Automatic calibration of the parameters and inputs of a coastal wave model with an evolutionary Bayesian method.

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INTRODUCTION

Long-term and good quality wave data series are required for any coastal engineering project. Reliable coastal wave data is only available in some countries, where long-term wave measurements are available and have been used for calibration and validation of high-quality and high-resolution wave hindcasts. For most regions of the world, typically in developing countries, only global reanalysis wave data is available (e.g. ERA-Interim), usually in combination with a short-term (i.e. several month) in-situ measured series obtained for a particular project.

The spatial resolution of global wave reanalysis is not enough for coastal applications; moreover, nearshore wave transformation processes are not properly accounted for. Therefore, wave data from global reanalysis must be transferred to the coast in a proper way before being used in coastal projects (i.e. data must be downscaled). Some methodologies have been developed for efficiently downscale wave data (e.g. Camus et al. 2011) that are based on the use of third generation coastal wave models (e.g. SWAN; Booij et al. 1999).

Even though wave reanalysis data are much reliable in an offshore location, inaccuracies are still expected. Particularly if the whole spectrum is considered and not only its main parameters. Beyond a proper performance of the coastal wave model, these errors will lead to model output errors in the coast. Therefore an input uncertainty treatment is also necessary to improve model coastal predictions.

While the use of third generation wave models with off-shore global wave reanalysis data as boundary condition, is widespread in coastal applications, there is no consensus about how these models should be calibrated and how to consider inaccuracies of the model inputs (waves in domain boundary and wind fields). To the best of our knowledge, these issues are addressed with ad hoc approaches developed for each project.

In this paper, we propose the use of Bayesian methodologies to deal with the calibration of the parameters of a third generation wave model and parameters defined to correct input data errors. Then, the method is applied in a study case in the Uruguayan Atlantic coast where a few months of wave spectrum measurements are available.

METHODOLOGY

In the Bayesian framework, model parameters are treated as probabilistic variables, and Markov Chain Monte Carlo (MCMC) algorithms are used to generate a stochastic simulation that successively visits solutions in the parameter space. Bayesian inference is used at each step, for selecting a new set of parameters on the basis of the results obtained in the previous steps and on the basis of available observations. Finally, the joint probability distribution of the parameters is estimated from the sample generated after the MCMC method has converged to a stationary situation.

One of these methods is the SCEM-UA algorithm, proposed by Vrugt et al. (2003), whose use is widespread for the calibration and uncertainty quantification of hydrological models. The method combines aspects of evolutionary algorithms, controlled random search and complex shuffling in order to improve convergence rate and avoid getting stuck at local optima. Finally, a set of parameters that minimize the target function is obtained, with an estimation of its posterior distribution. In order to make the most of the observed spectra, a measurement of the distance between modeled and observed spectrum was defined and used as target function.

Defining a set of correction parameters of input data, and join them with model parameters for calibration, was the way chosen to deal with input and model parameters uncertainty together. Moreover, regarding that error sources in reanalysis data may differ between wave systems (e.g. Sea waves and Swells generated in different zones), use different sets of correction parameters for different wave systems is proposed.

APPLICATION

SCEM-UA is applied in a study case in the Uruguayan Atlantic coast, where a few months of wave measurements are available. The method is used for calibration and uncertainty assessment of SWAN wave model parameters, and ERA-Interim wind and wave spectra correction parameters.

The target function is an error measurement of each bin of spectra, estimated assuming that errors are independent and identically distributed with a zero mean normal distribution. For application of SCEM-UA eight complexes with ten elements per complex are used, allowing for 500 evolutive steps with mixing population every three steps. At the end, there are 2500 sample points available to estimate the posteriori distribution.

A set of eighteen parameters were calibrated. Eight of them are parameters of the numerical model while the others ten are correction parameters of input data, one affecting the wind speed and the others nine affecting the offshore wave spectra.

Calibrated model parameters correspond to the parameterizations of the dissipative processes involved in the source term of the wave action balance equation. Three of them correspond to whitecapping

parametrization, four to depth-inducing wave-breaking and one to bottom friction.

Three wave systems were considered: Sea, Swell coming from the south and Swell coming from the east. Each wave system is affected by three parameters that attempt to correct bias in periods, bias in directions and deficiencies in energy density.

Figure 1 shows the evolution of the Markov Chain for three of these parameters (Direction BIAS of south Swell, dimensionless whitecapping dissipation coefficient and roughness length scale of the bottom). Figure 2 shows a comparison between the Integral Spectral Errors (ISE) obtained with different simulations: S1) input data without corrections and SWAN default parameters (default simulation), S2)

input data without corrections and best fit model

parameters, S3) best fit correction input parameters and default model parameters and S4) best fit input correction and model parameters. ISE is defined as the square root of the integral of the differences

between a modeled and observed spectrum in absolute value.

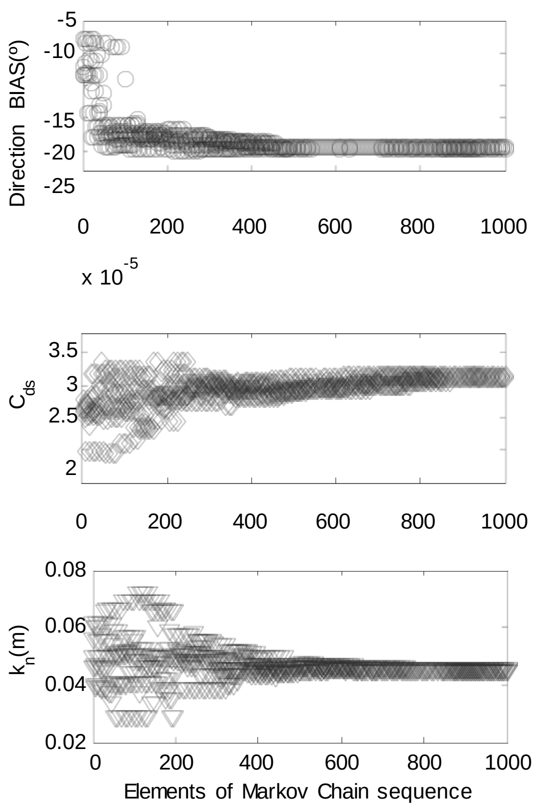


Figure 1 – Markov Chain evolution of Direction BIAS of south Swell (upper), dimensionless coefficient for determining the rate of whitecapping dissipation (middle) and roughness length scale of bottom

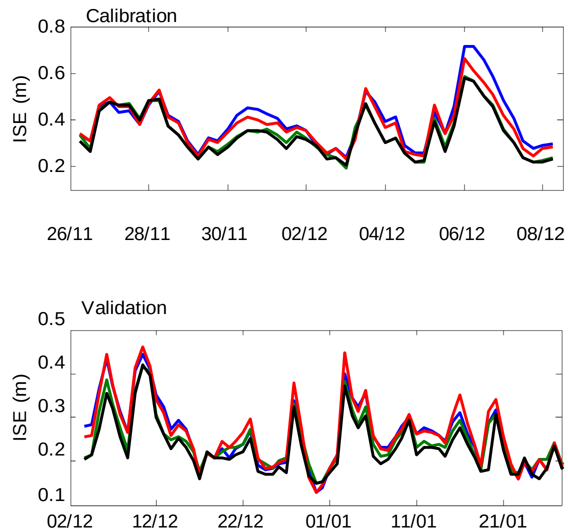
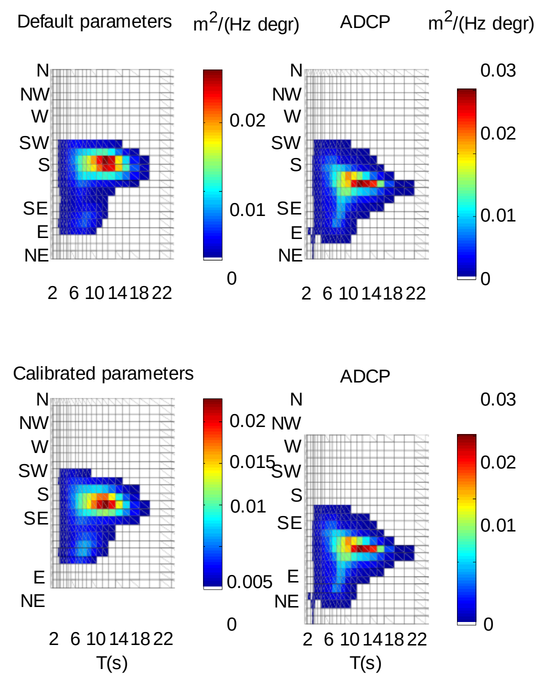


Figure 2 – ISE time series . S1 (blue), S2 (red), S3 (green) and S4 (black). Calibration period (upper) and validation period (lower).

Finally, Figure 3 shows the average spectra corresponding to observations (ADCP), default simulation, and best fit parameters simulation.



dissipation (lower).

Figure 3 – Average spectra corresponding to observations (ADCP), default simulation (S1) and best fit model and input correction parameters (S4) during the calibration period.

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Modelling the impact of fast wind changes on wind waves with the generalized kinetic equation

At present, all wind wave modelling is based on the numerical integration of the Hasselmann kinetic equation for the energy spectra of wave fields. This equation is derived under the quasi-stationarity assumption and, strictly speaking, is not applicable to situations with rapid changes of wind. On the other hand, the current approach to wave modelling is limited to spectral evolution and does allow to predict wave statistics beyond spectra, e.g. the probability density function (p.d.f.) of surface elevations, which is essential for applications. We present anew statistical model of wind waves, which allows for rapid wind changes and provides, along with the spectra, the information on the higher statistical moments of awave field, arising from wave interactions. This information, along with the higher moments due to bound harmonics, obtainable from the spectra, allows to predict the p.d.f. of surface elevations. The new statistical model is used to model the impact of an instant increase of wind, or arapid short-lived increase (squall) on wave spectra and the p.d.f. We show that asquall results in the increased probability of extreme wave events (freak waves).

The Optical Wavemeter

Optical techniques present a promising approach for the development of a method for measuring the state of the sea. This is a result of recent advances in photographic cameras and camcorders, as well as by advances in numerical image processing.
In principle, the height of the waves can be evaluated by the geometrical optics, while the periods of waves by Fourier techniques. There is also a large number of well-developed mathematical tools ready to be applied to this problem.
The optical sea state evaluation offers the advantage of being a remote measurement and its most promising aspect comes from the fact that a client-server application structure can be created to collect and distribute information cooperatively about the sea state all over the oceans using the web.

Wind-Generated Waves - Interface Between the Ocean and Atmosphere

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It is rapidly becoming clear that many large-scale geophysical processes are essentially coupled with the surface waves, and those include weather, tropical cyclones, climate and other phenomena in the atmosphere, at air/sea and sea/land interface, and many issues of the upper-ocean mixing below the surface. Besides, the wind-wave climate itself experiences large-scale trends and fluctuations, and can serve as an indicator for changes in the weather climate. In the presentation, we will discuss wave influences at scales from oceanic turbulence to climate, on the atmospheric and oceanic sides.

Wave mode conversion and reflection in the interaction of linear water waves with variable bathymetry

Karl Peter Burr

Water waves interaction with an one-dimensional variable bottom topography is considered. We assume bottom topographies slowly varying with respect to the incident wave field with small wave slope for depths such that the product between the typical wavenumber and depth is of order one. Under such assumptions, powerfull approximations are available, like geometrical optics based theories, mil-slope equations and the parabolic approximation.

Methods based on geometrical optics are wave refraction theories and are not able to predict wave reflection due to botton non-uniformities, unless a local analysis is performed at the regions where the geometrical optics approximation breaks down, which are called caustics for two-dimensional topographies and turning points for one-dimentional topographies. Considerable wave reflection is obtained through a local analysis of the wave propagation along caustics. For linear surface waves interaction with one-dimensional topographies, turning points appear only if we consider the space coordinate as a complex variable.

We apply geometric optics ideas to the interaction of linear surface gravity waves with a non-uniform bottom, and construct a high order asymptotic solution for the wave interaction problem. This asymptotic theory breaks down at turning points in the complex plane, which are the branch points of the uniform bottom dispersion relation, assumed locally valid. To continue the asymptotic solution through the turning points, we perform a local analysis of the wave propagation problem. This allow us to incorporate wave reflection and wave mode conversion to the refraction model. By wave mode conversion, we mean the coupling between the two propagationg wave modes and the evanescent wave modes that appear due to the bottom variation.

