Stanford VLF Remote Sensing

Science, Engineering, Educational outreach

Morris Cohen

Along with Phil Scherrer, Deborah Scherrer, Umran Inan, Ray Mitchell, Justin Tan

Space, Telecommunications and Radioscience Laboratory

Stanford University
Stanford, California 94305
http://www-star.stanford.edu/~vlf/
http://sun.stanford.edu

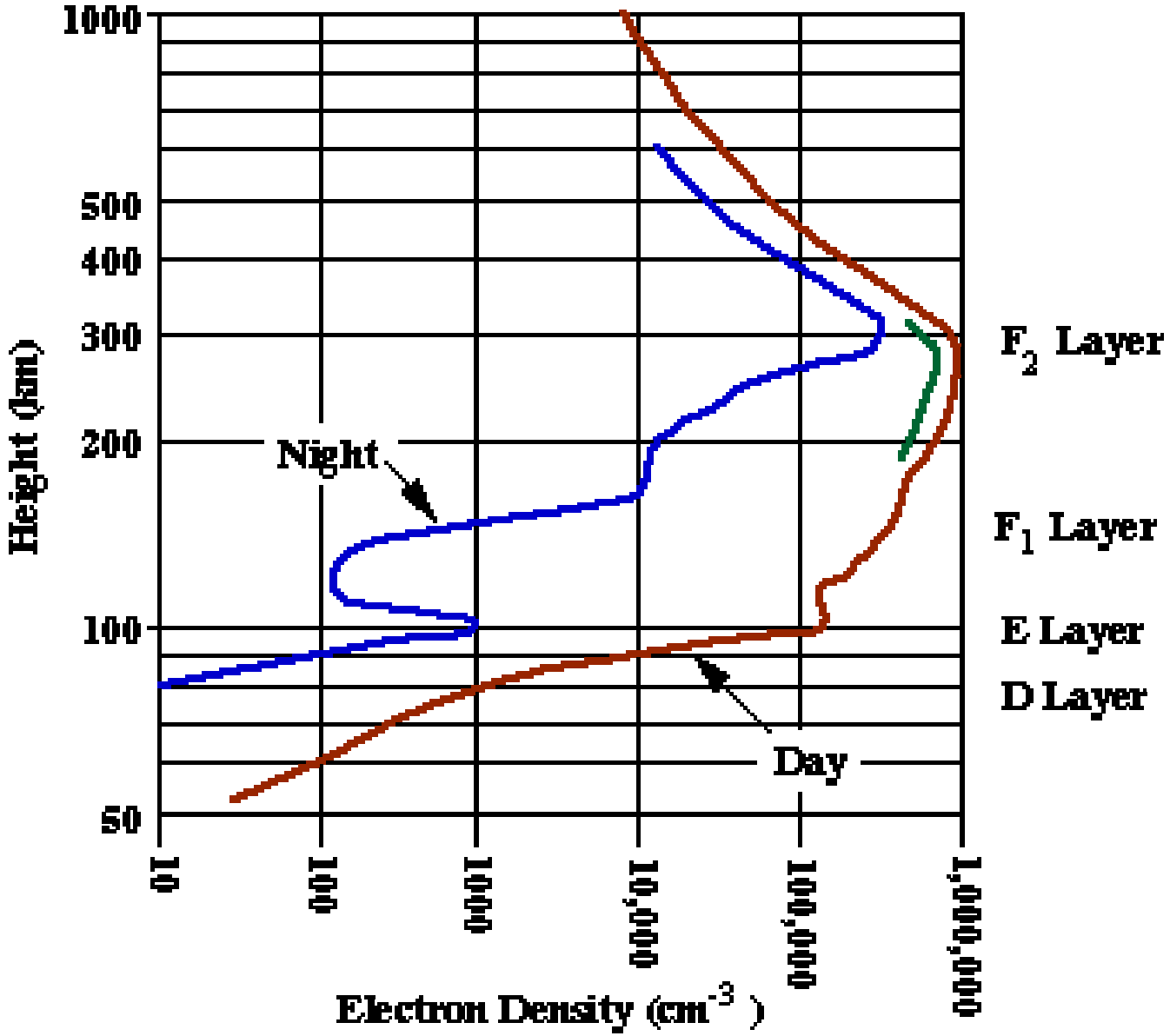
Stanford VLF Remote Sensing

- The collaborators
- Ionosphere/magnetosphere overview
- Electromagnetic effects
- SID Receiver
- AWESOME Receiver
- Educational Outreach

The Stanford Collaborators

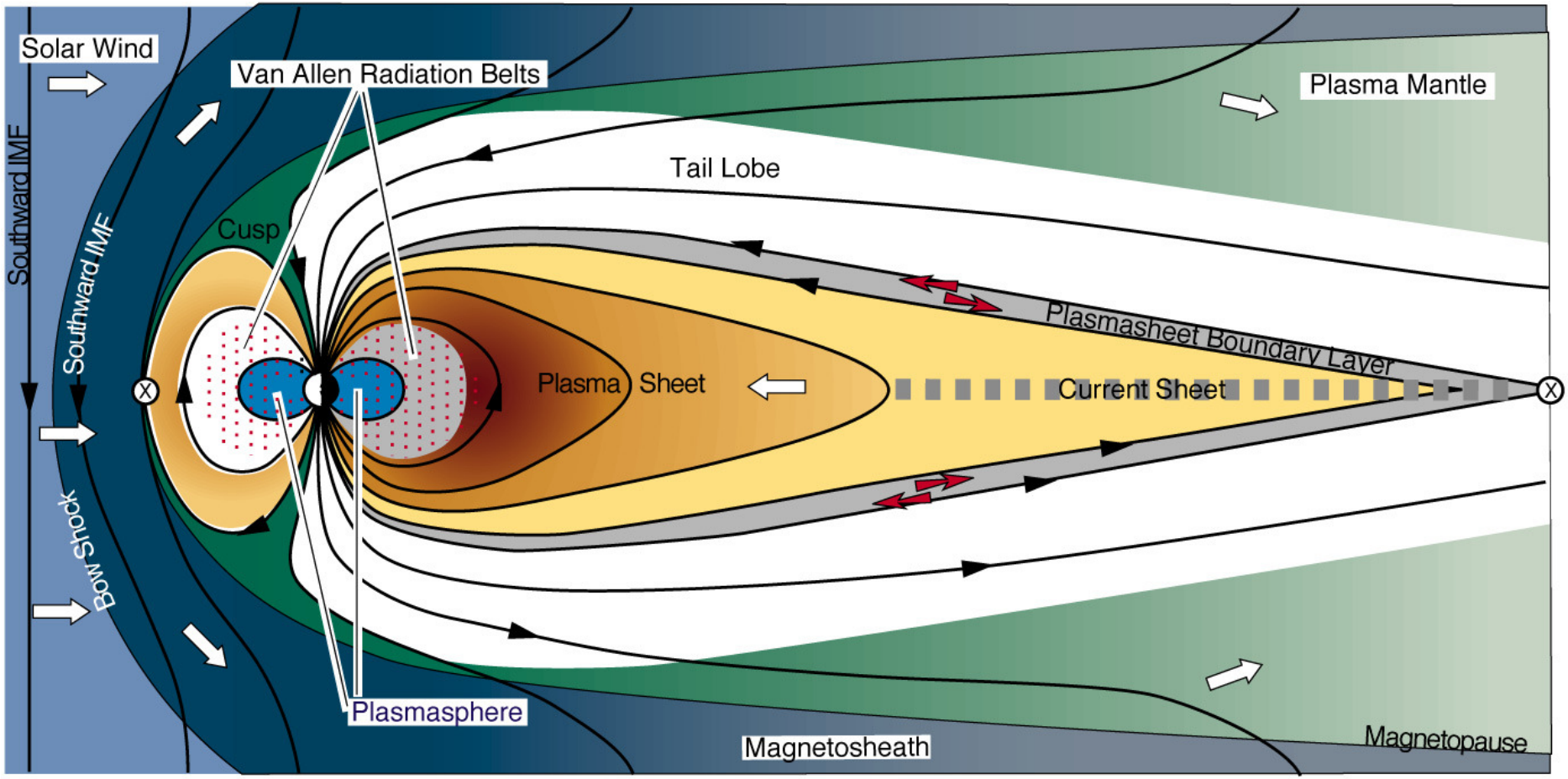
- Phil/Deborah Scherrer
  - Ray Mitchell
- Umran Inan
  - Morris Cohen
  - Justin Tan
- Center for Integrated Space Weather Modeling (CISM)

