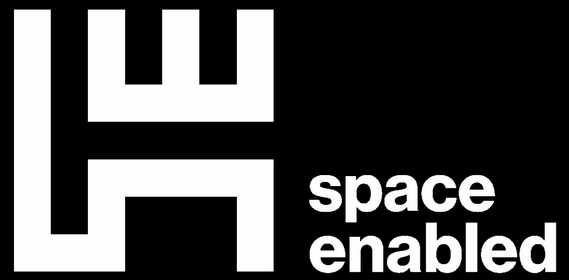
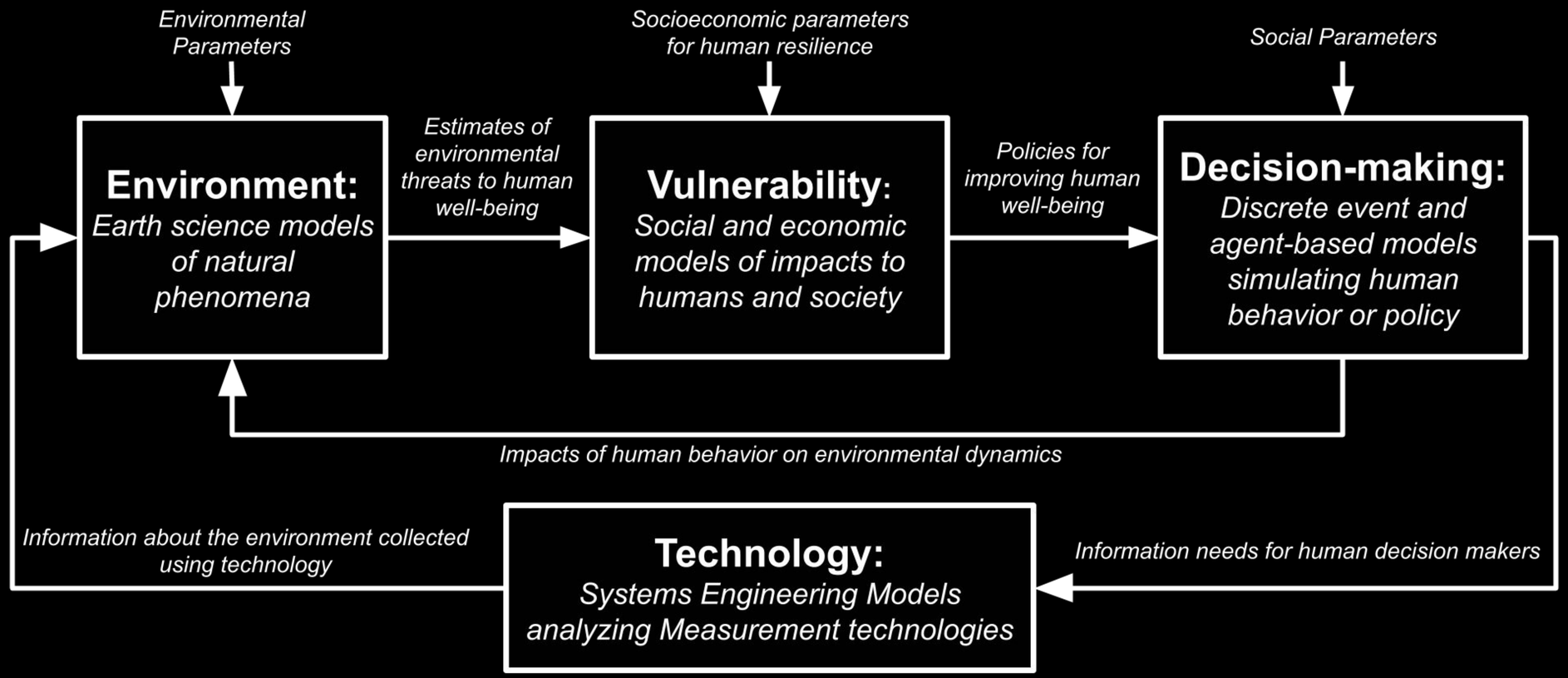
Vida Decision Support System: An International, Collaborative Project for COVID-19 Management with Integrated Modeling

Jack Reid, Seamus Lombardo, David Lagomasino, Eric Ashcroft, Mary Bracho, Mohammad Jalali, Amanda Payton, Katlyn Turner, Maggie Zheng, Danielle Wood



EVDT Framework

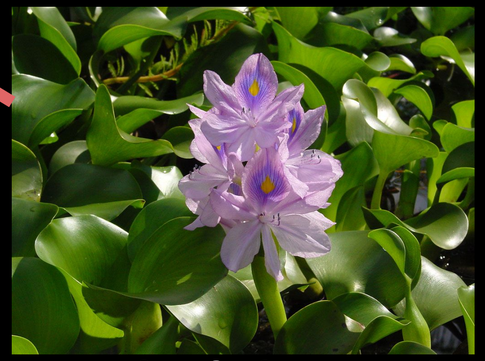


- What is happening in **the natural environment**?
- How will **humans be impacted** by what is happening in the natural environment?
- What **decisions are humans making** in response to environmental factors and why?
- What **technology system** can be designed to provide high quality information that supports human decision making?

Some Pre-Pandemic EVDT Applications

Mining in Ghana

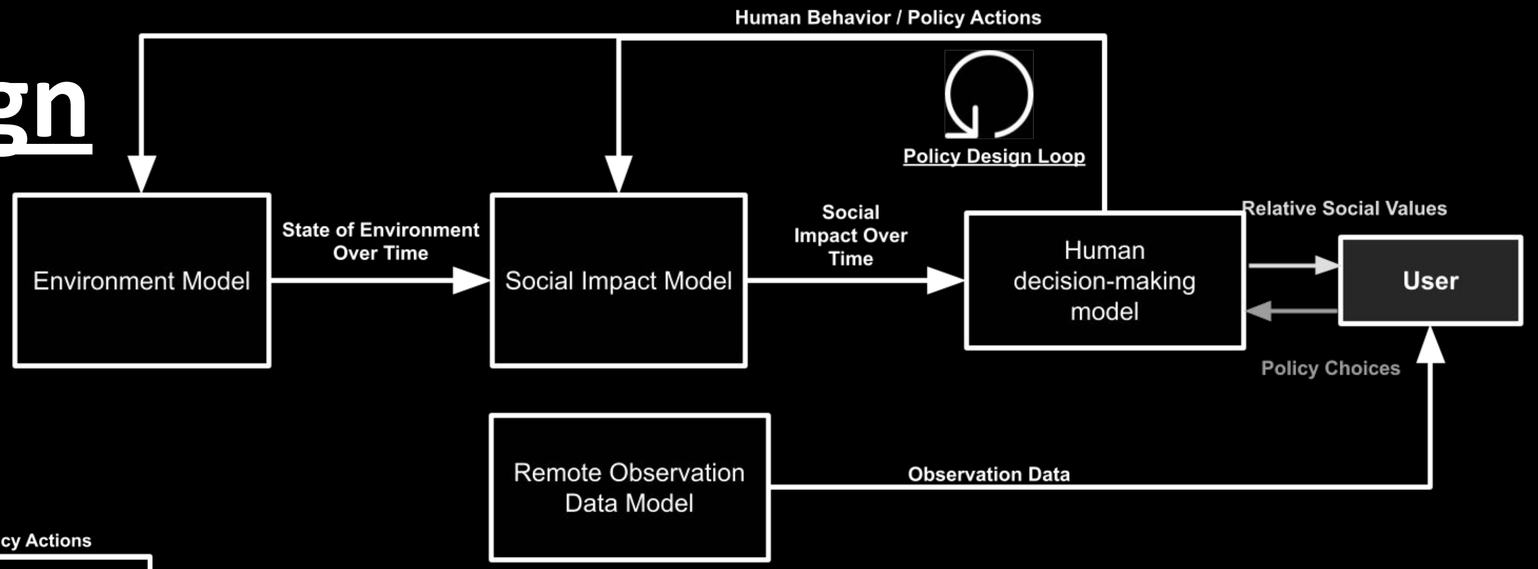
Mangroves in Rio de Janeiro

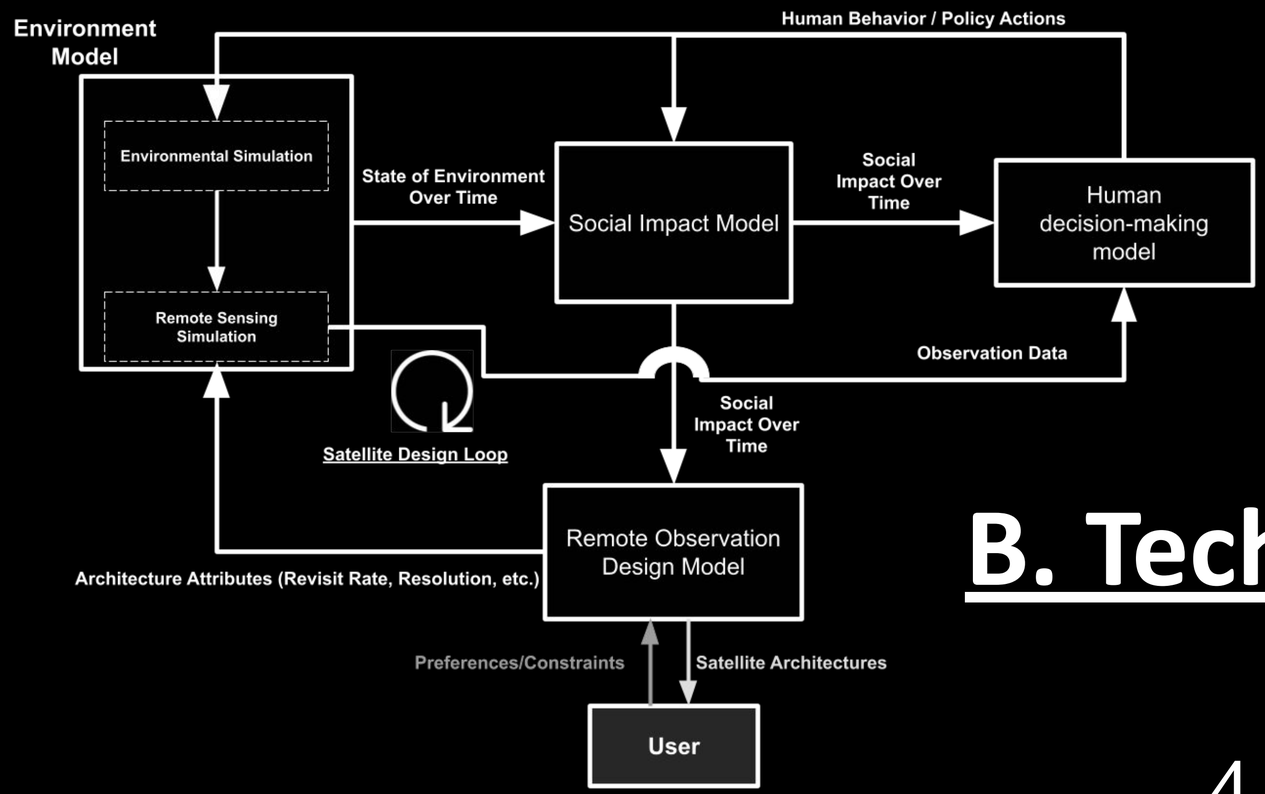


Water Hyacinth in Benin

Map adapted from the Nations Online Project.

