Value Assessment of an Atmospheric Composition (AC) Capability on NOAA's Next-Generation Geostationary and Extended Orbits (GEO-XO) Missions

GEO-XO Atmospheric Composition Value Assessment Writing Team

Lead Authors:

Gregory Frost, NOAA OAR CSL & CPO
Monika Kopacz, NOAA OAR CPO
Shobha Kondragunta, NOAA NESDIS STAR

Contributing Authors:

Ravan Ahmadov, NOAA OAR GSL & U Colorado CIRES
Jassim Al-Saadi, NASA LaRC
Arlyn Andrews, NOAA OAR GML
Christopher Barnet, STC
Victoria Breeze, NOAA OAR CPO
Julianna Christopoulos, NOAA OAR CPO (Lapenta Fellow)
Alice Crawford, NOAA OAR ARL
Lawrence Flynn, NOAA NESDIS STAR
Cory Martin, NOAA NWS NCEP EMC & Redline Perf Solns
Brian McDonald, NOAA OAR CSL
Jeff McQueen, NOAA NWS NCEP EMC
Fabien Paulot, NOAA OAR GFDL
Mike Pavolonis, NOAA NESDIS STAR
Irina Petropavlovskikh, NOAA OAR GML
R. Bradley Pierce, U Wisconsin SSEC
Karen Rosenlof, NOAA OAR CSL
Rick Saylor, NOAA OAR ARL
Tim Schmit, NOAA NESDIS STAR
Ivanka Stajner, NOAA NWS NCEP EMC
Diane Stanitski, NOAA OAR GML
James Szykman, NASA LaRC & US EPA

Atmospheric Composition (AC)

- Trace gases (<1%) + aerosols
- Thousands of distinct constituents
- Atmospheric lifetimes: seconds - centuries
- Sources: natural and anthropogenic activities
- Transformations: chemical reactions, atmospheric dynamics
- Sinks: stratosphere/ troposphere exchange, terrestrial/ oceanic uptake

GEO-XO Atmospheric Composition Value Assessment White Paper

(Written June - September 2020)

- Executive Summary
- Motivation and Background
- The Value of GEO-XO in NOAA Application Areas
  1. Air Quality Forecasting
  2. Weather and Climate Forecasting
  3. Fire Weather Forecasting
  4. Hazards Forecasting
  5. Greenhouse Gas Monitoring
  6. Stratospheric Ozone Monitoring
  7. Air Quality Monitoring
  8. Earth System Science
- Applications Traceability Matrix
- Potential Valuation Use Cases

NOAA's atmospheric composition observations and predictions save lives and protect property

NOAA's AC observation and prediction capabilities address all of these topics!

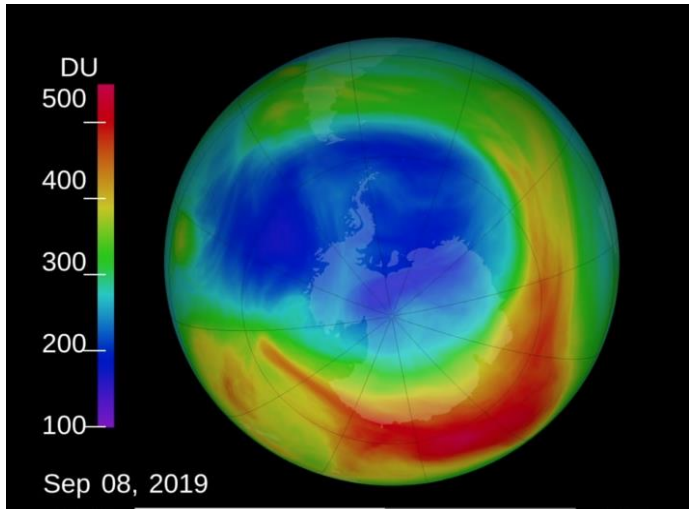
Air Quality

Wildfires

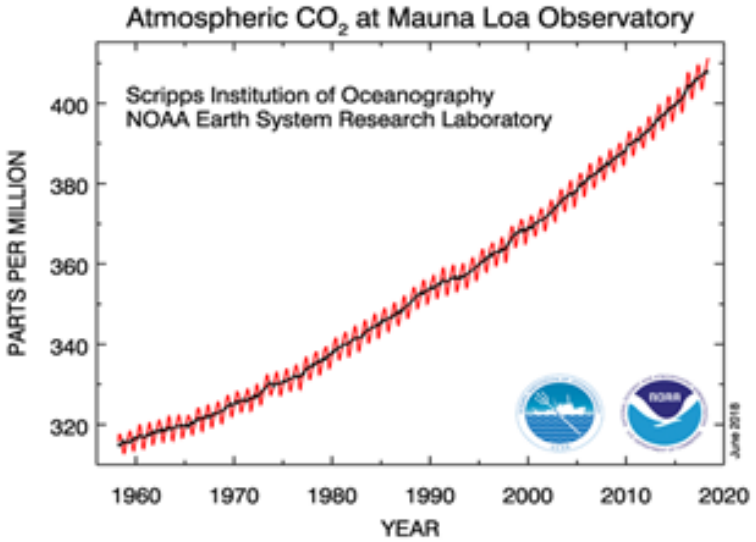
Hazards

Weather and Climate

Stratospheric Ozone



Greenhouse Gases



NOAA has many mandates to observe and predict AC

LEGISLATIVE

NOAA tracks the efficacy of various public laws.

