Week – 5 – April 29, 2014

NASA Satellite Trace Gas Products for Air Quality Applications

Pawan Gupta

ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

A project of NASA Applied Sciences

Action Items

- Assignments/Material/Recordings

http://arset.gsfc.nasa.gov/airquality/webinars/observations-tools-south-east-asia

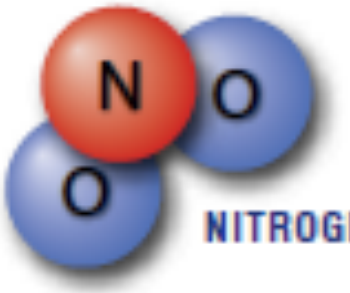
- Survey – Stay tuned, coming soon
- Future in-person/advance trainings

http://arset.gsfc.nasa.gov/airquality

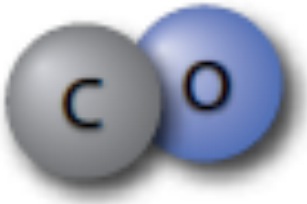
- List serve

https://lists.nasa.gov/mailman/listinfo/arset

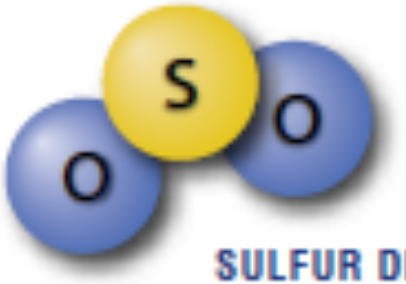
What are NASA instruments measuring?



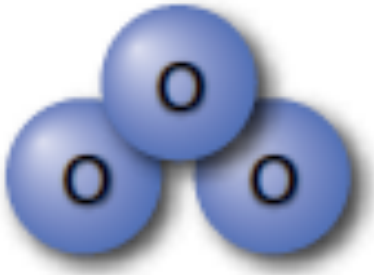
NITROGEN DIOXIDE



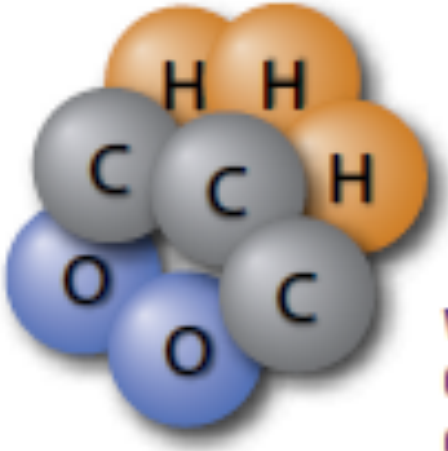
CARBON MONOXIDE



SULFUR DIOXIDE



OZONE



VOLATILE ORGANIC COMPOUNDS

AEROSOL

Focus: Three Remote Sensing Trace Gas Products

1. Tropospheric Column NO_2
   - From OMI (Ozone Monitoring Instrument) on-board Aura satellite (http://aura.gsfc.nasa.gov)
2. Boundary Layer SO2
   - From Aura OMI (http://aura.gsfc.nasa.gov)
3. Total Column and profile measurements of CO
   - From MOPITT (Measurements of Pollution in the Troposphere) on-board the Terra satellite

     (http://www2.acd.ucar.edu/mopitt)

Level 1 – Raw

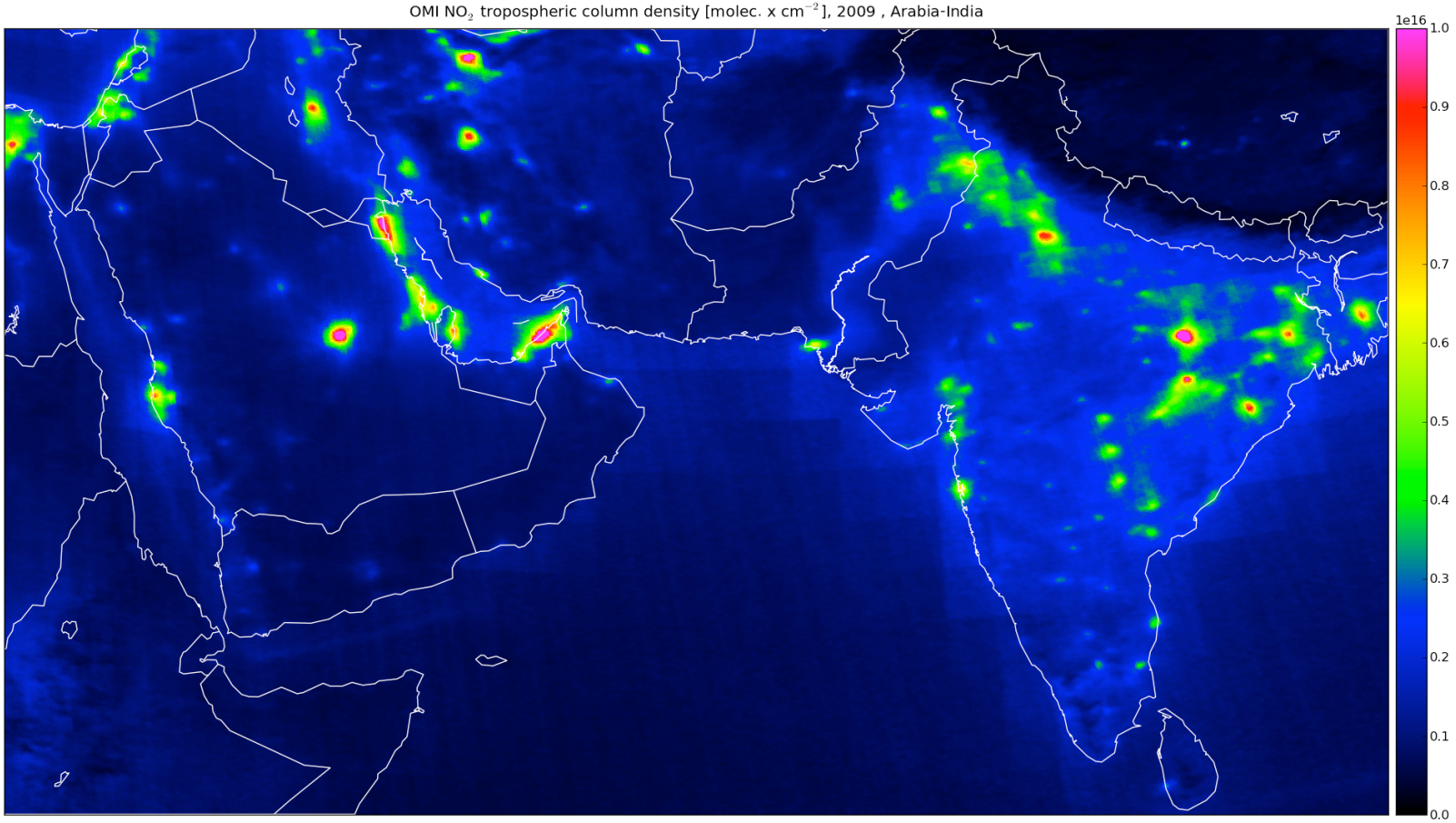
Level 2 – Orbit

Level 3 - Gridded

Highest Resolution, Difficult

Lower Resolution, Easy

Aura/OMI NO_2


OMI NO2 tropospheric column density [molec. x cm−2], 2009 , Arabia-India
1e16
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