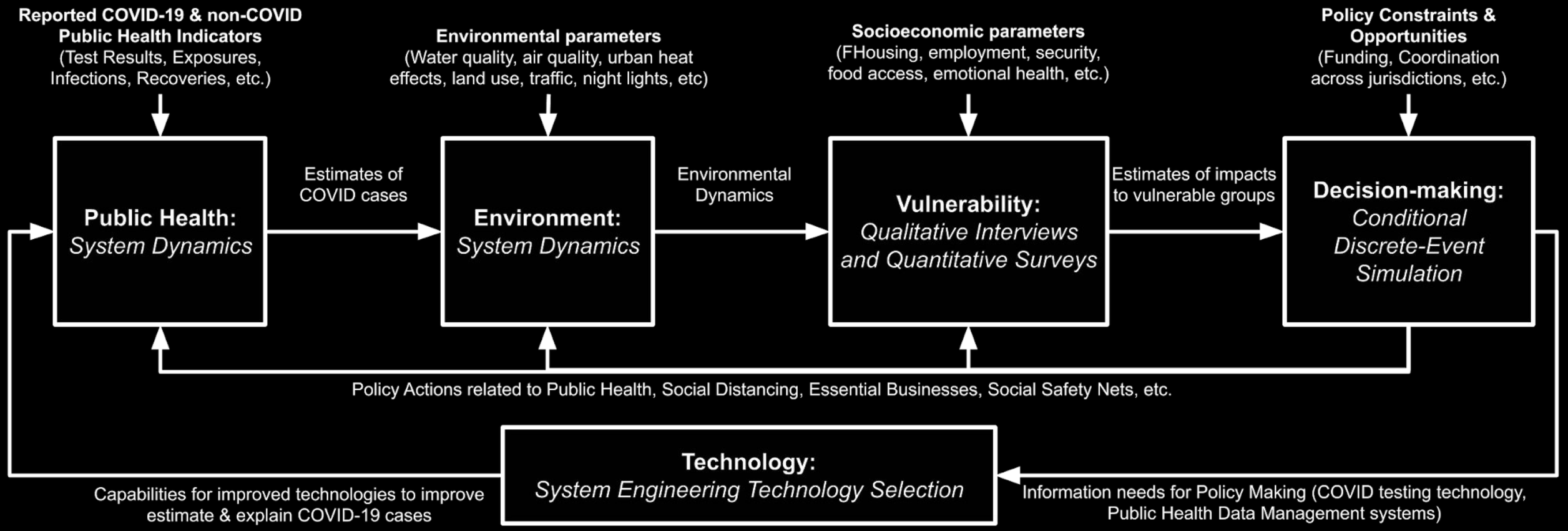
A. Policy Design



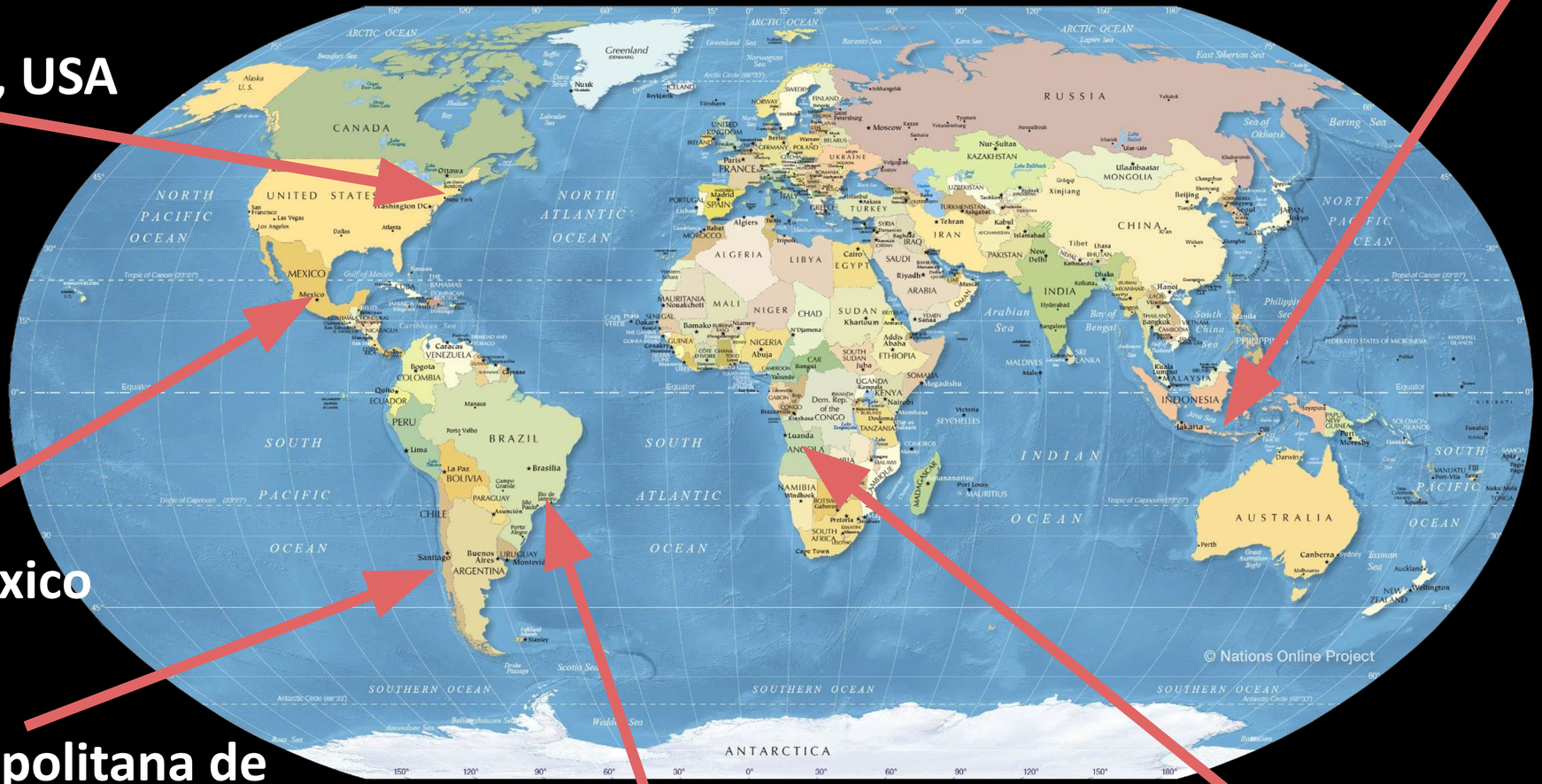


B. Technology Design

Vida Decision Support System



Vida DSS International Network



Java & Sulawesi, Indonesia

Boston, USA

Querétaro, México

Región Metropolitana de Santiago, Chile

Rio de Janeiro, Brasil

Luanda, Angola

Map adapted from the Nations Online Project.