- Direct Congressional appropriations
  - e.g., **FY19 Disaster Supplemental**
- **Clean Air Act** 1990 Title IV and Title VI, 42 U.S.C.
  - Ozone depletion: § 7401 et seq.
  - Lake/coastal deposition: § 7412(m)
  - Ecosystems: § 7403(e)
  - Acid deposition program: § 7403(j)
- **Global Change Research Act** of 1990, 15 U.S.C. § 2921 et seq
- Global Climate Protection Act of 1990, 7 U.S.C. § 6701 et seq.
- **Weather Research and Forecasting Innovation Act** (2017), Pub.L. 115–25
- National Climate Program Act, 15 U.S.C. § 2901-2908, at 2904(d) (4), et seq.
- Geophysical Surveys: Improvement of methods, etc., 33 U.S.C. §883(d)
- **National Weather Service Organic Act**, 15 U.S.C. § 313
- Federal Records Act as amended, 44 U.S.C. §3101 et seq.
- Data Quality Act, Public Law 106-554, Section 515, 2001
- 36 C.F.R., Chapter XII National Archive & Records Administration
- Coastal Zone Management Act of 1972, 16 U.S.C. 1450 et seq.
- Consolidated Appropriations Act, 2005, Public Law No. 108-447

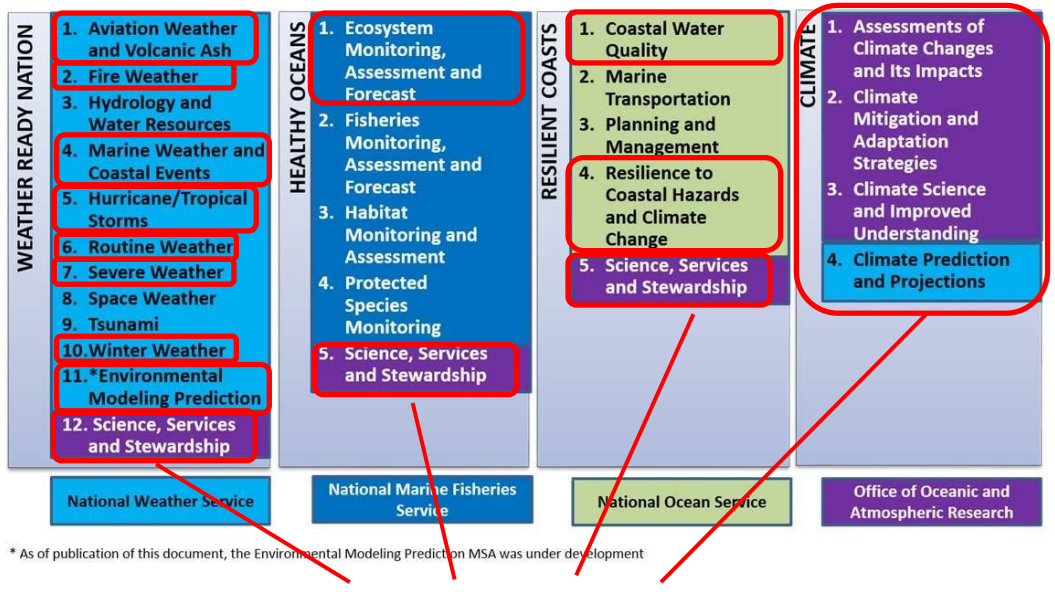
DIPLOMATIC

- U. N. Framework Convention on Climate Change (**UNFCCC**)
- **Montreal Protocol** on Substances that Deplete the Ozone Layer (and subsequent amendments)
- Global Earth Observation System of Systems (**GEOSS**)
- International Council of Scientific Unions (ICSU) guidelines/policy regarding World Data Centers (WDC)

