

Introduction

Satellite remote sensing technology and the science associated with the evaluation of the resulting data are constantly evolving. To meet the growing needs related to this industry, a team of personnel that understands the fundamental science as well as the scientific applications related to remote sensing is essential. Therefore, the future workforce that will excel in this field requires individuals who not only have a strong academic background, but have practical hands-on experience with remotely sensed data, and have developed knowledge of its real-world applications. NASA's DEVELOP Program has played an integral role in fulfilling this need.

DEVELOP is a NASA Science Mission Directorate Applied Sciences training and development program that extends the benefits of NASA Earth science research and technology to society. The Applied Sciences Program, part of NASA's Earth Science Division, focuses on conducting projects that innovatively utilize NASA Earth science research and satellite observations, model predictive capabilities, and technology to demonstrate operational decision-making benefits in a variety of application areas. These applications include Agriculture, Air Quality, Disaster Management, Ecological Forecasting, Public Health, Water Resources, and Weather. Leveraging the national investment in Earth satellite observation systems, the Applied Sciences Program seeks to increase the benefits to society through the widest practical use of NASA research and to bridge the gap between NASA technology and the public.

Consistent with the goals of the Applied Sciences Program, DEVELOP students conduct research in areas that examine how NASA technology can benefit partner organizations and construct projects that focus on the practical applications of NASA's Earth Science research results. Each one is carefully designed to fit into at least one of the previously mentioned above seven Applied Sciences focus areas, to use NASA's Earth Science satellite observations, and to meet partners' needs. Recommendations from the National Academy's *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (National Research Council, 2007), and the goals of the Group on Earth Observations (GEO) are also factored into project formulation to ensure alignment with anticipated future missions. These activities are conducted year-round during three terms that take place in the spring, summer, and fall. Advisors and mentors from NASA and partner organizations provide the guidance and support for this program, but DEVELOP is unique in that senior students lead the projects that focus on community concerns and public policy impacts.

Students currently enrolled in high school through graduate school levels, who have at least a 3.0 Grade Point Average (GPA), are eligible to apply for a DEVELOP internship position. In particular, students with strong interest in environmental, atmospheric, and the Earth sciences, computer science, Geographic Information Systems (GIS), and remote sensing are encouraged to submit an application. Admission is based upon a competitive application process, with applications available on-line. (http://develop.larc.nasa.gov/apply/new_application.doc). Internships are typically 8 to 10 weeks, with terms available three times a year: spring, summer and fall. DEVELOP teams are located across the U.S. (Figure 1). Each team location varies in size and student educational background. Summer terms typically host the largest number of student participants.

NASA Applied Science Fosters the Next

by Lauren M.

Program Evolution

In 1998, two students participating in the Langley Aerospace Research Summer Scholars (LARSS) Program and one student participating in the Summer High School Apprenticeship Research Program (SHARP) at NASA Langley Research Center co-authored the white paper *Practical Applications of Remote Sensing* (Bauer et al., 1998). At that time, the Digital Earth Initiative, a federal



Figure 1. U.S. background with DEVELOP team locations.

interagency project dedicated to creating a virtual representation of the Earth to further human understanding of the world, was piloting an effort to increase public access to federal information about the Earth and the environment. A proposal combining NASA's Digital Earth Initiative and the students' paper

Sciences' DEVELOP Program Generation of Earth Remote Sensing Scientists

Childs, Madeline W. Brozen, Jonathan L. Gleason, Tracey L. Silcox, and Lauren W. Underwood

advocated the formation of a student program, and in 1999 DEVELOP was formed.

Since its inception over a decade ago, the DEVELOP program has evolved into a nationwide internship program, with over 200 students involved each year. Participants from high school through the graduate level are selected through a competitive application process. Students are trained in the use of NASA science and technology products, which they will apply to future careers in science, technology, and public policy. They also gain experience in a professional setting and develop job skills under the unique guidance that NASA provides. Local communities benefit by gaining a greater understanding of how NASA's science and technology assists in improved policy decisions. Students present research results to partner organizations, who may then use NASA capabilities for enhanced decision support.

The DEVELOP Program also provides periodic opportunities for students to present the results of their research at national science and policy forums. This fosters contact with potential partners, extends NASA science and technology to a wider audience, develops presentation skills, generates project ideas, and aids in recruiting new students. DEVELOP students have presented at conferences, including those of the American Society of Photogrammetry and Remote Sensing (ASPRS), American Geophysical Union (AGU), American Meteorological Society (AMS), Southern Growth Policy Board (SGPB) and the Association of American Geographers (AAG).

