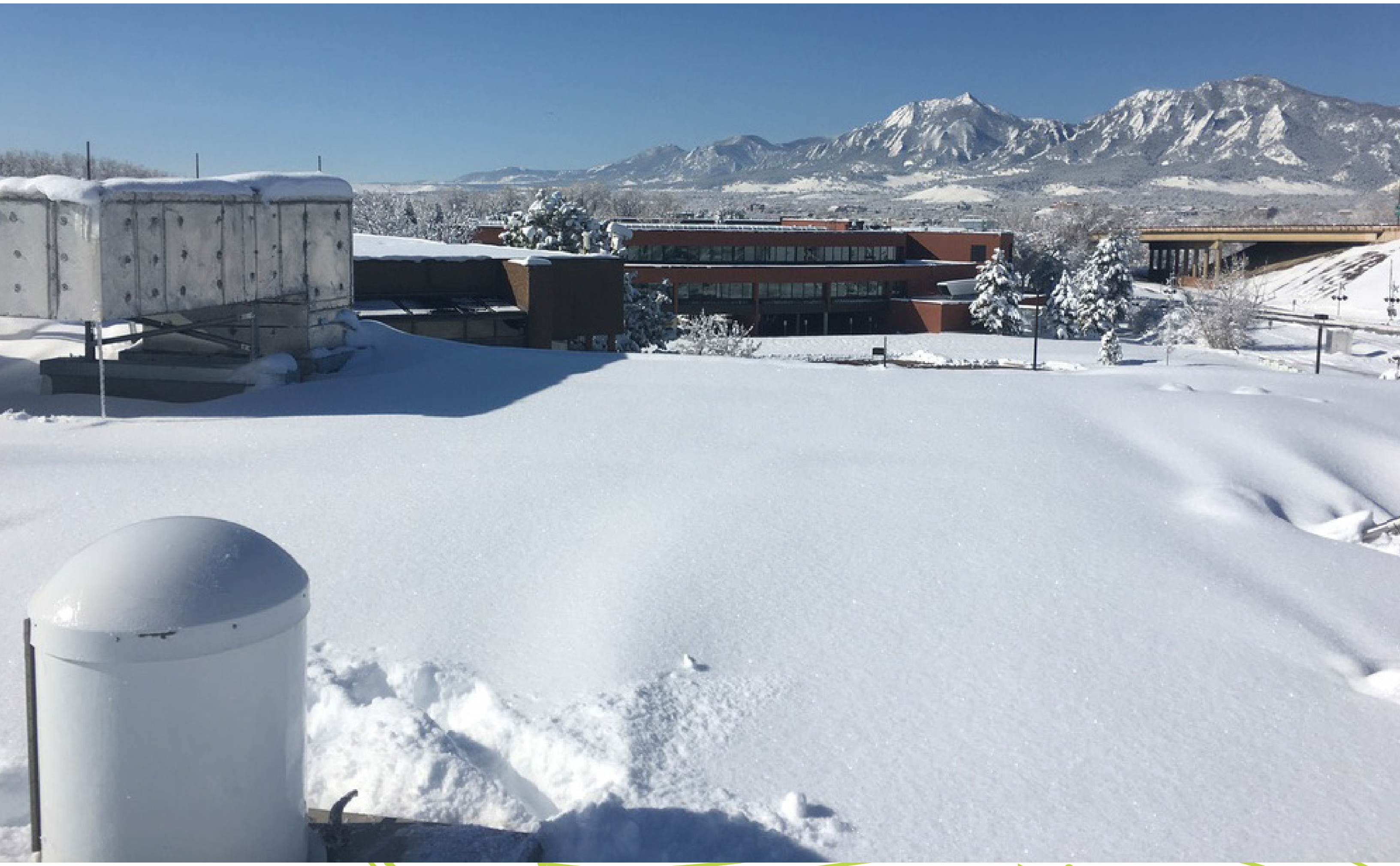

ACOM Strategic Science Plan

(2025-2029)

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Thank you for the contributions of the ACOM staff,
with special thanks to the Early Career staff

Design & layout by Shaun Bush, Gabe Lopez and Amy Brokaw

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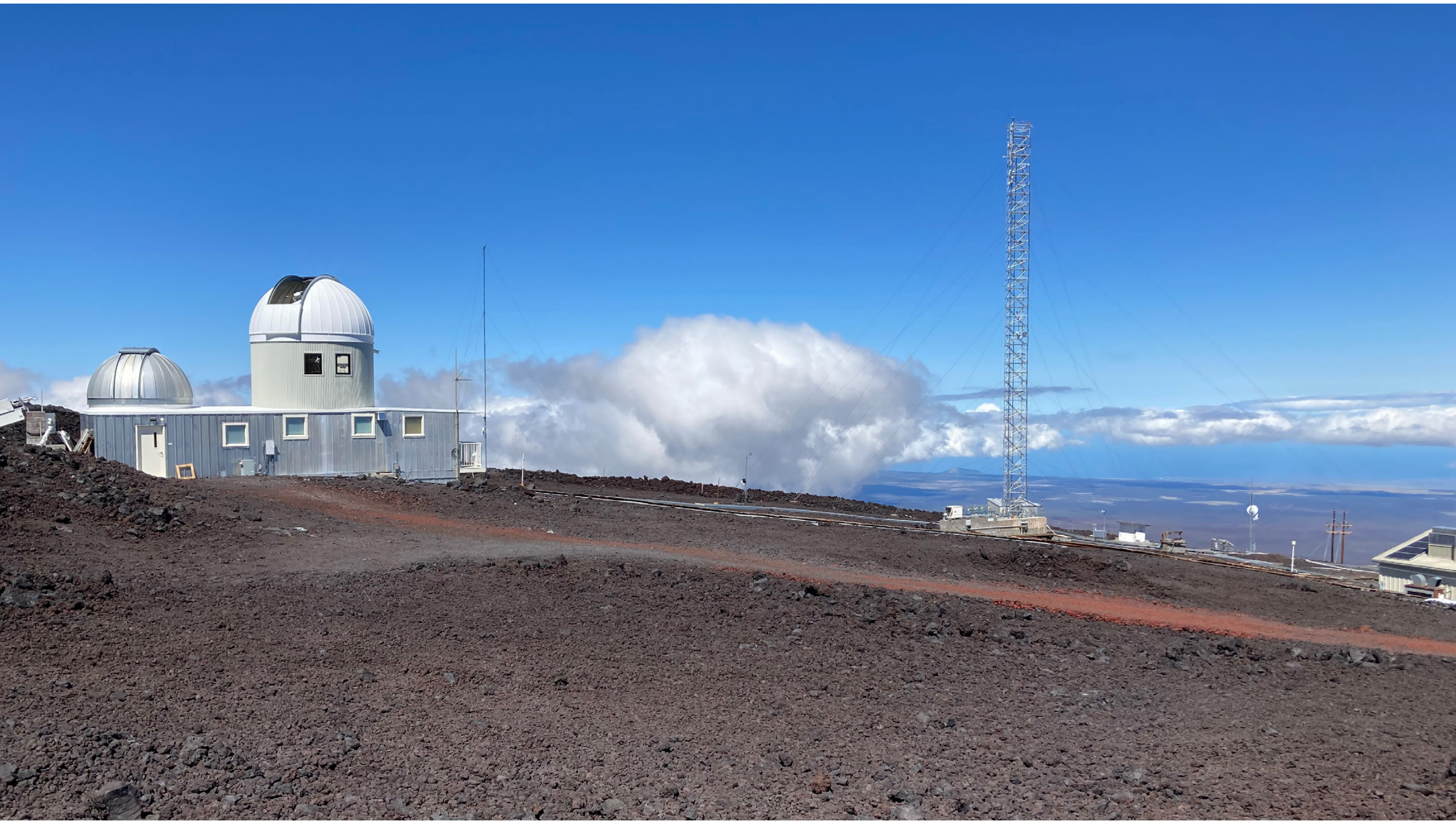


I. From the ACOM Director

Many elements of our daily lives-human health, food security, insurance costs, and economic development, to name a few-are shaped by our environment. Environmental challenges that threaten to disrupt these elements of our lives, such as extreme weather, poor air quality, and wildfires, require a fundamental understanding of atmospheric chemistry to develop lasting solutions.

Air quality is impacted by emissions; transformation of those emissions through chemical and physical processes and Earth system feedbacks; and transport of resultant products from one region to another, including oxidants, air toxics, aerosols, and long-lived gases. The atmospheric processes that result in products that are detrimental to our economy (e.g., through agricultural losses) and human health (e.g., through chronic exposure and illness) are extremely complex. Achieving understanding and predictability of these processes is crucial to finding solutions that can minimize poor air quality and promote resiliency.

