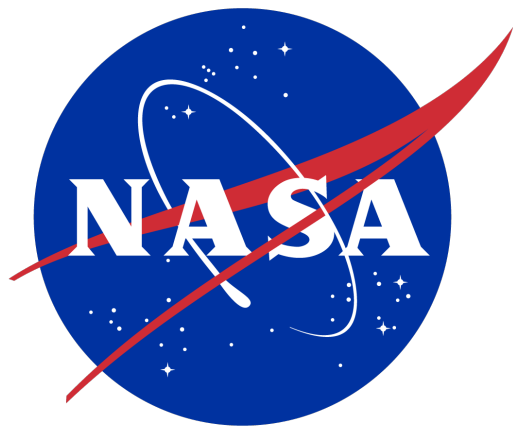# NASA Space Physics Data Facility (SPDF) and Heliophysics Digital Resource Library (HDRL) Data Archives and Services

R Candey, D Bilitza, S Boardsen, S Fooks, L Garcia, B Harris, J Ireland, L Jian, R Johnson, T Kalsulke, A Koval, T Kovalick, H Leckner, M Liu, S Lyatsky, K Marshall, P Makela, N Papitashvili, T Scott, J Smith, J Sun, B Thomas, R Yurow

Code 670/NASA Goddard Space Flight Center

Fall AGU 2023 Dec. 13

Poster:   SH33C-3064

https://spdf.gsfc.nasa.gov

and https://hdrl.gsfc.nasa.gov

# Heliophysics System Observatory

## Heliophysics Mission Fleet

Heliophysics missions are strategically placed throughout our solar system, working together to provide a holistic view of our Sun and space weather, along with their impacts on Earth, the other planets, and space in general. NASA's heliophysics mission fleet includes 19 operating missions using 26 spacecraft, 13 missions in development, 1 mission under study, a robust sounding rocket program and a variety of CubeSat missions.

- ESA = European Space Agency
- JAXA = Japan Aerospace Exploration Agency

*Numbers in parentheses indicate how many spacecraft each mission includes.

*Objects Not to Scale

| ● UNDER DEVELOPMENT | ● PRIMARY OPERATION | ● EXTENDED OPERATION | |
|---|---|---|---|
| AWE (ISS) | HelioSwarm (9) | Parker Solar Probe | ACE | SDO |
| Carruthers Geocorona Observatory | HERMES (Gateway) | Solar Orbiter (ESA) | AIM | SOHO (ESA) |
| | IMAP | | GOLD (SES-14) | STEREO |
| ESCAPADE (2) | MUSE | | Hinode (JAXA) | THEMIS-ARTEMIS (2) |
| EUVST (JAXA) | PUNCH (4) | | IBEX | THEMIS (3) |
| EZIE (3) | SunRISE (6) | | ICON | TIMED |
| GDC (6) | TRACERS (2) | | IRIS | Wind |
| | | | MMS (4) | Voyager (2) |
| | | | RAD (Curiosity) | |

Heliophysics Missions

science.nasa.gov/heliophysics

# *Where the System Observatory Comes Together*

- The HDRL enables the scientific analysis goals of the Heliophysics System Observatory:

  - Provisioning and curation of scientific big data from many sources, PetaByte volumes;  (the Foundation: data, metadata, standards)

  - Support for data analysis in multiple computational environments

  - Design and implementation of a collaborative open science infrastructure

  - Improving access to the data of the Heliophysics System Observatory (HSO) and NASA-funded research projects

  - Improving cross-mission and observation-model comparison, machine learning and other large-scale and collaborative analysis

  - Increasing discoverability and usability of data and model results, software and services, with more complete metadata and provenance and quality control

- HDRL components

  - Solar Data Analysis Center (SDAC) archives solar data (see poster at **SH33C-3063**)

  - Space Physics Data Facility (SPDF) archives non-solar data

  - Heliophysics Data and Model Consortium (HDMC) provides largely cross-cutting registry, access, and analysis standards and tools  (see poster at **U53B-0530)**

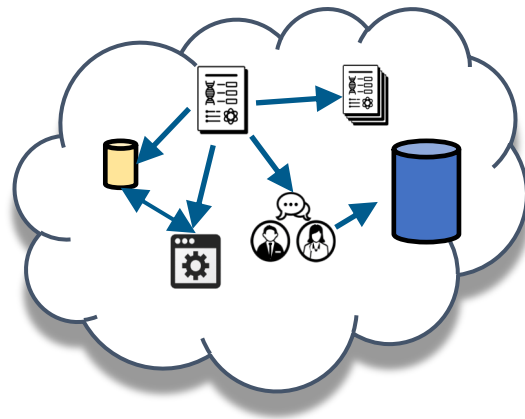# User-Driven Acceleration of Heliophysics Research

