AIR QUALITY RESEARCH OVERVIEW

Theme Lead: Dr. Steven Brown

StoryMaps under this theme

→ *1.1 Air Quality: Emissions to Impacts*

→ *1.2 Wild & Prescribed Fires: From the Lab to the Field*

→ *1.3 Atmospheric Composition, Chemistry and Dynamics*

NOAA CHEMICAL SCIENCES LABORATORY

CIRES

CSL Air Quality Research – The Mission

- Detect changes in the ocean and atmosphere
- Make forecasts better
- Drive innovative science
- NOAA vision area: Reduce societal impact from hazardous weather & environmental phenomena

Air Quality Impacts & Costs

Global

World Health Organization: ~7 million annual premature deaths; 4.2 from ambient (outdoor) pollution

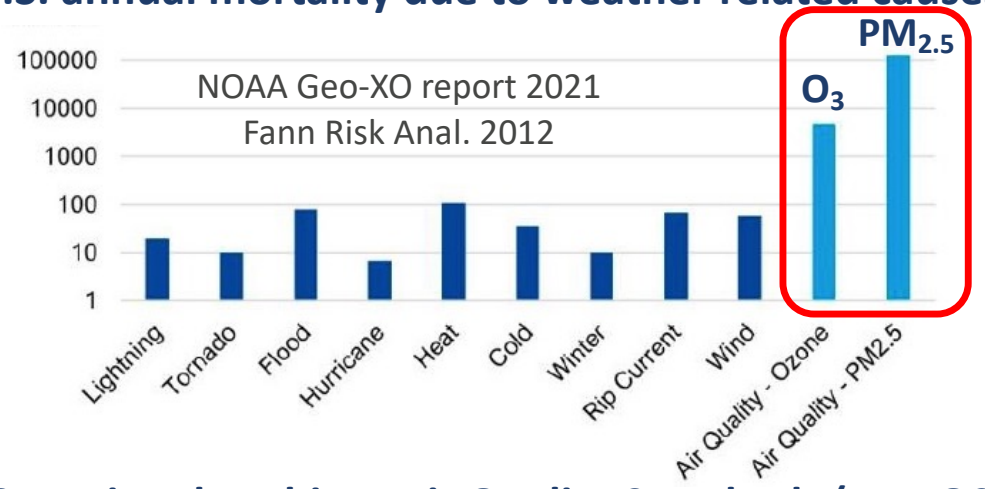
United States

Goodkind PNAS 2019: Poor AQ responsible for >100,000 deaths, $886 billion in damages annually

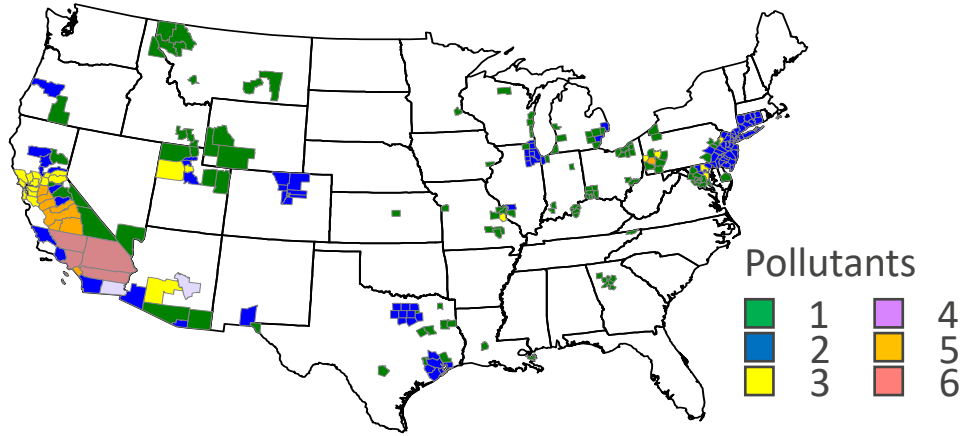
US EPA Green Book : 130 million residents in non-attainment areas (O_3: 122 million; $PM_{2.5}$: 31 million)

Air Quality is a costly and deadly issue affecting millions of people in the U.S. and billions globally

U.S. annual mortality due to weather related causes



U.S. National Ambient Air Quality Standards (NAAQS) Non-Attainment Areas (NAA) 2021



CSL Air Quality Research – The Approach

Business Model

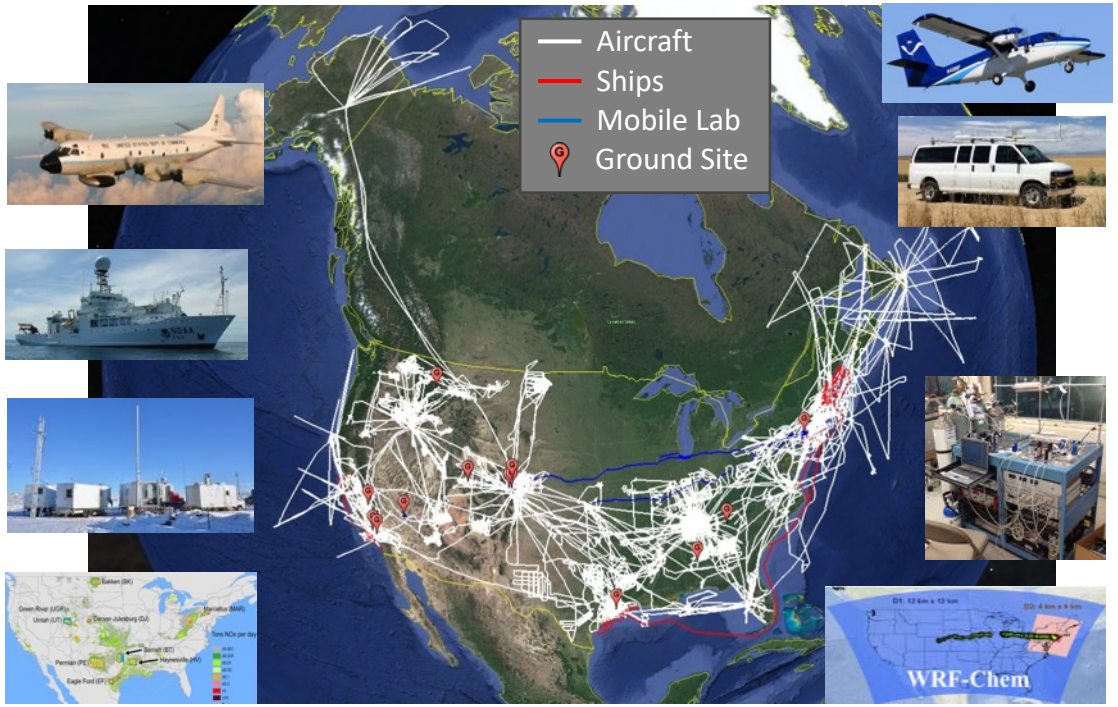
- Identify & define current air quality research needs
- Build partnerships with stakeholders & collaborators
- Execute & lead field intensives at a range of scales
- Laboratory studies of key chemical processes
- Interpret observations with research quality models
- Communicate findings to scientists, policy makers & the public

Deep Experimental & Modeling Expertise

- Instruments: State-of-the art trace gas, aerosol, meteorological
- Models: Emissions, mechanisms, 1-D, chemical transport
- Platforms: NOAA aircraft & mobile platforms, other agencies

Partnerships & Stakeholders

- State & local air quality agencies (CA, TX, UT, NY, CO, NV, etc.)
- Industrial (Oil & gas, agriculture, petrochemical, pwr. generation)
- Academic (Numerous partners, N. America & International)
- Federal agencies (NASA, EPA, NSF, DOE, USDA, JFSP, etc.)
- International (Europe, Asia Universities & National Labs, WMO)



