Drift Response of Monomolecular Slicks to Wave and Wind Action

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(Manuscript received 15 November 1976, in final form 13 July 1977)

ABSTRACT

The drift responses of monomolecular slicks to wind and wave action have been investigated in a laboratory wind-wave tunnel and in the field. The wind-wave tunnel was fitted with a mechanical wave generator which produced uniform long-crested gravity waves. The field studies were performed off the island of Sylt (German Bight) in the North Sea.

Laboratory results for the slick drift response to deep water gravity waves only were in excellent agreement with the Stokes irrotational mass transport drift velocity theory. The purely wind-induced slick drift was in good agreement with the results obtained by previous investigators using a variety of other floats. A number of laboratory and field investigations have been compared which show that the surface drift to wind speed ratio lies between 2.6–5.5%. A difference between the average ratios for the collected laboratory and field results indicates that the pure gravity wave drift component probably comprises 25–30% of the total surface drift. A qualitative example confirming this is demonstrated in the field studies.

A laboratory treatment of the combined wind and wave slick drift showed that the effects of wind and waves cannot be simply superimposed. In some cases the gravity waves appear to decouple the wind drift, especially at lower wind speeds.

1. Introduction

Man-made and natural slicks are widely prevalent in the world's oceans and especially in coastal waters. Until a few years ago, they were virtually neglected in meteorological and oceanographic research. However, it is now becoming clear that these slicks play very important roles in air-sea interaction processes including evaporation retardation (LaMer, 1962; Bean *et al.*, 1969) and a subsequent water surface temperature rise (Jarvis, 1962; Grossman *et al.*, 1969); gas exchange (Hawke and Alexander, 1962; Petermann, 1976); capillary wave damping (Garrett, 1967; Barger *et al.*, 1970); and spray and whitecap reduction (Miller, 1972). The ability of slicks to influence these processes may imply that standard meteorological and oceanographic measurements at the air-sea interface must account for the presence of slicks. For instance, remote sensing measurements depending on the capillary wave spectrum such as active radar backscatter could well be inaccurate when slicks are present, especially in low velocity wind situations when slicks are most prevalent and stable.

These slicks possess unique chemical and physical properties which have specific consequences on their response to hydrodynamic forces. One such response involves their drift velocity under the influence of wind and wave action. This study describes a laboratory investigation of this drift velocity determined separately for uniform wave action and wind action, respectively. It is eventually hoped to be able to predict accurately slick drift on natural waters. Accurate slick movement prediction could aid in pollution studies. The specific motivation for this study comes from a desire to be able to lay accurately large area (2 km^2) slicks such that they drift into instrumentation measuring various air-sea interaction parameters including air velocity and turbulence, air and water temperature, and the water wave spectrum. A number of slicks were produced during JONSWAP 74 and JONSWAP 75 (Joint North Sea Wave Project) where the need for reliably predicting slick drift became apparent.

The types of surface films dealt with in this study all fall into the group known as monolayers because they spread such that they are only one molecule thick or about 25 Å. These films have the ability to strongly dampen capillary waves as a result of their suppressing liquid flow at the air-water interface. Surface tension gradients are produced as passing waves cause alternate compression and expansion of the monolayer and some of the wave energy is dissipated.

Oleyl alcohol (9-octadecen-1-ol,cis) is the substance that has been most extensively used in field studies because it has a favorable balance of film properties including a high spreading rate, a high surface pressure, a high elasticity, a rela-

0022-3670/78/0142-0150$05.00

tively low solubility which helps give it a long life, and it very effectively damps capillary waves. Oleyl alcohol slicks have been observed to be still coherent at wind speeds of 10–12 m s^{-1} (Lange, 1976), where natural slicks, often referred to as "wind-streaks", break up as a result of wave action and bubbling processes at wind speeds of 4–7 m s^{-1}.

It should also be emphasized that monolayer slicks must be distinguished from heavy or crude oil slicks. The latter initially forms multilayer slicks up to several millimeters thick which do not exhibit a horizontal surface tension gradient and do not dampen waves nearly as effectively as monomolecular slicks. This results from the fact that these substances are strongly hydrophobic and contain no hydrophilic groups. Nevertheless, studying the behavior of monomolecular slicks finds application in crude oil pollution situations because these heavy oil slicks eventually become monomolecular or surface active as a result of ultraviolet irradiation and bacterial decay. This transformation can occur in several hours but usually occurs on the order of weeks or months. Also, since many monolayers possess such high surface pressures, they find application in the containment of crude oil spills as has been described by Garrett (1969).

