HysplRI Thermal IR (TQ4) Science Questions & Applications, Enabling Data Products, & Science Matrix Review

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TQ4 HysplRI Science Questions

TQ4 Overarching Question: *How does urbanization affect the local, regional, and global environment? Can we characterize this effect to help mitigate its impact and welfare?*

TQ4. Human Health and Urbanization Sub-questions

- How do changes in land cover and land use, in particular urbanization, affect surface energy balance characteristics that impact human welfare? [DS: 160-161, 166-167, 196, 198]
- What are the dynamics, magnitude, and spatial form of the urban heat island effect (UHI), how does it change from city to city, what are its temporal, diurnal, and nocturnal characteristics, and what are the regional impacts of the UHI on biophysical, climatic, and environmental processes? [DS: 158, 166-168]
- How can the factors affecting heat stress on humans be better resolved and measured? [DS: 156, 158, 160, 183-184]
- How can the characteristics associated with environmentally related health effects, that affect vector-borne and animal-borne diseases, be better resolved and measured? [DS: 156, 158, 160, 183-184]
- How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems, and urbanization? [DS: 156, 160-161, 166-167, 179,184]

Science Objectives	Measurement Objectives	Measurement Requirements	Instrument Requirements	Other Mission and Measurement Requirements
Urbanization and Human Health: How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?				
How do changes in local and regional land cover and land use, in particular urbanization affect surface energy balance characteristics that impact human welfare [DS: 160-161, 166-167, 196, 198]	Surface temperature Surface energy fluxes Surface emissivity terrestrial coverage	NEΔT 0.2-0.3 greater than 4 bands distributed between 8-12μm High spatial resolution (≤ 60 m) Accuracy 1.0K	260-360K NEdT 0.1K Acc 0.5K	High temporal resolution (weekly) Long term validation sites (incl. emissivity targets) and periodic urban campaigns
What are the dynamics, magnitude, and spatial form of the urban heat island effect (UHI), how does it change from city to city, what are its temporal, diurnal, and nocturnal characteristics, and what are the regional impacts of the UHI on biophysical, climatic, and environmental processes? [DS: 158, 166-168]	Day and night surface temperature Urban coverage Intra-seasonal measurements	High spatial resolution (≤ 60 m) Day/night observations Acc 1K Coregistration 0.2pix NEdT 0.2-0.3	>4 bands for accurate temp-emiss separation Do we need more bands for cloud masking at night? High spatial resolution (≤ 60 m) NEdT 0.1 Min T/Max T 260-360K for diurnal observations	High temporal resolution (weekly) Accuracy of 1 deg.K/NEΔT 0.2-0.3
How can the factoros influencing heat stress on humans be better resolved and measured. [DS: 156, 158, 160, 183-184]	Surface temperature Urban coverage	Acc. 1K Nedt 0.2-0.3K Daytime/nighttime observations Vegetated/non-vegetated surfaces	>4 bands for T-E separation Diurnal and nocturnal observations Low temperature and high temperature targets (NEΔT 0.2-0.3 K) Acc 0.5K	High temporal resolution (weekly) High spatial resolution (≤ 60 m) Accuracy of 1 deg.K/NEΔT 0.2-0.3 Air temperature
How can the characteristics associated with environmentally related health effects, that affect vector-borne and animal-borne diseases, be better resolved and measured? [DS: 156, 158, 160, 183-184]	Surface temperature Terrestrial coverage	Detection of wet/dry surfaces Daytime/nighttime observations Vegetated/non-vegetated surfaces	Multispectral thermal bands for surface temperature measurements (3-6 bands) Diurnal and nocturnal observations Low temperature and high temperature targets (NEΔT 0.2-0.3 K)	High temporal resolution (weekly) High spatial resolution (≤ 60 m) Accuracy of 1 deg.K/NEΔT 0.2-0.3 Soil moisture or precipitation Air temperature water inundation
How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems, and urbanization? [DS: 156, 160-161, 166-167, 179,184]	Surface temperature Surface energy balance Surface energy fluxes Global coverage	Daytime/nighttime observations Multispectral thermal measurements (3-6 bands) High spatial resolution High temporal resolution	Multiple spectral bands (3-6) for surface temperature and energy balance flux measurements Diurnal and nocturnal observations Low temperature and high temperature target discrimination	High temporal resolution (weekly) High spatial resolution (≤ 60 m) Accuracy of 1 deg.K/NEΔT 0.2-0.3

TQ4 HyspIRI Science Questions

Human Health and Urbanization Sub-questions

Uses of Space-based Observations to Address Human Health Concerns

In addressing human health and security concerns, space-based observations are most useful when used along with many other sources of data. Public-health and risk management decision making has benefited from space-based technologies, and can benefit further with improvements in these technologies, through applications that include:

- *Prediction of occurrence of disease or disease outbreaks.* Space-based observations provide spatial and temporal data on environmental changes that affect the conditions related to disease occurrence and can be combined within predictive frameworks to forecast health emergencies.
- *Rapid detection and tracking of events.* Given sufficient temporal or spatial detail, space-based observations can provide data to support rapid detection of environmental changes or pollution events that affect human health.
- *Construction of risk maps.* The spatial extent of space-based observations provides a means to identify spatial variability in risk, potentially improving the scale of environmental observations so that they match the scale of activities in human communities.
- *Targeting interventions.* Activities to reduce the vulnerability of human communities to health risks, including environmental, behavioral, educational, and medical interventions, can be guided, improved, and made more efficient by use of available and proposed space-based observational systems.
- *Enhancing knowledge of human health-environment interactions.* Basic research on the causes of disease is ongoing, and remote sensing of environmental parameters that affect health is crucial for investigations that improve understanding of the spatial and temporal dynamics of health risk.

(*Decadal Survey*, pp. 155-156)

TQ4 HyspIRI Science Questions

***Critical Questions on Human Health and Security as given in the Decadal Survey:* (p. 155)**

- How can remote sensing data be enhanced to assist detection and prediction of the places where disease risk is elevated or times when disease outbreaks are likely?
- Might such data enhance the rapid detection of events that threaten health or security?
- How can risk maps derived from space-based observations be used to enhance public health efforts directed at education and prevention?
- What new exchanges can expand interactions between remote sensing system designers and public health analysts that will help identify spatial and temporal risk patterns?
- What new understanding derived from remote sensing data can be used to target interventions aimed at reducing vulnerability of human communities to health risks?

TQ4 HysplRI Science Questions

Science Issue: How do changes in land cover and land use affect surface energy balance and the sustainability and productivity of natural and human ecosystems?

Changes in land cover and land use have profound affects on the environment and on surface energy balances. HysplRI data can provide significant improvement in measuring and evaluating these changes and their subsequent impacts on the sustainability and productivity of natural and human ecosystems be measured.

TQ4 HyspIRI Science Questions

Science Issue: How do changes in land cover and land use affect surface energy balance and the sustainability and productivity of natural and human ecosystems?

Approach

- **Use HyspIRI high spatial resolution, multispectral, and multitemporal TIR data to track energy balance and energy flux characteristics for changing land covers/land uses through time to provide synoptic views of impacts on surface energy fluxes, emissivity and temperature**
- **Use HyspIRI data in conjunction with spatial growth models to project land cover/land use changes in the future to assess impacts on natural and human ecosystems**

TQ4 HyspIRI Science Questions

Science Issue: How do changes in land cover and land use affect surface energy balance and the sustainability and productivity of natural and human ecosystems?

