Integrated Modeling for Sustainable Development

Jack Reid

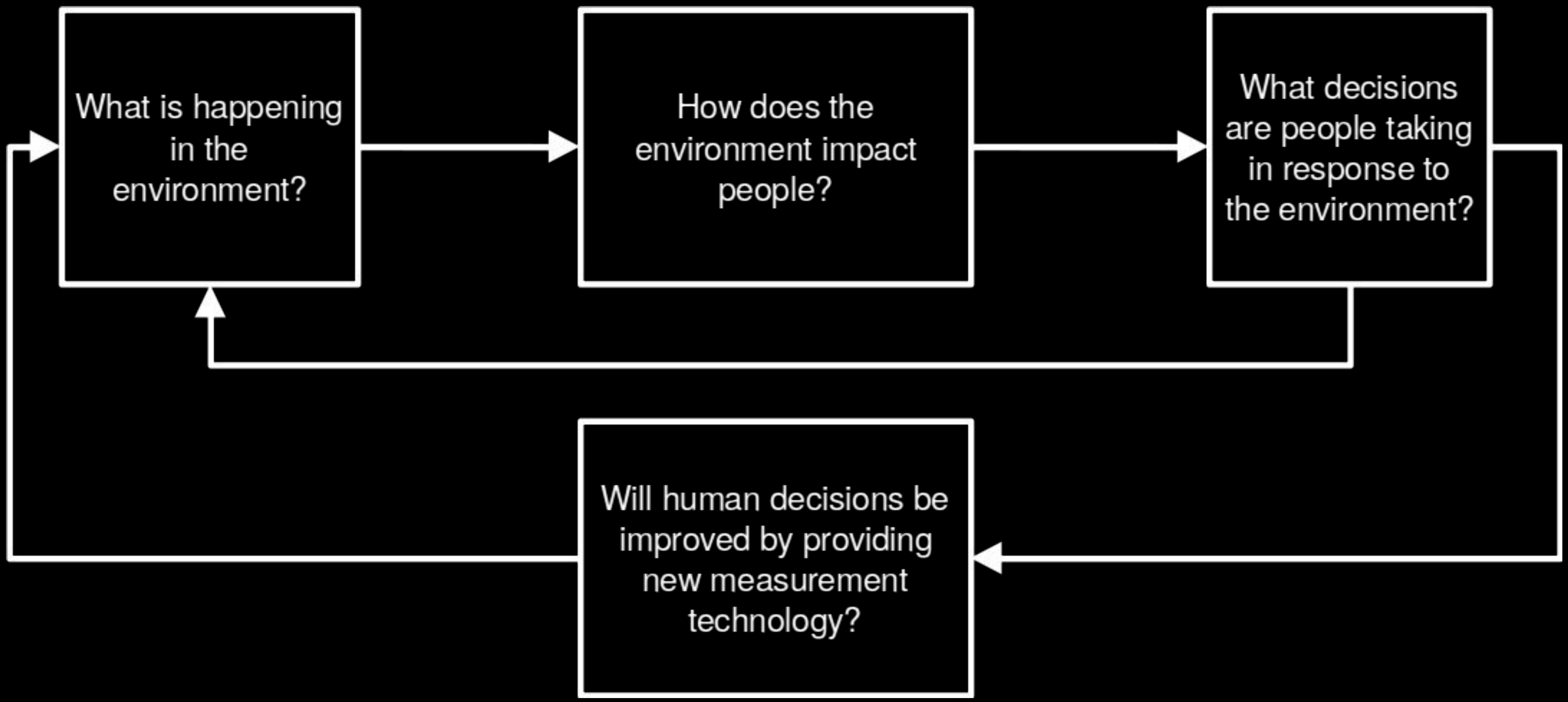
space enabled

Integrated Modeling Project

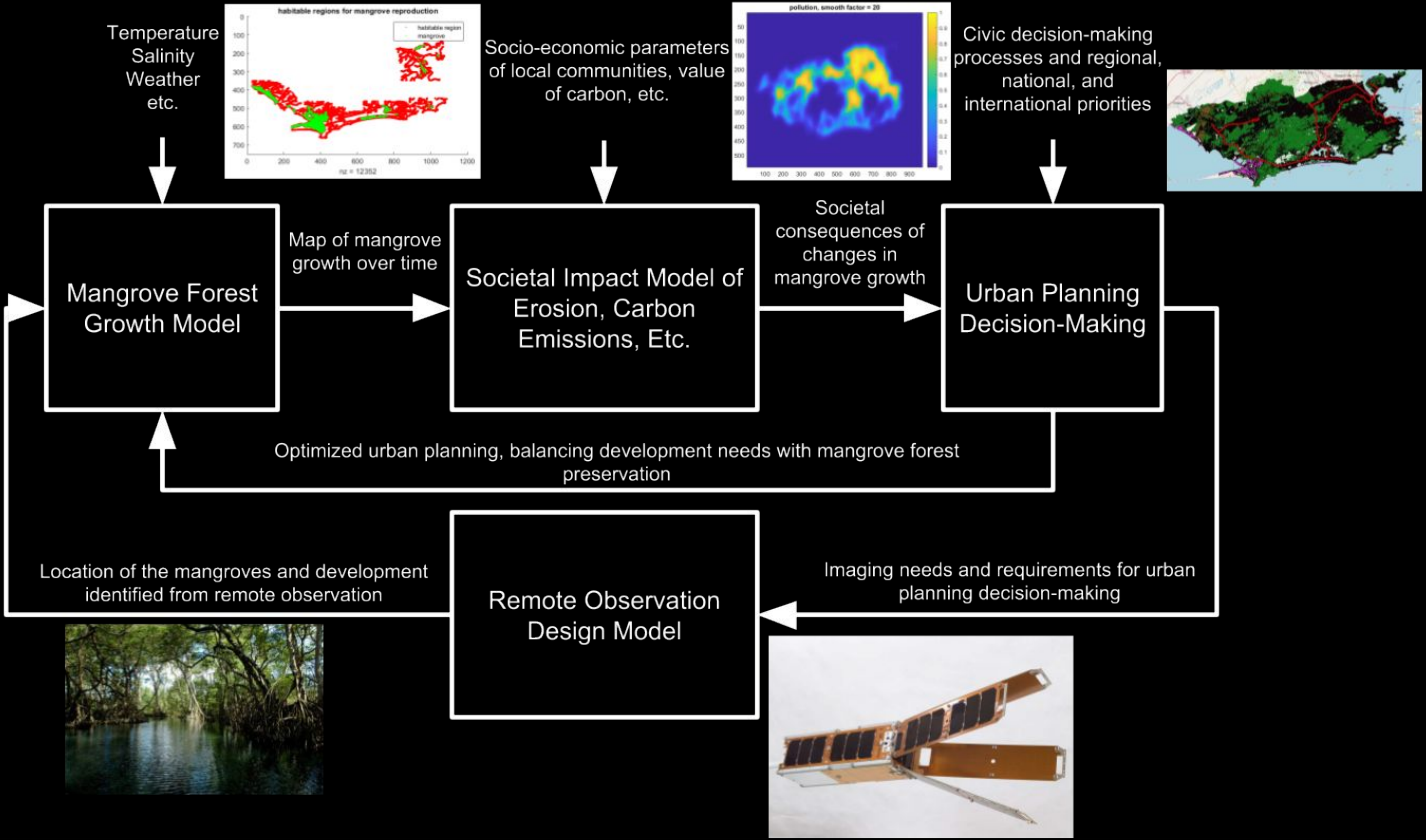
Goal: Develop a 4-part model to inform sustainable development policy-making and valuation of remote observation data

Jack Reid

Graduate Student, MIT Media Lab
Space Enabled research group



Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group


Temperature
Salinity
Weather
etc.
habitable regions for mangrove reproduction
Socio-economic parameters of local communities, value of carbon, etc.
pollution, smooth factor = 20
Civic decision-making processes and regional, national, and international priorities
Mangrove Forest Growth Model
Map of mangrove growth over time
Societal Impact Model of Erosion, Carbon Emissions, Etc.
Societal consequences of changes in mangrove growth
Urban Planning Decision-Making
Optimized urban planning, balancing development needs with mangrove forest preservation
Location of the mangroves and development identified from remote observation
Remote Observation Design Model
Imaging needs and requirements for urban planning decision-making

Steps

1. Understand the situation
   - Where are the mangroves and what pressures are they under?
   - What impacts do the mangroves have on the city?
   - What decisions are being made and how are they being made?
2. Develop model components
   - Remote observation simulation
   - Mangrove growth/decay
   - Societal impact
   - Human decision-making
3. Run workshops using integrated model with policymakers

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

Direct Benefits

- Improve decision-making
- Facilitate quantification of remote sensing value
- Assist design of satellites

