ATMOSPHERIC & SPACE TECHNOLOGY RESEARCH ASSOCIATES

SCIENCE + TECHNOLOGY + APPLICATIONS // *Bringing it all together*

Space Weather: Severe Geomagnetic Storm ReCap

Joe Kunches

Director, Space Weather Services

ASTRA

Boulder, Colorado

USA

19th Cross Polar Working Group

JCAB, Tokyo

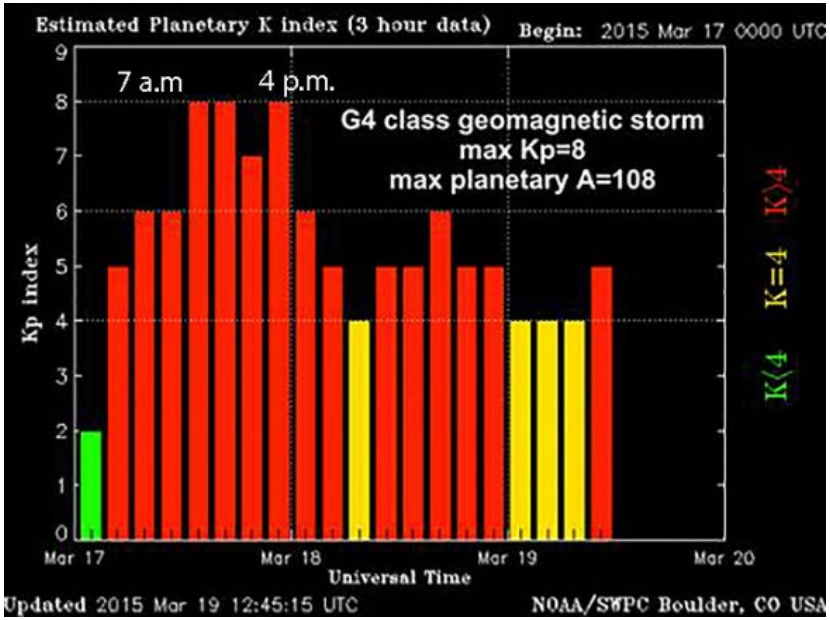
May 11-15, 2015

Highlights in 2015

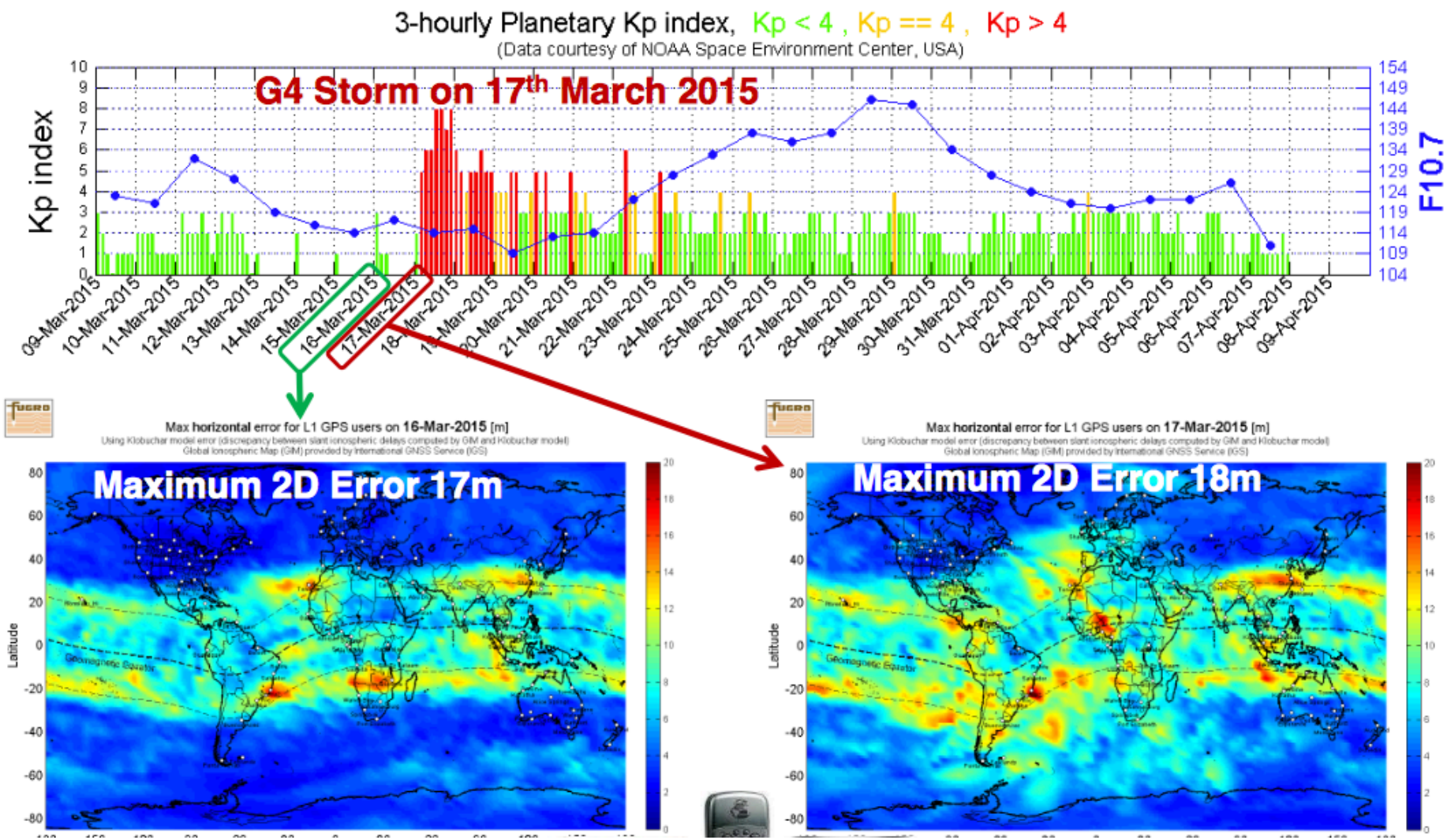
- G4 (Severe) Geomagnetic Storm March 17
  - G4 events rare, included impacts to
    - WAAS
    - Power Grid
    - HF Communications
- Occasional smaller storms occurred; the Sun is setting up for more repeatable geomagnetic storms this point of the cycle.
- Cycle 24 continues to weaken.

March 17 Geomagnetic Storm

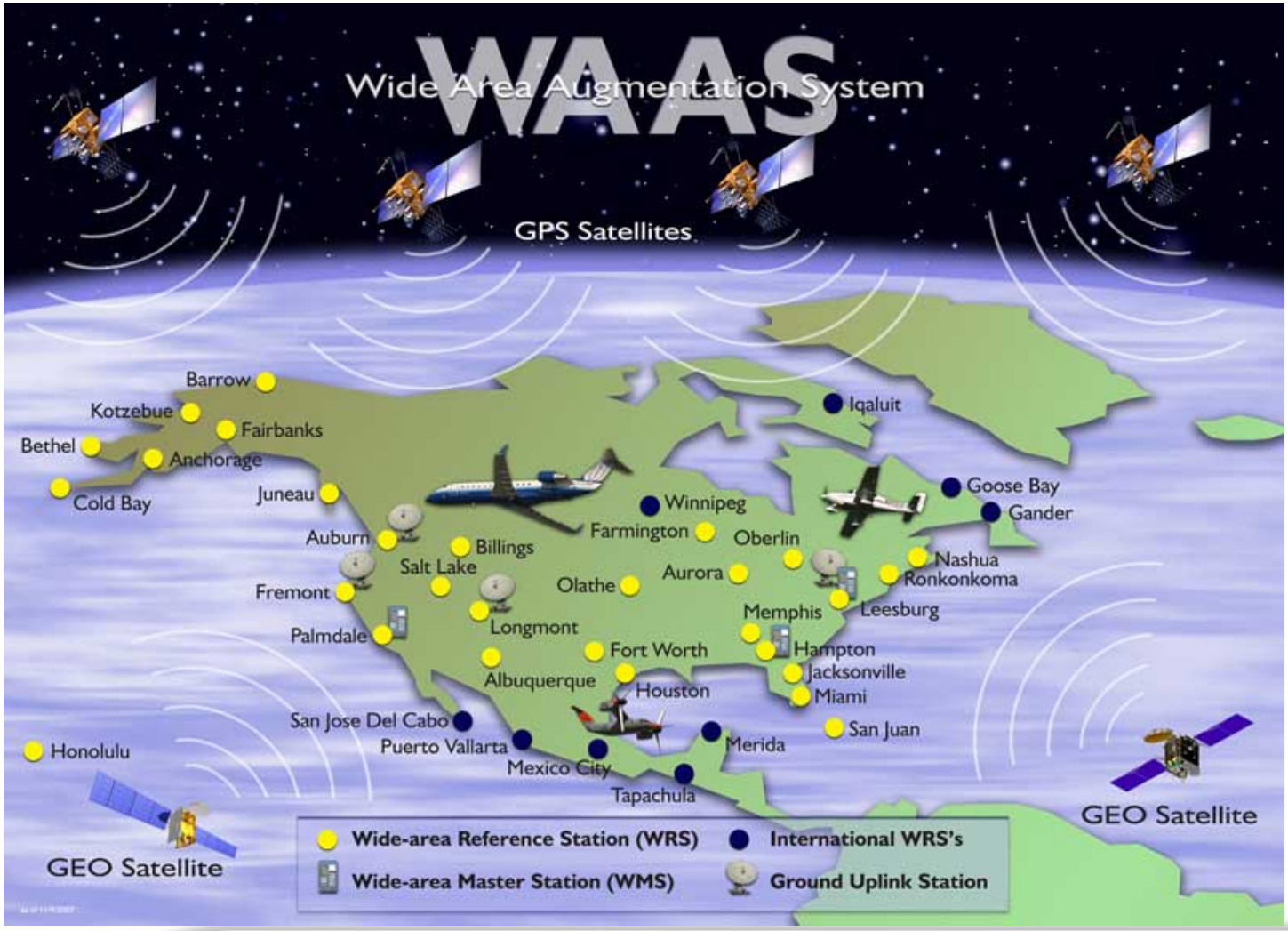
- Spawned by 2 CMEs on March 15
- Reached G4 – much higher than the predicted G1
- Lingered thru March 20



