NOAA Atmospheric Composition Plans

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National Environmental Satellite, Data, and Information Service

October 14, 2022

US President's Executive Orders

- Tackling the Climate Crisis at Home and Abroad
- Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis
  - Includes 1) Reducing Methane Emissions in the Oil and Gas Sector, 2) Protecting Our Air from Harmful Pollution
- Advancing Racial Equity and Support for Underserved Communities

National Oceanic and Atmospheric Administration
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New NOAA Climate Council to enhance delivery of climate science and services

Focus areas: Across NOAA, Climate Topics: NOAA leadership, climate science

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July 21, 2021

A collage of typical climate and weather-related events: heatwaves, drought, hurricanes, wildfires and changes in sea ice coverage. (NOAA)

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Weather, Water, and Climate Strategy

FY 2023-2027

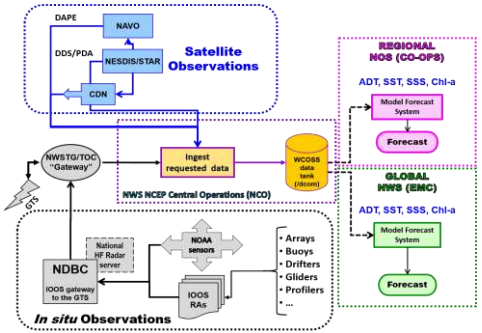
FIVE-YEAR OUTPUTS: MONITORING AND MODELING FOR CLIMATE CHANGE MITIGATION

Area	Output
Greenhouse Gas observation and Modeling Capabilities	1. Develop GHG observation and modeling capabilities with NOAA domestic and international partners to reliably track changes in natural and human-made GHG emissions and sinks over time and at local, regional, continental, and global scales. Ensure the quality and necessary scientific stewardship of in situ and remotely sensed data sets from NOAA and partner observing systems.
Models, Tools, and Products for Climate Mitigation	2. Be a reliable provider of models, tools and products for decision makers to determine the feasibility of achieving climate mitigation targets, taking into account anthropogenic emissions, ocean fluxes, and feedbacks in the earth system, and to evaluate the broader climate implications of various mitigation measures.
Quantification of Key Emission Sources Products and Services	3. Deliver products and services that improve quantification of key emission sources to help decision makers at various scales identify important mitigation opportunities. Such sources include GHG emissions from urban sources, from the land-use and agricultural sectors, methane leaks from industry, and small quantities of potent GHG emissions from niche applications.

NESDIS

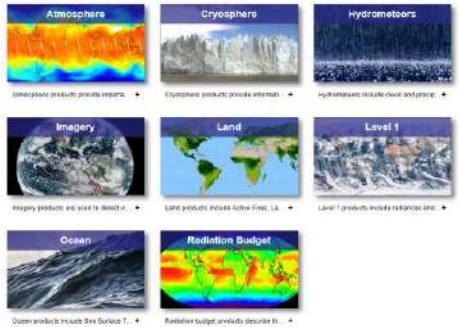
Provide secure and timely access to global environmental data and information from satellite and other sources to promote and protect the Nation's security, environment, economy, and quality of life.

Operate Satellites, Data Distribution and Services



- Operational processing and dissemination
- Data stewardship and archive
- Assessments (State of the Climate)
- Quality Assurance/Control (QA/QC)
- NRT monitoring (CoastWatch/OceanWatch)

Develop Science Algorithms

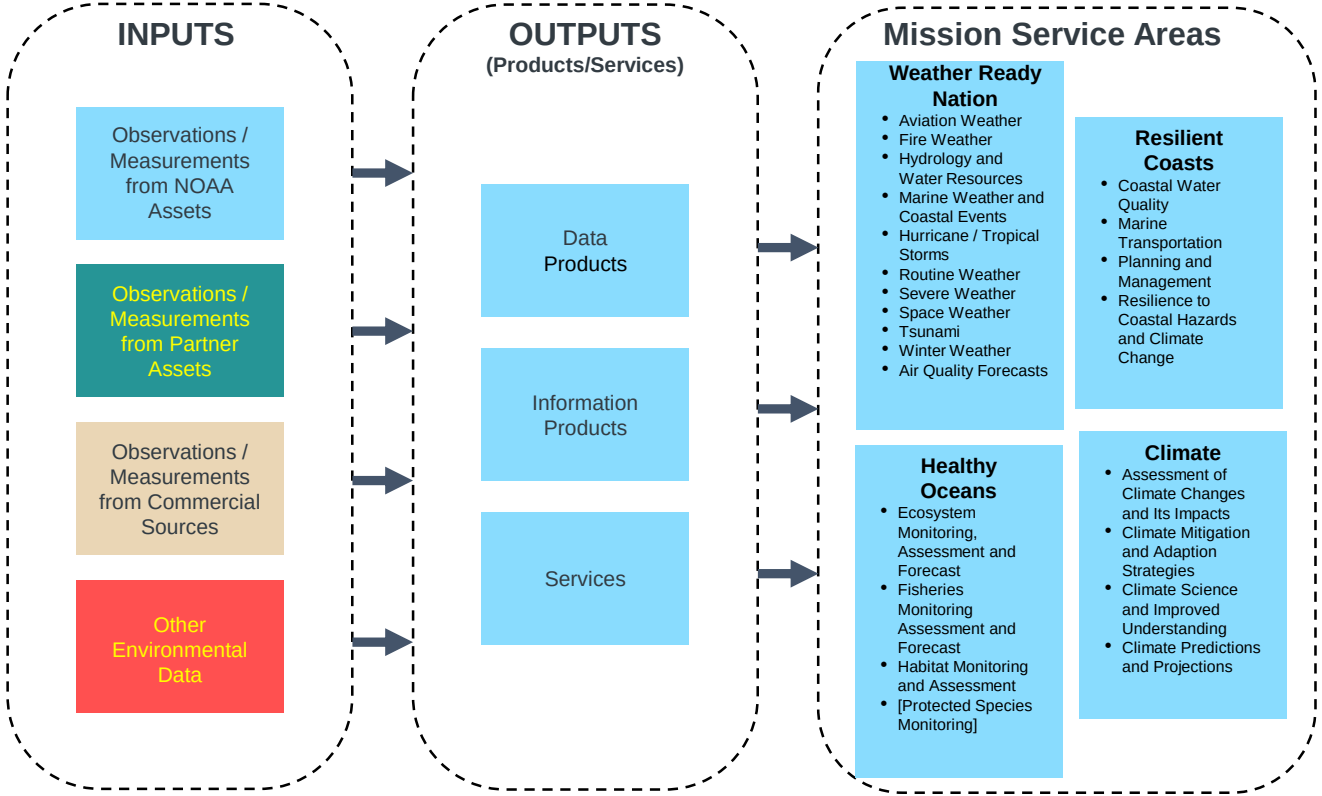


- Satellite instrument cal/val
- Level 1-4 product development and R2O
- Data assimilation/observation operators, radiative transfer

