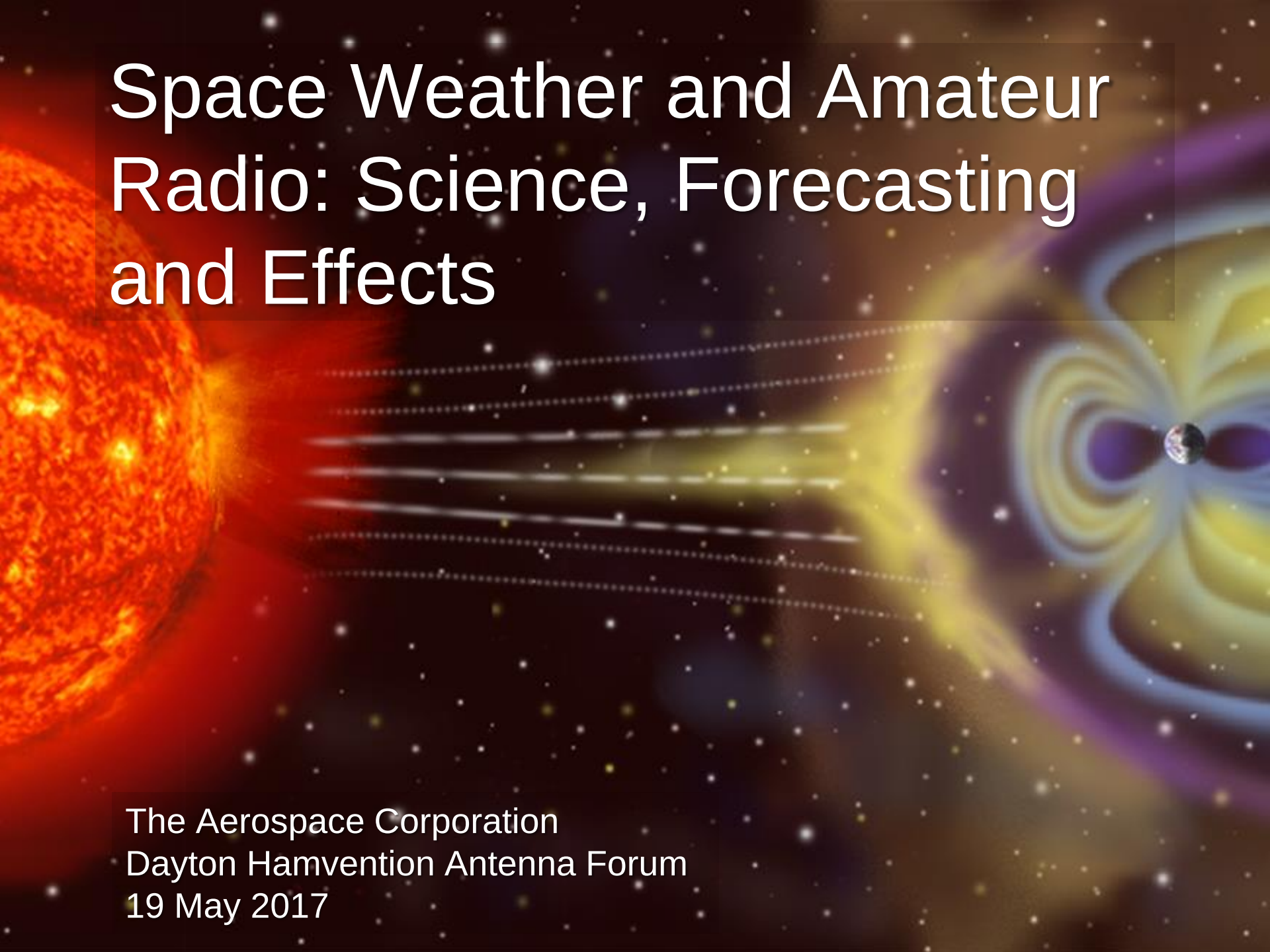


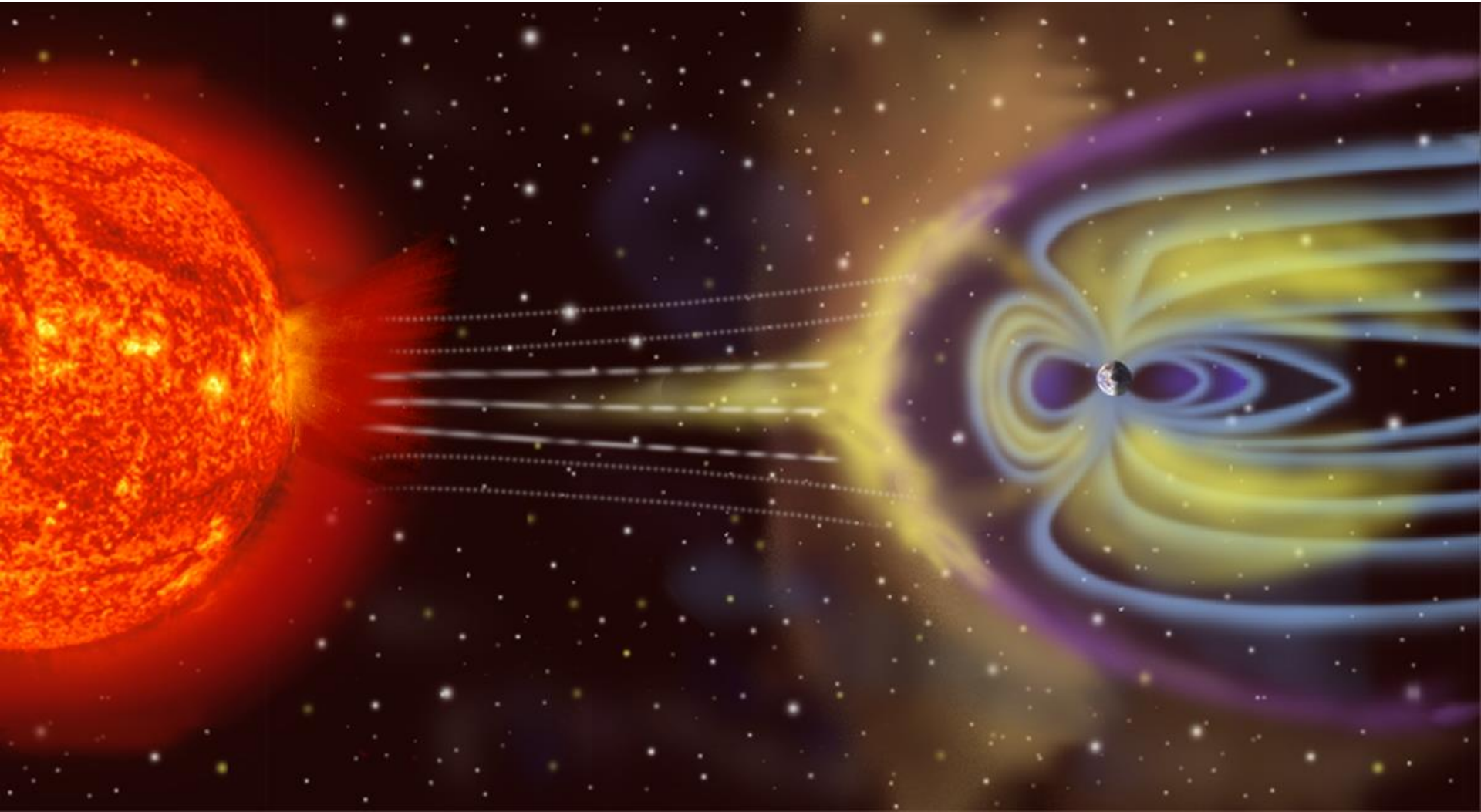
Space Weather and Amateur Radio: Science, Forecasting and Effects

The Aerospace Corporation
Dayton Hamvention Antenna Forum
19 May 2017

What is Space Weather?

