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

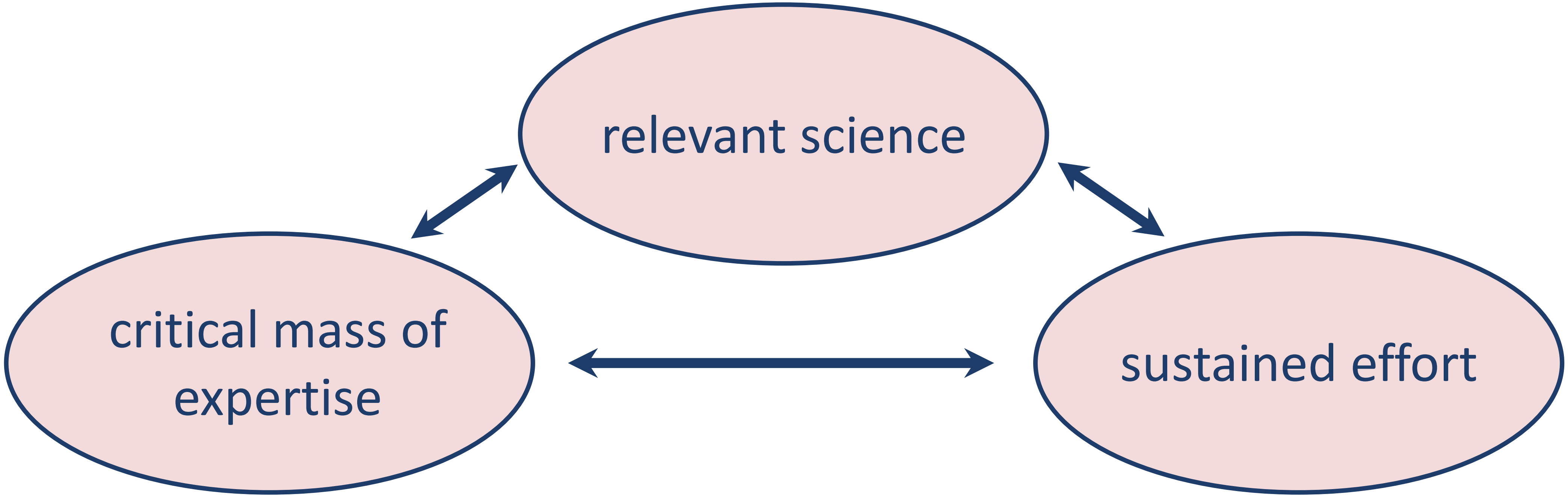
NOAA: Understand and predict changes in climate, weather, oceans, and coasts

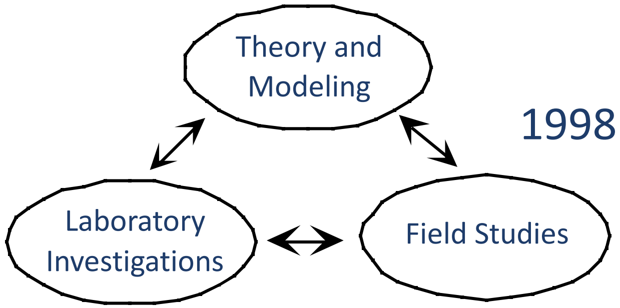
OAR: Detect changes in the ocean and atmosphere

