# IS Coordinated Science at Mid-Latitudes

## Madrigal as a Scientific Tool

Anthea Coster, MIT Haystack Observatory

Outline

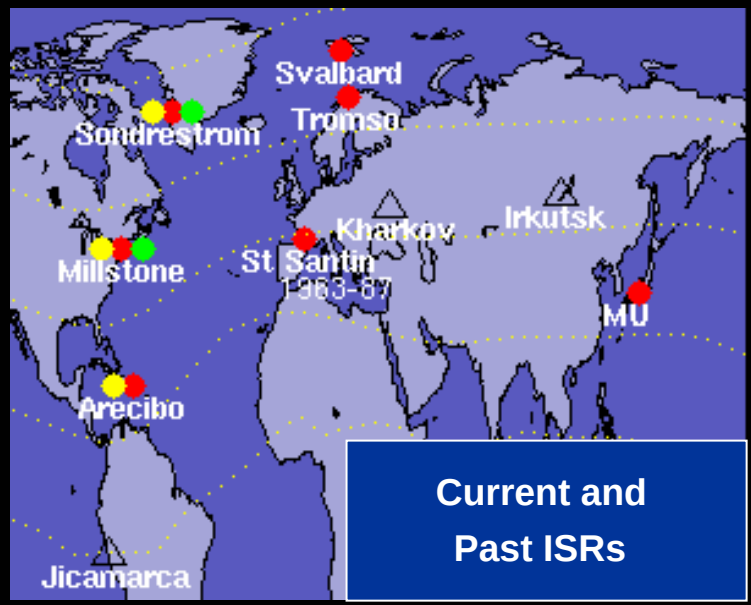
Storm Studies

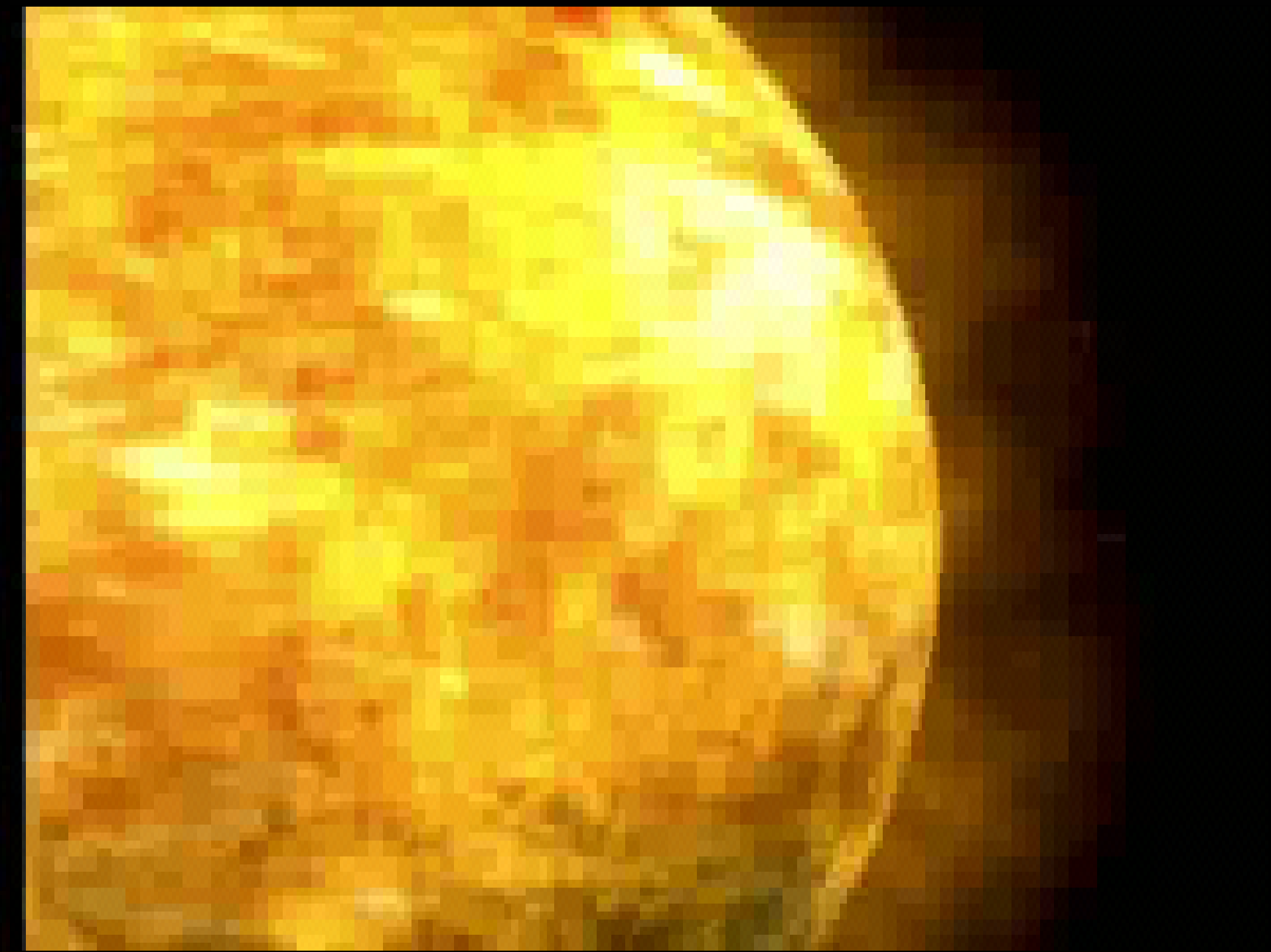
Modeling

Instabilities

SED

Madrigal



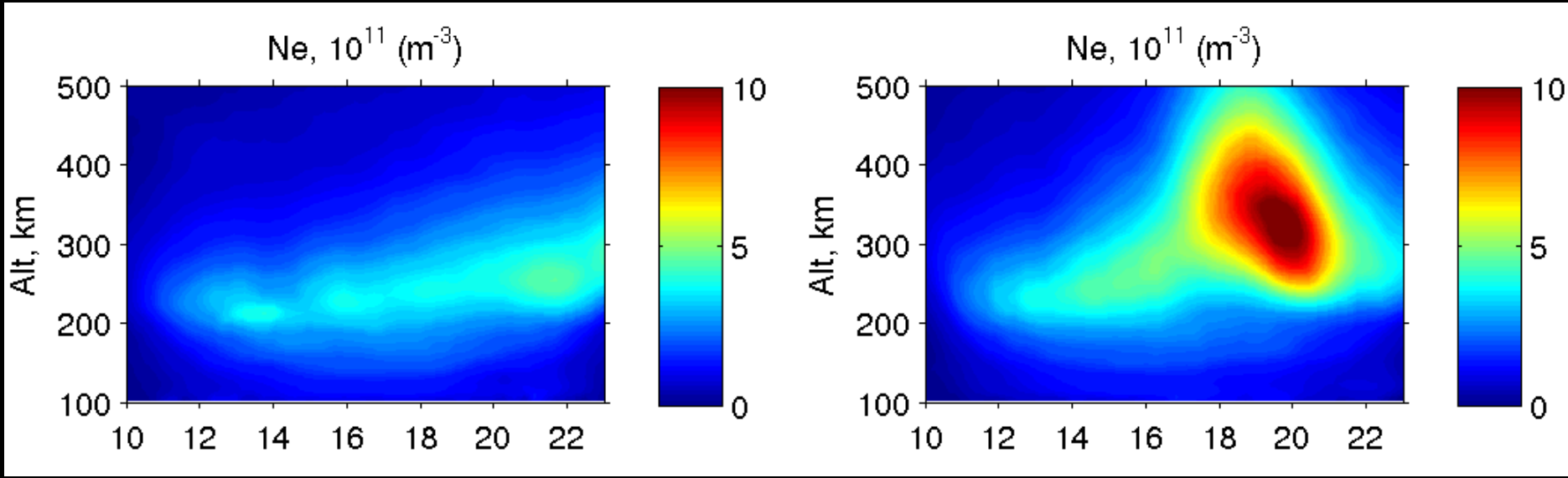


# Positive Phase Storm Studies

## Millstone Hill ISR, Ne

Sep 8, 2005

Sep 10, 2005

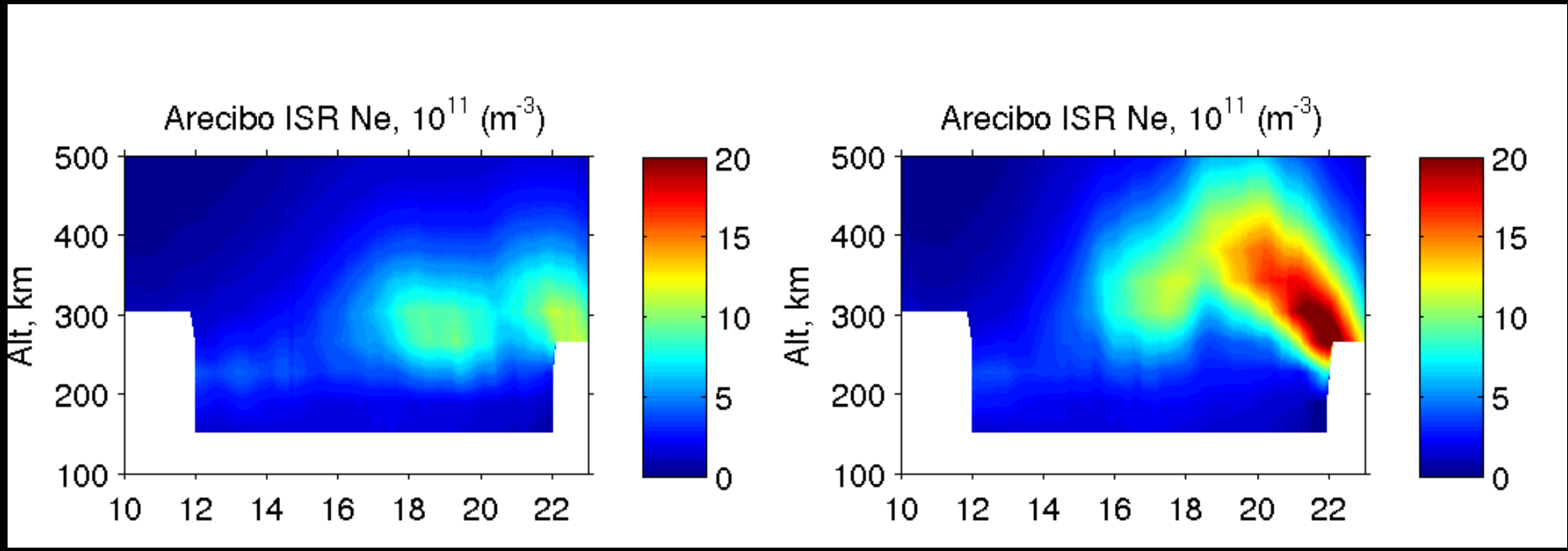



- Daytime positive phase lasting for ~13 hours
- Background increase after the sunrise; main increase after 17 UT
- Maximum Ne at 19-20 UT
- Increase in $h_mF2$ by ~100 km
