The NASA Short-term Prediction Research and Transition Center and a Paradigm for Engaging Stakeholders

AOS Applications Seminar Series

17 November 2021

Emily Berndt[1,2], Aaron Naeger[2,3], Anita LeRoy[2,3], and Aaron Jacobs[4]

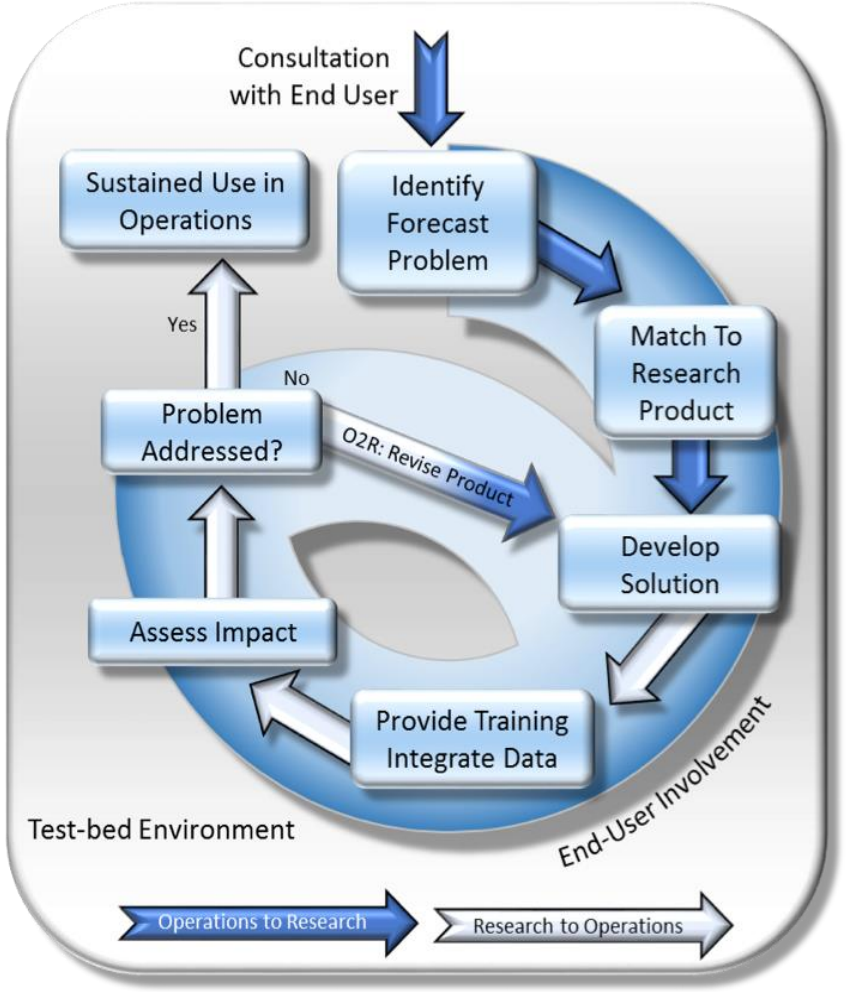
[1]NASA Marshall Space Flight Center, [2]Short-term Prediction Research and Transition Center,
[3]University of Alabama in Huntsville Earth System Science Center,
[4]NOAA National Weather Service Juneau Alaska

NASA SPoRT Overview

SPoRT was established in 2002 in the Weather Focus Area with a focus on transitioning unique NASA satellite observations and research capabilities to end users to improve short-term operational weather forecasting and decision support.

The SPoRT paradigm (right) has been used to successfully *'transition'* over 40 satellite datasets and research capabilities to operational users for nearly 20 years.

- SPoRT has built and maintained a strong relationship between NASA and NOAA/NWS. The project actively collaborates and provides support to over 30 NWS offices in all 6 NWS regions and multiple NWS National Centers (e.g., WPC, SPC, AWC, OPC, NHC).
- SPoRT's user-focused "research-to-operations" and "operations-to-research" paradigm and applications-based training concepts have been adopted by other groups nationally and internationally.
- SPoRT remains focused on applying and utilizing its "research-to-operations" paradigm to support the current suite of NASA satellites, Early Adopter Programs and upcoming future missions, with a focus on future missions related to the Earth System Observatory.



An iterative process between scientists, algorithm/product developers, and end users is key to transition of research to the community of end users.

SPoRT Decade Review: 2010-2019

NASA SPoRT Team Structure

Over the past several years, SPoRT has been broadening its reach and has begun to apply its known "research-to-operations" paradigm to a number of new partners that can benefit from the integration of unique NASA satellite observations and research capabilities.

Current SPoRT "research-to-operations" Thematic Areas:

Research Areas:

- Tropical Meteorology
- Atmospheric Remote Sensing
- Lightning/ Convection
- Air Quality / Human Health
- Land Surface Remote Sensing
- Machine Learning

Transition Activities:

- End-User Training
- Product Assessments
- Data Production

Current Partners

NOAA National Oceanic and Atmospheric Administration, U.S. Department of Commerce

National Weather Service

USDA

SERVIR

Forest Service, U.S. Department of Agriculture

USGS science for a changing world

National Drought Mitigation Center, University of Nebraska

Smithsonian

FEMA

National Guard

United States Environmental Protection Agency

CAL FIRE Since 1885

U.S. Department of the Interior, Bureau of Reclamation

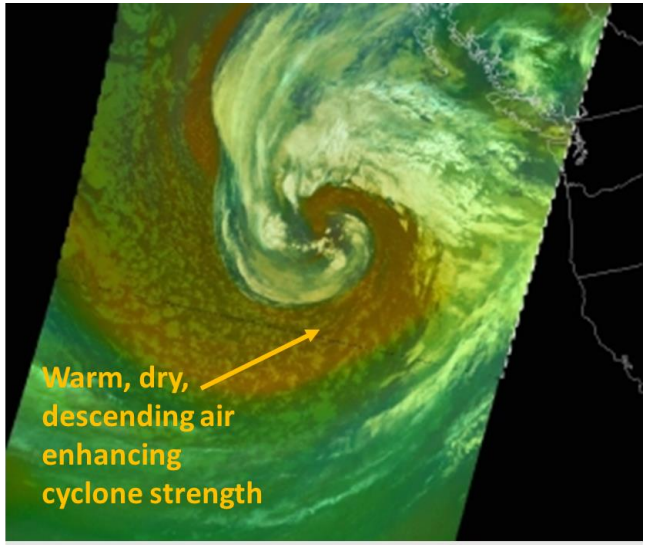
AICC

Remote Sensing – Multispectral Imagery

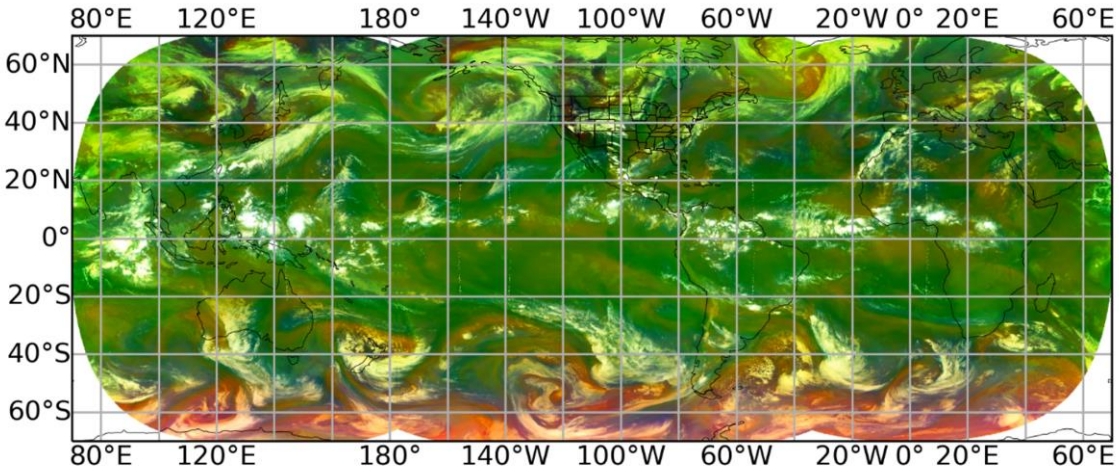
Project Objective: Development and refinement of multispectral composite (e.g., RGB) imagery to support weather forecasting applications and applied research. Early focus on use of NASA data to prepare forecasters for GOES-R and development of innovative display capabilities.

