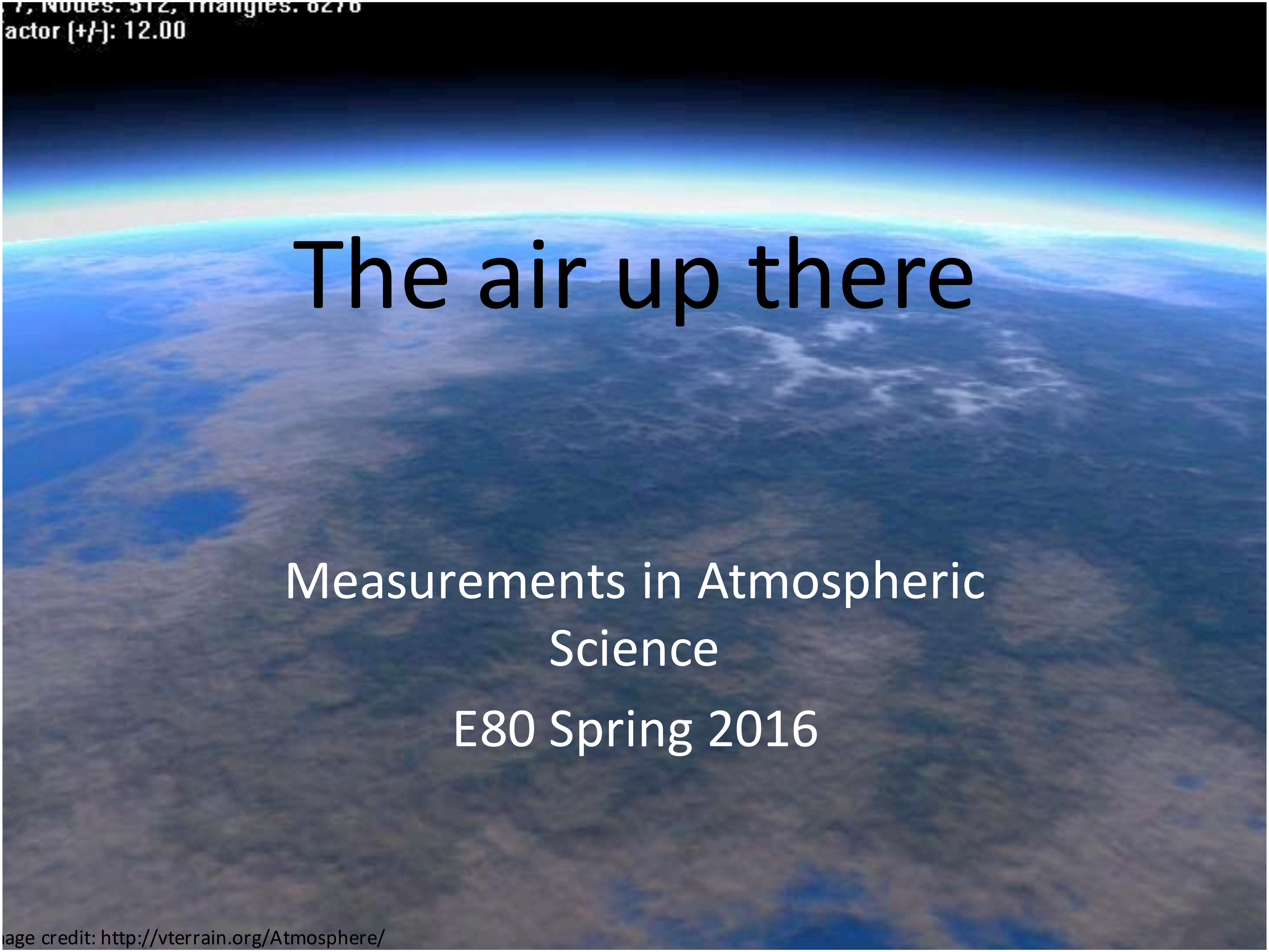



# The air up there

Measurements in Atmospheric Science

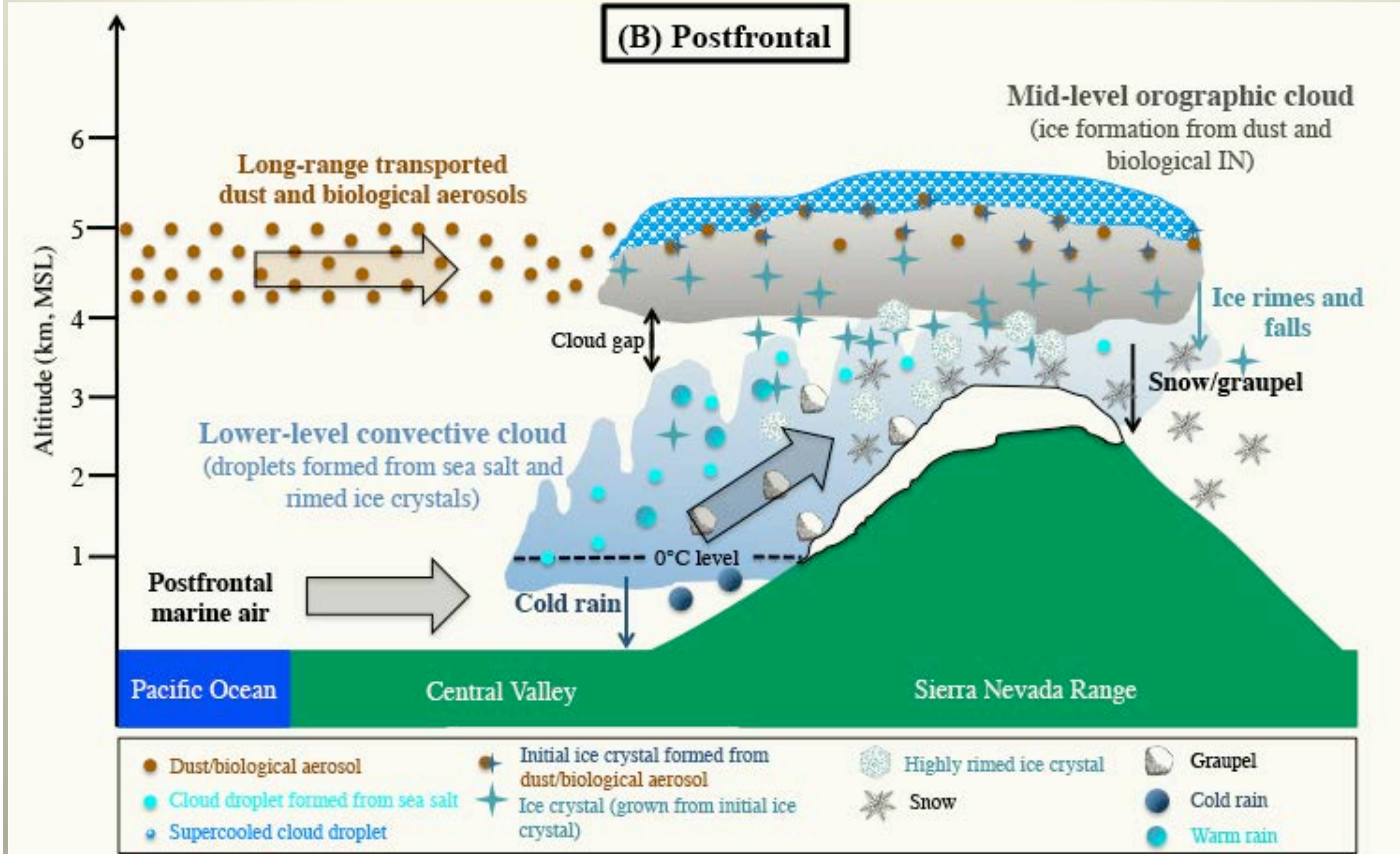
E80 Spring 2016

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

# For La Nina winters, cloud seeding

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

1. Atmospheric science across the disciplines
2. Activism, art, and air pollution
3. Basic concepts in atmospheric science
4. Why and how to make atmospheric measurements
5. What you might consider for your rocket
6. Where did the air come from? HYSPLIT back trajectory models

# 1. Atmospheric Science across the disciplines

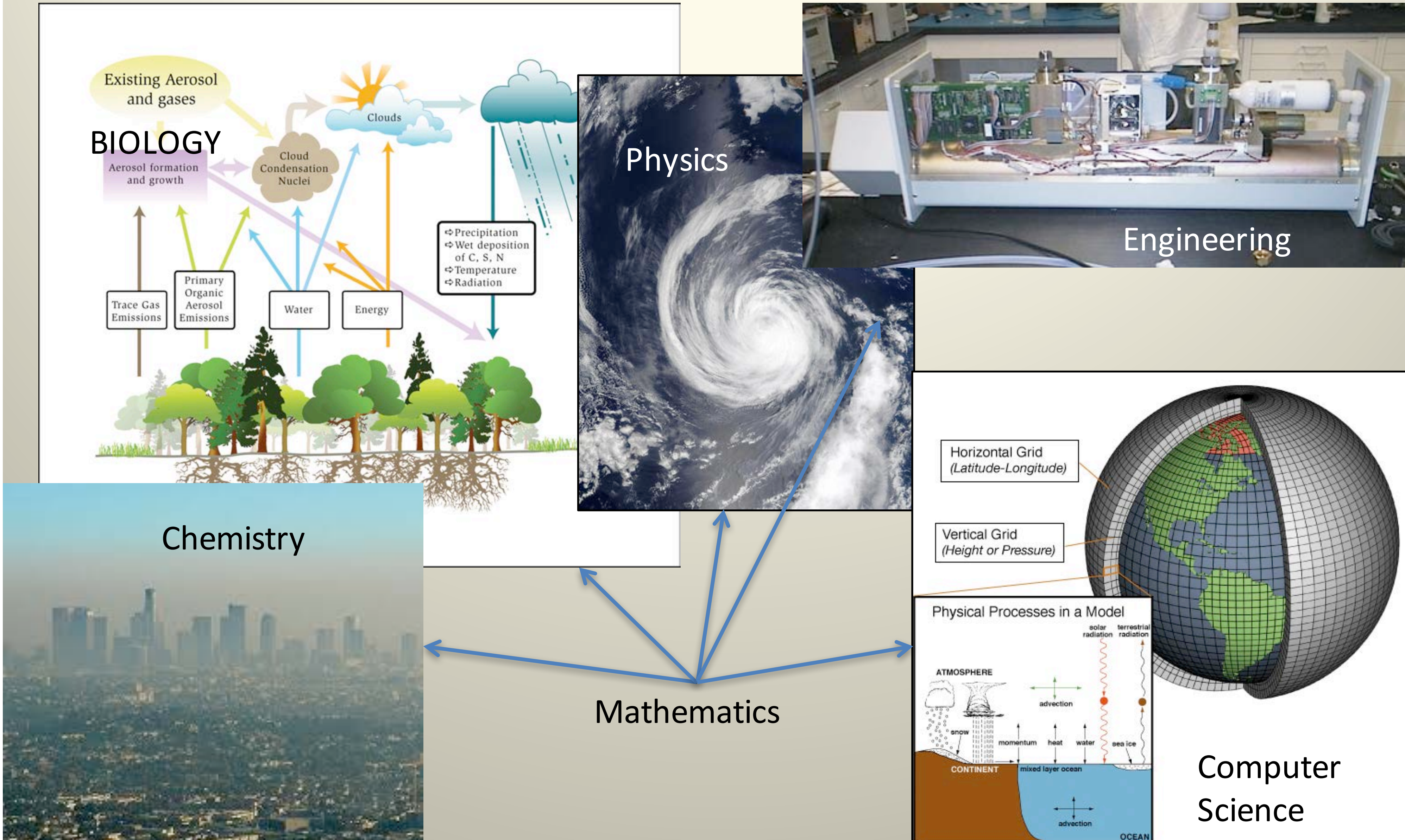
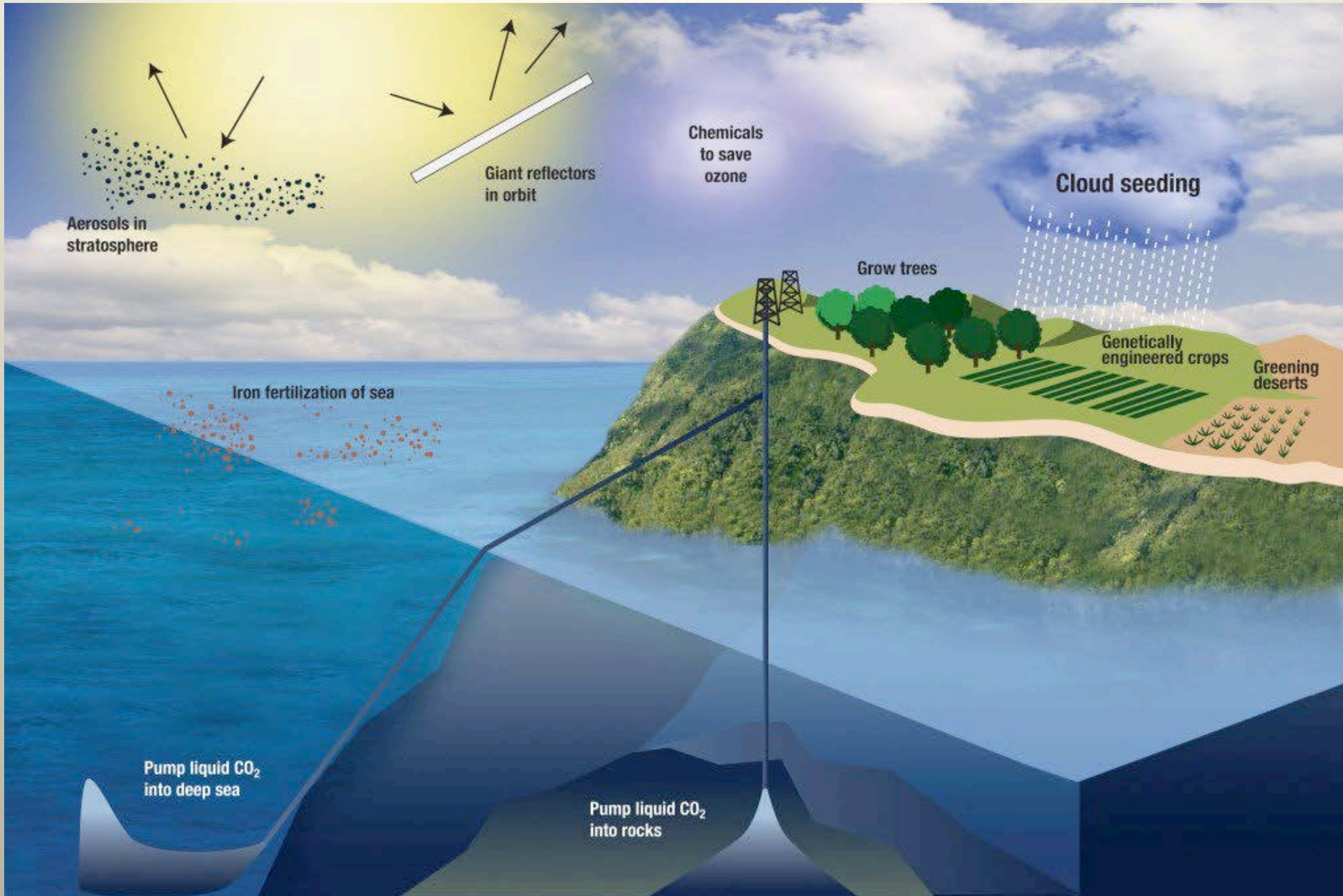



