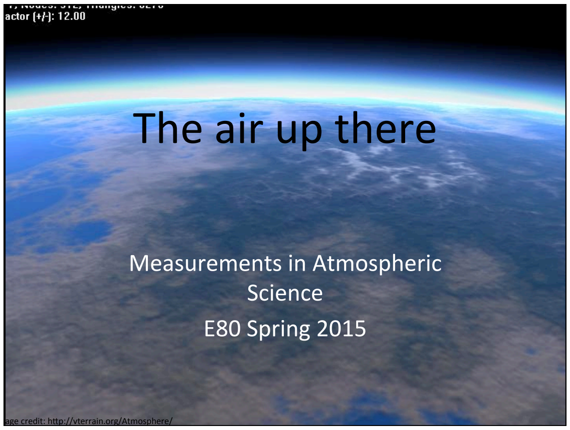


The air up there

Measurements in Atmospheric Science

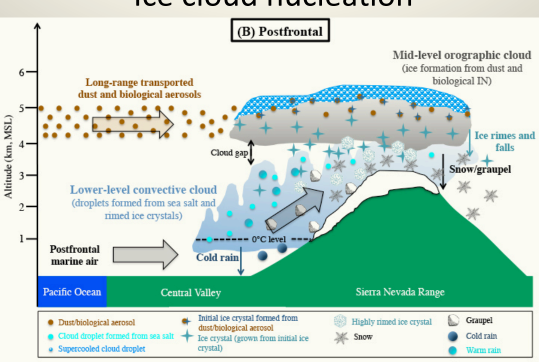
E80 Spring 2015

age credit: http://vterrain.org/Atmosphere/

California's dry winter – need a silver bullet?

Cloud seeding tower at the summit of Alpine Meadows ski area near Lake Tahoe, California. (Lauren Sommer/KQED)

Ice cloud nucleation



Concepts in Atmospheric Science

- Atmospheric science across the disciplines
- Why and how to make atmospheric measurements
- What you might consider for your rocket
- Where did the air come from? HYSPLIT back trajectory models

Atmospheric Science across the disciplines

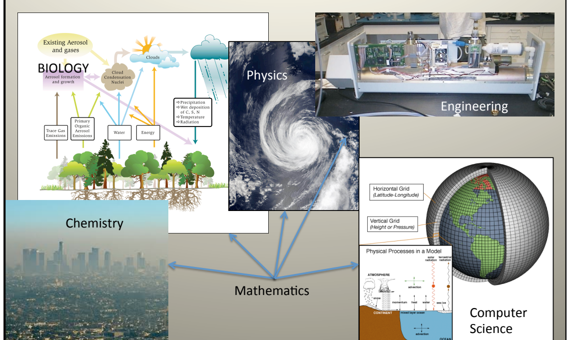
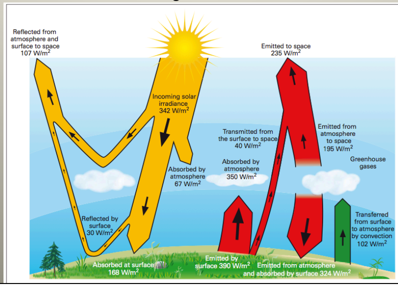


Image credits: atmos.washington.edu, acd.ucar.edu, caice.ucsd.edu, oar.noaa.gov, chemwiki.ucdavis.edu

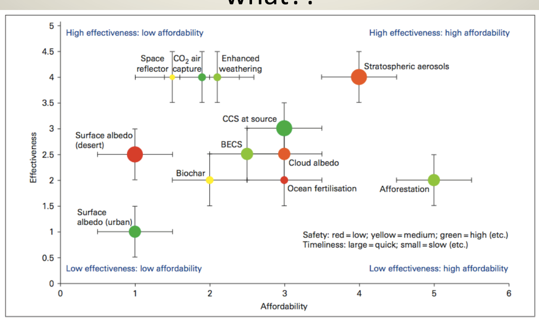
What is geoengineering?

Geoengineering requires understanding atmospheric composition and it's changes

Geoengineering: Intentional, large scale intervention in Earth's climate system designed to counteract climate change



Geoengineering: you want to do what??