Wave climate variability and trends in front of Santa Catarina island, south of Brazil, over six decades (1948-2008) and its relationship with different climate indices

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This paper describes the interannual variability and trends of the wave climate in front of Santa Catarina island, using 60-years reanalysis data, and determine the principle drivers of the variability. A 1948-2008 (every hour) hindcast series obtained by the Environmental Hydraulics Institute "IH-Cantabria" from University of Cantabria inserted in the Coastal Management System "SMC – Brasil" was used as database. The wave climate analyzes were given in two ways: (1) temporal average values (annual and seasonal) and; (2) extreme events values (Hs_{12}). In an attempt to justify the variability of wave climate a correlation's analysis between Hs, Hs_{12}, Tp, energy flux (EF) and directional energy flux (DEF) and 8 climate indices data (AO, AAO , MEI, NAO, OCI, PDO, PNA, SOI) was also held. The following results were found: Hs mean of 1.76m, peak period (Tp) mean of 8.32s and directional energy flux mean of 138°. Seasonally, higher wave heights were found in winter (average of 1.87m) with maximum Hs reaching 5.2m and predominant direction of S-SE (144°). Tendencialy, the results of Hs and Tp have risen gradually over the years, observing a total increase of 16cm and 0.5s for Hs and Tp respectively. Likewise, the directional energy flux that reach Santa Catarina coast has changed, rotating clockwise a total of 9,35°. By linking these parameters with climate indices, a correlation with 5 of the 8 indices was found, where only PDO found correlation with all the wave climate variables analyzed. Still correlating only events of El Niño and / or La Niña with the dataset, it is possible to infer that El Niño events have inverse correlation with DEF, that is, the warmer seawater, lower the direction values (over east) and also lower the EF (with not that strong correlation, maximum -0.54). The opposite is true in La Niña years. This reduction in Hs in periods of El Niño may be associated with the blocking of cold fronts and consequently southern quadrant waves (higher heights) for the South Atlantic High.

Brazil Current Instability Waves Off Southeast Brazil

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The Brazil Current (BC) is the weakest and shallowest of all subtropical western boundary currents of the world ocean as it flows over the Brazilian continental margin. It reaches only 500 m deep and its characteristic transport is about 6 Sv off Southeast Brazil. In the 21S-25S latitude range, it has been reported frequent large meandering and eddy shedding in the Cape São Tomé (22S) and Cape Frio (23S) surroundings. The associated BC-superposed vorticity waves are therefore unstable. We then present here a suite of linear instability analyses on such waves that spans from classical quasi-geostrophy to primitive equation modeling. In particular, we discuss and use the contour dynamic technique to investigate the quasi-stationary oceanward-growing cyclonic meanders off the above-referred capes. Observational evidence and validation of the obtained theoretical results are sought and presented.

WAVE AND WIND CHARACTERIZATION NEAR AÇÚ PORT REGION- RIO DE JANEIRO - BRAZIL

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Abstract

This work presents a sea state characterization for deep and intermediate waters, during 2013, near the Industrial Complex of Açú Port. Information about sea conditions in this area is extremely important due to vessel operation, navigation conditions or investigations about impacts from port constructions in the local coastal region. For deep and intermediate waters characterization wave and winds data are used, beyond that numerical modeling is also considered. Waves data were collected using an Acoustic Doppler Current Profiler (ADCP) in a depth of 28 m depth and 48 km away from the north coast of Rio de Janeiro, at coordinates 21.90 ° W and 40,6072º S. Wind data were collected using a meteorological station installed on the Terminal 2 Access Bridge of Açú Port, at coordinates -40.999 ° W and 21.814 ° S. The data recordings were made on January and February, and between April and September 2013. To verify monthly variation during 2013 were analized waves statistical parameters from WAVEWATCHIII simulation (significant wave height (Hs), peak period (Tp) and peak direction (DP), which characterize the local sea conditions). As initial and boundary conditions were used wind and ice high resolution reanalysis products Climate Forecast System (CFS) database, from the National Centers for Environmental Prediction (NCEP) (SAHA; et al, 2011), . For grids configuration during waves simulation were implemented a grid with 1° resolution that covers the Atlantic Ocean and part of the Pacific Ocean and has a resolution of 1 °; and a second grid covering the South Atlantic with a spatial resolution of 0.25 °. Through coherence indices analyses, was observed that Hs and Tp values are strongly correlated, whereas Dp has moderate correlation. Using model results, it is possible to construct time series of wave parameters and verify the seasonal variation of them during 2013.

Key-words: wave modelling, wave ADCP, navigation conditions.

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ABSTRACT

SAMPLING ERROR IN THE ESTIMATION OF SIGNIFICANT WAVE HEIGHT EXTREME VALUES FROM BUOY DATA

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The evaluation of extreme wave significant height and of their dependence on return period is an all-important step in the design and the risk assessment of coastal and offshore structures, ships, and ship routing. The basic data for this kind of studies are generally provided by in-situ wave meters, satellite altimeters, meteo-wave models, or by a combination of all three. All these sources are affected by errors in various ways and to different extents: the limitations of models and of satellite altimeters as a source of historical data are obvious and are discussed elsewhere. In situ wave-metres, if available, are normally the best choice but –as it will be shown in the paper– when used to determine extreme values they are affected by a strong bias. A bias in the determination of extreme values is indeed present in all sources of data whenever the sampling of the relevant parameters (as for instance the significant wave heights) is carried out with a too long time interval as compared with the inherent time constant of the phenomenon (in our case the storm evolution)

As the sampling interval of the significant wave height measurements increases, the probability that extreme values may be missed increases as well. Since past historical data records often only provide data sampled at 3 or 6 hour intervals, the estimation of high return time wave heights can be seriously biased, as compared with high density data – half an hour or less. The paper will indicate a method to estimate such a bias, and to compute significant wave heights as a function of the return period, with a given non-exceedance probability.

This result may help make use of historical wave meters data, which were often collected with a low time resolution, and may also provide a tool to improve the application of wave generation models in estimating extreme values.

Unmasking the Rogue – The Making of the Andrea Wave

Mark Donelan

Abstract

Capturing a rogue wave with a recording device is unusual, but a few have been measured from oil platforms in the North Sea. Of these the Andrea wave (Magnusson and Donelan, 2013) is the most roguish, having a crest height to significant height ratio of 1.63: crest height 14.97 m; significant height 9.18 m. The Andrea wave is unique in that it was recorded by an array of laser range finders, allowing frequency, wavenumber directional analysis. The nonstationary analysis tool, the Wavelet Directional Method (WDM, Donelan, Drennan, & Magnusson; 1996), is used to reveal the propagation of groups in various frequency bands from different directions. A rogue wave occurs when several groups around the peak frequency come together with their crests in phase, providing constructive interference. Propagation of these groups with their observed wavenumbers reveals that Andrea hit its peak downwave of the laser array. The maximum possible rogue is obtained by combining the groups shifted in time so that all groups arrive at a point with their maximum crests in phase. This process can be done for any directionally resolved wave record, yielding a constant maximum crest height to significant height ratio. The design and operational consequence of this ratio is obvious and completely replaces the rather curious concept of a 100 year wave, which could occur tomorrow.

The simulaPon of fluids is an imporant tool in computer graphics, e.g., for
generaPng realisPc animaPons of water flow synthePcally rendered as a video.
This work aims at the reconstrucPng a model of an actual real fluid interface and its moPon
from that observed by one or more real video cameras. The obtained model can then be used for simulaPng the moPon of
ocean surface paJerns as observed in the real world. Moreover, this
simulaPon can be matched to video at new Pme instants in order to predict and
track the actual condiPons of the observed fluid. We present and discuss a few recent advances
in a such a larger effort to perform the inverse problem of generaPng graphics
fluid simulaPons from real-world imagery.

The image-based fluid modeling approach proposed in this
work is part of a larger effort with applicaPons to the online monitoring of
ocean condiPons for aiding offshore processes of oil drilling, among others.
Our contribuPon starts with a broad discussion of the engineering, mathemaPcal and
computaPonal issues around the design of such a system in real contexts,
from the perspecPve of our experience with photogrammetry, ocean engineering,
and geometric computer vision. AYer discussing a possible system design, we then focus on
specific aspects such as mulPple view stereo and performing robust,
self-calibraPng geometric measurements from images.
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Local dimensionality of ocean waves

We employ a generalised concept of esemble dimension to the dynamics of ocean waves, aiming at establishing the regions of the globe´s oceans which have lower/higher local dimensionality. Bred vectors of surface winds, obtained by the CPTEC/INPE-AGCM atmospheric ensemble system, are employed and used as forcings of multiple runs of the WAM model.
Ensemble members of an ocean wave ensemble prediction system is then used to compute the E dimension of the ocean waves. The numerical results show the local low dimensionality of the significant wave height, swell height and peak period as well as the ensemble spread of the wind fields used in the experiment. Implications of the results for assimilation schemes will be discussed.

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Fundamental Model Tests in the Wave and Current Channels in LOC-COPPE/UFRJ

By Antonio Carlos Fernandes

LOC-COPPE/UFRJ

The LOC-COPPE/UFRJ, The Laboratório de Ondas e Correntes (Laboratory of Waves and Currents) has two main facilities: The Wave Channel and the Current Chanel.

The Wave Channel has two wave makers being one proposed to be used as a dynamic wave absorber. This channel has been used in several applications. Among them, the presentation will describe the roll behavior of a floating platform section. This kind of test has been used to understand the interaction of the free surface with the vortices generated by the section where a large bilge keel is installed. PIV (Particle Image Velocimeter) has been used for this. The VSIV (vortex self-induced vibration) is another research worth to be mentioned.

The Current Channel has been used to study, again among others, the use of interceptors in planning boats. It has been used to prove the effectiveness of a new turbine the VAACT (Vertical Axis-Autorotation Current Turbine).

Several applications have been favorably compared with CFD (Computer Fluid Dynamics) codes.

WAVE REFLECTION AND SWASH MOTIONS ON A LOW-SLOPING BEACH

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Keyword
Swash, wave energy fluxes, wave reflection, infragravity.

1. Introduction

Energy spectra in wave-driven shoreline oscillations (swash) can be dominated by low-frequency infragravity (*IG*) waves (0.004–0.05 Hz), whose frequencies are below the sea-swell frequency range (0.05–0.4 Hz) that normally dominates the offshore wave spectrum (e.g., Guza and Thornton, 1982). These waves have relatively low steepness and are normally observed to be forced and reflected in very shallow water. Here we present field observations of swash and waves in very shallow water on a low-sloping dissipative beach where *IG* dissipation was high and modulated the swash energy.

2. Methods

The dataset analyzed here was obtained at Ngarunui beach, a low-sloping (tanβ~0.01) dissipative beach located in Raglan, New Zealand. Offshore wave conditions during the experiment were mild (significant wave height in 17 m water depth and peak wave period around 1.2 m and 11 s), and the (spring) tidal range of 3.1 m yielded an intertidal region with cross-shore scale of about 300 m.

Simultaneous time series of pressure and velocity were recorded using three ADVs in the intertidal region and an ADCP offshore in about 17 m water depth. The ADVs collected 20-min-long time series every half-an- hour, over three partial tidal cycles (when the sensors were submerged). The measurements spanned cross-shore distances from the shoreline from 50 m (h = 0.55 m, where h is the mean local water depth) to 184 m (h = 2.60 m). The ADCP collected hourly, 20-min-long, simultaneous time series of near-bottom pressure and near-surface velocity. In addition, swash motions were measured continuously during daylight hours along the two alongshore locations where the ADVs were deployed on the beach using a video technique (see Aagaard et al., 1989).

Shoreward and seaward propagating components of the linear energy fluxes were estimated from the time series of pressure and velocity from each ADV using the method described by Sheremet et al. (2002). Bulk *IG* reflection coefficient R^2 was calculated for defined *IG* frequency bands as the ratio between the (frequency- integrated) seaward and shoreward fluxes components. Swash spectra were calculated from time series of vertical runup elevation.

3. Results and conclusion

The intertidal beach morphology was concave upward shoreward of the location of the ADVs (Fig. 1a). The local slope tanβ increased by a factor of 4 from 0.008 at the lowermost to 0.032 at the uppermost location where swash was measured and no sandbar was observed over the intertidal region. The Iribarren number ξ_0

$$\xi_0 = \frac{\tan\beta}{\left(H_0/L_0\right)^{1/2}}, \tag{1}$$

calculated using the local slope at the mean swash location tanβ and linear wave theory to estimate deep water wavelength L_0 was characteristic of highly dissipative conditions, with small values changing by a factor of 4 (following tanβ) from low tide (ξ_0 ~ 0.1) to high tide (ξ_0 ~ 0.4).

Swash motions were highly dominated by *IG* frequencies (with peaks between 0.01 and 0.02 Hz), which accounted on average for 96% of the runup variance. Similar to the ξ_0, runup was strongly modulated by the tide with significant runup height *Rs* increasing by up to a factor of 3–4 from low to high tide over the concave intertidal slope (Fig. 1a).

