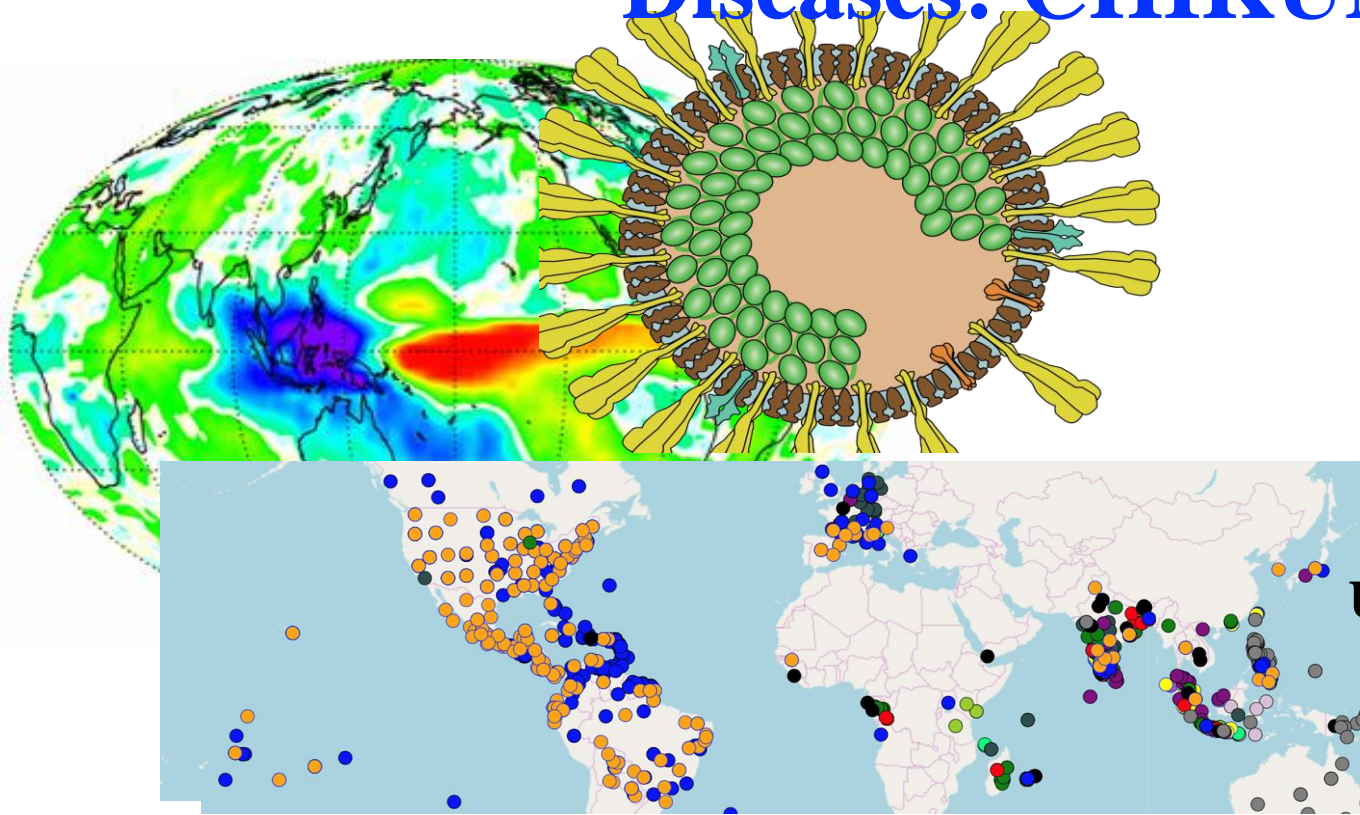# Mapping, Monitoring and Forecasting Climate-sensitive Diseases: CHIKUNGUNYA (CHIKRisk)

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Greenbelt, MD.

NASA Health and Air Quality Applications Program Review
September 21, 2020

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NASA Goddard Space Flight Center**

CHIKUNGUNYA VIRUS (CHIKV)

- Mosquito-borne, viral infection

- First described in Tanzania in 1952 – derived from Makonde word **kungunyala** meaning "that which bends up"

- Know to circulate in a sylvatic cycle between forest-dwelling mosquitoes and nonhuman primates in Central/East Africa

- Symptoms include fever, rash and severe joint pains that may cause stoop posture

- Rarely causes death, but can be debilitating

- Neither vaccine nor specific medicine are available for Chikungunya

- Loss of Duty Days due to sickness

- Economic impacts – especially tourism during epidemic periods

- Episodic epidemics and outbreaks across the tropics

- Transmitted by *Aedes aegypti* and *Aedes albopictus* mosquito vectors

BACKGROUND AND MOTIVATION

- Chikungunya outbreaks in East Africa and Indian Ocean Islands – drought-associated [Chretien JP et al., 2007]

- ENSO teleconnections – opposing anomaly conditions between Rift Valley fever (wet and cool) and chikungunya (hot and dry) in Africa and SE Asia [Anyamba et al., 2012]

- Chikungunya spread – mutation of East/Central Africa genotype enhance transmission by *Aedes Albopictus* to Asia and other areas [Zeller et al., 2016]

- Global spread – Italy (2007), Americas (2013 – to present)

