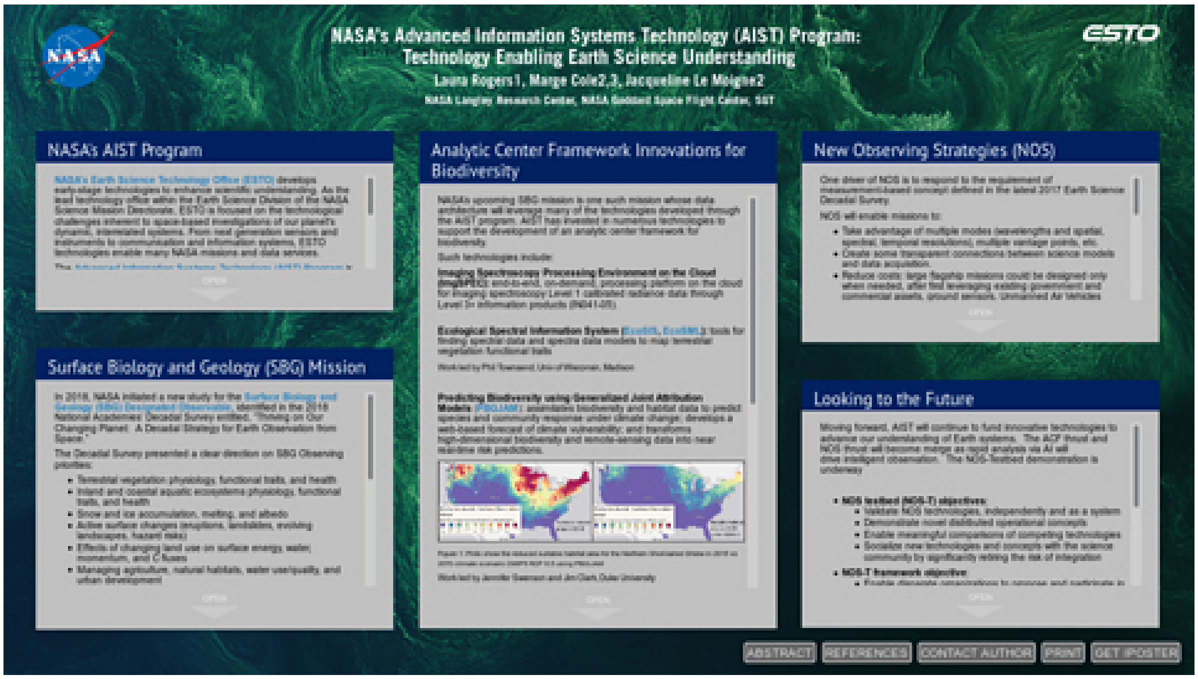
NASA's Advanced Information Systems Technology (AIST) Program: Technology Enabling Earth Science Understanding



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NASA'S AIST PROGRAM

NASA's Earth Science Technology Office (ESTO) (https://esto.nasa.gov/)

- Lead technology office within the Earth Science Division of the NASA Science Mission Directorate
- Develops early-stage technologies to enhance scientific understanding.
- Focused on the technological challenges inherent to space-based investigations of our planet's dynamic, interrelated systems. From next generation sensors and instruments to communication and information systems, ESTO technologies enable many NASA missions and data services.

The **Advanced Information Systems Technology (AIST) Program (https://esto.nasa.gov/aist/)** is one focal area of ESTO.

- AIST innovates information system technologies that enable the development of new observing systems as well as agile science investigations through data analytics and artificial intelligence tools and algorithms.
- AIST utilizes an end-to-end development approach with the goal of infusing mature technologies into future missions, measurements, and analysis.

The AIST Program has two primary thrusts:

1. Analytic Center Framework

Data exploitation and analysis to make observational data and model output more accessible and usable to scientists conducting specific investigations to:

- Enable the extraction of higher-level science content and information from the data.
- Accelerate scientific discovery by harmonizing the data, tools, and computational resources.

2. New Observing Strategies

Enables new observation measurements and information products via

- Multi-sensor nodes producing measurements integrated from multiple vantage points and in multiple dimensions (spatial, spectral, temporal, radiometric) and
- Providing a unified picture of the physical process or natural phenomenon

SURFACE BIOLOGY AND GEOLOGY (SBG) MISSION

In 2018, NASA initiated a new study for the **Surface Biology and Geology (SBG) Designated Observable** (https://sbg.jpl.nasa.gov/#), identified in the 2018 National Academies' Decadal Survey entitled, "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space."