DEVELOP teams partner with end-users (organizations who can use project results) to extend the use of NASA science and technology (including satellite data from NASA and other agencies) to the public and to enhance decision support for NASA partners. Satellite observations used have included the Moderate Resolution Imag-

ing Spectroradiometer (MODIS); Landsat Thematic Mapper and Enhanced Thematic Mapper Plus; Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER); Ice, Cloud, and land Elevation Satellite (ICESat); Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO); Advanced Microwave Scanning Radiometer Earth Observing System (AMSR-E); Quick Scatterometer (QuikSCAT); Tropical Rainfall Measuring Mission (TRMM); Jason-1; and CloudSat. DEVELOP students also consider how data from future missions and sensors, like that of the Active Sensing of Carbon Emissions over Nights Days and Seasons (ASCENDS), and Climate Absolute Radiance and Refractivity Observatory (CLARREO), could benefit future research activities.

To date, NASA's DEVELOP program has engaged over 1,500 students and now has teams situated at six NASA Centers and three local government organizations: Langley Research Center, Hampton, Virginia; John C. Stennis Space Center, Mississippi; Ames Research Center, Moffett Field, California; Goddard Space Flight Center, Greenbelt, Maryland; Marshall Space Flight Center, Huntsville, Alabama; Jet Propulsion Laboratory, Pasadena, California; Wise County, Virginia; Mobile County Health Department, Mobile, Alabama; and, Great Lakes and St. Lawrence Cities Initiative, Chicago, Illinois.

The following is a short history and synopsis of activities at each DEVELOP team location.

Langley Research Center

DEVELOP was initiated at Langley Research Center in 1998. In 2001, the DEVELOP Program was challenged to expand activities nationwide, and the National Program Office was established. Both the National Program Office and the Langley DEVELOP activity are

organizationally structured within Langley's Science Directorate. The Science Directorate is a NASA organization devoted to finding out how the Earth and its atmosphere are interacting and changing, and what that means for the health of the planet and quality of life. Scientists within the Science Directorate study changes in the Earth and its atmosphere. Because of science advisor expertise in that field, many DEVELOP projects at Langley focus on air quality related topics. However, student research in other application areas is also conducted there. Examples of projects include examination of global climate change impacts on Virginia's coastline, data product statistical analysis and a Google Earth visualization tool for the NASA CALIPSO Science Team, and analysis of air quality in Texas.

The Virginia Climate Change team utilized data from the Shuttle Radar Topography Mission (SRTM) and MODIS on the Aqua mission to investigate sea level rise in the Hampton Roads area of Virginia (Figure 2). Results were presented to the Virginia General Assembly and used by the Governor's Commission on Climate Change. Students worked with the CALIPSO Science Team to conduct statistical analyses to determine the accuracy of the expedited versus the nominal CALIPSO Lidar Level 2 Vertical feature mask data products. Students also created a data visualization tool using Google Earth for the CALIPSO Science Team (Figure 3). The Texas Air Quality team examined satellite, aircraft, and surface aerosol observations to investigate the ability to infer surface Particulate Matter 2.5 (PM 2.5) from satellite Aerosol Optical Depth (AOD) measurements. CALIPSO data and Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPPLIT) Model back trajectories were used to track aerosol sources indicating that Saharan dust was present in the Houston area. This study was presented at the 2008 AGU and 2009 AMS conferences.

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Figure 2. Landsat image from 2007 overlaid with a historic map from 1607 of the Hampton Roads, Virginia area. The overlaid Landsat image denotes sea level rise (in blue; i.e., land where trees were previously in foreground-lower left, is now water) over the past 400 years.

