Wave Attenuation on Muddy Bottoms – A Multidisciplinary Field Study Offshore Cassino Beach, Southern Brazil

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LONG-TERM GOALS

- To improve the understanding of the dynamics of shoaling waves and sediment transport in the coastal zone in areas with presence of significant cohesive sediment deposits.

- To improve the knowledge of the southern Brazil coastal water sediment and wave dynamics.

OBJECTIVES

- To characterize the wave attenuation over muddy bottoms, considering the geotechnical and rheological properties of the deposits.

- To evaluate the performance of wave transformation models over heterogeneous beds.

- To evaluate the behavior of the lutocline formed under wave action and the importance of wave-associated sediment transport.

APPROACH

A field experiment was performed offshore Cassino Beach, Southern Brazil. In this area mud deposits were observed, mainly originated from the Patos Lagoon. Episodically, and associated with storm waves able to transport the mud from offshore to the beach, the usual sandy beach is covered by mud. This is a unique process along the Brazilian coastline, and the field experiment aimed to record the event of mud ressuspension and onshore transport measuring the waves, near-bottom currents, concentration of suspended sediments, and changes in the characteristics of bottom sediments. The experiment occurred in May-June 2005, as the record of previous events indicate is the time of the highest probability of offshore mud to be transported onshore due to higher wave energy. Unfortunately the last event of mud deposit on the beach occurred in November 2004 (Figure 1). However, the collected data set is still valuable and will help to a better understanding of waves transformation in the inner shelf and nearshore. A major issue that might restrict data analysis was the loss of equipment due to the strong fishing activity in the area. A summary of the field experiment achievements is described in this report.

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Figure 1: A fluid mud event occurred in Cassino beach on November 12, 2004 (2 top pictures). The 2 lower pictures show the beach-face 3 days after the event. Pictures a, b and d looking seaward, c is looking landward. Photos by: M. Aline Lisniowski (a,b) and Luciana S. Esteves (c,d).

RESULTS

Introduction

The field work consisted in the characterization of the deposit, wave measurements along the mud deposit, current and SSC measurements in the near bottom in the mud deposit, and a nearshore study. This nearshore study, not supported by this Grant, consisted in observations of waves and currents using Argus and X-band radar systems, beach and nearshore bathymetry, recording of bedforms evolution using a ripple profiler, and measurements of waves (pressure and PUV sensors), currents and SSC in the surf-zone.

Main forcings in the system

The hydrodynamic of the Patos Lagoon and the inner continental shelf is mainly forced by meteorological effect. The average astronomical tidal amplitude is about 0.5 m with a dominant O_1 diurnal component. Freshwater discharges play an important role on the system hydrodynamics. Local and remote winds generate water level oscillations of periods ranging from 3 to 5 days (Figure 2).

