
Chapter 6
Summary and conclusions

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6.1. Summary

Wave characteristics along the Indian coast have been studied by several researchers. Probably, this may be the first attempt to study seasonal response of coastal waves and wave transformation along the Indian coast using measurement, modelling and remote sensing. The broad objectives of the present study are:

- understanding the wave generation and propagation processes in the select nearshore regions along the Indian coast through measured data
- validation of wave modelling results of deep and shallow waters using measurements and remote sensing data
- to study the interaction between pre-existing swells and wind seas generated by coastal winds
- prediction of wave transformation along the select Indian coasts using high resolution winds such as MM5

Wave data collected using directional wave rider buoys, moored data buoys and non-directional wave recorder have been analysed. Wind data were measured using Autonomous Weather Station (AWS) at various coastal stations. Apart from measurements, significant wave heights (H_s) derived from Jason-1 altimeter were used for deep water wave analysis as well as model validation/comparison. Wind data from QuikScat scatterometer and re-analysed winds such as NCEP, CERSAT/IFREMER blended and NCMRWF were considered for the analysis, and applied as input to numerical wave simulations. Fine resolution coastal winds off Goa have been simulated using Mesoscale Model (MM5) to study the wind sea generated by sea breeze – land breeze system during pre-monsoon season.

The specific investigations carried out in the present study are as follows:

- i) analysis of spectral wave characteristics along the Indian coast during monsoons and extreme events
 - ii) dominance of swells over wind seas along the west coast of India
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- iii) setting up of a numerical model for the Indian Ocean, and validation of model results with measurements and remote sensing data
- iv) identification of potential swell generation areas, and propagation of these swells in the Arabian Sea and their impact on the west coast of India
- v) characteristics of “Shamal” swells – generation and propagation, and their influence along the west coast of India
- vi) superimposition of pre-existing swells over wind seas off Goa coast during pre-monsoon season
- vii) wave transformation along select open coasts and semi-enclosed regions

Spectral characteristics during monsoons and extreme events have been studied using wave spectra measured off Paradip and Goa, along the east coast and west coast of India, respectively. Multi-peaked spectra with spectral peaks in the low and high frequency regions have been observed, indicating the presence of different wave systems in the region. The spectral peak in the low frequency region indicates the dominance of distant swells and that in the high frequency region indicates the dominance of wind seas. During extreme events, the spectra are single-peaked and the energy is centred on a narrow band in the low-frequency region with an average directional spreading of 20°. It is evident from the spectra that wave energy during the southwest monsoon season is higher than the northeast monsoon season along the east coast as well as west coast of India.

Wind sea and swell energies have been separated, and the respective parameters have been calculated from the wave energy spectra using the methodology proposed by Gilhousen and Hervey (2001). It has been found that swells are dominated along the west coast of India during SW monsoon (93%) and NE monsoon (67%) seasons; however, wind seas are dominated during pre-monsoon season (51%). Annually, the dominance of swells is around 70%. The mean wave periods (T_m) during SW monsoon season are generally above 5 s, whereas, T_m are below 5 s during other seasons, indicating the superimposition of local wind seas over pre-existing swells during the pre-monsoon and NE monsoon seasons. The predominant swells observed along the west coast of India during pre-monsoon and NE monsoon seasons are in the SW/SSW directions, which are mostly propagated from the south Indian Ocean. However, the predominant swells during SW monsoon season are generated from the north Indian Ocean. NE monsoon winds could have negligible impact along the west coast of India, as waves generated due to these winds propagate away from the coast. Wind seas are predominantly in the NW direction during pre-monsoon and NE

monsoon seasons, and those during pre-monsoon season are generated by sea breeze. It has been found that the nearshore waves during extreme events are dominated by swells.

Numerical models were set up for large domain (the Indian Ocean region) and small domains (off Goa, Ratnagiri, Dwarka, Paradip and Dhamra) to simulate waves during various seasons. Model results have been validated with measurements at deep water locations as well as nearshore depths, and the match is very good. Correlation coefficients of model and measured H_s and T_m at a deep water location off Goa are 0.96 and 0.85, respectively, and at a nearshore location off Goa are 0.96 and 0.83, respectively. The bias and r.m.s. error between measured and model wave parameters are as follows: H_s : 0.00 and 0.37 m, respectively in deep water; 0.06 m and 0.29 m, respectively in a nearshore depth; T_m : -0.32 s and 0.80 s, respectively in deep water, and 0.10 s and 0.80 s, respectively in a nearshore depth.

Coastal wind seas off Goa simulated using MM5 winds are validated with measured wind sea parameters off Goa and the match is very good. The correlation coefficient, bias and r.m.s. error between measured and modelled wind sea H_s are 0.73, 0.03 m and 0.12 m, respectively. Diurnal variations associated with winds are evident in the simulated wind sea parameters also.

Analysis of winds and simulated waves in the Indian Ocean revealed the areas of potential swell generation; these swells propagate in the Arabian Sea and effect the west coast of India. Predominant swells are in the SW direction during SW monsoon season and in the SW/SSW and NW directions during both pre-monsoon and NE monsoon seasons. The potential swells are generated primarily in the following areas: (i) area covered by 52.5° E to 62.5° E and 5° S to 15° S for SW swells during SW monsoon season, (ii) area covered by 40° E to 70° E and 30° S to 50° S for SW/SSW swells during pre-monsoon and NE monsoon seasons and (iii) area covered by 60° E to 67.5° E and 17.5° N to 25° N for NW swells during pre-monsoon and NE monsoon seasons.

Shamal winds are meteorological events associated with winds, which normally occurs in the Arabian Peninsula, especially during the winter season. They generate large swells in the Persian Gulf and in the Arabian Sea. Characteristics of the “Shamal” swells were studied by analyzing measured wave parameters along the west coast of India during winter season. Increase in wave heights associated with decrease in swell periods and a common propagation direction (NW) for wind sea and swell are the distinct features of the Shamal swells. The associated significant wave heights and mean swell periods are between 1.0

and 2.0 m and between 6.0 and 8.0 s, respectively. Numerical simulations reproduced the Shamal swells in the Arabian Sea. It has been found that the Shamal swells are generated in the Gulf of Oman and off the east coast of Oman, which propagate to the west coast of India in the NW direction. The analysis of swell parameters extracted at 6 locations (Dwarka, Mumbai, Ratnagiri, Goa, Mangalore and Kochi) along the west coast of India indicates that the swell heights are larger off Dwarka and relatively smaller off Kochi, i.e., in the decreasing order of magnitude from north to south. The swells reach first along the Gujarat coast and then on the Kerala coast with time lags according to their arrivals.

