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1. Course Overview

- Lectures are important but irregular - sometimes on Tuesday, sometimes on Thursday. See schedule and watch web page or follow lectures for possible changes.
- Exercises are more important. Six exercise sheets will be distributed and each will be discussed in more than one section, with possible exception of the last one.
- Regular attendance in lectures and exercises is expected.
- Course grade will be based on an oral examination joint with thermodynamics. Dates are fixed for the 14-16.2.2010.
- A certain amount of background knowledge is assumed - some of this is reviewed in first exercise sheet, see also first exercises.
- References that you might find useful are given on the syllabus, many of these we hope to reserve in the library.
- Course webpage and librarian reserve list should be available by the end of this week.
2. What Is A Cloud?

A cloud is in first place a dispersion - often a dispersion of particles in suspension. Here we can think of a cloud of dust or even a smoke cloud. More generally we hear phrases like cloud computing, the dispersion of signals across the internet.

In the atmosphere we speak of a cloud as a dispersion of water in the condensed phase some in suspension - that is to say floating in the air. Moreover we speak of suspensions that are visible to the eye, so in regular terms clouds are identified as mostly by their optical properties as by their physical properties. A cloud boundary is defined by the line where the dispersion becomes too dispersed to see. But this depends on how well we can see, and how well the cloud is illuminated.

Can a cloud exist if it is too dark to see it?

Can a cloud exist if it is too thin (too dense) to be seen with the naked eye?

If clouds can be arbitrarily dispersed then how do we define how Cloud Boundaries are

If we can not define where a cloud boundary is how can we say how cloud it is.

The question: how cloudy is it is a very common question, but one that proves difficult, perhaps somewhat to answer precisely, because the answer depends so much on how you define a cloud - or a cloud boundary. Nonetheless it is an essential one.

If we think of clouds as suspensions then the question is: suspensions of what? The atmosphere contains suspensions of many types of particles - all in "drying states" of suspension. The smallest component of the atmospheric aerosol have a size of a.m. the largest hydrometeors are tens of cm.

- Sam Dinnager
- Newt Fomon Aerosol Particle
- 20cm Hailstone
This is an enormous range in size
\[ D = 10^{-9} \text{m} - 10^1 \text{m} \sim 10^8 \]

If mass is proportional to diameter cubed then this range is \( 10^{24} \)

Main different types of particles and as a rule the smallest are the most prevalent. Clouds are associated with a small subset of these particles. Those associated with water condensation or sublimation.

\[ \text{Ice Crystals} \quad \text{Ice} \quad \text{Ice} \quad \text{Ice} \]
\[ \text{Acrosa} \quad \rightarrow \quad \rightarrow \quad \rightarrow \]
\[ \text{Water} \quad \text{Water} \quad \text{Water} \quad \text{Water} \]
\[ \text{Droplets} \quad \text{Droplets} \quad \text{Droplets} \quad \text{Droplets} \]
\[ 10 \mu \text{m} \quad 100 \mu \text{m} \quad \text{Rain} \quad \text{Rain} \]
\[ \text{Droplets} \quad \text{Droplets} \quad \text{Droplets} \quad \text{Droplets} \]
\[ 10 \mu \text{m} \quad 100 \mu \text{m} \quad 10 \mu \text{m} \quad 10 \mu \text{m} \]
\[ 1 \text{mm} \quad 1 \text{mm} \quad 1 \text{mm} \quad 1 \text{mm} \]

Small drops or spheres sediment slower
\[ v \sim D^2 \] so a 1 mm across has \( \sim 35 \text{mm/s} \)
10 \( \mu \)m Droplet has \( \sim 3.5 \text{mm/s} \)
100 \( \mu \)m Drizzle has \( \sim 35 \text{cm/s} \)

The time a particle takes to fall decreases

Linearly on its fall speed so small particles sediment or fall, more, more slowly, which explains their generally higher concentrations

While a drizzle droplet can take 45 minutes to fall 1km a large raindrop can fall 1km in 2min.

Precipitation - or Niederschlag is associated with particles that easily, open formation fall out of the sky.
So clouds for the most part are suspensions of small water droplets or ice crystals. They are necessarily dispersions, but not so dispersed as to be invisible.