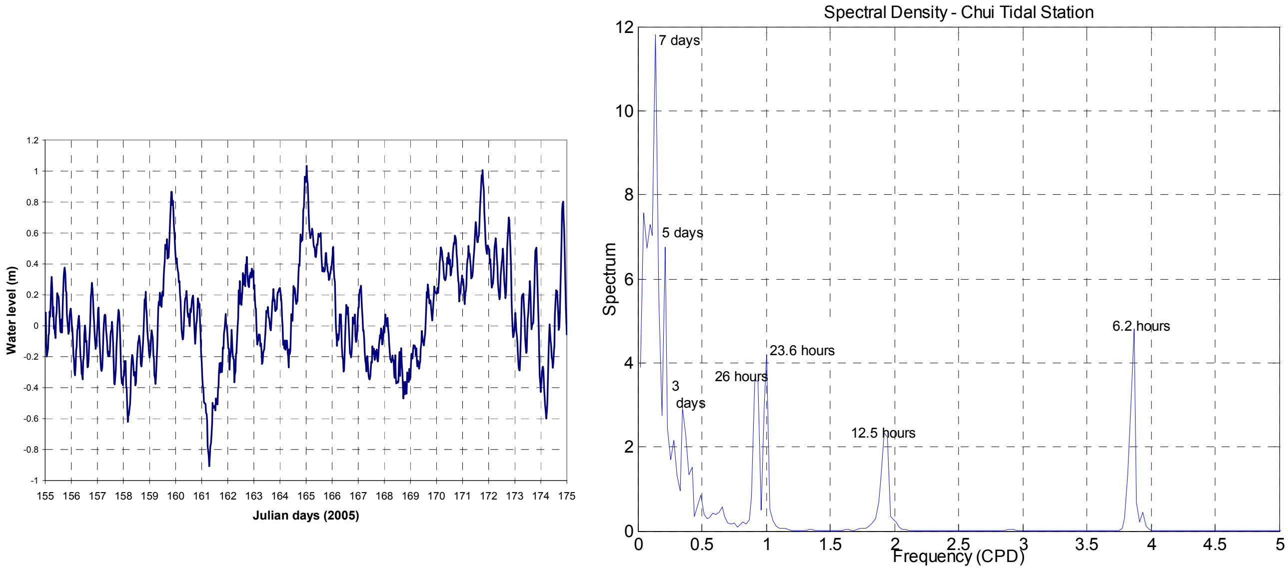


Figure 2: Measured values and and spectrum of the water level at Chuí coastal station (~ 200km south from Cassino)

To establish the influence of tides, meteorological forcing, freshwater discharge in the general circulation in the coast and the sediment exchange between the Lagoon and the coastal area, and ultimate in the formation of the mud deposit, several modeling approaches are being carried out. The data base is gathered from previous measurements and some of the measurements during this experiment. Water levels, measured at three stations over the coast, are one of the data set collected for this purpose.

The axis of the Lagoon and the coast orientation are northeast-southwest (NE-SW). The most frequent winds in the area, NE quadrant winds, cause set-up at the mouth of the lagoon and set-down in the coastal waters. Thus, a pressure gradient between them is created, driving currents outwards the lagoon and a large amount of sediments are exported to the shelf, transported southwards by the wind-driven currents, as illustrated in the simulations of Figure 3.

