Complementarity of S5P TROPOMI and SNPP VIIRS, OMPS, and CrIS Measurements for Atmospheric Chemistry Monitoring – Some Examples and Case Studies from NOAA

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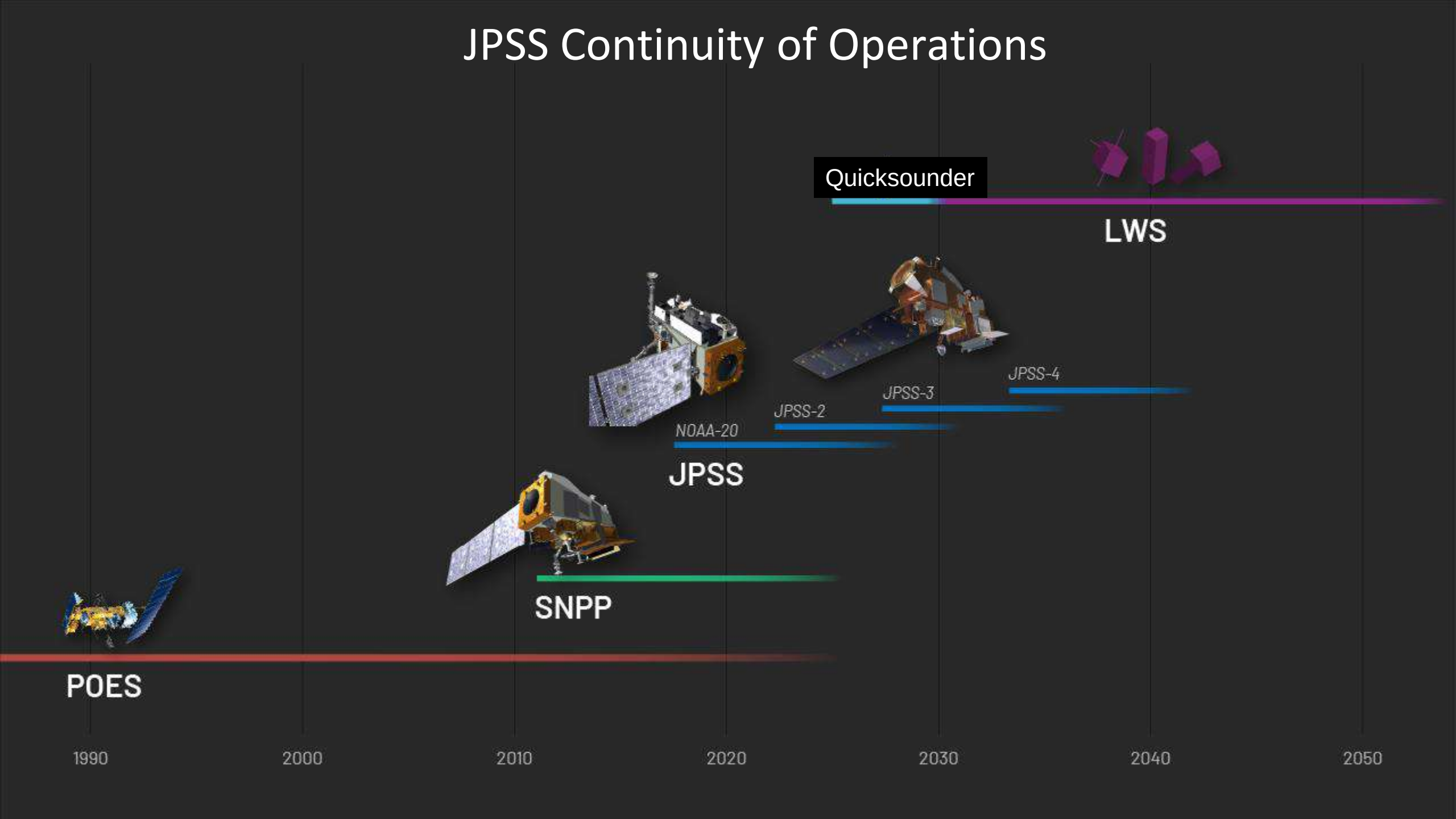
NOAA
National Environmental Satellite, Data, and Information Service

October 10-14, 2022
Sentinel-5P Mission:5 years anniversary
Taormina, Italy

Outline

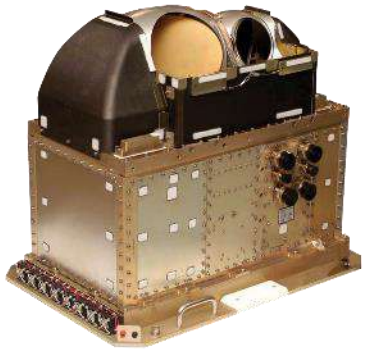
- The JPSS Mission and its contributions to Atmospheric Composition (AC)
- NOAA AC application areas
- Examples of TROPOMI and JPSS working together (CO, Aerosols, CH_4, NO_2)
- Upcoming AC field campaigns in the US
- JPSS-2 launch

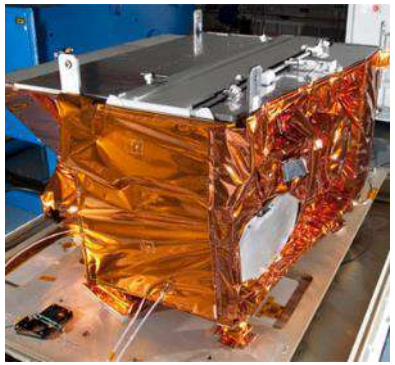
JPSS Continuity of Operations

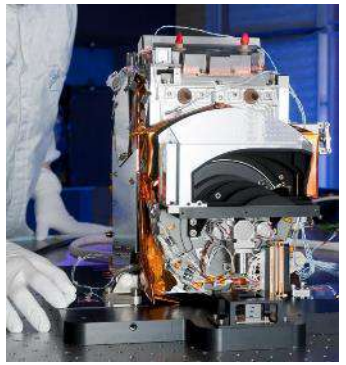


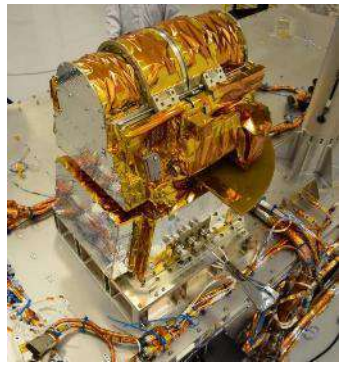
JPSS Sensors

MW	IR	Vis to IR	UV
ATMS	**CrIS** ✓ AC	**VIIRS** ✓ AC	**OMPS** ✓ AC	**CERES**
Advanced Technology Microwave Sounder	Cross-track Infrared Sounder	Visible Infrared Imaging Radiometer Suite	Ozone Mapping and Profiler Suite	Clouds and the Earth's Radiant Energy System





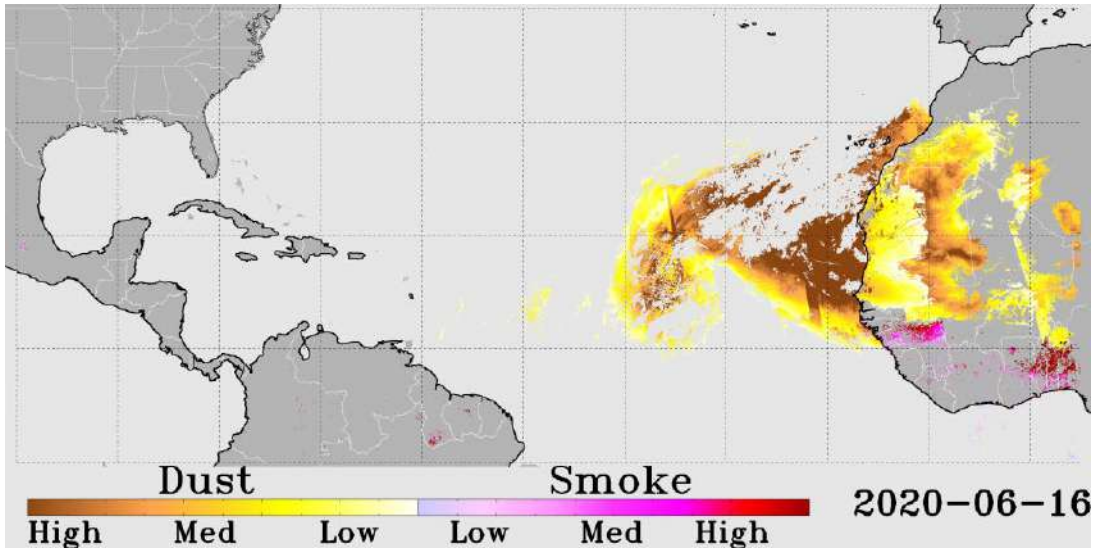




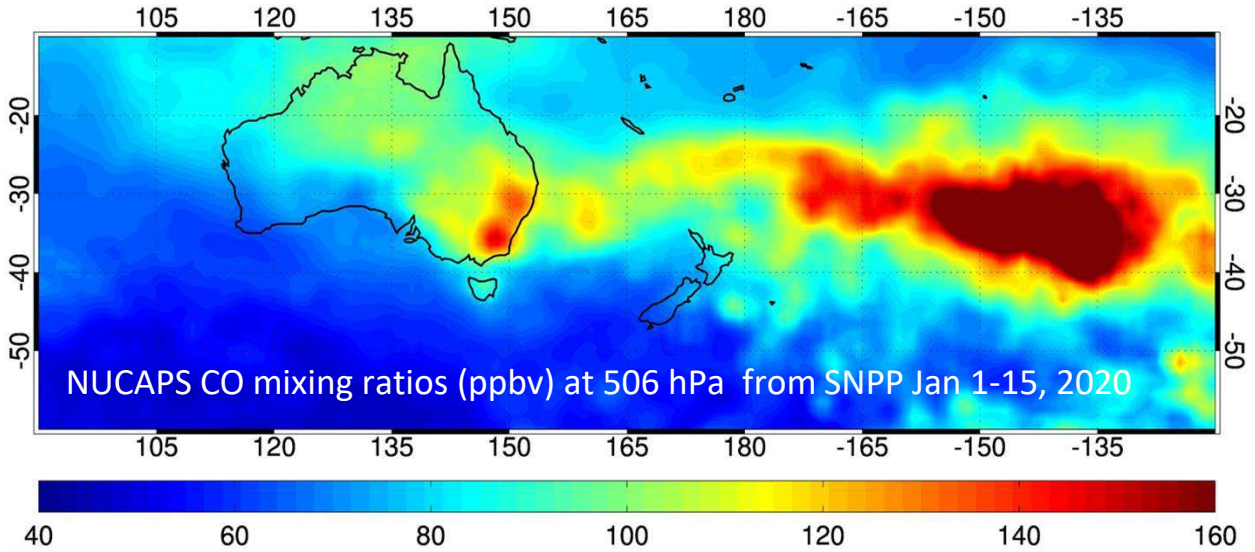
ATMS and CrIS together provide high vertical resolution temperature and water vapor information needed to maintain and improve forecast skill out to 5 to 7 days in advance for extreme weather events, including hurricanes and severe weather outbreaks.		VIIRS provides many critical imagery products including snow/ice cover, clouds, fog, aerosols, fire, smoke plumes, vegetation health, phytoplankton and chlorophyll abundance.	Ozone spectrometers for monitoring ozone hole and recovery of stratospheric ozone and for UV index forecasts.	Scanning radiometer which supports studies of the Earth Radiation Budget (ERB). **Discontinued after JPSS-1 (NOAA-20). Replaced by Libera on JPSS-3*
NORTHROP GRUMMAN	HARRIS	Raytheon	Ball	NORTHROP GRUMMAN