Indirect Benefits

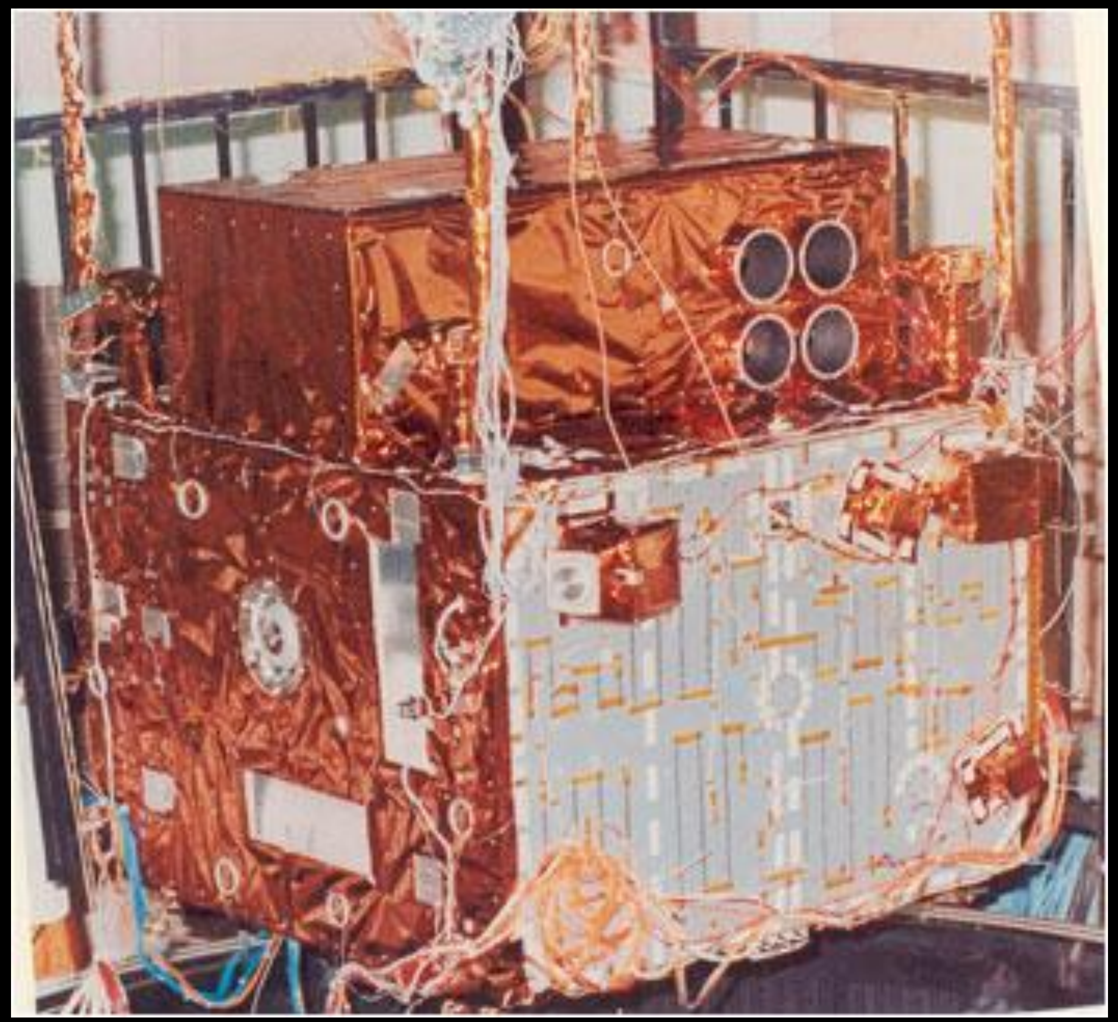
- Reduce burden-of-entry
- Allow end-users to specify and vocalize “gaps”
- Raise awareness of value of remote sensing data

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

Email: jackreid@mit.edu

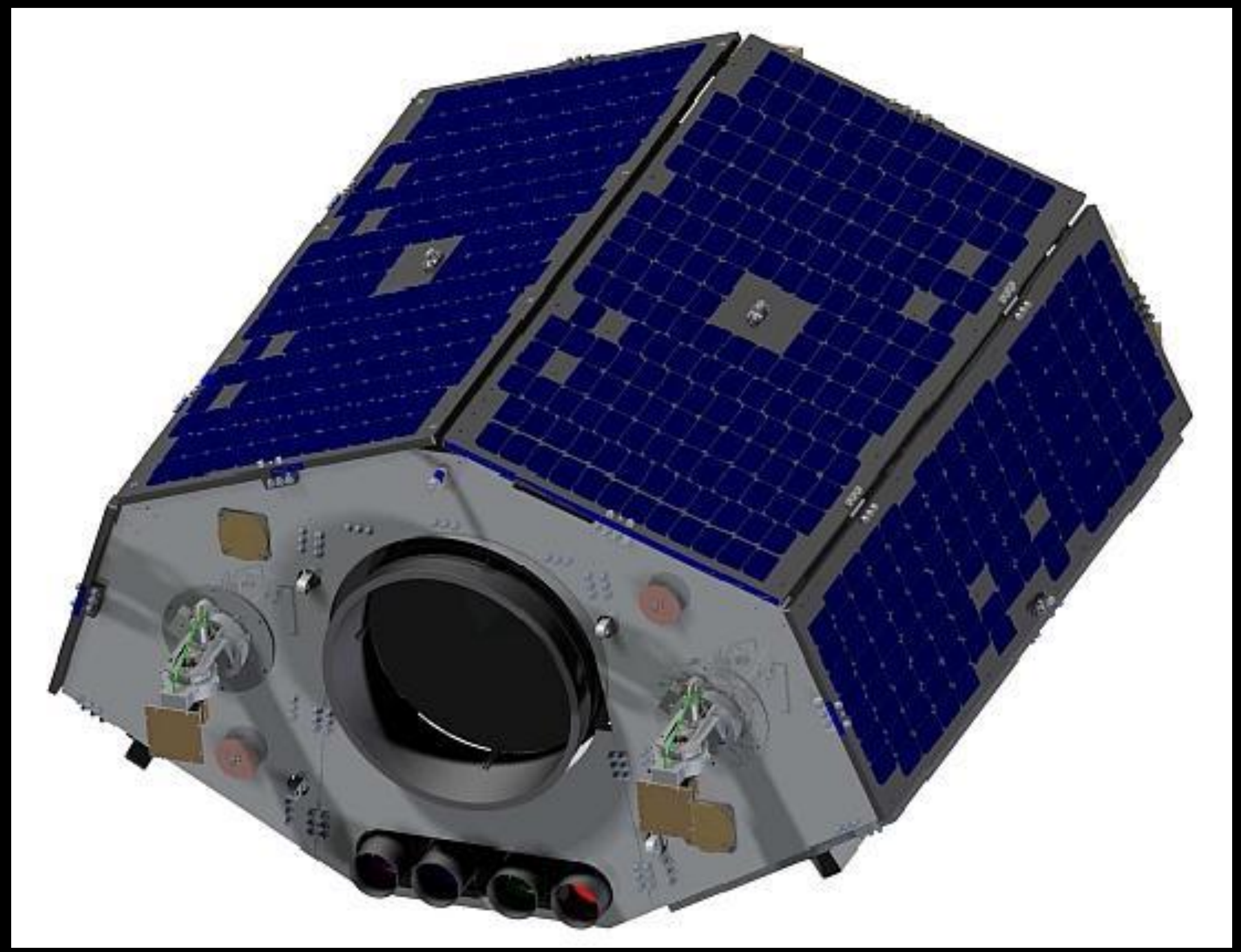
Project Webpage: https://www.media.mit.edu/people/jackreid/overview/

IRS-P2



"National Natural Resources Management system - an integrated resource management system aimed at optimal utilisation of country's natural resources by a proper and systematic inventory of the resource availability using remote sensing data in conjunction with conventional techniques"

NigeriaSat-2



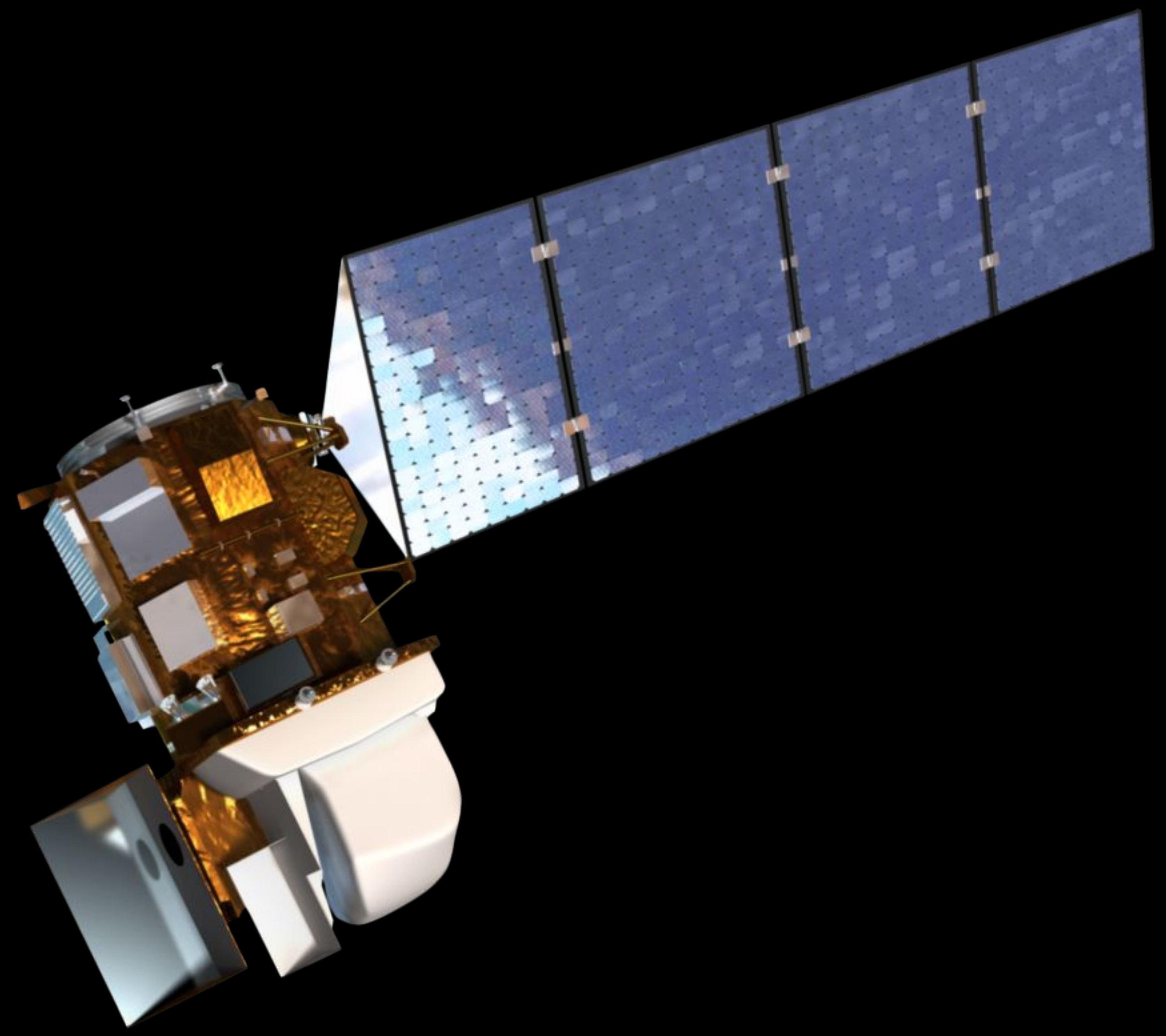
"Nigeria Sat-2 is designed with some key Nigerian objectives in mind:

- To support food supply security, agricultural and geology applications
- To support mapping and security applications
- To provide continuity and compatibility with the existing NigeriaSat-1 system"

Kasturirangan, K. (1995). *Remote Sensing in India-Present Scenario and Future Thrusts*. *Photonirvachak Journal of the Indian Society of Remote Sensing* (Vol. 23).

Da, A., Curiel, S., Carrel, A., Cawthorne, A., Gomes, L., Sweeting, M., & Chizea, F. (2012). Commissioning of the NigeriaSat-2 High Resolution Imaging Mission. In *Small Satellite Conference*. Logan, UT: AIAA/Utah State University .

