

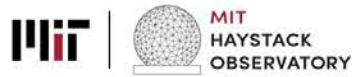
# The Madrigal Database

**Anthea Coster, Bill Rideout, Nestor Aponte, MIT Haystack Observatory**

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# www.haystack.mit.edu



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[About](#) [Our Researchers](#) [Astronomy](#) [Geodesy](#) [Geospace](#) [Space Technology](#)

## Welcome to Haystack

Radio science & technology research center

Latest developments



Geodesy: measuring Earth



Geospace from A to Z



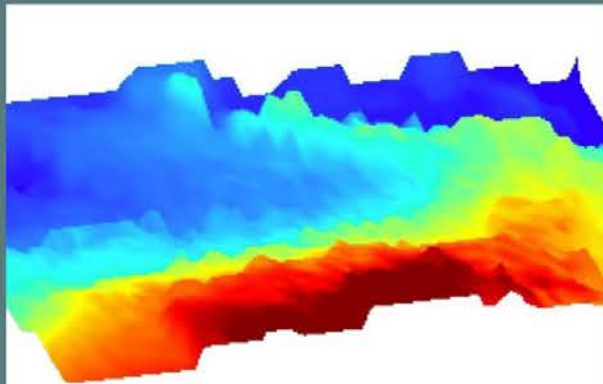
# MIT Public Outreach and Lesson Plans

<https://www.haystack.mit.edu/haystack-public-outreach/k-12-lesson-plans/>

<https://www.haystack.mit.edu/haystack-public-outreach/>



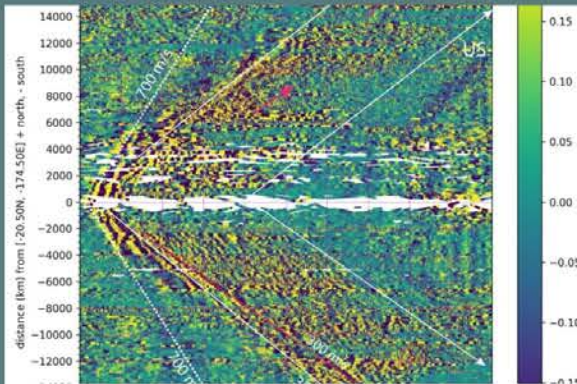
# Hit “Latest Developments”. Try today!!!



## Imaging geomagnetic storms in the Earth's ionosphere—in 3D

A team of researchers led by MIT Haystack Observatory has created a system to image in 3D ionospheric changes during storms.

[Read more](#)



## 2022 Tonga volcanic eruption induced global propagation of ionospheric disturbances via Lamb waves

This study provides substantial first evidence of long-duration Lamb wave imprints in the global ionosphere.

[Read more](#)



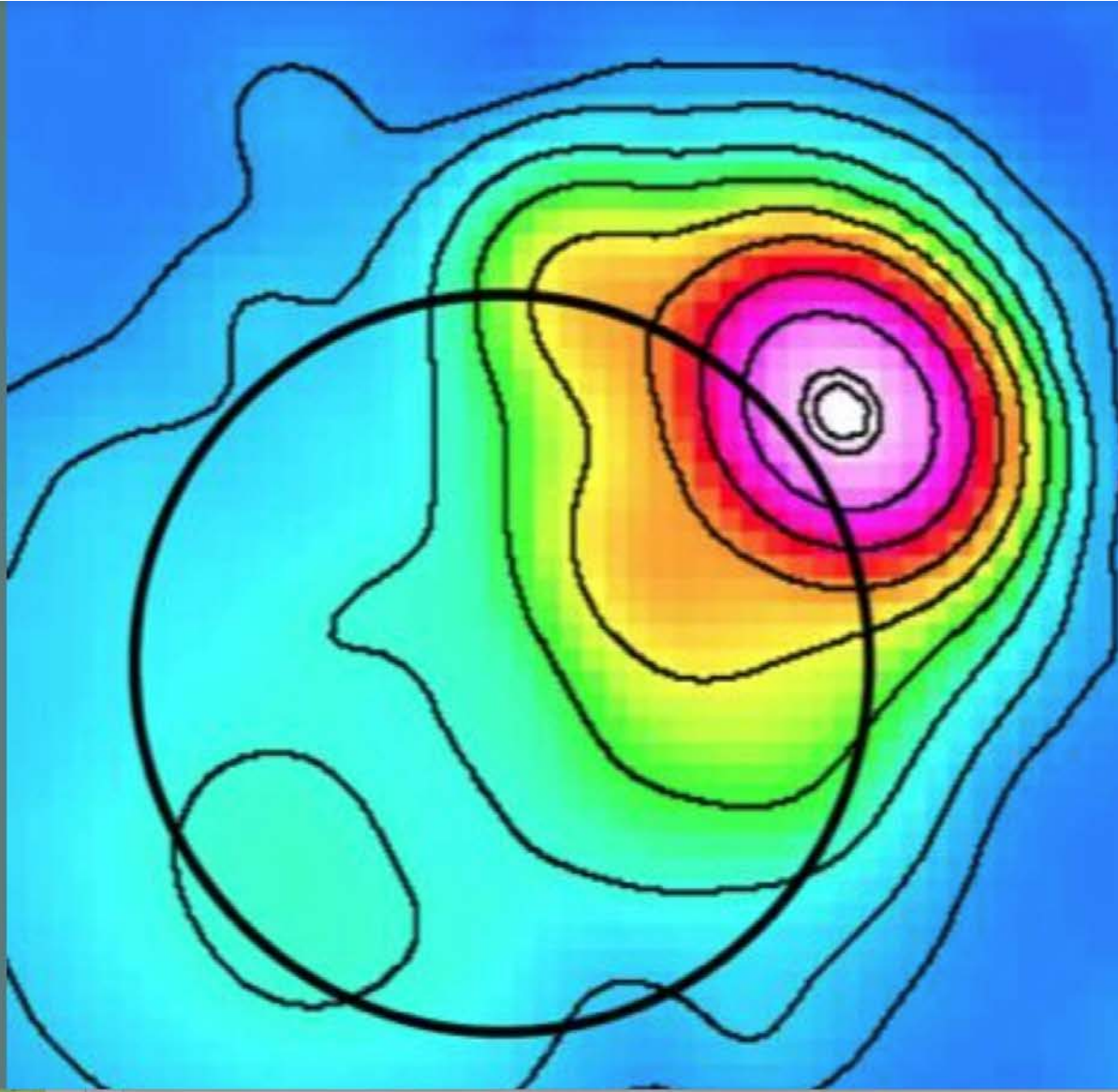
## Swoboda awarded ONR Young Investigator Program grant

Dr. John Swoboda receives grant from the Office of Naval Research.