EXECUTIVE

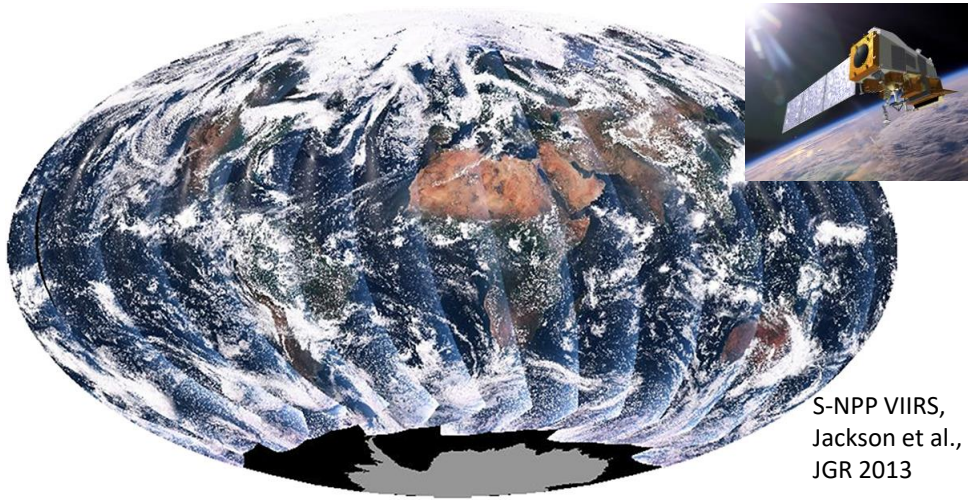
- Numerous **interagency agreements**: Federal, state/local/tribal (S/L/T)
- **National Response Framework**: Annexes assign dispersion prediction responsibilities for smoke, radioactive and hazardous materials to NOAA.
- **Federal Radiological Emergency Response Plan**: NOAA is primary DOC agency assisting Federal, State, local orgs. in a radiological emergency.
- Strategic Plan for the U.S. Integrated Earth Observations System (IEOS), USGEO Report, 2005
- President's Security and Prosperity Program of North America Initiative (SPP), 2005
- U.S. Ocean Action Plan/ Charting the Course for Ocean Science for the United States for the Next Decade (2007)
- Department Administrative Order (DAO) 212-2 Information Technology Handbook

NOAA's Mission Service Areas

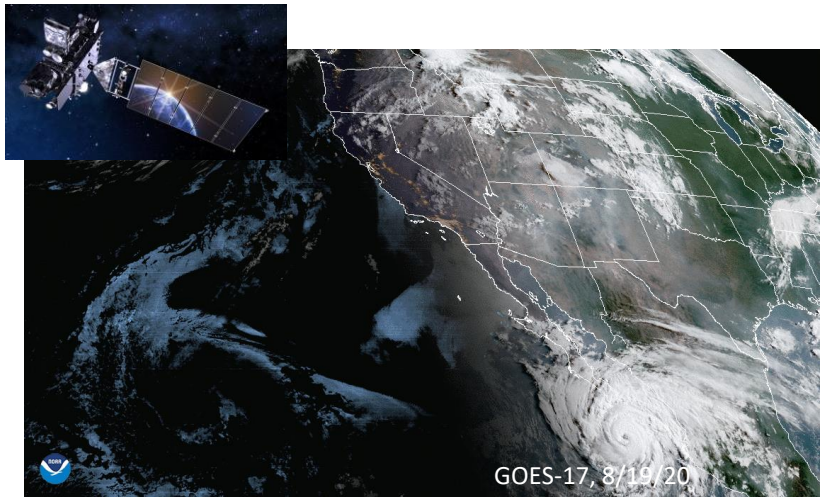


Atmospheric composition informs many NOAA MSAs

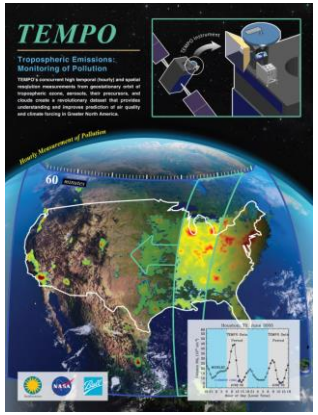
Space-based platforms extend spatial and temporal reach of NOAA's AC observing capabilities

