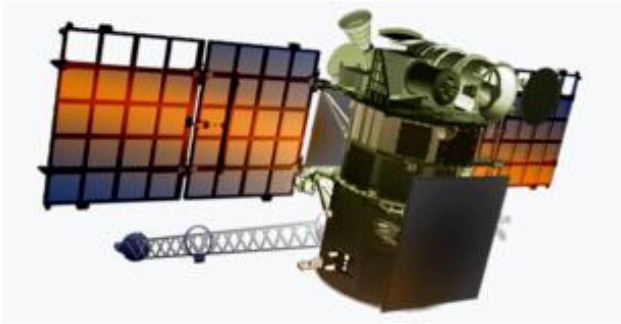


SOLAR WEATHER MEASUREMENT TOOLS

Lewis Thompson

W5IFQ

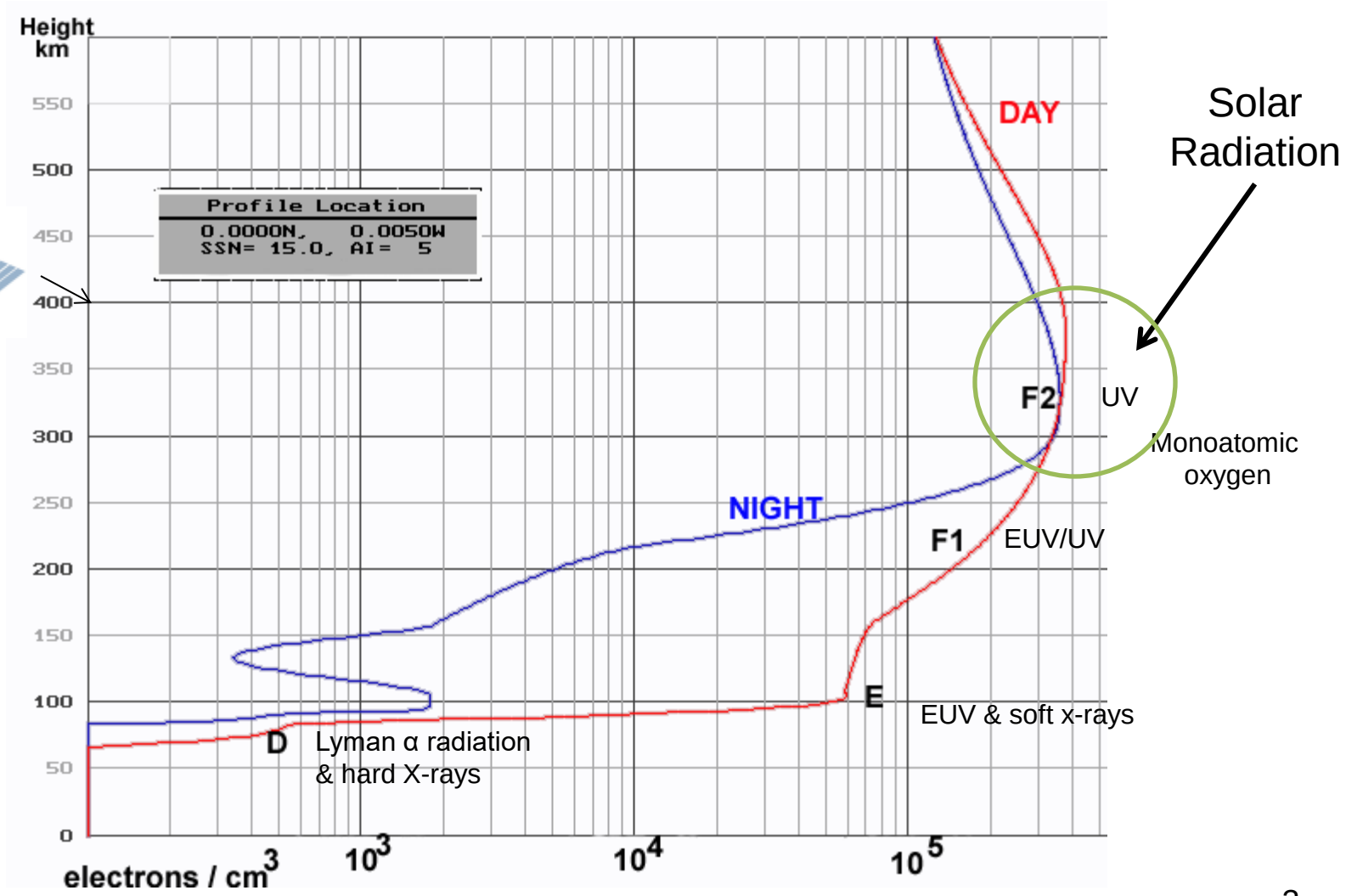
4 AUG 2020

Outline

- Ionospheric Ionization Estimations
  - Solar Flux
  - Sun Spot Number
- Geomagnetic Measurements
  - Kp
  - Dst
- Solar X-Ray Intensity Measurements
- Solar Wind Measurements
  - Coronal Holes
  - CME

Ionosphere Structure

Gravity



Solar Radiation

Solar Ionization Indicators

- **Solar Flux (SF)**
  - Measure of solar radio noise at 2800 MHz (10.7 cm)
  - Varies from 50 to 300
  - Increased SF leads to higher MUF
  - 11-year cycle
  - Does not exactly track propagation conditions
- **Sun Spot Number (SSN)** (Wolf or Zurich)
  - Special count of # of visible sun spots
  - Varies from 0 to 200+
  - 11-year cycle
  - 12 month running average produces best “fit” with propagation conditions.
  - Increased SSN leads to higher MUF
  - Solar Flux and SSN are mathematically related

SOLAR FLUX MEASUREMENTS

- The various manifestations of solar activity are driven by the total amount of magnetic flux emerging through the photosphere into the chromosphere and corona, and its temporal and spatial distribution. For reasons not clearly understood, solar activity ebbs and flows over a cycle of about 11 years. The 10.7cm Solar Flux is a measurement of the integrated emission at 10.7cm wavelength from all sources present on the disc. It is almost completely thermal in origin, and directly related to the total amount of plasma trapped in the magnetic fields overlying active regions. This in turn is related to the amount of magnetic flux. A comparison made over more than a solar activity cycle show that there is indeed a linear correlation between the 10.7cm Solar Flux and the total photospheric magnetic flux in active regions.

- The 10.7cm Solar Flux, i.e., the solar flux density at 10.7cm wavelength is measured using two fully automated radio telescopes (called *Flux Monitors*), located at the Dominion Radio Astrophysical Observatory.

- The two instruments record the strength of the solar radio emission at 10.7cm wavelength each day for as long as the Sun is above the horizon. In addition, the instruments interrupt the continuous monitoring each day to make three precise measurements of the solar flux density. These measurements constitute the 10.7cm Solar Flux index.

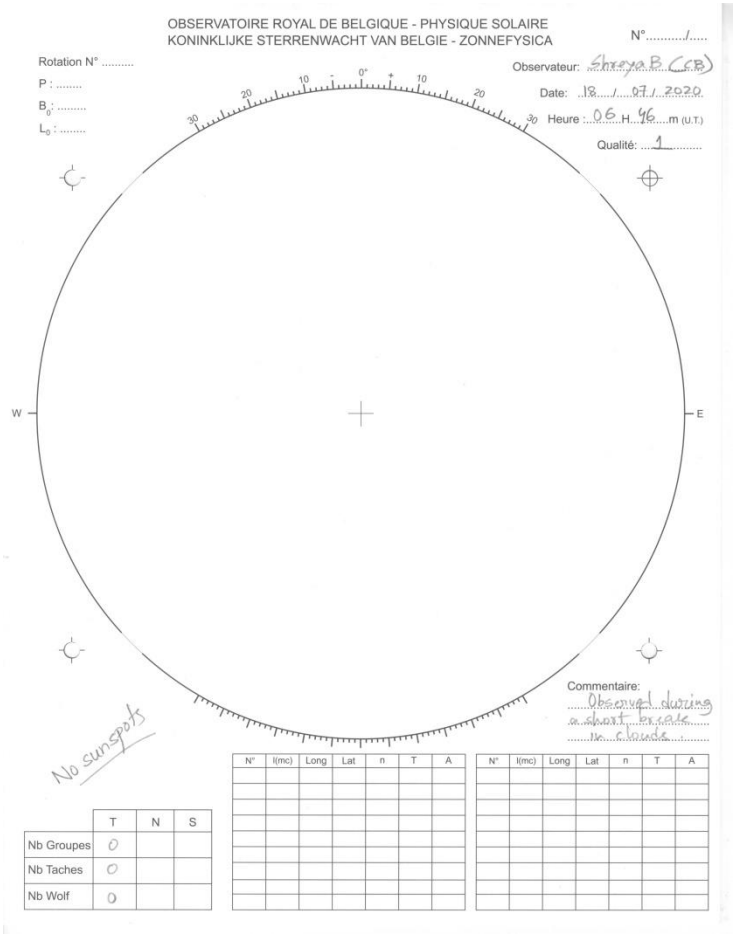
Solar Flux Monitor at Dominion Radio Astrophysical Observatory

Kaleden, British Columbia, Canada

Sunspot Number

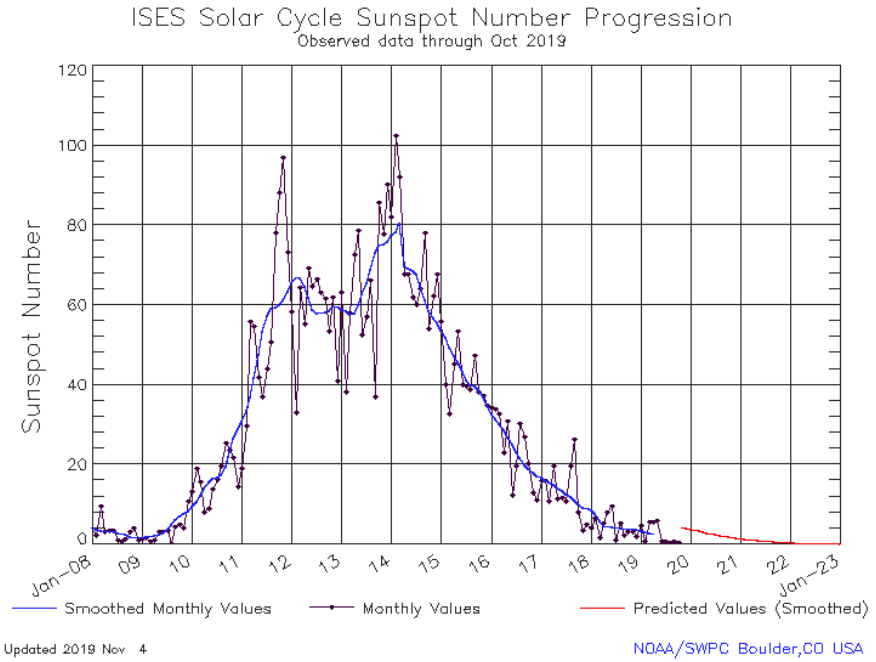
Visual count of Sunspots by observers:

