CSD air quality research overview

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Air quality research is key to the NOAA mission

NOAA Next Generation Strategic Plan
2009-2014

long-term

WEATHER-READY NATION

objectives

- Reduced loss of life, property, and disruption from high-impact events
- Improved freshwater resource management
- Improved transportation efficiency and safety
- Healthy people and communities due to improved air and water quality services

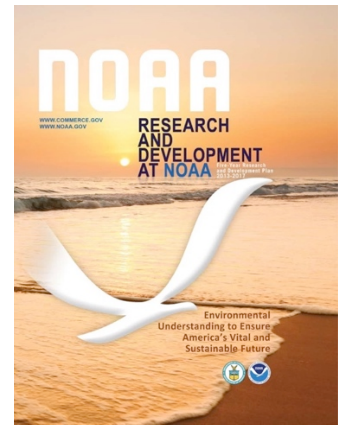
enterprise-wide capability

SCIENCE AND TECHNOLOGY

objectives

- A holistic understanding of the Earth system through research
- Accurate and reliable data from sustained and integrated Earth observing systems
- An integrated environmental modeling system

NOAA 5-Year Research Plan
2013-2017



Objective:

Improve understanding of the changing atmospheric composition of long-lived greenhouse gases and short-lived climate pollutants (e.g., aerosols, tropospheric ozone).

Over the next 5 years, NOAA aims to:

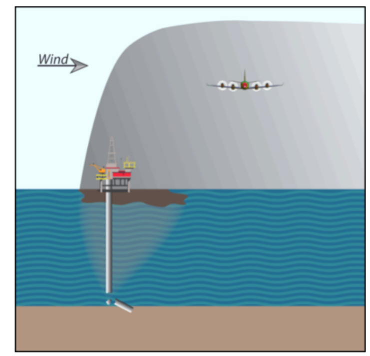
Determine the effects of increasing emissions in different regions of the U.S. (e.g. urban emissions, and oil and natural gas development activities emissions) on climate and regional air chemistry.

CSD air quality research overview

CSD takes an end-to-end approach to air quality research:

Identify
- Prioritize scientific focus based on societally-relevant issues

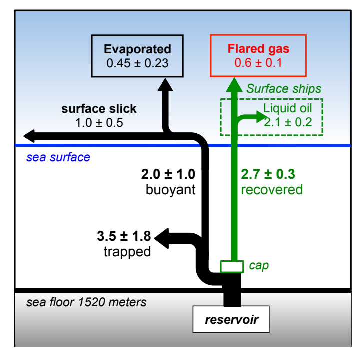
Investigate
- Develop purpose-built instruments when required
- Deploy in targeted field measurement intensives
- Interpret field data to improve process-level understanding
- Quantify salient features in controlled laboratory studies
- Evaluate state of understanding using numerical models



Communicate
- Distill findings in publications in peer-reviewed literature and in *state-of-science syntheses* provided directly to stakeholders

Collaborators and stakeholders (a partial list):

- **Industry:** petrochemistry, power generation, oil & gas development, agriculture …
- **Other NOAA:** all ESRL divisions, other OAR labs, other line offices, NWS …
- **Federal agencies:** EPA, U.S. Geological Survey, Bureau of Land Management …
- **State and local governments:** in Texas, Nevada, California, Utah, Colorado …
- **numerous University and international partners**
- **the U.S. public**



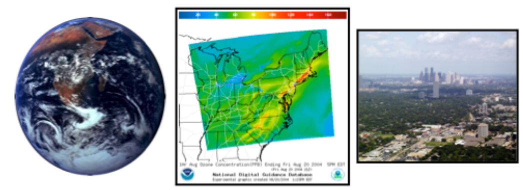
Today's air quality research topics

Emissions sources

Concentrations in air

atmospheric transport
atmospheric processing
atmospheric removal

Air quality impacts



Global Regional Local

Today's session includes CSD work on:

1. **Transported background O_3 (2 talks)**
2. **Satellite observations (1 talk)**
3. **Atmospheric particles (1 talk)**
4. **Chemistry after dark (1 talk)**
5. **Air quality forecasting (1 talk)**
6. Impacts of energy development (tomorrow's session)

