Connecting Amateur Radio and Atmospheric Science: The CEDAR Madrigal Database

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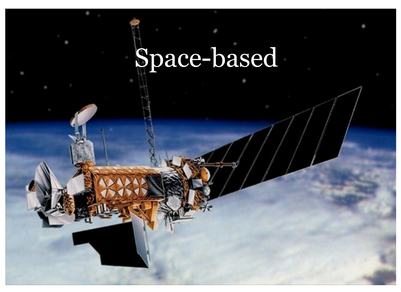
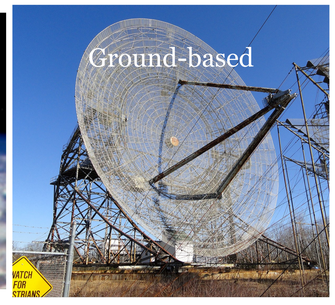
Abstract: The CEDAR Madrigal database is a cornerstone repository for upper atmospheric research, providing open, standardized access to a vast archive of geospace observations. Catering specifically to the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) research community, Madrigal integrates data from a global network of instruments—including incoherent scatter radars, ionosondes, Fabry–Perot interferometers, GNSS receivers, magnetometers, and recently, aggregated PSKReporter, WSPRNet, and RBN data collected and provided by members of the amateur radio community.

For the Ham Radio Science Citizen Investigation (HAMSci) community, the Madrigal database is particularly valuable as a bridge between professional geospace research and citizen science–driven radio propagation studies. Madrigal's curated ionospheric parameters and contextual space weather data enable HAMSci researchers to validate, interpret, and model amateur radio observations such as HF propagation paths, Doppler shifts, and signal variability. The database supports reproducible science, facilitates cross-comparison between citizen and professional datasets, and lowers barriers for collaboration by providing programmatic access and well-documented formats. As HAMSci continues to expand its role in space weather research, the CEDAR Madrigal database serves as an essential resource for integrating amateur radio measurements into the broader heliophysics research ecosystem.

What kinds of data do we have?

Popular data products:
GNSS TEC, DMSP, Ionospheric radars



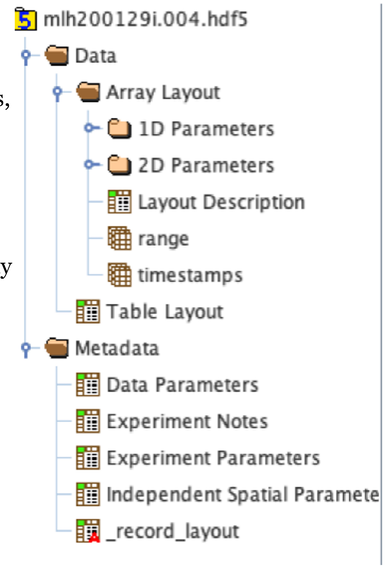


- World-wide Global Navigation Satellite System (GNSS) derived ionospheric Total Electron Content (TEC)
- Incoherent (and coherent) scatter ionospheric radars
- Fabry-Perot Interferometers
- Lidars
- Magnetometers
- Ionosondes
- Meteor radars
- Ionospheric satellite data: Defense Meteorological Satellite Program (DMSP), Jason/Topex
- **Amateur Radio Signal Report - HamSCI data**

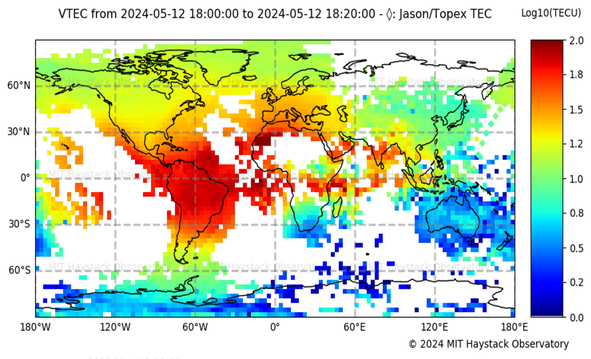
For full listing of instruments in Madrigal, please visit
https://cedar.openmadrigal.org/instMetadata

How is Madrigal data organized?