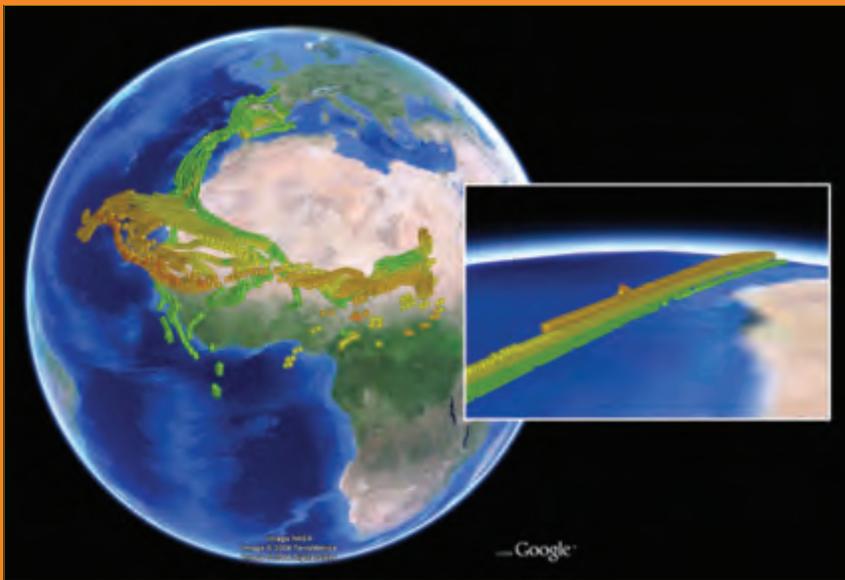


Figure 3. CALIPSO Air Parcel Back Trajectories off Western Africa displayed in Google Earth™. The color of each air parcel indicates its respective altitude above mean sea level: Green = 0-2000 m; Yellow = 2000-4000 m; Orange = 4000+ m.

The DEVELOP program is an outstanding opportunity for students. Not only do the students perform exemplary work of great benefit to end users and partners, they also get to develop leadership and presentation skills. It also provides a unique opportunity to catch a glimpse of what the day-to-day work of a NASA researcher entails."

-- John Haynes, Program Manager for Weather Applications, Public Health Applications, and the Gulf of Mexico Initiative in the Applied Sciences Program of the NASA Science Mission Directorate

John C. Stennis Space Center

The Stennis Space Center DEVELOP team, located in coastal Mississippi near the Louisiana border, was established in the fall of 2002. The team's primary focus has been on land use analysis and on Ecological Forecasting and Disaster Management issues in the Gulf of Mexico region, and more recently extended to include Water Resource Management. Under the guidance of Stennis science advisors, the team has excelled in the innovative application of NASA sensors to Gulf Coast environmental issues. One project used NASA's ICESat Geoscience Laser Altimetry System (GLAS) sensor (originally designed to measure polar ice caps) to detect and assess coastal forest damage and carbon storage loss due to Hurricane Katrina. Results from this research were presented at multiple conferences including the 2008 AGU Fall Meeting, the AAG 2008 Annual Meeting, and the 2009 AMS Annual Meeting. In 2006, Stennis DEVELOP students collaborated with students from the Mobile County Health Department DEVELOP team, and placed first in the undergraduate student paper competition at the 2006 ASPRS/Management Association for Private Photogrammetric Surveyors (MAPPS) Mid-South Region Conference in San Antonio, Texas. By leveraging Stennis Space Center's unique access to a broad range of applications in a coastal setting, the Stennis DEVELOP team has established partnerships with local entities such as the Pontchartrain Institute for Environmental Sciences (PIES) and the Mobile Area Water and Sewer System (MAWSS). During the 2009 spring term, one study focused on the land cover classification of the Big Creek Lake watershed in Mobile County, Alabama, which used ASTER imagery to determine land use, and soil survey data to create soil erodibility, and organic content risk maps. This project combined all three factors to create an overall risk factor map (Figure 4) for pollution mitigation and watershed management for MAWSS. A second project worked in coordination with PIES to utilize ASTER and Landsat data to detect change and loss caused by tropical cyclonic events in the Chandeleur Islands over the past 12 years (Figure 5). These results supplemented ongoing efforts by PIES to assess the health of the island chain and supported the team's objective of applying NASA Earth Observing Systems (EOS) results to benefit the Gulf of Mexico region.

