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APPLIED SCIENCES

HEALTH & AIR QUALITY

William Pan
April 23, 2024
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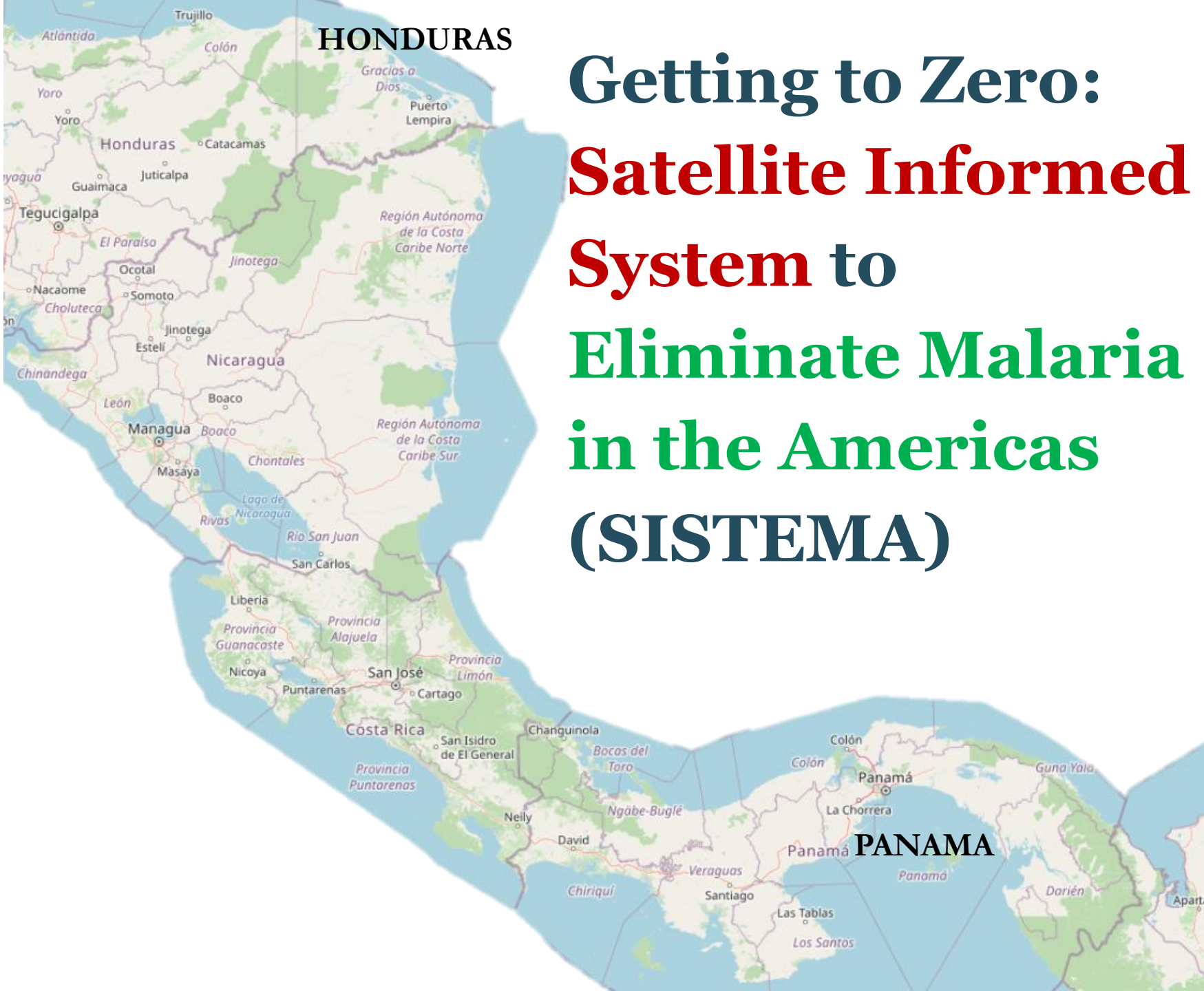

Getting to Zero: Satellite Informed System to Eliminate Malaria in the Americas (SISTEMA)

Project 21-HAQ21-0026 Summary

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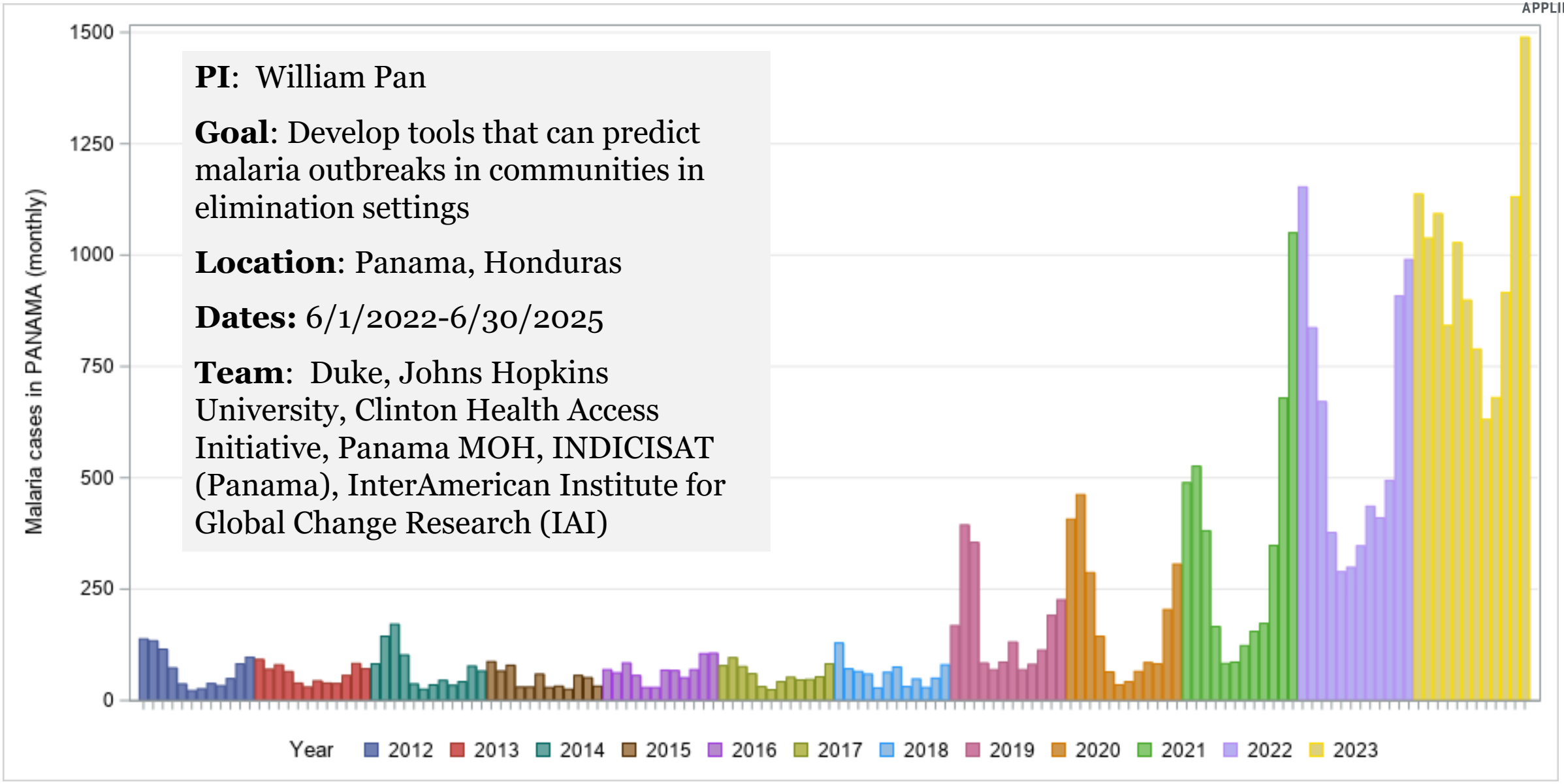
PI: William Pan

Goal: Develop tools that can predict malaria outbreaks in communities in elimination settings

Location: Panama, Honduras

Dates: 6/1/2022-6/30/2025

Team: Duke, Johns Hopkins University, Clinton Health Access Initiative, Panama MOH, INDICISAT (Panama), InterAmerican Institute for Global Change Research (IAI)



