ADVANCED NASA ENVIRONMENTAL DATA FOR STUDYING PUBLIC HEALTH: DATA ACQUISITION, EXPLORATION, ACCESS AND RETRIEVAL SERVICES TODAY, ANALYTICS TOMORROW

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Meredith Golden, CIESIN at Columbia University

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ISPRS / MEDGEO / Holistics for Health, Arlington

Presentation Purpose

- To discuss the availability and usefulness of remote sensing data in support of public health research, surveillance, and modeling
- To discuss NASA developed remote sensing tools and services that facilitate finding, accessing and using remote sensing … in support of public health research, surveillance, and modeling
- To stimulate thought on cross analyzing large amounts of heterogeneous data

Environmental Health

Environmental health is **that branch of public health** that is concerned with all aspects of the natural and built environment that may affect human health. The field of environmental health is closely related to environmental science and public health as environmental health is **concerned with environmental factors affecting human health**.

World Health Organization:

(http://www.who.int/topics/environmental_health/en)

Environmental health addresses all the physical, chemical, and biological factors external to a person, and all the related **factors** impacting behaviours. It encompasses the assessment and control of those **environmental factors that can potentially affect health**. It is targeted towards preventing disease and creating health-supportive environments. This definition excludes behaviour not related to environment, as well as behaviour related to the social and cultural environment, and genetics

Remote Sensing Data and Public Health

Key information required by epidemiological studies is the spatial and temporal distributions of **environmental factors** and their proximity to concerned cohorts

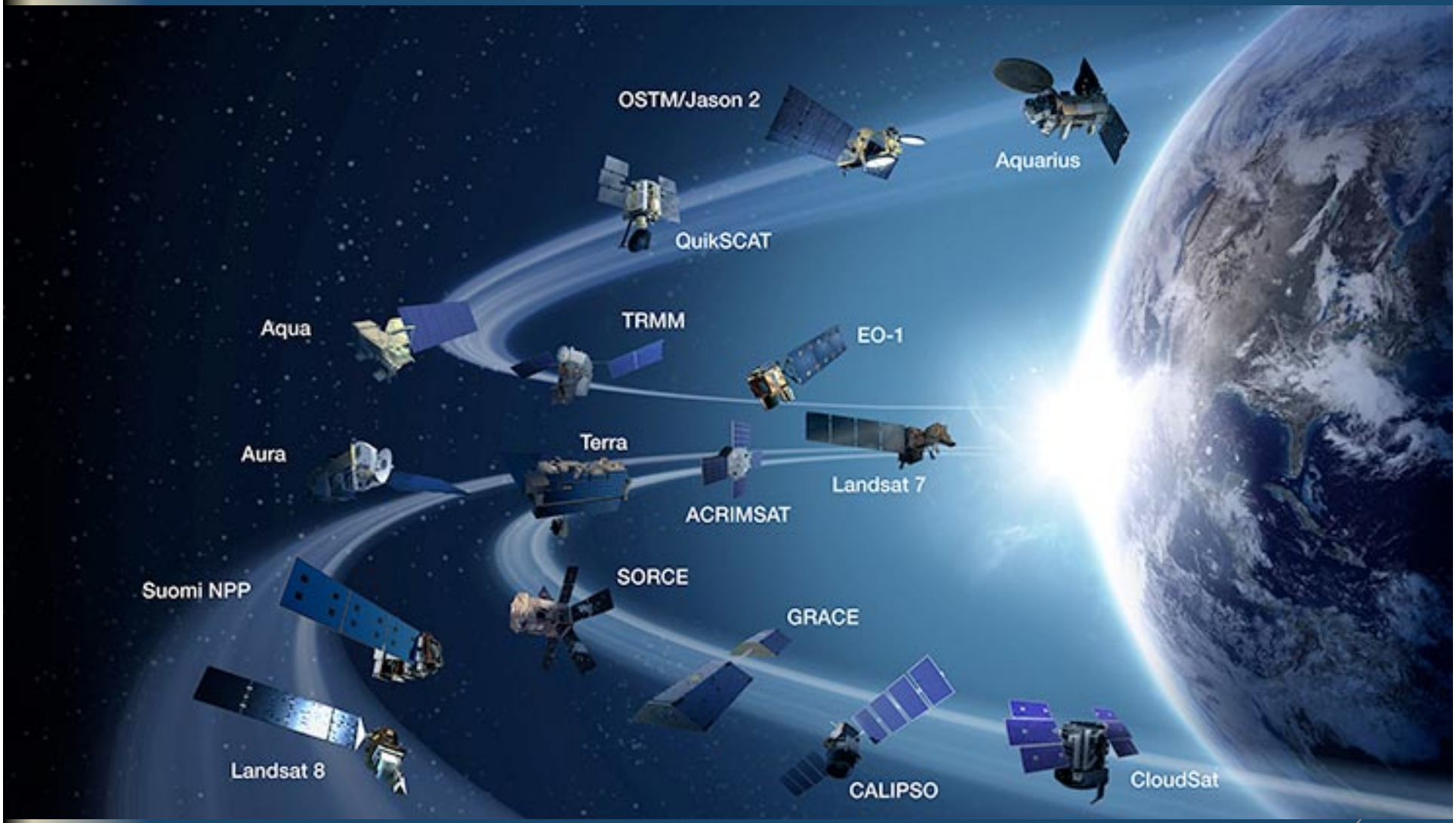
- Remote sensing data provides evenly gridded spatial coverage
- Collection is quick and systematic
- Provides global coverage

Remote Sensing Data, Environmental Health, and Public Health

The potential of Remote Sensing data to contribute measureable Environmental Health factors to Public Health research is evident, if not fully realized

NASA's Earth Observing System Operating Missions

EOS Science Project Office, Image by Jenny Mottar



Remote Sensing Measurements Found Useful for Public Health Research and Modeling

(not exhaustive)

Vector Borne Disease Research

- Precipitation
- Land Cover Type
- Normalized Difference Vegetation Index (NDVI)
- Leaf Area Index
- Soil Moisture
- Terrestrial Water Storage
- Surface Temperature
- Relative Humidity
- Wind
- Surface Reflectance
- Solar Radiation
- Topography (Digital Elevation Maps)

Remote Sensing Measurements Found Useful for Public Health Research and Modeling

(not exhaustive)

Water Borne Disease Research

- Precipitation
- Land Use/Cover Type
- Ocean Color
- Temperature

Remote Sensing Measurements Found Useful for Public Health Research and Modeling

(not exhaustive)

