Environmental Public Health Applications Using Remotely Sensed Data

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ONE step...BEYOND Workshop

European Space Agency/European Space Research Institute

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NASA/MSFC Environmental Public Health Team Members

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NSSTC at NASA/MSFC

❖ **The Focus of NASA Public Health Program:**

The Public Health application area focuses on Earth science applications regarding ***environmental health issues, infectious disease, and emergency preparedness and response***. The application explores issues of toxic and pathogenic exposure, as well as natural and man-made hazards and their effects, for risk characterization/mitigation and improvements to health and safety.

❖ **MSFC Previous and Current Projects:**

- Health and Environment Linked for Information Exchange in Atlanta (HELIX-Atlanta) (Partners: CDC, Kaiser Permanente)
- Linking NASA Environmental Data with a National Public Health Cohort Study (REGARDs) to Enhance Public Health Decision Making (University of Alabama at Birmingham; CDC)
- Integration of NASA research results to enhance a decision support tool for asthma surveillances, prediction and intervention (Partners: University of Mississippi Medical Center, CDC)
- Enhancing Environmental Public Health Tracking (EPHT) with Satellite-Driven Particle Exposure Modeling and Epidemiology (Partners: Emory University; CDC)
- Using NASA Data and Models to Improve Heat Watch Warning Systems for Decision Support (Partners: Indiana University - Purdue University Indianapolis; CDC)
- Integration of Airborne Dust Prediction Systems and Vegetation Phenology to Track Pollen for Asthma Alerts in Public Health Decision Support Systems (Partners: University of Arizona; University of New Mexico; CDC)
- Development and Implementation of a Climate Change Module for EPHT Utilizing Remote Sensing Data (Partners: CDC)
- Asthma and Air Quality in the Presence of Fires: A Foundation for Public Health Policy in Florida (Partners: University of Florida, CDC)
- Using Remote Sensing and Environmental Data to Quantify Social Vulnerabilities to Heat Stress and Strengthen Environmental Public Health Tracking and Heat Mitigation Efforts (NY State Health Dept., NY City Health Dept., FL State Health Dept., CDC)
- Development of National Future Extreme Heat Scenarios to Enable the Assessment of Climate Impacts on Public Health (Partners: CDC)
- Environmental Context of Health Disparities (Partners: Meharry Medical College, University of Tennessee-Knoxville, and Tulane)
- UAB Laboratory for Global Health Observation (LGHO) and DEVELOP Projects (ex. Predictive Risk Modeling of Vector-Borne Infectious Diseases such as Dengue Fever, West Nile Virus and Lyme Disease by means of NASA Earth Observation Systems)

NASA Applied Sciences Program

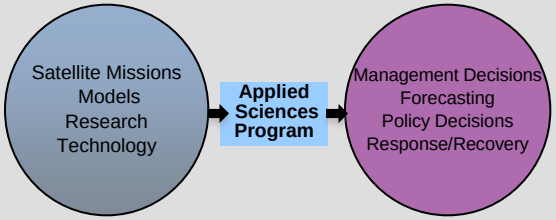
Purpose

Lead efforts in building knowledge and developing abilities to effectively apply Earth observations;

Develop applications knowledge for applying Earth science to serve society;

Assist in transitioning applied knowledge to organizations that can directly apply it to solve societal issues.

NASA Applied Sciences Program Architecture



Emphasis in 4 Applications Areas


Water Resources

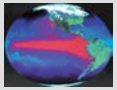

Disasters


Ecological Forecasting


Health & Air Quality

Opportunities to Expand and Crosscut


Agriculture


Climate


Weather

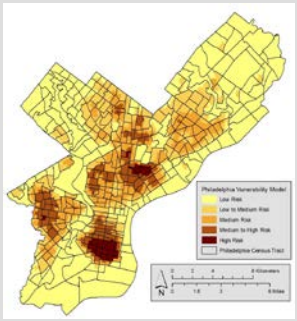

Energy


Oceans

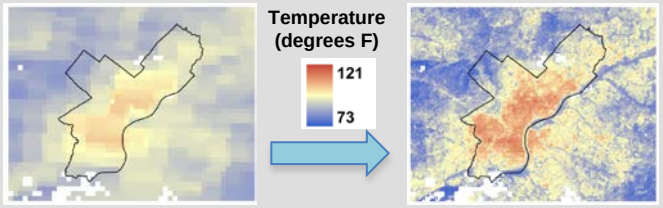
Public Health Applications: Urban Heat Vulnerability

Heat within a city is not uniform. In fact, large temperature differences exist due to the location of parks, urban forests, water bodies and the highly developed urban core. Fine-scale mapping of temperature variations is proving useful for assessing areas where residents are most vulnerable to the effects of heat.

MSFC scientists have worked with Indiana University and several cities health departments to combine fine-scale satellite data with socio-economic data to map heat vulnerability across cities.



Heat vulnerability map for Philadelphia, PA based on surface temperatures and socio-economic data.

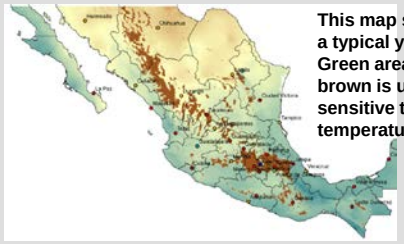


MSFC scientists have developed a method for extracting finer-scale land surface temperature information from NASA satellite data. Left panel: MODIS temperature data. Right panel: result of 'sharpening' the image, resulting in the ability to differentiate areas of relative coolness and heat.

Relationships Between the Environment and Dengue Fever in Mexico

MSFC scientists worked with CDC and the University of Veracruz, Mexico to develop a habitat suitability model for the *Aedes aegypti* mosquito, the primary transmitter of Dengue Fever in Mexico. Using inputs such as winter temperatures, precipitation and terrain height (right), the model indicates the likelihood of *Aedes aegypti*, and therefore Dengue Fever, across Mexico.


Mean winter minimum temperature

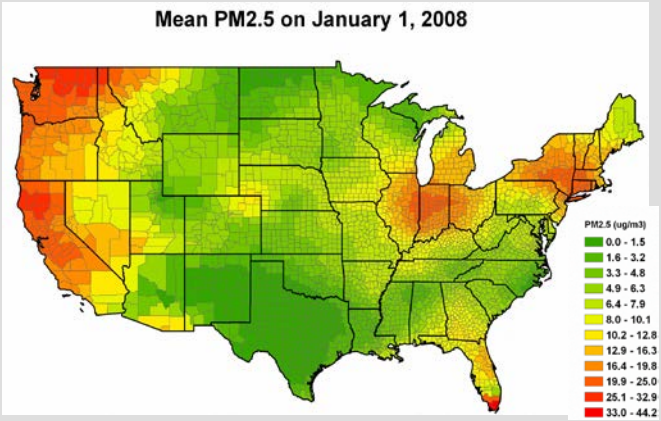


This map shows habitat suitability for a typical year in the current climate. Green areas are most suitable, while brown is unsuitable. Habitat is very sensitive to elevation and temperature.

NASA Satellite Data and Models Enhance Air Pollution Monitoring for Public Health

Air pollution has very serious public health impacts in the U.S. One type of pollution – fine particulate matter or $PM_{2.5}$ – has particularly adverse effects on respiratory and cardiovascular diseases and conditions. MSFC scientists use a novel method to combine data from NASA satellites and ground monitors to provide daily estimates of $PM_{2.5}$ across the U.S.

