



Simplifying access to CEDAR data with HAPI – an intro, tutorial, and status

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Focus of this talk is: Interoperability

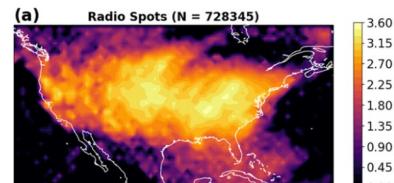
- **motivation** – approaching urgent
- **introducing HAPI**: a common access mechanism for time series data
- **example**: using HAPI to access SuperMAG and INTERMAGNET and CDAWeb
- **CEDAR data available** via HAPI (or soon to be available)



Geospace Analysis Increasingly Requires Data from Many Diverse Sources

Example: Traveling Ionospheric Disturbances

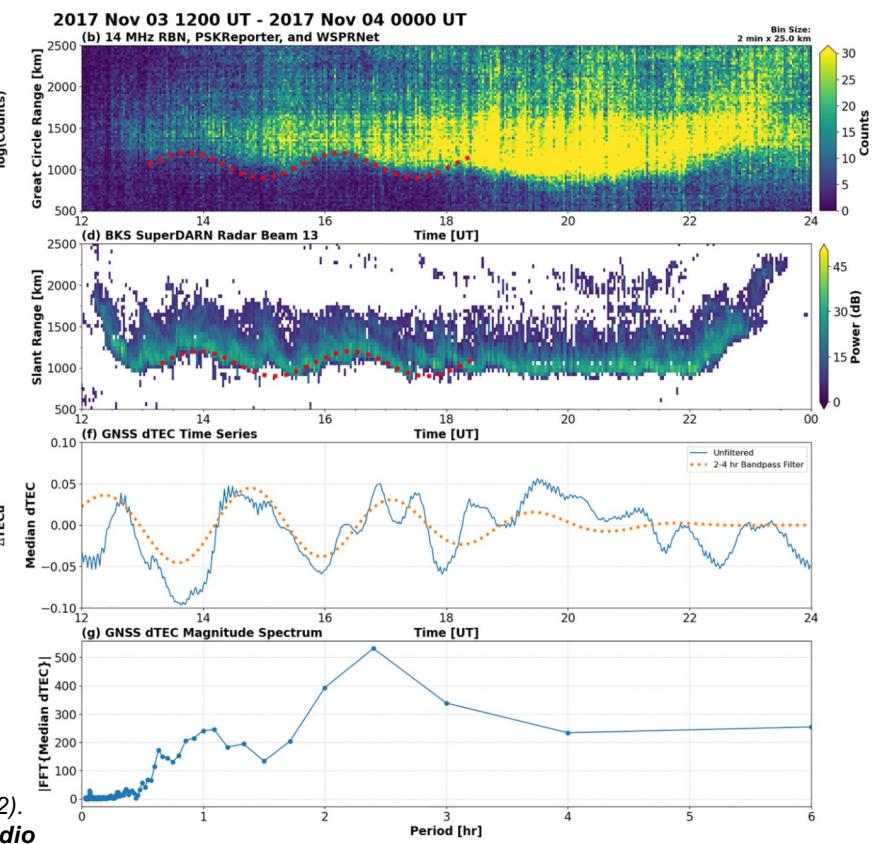
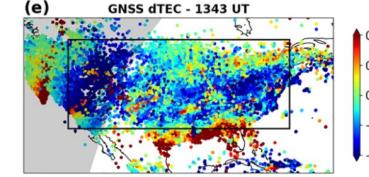
ham radio data (HF contact midpoints)



radar backscatter data



GNSS Total Electron Content (TEC)



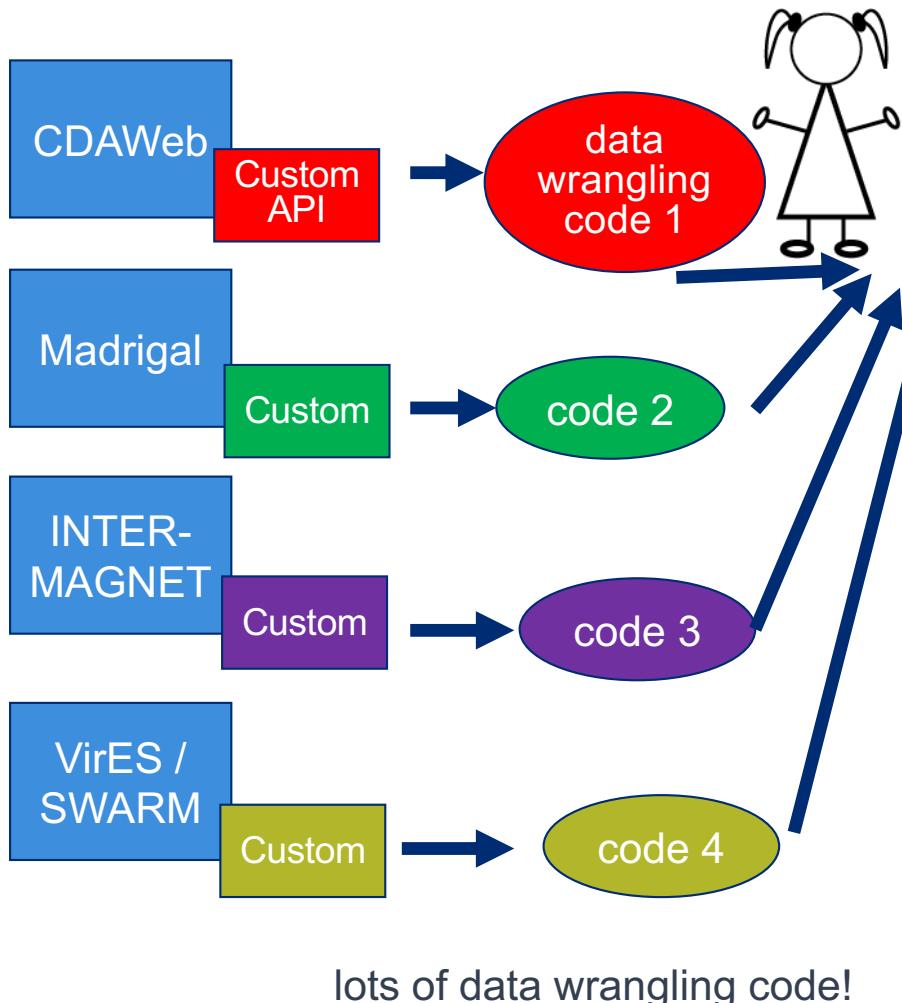
Frissell, N. A., Kaepller, S. R., Sanchez, D. F., Perry, G. W., Engelke, W. D., Erickson, P. J., et al. (2022). *First observations of large scale traveling ionospheric disturbances using automated amateur radio receiving networks.*