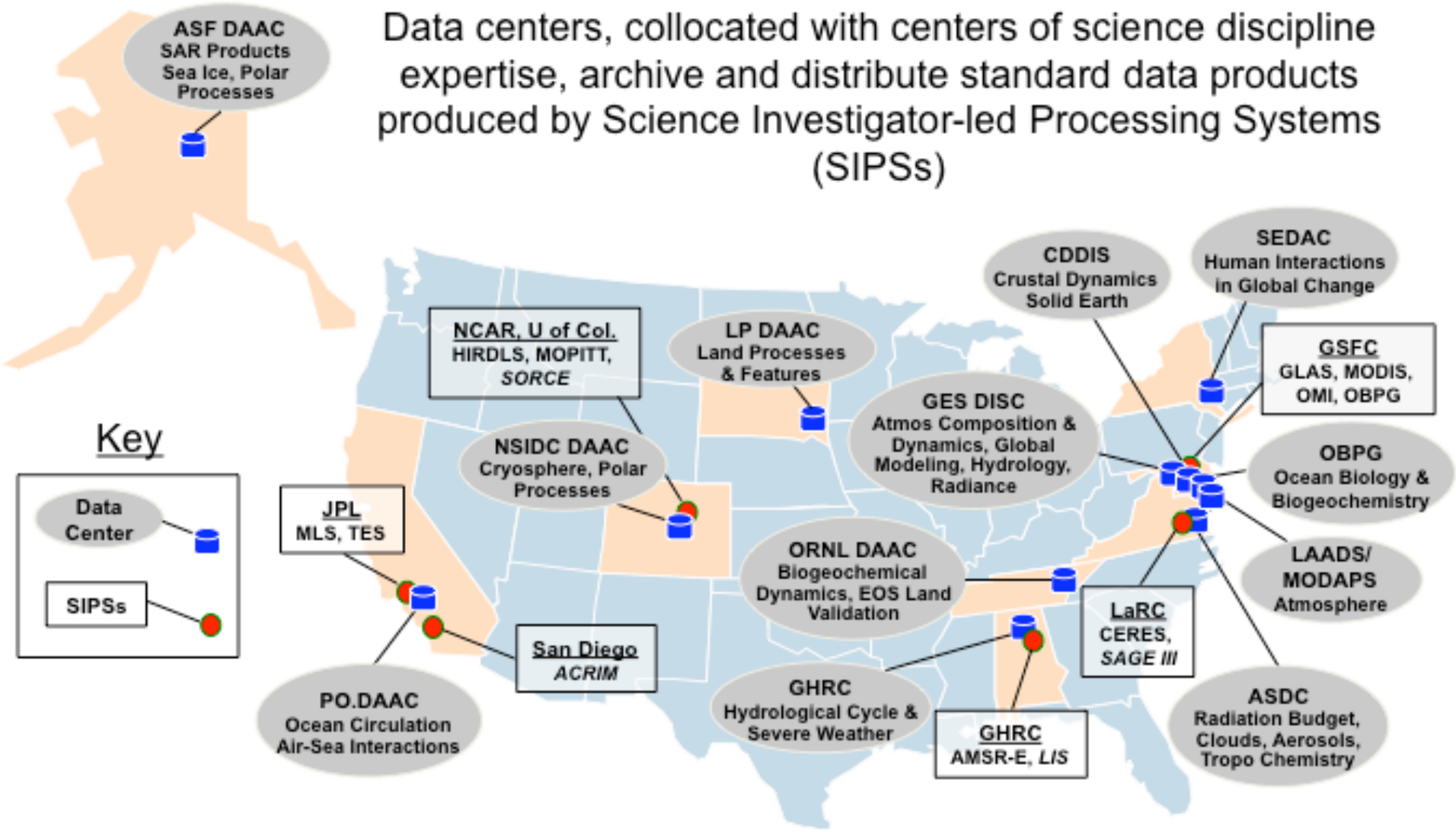
Air Pollution Related Disease Research

- Aerosol
- Atmospheric Chemistry components
- Normalized Difference Vegetation Index (NDVI)
- Surface Temperature
- Solar Insolation
- Relative Humidity

EOSDIS Facilities

https://earthdata.nasa.gov/data/data-centers

Data centers, collocated with centers of science discipline expertise, archive and distribute standard data products produced by Science Investigator-led Processing Systems (SIPSs)



EOSDIS – Earth Observing System Data and Information System
DAAC – Distributed Active Archive Center

NASA's Earth Science Data Centers	Discipline
Alaska Satellite Facility SAR Data Center (ASF SDC) website: http://www.asf.alaska.edu	• Synthetic Aperture Radar (SAR) • Sea Ice • Polar Processes • Geophysics
Crustal Dynamics Data Information System (CDDIS) website: http://cddis.gsfc.nasa.gov/	• Space Geodesy
Global Hydrology Resource Center (GHRC) website: http://ghrc.msfc.nasa.gov/	• Hydrologic Cycle • Severe Weather Interactions • Lightning • Atmospheric Convection
Goddard Earth Sciences Data and Information Services Center (GES DISC) website: http://disc.sci.gsfc.nasa.gov/	• Global Precipitation • Solar Irradiance • Atmospheric Composition • Atmospheric Dynamics • Global Modeling
Land Processes (LP) DAAC website: https://lpdaac.usgs.gov/	• Surface Reflectance • Land Cover • Vegetation Indices
Level 1 Atmosphere Archive and Distribution System (MODAPS LAADS) website: http://ladsweb.nascom.nasa.gov/	• Radiance • Atmosphere

NASA Langley Research Center Atmospheric Science Data Center (LaRC ASDC) website: http://eosweb.larc.nasa.gov/	• Radiation Budget • Clouds • Aerosols • Tropospheric Chemistry
National Snow and Ice Data Center (NSIDC) DAAC website: http://nsidc.org/	• Snow • Ice • Cryosphere • Climate
Oak Ridge National Laboratory (ORNL) DAAC website: http://daac.ornl.gov/	• Biogeochemical Dynamics • Ecological Data • Environmental Processes
Ocean Biology Processing Group (OBPG) website: http://oceancolor.gsfc.nasa.gov/	• Ocean Biology • Ocean Color • Biogeochemistry • Sea Surface Temperature
Physical Oceanography (PO) DAAC website: http://podaac.jpl.nasa.gov/	• Sea Surface Temperature • Ocean Winds • Circulation and Currents • Topography and Gravity
Socioeconomic Data and Applications Data Center (SEDAC) website: http://sedac.ciesin.columbia.edu/	• Human Interactions • Land Use • Environmental Sustainability • Geospatial Data • Multilateral Environmental Agreements

In addition to remote sensing data…

NASA remote sensing data services to facilitate public health research have been developed through NASA ROSES Decision Support Projects and by EOSDIS Data Centers

The public health community has become better served with remote sensing data, tools and information services through NASA projects that address specific research and facilitate data acquisition.

Exemplary Public Health Services Developed by NASA ROSES Decision Support Projects and EOSDIS Data Centers

- Remote sensing data and associated tools utilized in monitoring geophysical measurements for malaria surveillance
  - P. Ceccato, Columbia University
- Evaluation and assessment tool that uses environmental measurements for preparing for, and responding to, extreme heat event
  - S. Maxwell, BioMedware
- Feasibility of improving dust forecasting leveraging existing technologies
  - K. Bendict, EDAC University of New Mexico
- Interactive tools and information services for visualizing and analyzing health related socioeconomic data integrated with remote sensing data
  - M. Golden, R. Chen, SEDAC CEISEN Columbia University
- Interactive tools and information services for accessing, discovering, visualizing, and analyzing remote sensing environmental data used by public health researchers and modelers
  - S. Kempler, GES DISC NASA/GSFC

The Use of Remote Sensing Data for Monitoring Rainfall, Vegetation and Water Bodies for Malaria Surveillance

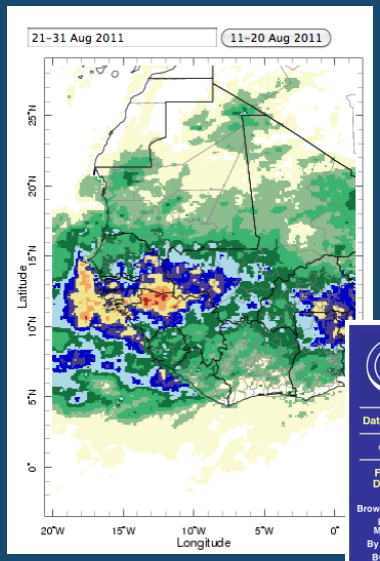
Pietro Ceccato, Columbia University

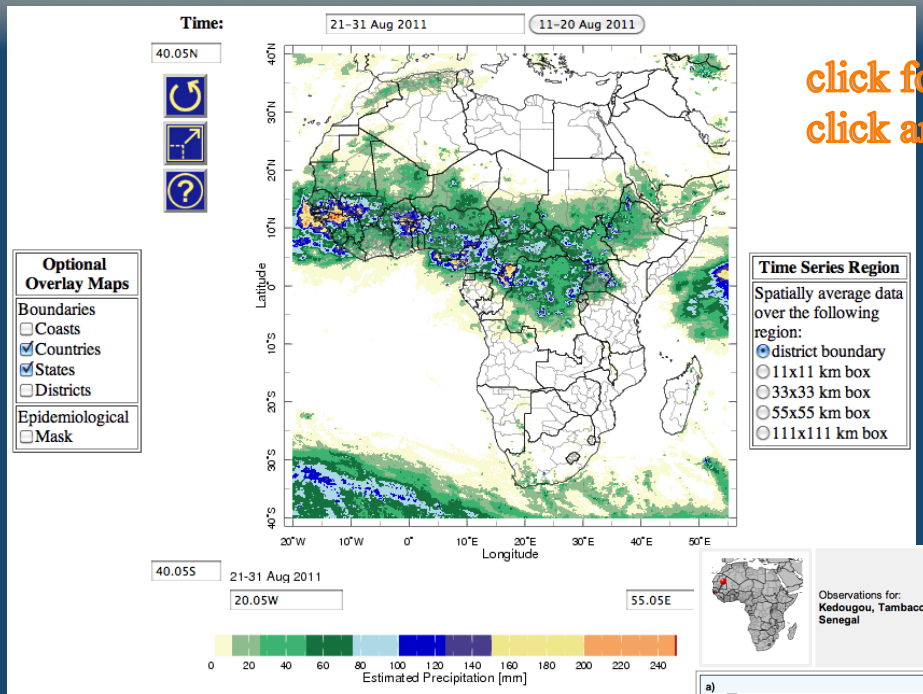
- Monitoring variations in environmental conditions such as rainfall and vegetation helps decision-makers to assess the risk levels of malaria epidemics.

- The International Research Institute for Climate and Society (IRI) has developed the Malaria Early Warning System (MEWS) to enable users to gain a contextual perspective of the current rainfall.