Planning

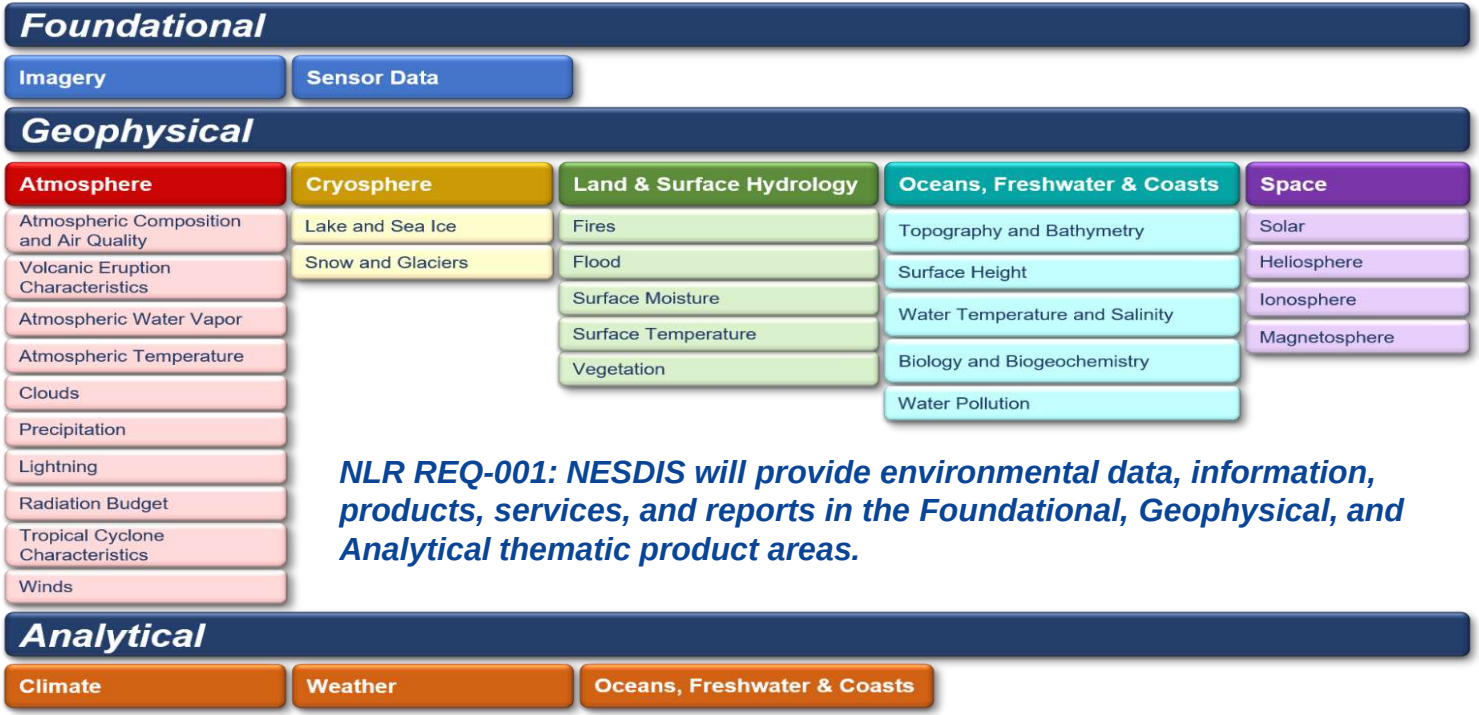
- Outreach and user-engagement
- Requirements definition
- Architecture studies (value assessments, OSSEs, OSEs)

The NESDIS Portfolio Supports NOAA and Partner Missions



** NESDIS Products/Services also support the DoD tactical, NASA science and Emergency Management missions*

NESDIS Level Requirements [REQ-001]

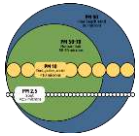


NLR REQ-001: NESDIS will provide environmental data, information, products, services, and reports in the Foundational, Geophysical, and Analytical thematic product areas.

Level 2 AC Product Development

- **Establish near-real-time data access** to existing and new low-Earth-orbit (LEO) and geostationary (GEO) satellite observations
- **Develop AC enterprise algorithms** that provide consistent products from NOAA and non-NOAA satellite instruments
- **Produce synergistic products** that combine information from different LEO/LEO, GEO/GEO, LEO/GEO instruments

Aerosols:
Optical depth
Optical properties
Layer height
Surface concentration



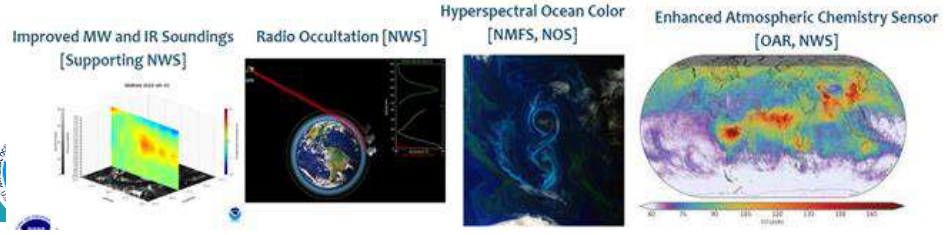
Trace gases:
Ozone (total, profile, PBL)
Carbon monoxide
Carbon dioxide
Methane
Nitrogen dioxide
Formaldehyde
Sulfur dioxide

Fires:
Detection
Radiative power
Emissions
Smoke concentration

Growing User Needs

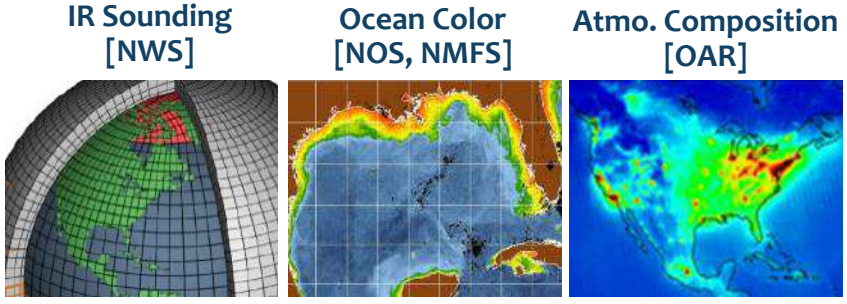
LEO: Users expect NOAA provide improved observations and forecasts:

- **Higher resolution forecasts for short term and long term weather prediction** - improved microwave, infrared and RO soundings. More frequent observations with improved spatial and vertical resolution to measure the atmosphere closer to Earth's surface
- **The Blue Economy and coastal communities requires improved information on phytoplankton and harmful algal blooms** - hyperspectral ocean color imagery at improved spatial resolution
- **Timely and accurate forecasts of air quality hazards require enhanced atmospheric chemistry sensors** for monitoring gases such as sulphur dioxide that cause smog. Improved measurements of ozone and trace gasses such as nitrogen dioxide, methane and formaldehyde are need to assess climate change.



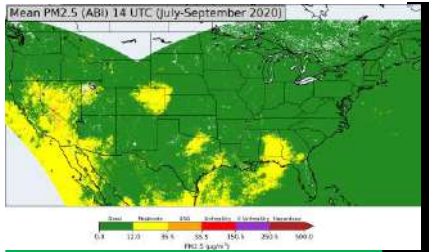
GEO: Users expect NOAA to meet new requirements with new observations

- **Improved numerical weather prediction and local nowcasting** - delivered by Hyperspectral IR Sounder
- **Monitoring dynamic coastal/ocean features, ecosystem change, water quality, and hazards** - delivered by Ocean Color Instrument
- **Monitoring air quality and linkages with weather and climate** - delivered by Atmospheric Composition Instrument

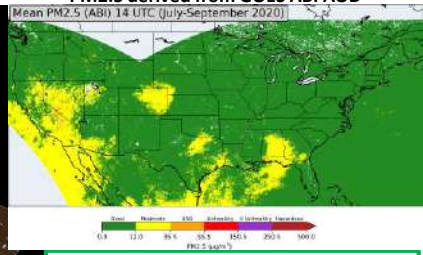


GeoXO's Multi-Instrument Synergy for Atmospheric Composition Observations

PM2.5 derived from GOES ABI AOD



PM2.5 derived from GOES ABI AOD



GeoXO Constellation

(Preliminary, pending program approval)

Vis/IR Imager (GXI)
- Fire detection
- Fire radiative power
- Aerosol type
- Aerosol optical depth
- Aerosol concentration

