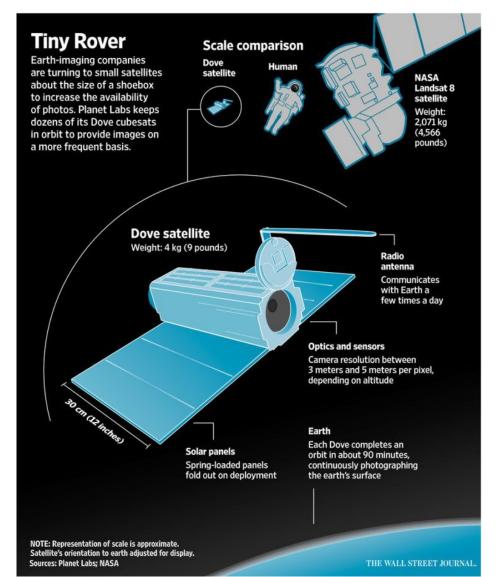
# Using daily PlanetScope imagery to estimate seagrass density and blue carbon.

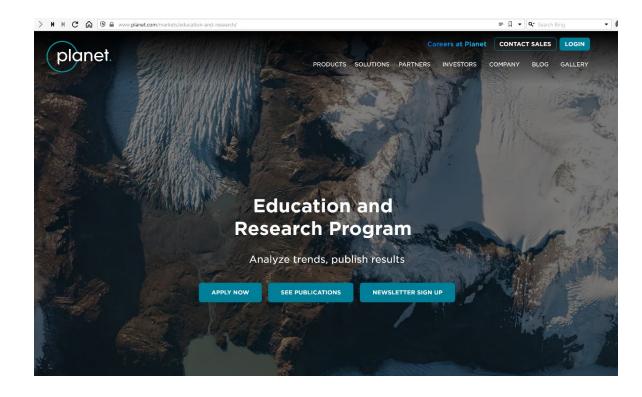
Victoria Hill, Richard Zimmerman Department of Ocean and Earth Sciences. Old Dominion University, Norfolk. Virginia. USA



# PlanetScope



- Multispectral, high spatial resolution
  - 4 m 3, 4 & 8 band multispectral
  - 1 m multispectral (skysat)
  - Almost daily coverage (Over 100 satellites)



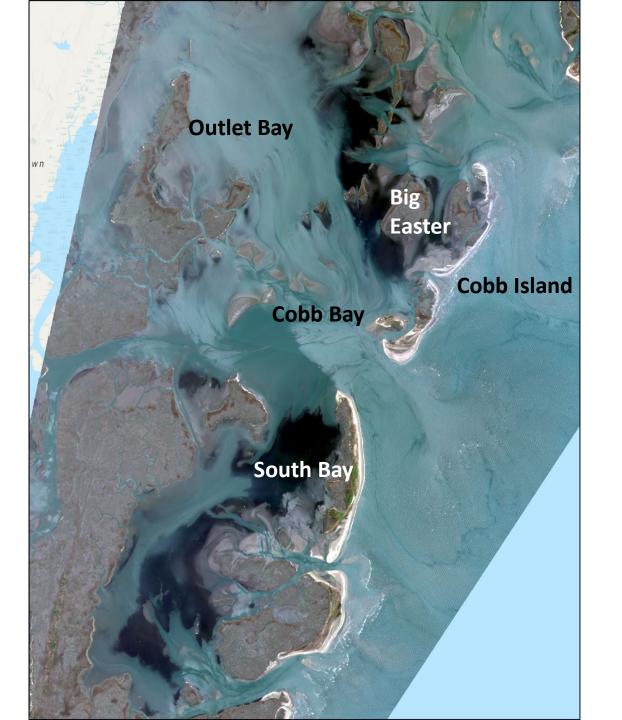
# Chesapeake Bay sites of interest.

- 5 sites
- Ranging from saline to fresh



# South Bay & Spider Crab

- Planet passes every day, often multiple passes from different sensors.
- Images good for seagrass identification.
  - Low tide
  - Low turbidity
  - Low cloud cover.



#### South Bay & Spider Crab

#### 

|     |     | Ja  | nua  | ary |     |     |     |     | Fel | bru | ary | 8   |     |     |     | N   | larc | h   |     |      |
|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|------|
| Sun | Non | Tee | Wed  | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Non | Tee | Wed  | Thu | Fri | Set  |
|     |     | 1   | z    | 3   | 4   | 5   |     |     |     |     |     | 1   | 2   |     |     |     |      |     | 1   | 2    |
| 6   | 7   | 8   | 9    | 10  | 11  | 12  | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 3   | 4   | 5   | 6    | 7   | 8   | 9    |
| 13  | 14  | 15  | 16   | 17  | 18  | 19  | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 10  | 11  | 12  | 13   | 14  | 15  | 16   |
| 20  | 21  | 22  | 23   | 24  | 25  | 26  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 17  | 18  | 19  | 20   | 21  | 22  | 23   |
| 27  | 28  | 29  | 30   | 31  |     |     | 24  | 25  | 21  |     | 28  |     |     | 24  | 25  | 26  | 27   |     | 29  | 30   |
|     |     |     |      |     |     |     |     |     |     |     |     |     |     | 31  | -   |     |      |     |     |      |
|     |     | 1   | \pri | Ľ.  |     |     |     |     | 1   | May |     |     |     |     |     | J   | lun  | e   |     |      |
| Sun | Mon | Tue | Wed  | Thu | Fri | Sat | Sun | Mon |     |     |     | Fri | Sat | Sun | Non | Tae | Wed  | Thu | Fri | Sat  |
|     | 1   | 2   | 3    | 4   | 5   | 6   |     |     |     | 1   | 2   | 3   | .4  |     |     |     |      |     |     | 1    |
| 7   | 8   | 9   | 10   | 11  | 12  | 13  | - 5 | 6   | 73  | 8   | 9   | 10  | 11  | 2   | 3   | 4   | 5    | 6   | 7   | 8    |
| 14  | 15  | 16  | 17   | 18  | 19  | 20  | 12  | 13  | 14  | 15  | 16  | 17  | 18  |     | 10  | 11  | 12   | 13  | 14  | 15   |
| 21  |     | 23  | 24   | 25  | 26  | 27  | 19  | 20  | 21  | 22  | 23  | 24  | 25  | 18  | 17  | 18  | 19   | 20  | 21  | 22   |
| 28  | 29  | 2.2 |      | -   | -   | -   | 2   | 27  |     | 29  |     | 31  | -   | 23  | 24  | 25  | 26   | 27  | 28  | 29   |
| -   |     | ~   |      |     |     |     |     | -   | -   |     | ~   |     |     | 30  | -   | -   |      | 1   |     |      |
|     |     |     | July | ,   |     |     |     |     | A   | ugu | st  |     |     |     | 5   | Sep | ten  | nbe | r   |      |
| Sun | Mon | Tat | Wed  | Thu | Fri | Sat | Sun | Mue | Tae | Wed | Thu | Fri | Sat | San | Non | 340 | Wed  | Thu | Fri | Sat  |
|     | 1   | 2   | 3    | 4   | 5   | 6   |     |     |     |     | 1   | 2   | 3   | 1   | 2   | 3   | 4    | 5   | 6   | 7    |
| 7   | 8   | 9   | 10   | 11  | 12  | 13  | 4   | 5   | 6   | 7   | 8   | 9   | 10  |     | 9   | 10  | 11   | 12  | 13  | 14   |
| 14  | 15  | 16  | 17   | 18  | 19  | 20  | 11  | 12  | 13  | 14  | 15  | 16  | 17  | 15  | 16  | 17  | 18   | 19  | 20  | 21   |
| 21  | 22  | 23  | 24   | 25  | 26  | 27  | 18  | 19  | 20  | 21  | 22  | 23  | 24  | 22  | 23  | 24  | 2    | 26  | 27  | 28   |
| 28  | 29  | 30  | 31   | 200 |     |     | 25  | 26  | 27  | 28  | 29  | 30  | 31  | 29  | 30  |     |      | 100 |     | 1700 |
|     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |     |     |      |     |     |      |
|     |     |     |      |     |     |     |     |     |     |     |     |     |     |     |     |     |      |     |     |      |

