NASA Earth Remote Sensing Resources for Public Health:

A Thermodynamic Paradigm for Studying Disease Vector's Habitats & Life Cycles Using NASA's Remote Sensing Data

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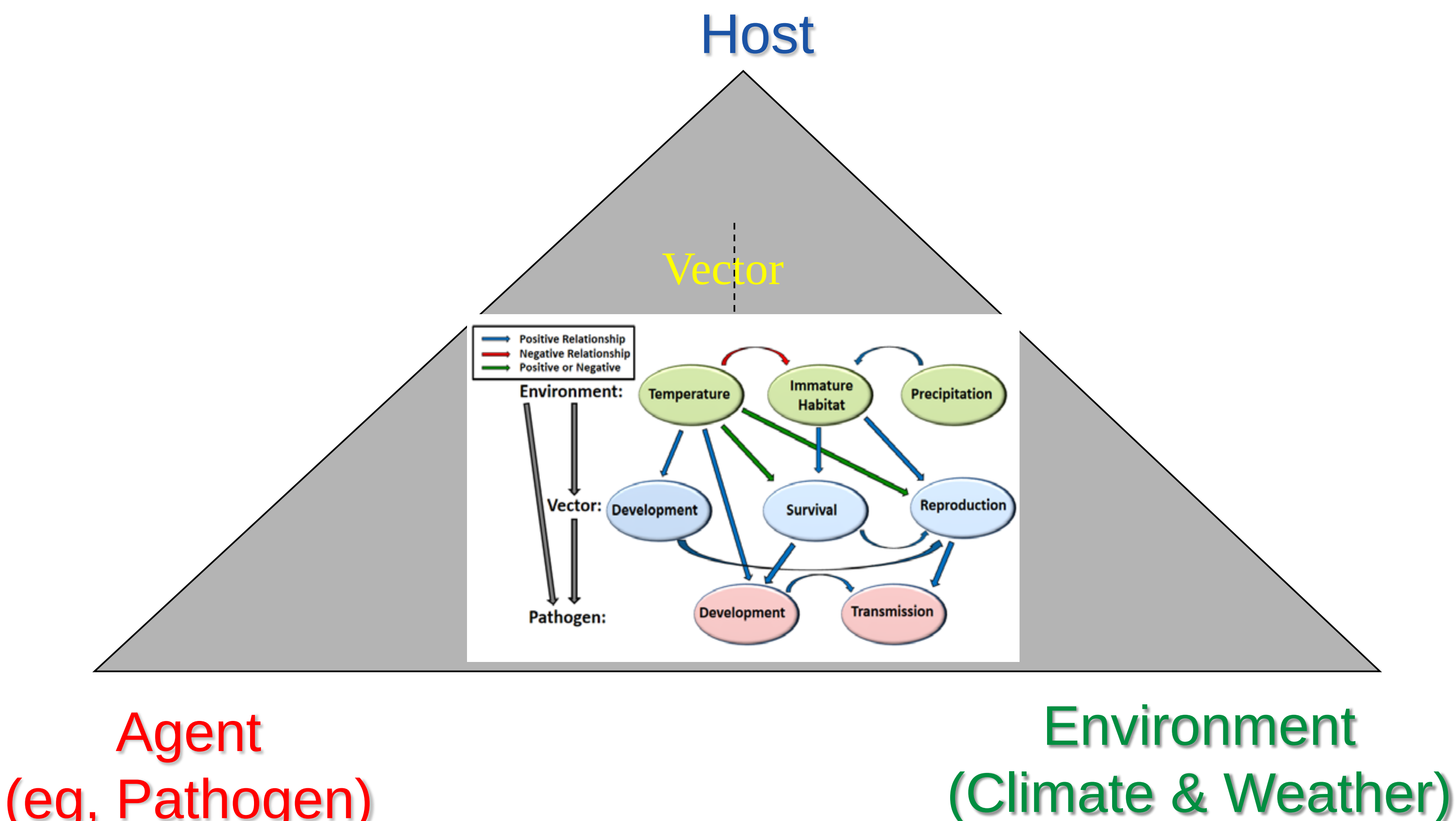
☀ θΔ ics ☐

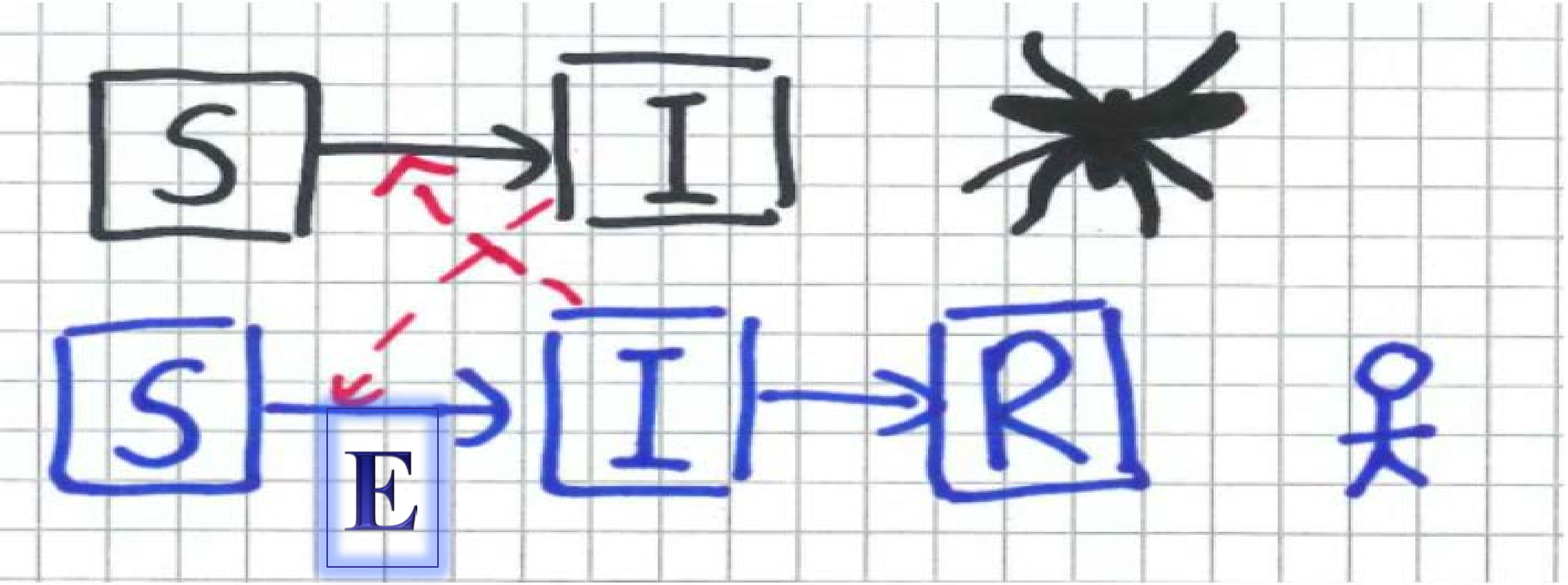
Epidemiologic Triangle of Disease (Vector-borne Diseases)

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



Morin 2014

1915 Ross Model For Vector-borne Malaria Transmission



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

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

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.

Impacts of Temperature on Vector Life Cycle

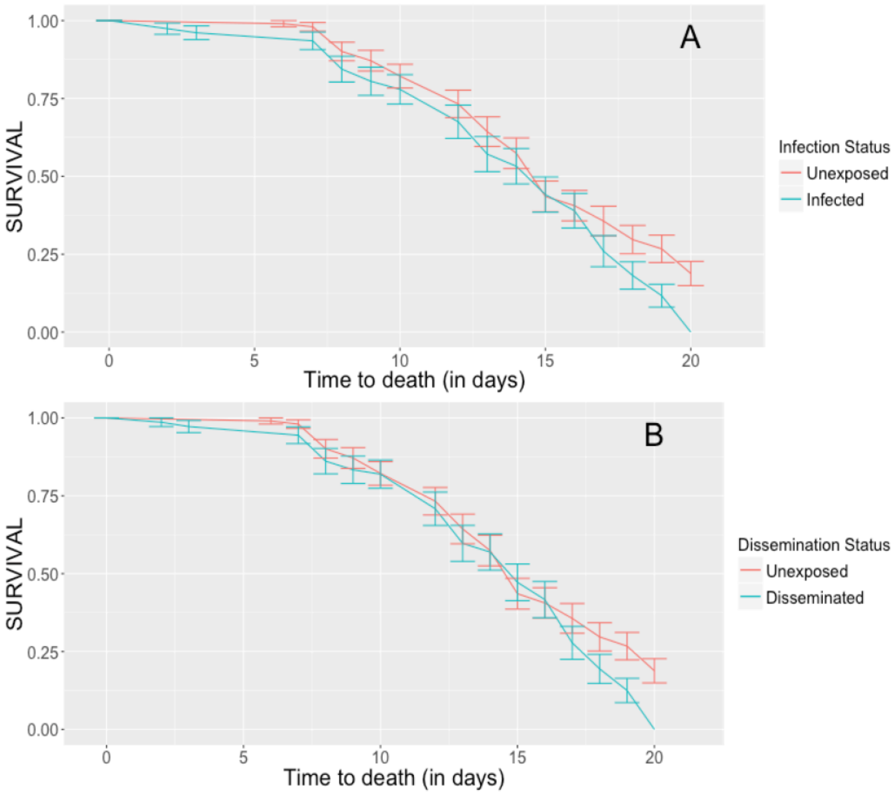


Figure 6 (from Christofferson & Mores 2016): Survival curves for comparisons of A) unexposed to infected mosquitoes at 30°C and B) unexposed to mosquitoes with a disseminated infection were significantly different.

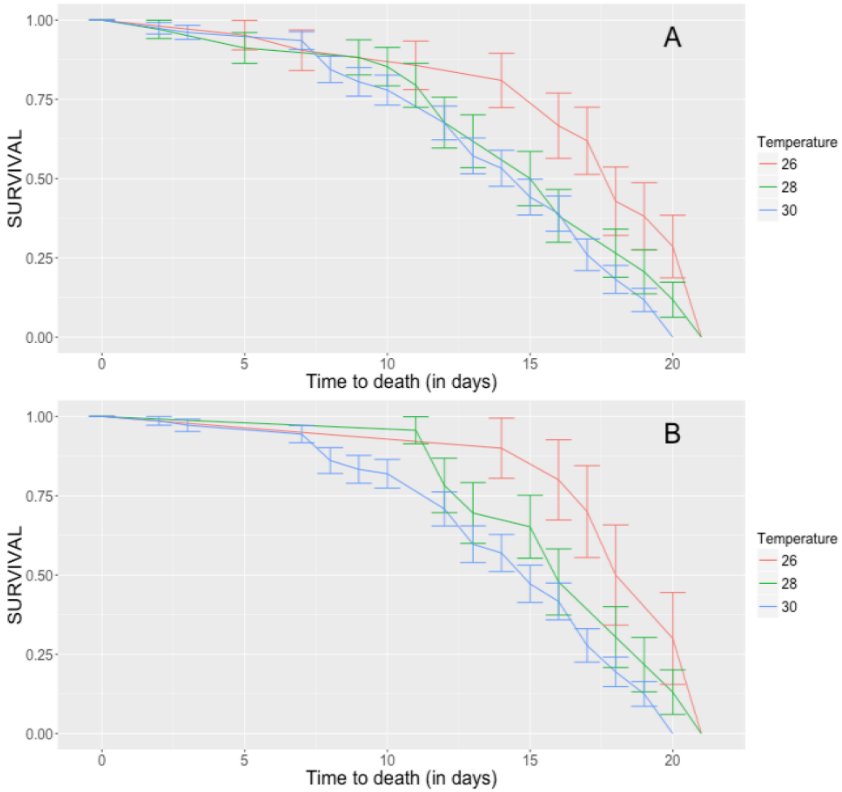


Figure 7 (from Christofferson & Mores 2016): Survival curves for comparisons of A) infected mosquitoes across all three temperatures and B) mosquitoes with a disseminated infection across all three temperatures. Significant differences were found only between 26°C (red) and 30°C (blue) in both cases.