Image credits: atmos.washington.edu, acd.ucar.edu, caice.ucsd.edu, oar.noaa.gov, chemwiki.ucdavis.edu

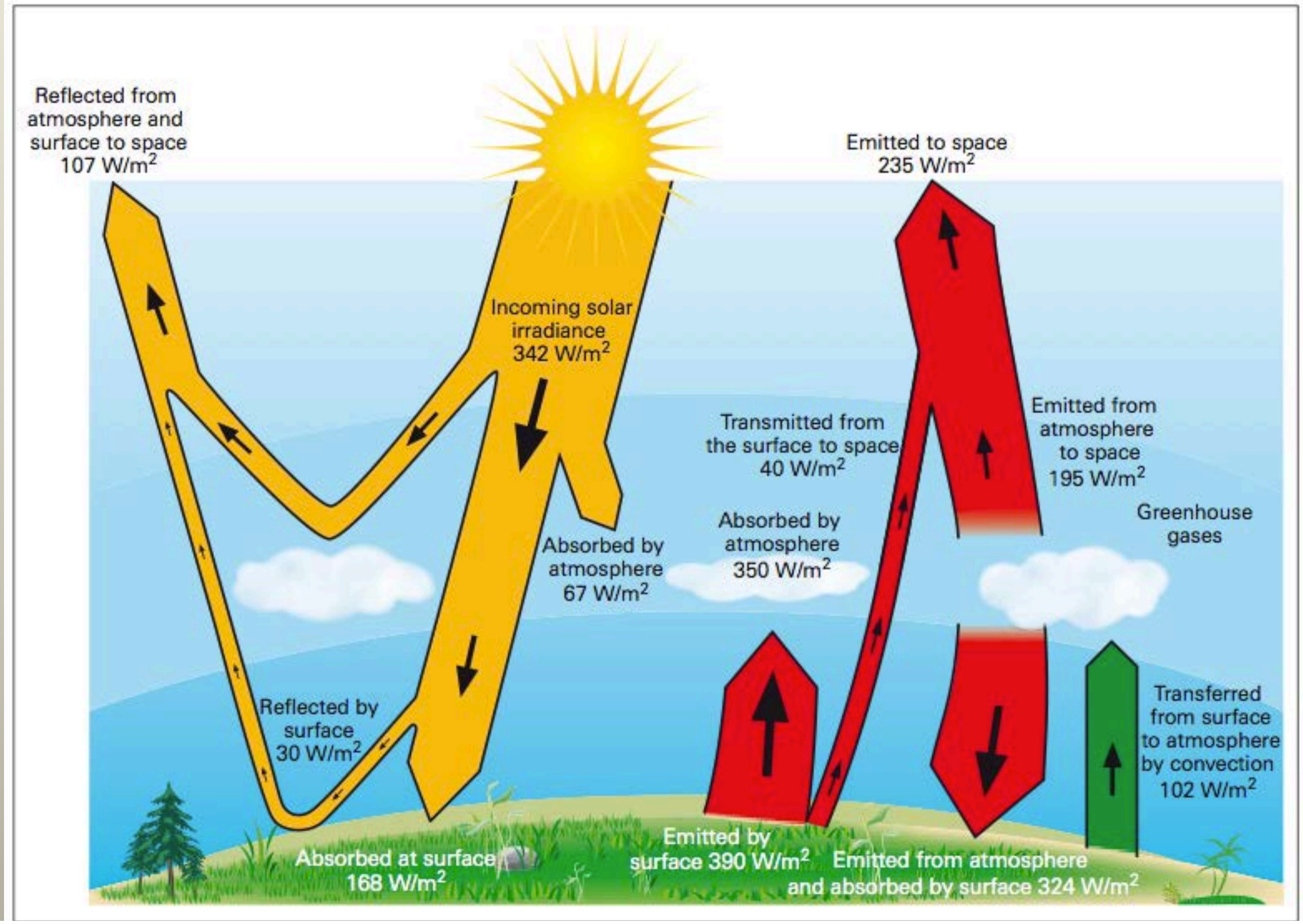
# What is geoengineering?



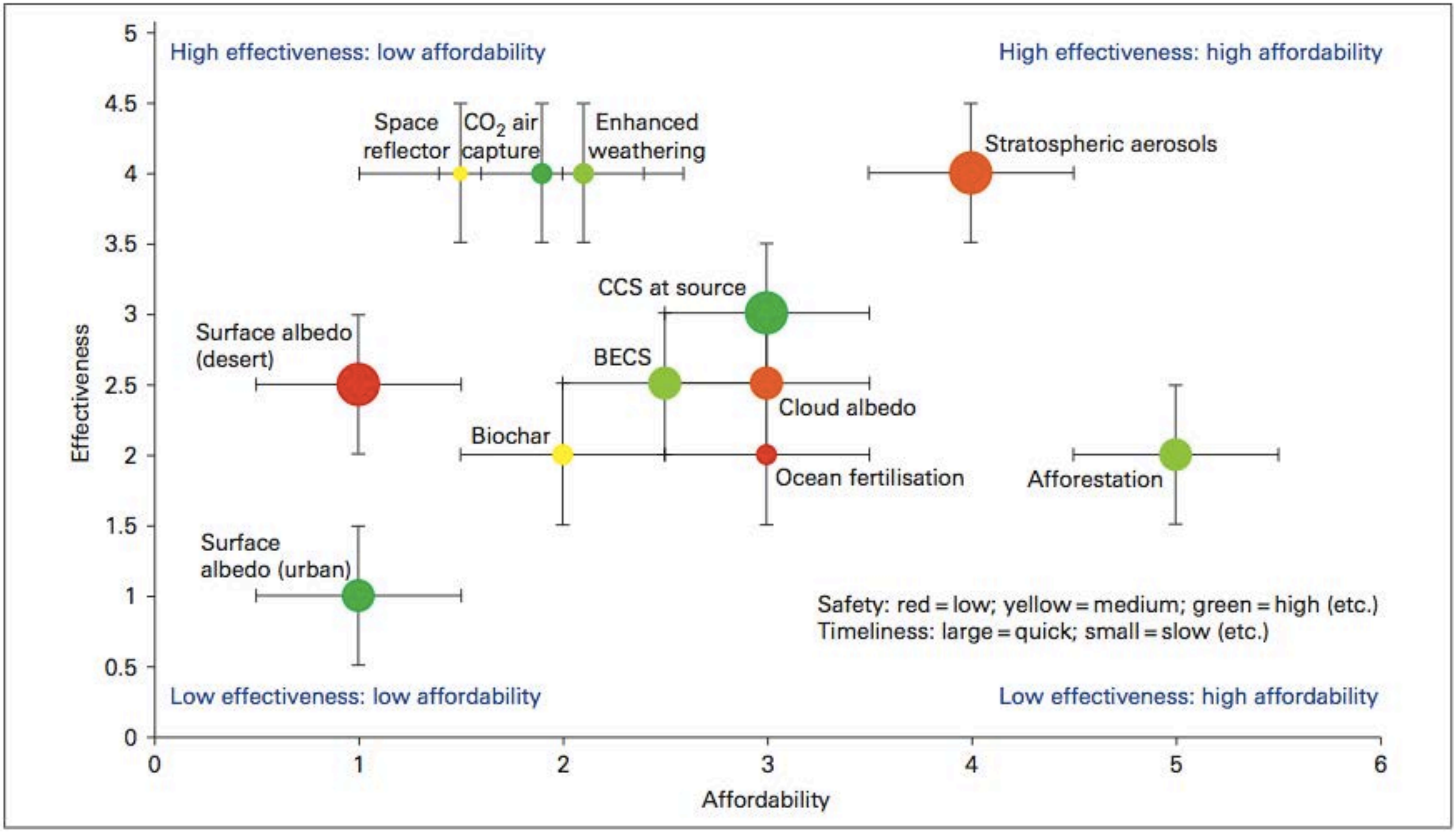

http://www.collective-evolution.com/2013/04/29/geoengineering-chemtrails-what-in-the-world-are-they-spraying-and-why/

# Geoengineering requires understanding atmospheric composition and it’s changes

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

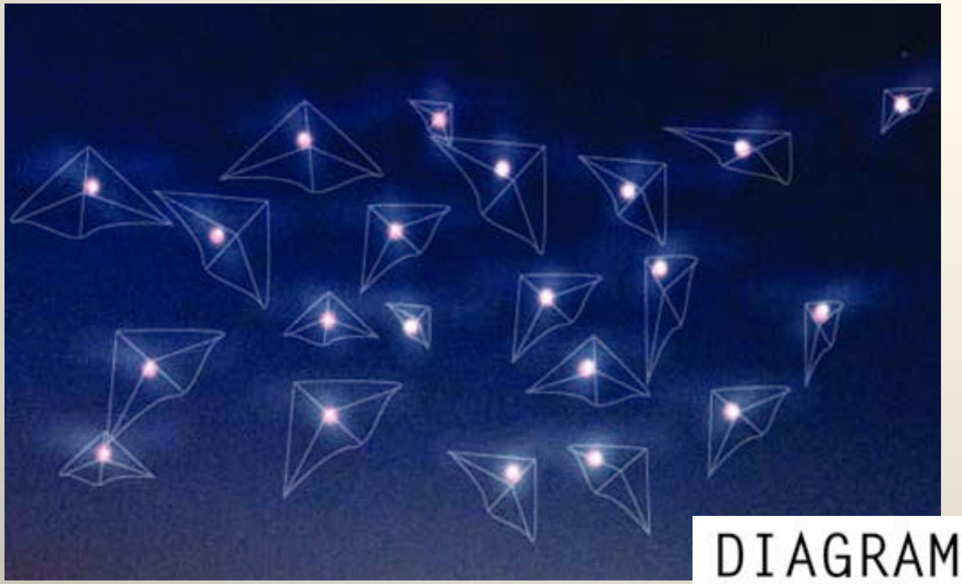


# Geoengineering: you want to do what??




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

# 2. FLOAT - Activism, art, and air pollution




http://inhabitat.com/float-beijing-monitors-air-quality-with-high-flying-kites/ ;
http://www.theguardian.com/world/gallery/2015/dec/09/beijing-residents-blanketed-by-pollution-in-pictures