The Decadal Survey presented a clear direction on SBG Observing priorities:

- Terrestrial vegetation physiology, functional traits, and health
- Inland and coastal aquatic ecosystems physiology, functional traits, and health
- Snow and ice accumulation, melting, and albedo
- Active surface changes (eruptions, landslides, evolving landscapes, hazard risks)
- Effects of changing land use on surface energy, water, momentum, and C fluxes
- Managing agriculture, natural habitats, water use/quality, and urban development

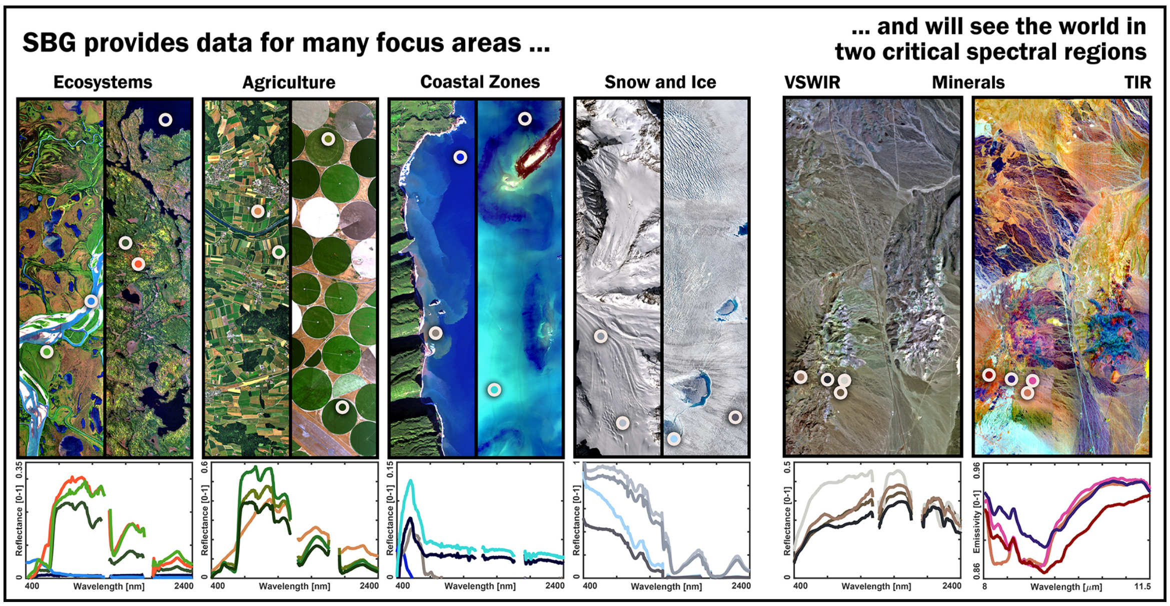

Image Credit: NASA SBG Study Team

ANALYTIC CENTER FRAMEWORK INNOVATIONS FOR BIODIVERSITY

NASA's upcoming SBG mission is one such mission whose data architecture will leverage many of the technologies developed through the AIST program. AIST has invested in numerous technologies to support the development of an analytic center framework for biodiversity.

Such technologies include:

Imaging Spectroscopy Processing Environment on the Cloud (ImgSPEC): end-to-end, on-demand, processing platform on the cloud for imaging spectroscopy Level 1 calibrated radiance data through Level 3+ information products (IN041-05).

Ecological Spectral Information System (EcoSIS (https://ecosis.org/), EcoSML (https://ecosml.org/)): tools for finding spectral data and spectra data models to map terrestrial vegetation functional traits

Work led by Phil Townsend, Univ of Wisconsin, Madison

Predicting Biodiversity using Generalized Joint Attribution Models (**PBGJAM (https://pbgjam.env.duke.edu/)**): assimilates biodiversity and habitat data to predict species and community response under climate change; develops a web-based forecast of climate vulnerability; and transforms high-dimensional biodiversity and remote-sensing data into near real-time risk predictions.

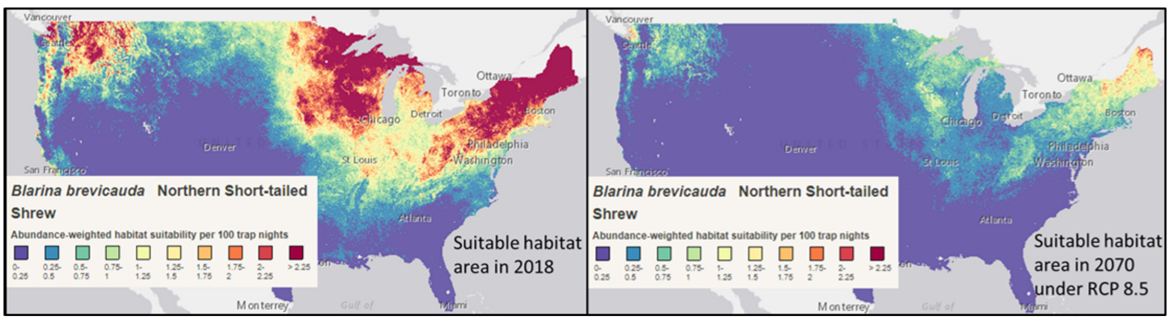

Figure 1: Plots show the reduced suitable habitat area for the Northern Short-tailed Shrew in 2018 vs 2070 climate scenario CMIP5 RCP 8.5 using PBGJAM (Clark, J.S. and D. Taylor -Rodrigues, 2016)