Cross-Benefit of Science/Applications:

- Operations to research feedback led to development of additional RGBs, refinement of recipes, and intercalibration/limb-correction methods
- Interaction with World Meteorological Organization experts and NOAA NWS to guide RGB standards
- Development of applications training including SPoRT applications library, modules, and contributions to official GOES-R NWS training
- Data from GOES-R receiving station at MSFC provide low latency RGBs to NASA's Worldview and NOAA NWS National Centers



Aqua MODIS RGB Air Mass image from 1130 UTC on 23 Sept. 2014



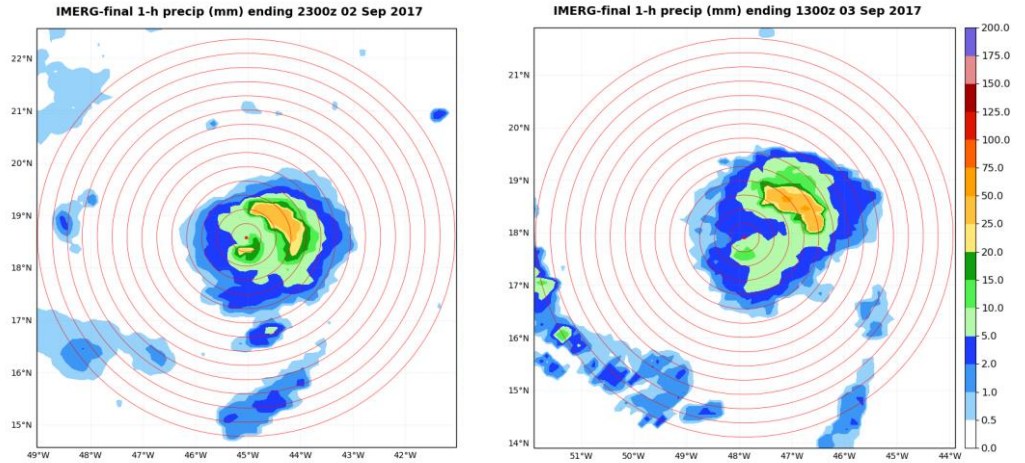
Example of limb corrected and intercalibrated Air Mass RGB, globally composited AMI, AHI, GOES-17, GOES-16, and SEVIRI

SPoRT Lead / PI: Emily Berndt

Funded by NASA Research Announcement NNH19ZDA001N-ESROGSS ROSES-2019

Tropical Meteorology – Tropical Cyclone Diurnal Cycle

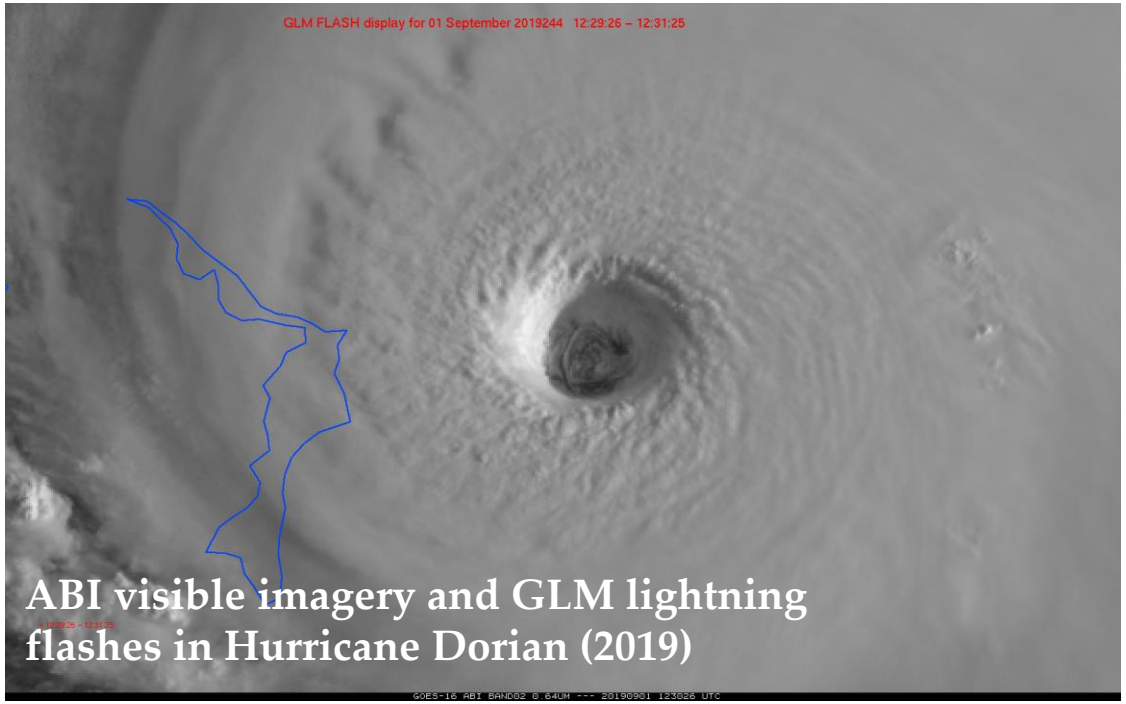
Project Objective(s): Recent studies have documented a distinct expansion/contraction of tropical cyclones (TCs) throughout the day, called the TC diurnal pulse. SPoRT seeks to advance our understanding of these diurnal pulses using remotely sensed observations of thermodynamic soundings, rainfall, wind speed, and lightning, alongside idealized numerical modeling.



GPM IMERG reveals an expanding rain field associated with the TC diurnal cycle.

Cross-Benefit of Science/Applications:

- Leverage observations from the GPM mission and future TROPICS and AOS missions to characterize the diurnal pulse of TC convection and rainfall.
- GPM IMERG rainfall and CYGNSS winds help to diagnose changes in storm structure
- Characterize the variability in lightning flash characteristics across the TC diurnal pulse using GLM.
- Create real-time diagnostics of TC rainfall and lightning using GPM and GLM.
- Synergy with Applied Sciences TROPICS DPA and Early Adopter roles
- Interaction with existing partnerships with NOAA NWS, NOAA's Hurricane Research Division (HRD), NCAR, and University researchers



SPoRT Lead / PI: Patrick Duran

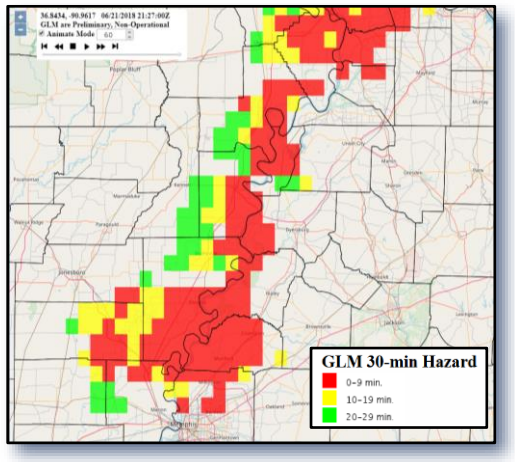
Lightning/Convection - Lightning Safety

Project Objective: Improve and refine lightning safety metrics to take advantage of new technologies

Cross-Benefit of Science/Applications:

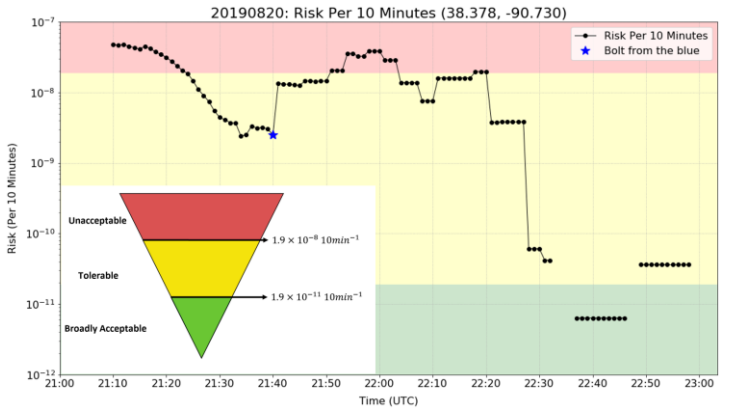
- Improvement of lightning safety methodologies leads to time and cost savings, and reduced down-time and false alarms
- Methods are applicable to all NASA Centers, the public, and eventually the globe.
- Continue the development of machine learning methods to predict lightning initiation, propagation and cessation, and expand globally in next decade.
- Utilize microwave (e.g., GPM, TROPICS, future AOS) information to characterize storm structure at lightning initiation and cessation for areas with poor radar coverage.

SPoRT Stoplight Product



Observed Lightning in the last 30 minutes from GLM near Memphis, TN on 21 June 2018