The Ionosphere



Source: HAARP

The Magnetosphere

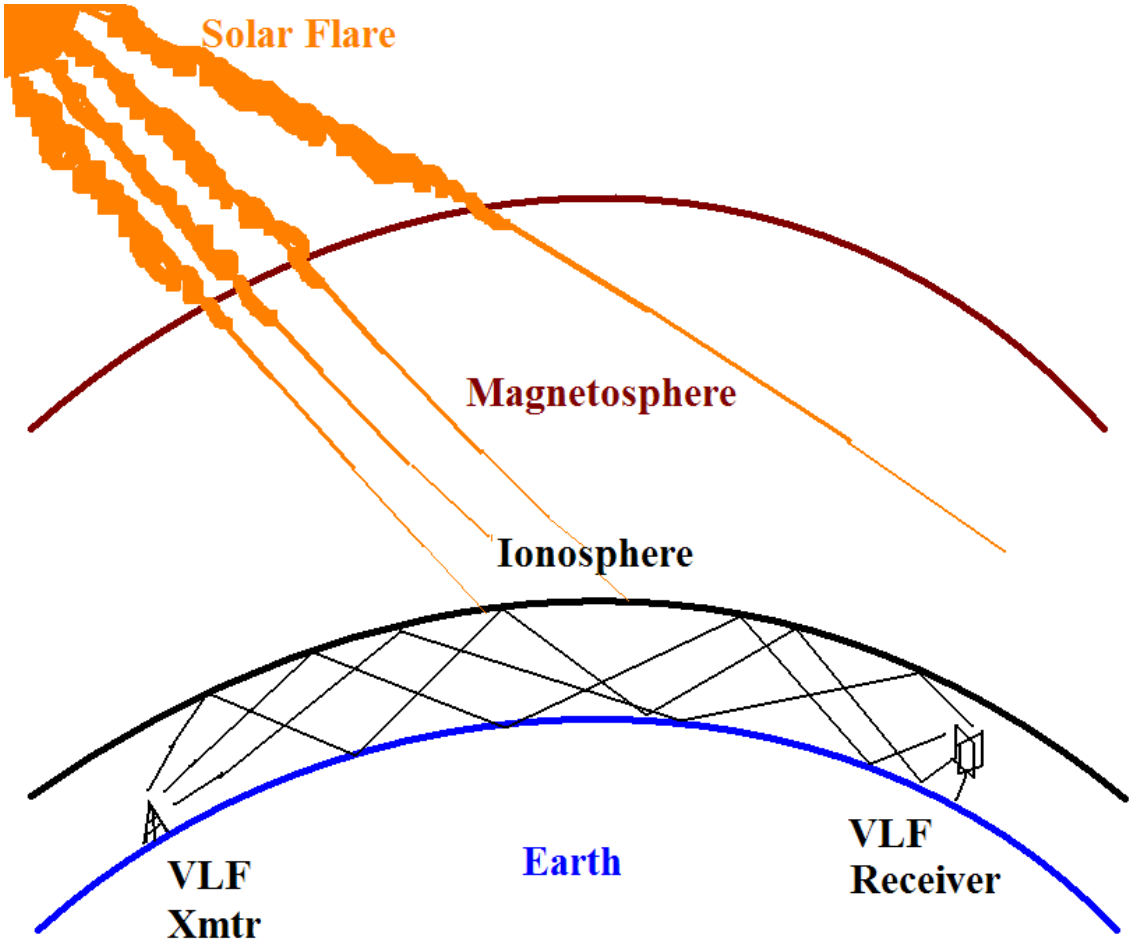


Source: NASA, Rice University

Electromagnetic Effects

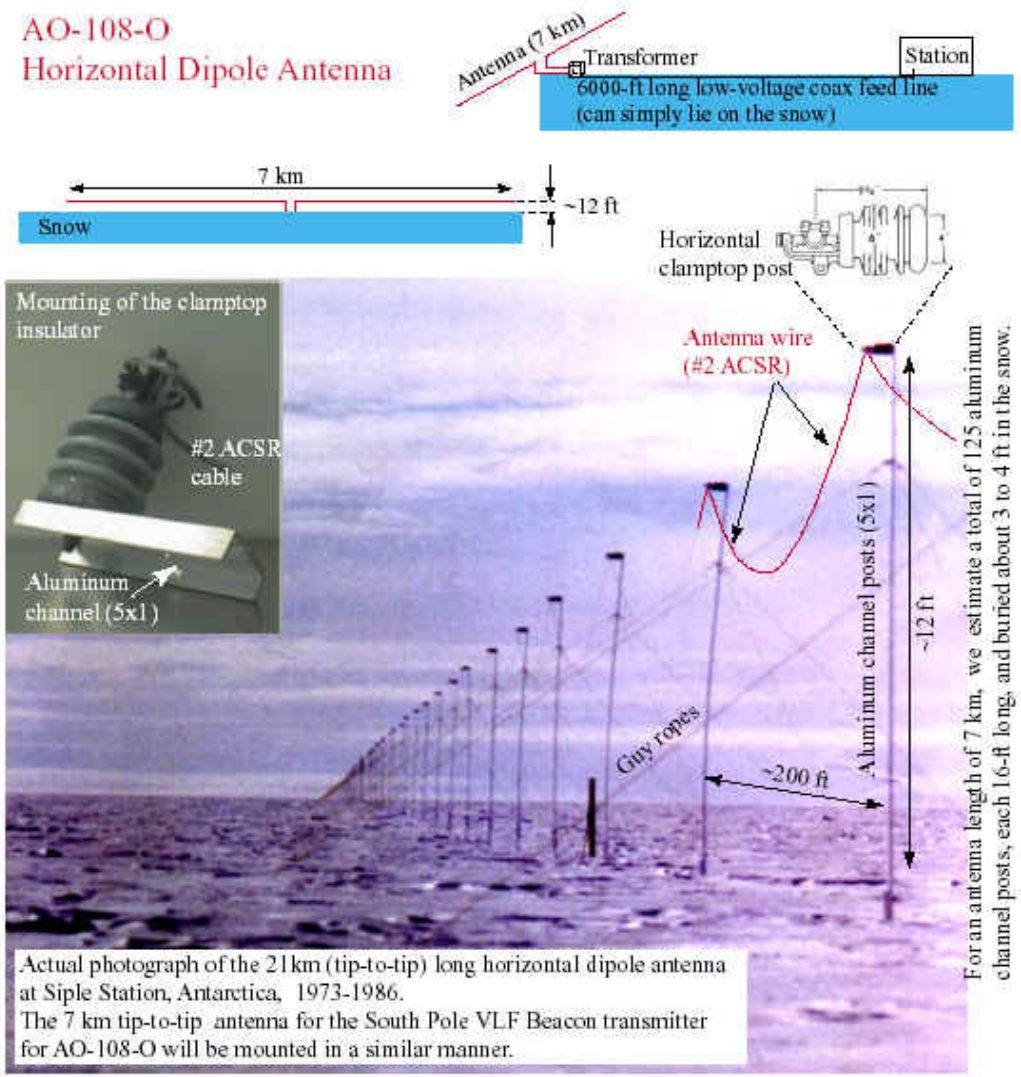
- Solar Flare Detection
- Cosmic Gamma Rays
- Chorus Emissions
- Lightning
- Whistler waves
- LEP Events, hurricane studies
- Early/fast Events
- Mesospheric lightning discharges
  - Sprites, elves, blue jets, TGFs

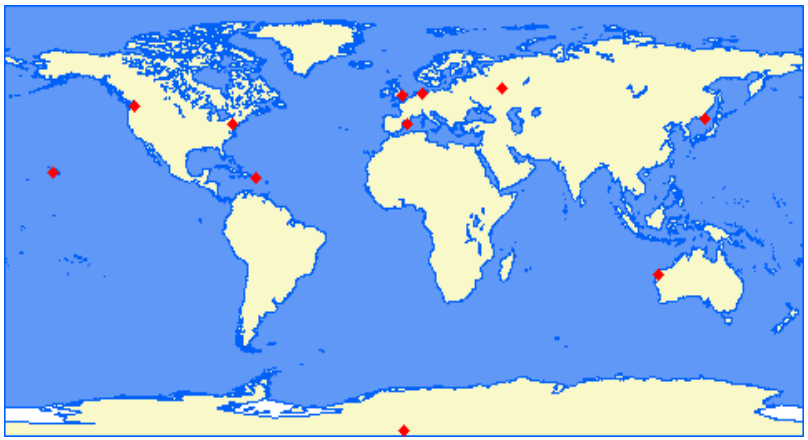
Sudden Ionospheric Disturbance



- Strong solar flares penetrate to lower ionospheric region, cause transient changes

