



Department of Geography and the Environment Villanova University

Background:

In 2020, Villanova purchased Pleiades and WorldView-2 (WV-2) satellite imagery of the area of the marshes of Plum Island Sound, Massachusetts (Figure 1) with the Pennsylvania View (PA View) grant funding. The imagery acquired with grant funding was in June of 2017 and June of 2018 for NDVI analysis, and was augmented with a supplemental department purchase of WorldView-3 (WV-3) satellite imagery from January 2018 to perform ice raft analysis. The WV-3 imagery acquired would be just after the January 2018 Northeastern U.S. blizzard (bomb cyclone) and the June imagery from 2017 and 2018 were used to perform vegetation analysis to determine the extent of winter storm damage on the marsh habitat. The Plum Island marshes are a study area for one of the Villanova Environmental Science graduate students who is investigating the effect of storms on sediment deposition including via a mechanism called ice rafting. After an extended cold period, sediment can freeze to the undersides of ice formed in the creek beds or tidal banks of a marsh and can be carried onto the marsh surface during a spring tide or storm event. This project is using high resolution imagery and image processing techniques to determine if ice rafting can be detected in high resolution imagery and if so, analyze the impacts and extent. In addition, imagery collected in June of 2017 and again in 2018 will be analyzed with Normalized Differential Vegetation Index (NDVI) processing to determine differences in vegetation vigor of the marsh grass (*S. alterniflora*) from winter storms.

It is anticipated that high and medium resolution satellite imagery should be sufficient to detect environmental changes in marsh habitat from these storms. It is not clear that the aforementioned ice rafting will be visible even in high resolution satellite imagery. The imagery can also be used by future undergraduate and graduate students who will have projects in the Plum Island marshes. The project will introduce the Remote Sensing students to geographic technologies and techniques.

Summary of January 2018 Bomb Cyclone¹:

Being the most geographically proximate to the storm's track, Massachusetts bore the highest impacts of all U.S. East Coast states. Winds gusted to hurricane-force at 76 miles per hour (122 km/h) on Nantucket and over 70 mph (110 km/h) on mainland Massachusetts. Figure 2 shows a weather satellite image of the storm.

At least 17.0 inches (430 mm) of snow fell on the Boston area, and 14.1 inches (360 mm) fell in Providence, Rhode Island. In Boston, a storm tide of 15.16 ft (4.62 m) was recorded during the blizzard which flooded areas of the financial district, including a subway station. This beat the previous record set in 1978 by the Blizzard of 1978. Significant coastal flooding occurred in Maine and New Hampshire. Figure 3 shows the advisories and warnings that were issued and Figure 4 shows the storm track up the East Coast.

Analysis Results to Date:

Figure 5 shows the most recent versions of the two Normalized Differential Vegetation Index (NDVI) images (June 2017 and June 2018) for comparison. NDVI is an image processing technique that measures the health or vigor of vegetation.

Our eye perceives healthy vegetation as green. Healthy plants also have a high reflectance in Near Infrared (NIR) region between 0.7 to 1.3 μm . This is primarily due to internal structure of plant leaves. Give high reflectance in NIR and high absorption in Red spectrum, these two bands are used to calculate NDVI. So, the following formula gives Normalized Difference Vegetation Index (NDVI).

- $\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red})$

The NDVI value varies from -1 to 1. A higher, positive value of NDVI indicates high Near Infrared (NIR) reflectance, and means dense greenery. Generally, we obtain following result:

- NDVI = -1 to 0 represent water bodies
- NDVI = +0.1 to 1 represents vegetation in various states of health

Figure 5 comparison indicates there is clearly a difference, qualitatively and quantitatively, between the Plum Island marsh vegetation vigor from 2017 to 2018. This suggests the January 2018 bomb cyclone and the associated ice rafting event may have had an impact on the next season's marsh vegetation habitat. The NDVI results are preliminary and further analysis is ongoing. The next step was to verify if ice rafting occurred as a result of the storm, and if it did, it may explain the differences in marsh vegetation health and reflectance in June of 2018 from June of 2017.

