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An estimate of the surface heat fluxes transfer of the Persian Gulf with the overlying atmosphere

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ABSTRACT

The ocean heat exchange process is a key mechanism in climate variations over a broad time – scale. In this study, the long–term mean surface heat fluxes over the Persian Gulf have been estimated by the empirical relations using data derived from National Oceanic and Atmospheric Administration (NOAA). The basin-averaged annual mean values of heat transfer due to solar radiation, sensible heat flux, long-wave radiation flux and latent fluxes are about 219,−14, −75 and −136, respectively. Therefore, the long – term annual mean net heat flux is about −6 W m^{-2} (negative sign means upward heat flux) and shows a very good agreement with the direct measured advective value through the Hormuz Strait. The spatial distribution of the surface heat fluxes, which has not been investigated before, show relatively large spatial variation in latent heat flux. The annual mean net heat flux spatial distribution varies from about −30 to 10 W m^{-2}, with greatest heat loss in south-eastern and northwestern regions of the Gulf. In mid – winter (January), the northern region along the Iranian coast loses heat (about 20–80 W m^{-2}) but southern and north-western shallow regions gain heat (about 15 W m^{-2}) from the atmosphere. In mid-summer (July) the spatial variation in net heat flux is weak and is positive at most all over the Gulf.

1. Introduction

The Persian Gulf (Fig. 1) is a shallow, semi-enclosed basin situated in an arid zone with a mean depth of about 36 m where evaporation greatly exceeds precipitation and river runoff. Circulation in the Persian Gulf is dominated by density – driven currents, which are generated and sustained by evaporative losses and radiative heat transfer and slightly by freshwater inflow at the head of the Gulf. These features lead to an inverse estuarine circulation with a fresh surface inflow from Gulf of Oman and a highly saline water leaving the Gulf through the deep part of the Hormuz Strait.

Accurate information of surface heat flux is needed to describe the air – sea interaction. It is indispensable for modeling of the ocean and atmosphere circulation being used as the thermal boundary condition (Hirose & Kim Yoon, 1996). The heat budget for a semi – enclosed sea such as the Persian Gulf, is determined by the net flow of heat entering or leaving the system. The components of the heat budget include terms which define heat conduction through the solid boundaries, heat transfer between the atmosphere and the sea surface,

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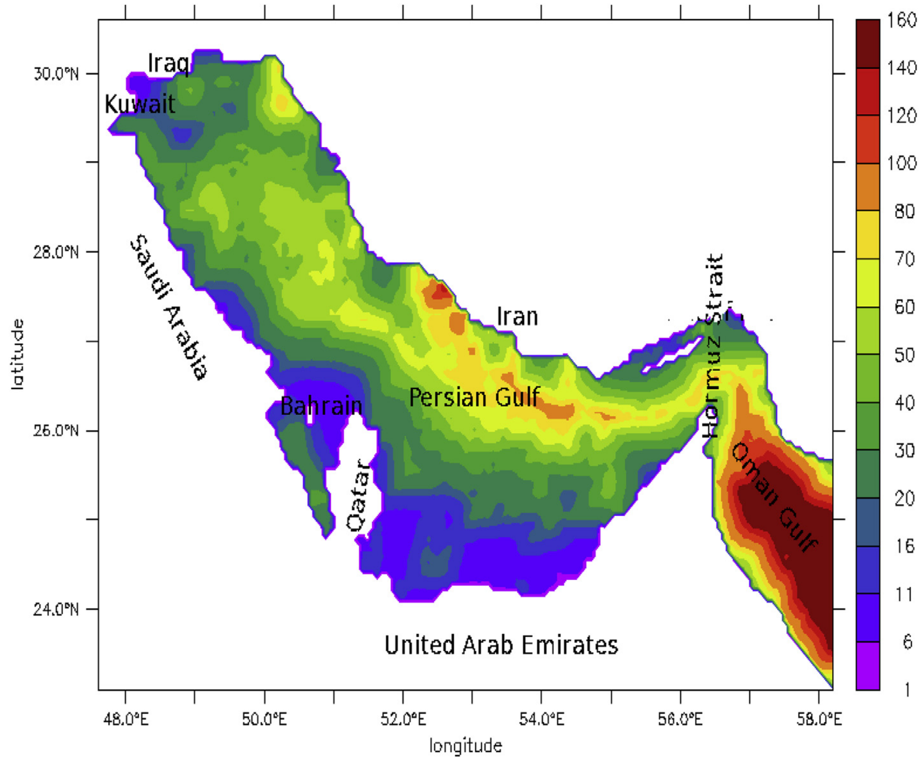

Fig. 1 – Bathymetry (meter) and map of the Persian Gulf.

and advective heat fluxes through the Strait communicating with the exterior. The surface heat fluxes are made up of solar radiation, the loss due to long wave radiation, the loss/gain due to evaporation/condensation and the loss/gain due to conduction.

Based on long – term moored time series observations at the strait of Hormuz, Johns et al. (2003) investigated the water exchange between the Persian Gulf and Indian Ocean. Their calculations of the advective heat and freshwater flux through the Strait led to estimates of 1.68 ± 0.39 m/yr for the net evaporation over the Gulf and a net annual heat loss over the Gulf of -7 ± 4 W m^{-2}. Basin-averaged annual mean heat flux derived from the SOC (Southampton Oceanography Centre) field gave an ocean gain of +53 W m^{-2}. Since there was a significant discrepancy between this result and the basin-averaged loss of -7 ± 4 W m^{-2} derived from estimate of advective fluxes through the Hormuz Strait, Johns et al. (2003) corrected the SOL flux estimate and obtained a revised value of the climatological basin mean net heat flux of 4 W m^{-2}. The positive value means that the Persian Gulf gains the heat at the air – sea surface and then out through the Strait Hormuz.

In this work, the heat flux components are evaluated by using empirical relations described in Section 2 and then seasonal and spatial variability of net surface heat flux over the Persian Gulf is investigated. The results of the net heat flux are used to estimate the net heat transport through the Strait of Hormuz.

The rest of this paper is organized as follows. In the next section, the basic formulate for the heat budget and data source are explained. The result of calculations of the surface heat fluxes over the Persian Gulf are described in Section 3. The last section gives the summary and discussion for this paper.

2. Materials and methods

2.1. *Basic formulate*

The different components of the heat flux at the sea surface are:

1. Insolation Q_s, the flux of solar energy into the sea.
2. Net Infrared Radiation Q_b, net flux of long – wave radiation from the sea surface.
3. Sensible Heat Flux Q_h, the turbulent transport of temperature across the air/sea interface.
4. Latent Heat Flux Q_e, the flux of energy carried by evaporated water.

In this paper the sign convention for heat flux components is that upward heat flow from the sea to the atmosphere is negative, while the downward heat flux from atmosphere to sea is positive. Then, the net heat flux through the sea surface Q_{net} is expressed as,

$$Q_{net} = Q_s + (Q_b + Q_h + Q_e) \quad (1)$$

The turbulent heat flux (Q_e, Q_h) is calculated by the bulk formulas:

$$Q_e = -\rho_a L_v C_E W(q_s - q_a) \quad (2)$$