Conclusions from this work inform air quality *and* climate science, by design

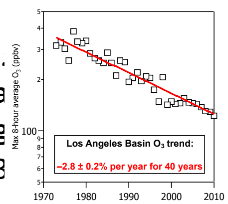
Topic 1: Transported background ozone

Motivation: U.S. National Ambient Air Quality Standard for ozone (O_3) is becoming more stringent over time, even as U.S. emissions decrease

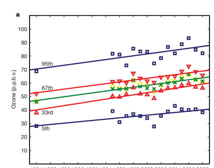
Background ozone – the fraction beyond local control – now contributes significantly to the total surface O_3 burden in many areas

Western regional O_3 trends

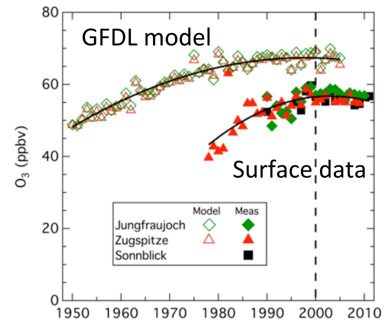
Los Angeles Basin: **O_3 maxima decreasing** Pollack *et al.*, 2013



Upwind of Los Angeles: **background O_3 increasing** Cooper *et al.*, 2010



Northern hemispheric O_3 trends



Parrish *et al.*, 2014

What's at stake here?

Attribution is increasingly important as total ozone approaches background levels

What's still needed?

Improved scientific understanding to guide control strategy formulation on ever-larger scales

local → regional → global

CSD research provides scientific information and analyses needed to:

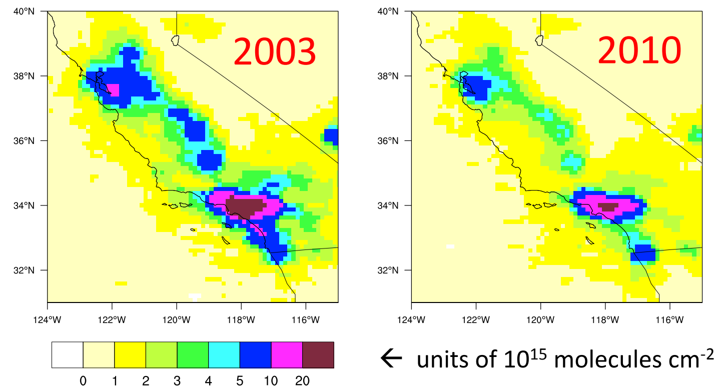
- Quantify background O_3 levels and trends across the U.S. (*Cooper, 3-1*)
- Diagnose and improve chemistry-climate model O_3 simulations (*Parrish, 3-2*)
- Apportion U.S. background O_3 to specific sources (*Langford, 5-2)*

Topic 2. Air quality trends from space

Motivation: Spaceborne data provide an unparalled spatial and temporal "vantage point"

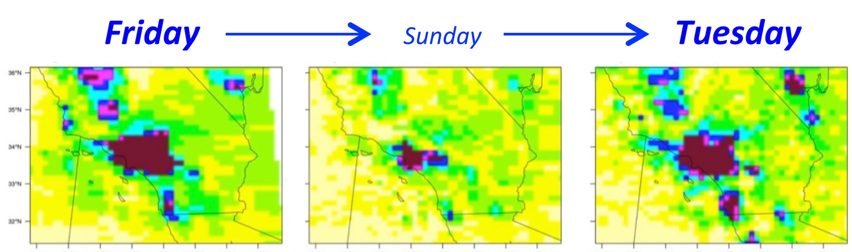
Long-term trends in NO_2: effects of tailpipe emissions controls

Data from the SCanning Imaging Absorption … (SCIAMACHY)
Kim et al., in preparation, 2015



Short-term changes in NO_2: reduced truck traffic on weekends

Data from the Ozone Monitoring Instrument (OMI)
Kim et al., 2009



Los Angeles, CA: 1, 3, and 5 July 2005

- CSD has **validated satellite retrievals** using chemical models constrained by our field observations.
- CSD developed a method to **improve emission inventories** using these results for better air quality forecasts.
- CSD synthesizes satellite retrievals, in situ data, and 3-D modeling to quantify AQ trends

