

Surface Wind Stress Curl over Arabian Sea during January & July 1983

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Distribution of wind stress curl over the Arabian Sea during Jan. and July 1983, has been computed using marine meteorological parameters – wind direction, wind speed, sea surface temperature and air temperature – collected from IDWR charts. During Jan. negative wind stress curl values are found over the central parts of Arabian Sea. Negative values of wind stress curl are observed in the northwestern parts of Arabian Sea during July.

It is well known that the wind-driven ocean circulation is not determined by the surface stress itself but by the curl of the wind stress. Therefore, it has become a quantity of paramount importance in the studies on oceanic circulations. The surface wind stress curl represents a sink of atmospheric vorticity over the oceans. Where stress curl is predominantly positive, there must be either horizontal influx or generation of vorticity by motions in the atmosphere. In the areas of negative surface stress curl, there must be correspondingly either outflow or destruction of the vorticity in the atmosphere.

Stommel¹ presented annual distribution of surface wind stress curl which covers the World ocean between 50° south and 50° north. Stress and the stress curl were drawn from the tables of Hidaka². Stommel¹ obtained approximately the same annual stress curl distributions as Mintz and Dean³ for winter and summer vorticity fields. In Stommel's¹ annual map, the strongest deviation of wind stress curl pattern from the pattern of Mintz and Dean³ also occurs in the Indian Ocean north of Equator. It was shown^{4,5} that during January negative values of wind stress curl are found in the northwestern part of the Arabian Sea, and during July strong negative values (anti-cyclonic vorticity) cover the entire north Indian ocean except along the coasts of Arabia and India, where small positive values are present.

In the present study an attempt has been made to obtain the surface wind stress curl over the Arabian Sea during Jan. and July 1983 using marine meteorological parameters, viz. wind speed, wind direction, sea surface temperature and air temperature.

Data on sea surface temperature, air temperature, wind speed and wind direction were obtained from the India Daily Weather Reports (IDWR) for Jan. and July 1983. Monthly averages of the parameters under consideration are arranged in 5 × 5 quadrangular grids.

Zonal (U) and meridional (V) components of the wind were computed using

$$U = F \cos \alpha; V = F \sin \alpha$$

where

α is angle of wind direction from the North and F is wind speed in m.sec^{-1} .

Drag coefficient – In the earlier studies⁶ the non-dimensional drag coefficient (C_D) which is dependent on wind speed but neutrally stable, was taken to be 0.8×10^{-3} for wind speeds $< 6.7 \text{ m.sec}^{-1}$ and 2.6×10^{-3} for wind speeds $> 6.7 \text{ m.sec}^{-1}$. Bunker⁷ gave a table of drag coefficients dependent on wind speed and stability. He formulated 6 normal equations from the tabular values of $(U^2 + V^2)^{1/2}$ and ΔT and solved by least squares for the coefficients of the best fitting second degree polynomial. The best fit is given by

$$C_D(M, \Delta T) = 0.934 \times 10^{-3} + 0.788 \times 10^{-4} M + 0.868 \times 10^{-4} \Delta T - 0.616 \times 10^{-6} M^2 - 0.120 \times 10^{-5} (\Delta T)^2 - 0.214 \times 10^{-5} M(\Delta T)$$

where M is $(U^2 + V^2)^{1/2}$, ΔT is the difference between air temperature and SST ($T_a - T_s$).

In this study the above formula is used to evaluate the drag coefficient.

Stress components – The zonal component (τ_x) and meridional component (τ_y) of the wind stress were calculated using the formulae⁵.

$$\tau_x = \rho_a C_D U (U^2 + V^2)^{1/2}$$

$$\tau_y = \rho_a C_D V (U^2 + V^2)^{1/2}$$

where ρ_a is the air density, which is a function of latitude (θ) for all seasons⁸ is computed using the following regression formulae

$$\rho_a \text{ is } (0.0022\theta + 1.136) \times 10^{-3} \quad \text{for } \theta > 20$$

