Transitioning NASA Earth Science to Address Real World Weather Related Issues

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Presented at CSPP/IMAPP User Meeting

Significant Contributions from
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Transitioning NASA Earth Science to Address Real World Weather Related Issues

Presentation topics:

NASA climate satellites provide unique measurement capabilities

Transition NASA EOS observations to the operational weather community facilitated by

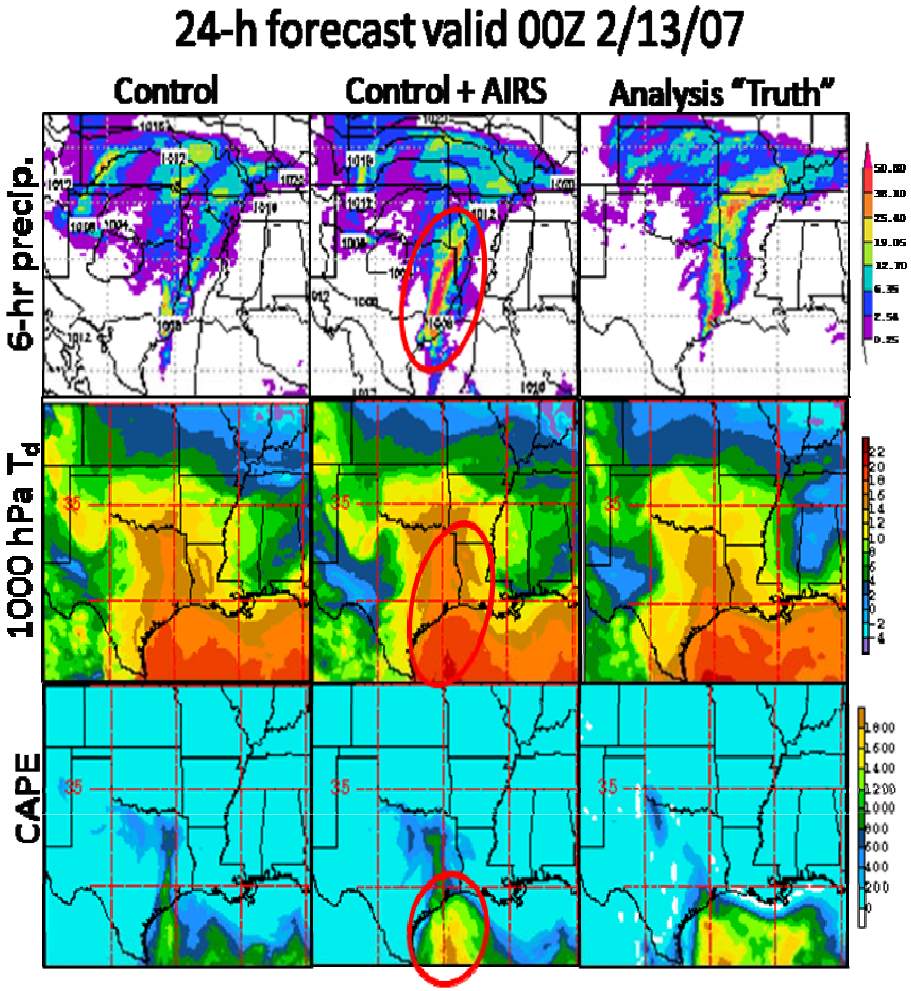
- direct broadcast data and processing software
- R2O "centers"
- advanced dissemination capabilities


NASA EOS SATELLITES
Aquarius
OSTM/Jason 2
Jason
QuikSCAT
EO-1
TRMM
Landsat-7
Aqua
ACRIMSAT
Terra
SORCE
GRACE
Aura
CALIPSO
CloudSat
Suomi-NPP

Climate versus Weather Monitoring

Many NASA satellite sensors have utility in monitoring "fast" climate processes (i.e. weather) on a regional and local scale

AIRS (Aqua) radiances and profiles integrated into regional forecast models run by weather forecast offices

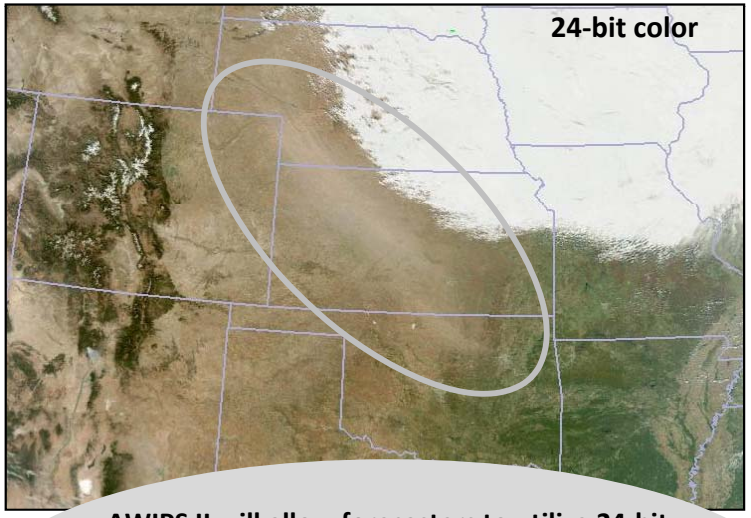


AIRS temperature and moisture profiles assimilated into WRF improve precipitation processes in data void regions (as shown in the Gulf of Mexico application).

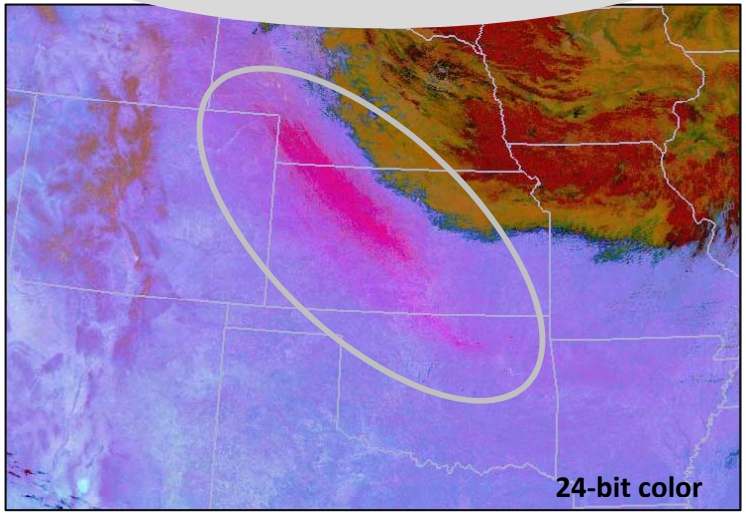
Climate versus Weather Monitoring

Many NASA satellite sensors have utility in monitoring "fast" climate processes (i.e. weather) on a regional and local scale

MODIS (Terra / Aqua) imagery mapping of visibility reductions due to smoke, dust transport, low clouds and fog, snow and ice, and derived surface parameters used to better define lower boundary fluxes of heat and moisture for model initialization



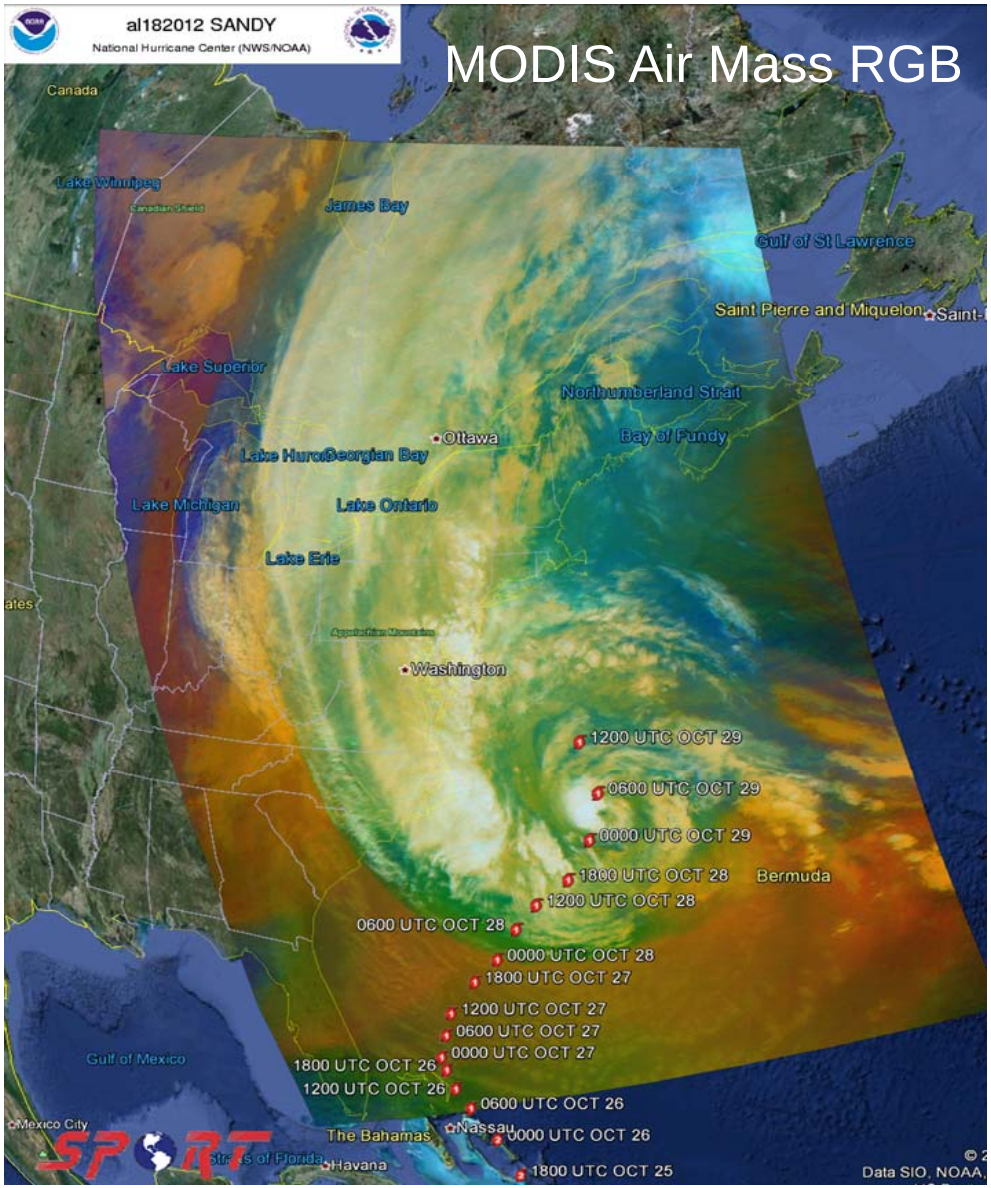
AWIPS II will allow forecasters to utilize 24-bit technology. The 24 bit dust RGB image (below) shows the improvement over fewer-color displays currently available in AWIPS and NAWIPS systems