Potentially, An Increased Risk of Transmission

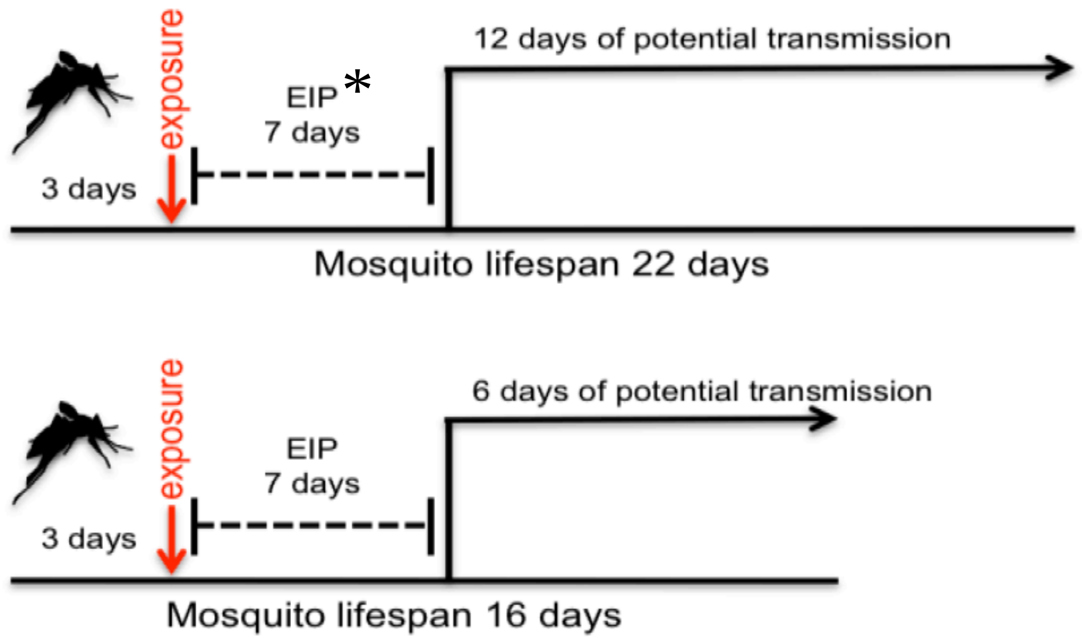
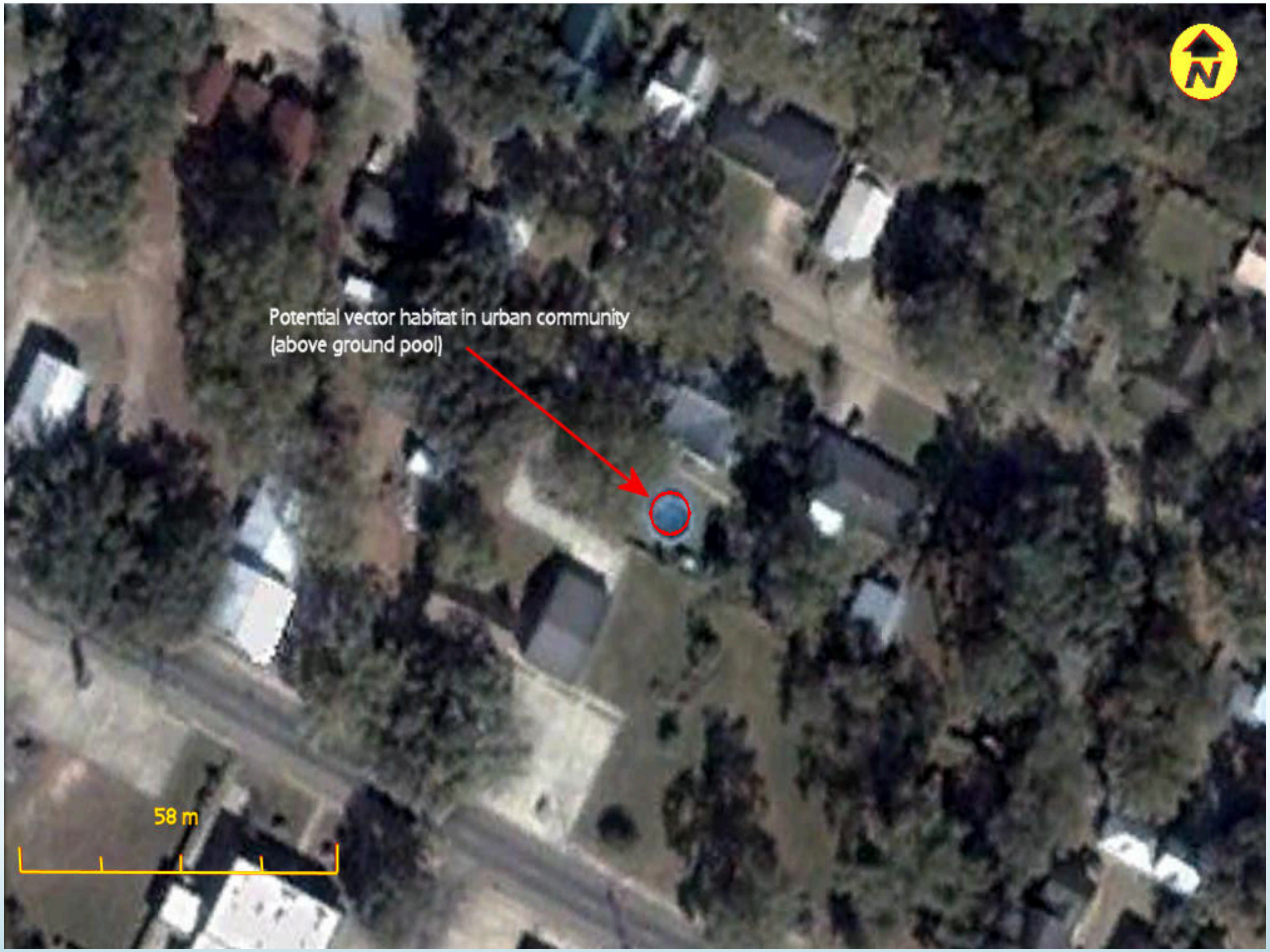


Figure 8 (from Christofferson & Mores 2016): Schematic demonstrating the impact of mosquito mortality on the cumulative transmission potential of an arbovirus.

*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)

Places that Produce *Anopheles* Mosquitoes

Backyard Swimming Pools Los Angeles County California.



Strengths Of Satellite Observations

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

A Ecological Thermodynamic Paradigm

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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.

Challenges

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Satellite Data

- repeat frequency & spatial resolution
- spectral bands available
- clouds
- life cycle
- cost
- data availability & timeliness of delivery

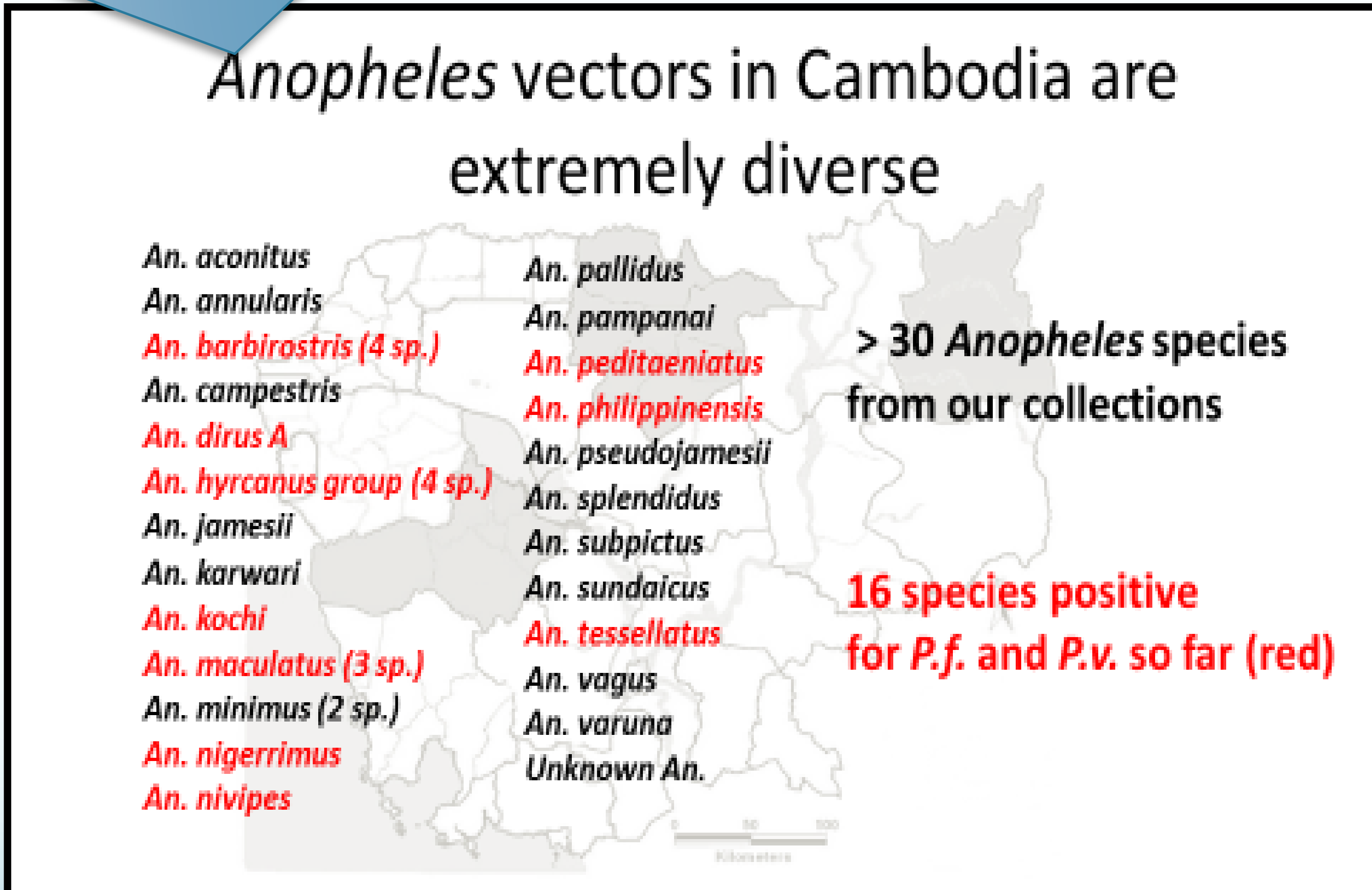
Public Health & Epidemiology

- availability of data & various sampling issues
- difficulty in getting access to sampling areas
- cost
- understanding of the data provided by satellites
- ***Define & quantify the multi-factorial relationships between hosts, agents, vectors and environment***

Environmental Surveillance and Monitoring System

Robert J. Novak, PhD
University of South Florida
College of Public Health
Department of Global Health

Plasmodium falciparum is a protozoan parasite, one of the species of Plasmodium that cause malaria in humans.
(P. vivax was also present in Cambodia)

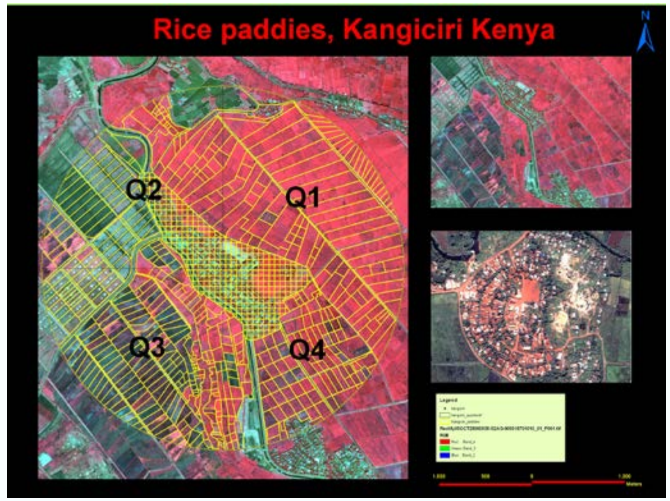


DELIVERABLES

1. To develop an “off the shelf” user friendly Product for “Environmental Surveillance and Monitoring using GIS, remote sensing technologies, providing for the basic elements applicable to multiple landscapes and geographic areas (global) to provide near real time information for decision makers at all levels of Government and malaria control operations.
2. The Product will provide the means for overlaying a measured and changeable grid for enhance logistics for surveillance and sampling from high resolution satellite data and the ability to create associated data files to specific areas of concern.
3. The product will also provide a user friendly means to identify and monitor aquatic and terrestrial mosquito habitats and create “unique habitat signature” for Anopheles species (habitat signatures to locate new and unknown habitats.
4. The Product will also provide “user friendly” means to create digital elevation, climate and vegetation models to locate and monitor areas of concern for malaria transmission.
5. The Product using remote sensing technology provides the means to detect plums of CO_2 and ammonia in 20 to 60 cm^2 units to locate areas of high attractive risk to human hosts.
6. The product will include open data architecture to accommodate multiple users and databases.
7. This new signature ability is combined with UAV (Drone) technology developed for mosquito surveillance and control to fine-tune habitat signatures regarding temporal habitat variations.

