PREFIRE at ASDC Revolutionizing Polar System Observations

The TIRS instrument, a pioneering endeavor, represents a pinnacle in Earth observation technology tailored specifically for Polar Science

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In the ongoing battle against climate change, early detection is key to minimizing impact on communities and ecosystems. Hosted by the Atmospheric Science Data Center (ASDC) at NASA's Langley Research Center, NASA/JPL UW-led PREFIRE mission aims to bridge a critical knowledge gap in climate science by focusing on the far-infrared (FIR) portion of the electromagnetic spectrum, which has been historically under-observed.

Introduction

The Arctic regulates the climate by venting excess energy received in the tropics. Nearly 60% of Arctic emission occurs at wavelengths longer than 15 μm (FIR) that have never been systematically measured. The Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE) quantifies spatial and temporal variability in spectral FIR emission and the atmospheric greenhouse effect.

The PREFIRE mission is comprised by two space-based Thermal InfraRed Spectrometers (TIRS) aboard two small 6U Cubesat satellites. Fundamentally, TIRS is a grating spectrometer with a slit projection on the ground aligned cross-track to the satellite motion - a so-called “push broom” configuration. TIRS contains a 2-dimensional focal plane array detector with one dimension aligned cross-track, parallel to the slit (spatial), and the other dimension containing the spectral information from the scene, perpendicular to the slit.

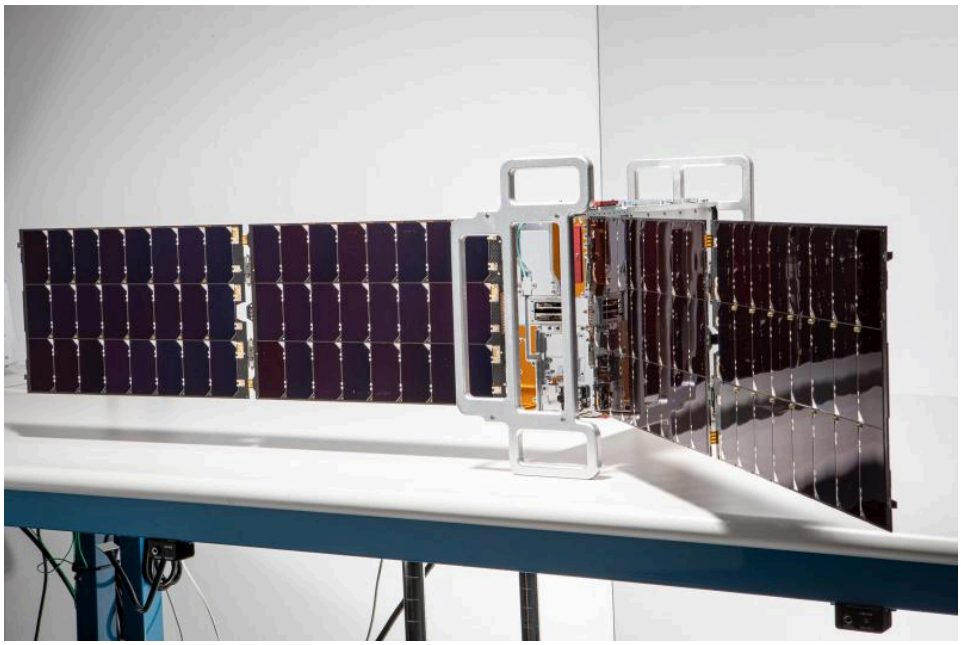
PREFIRE CubeSats represent a new frontier in spaceborne technology. These compact satellites, known as CubeSats for their standardized cube-shaped design, are equipped with cutting-edge sensors capable of detecting far-infrared radiation – a crucial indicator of polar energy emission efficiency.

PREFIRE CubeSats are part of a larger network of Earth observation satellites operated by NASA and other space agencies. By synergizing with existing satellite missions, such as GRACE and CRIS, PREFIRE CubeSats enhance the overall understanding of polar climate processes that

have global implications for severe weather frequency and coastal resilience. This integration ensures that decision-makers have access to accurate projections for sea level rise and storm preparedness.

The PREFIRE CubeSats are equipped with a Thermal InfraRed Spectrometer featuring a wide spectral bandwidth covering a majority of Earth's radiant emission:

- **Sampling:** 8 spatial x 64 spectral pixels, providing hyperspectral spatial information.
- **Spectral Range:** Covers wavelengths from 5 to 54 microns, capturing a wide range of thermal emissions.
- **Spectral Sampling:** With spectral sampling of less than 1 micron, the TIRS achieves fine spectral resolution, enabling identification of process signatures.
- **Optical System:** Utilizes an Offner optical system with a shaped groove grating, optimizing light dispersion and spectral resolution.
- **Detector Technology:** Equipped with thermopile detectors operating at ambient temperature, ensuring reliable performance in space environments.



