Scientific Instruments for High School Students

SID Space Weather Monitoring Program

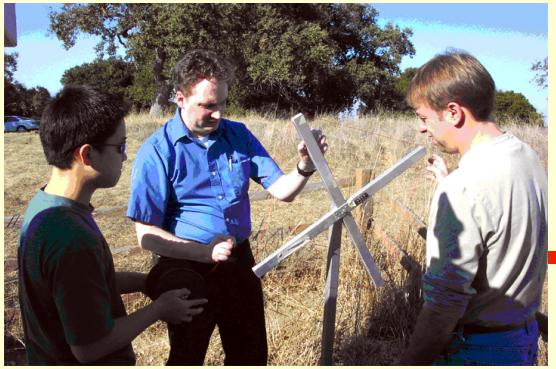
Deborah Scherrer

Stanford University, California USA

United Nations

How did you become interested in science?

- Would having access to a real scientific instrument and data in high school be inspiring to you?
- Would you be willing to work with students in your country to give them this experience?
- I have brought 10 instruments for you, the rest can be ordered for free.



SID Space Weather Monitor Project

- We designed simple-to-use space weather monitoring instruments for high school & early college students
- >800 distributed worldwide for the International Heliophysical Year and the International Space Weather Initiative (ISWI)
- Little or no cost to recipient

USA

Germany

Lebanon

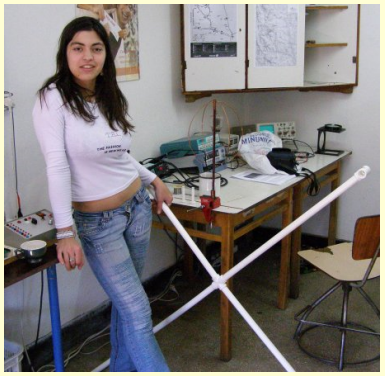
Mexico

Ethiopia

Nigeria

China

Taiwan



Romania

Uruguay

Why?

- Outreach & inspiring young people is part of the mission of SCOSTEP, ISWI, and the United Nations.
- Outreach & inspiring young people is part of the mission of the US National Science Foundation (NSF) & NASA, the organizations that funded our monitors.
- Outreach & inspiring young people is part of Stanford's mission - and **my** mission!

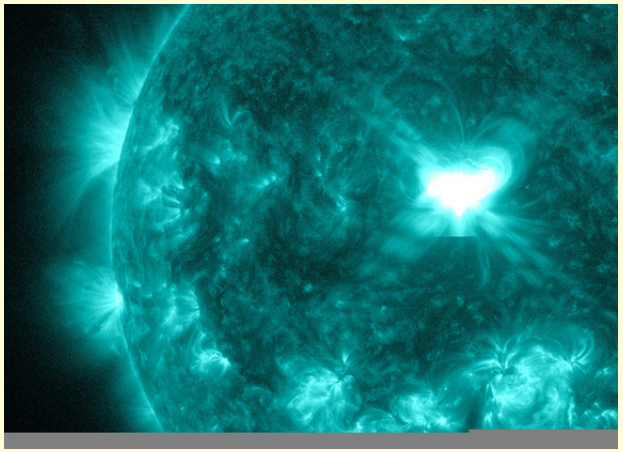
Our Objectives

- Enthuse and excite high-school-age students by providing hands-on access to real scientific data and equipment
- Provide proven, classroom-tested educational materials developed in partnership with teachers & researchers
- Arrange worldwide access between scientists, students, and teachers to encourage student research and understanding

SID Instruments

- Simple radio receivers that track VLF transmissions as they bounce off the Earth's ionosphere

- Primarily track solar-induced changes to the ionosphere, e.g. solar flares



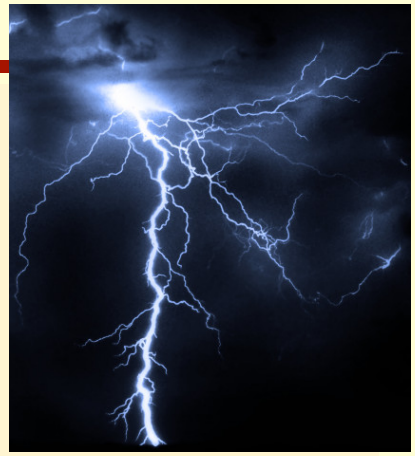
SID Instruments
3 versions

- AWESOME – part of the IHY & ISWI but no longer available

- Original SID – for IHY

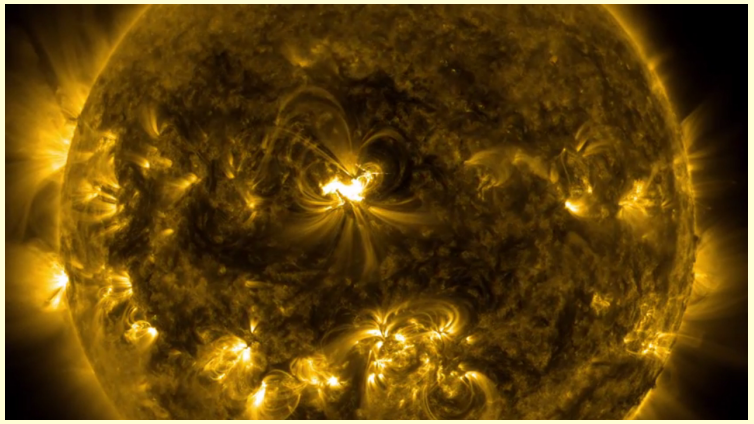
- **SuperSID** – redesigned for ISWI – better, simpler, cheaper

AWESOME Instruments



- Research quality, designed for graduate work.
- About 25 were placed as part of IHY and ISWI.
- AWESOME hardware is superior to SuperSID, with a much higher sampling rate. Primarily used to research nighttime phenomena like lightning, sprites, chorus, etc.
- Costly, relied on proprietary software, had to be installed by an expert.
- **No longer available**

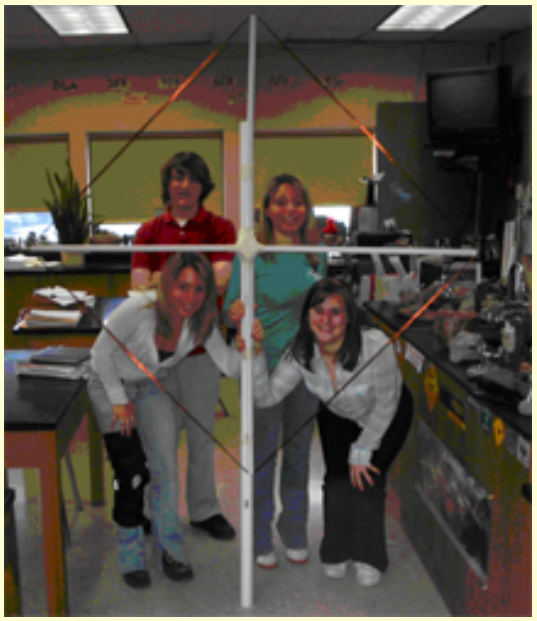
SuperSID Instruments

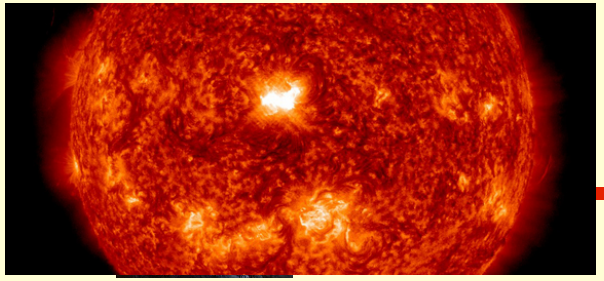


- Inexpensive, easy to install, low maintenance
- Software taps into several open source libraries (e.g. Python, MatPlotLib) for numerical analysis, graphics, & networking - making it inexpensive & extensible for academic environments
- Primarily used for tracking solar effects on ionosphere

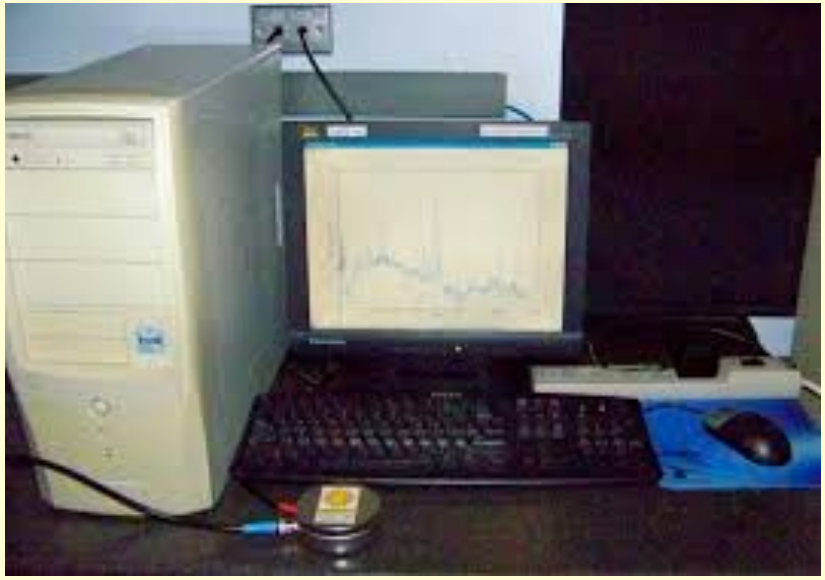
SuperSID Requirements

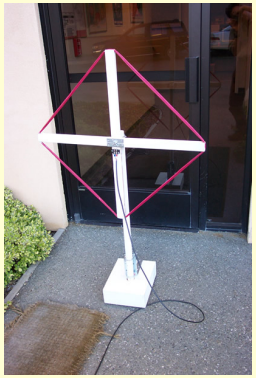
- Instruments are preassembled, with instructions & software
- Students build their own antenna, a simple & inexpensive un-tuned wire wrap
- Host site provides access to power & a simple computer (desktop) with a sound card (48kH is ok)
- Internet access is desirable but not required





