**Proposal for Wave Height Processing Project**

**EECE 6773, Fall 1997**

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## I. ABSTRACT

This project is intended to allow for the processing of wave height data in non-real time from a desktop terminal, with some focus on the possible eventuality of incorporating a C algorithm into a data processing gateway for near real-time data. The data come from various laser wave height sensors which are deployed in coastal regions on land-based towers. It is necessary to smooth the data and determine wave period, wavelength, and frequency. In addition to the above, the project will attempt to determine whether it is possible to recognize breaking wave phenomena from the wave height data.

## II. INTRODUCTION

A. Background

This project is based upon the work of the National Data Buoy Center (NDBC), the coastal and marine data gathering and dissemination arm of the National Weather Service (NWS) / National Oceanographic and Atmospheric Administration (NOAA). Various laser wave height sensors have been tested and deployed over the years in the hopes of arriving at an elegant solution to the problem of determining wave height from a coastal land based platform. Currently, a test is being conducted at the U.S. Army Corps of Engineersí pier in Duck, NC, between the two best laser wave height sensors and the Corps of Engineersí pressure-based Baylor wave height sensor (which is considered the standard of measurement). This data has been sampled at rates varying from 1.706 to 2 hZ. For the purposes of this project, only the 2 hZ data will be used.

Data returning from the laser wave height sensors are relative measurements and require division by sensor-specific constants followed by subtraction of the data mean to convert the wave heights to a measurement relative to sea level.

Data parameters useful to NWS and its forecasting offices are in the form of periodicity, maximum heights, and wavelengths. Wave spectra are useful for research interests, both government and private, but are typically not provided for forecasting.

B. Theory

**Notation:**

| | |
|---|---|
| a | m<br>wave amplitude, |
| c | over scelerity, |
| g | over s^2acceleration, |
| h | water depth, |
| k | over mnumber (2 / ), |
| t | , |

| | |
|---|---|
| T | period, |
| u | velocity component in the x direction |
| | |
| | over spotential, |

period and wavelength are simple parameters to determine and are typically provided from remote stations as a synoptic (hourly) message to forecast offices. Therefore when dealing with time series data, it is convenient to determine them in hourly samples.
waves are more difficult to determine than period and wavelength. The utility of knowing if breaking conditions exist is in providing the mariner a forecast with an idea of the ìroughnessî of a sea. A breaking wave is naturally going to be a steeper, and therefore a much more rough, wave to traverse.
determining whether a wave is breaking or not, an understanding of wave theory must be arrived at first. A quick summary, with respect to determining breaking waves in a shallow water environment, is as follows:

In short, breaking conditions exist when the horizontal particle velocity (u) at the crest of the wave equals or exceeds the wave celerity (c). Wave celerity is defined as:

$$c=\frac{dx}{dt}=\frac{\omega}{k}$$

is the circular frequency of the wave and is defined as:

$$\omega=[kg\tanh(kh)]^{\frac{1}{2}}$$

Therefore, the combination of these two equations results in a simplified form for c:

$$c=\left[\frac{g}{k}\tanh(kh)\right]^{\frac{1}{2}}$$

Horizontal particle velocity (u) is the next component of interest in determining if a wave is breaking. Simply, it is defined as:

$$u=\frac{d\phi}{dx}=\frac{agk}{\omega}\frac{\cosh(kz+kh)}{\cosh(kh)}\cos(kx-\omega t)$$

In shallow water (0<h/  0.05), the hyperbolic functions are approximated as sinh(kh) tanh(kh) kh, and cosh(kh) 1. Therefore, wave celerity and the particle velocity simplify to:

$$c=(gh)^{\frac{1}{2}}$$

and

$$u=\frac{agk}{\omega}\cos(kx-\omega t)=\frac{ag}{(gh)^{\frac{1}{2}}}\cos(kx-\omega t)$$

. Setting u equal to c gives:

$$\frac{ag}{gh^{\frac{1}{2}}}\cos(kx-\omega t)=(gh)^{\frac{1}{2}}$$

and

$$\cos(kx-\omega t)=\frac{h}{a}$$

Since cos(kx- t) = 1 at the crest of the wave, when h = a, the wave should be breaking. This is an easy way to determine whether gravity-induced breaking is occuring, but is insufficient to account for external forces, such as wind, which provide a shear action that can accelerate particle motion until it equals or exceeds celerity and thus results in breaking.

## III. PROJECT METHODOLOGY:

Clearly, gravity-induced breaking waves can be located by comparing wave amplitude with water depth. It is hoped that wind induced breaking waves can be located from comparison of the theoretical wave profile, h=a*cos(kx- t), with the actual wave profile.  Since wind induced breaking should be present in the experimental data but not in the first order theoretical profile, areas of discontinuity can be inspected in the frequency domain by using a wavelet or fourier transform (wavelet transforms seem to provide better peak information, which may be more useful to this type of analysis).  Hopefully, a frequency spectra can be identifies which would indicate with some reasonable degree of uncertainty that breaking is taking place.

Experiments to test these theories are currently being conducted in Mathcad and Matlab.  As this is a very unexplored area, it is uncertain at this time as to whether breaking wave detection will be successful.  At the minimum, however, time series analysis, determination of basic wave properties, and intercomparison of the two laser sensors and the pressure sensor will provide value to NDBC and NWS forecasting.