Essentially Space Weather is:

A planet's interaction with its host star and the surrounding space environment.

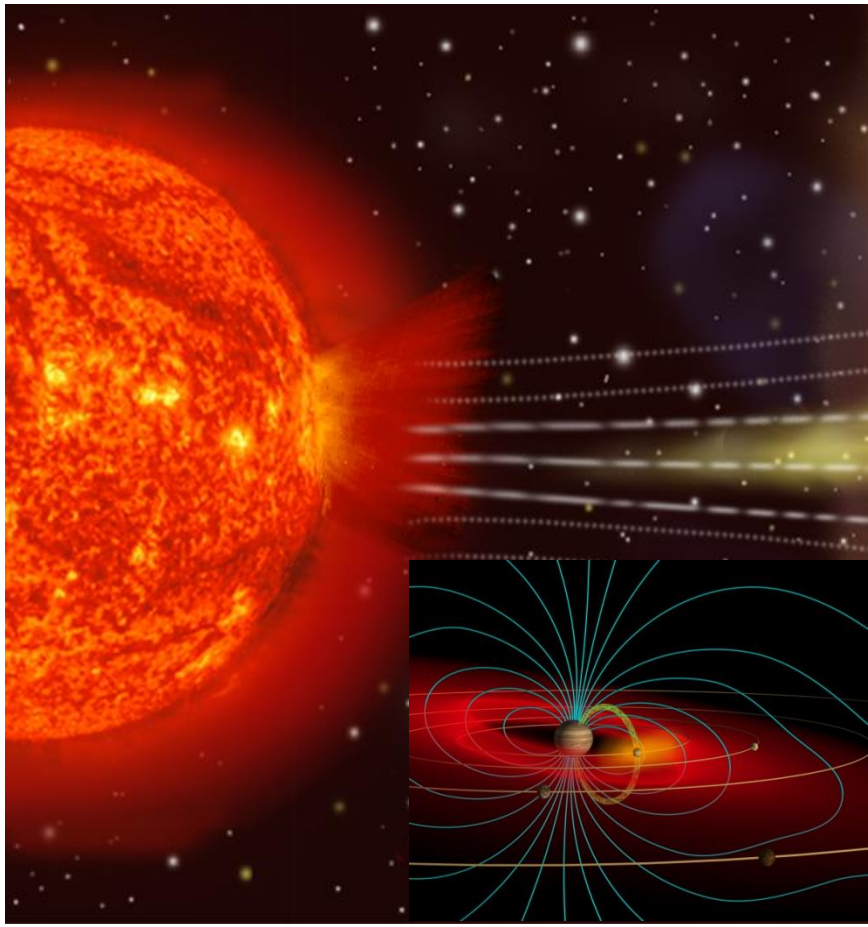


What is Space Weather?

More generally, it occurs at planets, moons, comets, asteroids, and other celestial bodies in the universe.

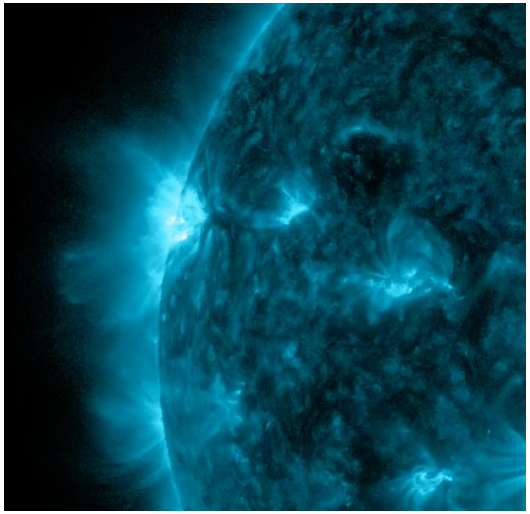
In our solar system

- We see aurora at Jupiter, Saturn, and recently at Uranus and Mars
- Effects are studied at Io, Europa, Ganymede, and Titan to name a few
- Highlight **Sun-driven processes**
- Will not cover other sources of space weather
  - Galactic and anomalous cosmic rays
  - Micrometeroids & interstellar dust
  - Space junk

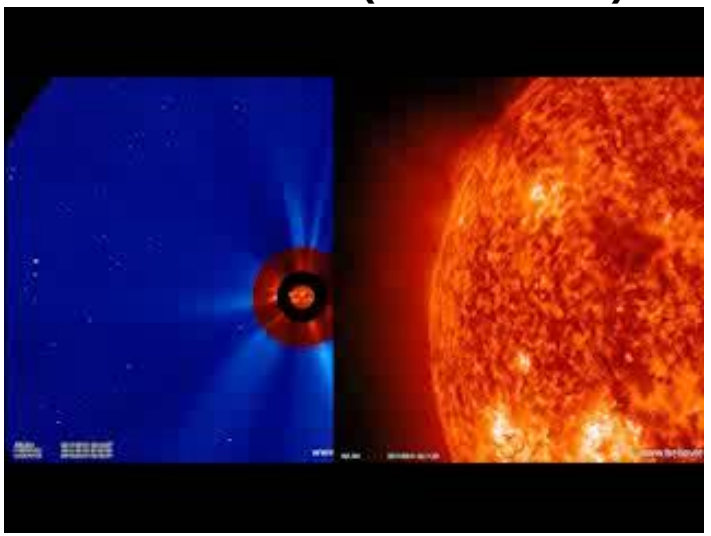


Four Basic Types of Solar Phenomena Affecting Earth

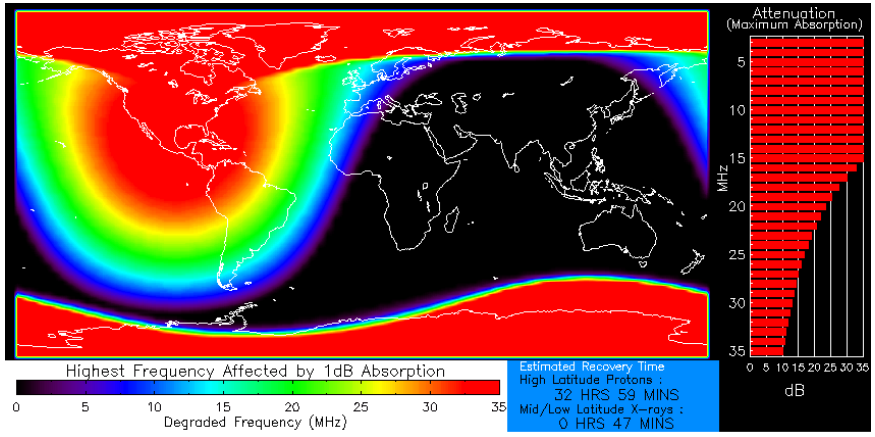
Solar Flares



Solar Storms (a.k.a. CMEs)