Potential Level 3 Products

- **Multispectral thermal IR land cover maps at a high spatial resolution (< 60m) on a weekly basis for long-term validation of surface energy responses and changes in emissivity**
- **Integration of HyspIRI TIR data with spatial modeling to assess changes in land cover/land use through time and subsequent changes in thermal energy responses**

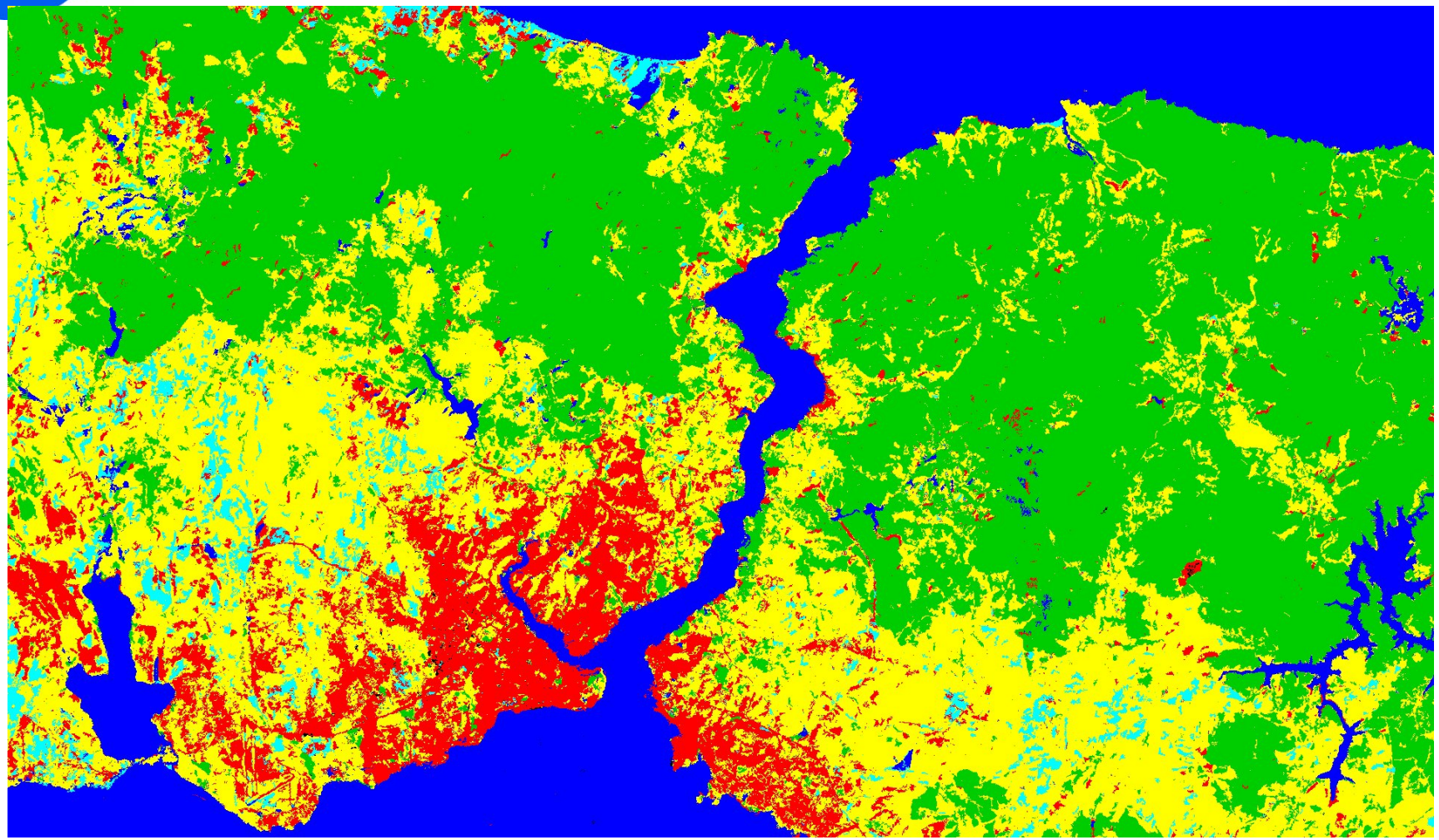
1986

Land Processes Group, NASA Marshall Space Flight Center, Huntsville, AL

2007

Land Processes Group, NASA Marshall Space Flight Center, Huntsville, AL

1986



Land Processes Group, NASA Marshall Space Flight Center, Huntsville, AL

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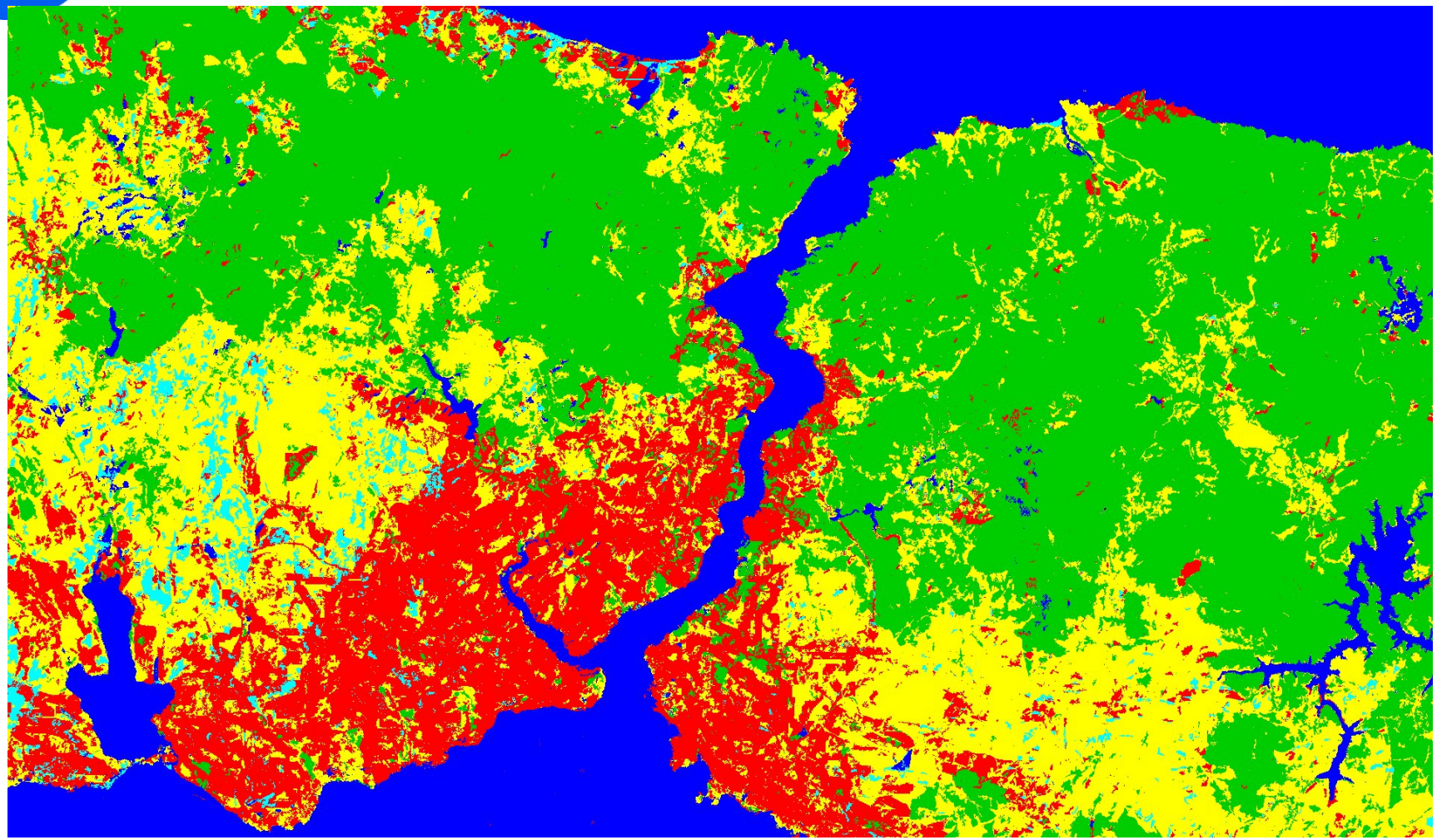

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TQ4 HyspIRI Science Questions

Human Health and Urbanization Sub-questions

ATLAS thermal IR daytime image Huntsville, AL

TQ4 HyspIRI Science Questions

Human Health and Urbanization Sub-questions

ATLAS thermal IR nighttime image Huntsville, AL

TQ4 HysplRI Science Questions

Science Issue: How do changes in land cover and land use affect surface energy balance and the sustainability and productivity of natural and human ecosystems?