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

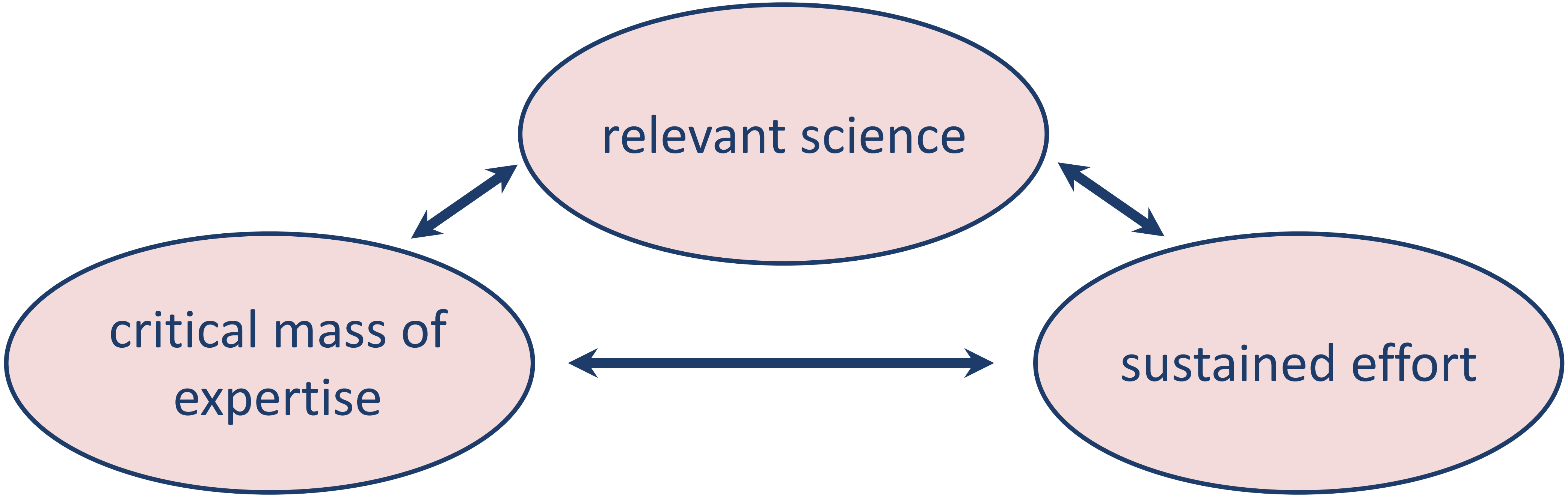




1998

2015

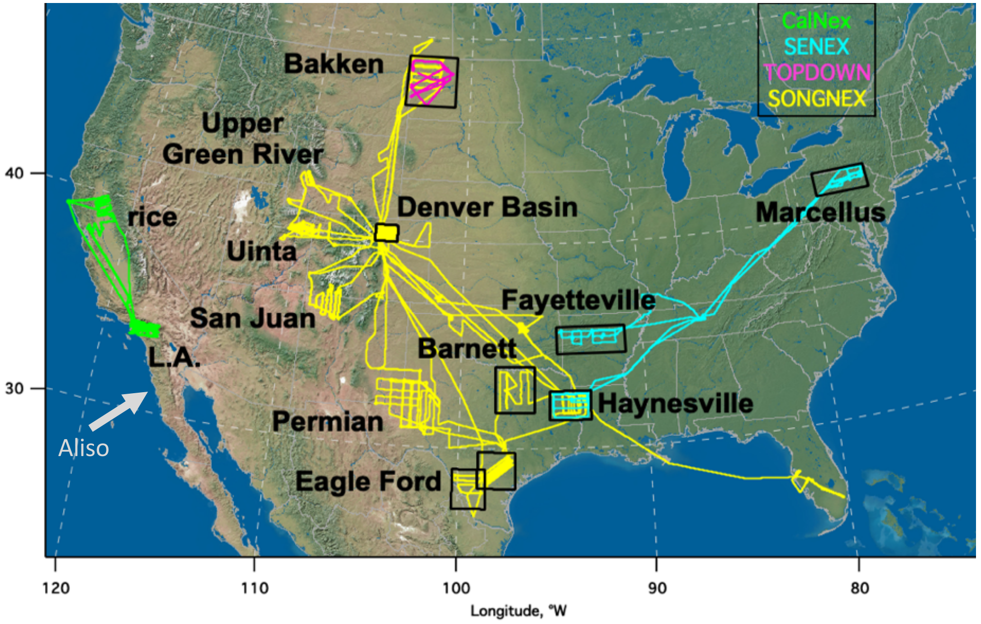
Outline



- 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

Sustained efforts: Greenhouse gases

StoryMaps 2.3.2 and 2.3.3



Science REPORTS

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

Assessment of methane emissions from the U.S. oil and gas supply chain

Ramón A. Alvarez[1*], Daniel Zavala-Araiza[1], David R. Lyon[1], David T. Allen[2], Zachary R. Barkley[3], Adam R. Brandt[4], Kenneth J. Davis[3], Scott C. Herndon[5], Daniel J. Jacob[6], Anna Karion[7], Eric A. Kort[8], Brian K. Lamb[9], Thomas Lauvaux[3], Joannes D. Maasakkers[6], Anthony J. Marchese[10], Mark Omara[1], Stephen W. Pacala[11], Jeff Peischl[12,13], Allen L. Robinson[14], Paul B. Shepson[15], Colm Sweeney[13], Amy Townsend-Small[16], Steven C. Wofsy[6], Steven P. Hamburg[1]

Methane:

Multiple field missions over ~ 10 years

- Major US production regions
- Rice-growing regions
- Urban area
- Major leak

CSL makes sustained commitments to understand greenhouse gases.

Sustained efforts: Greenhouse gases

StoryMaps 2.3.2 and 2.3.3

TOAR FAQ

TOAR Main Page

TOAR Phase - I (2014-2019) Completed

TOAR Phase - II (2020-2024) In Progress

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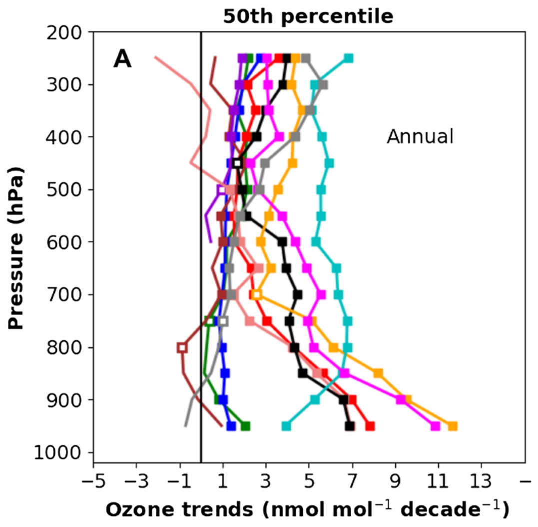
Dr. Martin G. Schultz
Forschungszentrum Jülich
Germany

TOAR
tropospheric ozone assessment report



Ozone:

Ten-year effort
CSL co-chair
CSL lead authors on major papers

ELEMENTA Science of the Anthropocene

Gaudel, A, et al. 2018. Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation. *Elem Sci Anth,* 6: 39. DOI: https://doi.org/10.1525/elementa.291

RESEARCH ARTICLE

Tropospheric Ozone Assessment Report: Present-day distribution and trends of tropospheric ozone relevant to climate and global atmospheric chemistry model evaluation