2. Wind-wave tunnel description

A complete description of the wind tunnel facility may be found Hühnerfuss *et al.* (1976). The test section of the tunnel is 15 m long, 1 m wide, with a water depth of 0.5 m and an air duct height of 1 m. The tunnel is of steel frame construction and is fitted with a blower driven by a 30 hp variable speed electric motor which produces a maximum wind of 25 m s^{-1}. A honeycomb (Hexcel 9.5 mm aluminium) is fitted at the tunnel entrance to provide a more uniform air flow. A hinged flap-type generator provides uniform shallow and deep water waves up to 8 cm in height, ranging in frequency from 0.6 to 2.5 Hz.

At the beach end the tunnel is fitted with an oil film gathering apparatus consisting of a perforated tube situated horizontally across the tunnel at the water surface. This tube is connected to a tank which is placed under a vacuum and sucks a film-air-water mixture off the surface. The film is concentrated at the beach end by a low velocity wind. The beach, consisting of wooden lathes covered by a cocus fiber mat impregnated with plastic (Terrafix), is constructed so that it can be easily raised during the film cleaning operation. The beach was placed at a 5:1 inclination and absorbed 95% of the incoming wave energy.

Waves were measured with standard resistance-type probes. Air velocity measurements were performed with a 3 mm diameter pitot-static tube connected to a very sensitive capacitance pressure transducer (MKS Baratron).

3. Procedure for surface drift measurements

Before each run, the beach was raised and a low velocity wind was produced to concentrate the surface material at the far end of the channel, where it could be sucked off. This procedure was continued until a fixed maximum surface tension could be measured using the calibrated drop method of Adam (1937).

Slicks were produced on the cleansed water surface which had been sprinkled with a very pure talcum powder to aid in discerning the slick. Due to its extreme spreading, very small amounts of the slick material were needed to produce the slicks used in this experiment. Also, very exact volumes were needed to consistently produce the same size slicks. This was facilitated by diluting the slick material in a solution of heptane which would rapidly evaporate upon spreading, with the slick remaining. For the oleyl alcohol slicks, 48 mg of 95% pure oleyl alcohol were mixed with 100 ml of heptane. Between 2 and 3 ml of this solution were needed to produce 200 cm × 80 cm slicks, depending on the water temperature.

After the slick was produced and found not to drift, i.e., no remnant currents were present from a previous run, the wave generator or wind blower was started. A typical run consisted of timing the drift of the slicks over 5–20 intervals where each interval was 10–100 cm in length. The number of intervals timed and their lengths depended upon how fast the slick drifted or how soon it became too difficult to discern the slick because of its being distorted by wave action. The total timed drift path was usually 2–3 m long. By timing the slick over a number of intervals, its acceleration could be followed and intervals showing that the drift was steady could be easily selected and averaged to obtain the drift velocity.

A further precaution was observed with respect to the buildup of the subsurface return current which arises since the net mass flux across any vertical transverse cross section of the channel must be zero when steady-state conditions exist. Ünlüata and Mei (1970) showed that this current builds up in about L/u_{Stokes} seconds, where L is the channel length and u_{Stokes} the wave-induced surface drift velocity. Russell and Osorio (1958) reported subsurface return flows which were as high as 12% of the surface drift velocity and should thus be avoided in order to simulate more accurately open ocean conditions where such currents would be minimal or nonexistent. Since the channel used in this study was quite long (18 m), all drift measurements could be performed before the backflow developed even though steady wave conditions and steady drift had been established.

4. Wave-induced drift

Gravity waves exhibit a mass transport or drift velocity. The first-order solution for the irrotational wave theory suggests that mean motion exists. Stokes (1847) was the first to show the existence of a second-order mean forward velocity of fluid particles associated with gravity waves. For deep water waves, which were used exclusively in this experiment, the Stokes surface drift is within 0.5% of

$$u_{\text{Stokes}} = ck^2a^2 = c(\pi H/L)^2,$$

where c is the phase velocity, a the wave amplitude, k the wavenumber, H the wave height ($=2a$ assumed) and L the wavelength.

Phillips (1966) and Huang (1970) have derived first-order expressions for the vorticity arising in a free surface boundary layer. For the waves used

