NASA and International Open Standards and the Future of Space Weather Studies

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Virtual Observatory

- A "virtual observatory" is a system that provides a general capability to perform queries for datasets and to access them when found.
 - Ideally, we want all the variegated datasets from diverse observatories and models to look "the same" making analysis enormously easier. (*Virtual* Heliophysics System Observatory)
- The use of **standards** allows **applications** and **interoperable tools** to share data transparently. A VO is *the invisible machinery that allows us to work efficiently.*
- Format, metadata, and data-access API standards are all needed to provide a unified HP data environment.



Behavioral Standards: Open Data; Data Usability

- From the NASA HP Data Policy:
 - Embracing NASA's open data policy that high-quality, highresolution data, as defined by the mission goals, will be made publicly available as soon as practical, and
 - Adhering to the goal of early and continuing independent scientific data usability, which requires *uniform descriptions* of data products, adequate *documentation*, sustainable and open data *formats*, easy electronic *access*, appropriate analysis *tools*, and care in data *preservation*.
- Authors, reviewers, and journal editors should be continually vigilant about the need for citations (DOIs?)
- Openness leads to better data, more use, more citations.

STANDARDS, STANDARDS, STANDARDS

- Data format (FITS, CDF, NetCDF): Self-describing, with standard metadata for easy reading by standard tools. [EU: VOTable (IVOA)]
- Basic registration metadata terms and format (SPASE): Easy access to all datasets; inventory tracking; good product use guides.
- General API for data access (HAPI): Let all tools have easy access to data, independent of underlying format. (Machine to machine)



A standard for serving time series data: the Heliophysics Application Programmer's Interface (HAPI)

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"HAPI" Motivation: The Main Vision



Many benefits

- 1. easy to cross compare data from multiple missions
- scientists can keep using current workflows (reader plugins can upgrade existing tools)
- 3. data center usage documentation is simpler, since it uses a standard
- 4. higher order services can be written to do common or advanced tasks (merging of data products, spike removal, caching for faster operations; data mining, big data analysis.)

Heliophysics API ("HAPI")

- An Application Programming Interface (API) is a set of subroutine definitions, protocols, and tools for building application software.
- An API provides building blocks.
- HAPI provides a uniform means for data access, computer to computer.
- A URL delivers data to a browser or app:
- <u>http://hapi-</u> <u>server.org/hapi/data?id=/path/to/ACE_MAG&time.min=2016-01-</u> 01&time.max=2016-02-01
- Clients (users) generate URLs (by hand or by app); Servers interpret and respond to the URLs, delivering information and/or data.

Details of the HAPI specification

The 4 required HAPI Endpoints:

All endpoints must be directly below a URL that ends with 'hapi'

- http://example.com/hapi/capabilities
 - describes options implemented by the server
- http://example.com/hapi/catalog
 - list of datasets at the server
- http://example.com/hapi/info
 - show metadata for one dataset at a time (basically a data header)
- http://example.com/hapi/data
 - retrieve a stream of data content for one dataset over a specific time range

Adding HAPI compliance to your server

- HAPI may be an *additional* access mechanism
- Reference implementations are being written now to be adapted by other groups
- Current HAPI spec members are also happy(!) to help
- A testing mechanism is available to check for compliance
- Testing can also be done with (existing) HAPI Clients: Autoplot, a simple Python client, and IDL

Find code here: https://github.com/hapi-server

A Simpler Route to having a HAPI Server

Take advantage of an server (written as a service) to attach the capability to your server.



Standards-Based Tools

- Standards have allowed us to implement a number of services:
 - A general product finder and accessor (Heliophysics Data Portal)
 - CDAWeb
 - General analysis tools ("Autoplot," "SPEDAS" and "SolarSoft" with graphical and other tools and direct data access via VSO, CDAWeb, and other APIs)
 - A viewer for a wide variety of solar images with overlays, movies, and events (Helioviewer)
 - Data/model comparison tools
 - Other search engines, visualization tools, etc.