GPS Error Footprint Increase



SBAS (WAAS) Infrastructure



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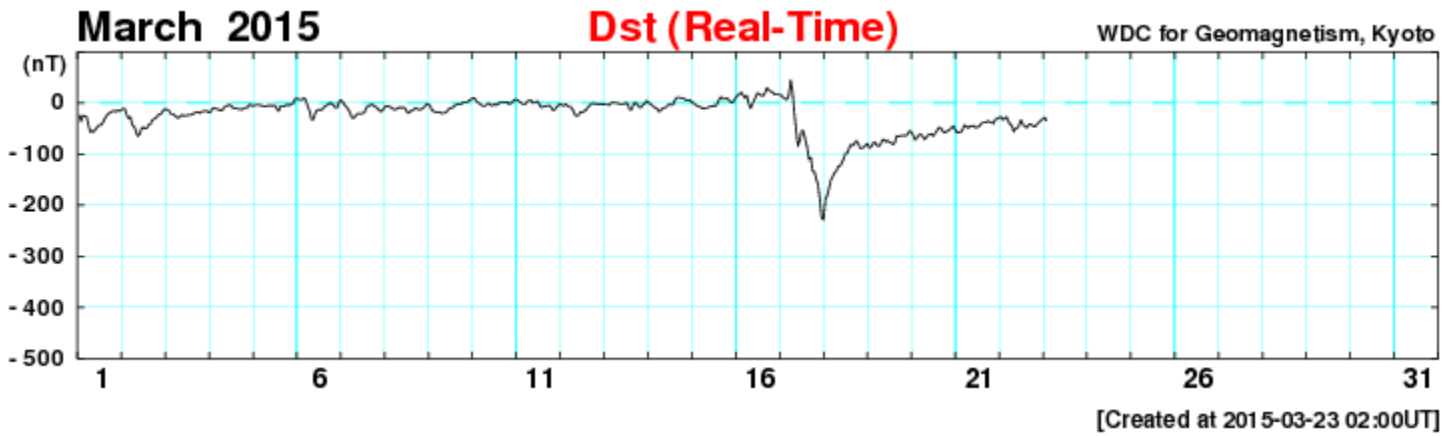
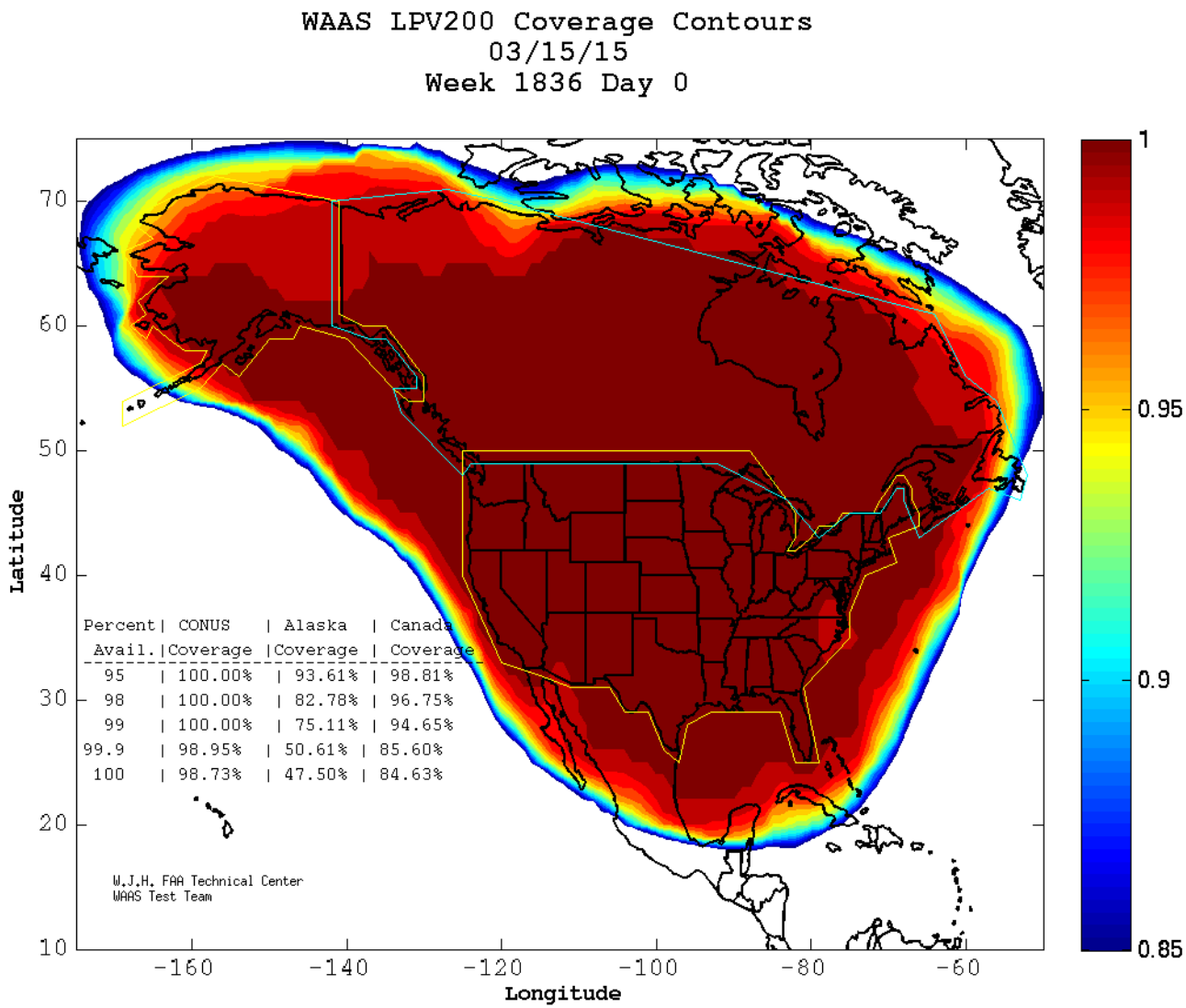
