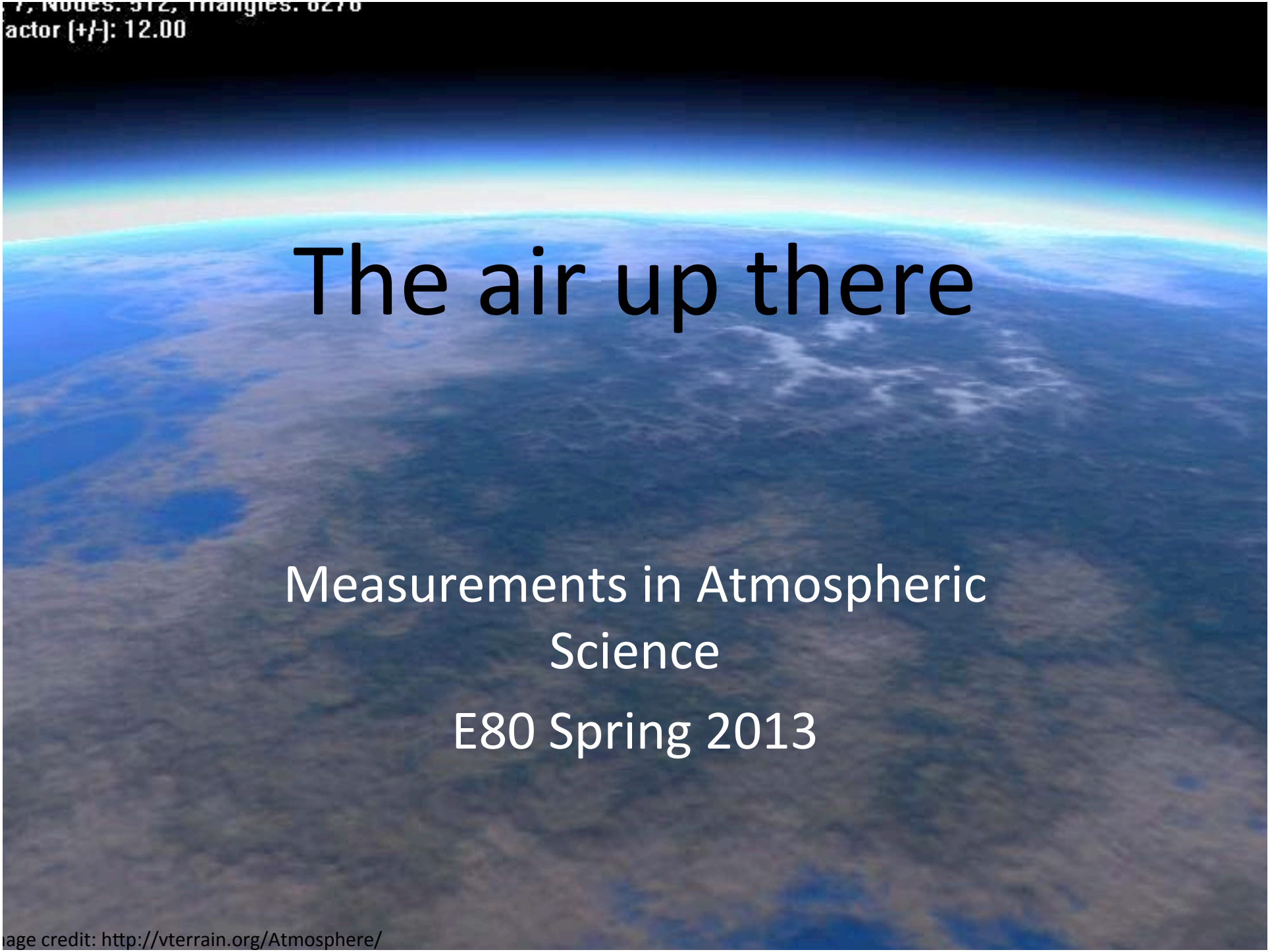


The air up there

Measurements in Atmospheric Science

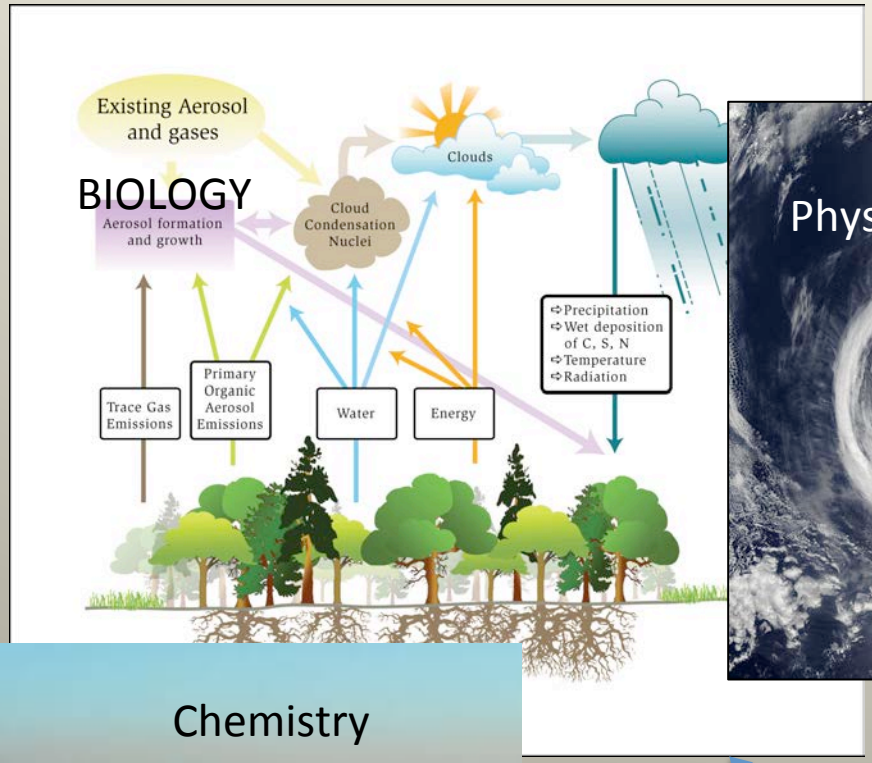
E80 Spring 2013

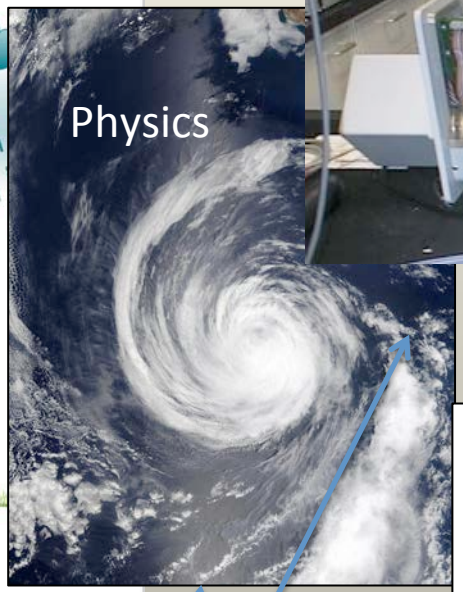
age credit: http://vterrain.org/Atmosphere/

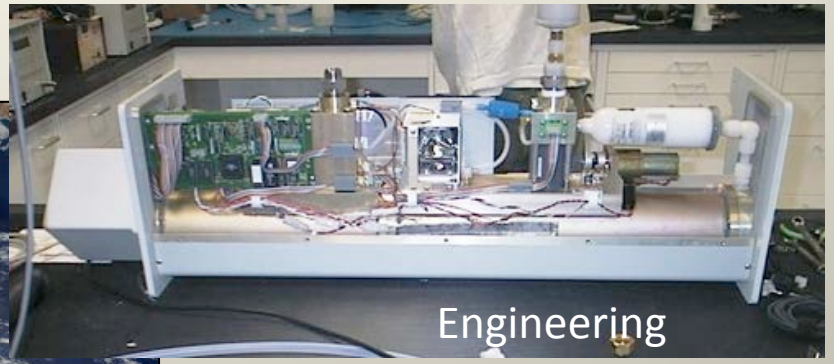
Concepts in Atmospheric Science

- Atmospheric science across the disciplines
- The basics
- Why atmospheric measurements?
- Platforms for atmospheric measurements
- What you might consider for your rocket
- Where did the air come from? HYSPLIT models