|     |     | 00  | tot | ю   |     |     |     | 1   | Nov | /em | ibe | r . |     |     | 1   | Dec | em  | be  | r   |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Sun | Mee | 140 | Wed | Thu | Fri | Sat | Sen | Mee | 140 | Wed | The | Fri | 841 | See | Mon | 740 | Wed | Thu | Fri | 841 |
|     |     |     | 2   |     |     |     |     | 1   |     |     |     |     |     | 1   |     |     |     |     |     |     |
| 6   | 7   | 8   | 9   | 10  | 11  | 12  | 3   | 6   | 5   | 6   | 7   | 8   | 9   |     | 9   | 10  | 11  | 12  | 13  | 14  |
| 13  | 14  | 15  | 16  | 17  | 18  | 19  | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 15  | 16  | 17  | 18  | 19  | 20  | 21  |
| 20  | 21  | 22  | 23  | 2   | 25  | 26  | 17  | 18  | 19  | 20  | 21  | 22  | 23  | 22  | 23  | 24  | 25  | 26  | Z7  | 28  |
| 27  | 28  | 29  | 30  | 31  |     |     | 24  | 25  | 26  | 27  | 28  | 29  | 30  | 29  | 30  | 31  |     |     |     |     |
|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

|     |     | Ja  | nua | ary |     |     |     |     | Fe  | bru | ary |     |     |     |     | N   | larc | h   |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|
| Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed  | Thu | Fri | Sat |
|     |     |     | 1   | 2   | 3   | 4   |     |     |     |     |     |     | 1   | 1   | 2   | 3   | 4    | 5   | 6   | 7   |
| 5   | 6   | 7   | 8   | 9   | 10  | 11  | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 8   | 9   | 10  | 11   | 12  | 13  | 14  |
| 12  | 13  | 14  | 15  | 16  | 17  | 18  | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 15  | 16  | 17  | 18   | 19  | 20  | 21  |
| 19  | 20  | 21  | 22  | 23  | 24  | 25  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 22  | 23  | 24  | 25   | 26  | 27  | 28  |
| 26  | 27  | 28  | 29  | 30  | 31  |     | 23  | 24  | 25  | 26  | 27  | 28  | 29  | 29  | 30  | 31  |      |     |     |     |

|     |     | 1   | Apri | 1   |     |     |     |     | 1   | May | 1   |     |     |     |     |     | lun | e   |     |     |
|-----|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Sun | Mon | Tue | Wed  | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|     |     |     | 1    | 2   | 3   | 4   |     |     |     |     |     | 1   | 2   |     | 1   | 2   | 3   | 4   | 5   | 6   |
| 5   | 6   | 7   | 8    | 9   | 10  | 11  | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 7   | 8   | 9   | 10  | 11  | 12  | 13  |
| 12  | 13  | 14  | 15   | 16  | 17  | 18  | 10  | 11  | 12  | 13  | 14  | 15  | 16  | 14  | 15  | 16  | 17  | 18  | 19  | 20  |
|     |     |     |      |     |     |     | 17  |     |     |     |     |     |     |     |     |     | 24  |     |     |     |
| 26  | 27  | 28  | 29   | 30  |     |     | 24  | 25  | 26  | 27  | 28  | 29  | 30  | 28  | 29  | 30  |     |     |     |     |
|     |     |     |      |     |     |     | 31  |     |     |     |     |     |     |     |     |     |     |     |     |     |

Sun

12 19

Designed by 123Fm

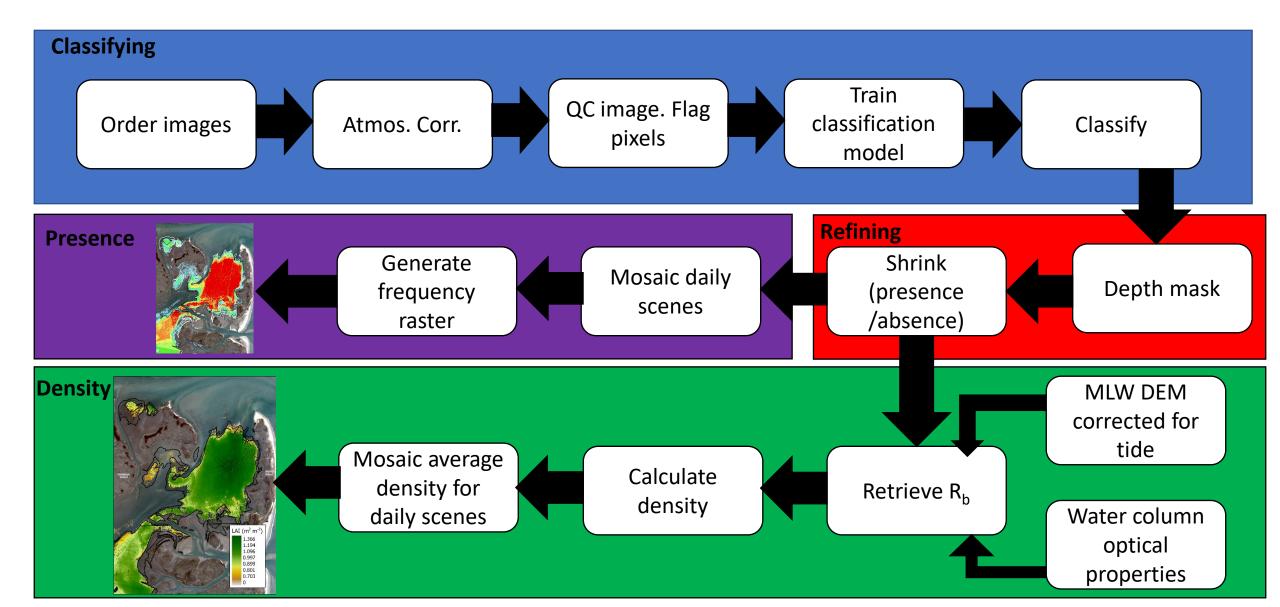
|     |     | July | /   |     |     |     |     | A   | ugu | st  |     |     |     | 5   | Sep | ten | nbe | r   |     |
|-----|-----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Mon | Tue | Wed  | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|     |     | 1    | 2   | з   | 4   |     |     |     |     |     |     | 1   |     |     | 1   | 2   | 3   | 4   | 5   |
| 6   | 7   | 8    | 9   | 10  | 11  | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
| 13  | 14  | 15   | 16  | 17  | 18  | 9   | 10  | 11  | 12  | 13  | 14  | 15  | 13  | 14  | 15  | 16  | 17  | 18  | 19  |
| 20  | 21  | 22   | 23  | 24  | 25  | 16  | 17  | 18  | 19  | 20  | 21  | 22  | 20  | 21  | 22  | 23  | 24  | 25  | 26  |
| 27  | 28  | 29   | 30  | 31  |     | 23  | 24  | 25  | 26  | 27  | 28  | 29  | 27  | 28  | 29  | 30  |     |     |     |
|     |     |      |     |     |     | 10  | 31  |     |     |     |     |     |     |     |     |     |     |     |     |

