PAGE 1 (Cover)

{Insert new NASA Earth logo}

Research and Analysis Program

PAGE 2 (Inside cover, LT side) – Pretty Earth image and R&A overview

Explaining Earth Observations

The Earth Science Research and Analysis (R&A) program works with NASA scientists, domestic and international partners, and researchers at universities, nonprofits, and other government agencies to support integrative scientific research into the Earth and its systems. This research is divided into six key focus areas, which help us detect and predict conditions on Earth, push the boundaries of existing scientific hypotheses, and teach us about our home planet.

PAGE 3 (Inside cover, RT side) – Focus Area Descriptions

R&A Program Focus Areas:

Atmospheric Composition Supports research into Earth's lower atmosphere, including air quality, solar radiation and climate.

Carbon Cycle & Ecosystems Supports research into Earth's ecosystems, including biological diversity, land cover and land use change, and how nutrients cycle between the land, ocean and atmosphere.

Climate Variability & Change Supports research into the dynamic nature of the Earth, including how the ocean, atmosphere, ice- and land-cover affect Earth's climate and how these systems will evolve over time.

Earth Surface & Interior Supports research into solid-Earth processes, including natural hazards, plate tectonics, and geomagnetism from crust to core.

Water & Energy Supports research into the distribution, transport and transformation of water and energy, including global precipitation and the effects of extreme weather events, water quality and water availability.

Weather Supports research into the dynamics of the atmosphere, including its interaction with Earth's other systems and extreme weather events.

PAGE 4 (LT-most page of inside spread)

Advancing Earth Science

The R&A program collects and analyzes integrative measurements from Earth-observing satellites, airborne campaigns and surface-based instruments to advance our understanding of the Earth and its systems and to provide real-world inputs for quantitative models.

- **Satellite data records:** Provide detailed scientific observations on global and regional scales to advance our understanding of Earth as an integrated system.
- **Airborne science:** Help scientists test new measurement approaches, collect detailed *in situ* and remote-sensing observations, and provide complementary observations to calibrate and validate satellites.
- **Surface-based measurements:** Provide unique observational capabilities that complement satellite measurements and provide calibration, validation and algorithm testing capability.
- **Modeling:** Estimatesthe current state of components within the Earth system and the mechanisms that couple them, 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:** Converts satellite observations into scientific data products and allows scientists to execute large-scale modeling, data assimilation and reanalyses efforts.

Comment [AS1]: I modified and swapped this paragraph with the one that was originally under "Advancing Earth Science." I think this works better here; what do you think?

Comment [AS2]: Does this help address Mike's concern about introducing the focus areas? I'm not sure what the exact reasoning is for the specific focus areas, and I can't find it on the website.

Comment [JAK3]: A little more commonality among the descriptions would be helpful. Also, an introductory paragraph or sentence about the focus areas are built (and why they're there) can help. So, some rewording to these may be called for.

Comment [AS4R3]: I attempted to streamline the wording and make it more similar. Let me know what you think—I might have taken it too far…

Comment [JAK5]: Mike wants to be sure that we use the term "integrates" here – and that may be better than "collects"

Comment [AS6R5]: How about this?

Comment [AS7]: I think this paragraph works better here because it sets up the descriptions of the programmatic elements; what do you think?

PAGE 5-7 (inside spread) – Research Examples

Observing atmospheric impacts of the Clean Air Act. The National Ambient Air Quality Standards within the Clean Air Act place restrictions on pollutants, including nitrogen dioxide from cars and power plants, that can be emitted into the atmosphere. Using data from the Ozone Monitoring Instrument (OMI) aboard the Aura satellite, scientists funded by NASA's Atmospheric Composition focus area found that NO_2 levels over the United States decreased 20-60% from 2005-2014, demonstrating the value of satellite remote sensing for detecting changes in the concentration of atmospheric pollutants.