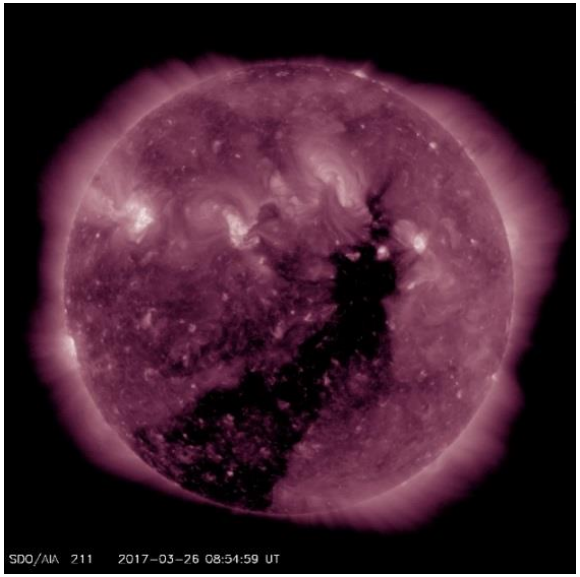
Solar Radiation Storms



Moderate X-ray flux
Product Valid At : 2015-06-22 18:23 UTC

Moderate Proton Flux
NOAA/SWPC Boulder, CO USA

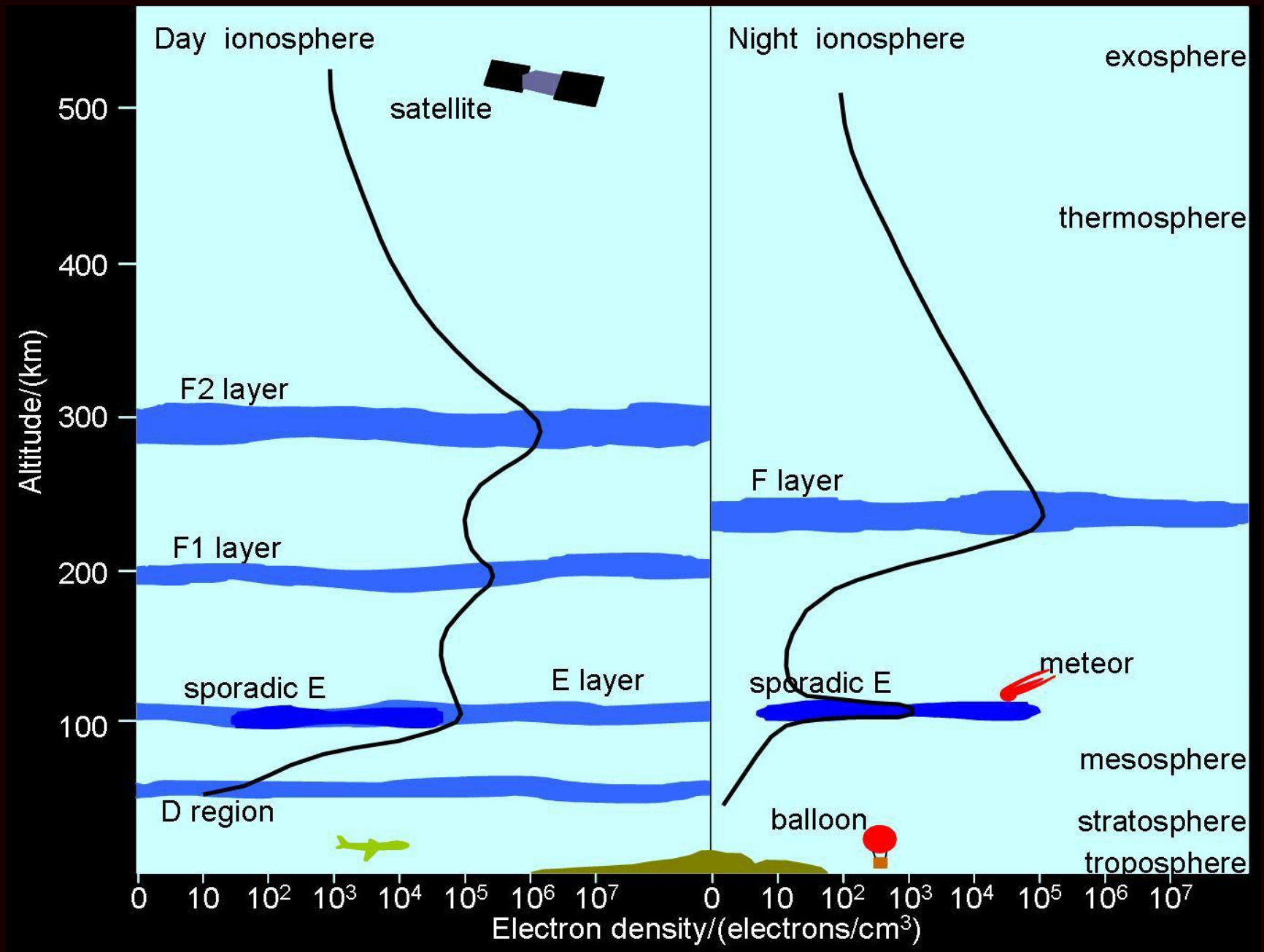
Coronal Holes (Fast Solar Wind)



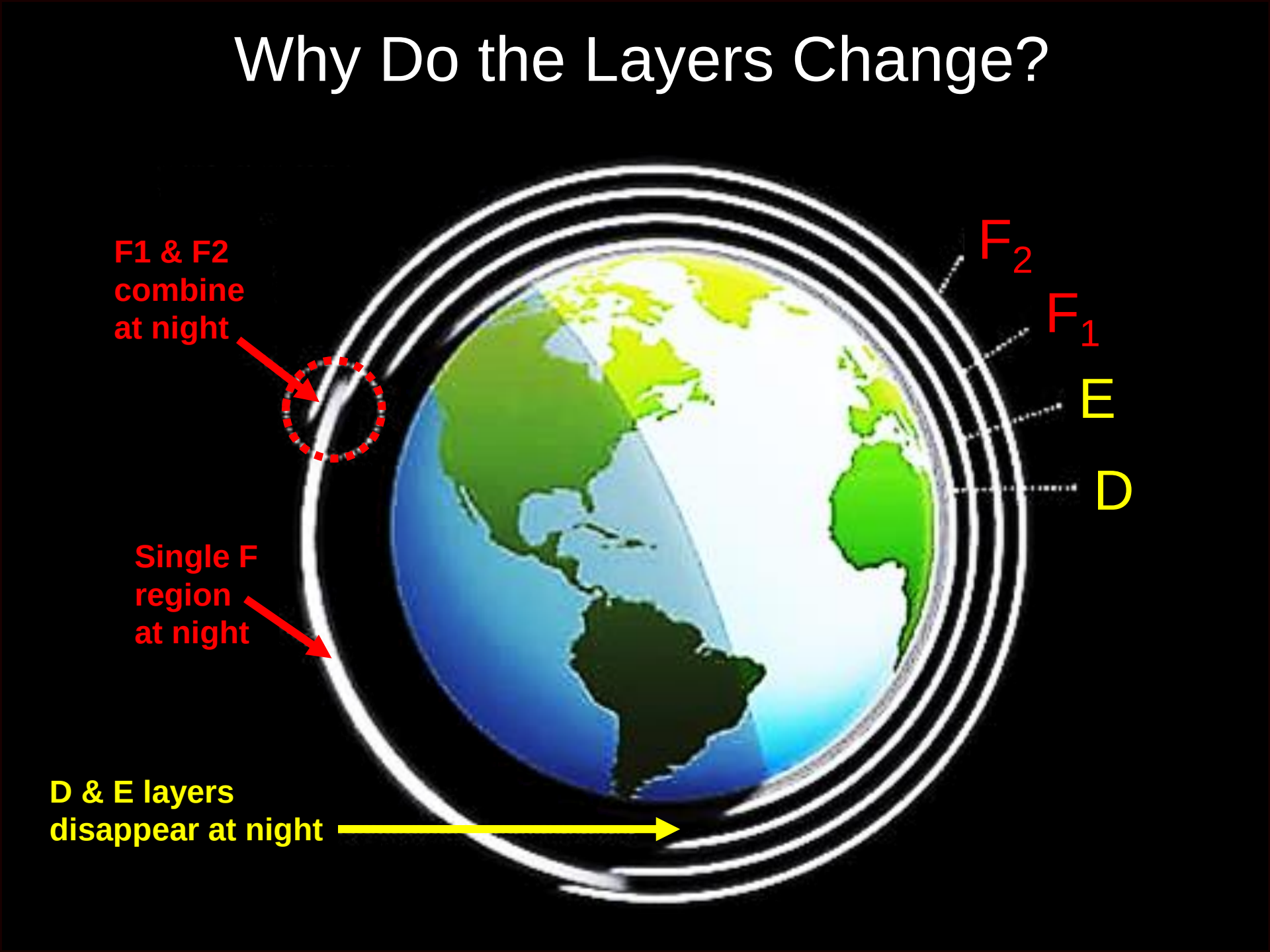
What is the Ionosphere?