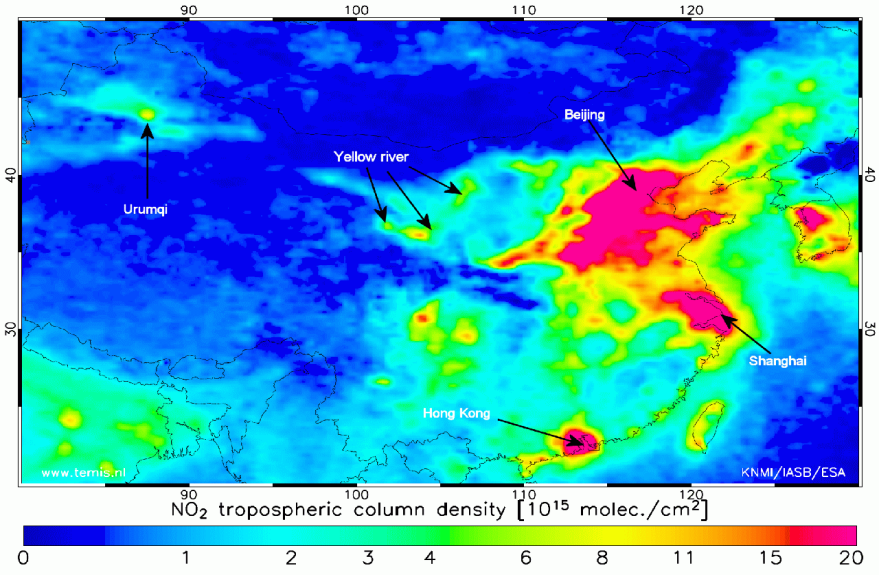
OMI Tropospheric Column NO_2 for AQ appl.

- Two *Separate* Algorithms
  1. NASA/GSFC "Standard Product"
     - Level 3 data 0.25x0.25 degree gridded
     - Data Short name = OMNO2d
  2. KNMI (Royal Netherlands Meteorological Institute) DOMINO (Near-Real Time) Product
     - Level 2 data and images available from KNMI and TEMIS.
     - Data Short Name = OMDOMINO
     - http://www.temis.nl/airpollution/no2.html
     - Includes data/images from European Satellite instruments: GOME, GOME-2, SCIAMACHY

GSFC Standard Product for AQ Applications

Data Set Short Name = OMNO2d

- Product Level = 3
- Begin Date = October 1, 2004
- Resolution = 0.25°lon x 0.25°lat
- Version = 003
- Cloud-screened best observation
- Production Frequency: Daily
- Granule (File) Coverage: 15 orbits
  File Size (Approx): 2.5 MB
- Data Format = HDF (hierarchical data format)

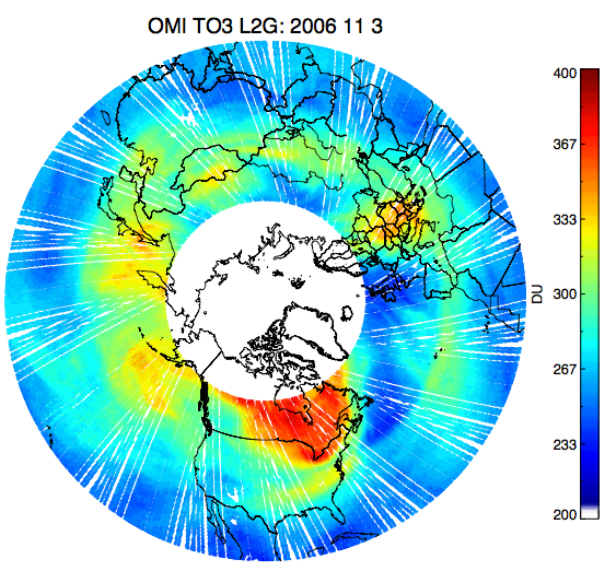


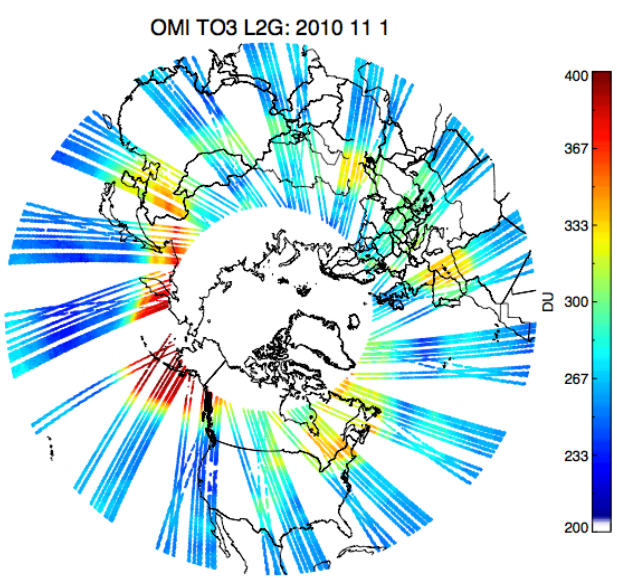
Data are publicly available here:
http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2d_v003.shtml

Important information regarding OMI

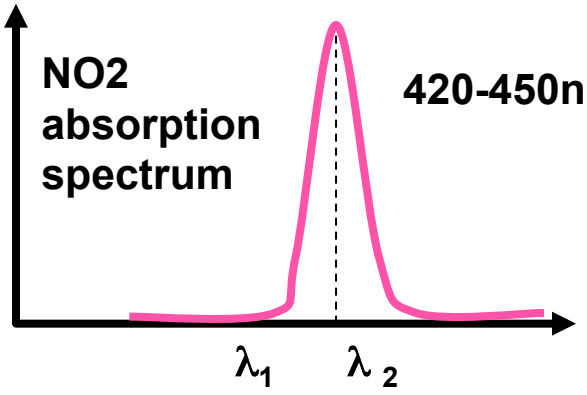
Almost 50% data loss since 2008
(row anomaly effect)