GEO-West

Visible/Infrared Imager
Lightning Mapper
Ocean Color

GEO-Central

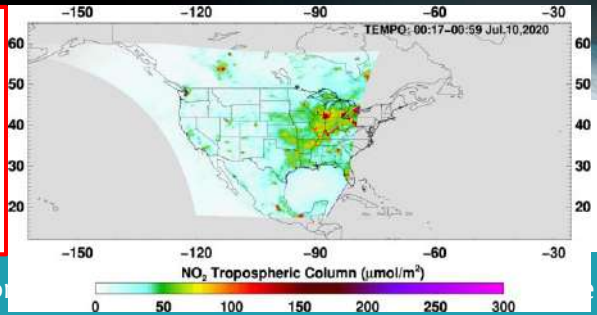
Hyperspectral Infrared Sounder
Atmospheric Composition
Partner Payload

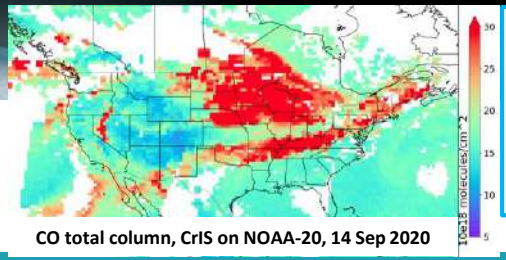
GEO-East

Visible/Infrared Imager
Lightning Mapper
Ocean Color

Vis/IR Imager (GXI)
- Fire detection
- Fire radiative power
- Aerosol type
- Aerosol optical depth
- Aerosol concentration

UV/Vis Spectrometer (ACX)
- Ozone
- Nitrogen dioxide
- Sulfur dioxide
- Formaldehyde
- Aerosol layer height





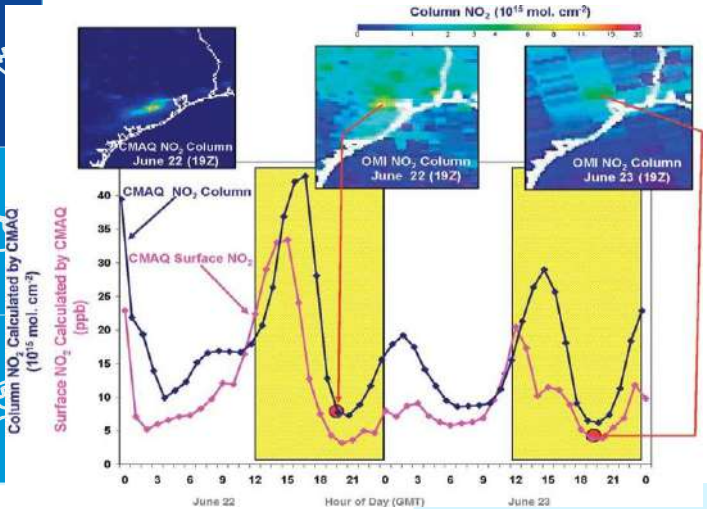
CO total column, CrIS on NOAA-20, 14 Sep 2020

IR Sounder (GXS)
- Ozone
- Carbon monoxide
- Carbon dioxide
- Ammonia

GeoXO: ACX Summary (What and Why)

NASA's TEMPO instrument will provide GEO air pollution data over CONUS for research applications beginning in 2023.

TEMPO pixels over Washington DC region



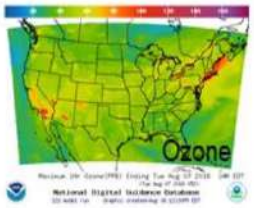
Fishman et al., BAMS, 2008

Attribute	What	Why
Coverage	CONUS, southern Canada, northern Mexico, Caribbean	Hourly inputs to national air quality, hazard and fire forecasting capabilities and warnings.
Spatial Resolution	8x3 km^2 @ nadir	Resolve sources, including cities, highway corridors, airports, oil/gas fields, large point sources like fires and power plants.
Temporal Resolution	60 min	Capture diurnal variations in pollution emissions, photochemistry, and exposure. Detect episodic events like wildfires and volcanoes. Select for cloud-free conditions. Increase geographic coverage compared with LEO or surface observations.
Spectral Coverage / Resolution	UV: 300-500 nm Vis: 540-740 nm Both @ 0.6 nm	UV: ozone, nitrogen dioxide, formaldehyde, sulfur dioxide, absorption aerosol optical depth. Vis: cloud/aerosol layer height, PBL ozone, vegetation.

National Air Quality Forecast Capability

We improve the basis of air quality alerts and provide air quality information to people at risk to further NWS mission of protecting life and property and the enhancement of the national economy.

National Air Quality Forecast Capability (NAQFC) develops and implements operational air quality forecast guidance for the United States.



<u>Operational Forecast Products (48/72 hours):</u>

- Ozone nationwide (CMAQ)
- Fine particulate matter (PM2.5) nationwide (CMAQ)
- Smoke nationwide (HYSPLIT)
- Dust over CONUS (HYSPLIT)

Air quality forecasting relies on a strategic partnership with the Environmental Protection Agency (EPA) and state and local air quality forecasters.

National Air Quality Forecast Capability

Model: Linked numerical prediction system

Implemented on the NCEP operational supercomputers

- *NOAA NCEP Global Forecast System V16 (GFS) numerical weather prediction*
- *NOAA/EPA Community Multiscale Air Quality (CMAQ) V5.3.1 model for ozone and PM2.5 predictions*
  - *Chemistry: CB06, AERO7*
- *NOAA HYSPLIT model for smoke and dust prediction*

Observational Input:

- *NWS weather observations; NESDIS Hazard Mapping system (HMS) fire locations, BLUESKY; climatology of regions with dust emission potential*
- *EPA emissions inventory: NEI 2016*

Gridded forecast guidance products:

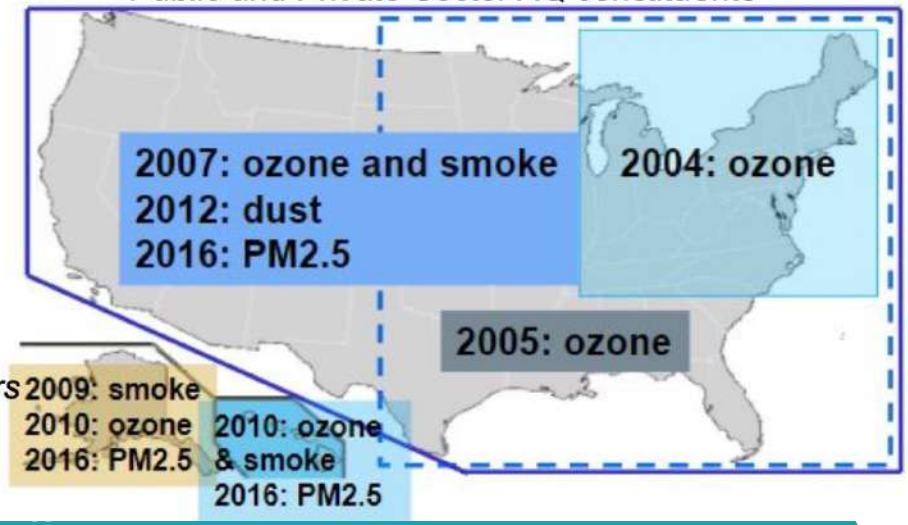
- *On NWS servers: airquality.weather.gov and ftp-servers (12 km resolution, hourly for 72 hours)*
- *Updated 2x daily*

Verification basis, near-real time:

- *Ground-level AIRNow observations of surface ozone and PM2.5*
- *Satellite observations of smoke and dust*

Customer outreach/feedback

- *State & Local AQ forecasters coordinated with EPA*
- *Public and Private Sector AQ constituents*



NOAA User Readiness Plan for Atmospheric Composition observations from Space (NURPACS)

