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A Polarimetric Segmentation Approach for Soil Moisture Active/Passive (SMAP) Mission: Algorithm Description and Results

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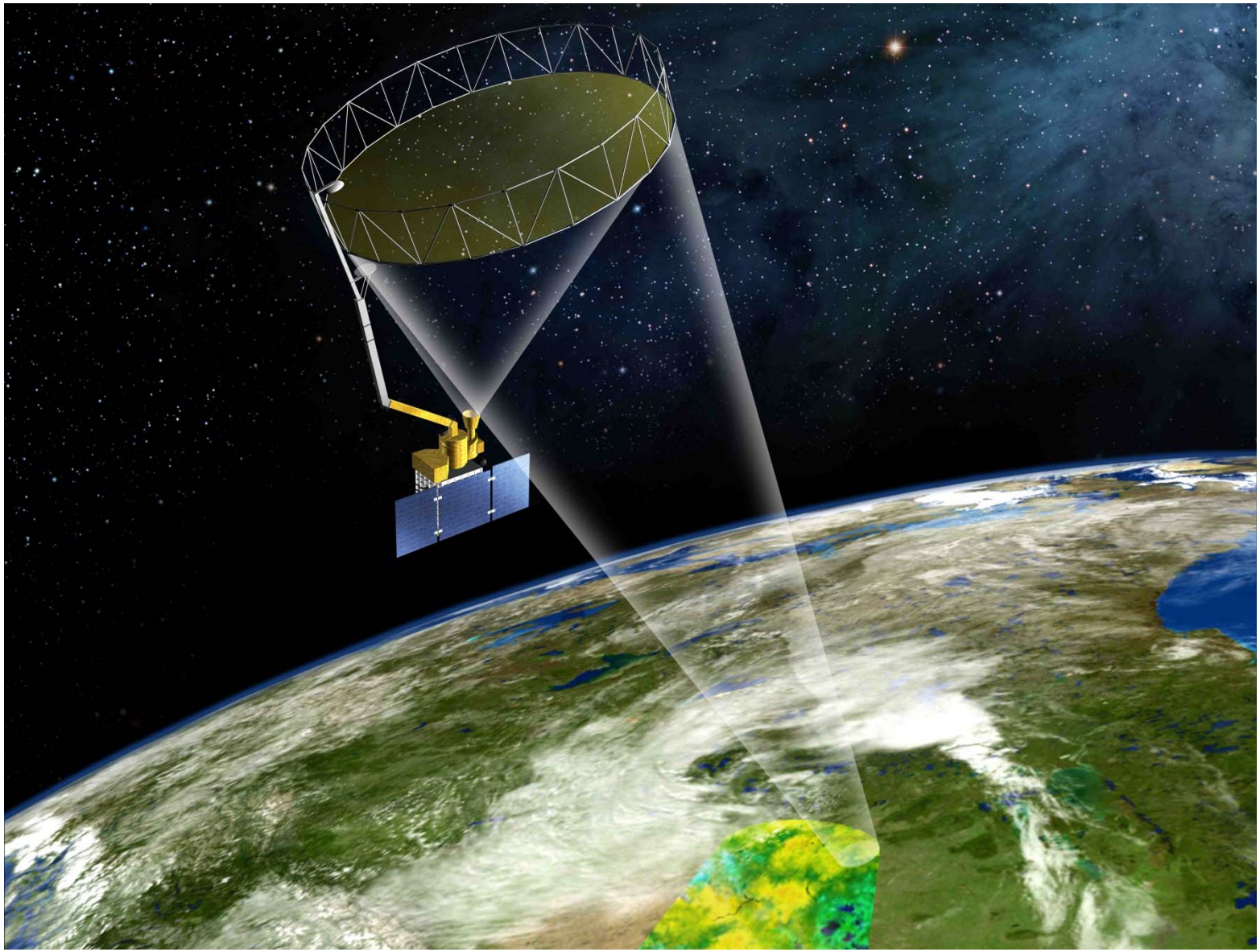
What is SMAP?



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SMAP Instruments

- Radar
  - Frequency: 1.26 GHz
  - Polarizations: VV, HH, HV (not fully polarimetric)
  - Relative accuracy (3 km grid): 1 dB (HH and VV), 1.5 dB (HV)
  - Data acquisition:
    - High-resolution (SAR) data acquired over land
    - Low-resolution data acquired globally
- Radiometer
  - Frequency: 1.41 GHz
  - Polarizations: H, V, 3rd & 4th Stokes
  - Relative accuracy (30 km grid): 1.3 K
  - Data collection:
    - High-rate (sub-band) data acquired over land
    - Low-rate data acquired globally
- Antenna
  - Conically-scanning deployable mesh reflector shared by radar and radiometer
  - Diameter: 6 meters
  - Rotation rate: 14.6 RPM
  - Beam efficiency: ~90%
  - Spatial Resolution:
    - Radiometer (IFOV): 39 km x 47 km
    - SAR: 1-3 km (over outer 70% of swath)
  - Swath width: 1000 km

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SMAP Mission

- SMAP will provide global measurements of soil moisture and its freeze/thaw state.
- 680-km near-polar, sun-synchronous orbit, with equator crossings at 6 am and 6 pm local time.
- The measurement swath width is 1000 km, providing global coverage within 3 days at the equator and 2 days at boreal latitudes (>45 degrees N).
- SMAP science measurements will be acquired for a period of three years
- Data products from the SMAP mission will be made available through a NASA-designated data center.