- Effect of drought / temperature induced dehydration on blood feeding frequency [Hagan et al., 2007]
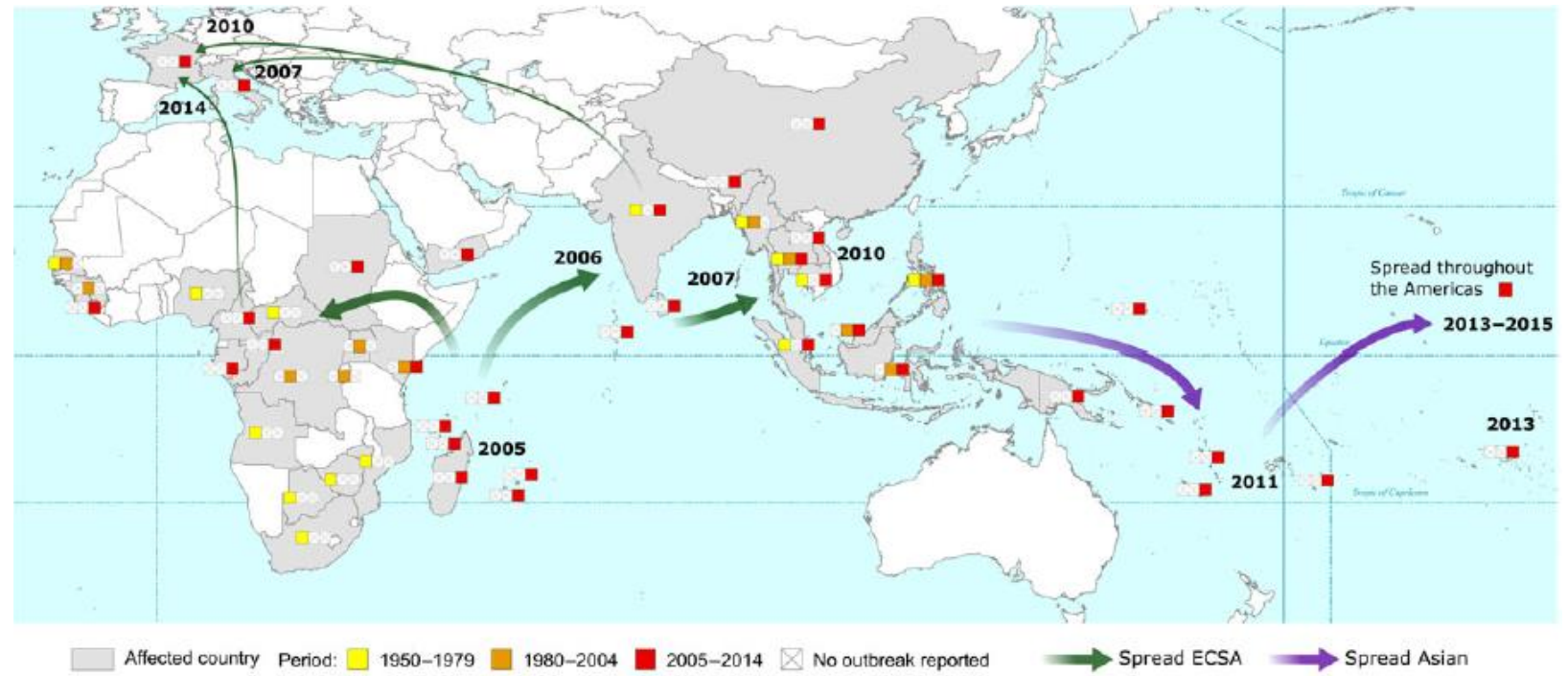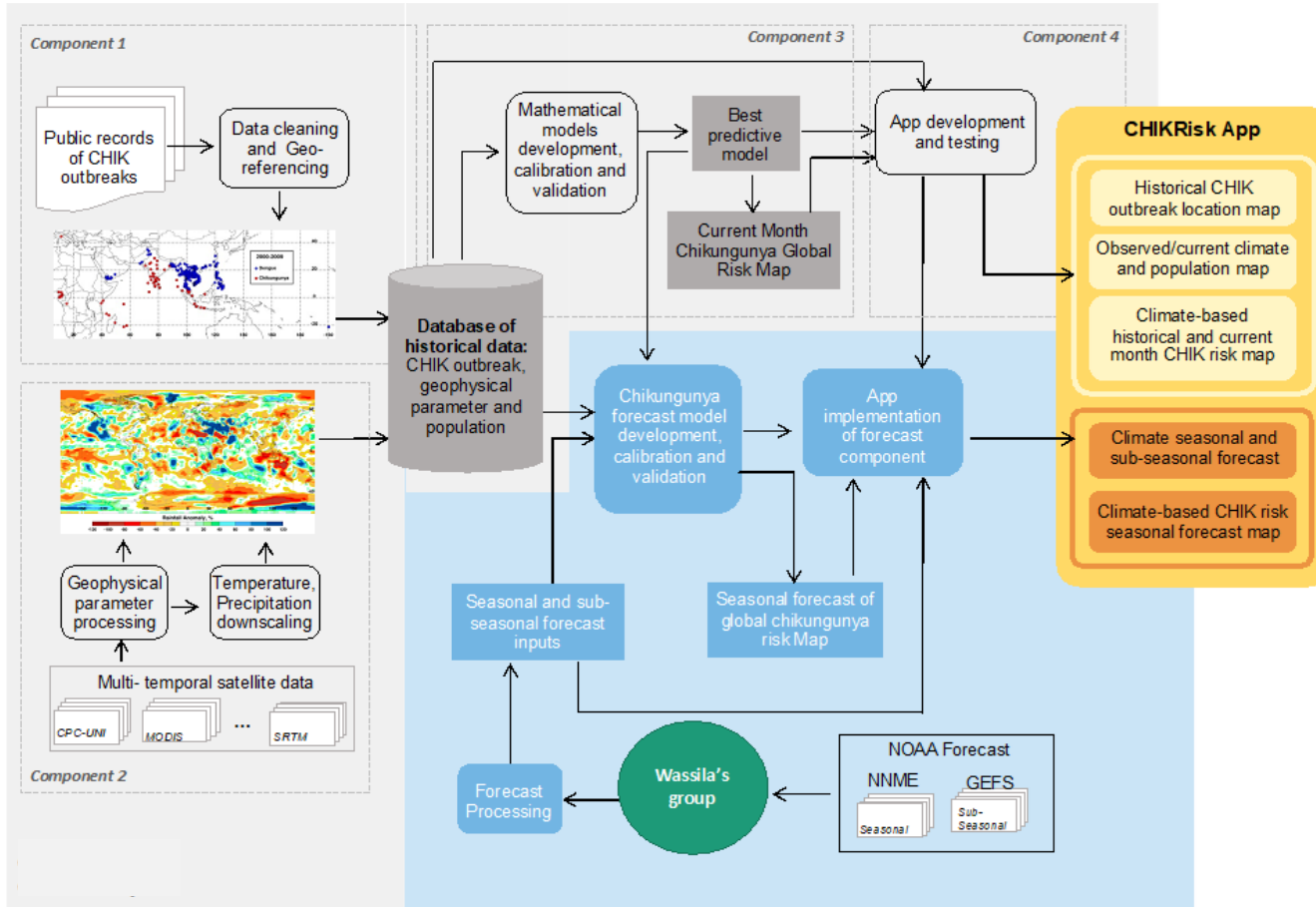

[Zeller et al., 2016]

CLIMATE ANOMALIES

- Chikungunya activity in eastern Africa and southeast Asia, 2004 – 2007
- Hot and dry conditions persist in locations reporting chikungunya activity

Land Surface Temperature, Jun 2004 - Aug 2004

Rainfall Anomaly, Dec 2006 - Feb 2007
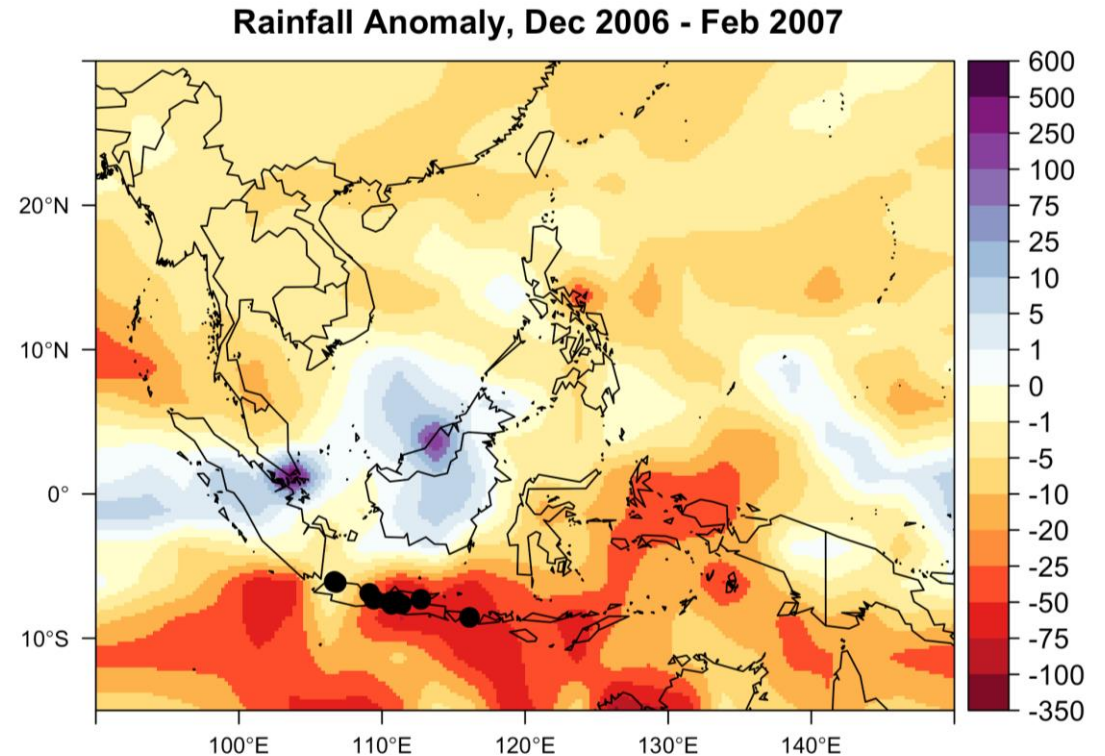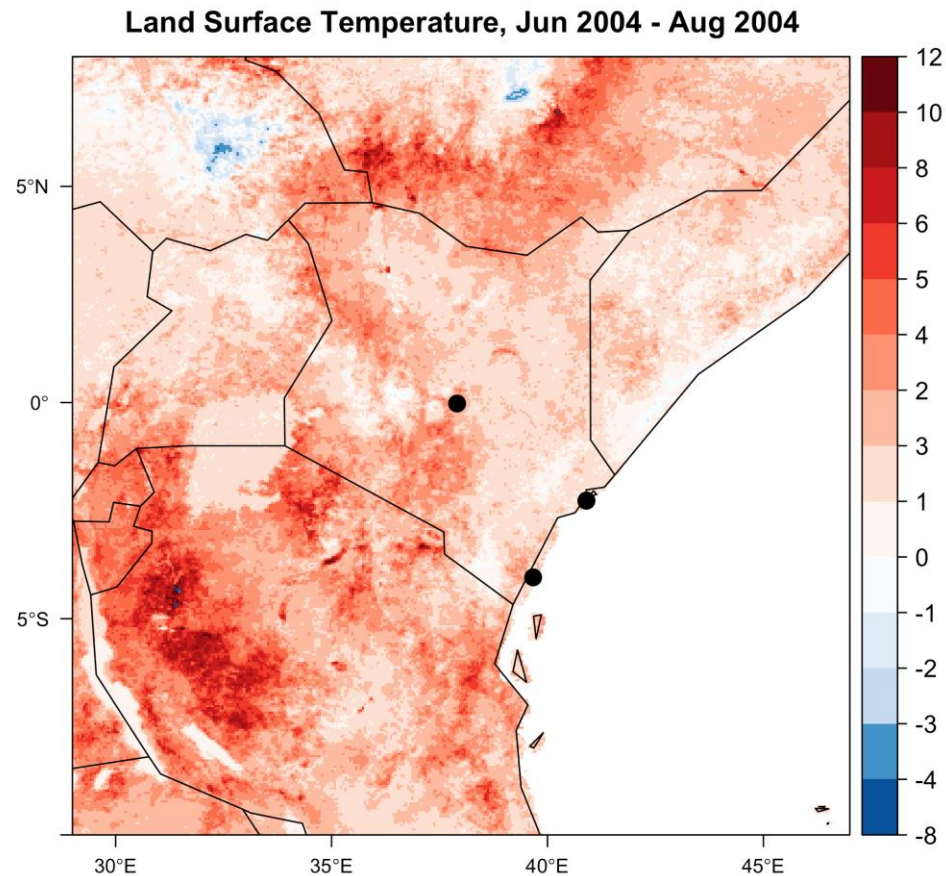
PROJECT OVERVIEW