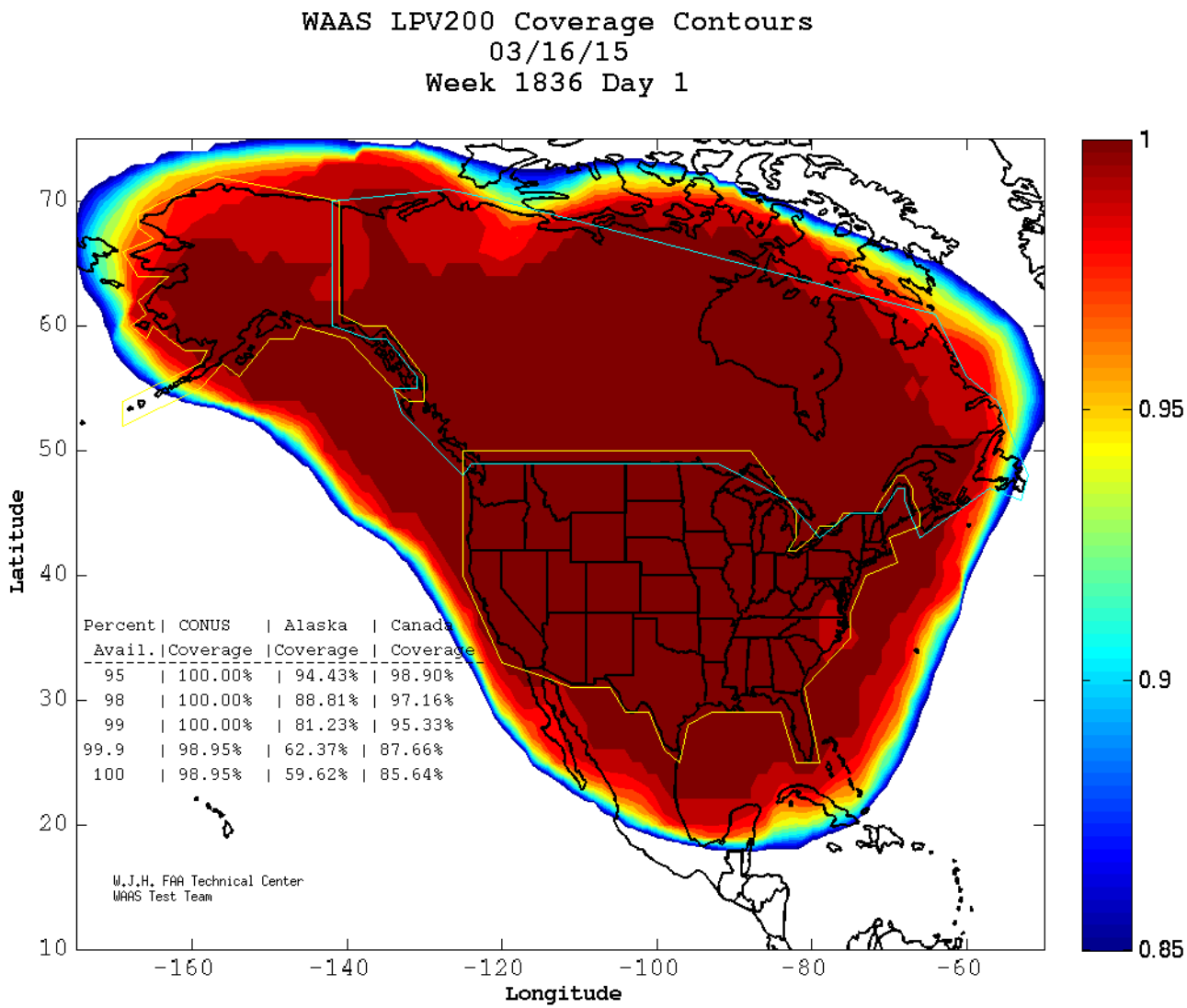
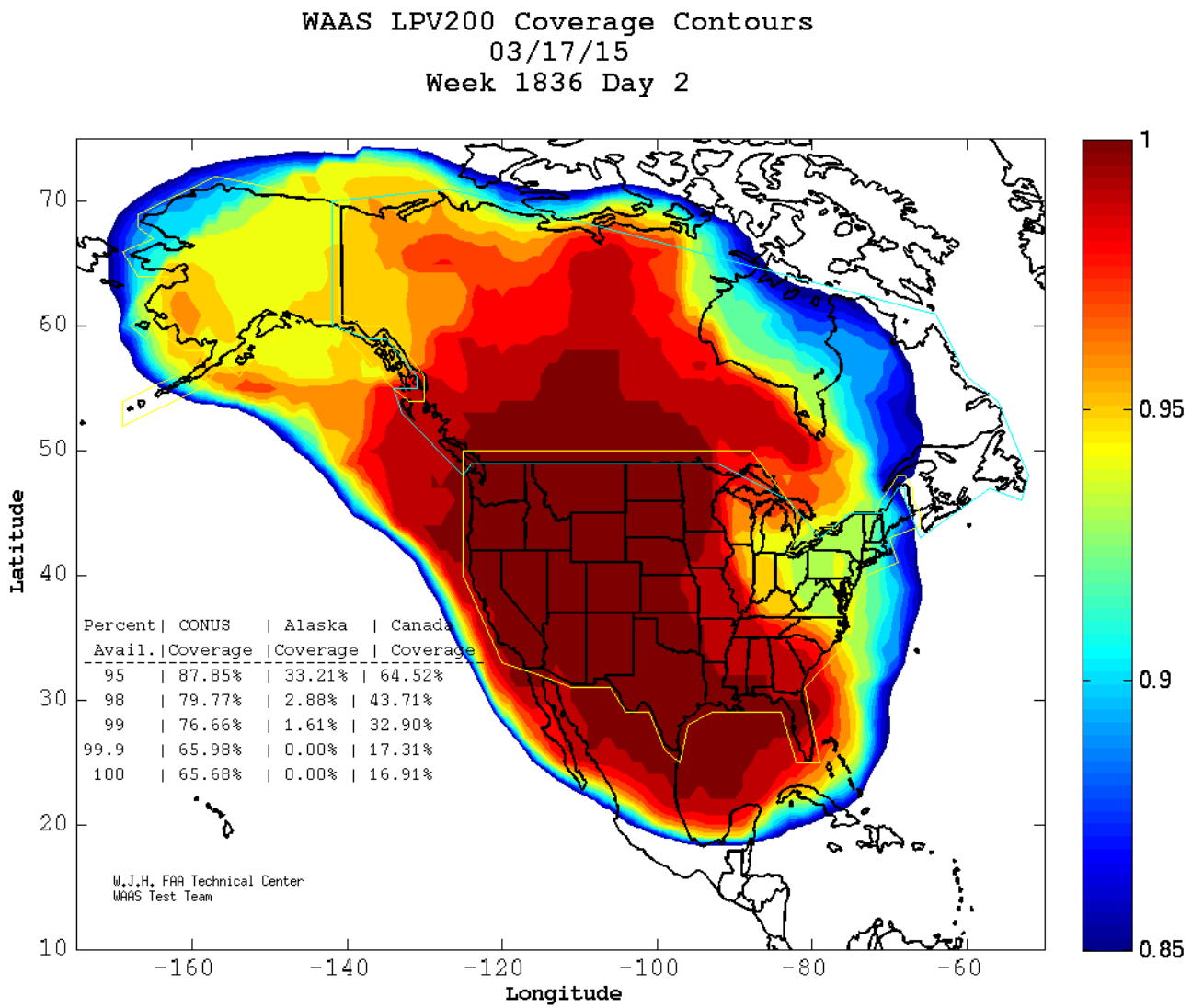
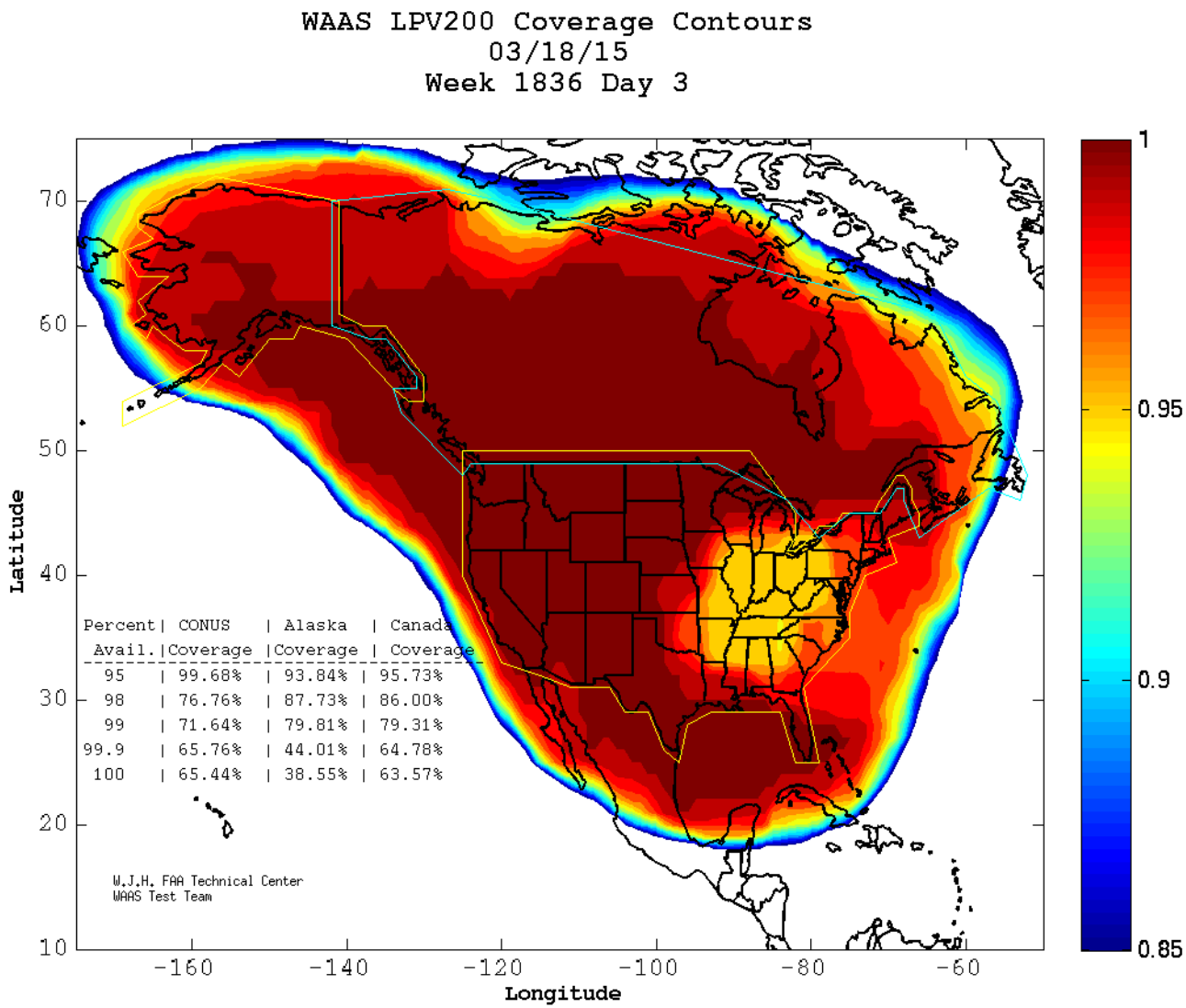
2015 St. Patrick's Day Storm Impact on WAAS