Landsat 8



- Pixel Size: 15m/30m/100m (panchromatic/multispectral/thermal)
- Scenes/Day: 700
- Scene Width: 185 km (pushbroom)
- Overpass Frequency: Every 16 Days (8 with Landsat 7)
- Spectral Frequencies: Visual and Infrared (Both Short and Long)

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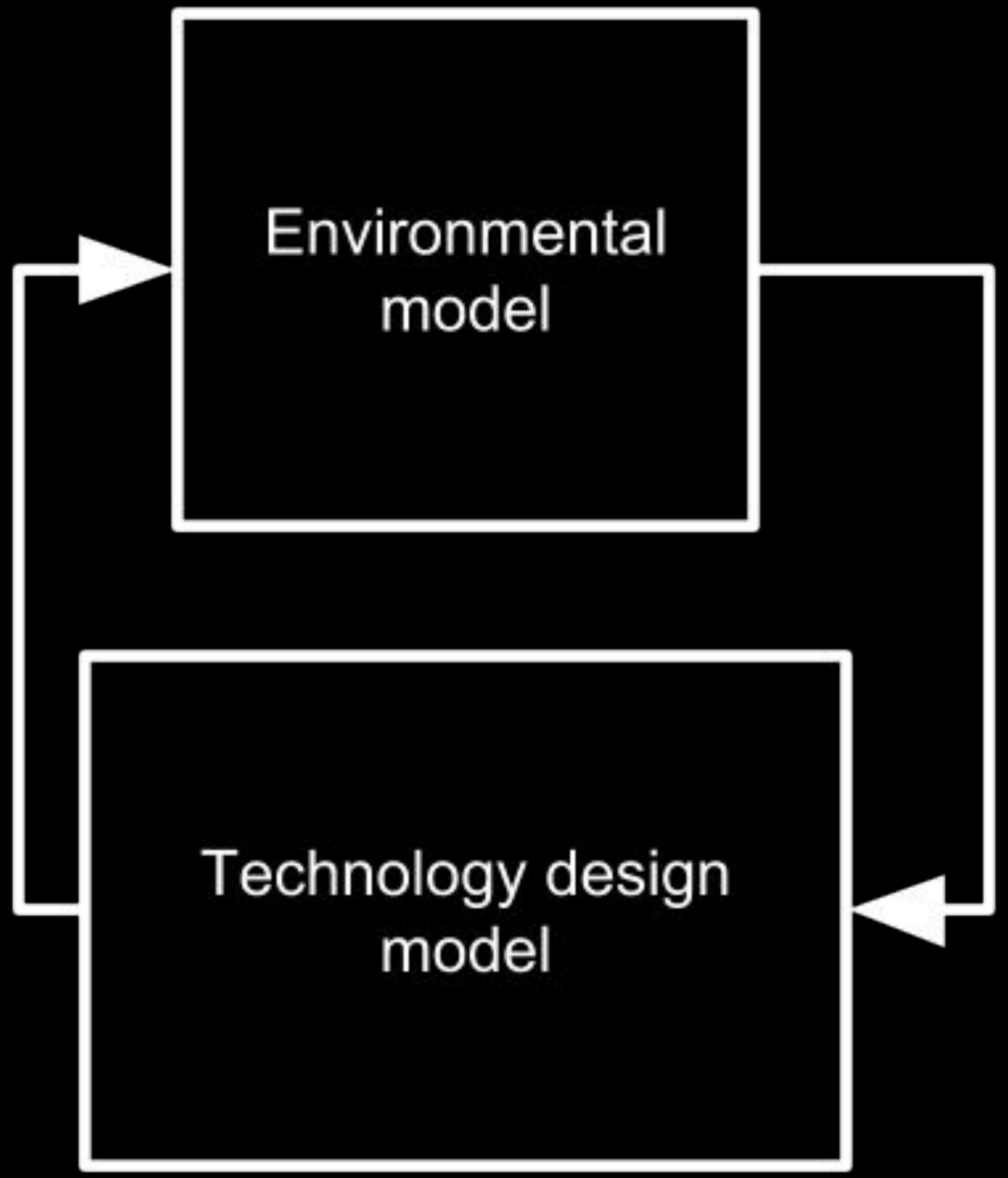
Graduate Student, MIT Media Lab
Space Enabled research group



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Graduate Student, MIT Media Lab
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Emergency	Phase	Spatial Resolution	Time Resolution
Floods	Monitoring	30–100 *m*	12 *h*
	Management	10–100 *m*	3–12 *h*
Landslides	Monitoring	30–250 *m*	1 *d*
	Management	10–100 *m*	3–12 *h*
Earthquakes	Management	1–100 *m*	3–12 *h*
Volcanoes	Monitoring	30 *m*	1 *d*
	Management	10–30 *m*	6 *h*–1 *d*
Fires	Monitoring	100 *m*	1–3 *h*
	Management	30 *m*	0.25 *h*
Sea pollution	Monitoring	1 *km*	1 *d*
	Management	100 *m*	6–12 *h*
Border monitoring	Monitoring	1–10 *m*	3 *h*
Humanitarian Emergencies	Management	1–10 *m*	1–3 *h*

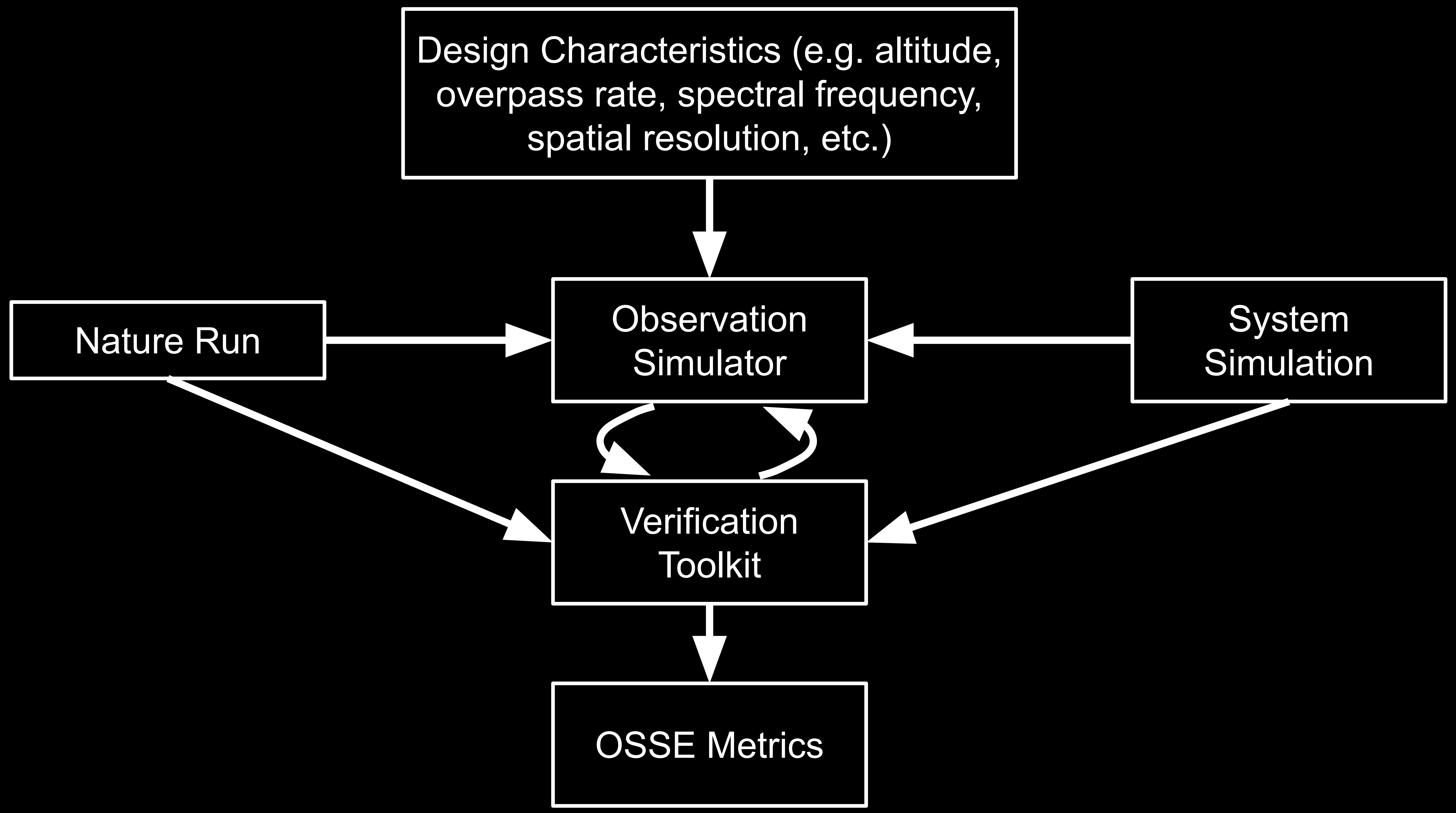
#	User requirements	Sensor requirements		
		Spatial resolution	Spectral resolution	Temporal resolution
1	Agriculture, climate, environ.	3–5 m	Multi-spectral	Montly, summer/winter
2	Environmental Impact Assessment, Farmer Settlement, housing, planning and urban planning, Border Monitoring	0.6–1 m	PAN, RGB	p.a., every 1–2 yr
3	Disaster monitoring	1–250 m	Pan, VIS, NIR, MIR, TIR	2 per day (night and day)
4	Land use/cover mapping	0.5–5 m	Pan	1 per 2 days
5	Water management, Land use and Land care	10 m	Multi-spectral	bi-annual, quarterly
6	Managed Agriculture	< 3 m/ < 40 m	VIS, NIR/-SWIR	1 day–2 weeks/1 weeks–6 months
7	Map food vulnerability	10 m	VIS, NIR	1 month
8	Water quality monitoring	Unsure	Hyperspedctra	Bi-annual, summer/winter
9	Water resources assessment	1–10 m	VIS, NIR	1 per week
10	Drought status, disaster, global	250 m–1 km	Multi-spectral, IR	1 h daily
11	Land use and land care, water management, food security	20–30 m	Multi-spectral, IR	Quarterly, summer/winter
12	Mineral, oil and gas exploration	1–30 m/60 m	Pan, VIS, NIR, SWIR, TIR	1 per 6 month
13	Fishing	10 m/60 m	VIS, NIR, MIR/TIR	1–3 days/1–3 days
14	Peace keeping missions	< 1 m	Pan, VIS, NIR, TIR	1 per day

Santilli, G., Gessini, P., & Vendittozzi, C. (2018). Remote Sensing based on CubeSats: is there any added value? In *United Nations/Brazil Symposium on Basic Space Technology: "Creating Novel Opportunities with Small Satellite Space Missions"*. United National Office of Outer Space Affairs.