- Ionosphere is a charged plasma layer above the atmosphere comprised of ions and electrons
- It would be neutral but it gets charged from exposure mainly to the Sun’s UV radiation
- This charged nature facilitates radio propagation

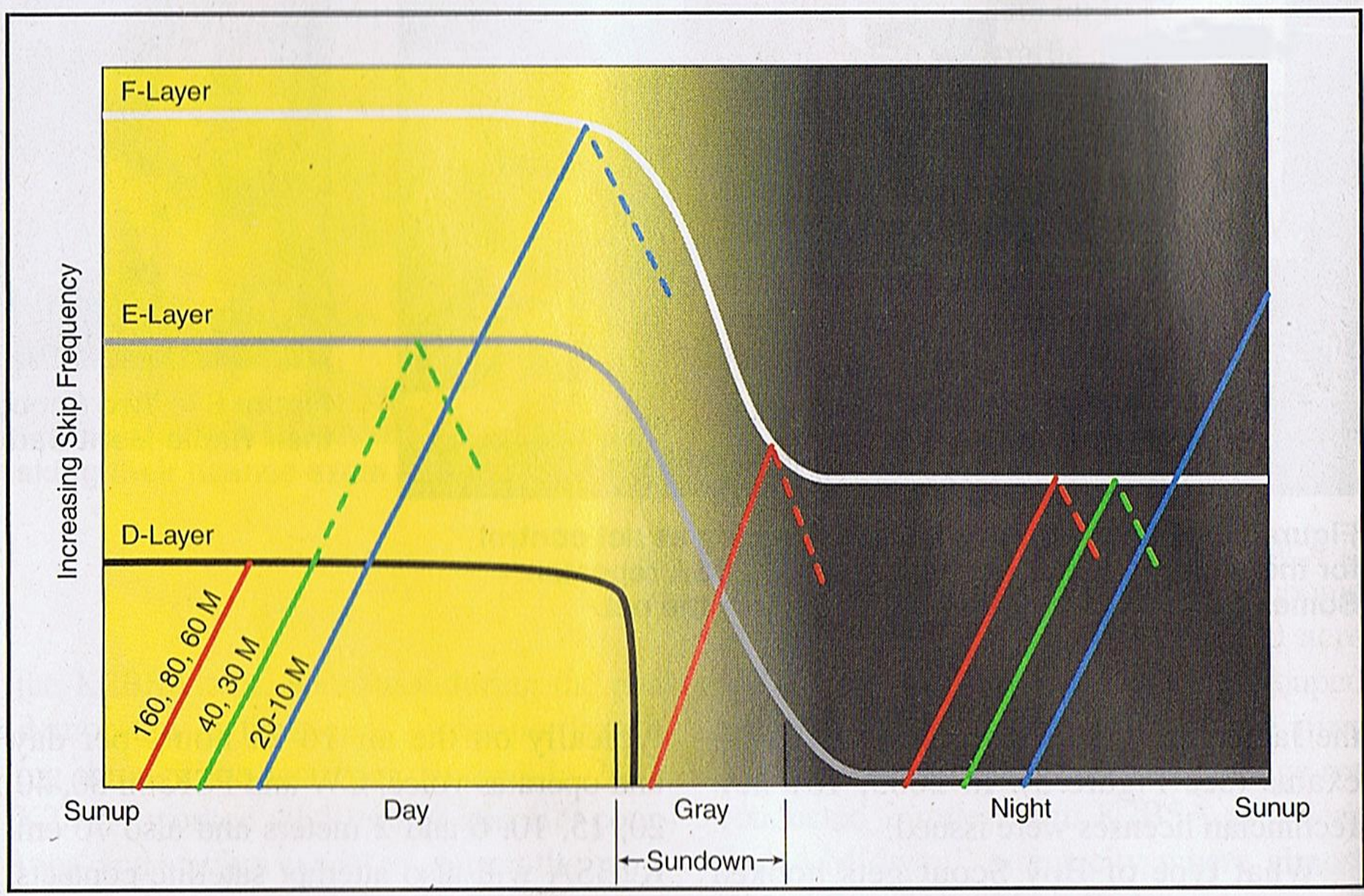
What are Ionospheric Layers?



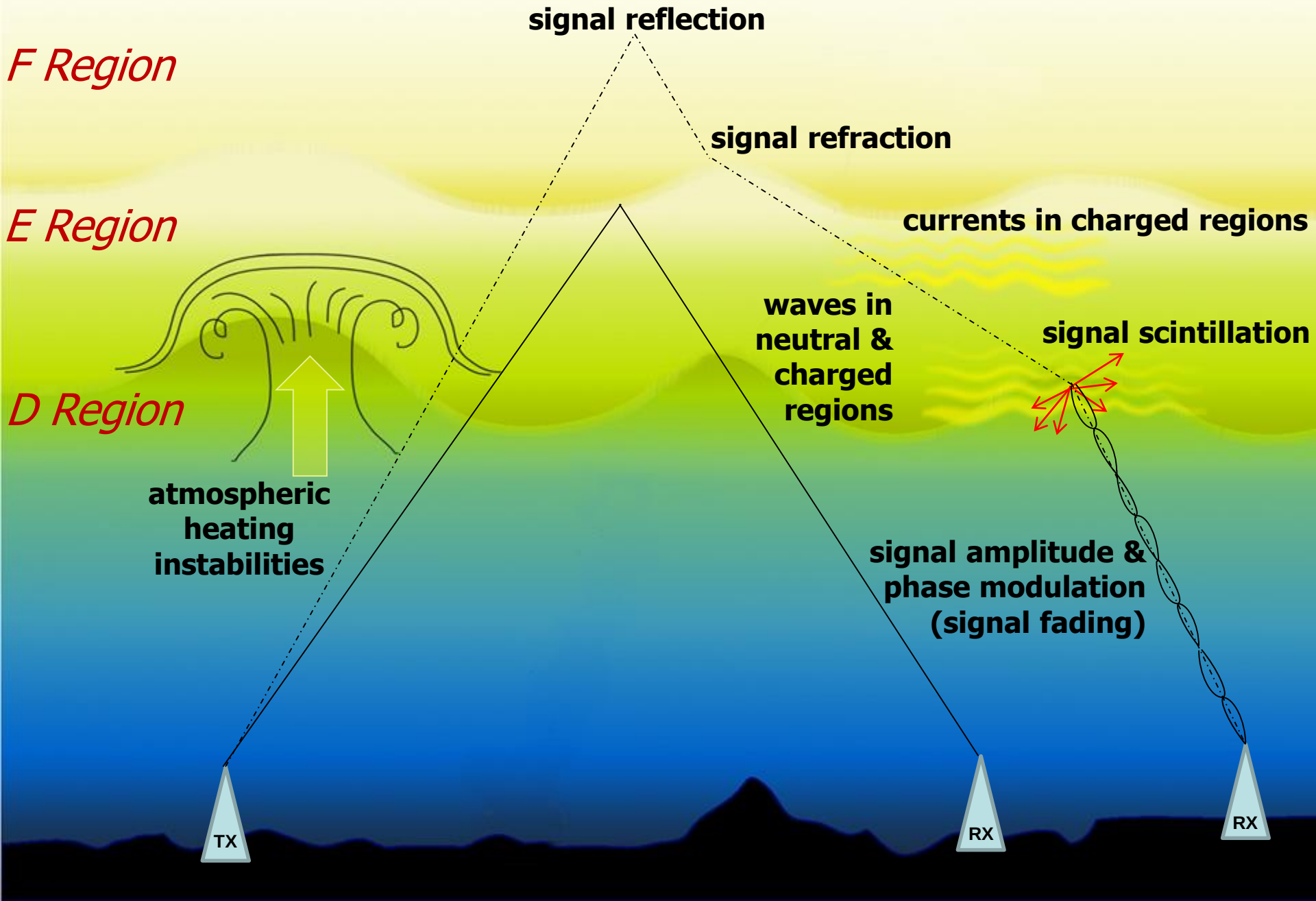
Why Do the Layers Change?



