Time-frequency Study of Nearshore Wind and Wave Processes

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Overview

Surface wind-generated gravity waves represent a primary driving force for dynamic processes in the oceans and lakes. As long as wind waves are ubiquitous features on the surfaces of the oceans and lakes, so too are the breaking waves appearing in the form of whitecaps woven in the midst of the wind waves. These waves induce intermittent temporally and spatially energetic mixing events at the sediment-water boundary which affect the redistribution of sediment, heat, and biogeochemical substances (such as nutrients and pollutants). While the importance of surface waves is well recognized, the study of the processes of the surface wind-generated gravity waves appears to have stagnated. At present there seems to be uncertainty as to how to proceed.

We think the there is a need to rethink the basic research approach to wind wave studies. Conventional wind waves studies such as the stationary Gaussian random process, the frequency energy spectrum, and the significant wave height are all based on conceptual frameworks devised over 4 decades ago. These approaches worked quite well for many years in practical applications but they may now be on the verge of obsolescence. Any casual observer looking at the ocean or at lake surfaces cannot possibly conclude that the processes they are seeing are “stationary” by any stretch of imagination. We see it as our challenge to address the non-stationary aspect of the ocean and lake surfaces, and to re-think the earlier approach of relying on frequency spectrum. We seek a fresh and novel new approach and ideas for surface wind wave studies.

2006 Plans

In spite of the fact that breaking waves are integral components of the wind wave system, they have been largely ignored in wave modeling development and general studies. Most of the vast amounts of the available time series data of wind waves undoubtedly contain breaking waves, nevertheless most of the conventional study of wave modeling and wave data analysis based on theses time series recordings were performed as if the breaking waves were entirely absent.

An early attempt (Liu in Annales Geophysicae, 1993) used continuous wavelet transform and the complex valued Morlet wavelet to estimate local surface acceleration and thereby detect wave breaking events through a given limiting fraction of gravitational acceleration. The approach remained idle until we meet Alex Babanin who has just the kind of breaking wave field measurements that can be used to test and substantiate our 1993 proposition. This collaborative work has been making encouraging progress. Additionally, we recently were able to acquire 5 GB of continuously recorded high quality time series wave data from western Pacific Ocean northeast of Taiwan from Prof. C. H. Tsai of National Taiwan Ocean University. We wish to continue these collaborations on breaking wave field measurements.

Accomplishments

We have been involved in wind wave studies since 1998. We have experimented with a number of different research approaches and worked with data from a variety of instrumentation deployed in Lake Michigan over this timeframe including Acoustic Doppler Current Profilers (ADCP's), waveriders, tripods equipped with: pressure sensor, current meter, thermistor, and a transmissometercurrent meters. Beginning in summer of 2003 we shifted our research effort externally available wave data. We are now studying the detection of breaking waves in the time series using Wavelet Transform in collaboration with Alex Babanin. Additionally, are collaborating with C. H. Tsai studying continuously recorded high quality time series wave data from western Pacific Ocean northeast of Taiwan.

In 2003 started by analyzing the new wave data recorded by the two bottomed-mounted, upward-looking Acoustic Doppler Current Profiler (ADCP) deployed in eastern Lake Michigan in the late autumn of 2002. The two gages were deployed at depths of 20 m and 12 m. From the middle of October to the beginning of December, over 40 days of continuous, non-intermittent wave measurements were collected. As ADCP's are well known for current measurements, wave measurement is their developed function. While the wave measurements have been quite successful, we found, at some unknown and difficult to trace frequencies the surface recording tends to become noisy. So while it provides reasonable general wave conditions we are not yet able to work with its time series data. In the later part of the year we shifted our effort to study the detection of breaking waves in the time series using Wavelet Transform in collaboration with Alex Babanin of the University of Adelaide of Australia who has breaking wave measurements from Lake George and Black Sea.

Prior to 2003 we focused on an analysis of the data collected from this instrumentation during the field seasons of 1998-2000. The effort concentrated on determining the differences between the wave parameters derived from the observations and those calculated by the GLERL-Donelan wave model. The wave model tends to under estimate the wave periods, so the bottom stresses calculated from the model results are usually less than those derived from the observations. This may be important when analyzing the results at a specific site, but for lake-wide models other sources of error are probably more important. The present sediment resuspension model is being modified to calculate the shear stress in order to model the measured results from the 18 deployments in Lake Michigan conducted over the last few years. No more sediment resuspension study will be done in this program.

Deployment of Waverider Buoy

The Waverider and two other moorings were deployed near Muskegon in the spring of 2000 to collect simultaneous surface measurements and water pressure measurements of wave heights. Analysis of the 1998-1999 data has proceeded continuously. The data show that the occurrence of waves with periods greater than 8 seconds is more frequent than previously thought, and that the present wave model does not accurately calculate the wave periods. Further analysis on applying the time-frequency wavelet spectrum analysis leads to new approach of identifying wave groups in each of the measured time series and defining relevant empirical wave group dimensional parameters. The results led to two normalized non-dimensional wave group parameters through classic dimensional analysis that provided new perspectives on wave grouping characteristics.

In 1998-99 an essentially complete time series records of wave parameters were obtained from the moorings at Michigan City, Benton Harbor, and Milwaukee. A complete time series record of water transparency was collected at the Milwaukee mooring and a partial one from Michigan City. In addition, measurements of water transparency and water temperature were obtained from 8 water intake plants.

In 1998, an instrumented NDBC buoy 45011 was deployed in 1997 in the eastern Lake Michigan nearshore area near Grand Haven, Michigan at 43.02N and 86.27W. A number of interesting wave growth episodes were recorded. Besides research use of the measured data, the availability of lake meteorological information in the nearshore area has also received appreciative and favorable comments from nearshore lake users. In 1998, however, because of funding shortage the NDBC buoy measurement had been discontinued. Instead we chose to explore making underwater pressure sensor measurements of surface waves during the winter season.

In preparation of the instrument deployment, one tripod was modified to collect time series wave data and deployed in June and July of 1998. The test development was successful and three other tripods were modified prior to deployment in October.

Five moorings were deployed in October and November of 1998. Four of these (located near Milwaukee, Muskegon, Benton Harbor, and Michigan City) are tripods equipped with a pressure sensor, a current meter, a thermistor, and a transmissometer. The 5th mooring is an acoustic current meter, located near Muskegon to provide observations of the near bottom wave orbital velocities.

Products

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