Science + Technology Activity

TRL 7 – We have demonstrated the technology

TRL 8 – Field testing with field application this year

CHIKRisk App addresses
- Where has chikungunya activity occurred
- Where is it occurring now
- Which regions are currently at risk for chikungunya
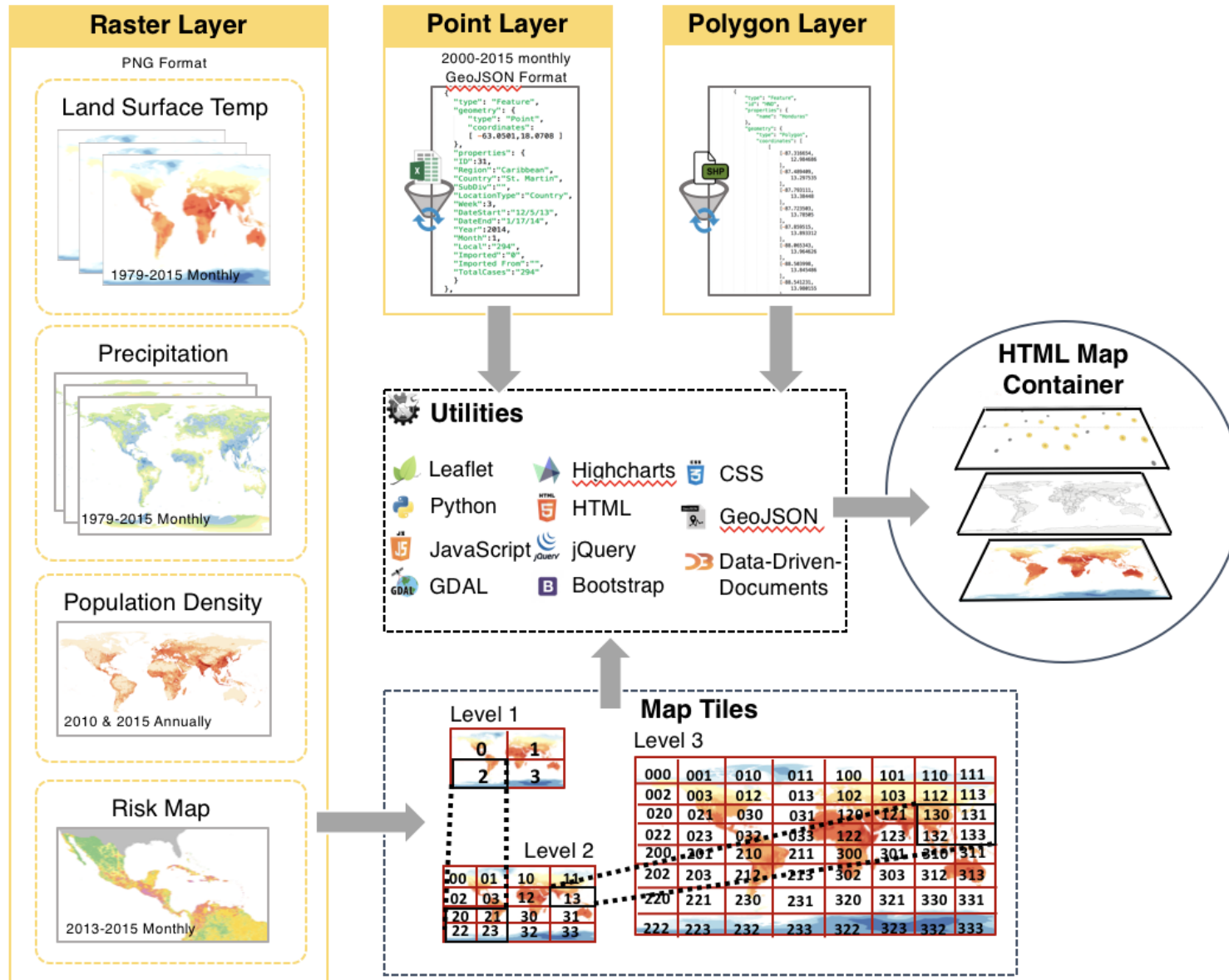- Which regions are at risk in the future

Products
- Monthly chikungunya risk map
- Forecast risk map (up to 6 months lead time)
- Locations of reported chikungunya occurrence

Customers
- Defense Health Agency – Armed Forces Health Surveillance Center
- Pan-America Health Organization

CHIKRisk App

CHIKUNGUNYA HISTORICAL OCCURRENCE DATA

Main Resource

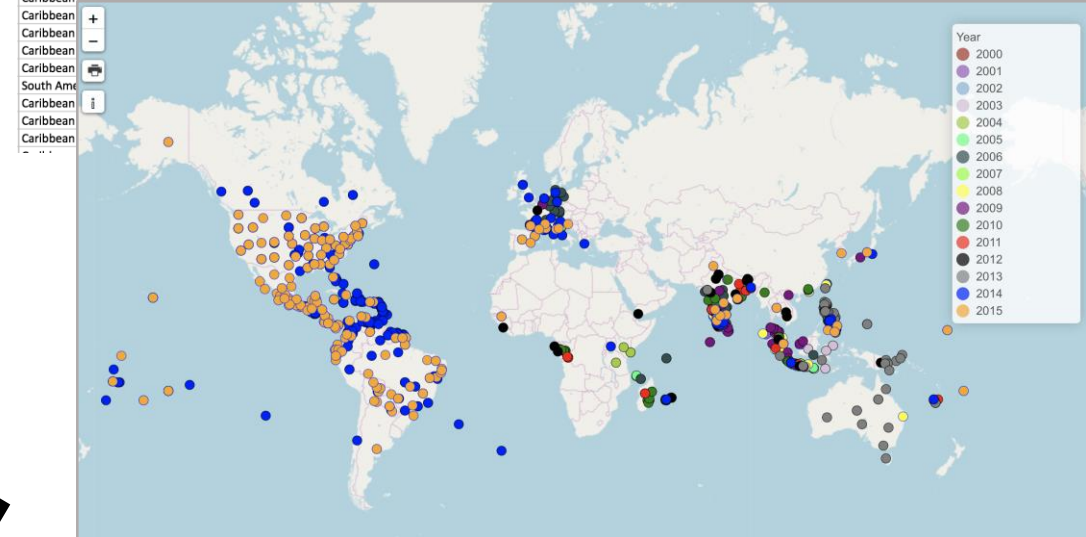- Reported outbreaks catalogued and georeferenced based on closest "named" location

Costa Rica. 4 Mar 2016. (reported) 1167 cases; Localities most affected: Central Pacific coast 555 cases; Guanacaste province 372 cases

Honduras. 29 Feb 2016. (reported) 4000 cases; Deaths

CHIKUNGUNYA HISTORICAL OCCURRENCE DATA

ProMED, 1999 to present

Other Sources:

Armed Forces Health Surveillance Branch (AFHSB) Health Surveillance Update (AHSU) reports – for confirmation (2014 – Present)

Weekly, country-level, chikungunya bulletin for the Americas, 2014 – 2017
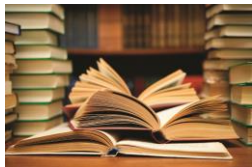
Literature – searched through PubMED for outbreaks prior to 2000; **Local Ministry of Health** publications, including CDC MMWR

Historical chikungunya locations from literature

Year of Incidence

- <1900
- 1901 - 1951
- 1952 - 1970
- 1970 - 1990
- 1991 - 2000
- 2001 - 2010
- >2010