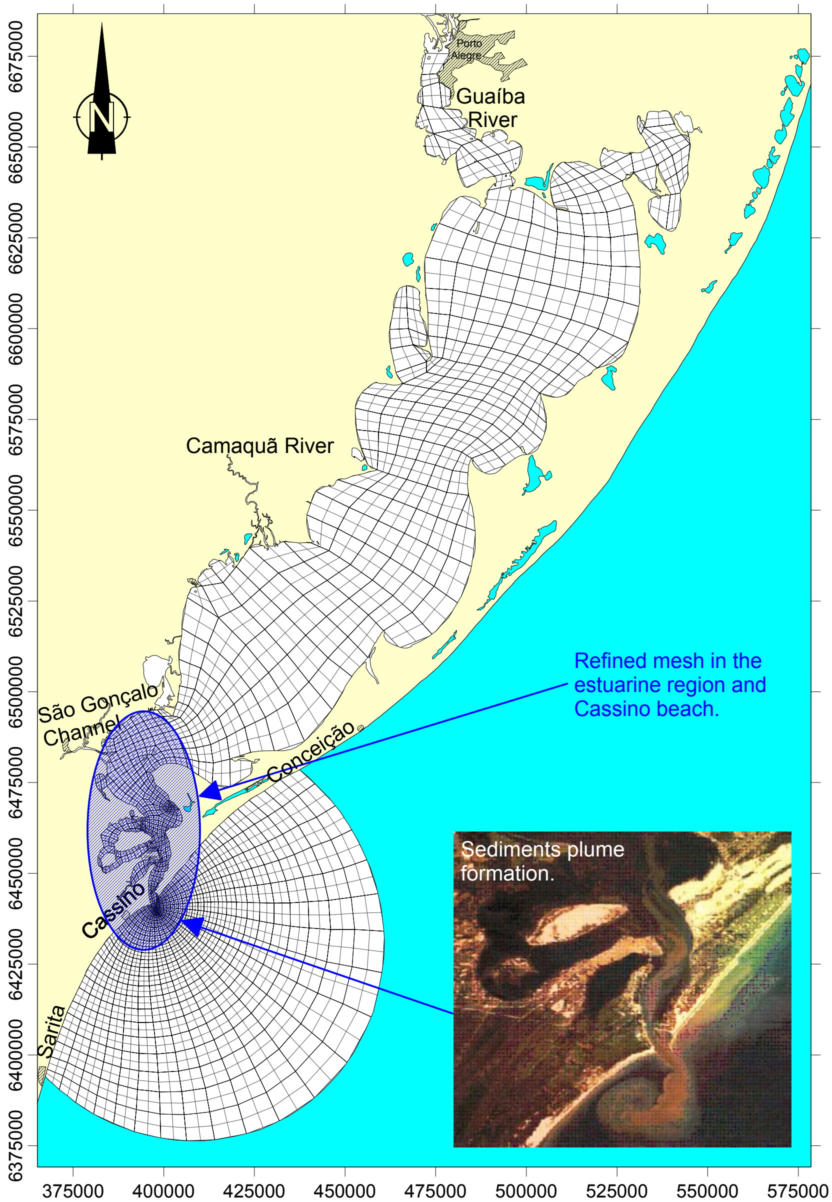


Figure 3a: Finite element mesh for the 2DH hydrodynamic model: dos Patos Lagoon and adjacent coastal area.

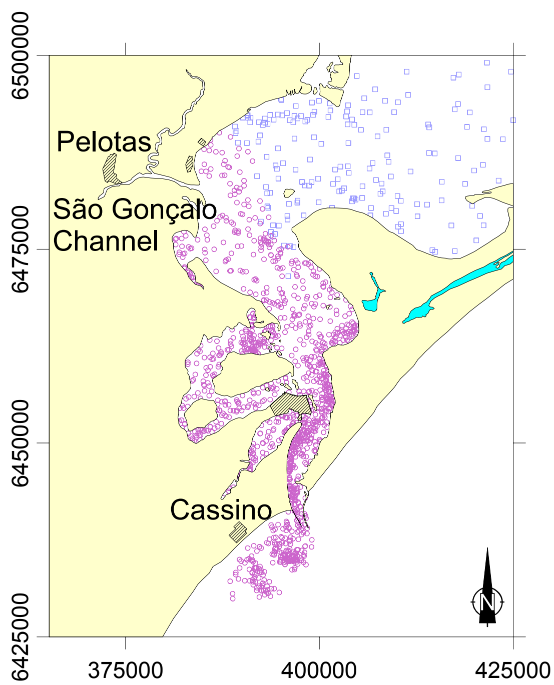


Figure 3b: Simulated typical sediment transport pattern for moderate north wind (5-8m/s) and low fresh

Characterization of the mud deposit

The composition of the mud in Cassino was obtained by X-ray diffractometry, and showed that the most abundant components found in the < 2µm size fraction, in decreasing order, were smectite (37-43%), illite (32-36%) and kaolinite (14-23%), which together with quartz (1-3%) were found in all samples. Gypsum and chlorite were identified in only a few samples ranging, respectively, between 7-12% and 1-3%. The high content of smectite confers high cohesiveness to the material, expressed by the high cation exchange capacity, which ranged between 74,3 to 169,2 meq/100g.

Rheometric properties of the mud, were determined using a coaxial rheometer (Brookfield Engineering), with CC45 spindle, in a controlled temperature of 26.5 ^{o}C, increasing the applied shear stress. Figure 4 shows an example of the behavior of shear, strain rate and apparent viscosity.