Atmospheric Science across the disciplines







Mathematics

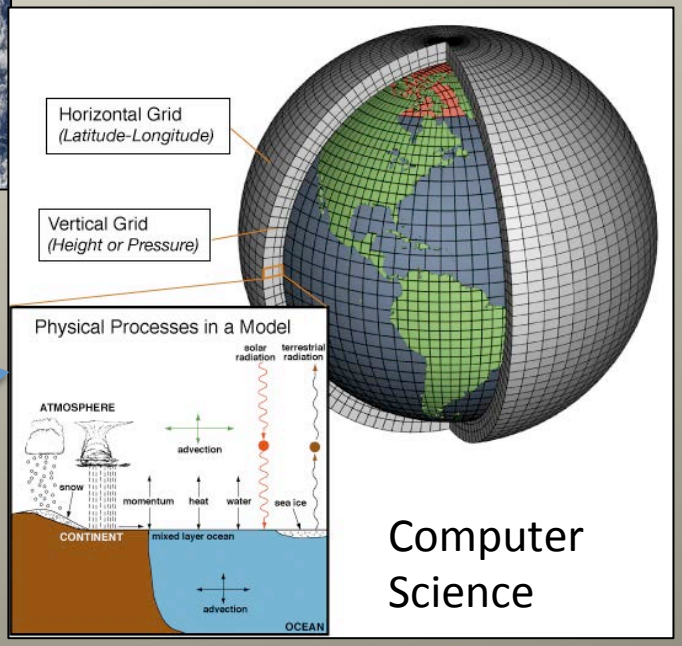


Image credits: atmos.washington.edu, acd.ucar.edu, caice.ucsd.edu, oar.noaa.gov, chemwiki.ucdavis.edu

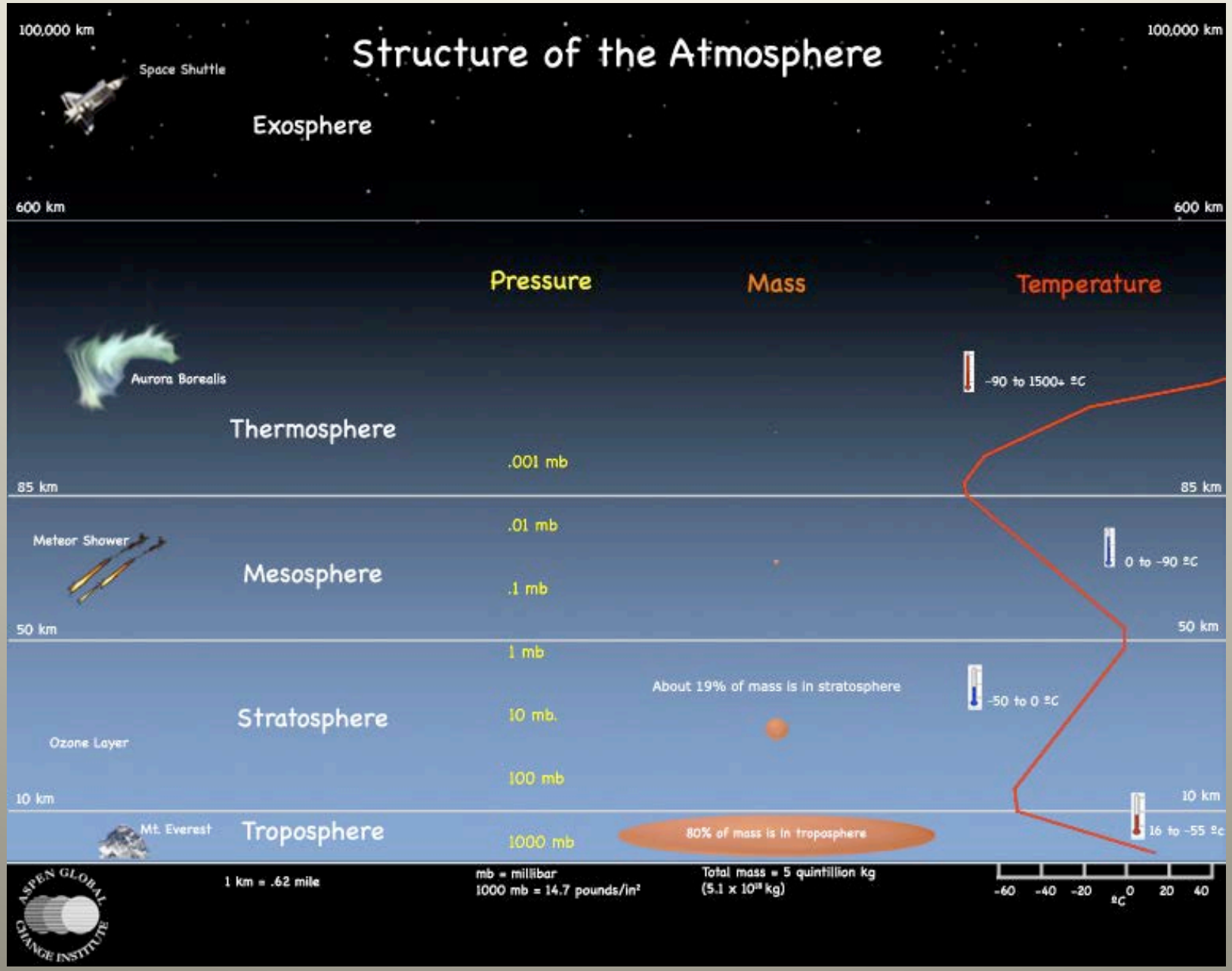


Image credit: agci.org

Planetary boundary layer vs the free troposphere

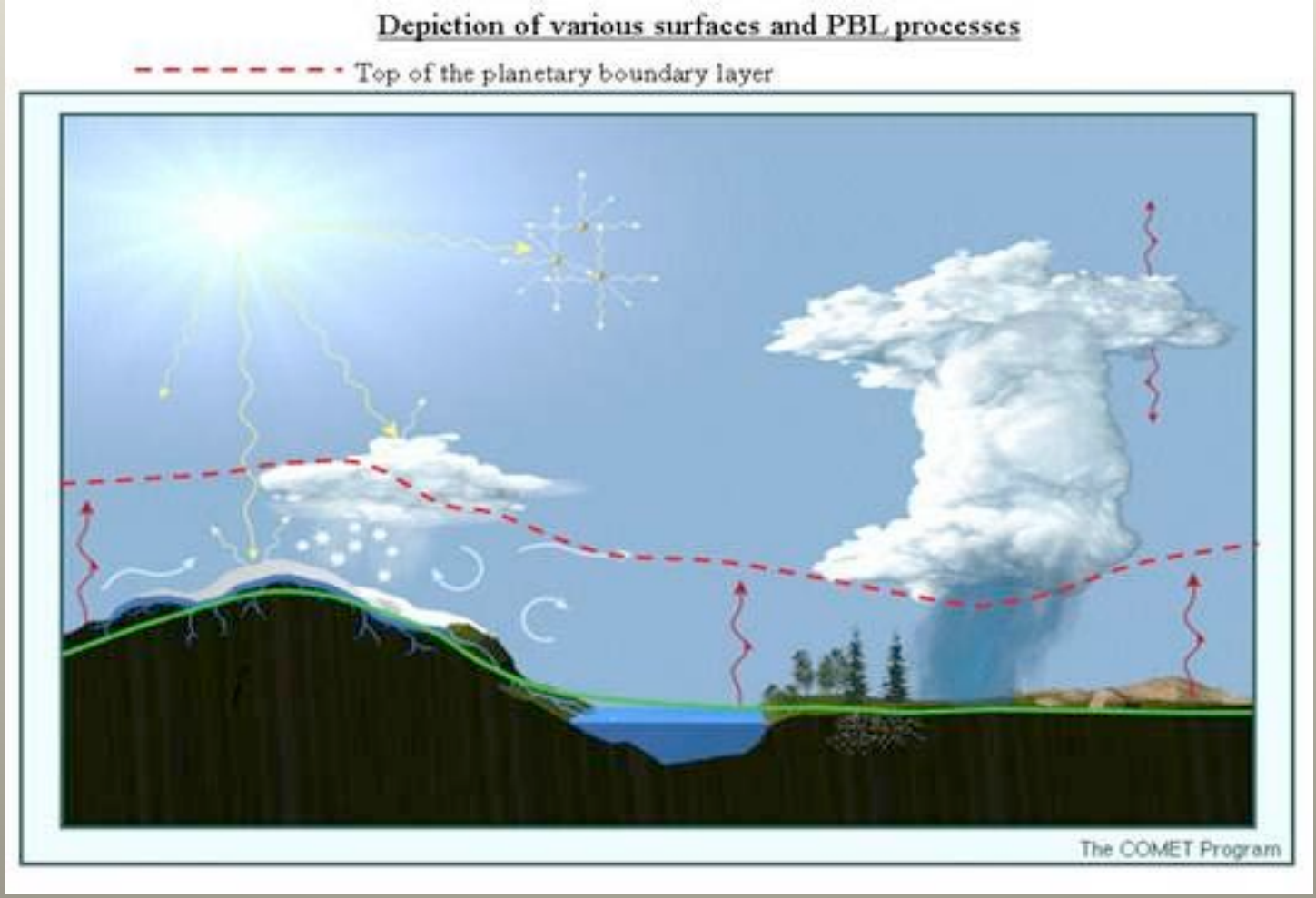


Image credit: esrl.noaa.gov

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).

