Goddard DEVELOP Students: Using NASA Remote Sensing Technology to Study the Chesapeake Bay Watershed

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Introduction

The DEVELOP National Program is an Earth Science research internship, operating under NASA's Applied Sciences Program. Each spring, summer, and fall, DEVELOP interns form teams to investigate Earth Science related issues. Since the Fall of 2003, Goddard Space Flight Center (GSFC) has been home to one of 10 national DEVELOP teams. In past terms, students completed a variety of projects related to the Applied Sciences "Applications of National Priority," such as Public Health, Natural Disasters, Water Resources, and Ecological Forecasting. These projects have focused on areas all over the world, including the United States, Africa, and Asia. Recently, Goddard DEVELOP students have turned their attention to a local environment, the Chesapeake Bay Watershed.

The Chesapeake Bay Watershed is a complex and diverse ecosystem, spanning approximately 64,000 square miles. The watershed encompasses parts of six states: Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, as well as the District of Columbia. The Bay itself is the biggest estuary in the United States, with over 100,000 tributaries feeding into it. The ratio of fresh water to salt water varies throughout the Bay, allowing for a variety of habitats. The Bay's wetlands, marshes, forests, reefs, and rivers support more than 3,600 plant and animal species, including birds, mammals, reptiles, amphibians, fish, and crabs. The Bay is also commercially significant. It is ranked third in the nation in fishery catch, and supplies approximately 500 million pounds of seafood annually.

In addition to its abundant flora and fauna, the Chesapeake Bay watershed is home to approximately 16.6 million people, who live and work throughout the watershed, and who use its diverse resources for recreational purposes. Over the past several decades, the population throughout the watershed has increased rapidly, resulting in land use changes, and ultimately decreasing the health of the Chesapeake Bay Watershed.

Over the course of 2009-2010, student teams carried out two independent research projects focused on the Chesapeake Bay Watershed. The first investigated the threat of invasive species to forests in Maryland. The second investigated the detection of winter cover crops throughout the watershed from satellite data.

Chesapeake Bay Watershed Invasive Species Forecasting

The United State's Department of Agriculture's (USDA) National Invasive Species Information Center (NISIC) defines an invasive species as a species that is non-native, or alien, to the ecosystem under consideration, and whose introduction causes or is likely to cause economic or environmental harm. Economically, the impact from invasive species is estimated to be $100 to $200 billion per year in the United States alone. Environmentally, invasive species often outcompete native plant species, creating a monoculture. Further, invasive monocultures often do not support the same insect and animal populations that the original, native ecosystem supported.

A new invasive species, Wavyleaf Basketgrass (WLBG), (*Oplismenus hirtellus ssp. undulatifolius*) was first found in Maryland in 1996 in the Patapsco Valley State Park. Since its discovery, WLBG has been recorded growing in coastal plane, piedmont, and montane regions of Maryland. The species does not tolerate direct sunlight, and is found in full canopy forests and shady riparian zones. Soil testing at WLBG invasion sites shows that the species can thrive in a wide range of pH levels.

Overall, WLBG has similar habitat preferences as Microstegium – Japanese stiltgrass. This invasive is the most damaging invasive plant in the Mid-Atlantic region. It has spread across the entire east coast since its introduction to the U.S. 100 years ago, outcompeting native vegetation and covering forest floors. WLBG has been found to be considerably more competitive than the Japanese stiltgrass when invading forested areas. A return trip to the site of initial discovery in 2007 revealed that the original 50 ft patches had increased to diameters of up to 500 ft, scattered across more than 1000 acres of forest. It is estimated that this species could invade 10% of the forests in the eastern US in the next decade.

In response to the threat that WLBG poses on forests throughout the Chesapeake Bay Watershed, the Maryland Department of Natural resources (MD DNR) approached DEVELOP for assistance in developing a method for early detection and rapid response to WLBG invasions. Students worked with NASA science advisor **John L. Schnase, PhD** [NASA Goddard Space Flight Center (GSFC)], to identify areas at highest risk of invasion. Shnase, representing NASA's Applied Science Program, worked in partnership with the US Geological Survey (USGS), the National Park Service (NPS), the Bureau of Land Management (BLM), and other federal agencies, to develop NASA's Invasive Species Forecasting System (ISFS). The ISFS is an ecological modeling framework that uses remotely sensed environmental predictors in combination with observational data on plant locations, to produce landscape-scale predictive habitat suitability maps for invasive species of interest.