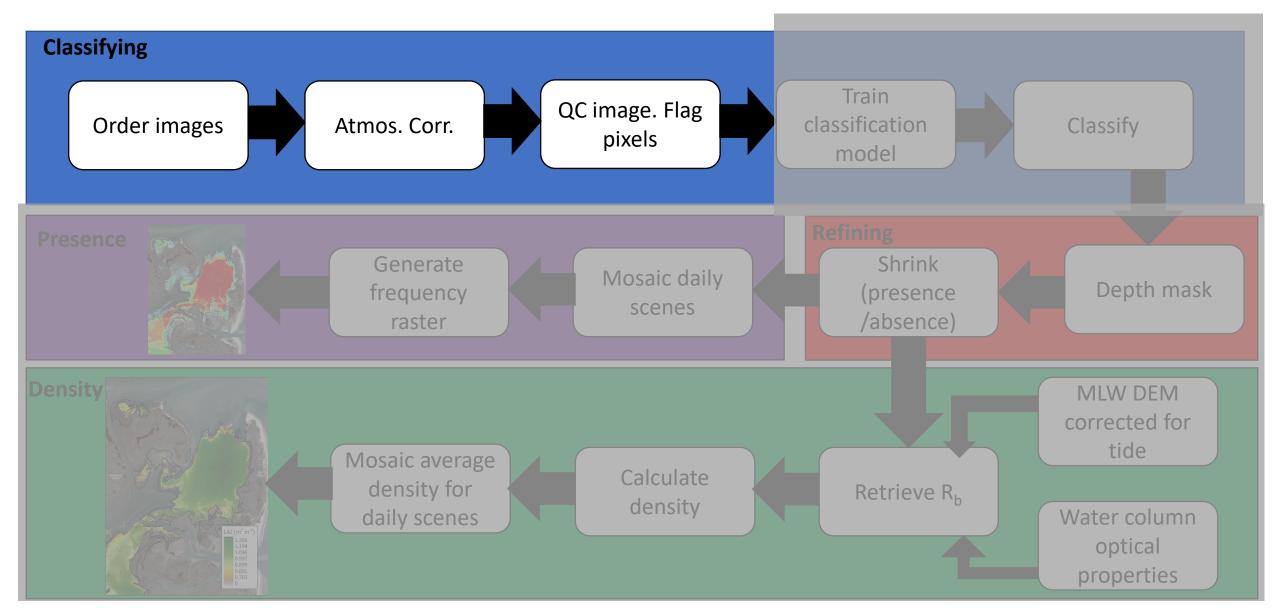
|     |     | 00  | tot | ber |     |     |     | 1   | Nov | /em | be  | r   |     |     | - 3 | Dec | cem | be  | r   |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed | Thu | Fri | Sat |
|     |     |     |     | 1   | 2   | 3   | 1   | 2   | 3   | 4   | 5   | 6   | 7   |     |     | 1   | 2   | 3   | 4   | 5   |
| 4   | 5   | 6   | 7   | 8   | 9   | 10  | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 6   | 7   | 8   | 9   | 10  | 11  | 12  |
| 11  | 12  | 13  | 14  | 15  | 16  | 17  | 15  | 16  | 17  | 18  | 19  | 20  | 21  | 13  | 14  | 15  | 16  | 17  | 18  | 19  |
| 18  | 19  | 20  | 21  | 22  | 23  | 24  | 22  | 23  | 24  | 25  | 26  | 27  | 28  | 20  | 21  | 22  | 23  | 24  | 25  | 26  |
| 25  | 26  | 27  | 28  | 29  | 30  | 31  | 29  | 30  |     |     |     |     |     | 27  | 28  | 29  | 30  | 31  |     |     |
|     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

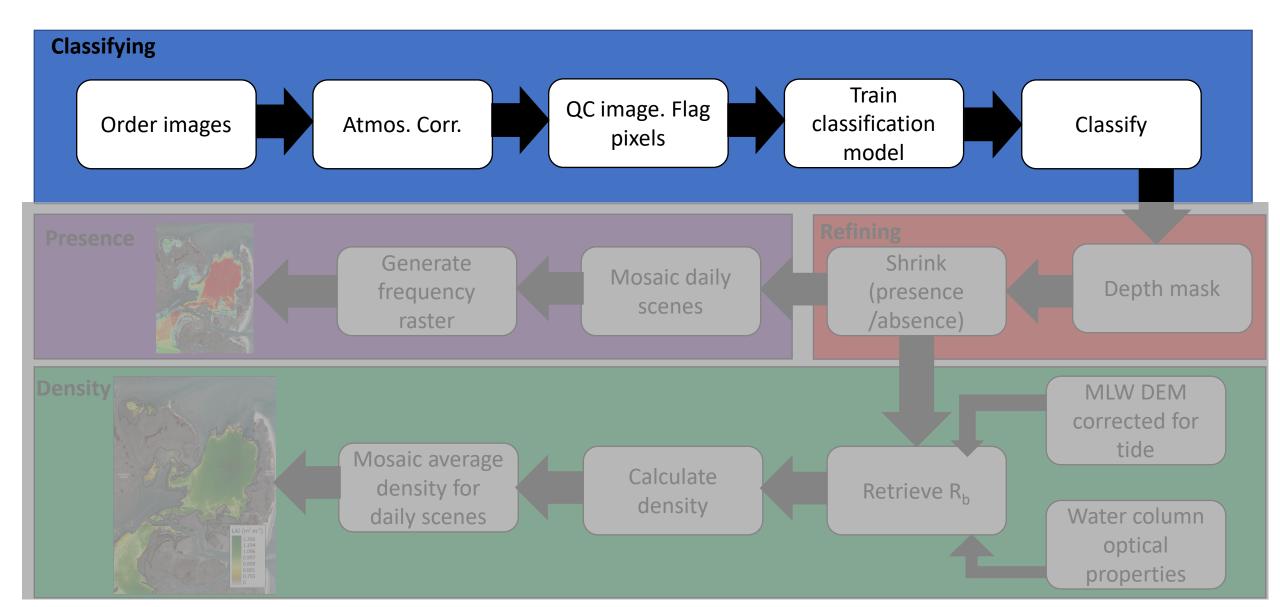
#### 

|     |     | Ja    | nua    | ary  |     |     |     |          | Fe  | bru | ary | ß   |     |     |     | N   | larc | h    |     |      |
|-----|-----|-------|--------|------|-----|-----|-----|----------|-----|-----|-----|-----|-----|-----|-----|-----|------|------|-----|------|
| Sun | Mon | Tue   | Wed    | Thu  | Fri | Sat | Sun | Mon      | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed  | Thu  | Fri | Sat  |
|     |     |       |        |      | 1   | 2   |     | 1        | 2   | 3   | 4   | 5   | 6   | -   | 1   | 2   | 3    | 4    | 5   | 6    |
| 3   | 4   | 5     | 6      | 7    | 8   | 9   | 7   | 8        | 9   | 10  | 11  | 12  | 13  | 7   | 8   | 9   | 10   | 11   | 12  | 13   |
| 10  | 11  | 12    | 13     | 14   | 15  | 16  | 14  | 15       | 16  | 17  | 18  | 19  | 20  | 14  | 15  | 16  | 17   | 18   | 19  | 20   |
| 17  | 18  | 19    | 20     | 21   | 22  | 23  | 21  | 22       | 23  | 24  | 25  | 26  | 27  | 21  | 22  | 23  | 24   | 25   | 26  | 27   |
| 24  | 25  | 26    | 27     | 28   | 29  | 30  | 28  |          |     |     |     |     |     | 28  | 29  | 30  | 31   |      |     |      |
| 31  |     |       |        |      |     |     |     |          |     |     |     |     |     |     |     |     |      |      |     |      |
|     |     | 1     | Apri   | il i |     |     |     |          | 1   | May | 1   |     |     |     |     |     | Jun  | e    |     |      |
| Sun | Mon | Tue   | Wed    | Thu  | Fri | Sat | Sun | Mon      | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed  | Thu  | Fri | C at |
|     |     |       |        | 1    | 2   | 3   |     |          | _   |     |     |     | 1   | _   |     | 1   | 2    | 3    | 4   | 5    |
| 4   | 5   | 6     | 7      | 8    | 9   | 10  | 2   | 3        | 4   | 5   | 6   | 7   | 8   | 6   | 7   | 8   | 9    | 10   | 11  | 12   |
| 11  | 12  | 13    | 14     | 15   | 16  | 17  | 9   | 10       | 11  | 12  | 13  | 14  | 15  | 13  | 14  | 15  | 16   | 17   | 18  | 19   |
| 18  | 19  | 20    | 21     | 22   | 23  | 24  | 16  | 17       | 18  | 19  | 20  | 21  | 22  | 20  | 21  | 22  | 23   | 24   | 25  | 26   |
| 25  | 26  | 27    | 28     | 29   | 30  |     | 3   | 24<br>31 | 25  | 26  | 27  | 28  | 29  | 27  | 28  | 29  | 30   |      |     |      |
|     |     | _     | July   |      |     |     |     |          |     | ugu |     |     |     |     |     | •   | ten  | _    | r   |      |
| Sun | Mon | Tue   | Wed    |      |     | Sat |     |          |     | Wed |     |     |     | Sun | Mon | Tue |      |      | Fri | Sat  |
|     |     |       |        | 1    | 2   | 3   | 1   | 2        | 3   | 4   | 5   | 6   | 7   |     |     |     | 1    | 2    | 3   | 4    |
| 4   | 5   | 6     | 7      | 8    | 9   | 10  | 8   | 9        |     | 11  |     | 13  | 14  | 5   | 6   | 7   | 8    | - C  | 10  | 11   |
| 11  | 12  | 13    |        | 15   | 16  | 17  | 15  | 16       | 17  | 18  | 9   | 20  | 21  |     | 13  |     | 5    | 1.00 | 17  | 18   |
| 18  | 19  | 20    | 21     | 22   | 23  | 24  | 22  | 23       | 24  | 25  | 26  | 27  | 28  | 9   |     | 21  |      | 23   | 24  | 25   |
| 25  | 26  | 27    | 28     | 29   | 30  | 31  | 29  | 30       | 31  |     |     |     |     | 26  | 27  | 28  | 29   | 30   |     |      |
|     |     | 00    | tob    | ber  |     |     |     |          | Nov | vem | be  | r   |     |     |     | Dec | cem  | be   | r   |      |
| Sun | Mon | Tue   | Wed    | Thu  | Fri | Sat | Sun | Mon      | Tue | Wed | Thu | Fri | Sat | Sun | Mon | Tue | Wed  | Thu  | Fri | Sat  |
|     |     | 58.86 | 220033 |      | 1   | 2   |     | 1        | 2   | 3   | 4   | 5   | 6   |     |     |     | 1    | 2    | 3   | 4    |
| 3   | 4   | 5     | 6      | 7    | 8   | 9   | 7   | 8        | 9   | 10  | 11  | 12  | 13  | 5   | 6   | 7   | 8    | 9    | 10  | 11   |
| 10  | 11  | 12    | 13     | 14   | 15  | 16  | 14  | 15       | 16  | 17  | 18  | 19  | 20  | 12  | 13  | 14  | 15   | 16   | 17  | 18   |
| 17  | 18  | 19    | 20     | 21   | 22  | 23  | 21  | 22       | 23  | 24  | 25  | 26  | 27  | 19  | 20  | 21  | 22   | 23   | 24  | 25   |
| 24  | 25  | 26    | 27     | 28   | 29  | 30  | 28  | 29       | 30  |     |     |     |     | 26  | 27  | 28  | 29   | 30   | 31  |      |
| 31  |     |       |        |      |     |     |     |          |     |     |     |     |     |     |     |     |      |      |     |      |
| che | -   | om    |        |      |     |     |     |          |     |     |     |     |     |     |     |     |      |      |     |      |

