The air up there

Measurements in Atmospheric Science

E80 Spring 2016

Image credit: http://vterrain.org/Atmosphere/
For La Nina winters, cloud seeding
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?

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

3. Basic concepts in atmospheric science

Image credit: agci.org
Radiation Inversion

Temperature reduces with height above the inversion layer.

Warmer layer of air above remains unaffected by the cold surface.

Lower layer cools by contact with the cold surface.
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.”
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?
One of the most important atmospheric measurements of our time was performed by Charles David Keeling.
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)

The Southeast Pacific Climate System

VOCALS-REx Study Region

Wood et al., 2007 Program Summary
MAGIC: Using cargo ships for atmospheric research

MAGIC takes place on the Horizon Lines Cargo container *Spirit*.

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?

NO$_2$ is a tracer of fossil fuel combustion-related pollution.
Role of NO$_x$ in photochemical smog
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 sources are anthropogenic (combustion) and photochemical processing of other pollutants.
- 60 day life time.
- About 1000 Tg C per year from human sources (compare to 150 Tg C per year natural).
- It makes a great tracer for anthropogenic activity (people normalize their measurements to CO to account for dilution).

[Image: CO concentration over different altitudes and dates]
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:
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 O₃

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

1984: Joseph Farmer and colleagues at British Antarctic Survey measure O₃ with a Dobson Spectrophotometer and discovered that it was 35% lower than 1960 levels

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

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

1986: Mission to Antarctica in local spring (August) organized by S. Solomon (NOAA)
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
Particles enriched in Ca (relative to sea water) have been attributed to coccolithophores [Sievering et al., 2004].

Other types of phytoplankton (diatoms) have been observed in aerosol samples [Leck and Bigg, 1999; 2005].

Coccolithophores produce long-chain hydrocarbons called alkenones, containing many repeating units of -CH₂.

Previously unknown to exist in the atmosphere at 200 nm (thought to be confined to sizes larger than 1 micrometer).

Calcareous Phytoplankton Fragments: Phytoplankton in the air?

Barents Sea on 1 August 2007: bloom covering approximately 150,000 km².

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

Hawkins and Russell, 2010b
Coupling rockets with models