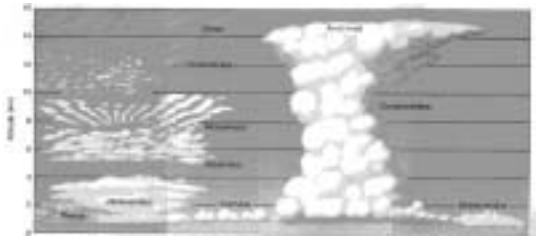
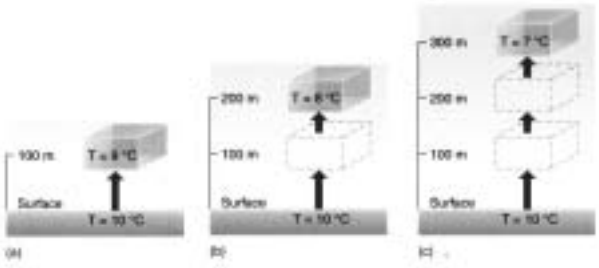
Lecture 4: Capricious Clouds



(from "*The Blue Planet*")

- Moisture In the Atmosphere
- Cloud Formation
- Cloud Types
- Cloud Role In Climate Change

Adiabatic Lapse Rate



(from *Understanding Weather & Climate*)

- Adiabatic lapse rate
  = 10°C/km or 1°C/100m
  = air temperature in a rising balloon drops 1°C every 100m.

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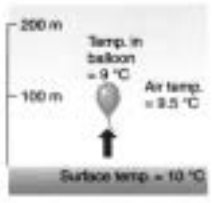
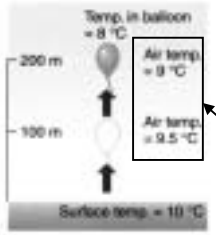
Environmental Lapse Rate





- The environmental (or ambient) lapse rate is referred to the vertical change in temperature through still air.
- The environmental lapse rate is not fixed. It changes from day to day and from place to place.

environmental lapse rate =0.5°C/100m

(from *Understanding Weather & Climate*)

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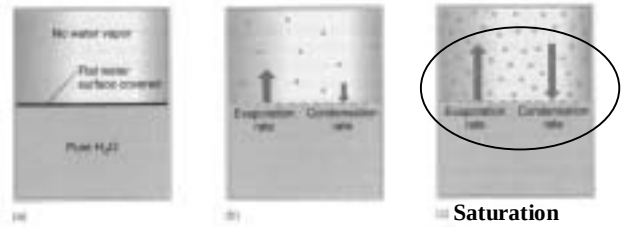
Water Vapor In the Air



Saturation

(from *Understanding Weather & Climate*)

- **Evaporation:** the process whereby molecules break free of the liquid volume.
- **Condensation:** water vapor molecules randomly collide with the water surface and bond with adjacent molecules.

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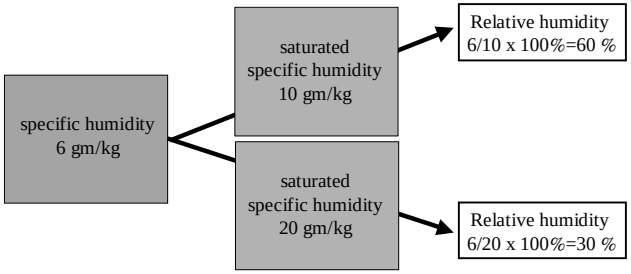
Specific .vs. Relative Humidity



- Specific Humidity: How many grams of water vapor in one kilogram of air (in unit of gm/kg).
- Relative Humidity: The percentage of current moisture content to the saturated moisture amount (in unit of %).
- Clouds form when the relative humidity reaches 100%.

How Much Water Vapor Is Evaporated Into the Atmosphere Each Year?

- On average, 1 meter of water is evaporated from oceans to the atmosphere each year.
- The global averaged precipitation is also about 1 meter per year.

How Much Heat Is Brought Upward By Water Vapor?

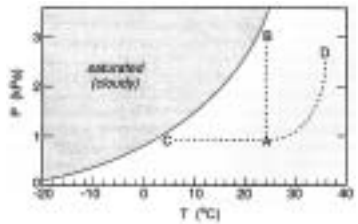
- Earth's surface lost heat to the atmosphere when water is evaporated from oceans to the atmosphere.
- The evaporation of the 1m of water causes Earth's surface to lost 83 watts per square meter, almost half of the sunlight that reaches the surface.
- Without the evaporation process, the global surface temperature would be 67°C instead of the actual 15°C.

"Runway" Greenhouse Effect

- If a planet has a very high temperature that the air can never reach a saturation point

➔Water vapor can be added into the atmosphere.
➔More water vapor traps more heat (a greenhouse effect)
➔The planet's temperature increases furthermore
➔ Ever more water evaporated into the atmosphere
➔ More greenhouse effect
➔ More warming
➔ More water vapor
➔ …..

How to Saturate the Air?



(from "*IS The Temperature Rising*")

- Two ways:

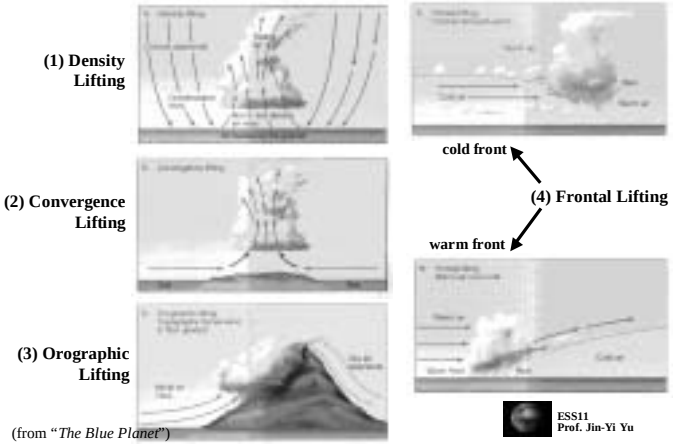
(1) Increase (inject more) water vapor to the air (A→ B).