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NURPACS Writing Team

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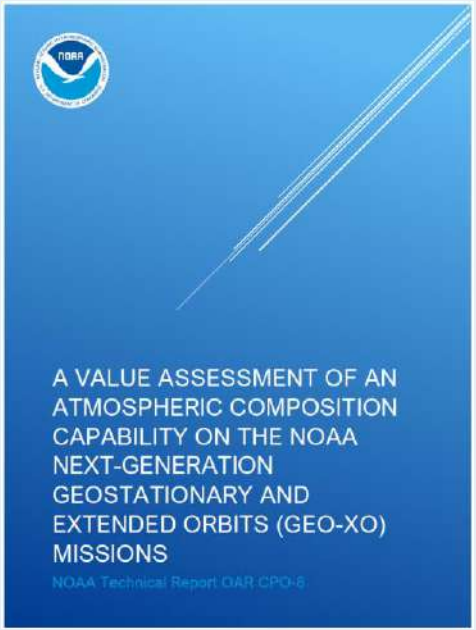
Drivers for NURPACS

OAR, NESDIS, & NWS have a satellite-based atmospheric composition (AC) observations strategy.



https://doi.org/10.25923/1s4s-t405

OAR already relies on NESDIS Atmospheric Composition products to inform research advancements and to develop and improve forecasting tools.

NWS will increasingly rely on NESDIS AC products to inform its operational forecasts of air quality, weather, and climate that protect lives and property.

NESDIS, OAR, and NWS need a plan to implement this AC observations strategy:

- **Develop and evaluate** new satellite AC products
- **Demonstrate** these AC products in NOAA applications
- **Transition** AC products into NOAA operations

A NOAA AC user readiness plan would benefit **all of NOAA**:

- Informing LO **Annual Operating Plans**
- Guiding future LO **budget planning**
- Aligning LO plans towards a **NOAA enterprise approach**

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Earth System Research Laboratories

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The **Global Monitoring Laboratory** (GML) of the National Oceanic and Atmospheric Administration conducts research that addresses three major challenges: greenhouse gas and carbon cycle feedbacks, changes in clouds, aerosols, and surface radiation, and recovery of stratospheric ozone.

News Publications Seminars

Air Resources Laboratory

Investigating processes in the Earth's Boundary Layer

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Atmospheric Sciences Modeling Division – College Park, Maryland

ARL's ASMD develops and improves dispersion and air quality models; collects research-grade atmospheric and deposition measurements of select air quality parameters, and provides climate-relevant datasets and assessments of climate variability and trends. Some products developed by ARL augment the operational product suites of the NOAA service-oriented line offices, particularly the National Weather Service. Other products are state-of-the art, web-based assessment tools that serve university researchers, federal research agencies, and international partners.

ASMD is located at the NOAA Center for Weather and Climate Prediction (NCWCP).

Chemical Sciences Laboratory

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Advancing our understanding of atmospheric composition and climate

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Research Highlights

Earth's Radiation Budget

SABRE

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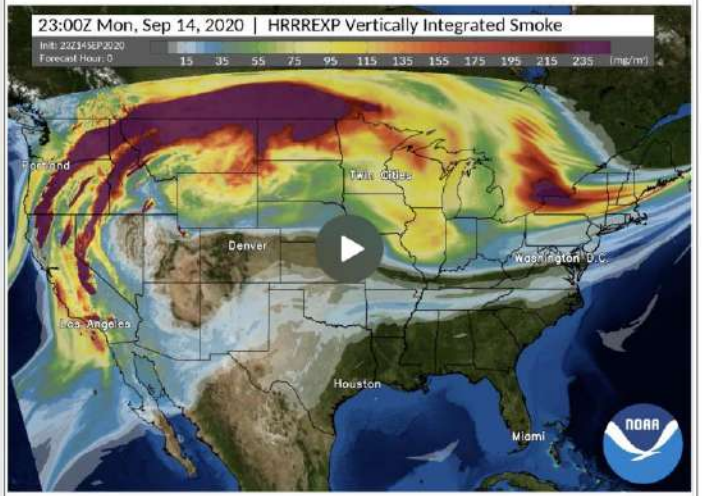
Science Reviews

Global Modeling Lab.

Weather Research and Forecasting model coupled to Chemistry (WRF-Chem)

