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Scattering of Sea wave at the Arabian Ocean undulating bed Topography

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Abstract: ***A new approximation to wave scattering is derived that include both progressive and decaying wave mode terms and its accuracy is tested.***

Keywords: Wave Scattering, Sea Surface, Arabian Sea,Topography**.**

1. Introduction

The Arabian Sea's surface area is about 3,862,000 km^2 (1,491,130 sq mi).[2] The maximum width of the Sea is approximately 2,400 km (1,490 mi), and its maximum depth is 4,652 metres (15,262 ft). The biggest river flowing into the Sea is the Indus River.The Arabian Sea has two important branches — the Gulf of Aden in the southwest, connecting with the Red Sea through the strait of Bab-el-Mandeb; and the Gulf of Oman to the northwest, connecting with the Persian Gulf. There are also the gulfs of Cambay and Kutch on the Indian coast.

We are going to study the wave scattering of these waves in the region mentioned this paper a few research moorings providing intensive periods of observations are used to validate an ocean model and develop assimilation routines**.**

2. Detailed Outline:

A long understanding but persistent problem in the area of water wave theory is the determination of the effect of bed topography and obstacles on a given wave field. An example of a practical problem faced by coastal engineers is to predict the amplitude of waves in harbours, where both man-made breakwaters and the shape of the sea bed affect the wave behavior. Such problems involve the scattering, diffraction and refraction of waves and are mathematically formidable for linearised theory, even with relatively simple bed and for obstacle geometries.

3. Scope of the proposed study

3.1 Bed Topography:

The work presented in this thesis is solely concerned with the effect of bed topography on an incident wave train. We do not address problems where an obstacle, such as a barrier affects an incident wave train- except for mentioning them in this introduction and noting the solution methods used. The effect of variations in the still water depth on an incident wave train is examined using linearised theory. We prescribe the incident wave train and the deviation in the still water depth and seek the additional waves, the scattered waves, caused by this deviation. A typical problem requires the determination of a velocity potential satisfying Laplace's equation within the fluid~ a mixed boundary condition on the free surface~ and a given normal velocity on rigid boundaries~ If the fluid domain extends to infinity- a radiation condition is required to ensure uniqueness. This boundary value problem is well known and is formally presented. We shall refer to the problem of finding a solution of the boundary value problem as the full linear problem. Analytic solutions of the full linear problem are rare for any deviation from the constant water depth case.

3.2 Body paragraphs

The dynamic coupling of oceanic and atmospheric processes is inextricably linked to the fluxes across the marine boundary layer. Knowledge of their variability on different space-time scales is therefore crucial for understanding ocean-atmosphere interaction. Thermodynamic interactions across the air-sea interface are complex and varied. The sea surface receives short-wave solar radiation of which an amount is rejected while the remainder penetrates into the oceanic surface layer. Long-wave radiation is emitted from the ocean surface into the atmosphere, as well as from the atmosphere into the ocean surface. Alongside the radioactive transfers, are sensible and latent heat transfer. Sensible heat raises or lowers air temperature by conduction. The larger component is the latent heat transfer due to evaporation. Momentum transfer is also in operation generated as the winds blow across the air-sea interface.