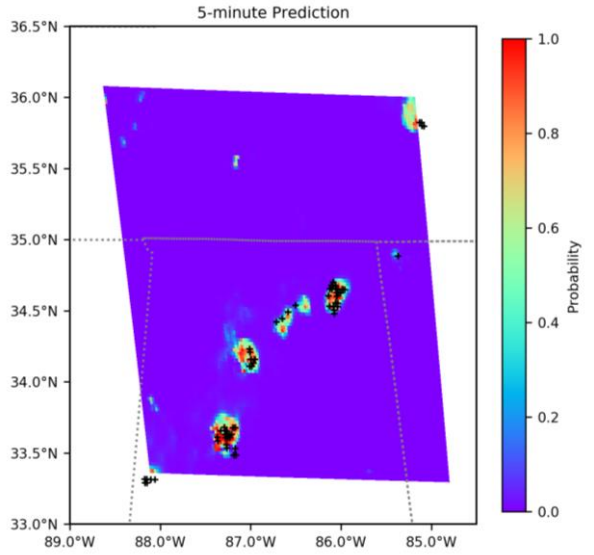
SPoRT Lightning Risk



Time trend of lightning risk at a bolt from the blue incident

ML for short term prediction of lightning

5 Minute prediction of lightning activity (Contours) and verification of lightning occurrence (black + signs)



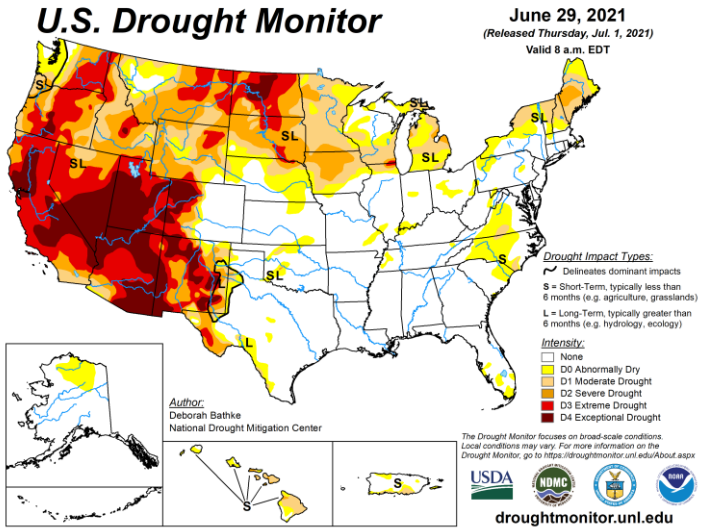
SPoRT Lead / PI: Chris Schultz

Land Surface Remote Sensing - Land Information System

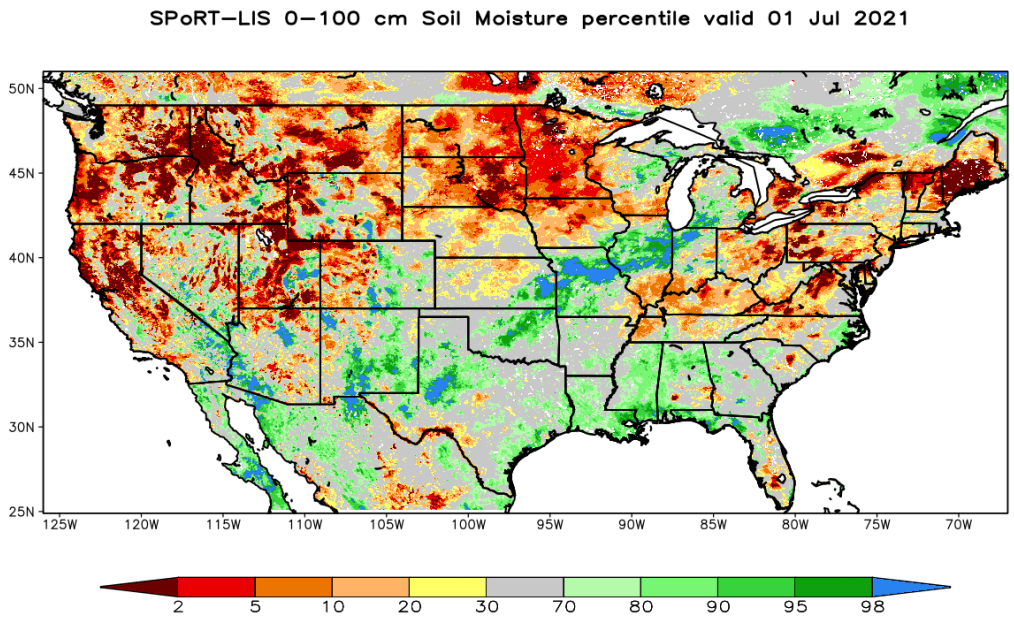
Project Objective: Development of high spatial resolution land-surface fields for improved situational awareness

Cross-Benefit of Science/Applications:

- Multiple end-users in NOAA/NWS (available in 30+ NWS WFO offices), drought monitoring community, wildfire community, private-sector organizations
- Proven vehicle for applications and research activities in flooding, drought, and wildfire research
- Development of applications training for use in flash flood guidance and drought monitoring for improved situational awareness
- Continued transition activities with new stakeholder organizations
- Continued engagement with NASA-GSFC LIS Team

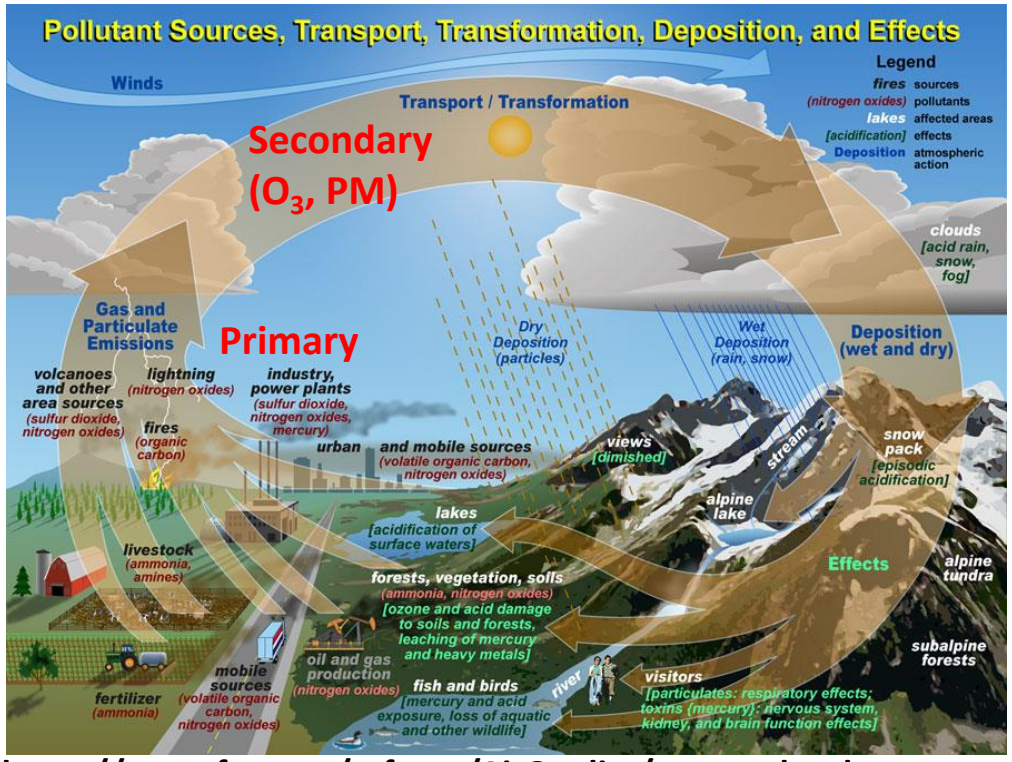


June 2021 US Drought Monitor (top) and 0-100 cm soil moisture percentile from SPoRT-LIS for 1 July 2021.



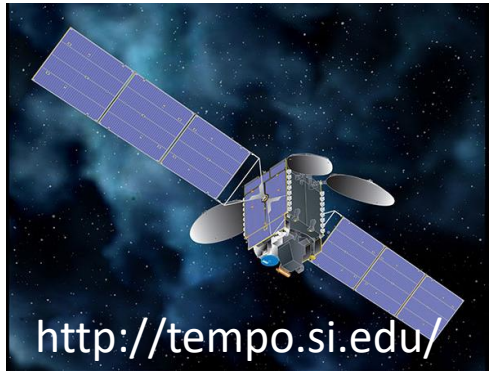
SPoRT Lead / PI: Chris Hain

Health and Air Quality – TEMPO Mission & Science Objectives



https://www.fws.gov/refuges/AirQuality/sources.html





Expected launch date: December 2022

on geostationary satellite with Field of Regard over Greater North America

TEMPO Early Adopters / Applications Program site
https://weather.msfc.nasa.gov/tempo/

TEMPO Science Objectives:

- Assess the temporal and spatial variations of emissions of gases and aerosols
- Determine the processes that transform tropospheric composition and air quality (AQ) over range of spatial and temporal scales (e.g., urban, diurnal)
- Understand how air pollution drives climate forcing and how climate change affects AQ
- Characterize how observations from space can improve AQ forecasts and assessments
- Understand the impact of episodic or disaster events (e.g., wildfires) on AQ
- Characterize the role of intercontinental transport on AQ

TEMPO science objectives have large overlap with AQ and aerosol related objectives of AOS

Health and Air Quality – TEMPO Data Products

Level	Product	Major Outputs	Res km^2 **	Freq/Size
L0	Digital counts	Reconstructed / reformatted digital counts	2.0 x 4.75	Daily/hourly
L1-b	irradiance	Calibrated & quality flags		daily
	radiance	Geolocated, calibrated, viewing, geolocation & quality flags	2.0 x 4.75	Hourly, granule
L2	Cloud ★	Cloud fraction, cloud pressure	2.0 x 4.75	Hourly, granule
	O_3 profile	O3 profile, total/strat/trop/0-2 km O3 column, errors, a priori, averaging kernels	8.0 x 4.75	Hourly, granule
	Total O_3	Total O3, Aerosol Index, cloud fraction	2.0 x 4.75	Hourly, granule
	NO_2 ★	SCD, strat./trop. VCD, error, shape factor, scattering weights	2.0 x 4.75	Hourly, granule
	H_2CO ★	SCD, VCD, error, shape factor, scattering weights	2.0 x 4.75	Hourly, granule
	$C_2H_2O_2$		2.0 x 4.75	Hourly, granule
	H_2O		2.0 x 4.75	Hourly, granule
	BrO		2.0 x 4.75	Hourly, granule
	SO_2 ★	SCD, VCD (PBL,TRL,TRM,TRU,STL)	2.0 x 4.75	Hourly, granule
	Aerosol ★	AAI, UVAOD, UVSSA, AOCH, VISAOD	8.0 x 4.75	Hourly, granule
	TEMPO/GOES-R Synergistic	Radiance, aerosol, cloud & mask, fire/hotspot, lightning, snow/ice, etc.	2.0 x 4.75	Hourly, granule
L3	Gridded L2	Same as L2	2 x 2 (TBD)	Hourly, scan
L4	UVB	UV irradiance, erythemal irradiance, UVI	TBD	Hourly, scan