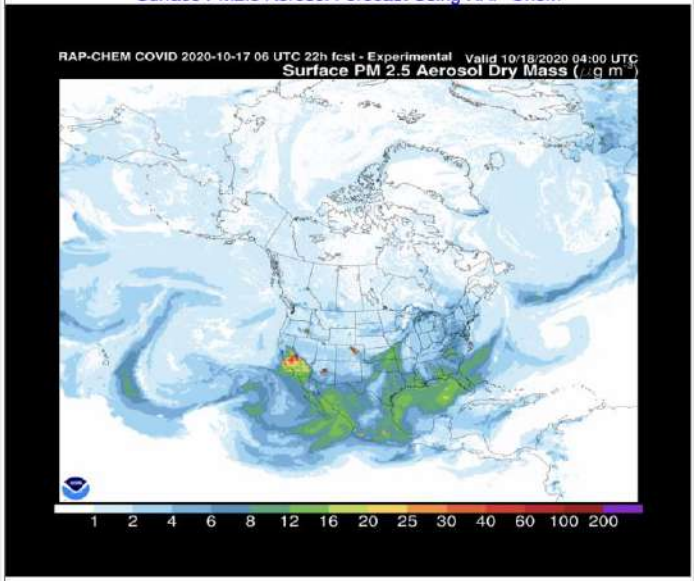
Smoke forecast using HRRR-Smoke



https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/

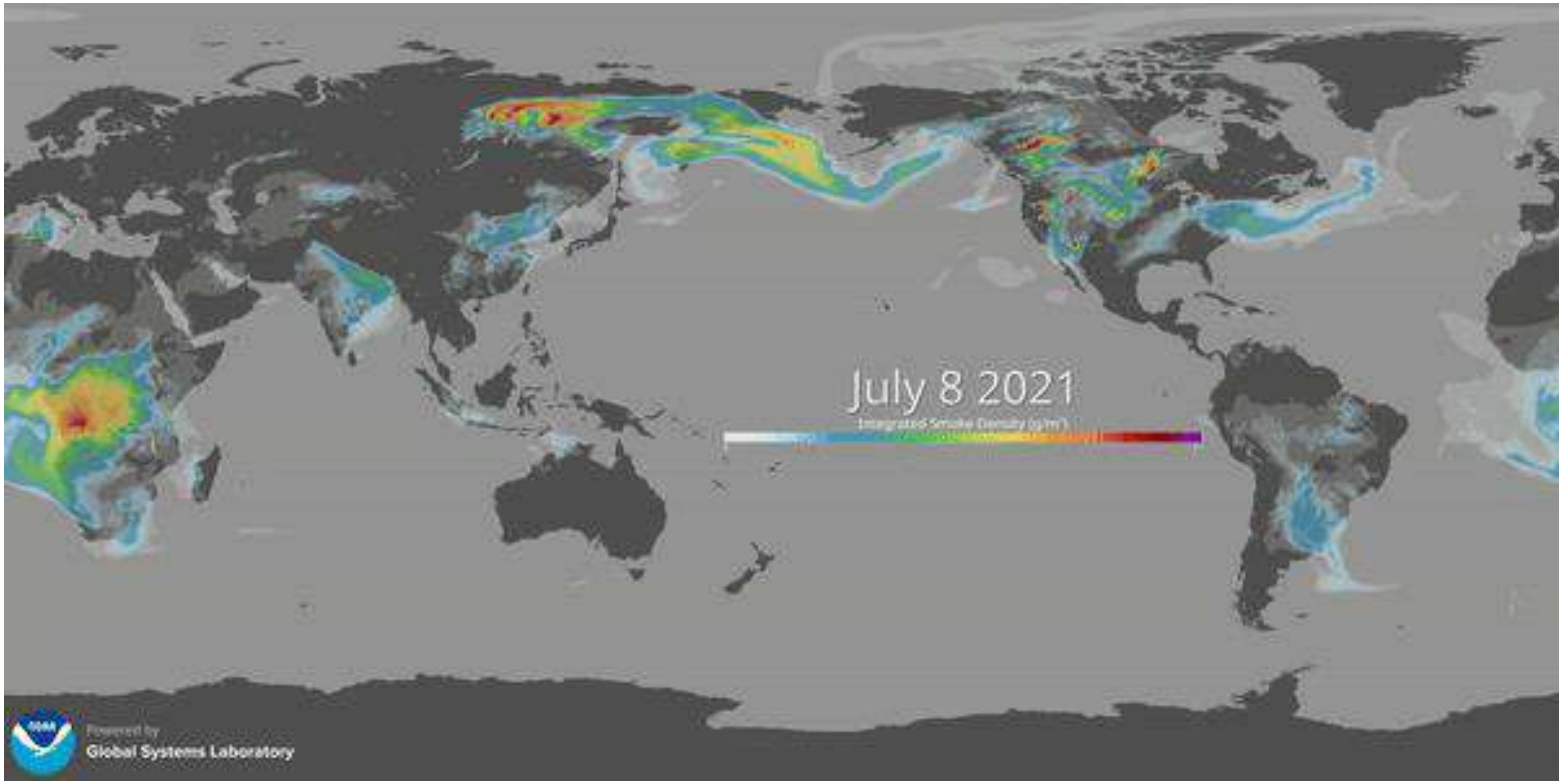
WRF-Chem

Surface PM2.5 Aerosol Forecast Using RAP-Chem



https://rapidrefresh.noaa.gov/RAPchem/

GEFS-Aerosols produces seven-day forecasts of the global distribution of some primary air pollutants: smoke, soot, organic carbon, sulfate, and large and small particles of dust and sea salt - collectively known as aerosols. Because these aerosols affect the weather, the model also provides weather forecasts. The new model is also capable of predicting the atmospheric impact of volcanic eruptions, which can disperse quantities of ash and other particulates over wide areas.



Climate Program Office

ADVANCING SCIENTIFIC UNDERSTANDING OF CLIMATE, IMPROVING SOCIETY'S ABILITY TO PLAN AND RESPOND

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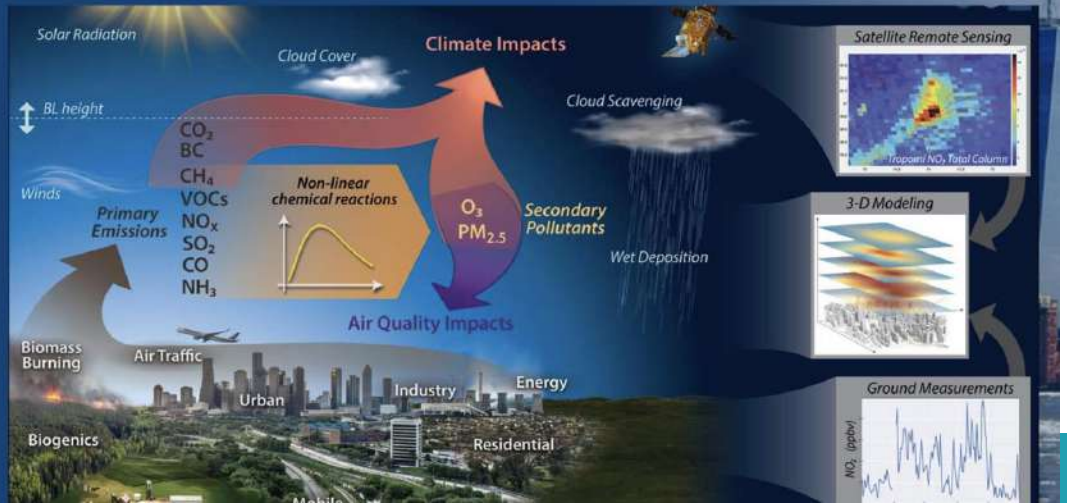
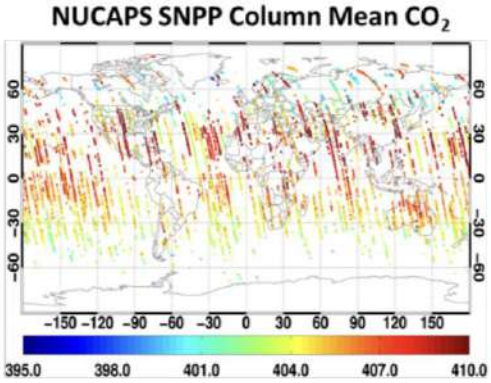
Atmospheric Chemistry, Carbon Cycle and Climate (AC4)

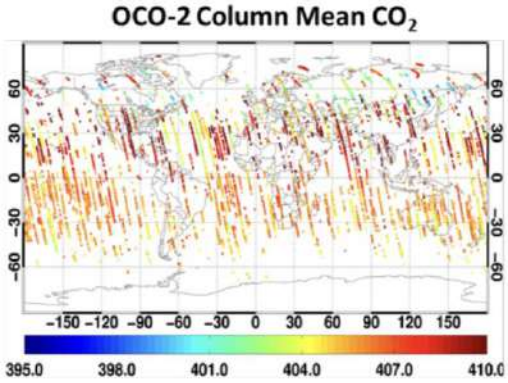
AC4 is a competitive research program that incorporates research on atmospheric chemistry and the carbon cycle. In collaboration with the NOAA Laboratories and the academic community, the AC4 program supports research to determine the processes governing atmospheric concentrations of trace gases and aerosols in the context of the Earth System. The program aims to contribute a process-level understanding of the Earth System through observation, modeling, analysis, and field studies to support the development and improvement of models, and to inform carbon and air pollution management efforts.



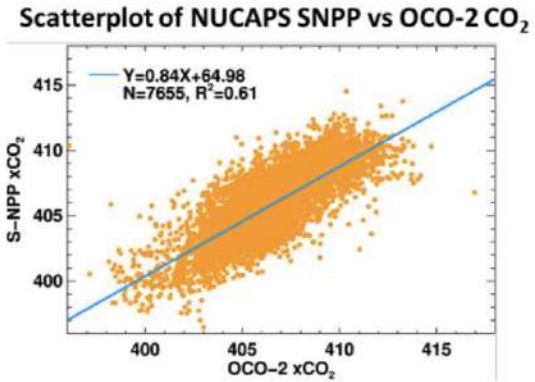
NESDIS – Data provision and error analysis

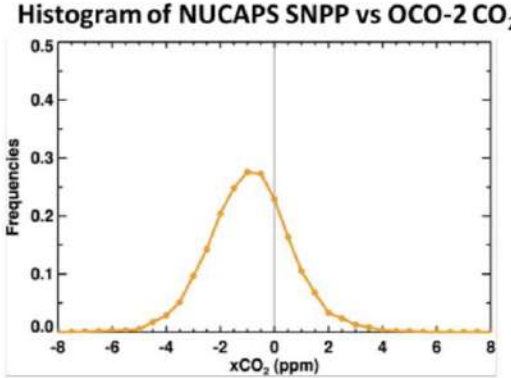
NUCAPS Carbon Dioxide versus OCO-2





Credit: Juying Warner (UMD)





