To obtain both types of data (the gridded gps and los files), go to a madrigal website.

http://cedar.openmadrigal.org

You may have to register your name and institution.

Then - from the main page select : Access Data

A list will appear – hit select single experiment to start.

Access data -	Access metadata - Run mo		dels -	Documentation	Other Madrigal sites -	OpenMadrigal		
l ist experiment	٩							
List experimente								
Select single experiment								
Create a command to download multiple exps				Welcome to the CEDAR Madrigal Databa				
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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 metac 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 seve 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

The CEDAR Madrigal database architecture and implementation meets and exceeds FAIR guiding principles in all aspects.

e 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 re ect to discuss the intended usage. Data are often subject to limitations which are not immediately evident to new users. Before they are formally submitted, a-supplying organizations along with an offer of co-authorship to scientists who have provided data. This offer may be declined. The Database and the organ whenever this data is made available through another database. If you have any questions about appropriate use of these data, contact brideout@haystack

CEDAR H	ome A	ccess data -	Access metadata	a - Run n	nodels -	Docum	enta
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	at 🔽					List	Madr

Choose instrument category(s):

Individual Ground Based Satellite Receivers Distributed Ground Based Satellite Receivers Photometers

Cround Doood Color Doooiyora

Choose instrument(s) (Year range shows data available):

World-wide GNSS Receiver Network [1998-2022]

GNSS Scintillation Network [2017-2022]

SHOW OF ITY

Start date

2022-03-01	00:00:00	
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End date

List experiments

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CEDAR Home	Access data - Access metadata - Run models -	Documentation Other Madrigal sites - OpenMa	drigal		
		List of selected Ma	adrigal experiments		
Madrigal site	Instrument name	Start	End	Experiment name	
CEDAR	World-wide GNSS Receiver Network	2022-02-28 00:00:00	2022-03-01 00:00:00	World-wide TEC from GPS/GLONASS	
CEDAR	World-wide GNSS Receiver Network	2022-03-01 00:00:00	2022-03-02 00:00:00	World-wide TEC from GPS/GLONASS	
CEDAR	World-wide GNSS Receiver Network	2022-03-02 00:00:00	2022-03-03 00:00:00	World-wide TEC from GPS/GLONASS	

PI: Anthea Coster - please contact before using this data

Email me if this experiment OR if any World-wide GNSS Receiver Network experiment is updated.

Show non-default files:

Select file:

✓ Select file

gps220301g.002.hdf5: TEC binned 1 degree by 1 degree by 5 min - final los_20220301.001.h5: Line of sight TEC data - Final site_20220301.001.h5: List of sites used in daily TEC data - Final

Binned TEC 1 deg by 1 deg LOS TEC List of all receiver sites

PI: Anthea Coster - please contact before using this data

Email me if this experiment OR if any World-wide GNSS Receiver Network experiment is updated.

Select file:



Data source list for TEC processing

- Python programming tips for reading line-of-site TEC files
- Papers describing processing algorithms used
- Click here for TEC maps for 2022-03-01
- Create interactive TEC/SuperDARN plots
- Click here for plots of raw LOS converted to vertical TEC for 2022-03-01

VEC from 2022-03-01 05:00:00 to 2022-03-01 05:20:00 - (): Jason/Topex TEC Log10(TECU)



PI: Anthea Coster - please contact before using this data

Email me if this experiment OR if any World-wide GNSS Receiver Network experiment is updated.

Select file:

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	Plots/Docs	Download file -	Print file -	View file info	Cite this file

aps220301a 002 hdf5: TEC binned 1 degree by 1 degree by 5 min - final \sim

- Data source list for TEC processing
- Python programming tips for reading line-of-site TEC files
- Papers describing processing algorithms used
- Click here for TEC maps for 2022-03-01
- Create interactive TEC/SuperDARN plots
- Click here for plots of raw LOS converted to vertical TEC for 2022-03-01 —



Pl: Anthea Coster - please contact before using this data

Email me if this experiment OR if any World-wide GNSS Receiver Network experiment is updated.