Black text: Baseline products; **Orange text**: Additional / proposed products

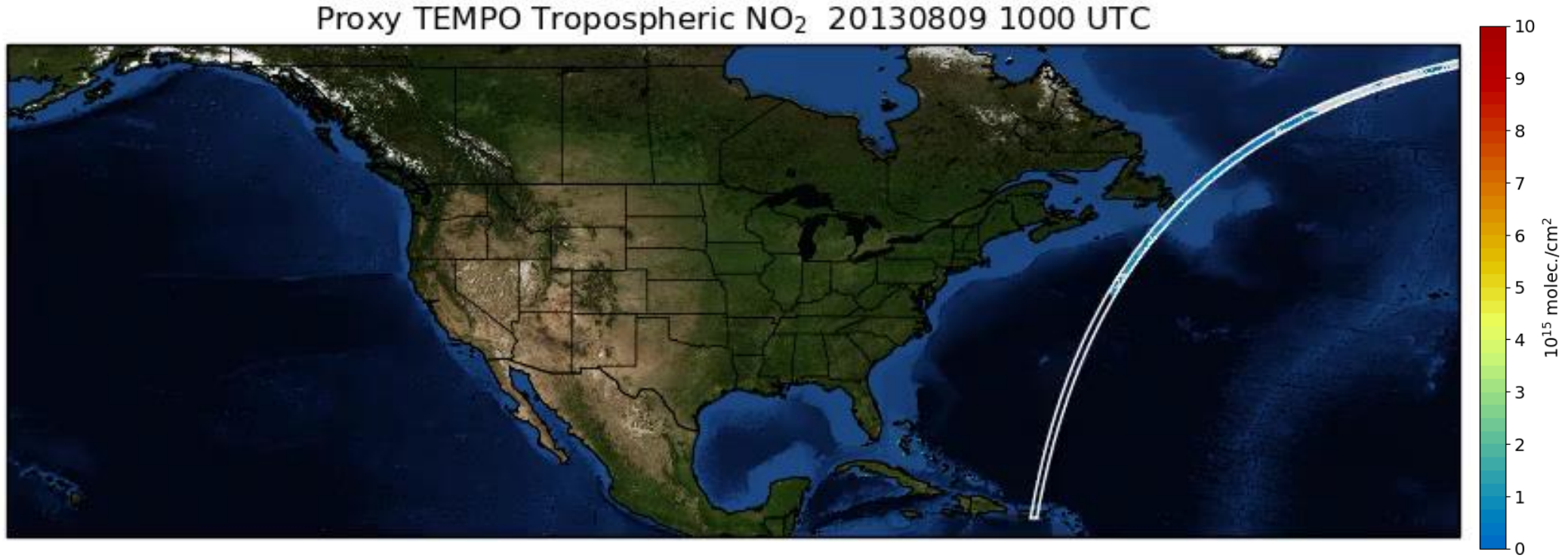
★ **Near real-time products (latency < 3 hours)**

** Center of Field of Regard

SCD: Slant Column Density
VCD: Vertical Column Density

AAI: Aerosol Absorption Index
UVAOD/VISAOD: UV/VIS Aerosol Optical Depth
UVSSA: UV Single Scatter Albedo
AOCH: Aerosol Optical Centroid Height

Health and Air Quality – TEMPO Early Adopter Program Overview



Early Adopter Program Objectives:

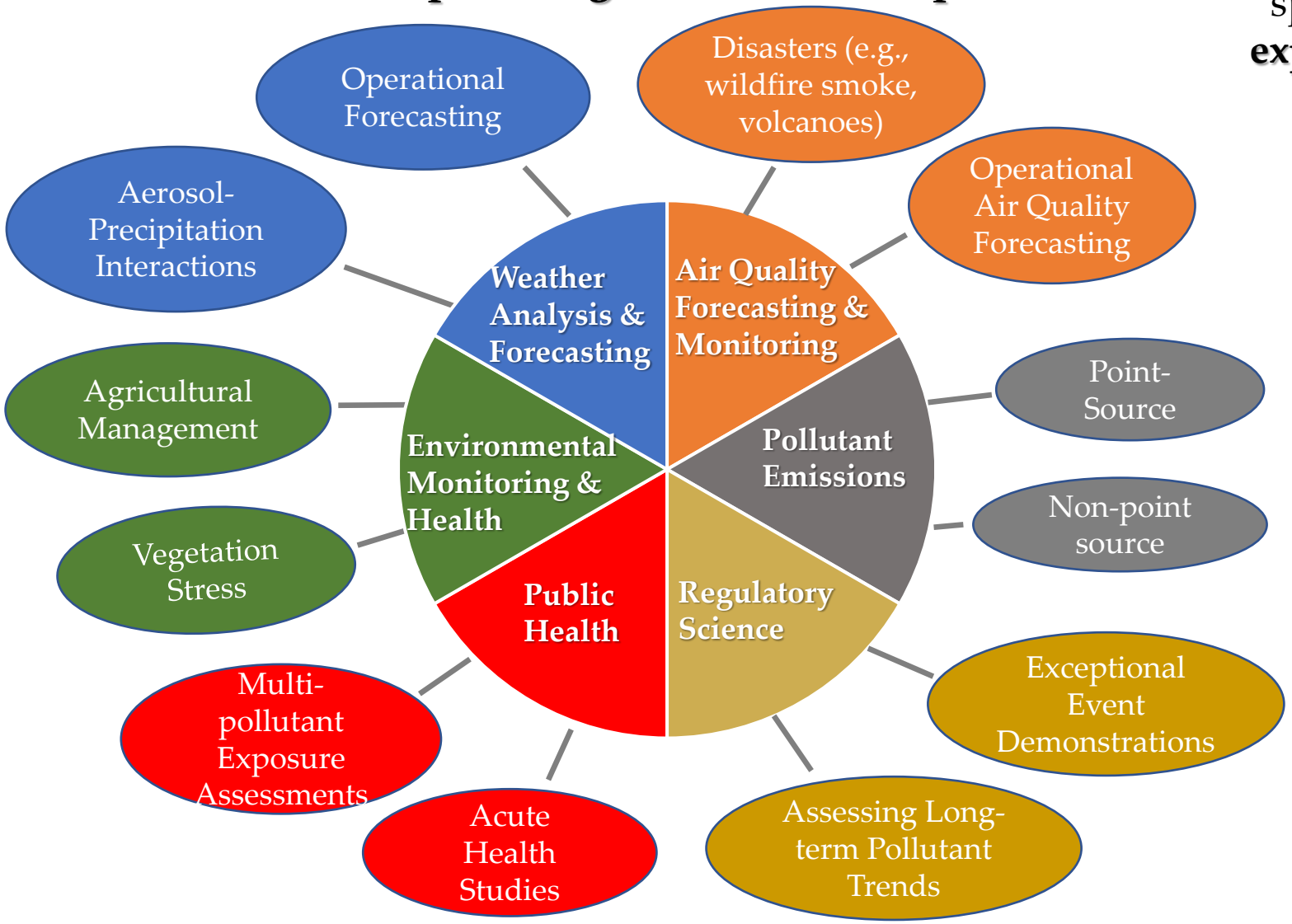
- Engage a broad spectrum of stakeholders / end users to expand the use of TEMPO data and characterize user needs
- Use current sensors and proxy data to demonstrate TEMPO capabilities and enhance air quality & health applications
- Align the TEMPO observing time, products, and data interfaces to user needs and applications

Goal:

- Prepare users for operational TEMPO data and maximize and accelerate the value of TEMPO data for societal benefit

Health and Air Quality – TEMPO Applications

Application focus areas of TEMPO Early Adopter Program & Green Paper



TEMPO Green Paper – Living document specifying fundamental and **applied science experiments** in preparation for TEMPO launch

https://weather.msfc.nasa.gov/tempo/

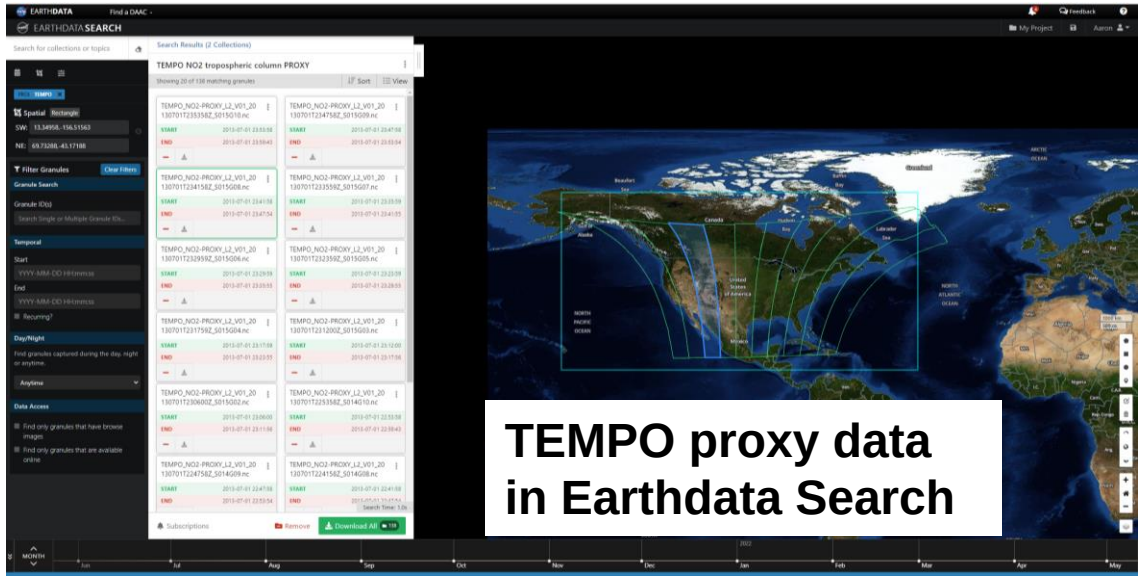
- Input from stakeholders / end users on impactful applications are key to building a comprehensive Green Paper of designated experiments
- Identifying and implementing applications from a diversity of end users will enhance societal benefits of TEMPO data after launch

***TEMPO applications closely align with Health, Air Quality, & Disaster applications of AOS**

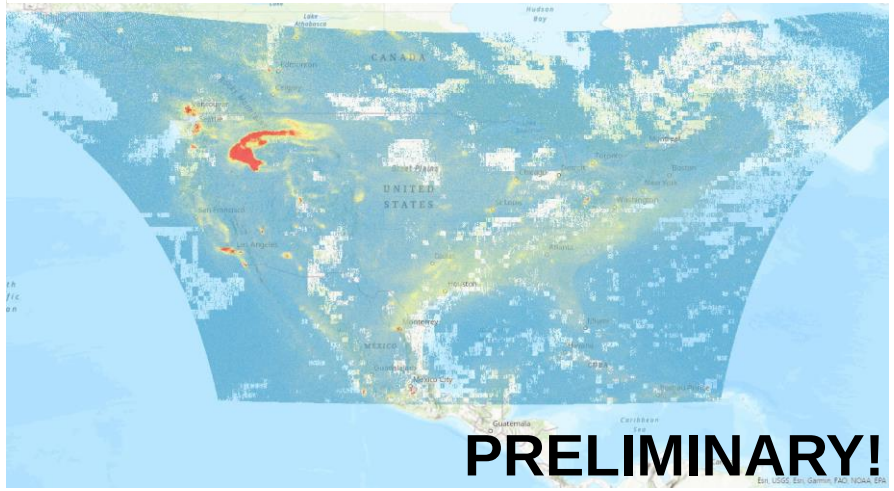
***Synergistic products from TEMPO & AOS can enhance application benefits**

