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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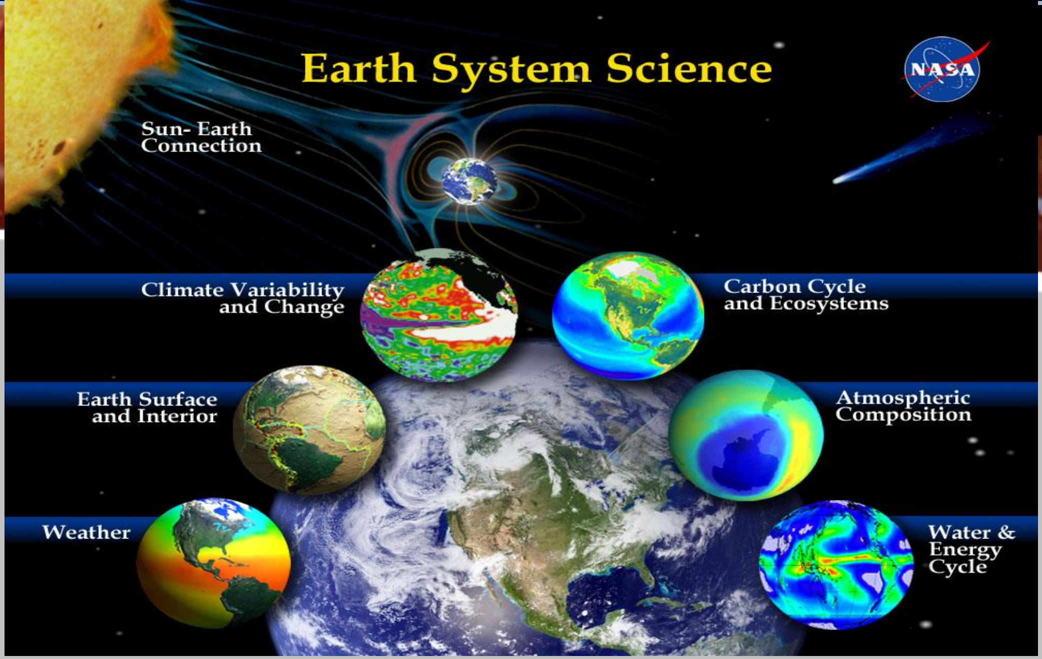
☼ θΔ ics □



NASA Applied Sciences Program Mission Statement

Advance the realization of societal and economic benefits from NASA Earth science by identifying societal needs, conducting applied research and development, and collaborating with application developers and users.

NASA Public Health Application Areas

Earth science applications for public health and safety, particularly regarding infectious disease, emergency preparedness and response, and environmental health issues…….

igure 3-4 Photograph of Gaspard Felix Tournachon (1820-1910), the famous Parisian photographer. He called himself Nadar. Here he is seen kneeling in a fragile balloon gondola. He obtained the first aerial photograph from a balloon in 1858 near Paris, France, and patented the aerial survey as we know it today. Unfortunately, the first aerial photograph did not survive (© Roger-Viollet, Paris, France; used with permission).

Figure 3-5 A portion of an aerial photograph of downtown Boston, MA, obtained by aeronauts James W. Black and Samuel A. King from a tethered balloon at an altitude of 1,200 ft on October 13, 1860. It is believed to be the first aerial photograph taken from a captive balloon in the United States and the earliest aerial photograph still in existence. It was obtained using a wet collodion plate (used with permission of the Smithsonian Institution, Washington, DC; #3B-15472).

Gaspard Tournachon, AKA Nadar 1858

Boston, MA 1860, Black & King


Earth Science Missions
ISS Instruments
LIS (2020), SAGE III (2020)
TSIS-1 (2018), OCO-3 (2018), ECOSTRESS (2017), GEDI (2018)
CLARREO-PF (2020)
JPSS-2 Instruments
RBI (2018), OMPS-Limb (2018)
Formulation
Implementation
Primary Ops
Extended Ops
Landsat 9 (2020)
PACE (2022)
GeoCARB (~2021)
TROPICS (12) (~2021)
MAIA (~2021)
Sentinel-6A/B (2020, 2025)
NI-SAR (2021)
SWOT (2021)
TEMPO (2018)
GRACE-FO (2) (2018)
ICESat-2 (2018)
CYGNSS (8) (2019)
NISTAR, EPIC (DSCOVR / NOAA) (2019)
SMAP (>2022)
Landsat 7 (USGS) (~2022)
QuikSCAT (2017)
SORCE, TCTE (NOAA) (2017)
Suomi NPP (NOAA) (>2022)
Terra (>2021)
Landsat 8 (USGS) (>2022)
Aqua (>2022)
CloudSat (~2018)
CALIPSO (>2022)
GPM (>2022)
Aura (>2022)
OSTM/Jason-2 (NOAA) (>2022)
OCO-2 (>2022)
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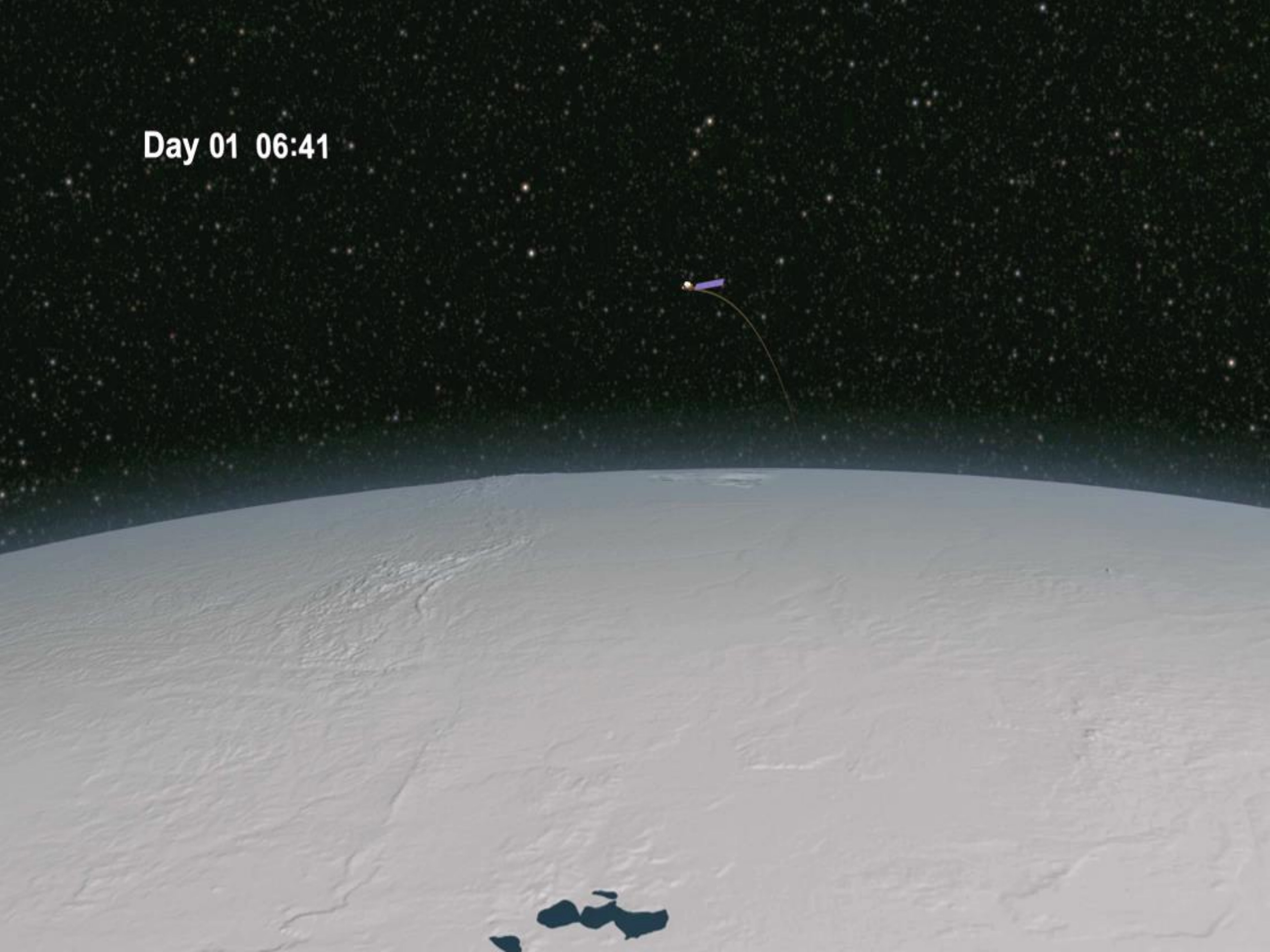
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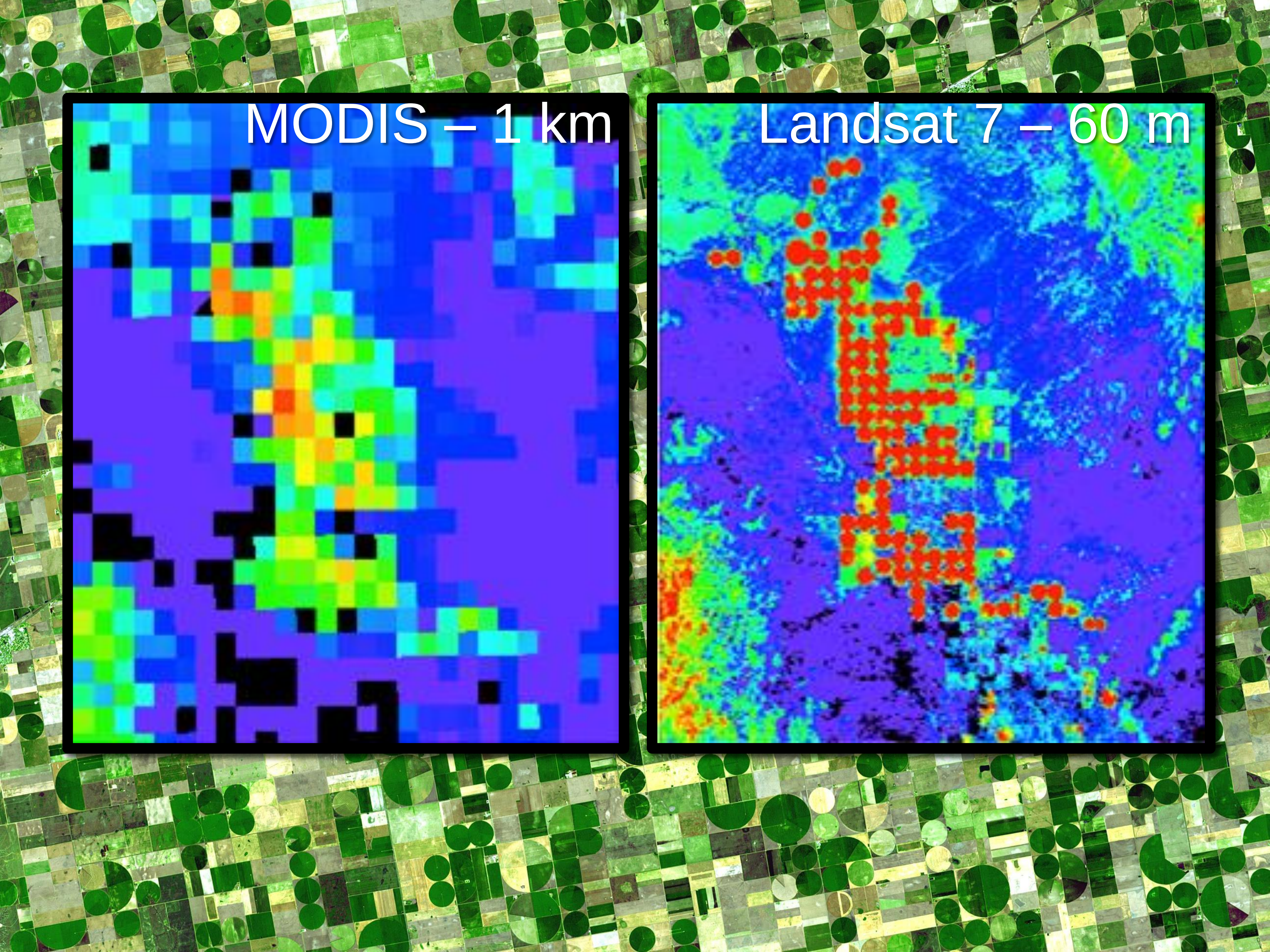
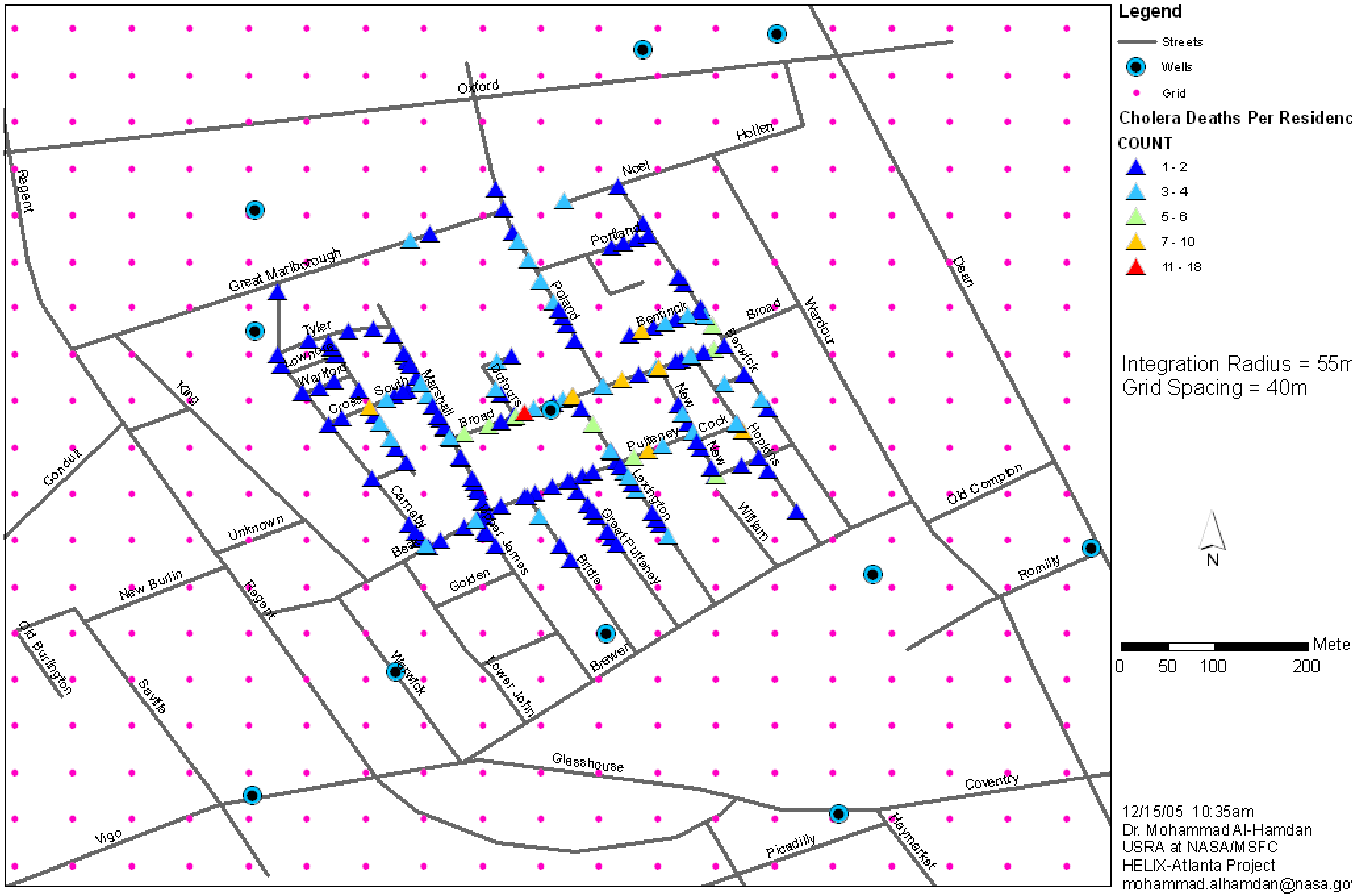