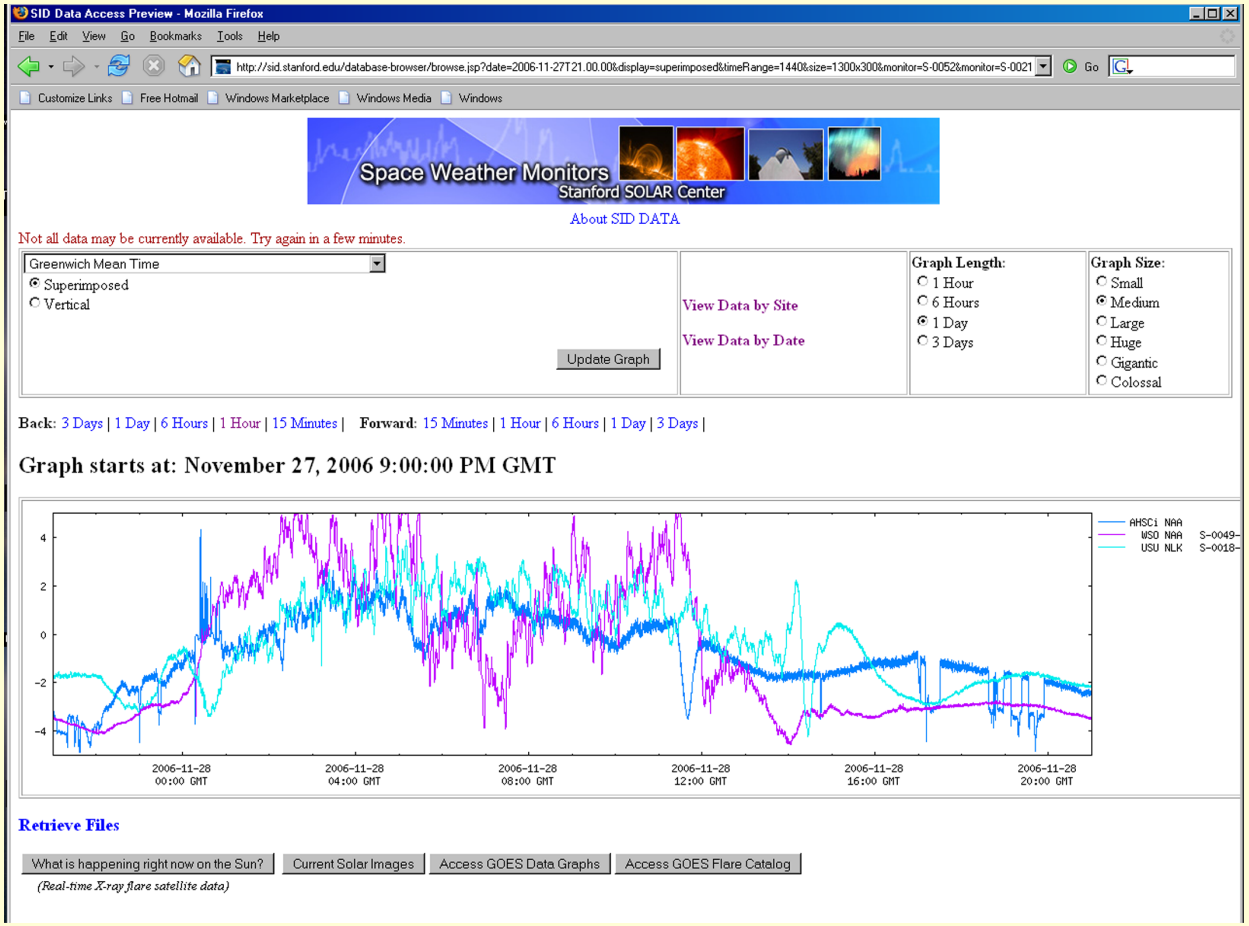
Sample Setup





Centralized Data Repository

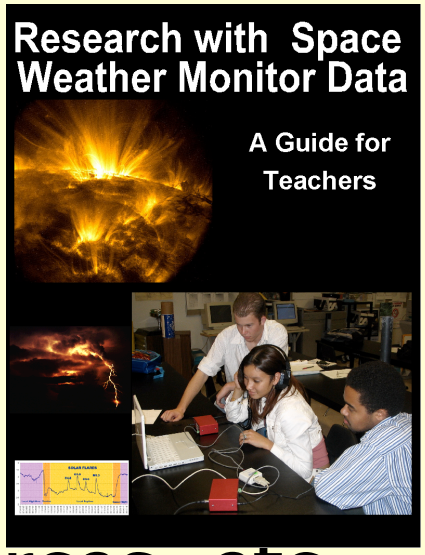
- Hosted at Stanford
- Accessible to anyone with internet
- Students ftp data (software provided)
- Data available to all & valuable to solar & ionospheric researchers

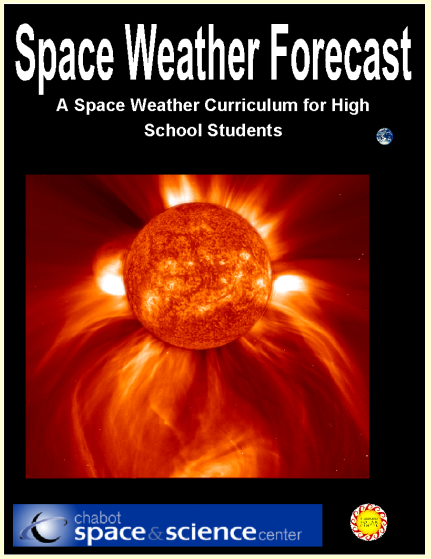


http://sid.stanford.edu/database-browser

Package includes extensive educational resources

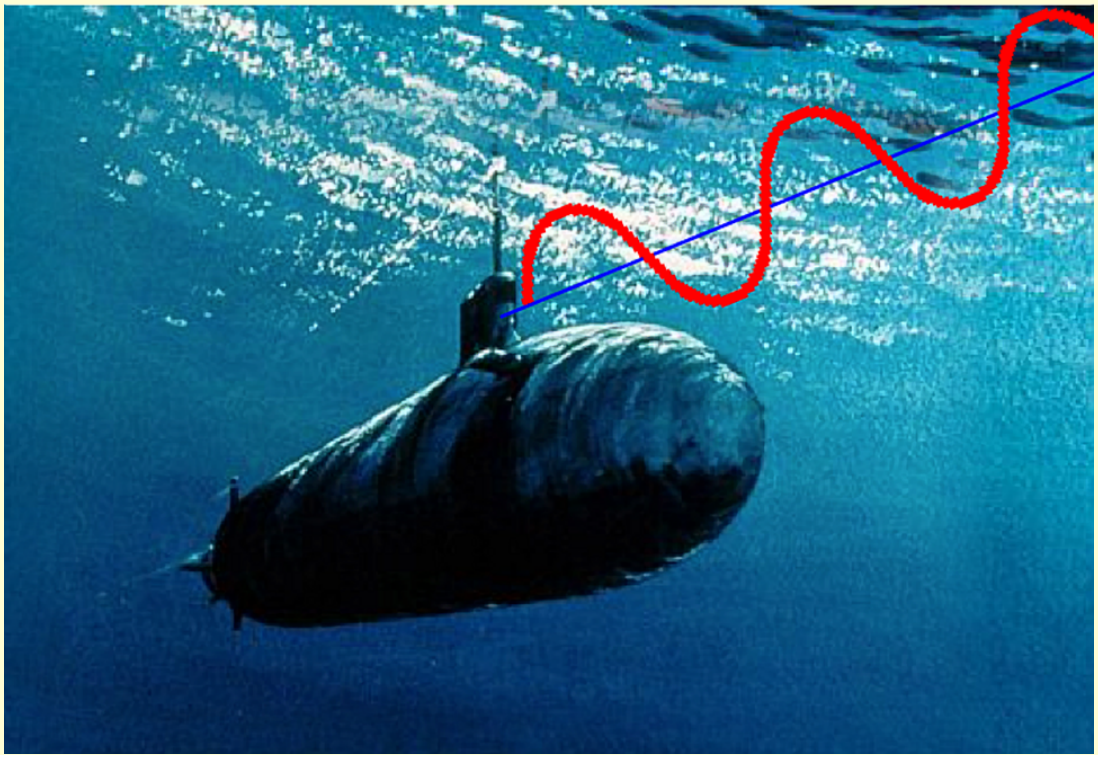
1. Manual with detailed installation instructions
2. Curriculum Guide for teachers
3. Research Guide for Students
4. CD with software, documents, presentations, resources, etc.





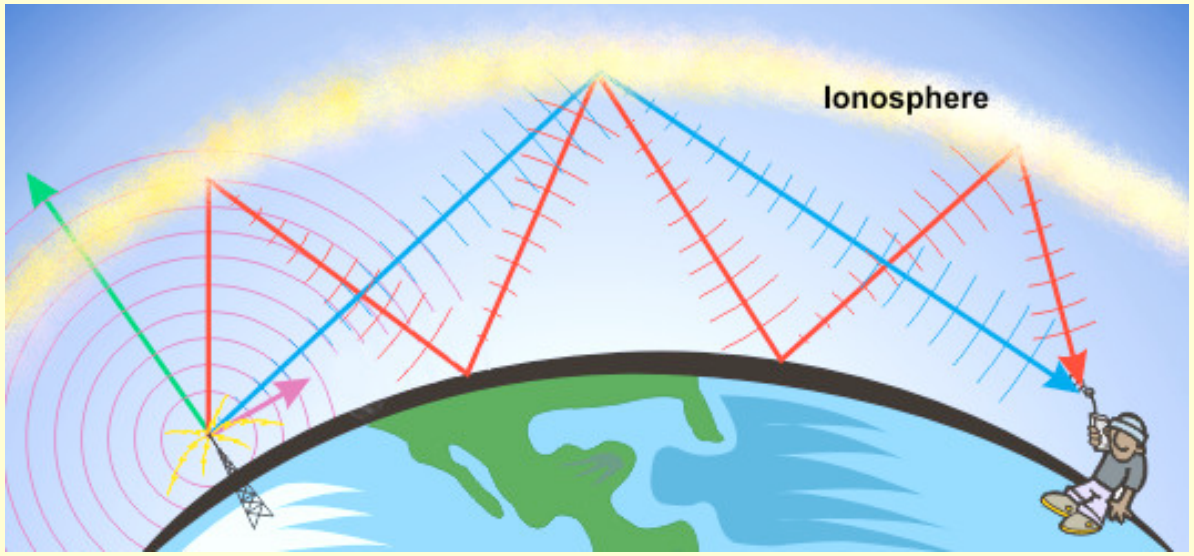
All instruments track VLF transmissions

- Conveniently for us, there are >30 VLF transmitters around the world
- They are used by governments to communicate with their submarines
- Why?



