Space Weather

Solar Physics and Terrestrial High Frequency Electromagnetic Effects

(in layman's terms so a normal person – like me – can actually understand it)

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For Sandoval County ARES

16 April 2007

Ye Be Warned

- I have more material than I can possibly present in an hour
- I'll skim over a lot of the information
  (just the parts I don't understand myself)
- Ask questions along the way
  (I'll probably have to fake an answer)
- I have some videos to do the talking for me

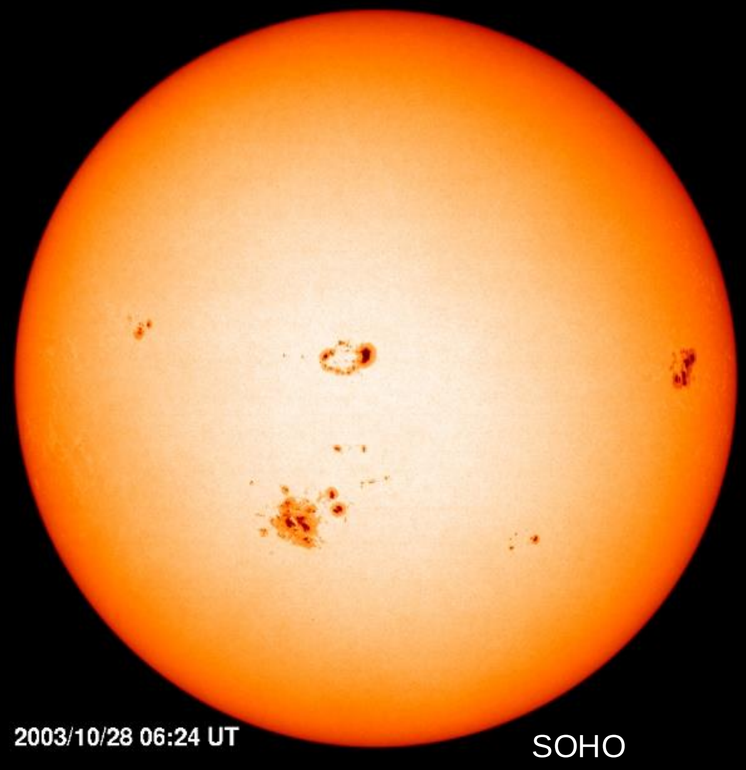
WARNING!!!
WARNING!!!
WARNING!!!
WARNING!!!

Let’s Meet Ol’ Sol

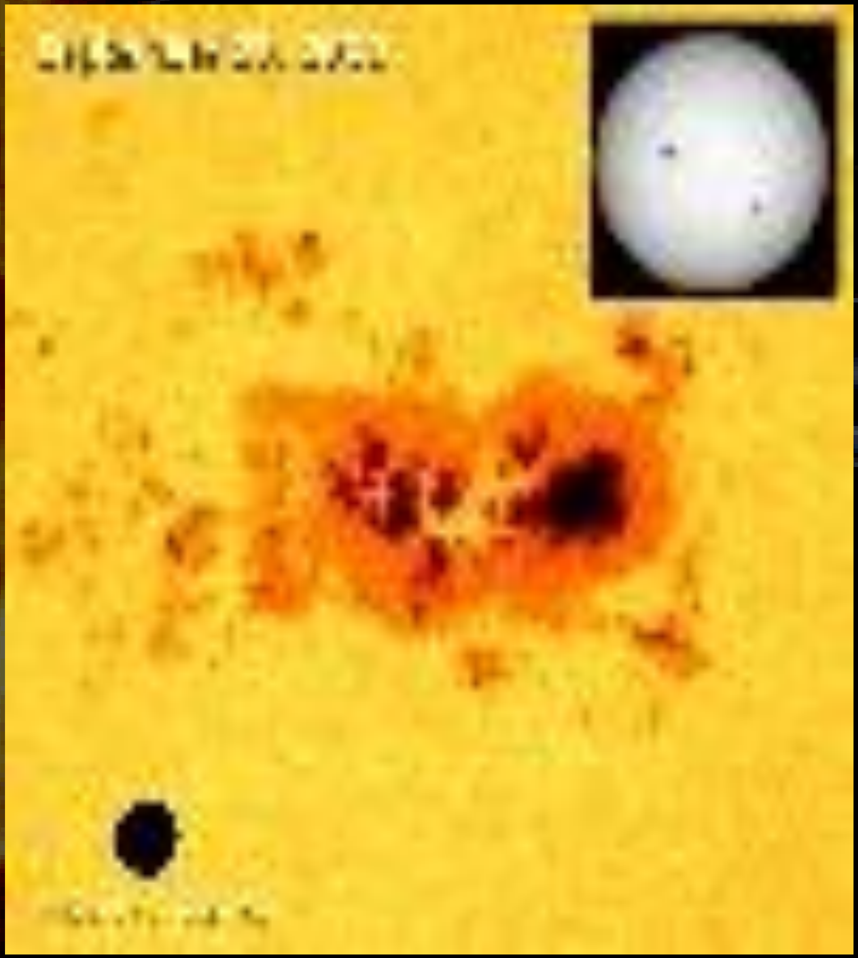
Master of the Solar System

Sol

- The Greeks called the Sun "Helios"; the Romans called it "Sol."
- The Sun is a class “G2V” medium sized, ordinary main-sequence star
- Third generation star, Fairly rich in metals



Characteristics



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- G2 implies that it has a surface temperature of approximately 5,500 K, giving it a white color
- The V (Roman five) indicates that the Sun is a main sequence star
  - generates its energy by nuclear fusion of hydrogen nuclei into helium
  - in a state of hydrostatic balance, neither contracting nor expanding over time
- Main sequence stars generate energy by nuclear fusion of hydrogen nuclei into helium
- There are more than 100 million G2 class stars in our galaxy
- Sun is actually brighter than 85% of the stars in the galaxy

Fun Sun Facts

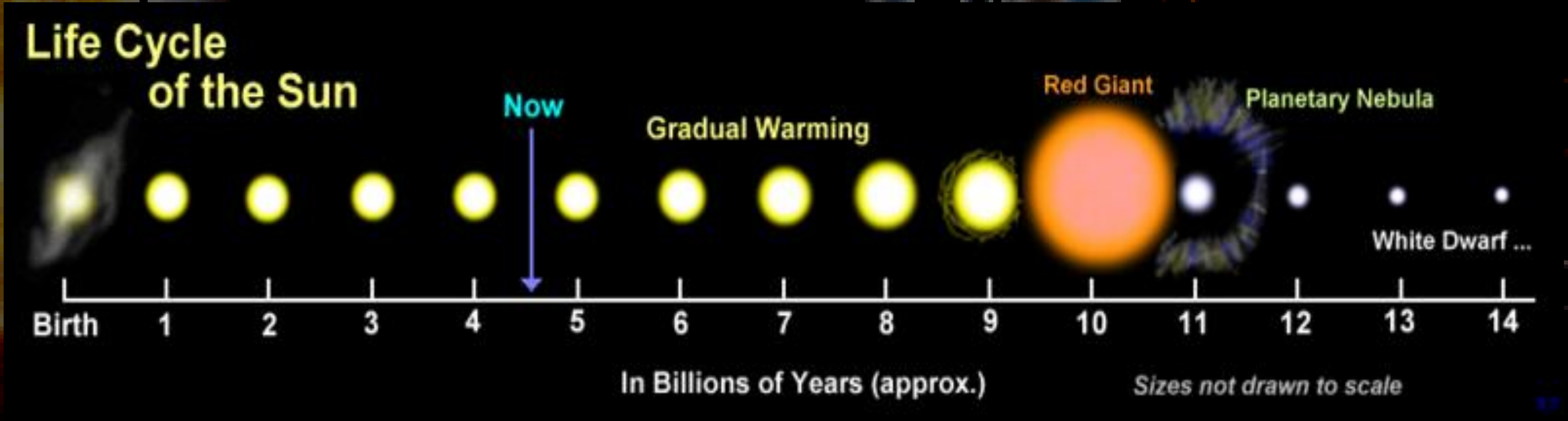
- Mean distance from Milky Way core ~2.5×10^{17} km (26,000 light-years)
- Velocity - 217 km/s orbit around the center of the Galaxy
- Mean diameter - 1.392×10^{6} km (109 Earths)
- Density - 1,408 kg/m^3
- Surface gravity - 273.95 m/s^2 (27.9 g)
- Temperature of corona – 5.5×10^{6} ºK (9.4×10^{6} ºF)
- Core temperature ~13.6×10^{6} ºK (24×10^{6} ºF)
- Luminosity – 3.827×10^{26} W
- Rotation period at equator – 25.38 days

- Mean distance from Earth 149.6×10^{8} km (92.95×10^{6} mi)
  - 8.31 minutes at the speed of light
- Photospheric composition (by mass)
  - Hydrogen 73.46 %
  - Helium 24.85 %
  - Oxygen 0.77 %
  - Carbon 0.29 %
  - Iron 0.16 %
  - Sulphur 0.12 %
  - Neon 0.12 %
  - Nitrogen 0.09 %
  - Silicon 0.07 %
  - Magnesium 0.05 %

Sun

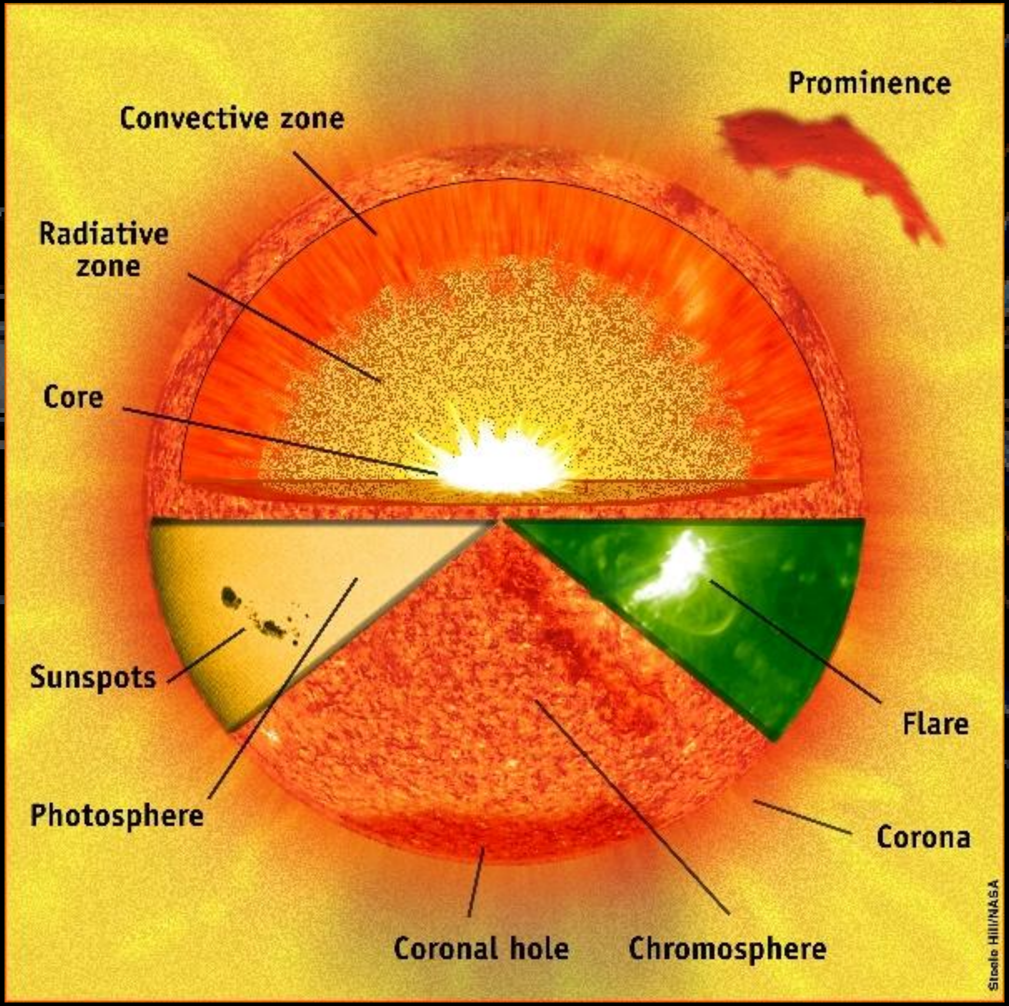
- Age - about 4.57 billion years
  - halfway through main-sequence evolution
  - Formation though have been triggered by shockwaves from a nearby supernova

(As an aside – you probably don't want to be anywhere near Earth in 4 to 5 billion years)



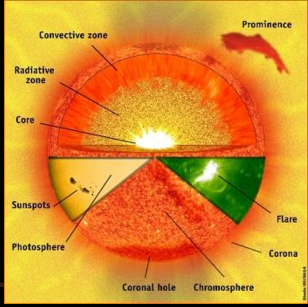
What Makes Sol Tick

Structure



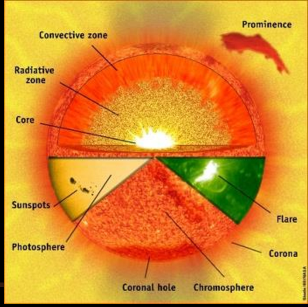
Prominence
Convective zone
Radiative zone
Core
Sunspots
Flare
Photosphere
Corona
Coronal hole
Chromosphere
Steele Hill/NASA