Brasil

México

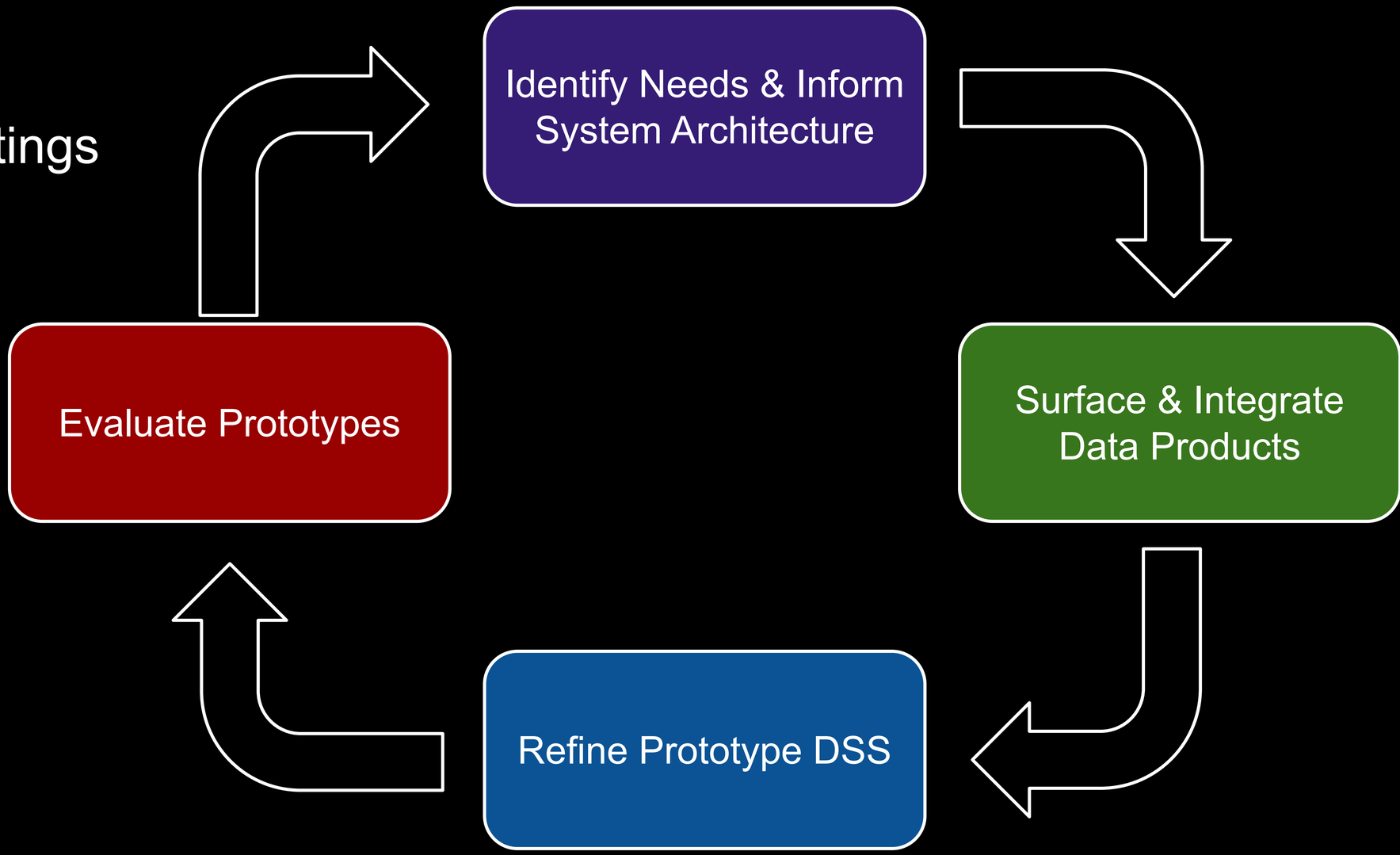
Indonesia

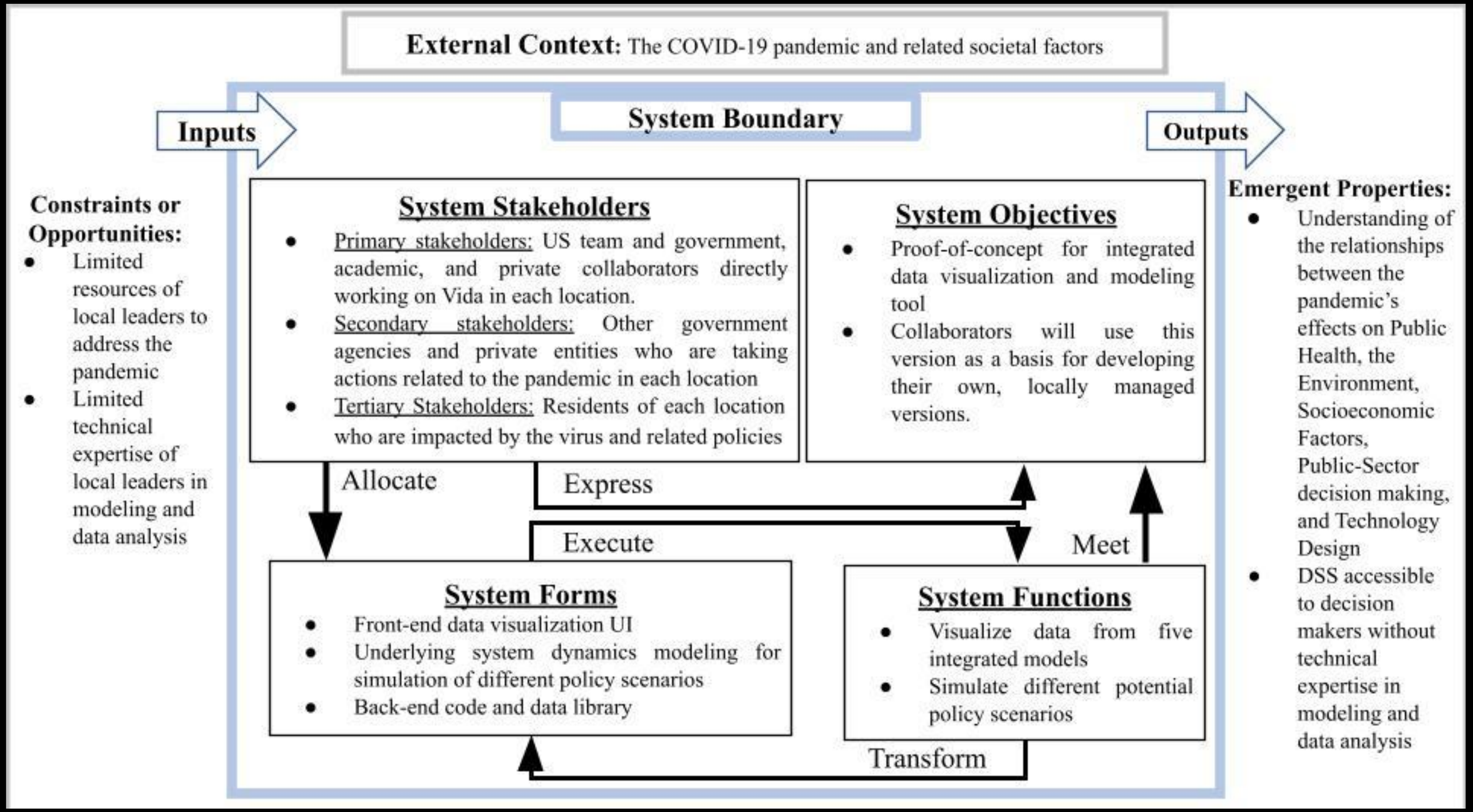
Chile

Angola

Stakeholder Involvement

- Weekly/Biweekly 1-on-1 meetings
- Monthly full network meetings
- Online collaboration
  - Data Repositories
  - Github
  - Browser-based DSS

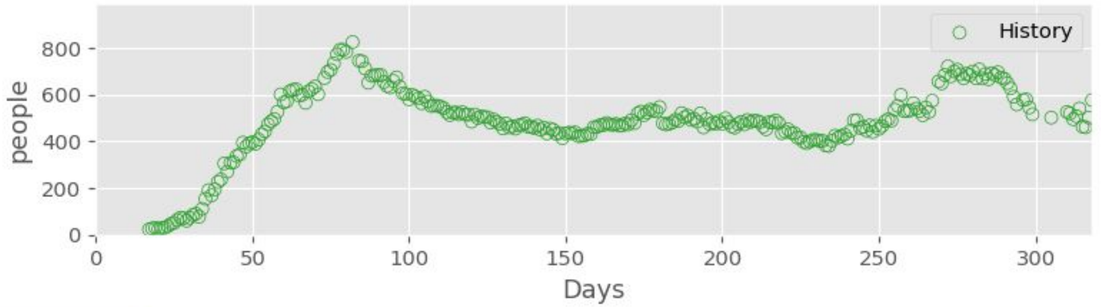



External Context: The COVID-19 pandemic and related societal factors
Inputs
System Boundary
Outputs
Constraints or Opportunities:
Limited resources of local leaders to address the pandemic
Limited technical expertise of local leaders in modeling and data analysis
System Stakeholders
Primary stakeholders: US team and government, academic, and private collaborators directly working on Vida in each location.
Secondary stakeholders: Other government agencies and private entities who are taking actions related to the pandemic in each location
Tertiary Stakeholders: Residents of each location who are impacted by the virus and related policies
System Objectives
Proof-of-concept for integrated data visualization and modeling tool
Collaborators will use this version as a basis for developing their own, locally managed versions.
Allocate
Express
Execute
Meet
System Forms
Front-end data visualization UI
Underlying system dynamics modeling for simulation of different policy scenarios
Back-end code and data library
System Functions
Visualize data from five integrated models
Simulate different potential policy scenarios
Transform
Emergent Properties:
Understanding of the relationships between the pandemic's effects on Public Health, the Environment, Socioeconomic Factors, Public-Sector decision making, and Technology Design
DSS accessible to decision makers without technical expertise in modeling and data analysis

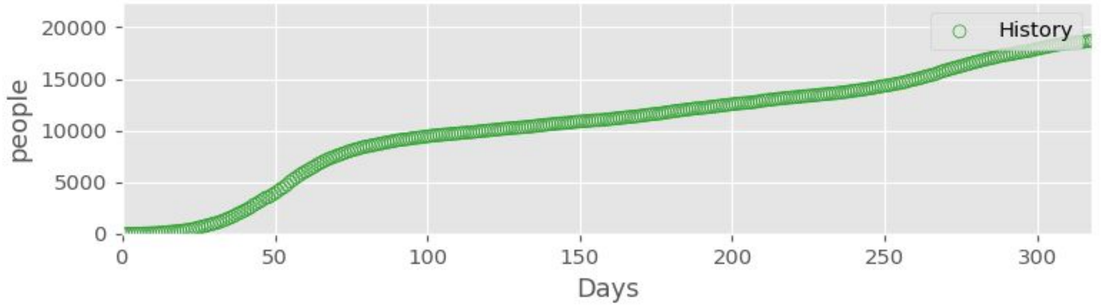
Data & Methods: Public Health

- COVID-19 health data collected by local authorities
  - Daily infections, hospitalizations, deaths, and recoveries
  - Daily PCR tests
  - Hospital bed capacity and availability
  - Ventilator use and availability
  - Vaccination rates

Graph 1: Hospitalized Population



Graph 2: Deaths



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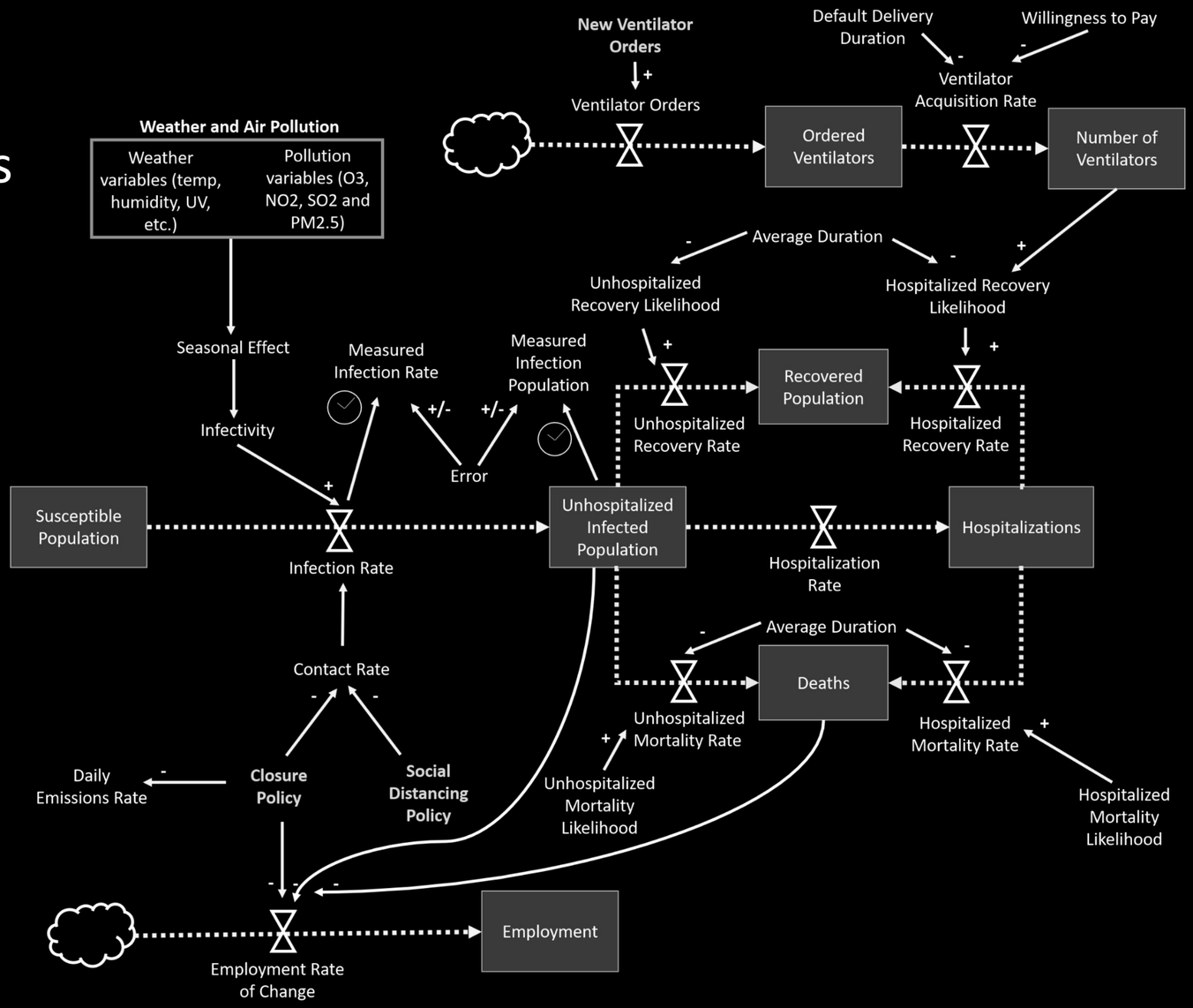
Data & Methods: Public Health

- Epidemiological Model: SEIR
- Modeling Approach: System Dynamics
- Integrates aspects of other Vida components
- Current version is non-spatial
- Adjusting assumptions and policy decisions can generate alternative scenarios



Data & Methods: Environment

- Air Quality (O3, NO2, SO2, PM2.5, PM10)
  - Remote: Sentinel 5P
  - In-Situ: Monitoring Stations (Brazil & Chile)
- Nightlights
  - VIIRS: VNP46A2 & VNP46A3
- Water Quality (NDTI, NDWI, other indices)
  - Landsat 7 ETM+, Landsat 8 OLI, and PlanetScope