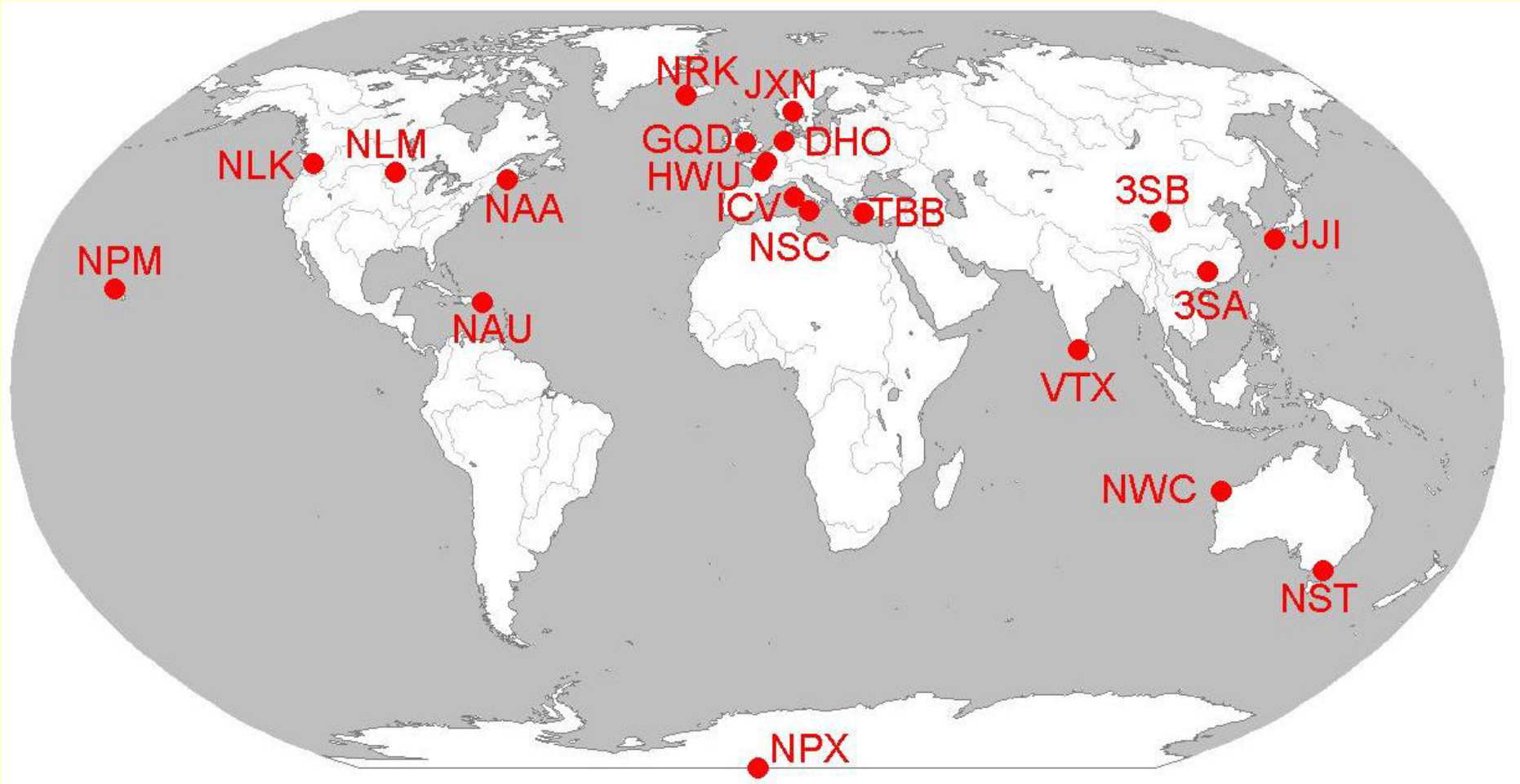
VLF transmissions

The VLF frequency range, ~3-30kH, can penetrate deep into the ocean

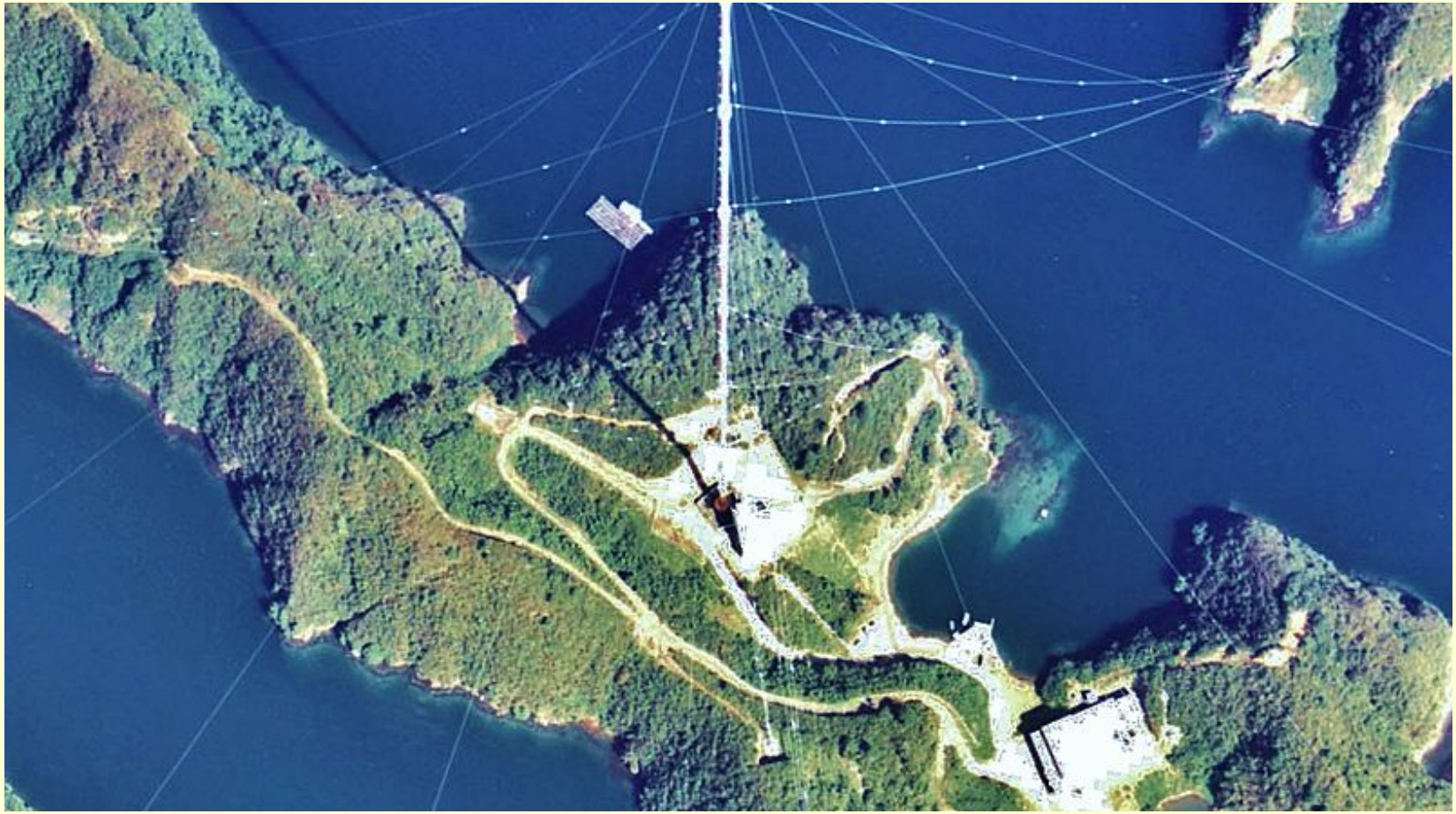


VLF waves bounce through the ionosphere waveguide, providing communications around the world

The >30 VLF transmitters can reach any point on Earth



The transmitters are large, often spanning mountain tops.



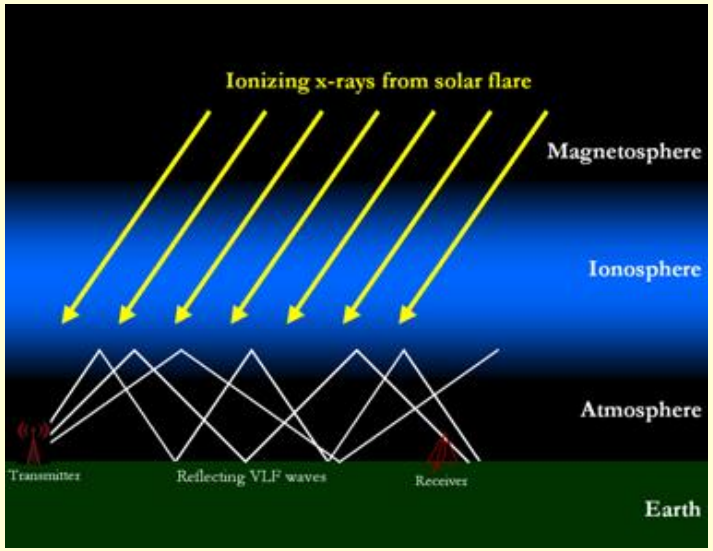
The instruments track **signal strength**, not content, as the VLF waves bounce in the wave guide.

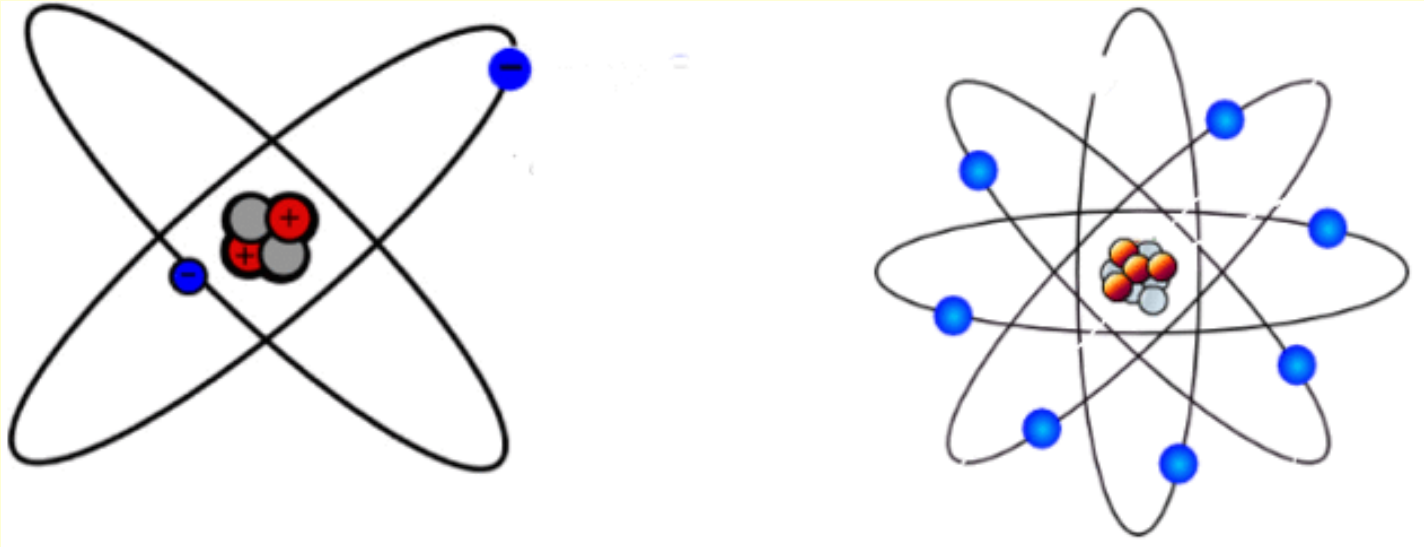
The Sun affects the ionosphere, and hence where the VLF signals bounce and their strength.

