NASA's NextGen Remote Sensing Instruments Have Arrived: Data Products For Studying Disease Vectors

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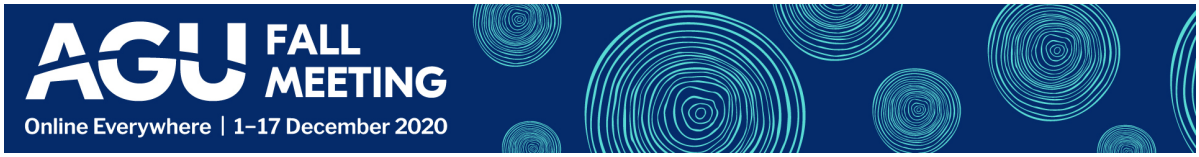


SATELLITE OBSERVATIONS PROVIDE KEY MEASUREMENTS FOR PUBLIC HEALTH APPLICATIONS

Strengths Of Satellite Observations in Public Health

Measures environmental state functions important to vector & disease life cycles (within vector)
Precipitation, soil moisture, temperature, vapor pressure deficits, wet/dry edges, solar radiation….

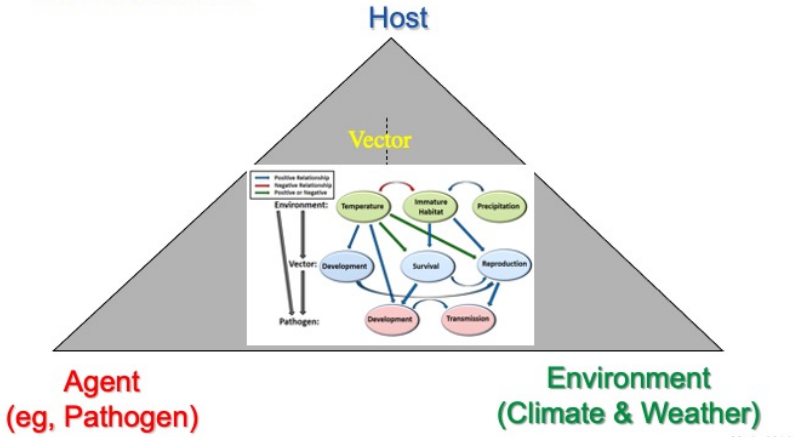
But also the interfaces as process functions:
Land use/cover mapping; Ecological functions/structure, canopy cover, species, phenology, aquatic plant coverage…..

And provides a Spatial Context
Spatial coverage & topography – local, regional & global…

Lastly, but perhaps the greatest strength:
Provides a time series of measurements

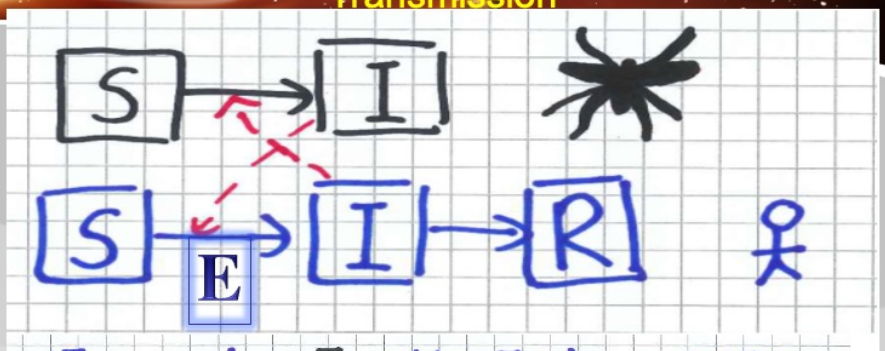
Epidemiologic Triangle of Disease (Vector-borne Diseases)

A multi-factorial relationship between hosts, agents, vectors and environment



Morin 2014

1915 Ross Model For Vector-borne Malaria Transmission



$$\frac{dI_h}{dt} = \alpha\lambda\omega I_m(1 - I_h) - \gamma I_h$$

$$\frac{dI_m}{dt} = \alpha v I_h(1 - I_m) - m I_m$$

Ross, Ronald. "Some a priori pathometric equations." British Medical Journal 1.2830 (1915): 546 http://equationsofdisease.wordpress.com