Atmospheric Composition (AC) Products from JPSS Sensors

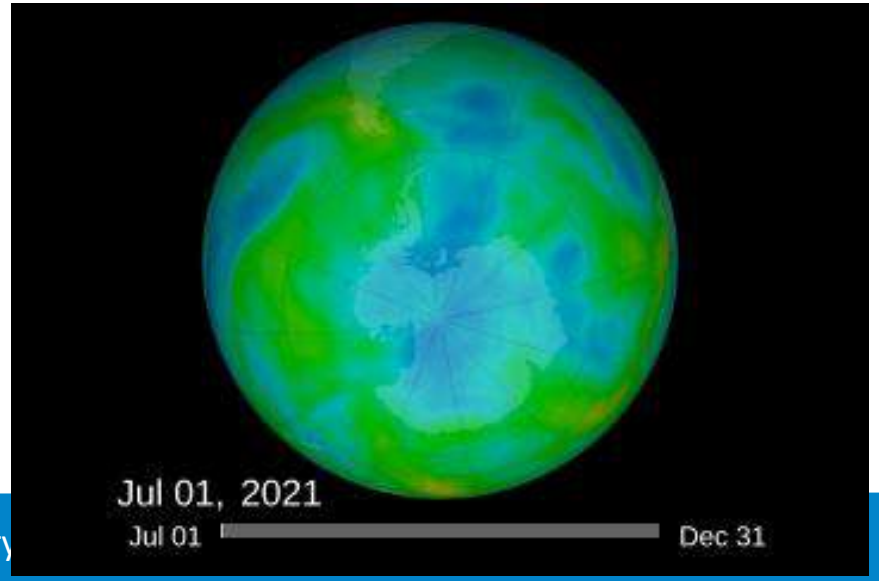
VIIRS
Aerosols, smoke, dust, volcanic ash



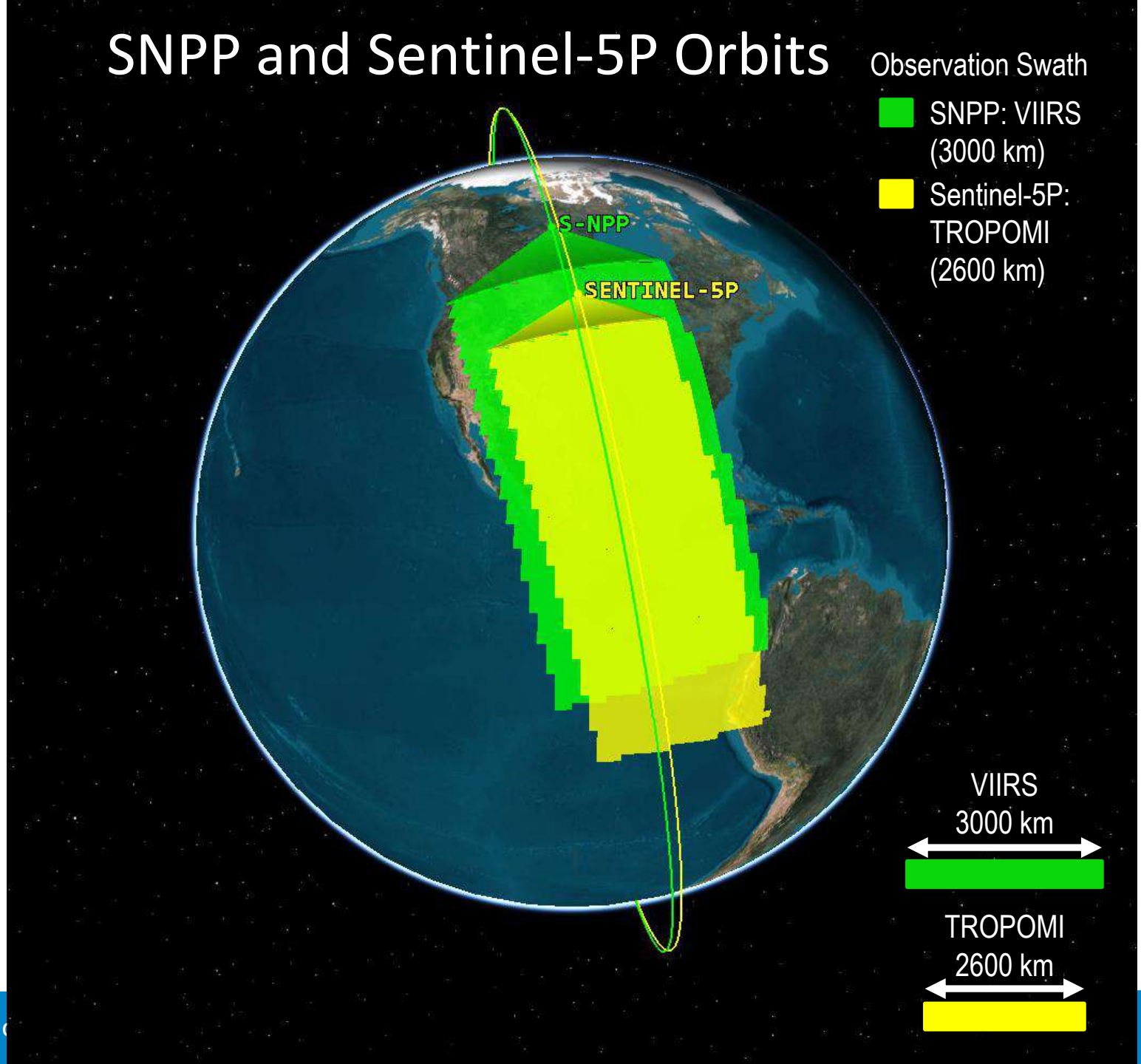
CrIS
Trace gasses (Ozone, CO, CH4, CO2 profiles)



OMPS
Ozone profiles, total ozone, SO2



SNPP and Sentinel-5P Orbits



Applications of JPSS and TROPOMI for Atmospheric Composition (AC) at NOAA

NOAA has numerous mandates to carry out research, observations, and predictions of air quality and atmospheric composition

LEGISLATIVE

- Direct Congressional appropriations
- Clean Air Act 1990
- Global Change Research Act of 1990
- Global Climate Protection Act of 1990
- 2017 Weather Research and Forecasting Innovation Act
- National Climate Program Act
- Geophysical Surveys
- National Weather Service Organic Act
- Federal Records Act as amended
- Data Quality Act
- National Archive & Records Administration
- Coastal Zone Management Act of 1972
- Consolidated Appropriations Act of 2005

EXECUTIVE

- Numerous interagency agreements
- National Response Framework
- Federal Radiological Emergency Response Plan
- Strategic Plan for the U.S. Integrated Earth Observations System
- President's Security and Prosperity Program of North America Initiative, 2005
- U.S. Ocean Action Plan/ Charting the Course for Ocean Science for the United States for the Next Decade, 2007
- Department Administrative Order 212-2 Information Technology Handbook

DIPLOMATIC

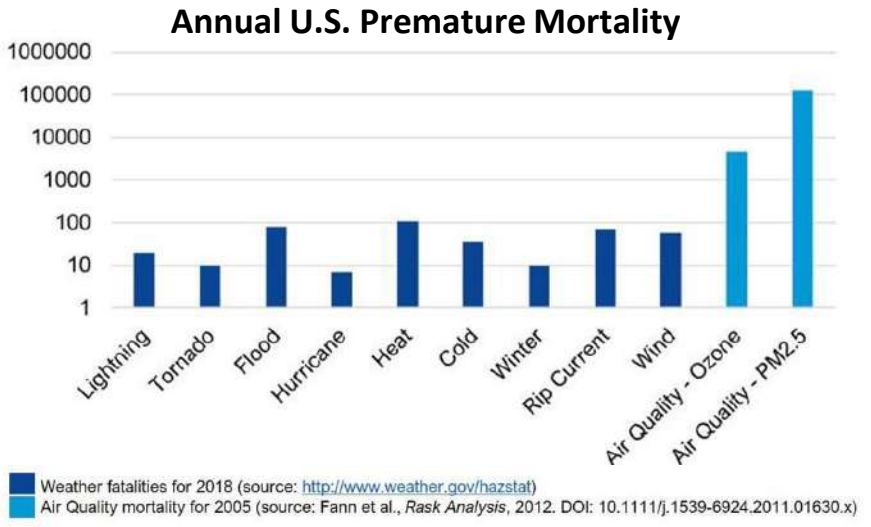
- U. N. Framework Convention on Climate Change
- Montreal Protocol on Substances that Deplete the Ozone Layer and subsequent amendments
- Global Earth Observation System of Systems
- International Council of Scientific Unions guidelines/policy regarding World Data Centers (WDC)

NOAA's Mission:

Science, Service and Stewardship

NOAA's Vision of the Future:

Healthy ecosystems, communities and economies that are resilient in the face of change



Air pollution results in **100,000+ premature deaths** and nearly **$1T in damages** in the U.S. annually, many times greater than mortality and damages from extreme weather events.

