OPTICAL-RADAR SYNERGY FOR WETLAND CHARACTERIZATION AND SURFACE WATER MONITORING

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[7] NASA Ames Research Center, Moffett Field, CA, USA
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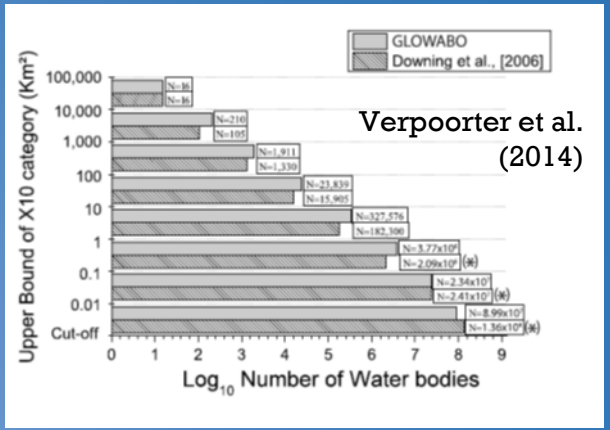
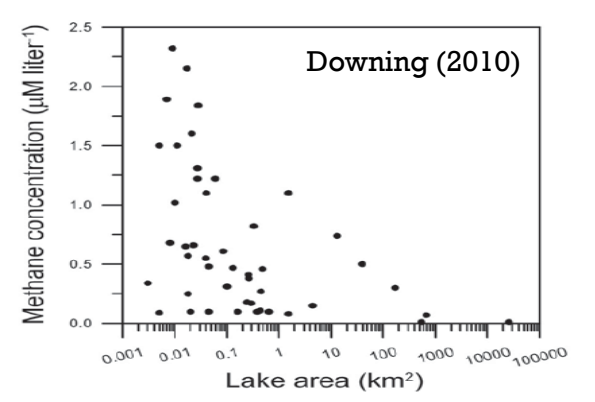
Land Use/Cover Changes, Environment and Emissions in South/Southeast Asia – An International Regional Science Meeting
Johor Bahru, Malaysia, 22nd-24th July, 2019

WETLANDS HIGHLY VALUABLE BUT EXTREMELY COMPLEX

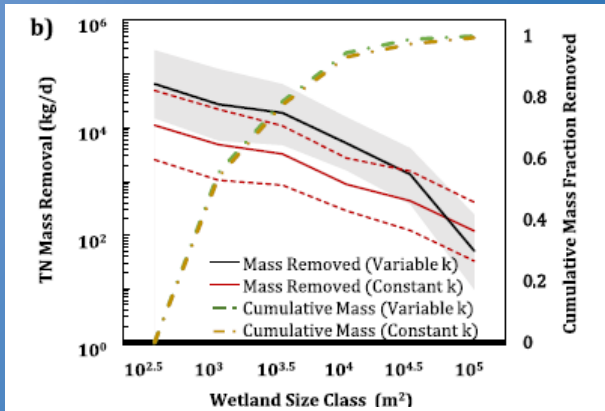
- Provide a wide range of ecosystem services
  - Biodiversity, nutrient/pollutants removal, ……
- Small ones disproportionally more important
  - Out-number larger ones
  - Higher methane concentration
  - More effective in removing nutrients
- …… but have complex and highly variable water regimes and vegetation communities



Verpoorter et al. (2014)



Downing (2010)



Cheng, F. Y.; Basu, N. B. (2017),

HIGH REQUIREMENTS FOR PRODUCING US NATIONAL WETLAND INVENTORY (NWI) DATA

Final Draft Wetlands Mapping Standard

FGDC Wetlands Subcommittee

January 2009

U.S. Fish & Wildlife Service

Data Collection Requirements and Procedures for Mapping Wetland, Deepwater, and Related Habitats of the United States (version 2)

U.S. FISH & WILDLIFE SERVICE - ECOLOGICAL SERVICES
DIVISION OF BUDGET AND TECHNICAL SUPPORT
BRANCH OF GEOSPATIAL MAPPING AND TECHNICAL SUPPORT
FALLS CHURCH, VA 2204

REVISED AUGUST 2015

KEY NWI MAPPING REQUIREMENTS

Table 2. Spatial Resolution Requirements of Base Imagery

	Lower 48 States, Hawaii, & Territories *	Estuarine & Lacustrine Deepwater **	Alaska (Including Deepwaters)
Resolution	1m	3m	5m
Scale	1:12,000	1:24,000	1:63,360

System	P - Palustrine							
Class	RB – Rock Bottom	UB – Unconsolidated Bottom	AB – Aquatic Bed	US – Unconsolidated Shore	ML – Moss-Lichen	EM – Emergent	SS – Scrub-Shrub	FO – Forested
Subclass	1 Bedrock 2 Rubble	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated	1 Moss 2 Lichen	1 Persistent 2 Nonpersistent 5 *Phragmites australis*	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen

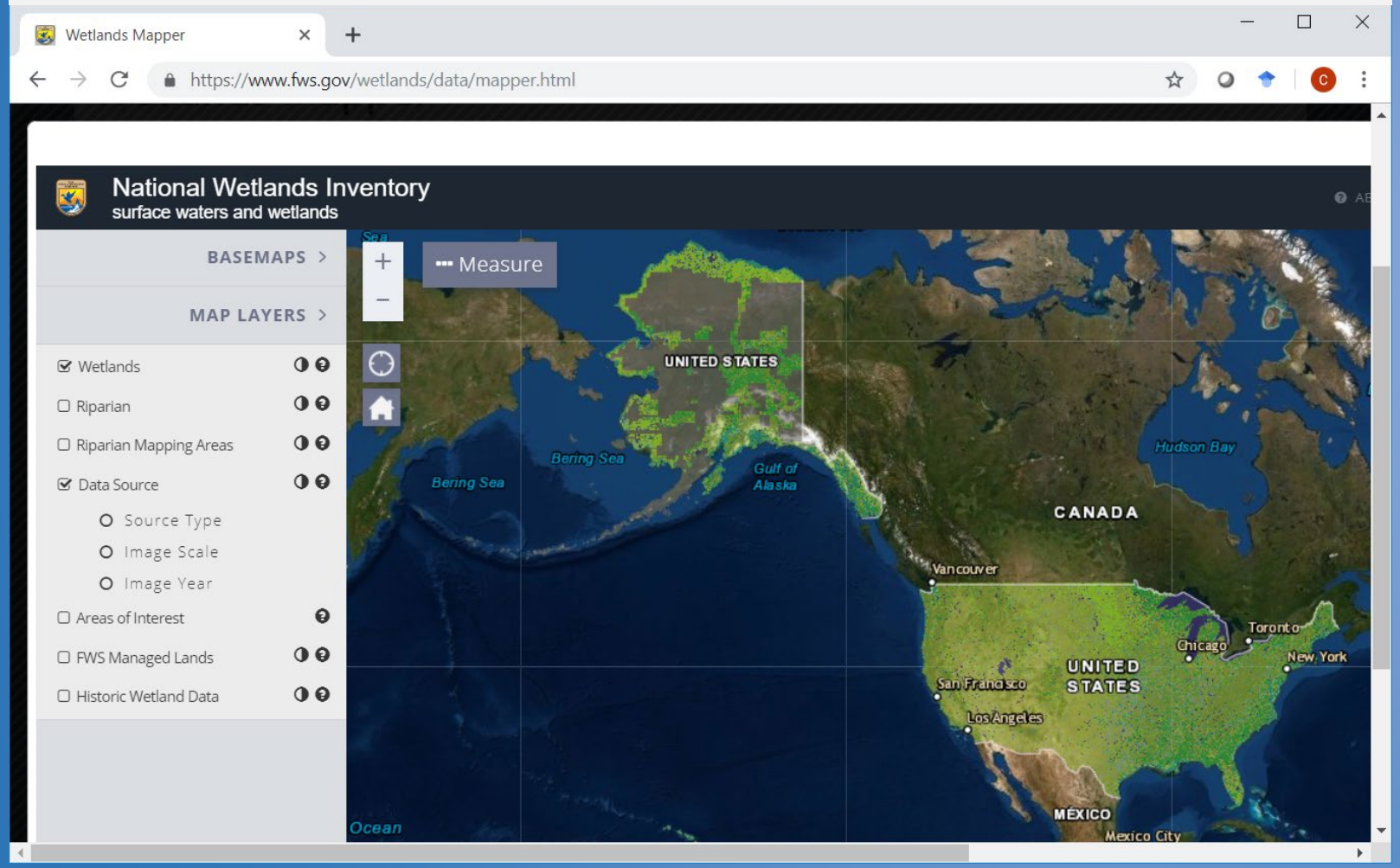
MODIFIERS

In order to more adequately describe the wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy.