Vectorial Capacity

$$VC = \frac{ma^2bp^N}{-\log(p)}$$

variable	definition
m	Mosquito:vertebrate density
a	Man biting rate of mosquito (alternatively, contact rate)
b	Vector competence (% mosquitoes that will become infectious)
p	Mosquito mortality (average lifespan)
N	EIP (time it takes for virus to be transmitted by a mosquito)

Figure 5: Vectorial Capacity (VC) equation and variable definitions.

Potentially, An Increased Risk of Transmission

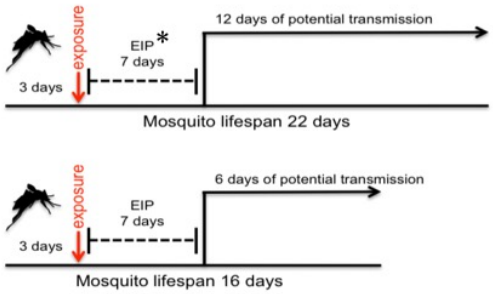


Figure 8 (from Christofferson & Mores 2016): Schematic demonstrating the impact of mosquito mortality on the cumulative transmission potential of an arbovirus.

*Extrinsic Incubation Period (EIP). This process is known to be influenced by both intrinsic (such as viral strain and/or mosquito population) and extrinsic factors (such as temperature and humidity)

SURFACE THERMAL MEASUREMENTS ARE SIGNIFICANT IN THE MEASUREMENT OF ENVIRONMENTAL FACTORS IMPORTANT IN DISEASE VECTOR HABITATS

A Ecological Thermodynamic Paradigm

θΔics

The epidemiological equations (processes) can be adapted and modified to *explicitly incorporate environmental factors and interfaces*

Remote sensing can be used to measure or evaluate or estimate *both environment (state functions) and interface (process functions).* The products of remote sensing must be expressed in a way they *can be integrated directly into the epidemiological equations.* The desired logical structures must be consistent with thermodynamic and with probabilistic frameworks.