- Decrease in Te by up to ~1000K, enhancement in Ti by 50-200K

# Arecibo Ne

Sep 8, 2005

Sep 10, 2005




Positive storm phase after ~15 UT

Maximum Ne at 21-22 UT, i.e. 1.5-2 hours later than at Millstone Hill

Uplift of the F-layer

# Positive phase mechanisms

- Increase in oxygen density (*Burns et al, 1991, 1995*)
- Equatorward meridional wind (*Jones and Rishbeth, 1971*)
- Electric field (*Lanzerotti et al., 1975, Huang et al., 2005, Swisdak et al., 2006*)
- Downward protonospheric plasma fluxes

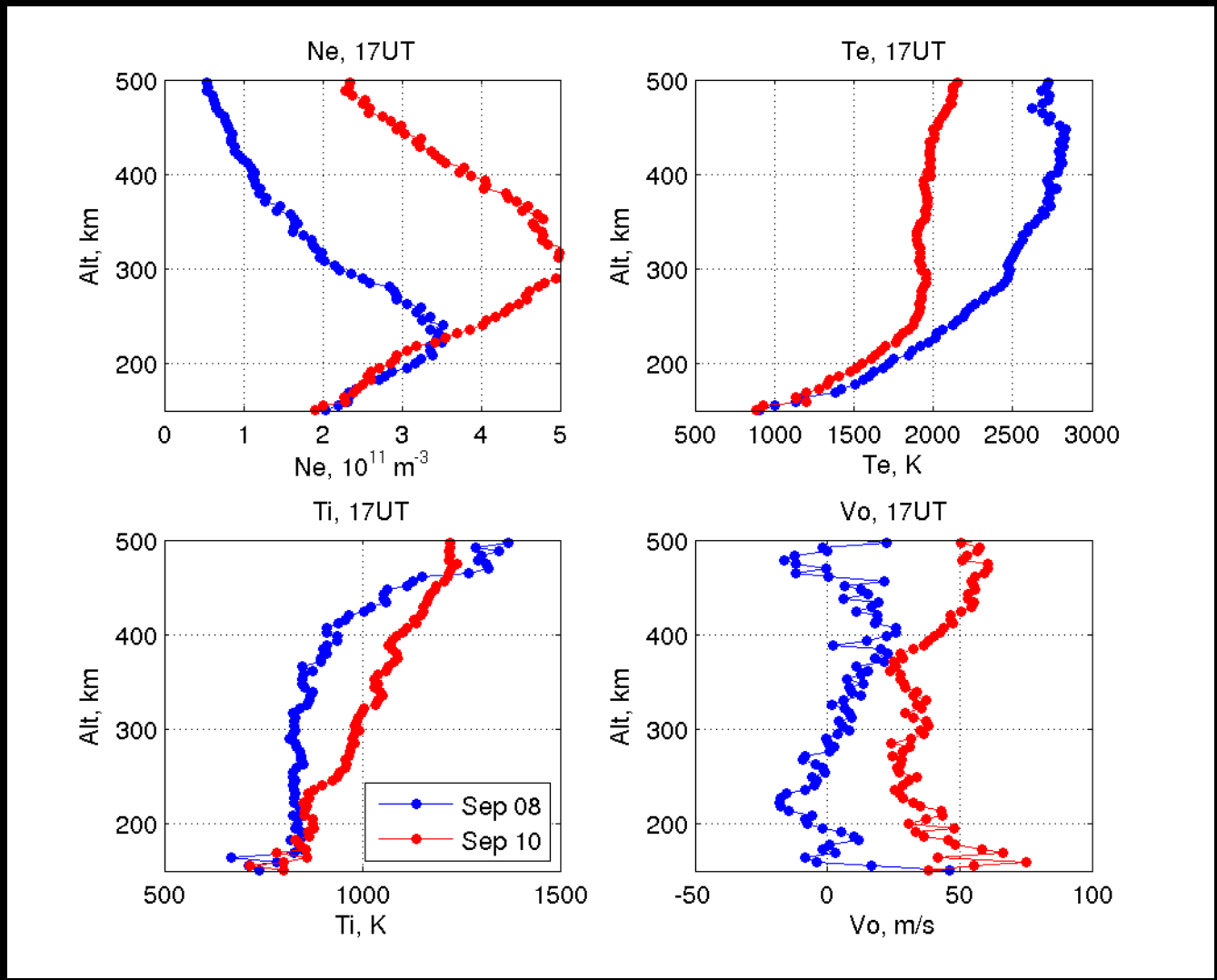
# Millstone Hill ISR: Ne, Te, Ti, Vi at 17 UT

