Here comes the Sun… or maybe not!

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The Relationship Between Very Low Frequency (VLF) Radio Signal Strength and Changes in the Ionosphere

Research Question

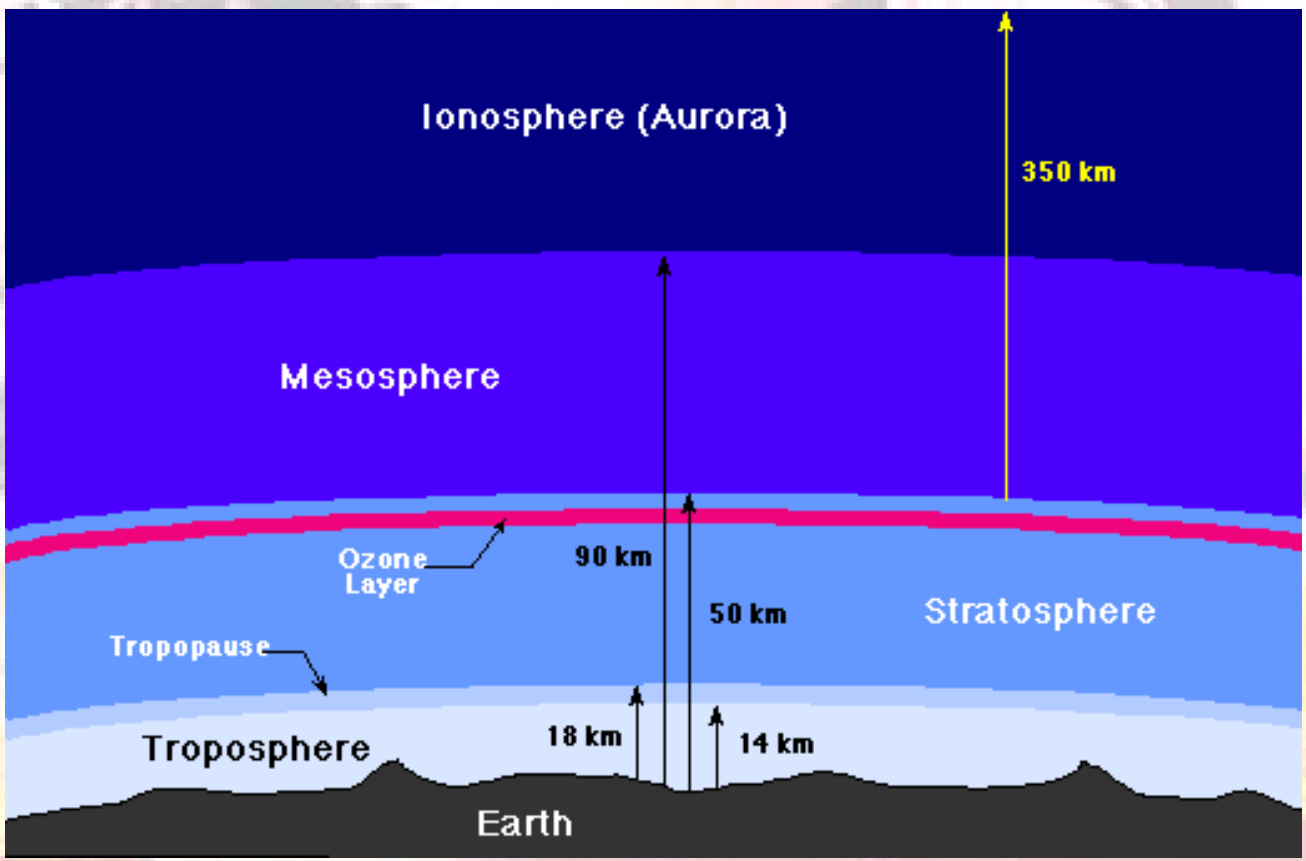
- Can we detect and interpret a change in very low frequency (VLF) electromagnetic signals.

Why do we care?

- Space Weather
- Aviation
- Astronauts
- Telecommunications
- Power Grids
- GPS

Ionosphere Primer

- That part of the upper atmosphere that is ionized by solar radiation

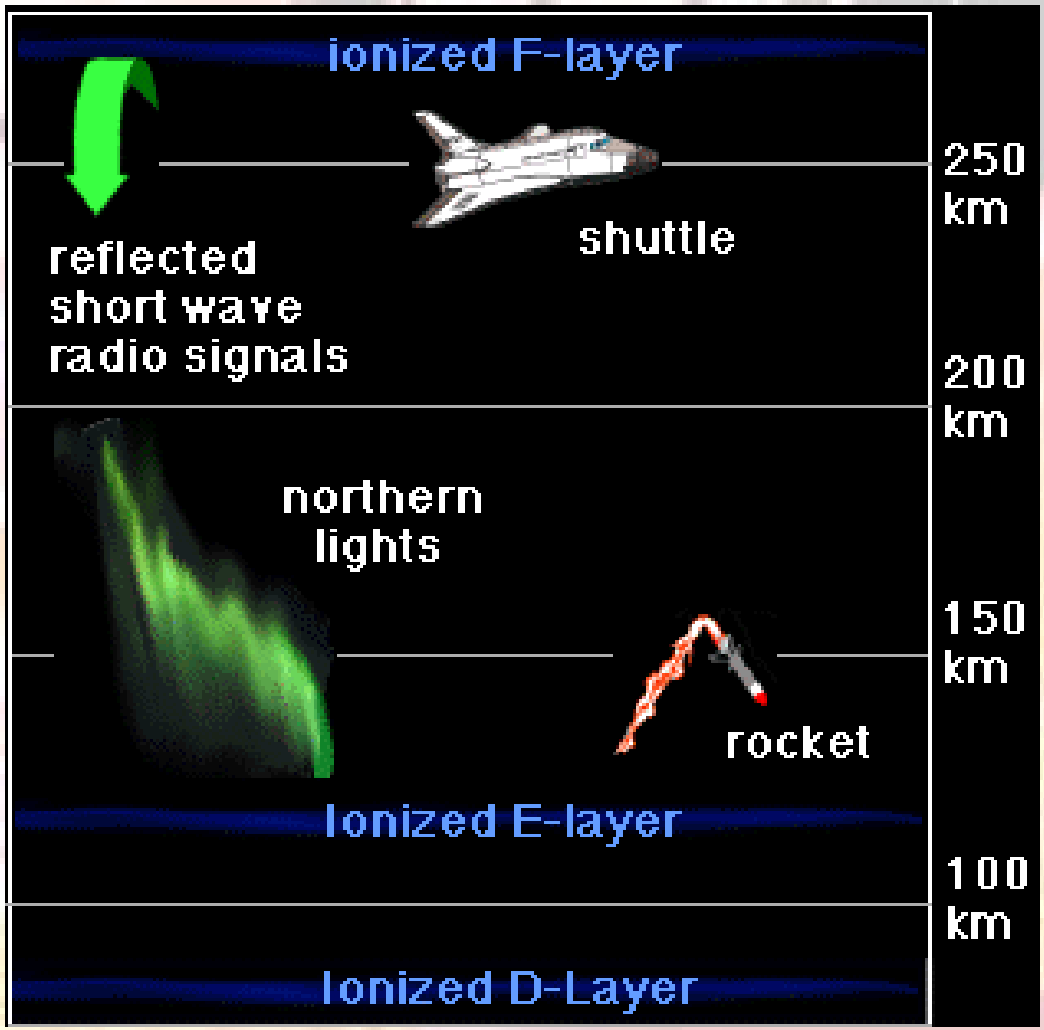


Ionosphere Primer cont'd.

- Solar energy in the form of x-rays and UV radiation strikes the ionosphere
- Ionizination – stripping off electrons from their nuclei…hence, ionosphere

Ionosphere Primer cont'd.