The mission of ACOM is to lead and support research within the university community, and across wider research networks, that advances the field of atmospheric chemistry. ACOM is unique because it integrates in-house expertise in field and laboratory measurements, satellite and ground-based retrievals, data assimilation, and multiscale atmospheric chemical modeling. While ACOM uses these core capabilities to advance atmospheric science, broad engagement with public and private sectors is required to truly address the pressing challenges and to support strategies that minimize the negative consequences of changes to our Earth system. ACOM is well positioned to bring researchers together from the atmospheric science community to support necessary scientific and technological advancements.

To that end, we have defined three science priorities that are focused on the future and recognize areas where atmospheric chemistry knowledge and tools are needed to support sustainable choices for current and future generations. We note that while these tools are required for understanding the Earth's atmosphere, they hold value and promise for understanding the atmospheres of other planets as well.

The first science priority addresses atmospheric composition and chemistry in the face of ongoing change. Outstanding questions include: What is the impact of the increasing wildfires and what are the feedbacks within the Earth system? What is the impact of increasing aerosol loads in the stratosphere or marine boundary layer? How can we be better positioned to understand and predict the full impacts of lower nitrogen oxide (NOx) chemical regimes?

The second science priority focusses on poorly-constrained emissions (both natural and anthropogenic), specific chemical and physical processes, and under-observed regions, to improve predictability of atmospheric gases and aerosols. In under-observed regions, many emission sources are poorly constrained or completely unknown, and this limits our capability to understand atmospheric composition. In Europe and the United States (US), thanks to effective science and technology, air quality has improved considerably. Nonetheless, despite reductions in emissions in the US and elsewhere, poor air quality remains a health concern for many. For example, in the Colorado Front Range, despite effective air quality regulation, surface ozone concentrations continue to remain high. Furthermore, in recent years, the US has experienced many unexpected extreme weather and fire events. This raises questions such as: Was El Niño driving these extremes? Are Earth system feedbacks also playing a role?

The third science priority recognizes the need to understand atmospheric chemical processes across molecular to global spatial and temporal scales. Here we focus on those research questions that are essential for understanding societally relevant challenges of the present and the future. The inherent complexity associated with this priority will benefit from application of artificial intelligence (AI) models. ACOM is exceptionally well-equipped to excel in this space with its laboratory, in situ, and remote sensing observational capabilities coupled with multiscale modeling capabilities that link highly detailed chemical mechanisms to Earth system models with chemistry through simplified parametrizations. While past research focused on single sources and regions (e.g., urban, remote), we must increasingly consider the mix of emission sources (e.g., urban, forest, agricultural) and their interactions which will require new process-level measurements and parametrizations for shared Earth system models.

Each science priority has associated objectives that will ultimately allow us to measure our successes, allocate resources, and determine personnel and infrastructure needs. Selection of these objectives was determined by the needs of the US-based research community and our public- and private-sector collaborations, and ACOM's current and future capabilities.

The National Academy of Sciences Report on the Future of Atmospheric Chemistry Research (2016) defines this ambition in recommendation 7: The National Center for Atmospheric Research (NSF NCAR), in conjunction with the National Science Foundation (NSF), should develop and implement a strategy to make NSF NCAR a vibrant and complementary partner within the atmospheric chemistry community. This strategy should ensure that scientific leadership at NSF NCAR has the latitude to set an energizing vision with appropriate personnel, infrastructure, and allocation of resources; and that the research capabilities and facilities at NSF NCAR serve a unique and essential role to the NSF atmospheric chemistry community. In this way we seek to reestablish ACOM as a collaborative hub to define and solve outstanding atmospheric chemistry problems of societal relevance.

Pieternel Levelt
ACOM Lab Director
NSF NCAR Associate Director

II. Overview

VISION:

ACOM accelerates scientific advancements and discoveries in atmospheric chemistry from molecular to global scales to address emerging questions in a changing world.

MISSION:

ACOM leads and supports community-driven research addressing air quality and Earth system challenges by:

ACOM Core Strengths and Capabilities:

Developing & applying world-class instruments, models, & facilities.

Integrating fundamental chemistry & atmospheric observations with numerical modeling.

Supporting staff & developing talent in a dynamic research environment.

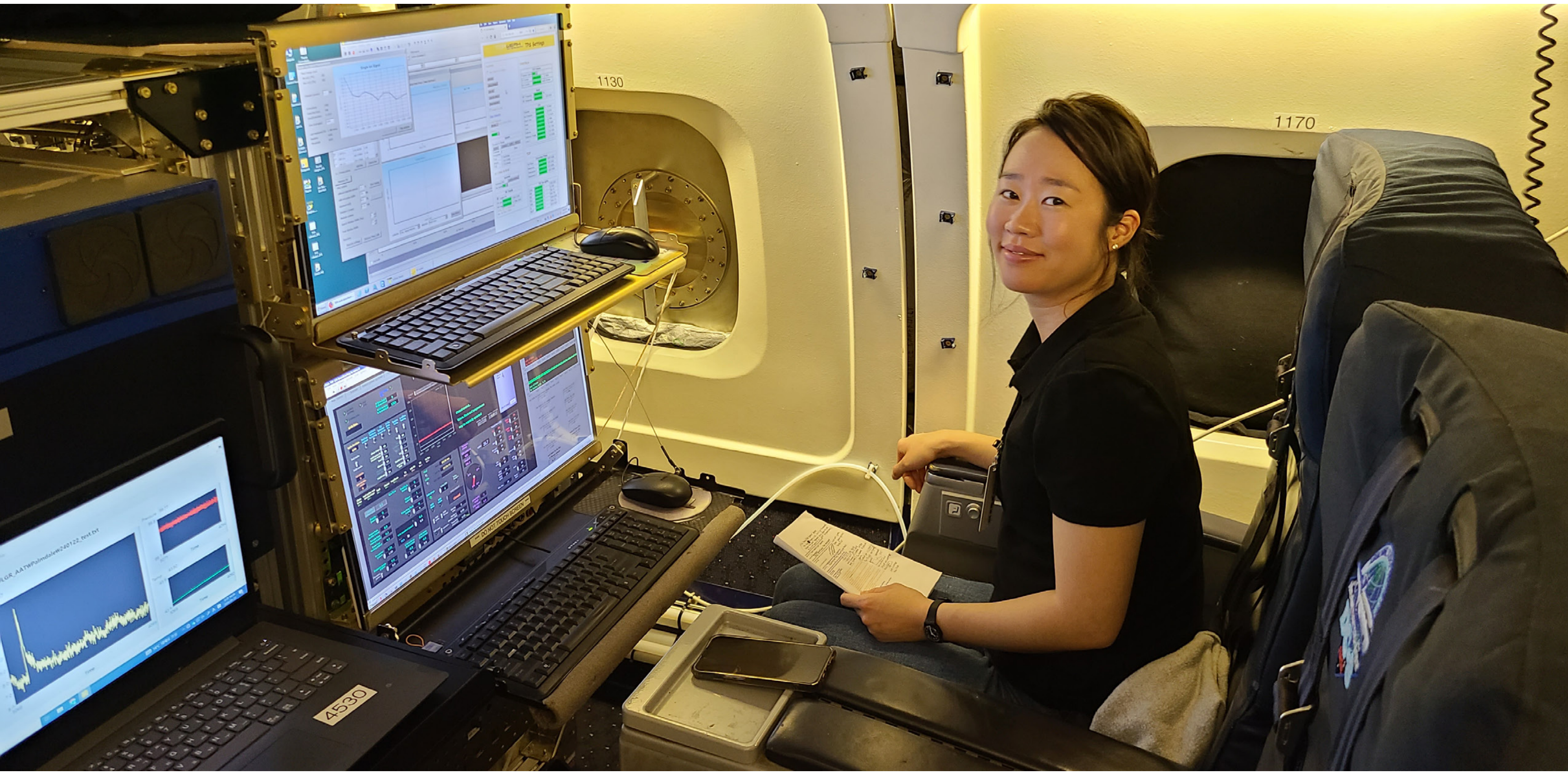
ACOM Laboratory Priorities:

Developing and applying state-of-the-science instruments, models, and facilities. Building capacity, sharing knowledge, and promoting excellence.

Elucidate changes in atmospheric composition and chemistry with changes in the anthroposphere.

Advance knowledge of under observed and poorly constrained emission sources, chemical and physical processes, and environments.