Ne

Te

Ti

Vi



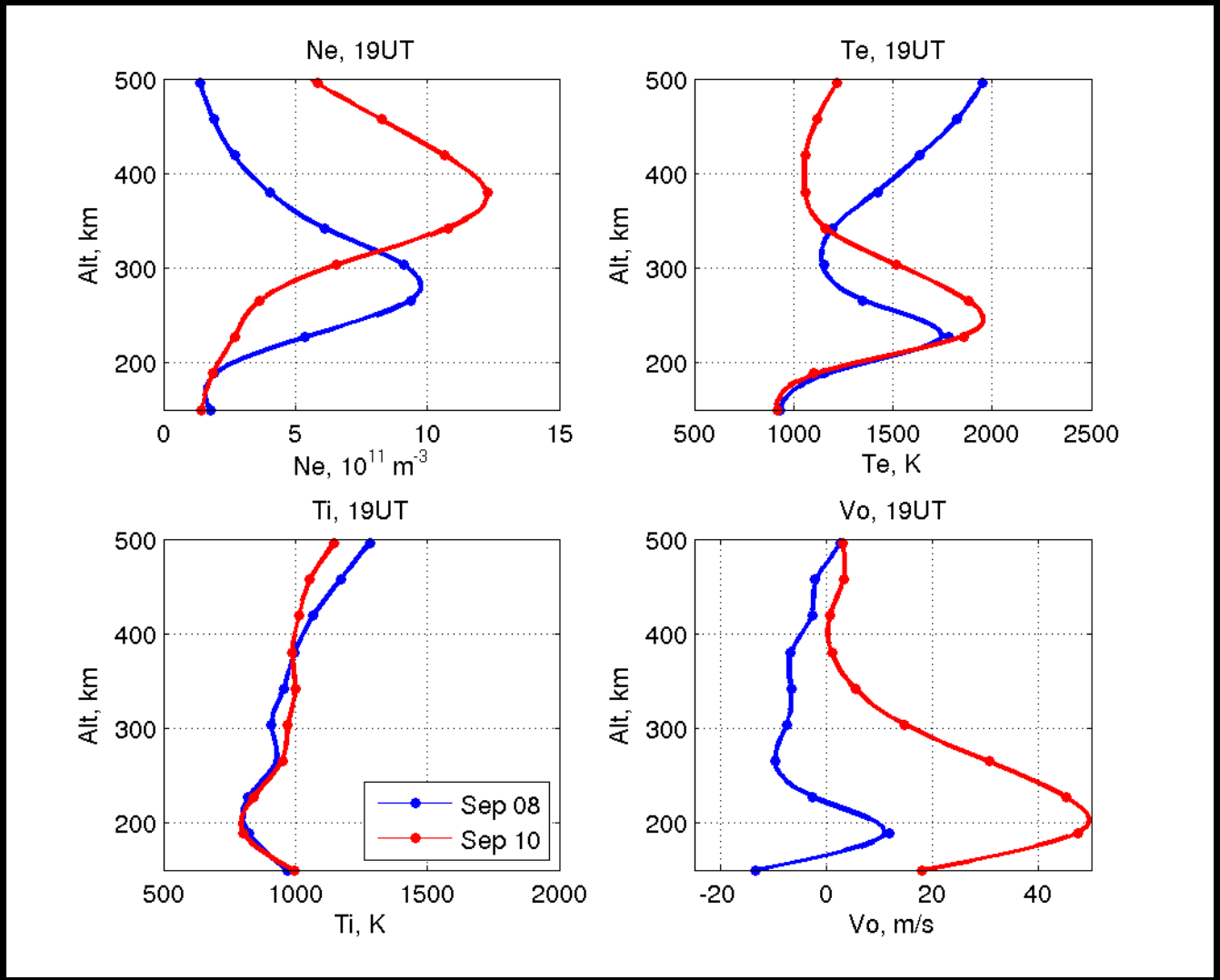
# Arecibo ISR Ne, Te, Ti, Vi at 19 UT

Ne

Te

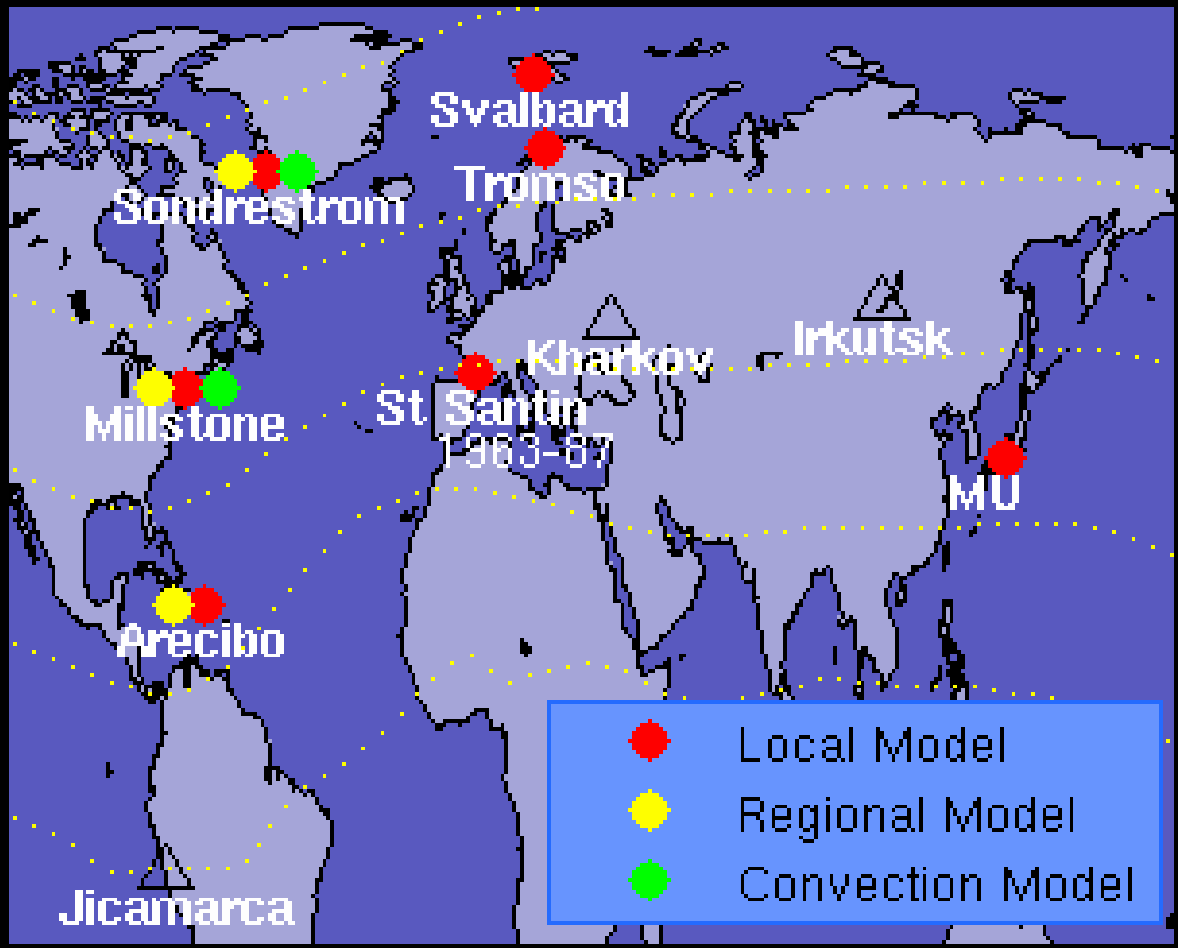
Ti

Vi



# Virtual ISR: ISRIM

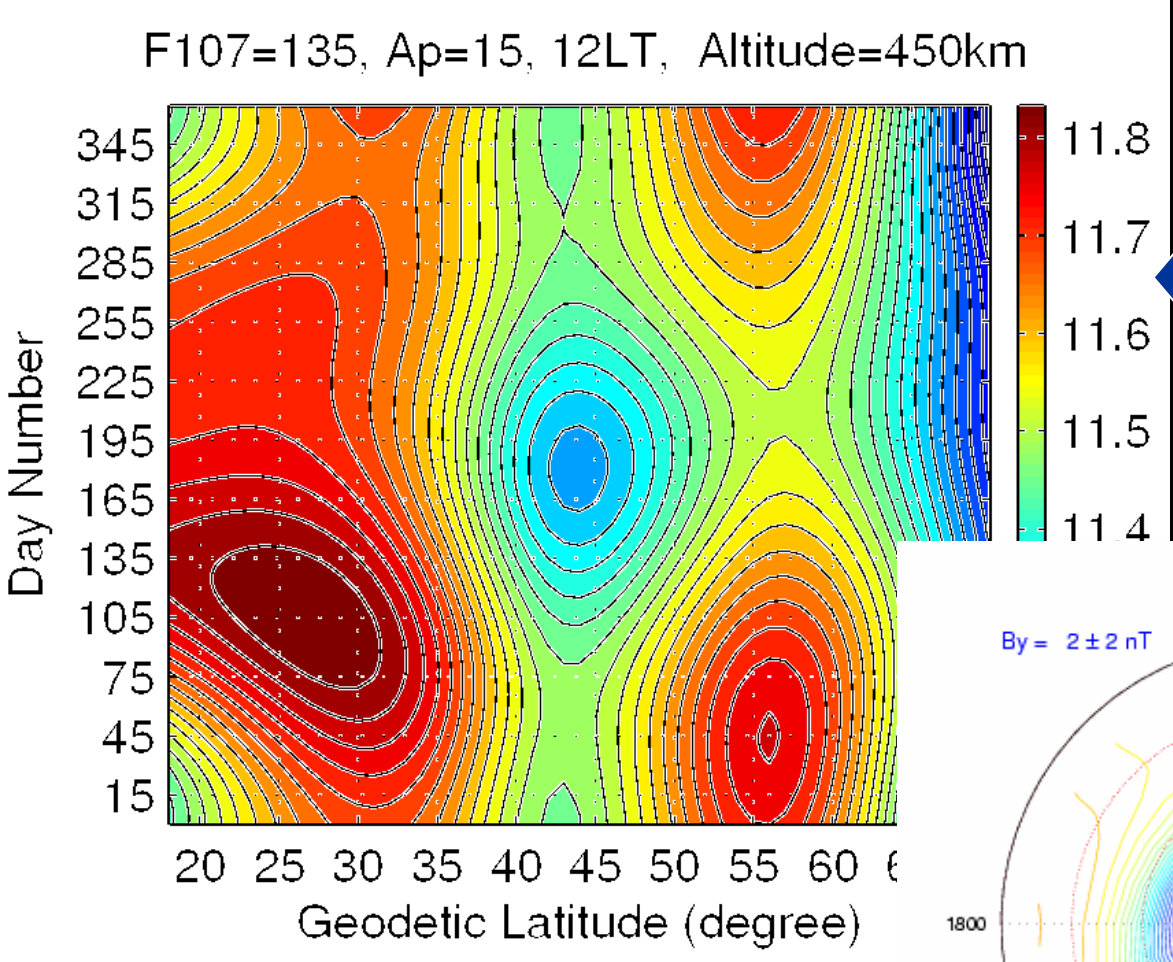
## incoherent scatter radar ionospheric model



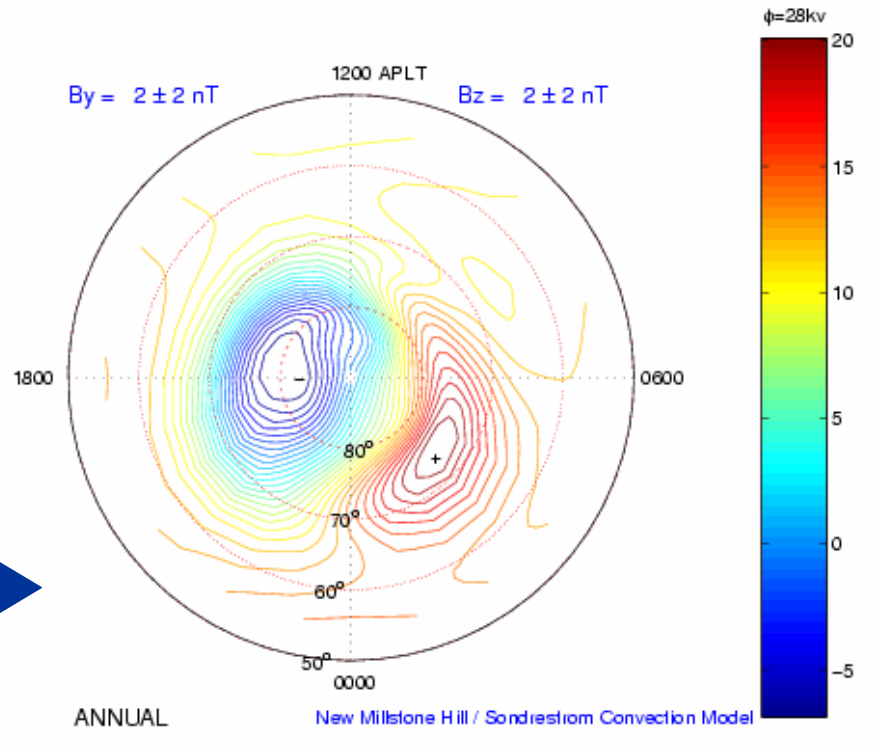

- ISRIM local climatology
- ISRIM regional climatology
- ISRIM local variability
- ISRIM convection