Level 3 Validation Approach

- **Collect *in situ* data on surface temperatures for various land covers to validate satellite-derived temperatures**
- **Model changes in land cover/land using existing mapped data to verify changes as observed from satellite data and subsequent surface energy balance changes**
- **Use satellite-derived data collected over multitemporal periods to model sustainability impacts using a spatial modeling architecture in conjunction with *in situ* and ancillary data**

TQ4 HyspIRI Science Questions

Science Issue: How do changes in land cover and land use affect surface energy balance and the sustainability and productivity of natural and human ecosystems?

Precursor Science

- **Airborne and field campaigns to collect HyspIRI-like data over various land covers (e.g., forest, agriculture, suburban, urban) at high spatial resolution (≤ 60m) for multitemporal (day/night and multi-day)**
- **Derivation of thermal energy balance characteristics from multiple spectral bands similar to HyspIRI for various land covers**
- **Ingestion of airborne/field campaign data into spatial modeling framework to evaluate potential for assessing land cover/land use changes**

TQ4 HysplRI Science Questions

Science Issue: What are the dynamics, magnitude, and spatial form of the UHI? How can it best be characterized?

Urban areas are considerably warmer than their rural counterparts as a result of the Urban Heat Island (UHI) effect. Although the UHI is known as a global phenomenon, we do not know how it changes based on urban landscape morphology or in different climatic regimes around the world. HysplRI data can provide significant improvement in measuring and evaluating the UHI and associated impacts on human health and the environment.

TQ4 HysplRI Science Questions

Science Issue: What are the dynamics, magnitude, and spatial form of the UHI? How can it best be characterized?

Approach

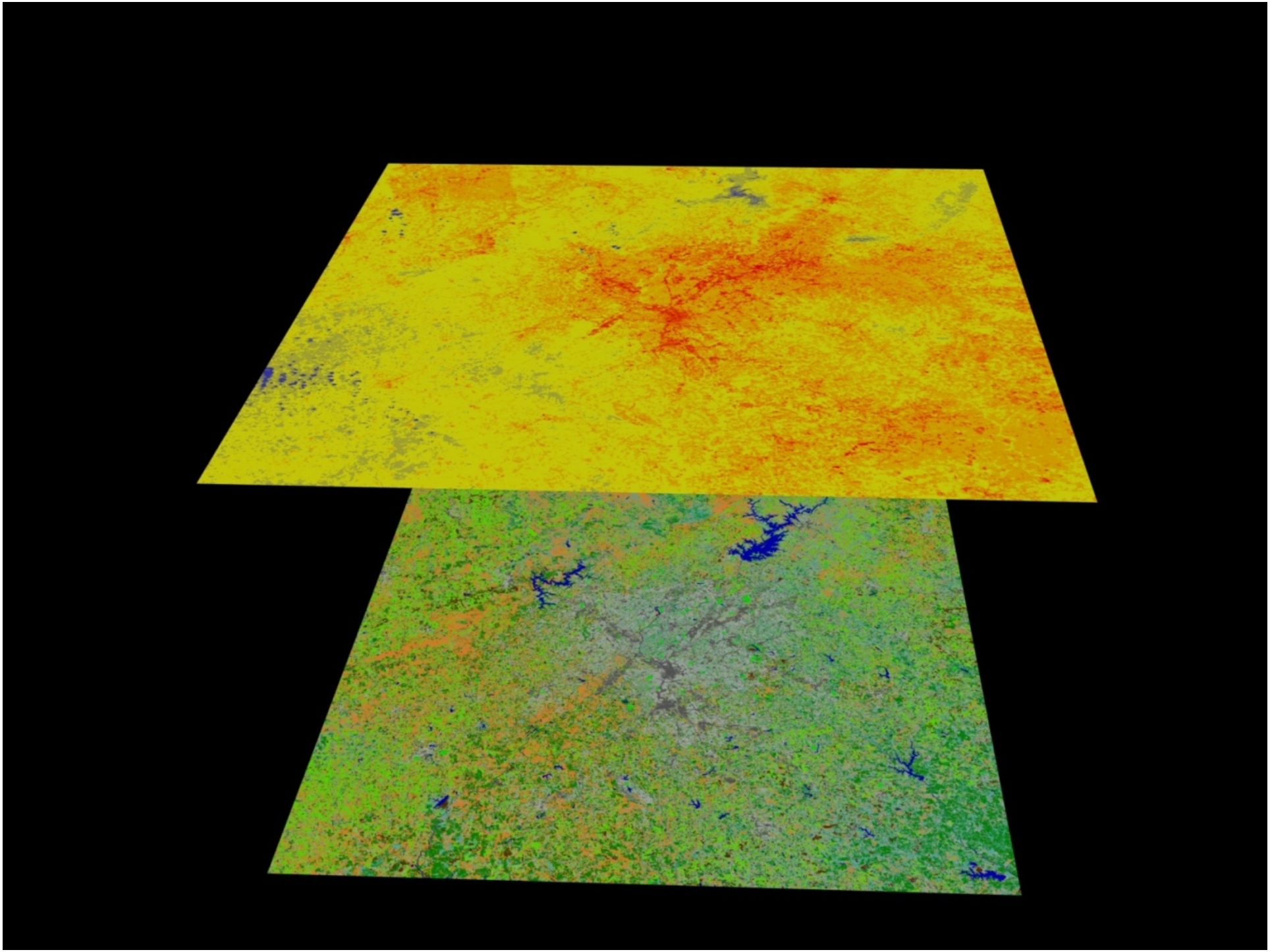
- **Use HysplRI high spatial resolution, multispectral, and multitemporal TIR data to observe and measure the UHI for cities around the world in differing climatic regimes**
- **Use HysplRI data in conjunction with *in situ* and modeled data to track and assess the impacts of the UHI on human well-being, such as heat stress**

