Using NASA Remote Sensing Data for Multiscale Air Quality Models

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Zhining Tao, NASA/GSFC/USRA GESTAR, Jennifer Wei, NASA/GSFC/ADNET

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To discuss the availability and usefulness of NASA remote sensing data, and data discovery and access services, in support of air quality research and modeling for public health studies

To discuss data usability issues and potential solutions that enable the use of remote sensing data in air quality modeling and research
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
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 Air Quality Modeling and Related Disease Research
(not exhaustive)

– Aerosol
– Atmospheric Chemistry components
– Normalized Difference Vegetation Index (NDVI)
– Surface Temperature
– Solar Insolation
– Relative Humidity
Exemplary NASA Air Pollution Related 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
EOSDIS – Earth Observing System Data and Information System
DAAC – Distributed Active Archive Center
<table>
<thead>
<tr>
<th>NASA's Earth Science Data Centers</th>
<th>Discipline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Satellite Facility SAR Data Center (ASF SDC) website: <a href="http://www.asf.alaska.edu">http://www.asf.alaska.edu</a></td>
<td>• Synthetic Aperture Radar (SAR)</td>
</tr>
<tr>
<td></td>
<td>• Sea Ice</td>
</tr>
<tr>
<td></td>
<td>• Polar Processes</td>
</tr>
<tr>
<td></td>
<td>• Geophysics</td>
</tr>
<tr>
<td>Crustal Dynamics Data Information System (CDDIS) website: <a href="http://cddis.gsfc.nasa.gov/">http://cddis.gsfc.nasa.gov/</a></td>
<td>• Space Geodesy</td>
</tr>
<tr>
<td>Global Hydrology Resource Center (GHRC) website: <a href="http://ghrc.msfc.nasa.gov/">http://ghrc.msfc.nasa.gov/</a></td>
<td>• Hydrologic Cycle</td>
</tr>
<tr>
<td></td>
<td>• Severe Weather Interactions</td>
</tr>
<tr>
<td></td>
<td>• Lightning</td>
</tr>
<tr>
<td></td>
<td>• Atmospheric Convection</td>
</tr>
<tr>
<td>Goddard Earth Sciences Data and Information Services Center (GES DISC) website: <a href="http://disc.sci.gsfc.nasa.gov/">http://disc.sci.gsfc.nasa.gov/</a></td>
<td>• Global Precipitation</td>
</tr>
<tr>
<td></td>
<td>• Solar Irradiance</td>
</tr>
<tr>
<td></td>
<td>• Atmospheric Composition</td>
</tr>
<tr>
<td></td>
<td>• Atmospheric Dynamics</td>
</tr>
<tr>
<td></td>
<td>• Global Modeling</td>
</tr>
<tr>
<td>Land Processes (LP) DAAC website: <a href="https://lpdaac.usgs.gov/">https://lpdaac.usgs.gov/</a></td>
<td>• Surface Reflectance</td>
</tr>
<tr>
<td></td>
<td>• Land Cover</td>
</tr>
<tr>
<td></td>
<td>• Vegetation Indices</td>
</tr>
<tr>
<td>Level 1 Atmosphere Archive and Distribution System (MODAPS LAADS) website: <a href="http://ladsweb.nascom.nasa.gov/">http://ladsweb.nascom.nasa.gov/</a></td>
<td>• Radiance</td>
</tr>
<tr>
<td></td>
<td>• Atmosphere</td>
</tr>
<tr>
<td>Data Center Description</td>
<td>Data Categories</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------</td>
</tr>
</tbody>
</table>
| NASA Langley Research Center Atmospheric Science Data Center (LaRC ASDC) | • Radiation Budget  
• Clouds  
• Aerosols  
• Tropospheric Chemistry |
| website: http://eosweb.larc.nasa.gov/ | |
| National Snow and Ice Data Center (NSIDC) DAAC | • Snow  
• Ice  
• Cryosphere  
• Climate |
| website: http://nsidc.org/ | |
| Oak Ridge National Laboratory (ORNL) DAAC | • Biogeochemical Dynamics  
• Ecological Data  
• Environmental Processes |
| website: http://daac.ornl.gov/ | |
| Ocean Biology Processing Group (OBPG) | • Ocean Biology  
• Ocean Color  
• Biogeochemistry  
• Sea Surface Temperature |
| website: http://oceancolor.gsfc.nasa.gov/ | |
| Physical Oceanography (PO) DAAC | • Sea Surface Temperature  
• Ocean Winds  
• Circulation and Currents  
• Topography and Gravity |
| website: http://podaac.jpl.nasa.gov/ | |
| Socioeconomic Data and Applications Data Center (SEDAC) | • Human Interactions  
• Land Use  
• Environmental Sustainability  
• Geospatial Data  
• Multilateral Environmental Agreements |
| website: http://sedac.ciesin.columbia.edu/ | |
At the GES DISC ...

