**NASA DEVELOP National Program**



NASA Langley Research Center

*Summer 2015*

North Carolina Ecological Forecasting

Evaluating the Application of NASA Earth Observations to Rapidly Detect Change in Wetland Types at a Regional Scale

 **Technical Report**

Rough Draft – June 25, 2015

Zand Bakhtiari, (Project Lead)

Stephen Zimmerman

Kayla Patel

Brad Gregory

Dr. Kenton Ross NASA DEVELOP National Program (Science Advisor)

Michael Bender, NASA DEVELOP National Program (Technical Lead)

# I. Abstract

[Placeholder - do not put anything here until the final draft submission. The abstract in the project summary is where the working draft of the abstract should “live”]

**Keywords**

Wetlands, Outer Banks, Albemarle Sound, Pamlico Sound, Land cover, Land cover change, Ecological Forecasting

# II. Introduction

**Background:** Coastal regions, such as the Albemarle-Pamlico estuary system, are heavily dependent on extensive healthy wetlands to provide a transitional buffer between terrestrial and aquatic ecosystems. These regions provide various ecosystem services that are commonly misunderstood. Wetlands are responsible for sediment trapping, shoreline erosion control by stabilizing loose soil with a dense root mat, filtering toxic heavy metals, and retaining overloaded nutrients from urban or agriculture runoff (Howarth et al. 1996, Lytle et al. 1998, Stevenson et al. 1985, Verhoeven et al. 2006). Vegetation in these ecosystems effectively remove toxic heavy metals such as Chromium (Cr) Cr(IV) from contaminated wastewater and can reduce the metal into a stable non-toxic form Cr(III) by a reduction mechanism (Lytle et al. 1998). Modern agriculture relies heavily on fertilizers to ensure a proper yield, however this overloads nutrients like nitrogen (N) and phosphorus (P) into watersheds. Wetland vegetation species are effective natural buffers to N and P overloading because of their nutrient retention properties in primary production (Verhoeven et al., 2006). Wetlands also offer predation refuge for juvenile fish species which supports local fishing industry by ensuring steady and healthy fish populations (Jude and Pappas, 1992). These ecosystems have very high primary production and effectively sequester carbon by fixing carbon dioxide (CO2) in the form of plant biomass (Whiting and Chanton 2001, Gross et al. 1990). Coastlines frequently subjected to hurricanes and heavy storms such as the eastern United States benefit greatly from wetlands’ ability to mitigate damage and flood conditions (Gedan et al. 2011). Ecotourism also benefits from extensive wetland ecosystems by offering economic opportunities in recreational water activities such as fishing, kayak/canoeing, and nature enthusiasts.

**Project Objectives:** This project looked at wetland extent in the Albemarle-Pamlico estuary over time. Using a dense time-stacking of Landsat Imagery, wetland extent were mapped throughout Albemarle Pamlico watershed between the years 2000 – 2015. NASA Earth Observing Systems (EOS), in particular Landsat-5, 7, and 8, were used to collect imagery. Two indices were used, one that measured change in water extent over the years and one that measured the relative health of the wetlands themselves. This two pronged approach sought to capture both natural and anthropogenic effects on the Albemarle Pamlico estuary system.

**Study Area:** The Albemarle-Pamlico watershed encompasses a large geographic area, approximately 30,000 square miles.  This includes 25 counties in Northeastern, North Carolina and 10 counties in Southeastern, Virginia.  The watershed is made of six major river basins and two major sounds. This project’s study area focused on the Albemarle and Pamlico estuary system, the second largest estuary system in the United States.

**Study Period:** The time period for this study took place over 10 years, 2000 – 2015.

**National Application:** This project contributes to NASA Ecological Forecasting by focusing on mapping wetland extent and creating a method to determine wetland health using remote sensing applications.

**Project Partners:** A partnership with Albemarle-Pamlico National Estuary Partnership (APNEP) has been growing since the fall 2014 term.  Jim Hawhee proposed this project with the intention of applying the methodology to all land cover types in the Albemarle-Pamlico region. The methodologies can also be applied to all National Estuary Programs (28 total) across the United States, who would like to more rapidly and accurately evaluate wetland extent trends within watersheds. APNEP staff is well-positioned to disseminate the results of this project to other programs and consult with them regarding the utility of the effort for environmental management purposes.