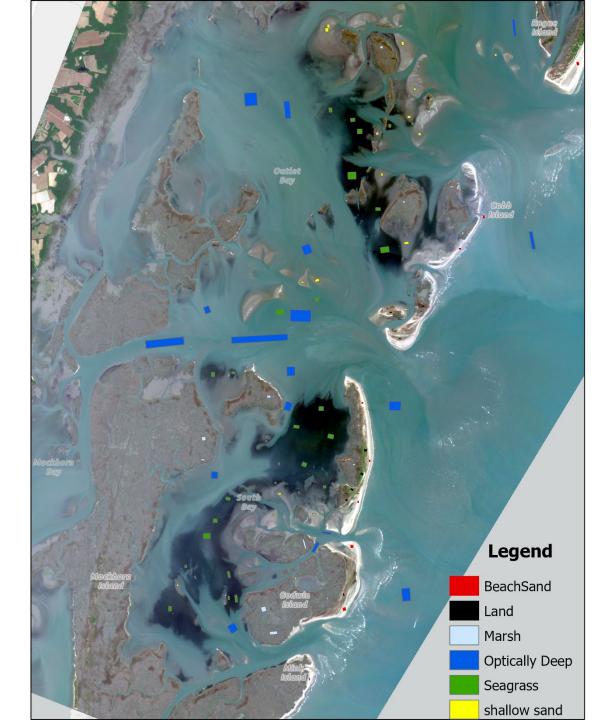
Designed by 123FreeVectors.com



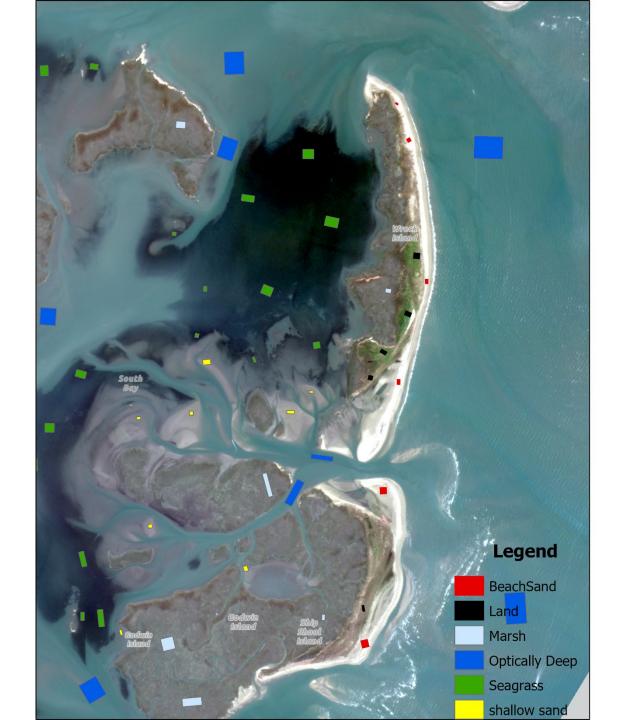


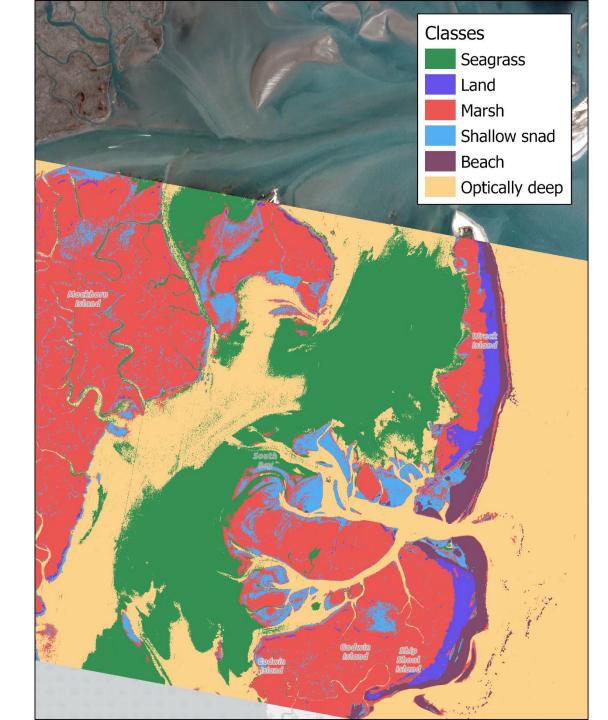


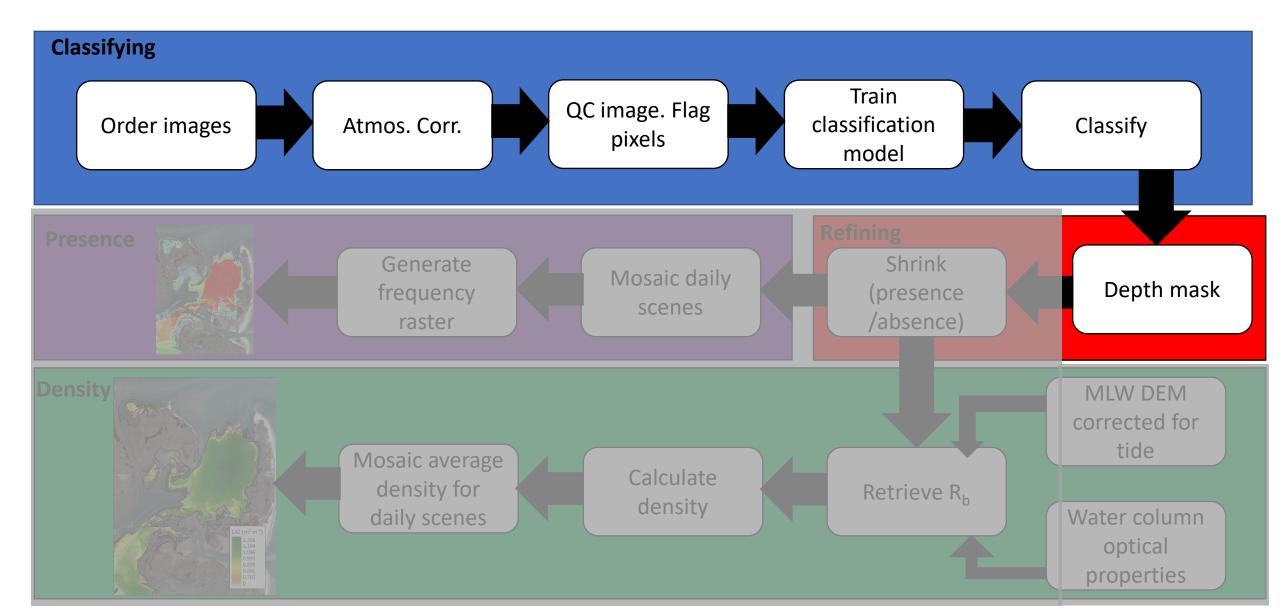
- Generate training patches for each target
  - Beach
  - Land
  - Marsh
  - Optically deep
  - Seagrass
  - Shallow sand