MODIS – 1 km
Landsat 7 – 60 m

Public Health Surveillance

Cholera Deaths Soho, London August-September, 1854

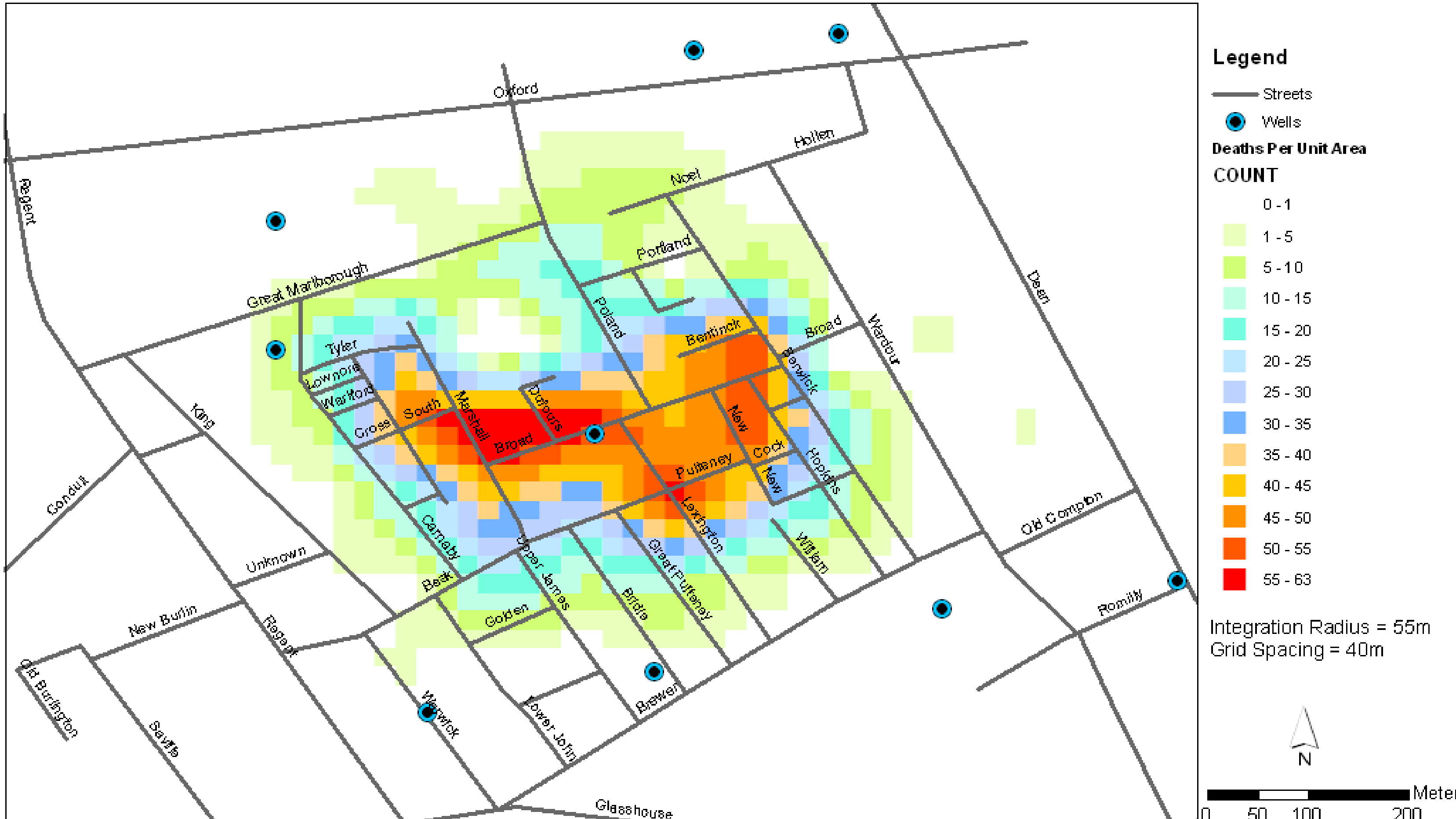


*Original data were published by C.F. Cheffins, Lith, Southampton Buildings, London, England, 1854 in Snow, John. On the Mode of Communication of Cholera, 2nd Ed, John Churchill, New Burlington Street, London, England, 1855.