Key Input Elements of the Cyber System Platform.

Community Based = Evidence Based Data



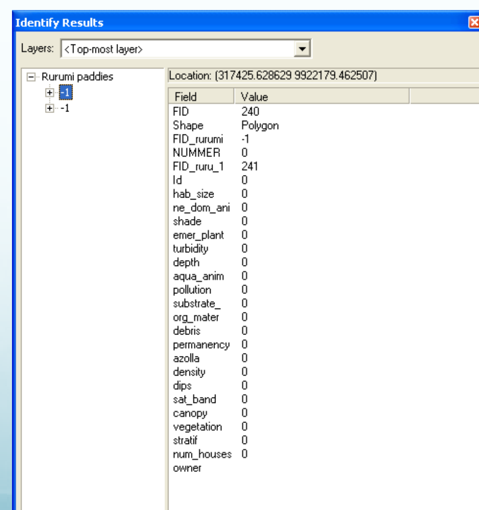
0.6m QuickBird
Image with digitized grid

Entomological Data Menu
- Adult Density
- Indoor Biting Collections
- EIR
- Larval Abundance
- Aquatic habitats
- Habitat productivity

Parasitology Data Menu
- Thick smear
- plasmodium type
- therapy

Family Information Menu
- House location
- House type
- Children
- Animals
- Roof type
- Cell phone number

A single location multiple data menu system



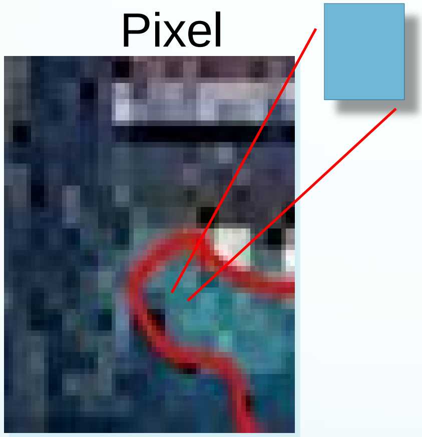
Environmental Data Menu
- flood pattern
- shade
- containers
- water sources

Mosquito Control Menu
- indoor type
- outdoor
- timing

Personal Protection Menu
- bed nets
- usage
- types
- location

Creating a Spectral Habitat Signature

0.2 – 0.6 m^2
Pixel



Spectral Band	Purpose
Coastal Blue	Vegetation and water depth based on chlorophyll
Blue	Vegetative analysis based on chlorophyll
Green	Plant vigor analysis
Yellow	Plant vigor on land and in the water
Red	Vegetation discrimination, soils, geology
Red Edge	Plant vigor
Near Infrared 1	Moisture content, plant biomass
Near Infrared 2	Moisture content, plant biomass

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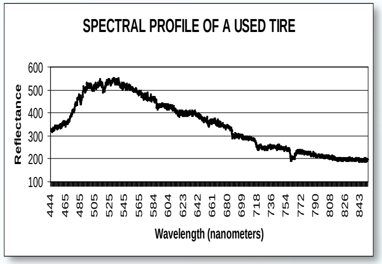
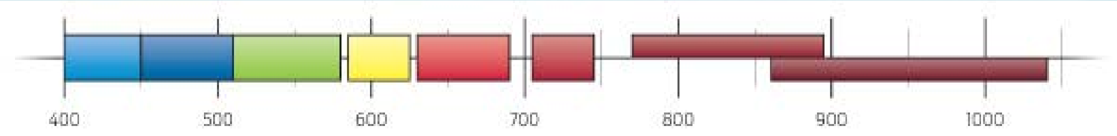
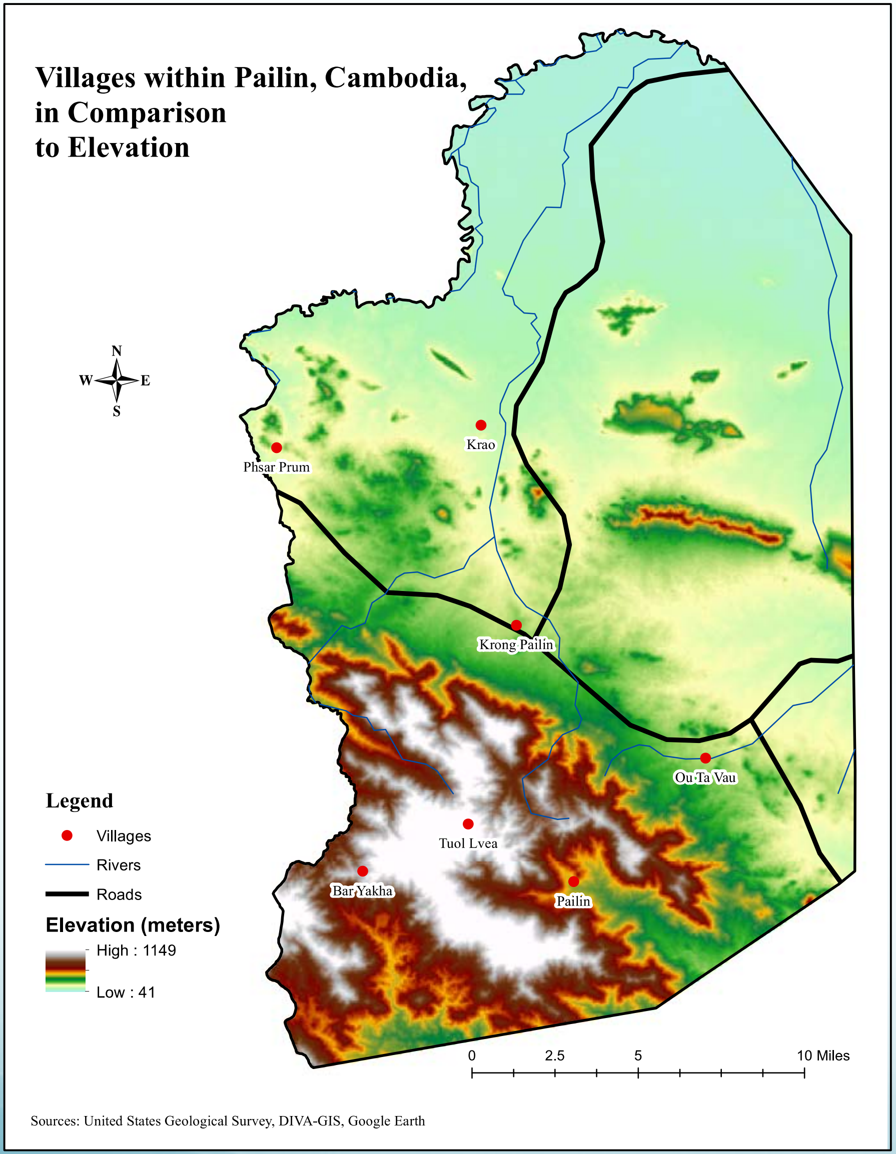