Superimposition of coastal wind seas with pre-existing swells during pre-monsoon season was investigated. A distinct and systematic diurnal variation in wind speed, wave height and wave period, especially increase in wave height and decrease in wave period following the increase in the intensity of coastal winds due to sea breeze system has been observed. During the onset of sea breeze, a wind wave system grows in time, following the progressive extension of the sea breeze area towards offshore. After cessation of the sea breeze, wave energy level gradually decreased and the associated wave period increases. During a typical daily cycle, the wave height reaches its peak early in the afternoon, then it decays progressively back to the swell conditions within 5 or 6 hours. It is evident from the wind sea that the wind sea H_s gradually increases towards the coast from offshore, and the maximum wind sea H_s has been observed close to the Goa coast. The wind sea growth towards the coast is proportional to the wind speed gradient, available fetch and sea breeze duration.

Wave transformation along the open coasts and semi-enclosed regions has been studied using measurements and simulations. Reduction in significant wave heights among two nearshore water depths measured off Goa, Ratnagiri and Dwarka were estimated. Least reduction is observed off Goa and maximum off Dwarka. In fact, a wind sea growth in the NE direction (away from the coast) off Dwarka has been observed, which sufficiently contributes to the prevailing waves at 30 m depth location. Simulated wave parameters at water depths of 100 m, 50 m, 30 m, 20 m, 10 m and 5 m off Mumbai, Goa and Kochi (along the west coast of India), and off Nagappattinam, Visakapattinam and Paradip (along the east coast of India) were analysed. Wave patterns along the west coast of India are nearly the same, but in increasing order of wave heights from south to north. It is found that wave dissipation is high off Mumbai and low off Kochi along the west coast of India. Wave heights along the east coast of India are in the increasing order during pre-monsoon and SW monsoon seasons, and in the decreasing order during NE monsoon season, from

south to north (Nagappattinam to Paradip), and the reduction among various depths are relatively less as compared to those along the west coast of India. Bottom dissipation causes higher reduction in wave heights over wide continental shelf, and the continental shelf of west coast is wider compared to east coast of India.

Wave transformation at naturally protected (Dhamra Port) and artificially protected (Mormugao Port) semi-enclosed regions has been studied. The Dhamra port is protected from direct waves by Kanika sands, Gahirmatha beach and surrounding mangroves, and is only partially open to the waves from NNE to NE and from ESE to SE. Diffraction and bottom dissipation play major role in controlling the wave energy while propagating towards the Port. The Mormugao Port is protected from waves by breakwaters, and during any season, wave height inside the port is very low, and only diffracted waves propagate towards the port. During an extreme event prevailed in the Arabian Sea, the significant wave height observed inside the port was only 0.33 m.

A case study was carried out to demarcate inland vessels' limit (IVL) limit off Mormugao Port region for demonstrating the operational use of wave model results. It has been found that during September – May, significant wave heights do not exceed 2.0 m off Mormugao port and coastal regions. Based on the significant wave height distribution around the coastal region, the IVL has been demarcated.

6.2. Conclusions

- Time series wave data measured off Goa (west coast of India) and off Paradip (east coast of India) distinctly show the response of coastal waves to the seasons and extreme events.
 - Monthly, seasonal and annual characteristics of wind seas and swells off Goa have been separated from the measured wave spectra using the separation frequency method. The wave pattern primarily follows swell pattern during most part of the year, especially during SW monsoon and NE monsoon seasons. Wind seas are dominated during pre-monsoon season.
 - Numerical model results have been validated with measurements in deep water as well as nearshore locations, and the match is very good.
 - MM5 winds have been simulated for Goa region during pre-monsoon season, and applied to simulate coastal waves off Goa. Significant improvement in simulated wave
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parameters was observed, urging the need of using high resolution winds for coastal wave predictions.

- Superimposition of locally generated waves from NW with the pre-existing swells from SW along the west coast of India results in diurnal variations in waves. Increase in wave height and decrease in wave period with increase in wind speed, especially during fair weather season, are the important effects of dominance of sea breeze.
 - Though waves during southwest monsoon season have high impact on the west coast of India, the wind seas super-imposed on pre-existing swells do cause geomorphological changes during non-monsoon months. The role of distant swells in modulating the wave generation along the west coast of India, where the impact of sea breeze is dominant during pre-monsoon season, is yet to be understood.
 - The “Shamal” swells were identified along the west coast of India during winter season. Increase in wave heights associated with decrease in swell periods and common propagation direction (NW) for wind sea and swell are the distinct characteristics of Shamal swells. Shamal swells are generated in the northwestern Arabian Sea, especially in the Gulf of Oman and off the east coast of Oman, and propagate towards the west coast of India in the NW direction. Influence of Shamal swells is the maximum along the Gujarat coast and the minimum along the Kerala coast.
 - Shamal winds can influence the wind-induced circulation in the Arabian Sea. Study on Shamal wind extension and their distribution along the west coast of India require fine resolution winds (e.g. MM5 winds). Even though swells from the south Indian Ocean are always present along the west coast of India, the presence of Shamal swells cannot be ignored.
 - Transformation of wave parameters in the nearshore depths at various locations along the Indian coast has been assessed. Wave height reduction is higher along the west coast compared to the east coast, since bottom dissipation causes higher reduction over wide continental shelf. Along the west coast of India, the wave dissipation increases from south to north (Kochi to Mumbai). Attenuation due to bottom friction varies along the west coast of India according to the size of the bottom sediments, and it is in the increasing order from the south to the north.
 - Wave patterns along the west coast of India are nearly the same, with wave heights increasing from south to north (Kochi to Mumbai). Wave heights along the east coast
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of India increase from south to north (Nagappattinam to Paradip) during pre-monsoon and SW monsoon seasons and decrease during NE monsoon season. Diurnal variations are evident at nearshore depths along the west coast of India during pre-monsoon season, but in the decreasing order of magnitude from north to south (Mumbai to Kochi).

- Wave modelling results have been applied to an operational use: based on the distribution of significant wave heights, inland vessel's limit (IVL) of the Mormugao port has been demarcated.

