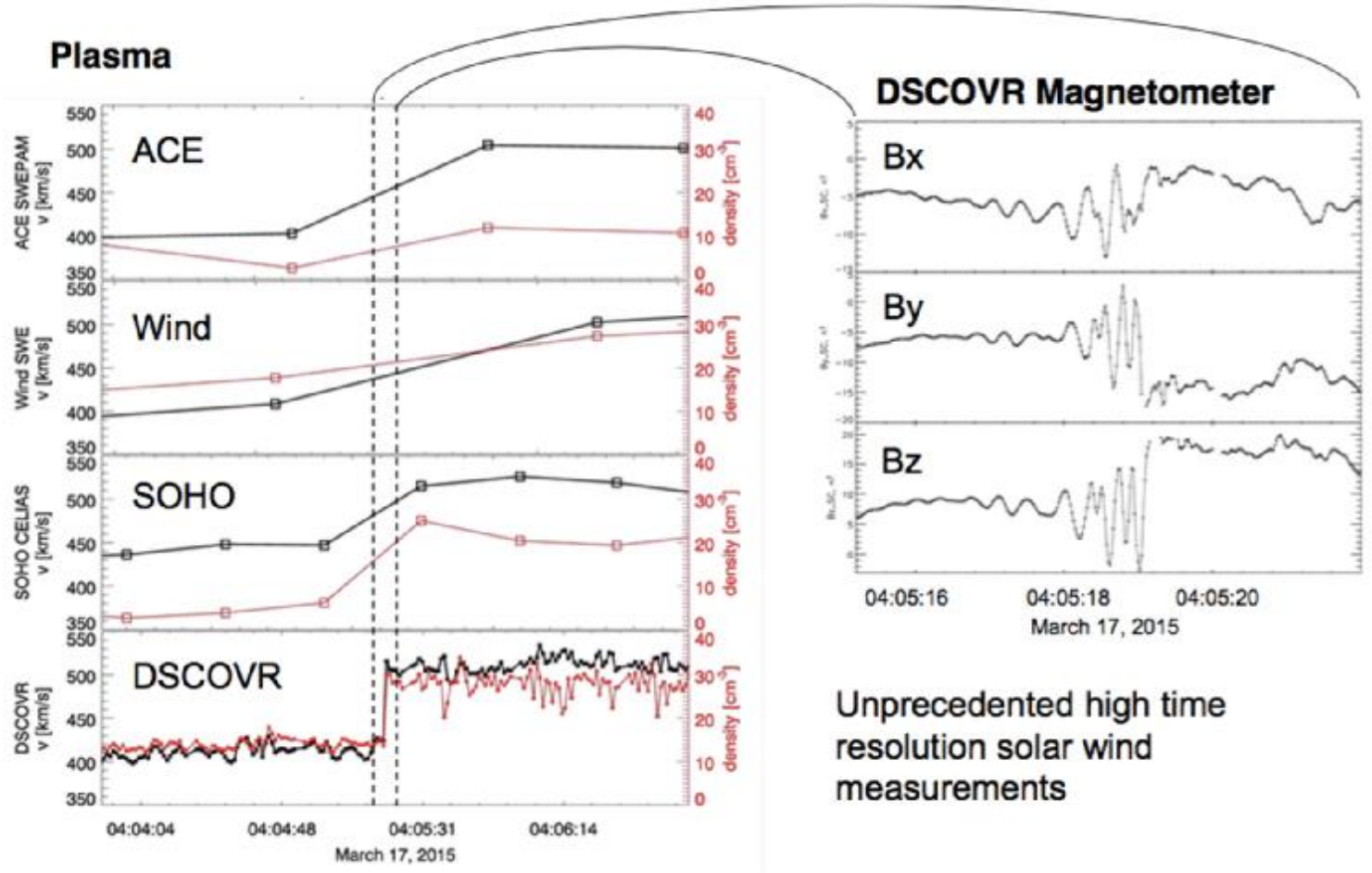


Faraday Cup performance

8 kV limit captures 98% of solar wind conditions measured since 1998



DSCOVR Update
Magnetometer Science Potential

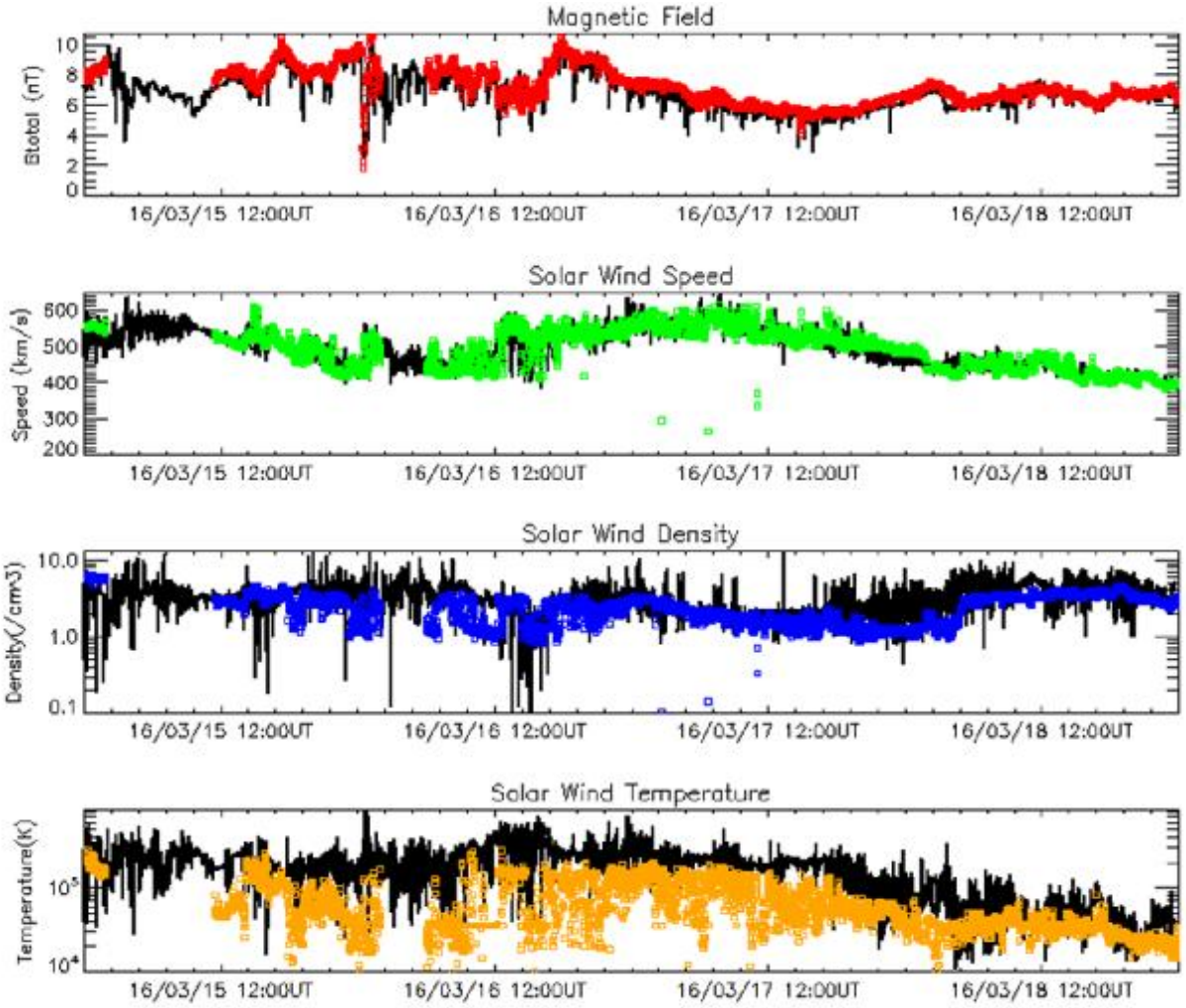


Unprecedented high time resolution solar wind measurements

DSCOVR Update

Plasma Measurements Compared to ACE

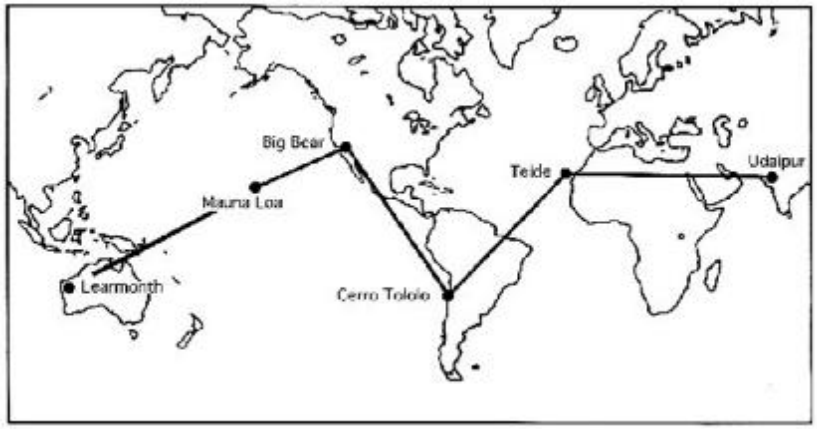
- Mag field and solar wind speed track ACE data very well.
- Density and temperature show significant noise and/or offset.