Climate versus Weather Monitoring

Many NASA satellite sensors have utility in monitoring "fast" climate processes (i.e. weather) on a regional and local scale

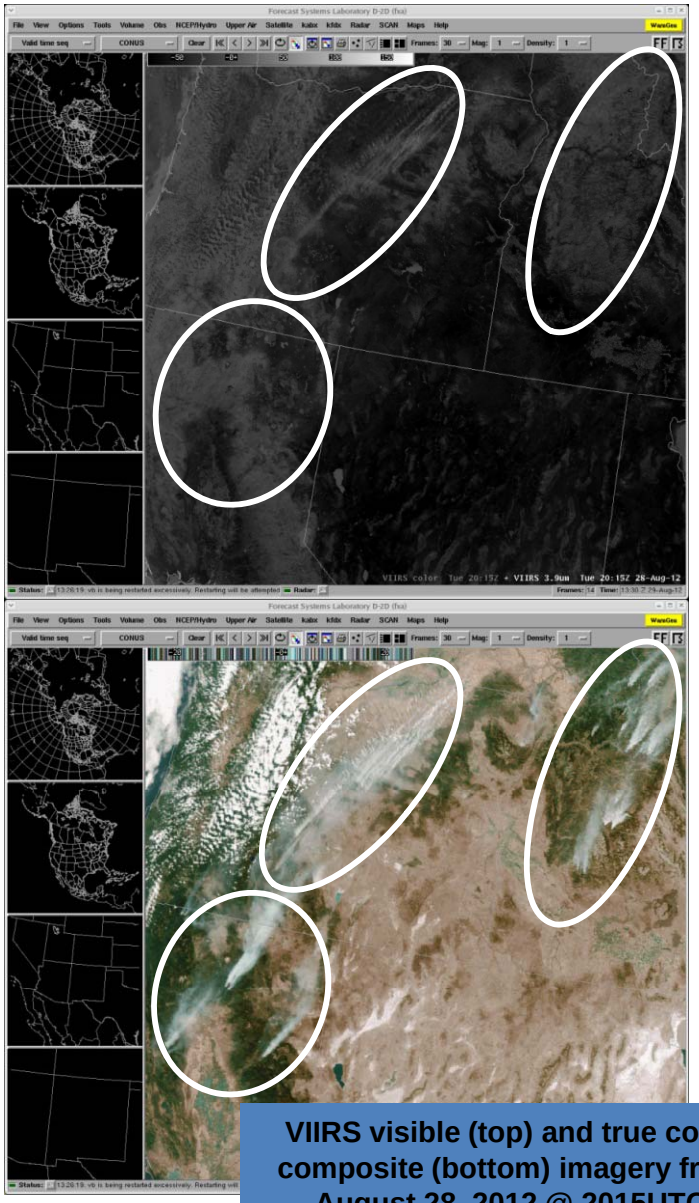
MODIS (Terra / Aqua) and VIIRS/CrIS imagery mapping of atmospheric dynamical processes through channel fusion and red-green blue composites highlighting various air mass characteristics.



Disaster Monitoring

Many NASA satellite sensors have utility in monitoring natural and man-made disasters

- OMI (Aura) mapping of ozone and SO_2
- MODIS (Terra/Aqua) and ASTER (Terra) mapping of wildfires and smoke, drought, coastal disasters (oil spills, harmful algae blooms, flooding, etc.)
- VIIRS (Suomi NPP) mapping of fires and smoke, night-time power outages
- ASTER (Terra), Landsat, to detect severe weather damage



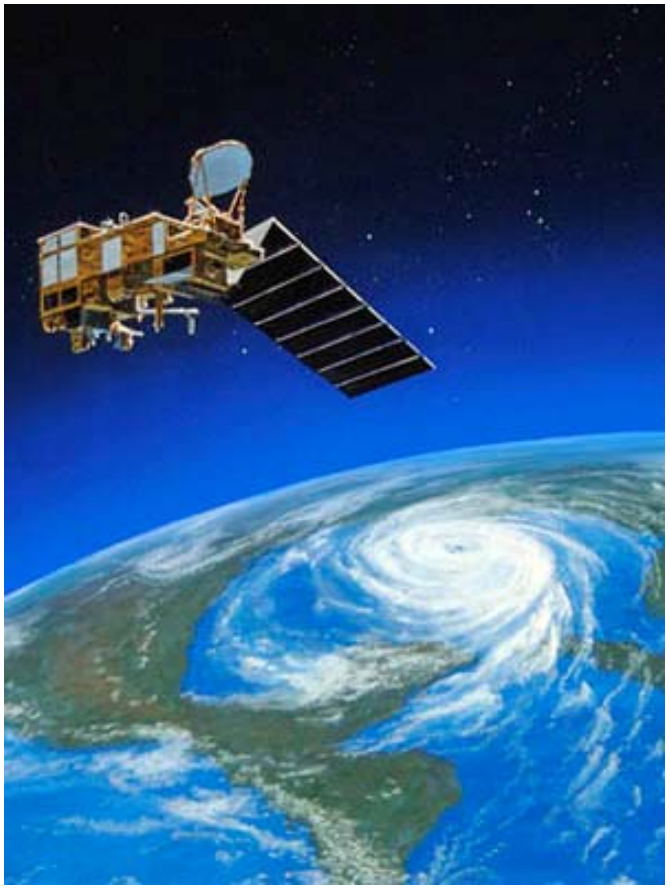
VIIRS visible (top) and true color composite (bottom) imagery from August 28, 2012 @ 2015UTC demonstrating smoke detection capabilities available to forecasters with VIIRS data in AWIPS

Data Access

Use of NASA satellite data in this way by the community is facilitated by

- Access to full resolution data (large data volumes) in real-time data (direct broadcast capabilities / reception)
- Rapid product generation (CSPP/IMAPP) and dissemination capabilities (data servers, sub-setters, WMS) including cloud resources
- Near real-time data archives and search ability
- Ability to integrate data with end user needs to address problem

Ultimate goal is to transition NASA experimental and research capabilities to operational agencies and decision makers for societal impact



Direct broadcast capabilities on many NASA satellites and open data policy facilitates use by hundreds of groups with X-band receivers around the world

NASA R2O Centers

In 2002, NASA established several projects to facilitate use of real-time use of Eos data for weather applications and societal benefit

Joint Center for Satellite Data Assimilation (JCSDA)

- NASA / NOAA / DoD
- Improvement in 2-10 day global forecasts through assimilation of Eos observations and forecast model advancements

Short-term Prediction Research and Transition (SPoRT) project

- NASA / NWS collaboration
- Improvement in 0-48 hour forecasts on a regional and local scale
- Use of satellite observations for nowcasting, data assimilation in regional models for short term prediction

Short-term Prediction Research and Transition (SPoRT)

SPoRT is focused on transitioning unique NASA, NOAA, DoD observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale.

- Close collaboration with numerous WFOs across the country
- SPoRT activities began in 2002, first products to AWIPS in 2003
- Co-funded by NOAA through "proving ground" activities

SPoRT Paradigm

- Match observations to forecast challenges
- Develop and assess solution in "testbed" environment
- Transition solution to decision support system
- Develop/conduct training, product assessment and impact

Benefit

- Demonstrate capability of NASA experimental products to weather applications and societal benefit
- Prepares forecasters for use of data from next generation of operational satellites (Suomi NPP/JPSS, GOES-R)

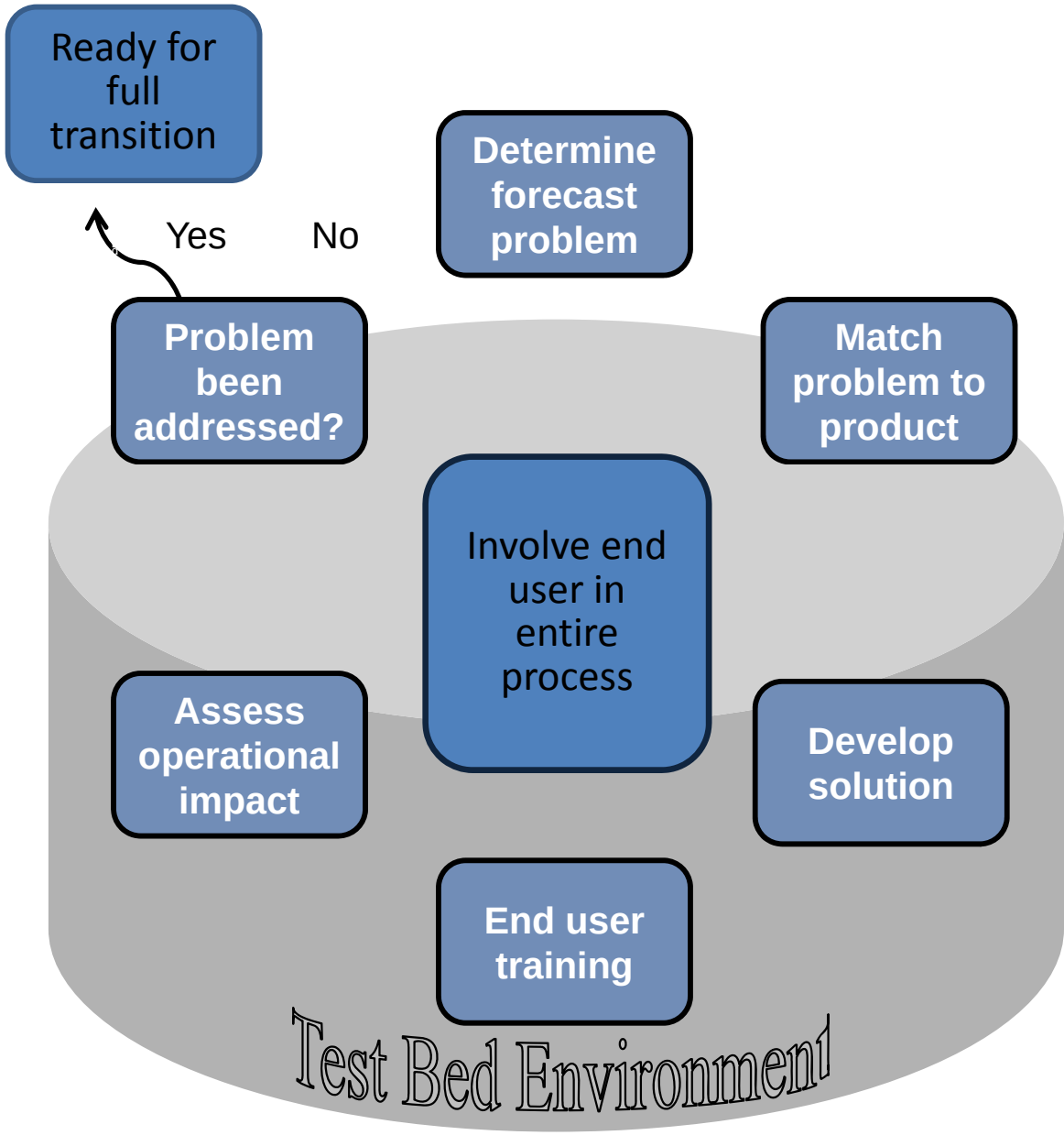
Research Data / Products to "Operations"