- A layer cake
- Each created at different altitudes and made up of different densities of ionization
- Each changes daily under the sun's influence



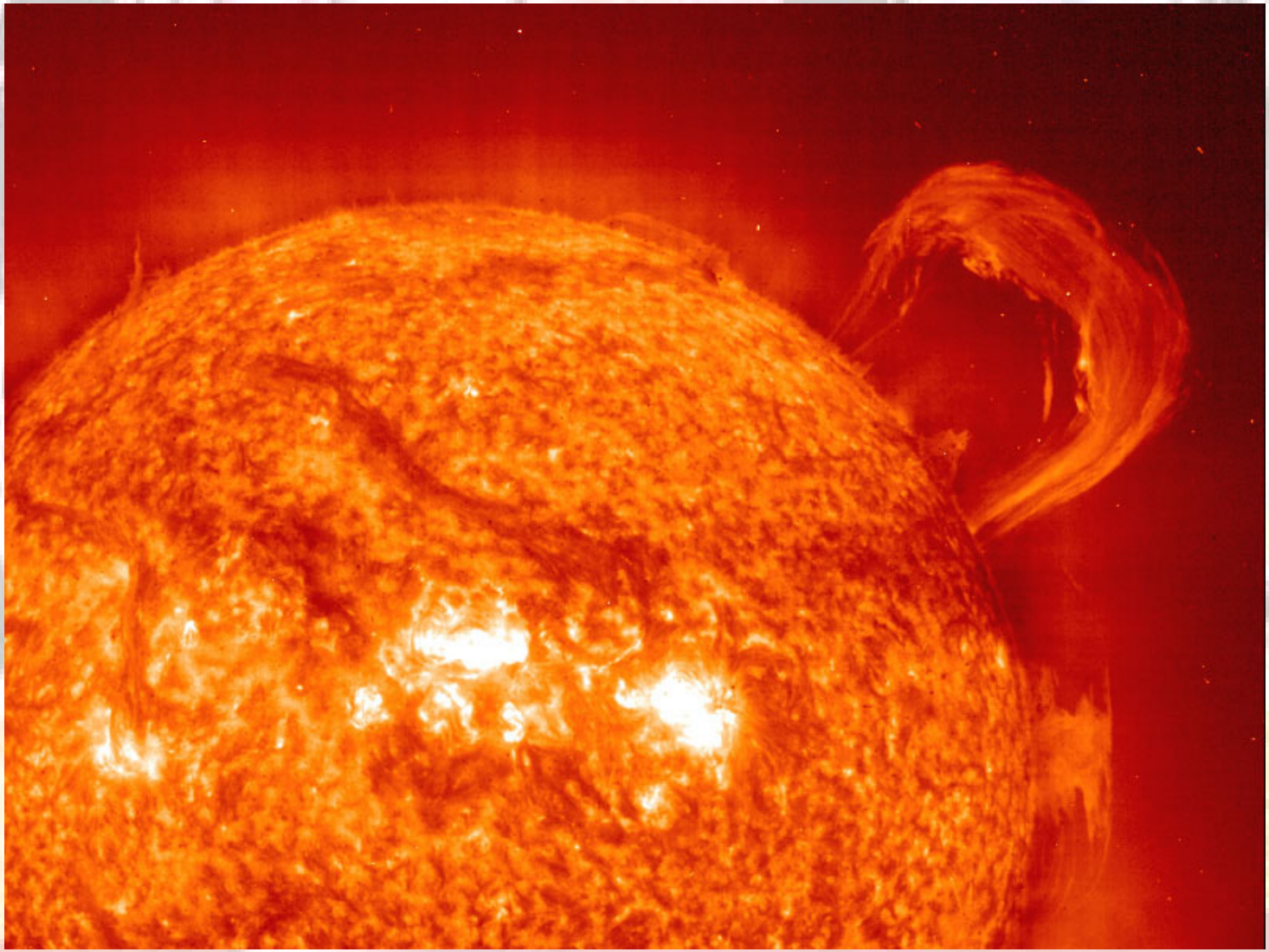
Ionosphere Primer cont'd.

- Variations in the density of the ionosphere are cause by
  - Day/night cycles
  - Geographic location (polar, auroral zones, mid-latitudes, and equatorial regions)
  - And……

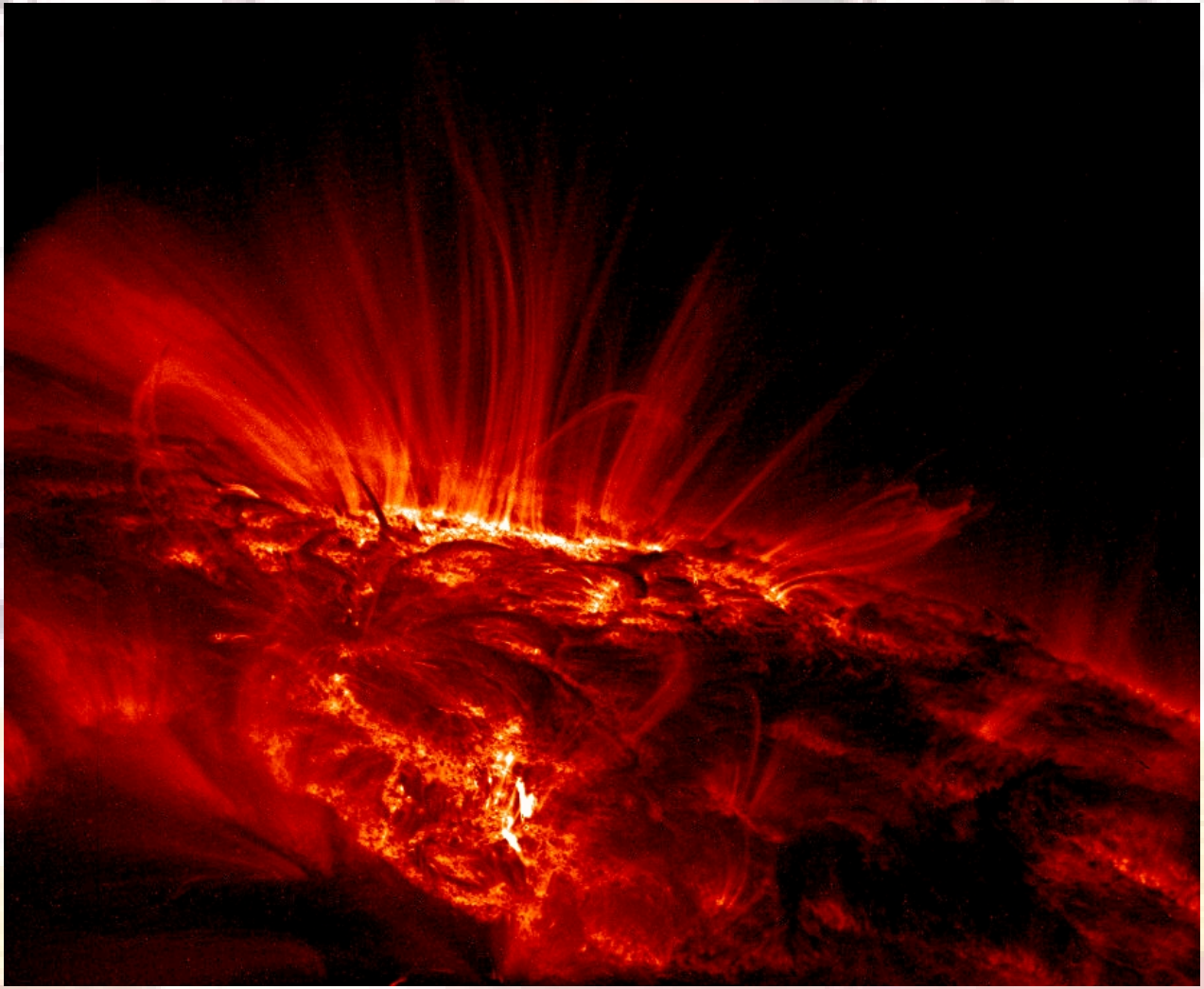
Ionosphere Primer cont'd.

- Sudden ionospheric disturbances – caused by increased solar activity (CME, solar flares, solar prominences)
- Cause dramatic changes to the ionosphere changing its density and location of the layers