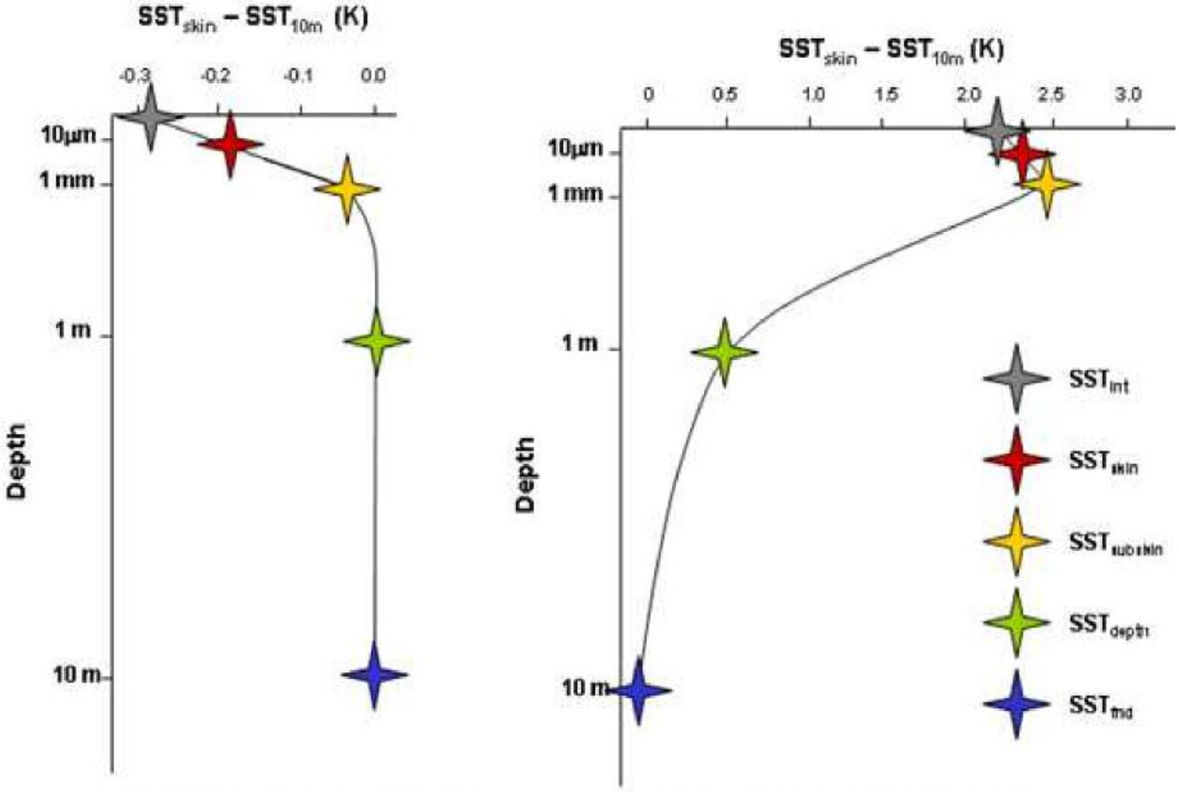
Calibration based on radiometric measurements can improve the accuracy of the formula for particular regions. For example this was done by Schiano [120] over the Mediterranean Sea where the transmission coefficient, was reduced from 0.7 to 0.66 due to a regional misevaluation of aerosols and water vapour attenuation. Schiano also showed how the coefficient Aa could vary according to measured water vapour density. This was only done in the clear sky case indicating an error not in the cloud correction of Reed, but the transmission coefficient originally chosen by Seckel and Beaudry [122]. A correction using an inverse method and direct ocean transport estimates by Isemer et al [55] over the North Atlantic Ocean also slightly reduced the transmission coefficient from 0.7 to 0.69 but also increased the cloud cover coefficient, Cn, from 062 to 0636. However an empirical formula such as this cannot be universally calibrated and its accuracy will always be restricted because the surface insolation is determined by not only the portion of cloud cover, but also the optical thickness of the cloud, which varies widely under the same cloud amount.

The major difference between the traditional method and method of assimilation which is hypothesised is that it is more accurate and advanced and can help in the mathematical model formation in dealing with the assimilation.

3.3 *Research Gaps identified:*

In the Indian context, the recent finding, that amongst the oceans, the warming of the Indian Ocean is second highest, is a cause of worry and calls for immediate attention. Even though climatological studies have been done in the past in the Indian Ocean encompassing the Arabian Sea and the Bay of Bengal, a comparative analysis of the changing Sea Surface Temperature (SST) pattern the gulfs of Arabian Sea (Persian Gulf, Gulf of Oman, Gulf of Aden, Gulf of Kutch, and Gulf of Khambhat) and the Red sea has not been done. The gulfs of the Arabian Sea are not just strategically important with rich sources of oil and natural gas but are also the hot spots of the marine biodiversity. However, in the recent years, there has been an expeditious change in the marine ecosystem of the eastern and western gulfs of the Arabian Sea and the Red Sea, owing to anthropogenic interference. Since 1990s, 40% of the coasts of the Persian Gulf have been modified. The Persian Gulf and the Red Sea areas have been reported to be warming rapidly owing to the developmental projects undertaken in the surrounding coastal countries. The Gulf of Kutch on the Indian coast is being aggressively developed as oil importing bases because of its proximity to the Middle East countries [29]. In general, the issues of common concern in the eastern and western gulfs of the Arabian Sea and the Red Sea include various anthropogenic activities like industrialization, coastal infrastructure development projects, setting up of new ports and oil terminals, oil pollution from shipping industry, overfishing, dredging, and increase in tourism and recreational activities, resulting in habitat destruction, changes in temperature and salinity profile, and causing a significant loss of biodiversity .

