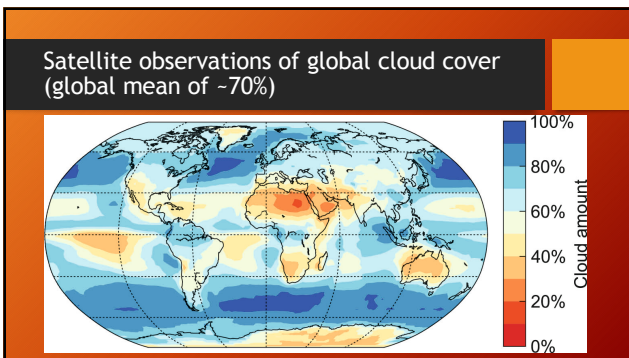


Lecture 1, GEF4310 "Cloud Physics"

Trude Storelvmo, Dept. of Geoscience, U. of Oslo
Spring 2018

Schedule, Spring 2018

Week #	Monday (exercises)	Tuesday (lectures)
1	(15/1) No class	(17/1) Introduction and descriptive overview of clouds (Ch. 1)
2	(22/1) No class	(24/1) Thermodynamics (Ch. 2.1 - 2.3)
3	(29/1) Thermodynamics exercises	(31/1) No class
4	(5/2) No class	(7/2) Thermodynamics (Ch. 2.4 - 3.5)
5	(12/2) Thermodynamics exercises	(14/2) Stability & convection (Ch. 3.1.5, 3.2, 3.3 and 4.2)
6	(19/2) Stability/convection exercises	(21/2) Atmospheric aerosols (Ch. 5)
7	(26/2) Aerosols exercises	(28/2) No class
8	(5/3) No class	(7/3) Droplet formation (Ch. 6)
9	(12/3) Droplet formation exercises	(14/3) Warm cloud microphysics (Ch. 7)
10	(19/3) Warm cloud microphysics exercises	(21/3) No class
11	Friday 23/3 Mid-term exam (NOTE: extra Q&A class will be scheduled this week)	(28/3) No class (Pisake)
12	(26/3) No class (Pisake)	(4/4) Ice nucleation (Ch. 8.1 and 8.2)
13	(2/4) No class (Pisake)	(11/4) No class (EGU)
14	(9/4) No class (EGU)	(18/4) Cold cloud microphysics (Ch. 8.3 - 8.5)
15	(16/4) Ice nucleation exercises	(25/4) Precipitation/radar (Ch. 9.1 - 9.4)
16	(23/4) Cold cloud microphysics exercises	(2/5) Aerosol/cloud radiative effects (Ch. 11)
17	(30/4) No class	(9/5) Aerosol-cloud interactions (Ch. 12.1 and 12.2)
18	(7/5) Precip./radar + radiative eff. exercises	(16/5) Cloud-climate feedbacks (Ch. 12.3)
19	(14/5) Aerosol/cloud interaction exercises	(23/5) Climate engineering (Ch. 12.4)
20	(21/5) No class (Pisake)	
21	Exam week of May 28 - Jun 2	



Reminder, global atmospheric circulation

The diagram illustrates global atmospheric circulation. On the left, a world map shows the South Pacific Convergence Zone (SPCZ), the Intertropical Convergence Zone (ITCZ) in January, and the ITCZ in July. On the right, a circular diagram shows the North Pole, Hadley cells, and Tropospheric jet streams. The diagram is credited to Wallace & Hobbs.

Overview of cloud types

- **Cumulus** = heap-like or cauliflower-like, usually associated with strong vertical motion (instability), vertical extent often larger than horizontal extent. Cloud lifetimes relatively short.
- **Stratus** = layered/flat clouds, usually connected to weaker & large-scale vertical motion, large horizontal extent. Longer cloud lifetimes.
- **Cirrus** = fibrous/wispy-looking clouds, generally high, always consist of ice.

Fog

The diagram shows three types of fog: Radiation fog (formed over cold ground), Steam fog (formed over warm water), and Advection fog (formed over cold air). A photograph shows fog at Gardermoen. The text indicates that fog covers 1% of land and ocean.