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Surface Radiation Budget

$$Q^* = (K_{in} + K_{out}) + (L_{in} + L_{out})$$

Q^* = Net Radiation

K_{in} = Incoming Solar

K_{out} = Reflected Solar

L_{in} = Incoming Longwave

L_{out} = Emitted Longwave

Surface Energy Budget

$$Q^* = H + LE + G$$

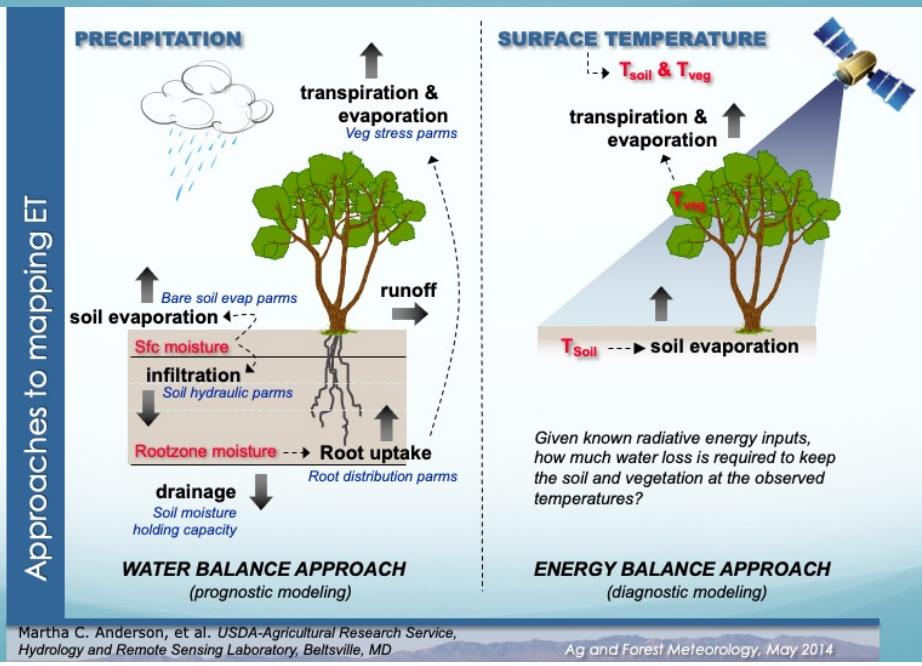
H = Sensible Heat Flux

LE = Latent Heat Flux

G = Storage (maybe + or -)

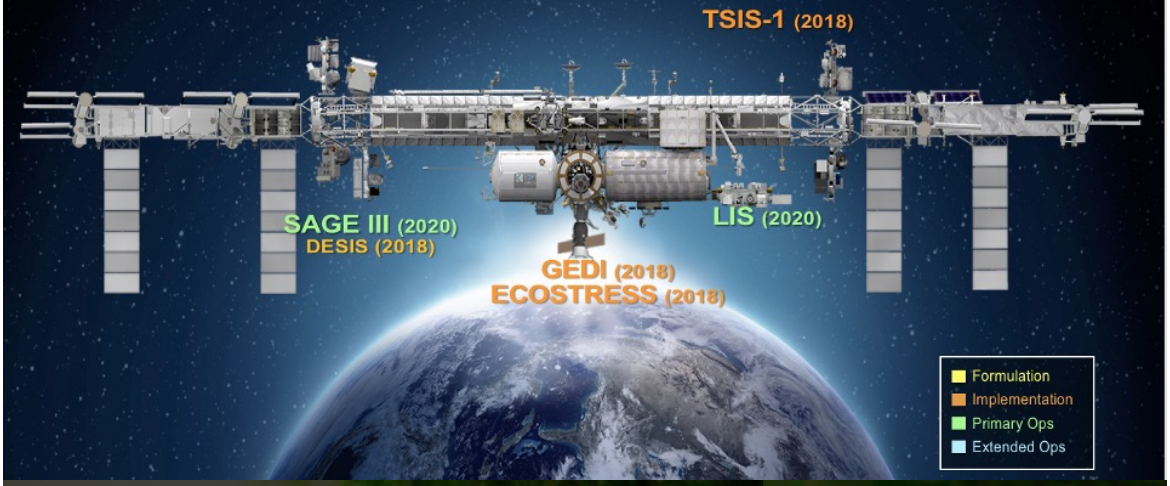
Surface Temperature

$$T_s = T_a + \frac{R_b}{C_\rho}\left(R_n - E\right)$$



CURRENT INSTRUMENTS ON THE INTERNATIONAL SPACE STATION

International Space Station
Earth Science Operating Missions

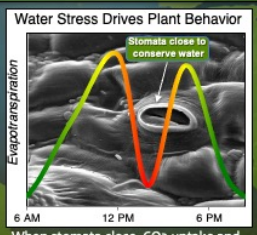


ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Dr. Simon J. Hook, JPL, Principal Investigator

*ECOSTRESS is providing critical insight into **plant-water dynamics** and how **ecosystems change with climate** via **high spatiotemporal** resolution thermal infrared radiometer measurements of evapotranspiration from the International Space Station (ISS).*



When stomata close, CO_2 uptake and evapotranspiration are halted and plants risk starvation, overheating and death.

Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

Science Objectives

- Identify **critical thresholds of water use and water stress** in key climate-sensitive biomes
- Detect the timing, location, and predictive factors leading to plant **water uptake decline** and/or cessation over the **diurnal cycle**
- Measure **agricultural water consumptive use** over the contiguous United States (CONUS) at spatiotemporal scales applicable to improve drought estimation accuracy

Hyperspectral Data from LEO

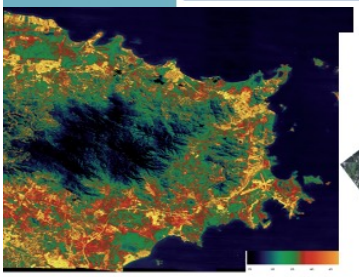
- Teledyne and DLR have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (DESIS) from the Teledyne-owned MUSES Platform on the ISS
- DESIS Provides:
  - 30 m GSD, 30 km swath
  - 235 contiguous bands of 2.55 nm
  - Senses from 400 nm to 1000 nm
- Commercially available in Q2, 2018 through Teledyne's Earth Sensor Portal

Ray Perkins, Teledyne Geospatial Solutions
17 October, 2017 NSSTC presentation

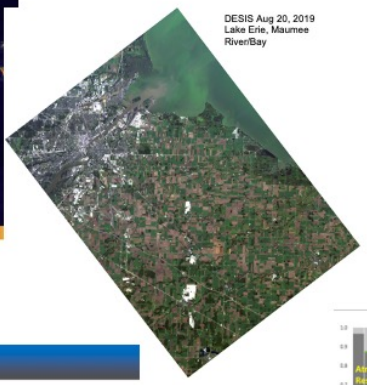
Global Ecosystem Dynamics Investigation Lidar (GEDI) *On ISS -public data release Nov 2019*

The GEDI instrument is a geodetic-class, light detection and ranging (lidar) laser system comprised of 3 lasers that produce 10 parallel tracks of observations.

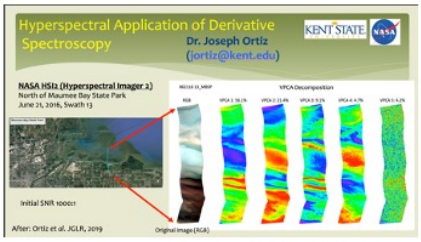
Forest height and vertical structure; habitat quality & biodiversity; Forest carbon sinks & source areas; loss of carbon from extreme events such as fires and hurricanes; parameterization of ecosystem models	Forest Management & Carbon Cycling
Canopy 3D structure that influences snowmelt, evapotranspiration, canopy interception of precipitation. Glacier surface elevation change; lake & river stage; snowpack elevation; coastal tides.	Water Resources
Improved canopy aerodynamic profiles to parameterize weather prediction models. Canopy and biomass products that initialize and constrain climate models; impacts of land use change on climate	Weather Prediction
Accurate bare earth and under canopy topographic elevations for improved digital elevation models from radar. Calibration of satellite based observations of surface deformation and earthquakes	Topography & Surface Deformation



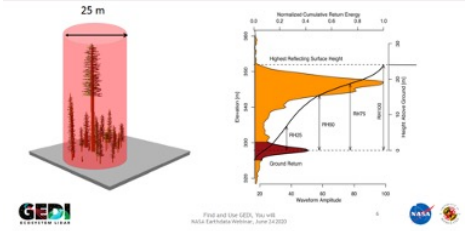
El Yungue, Puerto Rico
Aircraft Based ATLAS scanner
10m Thermal Data