6.3. Future perspective

The present work can be extended further to study the following aspects:

- ✓ Role of distant swells in modulating wave generation along the west coast of India, where the impact of sea breeze is dominant during pre-monsoon season, is yet to be understood – a detailed investigation is required.
 - ✓ Shamal winds can influence the wind-induced circulation in the Arabian Sea. Shamal wind extension along the west coast of India has to be analysed in detail utilising fine resolution atmospheric models.
 - ✓ Since, swells (SW/SSW) from south Indian Ocean are always present along the west coast of India, they interact with Shamal swells (NW) during Shamal events. The interaction of these multi-directional swells deserves special attention in future research.
 - ✓ A detailed field study should be carried out to understand the nature of attenuation of short period wind seas observed at the nearshore depths off Goa during pre-monsoon season.
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References

References

- Abdalla, S. and L. Cavaleri, 2002: Effect of wind variability and variable air density on wave modeling, *J. Geophys. Res.*, 107 (C7), 17-1/17-17.
- Abhijit Sarkar, M. Mohan and Raj Kumar, 1997: Inter-comparison of model-predicted wave heights with satellite altimeter measurements in the north Indian Ocean, *Ocean Eng.*, 24(9), 879-885.
- Aboobacker, V.M., P. Vethamony, K. Sudheesh and S.P. Rupali, 2009: Spectral characteristics of the nearshore waves off Paradip, India during monsoon and extreme events, *Nat. Hazards*, 49, 311-323.
- Aboobacker, V.M., Vethamony, P., Sudheesh, K., 2005: Wave characteristics off Paradip during monsoons as evident from measurements and modelling, *Proceedings of the National Workshop on Oceanographic Features of the Indian Coastal Waters, held at Naval Physical & Oceanographic Laboratory, Kochi*, 46-53.
- Ali, A.H., 1994: Wind regime of the Arabian Gulf, *The Gulf War and the environment*, Taylor & Francis, 206 pp.
- Al-Zanaidi, M.A. and W.H. Hui, 1984: Turbulent air flow water waves, *J. Fluid Mech.*, 148, 225-246.
- Aparna, M., S.R. Shetye, D. Shankar, S.S.C. Shenoi, P. Mehra, and R.G.P. Desai, 2005: Estimating the seaward extent of sea breeze from QuikSCAT scatterometry, *Geophys. Res. Lett.*, 32, L13601, doi:10.1029/2005GL023107.
- Ardhuin, F. and T. Herbers, 2002: Bragg scattering of random surface gravity waves by irregular seabed topography, *J. Fluid Mech.*, 451, 1-33.
- Ardhuin, F., L. Berotti, J.R. Bidlot, L. Cavaleri, V. Filippetto, J.M. Lefevre and P. Wittmann, 2007: Comparison of wind and wave measurements and models in the Western Mediterranean Sea, *Ocean Eng.*, 34, 526-541.
- Ardhuin, F., W.C. O'Reilly, T.H.C. Herbers and P.F. Jessen, 2003: Swell transformation across the continental shelf. Part I: Attenuation and directional broadening, *J. Phys. Oceanogr.*, 33 (9), 1921-1939.
- Baba, M., J. Dattatri and S. Abraham, 1989: Ocean wave spectra off Cochin, west coast of India, *Indian J. Mar. Sci.*, 18, 106-112.
-

- Baba, M., N.P. Kurian, K.V. Thomas, M. Prasannakumar, T.S.S. Hameed and C.M. Harish, 1983: Study of the waves and their refraction in relation to beach erosion along the Kerala coast, *Centre for Earth Science Studies, Technical Report*, No.29, 28 pp.
- Bagnold, R. A., 1946: Motion of waves in shallow water - interaction between waves and sand bottoms, *Royal Society of London*, 187, 1-18.
- Barber, N.F. and F. Ursell, 1948: The generation and propagation of ocean waves and swell, *Philosophical Transactions of the Royal Society of London*, 240A, 527-560.
- Barnett, T.P. and J.C. Wilkerson, 1967: On the generation of ocean wind waves as inferred from airborne measurements of fetch-limited spectra, *J. Mar. Res.*, 25, 292-328.
- Battjes, J. A. and J. P. F. M. Janssen, 1978: Energy loss and set-up due to breaking in random waves, *Proc. 16th Coastal Engineering Conference, Hamburg, Germany*, 569-587.
- Belcher, S.E. and J.C.R. Hunt, 1993: Turbulent shear flow over slowly moving waves, *J. Fluid Mech.*, 251, 109-148.
- Bentamy, A., D. Croize-Fillon, P. Queffeulou, C. Liu, and H. Roquet, 2009: Evaluation of high-resolution surface wind products at global and regional scales, *Journal of Operational Oceanography*, 2(2), 15-27.
- Bentamy A., H.L. Ayina, P. Queffeulou, and D. Croize-Fillon, 2006: Improved near real time surface wind resolution over the Mediterranean Sea, *Ocean Sci. Disc.*, 3, 435-470.
- Bhatt, V., R. Kumar, S. Basu, V.K. Agarwal, 2005: Assimilation of altimeter significant wave height into a third generation global spectral wave model, *IEEE Trans Geosci. Rem. Sens.*, 43, 110-117.
- Bhowmick, S.A., R. Kumar, S. Basu, A. Sarkar and V.K. Agarwal, 2009: Improvement in wave forecast using data assimilative coastal wave model, *Indian J. Mar. Sci.*, 38(2), 142-150.
- Bonnefond, P., B. Hanes, G. Born, P. Exertier, S. Gill, G. Jan, E. Jeansou, D. Kubitschek, O. Laurain, Y. Menard and A. Orsoni, 2003: Calibrating the Jason-1 measurement system: Initial results from the Corsica and Harvest verification experiments, *Adv. Space Res.*, 32 (11), 2135-2140.
- Booij, N., L.H. Holthaijsen and R.C. Ris, 1999: A third-generation wave model for coastal regions. 1. Model description and validation", *J. Geophys. Res.*, 104(C4), 7649-7666.
-