(More detail: Si-Wan Kim, 3-3)

Stakeholders:

TX Commission on Environmental Quality
California Air Resources Board
U.S. EPA and NASA
The European Space Agency

Topic 3. Atmospheric particles and air quality

NOAA | CIRES

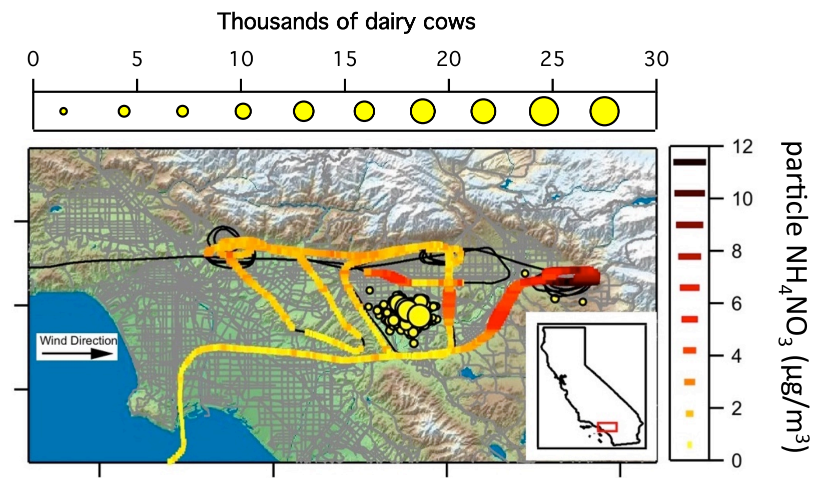
Motivation: Detailed, location-specific information on atmospheric particles (“aerosols”) is vital for policymakers to design effective control strategies

variety of aerosols → variety of sources → variety of AQ management options

CSD aerosol AQ work includes source and process characterization of:

- N_2O_5 uptake and chlorine activation *(Wagner et al., JGR, 2013)*
- Gas-to-particle conversion *(Nowak et al., GRL, 2012)*
- Black carbon soot aerosols *(Perring et al., GRL, 2011)*
- “Brown” carbon composition *(Washenfelder et al., GRL, 2014)*
- Secondary organic aerosols *(Middlebrook et al., PNAS, 2012)*

More detail: Joost de Gouw, 3-4



gas + *gas* ↔ ***particle***

$$NH_3 + HNO_3 \leftrightarrow NH_4NO_3$$

CSD measurements of all three species showed that dairy NH_3 emissions are a major contributor to the Los Angeles haze

Numerous stakeholders, e.g.:

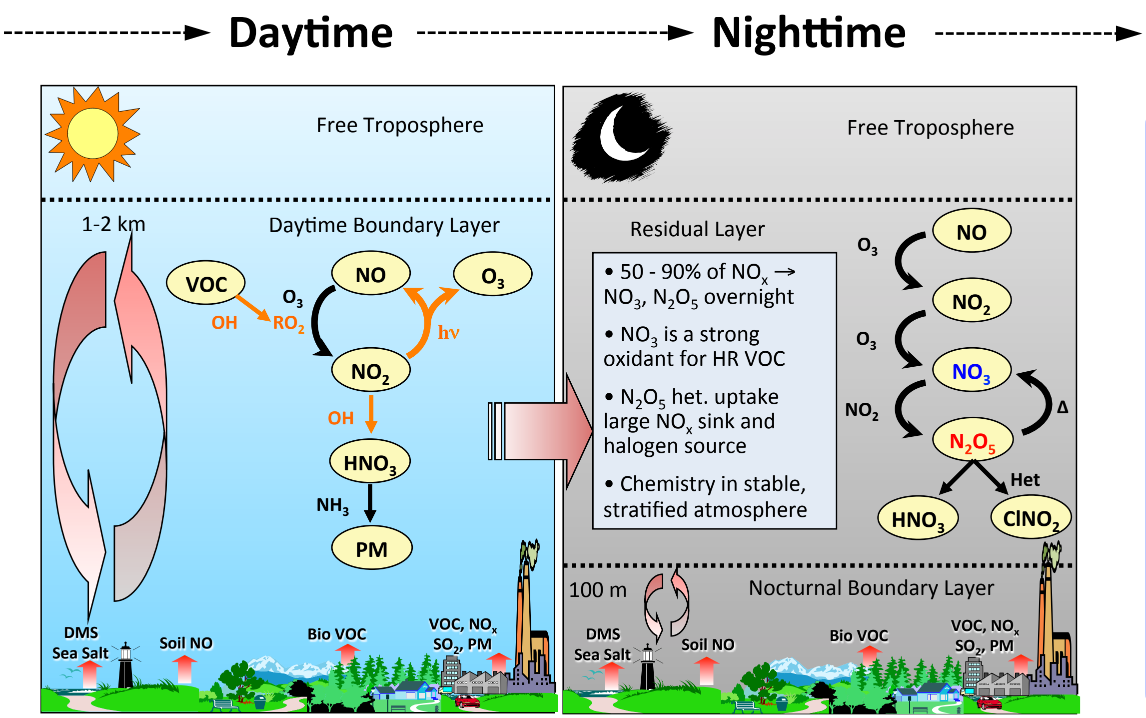
EPA United States Environmental Protection Agency