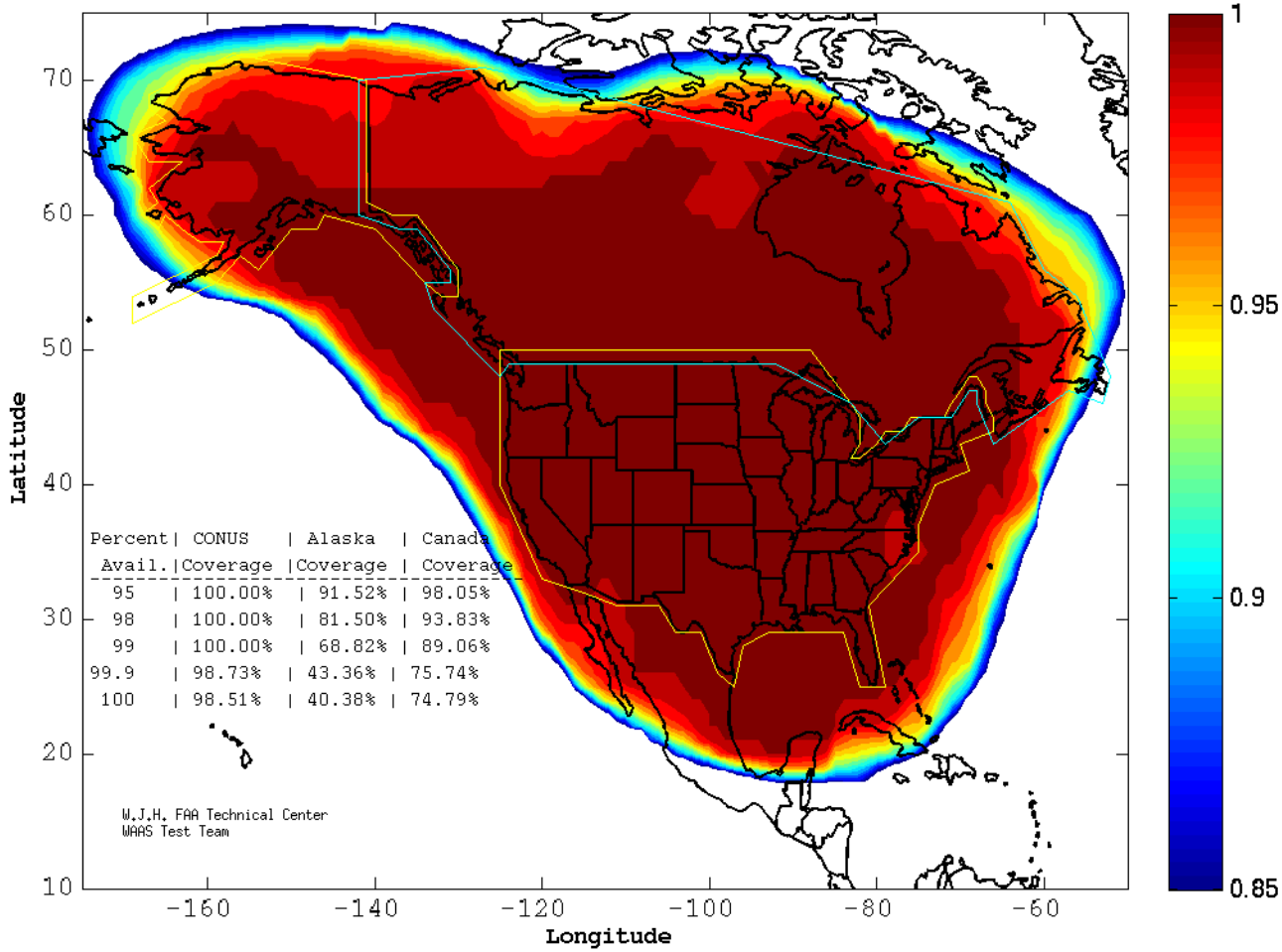

WAAS LPV200 Coverage Contours
03/15/15
Week 1836 Day 0
Latitude
Longitude
70
60
50
40
30
20
10
-160
-140
-120
-100
-80
-60
1
0.95
0.9
0.85
Percent Avail. | CONUS Coverage | Alaska Coverage | Canada Coverage
95 | 100.00% | 93.61% | 98.81%
98 | 100.00% | 82.78% | 96.75%
99 | 100.00% | 75.11% | 94.65%
99.9 | 98.95% | 50.61% | 85.60%
100 | 98.73% | 47.50% | 84.63%
W.J.H. FAA Technical Center
WAAS Test Team


WAAS LPV200 Coverage Contours
03/16/15
Week 1836 Day 1
Latitude
Longitude
70
60
50
40
30
20
10
-160
-140
-120
-100
-80
-60
1
0.95
0.9
0.85
Percent | CONUS | Alaska | Canada
Avail. | Coverage | Coverage | Coverage
95 | 100.00% | 94.43% | 98.90%
98 | 100.00% | 88.81% | 97.16%
99 | 100.00% | 81.23% | 95.33%
99.9 | 98.95% | 62.37% | 87.66%
100 | 98.95% | 59.62% | 85.64%
W.J.H. FAA Technical Center
WAAS Test Team

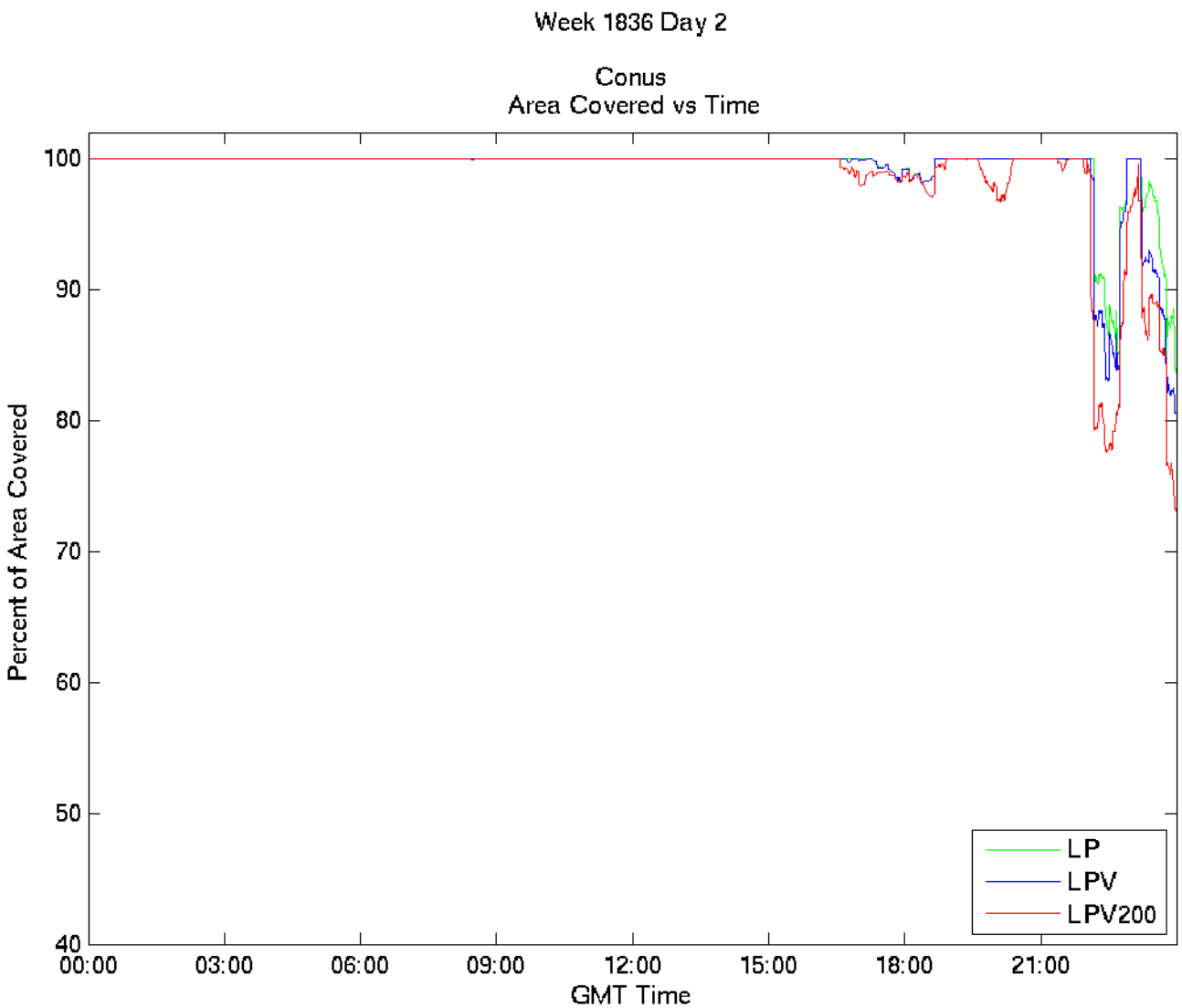

WAAS LPV200 Coverage Contours
03/17/15
Week 1836 Day 2
Latitude
Longitude
70
60
50
40
30
20
10
-160
-140
-120
-100
-80
-60
1
0.95
0.9
0.85
Percent | CONUS | Alaska | Canada
Avail. | Coverage | Coverage | Coverage
95 | 87.85% | 33.21% | 64.52%
98 | 79.77% | 2.88% | 43.71%
99 | 76.66% | 1.61% | 32.90%
99.9 | 65.98% | 0.00% | 17.31%
100 | 65.68% | 0.00% | 16.91%
W.J.H. FAA Technical Center
WAAS Test Team