This map shows daily averages of $PM_{2.5}$ at the county level for January 1, 2008. Note the very high levels in the Midwest and the West Coast.



Linking NASA Environmental Data with a National Public Health Cohort Study and a CDC on-line System to Enhance Public Health Decision Making

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National Center for Public Health Informatics, Centers for Disease Control and Prevention, Atlanta, Georgia

UAB THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

NSSTC

NASA

USRA STI Science and Technology Institute

CDC CENTERS FOR DISEASE CONTROL AND PREVENTION

Goals and Objectives

- **This project has dual goals in decision-making activities**
  - Providing information to decision makers about associations between environmental exposures and health conditions in a large national cohort study
  - Enriching the CDC Wide-ranging Online Data for Epidemiologic Research (WONDER) system by integrating environmental exposure data
- **Develop daily high-quality spatial data sets of environmental variables for the conterminous U.S. for the years 2003-2008 utilizing NASA data (Objective 1)**
  - Fine Particulates ($PM_{2.5}$) (NASA MODIS and EPA AQS)
  - Land Surface Temperature (NASA MODIS)
  - Solar Insolation and Heat-related Products (Reanalysis Data)
- **Link these environmental variables with public health data from a national cohort study and examine environmental health relationships (Objective 2)**
  - Cognitive Function
  - Hypertension
- **Make the environmental datasets available to public health professionals, researchers and the general public via the CDC WONDER system (Objective 3)**

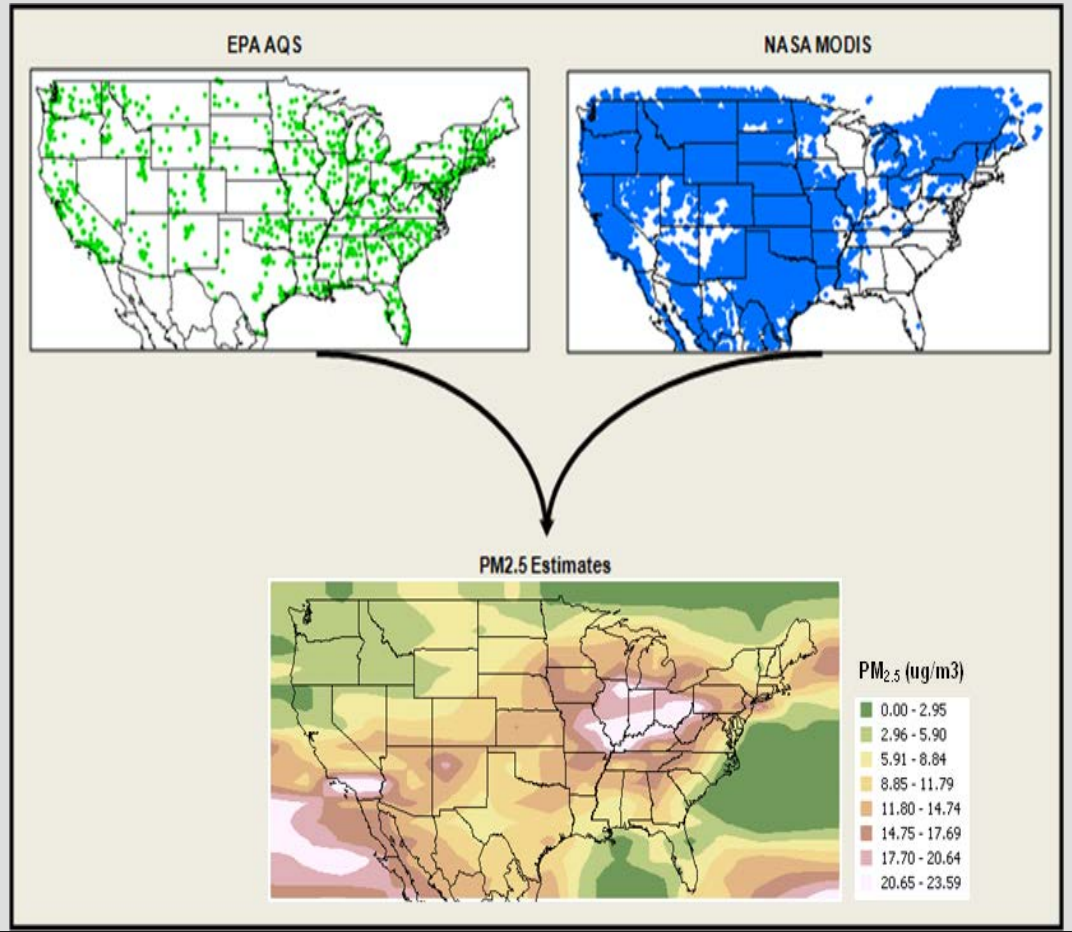
Environmental Health Implications

- **Fine Particulates (PM2.5)**
  - Human observation studies show that exposure to general pollution containing PM2.5 could cause inflammation, degradation, and oxidation in the brain when inhaled and could lead to altered regulation of biomarkers involved in cognitive function
  - Possible risk factor for cardiovascular and respiratory diseases
- **Solar Insolation**
  - Some research suggests that a relationship between sunlight exposure and cognition exists by affecting brain blood flow
- **Heat Exposure**
  - Some research suggests that a relationship between heat exposure and hypertension exists by affecting stress level

National Environmental Datasets (Objective 1)

Fine Particulate Matter ($PM_{2.5}$)

- Estimated ground-level $PM_{2.5}$ from MODIS AOD using published regression equations per EPA region per season
- Combined with EPA $PM_{2.5}$ data from the AQS for 2003-2008
- Modified and ran MSFC Surfacing Algorithm (Al-Hamdan et al., *JAWMA*, 2009; *Geocarto Int.,* 2014) to produce continuous spatial surfaces of daily $PM_{2.5}$ for the contiguous US for 2003-2008
- Use of MODIS $PM_{2.5}$ estimates together with ground observations (AQS) reduces RMS errors by 40% compared to estimates based on AQS data alone