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

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

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.

Outliers: How NASA "missed" the ozone hole

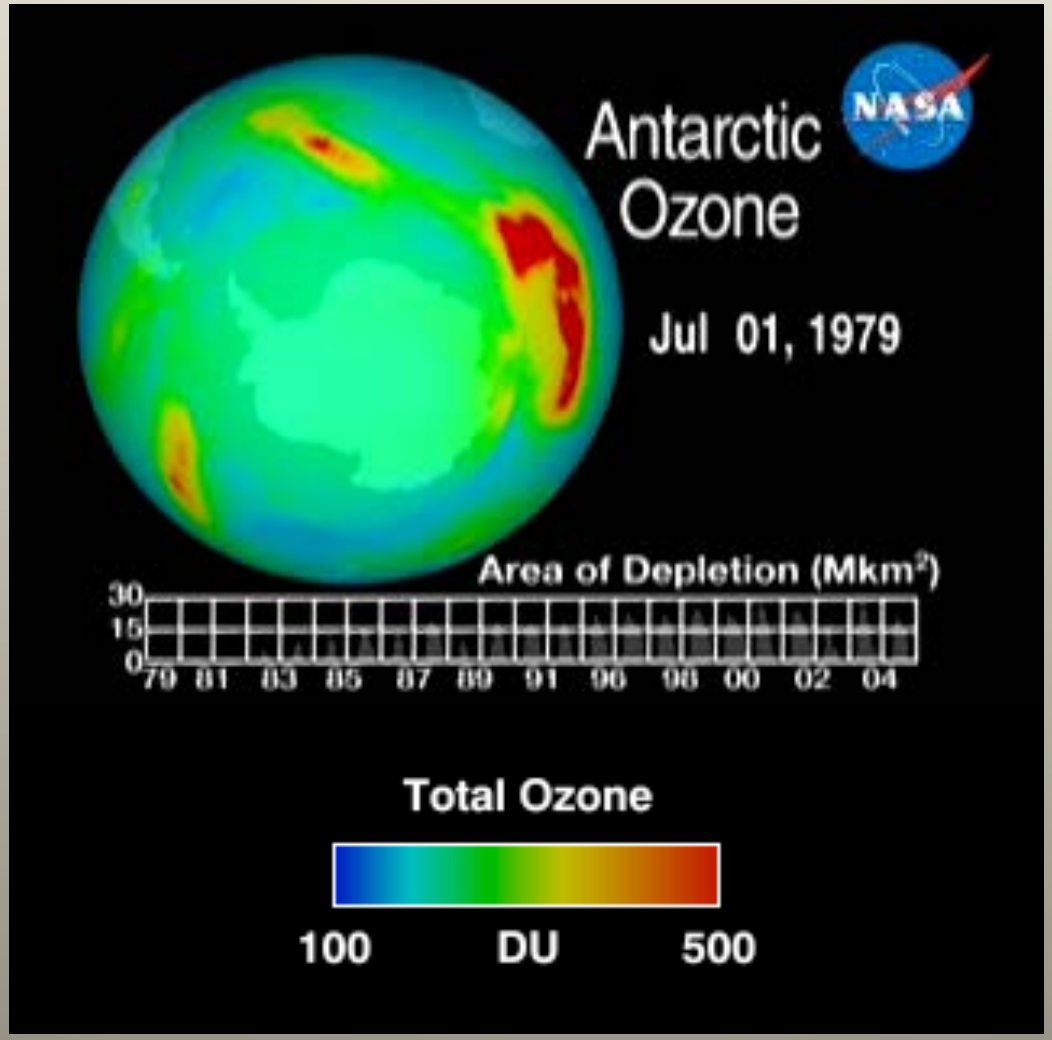
"Our software had flags for ozone that was lower than 180 DU, a value lower than had ever been reliably reported prior to 1983.

In 1984, *before publication of the Farman paper*, we noticed a sudden increase in 'low value' from October of 1983. We had decided that the values were real and submitted a paper to the conference the following summer when Joe's paper came out, showing the same thing.

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."

Visualized

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



Pay attention to southern hemisphere spring!

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.
- Cross border pollution issues

Introduction to Atmospheric Aerosols:
Particle Sources

Primary particles are <u>emitted as liquids or solids</u> to the atmosphere.

Secondary particles are <u>emitted as gas phase</u> components and later condense to form particles.

Primary particles that are transported in the atmosphere can <u>accumulate mass</u> from secondary components.