# 3. Basic concepts in atmospheric science

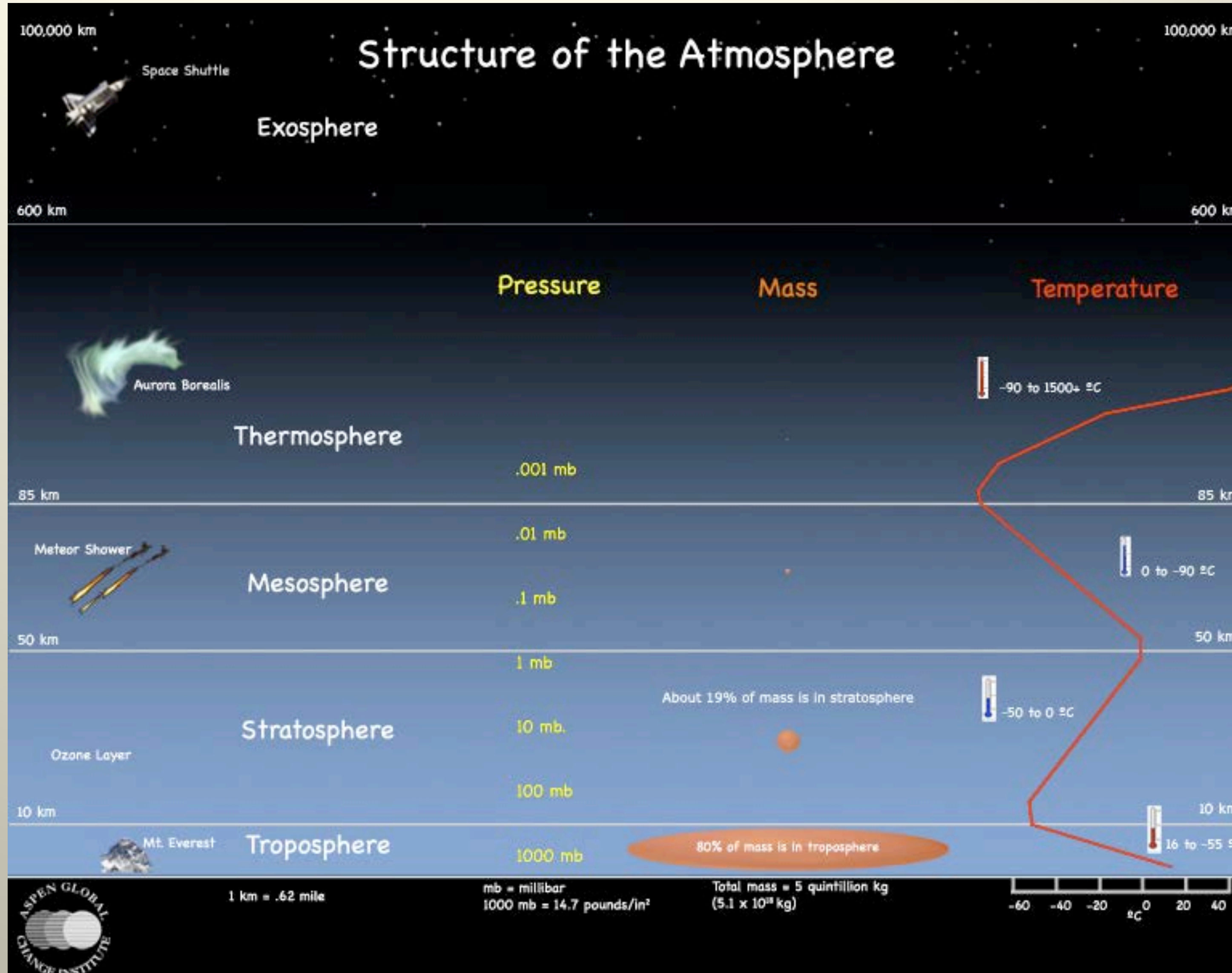
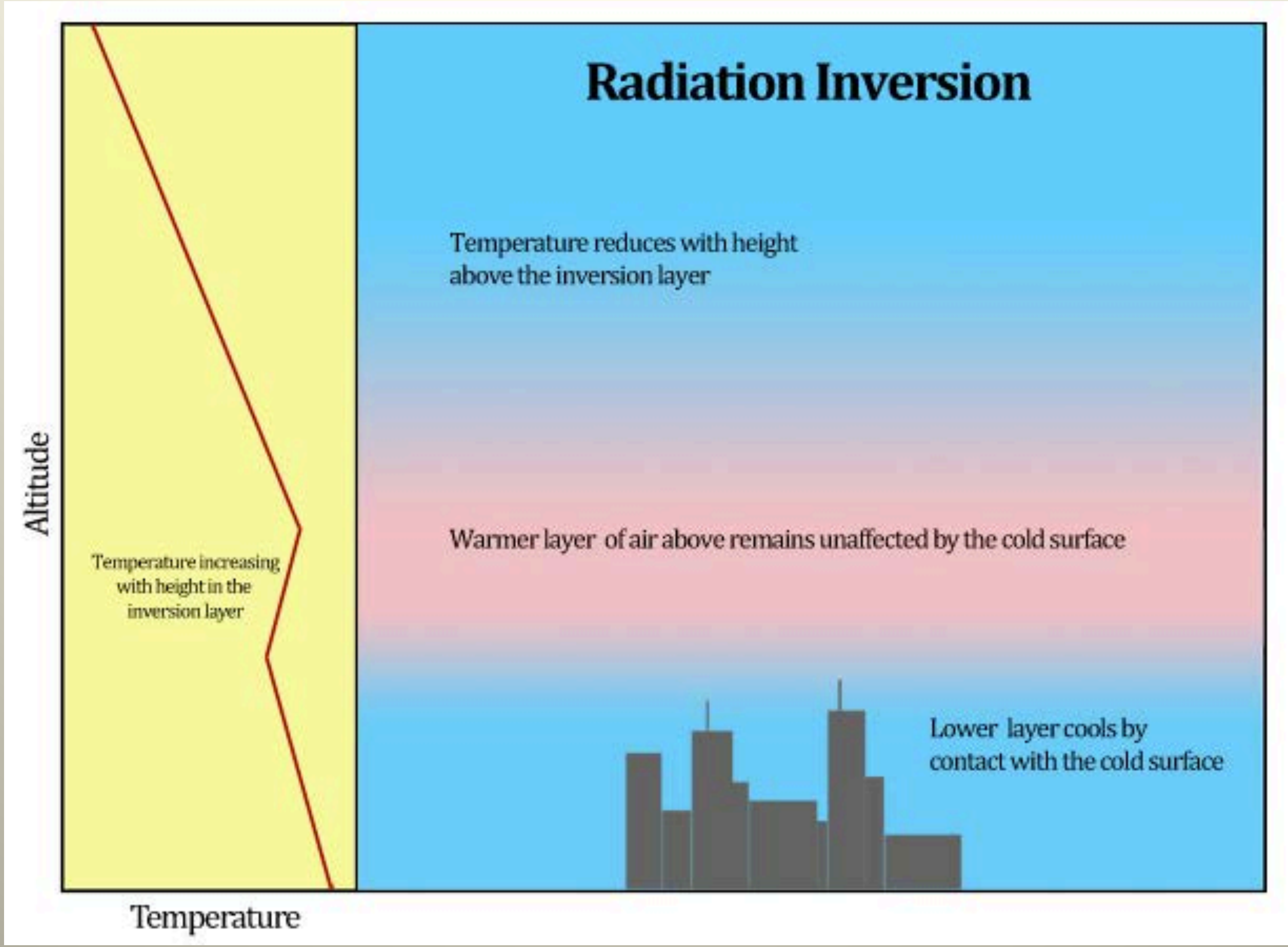



Image credit: agci.org

# Inversion layer



# What's going on in the troposphere?

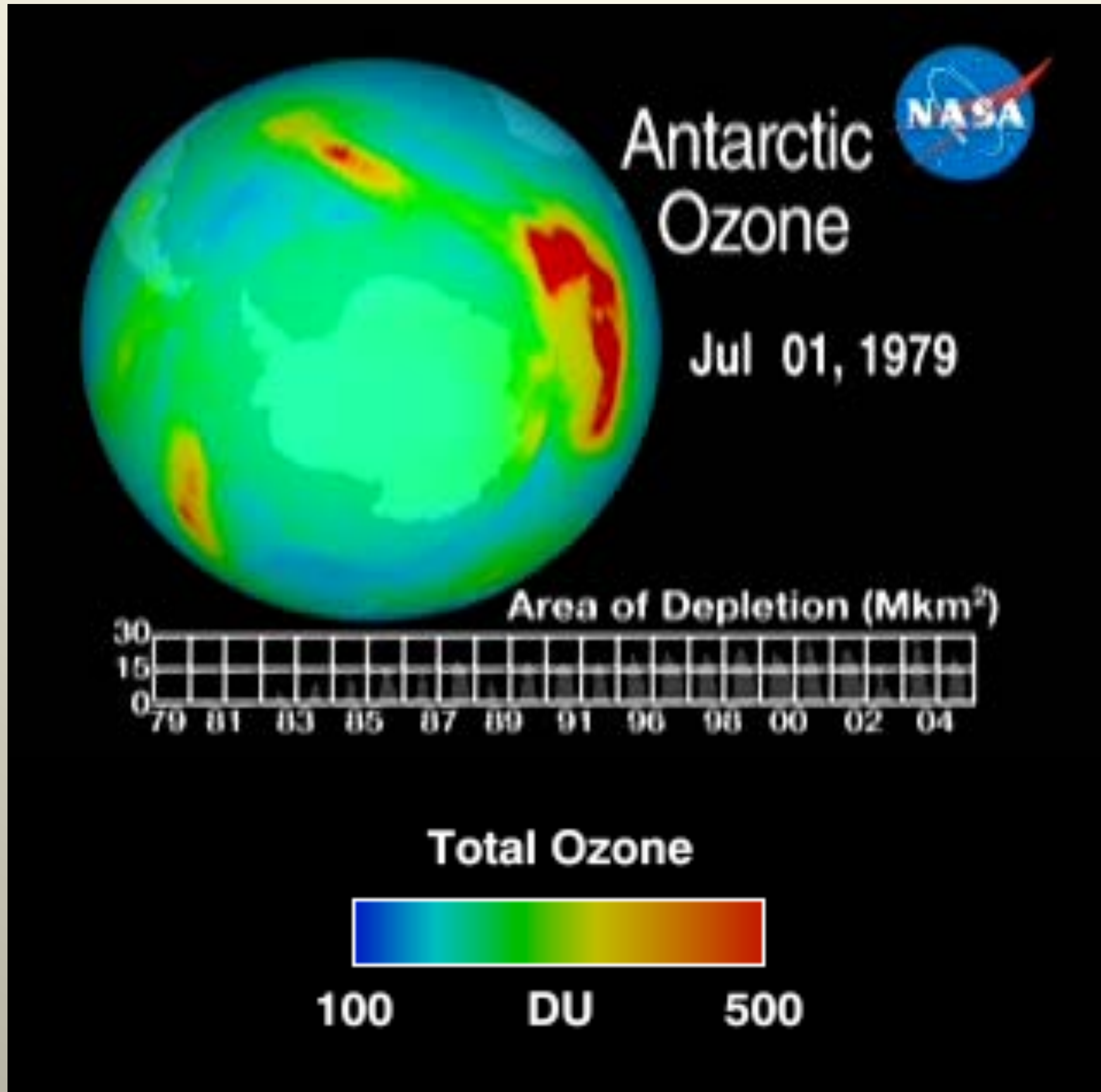
Nearly all

- 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!

