JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

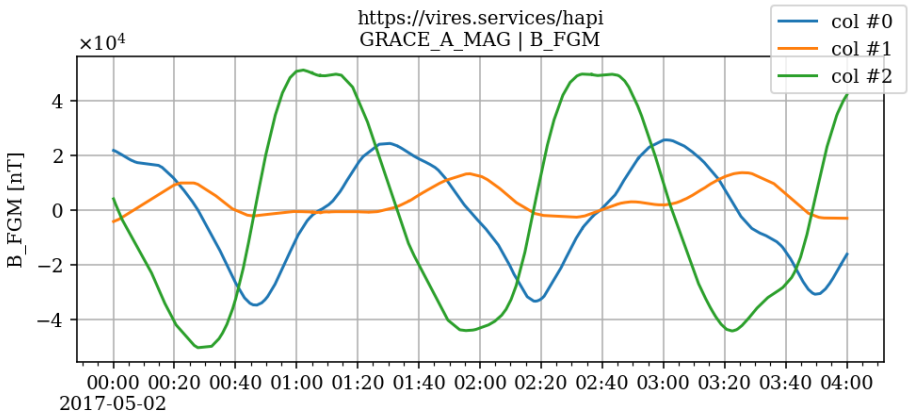
A Grass-roots Standard for Time Series Data in any Domain: HAPI

Heliophysics Application Programmer's Interface

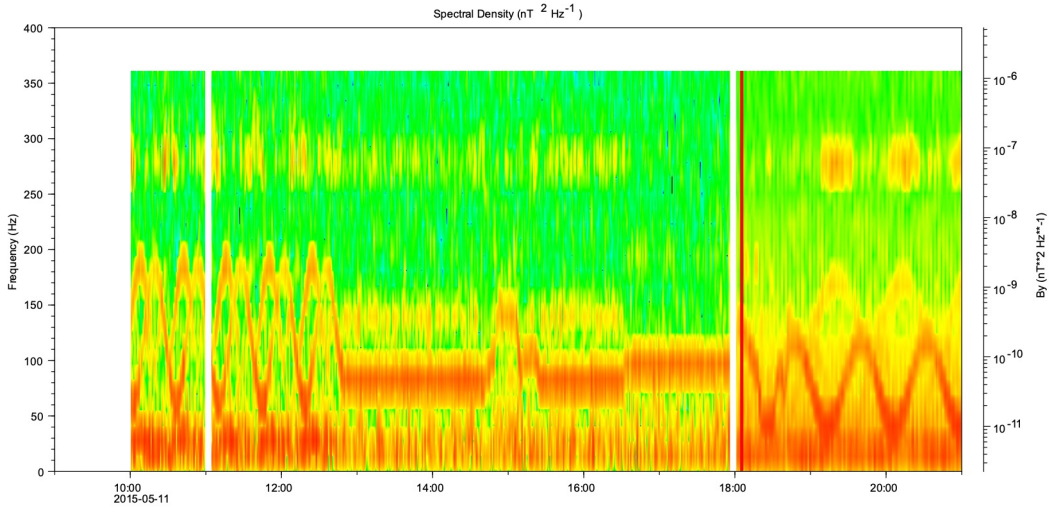
Jon Vandegriff, JHU/APL
Robert Weigel, George Mason University
Jeremy Faden, Cottage Systems
Alexander Antunes, JHU/APL

Heliophysics Time Series Data

Many datasets with measurements of Earth's near-space environment are time series



Scalar example:
space-based magnetic field



Higher dimensional data example:
energetic electron spectra

Definition of Time Series Data

- Tabular, numeric data **indexed only by time**
- Conceptually a uniform collection of identical records

Time	data1	scalar2	array	multiDimArray	string
t0	d0	s0	a0[11]	m0[3,8]	s0
t1	d1	s1	a1[11]	m1[3,8]	s1
t1	d2	s2	a2[11]	m2[3,8]	s2
t2	d3	s3	a3[11]	m3[3,8]	s3
t4	d4	s4	a4[11]	m4[3,8]	s4
t5	d5	s5	a5[11]	m5[3,8]	s5
t6	d6	s6	a6[11]	m6[3,8]	s6
…	…	…	…	…	…

This table may go on for years.

