



The PyHC Open Science Experiment

Rebecca Ringuette and many others

NASA GSFC Center for HelioAnalytics

Presented at the 2023 PyHC Spring Meeting at LASP/CU Boulder in Boulder, CO.

Session Outline

- Invited presentation on the **Open Science Framework** (10-15 min)
Presented by Gretchen Geugeun
- **Project Introduction** (15-20 min)
 - The PyHC Open Science Experiment
 - Project Tour
- **Open Science and Heliophysics Infrastructure** (5-10 min)
- **Discussion** (45 min): What PyHC software changes are needed to better support this project and, more generally, open science? What funding is needed to complete these tasks?

The Open Science Framework

Presented by Gretchen Geugeun

Link to slides:

https://docs.google.com/presentation/d/1vtSmbsDweTLmS8wGgfwNu9aDQMZ3iMnPQeQTIKJe_M/edit?usp=sharing

Project Introduction:

The PyHC Open Science Experiment

- The PyHC executable paper demonstrated:
 - How to **collaborate** between software developers/engineers and scientists,
 - How to **use multiple PyHC packages** to perform a science analysis,
 - How to produce an **executable paper** in Heliophysics, and
 - How such a collaboration **supports open science**.
- The goals for this work are to:
 - Apply the workflow developed to a **full-scale science** problem, specifically expanding the 2015 challenge with new data from MMS (<https://ccmc.gsfc.nasa.gov/challenges/gem-magnetopause/>),
 - Demonstrate how to **perform open science** in Heliophysics, and
 - Improve and **develop modern infrastructure** to streamline collaboration and contributions.

Project Introduction:

The PyHC Open Science Experiment

GEM Science Plan

- Expand to include multiple time ranges of MMS data where magnetopause crossings occurred (retrieved with **pySPEDAS**),
- Generate the predictions using the empirical Shue model (using **SpacePy**),
- Generate flythrough results for each contributed physics-based model output stored in s3 (via **Kamodo**),
- Encourage the community to provide metrics calculation scripts using the flythrough results (built on **PlasmaPy**), and
- Provide a platform where all contributors can search and reuse all components (on **HelioCloud**).
- Multiple members of the community are expected to lead portions of the project and produce multiple papers, including a summary paper (coordinated on the **Open Science Framework**).



NEED SOME
EXAMPLES!

Project Introduction: The PyHC Open Science Experiment

Open Science goal

- Perform the work **in the open** from the beginning,
- **Demonstrate** how to perform open science to the Heliophysics community and various agencies and nations,
- **Develop** any lacking infrastructure along the way (as reasonably possible),
- **Create** examples of rubrics for recognition/coauthorship and contribution/participation rules for open science, and
- **Publish** a paper describing the challenges discovered, lessons learned, advancements achieved, and how this work can be expanded upon.

Project Tour: OSF Project Page



A screenshot of an OSF project page. The header shows the OSFHOME logo, a search bar, and links for Support, Donate, Sign Up, and Sign In. Below the header, the project title "Comparing Magnetopause Crossings using Open Science" is displayed. The page includes metadata such as the contributor "Rebecca Ringuette", creation date "2023-05-08 09:29 AM", last updated date "2023-05-11 06:39 PM", and DOI "10.17605/OSF.IO/V4DRT". A description of the project is provided, detailing the collaboration between research software engineers, software developers, and scientists in heliophysics. The page also features a "Files" section with a search filter and a "Citation" section with a dropdown menu. The license is listed as "Apache License 2.0".



Please make
OSF/ORCID
accounts so I can
add contributors!

Project web page: osf.io/v4drt/ DOI: [10.17605/OSF.IO/V4DRT](https://doi.org/10.17605/OSF.IO/V4DRT)



Project Tour: HDRL's HelioCloud

- Cloud computing environment
- Executable and shareable notebooks
- Large file storage supported via public s3 buckets
- Initial compute and storage costs funded by HDRL

<https://daskhub.hsdcloud.org>

*...more tomorrow in
S. Antunes' presentation.*

The screenshot displays the JupyterHub interface for selecting a server. The navigation bar at the top includes the JupyterHub logo, 'Home', 'Token', 'Services', and a user profile 'raringuette' with a 'Logout' button. The main heading is 'Server Options'. Below this, there are seven server configuration options, each with a radio button and a description:

- ☒ **CPU Server**
Notebook server. 8GB RAM/2 CPU reserved. **Python/IDL**
- ☐ **Large CPU Server**
Large notebook server. 16GB RAM/4 CPU reserved. **Python/IDL**
- ☐ **X-Large CPU Server**
Extra Large notebook server. 32GB RAM/8 CPU reserved. **Python/IDL**
- ☐ **The Big Big CPU Server**
Use resources like you mean it. 64GB RAM/16 CPU reserved. **Python/IDL**
- ☐ **GPU Server**
Notebook server with access to an NVidia T4 GPU. Up to 16GB RAM/4 CPU. **Python Only**
- ☐ **GPU Server - Large**
Notebook server with access to an NVidia T4 GPU. Up to 32GB RAM/8 CPU. **Python Only**
- ☐ **GPU Server - X-Large**
Notebook server with access to an NVidia T4 GPU. Up to 64GB RAM/16 CPU. **Python Only**