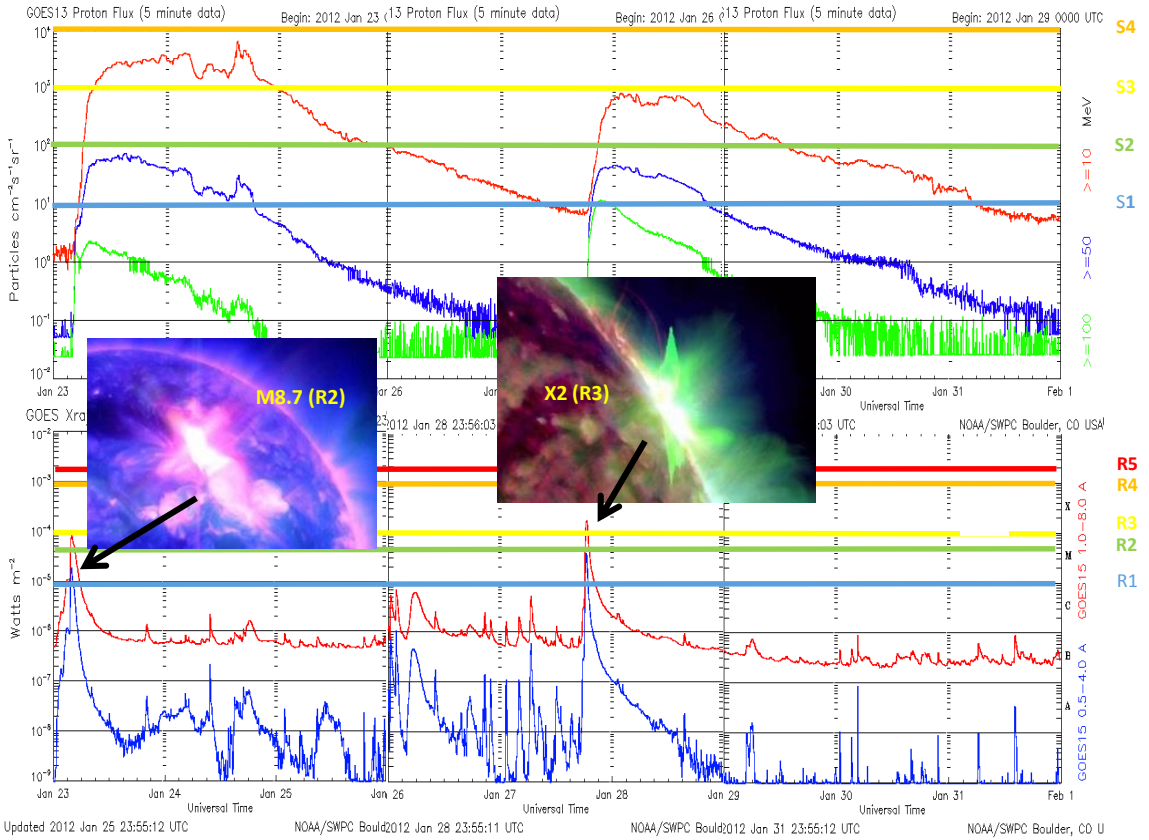
Ionospheric Layers & Signal Propagation



Space Weather Effects on Propagation

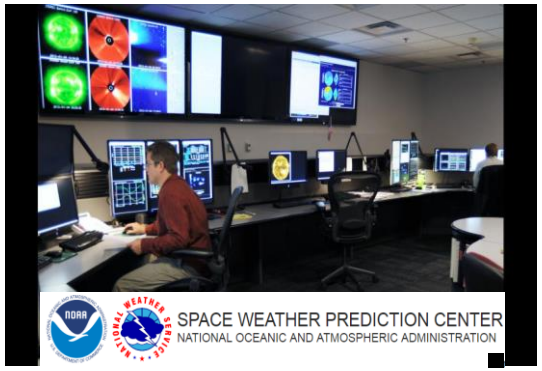


What Can a Typical Solar Storm Event Do?



Reprinted courtesy of NOAA

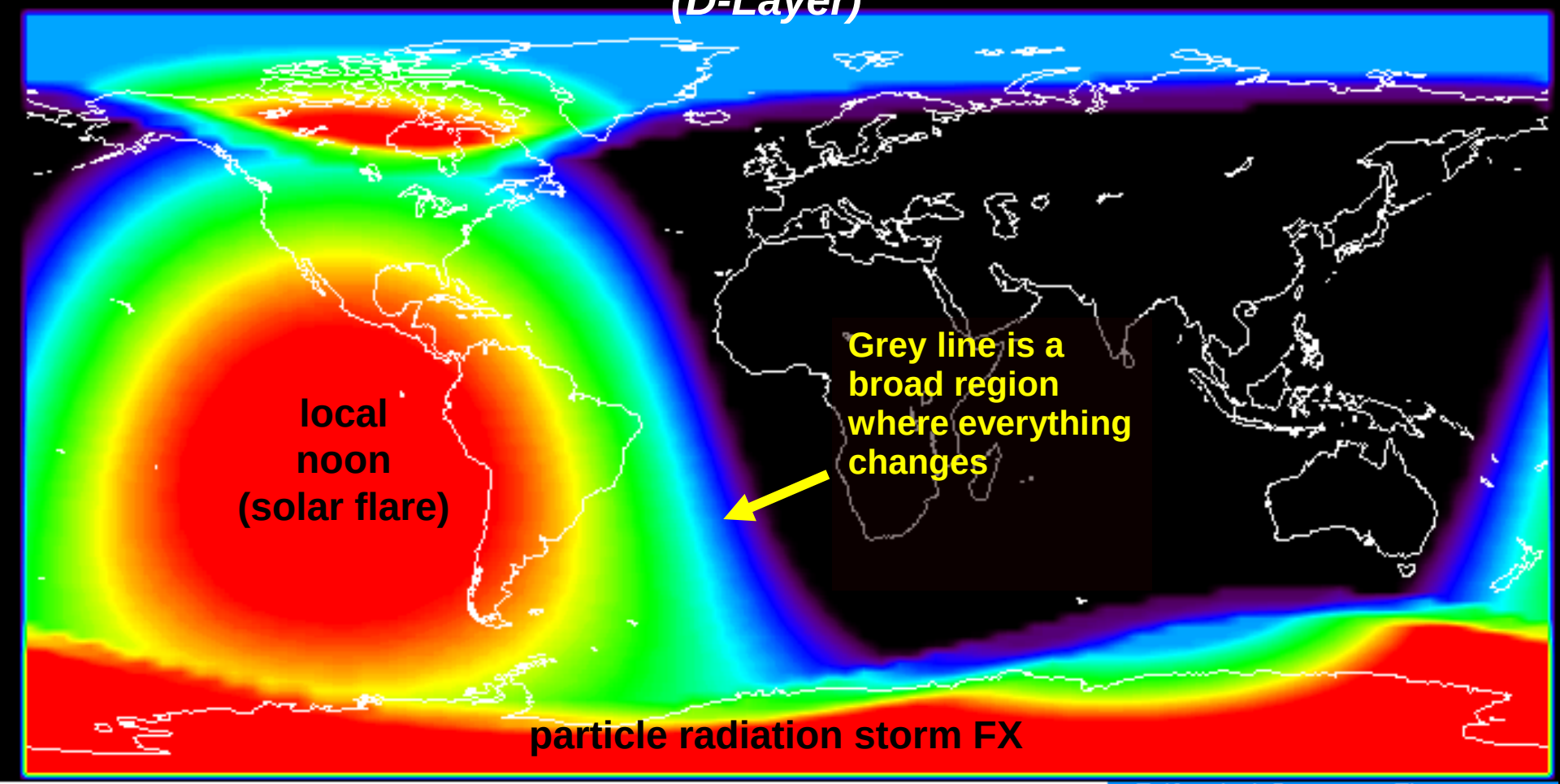
- Source of all official forecasting data is the NOAA Space Weather Prediction Center (SWPC)