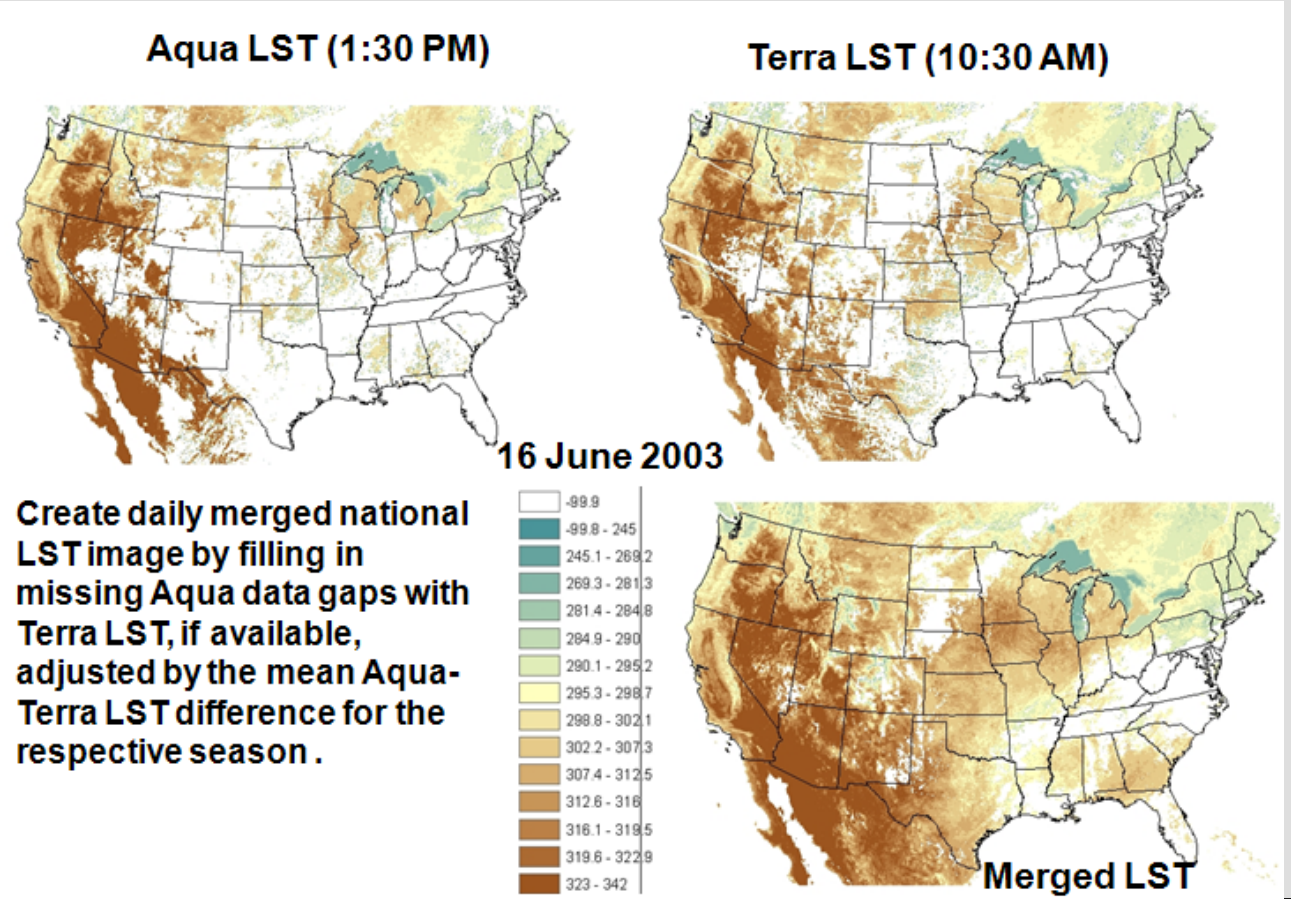


$PM_{2.5}$ on July 14, 2003

(10 km spatial resolution)

Land Surface Temperature (LST)

- Aqua and Terra daytime & nighttime data for 2003-2008 were processed
- Aqua-Terra differences were computed by season for 2003-2008
- Aqua data gaps were filled with Terra-adjusted LST (if available) by mean seasonal difference
- National merged Aqua-Terra daily LST dataset were generated for 2003-2008 for day & night (Crosson et al., *RSE*, 2012)
- Coverage improvement by 25% and 30% for daytime and nighttime overpasses, respectively

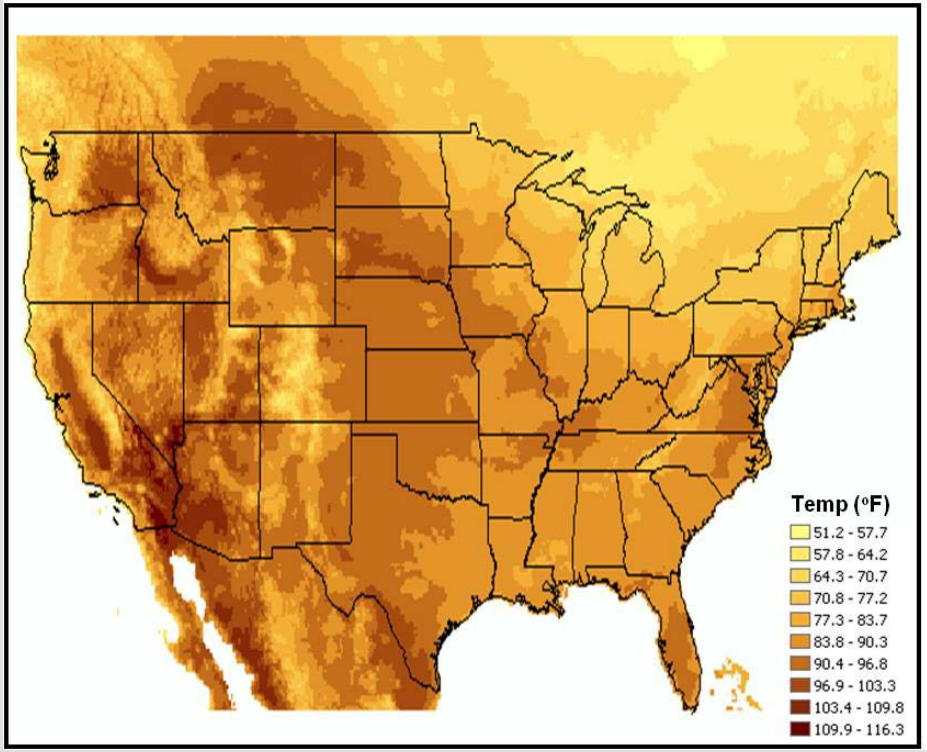


(1 km spatial resolution)

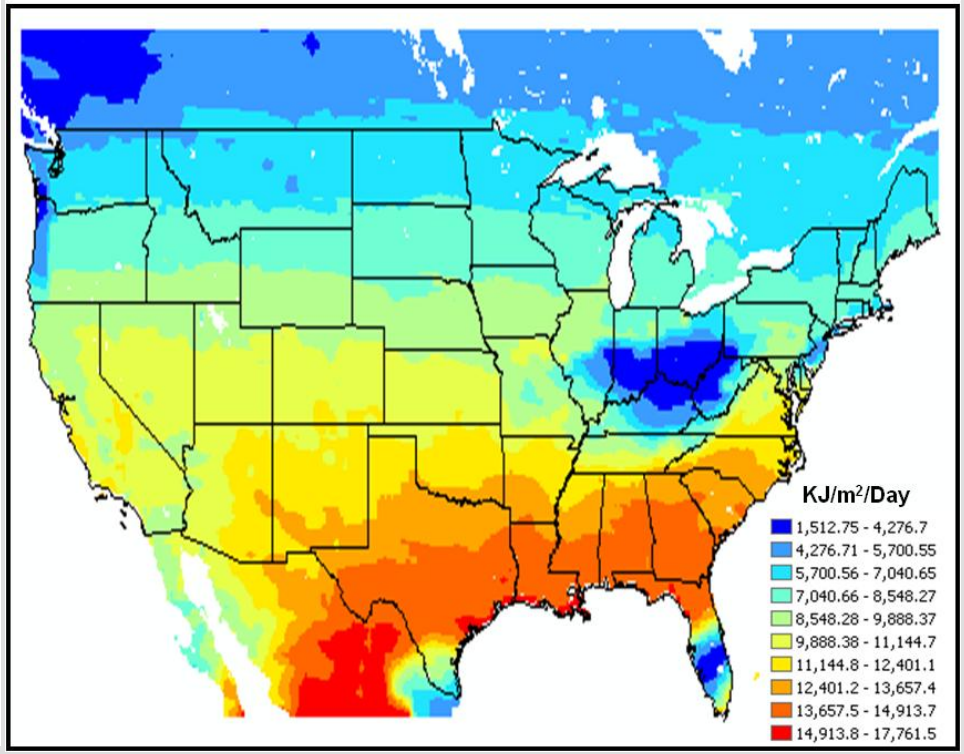
Heat and Solar Insolation

- NLDAS hourly meteorological data (air temperature, solar radiation, specific humidity, atmospheric pressure) for the 2003-2008 period were processed
- Daily statistics of Maximum Air Temperature, Minimum Air Temperature, Maximum Heat Index, and Total Solar Insolation were computed for 2003-2008