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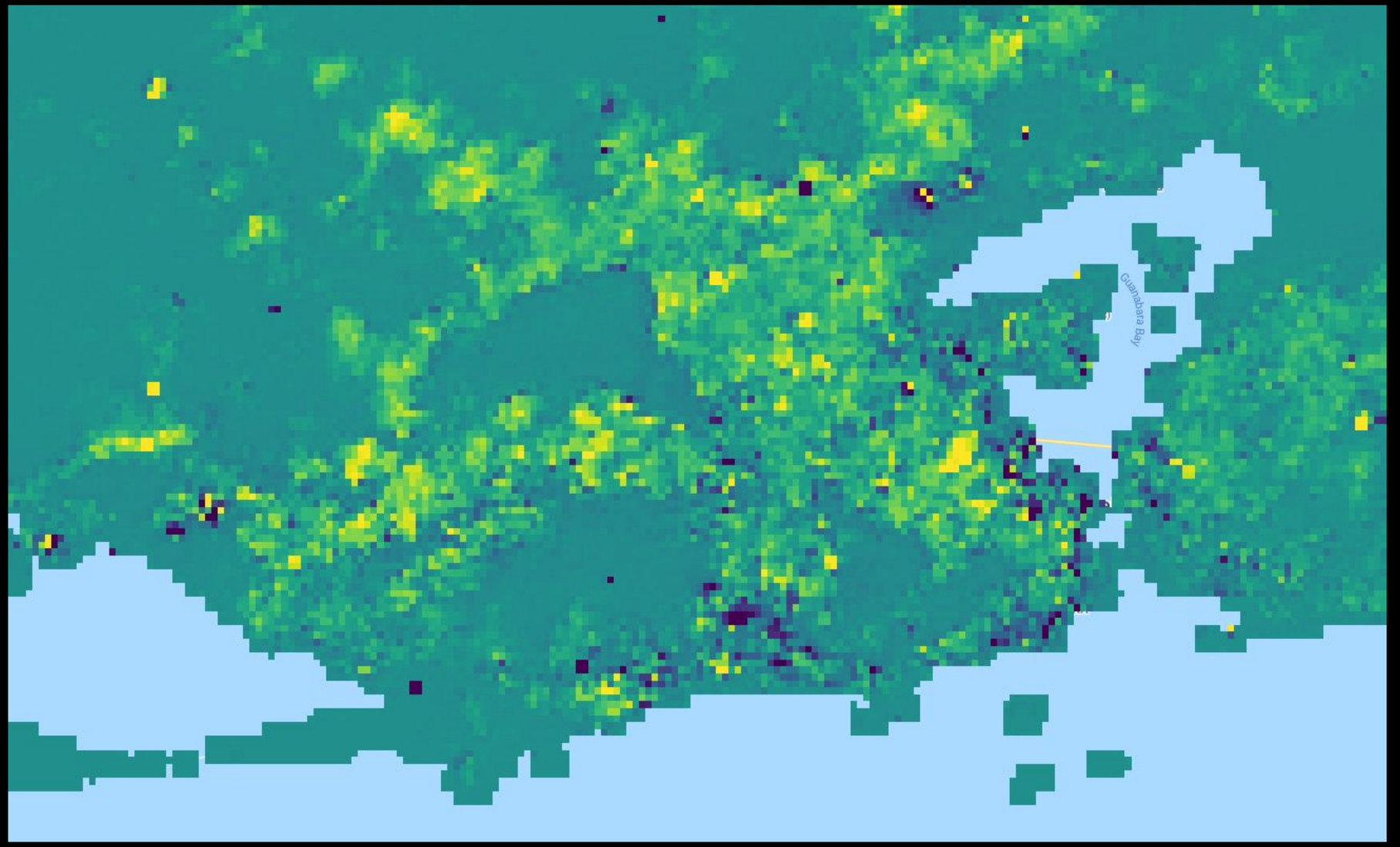
Ex) Rio de Janeiro Nightlight Changes (March - July, 2020)



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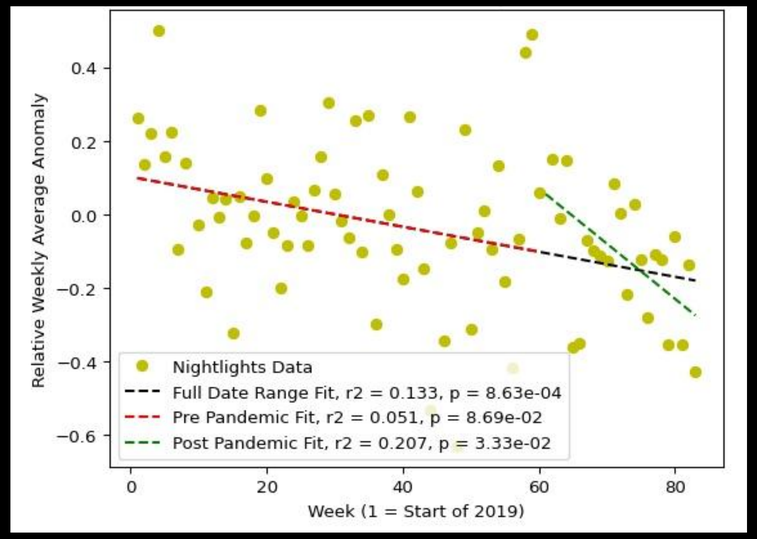
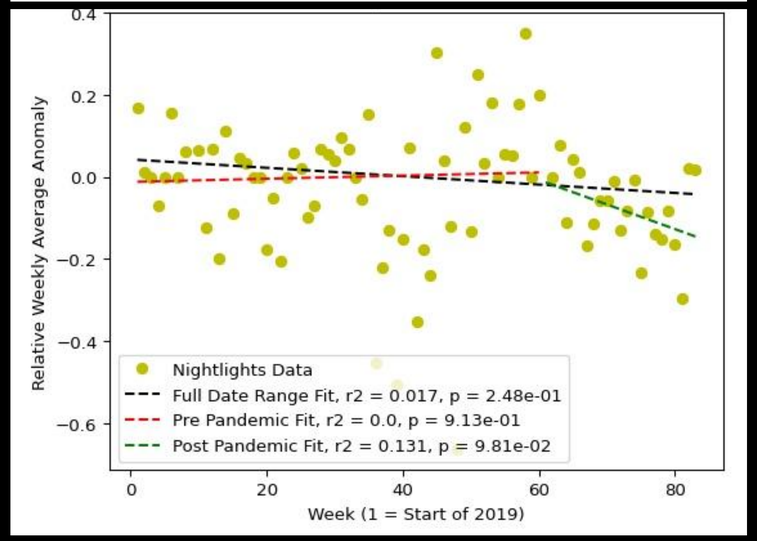
Rio de Janeiro, Brazil

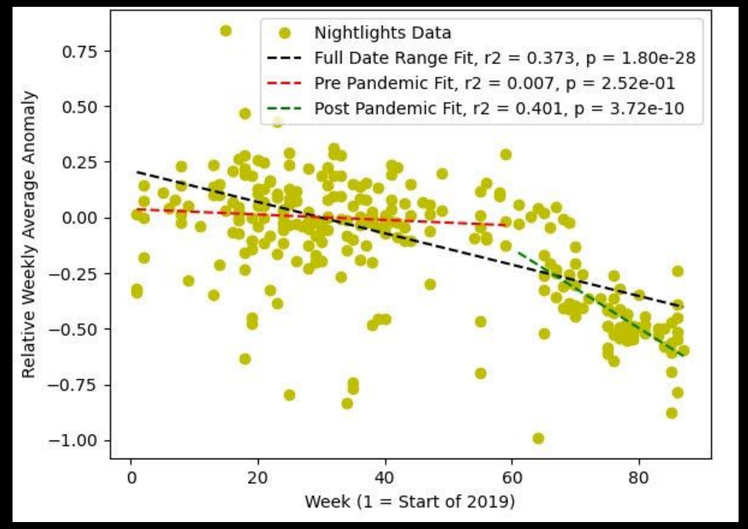
Santos Dumont Airport



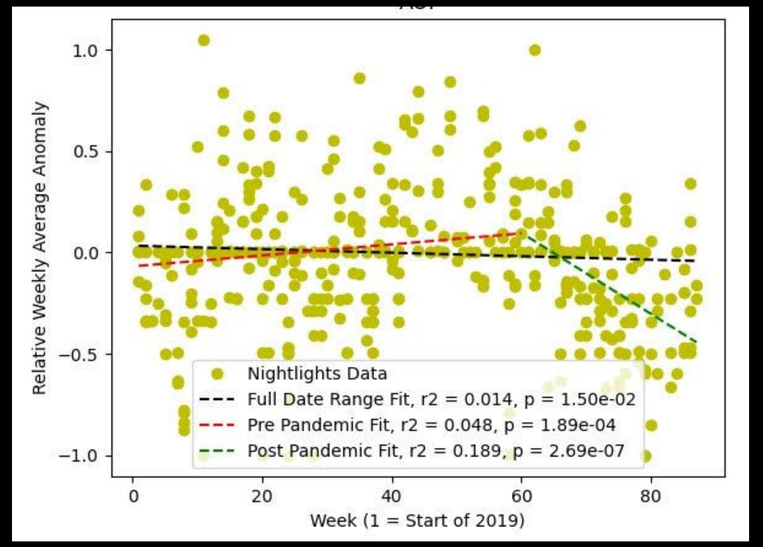
Ipanema



Bali, Indonesia



Ngurah Rai Airport



Island

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Ex) Rio de Janeiro PM10 Changes

- Relatively small changes in air quality detected once seasonal and long-term trends are taken into account
- What changes do exist point to an increase in PM10

Barrio	Code	Type	Pre vs Post T-Test P-Value	Anderson Darling P-Value	Change in Mean (Pre vs Post COVID)
Copacabana	AV	Tourist	0.956	0.1438	-0.0003
Bangu	BG	Mixed Use/Residential	0.2645	0.001	0.0042
Centro	CA	Downtown/Business District	0.0119	0.00002	0.0138
Campo Grande	CG	Mixed Use/Residential	0.3806	0.0217	0.0051
Irajá	IR	Urban/Residential	0.6295	0.0023	0.0022
Pedra de Guaratiba	PG	Rural	0.7844	0.0801	0.0014
São Cristóvão	SC	Downtown/Recreational	0.3913	0.0015	0.0041
Tijuca	SP	Mixed Use/Residential	0.0839	0.00003	0.0097