> 35 AQ field projects in the last two decades

Ground, towers, mobile labs, ships, aircraft, laboratory

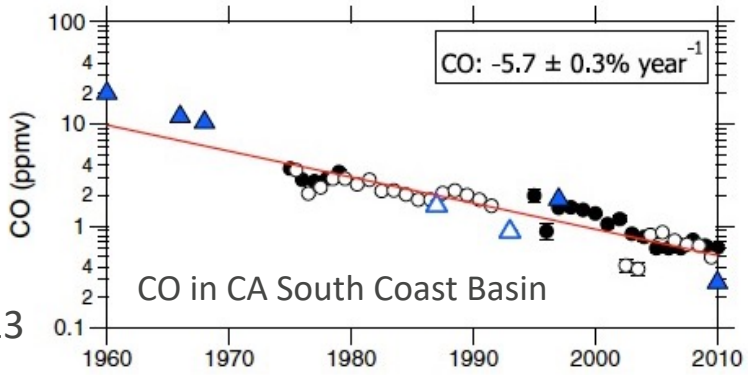
Model development parallels field intensives

CSL is a premier air quality research institute

CSL Air Quality Research – The Science

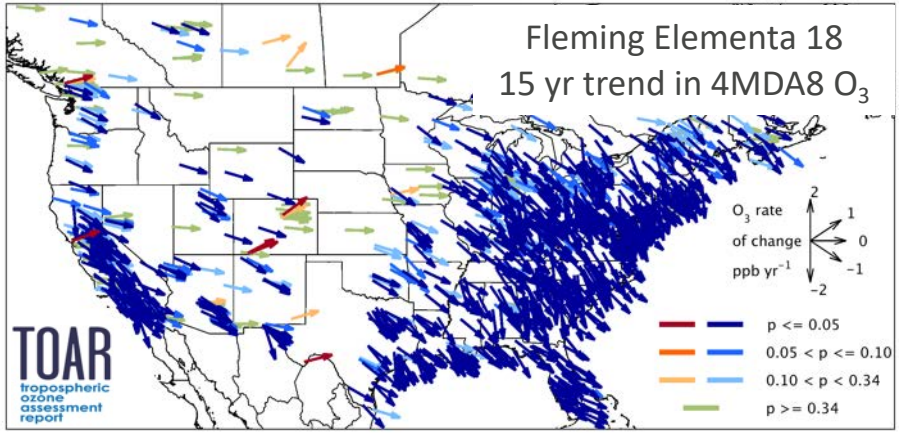
Emission reductions in the U.S. spanning 5 decades have redefined the science

Sustained reduction in U.S. combustion emissions



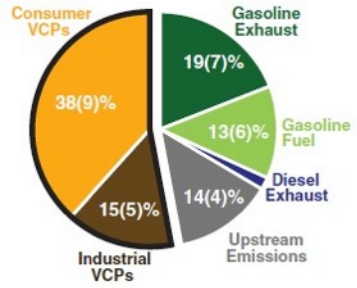
Pollack JGR 13

Dramatic improvement in urban O_3

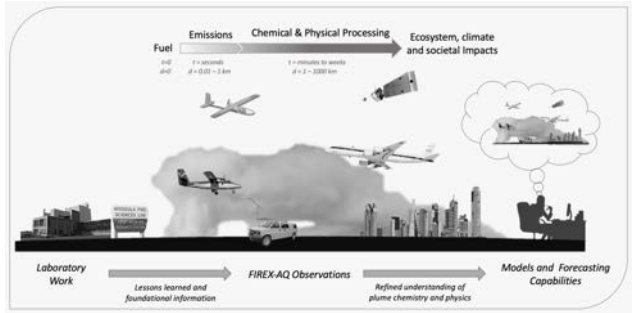


Current topics (partial list, this review)

- Volatile Chemical Products (VCPs) now dominate urban VOCs
- Biomass burning: Response to climate change & past suppression
- North American oil and gas: Impact from 15 years of development
- Summer vs. winter: Changing response of secondary pollutants
- Constraints on global emissions & atmospheric composition
- COVID-19 Lockdowns: A window into the future ?



McDonald Science 2018
Identify VCP Emissions



FIREX-AQ mission to
investigate biomass burning

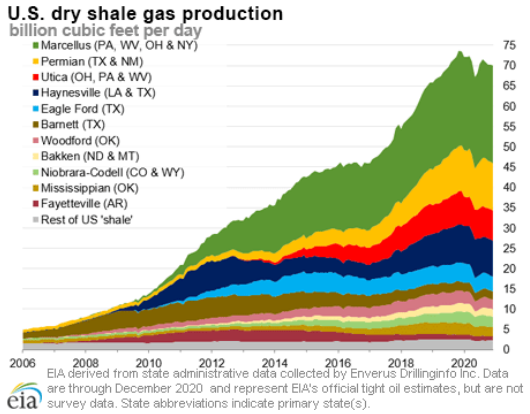
Scientific research underpins 50 years of progress in air quality and remains critically important today

Impacts of North American Oil & Gas Development

StoryMap 1.1.2

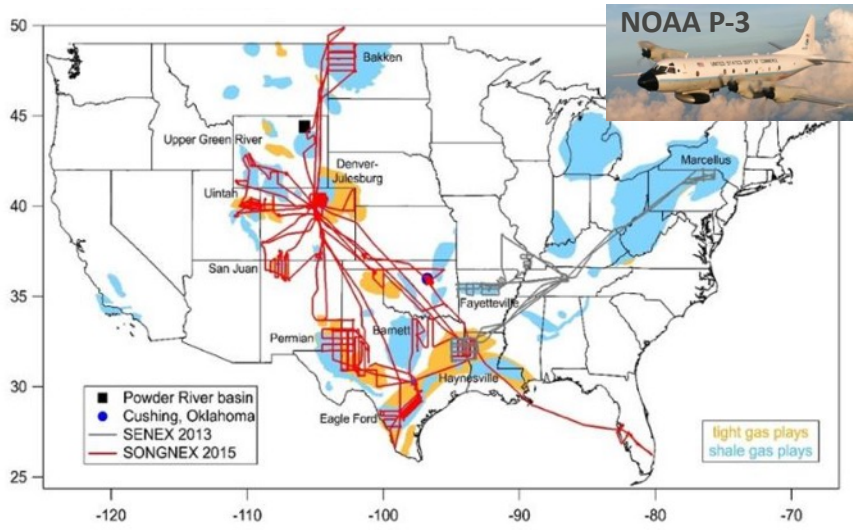
U.S. oil and gas production has increased dramatically since 2005, impacting GHG emissions and air quality

U.S. Energy Information Administration

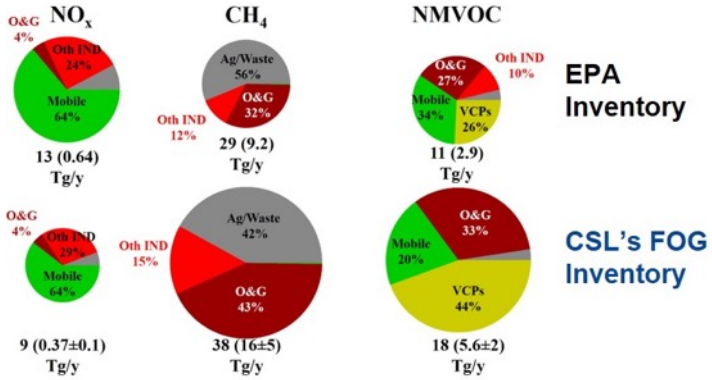


SONGNEX: Shale Oil & Natural Gas Nexus 2015

NOAA P-3 flights sampled more than 70% and 83% of U.S. shale gas and oil production, respectively



Fuel-based Oil and Gas (FOG) – Nationwide NO_x, methane and NMVOC Inventory



- FOG NO_x emissions nearly 2× smaller, VOC nearly 2× larger than EPA (NEI 2014) inventory

- Revised inventory agrees with top-down aircraft derived emissions to within 10% nationwide