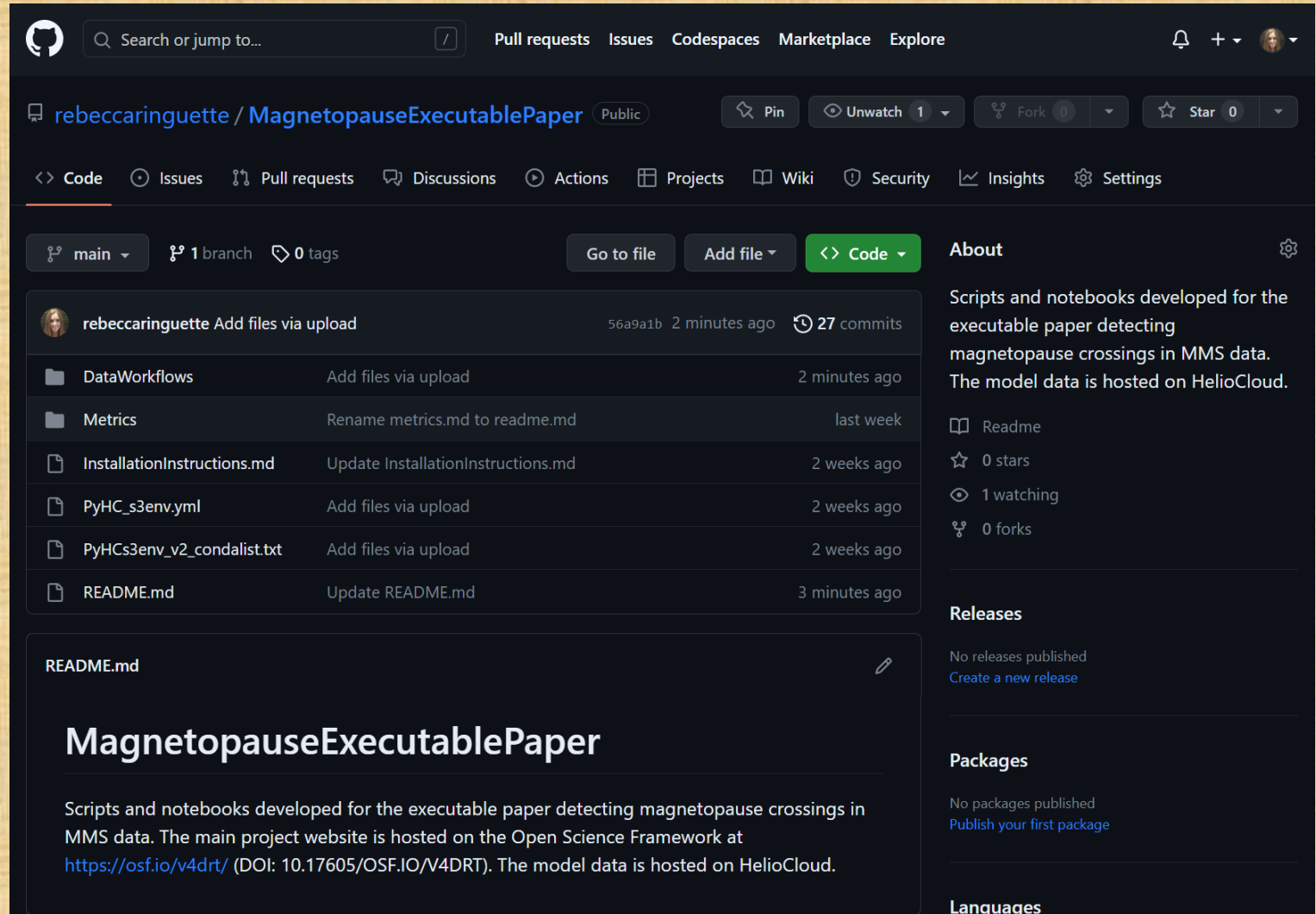
At the bottom of the page is a large orange button labeled 'Start'.

Project Tour: GitHub page



- Link to project webpage added to readme file.
- Scripts and notebooks stored in 'DataWorkflows' folder.
- Software environment information in top directory.

<https://zenodo.org/badge/latestdoi/631044088>



The screenshot shows the GitHub repository page for `rebeccaringuette / MagnetopauseExecutablePaper`. The repository is public and has 0 stars, 1 watch, and 0 forks. The main branch is `main` with 1 branch and 0 tags. The repository contains several files and folders, including `DataWorkflows`, `Metrics`, `InstallationInstructions.md`, `PyHC_s3env.yml`, `PyHCs3env_v2_condalist.txt`, and `README.md`. The `README.md` file is selected, showing the project title `MagnetopauseExecutablePaper` and a description: "Scripts and notebooks developed for the executable paper detecting magnetopause crossings in MMS data. The main project website is hosted on the Open Science Framework at <https://osf.io/v4drt/> (DOI: 10.17605/OSF.IO/V4DRT). The model data is hosted on HelioCloud." The right sidebar shows the repository's metadata, including the README, 0 stars, 1 watching, 0 forks, and sections for Releases and Packages.

rebeccaringuette / MagnetopauseExecutablePaper Public

Code Issues Pull requests Discussions Actions Projects Wiki Security Insights Settings

main 1 branch 0 tags Go to file Add file Code

rebeccaringuette Add files via upload 56a9a1b 2 minutes ago 27 commits

File	Commit Message	Time
DataWorkflows	Add files via upload	2 minutes ago
Metrics	Rename metrics.md to readme.md	last week
InstallationInstructions.md	Update InstallationInstructions.md	2 weeks ago
PyHC_s3env.yml	Add files via upload	2 weeks ago
PyHCs3env_v2_condalist.txt	Add files via upload	2 weeks ago
README.md	Update README.md	3 minutes ago

README.md

MagnetopauseExecutablePaper

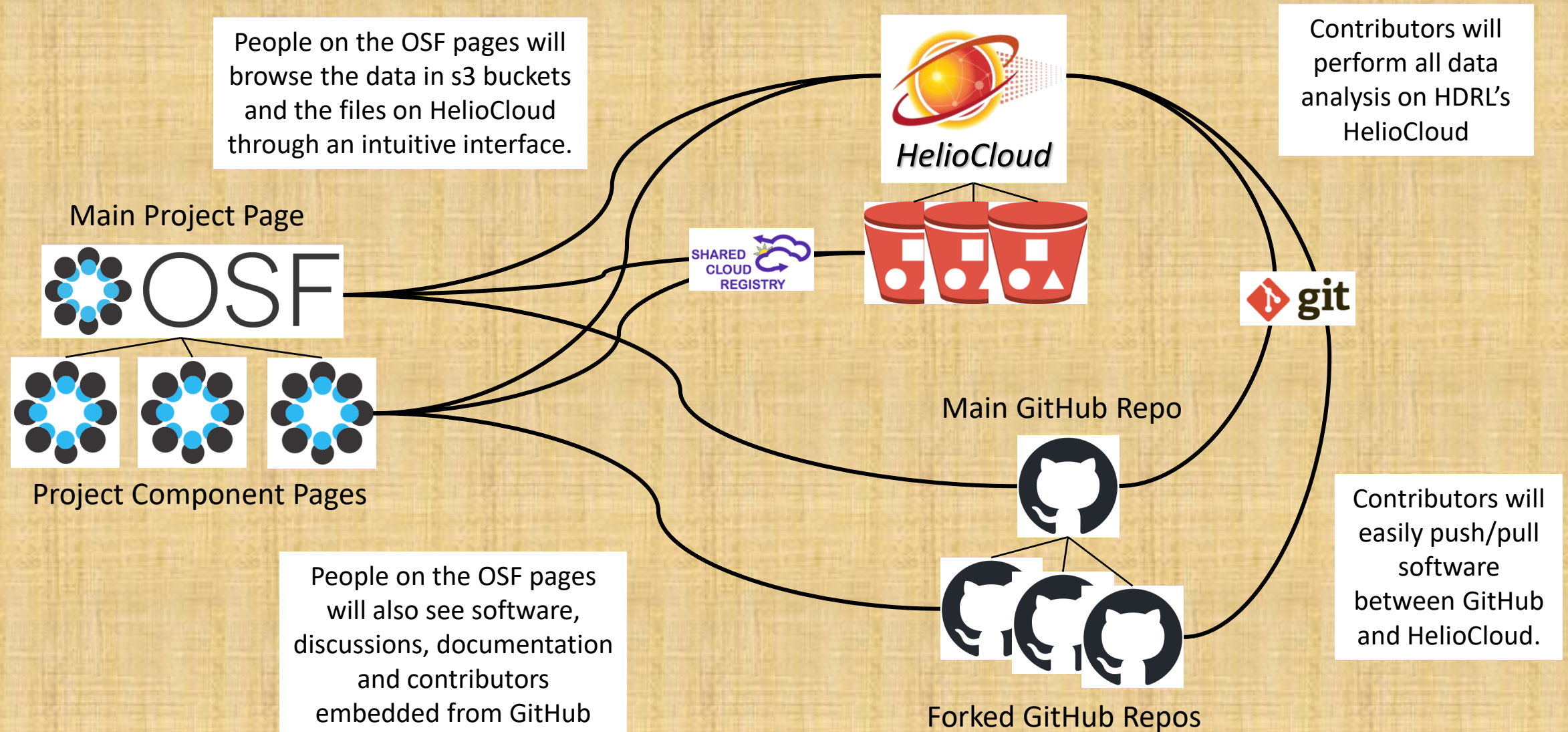
Scripts and notebooks developed for the executable paper detecting magnetopause crossings in MMS data. The main project website is hosted on the Open Science Framework at <https://osf.io/v4drt/> (DOI: 10.17605/OSF.IO/V4DRT). The model data is hosted on HelioCloud.