This image shows one of two shoebox-size Cubesats that make up NASA's PREFIRE.

Functionality and Operation:

The Thermal InfraRed Spectrometers onboard the PREFIRE CubeSats operates on the principle of spectroscopy, analyzing the unique spectral signatures emitted by objects in the far-infrared range. When the dry polar atmosphere weakens the Earth’s greenhouse effect, the additional emission of thermal radiation across the FIR spectrum is captured by the spectrometer and analyzed scientifically.

By splitting the incoming surface radiation into its constituent wavelengths, the TIRS can identify characteristic spectral features associated with different surfaces, distinguishing them for use in climatological projections that provide estimates of future climate change. Alternately, when TIRS detects clouds (instead of the surface), the (previously unmeasured) FIR properties of clouds are determined for similar needs. This allows for

more accurate detection and characterization of Earth's radiative balance.

The ASDC supports over 100 projects and provides access to more than 3,000 archived collections with a global user community from more than 160 countries. ASDC datasets were created from satellite measurements, field campaigns, ground sensors and modeled data products. ASDC projects focus on the Earth science disciplines of Radiation Budget, Clouds, Aerosols, and Tropospheric Composition.

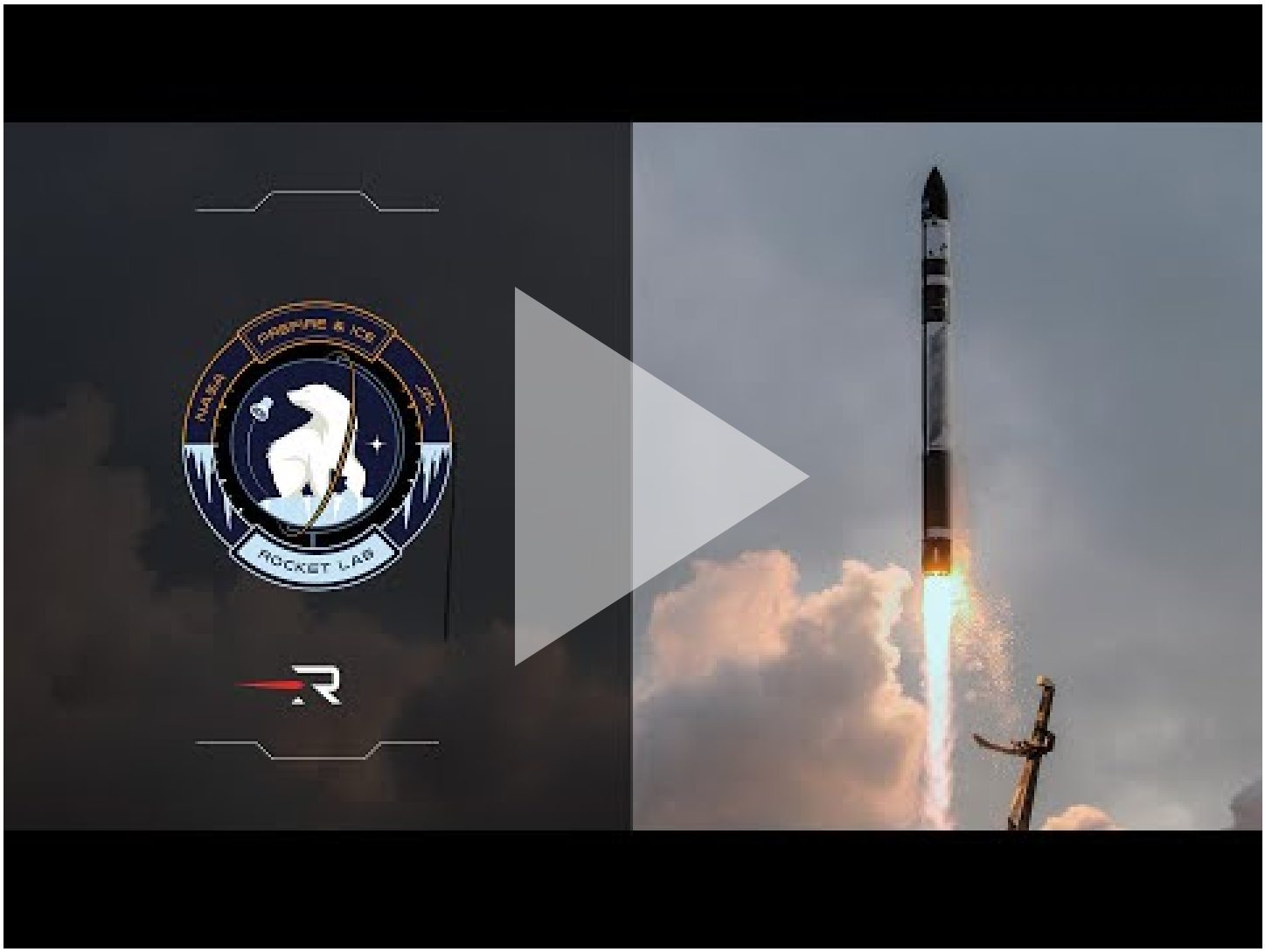
PREFIRE Launch

https://blogs.nasa.gov/smallsatellites/2024/04/29/launch-date-set-for-nasas-prefire-mission-to-study-polar-energy-loss/

NASA contracted Rocket Lab to launch PREFIRE mission satellites by company's Electron rockets from Launch Complex 1 in Māhia, New Zealand. The first satellite, SAT2, was launched on May 25th and the second one, SAT1 was launched on June 5th.

PREFIRE mission objectives

https://prefire.ssec.wisc.edu/



Rocket Lab's *PREFIRE and Ice* launch, the Electron rocket carries the second of two PREFIRE satellites toward space June 5th 2024 from Mahia, New Zealand at 3:15 pm NZST (3:15 am UTC)

Technological Marvel: The TIRS Instrument

The **Thermal InfraRed Sensor (TIRS)** on the PREFIRE mission (Polar Radiant Energy in the Far InfraRed Experiment) is a key instrument designed to capture detailed far-infrared (FIR) radiative fluxes.

The TIRS instrument aims to measure the far-infrared portion of the electromagnetic spectrum (wavelengths from 5 to 50 micrometers). These measurements are critical for understanding the

Earth's outgoing longwave radiation, particularly in the polar regions, where traditional observations have been lacking.

The instrument beamed back its First images on July 5th, 2024, showing the variations of surface and atmospheric emissions near the height of Arctic summer. As expected, the data reveal complex surface/atmosphere energy exchange processes occurring on short time-scales.