Our Sun creates the ionosphere

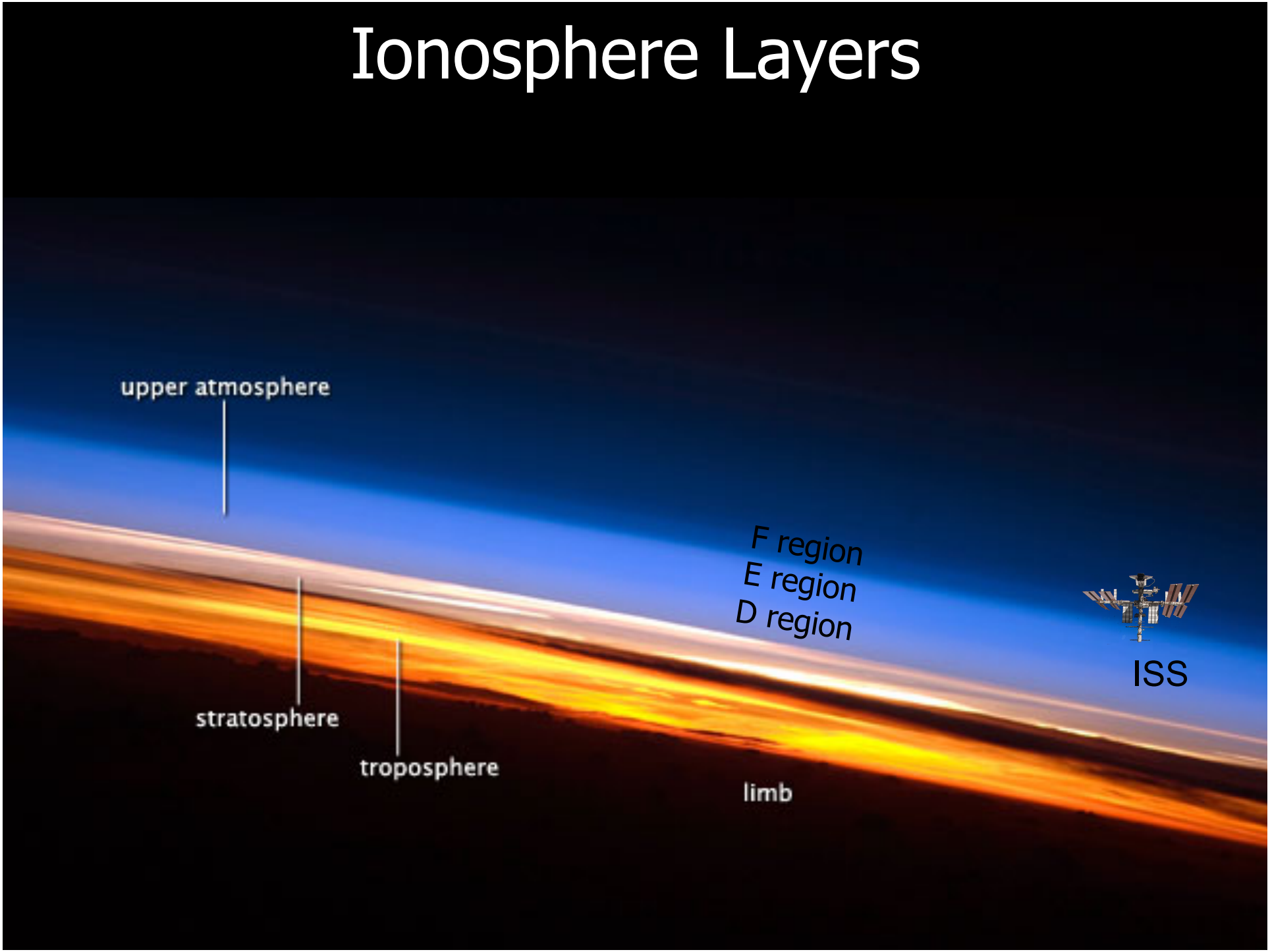
~85 km to ~600 km altitude

- The Sun's high energy ultraviolet light strips atoms in this area of one or more of their electrons, hence "ionizing" the ionosphere. The ionized electrons behave as free particles. Free electrons reflect the radio waves.



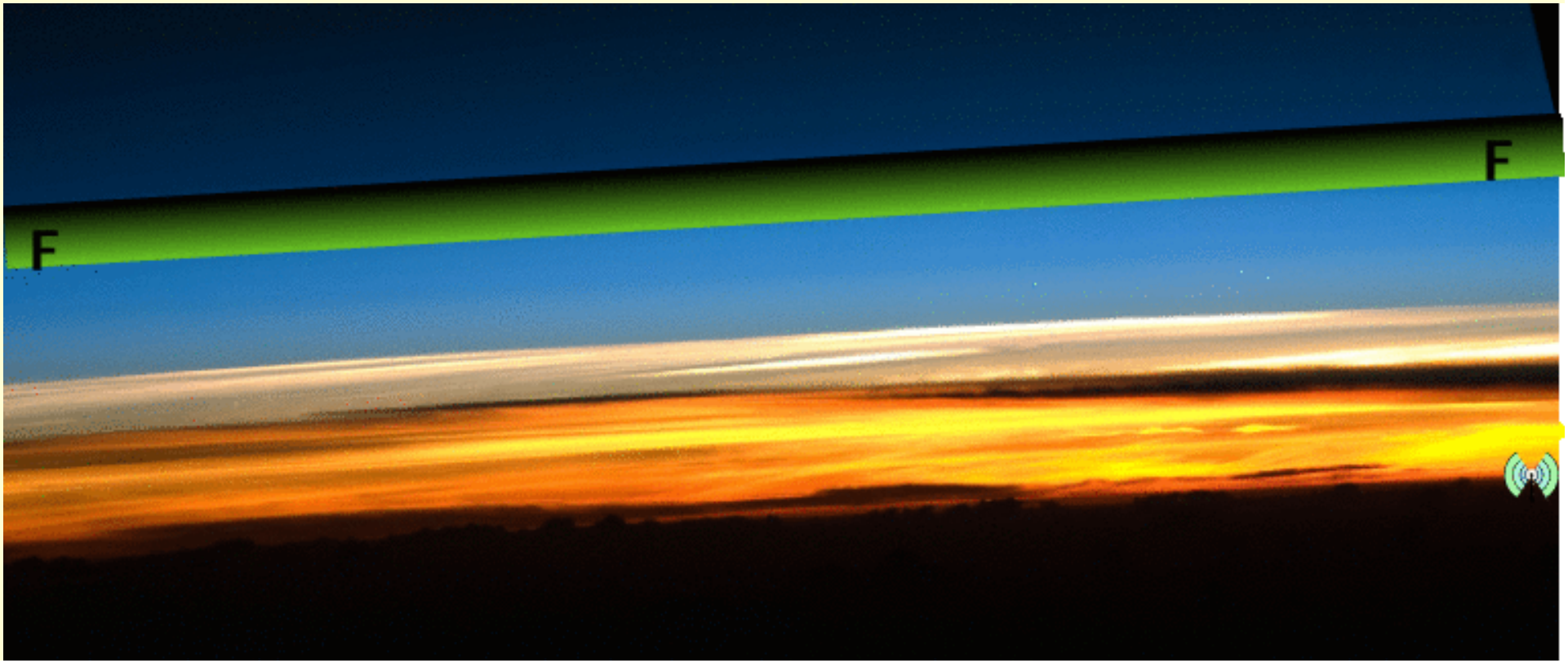


Ionosphere Layers



The ionosphere at night

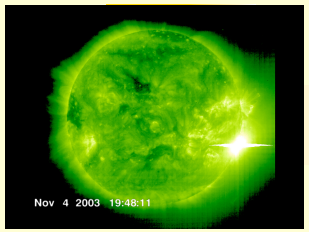
At night, the Sun does not reach the ionosphere. The primary ionization at night comes from cosmic rays, and the ionosphere is relatively thin. **At night, VLF waves reflect (refract) off the F layer, giving a strong signal.**



The ionosphere during the daytime

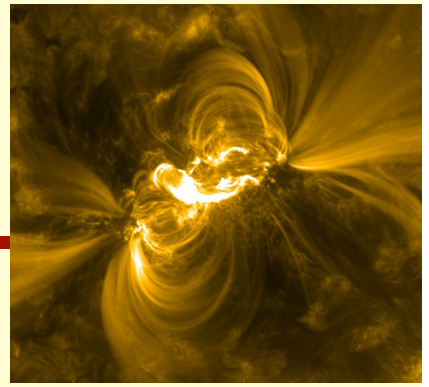
As the Sun strikes the ionosphere, it ionizes the atoms below the F layer. The E layer is created and the D layer is partially ionized. **VLF waves now reflect off the E layer, after traveling through D. Note how energy is lost penetrating the D layer.**

Solar Flare



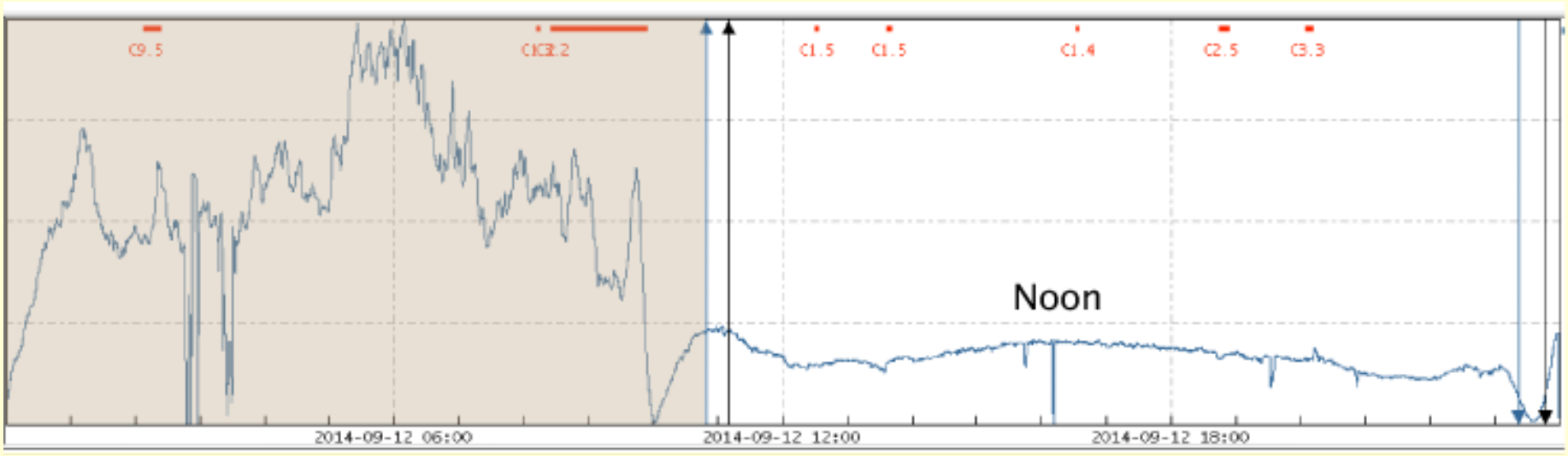
Flares on the Sun produce increased ultraviolet, X-ray, and gamma ray photons that arrive at Earth in ~8 minutes and dramatically increase the ionization. Hence the ionosphere becomes thicker. **Now VLF waves reflect off the D layer. The signal remains strong.**