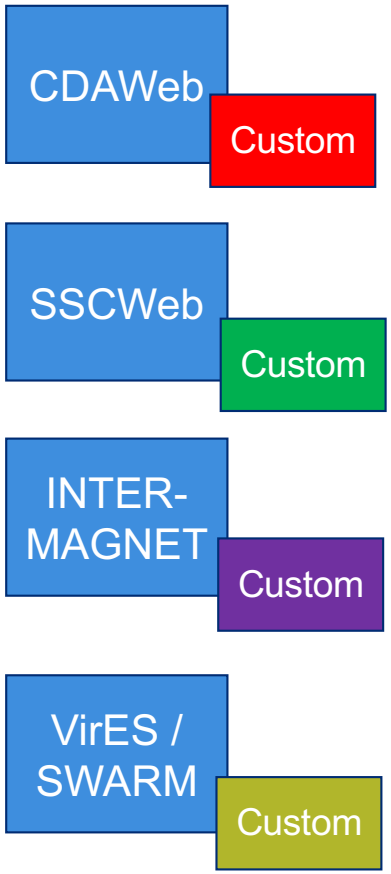
Storage arrangements vary:
- files (daily, yearly, etc)
- relational databases

strings can be URIs to images, but serving image data is not the main intent of HAPI

Lowest Common Denominator Access

Many data providers have similar APIs for time series data.

Each has unique customizations.



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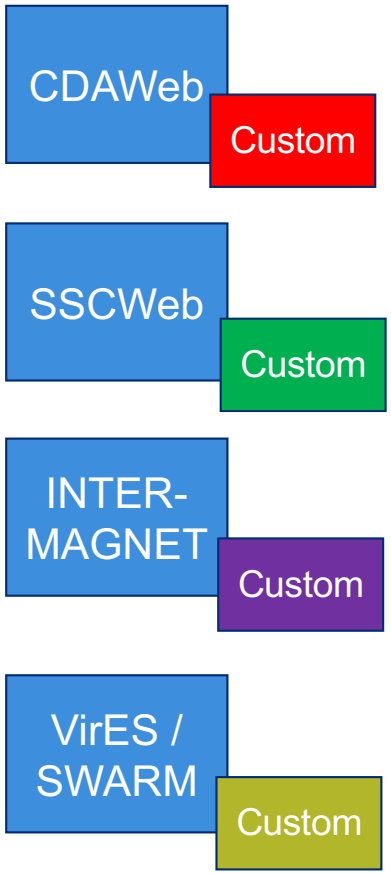