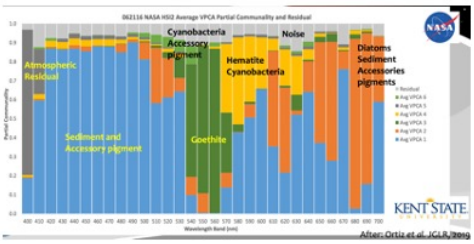


DESIS Aug 20, 2019
Lake Erie, Maumee River/Bay



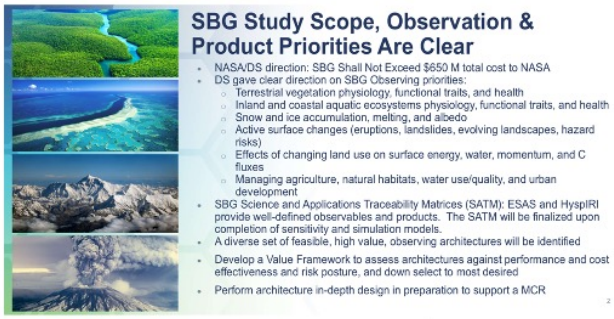
GEDI Lidar Measurements

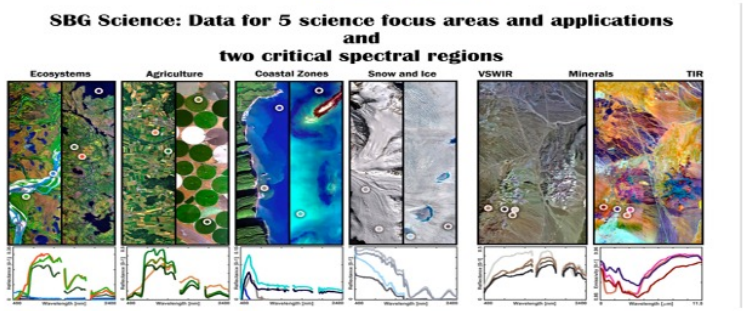


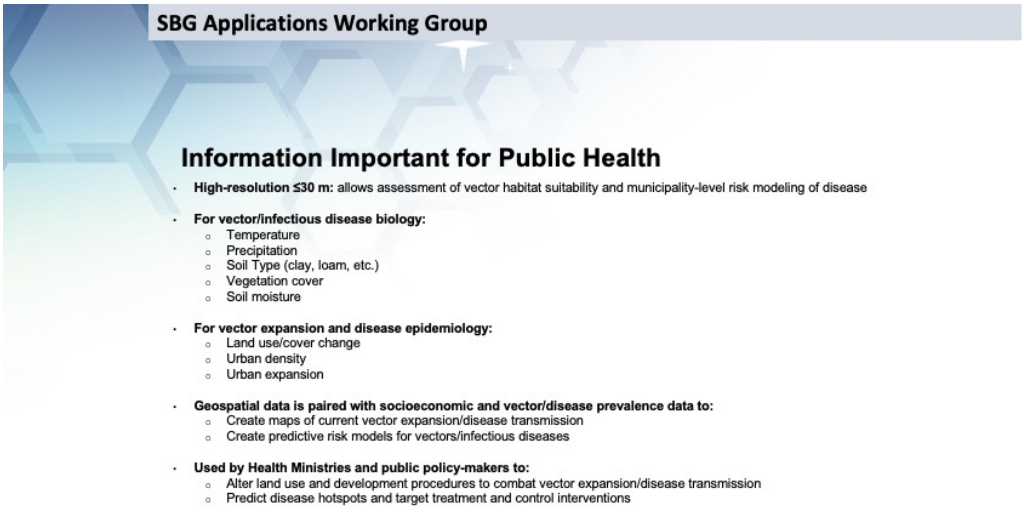


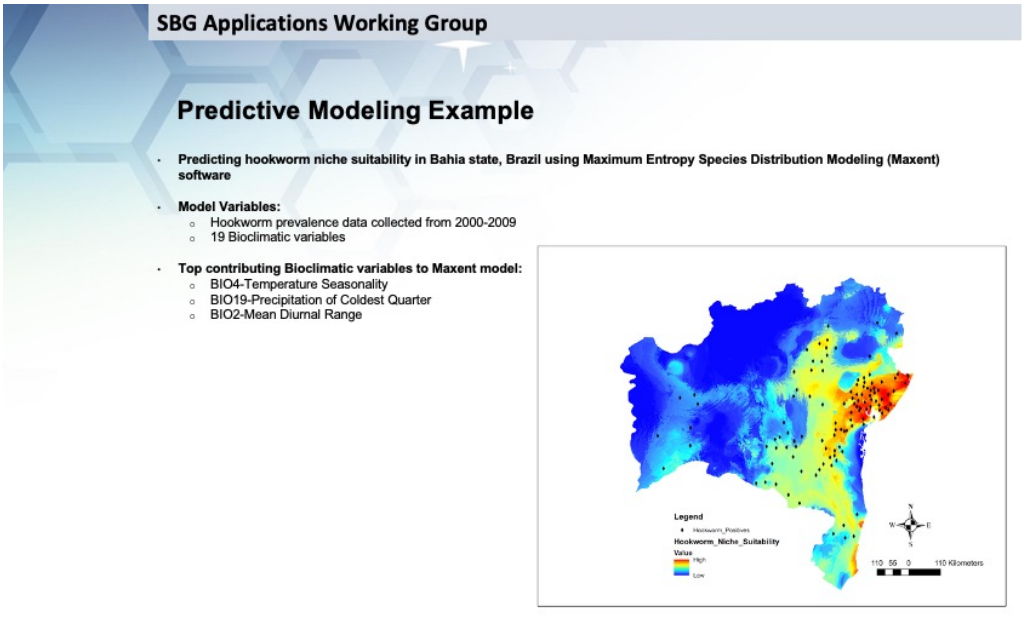