Releases
No releases published
[Create a new release](#)

Packages
No packages published
[Publish your first package](#)

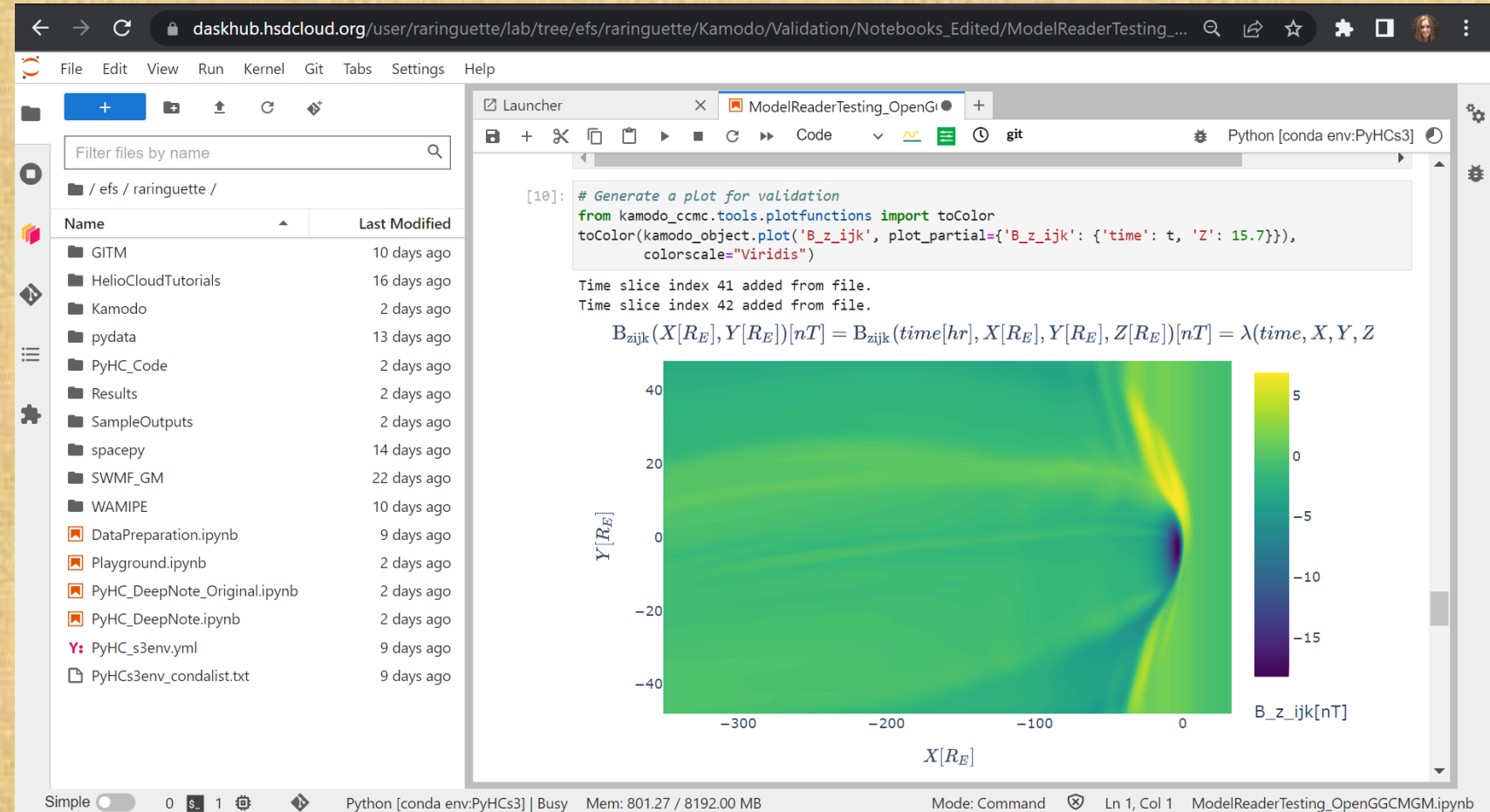
Languages

Project Tour: Linking It All Together



Project Tour: Current Status

- Project posted on OSF with a DOI
- Dependency conflicts resolved on HelioCloud
- ***Software runs on data in s3!*** (except for SWMF GM outputs)
- Workflows being planned and developed



Project Tour: Path Forward

- **Work out kinks** in running PyHC software on data in s3 buckets.
- **Add Contributors!** (*Make an account on OSF/ORCiD so I can add you!*)
- **Link** HelioCloud, OSF and GitHub together (easier said than done!).
- **Streamline** workflows for contributors (*NEED TESTERS!*).
- **Draft** contribution/participation rules based on JWST example.
- **Finalize** contribution/participation rules at Fall PyHC meeting.
- **Present** at AGU 2023 a (hopefully) ready environment.