Facilitate understanding of atmospheric processes from molecular to global scales with societal relevance.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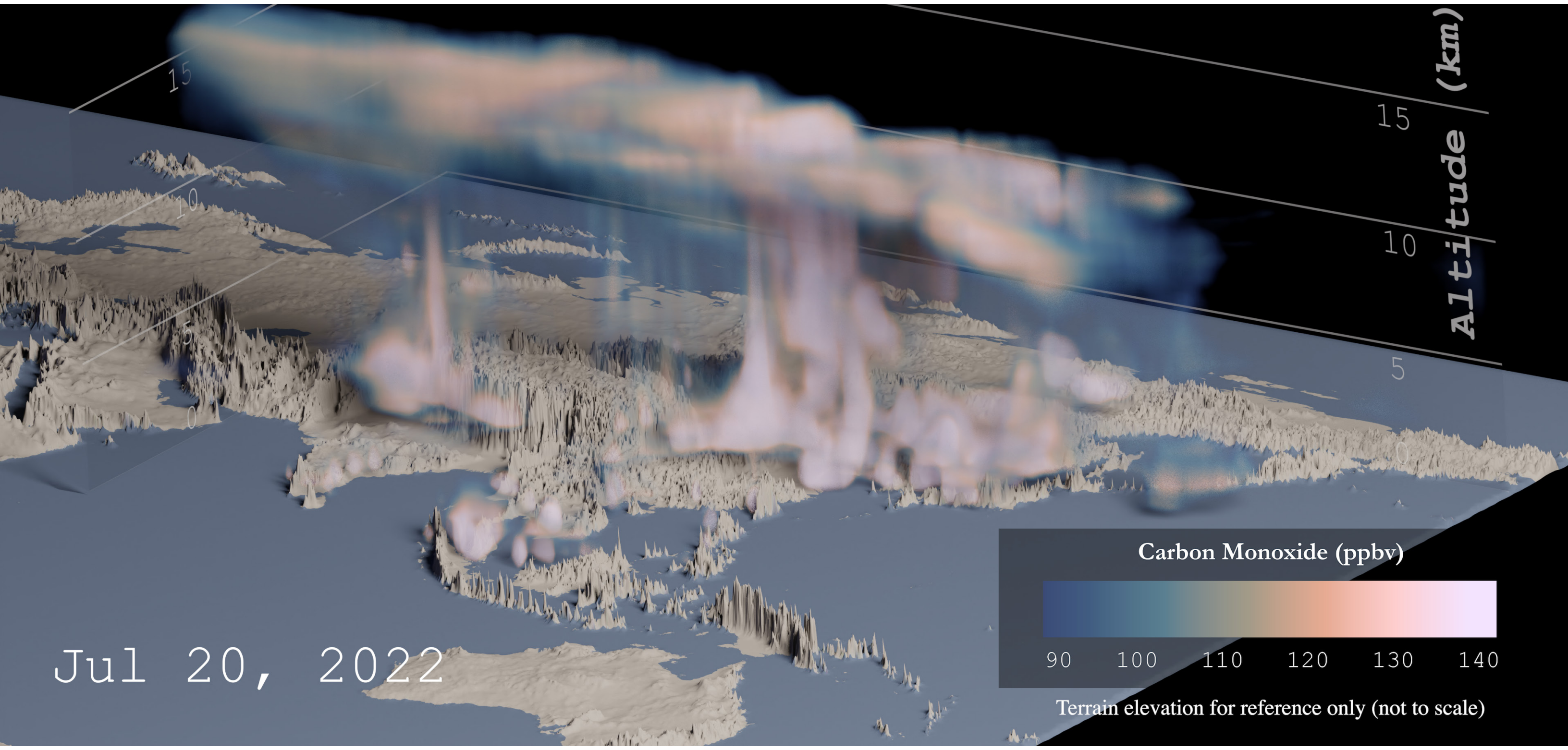
1170
4530

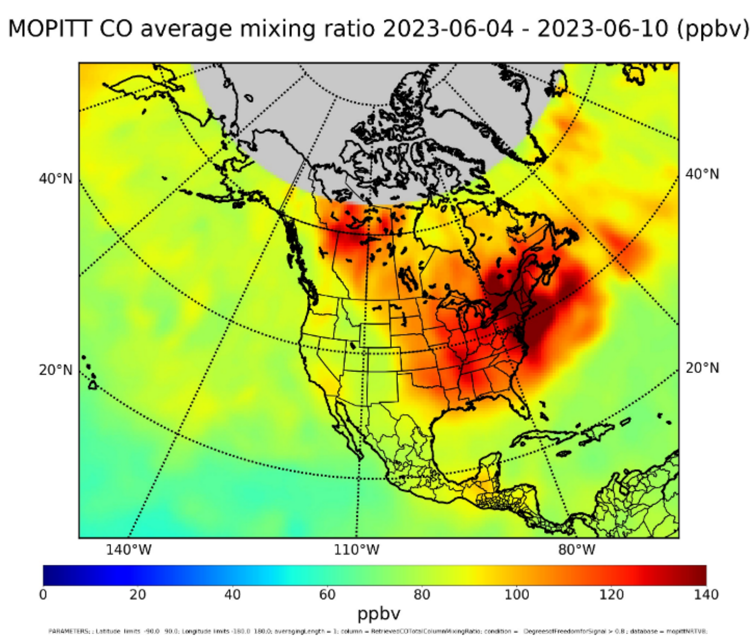

Altitude (km)
15
10
5
Carbon Monoxide (ppbv)
90 100 110 120 130 140
Terrain elevation for reference only (not to scale)
Jul 20, 2022

III. Core Strengths & Capabilities

ACOM science covers atmospheric chemistry and dynamics across multiple temporal and spatial scales that connect air quality and Earth systems: from days to decades and from the surface of the Earth to the upper atmosphere. ACOM scientists link fundamental and applied research through integrated field, laboratory, and modeling activities. Engineers and scientists work together to develop state-of-the-art instruments for the measurement of key trace gases, aerosols, and processes in the atmosphere, particularly for aircraft deployments (e.g., TOGA-TOF (VOCs), HARP (spectrally resolved actinic flux and irradiance), chemiluminescence (NO, NO2, fast O3), trace and greenhouse gases (CO, CO2, CH4, H2O, N2O)).

In FY 2024, 22 of X ACOM scientists and engineers participated in field campaigns. ACOM scientists and engineers are also extending observational capabilities for the community by developing advanced instrumentation that can fly in a pod under the wing of an aircraft (e.g., chemical ionization mass spectrometry, CIMS, for gases and aerosols), and can also be deployed for mobile, fixed site, and laboratory measurements. These in situ measurement capabilities provide detailed chemical information that is critical for understanding atmospheric composition and chemistry as relevant for achieving actionable and convergent science.

Remote sensing measurements, ground- and satellite-based, complement in situ measurements by providing observations over longer temporal and spatial scales. ACOM scientists are actively engaged in advancing remote sensing capabilities from instrument design to retrieval methods to data assimilation (e.g., MOPITT, OMI, HIRDLS), and in defining the next-generation constellation of low-Earth and geostationary orbit (GEO) satellites (e.g., TROPOMI, GEMS, TEMPO). ACOM recently highlighted the need for GEO instruments over the Southern Hemisphere and have proposed innovative satellite missions to ESA and NASA. ACOM is a lead in the FTIR NDACC network in which three instruments are from ACOM. ACOM scientists have extended the validation capabilities of ground-based networks by adding PANDORA and AERONET instruments at NSF NCAR, and have been working in close collaboration with the Earth Observation Laboratory (EOL) to deploy an MPD lidar that will measure the vertical distribution of aerosols and allow better comparisons and integration of surface and satellite-based observations. ACOM scientists are developing new retrieval techniques that lead to innovative products such as tropospheric ozone and CO sub-columns, and that will be used as input for the current ACOM-led TOAR assessment.



Complementing the field observation capabilities, ACOM scientists conduct laboratory studies using simulation chambers and flow tube reactors.

Such studies have elucidated numerous chemical pathways of important organic precursors that form the basis of the chemical mechanisms (e.g., MOZART) used for air quality modeling. These studies also contribute to the development and testing of highly detailed chemical mechanisms (e.g., GECKO-A). Modeling in ACOM has focused on the development, implementation, and evaluation of reduced form chemical mechanisms and associated processes in air quality and Earth system models (e.g., WACCM, MUSICA), but has also more recently focused on the convergent strengths of detailed mechanistic modeling and chemical speciation measurements for advancing predictive understanding (GECKO-A, MechGen). ACOM leadership of and participation in numerous field campaigns (e.g., FRAPPÉ, DISCOVER-AQ, CONTRAST, KORUS-AQ, WE-CAN, ATom, ACCLIP, Asia-AQ) over the past decades, in partnership with national and international communities, has provided critical observations for evaluating models, advancing knowledge, and delivering actionable science. These field campaigns bring together many of ACOM's modeling and observational capabilities and will continue to do so in the future.