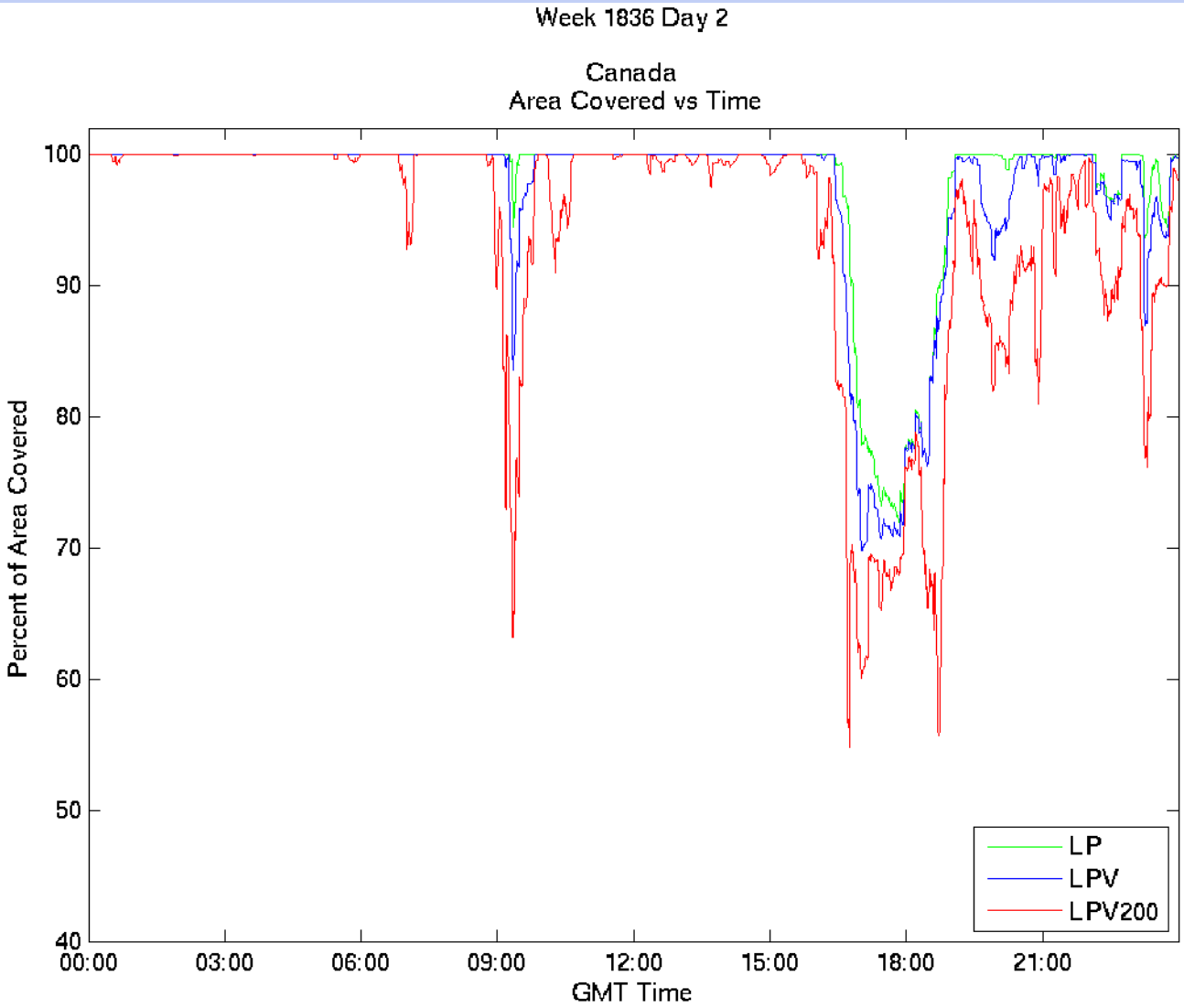

WAAS LPV200 Coverage Contours
03/18/15
Week 1836 Day 3
Latitude
Longitude
70
60
50
40
30
20
10
-160
-140
-120
-100
-80
-60
1
0.95
0.9
0.85
Percent | CONUS | Alaska | Canada
Avail. | Coverage | Coverage | Coverage
95 | 99.68% | 93.84% | 95.73%
98 | 76.76% | 87.73% | 86.00%
99 | 71.64% | 79.81% | 79.31%
99.9 | 65.76% | 44.01% | 64.78%
100 | 65.44% | 38.55% | 63.57%
W.J.H. FAA Technical Center
WAAS Test Team

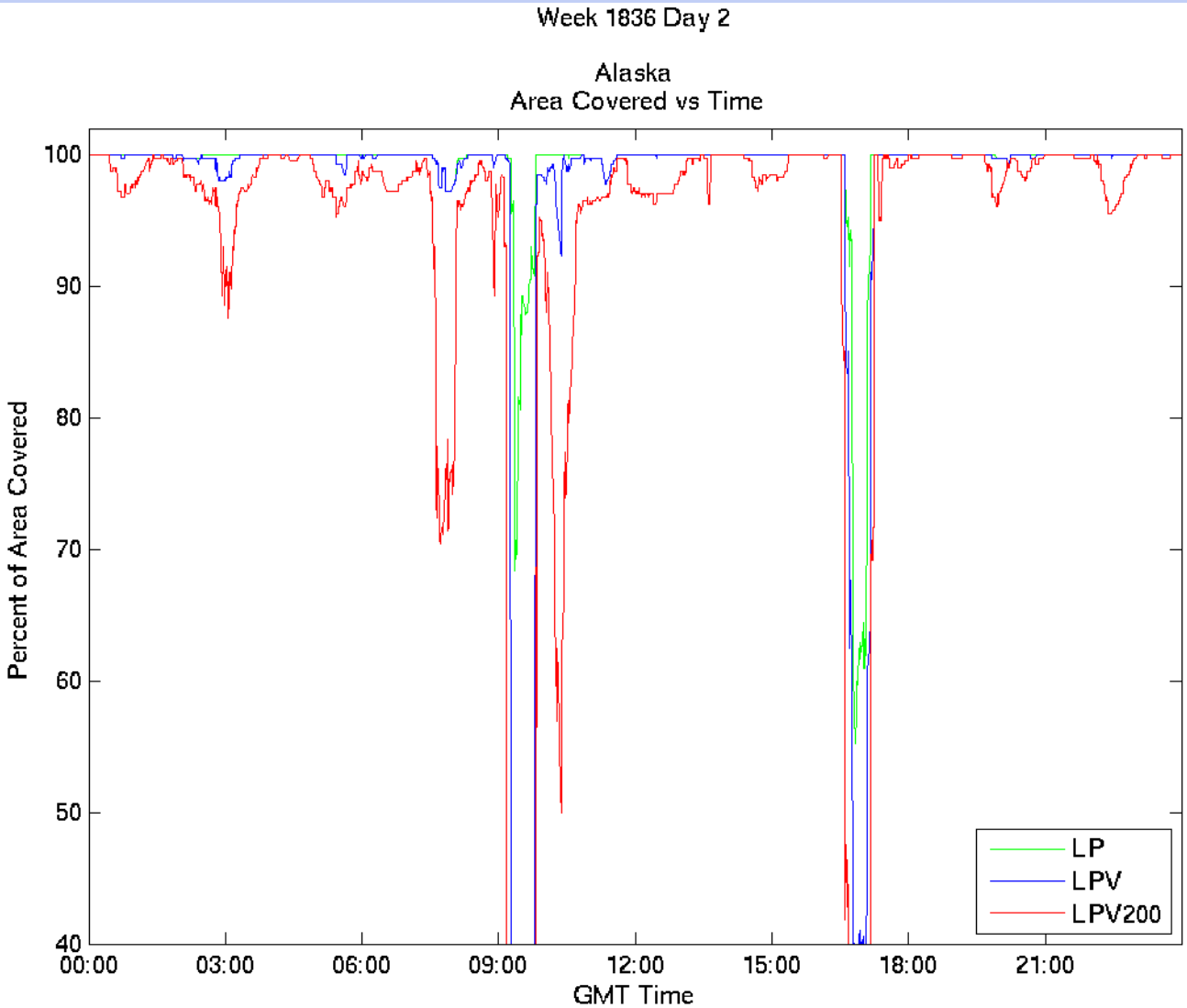
WAAS LPV200 Coverage Contours
03/19/15
Week 1836 Day 4



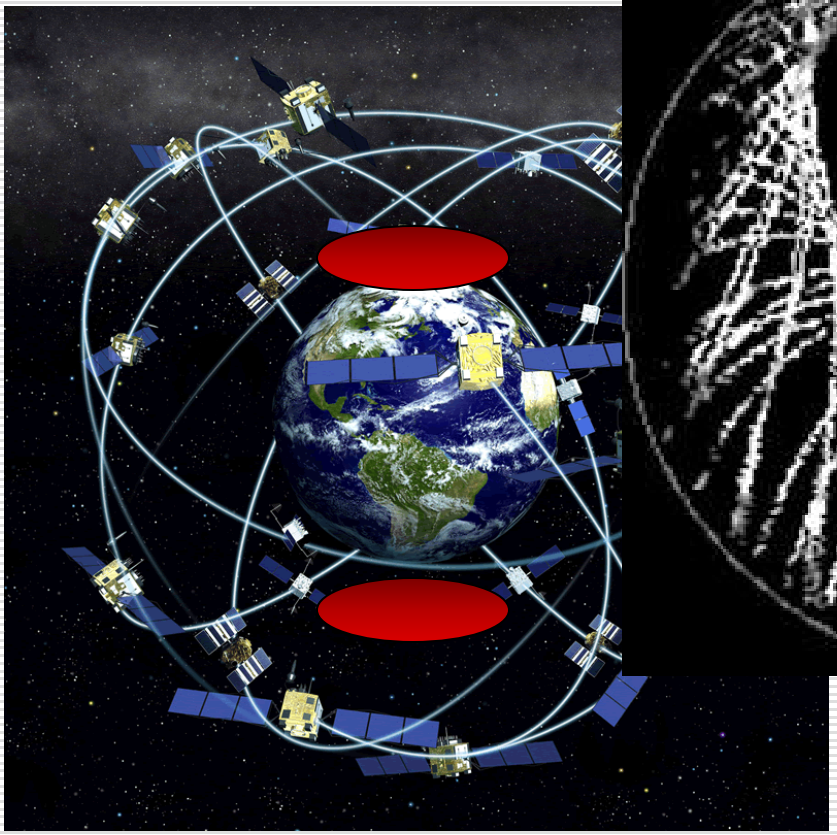
Percent Avail.	CONUS Coverage	Alaska Coverage	Canada Coverage
95	100.00%	91.52%	98.05%
98	100.00%	81.50%	93.83%
99	100.00%	68.82%	89.06%
99.9	98.73%	43.36%	75.74%
100	98.51%	40.38%	74.79%