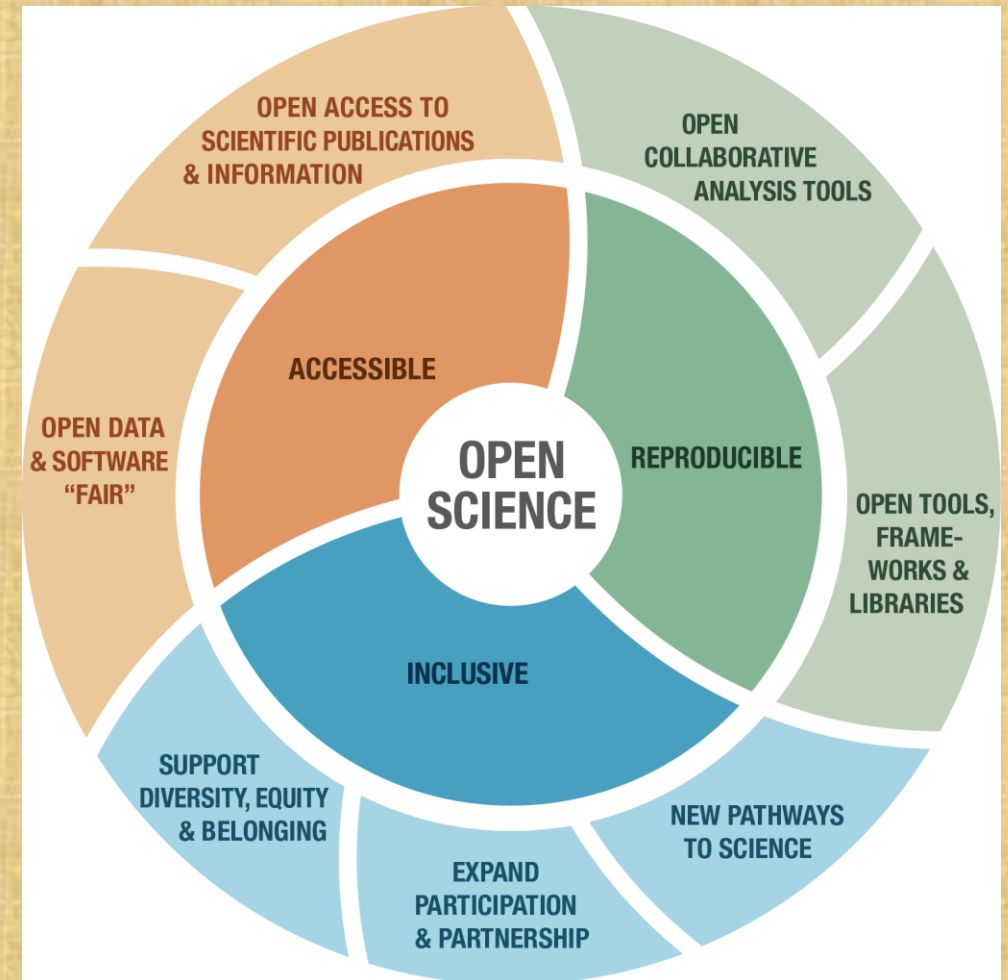
Any burning questions?

Open Science and Heliophysics Infrastructure

- **Open Science** is the principle and practice of making research products and processes available to all, while respecting diverse cultures, maintaining security and privacy, and fostering collaborations, reproducibility and equity.

(<https://www.whitehouse.gov/ostp/news-updates/2023/01/11/fact-sheet-biden-harris-administration-announces-new-actions-to-advance-open-and-equitable-research/>)

- **Why open science?**
 - Accelerates scientific discovery.
 - Greater collaboration and efficiency.
 - Enhanced transparency and reproducibility (NASEM, 2018, p. 3).
 - Mandated by the U.S. White House and NASA.
- Image Credit: NASA TOPS
(<https://zenodo.org/record/6565080#.ZFPvCnbMKUk>)



Open Science and Heliophysics Infrastructure

- **FAIR** components (***F**indable, **A**ccessible, **I**nteroperable, **R**eusable*):
 - *Making good progress*: publications, observed data, metadata,
 - *Needs focused development*: modeled data, software,
 - *Exploration required*: model codes, software environments,
 - *The great unknown*: people, relationships, collaborations, ...
- **Reproducible** results
 - Executable papers? Analysis environments? How long to maintain and what depth of reproducibility?
- **Open** processes
 - How to perform science in the open from the beginning?
- **Inclusive** collaborations
 - How to make collaborations open?

FAIR data and open-source software are NOT enough!

It is okay to start there, but we *must* look beyond for guidance on infrastructure design.

Observational Data

- A growing number of datasets...
 - Are **searchable** through a modern interface (using SPASE),
 - Have **citable** DOIs independent of publications,
 - Are **downloadable** both through web pages and APIs,
 - Are **browsable** via quick-look plots, and
 - Are available on the **cloud**.

How can PyHC better advertise data access and analysis support in PyHC packages?

The image shows two web interfaces. The top interface is the 'Heliophysics Data Portal' from the 'GODDARD SPACE FLIGHT CENTER Space Physics Data Facility'. It features a search bar with 'Text Restriction', 'Time Span Restriction' (YYYY-MM-dd or YYYY-DDD), and 'Element Restriction' (Resource type, Measurement type, Observatory Group, Observatory, Instrument, Observed region). The 'Current Product Restrictions' section shows 'Metadata contains 'electron'' and 'Metadata contains 'energy''. The main results table shows 301 products, with the first entry being 'MMS 3 Electron Drift Instrument (EDI) Quality Zero Counts, Level 2 (L2), Survey Mode, 0.125 s Data' with a DOI of 'https://doi.org/10.48322/cwb6-vf46'. The bottom interface is the 'Solar Data Analysis Center' (SDAC), which displays 'Current Solar Images' and a grid of five solar images from the 'Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA)'. The images are labeled with their respective wavelengths and timestamps: Fe XVIII 94 Å (2023/05/04 16:50:59), Fe XX 131 Å (2023/05/04 16:51:06), Fe IX/X 171 Å (2023/05/04 16:51:09), Fe XII 193 Å (2023/05/04 16:51:04), and Fe XIV 211 Å (2023/05/04 16:51:09).

GODDARD SPACE FLIGHT CENTER
Space Physics Data Facility

+ Goddard Home
+ Visit NASA.gov

Heliophysics Data Portal

"Find it. Browse it. Get it."

SPASE inside

Help Geo Orbits Helio Orbits SPASE Registry ADS Abstracts Feedback

Text Restriction
[Input Field] Add

Time Span Restriction ⓘ
YYYY-MM-dd or YYYY-DDD
from: [Input Field] to: [Input Field] Add

Element Restriction ⓘ
Resource type ⓘ
Measurement type ⓘ
Observatory Group ⓘ
Observatory ⓘ
Instrument ⓘ
Observed region ⓘ
Spec
Cade
Repo
Acce
Form

Current Product Restrictions Remove All
Metadata contains 'electron' Remove
Metadata contains 'energy' Remove