With post-storm (January 2018) WorldView-3 imagery purchased by the department to augment the study for ice rafting research, the student researcher has tried a few different classifications and is still evaluating whether unsupervised or object-based classification is best. The results are preliminary and further analysis will determine the optimum methodology.

Figure 6 shows an image that has WV-3 bands 4, 2, and 1, with ice raft polygons on top. The student performed a 15 class unsupervised classification with those bands and then the 'ice' class was used to create the ice raft polygons (anywhere ice was not on top of water). Preliminary results to date indicate the presence of ice rafts in the high-resolution imagery, which is very pleasing.

With some more work, the graduate student hopes to submit this for publication. Overall results to date are promising.

For the graduate student researcher, the project will provide practical experience to display and analyze satellite imagery, and to understand real environmental issues from natural disasters facing communities and the potential mitigation options that can be implemented. This project can be adapted as a lab exercise in future remote sensing, GIS or environmental studies classes.

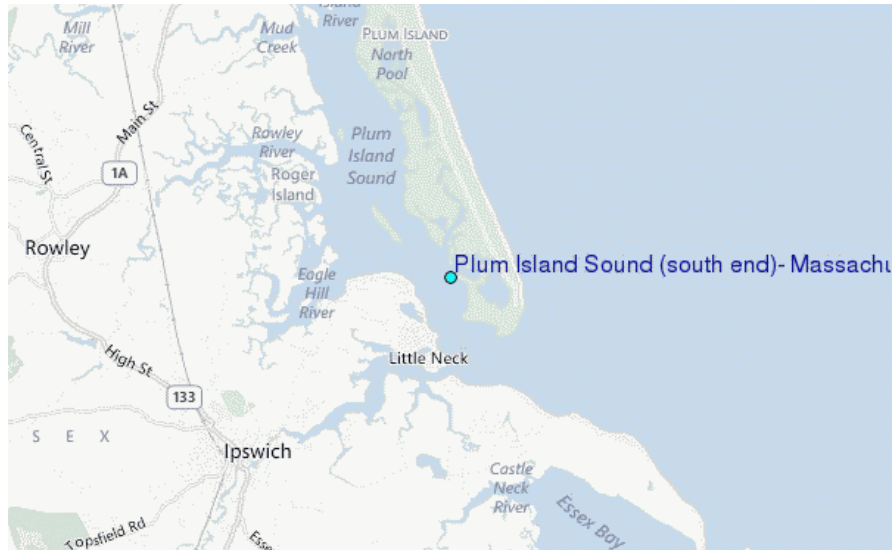


Figure 1. Map of the Plum Island Sound Study Area

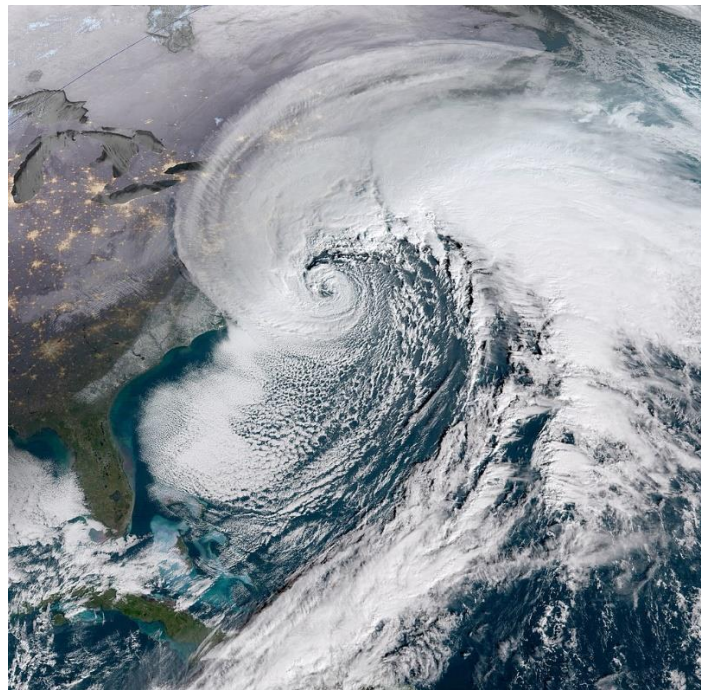


Figure 2. January 2018 Bomb Cyclone. Satellite image of a sprawling cloud structure centered horizontally. Cuba is visible on the bottom-left of the image while the eastern United States is visible on the left.