## "Preserve"
**Provide Foundational Services**
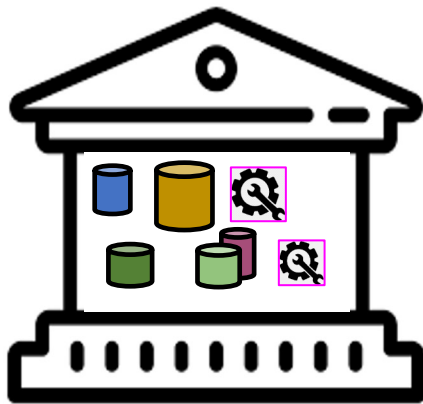
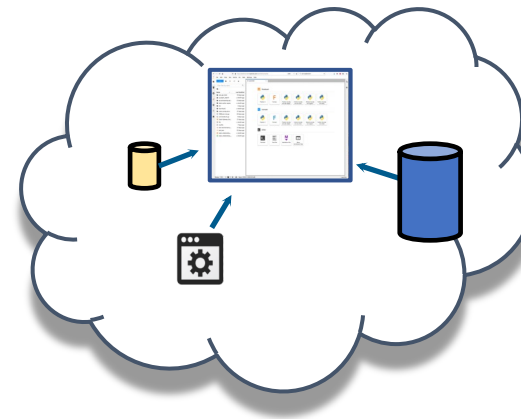*Maintain/upgrade existing archives and services in light of increasing demands driven by Big Data (variety & volume)*

## "Discover"
**Enhance Discoverability**

*Increased interlinking of research artifacts, ADS integration, DOIs, improved standards, etc.*
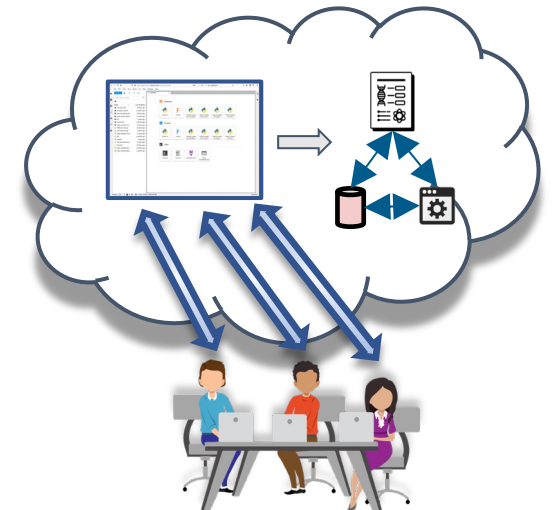
## "Explore Further"
**Unlock Potential**

*High End Compute close to big data (~PB) with software support (AI/ML, PyHC, etc.)*

## "Extend and Connect"
**Enable Team Open Science**

*Open Science; Collaborative Online Research, Compute, and Publishing Platform & Tools; Open Data; Citizen Science*

# Intro to SPDF

- Active archive of **in-situ data** from NASA heliophysics missions, and collaborative missions with other US and foreign agencies **relevant to NASA heliophysics science objectives** (planetary, NOAA, DoD, and ground-based magnetometers, aurora cameras, radars, etc.), from the Sun to the local interstellar medium, including planetary magnetosphere, ionosphere, thermosphere, and mesosphere

- SPDF provides three main science-enabling services besides archiving data
  - CDAWeb (Coordinated Data Analysis Web): browse, correlate, and display
  - SSCWeb (Satellite Situation Center): orbit/ground track displays and queries
  - OMNIWeb and COHOWeb for solar wind plasma, fields, and energetic particles

- SPDF enables multi-instrument, multi-mission heliophysics science
  - Specific mission/instrument data in context of other missions/data
  - Specific mission/instrument data as enriching context for other data

- SPDF also builds critical infrastructures for the **heliophysics data environment**:
  - Common Data Format (CDF) self-describing science file format https://cdf.gsfc.nasa.gov
  - Heliophysics Data Portal https://heliophysicsdata.gsfc.nasa.gov discipline-wide data inventory and access service
  - ISTP Metadata Guidelines

# Space Physics Data Facility
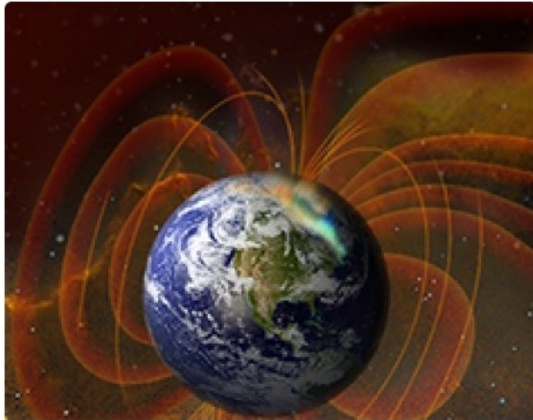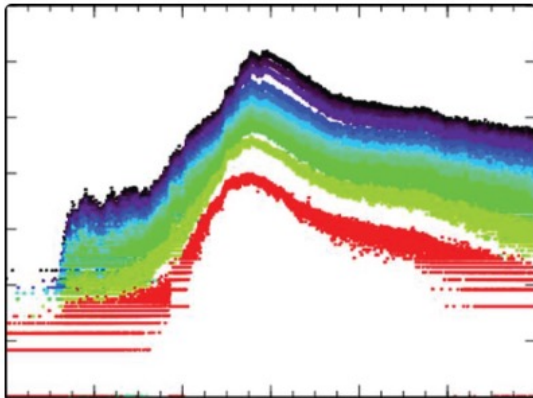
## SPDF Archive

Access to the Space Physics Data Facility (SPDF) public archive by directory, with additional access methods(including web services).