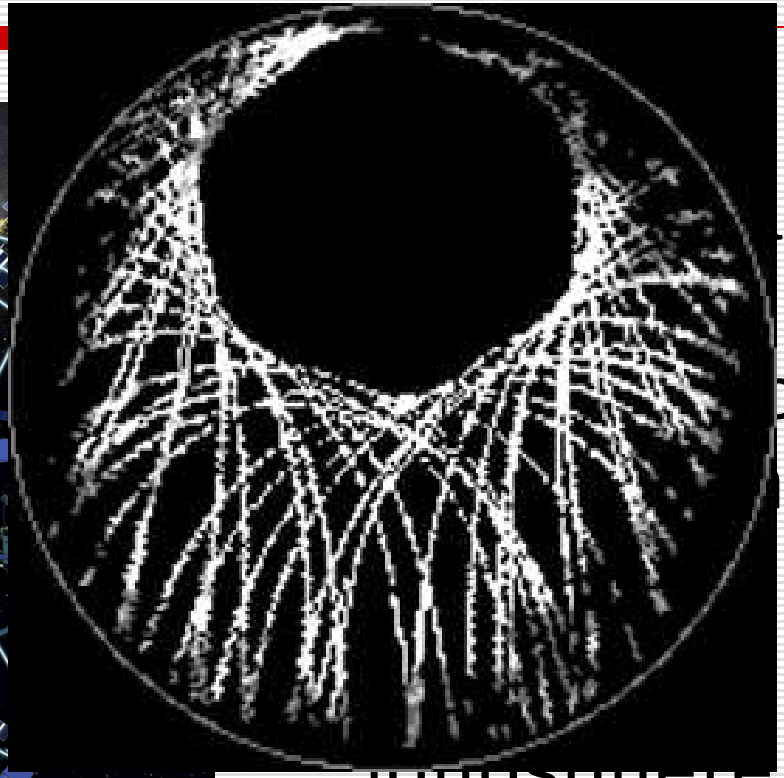

Week 1836 Day 2
Conus
Area Covered vs Time
Percent of Area Covered
100
90
80
70
60
50
40
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
GMT Time
LP
LPV
LPV200


Week 1836 Day 2
Canada
Area Covered vs Time
Percent of Area Covered
100
90
80
70
60
50
40
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
GMT Time
LP
LPV
LPV200


Week 1836 Day 2
Alaska
Area Covered vs Time
Percent of Area Covered
100
90
80
70
60
50
40
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
GMT Time
LP
LPV
LPV200

GPS: Consequences of a 55° Inclination





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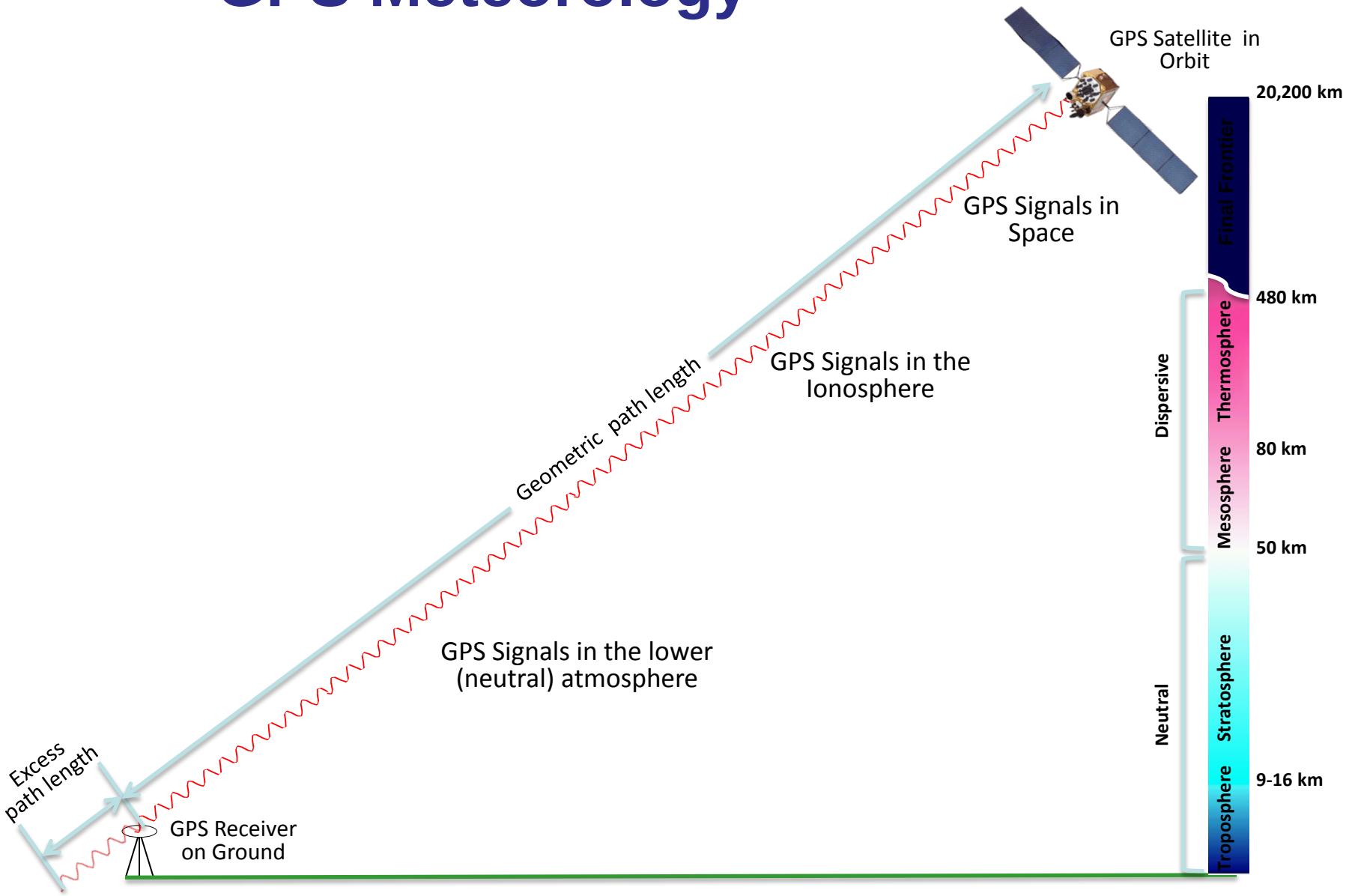
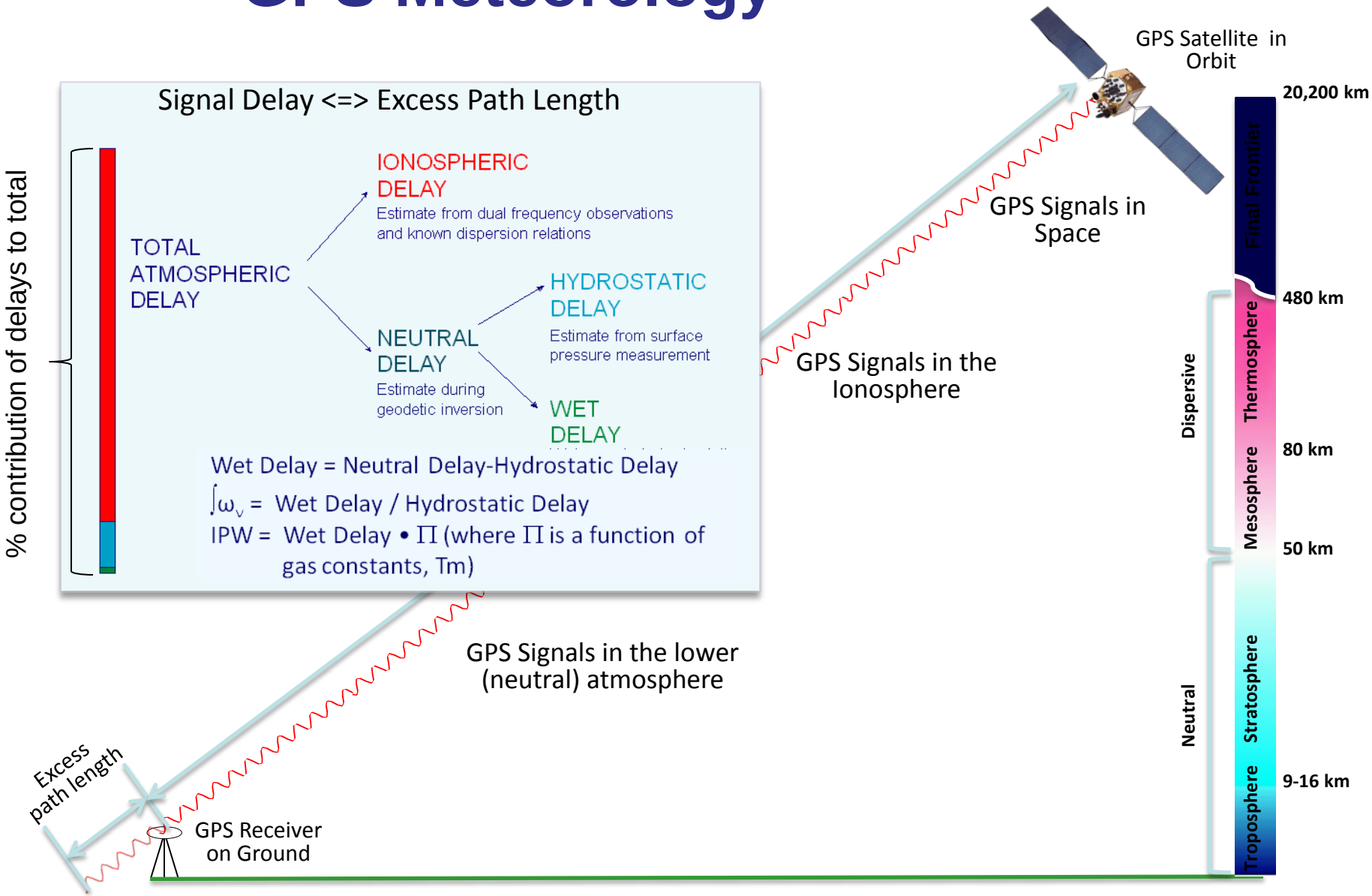
ionosphere

