CLIMATE RESEARCH OVERVIEW

Theme Lead: Dr. Daniel Murphy

StoryMaps under this theme
→ 2.3 Greenhouse Gases and Short-Lived Climate Forcers
→ 2.2 Aerosols and Their Role in Climate
→ 2.1 Aerosol–Cloud Interactions
Introduction

NOAA: Understand and predict changes in climate, weather, oceans, and coasts

OAR: Detect changes in the ocean and atmosphere

What we do at CSL:

• Modeling of aerosol-cloud interactions
• Climate properties of atmospheric aerosol
• Emission sources, budgets, and trends for greenhouse gases
• Laboratory measurements for ozone depleting substances
My diagram of science at a NOAA lab

relevant science

critical mass of expertise

sustained effort

Theory and Modeling

Laboratory Investigations

Field Studies

1998 2015

OZONE LAYER

AIR QUALITY

CLIMATE CHANGE

NOAA CSL Science Review, 23-25 February 2021
Outline

- Not a summary of everything in the StoryMaps
- Use a few of the StoryMap highlights as illustrations
- Case study of large eddy simulations
- Case study of dust
- Case study of aerosol optical properties
Assessment of methane emissions from the U.S. oil and gas supply chain


Cite as: R. A. Alvarez et al., Science 10.1126/science.aar7204 (2018).

Methane:

Multiple field missions over ~ 10 years
• Major US production regions
• Rice-growing regions
• Urban area
• Major leak

Sustained efforts: Greenhouse gases

CSL makes sustained commitments to understand greenhouse gases.
Sustained efforts: Greenhouse gases

Ozone:

Ten-year effort
CSL co-chair
CSL lead authors on major papers
Foundational measurements: Light-absorbing carbon

Light absorption due to black carbon is an essential climate forcing measurement

CSL developed a photoacoustic instrument
- a fundamental technique
- our design is used at several other labs
- and we developed automated calibrations

CSL led an in-flight comparison to a GML instrument

CSL is also a leader in developing and deploying SP2 black carbon

An intercomparison of aerosol absorption measurements conducted during the SEAC²RS campaign

B. Mason\textsuperscript{a,b,}, N. L. Wagner\textsuperscript{ab,}, G. Adler\textsuperscript{a,b,}, E. Andrews\textsuperscript{a,b,}, C. A. Brock\textsuperscript{a,}, T. D. Gordon\textsuperscript{h,xx,},
D. A. Lack\textsuperscript{a,b,}, A. E. Perring\textsuperscript{h,+++}, M. S. Richardson\textsuperscript{a,b,}, J. P. Schwarz\textsuperscript{a,b,}, M. A. Shook\textsuperscript{a,},
K. L. Thornhill\textsuperscript{a,}, L. D. Ziemba\textsuperscript{a,}, and D. M. Murphy\textsuperscript{a,}

CSL measures fundamental climate parameters.
Foundational measurements: Light-absorbing carbon

Light absorption due to black carbon is an essential climate forcing measurement

CSL developed a photoacoustic instrument
- a fundamental technique
- our design is used at several other labs
- and we developed automated calibrations

Met Office/University of Exeter improved our design. We implemented their improvements.

CSL measures fundamental climate parameters.
Cloud formation is influenced by the availability of cloud nuclei (CCN)

No commercial instruments measure the relevant size range (≈ 60 nm) with sufficient time response and sensitivity for aircraft measurements.

Multiple processes contribute to new particle formation.

Atmospheric dynamics modulate the growth to CCN.

“Working here I can walk down the hall and talk to an expert on everything I need.”

CSL has the expertise to tackle complex problems.
Climate-relevant focus: Large eddy simulations

Extended StoryMap 2.1.4

What is the impact of anthropogenic aerosol on low-level clouds?

In last 5 years:
- Improved microphysics
- Dynamical buffering
- Feedbacks via winds and sea-salt aerosol
- Metastable states for the cloud field
- Lessons for large-scale models
- Statistically representative aerosols and meteorology

A long-term study of aerosol–cloud interactions and their radiative effect at the Southern Great Plains using ground-based measurements

Elisa T. Sena1,2, Allison McComiskey3, and Graham Feingold2

2016

CSL aerosol-cloud research addresses major problems.

[Graph showing correlation coefficients with aerosol and liquid water path]
Climate-relevant focus: Large eddy simulations

**What is the impact of anthropogenic aerosol on low-level clouds?**

Going beyond case studies and scenarios:

- *many* LES simulations
- build an emulator to map those simulations to real-world situations
- one conclusion: short-term perturbations like ship tracks overestimate the impact of extended forcings

---

**Aerosol-cloud-climate cooling overestimated by ship-track data**

Franziska Glasmeier1,2,3, Fabian Hoffmann1,4,5, Jill S. Johnson1, Takahide Fujita6, Ken S. Carslaw5, Graham Feingold1

---

NOAA CSL aerosol-cloud research addresses major problems.
**Case study: Smoke in the upper troposphere**

**Upper troposphere aerosol composition**

Recent CSL work:
- PALMS single particle mass spectrometer
- + optical particle counters
- + custom sampler to improve statistics
- + innovative data analysis

**Widespread biomass burning smoke throughout the remote troposphere**


Froyd et al., 2019

Schill et al., 2020

**Sustained effort at CSL resulted in totally new measurements.**
Case study: Dust in the upper troposphere

**Dust is crucial to the formation of cirrus clouds**

Previously:

>> 100 papers about dust impacts on cirrus
many studies of dust near the surface

Almost no measurements of dust at cirrus altitudes

Here: forward trajectories with a detailed cirrus formation model with/without measured dust.

Model without dust (blue)
Dust often reduces ice number concentration by factors ~100
(brown)
But sometimes there isn’t enough dust (green)

CSL has made unique progress on a difficult and important problem.
Case study: Global aerosol properties

A new global map of aerosol light scattering (Chuck Brock)

- custom 10-channel counter for 3 to 60 nm (CSL)
- two heavily modified commercial optical counters (CSL)
- under-wing probe (U. Vienna)
- refractory black carbon (CSL)
- PALMS composition > 0.14 µm (CSL)
- AMS composition < 0.25 µm (U. Colorado)

Builds on decades of expertise

CSL makes basic but crucial measurements requiring multiple techniques.
Case study: Global aerosol properties

Checks on the aerosol properties:

- Check dry extinction against a precise and accurate cavity ring-down instrument (SOAP)
  - a custom instrument developed at CSL

- Check phase function against an independent imaging nephelometer
  - completely redesigned and rebuilt at CSL

We have confidence in these measurements.
It is hard to overstate the importance for satellite measurements

It isn’t just validation...

VIIRS and other instruments measure sunlight scattered at specific angles.

Models carry aerosol mass in modes or bins

You can’t compare models to satellite data without the type of information we are collecting.

CSL measurements enhance satellite data.
Future directions

• Continued incorporation of lessons from small-scale cloud models into larger problems
• Climate properties of the background and volcanic atmospheric aerosol
• Collaboration with NASA on regular aerosol measurements
• Continued budgets for greenhouse gases
• National resource for properties underlying global warming potentials