Core



- The core is the only location in the Sun that produces an appreciable amount of heat via fusion
- Energy is produced by nuclear fusion converting hydrogen into helium
- About 3.4×10^{38} hydrogen nuclei are converted into helium every second out of about ~8.9×10^{56} available in Sun
- Releases energy 383×10^{24} W or 9.15×10^{10} megatons of TNT per second
- Low rate of energy production in the Sun's core - about 0.3 μW/cm³, or about 6 μW/kg

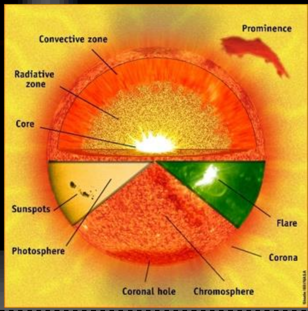
Core

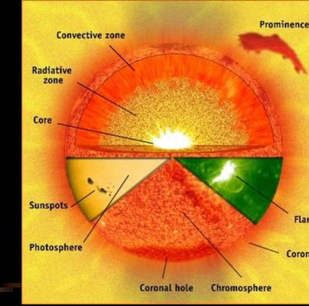


- The high-energy photons (gamma and X-rays) are absorbed in only few millimeters of solar plasma and then re-emitted again
- Estimates of the "photon travel time" to the surface range to as much as 50 million years
- Each gamma ray in the Sun's core is converted into several million visible light photons before escaping into space

Radiation zone

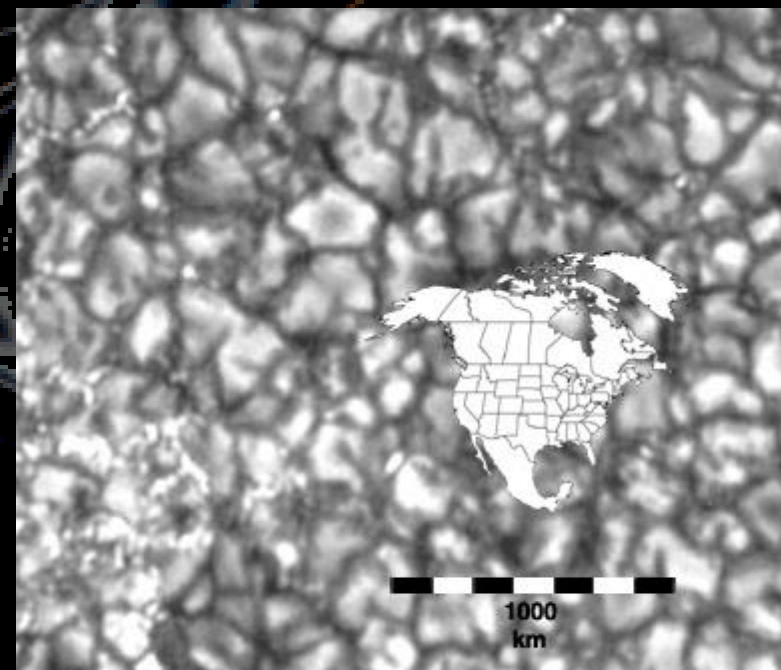
- From about 0.2 to about 0.7 solar radii
- Solar material is hot and dense
- No thermal convection
- Heat is transferred by radiation—ions of hydrogen and helium emit photons, which travel a brief distance before being reabsorbed by other ions
- Light in this layer takes millions of years to escape





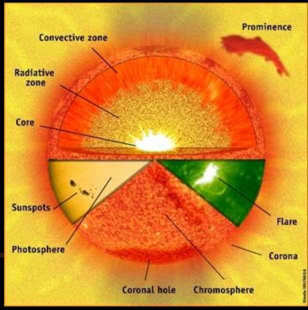
Convection zone

- From about 0.7 solar radii to the Sun's visible surface
- Thermal convection occurs as thermal columns carry hot material to the surface (photosphere) of the Sun (Think cauldron in a full rolling boil)
- Cool material plunges back downward to the base of the convection zone to be reheated
- Convective overshoot is thought to form the solar granulation on the surface



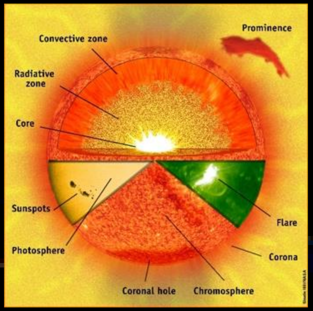
NASA/JPL

Photosphere



- The visible surface of the Sun
- Photosphere is actually tens to hundreds of kilometers thick
- Above the photosphere visible sunlight is free to propagate into space
- The visible light is produced as electrons react with hydrogen atoms to produce H^- ions

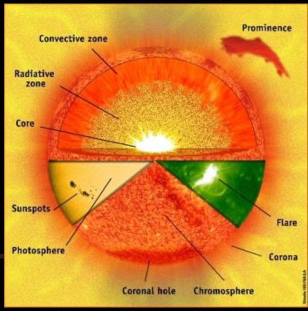
Atmosphere



- Parts of the Sun above the photosphere are referred to collectively as the *solar atmosphere*
  - comprise five principal zones:
  - the temperature minimum,
  - the chromosphere,
  - the transition region,
  - the corona, and
  - the heliosphere
- Heliosphere, the tenuous outer atmosphere of the Sun, extends past the orbit of Pluto to the heliopause

Photo by Luc Viatour: Chromosphere see during total Solar eclipse 1999, France

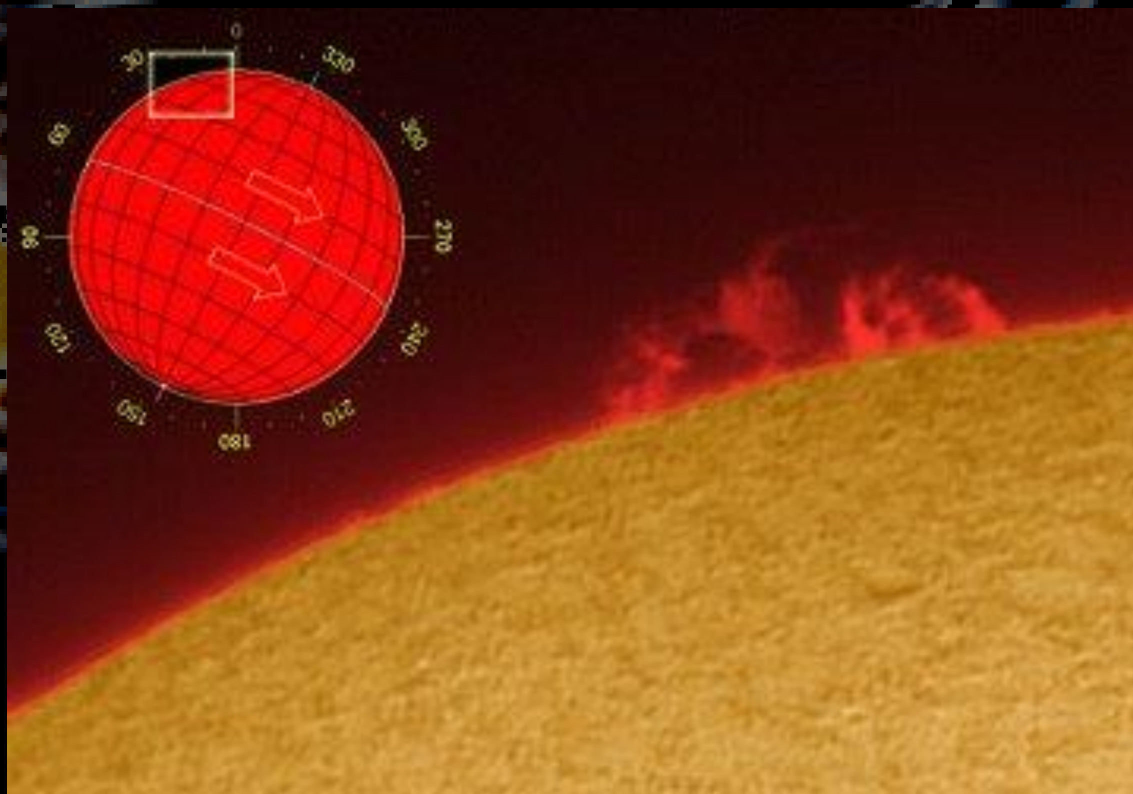
Atmosphere



- The chromosphere - thin layer about 2,000 km thick dominated by a spectrum of emission and absorption lines
- Above the chromosphere is a transition region in which the temperature rises rapidly from around 100,000 ºK to coronal temperatures closer to 10^6 ºK (1.8×10^6 ºF)
- The corona - the extended outer atmosphere of the Sun.
  - much larger in volume than the Sun
  - merges smoothly with the solar wind that fills the solar system and heliosphere

Sol’s Temper Tantrums

Or how to wreak some real havoc



Solar Prominences

Pete Lawrence of Selsey, UK

NASA
Animation

Solar Wind
A light breeze

- Stream of charged particles (plasma) ejected from the upper atmosphere of the Sun
- Mostly of high-energy electrons and protons (about 1 keV) that are able to escape the Sun's gravity
  - particles gain kinetic energy through a process that is not well understood – not all thermal process
  - 95% singly ionized hydrogen (protons)
  - 4% doubly ionized helium (alpha particles)
  - less than 0.5% other minor ions
    - Carbon, nitrogen, oxygen, neon, magnesium, silicon and iron are the dominant minor ions
- Near Earth, the velocity of the solar wind varies from 200 to 889 km/s - average is 450 km/s
- Solar wind ejects about 10^9 Kg/s of material (equivalent to a lump of Earth-density rock about 125 m across every second)

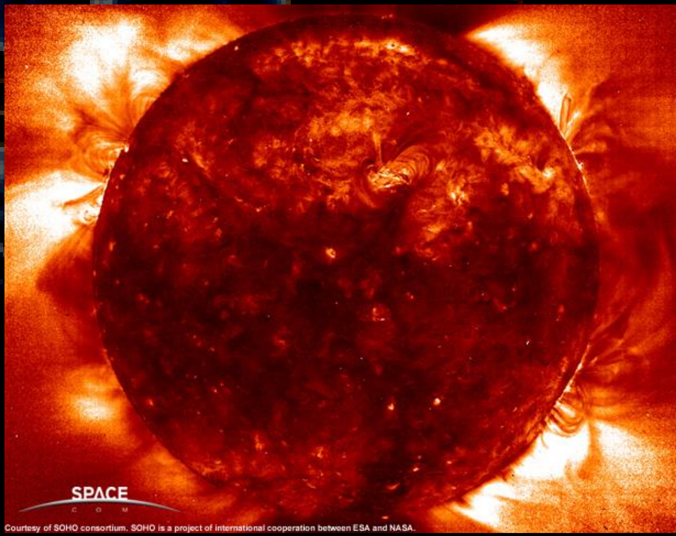
Coronal Holes
High Winds

- Regions where the corona is dark
- These features were discovered by X-ray telescopes
- Coronal holes are associated with "open" magnetic field lines and are often found at the Sun's poles
- Can occur anywhere on solar disk
- The high-speed solar wind is known to originate in coronal holes
- Can buffet the magnetosphere, cause auroras, and disrupt communications

SOHO Extreme-Ultraviolet Imaging Telescope, taken Oct. 19

Solar Flare
A Gale

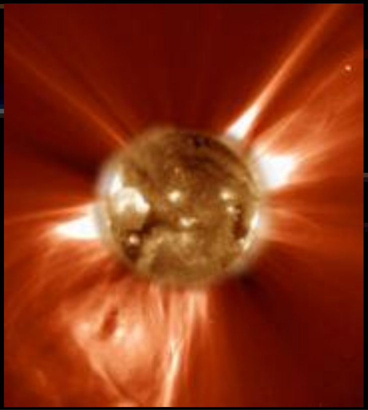
- A flare is defined as a sudden, rapid, and intense variation in brightness
- A solar flare occurs when magnetic energy that has built up in the solar atmosphere is suddenly released
- Radiation is emitted across virtually the entire electromagnetic spectrum, from radio waves to x-rays and gamma rays
- The amount of energy released = millions of 100-megaton hydrogen bombs exploding at the same time



SOHO image from Space.com

CME
Full Storm

- **Coronal mass ejection is** a plasma consisting primarily of electrons and protons (in addition to small quantities of heavier elements such as helium, oxygen, and iron), plus the entrained coronal magnetic field expelled from the surface of the Sun
- It carries its own magnetic field into space



Earths Defenses

- Nominally protected from the solar wind by our magnetic field
- Deflects charged particles
  - also serves as an electromagnetic energy transmission line to the Earth's upper atmosphere and ionosphere in the auroral zones
- We only notice the solar wind when it is strong enough for this energy to produce phenomena such as the aurora and geomagnetic storms

NASA

Magnetosphere

NASA Animation

- The Earth is a large magnet
- Our magnetic field is squashed by the solar wind
- Solar wind would singe our atmosphere if not for our magnetic field
- Flares and CME would do serious damage without it
- Can “ring” when CME strikes

Solar Wind Effects

- Mercury - stripped the atmosphere
- Venus – erodes atmosphere
  - space probes have discovered a comet-like tail that stretches back to the orbit of the Earth
- Earth - Geomagnetic storms
  - geomagnetic storms result when the pressure of plasmas contained inside the magnetosphere is sufficiently large to inflate and distort the geomagnetic field
  - can knock out power grids on Earth
  - ionizes the ionosphere
  - causes aurora
  - helps atmospheric matter to escape into the solar wind
- Mars – has removed up to a third of its original atmosphere
- Auroras on Earth, Jupiter, Saturn