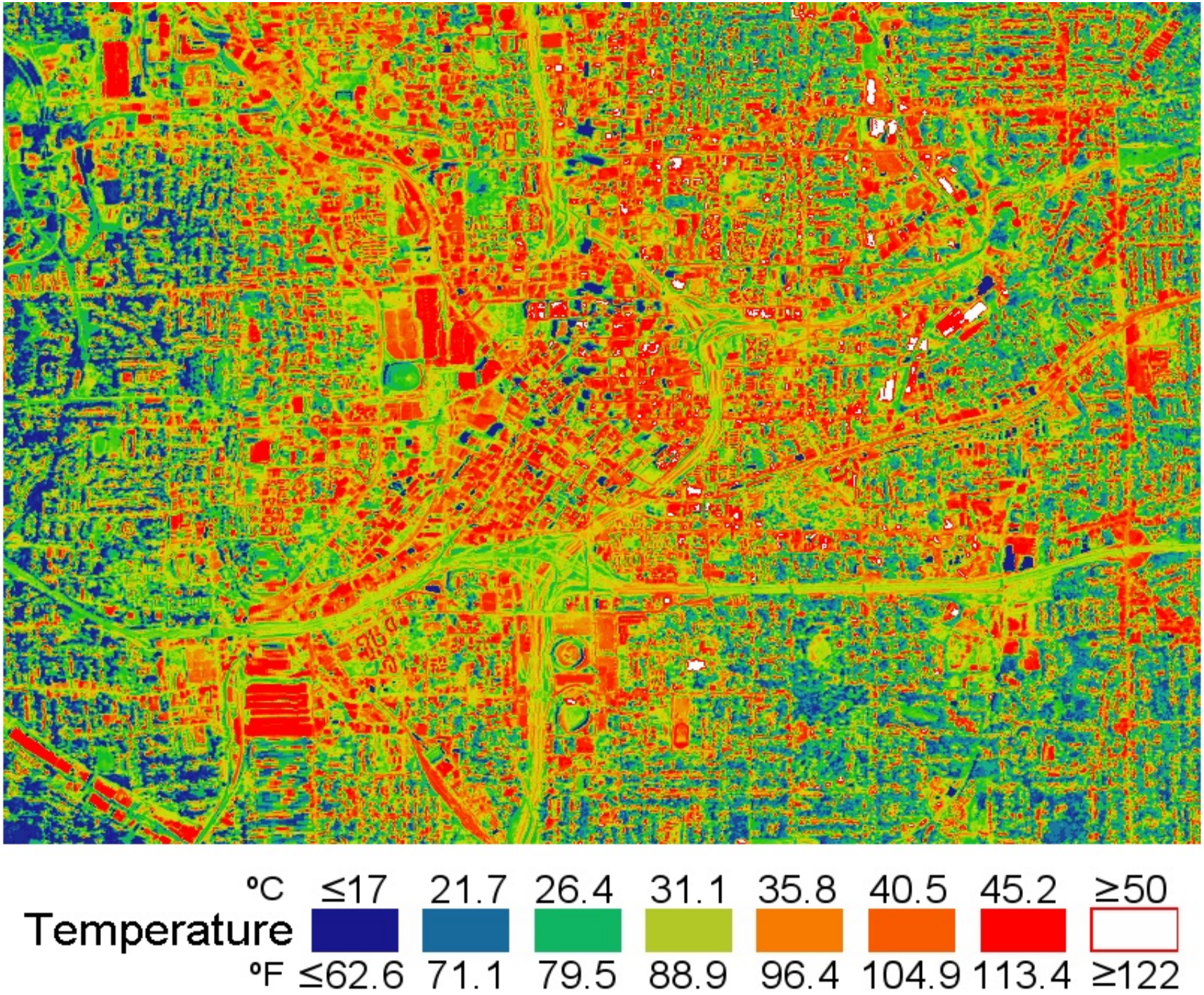
TQ4 HysplRI Science Questions

Science Issue: What are the dynamics, magnitude, and spatial form of the UHI? How can it best be characterized?

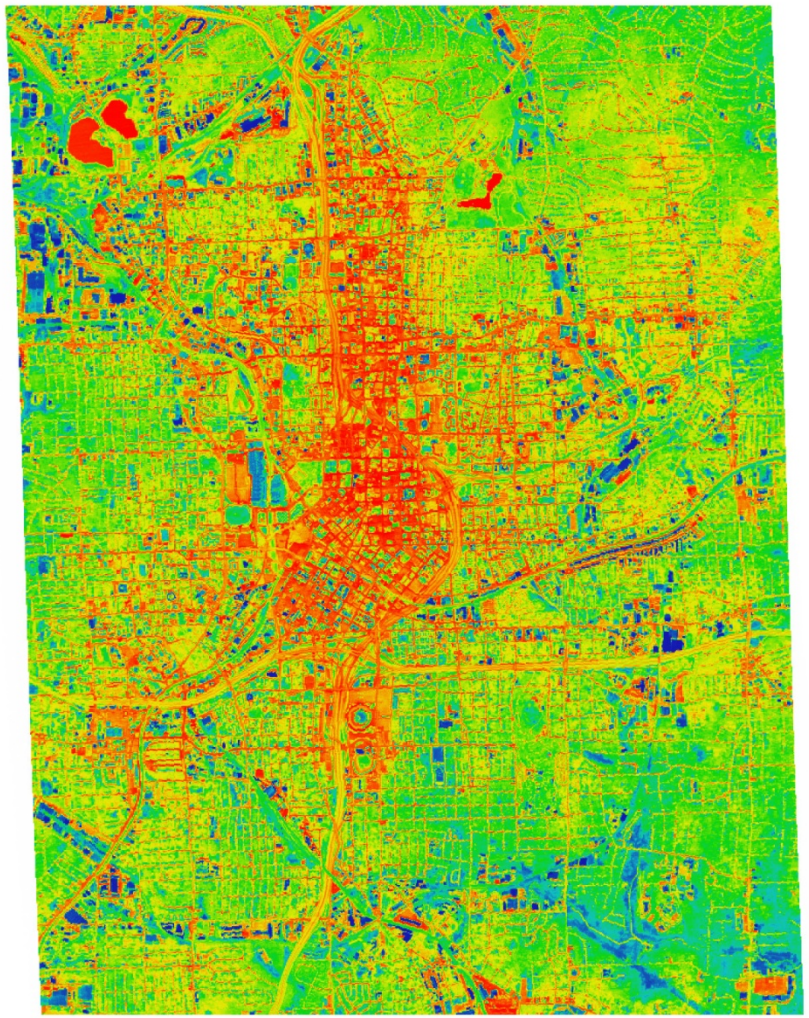
Potential Level 3 Products

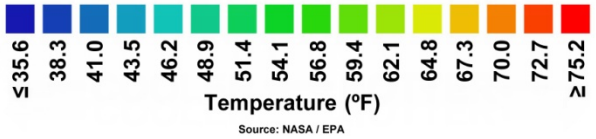
- **Maps of UHI development, extent and dynamics for various cities around the world using HysplRI high spatial resolution (≤ 60m) data**
- **Multitemporal (weekly, seasonal) maps of UHI dynamics**
- **Day/Night maps of UHI dynamics**




°C ≤17 21.7 26.4 31.1 35.8 40.5 45.2 ≥50
Temperature
°F ≤62.6 71.1 79.5 88.9 96.4 104.9 113.4 ≥122

Atlanta
Central Business District
Night Data – May 1997





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Central Business District
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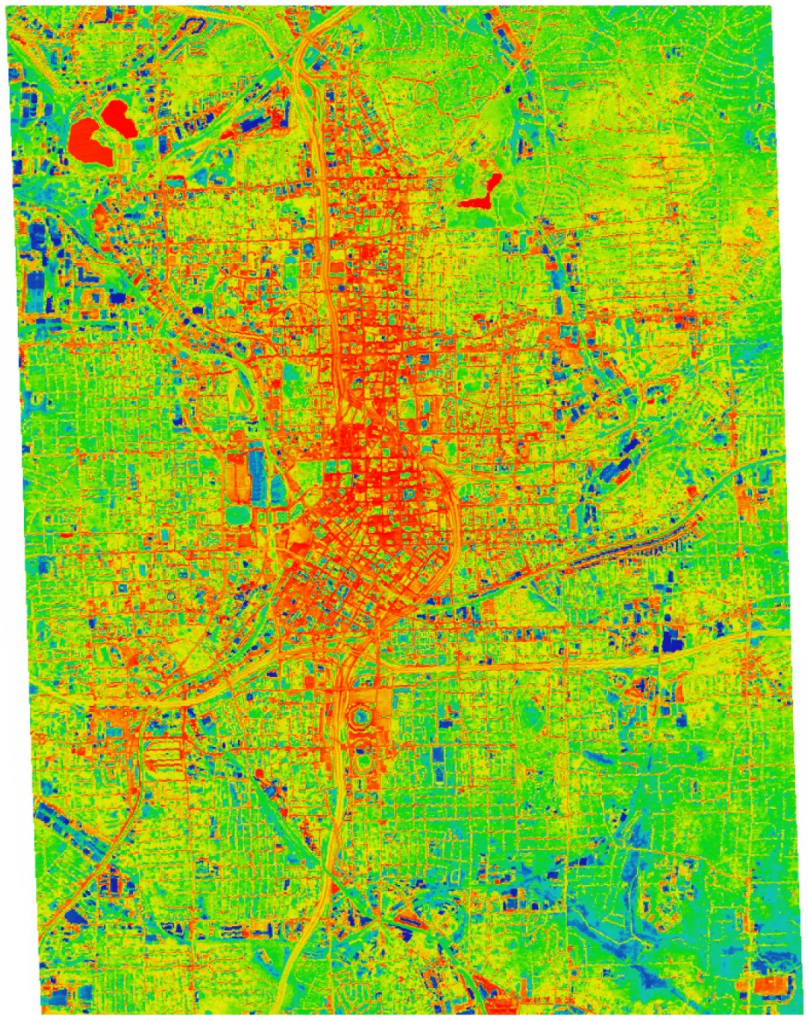
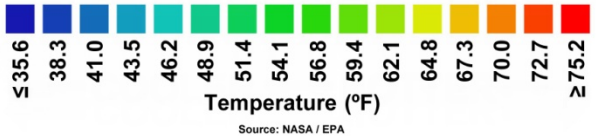




TQ4 HysplRI Science Questions

Science Issue: What are the dynamics, magnitude, and spatial form of the UHI? How can it best be characterized?

