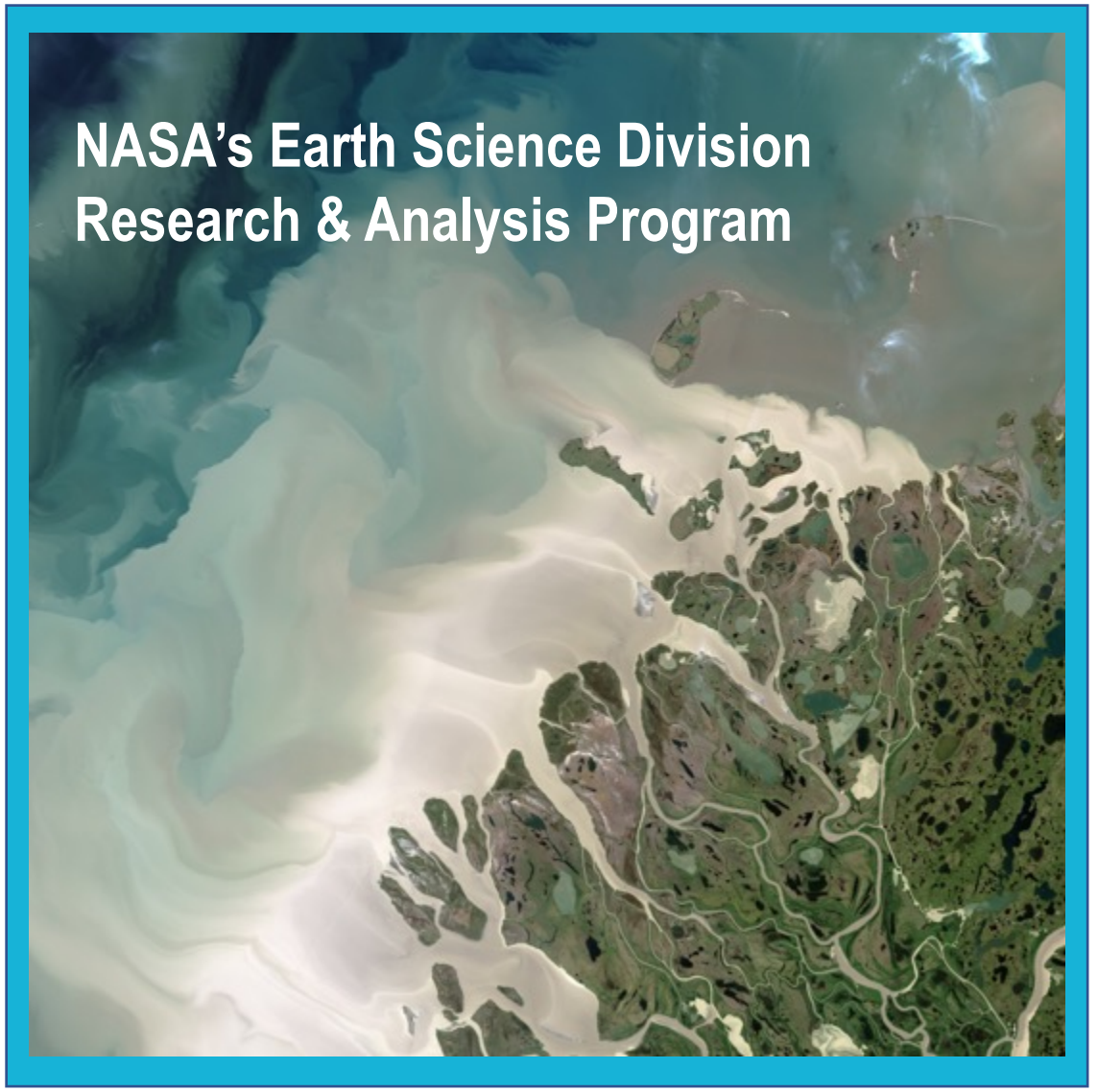
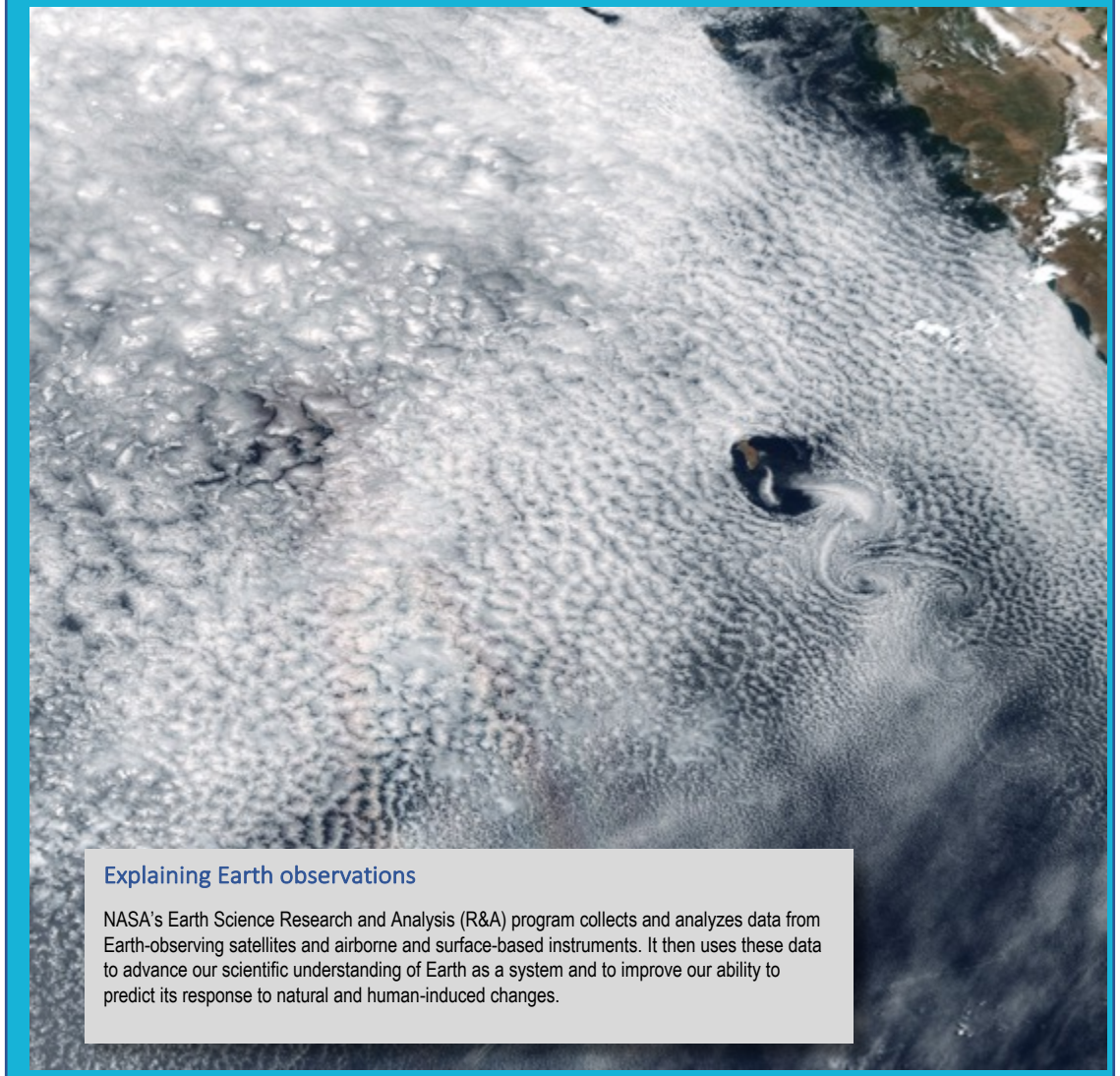