**Digital Data of Streets, Wells, and Deaths Residences which were used to creat this surface were downloaded from the UCLA Department of Epidemiology Website at http://www.ph.ucla.edu/epi/snow.html.

Public Health Surveillance

Cholera Deaths Soho, London August-September, 1854



12/15/05 10:35am
Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC
HELIX-Atlanta Project
mohammad.alhamdan@nasa.gov

*Original data were published by C.F. Cheffins, Lith, Southhampton Buildings, London, England, 1854 in Snow, John. On the Mode of Communication of Cholera, 2nd Ed, John Churchill, New Burlington Street, London, England, 1855.
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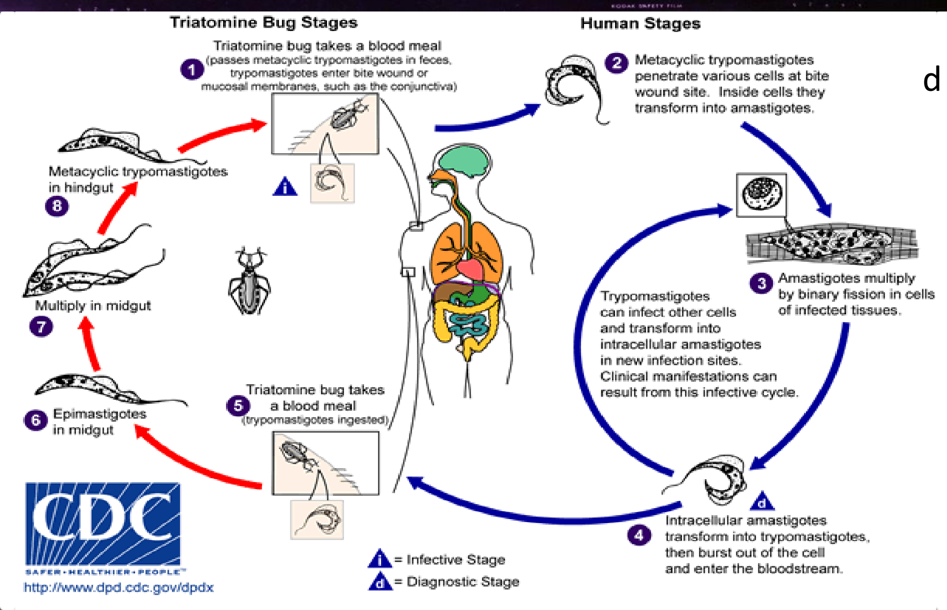
Courtesy: Dr. Jeff Luvall, NASA/MSFC

1

3

b

d



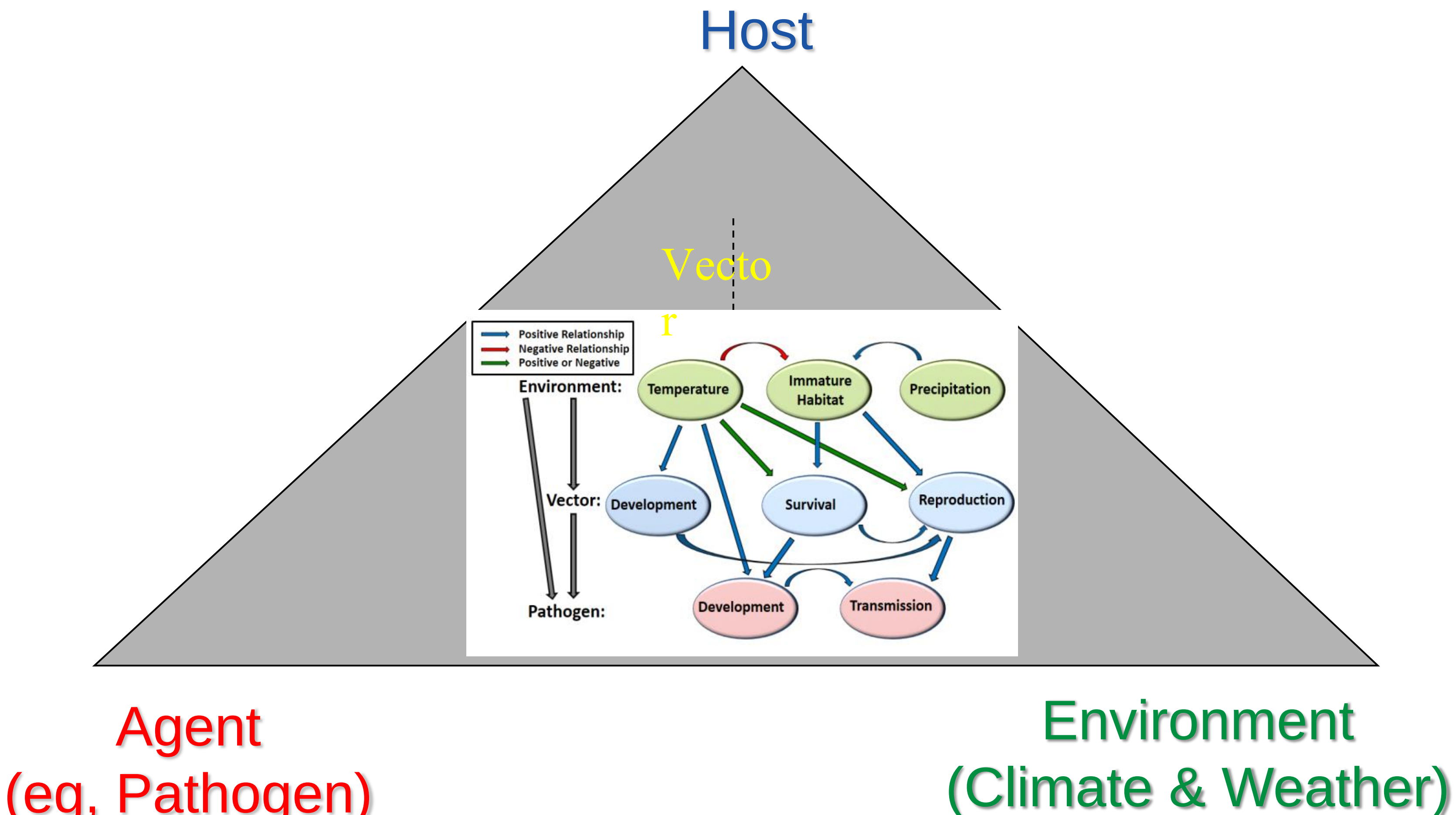
Triatomine Bug Stages
Human Stages
Triatomine bug takes a blood meal (passes metacyclic trypomastigotes in feces, trypomastigotes enter bite wound or mucosal membranes, such as the conjunctiva)
1
2
Metacyclic trypomastigotes penetrate various cells at bite wound site. Inside cells they transform into amastigotes.
3
Amastigotes multiply by binary fission in cells of infected tissues.
Trypomastigotes can infect other cells and transform into intracellular amastigotes in new infection sites. Clinical manifestations can result from this infective cycle.
4
Intracellular amastigotes transform into trypomastigotes, then burst out of the cell and enter the bloodstream.
5
Triatomine bug takes a blood meal (trypomastigotes ingested)
6
Epimastigotes in midgut
7
Multiply in midgut
8
Metacyclic trypomastigotes in hindgut
i = Infective Stage
d = Diagnostic Stage
CDC
SAFER·HEALTHIER·PEOPLE™
http://www.dpd.cdc.gov/dpdx

c

2

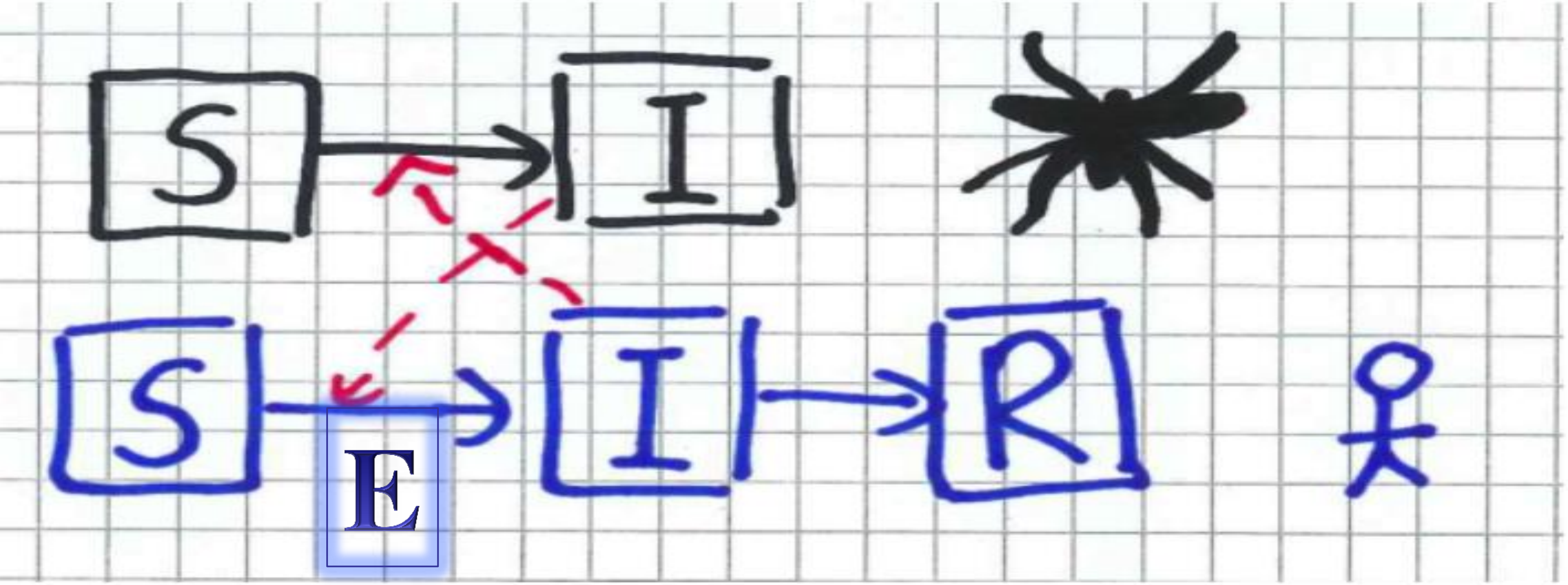
Epidemiologic Triangle of Disease (Vector-borne Diseases)

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.