- Bretschneider, C.L., 1963: Significant wave hindcast for station I. North Atlantic Storm, Dec. 1959, *Tech Report*, No. SN-77-1.
- C2-MUT-W-03-IF, 2002: QuikScat Scatterometer Mean Wind Field Products User Manual, France, *IFREMER*, Version: 1.0.
- Cavaleri, L. and M. Sclavo, 2006: The calibration of wind and wave model data in the Mediterranean Sea, *Coastal Eng.* 53, 613-627.
- Chalikov, D.V. and V.K. Makin, 1991: Models of the wave boundary layer, *Boundary-Layer Meteorol.*, 56, 83-99.
- Chambers, D.P., J.C. Ries and T.J. Urban, 2003: Calibration and verification of Jason-1 using global along-track residuals with TOPEX, *Marine Geodesy*, 26, 305-317.
- Chandramohan, P., V. Sanil Kumar and B.U. Nayak, 1991: Wave statistics around the Indian coast based on ship observed data, *Indian J. Mar. Sci.*, 20, 87-92.
- Coleman, J.M. and L.D. Wright, 1971: Analysis of major river systems and their deltas: procedures and rationale with two examples, *Louisiana State University, Coastal Studies Institute, Technical Report*, 95, 125 pp.
- Combes, J.A., A. Grossmann and Ph. Tchamitchian, 1989: Wavelets, Time-Frequency Methods and Phase space, *Springer-Verlag, Berlin*, 315.
- Darbyshire, J., 1961: Prediction of wave characteristics over the North Atlantic, *J. Inst. Navigation*, 14, 339-347.
- Datawell BV, 2006: Datawell wave rider reference manual, *Datawell BV, Zumerlustraat 4, 2012 LM Haarlem, The Netherlands*.
- Datawell, 2001: The W@ves21 spectral analysis tool, developed for analysis of the directional Wave Rider buoys from Datawell in the Netherlands, www.datawell.nl.
- Dhanya, P., P. Vethamony, K. Sudheesh, G. Smitha, M.T. Babu and T.M. Balakrishnan Nair, 2010: Simulation of coastal winds along the central west coast of India using the MM5 mesoscale model, *Meteorology and Atmospheric Physics*. (Article in Press).
- DHI, 2001: MIKE 21 Wave modelling user guide, *DHI Water & Environment, Denmark*, 66 pp.
- Dobson, F.W., 1971: Measurement of atmospheric pressure on wind-generated sea waves, *J. Fluid Mech.*, 48, 91.
-

- Dobson, F.W., S.D. Smith, and R.J. Anderson, 1994: Measuring the relationship between wind stress and sea state in the open ocean in the presence of swell, *Atmosphere-Ocean*, 32, 237-256.
- Dobson, R.S., 1967: Some applications of a digital computer to hydraulic engineering problems, *Dept. of Civil Engineering, Stanford University, Technical Report*, No. 80, 115p.
- Donelan, M.A., 1982: The dependence of the aerodynamic drag coefficient on wave parameters, *Proc. Of the first international conference on meteorological and air/sea interaction of the coastal zone; Amer. Meteor. Soc., Boston, Mass*, 381-387.
- Donelan, M.A., W.M. Drennan and E.A. Terray, 1999: Wavenumber spectra of wind waves in the range of 1–50 m, *In: Banner, M.L. (Ed.), The Wind-Driven Air–Sea Interface. School of Mathematics, The University of New South Wales, Sydney*, 35-42.
- Donelan, M.A., W.M. Drennan, and K.B. Katsaros, 1997: The air-sea momentum flux in conditions of wind sea and swell, *J. Phys. Oceanogr.*, 27, 2087-2099.
- Drennan, W.M., H.C. Graber and M.A. Donelan, 1999: Evidence for the effects of swell and unsteady winds on marine wind stress, *J. Phys. Oceanogr.*, 29, 1853–1864.
- Duchossois, G., 1991: The ERS-1 mission objectives, *ESA Bull.*, 65, 16-25.
- Earle, M.D., 1984: Development of Algorithms for separation of sea and swell, *National Data Buoy Centre Tech. Rep.*, MEC-87-1, 53 pp.
- Ebuchi, N., H.C. Graber and M.J. Caruso, 2002: Evaluation of wind vectors observed by QuikSCAT/SeaWinds using ocean buoy data, *J. Atmos. Oceanic Technol.*, 19, 2049-2062.
- Elgar, S. and R.T. Guza, 1985: Observations of bispectra of shoaling surface gravity waves, *J. Fluid Mech.*, 161, 425-448.
- El-Sabh, M.I. and T.S. Murty, 1989: Storm surges in the Arabian Gulf, *Nat. Hazards*, 1, 371-385.
- Fabrikant, A.L., 1976: Quasilinear theory of wind-wave generation, *Izv. Atmos. Ocean. Phys.* 12, 524-526.
- Freilich, M.H. and Guza, R.T., 1984: Nonlinear effects on shoaling surface gravity waves, *Philosophical Transactions of the Royal Society of London*, A 311, 1-41.
-

- Freilich, M.H., R.T. Guza and S. Elgar, 1990: Observations of nonlinear effects in directional spectra of shoaling gravity waves, *J. Geophys. Res.*, 95, C6, 9645-9656.
- Fu, L.L., E.J. Christenses, C.A. Yamarone, M. Lefebvre, Y. Menard and P. Escudier, 1994: TOPEX-POSEIDON mission overview, *J. Geophys. Res.*, 99 (C12), 24369-24381.
- Gelci, R., H. Cazale´ and J. Vassal, 1957: Pre´vision de la houle. Lame´thode des densite´s spectroangulaires, *Bull. Inf. Comite´ Central Oce´anogr. Etude Co^tes*, 9, 416-435.
- Gerling, T. W., 1992: Partitioning sequences and arrays of directional ocean wave spectra into component wave systems, *J. Atmos. Oceanic Technol.*, 9, 444-458.
- Gilhousen, D.B. and R. Hervey, 2001: Improved Estimates of Swell from Moored Buoys. *Proc. of the Fourth International symposium WAVES 2001, ASCE: Alexandria, VA*, 387-393.
- Gille, S. T., S. G. Llewellyn Smith, and S. M. Lee, 2003: Measuring the sea breeze from QuikSCAT Scatterometry, *Geophys. Res. Lett.*, 30(3), 1114, doi:10.1029/2002GL016230.
- Goodberlet, M.A., C.T. Swift and J.C. Wilerson, 1992: Validation of ocean surface wind fields and wave height measurements derived from data of the ERS-1 scatterometer and radar altimeter (early results), *Proc. Of the workshop on ERS-1 Geophysical Validation, Penhors, France, 27-30 April 1992; ESA WPP-36, European Space Agency, Paris*, 61-64.
- Graber, H. C., N. Ebuchi, and R. Vakkayil, 1996: Evaluation of ERS-1 scatterometer winds with wind and wave ocean buoy observations, *University of Miami Tech. Rep.*, RSMAS 96-003, 78 pp.
- Greenslade, D.J.M., 2001: The assimilation of ERS-2 significant wave height data in the Australian region. *J. Mar. Syst.*, 28: 141-160.
- Grell, G., J. Dudhia, and D.R. Stauffer, 1994: A description of the fifth-generation Penn State/NCAR Mesoscale Model (MM5), *NCAR Tech. Note, NCAR/TN398+STR*, 138 pp.
- Guedes Soares, C., 1984: Representation of double-peaked sea wave spectra, *Ocean Eng.*, 11, 185-207.
- Guedes Soares, C., 1991: On the occurrence of double peaked wave spectra, *Ocean Eng.*, 18, 167-171.
-