Historic 2020 Fire Season in Western US

- Extreme fires began mid-August, periodic surges in activity, still ongoing in late October
- Wildfires driven by record-setting heat waves, drought conditions, episodes of strong offshore (easterly) winds
- California:
  - 5 of top 20 largest wildfires in state history
  - Total of > 16.5 million km^2 burned so far (~2x more than previous record year of 2018)
  - Largest single fire in state history (August Complex): first “gigafire” (> 1 million acres/ 4 million km^2)
- Oregon:
  - > 4 million km^2 burned (state record)
  - Record-high concentrations of daily fine particles ($PM_{2.5}$)
- Colorado:
  - 3 largest wildfires in state history
  - East Troublesome Fire: grew 567,000 km^2 in 24 hours (21-22 Oct)

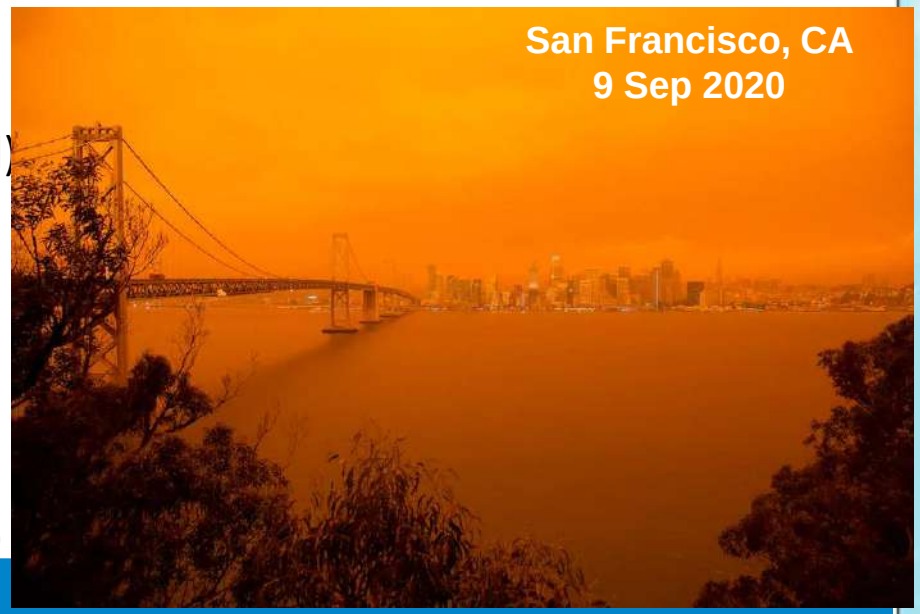
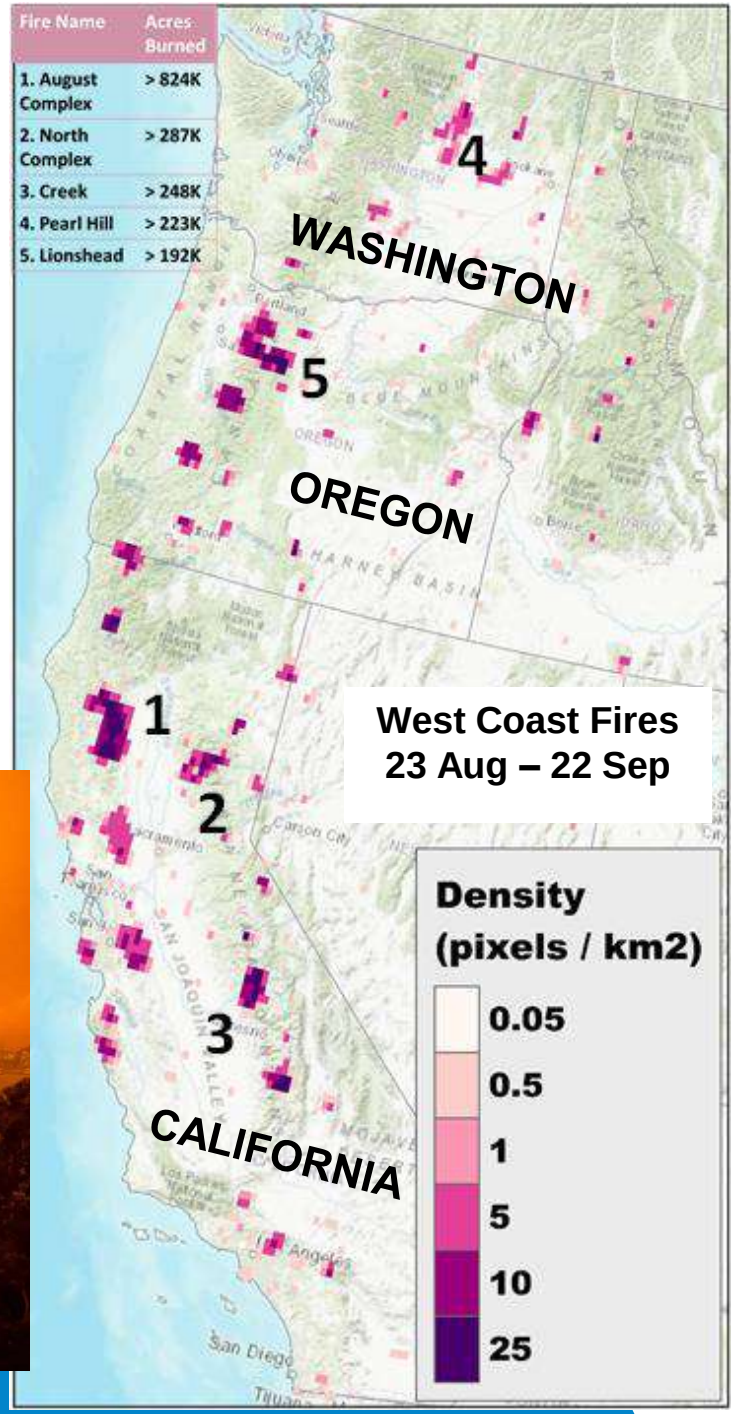
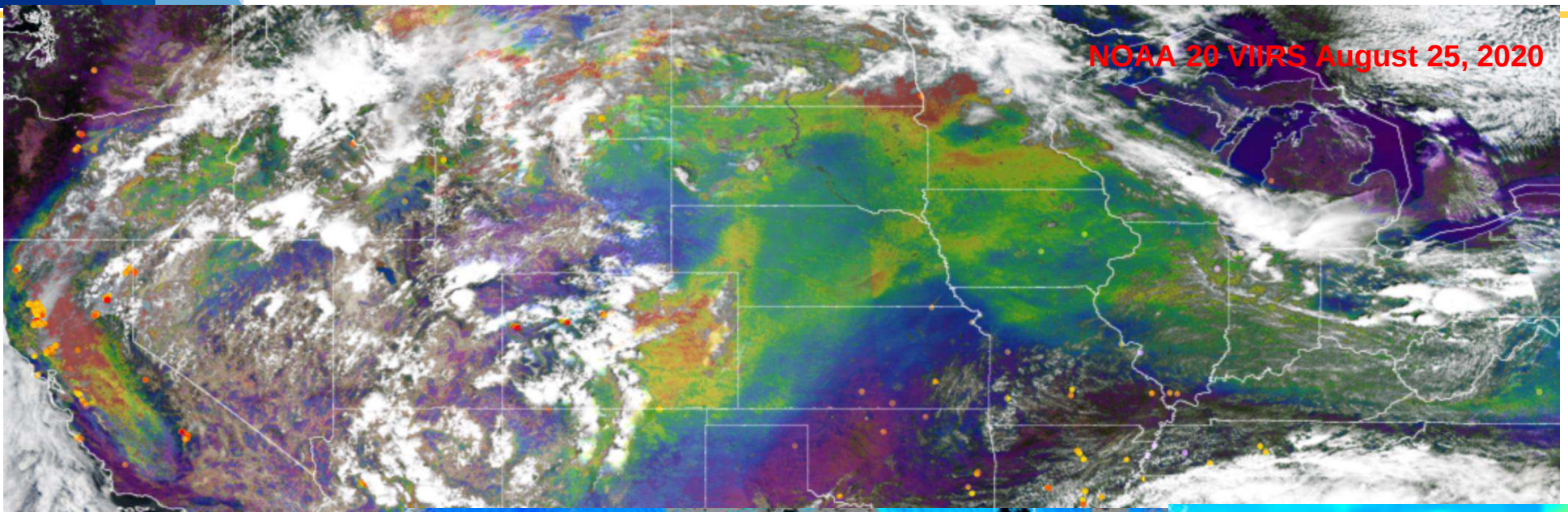