NLDAS Max Air Temperature on July 15, 2008



NLDAS Solar Insolation on January 1, 2008

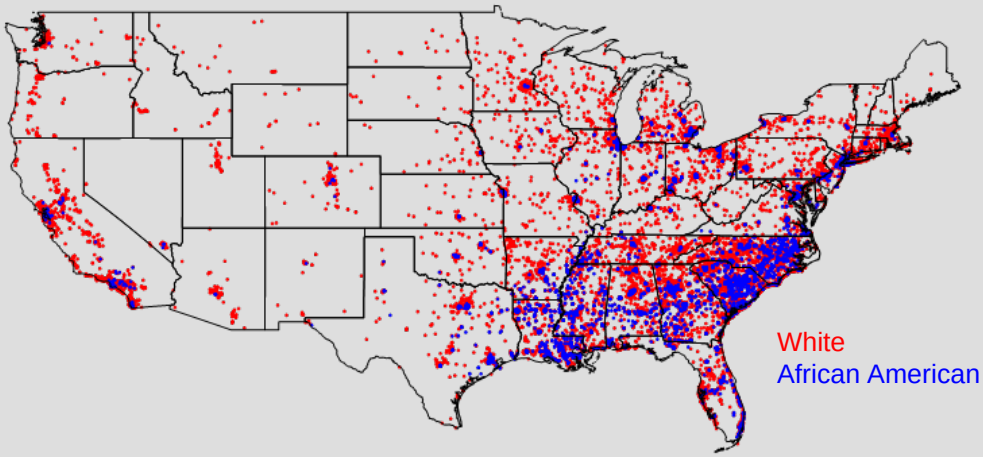


(~12 km spatial resolution)

Environmental Health Data Linkage (Objective 2)

REasons for Geographic And Racial Differences in Stroke (REGARDS) Study Population

- Longitudinal population-based cohort of over 30,000 volunteers age 45 and older
- Racial representation
  - 50% African American
  - 50% white
- Sex representation
  - 50% male
  - 50% female
- Geographic representation
  - 20% from the buckle of the stroke belt
  - 30% from the stroke belt
  - 50% from the rest of the contiguous US
- Successfully transferred from UAB to NASA/MSFC
  - BAA as per HIPPA Regulations
  - Data Encryption



Data Linkage for Biostatistical Analyses

- Link in a GIS the estimates of the $PM_{2.5}$, Solar Insolation, and Air Temperature with health data from all participants in the REGARDS study on the individual level at the geographic coordinates of their residences
- Sort the environmental data by participant ID, and merge in with the corresponding health data from the REGARDS database
- Determine whether exposures to these environmental risk factors are related to cognitive decline and other health outcomes such as hypertension, inflammation, and stroke

Participant ID	Lat	Lon	Day1 Solar Insolation ($KJ/m^2/Day$)	Day2 Solar Insolation ($KJ/m^2/Day$)	Day3 Solar Insolation ($KJ/m^2/Day$)	.....	Day365 Solar Insolation ($KJ/m^2/Day$)
1	99.045	-87.105	7950	8941	8945		7850
2	99.055	-89.036	7401	8501	8412		7501
3	99.065	-86.212	8001	7015	8251		8401
. . . . .							
30200	99.075	-87.855	15650	11402	15650		10750

Simulated example of the linked data set consisting of participant ID and the associated NLDAS solar insolation

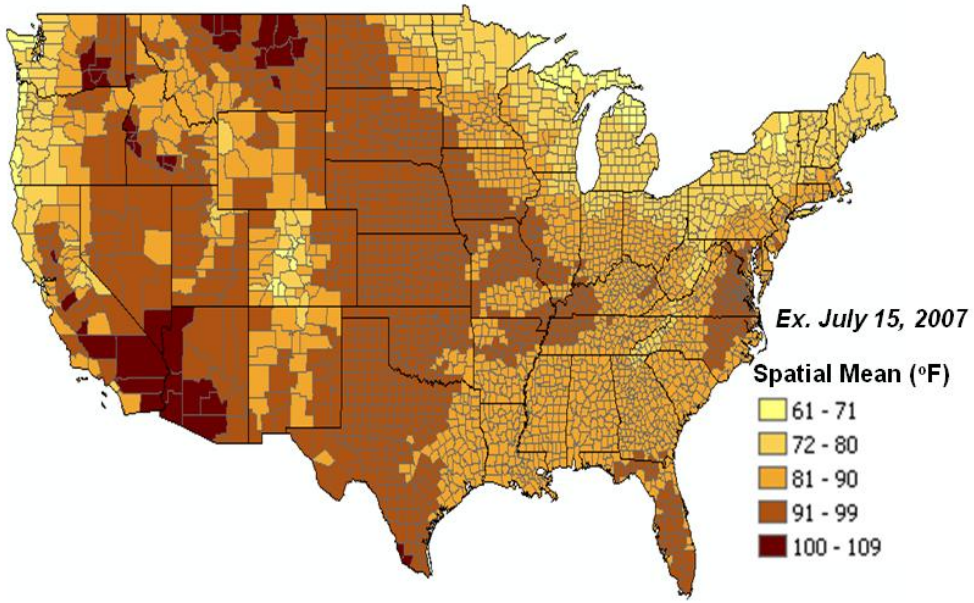
Data Dissemination via CDC WONDER (Objective 3)

Data Dissemination via CDC WONDER

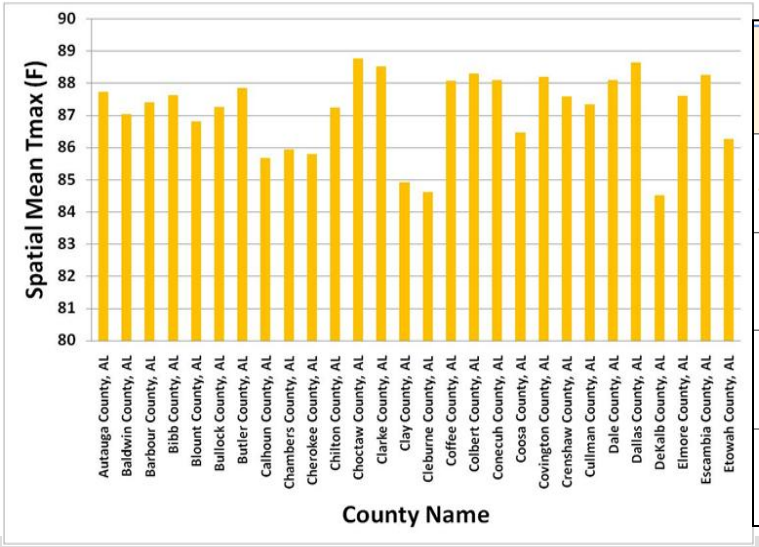
Tabular Grid-level Daily Data

Grid Cell ID	County, State	FIPS	Day1 Tmax (°F)	Day2 Tmax (°F)	Day3 Tmax (°F)	.....	Day365 Tmax (°F)
1	Kern, CA	06029	71	74	66		70
2	Kern, CA	06029	70	72	67		69
3	Kern, CA	06029	72	73	66		72
. . . . .							
103936	Aroostook, ME	23003	35	31	32		34