Work led by Jennifer Swenson and Jim Clark, Duke University

The **Spatiotemporal Observation Annotation Tool** (**STOAT (https://mol.org/stoat/about)**): platform for the fusion of spatiotemporal biodiversity data (e.g. occurrence records) with remote-sensing and other gridded environmental data. Data fusion (or environmental annotation) is conducted by retrieving environmental layer values associated with the spatiotemporal coordinates of biodiversity data. STOAT is part of Map of Life (https://mol.org/)

Work led by Walter Jetz, Yale University

The **Advanced Phenological Information System (APIS):** a suite of interactive tools for evaluating phenology data from multiple sources and across multiple spatial, and temporal scales. The tools focus on integrating time series from the phenocam with MODIS vegetation time series data products.

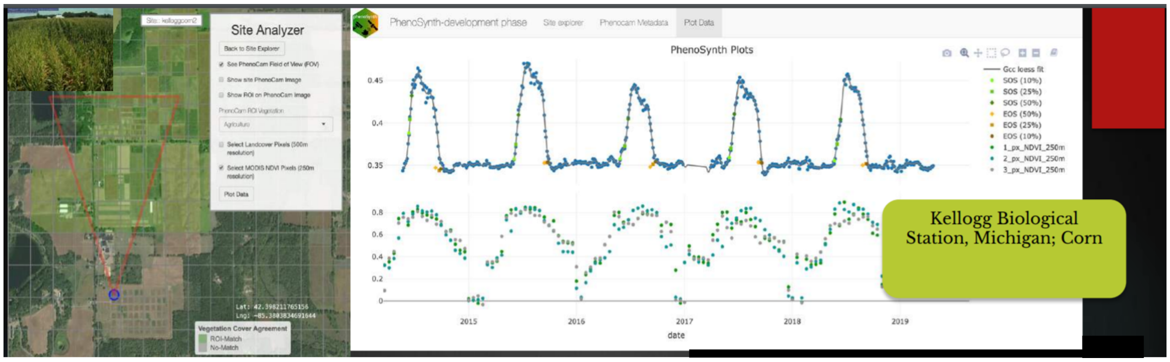

Figure 2: Seasonal corn phenology metrics from 2015-2020 at the Kellogg Biological Station, MIchigan using PhenoCam data analyzed with **PhenoSynth (http://phenocam.nau.edu/phenosynth/)**, a tool in the APIS suite

Work led by Jeff Morisette, National Invasive Species Council

NEW OBSERVING STRATEGIES (NOS)

One driver of NOS is to respond to the requirement of measurement-based concept defined in the latest 2017 Earth Science Decadal Survey.

NOS will enable missions to:

- Take advantage of multiple modes (wavelengths and spatial, spectral, temporal resolutions), multiple vantage points, etc.
- Create some transparent connections between science models and data acquisition.
- Reduce costs: large flagship missions could be designed only when needed, after first leveraging existing government and commercial assets, ground sensors, Unmanned Air Vehicles (UAVs), balloons, instruments on the International Space Station (ISS) and various SmallSats and CubeSats