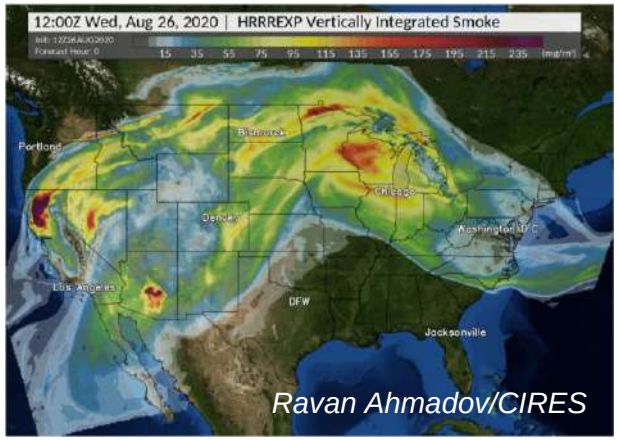
Photo courtesy of the Washington Post

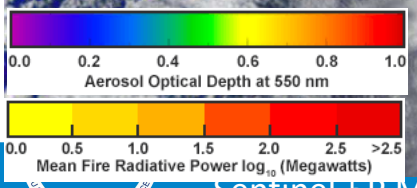


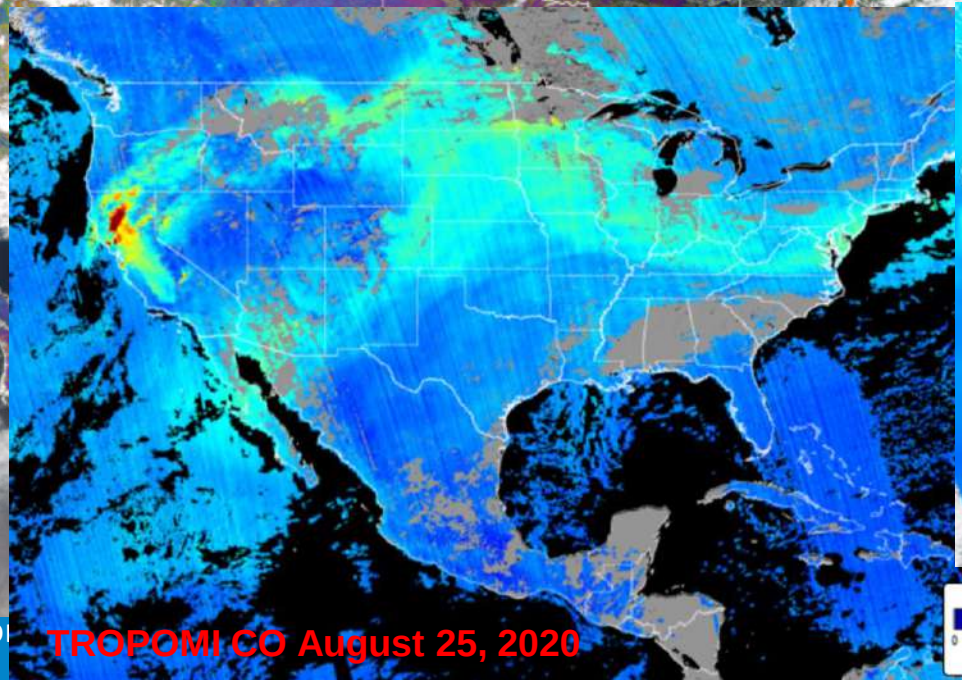
California Fires

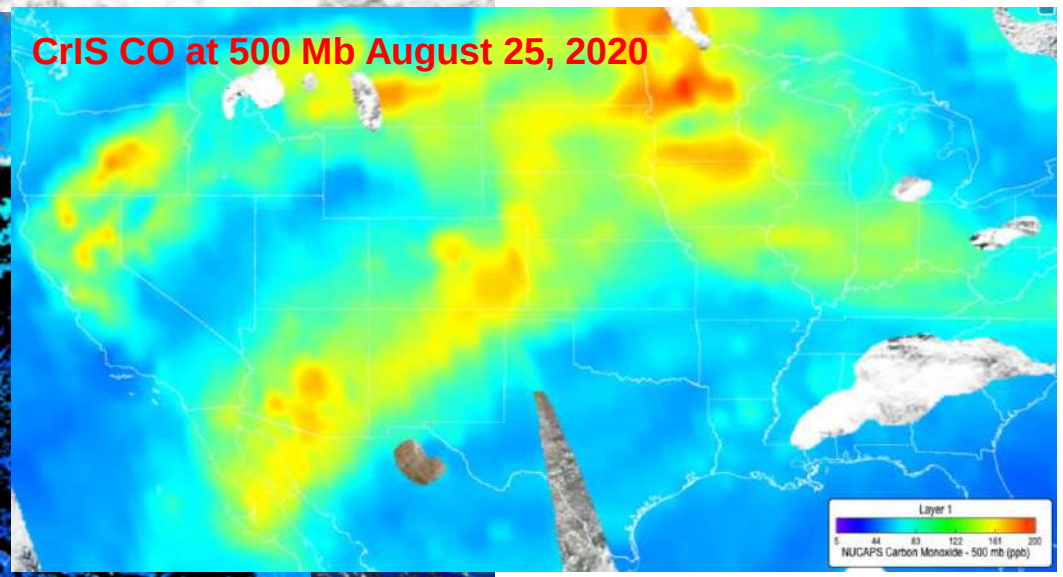


HRRR Vertically Integrated Smoke





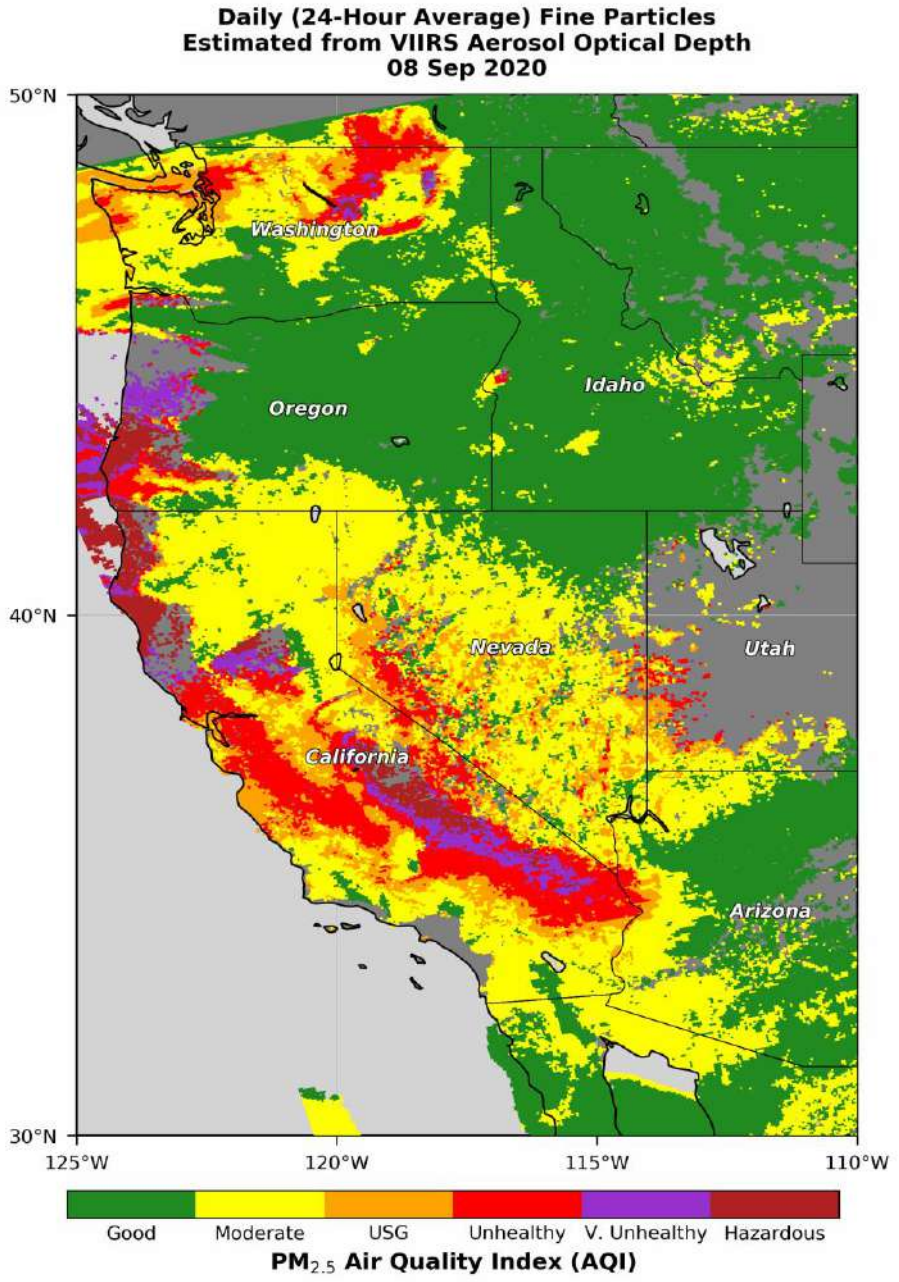


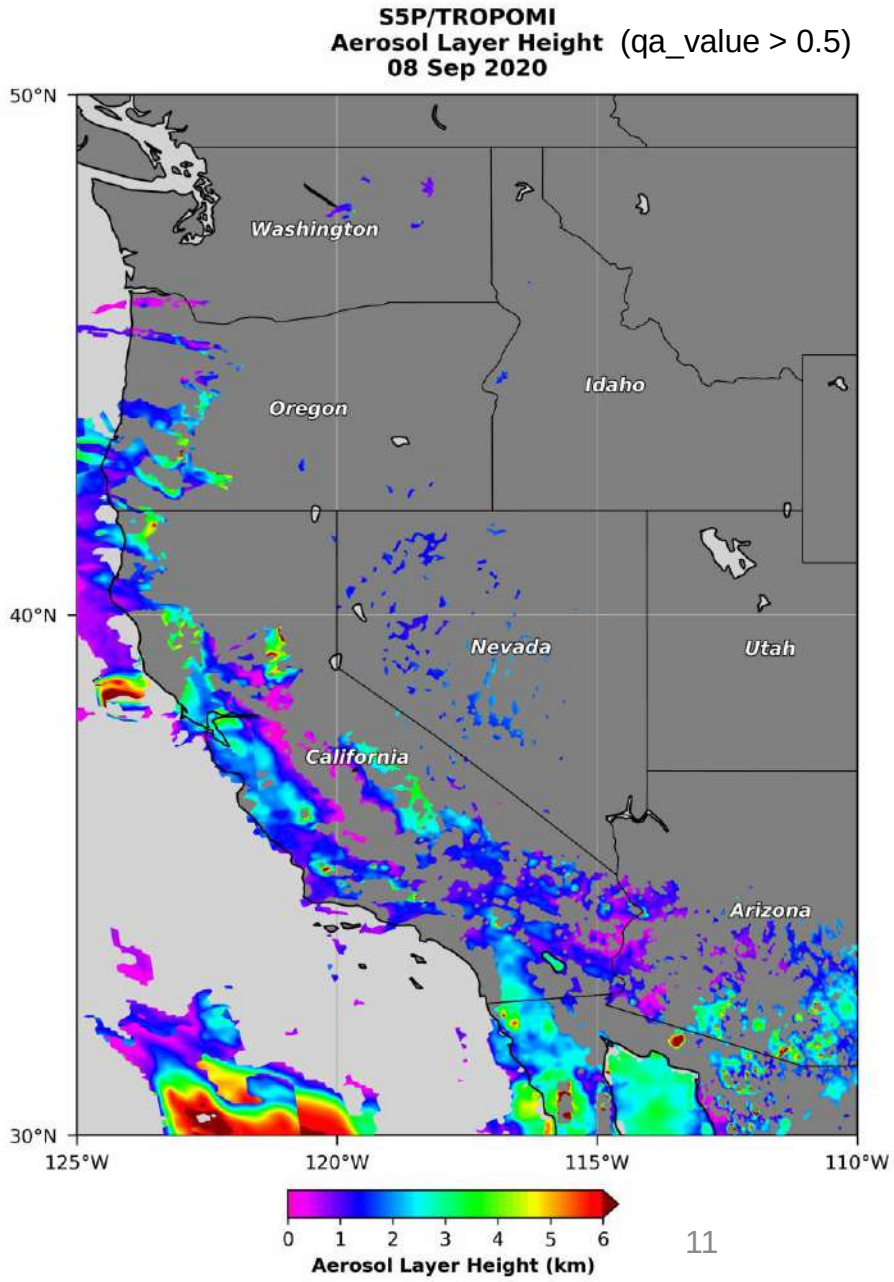


$PM_{2.5}$ Air Quality Impacts of Smoke Near Fires

- $PM_{2.5}$ estimated from quantitative VIIRS AOD fills in gaps in regulatory $PM_{2.5}$ monitor network
  - Combined AOD from VIIRS on SNPP and NOAA-20 to increase coverage
  - Daily maps generated for CONUS using dynamically tuned regression model coefficients
- Thick smoke at surface caused record-high daily $PM_{2.5}$
  - Orange, red, purple, maroon: daily $PM_{2.5}$ > US health standard
  - Oregon hardest hit (table)

