

# Sea-Air Heat Exchange Formulas

Guillaume Riflet, Isabella Ascione

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## 1 Sea-Air Heat Exchange

The source and sink terms of the tracer temperature near the surface writes

$$\frac{\partial T_s}{\partial t} = -\frac{Q}{\rho_s c_{ps} H}, \quad (1)$$

where all the quantities are described in table 1.

The water-air heat exchange,  $Q$ , is given in [1] by

$$Q = Q_B + L_v E + Q_s - Q_I, \quad (2)$$

where  $Q_B$  is the infrared radiation of water,  $L_v$  is the latent heat of vaporization of water,  $E$  is the evaporation flux,  $Q_s$  is the sensible heat exchange at the surface and  $Q_I$  and  $Q_{I_0}$  are the incident solar radiation and direct solar radiation, respectively.

The infrared radiation follows Stefan's Law, as seen in [1],

$$Q_B = \sigma T_s^4. \quad (3)$$

The evaporation flux is expressed as a function of air speed at a reference height and of the difference in specific humidity between the interface and the reference height, given in [1] by

$$E = \rho_a c_E U (q_s - q_a). \quad (4)$$

The sensible heat exchange is a function of air speed and of the temperature difference between the surface and the reference height, seen in [1] as

$$Q_s = \rho_a c_{pa} c_H U (T_s - T_a). \quad (5)$$

The incident solar radiation is proportional to the direct solar radiation modulated by the water surface albedo and by the cloud cover percentage, as suggested in [1]

$$Q_I = Q_{I_0} (1 - \alpha_s) (1 - 0.7 n_c) \quad (6)$$

Table 1: Parameters symbols, values and units

Symbol	Definition	Value	Units (IS)
$T_s$	Surface temperature	-	$K$
$T_a$	Air temperature	-	$K$
$t$	Time variable	-	$s$
$H$	Water control volume depth	-	$m$
$Q$	Total heat flux	-	$Wm^{-2}$
$Q_B$	Infrared radiation of water	-	$Wm^{-2}$
$L_v$	Water vaporization latent heat	$2.5 \times 10^6$	$Jkg^{-1}$
$E$	Evaporation rate	-	$kgm^{-2}s^{-1}$
$Q_s$	Sensible heat flux	-	$Wm^{-2}$
$Q_I$	Solar radiation	-	$Wm^{-2}$
$Q_{I_0}$	Direct solar radiation	-	$Wm^{-2}$
$\rho_s$	Water density	1000	$kgm^{-3}$
$\rho_a$	Air density	1.275	$kgm^{-3}$
$c_{ps}$	Water specific heat	4157	$Jkg^{-1}K^{-1}$
$c_{pa}$	Air specific heat	717.8	$Jkg^{-1}K^{-1}$
$q_s$	Specific humidity at interface (100%)	$1.50 \times 10^{-2}$	-
$q_a$	Reference specific humidity (50%)	$7.34 \times 10^{-3}$	-
$\sigma$	Stefan's constant	$5.67 \times 10^{-8}$	$Wm^{-2}K^{-4}$
$U$	Reference air speed	-	$ms^{-1}$
$c_E$	Dalton number	$1.5 \times 10^{-3}$	-
$c_H$	Stanton number	$1.1 \times 10^{-3}$	-
$\alpha_s$	Water surface albedo	-	-
$n_c$	Cloud cover percentage	-	-
$I_M$	Noon direct solar radiation	-	$Wm^{-2}$
$t_{sr}$	Sunrise	-	$s$
$t_{ss}$	Sunset	-	$s$

The direct solar radiation has a diurnal period where it is zero except between sunrise and sunset, where it follows a sinusoidal evolution for half a period. It can be parameterized by

$$Q_{I_0} = \begin{cases} I_M \sin\left(\pi \frac{t-t_{sr}}{t_{ss}-t_{sr}}\right) & \text{if } t \pmod{24h} \in [t_{sr} \ t_{ss}], \\ 0 & \text{otherwise.} \end{cases} \quad (7)$$

## 2 Water-Air Chlorine Exchange

A simple source and sink term for the tracer chlorine could be given by

$$\frac{\partial \text{Chl}}{\partial t} = -(1/T_1 + 1/T_2) \text{Chl} \quad (8)$$

where  $T_1$  is the evaporation period ( $\sim 24h$ ) and  $T_2$  is the bulk evaporation period due to chemical reactions ranging between  $1.35h$  and  $100h$  as proposed in [2].

## References

- [1] GILL, A. *Atmosphere-ocean dynamics*. Academic Press New York, 1982.
- [2] POWELL, J. C., HALLAM, N. B., WEST, J. R., FORSTER, C. F., AND SIMMS, J. Factors which control bulk chlorine decay rates. *Science* *34*, 1 (2000).
- [3] WOLFRAM—ALPHA. *knowledgebase*. 2012.