## CDAWeb

Coordinated Data Analysis Web (CDAWeb) provides data browsing and downloads in many formats, with access via web services, for most heliophysics level-2 datasets in CDF and netCDF files. Pregenerated plots for some missions are available through GIFwalk.

## SSCWeb

c.nasa.gov/archive_newdata_reqt.html

## NASA's Space Physics Data Facility (SPDF)

Heliophysics studies the nature and dynamic interactions of the Sun, the heliosphere, and the plasma environments of the planets and interstellar space. The Heliophysics Digital Resource Library (HDRL) archives and serves the heliophysics data, as a project in the Heliophysics Science Division (HSD) at NASA's Goddard Space Flight Center. **Space Physics Data Facility (SPDF)** is the active and permanent archive for the space physics data, while solar data is archived at Solar Data Analysis Center (SDAC), as components of the HDRL, per NASA's Heliophysics Science Data Management Policy.

SPDF provides multi-project, cross-disciplinary access to data to enable correlative and collaborative research across discipline and mission boundaries with present and past missions. Many datasets from current missions are updated regularly (even daily), including reprocessed data for older time periods, and SPDF only preserves the latest version. SPDF maintains the CDAWeb data explorer and browsing system, the SSCweb database of spacecraft orbits, the OMNIWeb cross-normalized database, and the Common Data Format (CDF) self-describing science data format and associated software.

### News & Announcements

**2023 November:** Try out our new prototype browser-based 4D Orbit Viewer to display the SSC spacecraft orbits in an interactive 3-D animation tool.

**2023 November:** The SPDF website has been completely revised to apply the US Web Design System (USWDS) to provide consistent usability, accessibility, editorial style, and a common look-and-feel across the US Government. We tried to preserve existing URLs where possible, and added an acronym/glossary list and a large list of heliophysics resources. Please contact us with any issues, additions, or suggestions.

**2023 November:** The PSP data have been extended to August 2023 (availability depending on data sets), covering Encounter 16 and some of Orbit 16. Please check CDAWeb for the data and PSP inventory plot and annual inventory plots for details.

### Meetings Relevant to Heliophysics Data and Infrastructure

### Join Email list for SPDF Announcements related to SPDF software and services (changes, upgrades, outages). Postings will be very infrequent but are especially useful to regular users of our services.