A. Gaudel[1,2], O. R. Cooper[1,2], G. Ancellet[3], B. Barret[4], A. Boynard[3,5], J. P. Burrows[6], C. Clerbaux[3], P.-F. Coheur[7], J. Cuesta[8], E. Cuevas[9], S. Doniki[7], G. Dufour[8], F. Ebojie[10], G. Foret[8], O. Garcia[11], M. J. Granados-Muñoz[12,13], J. W. Hannigan[14], F. Hase[15], B. Hassler[1,2,16], G. Huang[17], D. Hurtmans[7], D. Jaffe[18,19], N. Jones[20], P. Kalabokas[21], B. Kerridge[22], S. Kulawik[23,24], B. Latter[22], T. Leblanc[12], E. Le Flochmoën[4], W. Lin[25], J. Liu[26,27], X. Liu[17], E. Mahieu[27], A. McClure-Begley[1,2], J. L. Neu[23], M. Osman[29], M. Palm[6], H. Petetin[4], I. Petropavlovskikh[1,2], R. Querel[30], N. Rahpoe[23], A. Rozanov[23], M. G. Schultz[31,32], J. Schwab[33], R. Siddans[22], D. Smale[30], M. Steinbacher[34], H. Tanimoto[35], D. W. Tarasick[36], V. Thouret[4], A. M. Thompson[37], T. Trickl[38], E. Weatherhead[1,2], C. Wespes[7], H. M. Worden[39], C. Vigouroux[40], X. Xu[41], G. Zeng[43], J. Ziemke[42]

SCIENCE ADVANCES | RESEARCH ARTICLE

CLIMATOLOGY

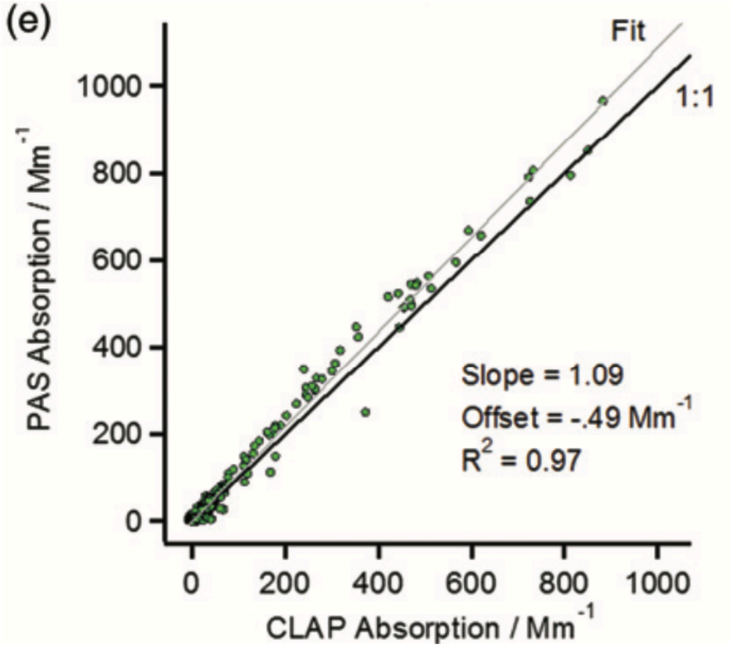
Aircraft observations since the 1990s reveal increases of tropospheric ozone at multiple locations across the Northern Hemisphere

Audrey Gaudel[1]*, Owen R. Cooper[1], Kai-Lan Chang[1], Ilann Bourgeois[1], Jerry R. Ziemke[2,3], Sarah A. Strode[2,4], Luke D. Oman[2], Pasquale Sellitto[5], Philippe Nédélec[6], Romain Blot[6], Valérie Thouret[6], Claire Granier[1,6]

CSL makes sustained commitments to understand greenhouse gases.

Foundational measurements: Light-absorbing carbon

StoryMap 2.3.4



AEROSOL SCIENCE AND TECHNOLOGY
2018, VOL. 52, NO. 9, 1012–1027
https://doi.org/10.1080/02786826.2018.1500012

Taylor & Francis
Taylor & Francis Group

Check for updates

An intercomparison of aerosol absorption measurements conducted during the SEAC^{4}RS campaign

B. Mason[a,b,*], N. L. Wagner[a,b], G. Adler[a,b], E. Andrews[a,b], C. A. Brock[a], T. D. Gordon[a,b,**], D. A. Lack[a,b], A. E. Perring[a,b,***], M. S. Richardson[a,b], J. P. Schwarz[a,b], M. A. Shook[c], K. L. Thornhill[c], L. D. Ziemba[d], and D. M. Murphy[a]

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

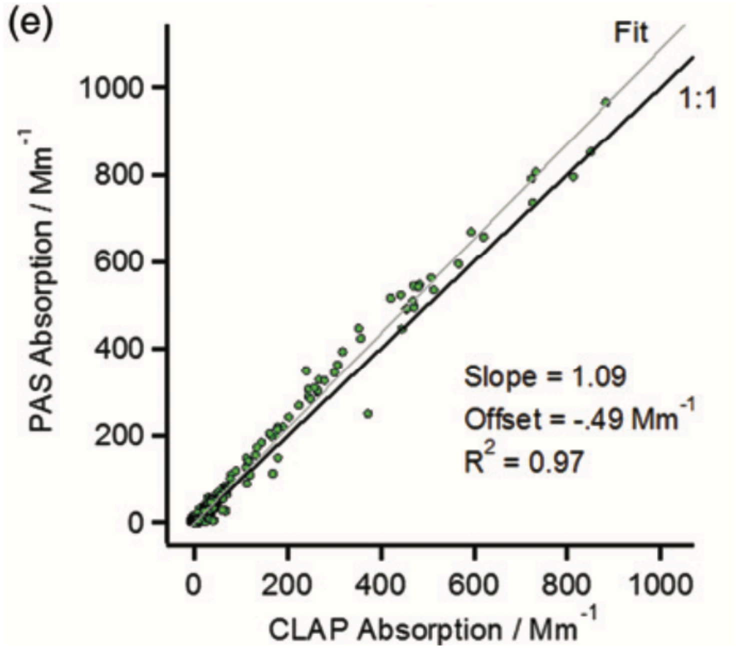
CSL developed a photoacoustic instrument
- a fundamental technique
- our design is used at several other labs
- and we developed automated calibrations

CSL led an in-flight comparison to a GML instrument

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

CSL measures fundamental climate parameters.