Potentially, An Increased Risk of Transmission

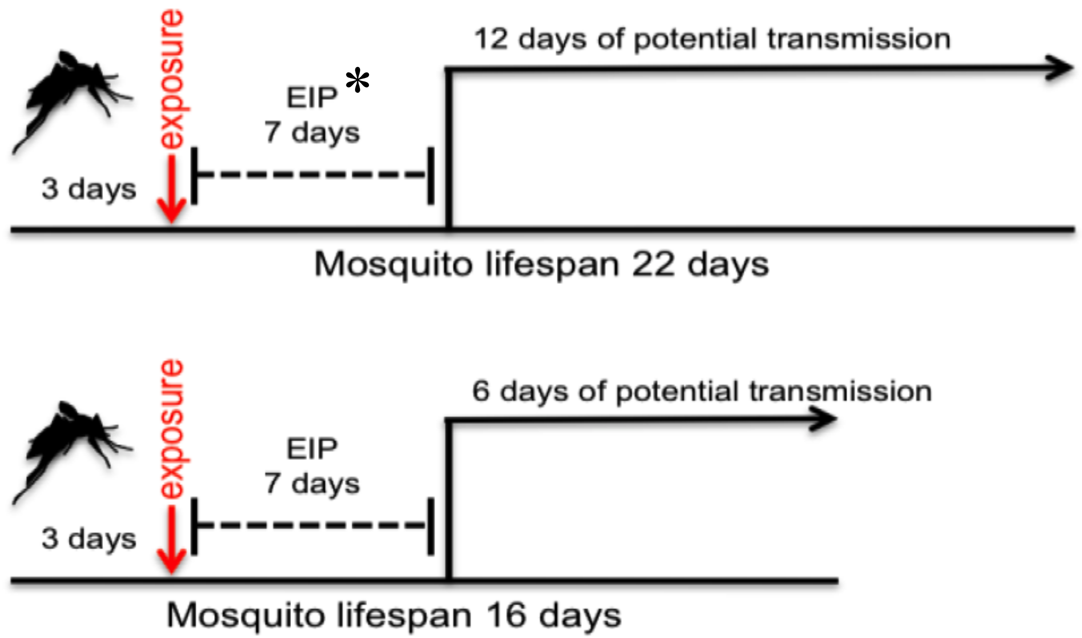


Figure 8 (from Christofferson & Mores 2016): Schematic demonstrating the impact of mosquito mortality on the cumulative transmission potential of an arbovirus.

*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)

Thermal Remote Sensing and the Thermodynamics of Ecosystem Development

Jeffrey C. Luvall[1], Doug Rickman[1], and Roydon F. Fraser[2]

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[2]University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

In Memory of James J. Kay 1954-2004

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
☀ θΔ ics ☐

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

☀θΔ ics □

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***

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

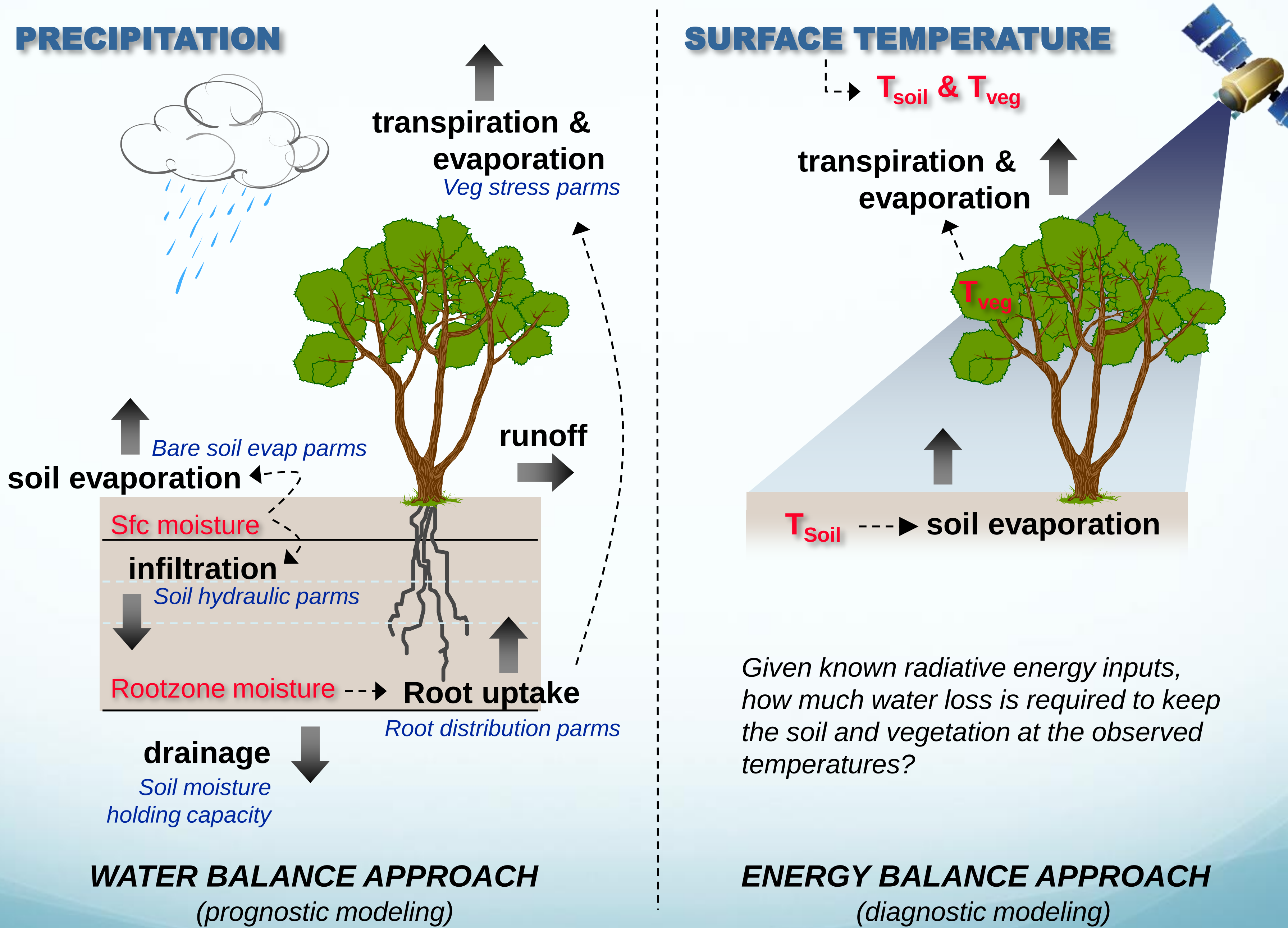
LE = Latent Heat Flux

G = Storage (maybe + or -)

Surface Temperature

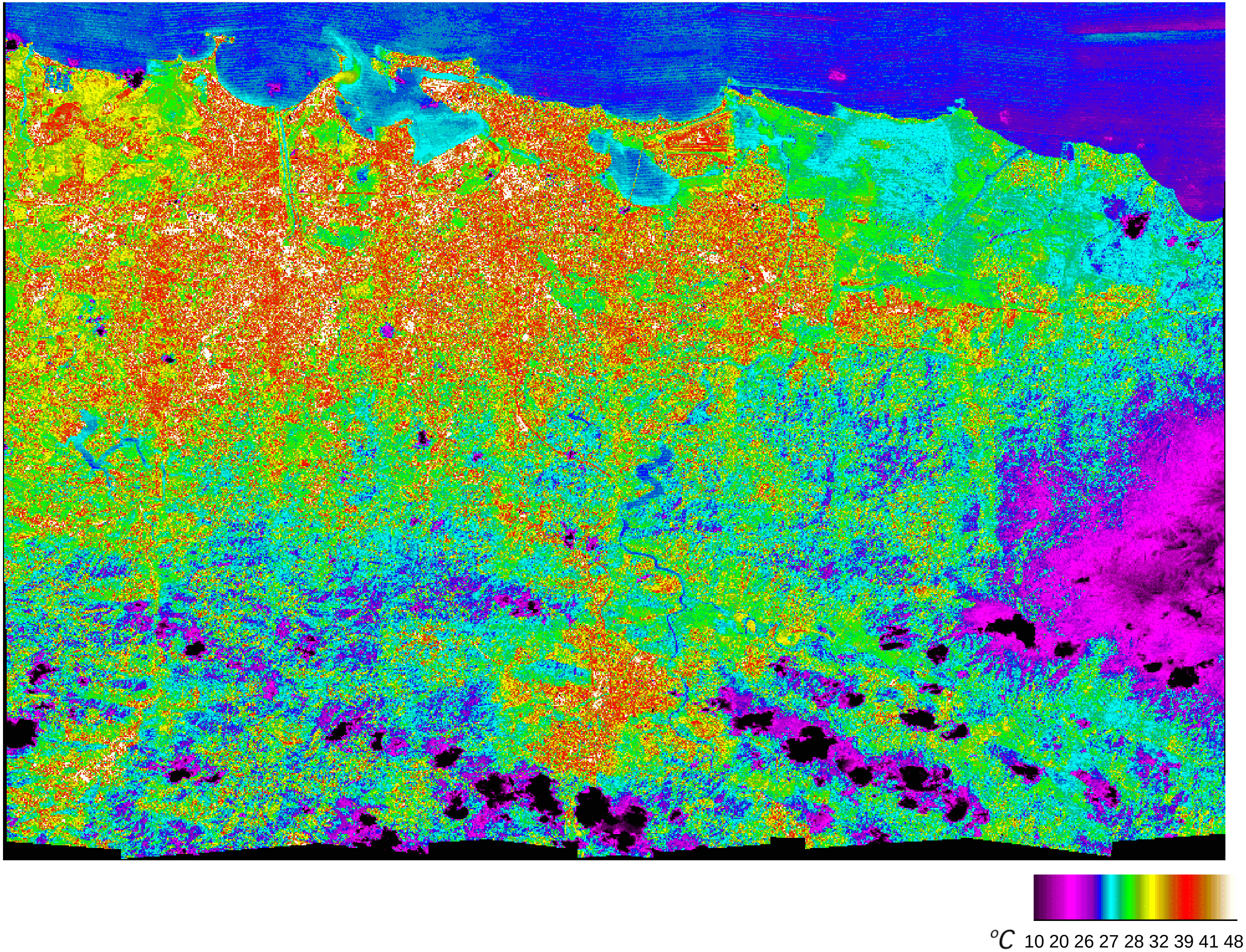
$$T_s = T_a + \frac{R_b}{C_r}\left(R_n - E\right)$$