ACOM stands as a center for the atmospheric chemistry community, facilitating scientific engagement and progress toward actionable science. ACOM's thriving visitor program brings together national and international researchers at every career stage for collaborative and training opportunities. In FY 2024 ACOM hosted 112 total visitors, including 38 long-term visitors with ongoing engagement. ACOM is committed to training the next generation of scientific leaders, for example through the ACOM-led Ralph Cicerone Program and the many NSF NCAR- and UCAR-led student internship programs (e.g., SOARS, ASP, and PDP). ACOM scientists and software engineers are dedicated to advancing NSF NCAR atmospheric chemistry models, by leading and participating in field experiments and satellite projects, and to making these models accessible, by leading numerous community workshops and user tutorials. In FY 2024, ACOM led 10 conferences and meetings and 13 workshops, tutorials, and colloquia. ACOM scientists partner with the broader scientific community through international initiatives including CCMI, IPCC, and IGAC. In FY 2024, ACOM staff served on 40 internal and 37 external committees.

ACOMs core strengths and capabilities lead to a range of outcomes that support our mission and vision. One of those outcomes is peer-reviewed publications. Over the last five year period, ACOM scientists led an average of 20 publications/year and contributed to an average of 120 publications/year. Recent ACOM publications are available through this link .

IV. Role of ACOM within NSF NCAR, NSF, & Beyond

NSF NCAR is a federally funded research and development center (FFRDC) sponsored by the National Science Foundation (NSF). Achieving predictability in our understanding of atmospheric chemistry and composition is an essential component of NSF NCAR's 'world-class research in Earth system science'. One of the unique attributes of a National Center is that research questions can be addressed by complementary approaches using facilities and expertise provided by different laboratories within that Center. ACOM is well-integrated in this endeavor within NSF NCAR and enjoys increasingly successful collaborations with its sister laboratories.

ACOM and MMM have partnered in many field campaigns, with MMM bringing critically relevant meteorological expertise. ACOM and CGD collaborate on the development of next-generation Earth system models spanning the ocean to the upper atmosphere, including the chemistry of greenhouse gasses and aerosols. ACOM has a growing number of collaborations with RAL to evaluate the impacts of poor air quality (including as driven by wildfires) on health, agriculture, and ecosystems from a multi-disciplinary perspective. ACOM works closely with EOL and the community to enable field measurements, particularly the deployment of ACOM instrumentation in aircraft campaigns. New collaborations between ACOM and HAO strive to extend the top of the WACCM whole atmosphere model to 500 km. ACOM is also leading an initiative, with HAO and UCP, to increase visibility and collaboration on satellite projects and satellite data across NSF NCAR. ACOM relies on CISL for provision of High Performance Computing (HPC) and data stewardship. Further, new partnerships are emerging with CISL to enable graphics processing unit (GPU)-compatible atmospheric chemistry codes and to improve data assimilation and Artificial Intelligence codes and related research.

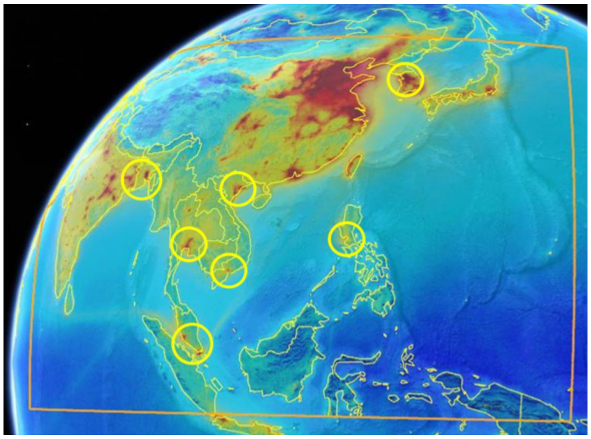
As an FFRDC, ACOM's projects are of sufficient scope and importance to require long-term planning and investment at a level difficult to sustain within a typical university research group. ACOM thus provides scientific and facility leadership to the benefit of the NSF Division of Atmospheric and Geospace Sciences (Atmospheric Chemistry) community, and scientists work collaboratively across NSF NCAR and with external partners to identify and engage in efforts to achieve both long- and short-term scientific goals and to benefit the nation. It is envisioned that the research described in this Science Plan will be developed through joint projects that engage colleagues within NSF NCAR, universities, government agencies, nonprofits, and the private sector. As the focal point for chemistry and composition research within NSF NCAR, ACOM also engages with stake-holders worldwide through the leadership of its scientists in international projects and service as experts on panels, committees, assessments and in global capacity building. ACOM also enjoys its role as an international meeting place hosting short- and long-term visitors, conferences, and workshops.

V. Cross-Laboratory Priority:
Developing & applying state-of-the-science instruments, models, & facilities for convergence science

This priority describes how we integrate the scientific strengths in ACOM to deliver our mission and vision. The objectives described within this priority address the cornerstones of ACOM and underlie everything we do. The examples under each objective illustrate our focus on strengthening fundamental capabilities that are essential across our projects and teams; achieving agile responsiveness, modernization, and modularity; and pursuing convergence science.

OBJECTIVE 1:
Build, maintain, and apply state-of-the-science atmospheric chemistry multiscale modeling capabilities for predicting gases and aerosols in the whole atmosphere.

Atmospheric chemistry modeling is a key tool for interpreting air quality and Earth system impacts of trace gases and aerosols. The interpretation is often scale-dependent, and model representations of large- and small-scale processes are often disjointed. The next generation Multi-Scale Infrastructure for Chemistry and Aerosols (MUSICA) allows for the simulation of large scale atmospheric phenomena, while simultaneously resolving chemistry at emission and exposure relevant scales (down to <4 km). The MUSICA initiative leverages the earth-system modeling framework developed at NSF NCAR through the well-established and scientifically-validated Community Earth System Model (CESM) and the extensive experience of modelers within ACOM. The ultimate goal of MUSICA is a modular framework, in which plug-and-play components (e.g., for photolysis, gas phase chemistry, aerosols chemistry) can be implemented in interchangeable configurations. ACOM's development of MUSICA aligns with the NSF NCAR-wide goal to develop and supply a unified community atmospheric modeling framework, realized through the System for Integrated Modeling of the Atmosphere (SIMA).



OBJECTIVE 2:
Integrate experimental observations and near-explicit chemical mechanisms development to provide critical constraints for multiscale modeling.

Recent field campaigns, in which ACOM was a key participant, have demonstrated strengths and weaknesses in our ability to simulate atmospheric chemical composition and chemical evolution at different scales. It is understood that there are many thousands of organic species and many thousands of reactions that may occur, which present a challenge to achieving accurate representation and predictive capability for models across scales. ACOM has developed the state-of-the-art Trace Organic Gas Analyzer (TOGA) coupled to a time-of-flight mass spectrometer

(TOGA-TOF) and is developing the complimentary community-requestable wing pod CIMS, which together bring ACOM to the forefront of reactive organic gas measurements. Simultaneously, ACOM is developing and applying the Generator of Explicit Chemistry and Kinetics of Organics in the Atmosphere (GECKO-A) as a novel method of interpreting complex field measurements. Critical input for GECKO-A comes from studies in our chamber facilities. By elucidating the complex chemistry of organic compounds in the atmosphere, and developing scalable chemical mechanisms for process-level to global-scale models, ACOM is positioning itself as a key community partner in bridging the gap from complex molecular-level in situ measurements to multiscale predictive modeling.

OBJECTIVE 3:

Leverage new satellite and ground-based remote sensing, and in situ measurement techniques, to increase understanding of chemical complexity, over previously unavailable spatial and temporal scales of observational data.

The temporal and spatial resolution of air pollutant data from the geostationary Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument will uniquely allow unprecedented study of diurnal variability and distinction between emissions and chemistry at multiple scales. ACOM scientists will play a key role in effectively assessing the quality and advancing the utility of the TEMPO data using rigorous validation and data-assimilation techniques developed through prior experience with MOPITT, OMI, TROPOMI and GEMS data. These techniques rely on comparisons to existing satellite data and ground- and aircraft-based measurements. ACOM will leverage network observations, like PANDORA, and will lead and support dedicated aircraft campaigns (e.g., AEROMMA, GOTHAAM, AiRMAP, SCENICS) and ground-based initiatives to support the use of TEMPO data to advance air quality research and convergence science strategies, including in urban environments, at the wildland-urban interface, and across airsheds as impacted from large sources.

