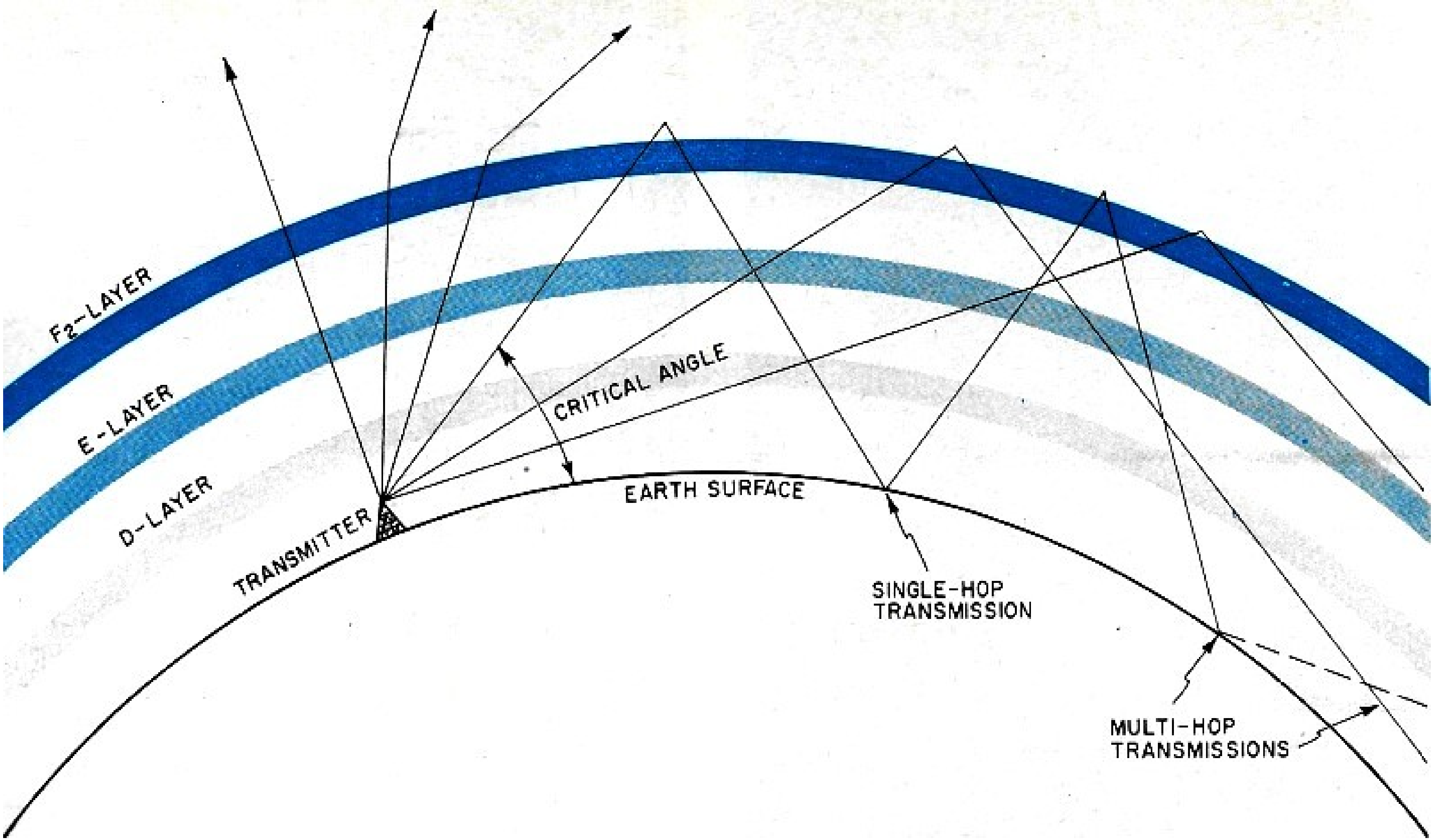
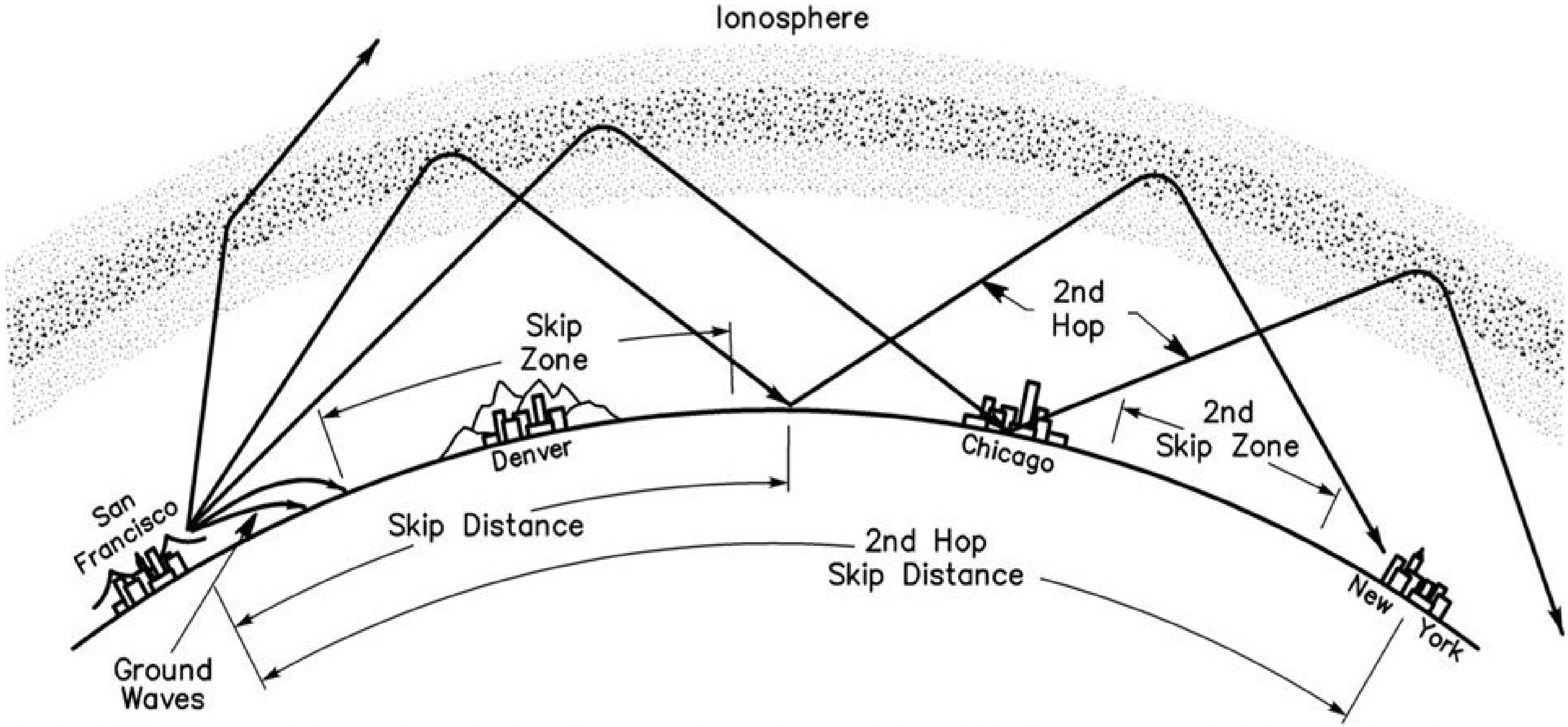
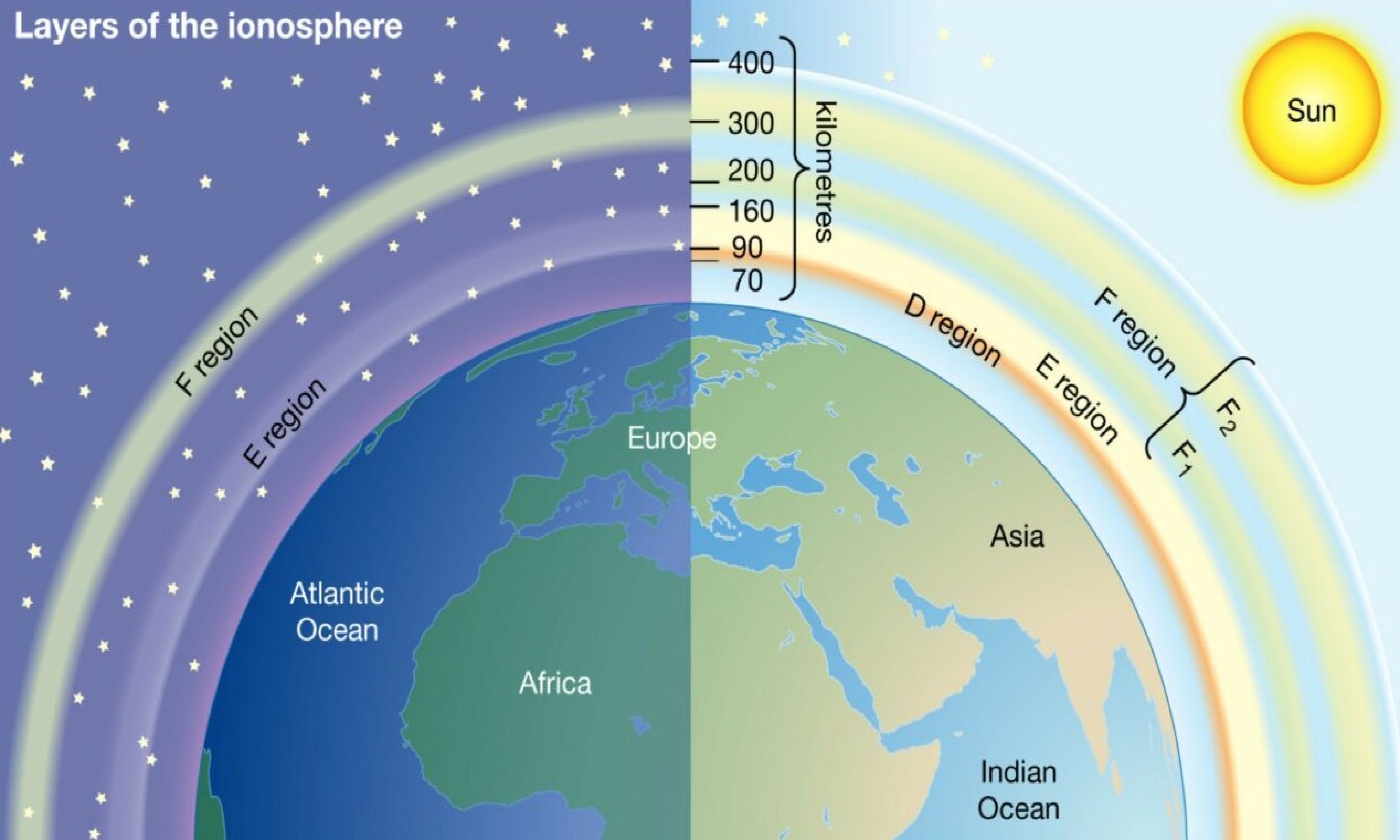
Basics of HF Propagation