**htttp://madrigal.haystack.mit.edu/models/**

Massachusetts Institute of Technology HAYSTACK




Ionospheric climatology derived from long-term and multiple ISR data. Midday Nel is shown to demonstrate the development of annual and semiannual ionospheric changes with latitude.

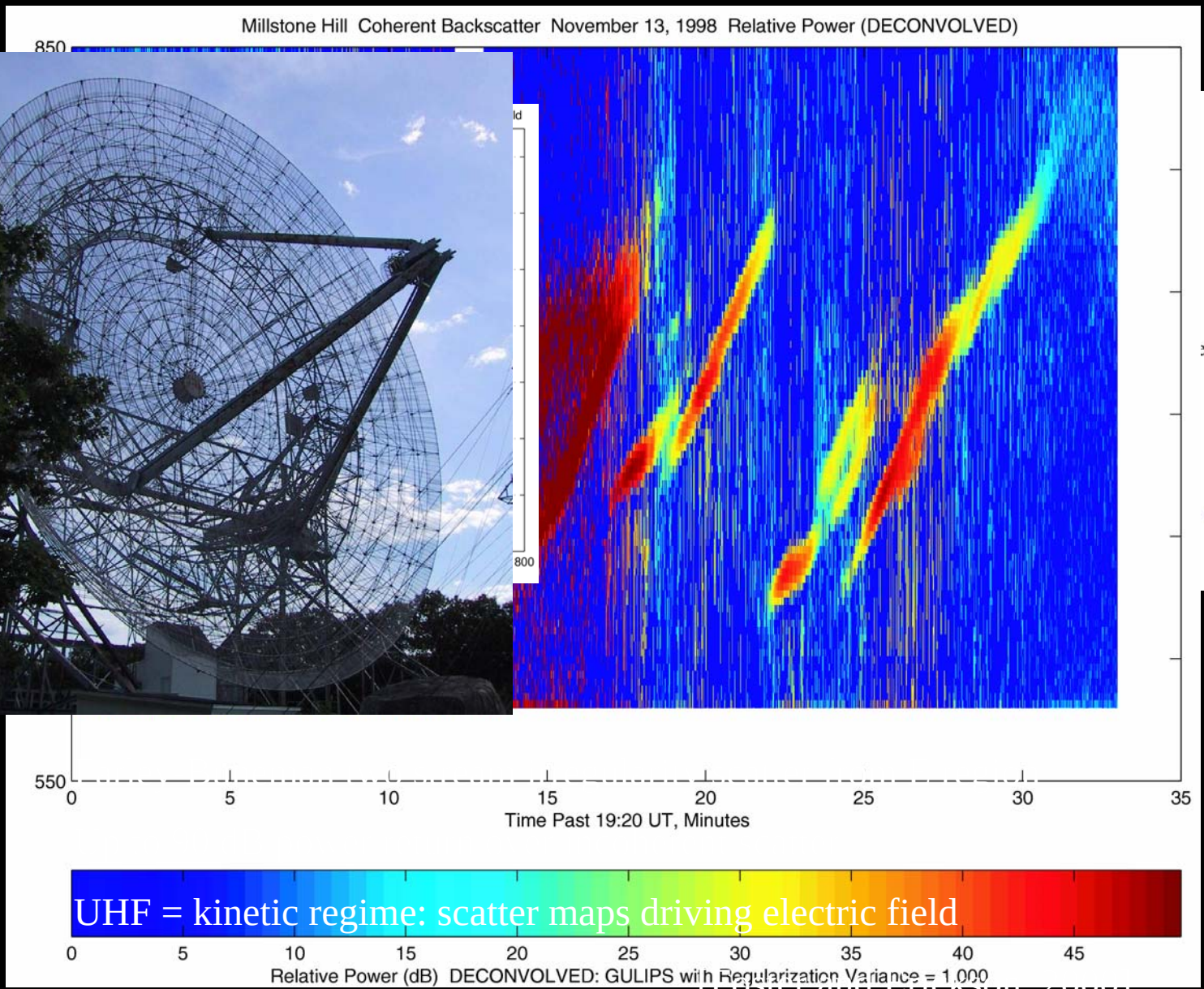



High latitude convection pattern derived from Millstone Hill and Sondrestrom ISR long-term observations.