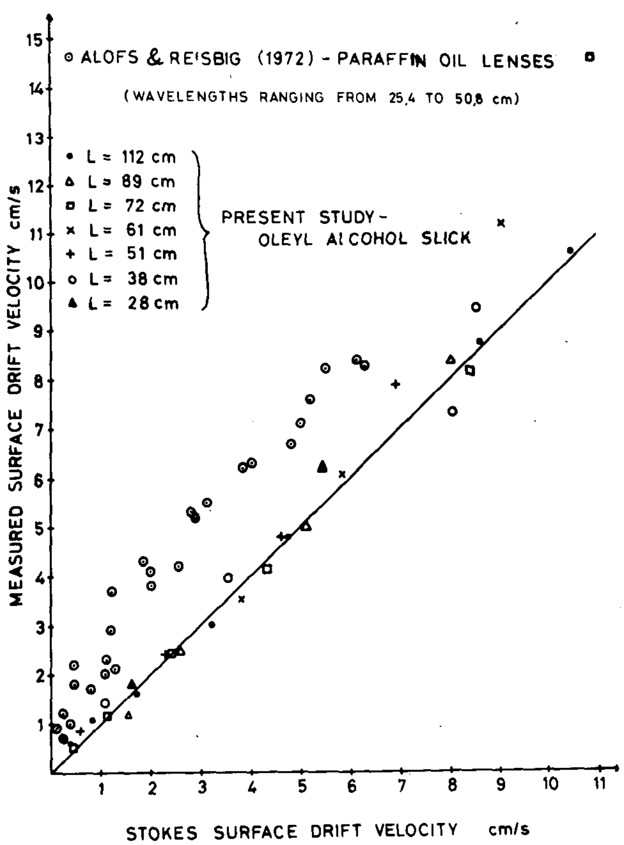

FIG. 1. Comparison of drift data from present study and from Alofs and Reisbig (1972) against the theoretical Stokes drift velocity.

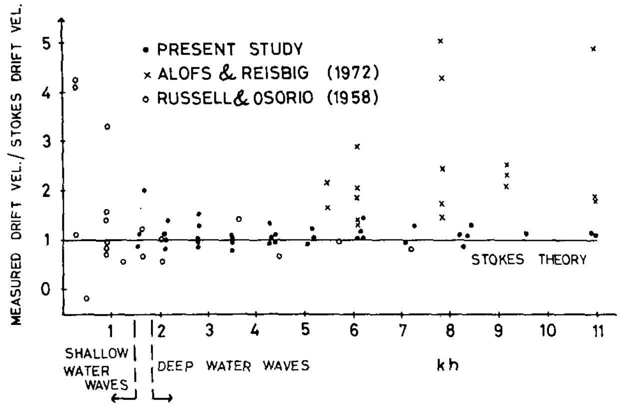

FIG. 2. Comparison of normalized surface drift as a function of kh.

in our experiments, the vorticity layer would be on the order of 0.5 mm thick (Lange, 1976). Within this layer the vorticity is no greater in magnitude than the irrotational rate of strain in the wave motion, i.e., it has little effect on the overall dynamics. Chang (1969), solving the problem *ab initio* with Lagrangian equations of motion for random waves, found that even with viscosity the mass transport velocity was essentially similar to the Stokes irrotational solution. However, as mentioned by Ünlüata and Mei (1970), a second-order vorticity diffuses downward from the surface and could become significant if the channel were deeper and the experiment of long duration, a situation we avoided in order to prevent the buildup of a subsurface return flow. Thus in an open ocean situation where deep water waves of long duration are present, the additional second-order vorticity could cause a higher surface drift than the Stokes drift.

Fig. 1 compares the experimental data to those of Alofs and Reisbig (1972). Alofs and Reisbig used 3 and 10 ml liquid paraffin lenses (5 and 10 cm diameter, respectively) and flexible quilted plastic sheets of the type commercially available for food wrapping (2.5 cm wide, 4.8–64 cm long, 0.015 cm thick) as floats. Their tank was 6.1 m long, 0.30 m wide and 0.45 m deep, and was fitted with a hinged flap wave generator similar to the one used in this experiment. Fig. 1 shows that the present study's data is in very good agreement with the theoretical Stokes drift, where Alofs and Reisbig's data lies 35–150% higher.

A further comparison with the data of Russell and Osorio (1958) is shown in Fig. 2, where the normalized drift velocities are plotted against kh, k being the wavenumber and h the mean water depth. Russell and Osorio's data also agree well with the Stokes solution for deep water waves. Also, the degree of scattering of the tank data of Chang (1969), for a wave drift that is induced by a random wave spectrum (which reduces to the Stokes

TABLE 1. Measured slick drift (cm s^{-1}) of various monolayers for two different wavelengths (slicks are about 2 m in length and each drift is the average of 2–3 runs).

	Surface tension (dyn cm^{-1})	L = 113 cm*	L = 60 cm**
Oleyl alcohol	32	0.92 ± 0.05	3.85 ± 0.05
Methyl palmitate	19	1.00 ± 0.07	3.80 ± 0.17
Sorbitan monooleate	41	0.98 ± 0.04	3.81 ± 0.16

* Stokes velocity = 0.82 cm s^{-1}.
** Stokes velocity = 3.43 cm s^{-1}.

solution for a sine wave), is of the same order of magnitude as that indicated in this study.