SPoRT Paradigm

- match forecast challenge to data/product
- develop solution / demonstrate in "test bed" environment
- integrate successful products into end user's decision support tools
- create product training
- perform product assessment

Maintain interactive partnership with end user throughout process

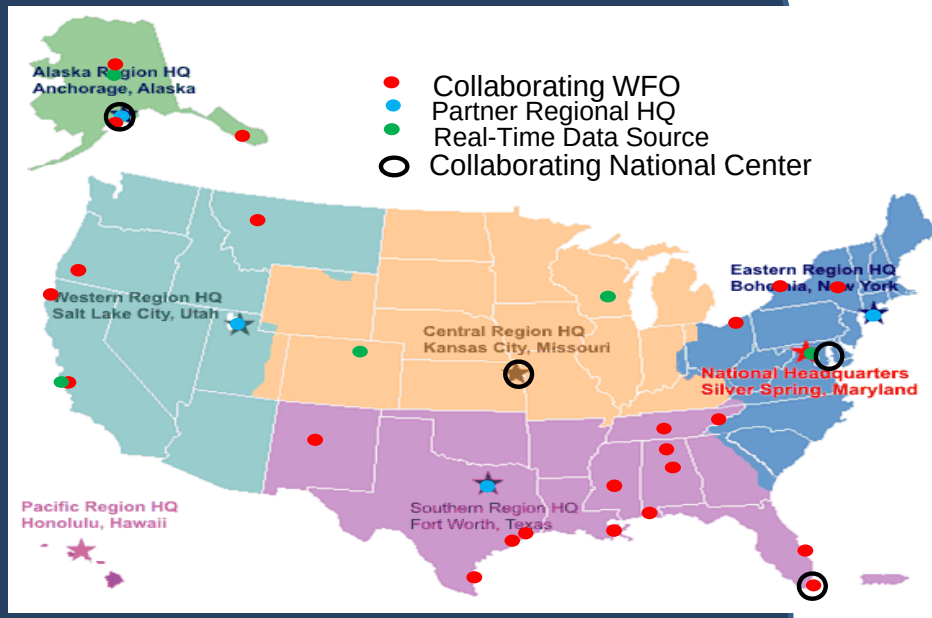
Need local end user advocate



Partnerships and End Users

Partnered with NOAA / University community / DoD

- Access to real-time experimental data / products
- Share expertise and algorithms
- Collaborations with NOAA CIs for GOES-R proxy products



End users

- Regular interactions with 24 WFOs
- National Centers and "testbeds"
- Private sector users

Data / transition / dissemination

- Suite of over 40 satellite derived products, analyses, forecast products
- Public ftp, Local Data Manager (LDM), WMS
- AWIPS, NAWIPS, AWIPS2, Google Earth, and others

Source of SPoRT Data and Products

Collaborative interactions with direct broadcast facilities at UW/SSEC/CIMSS, UAF/GINA – CSPP / IMAPP for processing and product production

- MODIS, AIRS, VIIRS imagery
- ADDE servers for sub-setting and dissemination

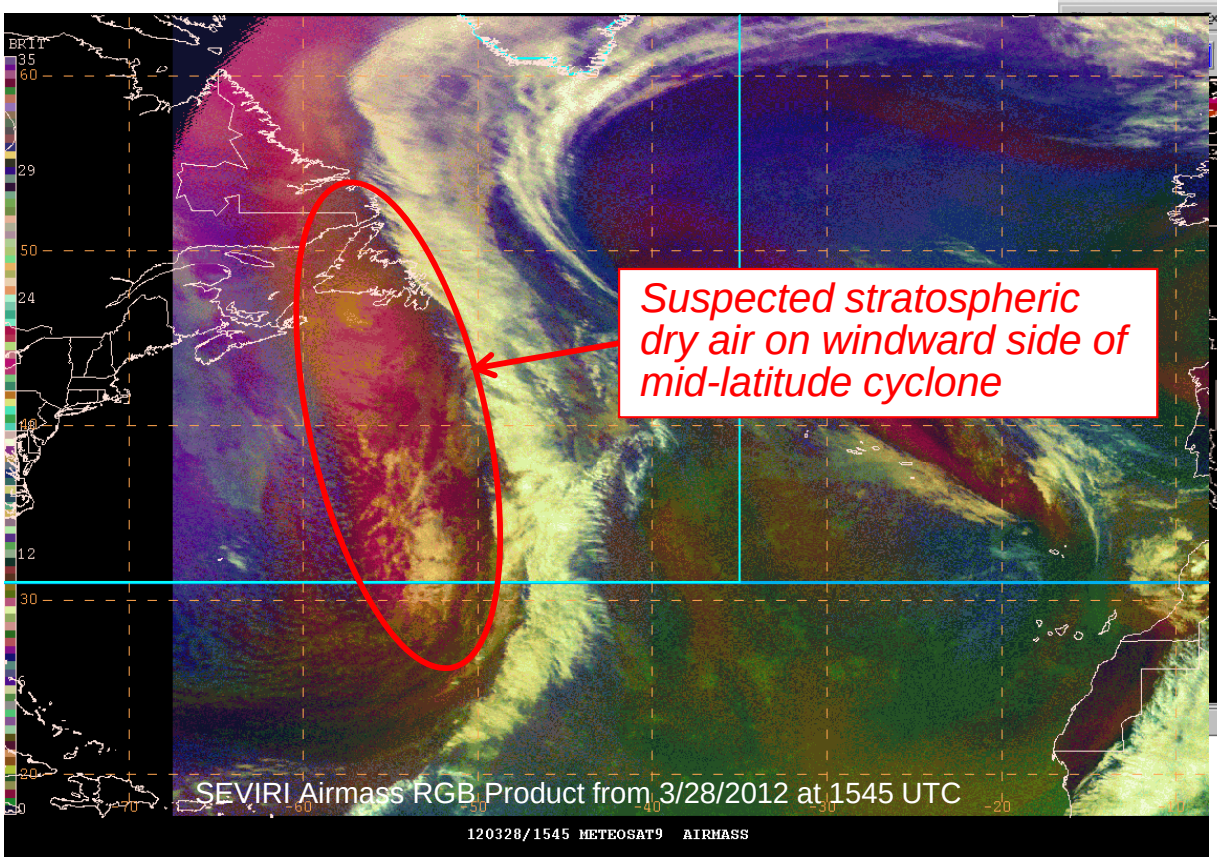
Land Atmosphere Near-real time Capability for EOS (LANCE)

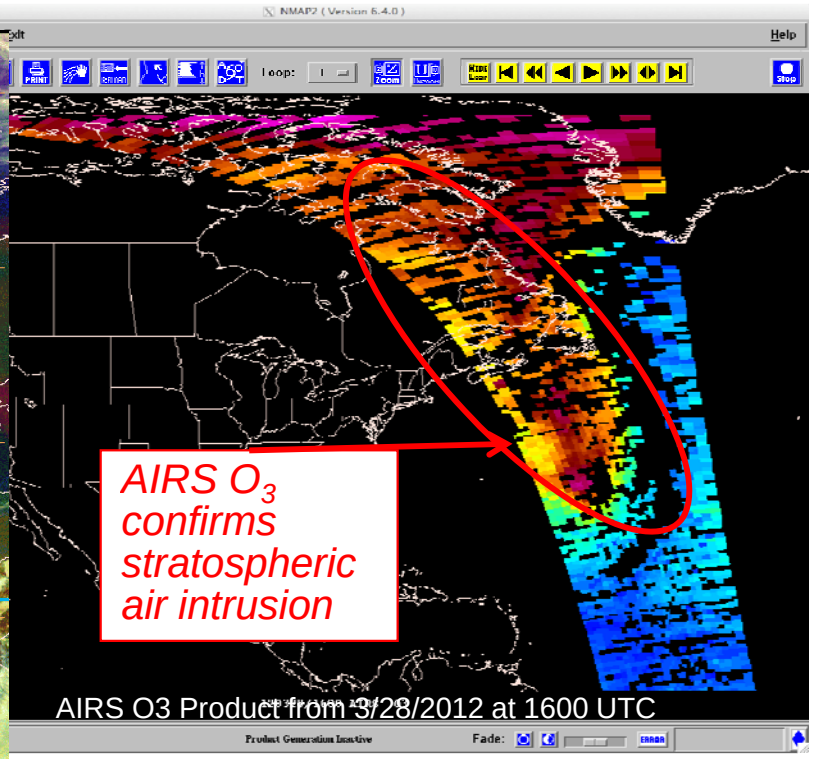
- Selected data and products (non-CONUS)

DoD and NESDIS near real-time data stores

Internally generated product suite based on LANCE and DB level 1 / 2 data streams

