Mid-Atlantic wetlands mapping at the 10-meter scale

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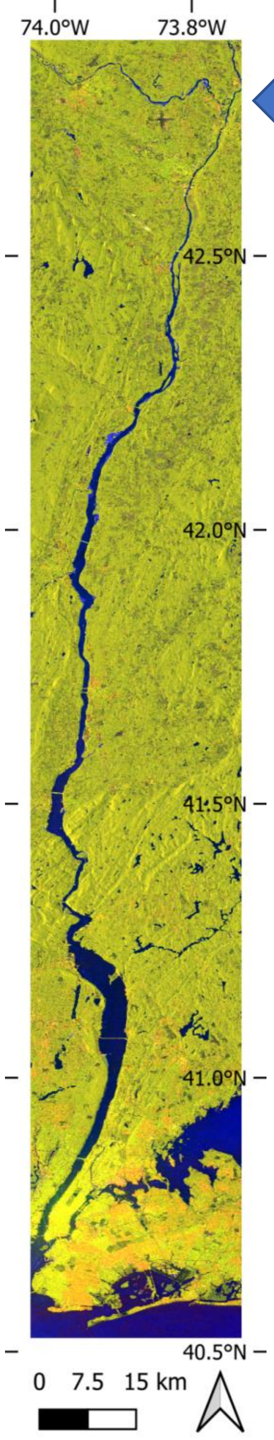
Primary research objective

- Moving from the 30-meter “Landsat” standard to 10-meter resolution wetlands mapping.

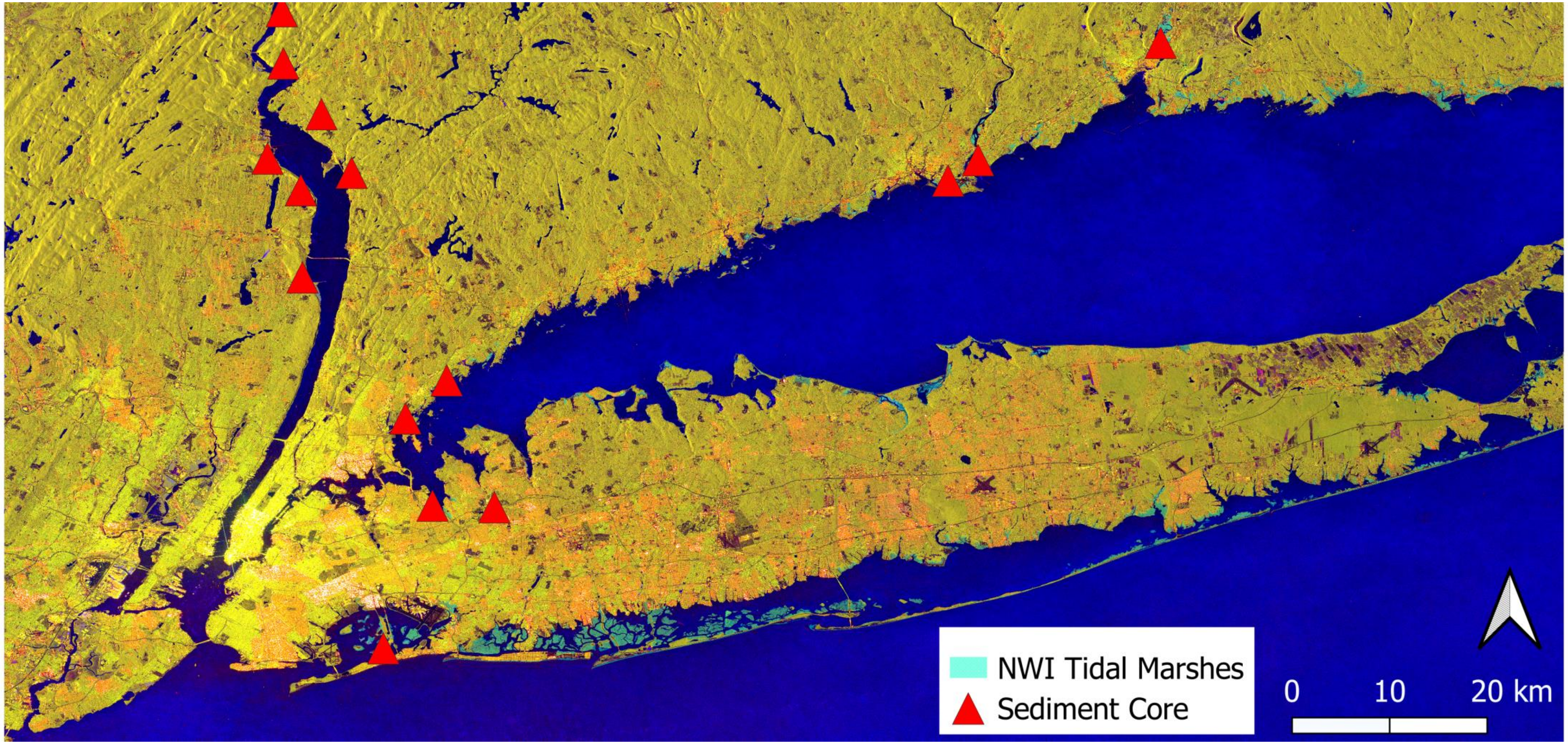
- Component of NASA Carbon Monitoring Systems (CMS) project
  - CMS project covers the tri-state region (Connecticut, New Jersey, New York).
  - ~ September 2023 start date