3495 datasets

398 datasets

2979 datasets

126 datasets

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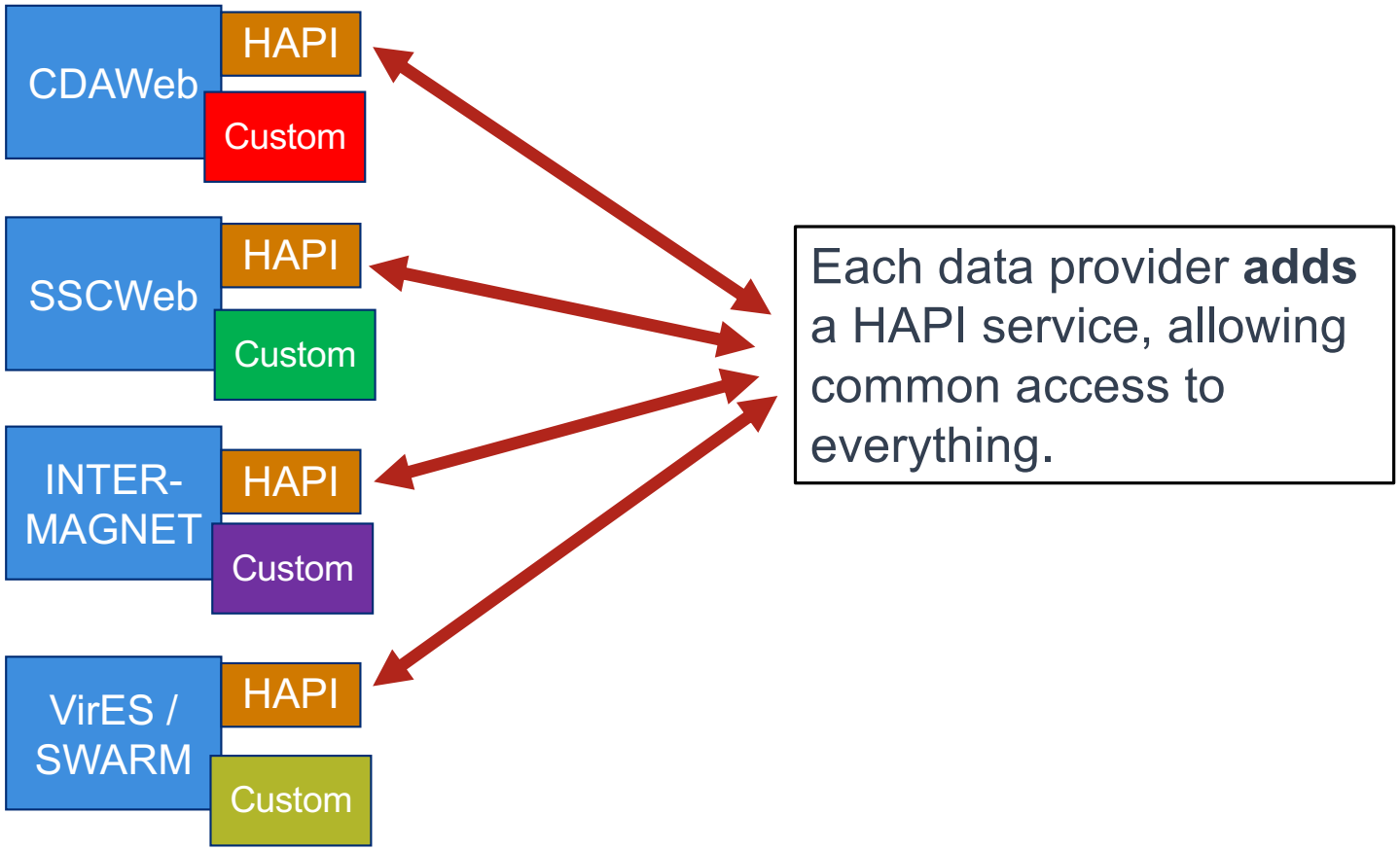

HAPI defines 5 URL endpoints every server must have

Endpoints must be directly below a URL that ends with '**`hapi`**'

- `https://example.com/`**`hapi`**`/`**`about`**
  - Server branding and citation information
- `https://example.com/`**`hapi`**`/`**`capabilities`**
  - describes options implemented by the server
- `https://example.com/`**`hapi`**`/`**`catalog`**
  - list of datasets at the server
- `https://example.com/`**`hapi`**`/`**`info`**
  - show metadata for one dataset at a time (basically a data header)
- `https://example.com/`**`hapi`**`/`**`data`**
  - retrieve a stream of data content for one dataset over a specific time range

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- `https://example.com/hapi/info` ← Retrieve metadata for dataset
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- `https://example.com/hapi/data` ← Stream data
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HAPI Requests and HAPI Data are Simple

Request:

HAPI Requests and HAPI Data are Simple

only three elements parameters needed to request data

data endpoint

Request:

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

(line breaks and spaces 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;

CSV is shown and it can be JSON or binary)

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(always the same format for all servers;

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- RESTful – no state so that each request is independent
- URLs representing the requests can be shared to communicate specific data

HAPI Offers Right-Sized “Generification”