DEVELOP students acquired a series of NASA satellite imagery, to provide ISFS with the necessary environmental data. A one year composite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite provided landcover data. Data from the Shuttle Radar Topography Mission (SRTM), which was flown onboard the space shuttle Endeavor, provided elevation data. From this data, slope and aspect layers were created. A series of Normalized Difference Vegetation Index (NDVI) phenology layers were acquired, which were derived from MODIS data. These layers included NDVI seasonal variation, NDVI annual maximum, NDVI green up, and NDVI brown down. In all, 38 data layers were used as inputs into the model. *In-situ* presence and absence points for WLBG were collected from several sources, including MD DNR records, private citizen accounts, and university researchers. DEVELOP students also accompanied the MD DNR on several field excursions to look for the species in local state parks.

The DEVELOP team brought these elements together within the ISFS to produce habitat suitability maps for the species. Since WLBG has not yet been listed on the national list of invasive species, MD DNR does not have the funds necessary to conduct exhaustive surveys for the species throughout the state. The predictive habitat suitability maps produced by the DEVELOP project can greatly enhance the ability of MD DNR to locate and eradicate WLBG from state and private lands, by allowing them to focus survey efforts on areas where the plant is most likely to occur.

Chesapeake Bay Agriculture and Water Resources

Approximately one quarter of the land in the Chesapeake Bay Watershed is used for agricultural purposes. When planted fields are harvested in the fall, residual nutrients are left behind in the soil. These nutrients may then be washed into local river and stream systems, where they become pollutants that flow into the Bay. This process, called nutrient loading, has negative impacts on the ecological and economic health of the Bay. Agricultural runoff is the largest source of nutrient loading to the bay annually, contributing to harmful algal blooms, submerged aquatic vegetation degradation, fish kills, and decreases in shellfish populations.

To mitigate the effects of agricultural runoff, farmers are encouraged to practice nutrient management during the fall and winter seasons. Cover crops are a widely accepted best management practice (BMP), having the ability to use residual nutrients and thus decrease nutrient runoff into the Bay. Cover crops are non-harvested, unfertilized, winter cereal grain crops, such as rye, wheat, and barley. Cover crop programs vary by state.

Of the states in the Chesapeake Bay Watershed, Maryland has the most extensive and well funded cover crop program, with over 1 million acres of cropland suitable for cover crop planting. In 1992, the Maryland Department of Agriculture (MDA) began a four-year incentive program to encourage farmers to adopt cover crops as a BMP for their land. Farmers who adopted this practice were offered $20 per acre planted to offset costs associated with implementation. In 2010, farmers who practice cover crop planting were eligible to receive up to $80 per acre planted with cover crops.

The Environmental Protection Agency (EPA) and its partners have created several models to examine the ecological process as at work throughout the watershed. The current model, the Chesapeake Bay Watershed Modeling System, is made up of several sub models. A hydrologic model uses rainfall, evaporation, and meteorological data to calculate theoretical runoff and subsurface flow for all land cover types in the watershed. A non-point source model then simulates soil erosion and projected pollutant loads from land to river, ultimately showing the flow of these nutrients into the Bay.

More detailed land cover and land use information could improve the predictions of this model. Funding for cover crop planting is not applied equally across the Chesapeake Bay Watershed, thus, cover crops are not planted uniformly in all suitable areas. Systematic assessments (e.g. yearly) of cover crops from satellite data are not currently used within the Chesapeake Bay Modeling System. The analysis of the spatial extent and temporal change of cropland using remotely sensed data is of critical importance to the analysis of nutrient loading to the Bay. These data have the potential to not only detect the spatial extent of winter cover crops across the entire watershed, but also to detect change in crop land area over time, allowing potential users and partners to detect areas where cover crop planting can be beneficial.