Examples of County-level Spatial and Temporal Statistics (Map and Chart) as provided by CDC-WONDER real-time data queries



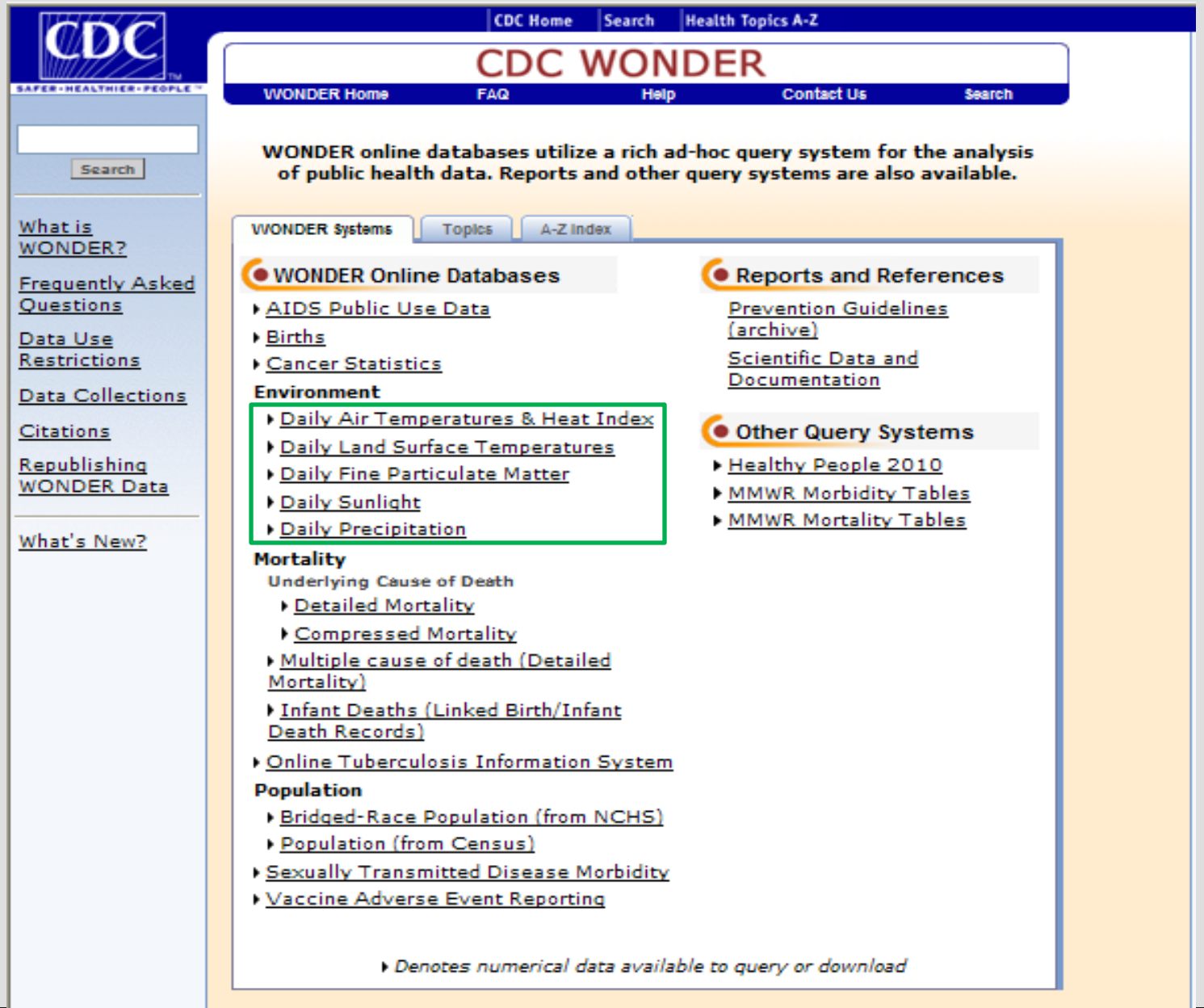
- Environmental exposure datasets will be made available to public health professionals, researchers and the general public via WONDER, where they can be aggregated to the county-level or higher as per users' need
- Users are able to spatially and temporally query datasets and create county- and higher-level maps and downloadable statistical tables and charts of data across the *contiguous* U.S.
- Enabling easy linkage of the environmental exposure data with other health data available via CDC WONDER



County	Avg Daily Max Air Temperature(F) # of Observations Range Standard Deviation
Autauga County, AL (01001)	87.85 11 (87.20 to 88.40) 0.43
Baldwin County, AL (01003)	85.82 26 (84.30 to 87.20) 0.61
Barbour County, AL (01005)	86.04 14 (85.50 to 86.60) 0.37
Bibb County, AL (01007)	86.92 9 (86.40 to 87.50) 0.31