Selected SPoRT Accomplishment: Operational Use of AIRS Total

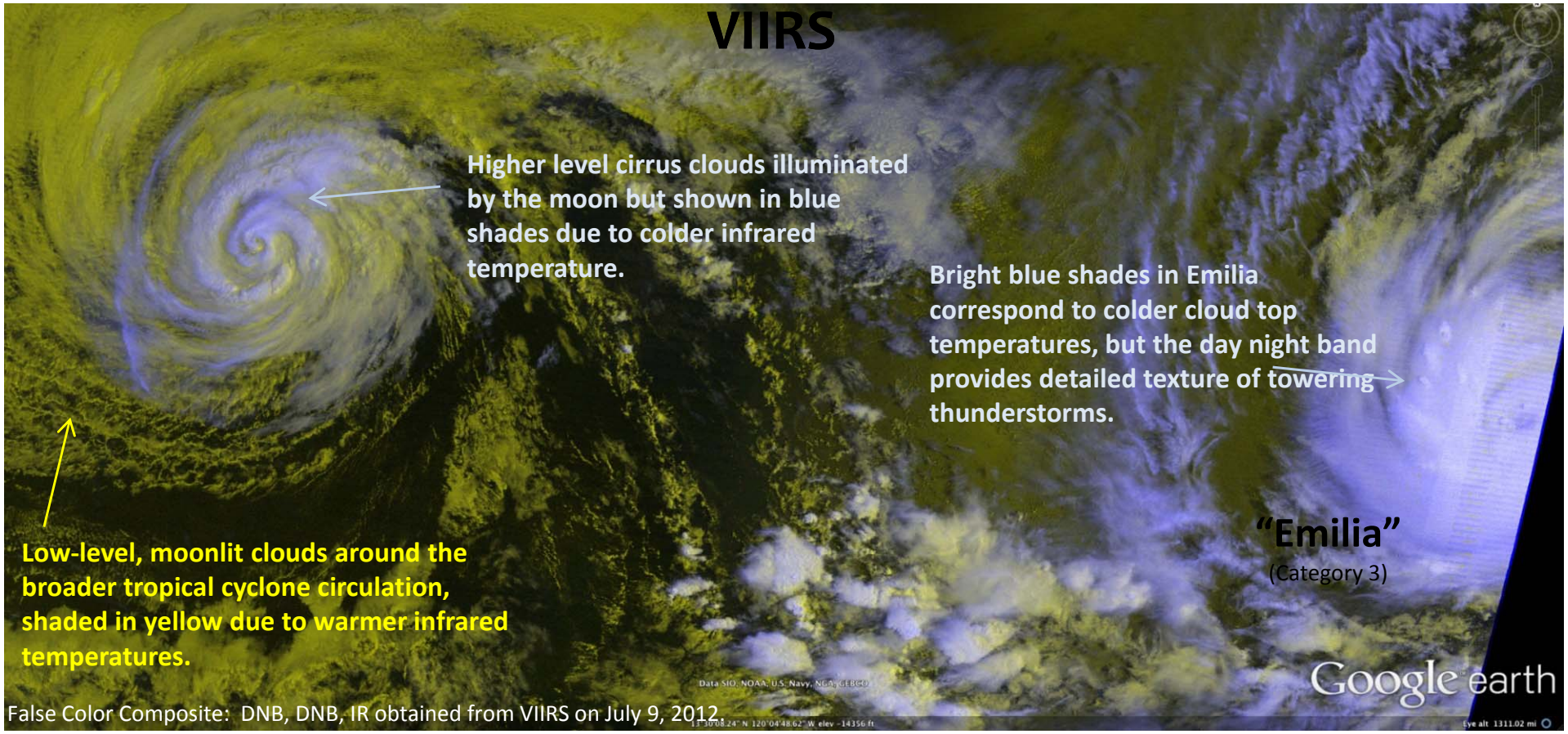




Courtesy of Bradley Zavodsky (MSFC), Andrew Molthan (MSFC), and Michael Folmer (NOAA/NCEP/OPC)

- Multispectral imagery (e.g. RGB airmass) is used by the National Centers for Environmental Prediction (NCEP) to detect stratospheric dry air associated with cyclone development
- Total ozone from AIRS is used to verify the presence of stratospheric air and may be able to quantify magnitude of intrusion
- SPoRT is providing both the RGB airmass and AIRS O_3 product to Hydrometeorlogical Predication Center (HPC) and Ocean Prediction Center (OPC) in N-AWIPS
- Future applications to ozone from CrIS and OMPS

Moonlit Hurricanes Daniel and Emilia as seen by S-NPP

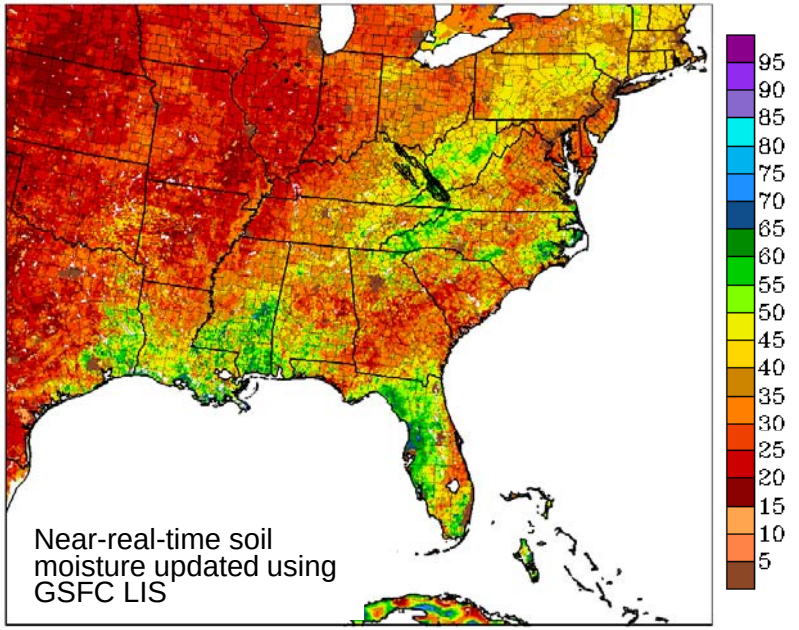


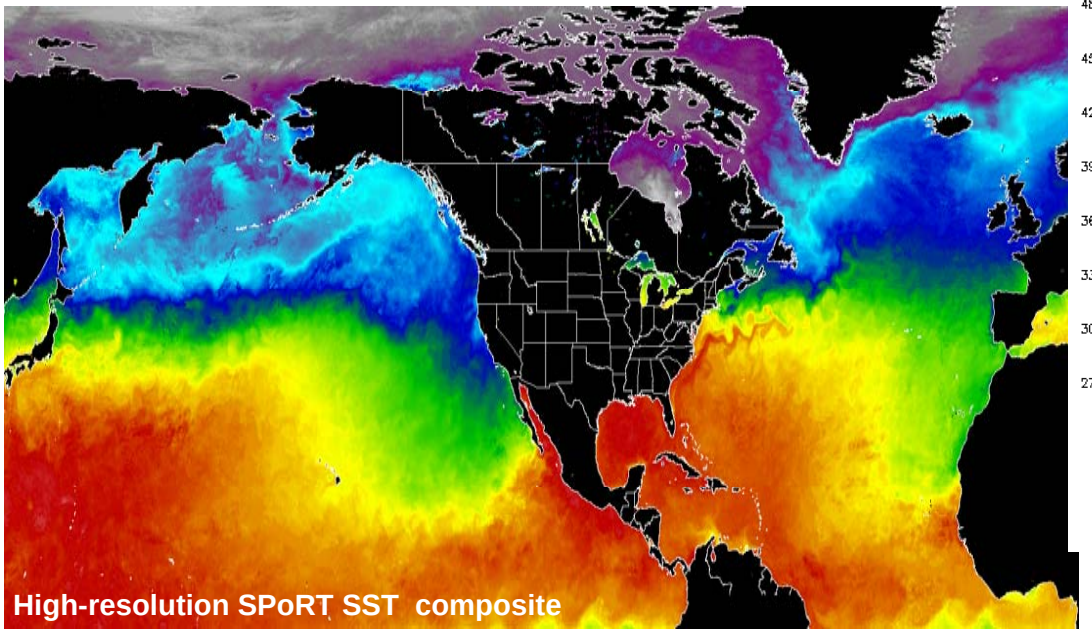
False Color Composite: DNB, DNB, IR obtained from VIIRS on July 9, 2012.

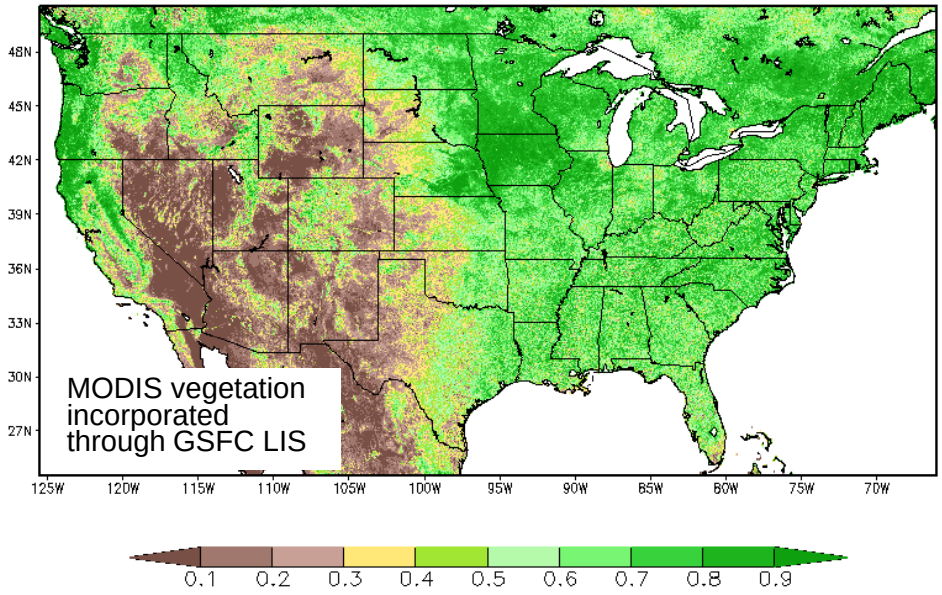
- SPoRT is transitioning the use of VIIRS data to National Weather Service operations, including use of a near constant contrast product derived from the new "day-night band (DNB)", which provides imagery from reflected moon light, city lights, and fires.
- Collaboration with the NRL provides this false color composite using the day-night band and infrared data to enhance the appearance of tropical cyclone features.