Water Regime			Special Modifiers	Water Chemistry		Soil
Nontidal	**Saltwater Tidal**	**Freshwater Tidal**		**Halinity/Salinity**	**pH Modifiers for Fresh Water**	
A Temporarily Flooded	L Subtidal	S Temporarily Flooded- Fresh Tidal	b Beaver	1 Hyperhaline / Hypersaline	a Acid	g Organic
B Seasonally Saturated	M Irregularly Exposed	Q Regularly Flooded-Fresh Tidal	d Partly Drained/Ditched	2 Euhaline / Eusaline	t Circumneutral	n Mineral
C Seasonally Flooded	N Regularly Flooded	R Seasonally Flooded-Fresh Tidal	f Farmed	3 Mixohaline / Mixosaline (Brackish)	i Alkaline	
D Continuously Saturated	P Irregularly Flooded	T Semipermanently Flooded-Fresh Tidal	m Managed	4 Polyhaline		
E Seasonally Flooded/ Saturated		V Permanently Flooded-Fresh Tidal	h Diked/Impounded	5 Mesohaline		
F Semipermanently Flooded			r Artificial Substrate	6 Oligohaline		
G Intermittently Exposed			s Spoil	0 Fresh		
H Permanently Flooded			x Excavated			
J Intermittently Flooded						
K Artificially Flooded						

CURRENT STATUS OF NWI DATA

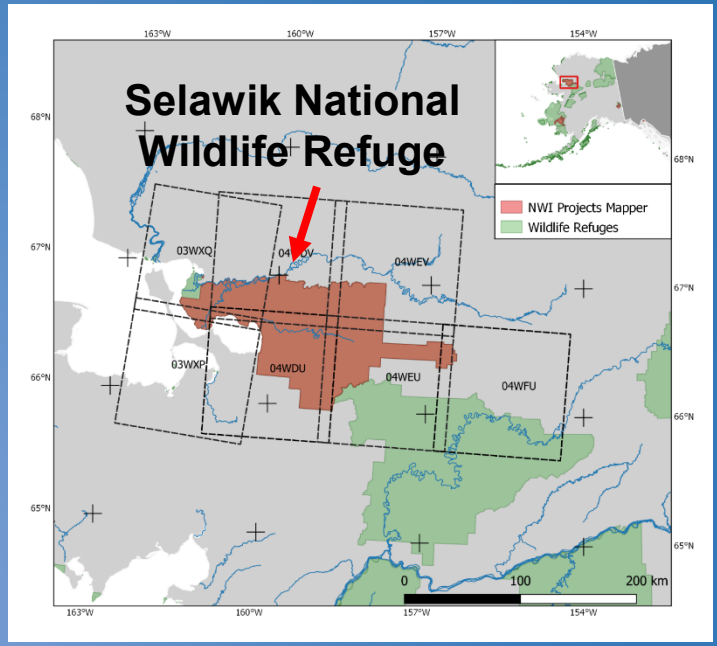
https://www.fws.gov/wetlands/data/mapper.html



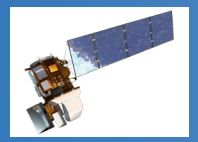
Challenges in Alaska

- Base imagery
- Field data collection difficult
- Mapping procedure largely driven by image analysts

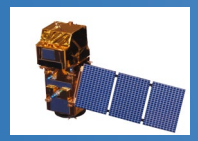
EXPLORE USE OF AVAILABLE OPTICAL AND RADAR ASSETS FOR WETLAND MAPPING



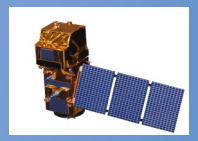
Optical



Landsat-8: 16-day revisit



Sentinel-2: 10-day one satellite, 5-day with two satellites



RADAR

Sentinel-1: 12-day revisit one satellite, but current acquisition scenario for two satellites provides 12-day revisit in most areas

METHODS TARGET VEGETATION AND WATER REGIME OF THE CLASSIFICATION SYSTEM

System	P - Palustrine							
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H Permanently Flooded			x Excavated			
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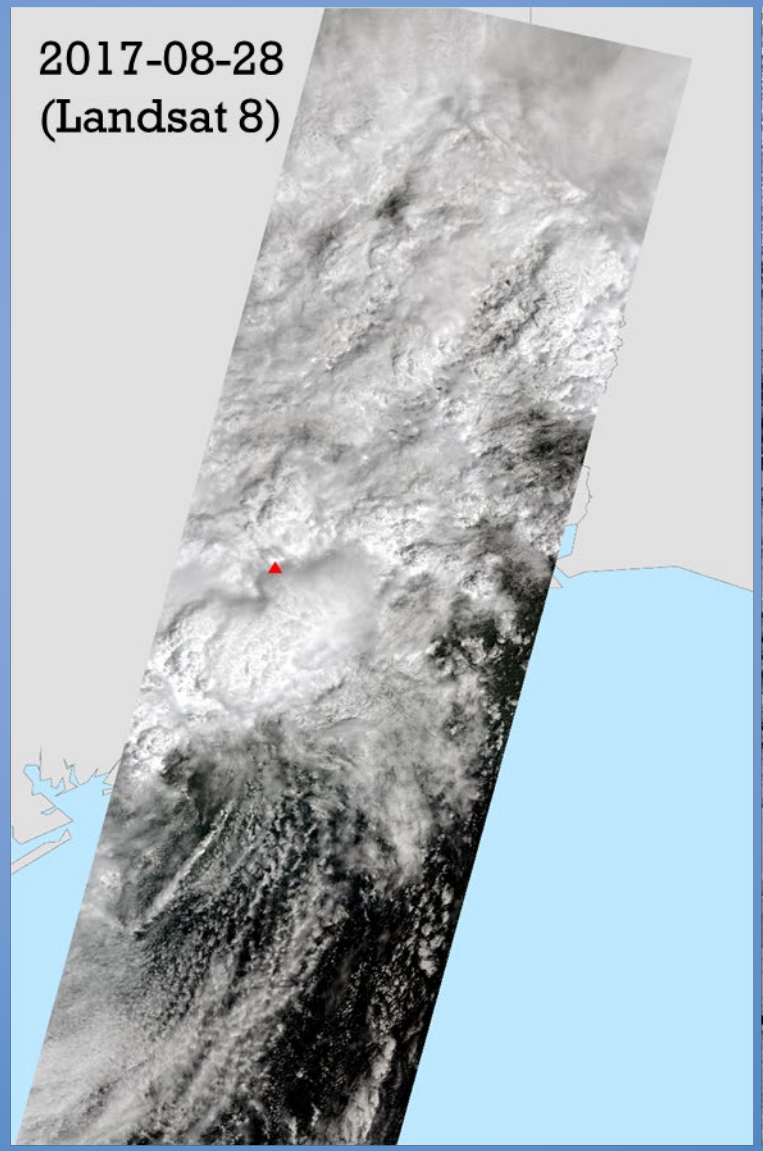
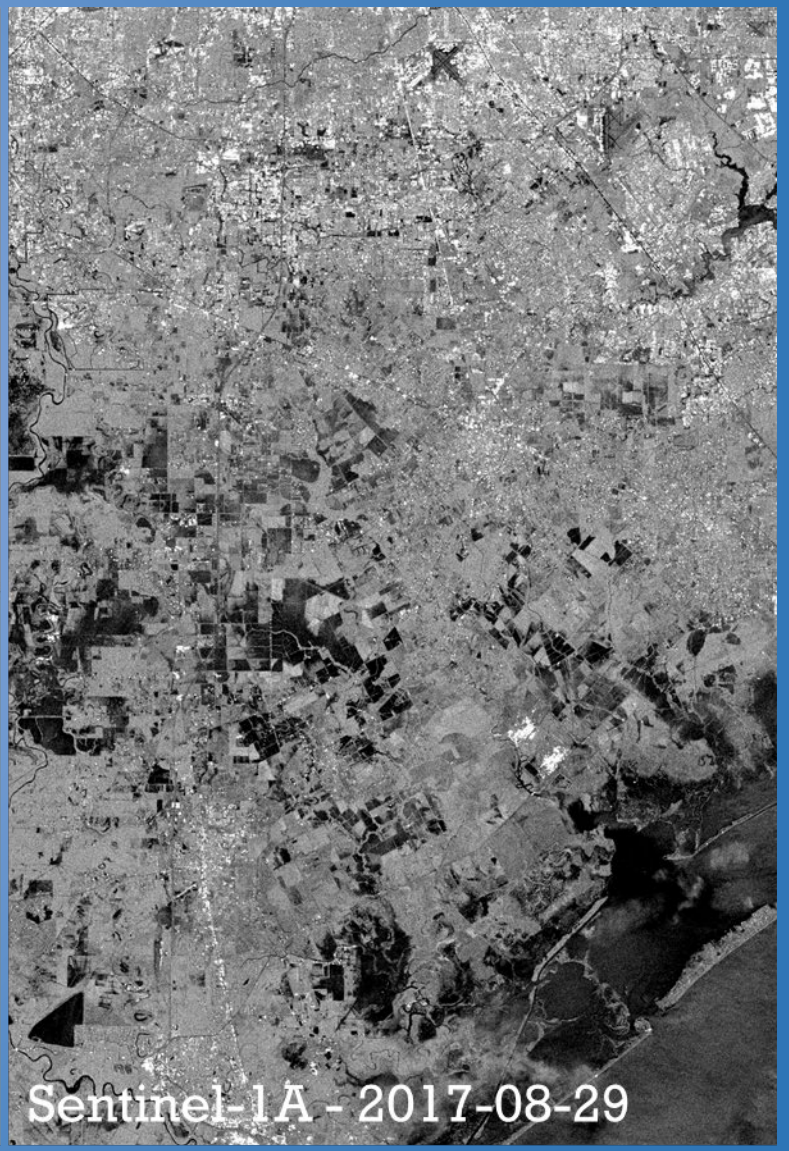
K Artificially Flooded						