Geoengineering the Climate: Science Governance, and Uncertainty (2009), The Royal Society

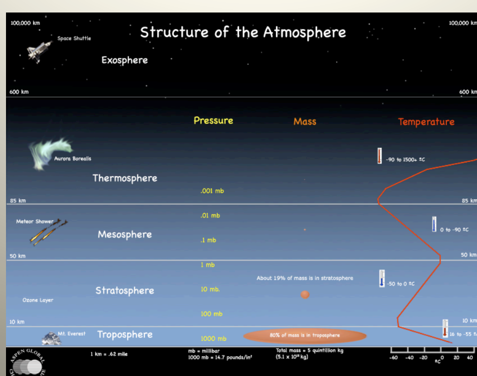
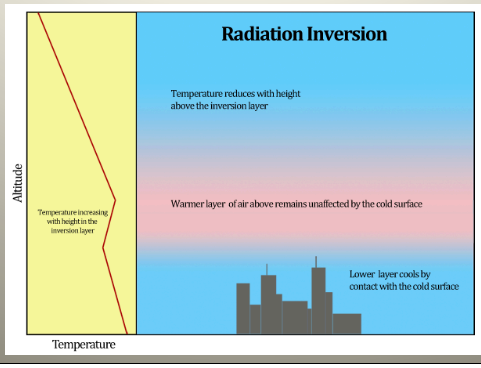


Image credit: agci.org

Inversion layer



What's going on in the troposphere?

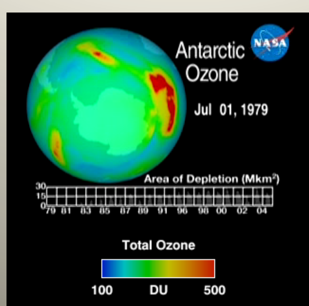
Nearly all

- weather (clouds, rain, tornados, hurricanes, snow)
- anthropogenic (human-caused) pollution
- transport of anthropogenic and natural chemicals (think dust storms, wildfires)
- warfare related emissions (weaponized aerosols)
- molecules relevant to climate change (because most of the mass is here).

What's not?

Visualized

Video Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio



Pay attention to southern hemisphere spring!

Outliers: How NASA "missed" the ozone hole

"Our software had flags for ozone that was lower than 180 DU, a value lower than had ever been reliably reported prior to 1983.

In 1984, *before publication of the Farman paper*, we noticed a sudden increase in 'low value' from October of 1983. [...]

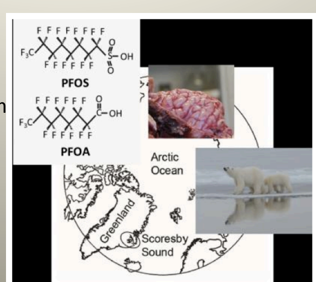
As the first one in print, he gets full credit for discovery of the ozone hole. It makes a great story to talk about how NASA "missed" the ozone hole, but it isn't quite true."

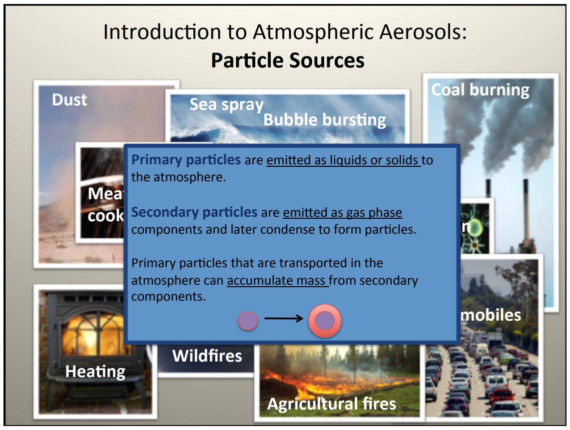
Practical uses for atmospheric measurements

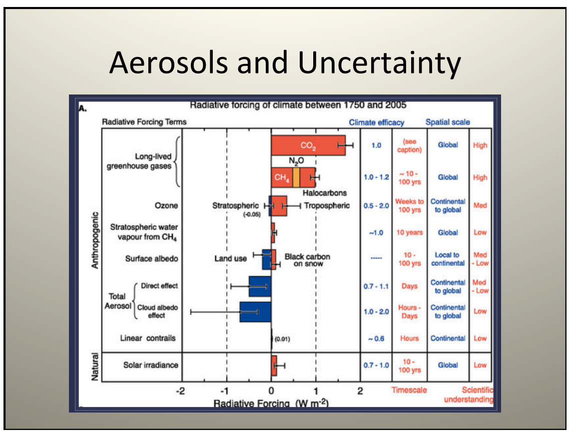
- Air quality control and monitoring (including airborne pathogens)
- Better prediction of tornadoes and hurricanes (improve early warning)
- Changes in patterns (rain, storm tracks) due to changing climate
- Monitoring greenhouse gases and short-lived climate forcers (like soot).
- Cross-border pollution issues