Sunspots

- Flares erupt from sunspots
  - Caused by magnetic fields
  - magnetic flux tubes curl up like a rubber band and puncture the sun's surface
  - at the puncture points convection is inhibited
  - the energy flux from the sun's interior decreases cooling the surface

NASA Animation

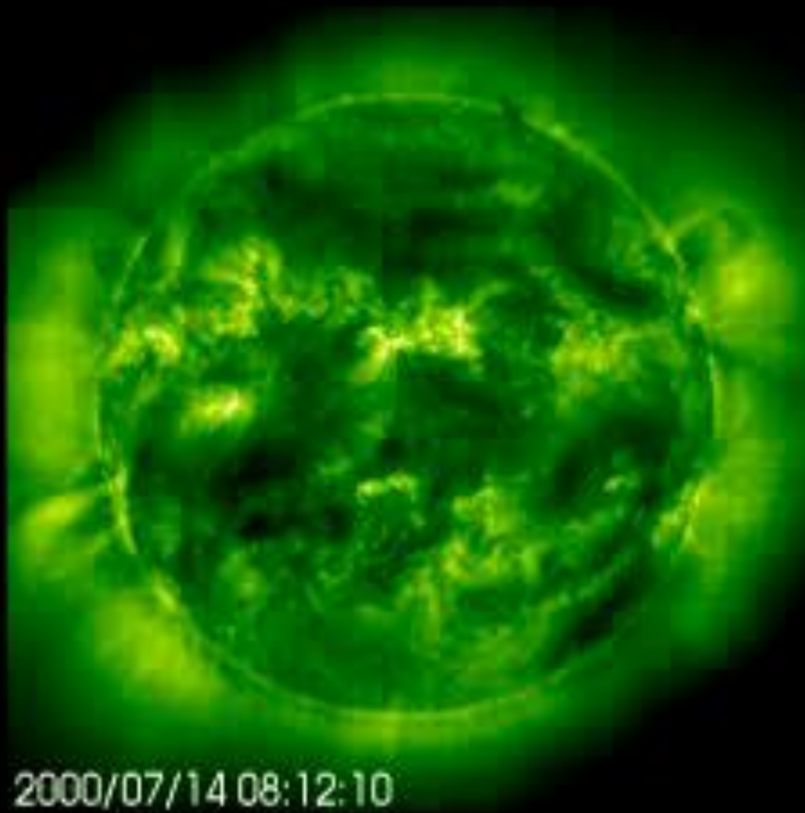
Solar Field Wrapping

- Sunspots are the visible counterparts of magnetic flux tubes in the convective zone of the sun that get "wound up" by differential rotation

NASA

Flares

- Caused by magnetic field lines snapping
- An explosion from the Sun
- Throws off solar material into space
  - X-rays, Gama Rays, and charged particles



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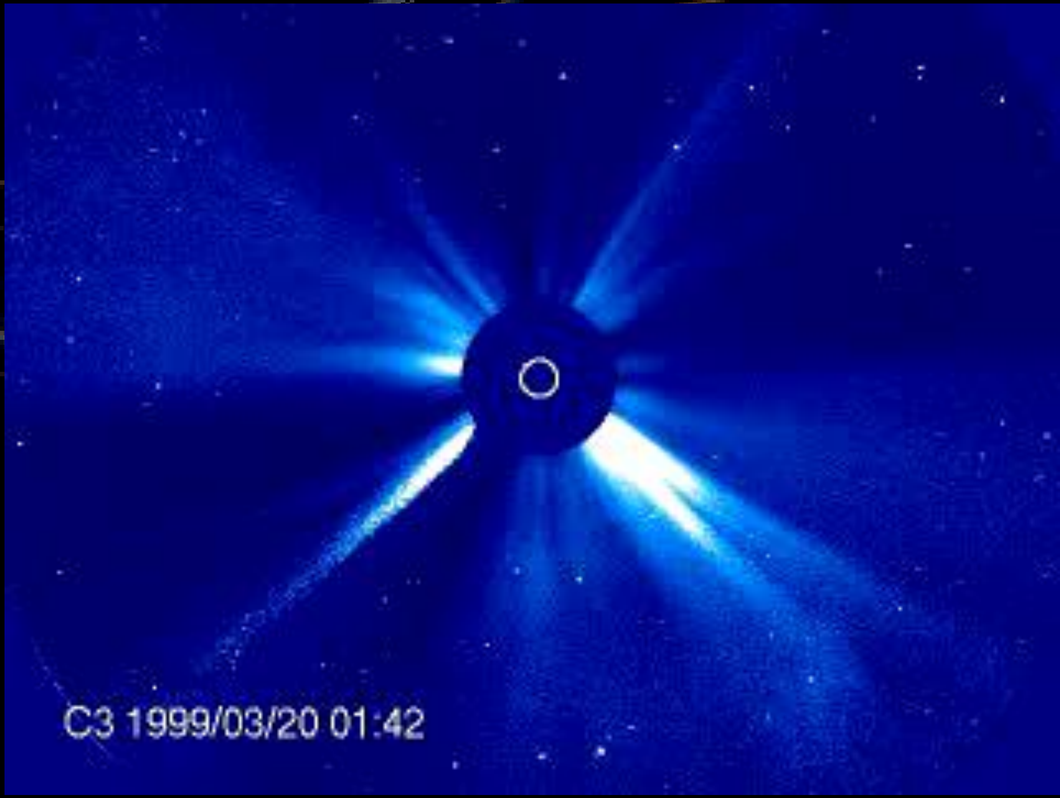
CMEs

- Flares produce Coronal Mass Ejections
- Large amounts of solar gas ejected
- Can cause havoc if the CME is directed toward Earth



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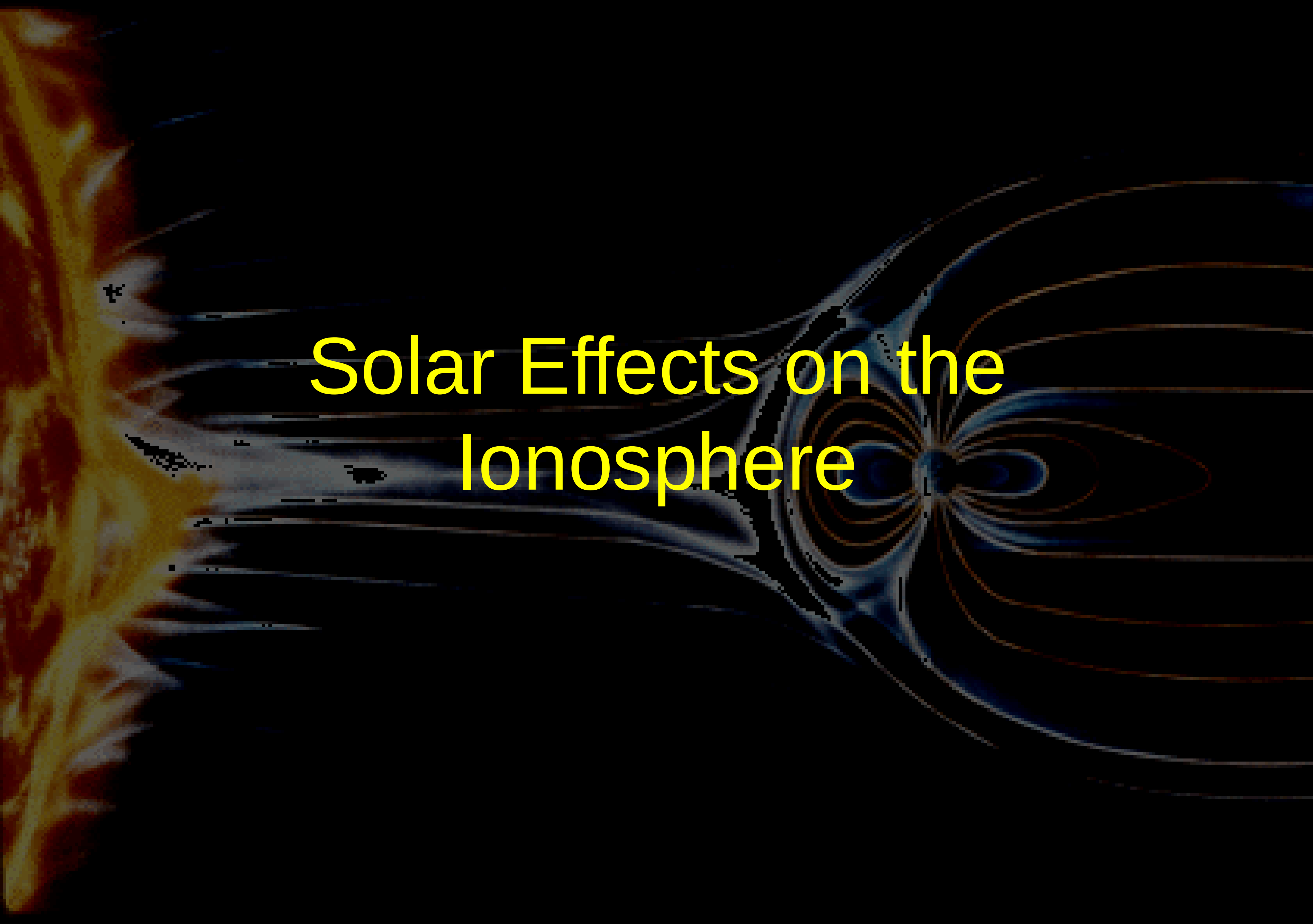
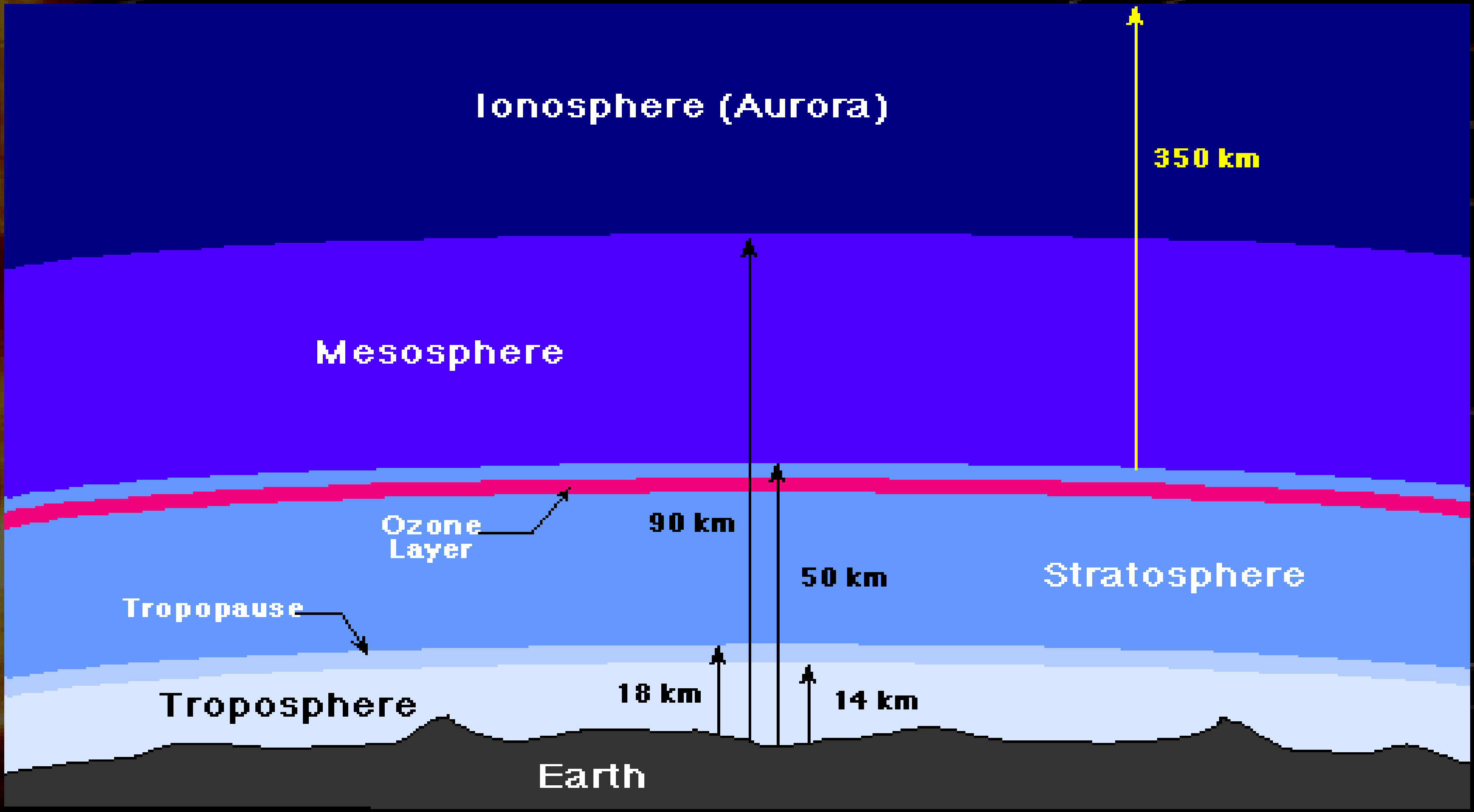
Why Care about Solar Flares?