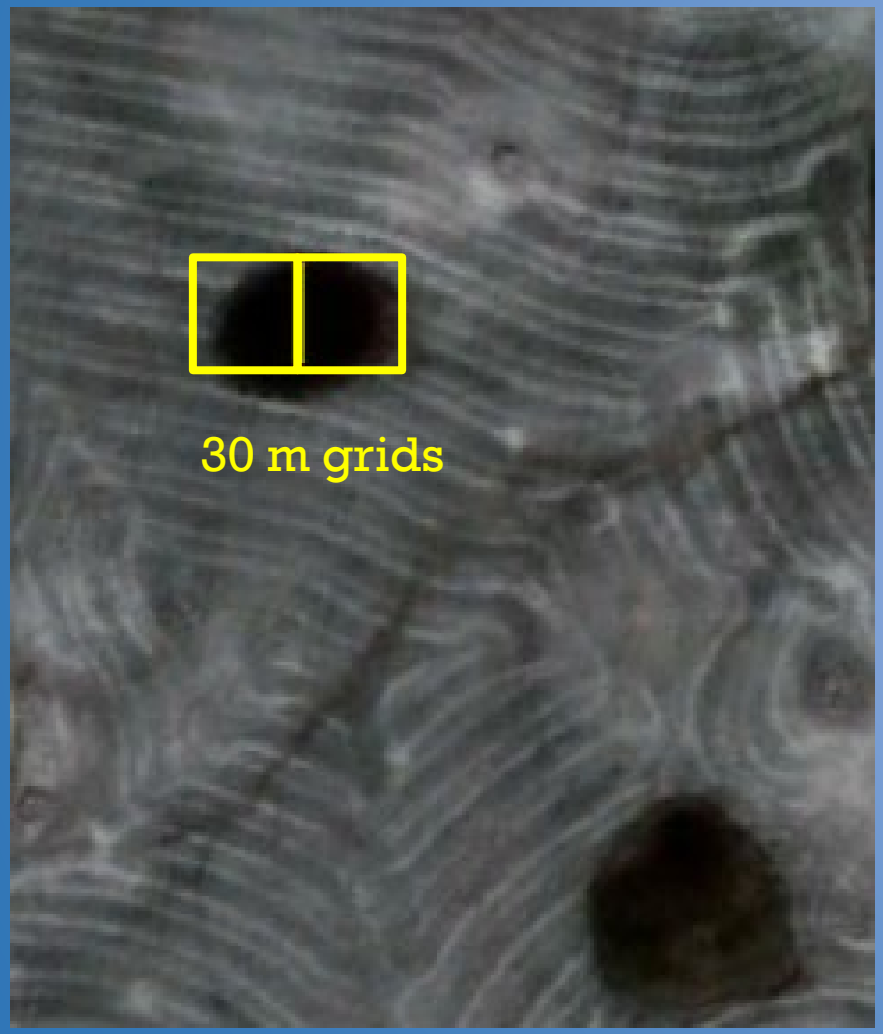
WATER REGIME MAPPING APPROACH

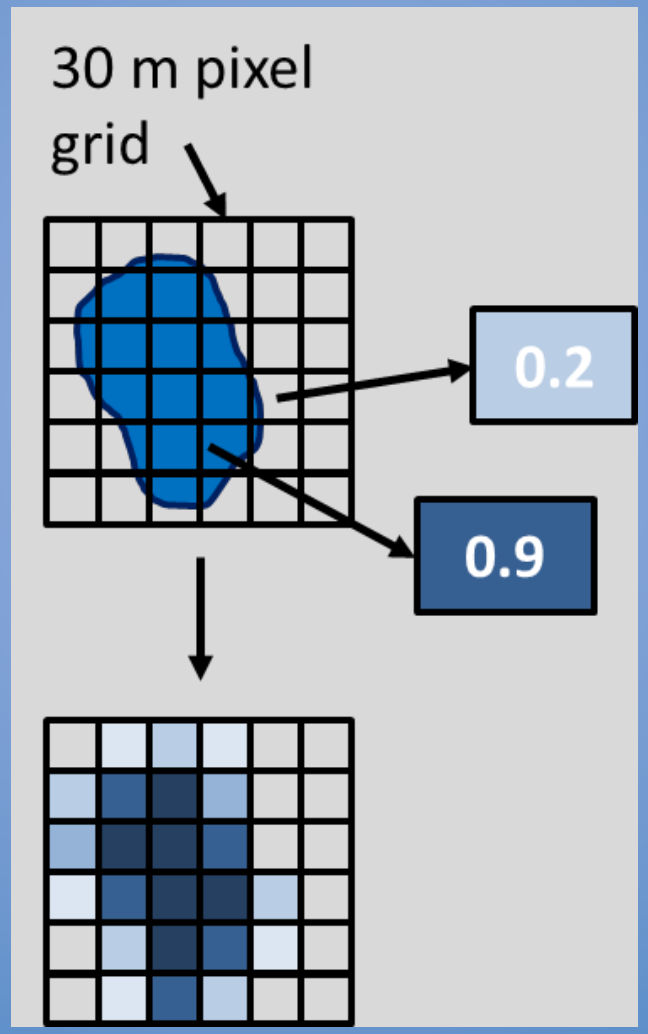
- Automated surface water mapping algorithms
  - Optical algorithm
  - Radar algorithm
- Temporal aggregation to reduce noises





AUTOMATED ESTIMATION OF SUBPIXEL WATER FRACTION (SWF)



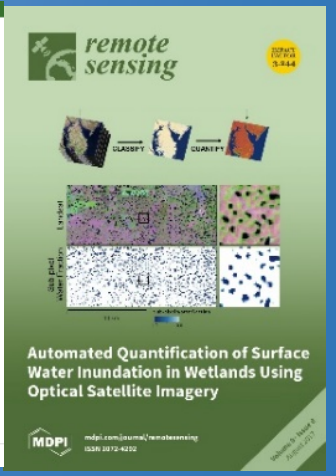


waffls:

"**wa**ter **f**raction **f**rom **L**andsat and **S**entinel-2"