The wave reflection coefficient R^2 for partitioned *IG* bands increased with decreasing frequency and increasing ξ_0 but was always smaller that one (Fig. 1b), indicating *IG* dissipation. The two highest-frequency bands (0.025–0.035 Hz and 0.035–0.05 Hz) appeared to be saturated for ξ_0<0.3 (Fig. 1b), in agreement with

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observations of Ruessink et al. (1998) under high-energy conditions. The reflection coefficient for the three *IG*
partitions was well parameterized by a normalized bed slope parameter β_H (Battjes et al., 2004)

$$\beta_H = \frac{\beta}{\omega}\sqrt{\frac{g}{H(\omega)}}\,, \qquad (2)$$

where ω is the radian wave frequency, *g* is the acceleration due to gravity and $H(\omega)$ is the height of waves with radian frequency ω (see Fig. 1c). Overall, our observations show that strong *IG* dissipation can occur under mild offshore wave conditions if the beach slope near the shoreline is sufficiently gentle, and suggest that the degree of *IG* dissipation can modulate runup energy under these conditions.

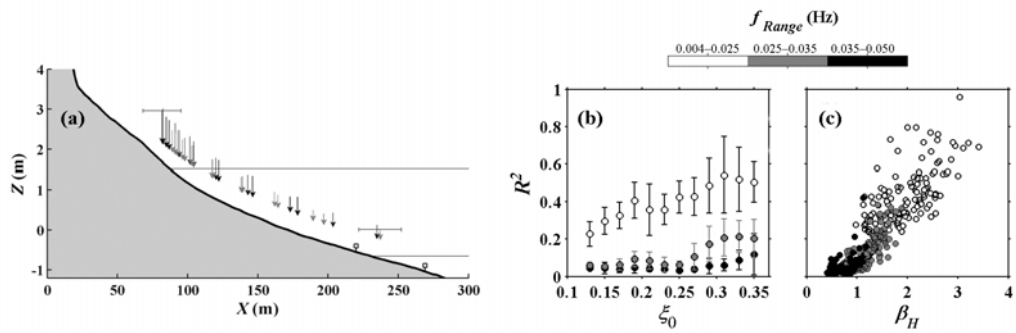

Figure 1. (a) Beach profile averaged over the region where the three ADVs (white squares) were deployed. Horizontal lines show the shallowest and deepest mean water levels at which waves were measured in the surfzone. Vertical arrows point to the mean position of each swash run with their length corresponding to the respective value of *Rs*. Horizontal bars at the top of lowermost and uppermost arrows highlight the typical cross-shore extension of the swash for these time series. (b–c) Reflection coefficient R^2 of partitioned *IG* bands, shown by the colors, as a function of (b) Iribarren number ξ_0 and (c) normalized bed slope parameter β_H. Data for each frequency band have been grouped in panel (b) by 0.02 ξ_0 intervals, with the circles and bars representing the average and standard deviation associated with each group.

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The European offshore wind and wave energy resource analysis – Combined exploitation - Analysis of extremes

George Kallos

with contribution from

G. Galanis, C. Kalogeri, P. Patlakas, C. Stathopoulos, A. Liakatas

Abstract

The renewable energy production in Europe covers already a considerable amount and the target is to cover 20% of its needs until 2020. Offshore energy production has already a considerable portion with the aim to cover the 4% of the electrical demand until 2020. The near-shore installed capacity is already at condensed levels. The demand for expansion requires new installations in areas with depths reaching even the 500 m. The technological challenges faced in such cases are considerable while the exploitation of only one resource, the wind, is not always economically feasible. Therefore, the combined exploitation of more than one resource is necessary. The widely available resource, except of the wind, is the waves. Deep offshore technology is at an early stage of development facing great challenges. In order to optimally harvest the power from winds and waves there is need for a detailed resource characterization taking into consideration the diversity of the two resources. The lack of dense and long-operating observational network makes the use of numerical models and remote sensing platforms a must. The use of numerical wave modeling systems for monitoring and estimating renewable energy resources is receiving increased attention as a result of the novel policies adopted in the energy market. In this framework, the MARINA Platform, bridging leading European research groups and companies activated on the exploitation of renewable energy resources, provides novel products and methodologies for the estimation and exploitation of the wave power potential and the evaluation of multi-purpose platforms for marine renewable energy. One of the main outcomes of the above project is a ten- year (2001-2010) data base of high resolution atmospheric and wave parameters that are used for monitoring the distribution of wind and wave power potential over different areas of the European coastline. Ssatellite measurements are of significant importance in this context since they can be utilized for the optimization and evaluation of model results. This database has been used to analyse extreme conditions (high and low) and spot areas for combined use of wind and wave power generation in deep offshore locations. Model evaluation was a major task of the MARINA project where buoy and SAR observations were utilized. The evaluation was focusing mainly on the behaviour of the wave parameters that directly or indirectly affect the wave energy potential as well as the stochastic distribution of the latter.

Internal Solitary Waves off the Amazon River Mouth: coherence crestlengths and generation mechanism

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Abstract

A comprehensive dataset of Synthetic Aperture Radar (SAR) images (*RADARSAT, ERS, ENVISAT, TerraSAR-X*) is used, for the first time, to investigate the full 2-D structure of internal solitary waves (ISWs) over the continental shelf off the Amazon River mouth (ARM) influenced by the North Brazil Current (NBC) along the northern coast of South America. Although three different groups of ISWs are identified according to their direction of propagation and possible generation mechanisms, our focus in this paper will be on those waves which propagate southeastward, i.e. over the continental shelf in the opposite direction to the NBC flow. Unambiguously, the primary region of ISW activity is the mid- and outer-shelf regions approximately between 1^o-6^{o}N and 51^o-47^{o}W. ISW packets emerging from this area are regularly observed to reach crestlengths from a few kilometers up to 35 km, although the majority of observations is characterized by crestlengths < 13 km with a mean value of ~ 8 km for all the waves observed. The inter-packet separation is ~ 5 km with the distance between consecutive crests within a given packet of ~ 0.5 km. The generation mechanism of the ISWs does not seem to be solely related with the semidiurnal tides, but appears instead to result from a combination between the NBC, tidal currents and the localized bottom topographic features around to the 80-m isobath. Solutions of a boundary-value problem at different moments in time, and at the positions where the SAR-derived ISW signatures are identified, show that these waves are nearly in the transcritical regime for mode-1 non-hydrostatic linear waves propagating upstream the NBC. The longevity of these waves is unknown at present, and they may play a relevant role for mixing between fresh riverine and ocean water.

NUMERICAL SIMULATION OF WAVE PROPAGATION AT CASSINO BEACH (SOUTH OF BRAZIL)

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Keywords: Spectral wave propagation, Mike 21 SW, Cassino beach.

1. INTRODUCTION

The knowledge of wave conditions is the most important factor for the success of coastal engineering projects. Ideally, the wave measurements are the best way to understand the wave behavior; however, the lack of long term measurements makes the numerical simulations as an interesting alternative to study wave propagation in coastal areas (Ardhuin et. al., 2006). However, for a reliable numerical simulation, calibration and validation of the model with, at least, short term local wave measurements are necessary.

Inserted in this context, this paper shows the calibration and the validation of the numerical model of spectral wave propagation and generation Mike 21 SW at Cassino beach, in the south of Brazil. Thus, the numerical results of significant wave height (Hs), peak period (Tp) and peak direction (Dp) are compared with local short term and long term measurements. Some characteristic frequency spectra obtained numerically are also compared with the measured ones.

2. METHODOLOGY

The numerical model of spectral wave propagation and generation Mike 21 SW was used for the numerical simulations. Mike 21 SW is a phase-averaging model that employs the volume finite method to solve the govern equations (DHI, 2014). An unstructured mesh of 4.012 nodes was used for the domain discretization (Fig. 1). The bathymetry data were acquired from nautical charts and the values of water depth were interpolated in the mesh nodes by the inverse distance weighted method. The wave data imposed on the external boundary of the domain and the wind data used to local wave generation were obtained by NOAA/NCEP database.

In order to calibrate the model, analyses of the wave generation by the local wind, the bottom friction coefficient and the time formulation (quasi-stationary and non-stationary) were carried out. Results of Hs, Tp and Dp were compared with measurements of a directional waverider buoy and an ADV (Acoustic Doppler Velocimeter) located 25 m and 12 m deep (Fig. 1), respectively, in May, June and July 2005. For a better understanding, some characteristic simulated frequency spectra were compared with the measured ones.

The validation step, which was carried out after the calibration, consists of comparing numerical results with those obtained by measurements of a directional waverider buoy located 15 m deep (Fig. 1) from 1996 to 1999. A statistical analysis quantified the numerical error by using the dimensionless parameter relative bias (Rbias) and scatter index (SI).

3. RESULTS

Fig. 1 shows a comparison of Hs, Tp and Dp and those measured by an ADV for one month. Good agreement between the numerical and measured values of Hs, Tp and Dp are noted. At some instants, there is an abrupt variation of Tp and Dp. These events are related to the existence of bimodal structures in wave spectra. The biggest differences between the simulated values of Tp and Dp and the measured ones occur in these instants.

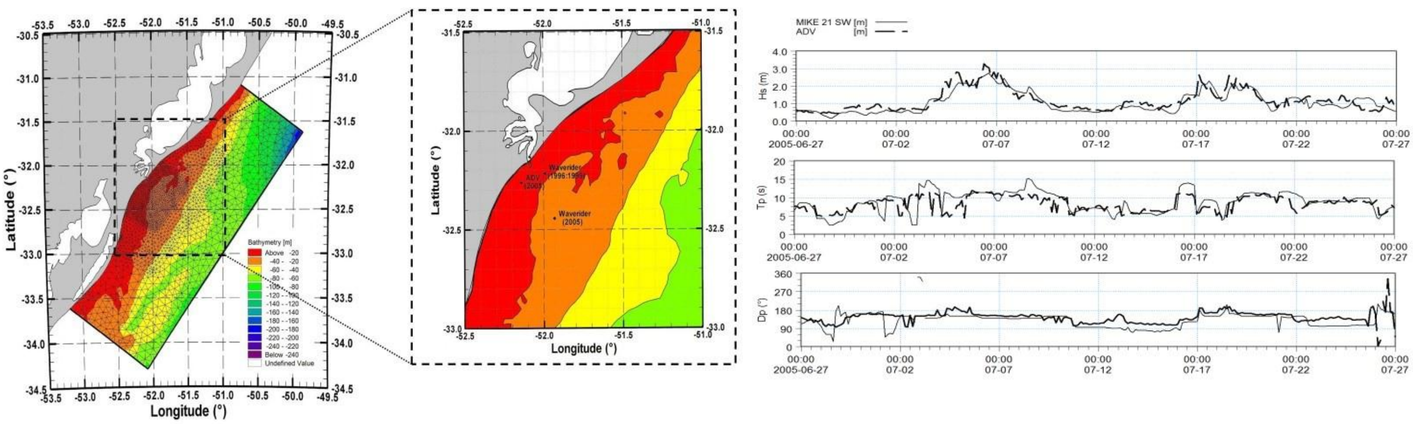

Figure 1 - Computational mesh, bathymetry and location of the measurement points (left) and comparison of Hs, Tp and Dp time series and those measured by an ADV (right).

The calibration step enabled the following conclusions: a) wave generation by the local wind is very important, although the computational domain dimensions limits the wind fetch; b) bottom friction dissipation in the bed forms is also important due the large continental shelf with low slope; c) the differences of the simulated results using quasi-stationary and non-stationary formulation are small.

In the validation step, a comparison between numerical and long term measured results was performed. In this analysis, Rbias of -0.030, -0.162 and -0.110 and SI of 0.274, 0.302 and 0.257 (for Hs, Tp and Dp, respectively) were obtained. These results showed that the numerical model was able to estimate the local wave conditions with good accuracy.

4. CONCLUSION

In this paper, the spectral numerical model of wave propagation and generation Mike 21 SW was calibrated and validated in the interested region. Numerical values of Hs, Tp and Dp and some characteristic frequency spectra were compared with measurements and it was noted a good agreement. Consequently, the numerical model Mike 21 SW shows to be an excellent tool to wave hindcast and forecast.

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“There is no such thing as freaque waves!”

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Abstract

Over a decade ago, we first contemplated (Liu and Pinho, 2004) the contention that freaque waves are more frequent than rare when freaque waves were still generally regarded as rare occurrences. Now a decade later, upon widely enthusiastic researches, we have encapsulated our new thinkings in the above title and concluded that there is really no such thing as freaque waves – all are just part of the ocean waves because no one can readily point to a specific type of wave in the ocean to call it freaque waves! Freaque waves are mostly after thoughts, only after it has happened can anyone be reflecting upon it to indicate what had happened was a freaque wave. So the statement given above between the quotations is really a valid one not some jargonish irrationalities. In this paper we wish to further explore this assertion and try to evince that there are indeed no such things as freaque waves!

Wave Climate and Events Migration Mud at Cassino Beach, RS, Brazil: An Investigation

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ABSTRACT

The occurrence of mud at Cassino Beach has always raised the curiosity of the local community and the interest of researchers. The phenomenon is natural/anthropogenic origin, have been reported by several authors since 1972. Sedimentological data show that the Patos Lagoon is the major source of fine sediment to the inner shelf adjacent.
More recently studies have associated these events with migration of anthropogenic origin (dredging the access to the Port of Rio Grande channel). Owing to economic and environmental consequences observed in the region each deposition, is essential to understand the mechanisms that control the dynamics of these deposits. This dynamic is directed linked to the wave climate of the region.