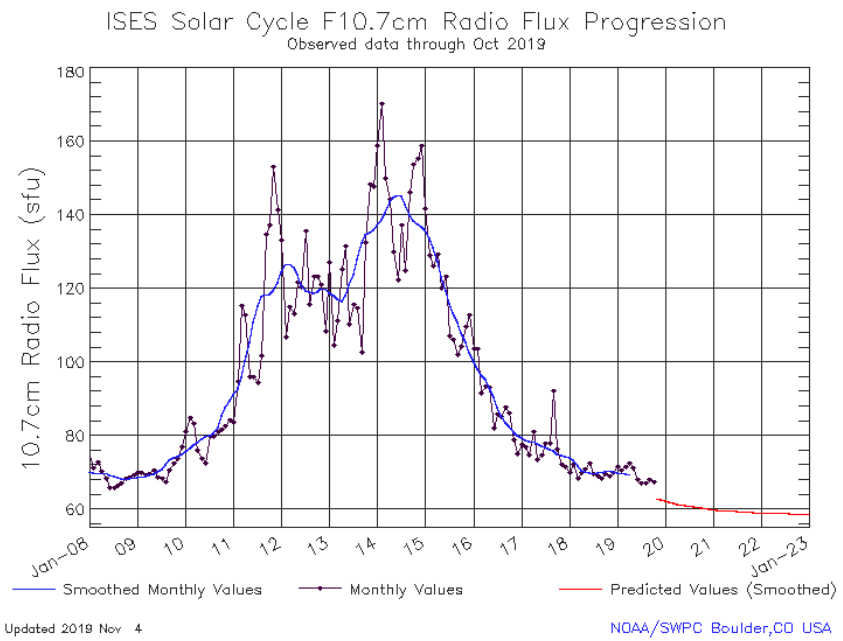
R = (10*G + S)*K
Where:
R = the sunspot number
G = the number of sunspot groups observed
S = the count of all sunspots in all groups
K = a scaling number to compensate for variables

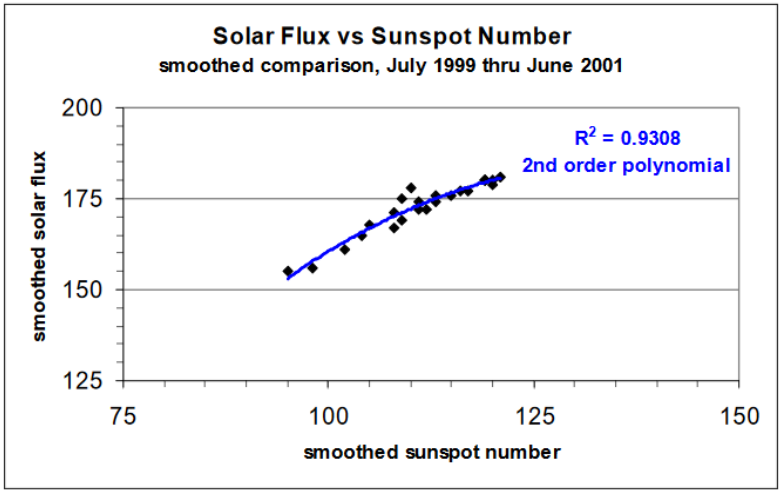


Until 1980, traditionally, the sunspot number was essentially the Wolf number provided by the Zürich observatory, with some cross-validation relative to a network of supporting stations.
Since 1981, in Brussels, it was decided to derive the daily sunspot number from an average of all observations from a large worldwide network.

SSN & Solar Flux



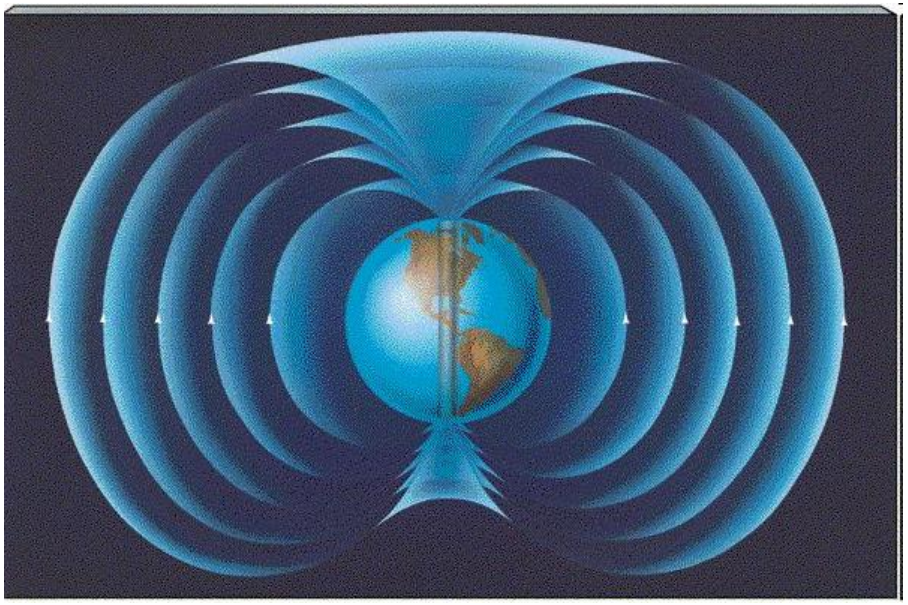




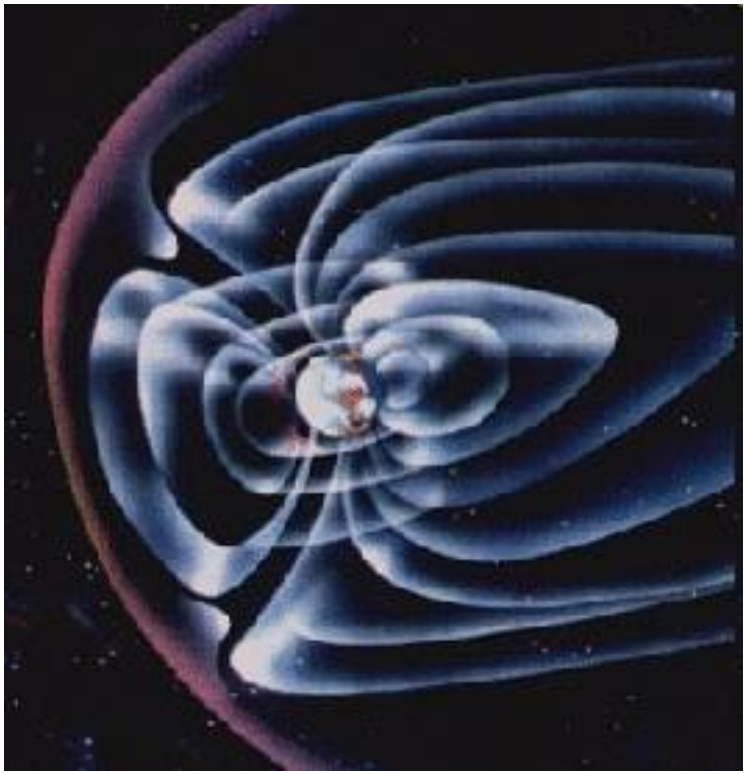
Outline

- Ionospheric Ionization Estimations
  - Solar Flux
  - Sun Spot Number
- Geomagnetic Measurements
  - Kp & Ap
  - Dst
- Solar X-Ray Intensity Measurements
- Solar Wind Measurements
  - Coronal Holes
  - CME