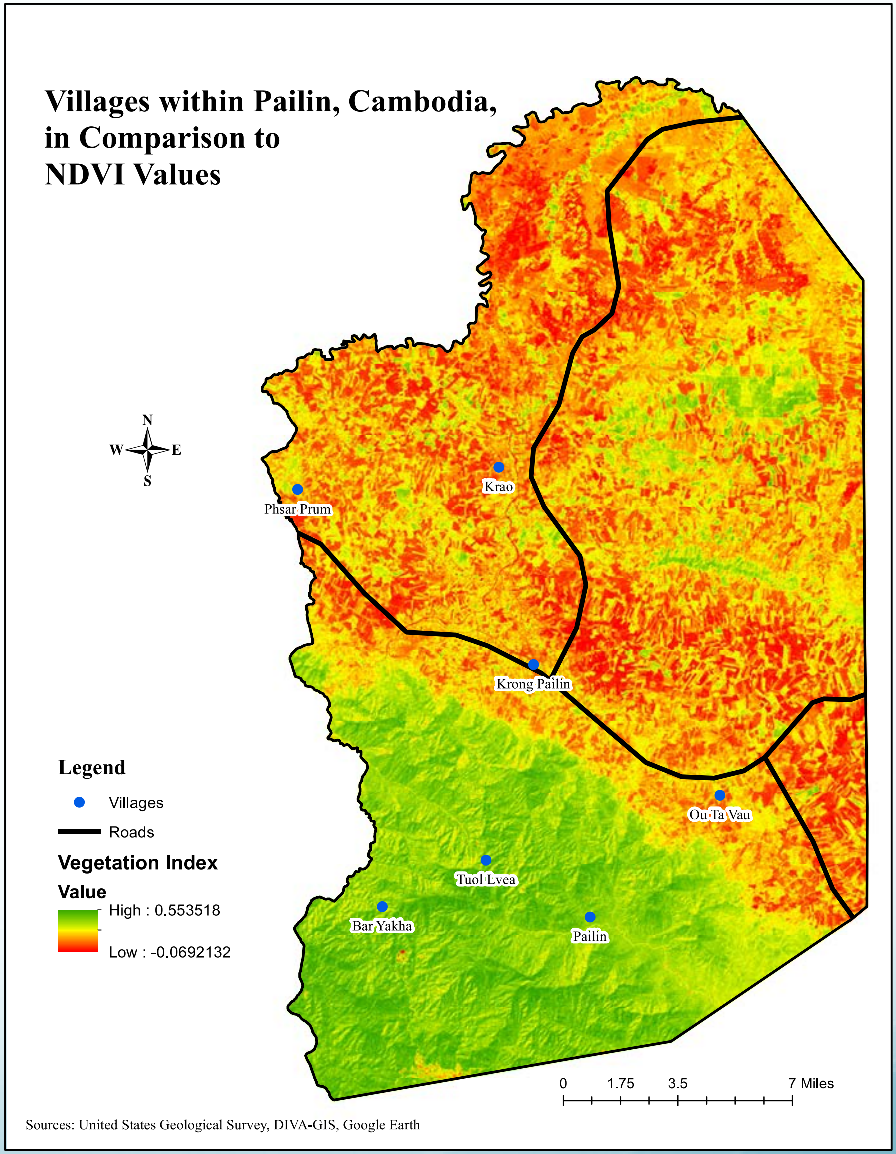
Spectral Signature

The "Intelligent" Pixel

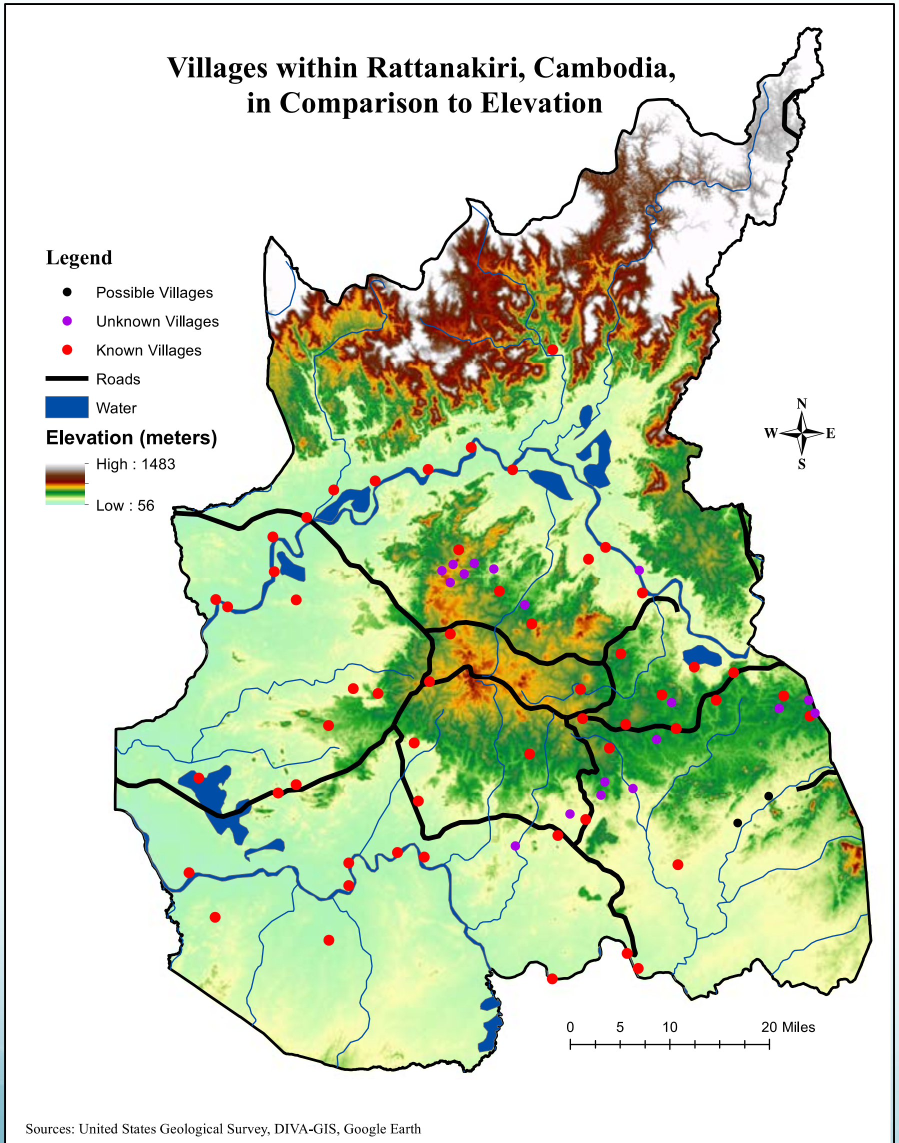


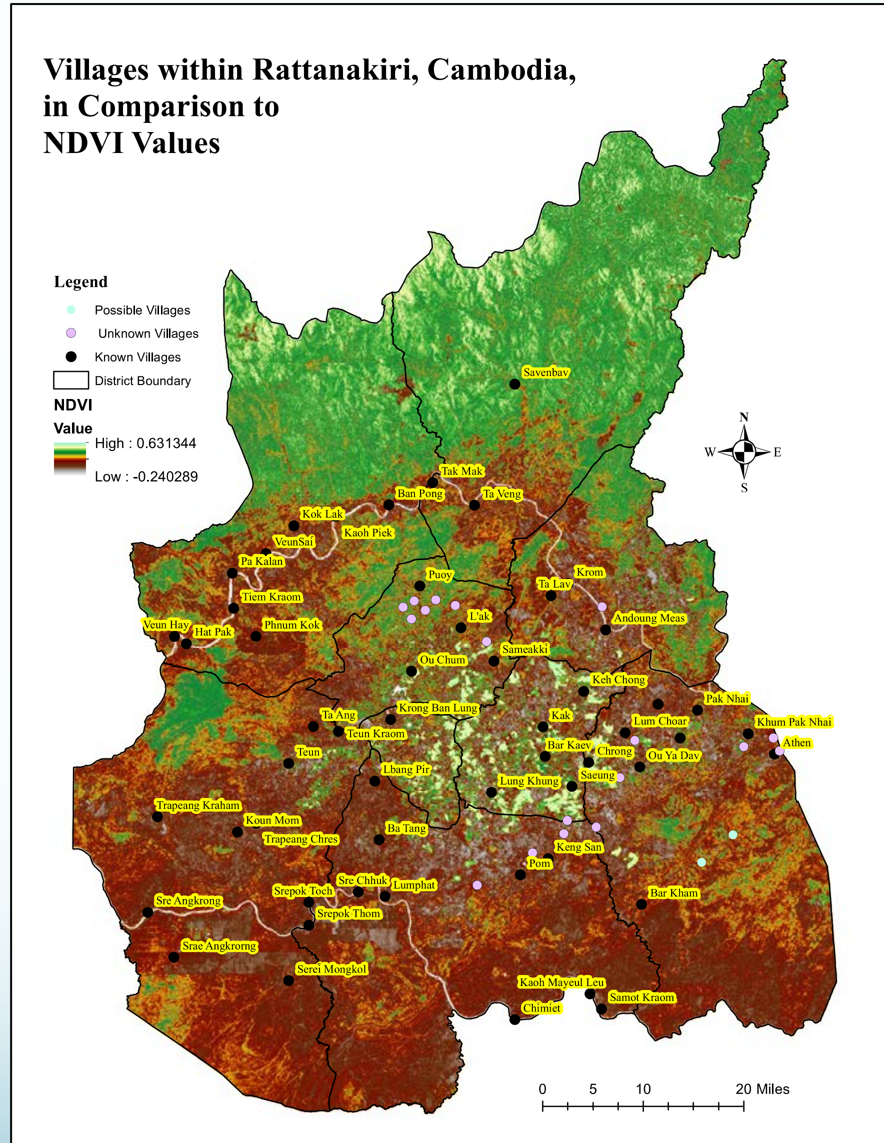
Pailin Cambodia





RattanKiri Elevation and NDVI Maps



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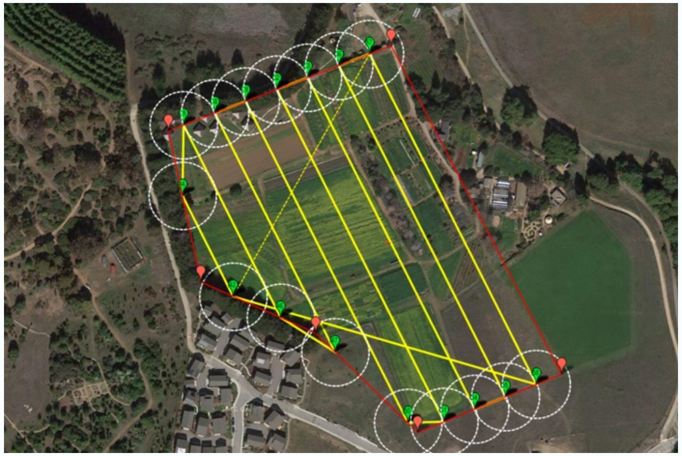



HyspIRI Science and Applications Workshop
17 to 19 October 2017, Caltech, Pasadena, CA

Key Science and Science Applications

Climate: Ecosystem biochemistry, condition & feedback; spectral albedo; carbon/dust on snow/Ice; biomass burning; evapotranspiration.

Ecosystems: Global plant functional-type, physiological condition, and biochemistry including agricultural lands.

Fires: Fuel status, fire occurrence, severity, emissions, and patterns of recovery globally.

Coral reef and coastal habitats: Global composition and status.

Volcanoes: Eruptions, emissions, regional and global impact.

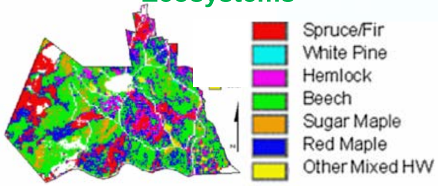
Natural and resources: Global distributions of surface mineral resources and improved understanding of geology and related hazards.

Societal Factors: Urban environment, habitability and resources.

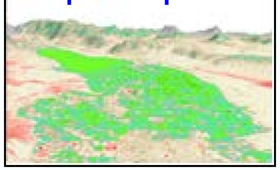
Mission Urgency

The HyspIRI science and application objectives are important today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.

Ecosystems



Evapotranspiration



Measurement

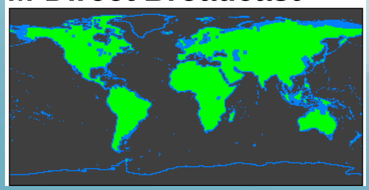
Imaging Spectrometer (VSWIR)

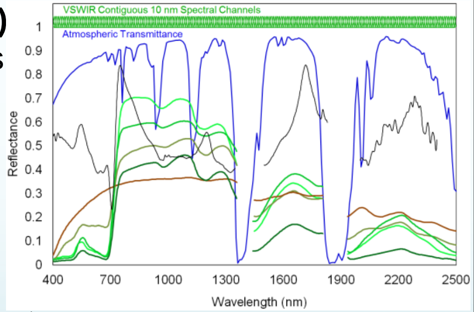
- 380 to 2510 nm in 10nm bands
- 30 m spatial sampling
- 16 days revisit
- Global land and shallow water

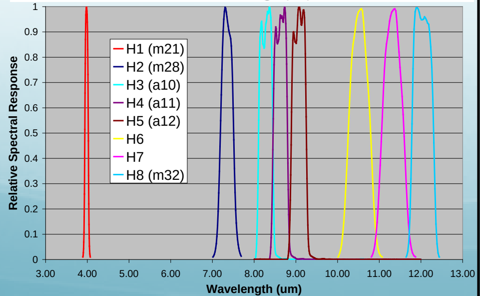
Thermal Infrared (TIR):

- 8 bands between 4-12 µm
- 60 m spatial sampling
- 5 days revisit
- Global land and shallow water

IPM-Direct Broadcast







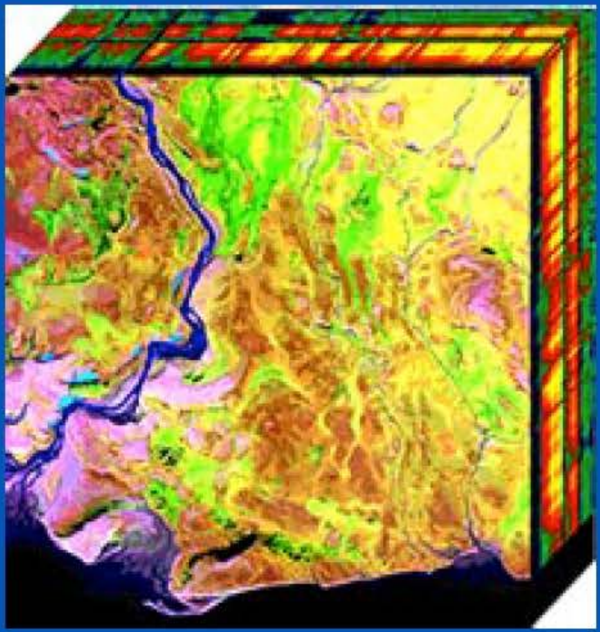
Workshop Objectives

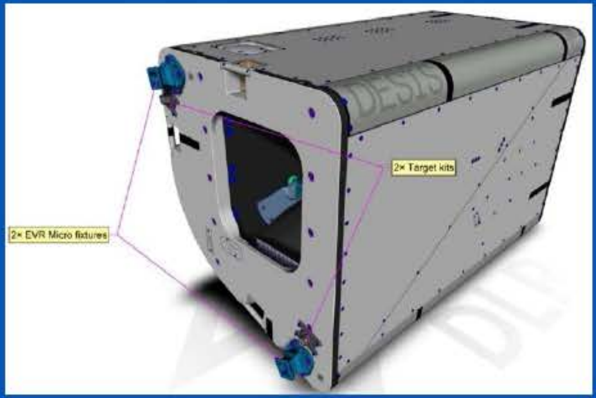
- Interact with broad science and applications research community
- Review science inputs to the Decadal Survey
- Review HyspIRI Mission Concept efforts in 2017
- Discuss ECOSTRESS TIR mission headed to the ISS
- Present new relevant Science and Applications Research
- Review results from the U.S. HyspIRI preparatory airborne campaigns
- Review AVIRIS-NG VSWIR Asian Environments campaign in India
- Support current Decadal Survey process