- Only considering HF Frequencies
  - HF = 3 Mhz to 30 Mhz
  - 80M to 10M amateur bands (160M is Medium Frequencies, 6M is low VHF)
- Will consider propagation only by line-of-sight or via the ionosphere (will not consider ducting, tropospheric bending, or scattering)
- Radio Waves are Refracted, not Reflected

- Refraction requires either a density change (ducting, tropospheric bending) or charged particles (ionosphere)
- Charged particles are created by knocking electrons or ions off of neutral atoms or molecules
  - More electrons than protons so “Electron Density” is the primary measure
  - Low in atmosphere recombination happens very fast so free charged particles last a very short time
  - As density of atoms decreases, free charged particles last longer before recombination
  - Limited by too low a density → no particles


F2-LAYER
E-LAYER
D-LAYER
CRITICAL ANGLE
TRANSMITTER
EARTH SURFACE
SINGLE-HOP
TRANSMISSION
MULTI-HOP
TRANSMISSIONS

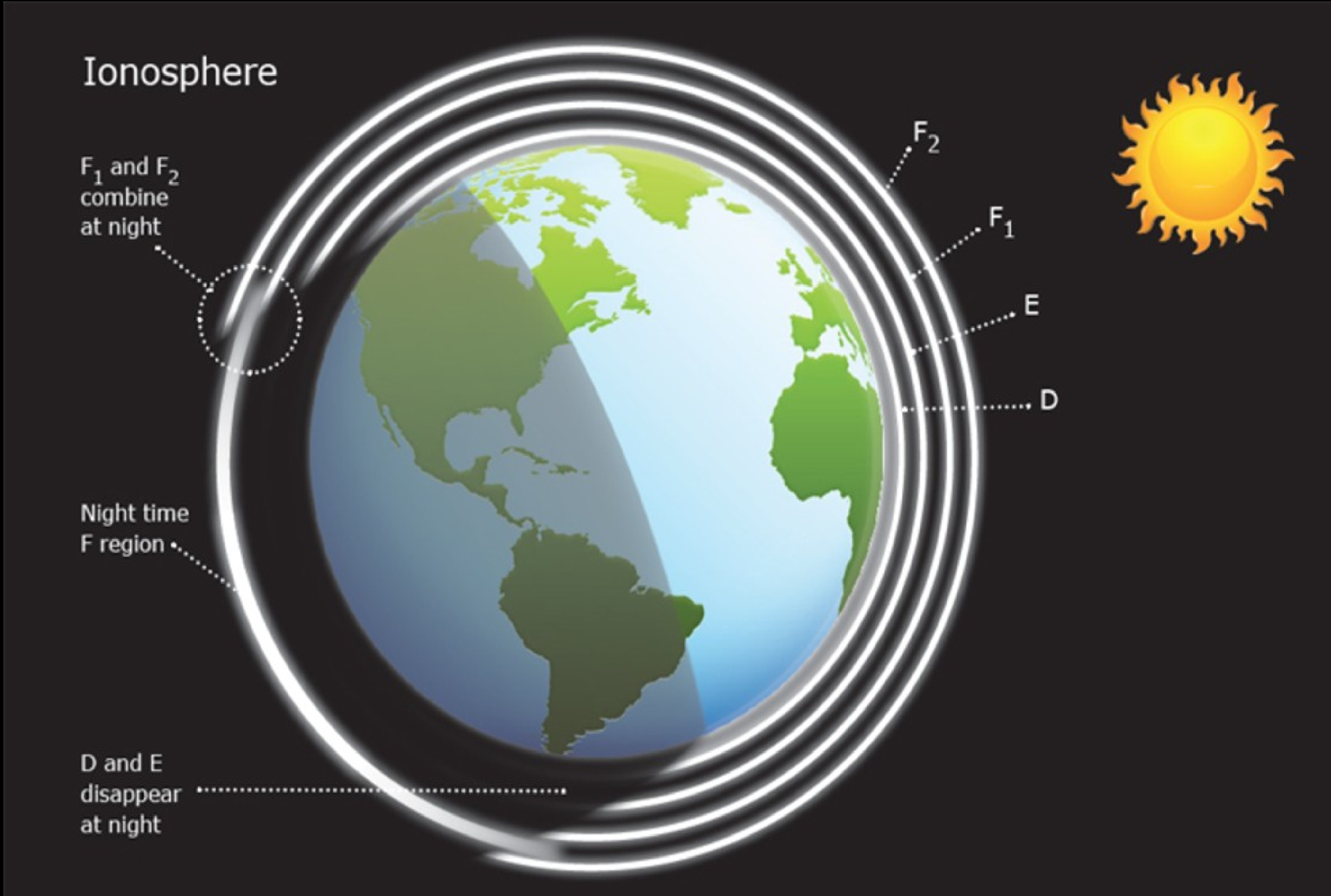

Ionosphere
Skip Zone
2nd Hop
2nd Skip Zone
Denver
Chicago
San Francisco
Skip Distance
2nd Hop Skip Distance
New York
Ground Waves



Layers of the ionosphere
400
300
200
160
90
70
kilometres
Sun
F region
E region
D region
E region
F region
F2
F1
Europe
Asia
Atlantic
Ocean
Africa
Indian
Ocean

Normal Sun

- Extreme UV ionizes atomic Oxygen at 120-400km altitude (F layer)
- Soft X-ray and far UV ionizes O_2 at 70-120km altitude (E layer)
- Lyman α plus X-rays ionize NO and air (N_2 and O_2) at 50-90km altitude (D layer)