Earth Observations, Models, and/or Technologies

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Satellite Sensor/Model/Tech.	Product Used	Temporal Coverage and Latency required	Comments
Optical	AVHRR	1000m	1992-93
Optical	MODIS	500m	2001-2019
Optical & Microwave	LandSAT, ALOS, SPOT	100m	2012
Optical	LandSAT	30m	1999-2020
Optical	Sentinel-2	30m	2017
Optical	MODIS & LandSAT	30m	2000-2020
Microwave (L)	JERS, ALOS/PALSARI1-2	12.5m	1996, 2007-10, 2015-20
Microwave (C)	Sentinel-1	12.5m	2014-present
Microwave (L)	NISAR	10	2023-2025

Project Partners/Collaborators

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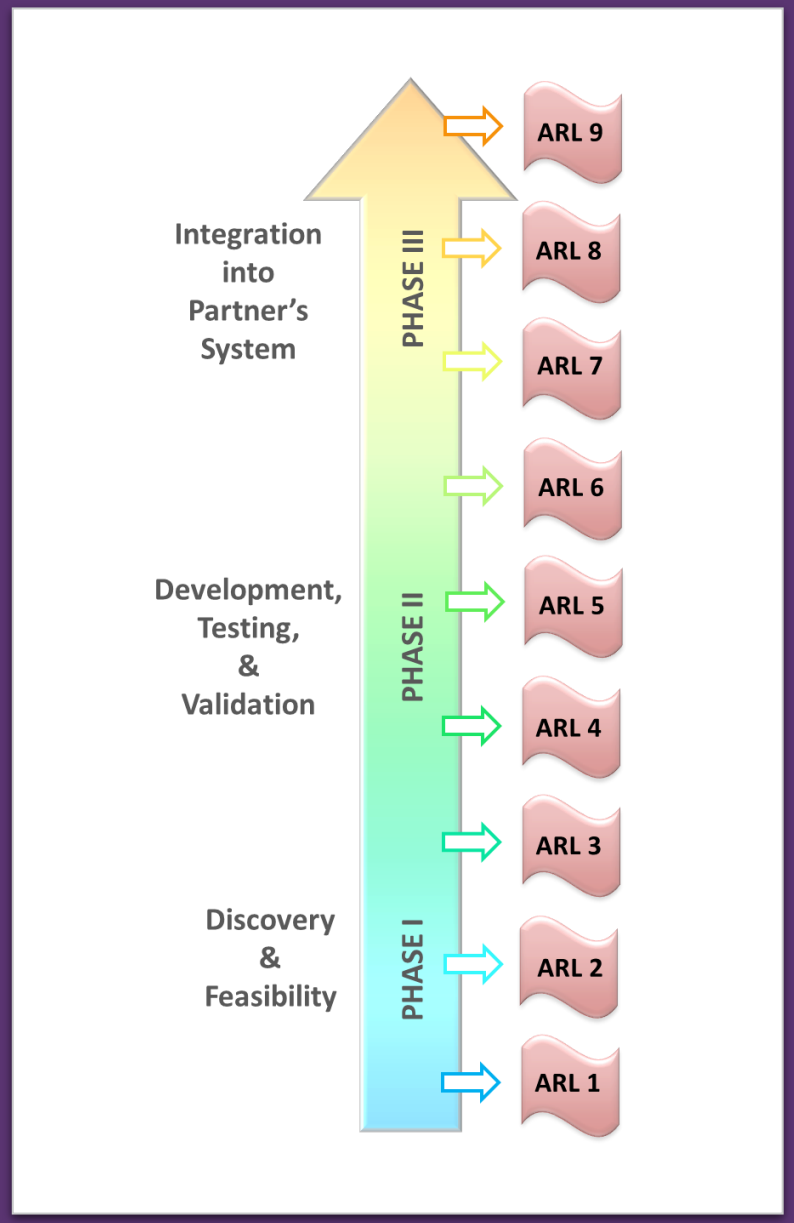
Role	Name	Affiliation	Organization Type
Co-I, LDAS development Post-doc, LDAS development	Ben Zaitchik, Prakrut Kansara, Manuel Narvaez	Johns Hopkins University	University
Entomologist, Vector ecology model Master student	Jose Loaiza, Alejandro Almanza	INDICISAT	Research Institute
Co-I, Malariaologist & modeler Clinical expert, Vector modeler Co-I, Macro-climate cycling & malaria Post-doc, climate-malaria modeling Co-I, LULC analyst Dashboard Developer	Mark Janko, Paul Lantos, Sara O'Malley, Ximena Gonzalez, Hena Vahder Shineng Hu, Mengxin Pan Peter Harrell, Perla Medrano John Fay, Pamela Chacon	Duke University	University

END-USERS & KEY STAKEHOLDERS Decision-Making Activity		
Clinton Health Access Initiative	**PANAMA**: Justin Lana & Oggun Cano; **HONDURAS**: Sarah Park	Technical support for malaria surveillance & decision-making by National Malaria Control Programs (NMCPs)
IAI UNDCO	Anna Stewart Christian Lara	Provides technical assistance to government agencies to support decision-making
Ministry of Health	**PANAMA**: Carmen Perez, Lizbeth Cerezo **HONDURAS**: Oscar Urrutia, Lorenzo Pavón	(1) Decisions on when/where interventions deployed; (2) integration of environmental data into decision-making (i.e., activity 1); and (3) Improvement in deployment of intervention based on retrospective analysis

Schedule & Milestones (startdate 6/1/2022)

Expected ARL	Time	Expected Milestone	Observed/Comments
4	Y1, Q1 9/1/22	**Data acquisition** (Surveillance, GIS, Vector, Intervention, EO Images & regular updates)	EO Images obtained, MOU with CHAI signed. Honduras malaria surveillance data shared in May 2023. Panama malaria surveillance data expected June 2023
4	Y1, Q2 12/1/22	**Data acquisition; LDAS** (5km hydrometeorological data)**; Pan Tropical** (assessment of teleconnections between pan-tropical ocean basins on malaria incidence and vector densities); **LULC** (high and low resolution land cover analysis)	LDAS runs begin, Pan tropical analysis is being evaluated with malaria data from the Amazon since it is available, Land cover data downloaded and processing ongoing,
4	Y1, Q3 3/1/23	**Malaria Elimination Support Models (MESM) – MESM1** (Vector Ecology Models), **MESM2** (Malaria Early Warning)(development, validation, outputs); **LDAS, Pan-Tropical, LULC**	LDAS output provided; Vector data obtained and MESM1 models begun; Honduras surveillance data shared but Panama data pending, so MESM2 models have not started
4	Y1, Q4 6/1/23	**MESM1, MESM2, Capacity Building** (Training, Dashboard)	Preliminary dashboard created for malaria forecasts. This needs to be evaluated against the current dashboard in use by CHAI.
5	Y2, Q1 9/1/23	**Environmental Characterization System (ECS) –** (combines & updates Data, LDAS, LULC, Pan-tropical) **Pan-Tropical models, MESM1, MESM2**	Meta-analysis of SST has been completed to identify different zones of SST associated with malaria cases by epidemiological week.
5	Y2, Q2 12/1/23	**Pan-Tropical, MESM1, MESM2, Capacity Building**	Prelim forecast models have been developed using Machine Learning. Vector models are still being analyzed .
6	Y2, Q3 3/1/24	**Pan-Tropical, MESM1, MESM2, ECS Development**	Meetings with Panama-MOH held. Meetings with Honduras MOH will begin April 1, 2024. These will be meetings to support feedback between MOH and SISTEMA team, which will facilitate mutual understanding and future adoption
6	Y2, Q4	**Pan-Tropical, MESM1, MESM2, Capacity Building**	
7	Y3, Q1	**Pan-Tropical, MESM1, MESM2, Data Updates**	
7	Y3, Q2	**Pan-Tropical, MESM1, MESM2, ECS Development, Capacity Building**	
8	Y3, Q3	**Pan-Tropical, MESM1, MESM2, Data Updates, Capacity Building**	
8	Y3, Q4	**Pan-Tropical, MESM1, MESM2, ECS Development, Capacity Building**	