Foundational measurements: Light-absorbing carbon



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StoryMap 2.3.4

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

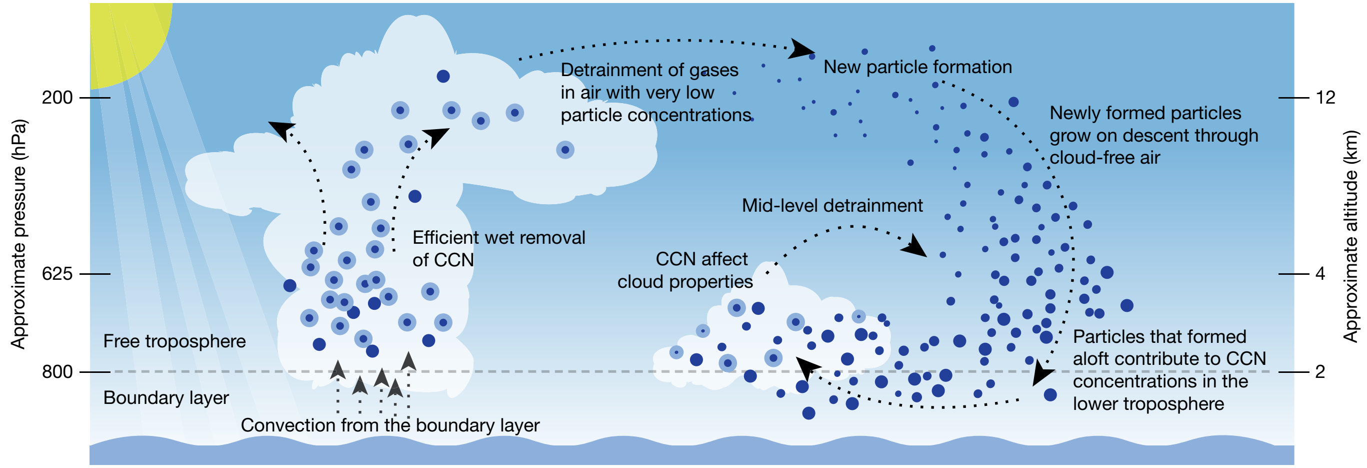
CSL developed a photoacoustic instrument
- a fundamental technique
- our design is used at several other labs
- and we developed automated calibrations

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

CSL measures fundamental climate parameters.

Critical mass of expertise: Tropical cloud nuclei

StoryMap 2.1.1



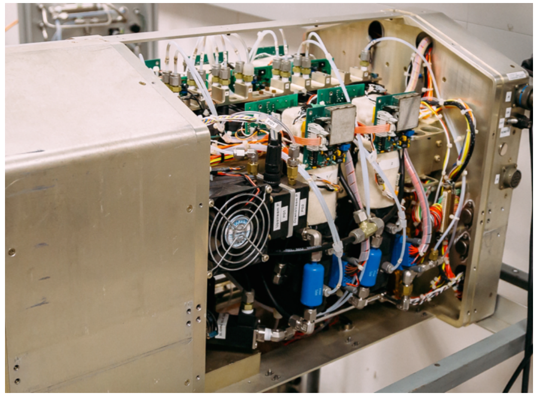
Cloud formation is influenced by the availability of cloud nuclei (CCN)

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."



LETTER 17 OCTOBER 2019 | VOL 574 | NATURE | 399

https://doi.org/10.1038/s41586-019-1638-9

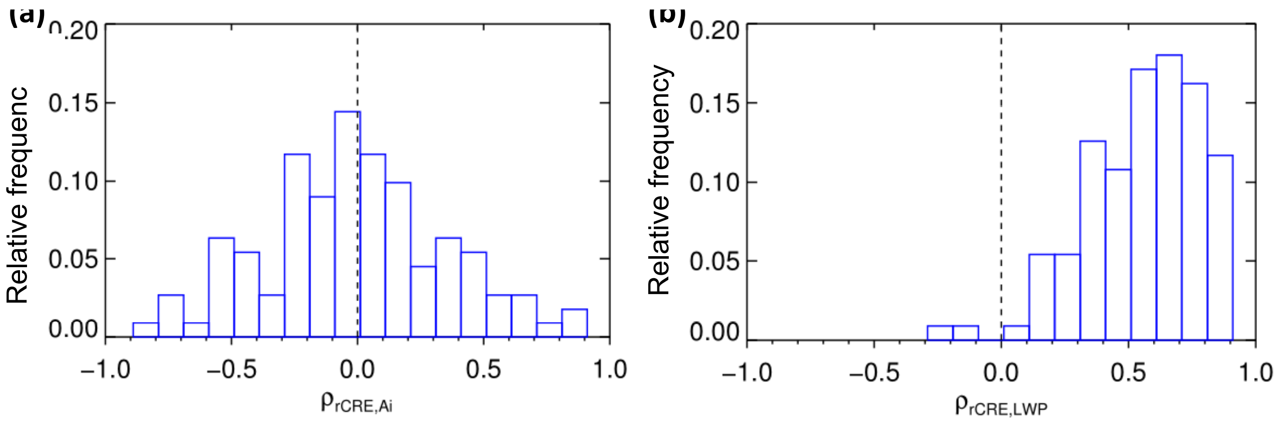
A large source of cloud condensation nuclei from new particle formation in the tropics

Christina J. Williamson[1,2]*, Agnieszka Kupc[2,3], Duncan Axisa[4,9], Kelsey R. Bilsback[5], ThaoPaul Bui[6], Pedro Campuzano-Jost[1,7], Maximilian Dollner[3], Karl D. Froyd[1,2], Anna L. Hodshire[5], Jose L. Jimenez[1,7], John K. Kodros[5,10], Gan Luo[8], Daniel M. Murphy[2], Benjamin A. Nault[1,7], Eric A. Ray[1,2], Bernadett Weinzierl[3], James C. Wilson[4], Fangqun Yu[8], Pengfei Yu[1,2,11], Jeffrey R. Pierce[5] & Charles A. Brock[2]

CSL has the expertise to tackle complex problems.