In this regard, the present work was taken up to study the monthly, seasonal, and annual pattern of Sea Surface Temperature (SST) and to analyse its changing pattern with emphasis on interannual variability in the eastern (Gulf of Kutch and Gulf of Khambhat) and the western gulfs (Persian Gulf, Gulf of Oman, and Gulf of Aden) of the Arabian Sea and the Red sea.



(a) Night time situation, light wind

(b) Day time time situation, strong solar radiation and light winds

Figure 1: Differential Scattering of waves

3.4 Tables

Place table titles above the tables.

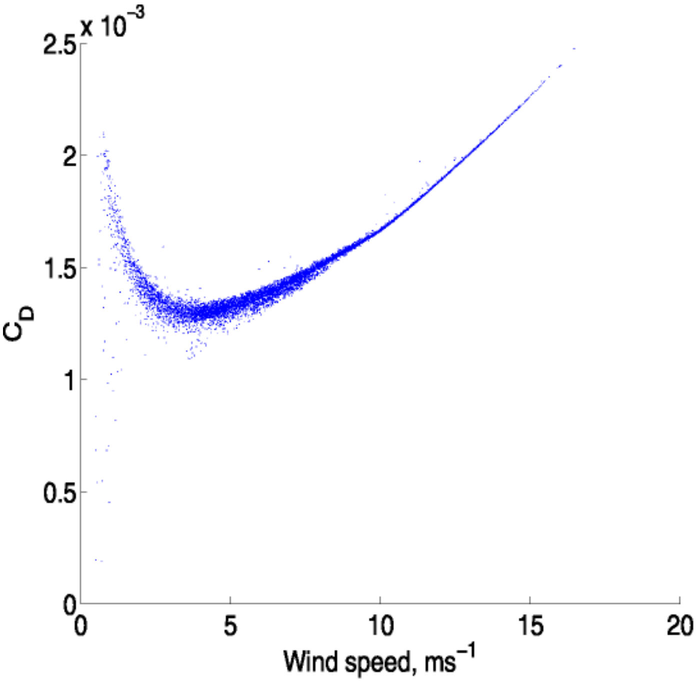


Table: Wave Scattering

3.5 Sections headings

Meteorological and sea temperature observations are obtained from the Indian Metrological Institute (MET Office) upper ocean mooring data archive; this is publicly available . Work presented here uses time series from three of these deployments. Details of the locations, duration, and frequency of data for each time series is given in Table 4.1. The meteorological variables consist of the wind speed components u and v, air temperature Ta, relative humidity $_{qrh,}$ and air pressure p. These variables are needed in the air-sea flux parameterisations (see Section 3.5). The sea temperature observations,^{obs} (z), at various depths z (within the top 150 m there are 29 observation depths at Arabian Sea, 34 at COARE, and 12 at Subduction) are linearly interpolated onto the model grid and are used to initialise the model simulations. The observed temperature time series are further used to assess how well the model performs by making model-observation comparisons.

Sites	Location	Duration	Frequency
Arabian Sea	15 N 61 E	17/10/94 17/10/95	^{obs}(z) every 15 min u, v, Ta, $_{qrh,}$ and p every 7.5 min
COARE	1 S 156 E	01/11/92 01/03/93	^{obs}(z) every 15 min u, v, Ta, $_{qrh,}$ and p every 7.5 min
Subduction	26 N 29 W	24/06/91 16/06/93	^{obs}(z) every 15 min u, v, Ta, $_{qrh,}$ and p every 15 min

Table 4.1: Locations, deployment duration, and data frequency at the three mooring sites.