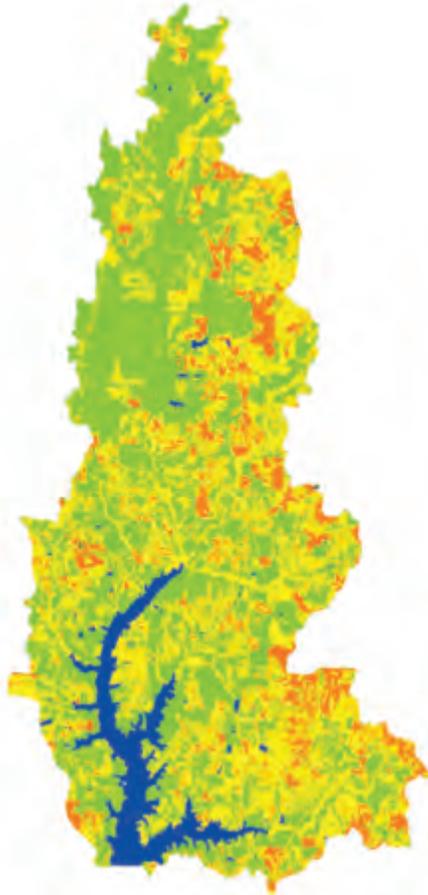


Figure 4. Relative nonpoint source pollution risk map of the Big Creek Lake, Alabama watershed created using ASTER imagery based upon land use/land cover, soil erodibility, and soil organic content factors; orange denotes areas of higher risk.



Figure 5. Major hurricane damage over time, on the Chandeleur Islands, LA represented using Normalized Difference Vegetation Index change detections utilizing ASTER and Landsat 5 TM data (left to right, respectively: Hurricane Georges, 1998; Hurricane Katrina, 2005; and Hurricane Gustav, 2008).



Ames Research Center

The Ames Research Center DEVELOP team, located in Mountain View, California, was established in the summer of 2003. Leveraging the strengths of NASA advisors at Ames Research Center, the team has excelled in conducting projects in the Western United States that focus on the Ecological Forecasting and carbon management, Public Health, and Air Quality Applied Sciences applications. Ames DEVELOP interns have researched different aspects of Ecological Forecasting including walrus habitat in the Bering Sea; vegetation anomalies in Yosemite National Forest, California; biological control of invasive species in Dinosaur National Monument, Utah; and burn severity in the Tripod Complex fire in Washington. For the Washington Ecological Forecasting project, enhanced burn severity maps were created from Landsat and MODIS

images calibrated with field measurements (Figure 6). During the 2007 and 2008 summer terms, Ames students conducted the Pacific Region Integrated Climatology Information Products (PRICIP) Disaster Management project. During this PRICIP study, students built a graphical interface capable of combining multiple datasets, such as TRMM, QuikSCAT, MODIS, and AMSR-E, for use by coastal management decision makers. Additionally, due to substandard air quality in the San Joaquin Valley, multiple projects seeking to improve correlations between MODIS AOD and ground-based PM 2.5 measurements (Figure 7) were undertaken. Most recently, students investigated the high surface reflectance of the valley and its impact on the MODIS AOD algorithm, to assist air quality regulatory agencies.

Goddard Space Flight Center

The Goddard Space Flight Center, located near Washington, D.C., in Greenbelt, Maryland, began their DEVELOP program in fall 2004. There, students work with Goddard science advisors performing cutting edge research in the Applied Sciences field. The Goddard DEVELOP team has continually worked on challenging Earth science projects with both national and international impacts. The Pacific Disaster Management project explored thermal anomalies as a possible precursor to major earthquake seismic events for earthquake prediction in Russia (Figure 8). By combining data from NASA's Atmospheric Infrared Sounder (AIRS) sensor with data from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP), a database of thermal transient

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Figure 6. A burn severity map for the Tripod Complex Fire, Washington and the resulting correlated field measurements using MODIS and Landsat 5 TM; areas in red indicate the highest burn severity.

field and major seismic events was created for 2000–2008 (Fisher et al., 2006). The Air Quality-Global Boundary Layer Aerosol Distributions project takes a global approach at validating and improving the remote sensing data of aerosols. DEVELOP’s Water Resources teams at Goddard have promoted the use of remote sensing in the Chesapeake Bay Watershed through student-led NASA Ocean Color data products workshops. The team has also conducted a recent year-long feasibility study assessing the potential use of sensor webs by the Chesapeake Bay Program for watershed resource management and estuary modeling.

Marshall Space Flight Center

The Marshall DEVELOP team, located in Huntsville and Birmingham, Alabama, was initiated in the summer of 2008 and has primarily conducted research that supports the Public Health application area. The Marshall DEVELOP team has presented study results to organizations such as the Jefferson County Department of Health and the University of Alabama at Birmingham School of Public Health. In the spring 2009 project, students examined ASTER data to identify potential habitats for West Nile Virus vectors in Illinois. Students correlated environmental factors and West Nile Virus outbreaks.