The deployment of PREFIRE SAT-1 in the Low Earth Orbit

PREFIRE Mission Objectives

Far-infrared radiation (wavelengths between 15 to 100 micrometers) plays a crucial role in the Earth’s energy budget. It affects the outgoing longwave radiation (OLR) and is vital for understanding the heat exchange between the Earth's surface and the atmosphere, especially in polar regions. Despite its importance, this portion of the spectrum has not been spectrally measured by previous Earth observing missions.

The Arctic, in particular, experiences dramatic seasonal variations in FIR emissions due to its unique surface properties and atmospheric conditions. Understanding these variations is essential for improving climate models, especially regarding the ice-albedo feedback mechanism and cloud radiative effects, which are key to predicting future climate scenarios.

PREFIRE’s contributions are expected to revolutionize our understanding of the Earth’s climate system, particularly in the context of polar dynamics. By providing unprecedented insights into the far-infrared portion of the spectrum, PREFIRE will enhance our knowledge of how the Arctic and global energy budgets are changing in response to human activities and natural variability.

Furthermore, the success of PREFIRE will set a precedent for future missions focused on under-observed aspects of the Earth system. The methodologies and technologies developed for PREFIRE can be adapted and expanded to other areas of climate research, leading to a more comprehensive understanding of our planet.

The PREFIRE mission, supported by the ASDC, is a groundbreaking effort in Earth system science. By focusing on the far-infrared emissions and their role in the Earth's energy budget, PREFIRE is set to provide critical data that will improve climate models and enhance our understanding of polar processes. The ASDC’s expertise in data management ensures that PREFIRE’s findings will be accessible and impactful, contributing to the global effort to address climate change and protect our planet's future.

1. Quantify snow and ice FIR emissivity spectra and their variability on seasonal scales

2. Quantify the FIR Greenhouse Effect (GHE) and its response to seasonal variations in cloud cover and water vapor

3. Quantify (1) and (2) for sub-daily melt processes

ASDC Data Access

The Atmospheric Science Data Center (ASDC) at NASA’s Langley Research Center plays a pivotal role in the PREFIRE mission. The ASDC is responsible for the data management and distribution aspects of the mission, ensuring that the data collected by PREFIRE’s CubeSats is ingested, archived, and made accessible to the scientific community and the public.

