Lecture 3
Observations
September 11, 2006

Homework Due September 18, 2006
TYU Ch1: 3,4,5,8,11,13,16,19;       TYPSS Ch1: 1
TYU Ch 2: 1,2,6,9,13,14,16,20,22;  TYPSS Ch2: 2
TYU Ch 3: 1,2,3,7,8,11,12,14,16;    TYPSS Ch 3: 2
Primary State Variables

Atmospheric conditions are defined in terms of “state” variables that are directly observed. The primary state variables are:

1. Pressure (force/unit area)
   a) Pascal (Pa) 1 Pa=1 Nt/m**2=1 kg /(s**2 m)
   b) Millibar (mb) or hecto Pascal (hPa)
   c) Psi (Lb/in**2)
   d) Inches Hg
   e) mm Hg (torr)
   f) Atmosphere (bar) 1 bar=14.7 psi=100,000 Pa=1,000 hPa=1,000 mb=29.53 in Hg=751.88 torr
   g) Standard pressure=1013.25 hPa=1013.25 mb=14.7 psi=29.92 in Hg=761.84 torr
Primary State Variables
(continued)

2. Temperature
   a) Celsius (C) (all observations and forecasts)
   b) Kelvin (K) (research)
   c) Fahrenheit (F) (surface maps and forecasting in US only)

3. Humidity
   a) Dew point
      i. Fahrenheit (surface and forecasting in US only)
      ii. Celsius (all other maps and forecasts)
   b) Mixing ratio (research, operations)
   c) Specific humidity (research, operations)
   d) Relative humidity (%) (Forecasts, public reports)

4. Wind
   a) Direction, speed
      i. Degrees, m/s (research)
      ii. Labeled direction (NW, S, etc), knots  all obs, forecasts
         i. Note: 1 kt=1.15 mph=0.5 m/s
   b) N-S and E-W components (m/s) (research)
Primary Observed “Weather” Variables

1. Cloud Cover
   a) % of sky covered
   b) Low level type
   c) Mid level type
   d) High level type

2. Visibility

3. Precipitation
   a) Rate (in/hr)
   b) Type (snow, moderate snow, light rain, drizzle, etc)
   c) Accumulation (2 inches since 12z)

4. Thunder

5. Pressure tendency
   a) Shape of curve
   b) mb of change over 3 hr period
   c) Height (m) change over 12 hr period
Some weather symbols used to convey observations.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No clouds</td>
</tr>
<tr>
<td>1</td>
<td>Clouds, thin or wispy</td>
</tr>
<tr>
<td>2</td>
<td>Clouds, more than half of sky</td>
</tr>
<tr>
<td>3</td>
<td>Clouds, thick</td>
</tr>
<tr>
<td>4</td>
<td>Streaks or bands</td>
</tr>
<tr>
<td>5</td>
<td>Snow, rain, or drizzle</td>
</tr>
<tr>
<td>6</td>
<td>Hail, sleet</td>
</tr>
<tr>
<td>7</td>
<td>Tornado, funnel cloud</td>
</tr>
<tr>
<td>8</td>
<td>Shower, thunderstorms</td>
</tr>
<tr>
<td>9</td>
<td>NOT USED</td>
</tr>
<tr>
<td>L</td>
<td>Low cloud</td>
</tr>
<tr>
<td>M</td>
<td>Middle cloud</td>
</tr>
<tr>
<td>H</td>
<td>High cloud</td>
</tr>
</tbody>
</table>
More Precipitation Symbols
Observations

Synoptic Meteorology

Synoptic means “at the same time”

Synoptic observations are coordinated to be taken at standard synoptic times

Surface observations times:
- Once every hour

Upper air observations:
- Once every 12 hours, i.e. 0000 UTC and 1200 UTC

(same as 0000Z and 1200Z)
Average surface station spacing
~100 km
Surface observations