Solving the mystery of hurricane intensification. Although scientists have significantly improved the ability to predict when and where hurricanes will strike, it is still difficult to predict a storm's intensity. Research associated with NASA's Weather focus area seeks to understand what makes hurricanes strengthen and weaken. Observations collected during the Hurricane and Severe Storm Sentinel (HS3) airborne campaign, combined with model simulations, showed that counter to expectations, Saharan dust surrounding a storm system does not automatically weaken it. This new information may be incorporated into forecast models and aid in our ability to predict storm strength in the future.

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 Southern Ocean. NASA's airborne Operation IceBridge, associated with the Climate Variability & Change focus area, first observed the rift in November 2016, and imagery from MODIS on NASA's Aqua satellite confirmed the final rupture.

Tracking water during drought. From 2014-2016, up to 60% of California was under "exceptional drought" conditions. During that time, research funded by NASA's Energy & Water Cycle focus area helped scientists and communities better understand the distribution of freshwater throughout the state. Observations and model output from NASA's Airborne Snow Observatory and GRACE satellite mission revealed where freshwater was previously stored, estimated drought severity, and discovered how groundwater levels were subsequently affected. These data helped scientists gain a more holistic understanding of the water cycle during a drought.

Mapping forest evolution. Researchers funded by NASA's Carbon Cycle & Ecosystems focus area developed a way to tell a tree's age using lasers. 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, correlates with tree age. These data can be used to create large-scale maps showing changes in the structure and spatial distribution of forests as northern climates continue to warm. These changes affect wildlife habitat, climate feedbacks, and hydrological and biogeochemical cycles.

Measuring mountain movements. Although plate tectonics is largely responsible for causing mountain uplift, researchers funded by NASA's Earth Surface and Interior focus area used a new method for mapping the vertical velocities of solid Earth called GPS imaging to show that humans may also have an effect. While human-controlled groundwater pumping during periods of extreme drought caused California's Central Valley to sink, it also led the Sierra Nevada to rise faster than natural drivers alone would suggest. This new technique will help scientists identify interesting geophysical phenomena and improve our understanding of how the solid Earth moves.

PAGE 8 (Back Cover) – More Info & Captions

For more information, please visit science.nasa.gov/earth-science/programs/research-analysis

Image Captions:
Front and Back Covers: The Alaska range south of Fairbanks taken during NASA's ABoVE airborne campaign (photo by Ross Nelson/NASA). **Inside Gate:** Von Kármán vortices over the North Atlantic Ocean from the MODIS instrument on the Aqua satellite (image from Jeff Schmaltz/LANCE/EOSDIS MODIS Rapid Response). **Inside Spread**

from Top Left to Bottom Right: Nitrogen dioxide pollution over the United States in 2005 from NASA's Ozone Monitoring Instrument (OMI) (image by T. Schindler/NASA Goddard's Scientific Visualization Studio); The calving of the A-68 iceberg from the Larsen C ice shelf in natural color (left) and in false color thermal image (right) on September 16, 2017 from the Operational Land Imager and Thermal Infrared Sensor, respectively, on the NASA/USGS Landsat 8 satellite (image from J. Stevens/NASA Earth Observatory); Trembling aspen (*Populus tremuloides)* forest, near Ester Dome, Alaska (photo by Peter Griffith/NASA); Infrared image of Hurricane Edouard as it rapidly intensified during the HS3 airborne campaign in 2014 (image from MSFC MARC Earth science branch/NASA); Trends in total water storage in California, Nevada and bordering states from NASA's GRACE mission, September 2011 to September 2014 (image from NASA JPL/Caltech); Result of GPS Imaging of vertical velocities plotted over topography in California—red values are positive (upward) and blue values are negative (downward) (image from Hammond, W. C., G. Blewitt, and C. Kreemer (2016), GPS Imaging of vertical land motion in California and Nevada: Implications for Sierra Nevada uplift, J. Geophys. Res. Solid Earth, 121, 7681–7703, doi:10.1002/2016JB013458).