4.1 Radiant Heating Parametrization:

An introduction to ocean radiant heat parameterisations is there. The public domain version of GOTM uses the 2-band parameterisation of Paulson and Simpson [100]. This is wholly inadequate for the purposes of modelling near surface temperature variability and so Paulson and Simpsons extension to a 9-stream parameterisation [101] was implemented into GOTM by S. Hallsworth [50]. This division of solar radiation incident at the surface into further discrete wavelength bands provides much needed additional resolution of the rapid attenuation of larger wavelengths at the near surface. Improvements in the near surface temperature profiles were found when using the 9-band over the 2-band parameterisation. Results from using the 2-band (with Jerlov water type 1, the most representative of the open ocean [129]) and 9-band schemes were compared by performing model simulations forced with SWR and LWR observations at the three mooring sites. RMS error in SST over all model-observation differences at every observation depth in the top 10 metres (0.45, 0.55, 1.1, 1.58, 2.0, 2.5, 6.94, 7.44, and 9.77 metres at COARE; 0.17, 0.43, 0.92, 1.37, 1.41, 1.8, 1.91, 2.4, 3.5, 4.5, 5.0, and 10.0 metres at the Arabian Sea; and 1.0 and 10.0 at the Subduction Site) were then calculated. The RMS error improvements in favour of the 9-band radiation scheme at the Arabian Sea is 2 3 7 C to 2 4 9 C and at the Subduction site 093 C to 095 C. However, the COARE site showed the 2-band scheme reduced.

4. Equations

We have found the RMS errors which we have tabulated in the detailed form here which can innumerate the data of the Arabian Sea along with the sites which have been used as the reference here.

	RMS Errors			
Site	SST (C)	Diurnal Warming (C)	MLD (m)	Stratification (C)
COARE	0.29	0.36	14.85	0.22
Arabian Sea	0.71	0.26	23.81	0.23
Subduction	0.66	0.18	26.19	0.14

5. Cloud Corrections

This cloud correction method to determine cloud values is not necessarily always physically realistic as the cloud amount is also compensating for other causes of error present in the model. This is particularly true when implementing the scheme at the Arabian Sea site where it is known that on certain occasions the major source of error is due to advection.

References

[1] J.Icarus Allen, J. R. Siddorn, J. C. Blackford, and F. J. Gilbert. Turbulence as a control on the microbial loop

in a temperate seasonally stratified marine systems model. J. Sea Res., 52:120, 2004.

[2] S. P. Anderson and R. A. Weller. Surface buoyancy forcing and the mixed layer of the western Pacific warm pool: Observations and 1d model results. J. Climate, 9:30563085, 1996.

[3] I. Andreu-Burillo, J. Holt, R. Proctor, J. D. Annan, I. D. James, and D. Prandle. Assimilation of sea surface temperature in the POL coastal ocean modelling system. J. Mar. Syst., 65:2740, 2007.

[4] J. D. Annan and J. C. Hargreaves. Sea surface temperature assimilation for a three-dimensional baroclinic model of shelf seas. Cont. Shelf Res., 19:15071520, 1999.

[5] WHOI Upper Ocean Mooring Data Archive. http://kuvasz.whoi.edu/uopdata/uopdata.html, April 2007.

[6] B. Barnier, L. Siefridt, and P. Marchesiello. Thermal forcing for a global ocean circulation model using a three-year climatology of ECMWF. J. Mar. Syst., 6:363380, 1995.

[7] M. J. Bell, R. M. Forbes, and A. Hines. Assessment of the FOAM global data assimilation system for reat-time operational ocean forecasting. J. Mar. Syst., 25:122, 2000.

[8] M. J. Bell, M. J. Martin, and N. K. Nichols. Assimilation of data into an ocean model with systematic errors near the equator. Q. J. R. Meteorol. Soc., 129, 2003.

[9] D. J. Bernie, S. J. Woolnough, J. M. Slingo, and E. Guilyardi. Modelling diurnal and intraseasonal variability of the ocean mixed layer. J. Climate, 18:11901202, 2005.

