MET 200 Lecture 7 Cloud Forms

Cloud forms and what they tell us.

Colorado's "biblical" flood

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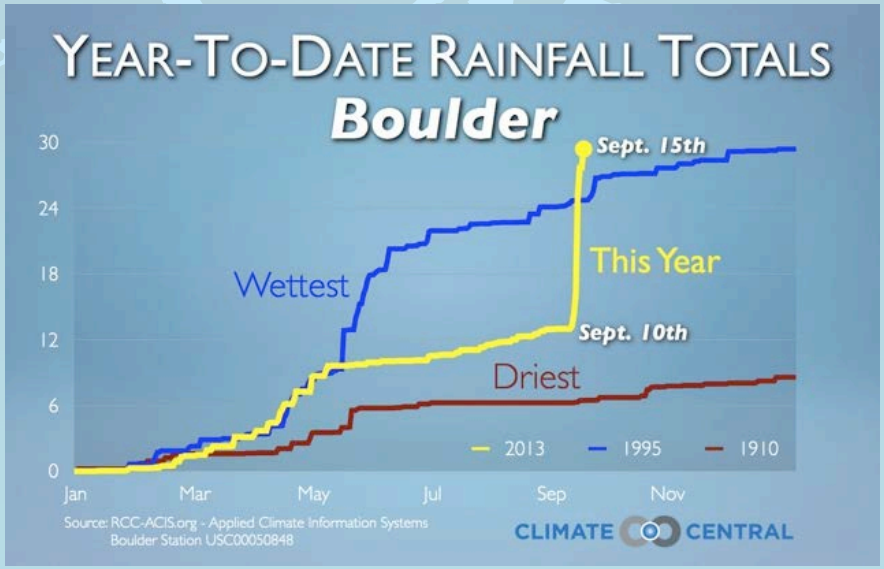
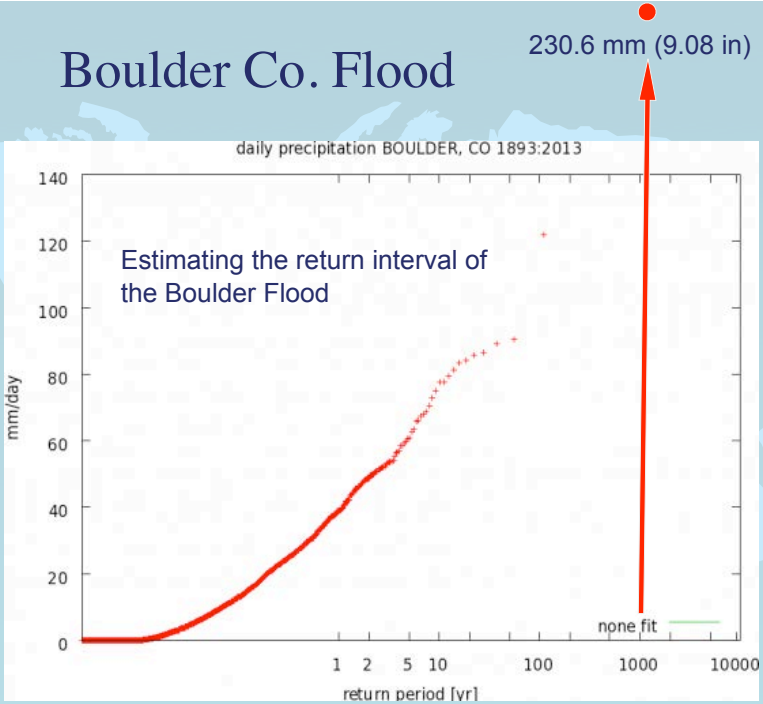
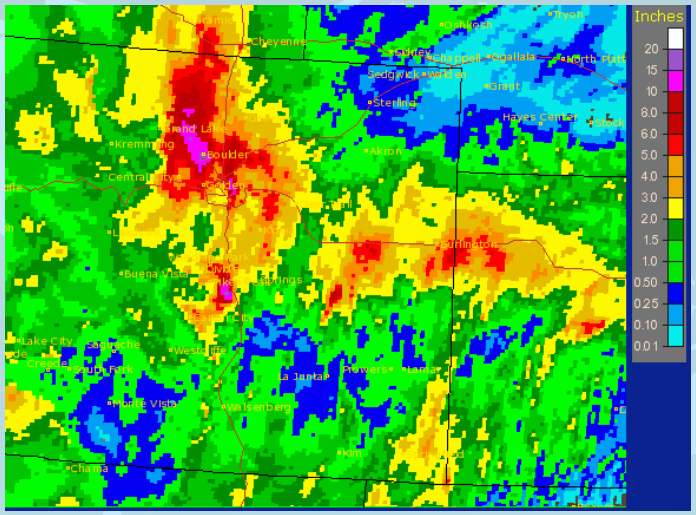