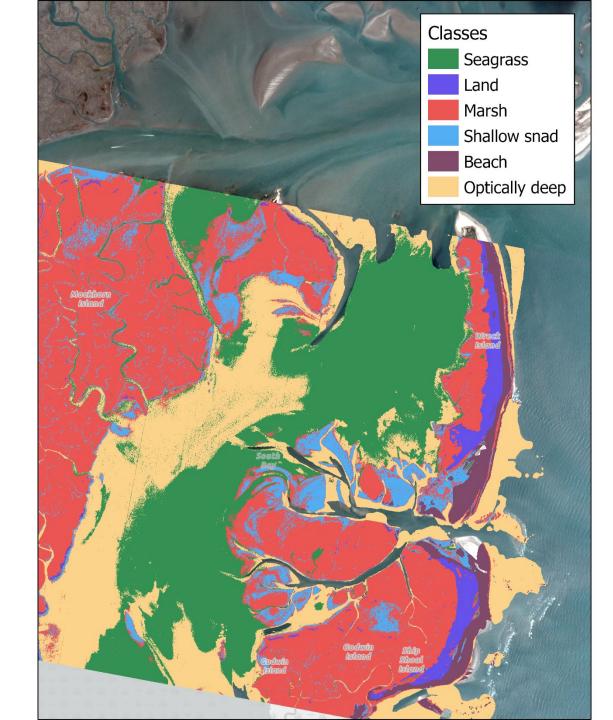
- Generate training patches for each target
  - Beach
  - Land
  - Marsh
  - Optically deep
  - Seagrass
  - Shallow sand
- Training patches for each image, or select areas that are consistent over time.
- Classification is run on all images using the same patch locations.
- Each individual image is trained and classified.

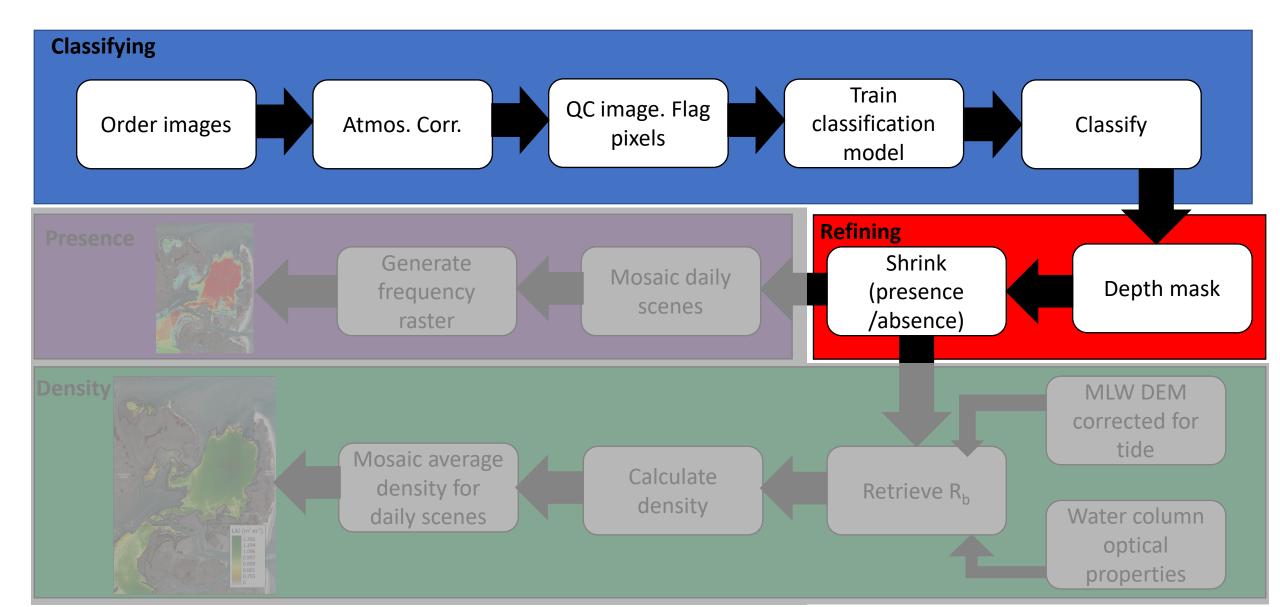






Depth mask removes green optically deep water.





#### Shrink

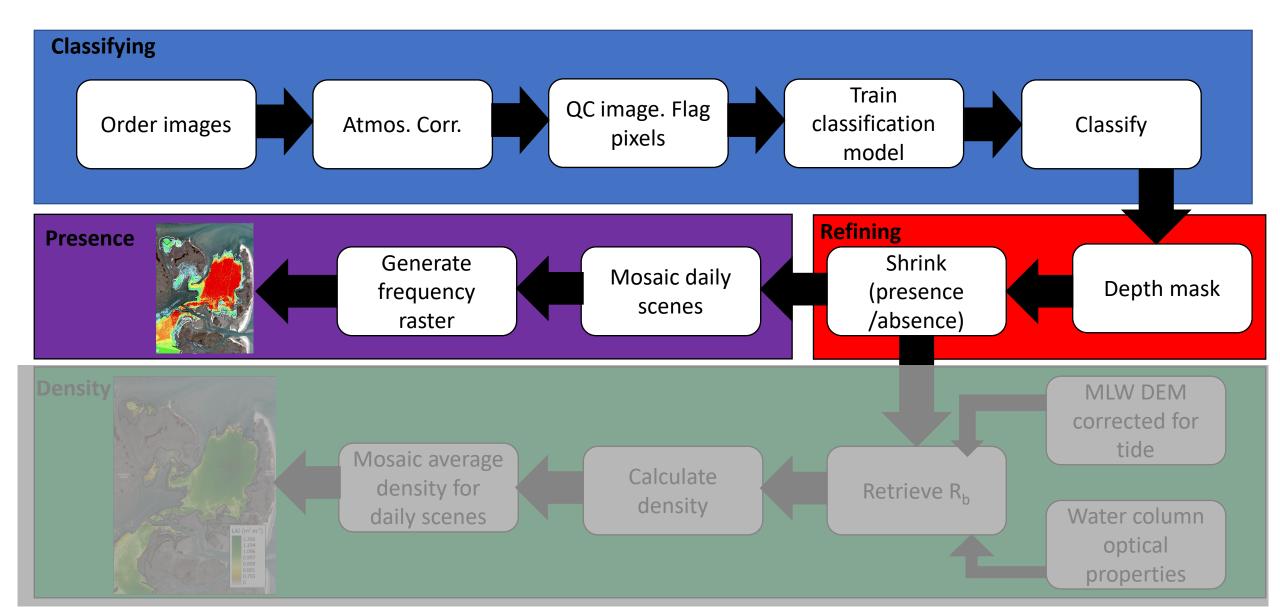
Removes single seagrass pixels with no neighboring pixels



#### Shrink

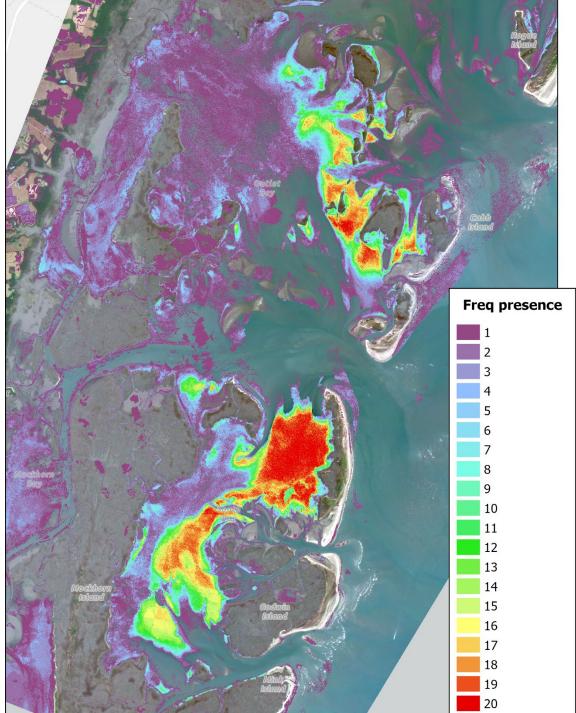
Removes single seagrass pixels with no neighboring pixels