Meteogram for Buffalo, New York
From 2000 UTC 26 December 2001 to 2000 UTC 27 December 2001

- Temperature
- Dew Point Temperature
- Snow Depth (inches)
- Visibility (miles)
- Wind (knots)
- Cloud Level (feet)
- Pressure (mb)

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Convention al upper air observations by Radiosonde Balloon

Courtesy of National Weather Service
Average spacing of upper aqir observations ~400 km
Radiosonde and Rawinsonde

- The **radiosonde** is a balloon-borne **instrument platform** with radio transmitting capabilities. Originally named a radio-meteorograph, the instrument is now referred to as a radiosonde, a name apparently derived by H. Hergesell from a combination of the words "radio" for the onboard radio transmitter and "sonde", which is messenger from old English.
- The radiosonde contains instruments capable of making direct **in-situ** measurements of air temperature, humidity and pressure with height, typically to altitudes of approximately 30 km. These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package. The ascent of a radiosonde provides an indirect measure of the wind speed and direction at various levels throughout the troposphere. Ground based radio direction finding antenna equipment track the motion of the radiosonde during its ascent through the air. The recorded elevation and azimuth information are converted to wind speed and direction at various levels by triangulation techniques.
- A **rawinsonde** (or radio wind sonde) is a radiosonde package with an attached radar reflector that permits radio-direction finding equipment to determine the wind direction and wind speed at various altitudes during the ascent of the package.
Measurements of Rawinsonde

a) Pressure (measured with aneroid marometer)
   a) The radiosonde measures pressure by means of an aneroid barometer, consisting of a small, partially evacuated metal canister. This temperature compensated instrument is central to the instrument package. The volume of the canister expands as the radiosonde ascends, in response to a reduction in the atmospheric pressure aloft. The aneroid is designed to register pressures from 1040 mb to 10 mb or less. The aneroid also serves another function as described below. A pen arm is attached to the aneroid.

b) Temperature (measured with thermistor)
   a) The resistance thermistor is a white ceramic covered metallic rod that serves as a temperature sensor on most American radiosondes. The diameter of the rod is approximately 0.7 mm and its length is no more than 2 cm. The electrical resistance of this rod changes with a change in the air temperature. To increase contact with the air, the thermistor is located on an outrigger, extended a distance from the outside of the instrument package. The thermistor is white to minimize the heating by sunlight. The temperature range for the thermistor lies between approximately +40° C to 90° C.

c) Humidity (measured with hygristor)
   a) The hygristor is a humidity sensor consisting of a glass slide or plastic strip covered with a moisture sensitive film of lithium chloride (LiCl) and a binder; metal strips are located along the edges. The electrical resistance of the chemical changes with a change in the atmospheric humidity. The hygristor is located within the instrument package at a place where the outside air passes the hygristor. The hygristor on most radiosondes is designed to record the ambient relative humidity in the range from 15% to 100%.

d) Wind
   a) Balloon tracking from launch point

e) Height (meters above mean sea level, MSL) of the point where a specified pressure value occurs. For instance, 500 hPa pressure might be measured to occur at 5,542 m above sea level. Although the radiosonde measures this pressure directly, the height is actually calculated from the pressure, temperature and humidity. A radiosonde observation of pressure, temperature, humidity, height and wind is recorded as often as every couple of millibars of pressure fall (the pressure falls as the balloon gains altitude), but is ALWAYS recorded at the mandatory pressure levels:
   a) 1000 hPa (near sea level)
   b) 925 hPa Low level jet, nocturnal PBL (planetary boundary layer) height
   c) 850 hPa (just above daytime PBL, valid free air temperatures)
   d) 700 hPa (middle of 1000-500 hPa layer, steering currents for lower troposphere)
   e) 500 hPa (middle of troposphere, steering currents for tropospheric weather systems level of non divergence)
   f) 300 hPa (Height between mid-latitude and polar tropopause, , polar jet stream)
   g) 250 hPa (compromise between 200 hPa ad 300 hPa)
   h) 200 hPa (between f tropical and mid-latitude tropopause sub tropical jet stream)