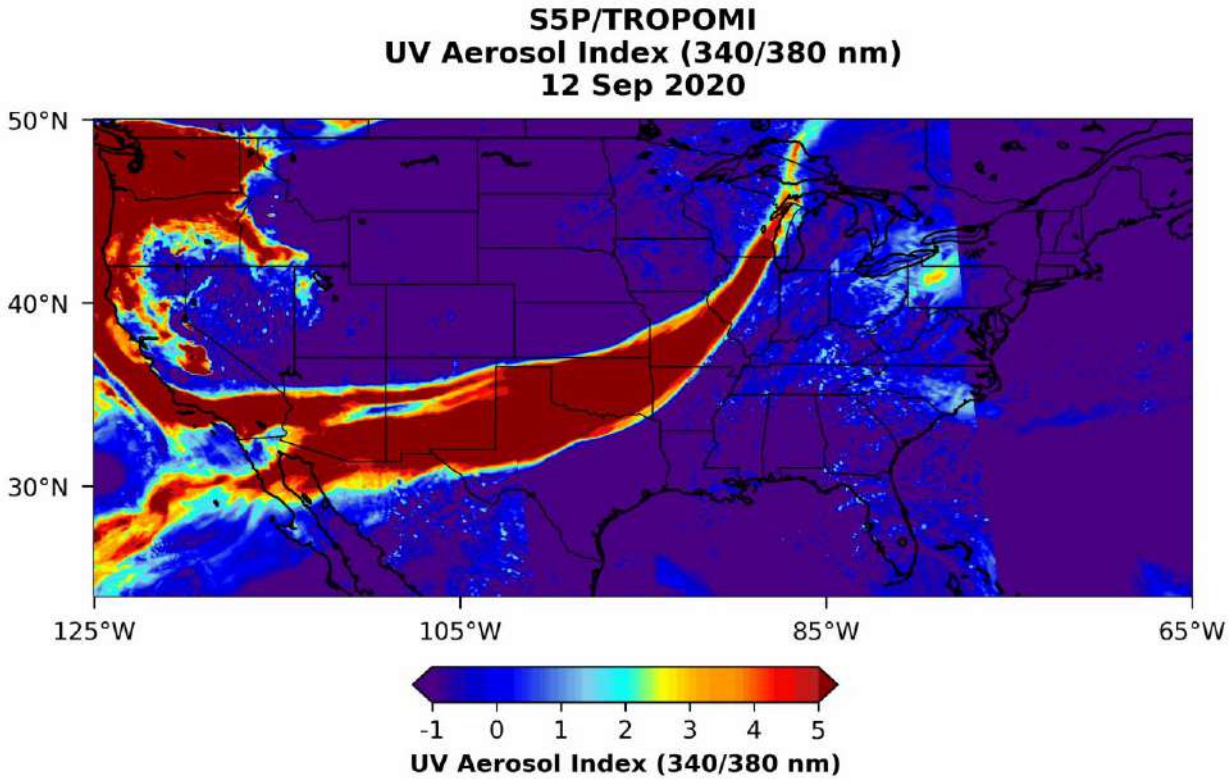
Amazon Park (Eugene, OR)	Daily $PM_{2.5}$ ($\mu g/m^3$)
US Standard	35
Highest 2019	30
Highest 2017	200
13 Sep 2020	**435**





12-16 Sep 2020: Smoke Transported across CONUS

- TROPOMI AI shows smoke quickly transported across CONUS
- Where is the transported smoke vertically in the atmosphere?
- TROPOMI ALH (qa_value > 0.5) suggests smoke above surface, but slightly lower than lidar, aircraft measurements



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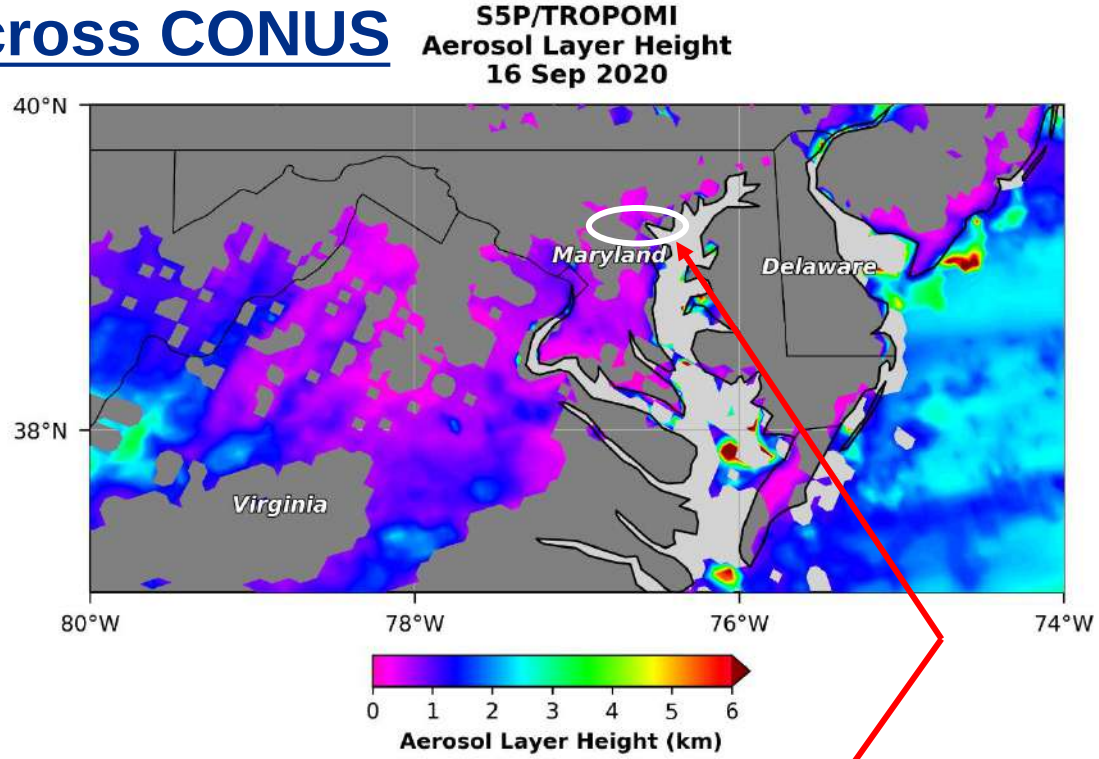
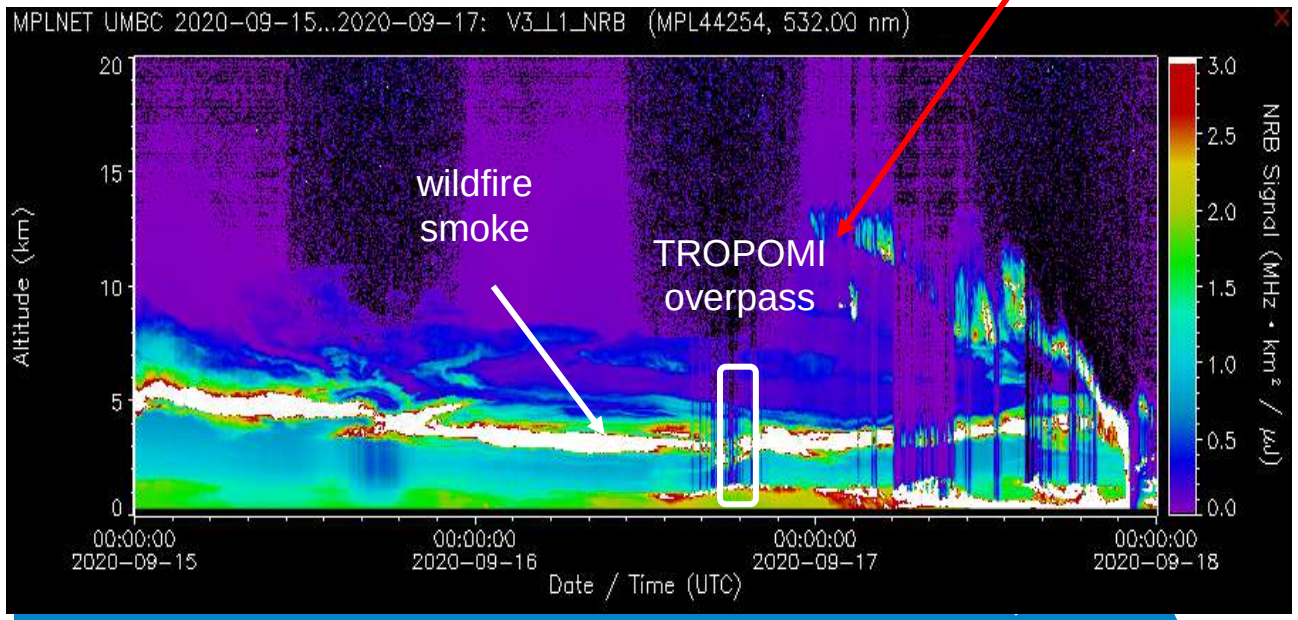
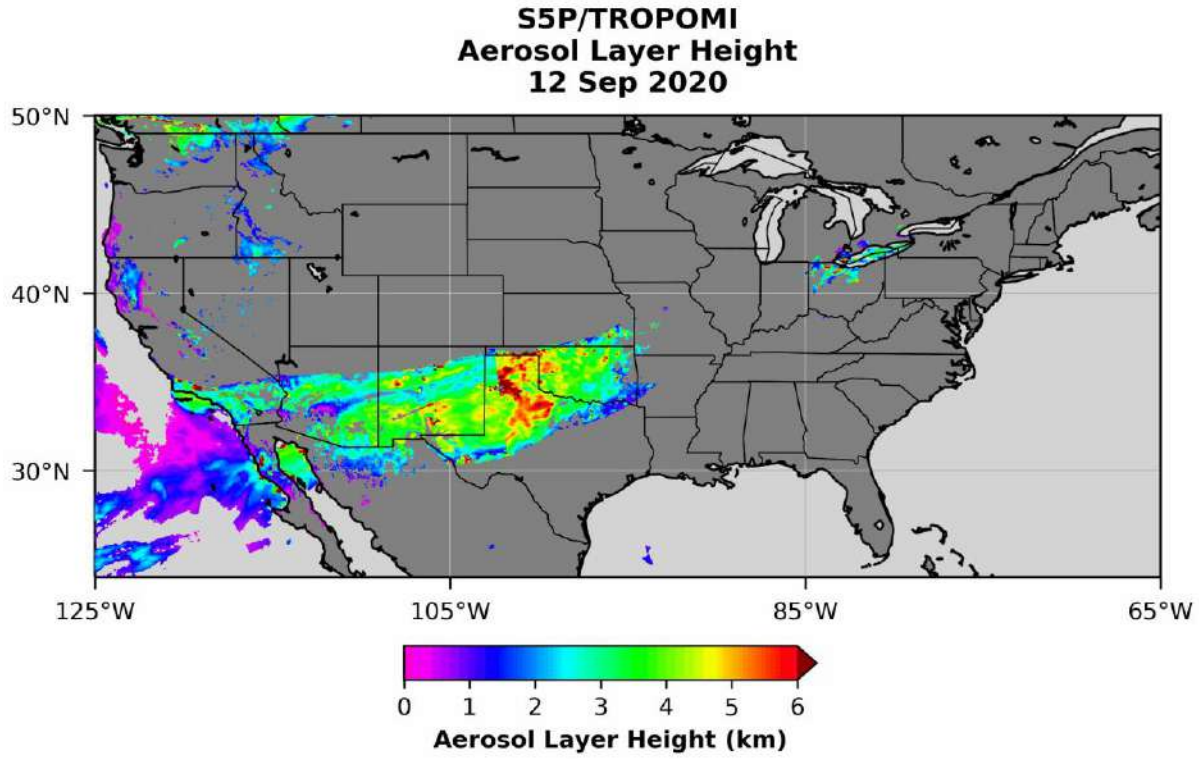
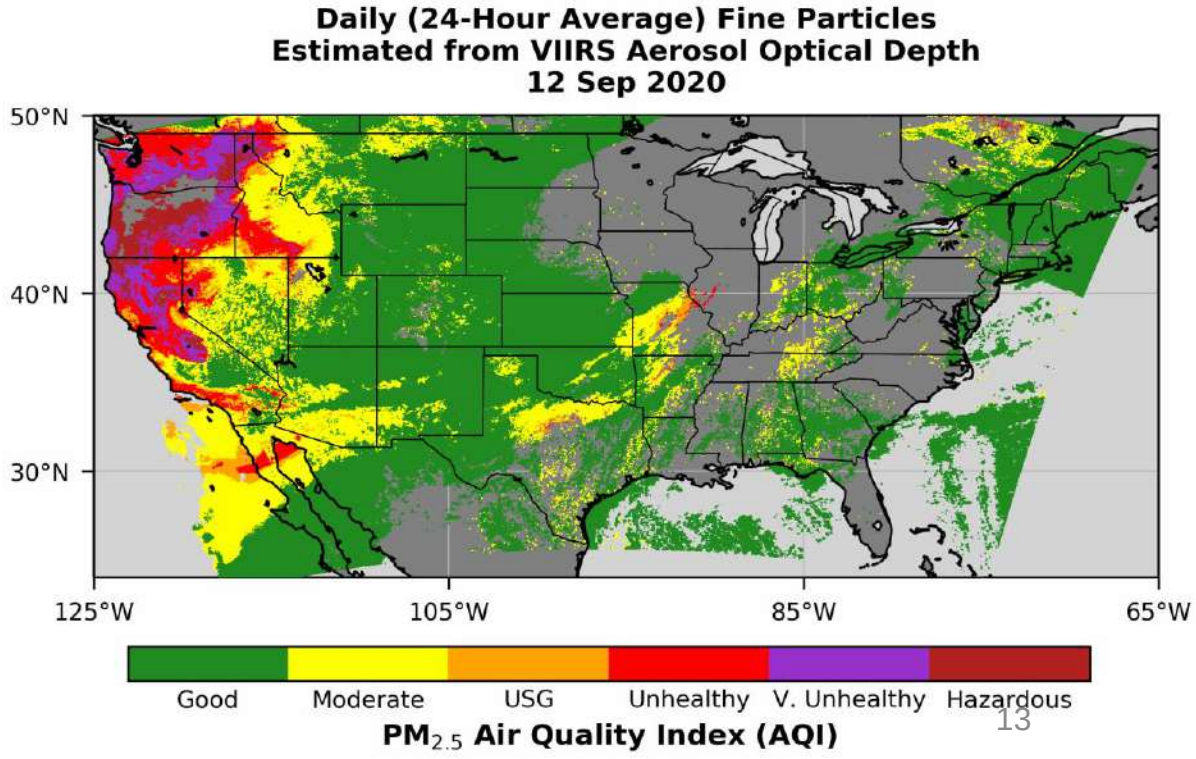