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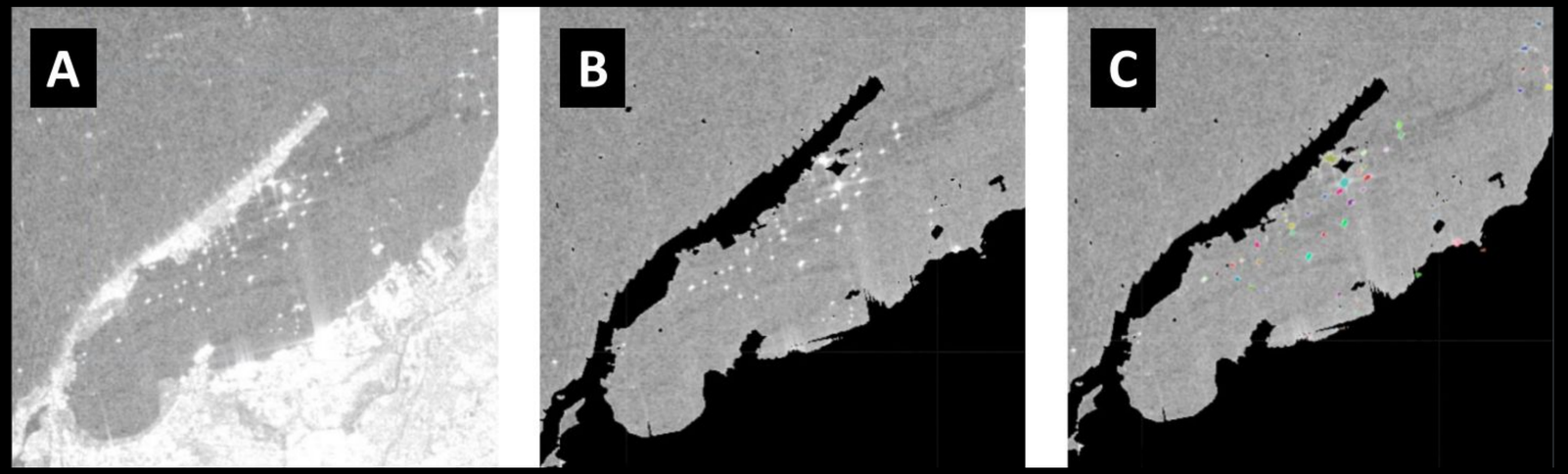
Data & Methods: Vulnerability



Images and analysis done by Amanda Peyton

- Socioeconomic Data
  - Ex) Poverty Rates, Employment Rates, GDP
  - Sources: Local government authorities, NASA SEDAC
- Mobility & Transit Data
  - Telecoms-based mobility data (as reported by Google and local authorities)
  - Public transit usage (as reported by local authorities)
  - Airline Flights (as reported by local authorities)
  - Ship counts and wait periods (as detected in Sentinel radar imagery)

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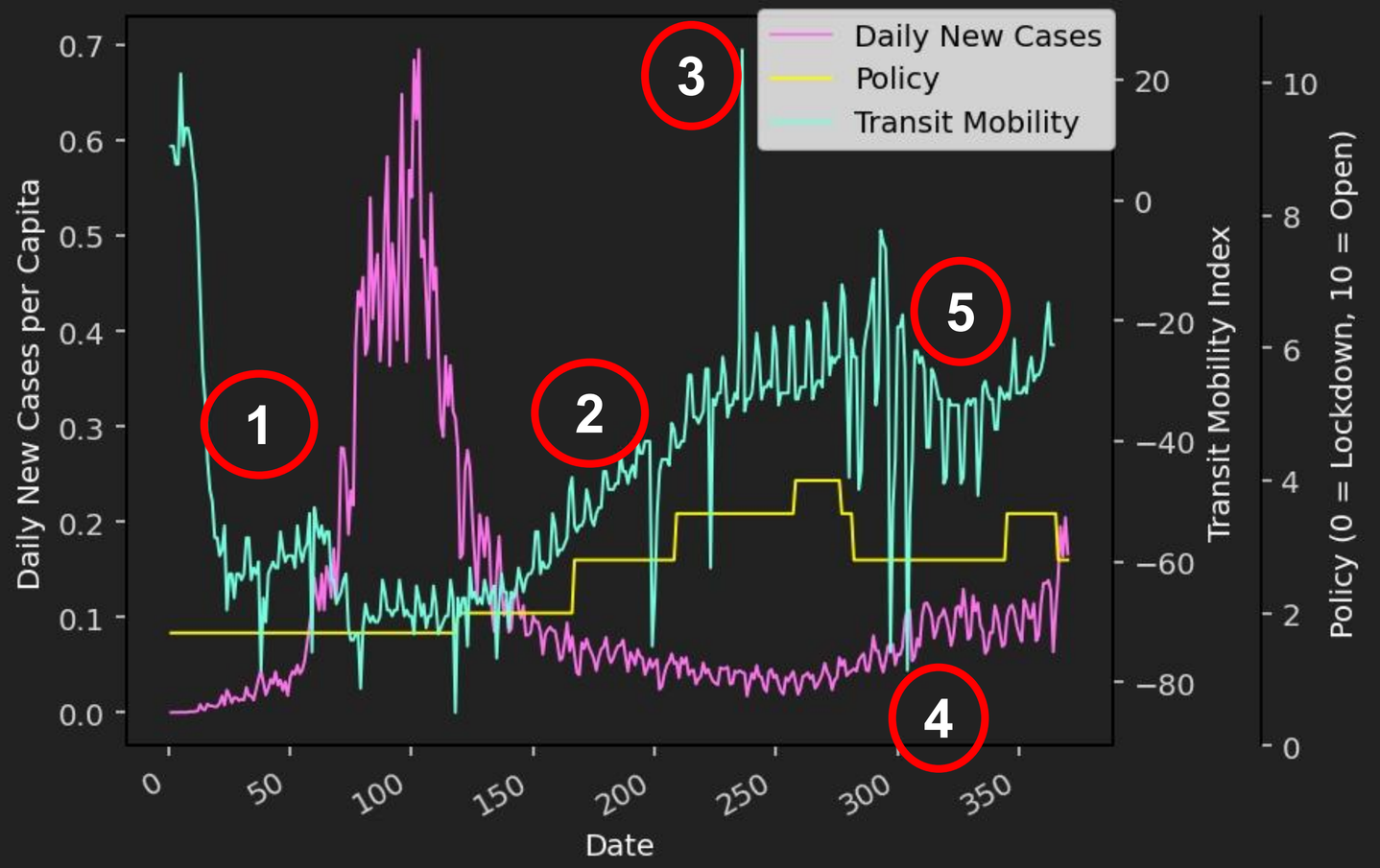
Ex) Metropolitana, Chile Mobility Changes



1. Mobility falls, notably *after* the initial wave of policy restrictions went into effect
2. As New Cases decline and policy relaxes, mobility rises
3. Chile has a constitutional referendum
4. Christmas & New Years
5. A rise in new cases prompts a policy restriction, decreasing mobility temporarily

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Data & Methods: Decision-making

- COVID-19 Social Distancing Requirements & Closures
  - Announcements, histories, definitions, and conditions created by local authorities
  - Ongoing effort to compare policies using standardized, quantitative comparisons based on the CoronaNet Research Project

Recovery Plan Indicators

updated 01/10/2020

Reference Date: 07/29/2020

GROUP	ANALYSIS PARAMETERS		PRIMARY INDICATORS	Comparison with previous days: F-1	D-5	D-4	D-3	D-2	D-1	07/16/2020 Ref. Previous Phase	7/29/2020 Result	WE ARE IN PHASE 6B (Since 01/10/2020): PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6
HEALTH SYSTEM RESPONSE CAPACITY	Capacity of ICU beds	1	Percentage of occupancy of dedicated adult ICU beds COVID (ICU SRAG) METRO I SUS bed (7-day moving average)	✗	✓	✓	✓	✓	✓	69.4	71.2	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		2	Occupancy rate of supplementary sector ICU beds (moving average 7 days) (a)	✗	✗	✗	✗	✗	✗	67.9	70.0	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		3	Percentage of occupancy of life support beds REDE SUS Territory of the municipality (moving average 7 days)	✗	✓	✓	✓	✓	✓	76.0	77.0	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
		4	ICU COVID beds (REDE SUS) per 100k inhabitants (b)	✗	✗	✗	✗	✗	✓	6.59	6.41	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
TRANSMISSION LEVEL	Variation of deaths	5	Death Variation Rate by COVID19 in each period (Information released at 6 pm on the day, referring to the previous day) (c)	✗	=	✗	=	✓	✓	0.92	0.95	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
	Growth of hospitalized cases	6	Rate of Variation of Inpatients (Clinical + ICU) in each period (Information released at 6 pm on the day, referring to the previous day) (c)	✗	✓	✓	✓	✓	✓	0.92	0.95	Favorable	Favorable	Favorable	Favorable	Favorable	Favorable
	Variation of new cases	7	Number of cases reported by Influenza Syndrome (SG) in the last two epidemiological weeks of notification (d)	✓	✓	✓	=	=	=	16,554	13,931	Favorable	Favorable	Favorable	Favorable	Favorable	Not Favorable
OPINION FOR OPENING PHASE ACCORDING TO PRIMARY INDICATORS												Favorable	Favorable	Favorable	Favorable	Favorable	Not Favorable

For more information, see https://riocontraocorona.rio/ and http://inteligencia.rio/planoretomada

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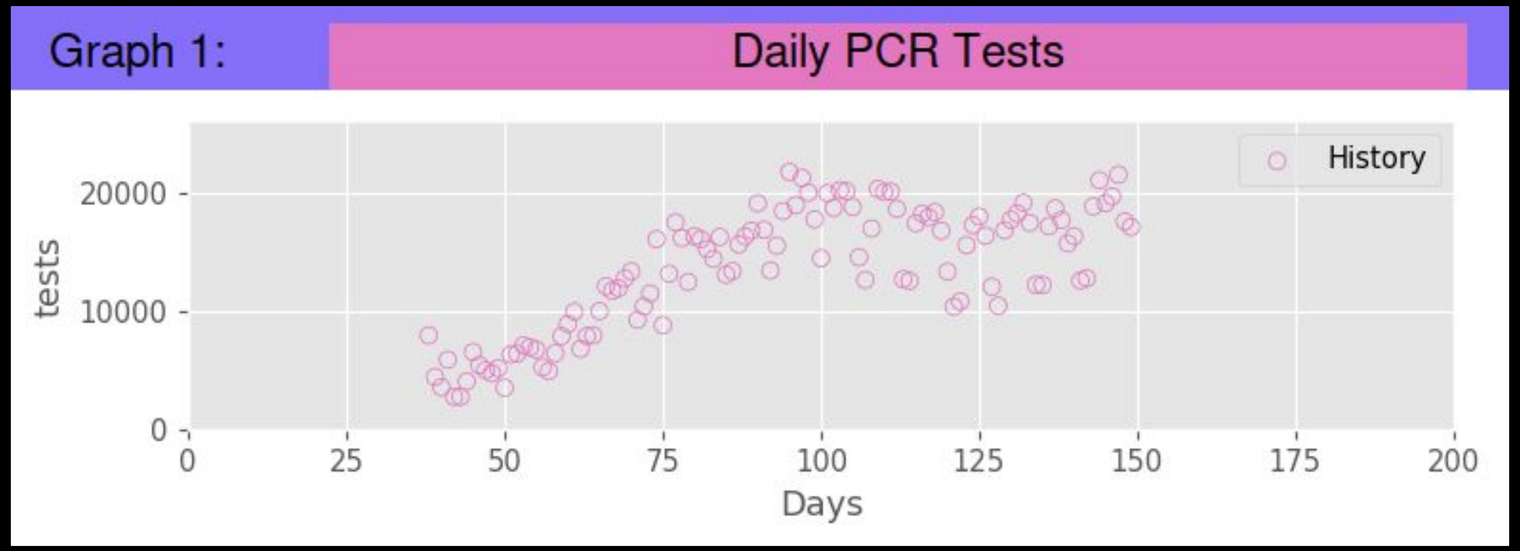
Data & Methods: Technology

- Earth observation systems are still relevant!
  - Additional relevant platforms like VIIRS, MODIS, Planet, Maxar, etc.
- Various public health sensing technologies and regimes
  - PCR and other tests to identify the actively infected
  - Antibody tests to identify those previously infected



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User Interface

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Ongoing and Future Work

- Automating data updates and ingestion
- Standardizing architecture to facilitate reuse
- Add simulation capabilities to the online version
- Improving visualizations
- Adding a spatial component to the epidemiological model
- Continue air quality and nightlight analysis