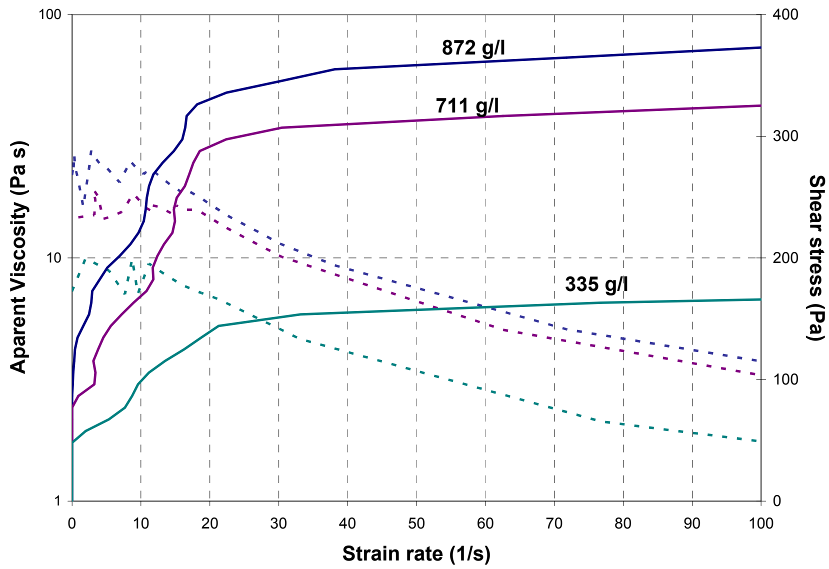


Figure 4: Rheologic behavior of mud from Cassino for different concentrations.

Table 1 show results of the geotechnical properties of the mud in one of the cores taken at 10m depth. The three sub-samples, A, B, and C, of about 20cm each, show high liquidity index, typical of a viscous behavior of the material.

Table 1: Main properties of mud in core taken at 10m depth, in front of Cassino beach.

Samples	Physical Index						Atterberg Limits			Liquidity Index	Grain size analysi		
	W (%)	S (%)	γs (kN/m^3)	γ (kN/m^3)	e	n (%)	wL (%)	wP (%)	PI (%)	I_L	Sand (%)	Silt (%)	Clay (%)
T17-A	217	100	24,00	12,40	5,42	84,50	146	59	87	1,82	9	22	69
T17-B	166	100	25,80	12,80	4,28	78,15	137	46	91	2,32	15	21	64
T17-C	188	100	27,80	12,80	5,22	84,02	122	40	82	1,80	20	17	63

The extension of the mud deposit was first surveyed using seismic and sediment sampling in October 2004. In this opportunity only the echosounder of 210kHz worked properly and the records exhibited a double signal in some areas, as shown in the example of Figure 5. Based on the thickness of the double signal observed in the records, the map of Figure 4 was obtained. The use of the 210kHz echosounder to determine thickness of the fluid mud was controversial, as many participants considered the data only qualitative. In fact, in the nearshore surveys the same pattern was observed when the bottom changed from sandy to muddy, as illustrated in Figure 6.