Transported Smoke Above Surface, Minimal Impact on $PM_{2.5}$

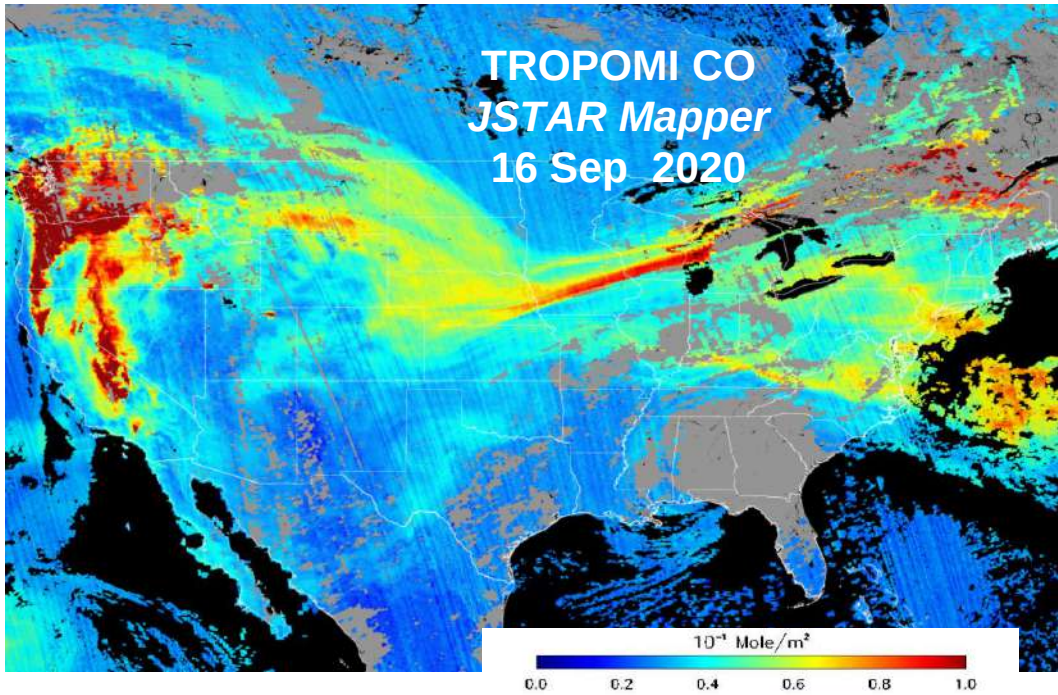
- TROPOMI ALH: first satellite product to provide vertical aerosol distribution on regional scale in NRT!
  - Known issues related to filtering based on AI (degraded, will be resolved with upcoming calibration updates); surface albedo and viewing geometry are other possible sources of uncertainty
  - Working with S5P science team (Martin de Graaf) to continue evaluating ALH in operational environment
- VIIRS AOD-estimated $PM_{2.5}$ confirms transported smoke had limited impact on surface $PM_{2.5}$ downwind (green and yellow shading)
- Visibility impacts of transported smoke noticed by public; confusion about “clean” air quality conditions



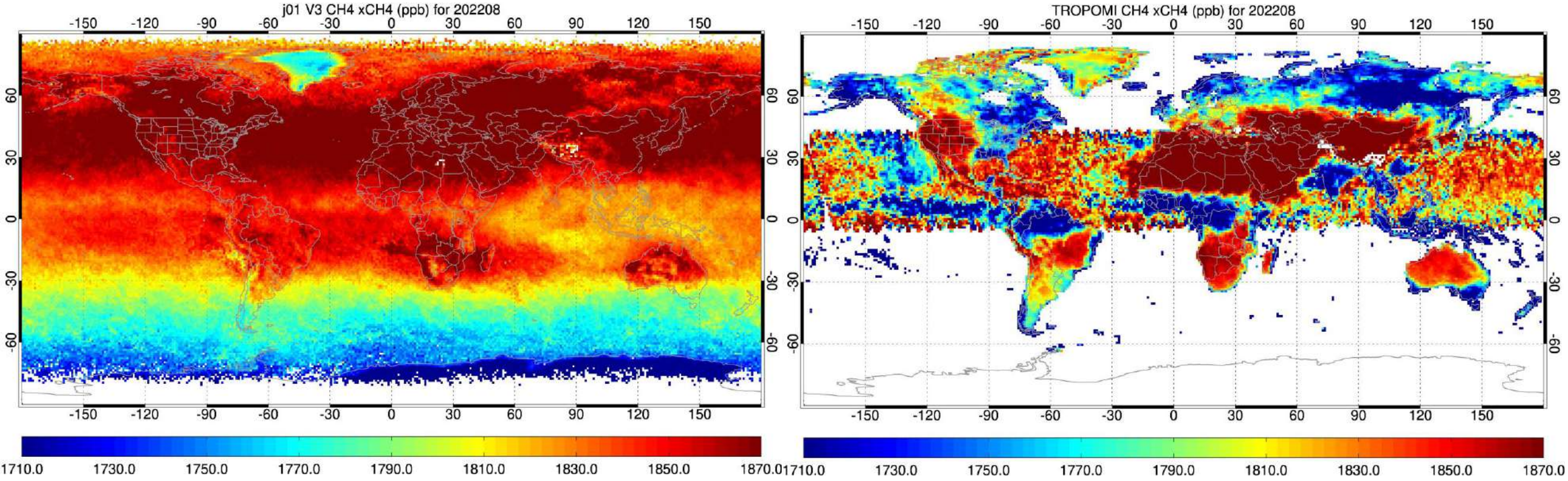


Summary

- TROPOMI and VIIRS multi-satellite sensors analysis necessary to accurately assess impacts of wildfire smoke on surface $PM_{2.5}$ air quality
  - Individual satellite products don't provide complete picture
- TROPOMI AI and VIIRS AOD show geographic extent and transport of thick smoke
  - AI: continuous coverage of smoke, even in cloudy regions
  - AOD: intensity of smoke, but some breaks in coverage
- Surface $PM_{2.5}$ estimated from VIIRS AOD fills in gaps in regulatory monitor network
- TROPOMI ALH indicates vertical distribution of smoke in atmosphere on a regional scale
  - First satellite ALH product available operationally for air quality applications
  - Supplements new VIIRS AOD-estimated $PM_{2.5}$ product
- End users in US utilize TROPOMI products in near real-time
  - Global TROPOMI AI, CO, NO_2 imagery available from NOAA's JSTAR Mapper website
  - US Forest Service, and operational AQ forecasters access TROPOMI CO and NO2 imagery from STAR website