California Air and Resources Board

Texas Commission on Environmental Quality

Topic 4. Nighttime chemistry impacts

Motivation: Nighttime chemistry influences secondary aerosol formation and ozone on regional and global scales, yet there are few data with which to constrain air quality models



CSD research after dark has:

- Provided unique airborne studies quantifying nighttime residual layer chemical processing by NO_3
- Quantified nighttime rates of N_2O_5 uptake to aerosol
- Discovered key chlorine activation processes mediated by N_2O_5
- Assessed nighttime oxidation of natural and anthropogenic volatile organic compounds (VOCs)

More detail: Steve Brown, 3-5

Stakeholders: U.S. EPA regulatory air quality model teams, NOAA 3D air quality modelers, other NOAA laboratories, Federal and state government agencies, University research partners

Topic 5. AQ forecast model improvement

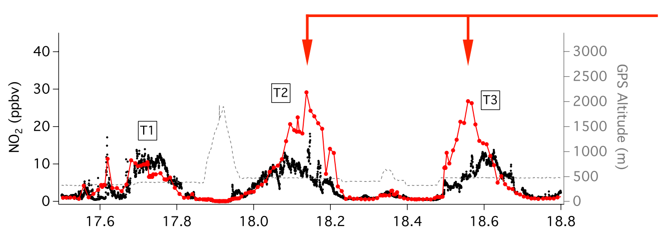
Motivation:
Forecasts challenge the predictive capabilities of 3-D regulatory models to reproduce salient features of the atmospheric chemical and microphysical state → **assessing health impacts of criteria pollutants**

CSD research: Critical evaluation of gridded emissions from EPA National Emissions Inventories (NEIs) as forecast model input

NEI + 3D model → compare to observations

Impacts: identified multiple major errors in source sector apportionment in the NEIs, sufficient to confound regulatory strategies based on emissions reductions

obs. in **black** NEI & WRF-Chem in **red**



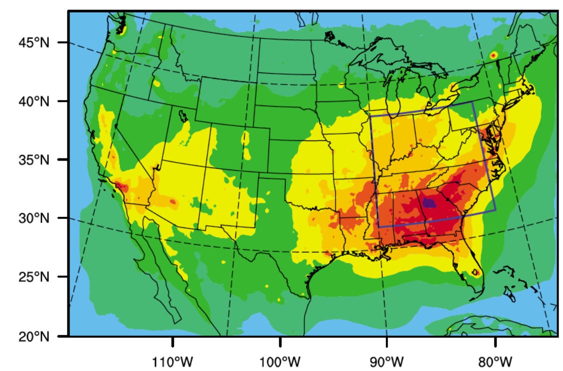
Houston ship emissions overestimated by the NEI

Kim et al., *ACP* (2011)

CSD research: Included a *volatility basis set (VBS) formulation* for secondary organic aerosol in the Weather Research and Forecasting with Chemistry (WRF-Chem) model *(*Ahmadov *et al., 2012)*