VLF Transmitters

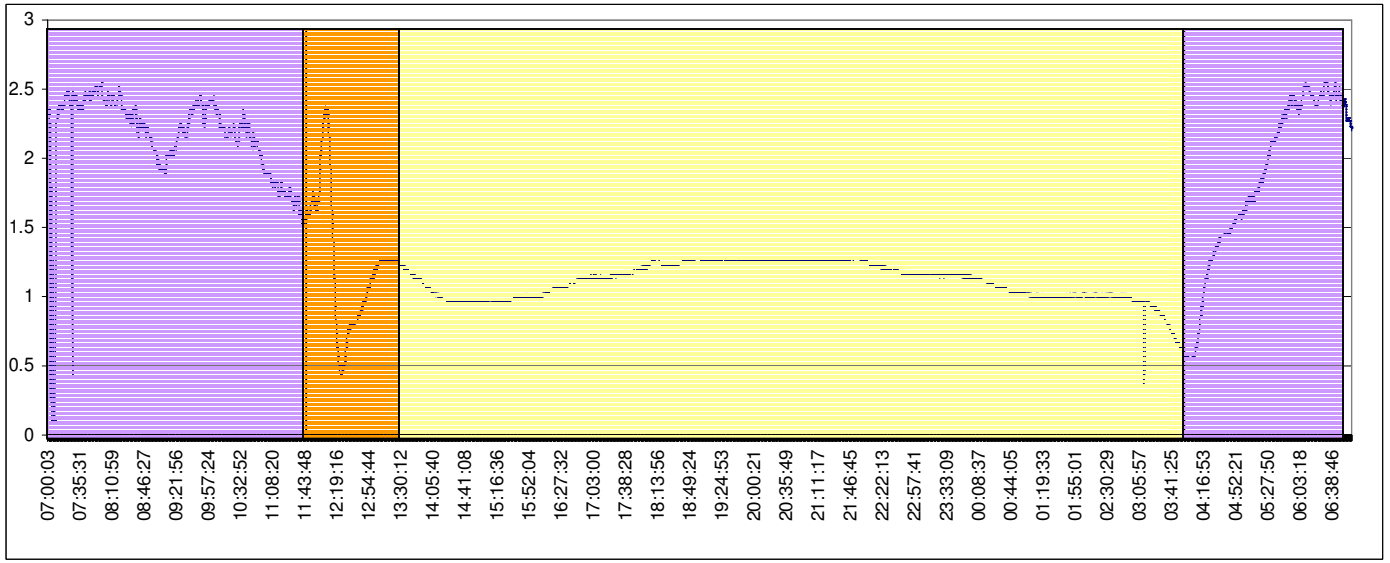




Source: Great Circle Mapper, Karl Swartz

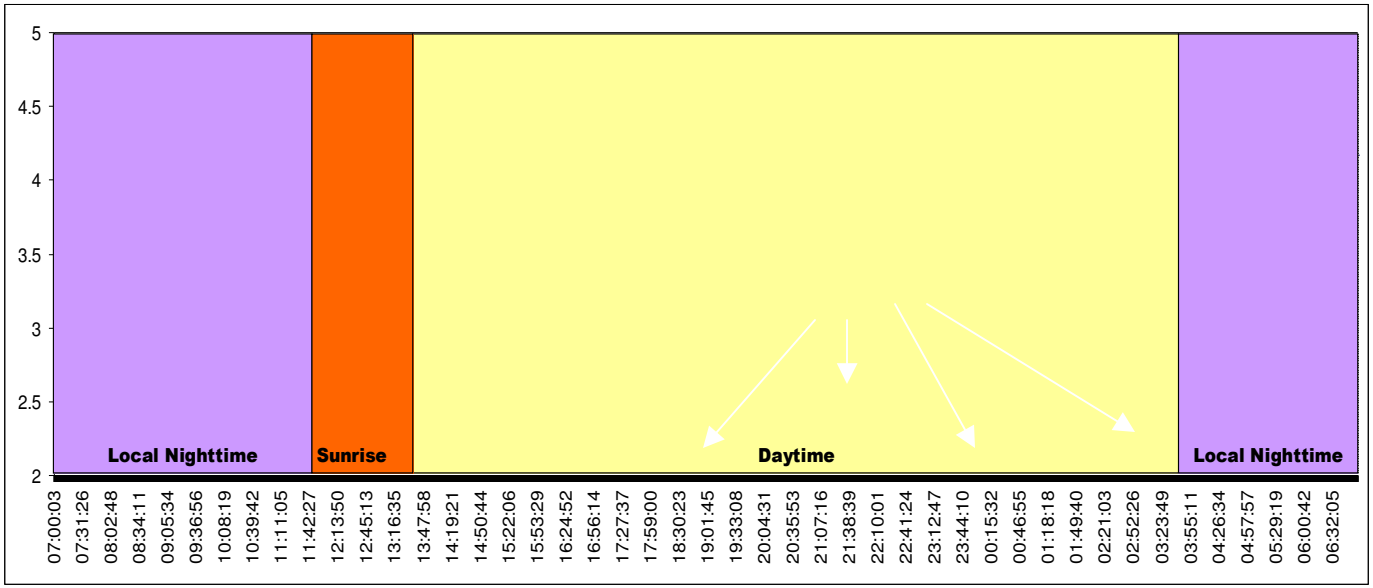
SID Event – an Example

Quiet Day



NLK
24.8 kHz

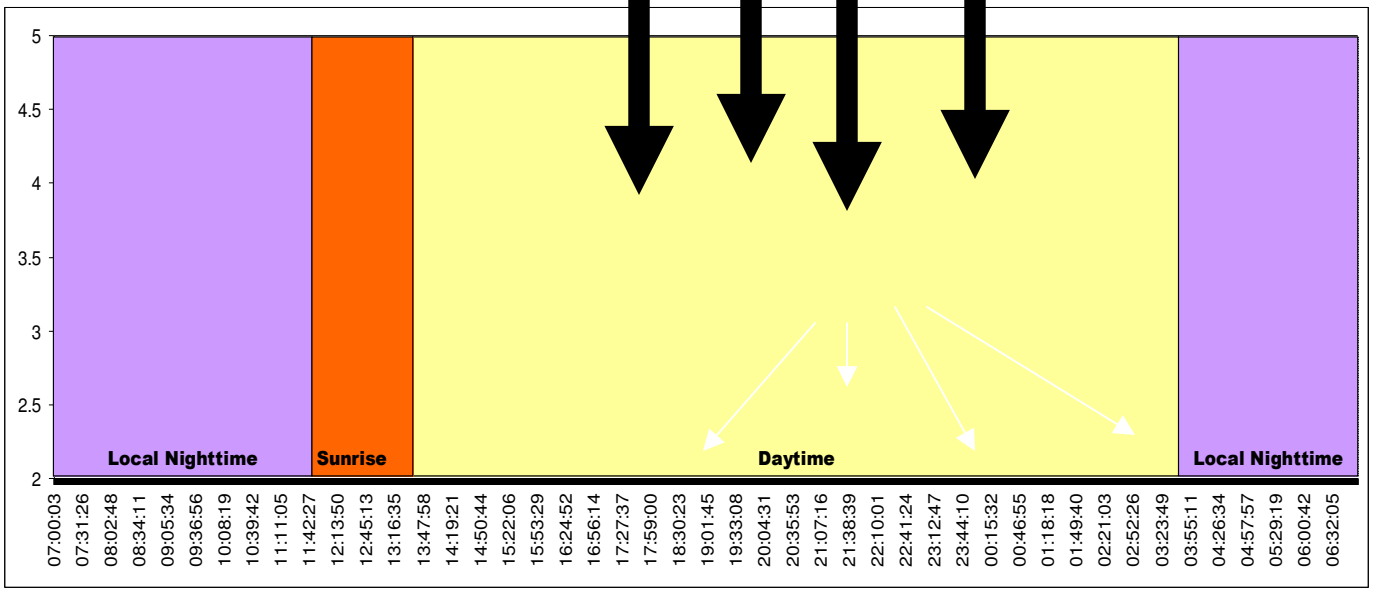
Active Day



Source: Ray Mitchell

SID Event – an Example

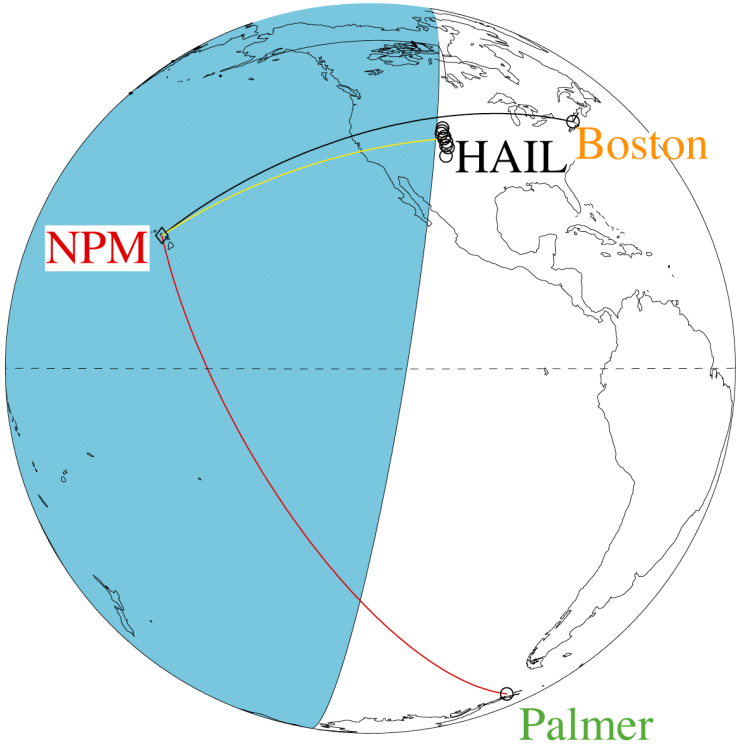
