NASA'S EARTH INFORMATION SYSTEM

OPEN, ACCESSIBLE AND INTEGRATED SCIENCE TO IMPROVE LIFE ON EARTH

NASA is best known for space-based missions: Satellites looking out into the solar system and beyond, probing the depths of the universe. A large fleet of satellites, however, gaze down at our own planet, measuring varied aspects of our atmosphere, land surface, and ocean.

NASA collects, processes, and releases data from these missions for anyone in the world to use. Individually, these datasets give an incomplete and often biased picture, but when combined with our physical understanding of Earth systems, we can generate products that are not only complete, but easier for people to understand and utilize.

Translating Science into Actionable Information

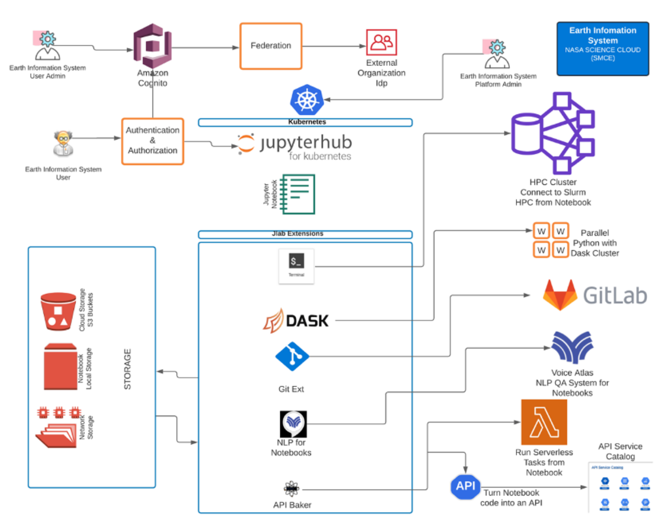
Consider this example: Many Earth-gazing satellites measure radiance, but what people actually care about deriving from this data is information on global temperature and how it's changing.

Likewise, while people are more interested in temperature change than in satellite radiance, they are a lot more interested in local-scale impacts. NASA's **Earth Information System** (EIS) translates scientific results into actionable information by tackling specific, local-scale questions, such as:

Will my area flood during the next big storm?

Will the air in my area be unsafe to breathe because of smoke from fires?

Will there be enough water for my crops this season?



A detailed look at the SMCE open infrastructure components built using AWS services

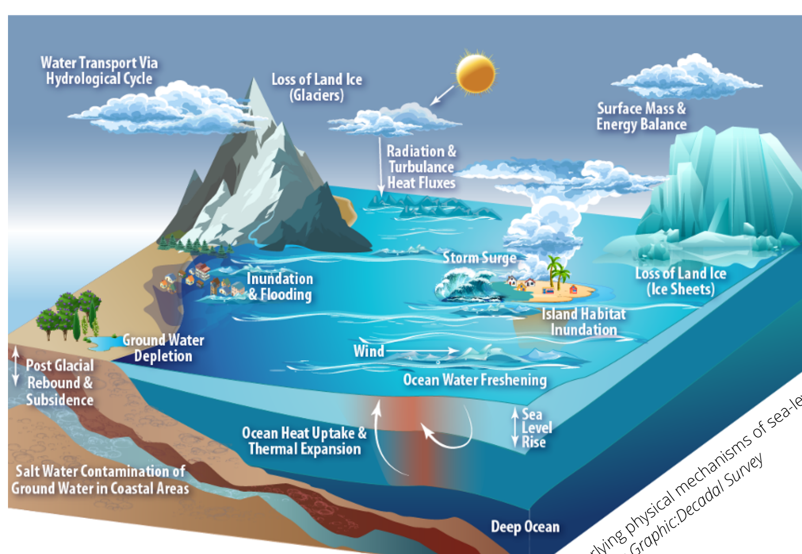
The ability to answer these questions requires seamless access to satellite data and model output that simultaneously advances NASA's science goals and meets a broad range of stakeholder needs. EIS takes all of NASA's Earth Science capabilities, which are already powerful in isolation, and combines them to do new and interesting science by taking advantage of the new capabilities of cloud computing. EIS then delivers that science to the people who need it.

At a Glance: EIS Pilot Studies

EIS combined the unique scientific and engineering strengths of NASA's centers to develop a unified cyberinfrastructure for Earth Science and applications. This integrated platform was applied to three pilot studies over a six month period: Sea-Level Change, Fires, and Freshwater.