- January 23-30, 2012 solar storm series of events caused
  - 2 radio blackouts
  - 2 radiation storms
  - 1 geomagnetic storm

HF Band Communications Disruption During Typical Storm

(D-Layer)



Highest Frequency Affected by 1dB Absorption

0 5 10 15 20 25 30 35

Degraded Frequency (MHz)

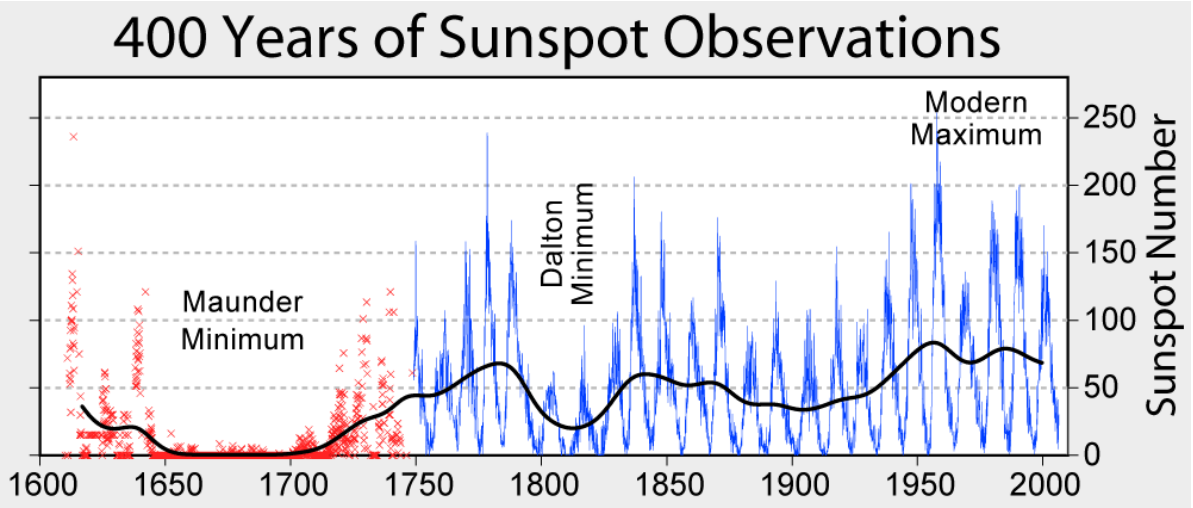
Estimated Recovery Time
High Latitude Protons :
No Estimate
Mid/Low Latitude X-rays :
0 HRS 50 MINS

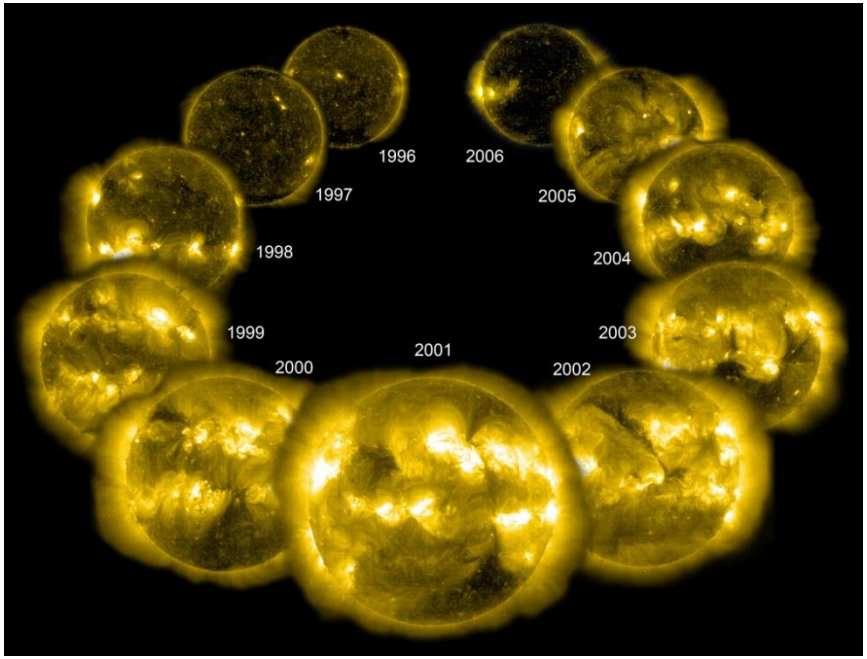
Moderate X-ray flux
Product Valid At : 2012-01-27 19:00 UTC

Normal Proton Background
NOAA/SWPC Boulder, CO USA

What about Solar Variability?

- Sun's activity cycle has a quasi 11-year periodicity
- Solar magnetic field constantly reversing orientation
- Activity increases for few years surrounding field reversal (solar maximum) and decreases when field becomes ordered again (solar minimum)
- Other competing cycles cause deviations from 11-years and modulate the strength of the cycle over the long-term
- Sunspot numbers are used as a proxy for solar activity