Approaches to mapping ET



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

San Juan F5 Mosaic Temperature



Remote Sensing of Environment 115 (2011) 1772–1780

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

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*

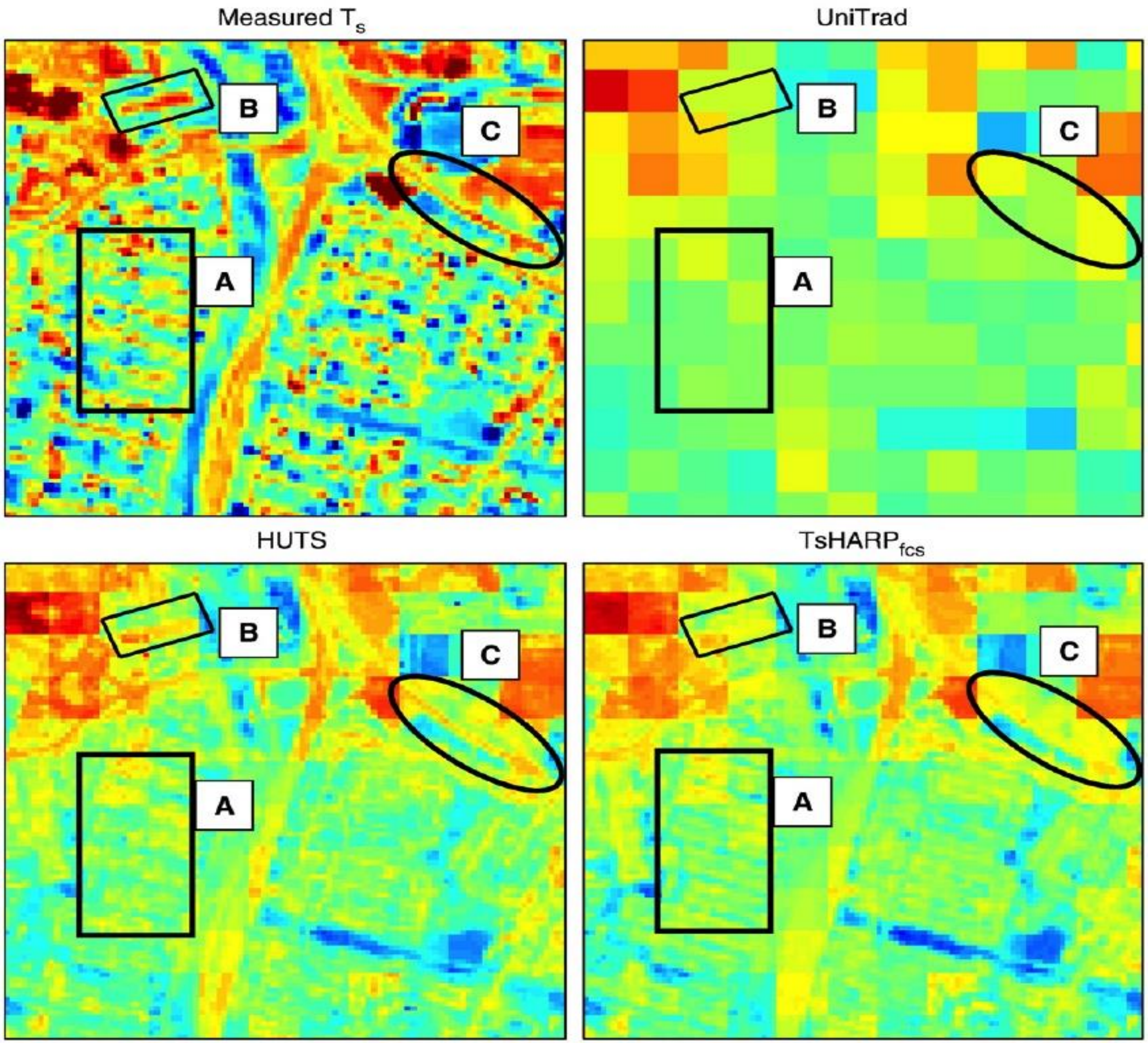
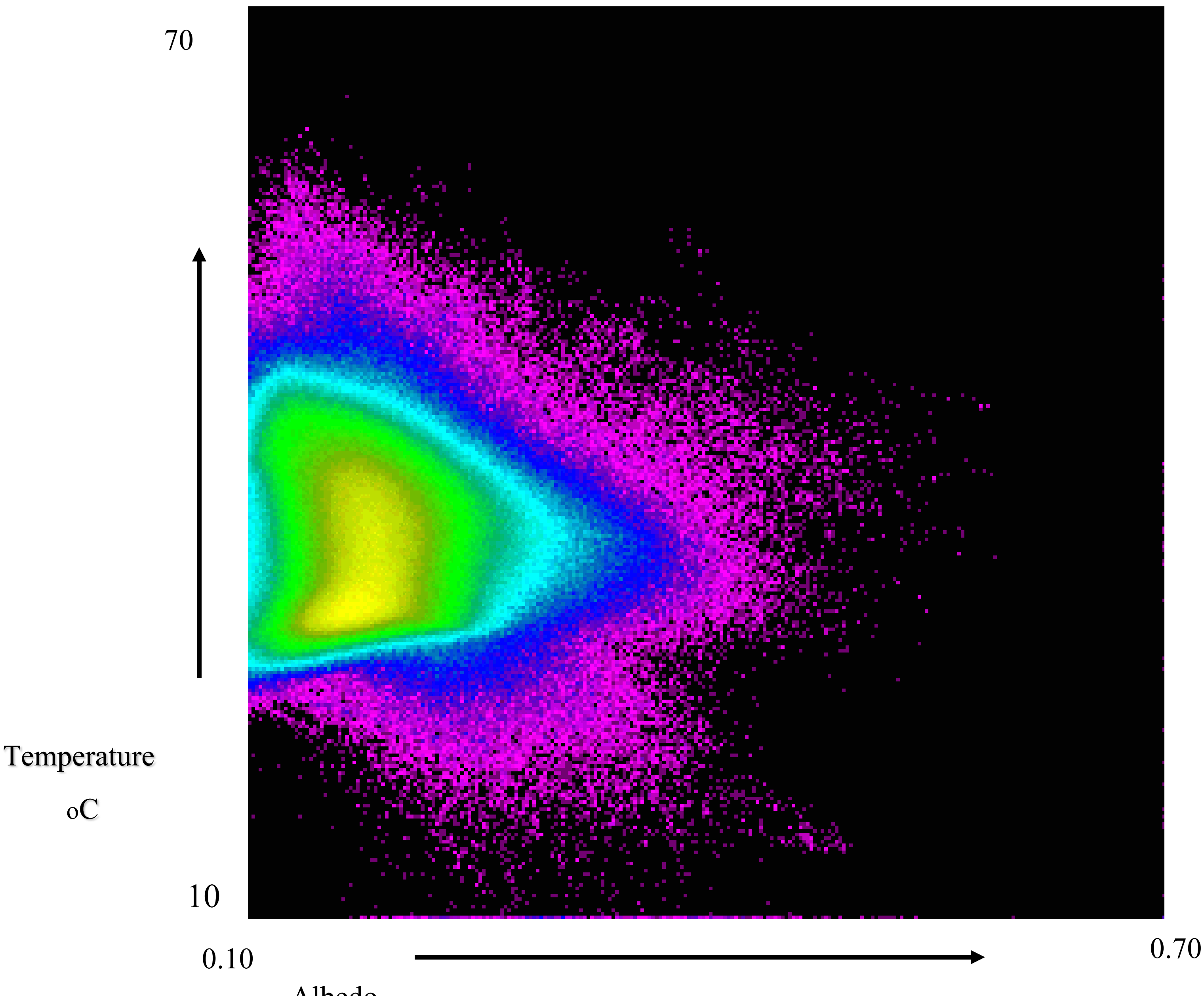


Fig. 5. Sharpened T_s zoomed in to a 100 × 100 pixel urban region (centered at 18.390698°N, 66.153084°W) at 10 m resolution. The figure shows a major highway intersection (Cll 2 and Carr 174). To the south of the east–west highway are mostly residential neighborhoods with trees, while parks, parking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