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Why Segmentation?

- No single scattering model exists that accurately represents observations from bare surfaces all the way to mature forests
- The SMAP mission plans to use algorithms tuned to specific classes of vegetation to make the problem more tractable
- We need to find a simple way to decide which one of the algorithms to apply to a specific pixel when we invert for soil moisture
- In addition, the radiometer algorithm requires knowledge of open water bodies, so we need to identify transient water bodies from the radar data.

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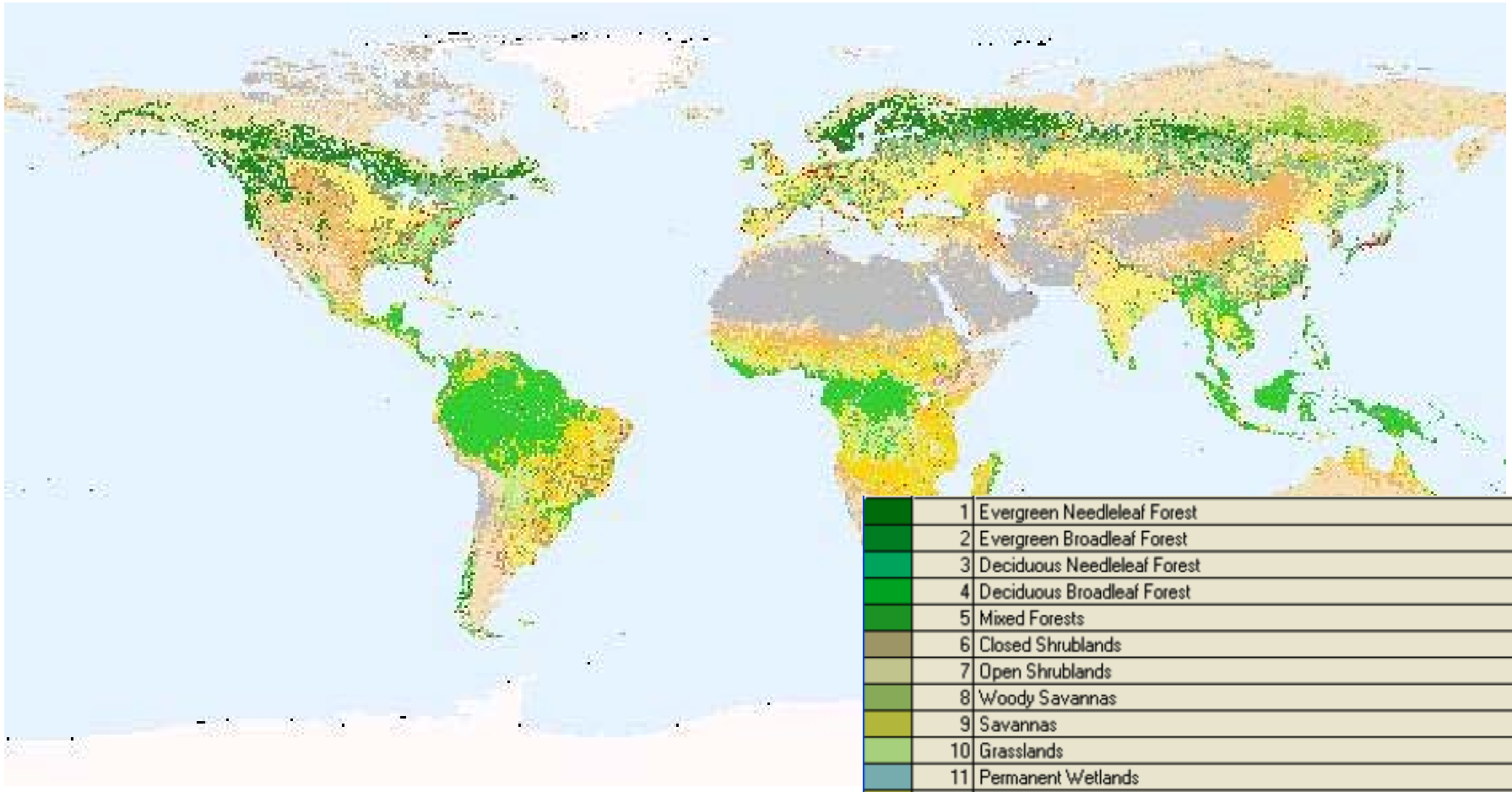
SMAP Classes



1	Evergreen Needleleaf Forest
2	Evergreen Broadleaf Forest
3	Deciduous Needleleaf Forest
4	Deciduous Broadleaf Forest
5	Mixed Forests
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands
13	Urban and Built-Up
14	Cropland/Natural Vegetation Mosaic
15	Snow and Ice
16	Barren or Sparsely Vegetated
17	(IGBP Water Bodies, recoded to 0 for MODIS Land Product consistency.)
254	Unclassified
255	Fill Value

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Methodology

- The fundamental difference between the algorithms is that they apply to different levels of biomass
- Radar observations suggest that (up to a certain level) increase in biomass leads to increase in observed scattering randomness
- Can we find a simple algorithm that identifies different levels of randomness in the scattering?