# <u>Outliers:</u> 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. [...]

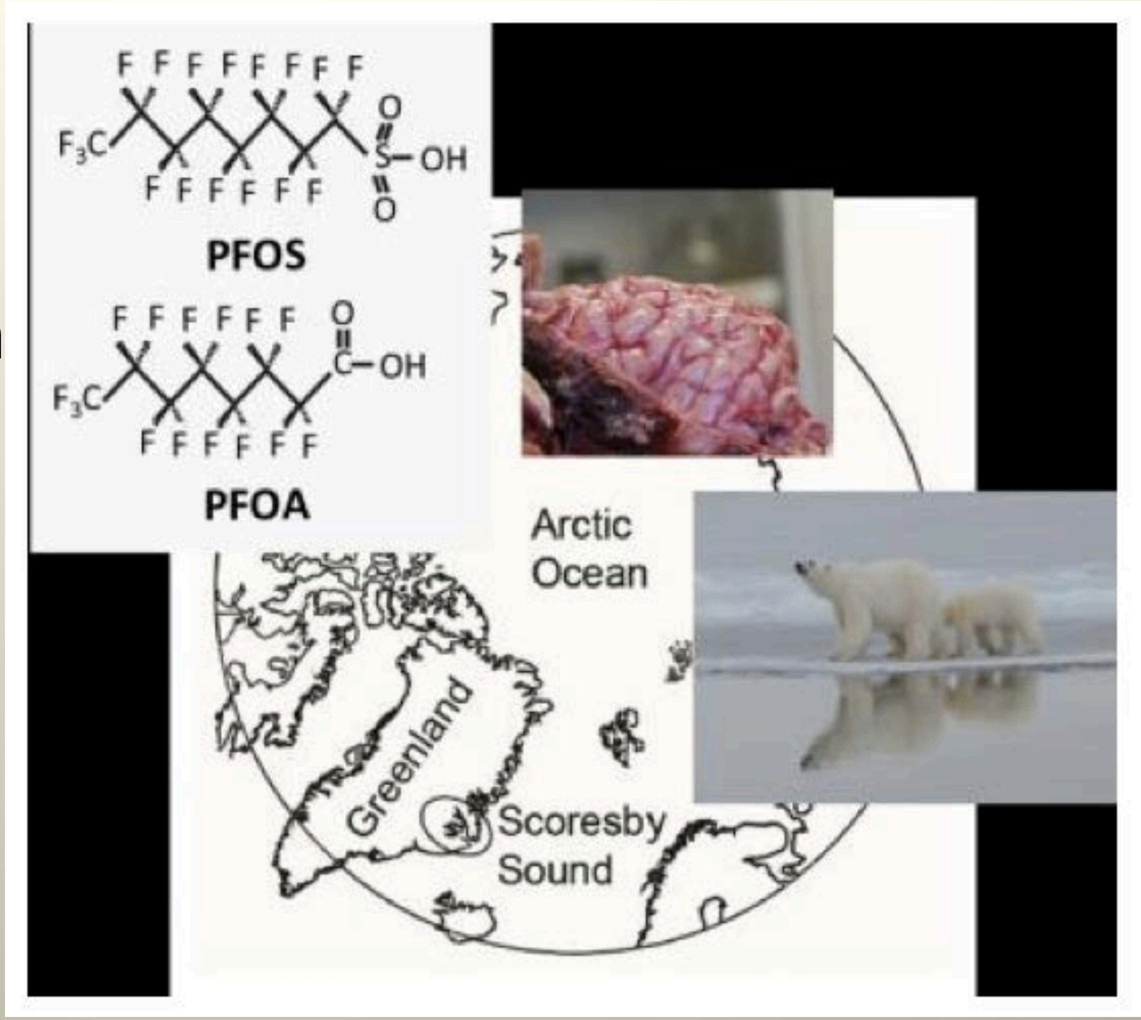
As the first one in print, he gets full credit for discovery of the ozone hole. It makes a great story to talk about how NASA "missed" the ozone hole, but it isn't quite true."

# 4. Practical uses and methods 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



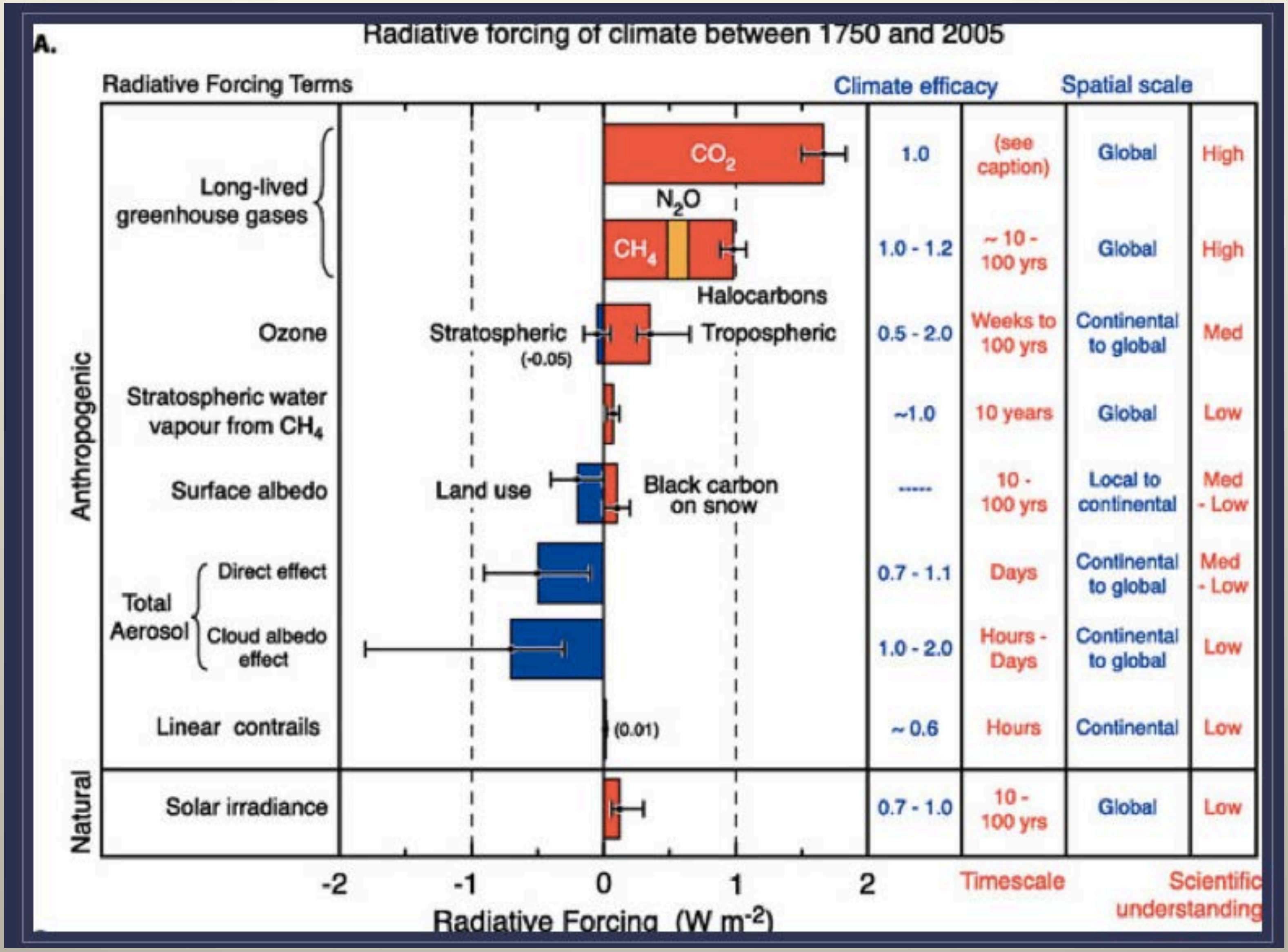
# Introduction to Atmospheric Aerosols:
# **Particle Sources**


**Primary particles** are emitted as liquids or solids to the atmosphere.

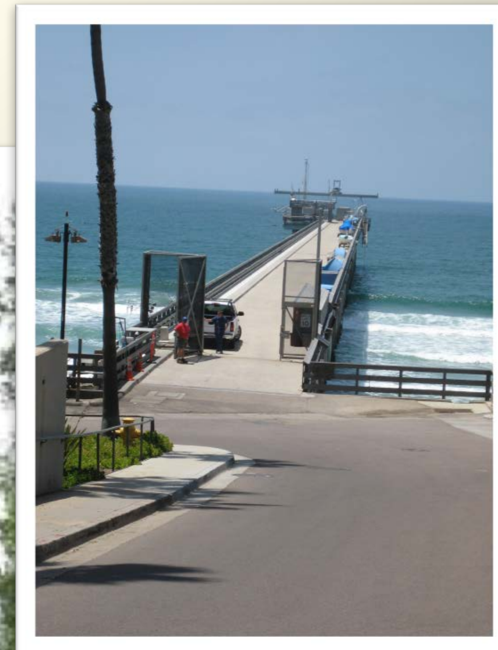
**Secondary particles** are emitted as gas phase components and later condense to form particles.

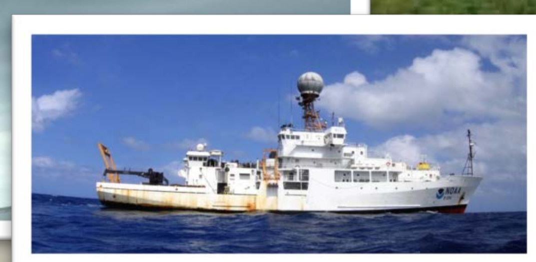
Primary particles that are transported in the atmosphere can accumulate mass from secondary components.

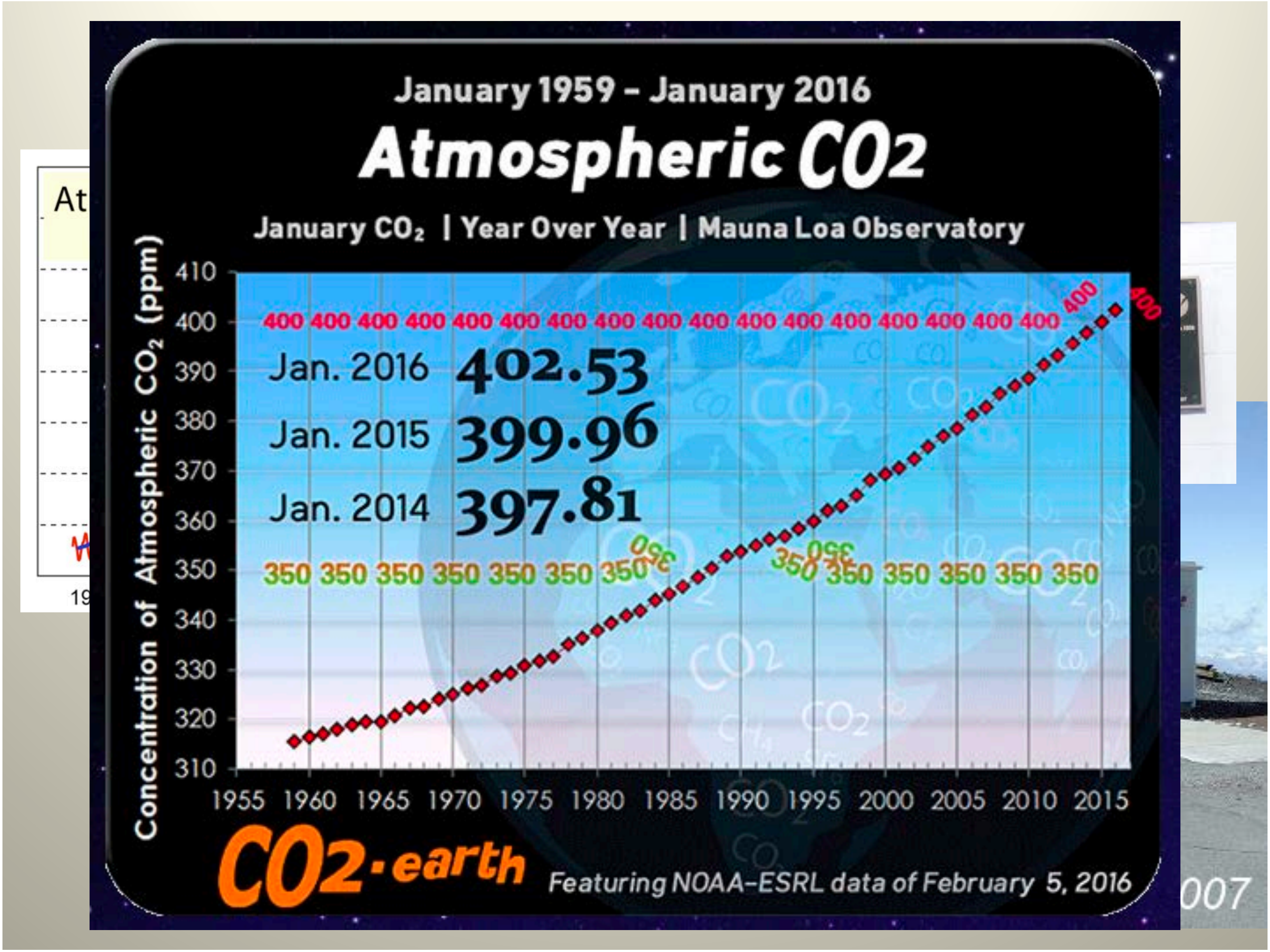
# Aerosols and Uncertainty



# Where are measurements made? And how?



January 1959 – January 2016
Atmospheric CO2
January CO₂ | Year Over Year | Mauna Loa Observatory
Concentration of Atmospheric CO₂ (ppm)
Jan. 2016 402.53
Jan. 2015 399.96
Jan. 2014 397.81
410
400
390
380
370
360
350
340
330
320
310
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
CO2·earth
Featuring NOAA-ESRL data of February 5, 2016