San Juan Puerto Rico
Albedo vs Temperature



Thermal Response Number

TRN = Q*/delta T

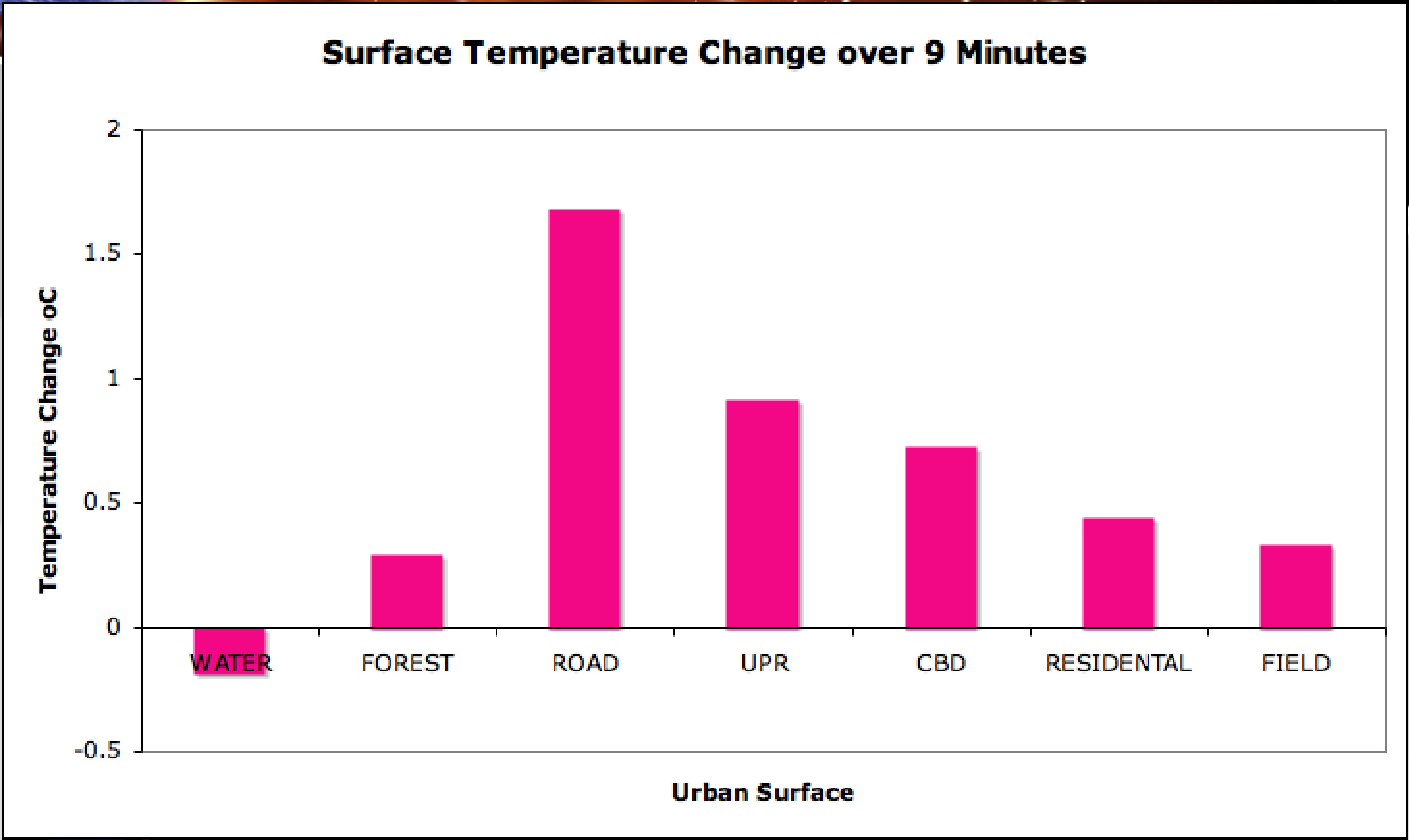
where:

Q* = net radiation

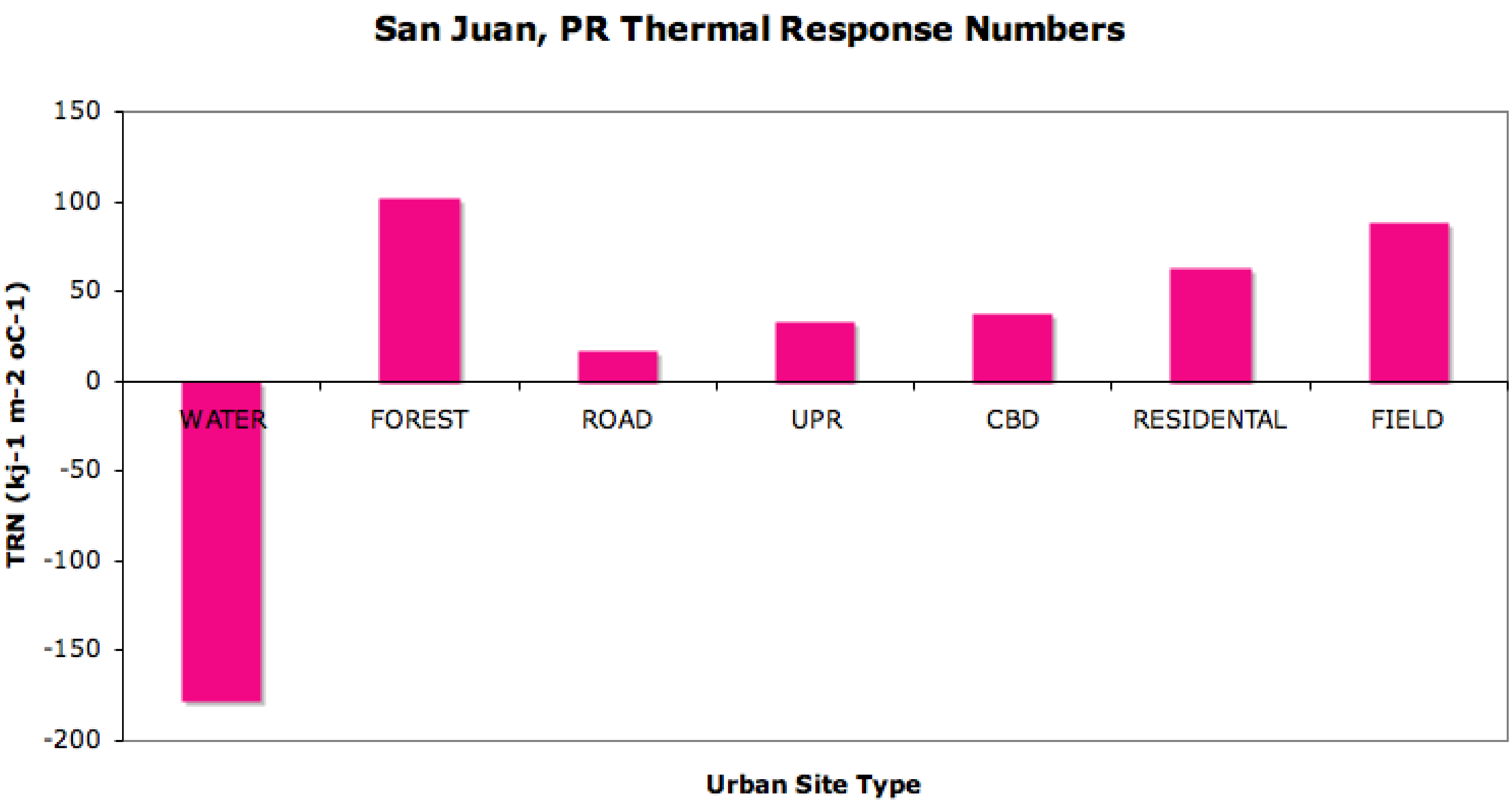
delta T = change in temperature

- Uses the change in surface temperature between 2 measurement times
- Uses surface net radiation as amount of energy available the surface for partitioning
- Produces a quantifiable value (kj m-2 oC -1)
- Allows the classification of land use in terms of energy partitioning

Luvall & Hobo 1989

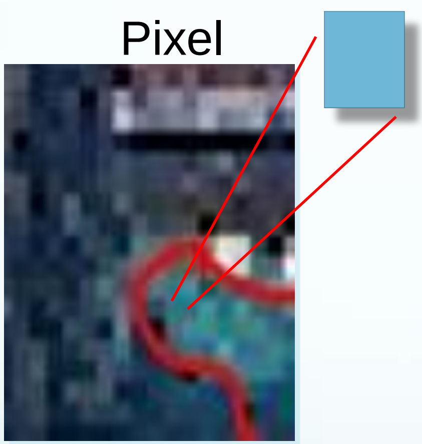


Surface Temperature Change over 9 Minutes
Temperature Change oC
2
1.5
1
0.5
0
-0.5
WATER
FOREST
ROAD
UPR
CBD
RESIDENTAL
FIELD
Urban Surface


San Juan, PR Thermal Response Numbers
150
100
50
0
-50
-100
-150
-200
TRN (kj-1 m-2 oC-1)
WATER
FOREST
ROAD
UPR
CBD
RESIDENTAL
FIELD
Urban Site Type

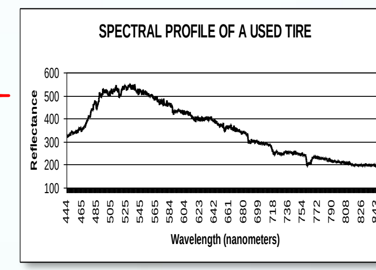
Creating a Spectral Habitat Signature

0.2 – 0.6 m^2
Pixel



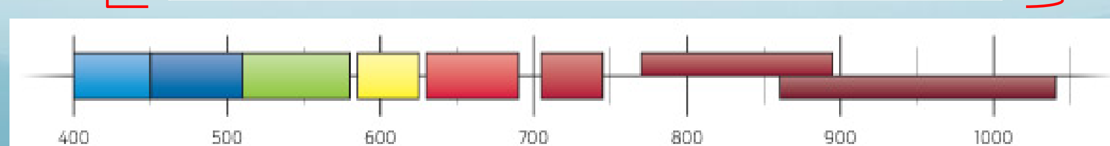
Spectral Band	Purpose
Coastal Blue	Vegetation and water depth based on chlorophyll
Blue	Vegetative analysis based on chlorophyll
Green	Plant vigor analysis
Yellow	Plant vigor on land and in the water
Red	Vegetation discrimination, soils, geology
Red Edge	Plant vigor
Near Infrared 1	Moisture content,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

01001110010100001111
01100001000010010010
11110111011111001101
11000011010101101000
10111010101010001000
100001000100



Spectral Signature

The "Intelligent" Pixel



HyspIRI Science and Applications

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.

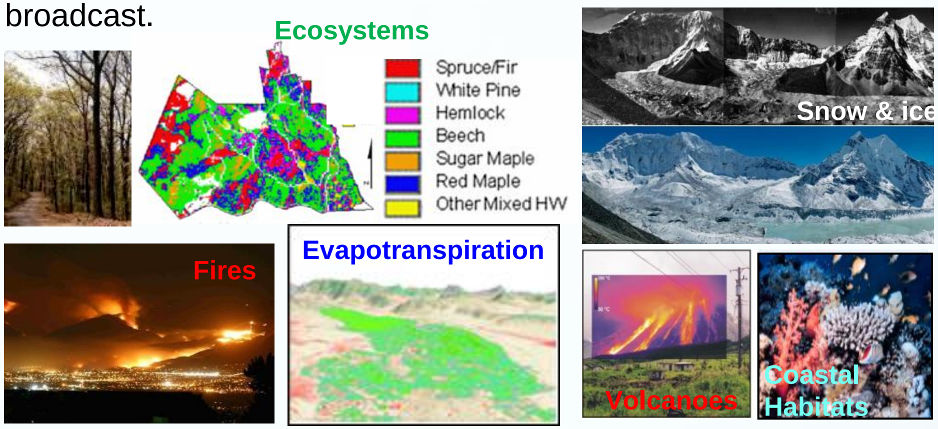
Volcanoes: Eruptions, emissions, regional and global impact.