Climate-relevant focus: Large eddy simulations

Extended StoryMap 2.1.4



to aerosol

to liquid water path

- correlation coefficients: 14 years of data
- influence of meteorology >> aerosol influence

=> must consider susceptible cloud fields

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

Elisa T. Sena[1,2], Allison McComiskey[3], and Graham Feingold[2] 2016

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

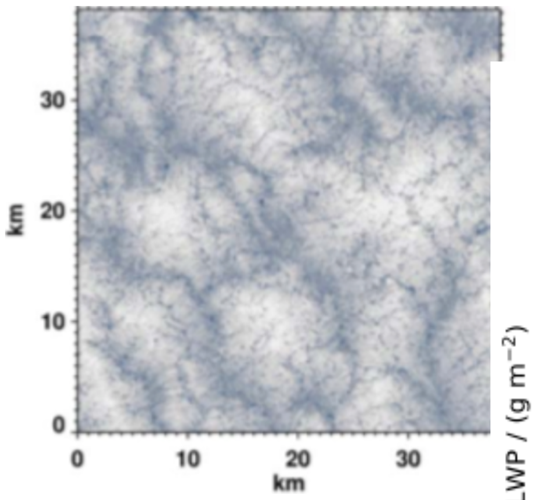
In last 5 years:

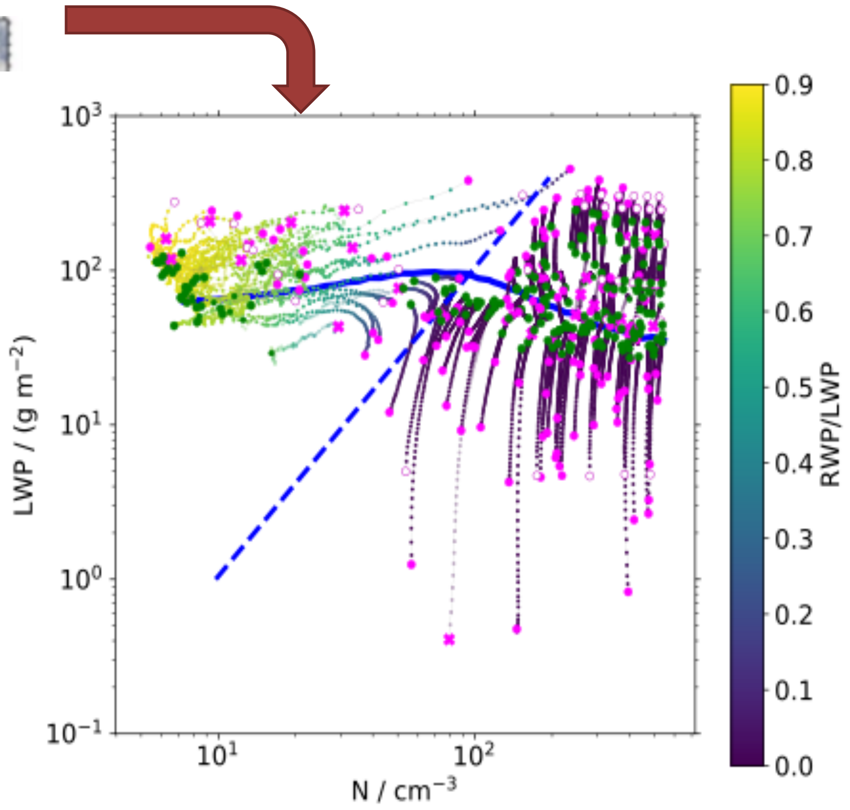
- Improved microphysics
- Dynamical buffering
- Feedbacks via winds and sea-salt aerosol
- Metastable states for the cloud field
- Lessons for large-scale models
- Statistically representative aerosols and meteorology

CSL aerosol-cloud research addresses major problems.

Climate-relevant focus: Large eddy simulations

Extended StoryMap 2.1.4





Science AAAS

RESEARCH ARTICLE

CLIMATE

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

Franziska Glassmeier[1,2,3]*, Fabian Hoffmann[3,4,5], Jill S. Johnson[6], Takanobu Yamaguchi[3,4], Ken S. Carslaw[6], Graham Feingold[4]

2021

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

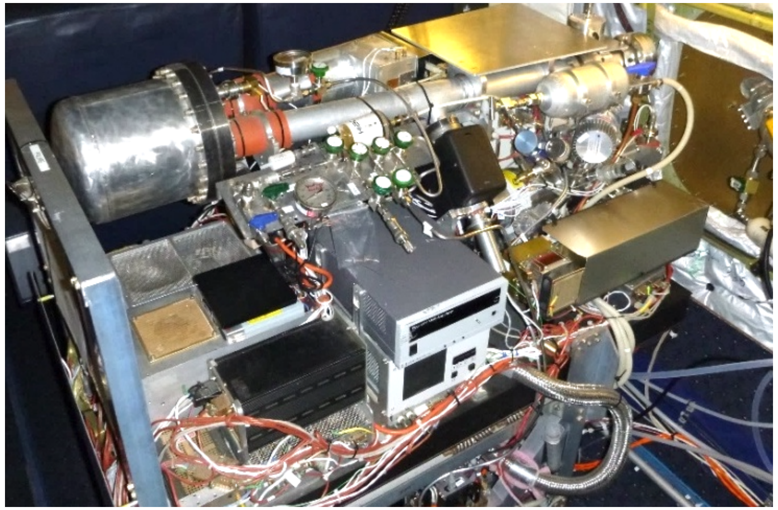
Going beyond case studies and scenarios:

- *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

CSL aerosol-cloud research addresses major problems.