Information and Registration at: http://hyspiri.jpl.nasa.gov

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





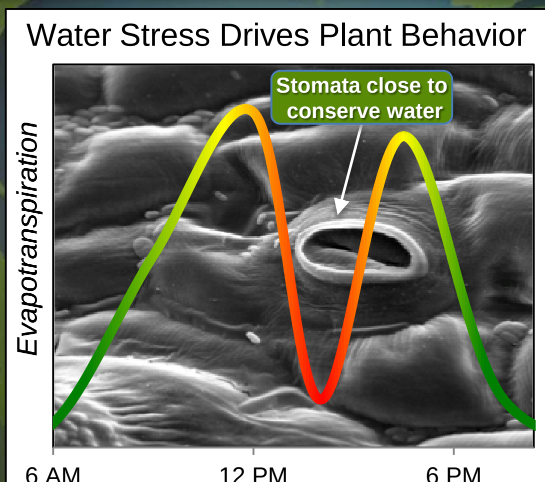
Ray Perkins, Teledyne Geospatial Solutions
17 October, 2017 NSSTC presentation

ECOSTRESS

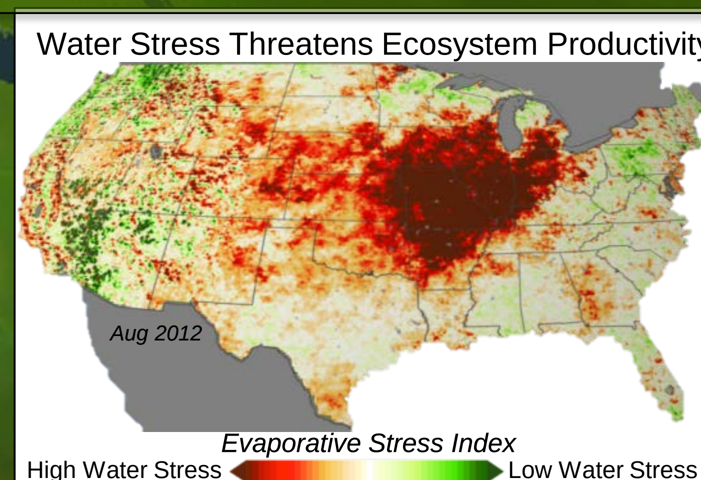
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

Dr. Simon J. Hook, JPL, Principal Investigator

*ECOSTRESS will provide 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

Compact Snapshot Image Mapping Spectrometer (SNAP-IMS) with an Unmanned Aerial Vehicle for Hyperspectral Terrain Imaging

Jason G. Dwight[1], Tomasz S. Tkaczyk[1], David Alexander[2], Michal E. Pawlowski[1], Jeffrey C. Luvall[3], Paul Tatum[3], and Gary J. Jedlovec[3]

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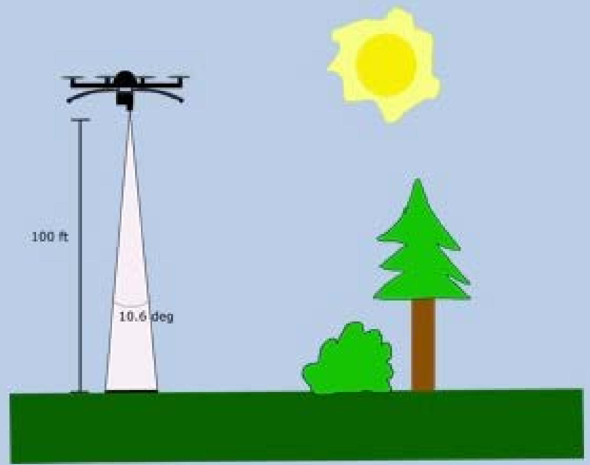


SNAP-IMS Specifications	
Dimensions	288x150x160 mm
Mass	3.6 kg
FOV	10.6˚
IFOV	.03˚
Spectral Range	485 nm – 650 nm
Spectral channels	55
Spatial Samples	350x400

Visible Derivative Spectroscopy of Mu
and Hyperspectral Images: A New App
Algal and Cyanobacterial Differentiati

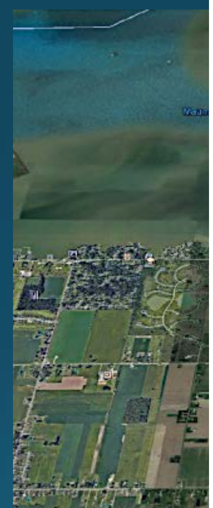
Dr. Joseph Ortiz

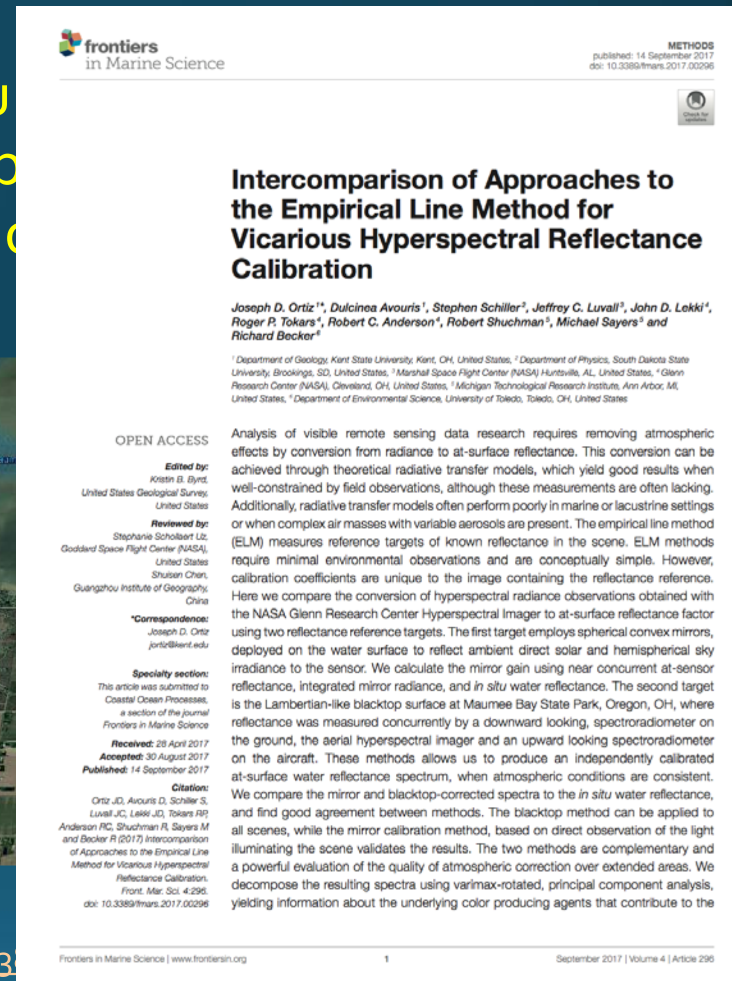
(jortiz@kent.edu),

Kent State University

Department of Geology

Collaborators: D. Avouris (KSU), Stephen Schiller (SDSU), Jeff Luvall (NASA-Marshall), John Lekki, RogerTokars, Robert Anderson, Robert Shuchman, Michael Sayers, and Richard Becker





frontiers in Marine Science

METHODS
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Intercomparison of Approaches to the Empirical Line Method for Vicarious Hyperspectral Reflectance Calibration

Joseph D. Ortiz[1], Dulcinea Avouris[1], Stephen Schiller[2], Jeffrey C. Luvall[3], John D. Lekki[4], Roger P. Tokars[4], Robert C. Anderson[4], Robert Shuchman[5], Michael Sayers[5] and Richard Becker[6]*

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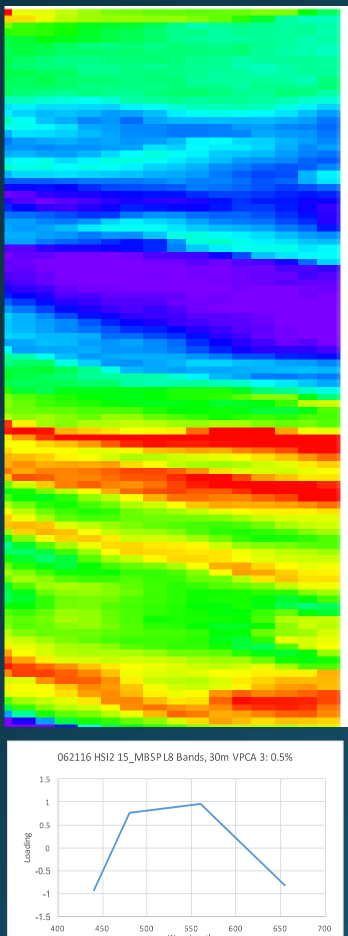
Analysis of visible remote sensing data research requires removing atmospheric effects by conversion from radiance to at-surface reflectance. This conversion can be achieved through theoretical radiative transfer models, which yield good results when well-constrained by field observations, although these measurements are often lacking. Additionally, radiative transfer models often perform poorly in marine or lacustrine settings or when complex air masses with variable aerosols are present. The empirical line method (ELM) measures reference targets of known reflectance in the scene. ELM methods require minimal environmental observations and are conceptually simple. However, calibration coefficients are unique to the image containing the reflectance reference. Here we compare the conversion of hyperspectral radiance observations obtained with the NASA Glenn Research Center Hyperspectral Imager to at-surface reflectance factor using two reflectance reference targets. The first target employs spherical convex mirrors, deployed on the water surface to reflect ambient direct solar and hemispherical sky irradiance to the sensor. We calculate the mirror gain using near concurrent at-sensor reflectance, integrated mirror radiance, and *in situ* water reflectance. The second target is the Lambertian-like blacktop surface at Maumee Bay State Park, Oregon, OH, where reflectance was measured concurrently by a downward looking, spectroradiometer on the ground, the aerial hyperspectral imager and an upward looking spectroradiometer on the aircraft. These methods allows us to produce an independently calibrated at-surface water reflectance spectrum, when atmospheric conditions are consistent. We compare the mirror and blacktop-corrected spectra to the *in situ* water reflectance, and find good agreement between methods. The blacktop method can be applied to all scenes, while the mirror calibration method, based on direct observation of the light illuminating the scene validates the results. The two methods are complementary and a powerful evaluation of the quality of atmospheric correction over extended areas. We decompose the resulting spectra using varimax-rotated, principal component analysis, yielding information about the underlying color producing agents that contribute to the