Showing 301 - 320 of 562 Results View Current List Sort by Observatory

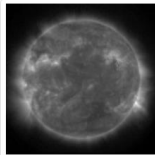
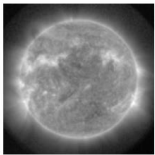
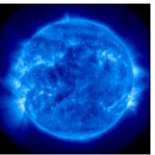
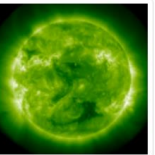
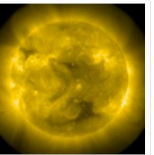
#	Products (& SPASE descriptions)	Information and Access Links
301	MMS 3 Electron Drift Instrument (EDI) Quality Zero Counts, Level 2 (L2), Survey Mode, 0.125 s Data https://doi.org/10.48322/cwb6-vf46	<ul style="list-style-type: none">• FTPS from the MMS SDC (not with most browsers)• HTTPS from the MMS SDC• FTPS from SPDF (not with most browsers)• HTTPS from SPDF• CDAWeb• CDAWeb HAPI Server• The Magnetospheric Multiscale (MMS) Mission home page at Goddard Space Flight Center (GSFC)• Data Caveats and Current Release Notes at LASP MMS Get Data/Plots

Solar Data Analysis Center

Home Solar Images News Research Data Online Web Resources Outreach About

Current Solar Images
Click on any of the following thumbnail images for the most recent, solar image of each type in the SDAC archive, at the highest resolution available on the same day as the images are obtained. The page automatically reloads images every 30 minutes. All times are in coordinated Universal Time (UTC).

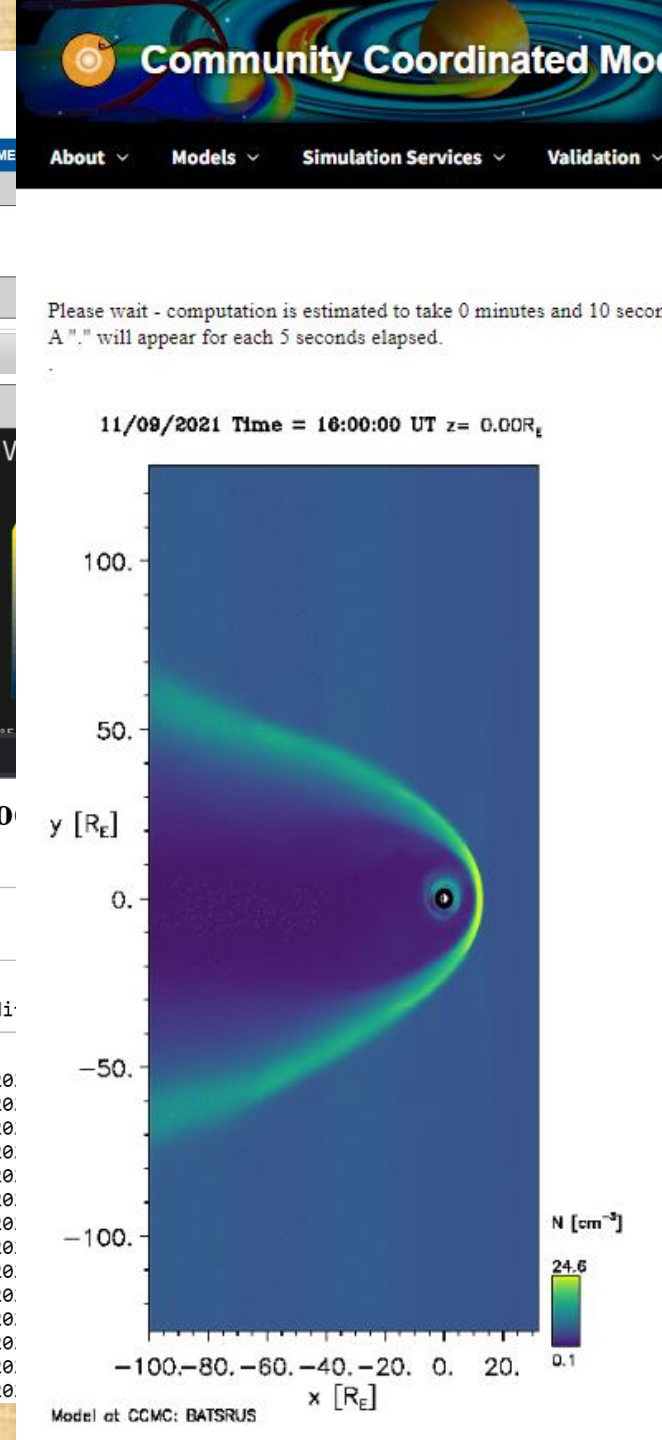
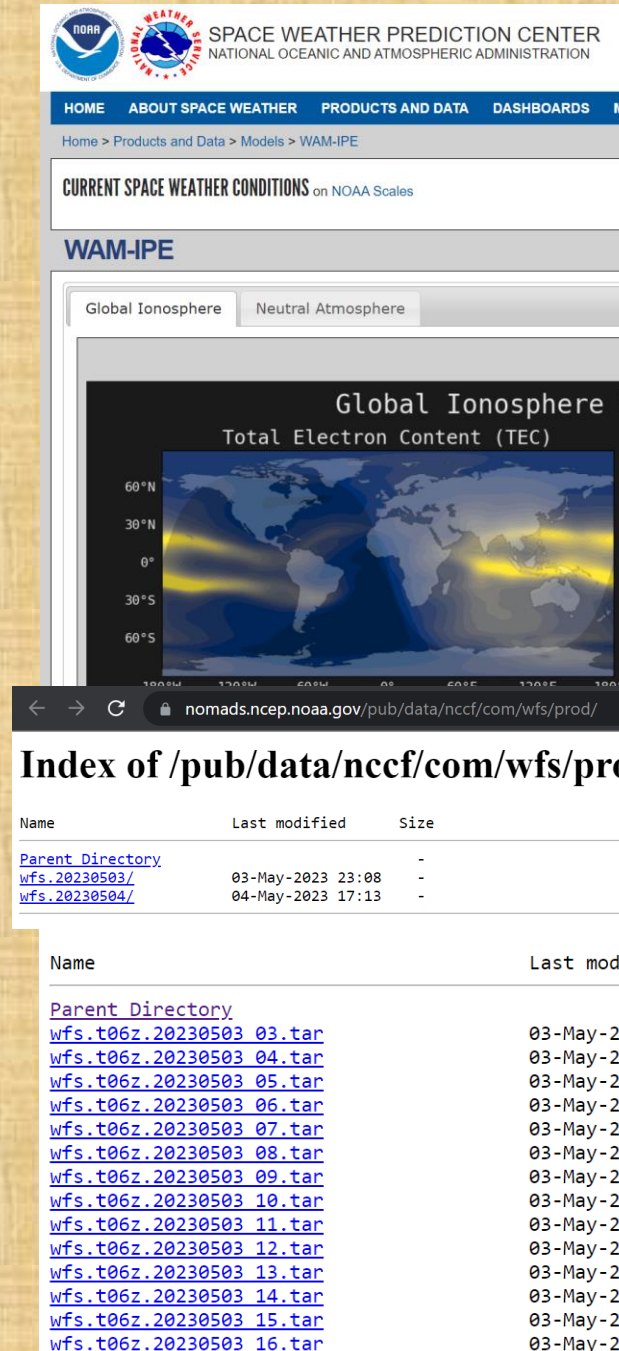
Solar Dynamics Observatory (SDO)
Atmospheric Imaging Assembly (AIA)