The DEVELOP Winter Cover Crop team worked in collaboration with NASA science advisor, **Dr. Eric Brown de Colstoun** [NASA Goddard Space Flight Center (GSFC)] to generate satellite-based leaf-on and leaf-off maps of agricultural lands subject to the Winter Cover Crop program in Maryland. The team mosaicked a series of Landsat 5 Thematic Mapper (TM) scenes with coverage of the watershed. The Normalized Difference Vegetation Index (NDVI) for each scene was calculated, an index broadly indicative of canopy greenness, to determine the difference between vegetated and non-vegetated regions in the scenes. The scenes were then overlaid with the National Crop Land Dataset, which outlines all land parcels designated as croplands by the United States Department of Agriculture (USDA). All pixels with an NDVI of 0.3 or greater, which fell within the boundaries of the USDA cropland parcels, were identified. The combined mosaics and NDVI calculations allowed for the creation of a map delineating areas where winter cover crops are planted and grown. To the team's knowledge, this was the first such map derived from satellite data for this region.

This project demonstrated the potential of Landsat data to identify cover crop coverage in the Chesapeake Bay Watershed region. The calculated NDVI and the leaf-off mosaic generated from Landsat 5 TM offers enhanced detection of winter cover crop distribution on agricultural fields that are likely to have high levels of residual nitrates and other nutrients following fall harvests. The products produced by the team show that remote sensing has the potential to be of great benefit to the ongoing effort to restore the Chesapeake Bay. Decisions makers can use these maps to identify with a high risk areas of nutrient loading due to lack of cover crops.

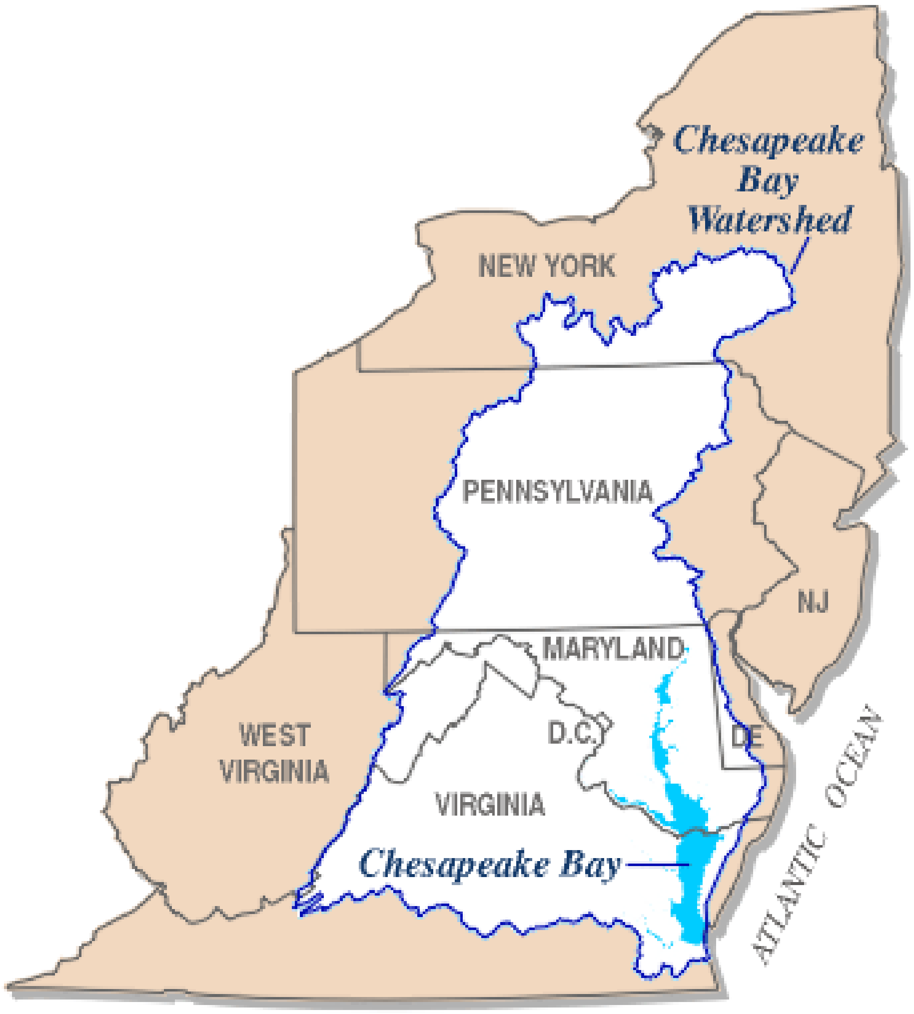
Conclusion

Students gain valuable experience conducting DEVELOP projects, while directly impacting the partners and local communities with which they work. DEVELOP interns have the opportunity to work directly with NASA scientists, who teach them how to conduct applied scientific research and better prepare them for the future. Students gain hands on experience with NASA remote sensing technology, as well as spatial analysis tools, and their application to the investigation of earth science issues. Through these projects, students at Goddard were able to gain a new perspective on the Chesapeake Bay Watershed, and to benefit their local community in which they live, learn, and work.