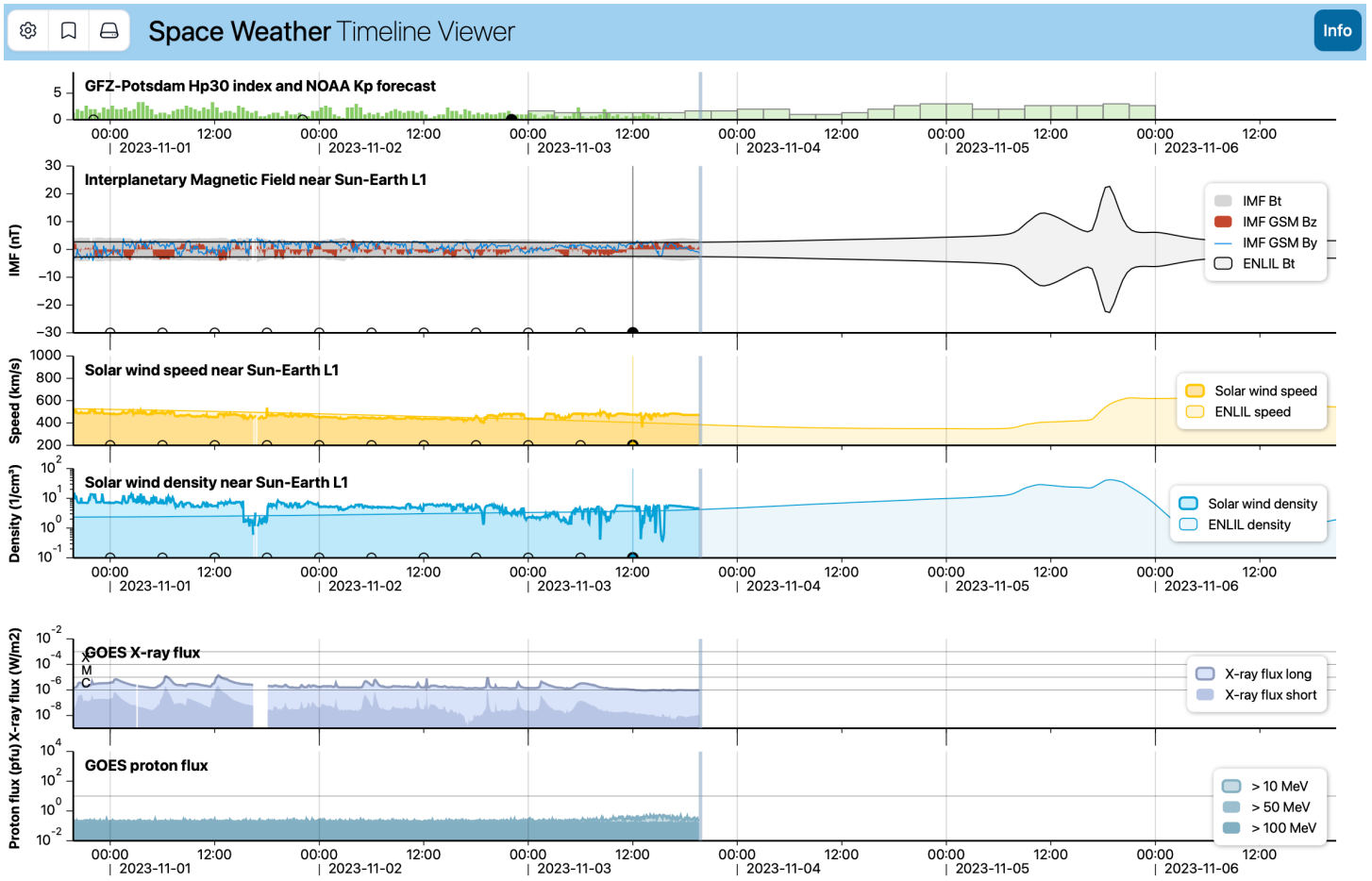
- Is close to what time series data providers are already doing
- Encourages finalized, clean “dataset” concept
  data must be in final form with no data tweaking options
- Has small amount of required metadata
  just enough to make a meaningful plot
- Can represent all features of FAIR data
  and can represent data that is not yet FAIR
- Does not require any specific semantics for the data