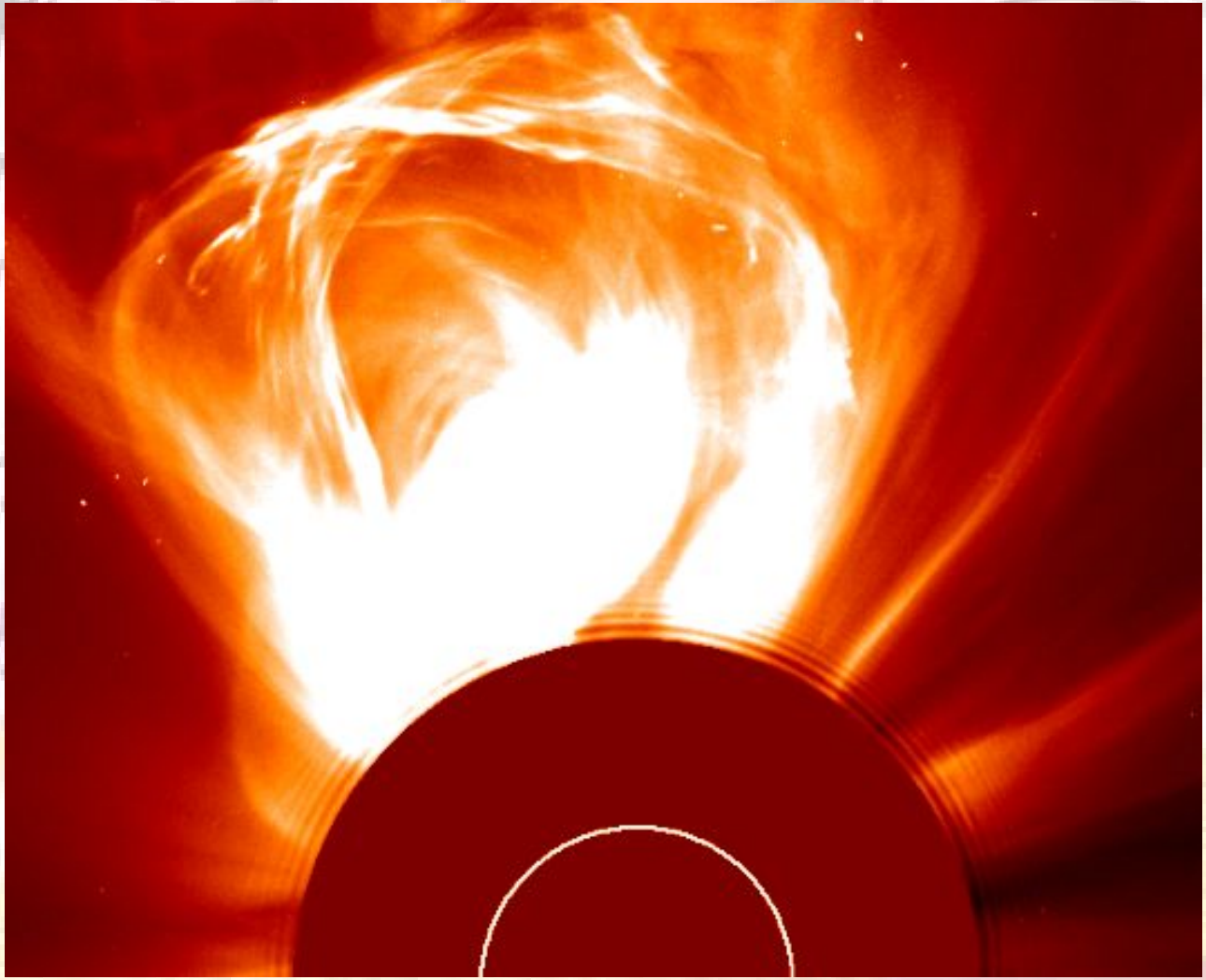
Solar Prominences



Solar Flares



Coronal Mass Ejections

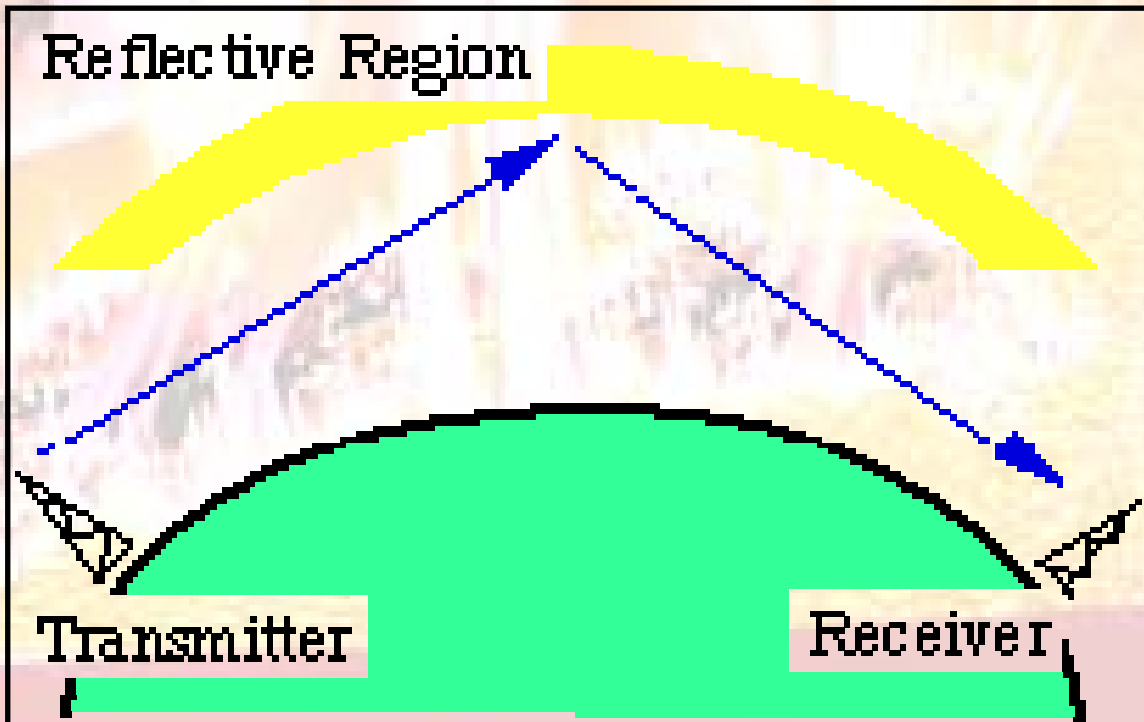


Ionosphere Primer cont'd.

- These explosions can hurl matter and energy earthward
- Matter arrives 72 hours later
- Energy arrives 8 minutes later
- Our space weather monitor tracks the energy

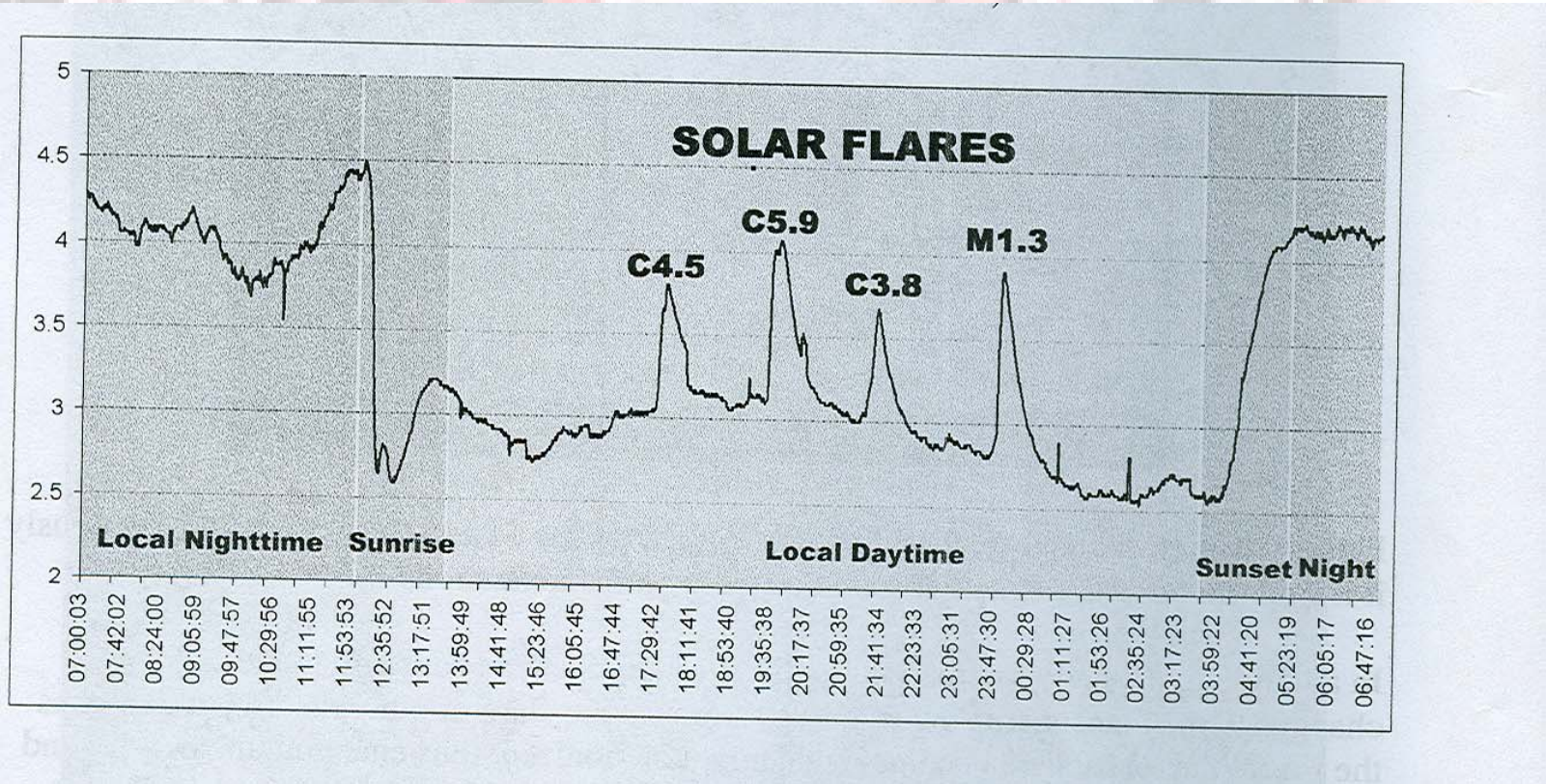
Ionosphere Primer cont'd.

- The ionosphere, now highly charged can strongly influence the propagation of very low frequency (VLF) signals.
- These bounce or reflect off the ionosphere, allowing radio communication over the horizon and around our curved Earth.



Ionosphere Primer cont'd.

