

DISSOLVED OXYGEN (DO) CHEAT SHEET

CENTRE FOR MARINE APPLIED RESEARCH (CMAR)

$$[DO_{\% \text{ saturation}}] = [DO_{\text{corrected}}] / [DO_{\text{solubility}}] \quad [DO_{\text{corrected}}] = [DO_{\text{measured}}] * F_S * F_P$$

Only use when
 0 °C < T_{Celsius} < 40 °C
 0 < Salinity < 40 PSU
 0.5 < Pressure < 1.1 ATM

DO Solubility

- DO solubility is the maximum DO concentration based on temperature, salinity, & pressure conditions.
- Two common equations for calculating DO solubility are presented below. See USGS 2011 for comparison of these and other equations.
- Calculated DO solubility can be used to convert measured DO from units of concentration to percent saturation.

Salinity Correction Factor (Fs)

- Some DO sensors do not account for salinity. When these sensors are deployed in salt water, the observations should be adjusted using a salinity correction factor.
 - E.g., the HOBOb Dissolved Oxygen Logger (U26-001) is an optical sensor that measures dissolved oxygen concentration (mg/L) without accounting for salinity.
- Three salinity correction factor equations are presented below.

Pressure Correction Factor (Fp)

- Calculated or observed DO measurements taken where pressure differs substantially from 1 atm should be adjusted using a pressure correction factor.
- CMAR assumes sea-level deployments are at 1 atm.

Benson & Krause (1984)

- Equation 32 (for units of mg/kg, which is equivalent to mg/L) is an empirical equation fitted to values calculated from formulas derived from first principles.
- This equation is used by [USGS DOTABLES](#) to calculate DO solubility.
- This equation is an option for calculating DO solubility in the CMAR strings package.

Benson & Krause (1984)

- This is the final term of the Benson & Krause (1984) DO solubility in salt water equation.
- This equation is used by [USGS DOTABLES](#) to calculate salinity correction factor.
- This equation is an option calculating salinity correction factor in the CMAR strings package.

Benson & Krause (1984)

- The pressure correction factor in the CMAR strings package depends on barometric pressure, water vapour pressure, and the second virial coefficient of oxygen.

$$F_P = P * \frac{\left[\left(1 - \frac{P_{wv}}{P}\right) (1 - \theta P) \right]}{\left[(1 - P_{wv}) (1 - \theta) \right]}$$

Partial pressure of water vapor (atm)
Barometric Pressure (atm)

↓
↓

↑
Second virial coefficient of oxygen ↑

$$[DO] = \exp \left[A_0 + \frac{A_1}{T_{\text{Kelvin}}} + \frac{A_2}{T_{\text{Kelvin}}^2} + \frac{A_3}{T_{\text{Kelvin}}^3} + \frac{A_4}{T_{\text{Kelvin}}^4} - S * \left(B_0 + \frac{B_1}{T_{\text{Kelvin}}} + \frac{B_2}{T_{\text{Kelvin}}^2} \right) \right]$$

$$F_S = \exp \left[-S * \left(B_0 + \frac{B_1}{T_{\text{Kelvin}}} + \frac{B_2}{T_{\text{Kelvin}}^2} \right) \right]$$

$$T_{\text{Kelvin}} = T_{\text{Celsius}} + 273.15$$

$$P_{wv} = (1 - 5.370E-4 * S) *$$

$$\exp \left[18.1973 * (1 - 373.16 / T_{\text{Kelvin}}) + 3.1813E-7 * (1 - \exp(26.1205 * (1 - T_{\text{Kelvin}} / 373.16))) - 1.8726E-2 * (1 - \exp(8.03945 * (1 - 373.16 / T_{\text{Kelvin}}))) + 5.02802 * \log(373.16 / T_{\text{Kelvin}}) \right]$$

$$\theta = 0.000975 - (1.426E-5) * T_{\text{Celsius}} + (6.436E-8) * T_{\text{Celsius}}^2$$

Garcia & Gordon (1992)

- This equation is an updated version of the Benson & Krause (1984) equation, with additional terms and scaled temperature (Ts) to improve fit at extreme temperature and salinity values. However, added refinement may not be necessary or worthwhile for all applications (USGS 2011).
- Equation 8, with coefficients from Table 1 (Garcia & Gordon 1992) and conversion factor from cm³/dm³ to mg/L (USGS 2011).
- This equation is an option for calculating DO solubility in the CMAR strings package.

Garcia & Gordon (1992)

- This is the final term of the Garcia & Gordon (1992) DO solubility equation.
- This equation is the default option for salinity correction factor in the CMAR strings package.

$$F_S = \exp \left[S * (B_0 + B_1 * T_S + B_2 * T_S^2 - B_3 * T_S^3) + C_0 * S^2 \right]$$

$$[DO] = 1.42905 * \exp \left[A_0 + A_1 * T_S + A_2 * T_S^2 + A_3 * T_S^3 + A_4 * T_S^4 + A_5 * T_S^5 + S * (B_0 + B_1 * T_S + B_2 * T_S^2 - B_3 * T_S^3) + C_0 * S^2 \right]$$

$$T_S = \ln \left[\frac{298.15 - T_{\text{Celsius}}}{273.15 + T_{\text{Celsius}}} \right]$$

Coefficients

	Benson & Krause	Garcia & Gordon	HOBOWare
A_0	-1.3590205E+02	2.00907	-
A_1	1.575701E+05	3.22014	-
A_2	-6.642308E+07	4.0501	-
A_3	1.243800E+10	4.94457	-
A_4	-8.621949E+11	-2.56847E-01	-
A_5	-	3.88767	-
B_0	1.7674E-02	-6.24523E-03	-6.246090E-03
B_1	-1.0754E+01	-7.37614E-03	-7.423444E-03
B_2	2.1407E+03	-1.03410E-02	-1.048635E-02
B_3	-	-8.17083E-03	-7.987907E-03
C_0	-	-4.88682E-07	-4.6799830E-07

References

- Benson, B. B., & Krause Jr., D. (1984). The concentration and isotopic fractionation of oxygen dissolved in freshwater and seawater in equilibrium with the atmosphere.1. Limnology and Oceanography, 29(3), 620-632. doi:https://doi.org/10.4319/lo.1984.29.3.0620
- Garcia, H. E., & Gordon, L. I. (1992). Oxygen solubility in seawater: Better fitting equations. Limnology and Oceanography, 37(6), 1307-1312. doi:https://doi.org/10.4319/lo.1992.37.6.1307
- USGS. (2011). Analysis to Support the Replacement of Weiss (1970) Equations by Benson and Krause (1980, 1984) Equations for USGS Computation of Solubility of Dissolved Oxygen in Water. (Technical Memorandum 2011.03).
- USGS. (2019). DOTABLES. Retrieved from https://water.usgs.gov/water-resources/software/DOTABLES/

Dissolved Oxygen Assistant for HOBOWare Pro Software (2021)

- This equation, modified from Garcia & Gordon (1992) is the same form of the equation, with different values for the coefficients.
- "Adjustments in the equations were developed to better work with the tech we use to measure DO. During the development process for the U26 logger and the supporting software, the equations we use were thoroughly tested to insure accuracy, and have stood the test of time." - (HOBOWare Tech Support, pers. comm.)

$$F_S = \exp \left[S * (B_0 + B_1 * T_S + B_2 * T_S^2 - B_3 * T_S^3) + C_0 * S^2 \right]$$

$$T_S = \ln \left[\frac{298.15 - T_{\text{Celsius}}}{273.15 + T_{\text{Celsius}}} \right]$$