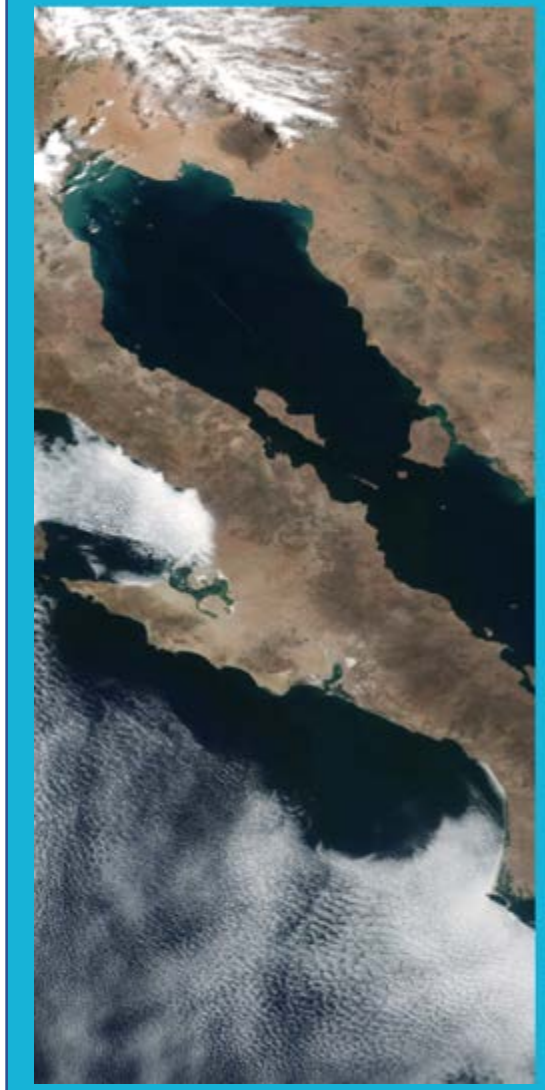