Geophysical Research Letters, 49, e2022GL097879. <https://doi.org/10.1029/2022GL097879>



HAPI, Vandegriff et al

CEDAR June 9-14, 2024



The screenshot shows two web pages side-by-side. The left page is the **GODDARD SPACE FLIGHT CENTER Space Physics Data Facility**, featuring a NASA logo, a menu bar with links like '+ SPDF HOME', '+ MISSION DATA', '+ ModelWeb at CCMC', '+ SCIENCE ENABLED', and '+ AND MORE', and a section titled 'Accessing CDAWeb Data From IDL' with a sub-section 'Download Python, Matlab, or IDL APIs to remotely access M...'. The right page is the **INTERMAGNET - British Geological Survey** website, with a prominent 'VirES' logo and a section titled 'Space Weather Data Portal' featuring a visualization of space weather data.



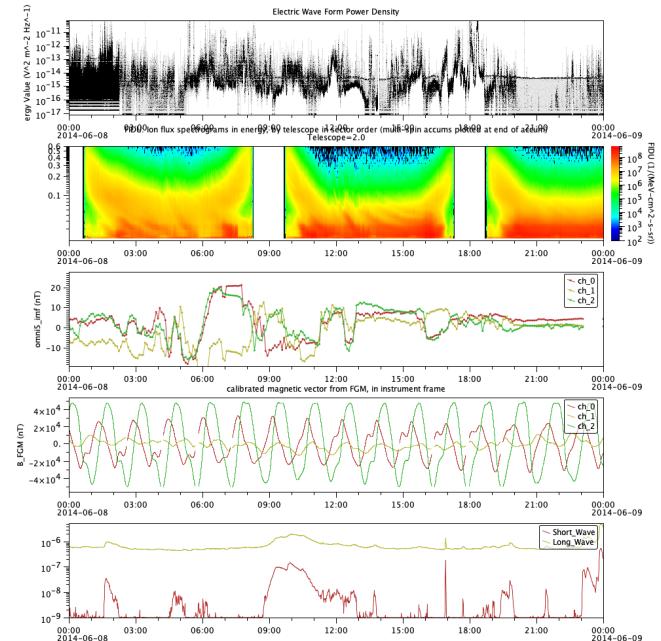
Heliophysics Application Programmer's Interface (HAPI): a common access mechanism for time series data

Time series dataset: tabular data that is indexed by time

Time	data1	scalar2	array	multiDimArray	URI string
t0	d0	s0	a0[11]	m0[3,8]	http://data.org/image0.fits
t1	d1	s1	a1[11]	m1[3,8]	http://data.org/image1.fits
t1	d2	s2	a2[11]	m2[3,8]	http://data.org/image2.fits
t2	d3	s3	a3[11]	m3[3,8]	http://data.org/image3.fits
t4	d4	s4	a4[11]	m4[3,8]	http://data.org/image4.fits
t5	d5	s5	a5[11]	m5[3,8]	http://data.org/image5.fits
t6	d6	s6	a6[11]	m6[3,8]	http://data.org/image6.fits

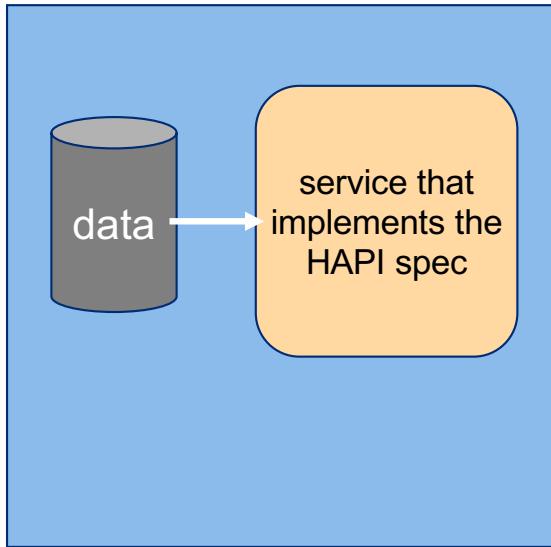
Conceptually, this table may go on for years, or even decades.
Data may be stored in chunks (daily or yearly files), or in a database.

Users should not need to care about how this data is stored!!!