How all this looks to a SID Monitor

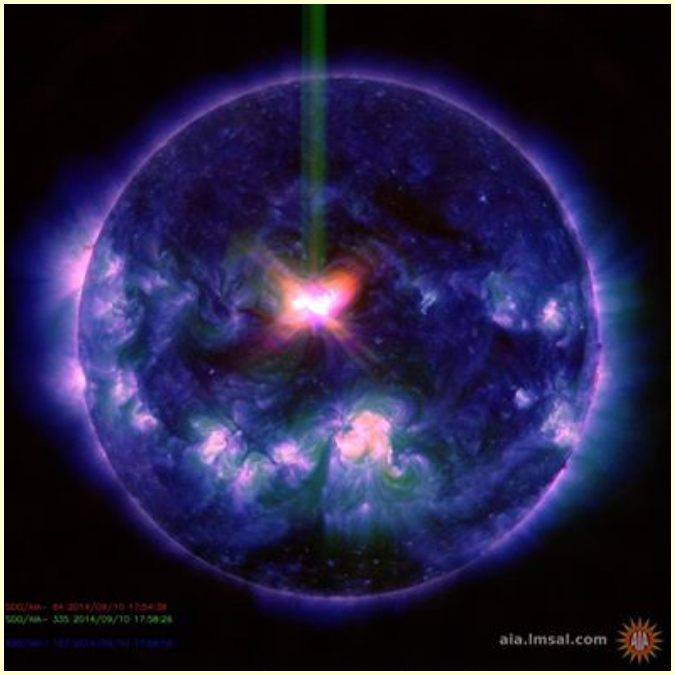


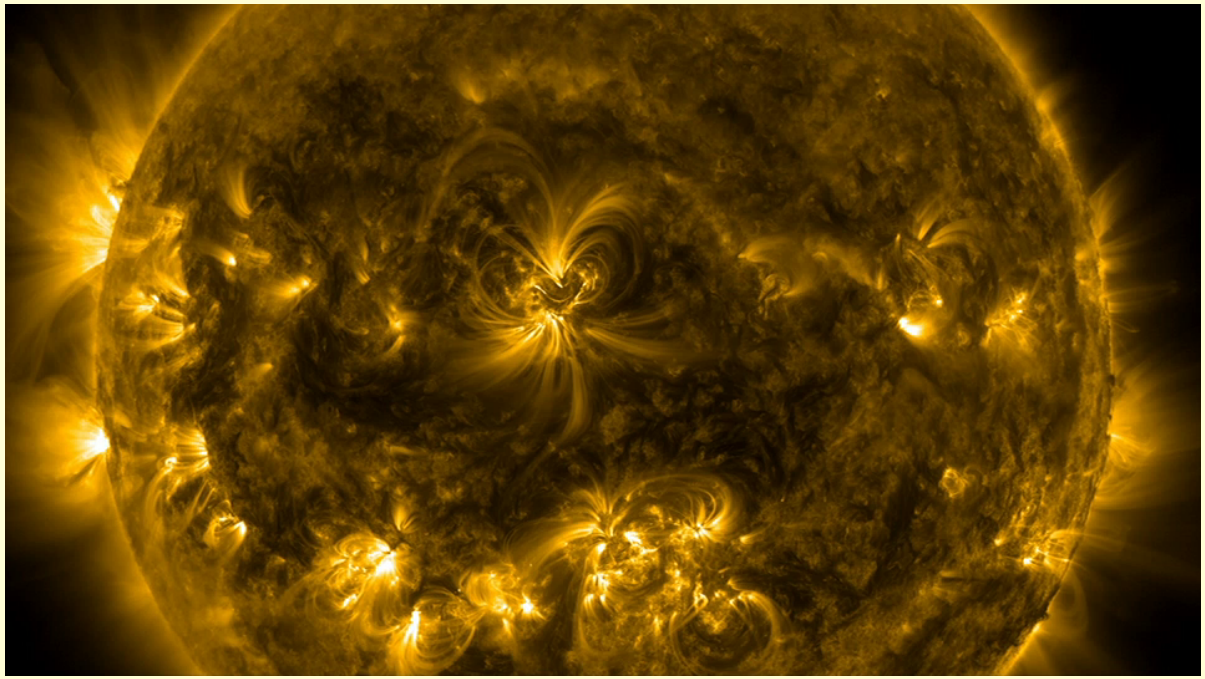
- SIDs track VLF signal strength over time
- Each instrument monitors signal strength from 1-4 specific VLF transmitters
- SIDs use a 5 second sampling rate (hence not suitable for lightning)
- Data are graphed and easy to understand, similar to seismograph data

Normal 24 Hr. Day



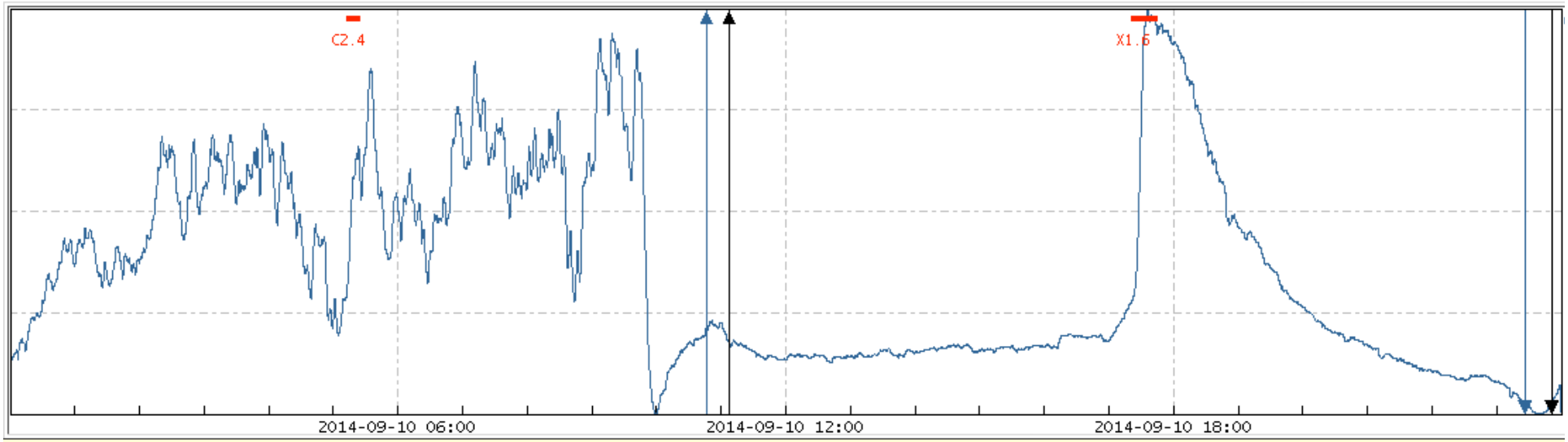
X1.6 Solar Flare - 10 Sept 2014





Images from the AIA instrument on NASA's Solar Dynamics Observatory (SDO) spacecraft, on which Stanford has the HMI instrument.