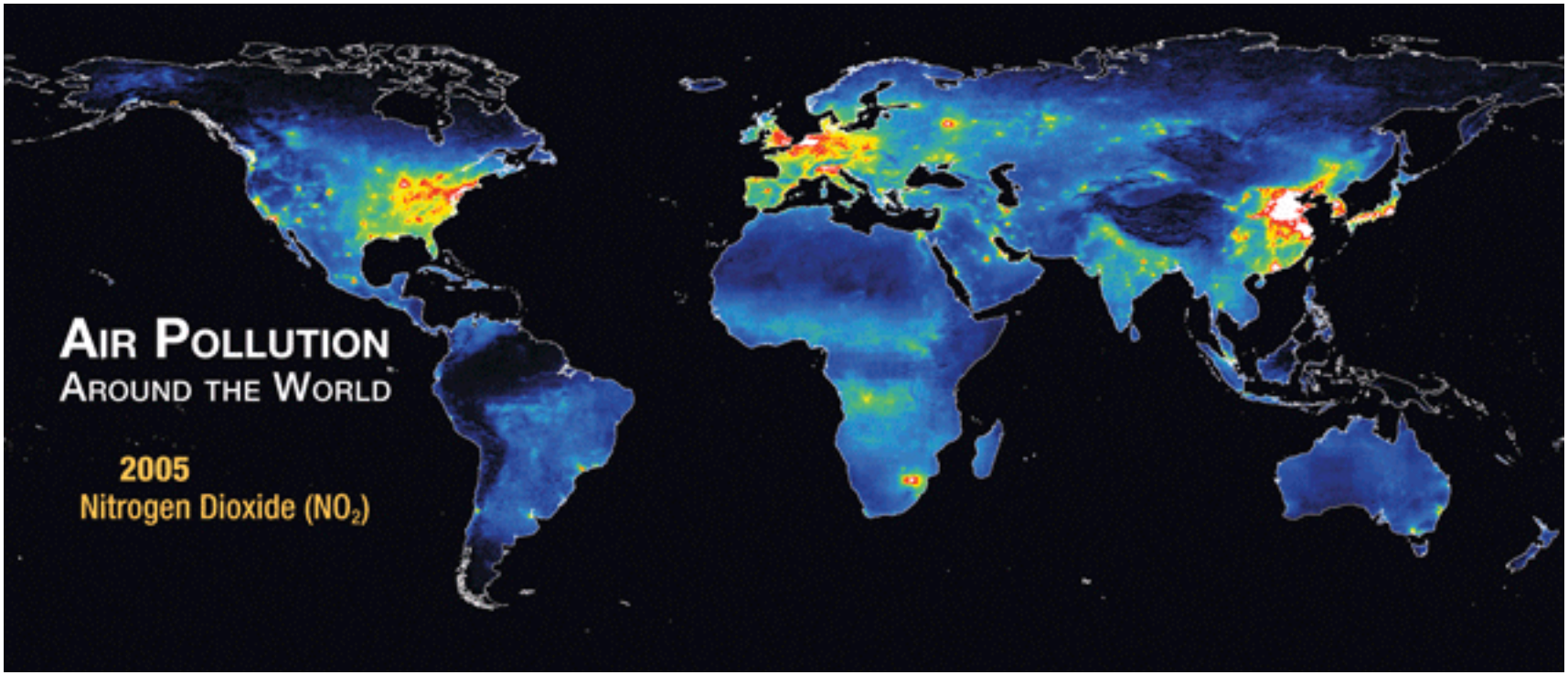
Affects O_3, SO_2, and to some extent NO_2 OMI Products



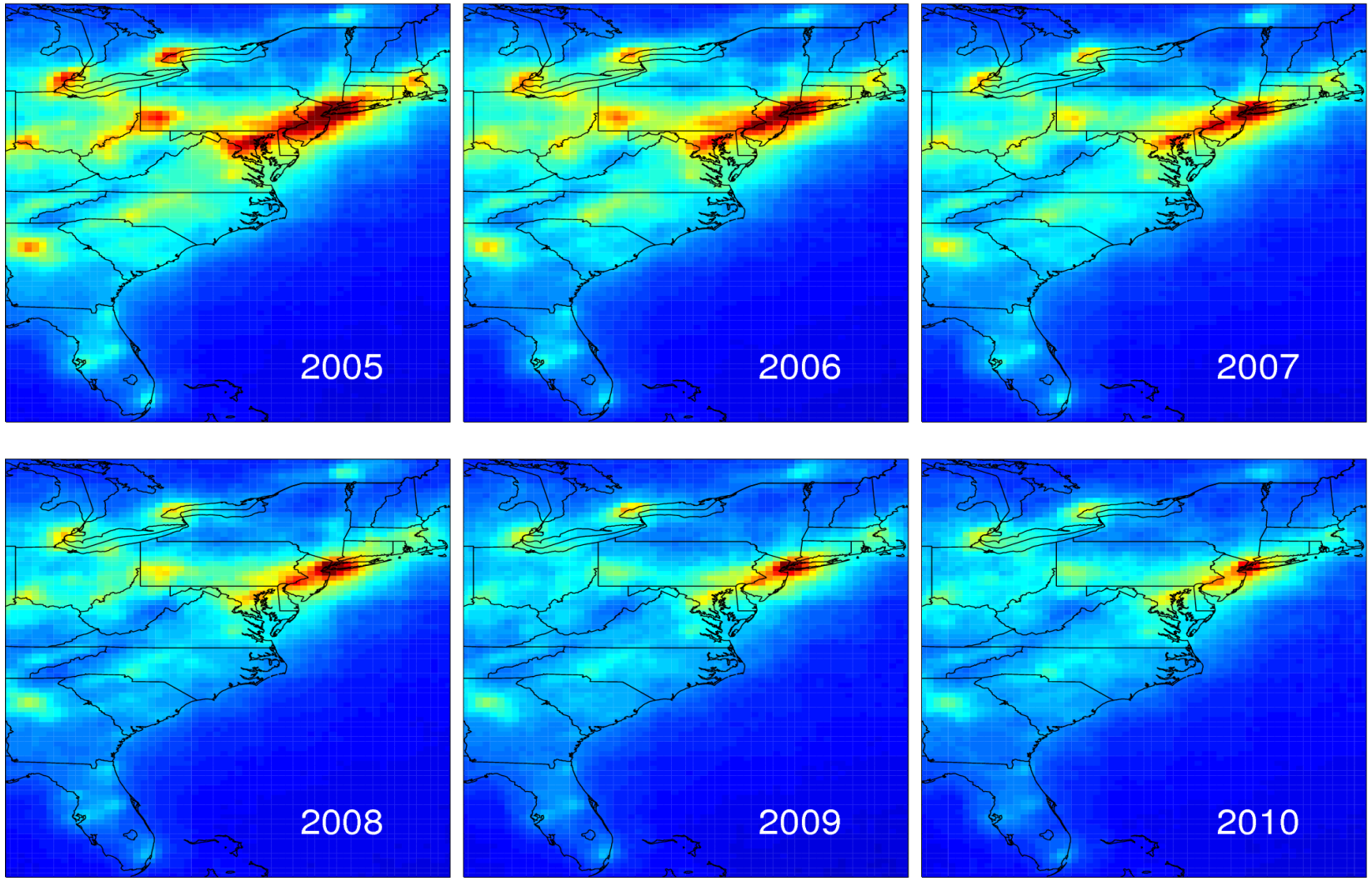


Examples of OMI NO_2 Applications


NO2
absorption
spectrum
420-450nm
λ1
λ 2


AIR POLLUTION
AROUND THE WORLD
2005
Nitrogen Dioxide (NO2)

$OMNO_2$ Standard Product shows declining trends over the Eastern US ~10%/year

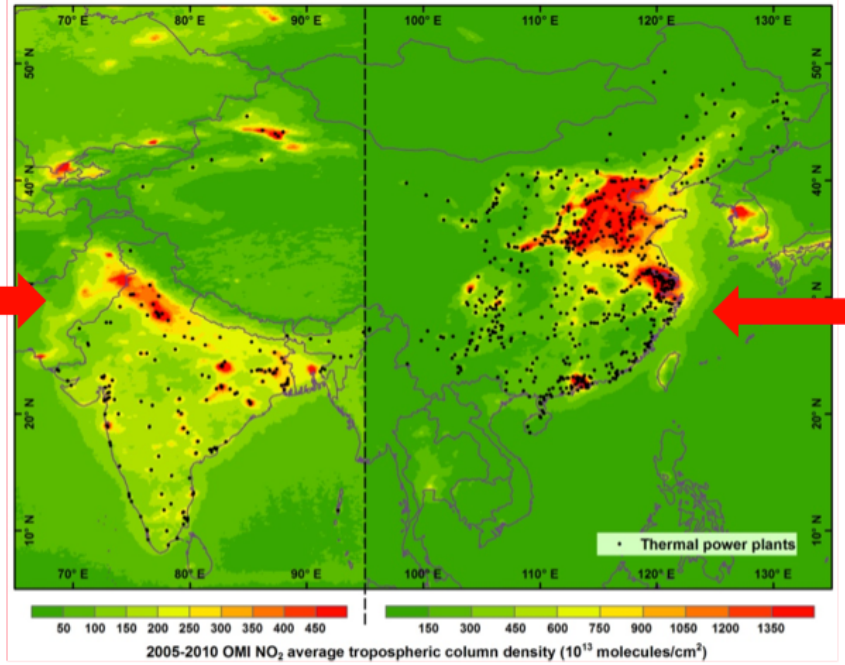


Lok Lamsal, 2012

David Streets and Zifeng Lu
Decision and Information Sciences Division
Argonne National Laboratory

