Cloud forms and what they tell us.

Colorado’s “biblical” 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

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

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
- Cirrostratus
  - Thin and sheetlike
  - Sun and moon clearly visible through them
  - Halo common - indicates ice
  - Often precede precipitation
- Cirrocumulus
  - Made of supercooled water droplets
  - Small, rounded white puffs individually or in long rows (fish scales; mackerel sky)

Cirrus with Fog
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
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/Fog**

**Fog**
Nimbostratus

Stratocumulus from below

Fractus

Fractus
**Stratiform cloud layers**

**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.
Cumulonimbus

Cumulus Congestus

Cumulonimbus

Cumulonimbus and Anvil
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 the rising portion of the wave and warms during descent. Clouds form near the peaks of the waves. A large swirling eddy forms beneath the lee wave cloud—observed in the formation of rotor clouds. Very dangerous for aircraft.
Summary of Cloud Types

Clouds are categorized by their height, appearance, and vertical development.

- **High Clouds**: generally above 16,000 ft at middle latitudes (>6 km)
  - Main types: Cirrus, Cirrostratus, Cirrocumulus
- **Middle Clouds**: 7,000-23,000 feet (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
Questions?

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