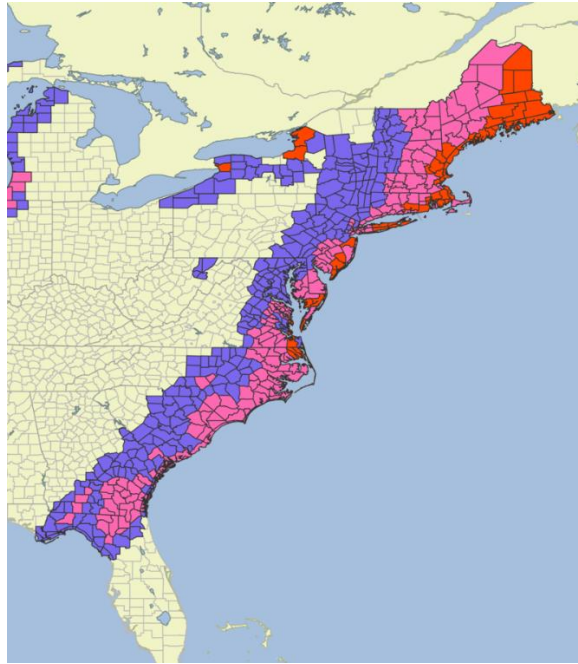


Figure 3. All winter weather advisories, winter storm warnings, and blizzard warnings in the Eastern United States from January 2 to January 5.

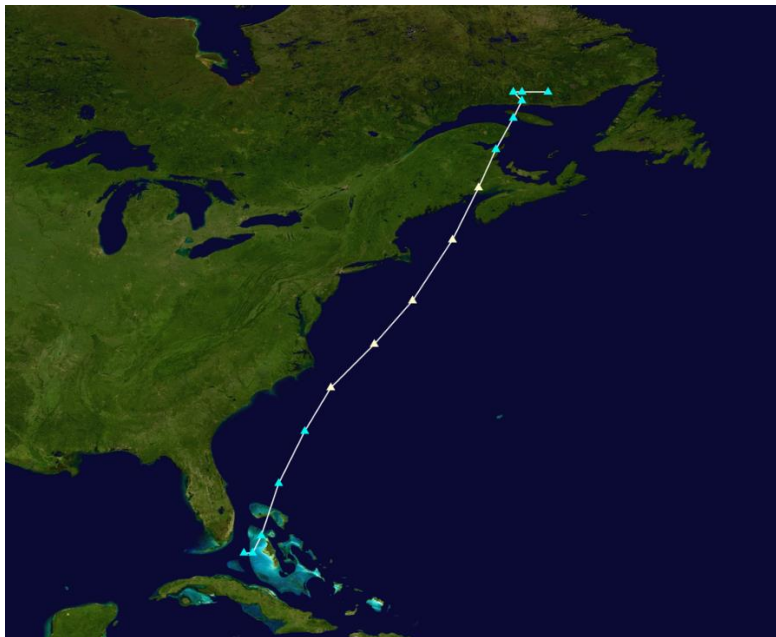


Figure 4. Map plotting the track and the intensity of the storm, according to the Saffir–Simpson scale