Boulder Co. Flood



Boulder Co. Flood



Rainfall amounts for the seven days ending at noon MDT on Friday, September 13, ranged from 5 to 10-plus inches across large swaths of the Colorado Front Range, with similar amounts eastward into northwest Kansas.

Boulder Co. Flood

Boulder Co. Flood

Between 00Z Thursday 9/12 (6 PM Mountain Daylight Time on Wednesday) and 00Z Friday 9/13, a total of **9.08"** was measured at the official Boulder site. From 6 PM Monday 9/9 through 6 PM Friday 9/13, the grand total was a whopping **14.71".**

Boulder Co. Flood

- Boulder's previous record for wettest calendar day—4.80" (July 31, 1919)—was shattered.
- The single day of rain on Thursday was also nearly twice as much as any other entire September has produced (5.50", in 1940).
- The full week's rainfall easily topped the 9.59" observed in May 1995, Boulder's wettest month up to now.
- This week's precipitation also exceeded the 12.96" that fell in Boulder during this entire year up to September 8. It put the city within striking distance of wettest year on record (29.93", set in 1995), with only about 2" more needed by December 31 to break that mark.

Cloud Stories

Clouds can tell us many things about our atmospheric environment including

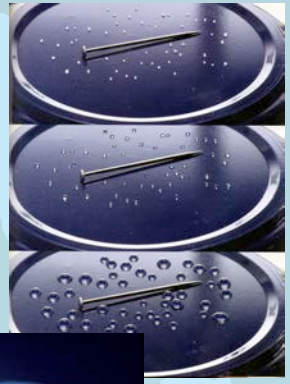
- Atmospheric stability
- Cloud microphysics, e.g., ice vs liquid
  - Ice can survive a long time outside of a cloud boundary making the cloud edges diffuse.
- Wind speed and direction at levels of the clouds
- Wind shear in precipitating clouds

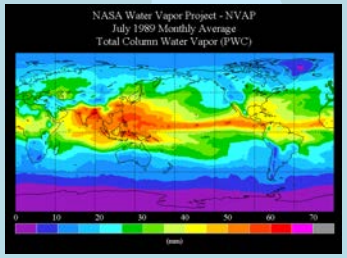
Previous Lecture: Cloud Formation

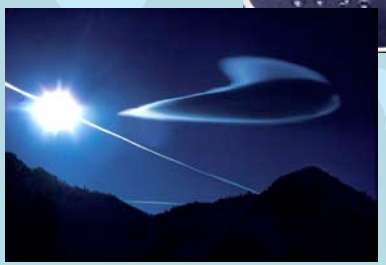
Cloud Formation

All clouds require 3 things

1. Water vapor
2. Cloud Condensation nuclei (CCN)
3. Cooling - heat transfer out of air parcel or work done by air molecules in parcel.







Mechanisms for Cooling the Air

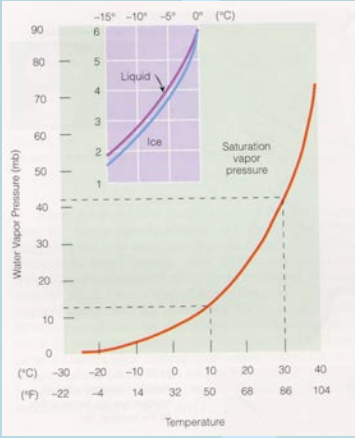
(1) Lifting – most clouds form when air is lifted.
- a) Convergence – low press center – stratus
- b) Mountains – lifting by terrain
- c) Fronts – lifting over denser air.
- d) Warm air relative to surroundings
  - i) Fires, volcanoes – cumulus
  - ii) Latent heat