The data collected in this experiment thus appear to fit the theoretical Stokes solution quite well, as do those of Chang (1969) and Russell and Osorio (1958). The question is why do the data of Alofs and Reisbig show a drift velocity up to 150% higher than Stokes drift? They suggest that the subsurface backflow reported by other investigators may be responsible for lower velocities than those they measured. However, in the present study the backflow was avoided and in Russell and Osorio's experiment the maximum backflow was never more than on the order of 10%.

It is suggested that the properties of the floats may be the cause of the discrepancy in the drift velocities. Chang used 5 mm diameter wooden spheres and Russell and Osorio used unspecified neutrally buoyant particles. Alofs and Reisbig used liquid paraffin slicks and plastic foil which conceivably respond differently than small particle size floats. Also, the liquid paraffin is not monomolecular when spread and may be several millimeters thick penetrating the water far more deeply than the 25 Å thick monolayer. It also does not exhibit the elastic properties that monolayers such as oleyl alcohol possess. The relatively stiff floats of Alofs and Reisbig also drifted differently than the monolayers with respect to water wavelength. Alofs and Reisbig found that their floats first showed a steady drift when the float size exceeded the wavelength. The monolayer was also investigated in a similar manner and the size dependence was found to be absent.

Finally, additional monomolecular substances were compared to oleyl alcohol to determine whether drift response differences arose among monolayers possessing different properties. Methyl palmitate was chosen because it has a far lower surface tension than oleyl alcohol. Also, this compound is found in many natural films and thus is a good laboratory representative for measuring the dynamic response of natural films. Sorbitan monooleate has a substantially higher surface ten-

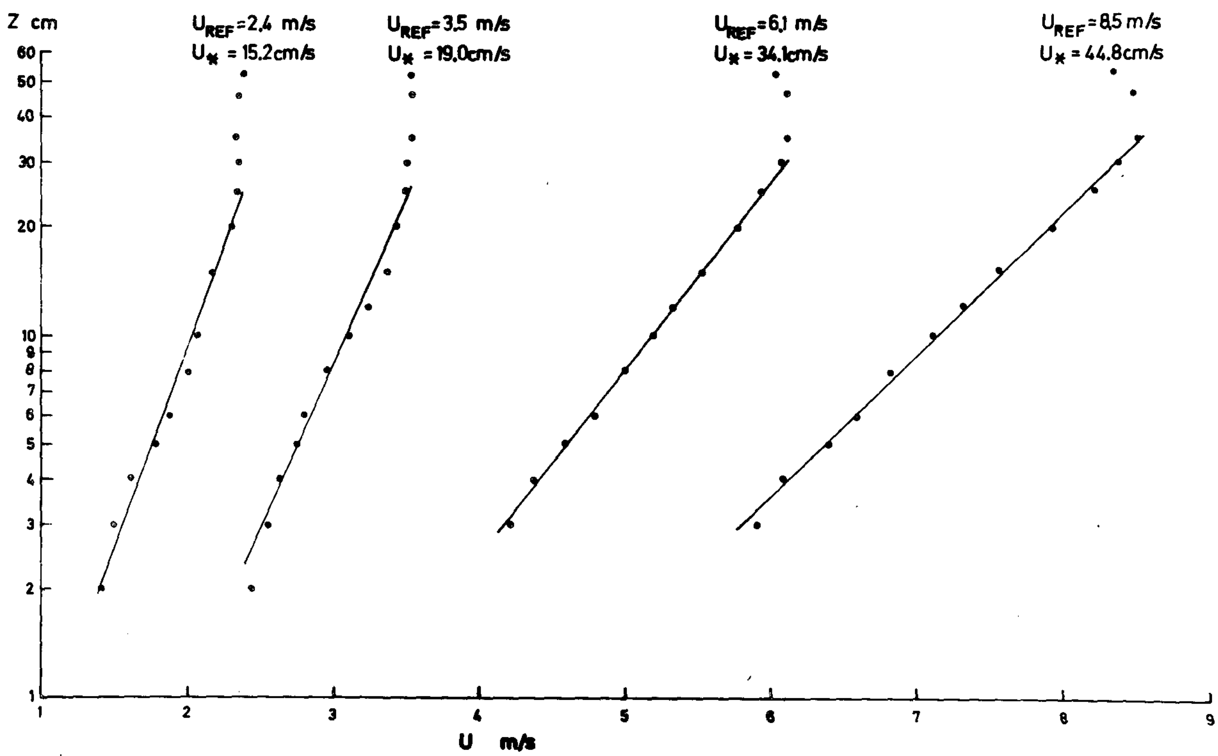

FIG. 3. Vertical wind velocity profiles measured at 9 m fetch.

TABLE 2. Slick drift rates (cm s^{-1}) as a function of wind speed (averages are each based on 3–5 runs).