Sea-Level Change: *Breaking barriers to collaboration & connecting process models to observations*

Global average sea level rise does not equip stakeholders with information about how sea level will impact communities; the public needs specific, local-scale information that NASA provides. The Sea-Level Change pilot study focused on the contribution of the Greenland Ice Sheet to sea-level change and its impact on the coast at Hampton Roads, VA. To address this, EIS-Sea Level Change implemented four existing process models on the Science Managed Cloud Environment (SMCE) that simulate ice sheet surface processes, ice sheet flow, ocean circulation, and solid earth adjustment to ice sheet mass change. Typically, these models are implemented and run on disparate, on-premises systems and researchers must spend time transferring and managing model inputs and outputs among one another. EIS saved users a great deal of time by implementing models on one cloud-based computational and analysis system, allowing users to share code, reproduce results, and build on what others had developed very quickly.



Underlying physical mechanisms of sea-level variability Graphic:Decadal Survey

The EIS Sea Level Change team implemented a tool to compare modeled ice sheet mass and thickness changes with satellite observations as well as an interactive plotting utility for visualizing vertical land motion at Hampton Roads. Guided by Open Science principles, scientists, cloud engineers, and software developers compiled and installed models and co-developed Jupyter notebooks to configure and launch the models and to analyze their output. By granting researchers access to Python programming language via Jupyter notebooks, analysis could be done using open-source libraries, without the need for proprietary software. This provided limitless possibilities for the types of calculations that could be done, differentiating the EIS collaboration hub from existing tools such as NASA's Data Analysis Tool, which, by design, has limits to the types of calculations that it can perform.

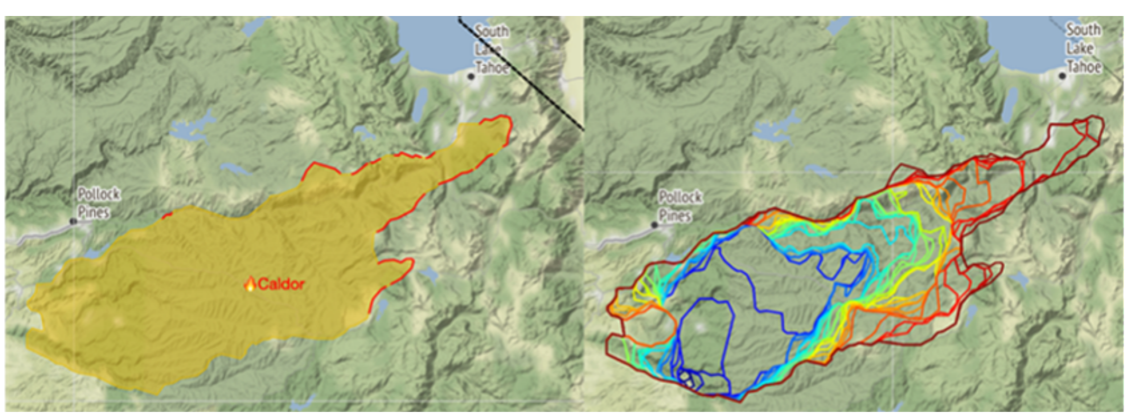
Fires: *Harnessing NASA's unique data and models to understand the impacts of new extreme fires in the earth system*

To thoroughly understand fires and their impacts, you need a breadth of information, including antecedent weather and climate conditions, land surface properties, active fire detections and high-resolution fuel maps, and information on factors that influence air quality both in the vicinity of the fire and elsewhere. NASA data and model output related to fires is scattered across a variety of data portals and distribution mechanisms, making it difficult to do truly comprehensive fire science, especially at the scale of individual fires. EIS-Fire brought all of this information to a single location, allowing people to comprehensively study individual fires. EIS utilized common storage location and cloud-optimized formatting of datasets to virtually eliminate complex and time-consuming procedures required to pre-process data, allowing more time for analysis. Rather than reinventing the wheel, EIS leveraged open community standards and tools, granting new users from anywhere, (both internal and external to NASA), access to the cloud platform in minutes.