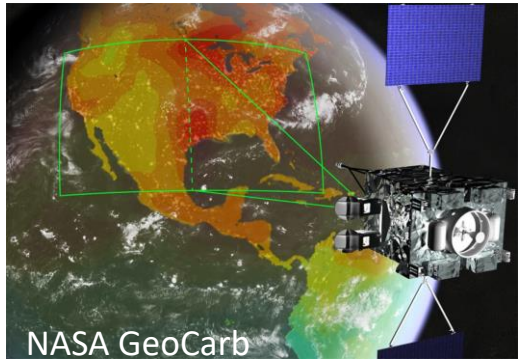


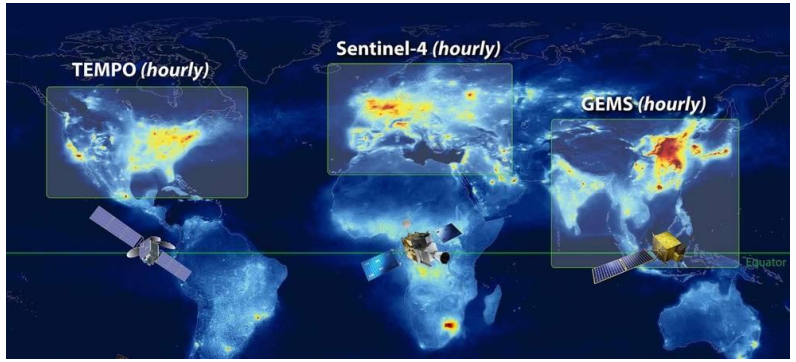
S-NPP VIIRS, Jackson et al., JGR 2013



Current and planned US GEO AC capabilities are limited

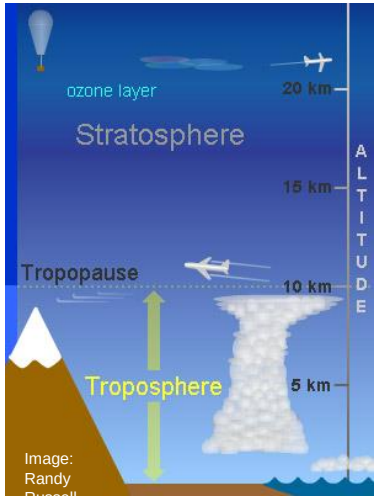




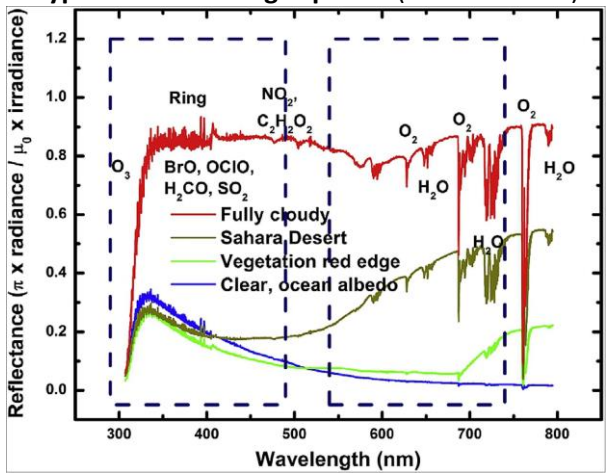


GEO-XO is the opportunity for the U.S. to establish an operational GEO AC capability

Space-based AC observing capability involves multiple instruments in LEO and GEO



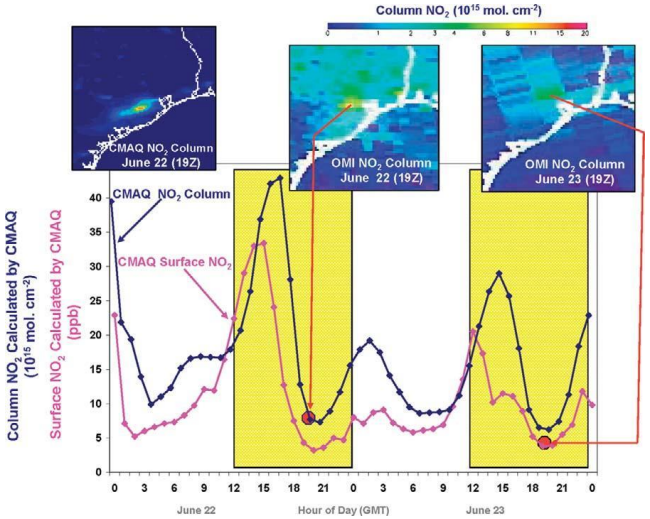
Typical TEMPO-range spectra (from GOME-1)



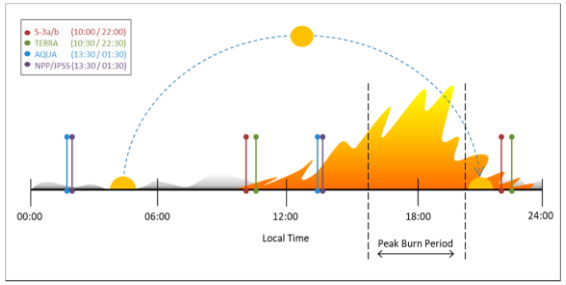
Physics and observing technology mandate a combination of instruments to measure atmospheric composition

- **Vis/IR Imager:** fires, aerosol type & optical depth
- **Thermal/near IR Sounder:** profiles and tropospheric columns of ozone and greenhouse gases
- **UV/Vis Spectrometer:** total and tropospheric columns of ozone and air pollutants, aerosol layer height

AC applications benefit from high temporal resolution of GEO



Fishman et al., BAMS, 2008



Johnston et al., Sensors, 2020

GEO captures hourly variations and rapid changes in AC:

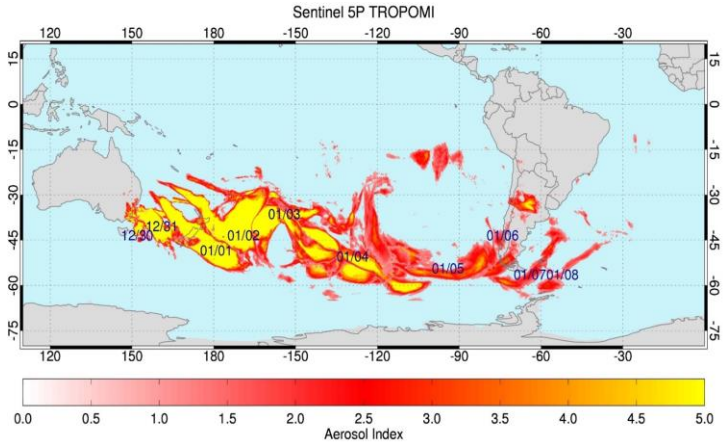
- Sources and sinks, including O_3 and aerosol precursor emissions and photochemistry
- Fire evolution and smoke injection height
- Pollution transport and PBL dynamics
- Net radiation and energy budget