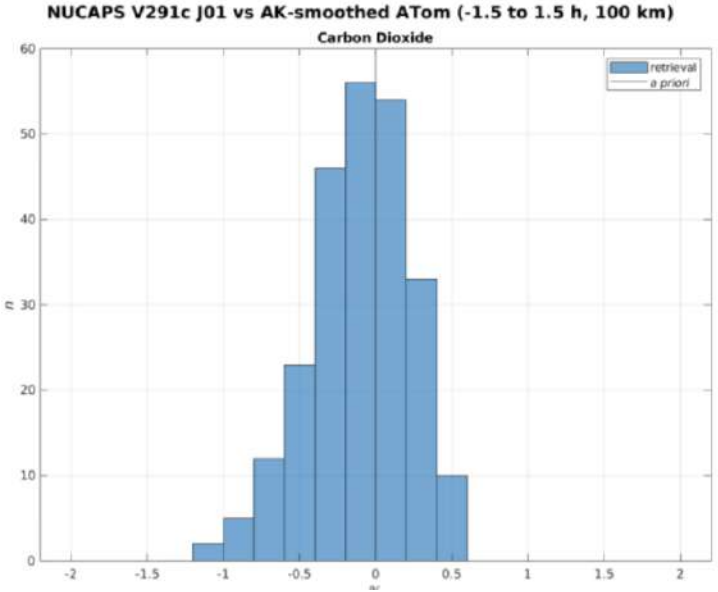
Intercomparisons with aircraft

Home > Browse > ATom > ATom DC-8 NOAA-Picarro-CO2-CH4-CO files

ATom DC-8 NOAA-Picarro-CO2-CH4-CO files

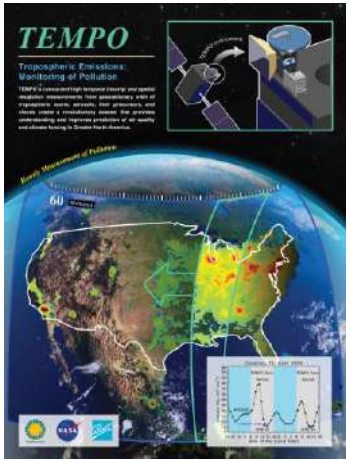
- **Mission:** ATom (5/9/2015-5/21/2018; Mission Website)
- **Measurement Platform:** DC-8 aircraft (Aircraft Webpage)
- **File Code:** NOAA-Picarro-CO2-CH4-CO
- **Measurement PI:** McKain
- **Description:** NOAA Picarro CO2, CH4, and CO
- **Documentation:**
  NOAA-Picarro_ATom1234_readme.pdf
- **Instrument:** NOAA Picarro
- **File Format:** Archive (plain-text) data file in ICARTT format

NOAA-20



Drivers for NURPACS

GeoXO, the 2031 - 2050 follow-on geostationary mission to GOES-R, includes an **Atmospheric Composition** instrument (**ACX**).



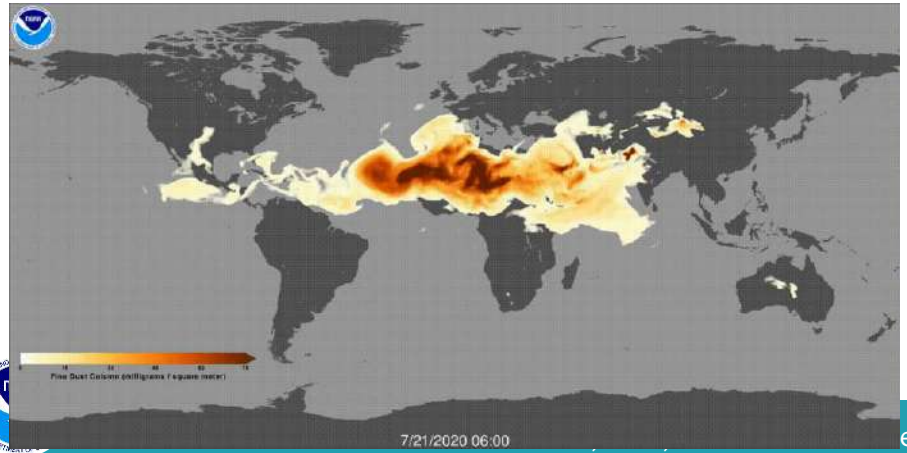
After launch in early 2023, NASA's **TEMPO** instrument will provide geostationary atmospheric composition data over CONUS for research applications, serving as **the prototype for ACX**.

TEMPO and ACX will provide **hourly observations of atmospheric composition,** instead of the once-per-day data currently available from LEO instruments.

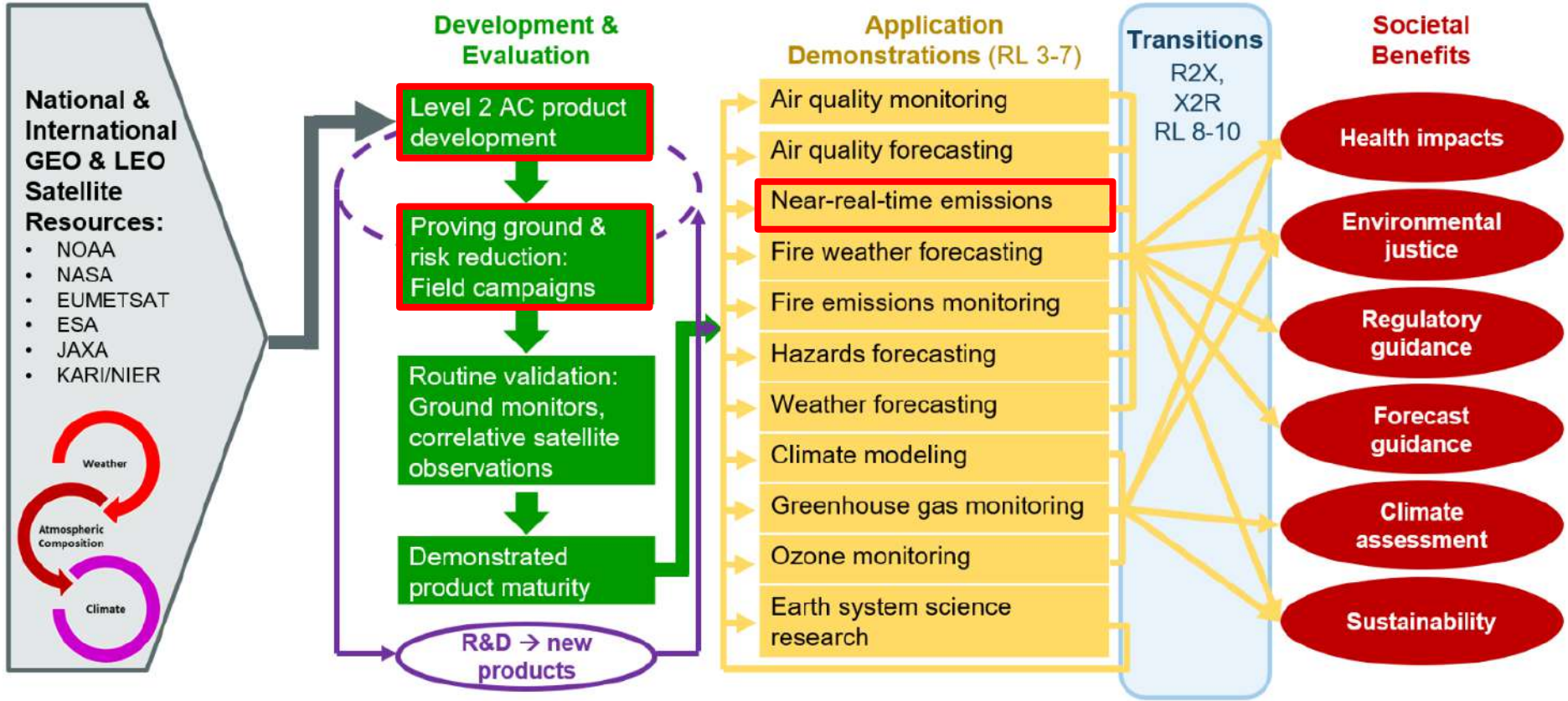
TEMPO and ACX hourly AC observations will be **game-changers** for NOAA's mission, informing near-real-time emissions adjustments, air quality and weather forecasting, and monitoring fires and other hazards. **Initiating user readiness planning now** is critical to ensure that these new and innovative datasets are fully exploited.