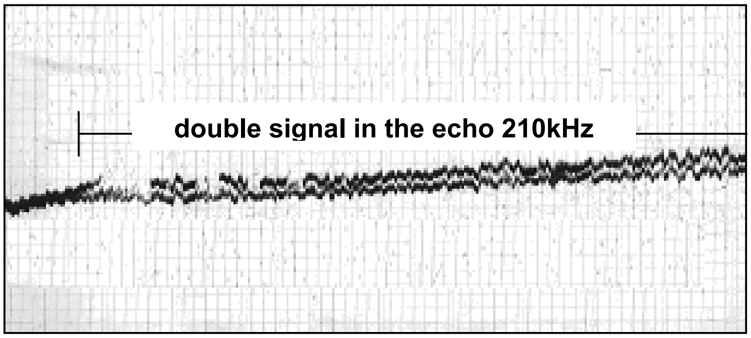


Figure 5: Double signal in echo sounder 210kHz

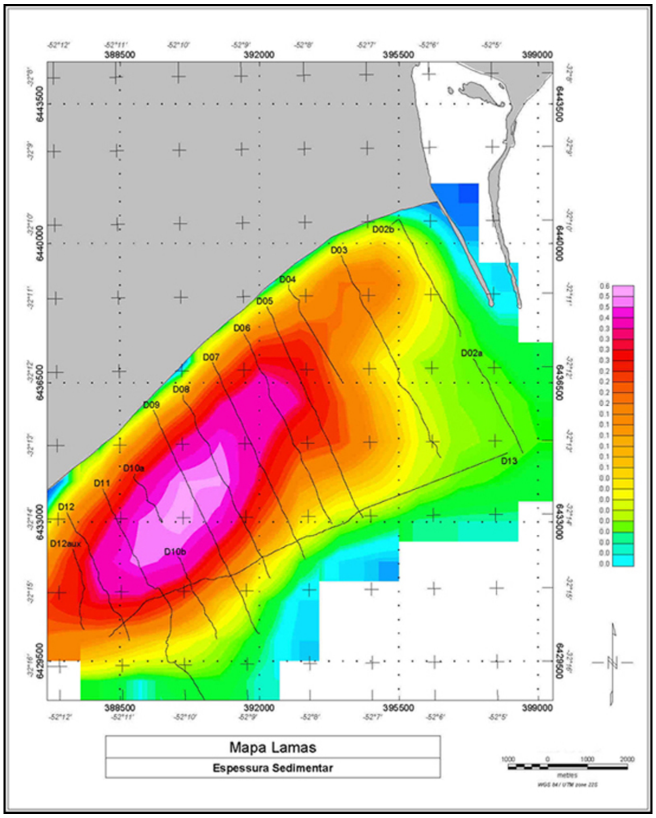


Figure 6: Map of thickness of the double signal in echo 210kHz

In March 2005, a new survey using double frequency echo sounder 33 and 210 kHz was also done in the transects indicated in Figure 7b. Figure 7a shows the differences in heights between both signals, after smoothing, for transect A. The results were not consistent with the cores and bottom surface samples and thus not considered conclusive regarding the extension of the mud deposit.

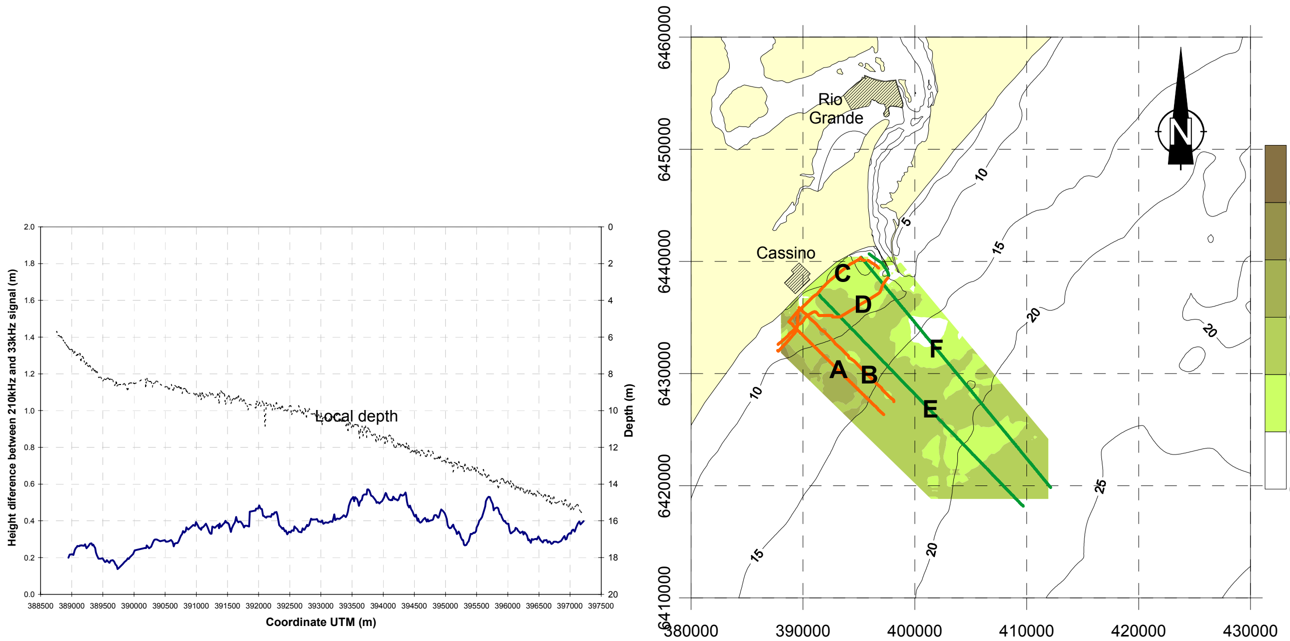


Figure 7: (a) Example of the height differences between the signals 33 and 210 kHz echo sounder, for transect A. The local depth is also indicated. (b) Map of the differences indicated in (a) for the double frequency survey.