GODDARD SPACE FLIGHT CENTER + Goddard Home Space Physics Data Facility + Visit NASA.gov A VO Face of the Inventory Uses standard metadata					
Heliophysics Data Portal "Find it. Browse it. Get it." SPASE inside Help Geo Orbits Helio Orbits SPASE Registry ADS Abstracts Weather Feedback					
Text Restriction Add	Cu N	o restrictions are currently set.	Purrent List Sort by Observatory		
Time Span Restriction () YYYY-MM-dd or YYYY-DDD	#	Products (& SPASE descriptions)	Access Links		
from:	1	ACE 27-day Survey Plots	Polar-Wind-Geotail 'gif-walk' site	Get Images/Plots	
to: Add Element Restriction () Resource type () Measurement type () Observatory Group () Observatory () (100's!)	2	ACE Cosmic Ray Isotope Spectrometer (CRIS) 1-Hour Level 2 Data	 FTP access to files at SPDF HTTP access to files at SPDF CDAWeb ACE Science Center FTP area ACE Science Center ACE Cosmic Ray Isotope Spectrometer (Home Page 	Get Data/Plots CRIS) Level 2 data	
Instrument (j) Observed region (j) Spectral range (j) Cadence (j) Repository Name (j)	3	ACE CRIS L2 1-day Z=3-28 flux data	 ACE Science Center ACE/CRIS L2 data in HDF via ftp CDAWeb FTP access to files at SPDF HTTP access to files at SPDF 	Get Data/Plots	
Access rights (j)	4	ACE Daily Survey Plots	Polar-Wind-Geotail 'gif-walk' site	Get Images/Plots	
Format (j	5	ACE Electron Proton Alpha Monitor (EPAM) 1-hour Key Parameter data	FTP access to files at SPDF HTTP access to files at SPDF CDAWeb	Get Data/Plots	

creader: Directly Read Data from CDAWeb into IDL

timename='jul_day' ;name of time variable -- Julian days start_time = '1998-06-10T00:00:00.0Z' ;start time stop_time = '1998-06-10T23:59:59.0Z' ;stop time dt_sec=10.0 ;sec -- bin size in seconds

dataset_id='WI_H0_MFI' ; CDAWeb dataset ID vars=['B3F1=Bmag3', 'B3GSE=Bx3,By3,Bz3'] ; CDAWeb variable names with locally assigned names

cdaweb_get_bin, dataset_id,vars,start_time,

stop_time,dt_sec,time_name=timename

dataset_id='WI_PM_3DP' vars=['P_DENS=np3', 'P_VELS=Vxp3,Vyp3,Vzp3', 'P_TEMP=Tp3', 'A_DENS=na3', \$ 'A_VELS=Vxa3,Vya3,Vza3', 'A_TEMP=Ta3']

cdaweb_get_bin, dataset_id,vars,start_time,

stop_time,dt_sec,time_name=timename,/autobad

No more writing code for every dataset.

The Internet functions as a local, easy to use hard drive. Prototype for more general "Virtual Observatory" access to any HP data. VSO does the same for Solar Data; "AMDA" (Europe) uses SPDF web services

cdaweb.gsfc.nasa.gov



SPEDAS (Space Physics Environment Data Analysis Software)

spedas.org

Generic IDL analysis tool with a stand-alone version and with direct links to much of Space Physics data, including all of SPDF.

Roughly the Space Physics equivalent of SolarSoft (supported via SDAC).

Developed by various missions, most recently THEMIS. Used now by MMS and many others.

(Like AMDA in the CDPP)



Helioviewer: Multispacecraft solar imaging and movie-making



Autoplot (autoplot.org)

Reads multiple formats including <u>Complex ASCII tables; Binary tables; Common Data Format (CDF);</u> NcML; SPASE; Cluster Exchange Format; NetCDF; OpenDAP; HDF5; TSDS; FITS; Excel; Wav; PNG, JPG, etc. For details and a full list, see Formats.

Makes "gif-walk" summaries; mutli-dataset overviews, etc.



Integrated Space Weather Analysis (iSWA) at CCMC: Observed and simulated near real-time data

Multiple plot types are available: •satellite B field •model output along satellite trajectory •data/model comparison •satellite location

The data/model plot on the right includes many parts: •model run (CCMC) •satellite trajectory (SSCWeb) •model interpolation (CCMC) •satellite data (CDAWeb) •collect plot pieces (VMR) •plotting (Autoplot)

http://vmr.engin.umich.edu

Data-Model Comparisons

Development effort: "Virtual Model Repository"

Uses Internet connectivity to load spacecraft data and simulations into the same visualization.

This is now being integrated into CCMC rather than being a separate tool.