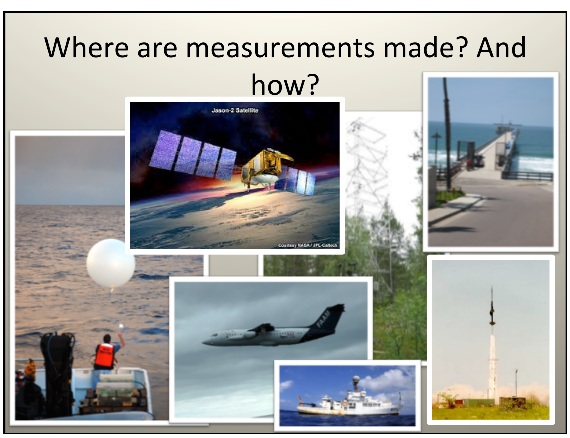
Transforming and transporting carcinogenic pollutants

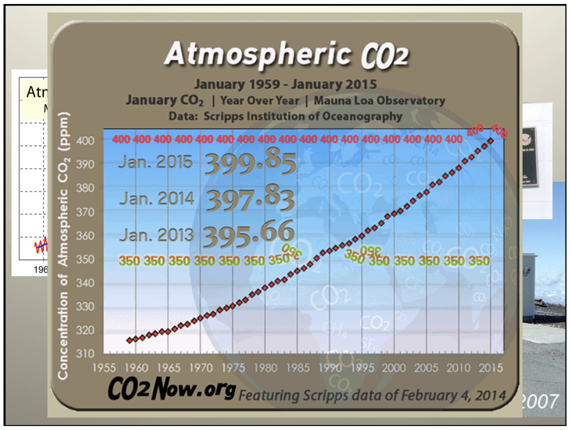
- Organofluorines bioaccumulate
- Precursor comes from chemical manufacturing of Teflon, Scotchguard, and similar products

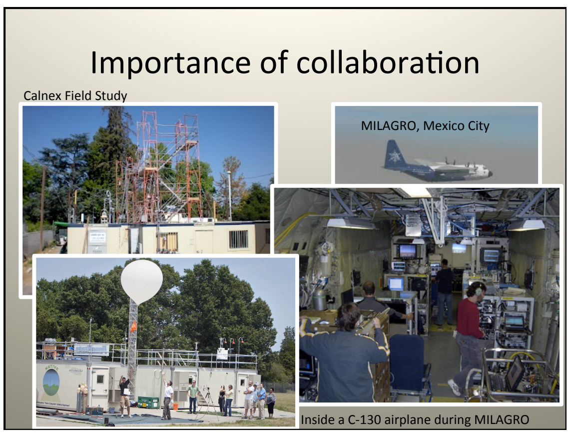


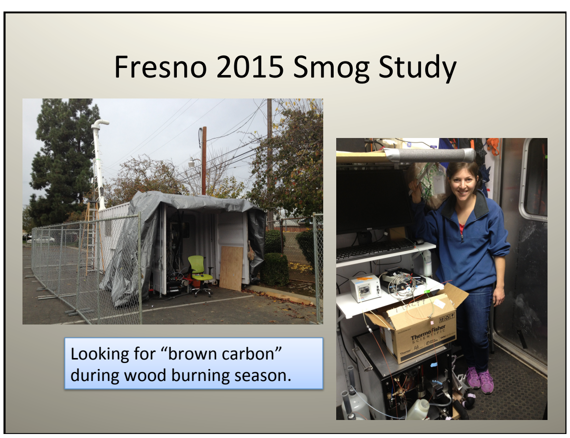

Introduction to Atmospheric Aerosols:
Particle Sources
Dust
Sea spray
Bubble bursting
Coal burning
Primary particles are emitted as liquids or solids to the atmosphere.
Secondary particles are emitted as gas phase components and later condense to form particles.
Primary particles that are transported in the atmosphere can accumulate mass from secondary components.
Heating
Wildfires
Agricultural fires