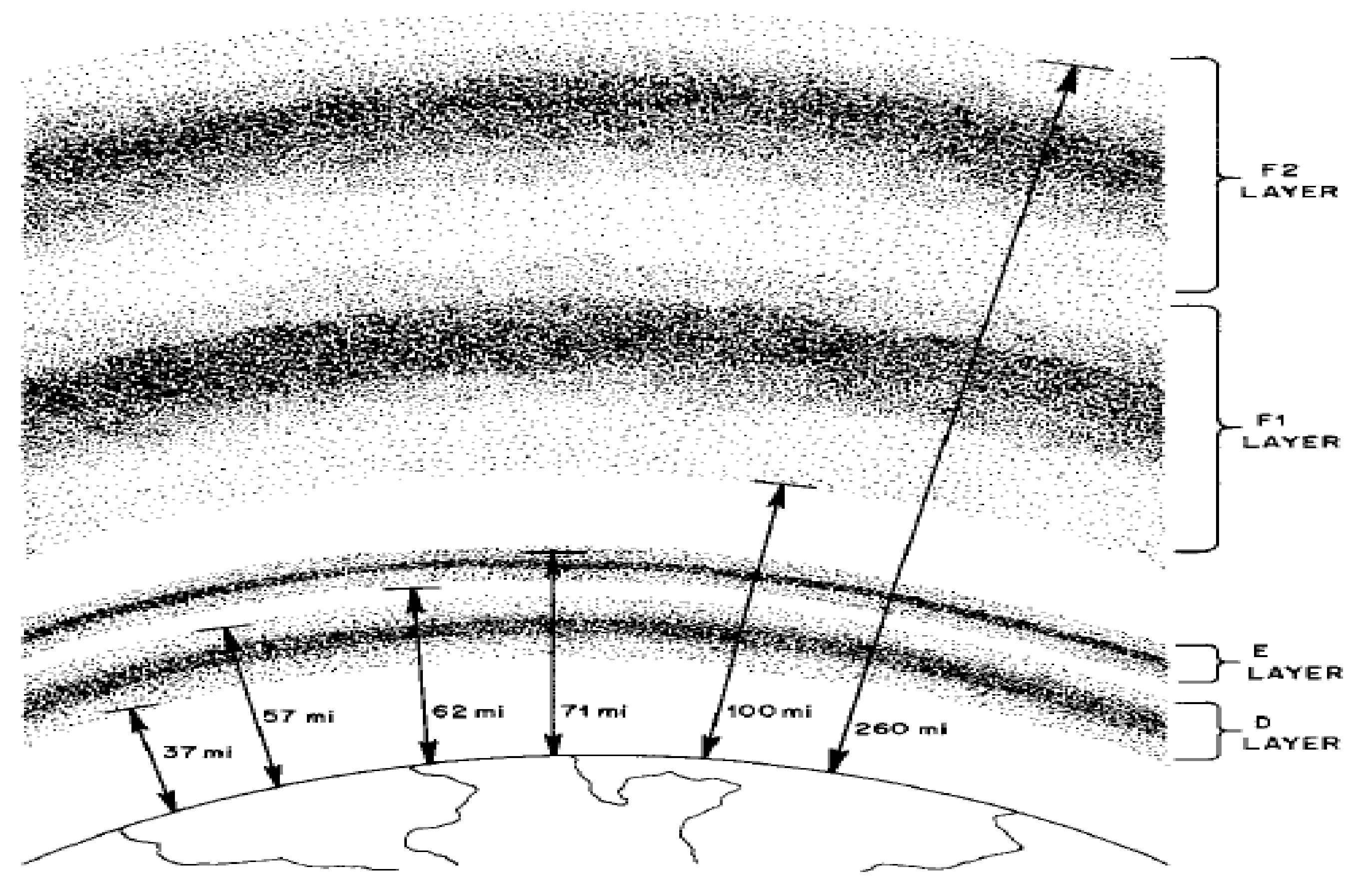
- **Solar flares have a direct effect on the Earth's atmosphere**
  - The Earth's upper atmosphere becomes more ionized and expands
  - Long distance radio signals can be disrupted by the resulting change in the Earth's ionosphere
  - A satellite's orbit around the Earth can be disturbed by the enhanced drag on the satellite from the expanded atmosphere
  - Satellites' electronic components can be damaged


Solar Effects on the
Ionosphere

The Atmosphere



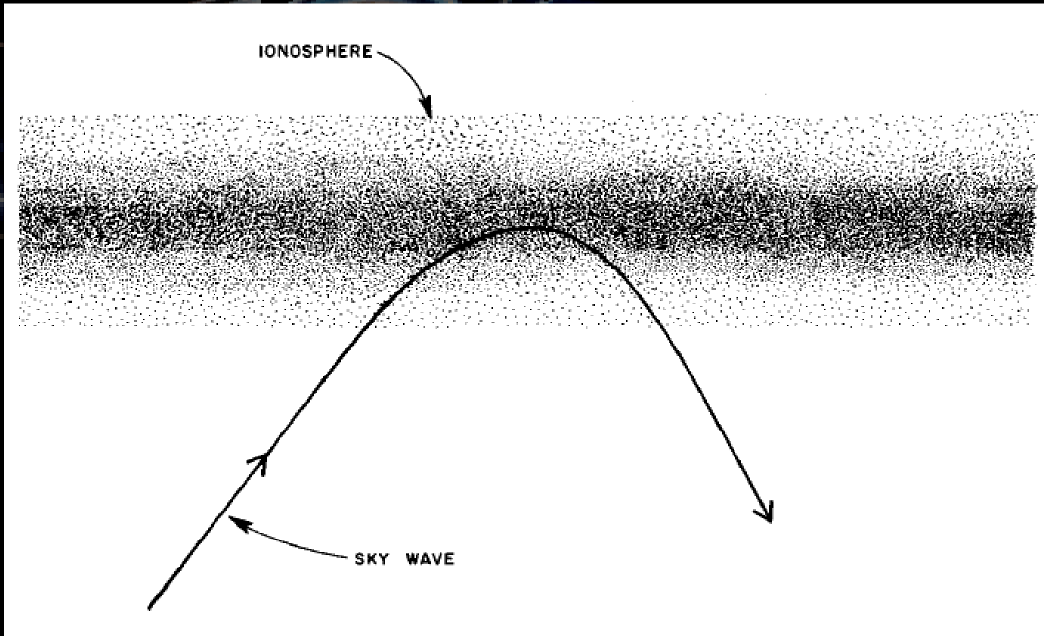
Ionosphere



ARRL Diagram

Skip from the E and F Layers

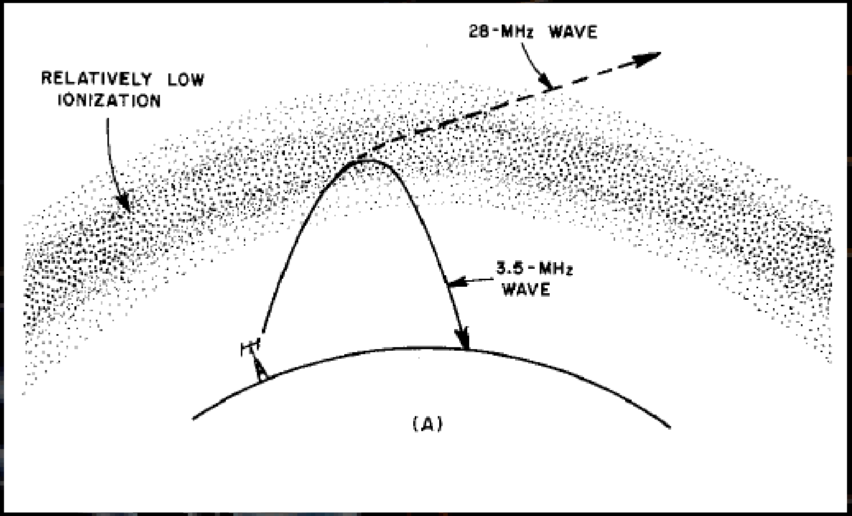
- Only the E and F layers will support skip
- The Ionosphere refracts (bends) a radio wave
- The amount of bending depends upon the number of ions in the layer

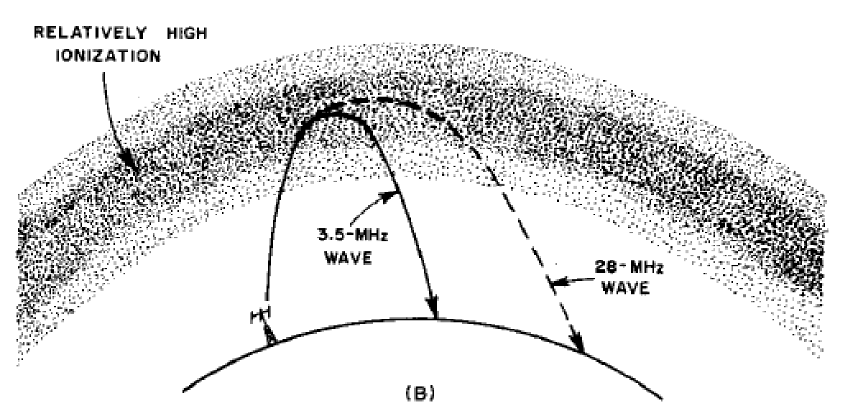


ARRL Diagram

Refraction vs. Frequency

- The amount of bending depends upon frequency and ionization
  - Low frequency waves bend easier than high frequencies
  - More ions bends the radio waves more





ARRL Diagrams

F-Layer

- **F-layer: Highest part of the ionosphere.**
  - The F-layer appears a few hours after sunset, when the F1- and F2-layers merge
  - Located between 250km and 500km above the Earth
  - Well into the night, this layer may reflect radio waves up to 20 MHZ (occasionally up to 25 MHZ)
  - Ions in the lower part of the F-layer are mainly NO^+ and are predominantly O^+ in the upper part.
  - Due to an unclear physical mechanism, the sunlight causes this F-layer to split into two distinct layers called the F_1- and F_2-layers.
  - Wavelengths of 100 to 1000 Angstroms (ultraviolet) ionizes the F region

F_1 -Layer

- **F1-layer:**
  - **Located between 150km and 200km in altitude**
  - **Occurs during daylight hours.**
  - **Maximum ionization is reached at midday**
  - **This layer merges with the F2-layer a few hours after sunset to reform the F-layer.**
  - **This layer reflects radio waves only up to about 10MHz**

F_2 - Layer

- **F2-layer: The important layer of the ionosphere**
  - **Located between 250km and 450km in altitude - occasional beyond 600km.**
  - **At the higher latitudes, this layer is located at lower altitudes.**
  - **This layer starts to develop about an hour before sunrise**
  - **Maximum ionization usually reached one hour after sunrise**
  - **Remains ionized until shortly after sunset.**
  - **F_2 can show great variability**
    - **peaks in the maximum ionization occurring at any time during the day**
    - **displays sensitivity to rapidly changing solar activity and major solar events**
  - **Contrasting all other layers of the ionosphere, the maximum ionization usually peaks during the winter months**
  - **Most importantly, F_2 can reflect radio waves up to 50MHz during a sunspot maximum and maximum usable frequencies can extend beyond 70MHz on rare occasions**

E-Layer

- **E-layer:**
  - **located just above the D-layer at an altitude of 90-150km**
  - **This layer can only reflect radio waves having frequencies less than 5MHz**
  - **It has a negative effect on frequencies above 5MHz due to the partial absorption**
  - **The E-layer develops shortly after sunrise and it disappears a few hours after sunset**
  - **The maximum ionization of this layer is reached around midday**
  - **Ions in this layer are mainly O_2^+.**
  - **10 to 100 Angstroms (soft X-rays) ionizes the E region**

Sporadic E-layer

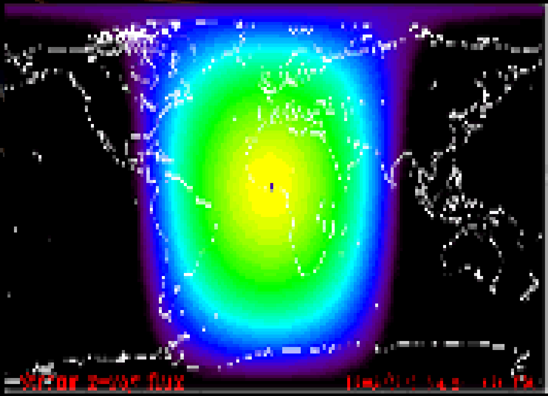
- E_s-layer: Also called the sporadic E-layer
  - Very different from the normal E-layer
  - Altitude varies between 80km and 120km
  - This part of the ionosphere is capable of reflecting radio waves well into the VHF-band (30-300 MHz) and even into the lower parts of the UHF-band (300-3000 MHz)
  - It is still a mystery as to how this layer actually develops
  - Appears mostly during the summer months and briefly at mid-winter
  - Peak occurs in the early summer
  - It can appear at any time of the day, with a preference for the late morning and early evening
  - May produce skip distances ranging from 400km to 2000km with unusually high signal strengths
  - Even with a fraction of a Watt and a small ground plane antenna, long range contacts are very common.