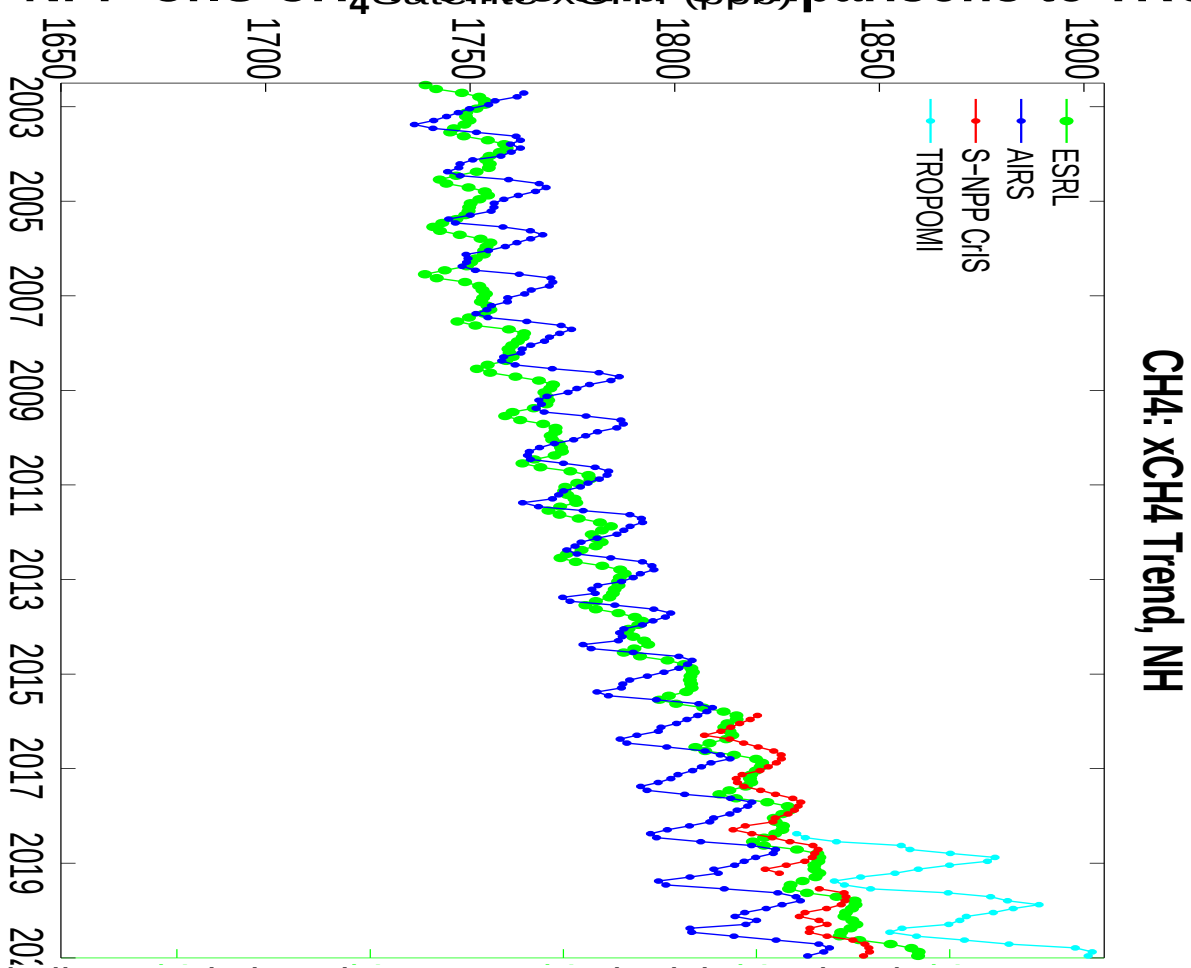


Comparison of CH_4 Products Between CrIS and TROPOMI August 2022 Monthly Mean



- CrIS CH_4 is higher than TROPOMI, and the differences are larger between the two at high latitudes which need further investigation. TROPOMI CH_4 being reprocessed.

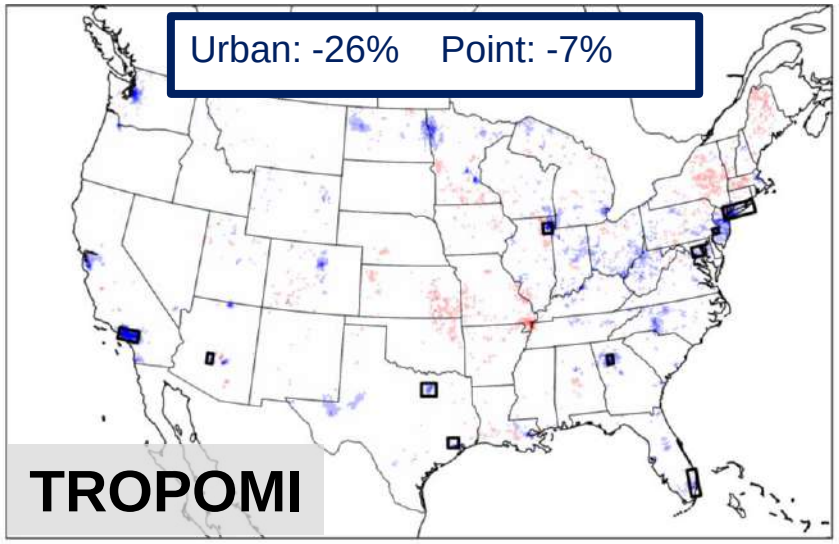
NUCAPS S-NPP CrIS CH_4 Trends and Comparisons to TROPOMI and AIRS



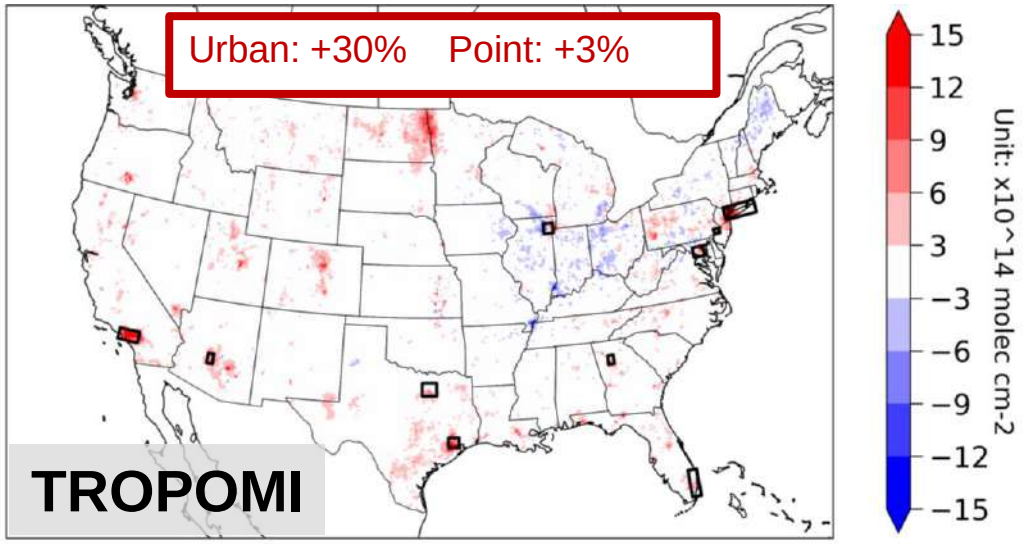
- All above datasets show similar trends in column averaged mixing ratios (xCH4 Parts-per-billion-volume) for satellites and ground mixing ratios for in situ data. This is for Northern Hemisphere only.
- AIRS did not show the sudden increase in 2015, while CrIS shows much higher values than AIRS, in better agreement with NOAA GML/ESRL in situ measurements.
- TROPOMI is land-only, so higher values than all others.

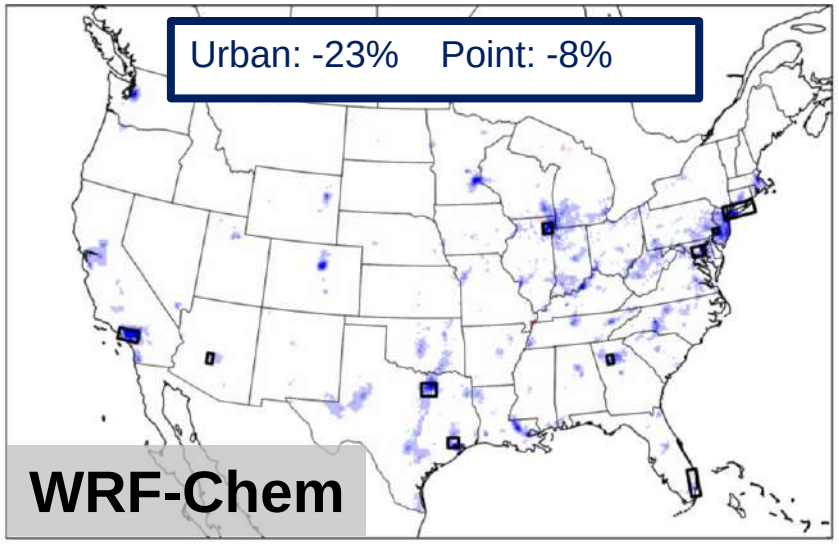
NRT Emissions Generally Capture Trends in TROPOMO NO_2

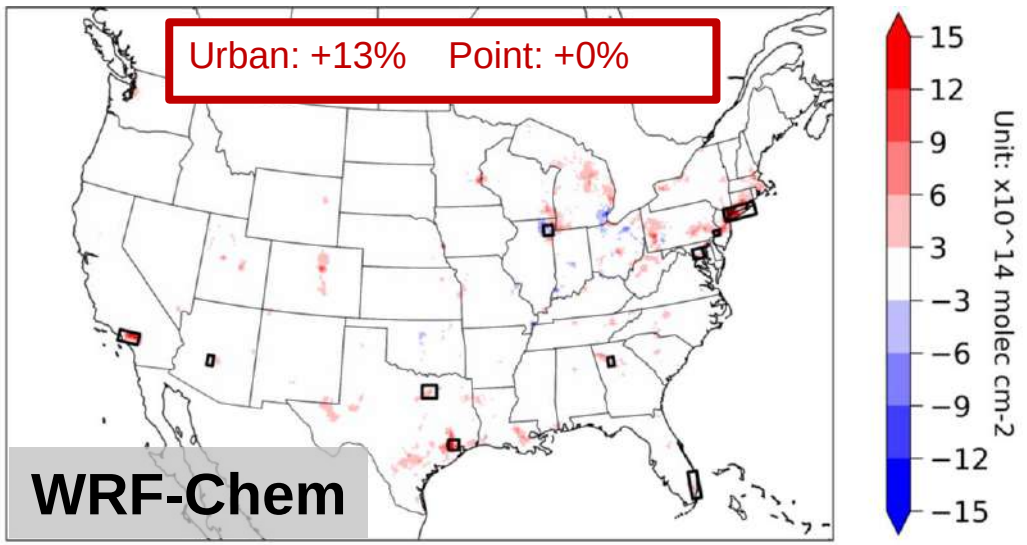
2019 → 2020 (Apr – Jul)