Reference	Slick drift			
Free stream wind speed (m s^{-1})	Station 5 (fetch = 7 m)	Station 6 (fetch = 9 m)	Station 7 (fetch = 11 m)	Average of station 5, 6, 7
2.4	9.4 ± 0.7	11.5 ± 0.7	9.5 ± 1.2	10.2
3.5	13.0 ± 0.6	12.4 ± 1.3	9.5 ± 0.4	11.6
6.1	17.2 ± 0.1	18.4 ± 1.9	17.0 ± 2.4	17.5
8.5	22.1 ± 0.9	26.7 ± 1.4		24.4

sion than oleyl alcohol and also possesses a very strongly hydrophilic molecule which penetrates the water surface more deeply than the other monolayers. This implies that it is more soluble and consequently has a shorter life span as a film. As can be seen in Table 1, the monolayers responded similarly in their drift, despite the differences in their properties.

In conclusion, the monolayers drifted according to the Stokes drift, in agreement with the investigations of Chang (1969) and Russell and Osorio (1958). Surface viscosity may play a slight role since there is tendency for the measured drift data to be slightly higher than the Stokes drift.

Phillips (1966) indicated that the presence of an oil film or layer of adsorbed material which is incompressible to tangential stresses could account for a higher surface drift. Huang (1970) presents a solution for the presence of such a surface film indicating a 25% drift speed increase. Huang's result may be suspect since Ünlüata and Mei (1970) have cast doubt on his film-absent surface solution. At any rate, the use of tangentially incompressible films by Alofs and Reisbig may help account for their high drift rates, though other float properties such as geometry and immersion depth are probably more significant.

5. Wind-induced drift

Fig. 3 shows the wind profiles measured in this study. Using the well-known logarithmic law

$$\frac{u}{u_*} = \frac{1}{K} \ln \frac{z}{z_0}, \quad u_* = (\tau_s/\rho)^{1/2}, \quad z_0 = \frac{\nu}{u_*}, \tag{2}$$

where K is the von Kármán constant, usually taken to be 0.4, z_0 a roughness parameter, τ_s the surface shear stress and ρ and ν the air density and viscosity, respectively.

The friction velocity u_* can be calculated from the slopes of the straight line portions of the wind

TABLE 3. Comparison of various laboratory and field studies on wind-induced surface drift. Average drift speed to wind speed ratios: laboratory studies 3.5 ± 0.7%, field studies 4.4 ± 0.9%.

	Type of study	Tunnel dimensions: Length (m)	Air duct height (m)	Water depth (m)	Method of drift determination	Wind speed range (m s^{-1})	Drift speed / wind speed (%)
Present study	laboratory	18.0	1.00	0.50	monolayer-oleyl alcohol	2.4–8.5	3.0–4.8
Wright and Keller (1971)	laboratory	4.9	open	0.28	0.64 cm^2 2 mil polyethylene spheres, disks, 0.32–1.27 cm diam	2.2–7.9	3.8–4.5
Wu (1968)	laboratory	14.0	0.30	1.20	spheres, 0.08–1.0 cm disks, 0.25 cm diam, 0.06 cm thick	3.5–13.4	2.8–4.8
Plate et al (1969)	laboratory	13.7	0.61	0.11	disks, 0.6 cm diam, wax paper	3.6–12.8	3.2
Mizuno and Mitsuyasu (1973)	laboratory	13.4	0.45	0.35	disks, 0.6 cm diam, paper	2.5–10.0	3.0–3.4
Dobroklonskiy and Lesnikov (1972)	laboratory	25.0	unknown	0.80	spheres, 0.04–0.3 cm diam, polystyrene	7.0–12.0	2.6–3.1
Keulegan (1951)	laboratory	20.0	0.15*	0.14**	paraffin flakes	3.0–12.0	3.3
O'Brien (1971)	laboratory	3.7	0.61	0.10	crude oil, fuel slicks	5.0–10.0	2.8–3.2
Shemdin (1972)	laboratory	45.7	1.02	0.92	disks, 0.6 cm diam, paper	3.1–9.1	2.6–2.9
Van Dorn (1953)	artificial pond	240.0	open	2.0	disks 2.54 cm diam, 0.13 cm thick, cork	3.0–13.0	3.0–4.3
McArthur (1962)	lake				monolayer-cetyl alcohol	2.7–7.0	4.8–5.8
Smith (1968)	open ocean				crude oil slick	unknown	2.6–4.7
Brockis (1968)	open ocean				crude oil slick	unknown	4.0
Tomczak (1964)	open ocean				crude oil slick	unknown	4.3
Tomczak (1964)	open ocean				plastic cards	up to 15.0	4.2
Hughes (1956)	open ocean				plastic cards	0.4–14.0	3.3

* Minimum.
** Maximum.

profiles. The free stream wind speed as determined from the vertical sections of the profiles shown in Fig. 3 is used as the reference velocity u_{ref}. When applying the criteria of Schlichting (1968), with the wind speed u replaced by $u - u_s$, following Wu (1968), where u_s is the surface drift velocity taken from Table 2, the wind flow was rough for all profiles. The oleyl alcohol wind-induced slick drifts measured in this study are summarized in Table 2. The experimental conditions for these and a few additional investigators are summarized in Table 3, along with the average drift rate to wind speed ratios.