Peer-Reviewed article: https://www.frontiersin.org/articles/10.33

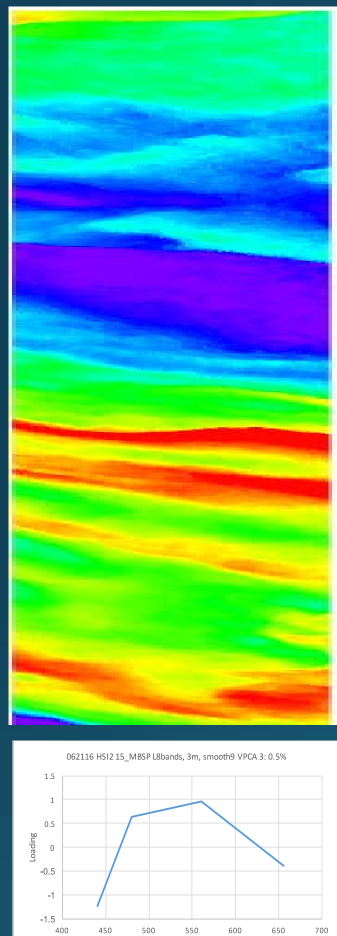
KSU Spectral Unmixing Experimental Outcome		
Spectral Placement and Resolution	Number of Components extracted	
	30m	3m
Landsat 8: Four bands: 440, 480, 560, 655 @ 20, 60, 60 and 30 nm resolution	3	3
NASA HSI2: 31 Bands 400-700 nm @10nm resolution	5	5

Ortiz et al., (HyspIRI 2017; jortiz@kent.edu)

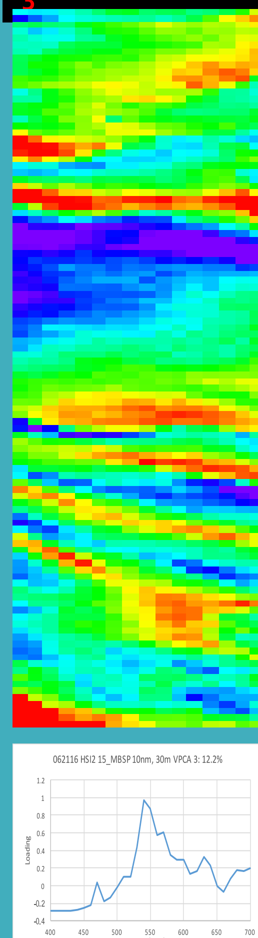
VPCA 3 Simulated L8 bands, 30m



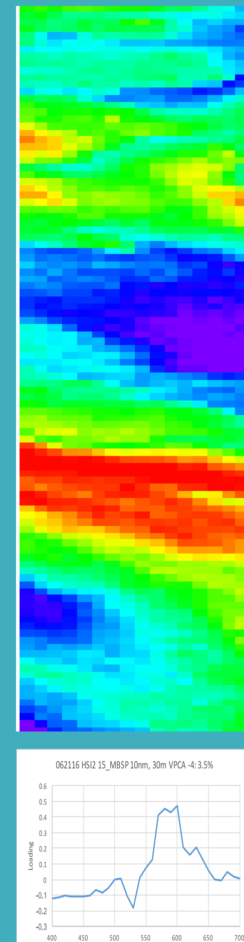
VPCA 3 Simulated L8 bands, 3m, smooth 9x9



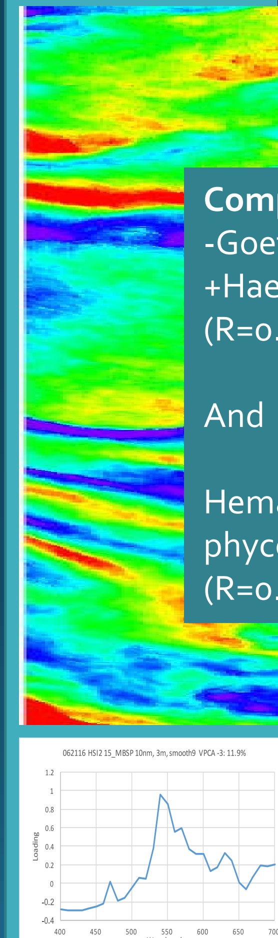
062116 15_MBSP 10nm, 30m, VPCA 3



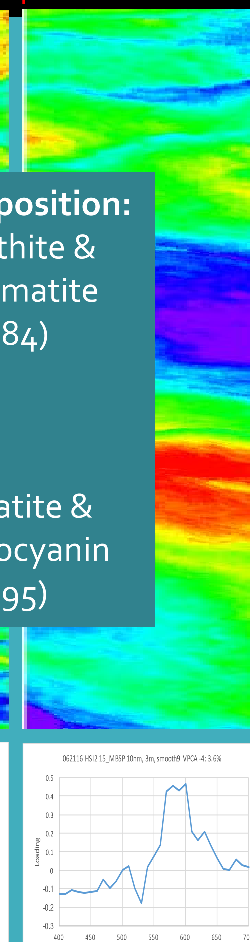
062116 15_MBSP 10nm, 30m, VPCA 4



062116 15_MBSP 10nm, 3m, SM9 VPCA-3



062116 15_MBSP 10nm, 3m, SM9, VPCA 4

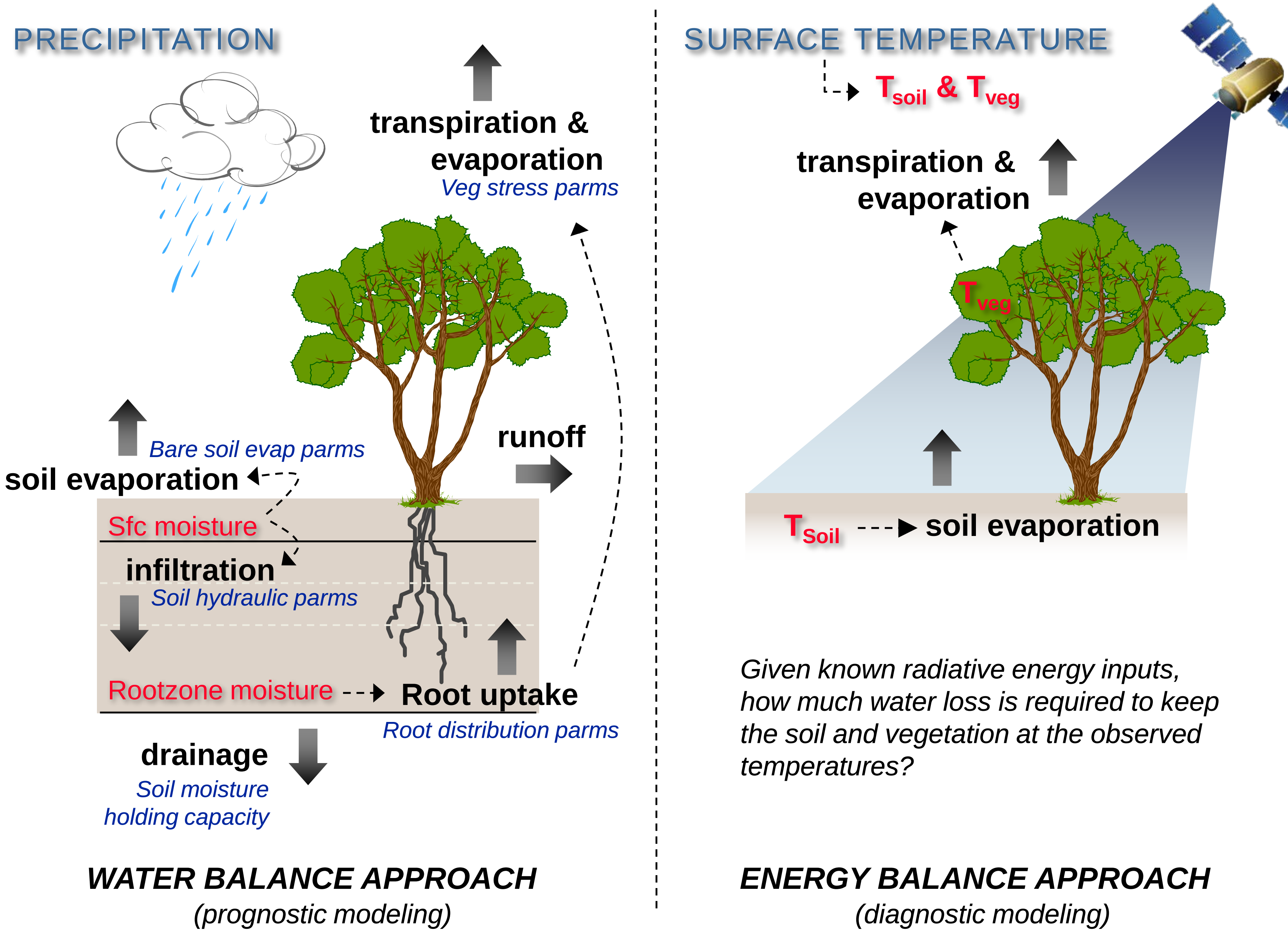


Composition:
-Goethite &
+Haematite
(R=0.84)

And

Hematite &
phycocyanin
(R=0.95)

Approaches to mapping ET



Martha C. Anderson, et al. *USDA-Agricultural Research Service, Hydrology and Remote Sensing Laboratory, Beltsville, MD*

Ag and Forest Meteorology, May 2014

Remote Sensing of Environment 115 (2011) 1772–1780

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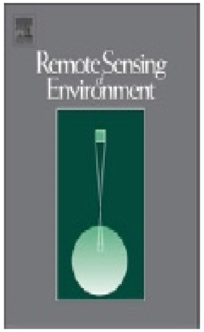


High-resolution urban thermal sharpener (HUTS)

Anthony Dominguez [a], Jan Kleissl [a,*], Jeffrey C. Luvall [b], Douglas L. Rickman [b]

[a] *University of California, San Diego, Department of Mechanical and Aerospace Engineering, USA*