EARTH'S MAGNETIC FIELD

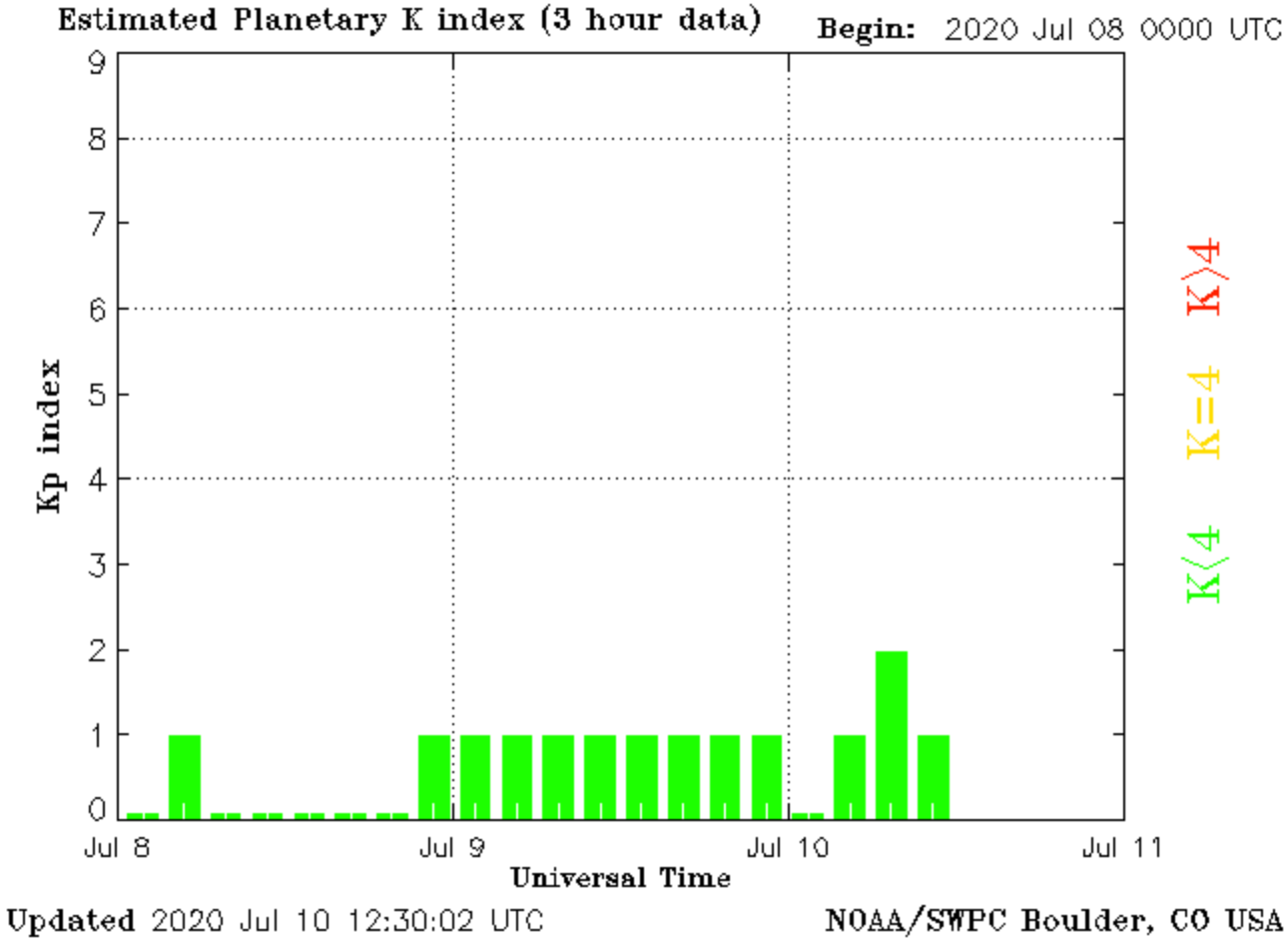


Without Solar Wind



Actual Magnetic Field
With Solar Wind

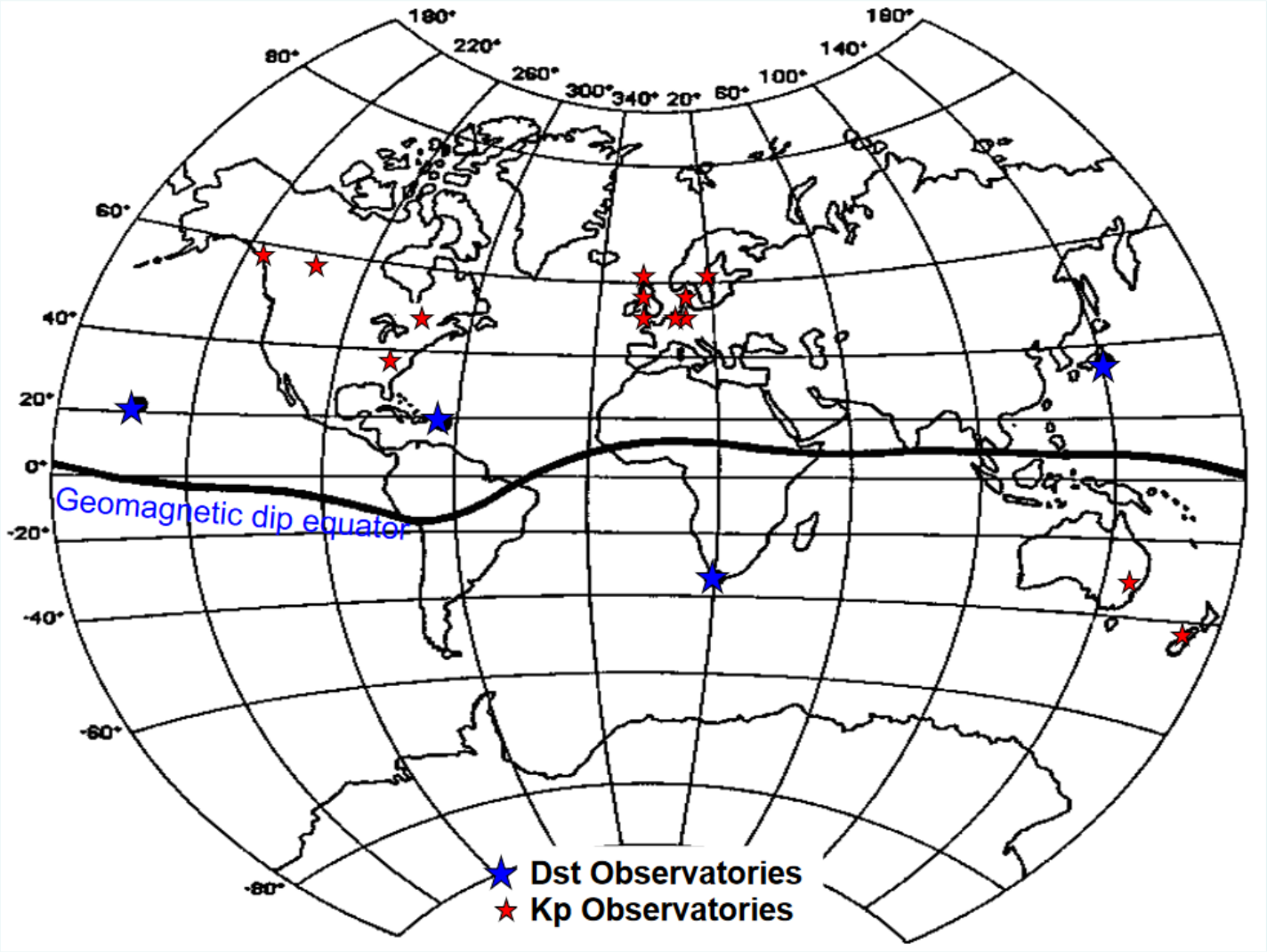
Planetary K index – 8 - 10 JUL 2020



Generally, as planetary K-Index rises, critical frequency is suppressed.

K-Index	Effect
0-2	Inactive/Quiet, no impact on HF
3-4	Unsettled/Active, minor HF fade in higher latitudes
5-6	HF fade at higher latitudes
7-8	HF sporadic
9	HF impossible above 40M

Kp and Dst Observatories



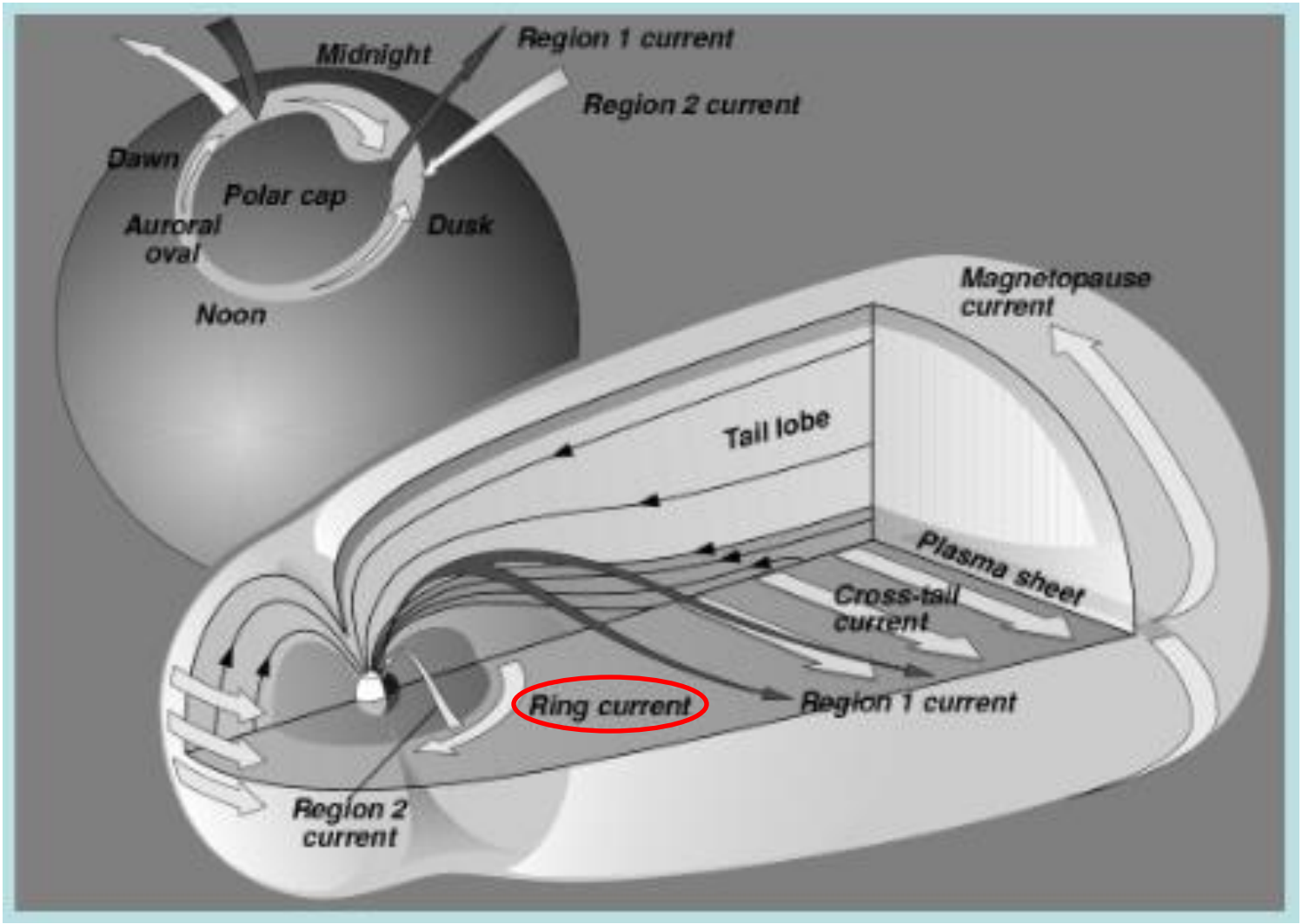
Kp Observatories

The 13 Observatories used to compute official Kp

listed in order of geomagnetic latitude

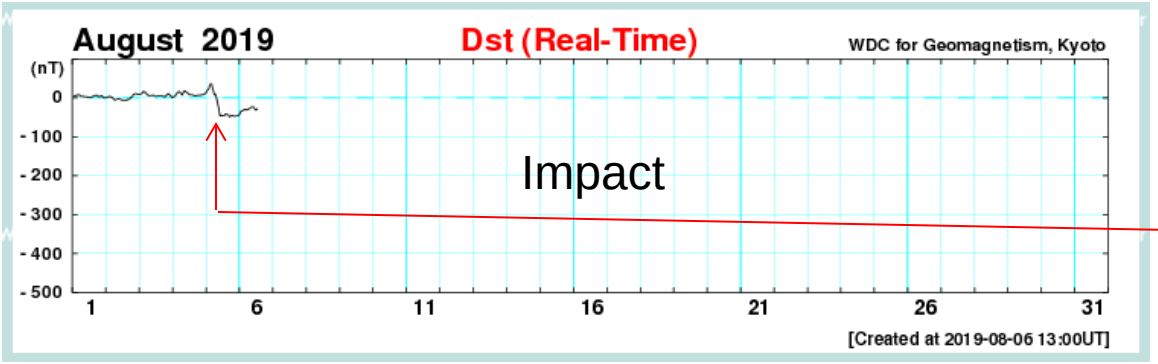
Observatory					Geographic		Geomagnetic		
#	Code	Name	Location	Active	Lat.	Long.	Lat.*	Long.*	K=9
1	**LER**	**Lerwick**	**Scotland**	1932-actual	60°08'	358°49'	62.0°	89.2°	1000 nT
2	**MEA**	**Meanook**	**Canada**	1932-actual	54°37'	246°40'	61.7°	305.7°	1500 nT
3	**SIT**	**Sitka**	**Alaska (US)**	1932-actual	57°03'	224°40'	60.4°	279.8°	1000 nT
4	**ESK**	**Eskdalemuir**	**Scotland**	1932-actual	55°19'	356°48'	57.9°	83.9°	750 nT
5	LOV	Lovö	Sweden	1954-2004	59°21'	17°50'	57.9°	106.5°	600 nT
	UPS	**Uppsala**	**Sweden**	2004-actual	59°54'	17°21'	58.5°	106.4°	600 nT
6	AGN	Agincourt	Canada	1932-1969	43°47'	280°44'	54.1°	350.5°	600 nT
	OTT	**Ottawa**	**Canada**	1969-actual	45°24'	284°27'	55.8°	355.0°	750 nT
7	RSV	Rude Skov	Denmark	1932-1984	55°51'	12°27'	55.5°	99.4°	600 nT
	BFE	**Brorfelde**	**Denmark**	1984-actual	55°37'	11°40'	55.4°	98.6°	600 nT
8	ABN	Abinger	England	1932-1957	51°11'	359°37'	53.4°	84.5°	500 nT
	HAD	**Hartland**	**England**	1957-actual	50°58'	355°31'	54.0°	80.2°	500 nT
9	**WNG**	**Wingst**	**Germany**	1938-actual	53°45'	9°04'	54.1°	95.1°	500 nT
10	WIT	Witteveen	Netherland	1932-1988	52°49'	6°40'	53.7°	92.3°	500 nT
	NGK	**Niemegk**	**Germany**	1988-actual	52°04'	12°41'	51.9°	97.7°	500 nT
11	CLH	Cheltenham	USA	1932-1957	38°42'	283°12'	49.1°	353.8°	500 nT
	FRD	**Fredericksburg**	**USA**	1957-actual	38°12'	282°38'	48.6°	353.1°	500 nT
12	TOO	Toolangi	Australia	1972-1981	-37°32'	145°28'	-45.6°	223.0°	500 nT
	CNB	**Canberra**	**Australia**	1981-actual	-35°18'	149°00'	-42.9°	226.8°	450 nT
13	AML	Amberley	New Zealand	1932-1978	-43°09'	172°43'	-46.9°	254.1°	500 nT
	EYR	**Eyrewell**	**New Zealand**	1978-actual	-43°25'	172°21'	-47.2°	253.8°	500 nT