The D-Layer

- The D-layer is not our friend
- Appears at an altitude of 50-95km
- Ionized by the Sun only on daylight side
  - develops shortly after sunrise and disappears shortly after sunset
  - 1 to 10 Angstroms (hard X- rays) ionizes the D region
  - reaches maximum ionization when the sun is at its highest point in the sky
- D-layer is a radio sponge
  - When ionized it starts absorbing radio waves
  - particularly those frequencies below 7MHz
- Responsible the the complete absorption of sky waves from the 80m and 160m amateur bands as well as the AM broadcast band during the daytime hours
  - AM broadcast range is low in day
  - AM broadcast range is high at night
- Fortunately, ions can recombine to neutral atoms quickly when the Sun quiets down

Sun’s Influence on Ionization

- Solar x-rays and gamma rays ionize the ionosphere
- Solar wind can ionize at high latitudes – aurora
- Solar flares can highly ionize the ionosphere – D, E & F
  - D-layer can absorb everything



D-layer absorption during a flare - NOAA

Aurora

NASA

- Earth's Magnetic field funnels ions to poles
- Ions strike air molecules and produce light
- Colors depend upon altitude and what atoms are excited

Predicting RF Propagation

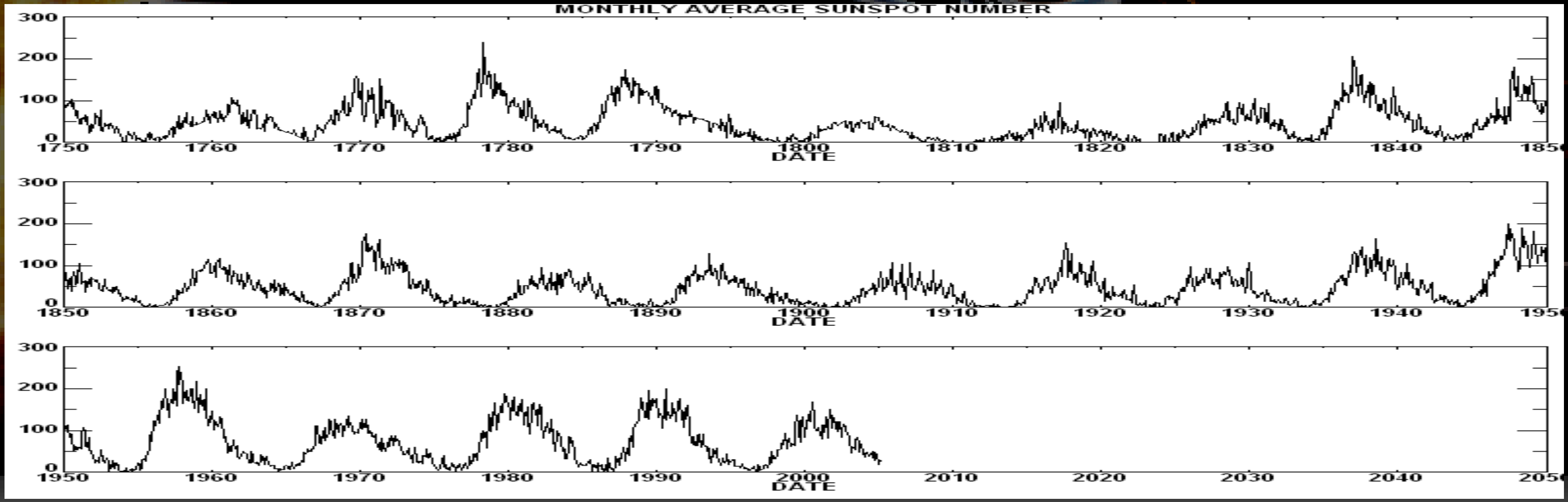
Watching the Sun

Solar Cycle

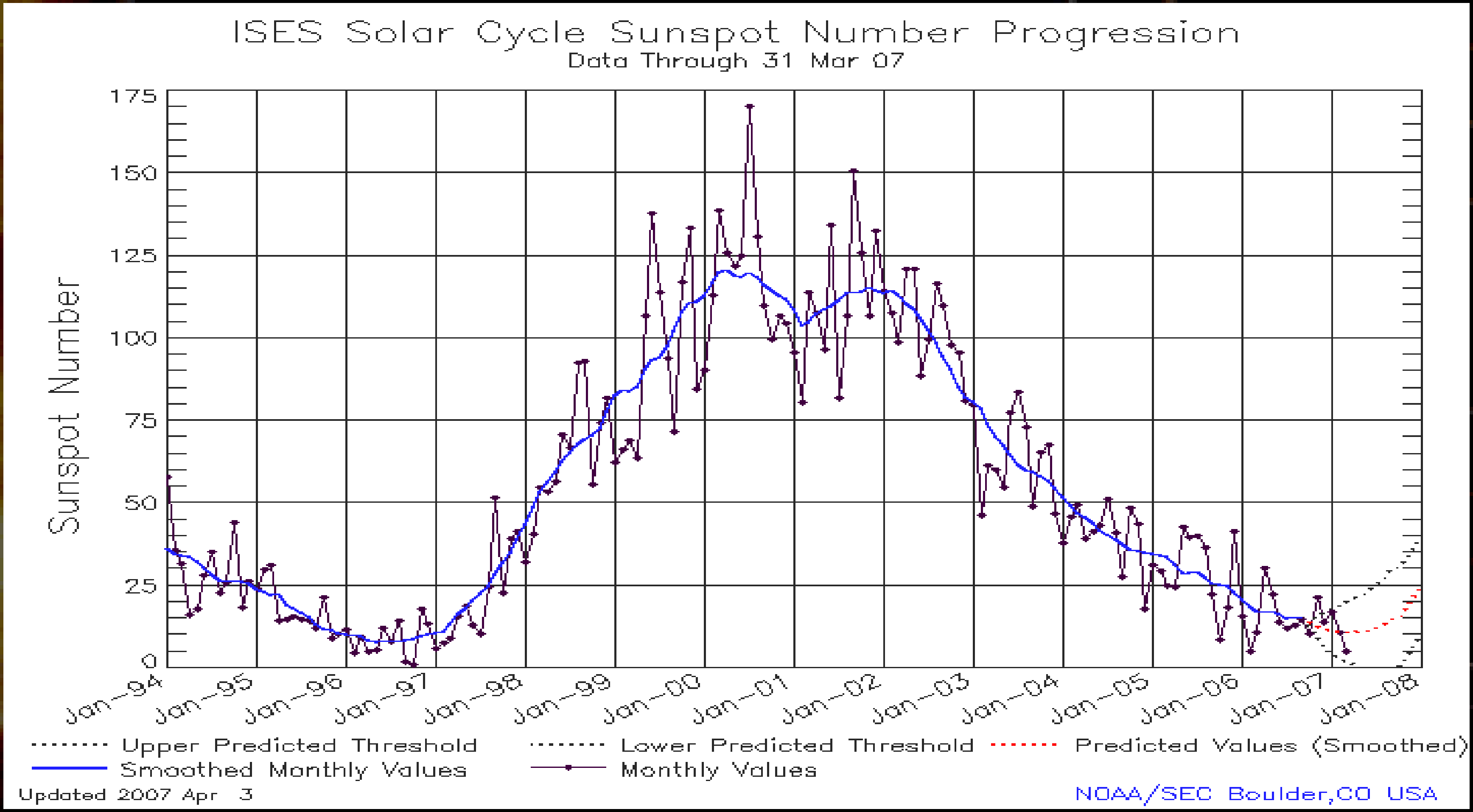
- Sunspot cycle is the eleven-year cycle of activity of the sun, discovered in 1843 by the German astronomer Heinrich Schwabe
- Cycles are determined by counting sunspots
- Solar cycle is not strictly 11 years long; it has been as short as 9 years and as long as 14 years in recently
- Last cycle – Cycle 23
  - solar maximum in 2001
- Next cycle – Cycle 24
  - minimum, the start of solar cycle, will or has occurred in 2007
  - predicted next maximum 2011 or 2012

Sun Spot Cycle

- Daily "Boulder Sunspot Number," is computed by the NOAA Space Environment Center using a formula devised by Rudolph Wolf in 1848
- The Boulder number (reported daily on SpaceWeather.com) is usually about 25% higher than the second official index, the "International Sunspot Number," published daily by the Sunspot Index Data Center in Belgium
- Wolf number: An observer computes a daily sunspot number by multiplying the number of groups seen by ten and then adding this product to his total count of individual spots



Current Cycle



Cause of the Cycle

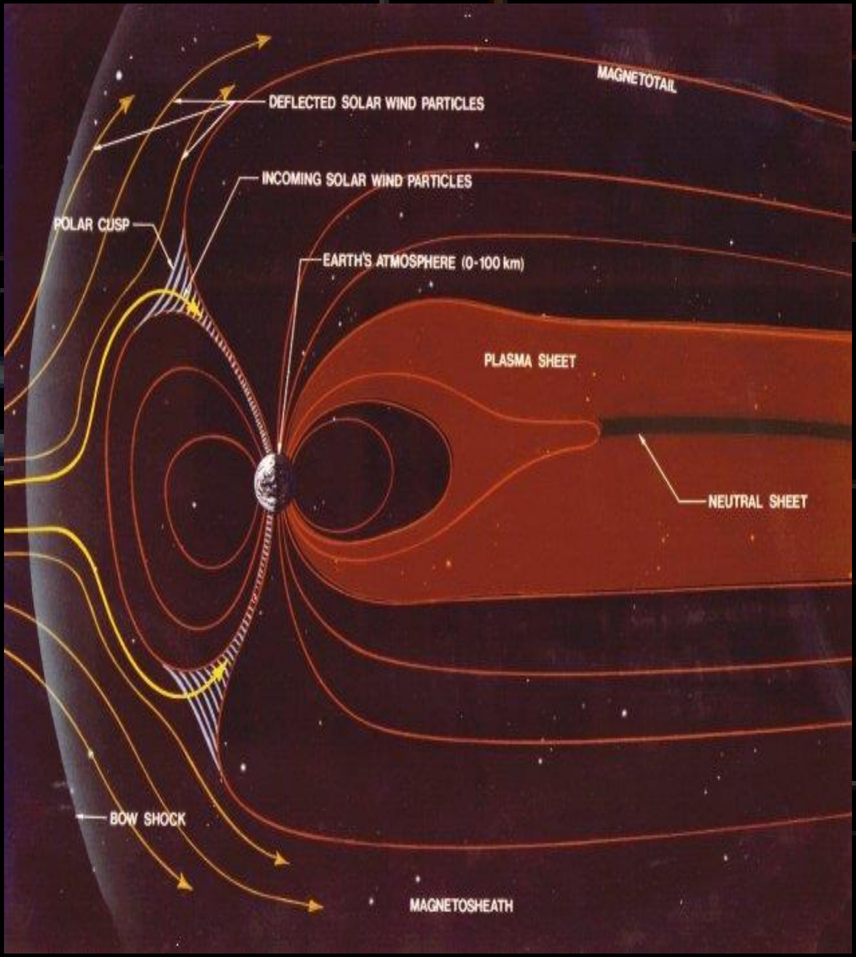
- Every 11 or so years, the Sun's magnetic poles reverse
  - north becomes south and south becomes north
  - as the field strength wanes, spots disappear
  - Near the end of a cycle, sunspots form with the opposite magnetic field
- Study suggests that CMEs play a central role in untangling field lines

Solar Flux

- Flux is measured using the noise generated by the Sun at 2800MHz (10.7cm)
- The flux value correlates well with F-layer ionization

Solar Wind

- Solar wind distorts the Earth's magnetic field
- Some charged particles can flow to poles – aurora
- Can cause the magnetic field to ring or oscillate
- On a "quiet" solar day the speed of this solar wind heading toward Earth averages about 400 km per second



Indices

- Variations in Earth's magnetic field are measured by magnetometers
- Two indices are computed:
  - K index
    - Range 0 to 9, 0 is quiet
  - A index
    - Uses the average of 8 K index readings
    - Range 0 to 400
- Generally an A index at or below 15 or a K index at or below 3 is best for HF propagation
- Elevated A and K indices reduce MUFs, but occasionally MUFs at low latitudes may increase when the A and K indices are elevated