[10] F. Bignami, S. Marullo, R. Santoleri, and M. E. Schiano. Longwave radiation budget in the Mediterranean Sea. J. Geophys. Res., 100:25012514, 1995.

[11] H. Burchard. Simulating the wave-enhanced layer under breaking surface waves with two-equation turbulence models. J. Phys. Oceanogr., 31:31333145, 2001.

[12] H. Burchard and K. Bolding. Comparative analysis of four second-moment turbulence closure models for the oceanic mixed layer. J. Phys. Oceanogr., 31:1943 1968, 2001.

[13] H. Burchard, K. Bolding, W. Kuhn, A. Meister, T. Neumann, and L. Umlauf. Description of a flexible and extendable physical-biogeochemical model system for the water column. J. Mar. Syst., 61:180211, 2006.

[14] H. Burchard, K. Bolding, T. P. Rippeth, A. Stips, J. H. Simpson, and J. Sundermann. Microstructure of turbulence in the northern North Sea: comparative study of observations and model simulations. J. Sea. Res., 47:223238, 2002.

[15] H. Burchard, K. Bolding, and M. R. Villarreal. GOTM, a General Ocean Turbulence Model. Theory, implementation and test cases. Tech. Rep. EUR 18745 EN, European Commission, 1999.

[16] H. Burchard, H. Lass, V. Mohrholz, L. Umlauf, J. Sellschopp, V. Fiekas, K. Bolding, and L. Arneborg. Dynamics of medium-intensity dense water plumes in the Arkona Sea, Western Baltic Sea. Ocean Dynamics, 55:391402, 2005.

[17] D. B. Chelton and M. H. Freilich. Scatterometer-based assessment of 10-m wind analyses from the operational ECMWF and NCEP numerical weather prediction models. Mon. Wea. Rev., 133:409429, 2005.

[18] D. Chen, S. E. Zebiak, and M. A. Cane. Initialization and predictability of a coupled ENSO forecast model. Mon. Wea. Rev., 125:773788, 1997.

[19] R. M. Clancy, J. M. Harding, K. D. Pollak, and P. May. Quantification of improvements in an operational global-scale ocean thermal analysis system. J. Atmos. Oceanic Technol., 9:5565, 1992.

[20] R. M. Clancy, P. A. Phoebus, and K. D. Pollak. An operational global-scale ocean thermal analysis system. J. Atmos. Oceanic Technol., 7:233254, 1990.

[21] N. E. Clark, L. Eber, R. M. Laurs, J. A. Renner, and J. F. T. Saur. Heat exchange between ocean and atmosphere in the eastern north Pacific for 1961-1971. Technical report, NOAA, 1974.

[22] M. C. Cooper and K. Haines. Data assimilation with water property conservation. J. Geophys. Res., 101:10591077, 1996.

[23] P. Cornillon and L. Stramma. The distribution of diurnal sea surface warming events in the western Sargasso Sea. J. Geophys. Res., 90:1181111815, 1985.

[24] P. D. Craig and M. L. Banner. Modeling wave-enhanced turbulence in the ocean surface layer. J. Phys. Oceanogr., 24:25462559, 1994.

[25] J. Crank and P. Nicolson. A practical method for numerical evaluation of solutions of partial differential equations of the heat-conduction type. Proc. Cam-bridge Philos. Soc., 43:5067, 1947.

[26] G. Danabasoglu, W. G. Large, J. J. Tribbia, P. R. Gent, and B. P. Briegleb. Diurnal coupling in the tropical oceans of CCSM3. J. Climate, 19:23472365, 2006.

[27] D. Dee and A. M. DaSilva. Data assimilation in the presence of forecast bias. Q. R. Meteorol. Soc., 124:269295, 1998.

[28] A. Defant. Physical Oceanography. Pergamon Press, 1961.

[29] J. Derber and A. Rosati. A global oceanic data assimilation system. J. Phys. Oceanogr., 19:13331347, 1989.

[30] F-X. Le Dimet and M. Ouberdous. Retrieval of balanced fields: an optimal control method. Tellus, 45A:449461, 1993.

[31] F. W. Dobson and S. D. Smith. Bulk models of solar radiation at sea. Q. J. R. Meteorol. Soc., 114:165182, 1988.

