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Determining wave direction using curvature parameters

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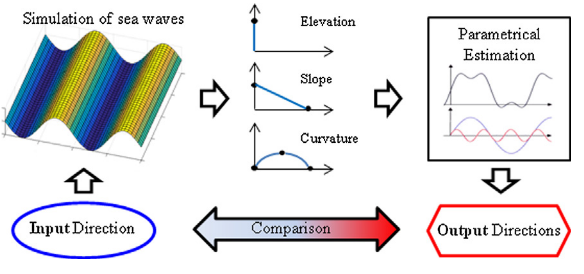
GRAPHICAL ABSTRACT



ABSTRACT

The curvature of the sea wave was tested as a parameter for estimating wave direction in the search for better results in estimates of wave direction in shallow waters, where waves of different sizes, frequencies and directions intersect and it is difficult to characterize. We used numerical simulations of the sea surface to determine wave direction calculated from the curvature of the waves. Using 1000 numerical simulations, the statistical variability of the wave direction was determined. The results showed good performance by the curvature parameter for estimating wave direction. Accuracy in the estimates was improved by including wave slope parameters in addition to curvature. The results indicate that the curvature is a promising technique to estimate wave directions.

- In this study, the accuracy and precision of curvature parameters to measure wave direction are analyzed using a model simulation that generates 1000 wave records with directional resolution.
- The model allows the simultaneous simulation of time-series wave properties such as sea surface elevation, slope and curvature and they were used to analyze the variability of estimated directions.

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- The simultaneous acquisition of slope and curvature parameters can contribute to estimates wave direction, thus increasing accuracy and precision of results.

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Method details

Numerical simulation

In this study, the method of wave simulation recording proposed by Goda [1], with directional resolution and based on trigonometric functions, was used. The method allows the simultaneous simulation of wave properties such as elevation (η), slope (η_x, η_y) and curvature (η_{xx}, η_{yy}) of the sea surface level (Eqs. (1)–(5), respectively)

$$\eta(x,y,t)=\sum_{m=1}^{M}\sum_{N=1}^{N}a_{m,n}\cos[k_m x\cos\theta_n+k_m y\sin\theta_n-2\pi f_m t+\varepsilon_{m,n}] \quad (1)$$

$$\eta_x(x,y,t)=\sum_{m=1}^{M}\sum_{N=1}^{N}a_{m,n}[-k\cos\theta_n]\sin[k_m x\cos\theta_n+k_m y\sin\theta_n-2\pi f_m t+\varepsilon_{m,n}] \quad (2)$$

$$\eta_y(x,y,t)=\sum_{m=1}^{M}\sum_{N=1}^{N}a_{m,n}[-k\sin\theta_n]\sin[k_m x\cos\theta_n+k_m y\sin\theta_n-2\pi f_m t+\varepsilon_{m,n}] \quad (3)$$

$$\eta_{xx}(x,y,t)=\sum_{m=1}^{M}\sum_{N=1}^{N}a_{m,n}[-k\cos\theta_n]^2\cos[k_m x\cos\theta_n+k_m y\sin\theta_n-2\pi f_m t+\varepsilon_{m,n}] \quad (4)$$

$$\eta_{yy}(x,y,t)=\sum_{m=1}^{M}\sum_{N=1}^{N}a_{m,n}[-k\sin\theta_n]^2\cos[k_m x\cos\theta_n+k_m y\sin\theta_n-2\pi f_m t+\varepsilon_{m,n}] \quad (5)$$

where θ is the wave direction, f is the frequency and ε phase. M and N are respectively the numbers of frequency and direction components. The random phase term ($\varepsilon_{m,n}$) has to be distributed between 0 and 2π. The wave number (k) has to satisfy the dispersion relation:

$$4\pi^2 f_m^2=gk\tan h(kh) \quad (6)$$

where g is the gravity acceleration and h is the local deep.

The term $a_{m,n}$ (Eqs. (1)–(5)) is the amplitude of the wave with m frequency and n direction and it is calculated by directional spectrum:

$$a_{m,n}=2\sqrt{S(f_m,\theta_n)\Delta f_m\Delta\theta_n} \quad (7)$$

The sampling rate ($\Delta t=t_{i+1}-t_i$) is usually constant in a simulated record wave. Thus the trigonometric functions can be obtained with $t=t_i$, using trigonometric relationships additions:

$$\cos(2\pi f_m t_{i+1})=\cos(2\pi f_m t_i)\cos(2\pi f_m\Delta t)-\sin(2\pi f_m t_i)\sin(2\pi f_m\Delta t) \quad (8)$$

$$\sin(2\pi f_m t_{i+1})=\sin(2\pi f_m t_i)\cos(2\pi f_m\Delta t)+\cos(2\pi f_m t_i)\sin(2\pi f_m\Delta t) \quad (9)$$