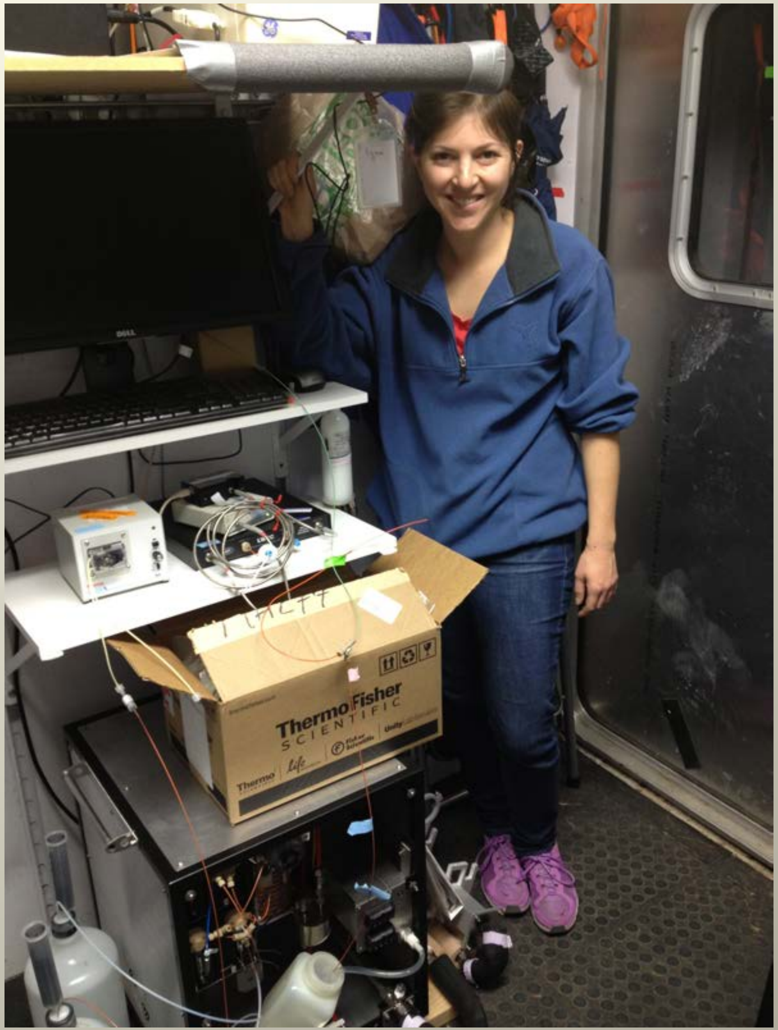
# Importance of collaboration

Calnex Field Study

MILAGRO, Mexico City

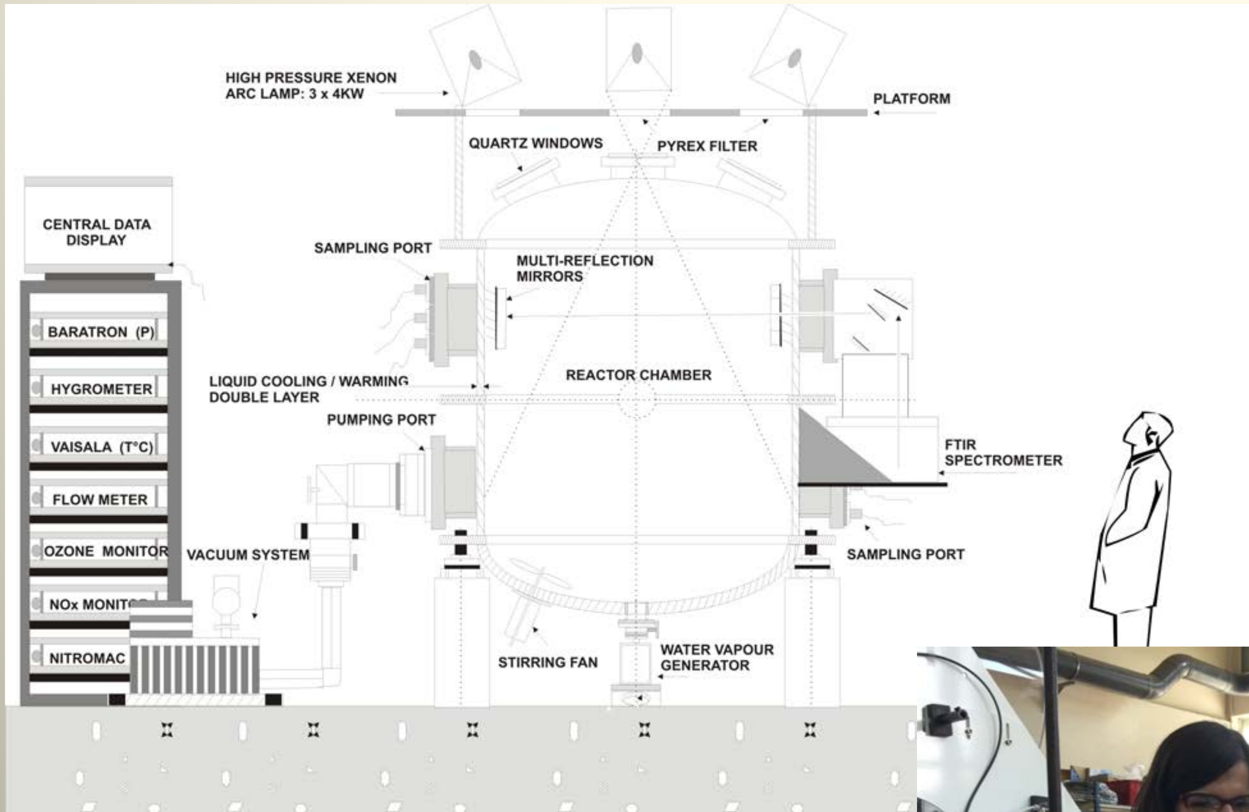
Inside a C-130 airplane during MILAGRO

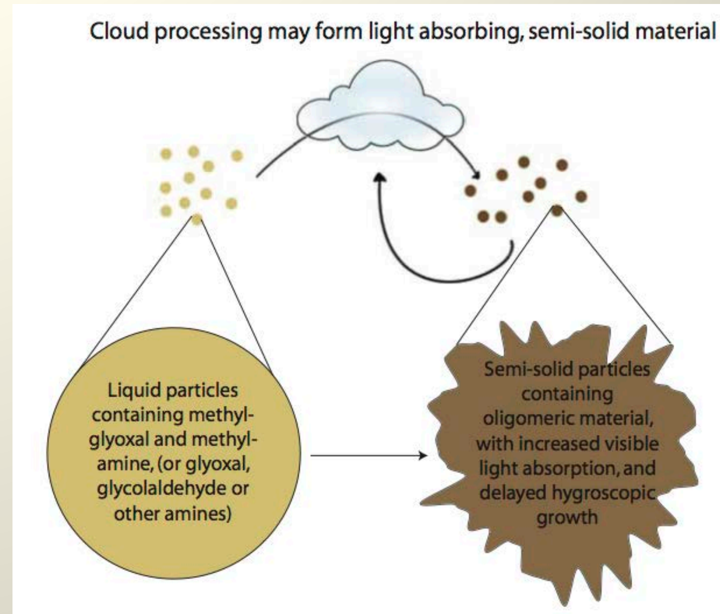
# Fresno 2015 Smog Study

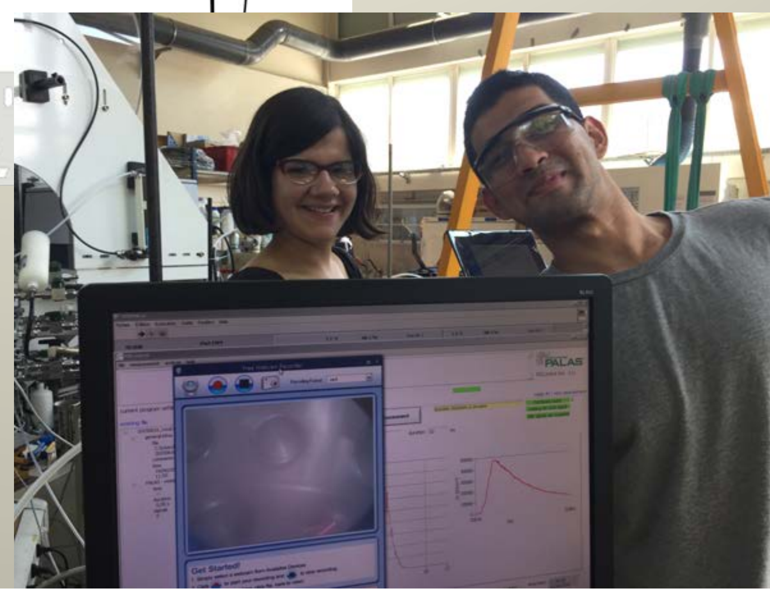



Looking for "brown carbon" during wood burning season.

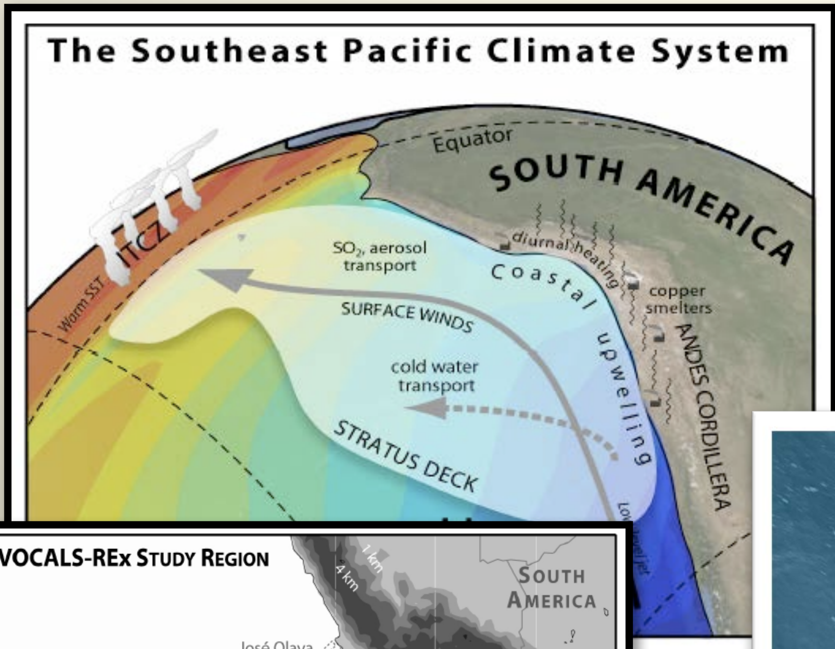
# Hawkins lab in Paris 2015

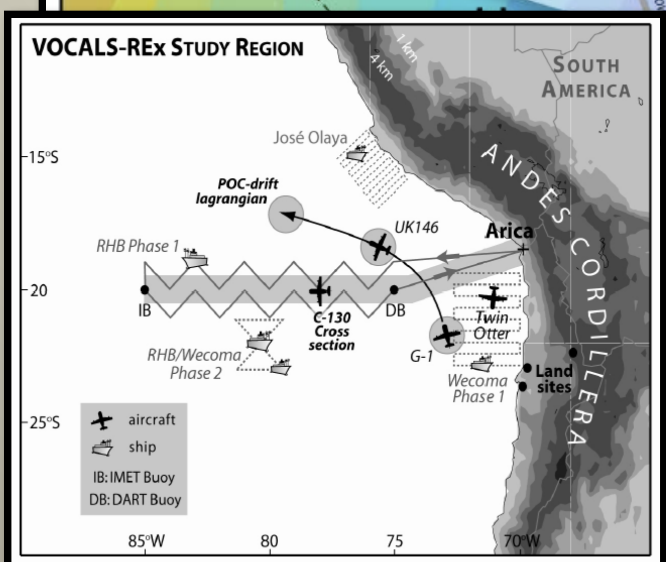


# VAMOS Ocean-Cloud-Atmosphere Land-Study Regional Experiment (VOCALS-REx)



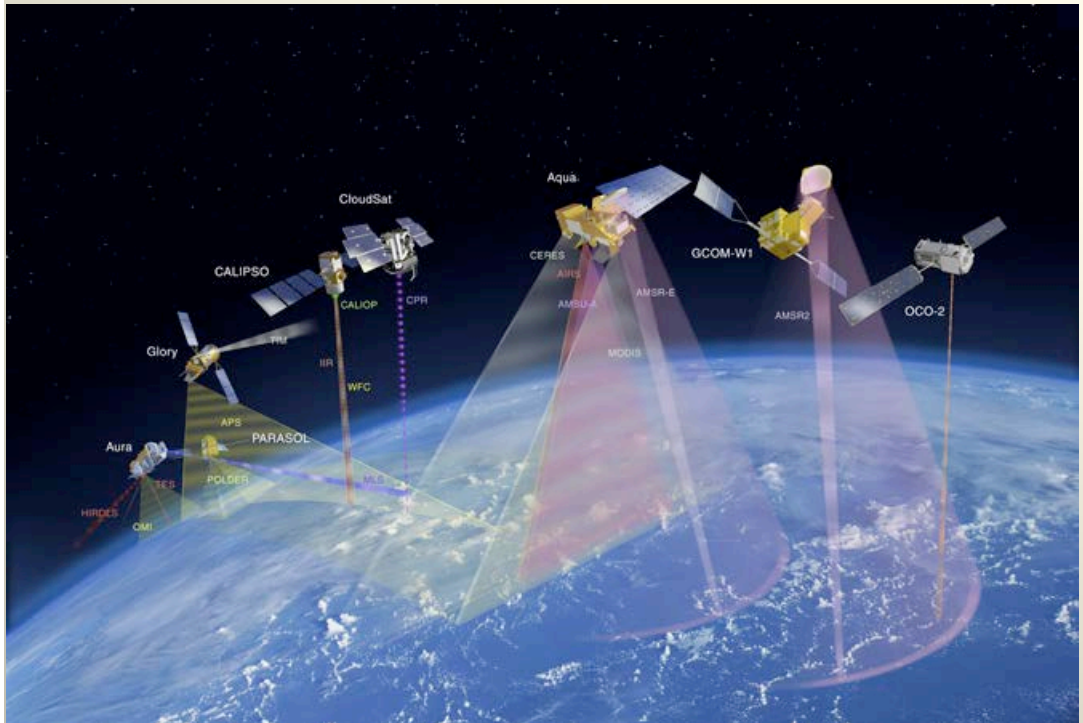




Wood et al., 2007 Program Summary

# MAGIC: Using cargo ships for atmospheric research


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?