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Polarimetric Measures of Randomness

- Polarimetric Entropy

$$H_T = -\sum_{i=1}^{3} P_i \log_3 P_i; \quad P_i = \frac{\lambda_i}{\lambda_1 + \lambda_2 + \lambda_3}$$

- Pedestal Height

$$Pedestal\ Height = \frac{\min(\lambda_1, \lambda_2, \lambda_3)}{\max(\lambda_1, \lambda_2, \lambda_3)}$$

- Radar Vegetation Index

$$RVI = \frac{4\min\left(\lambda_1, \lambda_2, \lambda_3\right)}{\lambda_1 + \lambda_2 + \lambda_3} = \frac{8\sigma_{hv}}{\sigma_{hh} + \sigma_{vv} + 2\sigma_{hv}}$$

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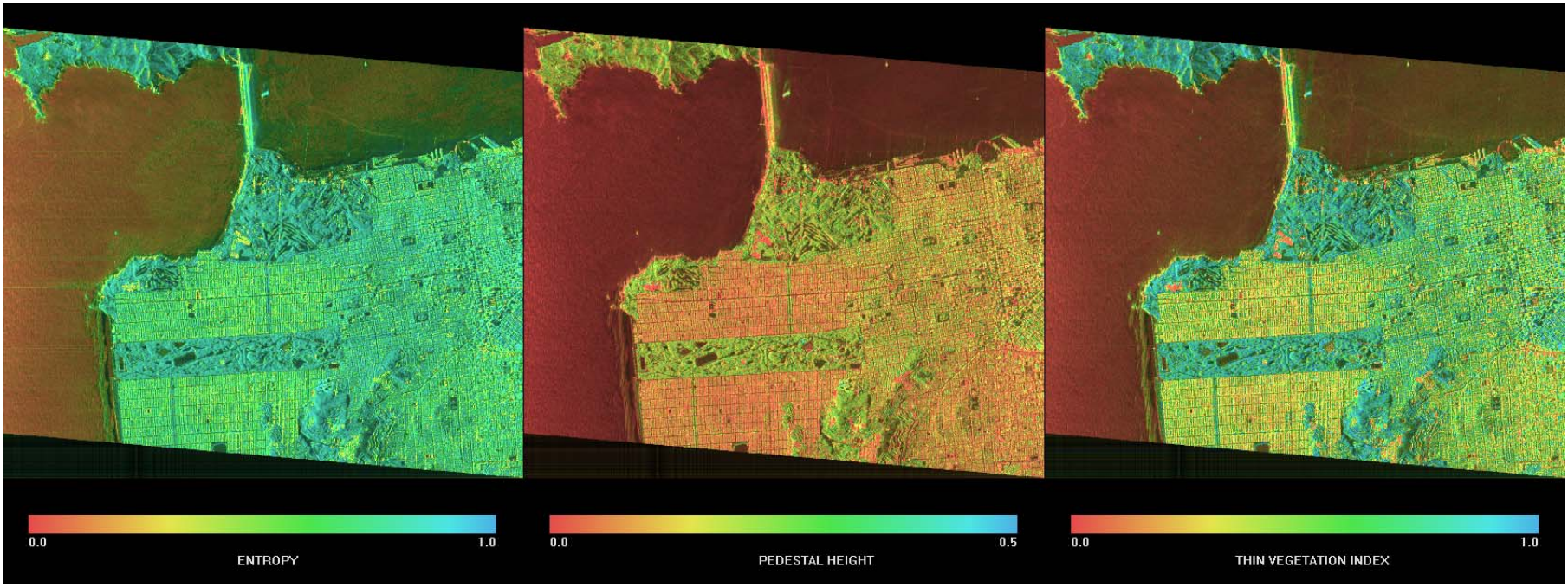
Polarimetric Randomness
San Francisco



The radar vegetation index is a good measure of polarimetric randomness,
But does not require full polarimetric data to calculate

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RVI and Biomass

IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 30, NO. 2, MARCH 1992

Dependence of Radar Backscatter on Coniferous Forest Biomass

M. Craig Dobson, *Senior Member, IEEE*, Fawwaz T. Ulaby, *Fellow, IEEE*, Thuy LeToan, Andre Beaudoin, Eric S. Kasischke, *Member, IEEE*, and Norm Christensen

REGRESSION RESULTS

$\sigma^{\circ}_{f,pp} = a_0 + a_1\beta + a_2\beta^2 + a_3\beta^3$ β = log Biomass (tons/ha)

Band	Frequency	Polarization	a_0	a_1	a_2	a_3	r^2
P-band	0.44 GHz	HH	-19.593	4.534	1.592	-0.4582	0.929
		VV	-19.486	4.037	0.826	-0.4381	0.904
		HV	-29.695	3.893	4.666	-1.5122	0.978
L-band	1.225 GHz	HH	-12.575	4.444	-1.545	0.2916	0.894
		VV	-13.957	4.144	-1.226	0.1815	0.916
		HV	-21.898	5.806	-0.336	-0.2580	0.957
C-band	5.3 GHz	HH	-10.138	3.464	-2.085	0.4924	0.547
		VV	-10.059	1.629	-0.644	0.1698	0.511
		HV	-16.856	4.060	-1.781	0.4006	0.749