Case study: Smoke in the upper troposphere

StoryMap 2.2.3



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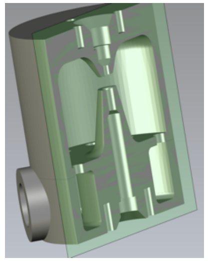


Upper troposphere aerosol composition

Recent CSL work:

PALMS single particle mass spectrometer

\+ optical particle counters

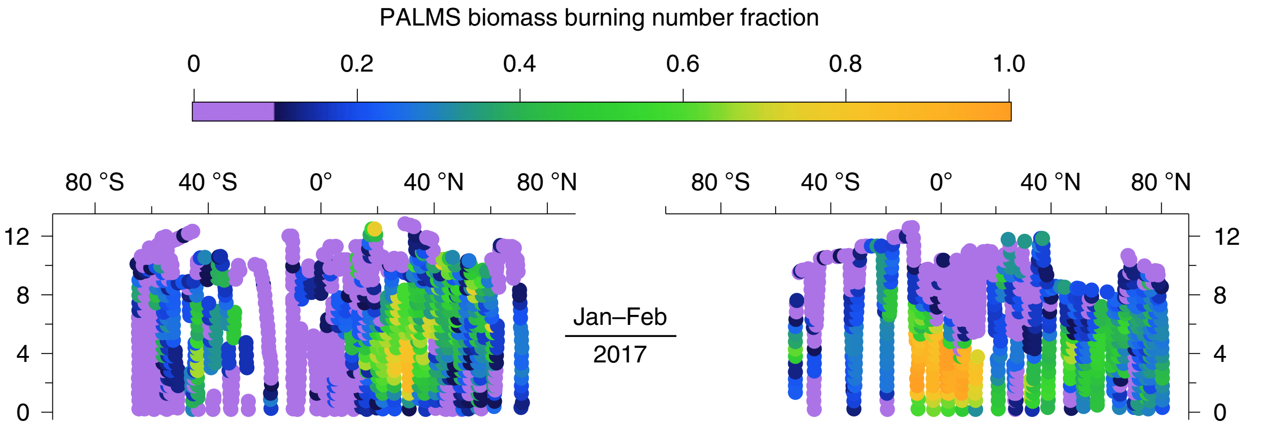
\+ custom sampler to improve statistics

\+ innovative data analysis

ARTICLES
https://doi.org/10.1038/s41561-020-0586-1
nature geoscience
Check for updates

Widespread biomass burning smoke throughout the remote troposphere

G. P. Schill[1,2✉], K. D. Froyd[1,2], H. Bian[3,4], A. Kupc[1,2,5], C. Williamson[1,2], C. A. Brock[1], E. Ray[1,2], R. S. Hornbrook[6], A. J. Hills[6], E. C. Apel[6], M. Chin[4], P. R. Colarco[4] and D. M. Murphy[1]

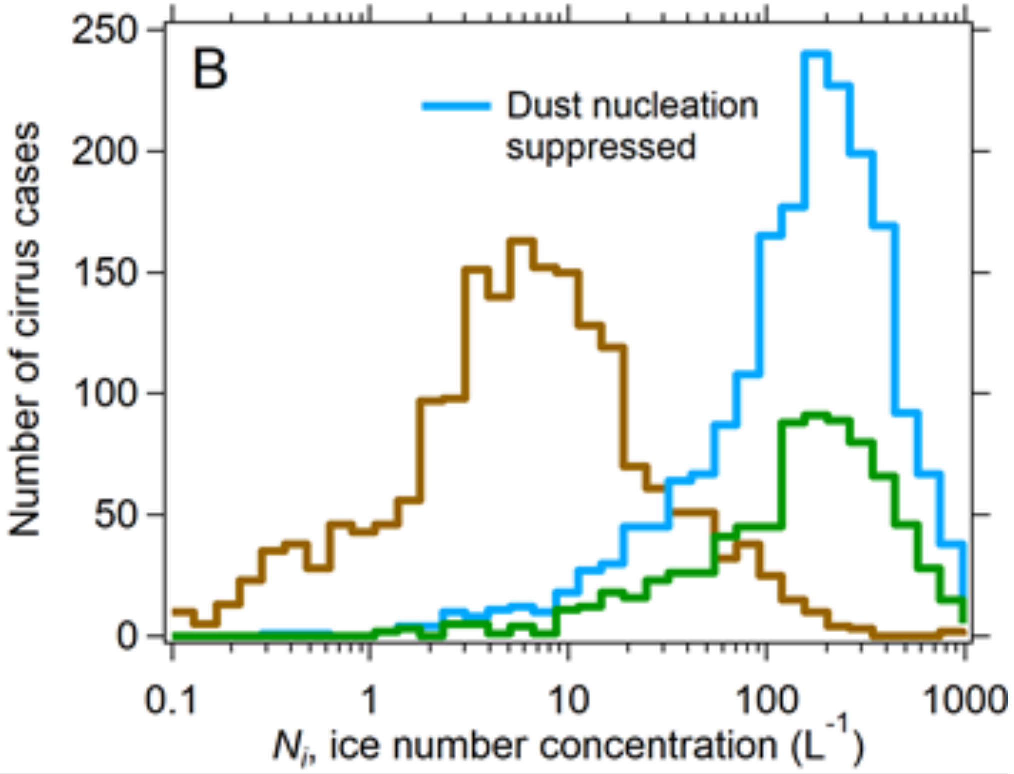


Froyd et al., 2019
Schill et al.. 2020

Sustained effort at CSL resulted in totally new measurements.