Level 3 Validation Approach

- **Validate surface temperature measurements for various materials across the urban landscape using *in situ* data collection techniques (e.g., radiometer)**
- **Compare with thermal IR remote sensing measurements collected over various cities (primarily in the U.S.)**

TQ4 HysplRI Science Questions

Science Issue: What are the dynamics, magnitude, and spatial form of the UHI? How can it best be characterized?

Precursor Science

- **Airborne and field campaigns to collect HysplRI-like data over several urban areas in the U.S. in different geographic regions at high spatial resolution (≤ 60m) for multitemporal (day/night and multi-day) periods**
- **Measure thermal energy characteristics for specific urban surfaces common to the city landscape (e.g., rooftops, pavement)**
- **Collect *in situ* surface temperatures to validate airborne data**

TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

- **Excess deaths occur during heat waves on days with higher-than-average temperatures, particularly in places where summer temperatures vary more or where extreme heat is rare**
- **Exposure to excessive natural heat caused 4,780 deaths during the period 1979-2002 in the U.S. as reported by the CDC**
- **An additional 1,203 deaths had hyperthermia reported as a contributing factor**
- **Climate variability and change will most likely exacerbate heat stress on humans during increasingly hotter summer weather**

TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

- **The Urban Heat Island (UHI) effect can potentially increase heat-related impacts by raising air temperatures in cities by 2º – 10º over surrounding suburban and rural areas**
- **Thermal remote sensing data with better spatial, multispectral, and radiometric characteristics, such as what HysplRI will provide are critical to developing a more complete understanding of the extent, diurnal, and energy balance characteristics of the UHI for cities around the world.**

TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

Approach

- **Collect HysplRI data in conjunction with times of high heat events (i.e., know when these events will most likely occur) over urban areas**
- **Obtain heat morbidity and mortality data from public health sources for heat events**
- **Evaluate relationships between high surface temperatures and morbidity/mortality data to derive quantitative assessments of heat stress indicators (e.g., where geographically morbidity/mortality occurred)**
- **Develop heat stress risk maps for cities around the world for use by public health officials**

TQ4 HyspIRI Science Questions

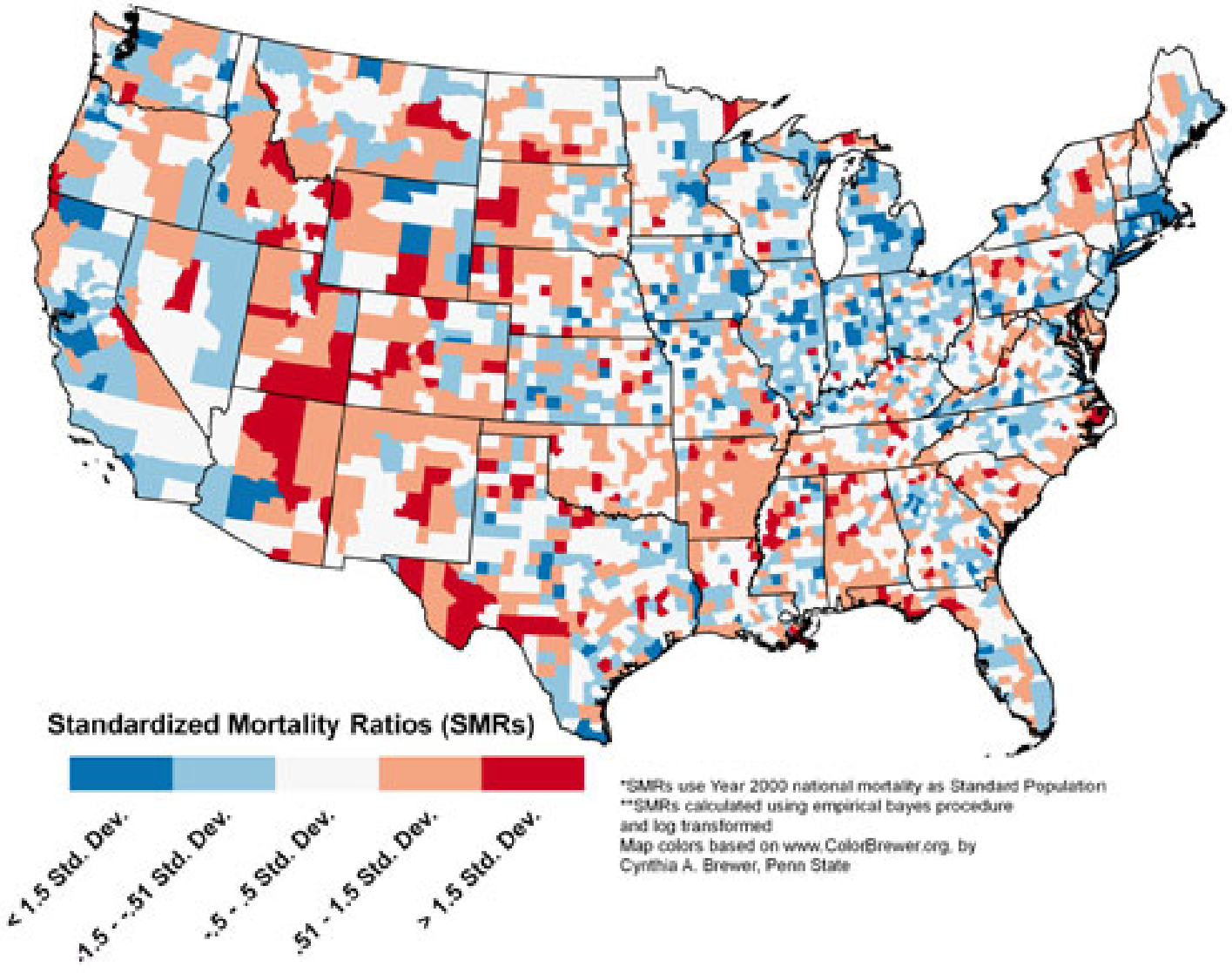
Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

Potential Level 3 Products

- **Heat stress maps as derived from HyspIRI thermal IR data for cities known to have morbidity/mortality cases during times of excess heat events**
- **HyspIRI modeled data to develop risk assessment maps for people who are at high health risk from heat-related events**

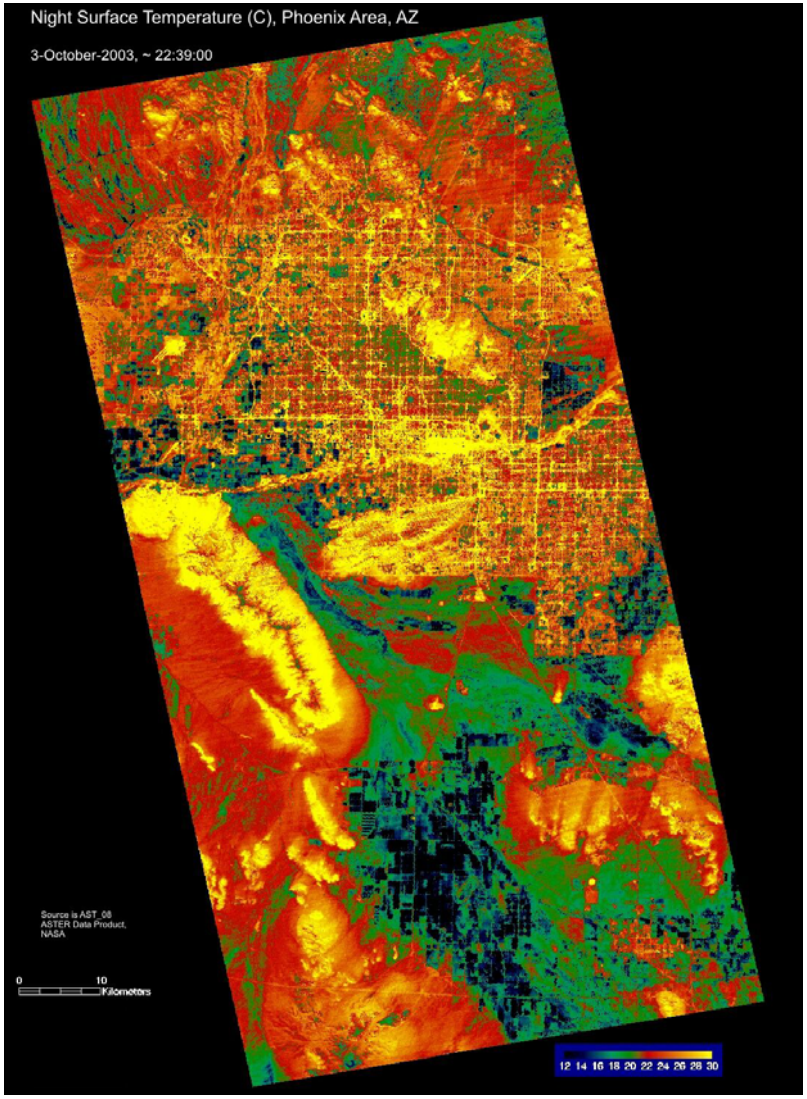
TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?