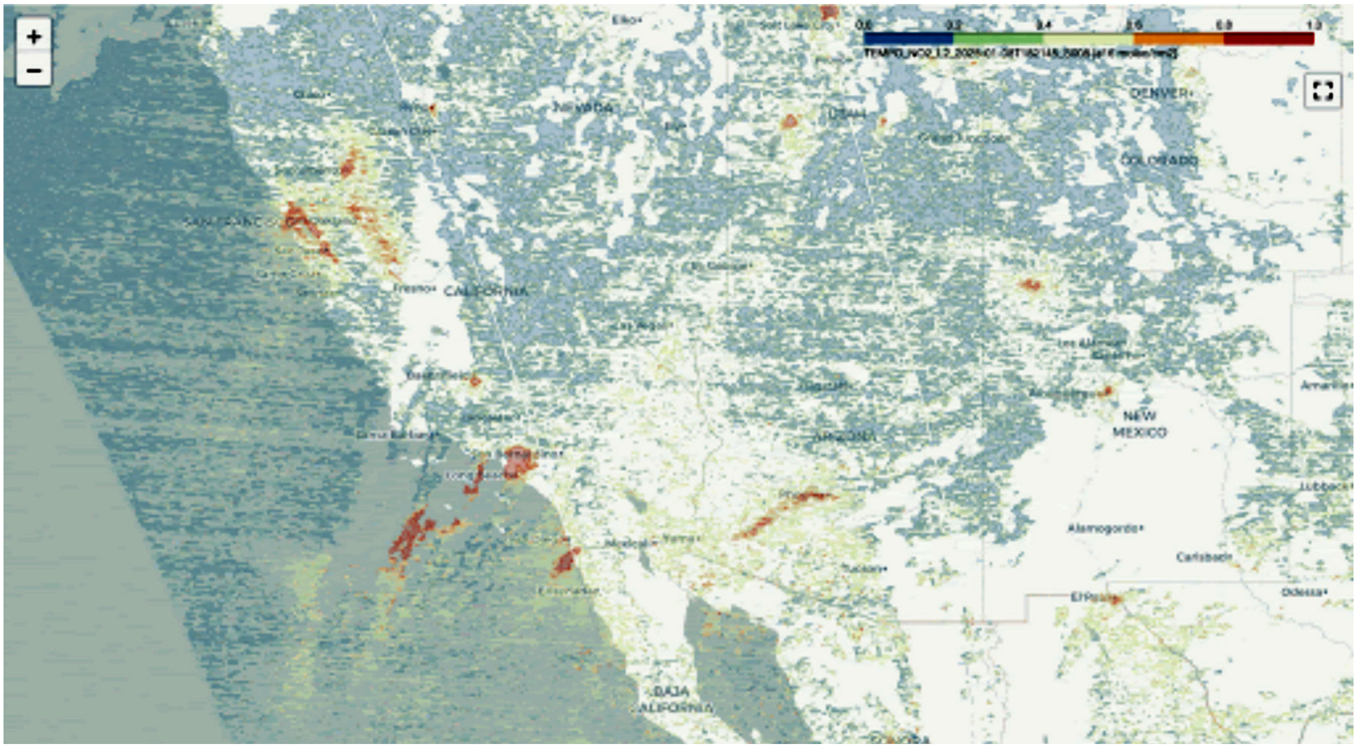
OBJECTIVE 4:

Maintain and develop capacity to deploy modular measurement capabilities with co-benefits of improving response to community inquiries during extreme events and providing higher spatial resolution observations for model development and testing.

Measurements of chemical tracers are essential for interpreting complex atmospheric chemistry and dynamics and to provide much needed information on potential health effects from poor air quality. However, such measurements over multiple regions and multiple seasons are sparse. ACOM has devel-oped two techniques that can be rapidly deployed to measure organic chemical tracers in response to sudden events such as chemical spills, fires at the wildland-urban interface, etc. The first is the whole air canister array (WASA) and the second is a unique UAV system, the Whole Air Sampling Pilotless Platform (WASPP), that can measure vertical and horizontal spatial gradients. Both consist of ready-to-deploy canisters that can be used to collect air samples in a desired region for analysis of more than 70 organic gases using TOGA systems. Additionally, ACOM is developing a LIF instrument for measurement of nitrogen oxides, with modular and easily serviceable/replaceable component to support rapid and agile deployment. ACOM has proposed development of a Moderate Resolution Pointing Interferometer (MRPI), which is a small trace gas instrument with centrally processed data that can be deployed individually or as part of a network, can be housed by non-experts, and can connect ground and satellite-based observations and fluxes at local to regional scales.

Finally, ACOM is investigating the use of low-cost sensors, like those used in the PurpleAir network, to build our capacity to react rapidly and agilely to extreme events impacting society.

VI. Science Priority 1:
Elucidate changes in atmospheric composition & chemistry with changes in the anthroposphere



OBJECTIVE 1:
Characterize chemistry-Earth system feed-backs in the troposphere and stratosphere using community chemistry models that allow representation of gases and aerosols in the whole atmosphere.

In addition to evaluation of the effects of changes in the Earth system on atmospheric composition, current research on stratospheric aerosol injection (SAI) focuses on the impacts of sulfate aerosols and alternative materials on changes in stratospheric heating, dynamics and the subsequent effects on the Earth system. The effects of SAI on atmospheric composition, ozone, ice clouds, and, associated feedbacks, remain largely unknown. ACOM is well poised to lead comprehensive modeling studies to quantify the global and regional impacts of SAI, and the associated uncertainties, using our state-of-the-art whole atmosphere chemistry climate model (WACCM). These capabilities allow regional refinement of km-scale resolution, which improves the representation of atmospheric dynamics and physics.

OBJECTIVE 2:
Determine the missing processes, and level of complexity in their representation, that limit predictability of atmospheric composition, air quality, and Earth system feedbacks.

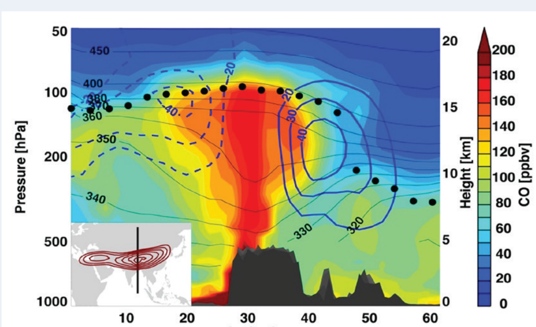
During the 2022 ACOM-led Asian Summer Monsoon Chemical & Climate Impact Project (ACCLIP), enabled by observational capabilities from ACOM, unprecedented and unexpected high concentrations of trace gases and aerosols were observed in the upper troposphere, down-stream of Asian monsoon convection. Building on these observations, ACOM will leverage new modeling infrastructure to investigate processes controlling atmospheric composition in an environment dominated by deep convection.

MUSICAv1 enables convection-resolving capabilities coupled with chemistry over a selected region within a global model grid, and demonstrates ACOM's abilities to represent gas, aerosol, and cloud chemistry over targeted regions while retaining the global context. These abilities allow us to lead and support science applications that require high spatial, temporal and vertical resolution modelling capability. Further, these studies allow us to quantify the effects of pollution in the Asian outflow on local to global scales, including the impacts on the US.

OBJECTIVE 3:
Determine the impact of changing emissions on atmospheric composition, air quality, and the Earth system.

There is a need to improve the predictive modeling capabilities for short-lived atmospheric constituents such as ozone and aerosols (and their precursors) and methane, to evaluate fundamental understanding and drive science for society. This requires estimating emission sources and maintaining state-of-the-art chemistry components for coupled Earth System modeling. Opportunities exist for verifying historic emissions estimates using reanalysis and inverse modeling. Further, as emissions respond to Earth system perturbations, local weather conditions, and land use and policy changes, there is a need and opportunity for estimating emissions of gases and particles from natural (e.g., desert dust, sea salt aerosols, soil, fires, wetlands) and anthropogenic sources. The increased use and availability of satellite observations and emerging techniques incorporating AI will enable these new emission estimates. ACOM will play a critical role as both lead and partner in improving and validating emissions estimates, through both field campaigns and modeling studies. As an example of the connection between atmospheric composition and chemistry, ACOM seeks to provide accurate and annually-varying methane emissions (determined using inverse modeling of satellite data) and assess the impact of those emissions on the Earth system.