python package for automated SWF estimation

https://github.com/bendv/waffls

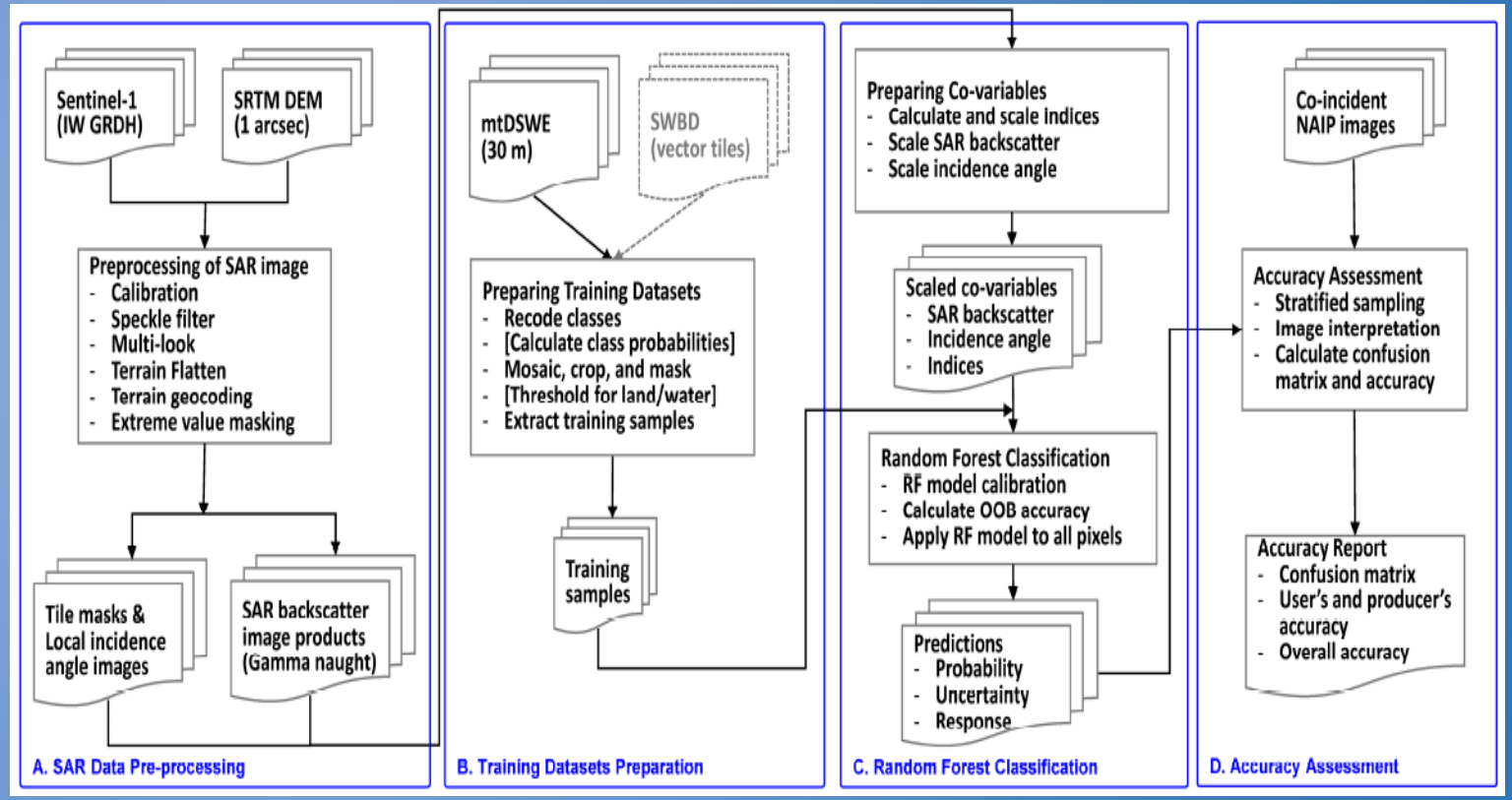


DeVries et al. *Remote Sensing* **2017**, 9(8):807

USE OPTICAL RESULTS TO AUTOMATE THE RADAR MAPPING ALGORITHM

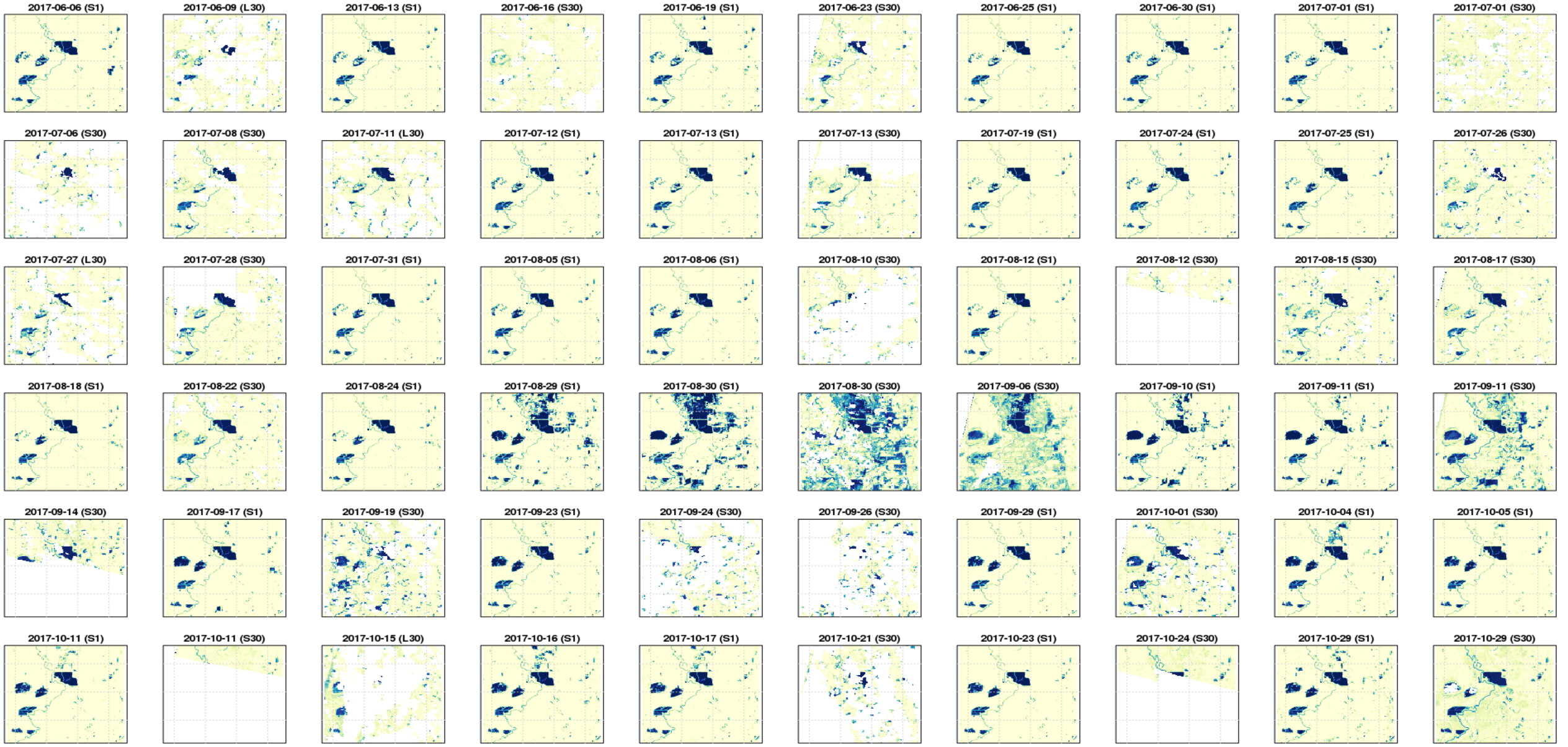
Key steps:

- Use historical optical results to identify
  - Permanent water bodies
  - Upland never inundated
- Select water and non-water training samples from the above
- Train machine learning algorithm and use it to produce classification map

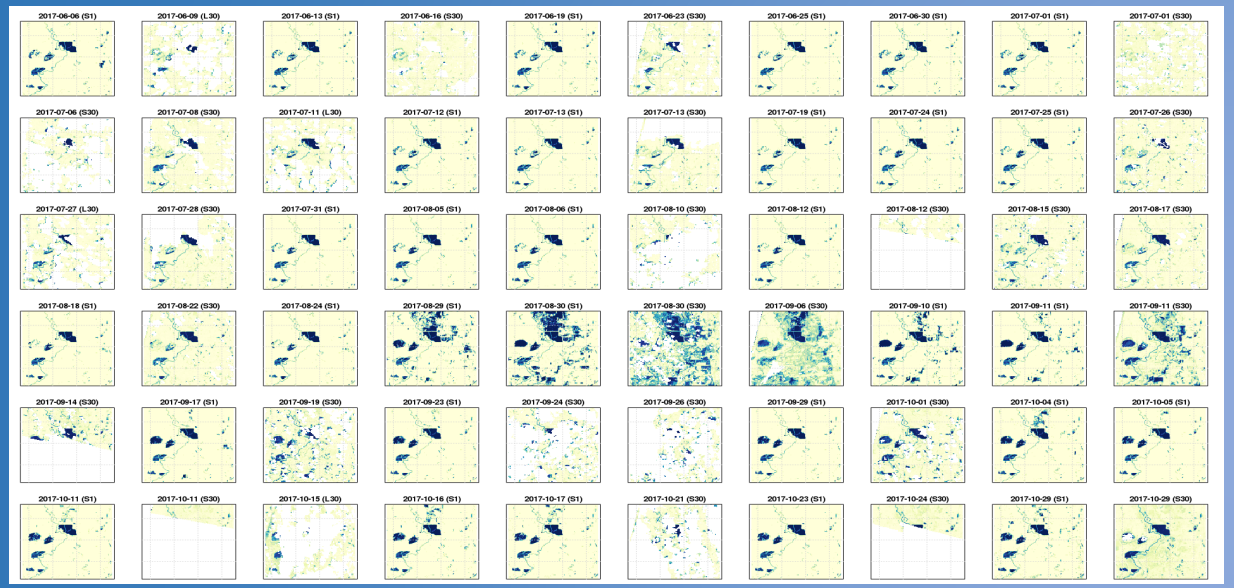


Huang, W., DeVries, B., Huang, C., Lang, M., Jones, J., Creed, I., & Carroll, M. (2018). Automated Extraction of Surface Water Extent from Sentinel-1 Data. *Remote Sensing, 10, 797.*

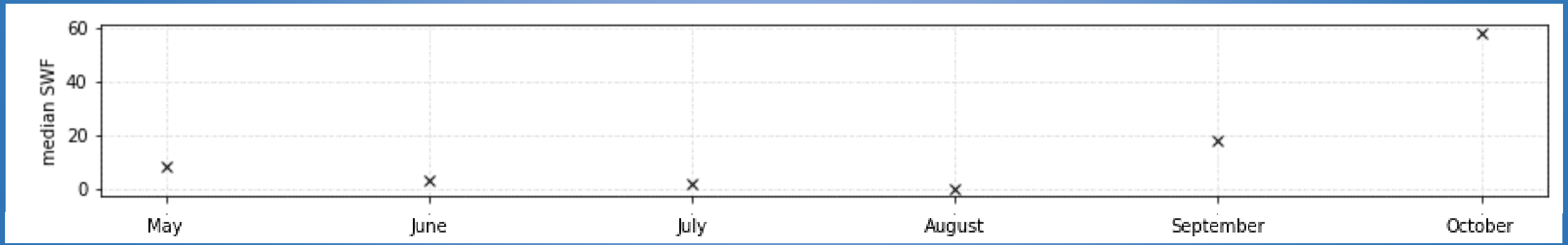
RESULTS FROM INDIVIDUAL OPTICAL-SAR OBSERVATIONS TEMPORALLY DETAILED, BUT VERY NOISY