elect file:

site_20220301.	~			
Plots/Docs	Download file -	Print File	View file info	Cite this file

YEAR	MONTH	DAY	HOUR	MIN	SEC	RECNO	KINDAT	KINST UT1_UNIX	UT2_UNIX	GPS_SITE	GDLATR	GDLONR
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0194'	3.91856e+01	1.39548e+02
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'019b'	3.91856e+01	1.39548e+02
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0bis'	5.77250e+01	1.18919e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0bru'	5.77300e+01	1.19721e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0frl'	5.76502e+01	1.19122e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0hdg'	5.92217e+01	1.79341e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0hna'	6.05349e+01	1.78800e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0kro'	5.76802e+01	1.19845e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0kth'	5.93499e+01	1.80694e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0lio'	5.93657e+01	1.81269e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0lod'	5.57669e+01	1.29957e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0mos'	5.93184e+01	1.80742e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0nyb'	6.57959e+01	2.31700e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0nyk'	5.87700e+01	1.69776e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0okc'	5.72519e+01	1.64654e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0oxe'	5.86710e+01	1.71070e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0skl'	5.54749e+01	1.42794e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0skn'	5.54138e+01	1.28579e+01
2022	3	1	11	59	59	0	3506	8000 1646092800.000	1646179199.000	b'0str'	5.89366e+01	1.11813e+01
2022	2	1	11	50	50	0	3506	8000 1646092800 000	16/6170100 000	h'0+vr'	5 922190+01	1 820560+01

VEC from 2022-03-01 00:00:00 to 2022-03-01 00:20:00 - (): Jason/Topex TEC Log10(TECU)



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

How to find all Kp's > 4 in 2021

From Access Data – select geophysical indices

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

	List Madrigal experiments
Use all Madrigal sites: 🗹	Show only defau
Choose instrument category(s):	Start date
All instrument categories	2021-01-01
Geophysical Indices	End date
HF Radars	2021-12-31
Choose instrument(s) (Year range shows data available): Interplanetary Mag Field and Solar Wind [1963-2022]	
Geophysical Indicies [1950-2022]	
AE Index [1978-1988]	
DST Index [1957-2022]	

 Show only default files: ✓

 Start date

 2021-01-01
 00:00:00

 End date

 2021-12-31
 23:59:59

List experiments

CEDAR Home	Access data -	Access metadata -	Run models -	Documentation	Other Madrigal sites +	OpenMadrigal				
	List of selected Madrigal experiments									
Madrigal site	Instr	ument name		Start		End	Experiment name			
CEDAR	Geop	physical Indicies		1950-01-01 00:0	0:00	2022-05-08 23:59:59	Kp; Ap; 10.7 cm flux; sunspot number etc			





List records in file

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

Print Madrigal file with selected parameters/filters

Print file

Experiment: Kp; Ap; 10.7 cm flux; sunspot number etc File: geo500101g.002.hdf5 Type of data: Geophysical Indicies

Format output Ξ
Show headers: All Missing value string: NaN
Select Parameters to include =
Select Filters to use (optional) =

Print Madrigal file with selected parameters/filters

Experiment: Kp; Ap; 10.7 cm flux; sunspot number etc File: geo500101g.002.hdf5 Type of data: Geophysical Indicies

Format output \equiv

Select Parameters to include ≡

Blue parameters are from the original file Grey parameters are derivable from those in the original file										
Madrigal Hdf5 Prolog Parameters										
Time Related Parameter										
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Geographic Coordinate										
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e tec_2015_3_17.mp4	Show									
CEDAR World-wide GNSS Receiver Network 2022-03-21 00:00:00	20									

Select Parameters to include

Select all parms in original file Unselect all parms in original file							
Blue parameters are from the original file Grey parameters are derivable from those in the original file							
Madrigal Hdf5 Prolog Parameters							
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			RECNO				
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Interplanetary Magnetic Field							
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	BZGSE	SWDEN	SWSPD	swq			

Select Filters to use (optional) =							
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Optional filters using any parameter mnemonic on this page	Lower limit (leave	blank if no lower limit)	Upper limit (leave blank if no upper limit)				
YEAR ~	2021		2022				
KP ~	4						
None ~							



If you want to create a citation to a **group** of files, instructions on using the globalCitation.py script are here.