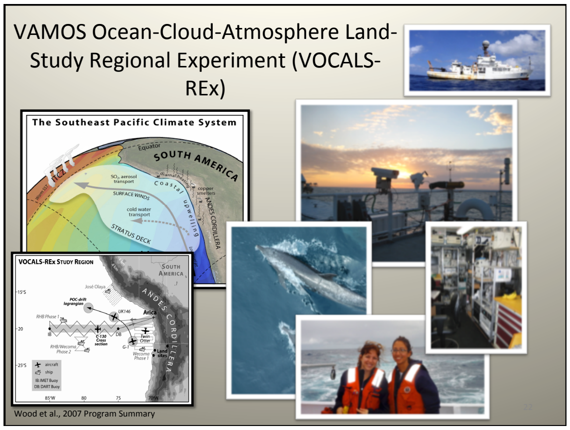

Aerosols and Uncertainty
A.
Radiative forcing of climate between 1750 and 2005
Radiative Forcing Terms
Climate efficacy
Spatial scale
Long-lived greenhouse gases
CO_2
N_2O
CH_4
Halocarbons
Ozone
Stratospheric
(-0.05)
Tropospheric
Stratospheric water vapour from CH_4
Surface albedo
Land use
Black carbon on snow
Total Aerosol
Direct effect
Cloud albedo effect
Linear contrails
(0.01)
Solar irradiance
Anthropogenic
Natural
1.0
1.0 - 1.2
0.5 - 2.0
~1.0
0.7 - 1.1
1.0 - 2.0
~ 0.6
0.7 - 1.0
(see caption)
~ 10 - 100 yrs
Weeks to 100 yrs
10 years
10 - 100 yrs
Days
Hours - Days
Hours
10 - 100 yrs
Global
Global
Continental to global
Global
Local to continental
Continental to global
Continental to global
Continental
Global
High
High
Med
Low
Med - Low
Med - Low
Low
Low
Low
-2
-1
0
1
2
Radiative Forcing (W m^{-2})
Timescale
Scientific understanding

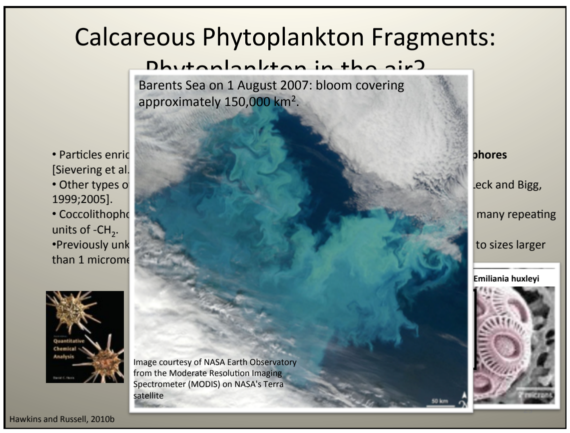

Where are measurements made? And how?
Jason-2 Satellite


Atmospheric CO2
January 1959 - January 2015
January CO2 | Year Over Year | Mauna Loa Observatory
Data: Scripps Institution of Oceanography
Concentration of Atmospheric CO2 (ppm)
Jan. 2015 399.85
Jan. 2014 397.83
Jan. 2013 395.66
CO2Now.org Featuring Scripps data of February 4, 2014


Importance of collaboration
Calnex Field Study
MILAGRO, Mexico City
Inside a C-130 airplane during MILAGRO

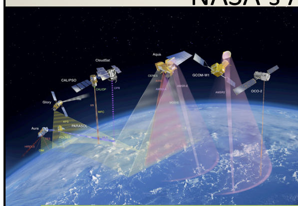

Fresno 2015 Smog Study
Looking for "brown carbon" during wood burning season.


VAMOS Ocean-Cloud-Atmosphere Land-Study Regional Experiment (VOCALS-REx)
The Southeast Pacific Climate System
SOUTH AMERICA
VOCALS-REx STUDY REGION
Wood et al., 2007 Program Summary


Calcareous Phytoplankton Fragments:
Phytoplankton in the air?
Barents Sea on 1 August 2007: bloom covering approximately 150,000 km².
• Particles enric
[Sievering et al.
• Other types o
1999;2005].
• Coccolithopho
units of -CH2.
•Previously unk
than 1 microme
phores
Leck and Bigg,
many repeating
to sizes larger
Emiliania huxleyi
Quantitative Chemical Analysis
Image courtesy of NASA Earth Observatory from the Moderate Resolution Imaging Spectrometer (MODIS) on NASA's Terra satellite
Hawkins and Russell, 2010b


MAGIC: Using cargo ships for atmospheric research
MAGIC takes place on the Horizon Lines Cargo container Spirit.
HORIZON
It all happens here.
Gathering cloud data from Long Beach to Hawaii, marine stratocumulus to tropical cumulus.