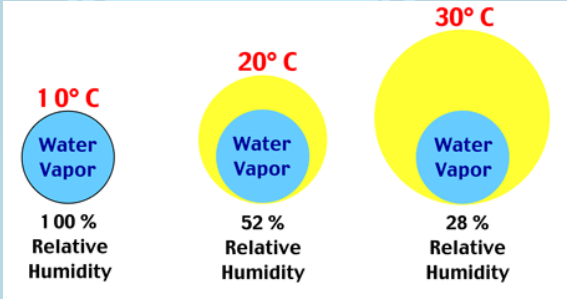
(2) Mixing – seeing your breath on cold day

(3) Contact – with cold surface – advection fog

(4) Radiation – ground fog

Cooling Increases Relative Humidity





The saturation vapor pressure of water increases with temperature. Therefore, if the amount of water in the air stays the same, but the temperature drops, then the relative humidity increases.

Lecture 7 Cloud Forms

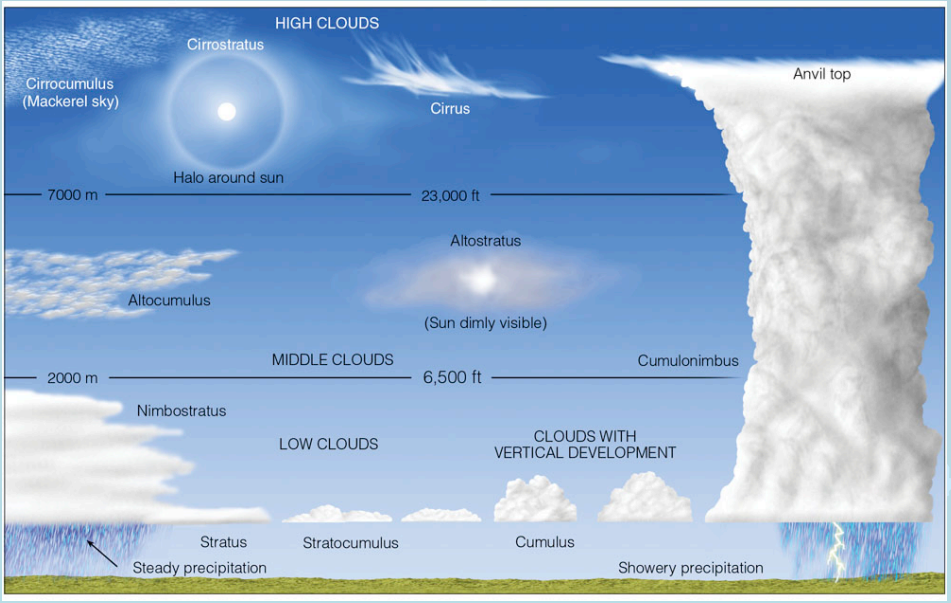
Cloud forms and what they tell us.

Cloud classification

Clouds are categorized by their height, appearance and vertical development

- High Clouds - generally above 23,000 ft at middle latitudes (>6 km)
  - Main types - Cirrus, Cirrostratus, Cirrocumulus
- Middle Clouds – 7,000-23,000 ft (2-6 km)
  - Main types – Altostratus, Altocumulus
- Low Clouds - below 7,000 ft (<2 km)
  - Main types – Stratus, stratocumulus, nimbostratus
- Vertically developed clouds (via convection)
  - Main types – Cumulus, Cumulonimbus

Cloud type summary



High Clouds

High clouds

- White during the day
- Red/orange/yellow at sunrise and sunset

– Cirrus
  - Made of ice crystals
  - Thin and wispy
  - Move SW to NE
  - Indicate fair weather

– Cirrocumulus
  - Made of supercooled water droplets
  - Small, rounded white puffs individually or in long rows (fish scales; mackerel sky)

– Cirrostratus
  - Thin and sheetlike
  - Sun and moon clearly visible through them
  - Halo common - indicates ice
  - Often precede precipitation