Stakeholders: Oil & gas industry, state level air quality regulators, U.S. EPA

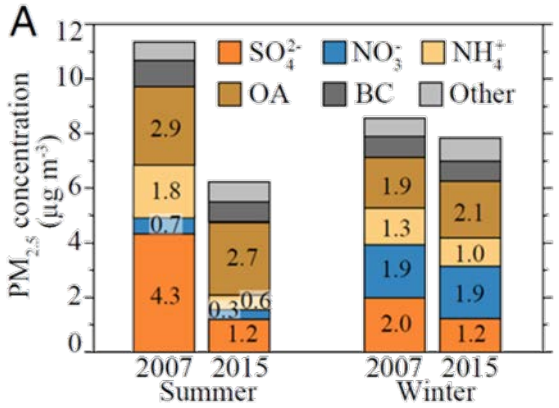
CSL research quantifies air quality and climate relevant emissions from U.S. shale oil & gas development

Winter Air Quality

StoryMap 1.1.3

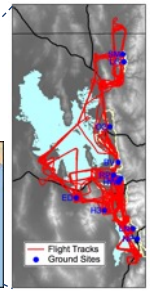
Response of $PM_{2.5}$ to emissions reductions weaker in winter than summer - points to lack of process understanding

Shah PNAS 2018

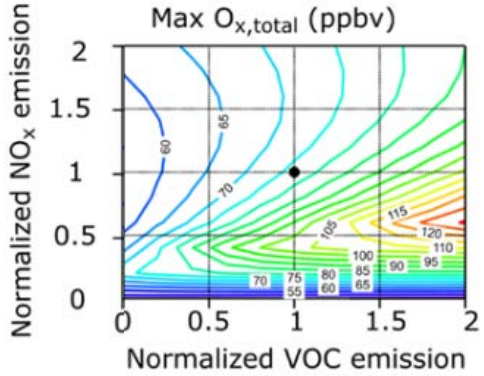


WINTER 2015: U.S. East Coast, NSF C-130

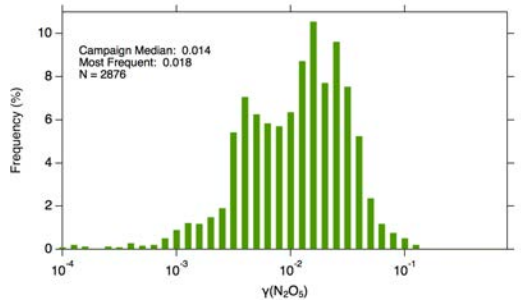
UWFPS 2017: Great Salt Lake Basin, NOAA Twin Otter



Womack GRL 2019: Winter $PM_{2.5}$ treated as odd oxygen, mitigation strategy analogous to summer O_3



McDuffie JGR 2018a,b: Parameterize N_2O_5 uptake coefficients & $ClNO_2$ yields to improve regional and global models



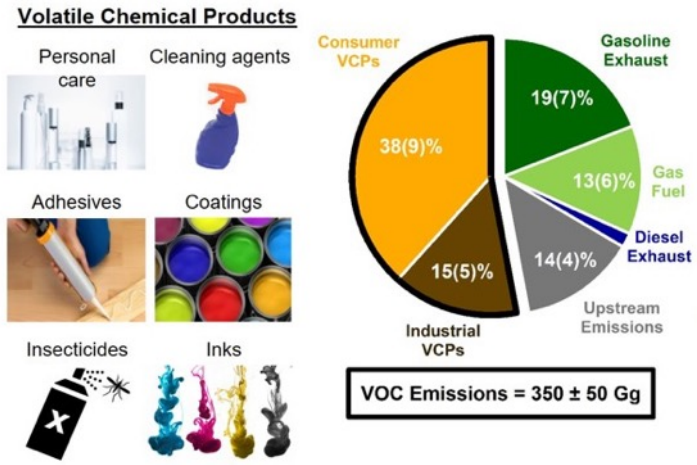
Stakeholders: Utah & East Coast AQ regulators, agricultural industry, NSF, EPA, international research community

CSL research provides fundamental process information to inform models and AQ mitigation strategies

VCPs: A New Paradigm for Urban Air Quality

StoryMap 1.1.4

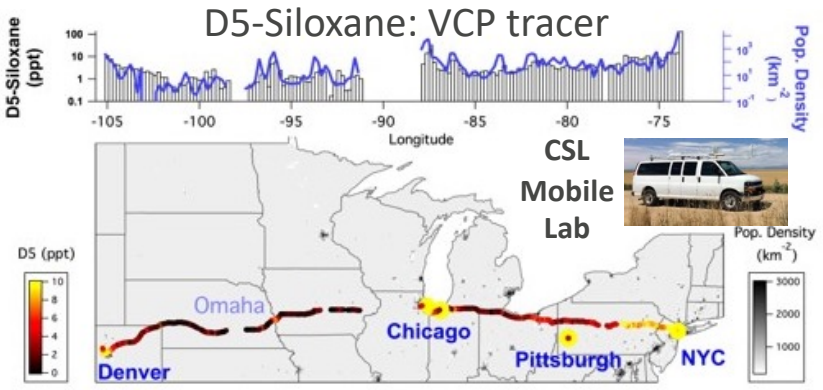
Volatile chemical products, VCPs, now exceed motor vehicles as urban VOC source



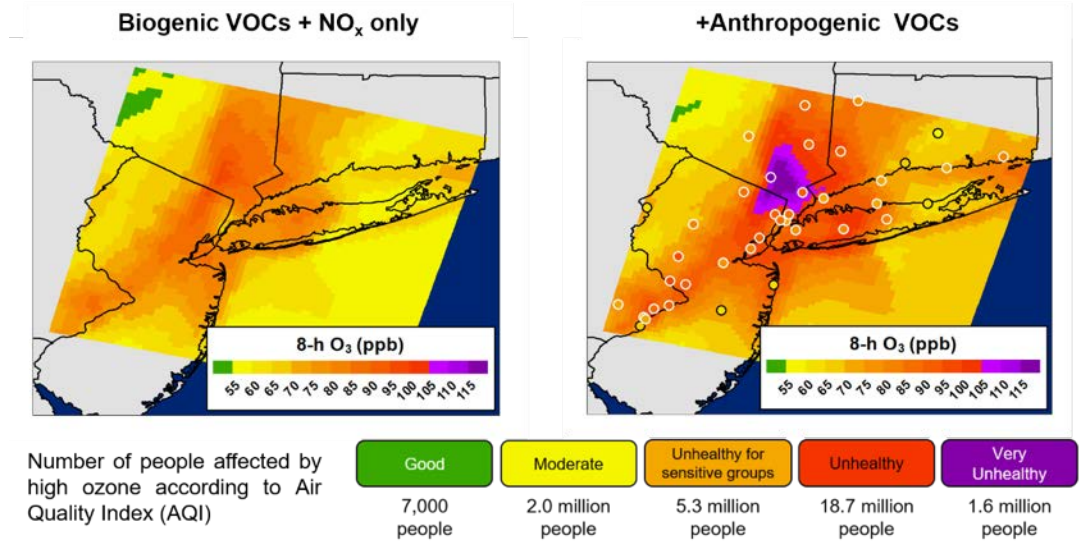
McDonald Science 2018

NY-ICE: New York Investigation of Consumer Emissions

CSL mobile lab samples New York, other urban areas, winter and summer 2018



Coggon 2021 (in review): Updated urban VOC inventory improves O_3 models and quantifies role of VCPs



Stakeholders: Petrochemical industry, New York & Connecticut Air Quality regulators, EPA, NASA

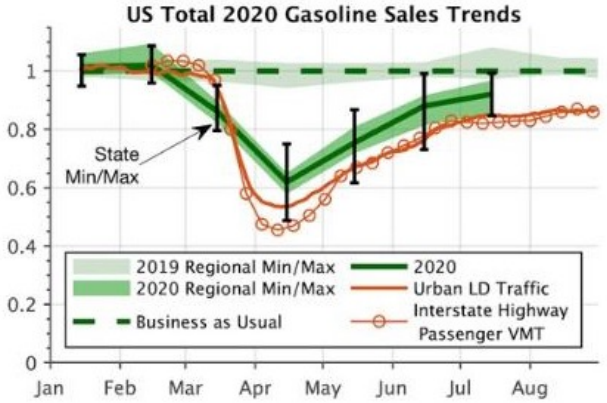
CSL research updates urban emissions inventory and improves predictive capability for O_3 pollution