CLIMATE AND ANCILLARY DATA

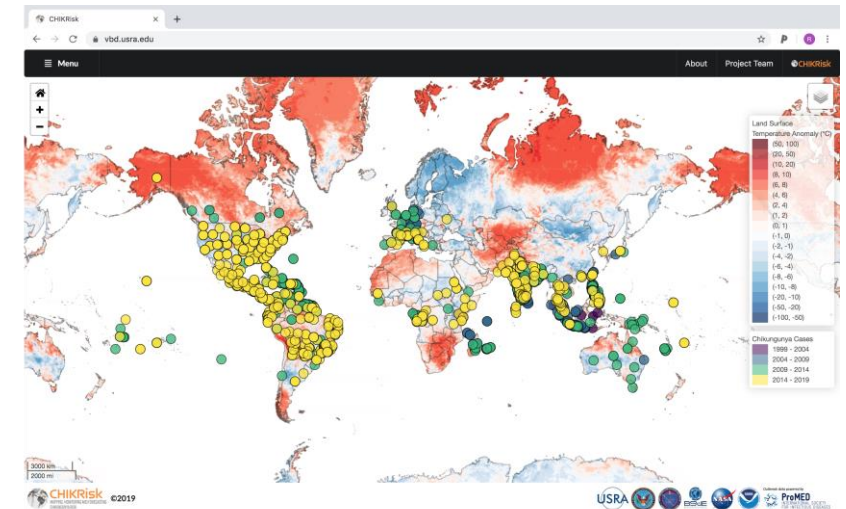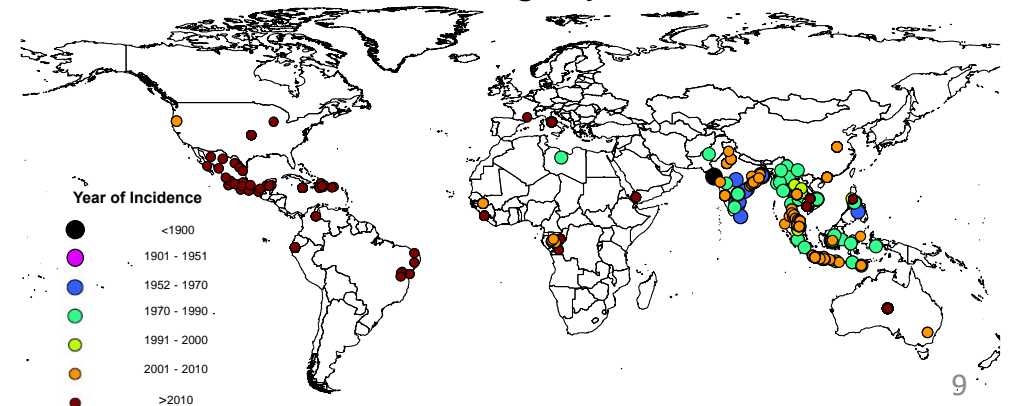| Geophyisical Variable	Dataset	Coverage		Resolution		Processing Status
		Spatial	Period	Spatial	Temporal	
Rainfall	Global Precipitation Climatology Project (GPCP)	Global	1979 - Current	1° (100 km)	Monthly	✓
	Tropical Rainfall Measuring Mission (TRMM) 3B42	50°N-50°S, 180°W-180°E	1998 - 2015	0.25°(25 km)	Monthly	Excluded
	GPM - 3IMERGHH	Global	2015 - Current	0.1° (11 km)	30 minutes	Excluded
	Climate Prediction Center Unified (CPC-UNI)*	Global	1979 - Current	0.5° (50 km)	Daily	✓
	CPC-UNI Morphing Technique (CMORPH)	Global	1998 - Current	8 km	30 min	✓
Land Surface Temperature	Moderate Resolution Imaging Spectroradiometer (MODIS)*	Global	2000 - Current	0.05° (5 km)	Daily	✓
Near Surface Temperature	Global Land Data Assimilation (GLDAS)	Global	2000 - Current	0.25°(25 km)	3-Hourly, Monthly	✓
Specific Humidity	Global Land Data Assimilation (GLDAS)	Global	2000 - Current	0.25°(25 km)	3-Hourly, Monthly	✓
Vegetation Index	Moderate Resolution Imaging Spectroradiometer (MODIS)	Global	2000 - Current	250 m	16 day	Excluded
Soil Moisture	Global Land Data Assimilation (GLDAS)	Global	2000 - Current	0.25° (25km)	3-Hourly, Monthly	✓
Elevation	Shuttle Radar Topography Mission (SRTM)	Global		90 m		
Population	NASA Socioeconomic & Social Data Center	Global		1 km		✓
Rainfall & Temperature Forecasts	The North American Multi-Model Ensemble*	Global		1° (~ 100 km)	Monthly, 3-Monthly	✓

* Available in CHIKRisk App

ANALYTICS: STATIC/ BASELINE INPUTS

Ae. Aegypti   Ae.Albopictus   Both

Population Density, 2015

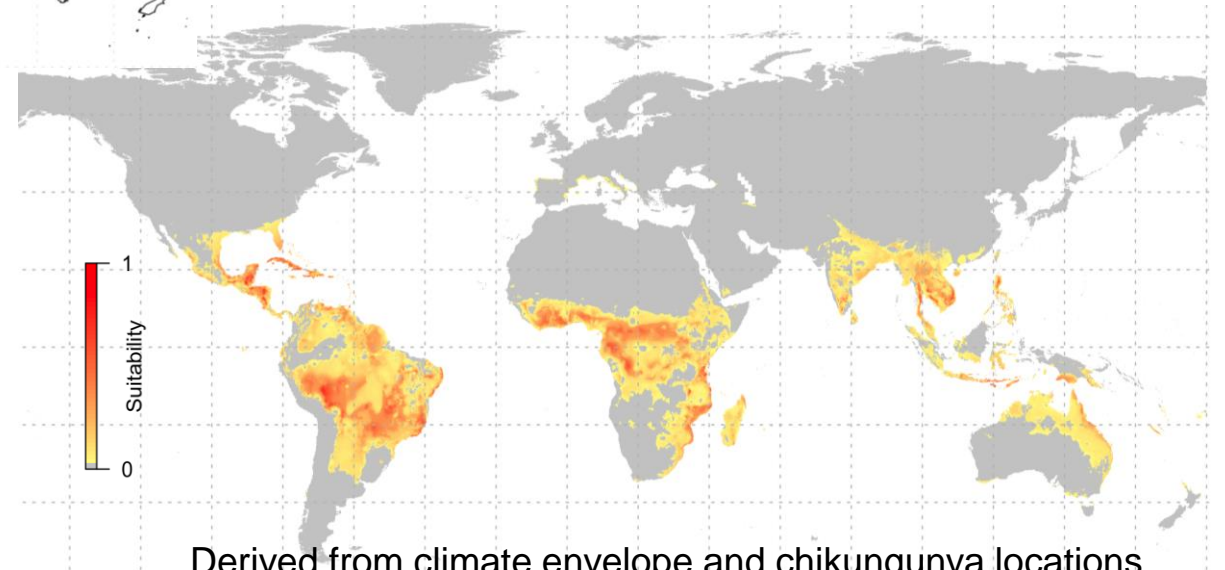Potential epidemic area
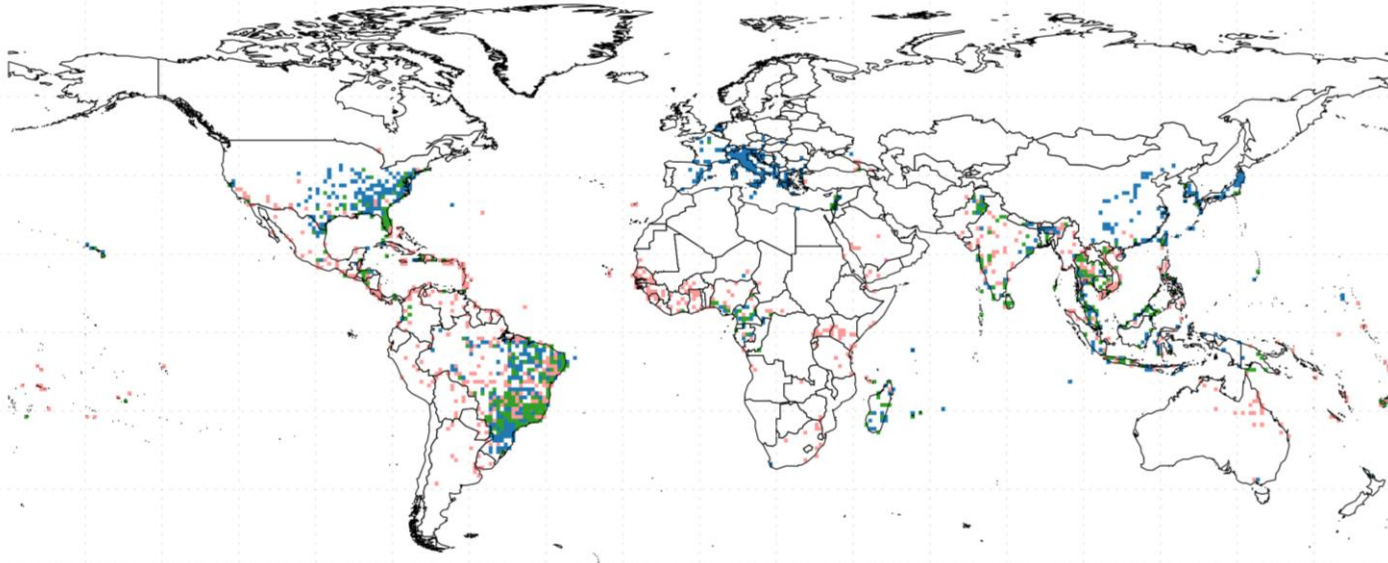
Mosquito vector locations