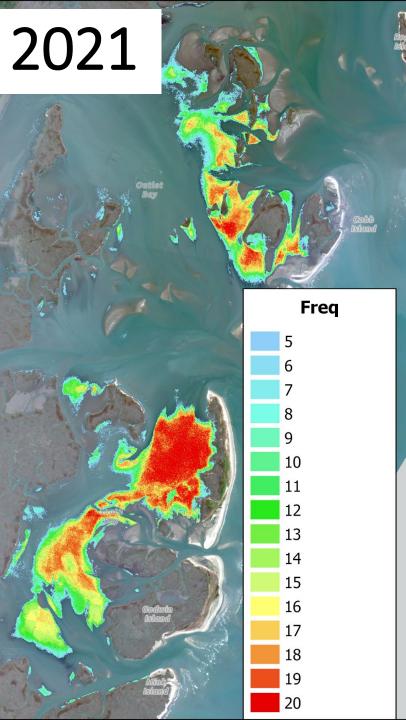


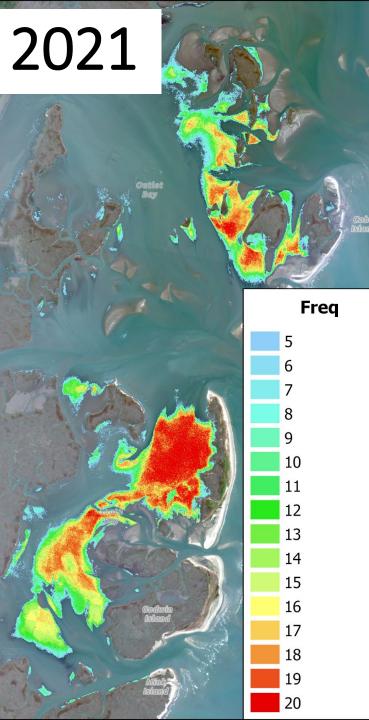


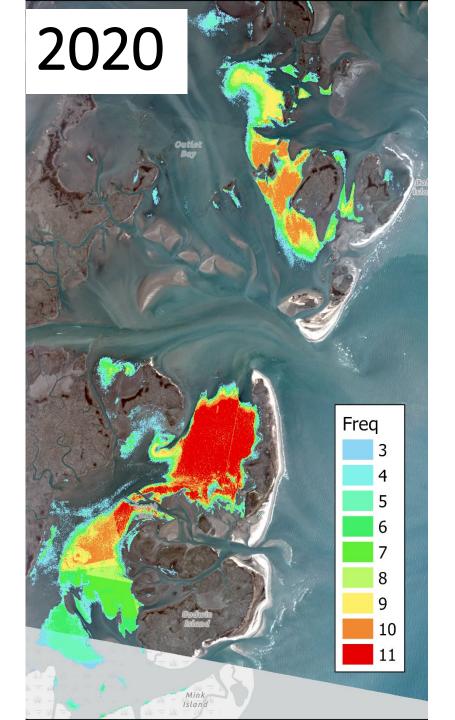
# 2021 – frequency presence

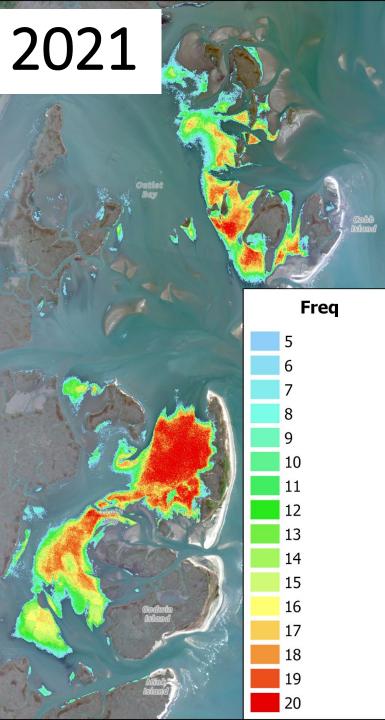
- Some areas have very low frequency of seagrass presence.
- These are images with increased turbidity close to land.
  - Are they misclassifications?
  - Generate mask for these areas?
    - Generate seagrass habitat areas and use to mask
  - Not use those images BUT they produce good classification in the seagrass meadows.
- Set a threshold for frequency presence.
  - Pixels with frequency less than 6 are set to null.