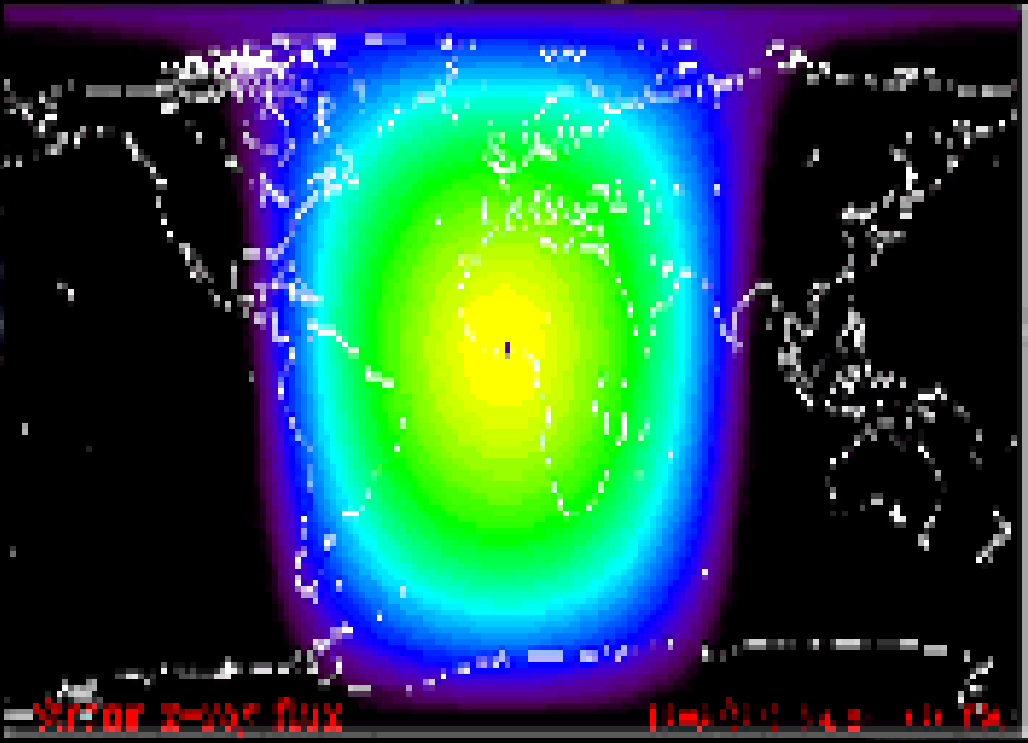
Index Ranges

K0=Inactive
K1=Very quiet
K2=Quiet
K3=Unsettled
K4=Active
K5=Minor storm
K6=Major storm
K7=Severe storm
K8=Very severe storm
K9=Extremely severe storm

A0 - A7 = quiet
A8 - A15 = unsettled
A16 - A29 = active
A30 - A49 = minor storm
A50 - A99 = major storm
A100 - A400 = severe storm

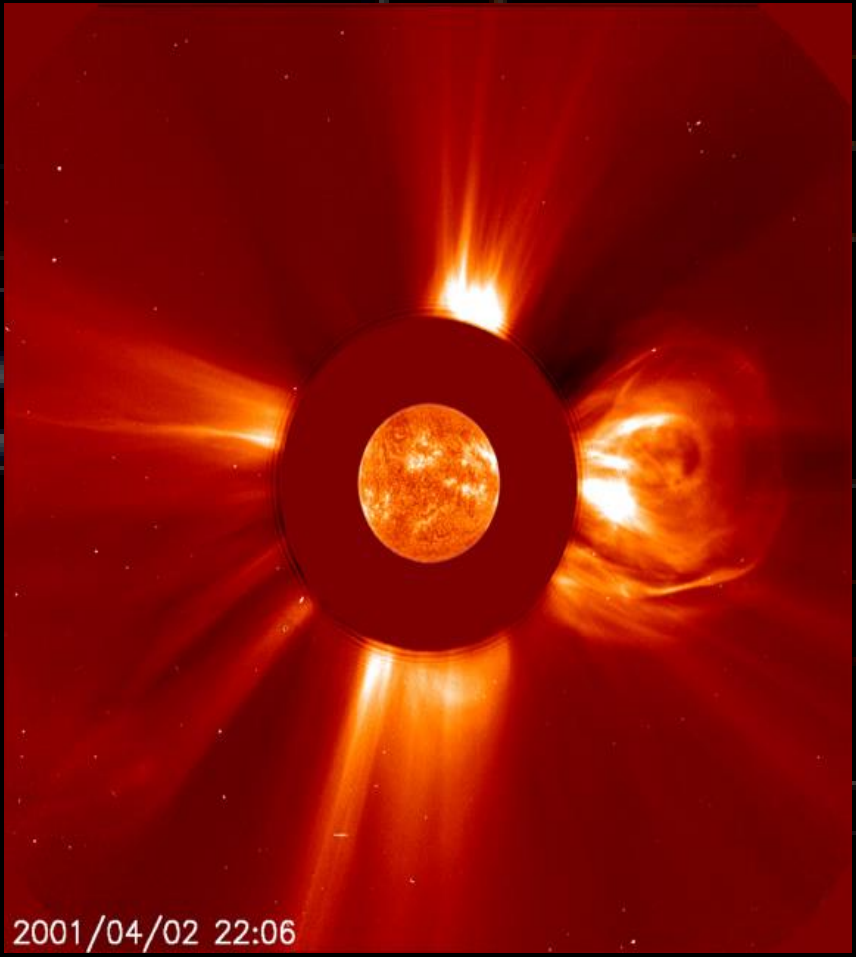
Flare Effects

- Most of the disturbances to propagation come from solar flares and CMEs
- Solar flares that affect propagation are called X-ray flares
  - wavelength 1 to 8 Angstrom range



Flare Classification

- Flares are classified as C, M, and X
  - C flares usually have minimal impact to propagation
  - M and X flares can have a progressively adverse impact to propagation
  - Largest recorded flare: 21:51 UT, Monday 2 April 2001, classified as at least an X20+



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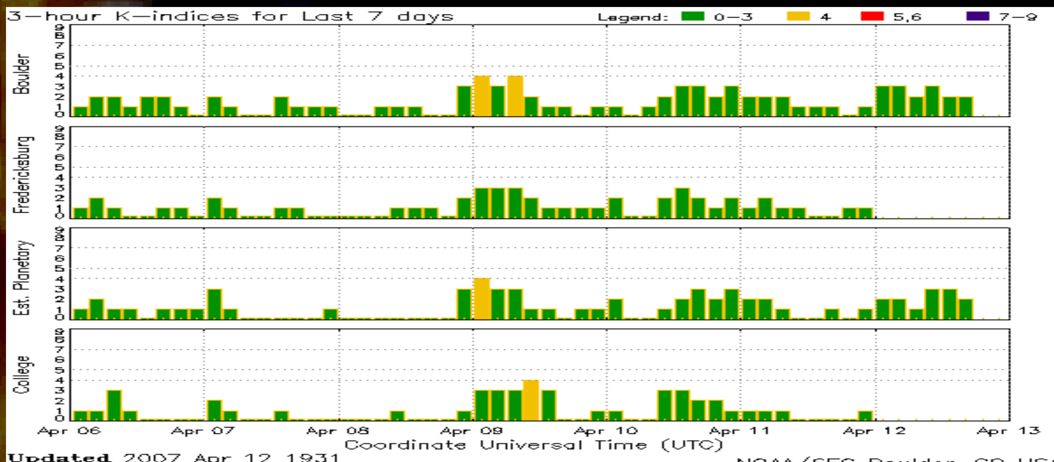
CMEs

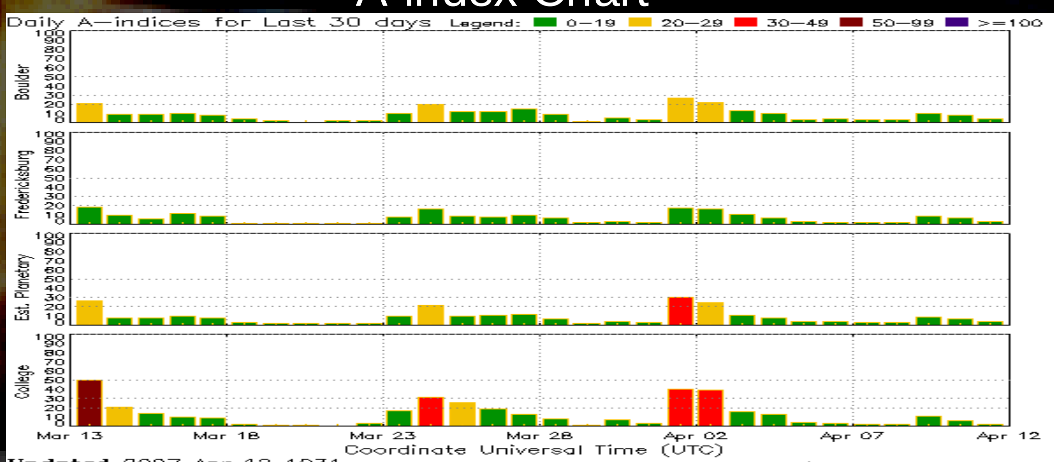
- A big shock wave heading toward Earth
- Average solar wind speed takes a dramatic jump
- If the polarity of the CME’s magnetic field is southward, can cause large variations in Earth's magnetic field
  - seen as an increase in the A and K indices

Data and Predictions

K-index Chart



A-index Chart



Prediction Chart

UTC Date	Radio Flux 10.7 cm	Planetary A Index	Largest Kp Index
2007 Apr 11	70	8	3
2007 Apr 12	70	10	3
2007 Apr 13	70	5	2
2007 Apr 14	70	5	2
2007 Apr 15	70	5	2
2007 Apr 16	75	5	2
2007 Apr 17	75	5	2
2007 Apr 18	75	5	2
2007 Apr 19	75	8	3
2007 Apr 20	75	20	5
2007 Apr 21	75	15	4
2007 Apr 22	75	10	3
2007 Apr 23	75	10	3
2007 Apr 24	75	8	3
2007 Apr 25	75	5	2
2007 Apr 26	75	5	2
2007 Apr 27	75	5	2
2007 Apr 28	70	25	5
2007 Apr 29	70	15	4
2007 Apr 30	70	10	3

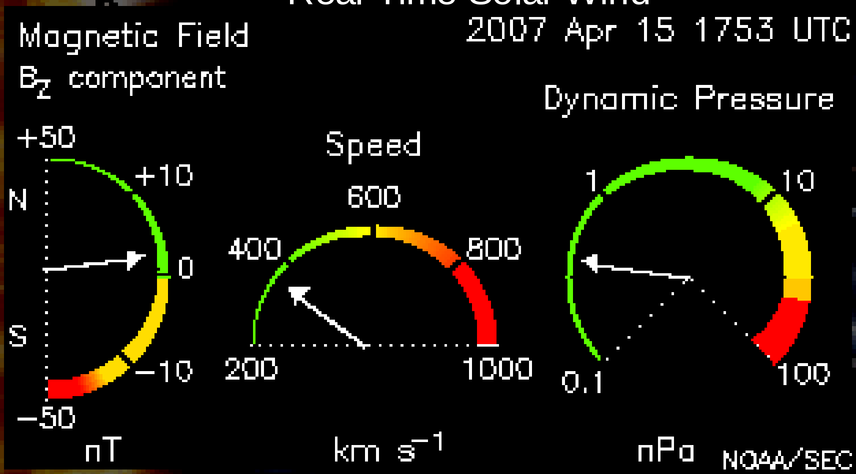
Where to Find Forecasts and Solar Information

- www.sec.noaa.gov/
  - www.sec.noaa.gov/radio/
- www.hamradio-online.com
  - www.hamradio-online.com/ipsdata.html
- www.spacew.com
- SpaceWeather.com
- WWV at 18 minutes past the hour every hour and WWVH at 45 minutes past the hour every hour
- Solar images: umbra.nascom.nasa.gov/images/latest.html

Monitoring the Sun

www.sec.noaa.gov/SWN/index.html

Real-Time Solar Wind



NOAA Scales Activity

Range 1 (minor) to 5 (extreme)

NOAA Scale	Past 24 hours	Current
Geomagnetic Storms	none	none
Solar Radiation Storms	none	none
Radio Blackouts	none	none

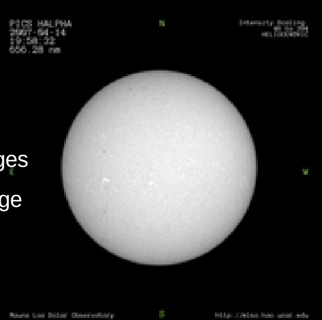
Latest Alert: April 10 1151 UTC ALERT: Electron 2MeV Integral Flux exceeded 1000pfu

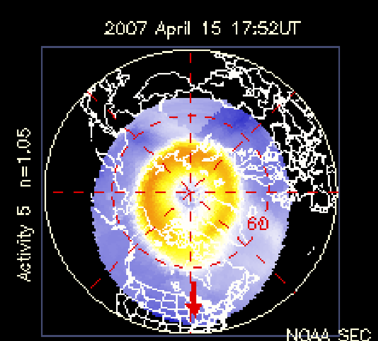
Last Advisory Bulletin: None in last 7 days.