Coverage over land and ocean - 1%

From R. Houze's Cloud Atlas


Stratus

Low Clouds (bases <2 km above ground)

STRATUS (St)



liquid usually <2 km



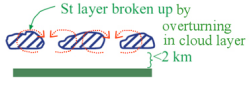
Covers 2-5% of land, 2-13% of ocean

From R. Houze's Cloud Atlas


Stratocumulus

Low Clouds (bases <2 km above ground)

STRATOCUMULUS (Sc)



St layer broken up by overturning in cloud layer <2 km



Covers 8-13% of land, 8-22% of ocean

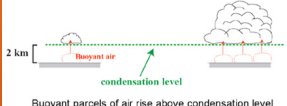
From R. Houze's Cloud Atlas

Cumulus

Low Clouds (bases <2 km above ground)

CUMULUS (Cu)

"Fair weather cumulus" "Towering Cu or cumulus congestus"




2 km

Buoyant air

condensation level

Buoyant parcels of air rise above condensation level

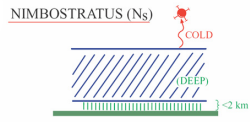


Covers 5-8% of land, 13-15% of ocean

From R. Houze's Cloud Atlas

Nimbostratus

Low Clouds (bases <2 km above ground)

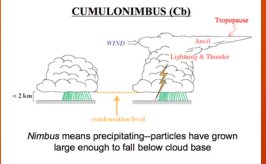


Covers 2-4% of land, 3-5% of ocean

From R. Houze's Cloud Atlas

Cumulonimbus

Low Clouds (bases <2 km above ground)

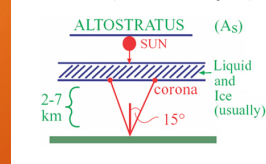


Covers 3-5% of land, 2-6% of ocean

From R. Houze's Cloud Atlas

Altostratus

Middle Clouds (bases 2-7 km above ground)



From R. Houze's Cloud Atlas

Alto cumulus

Middle Clouds (bases 2-7 km above ground)

ALTOCUMULUS (Ac)

2-7 km

From R. Houze's Cloud Atlas

Cirrus

High clouds (bases >7 km above ground)

CIRRUS

Young Intermediate Old

ice

Generating Cell

Strong wind

Fallstreaks (mares' tails)

Long streaky filaments

>7 km

From R. Houze's Cloud Atlas

Cirrostratus

High clouds (bases >7 km above ground)

CIRROSTRATUS (Cs)

SUN

(ICE)

"halo"

22°

>7 km

From R. Houze's Cloud Atlas

Cirrocumulus

High clouds (bases >7 km above ground)

CIRROCUMULUS
(Like Ac)

ICE

↑
> 7 km
↓

From R. Houze's Cloud Atlas

Cloud thermodynamic phase

Supercooled liquid fraction
Saitoh et al. (2010) and field observations

Liquid percentage

Mixed-phase percentage

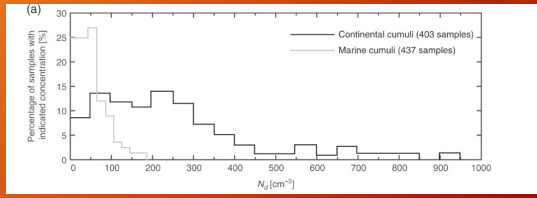
Ice percentage

Storelvmo (Annual Reviews, 2017)

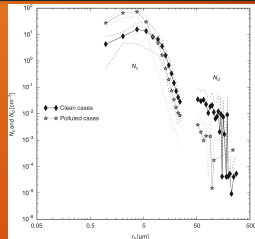
Cloud droplets vs. ice crystals

<p>Cloud droplets</p> <ul style="list-style-type: none"> • Typical size (radius) 2 - 25 μm • Typical number concentrations 10 - 1000 cm^{-3} • Typical liquid water contents: 0.1 - 5 gm^{-3} • Usually spherical 	<p>Ice crystals</p> <ul style="list-style-type: none"> • Typical size (length) 1 - 1500 μm • Typical number concentrations 10⁻⁴ - 10 cm^{-3} • Typical ice water contents: 10⁻⁴ - 0.5 gm^{-3} • Usually non-spherical (often hexagonal)
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Continental vs. marine clouds



Clean vs. polluted clouds



- Figure shows cloud droplet (N_d) and drizzle drop (N_r) size distributions for clean clouds (diamonds) and polluted clouds (asterisks).
- The size distributions tend to resemble gamma distributions.
- Polluted clouds have more/smaller cloud droplets, but fewer drizzle drops.