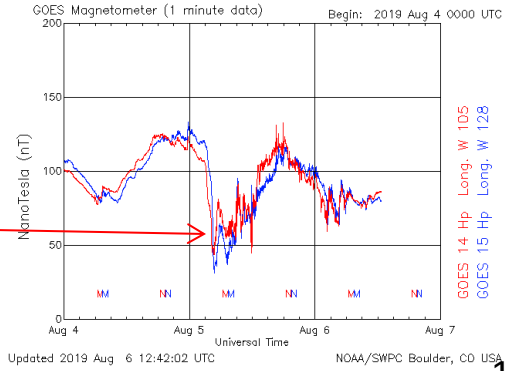
Equatorial Ring Current



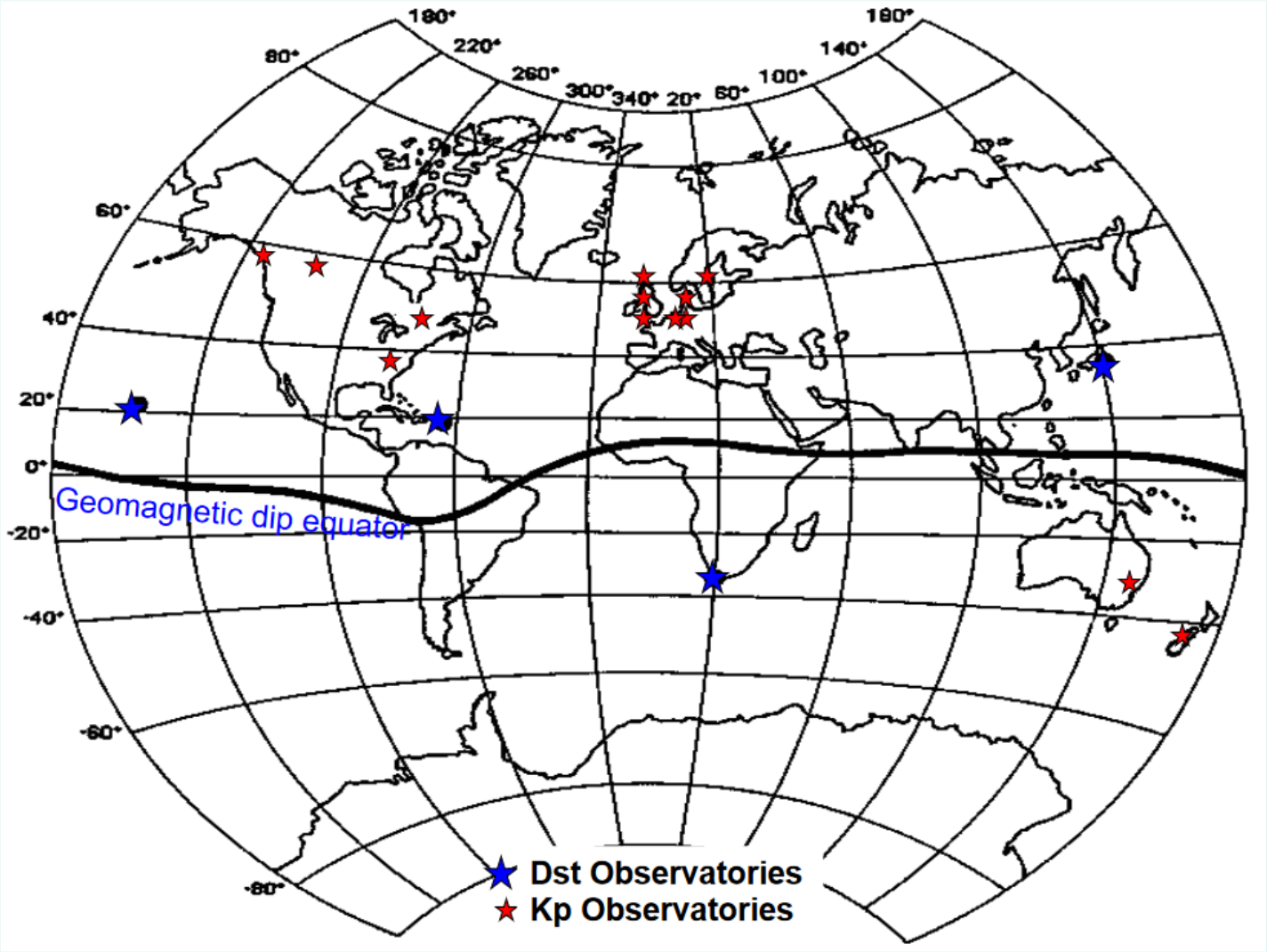
Dst Definition

- The Dst (disturbance storm time) index provides a measure of the Earth's geomagnetic activity. It can be used to quantify the severity of magnetic storms.
- Dst, expressed in nanoteslas, is based on the average value of the horizontal component of the Earth's magnetic field measured hourly at four near-equatorial geomagnetic observatories.
- During a magnetic storm, the Dst shows a sudden rise, corresponding to the storm sudden commencement, and then decreases sharply as the ring current intensifies.
- Once the IMF turns northward again and the ring current begins to recover, the Dst begins a slow rise back to its quiet time level.





Kp and Dst Observatories



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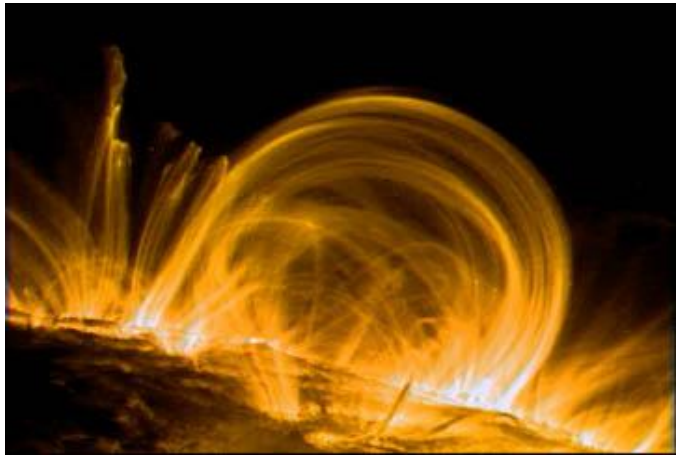
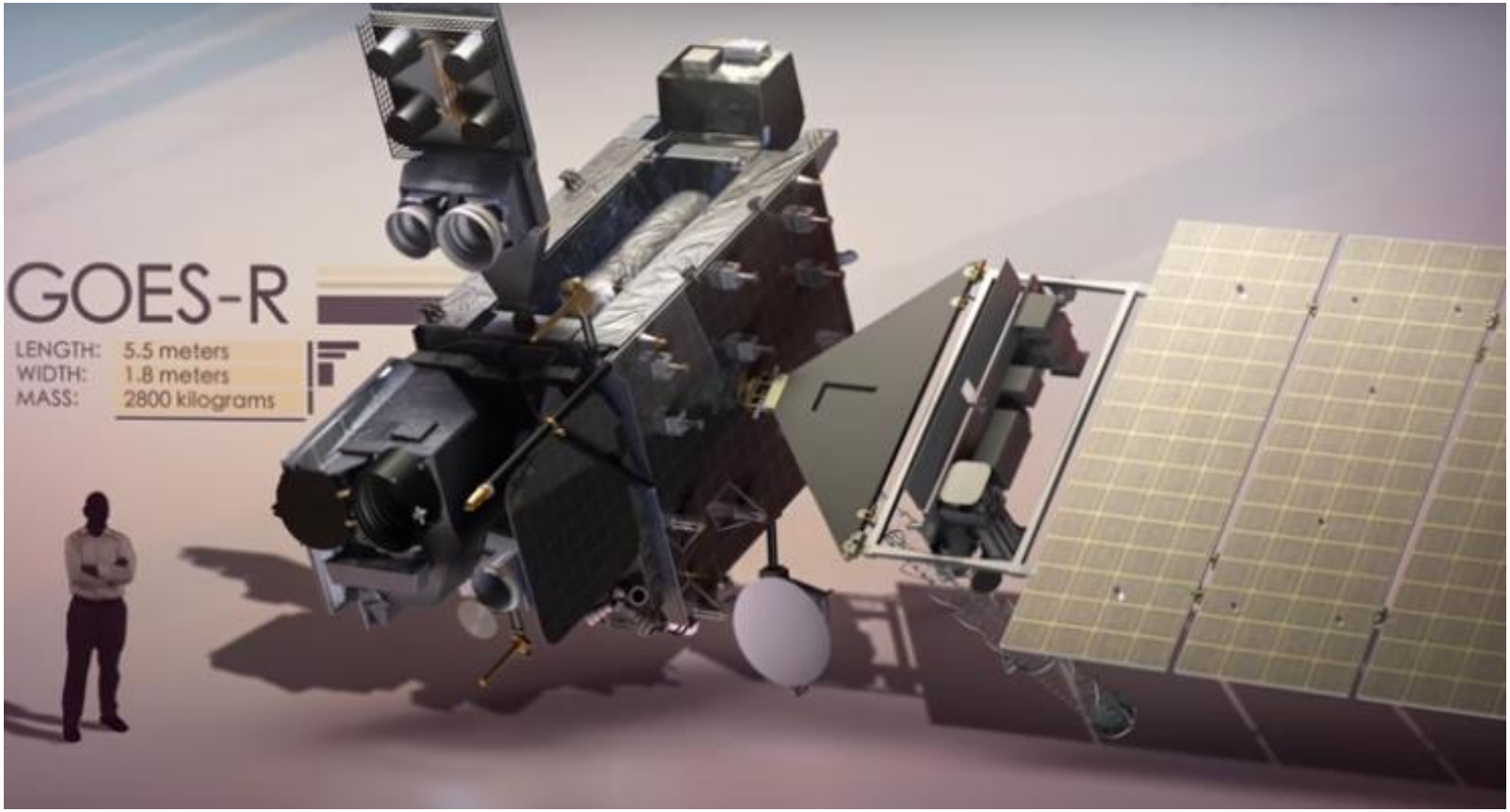
Solar X-Rays

- Radio Blackouts (8 minute arrival)
  - M or X class solar flare releasing high intensity X-rays
  - Produces SID (Sudden Ionospheric Disturbance)
  - Caused by Extreme D-layer absorption
  - Day time effect

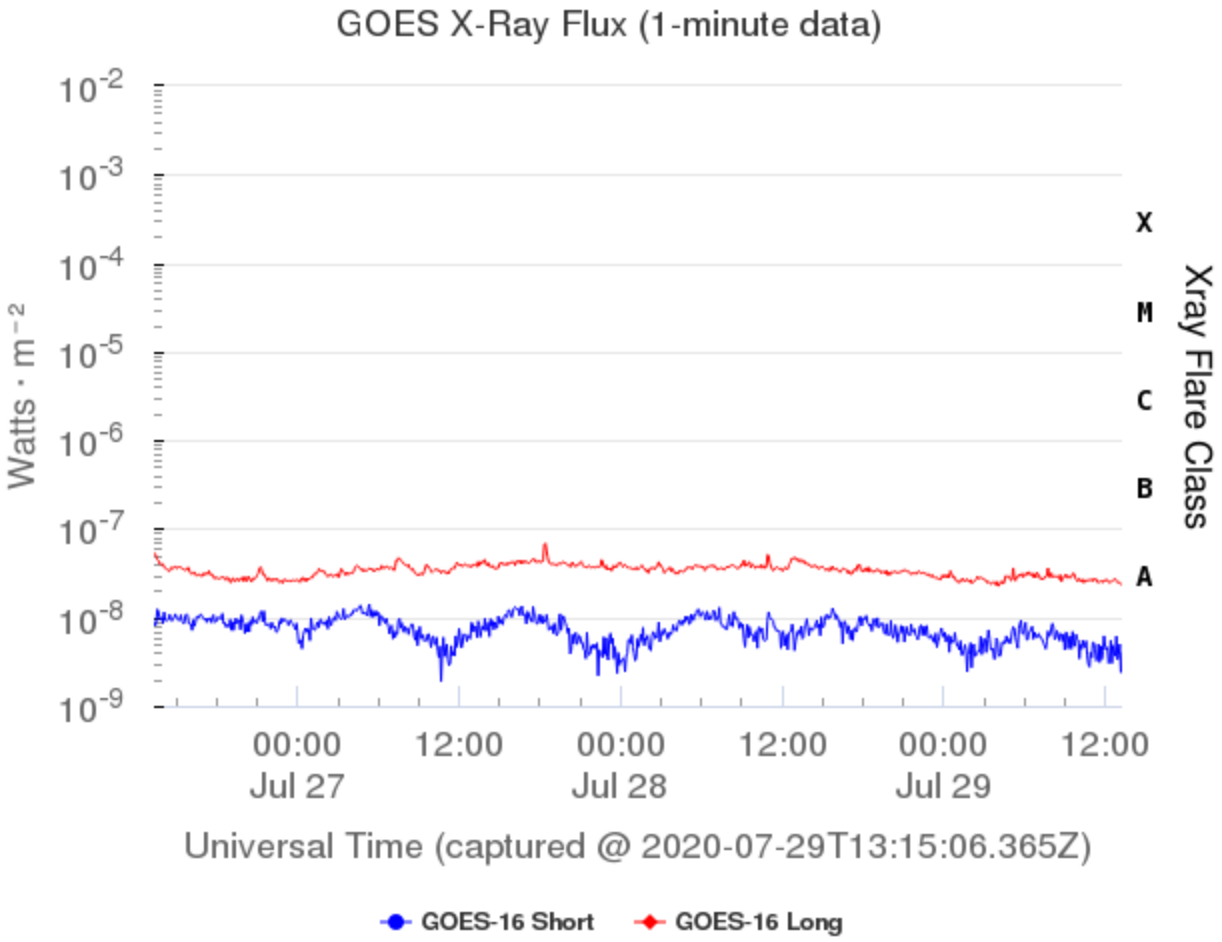


GOES 16 Satellite

(Geostationary Weather satellite)