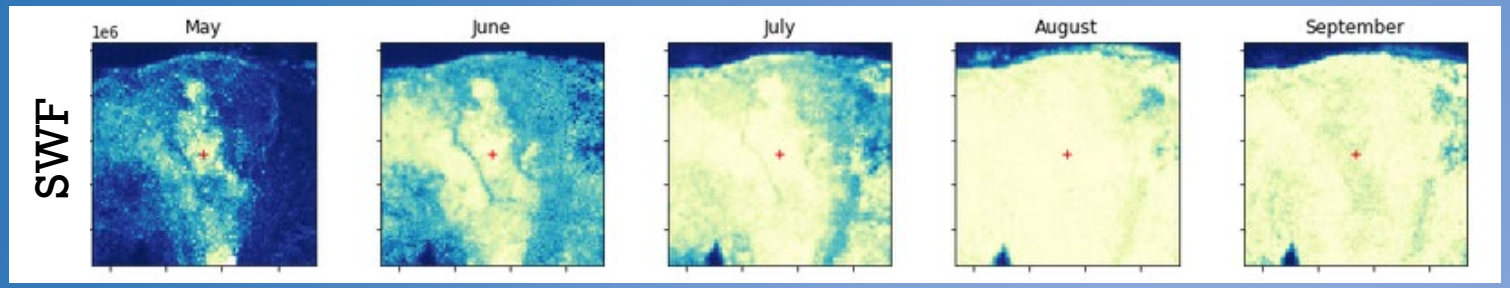
TEMPORAL AGGREGATION TO REDUCE NOISES

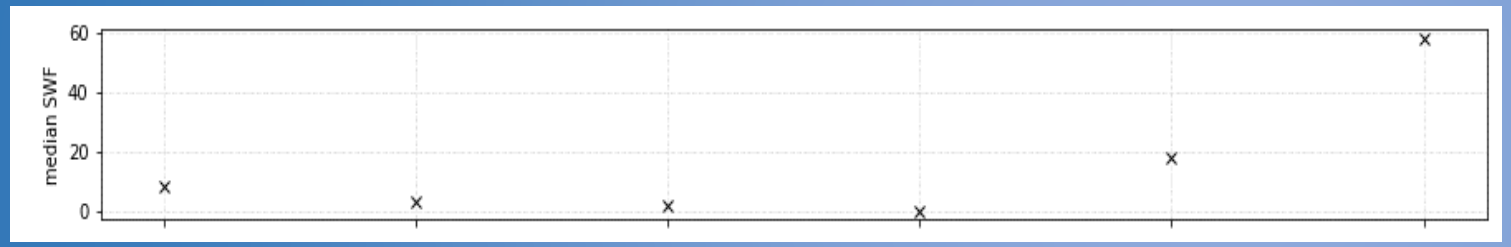


Monthly Median



DEFINE WATER REGIME CLASSES BASED ON MONTHLY COMPOSITES





Quantitative Rules to Define Surface Water Regime Classes

0 – not detected

1 – seasonally saturated

2 – permanently saturated

3 – intermittently inundated

4 – seasonally inundated

5 – seasonally inundated or saturated

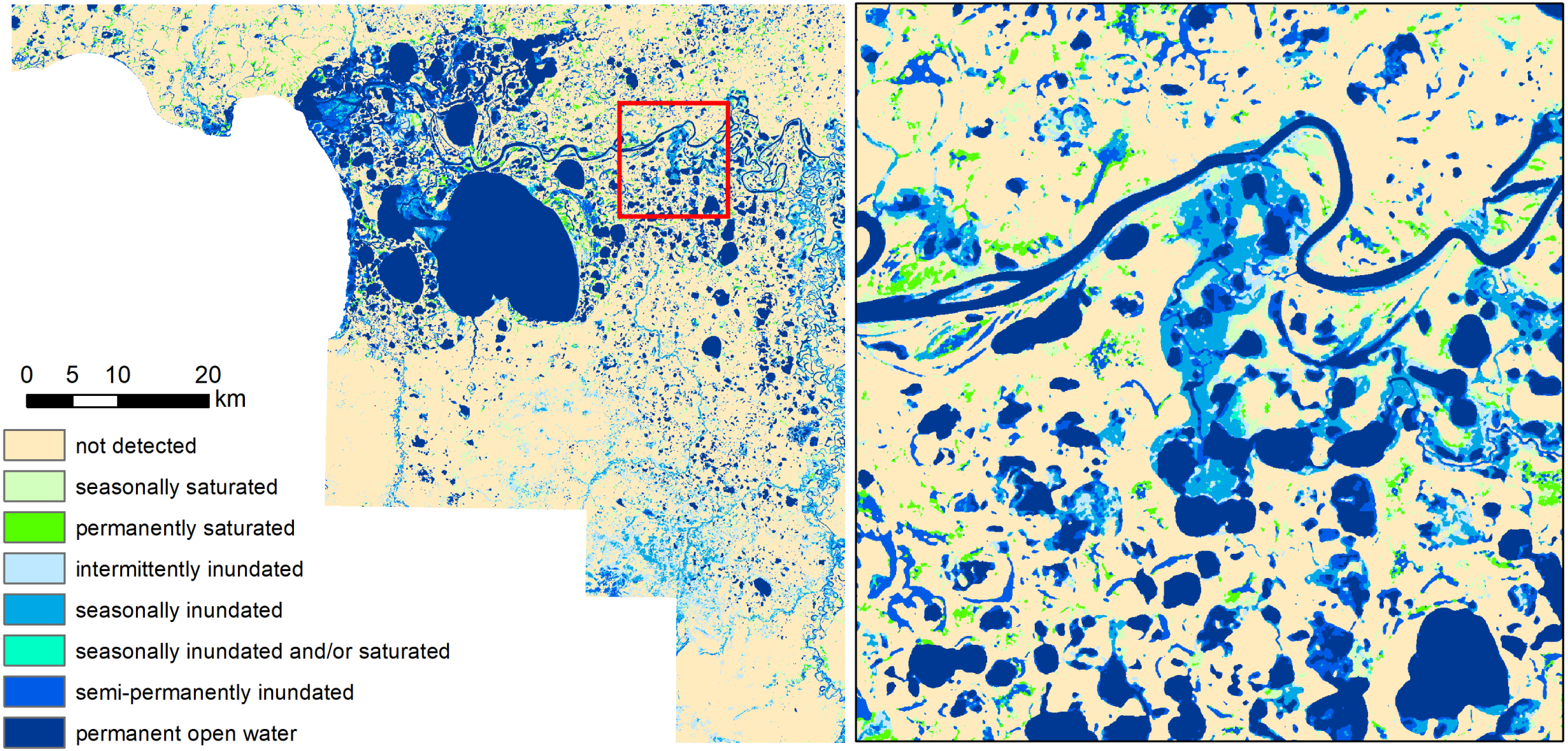
6 – semi-permanently inundated

7 – permanent open water

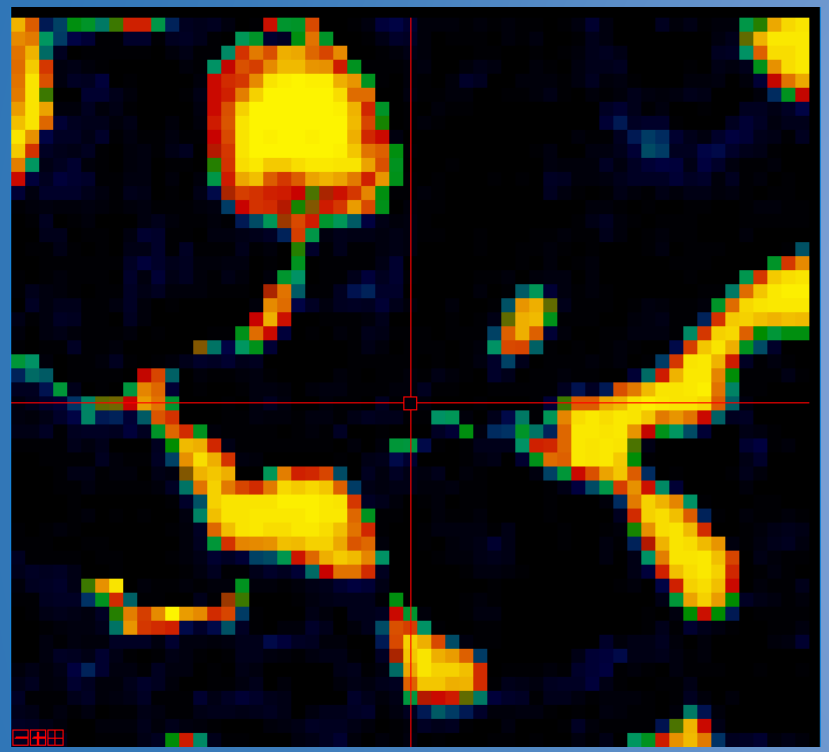
Seasonally Flooded (C) Surface water is present for extended periods (generally for more than a month) during the growing season, but is absent by the end of the season in most years. When surface water is absent, the depth to substrate saturation may vary considerably among sites and among years.

Intermittent (R4) This Subsystem includes channels that contain flowing water only part of the year. When the water is not flowing, it may remain in isolated pools or surface water may be absent.