Cirrus with Fog

Cirrus

Cirrus

Cirrus

Cirrostratus with Halo

Cirrostratus

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Cirrocumulus

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Cirrocumulus

27

Cirrocumulus

28

Contrail

Middle Clouds

- Altostratus
  - Gray, blue-gray
  - Often covers entire sky
  - Sun or moon may show through dimly
    - Usually no shadows
- Altocumulus
  - <1 km thick
  - mostly water drops, often supercooled
  - Gray, puffy
  - Differences from cirrocumulus
    - Larger puffs
    - More dark/light contrast

Altostratus

Altostratus

Altostratus

Altostratus Castellanus

Altocumulus

Altocumulus

Alto Cumulus

Alto Cumulus Undulatus

Low Clouds

- Stratus
  - Uniform, gray
  - Resembles fog that does not reach the ground
  - Usually no precipitation, but light mist/ drizzle possible
- Stratocumulus
  - Low lumpy clouds
  - Breaks (usually) between cloud elements
  - Lower base and larger elements than altostratus
- Nimbostratus
  - Dark gray
  - Continuous light to moderate rain or snow
  - Evaporating rain below can form stratus fractus

Stratus

Stratus/Fog

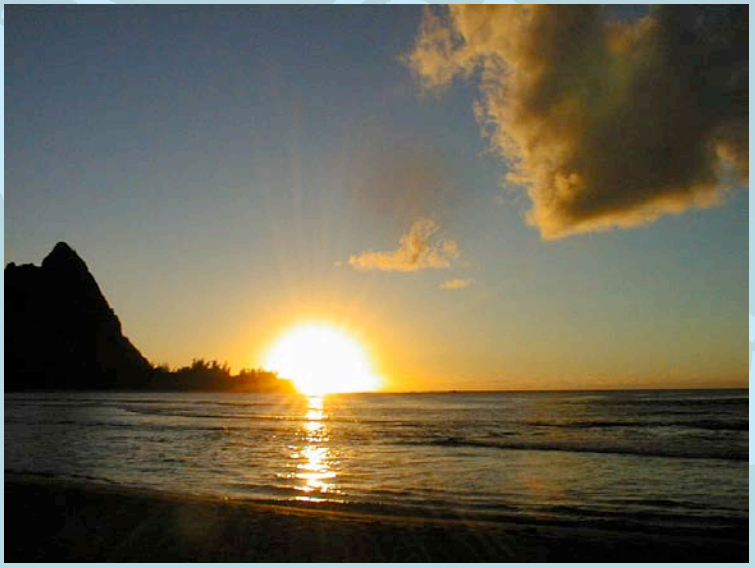
Fog

Nimbostratus

Stratocumulus from below

Fractus

Fractus



Stratiform cloud layers

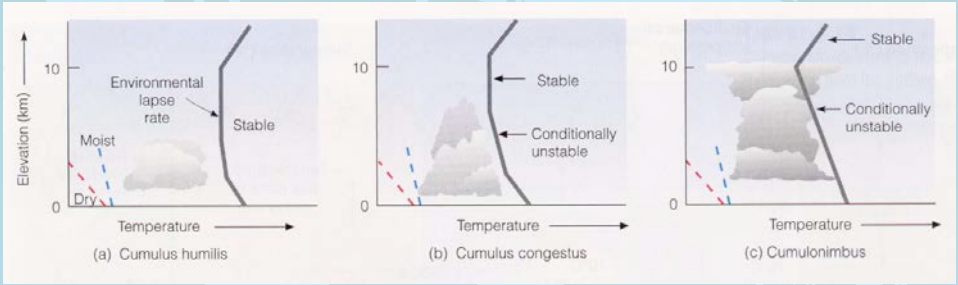
Stratiform cloud layers

Stratocumulus

Vertically developed clouds

- Cumulus
  - Puffy “cotton”
  - Flat base, rounded top
  - More space between cloud elements than stratocumulus
- Cumulonimbus
  - Thunderstorm cloud
  - Very tall, often reaching tropopause
  - Individual or grouped
  - Large energy release from water vapor condensation

What conditions support taller cumulus development ?