GPS Meteorology



GPS Meteorology



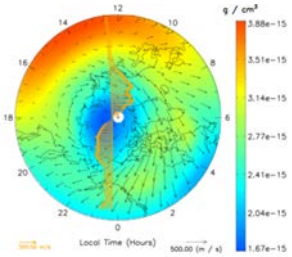
ASTRA: Overview

❖Science
❖ Technology
❖ Applications
Bringing It All Together

ASTRA

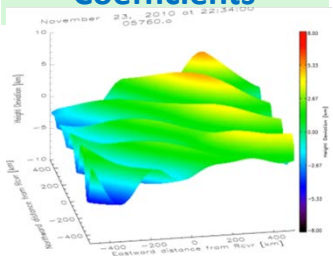
Modeling

- Physics-Based Modeling (TIMEGCM)
- Real-Time Specification of Ionosphere/ Thermosphere



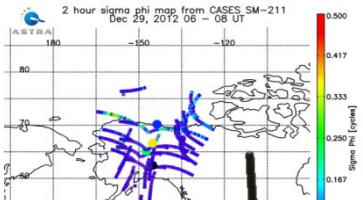
Data Assimilation

- High-latitude Electrodynamics (AMIE)
- Global Ionosphere (IDA4D)
- Thermospheric Neutral Density (ADAM)
- Satellite Drag & Ballistic Coefficients



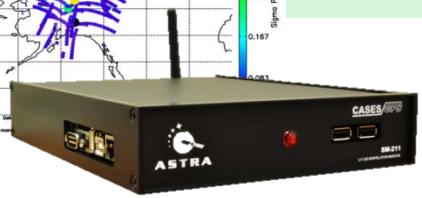
Data Services

- Space Based Data
- Ground Based Data
- Forensic Space Weather Analysis
- Space weather Phone Apps



Ground-based Instrument Development

- GPS-based Space Weather Monitor
- Low Power Ionospheric Sounder
- HF TID Mapper
- Laser Bathymetry
- Lidar Systems



Space Systems

CubeSat Missions
- NSF DICE Cubesat
- SMC SENSE
- AF DIME Cubesat

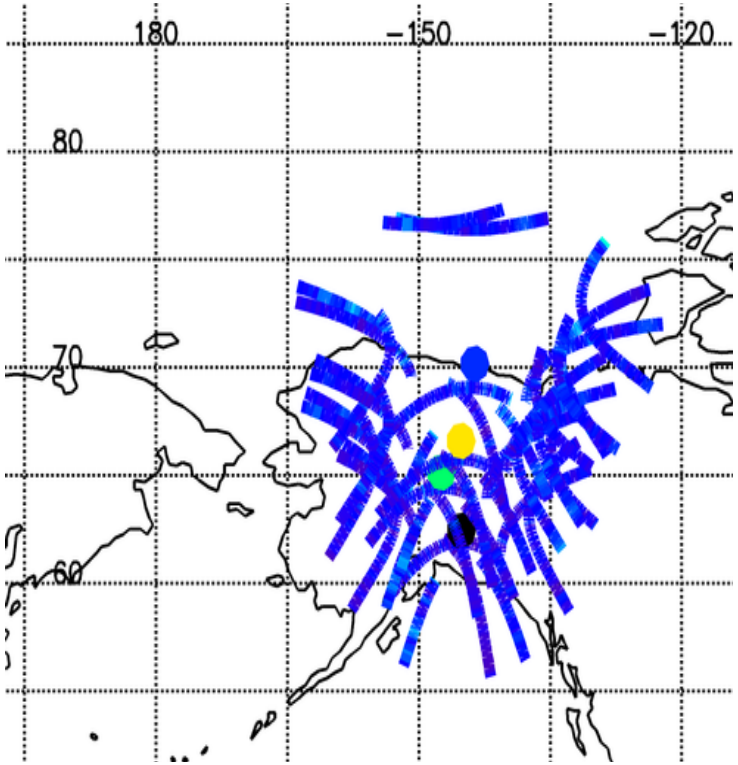
Plug-N-Play Avionics

CubeSat Instruments
- Scanning UV Photometer
- E-field Double Probe
- Topside Sounder
- Wind Profiler
- GPS-based Space Weather Monitor