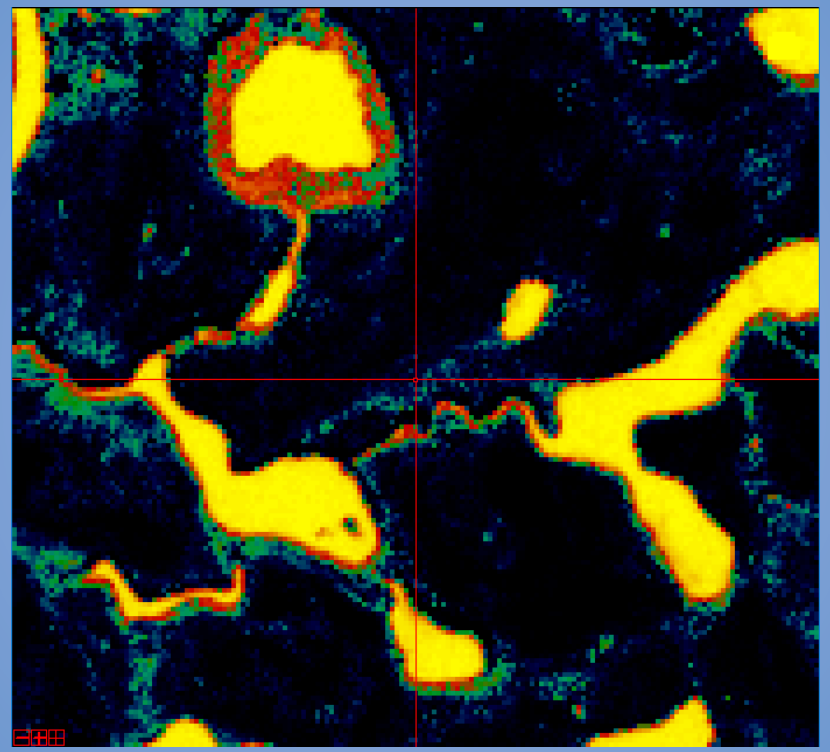
Rule-Based Surface Water Regime Map



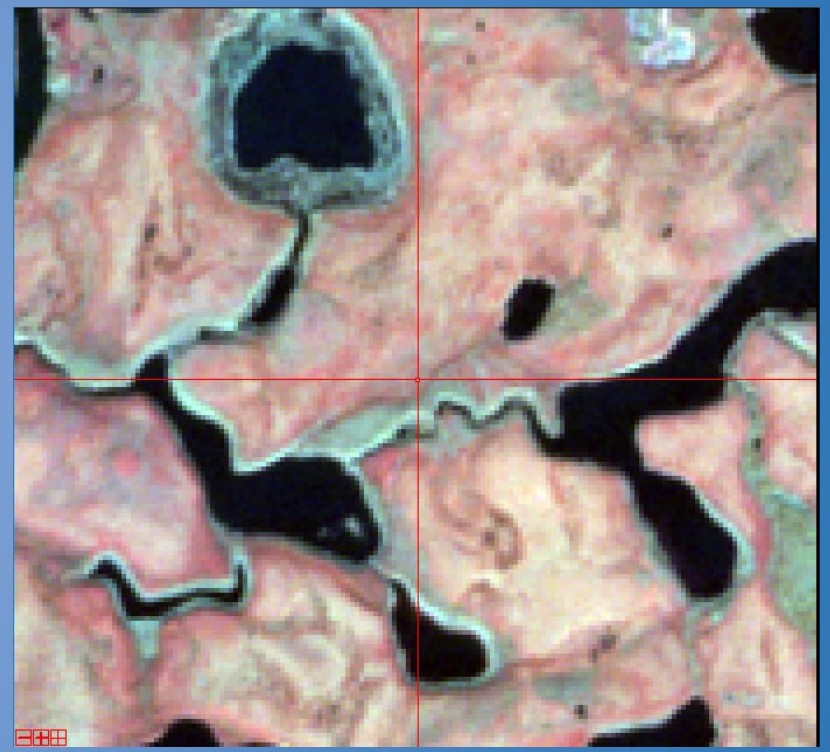
10-M DATA MUCH BETTER THAN 30-M DATA FOR SMALL WETLANDS



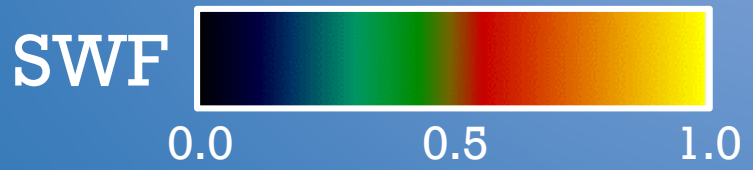
SWF (30m)



SWF (10m)



NIR-R-G (10m)



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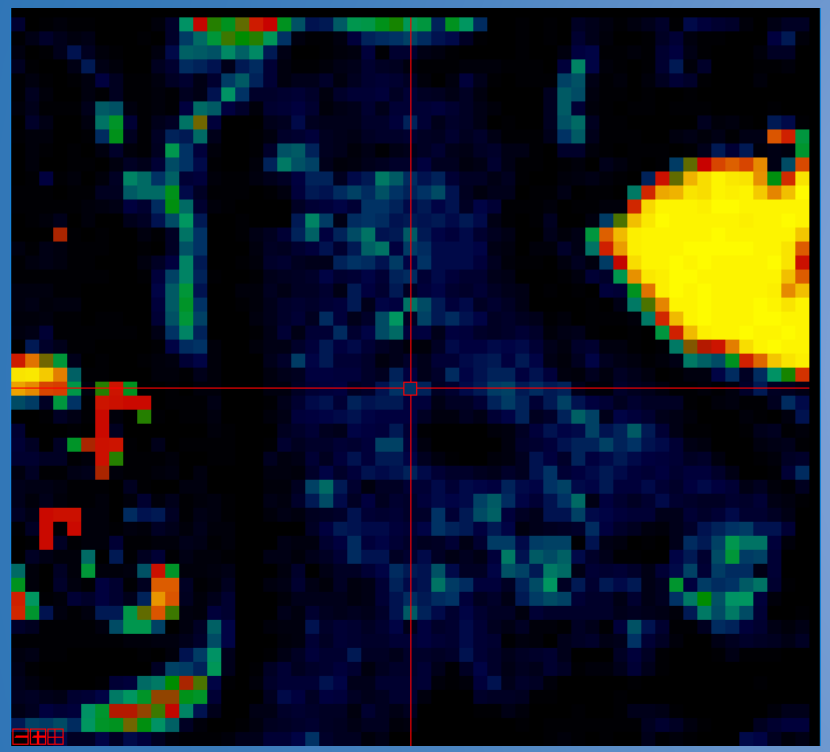
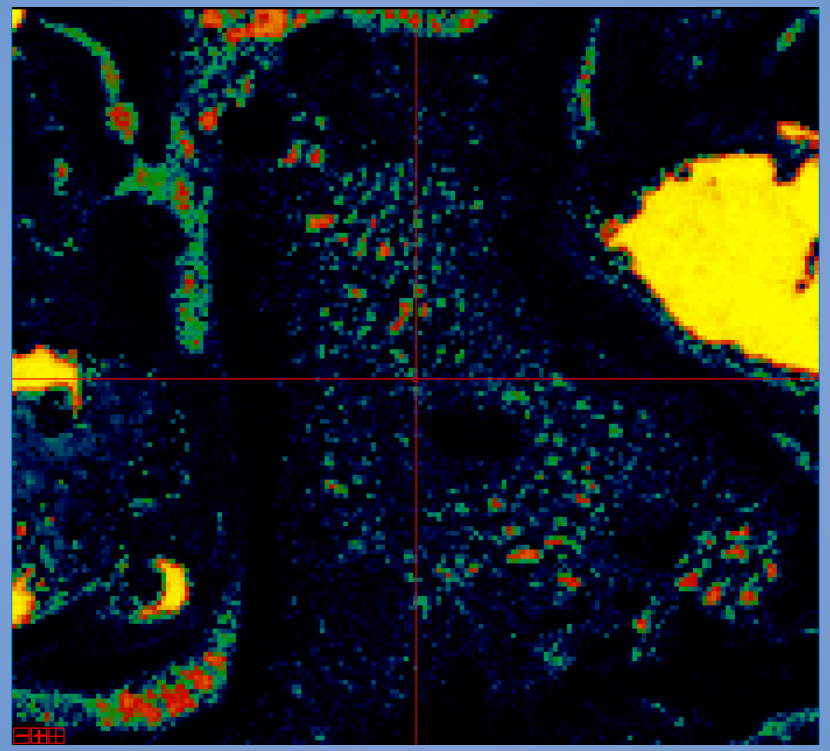


SWF (30m)



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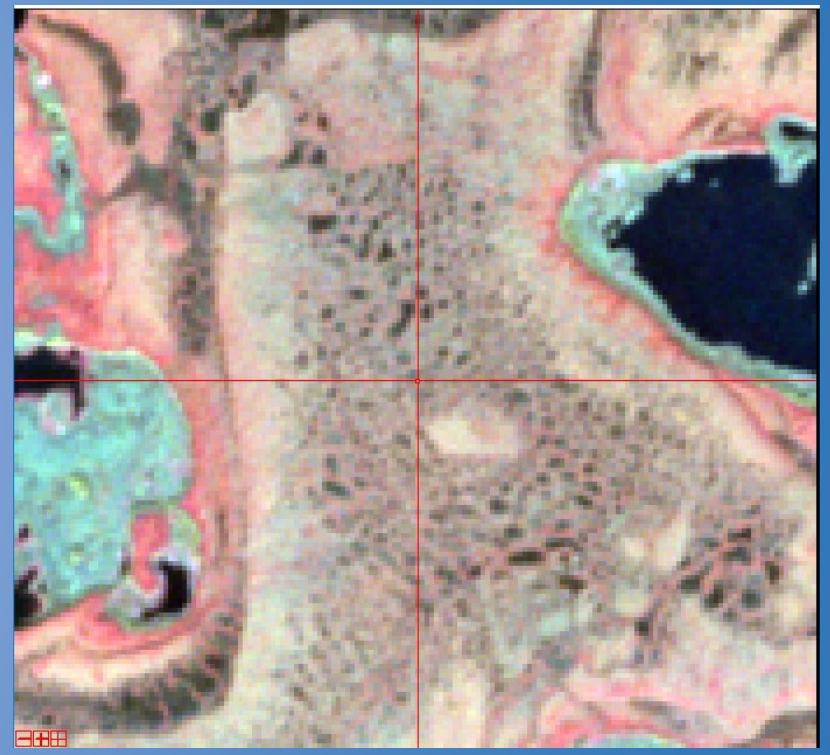