# III. Methodology

This analysis used Landsat 5 Thematic Mapper(TM), 7 Enhanced Thematic Mapper (TM+), and Landsat 8 Operational Land Imager (OLI)scenes (path 14, row 35) to examine changes in wetland health and shoreline extent from 2000-2015 (Table 1). In an effort to account for phenology changes associated with seasonality, a summer, fall, winter and spring image for each year was collected from USGS Earth Explorer (Table 2). Imagery with their acquisition dates and sensor are shown in table 3. Image pre-processing included extracting necessary image bands and calculating top-of-atmosphere reflectance for each scene.

Table 1: NASA Earth Observation Satellites used in analysis.

|  |  |
| --- | --- |
| **NASA EOS Used** | **Year** |
| Landsat 5 TM & Landsat 7 ETM+ | 2000 - 2013 |
| Landsat 8 OLI | 2013 - 2015 |

Table 2: Downloaded Landsat data with acquisition date and sensor provided. Landsat 5(LT5), Landsat 7 (LE7), and Landsat 8 (LC8).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Winter** | **Spring** | **Summer** | **Fall** |
| 2000 | 1/21/2000 **[LT5]** | 5/4/2000 **[LE7]** | 8/16/2000 **[LT5]** | 10/19/2000 **[LT5]** |
| 2001 | 2/8/2001 **[LT5]** | 4/29/2001 **[LT5]** | 7/10/2001 **[LE7]** | 10/30/2001 **[LE7]** |
| 2002 | 1/26/2002 **[LT5]** | 4/24/2002 **[LE7]** | 7/29/2002 **[LE7]** | 11/2/2002 **[LE7]** |
| 2003 | 12/28/2002 **[LT5]** | 4/3/2003 **[LT5]** | 8/25/2003 **[LT5]** | 11/13/2003 **[LT5]** |
| 2004 | 1/16/2004 **[LT5]** | 4/5/2004 **[LT5]** | 7/10/2004 **[LT5]** | 11/15/2004 **[LT5]** |
| 2005 | 2/19/2005 **[LT5]** | 5/10/2005 **[LT5]** | 8/22/2005 **[LE7]** | 11/26/2005 **[LE7]** |
| 2006 | 2/14/2006 **[LE7]** | 4/11/2006 **[LT5]** | 8/1/2006 **[LT5]** | 10/4/2006 **[LT5]** |
| 2007 | 1/24/2007 **[LT5]** | 4/30/2007 **[LT5]** | 7/19/2007 **[LE7]** | 10/15/2007 **[LE7]** |
| 2008 | 2/28/2008 **[LT5]** | 4/16/2008 **[LT5]** | 7/21/2008 **[LT5]** | 11/10/2008 **[LT5]** |
| 2009 | 3/18/2009 **[LT5]** | 5/21/2009 **[LT5]** | 8/9/2009 **[LT5]** | 11/5/2009 **[LE7]** |
| 2010 | 2/17/2010 **[LT5]** | 5/8/2010 **[LT5]** | 7/11/2010 **[LT5]** | 10/31/2010 **[LT5]** |
| 2011 | 1/3/2011 **[LT5]** | 4/25/2011 **[LT5]** | 7/14/2011 **[LT5]** | 10/18/2011 **[LT5]** |
| 2012 | 1/30/2012 **[LE7]** | 4/3/2012 **[LE7]** | 7/24/2012 **[LE7]** | 11/29/2012 **[LE7]** |
| 2013 | 3/5/2013 **[LE7]** | 4/14/2013 **[LC8]** | 7/19/2013 **[LC8]** | 11/8/2013 **[LC8]** |
| 2014 | 2/28/2014 **[LC8]** | 5/19/2014 **[LC8]** | 7/6/2014 **[LC8]** | 10/26/2014 **[LC8]** |
| 2015 | 2/15/2015 **[LC8]** | 5/22/2015 **[LC8]** | N/A | N/A |

The change analysis was two-fold, with an examination of coastline change and of overall wetland health throughout the time period. Data processing involved calculating three band indices, the Green Normalized Difference Vegetation Index (Green NDVI), a wetland health index, and Normalized Difference Pigment Index (NDPI) to assess changes in wetland characteristics over time. Green NDVI (equation 1) leverages the green and Near Infra-red (NIR) bands to highlight and measure surface water extent (McFeeters 2013). A threshold of 0 was applied to the index with values > 0 classified as water and values <= 0 classified as non-water (McFeeters 2013).