A fully dimensionless plot of the u_s/u_{ref} ratio against the Reynolds number based on the wind speed is shown in Fig. 4, where u_{ref} is the reference wind speed. The large spread in the data probably results from differences among the various investigators in defining the reference velocity. The friction velocity u_* would be a good basis for comparison but it was unavailable for most of the investigations. The solid and dashed lines show the averaged data of Keulegan (1951) without and with waves present, respectively. The difference between the lines was less than the scatter of Keulegan's data points. The data without waves were obtained by adding a detergent to the tank. Keulegan's data tended toward $u_s/u_{ref} = 0.033$, where the data of Wu (1968) tended toward a value of 0.048. Although Wu's data may be slightly high, possibly a result of the fact that he extrapolated the surface drift from vertical drift profiles rather than surface floats, the trend for the data to increase with higher drift rates is also confirmed by the data of Dobroklonskiy and Lesnikov (1972) and Shemdin (1972). The data of Van Dorn (1953) and McArthur (1962) were taken in a 2 m deep yacht pond and a lake, respectively. McArthur failed to mention the lake's depth which is no doubt very deep. McArthur's data for Fig. 4 have been arbitrarily plotted for a depth of 2 m. The data of Wright and Keller (1971) were taken in a partially uncovered laboratory channel and perhaps for this reason agree with the prototype data of McArthur and Van Dorn which indicate higher u_s/u_{ref} ratios.

The types of floats used in the studies of Table 3 should be mentioned briefly. In most cases small spheres or disks were employed. Some of the scatter in the data may be attributable to float differences. Wright and Keller (1971) found that the wind-induced drift was independent of float diameter but depended significantly on the float's depth of submergence. Typical drift rates found by Wright and Keller were 33 and 20 cm s^{-1}, corresponding to float submergence depths of 0.06 and 2.9 mm, respectively. This would suggest that the average surface drift to wind speed ratio found for the field studies is low, since the floats were generally thicker than in the laboratory studies; perhaps a ratio of 5% would be more realistic.

The average u_s/u_{ref} ratio in Table 3 is 3.5 ± 0.7% for the laboratory studies and 4.4 ± 0.9% for the field studies. A possible explanation for the difference between the laboratory and the field results may be that the field data were collected in the presence of developed deep water waves so that an additional drift due to the second-order vorticity,

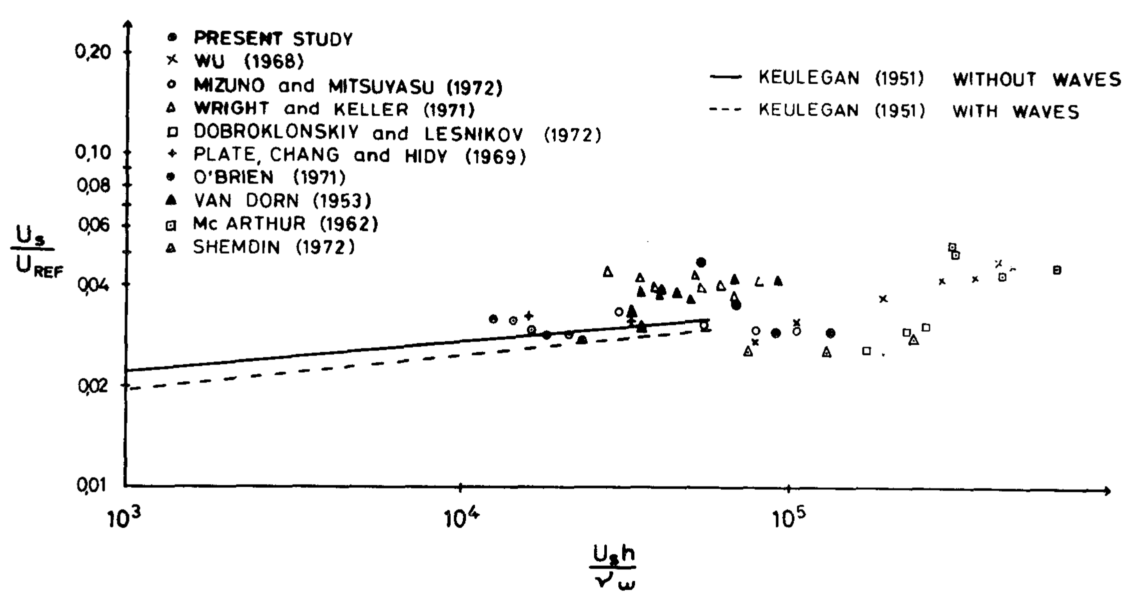

FIG. 4. Wind-induced surface drift rate to wind speed ratio as a function of Reynolds number based on surface drift.