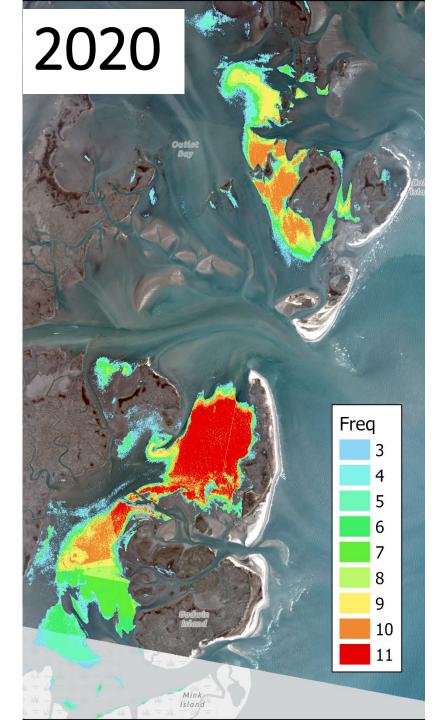




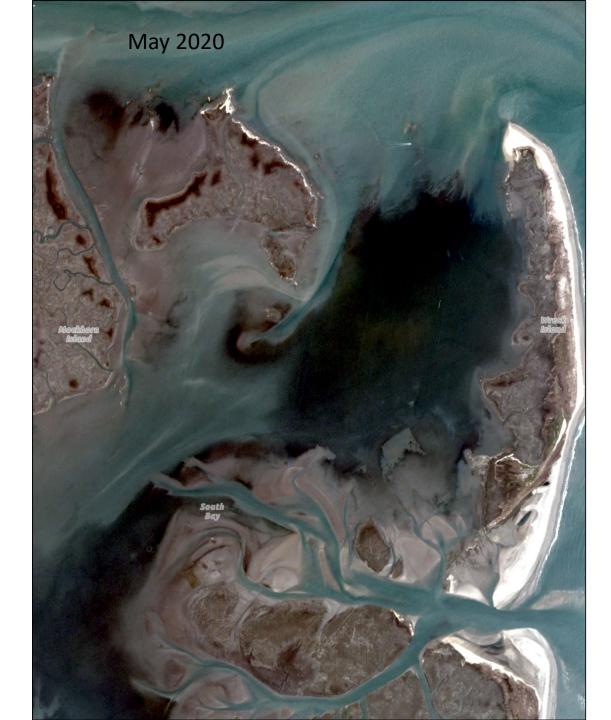


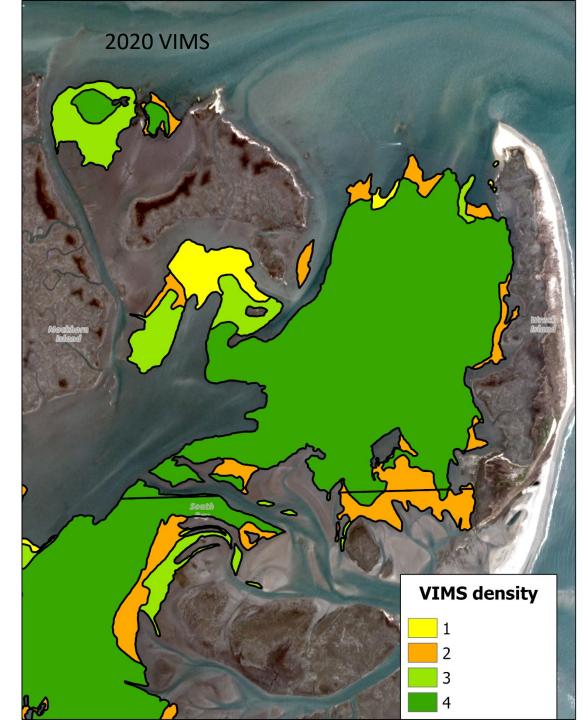


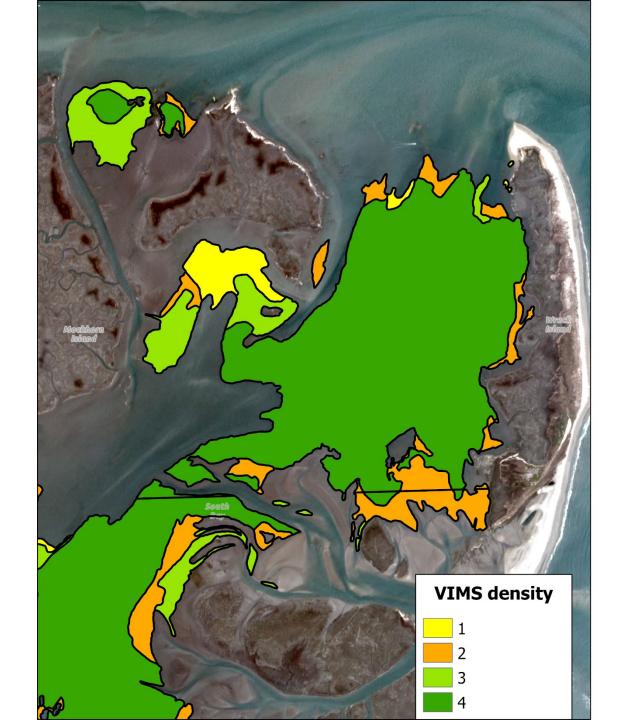


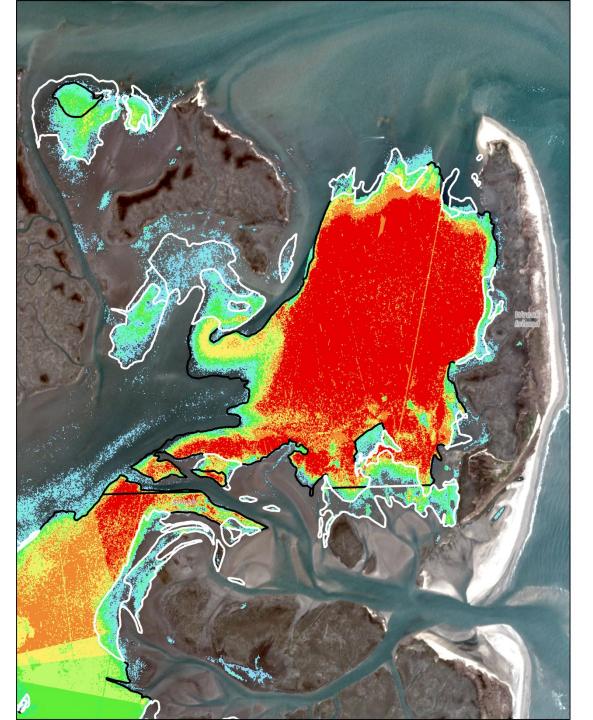


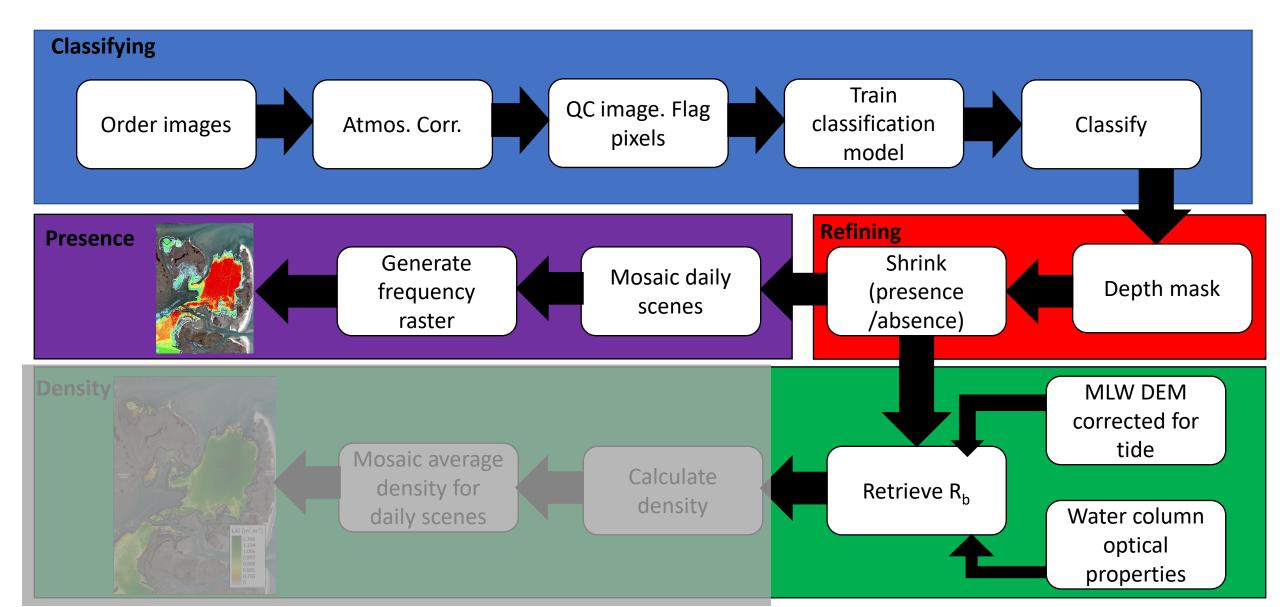
# Freq





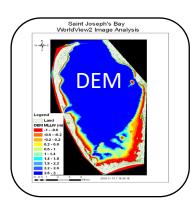


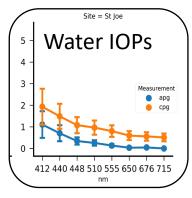




# From distribution to density







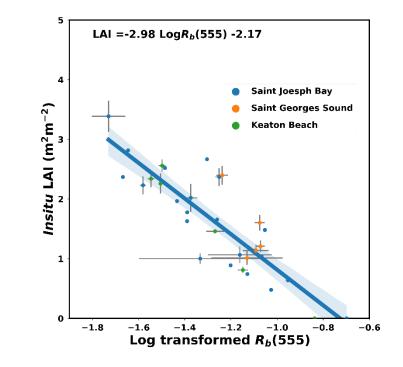
- <u>Atmospherically corrected</u> R<sub>rs</sub> from imagery
- $Q_{\rm b} = E_{\rm u}(z_{\rm b})/L_{\rm u}(z_{\rm b}) = \pi$
- *K*<sub>Lu</sub> & *K*<sub>d</sub> from *Hydrolight* using measured IOPs
- Water depth, DEM + tide

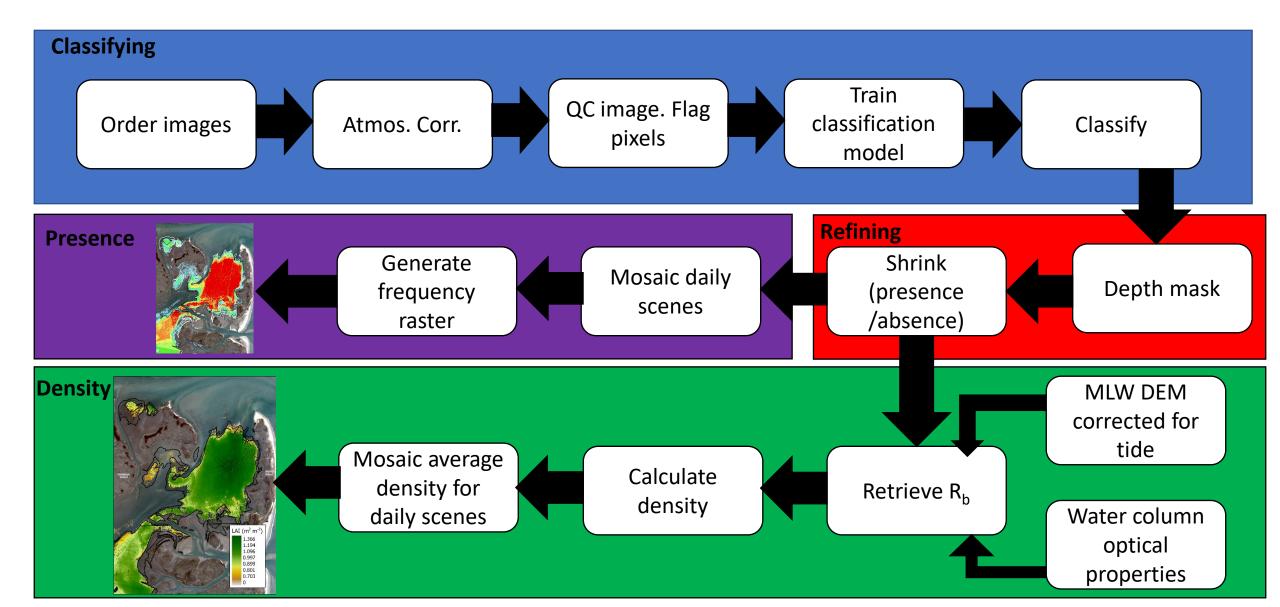
$$R_{b} = \frac{R_{rs}Q_{b}}{t} \frac{\exp\left[-K_{Lu}z_{b}\right]}{\exp\left(K_{d}z_{b}\right)}$$