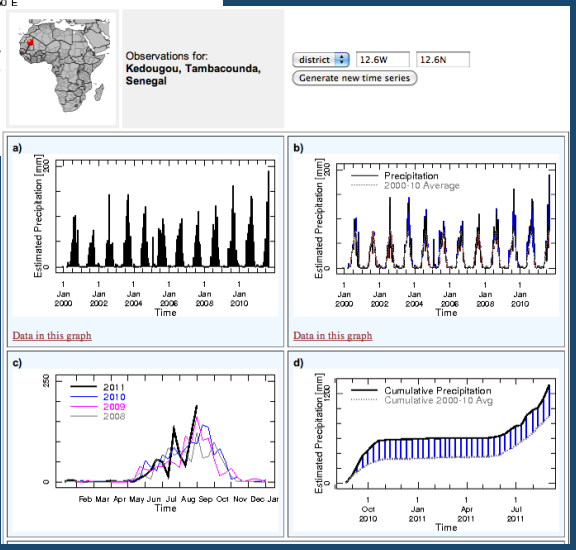
- MEWS uses data from located in the IRI Data Library, which includes remote sensing data such has from TRMM and MODIS

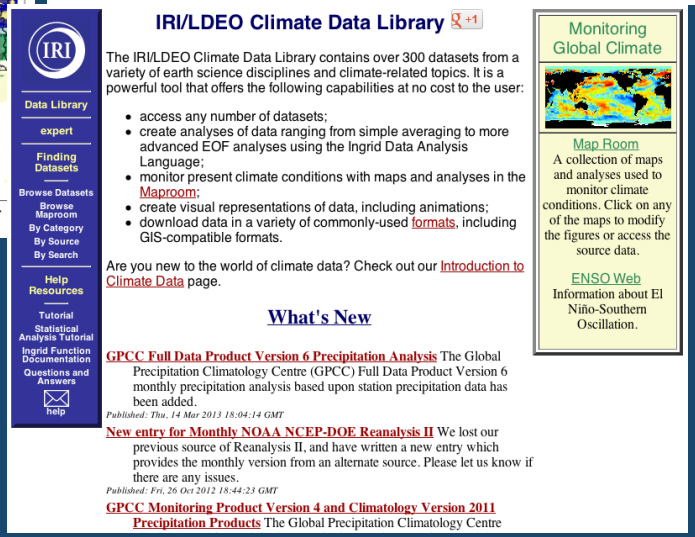
Malaria Early Warning System (MEWS)





click for information;
click and drag to zoom





From: http://iridl.ldeo.columbia.edu/maproom/.Health/.Regional/.Africa/.Malaria/.MEWS/

Internet-based Heat Evaluation and Assessment Tool (I-HEAT)

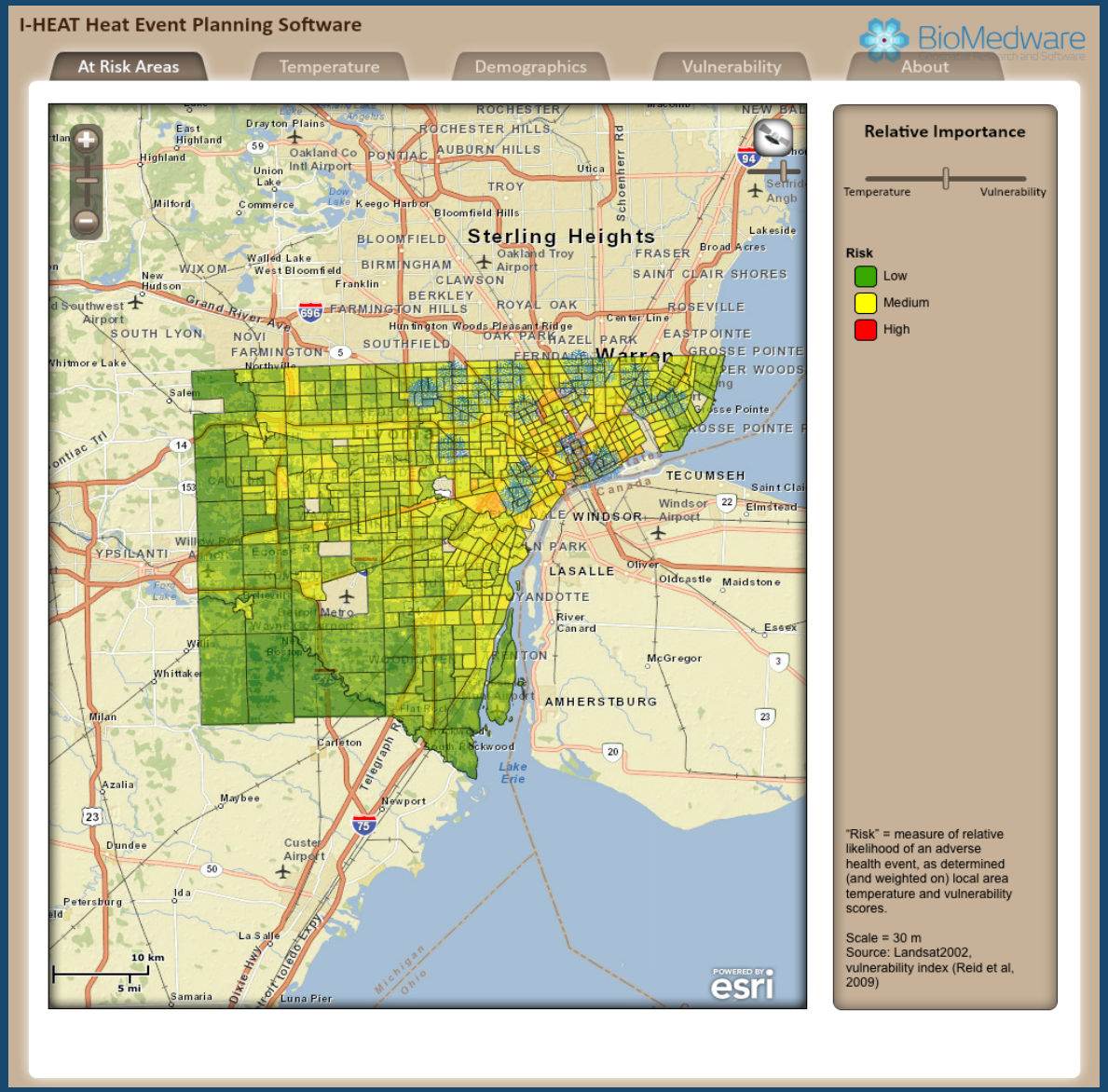
Susan Maxwell, et al, BioMedware

- Heat Evaluation and Assessment Tool (I-HEAT) will provide health professionals and risk assessors with an advanced geospatial web-based system for preparing and responding to emergency heat events, developing mitigation strategies, and educating the public.

- The system couples demographic and environmental data obtained from Landsat satellite imagery with browser-based software to model and map heat-related morbidity and mortality risks at the neighborhood level.

- Landsat data will be integrated with demographic, socio-economic, and health data in a heat-risk model.

I-HEAT interface showing a heat-risk map of Detroit, Michigan



From: http://www.biomedware.com/I-Heat/IHeatViewer.html

The Feasibility of Interoperable Multi-resolution Dust Modeling for Accelerated Forecast Availability

Karl Benedict, Earth Data Analysis Center (EDAC), University of New Mexico

- An information technology study to analyze the feasibility of developing a dust forecasting system with improved system performance and utility:
  - Timeliness to create forecast products
  - Spatial resolution of the forecast products relative to the preferred analytic and alert units (i.e. county, zip-code, etc.)
  - Utility of the forecast products – that they are in a usable form

- Conclusions:
  - Demonstrated efficient transfer of remote, remote sensing data
  - Alternate data transfer protocols & connectivity models are feasible
  - Simplified parallel execution has significant potential for deploying scalable modeling systems into commodity computing environments

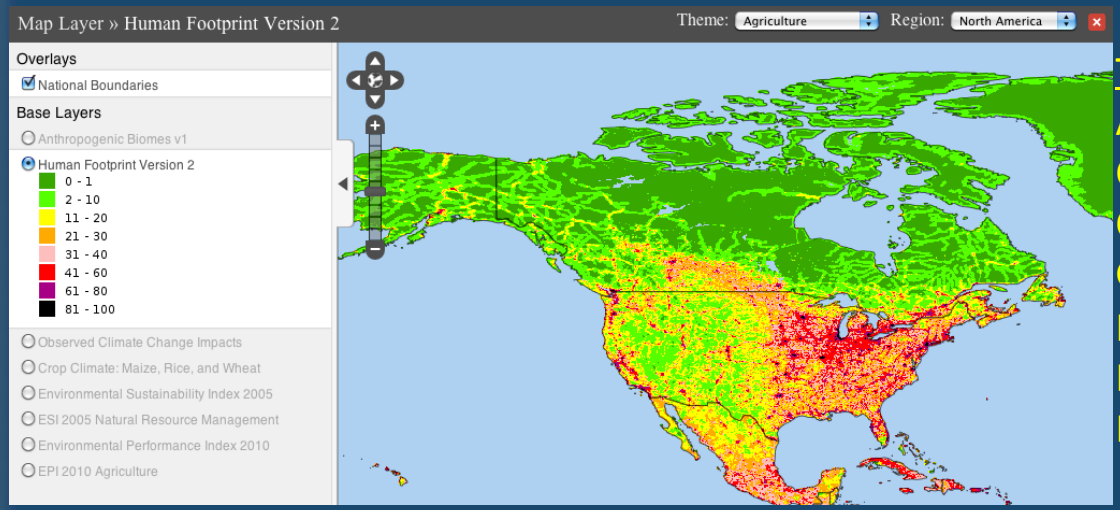
Health-related Data and Services from the NASA Socioeconomic Data and Applications Center (SEDAC)

Meredith L. Golden, Robert S. Chen, Socioeconomic Data and Applications Center (SEDAC), Center for International Earth Science Information Network (CIESIN) at Columbia University