- Pilot study in the tidal portions of Hudson River (NY)
  - CMS project lead Dorothy Peteet (Columbia/Lamont) has extensively surveyed wetlands.
  - High-quality training/validation datasets on wetlands and aquatic vegetation.



Pilot Hudson River study

CMS project wetlands mapping extent



Approaches for Hudson River pilot study

- Using multitemporal radar composites from Sentinel-1
  - Radar has issues with speckle noise reducing effective resolution.
  - Temporal compositing reduces speckle while maintaining 10-m spatial resolution.
  - Largely repeat approaches from Lamb et al. (2021)

- Using Sentinel-2 optical 10-m bands (blue, green, red, near infrared)
  - Previous Lamb 2021 used only normalized difference vegetation index (NDVI)
  - In the pilot study we're assessing more bands and indices
    - Using a single "growing season" image (July 9th 2023) and focusing on spectral information.
    - More on next slide.

- USGS DEM (10-m) provides elevation layer.

- Radar-optical-DEM layers stacked and classified on a per-pixel basis with random forest.

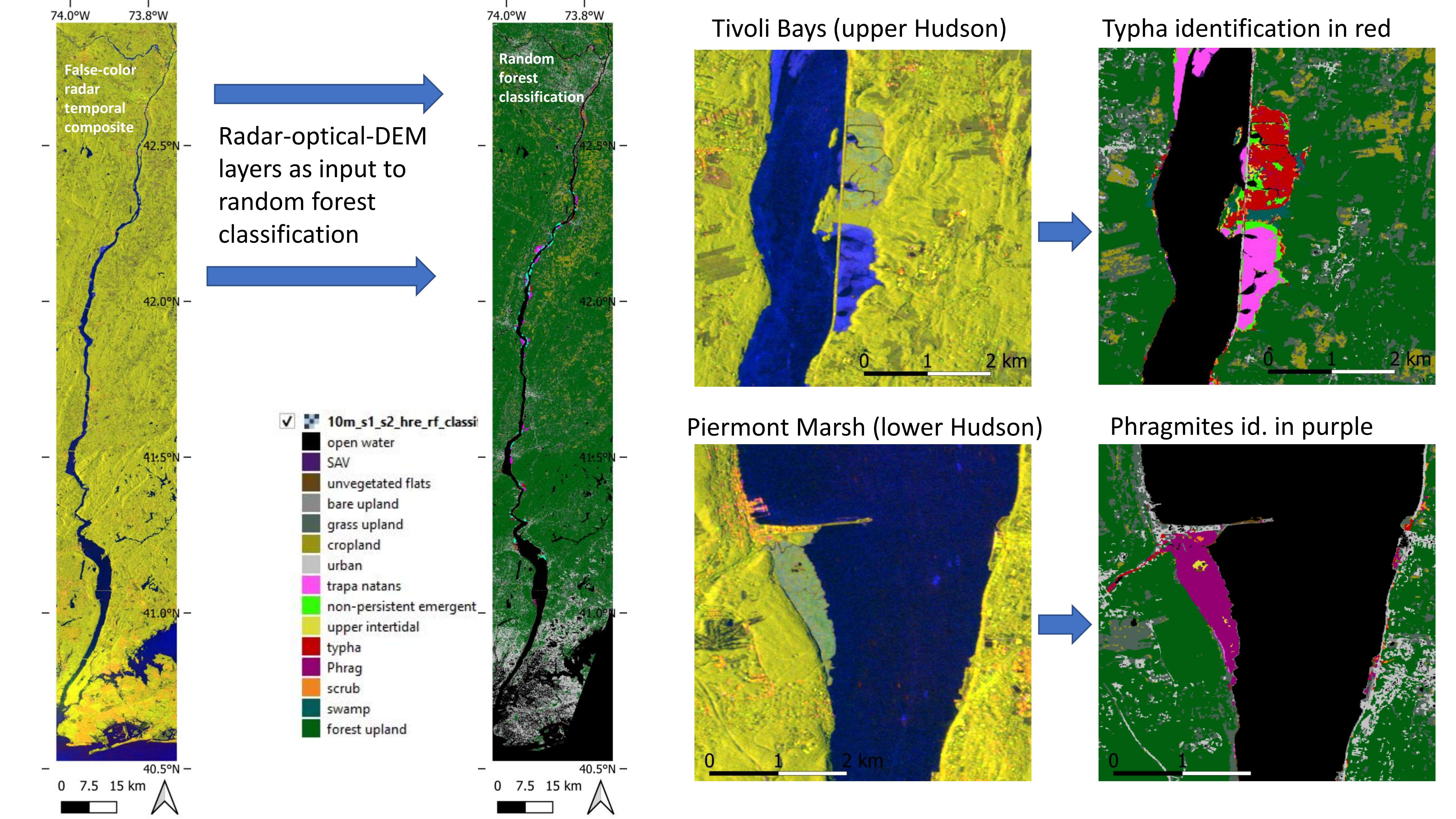
Sentinel-2 optical bands/indices (10 layers as random forest inputs)

- NDVI – normalized difference of near infrared and red bands.
  - Extremely useful for vegetation assessment.
- Also testing a water adjusted vegetation index (WAVI) used in several studies by Paolo Villa et al. (2013, 2015, 2017) using near infrared and blue bands.
- Normalized difference water index (NDWI) uses green and near infrared bands
- Band ratios indices identified in Martha Gilmore et al. (2004)
  - Blue/green (useful for Spartina patens/estuarine high marsh identification)
  - Green/red (useful for Tyhpa (cattail) identification)
  - Near infrared/red (useful for Phragmites identification)
- Four spectral band reflectances

Wetlands classes mapped with random forest

- Hudson River dominant wetlands classes “skew” towards freshwater tidal
  - Typha, Phragmites, non-persistent emergents (Nuphar, Peltandra), and upper intertidal mix

- The use of the radar-optical-DEM approach should still provide a useful indication of what’s plausible for a saline estuarine marsh classification.
  - Radar should capture structure changes, optical should capture brightness/color differences.
    - Low marsh (dominated by Spartina alterniflora) – high radar variability, low near infrared reflectance
    - Mid marsh (dominated by Juncus) – high radar backscatter, low visible reflectance
    - High marsh (mix of Spartina patens and Distichlis) – low radar variability, structure doesn’t change greatly nor is hydrology as impactful.