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

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

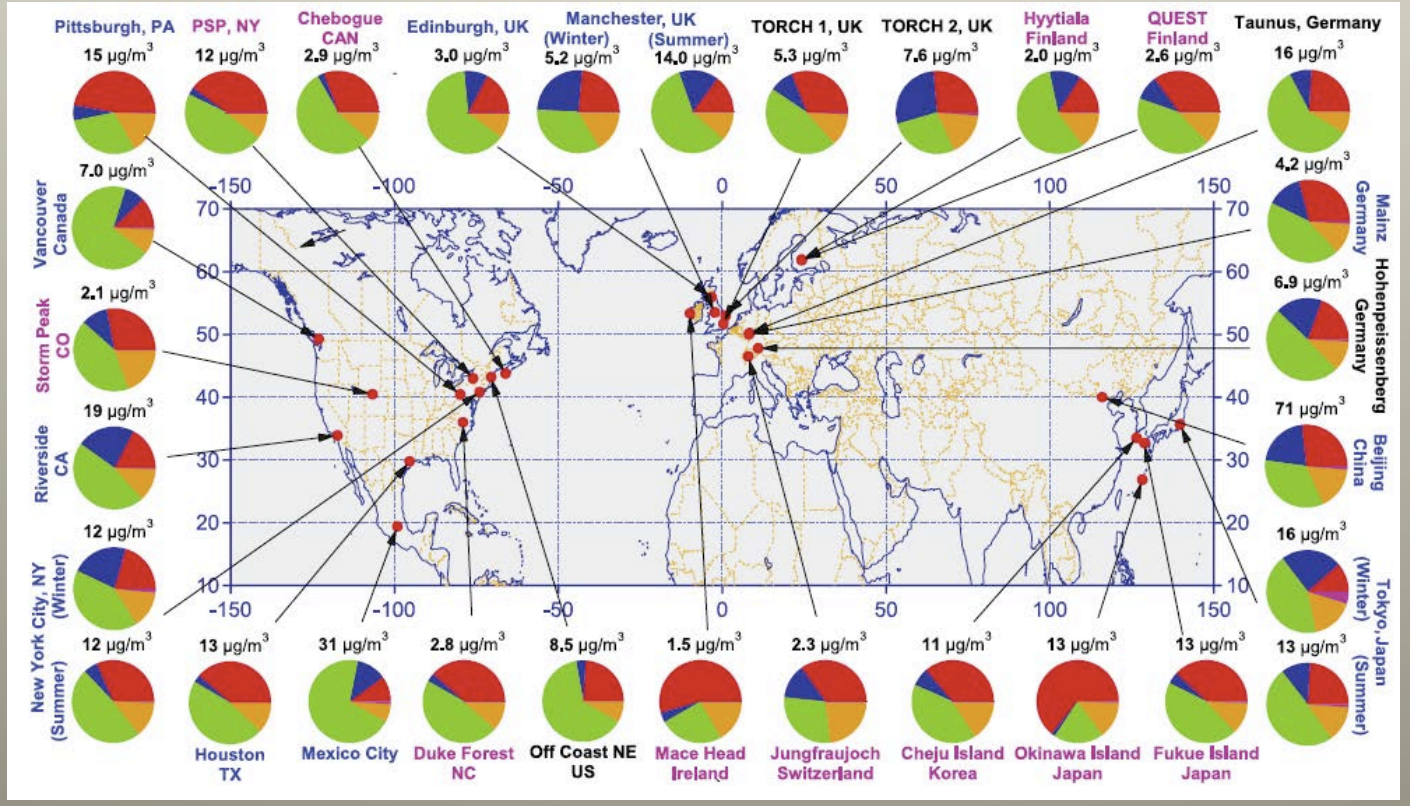
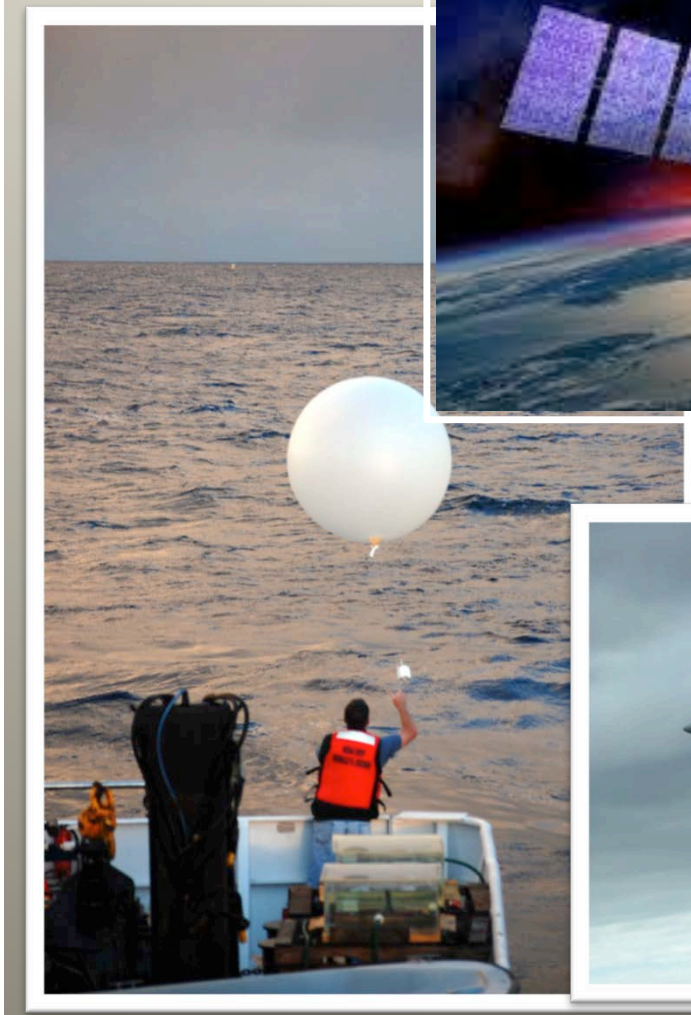
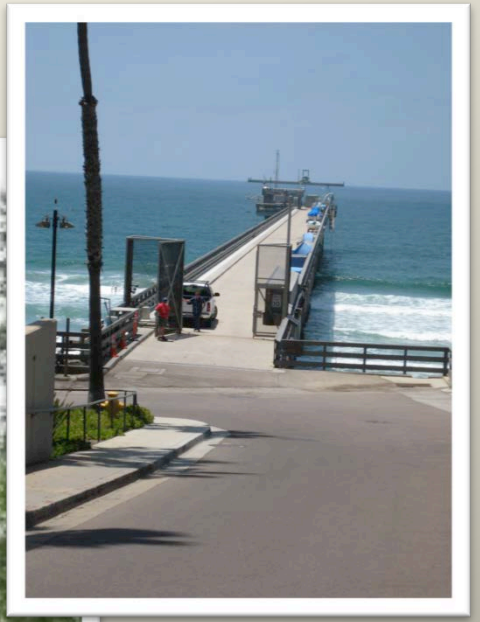
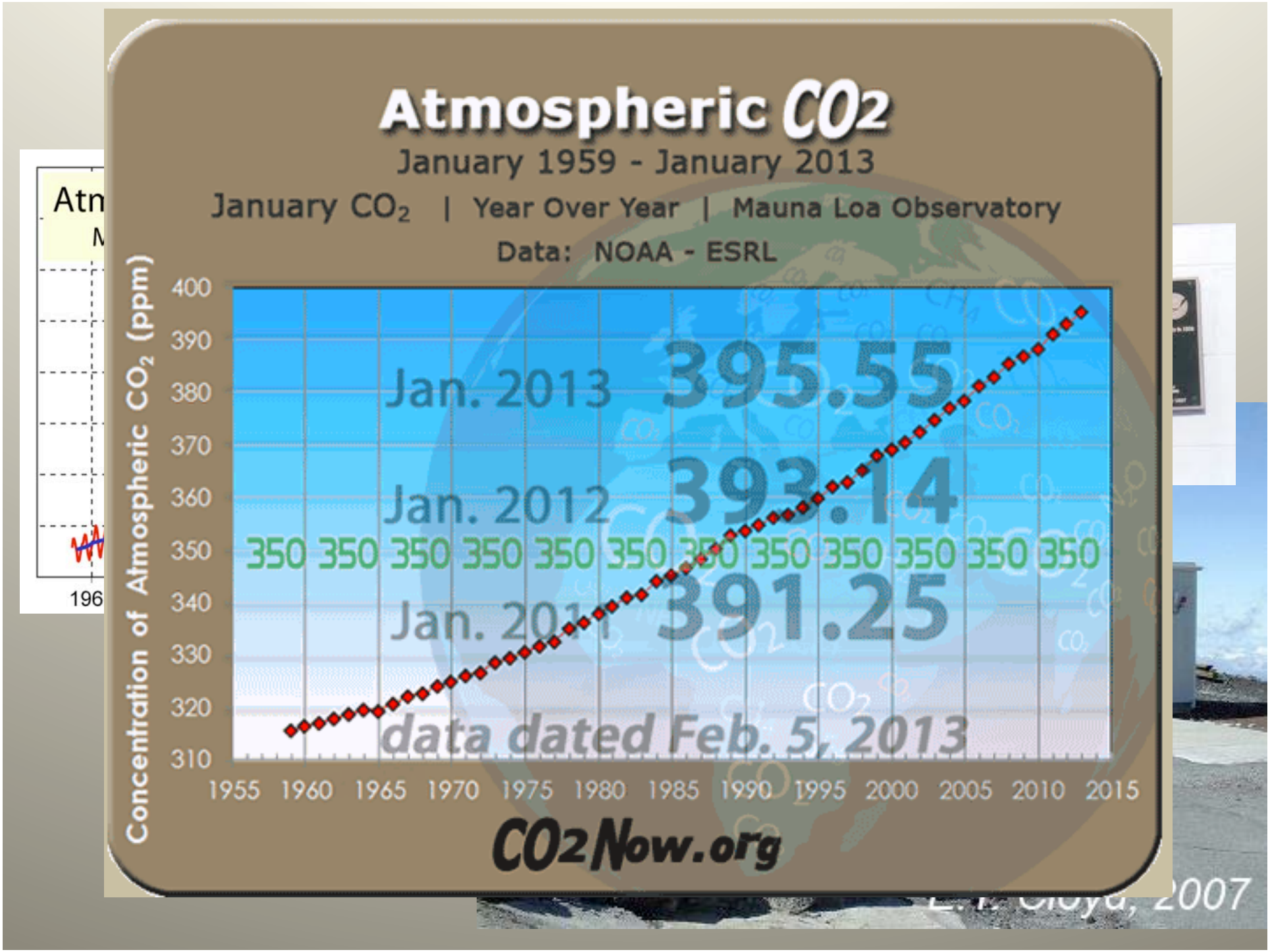


Figure from Zhang et al., 2007 GRL

Where are measurements made? And how?