TQ4 HyspIRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?



TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

Level 3 Validation Approach

- **Geo-locate “hot spots” in urban areas as identified from remote sensing data against known factors that contribute to heat stress (e.g., elderly population, income)**
- **Use morbidity/mortality data provided by public health agencies (e.g., CDC) to validate heat stress/risk maps**

TQ4 HysplRI Science Questions

Science Issue: How can factors affecting heat stress on humans be better resolved and measured?

Precursor Science

- **Airborne and field campaigns to collect high spatial resolution HysplRI thermal IR data (≤ 60m) over urban areas in the U.S. that have known cases of morbidity/mortality from heat stress at multiple diurnal periods, during high heat events if possible**
- **Map "hot spots" against demographic and geospatial factors such as population age, racial makeup, and income to develop heat stress risk maps**

TQ4 HyspIRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?

Space-based measurements of factors related to vector- and animal-borne diseases have been useful for risk management decision making by health professionals. More detailed satellite data, such as that to be provided by HyspIRI, are needed to further develop better risk assessments and disease and health hazard risk maps.

TQ4 HyspIRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?

Approach

- **Evaluate land cover, surface temperature and surface wetness conditions using HyspIRI thermal IR data where conditions are favorable for initiation of vector- and animal-borne diseases globally**
- **Use high spatial/multitemporal HyspIRI TIR data as inputs to disease models to produce risk maps for vector- and animal-borne disease outbreak and expansion globally**
- **Provide rapid tracking of vector- and animal-borne disease events globally**

TQ4 HyspIRI Science Questions

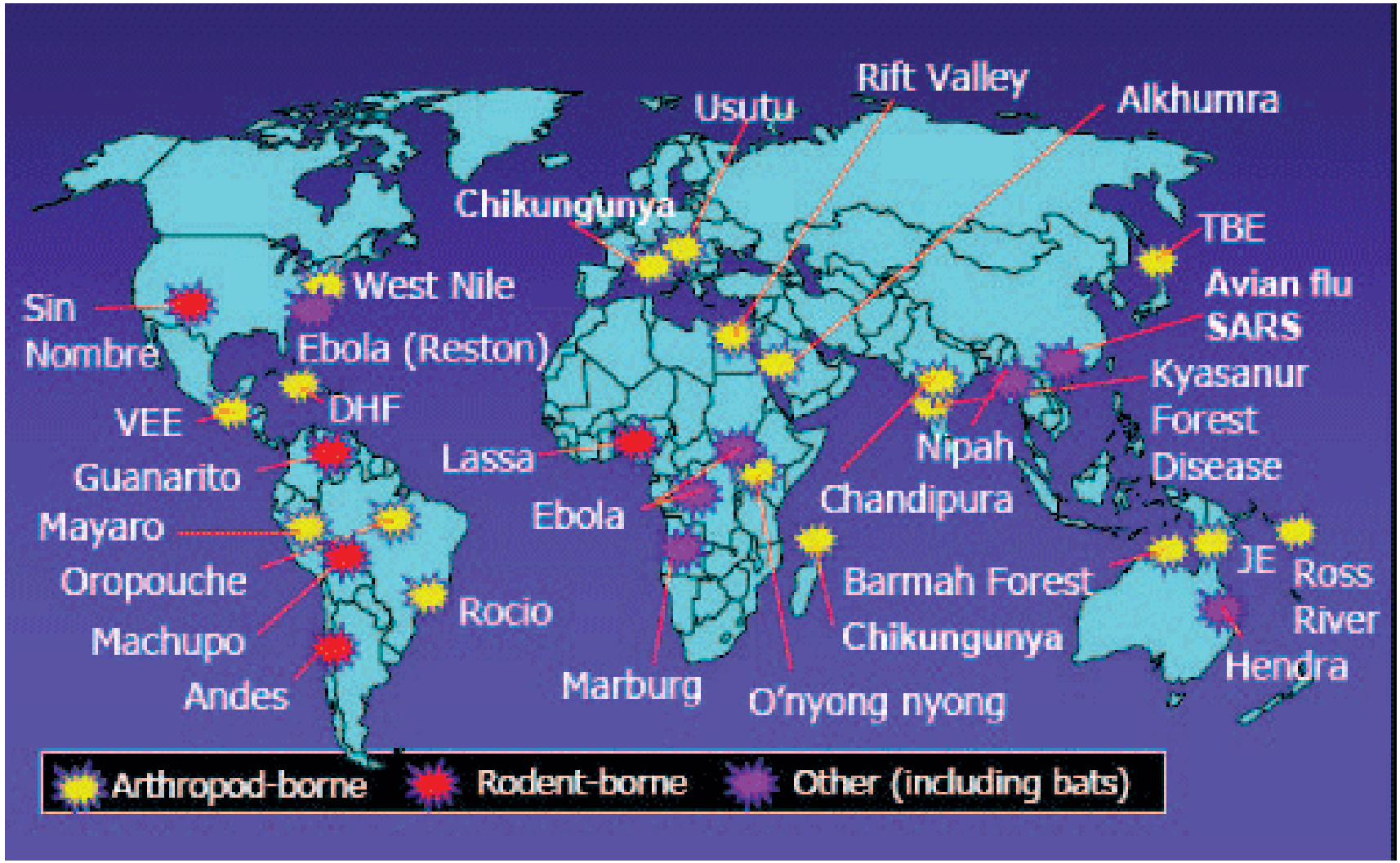
Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?

Potential Level 3 Products

- **Use HyspIRI TIR data to obtain observations and measurements of surface temperature and surface wetness as indicators of regions for possible disease transmission**
- **Use high spatial/temporal resolution, multispectral thermal HyspIRI data as inputs to disease models to produce risk maps for vector- and animal-borne disease persistence and expansion globally**