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Project Page:

https://www.media.mit.edu/projects/vida-decision-support-system/overview/

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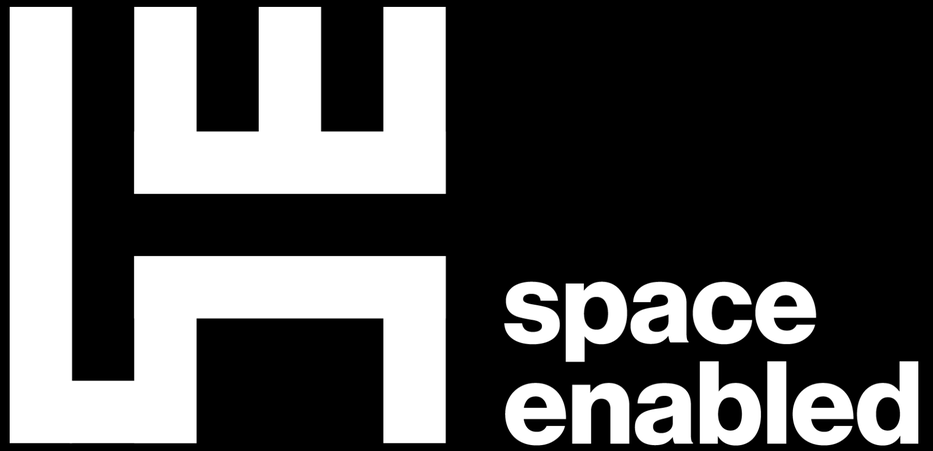
Acknowledgements:

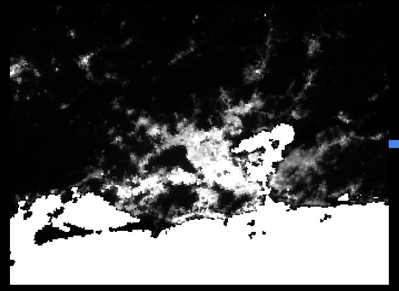
Soffen Memorial Fund

All of our collaborators

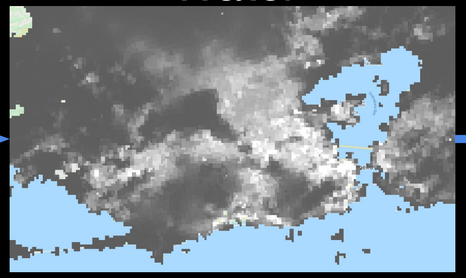


Methodology

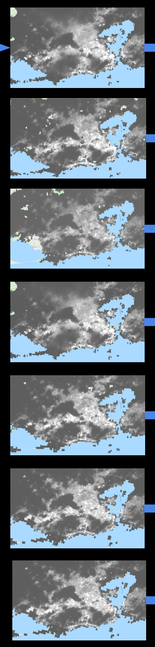
VNP46A2 Raw Image

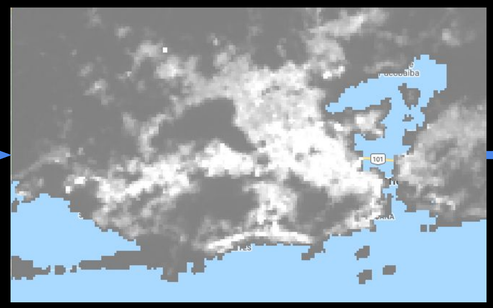


Filter
Area of Interest
Clouds
Water

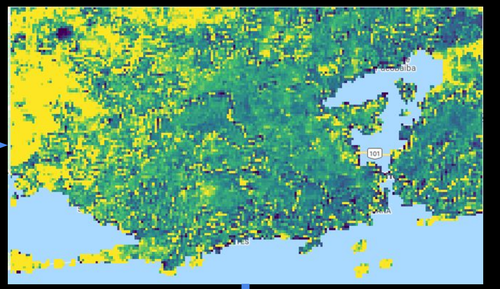


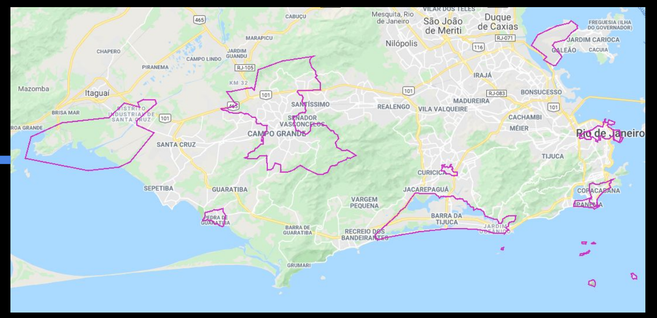
Weekly Averages





Percent Change Relative to 2019 Annual Average



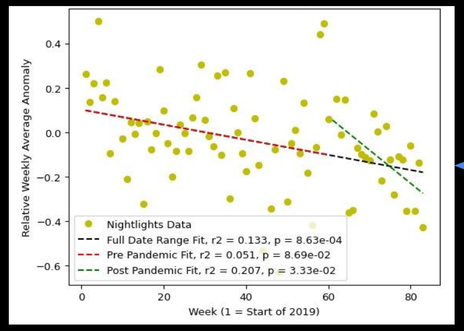


Select specific geographic subunits

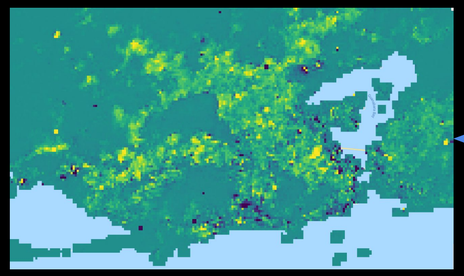
2019 - Start of Pandemic

Start of Pandemic - 1/Aug/21

Split Data into Temporal Categories

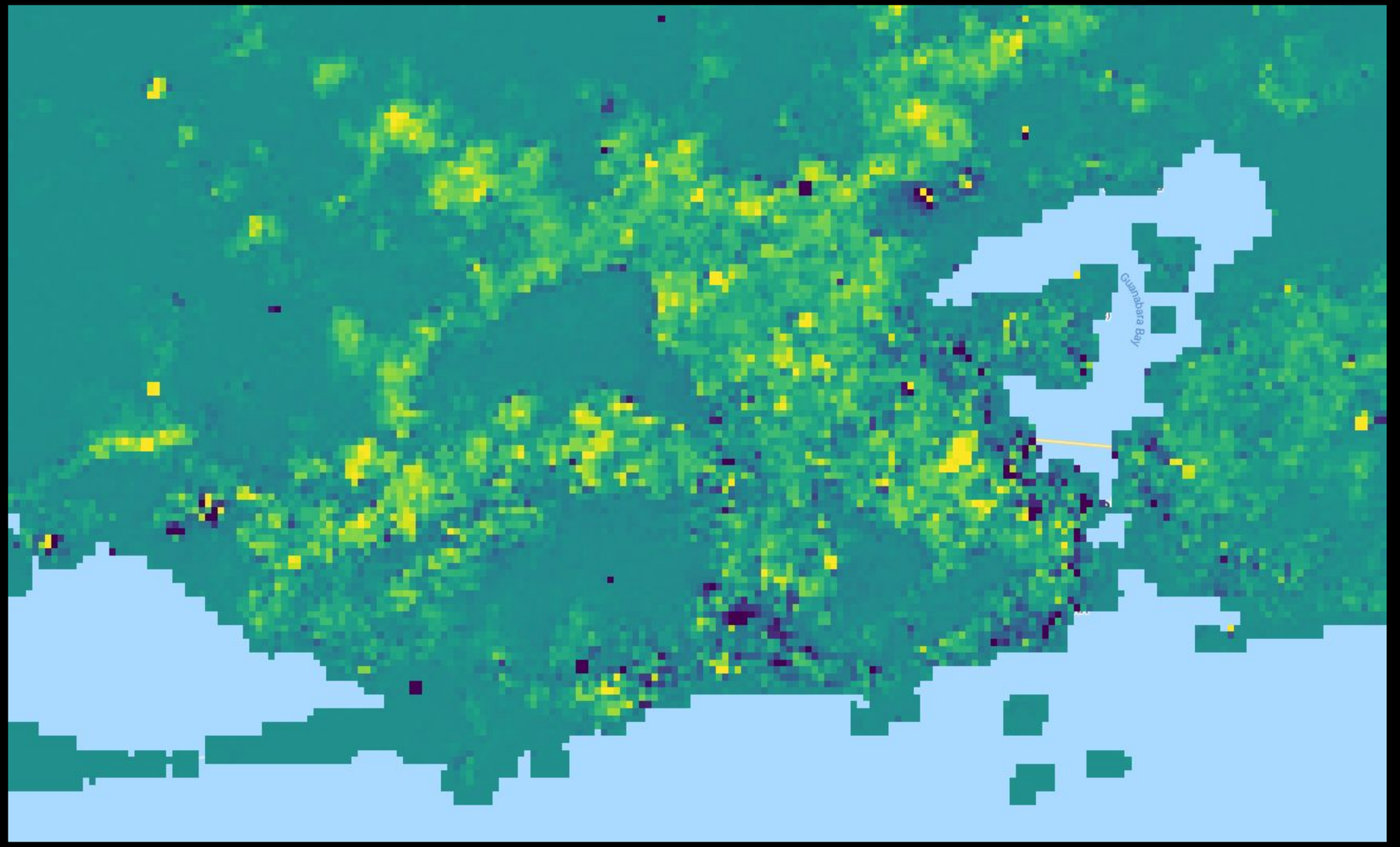


Statistical Analysis



Theil-Sen Slope Visualization

Visualization - Rio de Janeiro Changes (March - July, 2020)