[Read more](#)



# Astronomy and Astrophysics



## **Astronomy & Astrophysics**

### **PHYSICS OF BLACK HOLES**

Researchers at Haystack study supermassive black holes in the centers of galaxies to explore the fundamental physics of spacetime and understand how black holes shape their host galaxies.

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### **EPOCH OF REIONIZATION**

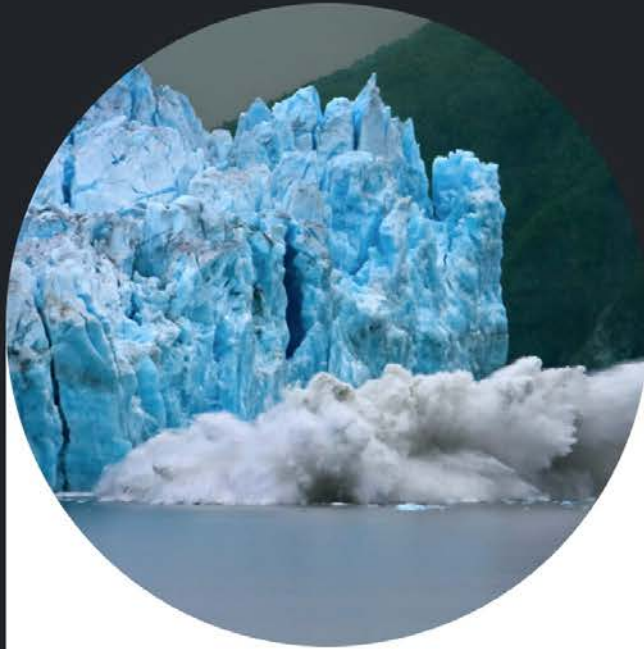
Haystack astronomers explore the onset of star and galaxy formation in the early phases of the universe.

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### **RADIO STARS**

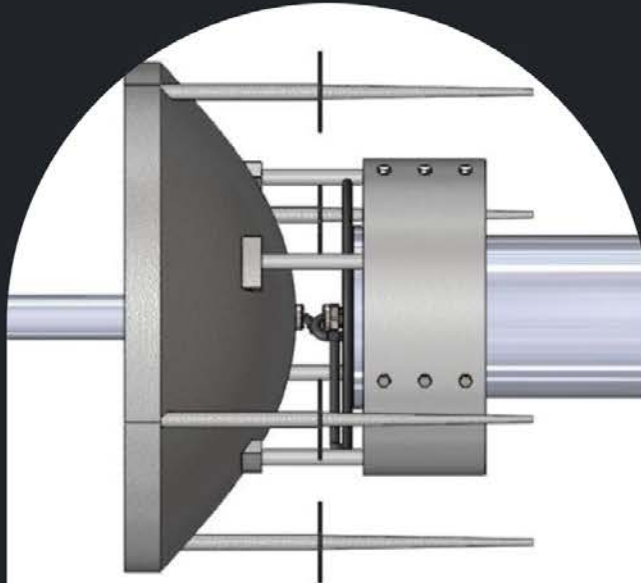
Investigators at Haystack use radio observations to explore the last stages in the lives of stars and learn more about the physical processes on the surface of the sun.

# Geodesy



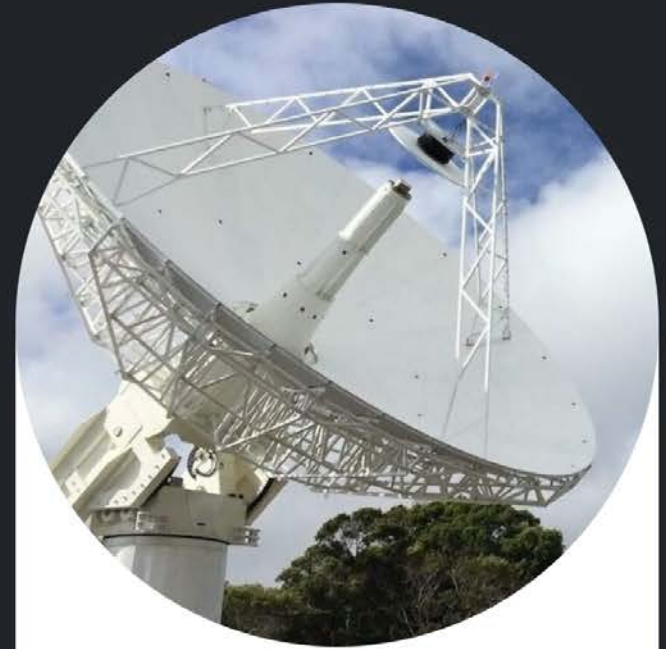
## **SIDEx: Sea Ice Dynamic Experiment**

Measuring ice in the Arctic Circle.



## **SGIP: Antarctic Seismo-Geodetic Ice Penetrator**

Monitoring the response of ice shelves in Antarctica to ocean forces.



## **Advancing VGOS**

The Haystack VLBI Geodetic Observing System (VGOS) signal chain has been in development since 2007 and in service since 2010. It was developed for NASA and has been installed in Texas and Hawaii.



# Geospace



# Geospace

[Home](#) > Geospace

The Atmospheric and Geospace Sciences group at Haystack conducts fundamental and collaborative scientific research into the complex and highly intercoupled near-Earth space environment using a wide variety of observational experimental data sets. These include radio (passive), radar (active), and other remote sensing tools using instruments such as incoherent/Thomson scatter radar, ionosondes, HF based convection radars (SuperDARN), optical neutral airglow observations, and in-situ satellite instruments, including small satellite platforms.

Studies of ionospheric response in both quiet and active times also involve collaborative data-model investigations using frontier whole atmosphere community models.