COVID-19 Lockdowns: A Window into the Future of Urban Air Quality

StoryMap 1.1.5

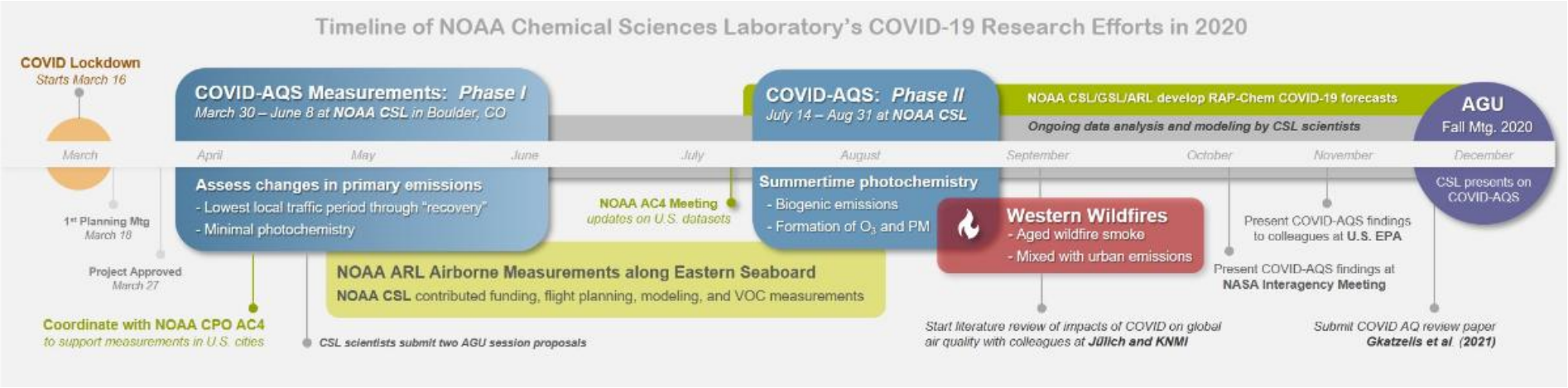
The COVID-19 lockdowns in 2020 forced deep reductions in transportation emissions – potentially illuminating an electric vehicle future

Harkins in prep. 2021



CSL COVID-19 initiatives

- COVID-AQS: local field intensive in spring and summer 2020 & airborne measurements on east coast
- National network for intensive AQ measurements
- Rapid update of emissions inventories
- Organize AGU sessions
- Collaborate with FZJ & international partners to synthesize developing scientific analysis for IPCC

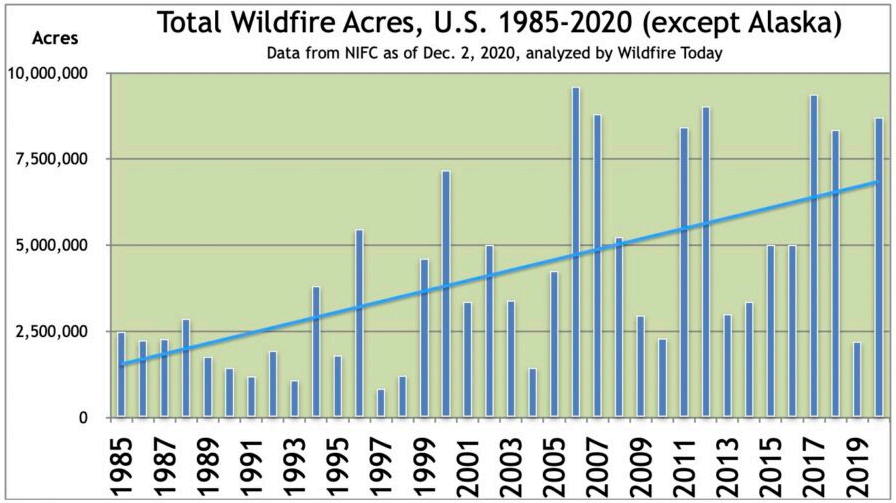


CSL provides national and global leadership to assess impacts from the temporary emissions reductions during COVID-19

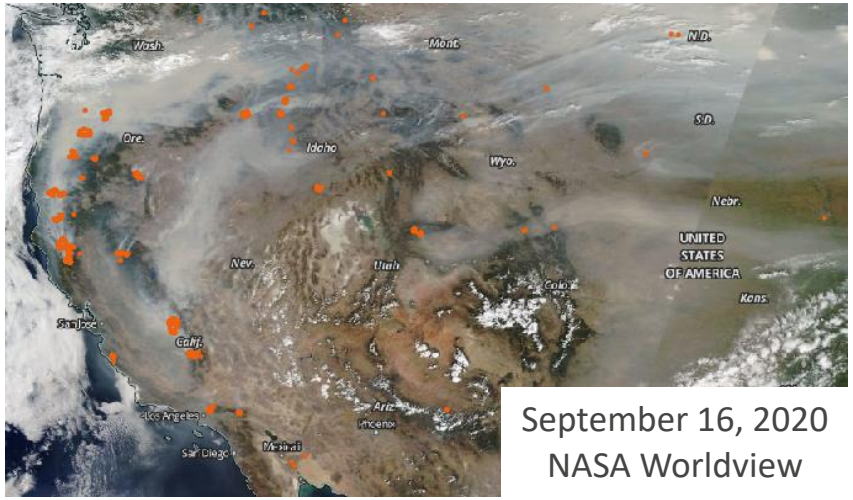
Biomass Burning

StoryMap 1.2.1

Wildfire area and biomass burning emissions are increasing in the U.S. as a result of climate change and past fire suppression