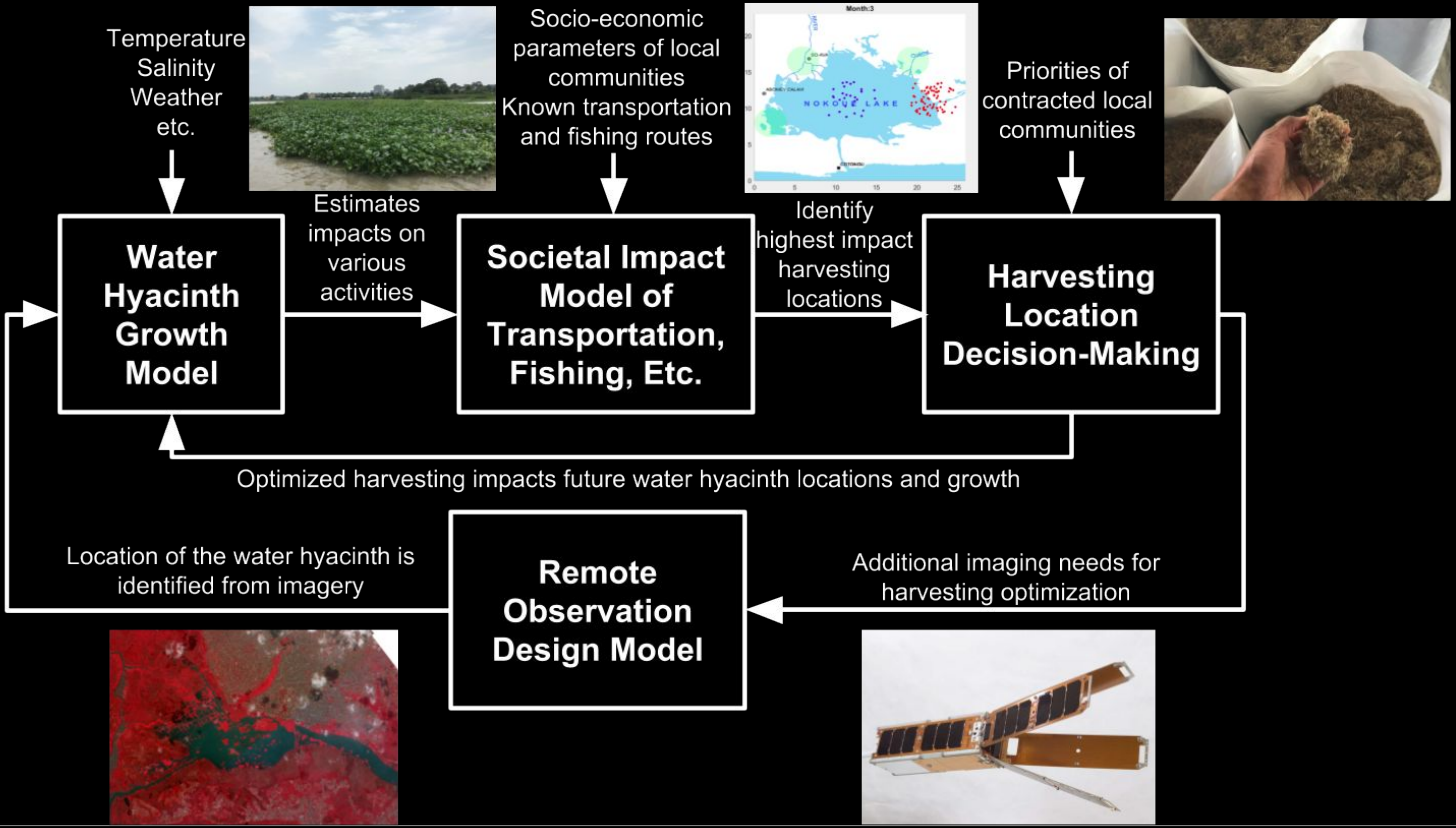
Santilli, G., Vendittozzi, C., Cappelletti, C., Battistini, S., & Gessini, P. (2018). CubeSat constellations for disaster management in remote areas. *Acta Astronautica*, *145*, 11–17. https://doi.org/10.1016/J.ACTAASTRO.2017.12.050

Mostert, S., & Jacobs, M. (2008). ARM constellation—Establishing a regional remote sensing asset. *Acta Astronautica*, *63*, 221–227. https://doi.org/10.1016/j.actaastro.2007.12.030

Observing System Simulation Experiment



S. V. Kumar et al., “Land information system: An interoperable framework for high resolution land surface modeling,” *Environ. Model. Softw.*, vol. 21, no. 10, pp. 1402–1415, 2006.



Jack Reid

Graduate Student, MIT Media Lab
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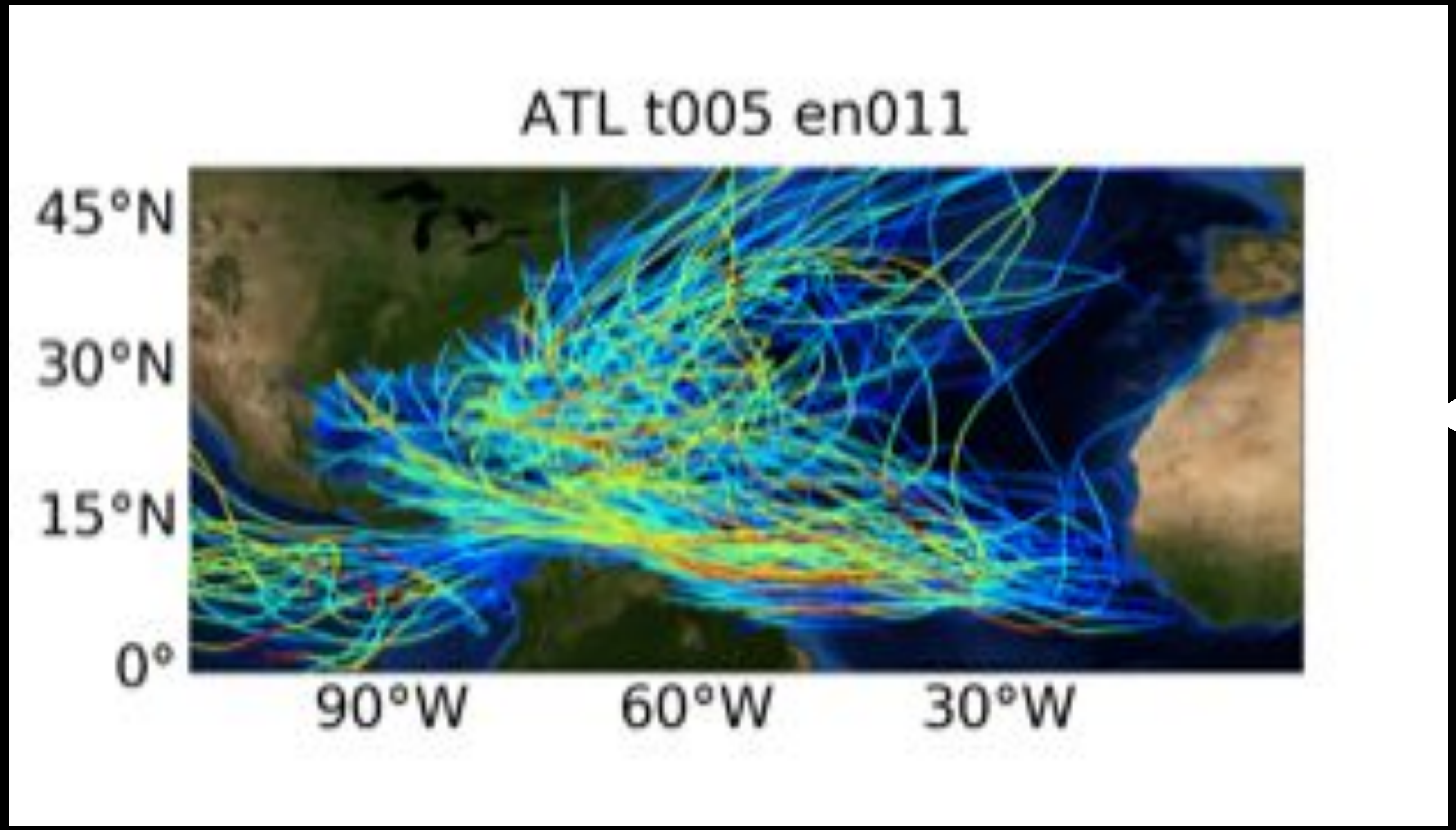
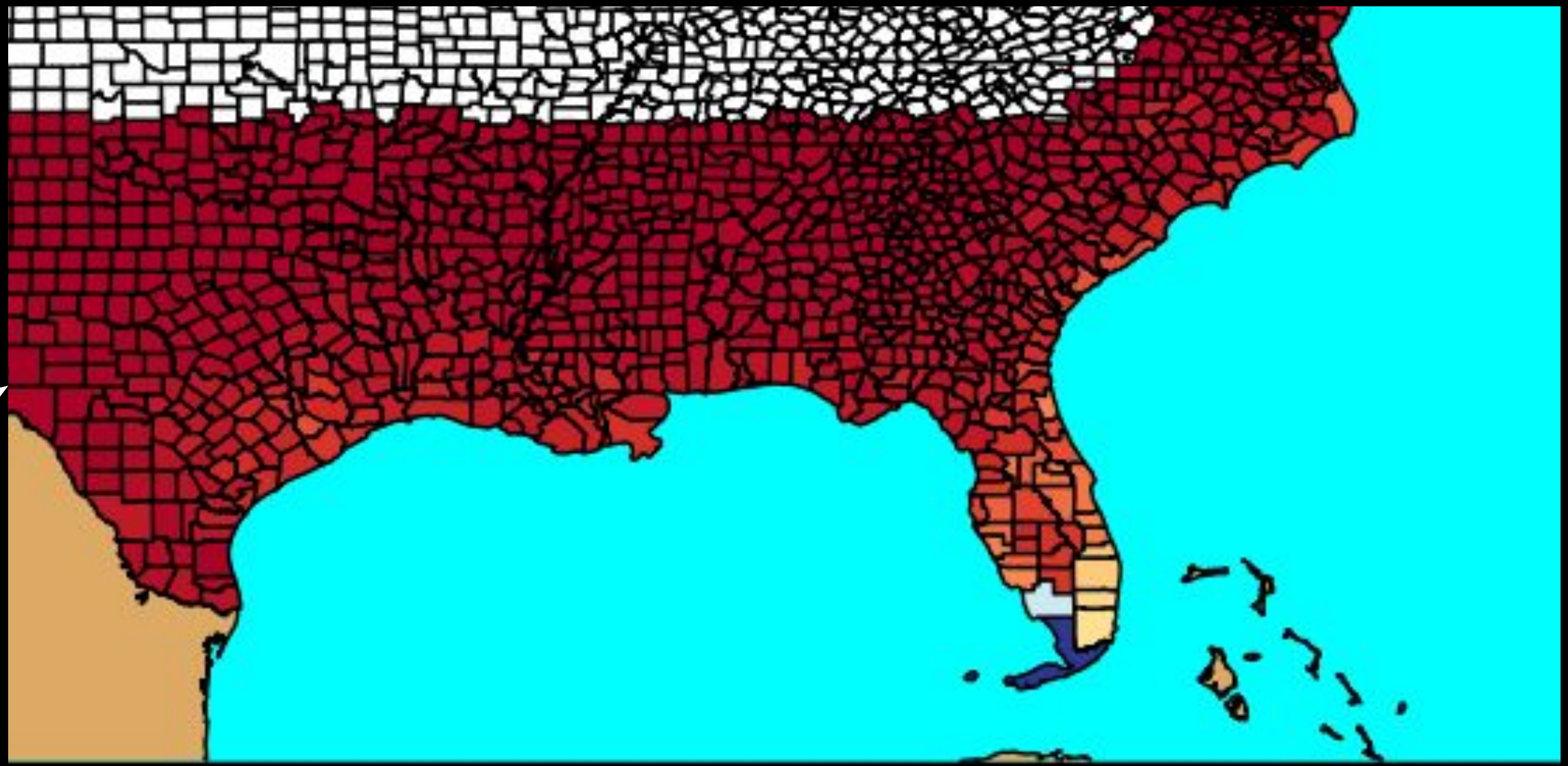
Water Hyacinth Vulnerability in April, November, December of 2018