GOES Data

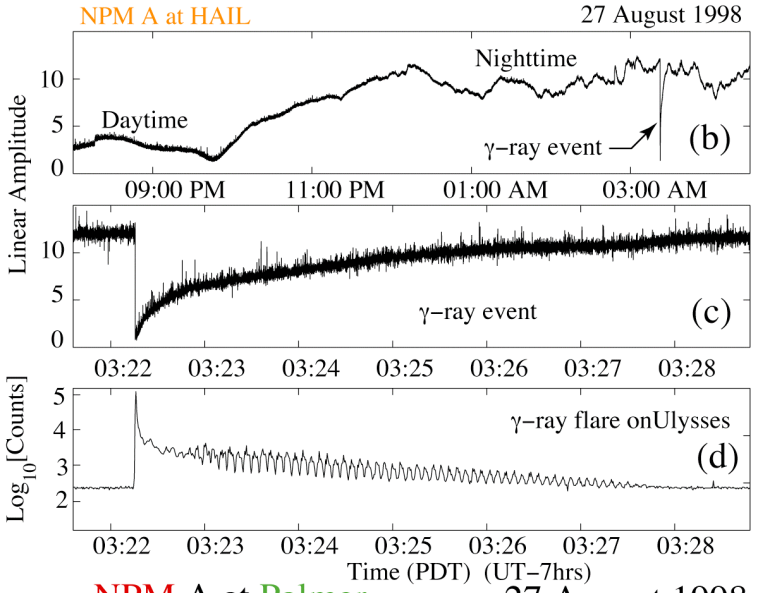


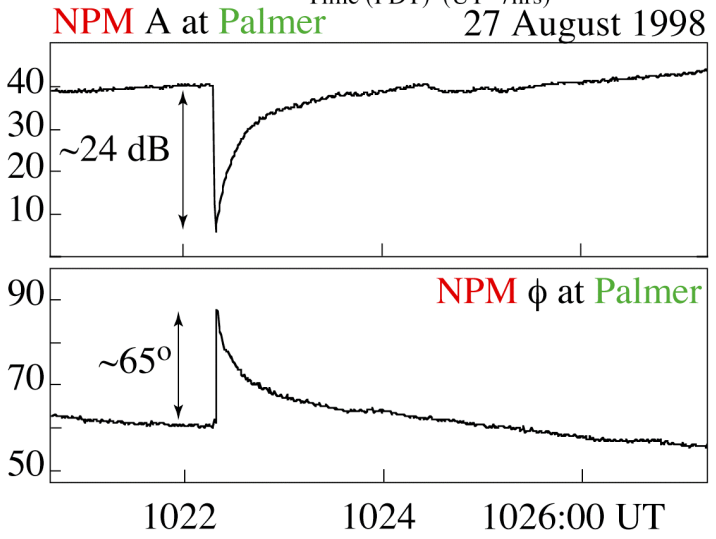
NLK
24.8 kHz

Active Day

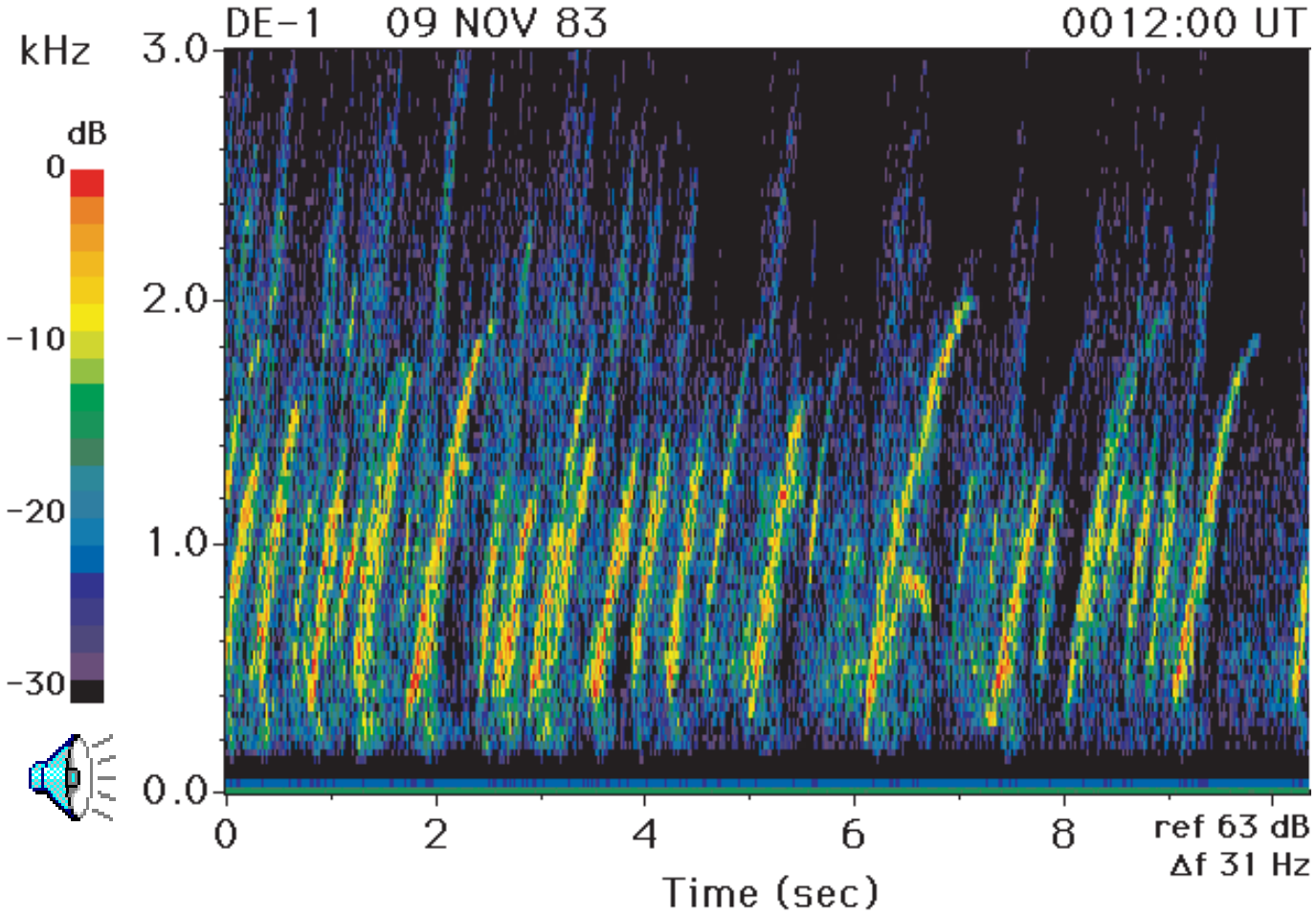
Cosmic Gamma Rays



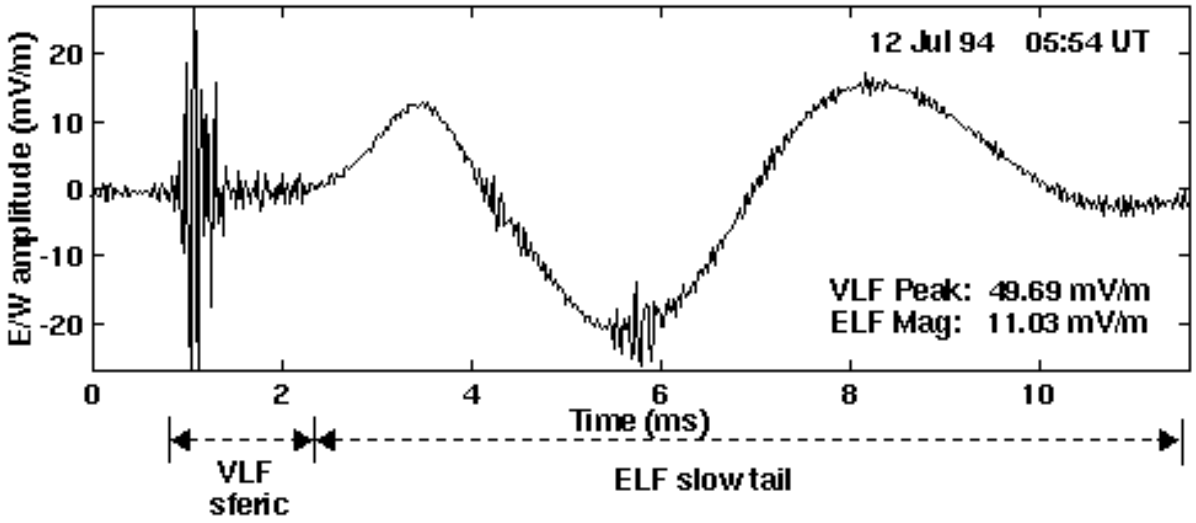


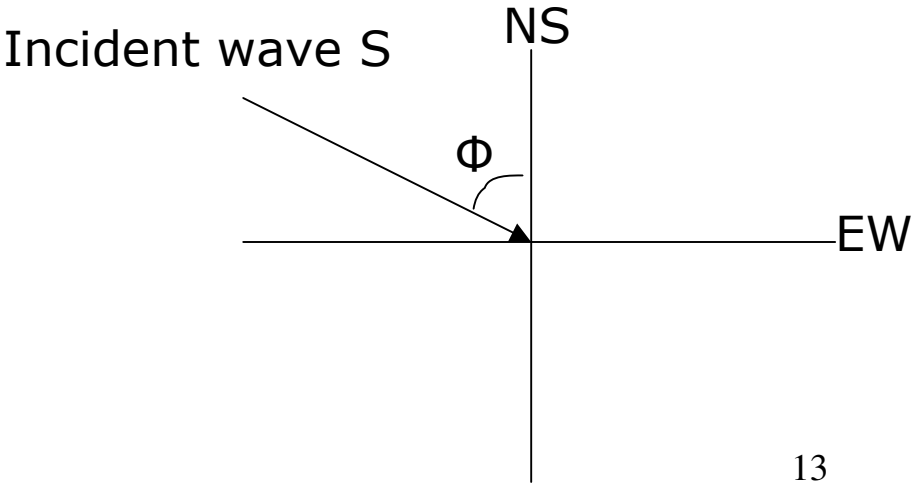


Chorus Emissions

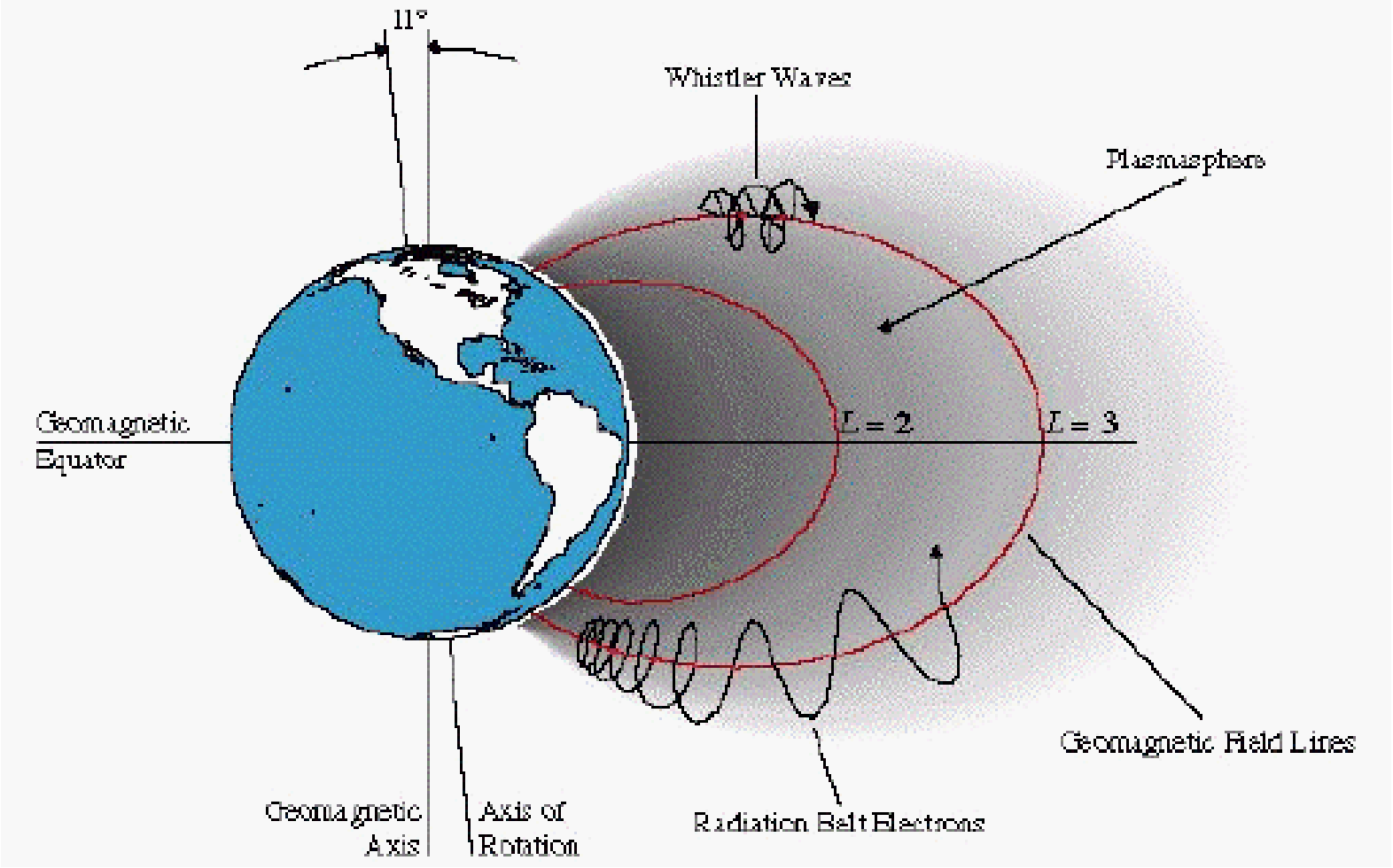