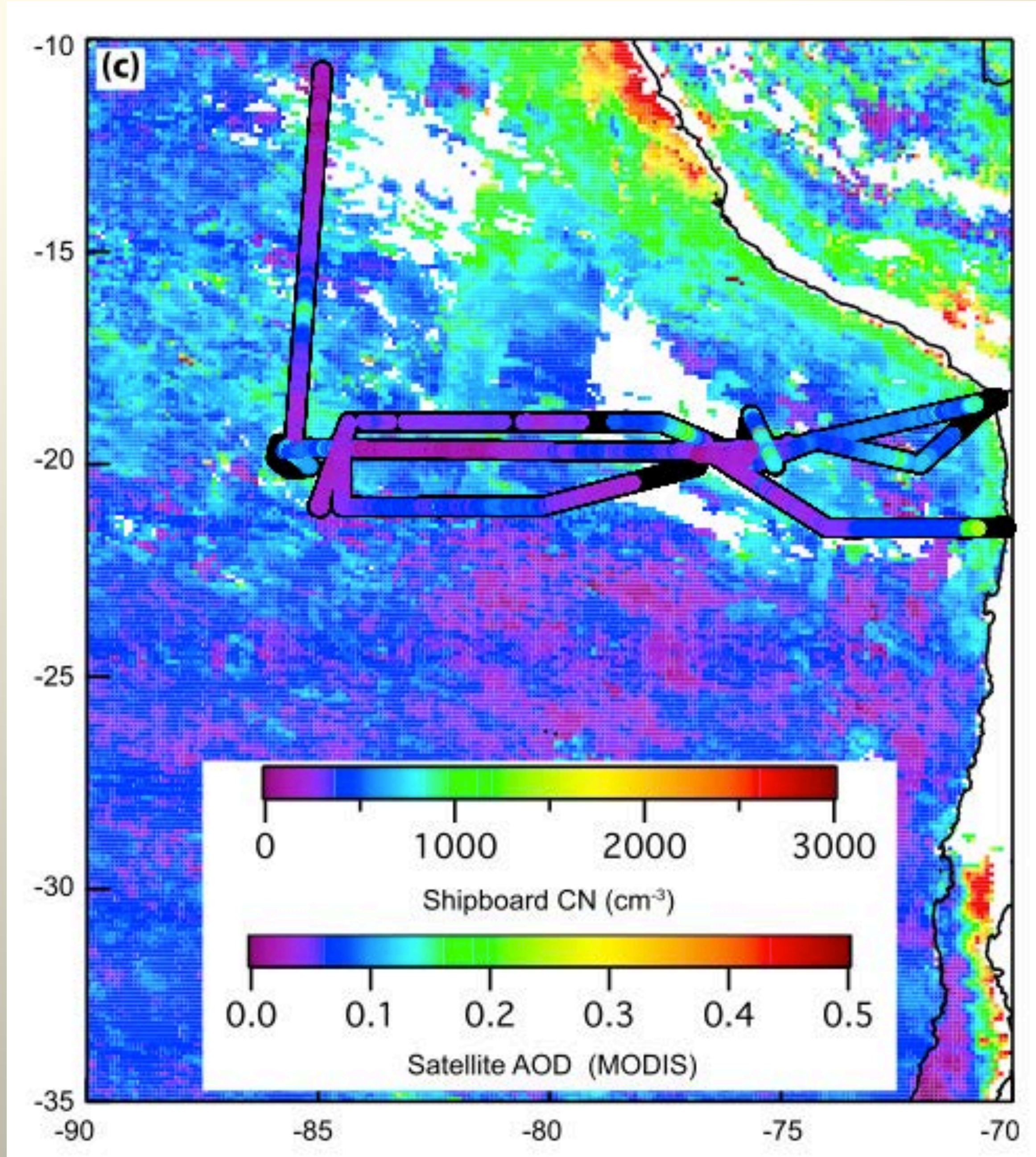
How will the monsoon cycle react to a warming world?

To what extent will a changing climate change the size and strength of hurricanes?

And what feedback cycles will encourage or discourage climate change?

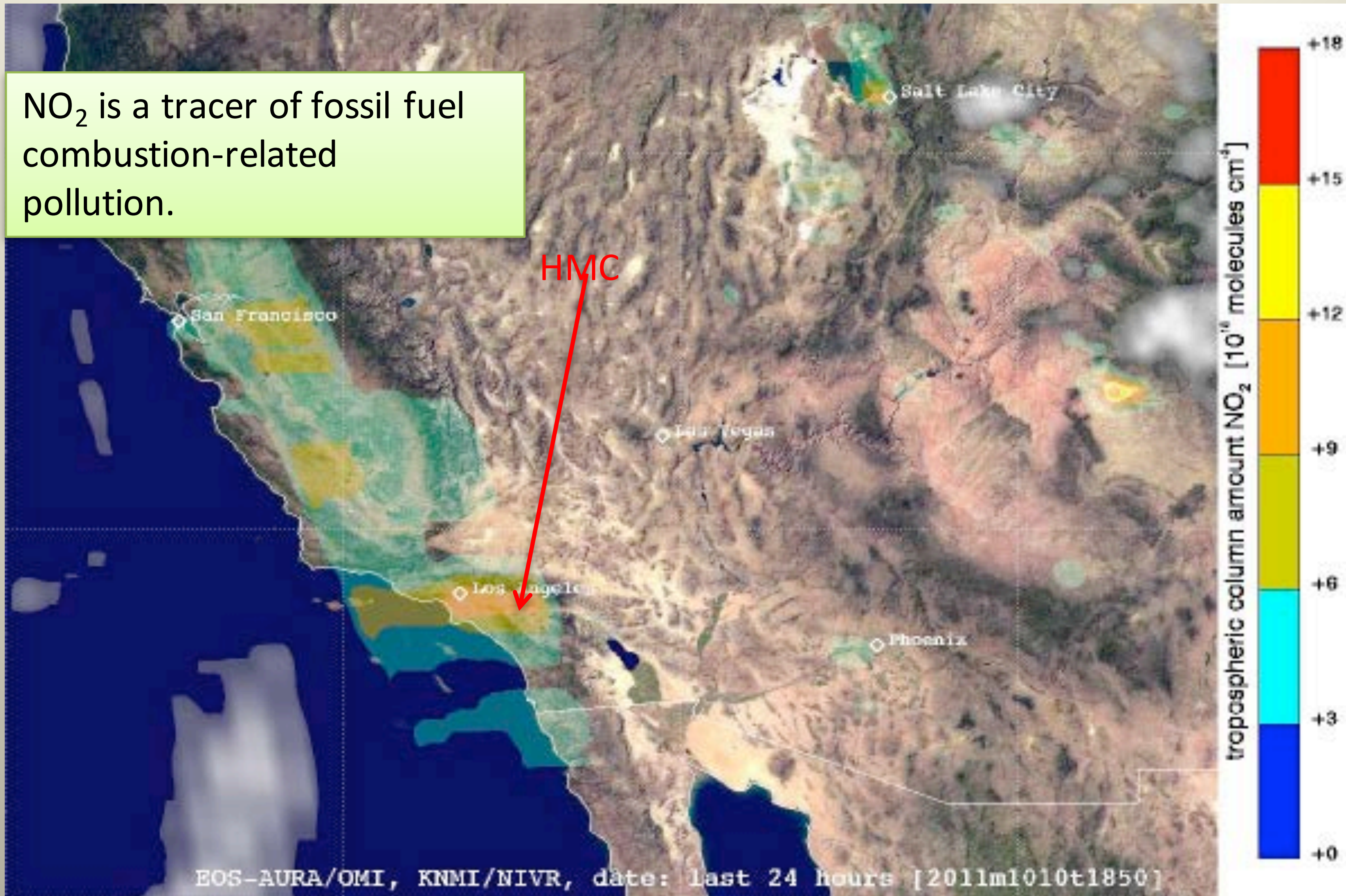
# Particle concentration by satellite

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



# What can satellite spectrophotometry do?

$NO_2$ is a tracer of fossil fuel combustion-related pollution.



# Role of $NO_x$ in photochemical smog

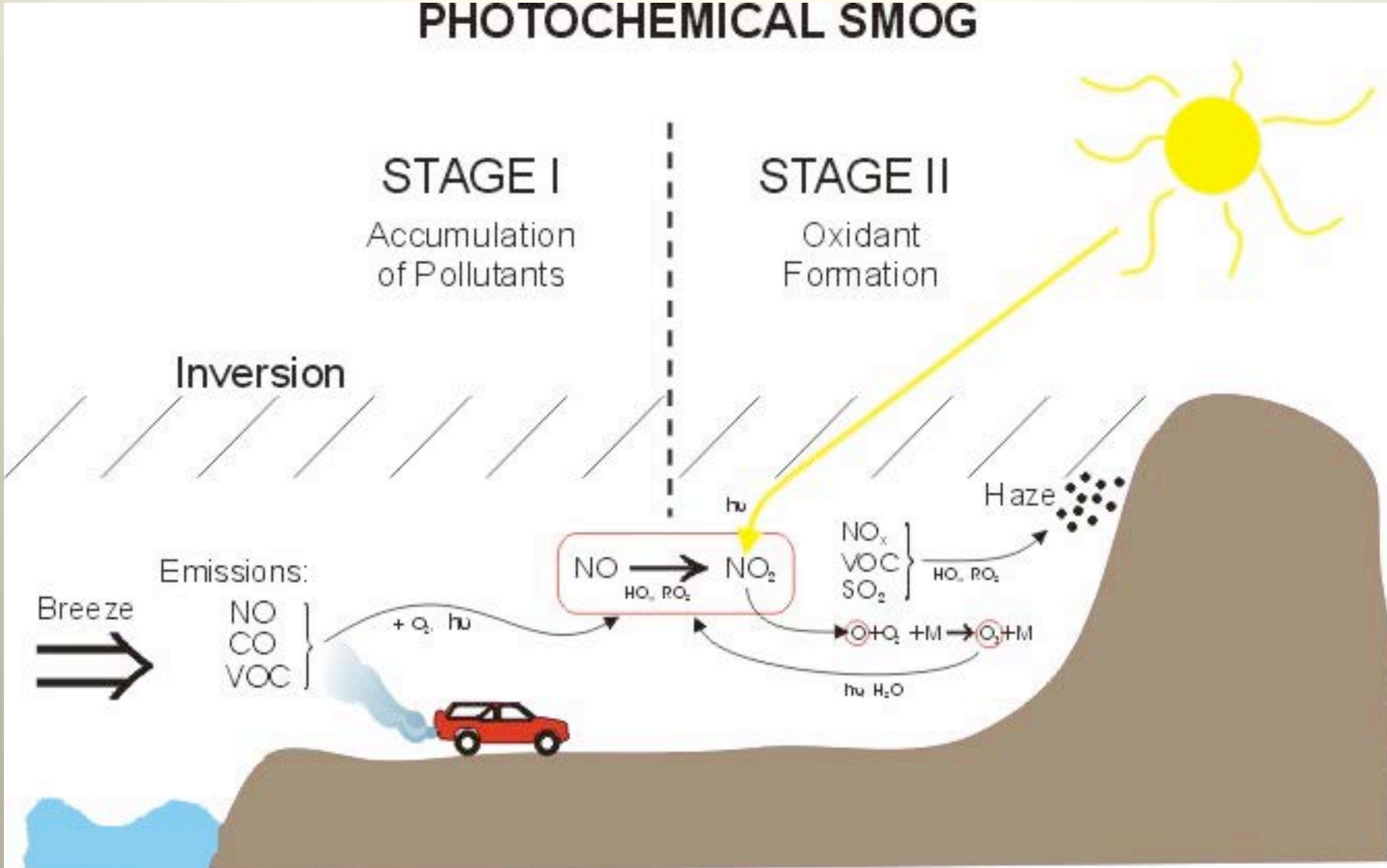
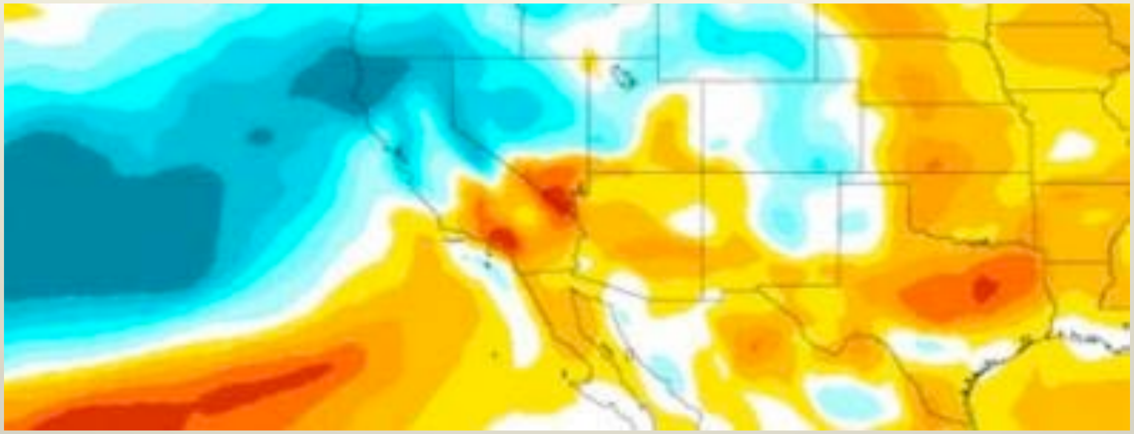