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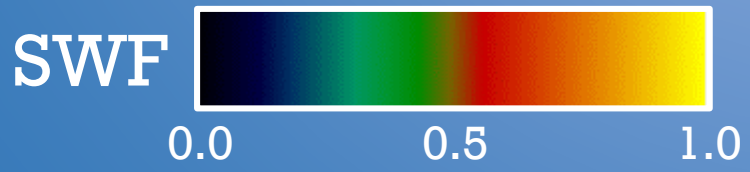

VEGETATION CLASSIFICATION: USE STANDARD MACHINE LEARNING APPROACH

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Simplify to create classes derivable from remote sensing data

- Not vegetated (NV)
- emergent (EM)
- scrub-shrub (SS)
- EM/SS
- forested (FO)
- SS/FO

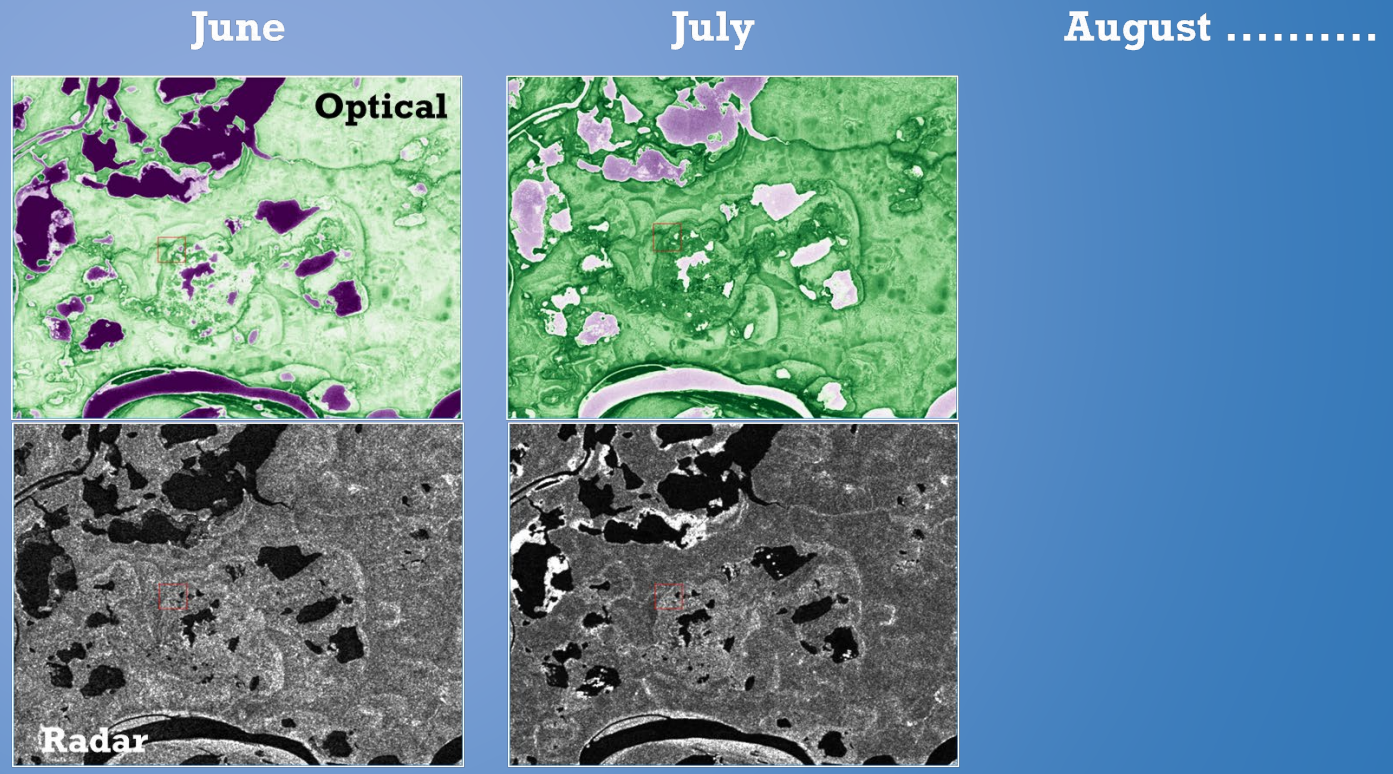
MONTHLY MEDIAN COMPOSITES USED IN VEGETATION CLASSIFICATION

Optical:

- spectral bands
- indices, e.g.:
  - NDVI, NDWI, NDSI

Radar:

- vv, vh backscatter
- indices, e.g.:
  - vh/(vv+vh)



VEGETATION CLASSIFICATION ACCURACY STATISTICS

Reference

Predicted

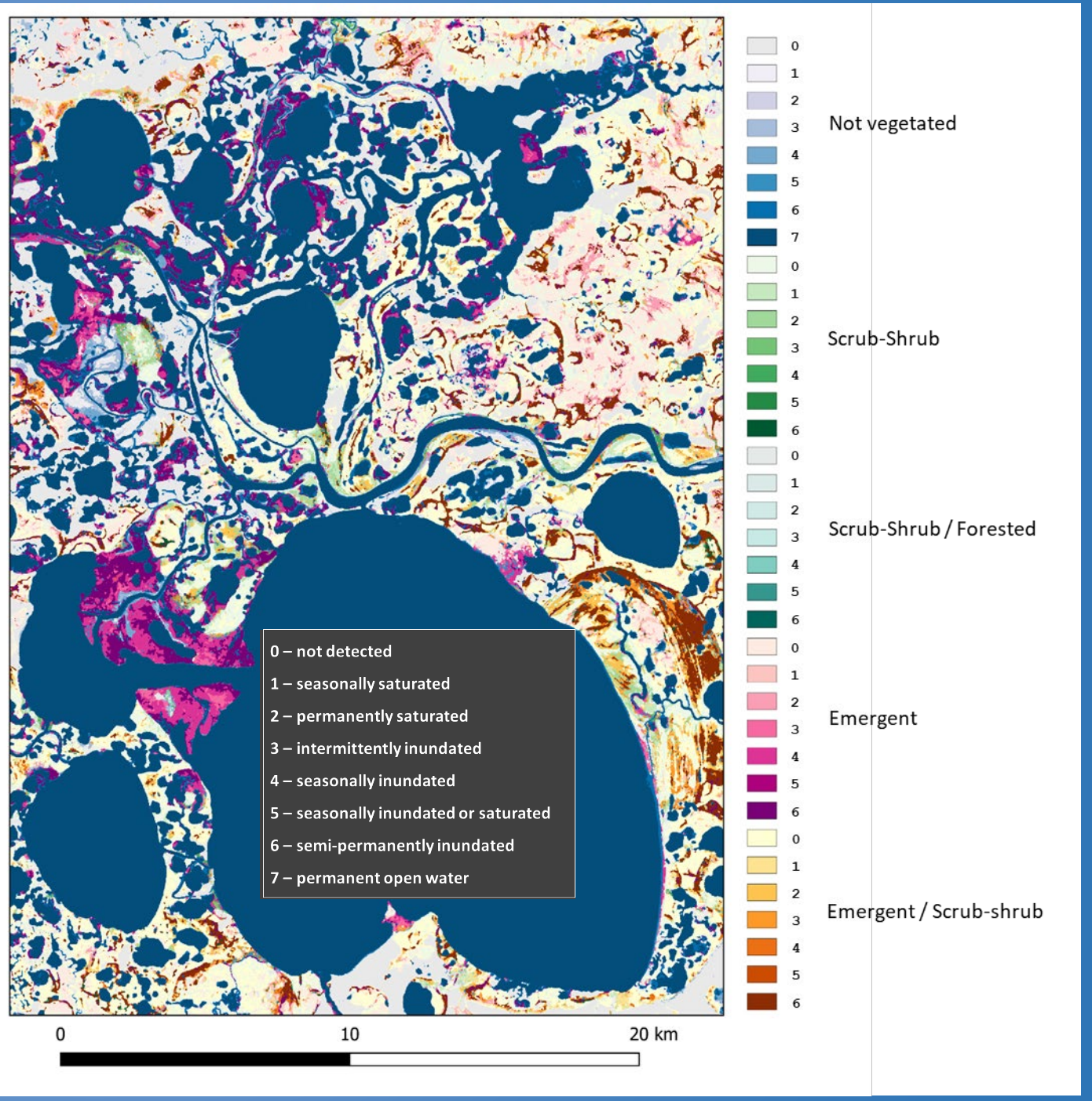
	NV	SS	SS/FO	EM	EM/SS	Sum	OA
NV	3543	363	107	729	265	5007	0.65
SS	383	2772	28	691	727	4601	
SS/FO	230	185	4620	161	278	5474	
EM	552	626	63	2221	578	4040	
EM/SS	292	1054	182	1198	3152	5878	
Sum	5000	5000	5000	5000	5000	25000	

Cell values = # of 10-m pixels

NV: not vegetated
SS: scrub-shrub
FO: forested
EM: emergent
OA: overall accuracy

WETLAND CLASSIFICATION BY VEGETATION TYPE AND WATER REGIMES

- 36 classes in total
  - 5 veg x 7 water + open water)
- Visually appealing
- Assessment
  - Vegetation: ~65%
  - Water regime: no reference data to assess, but method objective and repeatable
- Products being evaluated by NWI towards developing standard compliant products over Alaska



SUMMARY AND FUTURE OUTLOOK

- Detailed wetland classification possible with synergistic use of optical and radar time series observations
  - Quantitative measure of water regimes
  - Detailed wetland classification that considers both water regime and vegetation type
  - Great improvements in mapping small wetlands using 10 m data instead of 30 m data
- Significantly improved radar capabilities forthcoming
  - RADARSAT constellation - sub-weekly, C band
  - NISAR - L band, better mapping of woody wetlands
  - Optical-SAR synergy -> much needed spatial-temporal details for highly dynamic aquatic systems
    - Strong technical skills on cloud platforms needed to realize the full potential

THANK YOU!