[32] C. J. Donlon, P. J. Minnett, C. Gentemann, T. J. Nightingale, I. J. Barton, B. Ward, and M. J. Murray. Toward improved validation of satellite sea surface temperature measurements for climate research. J. Climate, 15:353369, 2002.

[33] C. J. Donlon and the GHRSST-PP Science Team. The recommended GHRSSTPP data processing specifications GDS (version 1 revision 1.5). Technical Re-port 17, GHRSST-PP, 2004.

[34] T. Ezer and G. Mellor. Data assimilation experiments in the Gulf stream region: How useful are satellite-derived surface data for nowcasting the subsurface fields. J. Atmos. Oceanic Technol., 14:13791391, 1997.

[35] C. W. Fairall, E. F. Bradley, J. S. Godfrey, G. A. Wick, J. B. Edson, and G. S. Young. Cool-skin and warm-layer effects on sea surface temperature. J. Geophys. Res., 101:12951308, 1996.

[36] C. W. Fairall, E. F. Bradley, J. E. Hare, A. A. Grachev, and J. B. Edson. Bulk parameterization of air-sea fluxes: Updates and verification for the COARE algorithm. J. Climate, 16:571591, 2003.

[37] C. W. Fairall, E. F. Bradley, D. P. Rogers, J. B. Edson, and G. S. Young. Bulk parameterization of air-sea fluxes for TOGA-COARE. J. Geophys. Res., 101:37473764, 1996.

[38] C. W. Fairall, J. B. Edson, S. E. Larsen, and P. G. Mestayer. Inertial-dissipation air-sea flux measurements: a prototype system using real-time computations. J. Atmos. Oceanic Tech., 7:425453, 1990.

[39] A. S. Fischer, R. A. Weller, D. L. Rudnick, C .C. Eriksen, C. M. Lee, K. H. Brink, C. A. Fox, and R. R. Leben. Mesoscale eddies, coastal upwelling, and the upper-ocean heat budget in the Arabian Sea. Deep-Sea Res. I, 49:22312264, 2002.

[40] P. Flament, J. Firing, M. Sawyer, and C. Trefois. Amplitude and horizontal structure of a large sea surface warming event during the Coastal Ocean Dynamics Experiment. J. Phys. Oceanogr., 24:124139, 1994.

[41] C. Gautier and R. Frouin. Net surface solar irradiance variability in the Central Equatorial Pacific during 1982-1985. J. Climate, 1992.

[42] C. L. Gentemann, C. J. Donlon, A. Stuart-Menteth, and F. J. Wentz. Diurnal signal in satellite sea surface temperature measurements. Geophys. Res. Lett., 30:1140, 2003.

[43] C. Gilman and C. Garrett. Heat flux parameterization for the Mediterranean Sea: The role of atmospheric aerosols and constraints from the water budget. J. Geophys. Res., 99:51195134, 1994.

[44] J. S. Jr. Godfrey, R. H. Johnson, R. Lukas, J.-L. Redelsperger, A. Sumi, and R. Weller. Coupled Ocean-Atmosphere Response Experiment (COARE): An interim report. J. Geophys. Res., 103:1439514450, 1998.

[45] G. J. Goni and J. A. Trinanes. Ocean thermal structure monitoring could aid in the intensity forecast of tropical cyclones. EOS, 84:573580, 2003.

[46] N. I. M. Gould and S. Leyer. An introduction to algorithms for nonlinear optimization. Technical Report 031, RAL, 2002.

[47] W. J. Gould and J. Turton. Argo - sounding the oceans. Weather, 61:1721, 2006.

[48] A. K. Grith and N. K. Nichols. Adjoint techniques in data assimilation for estimating model error. Journal of Flow, Turbulence and Combustion, 65:469 488, 2000.

[49] P. Y. Groisman, R. S. Bradley, and B. Sun. The relationship of cloud cover to near-surface temperature and humidity: comparison of GCM simulations with empirical data. J. Climate, 13:18581878, 2000.

[50] S. Hallsworth. Modelling the diurnal variation of sea surface temperature using a one-dimensional ocean temperature model. PhD thesis, University of Edinburgh, 2006.

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