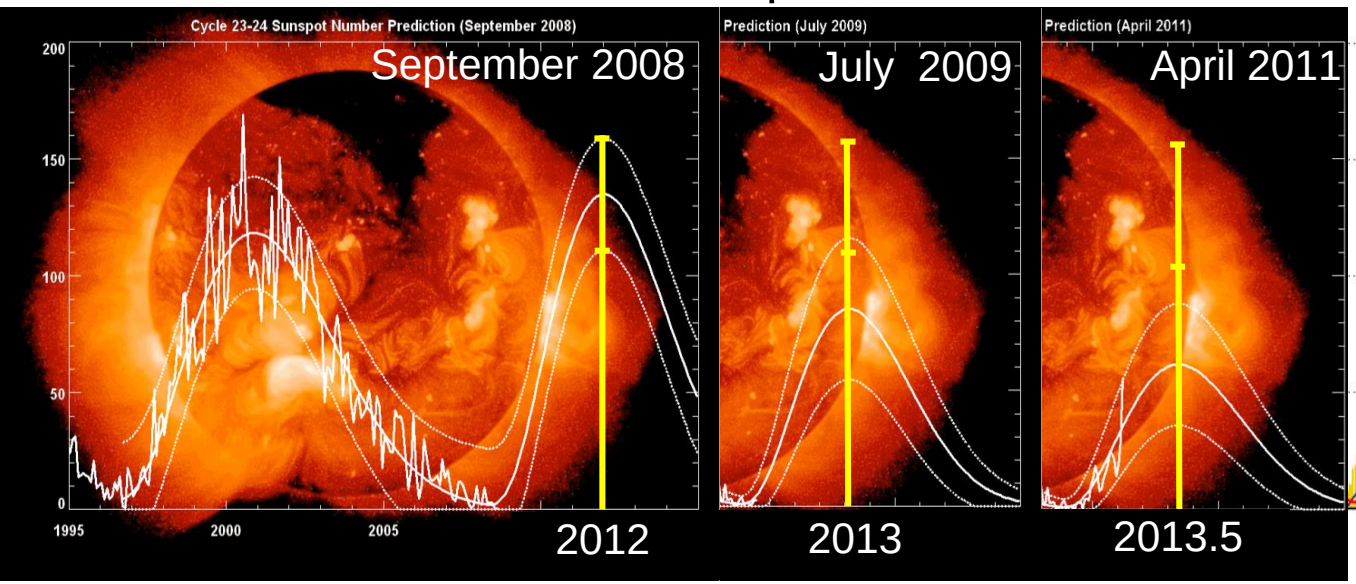


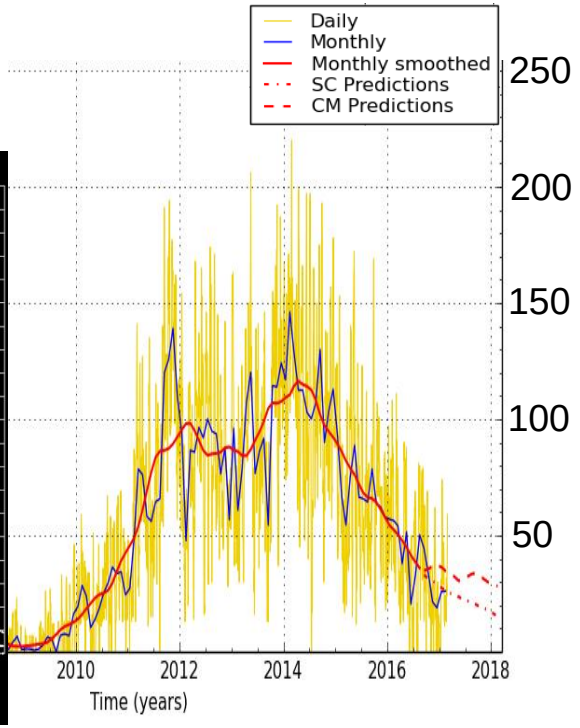


Solar Cycle: Where Are We Now?

- Recent solar cycles are showing dramatic changes, making predictions more complicated
- Consensus is we are in a new Dalton-like Minimum
  - Cycle is slower, up to 14 years
  - Lower luminosity, slower plasma currents beneath Sun's surface, lower magnetic field
  - lower activity at maximum
- Solar maximum double-peaked
  - First peak in 2011-2012, second peak 2014-2015

Recent Sunspot Number Predictions

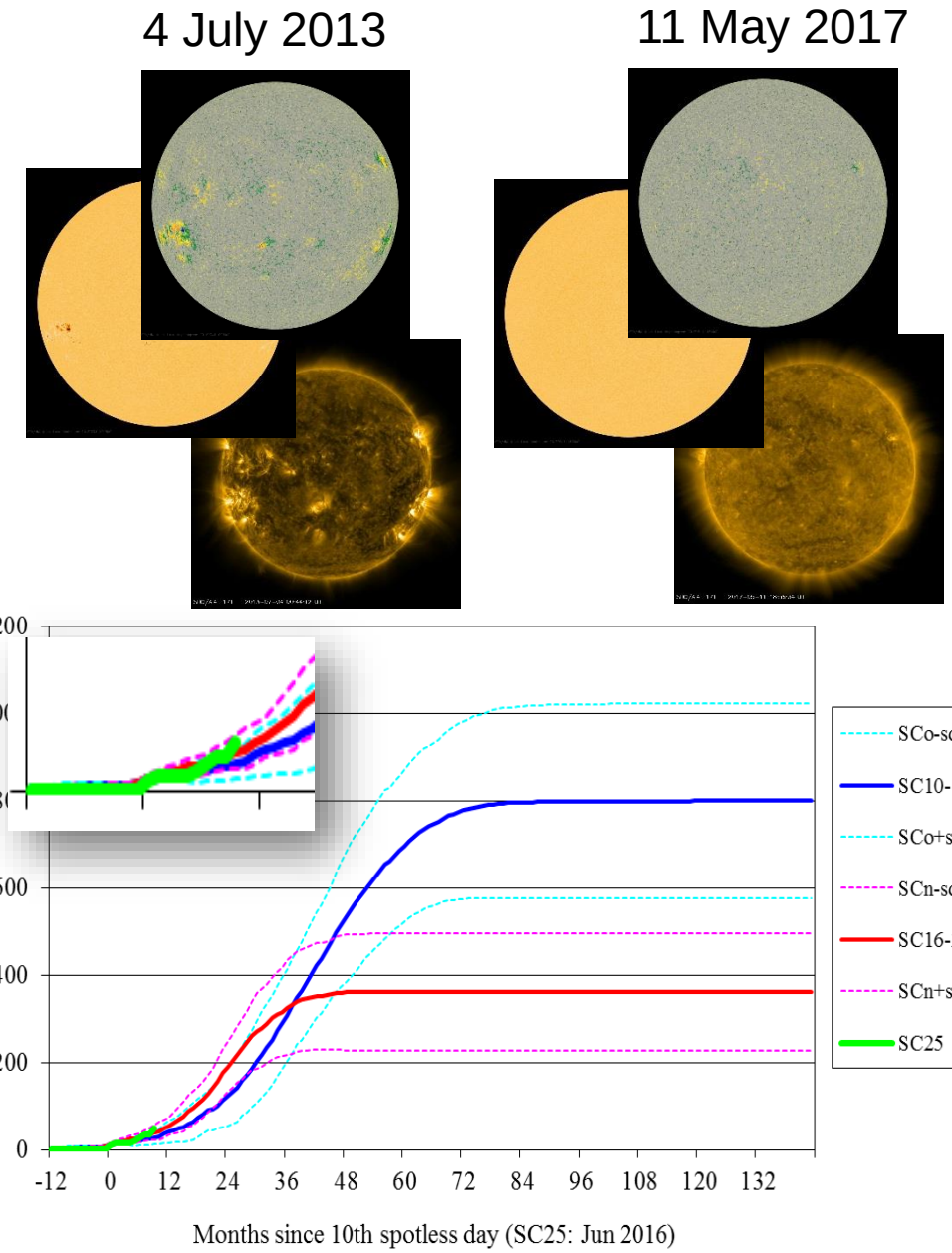




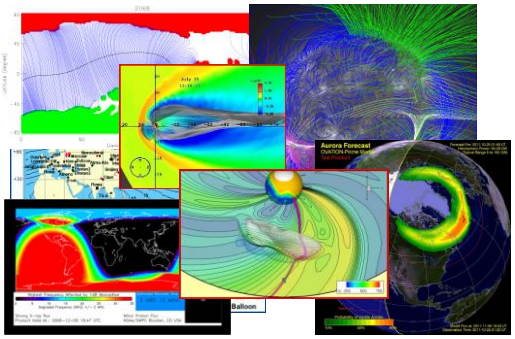
graphics (http://sidc.be/silso) Royal Observatory of Belgium 2017 March 1

Solar Cycle: Where Are We Now?