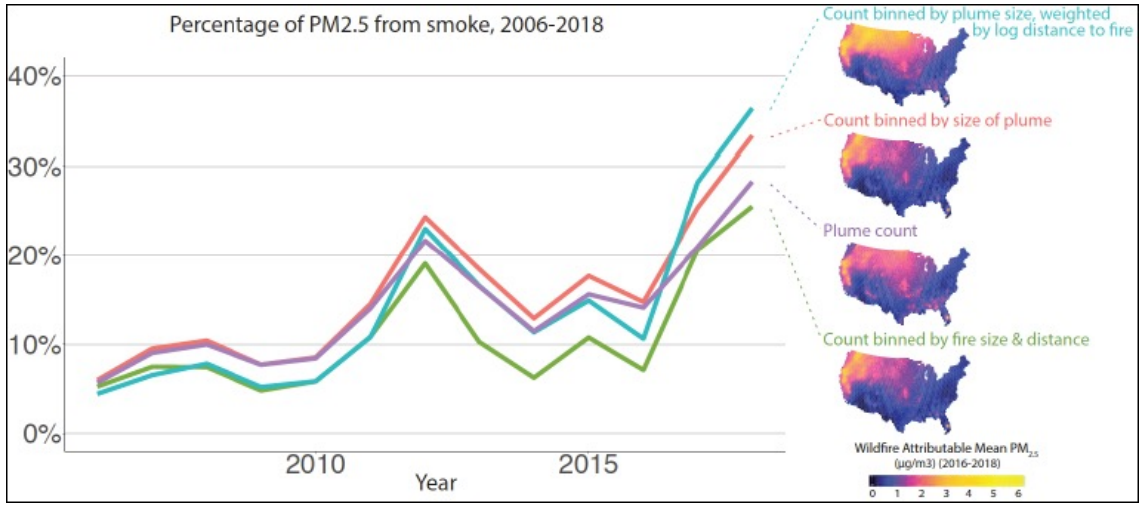


Wildfire Today
Dec 2020



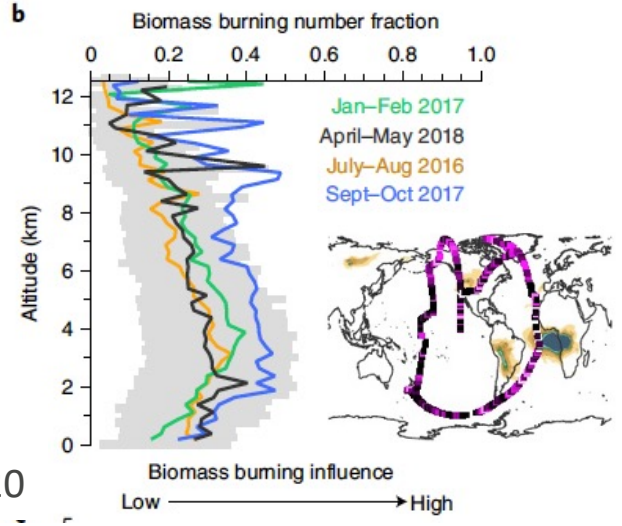
September 16, 2020
NASA Worldview

Biomass burning emissions increasingly affect U.S. air quality …



Burke PNAS 2021

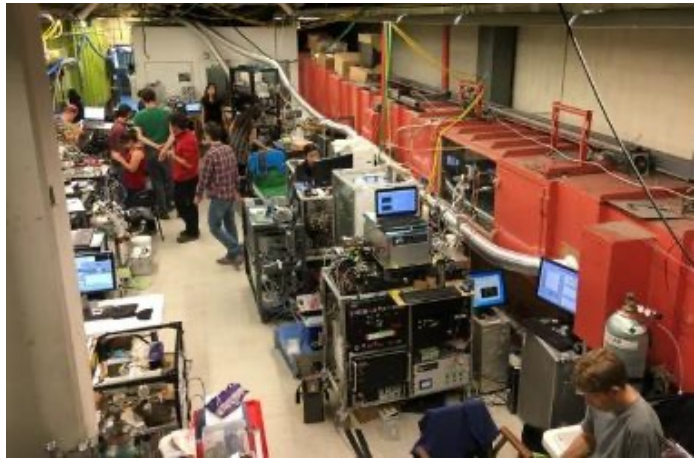
… and impact atmospheric composition at global scale

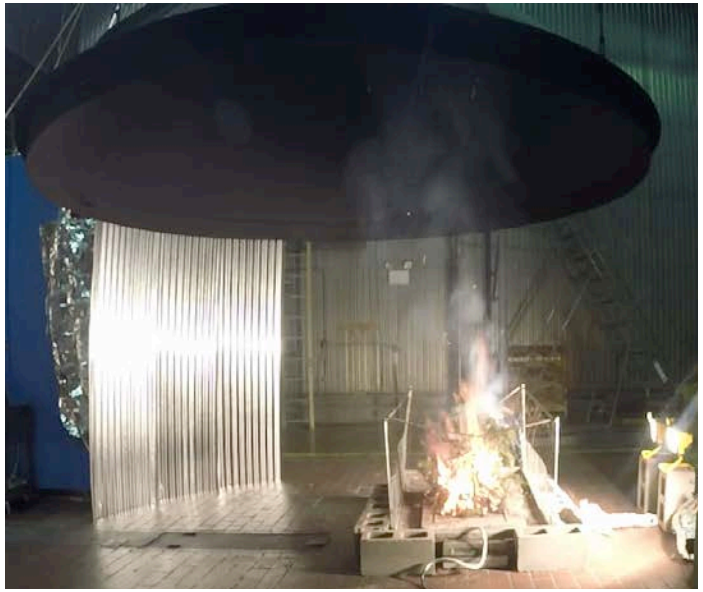


Schill Nature Geosciences 2020

Biomass Burning – The FireLab

StoryMap 1.2.2



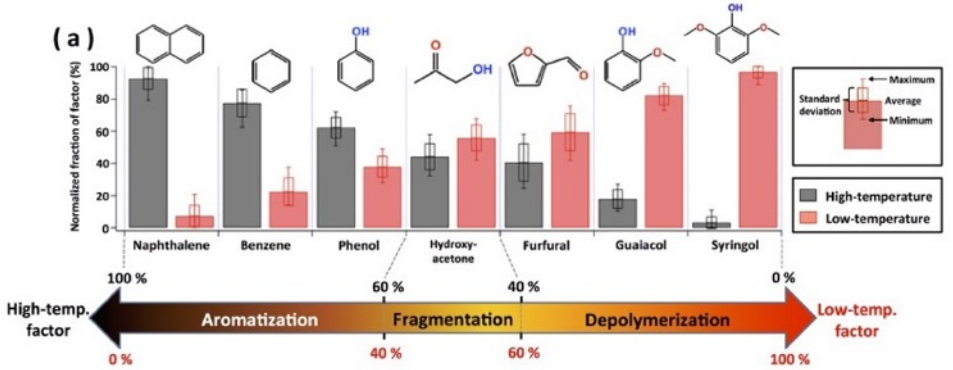


FireLab 2016 Campaign: USFS Missoula, MT Fire Sciences Laboratory

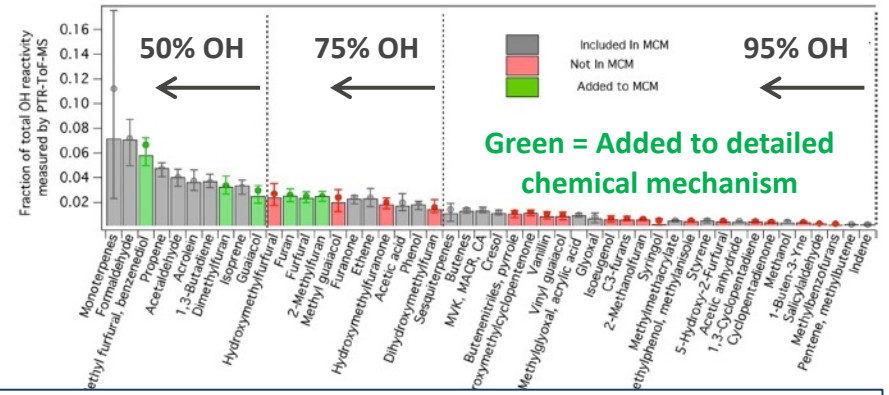
6 weeks, > 15 research groups, 50 instruments, 27 publications so far

Large scale campaign, suite of ***new instruments*** for updated emissions, chemistry

Emissions: Seikimoto ACP 2018 presents simple formalism comprising just two factors to represent complex fire VOC emissions