NASA's Earth Science Division
Research & Analysis Program



Explaining Earth observations

NASA's Earth Science Research and Analysis (R&A) program collects and analyzes data from Earth-observing satellites and airborne and surface-based instruments. It then uses these data to advance our scientific understanding of Earth as a system and to improve our ability to predict its response to natural and human-induced changes.



Advancing Earth science through partnerships

The R&A program supports and works with NASA scientists, domestic and international partners, academic institutions, nonprofits, and other government agencies to conduct high-level research through large-scale satellite missions, targeted field campaigns, data analysis, and advanced scientific computing. These data are used to complement, calibrate and validate satellite observations and provide real-world inputs for quantitative models that detect and predict conditions on Earth.

The R&A program achieves these goals through key programmatic elements, including:

- **Satellite data records:** These records provide detailed scientific observations on global and regional scales to advance our understanding of Earth as an integrated system.
- **Airborne science:** These field campaigns allow scientists to test new measurement approaches, collect detailed *in situ* and remote-sensing observations, and provide calibration/validation information for satellites.
- **Surface-based measurements:** These measurements provide unique observational capability and calibration/validation/algorithm testing capability for current and future satellite measurements.
- **Modeling:** Quantitative models provide a best estimate of the current state of many Earth system components, including short-term forecasts that support field missions and longer-term forecasts that assess Earth's response to various drivers of change.
- **High-end scientific computing:** This capability converts satellite observations into scientific data products and synthesizes long-term data sets to provide initial and boundary conditions, validation and verification references, and internal and external constraints for scientific models.

Atmospheric Composition The Atmospheric Composition focus area researches the composition of Earth's atmosphere, especially the troposphere and stratosphere, as it relates to climate change, ozone, aerosols, solar radiation, air quality, and surface emissions of gases and particulates.

Weather The Weather focus area researches the dynamics of the atmosphere and its interaction with the oceans and land, ranging from local processes lasting minutes to global-scale events predictable up to two weeks in advance.

Climate Variability & Change The Climate Variability & Change focus area provides global-scale observations on the ocean and ice, the physical and chemical mechanisms that affect them, and their interactions with the entire Earth system.

NASA's Earth Science Research and Analysis Program sponsors research pertaining to six key focus areas, which are listed here along with some examples of how R&A is advancing Earth system science:

Understanding airborne volcanic hazards. The **Atmospheric Composition focus area** used satellite data from NASA's **Multi-Angle Imaging Spectroradiometer (MISR)** to more accurately measure plume heights from erupting volcanoes. This information not only helped keep airline passengers safe, but will also be used to understand how locally emitted volcanic aerosols like ash and sulfur affect global phenomena like regional weather patterns and climate change.

Assessing impacts of atmospheric rivers. Atmospheric rivers are precipitation-heavy weather events that account for billions of dollars in damage around the world each year. Research from NASA's **Weather focus area** revealed that these events not only produce record-breaking rain, but also devastating surface winds. Using data from NASA's **Tropical Rainfall Measuring Mission (TRMM)**, researchers found that from 1997-2013, 14 of the 19 costliest wind storms over the U.S. and Europe were the result of atmospheric rivers.

Redrawing the map. In July 2017, approximately 2,240 square miles of ice—nearly the size of Delaware—broke off the Larsen C ice shelf in Antarctica and drifted into the Ocean. NASA's **Operation IceBridge airborne campaign**, funded by the **Climate Variability & Change focus area**, had been monitoring the ice shelf for months, and imagery from **MODIS on NASA's AQUA satellite** confirmed the rupture.

Calculating snow water equivalents. Many places on Earth rely on annual snowpack for the majority of their freshwater needs. Research from the **Water & Energy Cycle focus area** recently discovered that combining observations from NASA's **AQUA satellite Advanced Microwave Scanning Radiometer - Earth (AMSR-E)** instrument with current snow-water equivalent models increased the accuracy of liquid water estimates in mountainous terrain by more than 80%.

Mapping forest evolution. Researchers funded by NASA's **Carbon Cycle & Ecosystems focus area** have discovered a way to tell how old a tree is from space. Using a lidar-based mapper during the **Arctic - Boreal Vulnerability Experiment (ABoVE) airborne campaign**, scientists found that tree height, which can be accurately measured with lidar, highly correlates to tree age. These data can later be used to create large-scale maps showing the evolution and progression of forests as northern climates continue to warm.

Reevaluating the power behind tsunamis. New insights from NASA'S **Earth Surface & Interior focus area** revealed that horizontal displacement may play a larger role in tsunami energy than previously believed. Using data from NASA's **GRACE satellite,** the NASA/CNES **JASON satellite**, and land-based GPS data from the Geospatial Information Authority of Japan, scientists concluded that vertical displacement accounted for less than half the energy of the magnitude-9.0 2011 Tohoku tsunami and the magnitude-9.3 2004 Sumatra tsunami: most of the energy was from horizontal displacement.

Water & Energy The Water & Energy Cycle focus area studies the distribution, transport, and transformation of water and energy on Earth, including global precipitation, the inputs and outputs of Earth's water and energy systems, and remote sensing of land-based water, such as soil moisture, snow, groundwater, evapotranspiration, and water quality.

Carbon Cycle & Ecosystems The Carbon Cycle & Ecosystems focus area researches the cycling of carbon in reservoirs and ecosystems as it changes naturally, is changed by humans, and is affected by climate change.

Earth Surface & Interior The Earth Surface & Interior focus area supports research and analysis of solid-Earth processes and properties from crust to core. This includes providing the space geodetic observations and products foundational to many space missions.