• The GES DISC specializes in serving and supporting atmospheric, hydrologic, and precipitation remote sensing, and remote sensing based assimilated data

• The GES DISC provides data access, discovery, visualization, retrieval, and analysis services to glean information from data

• Many GES DISC datasets are useful for air quality research, modeling, surveillance, and decision support systems

• The GES DISC is one of several NASA data archives containing data useful for air quality research
Relating Remote Sensing Data to Air Quality 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 Air Quality Research and Modeling

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

<table>
<thead>
<tr>
<th></th>
<th>Remote Sensing Data</th>
<th>Assimilated Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol</td>
<td>OMI, TOMS, HIRDLS</td>
<td>GOCART</td>
</tr>
<tr>
<td>Atmospheric Composition</td>
<td>AIRS, OMI, MLS, HIRDLS</td>
<td>MERRA</td>
</tr>
<tr>
<td>Vegetation Index</td>
<td></td>
<td>GLDAS, NLDAS, MERRA</td>
</tr>
<tr>
<td>Surface Air Temperature</td>
<td>AIRS, TOVS</td>
<td>GLDAS, NLDAS, MERRA</td>
</tr>
<tr>
<td>Insolation</td>
<td>SORCE</td>
<td></td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>AIRS, OMI, MLS, TOMS</td>
<td>MERRA, NLDAS</td>
</tr>
</tbody>
</table>
GES DISC Data Search and Access Services

Choose:
- Keyword search
- Time Location...
- Project...
- Science Area

Other 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/

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

Choose:
- Keyword search, Time Location...
- Project...
- Science Area

Other 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/
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*.

Giovanni Data Discovery and Exploration

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)

**Web-based Services:**
- 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**
- Exploration
- Initial Analysis
- Use the best data for the final analysis
- Derive conclusions
- Write the paper
- Submit the paper

**Giovanni Data Discovery and Exploration**

*disc.sci.gsfc.nasa.gov/giovanni*
Choose Giovanni instance...

select location, time, measurement, and visualization
PM2.5 data in Giovanni

PM2.5 (EPA → DataFed → Giovanni)

The standard MODIS AOT

Deep Blue MODIS Aerosol Optical Depth

GOCART AOT
Let’s talk about NASA Remote Sensing Data Usability for Air Quality Research and Modeling

- Remote Sensing provides a significant resource in producing Environmental Health measurements valuable in studying Public Health, and specifically Air Quality

- Please note: NASA data is typically created to address specific science research questions, but broader use in science applications research is proven and effective

- When utilizing remote sensing data for science applications research, a very good understanding of the data is needed, as well as how the data needs to be made usable (interpreted) for the specific application research

- Time investment is needed... but worth it.
Interpreting NASA Remote Sensing Data for Air Quality Research and Modeling

Popular Air Quality Models:

• Community Multiscale Air Quality (CMAQ) model, developed jointly by the US Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA)

• NASA-Unified Weather Research and Forecasting (NU-WRF) model. The NU-WRF modeling system has explicit land-cloud-aerosol-precipitation interactions
Interpreting NASA Remote Sensing Data for Air Quality Research and Modeling

Technical Challenges:

• Having specialized data access services for Level 2 data: Regional modelers prefer high resolution satellite data, while most data services provide merged Level 3 products

• Obtaining quality filtered data: Data quality filtering requires in-depth understanding of the specific data product, and knowledge of common practices by the air quality and remote sensing communities

• Acquiring proper horizontal projections: Regional modelers define their own horizontal gridding with regular spacing in distance, not necessarily following latitude/longitude lines

• Acquiring data in formats that are model ready: Data needs to be converted into formats compatible with air quality models
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

The NASA Remote Sensing Data Interpretation for Air Quality Research and Modeling includes the following features:

- **Spatial projection** - Cast high-resolution Level 2 satellite data directly into dynamically generated user-defined regional model gridding.
- **Format conversion** - Convert HDF or netCDF data into model specific formats.
- **Quality filtering** - Apply quality control flags to filter data.
- **Temporal resolution adjustment** – Adjust desired data to extract data coincident with model requirement.
- **Model ready output** – Provide modelers output files in specific format and projection directly usable in their model, consistent with other model inputs.
- **Domain Definition** – Allow modelers to dynamically define their own domain
- **Browse images** – Allow quick look at domain data results
- **Expandability** – Provide capabilities that can be reused/adapted for other models.
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