NASA Dataset Use in NWS Local Models

- **NOAA National Weather Service (NWS) forecast offices support daily high-resolution local models through an end-to-end Environmental Modeling System (EMS)**
- **SPoRT has worked with EMS developers to incorporate SPoRT SST, MODIS vegetation, and land surface model output from GSFC's Land Information System (LIS)**
- **Ongoing collaboration with multiple NWS offices to actively evaluate NASA data impact on local EMS forecasts including transition of objective model verification scripts**



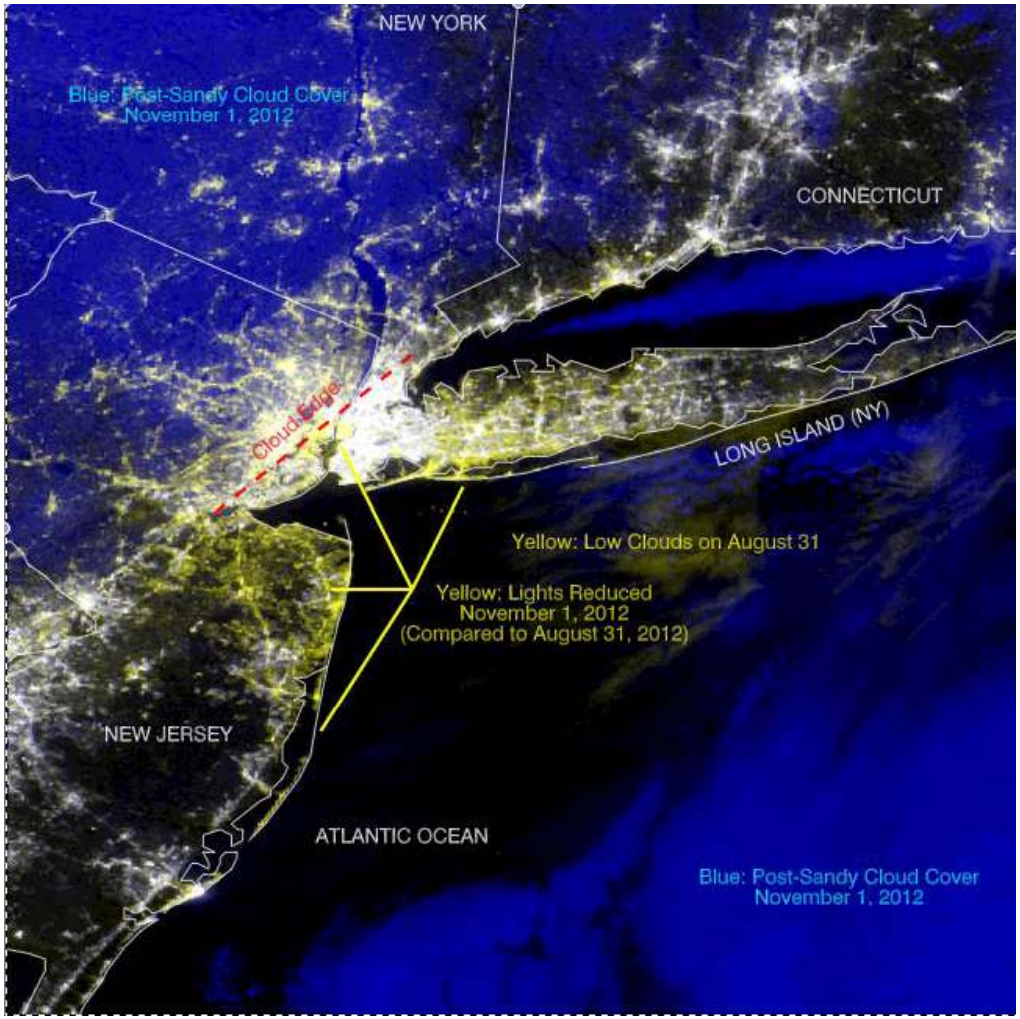




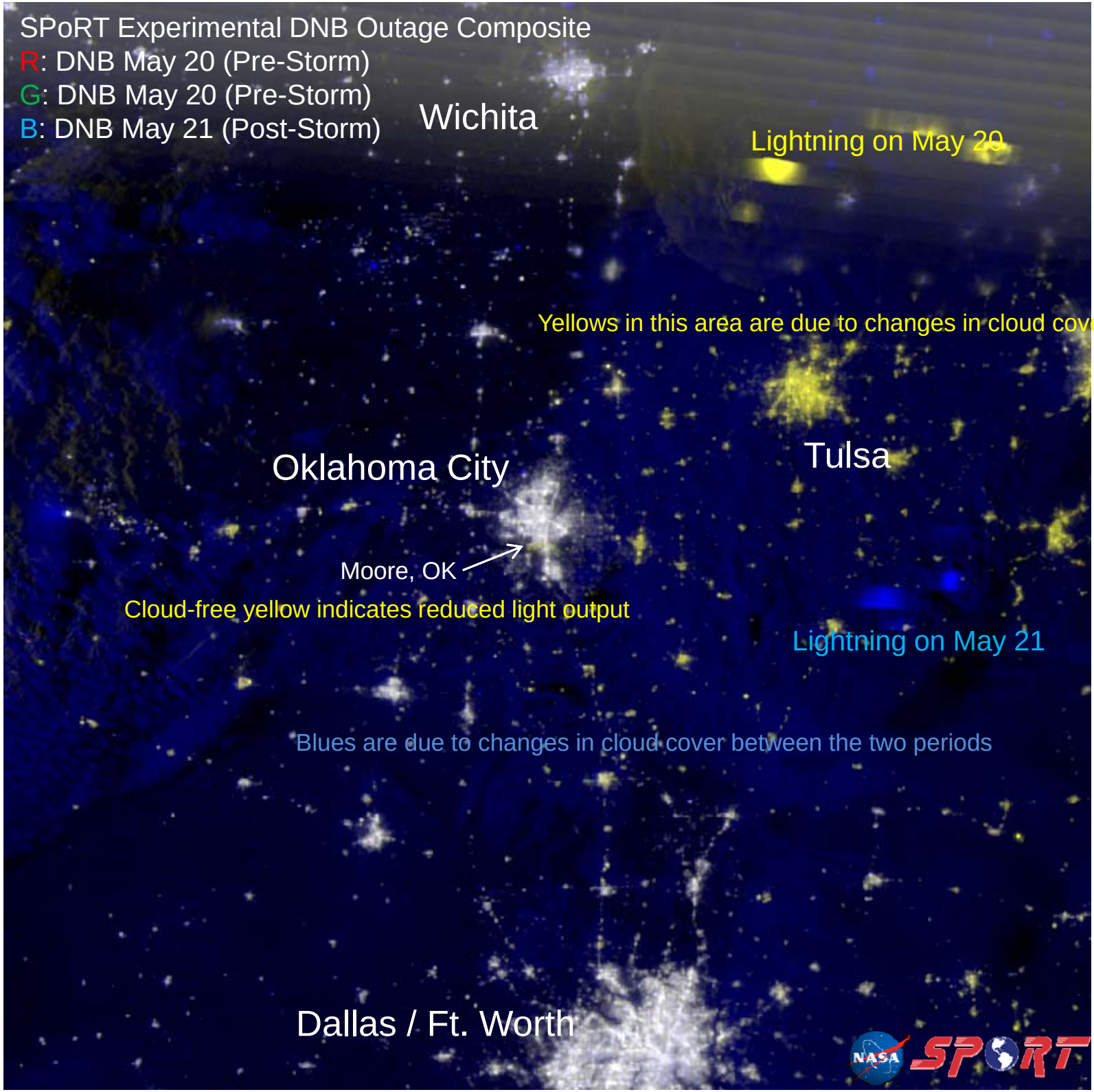
VIIRS "Blackout" Product for Disaster Applications

VIIRS day-night band (DNB) used to monitor city lights before and after power outages from Superstorm Sandy

- Pre-storm data from August 31 combined with post-storm data from November 1 is a color composite image
- Pre-storm "reflectance" data used in red and green channels, post-storm in blue channels
- "bright" sources in pre-storm data but not in post-storm data show up as yellow



VIIRS "blackout" product provided to USGS data portal and used by U.S. Army NorthCom, FEMA, and other relief agencies to stage resources


SPoRT Experimental DNB Outage Composite
R: DNB May 20 (Pre-Storm)
G: DNB May 20 (Pre-Storm)
B: DNB May 21 (Post-Storm)
Wichita
Lightning on May 20
Yellows in this area are due to changes in cloud cover
Oklahoma City
Tulsa
Moore, OK
Cloud-free yellow indicates reduced light output
Lightning on May 21
Blues are due to changes in cloud cover between the two periods
Dallas / Ft. Worth
NASA
SPORT

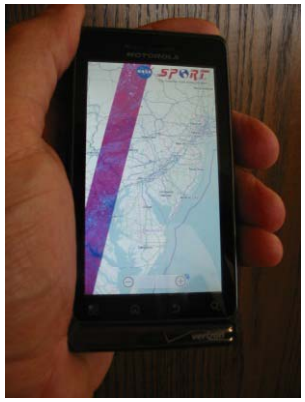
Web Services to Support Disaster Applications

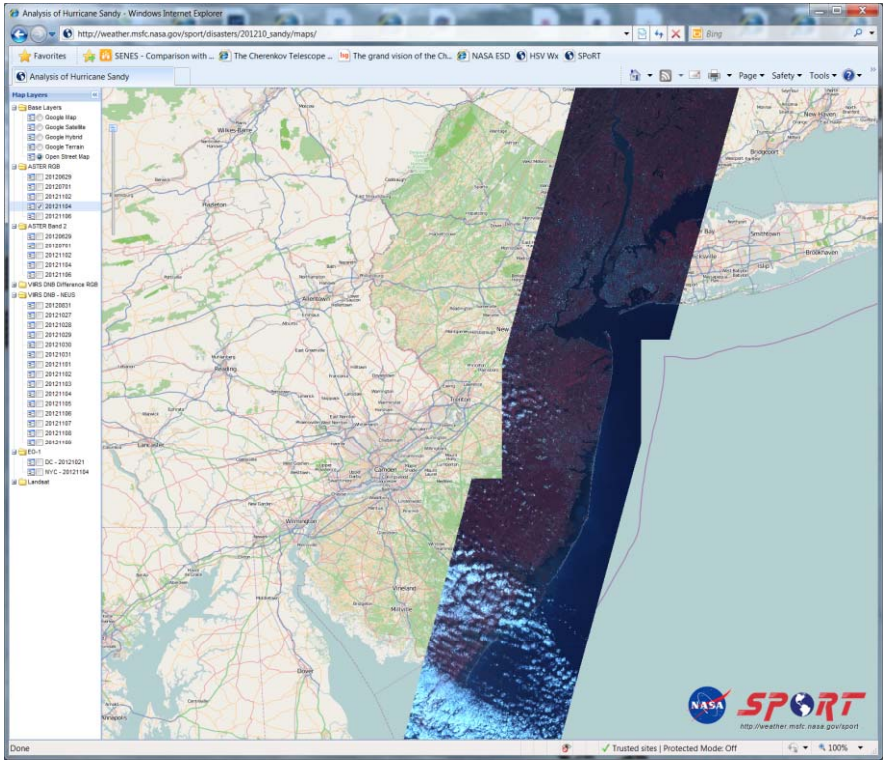
Need for access to real-time data and products supporting disaster applications "anytime and from any place"

Direct broadcast and near real-time capabilities key to success

SPoRT Web Services

- tiled imagery for a "Google Earth" roam and zoom
- web-based applications - tiled web service link
- Android and Iphone "apps"