Lightning Detection

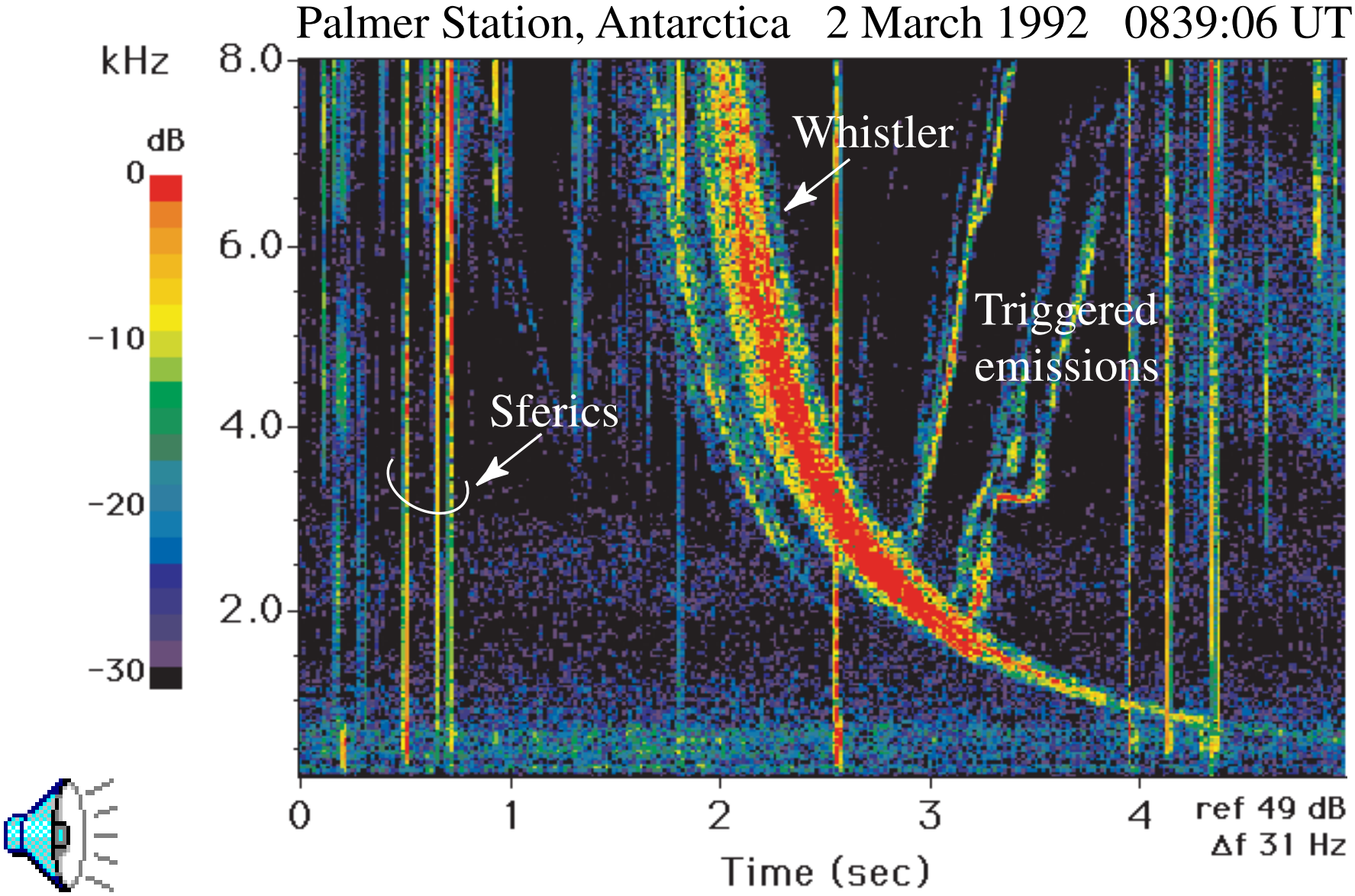




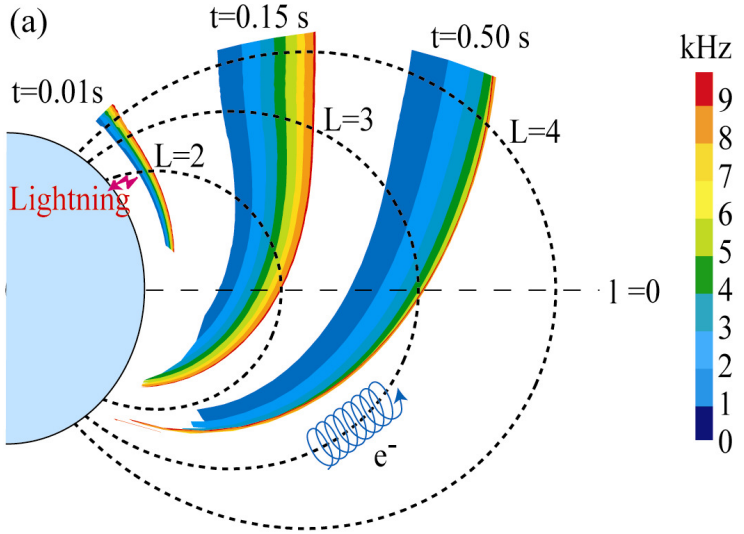
Whistlers in the Magnetosphere

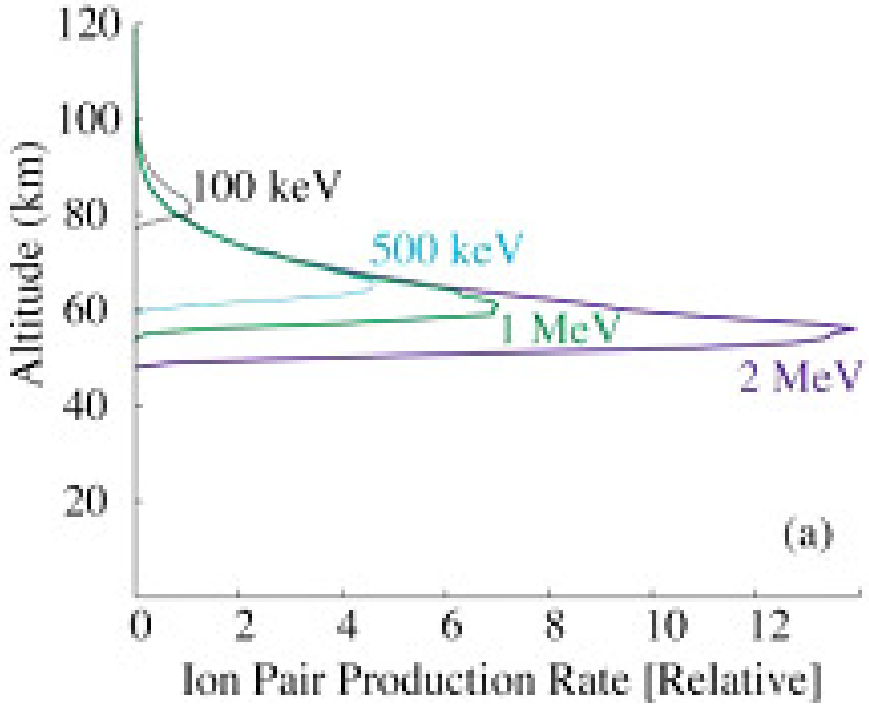


Whistler Wave – an Example



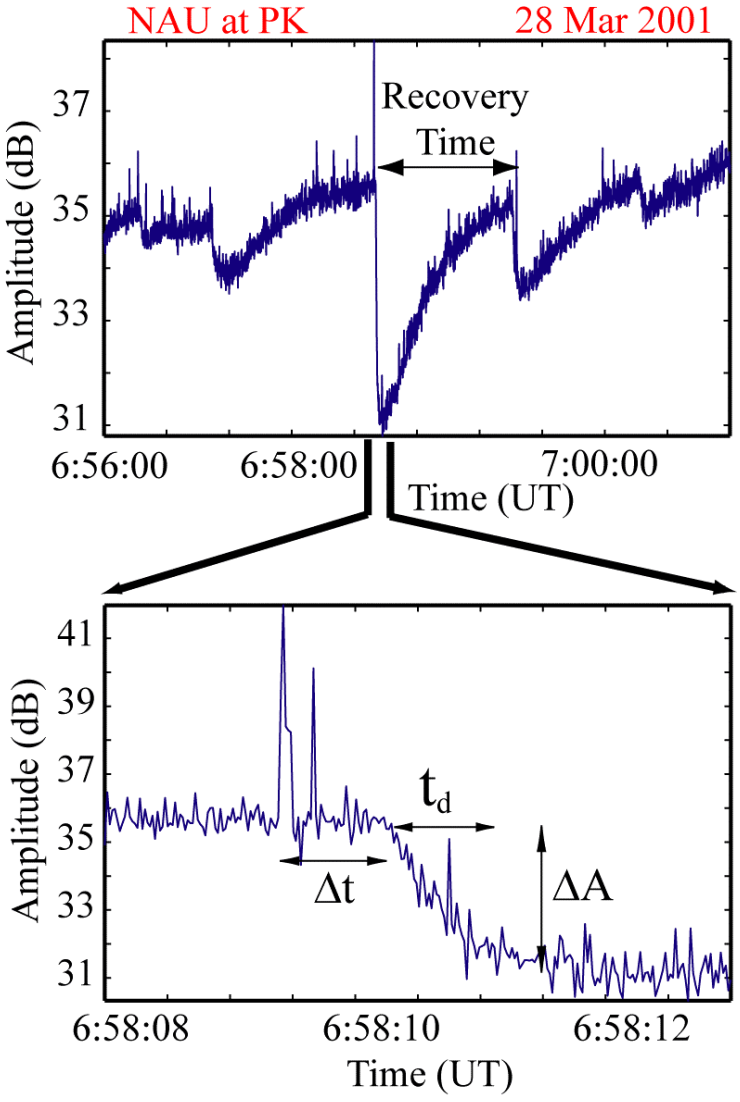
Lightning Induced Electron Precipitation (LEP Events)