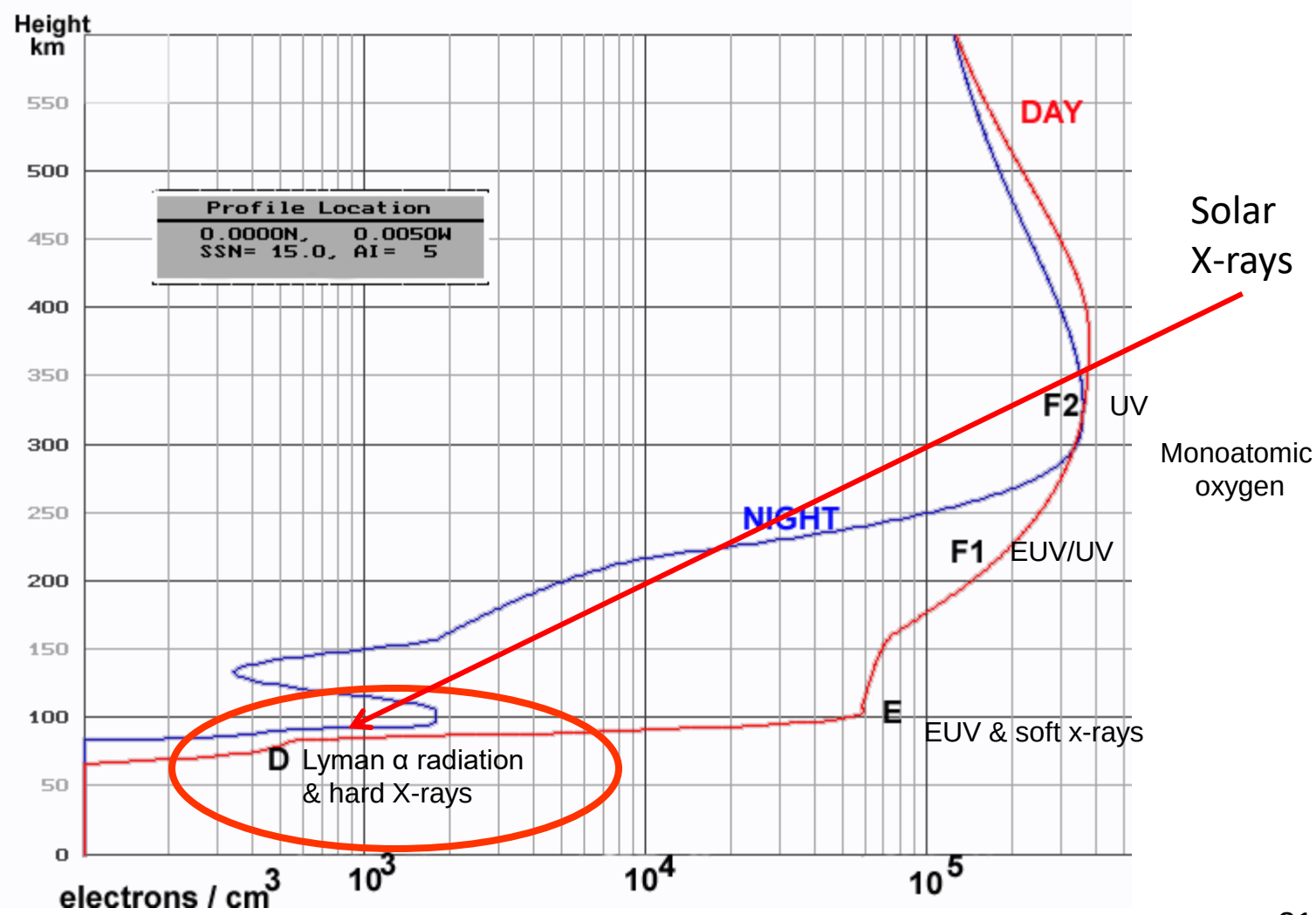
Solar X-Ray Flux: 27 – 29 JUL 2020



The X-ray radiation that ionizes the D-layer is the 1.0 - 8.0 A (red) plot. These measurements currently taken from the GOES 16 satelite.

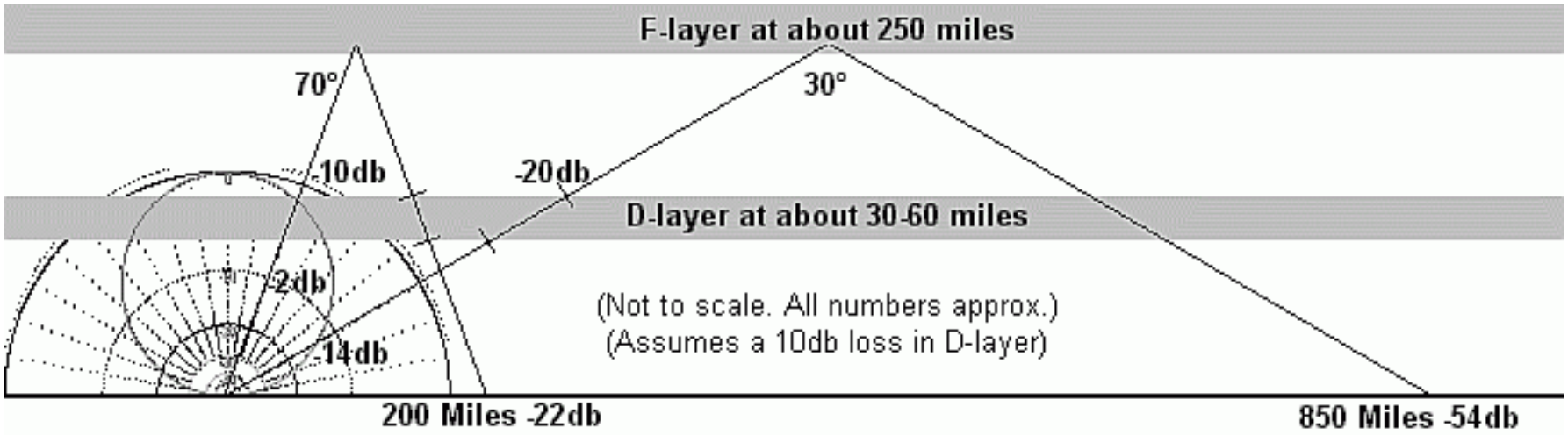
Flare Category	Effect
A1-B9	No or minor impact on HF
C1	Low absorption of HF signals
M1	Occaisional loss of radio contact on sun-lit side
M5	Limited HF blackout for several minutes
X1	Wide area HF blackout for approx. 1 hr
X10	HF blackout over most of sun-lit side for 1-2 hrs
X20	Complete HF blackout of all sun-lit areas lasting hours

D-Layer Absorption

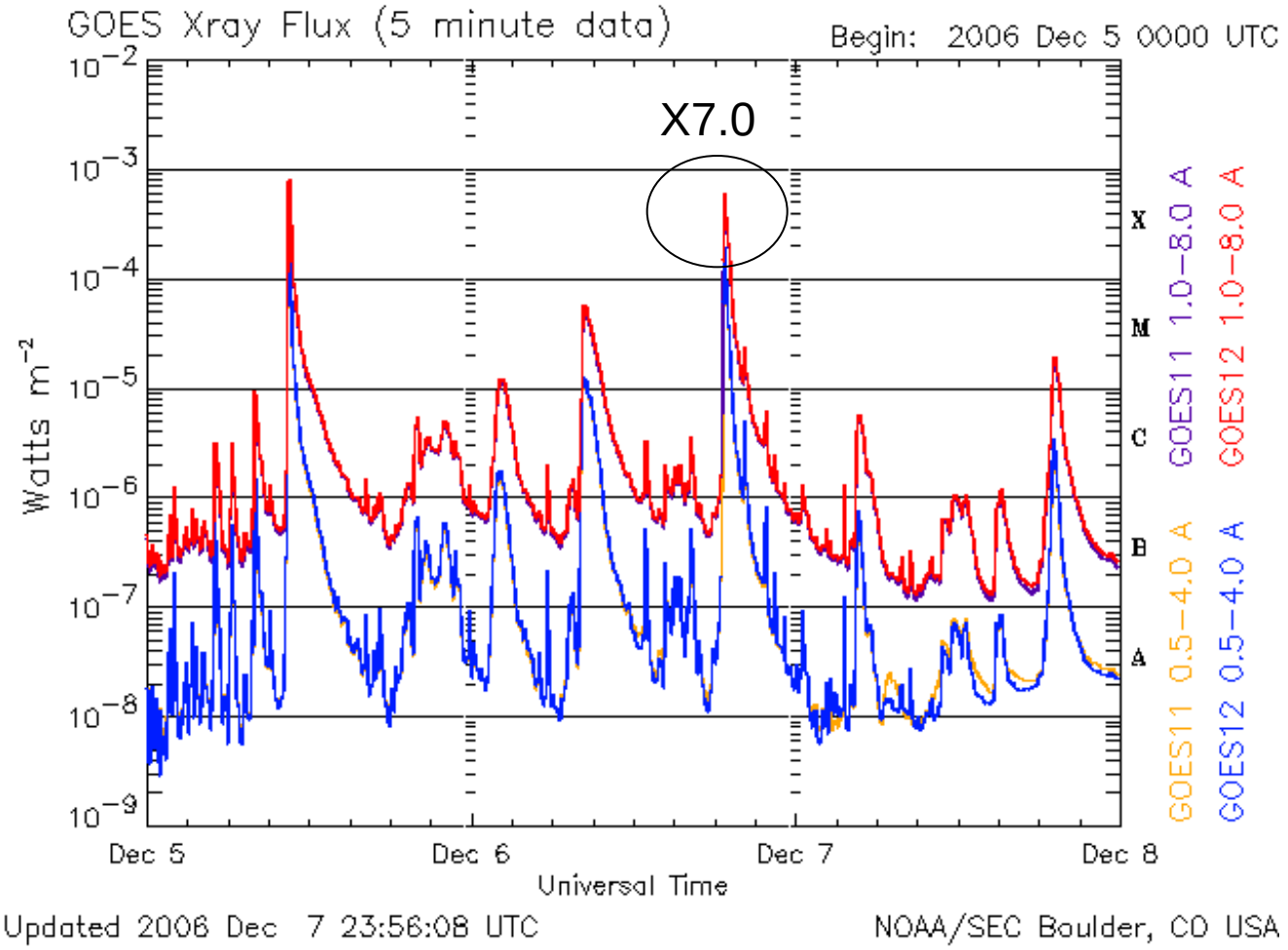


D-Layer Absorption

- Day-time effect
- Absorption is a function of $1/f^2$
- Can sometimes be compensated by power or bandwidth reduction



GOES X-Ray Flux (5-7 DEC 2006)