GeoServices Infrastructure for Real-Time Access to Satellite Data

Develop a suite of software that couples direct broadcast data feeds with a streamlined, scalable processing chain and geospatial Web services

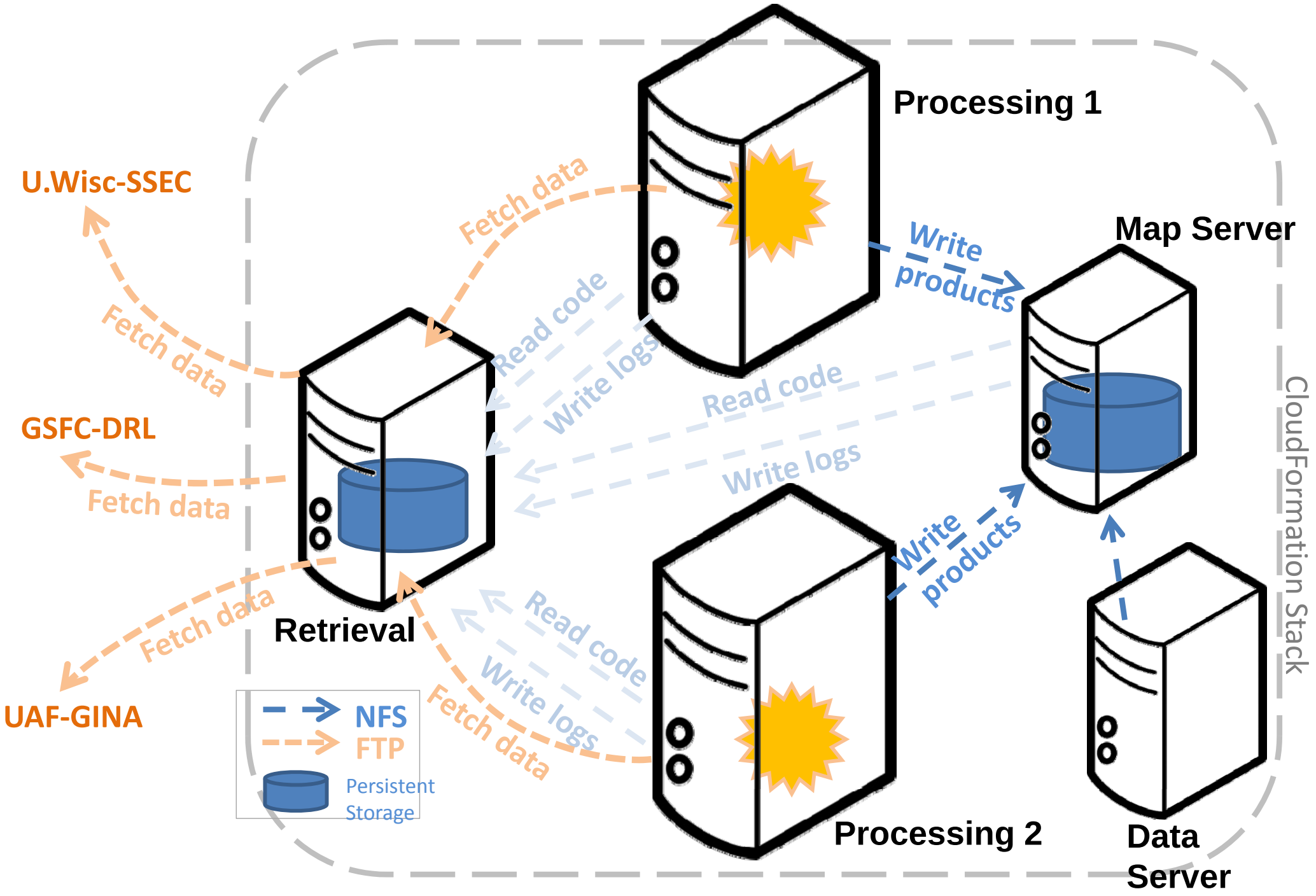
Permits many more time-sensitive applications to NASA satellite data

- use well-known, standard software interfaces such as OGC Web Services or OPeNDAP) – runs "in the cloud"
- serves a variety of end-user analysis and visualization tools,
- giving end user access into datasets of arbitrary size and resolution
- allows users to request and receive tailored products on demand (uses CSPP and IMAPP product routines)

John D. Evans, Eduardo G. Valente, Jr., Wei Hao, and Samir R. Chettri

Global Science & Technology, Inc. (GST) Greenbelt, MD

Scalable, Cloud-based Implementation



Example Products – MODIS/VIIRS

Individual channel imagery

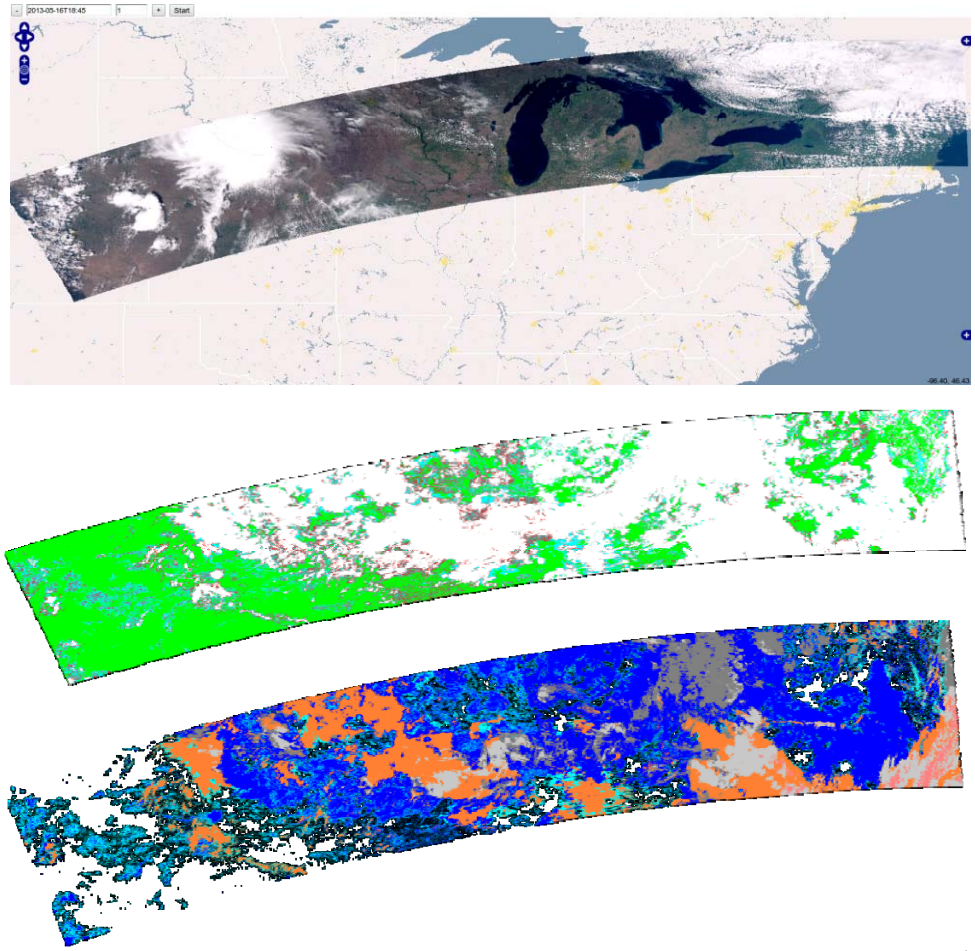
Aerosol Optical Depth

Cloud Mask

Cloud Top Pressure

Cloud IR Phase

Water Vapor / TPW



Rendered as GeoTIFF and serve them via Web Map Service (WMS)

John D. Evans, Eduardo G. Valente, Jr., Wei Hao, and Samir R. Chettri

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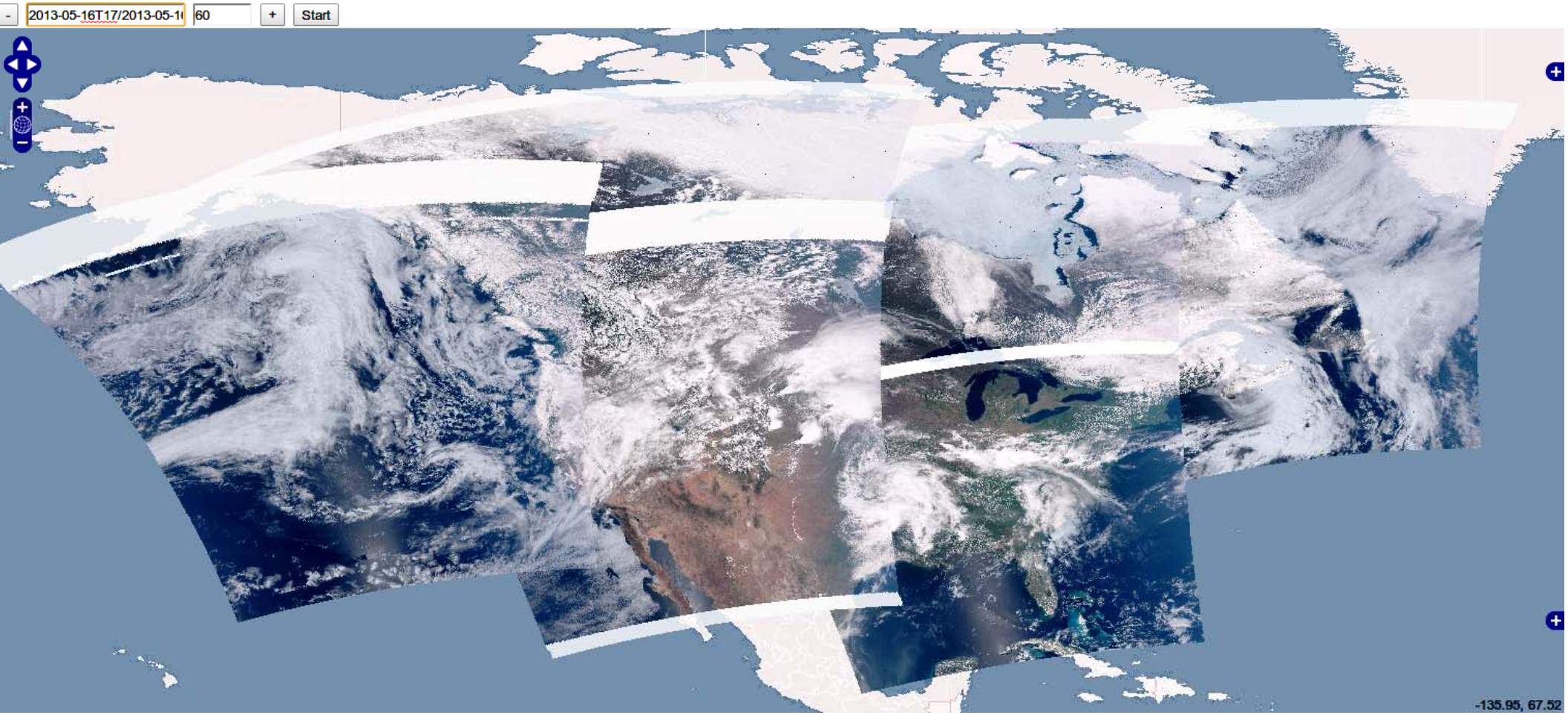
Interactive, Real-time Map Server