 Fe XVIII 94 Å 2023/05/04 16:50:59	 Fe XX 131 Å 2023/05/04 16:51:06	 Fe IX/X 171 Å 2023/05/04 16:51:09	 Fe XII 193 Å 2023/05/04 16:51:04	 Fe XIV 211 Å 2023/05/04 16:51:09
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Modeled Data

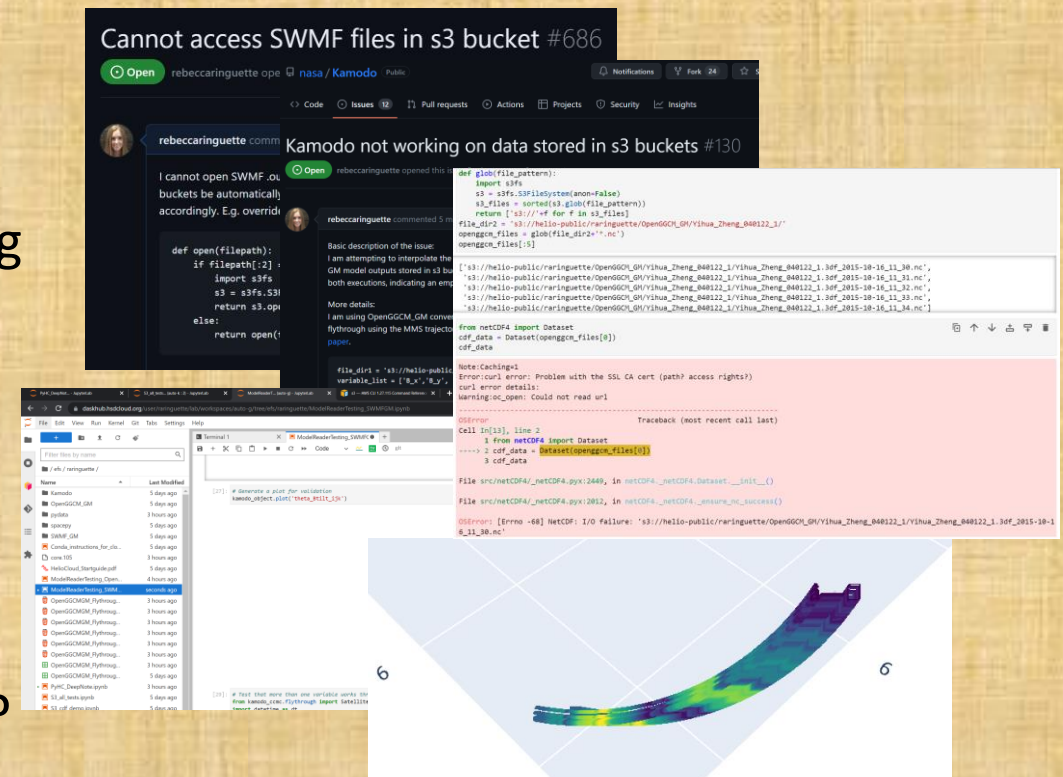
- Infrastructure supporting modeled data is **far less developed**.
 - No modern **search** interfaces,
 - **DOIs** are not assigned,
 - Few modeled datasets are **downloadable** through a website,
 - Only reduced versions are **available** through an API, and
 - Some quick-look **plotting** capabilities are available, but are not easily accessible.

How can PyHC help with these issues?



Software

- Sustained push is underway to **open-source all software** (including modeling code) generated with taxpayer dollars.
- Open-sourcing software is **NOT enough**.
 - Dependency conflicts (!),
 - Conda/pip installability on multiple operating systems (e.g. Mac, Windows, Linux),
 - Lacking documentation,
 - Need examples and tutorials,
 - Capability to run on the cloud,
 - Maintenance for long-term reusability,
 - Support staff for questions/problems, and
 - Containerization for software environments?



PyHC should take the lead here. What paths forward have low-hanging fruit?

Where is this going?



- Build a **distributed data infrastructure** system:
 - **Observational and modeled data** hosted and served by multiple institutions,
 - **Containerized model codes** available on the cloud from multiple institutions,
 - All searchable from a united modern interface through **connected metadata**,
 - All **accessible** using multiple methods (e.g. file links, APIs, quick-look plots).
- Build a **collaborative analysis infrastructure** system:
 - Analysis environments with **software already installed** (and referenceable),
 - **Reusable executable** analysis tutorials for how to use the data,
 - Searchable through **connected metadata**,
 - **Accessible** through the cloud (e.g. downloadable containers or cloud platforms).

How can PyHC prepare for, collaborate with, and enable these infrastructures?

Discussion Time!

Discussion: PyHC support of Open Science

miro free • PyHC 2... ⚙️ ↗ 🔍 > 🕒 📄 🖨️ 📅 📋 ⌵

👤 ⚡ 🔔 Present ▾

How can PyHC support Open Science?

Take a note!

Frame 1

What PyHC software changes are needed to better support the open science experiment? Which of these need funding?

- How to run on data stored in s3 buckets?
- What software standards or journals for OS data access (e.g. bioRxiv, iGEM)?

Take a note!

Take a note!

Frame 2

How can PyHC better advertise data access and analysis support in PyHC packages?

- Provide a central repository for code and data (e.g. GitHub, Zenodo)
- Create links to the online documentation from package README files

Take a note!

Take a note!

Frame 3

How can PyHC help with accessibility issues for modeled data?

- Provide guidance for community on writing models in other languages (e.g. C++, Java, Python, etc.)
- Provide a way to include models in other languages in a pipeline workflow

Take a note!

Take a note!

Frame 4

How can PyHC prepare for, collaborate with, and enable the next generation of infrastructures?

- Provide containerized analysis tutorials
- Publish a referenceable commercial PyHC software environment
- Demonstrate how to run software on the cloud
- Generate a DOI for software packages in PyHC as a service?

Take a note!

— 34%

Discussion: PyHC support of Open Science

Scan the QR code or use the link to contribute to the discussion!

<https://tinyurl.com/5n6tsxt6>



What PyHC software changes are needed to better support the open science experiment? Which of these need funding?

How to run on SWMF GM data stored in s3 buckets?

Need a metrics script examples that uses PlasmaPy

mean error, RMS, root square mean, absolute error

We need funding for long-term maintenance of code!



Code Standards implementing best practices

a common release schedule so that there is always a compatible / functioning, relatively recent and complete set of PyHC tools

standardized packaging
prereqs
install scripts
dir structure

PyHC packages should test against the main branch or release candidates of their dependencies

acknowledgment of the code in papers

understand/development of the metric of the code "usefulness"

DOI's for software - should PyHC offer DOI minting or should a DOI be required for software to be listed by PyHC?