In this section we describe the radiometric, spatial and spectral characteristics of a space-based scanning Thermal InfraRed Spectrometer

(TIRS) implemented for the Polar Radiant Energy in the Far-InfraRed Experiment (PREFIRE) mission.

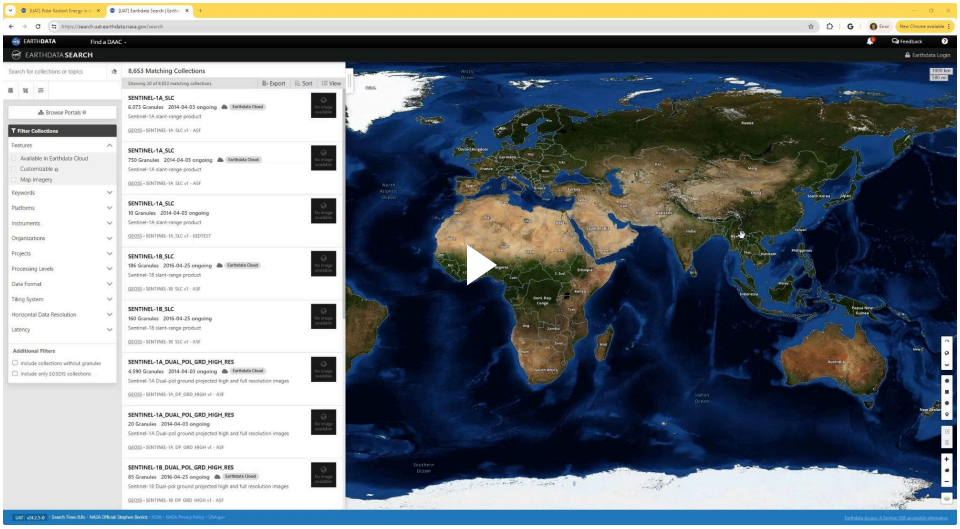
PREFIRE data represents a valuable resource for environmental researchers, educators and policymakers as it offers free and publicly accessible information crucial for understanding the radiation budget of planet earth.

The videos below demonstrates how you can search, access, and download the PREFIRE archived data at the ASDC website. Go to https://asdc.larc.nasa.gov/ and click on "DATA" in the upper right menu, where you can access data via Earthdata Search. Please note that all the data demonstrated in this article are simulated proxy data in the User Acceptance Testing (UAT) environment because the live PREFIRE data are currently undergoing calibration and validation.

Earth Data Search for data download and thumbnails Visualization

You can access PREFIRE simulated data through NASA Earthdata Search https://search.uat.earthdata.nasa.gov/search, you must be registered with an Earthdata Login account https://uat.urs.earthdata.nasa.gov/. Earthdata Search is an open-source platform provided by NASA under Open Source Software Policy SPD-41a. The platform facilitates access to Earth science data and tools, which were instrumental in conducting this study. Browse through the search results to find datasets related to the PREFIRE mission. NASA Earthdata Search provides detailed information about each

dataset, including its description, temporal coverage, and data format. PREFIRE data will be available for download from Earthdata Search in addition to thumbnail visualization, subsetting, and concatenation.