For more information, please visit the DEVELOP website, at http://develop.larc.nasa.gov

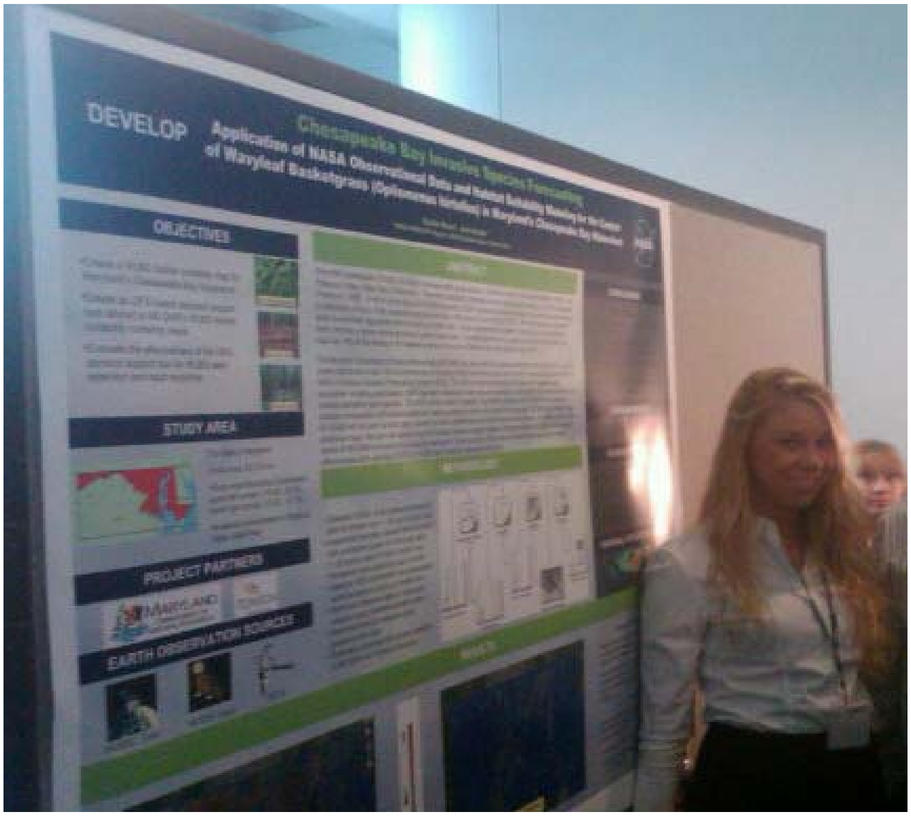
Images

The Chesapeake Bay Watershed



This image shows the outline Chesapeake Bay Watershed, the states included in the watershed, and the the Chesapeake Bay. *Image courtesy of the US Geological Survey (USGS)*.