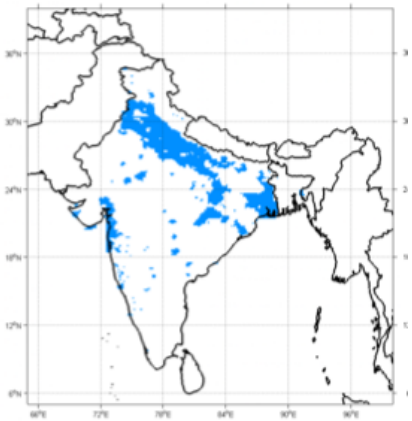
Uses OMI NO_2 tropospheric columns to constrain models to identify NOx emission sources.

STEM-modeled NO_2 columns ***[new collaboration with Greg C]***



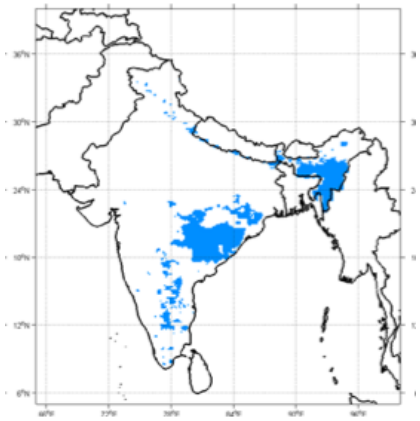
GEOS-Chem modeled NO_2 columns ***[Wang et al., 2012]***

OMI (2005-2011)



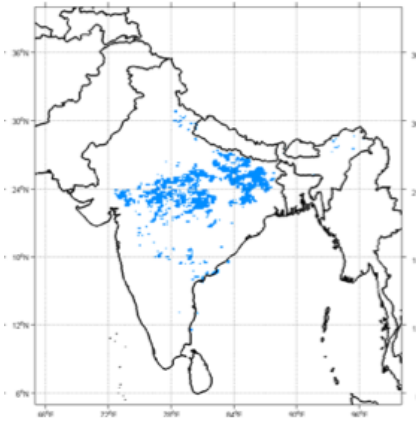
Dominant anthropogenic source regions

OMI (2005-2011)



Biomass burning regions

OMI (2005-2011)



Soil emission regions

OMI NO_2 Data Access

GES-DISC (Goddard Earth Science Data and Information Services Center)

- http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2d_v003.shtml
- Level 2, L2G, Level 3 (OMNO2d)
- HDF and NetCDF
- Documentation

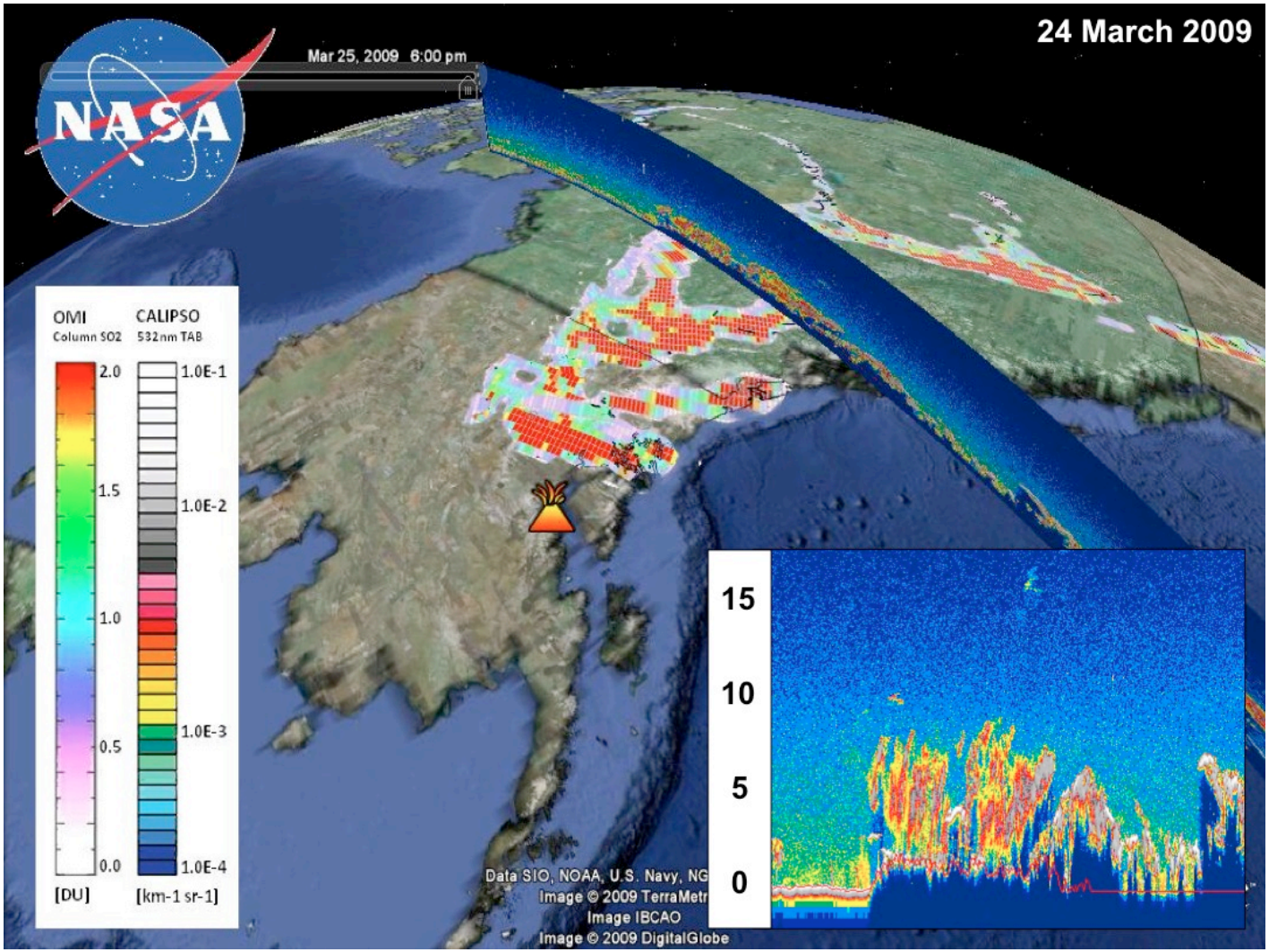
AVDC (Aura Validation Data Center)

- http://avdc.gsfc.nasa.gov
- Level 3 (OMNO2d)
- HDF, ASCII, KML formats
- Daily and monthly data and Images

GIOVANNI – an interactive visualization tool

- http://disc.sci.gsfc.nasa.gov/giovanni
- L2G, Level 3 (OMNO2d)
- HDF, ASCII, KML for Google Earth
- Subsetting available

Aura/OMI SO_2



Source: http://sun.aos.wisc.edu/research

A case study of the 2009 eruption of Mt. Redoubt, Alaska, US
The dispersion of volcanic ash was monitored using OMI column SO_2 and CALIPSO backscatter data.