Constant pressure surface weather maps are drawn for each of these mandatory pressure levels.
Sounding

An upper air sounding provides all primary state variables as a function of height from the surface up to about 50-100 hPa pressure level

Plot of sounding on a Stuve Diagram
(T vs. log P)

Plot of sounding on a Skew-T log P Diagram
(This diagram is preferred because the difference between two lines is proportional to the energy difference between the process or atmosphere that the lines represent)

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RADAR  
(RAdio Detection And Ranging)
RADAR Measures the strength of a reflected pulse of microwave radiation emitted by a radar transmitter

Reflectivity Factor is the strength of the echo reflected energy) measured relative to pulsed energy in units of dBz

dBZ are decibels 10(power of 10) of reflected energy

The higher the reflectivity factor, the more dense the precipitation in a region

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Next Generation Radar (NEXRAD)

• Measures:
  – Reflected energy (reflectivity)
  – Doppler shift of returned frequency
    • Derive inbound/outbound movement of precipitation
    • Derive turbulence in precipitation
NEXRAD sites over the US

A. NEXRAD radar locations

B. Area of coverage by each radar at 10,000 feet above ground level.

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NEXRAD Today

- Sites around the Nation
  http://www.rap.ucar.edu/weather/radar/

- Composites made by UW AOS Department
  http://www.aos.wisc.edu
Wind Profiler (upward pointing Phased array antenna)
Measures wind change with height

Courtesy of NOAA
Profiler data
Satellite measurements

A. Visible
B. Infrared
C. Derived (vapor)

http://www.aos.wisc.edu/weather
Geostationary Satellites

Goes 12

Goes 10

Goes 9

0000 UTC
3 January 2004

Indsat

Meteosat

Geostationary Operational Environmental Satellite)
Polar Orbiting Satellites

- **Modis**
- **NOAA satellites**
  - [http://amrc.ssec.wisc.edu/realnoaa.html](http://amrc.ssec.wisc.edu/realnoaa.html)
- **NASA Research Satellites (Earth Observing System)**
  - TRMM (Tropical Rainfall Measurement Mission) (Active Sensor)
    - K-band Radar on board
    - TRMM Microwave Imager (TMI) observe precipitation
  - **Modis**
    - [http://eosdb.ssec.wisc.edu/modisdirect/](http://eosdb.ssec.wisc.edu/modisdirect/)
    - [http://modis-atmos.gsfc.nasa.gov/IMAGES](http://modis-atmos.gsfc.nasa.gov/IMAGES)
A-Train

- **Calipso Lidar** (Light detection and Ranging, i.e. laser radar) Sensor
  - Detects haze, smoke
- **Cloud Sat** (Milimeter RADAR)
  - Detects small cloud drops, fog
- **Aqua** (modis satellite measuring IR Microphysical properties/visible at high resolution)
- **Parosol** (radiometer, polarimeter)
- **Aura** (Chemistry measurements) microwave limb sounder

Red indicates active sounder, ie. Satellite measures reflection of energy of a pulse that it sent.
Aircraft Observations

Aircraft data for 23-Jan-01 0000 to 23-Jan-01 0259Z
10131 reports shown, between -521 and 42999 ft.
Zoom = 1.50, Center Lat/Lon = (38.75, 98.10)

Courtesy of NOAA/FSL
National Lightning Detection Network

NLDN sensor locations

- IMPACT sensors
- TOA (LPATS) sensors

Courtesy of the American Meteorological Society and Global Atmospherics Inc.
Lightning Data

http://www.aos.wisc.edu/weather
The Automated Surface Observing System (ASOS)

http://www.aos.wisc.edu/weather/wx_obs
Ocean Buoy Data

Courtesy of NOAA