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

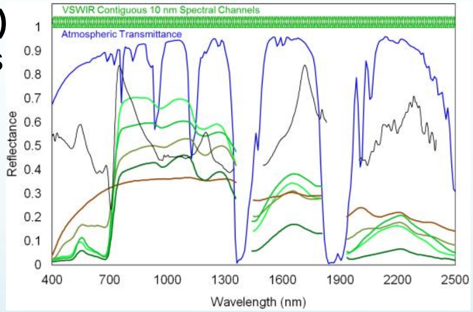
The HyspIRI science and application objectives are important today and uniquely addressed by the combined imaging spectroscopy, thermal infrared measurements, and IPM direct broadcast.



Measurement

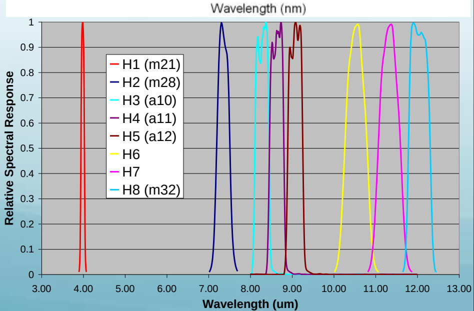
Imaging Spectrometer (VSWIR)

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

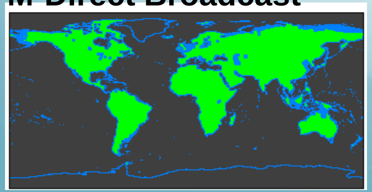


Thermal Infrared (TIR):

- 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

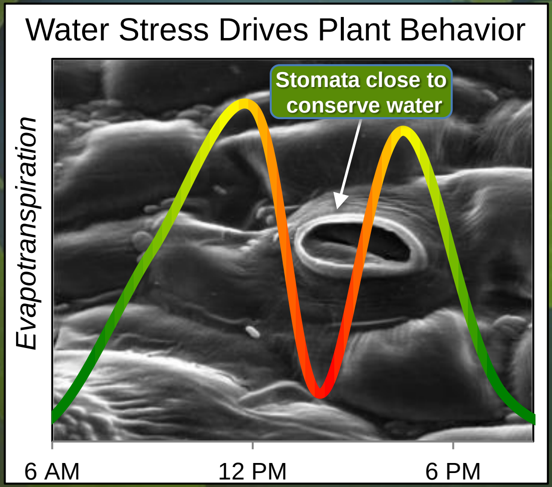
Information and Registration at: http://hyspiri.jpl.nasa.gov

ECOSTRESS

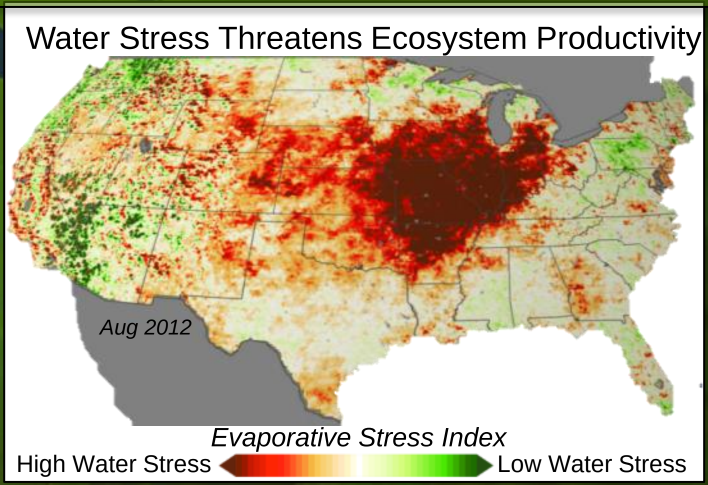
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

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.



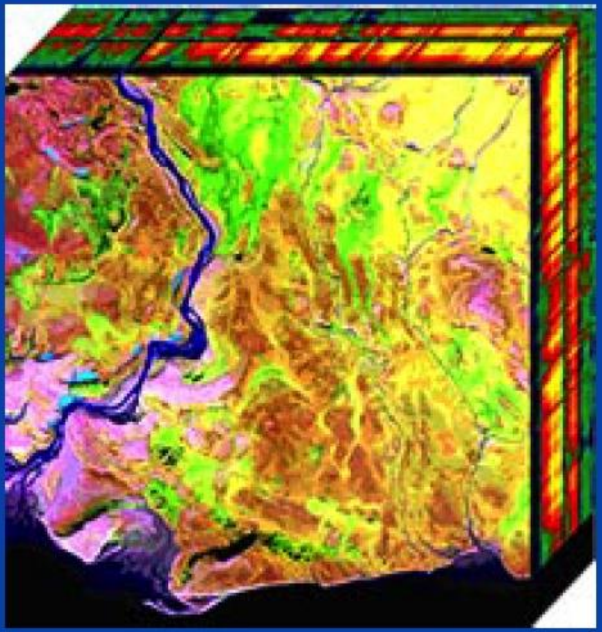
Water stress is quantified by the Evaporative Stress Index, which relies on evapotranspiration measurements.

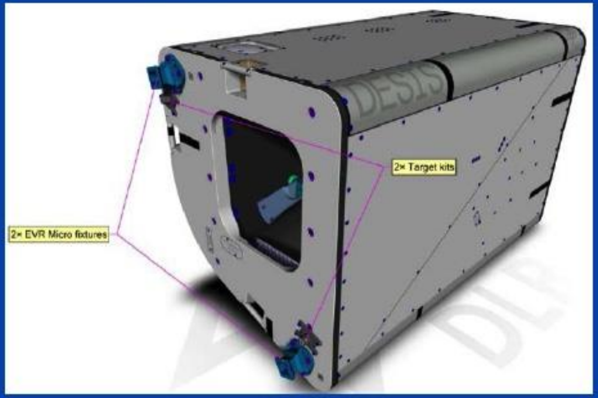
Science Objectives

- 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

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

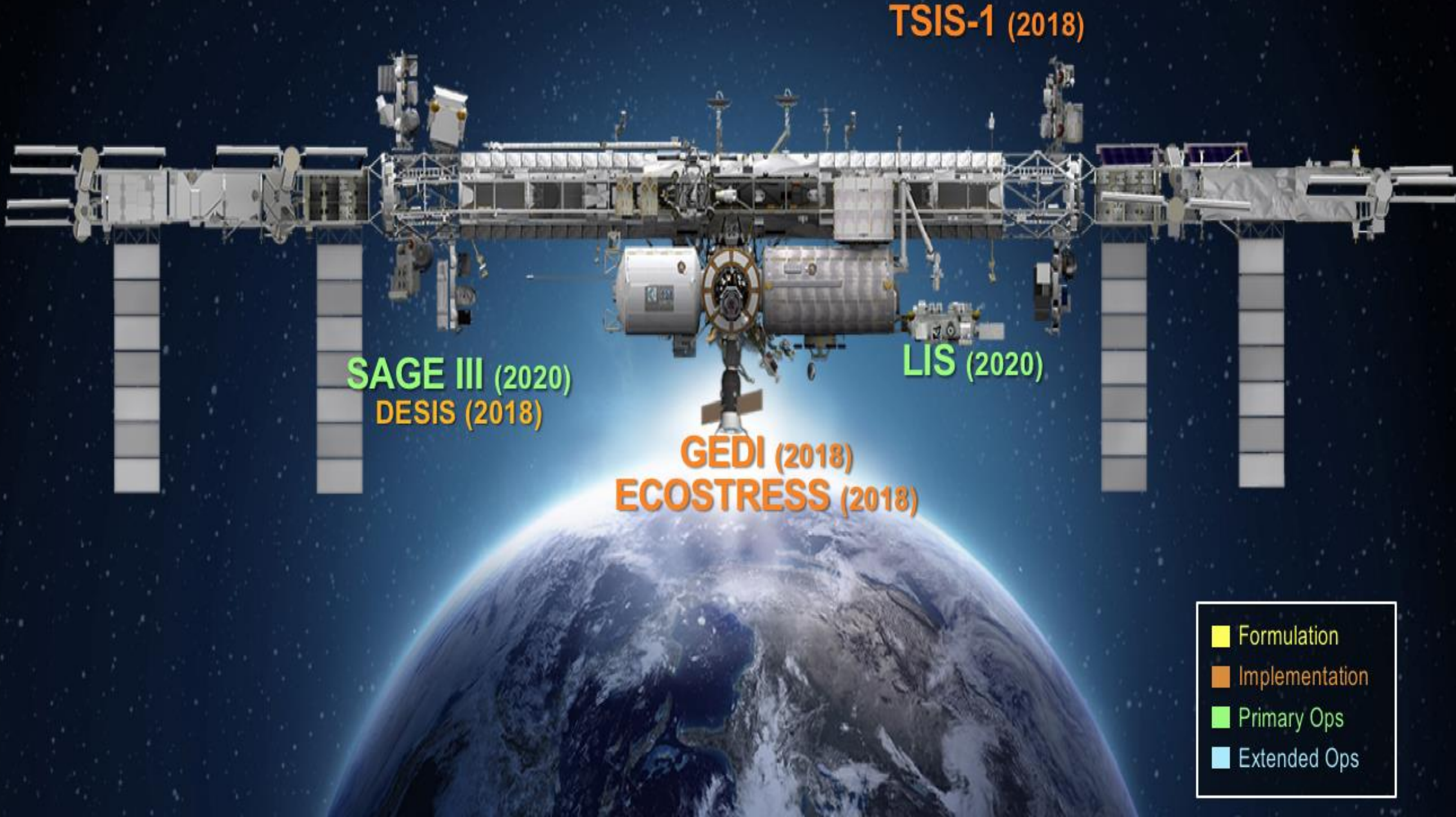
Global Ecosystem Dynamics Investigation Lidar (GEDI) (~2018)