GEO sampling increases AC data coverage:

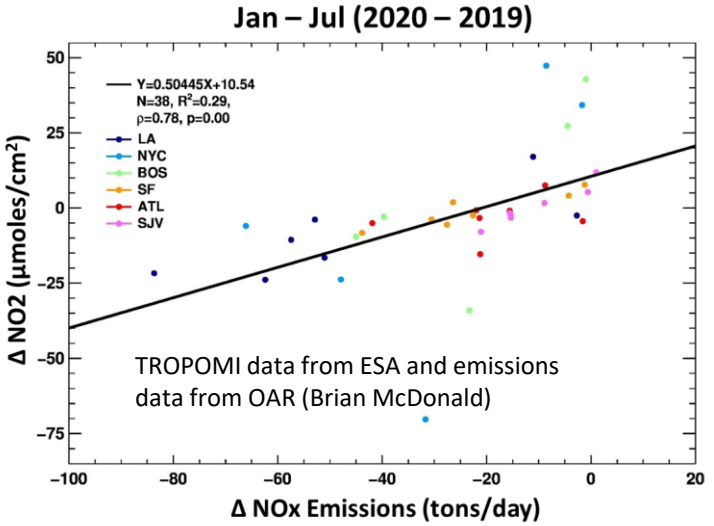
- Decreases chances of data loss to clouds
- Detects spatial gradients and rapid evolution needed for plume tracking

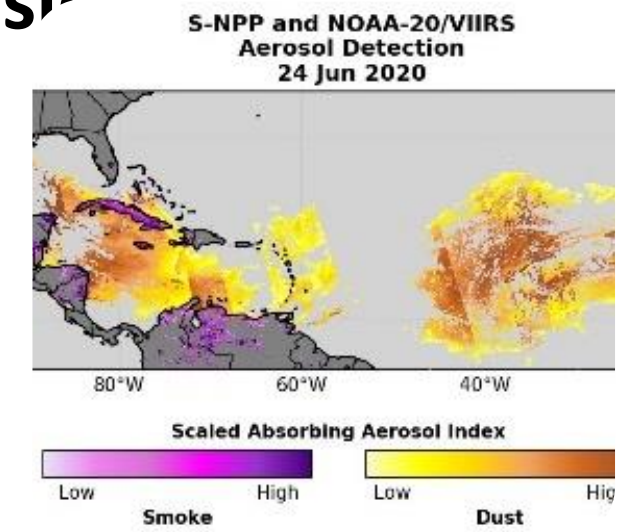
2020: A Case Study for the Benefits of a US AC Mission

Enormous smoke plumes from fires in Australia reached South America a week later: **UV/Vis spectrometer provides aerosol index and height of smoke plume transport**



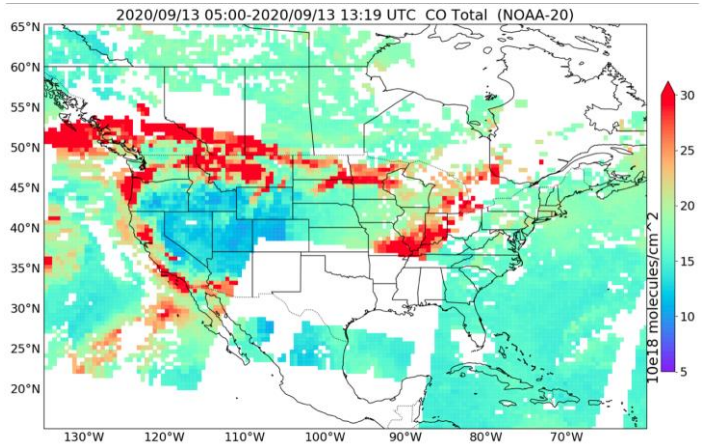
COVID-19 pandemic lockdowns resulted in reduced traffic emissions: **UV/Vis spectrometer detects boundary layer nitrogen dioxide and other precursors of urban smog**