This work presents a correlation between the mud migration events to the beach and the local wave climate. The aim is to achieve a better understanding of the mechanisms that lead to the remobilization of the mud banks. The methodology employed consists of analyses of measured data by a directional wave meter, wind data from NCEP/NCAR (reanalysis II) and modeled data with Wavewatch III. Results suggest that the Bad Weather from Southwest is the sea state present in the majority of mud events on the beach.

Non-tidal coastal sea level variation along Southeastern South America – Progress Report

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Two one year long, simultaneous, hourly data sets of sea level on sites along the coast of SE South America were analyzed to investigate non-tidal variations. The first data set includes sites on the S/SE coast of Brazil (from Rio Grande do Sul to Rio de Janeiro) and the second one covers the coast from Argentina up to Rio de Janeiro. In order to obtain the non-tidal signal, astronomical tides were removed with T_Tide and the "residuals" were decomposed into different frequency bands using Fourier techniques (FFT filtering). Results revealed a number of interesting features, some of which will be presented in the Symposium, focusing on the "synoptic band" (freq. band corresponding to 3 to 30 days) which is the most energetic band of the phenomenon.

Coastal sea level on the synoptic band shows strong evidence of a signal that propagates from South to North all the way from Patagonia to Rio de Janeiro with an apex on Mar del Plata where the signal acquires an amazing amount of energy. Propagation speed of the signal falls within phase speeds of Continental Shelf Waves which, according to theory, travel in the same direction (from S to N) along the shelf. Data suggests that these waves may play an important – perhaps dominant ? – role on the "climate" of coastal sea level variation in the synoptic band at the S/SE Brazilian coast. In Rio, for example, these variations seem to be dominated by remotely generated waves – something akin of a wind induced "swell" of *very long* wavelength.

However, since weather patterns also travel from S to N along the coast, a question arises regarding the role of locally forced variations on this signal. Two conceptual models to explain the phenomenon seem possible: (i) Pure local generation (without shelf waves) and (ii) remotely generated free shelf waves affected by local winds. The author is currently working to elucidate which model is more adequate to portray the phenomenon. Resonance between traveling coastal wind patterns and (free) shelf waves are also being considered to explain the extra large amplitude of sea level variations found in the area.

Development of a Brazilian Wave Buoy

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Meteocean in-situ data are required for many different roles in offshore hydrocarbon exploration and production: to provide design criteria for platforms and subsea systems, to support logistic operations with ships and helicopters and to assist on the decision making process in emergencies. As oil exploration in Brazil moves fast to ultra-deep waters as a result of recent pre-salt discoveries, the ocean environment plays an even more important role in defining engineering criteria and safeguarding offshore operations. Near real-time ocean data measuring systems based on moored surface buoys provide an adequate solution for these purposes, but long-term operation of such systems in Brazil is severely impaired by lack of local technical assistance from manufacturers and high costs associated with imports duties and logistics. To overcome some of these drawbacks, Petrobras R&D Center (CENPES) led the development of the so far called 'Brazilian Metocean Offshore Buoy' (BMO-BR) with local new technology-based firms, to know: HOLOS (composite hull construction), AMBIDADOS (CPU-sensors integration), NAVCON (CPU-sensors integration and MRU development). Two fully functional prototypes have been built with different payload/sensor configuration and are presently under sea trials to validate hull design criteria, data processing/storage/transmission performance and data quality. This work presents the BMO-BR development process and reports the good results achieved so far with emphasis on surface wave data processing from a fully MEM sensor (i.e. Microstrain GX3) and a locally built FOG-based motion reference unit.

Laboratory studies of energy dissipation under breaking waves

Jason P. Monty, J. H. Lee, A. Toffoli, A. Albarello, J. Elsnab and A. Babanin

Air-sea interaction processes such as heat, momentum and gas exchange are all significantly affected by wave-induced turbulence. Wave-breaking induces turbulence and enhanced mixing below the wave crests and limits the growth of waves due to energy dissipation (Young and Babanin 2006). While there has been many studies on breaking-wave-induced turbulence, there remain open questions, particularly near to the wave crests.

For modeling efforts, estimating dissipation accurately close to water surface is critical. Although there have been studies that provide paramaterisations of the dissipation rate, these are based on limited data near the surface. The objective of an ongoing study in the Michell Hydrodynamics Laboratory is to improve our overall understanding of wave induced turbulence. Data is provided through high- fidelity Particle Image Velocimetry (PIV) experiments in the Extreme Air-Sea Interaction (EASI) facility, which is a 60m long wave tank with the capability to blow air over the water surface at speeds exceeding 30 m/s. In this presentation, we seek to address and observe scale dependence of the energy dissipation close to the wave crests due to the wave induced turbulence. Mechanically generated monochromatic deep water waves without wind were first studied and then compared to the same mechanically driven waves with wind. It should be noted that background noise was sufficient to activate the modulational instability, resulting in breaking waves at the measurement location. The presentation will report results of the dissipation rate as a function depth, wave phase and wind conditions and compare these with previously published results.

Young, I. R., and A. V. Babanin, 2006: Spectral distribution of energy dissipation of wind- generated waves due to dominant wave breaking. *Journal of Physical Oceanography*, **36**, 376–394.

THE STATE OF THE ART, IN BRAZIL, IN WAVE MEASUREMENTS USING BUOY SYSTEMS

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This work aims to present some Brazilian initiatives in R&D and buoy deployments, which are concerned to reinforce of the constant ocean waves monitoring.

Some aspects of three buoy programs will be presented: the National Buoy Program (PNBOIA), the Modeling and Observation Oceanographic Network (REMO) and the Waves Network (Rede Ondas). Their objectives, methodology, some results and difficulties will be discussed.

To improve the wave measurement quality and the reduction of the costs some R&D actions are being done by the Brazilian research community and will be described. Studies in Data Quality Control and Data Assurance, with low cost inertial MEMS units (MicroElectroMechanical Systems) to get heave, pitch and roll data, and the development of hulls, sensors and control units for buoys, in cooperation of research centers and Brazilian companies.

Freak Waves in the Southern Ocean: A Preliminary Study

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The occurrence of freak waves (FW) has been observed and described all around the world. The Southern Ocean (SO) is known as one of the most energetic regions of all oceans, but due to the lack of observations, there are no works on the theme for that area. Based on data collected by a Triaxis buoy moored at 46.777 S; 141.993 E, from April to October 2013 (Rapizo et al, 2015), a preliminary study was carried out, allowing to verify some initial information.

To the analyses we use the heave data from the raw files provided by the software of the buoy. The time series were examined in the time domain, using up- and down-crossing methods. Therefore, the significant wave height (Hs) is defined as the mean of 1/3 biggest waves. In this work a wave is considered freak if its individual relation to Hs is greater or equal 2.

As expected, sea states at SO were very rough, and the mean Hs for the considered period was 3.96 (± 1.50) m, with a maximum value of 9.20 m.

The choice of method of analysis showed to be important on the determination of individual waves, and results for FW may slightly vary depending on it. For up- crossing processing, a total of 28 FW were found, with the maximum relation Hmax/Hs equal to 2.52 (Hmax: 8.1 m; Hs: 3.21 m), and the highest absolute height of 15.78 m. For down-crossing method, we found 25 FW with a maximum relation Hmax/Hs = 2.41 (9.03/3.75), and the highest absolute height of 14.29 m. However, both methods identified the same maximum wave, 17.03 m height, on September, 1st, 16:00 UTM, although it was not a FW. Generally, we found approximately 1 FW for every 9200 waves, which is much lower than the 1/3000 suggested by theory.

It was also possible to find two freak waves in the same record, on September, 26th, 12:00 UTM.

As the time series is too short, only very few statistical inference can be done. Future works will investigate other characteristics, like period, and vertical and horizontal asymmetry.

STUDY OF GRAVITY WAVES AND INFRAGRAVITY BAND SPECTRUM ON A COMPLEX INTERMEDIATE BEACH SYSTEM

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High energy of wave storm events can cause a shift of beach state from reflective or intermediate to dissipative in a matter of days. The return to reflective conditions under low energy can require weeks or months or longer. The modal (most commons current) beach state represents a response to the modal wave break characteristics (wave climate) and the prevailing sediment characteristics. Within the surf zone, free infragravity waves are usually cross-shore standing and take the form of either two-dimensional leaky waves or three-dimensional edge waves (the latter can be either longshore progressive or standing). Scientific attention in these waves was intensified (1970-1990) because they were thought to contribute significantly to shaping costal morphology, in particular the formation, position and plan shape of nearshore bars. The morphological response potentially caused by infragravity wave advection of sediment is considerable. This suggest that coastal engineering projects to protection, stabilization and others objectives (artificial surfing reefs) must be taken into account the suave orbital motions due to incident wind waves and all modes of infragravity waves.

While some investigations suggest that submerged breakwaters may result in larger salients than those would result from an emergent breakwater of similar size, other investigations indicate that submerged breakwaters may result in shoreline erosion in the lee of the structure. Several assumptions and simplifications have been made in those studies which may limit the validity and robustness of the presented results. The limitations associated with the numerical modelling include: neglecting of wave reflection caused by submerged breakwater and the beach, 2DH representation of hydrodynamics without morphological updating, consideration of only a single breakwater and parallel depth contours, and using the circulation patterns as a proxy for the determination the mode of shoreline response. Limiting assumptions in the theoretical equations derivation include: assumption of parallel depth contours, linear wave theory and shore normal waves, and omission of wave period (thus any effect of steepnes H_o/L_o) and wave–current interaction. Thereby, before engineering design guidelines can be developed for submerged coastal protection structures, a fundamental research challenge is to establish the main mechanisms that cause erosion and accretion in their lee. Waves at infragravity and near-infragravity frequencies are energetically secondary, but are probably fundamental in determining the net drift patterns of water and sediment and, thereby, influencing surf-zone morphology. But, definitive empirical verifications of the correlation between infragravity wave structure and bar positions are still missing.

This paper explores the gravity (G) and infragravity (IG) band of the spectrum that was carried out on intermediate beach type with a triangular rocky bank within wave breaking zone. The goal is to study the characteristics of this waves (G and IG) present in the different beach state with a submerged breakwater within beach system. To do this, we trying to understand the mode of dominant spectral peaks band.

The Reserva beach in Rio de Janeiro, Brazil, was chosen because is an oceanic beach dominated by high energy waves and there is a triangular beach rock with similar shape that have been studying to multifunctional submerged breakwater in last 15 decades. The wave climate in southeast Brazil is dominated by subtropical and extratropical cyclones and polar anticyclone fetches, that generates swell, wind sea and usually the occurrence of storm waves. The data were collected by using two acustic doppler velocity profiler in the rip current and one acustic doppler current profiler positioned very near of wave breaking point, outside of surf zone. The data was scale recorded during twelve hours in fifteen different wave events and beach type. The measurements were made in wind sea and swell conditions. The features of infragravity oscillations were measured in the presence of longshore-bar-trough, rhythmic-bar-and-beach and transverse-bar-and-beach topography. Analyses were carried out in terms of the spectral transformations of onshore and offshore velocity, outside and inside of surf zone. The similarity of the spectral transformation and the data in the infragravity band is strong evidence that the flow was dominated by free edge waves modes. Different structures exist in the infragravity band onshore and longshore spectra modulated by tidal oscillations and topography. In the intermediate beach states the dominant infragravity energy occurs at higher frequencies (at infragravity band) than in dissipative surf zones and differs between onshore and longshore energy. The position and spatial scale of natural ‘submerged breakwater’ in the Reserva beach system induce the wave break, and is responsible by a small scale of surf zone morphology. The shoreline response and morphology is being controlled by the energy present in the surf zone. Thus, the knowledge of sea state in the breaking zone is the key to provide information about infragravity mechanism excitations and the best way to design and to position a coastal engineering in the beach system.

WAVES BREAKING PARAMETERS ON BEACH BREAK, POINT BREAK AND REEF BREAK TO DESING ARTIFICIAL SURFING REEF

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1. Introduction

The scientific issues surrounding the development of sophisticated offshore protection structures that incorporate multiple benefits to multiple user-groups are new and complex. Such technologies rely on modifying various physical processes such as physics wave break, surf zone hydrodynamics, sediment transport pathways and sediment control points. The combination of coastal management techniques and innovative engineering methods can be used to improve the recreational and economic activity in coastal environments. The recreational, aesthetic and associated economic value of a high quality surfing break is often significant to coastal developmente of communities, and has been identified as a key tourist attraction in many locations around the world.

The economic impact of surfing break in the Gold Coast ranging from 20:1 to 70:1 and have been reported about more that US$10 billion per year (2013) are spent by surfers in accommodation, food, equipment, clothing and merchandise industries related to surfing.