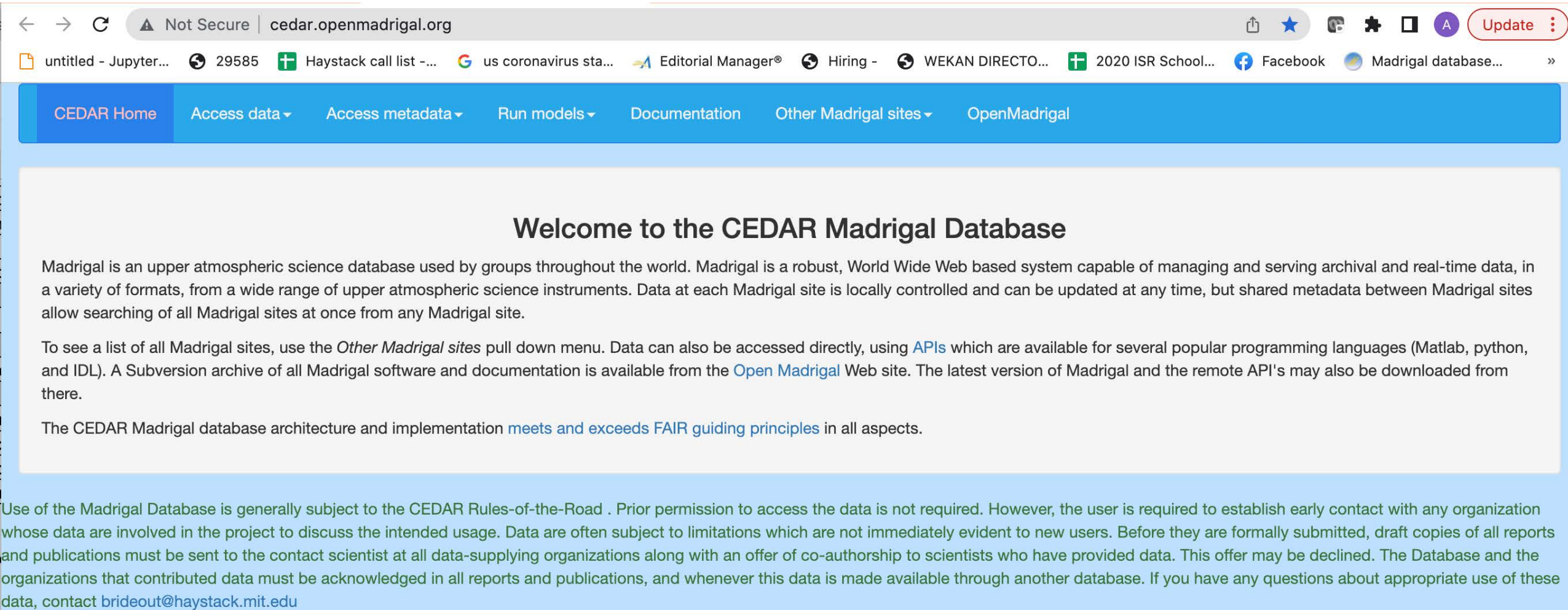
The Madrigal database is available at: <http://cedar.openmadrigal.org/>.



What is now available through CEDAR Madrigal Web

→ <http://cedar.openmadrigal.org/>

# Cedar Madrigal site: <http://cedar.openmadrigal.org>



The screenshot shows a web browser window with the address bar displaying "cedar.openmadrigal.org". The browser's address bar includes navigation icons (back, forward, refresh), a security warning "Not Secure", and a list of open tabs. The website's navigation bar is blue and contains links: "CEDAR Home", "Access data", "Access metadata", "Run models", "Documentation", "Other Madrigal sites", and "OpenMadrigal". The main content area has a light blue background and features a heading "Welcome to the CEDAR Madrigal Database". Below the heading, there are three paragraphs of text. The first paragraph describes Madrigal as an upper atmospheric science database. The second paragraph explains how to access data and software. The third paragraph states that the database architecture meets FAIR principles. At the bottom, a green text block provides information about the database's usage policies and contact details.

← → ↻ ⚠ Not Secure | cedar.openmadrigal.org

untitled - Jupyter... 29585 Haystack call list -... us coronavirus sta... Editorial Manager® Hiring - WEKAN DIRECTO... 2020 ISR School... Facebook Madrigal database... »

**CEDAR Home** Access data ▾ Access metadata ▾ Run models ▾ Documentation Other Madrigal sites ▾ OpenMadrigal

## Welcome to the CEDAR Madrigal Database

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. 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 from any Madrigal site.

To see a list of all Madrigal sites, use the *Other Madrigal sites* pull down menu. Data can also be accessed directly, using [APIs](#) which are available for several popular programming languages (Matlab, python, and IDL). A Subversion archive of all Madrigal software and documentation is available from the [Open Madrigal](#) Web site. The latest version of Madrigal and the remote API's may also be downloaded from there.

The CEDAR Madrigal database architecture and implementation [meets and exceeds FAIR guiding principles](#) in all aspects.

Use of the Madrigal Database is generally subject to the CEDAR Rules-of-the-Road . Prior permission to access the data is not required. However, the user is required to establish early contact with any organization whose data are involved in the project to discuss the intended usage. Data are often subject to limitations which are not immediately evident to new users. Before they are formally submitted, draft copies of all reports and publications must be sent to the contact scientist at all data-supplying organizations along with an offer of co-authorship to scientists who have provided data. This offer may be declined. The Database and the organizations that contributed data must be acknowledged in all reports and publications, and whenever this data is made available through another database. If you have any questions about appropriate use of these data, contact [brideout@haystack.mit.edu](mailto:brideout@haystack.mit.edu)