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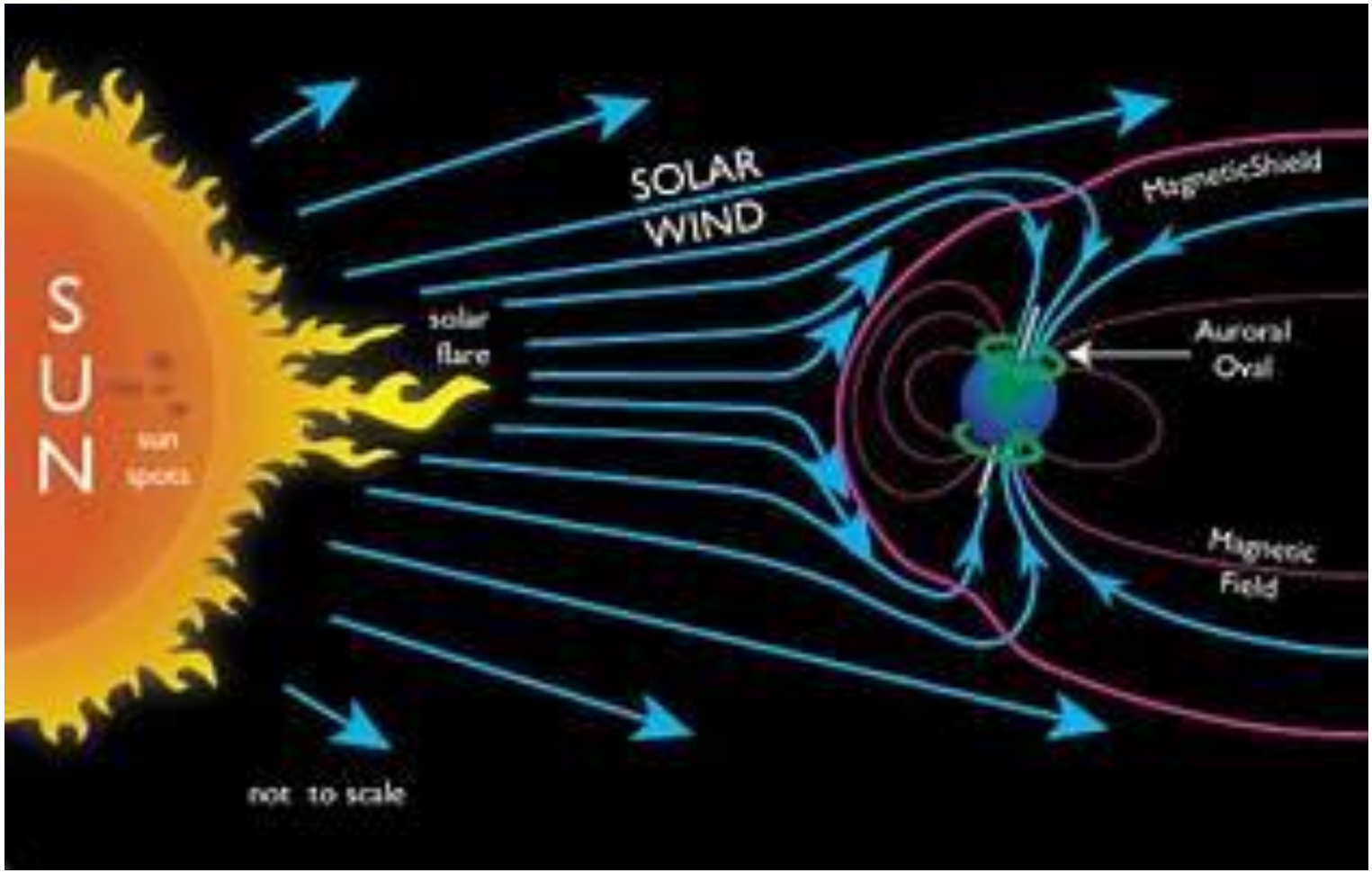
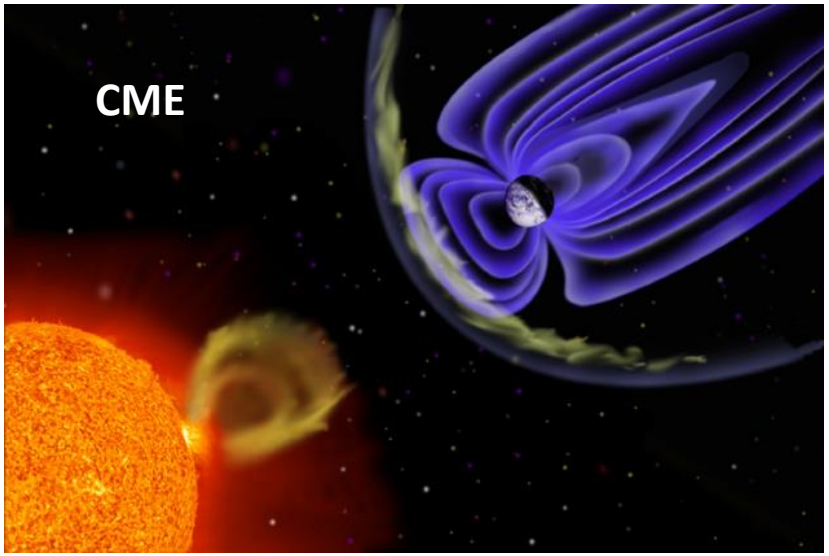
Solar Wind


SUN
sun spots
solar flare
SOLAR WIND
MagneticShield
Auroral Oval
Magnetic Field
not to scale

Geomagnetic Storms

- Caused by CME (Corona Mass Ejection) or Coronal Hole
  - Depressed MUF and increased D absorption
  - Indicated by increased K and A indices
  - Severity of effects function of polarity of Bz
    - Bz South – more severe effects

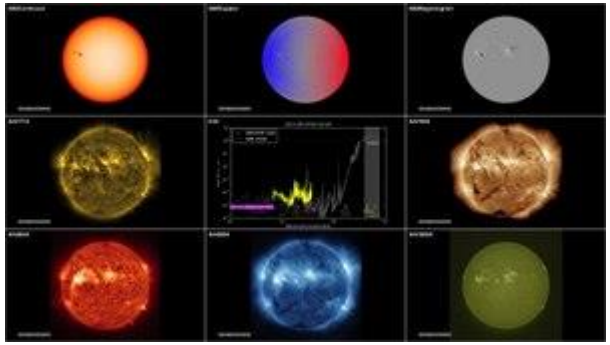


Forecasting – SDO Satellite

Location: Geosynchronous orbit
22,238 mi, 102° W LONG

Instruments:

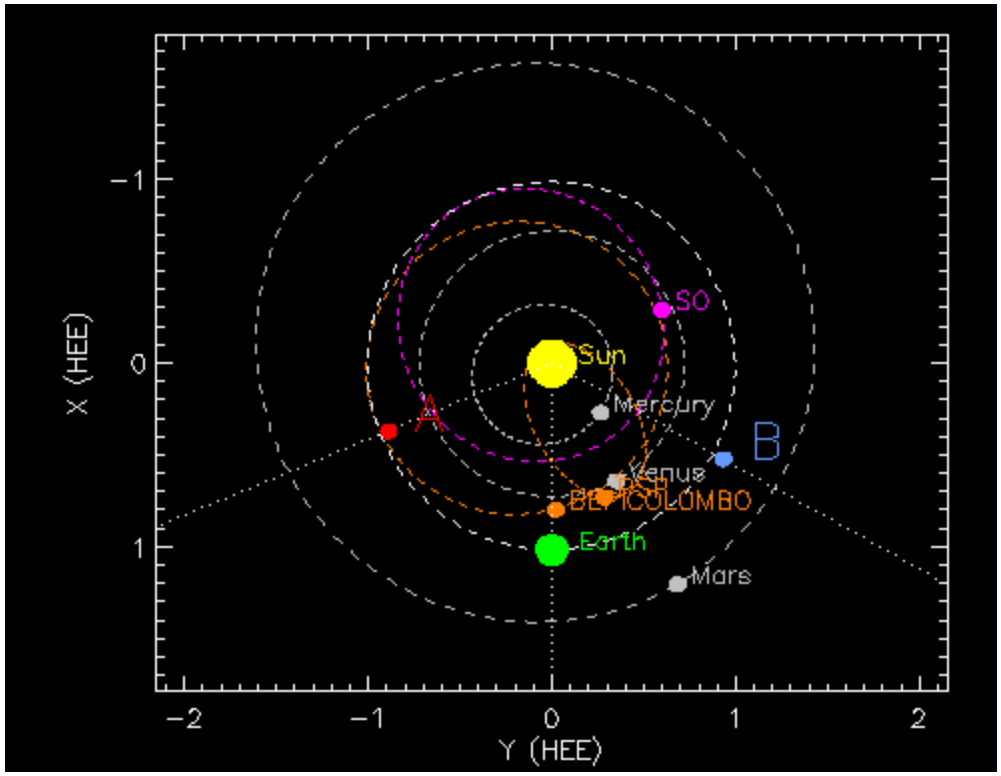
1. The Helioseismic and Magnetic Imager (HMI), studies solar variability and characterizes the Sun's interior and the various components of magnetic activity.
2. The Extreme Ultraviolet Variability Experiment (EVE) measures the Sun's extreme ultraviolet irradiance.
3. The Atmospheric Imaging Assembly (AIA), provides continuous full-disk observations of the solar chromosphere and corona in seven extreme ultraviolet (EUV) channels

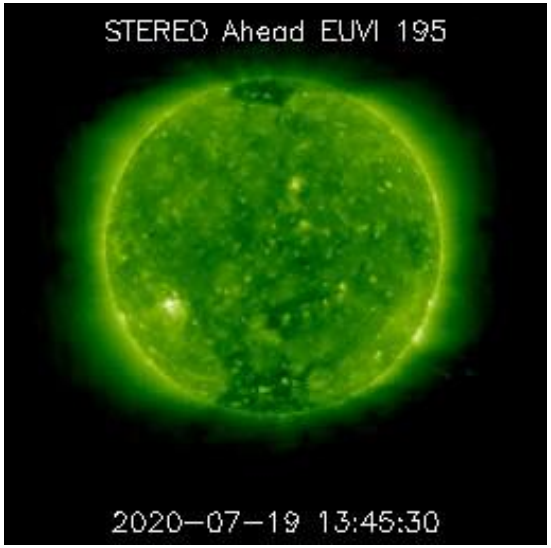


Forecasting – Stereo Ahead Satellite

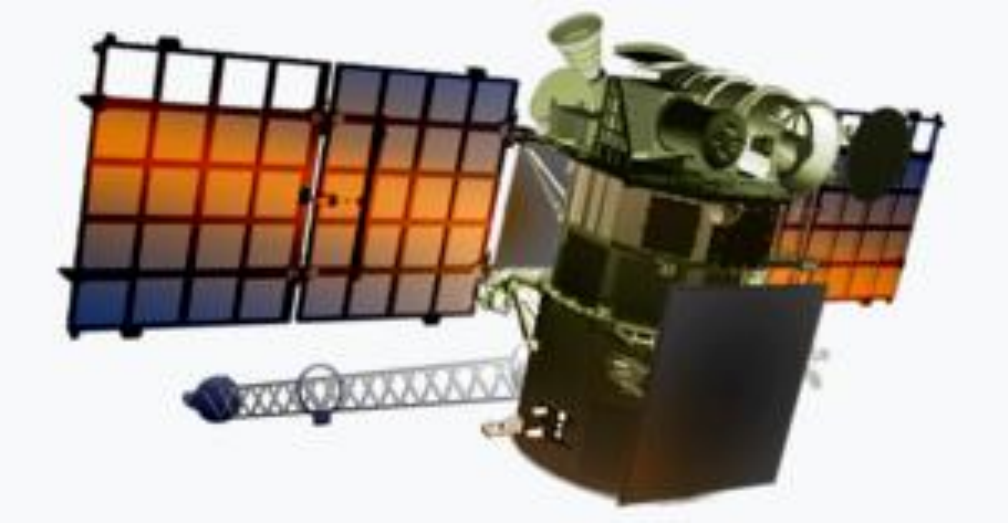
Location: In Earth's orbit

Forecast: CME detection, view of backside of Sun (see what is coming)