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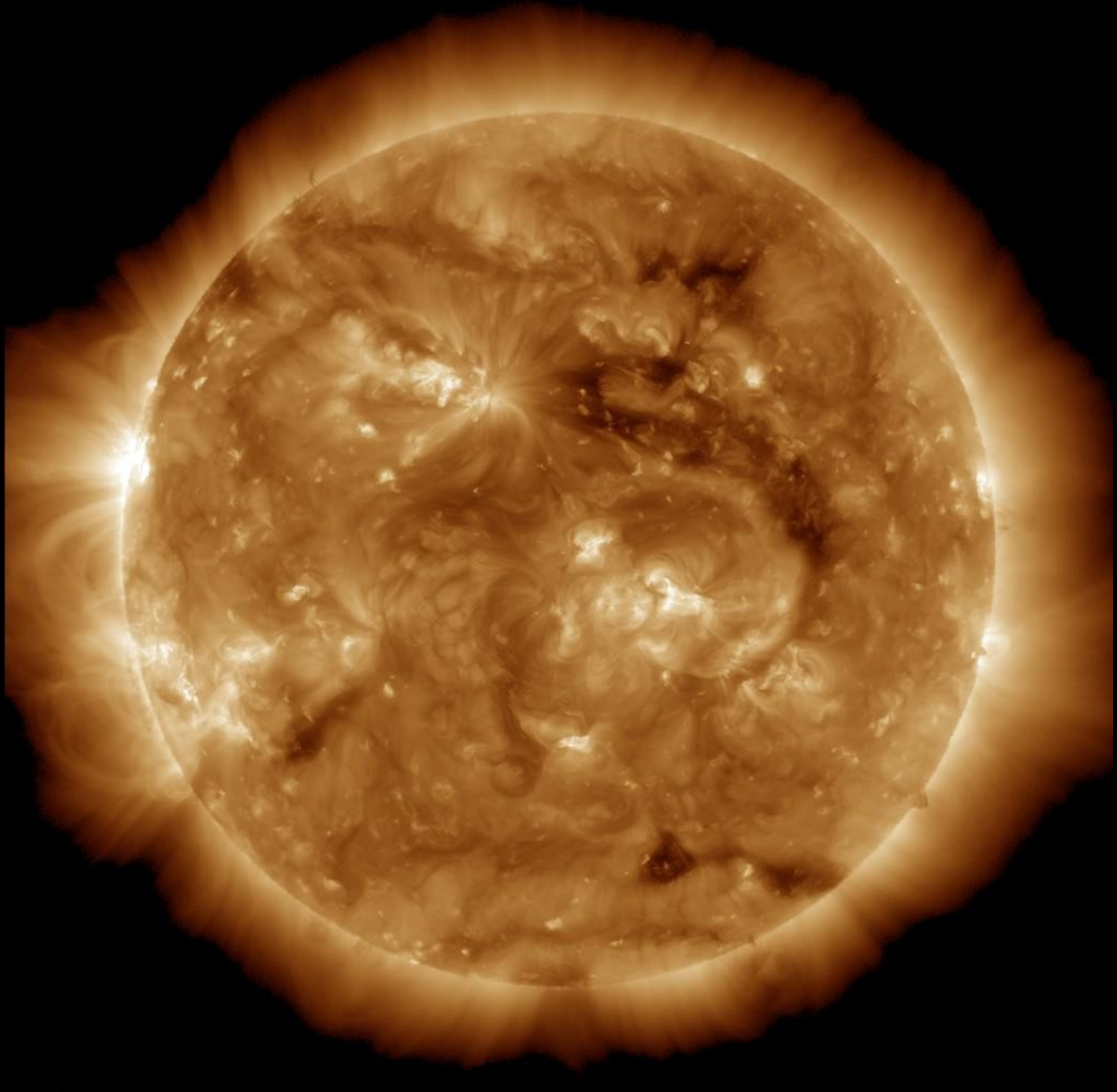
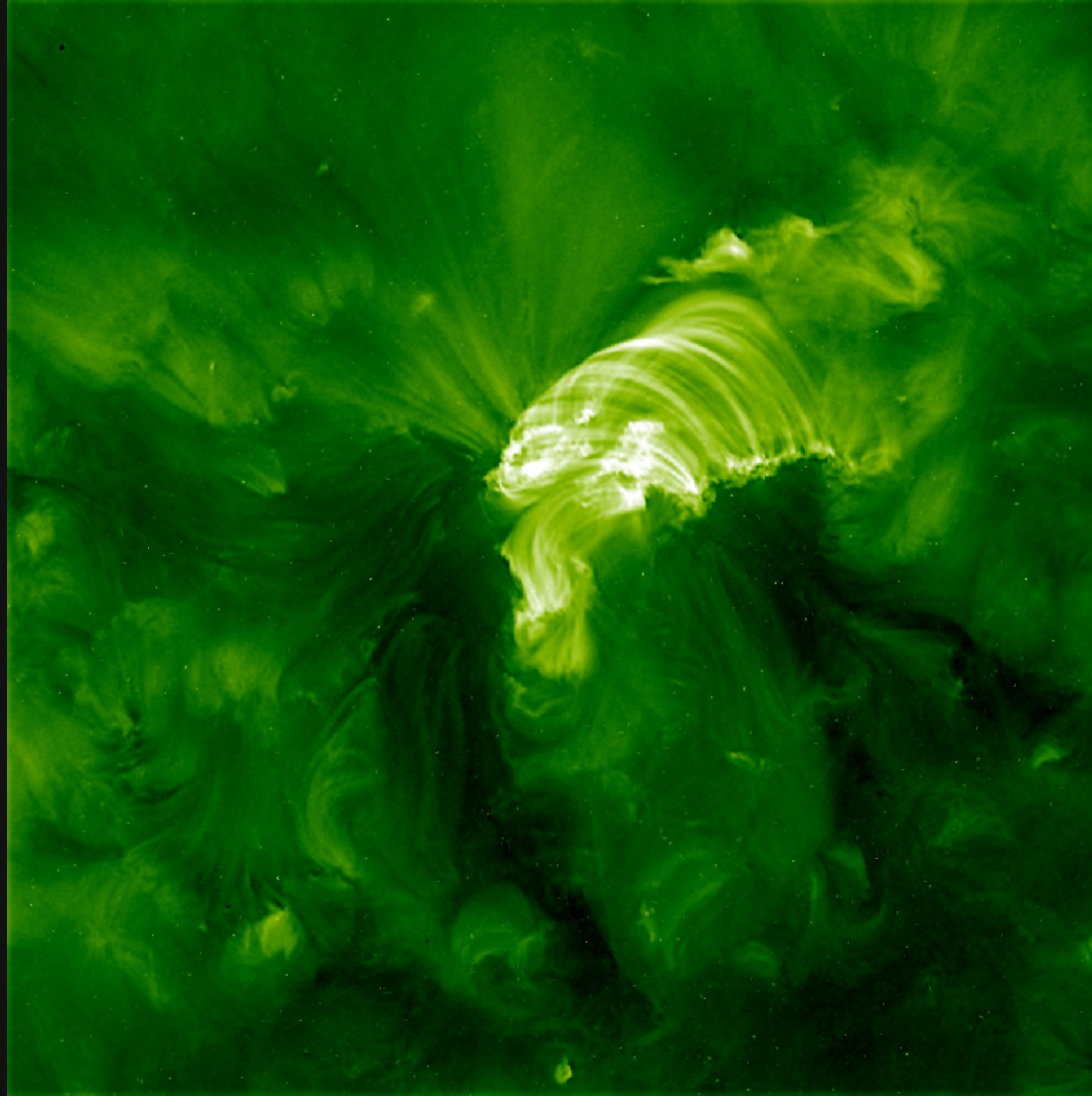
But This Isn’t the Whole Story

- Charged Particles stream from the Sun
- Two sources:
  - Solar Wind
  - Active Solar regions
- The particles interact with the Earth’s magnetic field and are directed toward the poles



Active Regions

- Places on Sun where Magnetic Fields are tangled
- Flux Tubes form over areas where magnetic fields are emerging from denser, lower regions
- Flux tubes are self-supporting but eventually run out of energy and collapse



High Solar Activity

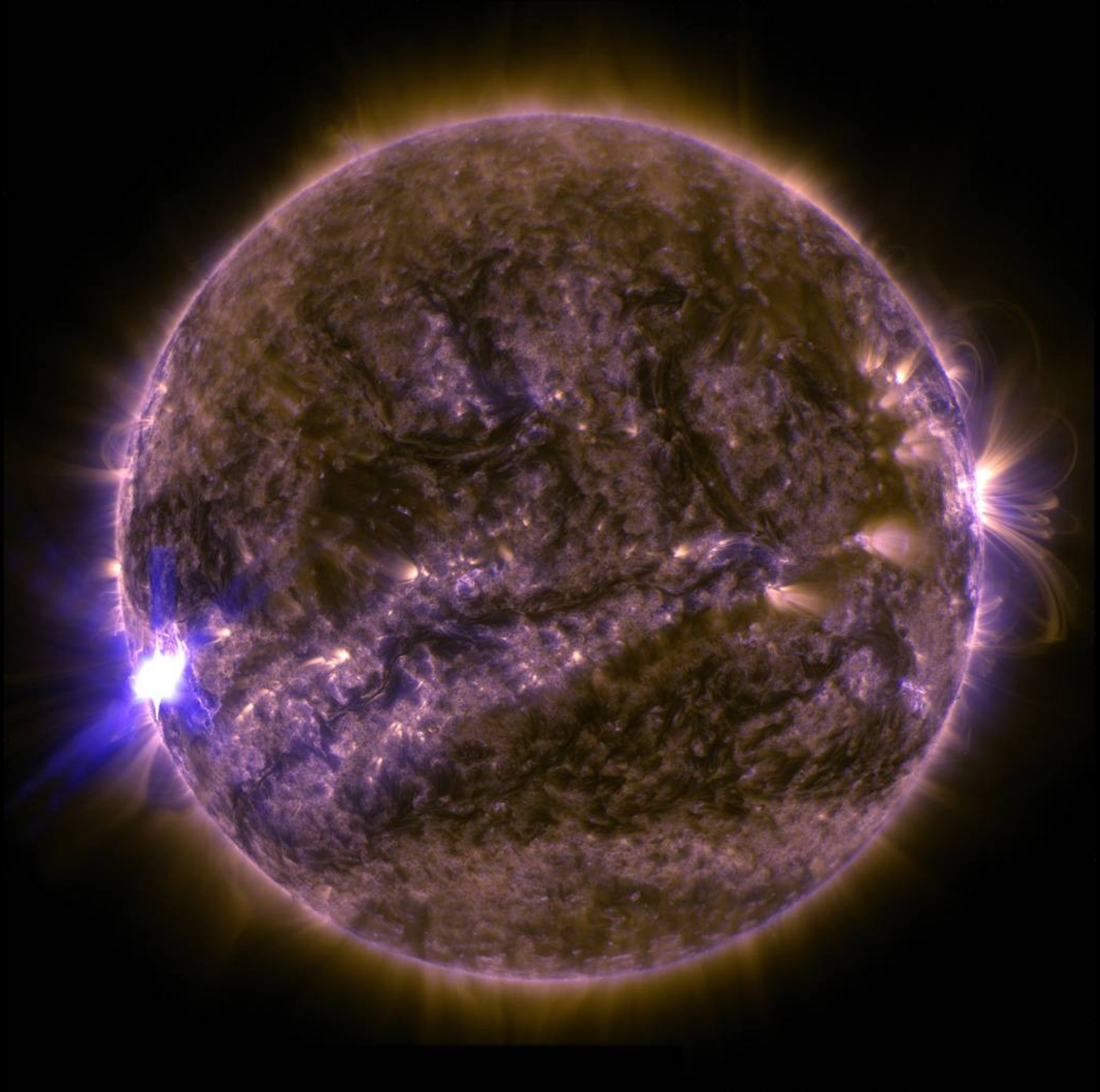
- More charged particles reach F layer making it denser and reflecting higher frequencies
- Some enhancement of D layer leading to increased absorption during the day
- DX is enhanced at higher frequencies and at night

High Solar Activity (cont.)

- Aurora occur more frequently, are brighter, and occur at lower latitudes.
- More energetic particles interact with the Earth’s magnetic field
- The Sun’s Magnetic Field is “tangled”
- Geomagnetic storms likely

Solar Flare

- Energy from recombination emits everything from Gamma Rays to Radio
- No Warning (everything travels at speed of light)
- Not affected by Earth's Magnetic Field