NASA'S DESIGNATED OBSERVABLE- SURFACE BIOLOGY GEOLOGY (SBG) WILL PROVIDE GLOBAL MEASUREMENTS

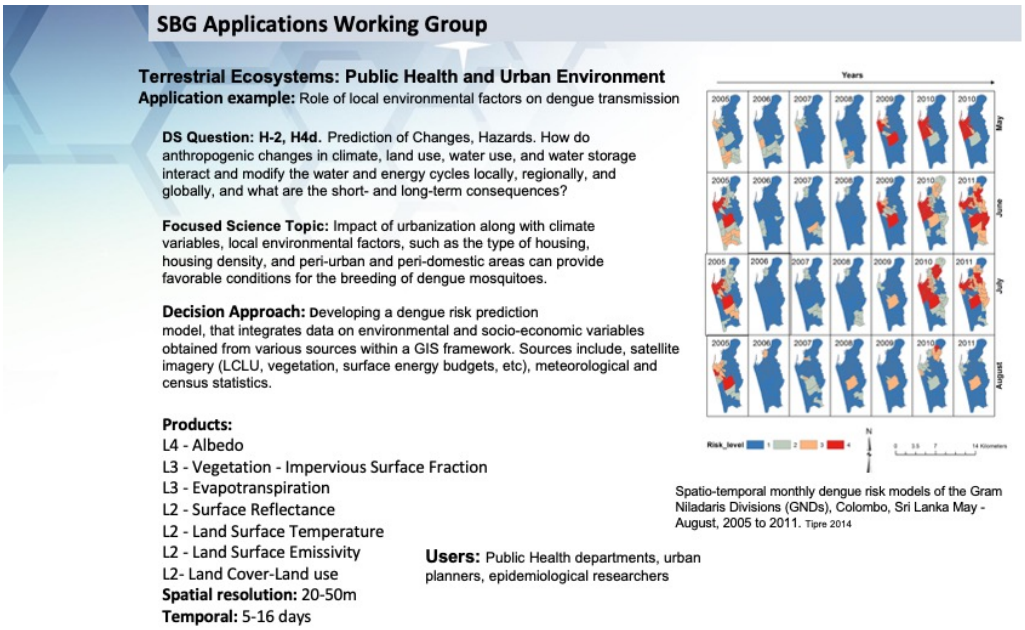

Thriving on Our Changing Planet
A Decadal Strategy for Earth Observation from Space
#EarthDecadal
The National Academies of SCIENCES ENGINEERING MEDICINE