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ARL Performance

- Start-of-Project ARL = 4 *(6/1/2022)*
  - Leveraging prior completed work in the Amazon to demonstrate potential
- Goal ARL = 8
- Current ARL = 6 *(3/1/2024)*
  - We have evaluated Machine Learning models to forecast malaria at different spatial scales and have had success in predicting past trends. We have evaluated how our method can inform local malaria trends and so far, the approach has been successful

ARL 6 - Supporting Evidence

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We have 3 main SISTEMA products:

1. The **Environmental Characterization System** or ECS
   - LDAS – modeling COMPLETE and VALIDATED
   - Pan-Tropical Analysis – model is COMPLETE, climate & malaria modelers working to develop joint model
   - LULC – all non-radar LULC classifications COMPLETE in Panama & Honduras
   - LULC Radar – analysis begins this month
2. **Vector Habitat Model**
   - Reconstructing *Anopheles* database - COMPLETE
   - Merged Vector, LDAS and LULC data –COMPELTE, model is pending
3. **Malaria Forecast Model**
   - Malaria Surveillance, LDAS, LULC and Pan-Tropical data merging COMPLETE
   - Machine Learning models COMPLETE
   - Dashboard with LDAS, Malaria Surveillance, etc. construction begun

ECS Accomplishments

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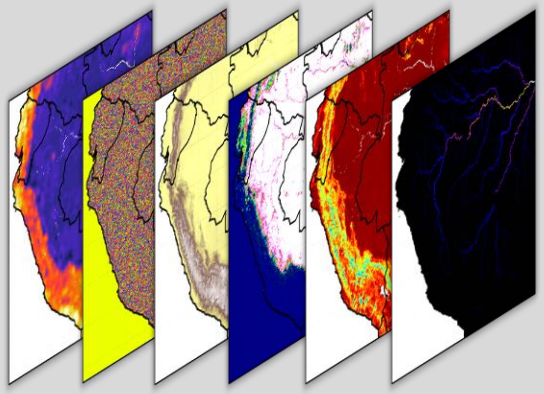
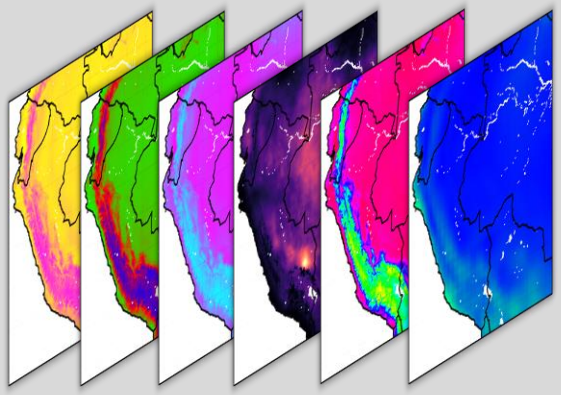
1. LDAS
2. **El NINO Forecasts**
3. **Pan-Tropical Malaria Modeling**

LANDSCAPE INFORMATION



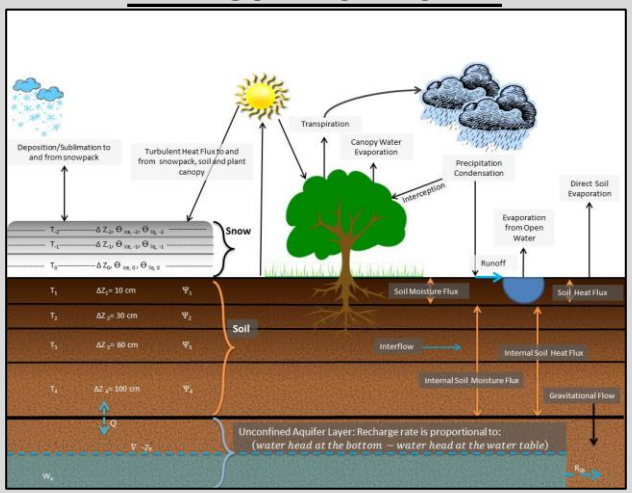
(SLOPE, ASPECT, ELEVATION, LANDCOVER, ALBEDO…)

METEOROLOGICAL INFORMATION



(RAINFALL, AIR TEMPERATURE, WIND SPEED, SOLAR RADIATION…)

LAND SURFACE MODEL

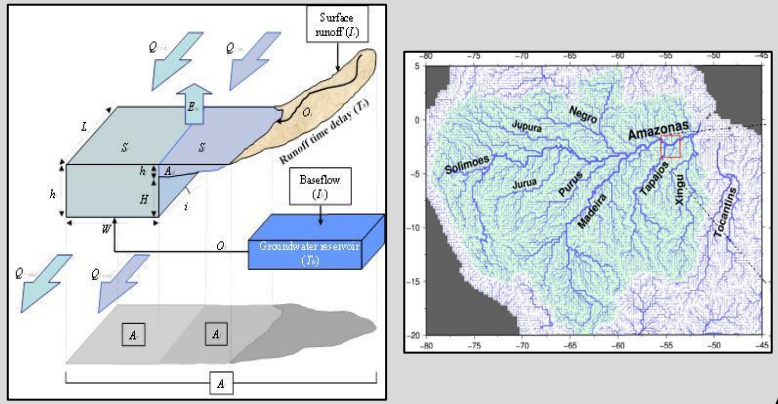


DATA ASSIMILATION (UPDATE OBSERVATIONS)