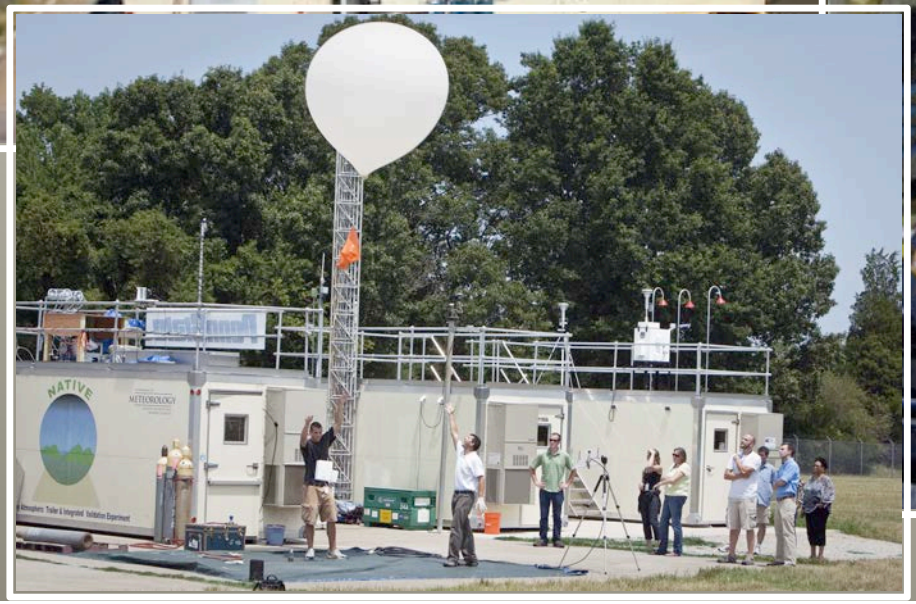





Atmospheric CO2
January 1959 - January 2013
January CO2 | Year Over Year | Mauna Loa Observatory
Data: NOAA - ESRL
Concentration of Atmospheric CO2 (ppm)
400
390
380
370
360
350
340
330
320
310
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Jan. 2013 395.55
Jan. 2012 393.14
350 350 350 350 350 350 350 350 350 350 350 350
Jan. 2011 391.25
data dated Feb. 5, 2013
CO2Now.org

Importance of collaboration

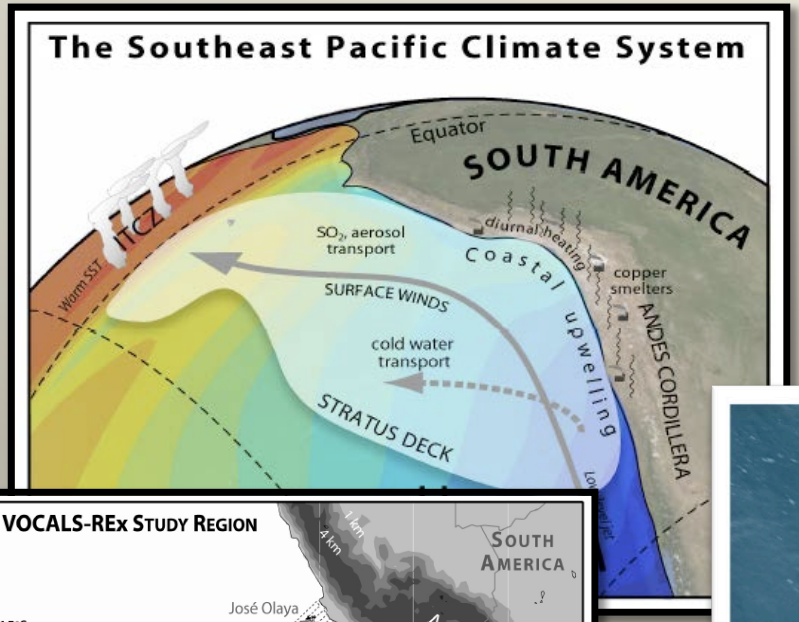
Calnex Field Study

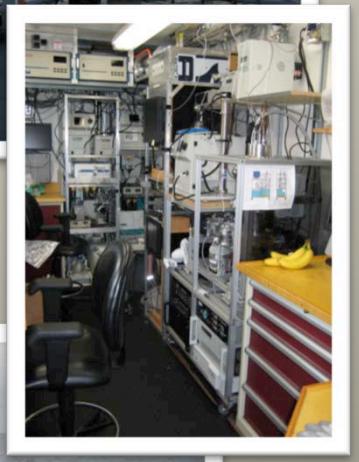


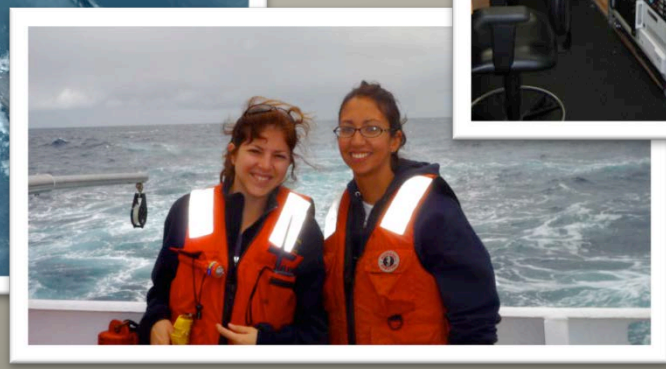
MILAGRO, Mexico City

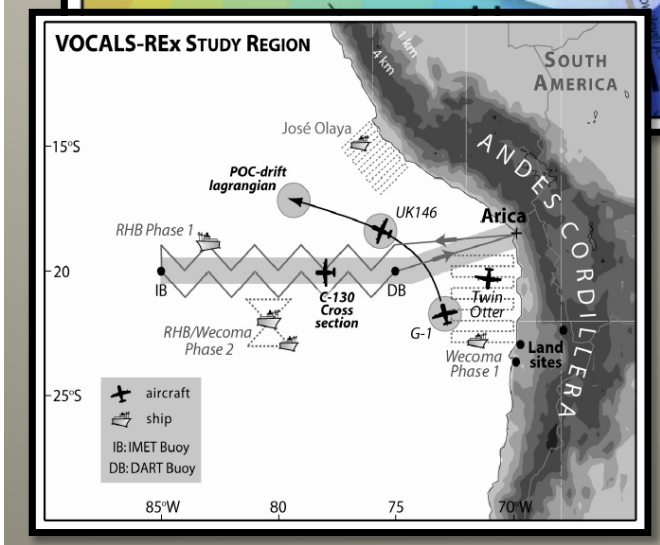
Inside a C-130 airplane during MILAGRO

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





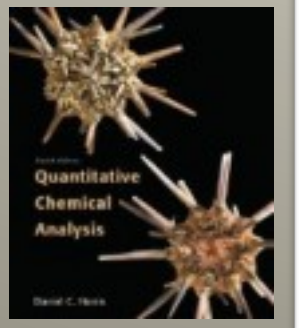




Wood et al., 2007 Program Summary

Calcareous Phytoplankton Fragments: Phytoplankton in the air?

• 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

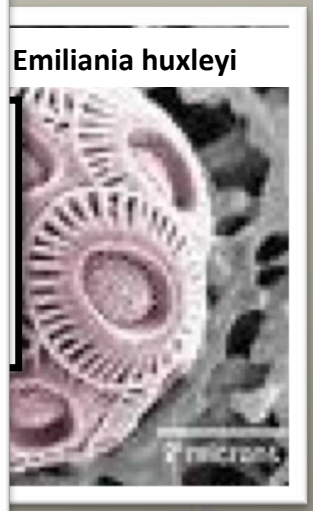


Barents Sea on 1 August 2007: bloom covering approximately 150,000 km^2.

Harris, 8th ed.
Coccolithophores produce 1/3 of all oceanic $CaCO_3$ and the average mass of E. huxleyi is increasing in response to ocean acidification.

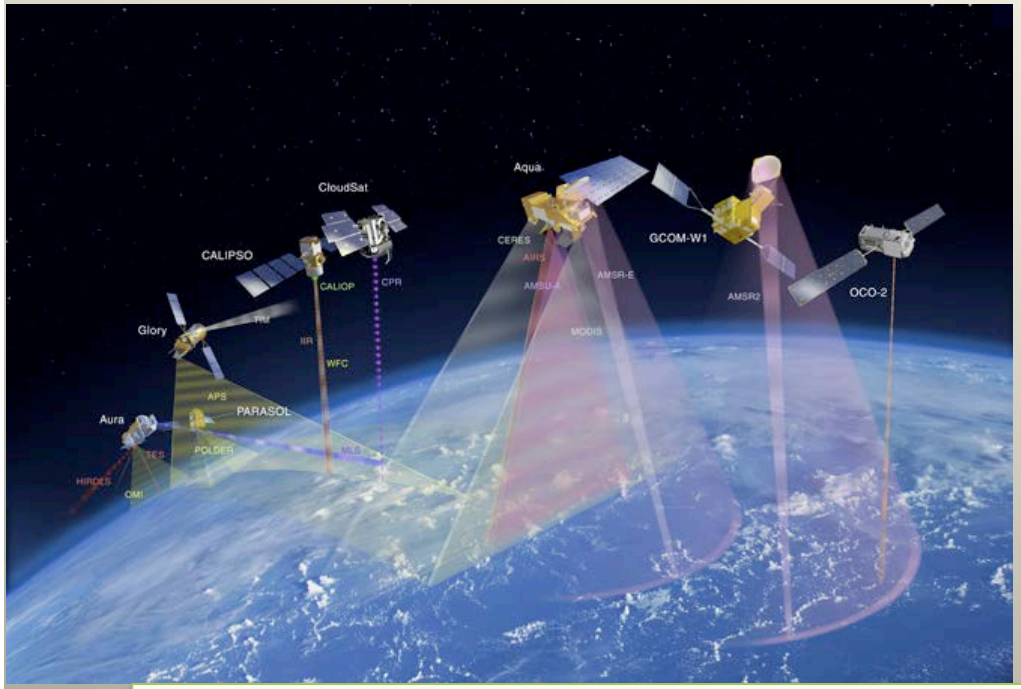
Can these phytoplankton keep up with our changing planet?