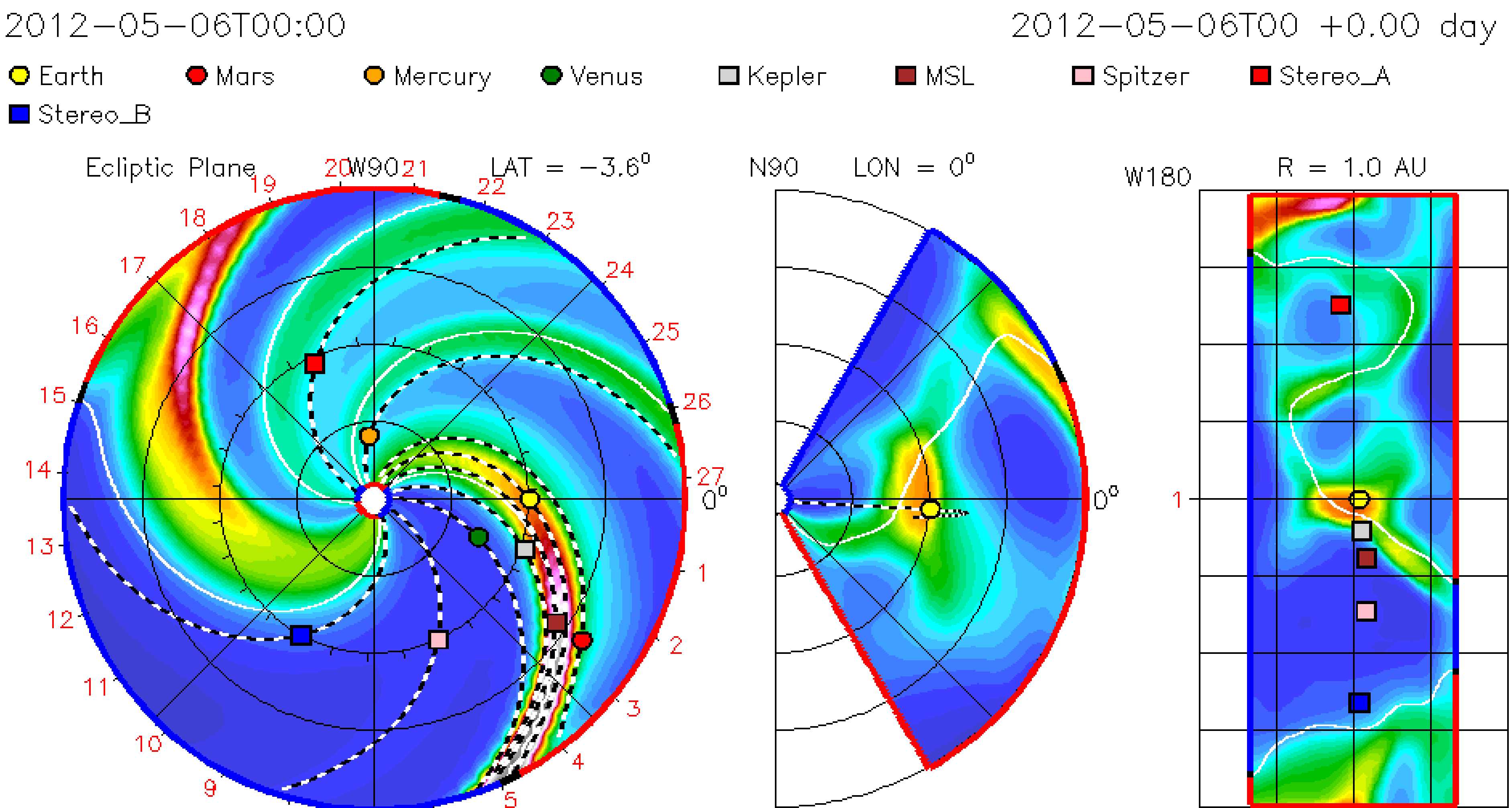


- Reconnections in Earth Magnetic Field can open ionosphere to more charged particles
- Solar ions reach lower into the ionosphere since there is less magnetic shielding
- Physical collisions and chemical reactions change makeup of the various layers
- X-rays are enhanced
- F layer can disappear
- D layer can be enhanced

→ Propagation can disappear

Coronal Mass Ejection

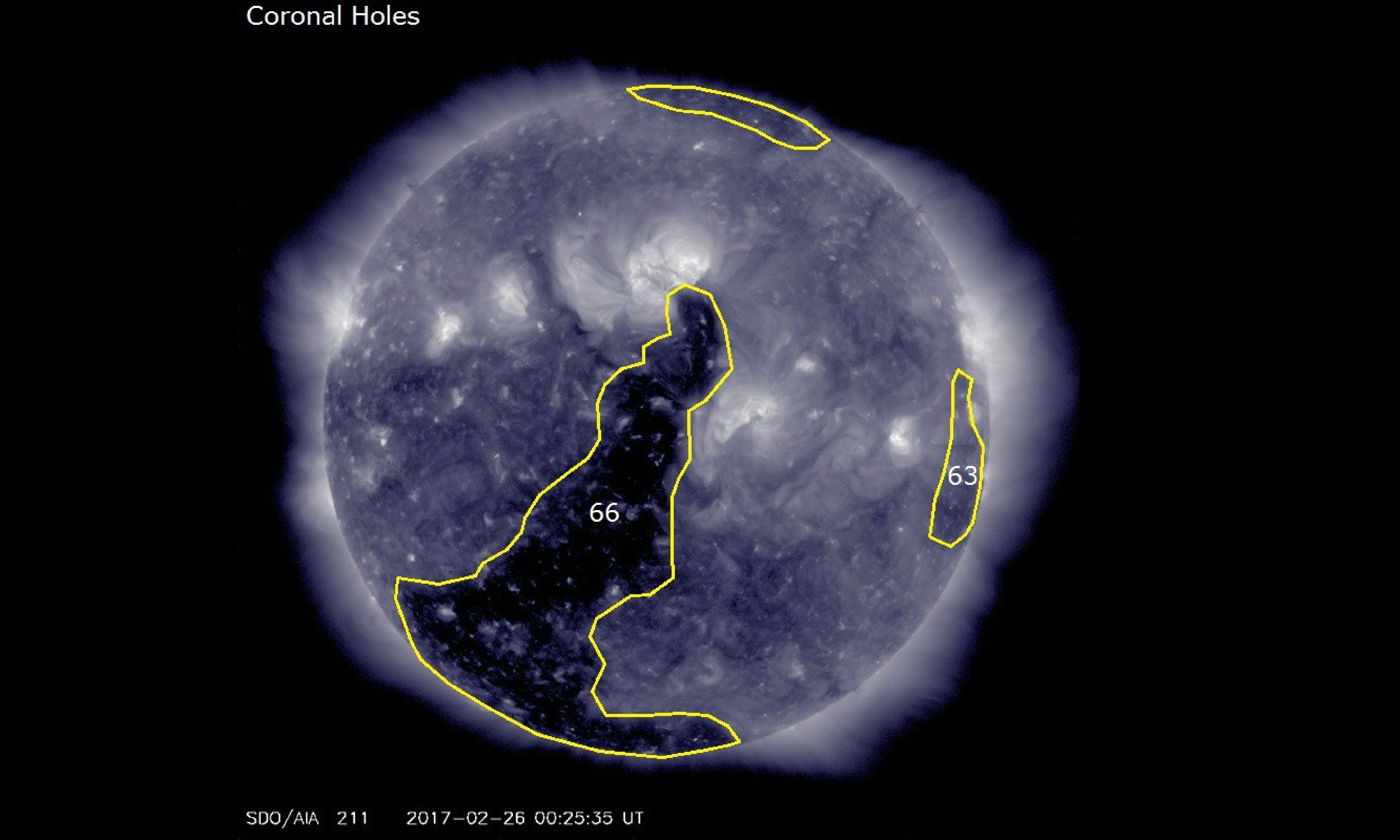
- Takes 2-3 days to reach Earth
  - Tracked by spacecraft
- Charged particles
  - Interact with Earth’s Magnetic Field
  - Cause Geomagnetic Storms
  - Aurora
  - May have enhanced propagation after everything calms down



2012-05-06T00:00
2012-05-06T00 +0.00 day
Earth
Mars
Mercury
Venus
Kepler
MSL
Spitzer
Stereo_A
Stereo_B
Ecliptic Plane
W90
LAT = -3.6°
N90
LON = 0°
W180
R = 1.0 AU
0°
1

Low Solar Activity

- Fewer active regions
  - Lower number of CMEs
  - Much lower number of flares
- Coronal Holes become major driver of propagation changes
  - Coronal Holes were postulated from Solar Minimum Geomagnetic storms
  - Later seen in extreme UV by spacecraft


Coronal Holes
66
63
SDO/AIA 211 2017-02-26 00:25:35 UT

Characteristics of the Ham Bands

- Below 10 MHz : Absorption (D layer) major influence on whether band is open
  - 80–40 Meters: open mostly at night
- Above 10MHz: Refraction (F layer density) major influence on whether band is open
  - 20–10 Meters: open during daytime
  - 20-17 Meters: sometimes open at night at cycle peak
- At 10MHz (30 Meters): “Always open” if MUF high enough

E layer is more important than previously thought:

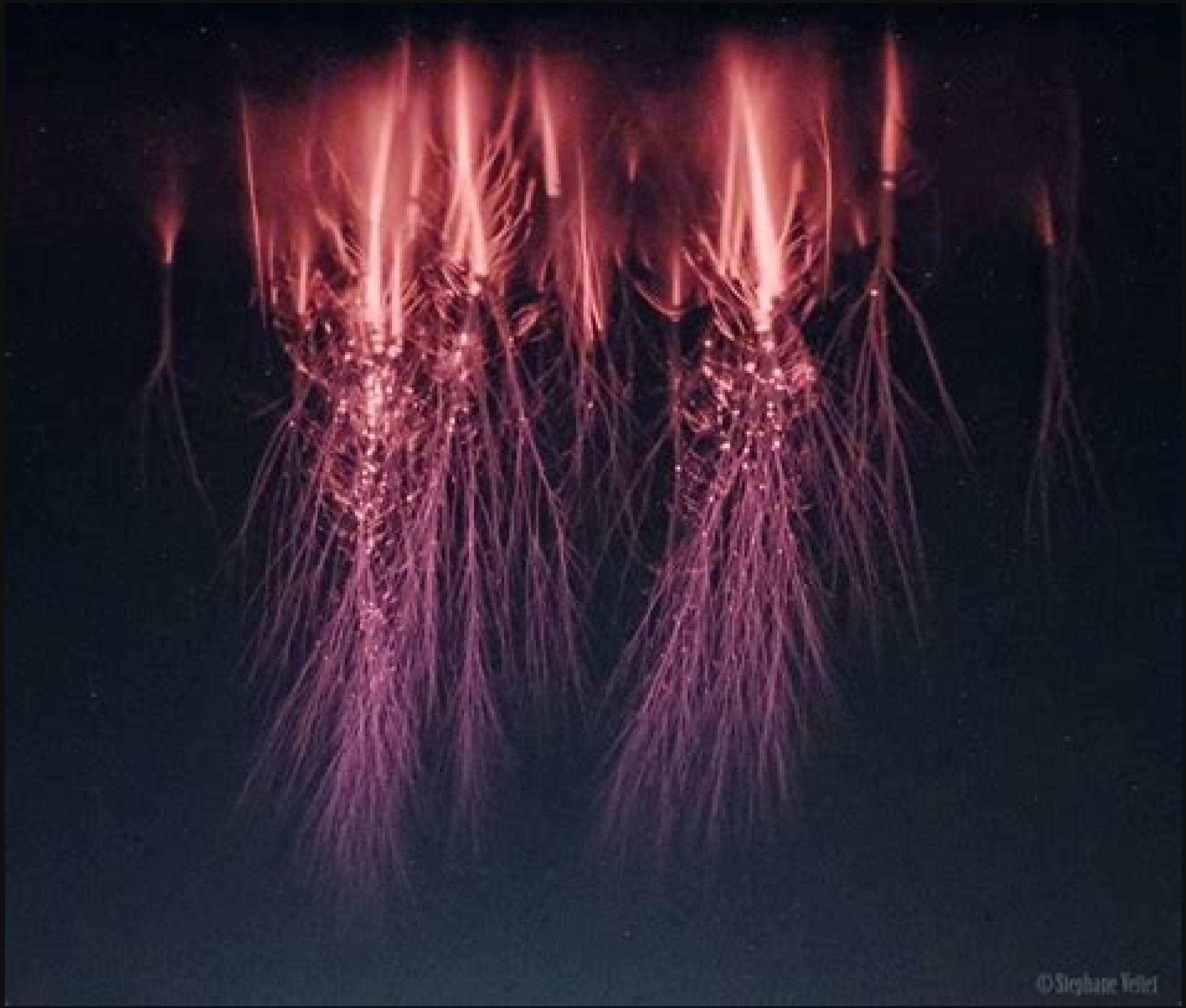
During the SEQP, the main propagation layer for 20M was the E layer!