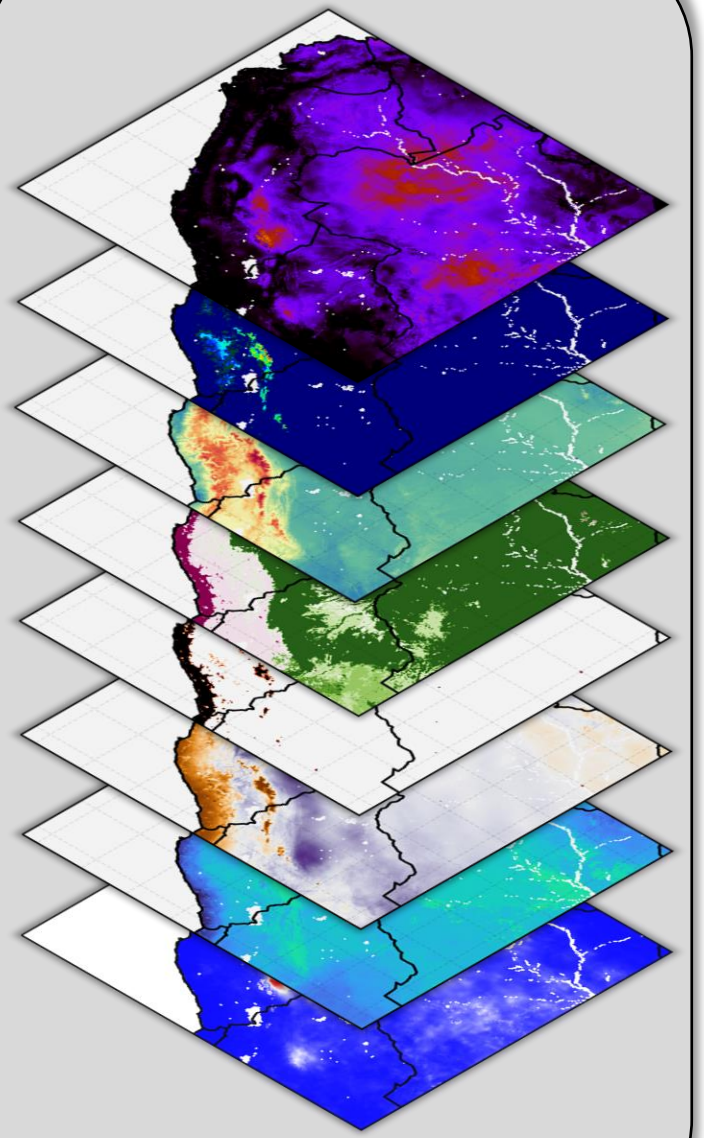
SATELLITE DATA

IN-SITU DATA

ROUTING MODEL

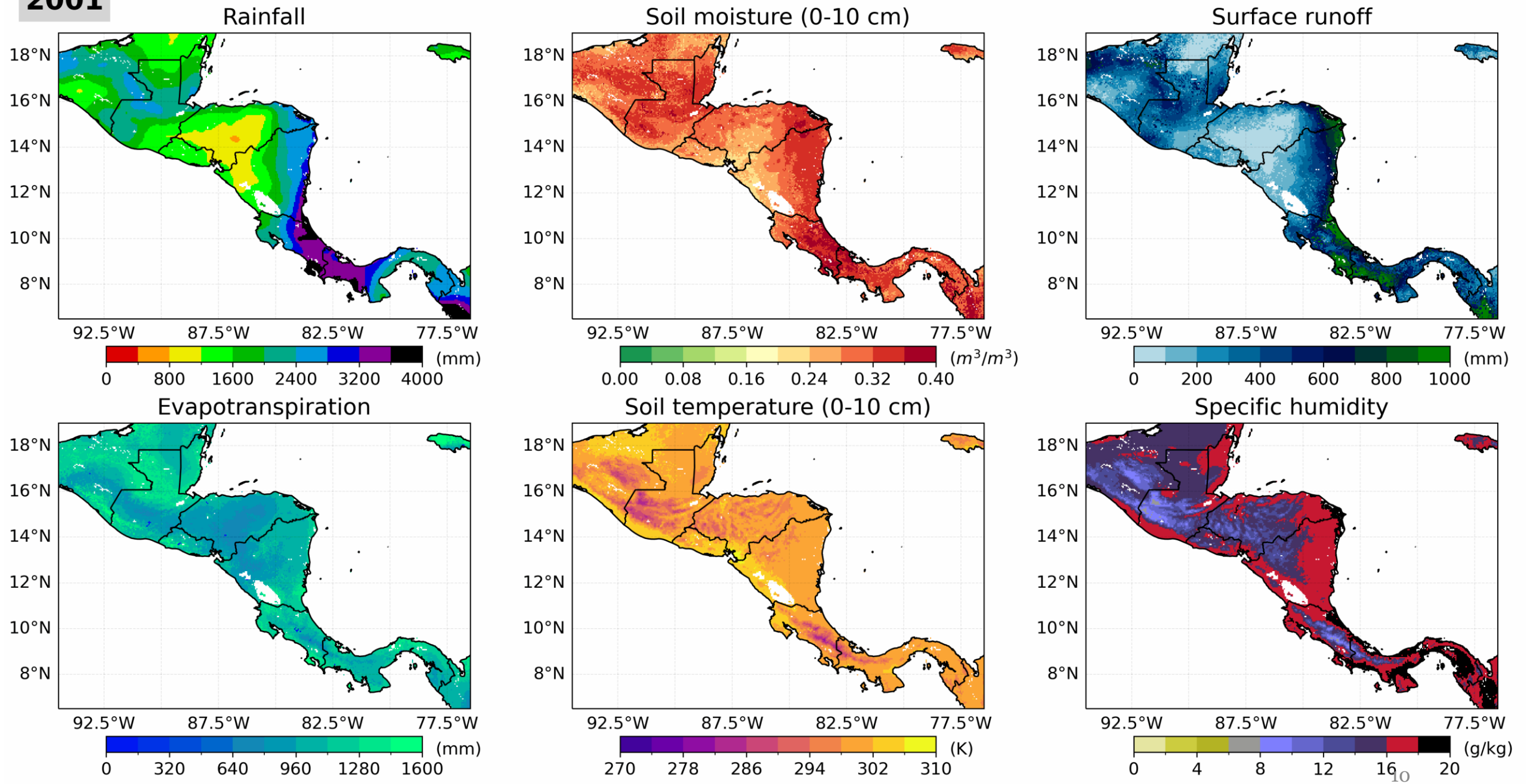


MODEL OUTPUTS



(SOIL MOISTURE, EVAPOTRANSPIRATION, SURFACE RUNOFF, STREAMFLOW…)

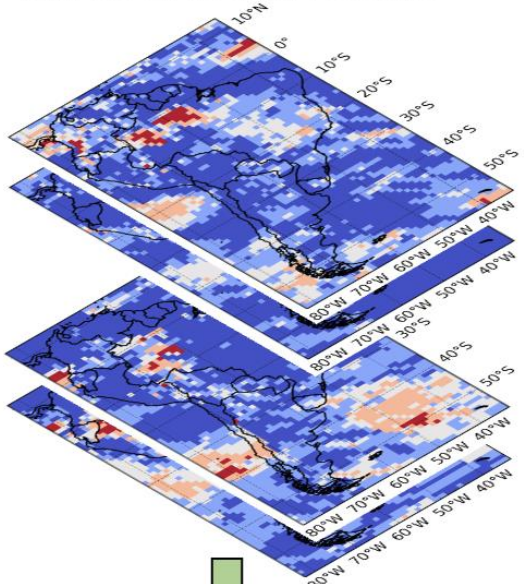
2001


Rainfall
18°N
16°N
14°N
12°N
10°N
8°N
92.5°W
87.5°W
82.5°W
77.5°W
0
800
1600
2400
3200
4000
(mm)
Soil moisture (0-10 cm)
0.00
0.08
0.16
0.24
0.32
0.40
(m^3/m^3)
Surface runoff
0
200
400
600
800
1000
(mm)
Evapotranspiration
0
320
640
960
1280
1600
(mm)
Soil temperature (0-10 cm)
270
278
286
294
302
310
(K)
Specific humidity
0
4
8
12
16
20
(g/kg)

