LABORATORY 1

WEATHER OBSERVATIONS AND MEASUREMENTS

MOTIVATION:

The condition of the atmosphere is determined by observing the state of the sky and measuring the visibility, precipitation, air temperature, dew point temperature (frost point), winds and pressure. These activities are identical to those a medical doctor performs to determine the condition of a patient. From the diagnoses, the doctor understands the condition of the patient and, hence, is able to prescribe a treatment. Likewise, from the diagnoses of the atmosphere, the meteorologist understands its condition and, hence, is able to make a prediction of future weather. Also, treatments can be applied to certain weather conditions; eg. to improve visibility in fogs and increase the snow packs in western USA mountainous regions (www.weathermodification.org).

To determine the condition of the atmosphere at Storm Peak Laboratory (SPL, 40.45° N, 106.74° W), we will make weather observations and measurements both at SPL Base (SPLB) and at SPL. A mid-mountain weather station (SPLM) will be established to make measurements automatically. Our data will be from one region in the atmosphere. However, additional data are collected in the region to more completely understand the weather at SPL. This is done by the National Weather Service (NWS, weather.noaa.gov). The NWS weather data is received at the CCNY Weather Station (J902). The NWS data collected at CCNY may be used to assist our analyses at CCNY of the data collected at SPL.

Here are some web-sites with useful weather information:
www.weather.unisys.com (Big picture)
www.rap.ucar.edu/weather (high-resolution satellite imagery)
www.arl.noaa.gov/ready.html (air parcel trajectories)
stormpeak.dri.edu (SPL weather)

OBJECTIVES:

Learn how to make weather observations and measurements at SPLB and SPL.

INSTRUMENTS:

Campbell Scientific automatic weather stations: thermometers (temperature), hygrometers (relative humidity), wind vanes (direction), anemometers (wind speed) and barometers (station pressure) are located at SPL (10,520 ft. MSL), SPLM (8500 ft. MSL) and SPLB (6,700 ft. MSL).
PROCEDURES:

The weather station at SPLM is solar-powered and, hence, self-contained. It will not require the student's attention, only the Prof's.

The following observations will be made at SPLB and SPL and the results recorded outside on the appropriate Outside data sheet and, then, transferred to the Weather Observations and Measurements sheets in the data books as follows:

<table>
<thead>
<tr>
<th>Weather Observations and Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location:</strong> SPLB</td>
</tr>
<tr>
<td><strong>Date</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>1/4</td>
</tr>
<tr>
<td>1/4</td>
</tr>
<tr>
<td>1/4</td>
</tr>
<tr>
<td>1/4</td>
</tr>
<tr>
<td>1/4</td>
</tr>
</tbody>
</table>
1. **Date**: ddmm format, 06Jan

2. **Time**: 24 hour clock format; 2000 instead of 8 pm

3. Determine the **cloud type** using the chart below from Gedzelman (1980, *Science and Wonders of the Atmosphere*):

- Low clouds: Stratus (St), Stratocumulus (StCu)
- Middle clouds: Altostratus (AtSt), Altocumulus (AtCu)
- High clouds: Cirrus (Ci), Cirrostratus (CiSt), Cirrocumulus (CiCu).
- Clouds of vertical development: Cumulus (Cu), towering Cu (TCu), cumulonimbus (Cb)

At night, it may not be possible to determine cloud type. If so just circle "Unkn", unknown.

---

A useful link for cloud photos: [www.uen.org/utahlink/weather/clouds/cloud_id.html](http://www.uen.org/utahlink/weather/clouds/cloud_id.html)
3 (continued). Determine the **cloud amount** as follows:
- Clear (**Clr**), 0/10th of sky covered with clouds
- Scattered (**Scat**), 1-3/10th of sky covered with clouds
- Broken (**Bkn**), 4-7/10 of sky covered with clouds
- Overcast (**Ovset**), 8-10/10th of sky covered with clouds

When SPL is in cloud (it's foggy), the cloud type and amount cannot be determined. Circle "in cloud" in the cloud-type column.

At night, it's not possible to determine cloud type or amount unless it either clear (can see stars in all quadrants of the sky) or it's overcast (cannot see any stars anywhere in the sky). In those cases you can circle, respectively, "clear" in the cloud type column and "overcast" in the cloud amount column.