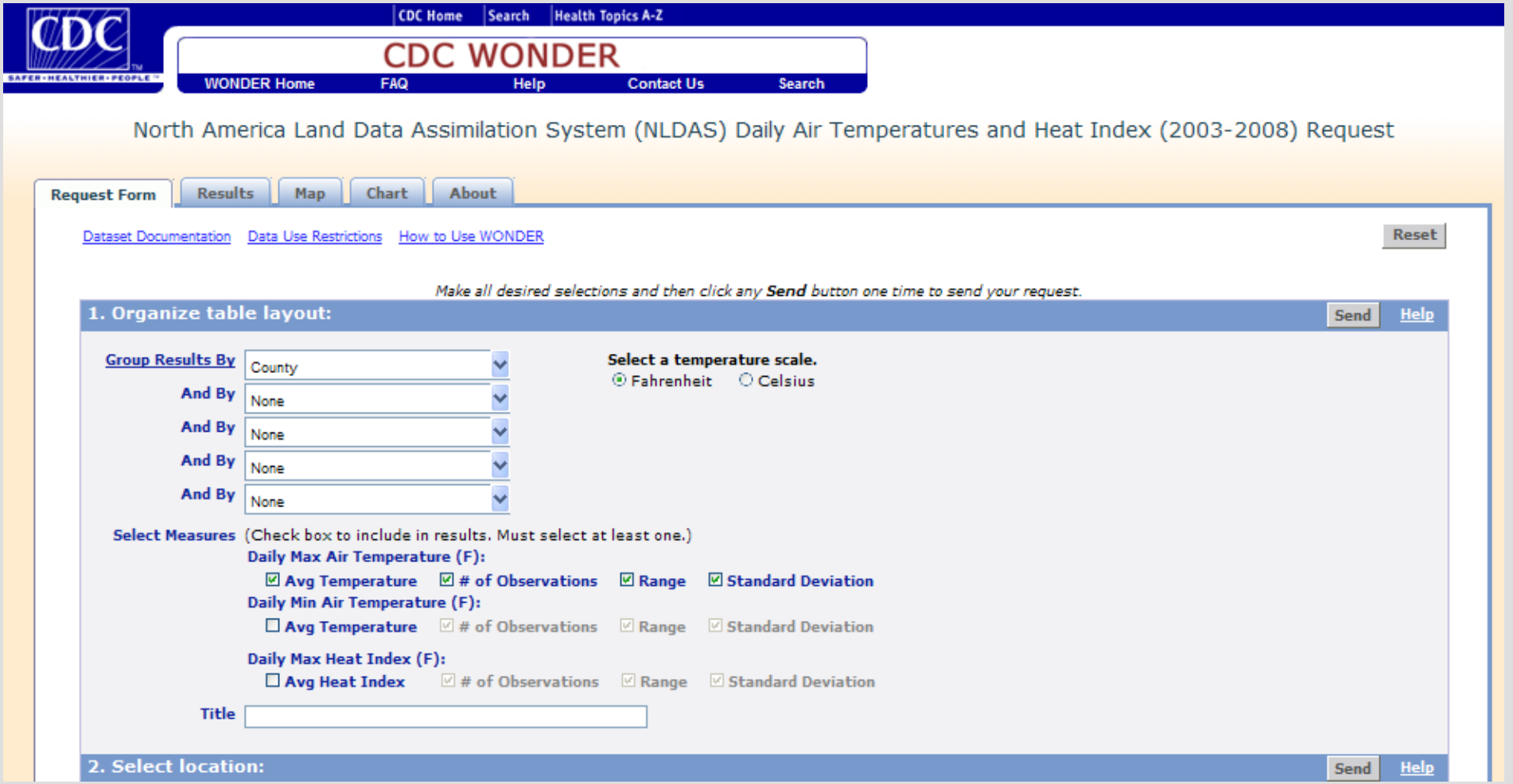
CDC WONDER Main Web Page

http://wonder.cdc.gov/



NLDAS-derived Heat-related Products on CDC WONDER

Now Available at http://wonder.cdc.gov/nasa-nldas.html



CDC WONDER Tabular Results

North America Land Data Assimilation System (NLDAS) Daily Air Temperatures and Heat Index (2003-2008) Results

Request Form | Results | Map | Chart | About

Dataset Documentation | Help for Results | Printing Tips | Help with Exports

Export | Reset

Quick Options | More Options

Top | Notes | Citation | Query Criteria

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Bibb County, AL (01007)	86.92 9 (86.40 to 87.50) 0.31
Blount County, AL (01009)	84.20 10 (83.60 to 84.90) 0.43
Bullock County, AL (01011)	86.57 10 (86.10 to 87.30) 0.44

CDC WONDER Map Results

North America Land Data Assimilation System (NLDAS) Daily Air Temperatures and Heat Index (2003-2008) Maps

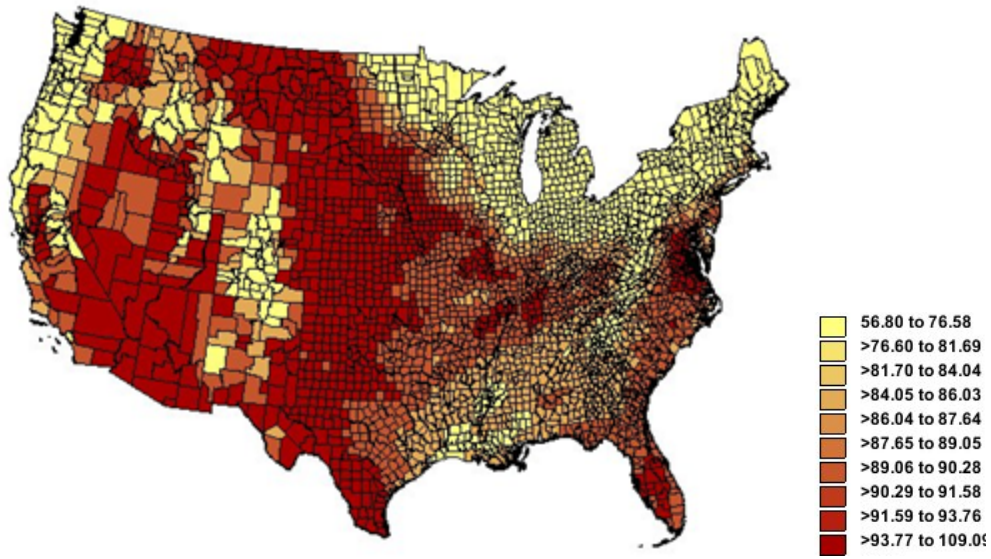
Request Form | Results | Map | Chart | About

Dataset Documentation | Help for Maps | Printing Tips

Reset

Top | Map Options | Notes | Citation | Query Criteria

Avg Daily Max Air Temperature(F) for The United States



CDC WONDER Chart Results

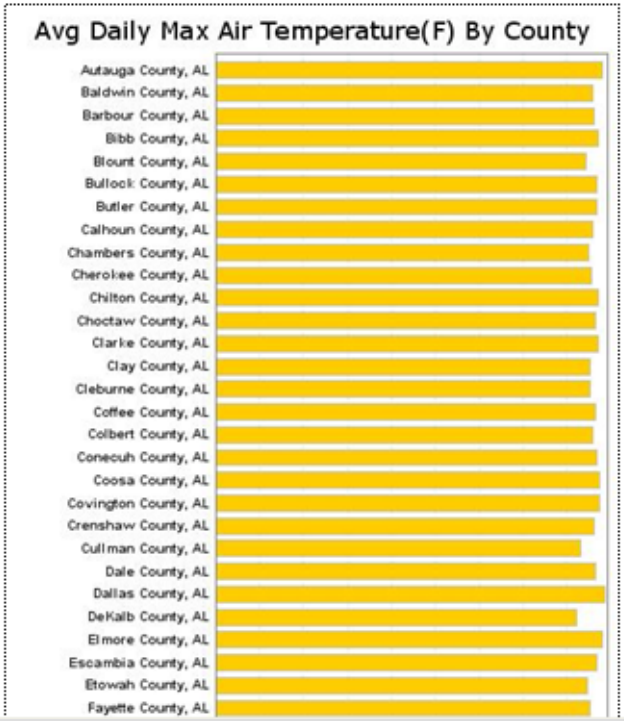
North America Land Data Assimilation System (NLDAS) Daily Air Temperatures and Heat Index (2003-2008) Charts