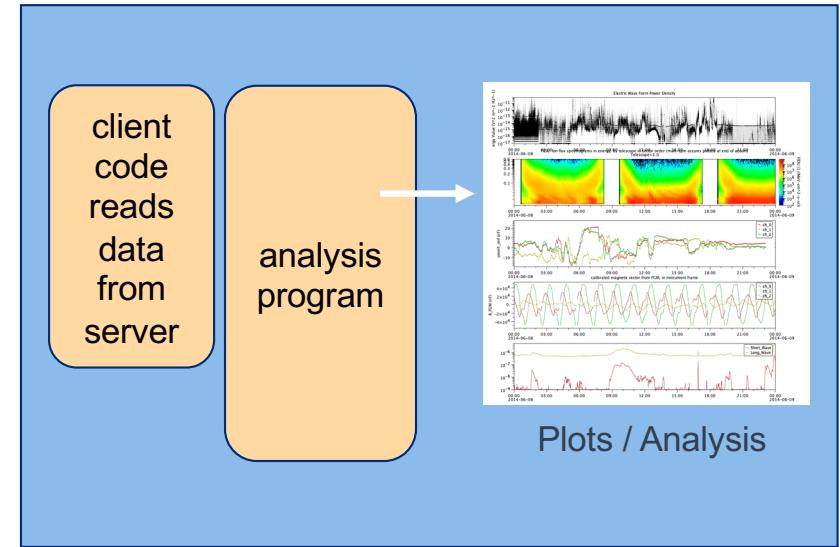


HAPI is a specification

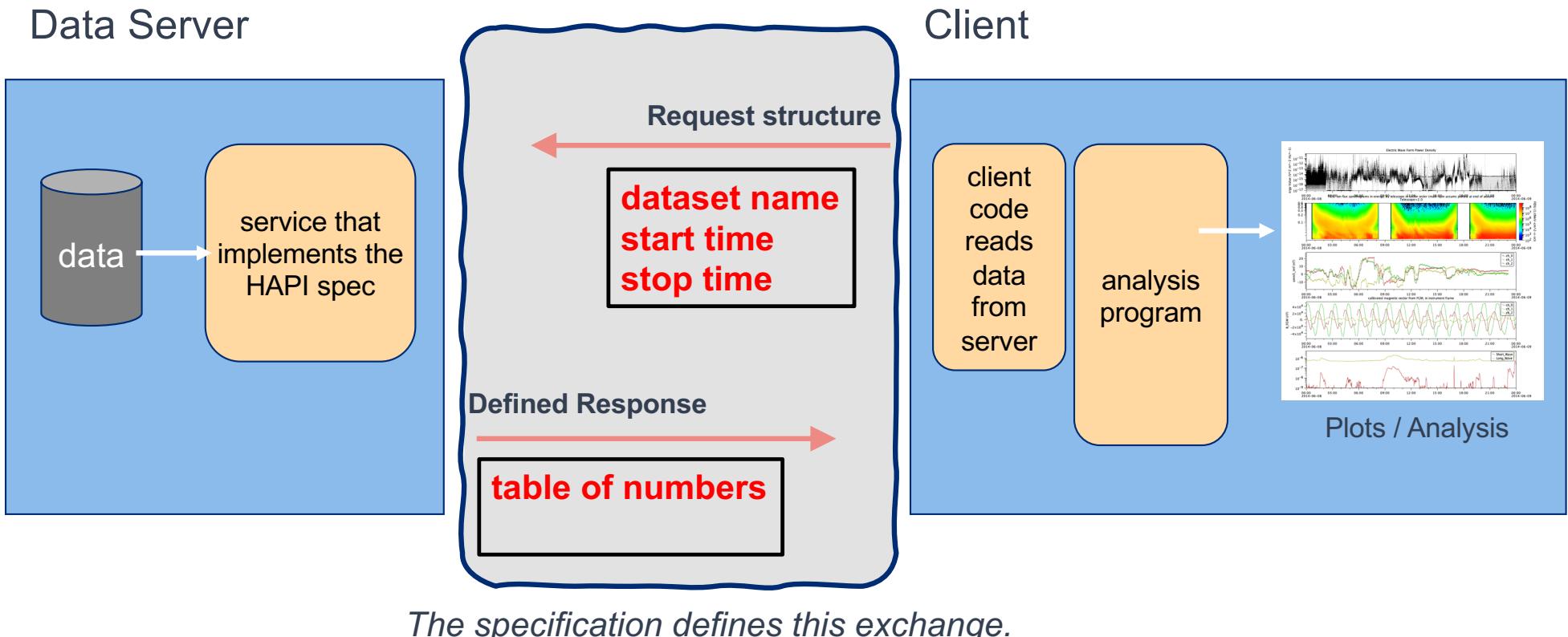
Data Server



Client



HAPI is a specification



HAPI Spec Details

Request:

```
http://server.org/hapi/data?dataset=ACE_MAG  
&start=2004-183T00:00Z  
&stop=2004-184T00:00Z
```