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

International Space Station

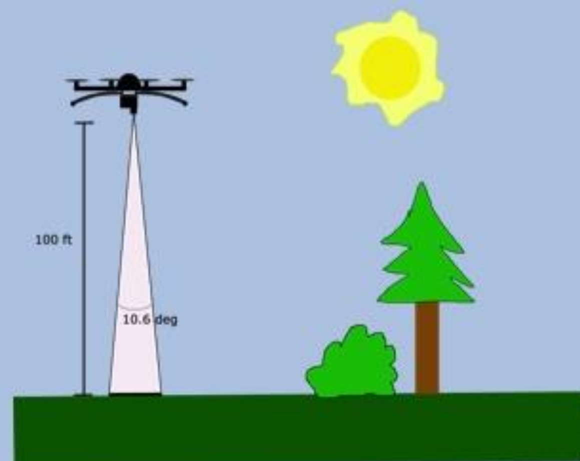
Earth Science Operating Missions



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]

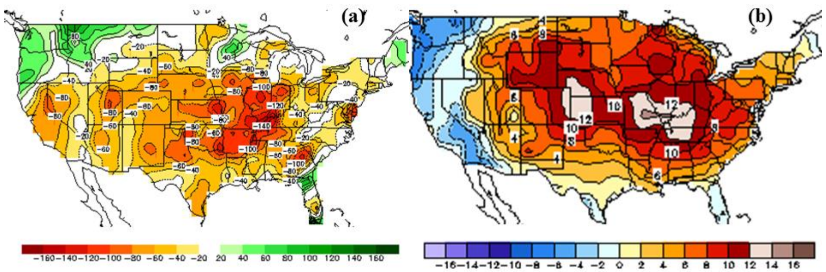
[1]Department of Bioengineering, Rice University, Houston, TX, 77005, United States
[2]Rice Space Institute, Rice University, Houston, TX, 77005, United States
[3]Marshall Space Flight Center, NASA, Redstone Arsenal, Huntsville, AL, 35812, United States



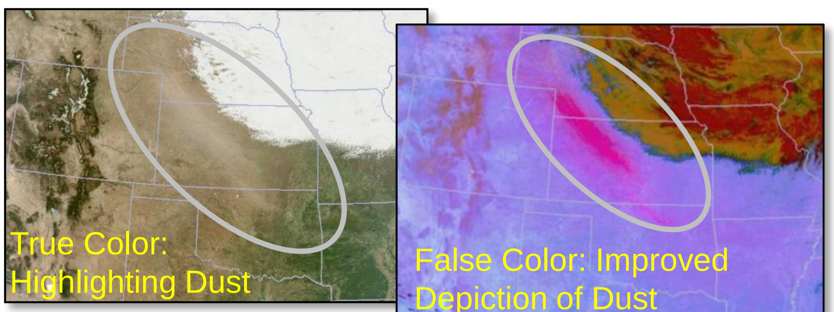
SNAP-IMS Specifications	
Dimensions	288x150x160 mm
Mass	3.6 kg
FOV	10.6°
IFOV	.03°
Spectral Range	485 nm – 650 nm
Spectral channels	55
Spatial Samples	350x400


1
5
4
2
3

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.

SPoRT » Real-Time Data » GOES-16 ABI Full Disk - » 11.20 um (Band 14)

SPoRT

Short-term Prediction Research and Transition Center

NASA

SPoRT is a NASA project to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale.

Real-Time Data | **Core Projects** | **GOES-R PG** | **JPSS PG** | **Transitions** | **Library** | **Organization**

The SPoRT web server will be affected by a power outage that is expected to last from Sunday morning, January 28, 2018 through Monday morning, January 29, 2018. During this time, access to the SPoRT site will be unavailable. We apologize for the inconvenience.

GOES-16 ABI Full Disk - 11.20 um (Band 14)
Jan. 25, 2018 - 14:30 UTC

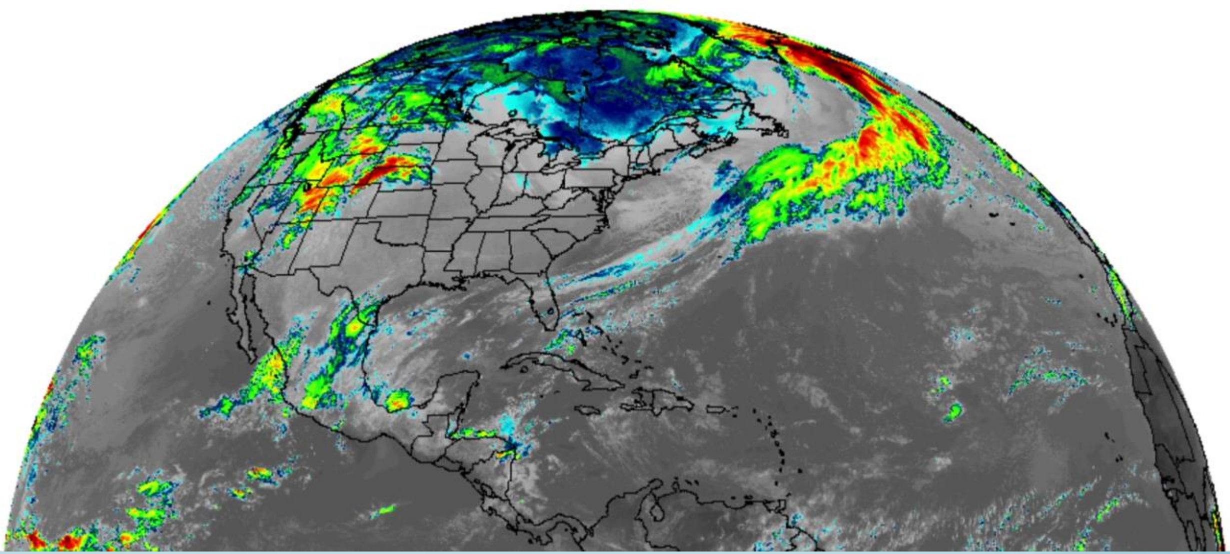
- **Sectors**: CONUS | Full Disk | Mesoscale 1 | Mesoscale 2
- **Quick Guides**: Air Mass RGB | Day Convection RGB | Daytime Microphysics RGB | Dust RGB | Nighttime Microphysics RGB
- Locations of mesoscale sectors

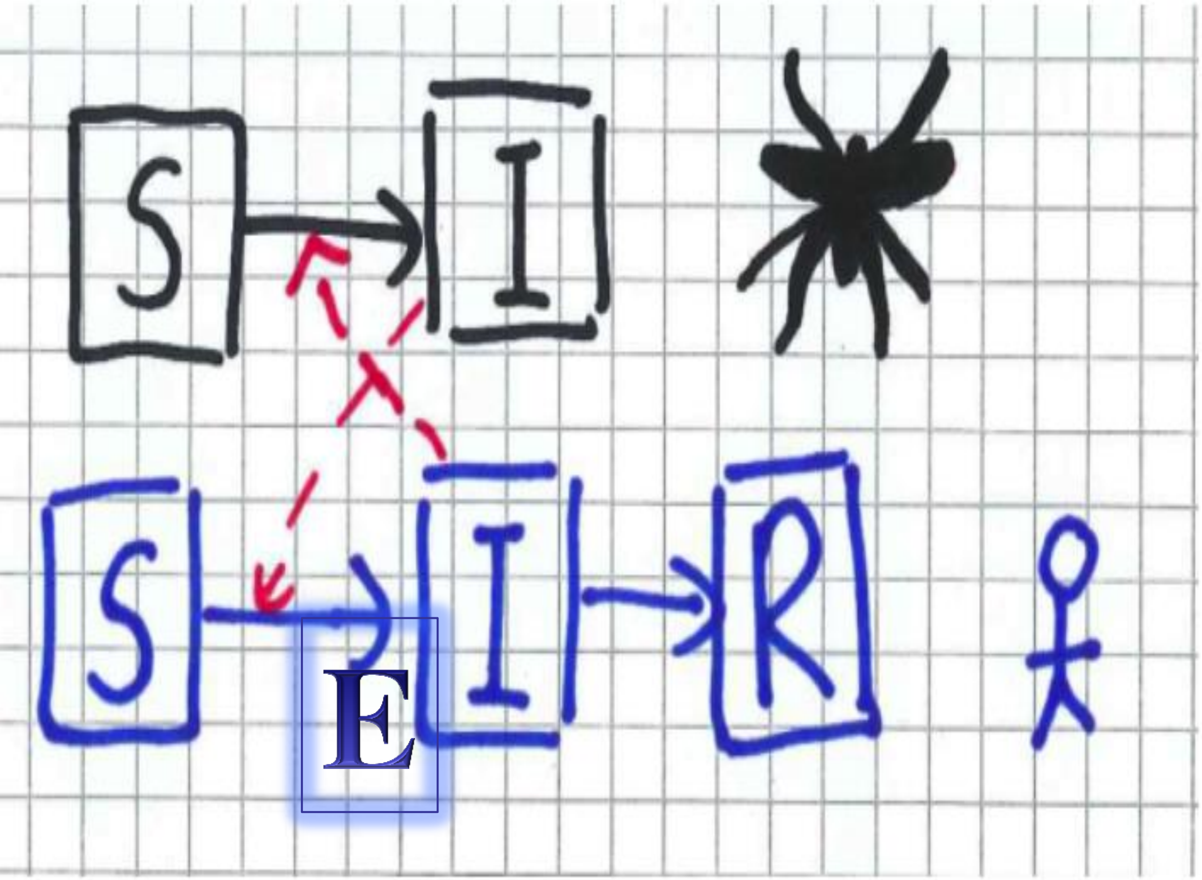
Select an image:

Jan. 25, 2018 - 14:30 UTC

« Previous Next »
by product

Products
0.47 um (Band 1)
0.64 um (Band 2)
0.87 um (Band 3)
1.38 um (Band 4)
1.61 um (Band 5)
2.25 um (Band 6)
3.90 um (Band 7)
6.19 um (Band 8)
6.95 um (Band 9)
7.34 um (Band 10)
8.50 um (Band 11)
9.61 um (Band 12)
10.35 um (Band 13)
11.20 um (Band 14)
12.30 um (Band 15)
13.30 um (Band 16)





☀θΔ ics □

- Temperature
- Soil moisture
- Preciptation
- Vapor Pressure (RH)
- Thermal Response Number
- Evapo-transpiration
- Solar Radiation

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

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