- VectorMap (Walter Reed Biosystematic Unit)
- VectorBase (National Institute of Allergy and Infectious Diseases (NIAID) Bioinformatics Resource Center (BRC))
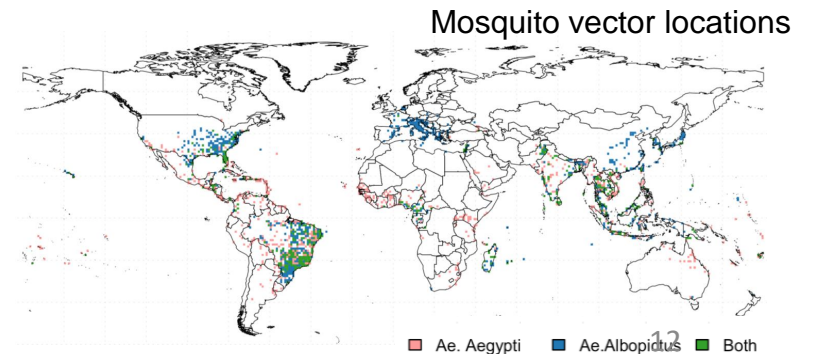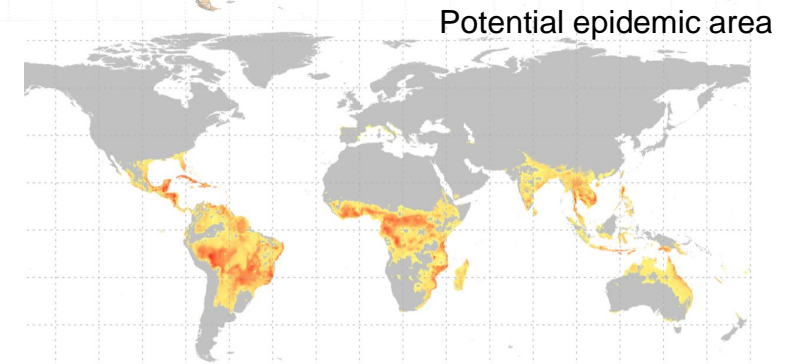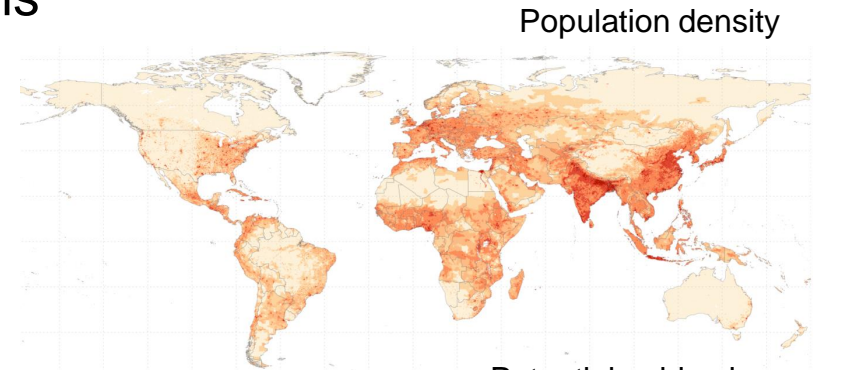
Suitability
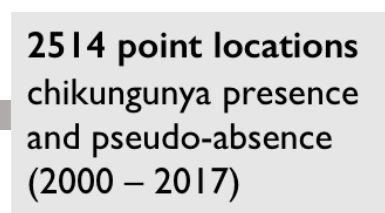
Derived from climate envelope and chikungunya locations

CURRENT CHIKUNGUNYA RISK MAPPING

Based on observed climate and historical chikungunya locations

Population density

90 Climate Variables

Land Surface Temperature

Precipitation

Air Temperature

Specific Humidity

Soil Moisture

anomaly

monthly

3 monthly

1 and 2 months lags

Machine Learning-Based Models
- Repeated 10-fold cross validations
- Final model is selected based on classification accuracy for data that had not been used in training the model

2514 point locations chikungunya presence and pseudo-absence (2000 – 2017)

Population Density

Chikungunya Risk Map

Chikungunya suitability map

Mosquito vector locations

Potential epidemic area

Mosquito vector locations

Accuracy
(calculated based on data not used in training the model)

Partial Least Square	0.808 (0.605, 0.775)
Neural Network	0.816 (0.783, 0.846)
Random Forest	**0.889 (0.861, 0.912)**
Support Vector Machine	0.815 (0.782, 0.844)

Ae. Aegypti   Ae.Albopictus   Both

CHIKUNGUNYA FORECAST

Substituted observed/assembled climate data with climate forecast

4 Climate Variables
- Precipitation
- Air Temperature
- anomaly
- monthly
- 3 monthly

Machine Learning-Based Models
- Repeated 10-fold cross validations
- Final model is selected based on classification accuracy for data that had not been used in training the model

2514 point locations chikungunya presence and pseudo-absence (2000 – 2017)

Population Density

Risk Map Model

Forecast Generation
Substitute air temperature and precipitation anomalies with forecasts data