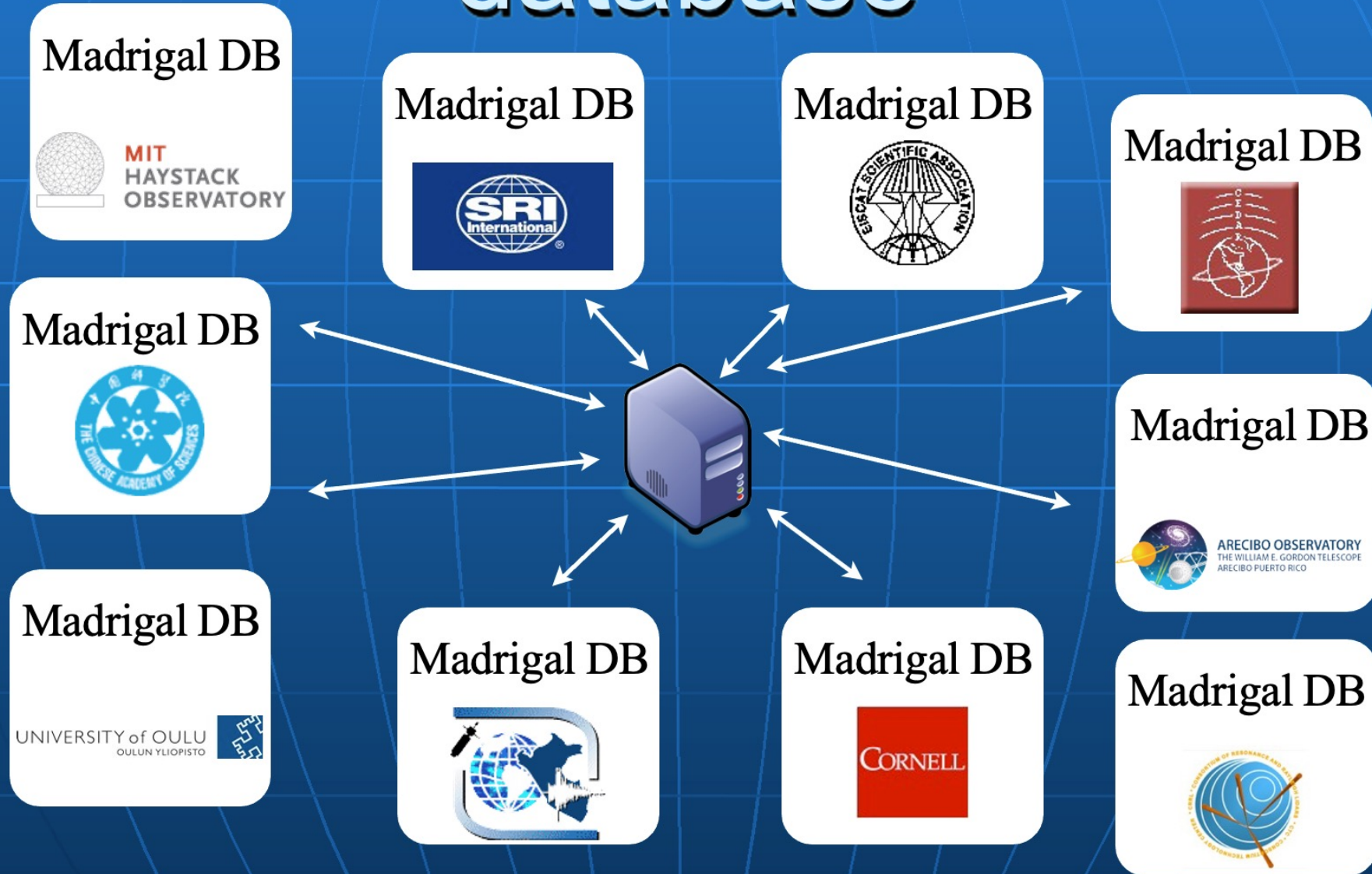
# What is Madrigal?

Distributed, open-source, standards-based local databases that share metadata and have VO-features built in

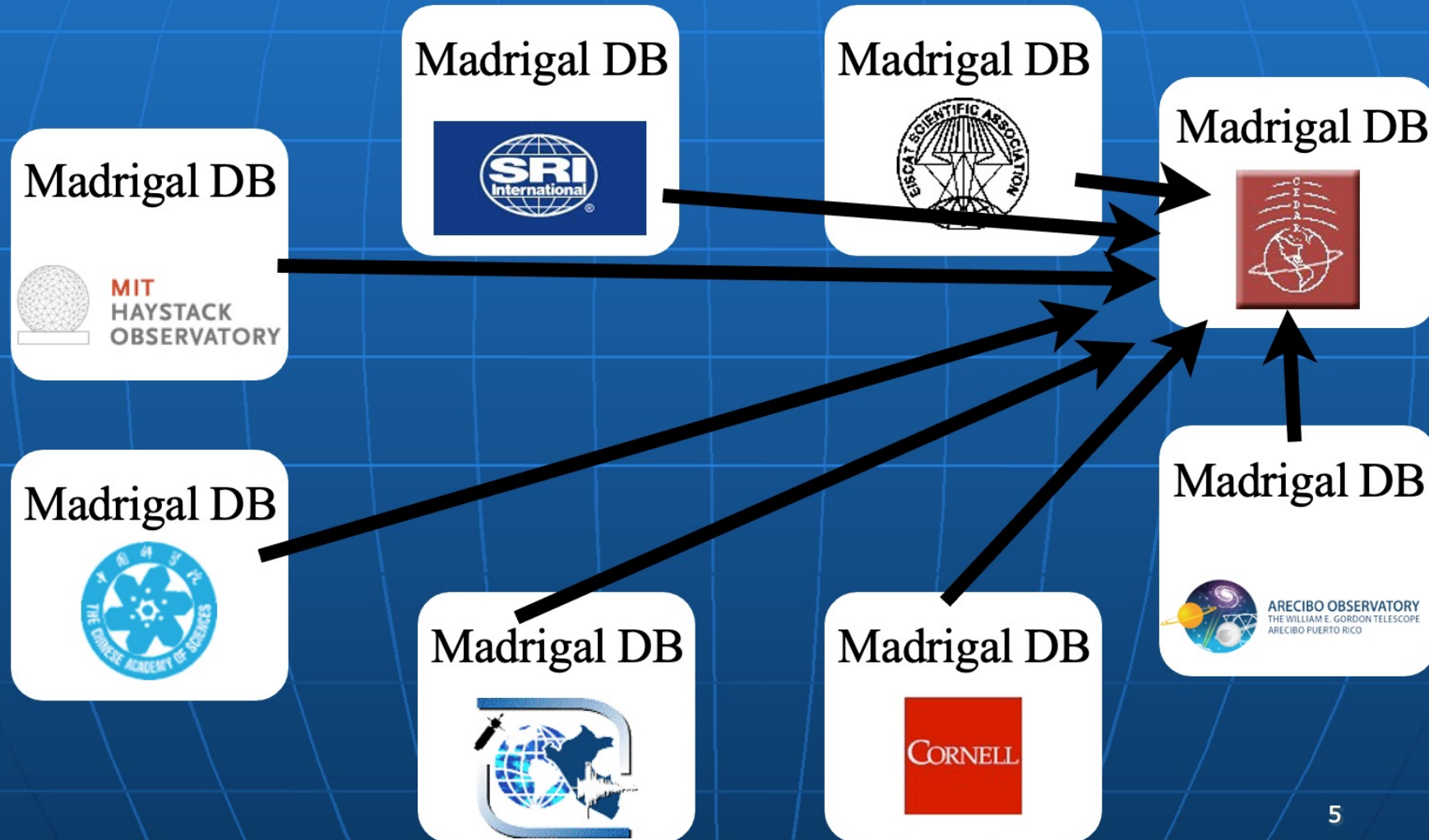




# Madrigal is a distributed database



# Cedar Madrigal archive imports all data weekly





# The Madrigal database stores data from a wide variety of upper atmosphere research instruments

Incoherent Scatter Radar



TEC via GPS



MF Radar



## Number of instruments in Madrigal:

- Incoherent scatter radars: 22
- MST radars: 3
- MF radars: 16
- Meteor radars: 7
- FPI: 23
- Michelson Interferometers: 6
- Lidars: 4
- Photometers: 4