Case study: Dust in the upper troposphere

Extended StoryMap 2.2.3



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)

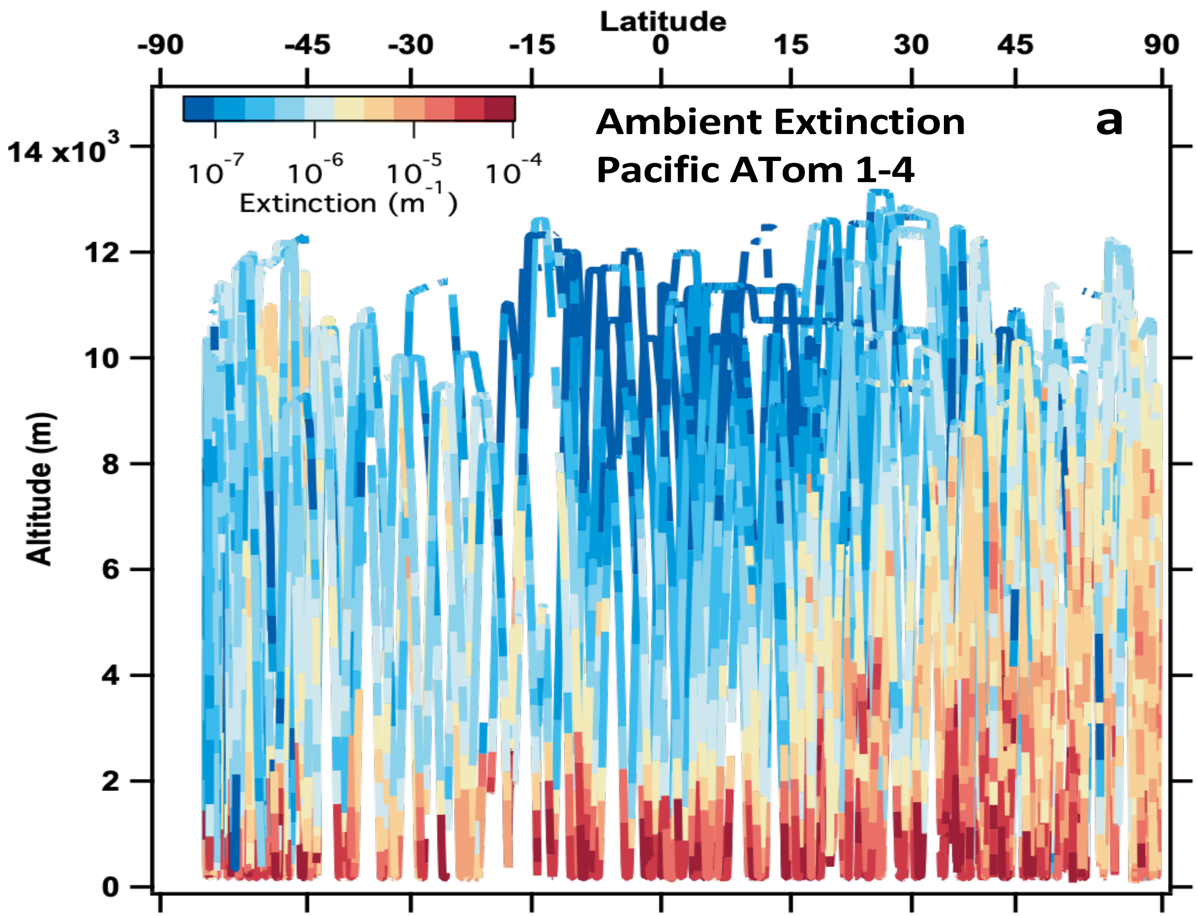
Dust often reduces ice number concentration by factors ~100 (brown)

But sometimes there isn't enough dust (green)

CSL has made unique progress on a difficult and important problem.

Case study: Global aerosol properties

StoryMap 2.2.3



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

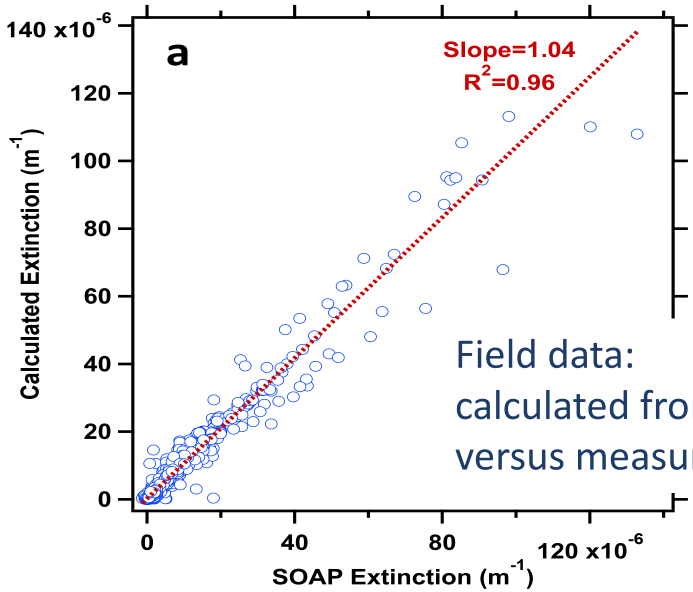
- custom 10-channel counter for 3 to 60 nm (CSL)
- two heavily modified commercial optical counters (CSL)
- under-wing probe (U. Vienna)
- refractory black carbon (CSL)
- PALMS composition > 0.14 µm (CSL)
- AMS composition < 0.25 µm (U. Colorado)

