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ترجمه مقاله ☒

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چکیده

جریان‌های الکتریکی تولید شده توسط حرکت مدور آب دریا در میدان مغناطیسی زمین، زمینه‌های مغناطیسی متناوب کوچکی را ایجاد می‌کنند. این میادین لحظه‌ای دارای فرکانس امواج اقیانوس هستند که توسط باد به این اطرف و آن طرف حرکت داده می‌شوند.این توصیف از میدان مغناطیسی ناشی از امواج دریا برای امواج یکنواختِ یک منطقه وسیع گسترش یافته است. برای یک طوفان موضعی اثر کاملاً واضح نمایش داده شده است، اما به خوبی تعریف نشده است. از آنجایی که حرکت ذرات آب یک موج یکنواخت با مدارهای مدور تخمین زده شده، توصیف بر حسب امواج حلزونی برای نشان دادن ویژگی‌های بارز میدان‌های مغناطیسی ناشی از هر دو سطح زیر و بالای سطح آب کافی است. در هر صورت، این میدان مغناطیسی القایی فرکانس موج آب را داراست و اندازه این میدان در محدوده ابزارهای تشخیص است. اثر خالص یک میدان مغناطیسی مدور در یک صفحه عمودی است که دارای یک دامنه متغیر و مدور و سرعت زاویه‌ای است، با چرخش رو به جلو زیر سطح معکوس و چرخش معکوس بالاتر از آن عمق پدیدار می‌شود.

The Induced Magnetic Field of Sea Waves

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Abstract. Electric currents generated by the circular motion of seawater in the earth's magnetic field give rise to small alternating magnetic fields. These minute fields have the frequency of the ocean waves whipped up by winds. For a 100-m wave with 5-m height, a period of 8 seconds, sea state 6, the field varies from about 3 γ at the surface of the sea wave to the order of 0.1 γ at a depth of 95 m. This is a less rapid decay than the magnetic field has above the surface due to the same induced currents in the seawater. The component of the field in the direction of propagation reverses direction at a depth of approximately 8 m and reaches a negative maximum at about 24 m. The net effect is a rotating magnetic field in a vertical plane having a cyclic varying amplitude and angular velocity, with forward rotation below the reversal level and reverse rotation above that depth. For a more usual wave (36-m length, 4.8 seconds period, and 0.82-m amplitude, a moderately rough wave in the lower edge of state 4) the field varies from about 0.6 γ at the surface to 0.1 γ at a depth of 22 m. The reversal of the field component in the direction of propagation of the sea wave in this case occurs at about 3 m.

Introduction. Small magnetic fields of electric currents induced by the motion of the wind-driven sea waves in the earth's magnetic field may be described by the usual electromagnetic theory for conducting mediums. Because seawater is a conducting fluid ($\sigma \approx 4$ mhos/m), its motion in the earth's field produces a transverse magnetic force per unit charge which is the induced electric field that causes the electric currents.

need be sufficient to provide the shifting surface charges.

The present study deals with magnetic fields below the water surface induced by the motion of the seawater in the earth's magnetic field. The procedure and the approximations made follow in general those of Crews and Futterman, including the designation of the approximately trochoidal wave form. Various solutions [*Lamb*, 1945; *Sverdrup et al.*, 1942] describe the water
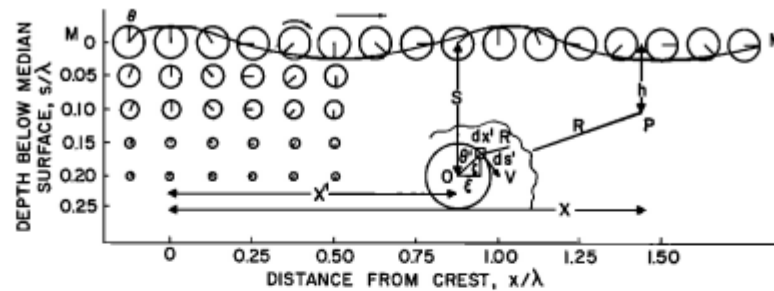
Fig. 1. Diagram of position of water particles at time $t = 0$ in $\cos(\omega t - kx') = \cos \theta'$. The abscissa and ordinate scales indicate the attenuation with depth as a function of wavelength. The abscissa scale is compressed by a factor of 2, and in the insert the source point at 0 is enlarged to show more detail. The depth s is measured from the mean position MM of the water particles at the surface.

r with depth. The velocity of the water particle has components

$$v_x(x', s, t) = \omega r_0 e^{-ks} \cos \theta' \qquad (1)$$

$$v_s(x', s, t) = -\omega r_0 e^{-ks} \sin \theta'$$

where $\theta' = \omega t - kx'$, angular frequency $\omega = 2\pi u/\lambda$, wave velocity $u = (g\lambda/2\pi)^{1/2}$, and x' is the distance of the equilibrium position of the water particle from the yz plane through the origin. If the wave propagation direction x makes a horizontal angle ϵ east of north, and δ is the dip angle, the earth's field has components $B_x = B \cos \delta \cos \epsilon = Bb$, $B_y = B \cos \delta \sin \epsilon$, $B_z = -B \sin \delta = -Ba$. In seawater of conductivity σ, the induced current density should be

$$\mathbf{B}' = \int I d\mathbf{l} \times \mathbf{r}/10^7 r^3$$

$$= (\mu_0/4\pi) \iiint (\mathbf{J} \times \mathbf{r}) \, dx' \, dy' \, dz'/r^3 \qquad (3)$$

for all points Q in the water. The distance $\mathbf{r}$ from Q to P (Figure 2) is given by

$$\mathbf{r} = \mathbf{i}(x - x' - r_0 e^{-ks} \sin \theta')$$
$$+ \mathbf{j}(y - y') + \mathbf{k}(s - h - r_0 e^{-ks} \cos \theta')$$
$$= \mathbf{i}X_1 + \mathbf{j}Y + \mathbf{k}Z_1$$

Using (2) and setting $\mu_0 \sigma u r_0 = 4C$, we can integrate (3) directly with respect to Y from $-\infty$ to $+\infty$. The integration yields, since $dy' = dY$,