Health and Air Quality – TEMPO Early Adopter Program Activities

- **TEMPO Early Adopter Program and NASA SPoRT** have been engaged with U.S., state, & local AQ agencies, NGOs, health organizations, academia, and private companies
  - Development and distribution of TEMPO proxy products to enable pre-launch understanding and application of TEMPO data
  - Hosted multiple hands-on tutorials to facilitate use of TEMPO proxy products and prepare user community for immediate application of operational TEMPO data
  - Hosted a series of workshops to engage users on the TEMPO mission and gather feedback on TEMPO data and applications
  - Led focused sessions and group discussions to understand and promote synergistic applications with other satellite instruments (e.g., ABI, MAIA, GLIMR)
  - Working with users to develop Green Paper experiments ideas and enable successful execution of experiments

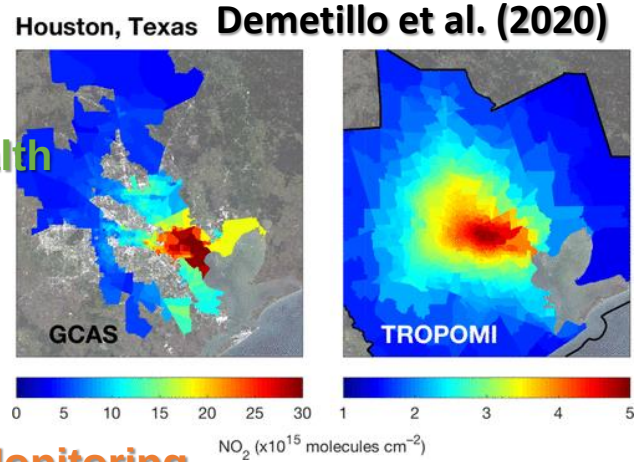


TEMPO proxy L3 tropospheric NO_2



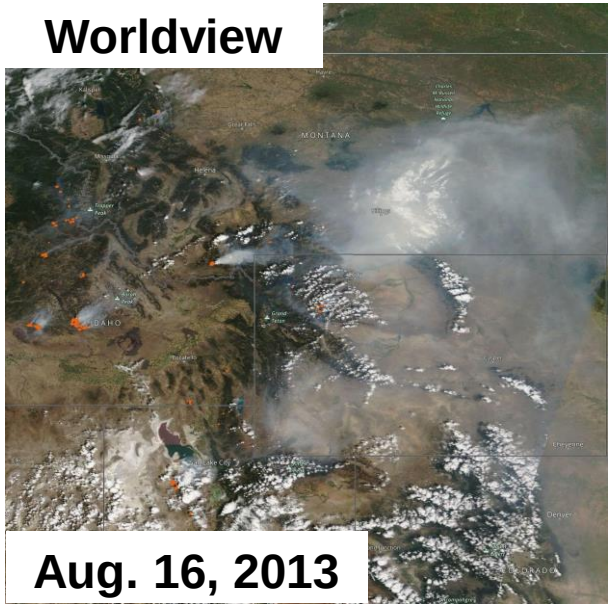
Example Green Paper Experiments:

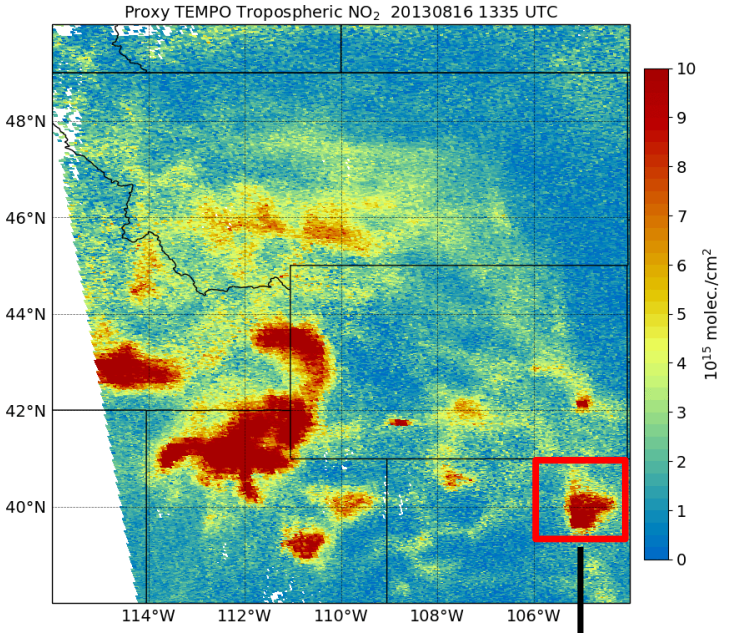
- **Observing NO_2 pollution inequality in North American cities** Environmental Monitoring & Health
  - TEMPO observations will provide new insight into the identity and timing of the emission sources and atmospheric drivers of air pollution inequality at intra-urban scales. TEMPO data will improve our ability to not only describe inequalities, but also to eliminate them through policy making.

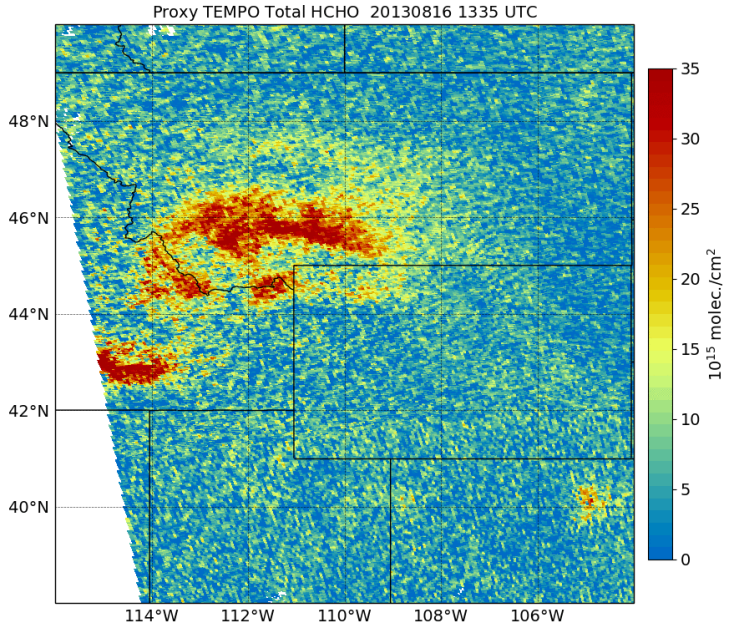


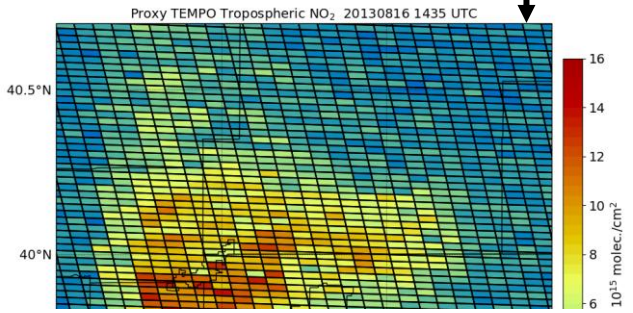
- **Examining impacts of warehouse density on Inland Empire Air Quality** AQ Monitoring
  - The logistics industry has greatly expanded in this region to accommodate increases in online shopping. This increase is associated with further declines in air quality throughout the region. TEMPO data will be used to examine columns of NO_2 and HCHO in the vicinity of extensive warehouse developments.
- **Tracking short-term public health outcomes using high-resolution TEMPO data** Public Health
  - Near real-time daytime hourly estimates of gaseous air pollutants from TEMPO will be included as acute exposures in epidemiological case-crossover analyses of children's asthma exacerbations in the greater New York metropolitan area.
- **High Resolution Scanning over the NYC Area** Regulatory Science
  - The area around NYC emits noticeably larger amounts of NO2 on days that monitor elevated ground level ozone. It is vital that the source, strength, and timing of the ozone precursors be determined. TEMPO will enhance source contribution assessments by scanning more frequently (e.g., every 10 min) and producing spatial resolution images greater than the nominal 2.0 km x 4.75 km pixel size.