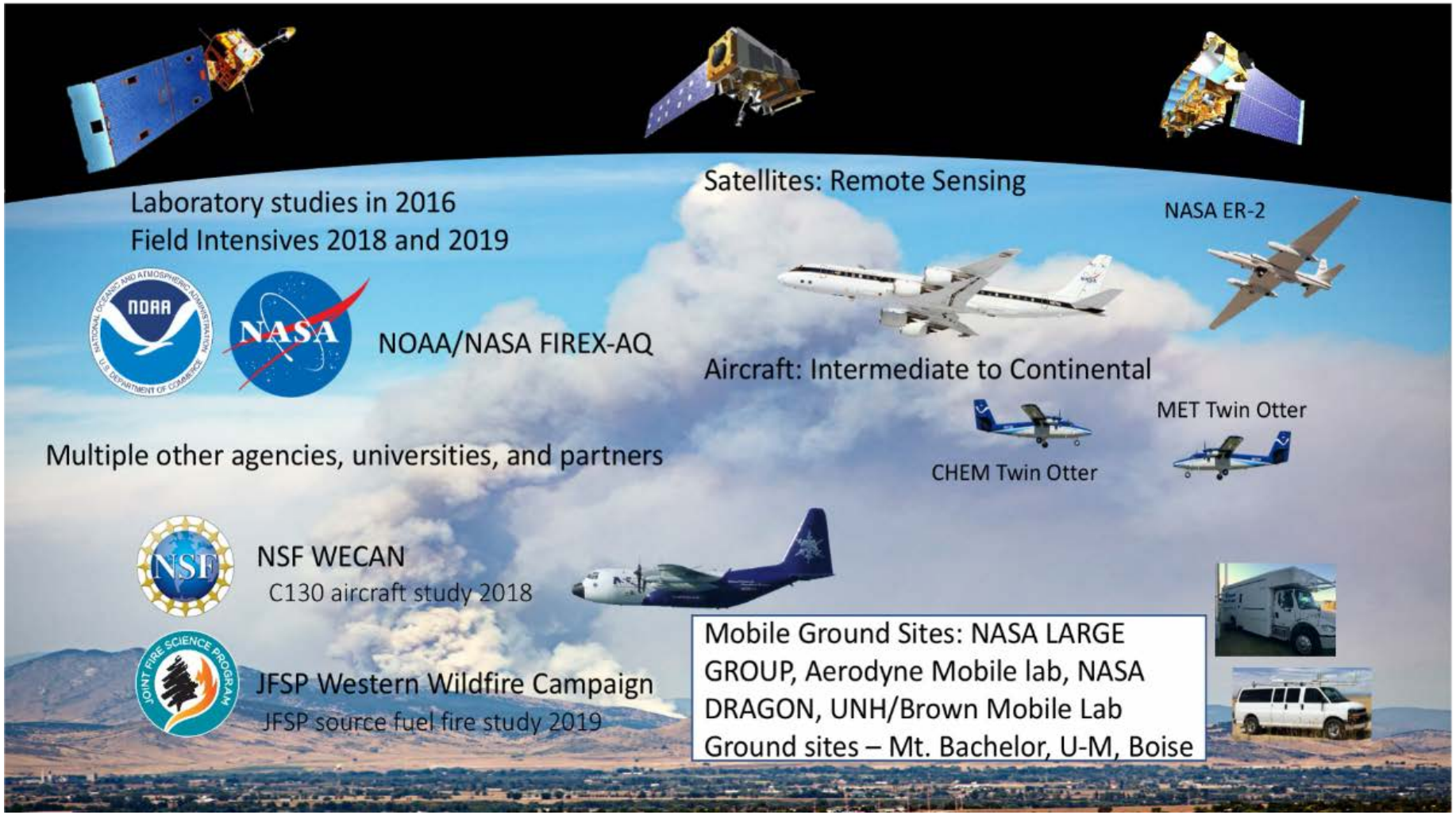
Chemistry: Coggon ACP 2019 identifies reactivity profile of fire VOCs to support chemical mechanism development and interpretation of field observations



CSL leads fully comprehensive biomass burning emissions & chemistry study

Biomass Burning – The Field Work

StoryMap 1.2.3

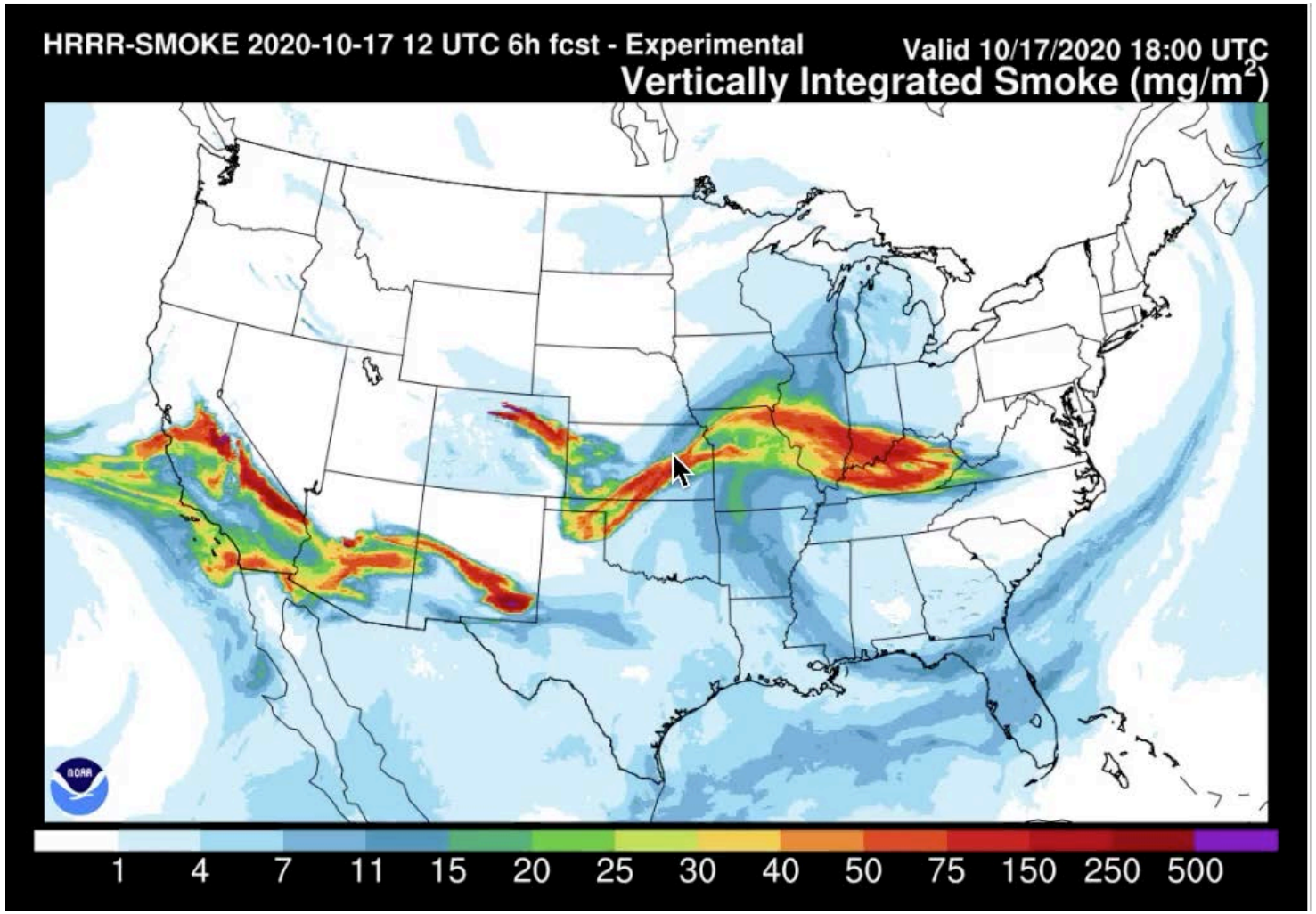


FIREX-AQ 2019

- 4 Aircraft (NASA DC-8, 2 NOAA Twin Otters, NASA ER-2)
- Mobile laboratories & ground sites (NASA LARGE, Aerodyne, DRAGON)
- Coordination with satellite remote sensing
- Partnership with wildland fire and fuels community
- NOAA & NASA together with other federal & state agencies (EPA, NSF, USDA, JFSP, CARB)

CSL leadership of large scale biomass burning intensive

Biomass Burning – The Models



Biomass Burning Models & Forecasts

- Wildfire and agricultural burning smoke impact air quality across the North American continent and beyond
- HRRR-SMOKE is a GSL product with an inert tracer to predict smoke impacts and a widely used tool now in the operational stage
- NOAA Rapid Refresh Chemistry (RAP-Chem) updates wildland fire inventories to aid in prediction of surface pollutants such as CO