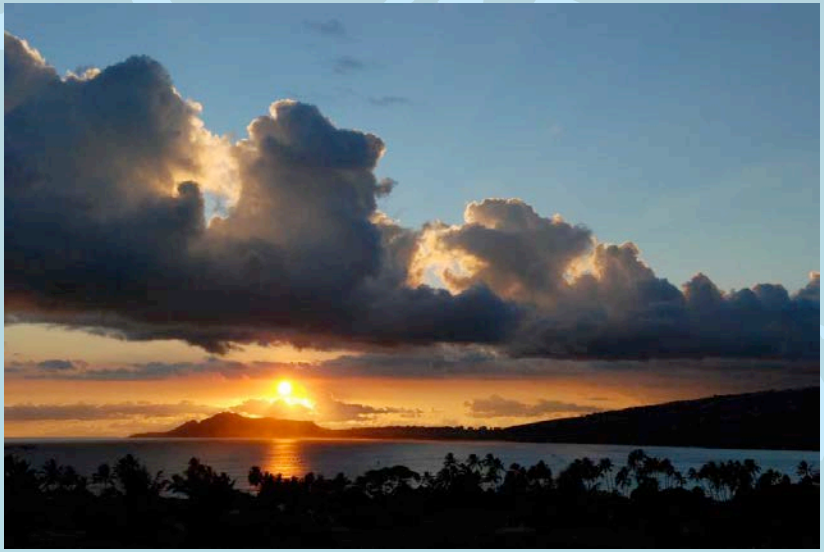
- A less stable atmospheric (steeper lapse rate) profile permits greater vertical motion
- Lots of low-level moisture permits latent heating to warm parcel, accelerating it upward
- To forecast changing weather you have to predict how the environmental lapse rate will change in time.