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RVI and Biomass

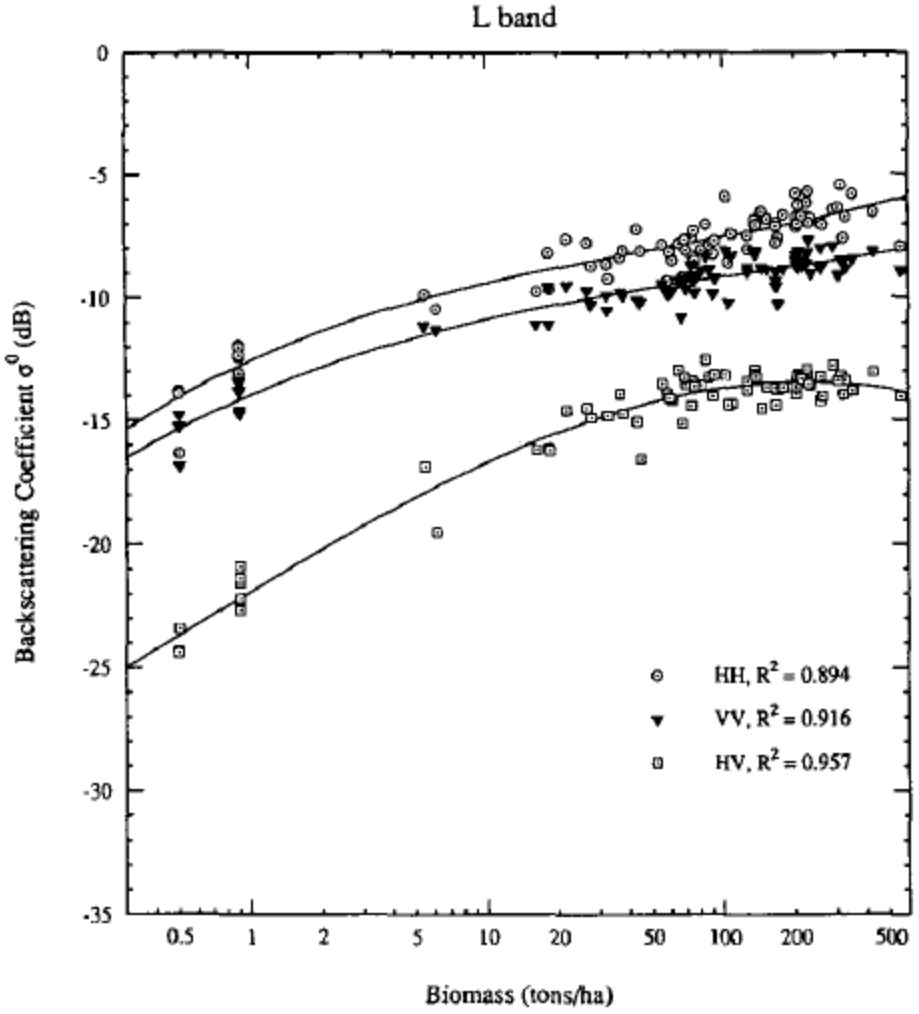

Fig. 2. Calibrated *L*-band backscatter as a function of the log of total aboveground biomass (tons/ha) of maritime pine and loblolly pine.