**Please contact us** with any questions, problems, suggestions, and other comments by emailing NASA-SPDF-Support@nasa.onmicrosoft.com
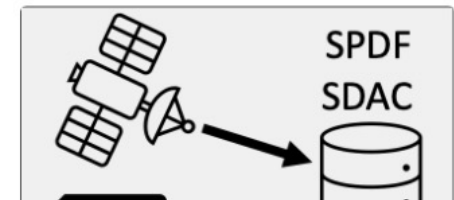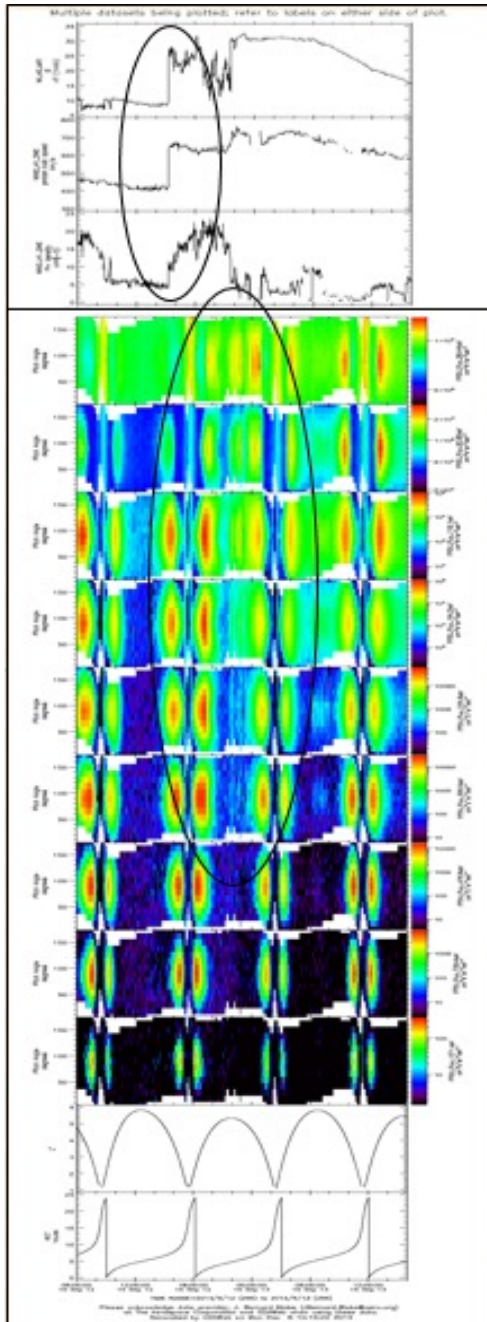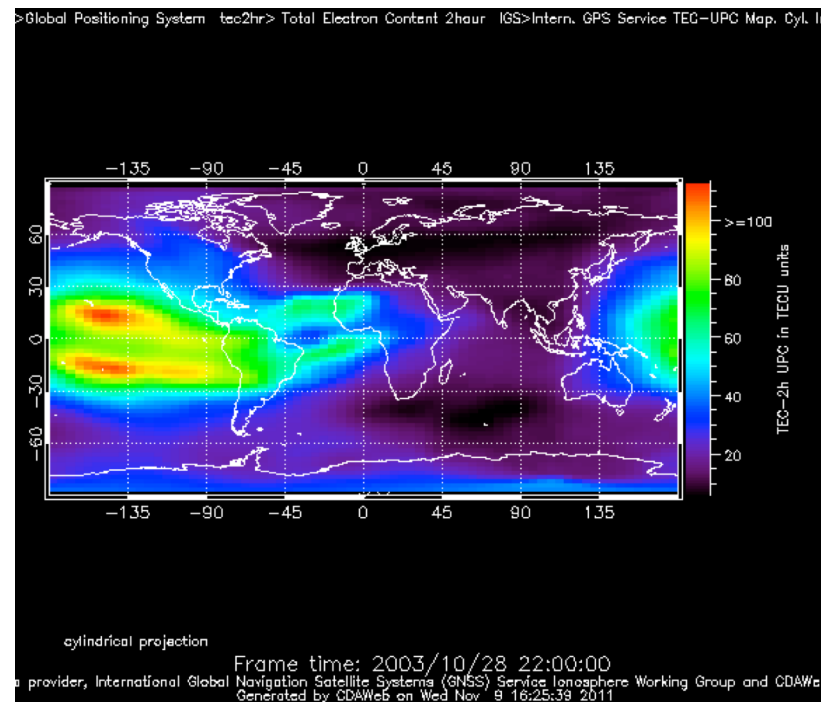
### OMNIWeb
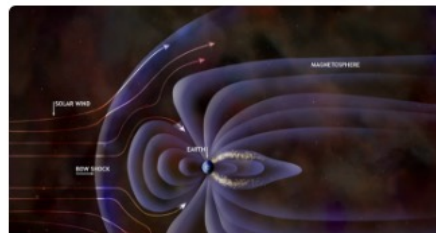
### Common Data Format (CDF)

