GeoHealth: A Surveillance and Response System Resource for Vector Borne Disease in the Americas

John Malone\(^1\), Rebecca Christofferson\(^1\), Jeffrey Luvall\(^2\), SJ Park\(^3\), Mara Bavia\(^4\), Elivelton Fonseca\(^5\), Prixia del Mar Nieto\(^1\), Moara Rodgers\(^1\), Raul Guimaraes\(^5\)

\(^1\)Pathobiological Sciences, LSU School of Veterinary Medicine;
\(^2\)NASA Marshall Space Flight Center, Huntsville AL,
\(^3\)Electrical Engineering and Computer Science, LSU
\(^4\)Federal University of Bahia, Salvador, Brazil
\(^5\)Sao Paulo State University, Presidente Prudente, Brazil
Objectives

- Construct a geospatial health resource data portal (GeoHealth) compatible with GEOSS

- Map and model the epidemiological risk of two prototype vector borne diseases: Visceral leishmaniasis and Aedes borne arboviruses

- Process big data to discover ‘hidden’ associations of disease for ecological niche modeling vs hypothesis-driven statistical analysis

- Implement dissemination and training programs to promote geospatial mapping and modeling for VBD as envisioned in GEOSS.
Clinical VL Infected Child with Hepatomegaly (Top)

Advanced VL Infection in a Dog, the Principal Reservoir (Below)
ZIKA IN THE AMERICAS
Following its arrival in the Americas in 2015, Zika virus is now being actively transmitted in many of the countries that harbour its main carrier, the *Aedes aegypti* mosquito.
Data Portal

All data clipped to the country boundary; WGS84 projection, 1 km spatial resolution; in ASCII format for Maxent or Bayesian modeling

This example shows the data available for Colombia

Worldclim (global coverage, 1km resolution) used for ecological Niche modeling and by climate change community

MODIS EVI, LST annual composites for 2005-2009

Socioeconomic Data at the Municipality level
GeoHealth Data Portal Content

**Regional Scale Data**

**Climate Data:**
* Worldclim - Precipitation, Tmax, Tmin, Potential Evapotranspiration monthly.
* Bioclim (1km²) - 50 year long term normal climate data.
* NCEP/NCAR CDAS Re Analysis (50km²); daily, complete data eg. specific humidity.

**Earth Observing Satellite data:**
* SRTM  Shuttle Radar Topography Mission (30m²)
* Global Precipitation Mission (GPM) – 3 hour/daily/monthly
* MODIS  8day-16day NDVI, LST, Land Cover (1km²);
* VIIRS 8day
* SMAP Soil Moisture (9km²); Resample to 1km²
GOES 16 –  Land Surface Temperature – 3 hour/daily
ECOSTRESS – 5day data; day-night pairs
DEISIS- 5 day hyperspectral data – selected sites

**Feature data**
* DIVA Political boundaries, World Wildlife Fund Ecosystems
* Hydrology – Rivers, streams, lakes; Watersheds
* Landscan – global population data; Census tract population data of Brazil
GeoHealth Data Portal Content

**Community Scale** (15-30 m)
Landsat 8; Landsat Legacy data; ASTER*
ESA Sentinel L2 and L1 (cloud-free)
Harmonized Landsat/Sentinel-2 (HLS) v. 1.2
Land Use, Soil Type

**Habitat-Household Scale** (<1m)
Worldview 2*, Worldview 3
Visceral leishmaniasis Incidence – 3 year periods
Sao Paulo State, Brazil

Human VL
Municipalities
- < 17,08/100.000
- 17,09 - 34,16/100.000
- 34 - 51,24/100.000
- 51,25 - 68,32/100.000
- > 68,34/100.000
Worldclim -
Asia Tmax6 clipped from Global PET12
WorldClim
Visceral Leishmaniasis

BioClim
Lutzomyia longipalpis

AUC VL Worldclim – 0.882
Tmax12 35.7%
Prec06 19.7%
Tmax01 13.9%

AUC LL BioClim – 0.835
Bio 14 21.3% - Prec Driest Mo
Bio 15 13.8% - Prec Seasonality
Bio 16 16.9% - Prec Wettest Q
Visceral Leishmaniasis

AUC VL SMAP – 0.884
Oct  27.1%
Aug  24.8%
Sept 20.4%

Lutzomyia longipalpis

AUC LL SMAP – 0.793
July 37.4%
Dec 17.0%
March 14.5%
Global Precipitation Model (GPM) – April, 2015
Models – Habitat-Household level

Teodoro Sampaio: Indices using World View 2

NDVI - Normalized difference vegetation index;
SAVI - Soil-adjusted vegetation index;
NDBI - Normalized Difference Built-Up Index;
WV-WI - WorldView Water Index;
NDSI – Normalized Difference Soil Index;
WV-NHFD - Non-Homogeneous Feature Difference;
NDMI - Normalized Difference Mud Index.
Teodoro Sampaio

Build up index

Mud Index

NDVI

NDWI

NHFD

Build up index

Without variable
With only variable
With all variables
SRTM - VL Surveillance and Response Systems - Bauru
VL Surveillance and Response Systems - Bauru

Vegetation and Kernel density – dog population
## Five Groups for Case-Control GIS/Hot Spot Guided

<table>
<thead>
<tr>
<th>Action</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collars All dogs survey (mass treatment) No GIS/Hot Spot Guided criteria Entire area</td>
<td>1) Serum Conversion of Dogs  2) Clinical cases dogs and Human  3) Sand Fly  - Population dynamics  - Infection rate  - Blood meal  4) Survey of KAP  - Knowledge-Attitude and Practice Cost-effective analysis and protocols for control programs</td>
</tr>
</tbody>
</table>
Visceral Leishmaniasis