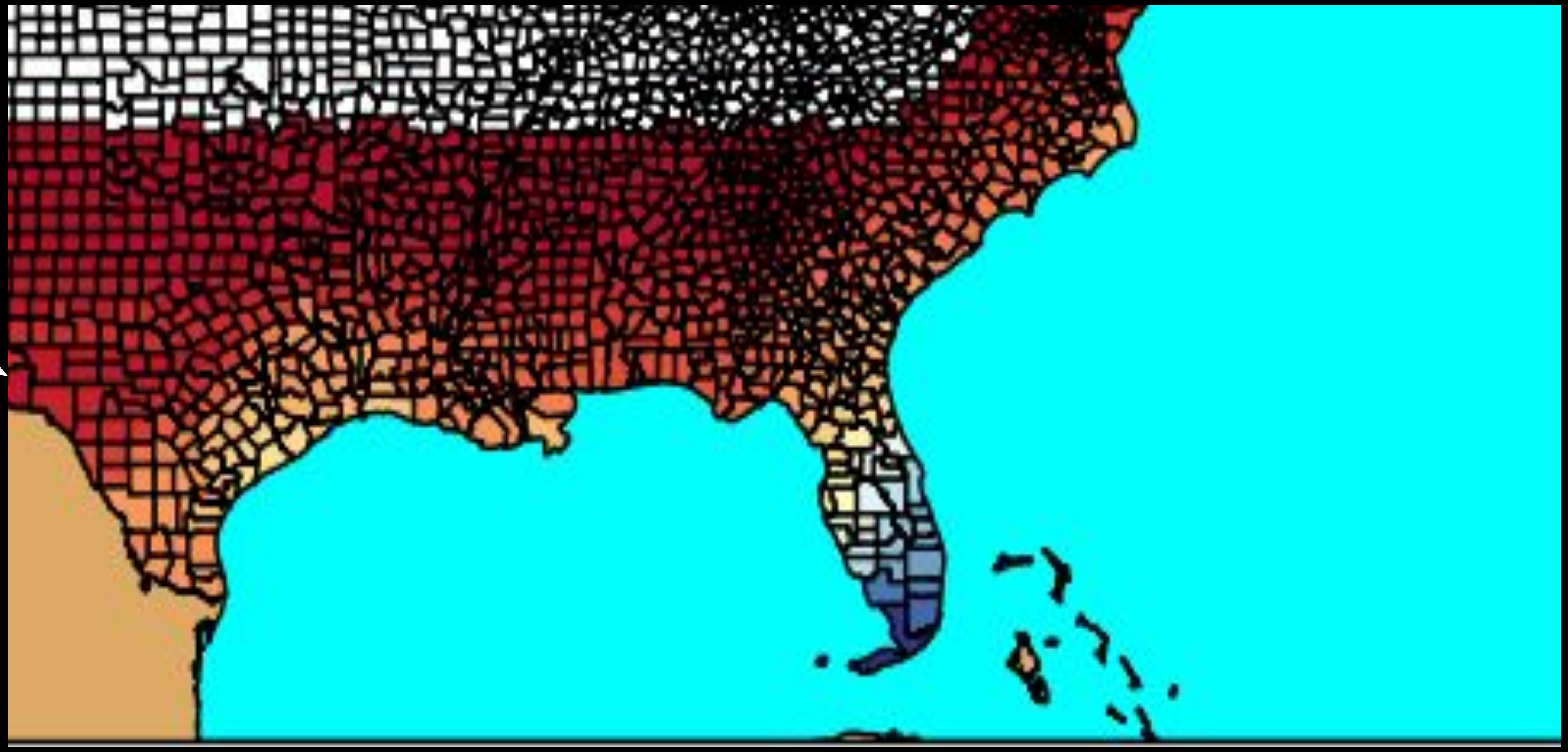
Scale	Water Hyacinth Presence	Population Density	Land Use	Waterways
1	0-3 pixels/900πm^2	0-23 people/100m^2	All other categories	Everything else
2	3-15 pixels/900πm^2	23-102 people/100m^2	Settlements, Swamp Forest	
3 (High Vulnerability)	15-29 pixels/900πm^2	102-405 people/100m^2	Irrigated Agriculture, Wetland	Inland Waterways