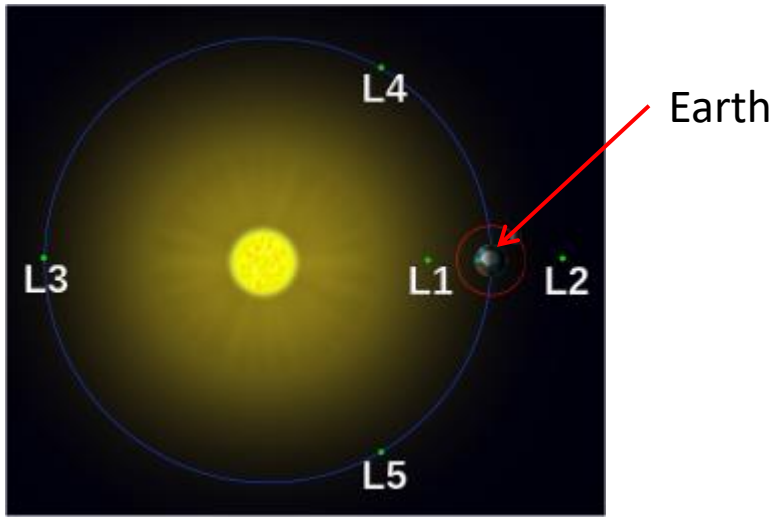


Warning – DSCOVR Satellite



Location: L1 Lagrange orbit
Launch Date: 2015
Note: Replaces ACE

Solar Wind: Plasma-Magnetometer (PlasMag)
Warning time – 60 minutes



Warning – ACE Satellite

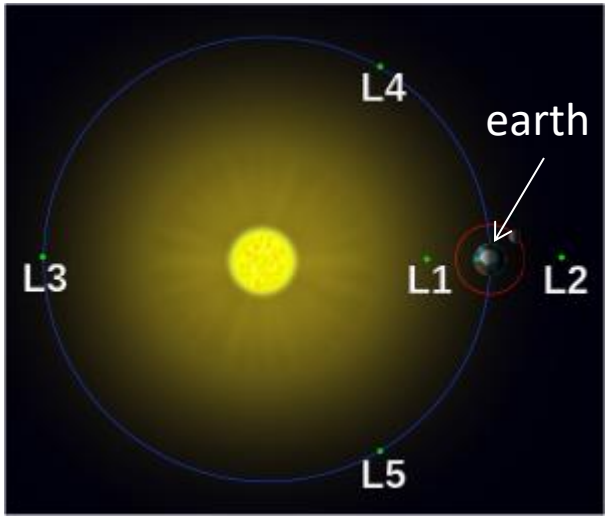
Location: L1 Lagrange orbit
Launch Date: 1997
Note: DSCOVR is replacement

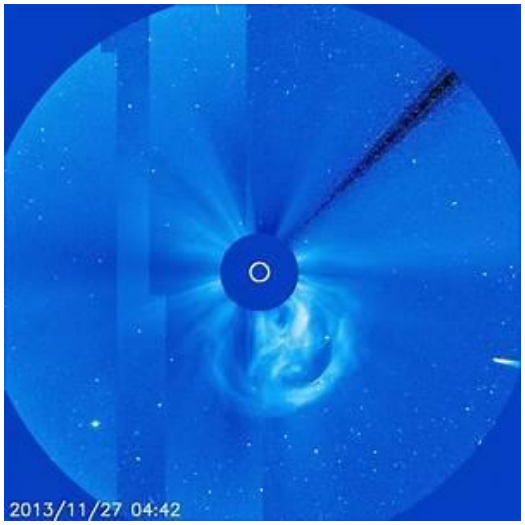
Real-Time Solar Wind System:
RTSW system is continuously monitoring the solar wind and producing warnings of impending major geomagnetic activity, up to one hour in advance. Warnings and alerts issued by NOAA allow those with systems sensitive to such activity to take preventative action. The RTSW system gathers solar wind and energetic particle data at high time resolution from four ACE instruments (MAG, SWEPAM, EPAM, and SIS), packs the data into a low-rate bit stream, and broadcasts the data continuously.

Warning – SOHO Satellite

Location: L1 Lagrange orbit
Launch Date: 1995

Instrument of Interest:
LASCO - Large Angle and Spectrometric Coronograph. LASCO observes the outer solar atmosphere (corona) from near the solar limb to a distance of 21 million kilometres. LASCO blocks direct light from the surface of the Sun with an occulter, creating an artificial eclipse





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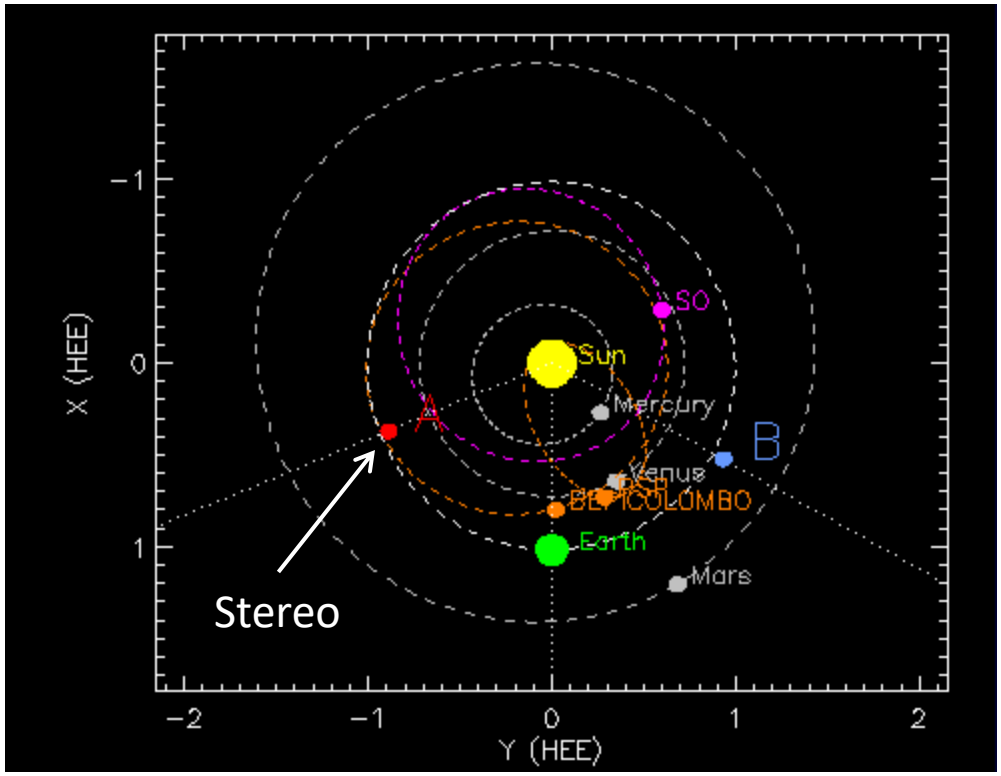
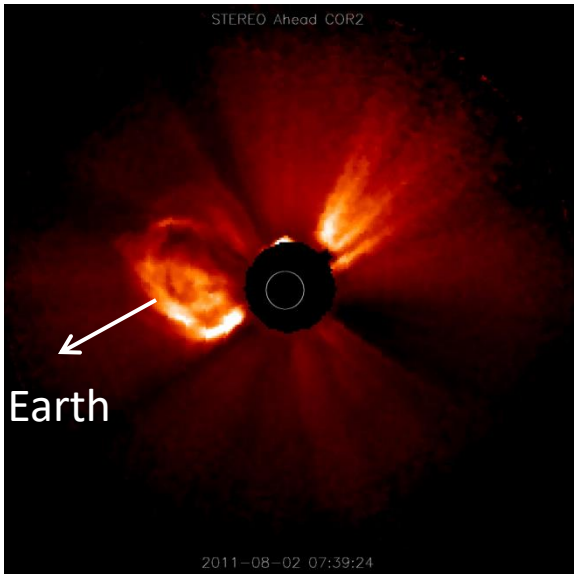
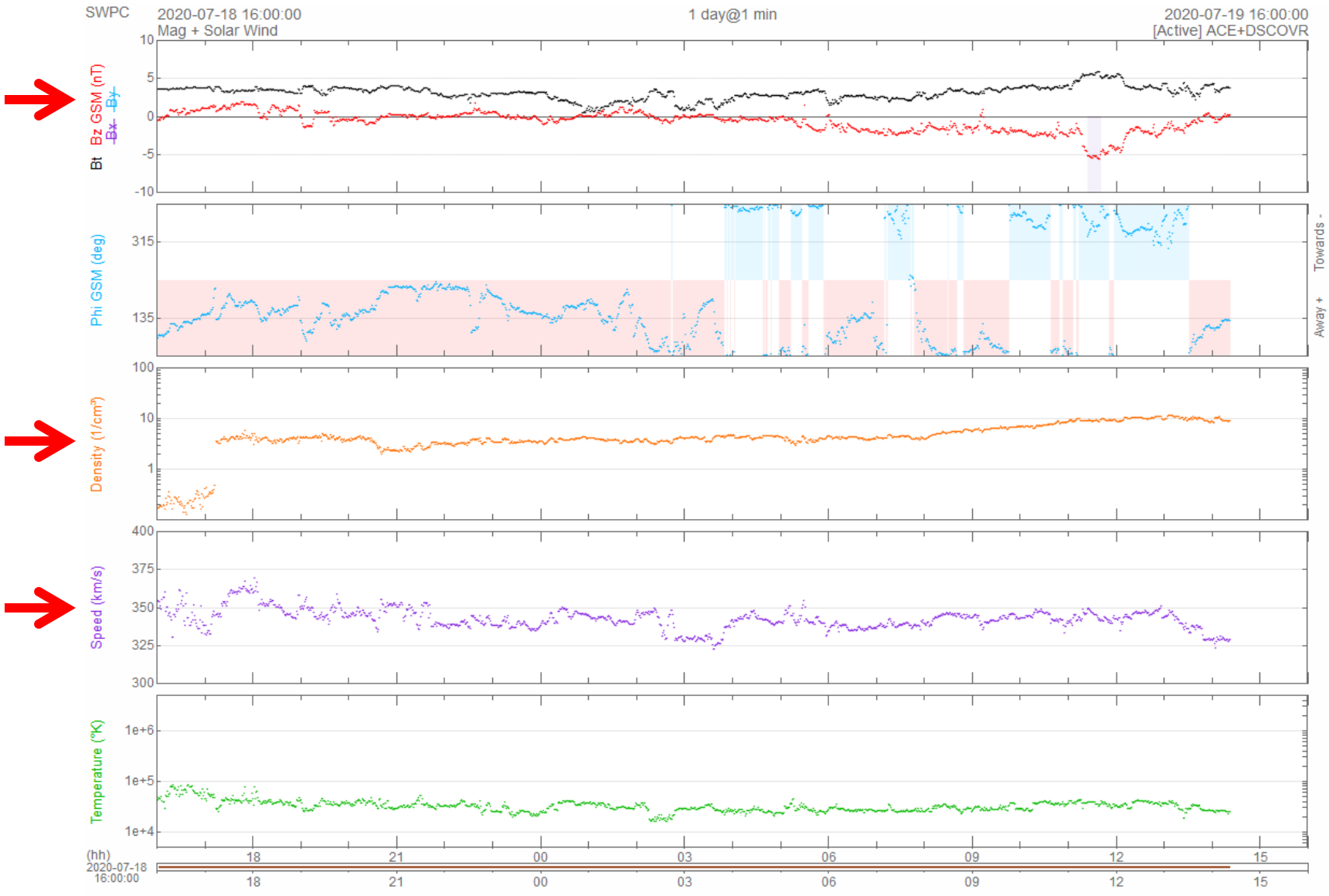