Jet Propulsion Laboratory

The Jet Propulsion Laboratory DEVELOP team in Pasadena, California, was established in the summer of 2008 and has worked in conjunction with DEVELOP students at Langley. The team’s initial project studied coastal upwelling off the coast of California (Figure 9), and specifically focused upon advancing coastal environments’ modeling capabilities using the MODIS instrument onboard the Aqua satellite, the Regional Ocean Modeling System (ROMS), and the Mesoscale Modeling System (MMS).

Regional DEVELOP Teams/Partnerships

Wise County, Virginia

In 2001, DEVELOP formed a partnership with the Circuit Court Clerk’s Office in Wise County, Virginia. This partnership enabled regional recognition of the DEVELOP program, and assisted in the national expansion of the program from Langley Research Center. DEVELOP students from the Wise County team have conducted research projects utilizing satellite remote sensing to investigate air quality and water resource management in the Appalachian region of Virginia, West Virginia, Kentucky and Tennessee. Wise County DEVELOP students also assisted

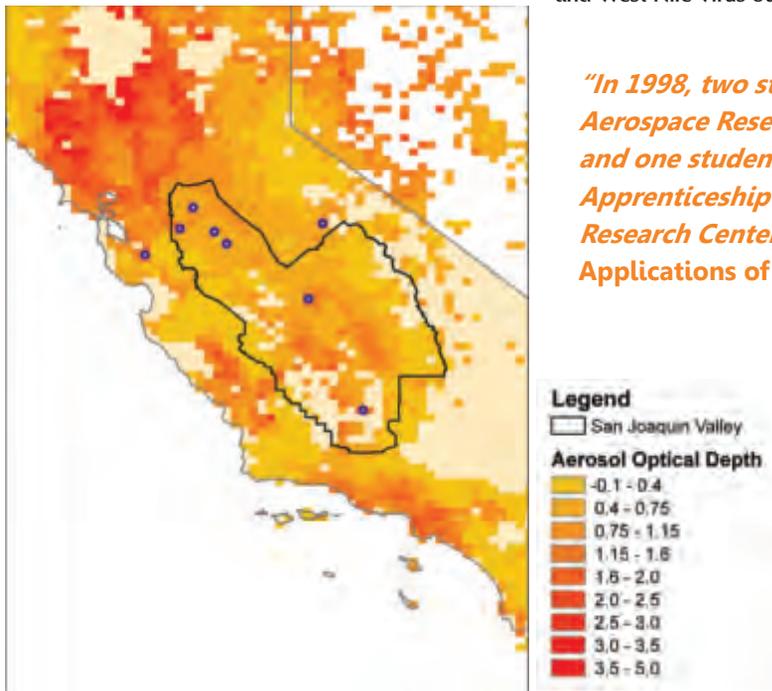


Figure 7. A map of the San Joaquin Valley, California on July 2, 2008, that shows the locations of the ground sites (indicated with purple dots from left to right: San Jose, Tracy, Stockton, Modesto, Turlock, Fresno, Yosemite, Bakersfield) and MODIS aerosol optical thickness.

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in creating a computer automated virtual environment (CAVE) system that has been used to demonstrate project outcomes in a three-dimensional environment. The excellence of the Wise County DEVELOP program was recognized by a House Joint Resolution, which was adopted by the Virginia General Assembly.

Mobile County Health Department, Alabama

The DEVELOP team in Mobile, Alabama, was established in the fall of 2003 with support from the Public Health Officer for Mobile County. Located in the Mobile County

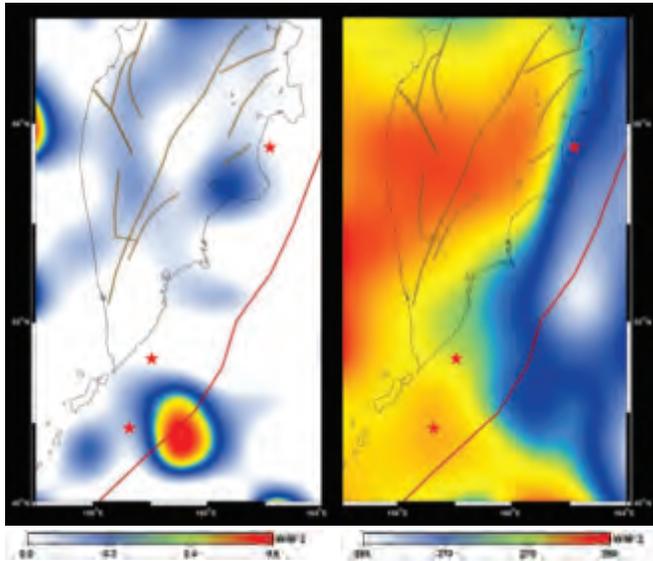


Figure 8. These images represent the processing of NASA AIRS data to detect thermal anomalies over Kamchatka (Russia). The map image on the left represents Outgoing Long wave Radiation (OLR) Mean of August 15, 2003–2007. The map image on the right represents OLR Anomaly for August 15, 2006. Earthquake epicenters for the entire month of analysis in the region of Kamchatka are represented by red stars, tectonic plate boundaries are denoted by the red lines, and major tectonic faults are denoted by the brown lines.