- SEDAC is a NASA Earth Science Data Center specializing in data related to human interactions in the environment, and in particular on demographic and socioeconomic data that can be integrated with remote sensing data
- SEDAC provides interactive tools and resources for the visualization and analysis of interdisciplinary data
- SEDAC has developed data and information resources used extensively in public health research and surveillance

SEDAC's Interactive Data Visualization Tools and Resources

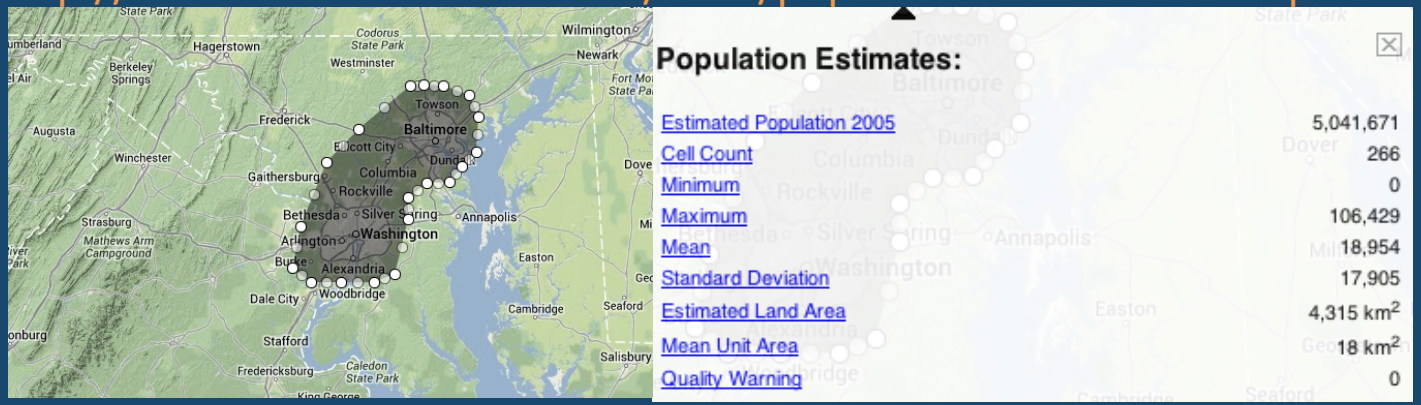
SEDAC Interactive Map Client http://sedac.ciesin.columbia.edu/maps/



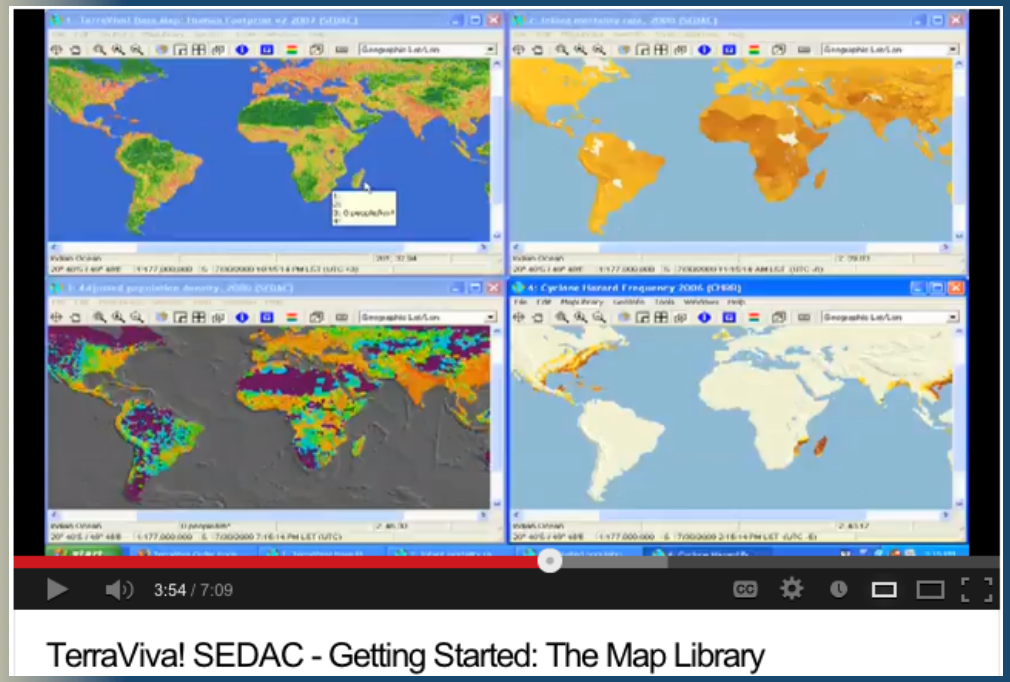
Themes:

- Agriculture
- Climate
- Conservation
- Governance
- Hazards
- Health
- Land Use
- Marine and Coastal
- Population
- Poverty
- Remote Sensing
- Sustainability
- Urban
- Water

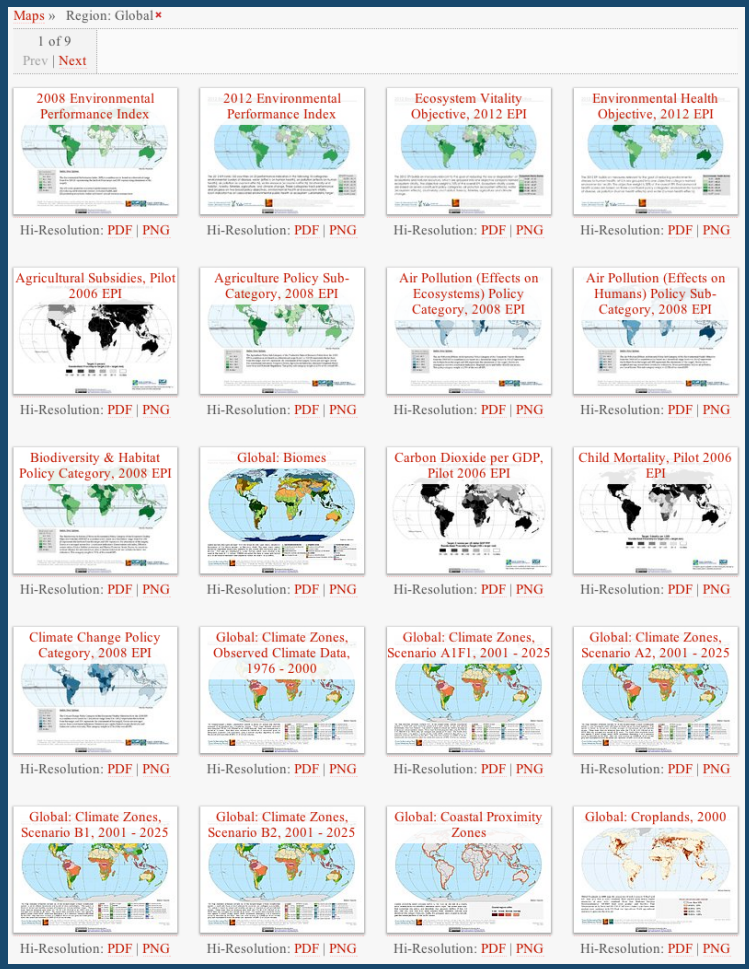
SEDAC Population Estimation Service
http://sedac.ciesin.columbia.edu/tools/population-estimation-mapclient



SEDAC's Interactive Data Visualization Tools and Resources



TerraViva! SEDAC: Standalone data and viewer
http://sedac.ciesin.columbia.edu/tools/terra-visa

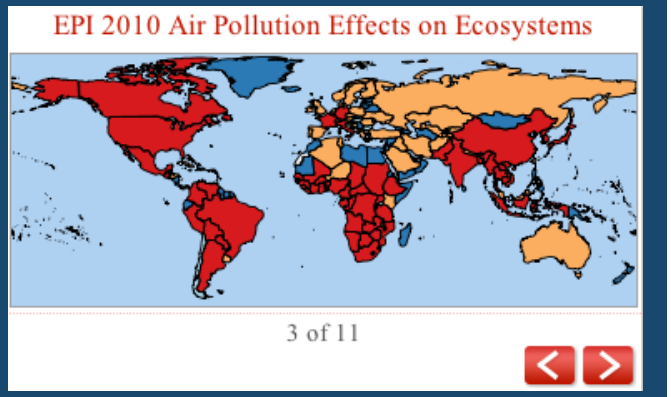


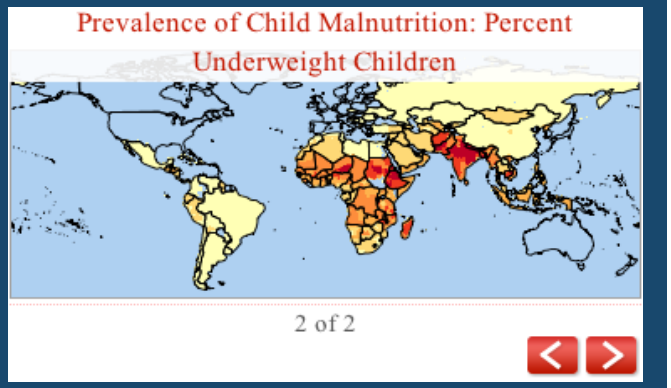
SEDAC Map Gallery – select Theme, Region, Location
http://sedac.ciesin.columbia.edu/maps/gallery/browse