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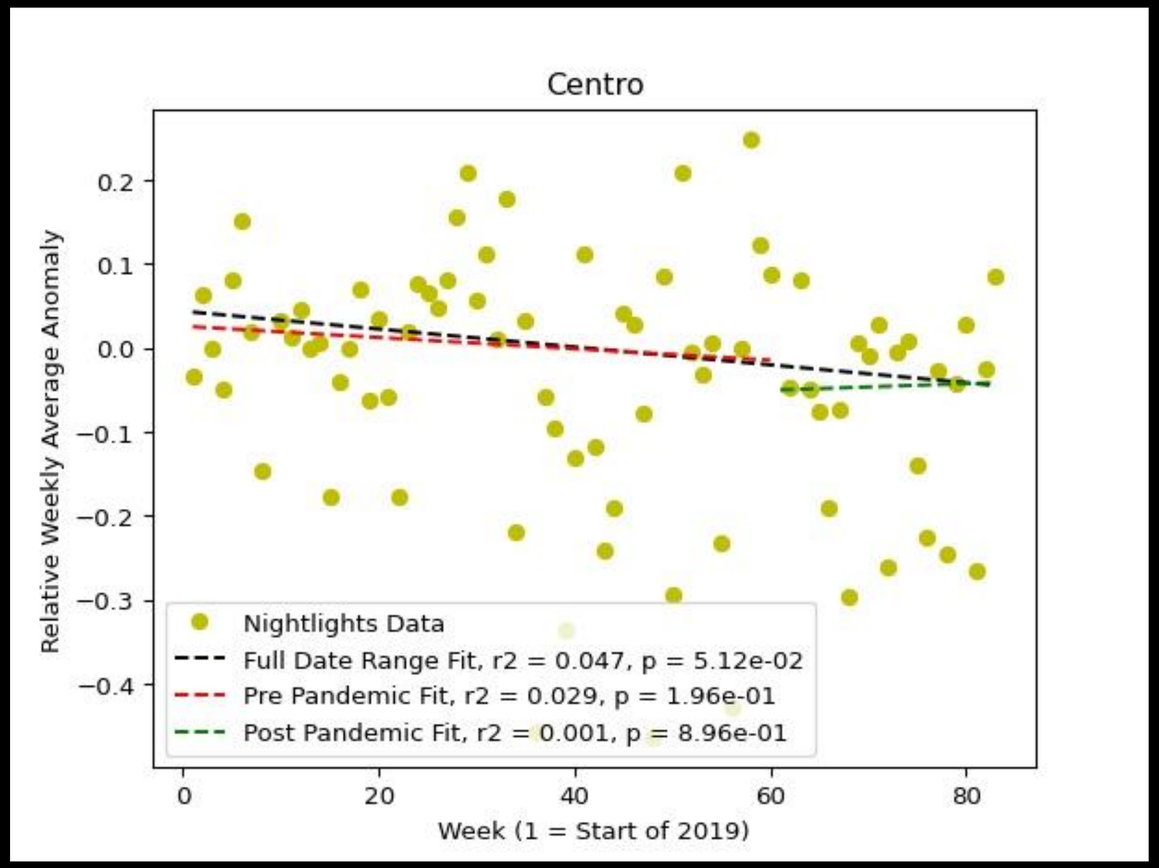
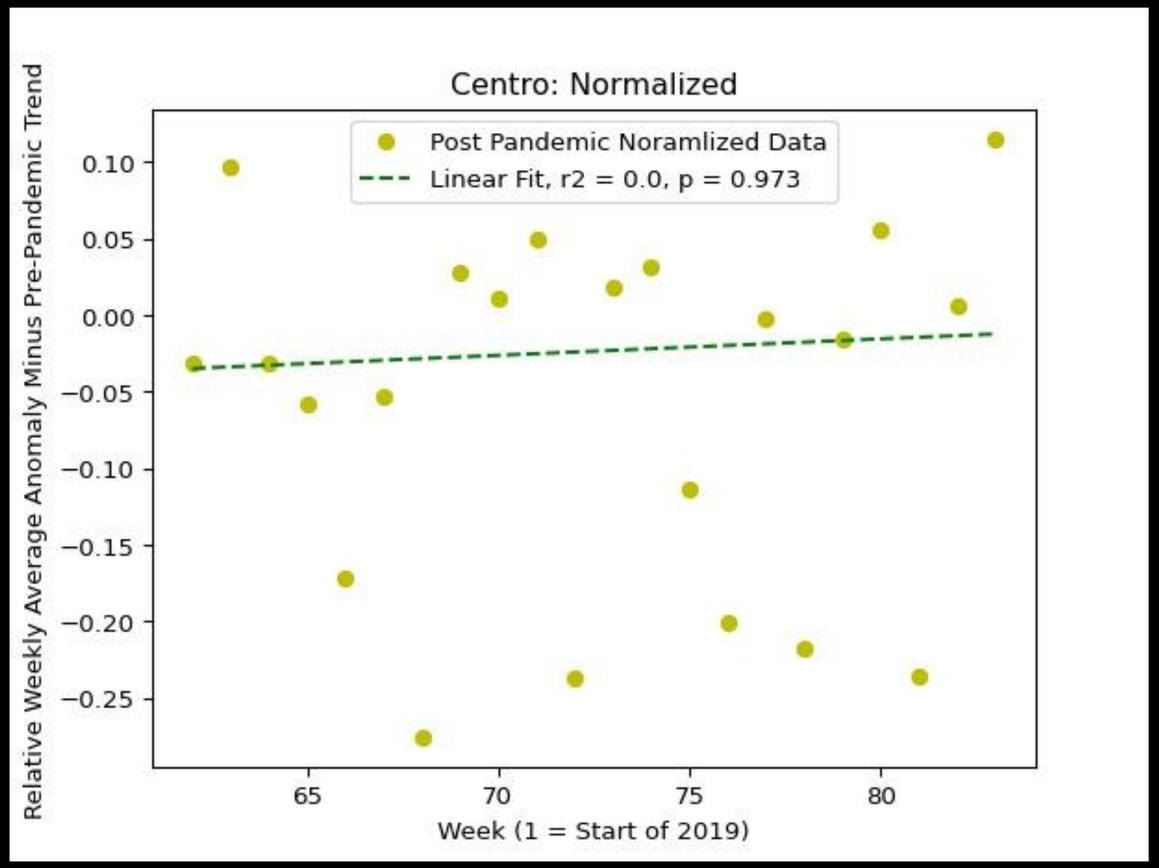
Statistics - Rio Changes



Percent Change Relative to 2019 Annual Average



Normalized:
(Post Pandemic Data - Red Line Trend)

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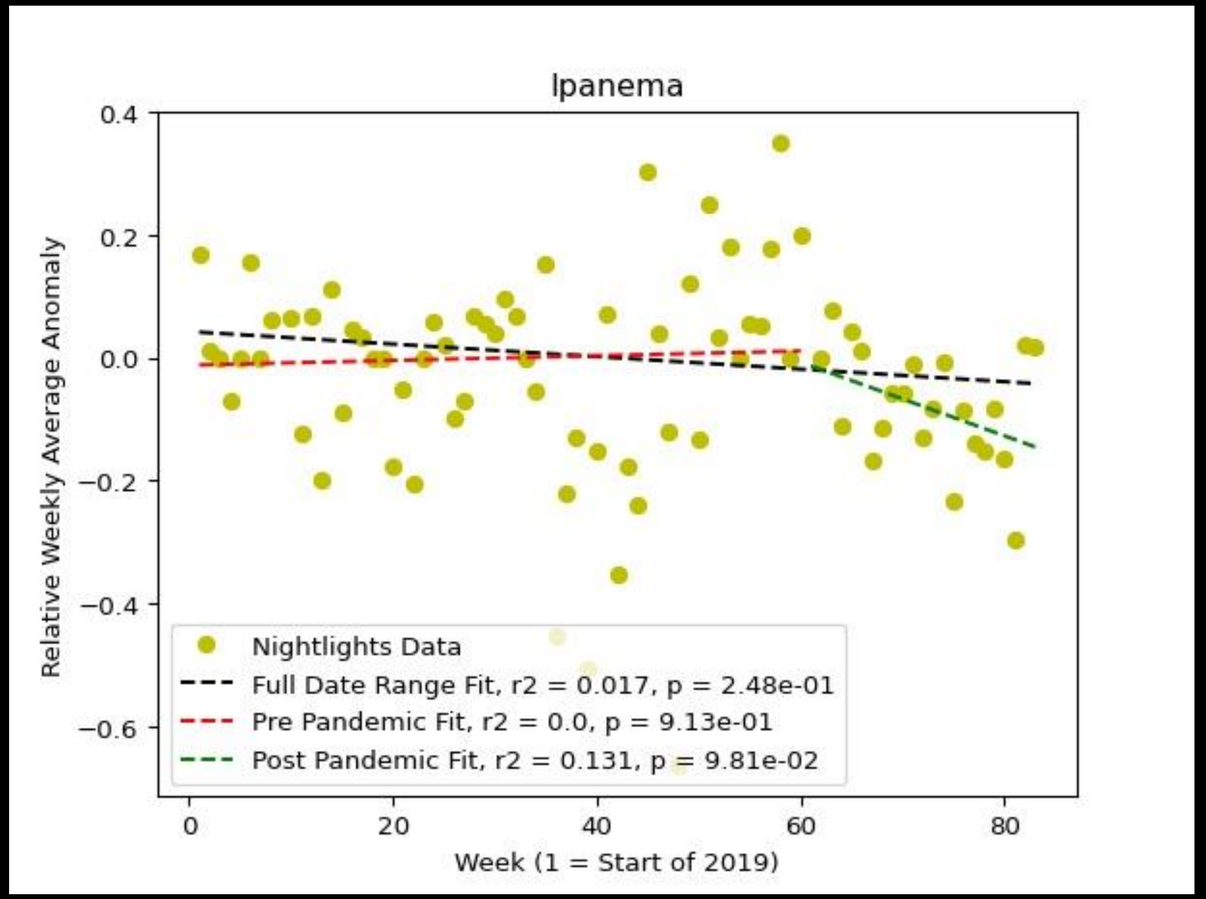
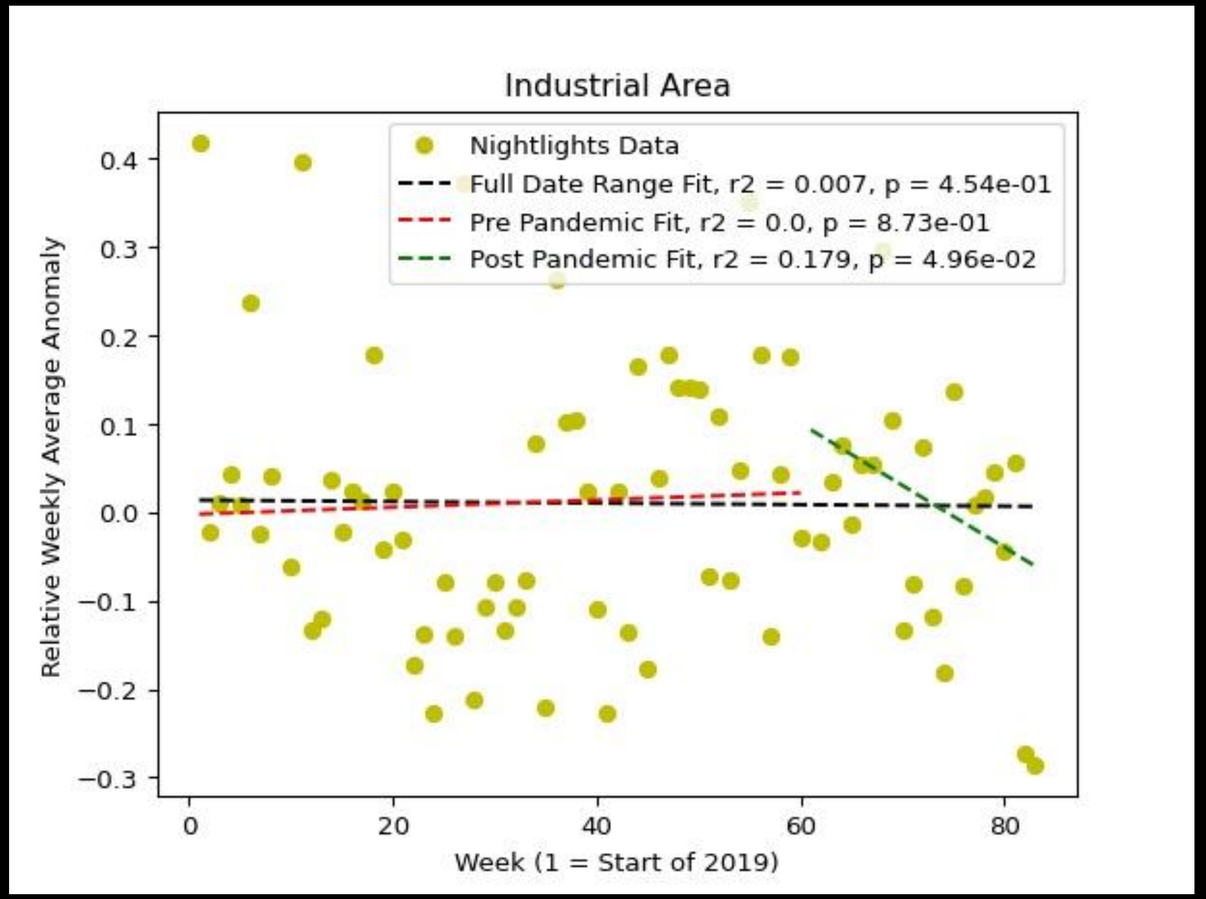
Statistics - Rio Changes