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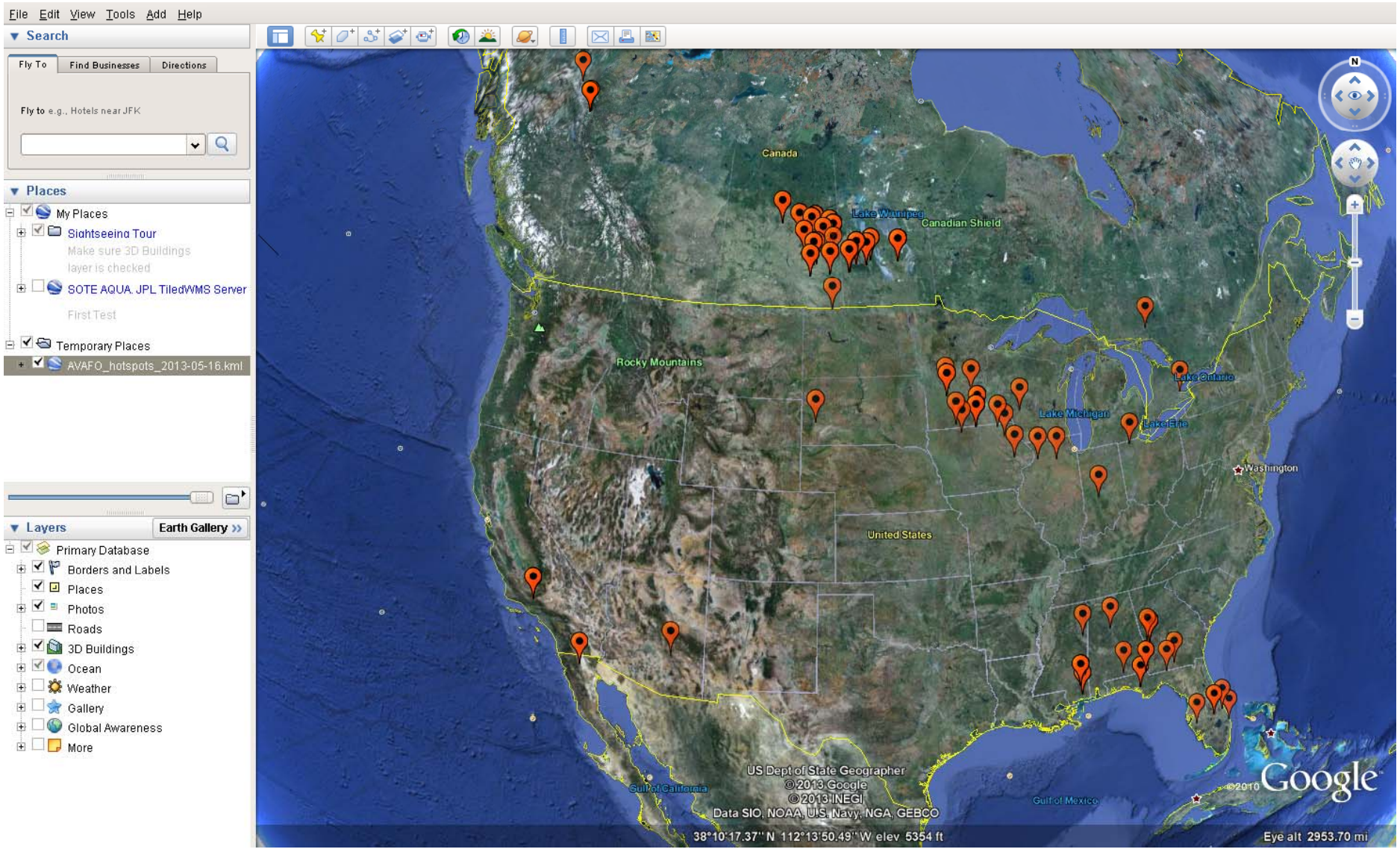
Global Science & Technology, Inc. (GST) Greenbelt, MD

CSPP EDR: Active Fires (AVAFO)



VIIRS Active Fire Hotspots

KML points extracted from CSPP Active Fires (AVAFO) EDRs, 2013/05/16

Taking Advantage of Cloud Computing

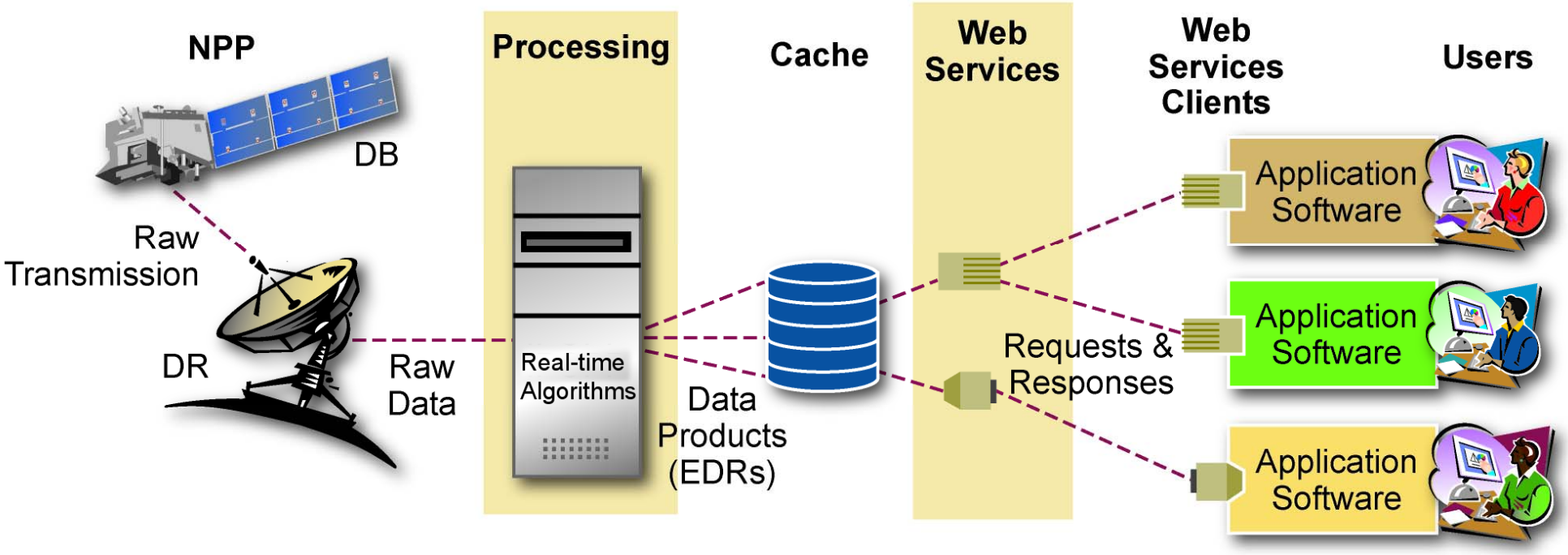
- Virtual computing
  - Retrieval, Processing, Map, Data servers
  - Each launched from stored virtual machine images
  - Provide persistent workflow details at launch time
  - Distribute loads across multiple servers if needed
  - Use larger or smaller instance types as needed
- Run (and pay for) servers only when needed
  - Instances can be started and stopped in minutes
  - Take advantage of spot pricing

Optimizing costs and performance

- Orbit-driven computing schedules
  - Launch virtual machine(s) based on each day's predicted overpass times
- Data-driven ("just-in-time") usage
  - Launch virtual machine(s) when new data found

- Use of Amazon "Spot Instances"
  - (Bid on unused computing capacity)
  - Hourly costs are typically 70-85% less **… but …** price spikes may terminate an instance at any time
    - Software must be able to resume interrupted workflows
  - Allows use of powerful virtual machines at low cost

Case study: Near real-time workflow



Case study: data streams

- *Gearing up:* Aqua MODIS Direct Broadcast
  - Using data and software from NASA's Direct Readout Laboratory (DRL)

http://directreadout.sci.gsfc.nasa.gov

  - *In particular:* International Polar Orbiter Processing Package (IPOPP)

- *Target:* Suomi-NPP Direct Broadcast
  - Suomi-NPP launched in 2011 launch
  - Direct Broadcast a vital alternative to the NASA/NOAA ground system

Use case: weather forecasting

- Working with NASA's Short-term Prediction Research and Transition program

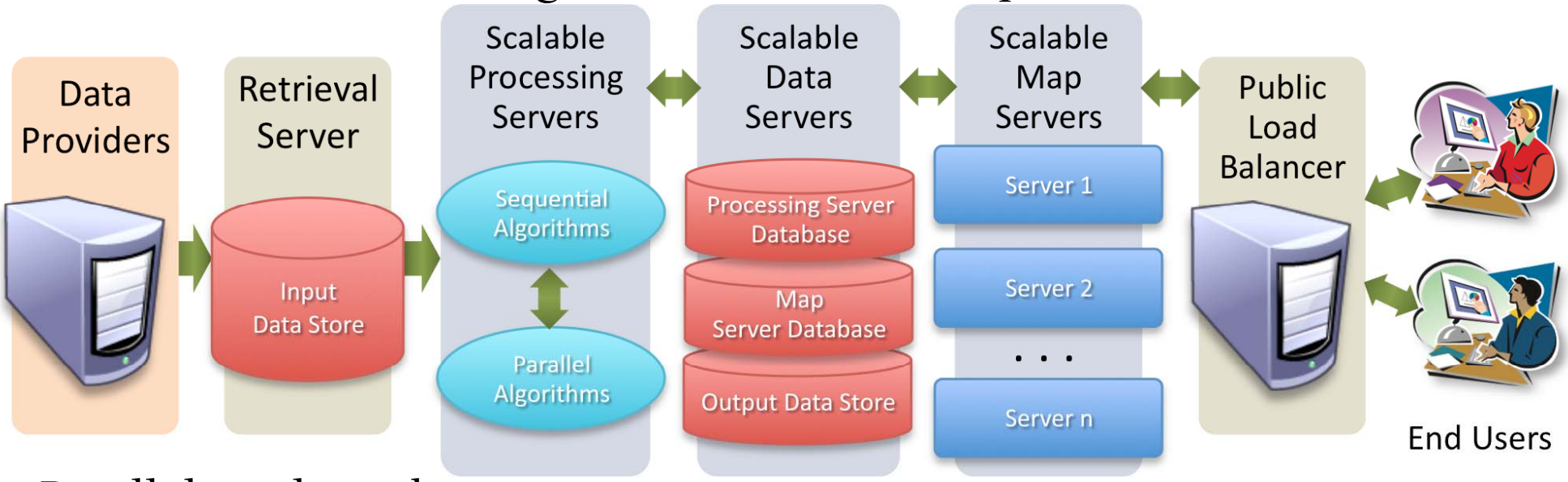
  http://weather.msfc.nasa.gov/sport

Why we went to the cloud

- Our in-house proof-of-concept quickly showed that
  - We would need a lot more bandwidth
  - We might need a full-blown data center for peak loads
  - Ensuring real-time throughput cost-effectively is hard
- Cloud Computing offered a way to
  - Get a lot of bandwidth on demand
  - Grow our computing capacity easily
  - Try out a variety of configurations without risk
- Infrastructure as a Service (IaaS) offered an easy transition
  - Amazon Elastic Compute Cloud (EC2)