Adoption of HAPI

- Committee on Space Research (COSPAR), Space Weather Panel:
  - adopted HAPI as standard for Space Weather Data: https://doi.org/10.1016/j.srt.2021.11.014
- 12 Data Centers using HAPI around the world, with several others on the way
  - about 11000 datasets total
- HAPI Clients in many languages (Python, Java, Matlab, IDL, R, Julia)
- HAPI Timeline Visualizer (not written by HAPI team)
- HAPI GitHub organization has 20+ related projects
  - all projects are open source
- Many tools to aid adoption
  - Reference severs
  - **Verification mechanism for testing server compliance to specification**
- Active development group comprised of people at four institutions

Royal Netherlands Meteorological Institute (KNMI) Space Weather Timeline Viewer

HAPI server and open-source Javascript HAPI client both developed externally to the HAPI team!



ESAC HAPI Server
Cluster-3 Electric Wave Form Power Density

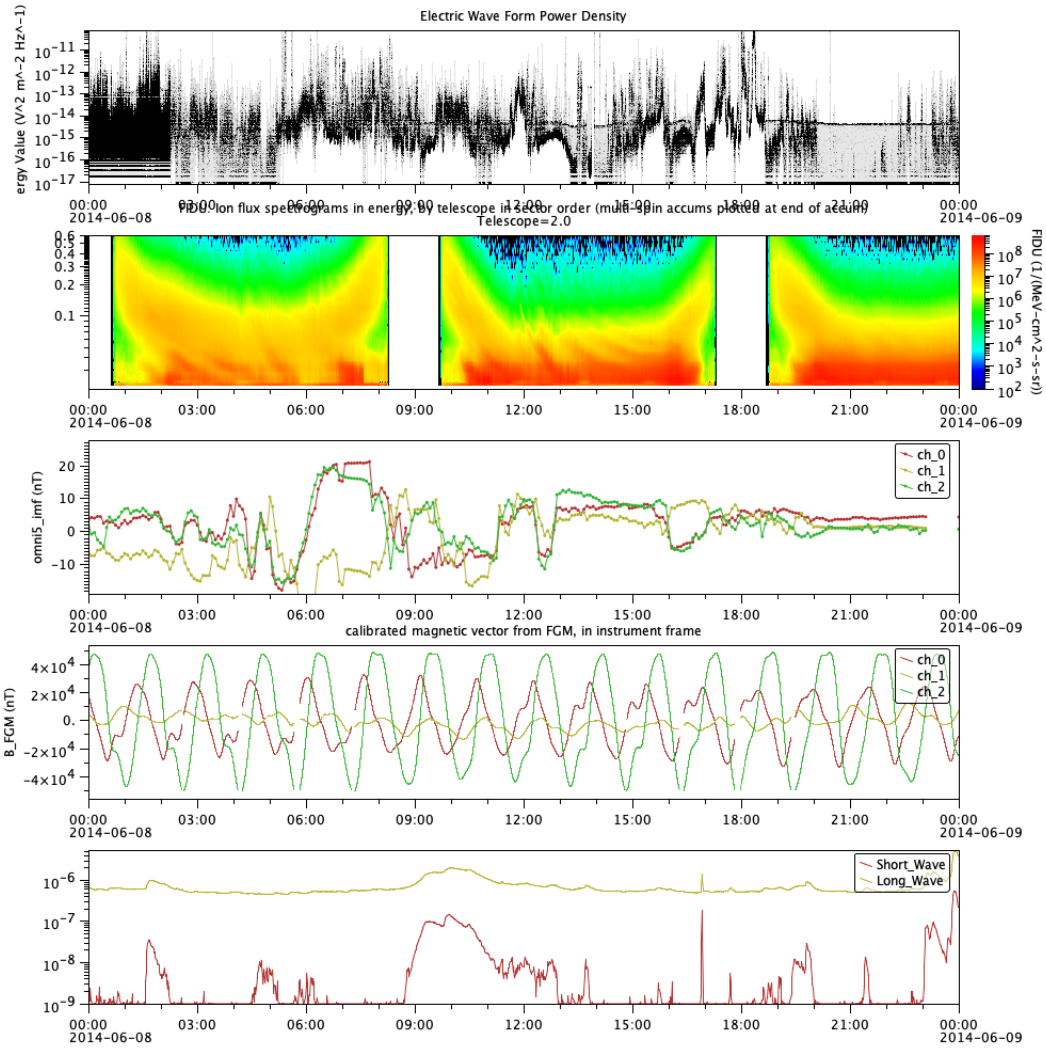
CDAWeb HAPI Server
Van Allen Probes, RBSPICE Ion Energy Spectrogram