- Strength of signal changes according to how much ionization has occurred

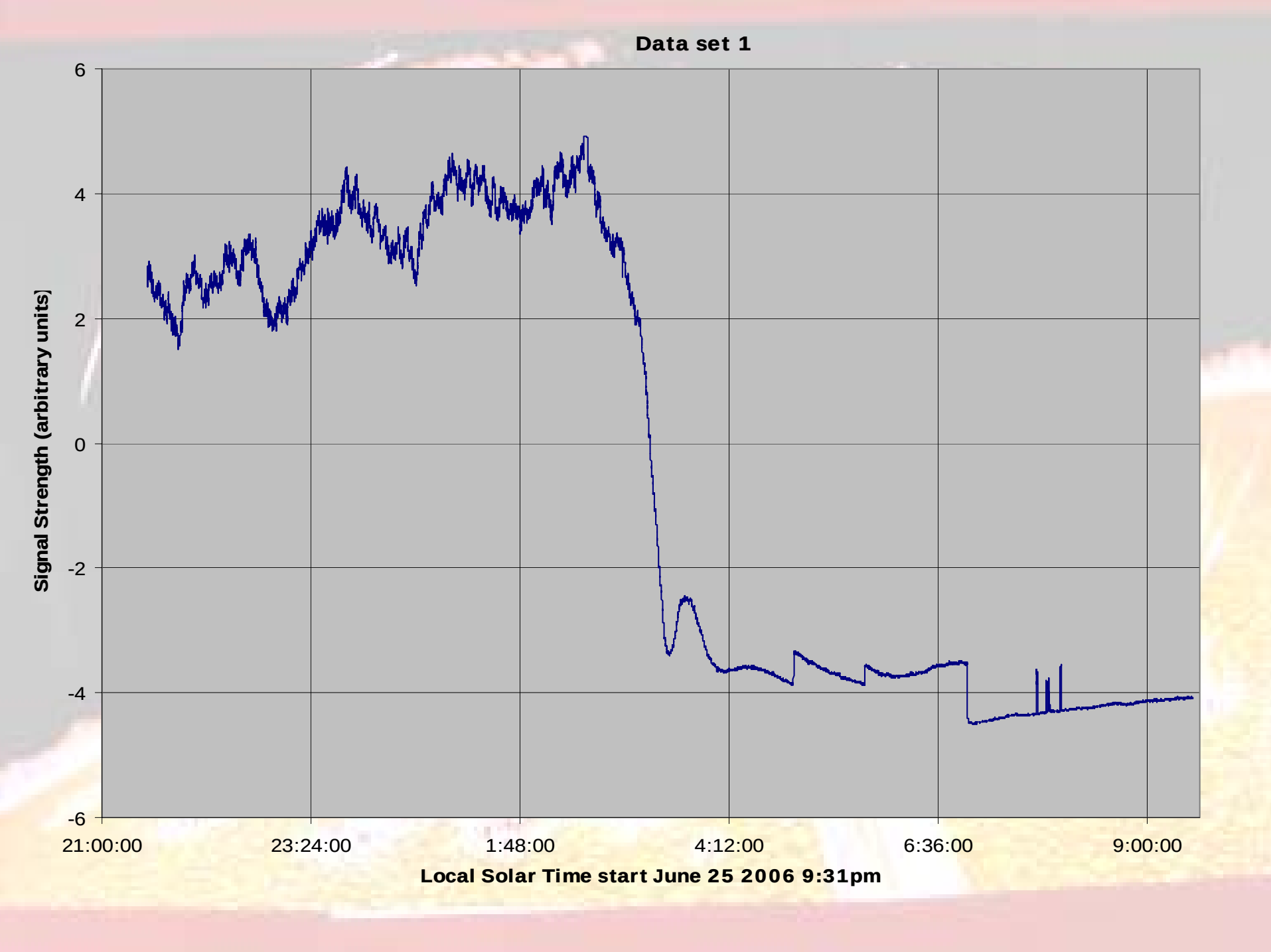


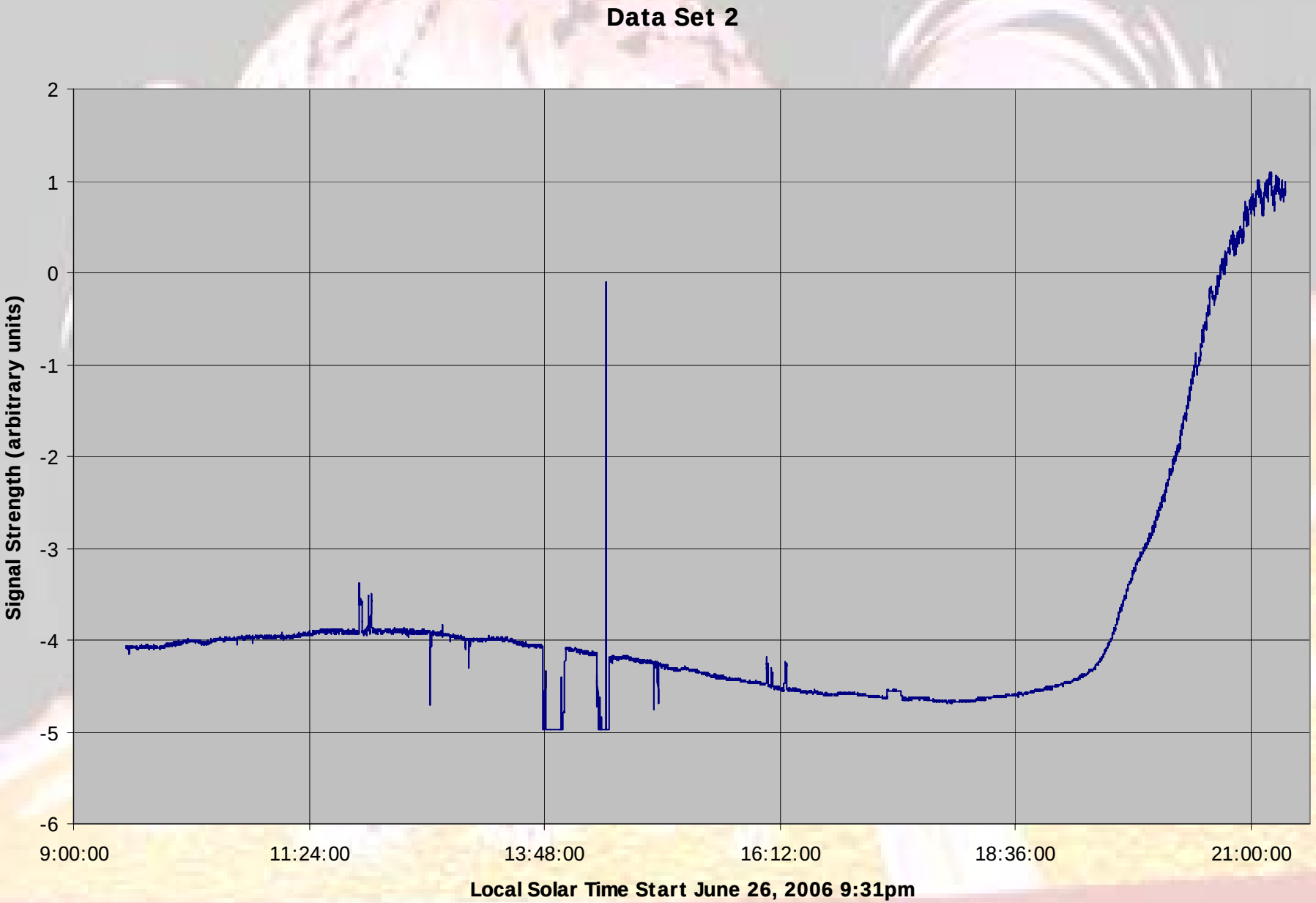
Ionosphere Primer cont'd.