The beach qualify analysis to recreational activities, and or to the development of an artificial surf reef design takes into account four mostly important wave parameters: breaking wave height (HB); wave peel angle (α); wave breaking intensity (B_I); and wave section length (S_L). The angle at which a breaking wave peels determines in part the quality and difficulty of a surfing wave. The peel angle of a breaking wave is the angle formed by the path ascribed at the point of the initiation of wave breaking, and the alignment of the adjacent unbroken wave crest. Other surfing wave parameters exist but they are only derivatives of these four main variables. The studies of surfing breaks examine how seafloor bathymetry transforms ordinary waves into surfing waves (surfable). Multi-purpose surfing reefs design for coastal protection and public amenity were studied through field research, physical and numerical modeling in last 20 years.

2. Objective

The purpose of this study is to examine the wave breaking parameters on sandy beaches in order to investigate the changes that a submerged structure can cause in waves breaking parameters at a beach break.

3. Materials and Method

The studied beaches were Leme, Copacabana, Arpoador, Leblon, São Conrado, Pepino, Barra da Tijuca, Reserva, Macumba, Prainha, Grumari, Guaratiba and Itacoatiara, all of them but the last are within Rio de Janerio city. Itacoatiara is localized in Niteroi city, all of them located in southeastern Brazil. These beaches are exposed, present moderate-to-high energy, microtidal sandy beach, and compose of medium grain size. The wave climate in southeast Brazil is dominated by subtropical and extratropical cyclones, and polar anticyclone fetches, that generates swell, wind sea and storm waves.

Parameters to qualify the breaking wave obtained through the use of a GPS (Global Position System) carried by a highly experienced surfer. The method made possible to obtain the wave breaking direction (validated with an Acoustic Doppler Current Profiler installed on the sea bottom), the trajectory of wave breaking (peel), the breaking velocity section and the peel angle rate.

In Reserva beach there is a triangular rocky bank (in plan: 63m base, 40m height;

1.8m depth to structure crest) in the wave breaking zone, approximately 130m off the coast line. These physical characteristics in the intermediate beach are ideal to study of the spatially and temporally wave breaking dynamic determinate by variable waves regime.

4. Results and Discussion

The field data was obtained between 2014 and 2015. Approximately one thousand waves were measured in 13 intermediate beaches. The wave breaking conditions were between 0.5m and 5m and wave period varied from 8s to 16s.

The wave peel angles were found to range from 55˚ to 70˚ at point breaks beaches, PBB (Leme, Arpoador, Leblon and Guaratiba), and 0˚ (clouse out) to 50˚ at beach breaks, BB (Copacabana, São Conrado, Barra da Tijuca, Macumba, Prainha and Grumari). The wave breaking intensity (such as calculated the Irribarren number) were very similar between both beaches (33 to 41). The wave section length can reached up to 300m at point breaks (Arpoador and Guaratiba) and ranged from 0m to 70m at beach break. Refraction around the large headland (Leme, Arpoador, Leblon and Guaratiba) causes the waves to re-align to more obliquely direction near the breaks (bars). The gradient between sand bar and adjacent nearshore produce the wave breaking trajectory.

The rocky bank at Reserva beach produced wave peel angle range and wave section length of 55˚ to 75˚ and 70m to 150m, respectively (these were found in both side peels). This is because depth gradients between the bank and sea floor control the refraction and converge the wave train to the point breaking.

The relationship between wave climate of Rio de Janeiro, peel angles, breaking wave velocity and beach type are demonstrated as a limiting for recreations and surfing activities. In addition, the presence of a submerged breakwater (rocky bank) ensures that surfers of a range of abilities would be sufficiently attractive by the reef.

5. Conclusions

The relatively high but temporally and spatially variable energy regimes of southeast coast of Brazil have afforded an excellent laboratory for studying the full natural range of wave breaking parameters. In the predominant time scale that wave climate produce the beach balneability (recreational activities at beach), a natural submerged rocky bank to improve wave breaking parameters in relation to beach breaks. The design and spatial scale of an artificial submerged breakwater to improve wave breaking parameters is unique to each beach and it is a relationships between the waves breaking parameters with observations a wide range of wave breaking in the own beach.

Title:
Assessing the risk of overtopping waves by lessons learned in time

Abstract:
A storm with easterly winds hit the Faroe Islands in the winter of 2014. The newly made main road, connecting the main islands to the northern part of the country, had to be closed due to severe overtopping waves. Investigations show that it was high waves, the direction of the waves and the timing of the storm at spring tides, which resulted in the road closing event.

As the circumstances do not fall within the usual frames covered by parametric engineering formulas, this study uses the limited operational history at the location in order to assess the risk of similar overtopping events. Using regional measurements from the road closing event, and comparing against measurements from similar but less severe events, it is possible derive threshold values for potential dangerous wave, water-level and tidal conditions. The risk assessment was derived by comparing these thresholds to more than 50 years of hindcasted wave, tidal and water-level time series. The results indicate that a road-closing level of overtopping might occur once every five years and that even more severe overtopping events are to be expected.

This ad hoc approach has challenges when it comes determining the precise values of the thresholds, the dependency of the derived risk assessment on these values, and the small number of events that meet the criteria. The strengths of this approach are that it can be used in any setting, and that is singles out historical events that can be further investigated individually and e.g. compared to local damage reports.

Bardur A. Niclasen

Laboratory study of non-breaking surface wave induced turbulence

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Abstract

We study nearly monochromatic surface waves in a small wave tank and its character to induce turbulence when the waves are still non-breaking. The wave tank facility of the Faculty of Marine Science of the University of Baja California has the capability to mechanically generate nearly monochromatic waves. The tank is approximately 12m x 0.5m x 0.3m and the waves were generated with various steepness (ak) from about 0.02 to 0.18, depending on each of the 184 experimental runs. We performed detailed measurements of the vertical profile of the 3d velocity field within a water column of about 0.035 m in length.
Routine data quality control includes the use of only high beam correlation signal within each of the acoustic beams used by the profiler. A rotation matrix was applied to the velocity data matrix in order to secure that the x; y; and z axes were properly aligned with the wave tank. Rather low wave reflection was required and obtained through the implementation of a beach at the end of the wave tank.
We were able to detect the intermittent nature of the turbulence as shown in a region following the -5/3 power law in the velocity spectra. Nevertheless, this spectral shape is being observed in most of our experimental results, including cases where the wave steepness was rather small. Root mean square values are obtained from the turbulent fluctuations time series to evaluate an integral quantity to characterise the turbulence intensity. This intensity is analysed in terms of the wave steepness showing a linear relationship. The turbulent kinetic energy dissipation rate is also estimated and the relevance of the velocity spectra directly estimated over a limited number of wavenumber bands is addressed.
This work represents a RugDiSMar Project (CONACYT 155793) contribution and support from CONACYT project CB-2011-01-168173 is greatly appreciated.

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DECADAL VARIABILITY OF THE WAVES CLIMATE THROUGH MODEL WAVEWATCH III IN SANTA CATARINA COAST

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Climate dynamics of the ocean and the atmosphere are strongly linked and therefore, changes in the atmosphere will cause changes in the dynamics and wave climate. Several evidences indicate changes of the Earth's climate, however, there are still uncertainties in relation to rates and patterns on these changes. In the last decades there has been a warming of the surface waters of the Southern Ocean, at the middle latitudes, causing a migration of the westerly winds in the direction of the pole. Particularly, in the South Atlantic Ocean and the South Indian Ocean, because of the migration of the winds, occurs the strengthening of the incoming hot and saline waters in the Atlantic Ocean by the Agulhas Current system, causing changes in the wind stress and in the wave climate of the South Atlantic and Southern Ocean.

Therefore, this work will reconstruct the wave climate, from 1979 to 2010, offshore the coast of Santa Catarina State, through the implementation of the wave model Wavewatch III. Firstly, the model will be run on a global domain grid with a horizontal resolution of 0.5°; a second regional grid of the South Atlantic Ocean will be nested to the global grid, with a horizontal resolution of 0.25°. Finally, a third high-resolution grid (1/16 °), of the continental shelf of the Santa Catarina State, will be nested to the regional grid. The data used to force the model are from two atmospheric data sources (CFSR and ERA-Interim reanalysis). The two numerical simulations will be compared through the analysis of the statistical parameters generated, like, significant wave height (Hs), mean period (Tm), peak period (Tp), peak direction (θp), middle management (θm), directional dispersion and directional spectra.

The generation of internal tides at the Vitória-Trindade Ridge in the South Atlantic

Afonso de Moraes Paiva, Guilherme Nogueira Mill, Vladimir Santos da Costa, Victor Bastos Daher, Simone Silva Barem Camargo, João Bosco Rodrigues Alvarenga

In this work we investigated the generation of internal tides at the Vitória-Trindade Ridge, a 950 km long east-west submarine seamount chain located around 20°S in the southwestern South Atlantic, and their further propagation, surface manifestation, and decay. Twenty years of sea surface height anomaly data from different satellite altimeters were analyzed, in combination with numerical results from a high resolution regional HYCOM simulation. Harmonic analysis was applied to the satellite along track time series, in order to extract amplitude and phase of the principal tidal components - associated with the surface signature of such long internal waves, and a two-dimensional plane wave fitting method was used to compute the energy fluxes associated to the waves propagation. We found a dominant phase-locked semidiurnal internal tide generated at the ridge, with amplitudes in the altimeter signal of ~2.5cm and wavelength of 120 km for the M2 component. Smaller amplitudes, between 1.0 and 2.0 cm were associated to the S2 component. The M2 internal tides radiate from the ridge both poleward and equatorward for more than 1000 km, before decaying below noise level. Numerical results indicate maximum isopicnal displacements on the order of 100 m at thermocline levels. Chlorophyll-a maps of the South Atlantic show that the Vitoria-Trindade Ridge seamounts are hot-spots of high phytoplankton biomass, surrounded by oligotrophic oceanic waters. It is hypothesized that the vertical movements associated with the locally generated internal tides may play an important role in sustaining the observed complex marine food webs, by bringing nutrient-rich subsurface waters to the euphotic zone. Observational and numerical results also indicate a coherent mode-1 M2 internal tide energy flux around 100 W/m. This valuer is smaller than the corresponding ones reported in highly energetic regions, such as the Hawaiian Islands or in the South China Sea, but significant when compared to fluxes generated nearby at the Brazilian slope. The results also indicate that the ridge geometry acts as a lens for the poleward propagating internal tide, with a focal region located about 300 km to the south, corresponding to the highest amplitudes both at the surface and subsurface levels.

DAAT - A NEW TECHNIQUE FOR OCEAN-WAVE DIRECTIONAL ANALYSIS

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Federal University of Rio de Janeiro

ABSTRACT

We present a directional wave analysis technique, DAAT, extensively used in the last years to investigate the wave climate in the Brazilian coast. DAAT uses wavelets to examine several frequency bands adaptively chosen to well represent the local climate.

In recent years there has been a great effort to improve spatial resolution in ocean-wave directional analysis, mainly that related to pitch & roll buoy data processing. With the same purpose we deveoped this DAAT technique,

Usually, all the spectral techniques, like the periodogram and other parametric ones, estimate the different parameters averaging through fixed segments of a wave record, with or without overlapping. These techniques assume a stationary process and aim to enhance the time-invariant characteristics of the process, cancelling or reducing the variant ones or the noise.

<u>DAAT, instead, selects the segments that will contribute to the estimators.</u>

Besides this noise or time-variant characteristics, the wave signal can be corrupted by noise produced by an incorrect response of the measurement system and interferences from the mooring system. We may also include distortions or non-linearities present in the time-variant characteristics of the wavefield, as pointed out by several authors. The mixture of different “seas” can also produce non-stationarities in the process. Averaging through fixed segments will produce some kind of weighted average. Even in the case of an incoming sea from a limited sector, the waves in a narrow frequency band are always combining in a constructive or destructive way, producing high and low spectral values. The average tends to hide an isolated <u>event,</u> defined here as the occurrence of wave group occupying a narrow frequency band and a limited direction sector.

DAAT, using wavelet transforms of sequential segments, calculates the main direction and the energy (spectrum) of each segment. These values are evaluated under several criteria and, eventually, the segment is considered with low noise, stable in direction and representative of the process and, in this way, selected to compose the averages. This technique allows the construction of $D_f(\square)$, the distribution of energy with direction for a given frequency band.

We also present a plotting technique for the evolution of the directional spectrum - PLEDS. the technique is very useful to understand the wave climate, to compare wave predictions with measurements and several other applications.

"Measuring Coastal Significant Wave Height from Radar Altimetry with ALES Retracker"

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For more than two decades, it has been possible to map the Significant Wave Height (SWH) globally through Satellite Radar Altimetry. SWH estimation is possible because the shape of an altimetric waveform, which usually presents a sharp leading edge and a slowly decaying trailing edge, depends on the sea state: in particular, the higher the sea state, the longer the rising time of the leading edge.

Particularly challenging for SWH detection are coastal data and low sea states. The first are usually flagged as unreliable due to land and calm water interference in the altimeter footprint; the second are characterized by an extremely sharp leading edge that is consequently poorly sampled in the digitalized waveform.