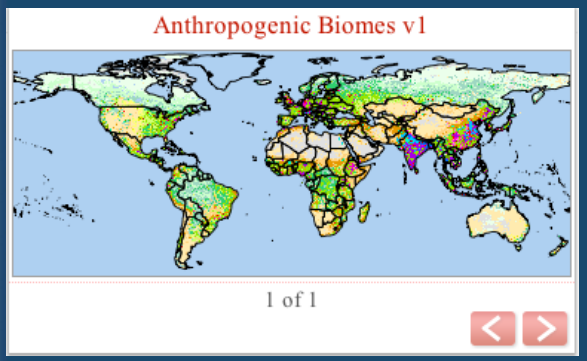
Selected Data and Information Resources Useful for Public Health Applications

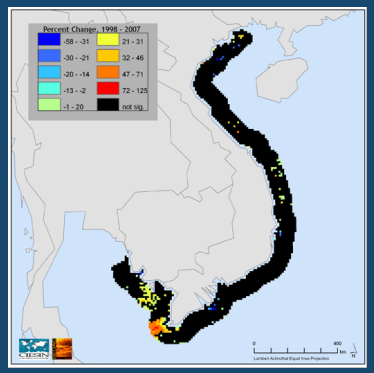
SEDAC's Collection of Public Health Related Data
(http://sedac.ciesin.columbia.edu/data/collections/browse)
including (to mention a few):

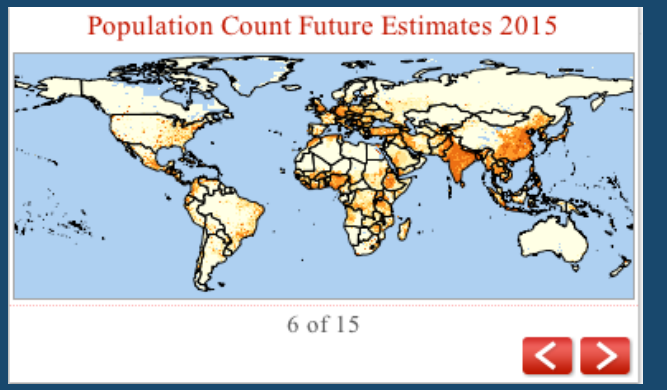
- Gridded Population of the World
- Global Rural-Urban Mapping Project
- Poverty mapping
- Population, Landscape, and Climate Estimates (PLACE)
- Indicators of Coastal Water Quality
- Environmental Performance Index 2010
- Anthropogenic Biomes
- Historical Anthropogenic Sulfur Dioxide Emissions











Remote Sensing Data and Information Services at the Goddard Earth Science Data and Information Services Center (GES DISC) Related to Public Health Research

Steven Kempler, GES DISC, NASA/GSFC

- GES DISC is a NASA Earth Science Data Center specializing in serving atmospheric, hydrologic, and precipitation remote sensing, and remote sensing based assimilated data
- GES DISC provides data access, discovery, visualization, retrieval, and analysis services to glean information from data
- Many GES DISC datasets are useful for public health research, modeling, surveillance, and decision support systems
- The GES DISC is one of several NASA data archives containing data useful for public health research

Relating Remote Sensing Data to Public Health Research

Temporal Coverage, Temporal Resolution, Spatial Resolution Considerations:

- Measurements with long temporal coverage are useful for long term studies and health trend relationships.
- High temporal resolution measurements support short term health variability studies.
- High spatial resolution measurements are used for relating to local, small region health studies.
- Lower resolution remote sensing measurements are sufficient for wider, regional public health studies

GES DISC Data Holdings Relevant to Public Health Research and Modeling

(See backup slides for spatial resolution, temporal coverage, usage, and health relevance… and acronym list)

	Remote Sensing Data	Assimilated Data
Precipitation	TRMM	GLDAS, NLDAS, MERRA
Water Runoff		GLDAS, NLDAS, MERRA
Vegetation Index		NLDAS, MERRA
Soil Moisture	AMSR-E	GLDAS, NLDAS, MERRA
Surface Air Temperature	AIRS, TOVS	GLDAS, NLDAS, MERRA
Aerosol	OMI, TOMS, HIRDLS	GOCART
Wind		GLDAS, NLDAS, MERRA, GSSTF2b
Solar Irradiance	SORCE, OMI	

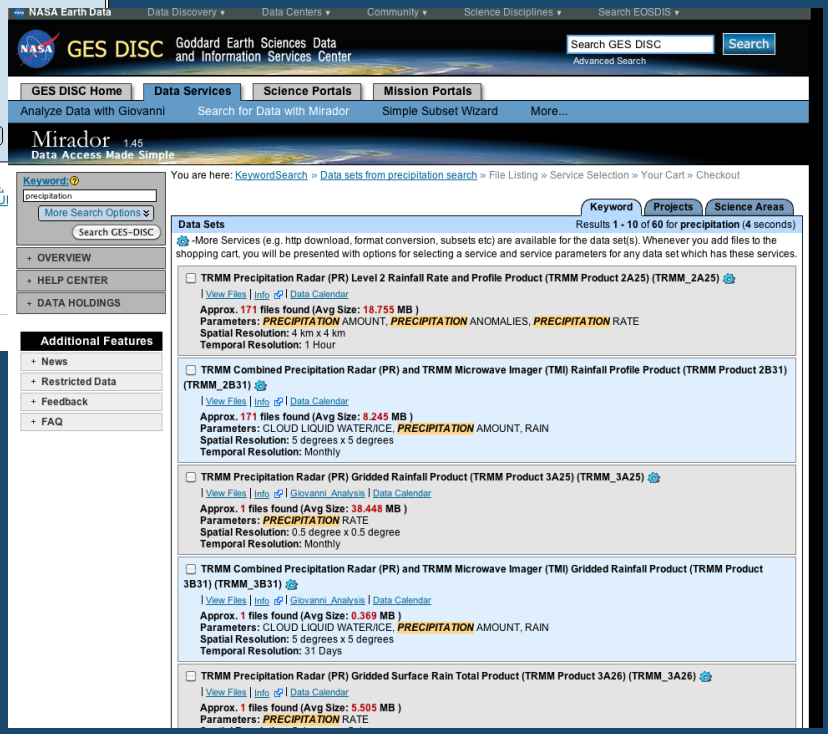
GES DISC Data Search and Access Services

Mirador
http://mirador.gsfc.nasa.gov

Choose:
Keyword search, Time
Location…

or Project…

or Science Area



Other GES DISC Data Search and Access Services

OPenDAP
http://disc.sci.gsfc.nasa.gov/services/opendap/

GrADS Data Server (GDS)
http://disc.sci.gsfc.nasa.gov/services/grads-gds

Web Map Service (WMS)
http://disc.sci.gsfc.nasa.gov/services/ogc_wms

Simple Subset Wizard (NASA Earth science data-wide data subsetting service)
http://disc.gsfc.nasa.gov/SSW/

GES DISC Information Exploration and Discovery Services

Giovanni - Goddard Interactive Online Visualization ANd aNalysis Infrastructure

https://disc.sci.gsfc.nasa.gov/giovanni

- Provides a simple and easy way to explore, visualize, analyze, and access vast amounts of Earth science remote sensing and model data.
- Is a Web-based application.
- Supported by NASA EOSDIS and several NASA-funded projects.

Giovanni Allows Researchers to Concentrate on the *Research*

The Old Way:

Pre-Science

- Find data
- Retrieve high volume data
- Learn formats and develop readers
- Extract parameters
- Perform spatial and other subsetting
- Identify quality and other flags and constraints
- Perform filtering/masking
- Develop analysis and visualization
- Accept/discard/get more data (sat, model, ground-based)

DO SCIENCE

- Exploration
- Initial Analysis
- Use the best data for the final analysis
- Derive conclusions
- Write the paper
- Submit the paper

Web-based Services:

Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

Giovanni

Mirador

- Read Data
- Extract Parameter
- Subset Spatially
- Filter Quality
- Reformat
- Reproject
- Visualize
- Explore
- Analyze

The Giovanni Way:

- Minutes
- Days for exploration

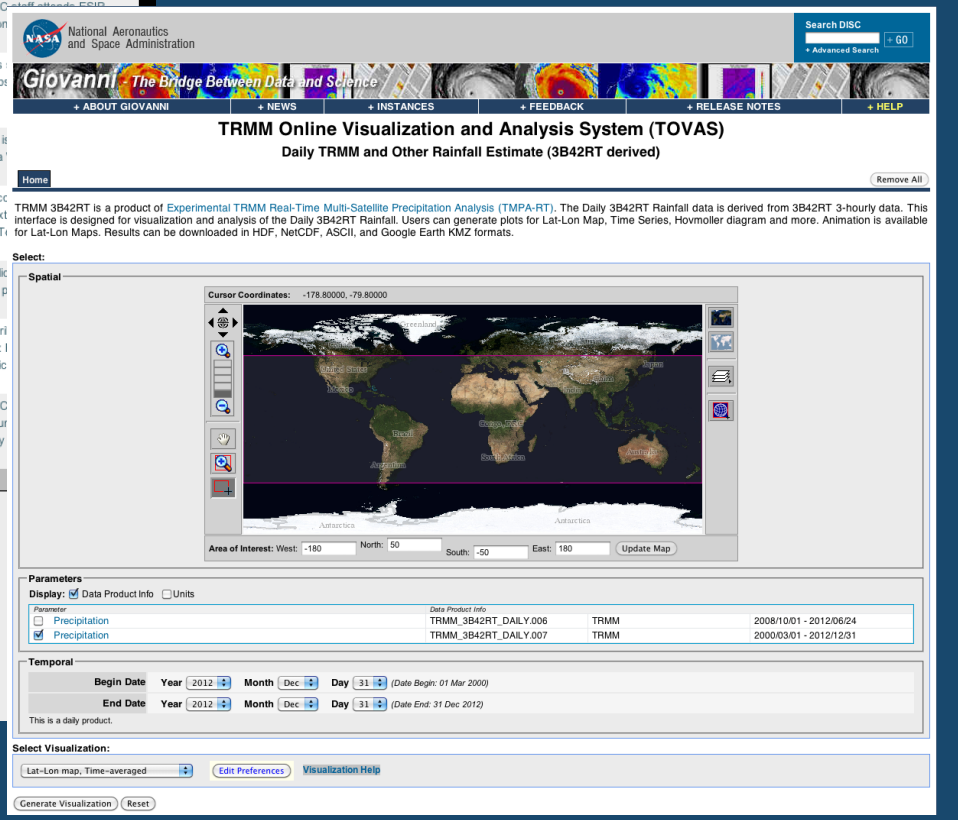
- Use the best data for the final analysis
- Derive conclusions
- Write the paper
- Submit the paper

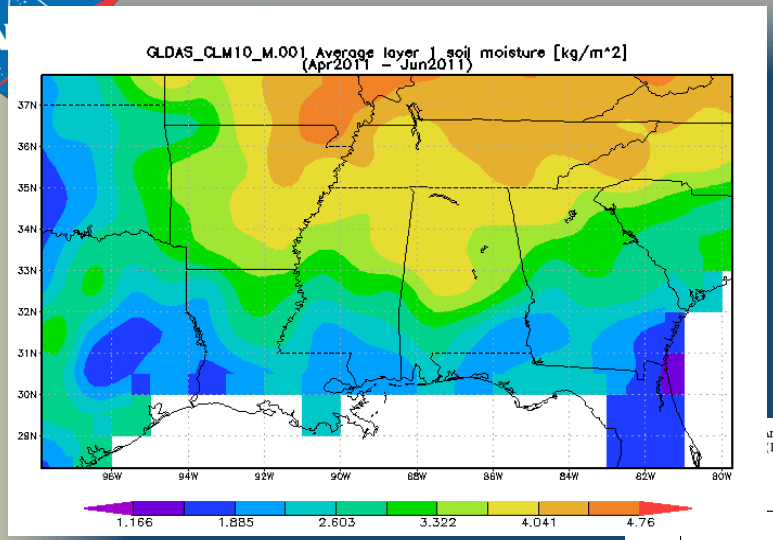
DO SCIENCE

Giovanni and other web-based tools allow scientists to ***compress*** the time needed for pre-science preliminary tasks: *data discovery, access, manipulation, visualization, and basic statistical analysis.*

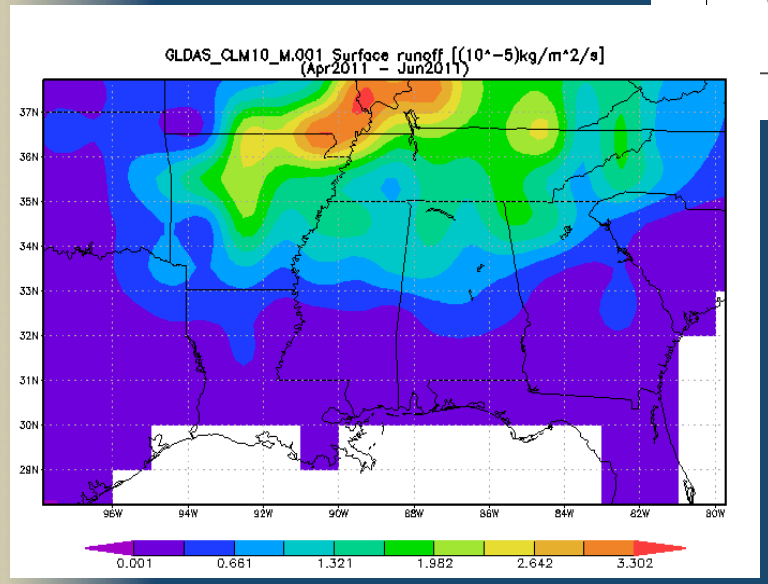
Choose Giovanni instance…

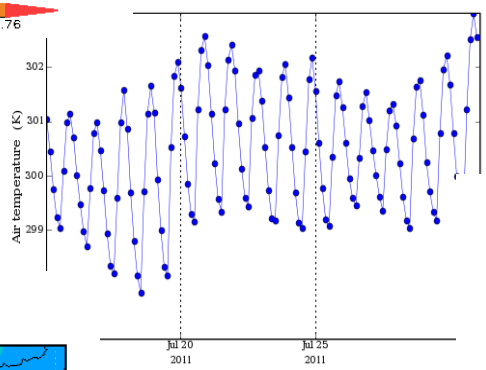
select location, time, measurement, and visualization