- Gunther, H., P.Lionello and B. Hansen, 1993: The impact of the ERS-1 altimeter on the wave analysis and forecast, *Report No. GKSS 93/E/44, GKSS, Germany*, 56p.
- Hanson, J. L., and O. M. Phillips, 2001: Automated analysis of ocean surface directional wave spectra, *J. Atmos. Oceanic Technol.*, 18, 277-293.
- Hanson, J.L. and O.M. Phillips, 1999: Wind sea growth and dissipation in the open ocean, *J. Phys. Oceanogr.*, 29, 1633-1648.
- Hanson, J.L., 1996: Wave spectral partitioning applied to the analysis of complex wave conditions in the North Pacific Ocean, Pre-prints, *Eight Conf. on Air-Sea Interactions and Symp. On Goals, Atlanta, GA, Amer. Meteor. Soc.*, 61-65.
- Harish, C.M. and M. Baba, 1986: On spectral and statistical characteristics of shallow water waves, *Ocean Eng.*, 13(3), 239-248.
- Hasselmann, D.E. and J. Bosenberg, 1991: Field measurements of wave-induced pressure over wind sea and swell, *J. Fluid Mech.*, 230, 391-428.
- Hasselmann, K. and S. Hasselmann, 1985: The wave model EXACT-NL, In: The SWAMP Group (Eds.), *Ocean Wave Modelling, Plenum Press, New York and London*, 256 pp.
- Hasselmann, K., 1962: On the non-linear energy transfer in a gravity-wave spectrum, Part 1. General theory, *J. Fluid Mech.*, 12, 481-500.
- Hasselmann, K., 1974: On the spectral dissipation of ocean waves due to white capping, *Boundary-Layer Meteorol.*, 6, 107-127.
- Hasselmann, K., T.P. Barnett, E. Bouws, H. Carlson, D.E. Cartwright, K. Enke, J.I. Ewing, H. Gienapp, D.E. Hasselmann, P. Kruseman, A. Meerburg, P. Muller, D.J. Olbers, K. Richter, W. Sell and H. Walden, 1973: Measurements of wind-wave growth and swell decay during the Joint North Sea Wave Project (JONSWAP), *Deutsche Hydrographische Zeitschrift*, A 8 (12), 1-95.
- Hasselmann, S., K. Hasselmann, J.A. Allender and T.P. Barnett, 1985: Computations and parameterizations of the non-linear energy transfer in a gravity-wave spectrum. Part 2: parameterizations of the non-linear transfer for application in wave models, *J. Phys. Oceanogr.*, 15, 1378-1391.
- Herbers, T.H.C., M. Orzech, S. Elgar and R.T. Guza, 2003: Shoaling transformation of wave frequency-directional spectra, *J. Geophys. Res.*, 108 (C1), 3013, doi:10.1029/2001JC001304.
-

- Herbers, T.H.C., N.R. Russnogle and S. Elgar, 2000: Spectral energy balance of breaking waves within the surf zone, *J. Phys. Oceanogr.*, 30, 2723-2737.
- Hersbach. H., 1997: Application of the adjoint of the WAM model to inverse wave modelling, *J. Geophys. Res.*, 103, C5, 10469-10487.
- Holthuijsen, L.H. and S. De Boer, 1988: Wave forecasting for moving and stationary targets. In: Schrefler, B.A. and Zienkiewicz, O.C., Editors, 1988, *Computer Modelling in Ocean Eng.*, 231-234.
- Hristov, T.S., S.D. Miller, C.A. Friehe, 2003: Dynamical coupling of wind and ocean waves through wave-induced air flow, *Nature*, 442, 55-58.
- Hubert W.E., D.R. Morford, A.N. Hull, and R.E. Englebretson, 1983: Forecasters handbook for the middle east/arabian sea, *Naval Environmental Prediction Research Facility Monterey, California*, CR83-06.
- IMD, 1996: Indian Daily Weather Reports, *India Meteorological Department, Pune, India*.
- Jacobs, S.J., 1987: An asymptotic theory for the turbulent flow over a progressive water wave, *J. Fluid Mech.*, 174, 69-80.
- Janssen, P.A.E.M, 1982: Quasilinear approximation for the spectrum of wind-generated water waves. *J. Fluid Mech.*, 117, 493-506.
- Janssen, P.A.E.M., 1989: Wave-induced stress and the drag of air flow over sea waves, *J. Phys. Oceanogr.*, 19, 745-754.
- Janssen, P.A.E.M., 1992: Experimental evidence of the effect of surface waves on the airflow, *J. Phys. Oceanogr.*, 22, 1600-1604.
- Janssen, P.A.E.M., 2004: The Interaction of Ocean Waves and Wind, *Cambridge University Press, Cambridge, UK*, 300 pp.
- Jeffreys, H., 1924: On the formation of waves by wind, *Proc. Roy. Soc.*, A107, 189-206.
- Jeffreys, H., 1925: On the formation of waves by wind II, *Proc. Roy. Soc.*, A110, 341-347.
- Jenkins, A.D., 1992: A quasi-linear eddy-viscosity model for the flux of energy and momentum to waves, using conservation law equations in a curvilinear system, *J. Phys. Oceanogr.*, 22, 843-858.
- Jiang, F. and A.J. Mehta, 1996: Mud banks of the southwest coast of India: V: wave attenuation, *J. Coast. Res.*, 12(4), 890-897.
-