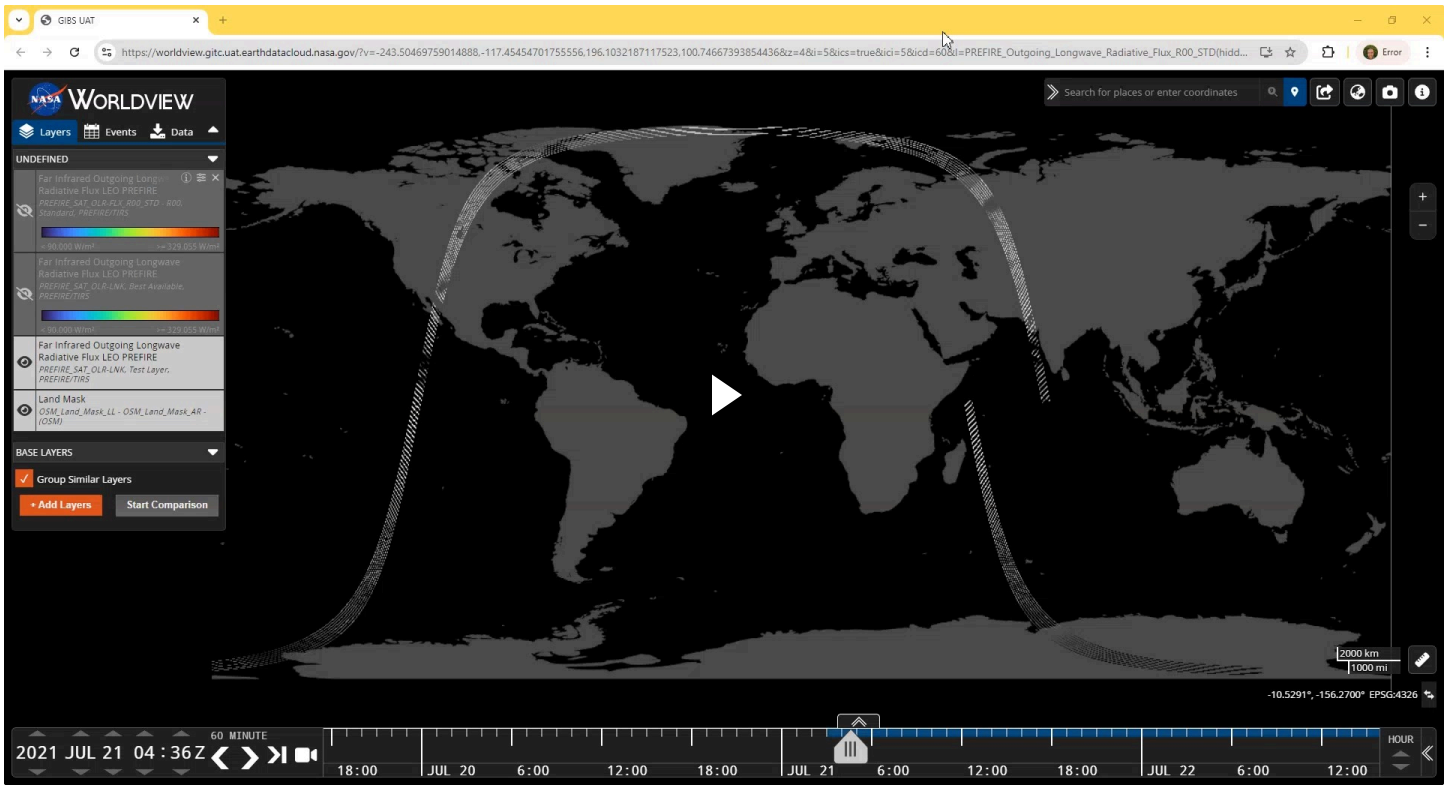
Outgoing Longwave Radiation Proxy Data with Thumbnails from PREFIRE Using NASA Earthdata Search UAT

NASA Worldview in the Cloud User Acceptance Testing (UAT) Environment

https://worldview.gitc.uat.earthdatacloud.nasa.gov/?v=-240.79315201927196,-94.8910521189323,186.92086906526694,117.4065843881331&z=4&i=5&ics=true&ici=5&icd=90&l=PREFIRE_Outgoing_Longwave_Radiative_Flux_Grayscale,OSM_Land_Mask&lg=true&t=2021-07-21-T04%3A36%3A00Z

Another way to explore PREFIRE data is to use the Worldview interface to select a date range, location, and specific data layers you are interested in. NASA Worldview allows you to visualize and download various Earth science data layers, including those related to air quality, climate, and environmental factors. Once you have

selected the desired data layers and timeframe, you can download the data for your research and analysis.