(2) Reduce the temperature of the air (A → C).

Why Clouds Form?

Clouds form when air rises and becomes saturated in response to adiabatic cooling.

Four Ways to Lift Air Upward



(from "*The Blue Planet*")

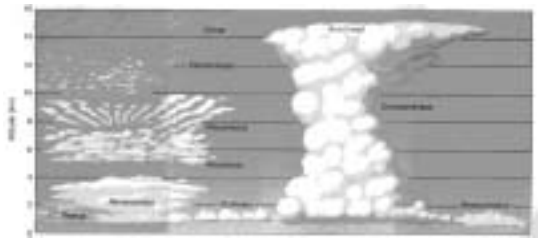
Cloud Type Based On Properties

- Four basic cloud categories:

✓ Cirrus --- thin, wispy cloud of ice.
✓ Stratus --- layered cloud
✓ Cumulus --- clouds having vertical development.
✓ Nimbus --- rain-producing cloud

- These basic cloud types can be combined to generate ***ten different cloud types***, such as cirrostratus clouds that have the characteristics of cirrus clouds and stratus clouds.

Cloud Types Based On Height



If based on cloud base height, the ten principal cloud types can then grouped into four cloud types:

- ✓ High clouds -- cirrus, cirrostratus, cirroscumulus.
- ✓ Middle clouds – altostratus and altocumulus
- ✓ Low clouds – stratus, stratocumulus, and nimbostartus
- ✓ Clouds with extensive vertical development – cumulus and cumulonimbus.

(from "*The Blue Planet*")

Cloud Classifications

Table 12.1 Classification of Clouds in the Troposphere by Altitude

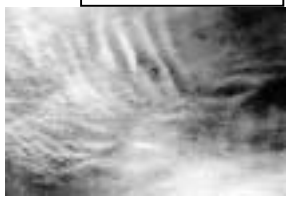
Height	Name	Shape and Appearance
High-level cloud: Cloud base 6 to 15 km above sea level	Cirrus	Feathery streaks
	Cirrocumulus	Small ripples and delicate puffs
	Cirrostratus	Translucent to transparent sheet, like a veil across the sky
Middle-level cloud: Cloud base 2 to 6 km above sea level	Altocumulus	White to dark gray puffs and elongated ripples
	Altostratus	Uniform white to gray sheet covering the sky
Low-level cloud: Cloud base below 2 km above sea level	Stratus	Uniform dull gray cover over the sky
	Nimbostratus	Uniform gray cover; rain generally falling
	Stratocumulus	Patches of soft gray, in places patches coalescing to a layer
Cloud with great vertical development: Cloud base below 3 km above sea level	Cumulus	Puffy cauliflower shape with flat base
	Cumulonimbus	Large, puffy, white, gray and black, great vertical extent, often with anvil-shaped head

(from "*The Blue Planet*")

High Clouds

1. Cirrus Clouds

3. Cirrocumulus Clouds



(from Australian Weather Service)

2. Cirrostratus Clouds

- ❑ High clouds have low cloud temperature and low water content and consist most of ice crystal.

Middle Clouds

4. Altostratus Clouds

5. Altocumulus Clouds

(from Australian Weather Service)

- ❑ Middle clouds are usually composite of liquid droplets.
- ❑ They block more sunlight to the surface than the high clouds.

Low Clouds

6. Stratus Clouds

8. Nimbostratus Clouds

(from Australian Weather Service)

7. Stratocumulus Clouds

- Low, thick, layered clouds with large horizontal extends, which can exceed that of several states.

Clouds With Vertical Development

9. Cumulus Clouds

10. Cumulonimbus Clouds

(from Australian Weather Service)

- They are clouds with substantial vertical development and occur when the air is absolute or conditionally unstable.

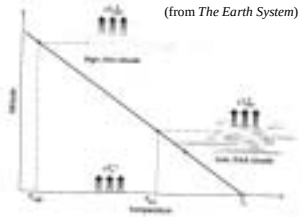
Polar Stratospheric Clouds (PSCs)

(Sweden, January 2000; from NASA website)

- In winter the polar stratosphere is so cold (-80˚C or below) that certain trace atmospheric constituents can condense.
- These clouds are called "polar stratospheric clouds" (PSCs).
- The particles that form typically consist of a mixture of water and nitric acid (HNO3).
- The PSCs alter the chemistry of the lower stratosphere in two ways:
  (1) by coupling between the odd nitrogen and chlorine cycles
  (2) by providing surfaces on which heterogeneous reactions can occur.

Cloud Role In Climate Change

(from *The Earth System*)



- Cloud effects is one of the most uncertain parts of climate prediction.
- Typically, clouds increase albedo ➔ a cooling effect
  clouds reduce longwave radiation ➔ a heating effect
- The net effect of clouds on climate depends cloud types and their optical properties, the insolation, and the characteristics of the underlying surface.
- In general, high clouds tend to produce a heating (positive) feedback. Low clouds tend to produce a cooling (negative) feedback.