Satellite measurements: NASA's A-Train

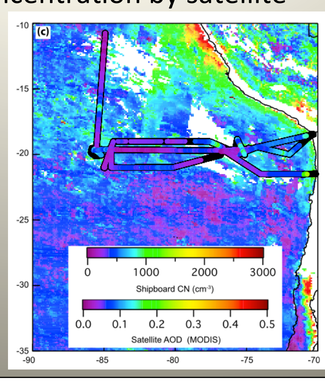


- Crosses the equator around 1:30 pm daily.
- Measures water vapor, temperature, rainfall, clouds, aerosols, greenhouse gases and more.

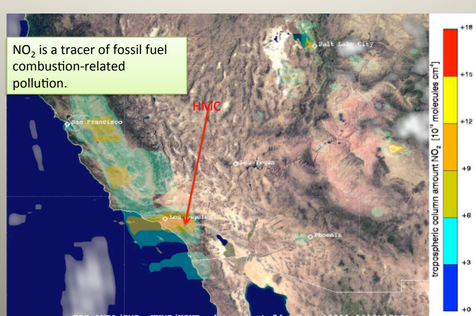
Questions only satellites can answer
What is the overall affect of aerosols and clouds on climate?
How much carbon is absorbed by forests?
How will the monsoon cycle react to a warming world?
To what extent will a changing climate change the size and strength of hurricanes?
And what feedback cycles will encourage or discourage climate change?

Particle concentration by satellite

- AOD is aerosol optical depth
- Parameterized by ground measurements
- Clouds interfere



What can satellite spectrophotometry do?



Role of NO_x in photochemical smog

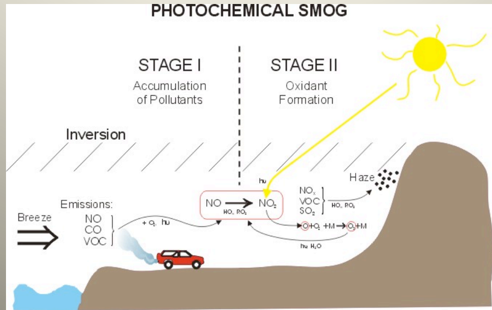
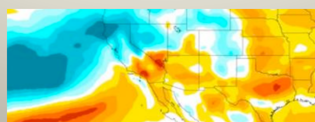


Image credit: www.ems.psu.edu

A great place to know about: NCAR

- [Models]



- [Measurements]
- [Black carbon and sea ice]

What might rockets add?

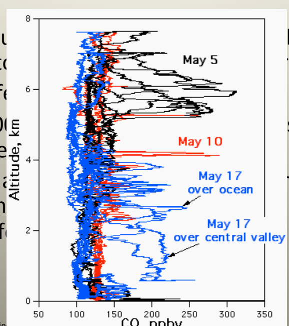
- Climate model “ground-truthing”
- Repeatable, local measurements
- Very high altitude studies (not yours), most useful above altitude for balloons (40 km) and below satellites (recall collaboration!).
- Lower cost than a fully instrumented aircraft
- Can be launched from remote locations (ships etc).
- Vertical profiles help meteorologists understand weather
- Complement ground-based measurements
- Can be launched at short notice of phenomena

What you might find interesting to measure by rocket

- Temperature, pressure, light intensity, relative humidity, and average wind speed.
- Trace gas (e.g. CO) concentration and particulate concentration.
- CO_2, which should be elevated below the inversion layer

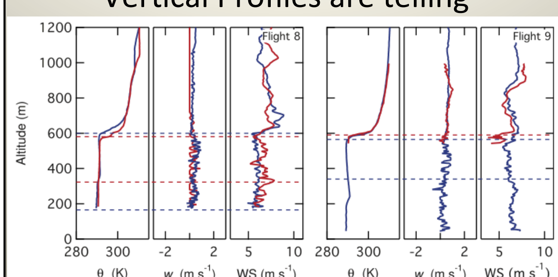
What's cool about CO?

