In the News: more record highs – fewer lows

More Record Highs and Far Fewer Lows
By ANDREW C. REVKIN

Scientists sifting for trends in record high and low temperatures across the United States have found more evidence of long-term warming of the climate, with the biggest shift coming through a reduction in record low nighttime temperatures. That is a pattern long predicted by climate scientists using computer simulations. The researchers said they sifted data carefully to avoid possible distortion of trends related to changes in instruments or conditions at and around weather stations. The changing ratio of cold and hot records is shown below (copyright U.C.A.R., graphic by Mike Shibao):

In the News: SNOW!!!

Snotel:
Bracket cr. 13”
Sacajawea 12”
Lick cr. 11”
Bridger 15”
Bozeman 24”
In the News: new all-time records!

BOZEMAN MONTANA SU (241044)

Daily Almanac

Date: Nov 12, 2009

<table>
<thead>
<tr>
<th>Daily Values</th>
<th>Observed</th>
<th>Normal</th>
<th>Record/Year</th>
<th>Prev Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Temperature</td>
<td>43</td>
<td>43</td>
<td>73 in 1999</td>
<td>57</td>
</tr>
<tr>
<td>Min Temperature</td>
<td>29</td>
<td>23</td>
<td>-23 in 1916</td>
<td>33</td>
</tr>
<tr>
<td>Avg Temperature</td>
<td>36.0</td>
<td>33</td>
<td>55.0 in 1999</td>
<td>45.0</td>
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<tr>
<td>Precipitation</td>
<td>1.62</td>
<td>0.04</td>
<td>1.62 in 2009</td>
<td>0.02</td>
</tr>
<tr>
<td>New Snowfall</td>
<td>16.2</td>
<td>-</td>
<td>16.2 in 2009</td>
<td>0.0</td>
</tr>
<tr>
<td>Snow Depth</td>
<td>24</td>
<td>-</td>
<td>24 in 2009</td>
<td>0</td>
</tr>
<tr>
<td>HDD (base 65)</td>
<td>29</td>
<td>32</td>
<td>76 in 1916</td>
<td>20</td>
</tr>
<tr>
<td>CDD (base 65)</td>
<td>0</td>
<td>0</td>
<td>0 in 2009</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Month-To-Date</th>
<th>Observed</th>
<th>Normal</th>
<th>Record/Year</th>
<th>Prev Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg Max Temperature</td>
<td>54.1</td>
<td>46.1</td>
<td>61.3 in 1999</td>
<td>50.6</td>
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<tr>
<td>Avg Min Temperature</td>
<td>29.3</td>
<td>25.5</td>
<td>9.4 in 1911</td>
<td>31.8</td>
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<tr>
<td>Avg Temperature</td>
<td>41.7</td>
<td>35.8</td>
<td>47.5 in 1999</td>
<td>41.2</td>
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<tr>
<td>Total Precipitation</td>
<td>1.68</td>
<td>0.48</td>
<td>2.42 in 1947</td>
<td>0.76</td>
</tr>
<tr>
<td>Total Snowfall</td>
<td>16.2</td>
<td>-</td>
<td>18.5 in 1922</td>
<td>2.4</td>
</tr>
<tr>
<td>Avg Snow Depth</td>
<td>2</td>
<td>-</td>
<td>6 in 1973</td>
<td>0</td>
</tr>
<tr>
<td>Total HDD</td>
<td>276</td>
<td>352</td>
<td>549 in 1935</td>
<td>204</td>
</tr>
<tr>
<td>Total CDD</td>
<td>0</td>
<td>0</td>
<td>0 in 2009</td>
<td>0</td>
</tr>
</tbody>
</table>

+ indicates record also occurred in previous years (last occurrence listed)

http://cateye.msu.montana.edu/
**Summary of October’s Weather**


- Average Temp = 40.2 °F, - 3.1 °F below normal
- Precipitation = 0.98 in - 0.13 less than normal
- 23 days with min. temperature < 32 °F

- 6 clear days
- 15 partly cloudy days
- 10 cloudy days

- Total HDD (base 65) = 757, 83 above normal
- Total HDD since July 1 = 945, -230 less than normal

- Total CDD (base 65) = 0, 0 less than normal
- Total CDD since Jan 1 = 339, 80 above normal
Midlatitude Cyclones

a. Why do we care about midlatitude cyclones?
b. Polar front theory
c. Life cycle of a midlatitude cyclone

http://upload.wikimedia.org/wikipedia/commons/2/2c/Feb242007_blizzard.gif
a. Why midlatitude cyclones?

Midlatitude cyclones:

Low pressure center characterized by the presence of frontal boundaries; travel great distances and affect large areas.

http://upload.wikimedia.org/wikipedia/commons/3/35/Extratropical_formation_areas.jpg
a. Why midlatitude cyclones?

Midlatitude cyclones:
a. Why midlatitude cyclones?