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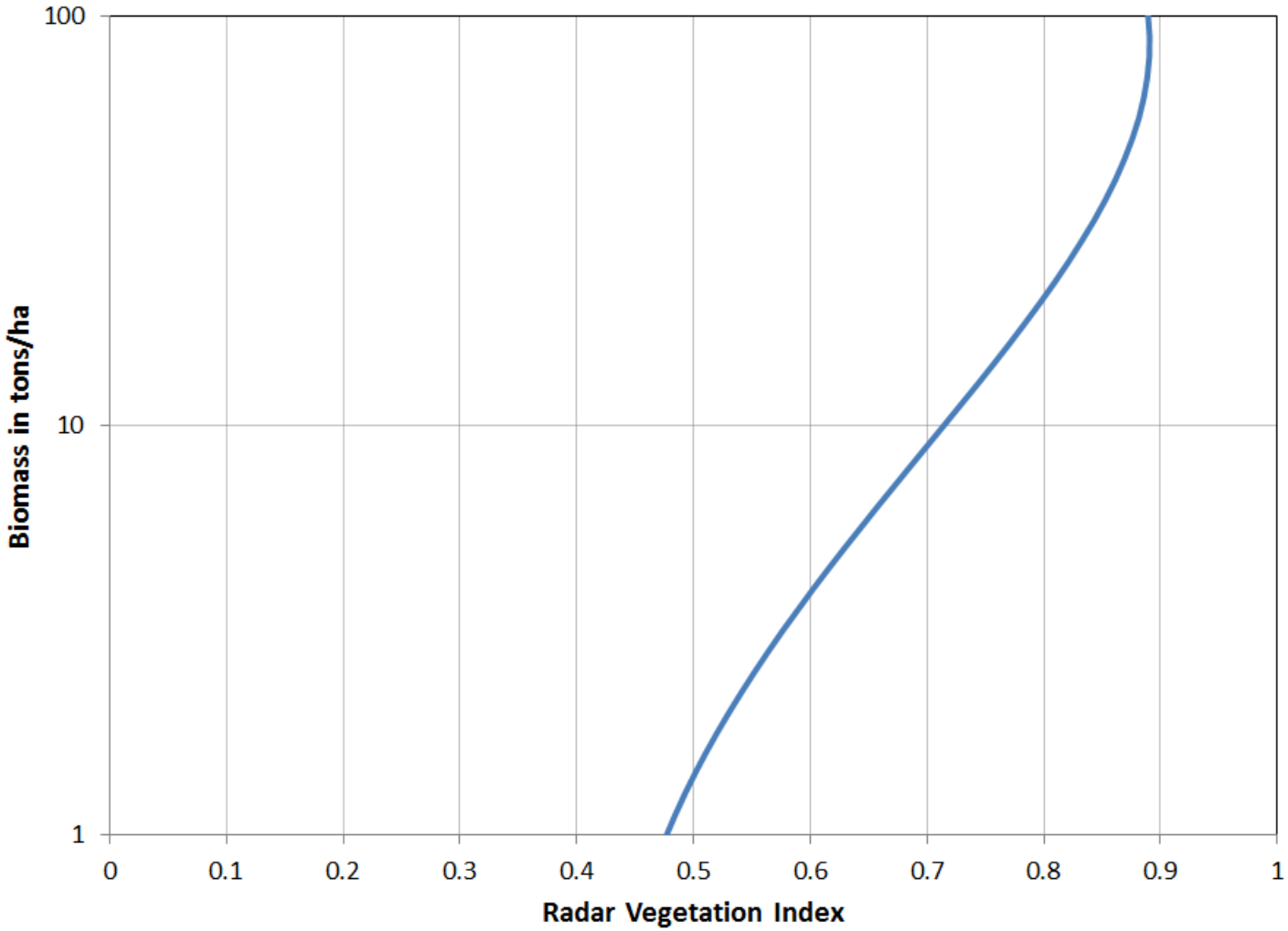

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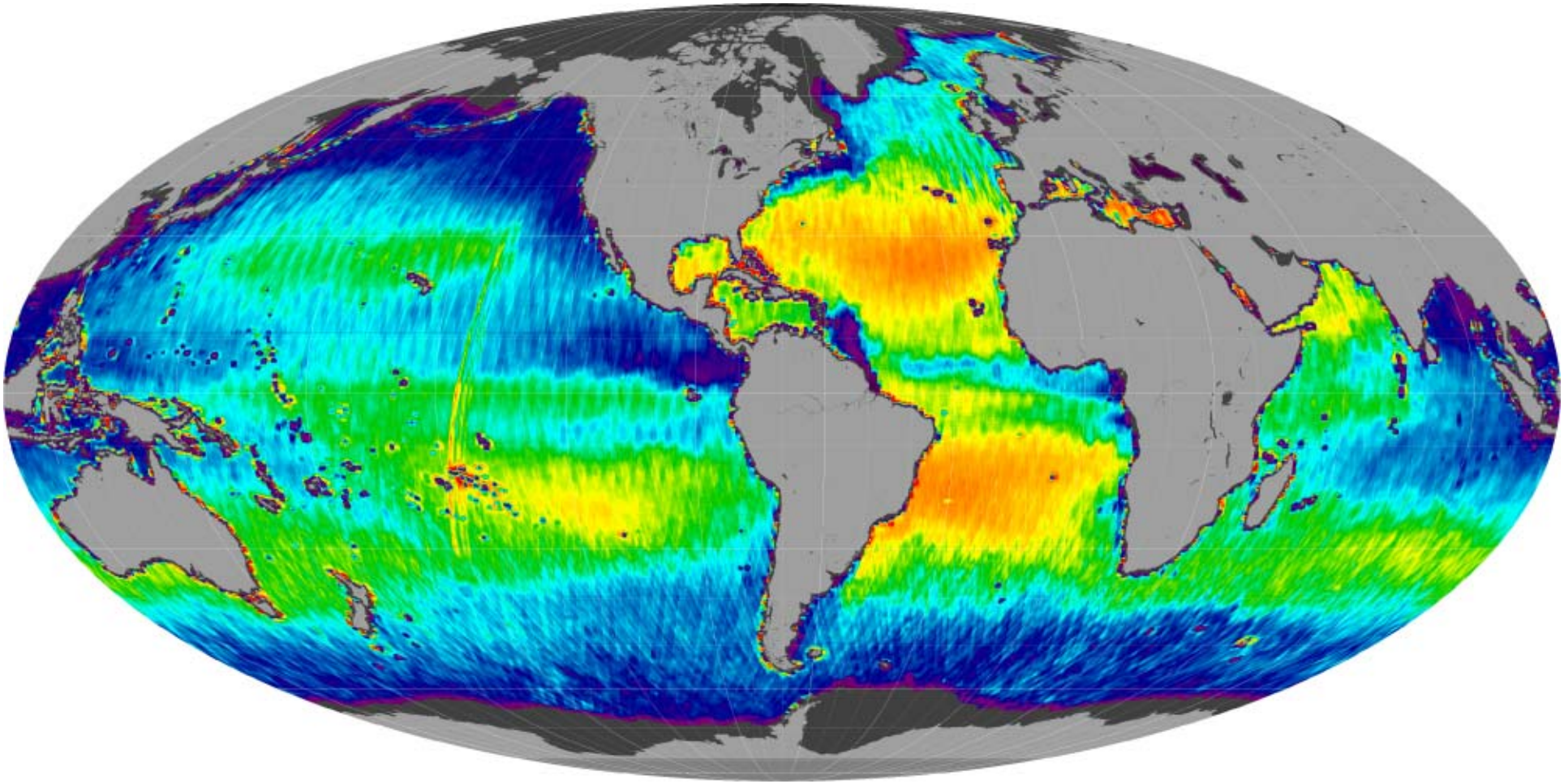
Salinity from Aquarius/SAC-D