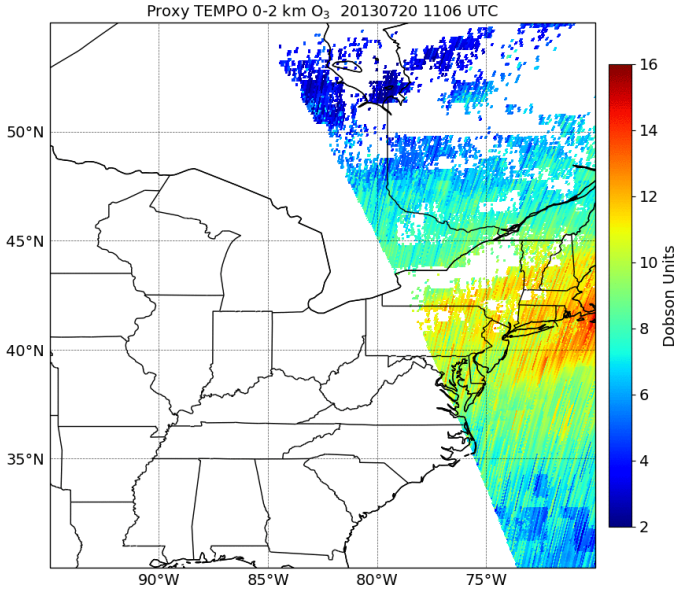
Health and Air Quality – TEMPO Proxy Data and Applications







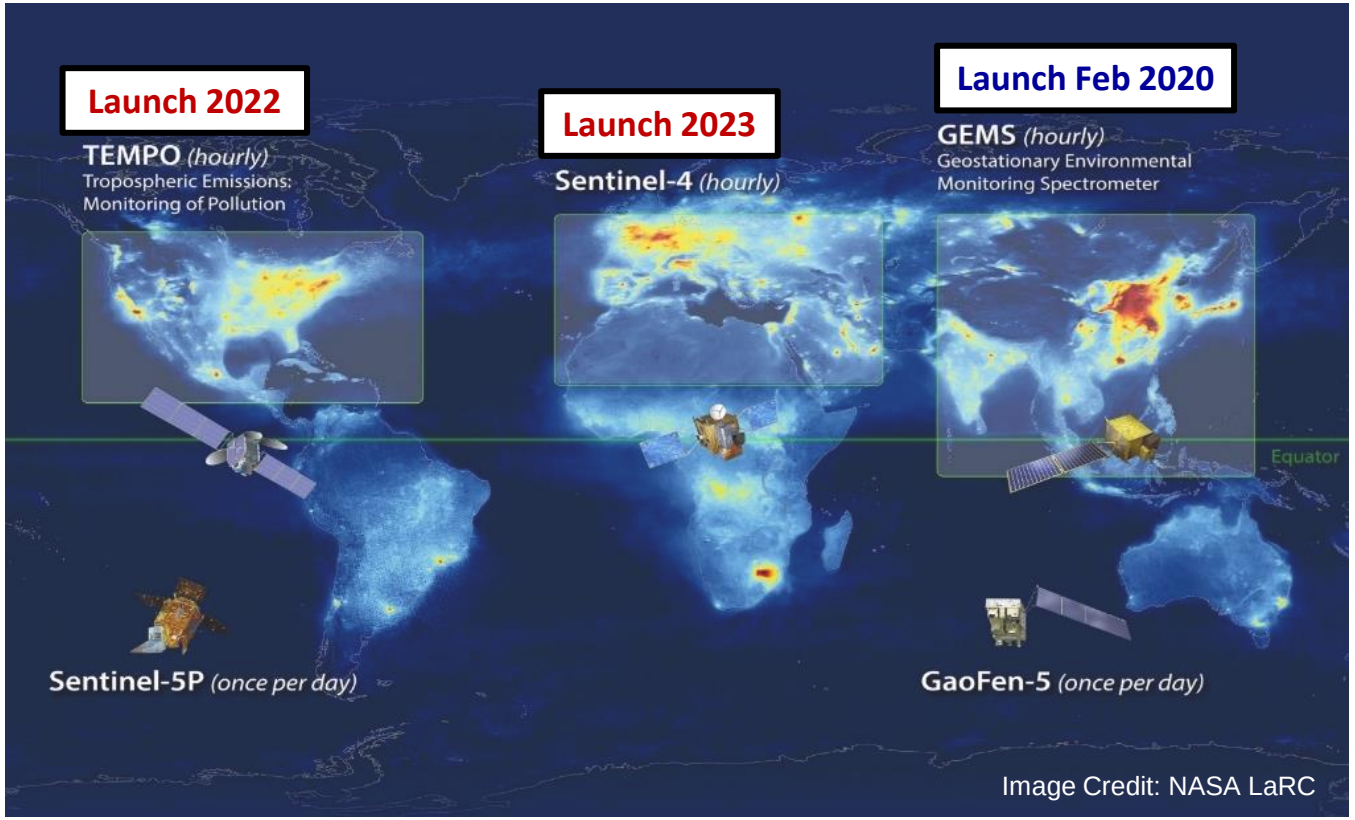


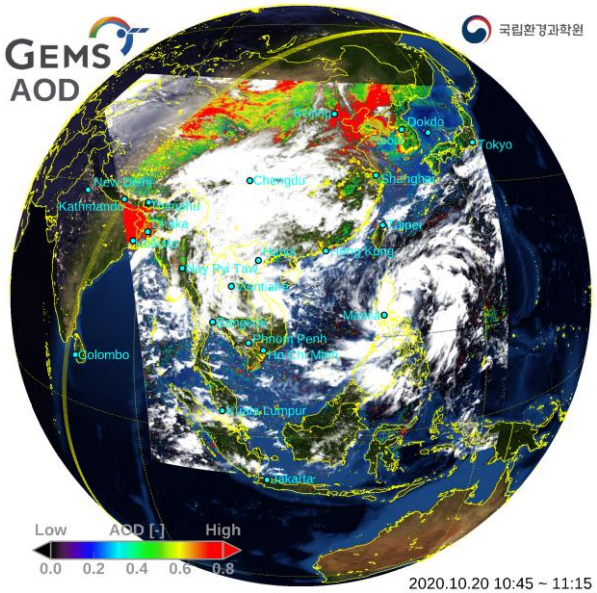


- TEMPO will monitor the diurnal variability of pollutant mixtures and concentrations and characterize fine horizontal gradients in pollutants
- Ozone pollution will be tracked in the tropospheric and 0-2 km layer throughout the daytime
  - Information on ozone pollution within the PBL where people live!

***Surface-gridded PM2.5 from AOS and 0-2 km O_3 from TEMPO can enable unprecedented AQ and Health studies**

Health and Air Quality – Geostationary Air Quality Constellation



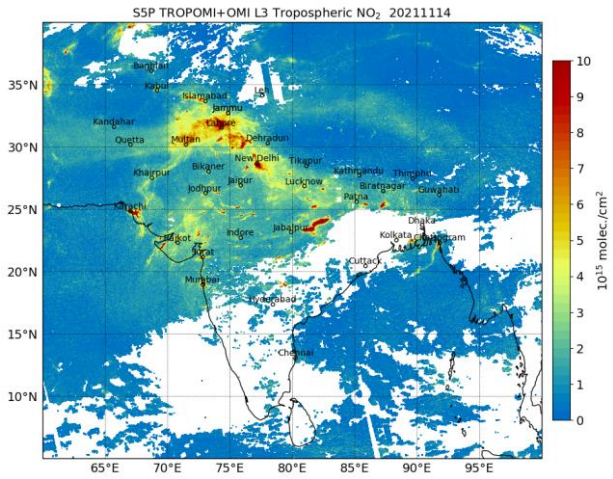


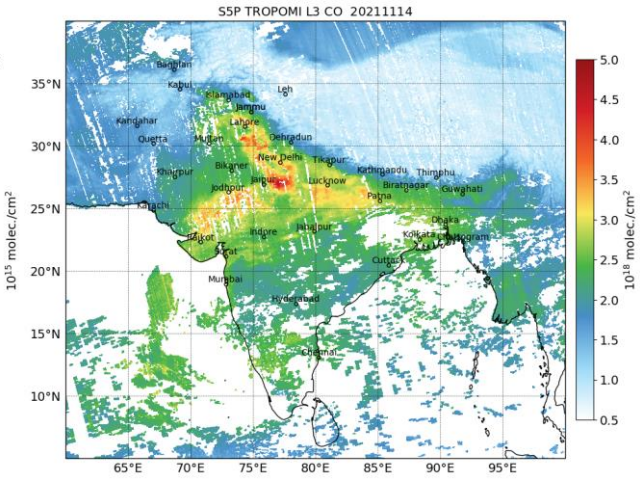
Credit: Ministry of Science and Technology Information and Communication·Ministry of Environment·Ministry of Oceans and Fisheries

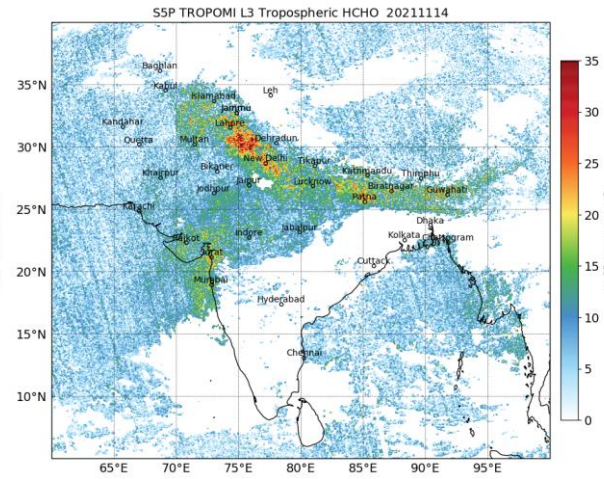


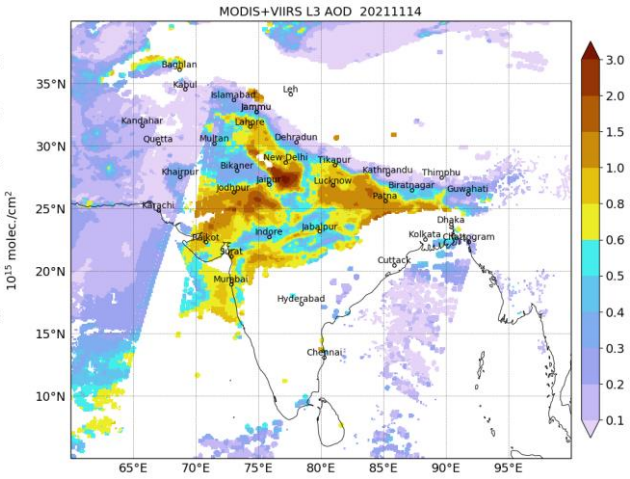
- GEMS mission is first to provide hourly daytime observations of trace gases and aerosols from space
- TEMPO and Sentinel-4 will follow to form revolutionary geostationary constellation of AQ observations
- NOAA's GEO-XO (2030s) will include a TEMPO-like spectrometer in geostationary orbit
- **Extension of TEMPO-like capabilities into the AOS mission lifetime**

