Large-scale, high-resolution wetland mapping with satellites for improved blue carbon estimates

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Introduction

- Coastal wetlands have the highest average carbon storage per land area among unmanaged terrestrial ecosystems.
- Mangrove range expansion is occurring globally, and could alter the carbon storage capacity of coastal wetlands.
- Accurate predictions of such carbon budget changes require up-to-date, high-resolution maps of these wetlands over time.
- Many organizations map wetlands, but their approaches differ in terms of:
  - Imagery type (e.g. aerial photograph vs satellite image)
  - Spatial Resolution
  - Wetland definition (e.g. saltmarsh vs mangrove vs aquatic vegetation
  - Mapping method (e.g. manual digitization vs semi-automated classification)
- These approaches tend to be time-intensive and inefficient.
- The result is a variety of wetland maps with substantial differences such as these:

Figure 1. Wetlands (red) in Fort De Soto Park in Tampa Bay, Florida as mapped by (left) NOAA Coastal Change Analysis Program 2010, (center) Southwest Florida Water Management District (SWFWMD) 2011, (right) National Wetland Inventory (NWI) 2009.

The primary objective of this study was to improve the accuracy, precision and efficiency of coastal wetland maps with automated processing and classification of 2-meter resolution satellite imagery.

Materials & Methods

- Study Area
  - Tampa Bay watershed (Fig 2)
  - 6,500 km^2
- Satellite Imagery Data
  - WorldView-2 satellite (Fig 3)
    - 130 images
    - Spatial Resolution: 2 meters
    - Spectral Bands: 8

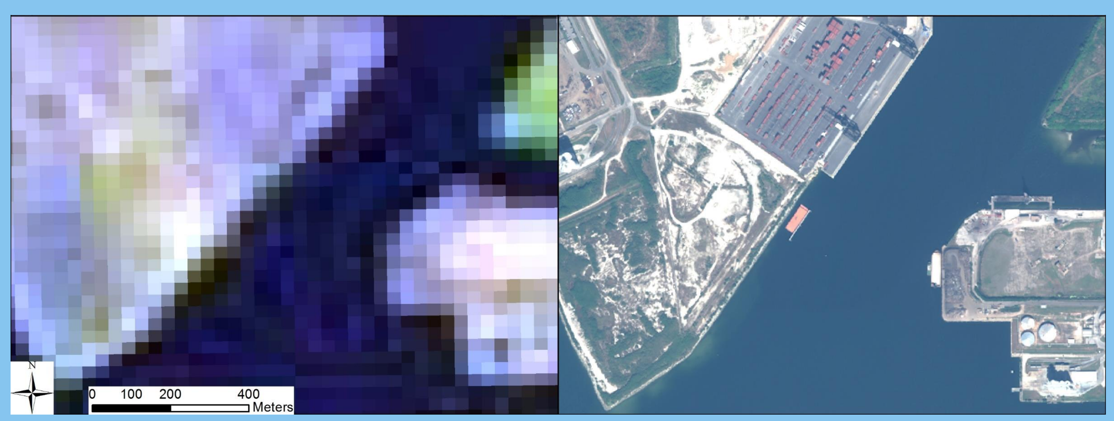

Figure 3. Comparison of spatial resolution between (left) Landsat (30-meter) and (right) WorldView-2 (2-meter) imagery.

Figure 2. Study area: Tampa Bay, Florida watershed.

- Image Processing
  - Python and Matlab scripts were written to perform the following processing steps: image projection, radiometric calibration, atmospheric correction, conversion to remote sensing reflectance, decision-tree image classification, moving-window smoothing
  - Classes identified: forested wetland, upland vegetation, bare and developed, water
- Supercomputer Batch Processing
  - Processing scripts were run over the USF supercomputing cluster (Fig 4)
    - 4,000+ processors, 2.5 terabytes memory
- Field Survey & Accuracy Assessment
  - 226 validation points were collected throughout the study area with a high-resolution Trimble GeoExplorer GPS unit
  - Field survey validation data was used to evaluate map accuracy.

Figure 4. Supercomputer example.

Results

- **Map Accuracy**
  - Our map (IMaRS hereafter) is compared to wetland maps produced by NOAA, Southwest Florida Water Management District (SWFWMD) and National Wetland Inventory (NWI)
  - Accuracies are determined with field validation points for forested wetland and upland classes

Table 1. Land cover classification accuracy.

