SEA-LEVEL PRESSURE REDUCTION

Near the bottom of the troposphere, pressure gradients are large in the vertical (order of 10 kPa km^{-1}) but small in the horizontal (order of 0.001 kPa km^{-1}). As a result, pressure differences between neighboring surface weather stations are dominated by their relative station elevations z_{stn} (m) above sea level.

However, horizontal pressure variations are important for weather forecasting, because they drive horizontal winds. To remove the dominating influence of station elevation via the vertical pressure gradient, the reported station pressure P_{stn} is extrapolated to a constant altitude such as mean sea level (MSL). Weather maps of **mean-sea-level pressure** (P_{MSL}) are frequently used to locate high- and low-pressure centers at the bottom of the atmosphere.

The extrapolation procedure is called **sea-level pressure reduction**, and is made using the hypsometric equation:

$$P_{MSL} = P_{stn} \cdot \exp\left(\frac{z_{stn}}{a \cdot \overline{T_v^*}}\right) \tag{9.1}$$

where $a = \Re_d/|g| = 29.3$ m K^{-1}, and the average air virtual temperature $\overline{T_v}$ is in Kelvin.

A difficulty is that $\overline{T_v}$ is undefined below ground. Instead, a fictitious average virtual temperature is invented:

$$\overline{T_v^*} = 0.5 \cdot [T_v(t_o) + T_v(t_o - 12\text{ h}) + \gamma_{sa} \cdot z_{stn}] \tag{9.2}$$

where $\gamma_{sa} = 0.0065$ K m^{-1} is the standard-atmosphere lapse rate for the troposphere, and t_o is the time of the observations at the weather station. Eq. (9.2) attempts to average out the diurnal cycle, and it also extrapolates from the station to halfway toward sea level to try to get a reasonable temperature.

Sample Application

Phoenix Arizona (elevation 346 m MSL) reports dry air with T = 36°C now and 20°C half-a-day ago. P_{stn} = 96.4 kPa now. Find P_{MSL} (kPa) at Phoenix now.

Find the Answer

Given: T(now) = 36°C, T(12 h ago) = 20°C,
z_{stn} = 346 m, P(now) = 96.4 kPa. Dry air.
Find: P_{MSL} = ? kPa

$T_v \approx T$, because air is dry. Use eq. (9.2) : $\overline{T_v^*}$ =

$$= 0.5 \cdot [(36°C) + (20°C) + (0.0065 \text{ K m}^{-1}) \cdot (346 \text{ m})]$$

$$= 29.16 °C \ (+ 273.15) = 302.3 \text{ K}$$

Use eq. (9.1):

$$P_{MSL} = (96.4 \text{ kPa}) \cdot \exp[(346 \text{ m})/((29.3 \text{ m K}^{-1}) \cdot (302.3 \text{ K}))]$$

$$= (96.4 \text{ kPa}) \cdot (1.03984) = \underline{\mathbf{100.24 \text{ kPa}}}$$

Check: Units OK. Physics OK. Magnitude OK.
Discus.: P_{MSL} can be significantly different from P_{stn}