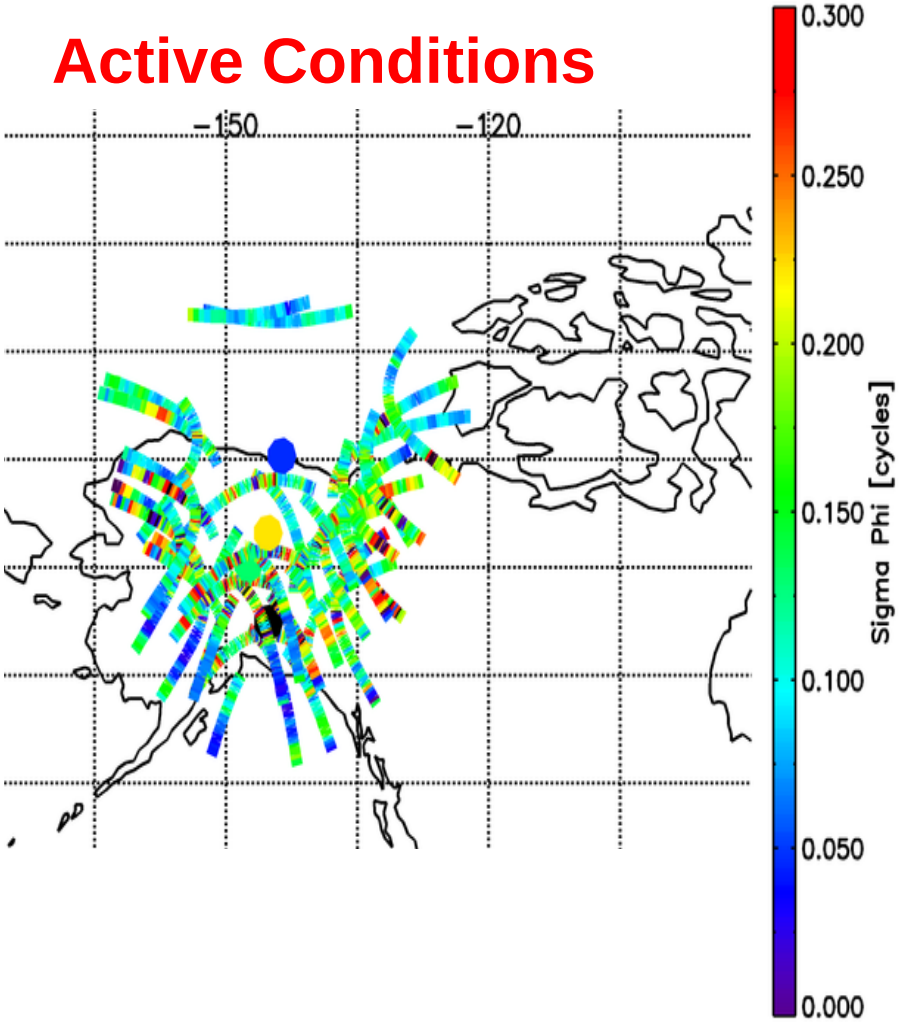
Satellite Aerodynamics

http://www.youtube.com/4spaceweather

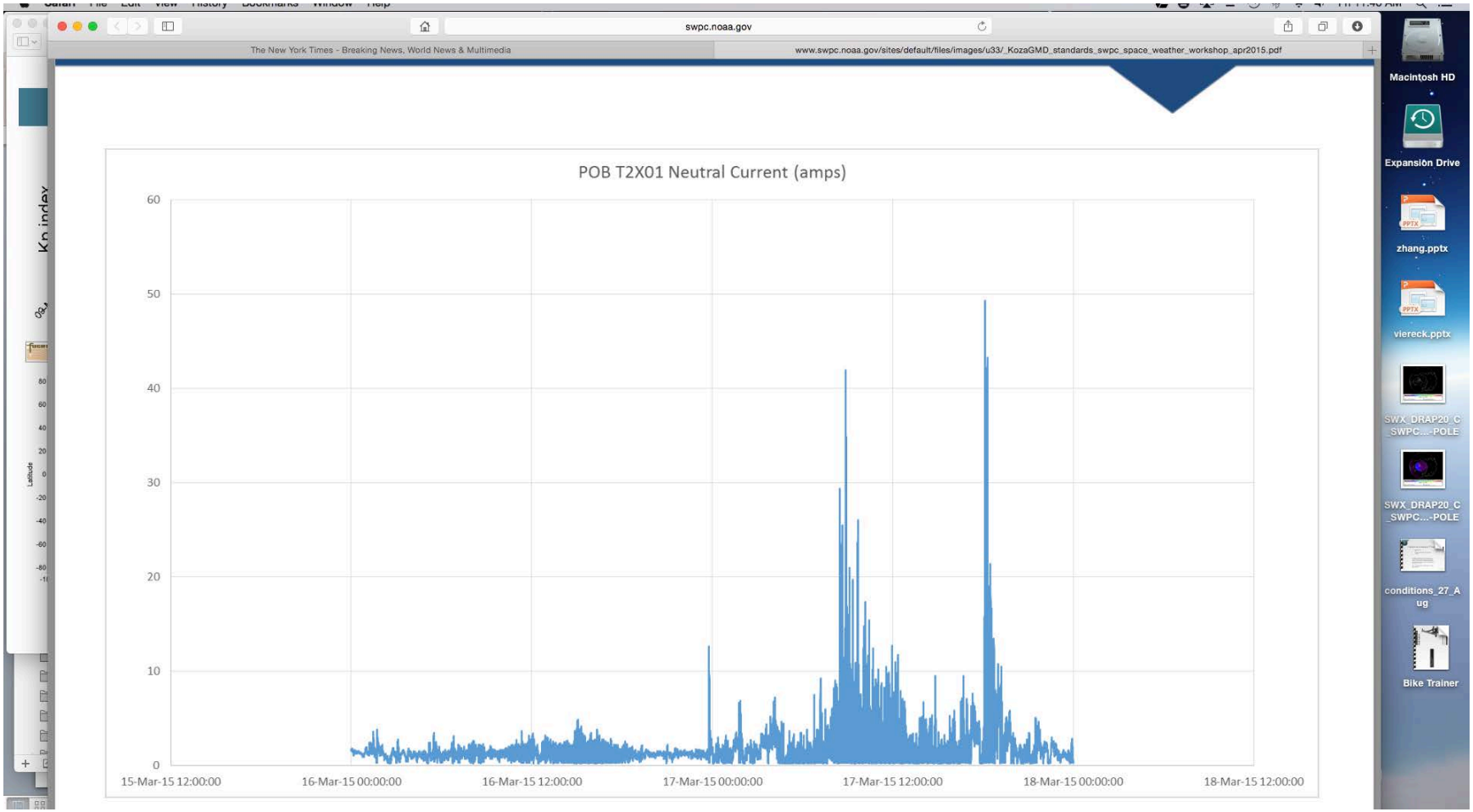
Quiet Conditions



Active Conditions



Power Grid – Induced Current



HF Communications

- Significant impacts reported, as far south as Oregon in the US

Effects of Solar Activity on HF Radio

When sunspot 2297 began tracking across the surface of the Sun, Operations was briefed during the NYC morning meetings.

The eruption on March 9th at 2353Z, (X-Ray flux exceeding M5 – NOAA scale R2-Moderate) over the Pacific that marginal impact to HF Comms at the SFO Comm Center from approximately 2353Z – 0045Z.

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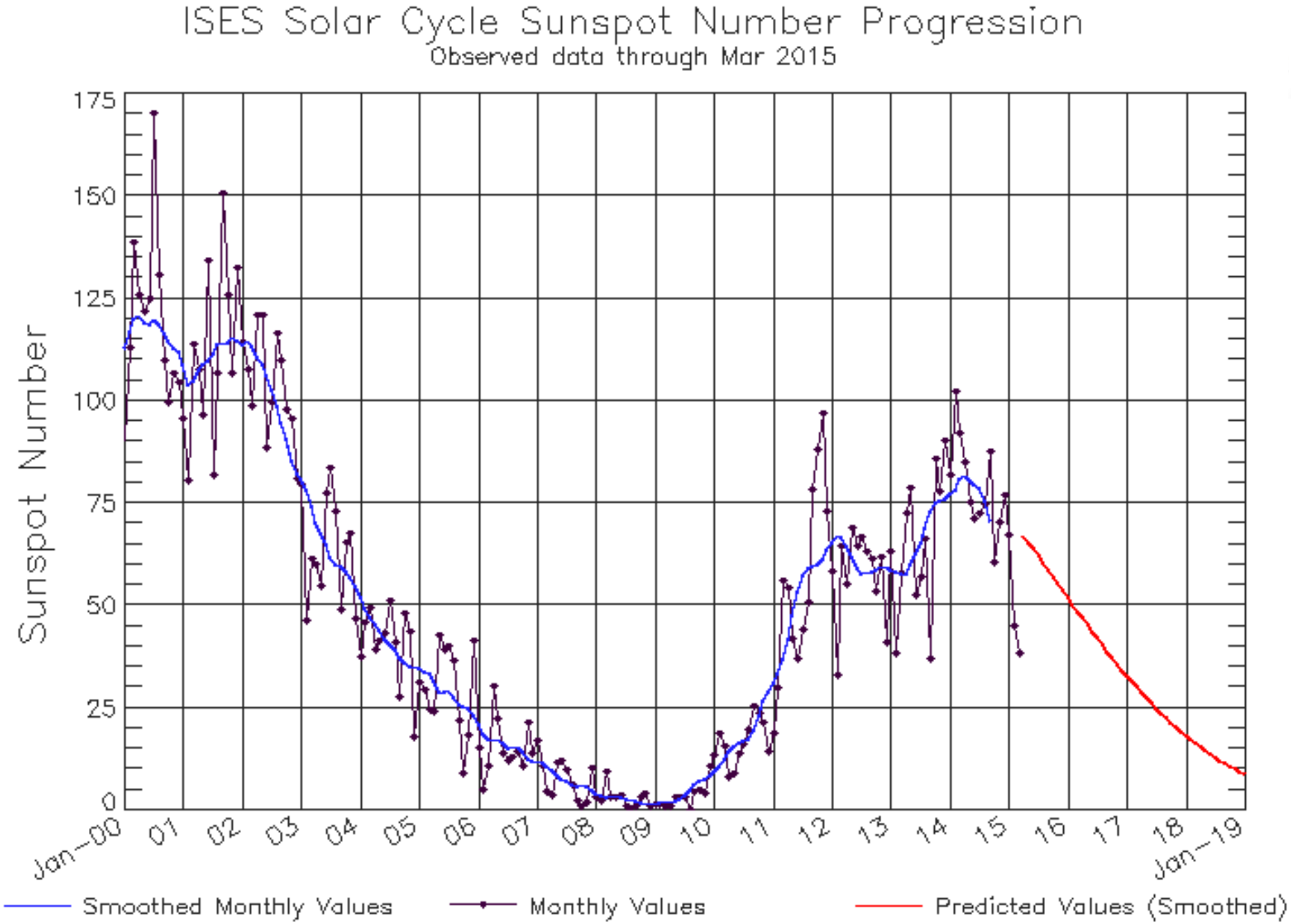
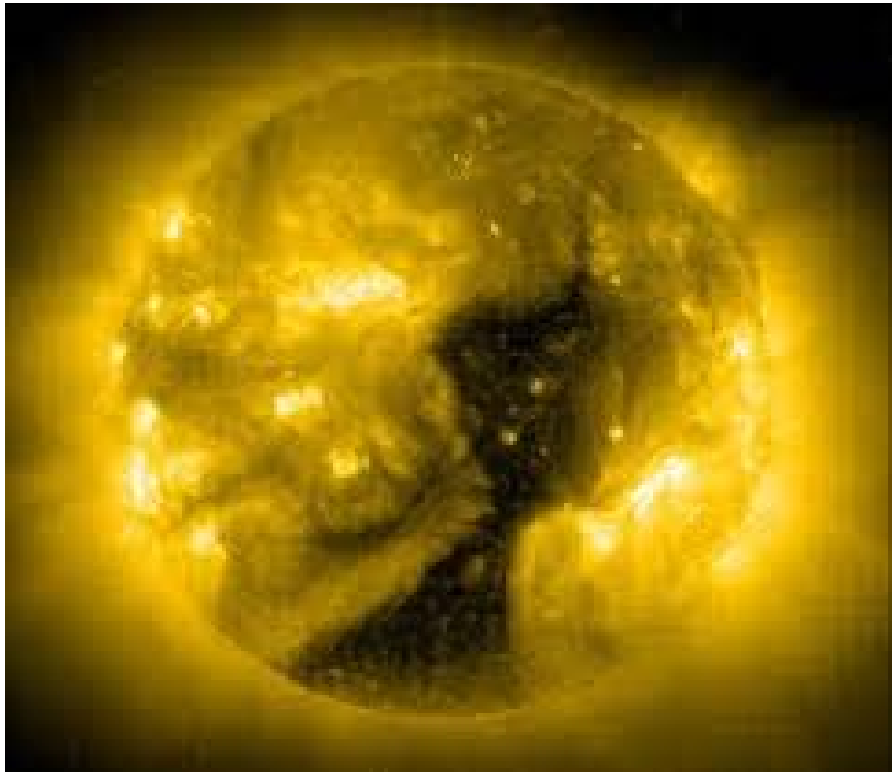

ISES Solar Cycle Sunspot Number Progression
Observed data through Mar 2015
Sunspot Number
175
150
125
100
75
50
25
0
Jan-00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Jan-19
Smoothed Monthly Values
Monthly Values
Predicted Values (Smoothed)
Updated 2015 Apr 6
NOAA/SWPC Boulder,CO USA

Coronal Holes

- Long-lived structures, allow fast solar wind to stream out
- Recur on a 27-day period
- Fast solar wind causes G1-G2 (minor to moderate) storming



Summary

- Severe Geomagnetic Storm March 17
- Navigation, electric power, and communications performance all affected
- Solar conditions now occurring enabling improved prediction of geomagnetic storms
- Polar operations can benefit from tailored services from ASTRA