FLOWCHART FOR CATEGORICAL PROBABILITY EXCEEDANCE MAPS

HINDCAST RECORD

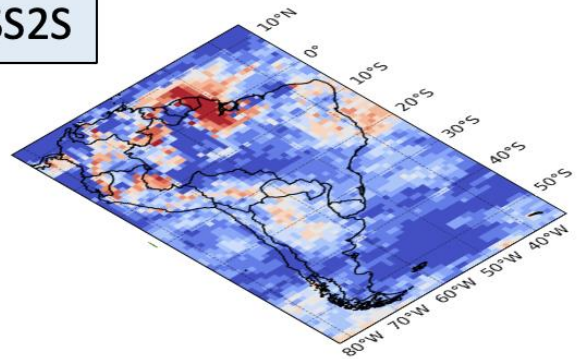
1981
1982
.
.
.
2015
2016



FORECAST

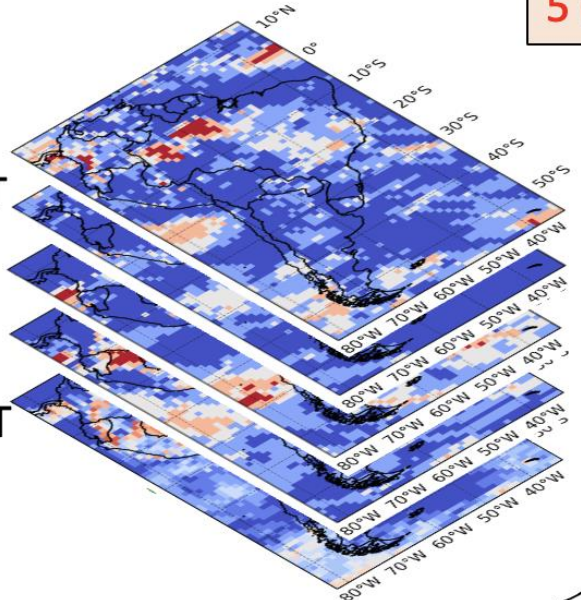
NMME
GEOSS2S

2023



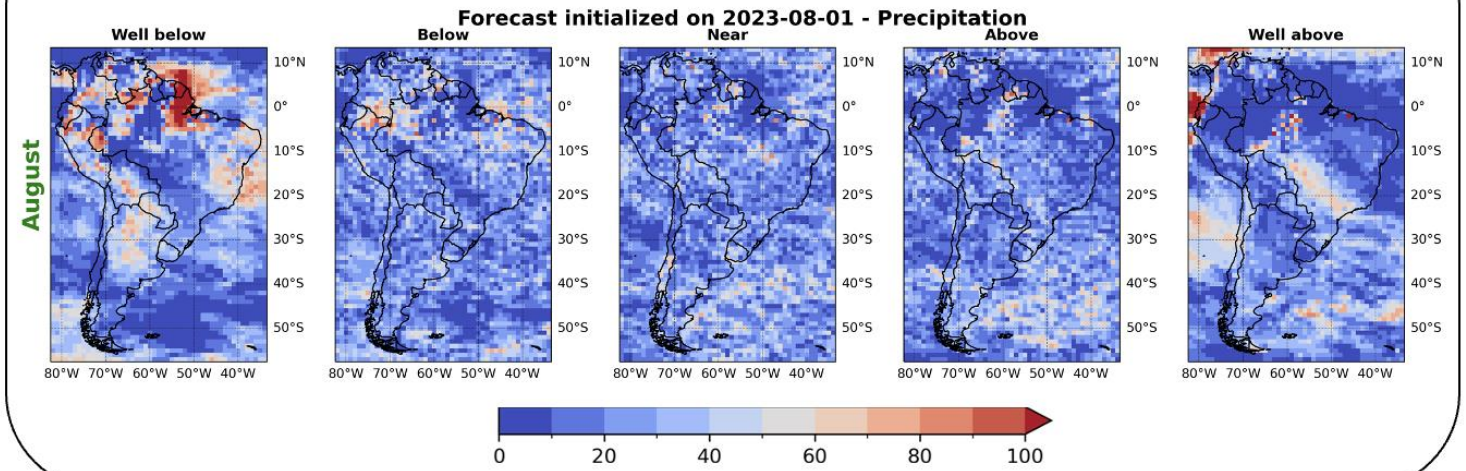
RANKED DATA

LOWEST
.
.
.
HIGHEST



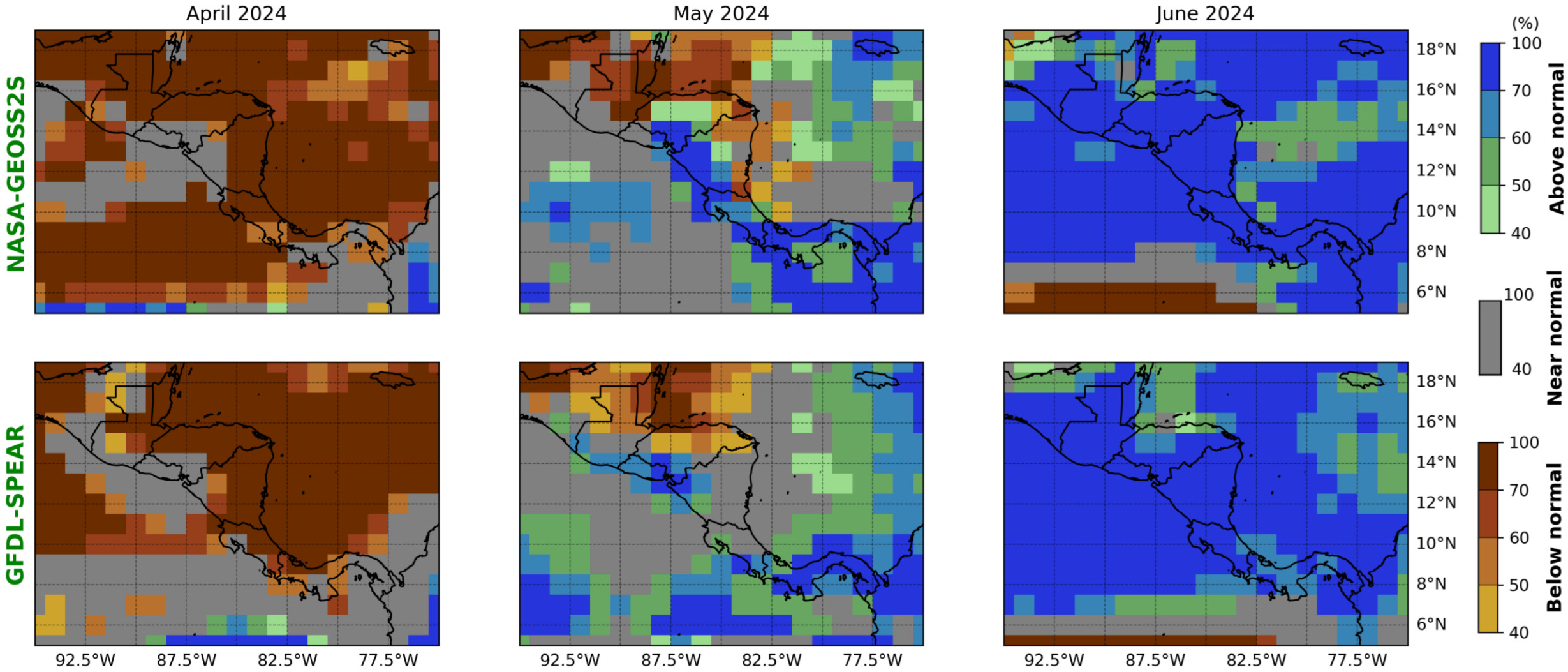
5 categories

QUINTILE CATEGORY PROBABILITY EXCEEDANCE MAPS



Precipitation - Forecast probability (Tercile categories)

[Issued April 1, 2024]



Dynamic SST Index Identification for Longer Lead Time of malaria forecast

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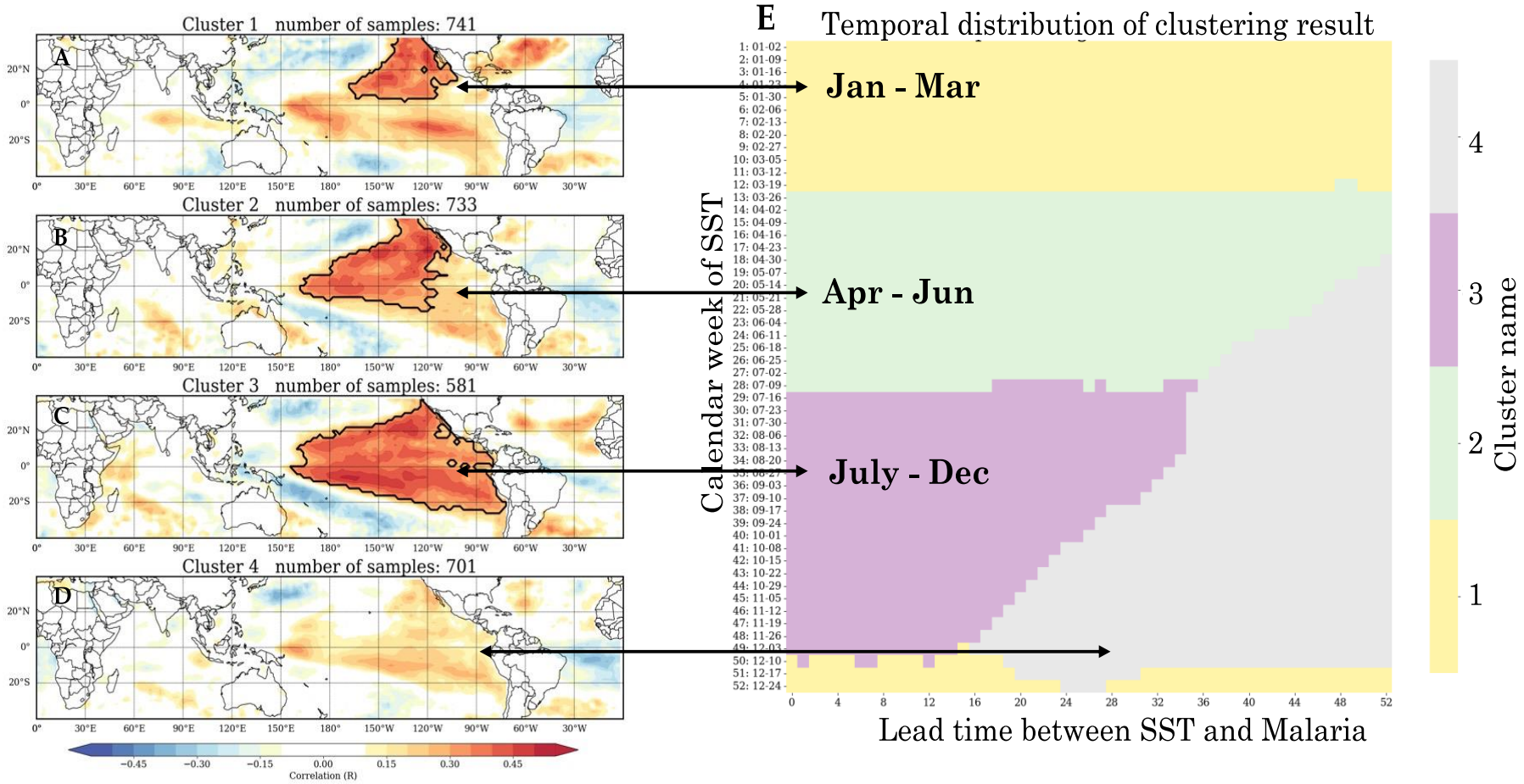
Dynamic sea surface temperature index identification