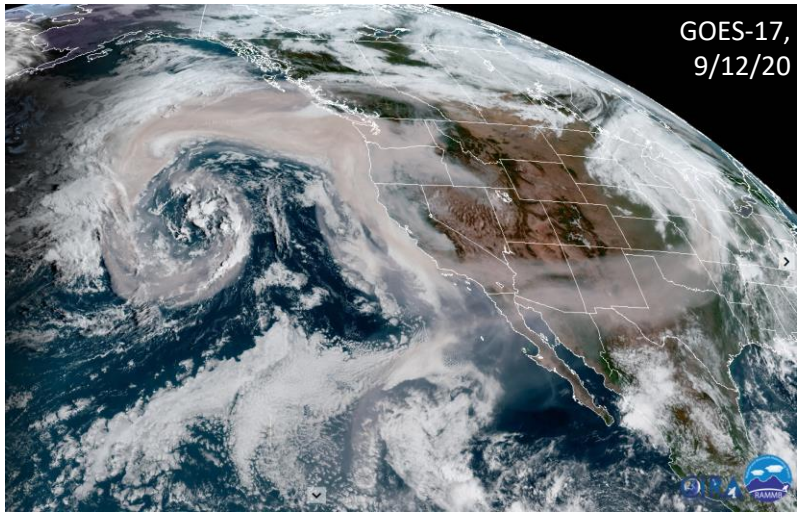
A month-long enormous dust storm spread from the Sahara to the U.S., impacting visibility and air quality: **Vis/IR imager allows dust and smoke aerosols to be distinguished**

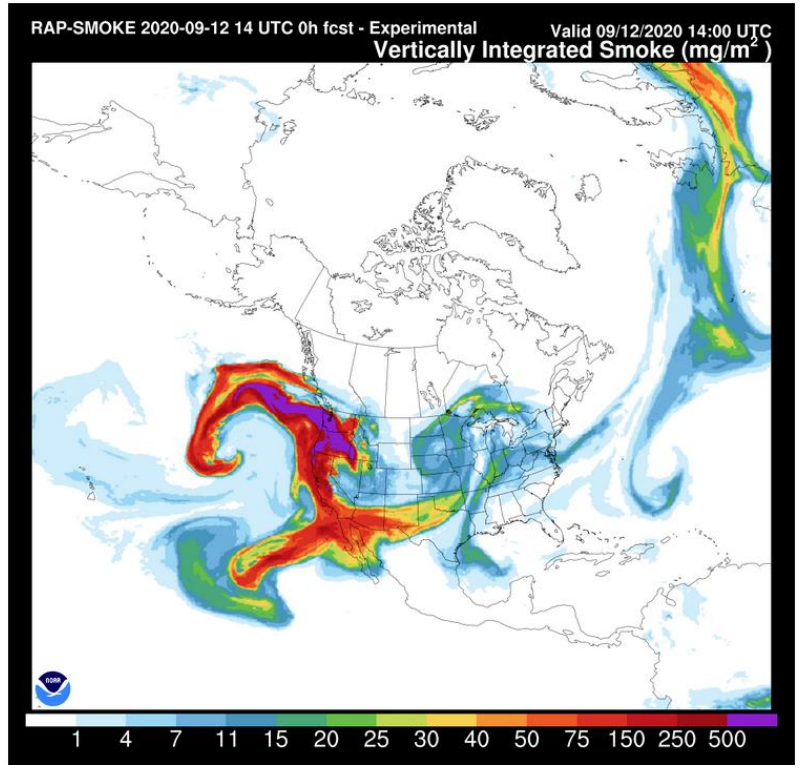
Record heat in the Arctic resulted in release of unprecedented amount of carbon emissions from Siberian fires: **Vis/IR imager tracks fire location and intensity and smoke aerosol optical depth**



Smoke from record breaking fire activity in the western United States spread over the nation and across the Atlantic: **TIR sounder follows carbon monoxide in smoke plumes**

Example of potential GEO-XO AC valuation use case: Wildfires





Epidemiology. 28(1):77–85, JANUARY 2017
DOI: 10.1097/EDE.0000000000000556, PMID: 27648592
Issn Print: 1044-3983
Publication Date: January 2017

Wildfire-specific Fine Particulate Matter and Risk of Hospital Admissions in Urban and Rural Counties

Jia Liu;Ander Wilson;Loretta Mickley;Francesca Dominici;Keita Ebisu;Yun Wang;Melissa Sulprizio;Roger Peng;Xu Yue;Ji-Young Son;G. Anderson;Michelle Bell;

J Am Heart Assoc. 2018 Apr 17; 7(8): e007492. PMCID: PMC6015400
Published online 2018 Apr 11. doi: 10.1161/JAHA.117.007492 PMID: 29643111

Cardiovascular and Cerebrovascular Emergency Department Visits Associated With Wildfire Smoke Exposure in California in 2015

Zachary S. Wettstein, BA, [1] Sumi Hoshiko, MPH, [2] Jahan Fahimi, MD, PhD, [3] Robert J. Harrison, MD, MPH, [4,5] Wayne E. Cascio, MD, [6] and Ana G. Rappold, PhD [6]

Who Among the Elderly Is Most Vulnerable to Exposure to and Health Risks of Fine Particulate Matter From Wildfire Smoke?