- Read-out algorithm not yet finalized at SWPC.



2016++: Operational funding from NOAA/NWS $820K

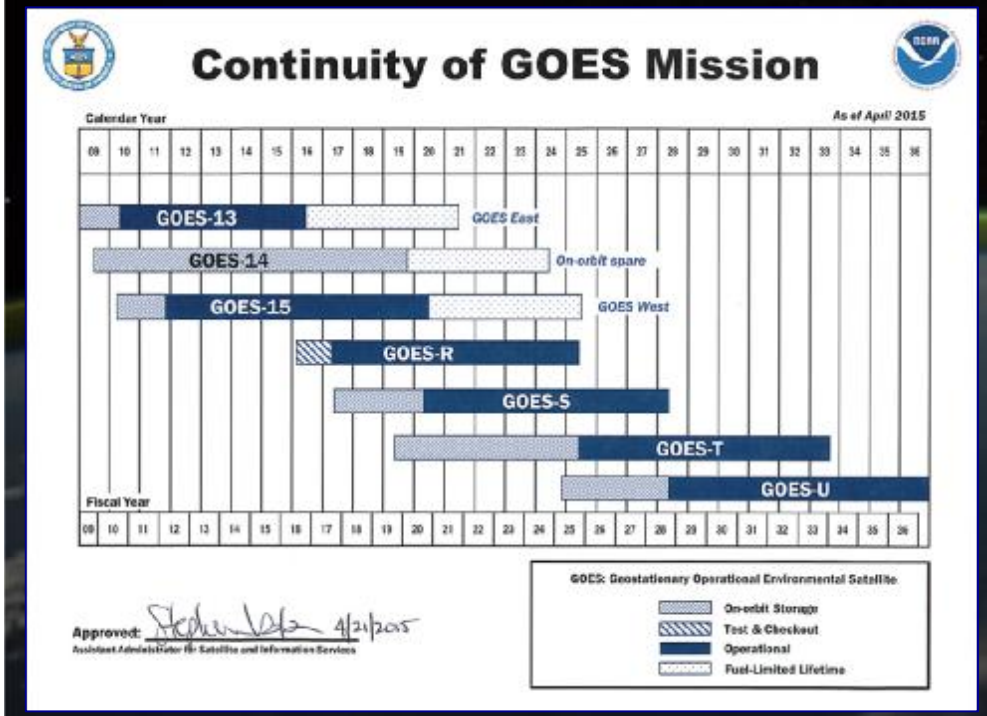
- Collaboration between NOAA/SWPC and National Solar Observatory, the newest Boulder space science organization.
- Magnetogram maps are primary input to WSA solar wind model.
- SWPC Data Processing Project: progress to date
  - Testing data flow from 6 sites into Boulder IDP data center.
  - Full operational data (mag and H-alpha) flow and processing by ~April 2017.