Studies of Atmospheric Composition and Air Quality in Asia



ACOM provides leadership in:

- State of the art aircraft measurements
- Forecast for flight planning using satellite observations
- Analysis of in situ and remote sensing data with model simulations for comprehensive regional understanding of campaign results

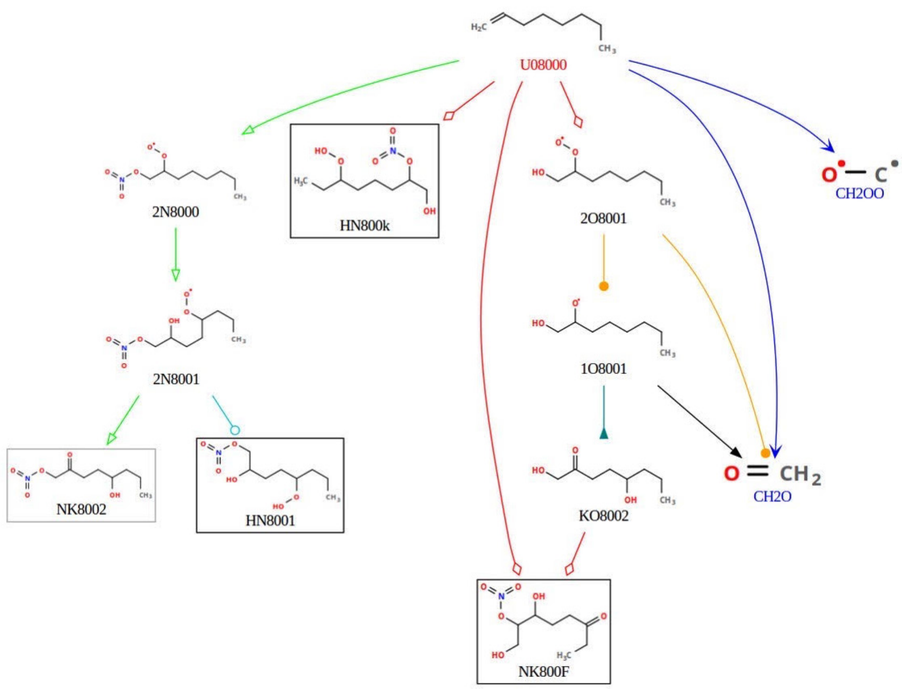
ACCLIP:

Investigate impacts of Asian gas and aerosol emissions on global chemistry and climate via the linkage of Asian Summer Monsoon convection and associated large-scale dynamics

Asia-AQ group photo, February, 2024, Clark International Airport, Philippines

VII. Science Priority 2:
Advance knowledge of under observed & poorly constrained emissions sources, chemical & physical processes, & environments with their air quality and Earth system impacts

OBJECTIVE 1:
Improve model representation of chemical and physical processes associated with clouds, an under-observed and poorly constrained aspect of atmospheric chemistry.



At any given time, clouds cover 60% of the Earth's surface impacting the atmosphere, including altering atmospheric composition. Clouds affect atmospheric composition through a variety of processes, including scavenging of trace gases and aerosols, lightning production of NOx, altering photolysis rates, and aqueous-phase chemistry. Conversely, aerosols and trace gases, through formation of secondary aerosols, affect cloud formation and microphysics creating feedbacks. The challenges of sampling trace gases and aerosols in the interstitial air of clouds, collecting sufficient amounts of cloud water for chemical analysis, and retrieving satellite data in cloudy regions have created a clear-sky bias in atmospheric chemistry research, limiting advancements in understanding and representing aqueous phase chemistry, especially organic acid formation. ACOM has led field campaigns and modeling studies to quantify the role of deep convection and of other types of clouds/cloud processes on composition of the atmosphere from the lower stratosphere to the boundary layer. Over the next few years, ACOM aims to improve global, regional, and local-scale model representations of aqueous-phase chemistry through analyses of measurements, and detailed modeling of these observations, via collaborations within NSF NCAR (e.g., MMM), and the university and cloud chemistry communities.

OBJECTIVE 2:
Develop and test scalable chemical mechanisms for representing chemistry of pollutants of emerging interest in modern chemical regimes.

With significant decreases in major emissions sources across the US and Europe, some attention has shifted to under-observed or poorly-constrained sources of pollutants, such as wildland fires and volatile consumer products, for understanding, predicting, and mitigating air pollution. New chemical mechanisms are needed to describe the atmospheric reactivity of compounds emitted from such sources, including (oxygenated-) aromatics and terpenes. These chemical mechanisms must be scalable for a range of applications (e.g., research to regulatory) and model scales (e.g., 0- to 3-D and local to global). They also must be considered community resources to support continued development, evaluation, and application. We will advance these outcomes through university partnerships and cross-lab linkages, in which we develop and contribute essential parameterizations needed to predict ambient air pollution and health impacts.

OBJECTIVE 3:

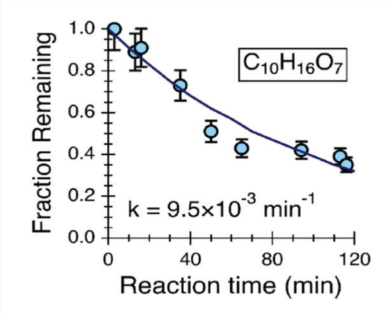
Determine the key processes that affect air quality in distinct chemical environments to improve short-term predictability and allow concurrent risk assessments of extreme events (heat waves, ozone exceedances, wildfires).

Given the increasing frequency of catastrophic "mega fires" and the complexity associated with developing scientific understanding, reliable modeling tools, and appropriate resiliency strategies, there is an urgent need for large-scale multidisciplinary research efforts with clearly defined convergence science and educational outcomes. ACOM is engaging in innovative collaborative research, with partners across NSF NCAR, university and other communities, to: integrate high-resolution fire behavior models with complex emissions and chemistry, and evaluate these models using multi-platform observations. Once verified, these high-resolution results can be used to develop parameterizations of fire behavior, emissions, and smoke chemistry along with ensembles and machine learning; integrated with regional scale parameterized emissions and chemistry (including aerosols) and used with regional to global land-atmosphere models. This will lead to integrated, simple to use observational packages for deployment during extreme events, including wildfires, for community education and for further model development and evaluation. These observational packages are also important for developing up-to-date safety procedures and assessing insurance costs. These initiatives are in various stages of development, with ACOM already engaged in cross-lab research of fire behavior, emissions, and chemistry. Linkages across scales and with observations will be required to improve predictability and allow concurrent risk assessments of extreme events including wildfires.

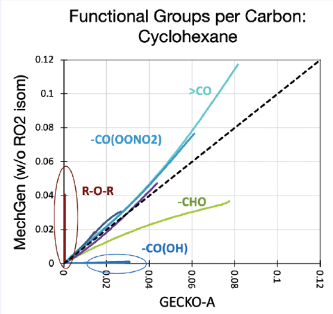
Mechanistic research to understand atmospheric oxidation processes

ACOM provides leadership in:

- Laboratory research to elucidate reaction pathways of understudied emissions and chemical regimes
- Collaborative experimental studies to complement field observations and air quality modeling
- Development and use of detailed and reduced atmospheric chemical mechanisms for simulations across scales

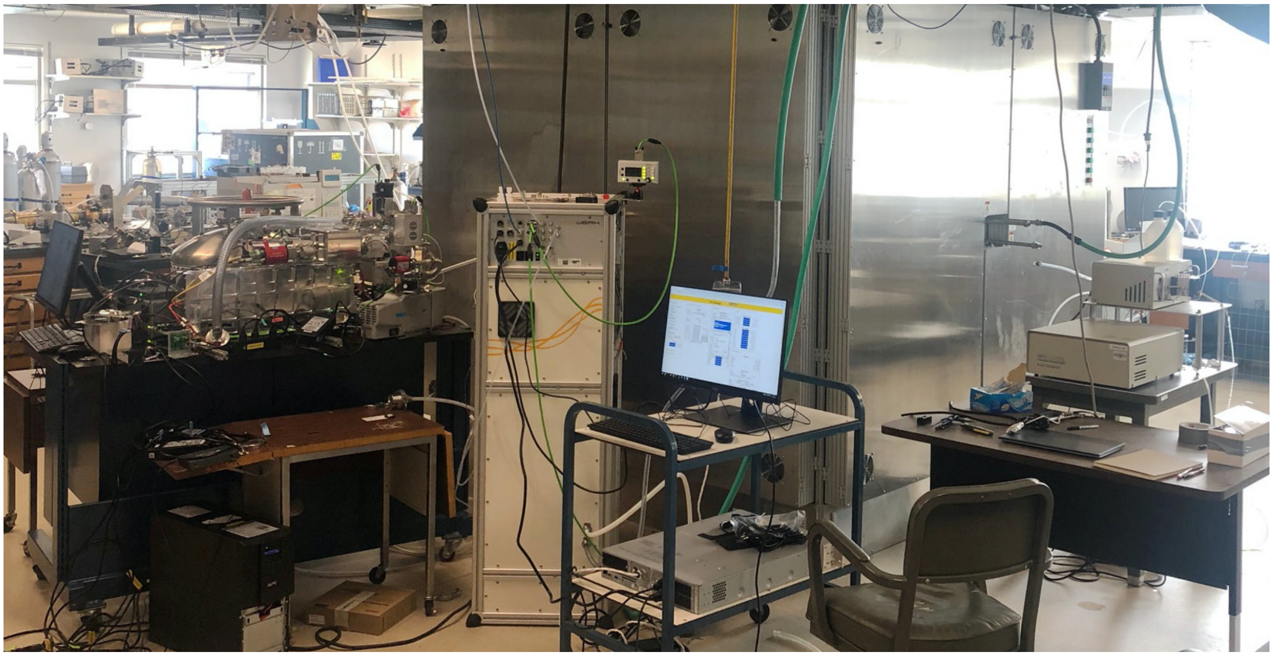


Dr. Quing Ye and other ACOM scientists collaborated with UC Merced to study the fate of highly oxidized molecures from monoterpene oxidation.
Fig. from Hao et al. in prep.