	IMaRS	NOAA	SWFWMD	NWI
Forested wetland (%)	**78.0**	62.7	64.7	30.7
Upland (%)	64.5	28.9	**67.1**	N/A
Overall (%)	**73.5**	51.3	65.5	30.7
Kappa	**0.42785**	0.11681	0.38160	0.12948

Table 2. Land cover area comparison (km^2).

	IMaRS	NOAA	SWFWMD	NWI
Bare and Developed	979	1326	1549	N/A
Forested wetland	1312	1439	442	705
Upland	3053	2502	1182	N/A
Total Vegetation	4364	3941	1624	705

- **Mapping Efficiency**
  - Processing time comparison
    - Manual use of ENVI software tools on a 64-bit Windows computer: ~24 hours/image
    - Supercomputer protocol developed here: **~10 minutes/image**

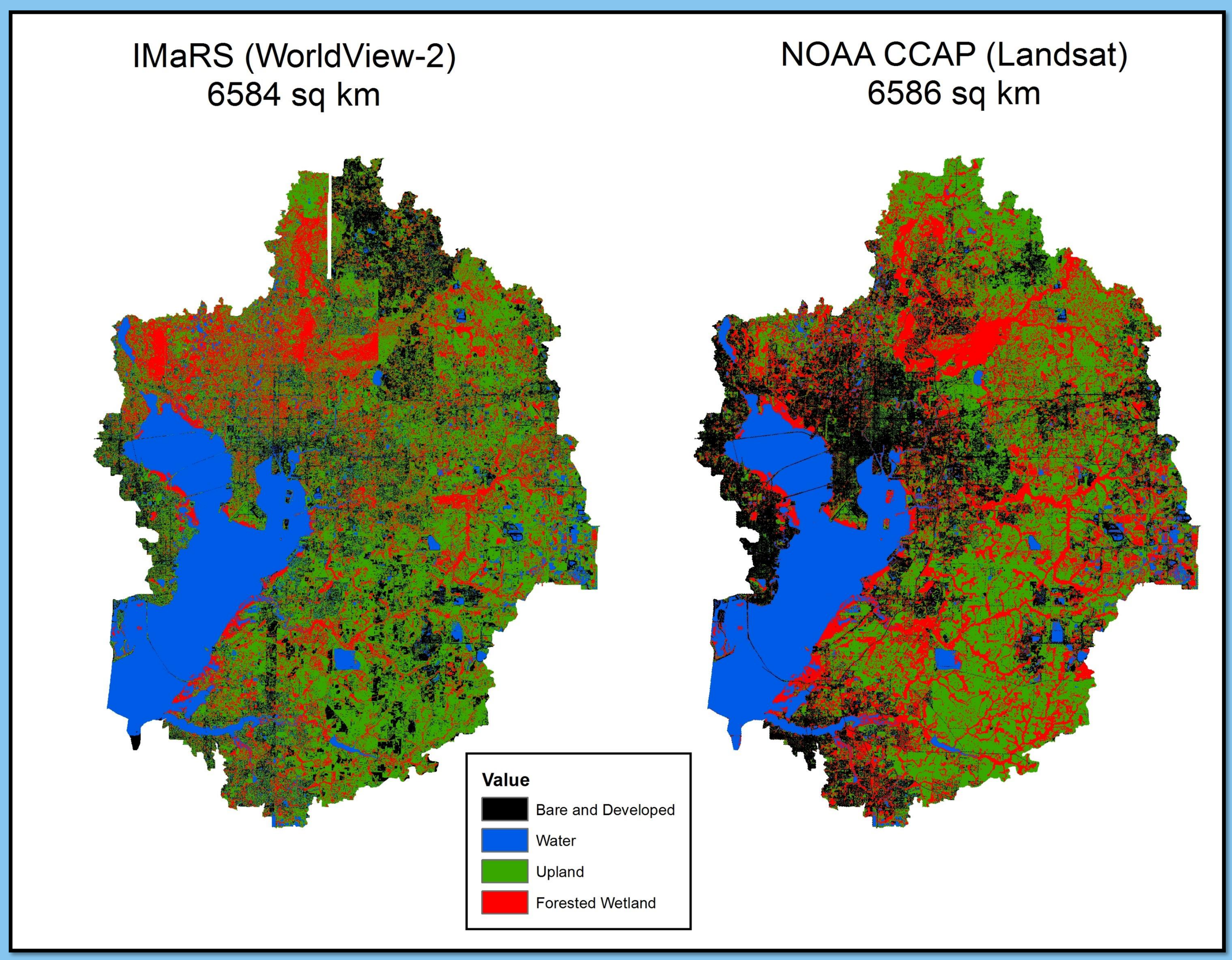

Figure 5. IMaRS and NOAA CCAP map comparison.

Conclusions

- Our protocol applied to 130 high-resolution satellite images produced more accurate wetland mapping results than comparable maps produced by state and federal agencies, revealing substantial discrepancies in wetland areal extent.