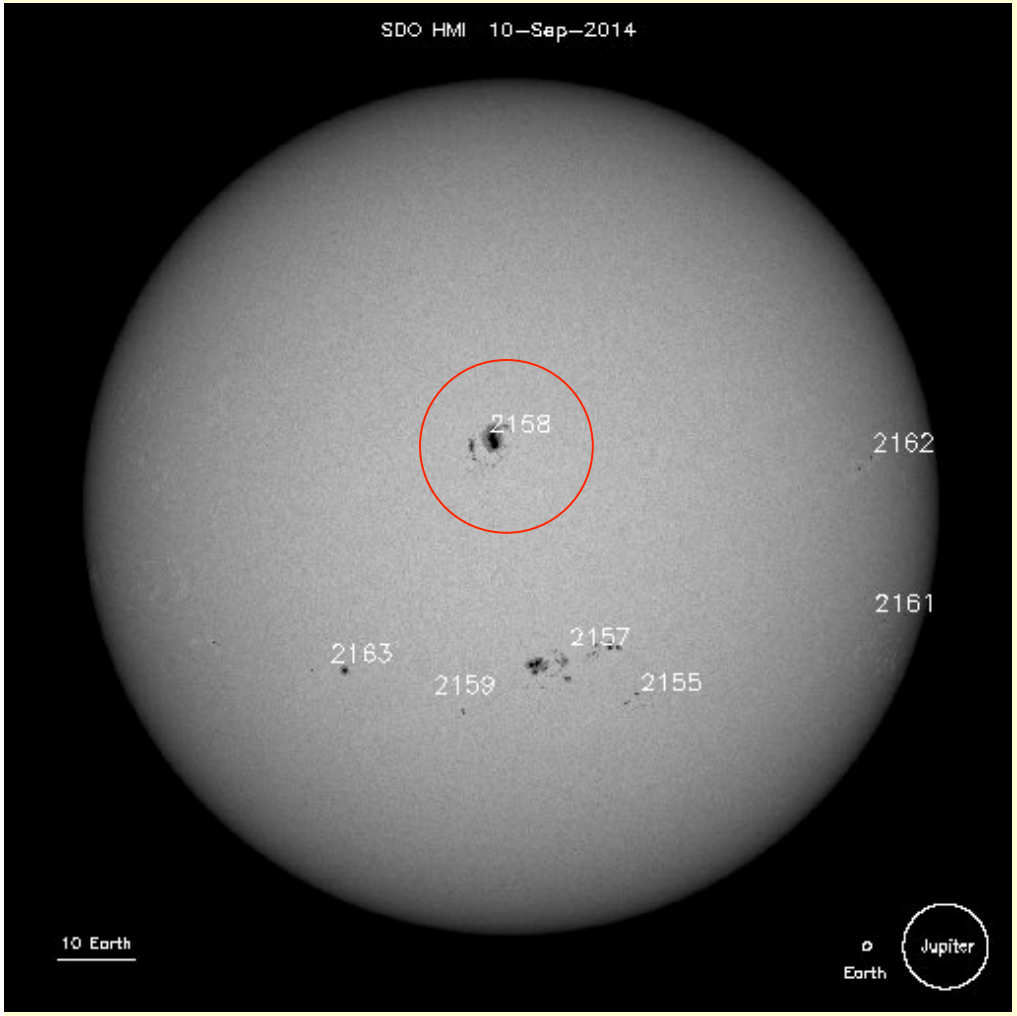
X1.6 Solar Flare
10 Sept 2014

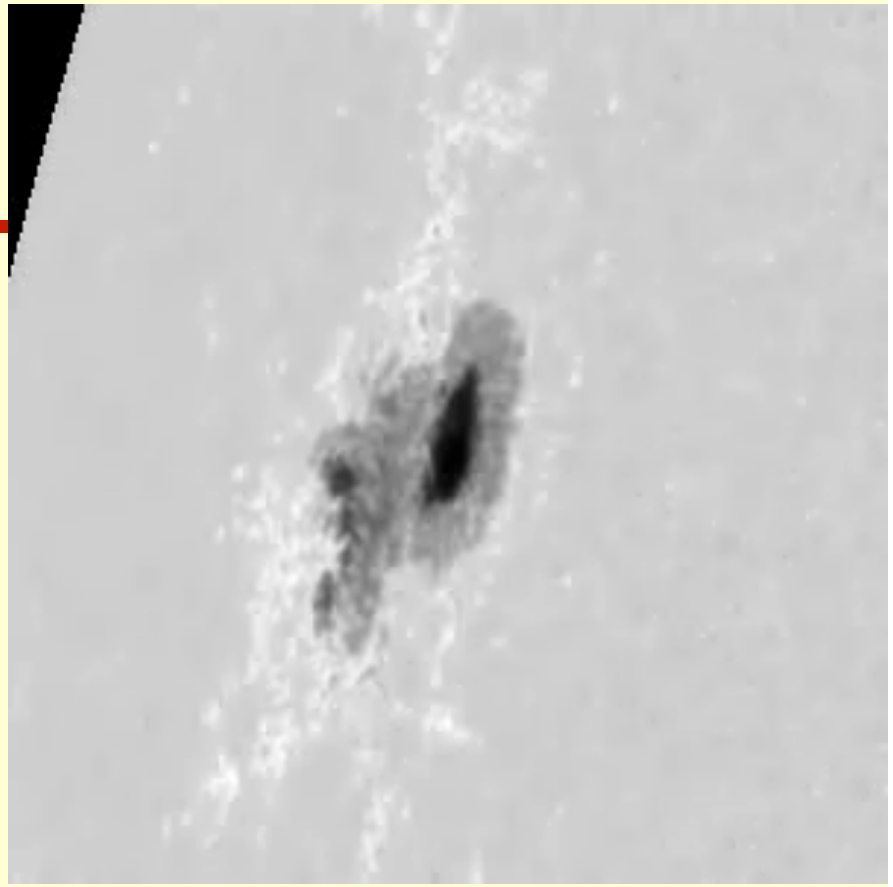


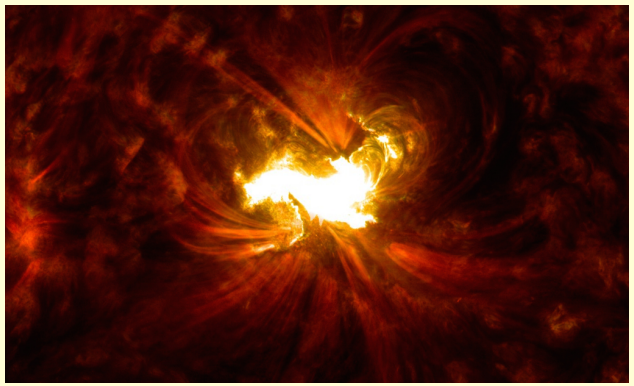
X1.6 Solar Flare

Picked up by SuperSID monitor
N2YO tracking NAA

AR 2158

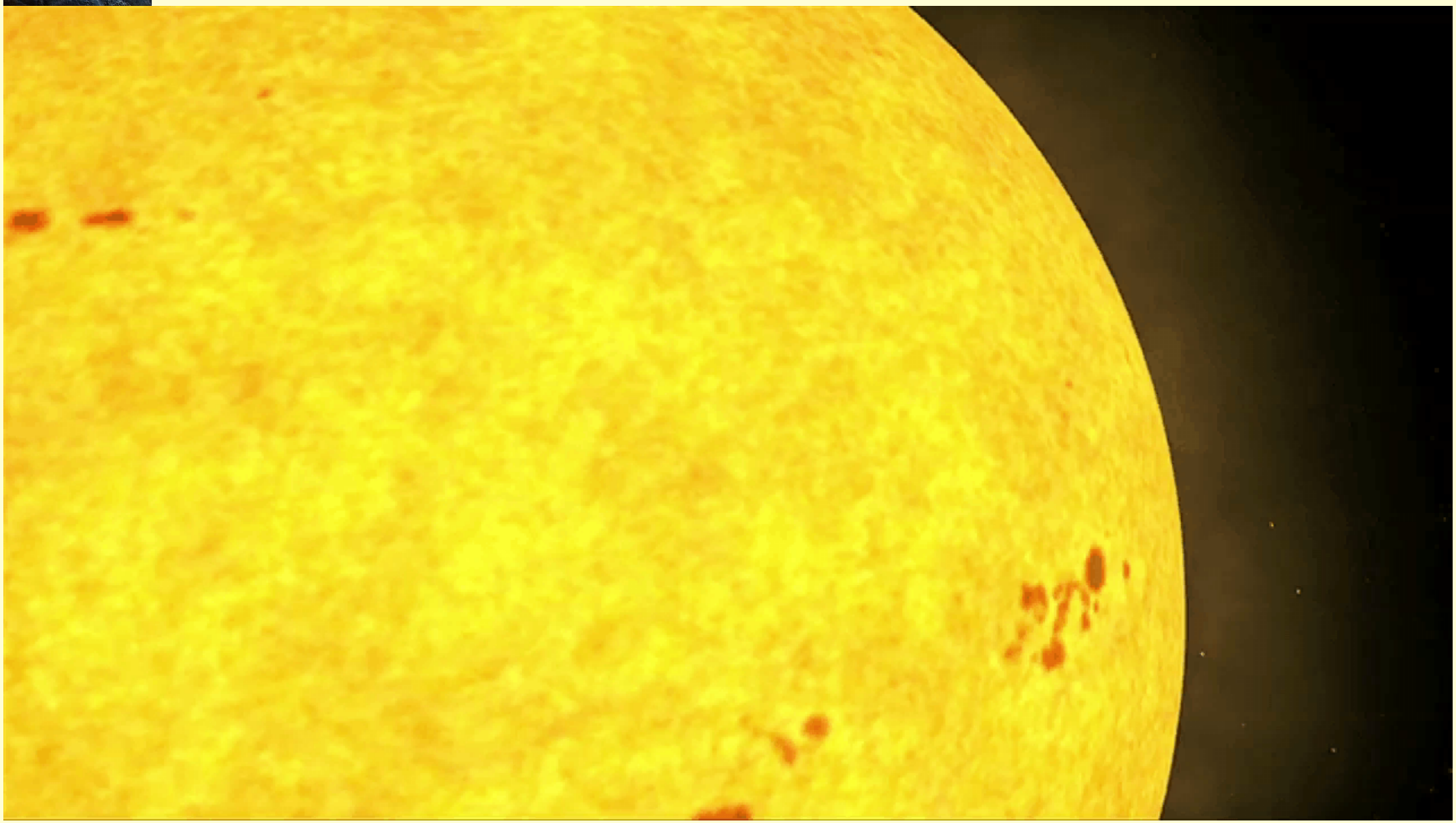

SDO HMI 10-Sep-2014
2158
2162
2161
2157
2163
2159
2155
10 Earth
Earth
Jupiter





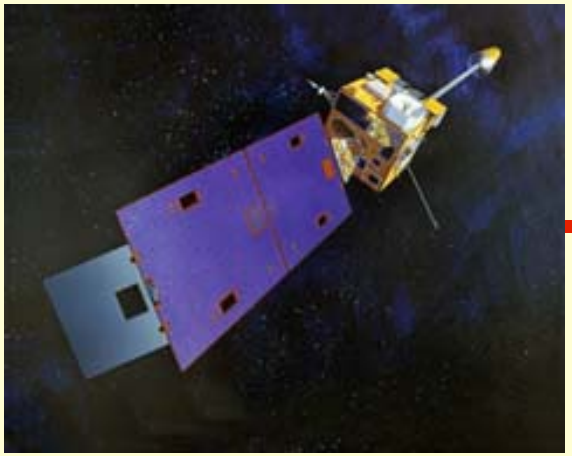
How flares originate (simplified)

~2 days later, the CME strikes Earth

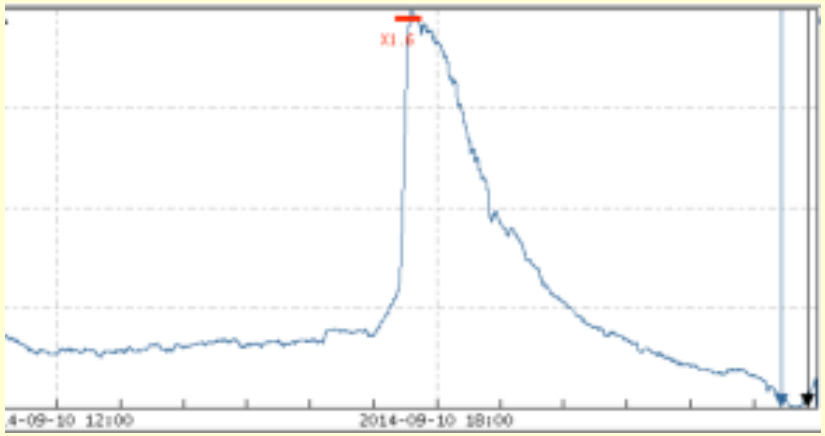


Generating beautiful aurora

What can students do once they observe a flare?