How can PyHC better advertise data access and analysis support in PyHC packages?

Generate a SPASE metadata record for software to better enable searchability at HDRL?

Create links on the archive dataset pages/entries to relevant tutorials?

Webinars (similar to pySPEDAS)

PyHC office hours?

More example notebooks in PyHC gallery that use multiple packages together

Improved keyword usage/search in PyHC Projects page

Also, improve the PyHC gallery ;)

Advertisement at ALL conferences

have a standard set of tutorials that anyone going to a meeting can take so that we have lots of representatives who do the training

we need an army of tutors - offer specific PyHC grants for people to do promulgation - or this could be an add-on to another grant - a little extra money to attend one or two extra meetings and give tutorials

<-- Category that separates solar physics, magnetospheric, etc?

Out-of-the-box: A custom GPT-powered chatbot on pyhc.org that can explain what's available in conversation

community crib sheets with examples for how to use a package - as someone learns to use a new package, the sample code they create (with some curation?) could be useful examples for the next newcomer

<--- Can pull from the PyHC summer school tutorials, our gallery, etc, and create some kind of nice pre-packaged set of examples for training?

Should PyHC hire a community manager like Astropy?

<-- include these in the PyHC gallery?

Data archives point to PyHC packages that work well with that data.

Hosting work parties to improve project documentation

booth with tutorials at meetings

How can PyHC help with accessibility issues for modeled data?

Provide guidance to community on calling scripts in other languages (e.g. C, C++, Fortran, IDL, etc)

get CCMC to engage more with the community and find out more about what users need

many modelers are using Paraview, so PyHC could spend resources to support Paraview

Advise on how to include scripts in other languages as dependencies in a pip/conda installation.

Simplify the process to have SpacePy as a dependency

Create metadata standard(s) for simulation inputs/outputs

standardized Data Storage format access methods

modeling results hosting/server should exist

make a specific call in the HTM NASA AO for improving model access

Partner with IHDEA

How can PyHC prepare for, collaborate with, and enable the next generation of infrastructures?

Provide containerized analysis tutorials

Publish a referenceable containerized PyHC software environment

Demonstrate how to run software on the cloud.

Generate a DOI for software packages in PyHC as a service

What software standards to pursue for s3 data access (e.g. boto3, s3fs)?

data access beyond local files of all kinds (HAPI, other companies' clouds)

Improve culture by building a foundation of psychological safety

Per Gretche's diagram where the last step before making open science required is making open science being rewarding, we should advertise how it's rewarding (and if we can't figure out how its rewarding to individuals, we reconsider making it more rewarding)

is Podman/Docker a viable 'package system' for prereqs+code to work?

<https://docs.sylabs.io/guides/3.5/user-guide/introduction.html>
(singularity)

Continued outreach to the next generation of scientific software developers and scientists through engaging and informative PyHC Summer schools, presentations and booths at other meetings, etc.

Funding for a software engineer who focuses on package/docs/testing infrastructure?

Docker alternative: <https://podman.io/>

The Execution Model prevent arbitrary code execution (aka no bitcoin mining and spam)

yearly simultaneous release of all PyHC packages for compatibility

Hackathon or similar to try out a lot of different ways to containerize/compartamentalize a turnkey py?HC environment

allow multiple options for obtaining a viable collection of PyHC tooling

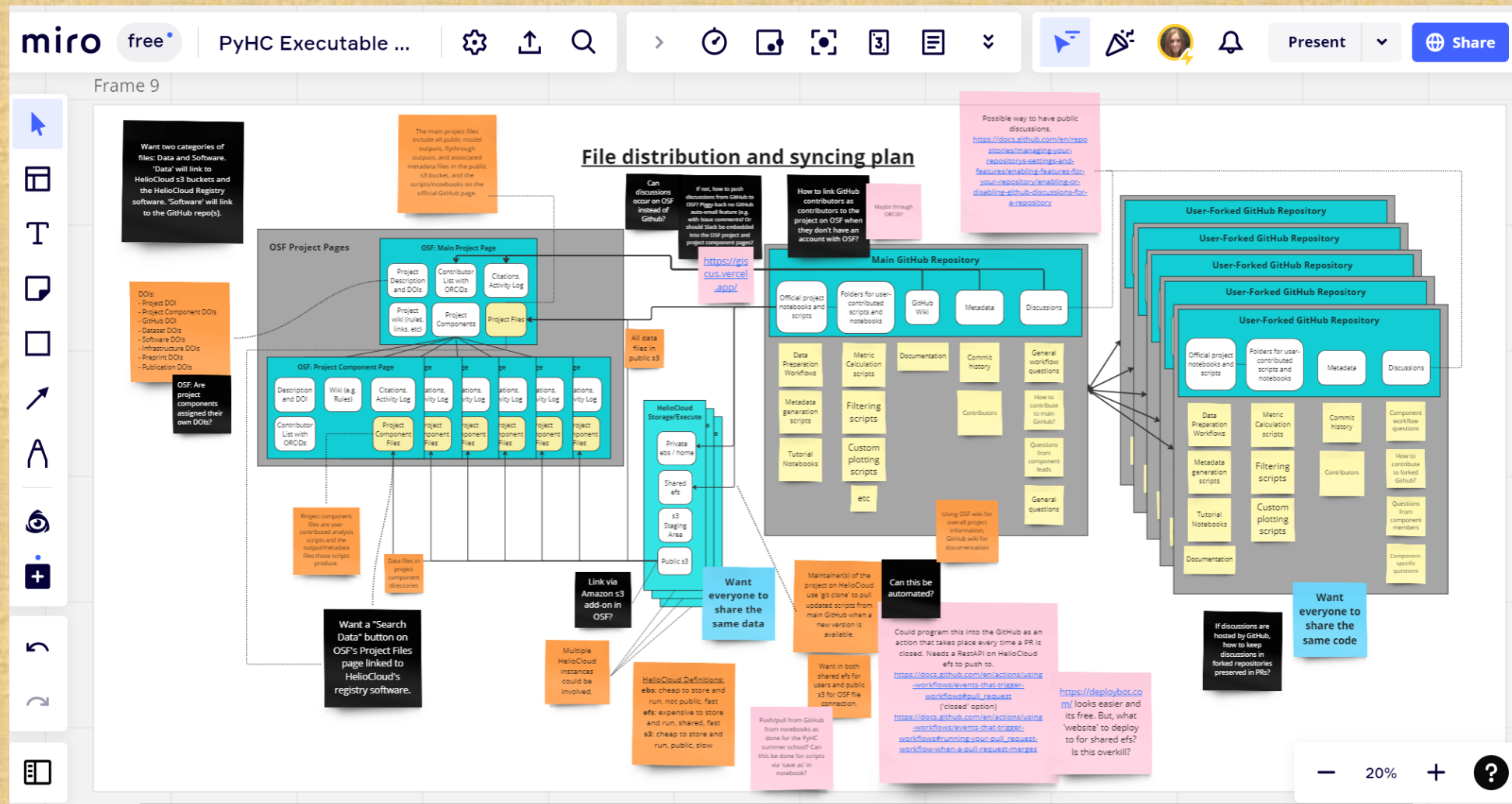
use singularity instead of Docker

Hardware dependence/support (large data, high core count, large memory, GPUs)