Massachusetts Institute of Technology

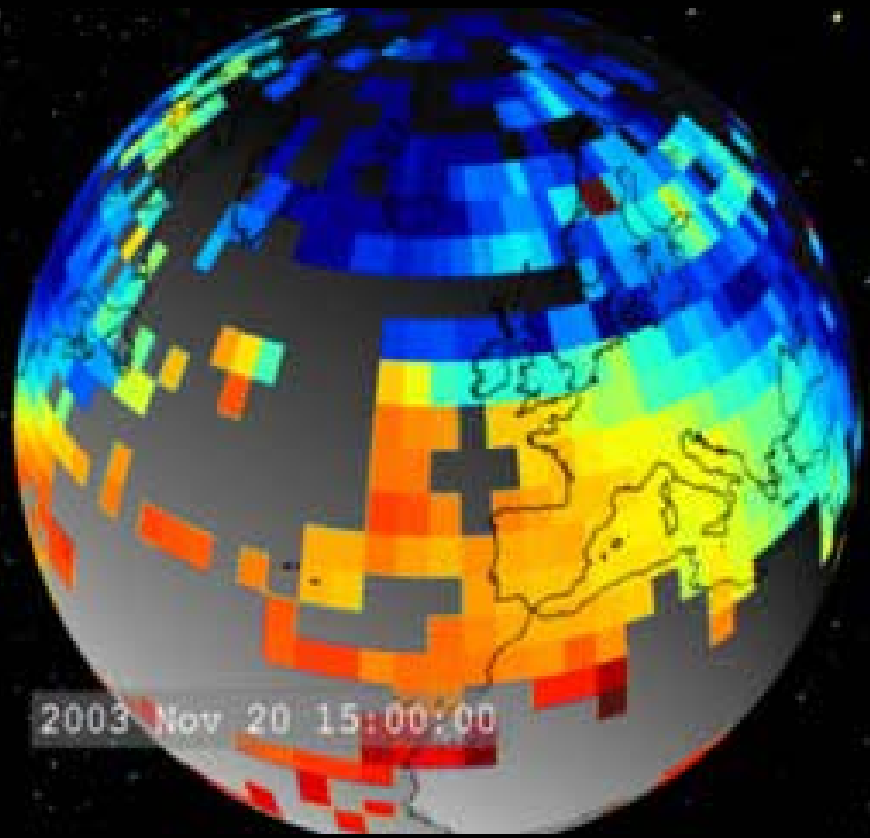
HAYSTACK

# UHF Coherent Backscatter: Microscale SAPS/SAID Physics

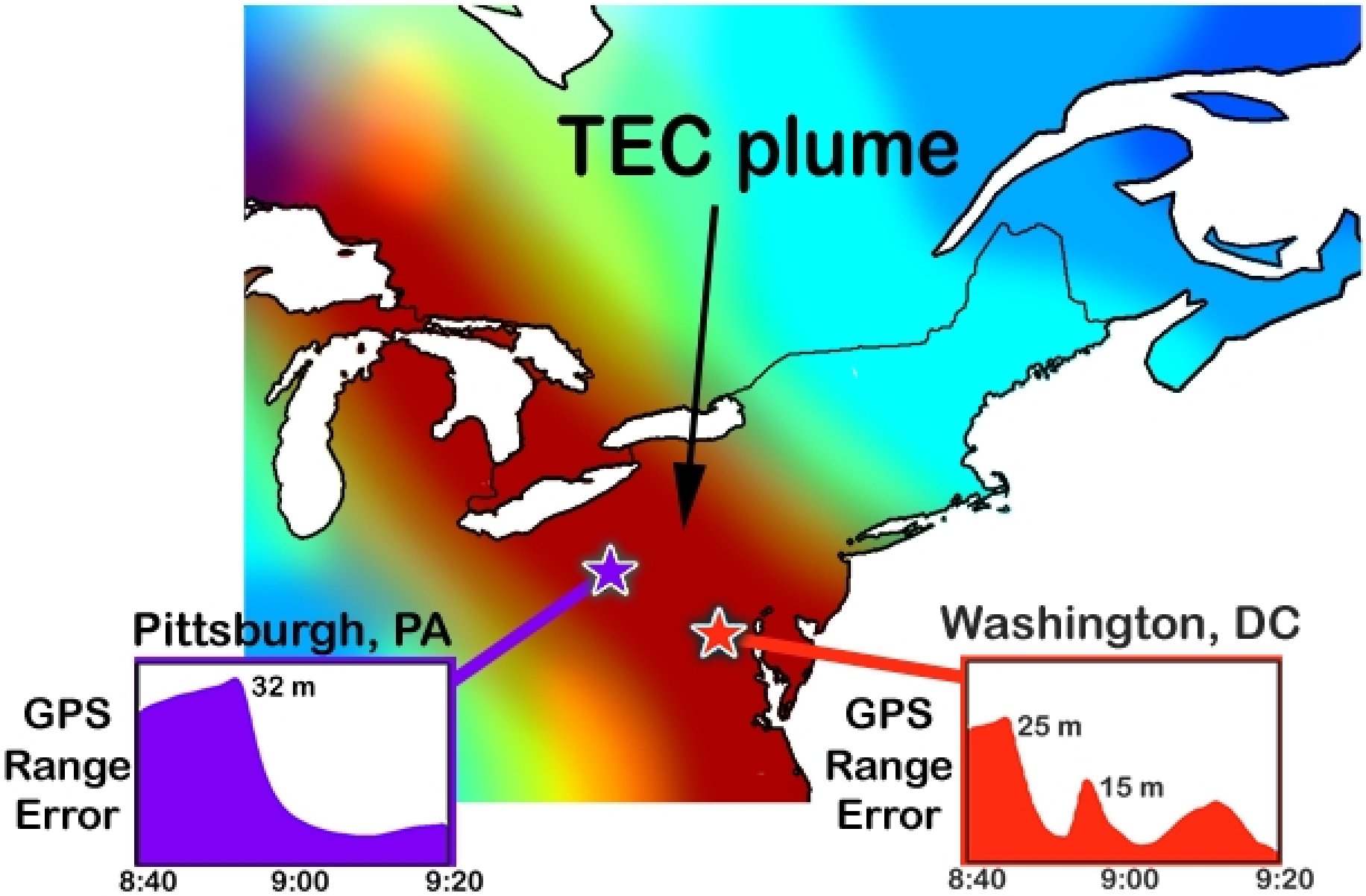



[Foster and Erickson, 2000]