Request Form | Results | Map | Chart | About

Dataset Documentation | Help for Charts | Printing Tips

Reset

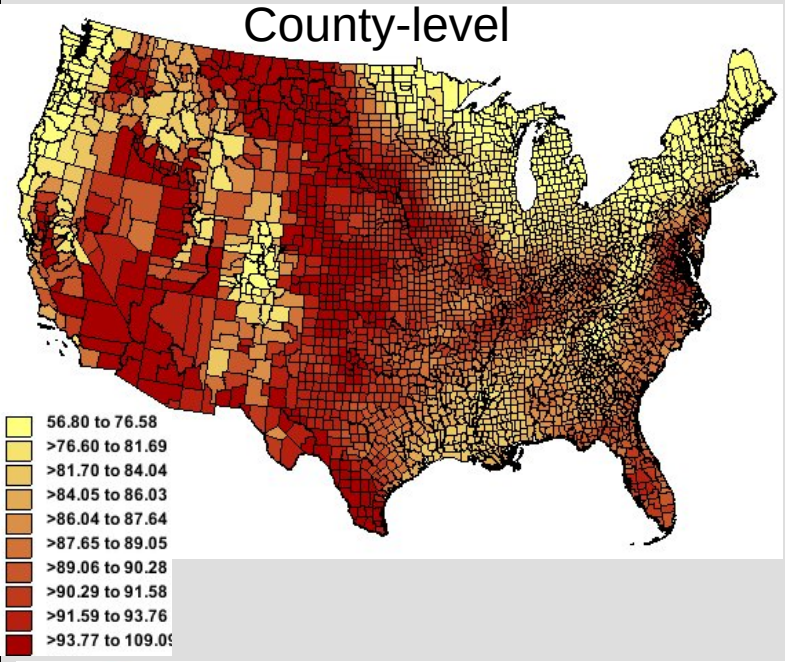
Top | Chart Options | Notes | Citation | Query Criteria