No GOES 12 SXI Images

Latest Mauna Loa Image

14 Apr 2007

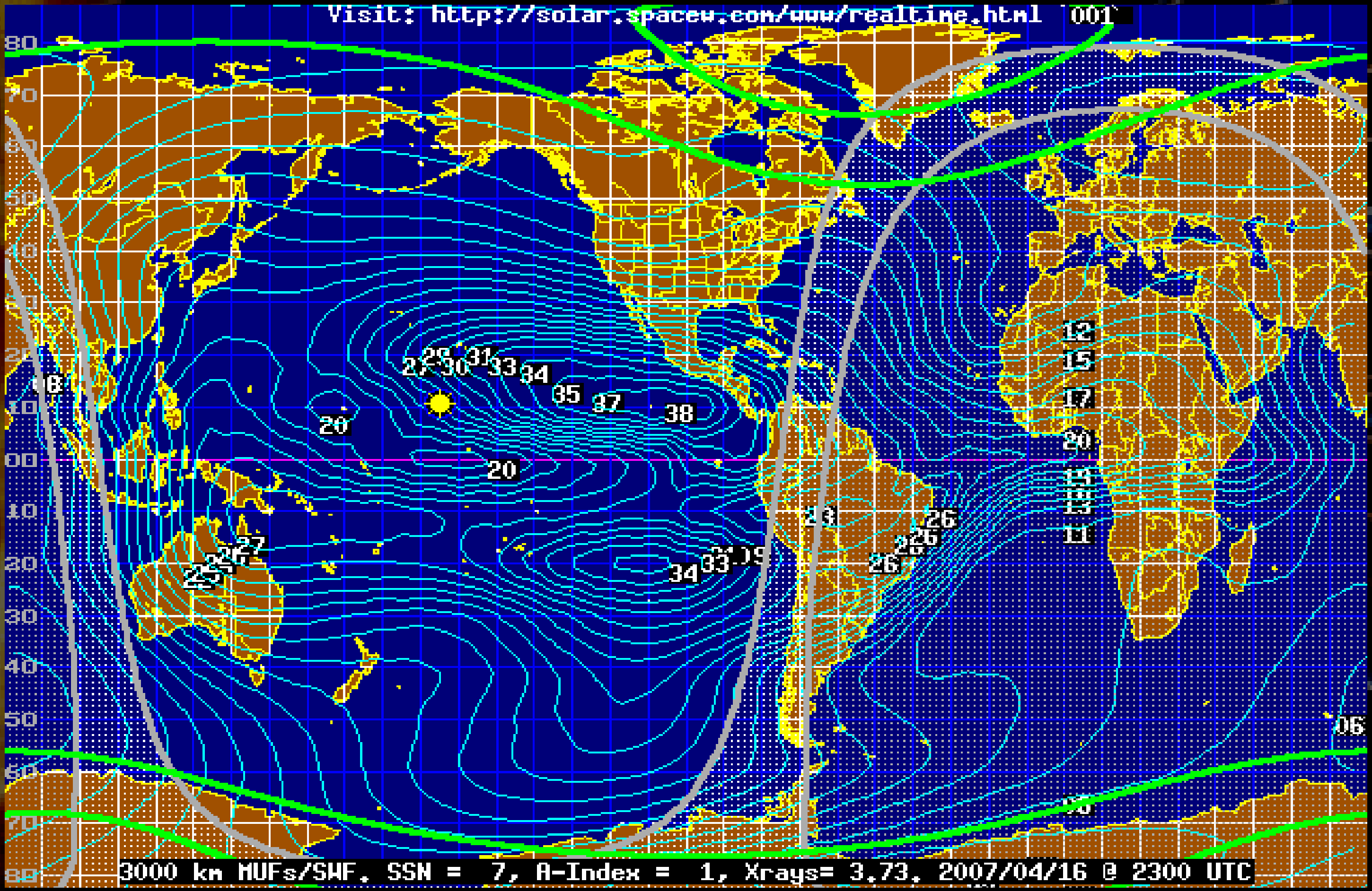




Auroral Map

NOAA/SEC

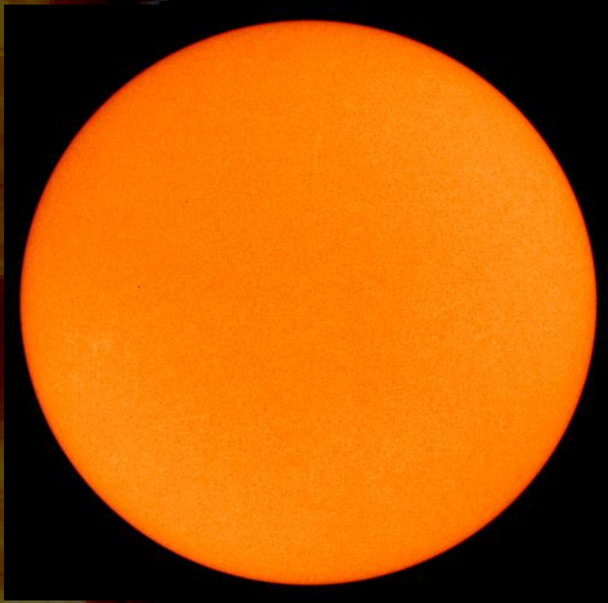
Predicted Maximum Usable Frequency



The MUF for any 3,000 kilometer path can be determined by finding the midpoint (or half-way point) of the path and examining the MUF at that midpoint on the map by finding the labelled MUF contour value. All contours are given in MHz.

www.spacew.com/www/realtime.php

16 April 2007



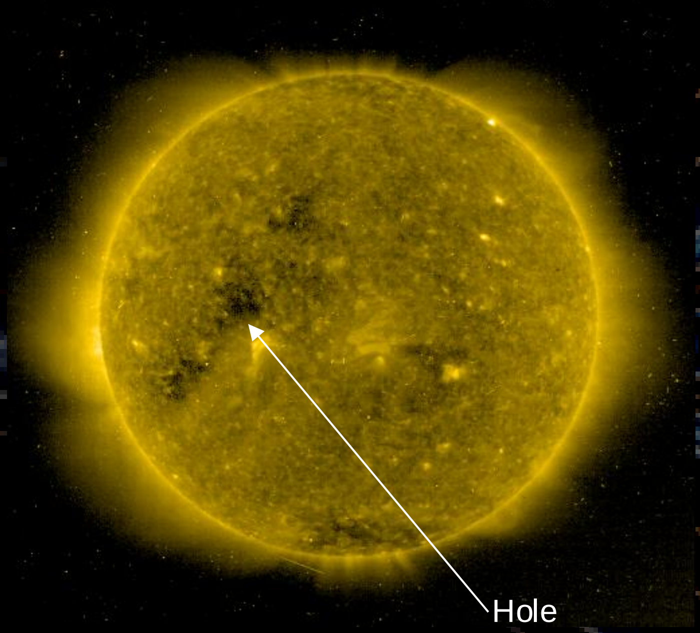
Sunspot Number: 0

SOHO/MDI

The sun is had a run of 11 days in a row with no sunspots. This marks the longest string of blank suns since 1996. That was a year of deep solar minimum, featuring blank intervals as long as 37 days. 2007 is shaping up to be the same--a deep nadir of the solar cycle.

A small spot that lasted only a couple of hours on the 14th, sunspot 951, interrupted the string.

SOHO Extreme UV



A weak solar wind stream flowing from the indicated coronal hole should reach Earth on or about April 17th.

Geomagnetic Storms: Probabilities for significant disturbances in Earth's magnetic field are given for three activity levels: active, minor storm, severe storm
Updated at 2007 Apr 14 2203 UTC

Mid-latitudes

	0-24 hr	24-48 hr
ACTIVE	10 %	10 %
MINOR	05 %	05 %
SEVERE	01 %	01 %

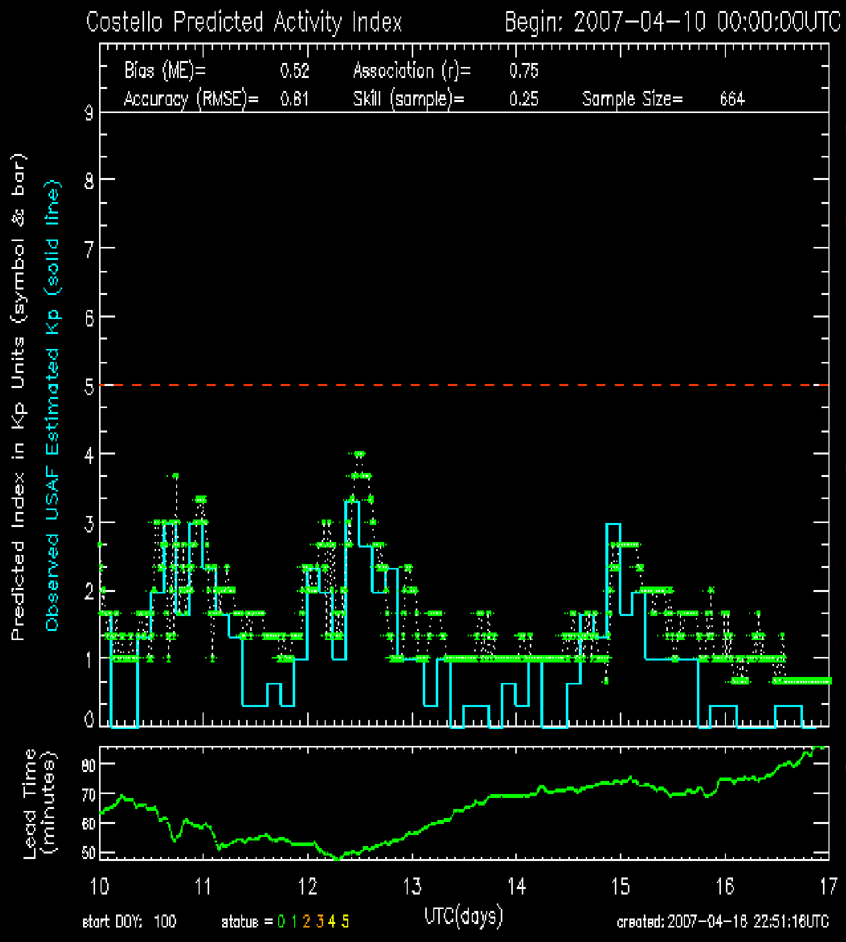
High latitudes

	0-24 hr	24-48 hr
ACTIVE	15 %	15 %
MINOR	05 %	05 %
SEVERE	01 %	01 %

SpaceWeather.com

Geomagnetic

UTC Date	Radio Flux 10.7 cm	Planetary A Index	Largest Kp Index
2007 Apr 16	75	5	2
2007 Apr 17	75	5	2
2007 Apr 18	75	5	2
2007 Apr 19	75	8	3
2007 Apr 20	75	20	5
2007 Apr 21	75	15	4
2007 Apr 22	75	10	3
2007 Apr 23	75	10	3
2007 Apr 24	75	8	3
2007 Apr 25	75	5	2
2007 Apr 26	75	5	2
2007 Apr 27	75	5	2
2007 Apr 28	70	25	5
2007 Apr 29	70	15	4
2007 Apr 30	70	10	3
2007 May 01	70	5	2
2007 May 02	70	5	2
2007 May 03	70	5	2
2007 May 04	70	5	2
2007 May 05	70	5	2