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Rio de Janeiro Changes

Area	Type	Pre vs Post T-Test P-Value	Normalized Data Linear Fit P-Value	Pre Pandemic Trend (*1000)	Post Pandemic Trend (*1000)
Barra da Tijuca	Tourist	0.000	0.11	-0.64	-3.73
Campo Grande	Suburb	0.503	0.93	0.25	0.62
Centro	Downtown	0.115	0.97	-0.67	0.40
Cidade de Deus	Mixed Use / Residential	0.433	0.01	-0.50	6.92
Cidade Nova	Downtown	0.604	0.88	-3.76	-3.27
City	Entire City	0.347	0.45	0.58	4.78
Copacabana	Tourist	0.769	0.90	-1.44	-0.71
Galeao Airport	Airport	0.000	0.24	-2.57	-7.22
Industrial Area	Heavy Industry	0.395	0.04	0.41	-7.00
Ipanema	Tourist	0.063	0.08	0.38	-6.00
Pedra de Guaratiba	Rural / Residential	0.052	0.70	-0.76	-2.40
Santos Dumont Airport	Airport	0.005	0.12	-3.38	-15.00

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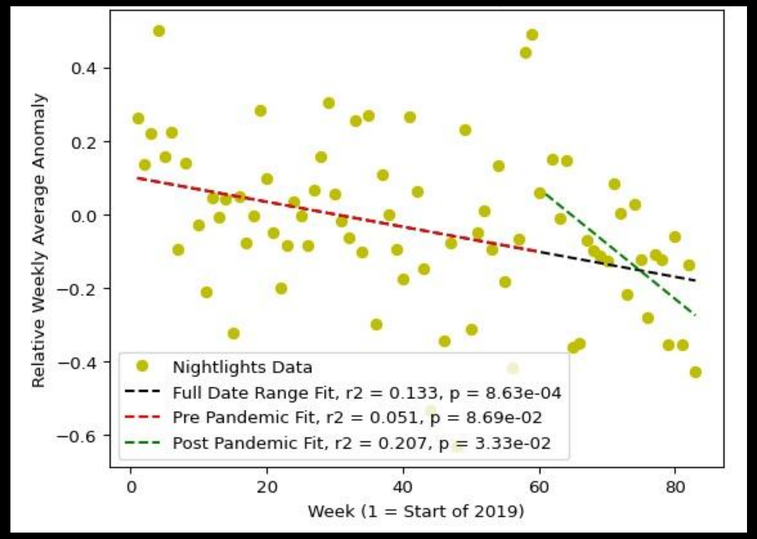
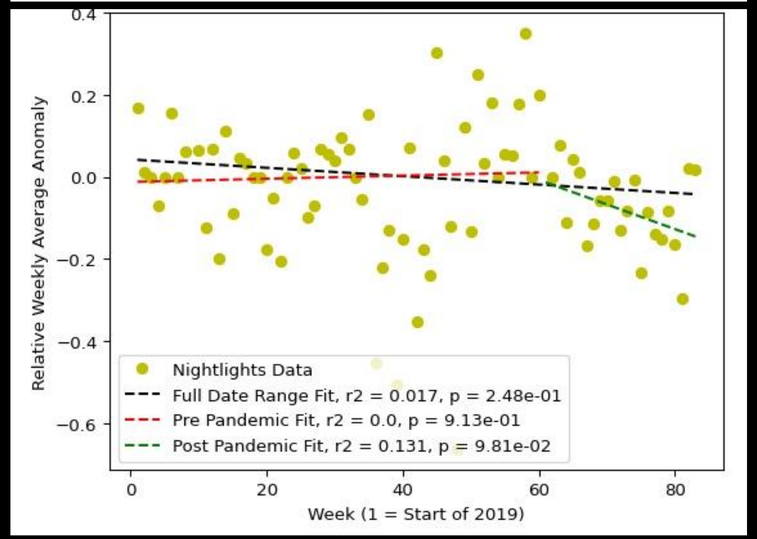
Rio de Janeiro, Brazil

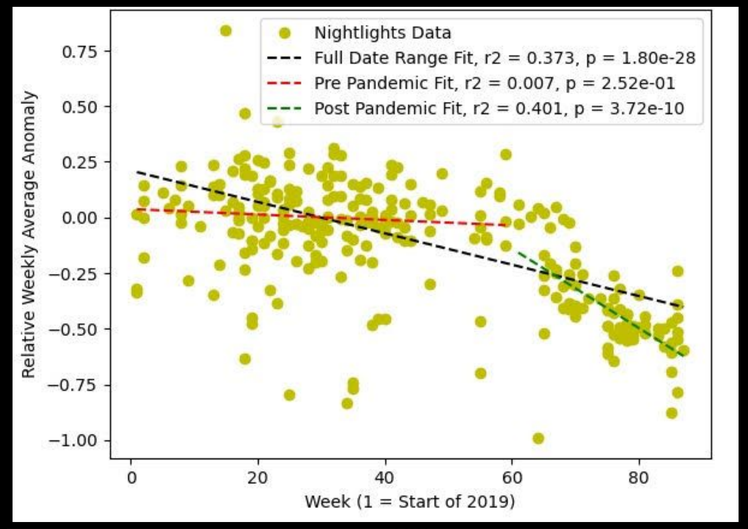
Santos Dumont Airport



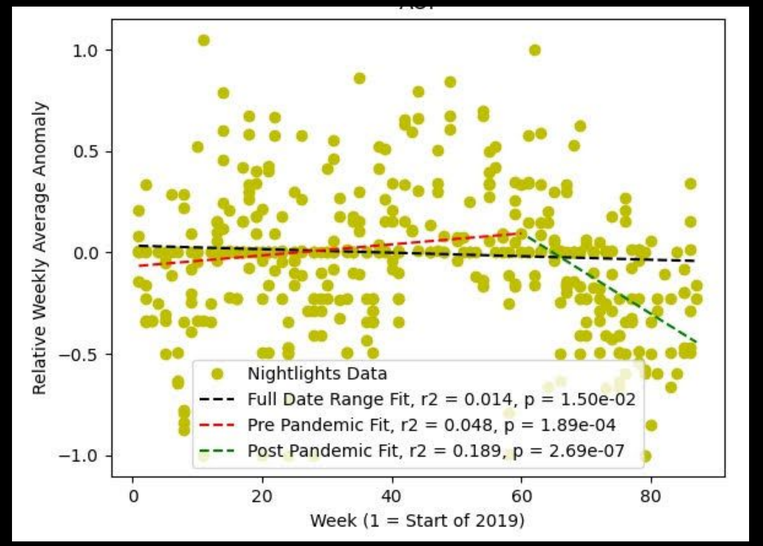
Ipanema



Bali, Indonesia



Ngurah Rai Airport



Island

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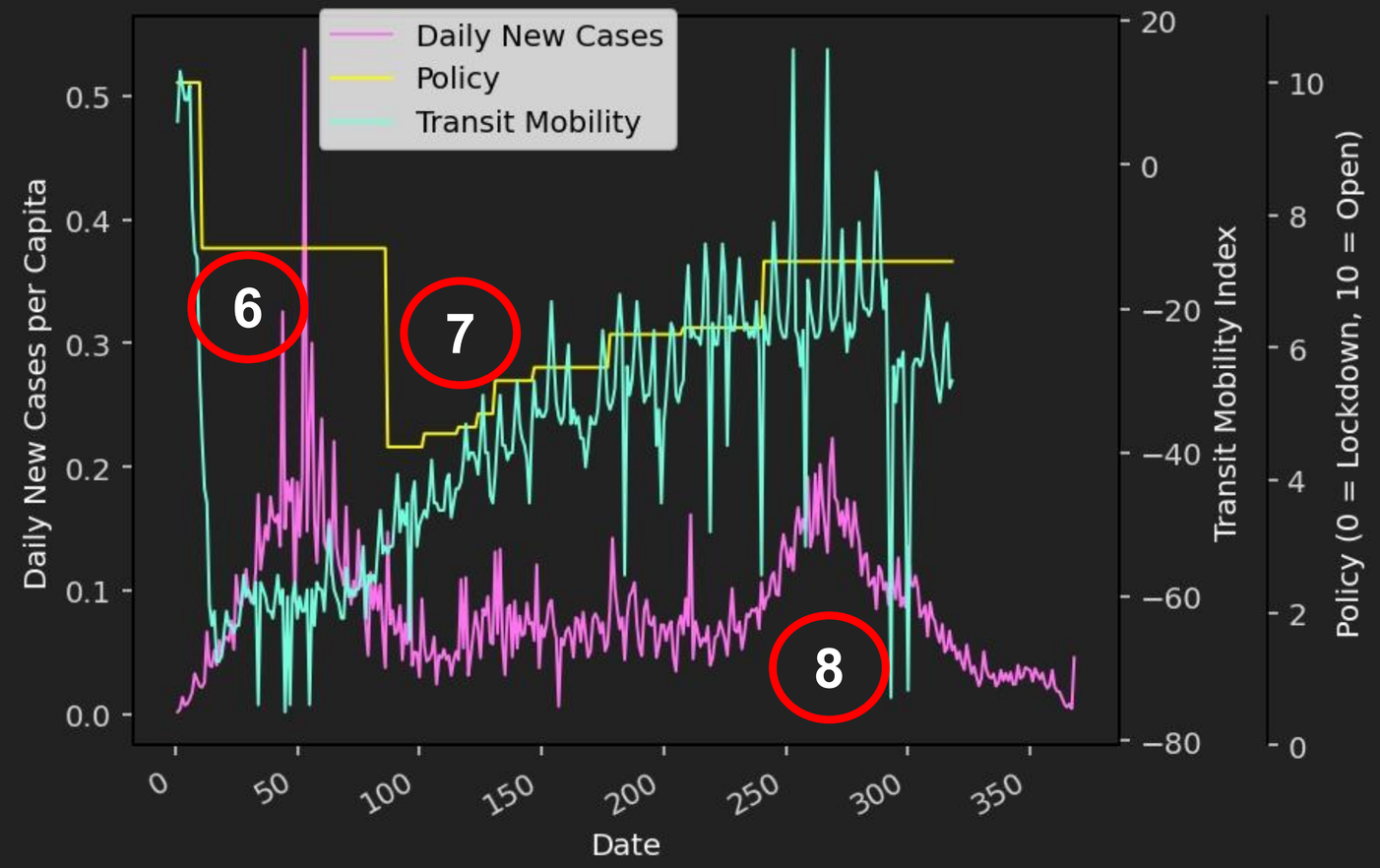
Rio de Janeiro



6. Mobility falls, matching or even leading actual policy changes
7. Mobility rises, leading policy changes upwards as case counts fall
8. Mobility drops starkly for Christmas and New Years, then returns to a lower level than previously, following a rise in cases and a new government with different priorities.

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