The aim of this talk is to present the Adaptive Leading Edge Subwaveform retracker (ALES), an algorithm for reprocessing altimetric waveforms that is able to provide more reliable SWH data in the coastal zone. The SWH estimations are validated in a particularly challenging area. The German Bight region presents both low sea state and coastal issues and is particularly suitable for validation, thanks to the extended network of buoys of the Bundesamt für Seeschifffahrt und Hydrographie (BSH). Results show that, when the satellite is approaching the coast, ALES estimations of SWH are generally better correlated with buoy data than standard processed products.

The ALES product is freely available online through the PO.DAAC Web Service for Jason-2 and Envisat and will be applied to other missions. As example of a possible application, it will be shown how the sea surface height estimated together with the SWH has been used in the ESA-funded eSurge project to measure storm surges.

Title

Design and Construction of an Active Wave Absorber in a Wave Channel

Authors

Rafael de Barros Passos (COPPE/UFRJ)
Prof. Antonio Carlos Fernandes (COPPE/UFRJ) Prof. Ramon Romankevicius COPPE/UFRJ)

Abstract

An important step in the development of new ocean structures is to conduct tests on reduced scale models in tanks that reproduce the environmental conditions of their operation. For the wave modeling in a 2D channel, waves are generated in one of its end by the wave-maker and they should not be reflected back to the tested vessel. If these reflected waves were not absorbed, they would interfere into the wave field that is under investigation. The simplest solution is the use of a passive beach to absorb the reflected waves, composed by a long ramp at the far end of the channel. As an alternative to these conventional beaches, wave-makers equipped with a designed control system can be used as active absorbers. These so-called active beaches have the advantage that they do not extend into the experimental domain of the basin and, at least in linear theory, low or zero reflection could be achieved. The objective of the present work is to design and construct an active wave absorption system into LOC, Laboratory of Waves and Currents, at COPPE/UFRJ. First results showed an absorption level comparable with the passive beach, however a careful tuning process is necessary to minimize the reflection coefficient.

Abstract – Brazilian Wave Symposium

Observation of PNBOIA's Metocean Buoys Deployed in Southern Coast of Brazil

Henrique P. P. Pereira; Vitor Lopes; Nelson Violante; Uggo F. Pinho; Carlos Eduardo Parente; Izabel C. M. Nogueira; Fabio Nascimento; Alexander V. Babanin

Despite being an important component in global wave climate several authors point out the scarcity of data regarding the Southern Ocean (Hemer et al. 2010; Chawla et al. 2013; Rapizo et al. 2015) and particularly the South Atlantic (SA) Ocean (Souza and Parente 1988; Cuchiara et al. 2009; Pianca et al. 2010). The shortage of observational ocean wave data in this area has resulted in numerical modeling becoming the most used tool for the investigation of its wave climate (Parise and Farina 2012).

The National Program of Buoys (PNBOIA) is a part of Brazilian Navy and its objectives encompass the collection of meteocean data in the Atlantic Ocean, by means of a network of moored buoys and drifters supporting meteorological and oceanographic activities important to Brazilian public institutions and companies. It is PNBOIA's intention to install a monitoring program with a total of 10 moored buoys. All the PNBOIA moored buoys measures atmospheric pressure, wind (direction, intensity and wind gust), relative air humidity, air temperature and dew point, solar radiation, ocean currents and sea surface temperature.

This paper presents basic wind generated wave characteristics for the southern offshore region of Brazil, based on a five month series (Feb/2012 – June/2012) of wave data sampled simultaneously by three directional wave buoys (Rio Grande/RS, Florianópolis/SC e Santos/SP). The statistical analysis presented here aims to describe the general wave parameters for each one of the three aligned buoys.

Sensor characteristics and settings are described as well as the methods applied to the raw data. Wave data analysis was performed both in the time (upward zero-crossings) and frequency domain. Statistics and distributions of the main wave parameters (Figure 1), spectral evolution of swell propagating events (Figure 2 and 3) and comparison between the observational data and a wave hindcast from WW3 (Figure 4) are also analyzed. Another interesting feature of this data set is that some sea states present a value of the ratio Hmax/Hs higher than 2 (Figure 5), what implies, by the criteria normally used to define freak waves (Liu 2007; Kharif and Pelinovsky 2003), that this kind of waves is present in the data set.

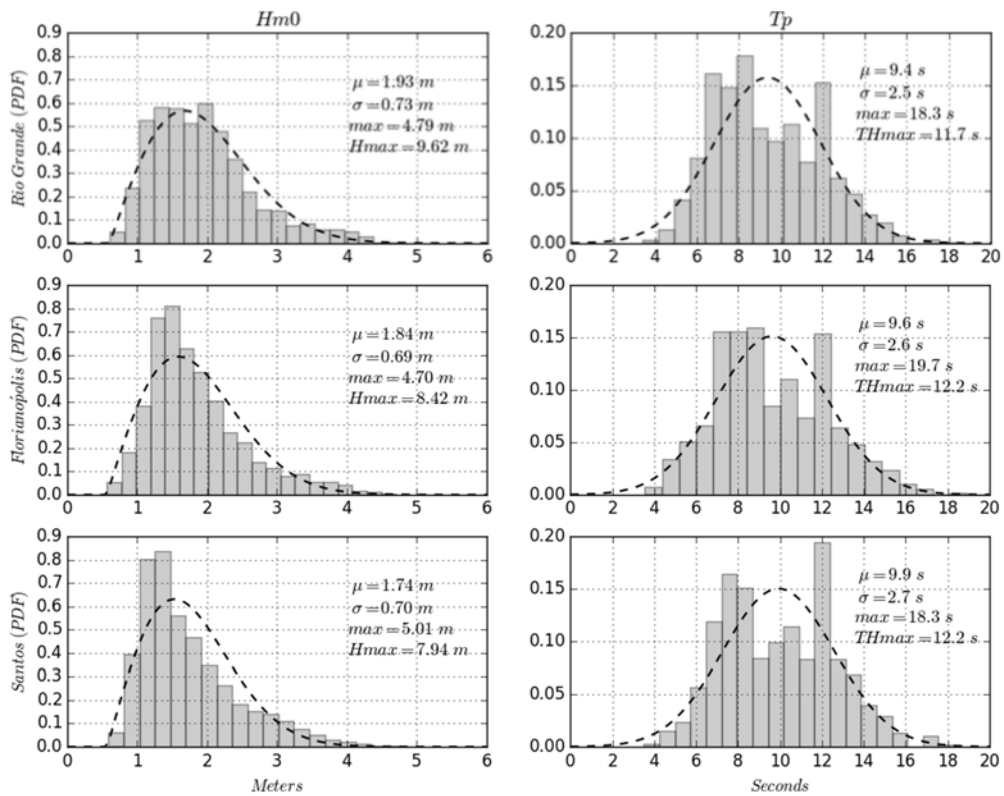

Figure 1 – Zero-moment wave height H_{m0} (left panels) and peak period T_p (right panels) Probability Distribution Functions (PDF) for the five months of simultaneous data.

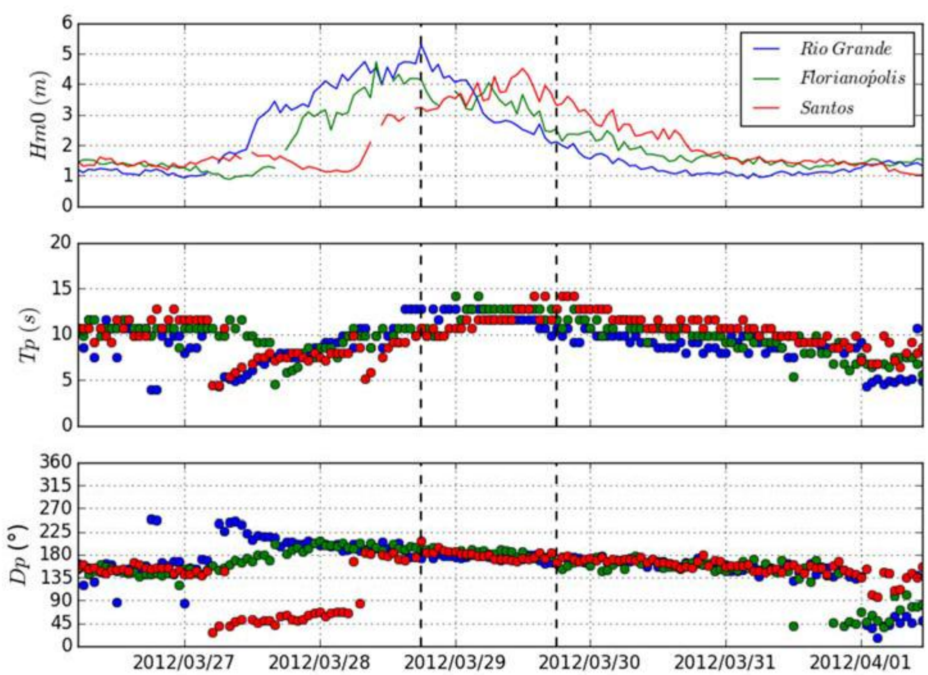

Figure 2 - From top to bottom, zero-moment wave height Hm0, peak period Tp and peak direction Dp, spanning the period between the end of March and the beginning of April, 2012. The colors are related to different directional wave buoys, the red is the northernmost one and the blue the southernmost one.

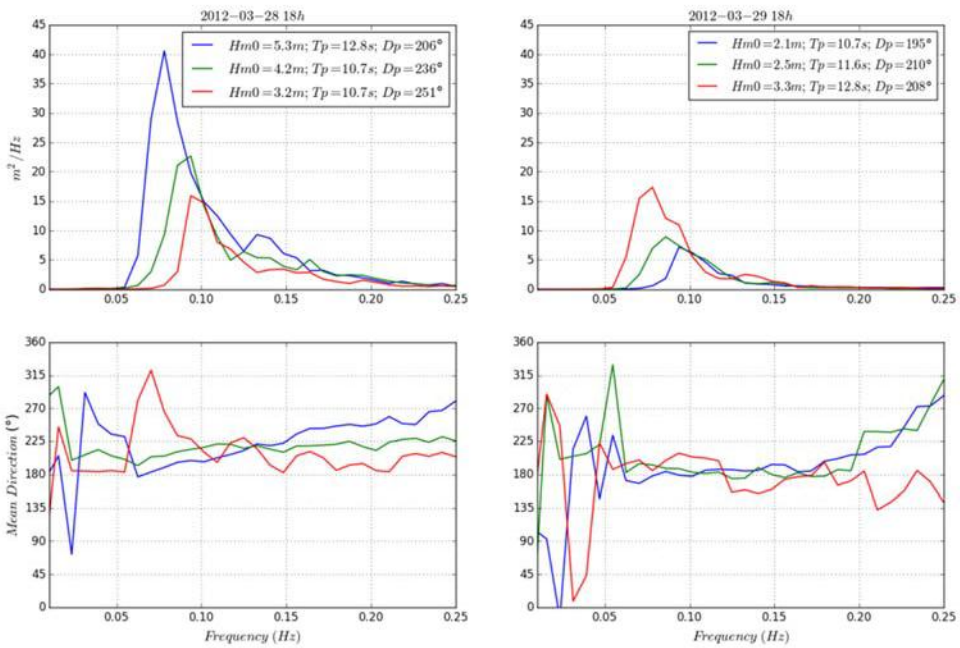

Figure 3 – Top panels display the variance spectra for the three southernmost buoys, blue Rio Grande, green Florianopolis and red Santos. The low panels show the (mainly) southerly propagation direction measured at each buoy. The left panels correspond to the moment depicted by the left vertical dashed line in Figure , while the right panels to the right vertical dashed line

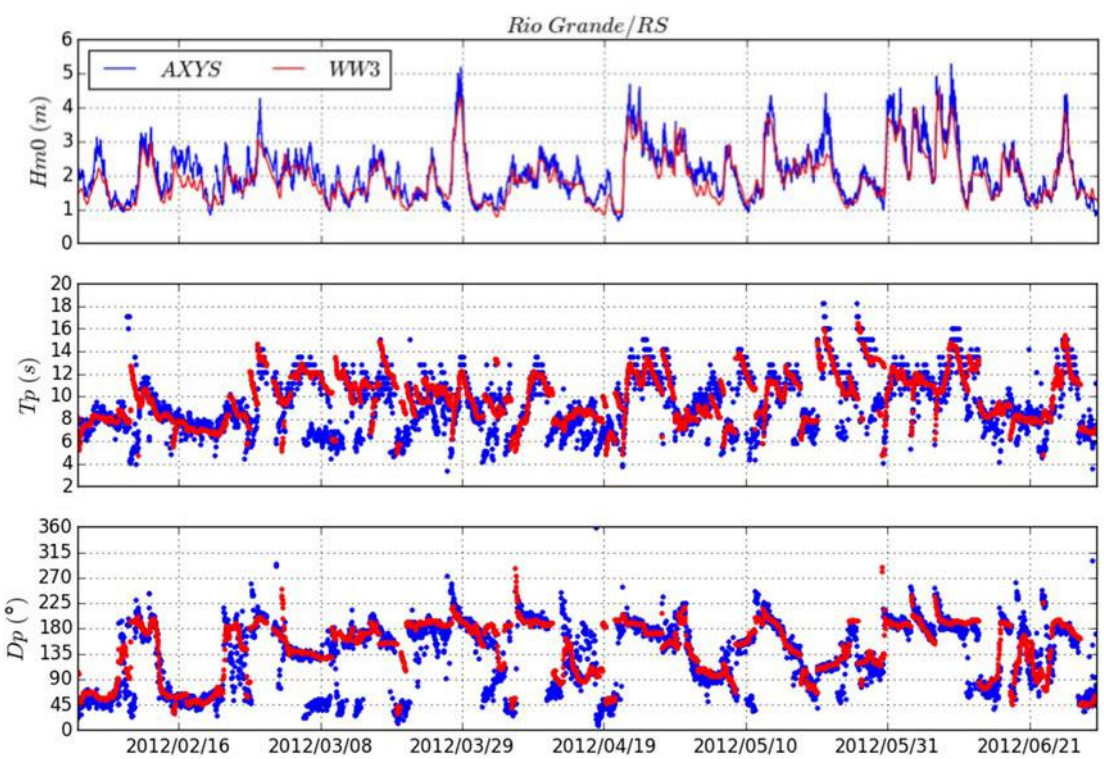

Figure 4 – Time series of zero-moment wave height H_{m0}, peak period T_p and peak direction D_p. (WW3 vs. Rio Grande buoy data).