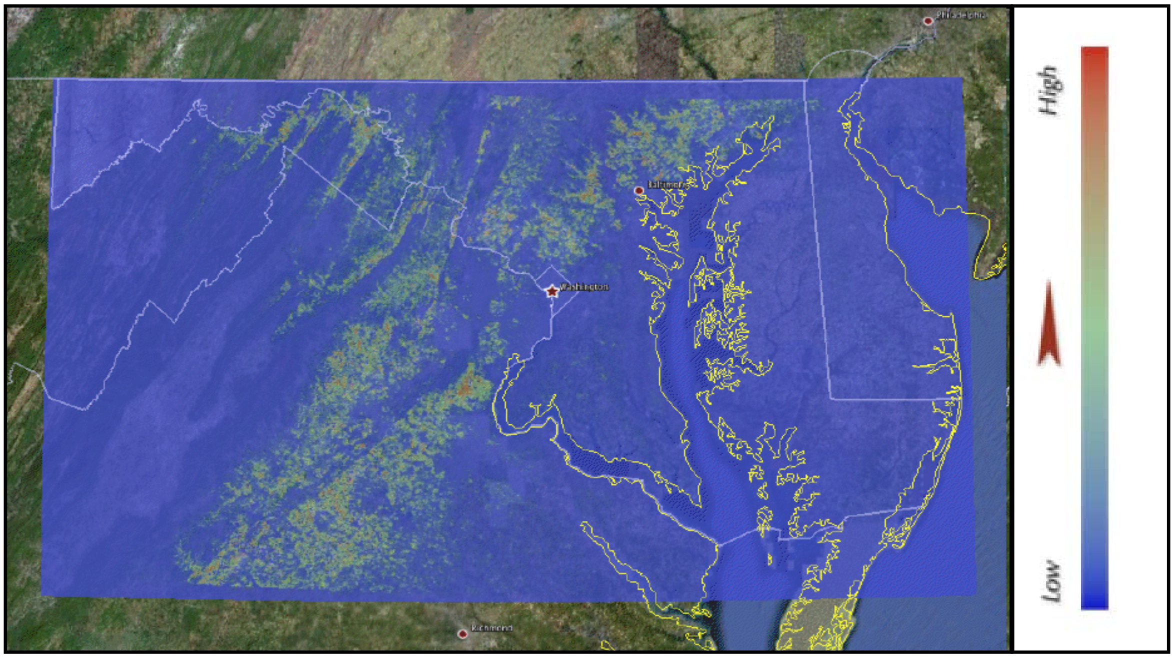
Chesapeake Bay Watershed Invasive Species Forecasting Images



Goddard DEVELOP Center Lead, **Rachel Moore** [University of Maryland, College Park - Environmental Science and Policy (Undergraduate), Geospatial Information Sciences (Graduate)], presents the Chesapeake Bay Invasive Species team research poster at the 2010 Goddard Space Flight Center Summer Intern Poster Session.

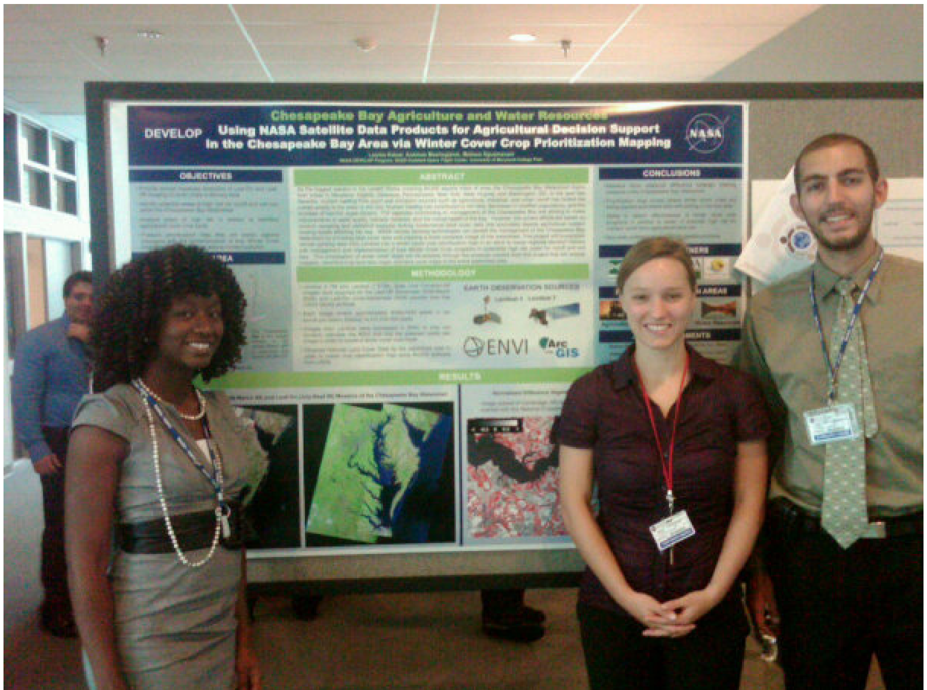
  

From left to right: Close-up of a Wavyleaf Basketgrass plant; Image Wavyleaf Basketgrass at the of site of initial discovery, in 1996; Image showing the spread of Wavyleaf Basketgrass through the site of initial discovery, in 2007. *Images courtesy of Kerrie Kyde, MD DNR.*