74.0°W
73.8°W
False-color radar temporal composite
42.5°N
42.0°N
41.5°N
41.0°N
40.5°N
0 7.5 15 km
Radar-optical-DEM layers as input to random forest classification
Random forest classification
10m_s1_s2_hre_rf_classi
open water
SAV
unvegetated flats
bare upland
grass upland
cropland
urban
trapa natans
non-persistent emergent
upper intertidal
typha
Phrag
scrub
swamp
forest upland
Tivoli Bays (upper Hudson)
Typha identification in red
0 1 2 km
Piermont Marsh (lower Hudson)
Phragmites id. in purple

Random forest classification accuracy

	open water	SAV	tidal flats	bare upland	grass upland	cropland	built up	trapa	non-persistent	upper intertidal	typha	phrag	shrub	swamp	forest	class.error	% error
open water	2278	90	40	40	19	3	16	1	1	0	2	1	0	0	7	0.088	8.81
SAV	286	633	26	1	0	0	0	54	0	0	0	0	0	0	0	0.367	36.70
tidal flats	33	29	912	10	1	0	2	1	5	2	2	3	0	0	0	0.088	8.80
bare_upland	24	0	6	1350	41	33	278	0	0	0	1	2	0	0	9	0.226	22.59
grass_upland	11	0	1	46	1208	421	111	0	0	2	1	2	0	0	143	0.379	37.92
cropland	0	0	0	26	398	1530	11	0	1	0	0	2	0	0	27	0.233	23.31
built_up	5	0	0	288	131	15	1199	0	0	0	1	2	0	0	89	0.307	30.69
trapa	17	12	1	0	0	0	0	960	10	0	0	0	0	0	0	0.040	4.00
non-persistent	1	0	0	0	0	1	0	10	793	0	2	1	0	0	0	0.019	1.86
upper intertidal mix	0	0	2	0	0	0	1	0	0	301	81	34	30	42	0	0.387	38.70
typha	0	0	1	0	0	0	0	0	2	22	964	4	3	4	0	0.036	3.60
phrag	0	0	0	1	1	0	0	0	0	6	14	968	6	4	0	0.032	3.20
shrub	0	0	0	0	5	0	0	0	0	44	13	10	235	185	5	0.527	52.72
swamp	0	0	0	0	0	0	0	0	0	18	7	8	42	918	7	0.082	8.20
forest	1	0	0	5	188	20	116	0	0	0	3	1	1	6	1625	0.173	17.34

Error rates below 5% for Trapa, non-persistent emergent, Typha, and Phragmites

Open water and swamp accuracies are high-biased due to training data selection but in reality are likely close to 5% (currently working on this issue)

Unvegetated tidal flats identified with error <10% is unexpected and highly promising