*(line breaks
for clarity)*

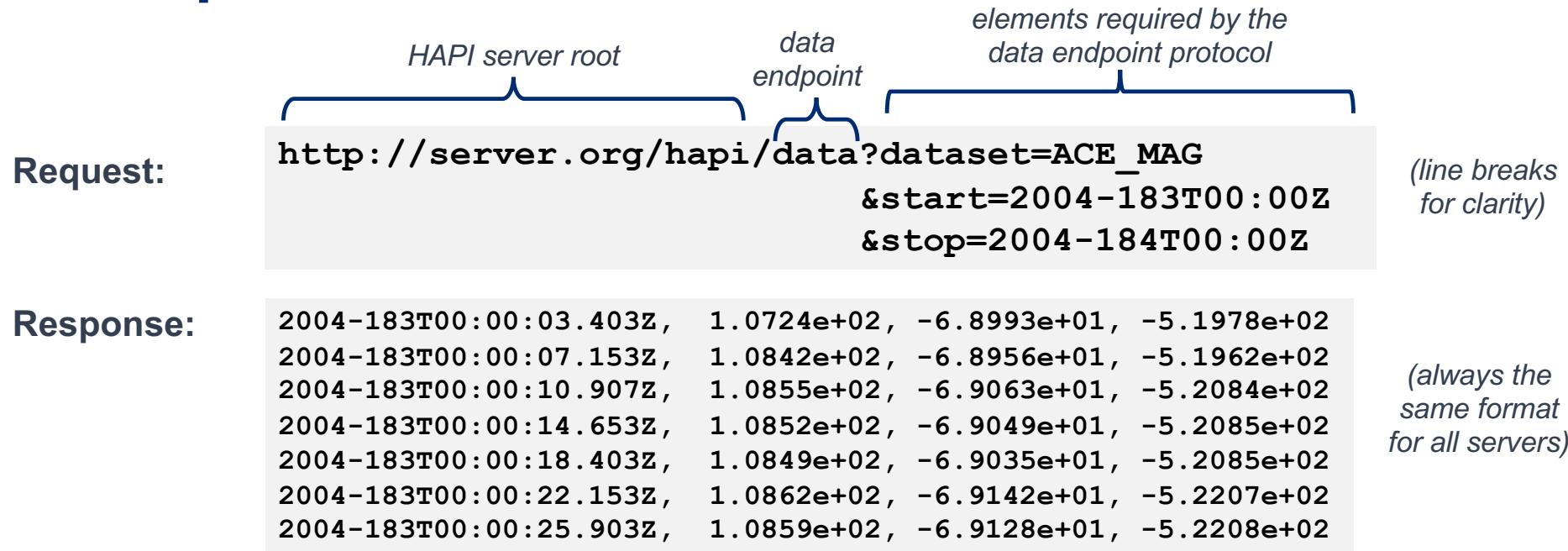
Response:

```
2004-183T00:00:03.403Z, 1.0724e+02, -6.8993e+01, -5.1978e+02  
2004-183T00:00:07.153Z, 1.0842e+02, -6.8956e+01, -5.1962e+02  
2004-183T00:00:10.907Z, 1.0855e+02, -6.9063e+01, -5.2084e+02  
2004-183T00:00:14.653Z, 1.0852e+02, -6.9049e+01, -5.2085e+02  
2004-183T00:00:18.403Z, 1.0849e+02, -6.9035e+01, -5.2085e+02  
2004-183T00:00:22.153Z, 1.0862e+02, -6.9142e+01, -5.2207e+02  
2004-183T00:00:25.903Z, 1.0859e+02, -6.9128e+01, -5.2208e+02
```

*(always the
same format
for all servers)*



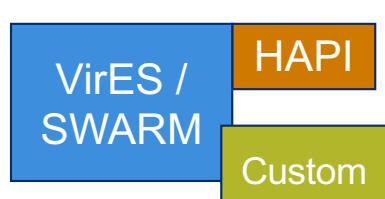
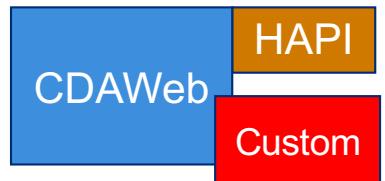
HAPI Spec Details



- Think of HAPI as “**http for data**” – a protocol for asking and getting something from a server
- RESTful – no state so that each request is independent
- URLs representing the requests can be thought of as (semi-)persistent identifiers
- Endpoints define the things you can ask of a HAPI server



<https://hapi-server.org>



Servers add HAPI so that they all have a common access pathway.

Content from each of these services can be accessed with the same code.

Single API offers benefits:

- simple discovery (which datasets do you have?)
- standardized access (fill my array)
- foundation for more advanced apps (data fusion, data cleaning, common visualization)

Each of these data centers has their own custom access mechanism, and they have also added a HAPI interface.



HAPI Example: SuperMAG and INTERMAGNET and CDAWeb

```
from hapiclient import hapi
from hapiplot import hapiplot

server      = 'http://ec2-54-92-164-109.compute-1.amazonaws.com:8000/hapi'
dataset     = "data_CKI"
start       = '2024-05-10T00:00:00Z' # Start and stop times
stop        = '2024-05-13T00:00:00Z'
parameters  = 'N'

data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)
```



HAPI Example: SuperMAG and INTERMAGNET and CDAWeb

```
from hapiclient import hapi
from hapiplot import hapiplot

server      = 'http://ec2-54-92-164-109.compute-1.amazonaws.com:8000/hapi'
dataset     = "data_CKI"
start       = '2024-05-10T00:00:00Z' # Start and stop times
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parameters  = 'N'

data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)
```

SuperMAG



HAPI Example: SuperMAG and INTERMAGNET

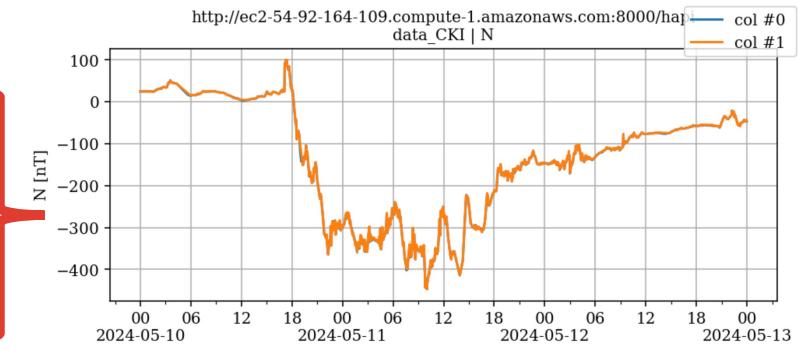
```
from hapiclient import hapi
from hapiplot import hapiplot

server      = 'http://ec2-54-92-164-109.compute-1.amazonaws.com:8000/hapi'
dataset     = "data_CKI"
start       = '2024-05-10T00:00:00Z' # Start and stop times
stop        = '2024-05-13T00:00:00Z'
parameters  = 'N'

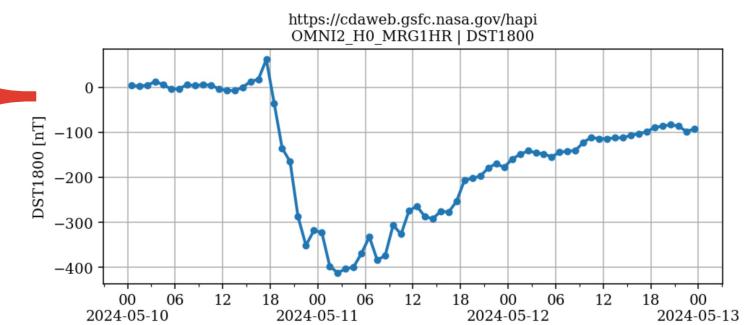
data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)

server      = 'https://cdaweb.gsfc.nasa.gov/hapi'
dataset     = 'OMNI2_H0_MRGR1HR'
parameters  = 'DST1800'
data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)
```