### Submit Data to HDRL Archives (SPDF and SDAC)

SPDF
SDAC

# Parameter Displays in CDAWeb



WIND MFI & SWE
Van Allen Probe A ECT & MagEIS
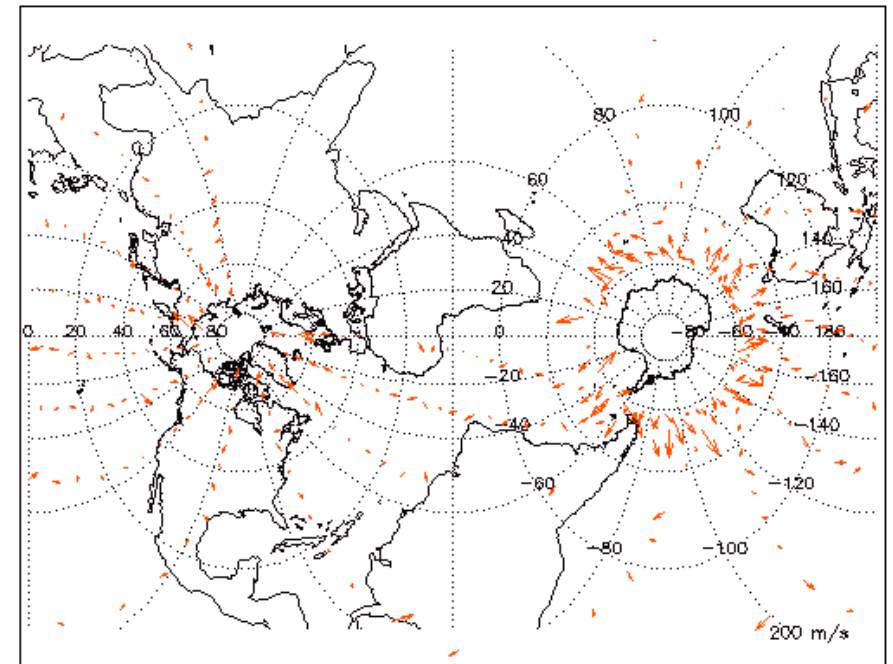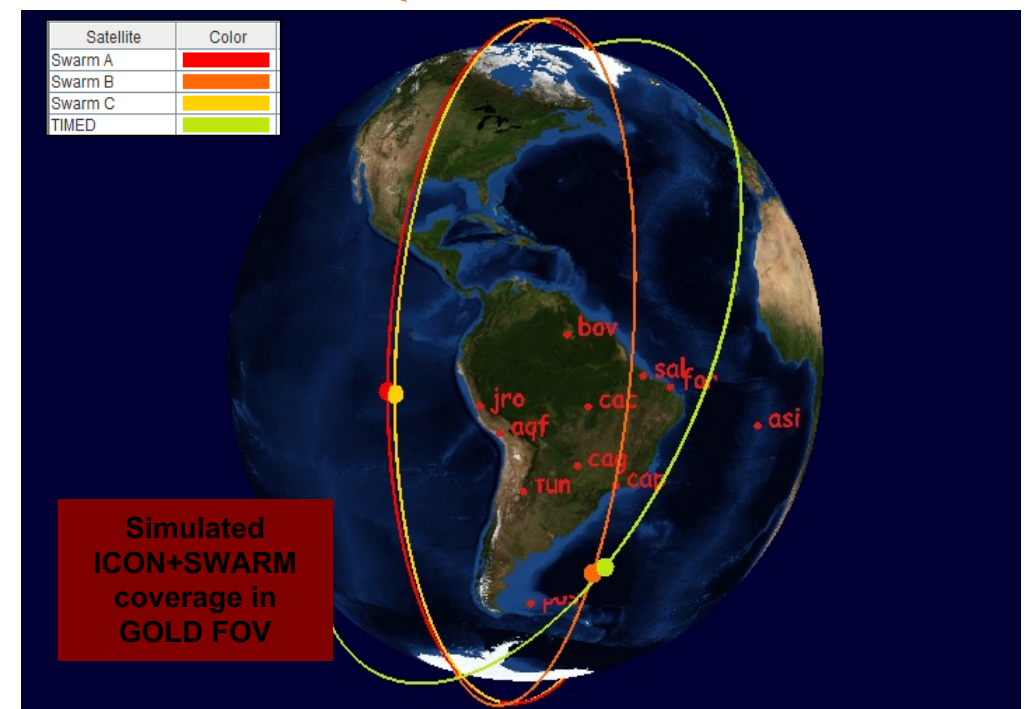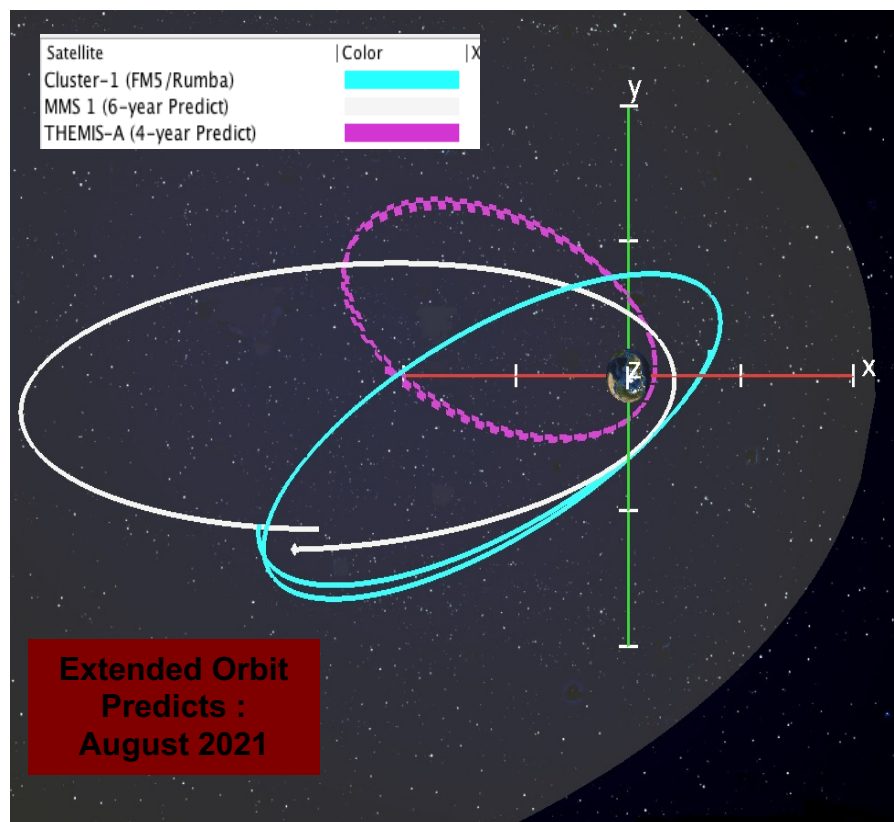