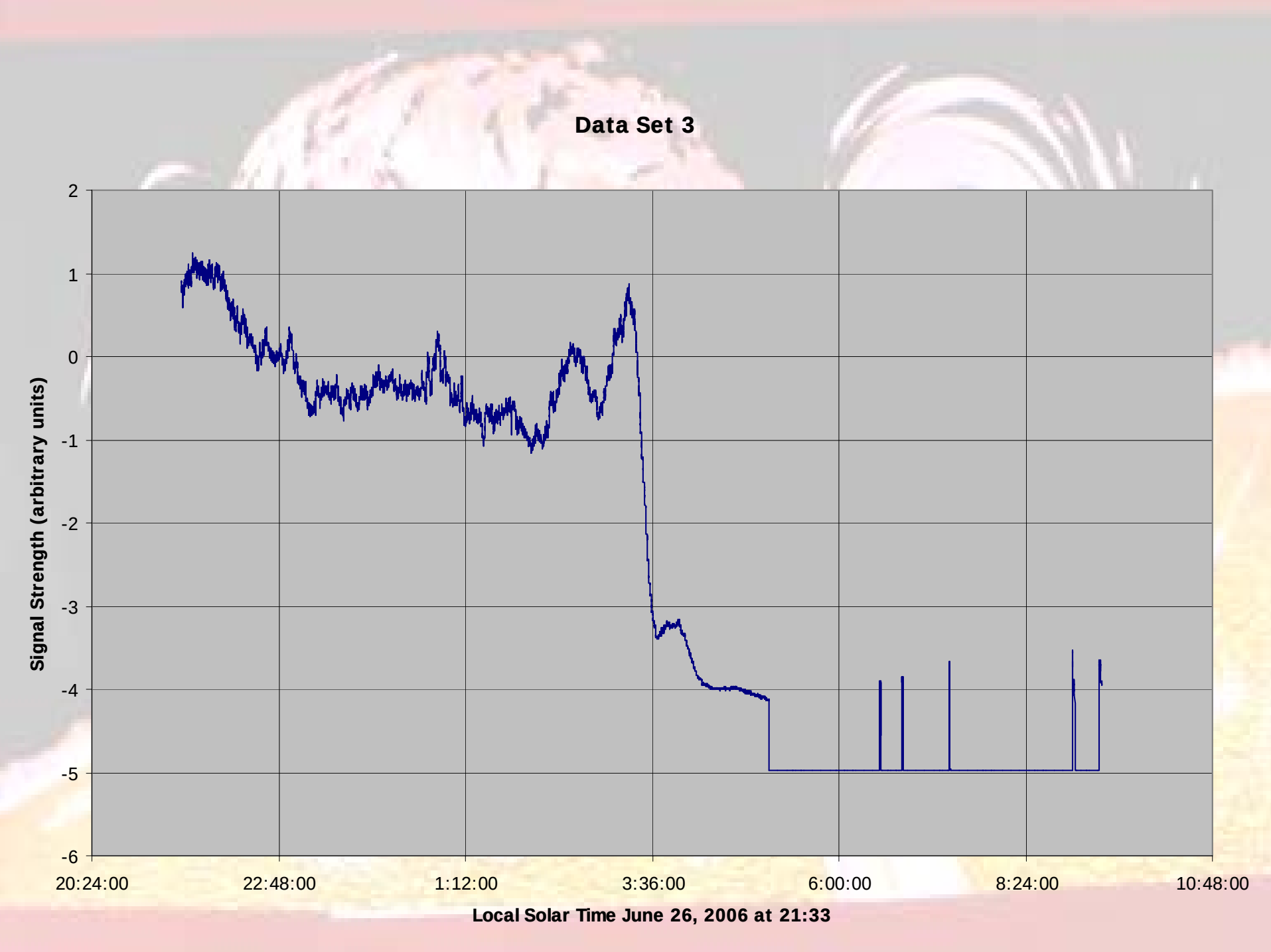
- Changes in signal strength indicate changes in the ionosphere which point to changes in solar activity.

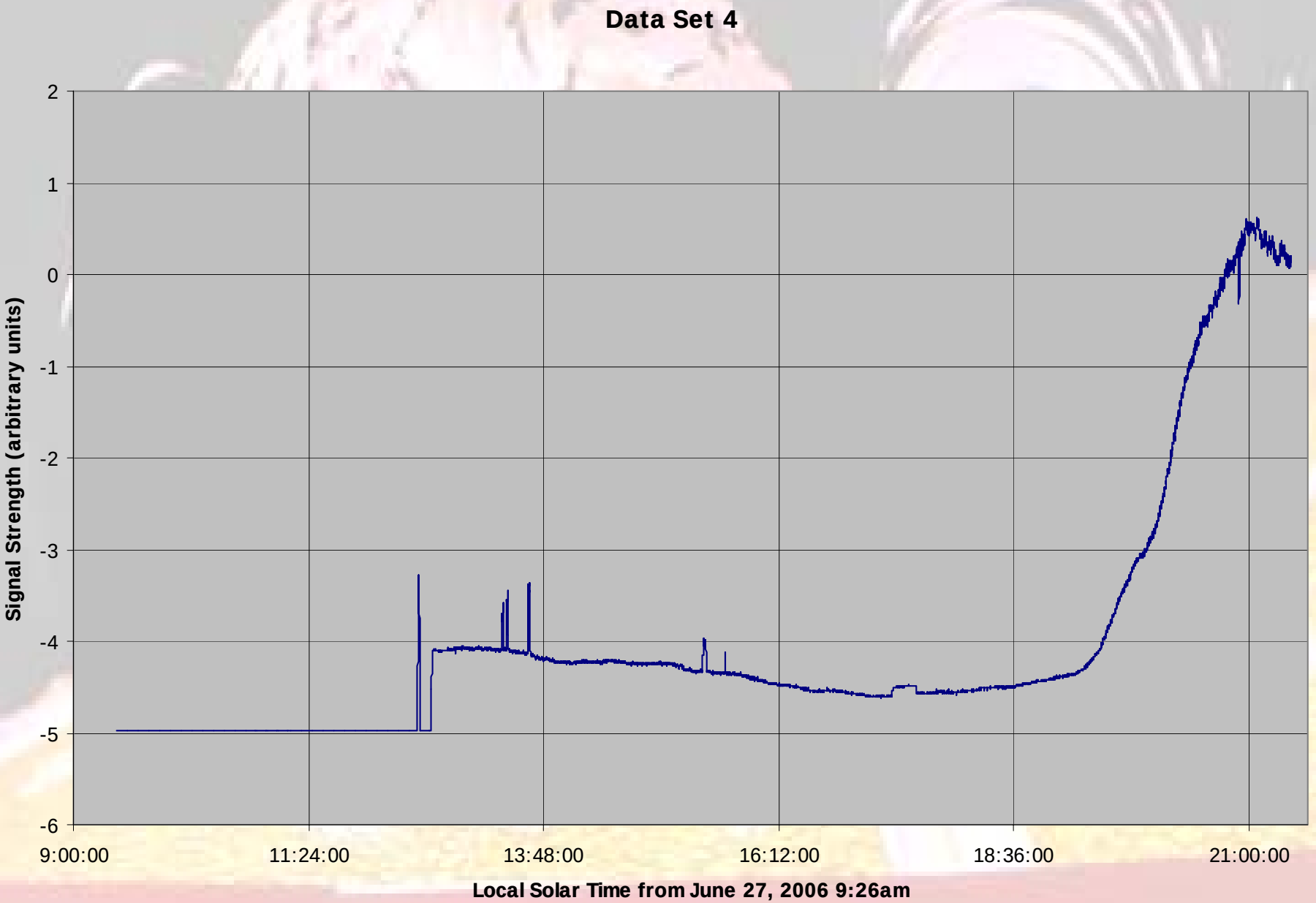
How the data was managed

- Data was collected at a rate of 1 sample every 2 seconds in 12 hour sets for a total of 4 data sets (48 hours)
- The output file was imported into Excel and time calculations were made
- Where significant events were noted, separate plots were made of those details
- A formal set of instructions for data manipulation is available


Data set 1
Signal Strength (arbitrary units)
6
4
2
0
-2
-4
-6
21:00:00
23:24:00
1:48:00
4:12:00
6:36:00
9:00:00
Local Solar Time start June 25 2006 9:31pm


Data Set 2
Signal Strength (arbitrary units)
2
1
0
-1
-2
-3
-4
-5
-6
9:00:00
11:24:00
13:48:00
16:12:00
18:36:00
21:00:00
Local Solar Time Start June 26, 2006 9:31pm