Equation 1: Green Normalized Vegetation Difference Index

The wetland health index (equation 2) is known for separating water from urban and wetland (Ozesmi and Bauer 2002). The ratio uses the NIR band and Shortwave Infra-red (SWIR) bands to highlight wetlands, allowing them to be easily visually identified. The NIR band highlights vegetation and shorelines and is often considered the most important band in wetland determination (Ozesmi and Bauer 2002). The SWIR band discriminates soil moisture content and vegetation helping to determine areas of frequently wet and inundated soils. Leveraging these bands highlights wetland health and extent, and when the index is calculated for each scene, these characteristics can be viewed across the time series.

Equation 2: Wetland Health Index

The NDPI index highlights the Carotenoid to Chlorophyll A ratio within leaves giving an indicator of the vegetation’s physiological health. Carotenoid persists longer in dying leaves, therefore the NDPI value generally increases in senescing or unhealthy leaves. Assessing this index for each season of each year between 2000 and 2015 gives an understanding of the ways in which wetland health within the study area has changed over time.

Equation 3: Normalized Differences Pigment Index

To account for seasonal and tidal water level differences, the binary land and water images, derived from the Green NDVI, were added together, and the resulting raster shows how frequently a pixel was considered water or land throughout the year, giving an understanding of shoreline extent for the time step. This method allows coastline changes along the Albemarle-Pamlico watershed throughout the time series to be examined without the influence of seasons or tides, and illustrates how coastal wetland locations have moved and shifted throughout the time period. The wetland health index and the NDPI were calculated for each image and complied into a short animation that allows the users to view the two indices in conjunction and visually assess wetland health over time.

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc.? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

Insert here. Keep to a concise paragraph or bullets of names. End with the following sentence.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# VII. References

Gedan K.B., M.L. Kirwan, E. Wolanski, E.B. Barbier, and B.R. Silliman. 2011. The present and future of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. *Climate Change,* 106: 7-29.

Gross M.F., V. Klemas, and M.A. Hardisky. 1990. Long-term remote monitoring of salt marsh biomass. *Remote Sensing of the Biosphere*, 1300: 59-70.

Jude D.J. and J. Pappas. 1992. Fish utilization of Great Lakes coastal wetlands. *Journal of Great Lakes Research*, 18: 651-672.

Lytle C.M., F.W. Lytle, N. Yang, J.H. Qian, D. Hansen, A. Zayed, and N. Terry. 1998. Reduction of Cr(VI) to Cr(III) by Wetland Plants: Potential for In Situ Heavy Metal Detoxification. *Environmental Science and Technology*, 32: 3087-3093.

Stevenson J.C., M.S. Kearney, and E.C. Pendleton. 1985. Sedimentation and erosion in a Chesapeake Bay brackish marsh system. *Marine Geology*, 67: 213-235.

Verhoeven J.T.A., B. Arheimer, C. Yin, and M.M. Hefting. 2006. Regional and global concerns over wetlands and water quality. *TRENDS in Ecology and Evolution*, 21: 96-103.

Whiting G.J. and J.P. Chanton. 2001. Greenhouse carbon balance of wetlands: methane emission versus carbon sequestration. *Tellus*, 53B: 521-528.

Insert references here. Only include articles/content cited in the body of text above. It’s great if you read many other articles, but they should not all be listed here unless they are being cited in this report.

Use whatever style you want - here are some options:

<http://www.dovepress.com/author_guidelines.php?folder_id=208>

<http://en.wikipedia.org/wiki/Citation>

<http://www.agu.org/pubs/pdf/AuthorRefSheet.pdf>

<http://linguistics.byu.edu/faculty/henrichsenl/apa/apa01.html>

# VIII. Content Innovation

In preparation for DEVELOP’s coming microjournal, please select two content innovation features to support your paper. For each item, please list the name of the feature, and include the tool itself if possible (eg. glossary terms and definitions). If the tool does not work in Microsoft Word (eg. Interactive MATLAB Figure Viewer), please list the file name and upload the related file to the microjournal folder on the DEVELOP Exchange. If you choose to use Inline Supplementary Material, please also include where the material should appear in the text.