# Madrigal is open-source

Madrigal Database

<http://www.openmadrigal.org/>

Apple Yahoo! Google Maps News (707) WGBH Popular Python Modules Haystack Madrigal CEDAR Millstone Wiki Mailing Lists

## The Open Madrigal Initiative

- [What is Madrigal?](#)
- [Download/update Madrigal](#) - includes Madrigal server and client APIs
- [Documentation](#)
  - [Web access](#)
  - [Script access](#)
- [Empirical Ionospheric Models](#)
- [Subversion Source Control](#)
- [Mailing Lists](#)
- [Administering OpenMadrigal](#)

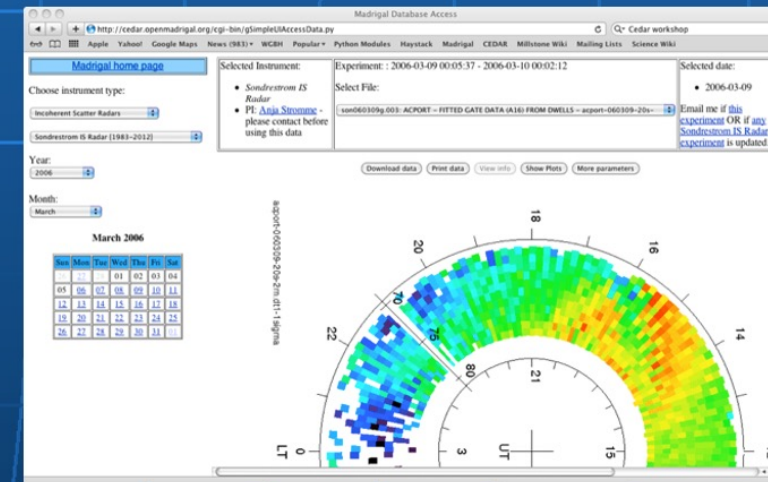
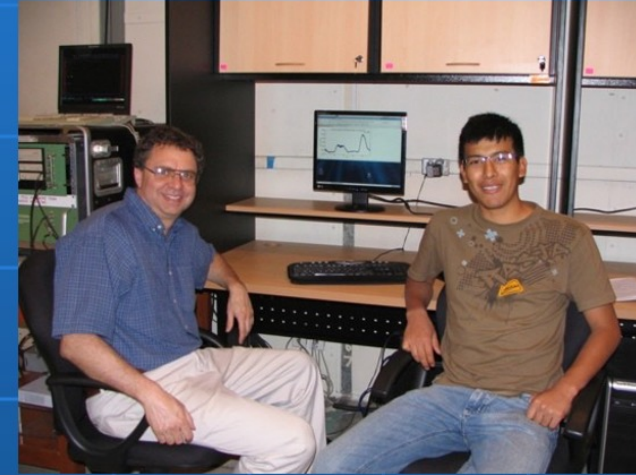
The OpenMadrigal project seeks to develop and support an on-line database for geospace data. The project has been led by [MIT Haystack Observatory](#) since 1980, but now has active support from [Jicamarca Observatory](#) and other community members. Madrigal is a robust, World Wide Web based system capable of managing and serving archival and real-time data, in a variety of formats, from a wide range of ground-based instruments. Madrigal is installed at a number of sites around the world. 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 from any Madrigal site.

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 instruments. Data can be accessed from the Madrigal sites at [Millstone Hill, USA](#), [EISCAT, Norway](#), [SRI International, USA](#), [Arecibo, Puerto Rico](#), [Cornell University, USA](#), [Jicamarca, Peru](#), the [Institute of Geology and Geophysics](#), the Chinese Academy of Sciences, and the [CEDAR Madrigal archive](#) using standard Web browsers; and directly, using APIs which are available for python, Matlab, and IDL.



Suggestions and comments should be directed to [madrigal@haystack](mailto:madrigal@haystack)

**Link to Subversion (source code)**



[www.openmadrigal.org](http://www.openmadrigal.org)

# Cedar file format:

## Cedar file format

- Developed in 1980
- 16 bit integer
  - Dynamic range problems

## Hdf5

- Scientific standard
- Float based
- Flexible arrangement
- Table data, optional grid

