Chap.6 Cloud formation
Chap.7 Precipitation processes
  – What processes drive precip. in Bozeman?
Chap.8 Atmospheric circulation
  Pressure distributions
  – El Nino/La Nina
Chap.9 Air masses and Fronts
Chap.10 Midlatitude cyclones
Chap.11 Lightning and thunderstorms
Lightning, Thunder, & Tornadoes

ERTH303 19 Nov., 2009

Lightning:
  a) Formation
  b) Types

Thunderstorms:
  a) Types
  b) Distribution

Tornadoes:
  a) Formation
  b) Distributions
Lightning

About 40,000 thunderstorms daily, each producing lightning:

- Discharge of electricity
  - 80% = cloud-to-cloud lightning [sheet lightning]
  - 20% = cloud-to-ground lightning
Lightning – (a) formation

Charge separation

- Positive charges aloft, negative in lower areas
- *Ice crystals needed for charge separation*
Lightning – (a) formation

Textbook Fig. 11-1
Lightning – (a) formation

Runaway discharges

- Lighting is different from a static electric spark
- Results from electrons accelerated to high speeds
  - Collisions cause an avalanche of runaway electrons
- Runaway breakdown
  - Energy is released when electrons accumulate in a small volume
Lightning – (a) formation

Components:

- **Stepped-leader**
  - Emanates from cloud base
- **When it connects with unlike charged area**
  - Electron flow = *return stroke*
    - *Illumination occurs and heating*
- **Multiple strokes**
  - *Dart leader and return stroke*
- **Lightning flash**
  - Combination of all strokes
Lightning – (a) formation
Positive lightning strokes:

- Often stronger than negative strokes
- Can occur several miles ahead of storm
Lightning – (a) formation

- **Forked**
- **Sheet (heat)**
- **Ball:**
  - round, glowing mass of electrified air; rolls in air or on surface
  - See “A Personal Account…” on p. 312!
  - [http://www.youtube.com/watch?v=6ioN-3UWYrY](http://www.youtube.com/watch?v=6ioN-3UWYrY)
Lightning – (a) formation

- St. Elmo’s fire
  - Ionization of air, before formation of cloud-to-ground lightning - glowing

- Sprites
  - Large, short-lived electrical bursts above cloud tops; occurs when lightning occurs below

- Blue jets
  - Upward-moving electrical ejections from the top of active thunderstorms
Lightning – (a) formation

Sprite (http://home.netcom.com/~sbyers11/RedSprite2.jpg)

Blue jet (textbook Fig. 11-6)
Lightning, Thunder, & Tornadoes

Lightning:
  a) Formation
  b) Types

Thunderstorms:
  a) Types
  b) Distribution

Tornadoes:
  a) Formation
  b) Distributions
Thunder Storms – (a) types

Air mass thunder storms:

- Localized, short-lived storms that dissipate in tens of minutes

- Cumulus Stage:
  - Localized convection
  - Adiabatic cooling
  - Condensation

Textbook Fig. 11-7
Thunder Storms – (a) types

Air mass thunder storms:

- **Mature Stage:**
  - Precipitation (rain or graupel)
  - Creates downdrafts
  - Cloud top extends to elevation of stability
  - Strong winds at cloud tops create anvil

Textbook Fig. 11-7
Thunder Storms – (a) types

Air mass thunder storms:

- **Dissipative Stage:**
  - Downdrafts occupy entire cloud base
  - Water vapor cut off

Textbook Fig. 11-7
Thunder Storms – (a) types

Severe Thunder Storms:
- Winds > 93 km/hr (58 mph)
- Hailstones > 1.9 cm (0.75 in) diam.
- Spawn tornadoes

Mesoscale convective complexes (MCC)
Thunder Storms – (a) types

Severe Thunder Storms:
[mesoscale = 10’s – 100’s of km]

- **Mesoscale convective systems (MCSs):**
  - Cluster of thunderstorms
  - When in a line = squall lines

- **Mesoscale convective complexes (MCCs):**
  - Circular or oval systems
Thunder Storms – (a) types

Mesoscale convective complex (MCC)

Textbook Fig. 11-9
Thunder Storms – (a) types

Squall line thunderstorms (MCS):

- Individual storms cells arranged in linear band (around 500 km long)
- Form in warm sector of a midlatitude cyclone, ahead of cold front