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



Hawkins and Russell, 2010b

NASA's A-Train



- Crosses the equator around 1:30 pm daily.
- Together they measure 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?

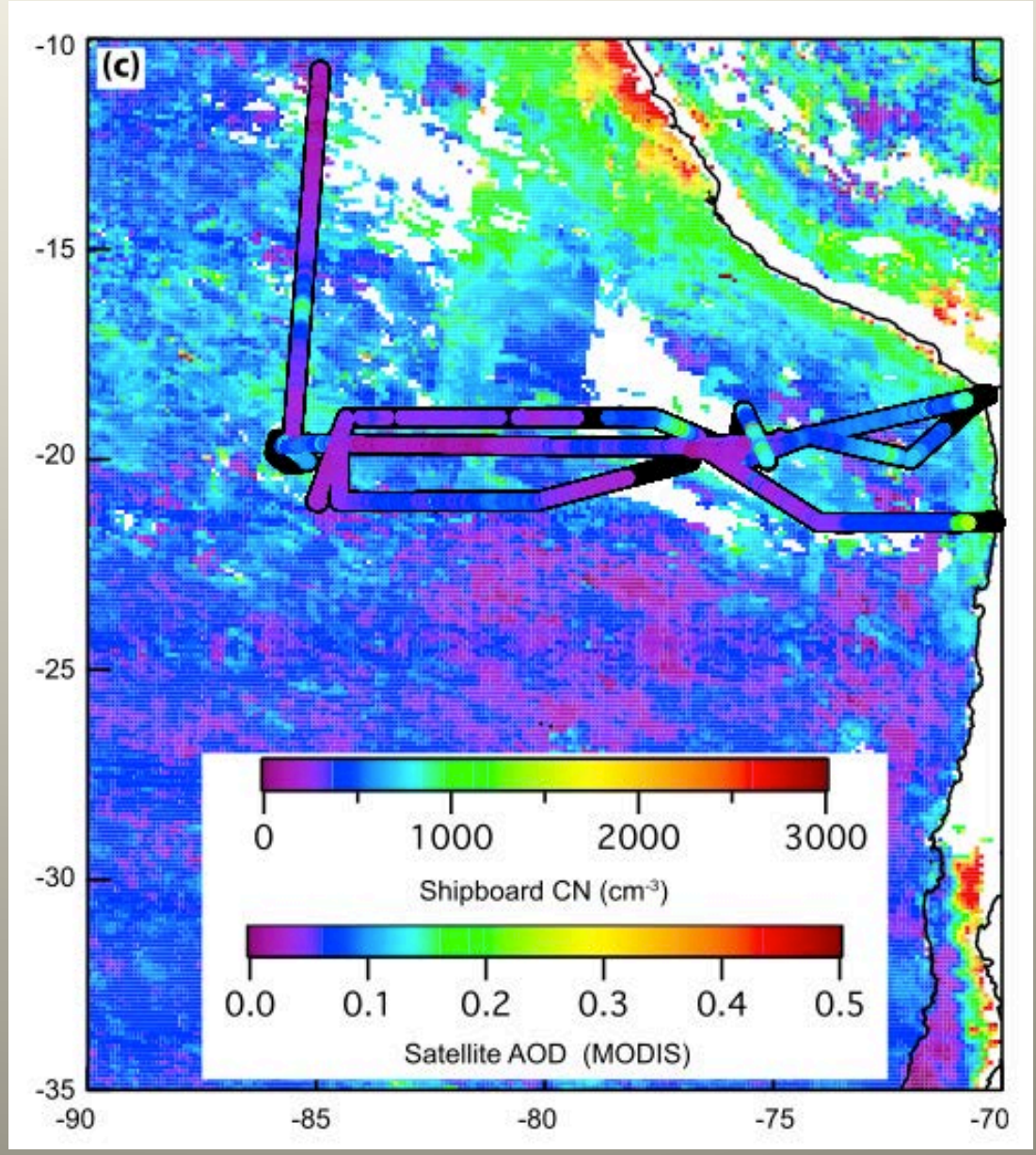
How will the monsoon cycle react to a warming world?

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

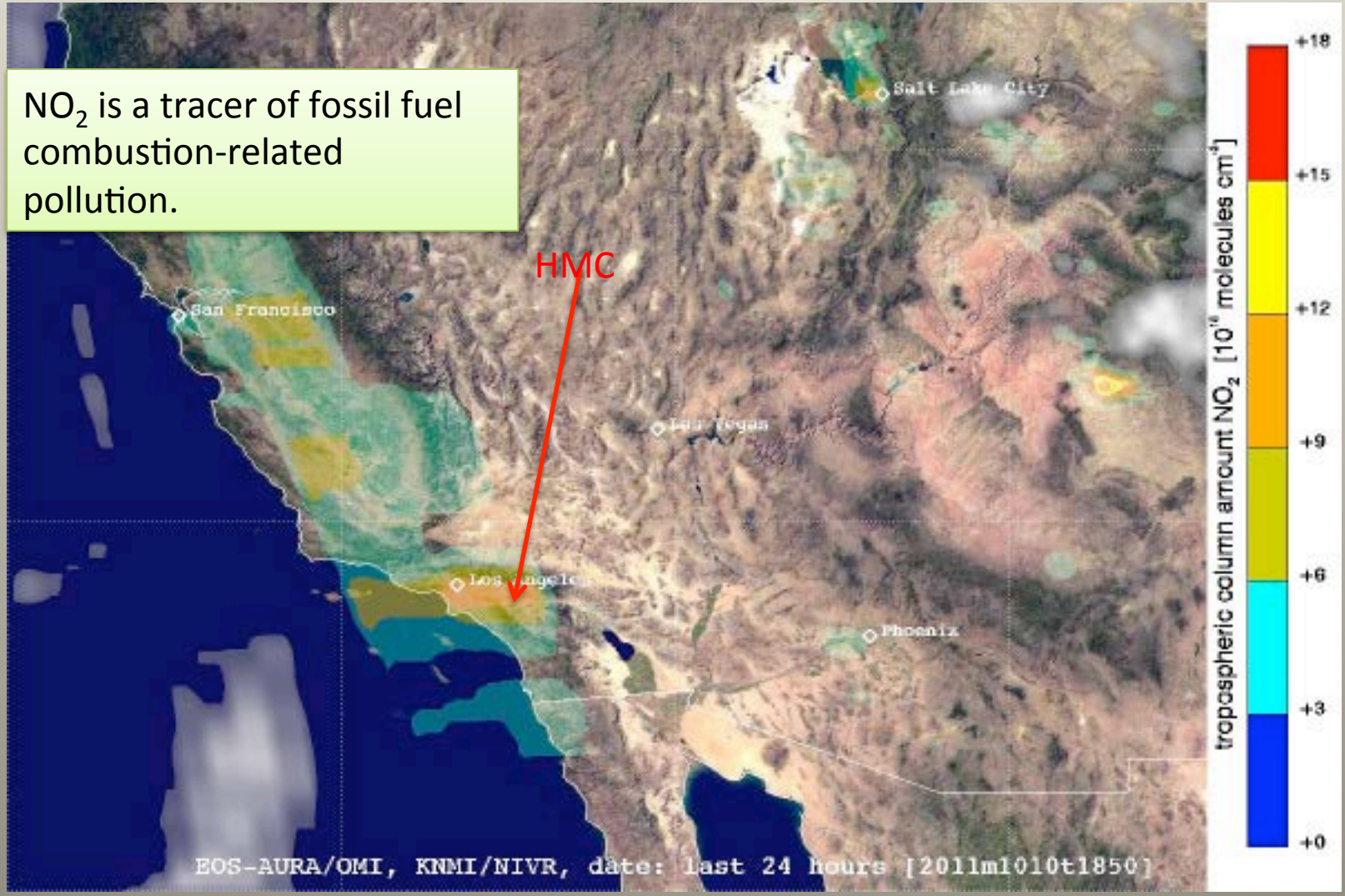
And what feedback cycles will encourage or discourage climate change?