- Major sou… bustion) and photo… pollutants
- 60 day life…
- About 10… sources (compare…
- It makes … ic activity (people n… to CO to account f…



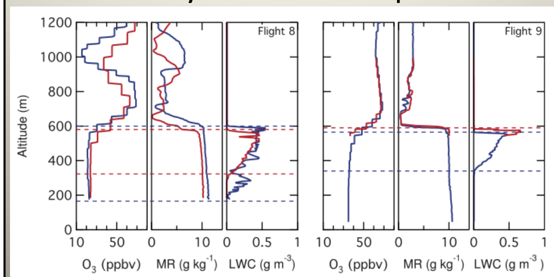
http://www.esrl.noaa.gov/csd/proje

Vertical Profiles are telling



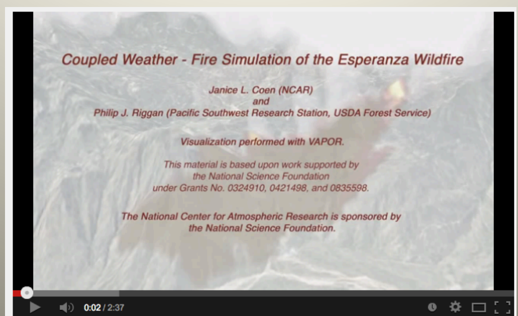
Potential temperature, vertical velocity, and wind speed

Cloud layers in vertical profiles

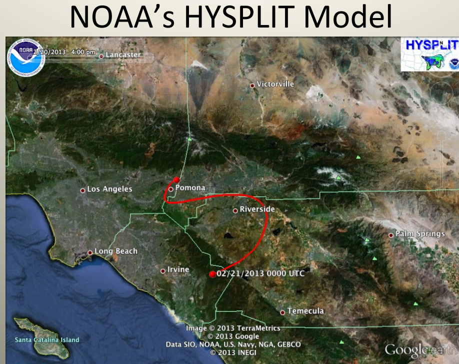


Ozone, water vapor mixing ratio, and liquid water content

Coupling rockets with models



NOAA's HYSPLIT Model



NOAA's HYSPLIT Model

Instructions:

1. Go to http://ready.arl.noaa.gov/HYSPLIT_traj.php
2. Select **Compute *archive* trajectories**
3. Leave "Number of locations" at 1, and use the normal type
4. Select the EDAS 40km 2004-present meteorological data set
5. Select your location one of three ways (today I picked Lat/Lon for Claremont, 34.0967°N and 117.7189°W, use negative for west))
6. Depending on how far back you want your trajectory to start, pick the date (I'm using 'current15days' here).
7. Select "backward" as the direction
8. Pick the time your rocket was sampling, in UTC time.
9. Select the run time (how far back in time you want to model).
10. Pick your desired altitude
11. Pick your plot style and features and output data type (Google Earth is possible)
12. Request trajectory, and wait!

Beijing smog problem – exacerbated by stagnant air and shallow boundary layer

- http://www.cnn.com/2013/01/14/world/asia/china-smog-blanket

Want to do atmospheric research at Mudd?

- Engineers make EXCELLENT atmospheric scientists
- Jonpaul Littleton – built a fog small chamber to simulate fog in the Hawkins lab
- Kaitlin Hansen and Michael Lertvilai built our large fog chamber
- and automated instruments (Labview), set up reaction chambers, and designed collection devices.

Email me! Lhawkins@g.hmc.edu or come to Jacobs 2313

The Ozone Hole Story

1973: Molina is a Postdoc with Roland, hypothesized that CFCs could destroy O_3

1983-1984: The Total Ozone Monitoring group at NASA notices an increase in "Low Value" flags in October data

1986: Mission to Antarctica in local spring (August) organized by S. Solomon (NOAA)

1978: Bans on aerosol CFCs but use increased in general, due to skeptics/ industry

1984: Joseph Farmer and colleagues at British Antarctic Survey measure O_3 with a **Dobson Spectrophotometer** and discovered that it was 35% lower than 1960 levels

1985: Farmer and NASA publicize results and the term "**ozone hole**" enters existence after satellite measurements reveal the shape and extent of the depletion.

Introduction to Atmospheric Aerosols: **Organic Components are Substantial**

Submicron particle composition from an aerosol mass spectrometer: organic and inorganic (sulfate, nitrate, and ammonium) components

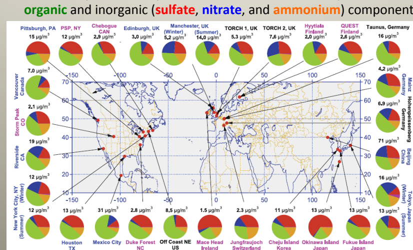


Figure from Zhang et al., 2007 GRL