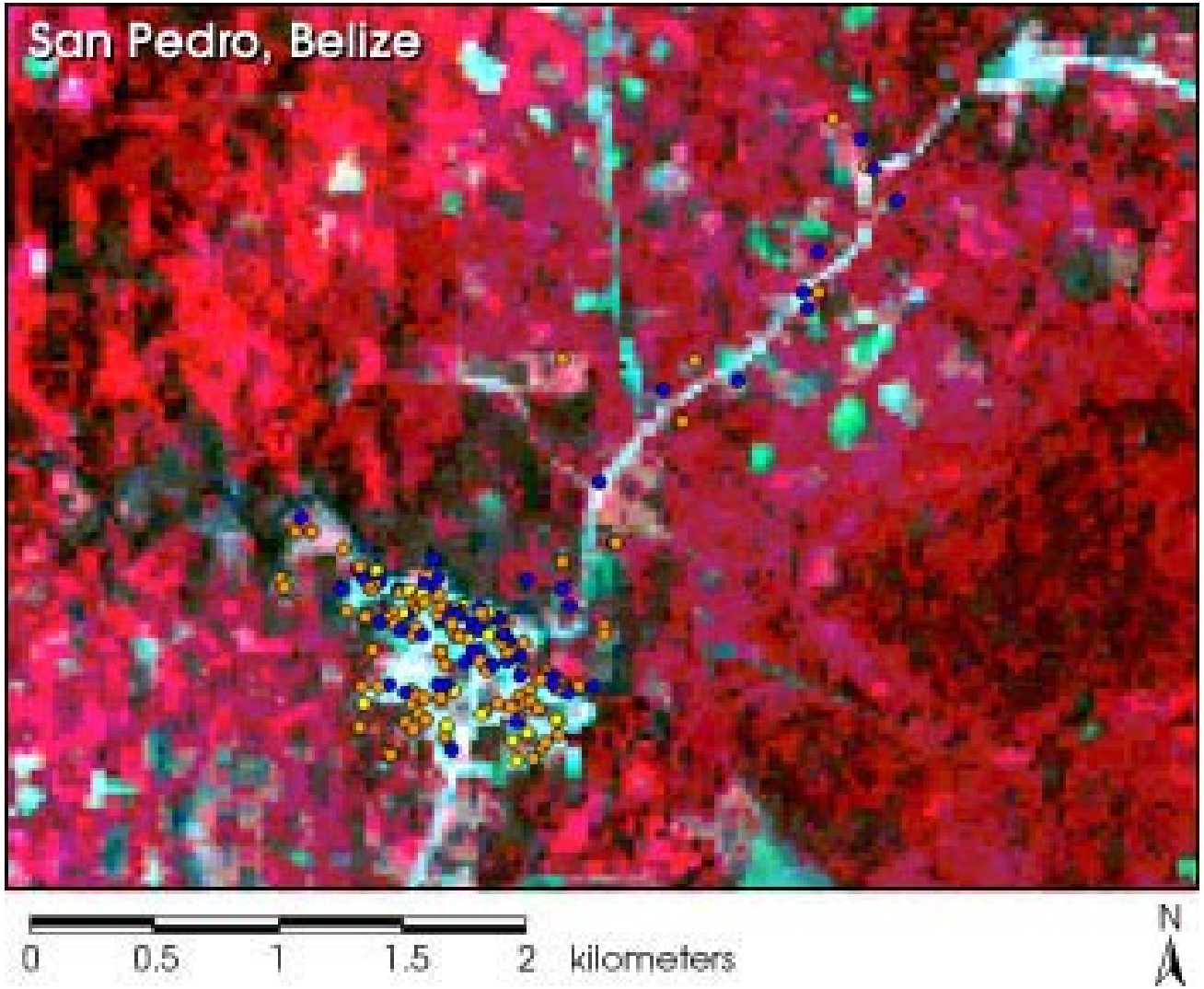
TQ4 HyspIRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?



TQ4 HysplRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved? human ecosystems and urbanization?



TQ4 HysplRI Science Questions

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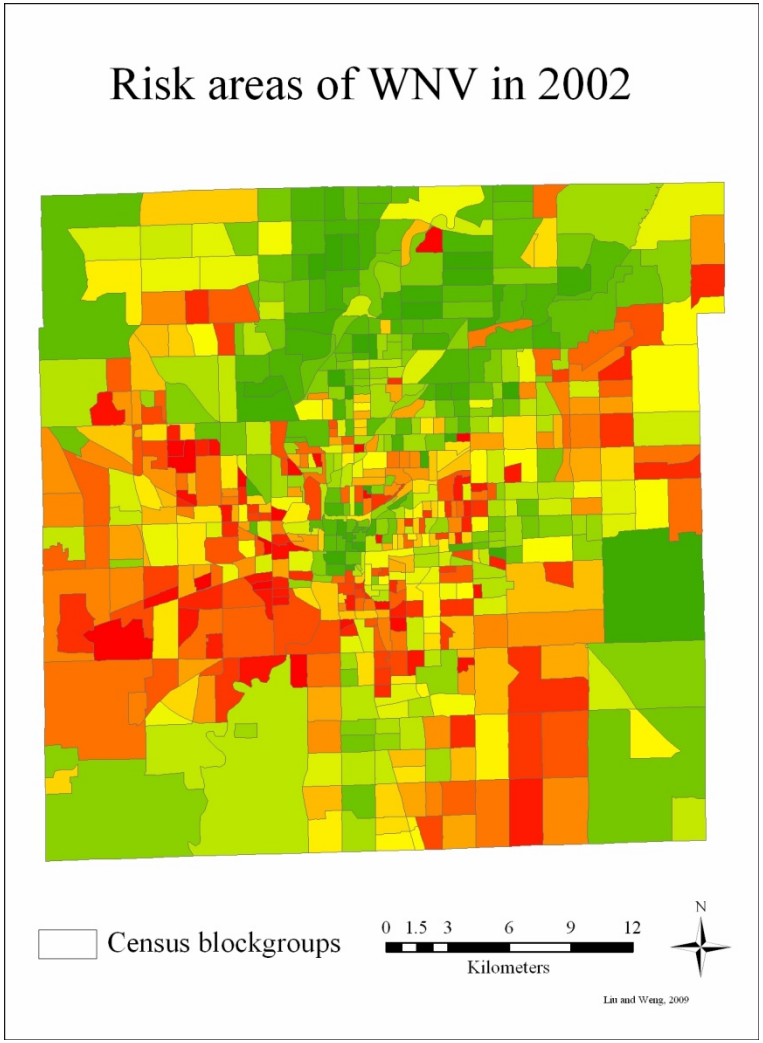


TQ4 HyspIRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?

Level 3 Validation Approach

- **Use current satellite thermal IR data (e.g., ASTER, Landsat, MODIS) to identify land cover/land use factors that are associated with vector- and animal-borne diseases (e.g., West Nile virus, malaria) as validation that these data can be used to develop disease risk maps**

TQ4 HyspIRI Science Questions

Science Issue: How can characteristics associated with environmentally-related health effects that affect vector-borne and animal-borne diseases be better measured and resolved?

Precursor Science

- **Characterize landscape attributes that contribute to risk factors of vector- and animal-borne diseases using current satellite data**
- **Develop disease risk maps using current satellite TIR data (e.g., ASTER, Landsat, MODIS) for areas of known diseases**
- **Airborne/*in situ* campaign to collect HyspIRI-like thermal IR data for areas of known risk factors for vector- and animal-borne diseases (high spatial resolution/multispectral/multitemporal data collection**

TQ4 HyspIRI Science Questions

Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?

Scale impacts the detection, observation, measurement and modeling of heat fluxes and energy balances across the earth. HyspIRI data will enable more precise quantitative assessment of how spatial and temporal scale impacts energy balances on human health, human ecosystems, and urbanization.

TQ4 HyspIRI Science Questions

Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?

Approach

- **Satellite observations for global measurement of surface temperature, energy balance, and energy fluxes at multitemporal scales**
- **Spatial models of land surface characteristics across differing horizontal and vertical domains for different biophysical and human environments**