SuperMAG



CDAWeb



HAPI Example: SuperMAG and INTERMAGNET and CDAWeb

```
from hapiclient import hapi
from hapiplot import hapiplot

server      = 'http://ec2-54-92-164-109.compute-1.amazonaws.com:8000/hapi'
dataset     = "data_CKI"
start       = '2024-05-10T00:00:00Z' # Start and stop times
stop        = '2024-05-13T00:00:00Z'
parameters  = 'N'

data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)

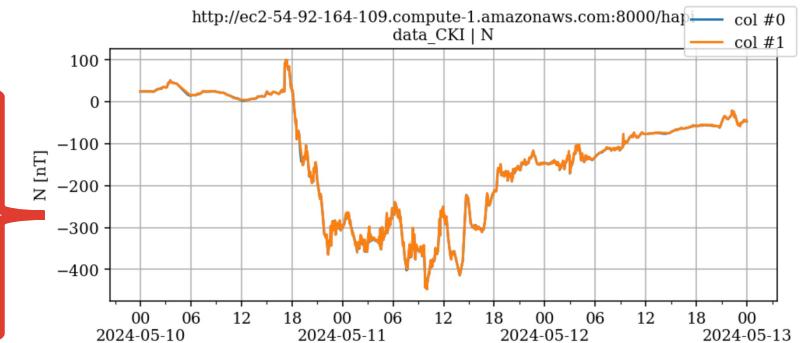
server      = 'https://cdaweb.gsfc.nasa.gov/hapi'
dataset     = 'OMNI2_H0_MRG1HR'
parameters  = 'DST1800'
data, meta = hapi(server, dataset, parameters, start, stop)
hapiplot(data,meta)

from hapiclient import hapitime2datetime
import matplotlib.pyplot as plt

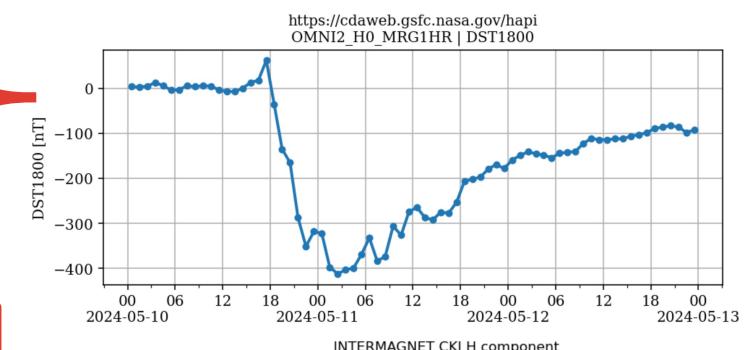
server      = "https://imag-data.bgs.ac.uk/GIN_V1/hapi"
dataset     = "ck/best-avail/PT1M/hdzf"
parameters  = "Field_Vector"
data, meta = hapi(server, dataset, parameters, start, stop)

# Extract time and one element of array to plot manually:
dateTimes = hapitime2datetime(data['Time'])
d = data['Field_Vector'][:,0]
fig, ax = plt.subplots()
ax.plot(dateTimes, d)
plt.show()
```

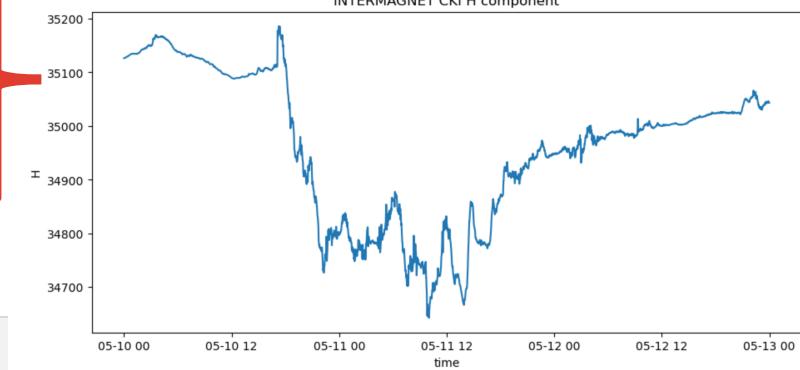
SuperMAG



CDAWeb



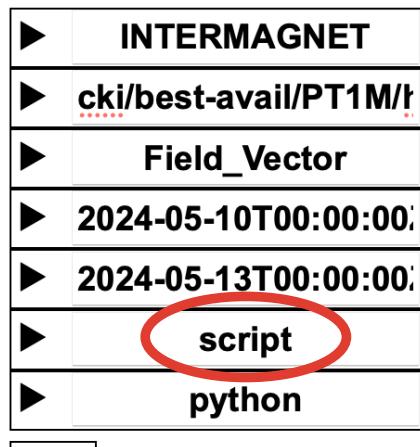
INTERMAGNET



HAPI Data Explorer Web Site (demo)

<https://hapi-server.org/servers/>

Select the server and datasets from dropdown menus:



Or you can ask for Python code needed to grab the data:

This site allows you to explore what data is available from all known HAPI servers.



```
Python 2.7 and 3 compatible
# Report software bugs/issues/feature requests at
# https://github.com/hapi-server/client-python/issues
# Report data server issues to e_ginman@bgs.ac.uk

# Install latest hapiclient package from https://pypi.org/project/hapiclient/
# Only needs to be executed once.
import os; print(os.popen('pip install hapiclient --upgrade').read())

from hapiclient import hapi

server      = 'https://imag-data.bgs.ac.uk/GIN_V1/hapi'
dataset     = 'cki/best-avail/PT1M/hdzf'
# Notes:
# 1. Use parameters=''' to request all parameters from cki/best-avail/PT1M/hdzf.
# 2. Multiple parameters can be requested using a comma-separated
#    list, e.g., parameters='Field_Vector,Field_Magnitude'
parameters = 'Field_Vector'
start       = '2024-05-10T00:00:00Z' # min 2013-10-25T11:41:00Z
stop        = '2024-05-13T00:00:00Z' # max 2024-06-12T23:59:00Z

data, meta = hapi(server, dataset, parameters, start, stop)
```

HAPI Data Explorer Web Site

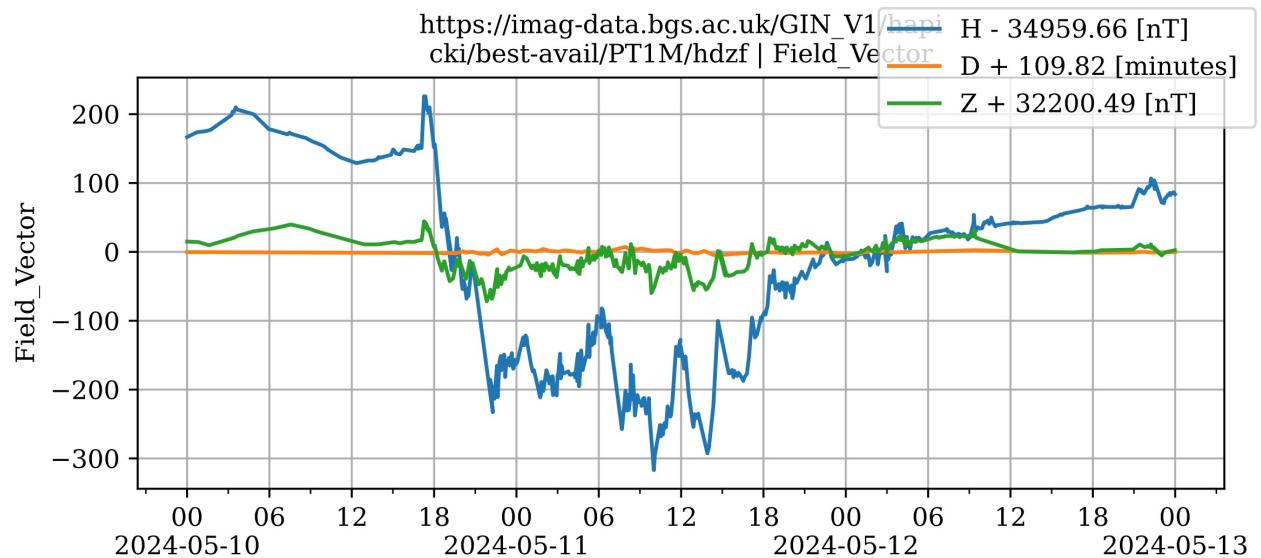
<https://hapi-server.org/servers/>

Select the server and datasets from dropdown menus:

- ▶ INTERMAGNET
- ▶ cki/best-avail/PT1M/t
- ▶ Field_Vector
- ▶ 2024-05-10T00:00:00
- ▶ 2024-05-13T00:00:00
- ▶ **image**
- ▶ hapiplot
- ▶ svg



This site allows you to explore what data is available from all known HAPI servers.



You can ask for a quick data plot.



Heliophysics / Geoscience is seeing HAPI added to many data providers.

Institution	Server	Type of Data	Num of Datasets
	CDAWeb	Heliophysics	2800
	SSCWeb	Ephemeris	250
	SDAC	Solar Images (URLs)	50??
	CCMC	Space Weather Indices	250
IRAP Plasma Data Ctr	AMDA	Helio. & Planetary Data and Ephemeris	500
University of Iowa	Das2 Server	Helio. & Planetary	30
 Laboratory for Atmospheric and Space Physics	LISIRD	Solar Irradiance	40
SWARM Mission	ViRES Data Server	Space Mag Data	14
INTERMAGNET	INTERMAGNET	Ground-based Mag	~1000
Royal Netherlands Meteorological Institute	KNMI	Space Weather	~100
	ESAC / Cluster Mission Data	Helio. (magnetosphere)	



HAPI,

More HAPI servers coming soon

Institution	Server	Type of Data	Num. Datasets
	ESAC Solar Orbiter and others	Heliophysics	lots
JHU / APL	SuperMAG	global ground mag	~500
JHU / APL	TIMED / GUVI	ionospheric images	~10
	PDS PPI Node	Planetary Plasma, Particle, and Fields	~1000
NOAA / SWPC	SWPC	Space Weather	~50

On the horizon			
CSA	Space Environment Canada (new initiative)	Ground-based ionospheric data	~1000
CEDAR / Madrigal	Open Madrigal	Space Weather	1000+ (??)
NCAR ? (<i>in discussion</i>)	Multiple	Atmospheric	TBD



Since 2021, HAPI is a COSPAR-endorsed standard for Space Weather data access

COSPAR Panel on Space Weather Resolution on Data Access

Accepted at COSPAR PSW Business Meeting on 18 July 2018 (updated 15 October 2021).