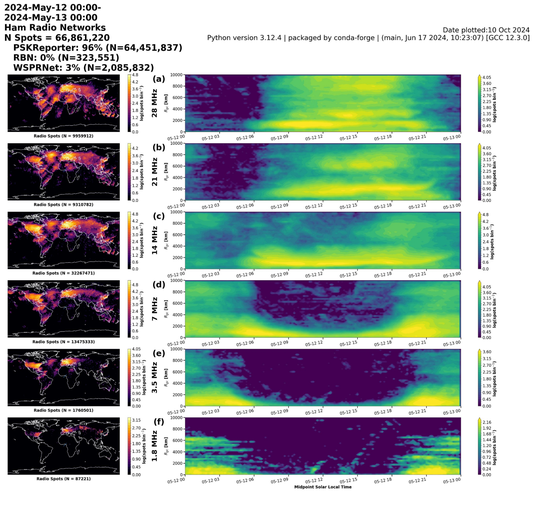
- Self-describing: well-defined parameters with standardized descriptions, units, definitions, notes included
- All parameters have corresponding uncertainty parameters
- Missing and assumed values included
- Download data in HDF5, NetCDF4, and comma delimited ascii



What kinds of science can I do with Madrigal data?



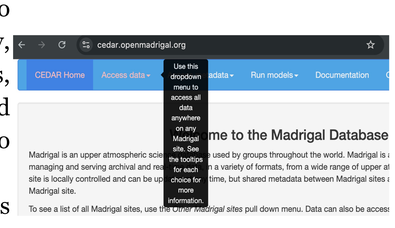
Global maps of total electron content from 6000+ ground receivers are available with resolution of 5-min in time and 1x1 degree in lat/lon, providing information about background electron density that affects propagation of radio waves at HF frequencies. This summary figure depicts a snapshot of global ionospheric conditions during the May 2024 Gannon storm.

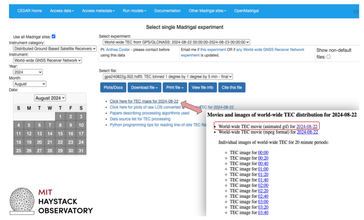


Summary figure of HF radio spots, showing radio wave propagation from 1.8 - 28 MHz over ranges of 0 - 10000 km, obtained from Amateur Radio Signal Report data during the May 2024 Gannon Superstorm.

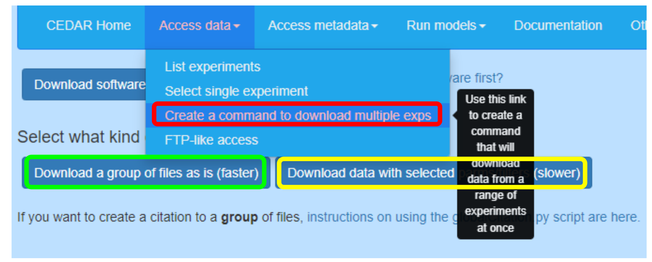
How can I get data from Madrigal?

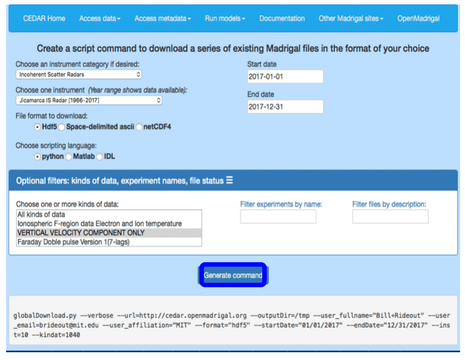
1. Web interface - discover what data is available
https://cedar.openmadrigal.org





2. Python, Matlab, IDL APIs - faster downloads, data flexibility; filter data by desired parameters





First, create a command
Next, download set of files as is or with selected parameters/filters, and go!

Example of Python script accessing HAMSci data in Madrigal

Get started with just a few lines of code!

```
# download a HAMSci Madrigal file
import madrigalWeb.madrigalWeb
madDB = madrigalWeb.madrigalWeb.MadrigalData('https://cedar.openmadrigal.org')
exps = madDB.getExperiments(8308, 2024,5,12,0,0,0,2024,5,13,0,0,0)
files = madDB.getExperimentFiles(exps[0].id)
# Madrigal is not login controlled; logging is done by the user passing
unverified ID
user_fullname = 'Example'
user_email = 'example@gmail.com'
user_affiliation= ‘HAMSci Workshop 2026’
madDB.downloadFile(files[0].name, '/tmp/test.hdf5', user_fullname, user_email,
      user_affiliation, format='hdf5')
# access data from a HAMSci Madrigal file
import h5py
With h5py.File(’/tmp/test.hdf5’, ‘r’) as f:
     path_length = f["Data/Table Layout”][“pthlen”]
```