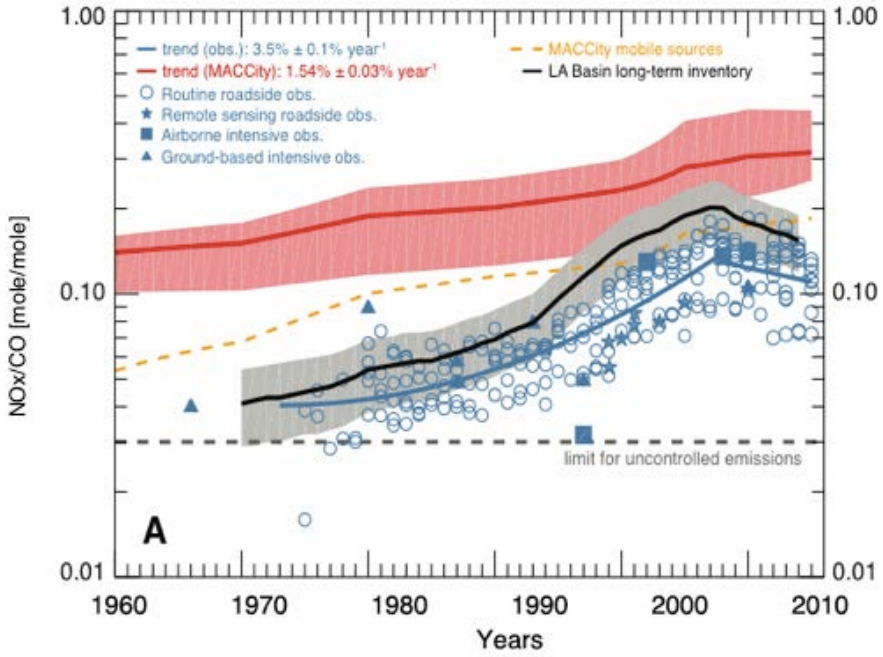
CSL research to operations transitions data from large scale FireLab and FIREX-AQ campaigns to operational forecast models

Global Emissions

StoryMap 1.3.2

Anthropogenic / Urban

Hassler GRL 2016: Inventory comparisons to long term trends of NO_x/CO in monitoring and field intensive data

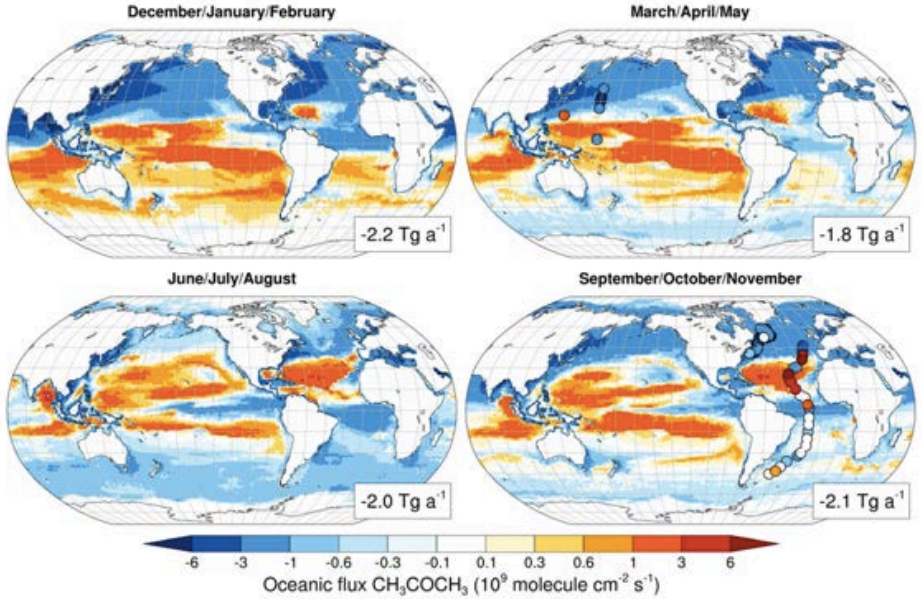


Fuel based (grey) superior to conventional (red) inventory

Range of Scales

Biogenic / Remote Atmosphere

Wang JGR 2020: Validation of modeled ocean flux of acetone at global scale against ATom observations



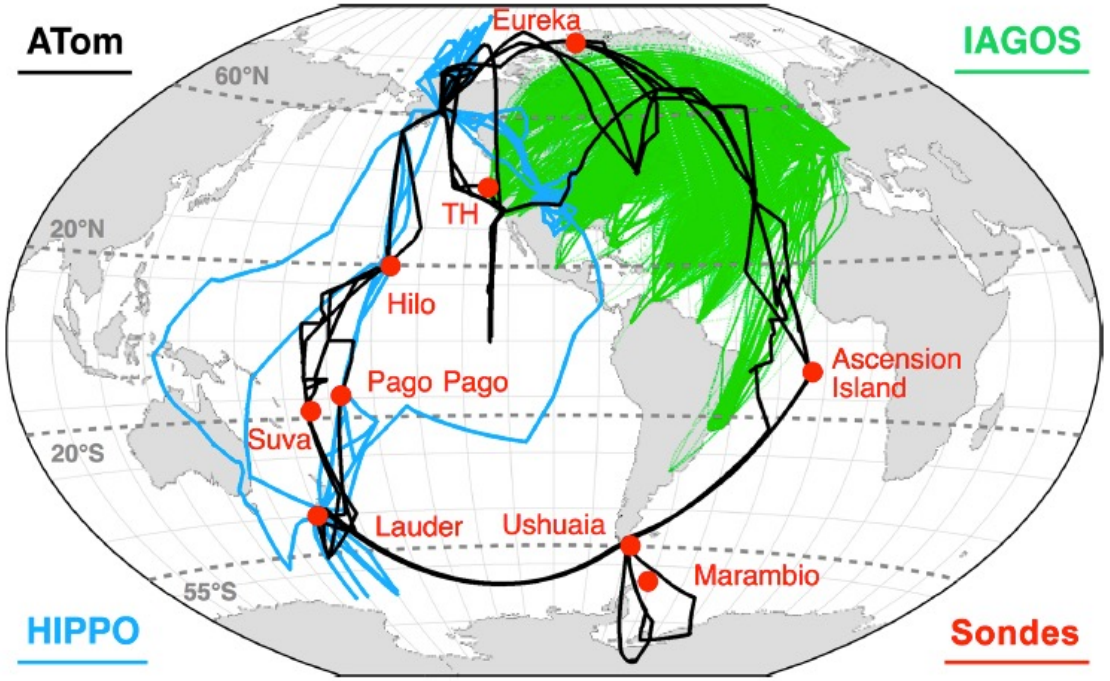
Bi-directional ocean flux for remote atmosphere HO_x source

CSL model – observation comparisons constrain emissions across a range of sources and scales

Atmospheric Composition

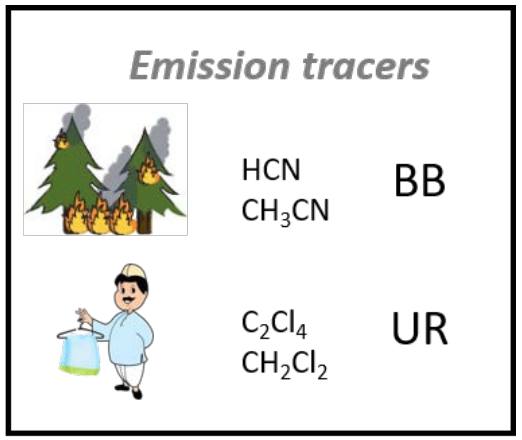
StoryMap 1.3.3

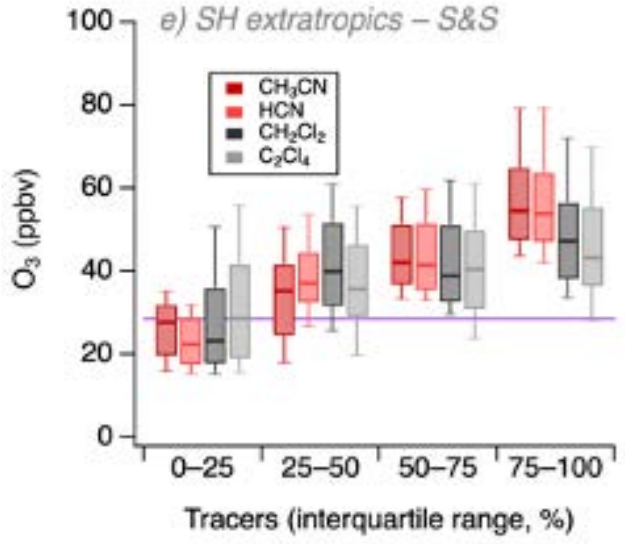
Ozone in the remote troposphere



Bourgeois ACP 2020: Extensive data set for remote tropospheric O_3 based on CSL (ATom) & collaborator measurements