Taking into account that:

1. It is in the general interest of the international heliophysics and space weather community that data be made as widely accessible as possible,
2. The open exchange of data benefits from well-defined and standardized methods of access,
3. The ILWS-COSPAR Roadmap has recommended to standardize metadata and harmonize access to data and model archives, and
4. The Heliophysics Application Programmer's Interface (HAPI) specification has demonstrated that it is comprehensive and can meet the needs of the community,

The COSPAR PSW resolves that there is a need for at least one common data access API to facilitate and enhance international access to data.

Therefore, it is recommended that:

1. HAPI <https://doi.org/10.5281/zenodo.4757597> be the common data access API for space science and space weather data.
2. Funding agencies provide encouragement and adequate support to enable data produced by projects to be accessed by using HAPI compliant services.



Important HAPI Links



Weigel et al, 2021, **HAPI: An API Standard for Accessing Heliophysics Time Series Data**, Journal of Geophysical Research, Vol 126, Issue 12, <https://doi.org/10.1029/2021JA029534>



HAPI Specification at Github
<https://github.com/hapi-server/data-specification>



HAPI Organization at Github
(many projects: clients in Python, IDL, Java, R, HAPI servers, a verifier for server developers)
<https://github.com/hapi-server>



Tutorial Jupyter Notebooks
<https://github.com/hapi-server/tutorial-python>

(These tutorials have been used at two PyHC summer schools.)



HAPI is a useful way to get data from many sources

ESAC HAPI Server
Cluster-3 Electric Wave Form Power Density

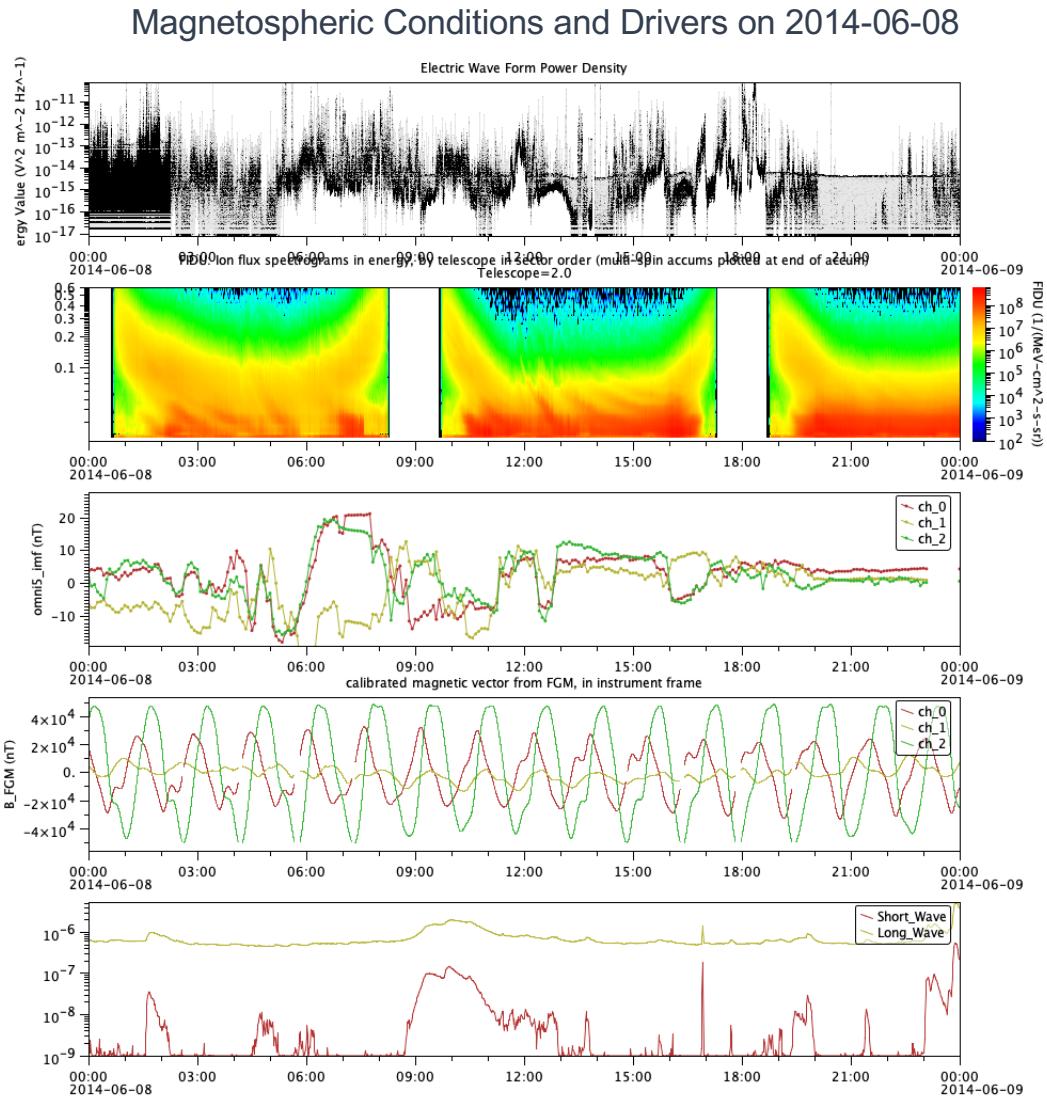
CDAWeb HAPI Server
Van Allen Probes, RBSPICE Ion Energy Spectrogram

5 different datasets from around the world plotted by one application
(Autoplot - see autoplot.org)