CEDAR Home	Access data -	Access metadata -	Run models -	Documentation	Other Madrigal sites -	OpenMadrigal		
Create a script command to download Madrigal data with selected parameters and filters								
Choose an instrume Geophysical Indice Choose one instrum	ent category if desir s nent <i>(Year range sh</i>	red: v nows data available):			Start date 1950-01-01			
Geophysical Indicies [1950-2022] 2022-12-31 File format to download: • Hdf5 • Space-delimited ascii • netCDF4								
If ascii, download result to: If ascii, download result to:								
Choose scripting language:								
Select parameters (required) =								
Optional filters: kinds of data, filter by parm, experiment names, etc ≡								
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Geographic Coordinate							
GDLAT	GLON						
Geophysical Index							
КР	DST			F10.7	FBAR		

If ascii, download result to: Directory File Choose scripting language: python Matlab IDL						
Select parameters (required) \equiv						
Optional filters: kinds of data, filter by parm, experiment names, etc ≡						
Choose one or more kinds of data: All kinds of data Geophysical Indicies	one or more kinds of data: Filter experiments by name: Filter files by description: of data sical Indicies Indicies					
Select data from only a part of the year by changing the values below:						
Optional seasonal start day/month: 1 1 0 0ptional seasonal end day/month: 31 12						
Add optional filters based on parameter values below:						
Optional filters using any parameter mnemonic for this instrument	Lower limit (leave blank if no lower limit)	Upper limit (leave blank if no upper limit)				
YEAR ~	2021	2022				
KP ~	4					
None ~						

Generate command

globalIsprint.py --verbose --url=http://cedar.openmadrigal.org -parms=YEAR,DAY,KP --output=example.txt -user_fullname="Anthea+J+Coster" --user_email=ajc@haystack.mit.edu -user_affiliation="MIT" --startDate="01/01/1950" --endDate="12/31/2022" -inst=210 --filter=YEAR,2021,2022 --filter=KP,4, --kindat=30007 To end on a new science result – data from the Tonga eruption

2022 Tonga volcanic eruption induced TID global propagation



This looping video shows a series of GOES-17 satellite images that caught an umbrella cloud generated by the underwater eruption of the Hunga Tonga-Hunga Ha'apai volcano on Jan. 15, 2022.

Crescent-shaped bow shock waves and numerous lighting strikes are also visible.

Credit: NASA Earth Observatory image by Joshua Stevens using GOES imagery courtesy of NOAA and NESDIS words from <u>https://www.jpl.nasa.gov/news/tonga-eruption-sent-ripples-through-earths-ionosphere</u>)

New Zealand (Animation)

Initial waves had huge amplitudes and wavelengths (~ 2K km!)

Subsequent waves had 300-500 km wavelengths









Beidou and GPS data coverage for Tonga eruption study $^{\times}$





MIT D HAYSTACK OBSERVATORY

Distance-Time plot to show eruption induced global TID propagation

https://www.frontiersin.org/articles/10.3389/fspas.2022.871275/full

Global View: N-S Propagation

- Evident TID
 occurrence was based
 on the distance from
 the epic center;
- TIDs reached 20K km distance 17 hrs after the eruption;
- Shock fronts travled at ~ 350 m/s
- Regional disturbances
 lasted for 8-10 hrs



Universal Time (hr)



BEIDOU has 5 GEOSTATIONARY satellites and 4 MEO satellites. The GEO satellites allow for accurate TEC data because of stationary ionospheric pierce point with fixed azimuth and elevation





Madrigal Data Base

How to get TEC data from Madrigal
How to access and filter Kp data

The Tonga data shows you how science has been enabled

 Learn more about Madrigal – API's, what is there
 http://cedar.openmadrigal.org/docs/name/madCont ents.html