Impacts: significant improvement of SOA predictions

Research to applications: the Ahmadov *et al.* VBS formulation is now standard in WRF–Chem



VBS improves SOA prediction fidelity in WRF-Chem (*Ahmadov et al., 2012*)

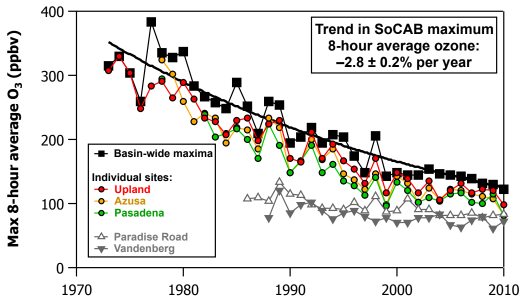
Stakeholders:
NOAA National Weather Service and NESDIS
U.S. Air Force, U.S Forest Service, and U.S. Dept. of Energy
University collaborators
Worldwide WRF-Chem modeling community

More detail: Stu McKeen 3-6
Ravan Ahmadov 4-5

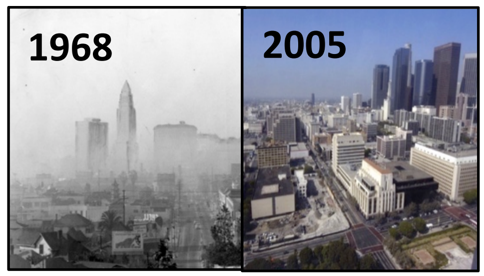
Air quality research is still critically necessary

Decades of emissions controls have improved U.S. urban and rural air quality …

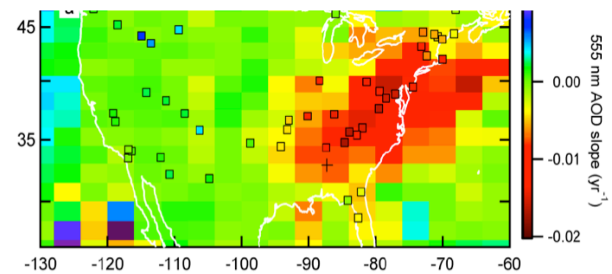
Decreases in urban O_3



Decreases in urban haze

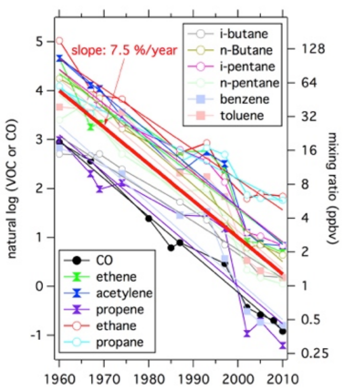


Decreases in sulfate aerosol

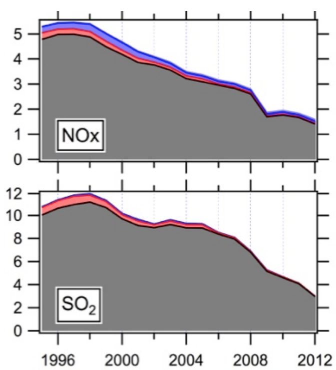


… as emissions and AQ standards evolve, additional timely information will be needed

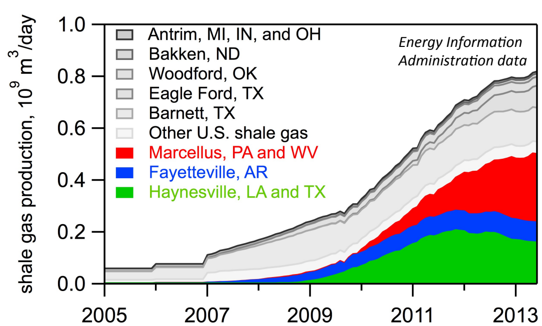
CSD research results



urban CO and VOCs
Warneke *et al.*, 2012



power plant NO_x and SO_2
de Gouw *et al.*, 2014



natural gas CH_4 and VOCs
Peischl *et al.*, 2015