Bourgeois 2021 (In prep)



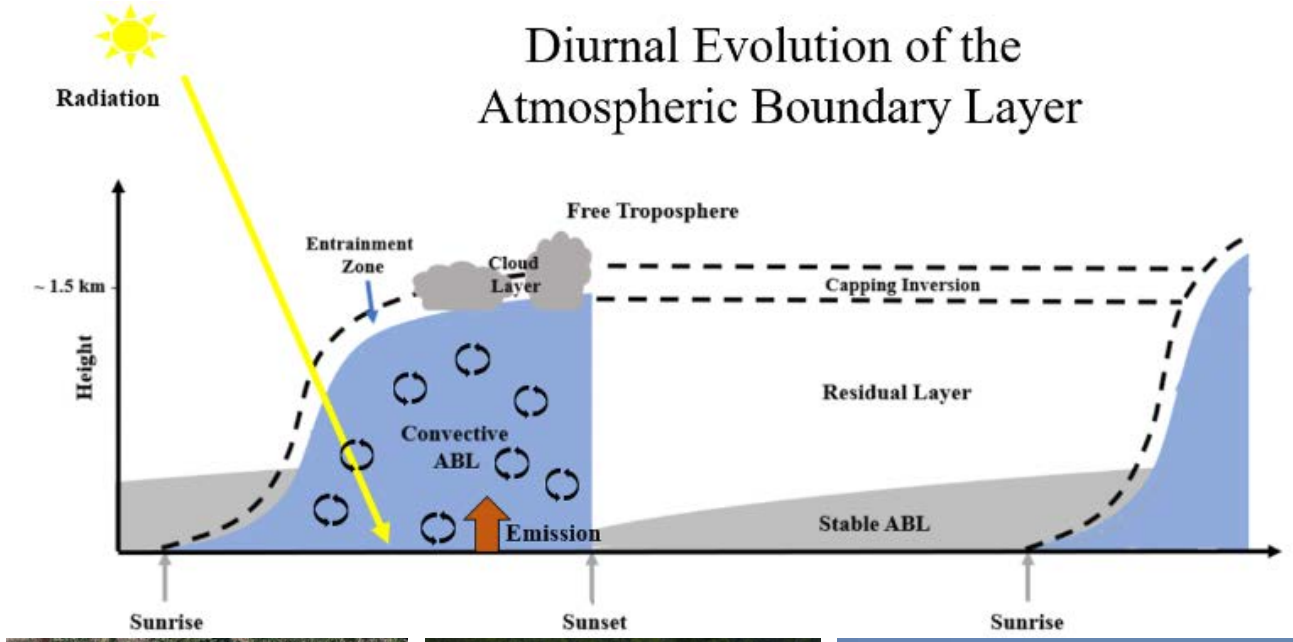


- Tracer relationships for urban (UR) and biomass burning (BB) contributions to remote O_3
- Influence of BB pervasive on remote tropospheric O_3 and larger than models

CSL drives new understanding of global O_3 distribution and sources

Atmospheric Dynamics

StoryMap 1.3.4



Doppler LIDAR: Mobile

Ground based

Aircraft

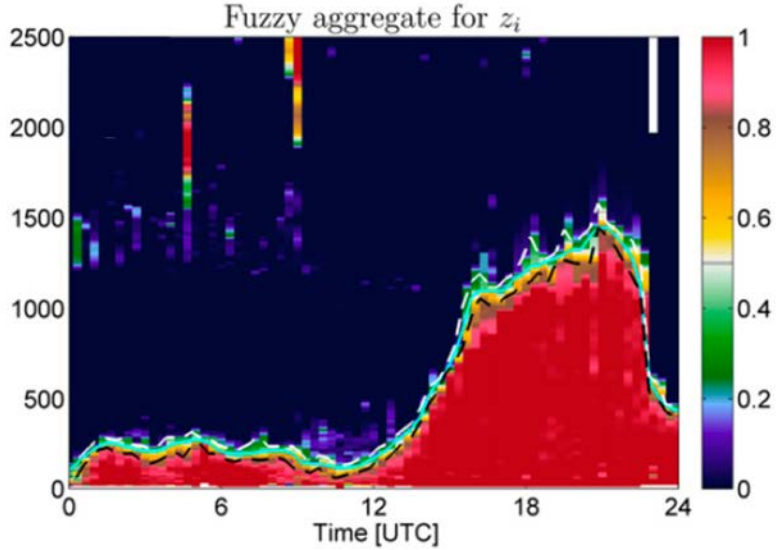
Accurate mixing & transport are required to understand emissions and chemistry of trace gases and aerosols

Deep CSL expertise in remote sensing instruments and interpretation for air quality research

LIDAR data + Fuzzy Logic for boundary layer height evolution

Bonin JTECH 2018

Data from INFLUX campaign



CSL is a global leader in technology & research in boundary layer dynamics

CSL Air Quality Research – The Future

Air Quality and its Impacts in a World of Shifting Emissions

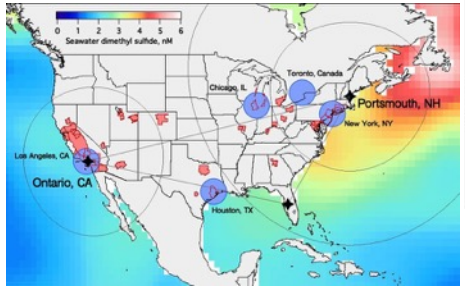
2022: AEROMMA / CUPiDS (Atmospheric Emissions and Reactivity from Megacities to Marine Areas / Coastal Urban Plume Dynamics Study)
2024: AQUARIUS (Air Quality Research in the Western U.S.)

Advanced Observations and Modeling

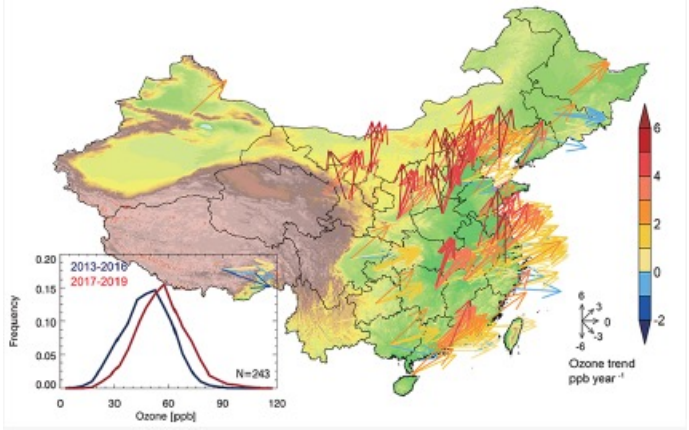
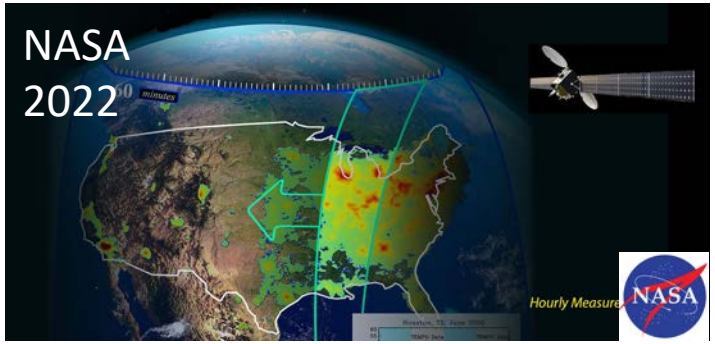
Geostationary satellite era
Near term: TEMPO, GEMS, SENTINEL
Longer term: NOAA Geo-XO constellation

Integrated Approaches and Skill Sets

Diverse workforce
National and international partnerships



Decreasing U.S. emissions, but AQ trends vary globally



Lu ES&T Lett 20