• Learn from previously developed interpreters: Wisconsin Horizontal Interpolation Program for Satellites (WHIPS) (Holloway, Univ. of Wisconsin)
• Utilize existing components for interpreting data:

<table>
<thead>
<tr>
<th>Component</th>
<th>Technical Approaches</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search NASA data</td>
<td>OpenSearch Services (OSS)</td>
<td>Use OpenSearch implementation to download distributed data location search result</td>
</tr>
<tr>
<td>Access and convert data to netCDF</td>
<td>OpenDAP</td>
<td>Coupled with OpenSearch, use the popular OpenDAP protocol for common data conversion.</td>
</tr>
<tr>
<td>Perform data quality screening</td>
<td>DQSS (Data Quality Screening Service); Alternative: NCO (netCDF Operators)</td>
<td>Use operational quality screening code to provide users with highly desired quality assessment.</td>
</tr>
<tr>
<td>Horizontal reprojection</td>
<td>IOAPI (Input/Output Application Programming Interface)</td>
<td>Open Source IOAPI provides reprojection routines tailored for AQ modeling</td>
</tr>
<tr>
<td>Convert data to IOAPI file format</td>
<td>IOAPI or NCO</td>
<td>IOAPI routines convert data into the specific output format, required for CMAQ modelers; Reusing Open Source NCO may require less overhead</td>
</tr>
<tr>
<td>Visualize data</td>
<td>PAVE (Package for Analysis and Visualization of Environmental data) and VERDI (Visual Environment for Rich Data Interpretation)</td>
<td>Used by AQ modelers, both PAVE and VERDI are flexible and distributable applications to visualize, specifically, environmental data.</td>
</tr>
</tbody>
</table>
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

Operational Architecture

Air Quality Model Users

User Request

On-line Access

Output to User

NASA Data Archive

Data Search (OpenSearch)

Data Access
Convert to netCDF (OPeNDAP)

QA Filtering (DQSS/NCO)

New Domain?

Yes

Domain Setup

No

TEMPORAL ADJUSTMENT & REPROJECTION (IOAPI)

Data Format Conversion (IOAPI/NCO)

Model-Ready Data

Data Domain Lineage

SATMAQ Output

Data Download

Visualization (PAVE/VERDI)
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

User interface to dynamically select data and domain:

1. Select Product:
   - OMI NO2
   - MODIS SO2
   - MODIS NDVI
   - AOD AIRS CO

2. Choose Domain:
   - EPA CONUS 36KM
   - LPRM Soil Moisture
   - TRMM Precipitation

3. Choose Data Format:
   - IOAPI
   - OAPI
   - netCDF
   - GRIB

4. Set Output Timestep:
   - Hourly

Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

Exemplary Remote Sensing Data Products:

<table>
<thead>
<tr>
<th>Instrument/Model Parameter</th>
<th>Spatial Coverage</th>
<th>Temporal Coverage</th>
<th>Expected End Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMI NO2 (Aura)</td>
<td>Global</td>
<td>2004-Present</td>
<td>NASA/NOAA</td>
</tr>
<tr>
<td>OMI SO2 (Aura)</td>
<td>Global</td>
<td>2004-Present</td>
<td>NOAA</td>
</tr>
<tr>
<td>MODIS Deep Blue AOD (Aqua)</td>
<td>Global</td>
<td>2002- Present</td>
<td>NASA/NOAA/CMAS</td>
</tr>
<tr>
<td>MODIS NDVI (Aqua)</td>
<td>Global</td>
<td>2002- Present</td>
<td>NOAA</td>
</tr>
<tr>
<td>LPRM Soil Moisture (AMSR-E)</td>
<td>Global</td>
<td>2002-Present</td>
<td>NOAA</td>
</tr>
<tr>
<td>AIRS Carbon Monoxide (Aqua)</td>
<td>Global</td>
<td>2002-Present</td>
<td>NASA/CMAS</td>
</tr>
<tr>
<td>MOPITT Carbon Monoxide (Terra)</td>
<td>Global</td>
<td>2000-Present</td>
<td>NASA/CMAS</td>
</tr>
<tr>
<td>TRMM Precipitation</td>
<td>Global</td>
<td>1998-Present</td>
<td>NASA/NOAA</td>
</tr>
</tbody>
</table>
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