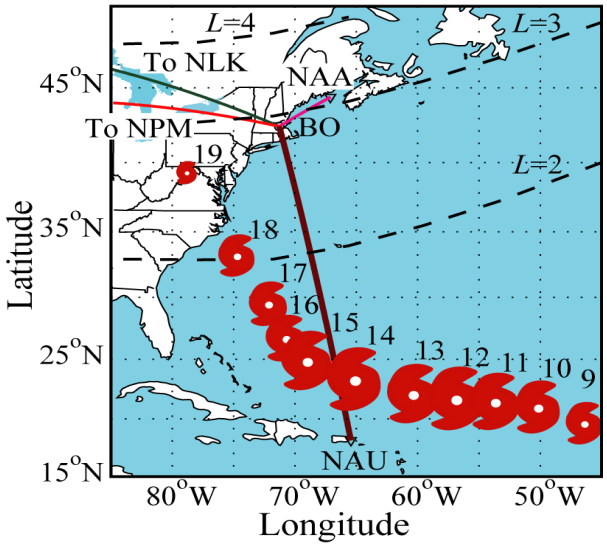




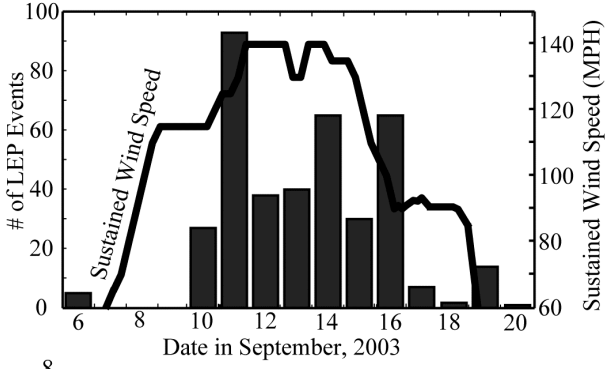
Source: Bill Peter

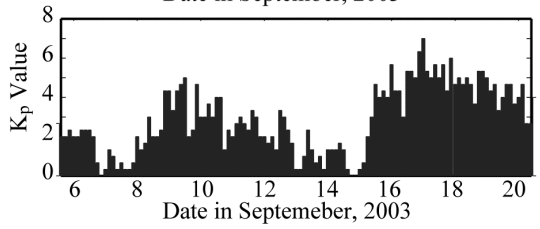
LEP Events – an Example



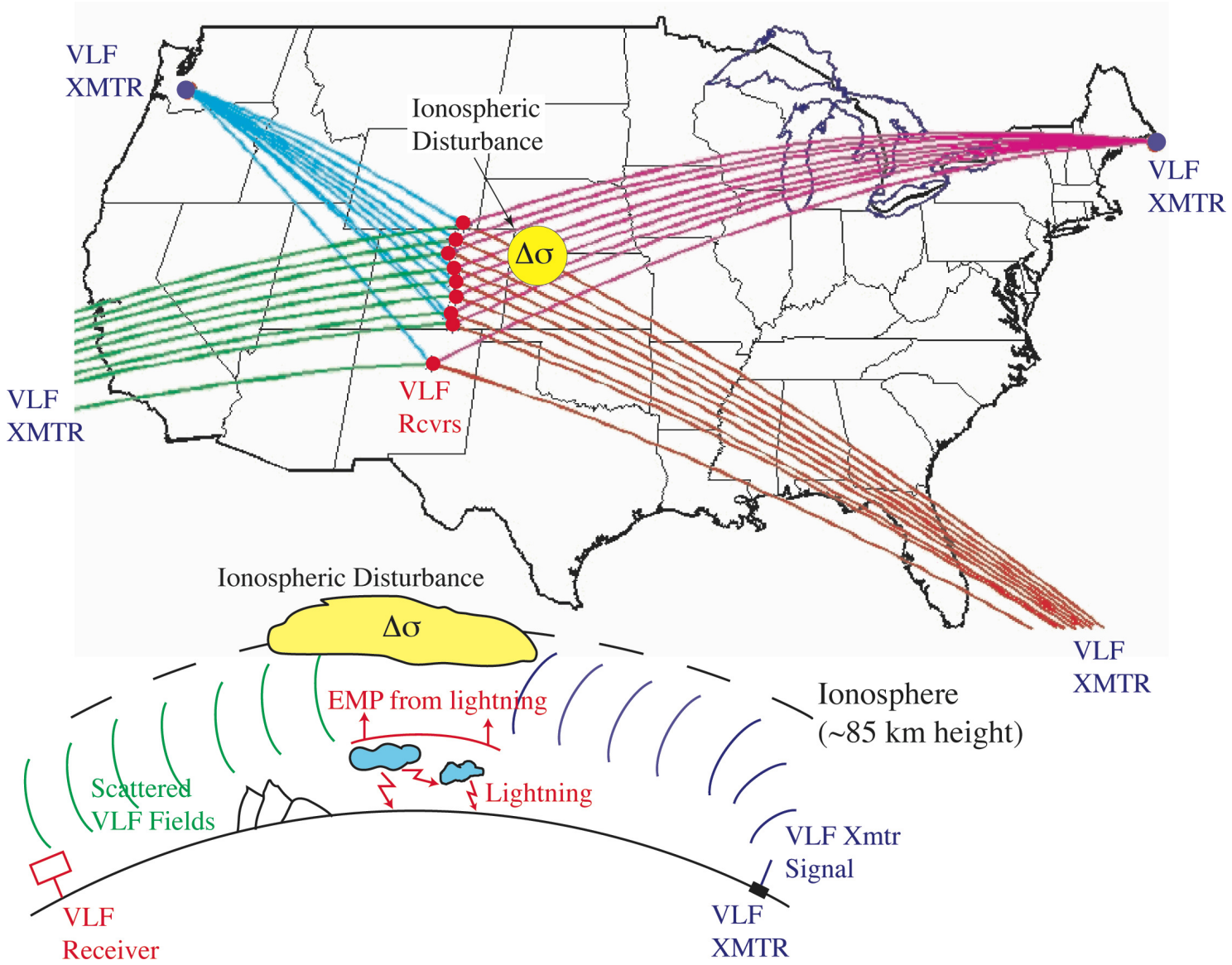


Hurricane Isabel



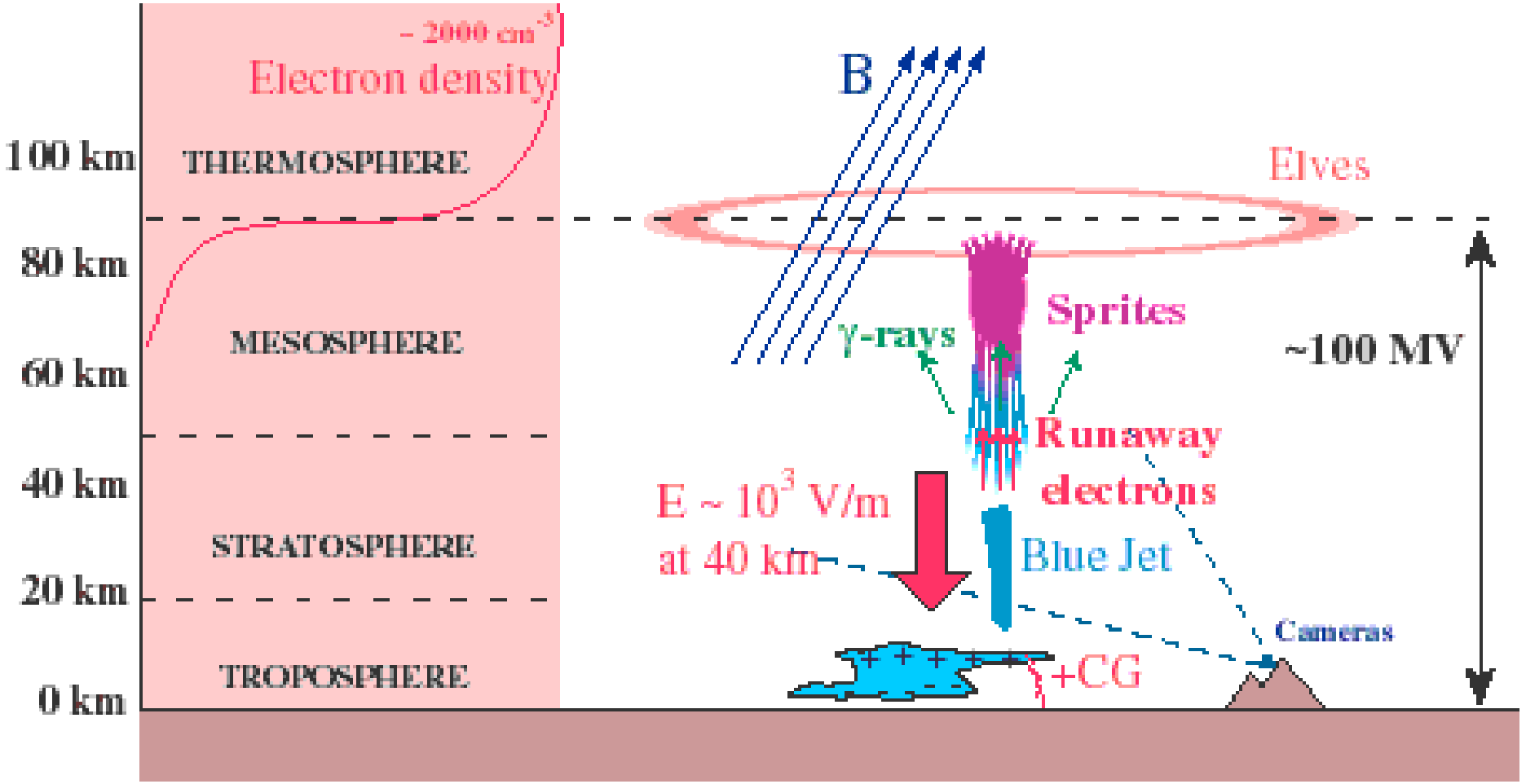


Early Fast Events



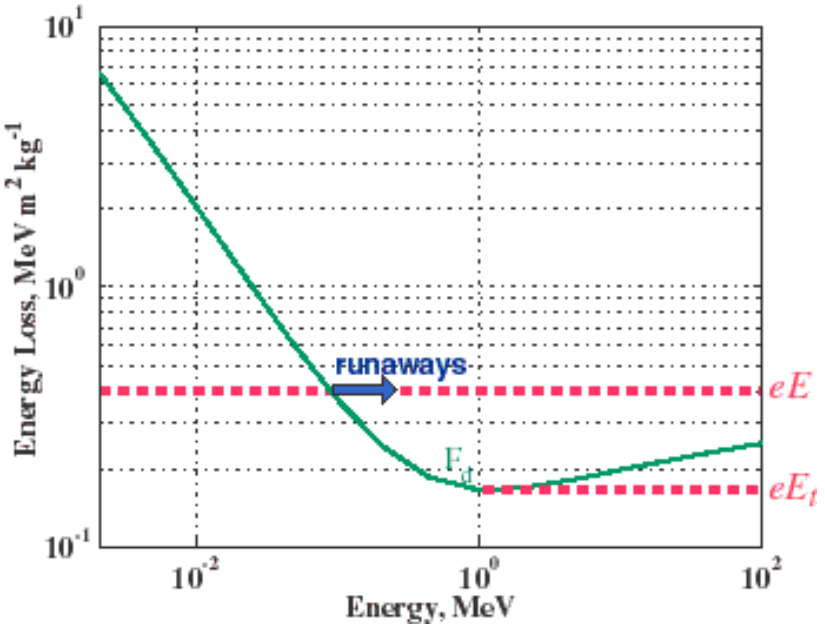
Source: Bill Peter

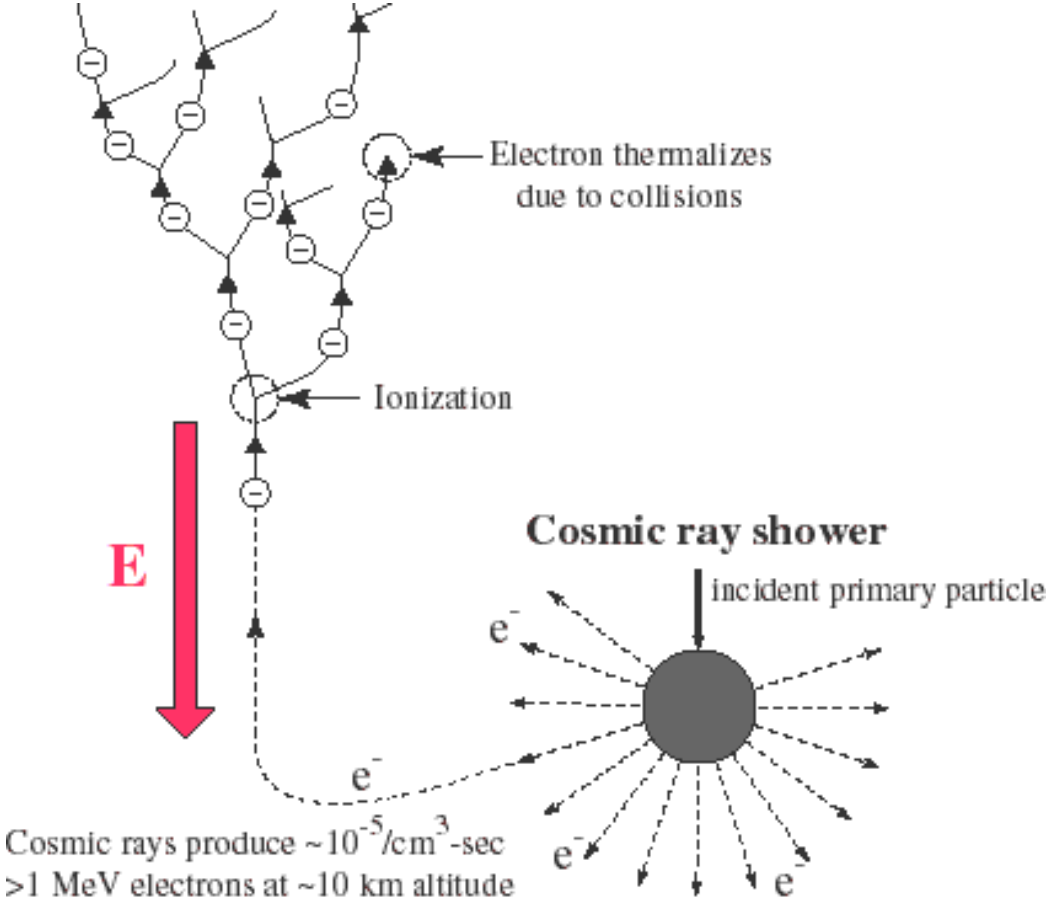
Mesospheric Phenomenon



Source: Nikolai Lehtinen

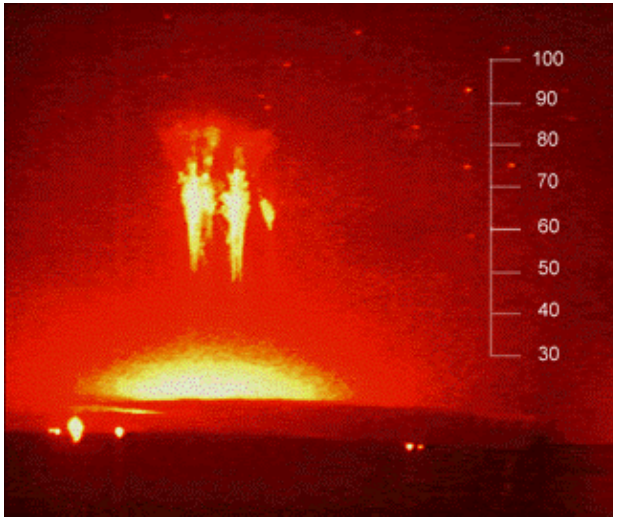
Runaway Electrons

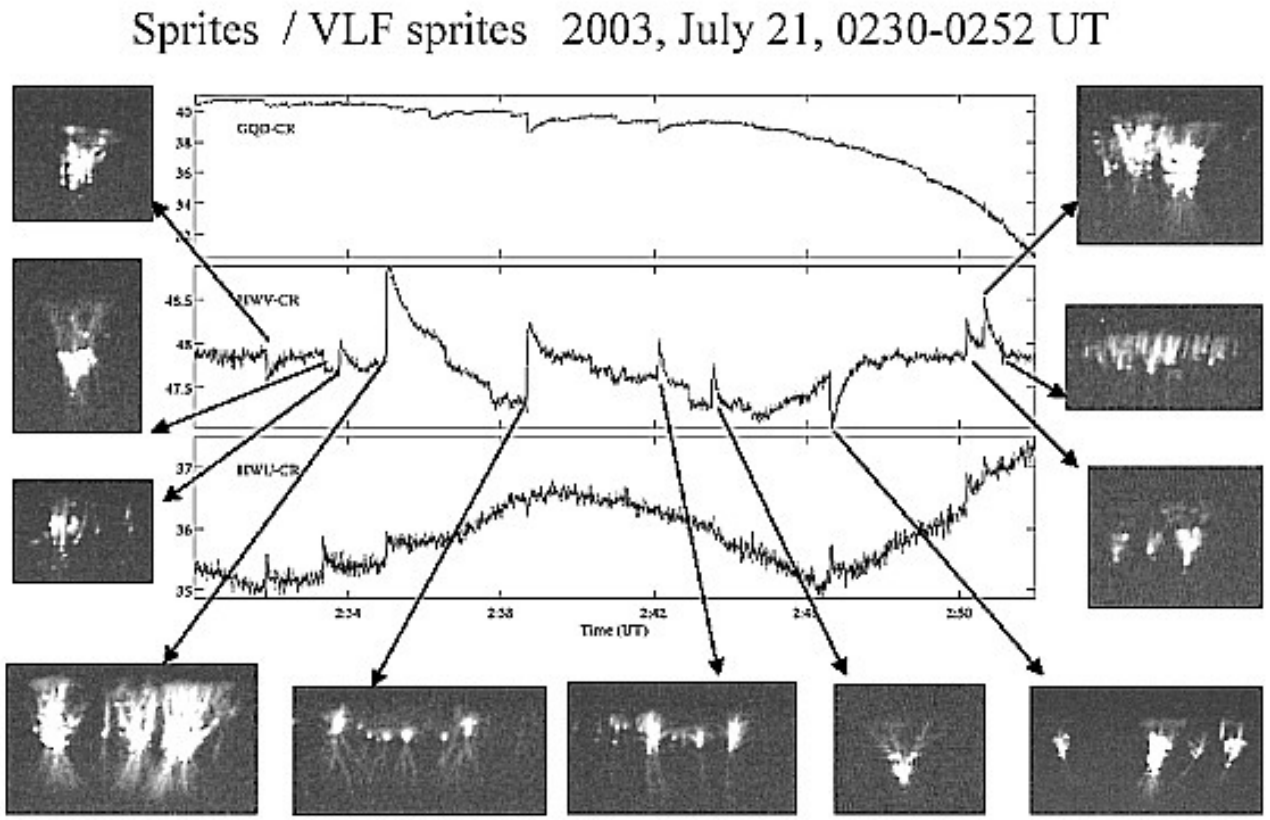




Source: Nikolai Lehtinen

Sprites and Early/Fast Events