- Johnson, H.K. and H. Kofoed-Hansen, 2000: Influence of bottom friction on sea surface roughness and its impact on shallow water wind wave modelling, *J. Phys. Oceanogr.*, 30, 1743-1756.
- Kalney, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, M. Chelliah, W. Ebsuzaki, W. Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, A. Leetma, R. Reynolds, R. Jenne and D. Joseph et al., 1996: The NCEP/NCAR 40-Year Reanalysis Project, *Bull. Amer. meteor. Soc.*, 77, 437-471.
- Kaminsky, G. M. and N. C. Kraus. 1993: Evaluation of depth-limited wave breaking criteria, *Proceedings of 2nd International Symposium on Ocean Wave Measurement and Analysis, Waves 93* (ASCE, New York), 180-193.
- Kinsman, B., 1965: Wind waves, their generation and propagation on the ocean surface, *Prentice-Hall Inc., Englewood Cliffs, New Jersey*, 676 pp.
- Kline, S.A., and J.L. Hanson, 1995: Wave identification and tracking system, *Applied Physics Laboratory, The Johns Hopkins University, Tech. Rep. STD-R-2436, Laurel, MD*, 44 pp.
- Komen, G.J., Cavaleri, L., Donelan, M., Hasselmann, K., Hasselmann, S. and P.A.E.M., Janssen, 1994: Dynamics and Modelling of Ocean Waves, *Cambridge University Press, Cambridge*, 532 pp.
- Kurian, N.P., K. Rajith, T.S. Shahul Hameed, L. Sheela Nair, M.V. Ramana Murthy, S. Arjun and V.R. Shamji, 2009: Wind waves and sediment transport regime off the south-central Kerala coast, India, *Nat. Hazards*, 49, 325-345.
- Kurian, N.P. and M. Baba, 1987: Wave attenuation due to bottom friction across the southwest Indian continental shelf, *J. Coast. Res.*, 3(4), 485-490.
- Kurian, N.P., M. Baba and T.S. Shahul Hameed, 1985: Prediction of nearshore wave heights using a wave refraction programme, *Coastal Eng.* 9 (4), 347-356.
- Linacre, E. and J. Hobbs, 1977: The Australian Climatic Environment, *John Wiley & Sons: Brisbane*, 354 pp.
- Liu, P.C., 2000: Is the wind wave frequency spectrum outdated, *Ocean Eng.*, 27, 577-588.
- Long, R. B., 1973: Scattering of surface waves by an irregular bottom, *J. Geophys. Res.*, 78 (33), 7861-7870.
-

- Maat, N., C. Kraan and W.A. Oost, 1991: The roughness of wind waves, *Boundary-Layer Meteorol.*, 54, 89-103.
- Mac Pherson, H. and P.G. Kurup, 1981: Wave damping at the Kerala mud banks, *Indian J. Mar. Sci.*, 10, pp. 154-160.
- Madsen, P. A., and O. R. Sorensen, 1993: Bound waves and triad interactions in shallow water, *J. Ocean Engineering*, 20(4), 359-388.
- Makin, V.K., V.N. Kudryavstev and C. Mastenbroek, 1995: Drag of the sea surface. *Boundary-Layer Meteorol.*, 73, 159-182.
- Mandal, S. and N. Prabaharan, 2010: Ocean wave prediction using numerical and neural network models, *The Open Ocean Engineering Journal*, 3, 12-17.
- Mandal, S., 1985: A numerical wave prediction model DOLPHIN: theory and test results, *Report no. 3-85, Delft. Univ. Tech.*, The Netherlands, 68 pp.
- Masselink Gerhard and Charithra B. Pattiarchi, 1998: The effect of sea breeze on beach morphology, surf zone hydrodynamics and sediment resuspension, *Marine Geology*, 146, 115-135.
- Mastenbroek, C., 1996: Wind-wave interaction, *Ph.D. Thesis. Delft Tech. Univ.*, 119 pp.
- Mastenbroek, C., V.K. Makin, A.C. Voorrips and G.J. Komen, 1994: Validation of ERS-1 altimeter wave height measurements and assimilation in a North Sea wave model, *The Glob. Atm. Oc. System*, 2, 143-161.
- Mathew, J., M. Baba and N.P. Kurian, 1995: Mud- banks of southwest coast of India I: Wave characteristics, *J. Coast. Res.*, 11(1), 168-178.
- Miles, J.W., 1957: On the generation of surface waves by shear flows, *J. Fluid Mech.*, 3, 185-204.
- Mitsuyasu, H., 2002: A historical note on the study of ocean surface waves, *J. Oceanography*, 58, 109-120.
- Munk, W. H., 1951: Origin and generation of waves, *Proc. First Coastal Eng. Conference, Long Beach, Calif.*, 1-4.
- Neetu, S., S. Shetye and P. Chandramohan, 2006: Impact of sea-breeze on wind-seas off Goa, west coast of India, *J. Earth Sys. Sci.*, 115(2), 229-234.
-

- Nikolayeva, Y.I. and L.S. Tsimring, 1986: Kinetic model of the wind generation of waves by a turbulent wind, *Izv. Acad. Sci. USSR, Atmos. Ocean Phys.*, 22, 102-107.
- Oost, W.A., G.J. Komen, C.M.J. Jacobs and C. Van Oort, 2002: New evidence for a relation between wind stress and wave age from measurements during ASGAMAGE, *Boundary-Layer Meteorol.*, 103, 409-438.
- Parvareh, A., S. Hassanzadeh, and M.H. Bordbar, 2005: Statistical analysis of wave parameters in the north coast of the Persian Gulf, *Annales Geophysicae*, 23, 2031-2038.
- Pattiaratchi, C., B.J. Hegge, J. Gould and I.G. Eliot, 1997: Impact of sea breeze activity on nearshore and foreshore processes in Southwestern Australia, *Cont. Shelf Research*, 17, 1539-1560.
- Peregrine, D.H., 1967: Long waves on a beach, *J. Fluid Mech.*, 27, 815-827.
- Philips, O.M., 1957: On the generation of waves by turbulent wind, *J. Fluid Mech.*, 2, 417-445.
- Philips, O.M., 1977: The dynamics of the upper ocean, *Cambridge University Press, Cambridge*, 336 pp.
- Pierson, W. J. and L. Moskowitz, 1964: A proposed spectral form for fully developed wind-seas based on the similarity theory of S. A. Kitaigorodskii, *J. Geophys. Res.*, 69(24), 5181-5190.
- Pierson, W. J. and W. Marks, 1952: The power spectrum analysis of ocean wave record, *Trans. Amer. Geophys. Un.*, 33, 834-844.
- Pierson, W. J., G. Neumann and R. W. James, 1955: Practical methods for observing and forecasting ocean waves by means of wave spectra and statistics, *US Navy Hydrographic Office Pub.*, 603.
- Plant, W.J., 1982: A relationship between wind stress and wave slope, *J. Geophys. Res.*, 87(C3), 1961-1967.
- Portilla, J., J.O. Francisco and J. Monbaliu, 2009: Spectral partitioning and identification of wind sea and swell, *J. Atmos. Oceanic Technol.*, 26, 107-122.
- Prasad Kumar, B. and G.W. Stone, 2007: Numerical simulation of Typhoon wind forcing in the Korean Seas using a spectral wave model, *J. Coast. Res.*, 23(2), 362-373.
-