Image credit: www.ems.psu.edu

# A great place to know about: NCAR

- Models



- Measurements

- Black carbon and sea ice

# 5. What might rockets add?

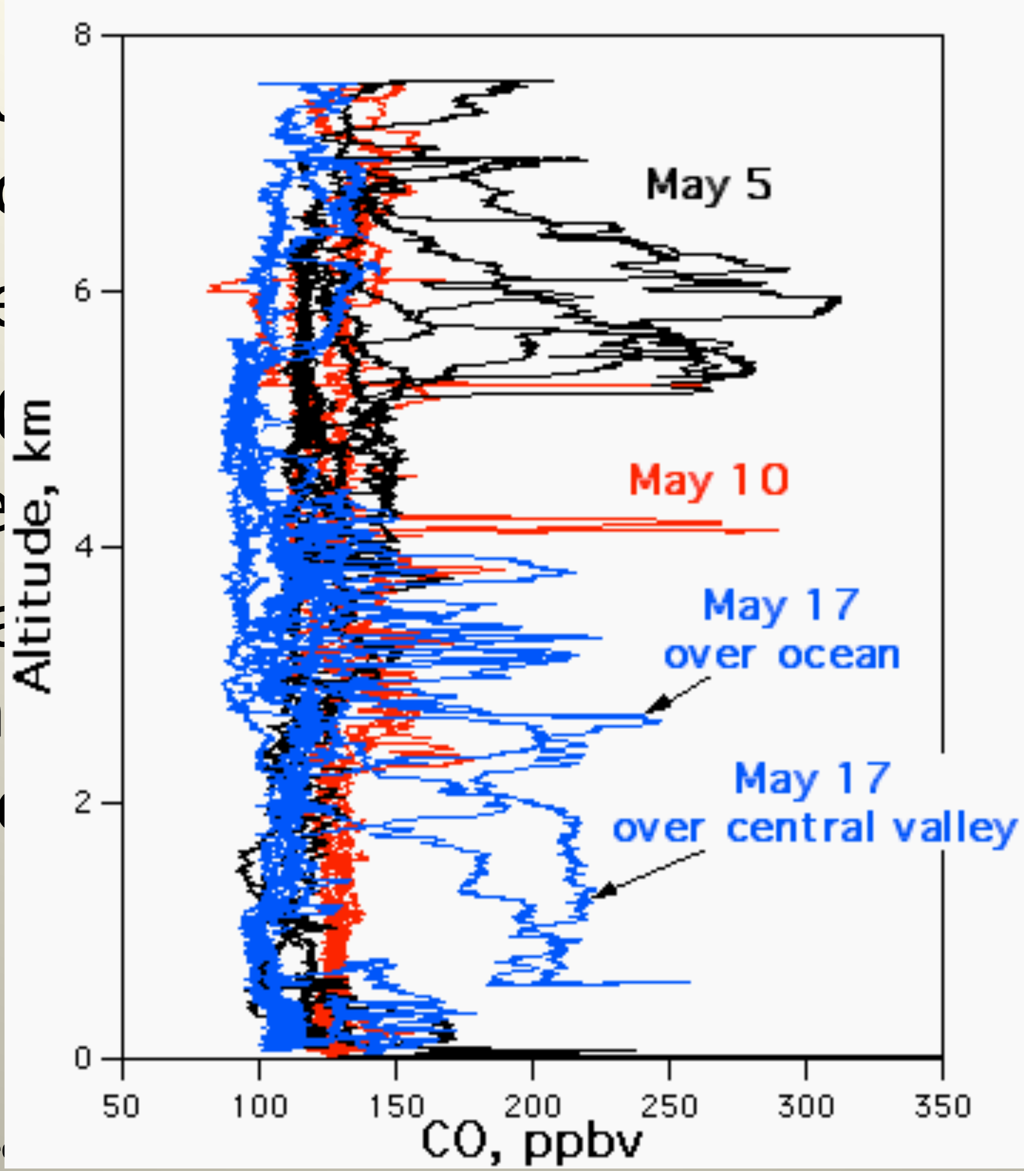
- Climate model “ground-truthing”
- Repeatable, local measurements
- Very high altitude studies (not yours), most useful above altitude for balloons (40 km) and below satellites (recall collaboration!).
- Lower cost than a fully instrumented aircraft
- Can be launched from remote locations (ships etc).
- 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

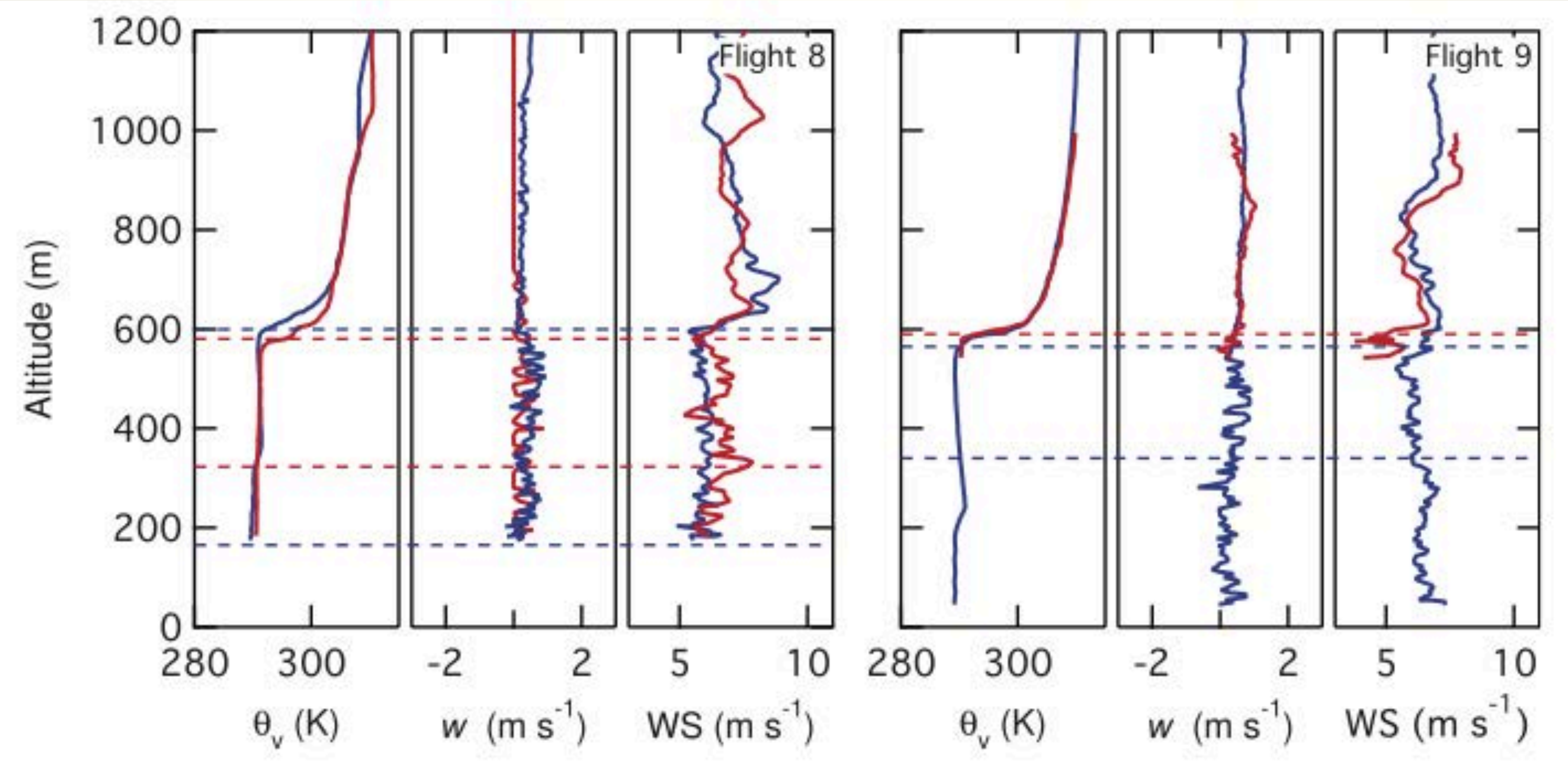
# What's cool about CO?