GPS International GNSS Service Total Electron Content



TIMED/TIDI Wind Vectors Movie Transverse Mercator Projection

# Satellite Situation Center (SSCWeb)

- Include most heliosphysics satellites and many ground stations

- Plot and list orbits of multiple spacecraft in a variety of coordinate systems

- **4D Orbit Viewer:** Interactive 4D animation of orbits

- Query for satellite-satellite and satellite-ground station conjunction



Extended Orbit Predicts : August 2021



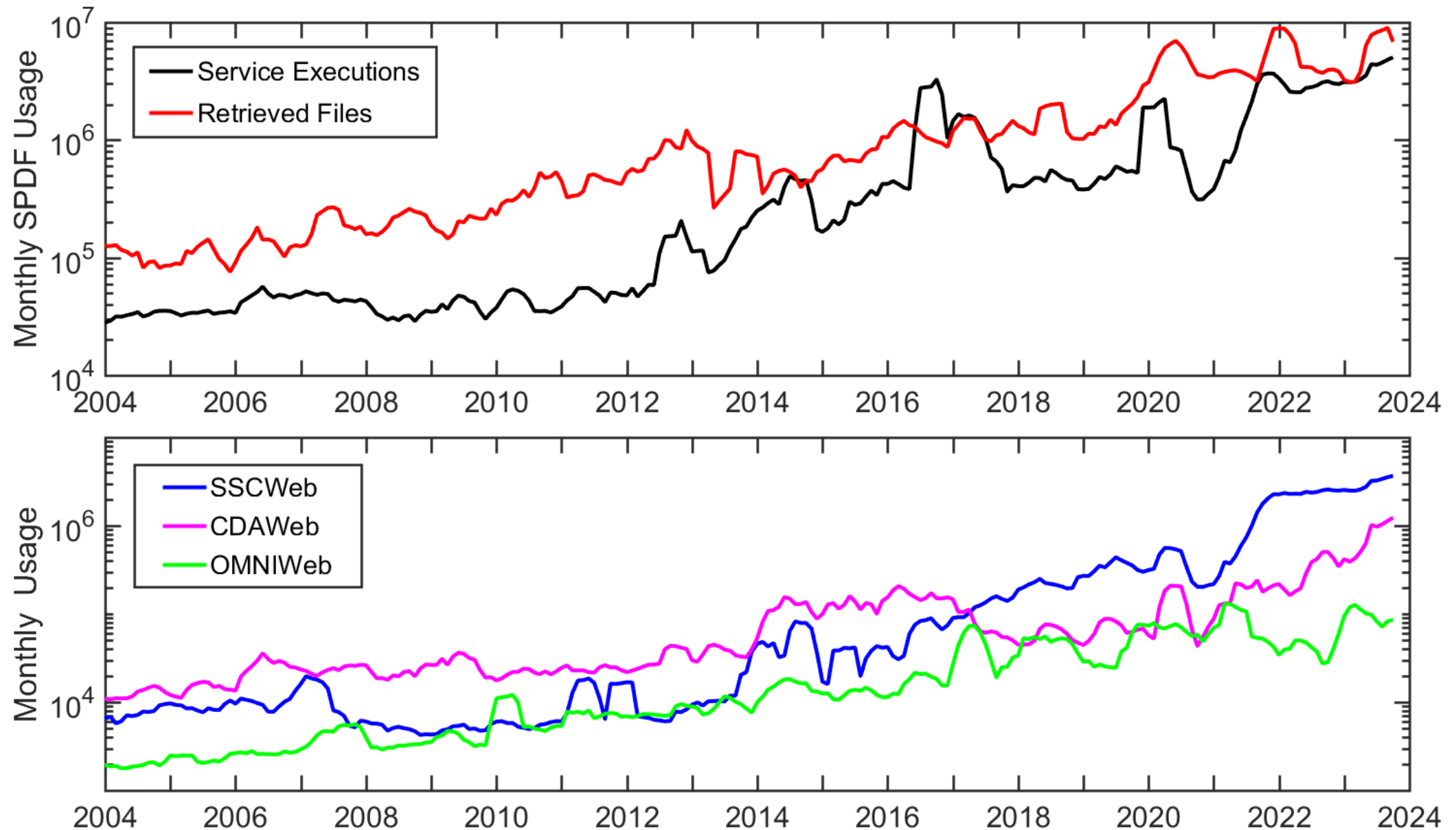Simulated ICON+SWARM coverage in GOLD FOV

# OMNIWeb Plus



- OMNI Data: Database of solar wind magnetic field and plasma parameters mapped to the nose of the Earth's bow shock

- Based on a large volume of quality-controlled satellite measurements (since Nov. 1963)

- **COHOWeb**: Solar wind field, plasma, and proton fluxes in other locations of heliosphere, especially useful for planetary studies and heliospheric model validation

- Interface for plotting, filtering, and downloading the data

# SPDF Recent Activities

- Added many new datasets from ICON, GOLD, Parker Solar Probe, IBEX, Solar Orbiter, MMS, and many other spacecraft, rocket, balloon, and ground instruments

- Continued ingesting CDFs from the Cluster archive, starting with the datasets identified as most important by Harri Laakso and Perrti Makela

- Automated ingest pipeline for > 75 missions out of over 200 missions for a total of ~4,000 datasets using ~550 TB

- Recent average monthly data ingestion rate:  ~0.7 million files, ~14 TB data

- Continuing the population of OMNI, COHO, SSC databases

- CDAWeb plot and display improvements, waveforms, inventory plots, time slices, audification

- Added SPASE Resource IDs and DOIs to CDAWeb metadata and displays

- New SPDF web site look & feel, based on US Web Design System

- Quick start guides, tutorials, improved documentation

- Developing JavaScript (browser-based) alternative to the Java-based 4D Orbit Viewer

- Added software API interface to Heliophysics Data Portal

# Mission Data Volume

Covering from 14 Rs to 160 AU, including magnetosphere – ionosphere – thermosphere – mesosphere (M-ITM) of applicable planets

# SPDF Statistics

See reports at https://cdaweb.gsfc.nasa.gov/publiclogs/



40% of heliophysics papers in 2022 AGU journals acknowledged SPDF services and data

# Planned SPDF Activities

- We are starting to copy all science-level data into HelioCloud for use with cloud-based analysis tools

- Standardize ISTP/IACG Metadata Guidelines with version control, etc.