- Currently nearing the end of the declining phase of the solar cycle
- Less solar storms due to fast solar wind from coronal holes
- Very infrequent solar storms from solar eruptions
- Average solar flux very low due to increasing number of “spotless days”
- But nearing solar minimum brings new opportunities
- Spotless Days can be used as a predictor of future activity
- Interesting trend developing but too early to be sure
- http://sidc.oma.be/silso/spotless



Space Weather Forecasting: A Return to the Sixties



Space Weather Prediction Centers

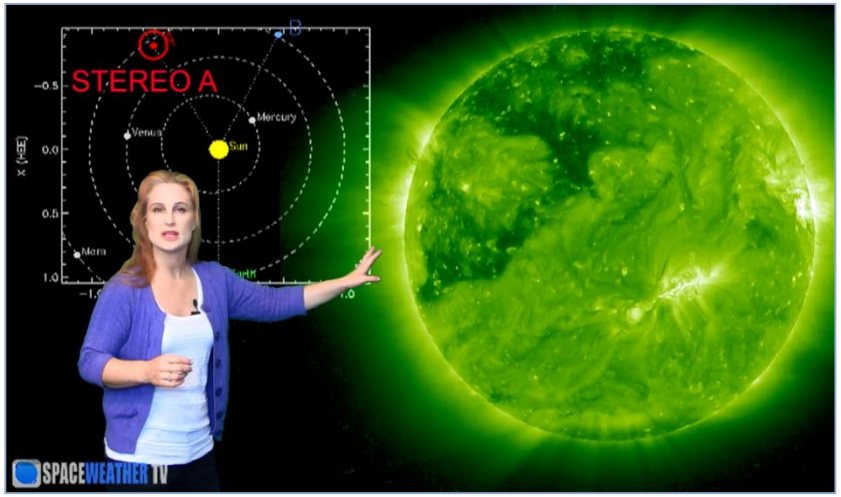
- Developed mainly as a response to super storms
- Models that predict solar fields, CME transit, magnetospheric responses→ solar storm alerts
- Radio blackouts, solar radiation storms→ FAA alerts
- Space and ground telescopes for 24/7 monitoring of Sun, even on the backside
- “Spaceship Earth” networks

~1960

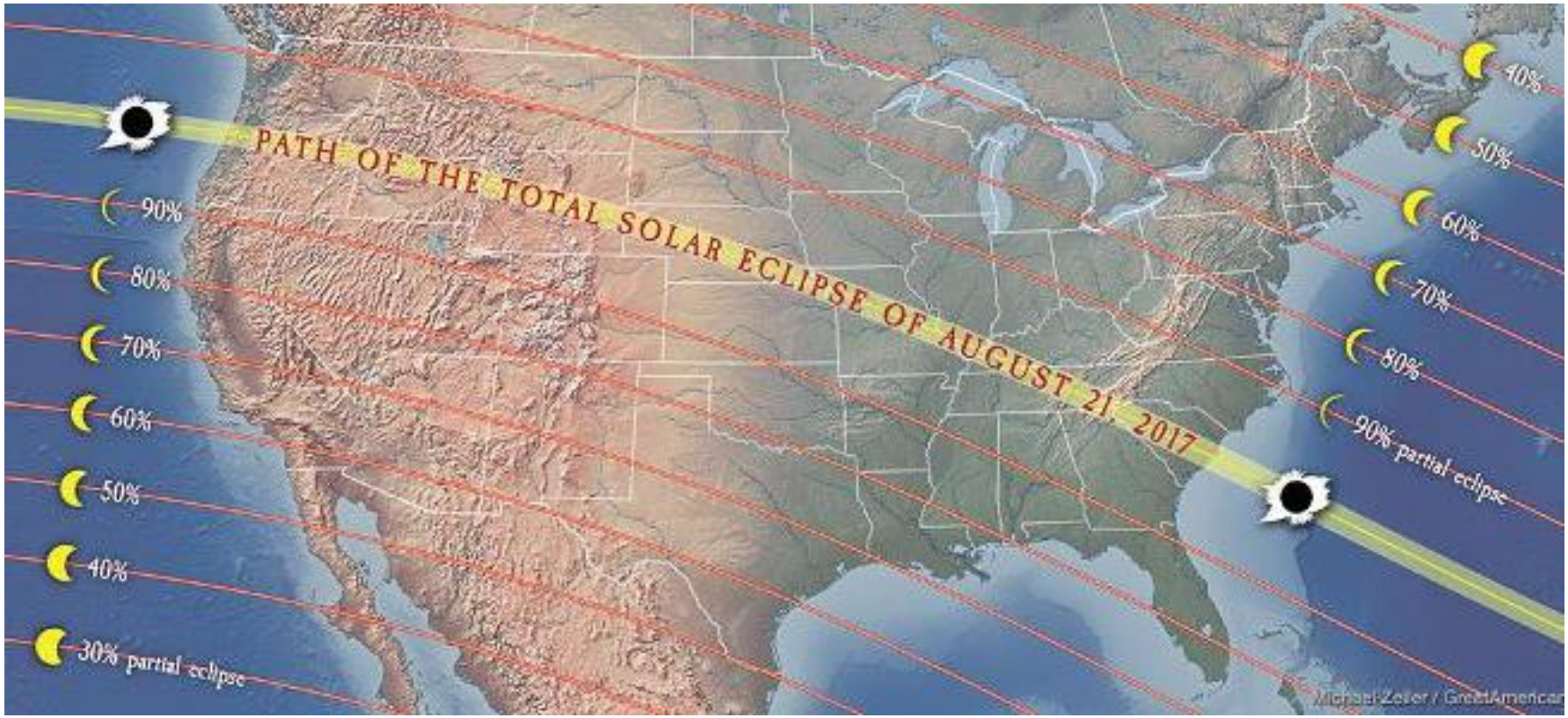
Harry Volkman: Broadcast Meteorologist

Today

Tamitha Skov: Broadcast Space Meteorologist



Total Eclipse on 21 August 2017



- First eclipse crossing entire continental USA in 100 years
- 90 minute eclipse will change conductivity in ionosphere and affect radio propagation
- Eclipse shadow has effects similar to dawn-dusk terminators, but moves in opposite direction
- Prior eclipse studies indicate D & E regions collapse quickly but F region response is controversial
- Join the study at http://www.HamSci.org

Our Future Relies on Predicting Space Weather

Reliance on Space is advancing:

- Wireless technologies
  - 6 Billion mobile phones in world today
  - GPS/GNSS receivers
  - Satellite service providers exploding
- Self-driving cars
  - CA law passed in 2012 Google car can share public roads
- Unmanned Aerial Vehicles (UAVs)
  - FAA allowed GPS/GNSS enabled drones share commercial airspace in 2015
- Space Tourism
  - World View performing manned test flights in 2017

For more information visit:

SpaceWeatherWoman.com

TamithaSkov on YouTube for weekly forecast videos: (http://www.youtube.com/user/SpWxfx)

*@**TamithaSkov** on Twitter for daily forecasts and often hourly updates*

***Space Weather Woman** on Facebook*

SpaceWeatherWoman@gmail.com