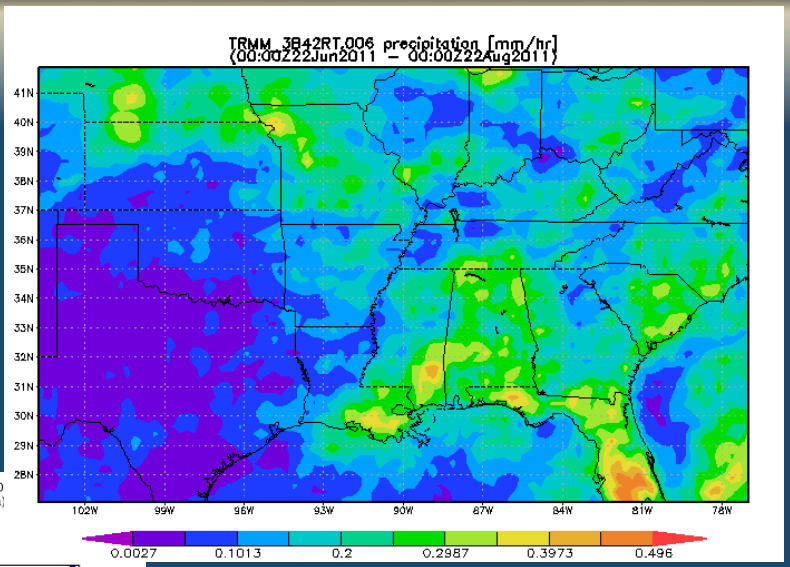


GLDAS soil moisture and surface runoff



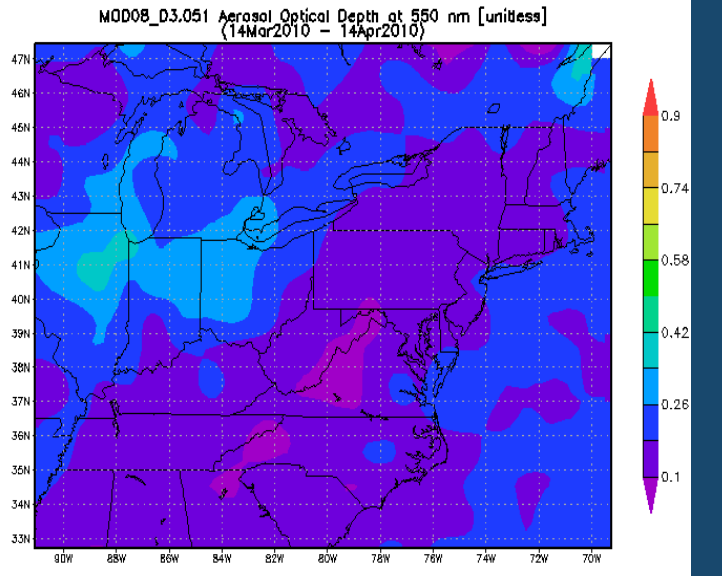


MERRA assimilated surface air temperature

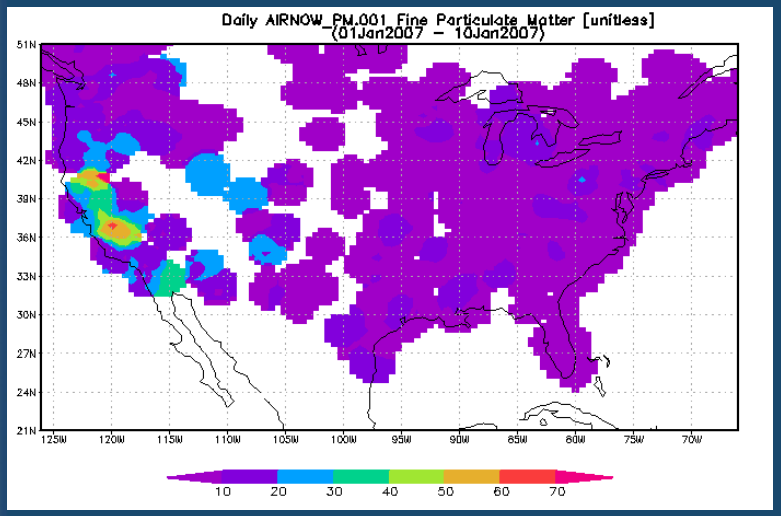


TRMM precipitation rate

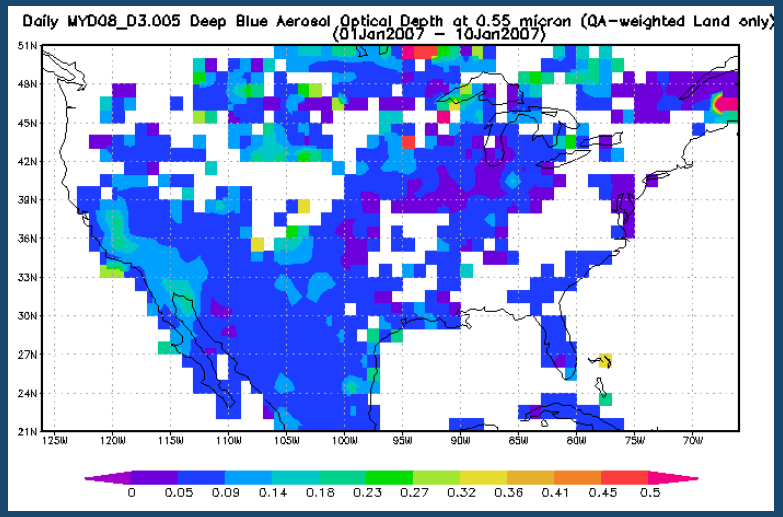
MODIS aerosol optical depth



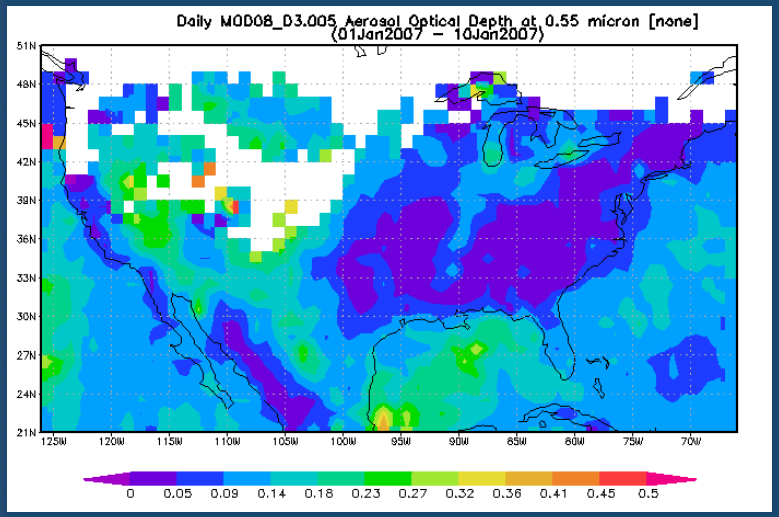
PM2.5 data in Giovanni



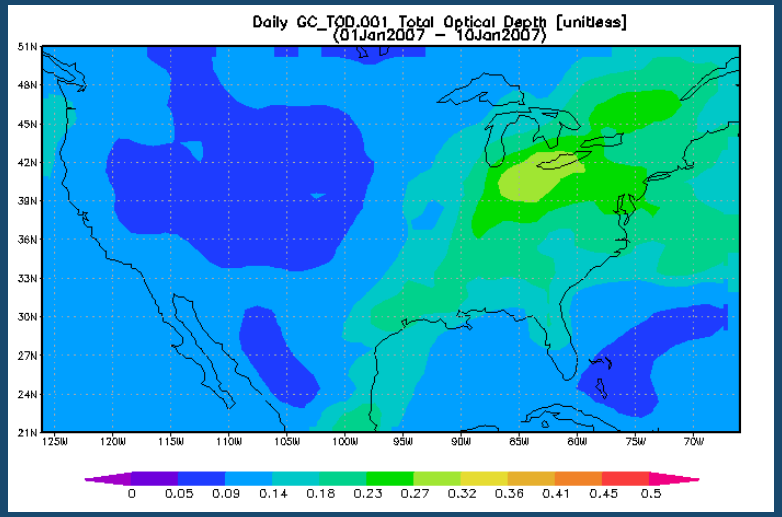
PM2.5 (EPA→ DataFed → Giovanni)



Deep Blue MODIS Aerosol Optical Depth



The standard MODIS AOT



GOCART AOT

Acquiring Remote Sensing Environmental Health Data is Not Unique to NASA

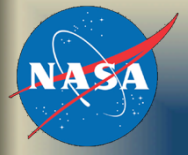
A good read:

Using Earth Observation Data to Improve Health in the United States
Accomplishments and Future Challenges*

Identifies the following U.S. government Earth observation and public health organizations providing/using remote sensing data to address health issues:

- **National Aeronautics and Space Administration**
- **National Oceanic and Atmospheric Administration**
- **United States Geological Survey**
- **Centers for Disease Control and Prevention**
- **Environmental Protection Agency**
- **National Institutes of Health**
- **Department of Defense/Armed Forces Health Surveillance Center**
- **U.S. Agency for International Development**

** A report of the Center for Strategic & International Studies (CSIS) technology and public policy program,* Lyn D. Wigbels, September 2011
(http://csis.org/files/publication/110927_Wigbels_UsingEarthObserHealth_WEB.pdf)



These tools are extremely useful for locating and accessing data…

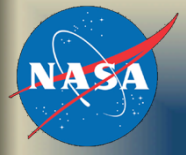
But really, we are just at the beginning stages of realizing the large amounts of heterogeneous data **available to us**, and figuring out how to glean out hidden information to enhance our subject knowledge

In addition, the CSIS Report provides other insights…

Good communication and understanding are needed between the data producers and health and environment researchers:

- Many Earth science initiatives do not consider how research can be applied to health community problems.
- There is also little feedback from the public health community on what it needs from Earth observation providers.
- Some, but not all, in the public health community use remote sensing data, resulting in communication gaps.

Thus, we need to develop expertise in both, utilizing remote sensing data, and their application to public health research, in order to cross analyze large amounts of remote sensing and related heterogeneous data, to glean out hidden information



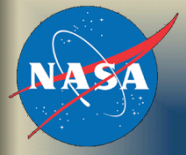
Analytics vs Analysis

Analytics - The process of examining large amounts of data of a variety of types … to uncover hidden patterns, unknown correlations and other useful information. (Source: http://searchbusinessanalytics.techtarget.com/definition/big-data-analytics)

Thus, analytics is not so much concerned with individual analyses or analysis steps, but with the entire methodology (Source: http://en.wikipedia.org/wiki/Analytics)

Data Scientist

who analyzes huge volumes of data as well as other data sources that may be left untapped by conventional programs. (Source: http://searchbusinessanalytics.techtarget.com/definition/big-data-analytics)



What Technology Investments Can Enable Analytics Capabilities?

http://www.atkearney.com/strategic-it/ideas-insights/article/-/asset_publisher/LCcgOeS4t85g/content/big-data-and-the-creative-destruction-of-today-s-business-models/10192

- **Vertical applications** or product suites (Hadoop, for example) provide data and processing while incorporating reporting and visualization tools.
- **Decision support** provides traditional dashboards and systems that are fortified by big data applications and visualization tools.
- **Reporting and visualization tools** represent the big data results in an easy-to-understand manner.
- **Analytics services** are the storage, processing, and applications that reinforce big data-enabled solutions, such as predictive modeling, forecasting, and simulation.
- **Parallel distributed processing and storage** enable massively parallel processing (MPP) and in-memory analytics for more-structured data.
- **Loosely structured storage** captures and stores less-structured data.
- **Highly structured storage** captures and stores traditional databases, including their parallel and distributed manifestations.