Jia Coco Liu, Ander Wilson, Loretta J. Mickley, Keita Ebisu, Melissa P. Sulprizio, Yun Wang, Roger D. Peng, Xu Yue, Francesca Dominici, Michelle L. Bell

American Journal of Epidemiology, Volume 186, Issue 6, 15 September 2017, Pages 730–735, https://doi.org/10.1093/aje/kwx141
Published: 10 August 2017 **Article history**

Impacts:

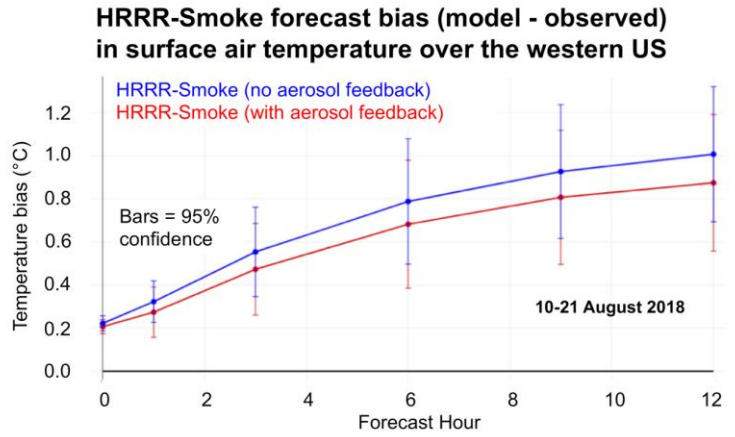
- Immediate wildfire threat to life and property
- Emissions and air quality impacts of smoke
- Impact of smoke aerosols on weather forecasts
- Acute and chronic health effects of smoke
- Environmental justice considerations

GEO-XO Instruments needed:

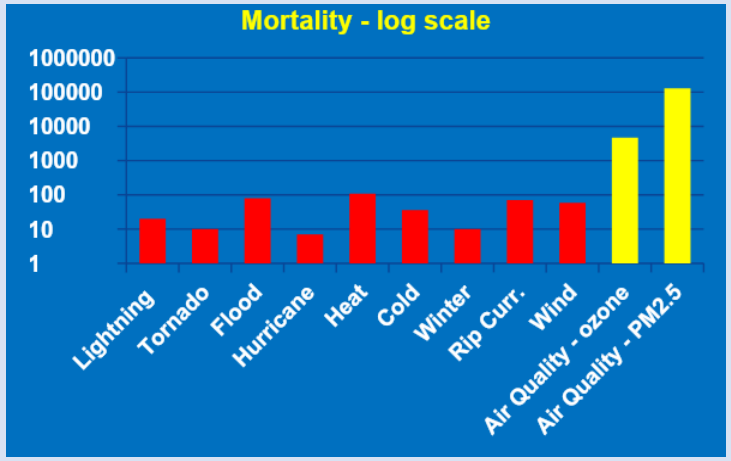
- Vis/IR Imager: fire detection + size + power, AOD
- T/NIR spectrometer: CO, CO_2
- UV/VIS spectrometer: O_3, NO_2, HCHO, glyoxal, aerosol index, aerosol layer height

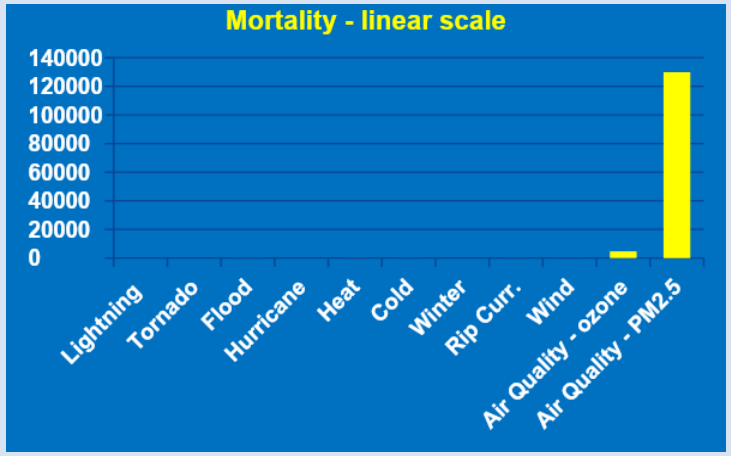
Capabilities to fulfill NOAA's mission:

- Continuous observing, real time with minimal latency
- Forecasts assimilate FRP, AOD, and trace gases to adjust emissions and obtain realistic source budgets