2020 → 2021 (Apr – Jul)

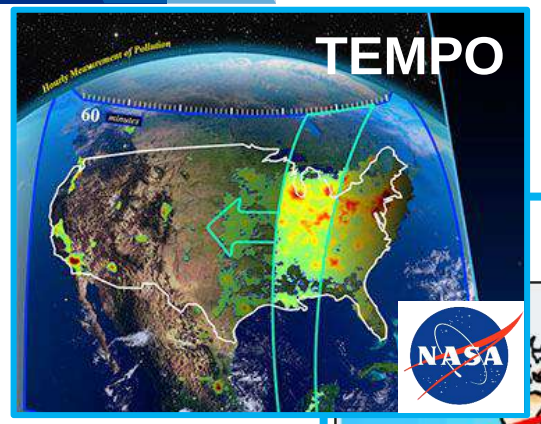






Jian He
NOAA Chemical Sciences Laboratory

2023 Field Work Sponsored by US Federal Agencies



AEROMMA

STAQS

NASA DC-8

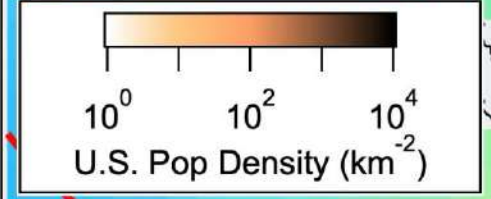
NASA G-V

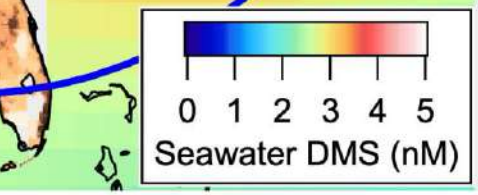
NOAA Twin Otter

NSF C-130

Columbus, OH

Palmdale, CA





CUPIDS

GOTHAAM

PAMS

PANDONIA

AERONET

TOLNet

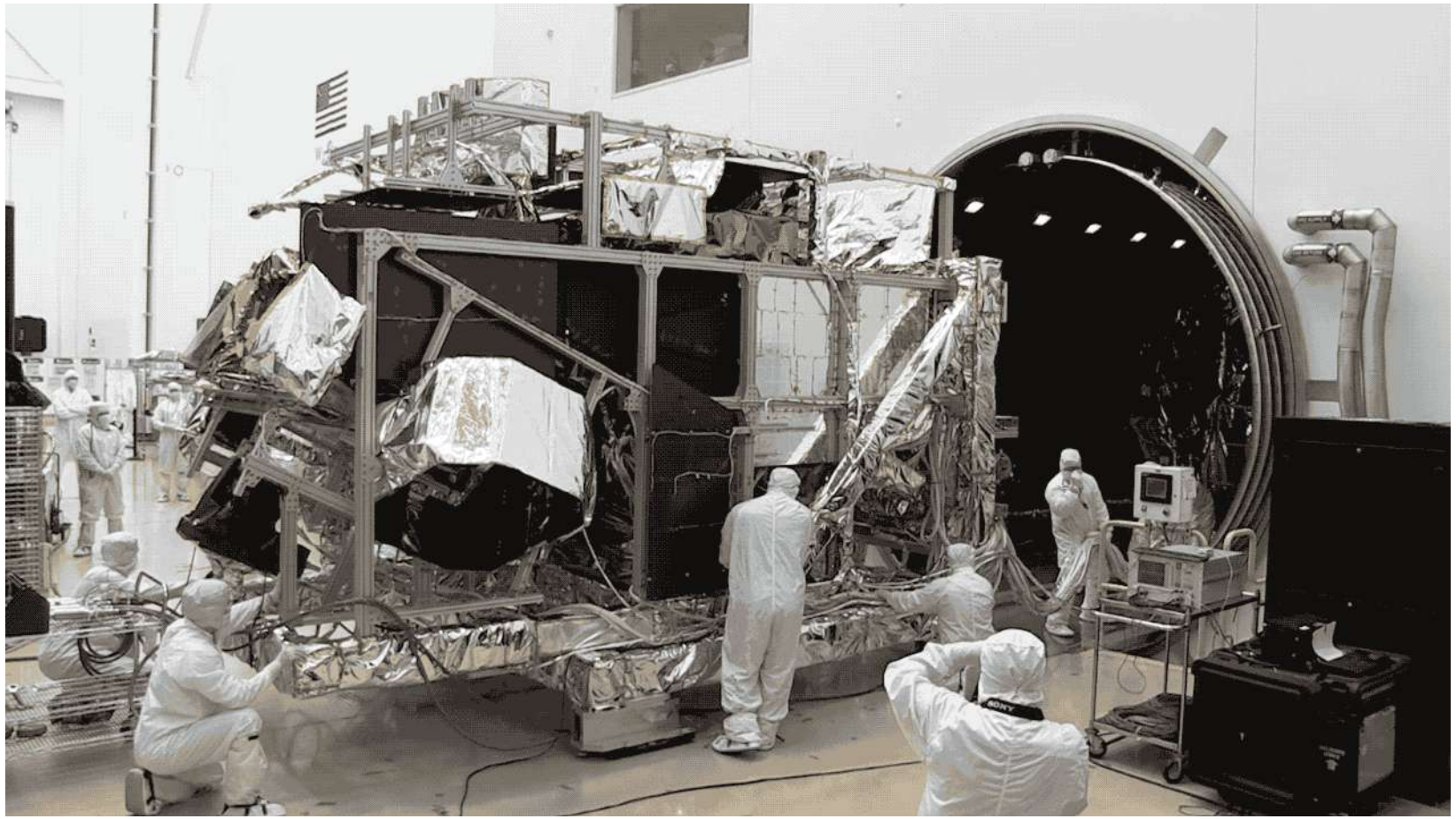
NIST Urban Test Beds

DOE CAPE

Preparing for JPSS-2 Launch on Nov 1, 2022


JPSS2
NOAA • NASA

JPSS-2 Satellite Entering TVAC



Courtesy: Northrop Grumman

Atlas V JPSS-2 Payload Fairing Painting

Courtesy: United Launch Alliance

JPSS-2 and Atlas-V Arrive for Launch

JPSS-2 Spacecraft Move To Aronson Table

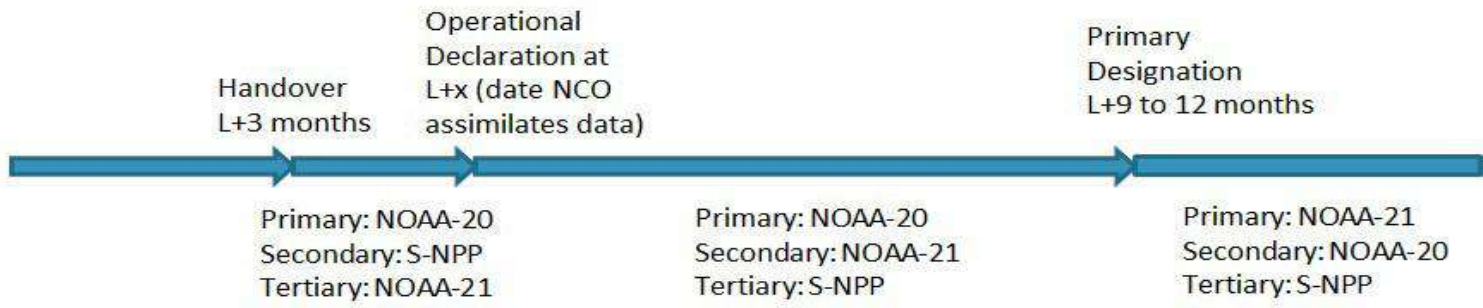
JPSS-2 Atlas V Fairing Fit Check

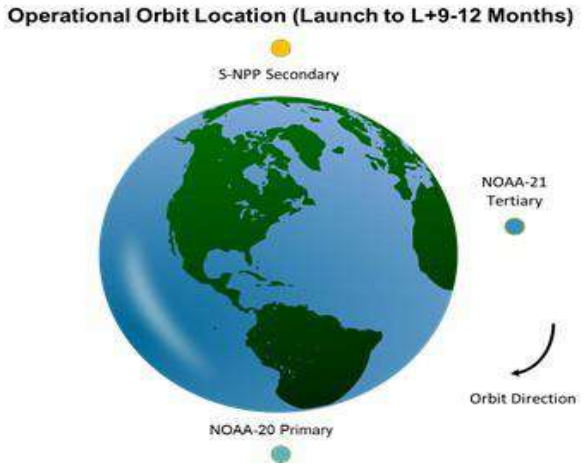
JPSS-2 Atlas V Booster Arrival, Offl oad, and Transport to HIF

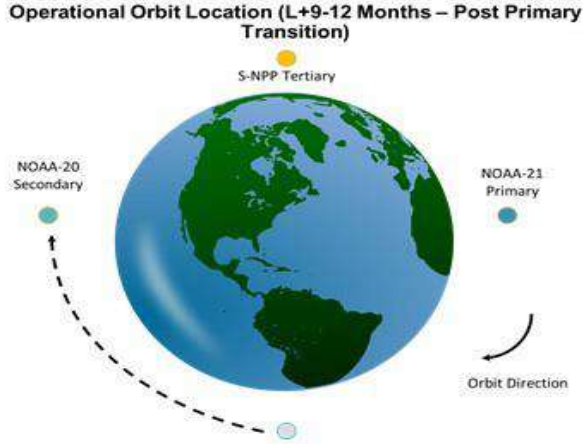
Courtesy: United Launch Alliance

JPSS-2 Launch and Transition to Operations

Launch Date: November 1, 2022 @ 0524 EST from Vandenberg AFB







Primary Satellite Designation Requirements:

-Key performance parameters (KPP) are met
-Prime instruments reached at least provisional maturity and were declared operational (data accepted by key stakeholders)
-NWS and mission partners agreed they were ready to transition

Summary

- Atmospheric composition measurements from JPSS and Sentinel 5P complement each other well
- TROPOMI AC products are routinely used at NOAA for a variety of applications and it is an important part of the LEO AC constellation
- JPSS-2 is ready to be launched on November 1, 2022 and will assure continuity of measurements
- There are several new opportunities for cal/val of satellite AC measurements through US field campaigns and in-situ measurements


JOINT POLAR SATELLITE SYSTEM PROGRAM
JPSS
NOAA • NASA
JPSS2
NOAA • NASA
GO JPSS-2 !!!