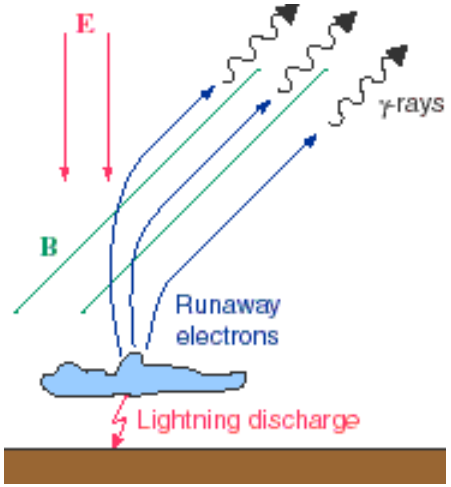


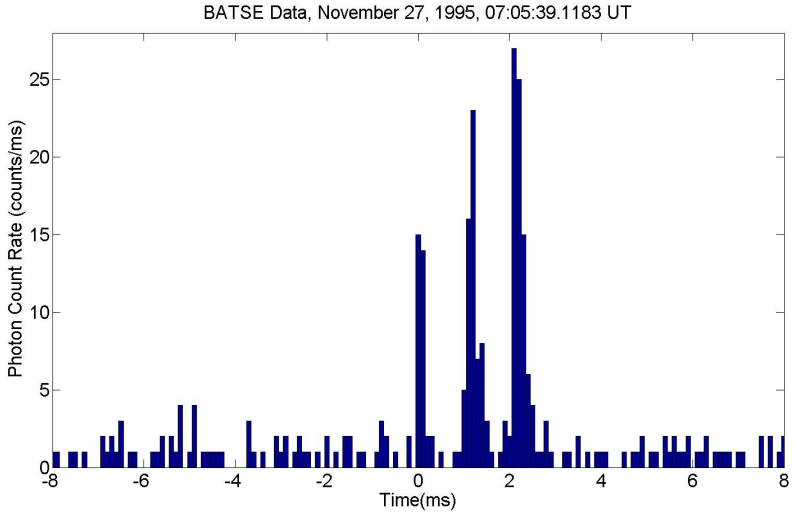


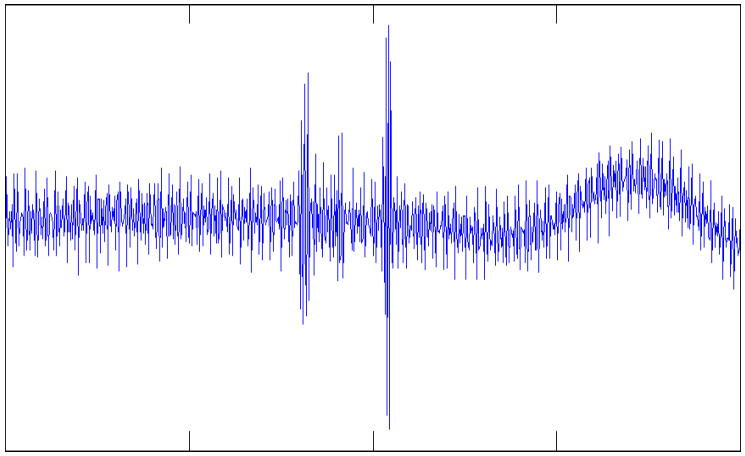
Early fast events are highly correlated with sprites, indicating connection with ionospheric heating and runaway electrons

Source: Robert Marshall

TGFs and Sferics







The Hardware

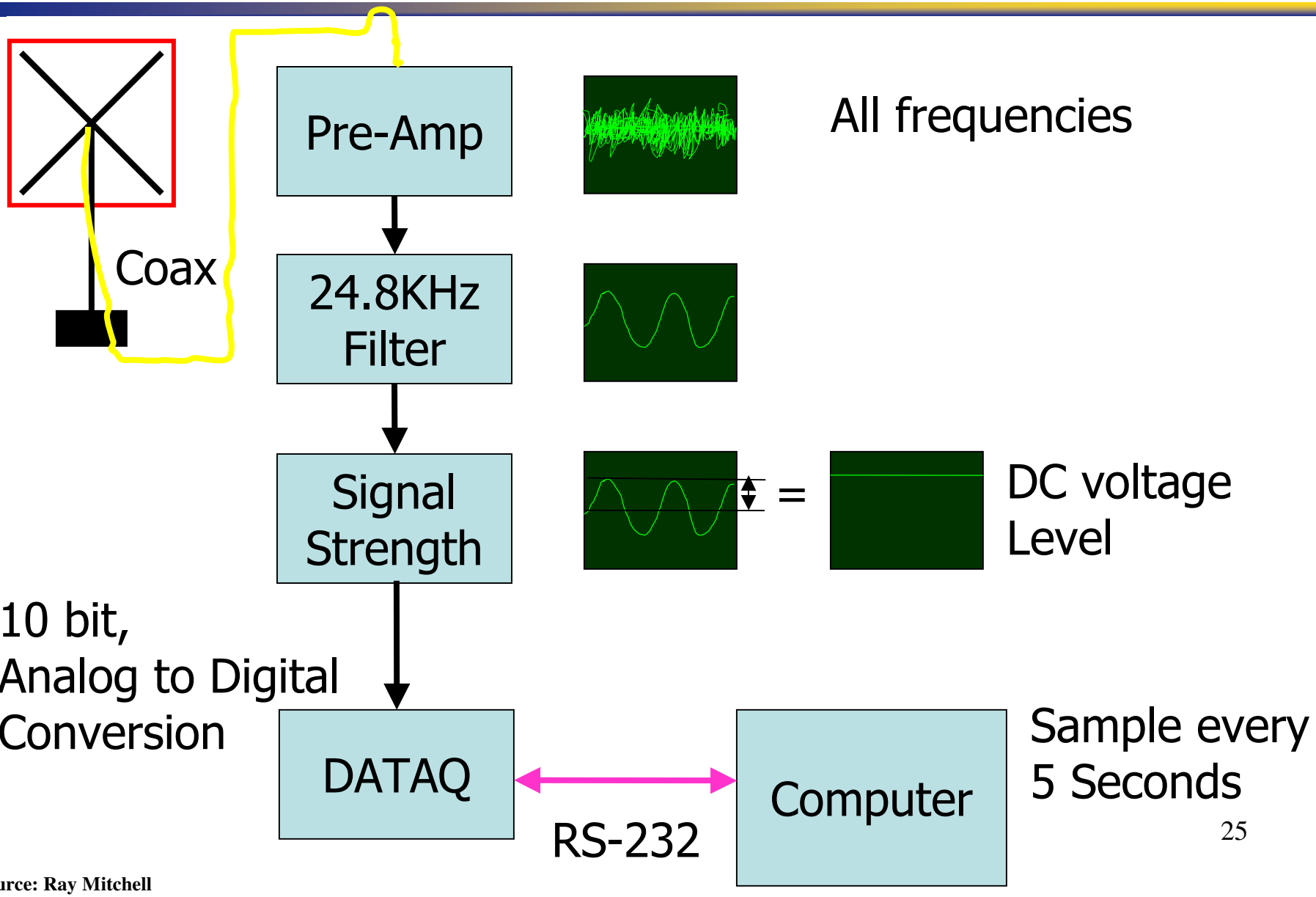
- SID Detector
- AWESOME Receiver

A tmospheric
W eather
E ducational
S ystem for
O bservation and
M odeling of
E ffects

The SID Detector

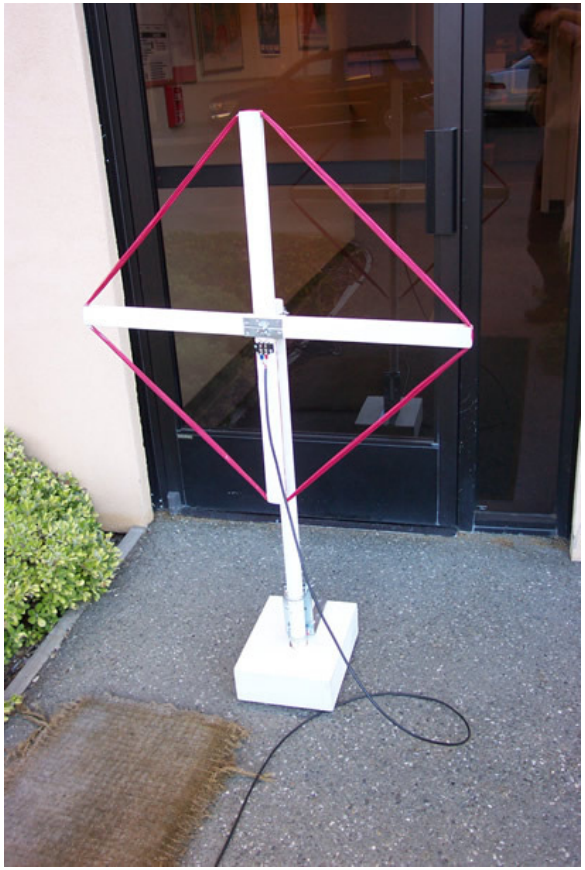
- Designed by Ray Mitchell
- Low cost, compact, easy to use
- Narrowband amplitude receiver
- 1 sample per 5 seconds