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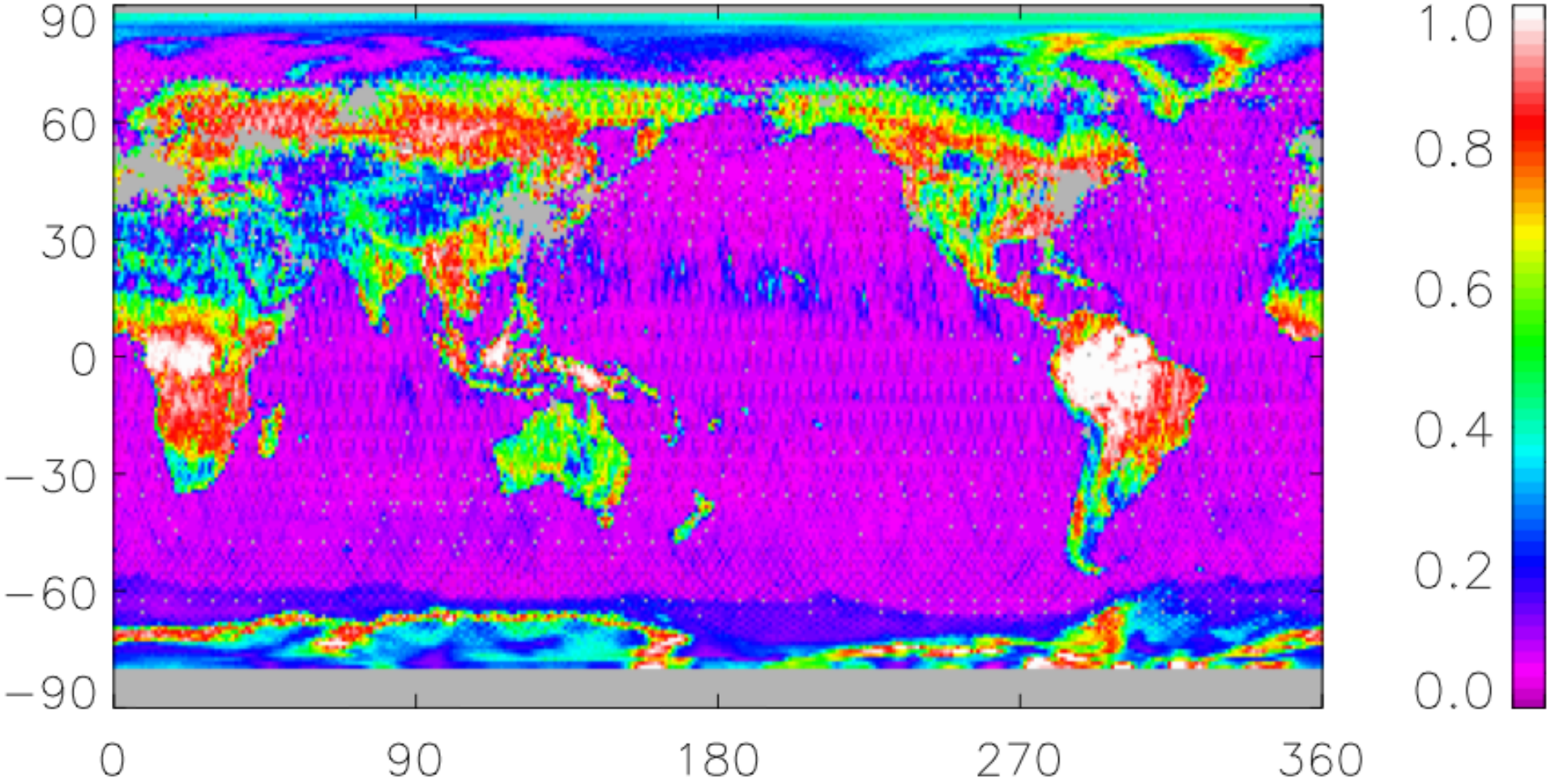
RVI from Aquarius/SAC-D