Particle concentration by satellite

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

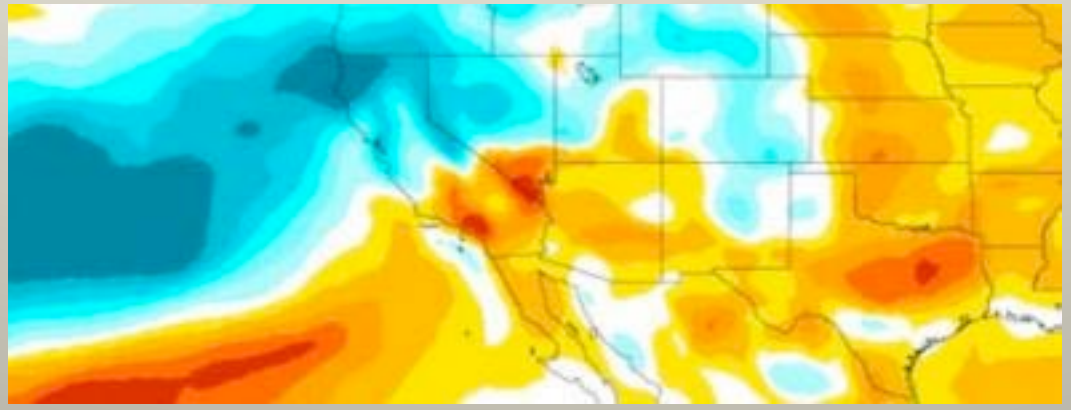


What can satellite spectrophotometry do?



A great place to know about: NCAR

- Models



- Measurements

- Black carbon and sea ice

What might rockets add?

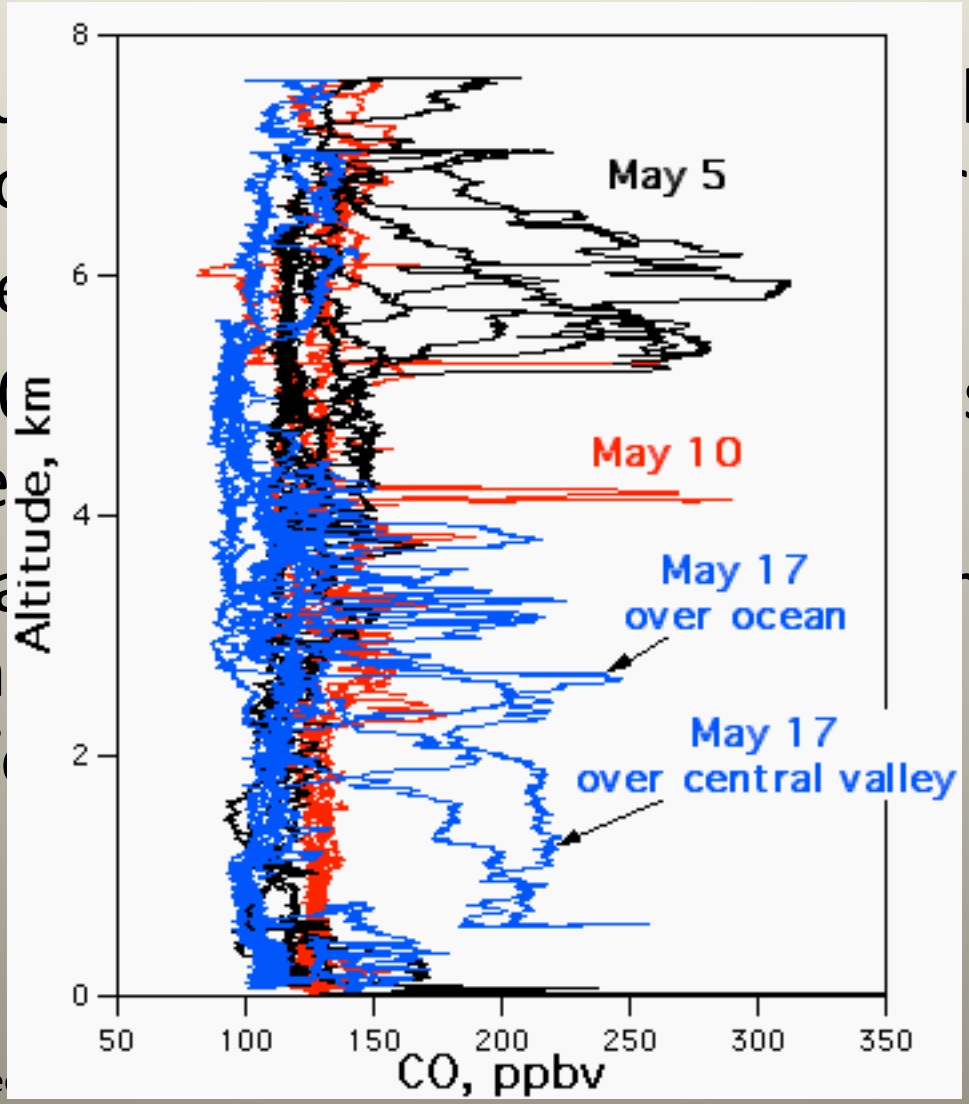
- Climate model “ground truthing”
- Repeatable, local measurements
- Very high altitude studies (not yours), most useful above altitude for balloons (40 km) and below satellites (recall collaboration!).
- Lower cost than a fully instrumented aircraft
- Can be launched from remote locations (ships etc).
- 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.
- Could you collect a sample of particulates? I have small discs that could be used to impact particles on during flight.

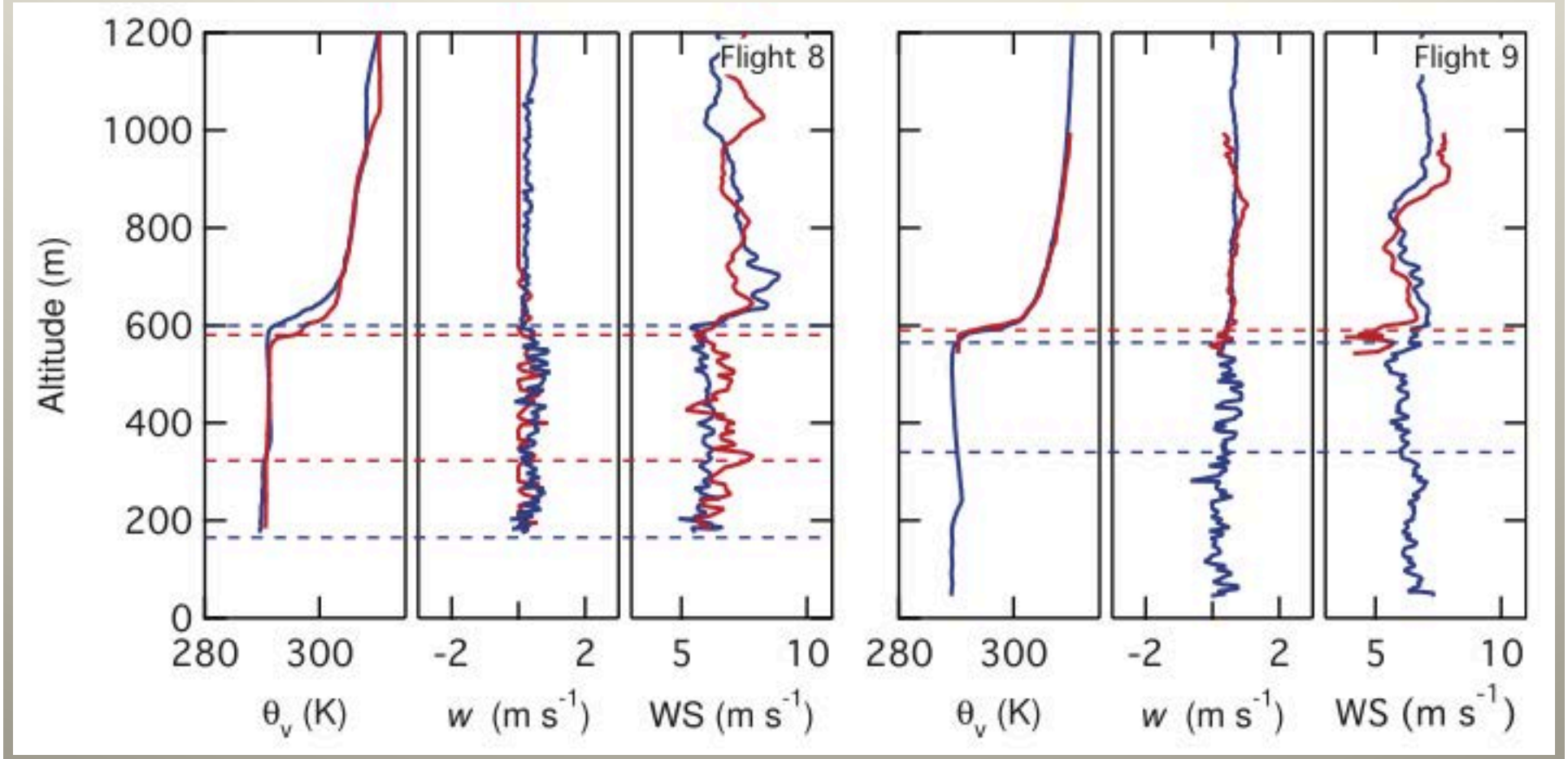
What's cool about CO?