4 SST clusters identified indicating high correlation with malaria rates at different times of the year with different lead times

Dynamic SST Index Identification for Longer Lead Time of malaria forecast

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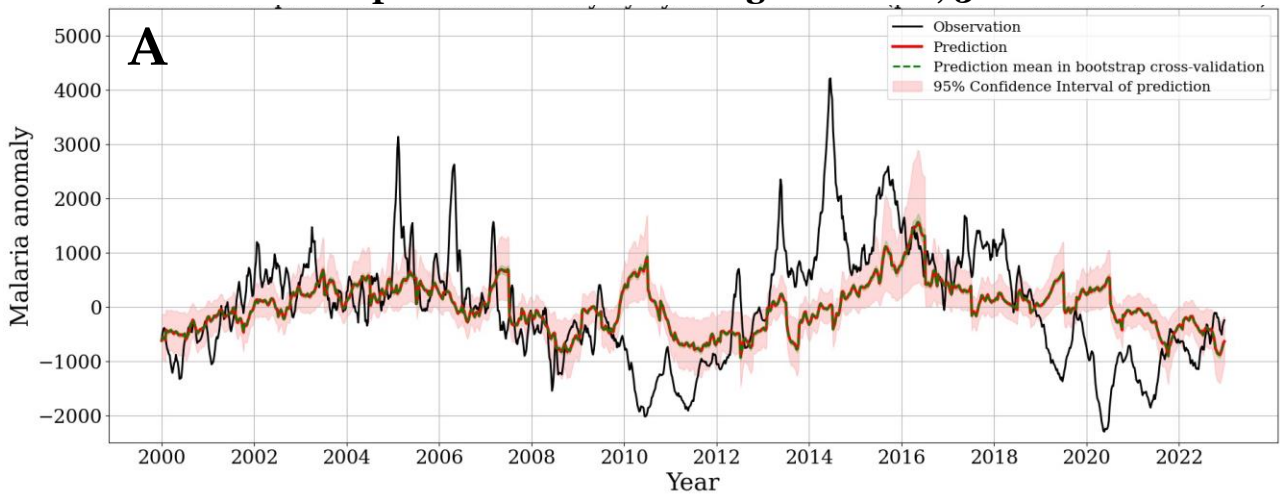
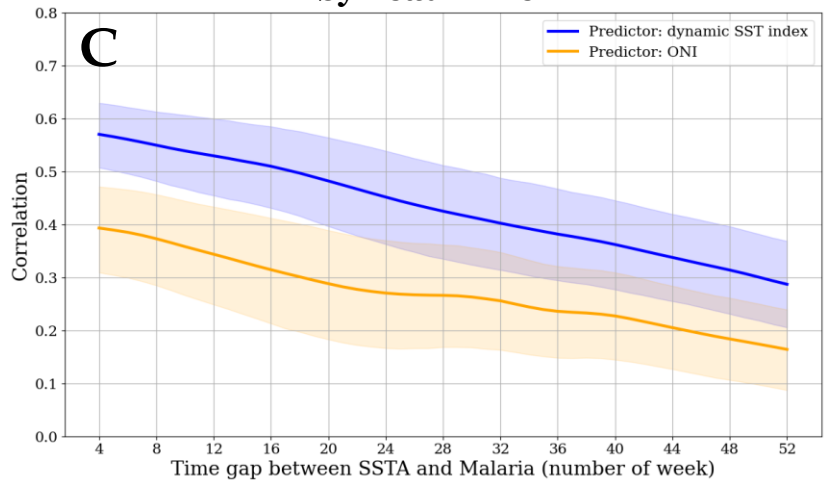
Observed vs predicted malaria using SST index, 30 wk lead time

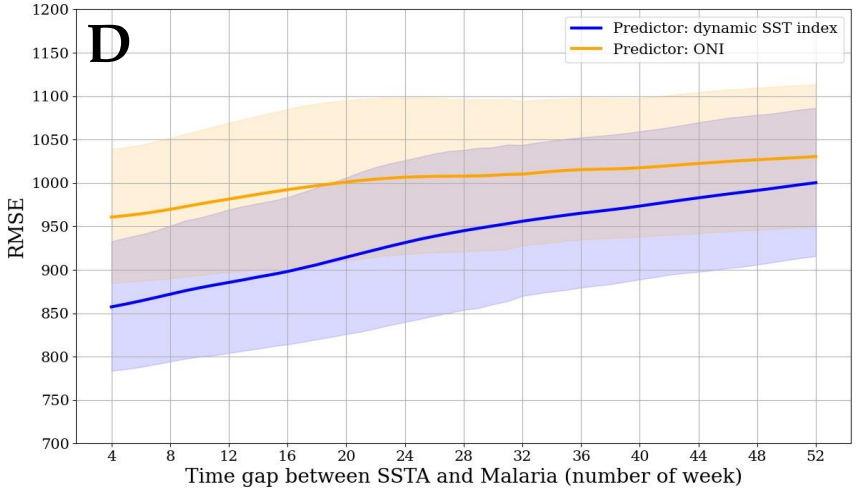


Observed vs predicted malaria using ONI ENSO index, 30 wk lead time

Correlation (observed, predicted malaria) by Lead Time



RMSE (observed, predicted malaria) by Lead Time



Our dynamic SST Index outperforms ONI ENSO Index for predicting malaria (30-week lead time)

Vector Habitat Modeling

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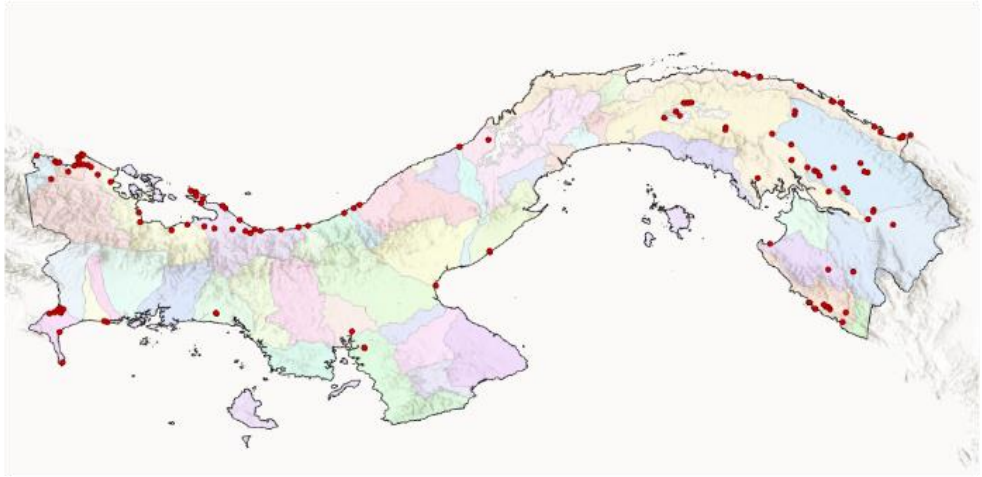
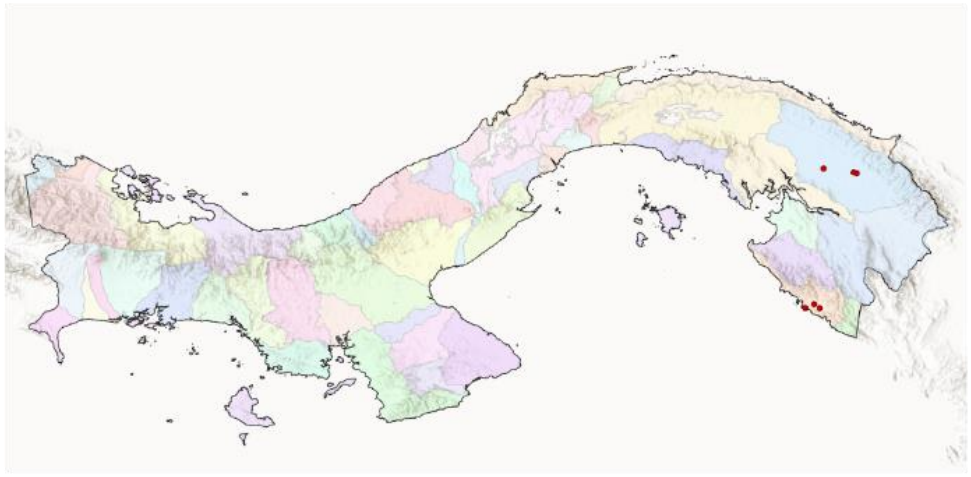
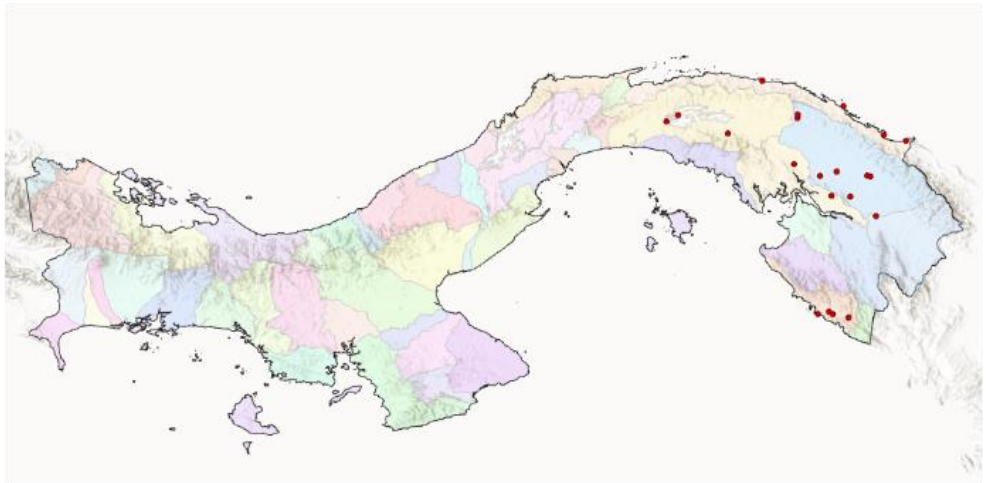
A. albimanus