Random Forest importance assessment

input layer	01-ow	02-sav	03-uvf	04-bare	04-grass	05-crop	06-built	07-trapa	08-NPE	09-UIT	10-typha	11-phrag	12-shrub	13-swamp	14-forest	MeanDecreaseAccuracy	MeanDecreaseGini
dem	0.055	0.053	0.174	0.010	0.159	0.234	0.119	0.216	0.236	0.192	0.309	0.377	0.213	0.302	0.345	0.185	1714.696
s2_blue	0.091	0.042	0.056	0.047	0.016	0.044	0.060	0.062	0.096	0.061	0.289	0.114	0.054	0.130	0.042	0.073	797.215
s2_green	0.042	0.051	0.051	0.034	0.016	0.031	0.029	0.118	0.145	0.037	0.255	0.076	0.039	0.040	0.117	0.065	886.285
s2_red	0.036	0.069	0.080	0.063	0.018	0.047	0.033	0.055	0.087	0.064	0.065	0.136	0.004	0.163	0.118	0.066	695.756
s2_nir	0.093	0.032	0.125	0.052	0.024	0.052	0.022	0.150	0.093	0.084	0.064	0.067	0.048	0.027	0.038	0.061	675.664
s2_summer_2022_ndvi	0.087	0.113	0.132	0.171	0.044	0.066	0.053	0.105	0.090	0.088	0.105	0.161	0.045	0.148	0.142	0.102	973.066
s2_summer_2022_wavi	0.277	0.090	0.110	0.114	0.050	0.115	0.067	0.124	0.088	0.113	0.098	0.092	0.087	0.084	0.080	0.115	1091.500
s2_summer_2022_ndwi	0.179	0.136	0.114	0.151	0.059	0.092	0.059	0.105	0.105	0.077	0.144	0.139	0.082	0.067	0.117	0.112	1118.060
s2_summer_2022_gb	0.147	0.040	0.061	0.036	0.022	0.128	0.083	0.107	0.056	0.104	0.136	0.128	0.081	0.177	0.017	0.086	940.682
s2_summer_2022_rg	0.036	0.065	0.187	0.135	0.006	0.042	0.017	0.170	0.061	0.097	0.078	0.207	0.019	0.329	0.070	0.088	913.831
s2_summer_2022_nr	0.080	0.114	0.132	0.173	0.049	0.062	0.050	0.112	0.096	0.087	0.105	0.152	0.050	0.132	0.143	0.101	975.881
s1_vv_mean_2022	0.051	0.117	0.057	0.028	0.015	0.051	0.056	0.138	0.049	0.024	0.049	0.054	0.037	0.138	0.079	0.060	656.887
s1_vh_mean_2022	0.118	0.109	0.047	0.031	0.033	0.139	0.081	0.236	0.141	0.060	0.143	0.150	0.063	0.190	0.185	0.114	1093.686
s1_vv_sd_2022	0.036	0.005	0.126	0.003	0.033	0.025	0.043	0.206	0.233	0.011	0.086	0.115	0.040	0.130	0.084	0.068	940.242
s1_vh_sd_2022	0.009	0.008	0.023	-0.003	0.015	0.140	0.062	0.040	0.203	0.013	0.016	0.029	0.020	0.077	0.097	0.051	873.343
s1_vv_mean_2022_spring	0.029	0.049	0.046	0.024	0.017	0.020	0.029	0.082	0.041	0.023	0.037	0.103	0.024	0.061	0.053	0.040	509.039
s1_vh_mean_2022_spring	0.042	0.031	0.034	0.022	0.031	0.046	0.041	0.159	0.092	0.047	0.100	0.097	0.029	0.079	0.120	0.062	736.018
s1_vv_mean_2022_summer	0.082	0.078	0.104	0.036	0.019	0.040	0.058	0.074	0.124	0.033	0.080	0.063	0.084	0.170	0.071	0.069	835.492
s1_vh_mean_2022_summer	0.081	0.051	0.087	0.018	0.027	0.018	0.052	0.033	0.076	0.026	0.052	0.079	0.034	0.068	0.041	0.048	625.708
s1_vv_mean_2022_fall	0.009	0.062	0.118	0.020	0.017	0.033	0.048	0.027	0.028	0.024	0.034	0.025	0.011	0.047	0.030	0.033	513.457
s1_vh_mean_2022_fall	0.036	0.040	0.055	0.010	0.025	0.035	0.057	0.097	0.042	0.046	0.046	0.044	0.001	0.092	0.032	0.042	528.900

The digital elevation model (DEM) was the most important layer as indicated by highest decrease in accuracy and decrease in Gini coefficient when removed from classification scheme…

…followed by Sentinel-2 normalized difference indices, and Sentinel-1 VH channel annual mean (rows shaded in grey)

High band importances for specific classes highlighted in non-grey colors

Implications for estuarine marsh mapping

- A combination of Sentinel-2 spectral bands and indices provided higher classification accuracy than Sentinel-1 radar, but not always for individual wetlands vegetation classes
  - Sentinel-1 annual mean of VH backscatter was highly important

- Low marsh, Juncus romerianus-dominated marsh, and high marsh have apparent brightness differences that should be captured by band spectral relationships and reflectance.

- PlanetScope’s eight bands at 3-m should improve results compared to Sentinel-2’s four bands at 10-m.
  - More spectral bands, more potential indices, more biophysical specificity.
    - Yellow band and two green bands have high potential utility here…

- CoNED 1-m DEM should also improve classification compared to 10-m NED DEM