– Shorter skip than F layer

But the E layer is Daytime only!

Sporadic E (Es)

- 15 years ago I would have said “No one understands Sporadic E”
- Small regions of charged particles causing refraction of higher HF frequencies for a limited geographic extent
- Turns out, Sporadic E is caused by weather!
  - Mostly by Thunderstorms and Thunderstorm causing conditions
  - Red Sprites are symptomatic of these regions


©Stephane Vetter

Low Solar Activity Propagation

- F layer less dense
  - Higher frequencies less likely to be refracted back to Earth
    - 15 – 10 meters: only during day (if then)
- E layer much less often in play
- D layer lower absorption
  - 80–30 meters → more DX
  - 80–40 meters open more during day

High Solar Activity Propagation

- F layer more dense than at lower activity
  - Higher frequencies more likely to be refracted back to Earth
    - 15 – 10 meters: open in daytime and sometimes at night
    - 17 – 20 meters: open 24 hours
- E layer much more in play
- D layer higher absorption
  - 80–40 never open in daytime

Things to Look For

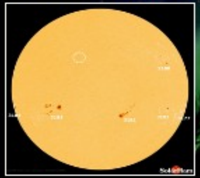
- Sunspot Number
  - Variable SSN for same activity
  - Input for propagation programs
    - Really need to use a smoothed number
- Solar Flux Index
  - More reliable than SSN
  - Lowest number ~65
- K index
  - Measures geomagnetic activity: High $\rightarrow$ bad
  - Various “Ks” for different Earth Latitudes (use K_p)

Other Things to Look For

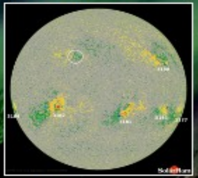
- Number and orientation of Active Regions
  - Are they facing us?
  - Are they “complex” or “simple”
- Coronal Hole?
- Z component of Solar Wind (Bz)
  - + or - ?
    - + aligned with Earth Field: repels
    - - anti-aligned with Earth Field: attracts
      - Solar Wind more likely to have an effect

SolarHam by Amateur Radio Station VE3EN

Space Weather for January 9, 2023 — UTC Time 00:30:24 Tuesday

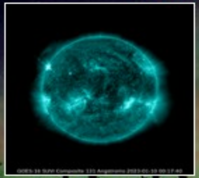


HMI Intensity
Latest | Movie | HARP



HMI Magnetogram
Latest | Movie

Coronal Holes
Analysis | Movie



AIA 131 (Latest)
Movie

SUVI 304 (Latest)
Movies

Latest Imagery: SDO | AIA | GOES-16 | GONG | STEREO | LASCO   **Video:** SDO | SOHO | STEREO | Helioviewer | YouTube

Solar Indices (Jan. 9 @ 21:05 UTC)

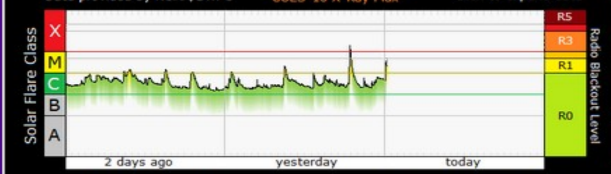
SFI	SSN	AREA
191	117	1810
▲ 7	▲ 13	▲ 600

WWV | Flux Data | Last 30 Days

Cycle 25 Progression

Solar Flare Detection

Data provided by NOAA/SWPC — GOES-16 X-Ray Flux — Click to expand data

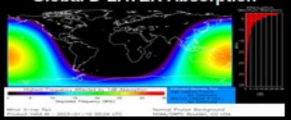


X-Rays
M2.1
Current

Solar Demon

Solar SOFT

Global D-LAYER Absorption



Current Solar Flare Threat

C-Flare: 99%	M-Flare: 70%
X-Flare: 35%	Proton: 15%

Probability Details

3 Day Geomagnetic Forecast

Jan. 9	Jan. 10	Jan. 11
2-3 (G0)	2-3 (G0)	3 (G0)

Max Kp

Jan. 9	Jan. 10	Jan. 11
M-Lat 01%	M-Lat 05%	M-Lat 10%
H-Lat 20%	H-Lat 30%	H-Lat 40%

Probabilities

Detailed Forecast

Flare Events (M2+) Past 48 Hours | Event Report | Top Solar Flares

M2.1	X1.9	M5.1
3181	3184	-

Visible Sunspot Regions | Sunspot Summary | SRS (txt)

3180	3181	3182	3183	3184	3185
B	BD	BGD	B	B	B

Geomagnetic Field and Aurora

Past 24 Hours: Quiet

Kp-Index | A-Indices | Magnetometers

Latest Space Weather News

Latest Solar Report | SWPC Space Weather Alerts | SolarHam News Archive

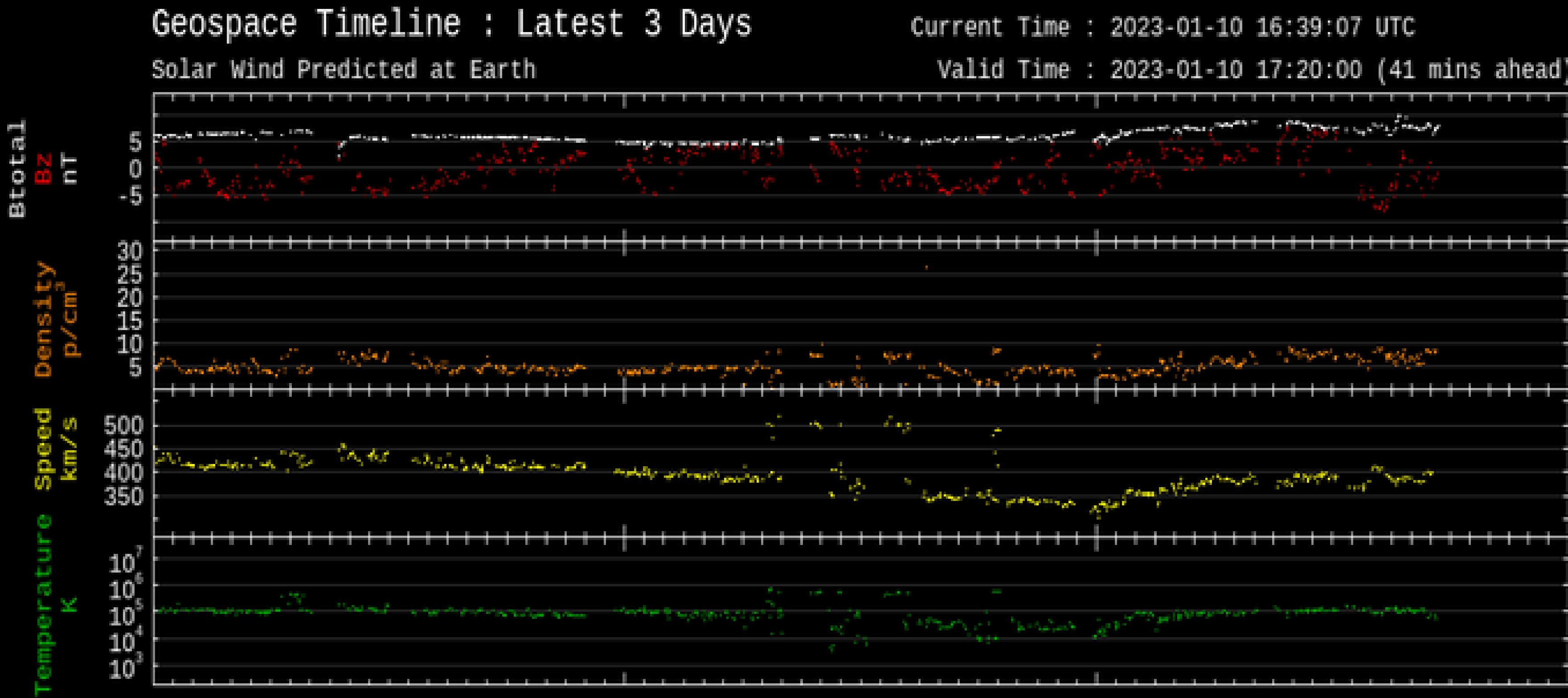
X1.9 Solar Flare

January 9, 2023 @ 19:45 UTC (UPDATED)