The vision: easily combine time series data from anywhere!

AMDA HAPI Server
Omni MAG data

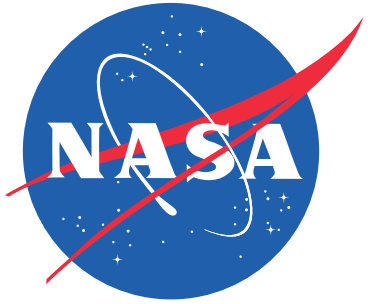
ViRES HAPI Server
GRACE-A MAG Data

CCMC ISWAT HAPI Server
GOES X-ray flux



2014-06-08

Grass roots effort - many international organizations help[ed develop and are using HAPI.



If you are interested in using HAPI

Main Project Web Site
https://hapi-server.org

HAPI Specification document
https://github.com/hapi-server/data-specification

GitHub Repo of HAPI Projects
https://github.com/hapi-server

HAPI Server Verification Tool
https://github.com/hapi-server/verifier-nodejs

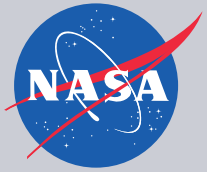
Mailing lists: `hapi-dev@groups.io` `hapi-help@groups.io` `hapi-news@groups.io`

Weekly developer's meeting:

Monday, 12pm Eastern US Time – open invitation for people with questions!!

Additional Material

Data Centers with serving data via HAPI

Institution	Server	Type of Data	Num of Datasets
	CDAWeb	Heliophysics	3495
	SSCWeb	Ephemeris	299
	SDAC	Solar Images (URLs)	79
	CCMC	Space Weather Indices	300
IRAP Plasma Data Ctr, France	AMDA	Helio. & Planetary Data and Ephemeris	1042
University of Iowa	Das2 Server	Helio. & Planetary	19
	LISIRD	Solar Irradiance	29
ESA SWARM Mission	ViRES Data Server	Space Mag Data	162
INTERMAGNET	INTERMAGNET	Ground-based Mag	2979
Royal Netherlands Meteorological Institute	KNMI	Space Weather	909
	**ESAC** / Cluster Mission Data	Helio. (magnetosphere)	1989

Coming soon

Institution	Server	Type of Data	Number of 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

On the horizon			
CSA	Space Environment Canada (new initiative)	Ground-based ionospheric data	~1000
CEDAR / NSF	Madrigal	Space Weather	1000+ (??)

HAPI Clients – all open source

Libraries

- Python library (Bob Weigel)
- IDL library (Scott Boardsen)
- Java library (Jeremy Faden, Larry Brown)
- Matlab library (Bob Weigel)
- R library (Daniel Wilborn)
- Julia (Zijin Zhang)

Applications

- SPEDAS (IDL, Eric Grimes)
- PySPEDAS (Eric Grimes; uses above Python library)
- Autoplot (Jeremy Faden – uses internal code)
- hapi-server.org/servers (JavaScript, Bob Weigel)
- KNMI visualizer (JavaScript, Eelco Doornbos)

Applications using HAPI, but not fully open source:

- LASP Space Weather Data Portal (JavaScript, Jenny Knuth)
- NOAA Space Weather Prediction Center forecast tools (Java, Mark Nakasone)

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