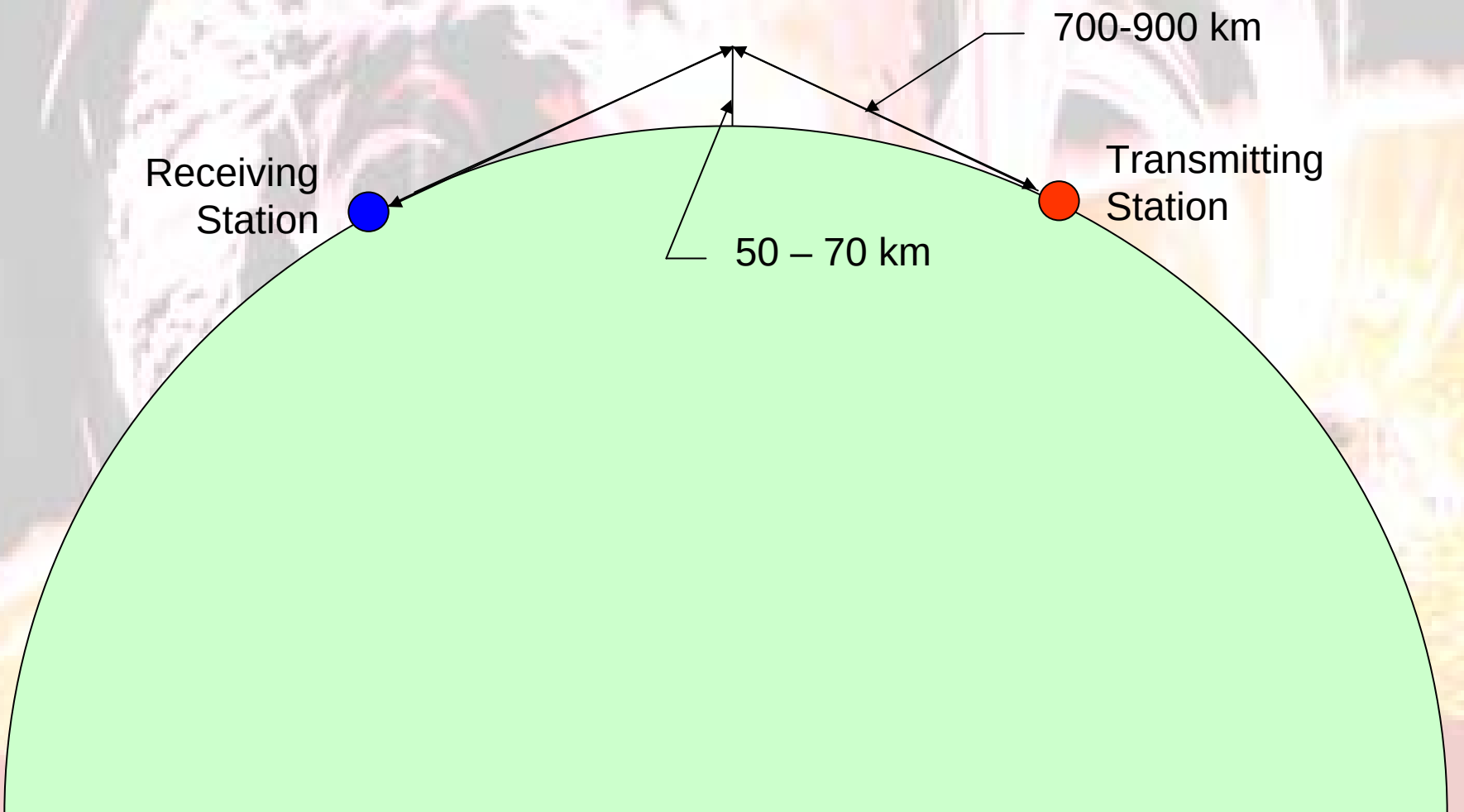

Data Set 3
Signal Strength (arbitrary units)
2
1
0
-1
-2
-3
-4
-5
-6
20:24:00
22:48:00
1:12:00
3:36:00
6:00:00
8:24:00
10:48:00
Local Solar Time June 26, 2006 at 21:33

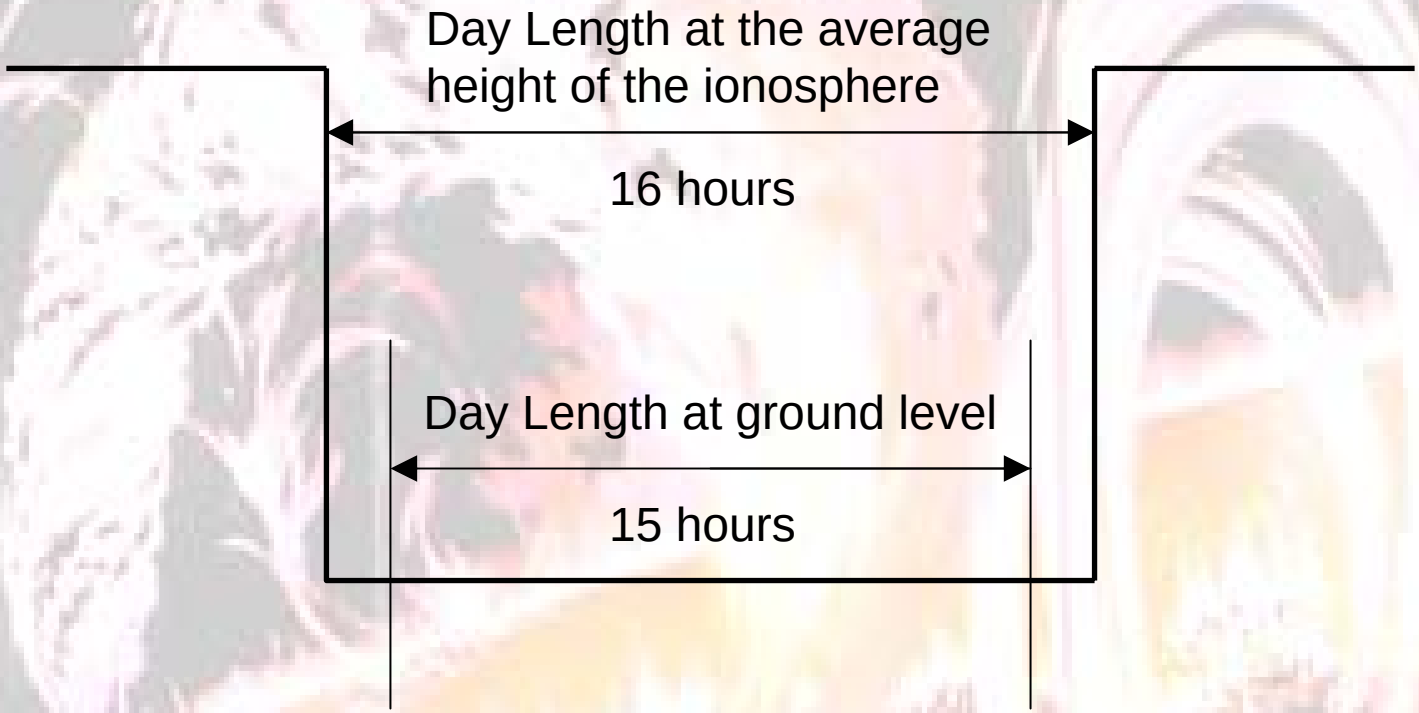

Data Set 4
Signal Strength (arbitrary units)
2
1
0
-1
-2
-3
-4
-5
-6
9:00:00
11:24:00
13:48:00
16:12:00
18:36:00
21:00:00
Local Solar Time from June 27, 2006 9:26am

The Geometry

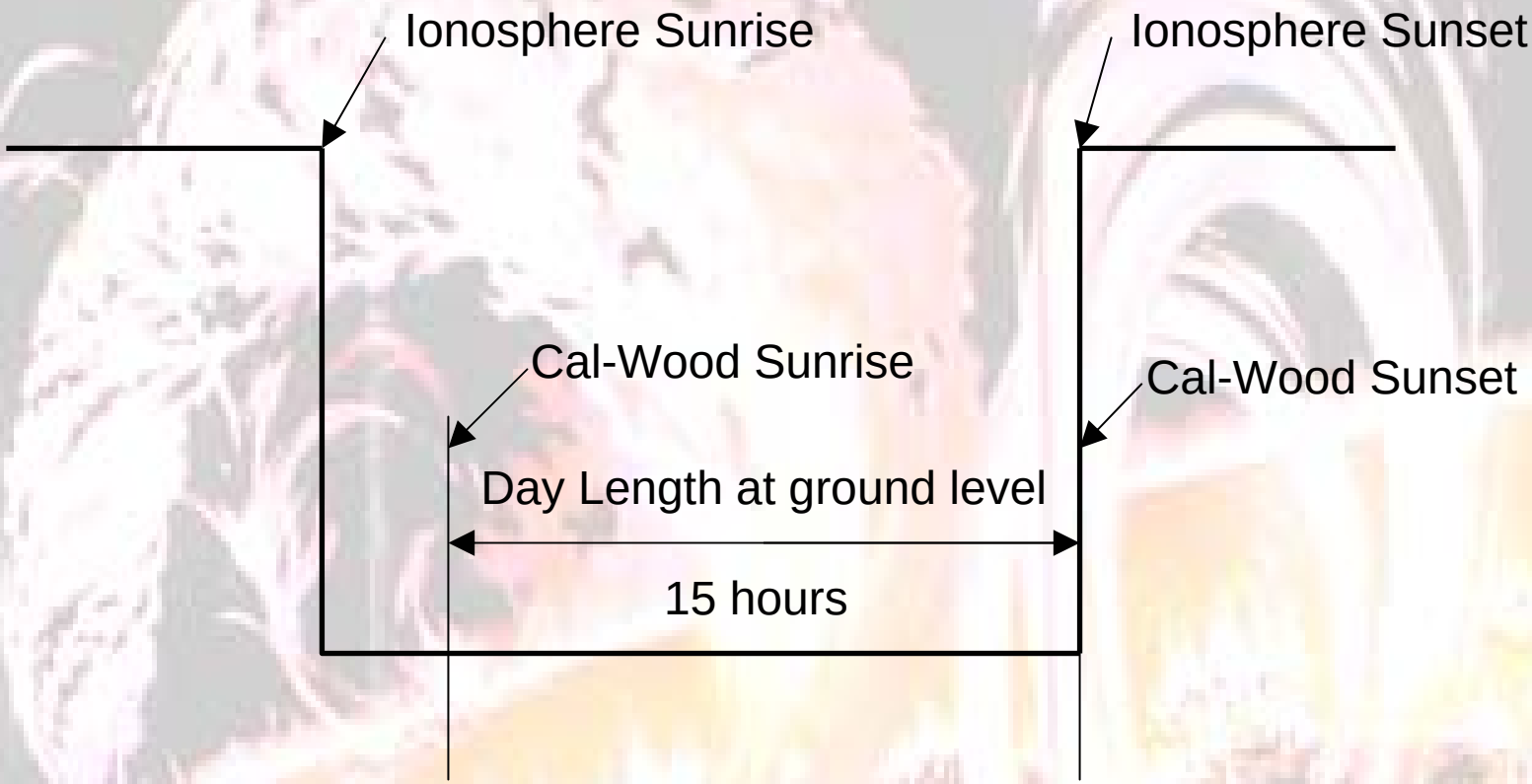
- The transmitting station is in LaMoure, North Dakota (46.37N, 98.33W)
- The height of the ionosphere above the Earth's surface is from 50 – 70 km
- Due to the curvature of the Earth, the signal is bouncing one time between the transmitting station and our receiver
- The bounce point is half way between LaMoure and Cal-Wood

