Part 1. Atmospheric Variables

Temperature – a measure of the kinetic energy of molecules – heat content of atmosphere or earth’s surface.

Humidity – moisture content of the atmosphere or how close it is to saturation.

Precipitation – supply of water substance from atmosphere-rain-snow-hail precip. Is very discontinuous in space.
Wind – air in motion – it is a vector having both magnitude (wind speed) and direction \((60^\circ - 120^\circ - 300^\circ)\).

Pressure – Force per unit area – or weight of an air column per unit area.

Horizontal pressure differences accelerate winds.
Part 2. Communication with the atmosphere or atmospheric sensors

T – thermomenters – mercury thermometers, bimetallic strips, resistance thermometers (thermistors), thermocouples, radiometers.

Recording - electronic magnetic tape – thermograph charts.

Humidity (RH) – hygrometers dew point/frost point hygrometers – cool air to saturation – most accurate.

Hygroscopic coated bars (carbon) which change conductivity with increasing moisture – wet/dry bulb – IR absorption sensors.
Pressure

Aneroid barometer (evacuated, expandable chamber)

Mercury barometer
Precipitation

Rain gauges – tipping bucket or weighing gauges – snow depth; snow weight (snow pillow)

Wind

Direction – weather vane
Speed – cup or propeller
Hot wire anemometers

Upper Air - radiosonde

T, P, RH, wind speed and direction by radiotheatolite tracking of balloon movement – New GPS positioning.

Satellite – cloud patterns, temp. of cloud tops, moisture in layers by microwave emissions.
FIGURE 2-1 Locations of all the NOAA synoptic and basic weather stations where meteorological data are collected to serve forecast programs and to provide data for international exchange as well as for all other uses. Observations on the amount of sky cover, type of clouds, wind, visibility, weather, temperature, dew point, and pressure are made at world standard synoptic times: 0000, 0600, 1200, and 1800 GMT. The basic observing stations also provide data at hourly intervals and include cloud height and altimeter settings for aircraft operations. (From "Operations of The National Weather Service." NOAA.)
Because weather systems are three dimensional, both surface and upper-air weather maps are needed. A very different approach is used for the two types of maps, however. Surface weather data are plotted on a constant altitude (usually sea-level) surface, and upper-air weather data are plotted on constant-pressure (isobaric) surfaces.
Upper Air Sounding Network

FIGURE 2-3 The location of rawinsonde stations, where observations of pressure, temperature, moisture, and winds aloft are made. These stations provide information on the third dimension (various heights) to supplement the horizontal distribution of measurements of the state of the atmosphere at 0000 and 1200 GMT. (From Operations of the National Weather Service, NOAA.)
Remote Sensors

• Fundamentals

• Advantages:
  o Fully automated thus require only an occasional technician.
  o Excellent coverage (horizontally) even over oceans.

• Disadvantages:
  o Does not measure state variables directly. They must be inferred or retrieved.
  o In the case of satellites, poor vertical resolution.
  o Expensive.
Electromagnetic Spectrum

$\gamma = \frac{c}{\lambda}$
Planck’s Law:

\[ E_{\lambda} = \frac{C_1}{\lambda^5 \left[ \exp\left(\frac{C_2}{\lambda T}\right) - 1 \right]} \]

\[ C_1 = 3.74 \times 10^{16} \text{Wm}^2, \quad C_2 = 1.44 \times 10^{-2} \text{m}^* \text{K} \]
Wein Displacement Law

\[ \lambda_{\text{max}} = 2897 \mu m K / T \]

Stefan Boltzman Law

Blackbody irradiance

\[ E^* = \sigma T^4 \]

(obtained by integrating Planck’s eqs. Overall wavelength

\[ \sigma = 5.67 \times 10^{-8} Wm^{-2} \text{deg}^{-4} \]
Kirchoff’s Law

\[ a_\lambda = E_\lambda \]

Materials that are strong absorbers at a \( \lambda \) are also strong emitters at that \( \lambda \).
\[ \mu = 10^{-4} \, cm = 10^{-6} \, m \]
Fig. 5.2. Atmospheric spectrum obtained with a scanning interferometer on board the Nimbus 4 satellite. The interferometer viewed the earth vertically as the satellite was passing over the North African desert. [After Hanel et al., 1972; from Faltridge and Platt, 1976.]
Polar Orbiting

Geostationary
3 Feb 987 00Z
Figure 7.15. 6.7 μm channel image, for 1 September 1983 at 0515 GMT, showing cool areas (light tones) and warmer, drier areas (dark tones).
Radars

Radar Reflectivity ($Z$)

$$A = N_i D_i^6$$

If size-spectra of drops can be estimated, then $Z \propto$ rain rate.
Triple Doppler Radars
Doppler Radars

(a) (b)
Velocity-Azimuth-Display (VAD)

Obtain average wind in layers for a column.
More accurate estimates of rainfall – rain vs. hail.
Wind Profilers

They don’t need precipitation or bugs to get reflection just variations in refractive index.

RASS Temp. Retrieval

\[ c_s \propto \sqrt{T_v} \]
Instrumented Aircraft

ACARS – winds, T
Coming soon RH
Gust Probes
Figure 2.15. Scan geometry for the NCAR ELDORA system.
Figure 1.8. Vertical temperature profile for the U.S. Standard Atmosphere.
Fig. 1.11 Meridional cross sections of longitudinally averaged temperature in degrees Celsius (---) and zonal wind in meters per second (---) for the northern hemisphere in January (a) and July (b). Positive zonal winds indicate flow from west to east. Heavy lines denote the tropopause and the Arctic inversion. (After Arctic Forecast Guide, U.S. Navy Weather Research Facility, 1962.)