Fair Weather Cumulus

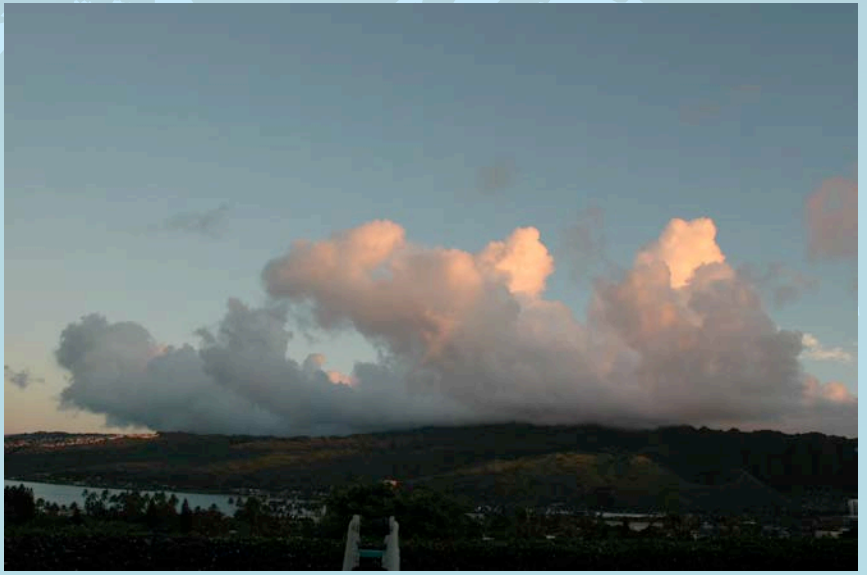
Fair Weather Cumulus

Fair Weather Cumulus

Cumulus



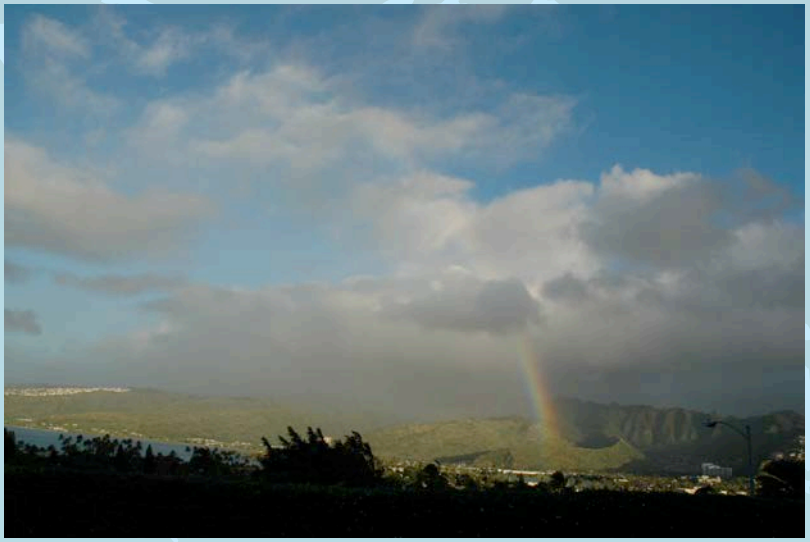
Cumulus



Cumulus Castelanus

Cumulonimbus

Cumulonimbus



Cumulus Congestus

Cumulonimbus

Cumulonimbus and Anvil

Cumulonimbus with Anvil

61

Cumulonimbus with Anvil

62

Cumulonimbus with Anvil

63

Tornado Funnel Cloud

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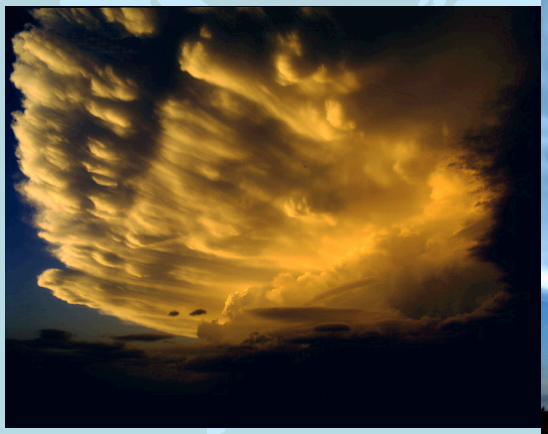
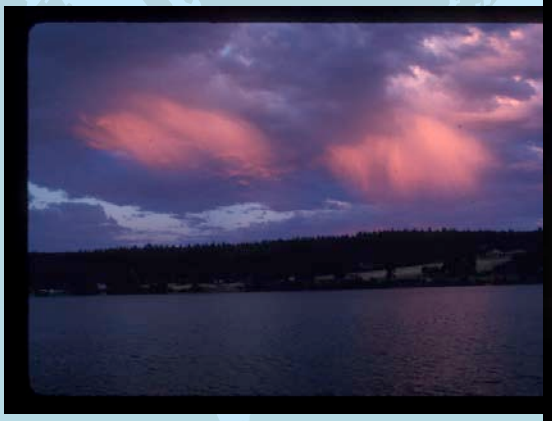
Mamatus

Mamatus



Virga



Lenticular clouds

- Stable air flowing over a mountain range often forms a series of waves
  - Think of water waves formed downstream of a submerged boulder
- Air cools during rising portion of wave and warms during descent
- Clouds form near peaks of waves
- A large swirling eddy forms beneath the lee wave cloud
  - Observed in formation of rotor cloud
  - Very dangerous for aircraft

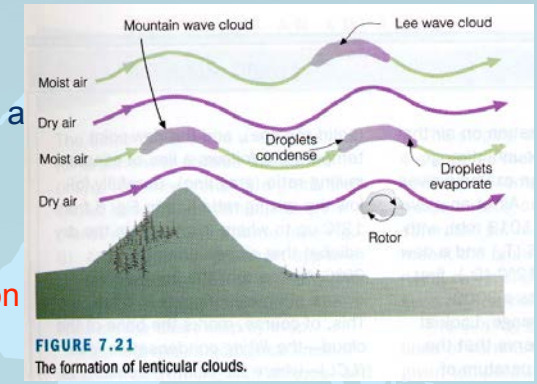


FIGURE 7.21
The formation of lenticular clouds.

Mountain Wave or Lenticular Clouds

Mountain Wave or Lenticular Cloud

Mountain Wave and Cumulus Clouds

Mountain Wave or Lenticular Cloud

Mountain Wave or Lenticular Cloud

Mountain Wave or Lenticular Cloud

Kelvin-Helmholtz Instability

Summary of Cloud Types

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Questions?

Smoke ring blown by the active vent at the summit of Mt Etna, Sicily, Italy.