4. Estimate **visibility** by locating the most distant object visible. For example, from **SPLB** report "Mt. Base", "T-head", "SPL". From **SPL** report "front yard" during an immersion in cloud and/or snowfall or "Bar-U-E" if you can see the lift. During out-of-cloud conditions with no snowfall, record the most distant town/landmark you can see: T-head is about 1 mile away, Wal Mart (big red sign) is about 5 miles away, Hayden is about 20 miles away, Craig is about 40 miles away and the Utah border (the horizon) is about 80 miles away.

5. At **SPLB**, read and record the values of **air temperature**, **relative humidity**, **wind direction and speed**, **station pressure** and the **voltage** on the battery from the display on the Campbell weather station as follows:
   a. Open the box.
   b. Press *6 on the 21X Micrologger
   c. Press A to advance through the data, press B to reverse through the data:
      1: Battery voltage (must be > 10.6 volts, if not tell the Prof.)
      2: Temperature (F)
      3: Relative humidity (%)
      4: Wind speed (knots, 0.34 knots reading when no cup movement)
      5: Wind direction (degrees true)
      6: Station pressure (mb)
   d. Leave display on battery voltage
   e. Close the box.

6. At **SPL** and **SPLB**, carefully observe the sky to determine if it is **snowing** (use a flashlight beam to illuminate the snow crystals at night) and answer Y if it is snowing and N if it is not snowing.

7. At **SPLB**, go to the edge of Pine Grove Road and observe the **condition of the road** surface: dry, dusty, wet, snow packed (this is to study the effect of cars on our particle counts).

8. At **SPLB**, the surveillance video-tape in room 309A must be changed during the 0800 observation at 07:45 MST. We use this tape to determine the hourly vehicle movements which, we in turn, correlate with our particle counts.
To operate the video:

- Initial start up at 1100 MST, just hit "record" (VHS tape = 120 min (standard recording))
- Every day at 07:45 MST
  1. Hit "Stop"
  2. Hit "Eject"
  3. Insert the next tape
  4. Hit "record"
- If the window fogs, increase the heater setting.

The procedures for operating the CCNY VCR for counting moving vehicles are in the VCR owners manual. The results are recorded as follows:

<table>
<thead>
<tr>
<th>Period (MST)</th>
<th>Number (from tape)</th>
<th>Significant weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>0900-1004</td>
<td>45</td>
<td>Clouds, snow @ SPL</td>
</tr>
<tr>
<td>1000-1044</td>
<td>40</td>
<td>Clouds forming</td>
</tr>
<tr>
<td>1100-1144</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>1200-1244</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>1300-1344</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>1400-1444</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>1500-1544</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>1600-1644</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>1700-1744</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1800-1844</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>1900-1944</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>2000-2044</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>2100-2144</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>2200-2244</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>2300-2344</td>
<td>160</td>
<td></td>
</tr>
<tr>
<td>0000-0044</td>
<td>170</td>
<td></td>
</tr>
</tbody>
</table>

9. At SPL, read the **temperature**, **relative humidity**, **wind direction/speed** values off the SPL web-page display. Note, **station pressure** is read from the CSI portable display.

All of the procedures so far have been to collect data. The data recorded by the automatic weather stations at **SPL**, **SPLM** and **SPLB** must be downloaded from the instruments so we can analyze the data. Most of the analysis will be done at CCNY. From these analyses we will detect known meteorological phenomena (eg. the mountain-valley diurnal wind cycle) and, perhaps, discover knew phenomena. The Prof's will work with the observers to conduct the downloading.

**CLOUD AND PRECIPITATION FORMATION PRIMER:**

The flow of stable, moist air over mountain ranges leads to cloud and precipitation formation on the windward slopes and warm, dry air flowing down the leeward slopes as described in most elementary meteorological texts (eg. Ahrens, *Meteorology Today*, 7th edition). Hindman (1986, *J. Clim. Appl. Meteor.*) described the phenomena for the Park Range (Figure 1 in the paper) and estimated only 6 to 14% of the moisture precipitates on the upwind slopes.

