Observations

- Two types: “direct” and “indirect”:
  - direct: measure at the location of the instrument.
  - indirect: measure remotely from the instrument.
    - “active”: emit radiation; analyze return (e.g., radar).
    - “passive”: analyze incoming radiation (e.g., camera).

Instruments

<table>
<thead>
<tr>
<th>quantity</th>
<th>direct</th>
<th>indirect</th>
</tr>
</thead>
<tbody>
<tr>
<td>temperature</td>
<td>thermometer</td>
<td>satellite (infrared).</td>
</tr>
<tr>
<td>pressure</td>
<td>barometer</td>
<td>satellite.</td>
</tr>
<tr>
<td>wind</td>
<td>anemometer</td>
<td>satellite (cloud track).</td>
</tr>
<tr>
<td>moisture</td>
<td>hygrometer</td>
<td>radar; satellite.</td>
</tr>
<tr>
<td>precipitation</td>
<td>rain gauge</td>
<td>radar; satellite.</td>
</tr>
</tbody>
</table>

Direct observation frequency

- **Surface observations** (airports and automated stations): hourly, or more frequent. Dense surface network.

- **Upper-level observations** (rawindsondes): twice daily (00 UTC, 12 UTC). Sparse surface network.

Typical errors

Surface observations

- sea level pressure
  - land stations; buoys: $\pm 0.5 - 1.0$ hPa
  - ships: $\pm 1 - 3$ hPa
temperature: ± 1° C.

wind speed and direction: ± 2–4 m s\(^{-1}\); ± 10°.

moisture (relative humidity): ± 10%.

**Rawindsonde observations**

\[
\begin{align*}
\text{geopotential height} & \\ 700 \text{ hPa} & 5–10 \text{ m} \\
500 \text{ hPa} & 10–15 \text{ m} \\
300 \text{ hPa} & 15–20 \text{ m} \\
100 \text{ hPa} & 20–30 \text{ m}
\end{align*}
\]

temperature: ± 0.5° C.

wind speed and direction: ± 5%; ± 10°.

**Typical contour intervals**

temperature: 5°, starting with 0° C.

pressure, geopotential height:

<table>
<thead>
<tr>
<th>level</th>
<th>contour interval</th>
<th>starting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean sea level</td>
<td>4 hPa</td>
<td>1000 hPa.</td>
</tr>
<tr>
<td>850 hPa</td>
<td>3 dam (30 m)</td>
<td>150 dam.</td>
</tr>
<tr>
<td>700 hPa</td>
<td>3 dam</td>
<td>300 dam.</td>
</tr>
<tr>
<td>500 hPa</td>
<td>6 dam</td>
<td>564 dam.</td>
</tr>
<tr>
<td>300 hPa</td>
<td>12 dam</td>
<td>948 dam.</td>
</tr>
</tbody>
</table>

**Miscellany**

pressure units: 1 bar = 10\(^5\) Pa. \(\rightarrow\) 1 mb = 1 hPa.

wind speed: 1 m s\(^{-1}\) = 1.95 knots = nautical miles/hour.
1 nautical mile = 1.15 statute miles (5280 feet).