Sensible and Latent Heat Fluxes in Coastal Waters of Dhahran, Arabian Gulf

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Abstract. Based on 30 years of meteorological data (1961-1990) at Dhahran and the sea surface temperature, the monthly means of sensible and latent heat fluxes in coastal waters of the Arabian Gulf are estimated using the bulk formulas. The stability of the atmospheric boundary layer; the thermal differences between sea-air and the corresponding wind speed at 10m are considered when choosing the heat transfer coefficients. The calculated mean annual sensible and evaporative fluxes are +0.1 and −133 w/m², respectively. The small annual mean of sensible heat flux indicates a near balance condition between summer and winter seasons. Maximum evaporation rate occurs in September while minimum rate in May. The latent heat flux compares favourably with the Pan measurements at the same location. It is concluded that the use of a constant transfer coefficient in earlier studies seems to overestimate the evaporative heat flux.

Introduction

The Arabian Gulf is characterized by a negative water budget since evaporation greatly exceeds precipitation and runoff. Being in an arid area in addition to its shallowness, the Arabian Gulf water is subjected to higher evaporation rate than any zonal water body. Evaporation from semi-enclosed seas has been the subject of considerable studies in the recent years because of its significance in determining the salt, heat and water budgets.

Due to high evaporation in the Gulf, a horizontal pressure gradient is developed and a less dense surface water flows from Gulf of Oman into the Arabian Gulf through Strait of Hormuz (Abdelrahman and Ahmad, 1993). Evaporation is one of the major causes for density variation along the Arabian Gulf and in turn for the density driven circulation.
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Fig. 1. Map of the Arabian Gulf showing the location of the coastal meteorological station (●) at Dhahran.

atures in degrees, $q_s$ and $q_a$ are the saturated specific humidity at sea surface temperature corrected for salinity and specific humidity in the air respectively, $W$ is the wind speed corrected to the standard elevation at $Z = 10$ m, $C_p$ is the specific heat of air at constant pressure, $C_e$ and $C_h$ are the heat exchange coefficients for evaporation and sensible heat respectively.

In terms of vapour pressures, equation (1) can be written and simplified as

$$Q_e = - \rho_a \cdot C_e \cdot L \{ 0.622 (\varepsilon_s - \varepsilon_a) W \}$$

where $\varepsilon_s$ is the saturated vapour pressure at sea surface temperature corrected for salinity and $\varepsilon_a$ is the vapour pressure at air temperature.

The values of latent and sensible heat fluxes depend much on the choice of heat exchange coefficients $C_e$ and $C_h$. Smith (1980) suggested that the sensible heat coefficient $C_h$ varies according to the stability of the atmospheric boundary layer. For unstable conditions, the sensible exchange coefficient is given $1.1 \times 10^{-3}$ while for the stable condition is $0.83 \times 10^{-3}$, thus $C_h$ does not increase with the increase in wind speed. Masagutov (1981) used a variety of eddy correlation measurements and prop-
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Using the bulk formula and considering the stability conditions, the sensible heat flux is calculated and shown in Fig. 3. The monthly mean sensible heat flux shows a seasonal pattern; a negative flux (loss from sea surface) during winter while water gains heat by conduction during summer. However, the net annual heat transfer between air-sea by conduction shows a small gain (0.1 w/m²). A small value of the net sensible heat (1 w/m²) was also obtained by Ahmad and Sultan (1991) in the same region but based on a common exchange coefficient for both latent and sensible fluxes. Considering a constant coefficient of $C_h = 1.3 \times 10^{-3}$, neglecting the stability of the atmospheric boundary layer, the sensible heat gain will increase to 2.6 w/m² which still comparable with earlier studies.

3. Temporal variations of the calculated sensible ($Q_h$) and latent ($Q_e$) heat fluxes: $C_e = 1.3 \times 10^{-3}$

The evaporative heat fluxes are calculated first by considering the stability of the atmospheric boundary layer and then by neglecting it. Following Masagutov (1981), a monthly coefficient is extracted based on the sea-air virtual potential temperature differences and the wind speed at 10 m. The resulting annual mean evaporative flux is $-133 \text{ w/m}^2$ (169 cm/year) with maximum in September and minimum in May as shown in Fig. 3. The flux increases to $-146 \text{ w/m}^2$ (185 cm/year) when an annual average of $C_e (1.15 \times 10^{-3})$ is applied (about 10% higher). An annual mean flux of $-165 \text{ w/m}^2$ (209 cm/year) results when $C_e$ is considered constant $1.3 \times 10^{-3}$ as suggested by Ahmad and Sultan (1991) at Dhahran.