SBG Study Scope, Observation & Product Priorities Are Clear
NASA/DS direction: SBG Shall Not Exceed $650 M total cost to NASA
DS gave clear direction on SBG Observing priorities:
Terrestrial vegetation physiology, functional traits, and health
Inland and coastal aquatic ecosystems physiology, functional traits, and health
Snow and ice accumulation, melting, and albedo
Active surface changes (eruptions, landslides, evolving landscapes, hazard risks)
Effects of changing land use on surface energy, water, momentum, and C fluxes
Managing agriculture, natural habitats, water use/quality, and urban development
SBG Science and Applications Traceability Matrices (SATM): ESAS and HyspIRI provide well-defined observables and products. The SATM will be finalized upon completion of sensitivity and simulation models.
A diverse set of feasible, high value, observing architectures will be identified
Develop a Value Framework to assess architectures against performance and cost effectiveness and risk posture, and down select to most desired
Perform architecture in-depth design in preparation to support a MCR


SBG Science: Data for 5 science focus areas and applications and two critical spectral regions
Ecosystems
Agriculture
Coastal Zones
Snow and Ice
VSWIR
Minerals
TIR


SBG Applications Working Group
Information Important for Public Health
High-resolution ≤30 m: allows assessment of vector habitat suitability and municipality-level risk modeling of disease
For vector/infectious disease biology:
Temperature
Precipitation
Soil Type (clay, loam, etc.)
Vegetation cover
Soil moisture
For vector expansion and disease epidemiology:
Land use/cover change
Urban density
Urban expansion
Geospatial data is paired with socioeconomic and vector/disease prevalence data to:
Create maps of current vector expansion/disease transmission
Create predictive risk models for vectors/infectious diseases
Used by Health Ministries and public policy-makers to:
Alter land use and development procedures to combat vector expansion/disease transmission
Predict disease hotspots and target treatment and control interventions


SBG Applications Working Group
Predictive Modeling Example
Predicting hookworm niche suitability in Bahia state, Brazil using Maximum Entropy Species Distribution Modeling (Maxent) software
Model Variables:
Hookworm prevalence data collected from 2000-2009
19 Bioclimatic variables
Top contributing Bioclimatic variables to Maxent model:
BIO4-Temperature Seasonality
BIO19-Precipitation of Coldest Quarter
BIO2-Mean Diurnal Range
Legend
Hookworm_Niche_Suitability
Value
High
Low
110 55 0 110 Kilometers



Join the SBG Applications Working Group (APPWG):

http://tinyurl.com/SBGApplicationsWG

SBG webpage:

https://sbg.jpl.nasa.gov/ (https://sbg.jpl.nasa.gov/)

ABSTRACT

Remote sensing can be used to measure, evaluate or estimate both the environment (state functions) and interfaces (process functions) defining vector habitats. The products of remote sensing can be integrated directly into the epidemiological equations to significantly enhance our understanding of disease vector's life cycles and habitats. The next generation of NASA's remote sensing instruments which have become recently operational will provide a significant enhancement in our ability to study disease vector's life cycles and habitats. These instruments are on the International Space Station (ISS) and include ECOSTRESS, DESIS, and GEDI. ECOSTRESS is a 5 channel, thermal IR instrument with 70 m resolution and approximately 1-5 day repeat cycle of day/night pairs. DESIS jointly developed by German Aerospace Center and Teledyne Brown Engineering is a hyperspectral sensor system of 235 channels and 30 m resolution. DESIS data is only being acquired on demand. GEDI is a high-resolution laser ranger used for observing Earth's forests and topography.

NASA's current ISS instrument configuration provides measurements of the critical environmental measures of environmental state functions important to vector & disease life cycles. Remote sensing data provide a spatial context and time series of landscape scale process functions represented by land use mapping and measurements of ecological functions. Global public health is entering a new information age through the use of spatial models of disease vector/host ecologies driven by the use of remotely sensed data to measure environmental and structural factors critical in determining disease vector habitats.

In 2018, NASA initiated a new study for the Surface Biology and Geology (SBG) Designated Observable, identified in the 2018 National Academies' Decadal Survey entitled, "Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space." (https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth) . The SBG is planned to collect global remote sensing measurements using a hyperspectral spectrometer and multispectral thermal data. These data sets will provide a significant enhancement in our ability to study disease vector's life cycles and habitats globally. The 3 sensors on the ISS provide precursor data to prepare the community for the application of future SBG data toward disease studies.