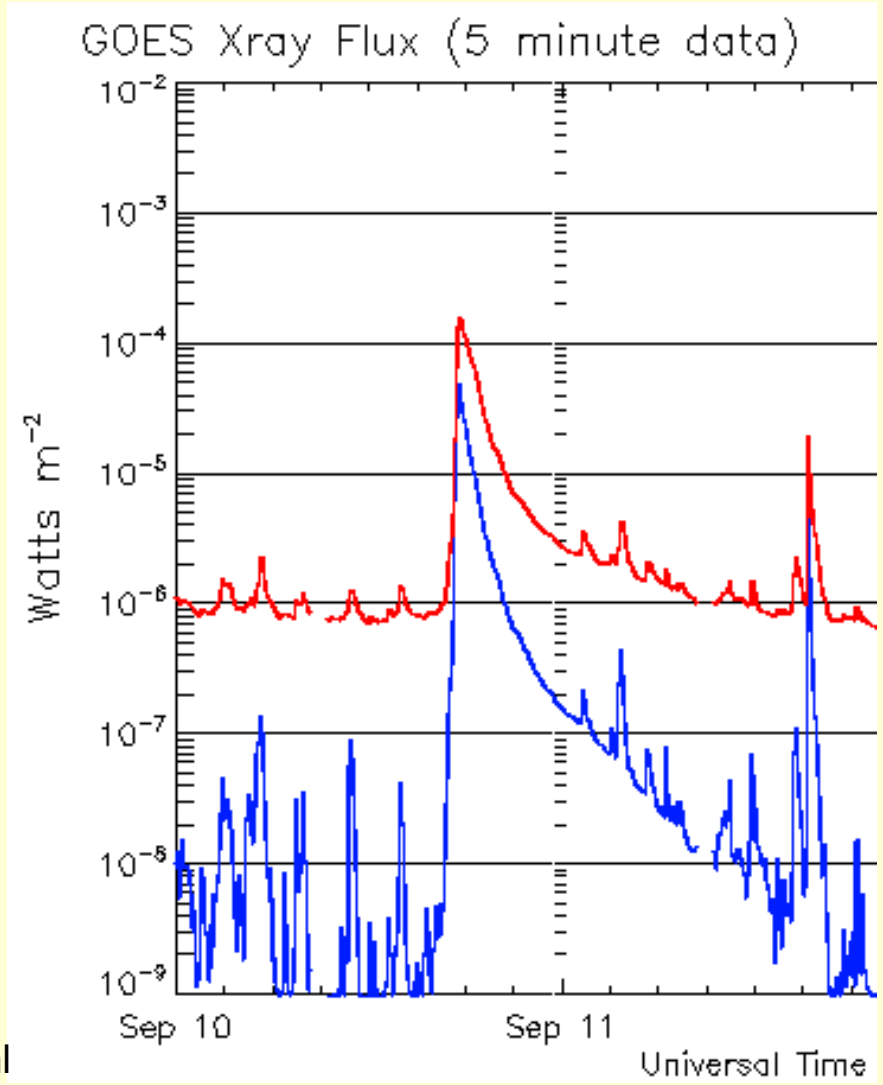


GOES satellite

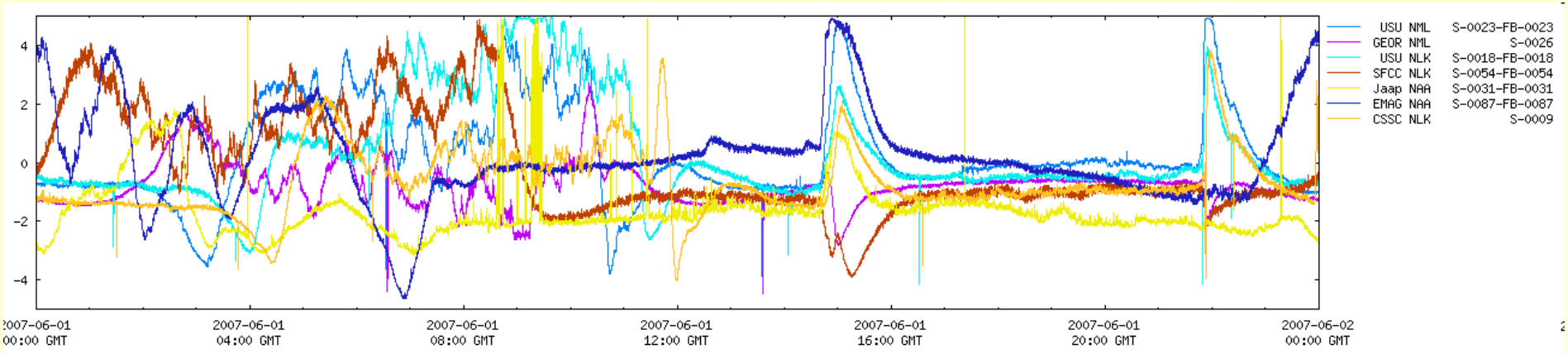


Compare and verify their data with GOES satellite

http://www.swpc.noaa.gov/rt_plots/xray_5m.html



Compare their data with other sites

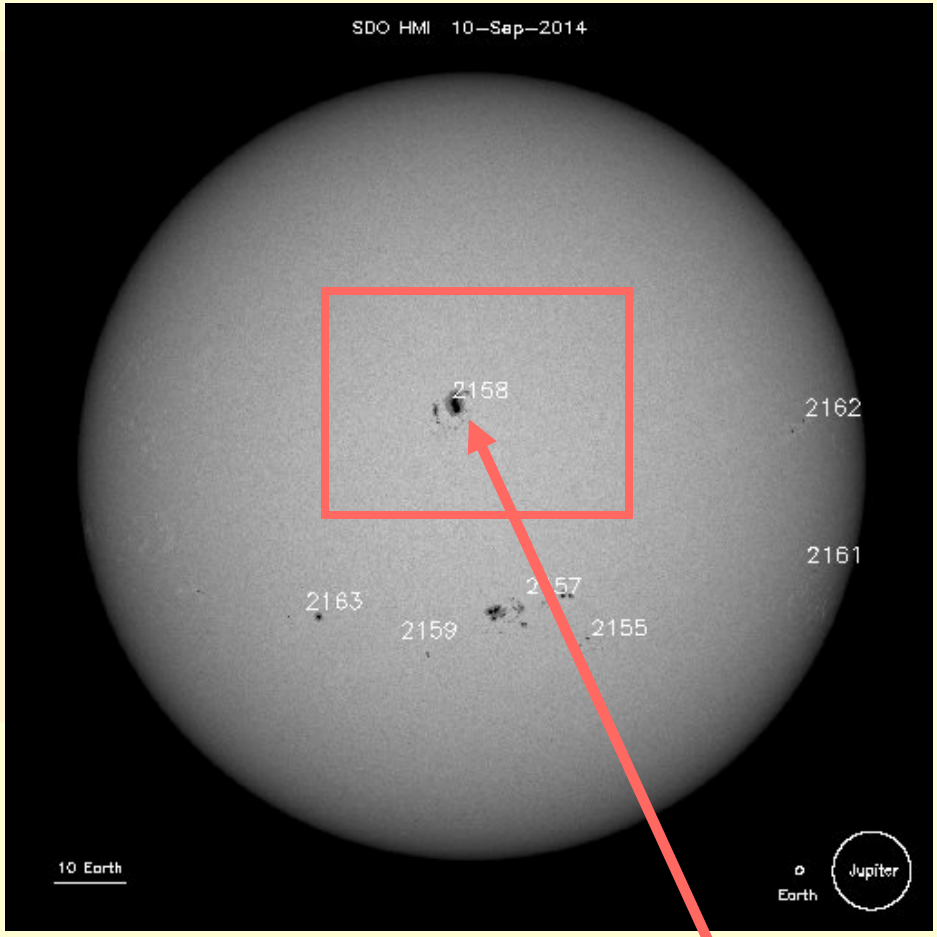


7 sites picked up this flare

M2.8 class solar flare on 1 June 2007

Note that 2 sites picked up the flare as a decrease, rather than increase, in signal strength. This is due to destructive interference of the VLF waves.

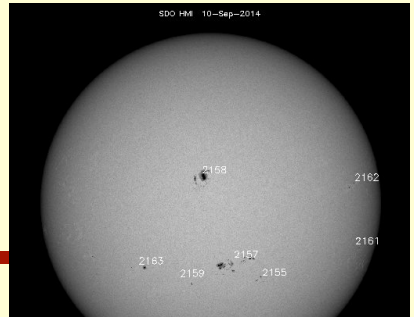
Using GOES & SOHO information, the flare can be tracked back to the solar active region that produced it.



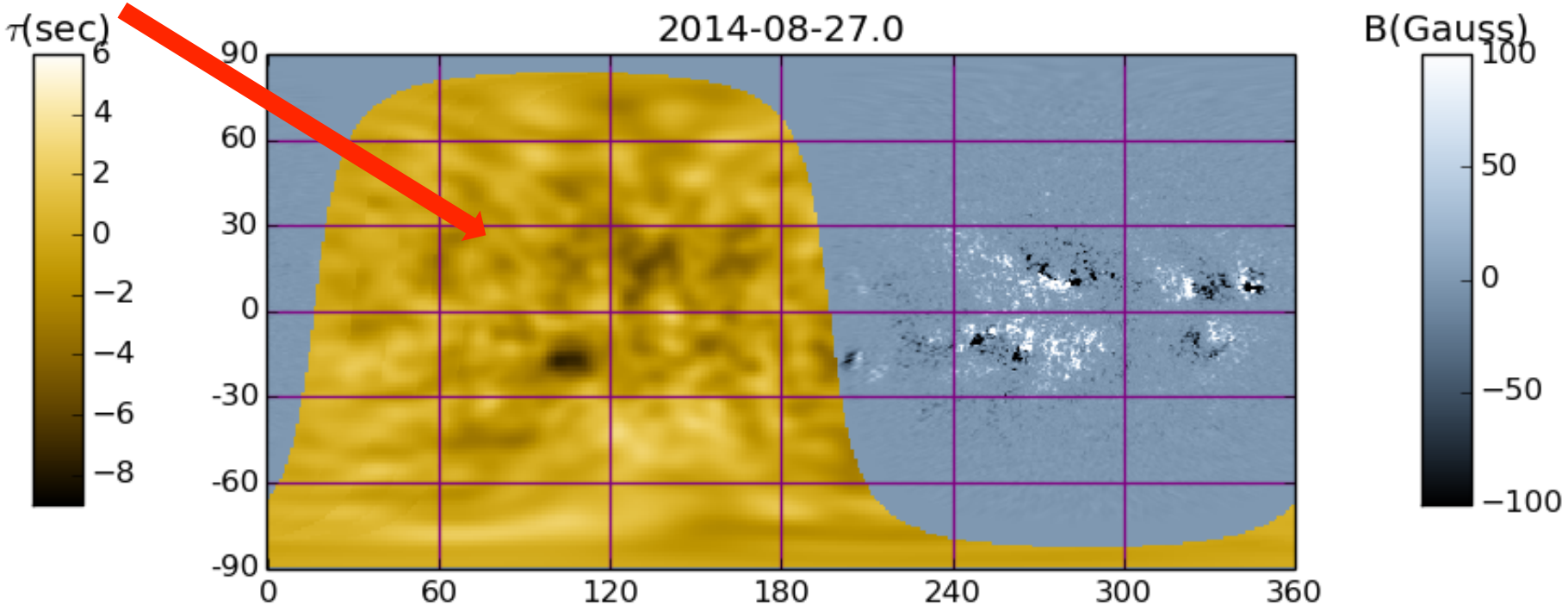
#Event	Begin	Max	End	Obs	Q	Type	Loc/Frq	Particulars		Reg#
5030	1659	1733	2240	HOL	3	FLA	N14E02	2B	UMB	2158
5030	**1721**	**1745**	**1820**	**G15**	**5**	**XRA**	**1-8A**	**X1.6**	**3.8E-01**	**2158**
5030 +	1723	1747	1916	SAG	G	RBR	410	5600	CastelliU	2158
5030 +	1723	1733	1827	SAG	G	RBR	4995	2700	CastelliU	2158

.....