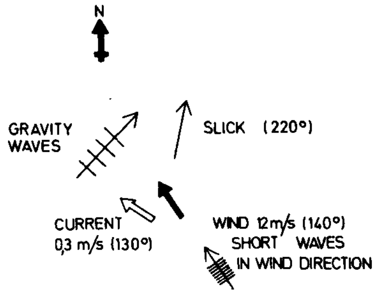

FIG. 5. Slick drift showing strong Stokes drift component due to presence of large gravity waves.

as mentioned in Section 4, and the wave-induced Stokes drift was present. This is in rough agreement with one of the results of Kenyon (1969), who has obtained a Stokes surface drift to wind speed ratio range of 1.6 to 3.6% using the empirical spectral forms of Pierson and Moscowitz (1964) for wind speeds at 19.5 m. Kenyon has mentioned that an angular spread in the energy spectrum might further reduce the Stokes drift component in the principle wave propagation direction. During our field studies in 1975 off the North German island of Sylt, we had one case apparently showing a strong Stokes drift component as shown in Fig. 5. Very large gravity waves were present overridden by ripples. Despite the strong wind, the gravity-wave-induced drift component caused the slick to drift well to the right of the wind. The current velocity was taken from Sager (1968) and the wind was recorded in hourly averages on a sand dune 28 km distant.

The authors produced a number of large area (1.5 km²) slicks off the North German Coast during the summers of 1974 and 1975. The slicks were produced by dropping uniform frozen chunks of oleyl alcohol from a helicopter in a regular pattern. The drift path of one such slick is shown in Fig. 6. The relative positions of the slicks were determined by logging the direction and distance from a fixed instrumentation pile to the slick's center with the helicopter. The helicopter's speedometer readings were corrected with the appropriate wind component. The current velocities are taken from Sager (1968) and the winds are hourly averages recorded on a dune at the land station on Sylt. As can be seen in the figure, a strong tidal current was present which made accurate tracking of the slick difficult. Nevertheless, a definite wind dependence of the drift is apparent, since the slick drifted faster in the southward direction while experiencing a positive (with respect to drift direction) wind component than in the northward direction where it drifted against the wind. This effect occurred despite a stronger current being present during the northward drift.

6. Wind and mechanical wave combined

Determining exactly what portion of the total drift is wave drift and what portion "pure" wind drift, appears to be difficult. One simple experiment was performed in the wind-wave tunnel where sets of runs were made with a wave drift only, a wind drift only and a combination of both, all using a 3 m long oleyl alcohol slick. The combined mechanical and wind waves were intended to simulate a gravity wave covered with small ripples. The results are summarized in Fig. 7 for cases of three different mechanical waves. The procedure used for determining the drift speed was similar to that described in Section 3, and the reference velocities are the free stream velocities as mentioned in Section 5. All slick drifts were timed over 2 m intervals. The last two intervals in a run were found to show similar drift rates indicating that the slick was not accelerating. The only exception was the 8.5 m s^{-1} wind situation for the 3.8 and 8.1 cm s^{-1} Stokes drift, where no intervals showed similar drift rates. For these runs only, the last interval (at the longest fetch) of the run was used.

Even with this relatively simple regular wave example, it appears that wave and wind drifts cannot be simply superimposed. Mechanically generated waves appear to retard the buildup of the sur-

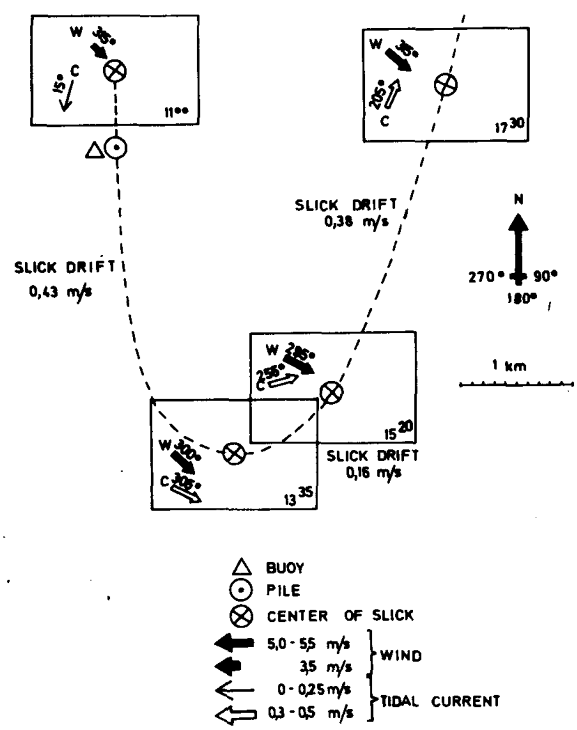

FIG. 6. Drift of large area slick 6 km off the island of Sylt on 22 August 1974.