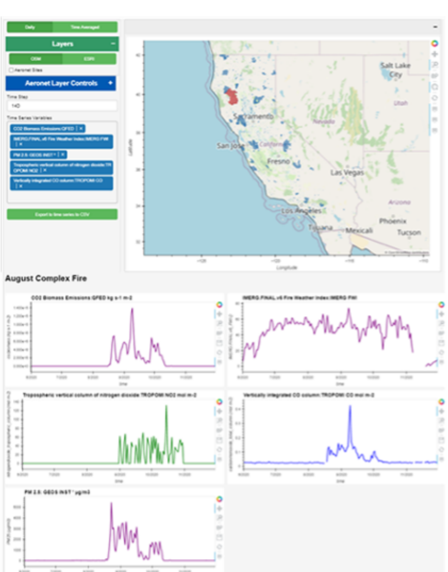
The EIS fire team translated low-level NASA data and model outputs (e.g., detailed chemical composition of the atmosphere from the GEOS model; pixel-level active fire detections), which normally require technical expertise to interpret, into information that stakeholders and the public could easily understand and utilize (e.g., near surface PM 2.5 estimates; individual fire perimeters and the location of the active fire line). To do this, the EIS-Fire team harmonized access to satellite, model, and ground-based datasets in cloud-optimized, analysis-ready formats. EIS demonstrated the ability to track individual fires using VIIRS data, and assimilated VIIRS active fire data to improve fire emissions in GEOS. This pilot study only scratched the surface of NASA fire data; looking to the future, there is plenty more to integrate in terms of unlocking real-time science and applications.

Freshwater: *Integrating data and models across the full water cycle to deliver actionable freshwater information*

Freshwater involves multiple earth systems interacting with each other; relying on isolated data or single models often leads to misleading results. Similarly to fire, a key theme of the Freshwater team was integrating multiple different sources of information from a variety of NASA models and data to truly understand an event; in this case, the 2019 floods in the US Midwest. These floods resulted from a perfect storm of compounding factors: high rainfall, rapid snowmelt, flooding, drenched soils, and ultimately delayed planting. The EIS-Freshwater environment materialized from the need for an interface that describes NASA water cycle science simply, in order to appeal to a broad set of users: from scientists and applied science users, to water managers and the public. The EIS-Freshwater pilot demonstrated examples of rapid innovation enabled by breaking down barriers to NASA data and models.



The EIS Fire pilot used a new VIIRS-based algorithm to demonstrate the ability to track the position of active fire fronts (left) and fire spread every 12 hours (right) for the Caldor Fire on September 1st, 2021.



Interactive dashboard displaying a time series of multiple satellite and model datasets spatially averaged over a selected fire perimeter.

Through open science tools, EIS Freshwater was able to effectively distribute water cycle science to a broad set of users. Multiple constraints from NASA remote sensing instruments were included, such as GPM, SMAP, GRACE-FO, AMSR2, and MODIS within the models. Each of these inputs were found to be critically important for capturing key processes and their impacts. The open science SMCE environment enabled the pilot project to interact more easily with science users in different realms, enabling rapid prototyping of models, including the remote sensing-informed hydrology outputs of LIS being used to develop water quality outputs with SWAT. The potential value of EIS-Freshwater was also demonstrated in economic impacts: each flood and drought case study examined in the pilot project had associated economic impacts of $3-35 billion dollars. In the future, EIS Freshwater can empower stakeholders and the general public by translating the data of water cycle science into actionable information by employing similar modeling/monitoring efforts in real-time.