Exemplary Analytics Techniques for Measuring Environmental Factors Useful in Public Health Research

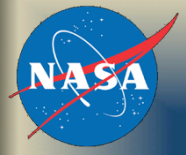
- Association rule learning
- Classification
- Cluster analysis
- Crowdsourcing
- Data fusion and data integration
- Data mining
- Ensemble learning
- Genetic algorithms
- Machine learning
- Neural networks
- Network analysis
- Optimization
- Pattern recognition
- Network analysis
- Optimization
- Pattern recognition
- Predictive modeling
- Regression
- Sentiment analysis
- Signal processing
- Spatial analysis
- Supervised learning
- Simulation
- Time series analysis
- Unsupervised learning
- Visualization

…and a few familiar technologies: Cloud computing, Distributed system. Hadoop, Mashup, R

Source: 'Big data: The next frontier for innovation, competition, and productivity', McKinsey Global Institute (http://www.mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation)

Conclusions

- Satellite remote sensing data and services hold great promise to alleviate limitations of monitor-based environmental data collecting
- Obstacles such as uncertainties in methodology, data accessibility (for epidemiologists) and data quality are being addressed
- Numerous community efforts are addressing these issues on local and global levels
- Sharing and analyzing data in new ways is increasing the depth of our understanding of public health challenges (http://asthmapolis.com/2013/02/leveraging-data-for-public-health/)



Thank You

Backup…

Exemplary NASA Vector Borne Disease Research Using Remote Sensing Data

- *Jorge Pinzon*/Science System and Applications, Inc (SSAI), Predicting Zoonotic Hemorrhagic Fever Events in Sub-Saharan Africa using NASA Earth Science Data for DoD - Global Emerging Infections Surveillance and Response System
- *Benjamin Zaitchik*/Johns Hopkins University, Development of a Detection and Early Warning System for Malaria Risk in the Amazon
- *Daniel Irwin and John Kessler*/NASA Marshal Space Flight Center, SERVIR Africa
- *Sue Estes*/NASA/USRA, Investigating the Potential Range Expansion of the Vector Mosquito Aedes aegypti in Mexico with NASA Earth Science Remote Sensing Results.
- *Michael Wimberly*/South Dakota State University, Enhanced Forecasting of Mosquito-Borne Disease Outbreaks Using AMSR-E
- *Richard Kiang*/NASA Goddard Space Flight Center, Modeling Global Influenza Risks using NASA Data
- *Richard Kiang*/NASA Goddard Space Flight Center, Avian Influenza Risk Prediction in Southeast Asia and Early Warning of Pandemic Influenza
- *Xiangming Xiao*/University of Oklahoma, Integrating Earth observations and satellite telemetry of wild birds for decision support system of avian influenza
- *Katia Charland*/Children's Hospital Boston, Application of NASA Data to Develop an Influenza Forecasting System

Exemplary NASA Water Borne Disease Research Using Remote Sensing Data

- *Richard Stumpf and Timothy Wynne*/National Oceanic Atmospheric Administration Ocean Service, Monitoring and Forecasting Cyanobacterial Blooms for Public Health Protection and Response
- *Zhiqiang Deng*/Louisiana State University, Feasibility Study of Satellite-Assisted Detection and Forecasting of Oyster Norovirus Outbreak
- *Charles Tilburg*/University of New England, Influence of Land-Use and Precipitation on Regional Hydrology and Public Health

Exemplary NASA Air Pollution Relate Disease Research Using Remote Sensing Data

- *Yang Liu*/Harvard School of Public Health, Enhancing Environmental Public Health Tracking with Satellite-Driven Particle Exposure Modeling and Epidemiology
- *Jeffrey Luvall*/NASA Marshall Space Flight Center, Integration of Airborne Dust Prediction Systems and Vegetation Phenology to Track Pollen for Asthma Alerts in Public Health Decision Support Systems
- *Leslie McClure*/University of Alabama at Birmingham, Linking NASA Environmental Data with a National Public Health Cohort Study to Enhance Public Health Decision Making
- *Stanley Morain*/University of New Mexico, Adding NASA Earth Science Results to EPHTN via the NM/EPHT System
- *Amy Huff*/Battelle Memorial Institute, Using NASA Satellite Aerosol Optical Depth Data to Create Representative PM2.5 Fields for Use in Human Health and Epidemiology Studies in Support of State and National Environmental Public Health Tracking Programs

GES DISC Data Useful for Public Health Research Activities

Measurement	GES DISC Dataset*	Spatial Resolution	Temporal Coverage	Current Usage/ Potential Usage	Health Relevance
Precipitation	TRMM	1/4 deg - 1 deg	1997 - present	See Pinzon, Zaitchik, Kiang, Tilburg	Vector Borne Diseases; Water Borne Diseases
	GPM	1/4 deg X 1/4 deg	Starting 2013		
	GLDAS	1/4 deg X 1/4 deg; 1 deg X 1 deg	1979 - present	GLDAS, MERRA NLDAS are of comparable resolution to TRMM	
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America		
	MERRA	1.25 deg X 1.25 deg	1979 - present		
Water Runoff	*Non GES DISC product often used*			USGS derived products (Tilburg)	Vector Borne Diseases; Water Borne Diseases
	GLDAS	1/4 deg X 1/4 deg; 1 deg X 1 deg	1979 - present	GLDAS, MERRA NLDAS provide assimilated alternatives	
	MERRA	2/3 deg X 1/2 deg	1979 - present		
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America		
Vegetation Index	*Non GES DISC product often used*			MODIS derived data has set the standard (Ponzon, Estes, Kiang)	Vector Borne Diseases; Air Pollution
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America	NLDAS, MERRA provide alternatives with higher temporal resolution	
	MERRA	2/3 deg X 1/2 deg	1979 - present		

Soil Moisture	NEESPI – AMSR-E	1 deg X 1 deg	2002 - present	See Zaitchik, Estes, Wimberly (uses AMSR-E)	Vector Borne Diseases
	LPRM using AMSR-E	25 km X 25 km	2002 - present	LPRM provides higher spatial resolution based on AMSR-E	
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America	GLDAS, MERRA NLDAS provide higher temporal resolution	
	GLDAS	1/4 deg X 1/4 deg; 1 deg X 1 deg	1979 - present		
	MERRA	2/3 deg X 1/2 deg	1979 - present		
Surface Air Temperature	*Non*	*GES DISC product*	*often used*	MODIS generated data has set the standard (Pinzon, Zaitchik, Estes, Kiang, Stumpf, McClure, Ceccato)	Vector Borne Diseases; Air Pollution
	AIRS	1 deg X 1 deg	2002 - present	See reference: Wallace	
	TOVS	1 deg X 1 deg	1984 - 1995	TOVS: Historical data	
	MERRA	2/3 deg X 1/2 deg; 1.25 deg X 1.25 deg	1979 - present	GLDAS, MERRA NLDAS provide higher temporal resolution data	
	GLDAS	1/4 deg X 1/4 deg; 1 deg X 1 deg	1979 - present		
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America		

Aerosols	*Non*	*GES DISC product*	*often used*	MODIS generated data (Liu, Morain)	Air Pollution
	OMI	24 km X 13 km; 1/4 deg X 1/4 deg	2004 - present	OMI is useful for low resolution applications	
	TOMS	1.25 deg X 1.0 deg	1978 - 2005	TOMS: Historical data	
	MERRA	2/3 deg X 1/2 deg; 1.25 deg X 2.0 deg	1979 - present	MERRA, GOCART provide higher temporal resolution	
	GOCART	2.5 deg X 2.0 deg	2000 - 2007		
Wind	Non	GES DISC product	often used	Local records used (Kiang)	Vector Borne Diseases; Air Pollution
	MERRA	2/3 deg X 1/2 deg; 1.25 deg X 1.25 deg	1979 - present	See reference: Lau	
	GLDAS	1/4 deg X 1/4 deg; 1 deg X 1 deg	1979 - present	GLDAS, NLDAS, GSSTF2b provide assimilated alternatives	
	NLDAS	1/8 deg X 1/8 deg	1979 - present North America		
	GSSTF2b	1 deg X 1 deg	1988 - 2008		
Solar Irradiance	*Non*	*GES DISC products*	*often used*	Local records used (Kiang); TOPS (Charland)	Air Pollution; Vector Borne Diseases
	SORCE		2003 - present	SORCE, OMI provide alternative global measurements	
	OMI	1/4 deg X 1/4 deg; 1 deg X 1 deg	2004 - present		

* Acronyms:
  - AIRS - The Atmospheric Infrared Sounder
  - AMSR-E - Advanced Microwave Scanning Radiometer-Earth Observing System
  - GLDAS - Global Land Data Assimilation System
  - GOCART - The Goddard Chemistry Aerosol Radiation and Transport model
  - GPM - The Global Precipitation Measurement
  - GSSTF2b - Goddard Satellite-based Surface Turbulent Fluxes Version-2b (Produced through a NASA MEaSURES funded project led by Dr. Chung-Lin Shie, UMBC/GEST, NASA/GSFC)
  - LPRM - Land Parameter Retrieval Model
  - MERRA - Modern Era Retrospective-Analysis for Research and Applications
  - MISR – Multi-angle Imaging Specroradiometer
  - MLS - Microwave Limb Sounder
  - MODIS - Moderate Resolution Imaging Spectroradiometer
  - NEESPI - Northern Eurasia Earth Science Partnership Initiative (Provided through a NASA MEaSURES funded project led by Dr. Gregory Leptoukh, NASA/GSFC)
  - NLDAS - North American Land Data Assimilation System
  - OMI - Ozone Monitoring Instrument
  - SORCE- The Solar Radiation and Climate Experiment
  - TES – Troposheric Emission Spectrometer
  - TOMS - Total Ozone Mapping Spectrometer
  - TOPS - Terrestrial Observation and Prediction System
  - TOVS - TIROS Operational Vertical Sounder
  - TRMM - Tropical Rainfall Measuring Mission