TQ4 HyspIRI Science Questions

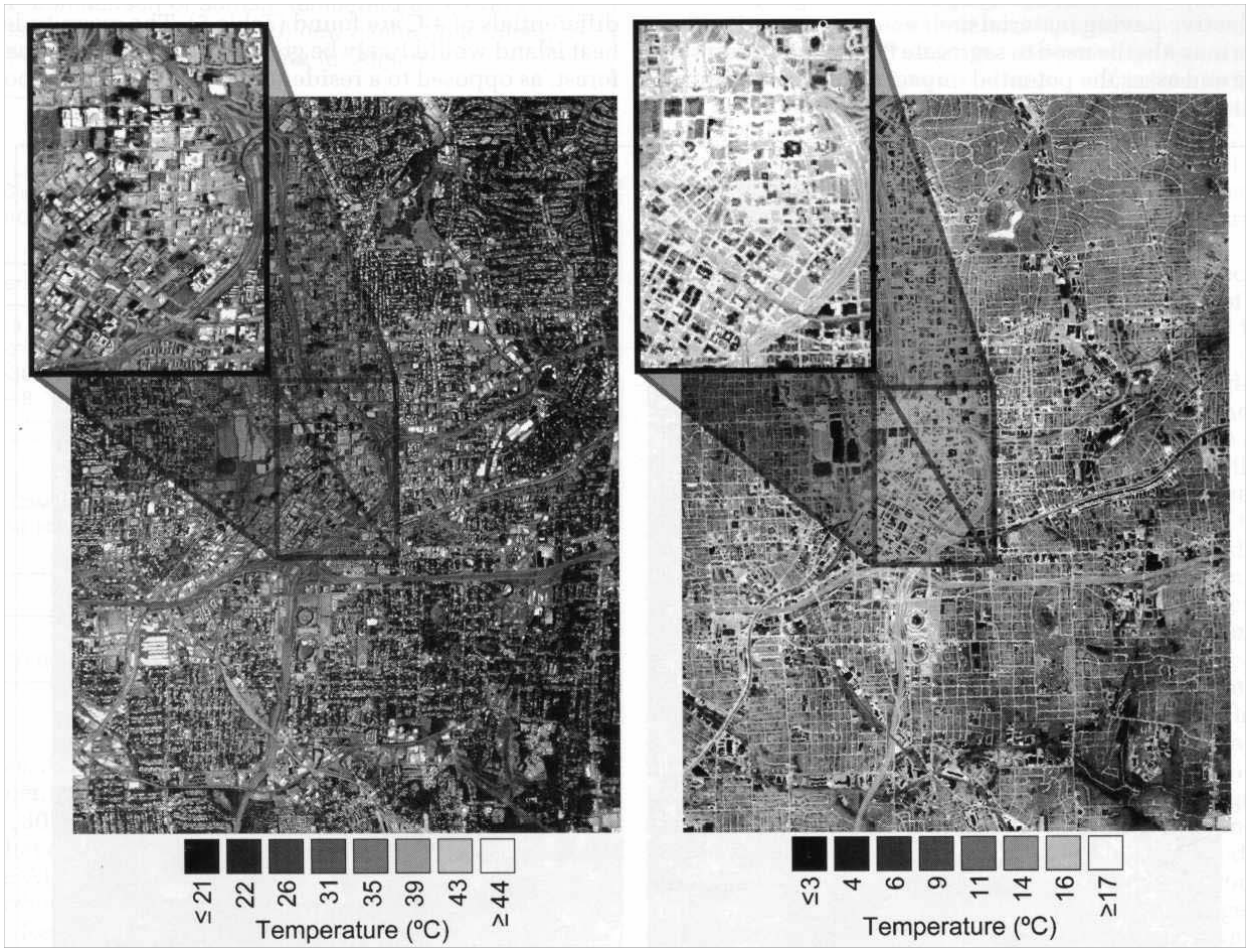
Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?

Potential Level 3 Products

- **Maps of heat flux dynamics for various natural (e.g., forest, desert, mountain) and human (e.g., agriculture) derived from high spatial/multitemporal resolution HyspIRI data over multiple time periods**
- **Maps of emissivity for various land covers around the globe using HyspIRI thermal IR data**
- **Maps of vertical dynamics of heat flux derived from HyspIRI thermal IR data (i.e., overlain on 3-D topographic perspective)**

TQ4 HyspIRI Science Questions

Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?



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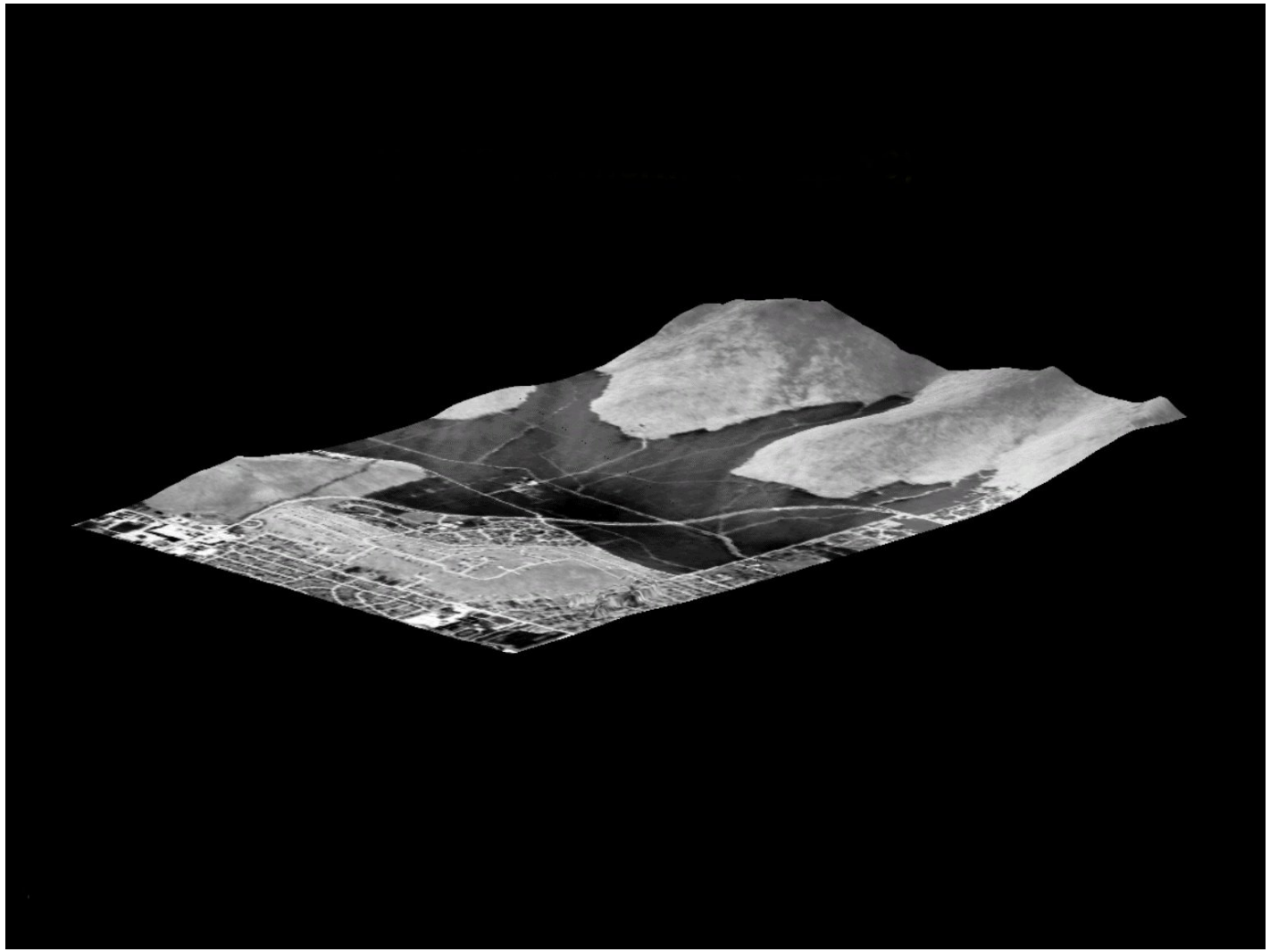

TQ4 HyspIRI Science Questions

Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?

Level 3 Validation Approach

- **Evaluate surface temperature and energy fluxes for various land covers/land uses across different temporal and horizontal/vertical scales as derived from current "HyspIRI-like" satellite data (ASTER, Landsat, MODIS) to assess how scale affects these parameters**
- **Use current high spatial/temporal resolution multispectral satellite data and airborne thermal data (e.g., MASTER) to quantify diurnal and nocturnal surface energy characteristics and establish baselines on scale impacts for land cover/land use surface energy fluxes globally**

TQ4 HyspIRI Science Questions

Science Issue: How do horizontal and temporal scales of variation in heat flux and mixing relate to human health, human ecosystems and urbanization?

Precursor Science

- **Use current TIR data (e.g., Landsat, MODIS, ASTER) to produce heat flux maps for land covers in different geographic regions around the globe (e.g., desert, forest)**
- **Conduct airborne field campaign using MASTER to collect "HyspIRI-like" thermal IR data (i.e., multispectral, ≤ 60m) to derive heat flux maps for different land covers**