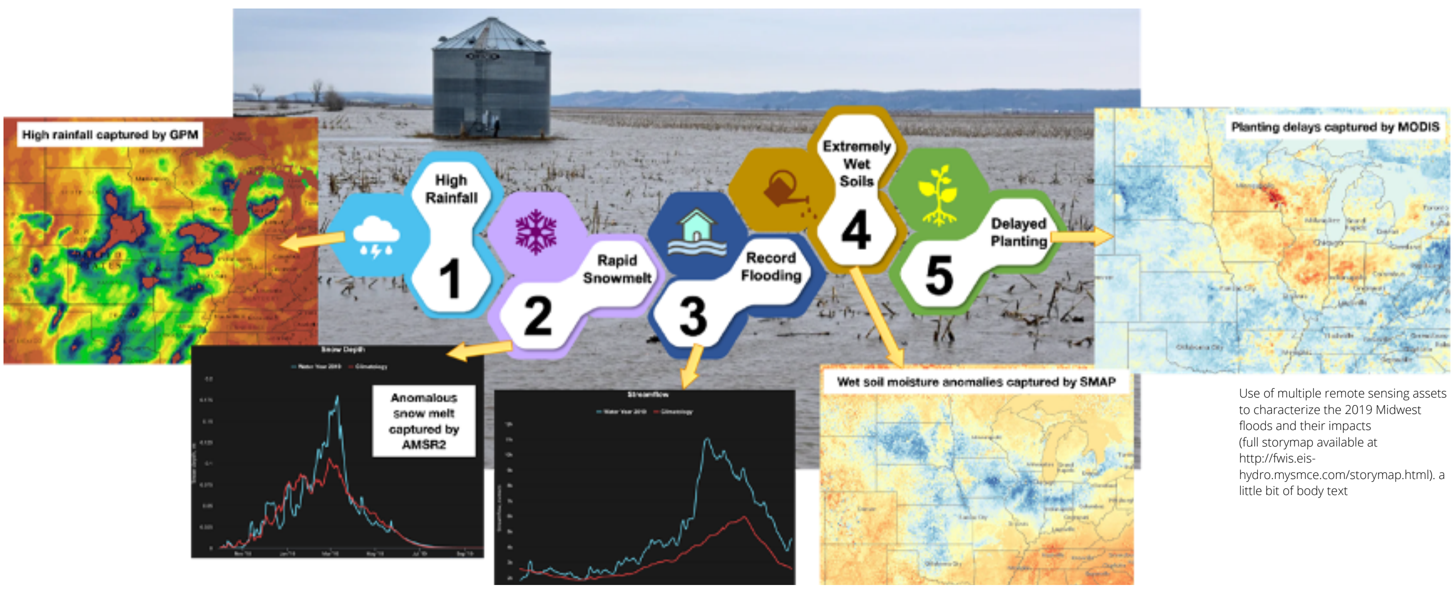
EIS Pilot Studies: Common Themes

1. Tackled complex Earth Science Decadal Survey questions using state-of-the-art models and observations from NASA and its partners.
2. Developed an open-source Scientific Collaboration Environment powered by emerging cloud computing capabilities.
3. Translated scientific results into actionable information for a wide range of users and stakeholders.

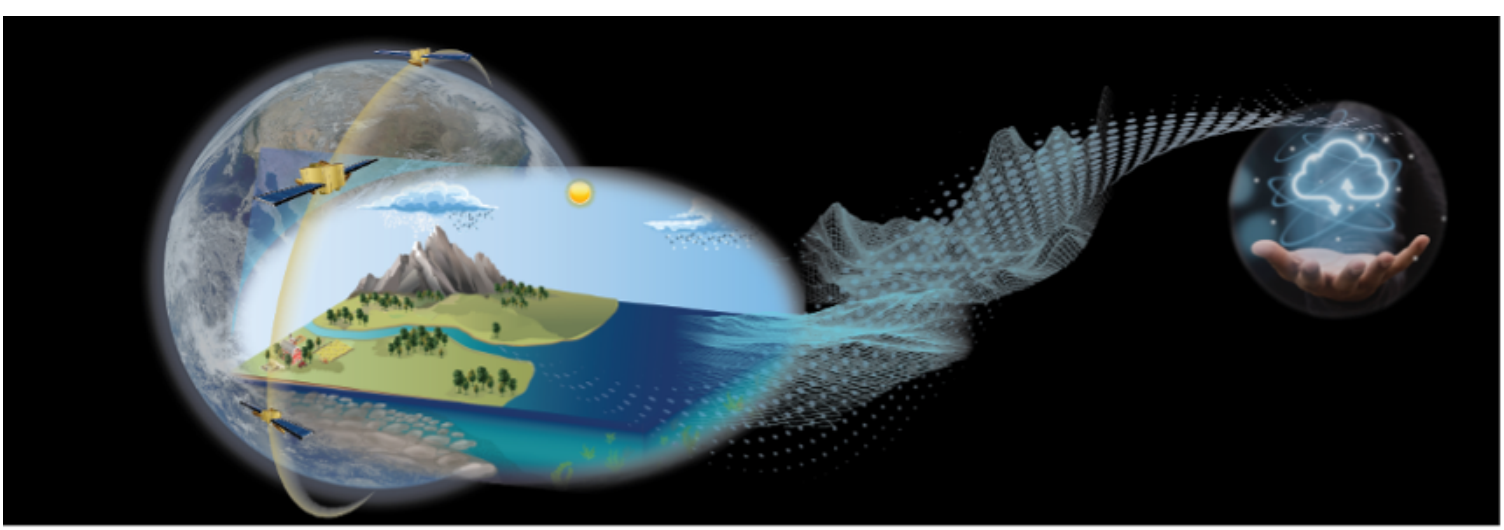
EIS eliminates the fractured nature of current data and computing systems by creating an open science ecosystem that delivers scientific results to the people who need it.

"Science based on integrating information from several approaches can lead to products where the insights from the whole are much greater than the sum of the parts."

[NAS Earth Science Decadal Survey, page 2-23]



Use of multiple remote sensing assets to characterize the 2019 Midwest floods and their impacts (full storymap available at http://fwis.eis-hydro.mysmce.com/storymap.html). a little bit of body text



The vision of EIS-Freshwater is the integration of NASA remote sensing and models through open science tools to enable science transition to a broad set of users.