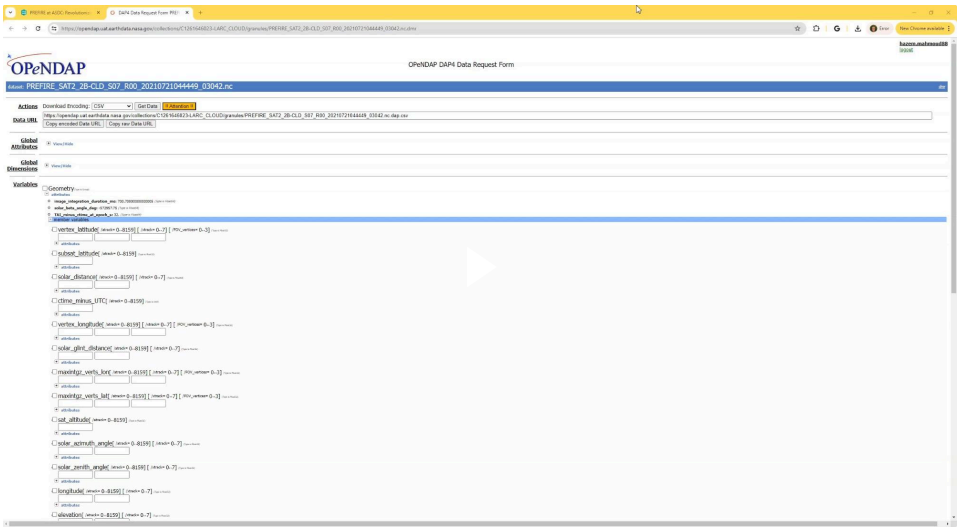


OLR Proxy Data from PREFIRE using NASA Worldview

Open-source Project for a Network Data Access Protocol (OPeNDAP) in the Cloud

https://opendap.uat.earthdata.nasa.gov/collections/C1261646023-LARC_CLOUD/granules/PREFIRE_SAT2_2B-CLD_S07_R00_20210721044449_03042.nc.dmr

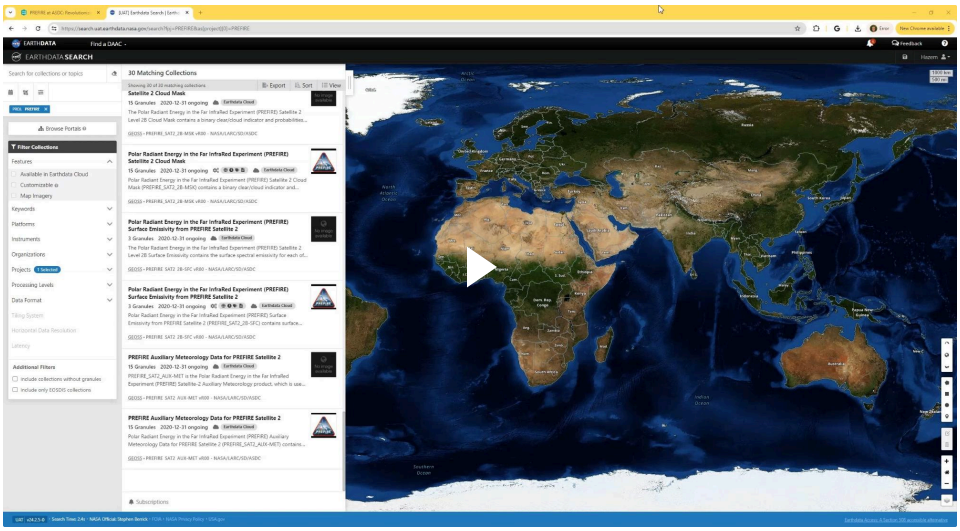
OPeNDAP is a protocol and software toolset designed to simplify and standardize the process of accessing scientific data remotely over the internet. To access PREFIRE data via OPeNDAP, you'll need to know the specific URL or server endpoint where the PREFIRE datasets are hosted. OPeNDAP URLs typically end with ".dap".



Cloud Pressure Proxy Data from PREFIRE subsetting and converting to CSV using OPeNDAP

PREFIRE on ArcGIS pro

PREFIRE data can be imported on ArcGIS pro. After importing the GEOTIFF files from PREFIRE, you can visualize and analyze the PREFIRE data using ArcGIS Pro's powerful geospatial tools, customize symbology, and apply various geoprocessing techniques to gain insights and Radiation budget understanding.