NDVI

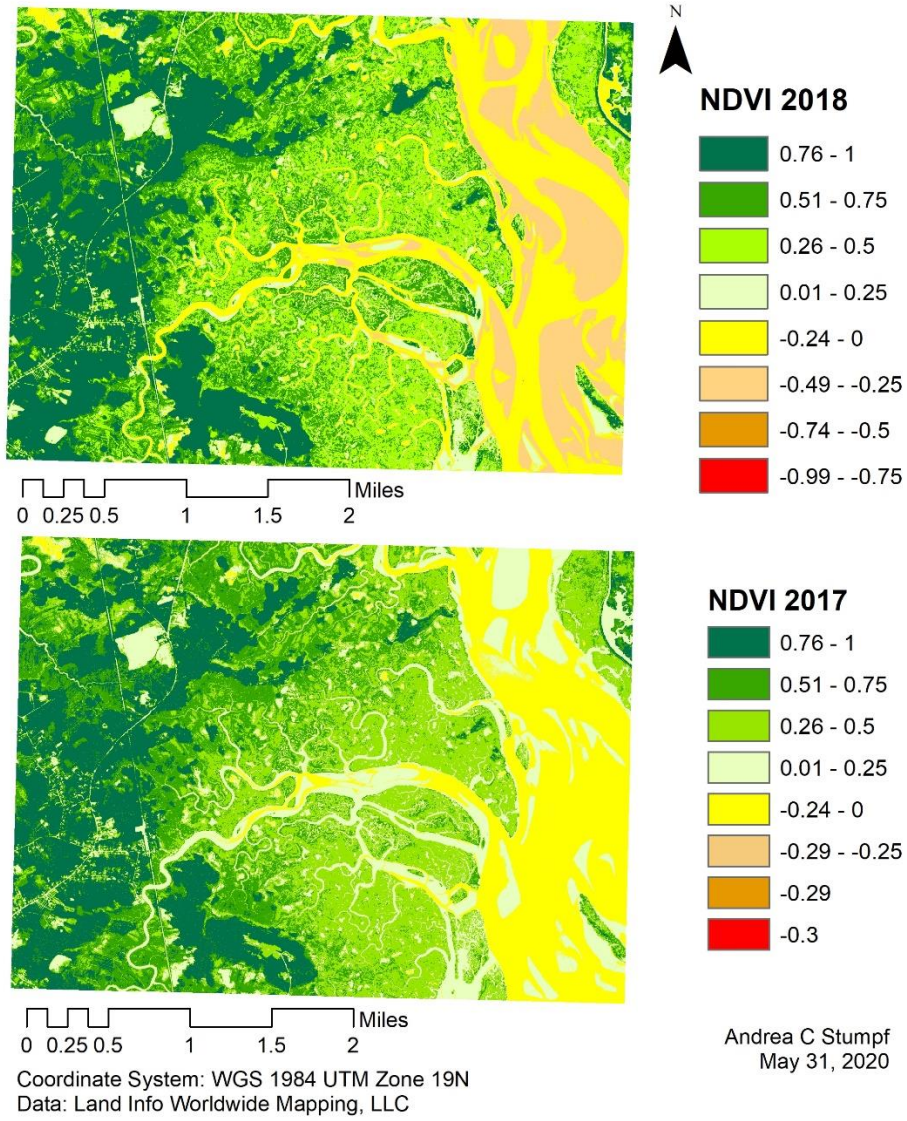
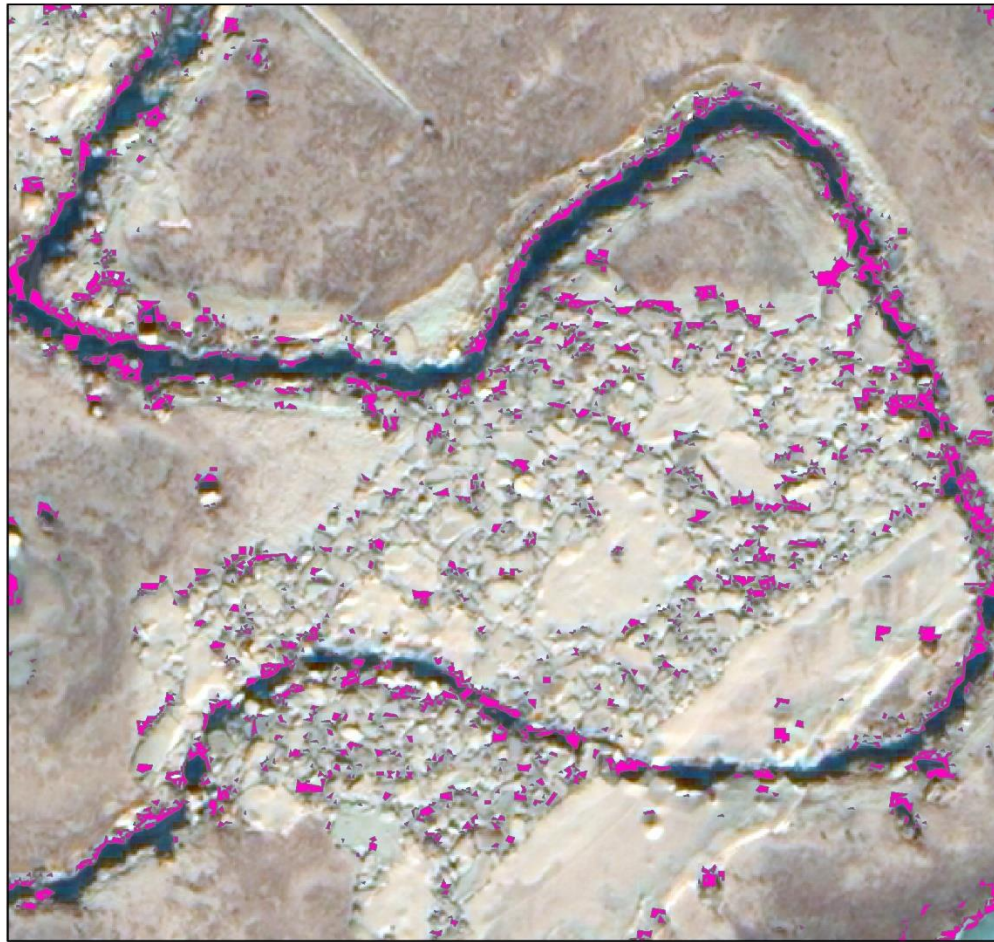