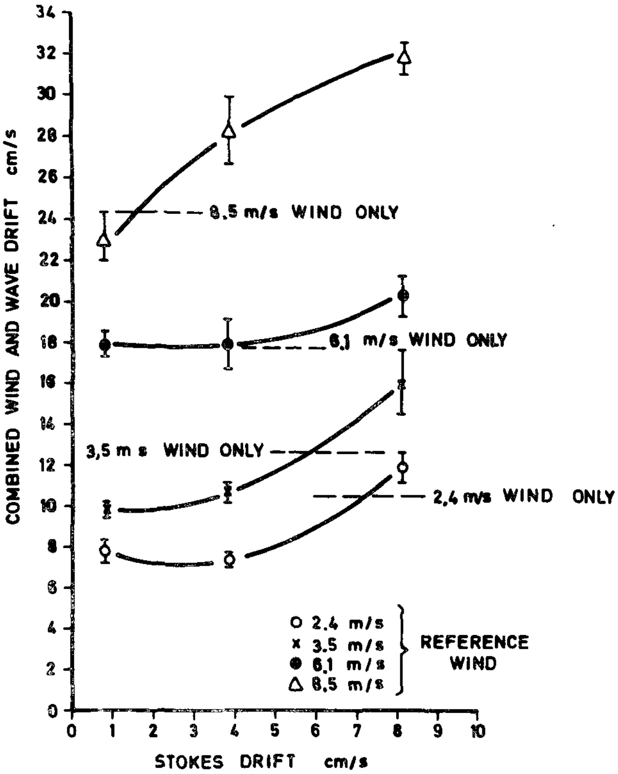

FIG. 7. Effect of gravity-wave-induced Stokes drift on the combined wind and wave surface drift of an oleyl alcohol slick. Each data point is the average of 3 to 4 runs. Dashed lines show drift response under wind influence only.

face drift until a higher reference wind speed of 8.5 m s^{-1} is reached. Reisbig *et al.* (1973) found a similar decrease in the net coupled drift which depended on the steepness of the mechanically generated waves. They used floats of a quilted plastic foil similar to those of Alofs and Reisbig (1972).

Another influencing factor may be that the slick itself affects the drift in that it dampens the normally present capillary waves. These results may also be an indication of the presence of nonlinear processes associated with wind wave generation.

7. Conclusions

The drift of a monomolecular slick appears to closely adhere to the irrotational Stokes mass transport drift when only gravity waves are present. The laboratory study showed that slicks responded similarily to small flakes or spheres under the Stokes drift, but that using relatively stiff and thick floats such as liquid paraffin or plastic foil results in drifts up to 150% higher than for the monomolecular slicks.

The laboratory wind-induced drift studies showed that monomolecular slicks responded quite similarly to drifts measured in a number of other investigations using a large variety of floats. However, here again caution must be exercised with respect to float properties. The depth of submergence of the float appears to be critical, since the float penetrates the surface water flow regime.

The drift response of three characteristically different monolayers was investigated and essentially similar results were obtained. Thus one may generalize that most films respond similarly to wave and wind drift as long as they are monomolecular when fully spread and are surface active, i.e., build up surface tension gradients under wave action.

A preliminary study with a combination of wind and mechanical waves showed that the drift response is quite complicated for this situation and that the separate wind and wave induced drift components may not be simply superimposed. The fact that a slick is employed, as opposed to light-weight surface particle floats, may well further complicate the situation, since the slick very efficiently damps capillary waves and thus interferes with wave generation and momentum exchange processes at the air-sea interface.

When a number of laboratory and field investigations are compared, it becomes clear that only ranges for the drift speed to wind speed ratios can be given. However, the spread appears fairly narrow and lies approximately between 2.6 and 5.5%. The field data show a 25–30% higher drift possibly resulting from an additional Stokes drift and increased vorticity induced by large waves. This agrees with a theoretical study by Kenyon (1969) based on an empirical energy spectrum and is qualitatively confirmed in a field study example where a well developed gravity field provided a strong contribution to the slick drift despite a strong wind coming from a different direction than the gravity waves.

Acknowledgments. This research was supported by the Deutsche Forschungsgemeinschaft (German Science Foundation) through the Sonderforschungsbereich 94-Meeresforschung. The authors wish to thank the Henkel Cie & GmbH, Düsseldorf, which generously provided the slick material (oleyl alcohol) at no cost.

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