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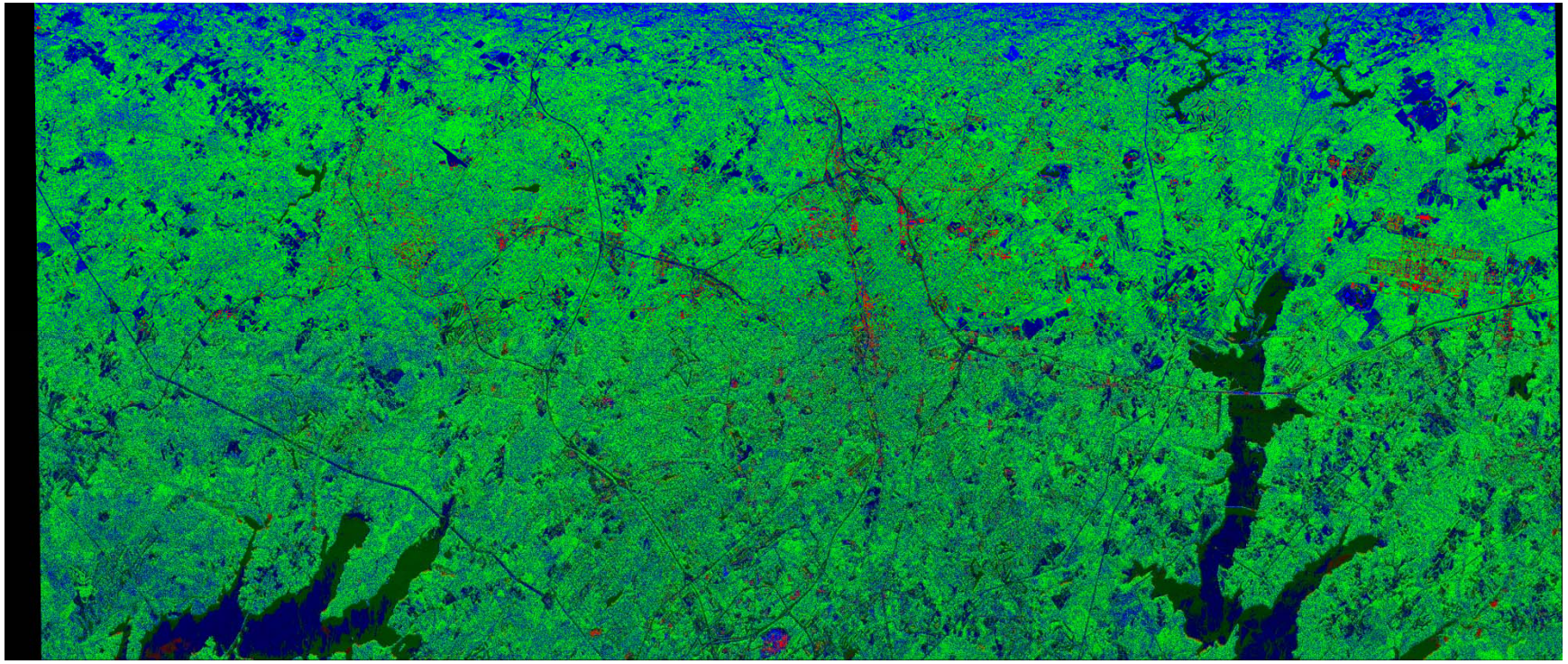
Unsupervised Classification



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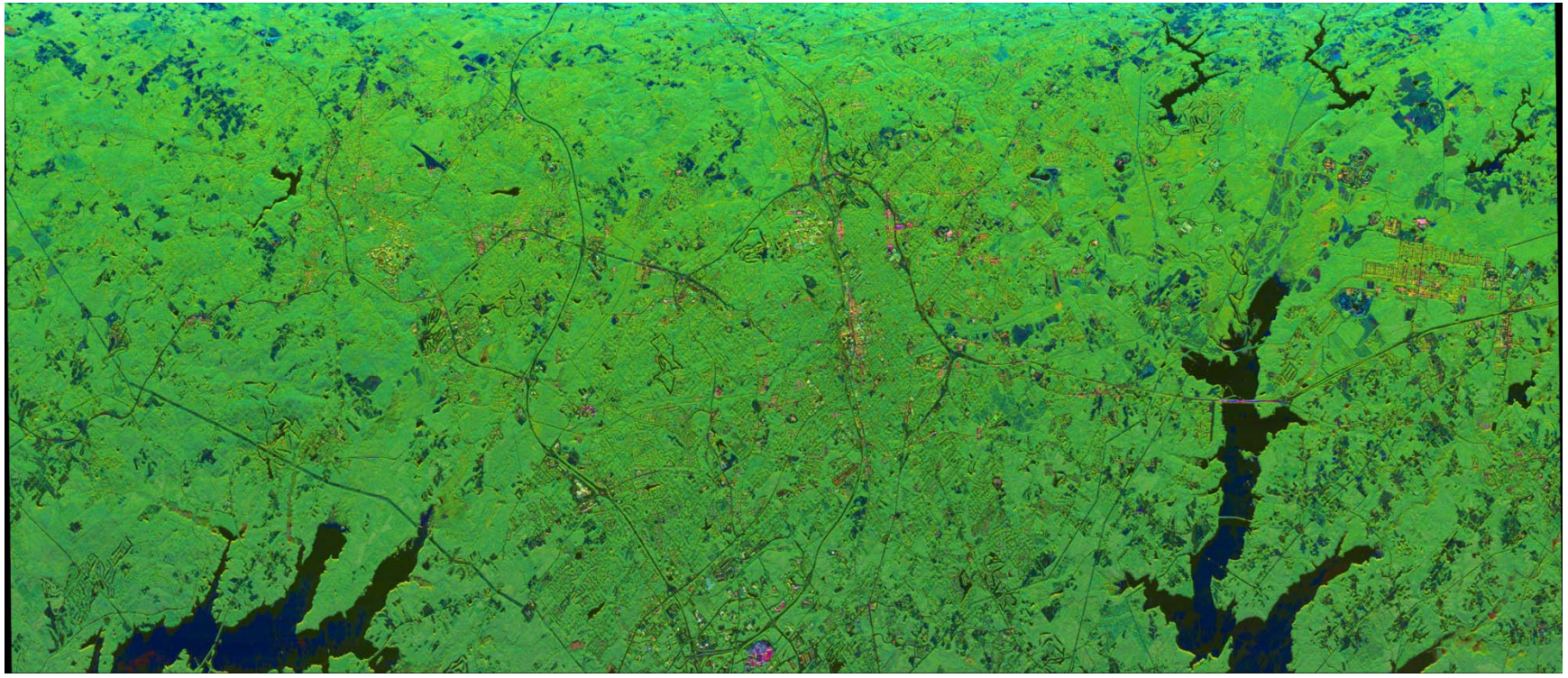
Decomposition