- $z_{\rm b}$  bottom depth from acoustic survey
- t air/sea transmittance of  $L_u(0.54)$

Hill, V. J., Zimmerman, R. C., Bissett, P., Dierssen, H. M., & Kohler, D. (2014). Evaluating Light Availability, Seagrass Biomass, and Productivity Using Hyperspectral Airborne Remote Sensing in Saint Joseph's Bay, Florida. *Estuaries and Coasts, 37*. doi:DOI: 10.1007/s12237-013-9764-3.

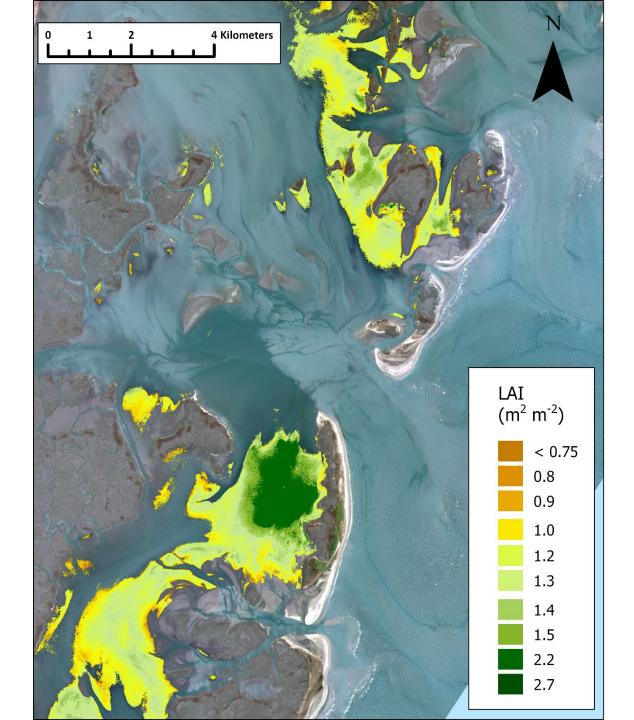
Dierssen, H., R. Zimmerman, R. Leathers, T. Downes, and C. Davis. 2003. Remote sensing of seagrass and bathymetry in the Bahamas Banks using high resolution airborne imagery. Limnol. Oceangr. **48**: **444-455**.





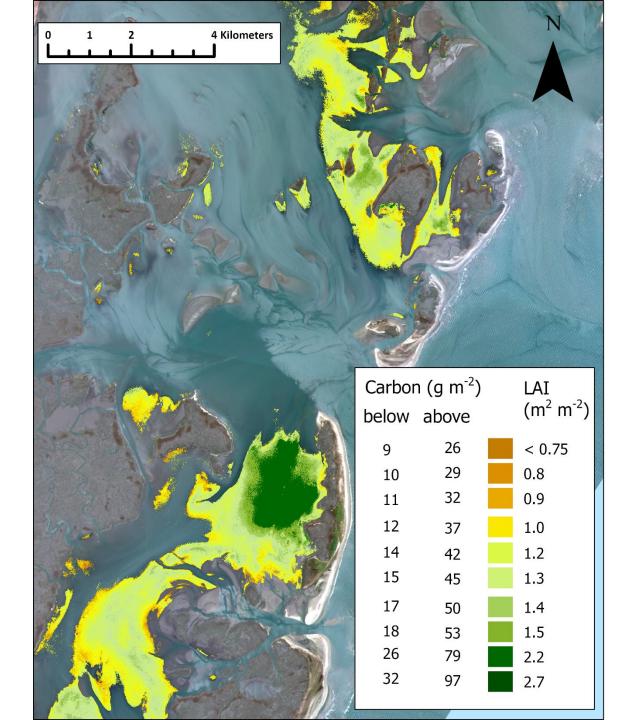
# 2021 – Leaf Area Index

- Average annual LAI
- Used frequency presence as a mask, values less than #6 were set to null.

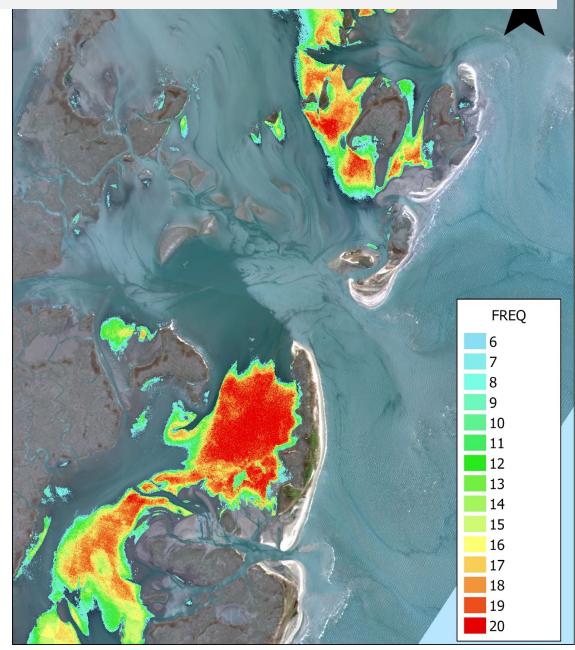


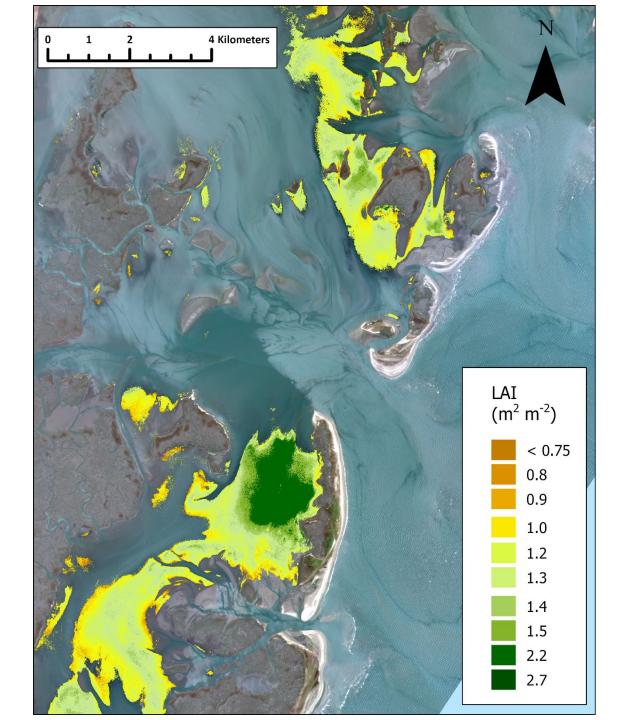
# 2021 – Carbon

- Use linear transfer coefficients to convert LAI to above and below ground carbon.
- Below ground carbon is based on in situ measurements. 1/3 of the above ground value.



## Distribution → Density





# Continuing work

- Partly automated processing.
- Working on training a machine learning algorithm to classify images without additional training.
- Refine QC techniques for each region.
- Frequency = density?
- Use high frequency of images to overcome turbidity and sparse areas.
- Sparse areas are still identified.
- Atmospheric correction needs to be addressed.