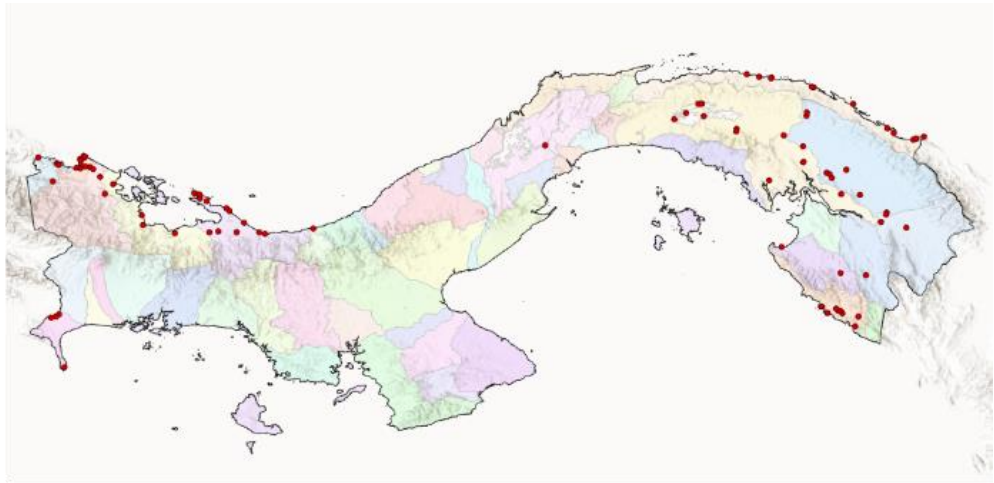
A. darlingi



A. pseudopunctipennis



A. punctimaculata



Malaria Forecast Model (2022)

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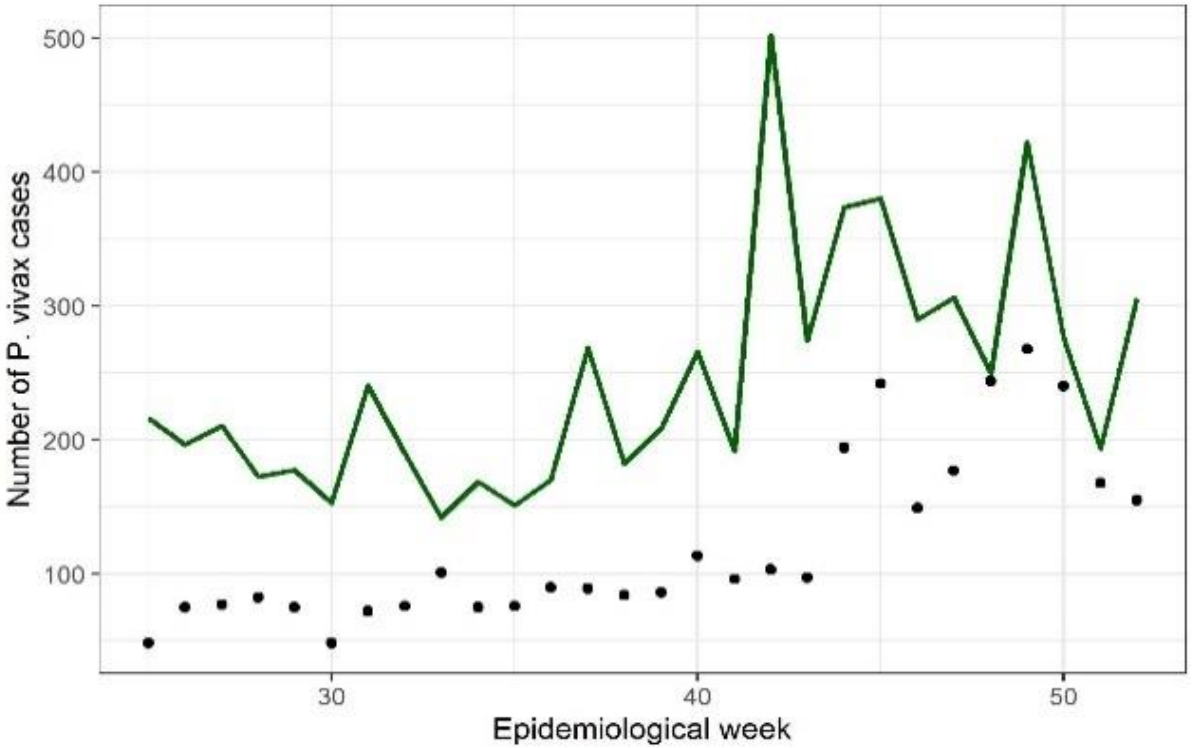
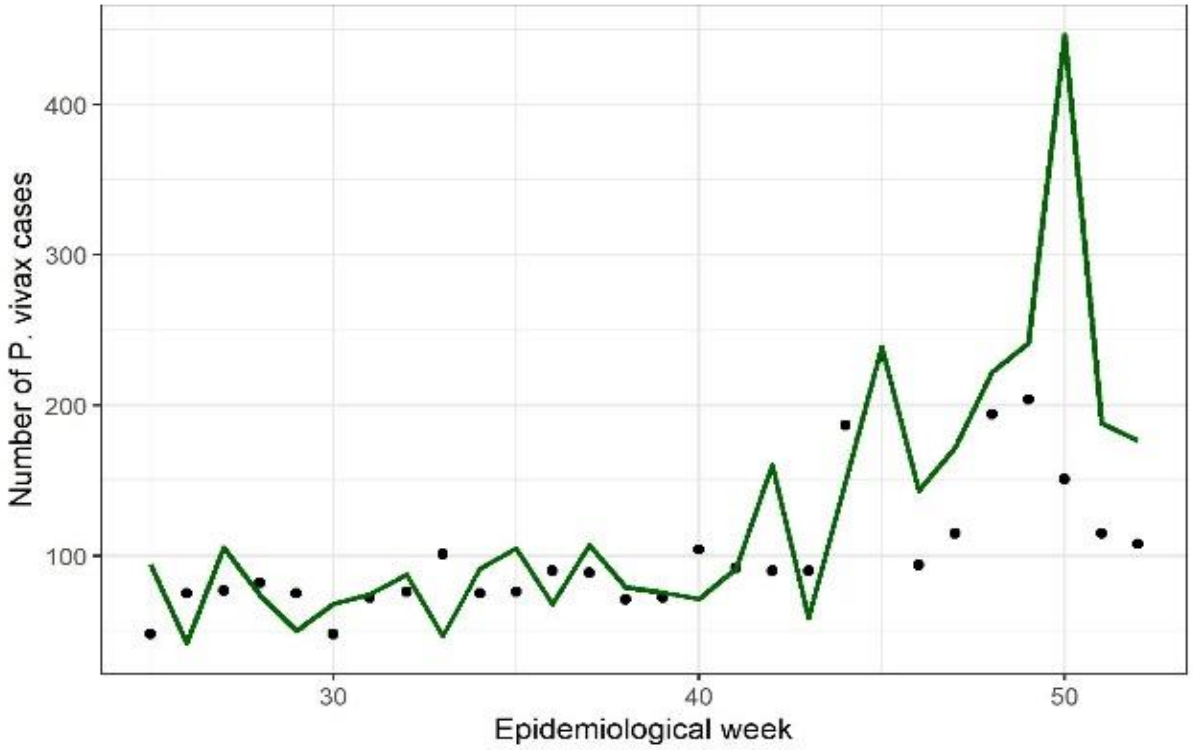
Forecasts at the **Locality (left)** and **Region (right)** Levels using *Extreme Gradient Boosting*