Learmonth, Australia



GOES-R Update

October 27 2016: GOES-R launch to Geosynch **à** GOES-16

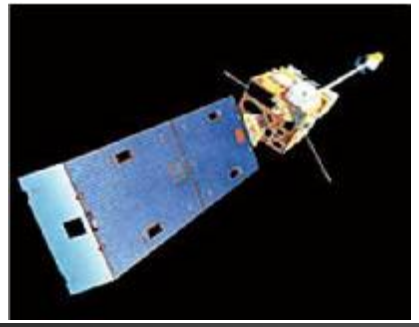


GOES-R SEISS

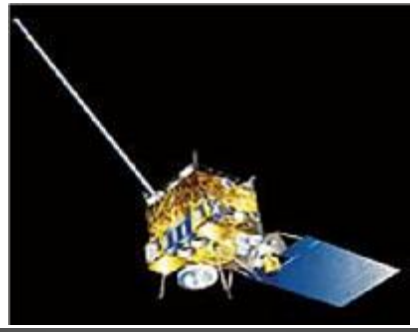
Improved particle radiation coverage

Satellite Series	Electrons 0.03-30 keV	Electrons 30-600 keV	Electrons >800 keV	Ions 0.03-30 keV	Protons 80-800 keV	Protons >740 keV	Heavy Ions, >10 MeV/n
GOES 8-12			√			√	He
GOES 13-15		√	√		√	√	He
GOES R-U	√	√ (gap 30-50 keV)	√	√	√	√	He, Z=4-29 (Be-Cu)
Space weather application	Frame charging, charging signatures	Frame and interior charging	Interior charging, radiation belt alerts	Frame charging signatures, ring current	Surface damage	SEP event alerts, surface damage	Single event effects

GOES 8-12



GOES 13-15



GOES R-U

COSMIC-2 Update

2016: First 6 equatorial satellites launched to 520 km.
2019: Second 6 polar satellites launched to 720 km*.

- Follow-on to successful COSMIC-1 mission that demonstrated RO utility for numerical weather prediction.
- Larger number of satellites and lower data latency to improve application to ionospheric data assimilation.
- Major effort underway at SWPC to develop data assimilation into WAM/IPE model.

* Launch net yet secured.

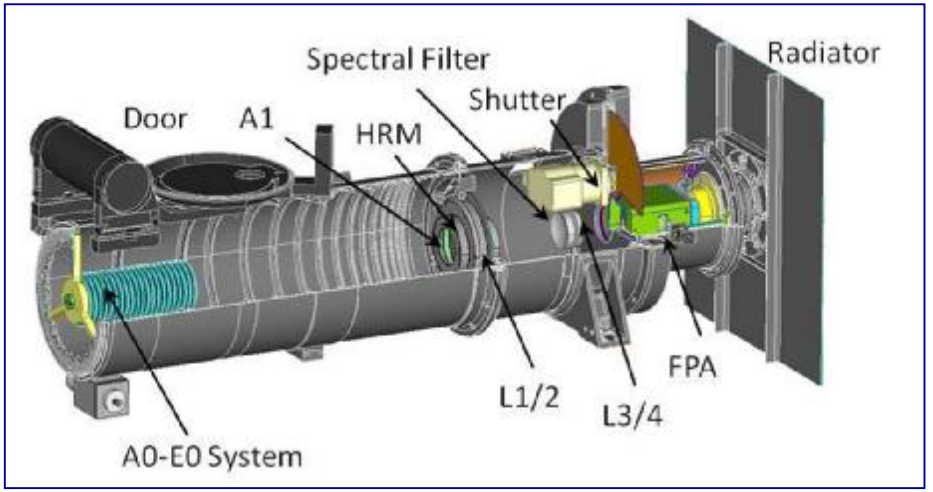
SWx Follow-On Mission Update

- NOAA FY17 Budget Blue-Book proposes mission budget profile.
- Primary instruments
  - NRL Compact Coronagraph (CCOR)
  - Solar Wind Plasma
  - Interplanetary mag field
- Orbit: L1 halo
- Goal: on station before SOHO EOL (2020—2022)