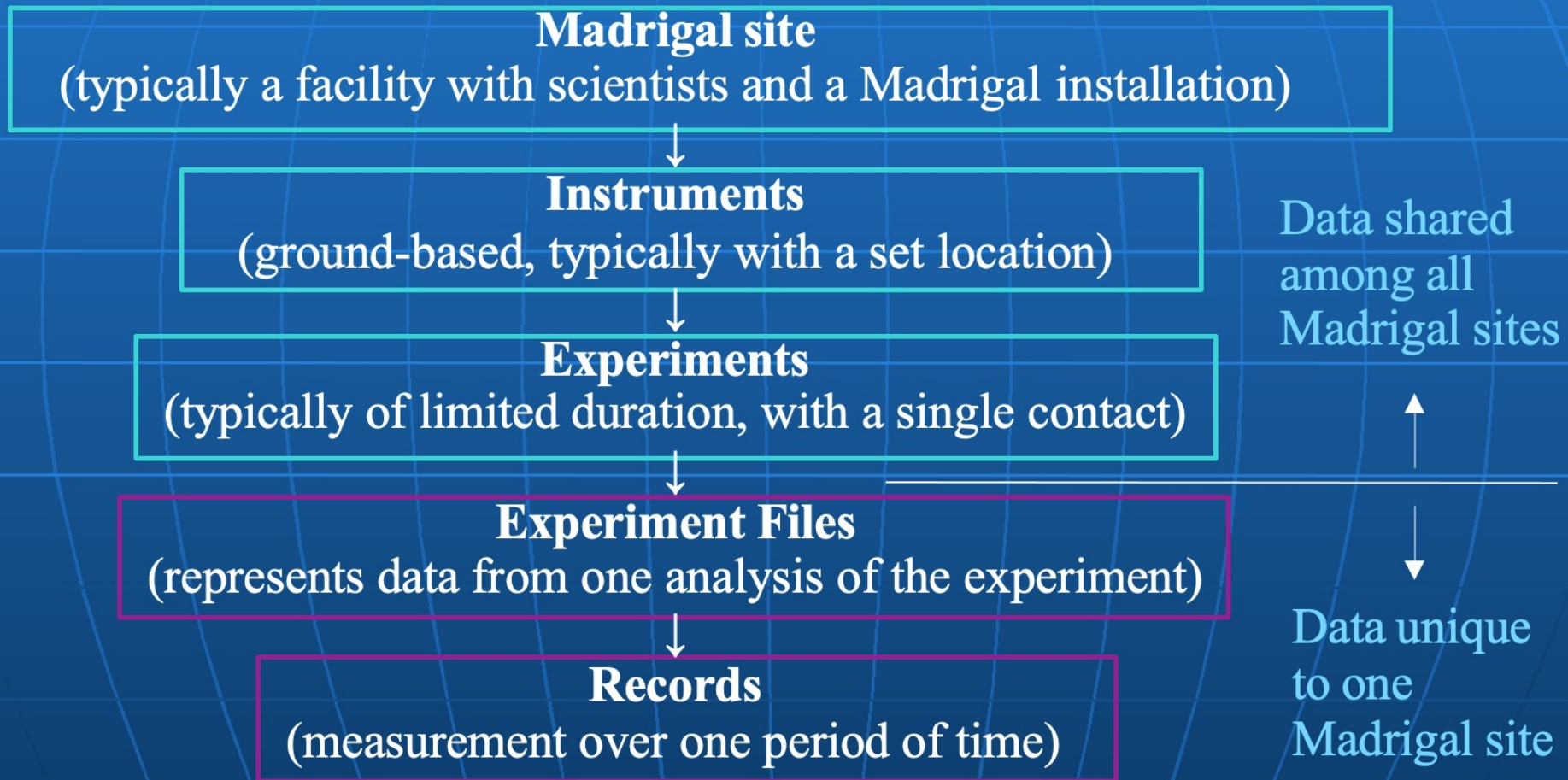
# What is the CEDAR database format?

<b>Madrigal 3.0</b>
Hdf5
Ascii, Hdf5, netCDF4
Cedar file
Ascii, Hdf5, netCDF4



- What do I need to understand about Madrigal to use it?

# Madrigal Data Model



# Madrigal Derivation Engine

- Derived parameters appear to be in file
- Engine determines all parameters that can be derived
- Easy to add new derived parameters using code written in C or Fortran



# Classes of derived parameters

- Space, time
  - Examples: Local time, shadow height
- Geophysical
  - Examples: Kp, Dst, Imf, F10.7
- Magnetic
  - Examples: Bmag, Mag conjugate lat and long, Tsyganenko magnetic equatorial plane intercept
- Models
  - Examples: MSIS, IRI

# Using Madrigal

# How can the Madrigal database be accessed?



User



Web interface

Web services API

- From anywhere on internet
- Python API
- Matlab API
- IDL API
- Others can be written



The python, Matlab, and IDL API's now all have a globalDownload method, which allows you to download any group of Madrigal files with one simple command.

**Download remote python Madrigal API** - This 2.2.1 release includes a new script, globalDownload.py, which allows a user to download any number of Madrigal files in either Hdf5 or ascii format. It also supports the new web services released in Madrigal 2.6. The method getExperiments now has a field realUrl that will give the real experiment url to any experiment.

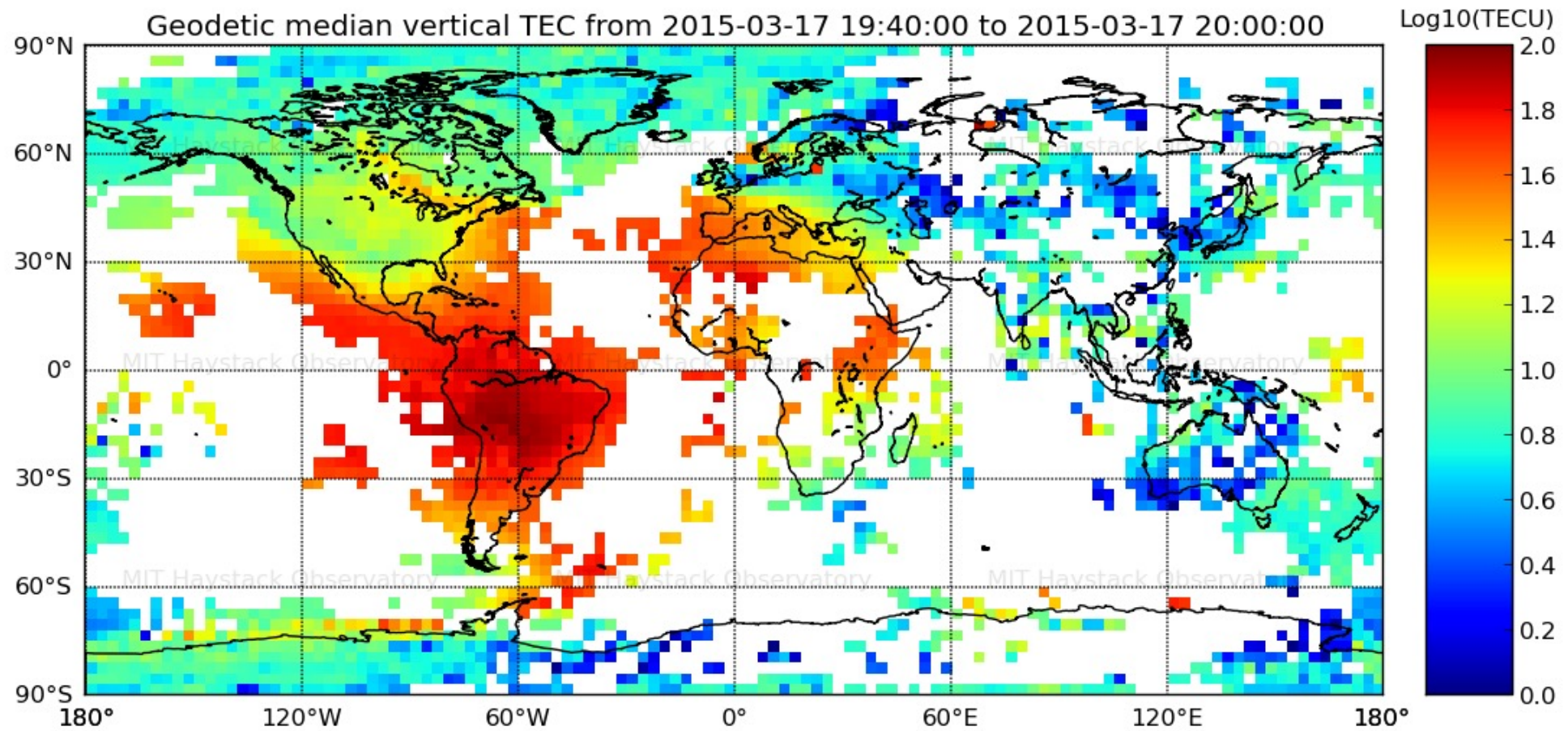
[remotePythonAPI-2.2.1.tar.gz](#) (last updated Jul. 30, 2014)