- **NASA SPoRT Health & AQ Thematic Area – Current & Future Activities**
  - Development of multi-sensor satellite products for air quality monitoring, with special attention on upcoming GEMS data!
  - Assimilation of satellite trace gas and aerosol products into regional, tailored air quality models for providing accurate and timely pollution forecasts
  - Designing lagrangian trajectory models to enable rapid response to hazardous air quality events and disasters
  - Assessing the impacts of soil NO_x emissions on air pollution using advanced satellite products (TEMPO!) in conjunction with ground-based and model data
  - Develop customized training modules, user guides, product documentation, and tools for users of satellite air quality products
  - Organize additional workshops, tutorials, and focused working group meetings to prepare for TEMPO launch
  - Develop plan for executing TEMPO Green Paper experiments, including prioritizing experiments, scheduling logistics, and working with users





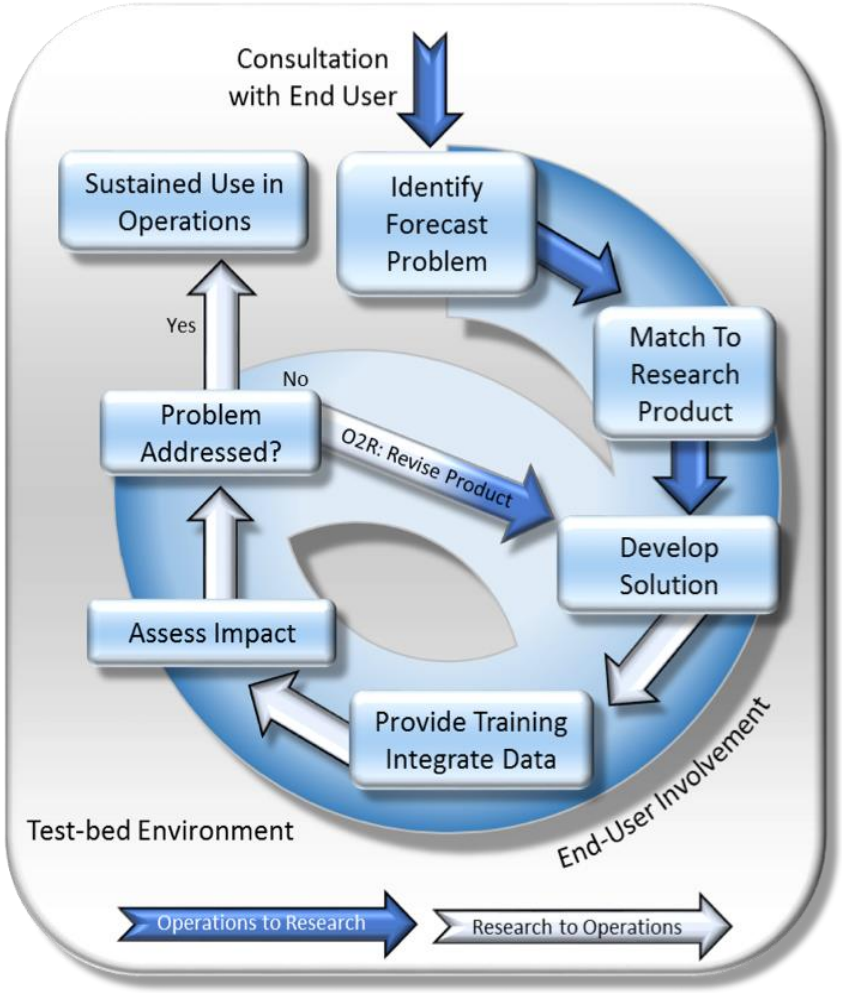




The Research to Operations/Applications Chasm:

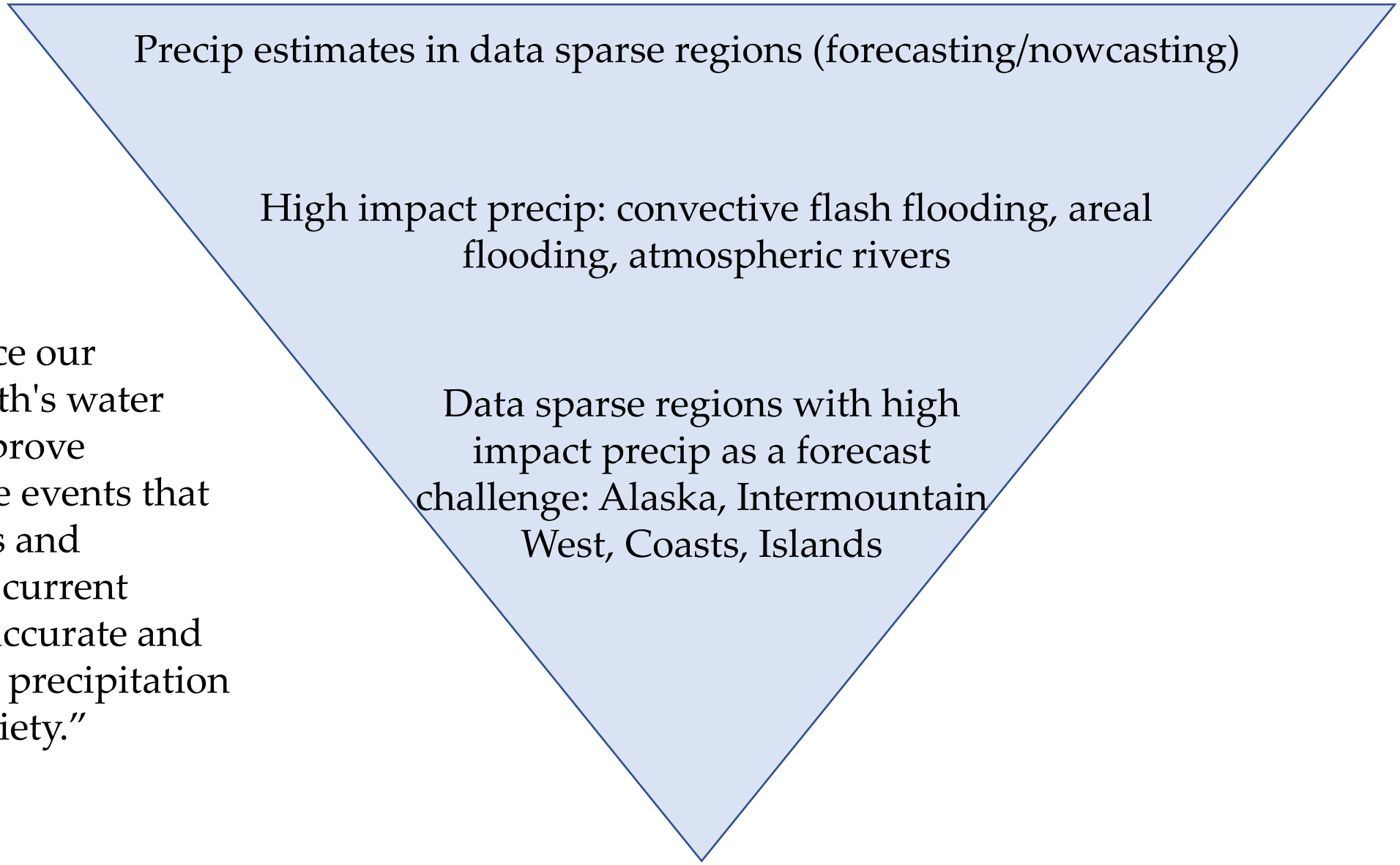
- How do you get promising, cutting-edge research to decision makers?
- How do you know what's promising?
- How can researchers learn what is needed in ops?
- What products, in what formats, at what latency, etc.?
- Who transitions and maintains the product?
- Who provides resources for all this?

? ? ? ? ?



Successful R2O/O2R requires intentionality.