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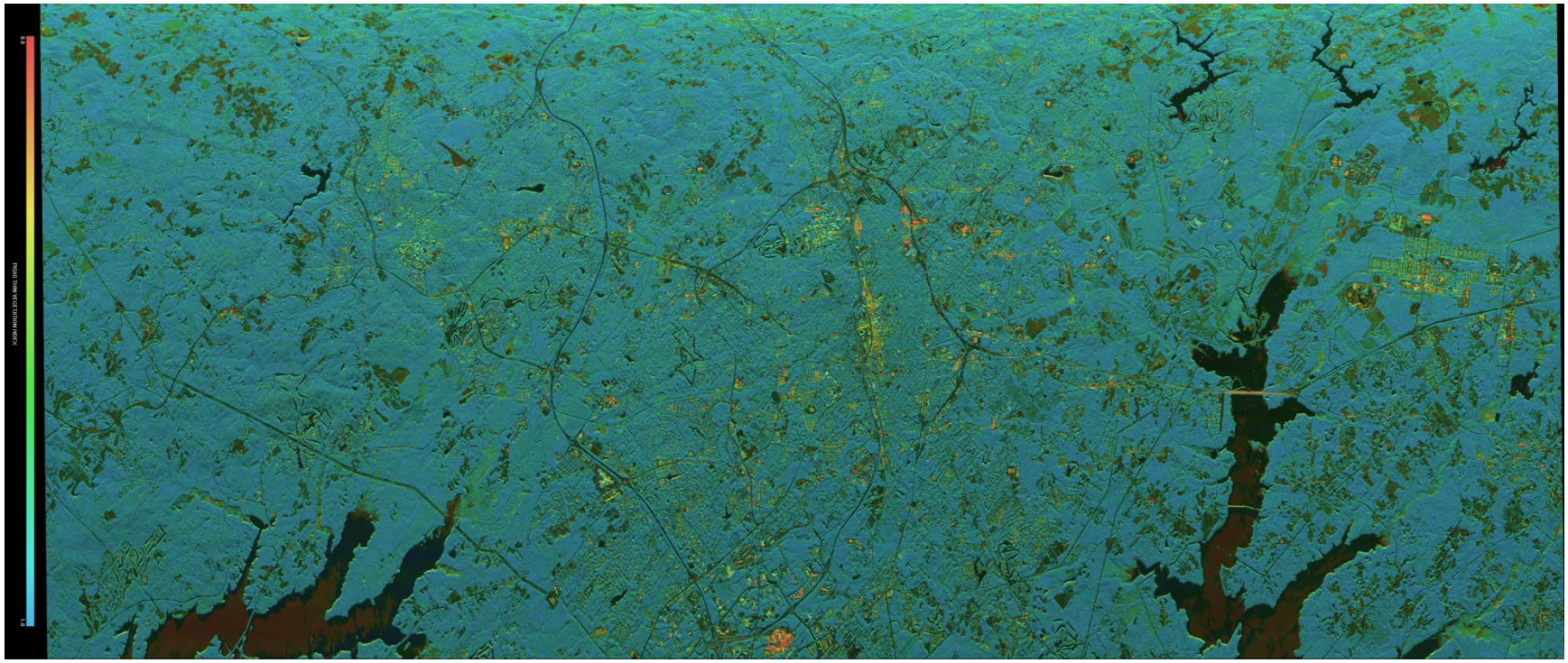
Duke Forest RVI



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Summary

- Unfortunately the SMAP radar system is not fully polarimetric, so we cannot use traditional polarimetric decompositions to segment images
- The radar vegetation index may prove to be a useful way to segment multi-polarization images
  - RVI theoretically increases as biomass increases
  - Shows very similar characteristics to polarimetric classifications and decompositions