[remotePythonAPI-2.2.1.zip](#) (last updated Jul. 30, 2014)

Documentation - [Scripts](#), [Tutorial](#), [Reference](#)

# **Standard TEC Data in Madrigal available since 2000**

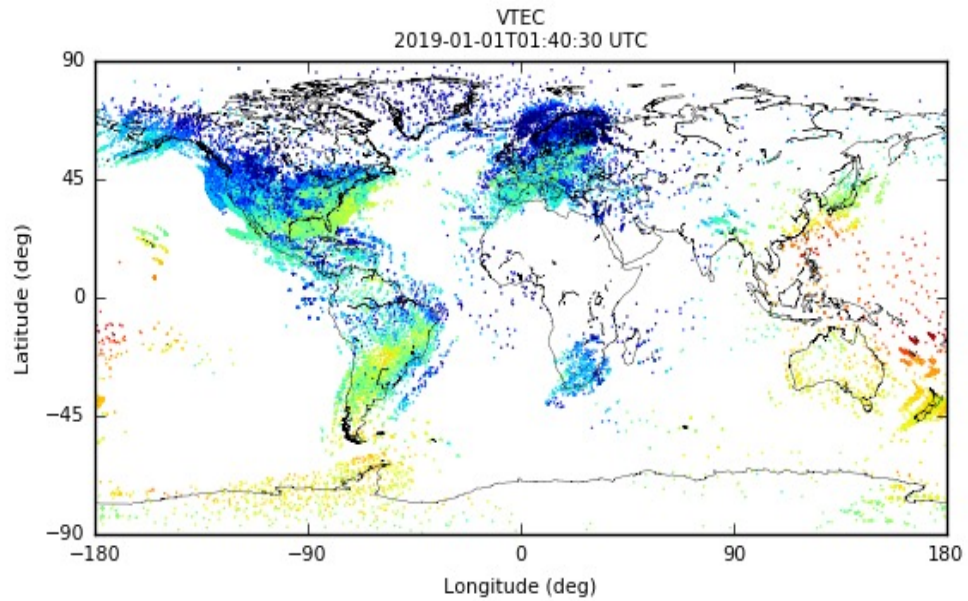
- 1. Provided in 1 degree by 1 degree bins**
- 2. Provided every 5 minutes**
- 3. Vertical TEC data estimates and Errors on these estimates**
- 4. Geographic Lat and Long**
- 5. Only provides data where observations are available. Does not attempt to model TEC where data is not available. Uses all GNSS data available.**
- 6. GLONASS TEC has been added observations**