- Developing new SKTeditor in JavaScript (browser-based), including defining SPASE metadata at the same time as defining the internal metadata and structure of the CDF/netCDF dataset

- Redesign of GIF-walk service to browse pre-generated plots

- Working on web services for burst mode data and science event lists (CMEs, bow shock crossings, etc.) and using by SSCweb and CDAWeb to better serve intermittent/burst data (find next/previous burst or event)

- HTML5/JavaScript-based browser interface for CDAWeb/SSCweb, to add interactive data plotting and sonification tied to the orbit display, (using JSON output from SSCweb and CDAWeb web services)

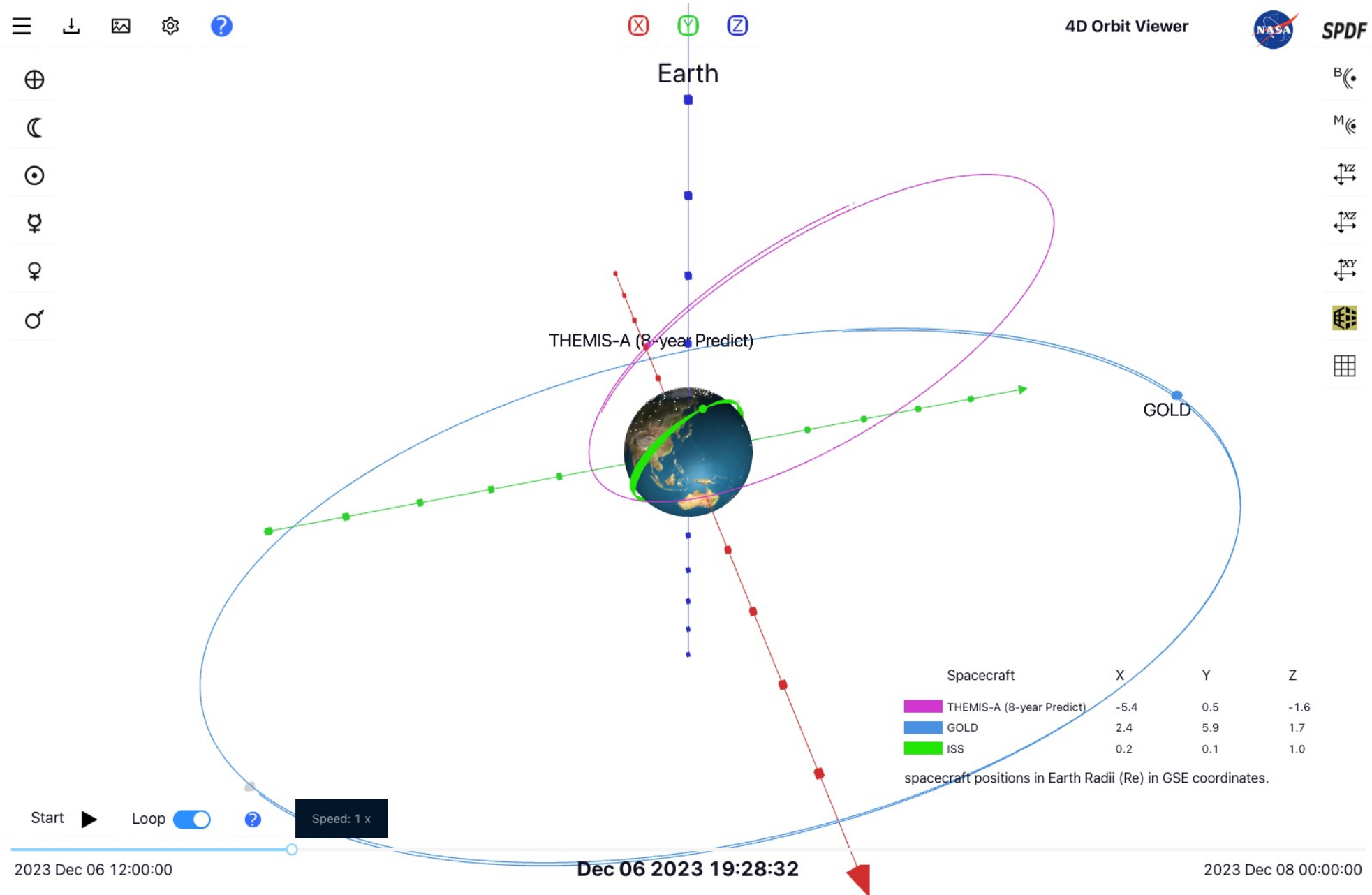# SPDF support over 132 Missions

*Only orbit data available

| | | | | | |
|---|---|---|---|---|---|
| ACE | Cassiope | GOES | LUNA | Pioneer | STEREO |
| Active* | Cluster | GOLD | Magsat | Pioneer 10 | Suisei |
| Aeros | Cosmos 900 | GMS 3 | MAP | Pioneer 11 | Swarm |
| AIM | C-NOFS | Granat | Mariner 10 | Pioneer Venus | Tatiana |
| Akebono* | CRRES | Hawkeye | Mars | Polar | THEMIS |
| Alouette1 | CSSWE | Helios | MAVEN | Prognoz | TIMED |
| Alouette2 | Dawn* | Hinode | MESSENGER | Reimei | TRACE |
| AMPTE | DEMETER* | Hinotori | Microlab 1 | Rosetta* | TWINS |
| APEX-MAIN* | DMSP | IMAGE | Mir* | RHESSI | UARS* |
| Apollo | Double Star* | IMP 7 | MMS | ROCSAT-1 | Ulysses |
| Aqua | DSCOVR | IMP 8 | MRO | SAMPEX | Van Allen Probes |
| Ariel-4 | DE | IMP_early | MSL | Sakigake* | Vega |
| Arase (ERG) | Equator-S | Interball | MSX* | San Marco | Venera |
| ARCAD | Explorer | ISEE | Munin | SCATHA* | Viking |
| ARTEMIS | FAST | ISEE 3-ICE | New Horizons | SDO | Voyager |
| ASTRID II* | FIREBIRD* | ISIS | NOAA* | SMILE | Voyager 1 |
| AE | Freja* | ISS | Oersted | SNOE | Voyager 2 |
| Aura | Galileo* | Jason 2 | OGO | SOHO | Wind |
| Aureol2 | GCOM W1 | Juno | Ohzora | SORCE | XMM-Newton |
| BARREL | Genesis | Kepler | PARASOL | Spartan-A | Yohkoh* |
| CALIPSO | Geotail | LANL | Parker Solar Probe | Spitzer | Zond |
| Cassini* | Giotto* | LRO | Phobos | Sputnik 1 | |

Total: ~10,000 datasets, ~550 TB data

Recent average monthly data ingestion rate: ~0.7 million data files, ~14 TB data

# 4D Orbit Viewer now in JavaScript
## https://sscweb.gsfc.nasa.gov/4dorbit/

# Rewrite of SKTeditor in JavaScript for laying out datasets and adding ISTP and SPASE metadata

# SPDF provides multiple services and access methods

- Direct file downloads via FTPS and HTTPS https://spdf.gsfc.nasa.gov/pub/data/

