

## Sources for physical properties of water in the WaterProp program

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### Density of water

A power function curve-fit was applied to data from the CRC Handbook of Chemistry and Physics:

$$\rho = \beta_0 + \beta_1 T + \beta_2 T^2 + \beta_3 T^3 + \beta_4 T^4 + \beta_5 T^5 + \beta_6 T^6$$

where  $\rho$  is the density of liquid water in  $\text{kg/m}^3$ ,  $T$  is the water temperature in degrees Celsius, and with the following parameters:

$$\begin{aligned}\beta_0 &= 999.845916 \\ \beta_1 &= 6.5700958E-2 \\ \beta_2 &= -8.7817835E-3 \\ \beta_3 &= 8.3996043E-5 \\ \beta_4 &= -7.8432029E-7 \\ \beta_5 &= 4.6724264E-9 \\ \beta_6 &= -1.2487522E-11\end{aligned}$$

### Viscosity of water

A formula provided in Sengers and Watson (1986) was used. See the original paper, the formula is too complex to present conveniently.

### Surface tension of water

The formula provided by Vargaftik *et al.* (1983) is used:

$$\sigma = 0.2358 \left[ \frac{647.15 - T_k}{647.15} \right]^{1.256} \left[ 1 - 0.625 \left( \frac{647.15 - T_k}{647.15} \right) \right]$$

where  $\sigma$  is the surface tension of water in units of N/m given  $T_k$  as the temperature in Kelvin.

### Saturation vapor pressure of water

The Sonntag 1990 formulae are used (Sonntag, 1990; Alduchov and Eskridge, 1996). The basic formula is:

$$E_w = e^{-[aT_k^{-1} + b + cT_k + dT_k^2 + e \log T_k]}$$

where  $E_w$  is the saturation vapor pressure in kPa units given  $T_k$  as the temperature in Kelvin. The parameters  $a$  through  $e$  for liquid or ice water are given as:

<u>Parameter</u>	<u>Liquid water</u>	<u>Ice water</u>
$a$	-6096.9385	-6024.5282
$b$	21.2409642	29.32736
$c$	-2.711193e-2	1.0613868e-2
$d$	1.673952e-5	-1.3198825e-5
$e$	2.433502	-0.49382577

### Saturation water vapor concentration

Vapor pressure is converted to vapor concentration (or density) by application of the Ideal Gas Law, giving:

$$\rho_w = \frac{2.167E_w}{T_k}$$

where  $\rho_w$  is the vapor density in  $\text{g/m}^3$  units given  $E_w$  (vapor pressure) in kPa units.

### References

Alduchov OA and RE Eskridge. 1996. Improved Magnus form approximation of saturation vapor pressure. *Journal of Applied Meteorology* 35:601-609.

Sengers JV and JTR Watson. 1986. Improved international formulations for the viscosity and thermal-conductivity of water substance. *Journal of Physical and Chemical Reference Data* 15:1291-1314.

Sonntag D. 1990. Important new values of the physical constants of 1986, vapor pressure formulations based on ITS-90 and psychrometer formulae. *Zeitschrift für Meteorologie* 40:340-344.

Vargaftik NB, BN Volkov, and LD Voljak. 1983. International tables of the surface-tension of water. *Journal of Physical and Chemical Reference Data* 12:817-820.