Steps to Develop NURPACS

- [x] **Establish team** of subject matter experts from across the Line Offices
- [x] **Map out full scope** of AC readiness plan
- [ ] **Identify key milestones** in product development, evaluations, and application demonstrations
- [ ] **Establish schedule** for delivery of milestones
- [ ] **Coordinate transition** pathways for successfully demonstrated products
- [ ] **Quantify** budgets for these activities
- [ ] **Receive LO concurrence** on NURPACS
- [ ] **Communicate NURPACS** to external user community
- [ ] **Assess process annually** and adjust plans accordingly

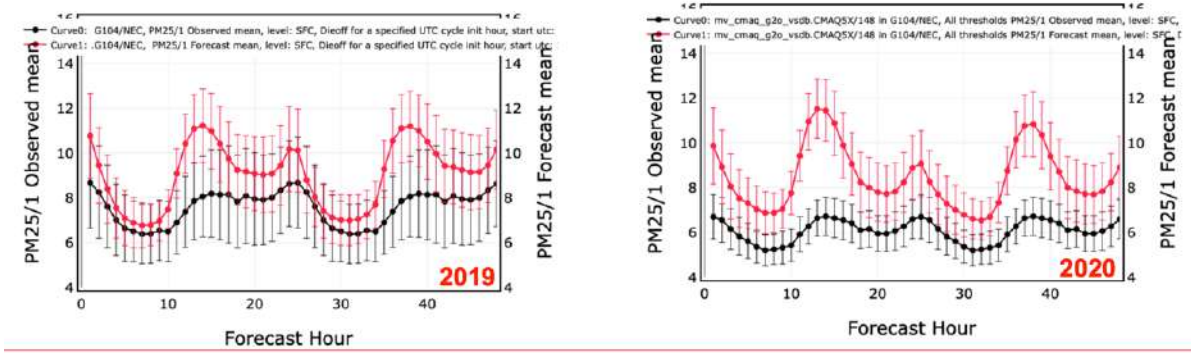


NURPACS Overview



Surface PM2.5 predictions in March

Obs vs fcst mean: NE US by forecast hour



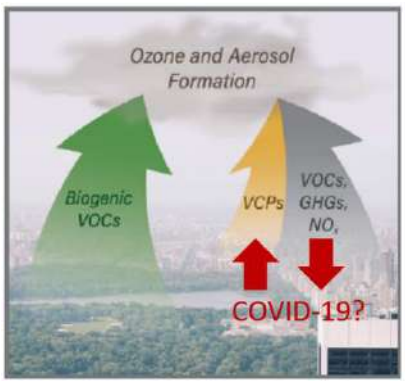
Emissions of pollutants and meteorology both influence PM2.5 concentrations.

Observed PM2.5 concentrations in Northeastern US (black) in March are lower in 2020 (right figure) than they were in 2019 (left figure).

However, operational model predictions (solid red) based on pollutant emissions data prior to COVID-19 pandemic produced higher PM2.5 in March 2020 than in March 2019, causing higher model overprediction in Northeastern US in March 2020.

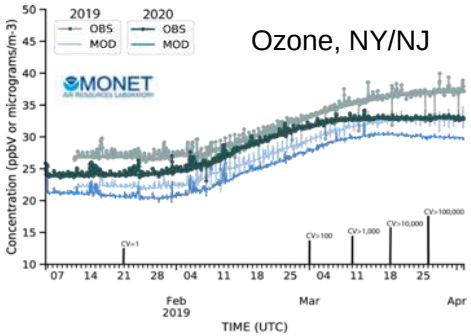
Is forecast bias due to nonrepresentative emission inventories?

Initial modeling and observational comparisons

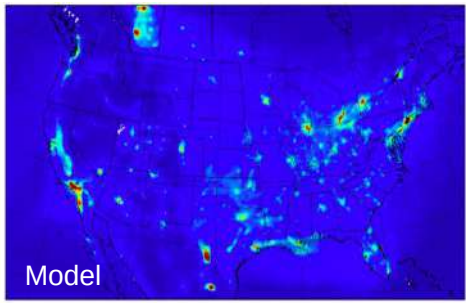


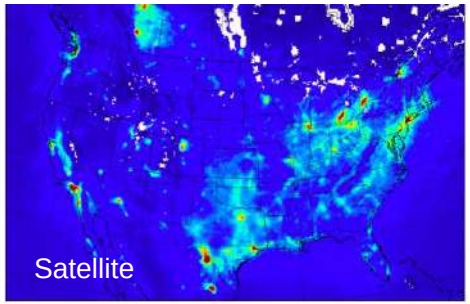
Rapid updates to emission inventory to account for emissions during crisis and recovery (CSL)

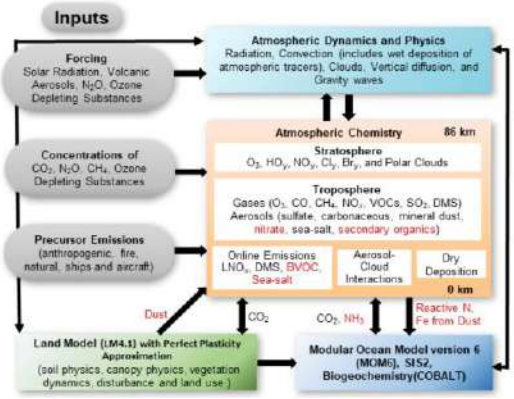
Compare NOAA operational air quality forecasts to monitoring network (ARL)



Model air quality with updated emissions and validate with satellite and in-situ observations (GSL, CSL, ARL)







Compare climate model of aerosols & clouds with satellites (GFDL)

Example of NURPACS Outputs: Near-Real-Time Emissions

Task 1 (FY22-26): Update anthropogenic nitrogen oxide and volatile organic compound emissions in near real-time ingesting LEO and GEO nitrogen dioxide and formaldehyde data, respectively. The focus will be on delivering operational products to the regional HRRR-Chem.

Task	FY22	FY23	FY24	FY25	FY26
Task 1.1	Milestone 22.1.1: Update a-priori bottom-up anthropogenic inventory to most recent year	Milestone 23.1.1: Generate weather-aware emission for AEROMMA domains; Model and evaluate satellite LEO and GEO NO_2 and HCHO using AEROMMA 2023 field campaign	Milestone 24.1.1: Develop and test emission data assimilation of NO_2 and HCHO for anthropogenic emissions	Milestone 25.1.1: Apply NO_2 and HCHO emission data assimilation and evaluate model performance	Milestone 26.1.1: Begin NRT emissions R2O in HRRR-Chem
FTE	1.0 FTE CSL 1.0 FTE ARL 1.0 FTE GMU	1.0 FTE CSL 1.0 FTE ARL 1.0 FTE GMU	1.0 FTE CSL 1.0 FTE ARL 1.0 FTE GMU	1.0 FTE CSL 1.0 FTE ARL 1.0 FTE GMU	1.0 FTE CSL 1.0 FTE ARL 1.0 FTE GMU

Summary

- A writing team of over 30 staff members from NESDIS, OAR, and NWS are developing NURPACS, a user readiness plan for NOAA's space-based atmospheric composition (AC) observations.
- NURPACS is NOAA's end-to-end roadmap to develop new satellite AC products, evaluate them with a host of observations, demonstrate their use in NOAA applications, and transition them into operations.
- The outputs from the NURPACS process will include the specific tasks needed to accomplish each of these activities, annual milestones for each task, and the level of effort and corresponding cost to achieve these milestones.