The second strongest solar flare of Cycle 25 in terms of peak X-Ray flux was just observed around AR 3184 at 18:50 UTC. This impulsive X1.9 flare does not look to be associated with a coronal mass ejection (CME) when

Real-Time Solar Wind (RTSW)

RTSW (SWPC) | Protons and Electrons | **CME Tracking**



Click to expand data

Propagation Illustrated by Propagation Predictions

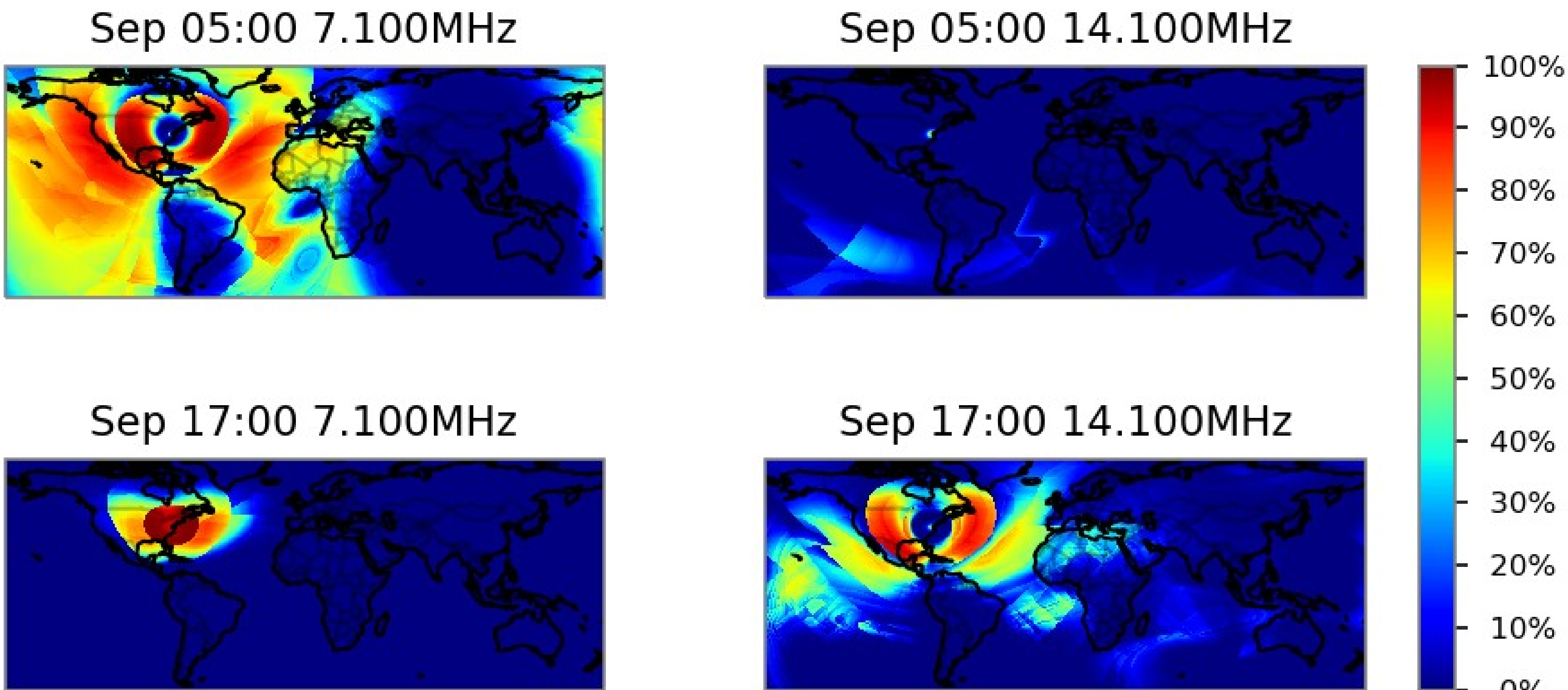
A note about the following plots:

- They are produced by propagation prediction programs
- They are not generated from a realistic amateur station, but are designed to illustrate propagation under certain conditions
- They are “Reliability” plots showing percentage of days per month that bands are open to location plotted. Reliabilty plots take more into account than straight signal strength or SNR plots so are better indicators of propagation

Following plot is of Low Sunspot Cycle Propagation

Midnight and Noon (local, not DST, 0500 and 1700 UTC)

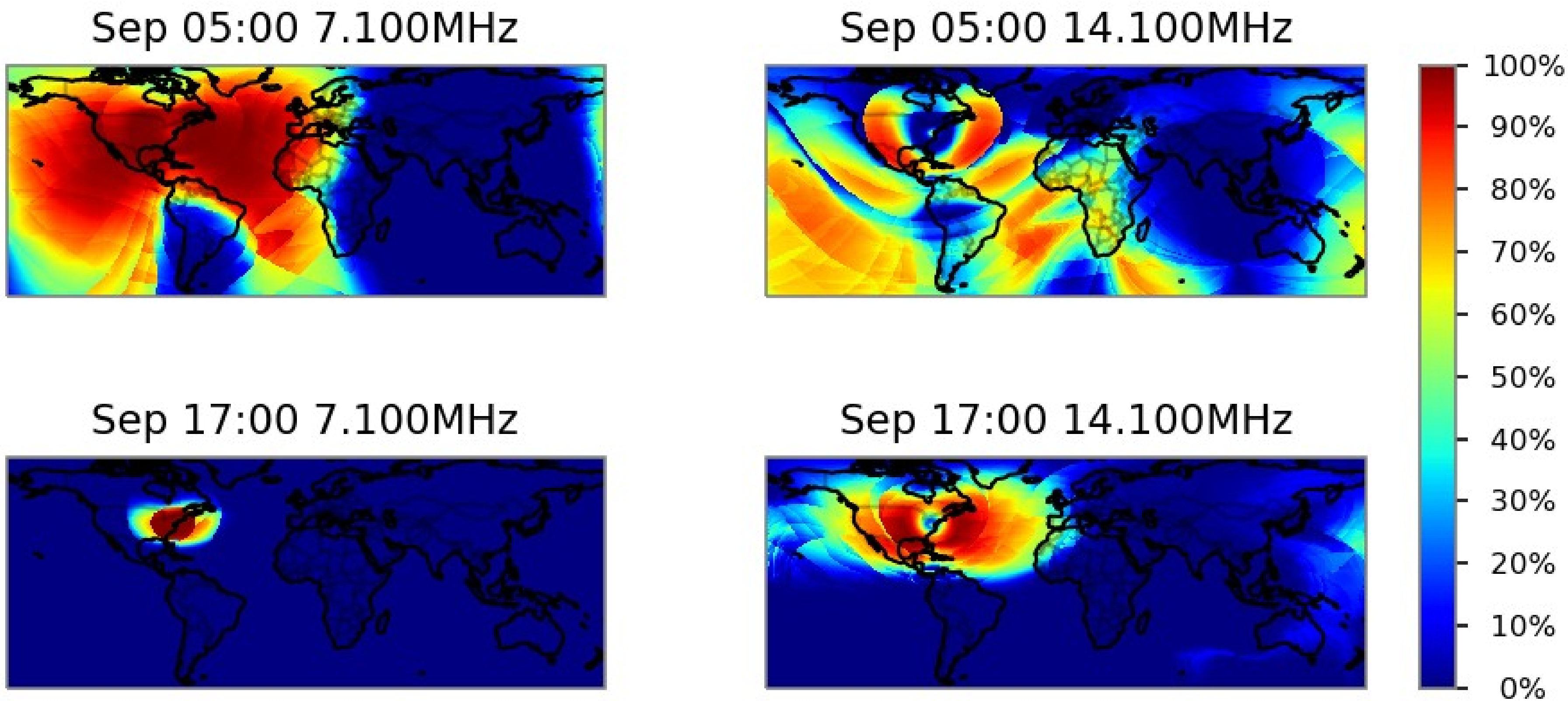
- 40M: Absorption Dominated
- 20M: Refraction Dominated


Sep 05:00 7.100MHz
Sep 05:00 14.100MHz
Sep 17:00 7.100MHz
Sep 17:00 14.100MHz
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

Following plot is of High Sunspot Cycle Propagation

Local Midnight and Noon (0500 and 1700 UTC)

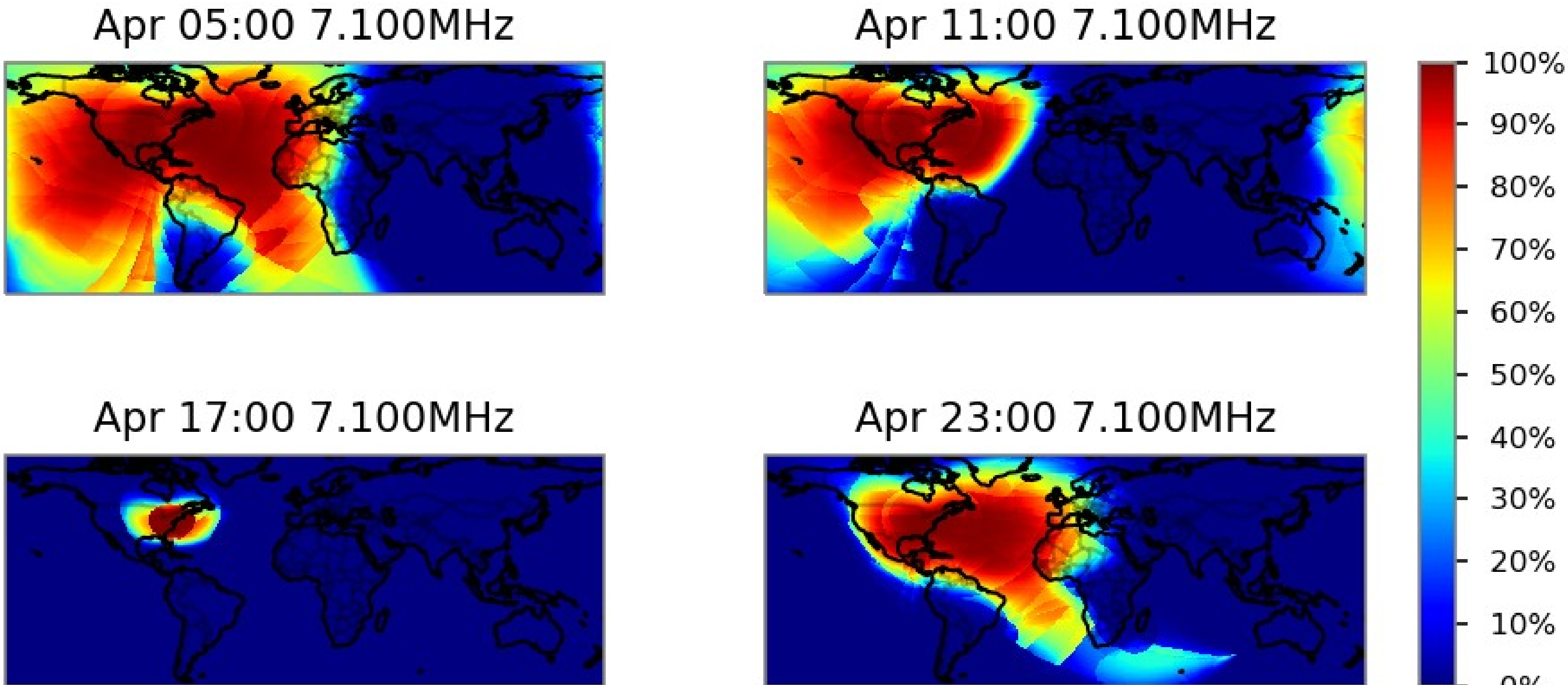
- 40M: Absorption Dominated
- 20M: Refraction Dominated