Ways to improve performance

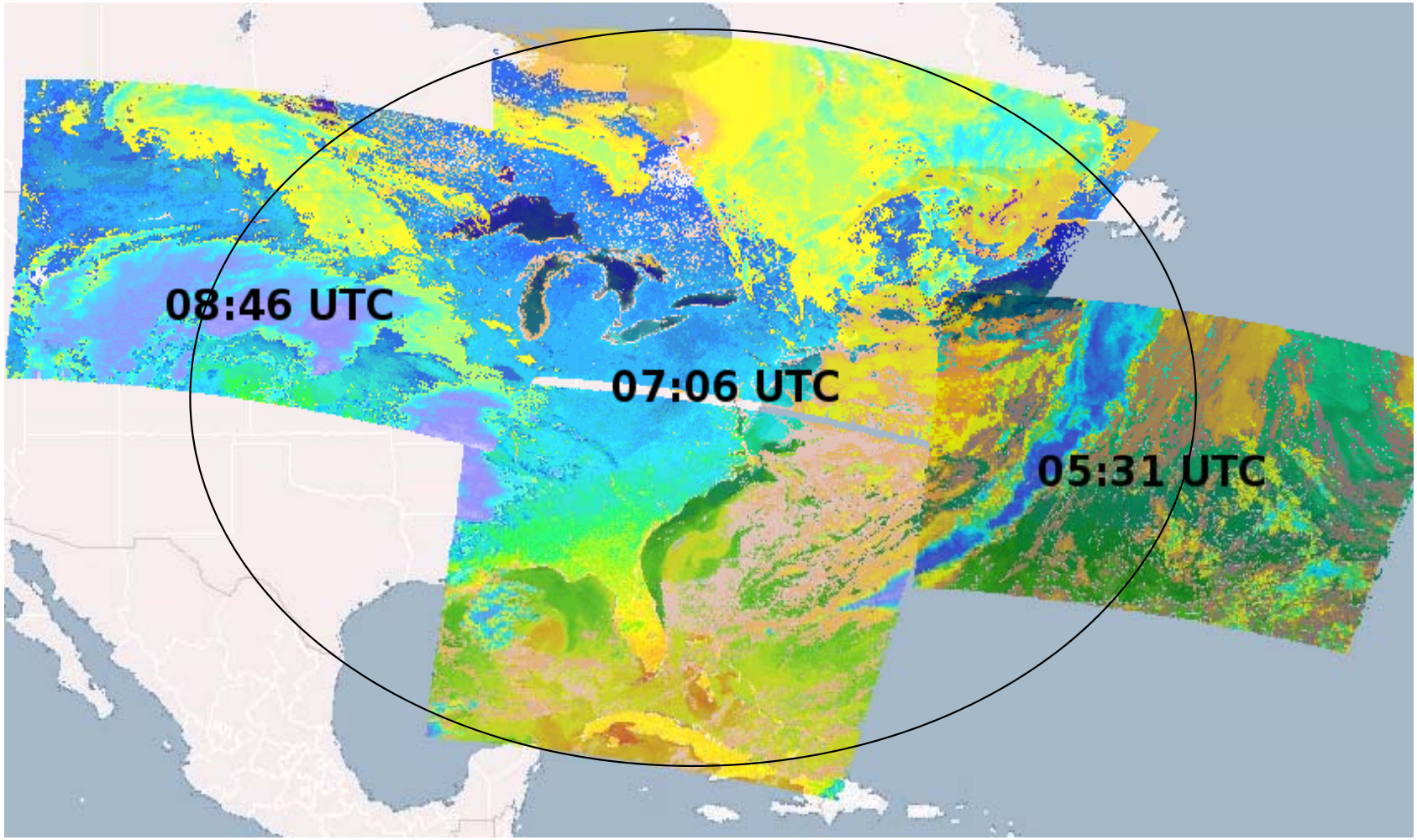
- Optimize IPOPP algorithm scheduling
- Use lots of fast CPU cores to handle backlogs
- Distribute services & algorithms across multiple machines



- Parallelize algorithms
- Compile algorithms to run on GPUs
- Streamed data / streamed processing

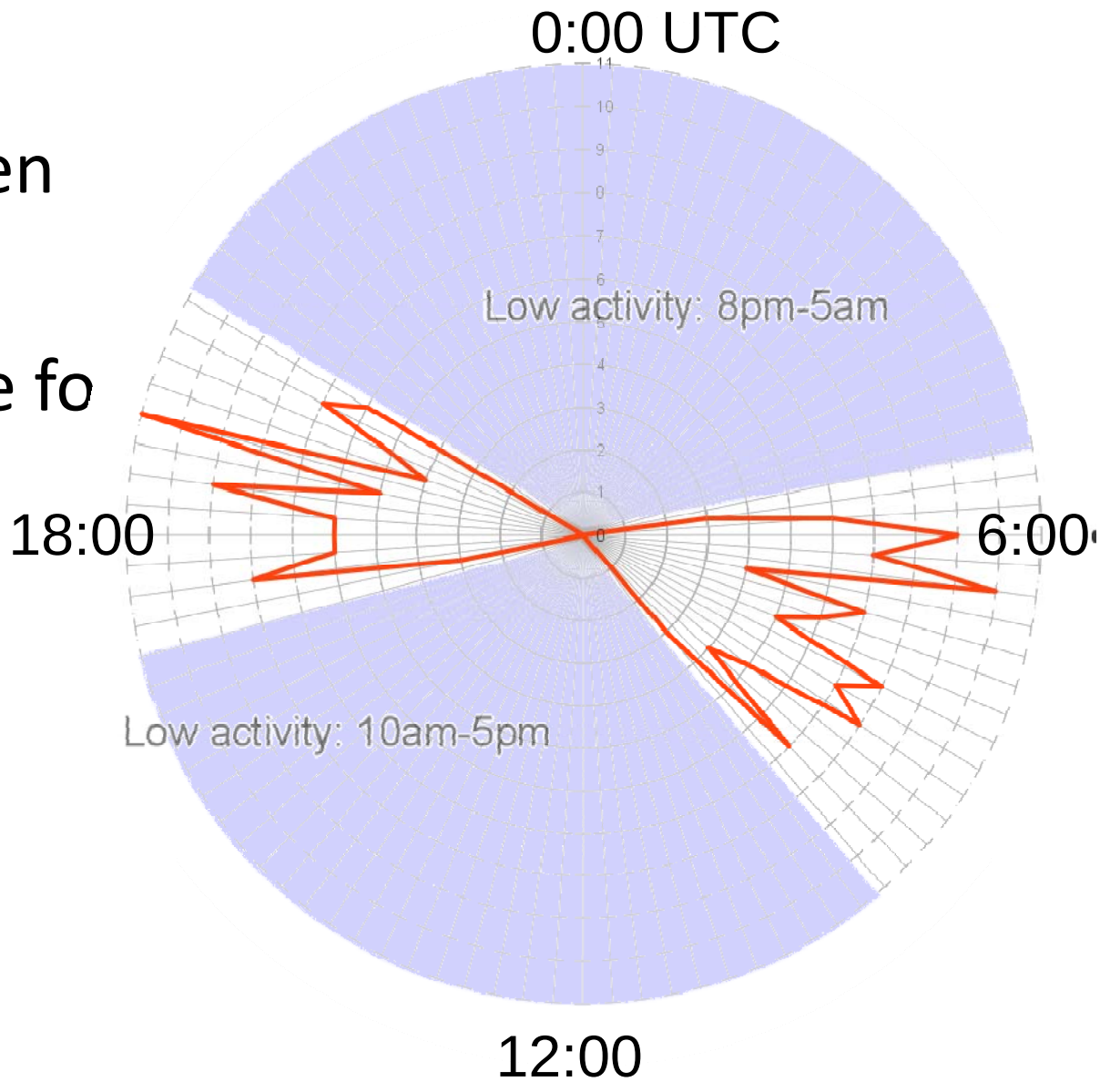
Daily cycle of data supply (& demand)

One morning's Direct Broadcast from NASA's Aqua satellite to a receiving station in Greenbelt, MD



Daily cycle of data supply (& demand)

- 2-3 overpasses, twice a day
- Scale down between overpasses
- Scale up just in time fo next overpass



Case study summary

- Proof of concept
  - Infrastructure as a Service made for a quick & easy transition
- Task effectiveness
  - Tried many different instance types @ low cost, no risk
  - Reduced latency from ~40 minutes to ~12
  - Significant add'l performance is clearly within reach
  - Gained significant bandwidth
- Cost effectiveness
  - Cloud computing costs are complex and significant

    (But so are data center costs)
  - Elastic provisioning and utility pricing worked well for us
    - Scaling up & down 2x/day will shrink our costs by 60+%

Cloud Computing Study Summary

- Elastic computing may suit CDR well
- Bandwidth may be a showstopper for traditional system design (archive-network-processing)
- Data-intensive science: “Scaling out”
  - Massive parallelization of data and processing
  - Eliminate gratuitous data movement
  - Look at other petabyte-scale projects (science, Web)
- Getting started on the cloud is easy; but making the most of it may require rethinking things
  - Approaches to storage and computation
  - System and network architectures
- NASA has started a cloud computing working group led by Andrew Molthan of SPoRT to research and develop a cloud enabled software stack.