- Prasad Kumar, B., R. Kalra, S.K. Dube, P.C. Sinha, A.D. Rao, R. Kumar and A. Sarkar, 2000: Extreme wave conditions over the Bay of Bengal during a severe cyclone - simulation experiment with two spectral wave models, *Marine Geodesy*, 23(2), 91-102.
- Quilfen Y., B. Chapron, F. Collard and M. Serre, 2004: Calibration/Validation of an altimeter wave period model and application to TOPEX/Poseidon and Jason-1 altimeters, *Marine Geodesy*, 27, 3-4, 511-534.
- Raj Kumar., S.A. Bhowmick, S. Ray, V. Bhatt, S. Surendran, S. Basu, A. Sarkar and V.K. Agarwal, 2009: Improvement in predictability of waves over the Indian Ocean, *Nat. Hazards*, 49, 275-291.
- Rao C.V.K.P. and M. Baba, 1996: Observed wave characteristics during growth and decay: a case study, *Cont. Shelf Res.*, 16(12), 1509-1520.
- Resio, D.T. and W. Perrie, 1991: A numerical study of nonlinear energy fluxes due to wave-wave interactions. Part 1: Methodology and basic results, *J. Fluid Mech.*, 223, 609-629.
- Richter, K., B. Schmalfeldt, and J. Siebert, 1976: Bottom irregularities in the North Sea. *Dtsch. Hydrogr. Z.*, 29 (1), 1-10.
- Rodriguez, G.R., and C. Guedes Soares, 1999: The Bivariate distribution of wave heights and periods in mixed sea states, *Journal of Offshore Mechanics and Arctic Engineering*, 121(2), 102-108.
- Roland B. Stull, 1988: An introduction to Boundary Layer Meteorology, Kluwer Academic Publishers, 666 pp.
- Sanil Kumar, V. and Ashok Kumar, 2008: Spectral characteristics of high shallow water waves, *Ocean Eng.*, 35; 900-911.
- Sanil Kumar, V. and N.M. Anand, 2004a: Variations in wave direction estimated using first and second order Fourier coefficients, *Ocean Eng.*, 31, 2105-2119.
- Sanil Kumar, V. and M.C. Deo, 2004b: Design wave estimation considering directional distribution of waves, *Ocean Eng.*, 31; 2343-2352.
- Sanil Kumar, V., K. Ashok Kumar and N.S.N. Raju, 2004c: Wave characteristics off Visakhapatnam coast during a cyclone, *Current Science*, 86, 1524-1529.
-

- Sanil Kumar, V., N.M. Anand, K.A. Kumar and S. Mandal, 2003a: Multi peakedness and groupiness of shallow water waves along Indian coast, *J. Coast. Res.*, 19, 1052-1065.
- Sanil Kumar, V., S. Mandal and K. Ashok Kumar, 2003b: Estimation of wind speed and wave height during cyclones, *Ocean Eng.*, 30, 2239-2253.
- Sanil Kumar, V., N.M. Anand, P. Chandramohan and G.N. Nayak, 2003c: Longshore sediment transport rate – measurement and estimation, central west coast of India, *Coastal Eng.*, 48, 95-109.
- Sanil Kumar, V., N.M. Anand and R. Gowthaman, 2002: Variations in nearshore processes along Nagapattinam coast, India, *Current Science*, 82, 1381- 1389.
- Sanil Kumar, V., K. Ashok Kumar and N.S.N. Raju, 2001: Nearshore Processes along Tikkavanipalem beach, Visakhapatnam, India, *J. Coast. Res.*, 17(2), 271-279.
- Sanil Kumar, V., K. Ashok Kumar and N.M. Anand, 2000: Characteristics of waves off Goa, west coast of India, *J. Coast. Res.*, 16(3), 782-789.
- Sanil Kumar, V., M.C. Deo, N.M. Anand and P. Chandramohan, 1999: Estimation of wave directional spreading in shallow water, *Ocean Eng.*, 26, 83-98.
- Satheesan, K., A. Sarkar, M. Parekh, M.R. Ramesh Kumar and Y. Kuroda, 2007: Comparison of wind data from QuikSCAT and buoys in the Indian Ocean, *International J. Rem. Sens.*, 28(10), 2375-2382.
- Seymour, R.J., 1977: Estimating wave generation on restricted fetches, *Proc. ASCE J. of Waterway Port, Coastal and Ocean Div.*, 103(2), 251-264.
- Shahul Hameed, T.S., N.P. Kurian, K.V. Thomas, K. Rajith and T.N. Prakash, 2007: Wave and current regime off the southwest coast of India, *J. Coast. Res.*, 23(5), 1167-1174.
- Shemdin, O. H., S. V. Hsiao, H. E. Carlson, K. Hasselman and K. Schulze, 1980: Mechanisms for wave transformation in finite depth water, *J. Geophys. Res.*, 5(C9), 5012-5018.
- Sheremet, A. and G. Stone, 2003: Observations of nearshore wave dissipation over muddy sea beds, *J. Geophys. Res.*, 108 (C11), 3357. doi:10.1029/2003JC00188, 21-11.
- Short, A. D., and N. L. Trenaman, 1992: Wave Climate of the Sydney Region, an Energetic and Highly Variable Ocean Wave Regime, *Aust. J. Mar. Freshwater Res.*, 43, 765-91.
- Simpson, J. E., 1994: Sea breeze and Local Wind, *Cambridge Univ. Press, New York*, 234 pp.
-