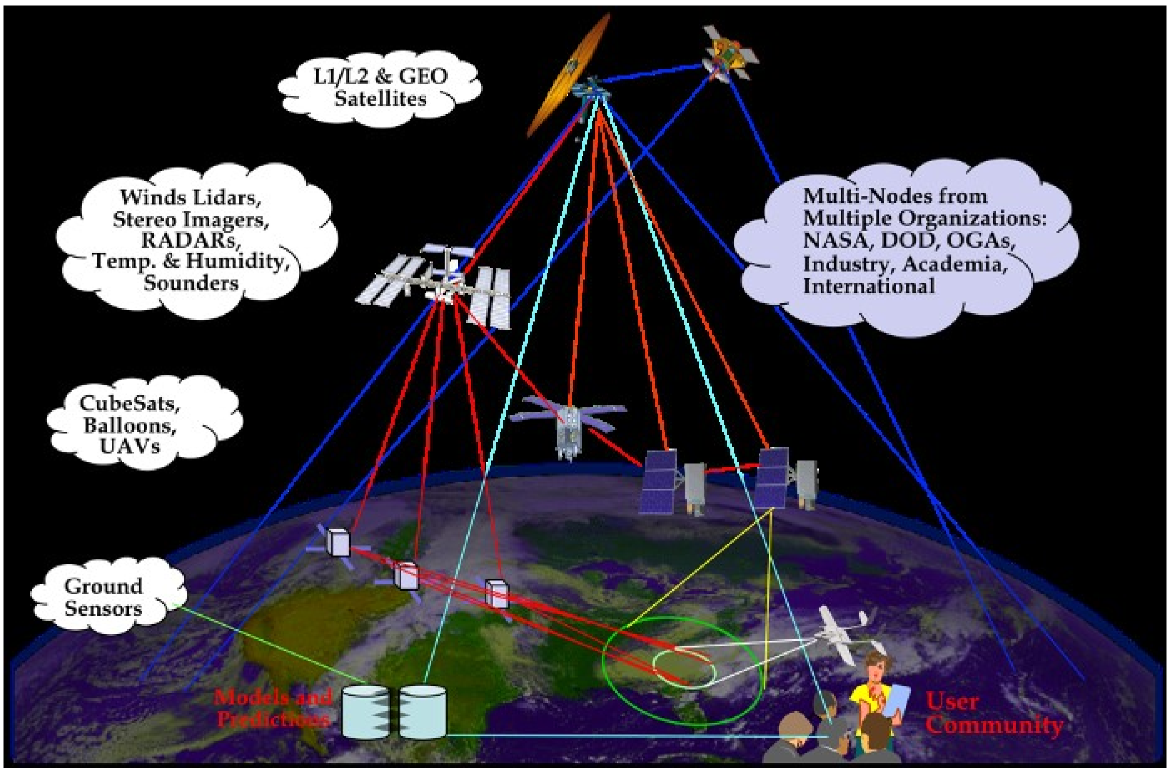

Figure 3: Multiple, collaborative sensor nodes producing measurements integrated from multiple vantage points and in multiple dimensions (spatial, spectral, temporal, radiometric); providing a dynamic and more complete picture of physical processes or natural phenomena (Le Moigne et al., 2019).

Go to the recent NOS Workshop website (https://esto.nasa.gov/nos-workshop/) to learn more

LOOKING TO THE FUTURE

Moving forward, AIST will continue to fund innovative technologies to advance our understanding of Earth systems. The ACF thrust and NOS thrust will become merge as rapid analysis via AI will drive intelligent observation.

[VIDEO] https://www.youtube.com/embed/TSEeK_xcHGA?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

The NOS-Testbed demonstration is underway

- **NOS testbed (NOS-T) objectives**:
  - Validate NOS technologies, independently and as a system
  - Demonstrate novel distributed operational concepts
  - Enable meaningful comparisons of competing technologies
  - Socialize new technologies and concepts with the science community by significantly retiring the risk of integration
- **NOS-T framework objective**:
  - Enable disparate organizations to propose and participate in developing NOS software and information technology

References

1. J. L. Moigne, M. M. Little and M. C. Cole, "New Observing Strategy (NOS) for Future Earth Science Missions," IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium, Yokohama, Japan, 2019, pp. 5285-5288, doi: 10.1109/IGARSS.2019.8898096

2. Clark, J.S. and D. Taylor -Rodrigues 2016. gjam: Generalized Joint Attribute Modeling, https://cran.rstudio.com/web/packages/gjam/index.html.

3. https://cce.nasa.gov/biodiversity/pdf/meetings/bio2019/wed/bo1_A_Morisette_Advanced%20Phenological%20Information%20System-compressed.pdf (https://cce.nasa.gov/biodiversity/pdf/meetings/bio2019/wed/bo1_A_Morisette_Advanced%20Phenological%20Information%20System-compressed.pdf)

ABSTRACT

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NASA's upcoming Surface, Biology and Geology (SBG) mission is one such mission whose data architecture will leverage many of the technologies developed through the AIST program. AIST has invested in numerous technologies to support the development of an analytic center framework for biodiversity. Projects range from on-demand data annotations to spectral data fusion using cloud computing to the integration and visualization of phenocam data against geospatial information. This talk will highlight current and future program concepts and interests.

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Clark, J.S. and D. Taylor -Rodrigues 2016. gjam: Generalized Joint Attribute Modeling, https://cran.rstudio.com/web/packages/gjam/index.html.

https://cce.nasa.gov/biodiversity/pdf/meetings/bio2019/wed/bo1_A_Morisette_Advanced%20Phenological%20Information%20System-compressed.pdf (https://cce.nasa.gov/biodiversity/pdf/meetings/bio2019/wed/bo1_A_Morisette_Advanced%20Phenological%20Information%20System-compressed.pdf)

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