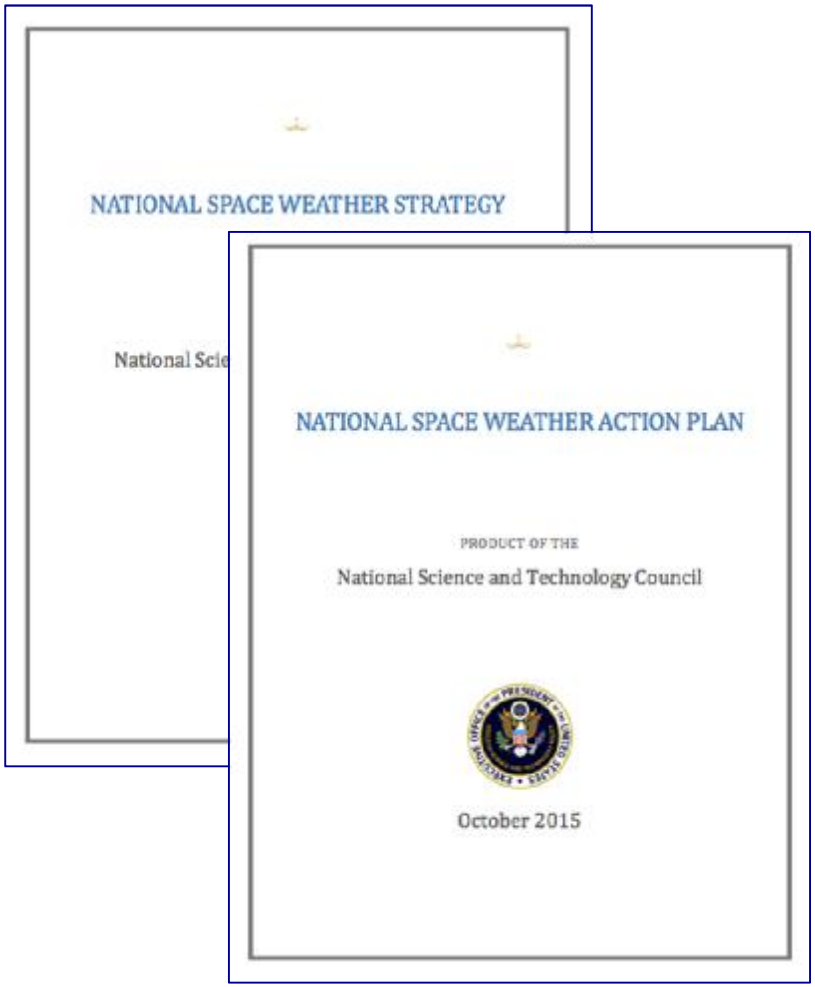
SPACE WEATHER FOLLOW ON

BUDGET AUTHORITY IN THOUSANDS

FY 2016 & Prior	$1,200	FY 2020	$154,500
FY 2017	$2,500	FY 2021	$81,500
FY 2018	$53,700	CTC	$278,200
FY 2019	$186,100	Total	$757,700



Space Weather Action Plan
Highlights in Observations, Data, and Research



- Chartered under White House Office of Science & Technology Policy (OSTP)
- Chaired by OSTP, National Weather Service, and Dept. of Homeland Security.
  - OSTP: policy lead
  - NWS: operational forecasting
  - DHS: mitigation and response
- Released 29-October-2015
- Outlines goals for operations, research, mitigation, and response in preparation for extreme events.
- Chapter 5 of Space Weather Action Plan (SWAP) addresses observations and research to sustain and improve prediction of space weather events.

For copies, google "OSTP space weather"

Baseline Operational Observing System

Critical measurements for operational SWx forecasting

SWAP Section 5.3

Defines observations required by operational space weather forecasting centers to execute baseline mission.

5.3.2 Sun-Earth line (L1) Orbit: sustain solar coronagraph CME and solar wind measurements	Current Capabilities: NASA SOHO  NOAA DSCOVR 	Future Capability: NOAA SWx Follow-On	
5.3.3 Geostationary Orbit: sustain or enhance solar imagery, X-ray irradiance, energetic particle, mag field	Current Capabilities: NOAA GOES RSTU 	Future Capability: ?	
5.3.4 Ground-based: sustain or enhance solar imaging and magnetic field measurements	Current Capabilities: NOAA-NSF GONG 	Future Capability: ?	
5.3.5 Ground-based: sustain or enhance solar radio measurements	Current Capabilities: USAF RSTN 	Future Capability: ?	
5.3.6 Ground-based: sustain or enhance the real-time geomagnetic field measurement network	Current Capabilities: USGS MagNet 	Future Capability: INTERMAGNET?	
5.3.7 LEO/MEO: enable and sustain GNSS radio occultation measurements for ionospheric characteristics	Current Capabilities: NCAR COSMIC 	Future Capability: COSMIC-2  CSP Data?	
5.3.8 Ground-based: sustain or enhance the worldwide neutron monitoring (NM) network	Current Capabilities: NSF Polar NM 	Future Capability: NOAA-NSF Global NM Net 	

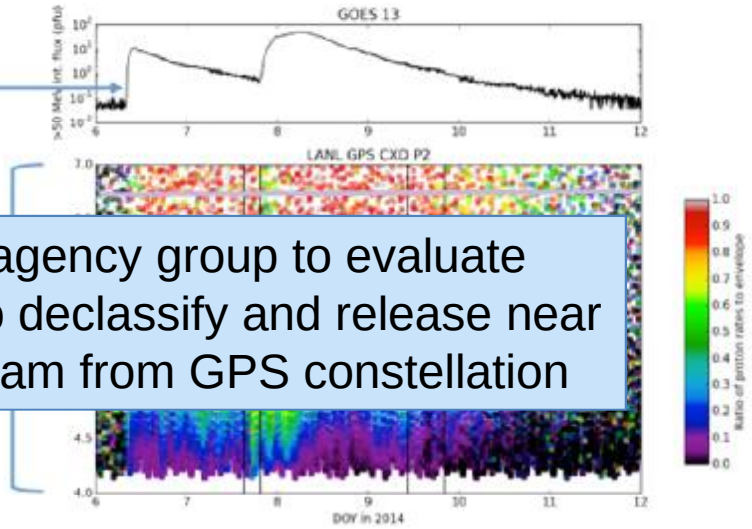
USAF GPS Particle Data Release

Preliminary One-Month Analysis

Comparison of GOES and GPS Protons During Solar Energetic Particle Events (SEPs) in January 2014