Health Department, DEVELOP has built a team that focuses on public health issues that impact the Mobile area and the Gulf Coast. The team is also uniquely located near the Dauphin Island Sea Lab, Alabama Department of Public Health Mobile Division Lab, and Mobile Bay. Therefore, this group is afforded the opportunity to merge available public health datasets with NASA EOS data. In the fall of 2008, the team extended beyond the Public Health application area into Disaster Management; focusing on assessing the Saffir-Simpson hurricane intensity scale by creating new hurricane intensity scales incorporating wind radii from offshore QuikSCAT data.

Great Lakes & St. Lawrence Cities Initiative, Illinois

Through continued interaction with state and local governments, a partnership was formed in 2008 with the Great Lakes and St. Lawrence Cities Initiative, which enabled students to work locally in the Great Lakes region. This group concentrates on environmental issues that affect the Great Lakes states and Canadian provinces. The team has focused on water level changes, invasive species outbreaks, and public health concerns in the Great Lakes. The 2008 fall

and spring 2009 project used NASA Ocean Color data products to identify harmful algal blooms—specifically blue-green algae eutrophication—in Lake Huron and in the western end of Lake Erie.

Future Activities

Potential DEVELOP projects may have an increasing international focus in support of GEO goals, and in particular may look toward supporting research projects in developing countries. This work would be built upon DEVELOP's previous research conducted in India and Africa. One project concentrated on the use of ASTER data to assess both tiger dispersal and isolation reduction in Assam, India to help wildlife management. Other projects utilized MODIS and TRMM observations over the African continent to measure vegetation change due to rainfall and correlated this with outbreaks of Rift Valley Fever and Malaria to aid public health officials.

The DEVELOP program is mentoring today's students in preparation for careers as tomorrow's scientists. Challenged to think outside the box, take initiative, and employ innovative ideas, students who participate in the DEVELOP Program leave prepared to

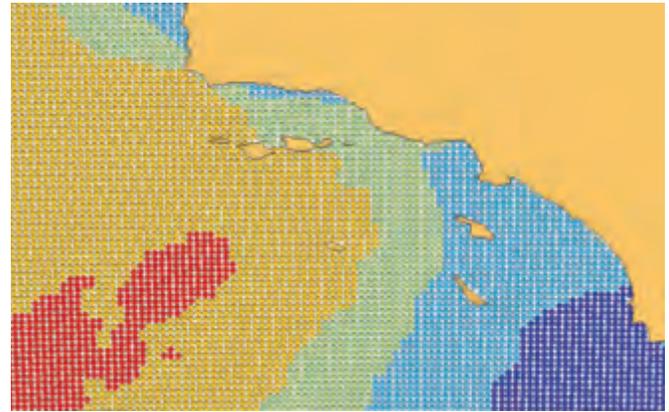
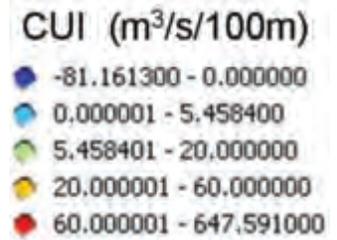


Figure 9. A coastal upwelling index in the Southern Californian region (right) made using MODIS, ROMS, and MMS that shows the strength and direction of upwelling.



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handle the challenges that face our society and future generations. DEVELOP students are delving into the frontiers of science and remote sensing and strengthening the future American workforce, all while extending the benefits of NASA Earth science research results for society.

“The DEVELOP program is an outstanding opportunity for students. Not only do the students perform exemplary work of great benefit to end users and partners, they also get to develop leadership and presentation skills. It also provides a unique opportunity to catch a glimpse of what the day-to-day work of a NASA researcher entails.”

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Further information about NASA's Applied Sciences Program can be found at <http://nasascience.nasa.gov/earth-science/applied-sciences> and information about DEVELOP is available at <http://develop.larc.nasa.gov>.

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