**Some options include:**

AudioSlides

Database Linking Tool

Data Profile

Executable Papers

Featured Author Videos

Featured Multimedia for this Article (video and podcast options)

Glossary Viewer

Inline Supplementary Material (figures, tables, computer code)

Interactive Map Viewer

Interactive MATLAB Figure Viewer

Interactive Plot Viewer

Nomenclature Viewer

# IV. Appendices

Tables

Table 1: NASA Earth Observation Satellites used in analysis.

|  |  |
| --- | --- |
| **NASA EOS Used** | **Year** |
| Landsat 5 TM & Landsat 7 ETM+ | 2000 - 2013 |
| Landsat 8 OLI | 2013 - 2015 |

Table 2: Downloaded Landsat data with acquisition date and sensor provided. Landsat 5(LT5), Landsat 7 (LE7), and Landsat 8 (LC8).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Winter** | **Spring** | **Summer** | **Fall** |
| 2000 | 1/21/2000 **[LT5]** | 5/4/2000 **[LE7]** | 8/16/2000 **[LT5]** | 10/19/2000 **[LT5]** |
| 2001 | 2/8/2001 **[LT5]** | 4/29/2001 **[LT5]** | 7/10/2001 **[LE7]** | 10/30/2001 **[LE7]** |
| 2002 | 1/26/2002 **[LT5]** | 4/24/2002 **[LE7]** | 7/29/2002 **[LE7]** | 11/2/2002 **[LE7]** |
| 2003 | 12/28/2002 **[LT5]** | 4/3/2003 **[LT5]** | 8/25/2003 **[LT5]** | 11/13/2003 **[LT5]** |
| 2004 | 1/16/2004 **[LT5]** | 4/5/2004 **[LT5]** | 7/10/2004 **[LT5]** | 11/15/2004 **[LT5]** |
| 2005 | 2/19/2005 **[LT5]** | 5/10/2005 **[LT5]** | 8/22/2005 **[LE7]** | 11/26/2005 **[LE7]** |
| 2006 | 2/14/2006 **[LE7]** | 4/11/2006 **[LT5]** | 8/1/2006 **[LT5]** | 10/4/2006 **[LT5]** |
| 2007 | 1/24/2007 **[LT5]** | 4/30/2007 **[LT5]** | 7/19/2007 **[LE7]** | 10/15/2007 **[LE7]** |
| 2008 | 2/28/2008 **[LT5]** | 4/16/2008 **[LT5]** | 7/21/2008 **[LT5]** | 11/10/2008 **[LT5]** |
| 2009 | 3/18/2009 **[LT5]** | 5/21/2009 **[LT5]** | 8/9/2009 **[LT5]** | 11/5/2009 **[LE7]** |
| 2010 | 2/17/2010 **[LT5]** | 5/8/2010 **[LT5]** | 7/11/2010 **[LT5]** | 10/31/2010 **[LT5]** |
| 2011 | 1/3/2011 **[LT5]** | 4/25/2011 **[LT5]** | 7/14/2011 **[LT5]** | 10/18/2011 **[LT5]** |
| 2012 | 1/30/2012 **[LE7]** | 4/3/2012 **[LE7]** | 7/24/2012 **[LE7]** | 11/29/2012 **[LE7]** |
| 2013 | 3/5/2013 **[LE7]** | 4/14/2013 **[LC8]** | 7/19/2013 **[LC8]** | 11/8/2013 **[LC8]** |
| 2014 | 2/28/2014 **[LC8]** | 5/19/2014 **[LC8]** | 7/6/2014 **[LC8]** | 10/26/2014 **[LC8]** |
| 2015 | 2/15/2015 **[LC8]** | 5/22/2015 **[LC8]** | N/A | N/A |

Equation example (from Colorado Water Resources’ Tech Paper)

“This runoff is calculated using the following equation:

Equation 2: Spatial distribution of runoff equation

where *pn* is the spatially distributed monthly precipitation data and *p* is the average climatic precipitation for the region.“