Understanding the Forecast Challenge



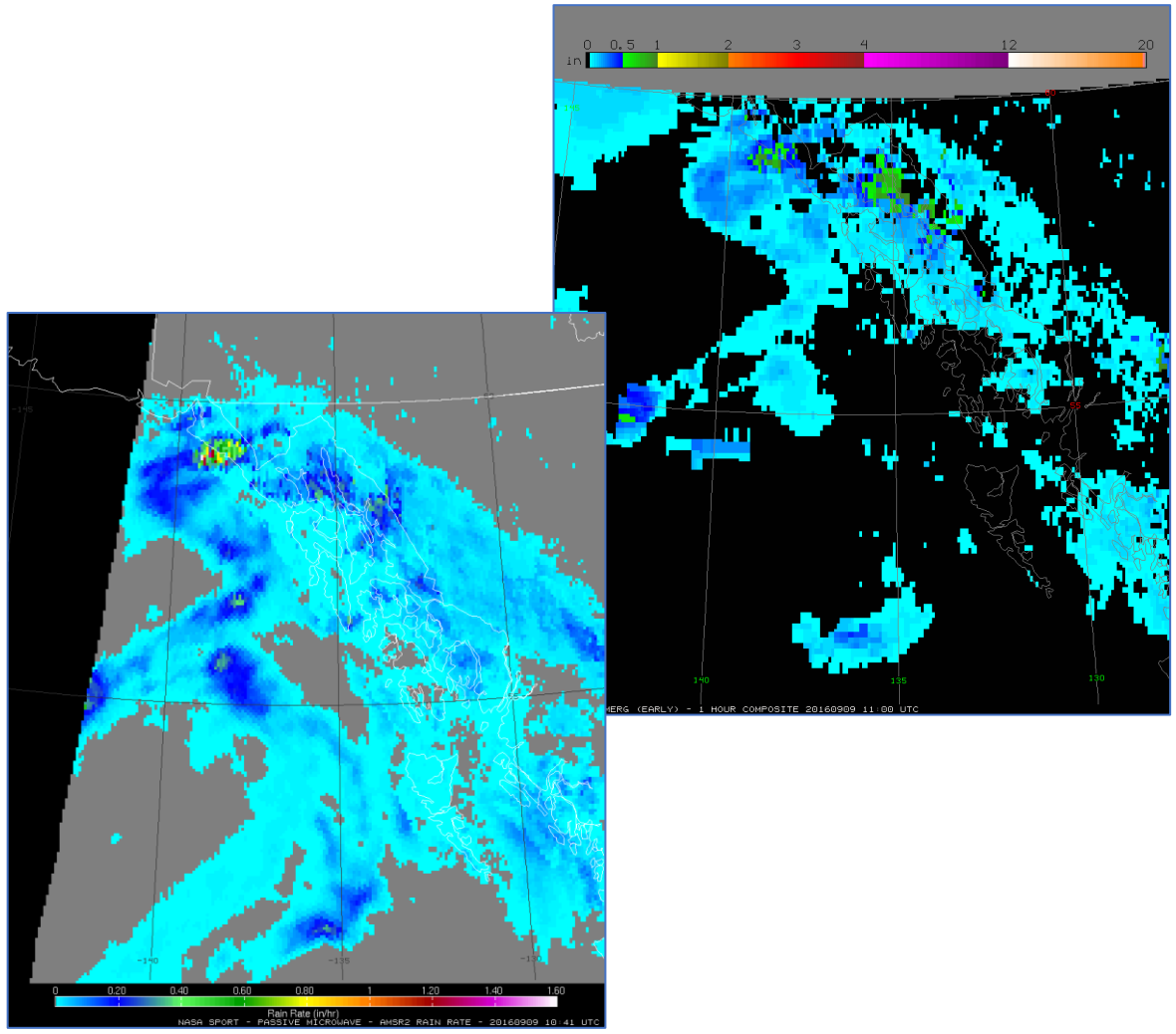
GPM aims to "advance our understanding of Earth's water and energy cycle, improve forecasting of extreme events that cause natural hazards and disasters, and extend current capabilities in using accurate and timely information of precipitation to directly benefit society."

Remote Sensing – Passive Microwave R2O/O2R

GPM Mission Science to Applications : Making GPM datasets accessible to end users, focusing on relevancy, latency, coverage. format, and ease of interpretation

The Details:

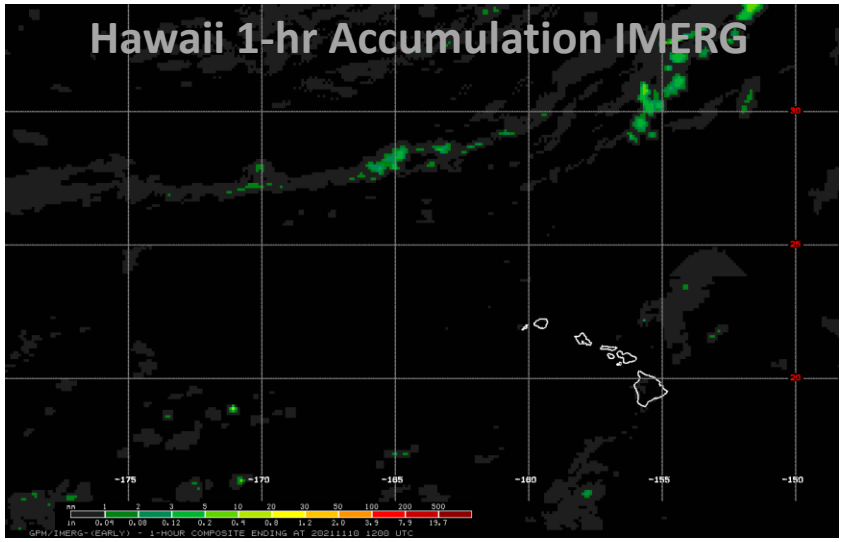
- **Relevancy:** Address forecast challenge for a specific set of end users
- **Latency:** GPM provides several precip-related datasets, but which ones are valuable for Weather Forecast Offices? For River Forecast Centers? (e.g., < 1 hr for WFOs, < 12 hrs for RFCs)
- **Coverage:** As much as possible, north of 60N (e.g., DPR is interesting and valuable, but too narrow for regular "operational" use)
- **Format:** Can we quickly acquire these datasets and turn them into something viewable at NWS offices, like AWIPS or a hydro model?
- **Interpretation:** e.g., L2 GPROF precip and L3 IMERG were chosen because they represent a kind of straight-forward "truth", resolution is appropriate (as opposed to, say, CMB the combined algorithm datatype)



Atmospheric river nowcasting and forecasting: using L2 rain rate and 1-hr accumulation of IMERG.

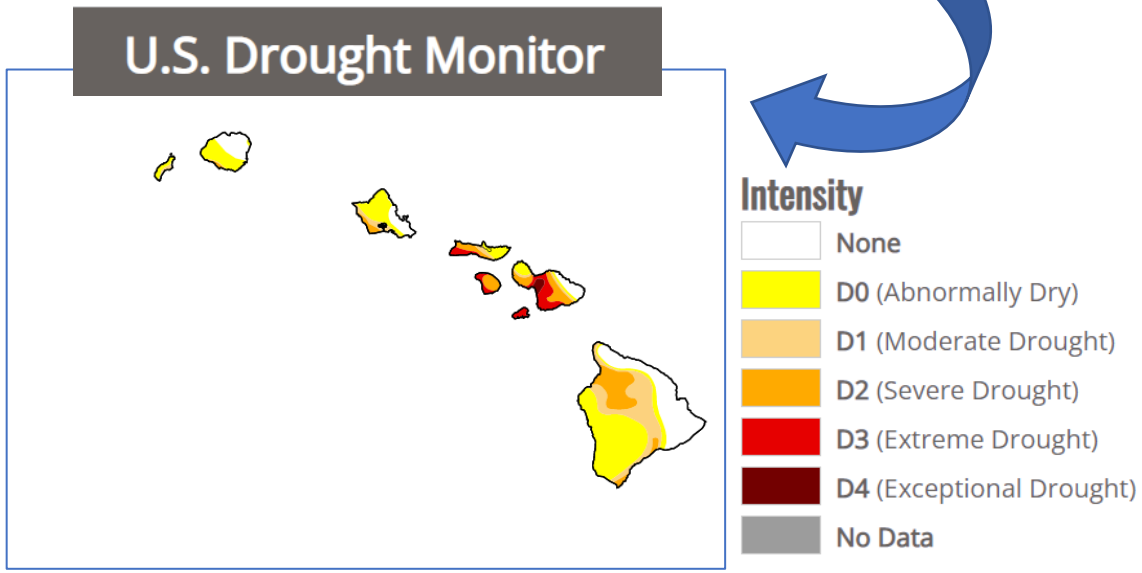
Other Considerations:

- **Validation:** GPM has loads of validation studies from different regimes/regions…and forecasters are interested!
- **Case analysis:** Validation studies show large statistical studies, but forecasters are looking at specific cases
- **The need for "value-adds":** accumulations (we created 1-hr to 7-day), targeted displays (USDM specific displays of IMERG accumulations)
- **"Off-Label Usage":** be open to non-traditional uses e.g., anticipating antecedent conditions for landslides; drought monitoring in data-sparse regions



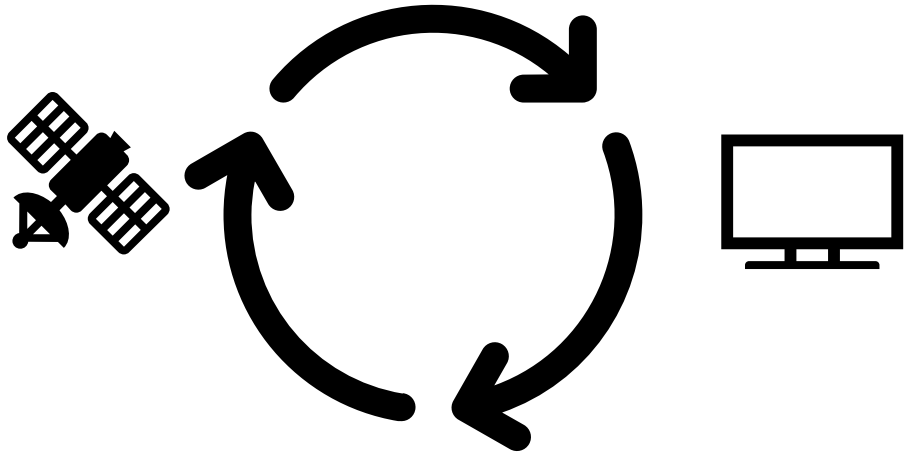
IMERG as a decision aid

Hawaii US Drought Monitor Report 9 Nov 2021



Benefits to GPM Science (Operation to Research Feedback):

- **Validation:** AK is different; GPM now does ground validation with support from forecasters.
- Forecasters provided **case examples** from regimes/events of interest to the GPM cal/val scientists on several occasions
- **Prioritization:** The need for gridded precip in AK and the value of IMERG helped G. Huffman prioritize some algorithm changes to earlier than anticipated to increase benefit of this data to end users (e.g., high-latitude data was prioritized 1.5 versions before the notional algorithm plan called for it)



LeRoy A. et al. (2020) Operational Applications of Global Precipitation Measurement Observations. In: Levizzani V., Kidd C., Kirschbaum D., Kummerow C., Nakamura K., Turk F. (eds) Satellite Precipitation Measurement. Advances in Global Change Research, vol 69. Springer, Cham. https://doi.org/10.1007/978-3-030-35798-6_23

NATIONAL WEATHER SERVICE
Building a Weather-Ready Nation

Usage Of NASA RainRate Products In NWS Alaska Operations & NASA SPoRT Interaction

NASA Atmosphere Observing System Applications Seminar

Aaron Jacobs:
Senior Service Hydrologist/Meteorologist, NWS WFO Juneau AK