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

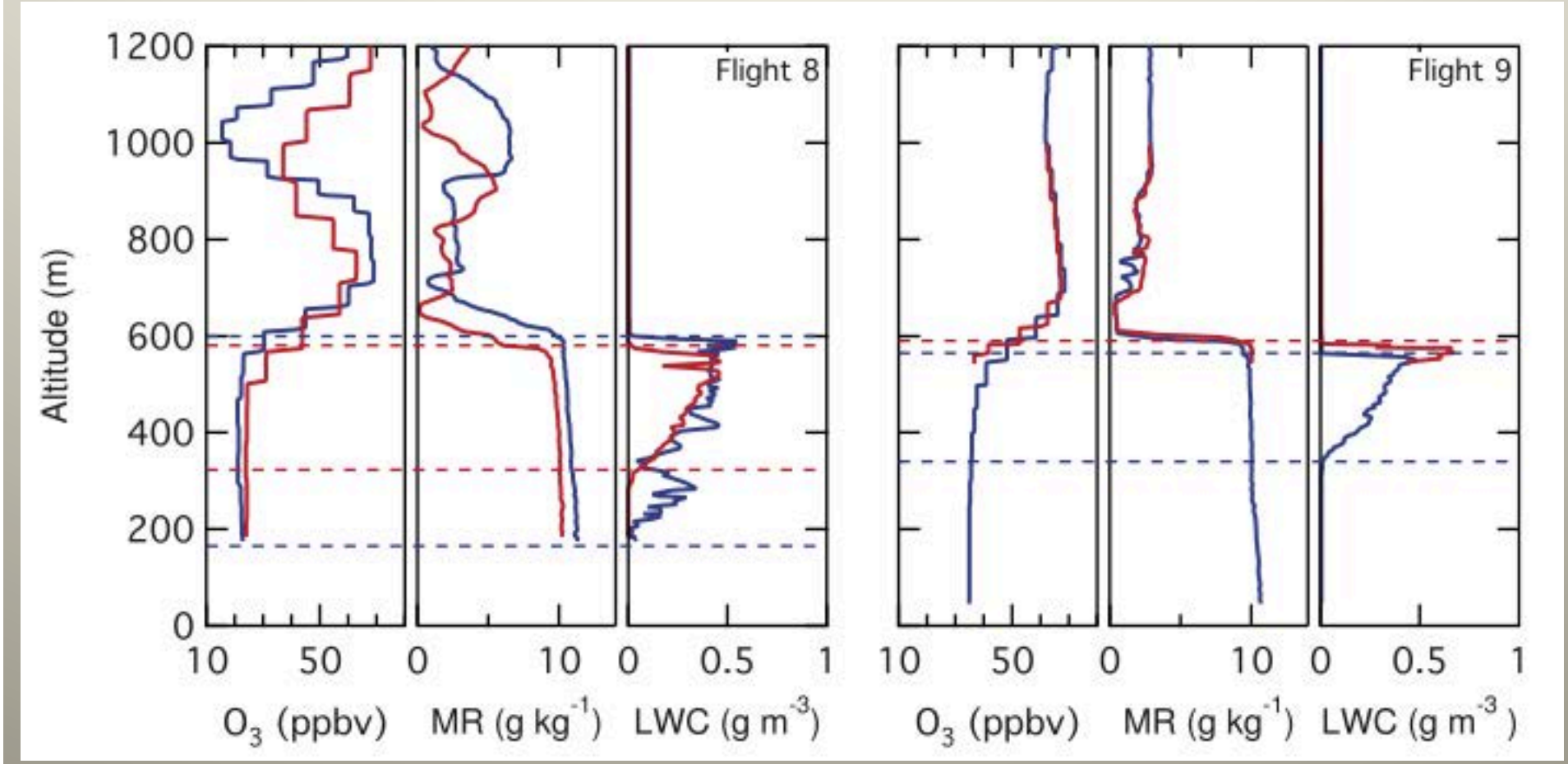


http://www.esrl.noaa.gov/csd/proje

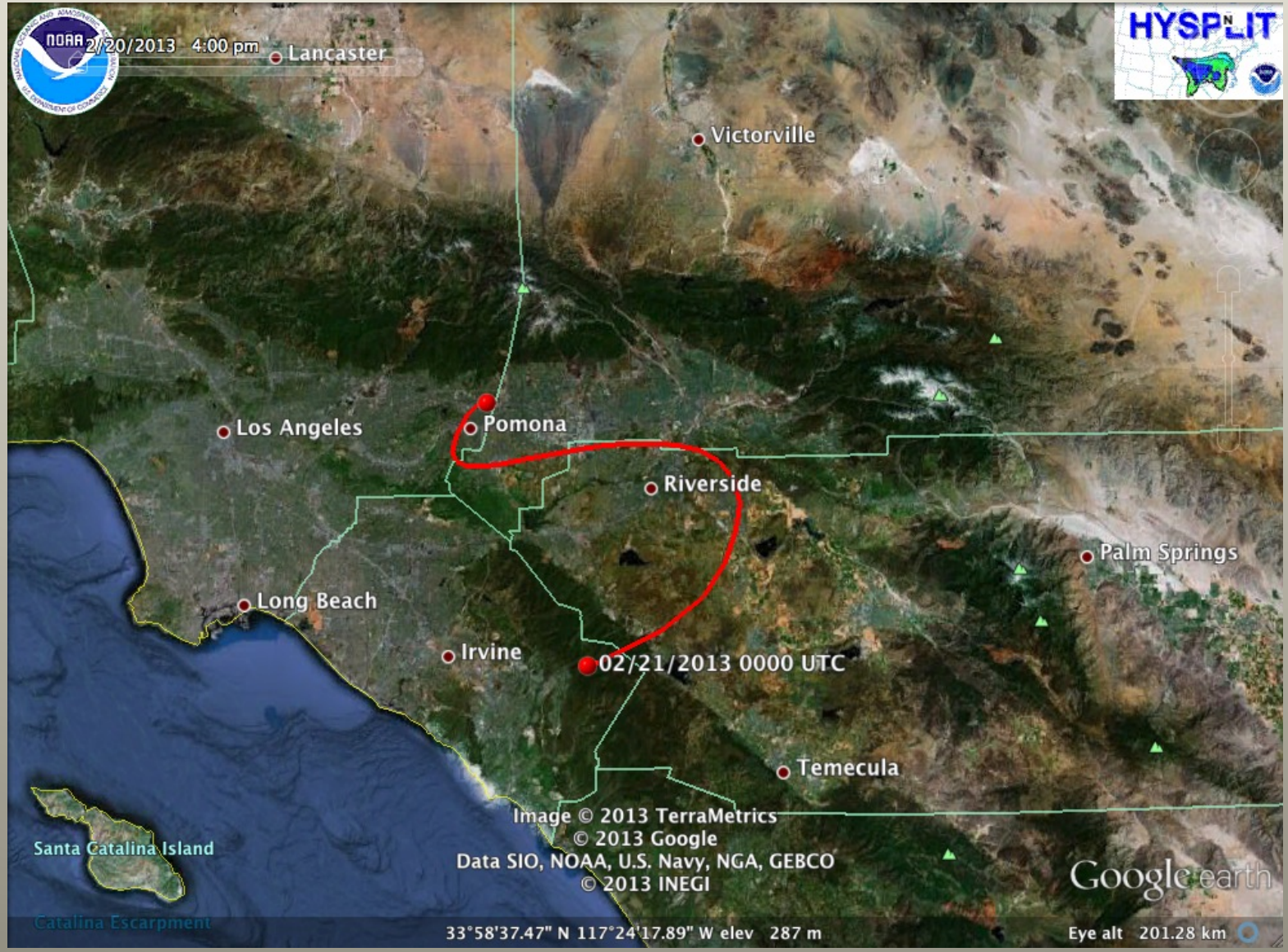
Vertical Profiles are telling



Cloud layers in vertical profiles



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!