NASA LCLUC Program

US FWS NWI Program

Free Data Policy

NASA HLS Project

Google Earth Engine

NASA NEX

Contact for follow-up discussions

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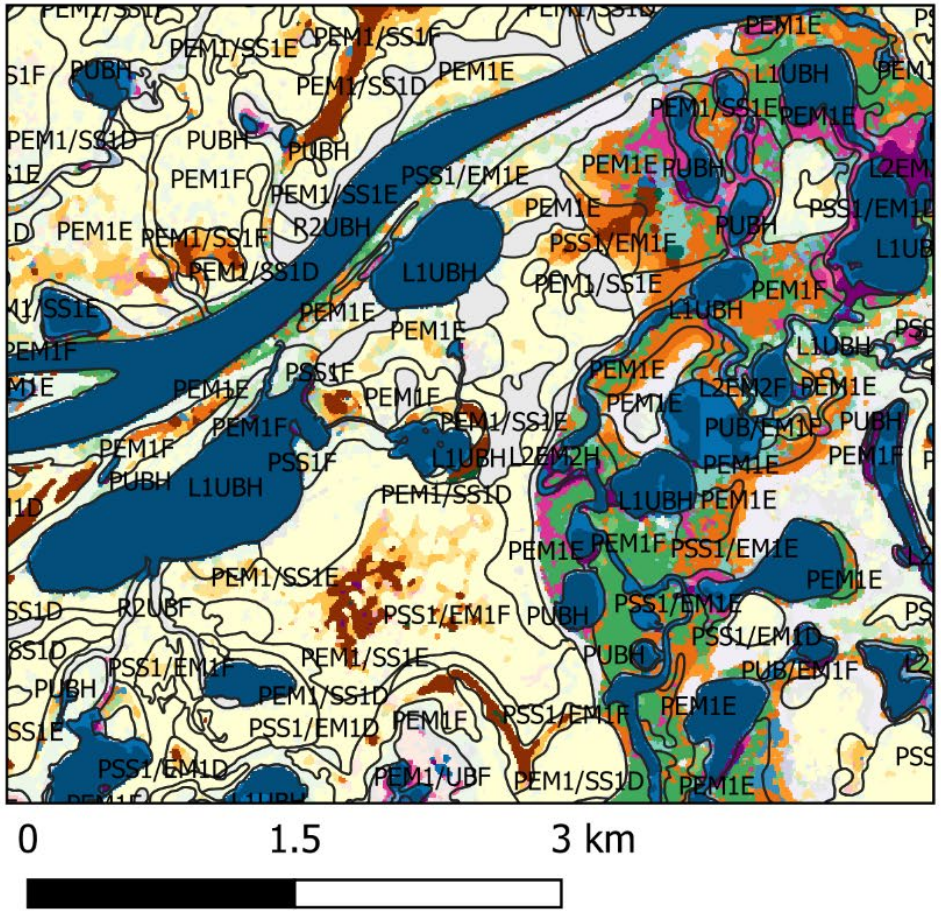
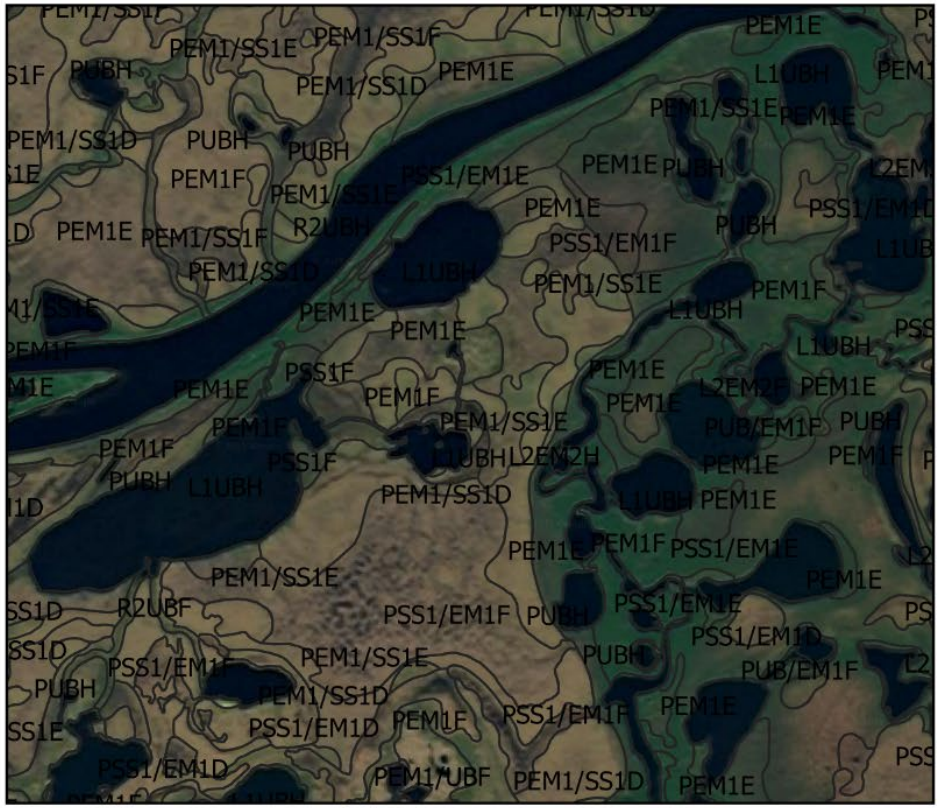




0 1 2 3 4 5 6 7 0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1 2 3 4 5 6

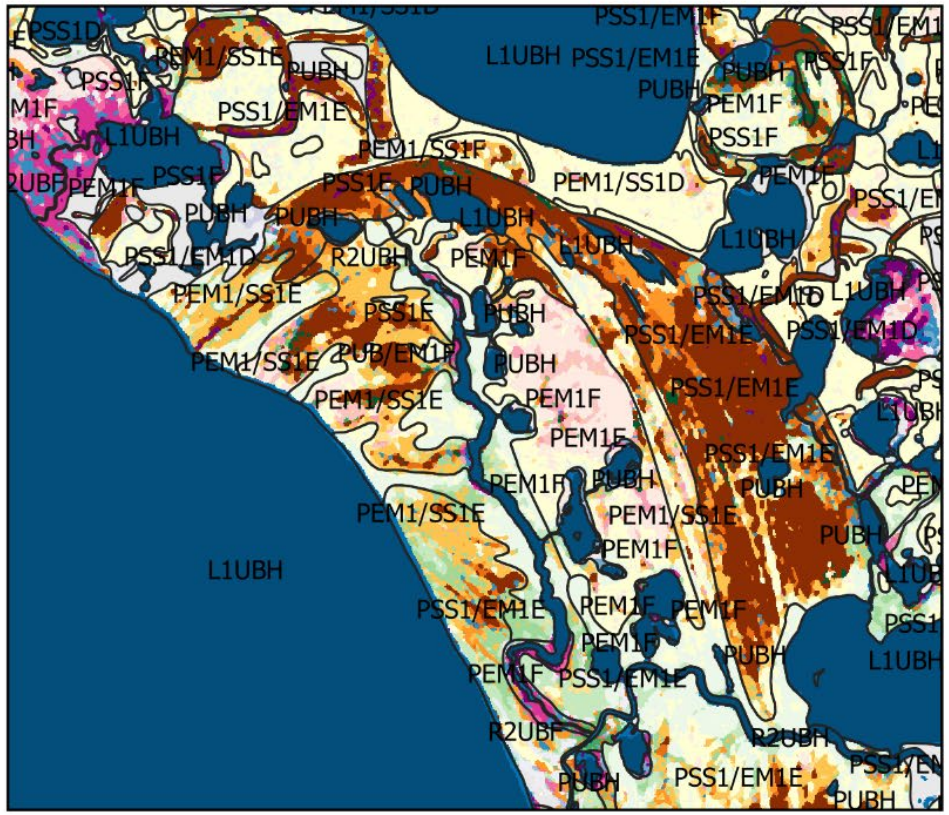
Not vegetated

Scrub-Shrub

Scrub-Shrub / Forested

Emergent

Emergent / Scrub-shrub



0 1.5 3 km

0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1 2 3 4 5 6 0 1 2 3 4 5 6

Not vegetated

Scrub-Shrub

Scrub-Shrub / Forested

Emergent

Emergent / Scrub-shrub