Sea-Air Heat Exchange Formulas

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1 Sea-Air Heat Exchange

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

$$\frac{\partial T_s}{\partial t} = \frac{Q}{\rho_s \, c_{ps} \, H}, \tag{1}$$

where all the quantities are described in table 1.

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

$$Q = Q_B + L_v \, E + Q_s - Q_I, \tag{2}$$

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],

$$Q_B = \sigma \, T_s^4. \tag{3}$$

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

$$E = \rho_a \, c_E \, U \, \left(q_s - q_a\right). \tag{4}$$

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

$$Q_s = \rho_a \, c_{pa} \, c_H \, U \, \left(T_s - T_a\right). \tag{5}$$

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]

$$Q_I = Q_{I_0} \left(1 - \alpha_s\right) \left(1 - 0.7 \, n_c\right) \tag{6}$$

Table 1: Parameters symbols, values and units

Symbol	Definition	Value	Units (IS)
T_s	Surface temperature	-	^oC
T_a	Air temperature	-	^oC
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	2.5×10^6	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}
ρ_s	Water density	1000	kgm^{-3}
ρ_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%)	1.50×10^{-2}	-
q_a	Reference specific humidity (50%)	7.34×10^{-3}	-
σ	Stefan's constant	5.67×10^{-8}	$Wm^{-2}K^{-4}$
U	Reference air speed	-	ms^{-1}
c_E	Dalton number	1.5×10^{-3}	-
c_H	Stanton number	1.1×10^{-3}	-
α_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

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

2 Water-Air Chlorine Exchange

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

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

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.