...and even tracked back to

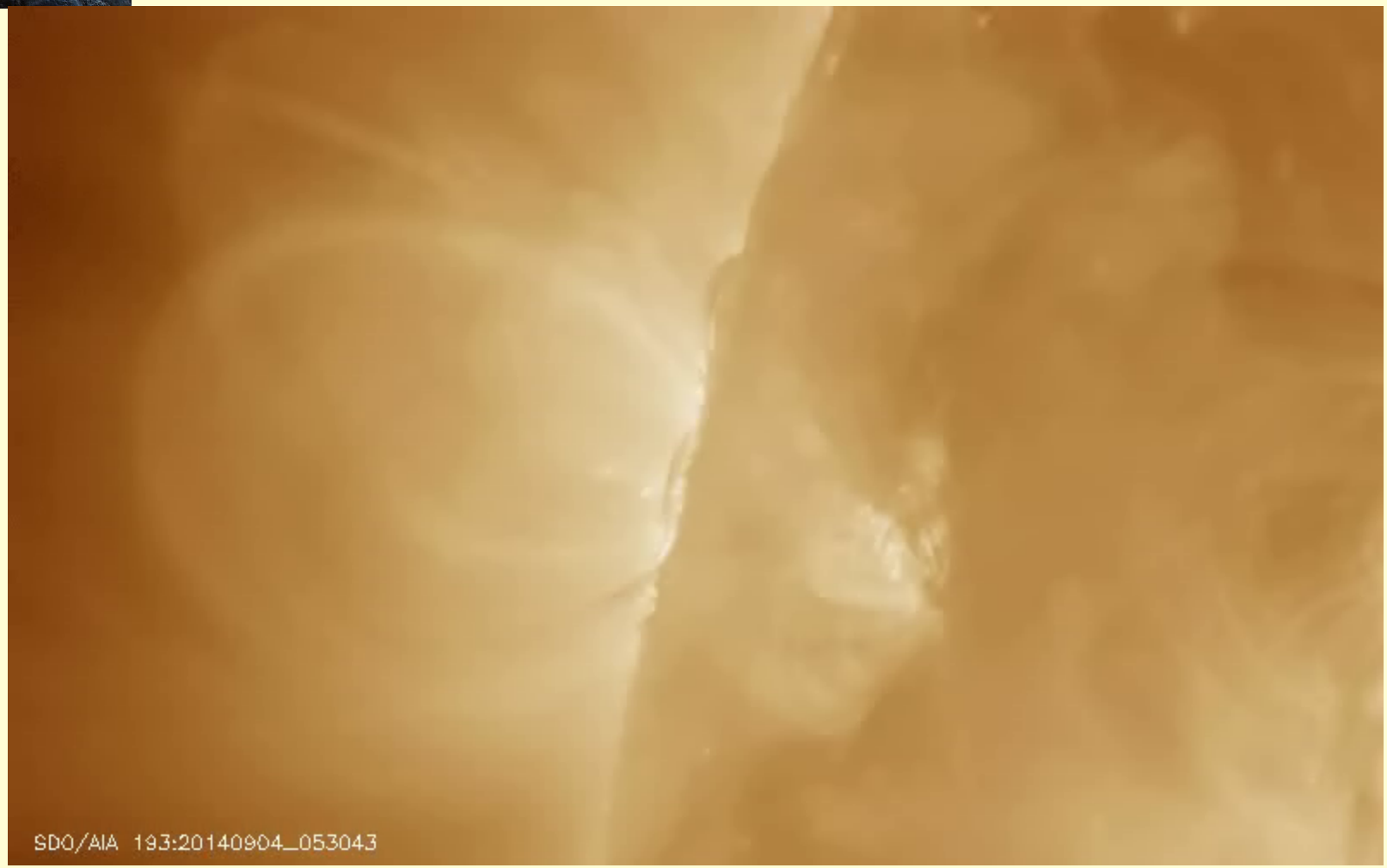


Active region 2158



the Farside (backside) of Sun

Or generate a movie of the flare

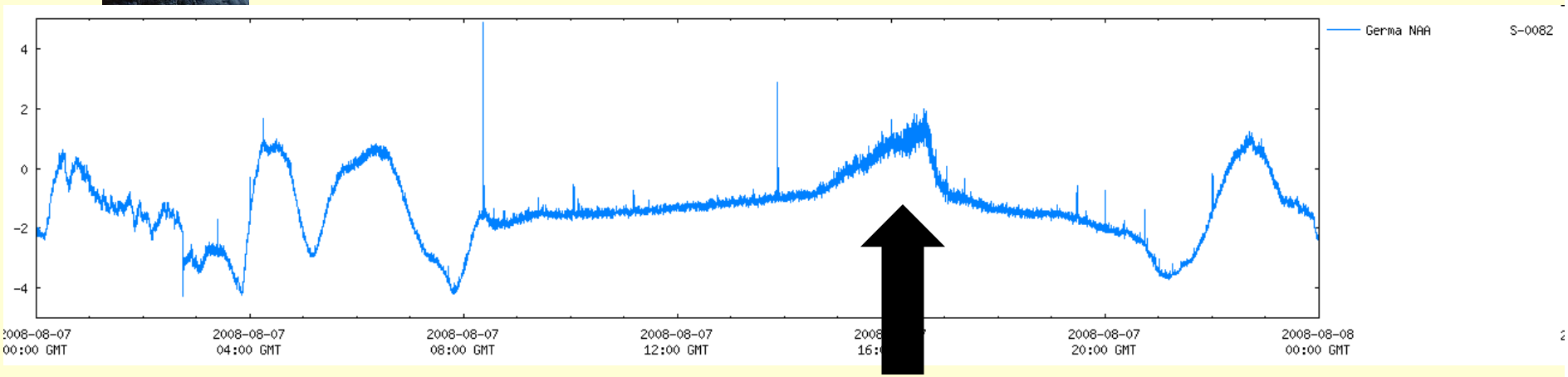


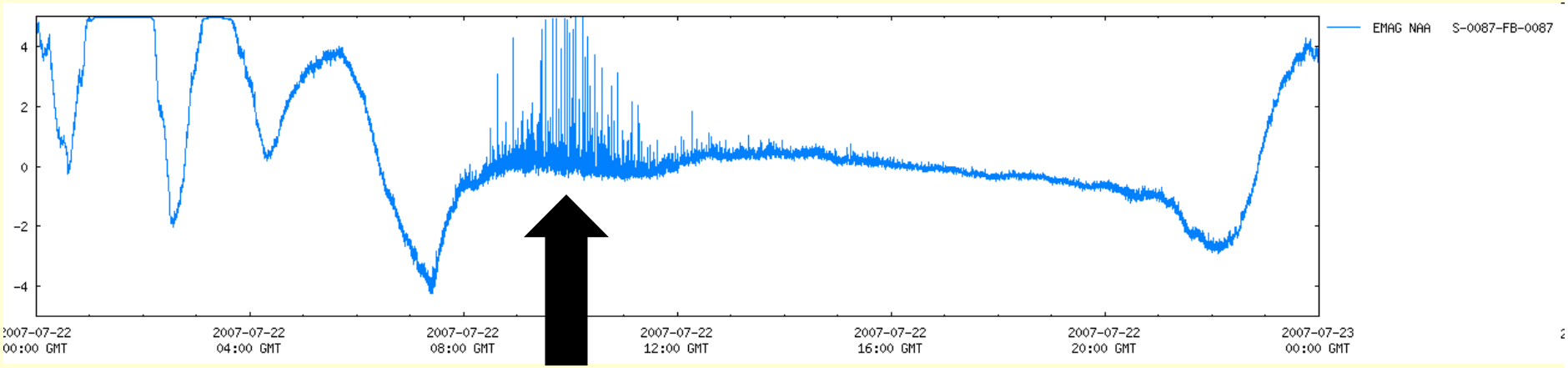
Student Research Topics

- Sunrise/sunset phenomena & changes over time, season, latitude, distance from transmitter, site, weather, etc.
- Identifying solar flares, tracking back to Sun, perhaps predicting
- Antenna design
- Unusual events – Thunderstorms, meteor showers, CMEs, GRBs, planetary waves, earthquakes
- Electrical interference
- Eclipses
- Correlation with local events (e.g. photovoltaic power plant increases associated with flares, local hospital admissions, etc.)

Thunderstorms

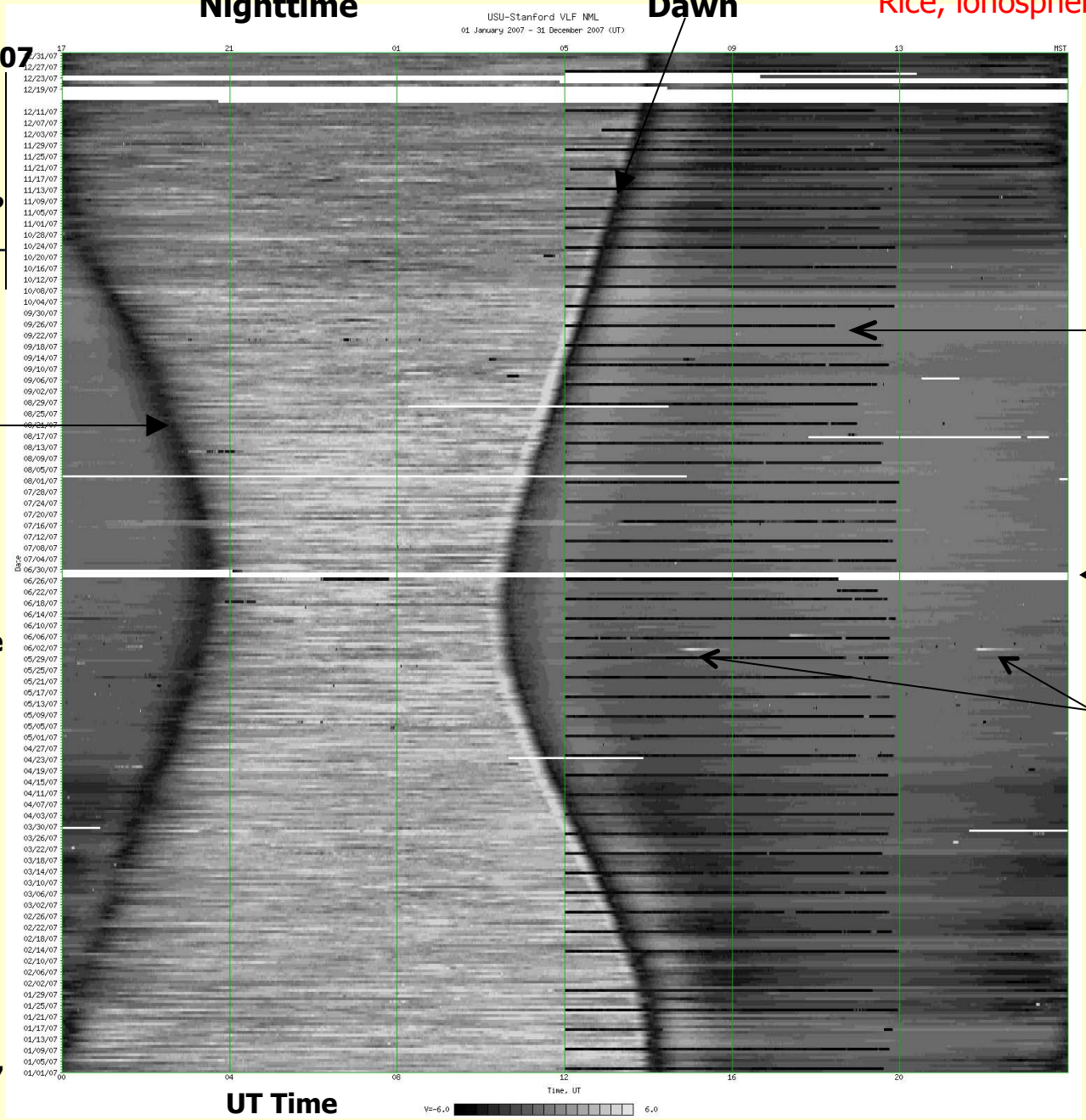
Thunderstorms detected by German students
Short distance between transmitter (DHO) and school



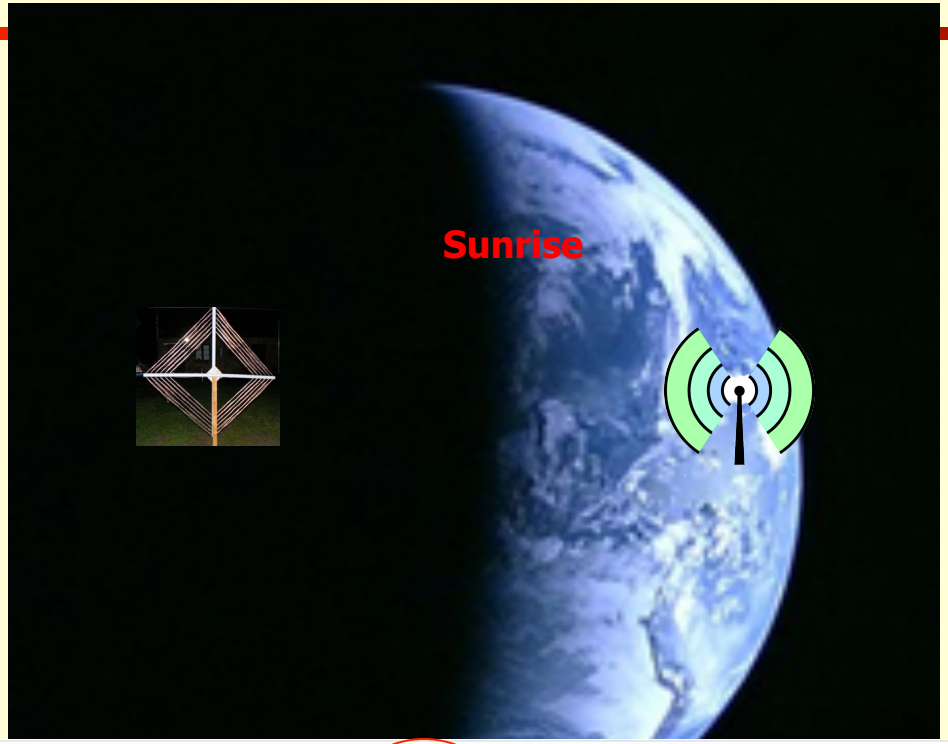


Ionospheric Research

One year of SID data, collected by Don Rice, ionospheric researcher

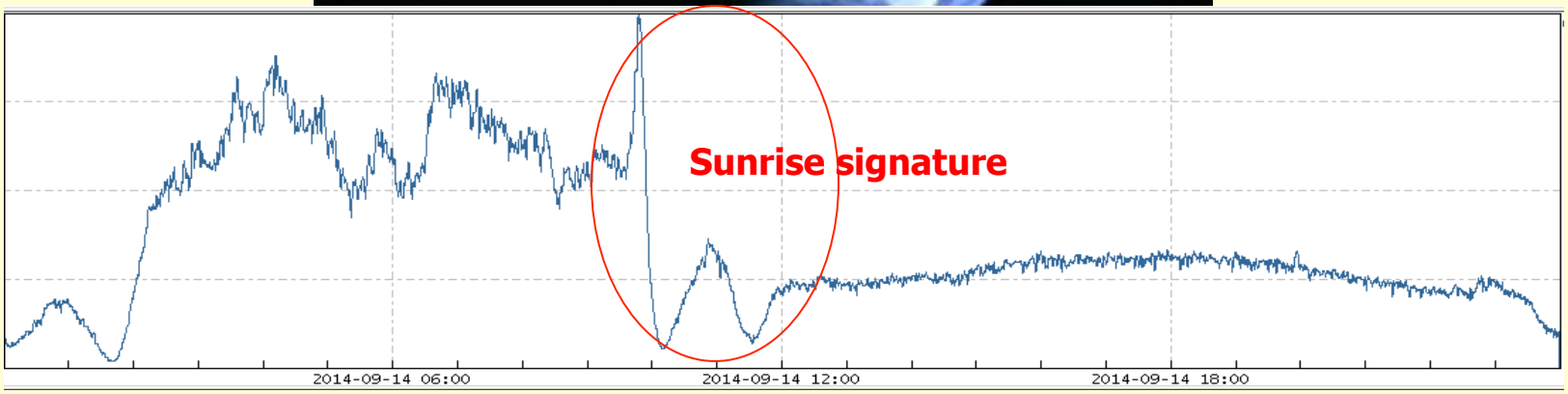


Thought problem: What location constitutes the sunrise in the SID data?



SID receiver

VLF transmitter



Obtaining Instruments

- Distribution through the Society of Amateur Radio Astronomers (SARA)
- Cost is ~US$50 plus shipping. Stipends often available.
- Cost is free for ISSS attendees. I have 10 to give away today. The rest of you will need to request an order form.

For more information:

http://solar-center.stanford.edu/SID

To request an order form, send email to:
superSID@radio-astronomy.org

Questions?

Thank you!