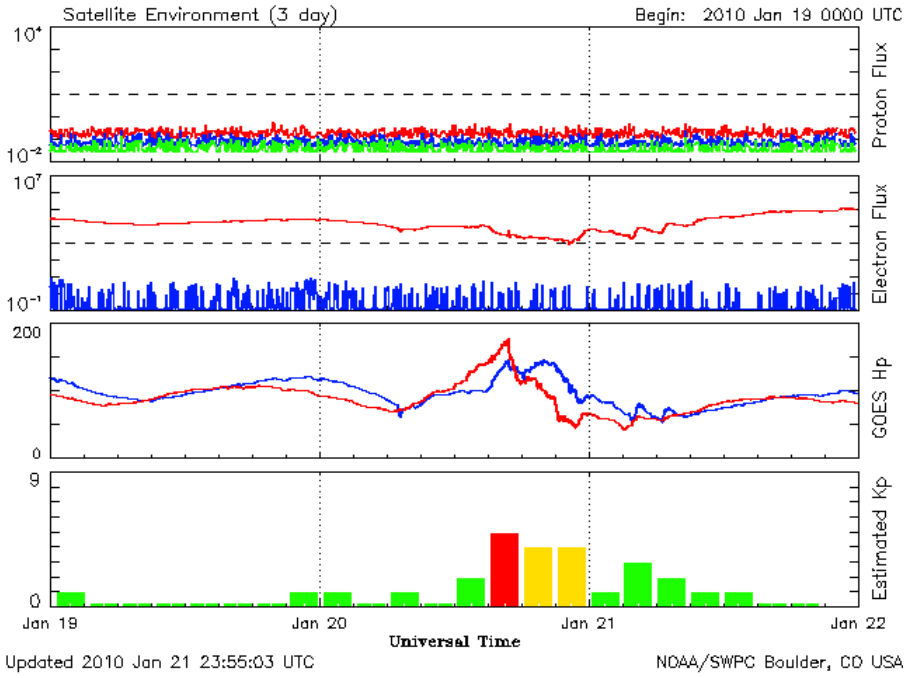


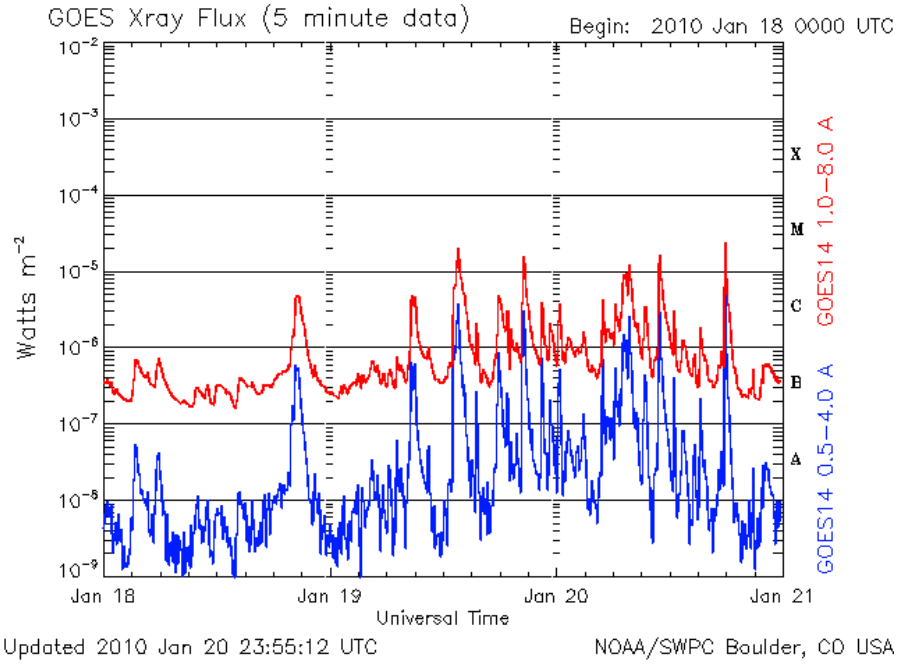
Warning – ACE & DSCOVR



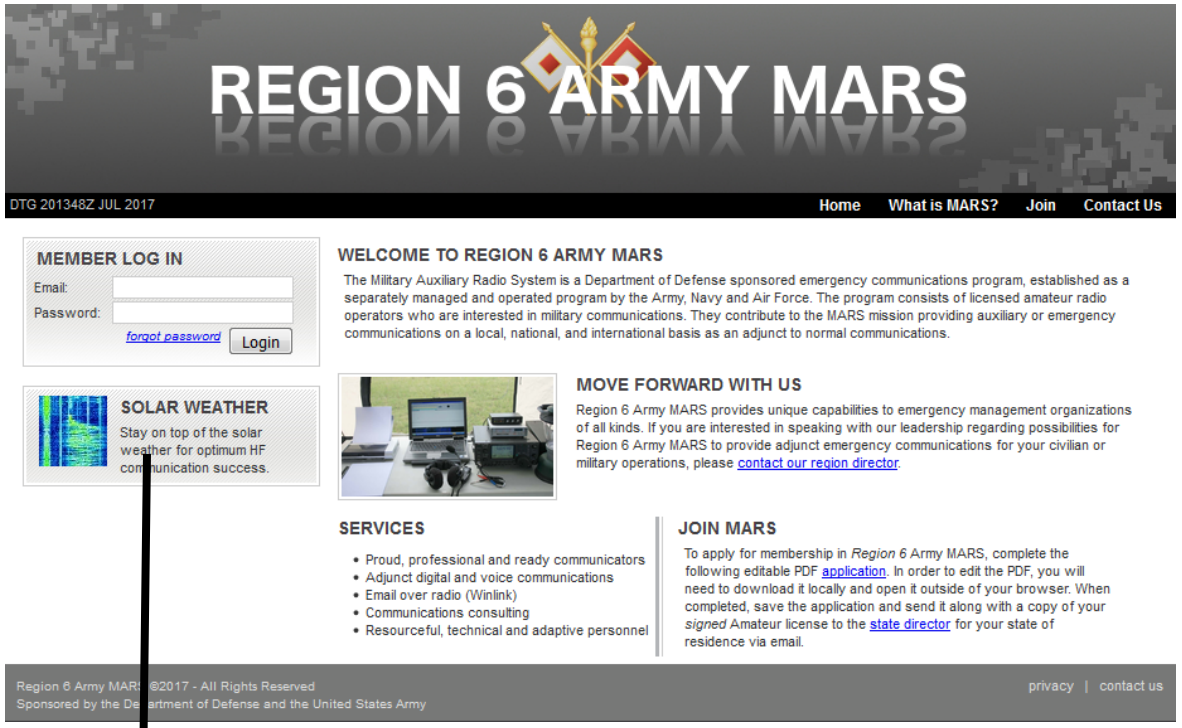
Solar & Geomagnetic Indicator Sources

- WWV – 2, 5, 10, 15, 20 MHz at 18’ pass each hour.
- Web site: http://www.swpc.noaa.gov/
- https://www.region6armymars.org/resources/solarweather.php





Ionosonde Data



Austin Ionosonde

Other Solar Weather Links of Interest

All Ionosondes →

- DIDBase - Select Station List then EGLIN then year/month/day/time for Ionosonde plot.
- NOAA Solar Weather - Solar Weather plots of Kp and X-Ray and other solar emissions.
- Solen Solar Weather - Good general solar forecast from an individual.
- Solar Ham - SolarHam provides real time solar news, as well as consolidated data from various sources.

FEMA

Disclaimer: The purpose of this briefing is to provide a ***Regional*** weather threat assessment and is meant as a general overview. County/Parish decision makers should consult their local NWS forecast offices for the latest detailed, local weather information. To find your local NWS forecast office, go to http://www.srh.noaa.gov and click on the "Weather Forecast Offices" tab and click on the map for your area.

FEMA Region 6 Weather Threat Briefing

Tuesday, July 01, 2014

Issued: 0800 CT

National Weather Service

Southern Region Headquarters
Regional Operations Center
Fort Worth, TX

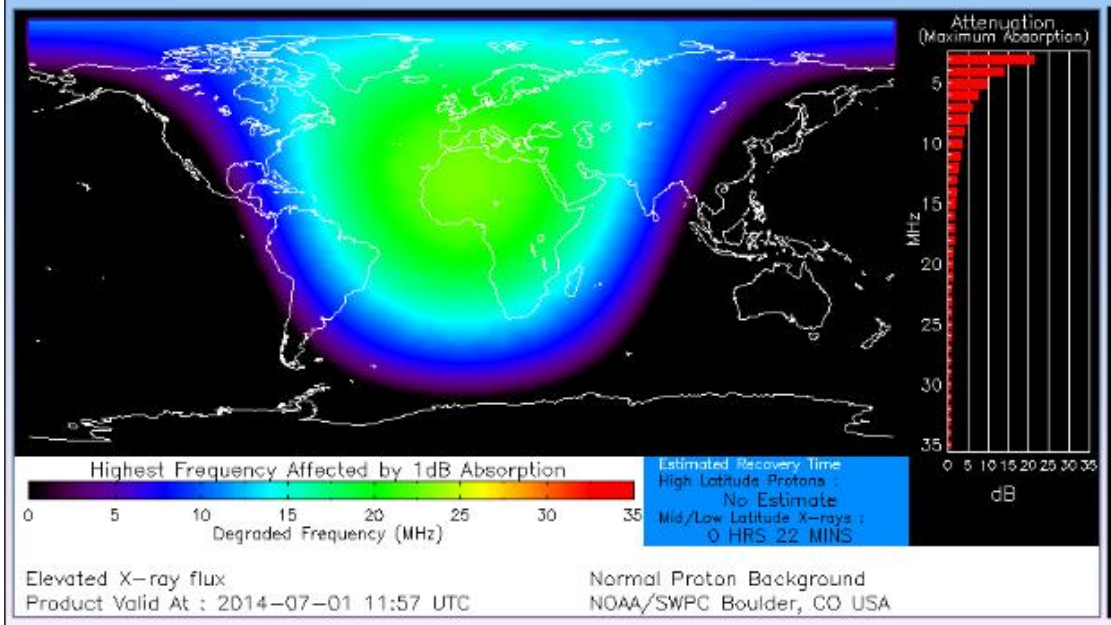
Day 1 Hazards: ***SLIGHT risk of severe storms over northern Arkansas. Hail and damaging winds the main threats.***

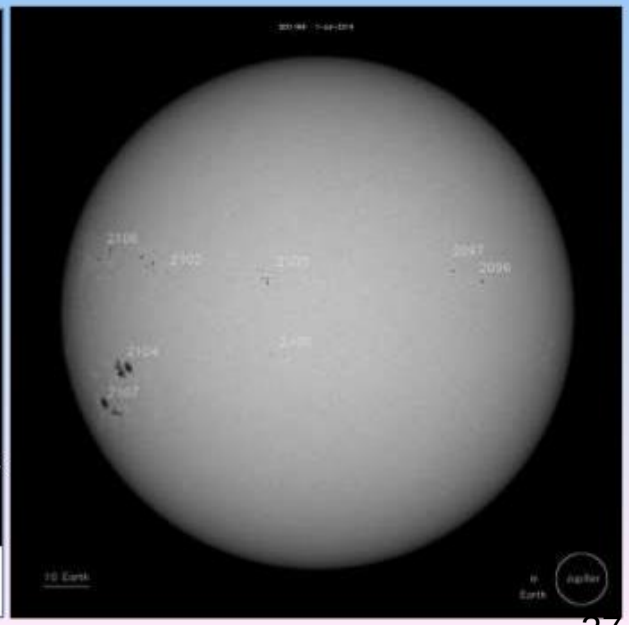
Space Weather 3-Day Forecast

	Tuesday	Wednesday	Thursday
Geomagnetic Storms	Quiet (Max Kp = 2)	Quiet to Unsettled (Max Kp = 3)	Quiet (Max Kp = 2)
Solar Radiation Storm (S1-S5)	5%	5%	5%
Radio Blackout (R1-R2)	40%	40%	40%
Radio Blackout (R3-R5)	5%	5%	5%

Click here for a Description of the Space Weather Storm Scales

Click here for the Latest 3-Day Space Weather Forecast Text





X-class solar flares. . Credit: SDO/HMI

Conclusions

- A number of US and European agencies provide a vast array of measurement tools that can provide to the Amateur Radio community HF propagation prediction. This includes:
  - Ionospheric ionization
  - Geomagnetic anomalies
  - Solar flare prediction and intensity measurement
  - Solar wind (CME and Coronal Hole) warnings

QUESTIONS?

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