NDVI and visceral leishmaniasis cases, seropositives dogs, sand fly (*Lutzomyia longipalpis*) in Feira de Santana, Bahia, Brazil (2000 to 2002)
Extrinsic Incubation Period (EIP). This process is known to be influenced by both intrinsic factors (such as viral strain and/or mosquito population) and extrinsic factors (such as temperature and humidity).
GeoHealth Project - Year 1

- **LSU Int’l Workshop** Jan 25
- **Official Start Date** Feb 13
- **Budget Start** Mar 25
- **Luvall LSU** Mar 23
- **Luvall Brazil** Apr 21-30
- **NASA Rev** May 29-31
- **Vermont** Sept 18-19
- **New Orleans ASTMH Mtg** Nov 1
- **52 wks**
- **Phase I** Construct Data Portal - JC McCarroll
  - **Q Rpt** May 14
  - **Q Rpt** Aug 14
  - **Q Rpt** Nov 15
  - **Ann Rpt** Feb 13
- **Phase II** Mapping and Modeling
  - **Sao Paulo Project** - Elivelton Fonseca UNESP at LSU May-Dec
  - **LSU Computer Science Grad Student**
  - **Colombia Project** – P Nieto
  - **Bahia Project** – Moara Martins
Objectives: Develop prototype risk models for visceral leishmaniasis and *Aedes*-borne arboviruses as part of the AmeriGEOSS initiative to demonstrate the benefits of satellite data products in mapping and modeling the ecological niche of vector borne diseases at different spatial and temporal scales.

- Access data from NASA’s current earth observing programs on GPM, GOES16/17, SMAP/SMOS, WorldView 2/3, Ecostress and SPoRT

- A number of active sensors will eventually provide direct estimates of the ecological niche of vector borne diseases in the Americas at a very high resolution.

Outputs Expected

- Development of a vector borne disease network and a data portal archive for the Americas.

- American continent data portal archives will be organized at Louisiana State University and the NASA Marshall Space Flight Center.

Leads and contributors

Lead: John B Malone, Louisiana State University ([vtmalon@lsu.edu](mailto:vtmalon@lsu.edu)) and Jeffrey C Luvall, NASA Marshall Space Flight Center, Huntsville, AL ([jluvall@nasa.gov](mailto:jluvall@nasa.gov))

2018-2020 Activities

During the period of the 2018-2020 work plan this activity will develop prototype risk models for visceral leishmaniasis and *Aedes*-borne arboviruses as part of AmeriGEOSS.

2018-2020 Resources

The activities are primarily carried out with support from NASA Grant 80NSSC18K0517 supplemented by work on a volunteer basis by colleagues employed at universities and public health agencies in the Americas.
The AmeriGEOSS initiative is a framework that seeks to promote collaboration and coordination among the GEO members in the American continent, “to realize a future wherein decisions and actions, for the benefit of the region, are informed by coordinated, comprehensive and sustained Earth observations and information”.
Schedule

Year I – GEO Community of Practice (CoP)

<table>
<thead>
<tr>
<th>GEO/ASTMH Meetings</th>
<th>Begin Internal Data Portal</th>
</tr>
</thead>
<tbody>
<tr>
<td>QRpt</td>
<td>QRpt</td>
</tr>
<tr>
<td>Annual Rpt</td>
<td></td>
</tr>
</tbody>
</table>

Develop Architecture and Content of GeoHealth Databases

Map and Model Leishmania and Arboviruses

Year II – GEO Initiative

<table>
<thead>
<tr>
<th>GEO Initiative Milestone</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>GEO/ASTMH Meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short course</td>
</tr>
<tr>
<td>GEO Graduate Course</td>
</tr>
<tr>
<td>Short course</td>
</tr>
</tbody>
</table>

Begin Open Access Data Portal

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>QRpt</td>
</tr>
<tr>
<td>Annual Rpt</td>
</tr>
</tbody>
</table>

Map and Model Leishmania and Arboviruses

Year III – GEO Broker Status

<table>
<thead>
<tr>
<th>GEO Broker Milestone</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>GEO/ASTMH Meetings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short course</td>
</tr>
<tr>
<td>GEO Graduate Course</td>
</tr>
<tr>
<td>Short course</td>
</tr>
</tbody>
</table>

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>QRpt</td>
</tr>
<tr>
<td>Final Rpt</td>
</tr>
</tbody>
</table>

Internet Dissemination, Implementation and Training via GEOSS

Map and Model Leishmania and Arboviruses
Figure 6 (from Christofferson & Mores 2016): Survival curves for comparisons of A) unexposed to infected mosquitoes at 30°C and B) unexposed to mosquitoes with a disseminated infection were significantly different.

Figure 7 (from Christofferson & Mores 2016): Survival curves for comparisons of A) infected mosquitoes across all three temperatures and B) mosquitoes with a disseminated infection across all three temperatures. Significant differences were found only between 26°C (red) and 30°C (blue) in both cases.
Visceral Leishmaniasis

Bahia municipalities classification level of VL transmission. 2013-16

2000 a 2016

- 6,165 cases (annual mean 385)
- Incidence: 1.3 to 11.8 (100,000 inhabitants)
- Mean lethality 6.7%

Source: SESAB/SUVISA/DIVEP, 2017