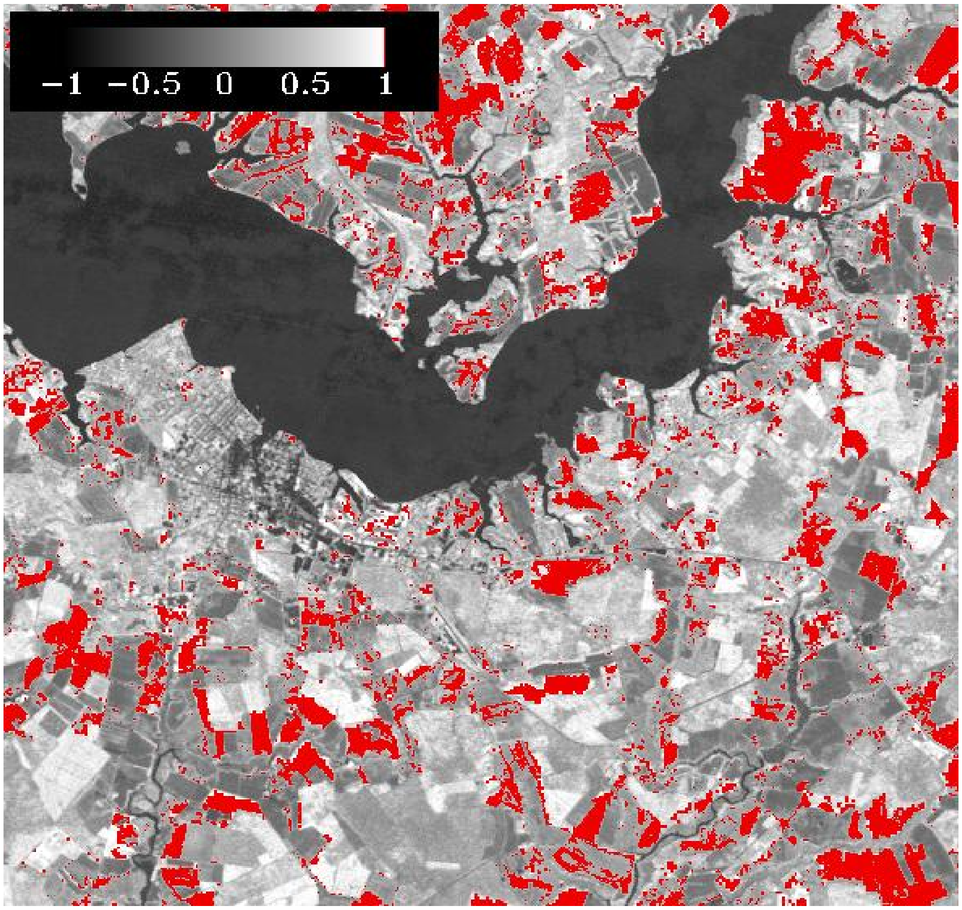


Map of predicted Wavyleaf basketgrass habitat suitability, produced during the Summer 2010 term. Map shows potential distribution of the species, with a graduated color symbology. Red areas have a high habitat suitability, while blue areas have low habitat suitability.

Chesapeake Bay Agriculture and Water Resources



Chesapeake Bay Agriculture and Water Resources team members **Melissa Oguamanam** [University of Maryland, College Park - Geography (Undergraduate/Graduate)]**, Lauren Kaiser** [University of Maryland, College Park - Geography (Undergraduate) **,** and **Andreas Moshogianis** [University of Maryland, College Park - Environmental Science and Policy (Undergraduate); University of Southern Mississippi, Stennis Space Center - Marine Science (Graduate)], present their research poster at the 2010 Goddard Space Flight Center Summer Intern Poster Session.



Chesapeake Bay Agriculture and Water Resources team final map results; map has been zoomed to the Choptank River in Cambridge, MD. Areas where winter cover crops have been planted are indicated in red.