[b] *NASA, Marshall Space Flight Center, AL 35812, USA*

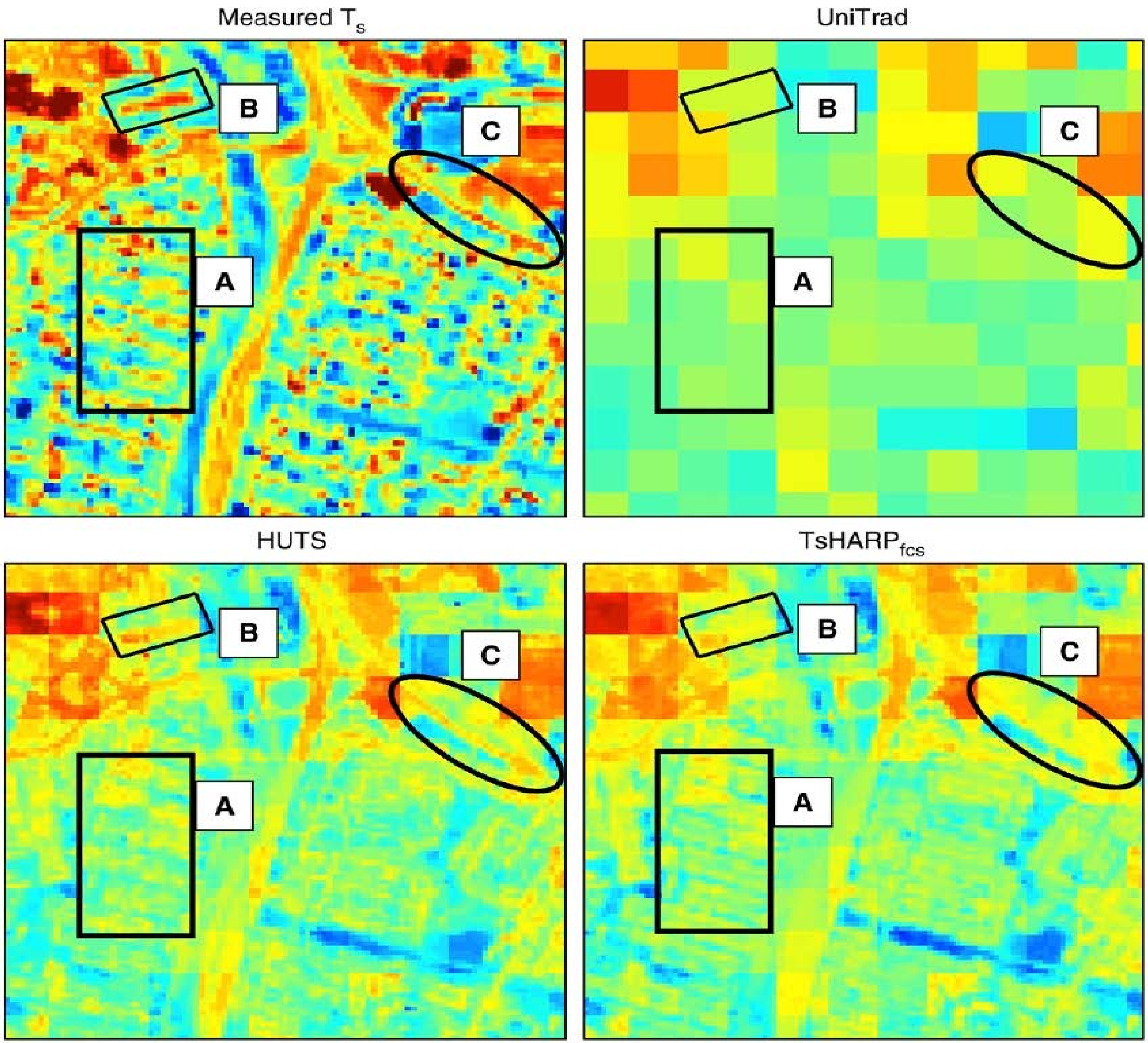
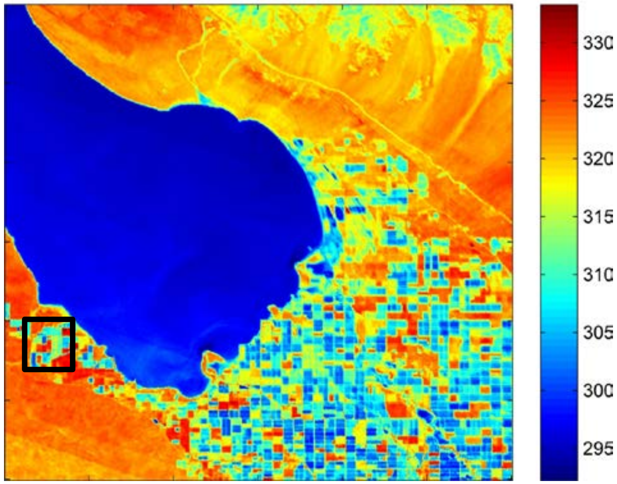


Fig. 5. Sharpened T_s zoomed in to a 100 × 100 pixel urban region (centered at 18.390698°N, 66.153084°W) at 10 m resolution. The figure shows a major highway intersection (Cll 2 and Carr 174). To the south of the east–west highway are mostly residential neighborhoods with trees, while parks, parking lots, and commercial buildings are to the north. West of

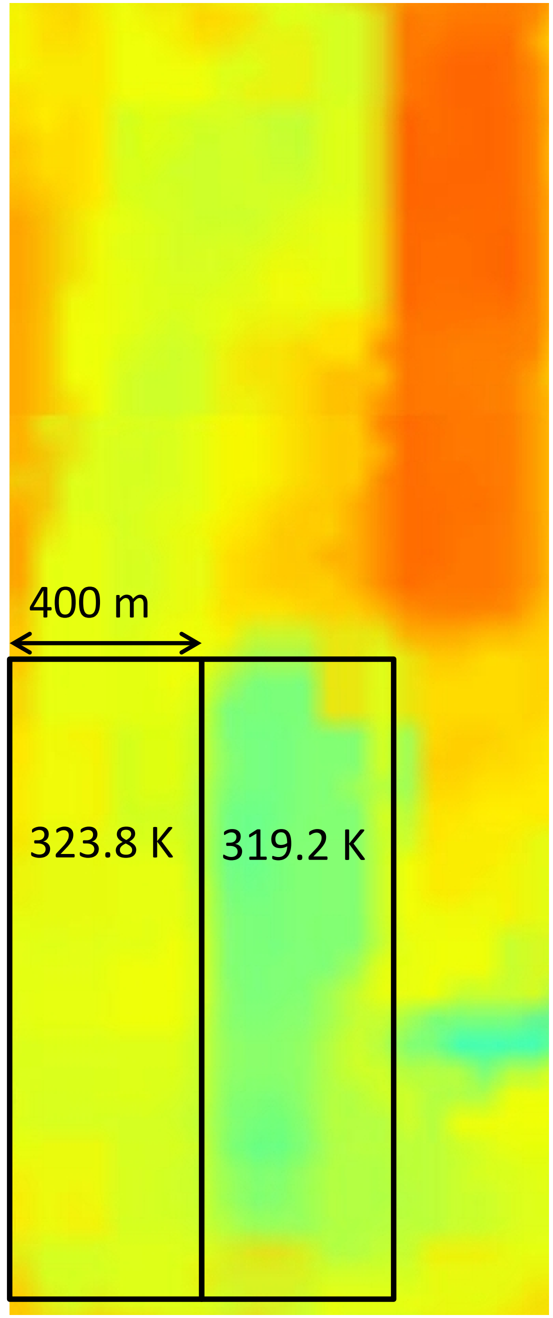
ECOSTRESS Simulated LST - 67m



1. **Signatures of vegetation stress are manifested in the LST signal *__before__* any visible deterioration of vegetation cover occurs.**

2. **The surface moisture state can be *__deduced directly__* from the remotely sensed LST.**

MASTER LST: 08/26/2014



Google Earth: 08/28/14

A high spatio-temporal resolution Land Surface Temperature (LST) product for urban environments

Glynn Hulley, JPL, PI
Jeffrey Luvall, MSFC, Co-I

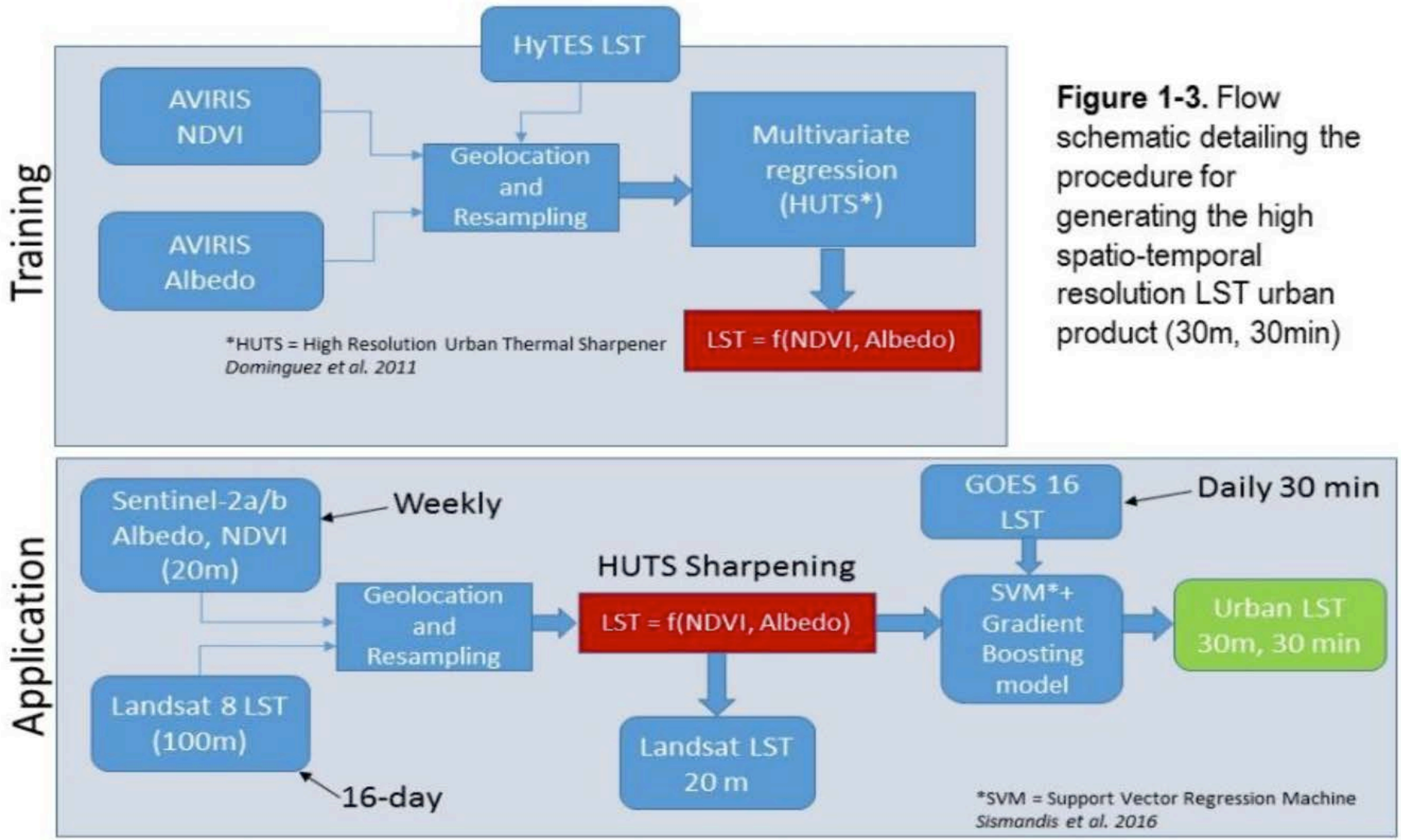


Figure 1-3. Flow schematic detailing the procedure for generating the high spatio-temporal resolution LST urban product (30m, 30min)

NSIDC

http://nsidc.org/data/SPL2SMAP_S/versions/1

Dear Colleague,

The beta version of the “SMAP/Sentinel-1 L2 Radiometer/Radar 30-Second Scene 3 km EASE-Grid Soil Moisture” data set is now available at the NASA National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC).

This product combines L-band radiometer measurements from SMAP and C-band radar measurements from Copernicus Sentinel-1 to produce high-resolution soil moisture estimates.

The SMAP Science Data System (SDS) began forward processing for this new data set on 27 October 2017. Data reprocessing from 01 April 2015 to 27 October 2017 will start in mid-November 2017. These data will be made available as they are processed and registered users will be notified when reprocessing is complete.

Users should be aware that these beta data use preliminary algorithms that are still being validated and are thus subject to uncertainties. The calibrated/validated release of this data set is expected to occur in Spring 2018.