Chikungunya suitability map

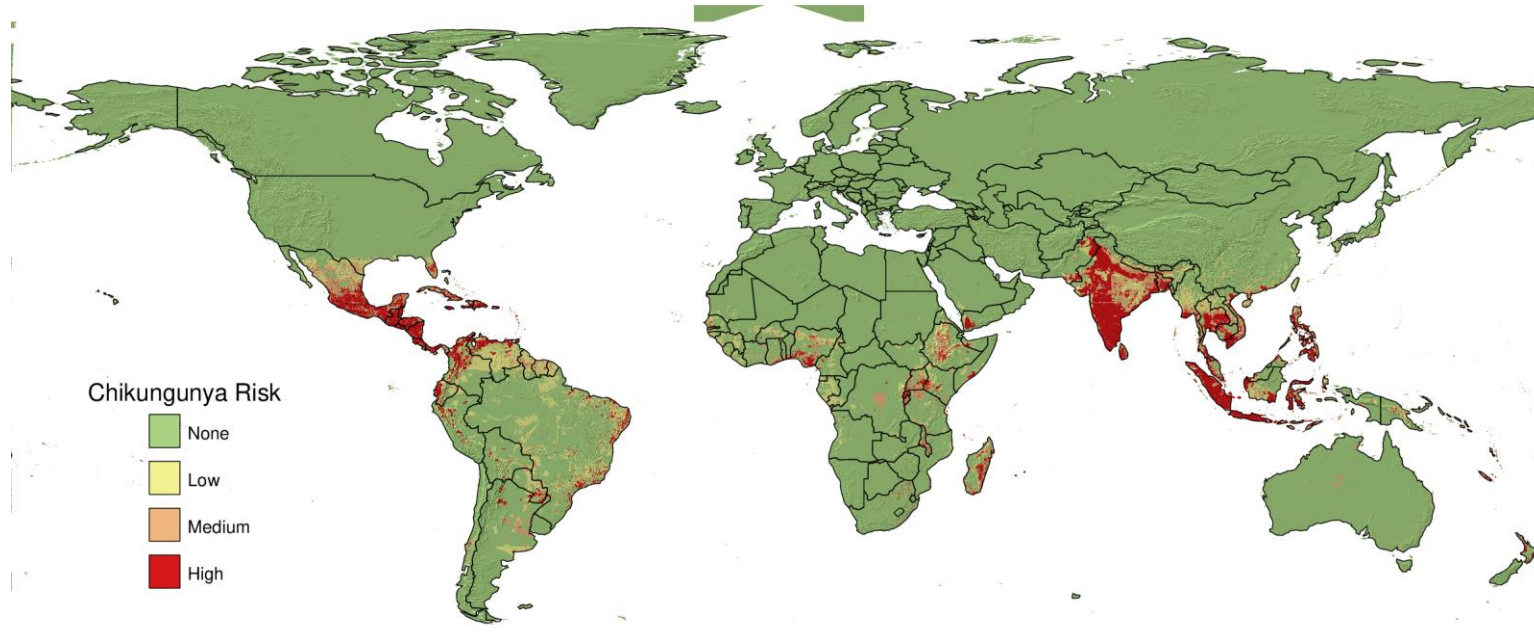Mosquito vector locations

Chikungunya Forecast Risk Map

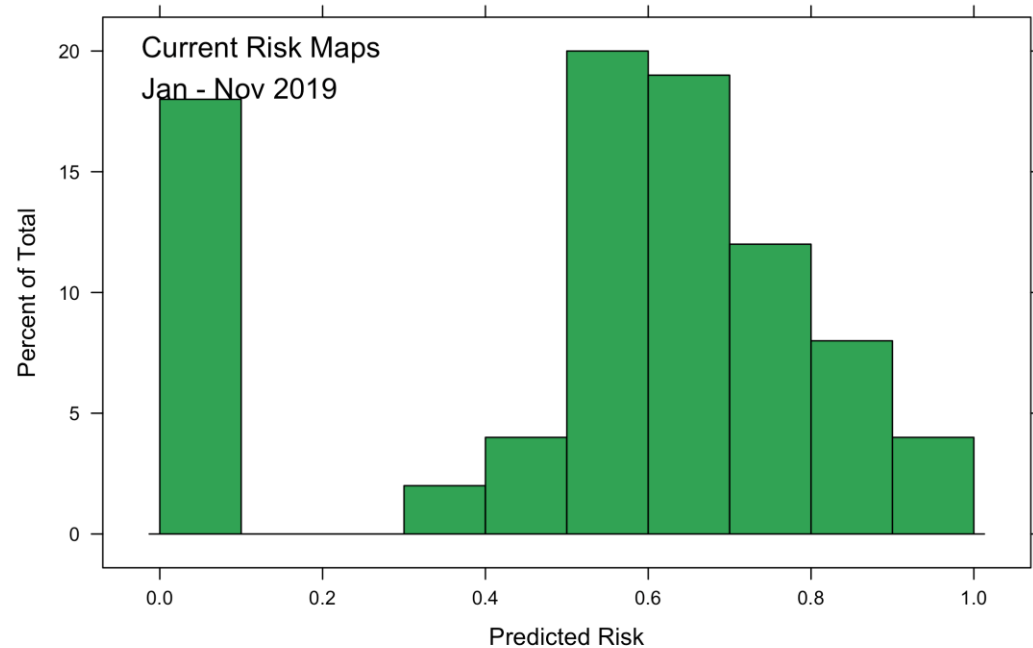Random forest had highest performance with accuracy of: 0.859 (95% CI: 0.829, 0.886)
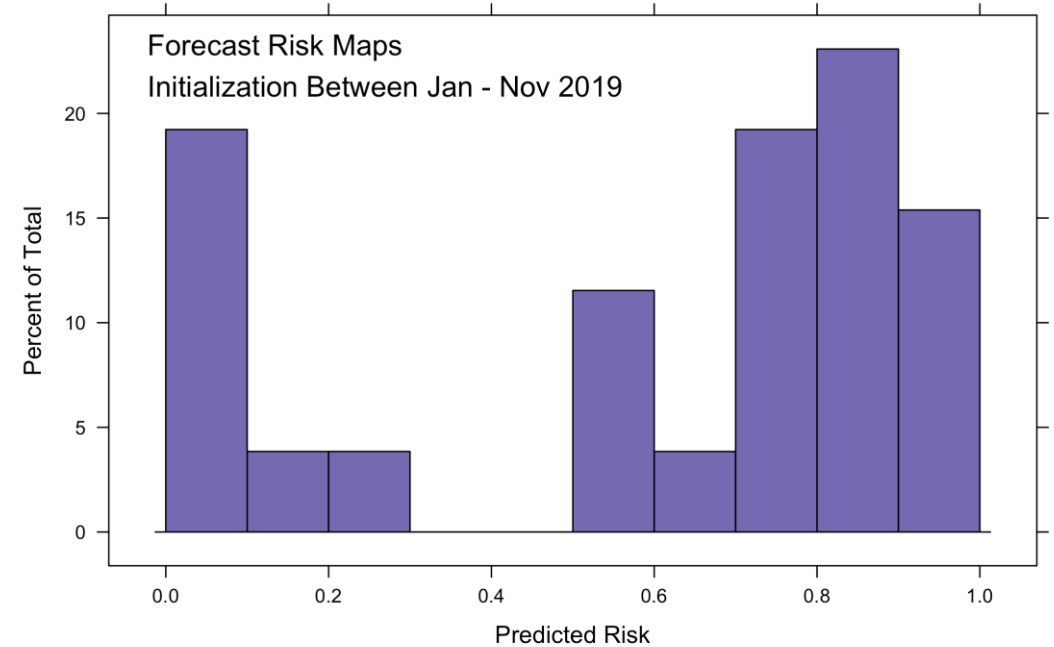
Chikungunya Risk for November 2019
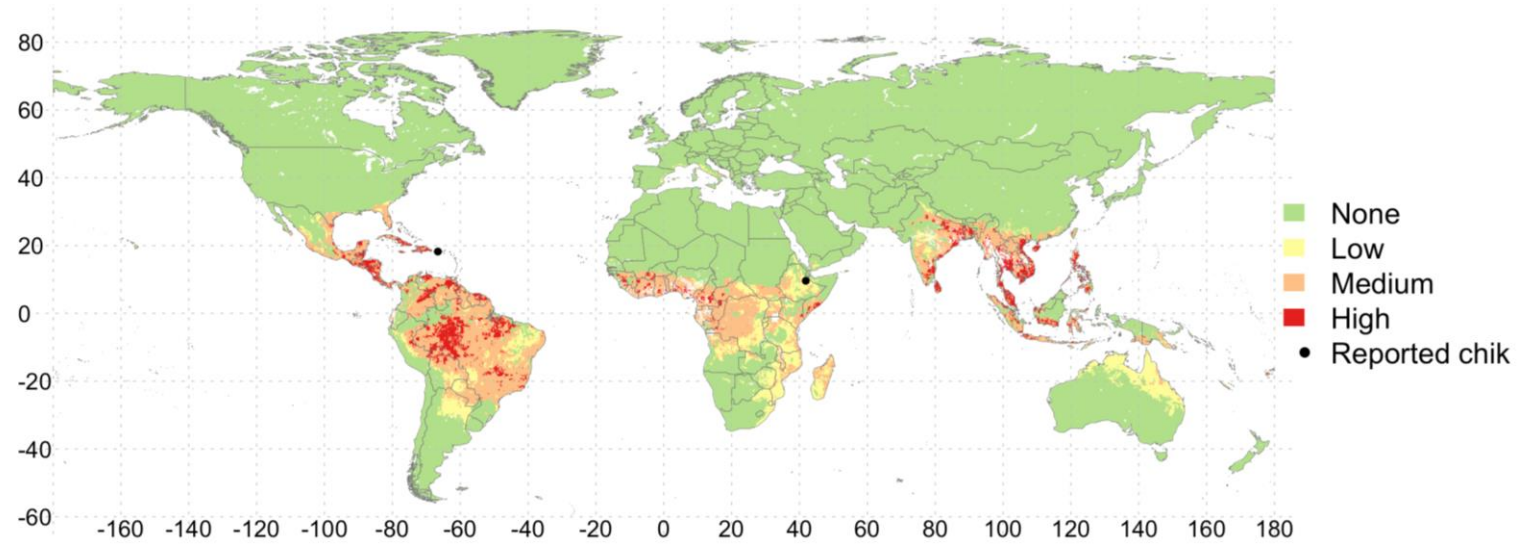
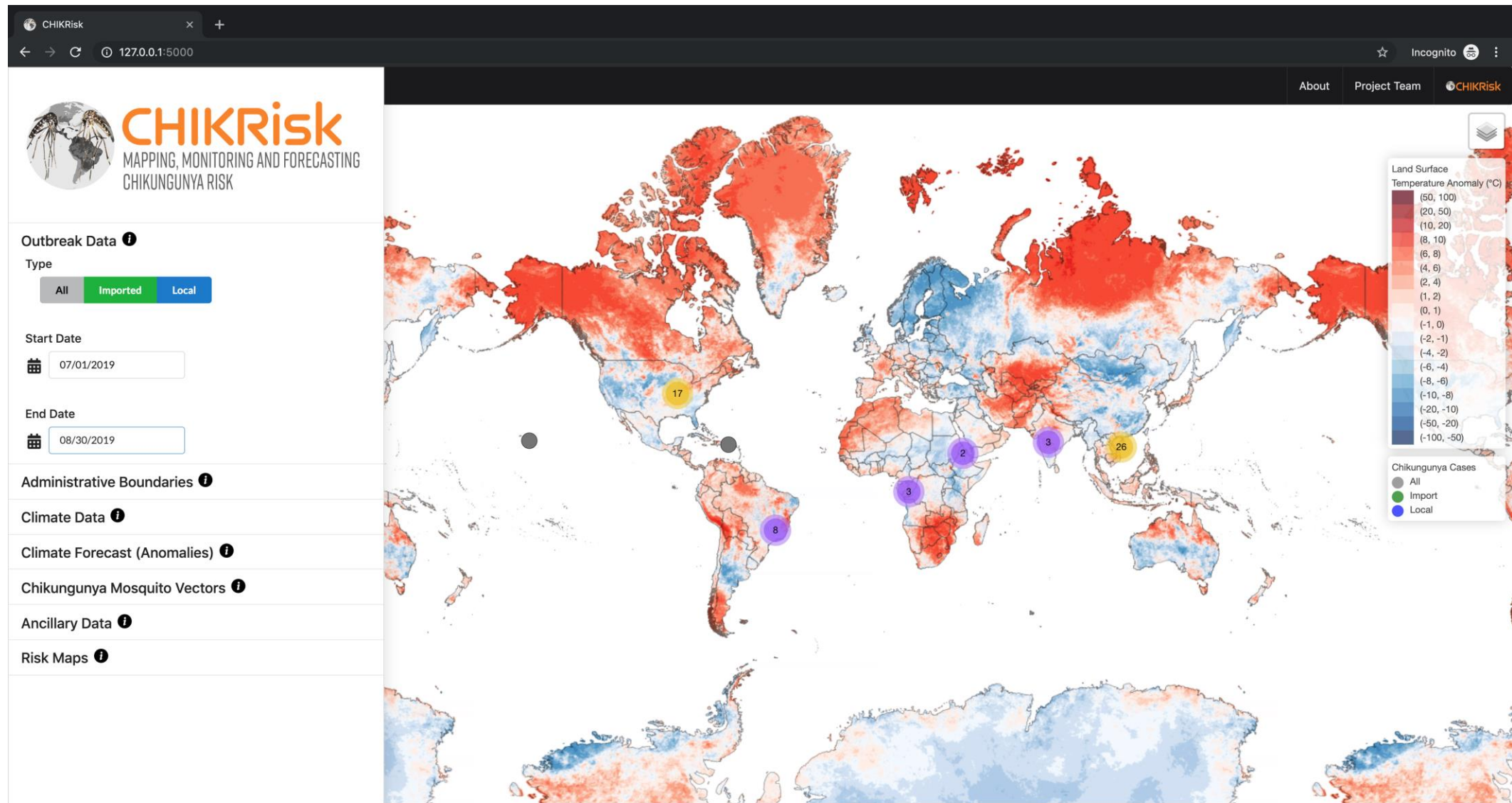Forecast Chikungunya Risk, October 2020