- NOAA GOES observations in Earth's equatorial plane about 6.6 Earth radii from center of Earth
- GPS observations of energetic particles that follow Earth's field lin… ab… ge…
- GPS observations complement GOES by providing a broad, time-evolving, radial profile of Earth's radiation environment that affect satellites
- During the event shown, on Jan 8, 2014, there was a launch delay of re-supply ship to ISS due to SEPs

OSTP will chair an interagency group to evaluate whether to request USAF to declassify and release near real-time particle data stream from GPS constellation



Top: GOES 13 > 50 MeV protons
Bottom: Ratios of 10-50 MeV proton rates to interplanetary levels observed between about 7 and 4 Earth radii as measured by GPS CXD on 13 satellites at 4-min cadence. Purple bar shows approximate GOES location.

Rodriguez, Singer and Onsager

SWAP Actions 5.6.2 and 5.6.3

Formalize / Define R2O and O2R processes in SWx

- 5.6 Improve the effectiveness and timeliness of the process that transitions research to operations

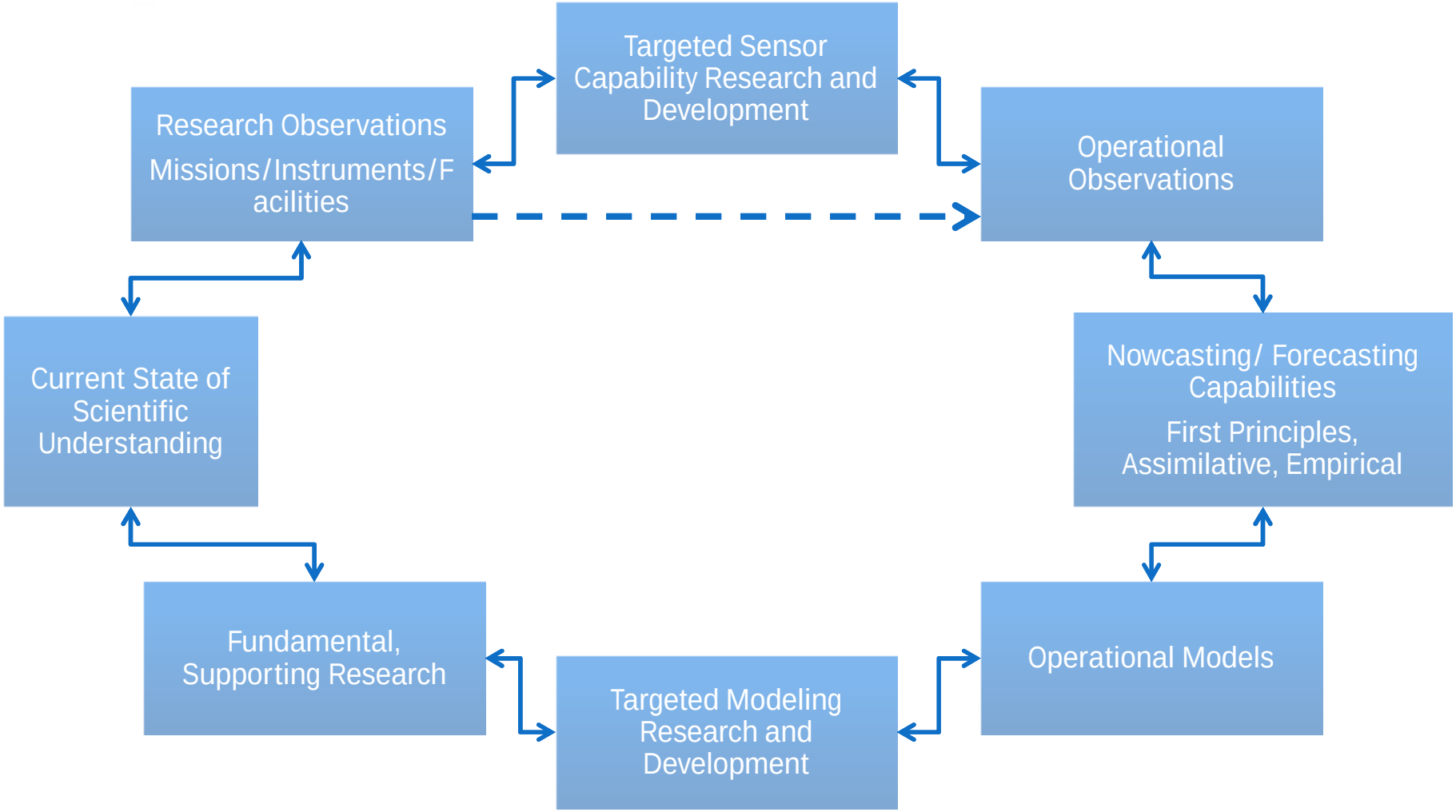
5.6.1 NASA and NSF lead: signed memorandum of understanding between modeling and forecasting centers (R2O).

5.6.2 DOC and DOD lead: complete plan for improving, testing, and maintaining operational forecast models and enabling operations to research feedback (O2R).