Sample Results: Comparison of daily OMI tropo. NO2 vertical column density (VCD) before and after quality control: a) no quality control; b) VCD quality flag set to zero; c) additional filtering with cloud fraction < 50%; and d) after VCD, cloud fraction, and row anomaly (set to 0) filtering.
Interpretation of NASA Remote Sensing Data for Air Quality Research and Modeling: Proof of Concept

Sample Results: Spatial projection of OMI NO2 Level 2 swath (left) into a Lambert Conformal CMAQ domain (12km x 12km over the continental United States) (right)
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

• Interpreting remote sensing data to address the specific needs of end user communities, such as air quality modelers and health impact studies, can be done, and should be further pursued to facilitate data usability by these communities
Thank You

Backup...
Exemplary NASA Vector Borne Disease Research Using Remote Sensing Data

- **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
- **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
# GES DISC Data Useful for Public Health Research Activities

<table>
<thead>
<tr>
<th>Measurement</th>
<th>GES DISC Dataset*</th>
<th>Spatial Resolution</th>
<th>Temporal Coverage</th>
<th>Current Usage/ Potential Usage</th>
<th>Health Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>TRMM</td>
<td>1/4 deg - 1 deg</td>
<td>1997 - present</td>
<td>See Pinzon, Zaitchik, Kiang, Tilburg</td>
<td>Vector Borne Diseases; Water Borne Diseases</td>
</tr>
<tr>
<td></td>
<td>GPM</td>
<td>1/4 deg X 1/4 deg</td>
<td>Starting 2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GLDAS</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>1979 - present</td>
<td>GLDAS, MERRA NLDAS are of comparable resolution to TRMM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present North America</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MERRA</td>
<td>1.25 deg X 1.25 deg</td>
<td>1979 - present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Runoff</td>
<td>Non</td>
<td><em>GES DISC product</em></td>
<td><em>often used</em></td>
<td>USGS derived products (Tilburg)</td>
<td>Vector Borne Diseases; Water Borne Diseases</td>
</tr>
<tr>
<td></td>
<td>GLDAS</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>1979 - present</td>
<td>GLDAS, MERRA NLDAS provide assimilated alternatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MERRA</td>
<td>2/3 deg X 1/2 deg</td>
<td>1979 - present</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present North America</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation Index</td>
<td>Non</td>
<td><em>GES DISC product</em></td>
<td><em>often used</em></td>
<td>MODIS derived data has set the standard (Ponzon, Estes, Kiang)</td>
<td>Vector Borne Diseases; Air Pollution</td>
</tr>
<tr>
<td></td>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present North America</td>
<td>NLDAS, MERRA provide alternatives with higher temporal resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MERRA</td>
<td>2/3 deg X 1/2 deg</td>
<td>1979 - present</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>NEESPI – AMSR-E</td>
<td>1 deg X 1 deg</td>
<td>2002 - present</td>
<td>See Zaitchik, Estes, Wimberly (uses AMSR-E)</td>
<td>Vector Borne Diseases</td>
</tr>
<tr>
<td>-----------------------</td>
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<td>----------------</td>
<td>-------------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td>LPRM using AMSR-E</td>
<td>25 km X 25 km</td>
<td>2002 - present</td>
<td>LPRM provides higher spatial resolution based on AMSR-E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present</td>
<td>GLDAS, MERRA NLDAS provide higher temporal resolution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GLDAS</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>1979 - present</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MERRA</td>
<td>2/3 deg X 1/2 deg</td>
<td>1979 - present</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Air Temperature</th>
<th>Non</th>
<th>GES DISC product</th>
<th>often used</th>
<th>MODIS generated data has set the standard (Pinzon, Zaitchik, Estes, Kiang, Stumpf, McClure, Ceccato)</th>
<th>Vector Borne Diseases; Air Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRS</td>
<td>1 deg X 1 deg</td>
<td>2002 - present</td>
<td>See reference: Wallace</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOVS</td>
<td>1 deg X 1 deg</td>
<td>1984 - 1995</td>
<td>TOVS: Historical data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MERRA</td>
<td>2/3 deg X 1/2 deg; 1.25 deg X 1.25 deg</td>
<td>1979 - present</td>
<td>GLDAS, MERRA NLDAS provide higher temporal resolution data</td>
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<tr>
<td>GLDAS</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>1979 - present</td>
<td></td>
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<tr>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present</td>
<td>North America</td>
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<td></td>
</tr>
<tr>
<td>Aerosols</td>
<td>Non</td>
<td>GES DISC product</td>
<td>often used</td>
<td>MODIS generated data (Liu, Morain)</td>
<td>Air Pollution</td>
</tr>
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<tr>
<td>OMI</td>
<td>24 km X 13 km; 1/4 deg X 1/4 deg</td>
<td>2004 - present</td>
<td>OMI is useful for low resolution applications</td>
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<td>TOMS</td>
<td>1.25 deg X 1.0 deg</td>
<td>1978 - 2005</td>
<td>TOMS: Historical data</td>
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<td>MERRA</td>
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<td>1979 - present</td>
<td>MERRA, GOCART provide higher temporal resolution</td>
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<tr>
<td>GOCART</td>
<td>2.5 deg X 2.0 deg</td>
<td>2000 - 2007</td>
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<table>
<thead>
<tr>
<th>Wind</th>
<th>Non</th>
<th>GES DISC product</th>
<th>often used</th>
<th>MODIS generated data (Liu, Morain)</th>
<th>Air Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERRA</td>
<td>2/3 deg X 1/2 deg; 1.25 deg X 1.25 deg</td>
<td>1979 - present</td>
<td>See reference: Lau</td>
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<tr>
<td>GLDAS</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>1979 - present</td>
<td>GLDAS, NLDAS, GSSTF2b provide assimilated alternatives</td>
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<td></td>
</tr>
<tr>
<td>NLDAS</td>
<td>1/8 deg X 1/8 deg</td>
<td>1979 - present North America</td>
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<tr>
<td>GSSTF2b</td>
<td>1 deg X 1 deg</td>
<td>1988 - 2008</td>
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<tr>
<th>Solar Irradiance</th>
<th>Non</th>
<th>GES DISC products</th>
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<th>MODIS generated data (Liu, Morain)</th>
<th>Air Pollution</th>
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<tbody>
<tr>
<td>SORCE</td>
<td>2003 - present</td>
<td>SORCE, OMI provide alternative global measurements</td>
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<tr>
<td>OMI</td>
<td>1/4 deg X 1/4 deg; 1 deg X 1 deg</td>
<td>2004 - present</td>
<td></td>
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</tbody>
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* 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 – Tropospheric Emission Spectrometer
  - TOMS - Total Ozone Mapping Spectrometer
  - TOPS - Terrestrial Observation and Prediction System
  - TOVS - TIROS Operational Vertical Sounder
  - TRMM - Tropical Rainfall Measuring Mission
# Customized domain definition