Example of potential GEO-XO AC valuation use case: Air Quality

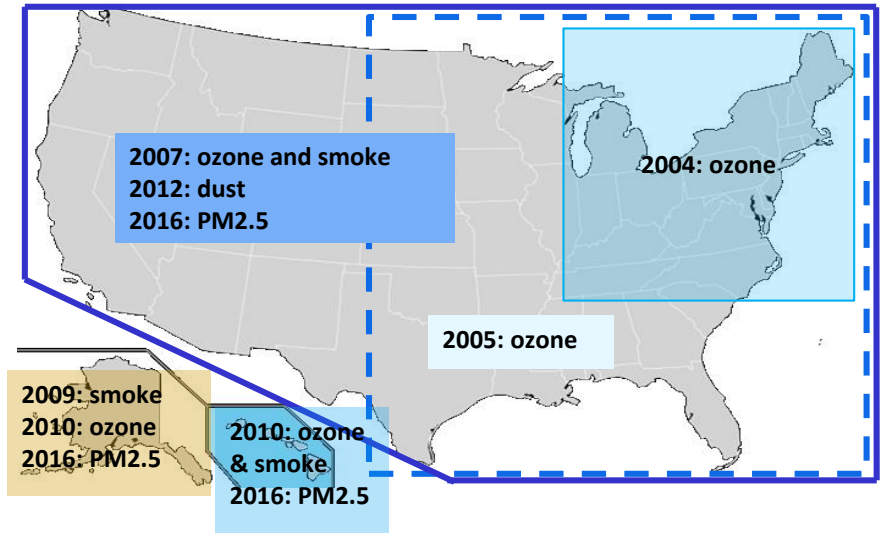




Red: US weather fatalities in 2018
(source: https://www.weather.gov/hazstat/)

Yellow: US air quality excess mortality for 2005
(source: Fann et al., Risk Analysis, 2012
https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1539-6924.2011.01630.x)

NOAA's National Air Quality Forecast Capability (NAQFC)

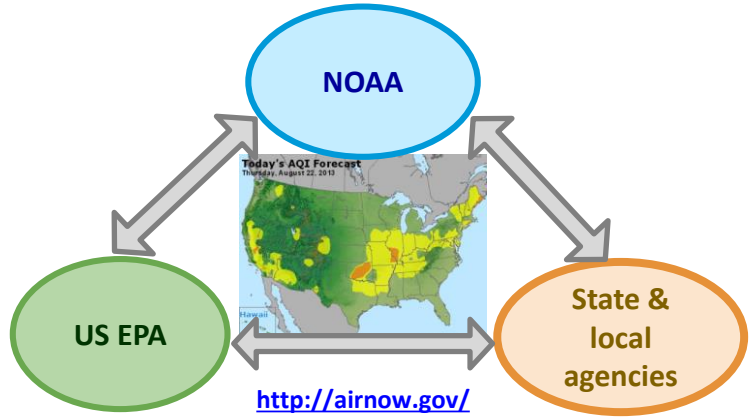


Impacts:
- Emissions and air quality impacts
- Impacts on weather forecasts
- Acute and chronic health effects
- Environmental justice considerations

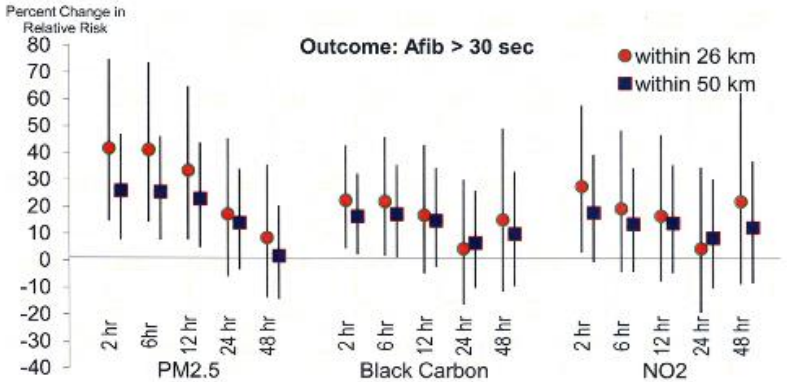
GEO-XO Instruments needed:
- Vis/IR Imager: AOD, fires, smoke/dust
- T/NIR spectrometer: CO, CO_2, CH_4
- UV/VIS spectrometer: O_3, NO_2, HCHO, glyoxal, aerosol index, aerosol layer height

Capabilities to fulfill NOAA's mission:
- Continuous observing, real time with minimal latency
- Forecasts assimilate AOD, trace gases to adjust emissions and obtain realistic source budgets

http://airquality.weather.gov/



Risk of Atrial Fibrillation With Air Pollution in Patients Living Within 26 km of the Air Pollution Monitoring Site



Link et al., J. Am. Coll. Cardiol., 2013

Cardiovascular risk increased by 40% after just two hours of PM2.5 exposure. GEO observations would provide data on PM2.5 and NO_2 exposure on hourly timescales.

Summary

- White paper provides motivation and describes needs for GEO-XO Atmospheric Composition (AC) capability in 8 NOAA application areas.
- NOAA's AC observations and predictions save lives and protect property.
- NOAA has many mandates to observe and predict AC, particularly understanding the linkages between weather, air quality, and climate.
- Space-based platforms extend spatial and temporal reach of NOAA's AC observing capabilities.
- Current and planned US GEO AC capabilities are limited.
- Space-based AC observing capability involves multiple instruments in LEO and GEO.
- AC applications benefit from high temporal resolution of GEO.
- This year has demonstrated a very compelling case for a US AC mission.
- Valuation use cases will demonstrate the economic and societal benefits of a GEO-XO AC capability.