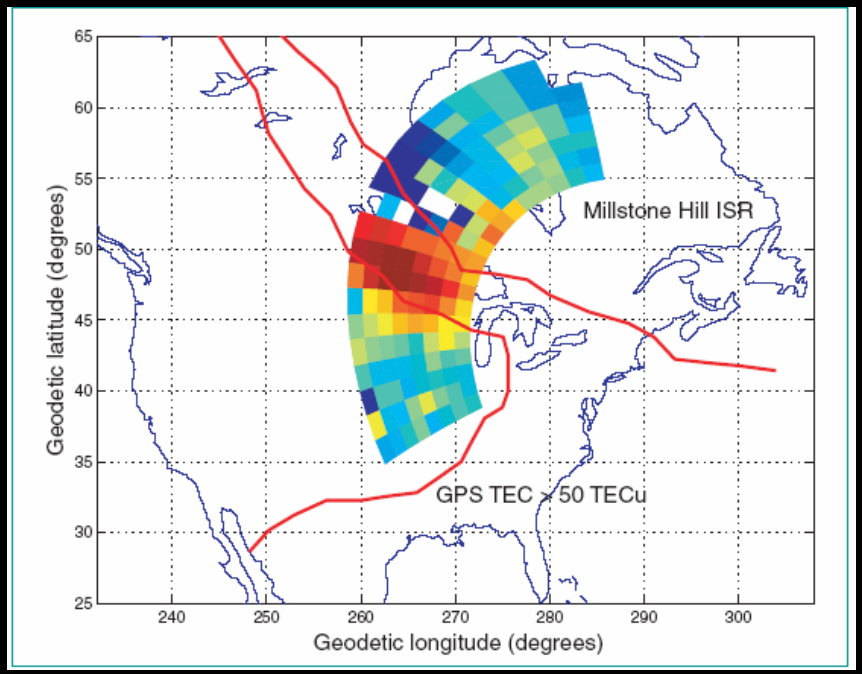
# 2003 Nov 20

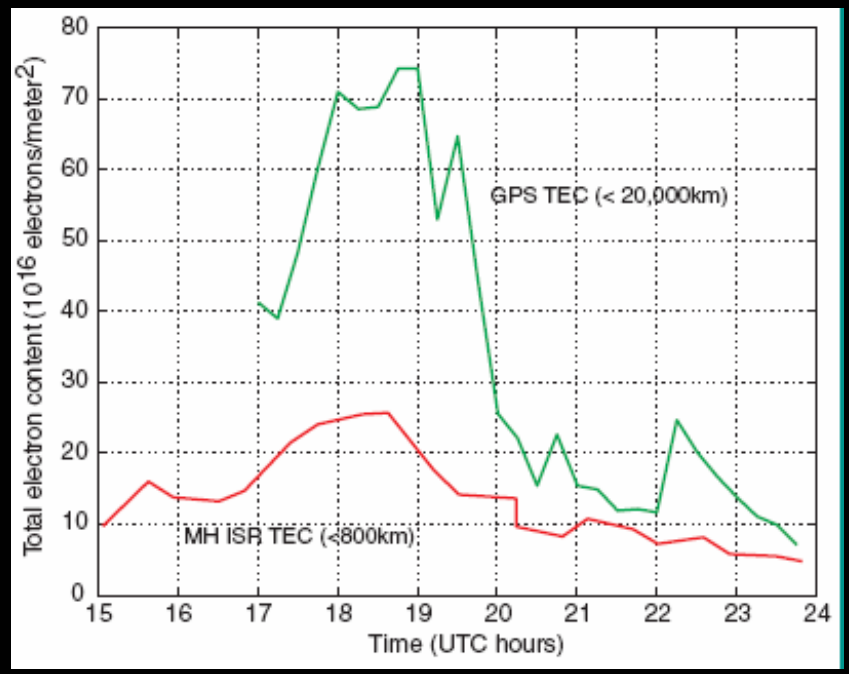


# November 20, 2003



# Millstone ISR and GPS TEC Observations



# MADRIGAL

A robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of ground-based instruments.

It is installed at a number of sites around the world. Each site controls their own Madrigal installation, and can add or upgrade their data from their instrument(s) on their site at any time.

- Tutorial
- Access Data
- Run Models
- Documentation
- Open Madrigal
- Space Science Resources
- Real-time Data Sources

# Welcome to the Madrigal Database at Haystack Observatory

*Try the new Simple Madrigal Data Access link on the Access Data page.*

Madrigal is an upper atmospheric science database used by groups throughout the world. Madrigal is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of upper atmospheric science instruments. The basic data format is the same as that used by the National Science Foundation supported Coupling, Energetics and Dynamics of Atmospheric Regions (CEDAR) program, which maintains a CEDAR Database at the National Center for Atmospheric Research (NCAR). Data files are easily exchanged between the two sites, but Madrigal has a significantly different emphasis. Data at each Madrigal site is locally controlled and can be updated at any time, but shared metadata between Madrigal sites allow searching of all Madrigal sites at once.

Data can be accessed from the Madrigal sites at Millstone Hill, USA, Arecibo, Puerto Rico, EISCAT, Norway, SRI International, USA, Cornell University, USA, Jicamarca, Peru, The Institute of Solar-Terrestrial Physics, Russia, and Wuhan Ionospheric Observatory, the Chinese Academy of Sciences. and directly, using APIs which are available for several popular programming languages. A CVS archive of all Madrigal software and documentation is available from the Open Madrigal Web site. The latest version of Madrigal may also be downloaded from there.


http://madrigal.haystack.mit.edu/madrigal/

# Madrigal web tutorial - Table of contents



Madrigal web tutorial - Table of contents | Doc home | Madrigal home

**Previous:** Madrigal user's guide **Up:** Madrigal user's guide **Next:** What is Madrigal?

# Access Madrigal Data

There are four ways to access Madrigal data. Choosing *Simple Madrigal Data Access* will allow you to print and plot Madrigal data via an easy to use interface. However, this interface does not allow you to see derived parameters or to filter data. To look at the data from a particular Madrigal experiment using the full-featured Madrigal interface, choose *Browse for Individual Madrigal Experiments*. To get data in ascii format from a group of Madrigal experiments all at once, choose *Global Madrigal Database Report*. To plot data from one or more instruments and/or experiments, choose *Plot Data from Instruments*.

---

## Simple Madrigal Data Access

The simple madrigal data access link allows new users of Madrigal to print and plot data easily. In order to make it easy to use, a number of Madrigal's capabilities are not available, including the ability to choose which parameters to print, the ability to display derived parameters, and the ability to filter data. Use the other three Madrigal interfaces below to access these more powerful capabilities. Click here for a tutorial on this way to access Madrigal data.

## Browse for Individual Madrigal Experiments

Browse for individual Madrigal experiments displays a list of available experiments, subject to user-specified filters. One of the filters specifies the instruments you want to see. For several of the incoherent scatter radars, for example Millstone and EISCAT, there are several options corresponding to different antennas. As a rule, select the first option, which displays all data from that instrument. In addition to the filters, a number of options may be selected on the form. For example, it is possible to display a combined listing of experiments at all Madrigal sites, or only the experiments at the current site. Click here for a tutorial on this way to access Madrigal data.

## Global Madrigal Database Report

This form allows you to generate a report on multiple experiments at once. Experiments can be filtered by instrument, kind of data, and date range or season. The data within any given experiment can be filtered using any parameter, measured or derived. Data from all experiments located in the local Madrigal database matching your criteria will be returned in a single report. Click here for a tutorial on this way to access Madrigal data.

## Plot Data from Instruments

## Simple Madrigal data access - select an instrument...

**Click on the instrument you want to get data or plots from:**

- Select an instrument
- Jicamarca IS Radar
- Arecibo IS Radar - Linefeed
- MU IS Radar
- Millstone Hill IS Radar
- Millstone Hill UHF Zenith Antenna
- St. Santin IS Radar
- St. Santin Nançay Receiver
- Chatanika IS Radar
- ISTP Irkutsk Radar

| | | | |
|---|---|---|---|
| Tutorial on this page | Return to Access Data page | Return to Madrigal home page | How is the simple data access different? |

*Please send any comments or suggestions to the Open Madrigal Users Mailing List.*

## Simple Madrigal data access - select dates...

Selected Instrument: *Millstone Hill IS Radar*

### Click on one or more dates you want data or plots from:

(Windows users: Hold down *Control* key to select more than one date)

2006-06-19
2006-06-16
2006-06-01
2006-05-31
2006-05-16
2006-05-02
2006-04-28
2006-04-12
2006-04-06
2006-04-05

Plot data

| | | | |
|---|---|---|---|
| Tutorial on this page | Return to Access Data page | Return to Madrigal home page | How is the simple data access different? |

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## Simple Madrigal data access - select parameter and y axis for plotting...