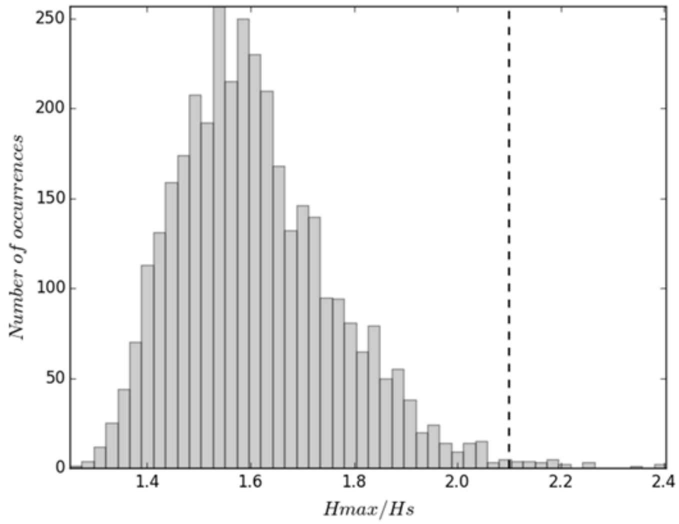

Figure 5 – Histogram for the ratio between maximum wave height (H_{max}) and significant wave height (H_S).

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Emergence of Short-Crestedness in Originally Unidirectional Nonlinear Waves – Revisited.

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Abstract.

Ocean waves forced by the wind are multi-directional, even if the wind direction is steady. Directionality can occur due to superposition of long-crested waves propagating at angle to each other. Lateral modulation of the wave crests, however, also takes place for strictly unidirectional waves, due to nonlinear effects. Here, short-crestedness of unidirectional waves is investigated. Two main laboratory experiments on the lateral instability of monochromatic, deep water, unidirectional, initially long-crested steep waves was performed in a large wave basin. The cross-modulation of wave crests is clearly visible, its magnitude depends on the wave steepness in the wave-propagation direction. Its spatial scale is comparable with the wavelength. Thus, short-crestedness is an inherent feature of nonlinear

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waves and should be taken into account when estimating directional properties of ocean waves.

SPECTRUM OF WIND DRIVEN ROSSBY WAVES ON A NON LINEAR QG MODEL

Paulo S. Polito e Wandrey Watanabe

The energy introduced by the large scale wind stress curl and its annual fluctuation forces Rossby waves in the ocean, and those ultimately drive the tropical and subtropical circulation. To characterize the evolution of the power spectrum of this system, a three-layers, non linear, quasi-geostrophic model (Q-GCM) was forced with an idealized wind. Four experiments were conducted, varying (1) the value of the reduced gravity in the upper interface, and (2) the deformation radii. For each set-up an ensemble average of 40 runs was analysed.

Long Rossby waves of the first baroclinic mode are evident in the ensemble averages. They are deterministic: their phase depends on the phase of the annual cycle of the wind stress curl. Their dispersion relation matches that of linear waves. Shorter Rossby waves are present in the individual runs. They are chaotic in the sense that their phase is not determined by the wind variability. These are clearly identified in the dispersion relation as critical-frequency Rossby waves. Their group velocity is nearly zero, with westward phase propagation.

Wavelet analysis of the waves generated by the variable Rossby radius of deformation was performed at different longitudes and latitudes. Annual linear Rossby waves were dominant and nearly non-dispersive in the tropical region. They went across the basin with approximately the same power until they reached the western boundary current. In subtropical latitudes a significant dispersion started at approximately 500 km west of the boundary. At all latitudes the power of short, critical-frequency Rossby waves increased westward. This downscale energy transfer between annual and critical-latitude waves seems to be an intermediary step before the predominantly non-linear western boundary current region. In that region the power was spread to the whole spectrum, upscale and downscale.

Wave spectra partitioning and long term statistical distribution

Jesús Portilla-Yandún[1], Luigi Cavaleri[2]

Abstract

Detailed statistical knowledge of the ocean wave environment is of paramount importance for many research and engineering applications (e.g., navigation, off-shore engineering, structural design, climate assessment, sediment transport). Presently the 2D wave spectrum is the standard variable for wave description, but the statistical information therein present is generally not fully exploited. Instead, integrated parameters are still commonly used. Although these parameters provide a good account of the wave characteristics in cases of uni-modal seas, they fail to properly represent waves in more complex situations. The simultaneous existence of locally generated waves (wind-sea) and one or more swell systems, for instance, is a situation that occurs very often. Using only integrated parameters is therefore insufficient, imprecise, and often misleading.

Herein we describe a method to statistically describe wave spectra based on partitions of long series of 2D-wave
spectra. A spectral partition is understood conceptually as a part of the spectrum that physically corresponds to a system of waves originated from the same meteorological event. The underlying assumption in the present method is that at any specific site the long term occurrence of waves in the spectral domain is defined by external environmental conditions. For instance, in the open ocean the presence of remotely generated swells is a common characteristic, while this condition can hardly be found in enclosed seas. Similarly, in the storm zones the presence of locally generated waves
can be expected whose characteristic follow certain patterns imposed by factors like the meteorological conditions, fetch dimension, coastal bathymetry and orography, among many others. These conditions define the long term wave spectral footprint, which is unique at every site. The purpose here is to characterize such a footprint in a statistical sense,
then showing how to exploit this information.

The ability of spectral indicators to summarize wave information while preserving the characteristics of wave systems allows us to engage into more intricate types of analysis, like for instance the spatial and temporal variations of wave systems. Moreover, other important analyses difficult to achieve in detail using only integrated parameters can be worked out in a more reliable way using spectral statistics. Some few applications that are worth mentioning, which are presently subject to ongoing work, are a) the definition of background errors in wave data assimilation systems, b) model evaluation at spectral level , c) selection of independente events for more accurate extreme valua analysis, d) wave climate patterns identification, among others.

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“Sensitivity of a spectral wave model to the nonlinear interactions”.

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Abstract

Extreme sea states present a threat to the North Sea offshore installations, such as oil and gas platforms and offshore wind farms, and a challenge to wave forecasting systems. In this paper, we study the ability of a 3rd generation spectral model to reproduce the extreme sea states. Measured and modelled times series and directional wave spectra are compared for a period in the winter of 2013-2014 where successive severe storms moved across the North Atlantic and the North Sea. The hindcast was performed with the WAVEWATCH III model (Tolman 2014) with high resolution in frequency, direction, time and space. Wave records from a Doppler radar and wave buoys were used to validate the wave model. An overall good agreement was obtained for integrated parameters, but discrepancies were found to occur in spectral shapes. This study highlights that the discrepancies between radar and model frequency spectra during the selected storms can be attributed to a slight shift of the spectral peaks and to an underestimation of the energy level at the frequency peak by the wave model. Hindcasts were conducted by using different methods for the computation of the nonlinear interactions: the discrete interaction approximation and the full Boltzmann integral. Differences at the spectral level will be presented and discussed.

Flow generated by surfaces waves

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Trajectories of fluid parcels on the surface have been described analytically for progressing irrotational waves, where particles move in the direction of wave propagation. Waves in the laboratory and in nature are more complex due to the development of instabilities that render ideal planar 2D propagating waves into complex
3D waves. The motion of particles in such waves is not well understood.

In this talk I will present experiments in the short wavelength gravity-capillary range that demonstrate the generation of surface flows by propagating waves driven by a vertically oscillating plunger. At low amplitude, in a quasi-linear wave regime, buoyant particle tracers move in the direction of the wave propagation. At high wave amplitude, modulation instability (or Benjamin-Feir instability) renders the planer wave front into wave packets. This affects the macroscopic flow such that floaters drift against the direction of the wave, towards the plunger wave source [1]. The role of surface vorticity generation by waves will be discussed.

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Current-Induced Dissipation in Spectral Wave Models

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Abstract

It is well known that spectral wave models fail to represent wave characteristics at strong negative current gradients. The poor representation of the spectral energy is tightly connected to the wave energy dissipation term currently employed by these models. Dissipation by breaking is calibrated to whitecapping in typical background conditions and overestimates wave heights at conditions of current-induced breaking. In this study, the currently implemented dissipation terms of spectral wave models are validated in conditions of strong currents. The data set used includes several acoustic wave and current sensors and a directional wave buoy, located along the Port Phillip bay entrance, Australia. All the main wave parameters are modulated at the tidal frequency due to the inversion of tidal currents. During ebb tides, the currents are opposing the wave propagation and a localized increase in wave height is observed over the tidal jet. To test the wave model's performance under such conditions, the Simulating WAves Nearshore (SWAN) is implemented. Input current fields are provided by the Delft3D model using surface elevation data of nearby stations as boundary conditions. Two dissipation terms currently implemented and available in SWAN are tested: the Komen and the Westhuysen terms. Additionally, we test a recent implementation of the new generation of physics-based dissipation terms (Rogers et al, 2012). The model performs well at flood and slack tides, but overestimates wave energy during ebb tides at the sensors located on the current jet. The physics-based term performs best at these conditions, however not satisfactorily. An alternative modification of this term is proposed, in which the dissipation rate is a function of the local currents. The proposed term aims to rapidly increase the dissipation rate when the relative shift of the intrinsic frequency due to currents is considerable. The modified term is tested and validated.

On the behavior of wave systems in the Eastern Equatorial Pacific under ENSO regime

Andrés Salazar, Jesús Portilla and Luigi Cavaleri

The analysis of the Earth climate is often complex because this includes several atmospheric and oceanographic processes that interact in ways not yet fully understood. Notably, the interaction of these two distinct fluids happens at the sea surface, where heat, momentum, moisture, and gases are exchanged. Therefore it is natural to expect ocean surface waves to play a major role in these processes and consequently to be a key component. From this point of view it essential to realize that these exchanges depend on the details of the wavy surface, details that are only poorly represented by the usual integrated parameters. In the present study we stress the value of the wave spectrum as the key information to use for any climatological study. This variable contains information about the surface energy distribution in space, and also in the frequency-direction domain. The advantage is that waves are the integrated effect of meteorological activity on the sea surface. Therefore they keep a longer memory of this activity, and also contain traceable information of events that occurred at remote locations. A methodology to derive spectral wave statistics has been proposed by Portilla et al., (2015). It is based on the concept of spectral partitioning, which is understood as an entity within the spectrum related to a single and independent meteorological event. With this approach it is possible to derive long-term spectral statistics that in turn are associated to particular climate patterns,
which can be analyzed separately. It turns out that at every specific site, these long-term spectral patterns are unique, being the result of the specific atmospheric and bathymetric conditions at the site. For the present study we use wave model data from the ECMWF ERA-Interim archive spanning 35 years. The study area is the Eastern Equatorial Pacific, a place dominated by long swells, but also influenced by the trade winds converging into that area from north and south because of its location in the Inter Tropical Convergence Zone. Particular attention is paid to the ENSO patterns, because of its great impact in the natural and socio-economic conditions of the region. We quantify the response of particular wave systems under ENSO conditions, from which a drastic decay of the southwesterly wave systems is notable. In addition, waves originated by the wind jets crossing the Central American isthmus are seen to take anomalous westerly directions.

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Geometry optimization of a wave energy point absorber for the Rio de Janeiro coast

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The proposed device for wave conversion in electricity is a bottom-mounted two-body point absorber that is designed for a site located near the Ilha Rasa Island in Rio de Janeiro. The bottom-mounted nearshore concept is chosen based on the site characteristics such as water depth, wave height and predominant periods, and seafloor bathymetry.