Figure 5. Normalized Differential Vegetation Index (NDVI) analysis of the June 2017 and June 2018 satellite imagery over Plum Island Sound.

Unsupervised classification



0 10 20 40 60 Meters

Ice raft polygons

Coordinate System: WGS 1984 UTM Zone 19N
Data: Land Info Worldwide Mapping, LLC

Andrea C Stumpf
May 31, 2020

Figure 6. Unsupervised image classification of the January 7, 2018 Plum Island Sound habitat just after the bomb cyclone.

Grant Purchased Pleiades & WV2 Archive Satellite Imagery:

- **AOI:** Plum Island, Massachusetts
- **Products:**
 - Pleiades 50cm/2m 4-Band Pan-Sharpended (Orthorectified) Product
 - WV2 50cm/2m 4-Band Pan-Sharpended (Orthorectified) Product
 - Custom Orthorectification/Co-Registration
- **Date of Imagery:**
 - Pleiades 06/08/2018
 - WV2 06/15/2017
- **Scene IDs:**
 - **Pleiades ID #1**
DS_PHR1B_201806081537470_FR1_PX_W071N42_0421_08076
 - **Pleiades ID #2**
DS_PHR1B_201806081538343_FR1_PX_W071N42_0117_04676
 - **WV2 ID**
103001006B91A400
- **Bit Depth:** 8-Bit and 16 Bit
- **Projection / Datum:** UTM / WGS84
- **Image Processing:** Orthorectification and Pan-Sharpening
- **Radiometric Correction:** Display (8-bit), Unstretched (16-bit)
- **Format:** GeoTiff (.tif)

Department Purchased WV3 Archive Satellite Imagery:

- **AOI:** Plum Island, Massachusetts
- **Product:** 30cm/1.2m 4-Band Pan-Sharpended (Orthorectified) Product
- **Date of Imagery:** 01/07/2018
- **Scene ID:** 1040010035076900
- **Bit Depth:** 8-Bit and 16-Bit
- **Projection / Datum:** UTM / WGS84
- **Image Processing:** Orthorectification and Pan-Sharpening
- **Radiometric Processing:** Stretched (8-bit) & unstretched (16-bit)
- **Format:** GeoTiff (.tif)

Citations:

¹ Wikipedia, https://en.wikipedia.org/wiki/January_2018_North_American_blizzard

Submitted By:

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