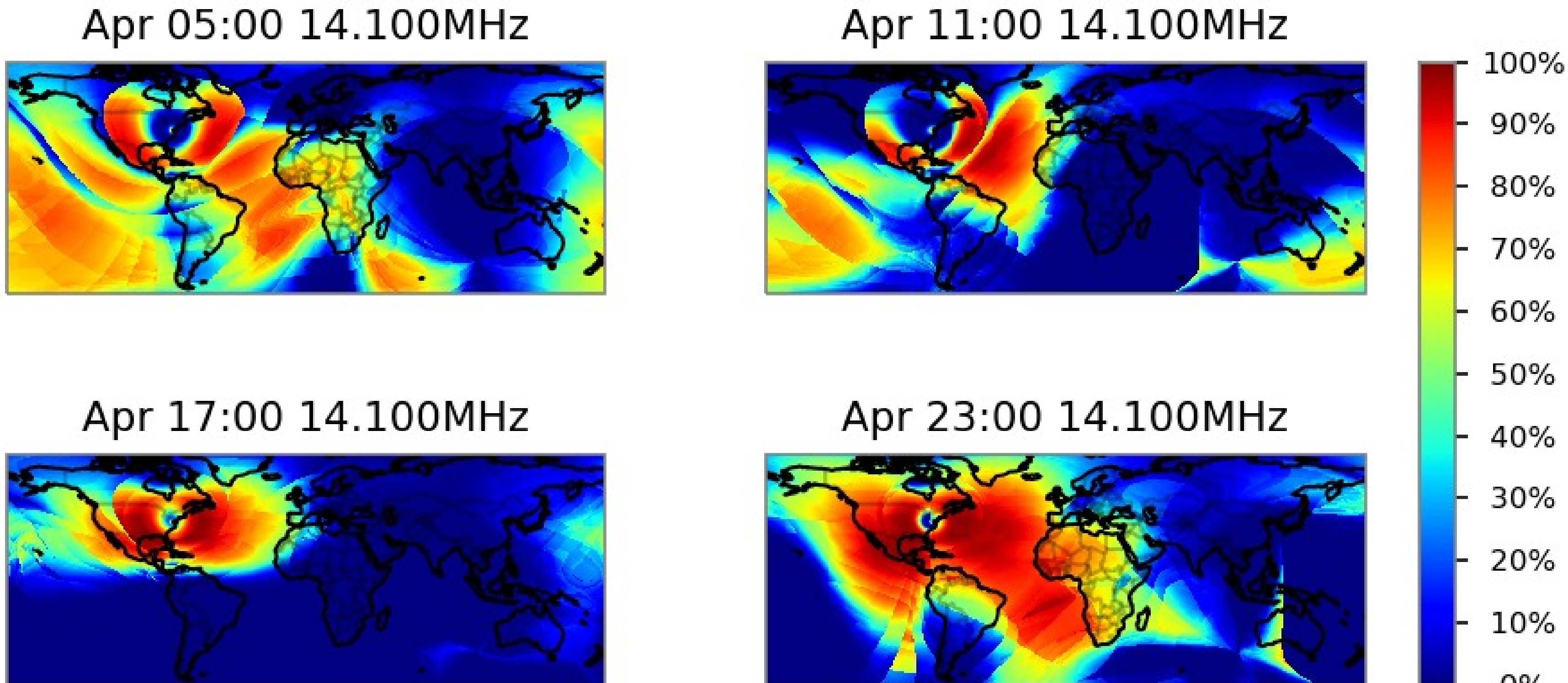
Sep 05:00 7.100MHz
Sep 05:00 14.100MHz
Sep 17:00 7.100MHz
Sep 17:00 14.100MHz
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

Following plots are of Present Sunspot Cycle Propagation

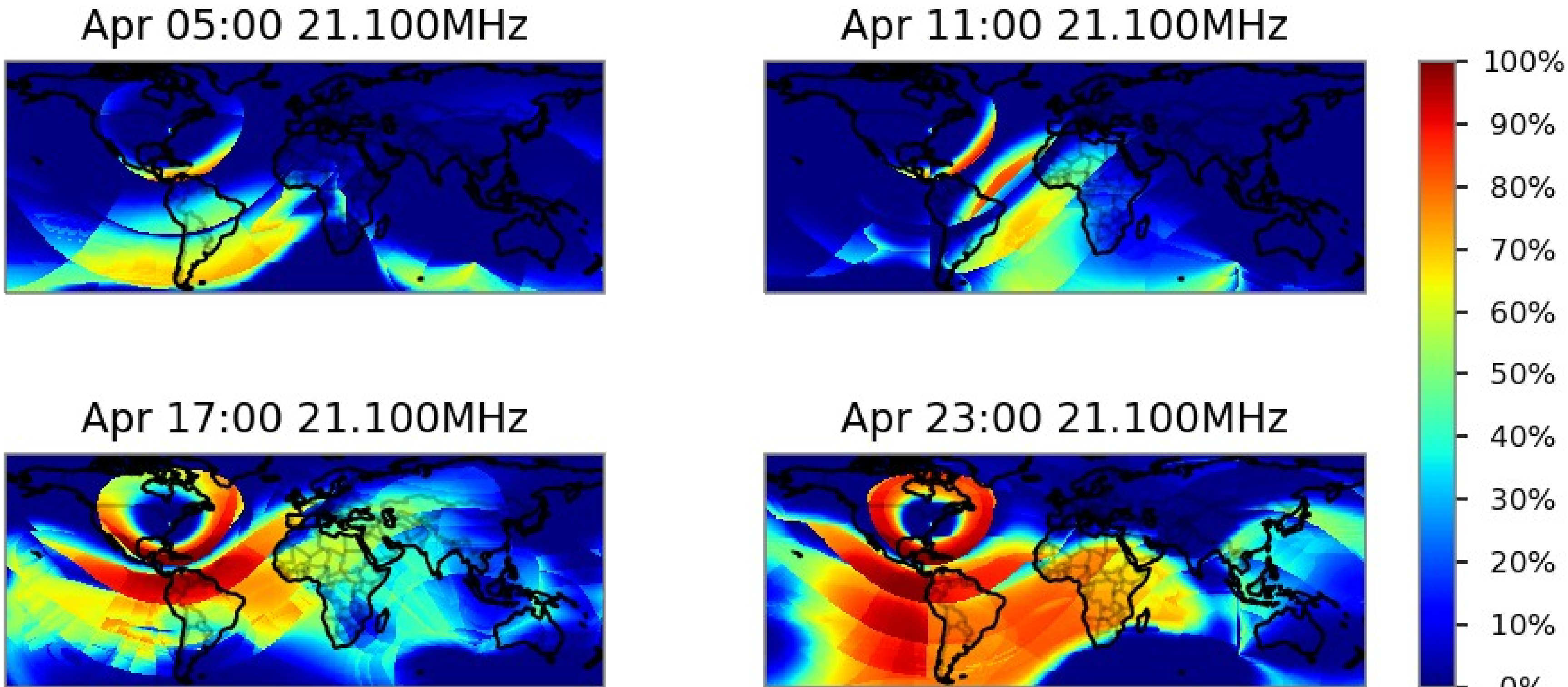
- 4 Times during day
  - 0500 UTC, 1100 UTC, 1700 UTC, and 2300 UTC
  - Midnight, 6 am, noon, and 6 pm Standard Time (not DST)
- Plots are 40M, 20M and 15M