**Midlatitude cyclones:**

Look at latest:

http://www.hpc.ncep.noaa.gov/basicwx/day0-7loop.html

http://upload.wikimedia.org/wikipedia/commons/3/35/Extratropical_formation_areas.jpg
a. Polar front theory
b. Life cycle of a midlatitude cyclone
c. Upper troposphere and surface processes
d. Upper-level flow and large-scale weather
e. Conveyor Belt model
Polar Front Theory:

- Vilhelm Bjerknes, Bergen Norway, early 20th century
- Described formation, growth, and dissipation of midlatitude cyclones

a. Polar Front theory
c. Life cycle of a midlatitude cyclone

Cyclogenesis
Life cycle of a midlatitude cyclone

Cyclogenesis:
b. Life cycle of a midlatitude cyclone

Cyclogenesis - 1

- Begins with a disruption of the polar frontal boundary

Textbook figure 10-1
b. Life cycle of a midlatitude cyclone

Cyclogenesis - 2

- “kink” in boundary; cold air pushes S, warm air pushes N
- Creates counter-clockwise rotation

Textbook figure 10-1
b. Life cycle of a midlatitude cyclone

**Cyclogenesis - 2**

- Low pressure deepens
- Warm and cold fronts emerge
- “Mature” cyclone

Textbook figure 10-1
b. Life cycle of a midlatitude cyclone

Mature cyclone:

- Precipitation along frontal boundaries
- Probability of precipitation increases towards the center of the cyclone

Textbook figure 10-2
b. Life cycle of a midlatitude cyclone

Occlusions

- End of cyclone’s life....
b. Life cycle of a midlatitude cyclone

Passage of a cyclone:

1. Cloud cover deepens; possible precip. (warm front)
2. Precip give way to warmer, clear conditions; winds shift form S to SW
3. Clear conditions give way to a cold front: fast-moving, heavy band of clouds and precip.
4. Cold front passes and brings clear, cold conditions
b. Life cycle of a midlatitude cyclone

Passage of a cyclone:

http://www.opc.ncep.noaa.gov/Loops/UA_CONUS_hires/UA_CONUS_hires_03_Day.shtml
Midlatitude Cyclones
GEOG 303 6 Nov., 2008

a. Polar front theory
b. Life cycle of a midlatitude cyclone
c. Upper troposphere and surface processes
d. Upper-level flow and large-scale weather
e. Conveyor Belt model
c. Upper troposphere processes

Vorticity:

- rotation of a fluid
- positive vorticity: air flow in direction of Earth’s rotation
- negative vorticity: air flow in opposite direct of Earth’s rotation

*Vorticity changes in the upper atm. lead to pressure changes near the surface...*
c. Upper troposphere processes

**Vorticity:**
- Increased vorticity $\rightarrow$ convergence
- Decreased vorticity $\rightarrow$ divergence

[Textbook figure 10-4]

Rossby wave
c. Upper troposphere processes

**Vorticity:**
- Increased vorticity $\rightarrow$ convergence
- Decreased vorticity $\rightarrow$ divergence

Textbook figure 10-7
c. Upper troposphere processes

Vorticity:

- **Cyclones** develop downwind of troughs
- **Anticyclones** develop upwind of troughs (downwind of ridges)

Textbook figure 10-7
c. Upper troposphere processes

500 height/ temp for 12Z 17 NOV 09

http://weather.unisys.com/upper_air/ua_500.html
c. Upper troposphere processes

http://weather.unisys.com/upper_air/ua_500.html
c. Upper troposphere processes

Dynamic low (cold-core low):
- low-pressure systems (cyclones) resulting from tropospheric motions

Thermal low (warm-core low):
- low-pressure caused by localized heating from below
c. Surface processes

Differences in surface temperature lead to upper level pressure gradients
c. Surface processes

Thus, near-surface temperatures strongly influence upper-level pressure distribution – e.g. jet stream is above polar frontal boundary.
Midlatitude Cyclones
ERTH 303 17 Nov., 2009

a. Polar front theory
b. Life cycle of a midlatitude cyclone
c. Upper troposphere and surface processes
d. Upper-level flow and large-scale weather
e. Conveyor Belt model
d. Upper-level flow and large-scale weather

Zonal flow: (W-E)

- Calm conditions
- No areas of widespread precip.
d. Upper-level flow and large-scale weather

**Meridional flow: (N-S)**

- Favors formation of cyclones and anticyclones
d. Upper-level flow and large-scale weather

Steering of midlatitude cyclones

- Systems parallel 500 mb flow, at $\frac{1}{2}$ speed
- Winter = strong flow aloft; more frequent storms

Textbook figure 10-16
Midlatitude Cyclones
ERTH 303 17 Nov., 2009

a. Polar front theory
b. Life cycle of a midlatitude cyclone
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e. Conveyor Belt model
Conveyor Belt Model:

- **Modern view of midlatitude cyclones**
- **Warm conveyor belt**
  - Originates near surface in warm sector
  - Frontal lifting results in precipitation
- **Cold conveyor belt**
  - Enters as an easterly belt flowing westward
- **Dry conveyor belt**
  - Upper-level, westerly flow
e. Conveyor Belts

Conveyor Belt Model:

- Dry conveyor belt
- Cold conveyor belt
- Cold front
- Warm conveyor belt
- Warm front
e. Conveyor Belts

Conveyor Belt Model:

- Cold Belt
- Dry Belt
- Warm Belt
In a middle latitude cyclone, this stage is called __________.

1. cyclogenesis
2. occlusion
3. maturity
4. senescence
In a middle latitude cyclone, this stage is called

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2. occlusion
3. maturity
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In a middle latitude cyclone, this stage is called

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1. cyclogenesis
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4. senescence
This diagram illustrates a _______.

1. middle latitude cyclone
2. cold front
3. flow in the stratosphere
4. Rossby wave
This diagram illustrates a _______.

1. middle latitude cyclone
2. cold front
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4. Rossby wave
10.08 Jet stream divergence causes _______.

1. middle latitude cyclones
2. sinking air
3. chaotic flow
4. anticyclones
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1. middle latitude cyclones
2. sinking air
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10.12 On this map, the surface low is located here because of _______.

1. a barotropic atmosphere
2. divergence aloft
3. convergence aloft
4. negative relative vorticity
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This upper air flow pattern is best termed “____.”

1. baroclinic
2. zonal
3. meridional
4. mythical
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