The geometry optimization process aiming at finding an optimal shape to a predefined wave climate condition, using the design of experiments (DOE) method, is applied. A simple linear damper model is employed to improve the power take-off (PTO) mechanism, and a latching control system is applied to adjust the system for the dominant sea states.

The optimization process is considered in two steps. Initially, the geometry of the passive system is determined, and then it is modified in the second step to work together with a latching control mechanism. The numerical models are developed using AQWA/ANSYS in the frequency domain. The MINITAB is used for applying the DOE method and MATLAB software supports the post-processing to calculate the mechanical power of the system.

Characterization of wave field evolution in a wind-wave tank under steady and unsteady wind forcing

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Wind velocity in nature varies both in magnitude and in direction, in time as well as in space. Spatial and temporal variability of wind forcing coupled with unsteadiness and inhomogeneity of wind waves in the ocean make acquiring quantitative statistical characterization of waves in field measurements extremely challenging. Results gained in field experiments inevitably exhibit considerable scatter. To gain better understanding of mechanisms leading to appearance and growth of wind-waves, laboratory experiments are thus indispensable. Although these experiments that are performed under controlled conditions offer clear advantages over field measurements, waves excited in any laboratory tank apparently are very different from those encountered in the ocean. Wavelengths even in the largest available facilities are shorter by orders of magnitude than those of typical sea waves. Ocean waves exhibit considerable angular spreading, whereas in wind-wave tanks such issues as the deviation of the wave propagation direction from that along the test section and the possible effect of side walls often do not attract sufficient attention. Young wind waves in laboratory are usually steeper than those in ocean; nonlinear effects that manifest themselves in numerous phenomena including wave breaking, Stokes drift current and frequency shift due to induced current, are thus more pronounced. Wind-waves in laboratory may contain considerable energy at wavelengths where the effects of capillarity become essential. Due to these and additional differences between water-waves in laboratory and in nature, the relevance of small-scale laboratory experiments to full-scale phenomena is often questioned.

In the present talk new results on temporal and spatial variation of wind-waves in a laboratory flume under steady and unsteady forcing are presented. Particular attention is given to the initial stages of wind-waves growth (in time as well as in space). An emphasis is made on examining the relevance of the results of this study to wind-waves in nature. Advantage is taken of the unique features of the experimental facility that include availability of diverse measuring techniques combined with an ability to carry out fully automated prolonged measurements under different forcing conditions without human intervention.[1,2] In addition to conventional wave gauges, independent measuring techniques such as point or scanning laser slope gauge and 3D reconstruction of stereo video images are applied. The laser slope gauge and 3D imaging results are used to extract spatial information on the evolving wind-wave field. These features facilitate accumulation of extensive data on the spatial evolution of statistical wave parameters for a variety of steady wind forcing conditions. At the next stage, extensive quantitative study of waves under unsteady forcing was carried out. In those experiments, numerous independent realizations of the wind-wave field were recorded under impulsive initiation of wind over water initially at rest, as well as after abrupt shut down of wind over an initially steady wind-wave field. Ensemble-averaged values of statistically significant parameters were calculated as a function of time elapsed since either initiation or shut-down of blowing. The transient results are discussed in relation to the local statistical parameters of wind-wave field under steady forcing accumulated in the present study, as well as in our earlier studies.[1,2] The obtained results enable offering a scenario for evolution of wind-waves in space and time under impulsive wind forcing.

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Swash Analysis and the Associated Beach Morphological Changes: an Infragravity Waves Approach

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The understanding of the swash processes is a current scientific research. Was verified that the hydrodynamic motions in coastal waters, like swash dynamics and alongshore currents, are most part of time dominated by long period waves, referred as infragravity waves ($f < 0.05$ Hz). Another interesting relationship to these waves are the features that are found at the nearshore zone, as the submerged sandbars and the beach cusps, once its length scales are very similar with the infragravity wave length. Thus, a better comprehension of this processes is of great significance. The infragravity waves dominate the swash motions in dissipative beaches as a result of a high dissipation area over the sand bars, where the waves break and consequently transfers energy from high frequency waves to infragravity ones. During 8 days, the swash was studied in Cassino Beach, a beach that fits with the definition of ultradissipative and dissipative states. Was seen that the infragravity band frequency of the runup elevations (Rig) dominates the swash zone reaching maximum and mean values of the significant runup elevations (Rs) of 97% and 92% respectively. The significant runup elevation (Rs) had a significant correlation with the significant incident waves (Hs) of $r = 0.78$, with a proportionality constant of 0.46Hs. The infragravity runup elevation (Rig) achieved a significant r of 0.79 and a proportionality constant of 0.45. The higher presence of incident frequencies on runup elevations (Rss) were obtained when the significant wave height were low, reaching a maximum of 35% of the significant runup elevation (Rs). The Rss was found to be saturated, which means that Rss do not increase with an increasing of Hs and the $f -$ slope rate decay for the saturated tail was f^{-3} . The infragravity frequencies spectrum were almost always white, without a predominant energy peak. The Iribarren number (ξ_0) was not seen to be able to parameterize the Rig/Hs as in other studies. This result could have two meanings: the ξ_0 range stays over the values that this relationship appears to change its behavior ($\xi_0 = 0.3$), or due to the Iribarren do not represents all the processes that are correlated with the presence of low frequencies band on the foreshore motions. A relationship between the variation of infragravity energy and the beach profile behavior was not clear, but the greater erosion patterns found here were associated with positive storm surges. Once the correlation between mean sea level and short-waves was insignificant, and that the runup spectrum at infragravity frequency bands are generally white, which means that an effective net sediment transport was not a consequence of the long period oscillations, the increasing of the incident frequency band (Rss) on the runup elevation (Rs) could be related with the beach profile erosion. The increasing of the incident runup energy on the positive storm surge events might be related with a decreasing of the probability of the waves break and thus less energy is transferred from incident frequencies to infragravity frequencies.

Reconstruction and Analysis of Wave Climate in Southern Brazil

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This paper presents the wave climate of southern Brazil for deep water (3000 m) and shallow water (17 m) at Tramandaí beach, based on two time series between 1997 and 2010, analyzed separately. The time series was obtained by reanalysis of data of the operational model NWW3 to deep water, and from this a hybrid methodology (statistical + dynamic) transfer (downscale) was applied, integrating numerical modeling of waves (dynamic) and mathematical tools (statistics) to reconstruct the full time series in the coastal area. The reconstruction methodology was validated by comparison with instrumented data measured in situ. The Delft3D-WAVE model used in numerical modeling of waves was also calibrated with instrumented data. Information on the wave regime in the southern Atlantic ocean is scarce and supported by observations of short periods only, and the only published work with long term observations refers to analyses performed on data from global reanalysis schemes. This work is unprecedented in the scale of the timeline that was analyzed, with a view to the rebuilding and subsequent analysis of a time series covering 14-yr for shallow waters offshore Brazil.

Wave Power Potential in Southern Brazil

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This paper presents the energy potential of waves in southern Brazil, in deep water (3000m) off the coast of Rio Grande do Sul state, in intermediate waters (17m), and shallow water (4.2m) in Praia Tramandaí, based on two distinct temporal series of fourteen (Jan / 1997-Dec / 2010), analyzed separately. The time series was obtained through data re-analysis of the operating model NWW3 (deep water), and from this was applied a hybrid methodology (Dynamic + statistics) transfer (downscale), integrating numerical modeling of waves (dynamic) and mathematical tools (statistics) to reconstruct the complete time series on the coast. The reconstruction methodology was validated by comparison with instrumented data measured in situ. Delft3D-WAVE model used in the numerical modeling of waves was also calibrated with instrumented data. Energy potential information of the waves in Brazil are limited, mainly generated by analysis of typical scenarios waves or isolated extreme events, not taking into consideration database exceed the period of one year. From the results obtained in this study it was established that there is energy dissipation along the propagation of waves on the Brazilian south platform, although the potential energy available for extraction remains significant, with 76.3 MW / m and 40.9 MW / m available per year in water intermediate and Tramandaí Beach, respectively.

Stereo video observations of short waves breaking modulated by longer waves

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Abstract

Ocean wave breaking plays an important role in marine environment systems and the atmosphere-oceans energy distribution. The entrainment of air bubbles is the main source of air–sea gas flux in the ocean and it provides an important contribution in term of aerosol as well as biological production in the ocean. Ocean wind waves can be highly random and the breaking distribution is regarded as strongly unpredictable. In deep water, the breaking process can be modulated by several nonlinear process, thus identifying the dominant system on individual breaking event can be a big challenge. Since the 60's, the breaking is mainly study in wave basins and laboratory controlled experiments. However, wave breaking in random ocean conditions is still poorly quantified and understood. Based on stereo video acquisition and image processing, this work aims to explore among other processes the role of short-scale wave breaking modulated by longer waves. The stereo video experiment was queried in 2013 from a research platform in depth of about 30 m and close to Katsiveli coast, Ukraine. Taking advantage of several image processing techniques, it is possible to identify the foam distribution both in space and time. Coupled with the stereo video data analysis it provides a proper estimation of the breaking over the 3D surface elevation $\zeta(x, y, t)$ and for a full three dimensional spectrum observation $E(k_x, k_y, f)$. So the application of different methods based on imaginary processing has been able to provide substantial and innovative data to look over ocean wave breaking properties.

Key notes: Stereo video; 3D spectrum; Modulation; Waves breaking

'WAVE DIFFRACTION AROUND ISLANDS FROM ERS-2 SAR IMAGES'

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This work investigates the effect of the Channel Islands, located in the North Pacific Ocean, off California, on swell attenuation. The determination of the spatial variation of waves around islands is an operationally complicated task, that demands a large number of in situ measurements. The use of satellite images with high spatial resolution, covering extensive areas, is an innovative approach. Spectral wave models commonly run by operational forecast centres do not compute diffraction directly, instead they use approximations to represent such variations. Here we present an attempt to quantify them. Employing a graphical tool to extract the wave spectrum from Synthetic Aperture Radar (SAR) images and also to isolate the different wave components (wind sea and swell), we select a low frequency system and analyse its spectral propagation. Directional spectra, from ERS-2 SAR images, are retrieved. Wave main parameters such as significant wave height, period, directional spreading and propagation direction were analysed for each image. Expressions are presented describing the energy level rise on the sheltered (in relation to swell propagation) side of the islands.

Resonant interaction of surface gravity waves under influence of external forcing

Takuji Waseda

The core of the third generation wave model is the resonant interactions among quartets of waves in a random directional wave field. Prior to the derivation of the nonlinear interaction source term by Hasselmann in 1962, Phillips discovered that four waves satisfying the resonant condition will slowly evolve in time and exchange energy among each other. When a slight mismatch from the resonant interaction is allowed, and when the resonance detuning annuls the amplitude dispersion, the modulational perturbation to the Stokes wave will grow exponentially in time, and the so-called Benjamin-Feir instability occurs. The BF instability is the key to understand the generation mechanism of the freak waves. In this study, we revisit the resonant interaction of surface gravity waves experimentally and numerically under influence of external forcing such as current and wind. In the first study, we show that the influence of random current field will suppress the resonant interaction of deterministic interaction among tertiary waves (Waseda et al. JFM 2016). Further analysis revealed that the random current field suppresses the development of high-frequency equilibrium tail of random directional waves (Rapizo et al. submitted). The second study shows that the influence of wind will enhance the dynamical cascade of resonant interaction of four waves, and as a result broaden the spectrum (Hirobe et al. to be submitted). For all these studies, the key is the resonance detuning due to external forcing, and up to this point, the seemingly complicated evolution of waves can be explained in the frame work of potential theory when the penalty of external forcing is given to the resonant detuning term.

Advantages of cloud computing for wave forecast systems

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One major drawback of weather forecast systems is the computational array needed. Normally, forecast agencies and companies use supercomputers networks in order to run Numerical Weather Prediction (NWP) models. However, the initial implementation costs and the logistic efforts to maintain these structures are very high. Moreover, regardless of the computer price, these servers need technical support, appropriate physical space and refrigeration, fast networks connections and efficient power supply.

With the development of cloud (or on-demanding) computing, it is nowadays possible to deploy and maintain a high performance server instance with very few effort. The increasing number of cloud-oriented technologies allows to build a network of remote high performance servers hosted on the cloud to process, store, and manage data more efficiently than on a local server or working station.

Even though the cost to deploy and implement/operate a cloud instance may overcome the price of a physical computer in long-term operations, the amount of resources saved in infrastructure and maintenance are an offset.

A great advantage is that most of the cloud computing providers offer a set of routines, protocols and Application Program Interfaces (APIs) to quickly build and manage new instances. These tools, associated with a framework of scripting languages, allow the dynamic creation (and destruction) of computing instances that are used to carry out several model runs over different (on-cloud) computing machines.

In this work we aim to present the advantages of cloud computing in a forecast company and how that could increase effectiveness.

Keywords: Waves forecast; APIs; Cloud computing; Multiples computer processing