VALIDATION

~ 80% of reported locations with chikungunya activity were predicted to be at risk by the current risk maps
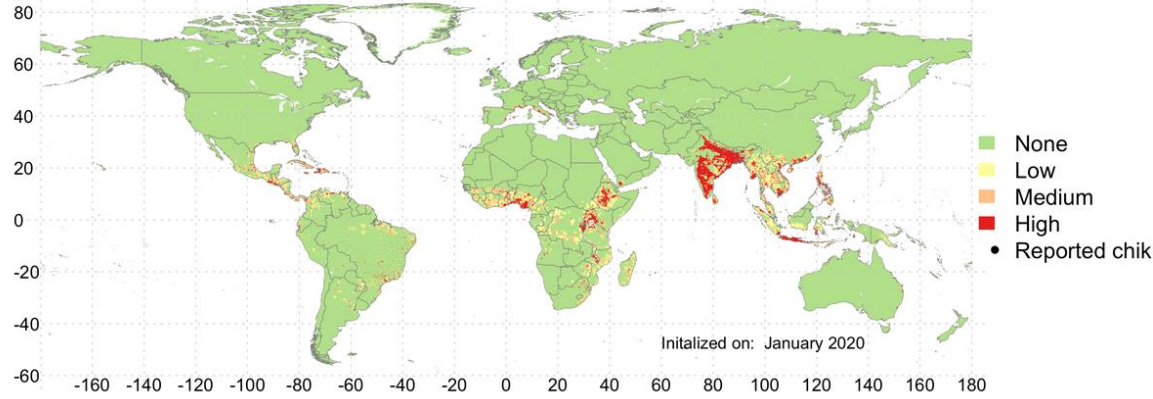
~70 % of reported locations with chikungunya activity were predicted to be at risk by the forecast risk maps
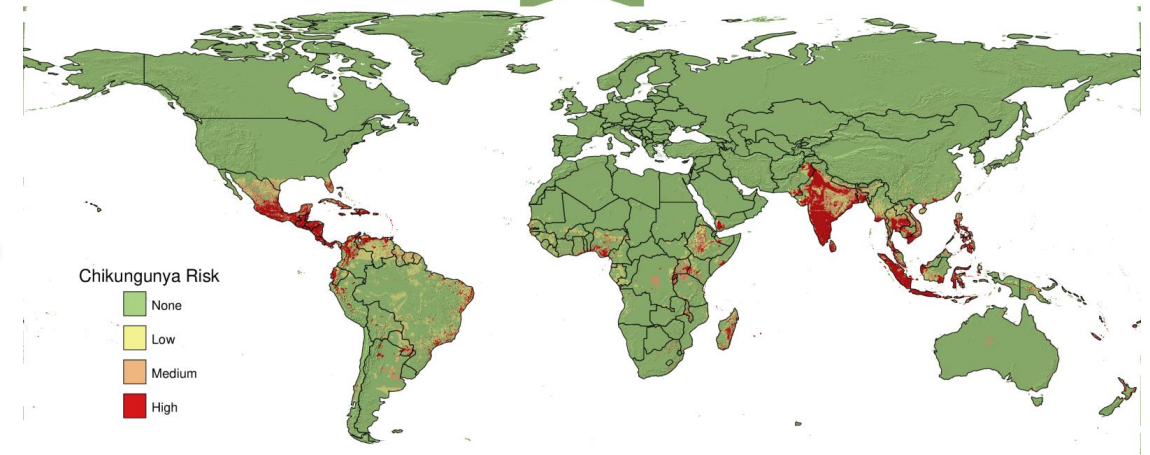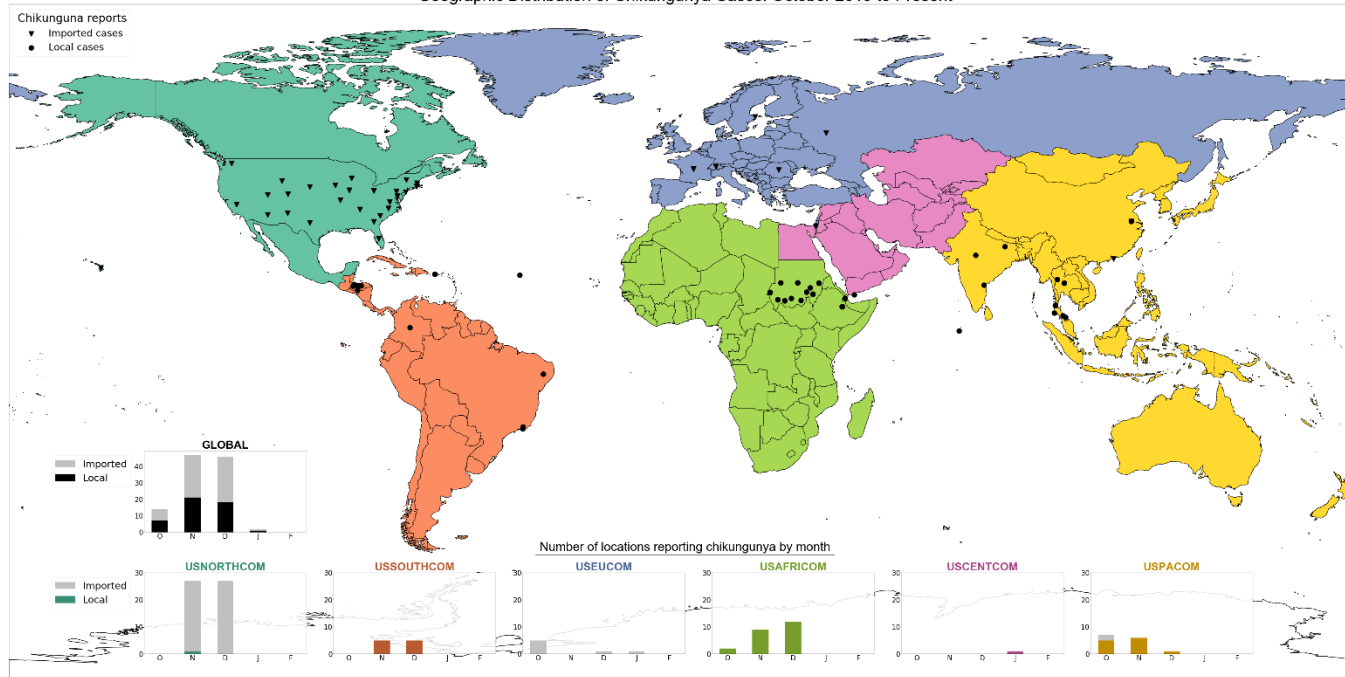
CHIKRISK APP

https://vbd.usra.edu

SAMPLE DoD PRODUCTS

Chikungunya Risk Forecast for July 2020

None
Low
Medium
High
• Reported chik

Initalized on: January 2020

Forecast Chikungunya Risk, October 2020

Chikungunya Risk
None
Low
Medium
High

Geographic Distribution of Chikungunya Cases: October 2019 to Present

Chikunguna reports
▼ Imported cases
• Local cases

GLOBAL
Imported
Local

Number of locations reporting chikungunya by month

USNORTHCOM   USSOUTHCOM   USEUCOM   USAFRICOM   USCENTCOM   USPACOM

- Defense Health Agency/ Armed Forces Health Surveillance Branch - Global Emerging Infections Surveillance (GEIS)
- Provide surveillance and risk forecast products to support **Combatant Command Force Health Protection (FHP) Decisions** (pre and post-deployment)