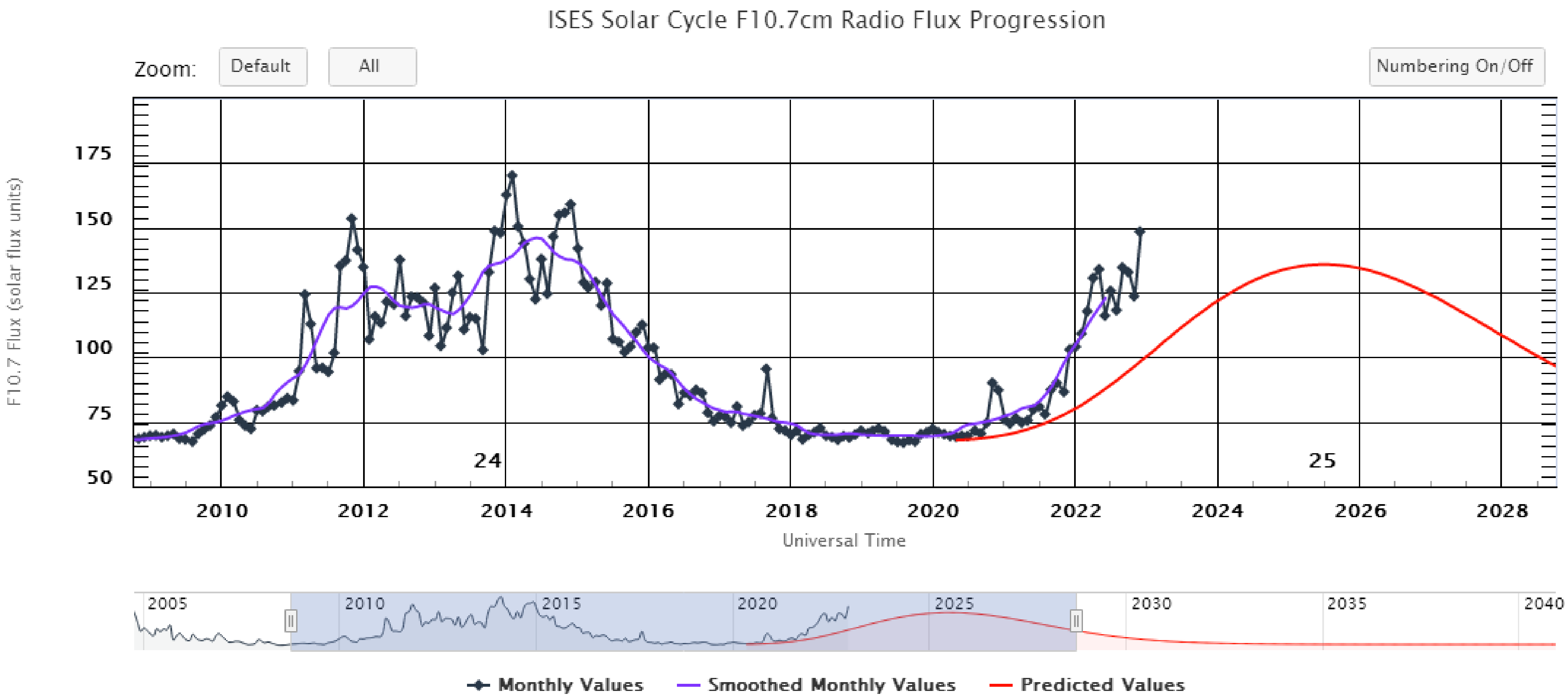
Apr 05:00 7.100MHz
Apr 11:00 7.100MHz
Apr 17:00 7.100MHz
Apr 23:00 7.100MHz
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%



Apr 05:00 14.100MHz
Apr 11:00 14.100MHz
Apr 17:00 14.100MHz
Apr 23:00 14.100MHz
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

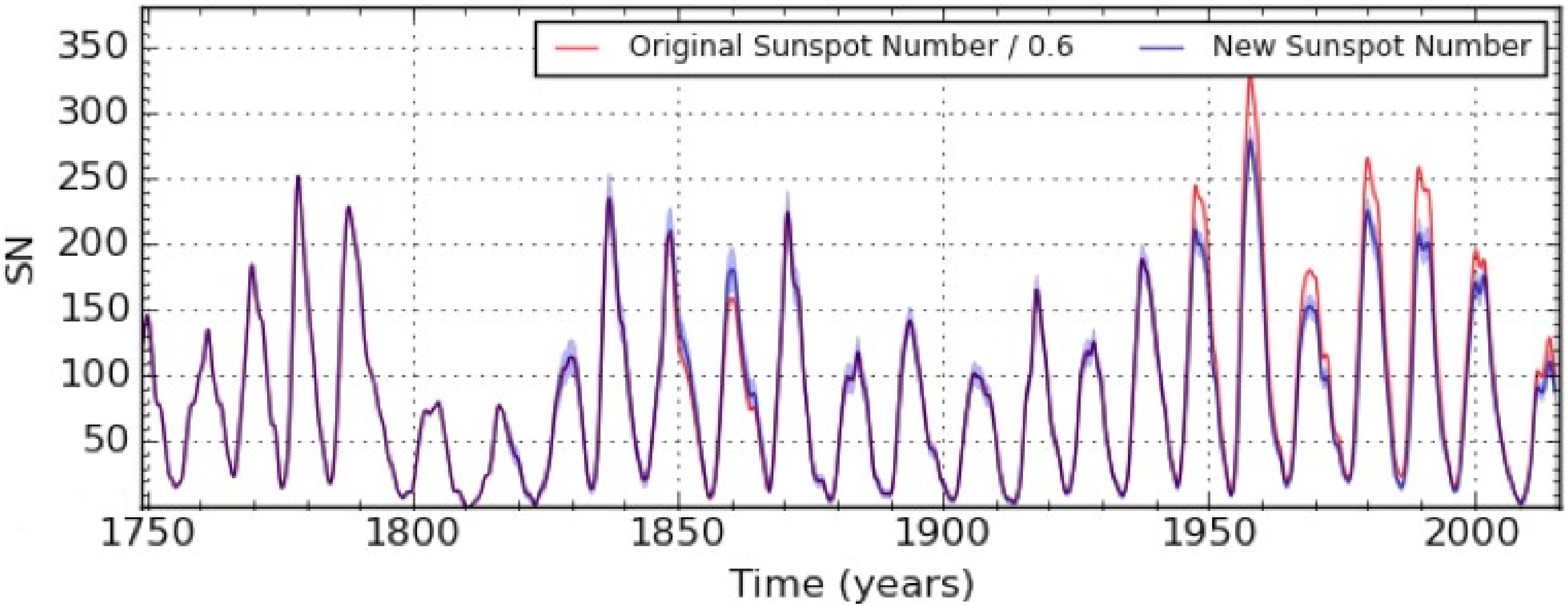

Apr 05:00 21.100MHz
Apr 11:00 21.100MHz
Apr 17:00 21.100MHz
Apr 23:00 21.100MHz
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

Where are we in the Sunspot Cycle?

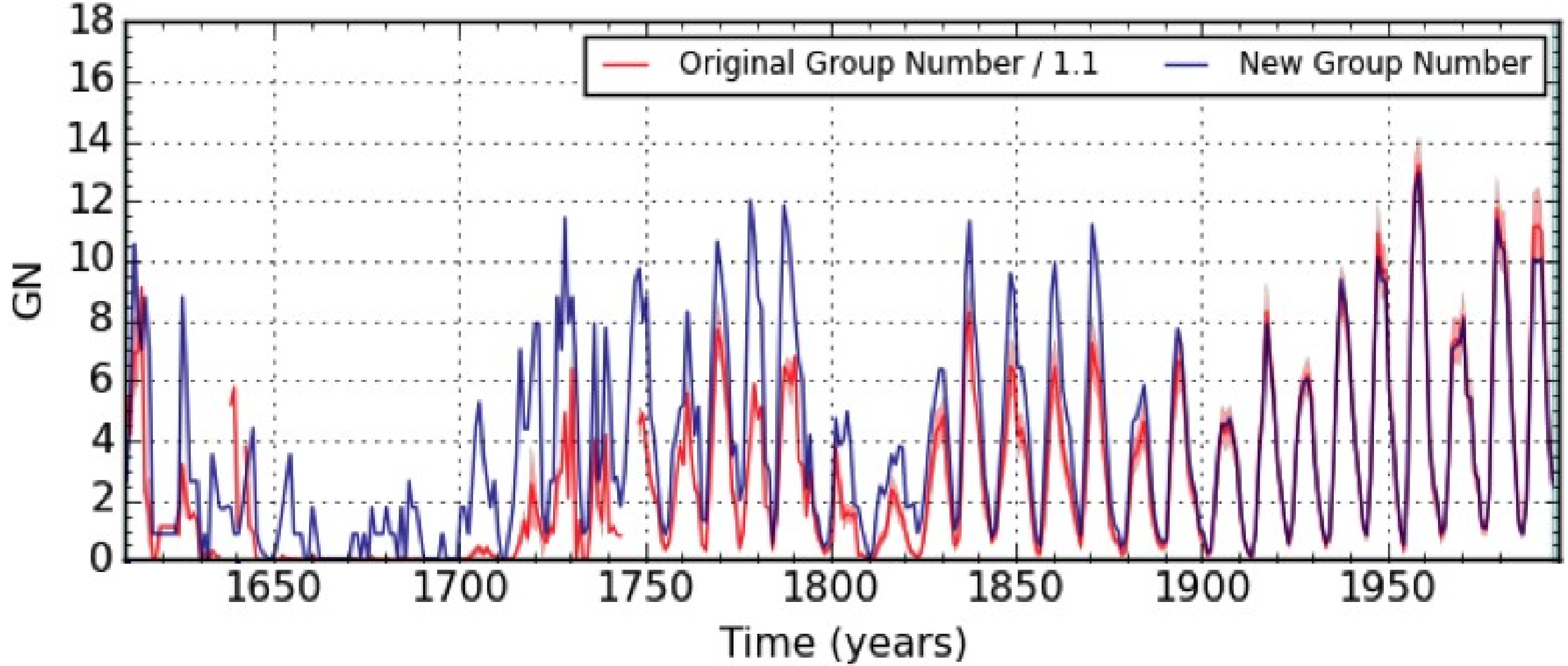

ISES Solar Cycle F10.7cm Radio Flux Progression
Zoom:
Default
All
Numbering On/Off
F10.7 Flux (solar flux units)
175
150
125
100
75
50
24
25
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
Universal Time
2005
2010
2015
2020
2025
2030
2035
2040
Monthly Values
Smoothed Monthly Values
Predicted Values

Following plots are of Historical Sunspot Cycles

- First Plot is SSN from 1750 when sunspot observations became reliable
  - Note 2 values: old method of sunspot number calculation and new method. New method approximately 1.5 times old number
- Propagation prediction programs are based on OLD method of calculating sunspot number!
- Second plot is reconstruction of cycles before 1750 using Sunspot Groups (better for early observations)
  - Again, old and new numbers indicated



Original Sunspot Number / 0.6
New Sunspot Number
SN
350
300
250
200
150
100
50
1750
1800
1850
1900
1950
2000
Time (years)


Original Group Number / 1.1
New Group Number
GN
Time (years)
0
2
4
6
8
10
12
14
16
18
1650
1700
1750
1800
1850
1900
1950