- Sindhu, B., I. Suresh, A.S. Unnikrishnan, N.V. Bhatkar, S. Neetu and G.S. Michael, 2007: Improved bathymetric data sets for the shallow water regions in the Indian Ocean, *J. Earth Sys. Sci.*, 116(3), 261-274.
- Smith, J.M. and C.L. Vincent, 2002: Application of spectral equilibrium ranges in the surf zone, *Proc. 28th Int. Conf. on Coast Eng., World Scientific*, 269-279.
- Smith, S.D., R.J. Anderson, W.A. Oost, C. Kraan, N. Maat, J. DeCosmo, K.B. Katsaros, K.L. Davidson, K. Bumke, L. Hasse and H.M. Chadwick, 1992: Sea surface wind stress and drag coefficients: the HEXOS results, *Boundary-Layer Meteorol.*, 60, 109–142.
- Snyder, R.L., 1974: A field study of wave-induced pressure fluctuations above surface gravity waves, *J. Marine Res.*, 32, 497-531.
- Snyder, R.L., F.W. Dobson, J.A. Elliot and R.B. Long, 1981: Array measurements of atmospheric pressure fluctuations above surface gravity waves, *J. Fluid Mech.*, 102, 1-59.
- Sonu, C.J., S.P. Murray, S.A. Hsu, J.N. Suhayda and E. Waddell, 1973: Sea-breeze and coastal processes, *EOS, Trans.Am.Geophys. Union*, 54, 820-833.
- Sudheesh K., P. Vethamony, M.T. Babu and S. JayaKumar, 2004: Assessment of wave modeling results with buoy and altimeter deep water waves for a summer monsoon, *Proceedings of the Third Indian National Conference on Harbour and Ocean Engineering (INCHOE - 2004). NIO, Goa (India)*, 184-192.
- Sullivan, P., J. McWilliams and C.H. Moeng, 2000: Simulation of turbulent flow over idealized water waves, *J. Fluid Mech.*, 404, 47-85.
- Sundara Raman, K.V., M.J. Varkey, P.K. Vijayarajan, V.C. John and M.X. Joseph, 1974: Waves in coastal waters off Mangalore Pt. I: distribution of wave characteristics, *Indian J. Met. Geophys.*, 25, 3&4, 453-460.
- Sverdrup, H.U. and W.H. Munk, 1947: Wind sea and swell: Theory of realtions for forecasting, *H.O. Pub. 601, US Navy Hydrographic Office, Washington, DC*, 44 pp.
- Swain, J., P.N. Ananth and C.V.K.P. Rao, 1993: Shallow water wave characteristics off Cochin during monsoon 1986, *Indian J. Mar. Sci.*, 22(4), 256-262.
-

- SWAMP Group, 1985: An inter-comparison study of wind wave prediction models. Part I, Principal results and conclusions, In: *Ocean Wave Modelling*, Plenum Press, New York, 256 pp.
- Tang, W. and W.T. Liu, 1996: Objective interpolation of scatterometer winds, *JPL publication*, 96, 19, 16 pp.
- Thornton, E.B. and R.T. Guza, 1983: Transformation of wave height distribution, *J. Geophys. Res.*, 88, 5925-5938.
- Tolman, H.L., V.M. Krasnopolsky and D.V. Chalikov, 2005: Neural network approximations for nonlinear interactions in wind wave spectra: direct mapping for wind seas in deep water, *Ocean Model.*, 8 (3), 253-278.
- Tolman, H.L., 1999: User Manual and System Documentation of WAVEWATCHIII version 1.18, *NOAA/NWS/NCEP/OMB technical note*, 166, 100 pp.
- Tolman H.L, 1998: Validation of NCEP's ocean winds for the use in wind wave models, *Global Atmos. Oc. System*, 6, 243-268.
- Torsethaugen K. and S. Haver, 2004: Simplified double peak spectral model for ocean waves, *Proceedings of ISOPE conference*, 3, 76-84.
- Vledder, G.Ph., 2001: Extension of the Discrete Interaction Approximation for computing nonlinear quadruplet wave-wave interactions in operational wave models, *4th ASCE International Symp. Ocean Waves, Meas. Anal., San Francisco, California, USA*, 540-549.
- Verhagen, H.J. and B. Savov, 1999: Sea breeze generated waves and Coastal Morphology, *Proc. Int. Medcoast conference on Wind and Waves, Antalya, Turkey*.
- Vethamony P., V.M. Aboobacker, K. Sudheesh, M.T. Babu and K. Ashok Kumar, 2009: Demarcation of inland vessels' limit off Mormugao Port region, India: a pilot study for the safety for inland vessels using wave modelling, *Nat. Hazards*, 49, 411-420.
- Vethamony, P., K. Sudheesh, S.P. Rupali, M.T. Babu, S. Jayakumar, A.K. Saran, S.K. Basu, Raj Kumar and Abhijit Sarkar, 2006: Wave modelling for the north Indian Ocean using MSMR analysed winds, *International J. Rem. Sens.*, 27, 18, 3767-3780.
- Vethamony P; K. Sudheesh, Asha Rajan, A.K. Saran, Sujit Basu, Raj Kumar and Abhijit Sarkar, 2003: Wave modelling using MSMR analysed winds, *Report No. NIO/TR/10/2003, February 2003, National Institute of Oceanography, Goa, India*.
-

- Vethamony P. and J.S. Sastry, 1986: On the characteristics of multi-peaked spectra of ocean surface waves, *J. Inst. Eng. India*, 66, 129-132.
- Vilsmeier R. and D. Hänel 1995: Adaptive solutions for unsteady laminar flows on unstructured grids, *Int. J. Numer. Meth. Fluids*, 22, 85-101.
- Violante-Carvalho, N., F.J. Ocampo-Torres and I.S. Robisonson, 2004: Buoy observations of the influence of swell on wind waves in the open ocean, *Applied Ocean Research*, 26, 49-60.
- WAMDI Group, 1988: The WAM model - A third generation ocean wave prediction model, *J. Phys. Oceanogr.*, 18, 1775-1810.
- Wang, D.W. and P.A. Hwang, 2001: An operational method for separating wind sea and swell from ocean wave spectra, *J. Atmos. Oceanic Technol.*, 18, 2052-2062.
- Wilson, B.W., 1955: Graphical Approach to the Forecasting of Waves in Moving Fetches, *U.S. Beach Erosion Board, Corps of Engineers, Dept. of the Army Techn. Memo.*, 73, 1-31.
- WISE Group, 2007: Wave modelling – the state of the art, *Progress in Oceanography*, 75, 603-674.
- WMO, 1998: Guide to wave analysis and forecasting, *World Meteorological Organization*, WMO-No. 702.
- Wright, L. D., J. D. Boon, S. C. Kim, and J. H. List, 1991: Modes of cross-shore sediment transport on the shoreface of the Middle Atlantic Bight, *Marine Geology*, 96, p. 19-51.
- Young, I.R., 1999: Wind generated ocean waves, in *Elsevier Ocean Engineering Book Series, Volume 2*, Eds. R. Bhattacharyya and M.E. McCromick, Elsevier.
- Zhukovets, A. M., 1963: The influence of bottom roughness on wave motion in a shallow body of water, *Izv. Acad. Sci. USSR Geophys. Ser.*, 10, 1561-1570.
-