Useful Links

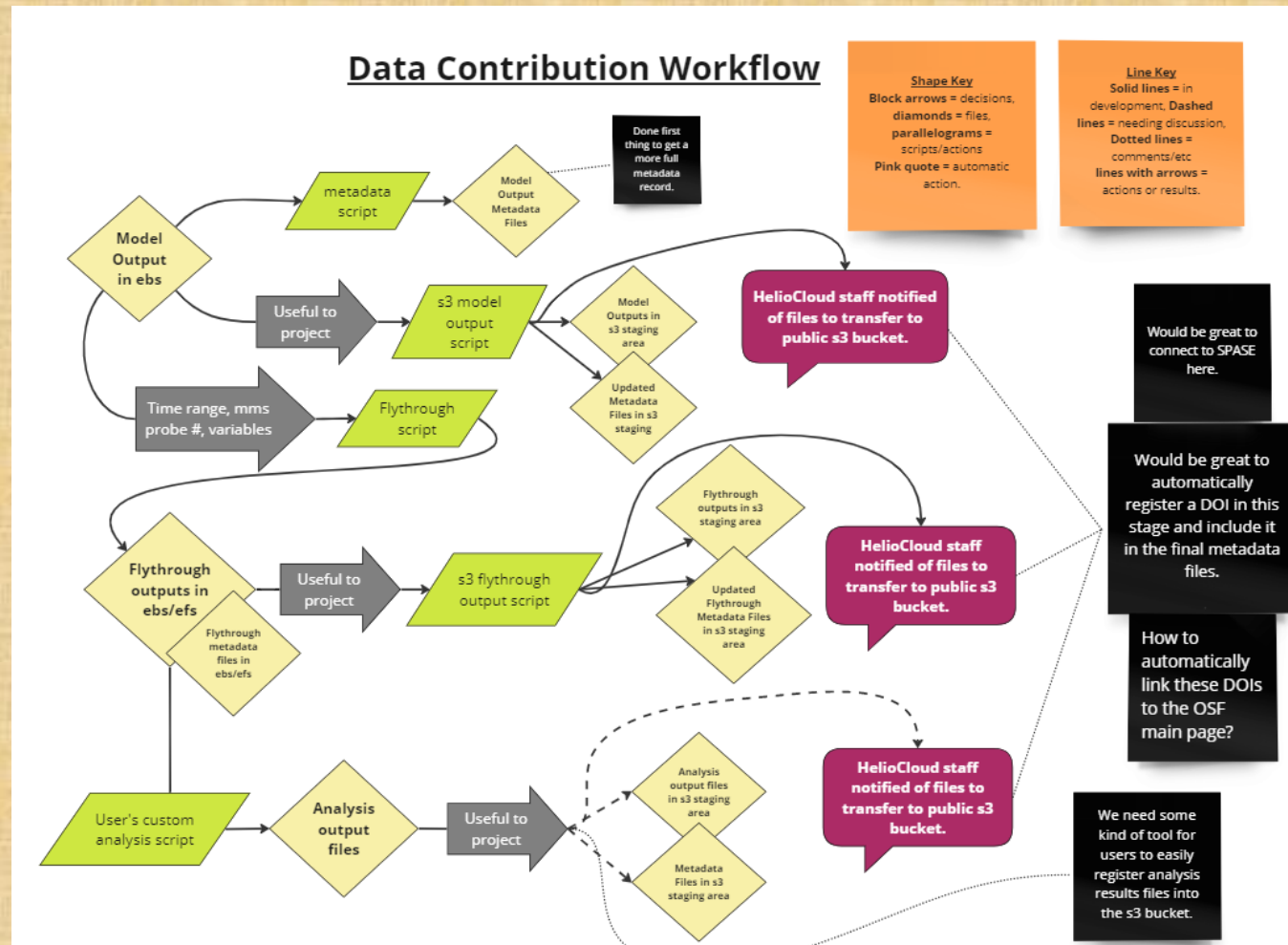
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- GitHub project page: <https://github.com/rebeccaringuette/MagnetopauseExecutablePaper> or <https://zenodo.org/badge/latestdoi/631044088>
- HelioCloud: <https://daskhub.hsdcloud.org>
- CCMC 2015 Magnetopause challenge: <https://ccmc.gsfc.nasa.gov/challenges/gem-magnetopause/>
- Polson et al. 2022 journal article: <https://doi.org/10.3389/fspas.2022.977781>
- Polson et al. 2022 on Deep Note: https://deepnote.com/workspace/shawn-polson-c095a0fb-f02d-416d-9c94-c4a9c4e8e54d/project/PyHC-Paper-101b9646-3fd0-4978-a48e-a4f3e708a0ac/notebook/Making_an_Executable_Paper_with_the_Python_in_Heliophysics_Community_to_Foster_Open_Science_and_Improve_Reproducibility-c3a5772e5ce24ce1942b001696d52251
- This presentation's link on PyHC's google drive: https://docs.google.com/presentation/d/1c2bP0zDdiJWMCPZZxzm9U3zx80NPH_SC/edit?usp=share_link&ouid=118198339287841207428&rtpof=true&sd=true
- Miro board link with preliminary project workflows (view): https://miro.com/welcomeonboard/Q05NeGI2M0taVGtxekJjZXkzVzJsdzFud3R3SIF4RWJ4RGNOXNBmazZheThhd1d4aUNLcIVDOFM1WHhXa01ZWXwzMDc0NDU3MzU3OTk0ODcyOTEyfDI=?share_link_id=953968385486
- Miro board link with PyHC 2023 spring session discussion (edit): https://miro.com/welcomeonboard/M2JRd2NNSXhPcXpPRXZJbDFHczcwRHNqYzUzSk9XeIBzeVdkT2p3NThhQIVBRkQ4VEJzaXc5MWNGT3dhUklxR3wzMDc0NDU3MzU3OTk0ODcyOTEyfDI=?share_link_id=522570131865

Project Tour: Preliminary Project Workflows



https://miro.com/app/board/uXjVMaO61l=/?share_link_id=703942255605

Project Tour: Preliminary Project Workflows



https://miro.com/app/board/uXjVMMaO61l=/?share_link_id=703942255605

Project Tour: Preliminary Project Workflows