The visible properties of clouds come from their ability to scatter radiation. This depends on the density of the cloud dispersion and the size of particles within the dispersion.

\[ A = A_{\text{Albedo}} \]
\[ A = \frac{T}{4 + T} \]
\[ T = L S N N^{1/3} \]
\[ L = \int N \cdot D^3 \cdot q \cdot n \cdot dA \]

The albedo of clouds depend on the amount of liquid in suspension and how it is distributed. If it is distributed in more and smaller drops then it reflects more.

The important point is that the microphysical structure of clouds—The detailed structure of the dispersion matrices both for the radiative properties of clouds, and their tendency to form precipitation.

**Key Points:**

1. A cloud is a dispersion in suspension—very hard to define precisely and quantify absolutely.
2. The character of this dispersion varies and matters is important.
5. Why are we interested in clouds

1) Because they are the vessels in which precipitation is developed — because they precipitate

2) Because they reflect radiation

3) Because they effectively emit and absorb terrestrial radiation

Some interesting facts about rain. The rainiest places on Earth get about 100 cm rain per year. In some years almost 30 cm of rain. Compare this to Hamburg which receives 770 mm of rain per year. The rainiest place in Germany is in the Allgau — Balderschwang in Bayern — 2460 mm of rain. The driest place is in Saxon-Anhalt, Aßberg. Reaches ~ 400 mm rain per year. A factor of eight difference.

The most rainfall in 1 hour minutes ~ 0.38 cm on Guadeloupe in the Caribbean. In 12 hours 1.35 m on La Reunion — both islands.

A bit of a pattern — rainy where it is warm, dry and more, but also hilly. Obviously the issue of rain formation has to do with more than microphysics, but also cloud and atmospheric dynamics.

The effect of clouds on visible radiation is to reflect it — this covers like planets. Altogether clouds reflect about 50% of radiation. Global warming effect of doubling CO2 has a net effect of about ~ 3 W m⁻².

But some of this effect of clouds is reduced because clouds also absorb and emit longwave radiation. The longwave effect of clouds amounts to about 25 W m⁻² of radiation.

For most situations, take ~ 30 W m⁻².
These values are global averages, locally the effects can be many times larger. The net effect of cloud depends on both the Sun (Solar Radiative Effect) and the LW (Infrared/Terrestrial Radiation) effect.

This in turn depends on cloud geometry, height thickness, as well as cloud microphysical properties.

4. Clouds Depend on Many Factors. Large Scale

Dynamic and Thermodynamic Processes govern the conditions that lead to the formation of clouds. Microphysical processes then influence the subsequent evolution of the cloud. Many of these microphysical processes depend on the form and distribution of the cloud droplets or ice crystals that initially form in clouds and this in turn depends on the character of the atmospheric aerosol.

Dynamic Process → Rate of Cooling and
Hence Production of Supersaturation

Initiate Microphysical Development → Evolution of the Cloud

+ Chemical Processes
Important Point: How important cloud microphysics processes are to the structure and distribution of clouds and radiation is not well understood - they are just one part of the puzzle of clouds. 

5.

We care about cloud microphysics because it connects the detailed structure of the cloud to the processes we care about - radiation and precipitation.

6. Different Ways of Classifying Clouds

- Cloud Types

  - Stratus
  - Altostratus

  - Cumulus
  - Cumulonimbus

  - Cirrus
  - Cirrostratus

www.wolkenatlas.de — Many Examples

Luke Howard applied Linnaean principles of natural history to name clouds - one of his admirers was Goethe - Carolus Linnaeus.


Goethe 1749 - 1832.

From satellites: Cloud top temperature & optical depth.

Midrange - low - high clouds as short cut for radiation.
Key Points

1. Intro - Syllabus Exercises

2. What Is A Cloud
   - Dispersion
   - Suspension
   - Problem Of Defining A Cloud
   - Micrometeor Theory / Properties

3. Our Interests In Clouds
   - Precipitation Facts
   - Sun Cloud Effects
   - LW Cloud Effects

4. Cloud Physics: OS Dynamics / Chemistry/Aerosol

5. Why Microphysics: AS A Bridge

6. Cloud Classification
   - From Harris to KCCO