Average Height of the Ionosphere

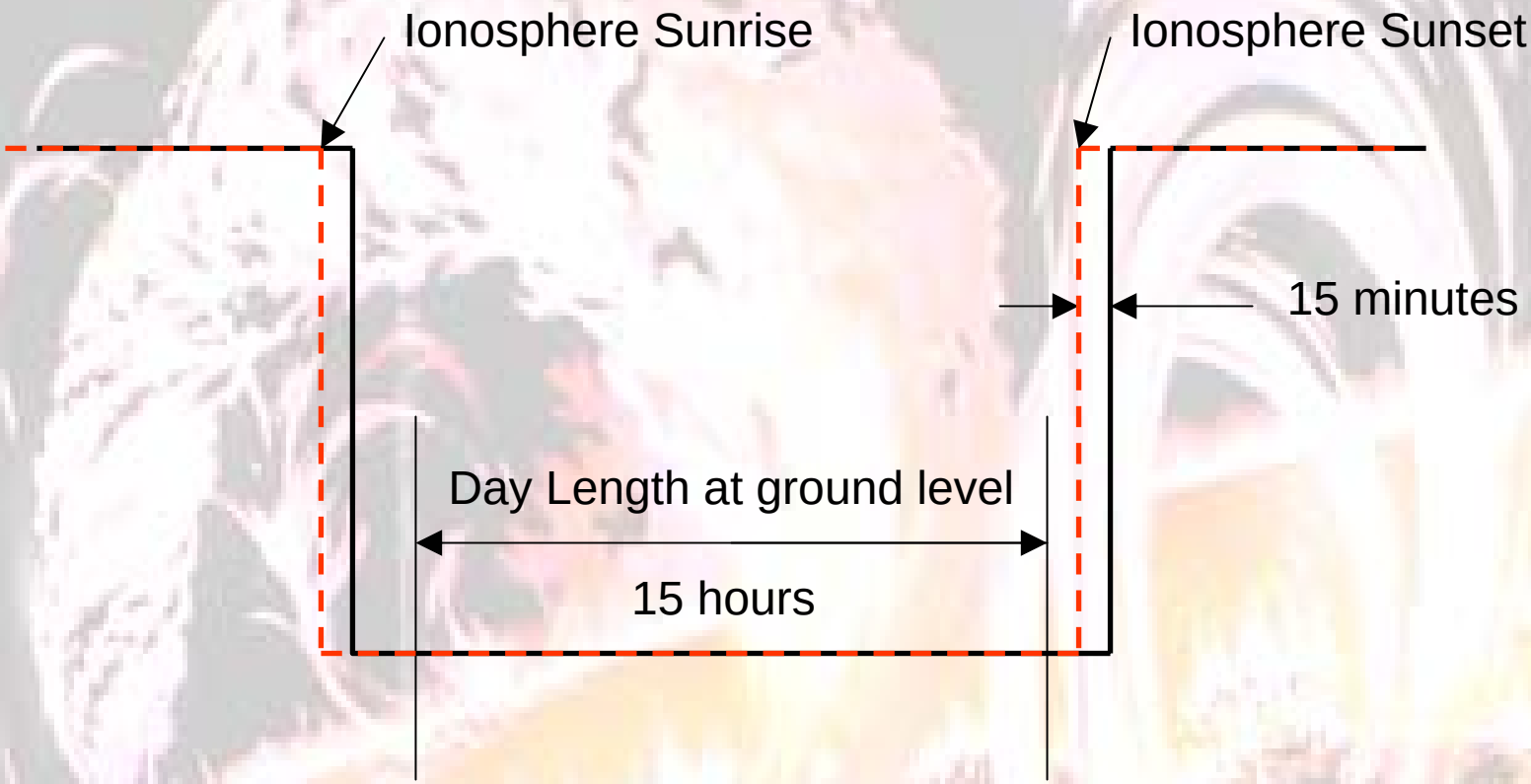




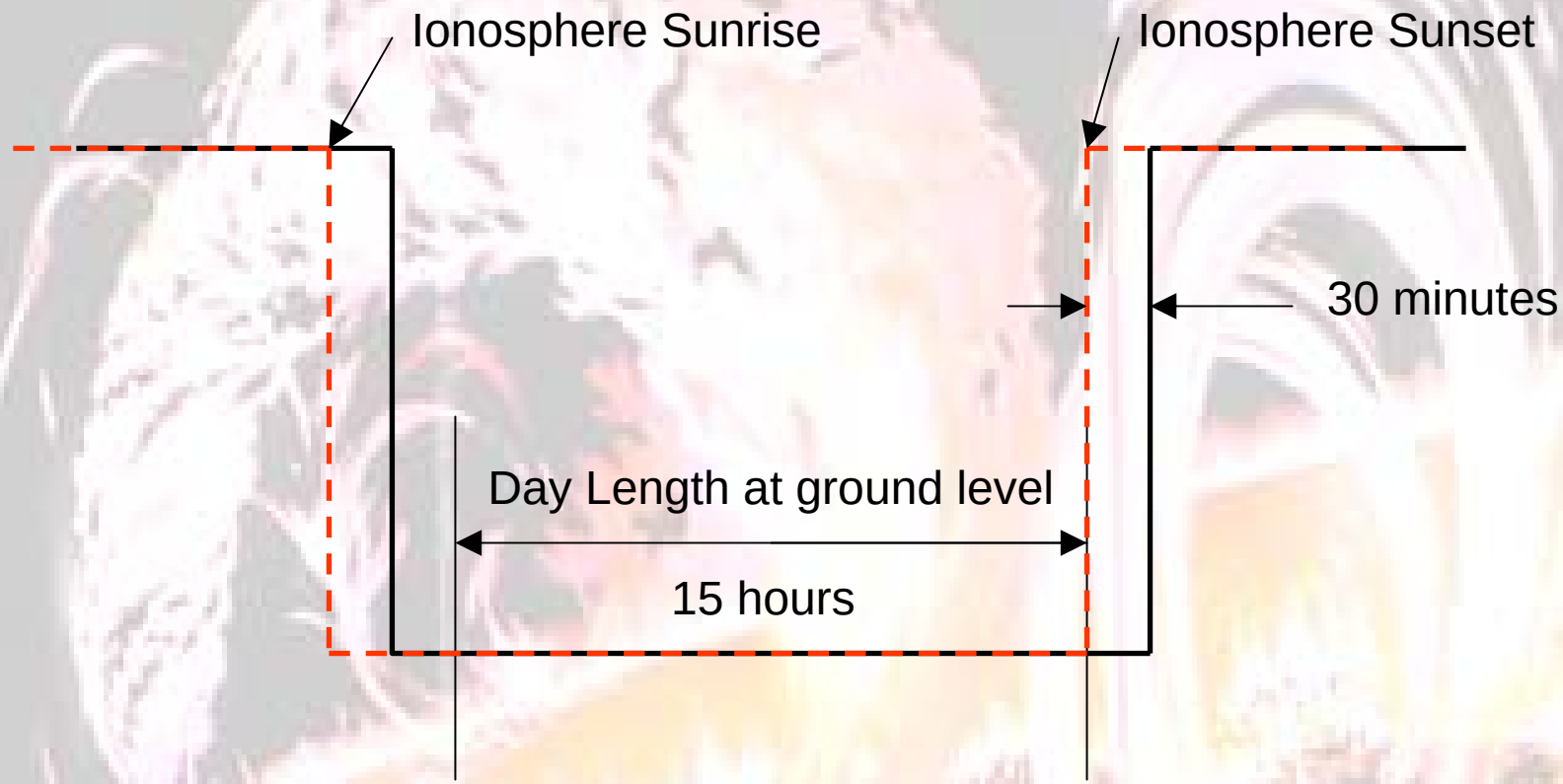
Relationship between day lengths at Earth's surface and at the ionosphere