9-month forecast across 340 localities where malaria cases >0



9-month forecast across REGIONS where malaria cases >0

Malaria Dashboards

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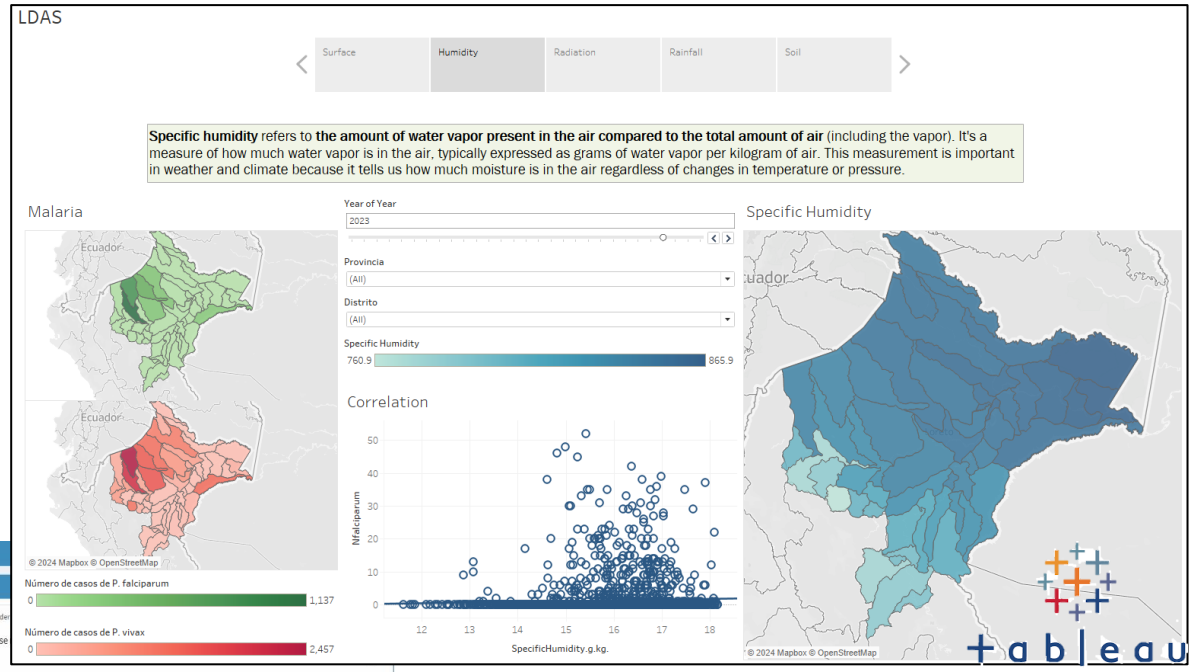
ArcGIS



Shiny
by RStudio

Mock-Ups of Dashboards

Data Flow

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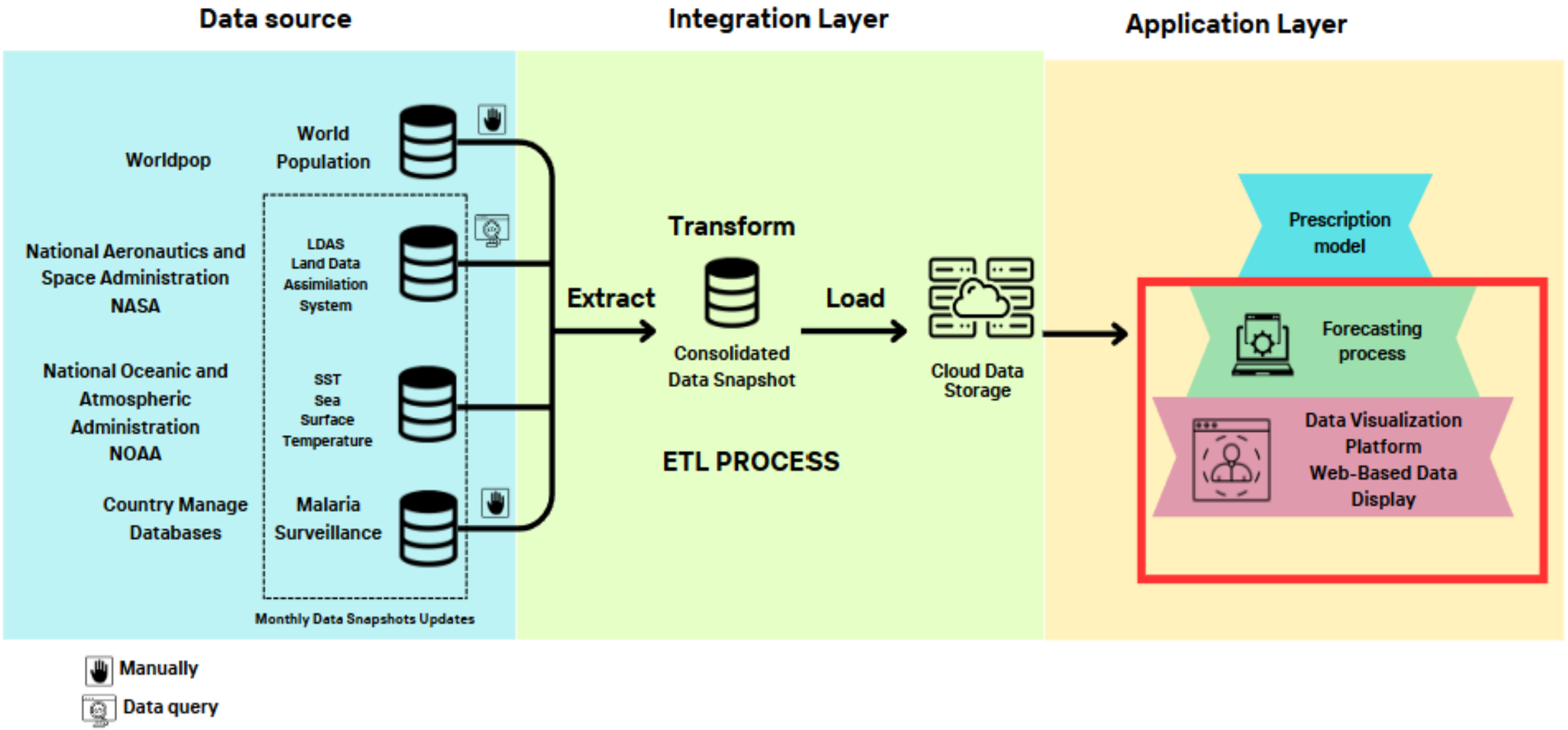

THANK YOU!

QUESTIONS?