Builds on decades of expertise

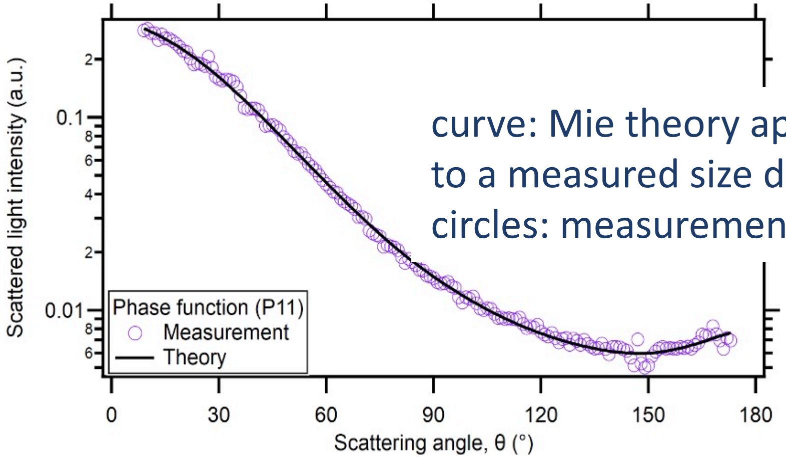
CSL makes basic but crucial measurements requiring multiple techniques.

Case study : Global aerosol properties

StoryMap 2.2.3



Field data:
calculated from size
versus measured



curve: Mie theory applied
to a measured size distribution
circles: measurements

Checks on the aerosol properties:

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

  - a custom instrument developed at CSL

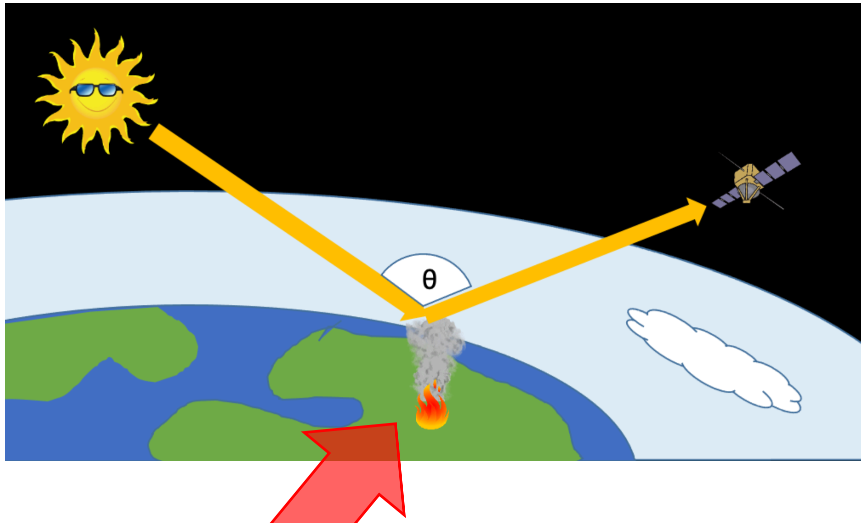
- Check phase function against an independent imaging nephelometer

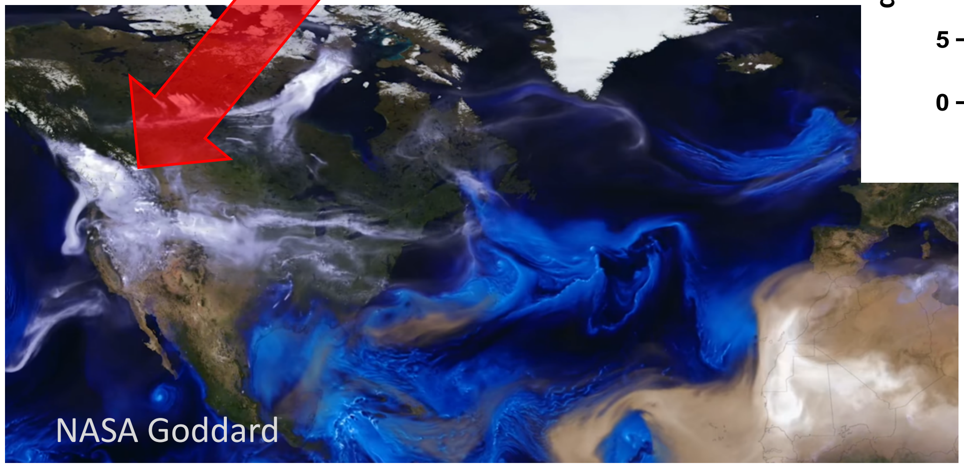
  - completely redesigned and rebuilt at CSL

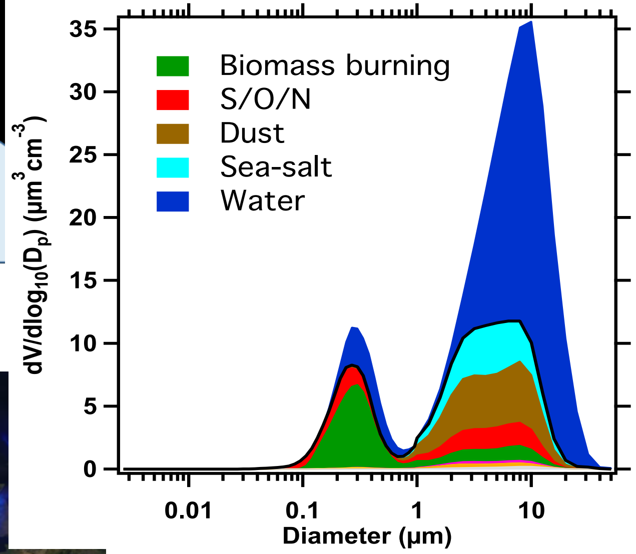
We have confidence in these measurements.

Case study : Global aerosol properties

StoryMap 2.2.3







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