$$d = c * v_w^k$$

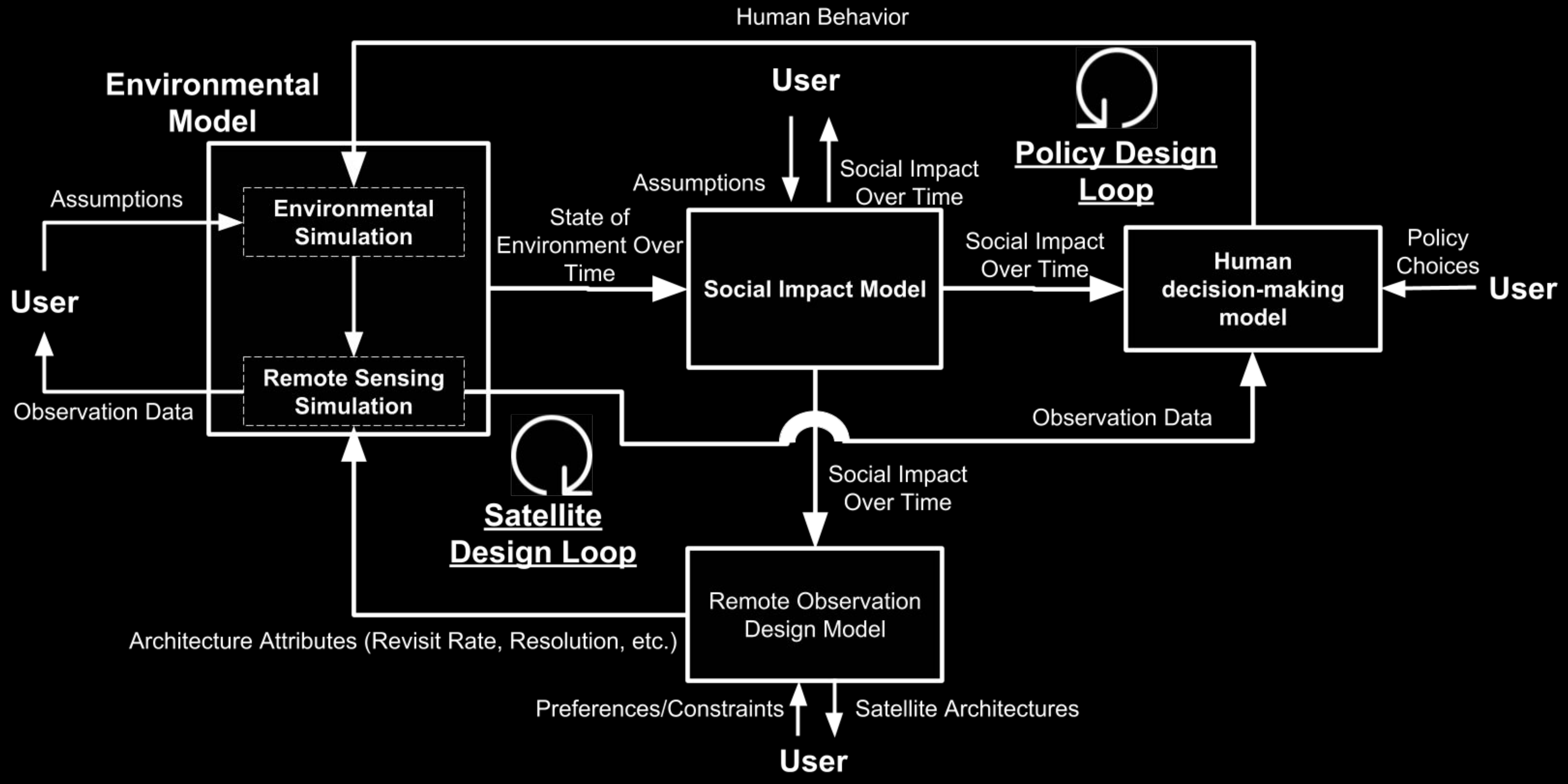
Friedman 1984





Hendrick 1966

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group



Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

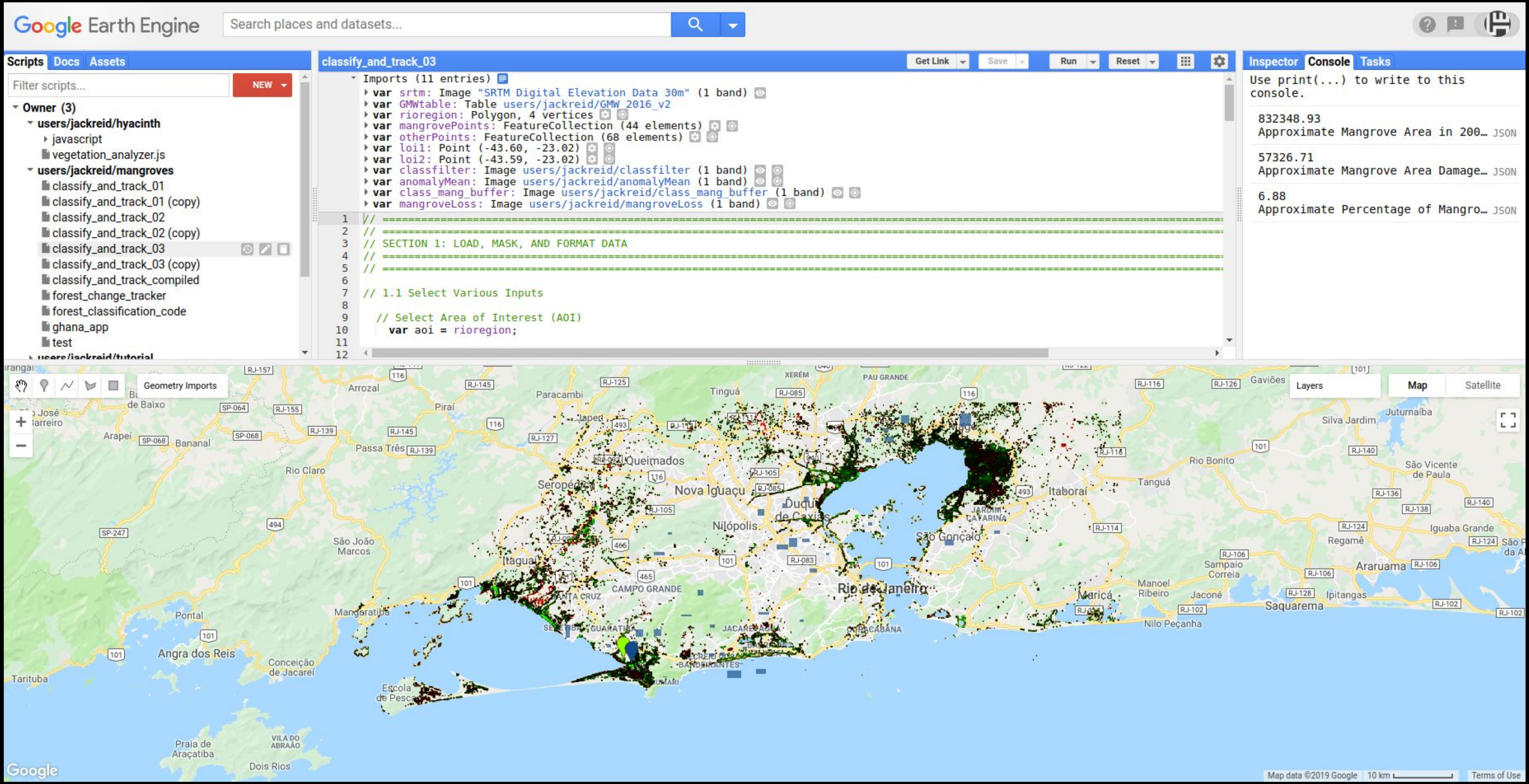
Longer term…

We would like there to be a *standard* and a *library of submodels*

- Develop a few case study models
- Develop a standard set of APIs
- Develop a library of submodels
- Expand to other technologies

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

Google Earth Engine



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Graduate Student, MIT Media Lab
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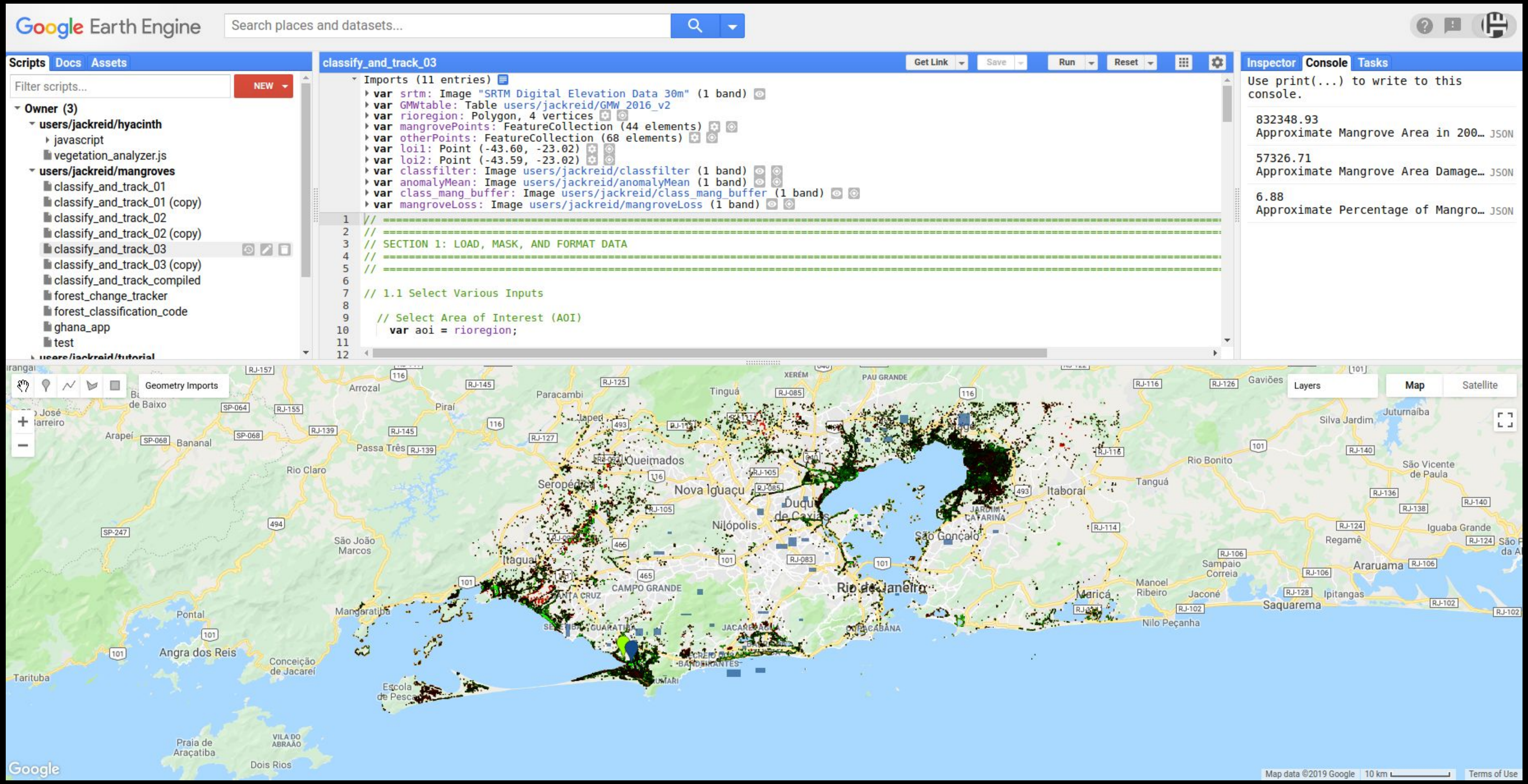
Google Earth Engine



Pros

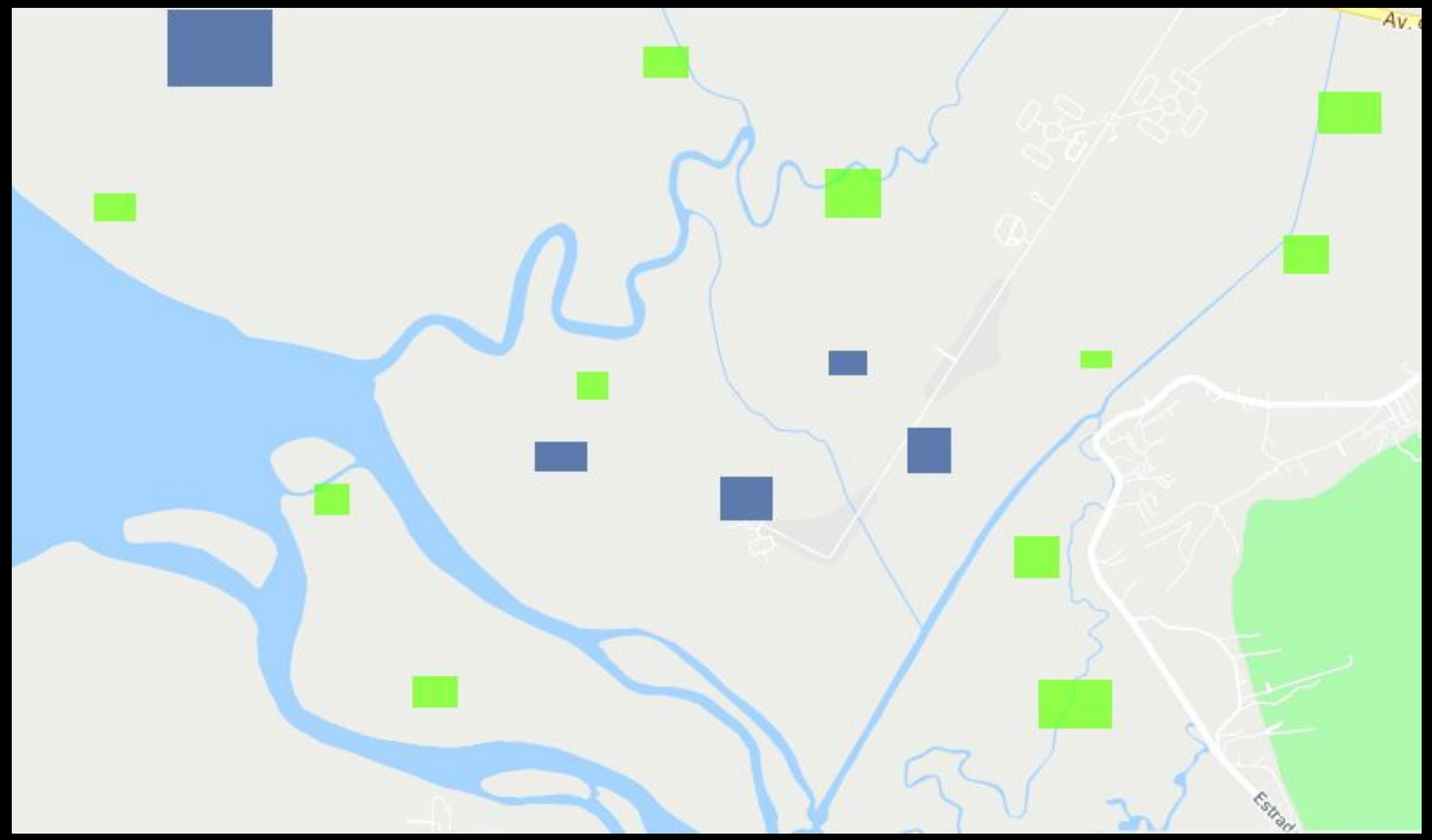
- Free
- Fast
- Plenty of pre-loaded data