Proving Ground & Risk Reduction: Field Campaigns

Evaluate satellite atmospheric composition observations with in-situ and remote-sensing instrumentation on research aircraft and ground-based platforms:

AEROMMA-TEMPO

- Evaluate TEMPO over US megacities and marine areas
- Spring/Summer 2023
- White paper: https://csl.noaa.gov/projects/aeromma/

Asia-AQ

- Evaluate GEMS over East Asian megacities
- Winter/Spring 2024
- White paper available soon

AQUARIUS

- Evaluate TEMPO over US urban and agricultural regions
- Winter 2025?
- White paper in BAMS: https://doi.org/10.1175/BAMS-D-20-0017.1

2026 and beyond: ?

Evaluations of TEMPO and GEMS prepare us for GeoXO ACX

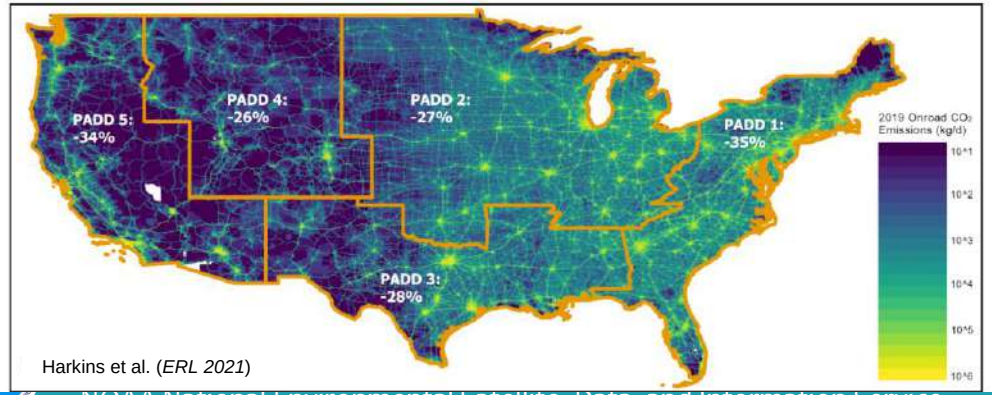
NOAA Application Demonstrations

OAR, NESDIS, & NWS collaborate to **demonstrate** utility of Atmospheric Composition products in a variety of NOAA **Applications** (RL 3-7).

Example: **Near-Real-Time Emissions**

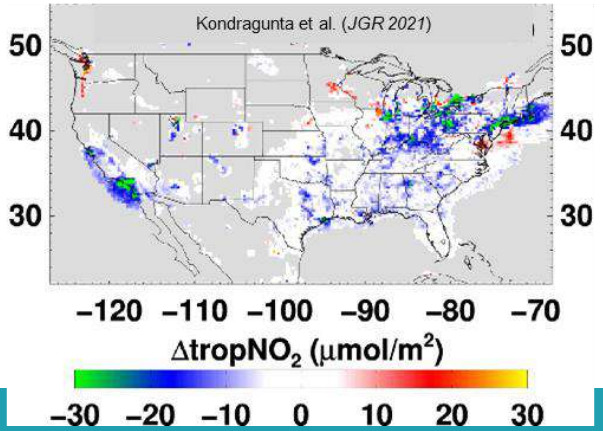
- **Emissions inventories**, key inputs to forecast models, are generally **out of date**
- **Forecast models** using out-of-date inventories **miss changes** from economic disruptions, e.g., COVID-19
- New NOAA effort will **use satellite atmospheric composition** data to produce **near-real-time emissions**

US Transportation Changes due to COVID-19 Pandemic



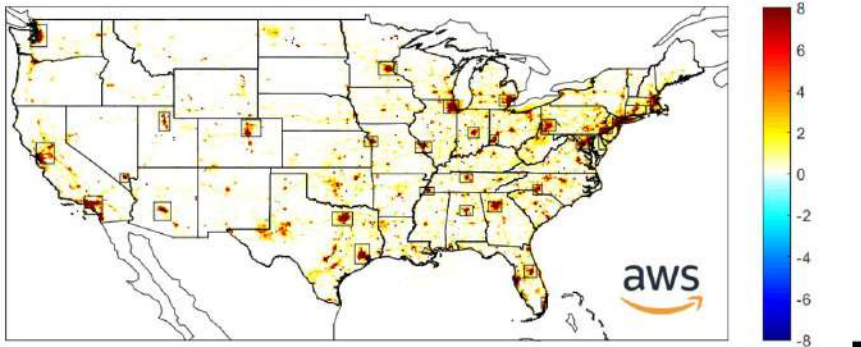
Harkins et al. (*ERL 2021*)

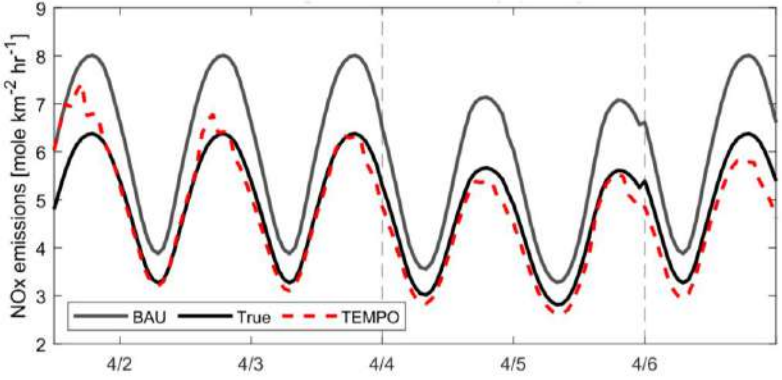
Changes in Satellite NO_2 Columns 2020 - 2019



AQ Tracker (12 km x 12 km, EAKF)

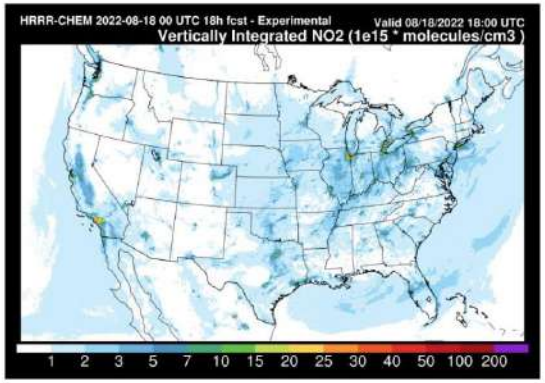
Business-as-usual (BAU) – COVID-19



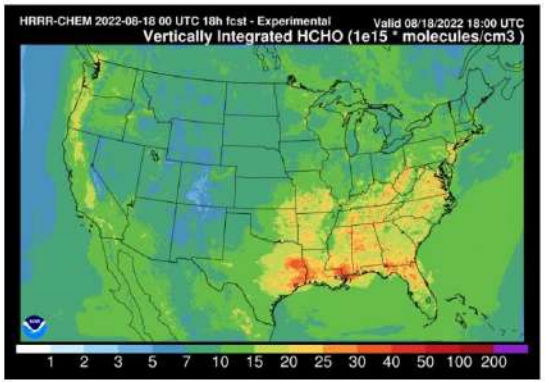


PIs: B. McDonald (CSL), A. Mizzi (Ames), D. Henze (CU)

HRRR-Chem (3 km x 3 km, full chem.)



NO_2



HCHO

https://rapidrefresh.noaa.gov/hrrr/HRRRchem/

PIs: J. Schnell, R. Ahmadov, G. Grell (GSL)