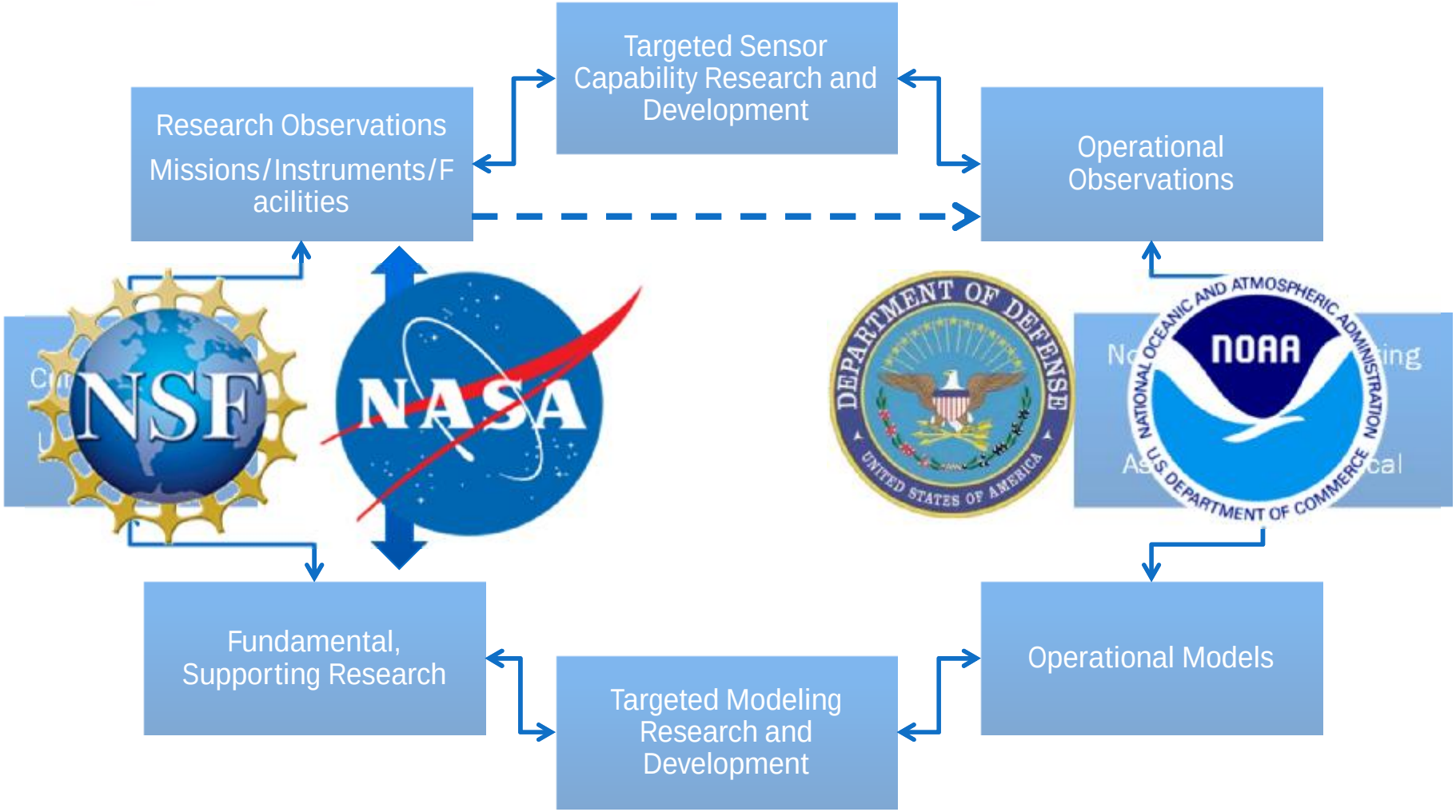
Progress to date:

- MOU drafted between NASA and NOAA/NWS/SWPC.
- OMB briefed on R2O and O2R concepts by NASA, NSF, NOAA, DOD on 2/29/16.
- Draft white paper on O2R requirements outlined.

Elements of R2O and O2R System



Elements of R2O and O2R System



O2R: Why it's needed

Once research models are transitioned to operations:

- The research community no longer has direct access to the (sometimes heavily modified) operational code.
- The research community lacks sources of funding for work on "applied research" models.
- The operations community typically lacks the scientific knowledge to upgrade the codes with new physics and/or algorithms.
- There is no mechanism for the operational community to transmit forecasting improvement requirements to the model developers.
- Example: WSA/Enlil at SWPC has not been touched since 2011.

Proposal:

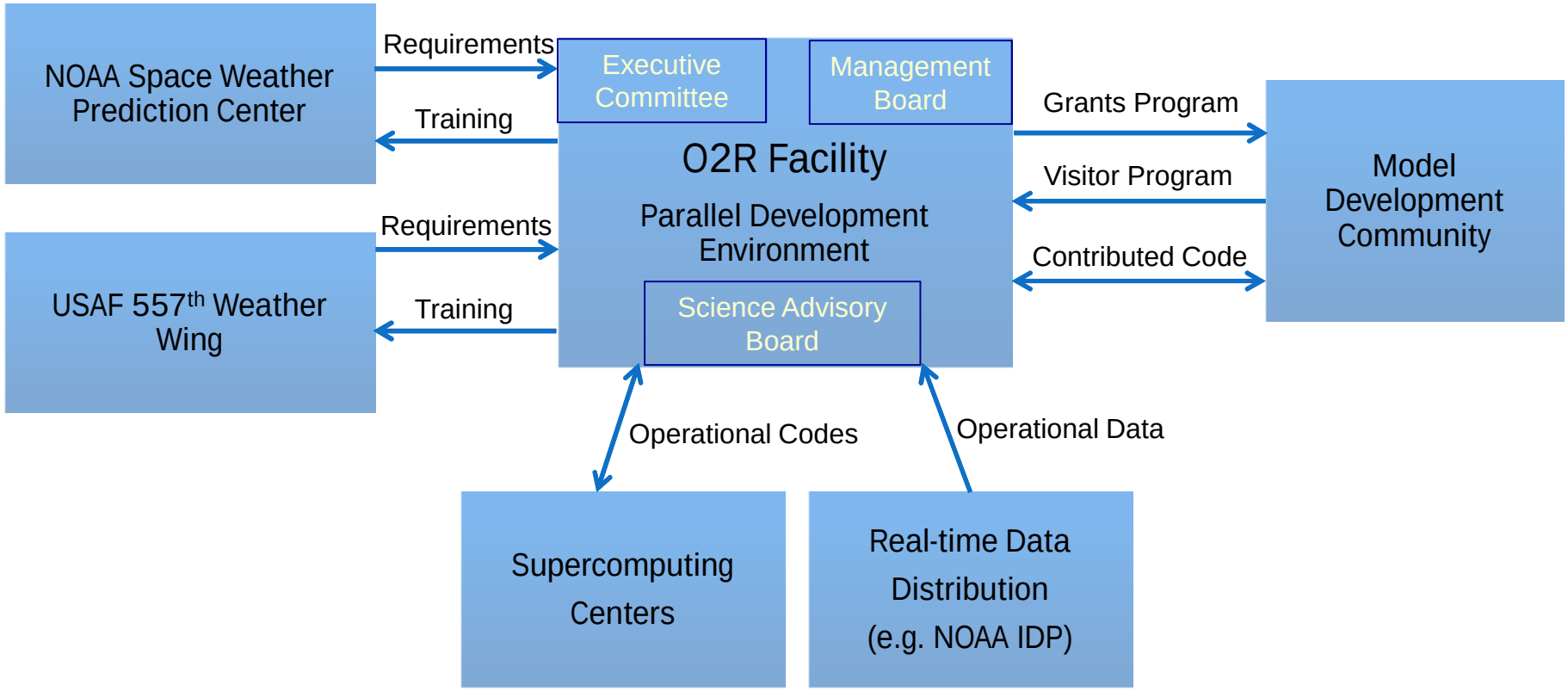
- An O2R "facility" where parallel versions of operational codes can be modified by researchers and tested with real-time or archived data against original code.
- Multi-agency support for grants to model development community.

NOAA's O2R Vision

Bridge between Ops and Research Communities

Operations

Research



Terrestrial weather analogs: JCSDA, NCAR DTC, CTB, NGGPS project, etc.

R2O & O2R: Next Steps

5.6.1: Finalize MOU between NASA and NOAA/NWS/SWPC.

5.6.2: Multi-step process to defining capability

- Publish white paper defining the issue and requirements: June 2016.
- Community meeting on concepts of operation, logistic issues, charter development, etc: August 16—17, 2016, Boulder, Colorado
- Submit O2R plan to OSTP: April 2016.

Collaboration on L5 Mission

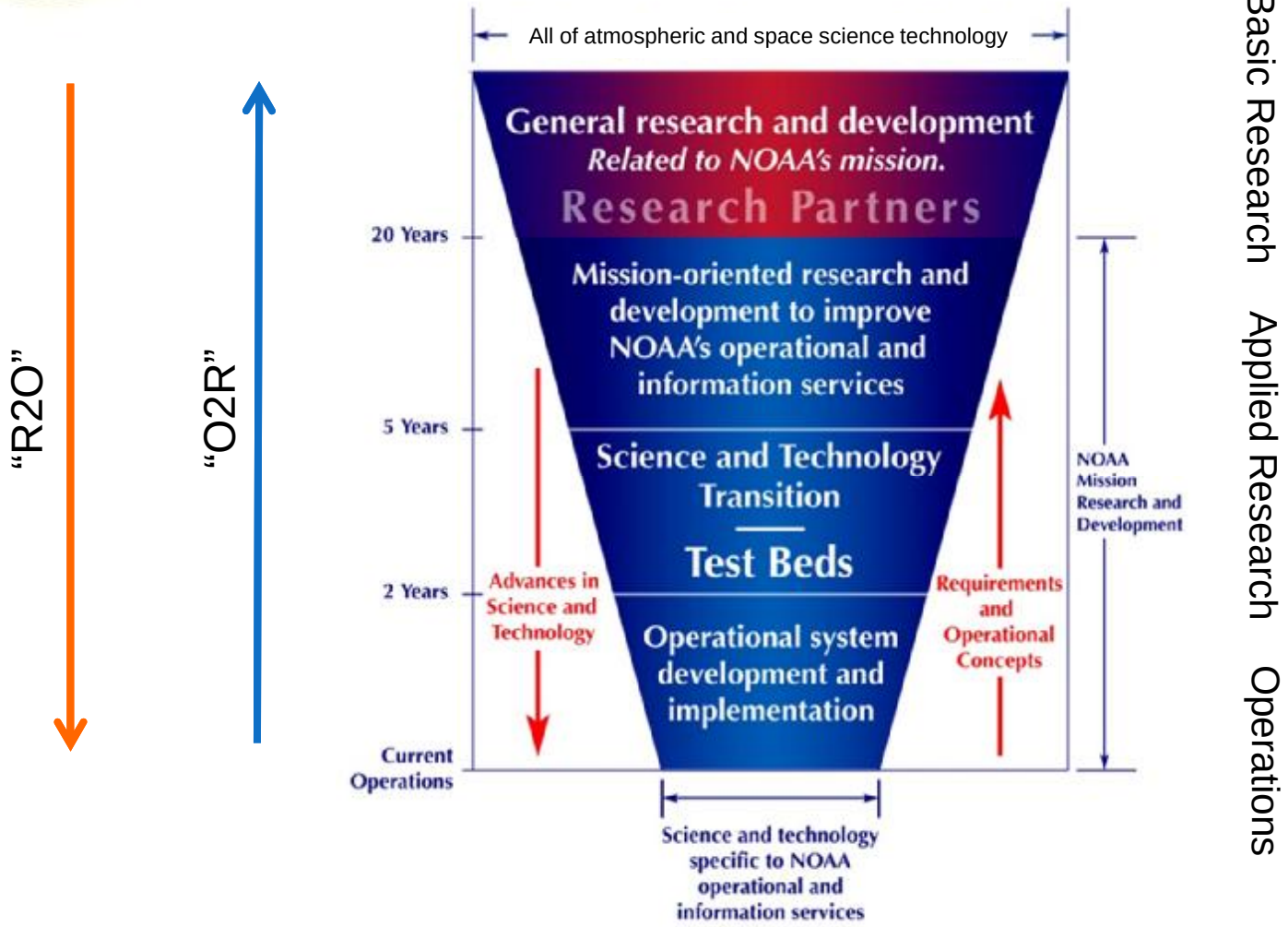
Combine with L1 Follow-On to increase accuracy