- The processing scripts developed here and run through batch processing on the USF supercomputing cluster reduced processing time from about 1 day per image to 10 minutes. All 130 images were mapped in under 24 hours, which would have taken manual methods approximately 3-5 months.
- Large-scale mapping of land cover using high resolution satellite images may be conducted using this method with unprecedented speed.
- Blue carbon budget estimates may be improved by applying this protocol to local, regional or global wetlands. More accurate estimates of static wetland extent and change over time will better constrain blue carbon storage, export and sequestration estimates.

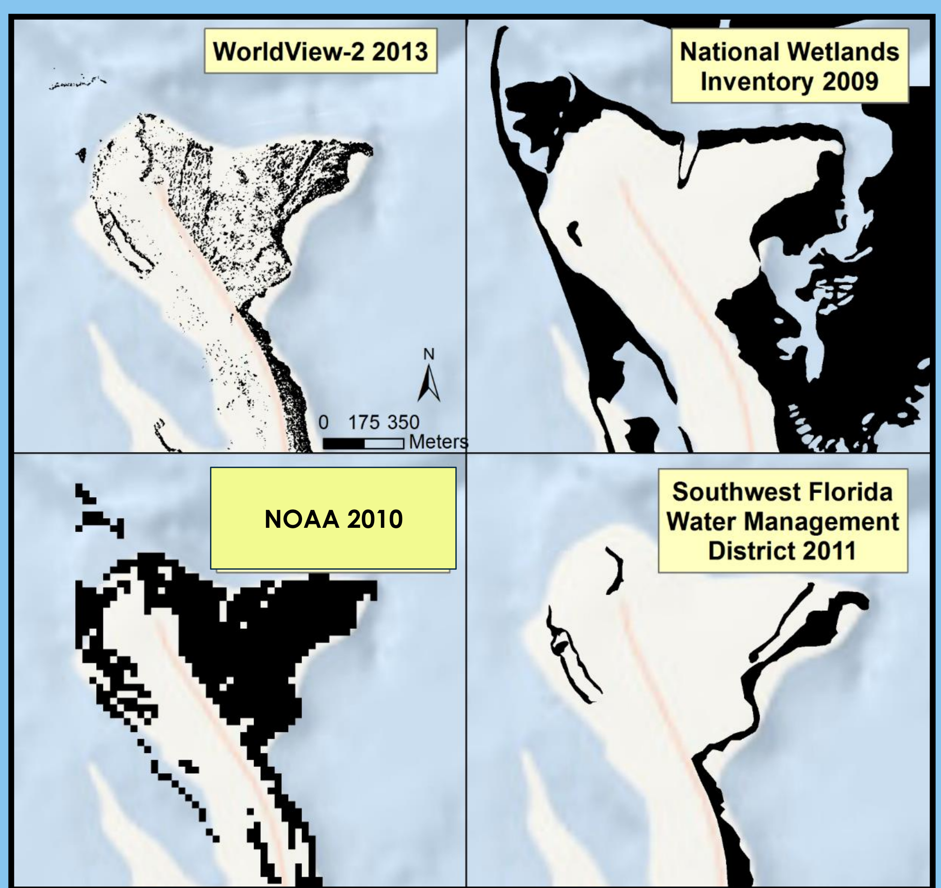

Figure 6. Comparison of wetland (black) mapping precision between map products for a study area subset.

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