Two ways to find your domain numbers:
1. Use `ncdump -h filename`;
2. Find them in your GRIDDESC file

**Enter your domain information:**

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<th>Parameter</th>
<th>Value</th>
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<td>NCOLS3D (no. of columns):</td>
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<tr>
<td>NROWS3D (no. of rows):</td>
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<tr>
<td>NLAYS3D (no. of layers):</td>
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<tr>
<td>P_ALP3D (alpha value):</td>
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<tr>
<td>P_BET3D (beta value):</td>
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<td>P_GAM3D (gamma value):</td>
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<tr>
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<td>YCENT3D (Y center):</td>
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<td>XORIG3D (X origin):</td>
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<td>YORIG3D (Y origin):</td>
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<td>XCELL3D (X spacing):</td>
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<tr>
<td>YCELL3D (Y spacing):</td>
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</tr>
</tbody>
</table>

[Add your domain button]
Interpreting NASA Remote Sensing Data for Air Quality Research and Modeling

- **Popular Air Quality Models:**
  - Community Multiscale Air Quality (CMAQ) model, developed jointly by the US Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA)
  - NASA-Unified Weather Research and Forecasting (NU-WRF) model. The NU-WRF modeling system has explicit land-cloud-aerosol-precipitation interactions

- **Interested Air Quality Projects:**
  - Deriving Information on Surface Conditions from Column and Vertically-Resolved Observations Relevant to Air Quality (DISCOVER-AQ) field campaigns. Designed to improve the interpretation of satellite observations to diagnose near-surface conditions relating to air quality. (Dr. Ken Pickering, DISCOVER-AQ Project Scientist)
  - **Air quality forecasting research** and integration into the NOAA air quality forecasting model system, lead by Dr. Pius Lee, NOAA Air Resources Laboratory (ARL).
  - **Community Modeling and Analysis System (CMAS)** center for air quality modeling community, directed by Dr. Adel Hanna. Distributes and supports air quality modeling, analysis, and decision support tools, including the CMAQ model, to over 5000 registered users.
  - University of Wisconsin (Tracy Holloway, also deputy leader of NASA’s Air Quality Applied Science Team [AQAST]) projects to analyze NO2 trends from hydrofracturing over North Dakota, isolating truck emissions on rural highways, and evaluating lightning NOx in CMAQ.