Selected Instrument:

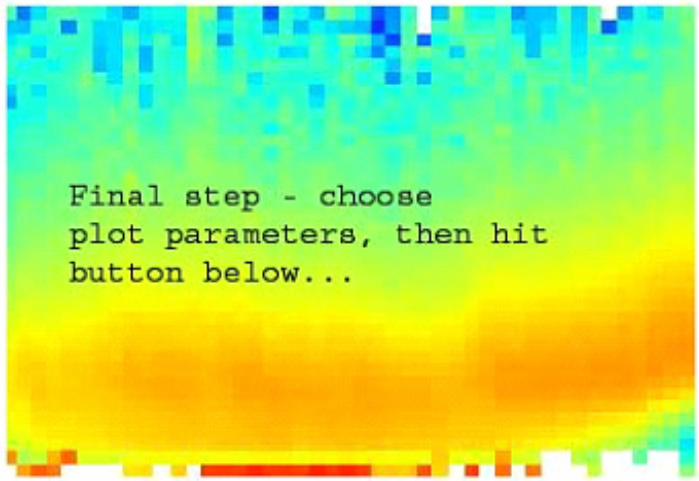
- *Millstone Hill IS Radar*

Selected dates:

- 2005-09-10

### Create a new plot...

**Choose parameter to plot:** Log10(uncorrected electron density)




Time

**Select y axis:** Altitude

### or, view existing plots and descriptions:

- 2005-09-10
  - INSCAL Analysis notes for mlh 1142298092
  - Electron density summary plots
  - Electron temperature summary plots
  - Ion temperature summary plots
  - Ion velocity summary plots

# Electron density summary plots for Millstone Hill Radar

# Sep. 10, 2005

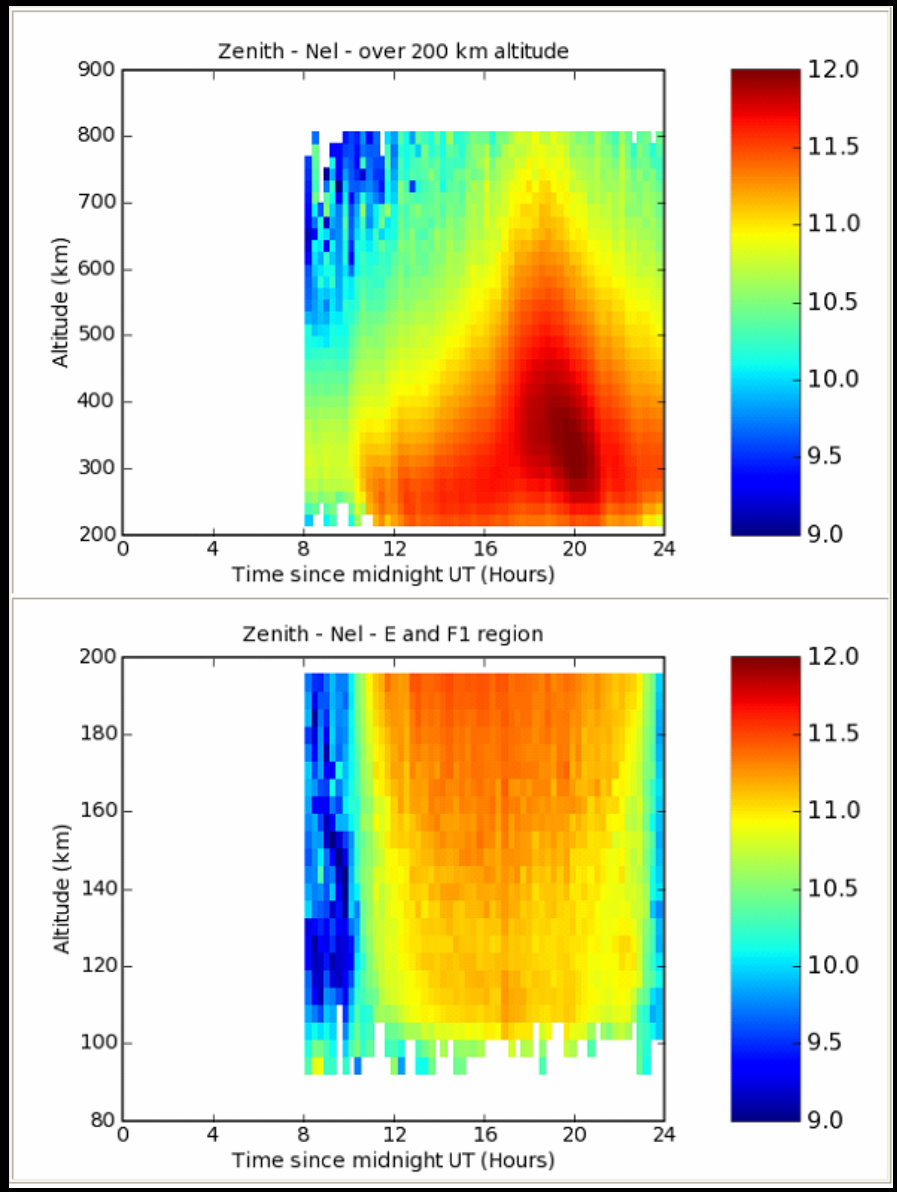
| Electron temperature summary plots | Ion temperature summary plots | Ion velocity summary plots |
|---|---|---|

## Rapid LTCS Experiment

*This is an experiment designed to provide rapid time coverage of the E-region and F-region ionosphere. This experiment is useful for providing high altitude resolution in the E-region and F-region along with sufficient pointing directions using MISA to provide electric field measurements. The dwell time in a given position is 8 minutes to provide the possibility of a long integration if needed. The overall cycle time of the experiment is 65 minutes with a measurement triplet every 32 minutes.*

This page has the following summary plots of electron density:

1. Zenith antenna - altitudes above 200 km versus time using single pulse measurements
2. Zenith antenna - E and F1-region altitudes versus time using alternating code measurements
3. Misa antenna - Azimuth=0°(North), Elevation=45°, altitudes above 200 km versus time using single pulse measurements
4. Misa antenna - Azimuth=0°(North), Elevation=45°, E and F1-region altitudes versus time using alternating code measurements
5. Misa antenna - Azimuth=-90°(West), Elevation=45°, altitudes above 200 km versus time using single pulse measurements
6. Misa antenna - Azimuth=-90°(West), Elevation=45°, E and F1-region altitudes versus time using alternating code measurements


Zenith - Nel - over 200 km altitude
Altitude (km)
900
800
700
600
500
400
300
200
0
4
8
12
16
20
24
Time since midnight UT (Hours)
12.0
11.5
11.0
10.5
10.0
9.5
9.0
Zenith - Nel - E and F1 region
Altitude (km)
200
180
160
140
120
100
80
0
4
8
12
16
20
24
Time since midnight UT (Hours)
12.0
11.5
11.0
10.5
10.0
9.5
9.0

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## Plot Data from Instruments

# Madrigal Experiment Selector

| Return to Madrigal homepage | Tutorial on this page | Return to access data page |
|---|---|---|

## Select instrument(s)

College Fabry-Perot
Sondre Stromfjord and Thule Fabry-Perots
Thule Fabry-Perot
Stockholm IR Michelson
CEDAR lidar
USU CCD Imager
CEDAR Imager
MIO
All-sky cameras at Qaanaaq
World-wide GPS Receiver Network

## Select list format

- [ ] Experiment ID
- [x] Madrigal Site
- [x] Start Date
- [x] Start Time
- [x] End Date
- [x] End Time
- [ ] Instrument Code
- [x] Instrument Mnemonic
- [ ] Instrument Name
- [x] Experiment Name

## Select date range

1 | 1 | 1950 Start Day, Month, Year

31 | 12 | 2006 End Day, Month, Year

## Options

| Sort Order | Date Order | Date Format | File Selection | Show Experiments at |
|---|---|---|---|---|
| (•) Date | (•) Earliest first | (•) 03/21/1999 | (•) Show Latest Files | (•) All Madrigal Sites |
| ( ) Instument | ( ) Latest First | ( ) 21.03.1999 | ( ) Show History Files | ( ) This Madrigal Site |

List selected data

# Madrigal Experiment Listing

| Return to Madrigal homepage | Tutorial on this page | Return to access data page |
|---|---|---|

| Site | Start Date | S Tm | End Date | E Tm | Inst | Experiment Name |
|---|---|---|---|---|---|---|
| GO Mills | 09/10/2005 | 0000 | 09/10/2005 | 2355 | gps | World-wide Vertical Total Electron Content |
| GO Mills | 09/11/2005 | 0000 | 09/11/2005 | 2355 | gps | World-wide Vertical Total Electron Content |

# World-wide GPS Receiver Network

## World-wide Vertical Total Electron Content

| | | |
|---|---|---|
| Return to Madrigal homepage | Tutorial on this page | Return to access data page |

---

**Start Time: 09/10/2005 00:00:00 End Time: 09/10/2005 23:55:00**

---

**CEDAR Format Datasets:**

- gps050910g.001 - default file for Minimum Scallop TEC Processing - status: final
  - View description from the catalog and/or header records
  - File Summary - Record summary, list of parameters in file, etc.
  - Data Browser (isprint) - Flat-file listing of a user-selected portion of the file
  - Download file - Download gps050910g.001 in selected format

---

**Additional information:**

- TEC Maps

**Notes**

Add to these notes

---

# ISPrint Database Browser

## Experiment: World-wide Vertical Total Electron Content

Return to experiment list | Return to Madrigal homepage | A tutorial on how to use this page | Return to access data page

Sat Sep 10 00:00:00 2005 - Sat Sep 10 23:55:00 2005 : World-wide GPS Receiver Network

**Available Filters - Using default or manually entered selections**

**Set data filters manually, or ...**

- Data will be listed only if it falls within the range of the filter
- For azimuth and elevation, two separate ranges can now be used
- Explanation of Filters

| | | | |
|---|---|---|---|
| Start date: | Sep | 10 | 2005 |
| Start time: | H: 0 | M: 0 | S: 0 |
| End date: | Sep | 10 | 2005 |
| End time: | H: 23 | M: 55 | S: 0 |

*Optional free-form filters using any parameter mnemonic on this page*

**...use a saved filter and parameter selection:**

Public Directories: jfoster:jfoster

Public filters: coherent1

You are not logged in.