AMDA HAPI Server
Omni MAG data

ViRES HAPI Server
GRACE-A MAG Data

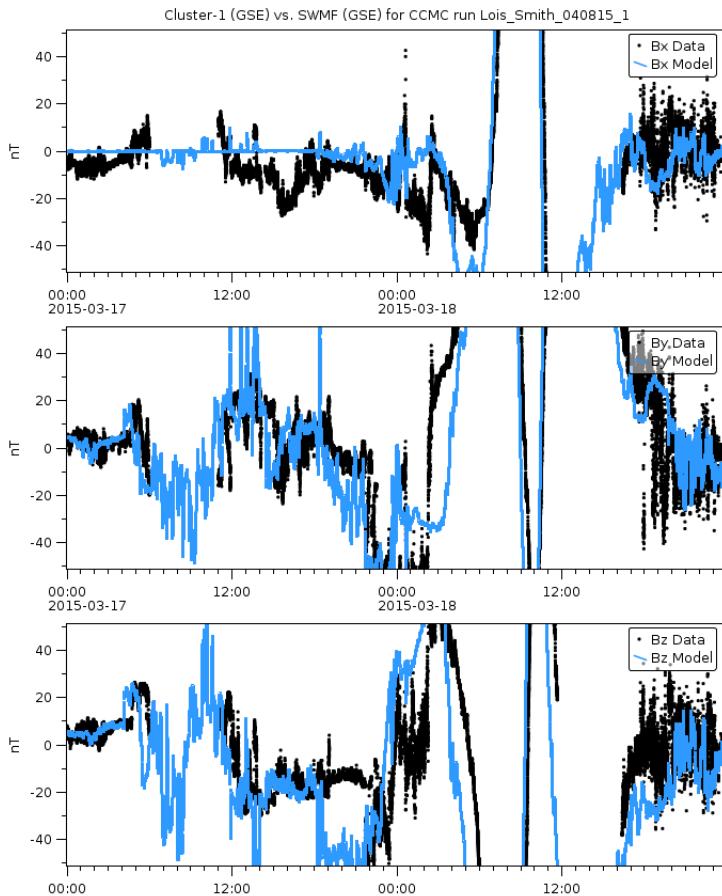
CCMC ISWAT HAPI Server
GOES X-ray flux



Backup Slides



CCMC example: Data-Model Comparisons



Steps:

- Use model data from SWMF.
- Get Cluster-1 ephemeris from **SSCWeb HAPI server**.
- Fly the Cluster-1 trajectory through the model output to get mag data along this trajectory
- Get Cluster-1 mag data from **CDAWeb HAPI server**.

This example is from the CCMC web page:

https://ccmc.gsfc.nasa.gov/ungrouped/GM_IM/GM_analysis.php?Pid=12870&Pt=BO&Ps=Cluster-1

Work is by Darren De Zeeuw.

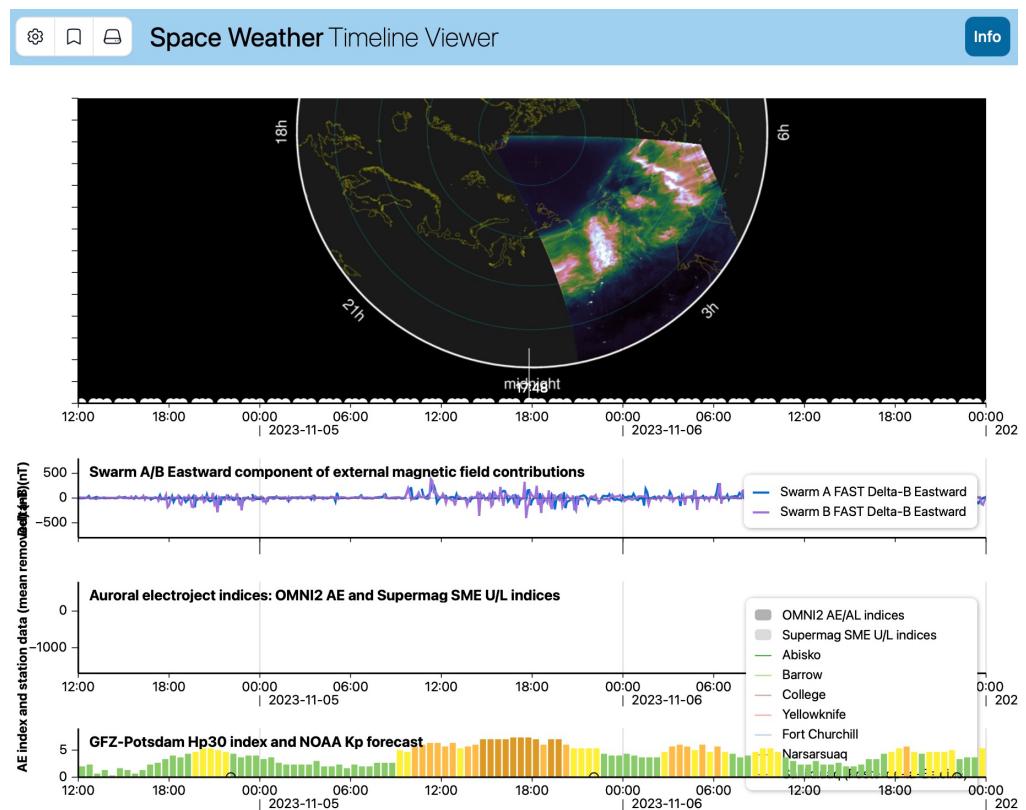
Using HAPI to Serve Images

KNMI Timeline Viewer

list image URLs in the data table:

Time	data1	URI string	Wave-length	Other Metadata
t0	d0	http://data.org/image1.fits	w0	m0
t1	d1	http://data.org/image2.fits	w1	m1
t3	d2	http://data.org/image3.fits	w2	m2
t3	d3	http://data.org/image4.fits	w3	m3
t4	d4	http://data.org/image5.fits	w4	m4
t5	d5	http://data.org/image6.fits	w5	m5
t6	d6	http://data.org/image7.fits	w6	m6

for auroral or solar images, a standard set of metadata columns would be useful
(would have to come from the community)



This HAPI client retrieves number and images using URLs in the data table.