Textbook Fig. 11-12
Thunder Storms – (a) types

Squall line thunderstorms (MCS):

- Strong vertical wind movement
Thunder Storms – (a) types

Squall line thunderstorms (MCS):

- Shelf clouds

Textbook Fig. 11-16
Thunder Storms – (a) types

Squall line thunderstorms (MCS):

- Shelf clouds

http://www.extremeinstability.com/stormpics/svrdsc00783.jpg
Thunder Storms – (a) types

SUPERCELL STORMS

- A single, extremely powerful single cell thunderstorm (20-50 km)
- Complex array of up- and downdraft relationships

http://www.extremeinstability.com/stormpics/svrdsco0783.jpg
Thunder Storms – (a) types

Textbook Fig. 11-19
Thunderstorms develop where moist air is forced aloft.
Thunder Storms – (b) distribution

Textbook Fig. 11-22

(a) 1998

Flashes km$^{-2}$ yr$^{-1}$

0 0.1 0.25 0.5 1 3 6 9
Thunder Storms – (b) distribution

(d) 1998–2000

Textbook Fig. 11-23
Lightning, Thunder, & Tornadoes

ERTH 303 19 Nov., 2009

Lightning:
  a) Formation
  b) Types

Thunderstorms:
  a) Types
  b) Distribution

Tornadoes:
  a) Formation
  b) Distributions
Tornadoes

- **Strong pressure gradients** (e.g., 100 mb)
- **Tornado characteristics and dimensions**
  - 100-yard average diameter
  - Movement = 50km/hr (30 mph) over 3-4 km (2-2.5 mi)
  - Winds = 65 km/hr (40 mph) to 450 km/hr (280 mph)
- **Tornado formation**
  - Squall lines, MCCs, supercells, tropical cyclones
Tornadoes – (a) formation

Supercell tornadoes

- Mesocyclone development

Textbook Fig. 11-25
Tornadoes – (a) formation

Supercell tornadoes

- Backsheared anvil
- Penetrating top
- Anvil
- Mammatus
- Height above surface (km)
- Approximate horizontal scale

Stratosphere

Troposphere

- Tornado
- Large hail
- Heavy rain
- Light rain
- Wall cloud
- Small hail

Textbook Fig. 11-27

Southwest

Northeast
Tornadoes – (a) formation

Nonsupercell tornadoes:

- Develop along convergent boundary

Textbook Fig. 11-29
Tornadoes – (b) distributions

Global tornado frequency:
Tornadoes – (b) distributions

US tornado frequency:

Textbook Fig. 11-31
Tornadoes – (b) distributions

Seasonal patterns:

Textbook Fig. 11-32, 11-33
Tornadoes – (b) distributions

Temporal patterns:

- > 88% kill no one
- 2% cause > 67% of all fatalities

## Tornadoes – intensity scale

### Table 11–2: Fujita Intensity Scale

<table>
<thead>
<tr>
<th>INTENSITY</th>
<th>WIND SPEED (km/hr)</th>
<th>WIND SPEED (MPH)</th>
<th>TYPICAL AMOUNT OF DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>&lt;116</td>
<td>&lt;72</td>
<td>Light: Broken branches, shallow trees uprooted, damaged signs and chimneys.</td>
</tr>
<tr>
<td>F1</td>
<td>116–180</td>
<td>72–112</td>
<td>Moderate: Damage to roofs, moving autos swept off road, mobile homes overturned.</td>
</tr>
<tr>
<td>F2</td>
<td>181–253</td>
<td>113–157</td>
<td>Considerable: Roofs torn off homes, mobile homes completely destroyed, large trees uprooted.</td>
</tr>
<tr>
<td>F4</td>
<td>333–419</td>
<td>207–260</td>
<td>Devastating: Frame houses completely destroyed, cars picked up and blown downwind.</td>
</tr>
<tr>
<td>F6</td>
<td>&gt;513</td>
<td>&gt;319</td>
<td>Inconceivable: Might possibly occur in small part of an F4 or F5 tornado. It would be difficult to identify the damage done specifically by these winds, as it would be indistinguishable from that of the main body of the tornado.</td>
</tr>
</tbody>
</table>

Note: F0 and F1 tornadoes are collectively called weak, F2 and F3 strong, and F4 and F5 violent.