- Orbit and ground track displays/queries via SSCWeb and 4D Orbit Viewer

- CDAWeb services:
    - Data files, plots and listings with supersets or subsets by time & selected variables, time-binning

    - Web service interfaces (REST, SOAP, IDL, Matlab, Java, Python)
      https://cdaweb.gsfc.nasa.gov/WebServices/

    - HAPI (Heliophysics API) https://cdaweb.gsfc.nasa.gov/hapi

    - Autoplot autoplot.org/help#CDAWeb

    - Other methods such as IDL
      https://cdaweb.gsfc.nasa.gov/alternative_access_methods.html

- The **SPASE** (Space Physics Archive Search and Extract http://www.spase-group.org/) team use the master CDFs to generate SPASE IDs and descriptions for all datasets, to add entries to the **Heliophysics Data Portal** https://heliophysicsdata.gsfc.nasa.gov and mint DOIs for each dataset

# Space Physics Data Facility (SPDF)
# https://spdf.gsfc.nasa.gov

The NASA Heliophysics Digital Resources Library (HDRL.gsfc.nasa.gov) coordinates the efforts of the Heliophysics archives and other data-related groups to increase discoverability and usability of data and model results, software and services. Among these are the non-solar NASA Heliophysics active final archive, the Space Physics Data Facility (SPDF https://spdf.gsfc.nasa.gov). SPDF works with current operating missions and the heliophysics community to ingest, preserve and serve a wide range of science-quality data from the mesosphere into the furthest reach of deep-space exploration. In order to promote open science and FAIR principles support, SPDF has been standardizing the ISTP Metadata Guidelines used for self-describing datasets, adding additional functionality to the CDAWeb data browsing system and SSCweb orbit services, improving the Heliophysics Data Portal (HDP) discipline-wide data inventory and access service based on the SPASE-group.org metadata and DOI landing pages, and copying the archives into the HelioCloud cloud-based collaborative data analysis environment. SPDF serves data from many missions and ground-based investigations, including from Parker Solar Probe, Solar Orbiter, ICON, MMS, Van Allen Probes, THEMIS/ARTEMIS, GOLD, ACE, Cluster, IBEX, Voyager, Geotail, Wind and many others.

https://spdf.gsfc.nasa.gov/pub/documents/SPDF/presentations/