The SID Detector – Overview

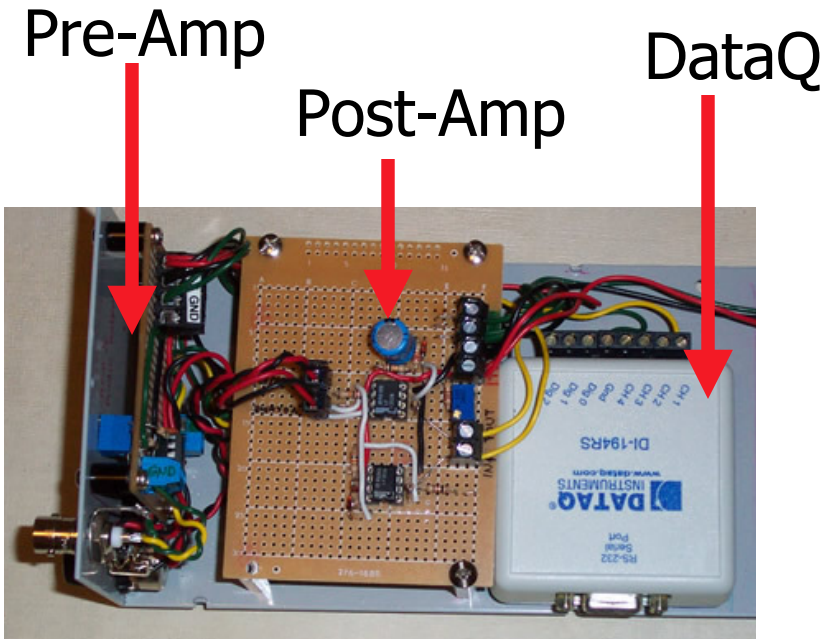


Source: Ray Mitchell

SID Detector - Pictures



Wire Loop Antenna

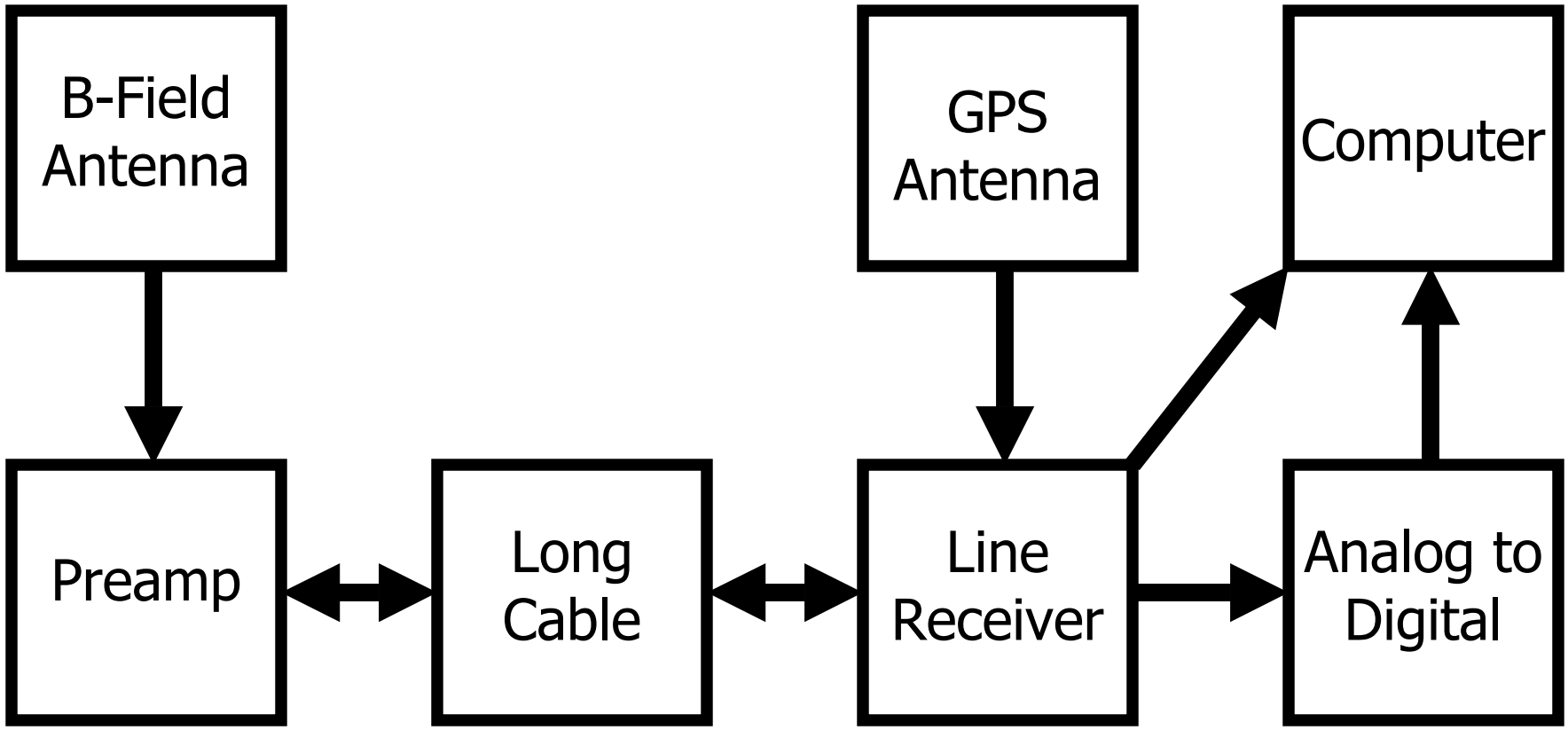


Source: Ray Mitchell

The AWESOME Receiver

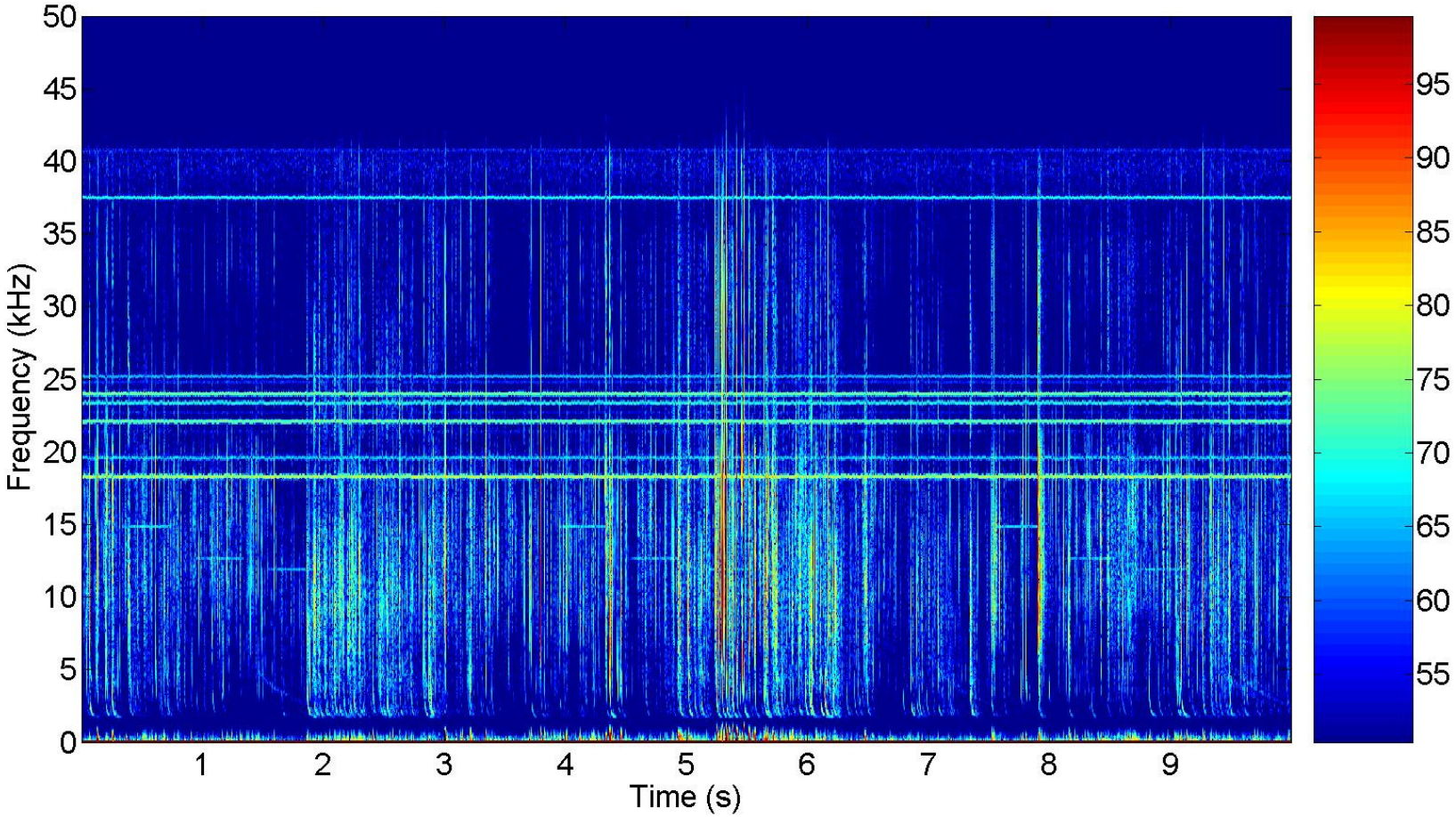
- Designed by Morris Cohen, Justin Tan
- Ultra sensitive
- Medium cost (~$2000)
- Narrowband amplitude/phase
- Broadband 100kHz data
- Deployed worldwide
- Auto-calibration

AWESOME Receiver – Overview



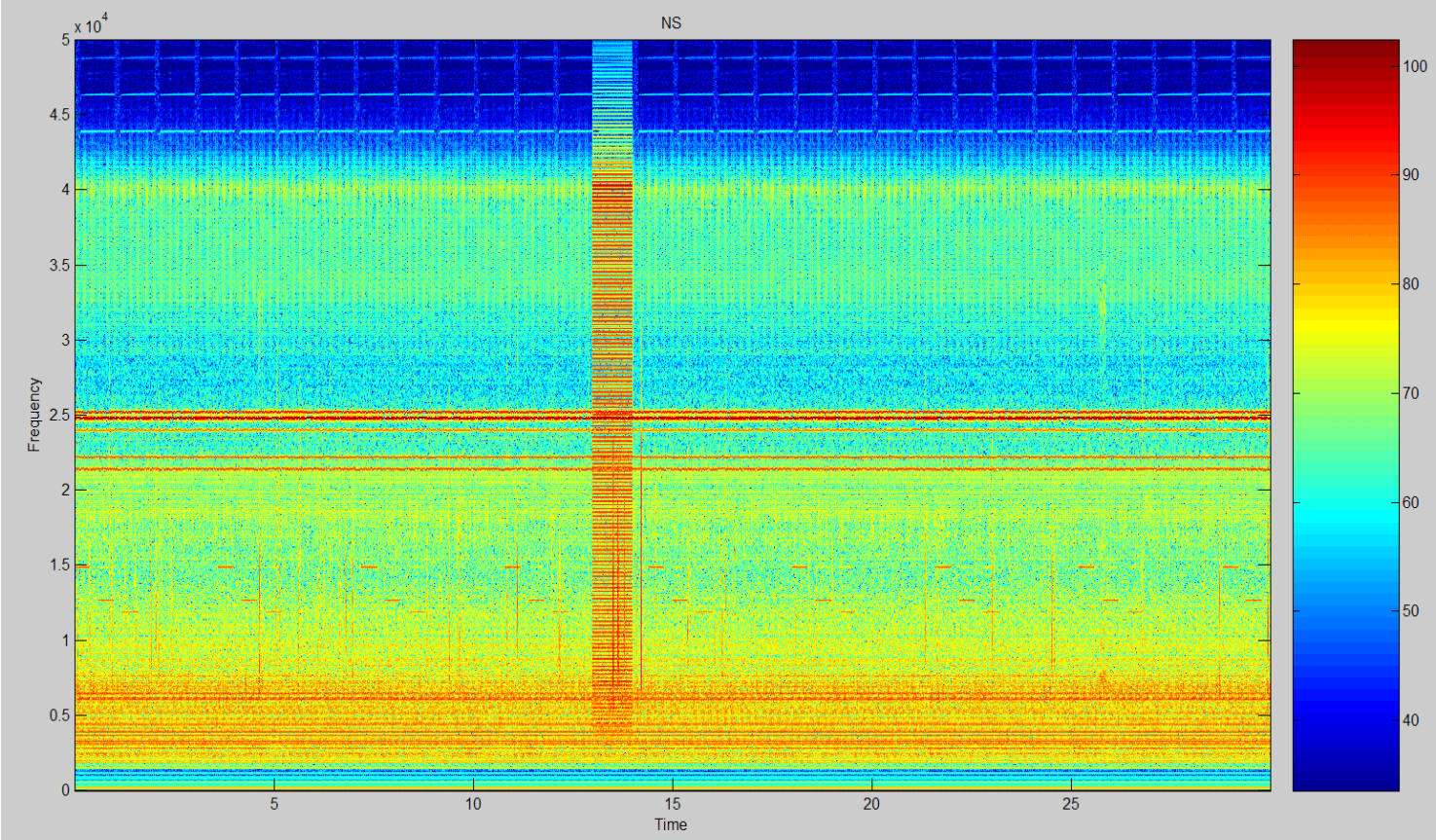
AWESOME Receiver – Pictures

AWESOME Receiver – Data



Data taken from Palmer Station, Antarctica

More Data, Calibration



Data taken from Homer, Alaska

Educational Outreach

- Center for Integrated Space Weather Modeling (CISM)
  - Run by Boston University
  - Stanford selected for educational outreach
- Distribute SID detectors widely
  - 3 Beta sites working
  - 100 units in production
  - 3 foreign sites planned (Tanzania, India, Tibet)
- Distribute selected AWESOME detectors

Educational Outreach (con't)

- Research purpose
  - data sent to Stanford via internet, DVDs
- Educational purposes
  - Monitor solar flares/VLF activity
  - Build antenna, maintain electronics
  - Participate in research campaigns
- Promote in developing countries through UN?
- http://solar-center.stanford.edu/~SID
- http://www-star.stanford.edu/~hail/

STANFORD
ELECTRICAL
ENGINEERING

Questions