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



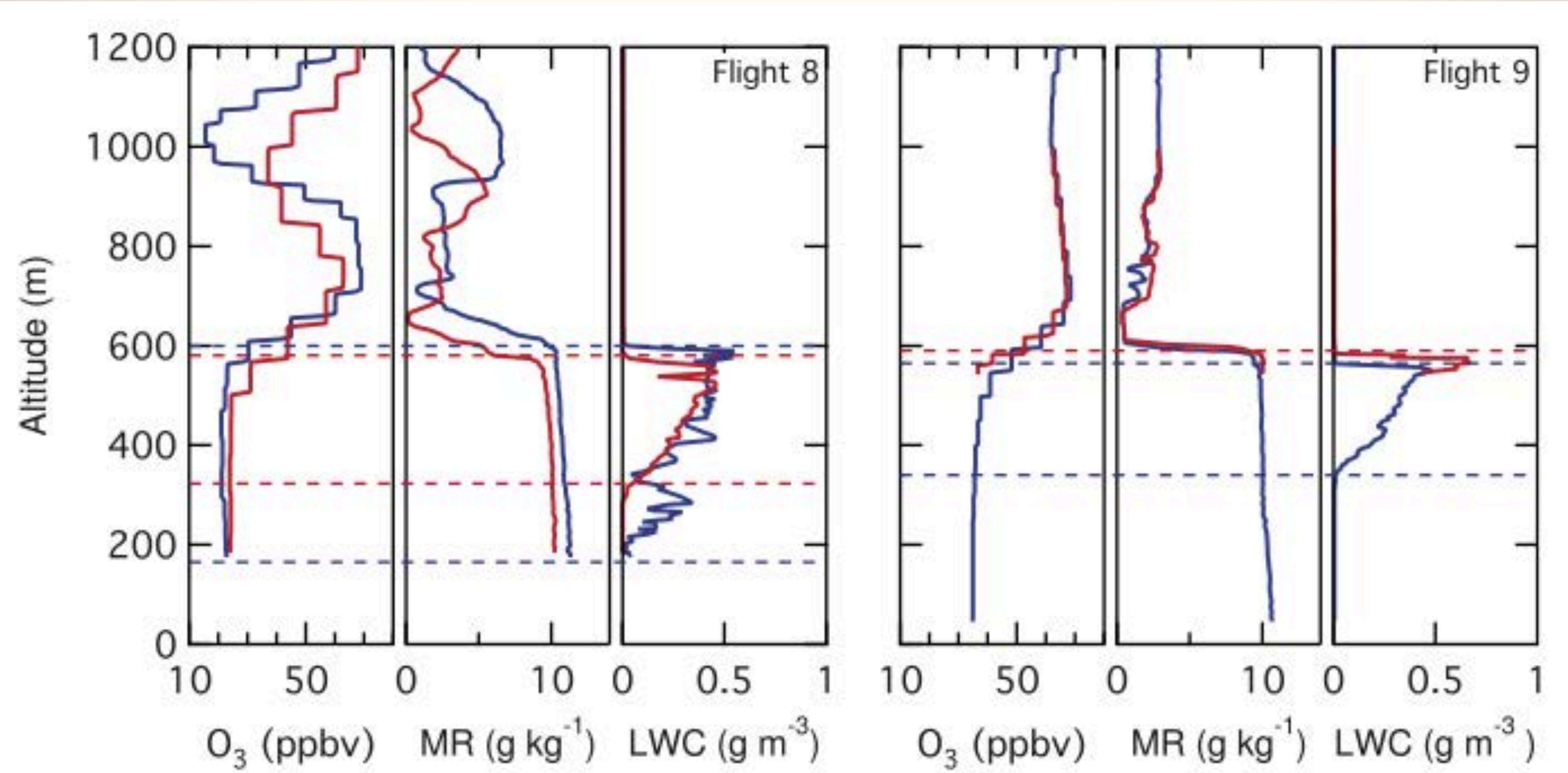

http://www.esrl.noaa.gov/csd/proje

# Vertical Profiles are telling



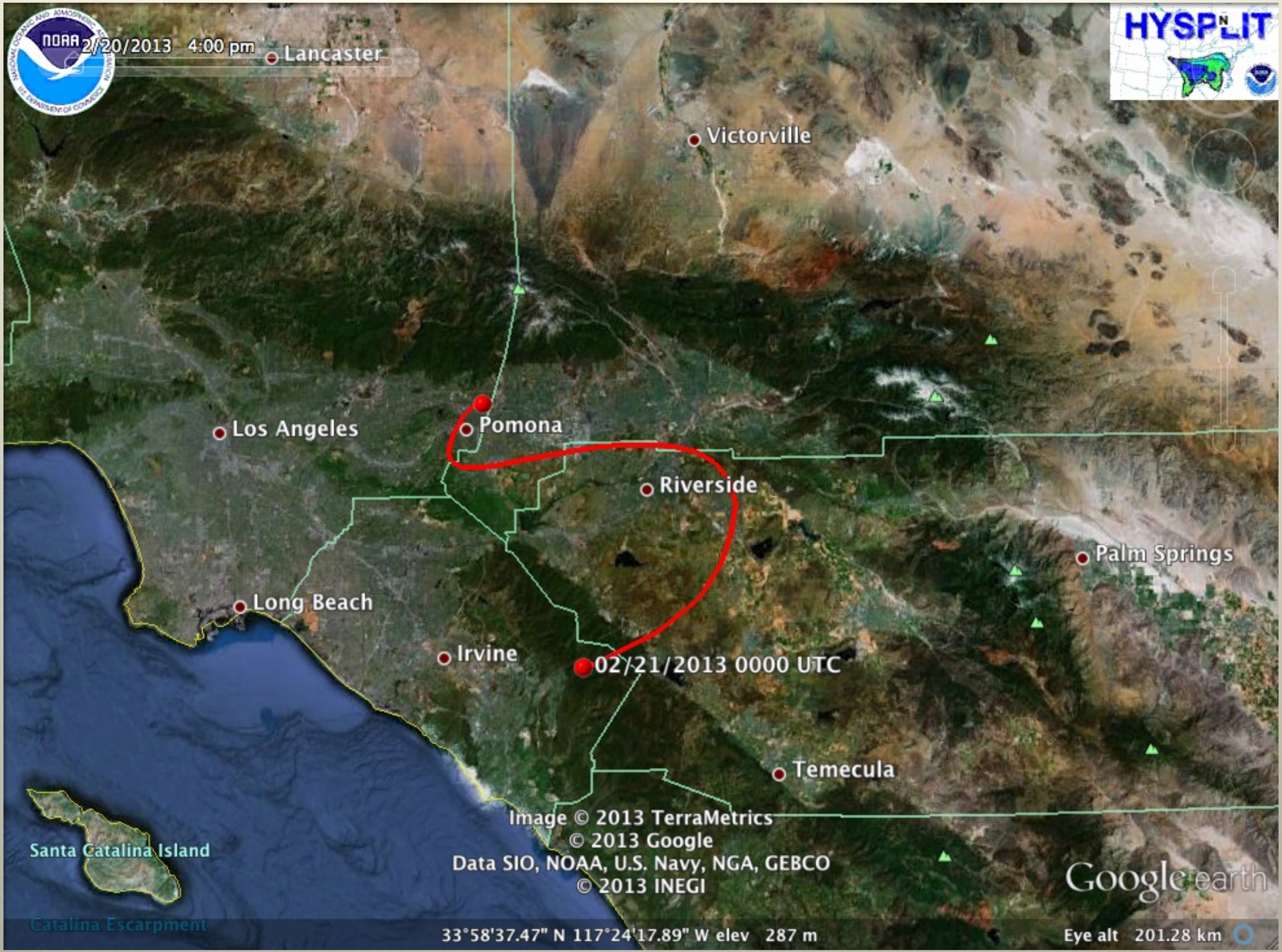

Potential temperature, vertical velocity, and wind speed

# Cloud layers in vertical profiles




Ozone, water vapor mixing ratio, and liquid water content

# NOAA's HYSPLIT Model



# 6. 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

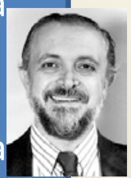
# Want to do atmospheric research at Mudd?

- 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.
- I need an impactor rebuilt this semester.

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

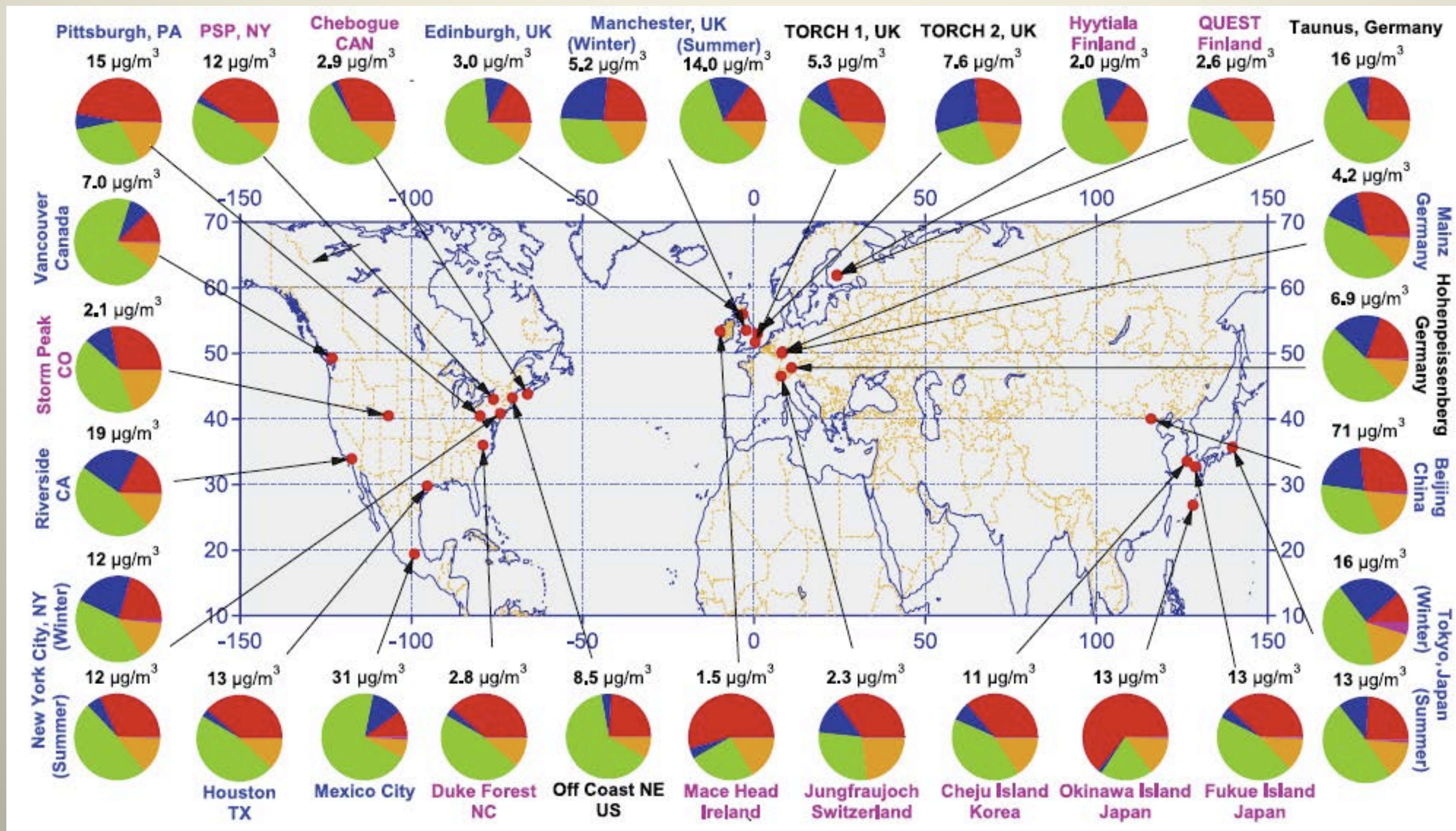
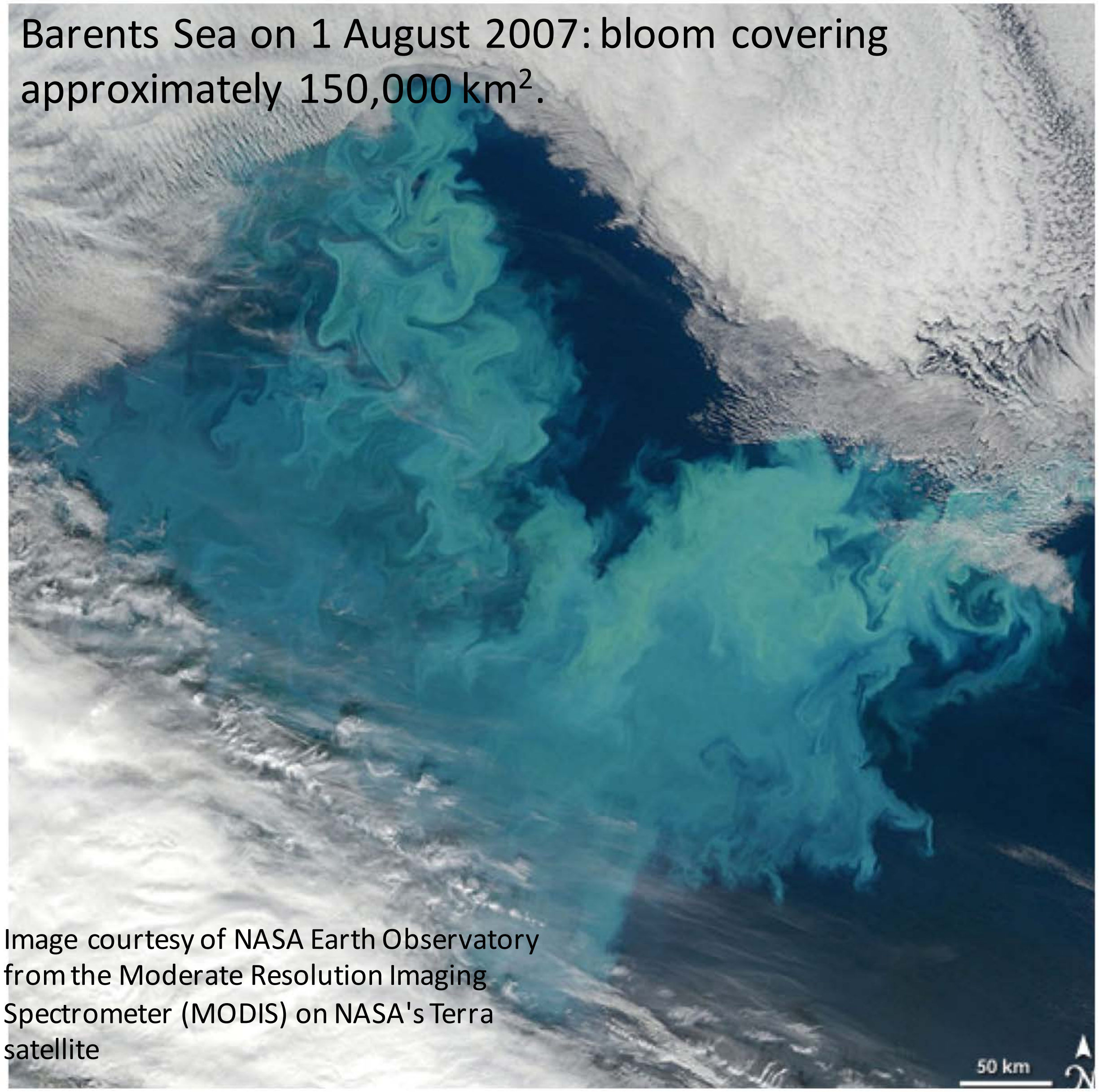





Figure from Zhang et al., 2007 GRL

# Calcareous Phytoplankton Fragments: Phytoplankton in the air?

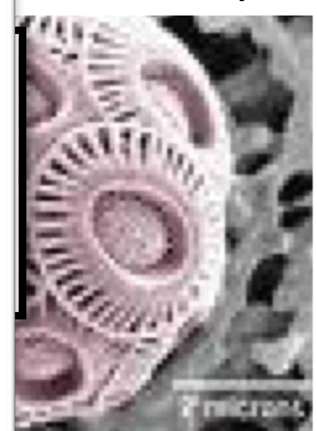



Barents Sea on 1 August 2007: bloom covering approximately 150,000 km$^2$.

Image courtesy of NASA Earth Observatory from the Moderate Resolution Imaging Spectrometer (MODIS) on NASA's Terra satellite

• Particles enric … **phores**
[Sievering et al. …
• Other types o… Leck and Bigg, 1999;2005].
• Coccolithopho… many repeating units of -$CH_2$.
•Previously unk… to sizes larger than 1 microme…


**Emiliania huxleyi**



Hawkins and Russell, 2010b

# Coupling rockets with models