To access data, documentation, and tools, please see the SMAP Web site at the NSIDC DAAC:
http://nsidc.org/data/smap/

SMAP - One day 3 km x 3 km pixel Surface Soil Moisture (0-5cm)

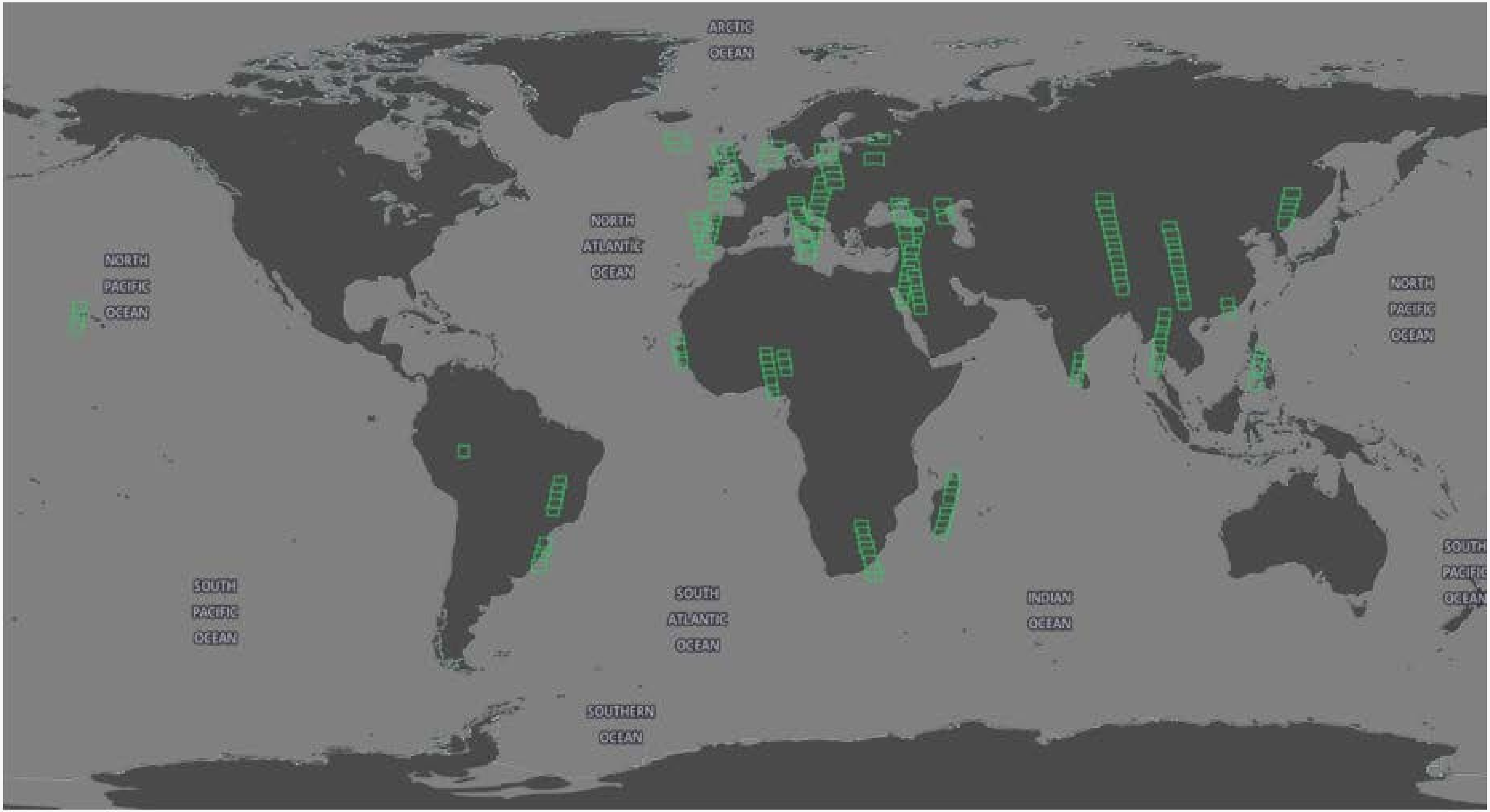
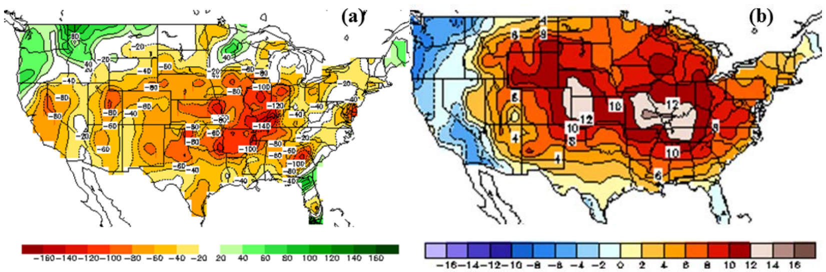
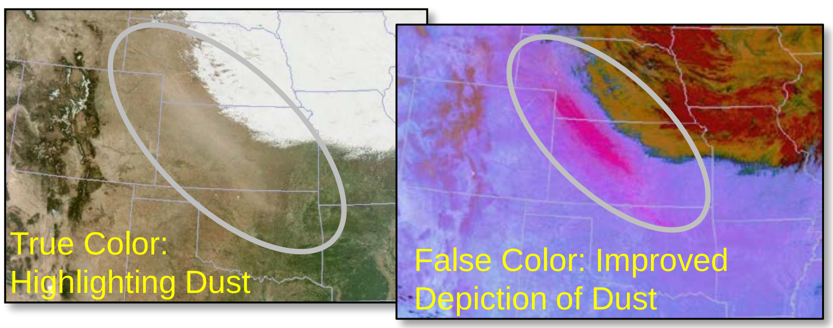


Figure 2. Spatial Coverage Map displaying SMAP/Sentinel-1A/1B match-up scenes. The map was created using the NASA Earthdata Search tool.

NASA’s Short-term Prediction Research and Transition (SPoRT) Center



Temperature and soil moisture anomalies for public health (extreme heat and cold) or environmental applications favorable for disease vectors



Multispectral remote sensing from VIIRS and MODIS for air quality and vegetation applications.

- The SPoRT Center focuses on the transition of “research to applications” for unique NASA, NOAA, and other-agency capabilities
- Current focus is on the use of land surface modeling and remote sensing for a variety of applications
  - Weather Analysis and Forecasting
  - Numerical Weather Prediction
  - Remote Sensing
  - Disasters
- SPoRT is well-suited to combine multiple products to support Public Health applications, through combination of satellite-derived and model-derived information.

Combined, modeling and remote sensing capabilities can support the generation of new Public Health products, alerts, and end training for end users.

KEY ATTRIBUTES OF THE SURVEILANCE AND MONITORING SYSTEM

(1) Determine the current and evolving state of malaria prevalence and incidence by analyzing, refining and validating existing and developed models;

(2) Provide training and courses designed to give professional and non-professional personnel an adequate knowledge of disciplines including entomology, parasitology, epidemiology, GIS/Remote sensing and computer technology.

(3) Guide the tailoring of intervention strategies to local landscape characteristics by integrating the implementation and analysis of multiple intervention tactics from environmental to clinical.

(4) Integrate climate, epidemiological and ecological data, to forecast critical potential high risk transmission areas and time periods.

(5) Analyze overall progress for households and communities, to determine health and economic implications associated with malaria reductions or increases.

(6) Identify and provide key data needs for operational managers, ministers of health, donors and scientific users.

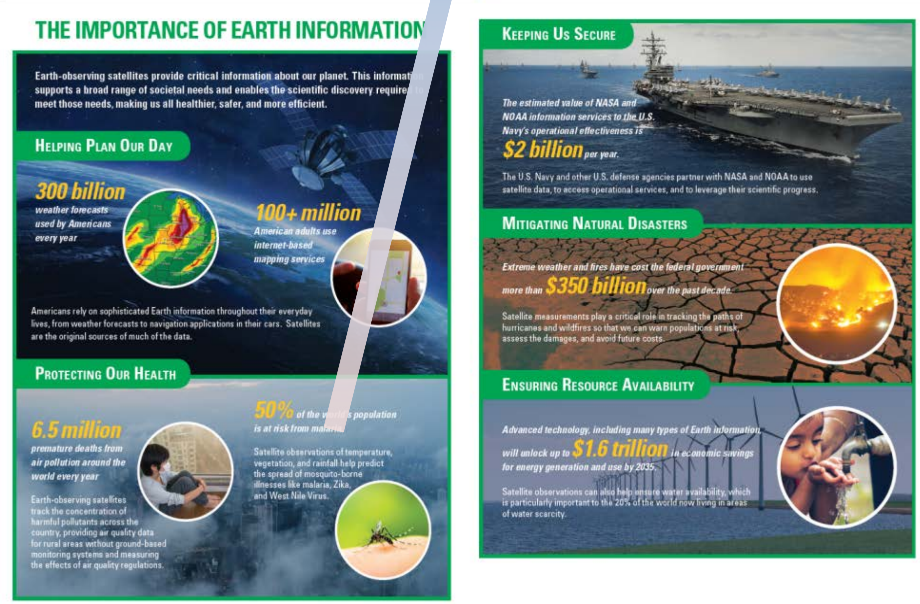
(7) Measure the performance and cost effectiveness of malaria control and/or other interventions by performing periodic cost-benefit analyses.

(8) Expand the surveillance system to different provinces or landscapes within country.

(9) Ensure built-in adaptability of this system to other diseases of public health importance.

(10) An open IT system design to accommodate other data-bases, partners, and sources of information

Earth Information is Increasingly Critical to *Thriving* on our Planet

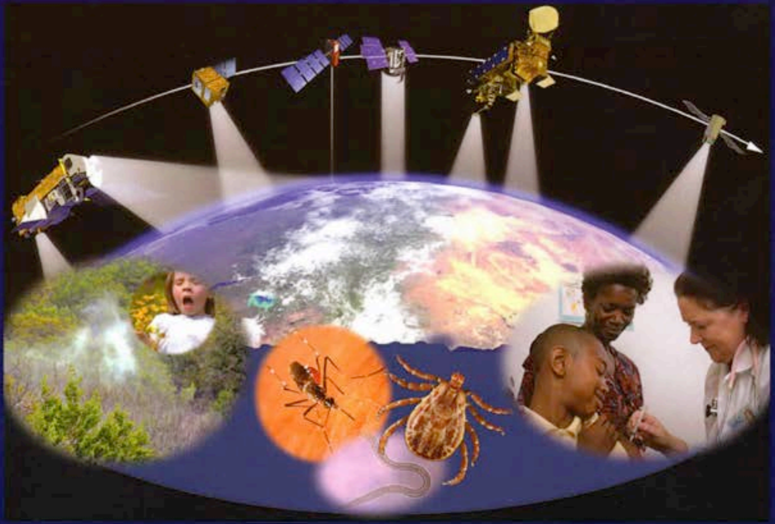


http://sites.nationalacademies.org/DEPS/ESAS2017/index.htm

Recommended NASA Priorities: Designated

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Aerosols	**Aerosol properties, aerosol vertical profiles, and cloud properties** to understand their direct and indirect effects on climate and air quality	Backscatter lidar and multi-channel/multi-angle/polarization imaging radiometer flown together on the same platform	X		
Clouds, Convection, & Precipitation	**Coupled cloud-precipitation state and dynamics** for monitoring global hydrological cycle and understanding contributing processes	Radar(s), with multi-frequency passive microwave and sub-mm radiometer	X		
Mass Change	**Large-scale Earth dynamics** measured by the changing mass distribution within and between the Earth's atmosphere, oceans, ground water, and ice sheets	Spacecraft ranging measurement of gravity anomaly	X		
Surface Biology & Geology	**Earth surface geology and biology,** ground/water temperature, snow reflectivity, active geologic processes, vegetation traits and algal biomass	Hyperspectral imagery in the visible and shortwave infrared, multi- or hyperspectral imagery in the thermal IR	X		
Surface Deformation & Change	**Earth surface dynamics** from earthquakes and landslides to ice sheets and permafrost	Interferometric Synthetic Aperture Radar (InSAR) with ionospheric correction	X		

ISPRS Book Series



Environmental Tracking for Public Health Surveillance

Editors: Stanley A. Morain & Amelia M. Budge

CRC Press
Taylor & Francis Group
A BALKEMA BOOK

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NASA Research

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NASA Research Announcement

Earth Science Applications: Health and Air Quality

Solicitation: NNH17ZDA001N-HAQ

Dates

Release	Feb 14, 2017
HAQ17 NOIs Due	Sep 18, 2017
HAQ17 Proposals Due	Nov 17, 2017

Announcement Documents

- DUE DATES: Table 2 lists all program elements in due date order (.HTML)
- DUE DATES: Table 3 lists all program elements in appendix order (.HTML)
- Summary of Solicitation corrected April 24, 2017 (.PDF)
- Full ROSES-2017 (Summary plus Appendices A-E) as amended and clarified (.PDF)
- A.1 Earth Science Research Program Overview as corrected March 9, 2017 (.PDF)
- A.39 Earth Science Applications: Health and Air Quality as amended (.PDF)

Program Element Information

- Research Opportunities in Space and Earth Sciences 2017 (ROSES–2017)

https://nspires.nasaprs.com/