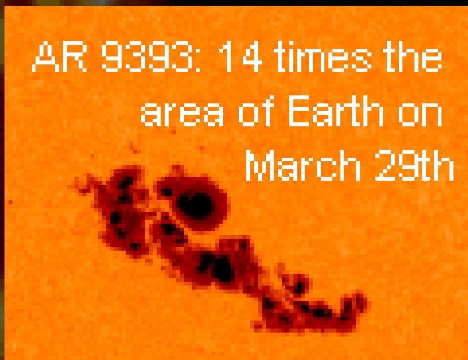


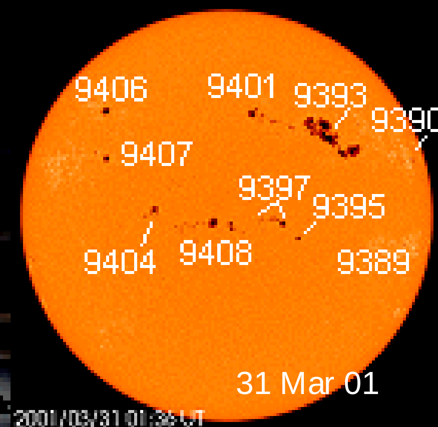
NOAA/SEC

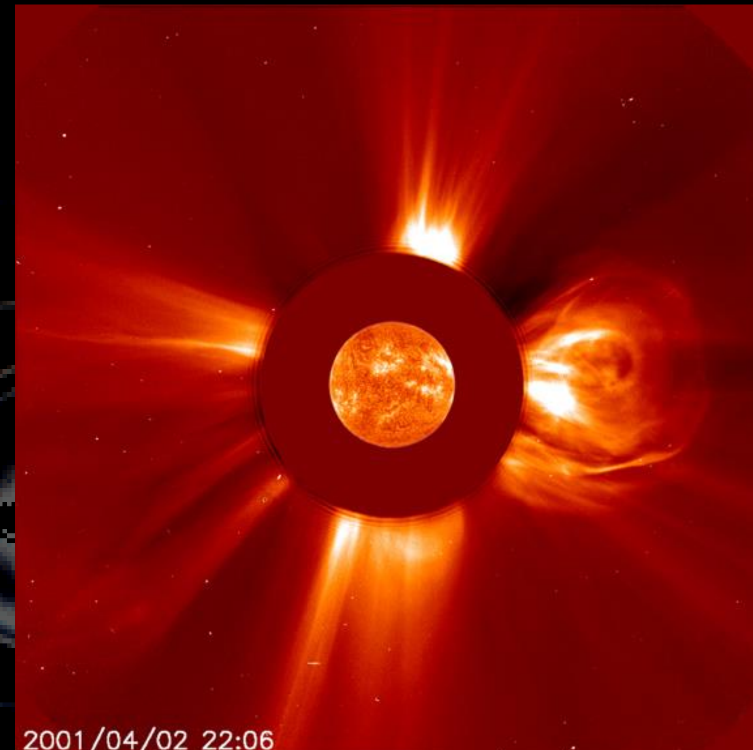
Filler Information

Just in case you were still really interested

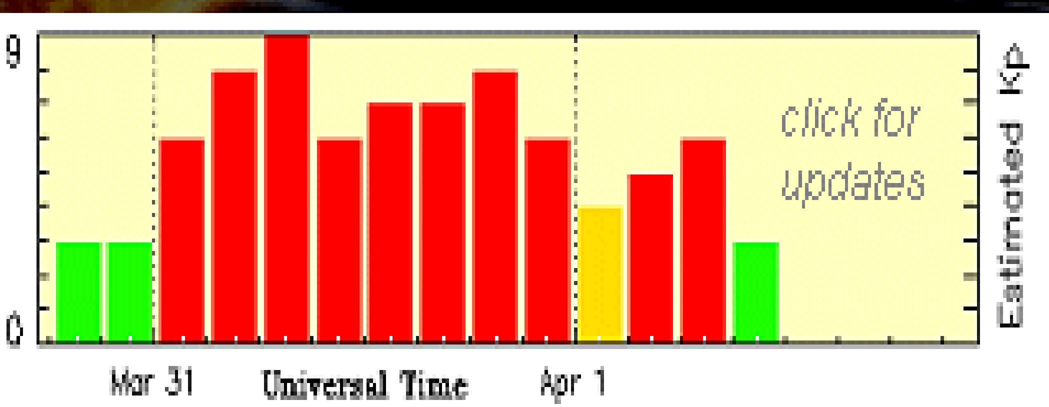
The Big Flare X-20+ from 9393







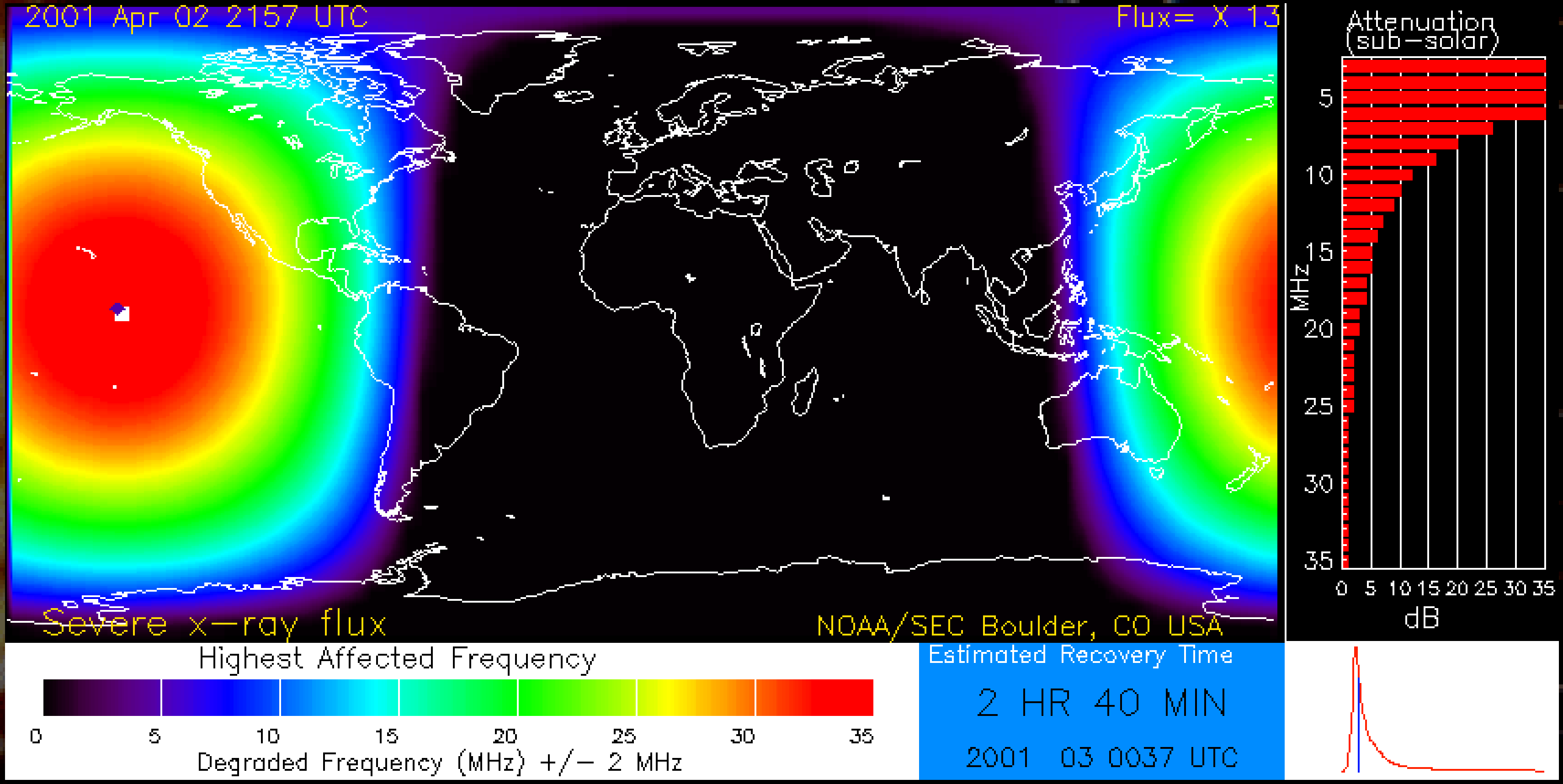
March/April 2001



Kp index from 28/29 Mar 01 X-class Flares

Northern Lights
John Russell,
Nome, Alaska

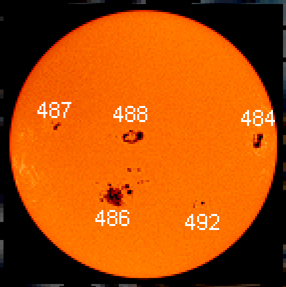
The Big Flare and the D-Layer

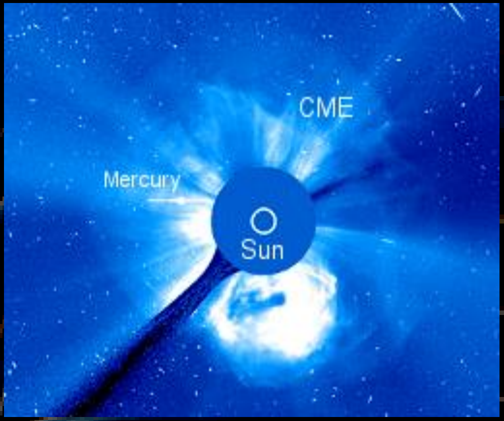


28 October 2003
X-17 & CME

28 Oct 03

One of the most powerful solar flares in years erupted from giant sunspot 486 this morning at approximately 1110 UT. The blast measured X17 on the Richter scale of solar flares. As a result of the explosion, a strong S3-class solar radiation storm is underway. … The explosion also hurled a coronal mass ejection (CME) toward Earth. When it left the sun, the cloud was traveling 2125 km/s (almost 5 million mph).





SpaceWeather.com

29 Oct 03

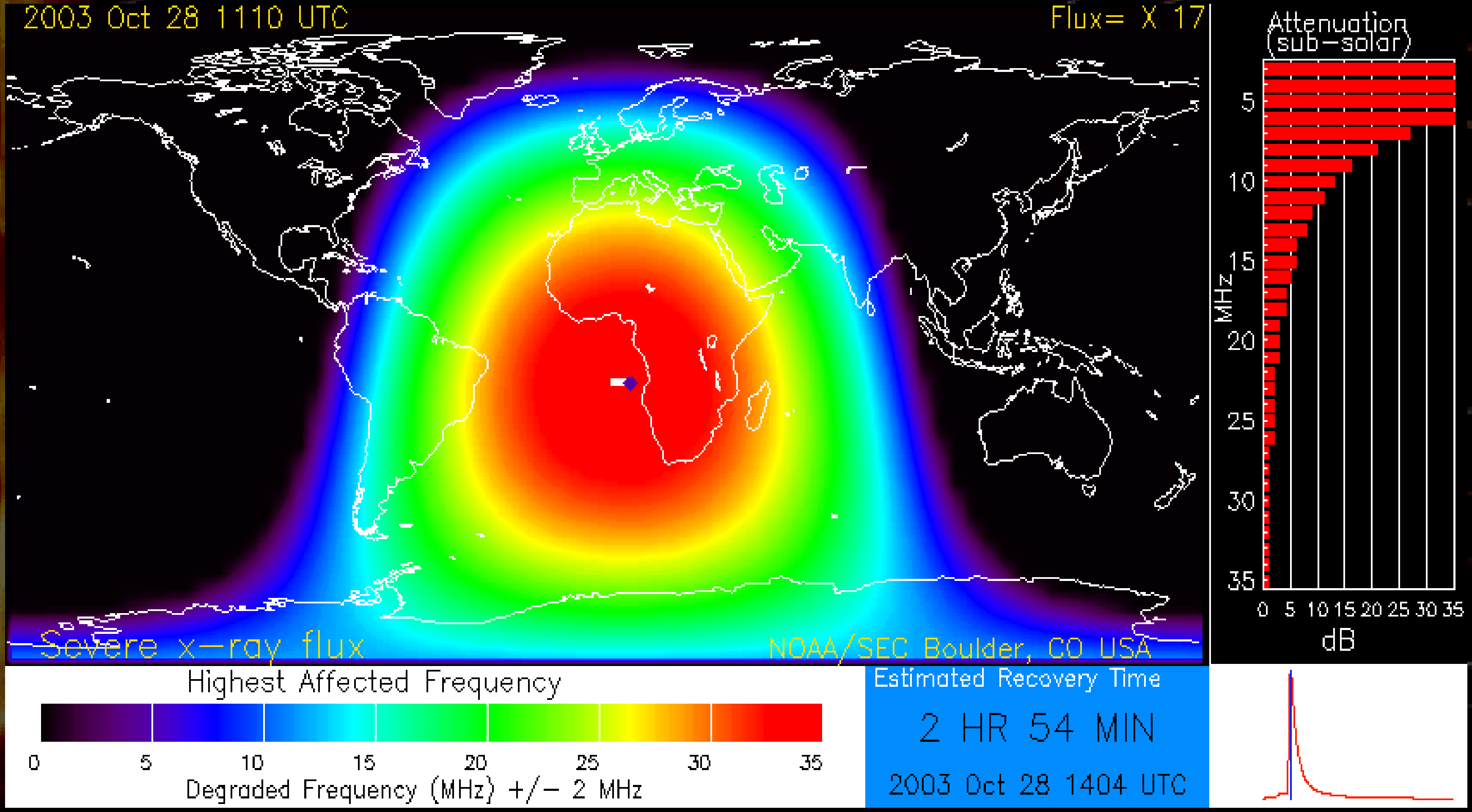
A coronal mass ejection swept past Earth today (at approximately 0630 UT on Oct. 29th) and triggered an intense geomagnetic storm. In the United States, Northern Lights (gallery) appeared as far south as Georgia, California, New Mexico, Arizona, Texas, and Oklahoma.

30 Oct 03

RADIATION STORM: Fast-moving protons, accelerated by the recent explosions on the sun, are streaming past Earth. This is what scientists call a proton storm. The ongoing storm rates an S3 on NOAA's space weather scale. Passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest x-ray).

Christie Ponder, near Houston, Texas, USA Oct. 29, 2003

29 Oct 2003, D-Layer



Solar Flares Effect GPS

During an unprecedented solar eruption last December, researchers at Cornell University confirmed solar radio bursts can have a serious impact on the Global Positioning System (GPS) and other communication technologies using radio waves. The findings were announced on April 4, 2007 in Washington, D.C., at the first Space Weather Enterprise.

[Flares produce] Radio waves are produced which then propagate to the Earth and cover a broad frequency range. The radio waves act as noise over these frequencies, including those used by GPS and other navigational systems which can degrade a signal.

Forecasters from the NOAA Space Environment Center in Boulder, Colorado, observed two powerful solar flares on December 5 and 6, 2006. These violent eruptions originated from a large sunspot cluster identified by NOAA. The December 6, 2006, solar flare created an unprecedented intense solar radio burst causing large numbers of receivers to stop tracking the GPS signal.

Excerpt from http://www.noaanews.noaa.gov/stories2007/s2831.htm

Conclusions

There are three key points to remember about solar radio bursts.

- "First, society cannot become overly reliant on technology without an awareness and understanding of the effects of future space weather disruptions," said Anthea Coster, Ph.D., MIT Haystack Observatory.
- Second, the December 6 event dramatically shows the effect of solar radio bursts is global and instantaneous.
- "Third, and equally important, the size and timing of this burst was completely unexpected and the largest ever detected. We do not know how often we can expect solar radio bursts of this size or even larger.“

Excerpt from http://www.noaanews.noaa.gov/stories2007/s2831.htm

The Solar & Heliospheric Observatory, is a project of international collaboration between ESA and NASA to study the Sun from its deep core to the outer corona and the solar wind.

- Launched on December 2, 1995
- Moves around the Sun in step with the Earth, by slowly orbiting around the First Lagrangian Point (L1)
- The L1 point is approximately 1.5 million kilometers away from Earth

esa NASA

sohowww.nascom.nasa.gov/

Solar TErrestrial RElations Observatory (STEREO)

The two nearly identical observatories - one ahead of Earth in its orbit, the other trailing behind - will trace the flow of energy and matter from the Sun to Earth. They will reveal the 3D structure of coronal mass ejections - violent eruptions of matter from the sun that can disrupt satellites and power grids -- and help us understand why they happen. STEREO will become a key addition to the fleet of space weather detection satellites by providing more accurate alerts for the arrival time of Earth-directed solar ejections with its unique side-viewing perspective.

National Aeronautics and Space Administration

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Licensed in 1978 as WB5YAZ

Life member, ARRL

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