## Available Parameters (Comprehensive)

- Description of parameters
- ISPrint(Short form)

*(parameters with regular typeface are derived)*

### Time Related Parameter

| | | | | |
|---|---|---|---|---|
| BDAY | BEG_UT | BHHMMSS | BHM | BMONTH |
| B_UTH | DAY | DAYNO | DUT21 | EHHMMSS |
| FYEAR | HOUR | JDAYNO | MD | MIN |
| MONTH | RECNO | SEC | SLT | UT |
| UT1 | UT2 | UTH | YEAR | |

### Geographic Coordinate

| | | | | |
|---|---|---|---|---|
| **GDLAT** | **GLON** | SDWHT | SZEN | |

### Geophysical Index

| | | | | |
|---|---|---|---|---|
| AP | AP3 | DST | F10.7 | FBAR |
| KP | | | | |

### Interplanetary Magnetic Field

| | | | | |
|---|---|---|---|---|
| BIMF | BXGSE | BXGSM | BYGSE | BYGSM |
| BZGSE | BZGSM | SWDEN | SWQ | SWSPD |
| | | | | |

### I. S. Radar Basic Parameter

# Experiment: World-wide Vertical Total Electron Content

Return to experiment list | Return to Madrigal homepage | A tutorial on how to use this page | Return to access data page

Sat Sep 10 00:00:00 2005 - Sat Sep 10 23:55:00 2005 : World-wide GPS Receiver Network

**Available Filters**

**Set data filters manually, or ...**

- Data will be listed only if it falls within the range of the filter
- For azimuth and elevation, two separate ranges can now be used
- Explanation of Filters

| | | | |
|---|---|---|---|
| Start date: | Sep | 10 | 2005 |
| Start time: | H: 0 | M: 0 | S: 0 |
| End date: | Sep | 10 | 2005 |
| End time: | H: 23 | M: 55 | S: 0 |

*Optional free-form filters using any parameter mnemonic on this page*

| Mnemonic (or Mnem1 +,-,*,/ Mnem2) (example: gdalt *or* gdalt - sdwht) Leave spaces between mnemonics and operator | Lower limit (leave blank if none) | Upper limit (leave blank if none) |
|---|---|---|
| gdlat | 40.0 | 44.0 |
| glon | 150.0 | 200.0 |

**...use a saved filter and parameter selection:**

| | |
|---|---|
| Public Directories: | jfoster:jfoster |
| Public filters: | coherent1 |
| Private Directories: | |
| Filters: | |
| User: **ajc** | |

*(parameters with regular typeface are derived)*

**Time Related Parameter**

| | | | | |
|---|---|---|---|---|
| ☐ BDAY | ☐ BEG_UT | ☐ BHHMMSS | ☐ BHM | ☐ BMONTH |
| ☐ B_UTH | ☐ DAY | ☐ DAYNO | ☐ DUT21 | ☑ EHHMMSS |
| ☐ FYEAR | ☐ HOUR | ☐ JDAYNO | ☐ MD | ☐ MIN |
| ☐ MONTH | ☐ RECNO | ☐ SEC | ☐ SLT | ☐ UT |
| ☐ UT1 | ☐ UT2 | ☐ UTH | ☐ YEAR | |

**Geographic Coordinate**

| | | | | |
|---|---|---|---|---|
| ☑ **GDLAT** | ☑ **GLON** | ☐ SDWHT | ☐ SZEN | |

**Geophysical Index**

| | | | | |
|---|---|---|---|---|
| ☐ AP | ☐ AP3 | ☐ DST | ☐ F10.7 | ☐ FBAR |
| ☐ KP | | | | |

**Interplanetary Magnetic Field**

| | | | | |
|---|---|---|---|---|
| ☐ BIMF | ☐ BXGSE | ☐ BXGSM | ☐ BYGSE | ☐ BYGSM |
| ☐ BZGSE | ☐ BZGSM | ☐ SWDEN | ☐ SWQ | ☐ SWSPD |
| | | | | |

**I. S. Radar Basic Parameter**

| | | | | |
|---|---|---|---|---|
| ☑ **TEC** | | | | |

**I. S. Radar Operation Parameter**

| | | | | |
|---|---|---|---|---|
| ☐ FOF2 | | | | |

**Please contact Millstone before using this data in a report or publication.**

NEW

Data derived from file
/opt/madrigal/experiments/2005/gps/10sep05/gps050910g.001:
Filters used:
Filter 1:
UT1
Range 1: Lower = 1757462400.0 (09/10/2005 0000:00), upper =
1757548500.0 (09/10/2005 2355:00)

Filter 2:
GDLAT
Range 1: Lower = 40, upper = 44

Filter 3:
GLON
Range 1: Lower = 150, upper = 200

World-wide GPS Receiver Network: 09/10/2005 0040:00-0045:00

| EHHMMSS | GDLAT | GLON | TEC |
|---|---|---|---|
| 4500 | 44.00 | 154.00 | 1.02000e+01 |
| 4500 | 44.00 | 155.00 | 1.03000e+01 |

World-wide GPS Receiver Network: 09/10/2005 0045:00-0050:00

| EHHMMSS | GDLAT | GLON | TEC |
|---|---|---|---|
| 5000 | 44.00 | 154.00 | 1.02000e+01 |
| 5000 | 44.00 | 155.00 | 1.04000e+01 |
| 5000 | 44.00 | 156.00 | 1.07000e+01 |

World-wide GPS Receiver Network: 09/10/2005 0050:00-0055:00

| EHHMMSS | GDLAT | GLON | TEC |
|---|---|---|---|
| 5500 | 43.00 | 156.00 | 1.10000e+01 |
| 5500 | 44.00 | 155.00 | 1.06000e+01 |
| 5500 | 44.00 | 156.00 | 1.07000e+01 |

World-wide GPS Receiver Network: 09/10/2005 0055:00-0100:00

| EHHMMSS | GDLAT | GLON | TEC |
|---|---|---|---|
| 10000 | 43.00 | 156.00 | 1.11000e+01 |
| 10000 | 43.00 | 157.00 | 1.13000e+01 |
| 10000 | 44.00 | 155.00 | 1.08000e+01 |
| 10000 | 44.00 | 156.00 | 1.08000e+01 |

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| EHHMMSS | GDLAT | GLON | TEC |
|---|---|---|---|
| 10500 | 42.00 | 157.00 | 1.18000e+01 |
| 10500 | 42.00 | 158.00 | 1.18000e+01 |
| 10500 | 43.00 | 156.00 | 1.12000e+01 |
| 10500 | 43.00 | 157.00 | 1.13000e+01 |
| 10500 | 44.00 | 153.00 | 1.09000e+01 |

# Matlab Scripts

Three different matlab scripts will be available which

1) **GetMadExpList1.m - This script finds experiments within specified dates and selects only default or realtime files within each experiments.**
2) **getGPSdata.m - Gets GPS TEC data from Madrigal**
3) **isrtec.m - downloads ISR data from an madrigal site (see siteURL) from the specified madrigal file (see madFile). It then calculates integrated electron content for each profile along the radar's line-of-sight.**

# ISR World Days – Long Runs

January, 1993 – 10 days
October, 2002 – 30 days
September, 2005 – 30 days
March-April, 2006 – 30 days

Modern ISRs such as ESR, AMISR and ZIP will be able to operate for even longer periods,