- 6.2.3 DOC and NASA will collaborate with academia, the private sector, and the international community to explore the potential benefits and costs of space-weather missions in orbits complementary to the sustained missions at the L1 Lagrangian point, which may include missions at the L5 Lagrangian point. Such missions may improve monitoring of CME properties and trajectories relative to Earth.
  - Simultaneous coronagraphs at L1 & L5 significantly increase accuracy of CME arrival time estimates (12—25% increase in SWPC study, in prep.)
  - Surprises such as St. Patrick's Day 2015 G-4 storm much less likely.
  - National and international mission studies are underway for several L5 mission alternatives.


Questions?

NOAA Research to Operations Funnel

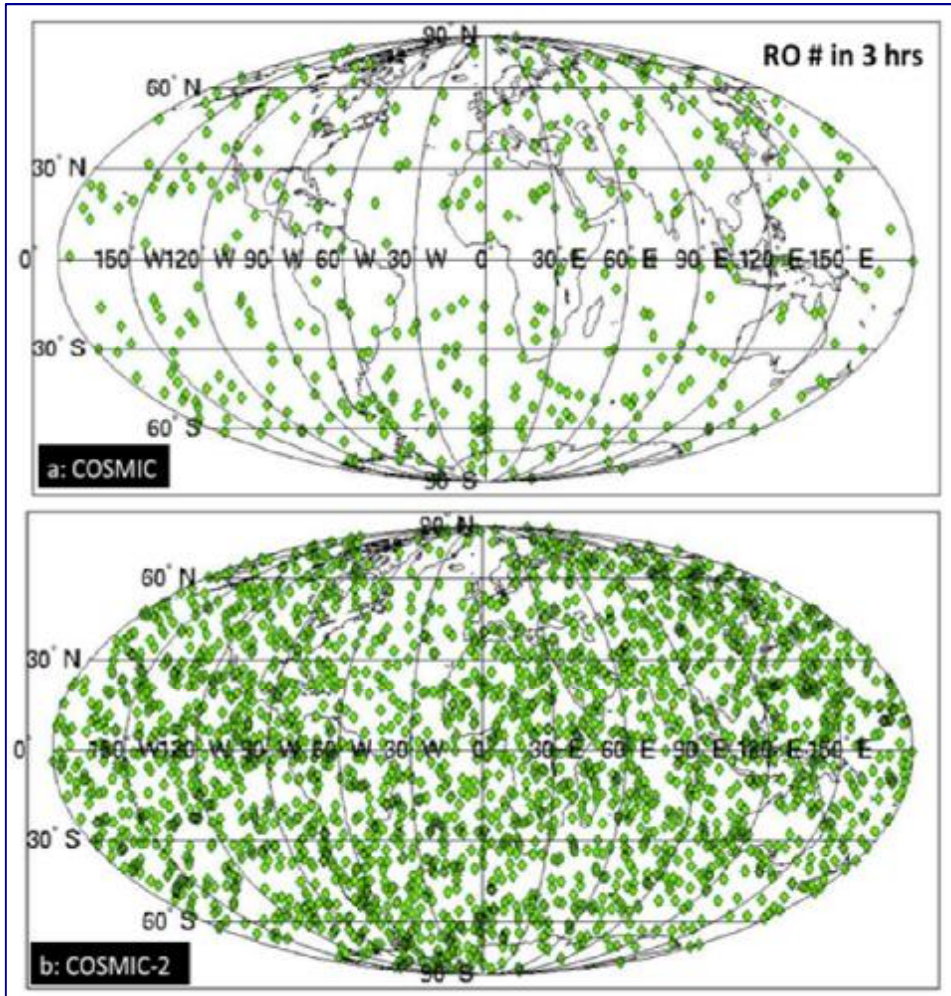
20+ year process to transition basic research to operations



FY17 Request: $10M for Research Transition Acceleration Program (RTAP)

Future SWx Observations

COSMIC-2 RO coverage compared to COSMIC-1



RO Payload	Satellite	Space Weather Payload
IGOR GPS ~2,000 per day Latency: 2 hr	6 LEO satellites ~72° inclination ~800 km altitude ~61 kg >0.68 for 2 years launched 2006	TIP TBB
TriG GPS+ GLONASS >8,000 tropo per day >12,000 iono per day Latency: 38 min	First Launch 6 LEO satellites ~24° inclination ~520 km altitude ~215 kg >0.66 for 5 years ~launch 2016	IVM RF Beacon
	Second Launch 6 LEO satellites ~72° inclination ~720 km altitude ~215 kg >0.66 for 5 years ~launch 2019	TBD

Courtesy Xinan Yue, UCAR