OMI SO2 Gridded Product Summary

- The OMI data product file contains 4 estimates of the total SO_2 column in Dobson Units.
- These correspond to 4 a-priori (climatological) vertical profiles for the SO_2 used in the retrieval algorithm.
- The 4 vertical profiles represent typical SO_2 vertical distributions for 4 SO_2 source regimes:

SO_2 Product	Level	Data Short Name	Sensitivity	Use
PBL SO_2	L3, 0.25°x0.25°	OMSO2e	< 1 km	Fossil fuel, industry
TRL SO_2 (Lower Troposphere)	L2G, 0.25°x0.25°	OMSO2G	~ 3 km	Industry outflow
TRM SO_2 (Mid-Tropopshere)	L2G, 0.25°x0.25°	OMSO2G	5 - 10 km	optimized for volcanic degassing with vents at ~5km altitude or above and emissions from effusive eruptions.
STL SO_2 (Lower Stratosphere)	L2G, 0.25°x0.25°	OMSO2G	15 – 20 km	intended for use with explosive volcanic eruptions

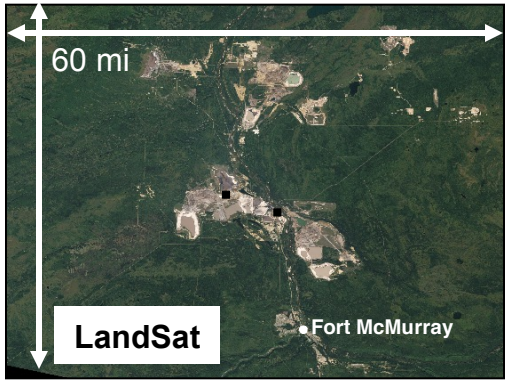
Note: OMSO2e ‘best’ product: Screens anomalous values due to cloudiness, high terrain and instrumental effects (row anomaly)
. L2G data are NOT screened.

Examples of OMI SO_2 Applications

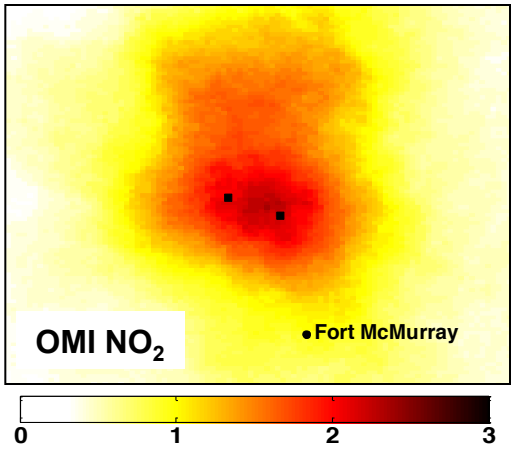
Aura/OMI measurements show distinct enhancements in NO_2 and SO_2 amounts over the Canadian oil sands

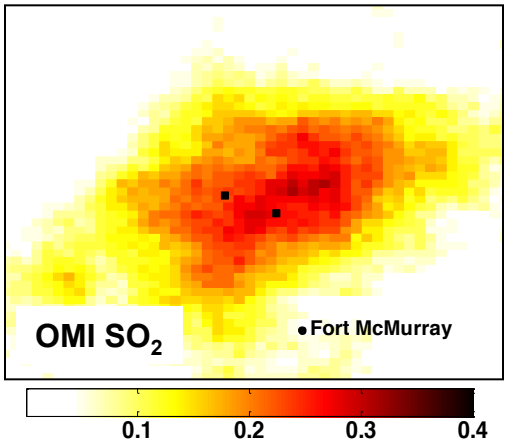
Environment Canada | Environnement Canada

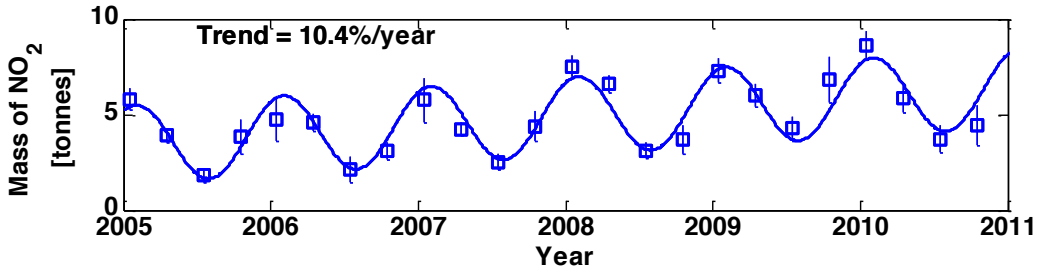
Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu



■ Surface Mining Operations





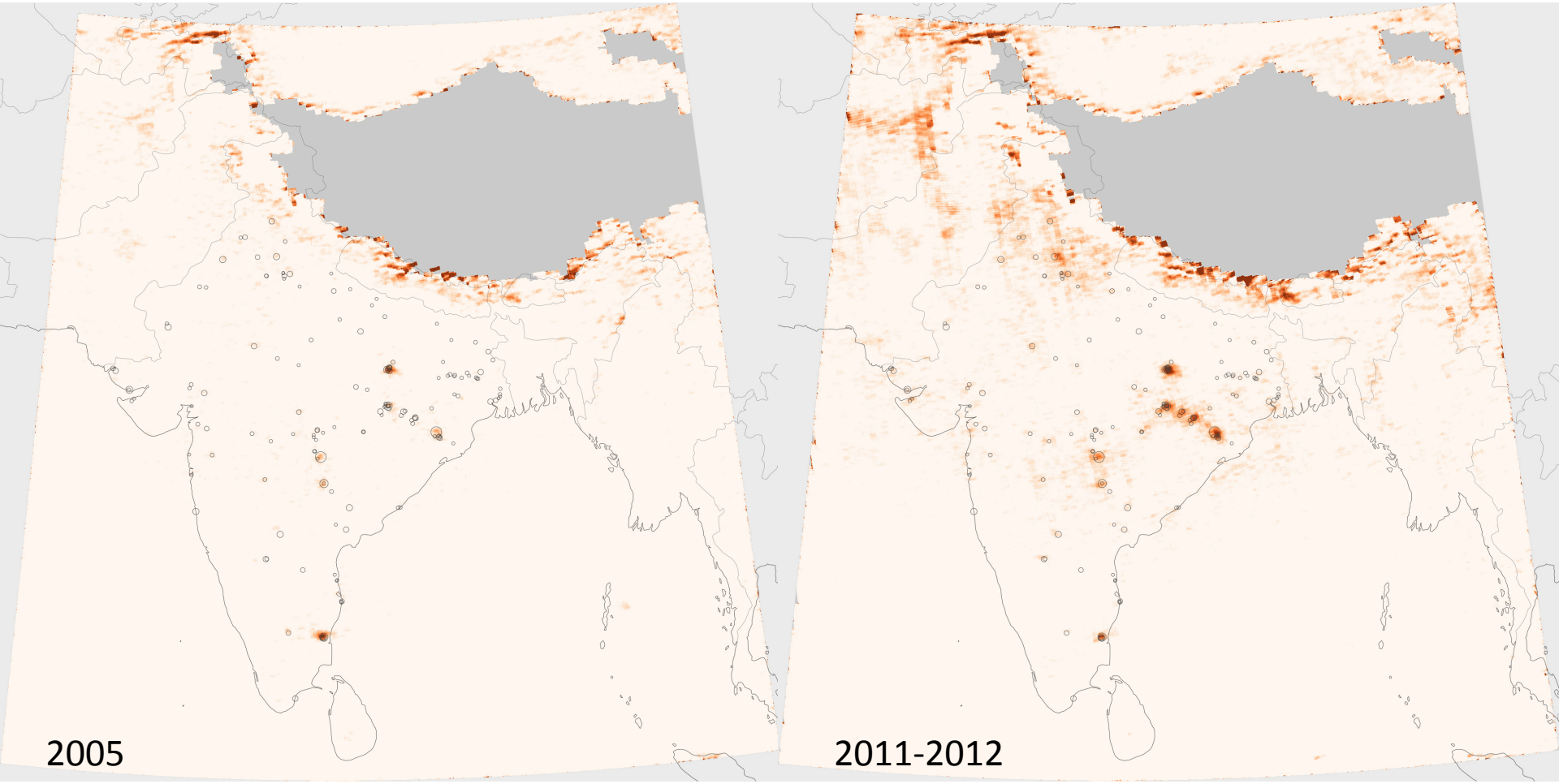


Data from the Ozone Monitoring Instrument (OMI) reveal distinct enhancements in nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) over a region of surface mining in the Canadian oil sands. The oil sands are located in the north-east corner of the province of Alberta, Canada and contain the second largest reserve (after Saudi Arabia) of oil globally. Shown along the top are maps over a portion of the oil sands where extensive surface mining occurs. These maps cover the same area: a NASA LandSat image from 2009 indicating vegetation removal in region of surface mining (left), OMI mean NO_2 (middle), and OMI mean SO_2 (right). OMI data were averaged over the period 2005-2010. White values indicate background levels, increasing through yellow-orange, with brown-black the largest. Maximum values clearly correspond to the location of the industrial activity. The time graph shows that NO_2 has been increasing at a rate of 10%/year over this period. Maximum values are comparable to those seen over medium-to-large North American power plants.
These results make use of improved OMI mapping techniques to resolve detail down to 5 miles. These are the first satellite-based results of pollution over the oil sands.

McLinden, C., et al., (2012), *Geophysical Research Letters*, in press

Aura/OMI SO_2

http://earthobservatory.nasa.gov/IOTD/view.php?id=82626



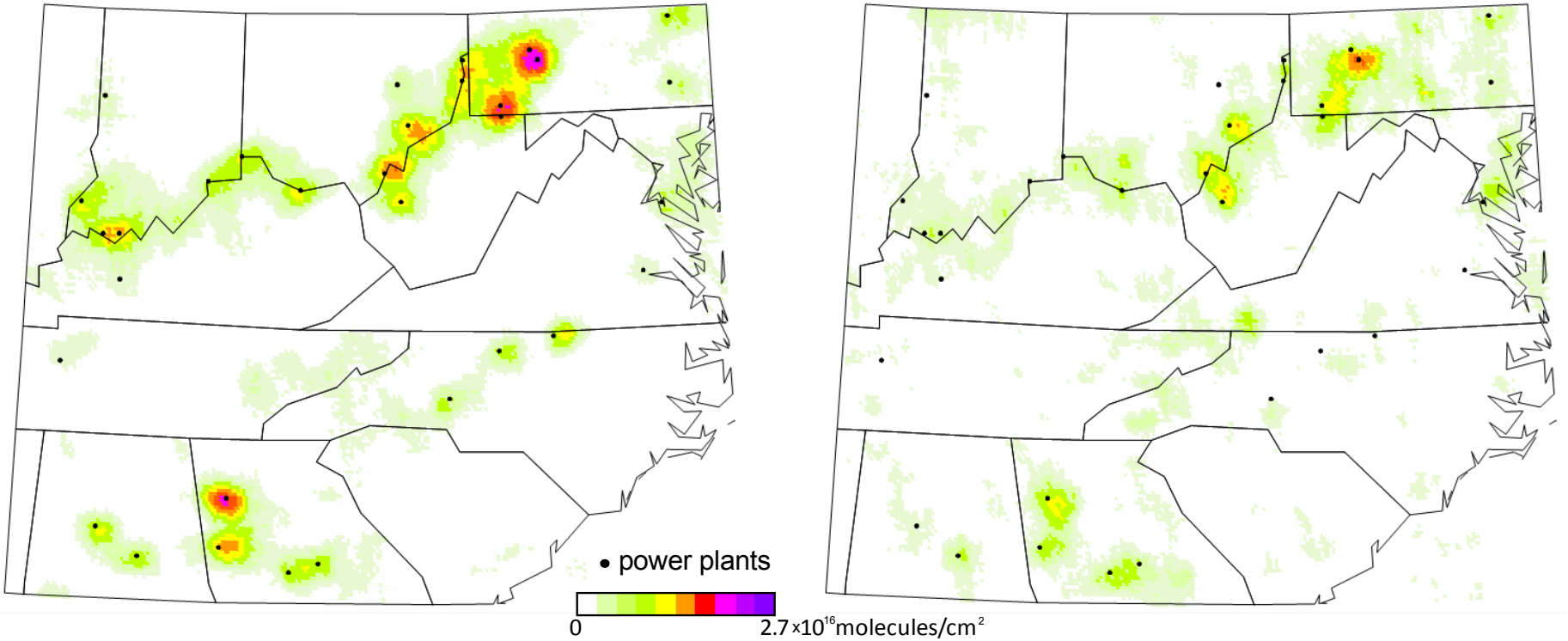
Study published by Lu et al., http://pubs.acs.org/doi/abs/10.1021/es4039648

Aura/OMI measurements show a decrease in SO_2 amounts over the Eastern United States

Environment Canada | Environnement Canada

Mean SO_2 values for 2005-2007

Mean SO_2 values for 2008-2010



The Ozone Monitoring Instrument (OMI) data confirm a substantial reduction in sulfur dioxide (SO_2) values around the largest US coal power plants as a result of the implementation of SO_2 pollution control measures. The figure shows average SO_2 values measured by OMI on the NASA Aura spacecraft for the periods 2005-2007 and 2008-2010 over the Eastern US where the majority of large SO_2 sources are located. Scientists use this information to identify anthropogenic sources of SO_2 and to estimate their emission rates. The greatest values are in violet; the lowest in green. Yellow to violet colors correspond to statistically significant enhancements in SO_2 pollution in the vicinity of largest SO_2 emitting coal-burning power plants indicated by the black dots.

Previous use of space-based SO_2 retrievals has been limited to monitoring plumes from volcanic eruptions and detecting anthropogenic emissions from large source regions as in China. A new spatial filtration technique allows detection of individual pollution sources in Canada and US.