Our meteorological measurements made a SPLB can be used predict the height of cloud base on the windward slopes of the Range below SPL. This information tells us how far SPL (3210 m MSL) is above cloud base. For example, at 1130MST on 15 January 2003, SPL was in cloud and the base was observed just below Thunderhead Lodge (about 2700 m MSL). The temperature and relative humidity at SPLB (2043 m...
MSL) were 29F (-2C) and 81%, respectively. Using the accompanying atmospheric thermodynamic diagram from Stull (Meteorology for Scientists and Engineers, 2nd edition), we plot the temperature and dew-point temperature (T_d) values for SPLB. We get the T_d value from the following relationship:

\[
\text{RH (\%)} = \left[ \frac{r (@ T_d)}{r (@ T)} \right] \times 100
\]

where \( r \) is the mixing ratio (grams of vapor per kilogram of air).

\[
r (@ T_d) = 0.81 \times 4.5 \text{ g/kg} = 3.6 \text{ g/kg or -4C}
\]

We plot the T and T_d values at 2 km on the diagram. Then, trace from the T value up the slope of the dry adiabat (this represents the cooling of the air parcel from SPLB being forced up the windward slope). Likewise, trace from the T_d up the slope of the constant mixing ratio line (this represents the moistening of the air parcel) until the it intersects the adiabat through the T value. The intersection is where the T and T_d values are the same and cloud is formed. The intersection occurred at about 2400 m MSL. So our cloud base was estimated to be about 300 m lower that that observed. Most likely the T_d value was too warm, too moist; moisture is the most difficult atmospheric variable to measure. It can be seen that cloud base height is extremely sensitive to moisture content of the air.

Further, we can estimate the amount of water condensed in the parcel as it rose from cloud base to SPL. The r value at cloud base is 3.6 g/kg. Now, from that point, we trace up the moist adiabat to the elevation of SPL and read of the r value, 2.6 g/kg. Now, the difference between the r values is the amount of moisture condensed: 3.6 - 2.6 or 1 g/kg. Now the density of air is about 1 kg/m^3. So, the amount of condensed water in the cloud at SPL should be about 1 g/m^3.

We go to the cloud measurements made at SPL at 1100 MST, and we find a liquid water content of 0.3 g/m^3 (measurements to be discussed in the Cloud droplet measurements laboratory). The formation of cloud droplets cannot account all of the condensed vapor. So, some of 0.7 g/m^3 of the missing condensed water was probably (1) removed by droplets colliding with falling snow crystals (it was snowing at SPL at 1100 MST) or (2) the water contained in the snow crystals could have accounted for the 0.7 g/m^3. But, it was blowing too hard to get replicas of crystals to determine the amount of water in the snow crystals (snow crystal measurements and observations to be discussed in the Snow crystal measurement laboratory).
THERMODYNAMIC DIAGRAMS – PART 4: APPLICATIONS

In previous chapters, we created various components of a thermodynamic diagram. These are reproduced here as Figs 6.1a–c, but with identical aspect ratios so that they can be overlaid. Fig 6.1d shows all the components combined into a complete, but simplified, thermodynamic diagram. It will be used throughout this chapter to study various atmospheric processes.

Figure 6.2 (next page)

Full T-log P thermodynamic diagram for the atmosphere. Thin vertical lines are isotherms T, labeled at bottom in °C. Thin horizontal lines are isoliths P, labeled at left in kPa. Thin dashed lines nearly horizontal are height contours z, labeled at right in km. Thin diagonal dotted lines slightly off-vertical are iso-θw lines, labeled at the top in °C. All these thin lines represent the state of the air. Thick lines represent adiabatic processes that can change the state. Heavy diagonal solid lines are dry adiabats, labeled by potential temperature at the bottom in °C. Heavy curved dashed lines are moist (saturated) adiabats, labeled by liquid-water potential temperature θe at the bottom in °C. [Potential temperature is defined using a reference pressure of 1000 hPa, and height is set to zero there.]

Figure 6.3

Construction of a thermodynamic diagram. The background of all the charts are isotherms (vertical thin solid lines), and isoliths (horizontal thin solid lines). (a) dry adiabats (from Fig 3.5) are diagonal solid lines.

(b) Isoliums (from Fig 5.4) are nearly vertical dotted lines.
(c) moist adiabats (from Fig 5.5) are curved dashed lines; and
(d) complete diagram. P is pressure, T is temperature, θ is mixing ratio, θw is potential temperature, and θe is liquid water potential temperature.

From STILL, 'METEOROLOGY FOR SCIENTISTS AND ENGINEERS 2nd Edition'

Laboratory 1, pg. 7