Level 2 OLR PREFIRE Data Hosted On ASDC Cloud Using ArcGIS Pro

Earthdata Subsetting and Concatenation for PREFIRE

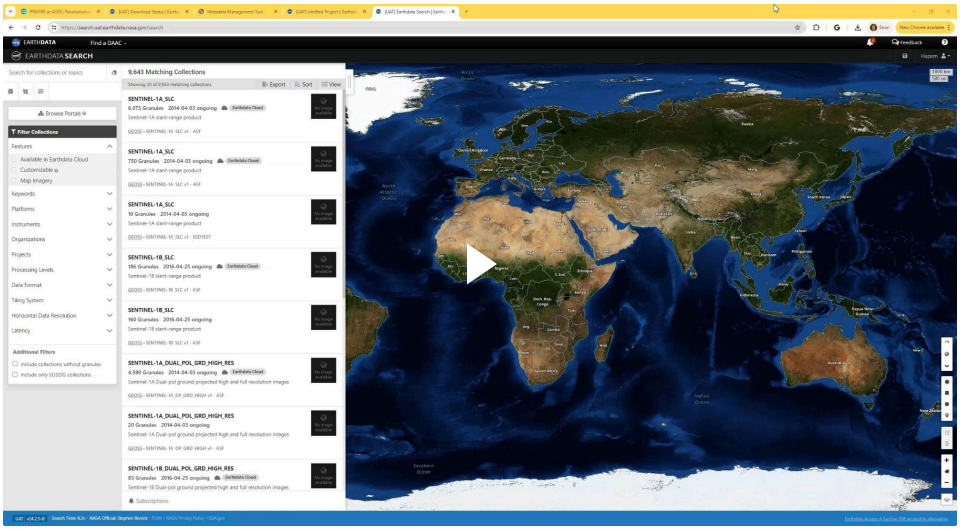
Harmony L2SS (Level-2 SubSetter) is a component of the Harmony project within NASA's Earthdata program. It refers to the software infrastructure and tools specifically developed for processing and generating Level-2 science data products from Earth observation satellite missions. L2SS provides variable, temporal and spatial subsetting for the selected variables in different forms of a bounding box.

This python tool (called “L2SS” or Level 2 Subsetter behind the scenes of Earthdata Search) subsets different file formats like hierarchical data – e.g., Network Common Data Form (netCDF) and Hierarchical Data Format (HDF) – files into a single file by variable/s with temporal and spatial filters.

Level-2 science data products are derived from raw satellite measurements and undergo various processing steps to extract meaningful information about the Earth's environment. These products often involve higher-level analysis, data fusion, and additional algorithms to generate geophysical parameters relevant to scientific research, such as atmospheric composition, land surface properties, or oceanic variables.

Configuration options allow the saving of temporary directories to facilitate testing in a local computing environment. The core functionality is configured such that It is

containerized and operates in configuration with NASA Harmony orchestrator service.



PREFIRE Cloud mask subsetting and concatenation using Harmony

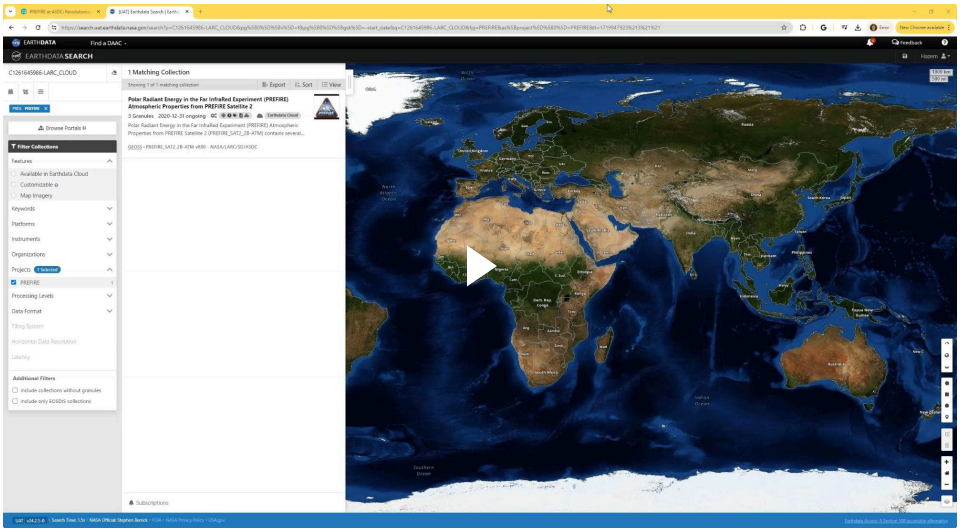
Earthdata conversion from NetCDF to ZARR for PREFIRE

Harmony provides a conversion service that allows users to convert NetCDF (Network Common Data Form) data files to the ZARR format. This conversion service enables users to leverage the benefits of the ZARR format, which is a more modern and efficient data storage format for multidimensional array data.

NetCDF is a commonly used format in Earth science for storing and sharing scientific data. However, as data volumes grow and the need for scalable and performant data storage arises, the ZARR format has gained popularity. ZARR offers advantages such as chunk-based storage, efficient compression, and parallel access to data, making it suitable for handling large and complex multidimensional datasets.

The Harmony NetCDF to ZARR conversion service allows users to transform their NetCDF datasets into the ZARR format, preserving the structure, metadata, and attributes of the original data. This conversion process involves rearranging and reorganizing the data into a ZARR hierarchy, optimizing it for storage and retrieval efficiency.

By converting NetCDF files to ZARR, users can benefit from improved data access and performance, reduced storage requirements, and enhanced compatibility with modern data analysis tools and libraries that have native support for the ZARR format.