Fioletov, V., et al., (2011), *Geophysical Research Letters*

Data/Images Access

Global Sulfur Dioxide Monitoring Homepage

- http://so2.gsfc.nasa.gov/
- Images, Documentation, Publications and Links

GES-DISC (Goddard Earth Science Data and Information Services Center)

- http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omso2e_v003.shtml
- Level 2, L2G, Level 3 (OMSO2e)
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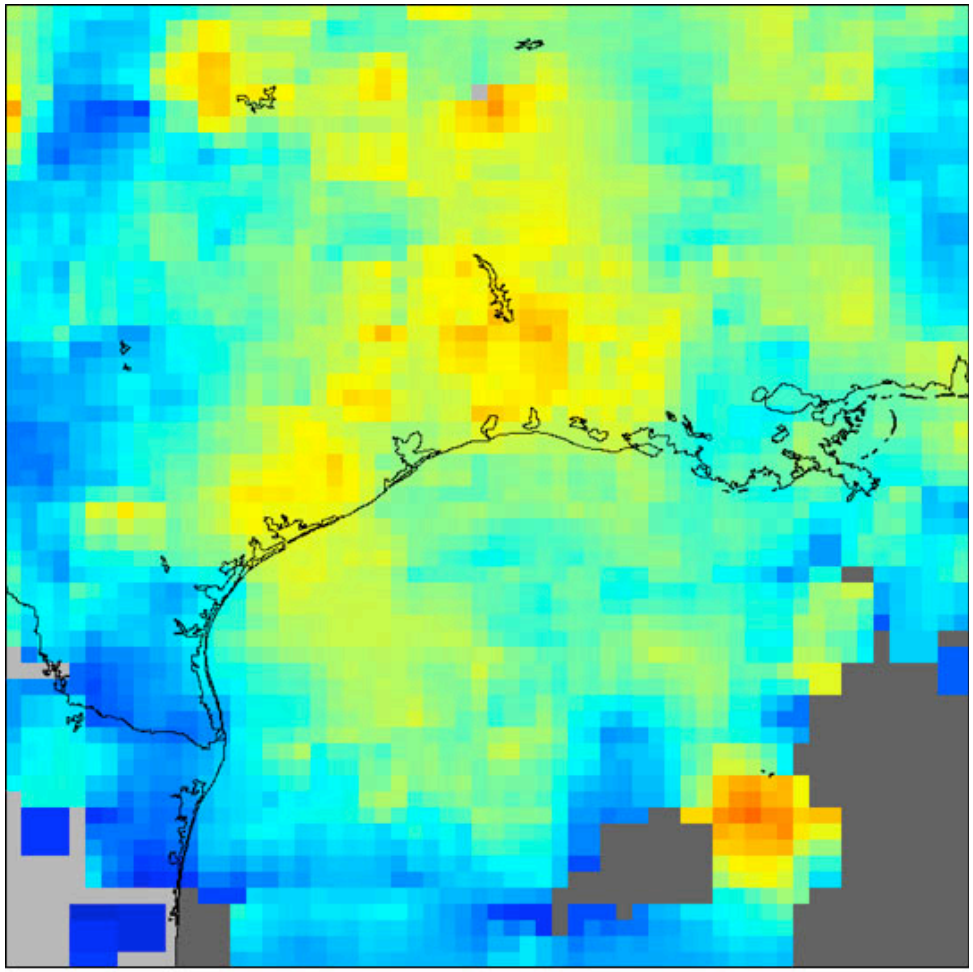
GIOVANNI – An interactive visualization tool

- http://disc.sci.gsfc.nasa.gov/giovanni
- L2G, Level 3 (OMSO2e)
- HDF, ASCII, KML for Google Earth
- Subsetting available

Worldview – Image: https://earthdata.nasa.gov/labs/worldview/

Terra/MOPITT CO



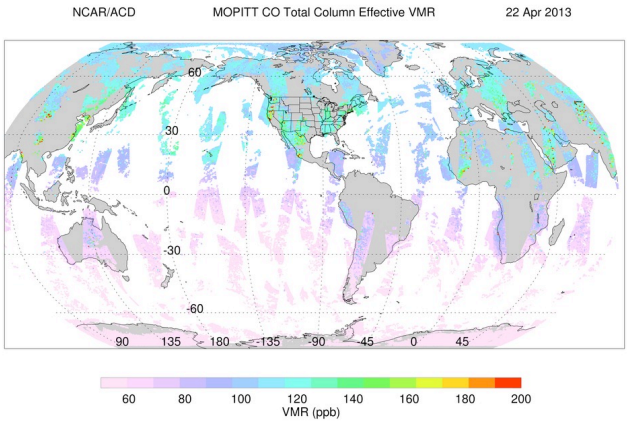
CO plumes at an altitude of roughly 2 km (700 millibars) over the Houston area and extending out over the Bay of Galveston. This image represents a composite of data collected over a 10-day period, September 6-15, 2002, by MOPITT.

http://earthobservatory.nasa.gov/IOTD/view.php?id=3173

MOPITT- Measurements of Pollution In The Troposphere

HOMEPAGE = http://www.acd.ucar.edu/mopitt/

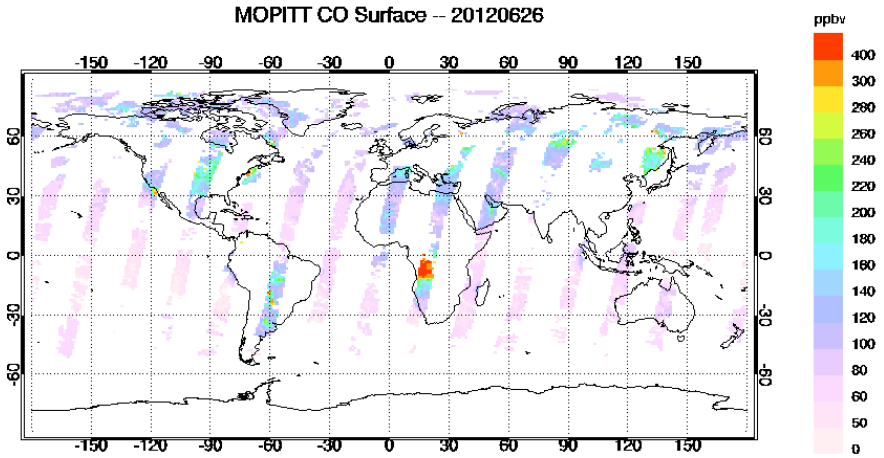
- Operational since March 2000
- A nadir sounding instrument
- Pixel resolution = 22km × 22km
- Swath width = 640 km
- Equator Crossing times = 10:00 AM, 10:10PM
- Vertical profiles of CO are obtained at 4.7 μm
  - Profile Units = Parts per Billion Volume mixing ratio (ppbv)
- Column CO are obtained at 2.2-2.4 μm
  - Column Units = molecules/cm2
- Current Version 6
- 9 vertical layers 900hPa – 100hPa
- Level 3 gridded data are 1deg x1deg resolution
- Original data format is in HDF

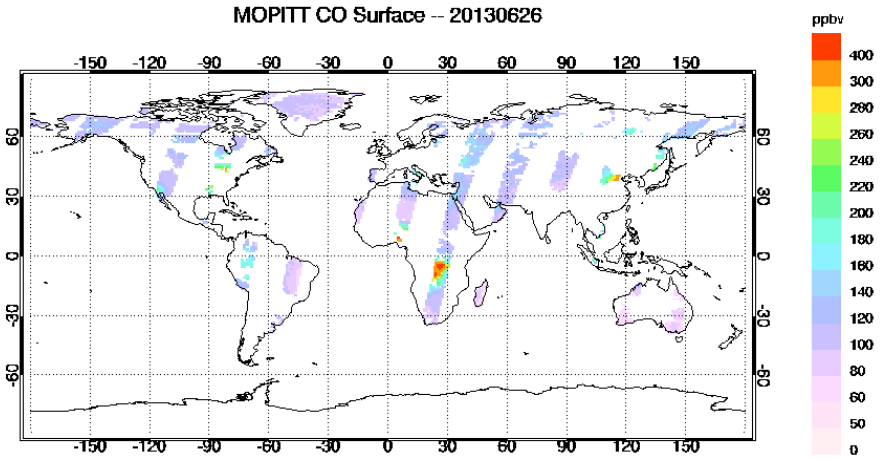


Due to large gaps between swaths, it takes 3 days worth of data to create a global composite