Dr. Julia Lee-Taylor presented the first comparison of detailed mechanism from GECKO-A and MechGen at the Atmospheric Chemical Mechanism Conference in Davis, CA

VIII. Science Priority 3:
Pursue integrated study of atmospheric processes from molecular to global scales to address societally relevant challenges.



OBJECTIVE 1:
Characterize spatial and temporal variability of natural and anthropogenic sources and their individual and combined effects on air quality, atmospheric composition, and the Earth system.

Despite decades of improvements in air quality, many US metropolitan areas are struggling to attain the National Ambient Air Quality Standards (NAAQS). In addition, there remain large differences in air pollution levels at the neighborhood scale. The Atlanta metropolitan area (AMA) is one such region, with O_3 and $PM_{2.5}$ levels approaching the NAAQS and one of the highest socioeconomic disparity levels of any large city. A large-scale multi-disciplinary field campaign, SCENICS (Stereoscopy of Multi-scale Chemical Exchanges and Interactions between a City and its Surroundings) is under discussion with the overarching goal of gaining an integrated understanding of the multiscale interactive chemical, meteorological, and biological processes that determine the atmospheric processing of primary and secondary pollutants within the urban core and the surrounding rural areas to support science that improves human health and public wellbeing. ACOM is acting in a lead role, coordinating project development and proposal preparation, providing expertise in field campaign planning and execution as well as (eventually) underpinning the campaign with in situ observational capabilities (e.g., NO/NO_2, VOCs with TOGA, O_3), satellite retrievals (e.g., from TROPOMI, TEMPO), chemical forecasts, and model simulations and analysis (e.g., MUSICA, MusicBox).

OBJECTIVE 2:
Improve our understanding and predictability of secondary aerosol formation and its changing roles in air quality and the Earth system.

To improve predictability of aerosol properties (concentrations, composition, optical properties) and to accurately quantify their effects human health and ecosystems, a more complete understanding of aerosol sources, chemistry, dynamics, and chemical and physical properties are needed. ACOM aims to contribute to this with their newly obtained FIGAERO and by using the ASCENT network. The ASCENT (Atmospheric Science and Chemistry mEasurement NeTwork) network fills an identified data gap in the US-the lack of ongoing measurements of aerosol chemical composition and physical properties at high time-resolution (minutes).

ASCENT will provide aerosol data at unprecedented spatial and temporal resolution from 12 stations across a range of ecosystems and environments within the US. With the new observations from ASCENT, ACOM plans to further fundamental knowledge and predictive capabilities of: 1) source-specific aerosol formation and aging processes to support estimates of aerosol toxicity and assessments of human exposure, and 2) aerosol optical properties in various environments (e.g., urban to remote, fresh to aged) and the link between near surface aerosol composition and size distributions and satellite-derived (e.g., the Multi Angle Imager for Aerosols, MAIA) aerosol concentrations, composition, and human exposure. In collaboration with EOL, ACOM is augmenting ASCENT surface measurements at the Denver site with MicroPulse DIAL Lidar measurements of vertical profiles of aerosol load, water vapor and temperature to provide the missing link between the surface composition and column integrated measurements. This will provide critical insights into the role of aerosol composition, water uptake and optical properties.

OBJECTIVE 3:

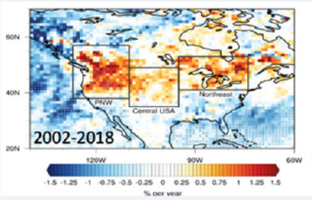
Deploy new measurement capabilities and develop new algorithms to constrain the oxidizing capacity of the atmosphere.

The troposphere sustains levels of key oxidants (O3, OH and NO3 radicals) needed to clean the atmosphere from the constant influx of trace gases (predominantly organics) emitted from natural and anthropogenic sources at the Earth's surface. Measurements of these trace gases are essential for interpreting complex atmospheric chemistry and dynamics. The suite of instruments deployed by ACOM (augmented by community collaborators) during aircraft campaigns provides quantitative information on sources and sinks for oxidants, as well as O3 levels. To this suite, we are adding a wing-pod CIMS instrument. The CIMS is uniquely suited to quantify highly oxygenated reaction products of VOC precursors, and mounted on an aircraft will allow data collection in complex environments (e.g., urban areas, wildland urban interface, agricultural regions). These measurements will significantly improve our ability to constrain factors controlling tropospheric oxidant levels and atmospheric composition more broadly. ACOM also seeks to develop instrumentation to directly measure OH, or OH reactivity, and other elusive products such as organic peroxy radicals, to further advance our ability to constrain the oxidizing capacity of the atmosphere.

Research to understand emissions from wildfires and impacts to air quality

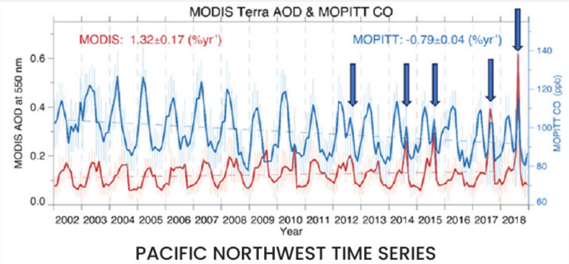
ACOM provides leadership in:

- Multi-decadal satellite date records of air pollution concentrations.
- Aircraft campaigns (WE-CAN, FIREX-AQ)
- Quantifying unknown and emerging emissions
- Understanding chemical and transport processes across scales relevant to large smoke plumes that impact downwind populations



ACOM demonstrated a change in the seasonal cycle of carbon monoxide (CO) due to increasing U.S. western wildfires.

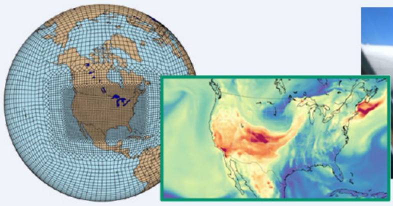
Arrows show years where both CO and aerosol (AOD) levels now have summertime peaks.