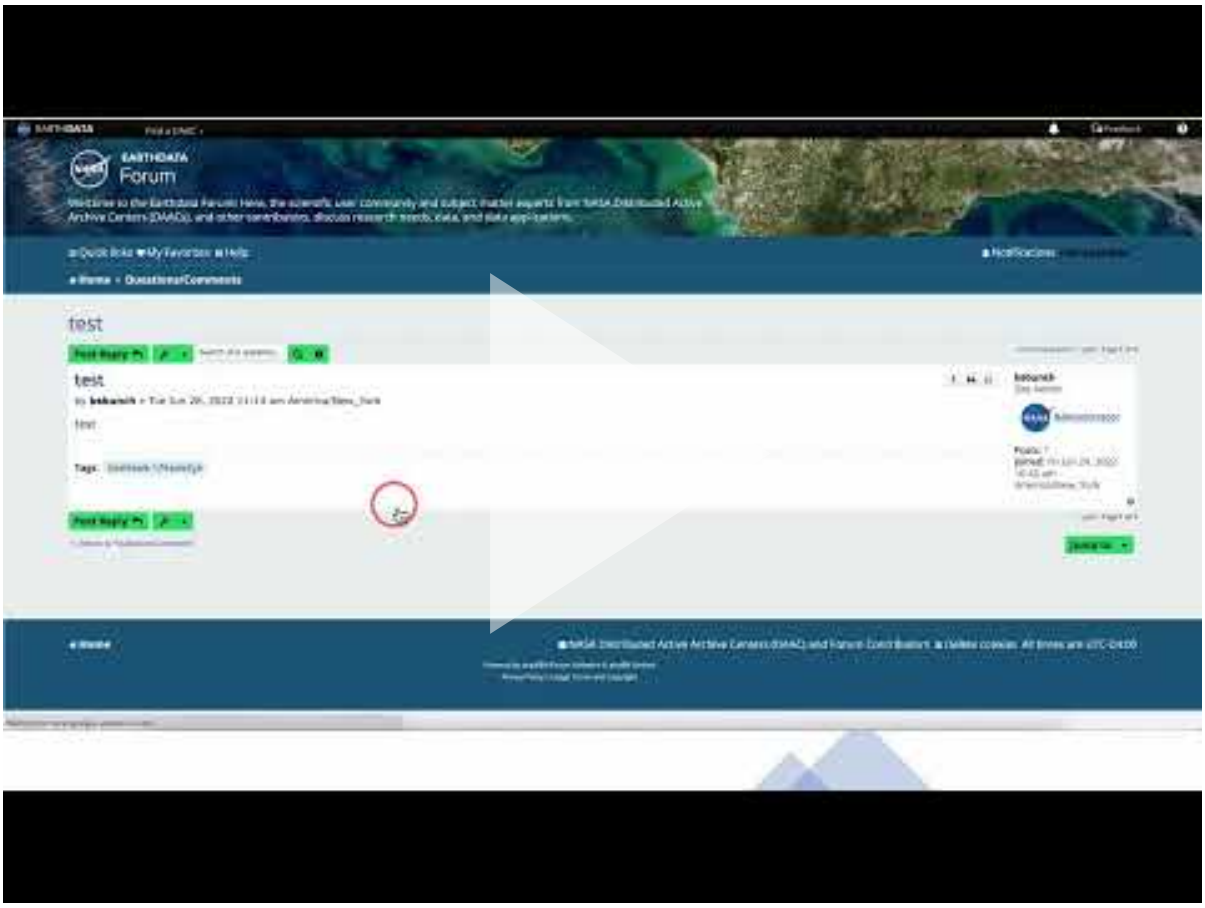
PREFIRE Data conversion using Harmony NetCDF to ZARR for Atmospheric properties Data Hosted On Earth Data Cloud

Earthdata Forum

https://forum.earthdata.nasa.gov/

The main objectives of the Forum are to improve user services and to support knowledge sharing and management throughout the NASA Earth science community. The Forum assumes both a proactive and

reactive approach to NASA products' scientific queries. The Forum proactively posts announcements and news regarding products, new data releases, and more. In addition, the Forum allows the scientific community to ask questions about NASA's products, tools, and services. All users of the Forum can navigate the site and view posts and announcements; however, to post a question to the Forum, a user must be registered with an Earthdata Login account.



NASA Earthdata Forum Quick Video Guide: How to Post a New Question

Acknowledgements:

- NASA (The National Aeronautics and Space Administration)
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