Cons

- Some data caps
- Cumbersome/buggy

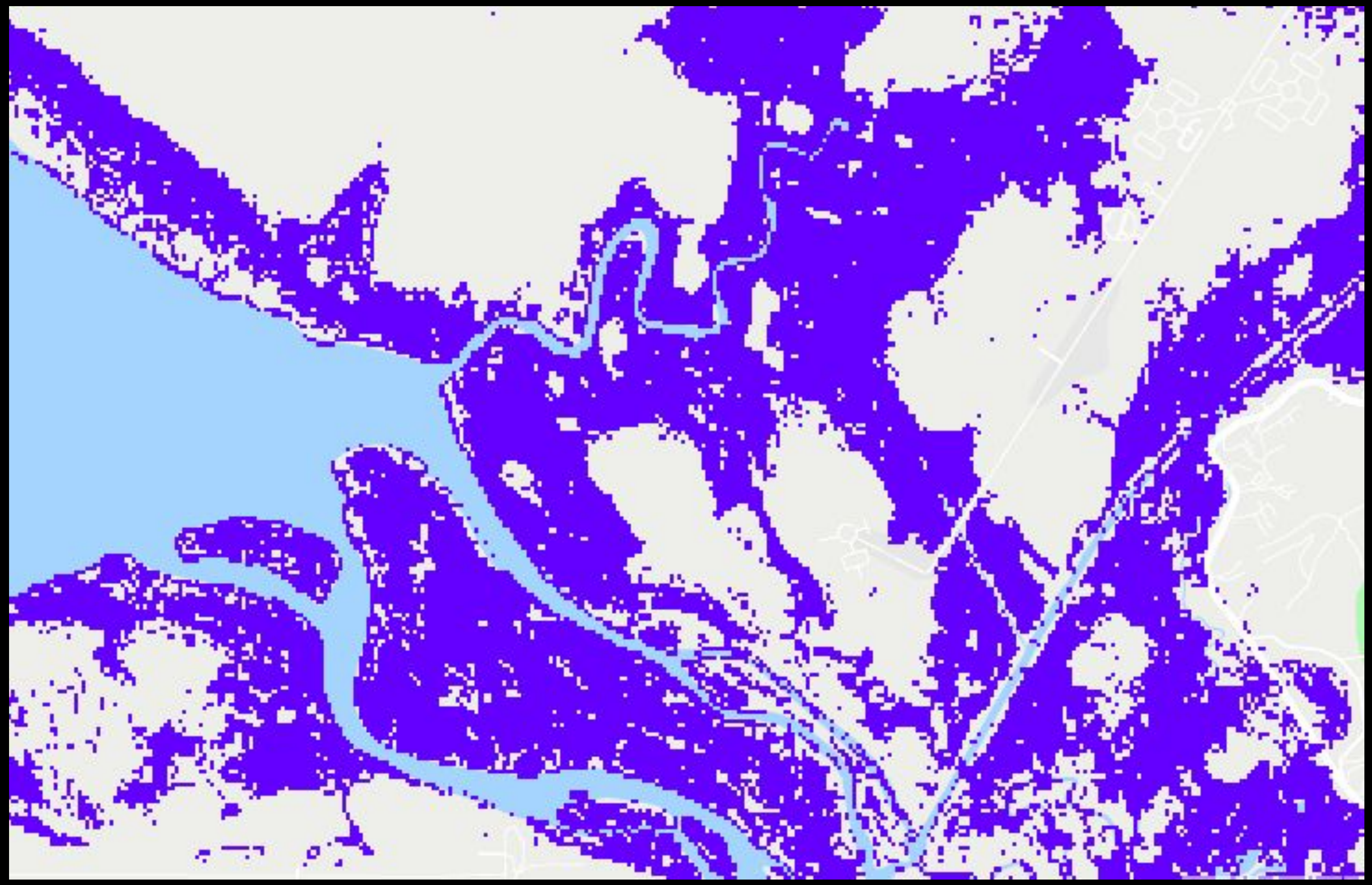
Mangrove Classification

Training Data



Sentinel or Landsat Imagery

Classified Mangroves



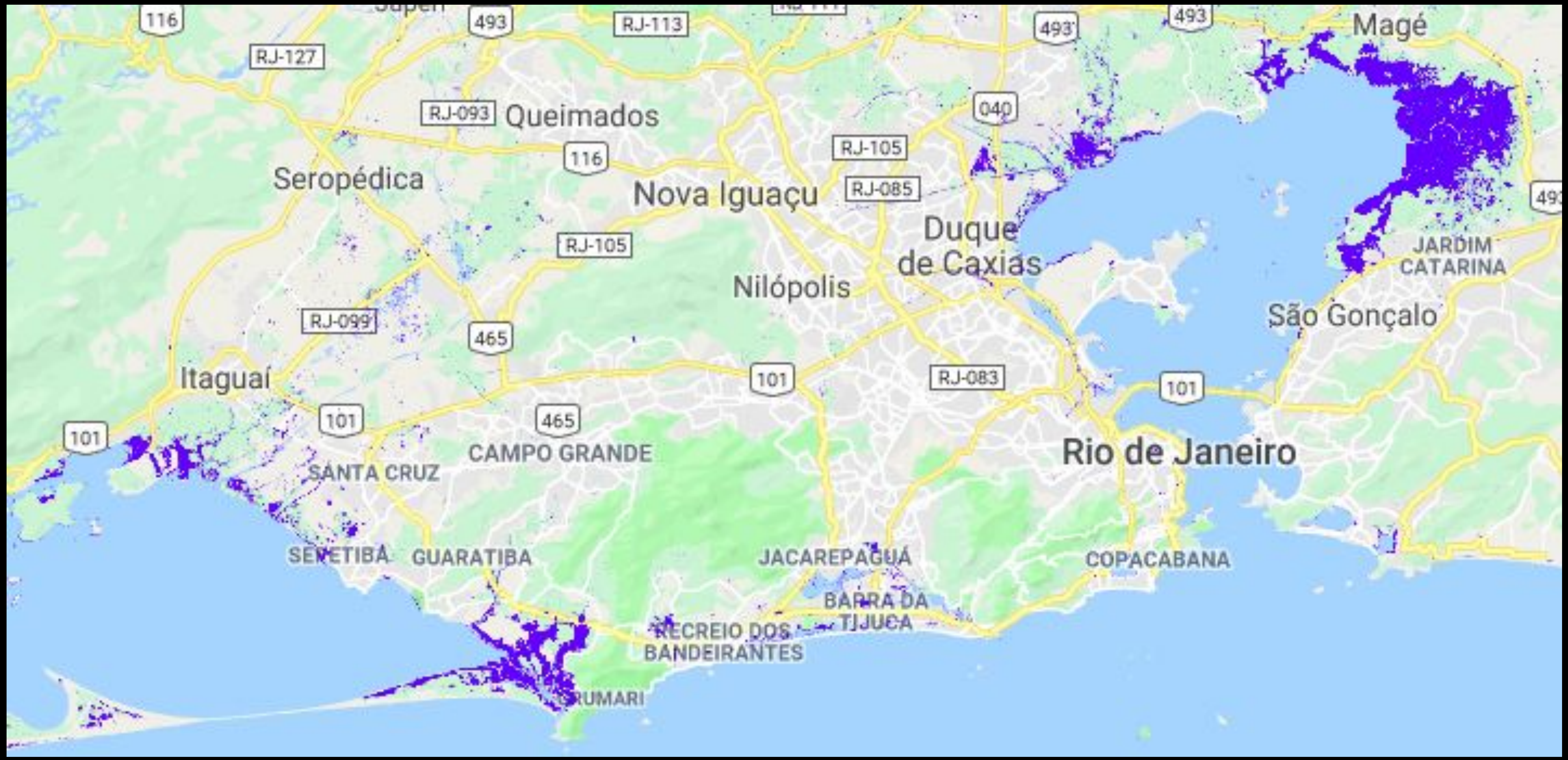
Jack Reid

Graduate Student, MIT Media Lab
Space Enabled research group

Mangrove Classification

Global Mangrove Watch - 2016

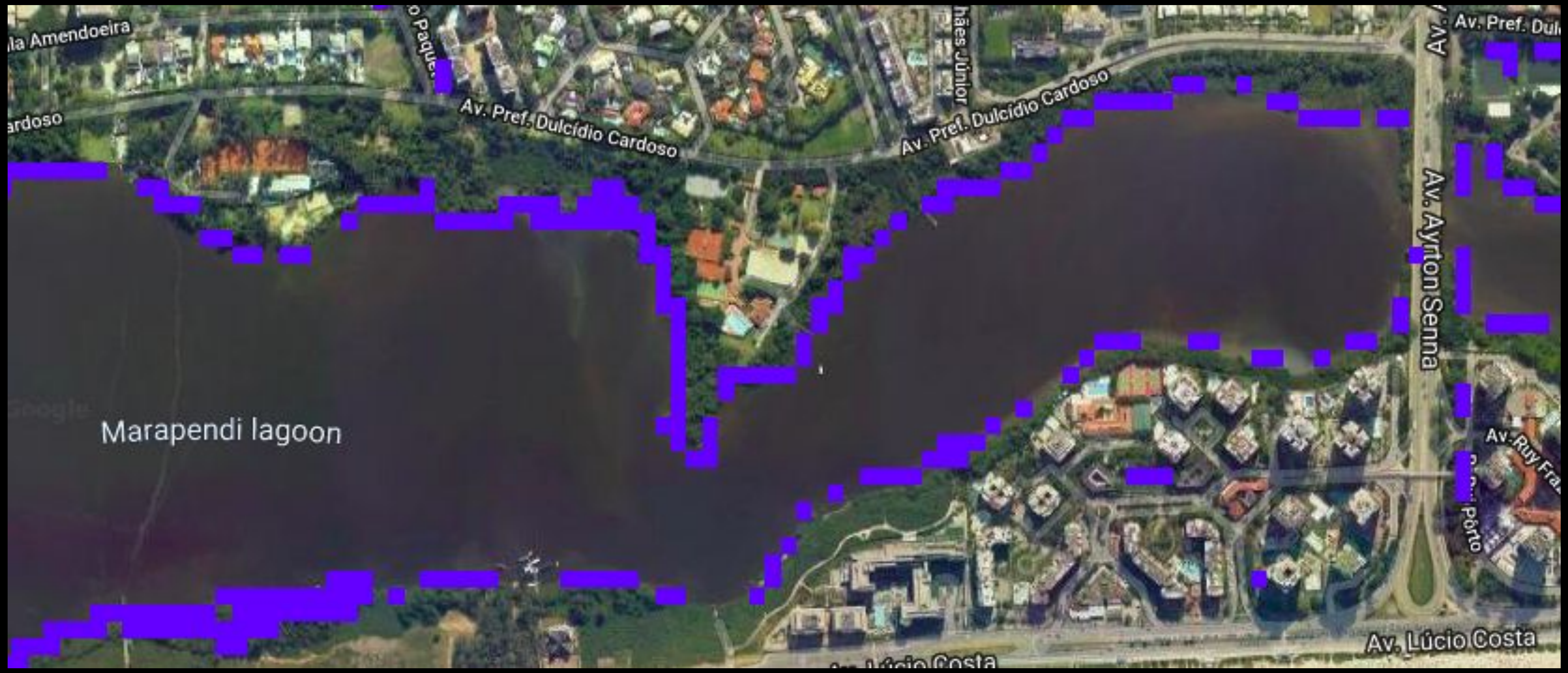
Classification - Sentinel 2018



Mangrove Classification

Google Maps - Satellite View

Classification - Sentinel 2018



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Aside on NDVI

$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$$

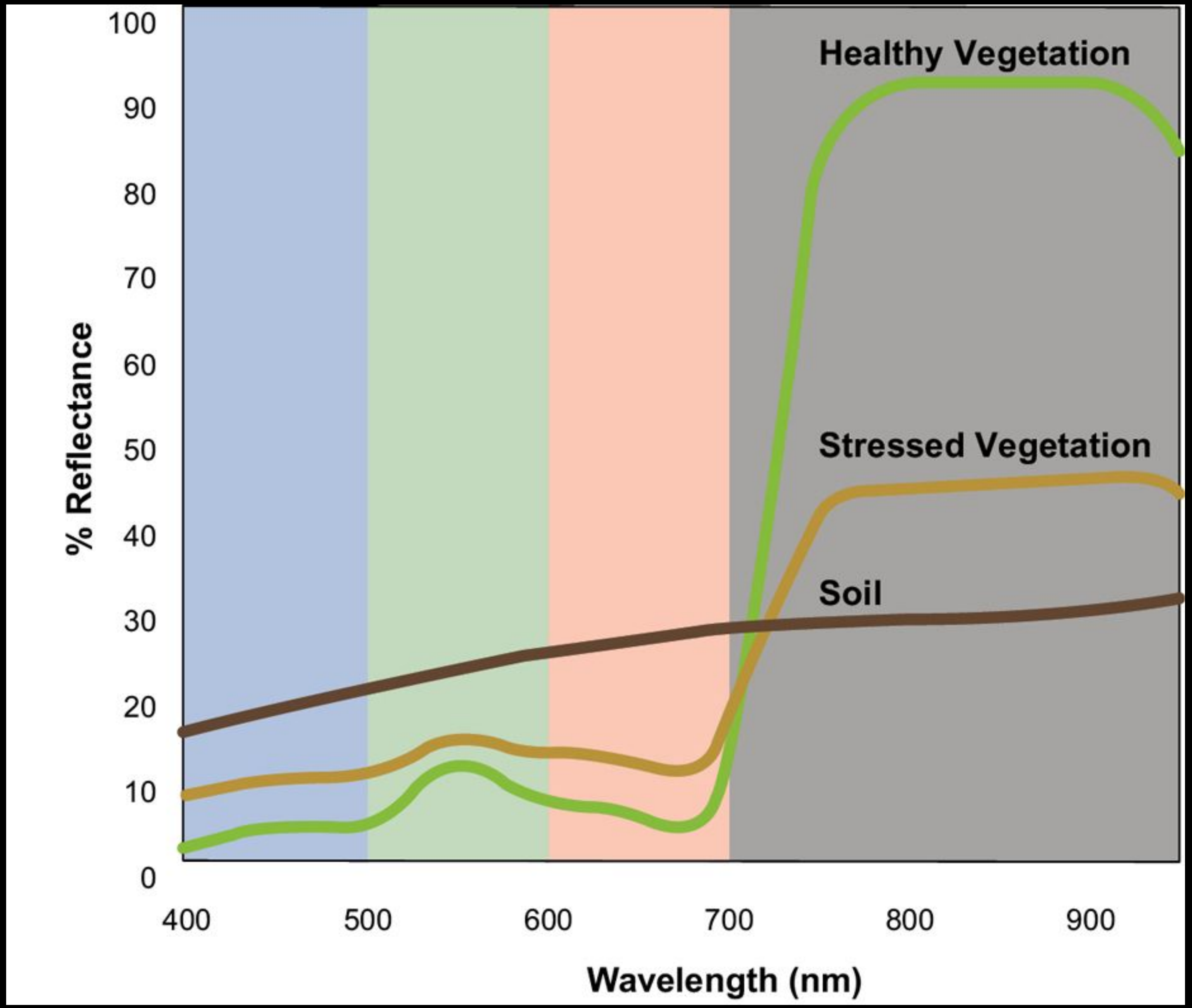


Chart from MidOpt

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

Mangrove Health Change Tracking

Median NDVI - Reference Period

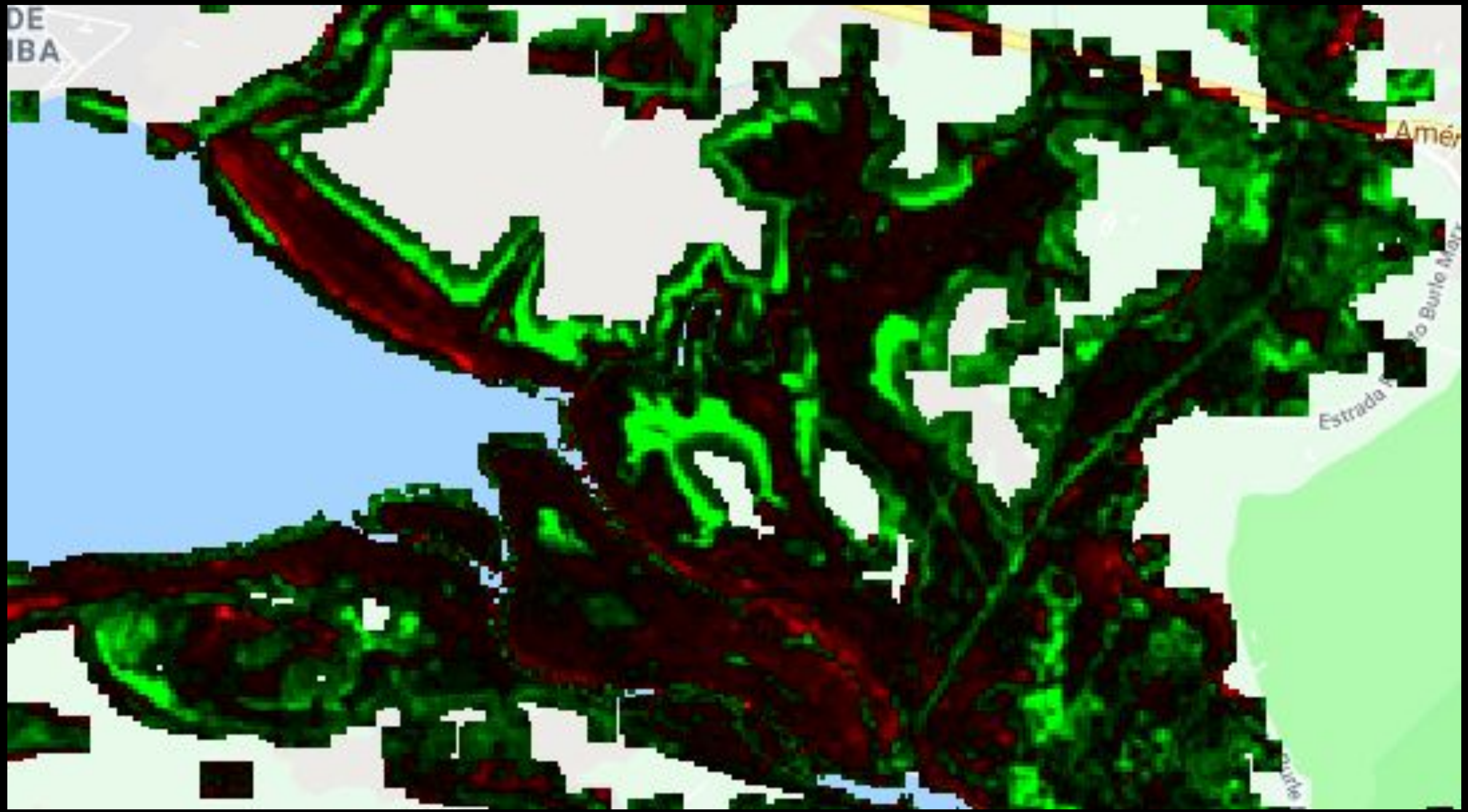
Reference Period: August 1999 - August 2001
Observation Period: September 2001 - September 2018

$$\text{Mean Anomaly} = \frac{\sum_{i=0}^{n}(NDVI_i - NDVI_{Ref})}{n}$$

Jack Reid
Graduate Student, MIT Media Lab
Space Enabled research group

Mangrove Health Change Tracking

NDVI Mean Anomaly



NDVI Mean Anomaly < -0.1

Full maps available at: https://jackreid.users.earthengine.app/view/jackreidrio

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Graduate Student, MIT Media Lab
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Earth Observation Data Application Levels

1. Earth Observation (EO) System Design & Implementation
2. EO System Operation, Data Retrieval, Calibration, & Validation
3. EO Data Correction and Processing
4. Earth Science Modeling & Assimilation of Earth Observations
5. EO Data Discovery & Visualization
6. EO Data Transformation
7. Knowledge Integration
8. Decision Support

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Graduate Student, MIT Media Lab
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