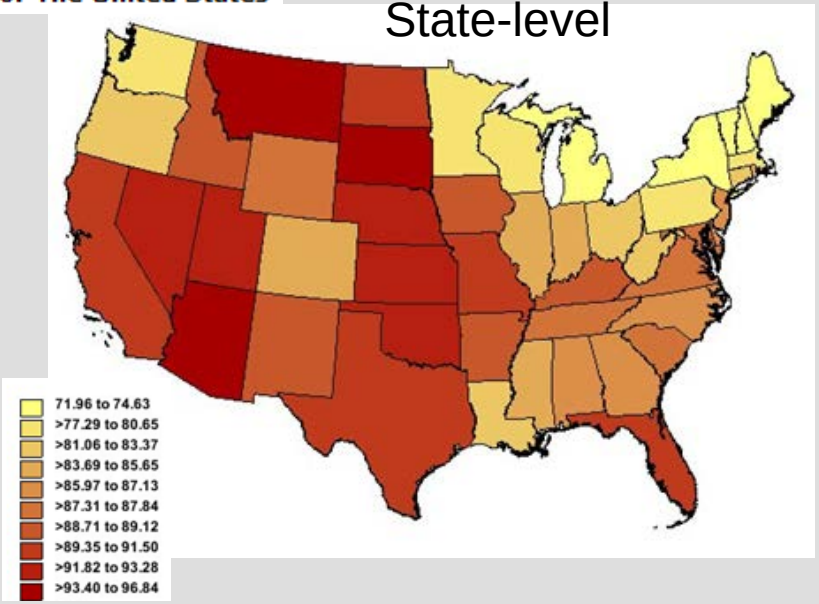
CDC WONDER Spatial Aggregation

Avg Daily Max Air Temperature(F) for The United States

County-level

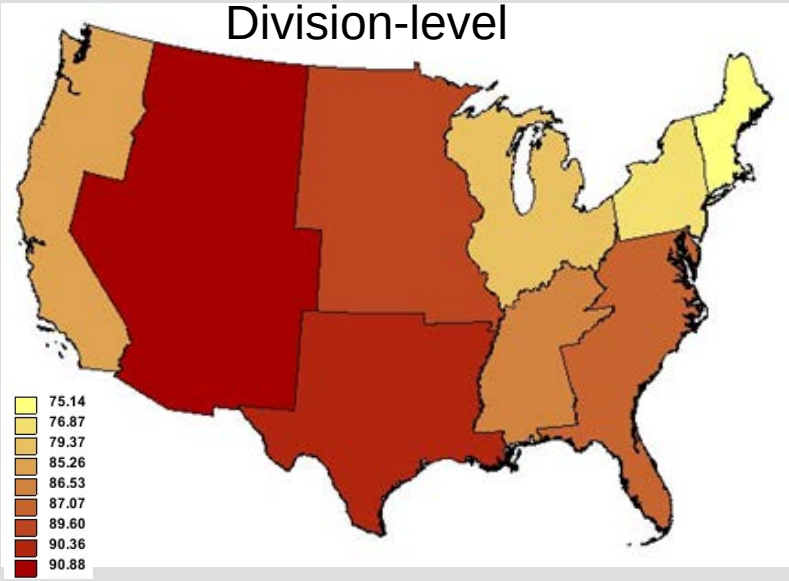


State-level

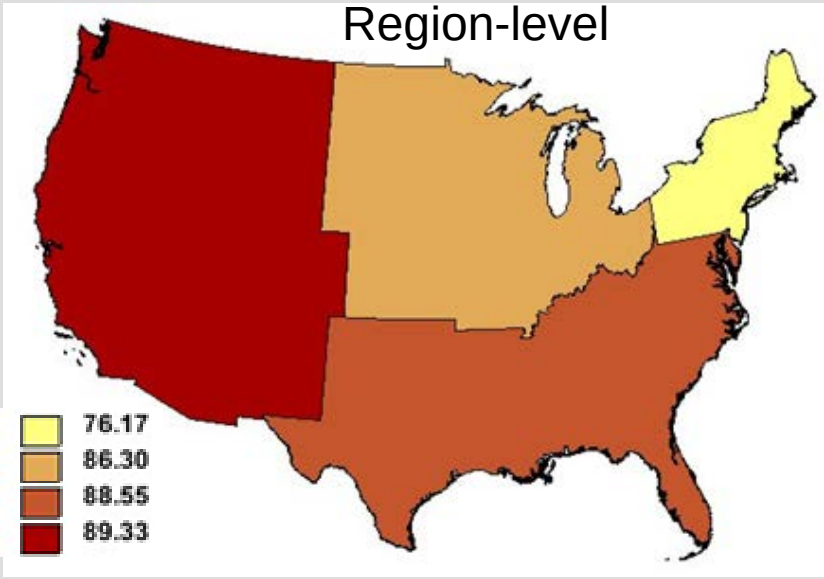


July 15, 2007

Division-level



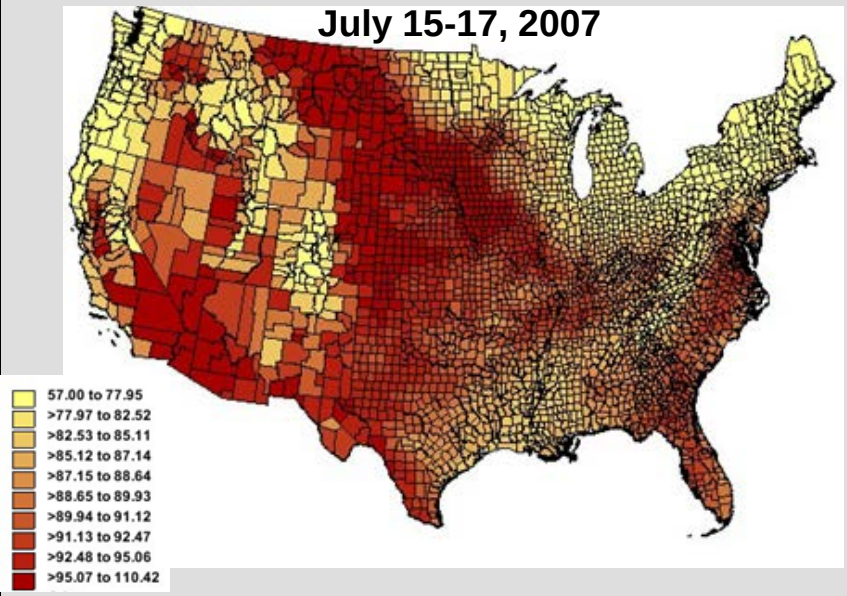
Region-level



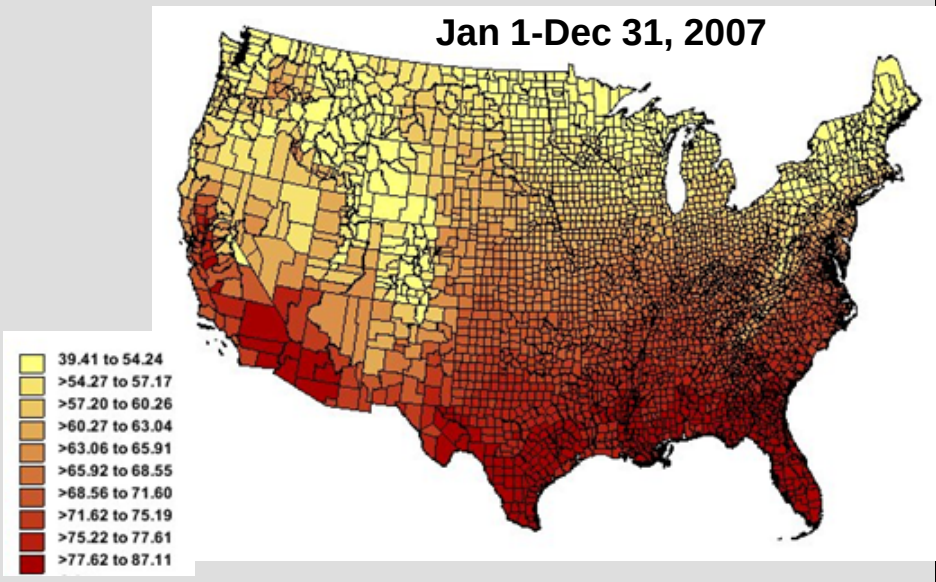
CDC WONDER Spatial/Temporal Aggregation

Avg Daily Max Air Temperature(F) for The United States

July 15-17, 2007



Jan 1-Dec 31, 2007



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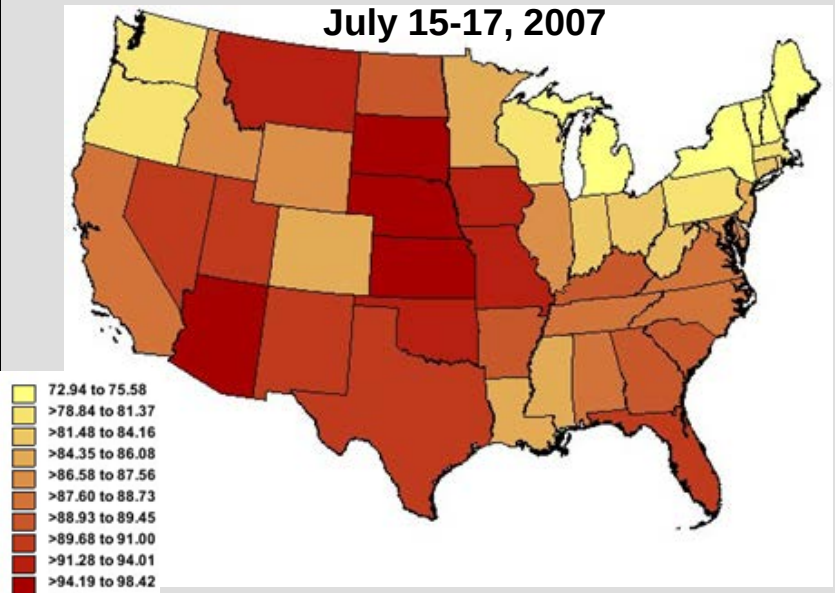

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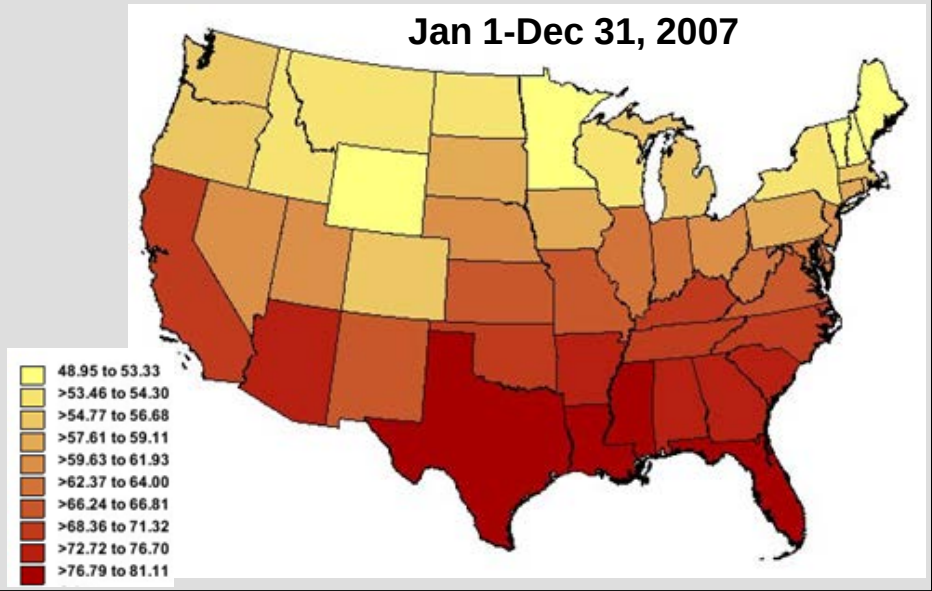

Summary

- Development of national daily products of $PM_{2.5}$,LST, maximum and minimum air temperature, maximum heat index, and solar insolation for 2003-2008
- Linkages of these data with public health data from the REGARDS national cohort study for environmental health correlation studies
- Dissemination of these environmental datasets to public health professionals, researchers and the general public via the CDC WONDER online system
  - Maximum and minimum air temperature and maximum heat index datasets, $PM_{2.5}$, LST, and solar insolation ***have been released at*** **http://wonder.cdc.gov/nasa-nldas.html**
- Providing a useful addition to CDC WONDER, allowing public health researchers and policy makers to better include environmental exposure data in the context of other health data available in CDC WONDER online system
- Substantially expanding public access to these NASA environmental datasets, making their use by a wide range of decision makers more feasible

Synergies

- Conversations, collaborations and partnerships help achieve more robust Decision Support Systems

- Downscaled LST and heat products
  - Public Health
  - Weather and Climate
  - Ecological Forecasting
  - Agricultural Applications

- Enhanced estimates of individual air pollution exposure
  - Air Quality Modeling
  - Public Health Applications

- Integration methods/procedures of Earth observations into Decision Support Systems and dissemination processes for societal benefits

Thanks!

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