17

PROGRESS

- Upgrades: App and Functionality – deployment early October 2020
    - New look map graphics
    - Time Series
    - Light weight – user oriented data
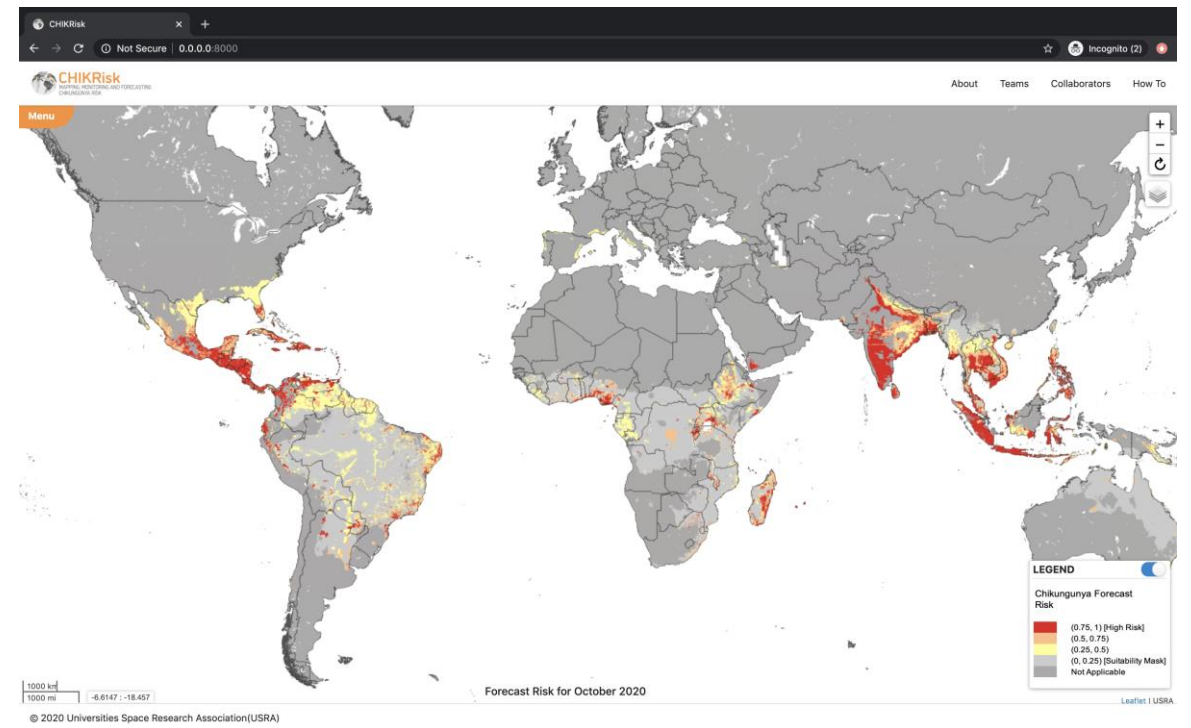
HIGHLIGHTS-1

- Featured Earth Observatory story to showcase the application of NASA Earth Science Data and Models: Of Mosquitoes and Models: Tracking Disease by Satellite https://earthobservatory.nasa.gov/features/disease-vector.

July 2020 Chikungunya Forecast Risk

Low — High
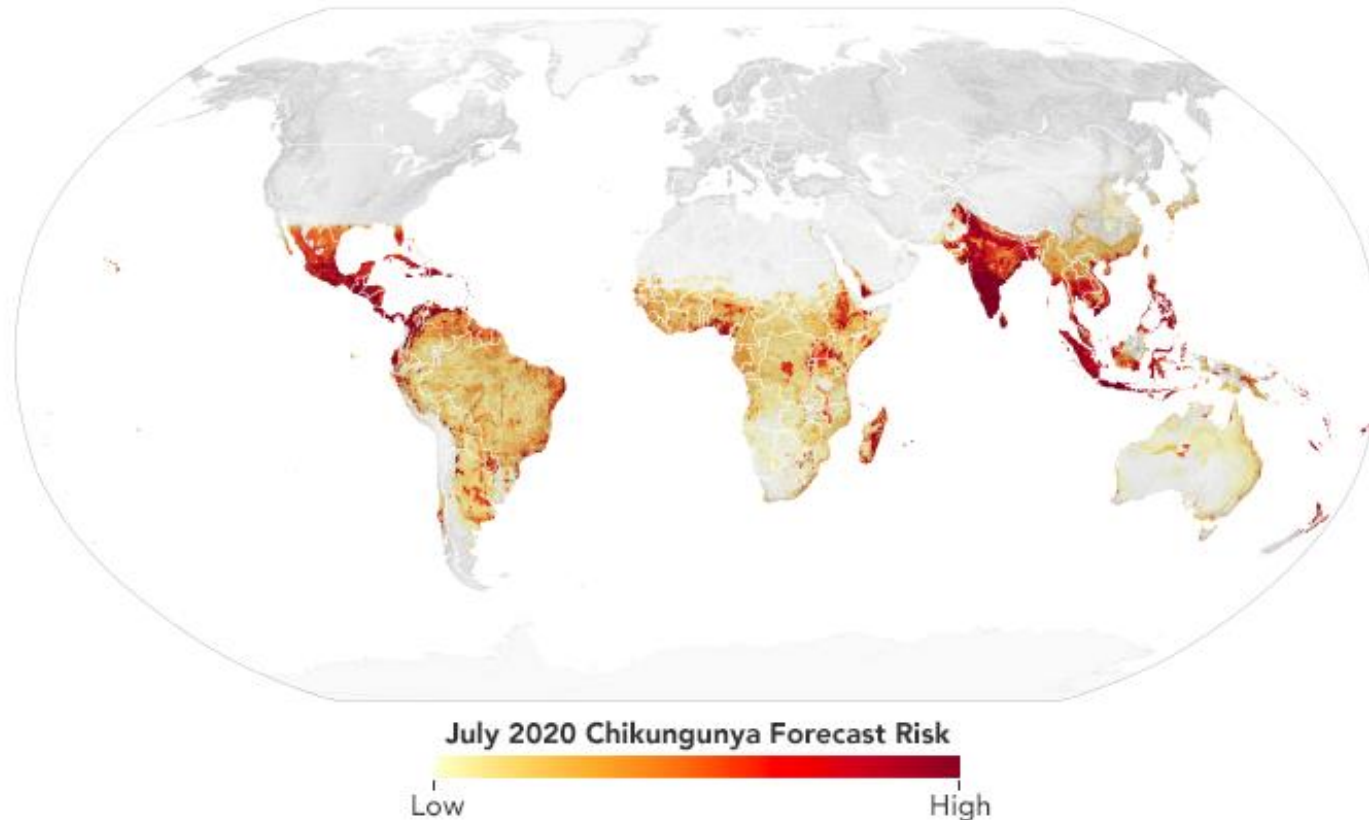
HIGHLIGHTS-2

- Featured on *Netflix Connected* series - **The Hidden Science of Everything** documentary with Latif Nasser **Episode 5: Clouds** showcasing how NASA satellite derived climate data, disease data from a variety of sources, in situ mosquito vector data is used to map and forecast areas at potential risk for disease outbreaks globally

https://www.youtube.com/watch?v=B-aZrftUPlk

HIGHLIGHTS-3

17 Rooms Flagship (virtual) Summit, September 20, 2020
- Structured based on Sustainable Development Goals (SDG's)
- Organized by The Brookings Institution & The Rockefeller Foundation
- Contributed to **Room 3** Initiative on **Transforming National and Global Epidemic Intelligence Systems** aimed determining systems, methodologies and infrastructure that will better prepare us for future outbreaks and pandemics
- Recognized the importance of the One Health Approach
- Reported to Amina Mohammed, Deputy Secretary-General, The United Nations.
- Implementation will be through UN Country Teams

CHALLENGES

- Budgetary Challenges – look to continue in FY2021
- Computational Resources
- Fieldwork