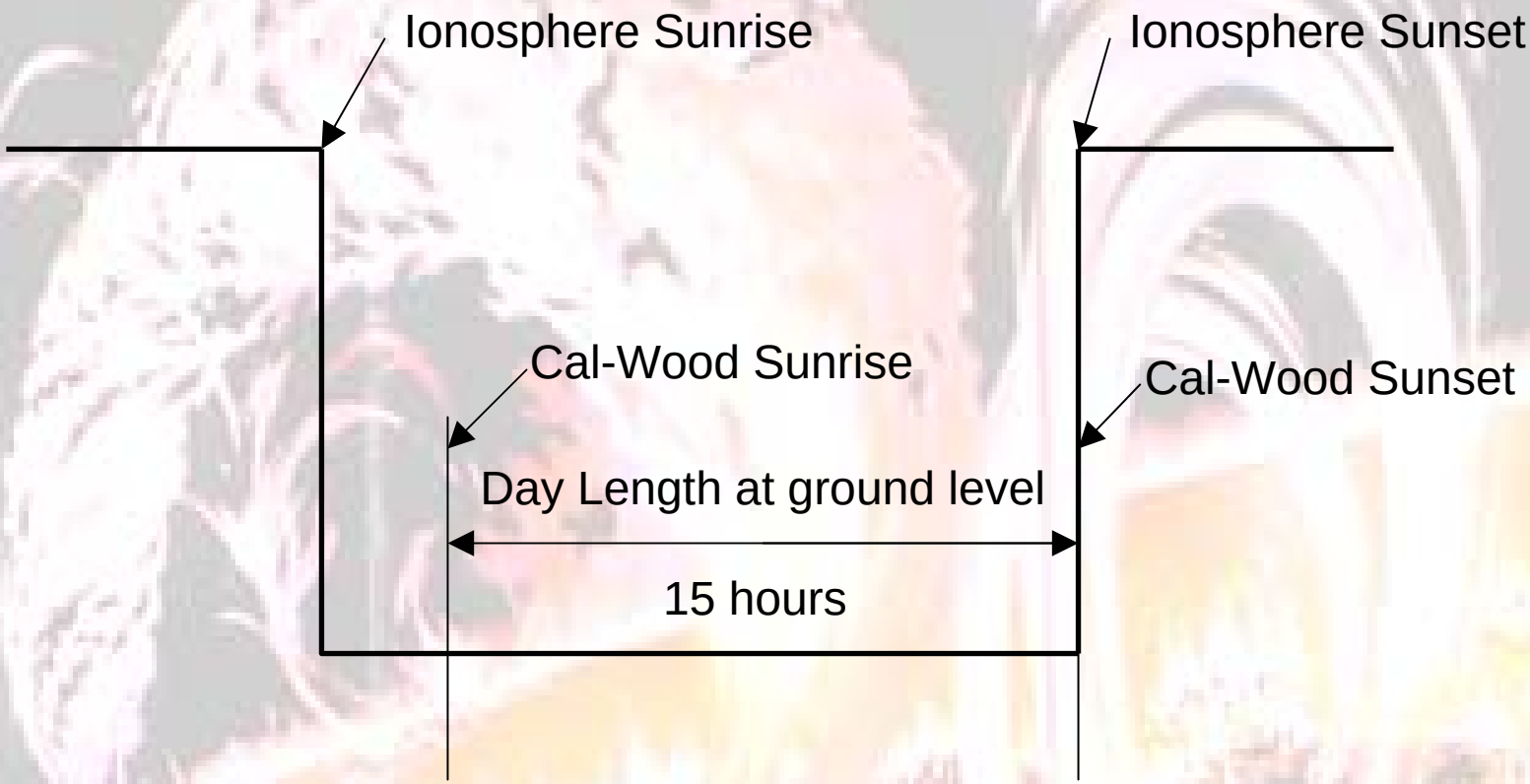
Observed relationships between sunrises and sunsets



Shift of ionospheric day to earlier time due to the reflection to the east of Cal-Wood



Further shift of ionospheric day to earlier time due to morning reflection off the ionosphere at a greater height



These observed relationships between sunrises and sunsets are thus explained by the combination of these two effects

Conclusions

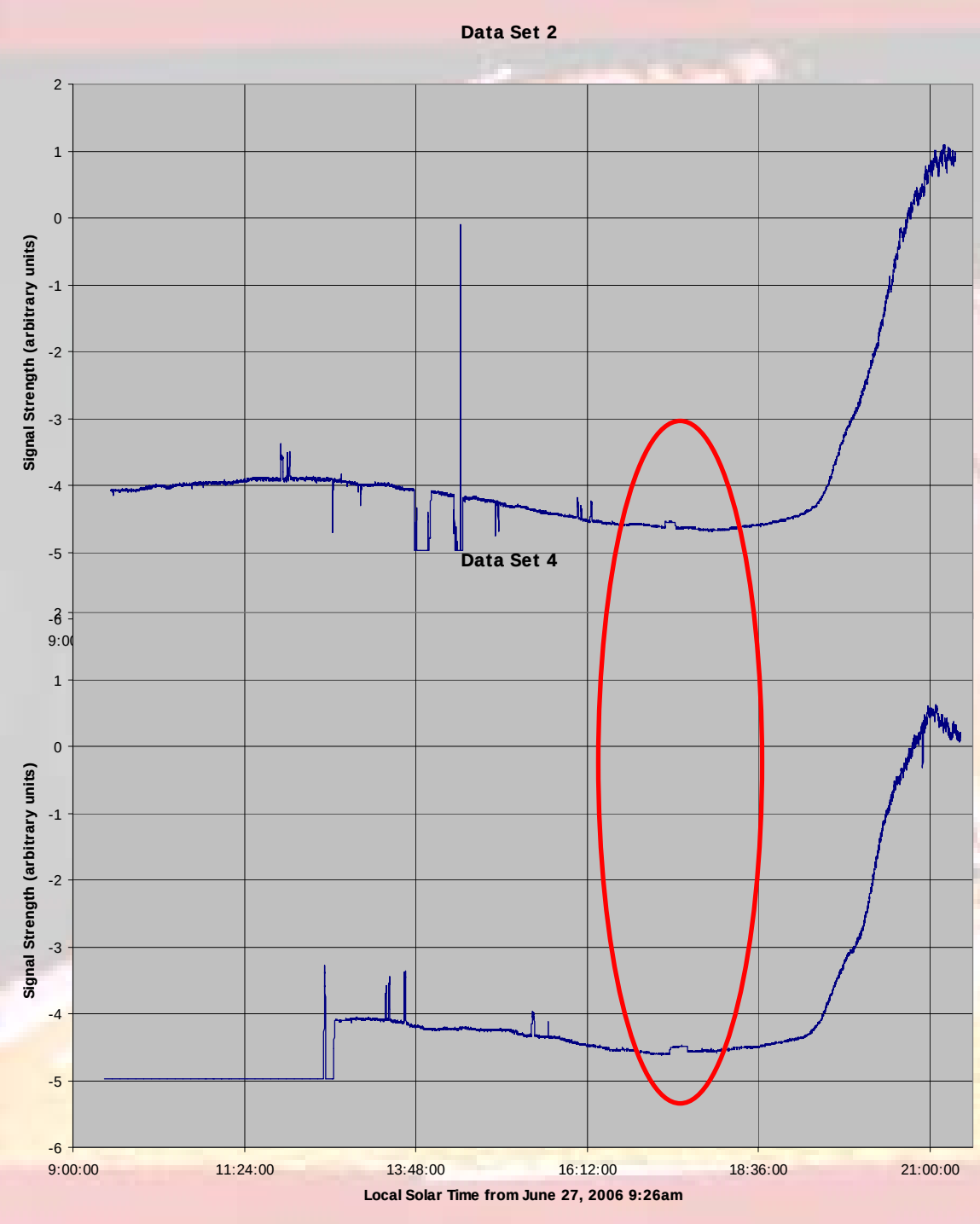
- Expected diurnal variations were detected and interpreted
- We found the length of the ionospheric day to be 16 hours
- This is consistent with an ionosphere at an average height of 60 km
- The ionospheric day was shifted 1 hour earlier than the local solar time
- This is consistent with a bounce point of 300 km east of Cal-Wood in combination with an ionosphere shifting from 50-70km

What we learned

- How to build an antenna
- How to calculate the difference between local and ionospheric diurnal cycle
- How to process the data received
- Where to search for explanations for any solar activity that may be detected

Problems or Detours

- Human interference with the antenna
- Calibration issues with SID Monitor
- Corrections to data due to calibration issues



Anomalies

- An interesting change in signal strength was detected on both collection days.
- The same signal signature was seen on the day after official data collection was completed.
- We have no clue about the origin of the signal but it is definitely not solar.

The Equipment

- Homemade Antenna
- Stanford Sudden Ionospheric Disturbance (SID) Monitor and associated software
- Analog to digital adapter
- Computer with a serial port or an adapter
- Powered speakers (optional)


CORONADO
P.S.T.

Our group would like to express our gratitude to Hartmut and Lars for their patience and direction while helping us (some more than others) learn new concepts and understand exactly what our data showed us. We started looking for one thing and completely ended up with something bigger and better than even they expected.

We would also like to thank the CIRES staff for purchasing the equipment needed to conduct this investigation. They were accommodating and