PACIFIC NORTHWEST TIME SERIES

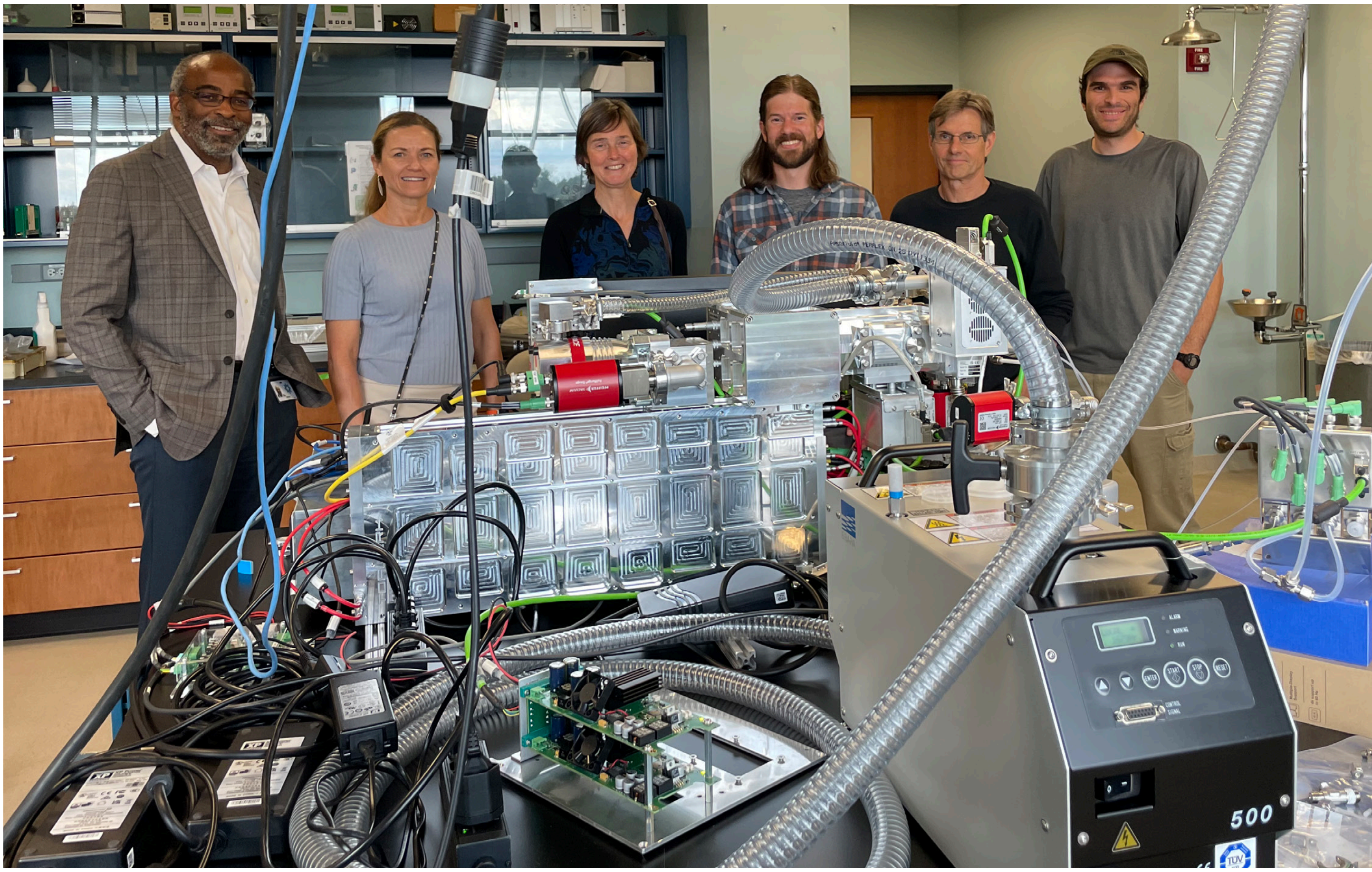
Buchholz, et al., Nature Comm., 2021

MUSICA model with regional refinement over U.S. allows full cemistry simulations at exposure scales.



IX. Cross-Laboratory Priority:
Building capacity, sharing knowledge, & promoting excellence

This priority reflects our commitment to enabling open exchange of knowledge and ideas, and broadening partnerships and engagement in STEM, as catalysts for advancing science. The objectives within this priority highlight ongoing and forthcoming efforts to engage in actionable and convergence science, including with leaders and stakeholders across society. The examples under each objective illustrate how we will achieve open communication and promote collaborative excellence.



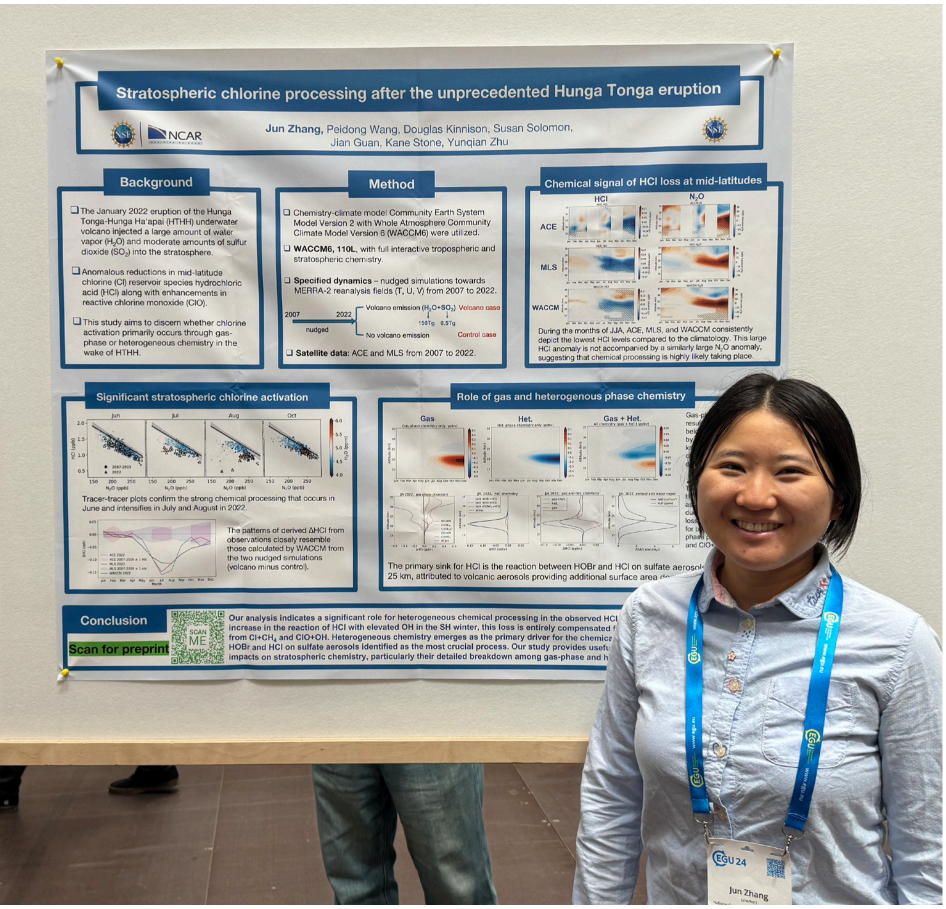
OBJECTIVE 1:
Facilitate open scholarly exchange with laboratory visitors and within our communities.

ACOM's Visitor Program is a prime example of how we facilitate scholarly exchange. With this program ACOM has welcomed hundreds of scientists fostering scientific and educational partnerships with members of the national and international atmospheric chemistry community. ACOM also hosts a weekly seminar program, inviting national and international speakers of all levels, and is open to the research community, serving in a hybrid mode so that all can join in-person or remotely.

OBJECTIVE 2:
Empower the next generation, elevating the voices of early career staff and honoring the voices of all staff.

The Early Career Scientists in ACOM led the creation of this Science Plan, including collecting and organizing information, structuring the document, and writing and editing. These Early Career scientists worked with Senior scientists and others across ACOM to create a plan that is based on the historical accomplishments of ACOM and empowers new talent to look into the future. ACOM is committed to maintaining an environment of respect and opportunity for our employees in all job classifications and at every career stage. We strive to enable open communication that allows everyone to contribute their unique talents.

ACOM has been training graduate students to solve problems of importance for public well-being, enabling science for society. One example is the Ralph Cicerone Fellow-ship in Earth System Science in which successful candidates receive financial support for four months, divided over two years, and benefit from the training and guidance of ACOM scientists on tools and techniques that enhance and support their graduate research. Another example is the Advanced Study Program (ASP) program in which each year students join ACOM to contribute to innovative and creative science.



OBJECTIVE 3:
Advance the broader NSF NCAR mission, including enabling and supporting a wide range of stakeholders.

Through several new initiatives, ACOM is broadening their engage-ment with scientists from different disciplines as well as stake-holders from entities that have been previously not engaged at all or engaged at a much later stage of a project development.

This includes, for example, local and state governments and the private sector. Through the afore-mentioned SCENICS project, ACOM will engage with these stakeholders in the research planning stage in order to achieve actionable and societally relevant outcomes. These efforts and experiences will facilitate an increased role for ACOM in developing collaborative and convergent science projects.

Appendix

ACOM ORGANIZATION STRUCTURE AS OF NOVEMBER 2024

ACOM Director's Office

Pieternel Levelt – Lab Director
Helen Worden – Deputy Director

Admin Team

Emily Doremire – Lab Administrator

Barbara Tunison
Debbie Ryan
Shaun Bush
Gabe Lopez
Sherie Palmer

Atmospheric Composition Remote Sensing & Prediction

David Edwards - Head

Rebecca Buchholz
Louisa Emmons
David Fillmore
Gene Francis
Benjamin Gaubert
John Gille
James Hannigan
Shawn Honomichl
Debbie Mao
Sara Martinez-Alonso
Ivan Ortega
Laura Pan
William Randel
Behrooz Roozitalab
Ren Smith
Jon Starr
Wenfu Tang
Emily Tinney
Daniel Ziskin

Experimental Science Section

Eric Apel - Head

Kelley Barsanti
Teresa Campos
Changmin Cho
Frank Flocke
Alessandro Franchin
Stephen Gabbard
Samuel Hall
Roger Hendershot
Alan Hills
Rebecca Hornbrook
Julia Lee-Taylor
Kirk Lesko
Richard Lueb
Sasha Madronich
John Orlando
Courtney Owen
Brett Palm
Sue Schauffler
Stephen Shertz
Kirk Ullmann
Andrew Weinheimer
Qing Ye
Kyle Zarzana

Modeling - The M in ACOM

Gabi Pfister - Head

Mary Barth
Martina Bramberger
Guy Brasseur
Matthew Dawson
Rolando Garcia
Jiwon Gim
Alma Hodzic
Douglas Kinnison
Danny Leung
Pablo Lichtig
Mijeong Park
Ajay Parottil
Ilaria Quaglia
Kwesi Quagraine (ASP)
Kyle Shores
Anne Smith
Montek Thind
Simone Tilmes
Francis Vitt
Stacy Walters
Fei Wu
Jun Zhang
Yingxiao Zhang (ASP)

STAFF PICTURE FROM RETREAT IN APRIL 2022

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