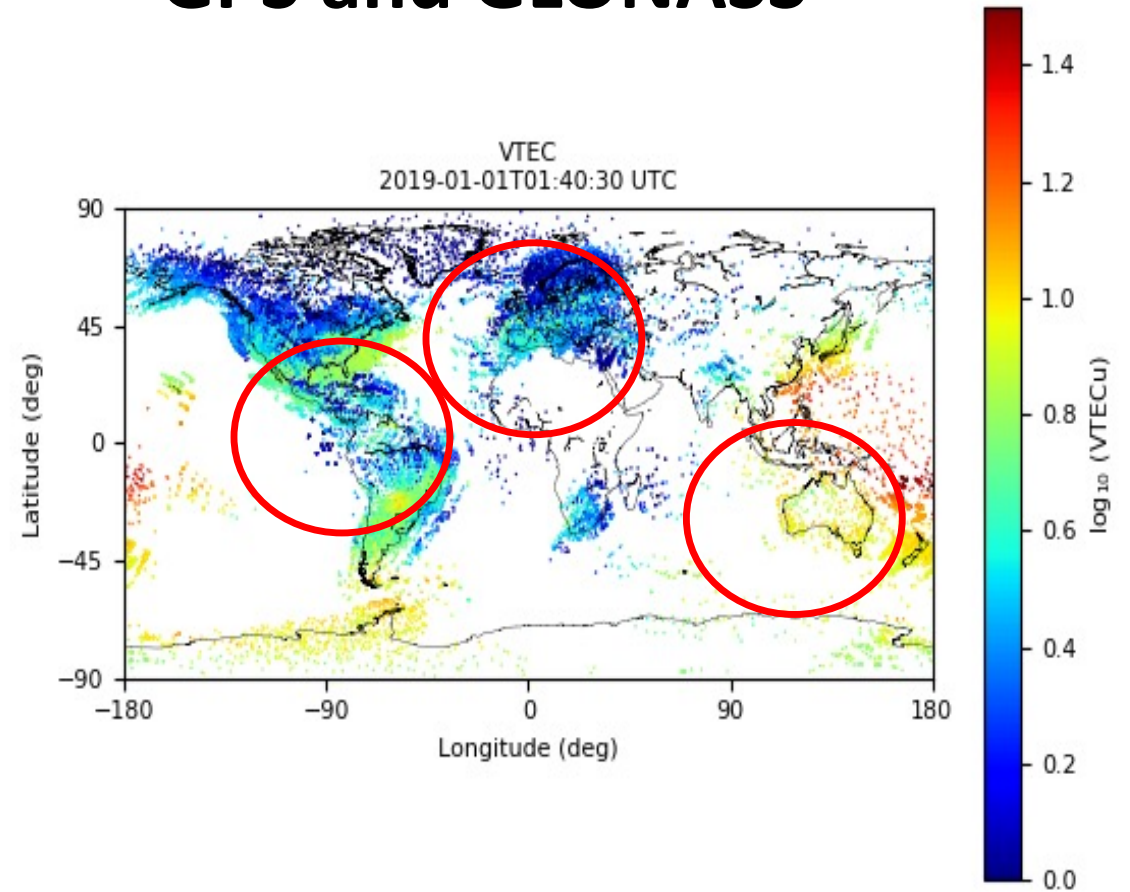
© 2015 MIT Haystack Observatory



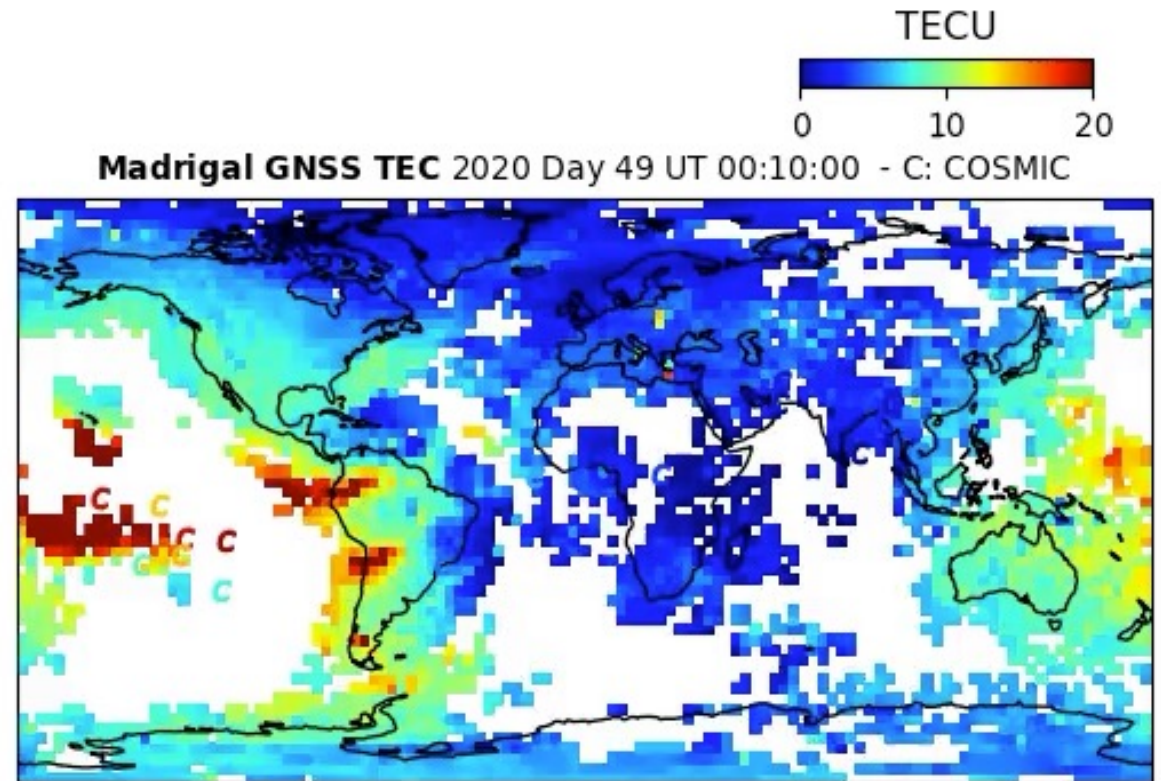
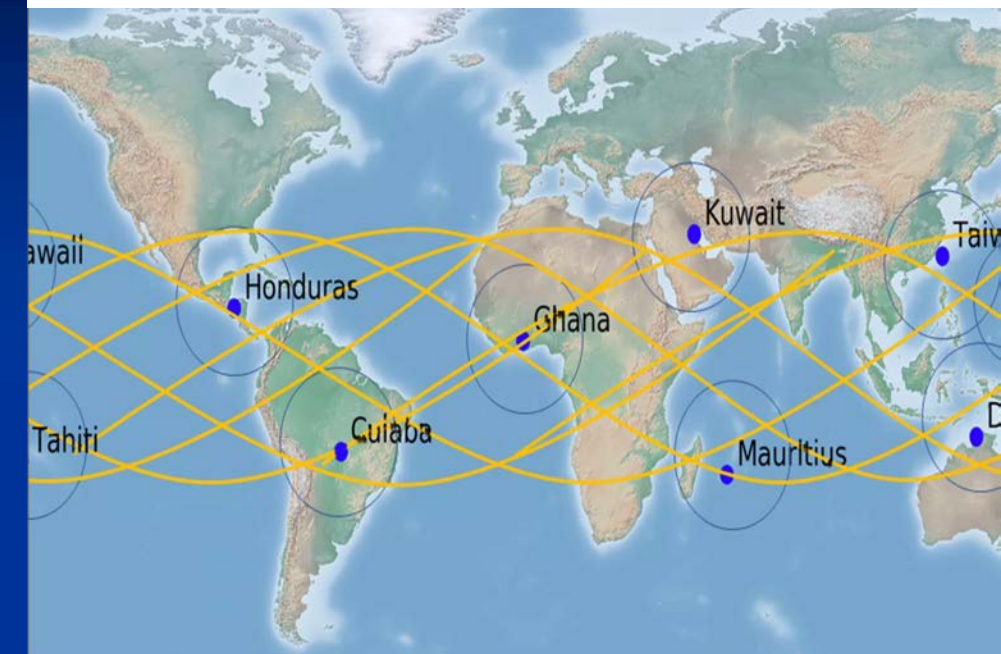
## GPS Only



## GPS and GLONASS



# COSMIC-2



## **Line of Site TEC Data in Madrigal available now for ~ 5 years**

- 1. Provided for every receiver**
- 2. Provided every 20-30 seconds**
- 3. Satellite and Receiver ID**
- 4. Geographic Lat and Long of Receiver**
- 5. Pierce Point: Altitude, Lat and Long**
- 6. Azimuth and Elevation to Satellite**
- 7. Files are LARGE**
- 8. HDF5 format**