MOPITT Product Images

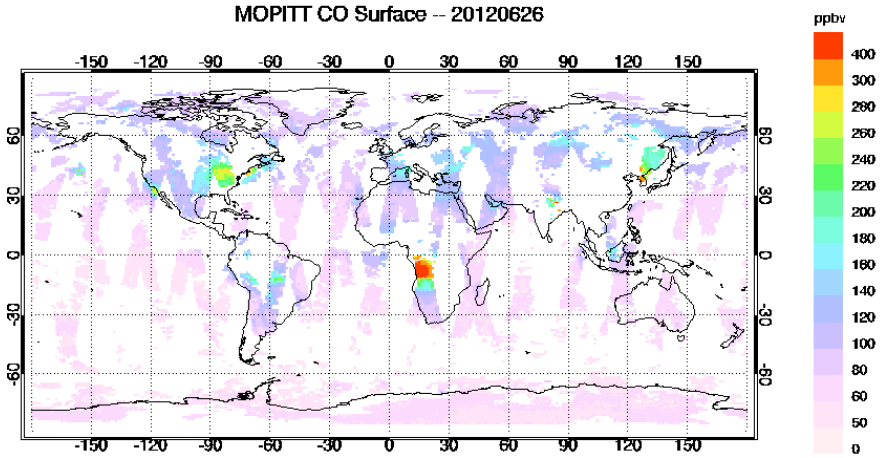
TIR/NIR
Daytime only

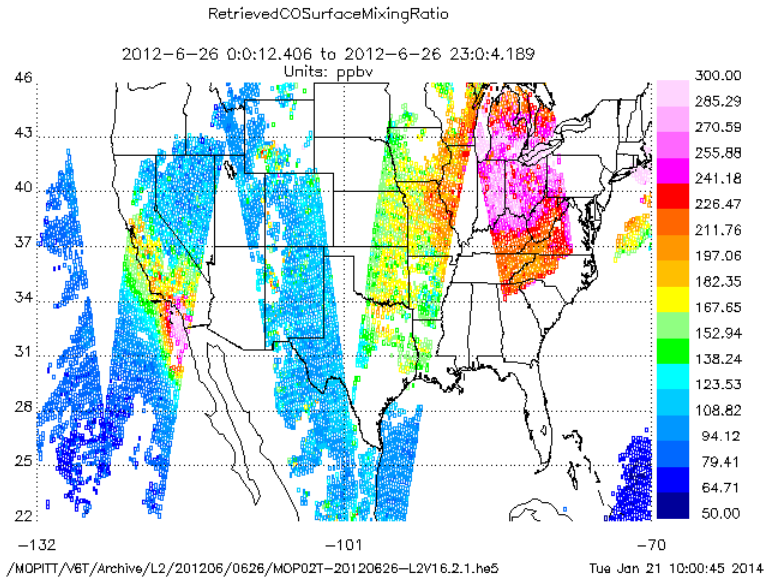


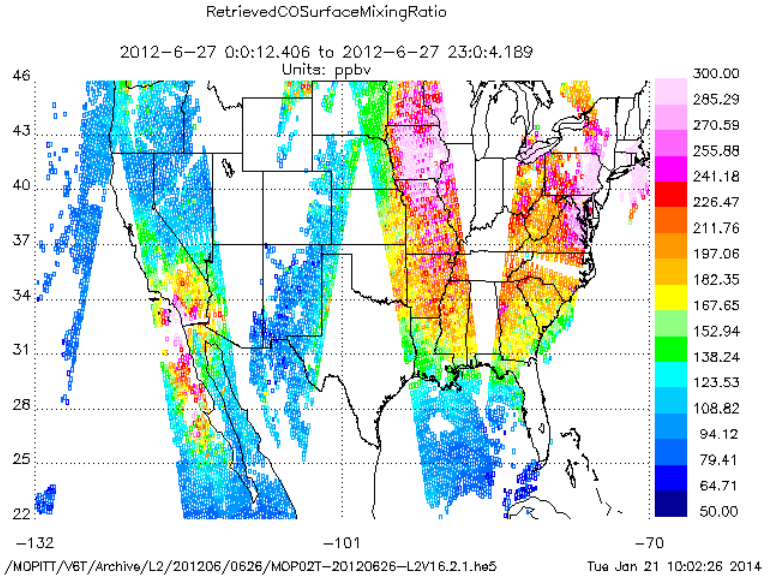


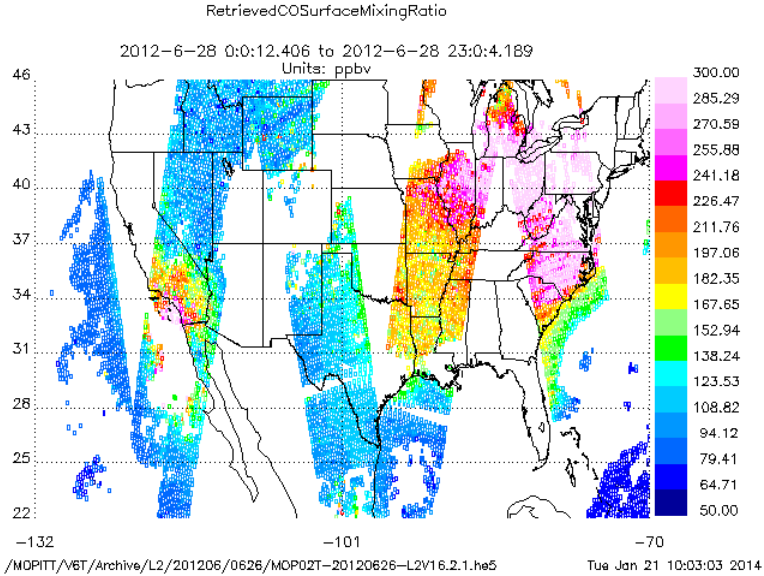
NIR-only
Daytime only

TIR-only
Daytime/Nightime









Big MOPITT Limitation!! – COVERAGE

Due to large data gaps, do not expect to get daily coverage in your domain of interest!!

Summary of Trace Gas Websites

GIOVANNI : http://disc.sci.gsfc.nasa.gov/giovanni

EOSDISC Reverb global search tool: http://reverb.echo.nasa.gov

GES-DISC: http://disc.sci.gsfc.nasa.gov

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

Worldview: https://earthdata.nasa.gov/labs/worldview/

Global Sulfur Dioxide Monitoring Homepage: http://so2.gsfc.nasa.gov/

Aura Homepage: http://aura.gsfc.nasa.gov

Aura Validation Data Center: http://avdc.gsfc.nasa.gov

OMSO2e Product:http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omso2e_v003.shtml

OMNO2d Product: http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/OMI/omno2d_v003.shtml

MOPITT Homepage: http://www2.acd.ucar.edu/mopitt/

MOPITT Interactive Visualization tool:

http://mopfl.acd.ucar.edu:8080/webviewV6/selectmopittfile