$$= 1.18 \times 10^{-3} \quad -20 \leq \theta \leq 20$$

$$= (-0.0028\theta + 1.124) \times 10^{-3} \quad \theta < -20$$

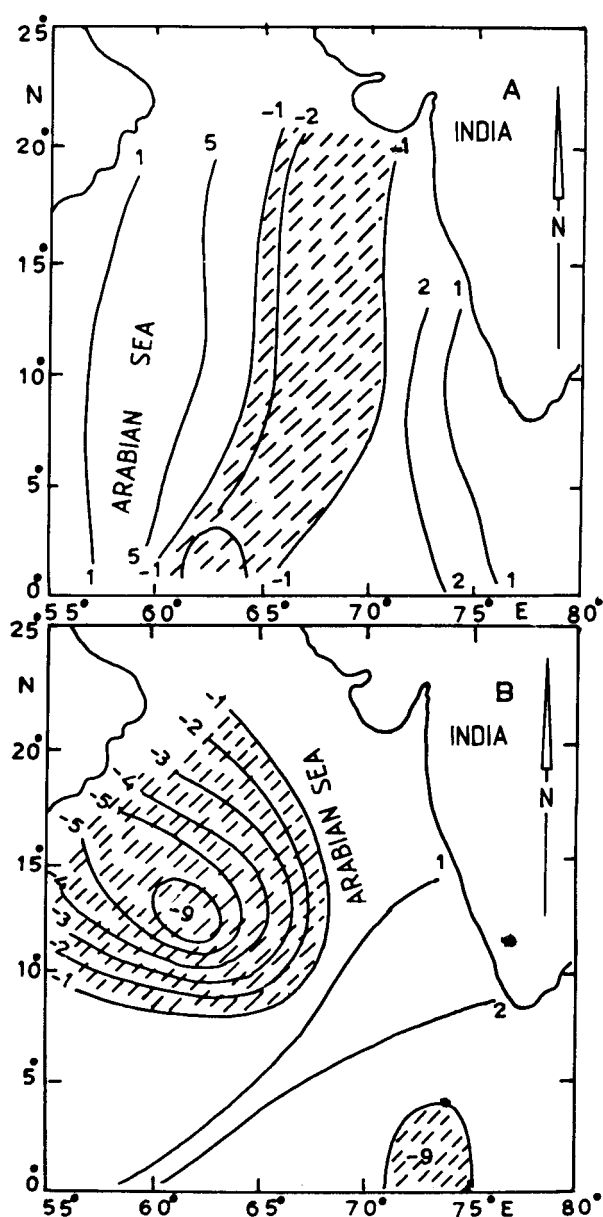


Fig. 1—Distribution of wind stress curl ($\times 10^{-8}$ dynes.cm $^{-3}$) over the Arabian Sea during (A) Jan. and (B) July 1983

Curl of the wind stress—The vertical component of stress is computed by the following formula⁴

$$\text{Curl}\tau_z = (1/R \cos \varphi) \left\{ \frac{\partial \tau_y}{\partial \lambda} - \frac{\partial}{\partial \varphi} (\tau_x \cos \varphi) \right\}$$

where R is the radius of the earth, φ is geographical latitude and λ is geographical longitude.

The following discretization formula is used to

approximate the curl values for the middle 5° square.

$$\text{Curl}\tau_z \approx (1/R \cos \varphi \Delta \varphi)$$

$$\left\{ \tau_{y4} - \tau_{y2} - \tau_{x1} \cos(\varphi + 5^\circ) + \tau_{x3} \cos(\varphi - 5^\circ) \right\}$$

Using the above formulae, distributions of wind stress curl over Arabian Sea during Jan. and July 1983 are obtained. Fig. 1A shows negative wind stress curl values in the central part of the Arabian Sea while earlier workers^{4,5} found these in the northwestern parts of Arabian Sea, during Jan. Hantel⁴ found small area of negative wind stress curl values in the central part of Indian Ocean (i.e. just below the Indian Peninsula). But in this study, no areas of negative wind stress curl values are found in this region. However, there is a fairly good agreement with the earlier results^{4,5}. During July, negative curl values are found (Fig. 1B) over the 3/4th of the Arabian Sea facing northwestward. When compared to the earlier results in this region^{4,5}, high negative values are found (up to -9×10^{-8} dynes cm $^{-3}$) during July in the middle southwestern part of Arabian Sea. From this, one can conclude that anti-cyclonic vorticity is found in the central part of Arabian Sea during Jan. whereas during July anti-cyclonic vorticity is found over the 3/4th of the Arabian Sea. Cyclonic vorticity is found along the west coast of India during July.

The wind stress curl data are useful in computing vertically integrated mass transport from Sverdrup relation. One well known application of this wind stress curl data is to obtain the vertical velocity at the bottom of the surface mixed layer of the Ocean⁹.

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