In 2005, grain size analysis of bottom sediment samples showed that the mud deposit was located between the depths of 9 m and 15 m. The grain size distribution of these samples showed from 75% to 100% of mud (silt + clay), with the clay size fraction comprising 25% to 59% of the sample. Samples were classified from coarse clay to fine silt, with D50 varying from 0.0028 mm to 0.011 mm (6.6 to 8.5Φ). Grain size of samples collected at depths shallower than 9 m, were comprised of 100% sand and were classified as fine sands with D50 around 0.11 mm (from 3.18 to 3.3Φ). Samples collected at depths deeper than 20 m, were classified as fine to very fine sands with D50 varying from 0.1 mm to 0.138 mm (2.85 to 3.3Φ). Such samples have from 3% to 21% of mud, with maximum of 6.2% of clay size particles.

Transparent cores have been used to sample the fluid mud. Immediately after the diver took the core, it was raised to the boat and sampled every 10cm, as shown in Figure 8. It was observed a sharp interface in the sediment suspension, indicative of the presence of a lutocline. The cores were collected manually, by divers. The height of the lutocline depended on the thickness of the mud able to sample. At the 12m station, where the mud deposit was thicker, the height of the lutocline was about ~1m from the hard bottom. At the 9m station it was ~0.5m. Below this level, sand was found.

Figure 8: Core taken at 12m station, and sampling procedure.

Wave, currents and turbidity measurements

Figure 9, shows the location of the mud patch, as indicated by the surface and core samples, and the location of the instruments. Three stations where instrumented in a transect through the mud deposit. One offshore, with a wave-rider measurement, located at 25m depth, which provides the wave entering the system. An intermediate, at 12 m depth, and the last one near the shore border of the mud patch, at 9m depth. Due to the high fishing activity it wasn't possible to implement a fourth station, as planned, which would be located at the off-shore border of the mud patch. In the station of 12m depth, an ADV measured currents at 1.5m from the bottom. In the station at 9m depth, waves and currents were measured with a NDP (Acoustic Doppler Profiler), and an ADV located 70cm from the bottom. At this station an array of 6 turbidimeters and an altimeter were deployed. Aiming to compare the wave attenuation through the muddy and sandy bottom, an ADV was deployed outside the mud deposit. Unfortunately the instrument was lost.

Two questions were formulated to be answered with the results of this experiment. One is related to the wave attenuation and its relationship with the mud deposit and ressuspension, and the second is related to the movement of the mud. Figure 10 shows some of the data collected (significant wave height at 25m and 9 m stations and one of the turbidimeter ouputs), highlighting some of the processes occurring over the Shelf. One day period is evident in the turbidity signal during low energy wave periods with strong ressuspension associated to the wave energy rising. A preliminary estimated value of the wave height at 9m depth station, considering the wave propagation from 25m depth after shoaling and rigid-bottom friction dissipation, super-estimates the wave height in 40 to 100% of the measured wave height values. It is hypothesized here that this is explained by the contribution of the mud bottom and must be accounted for differently than as the attenuation due to rigid-bottom. As mentioned, unfortunately, during the observation period no events of mud migration to the beach occurred. However, the measurements of the currents in the vertical profile and at a specific location near the bottom, together with turbidity measurements, may highlight the mechanisms for the movement of the mud under the different hydrodynamic forcings. For example, Figure 11 shows one sample of the velocity measurements near the bottom at the 9m station with a resultant towards the coast. Further analysis is needed to stress which mechanisms are responsible for the movement of the mud, in order to conclude about why the fine sediments accumulate in this mud deposit and under which conditions it migrates to the beach.

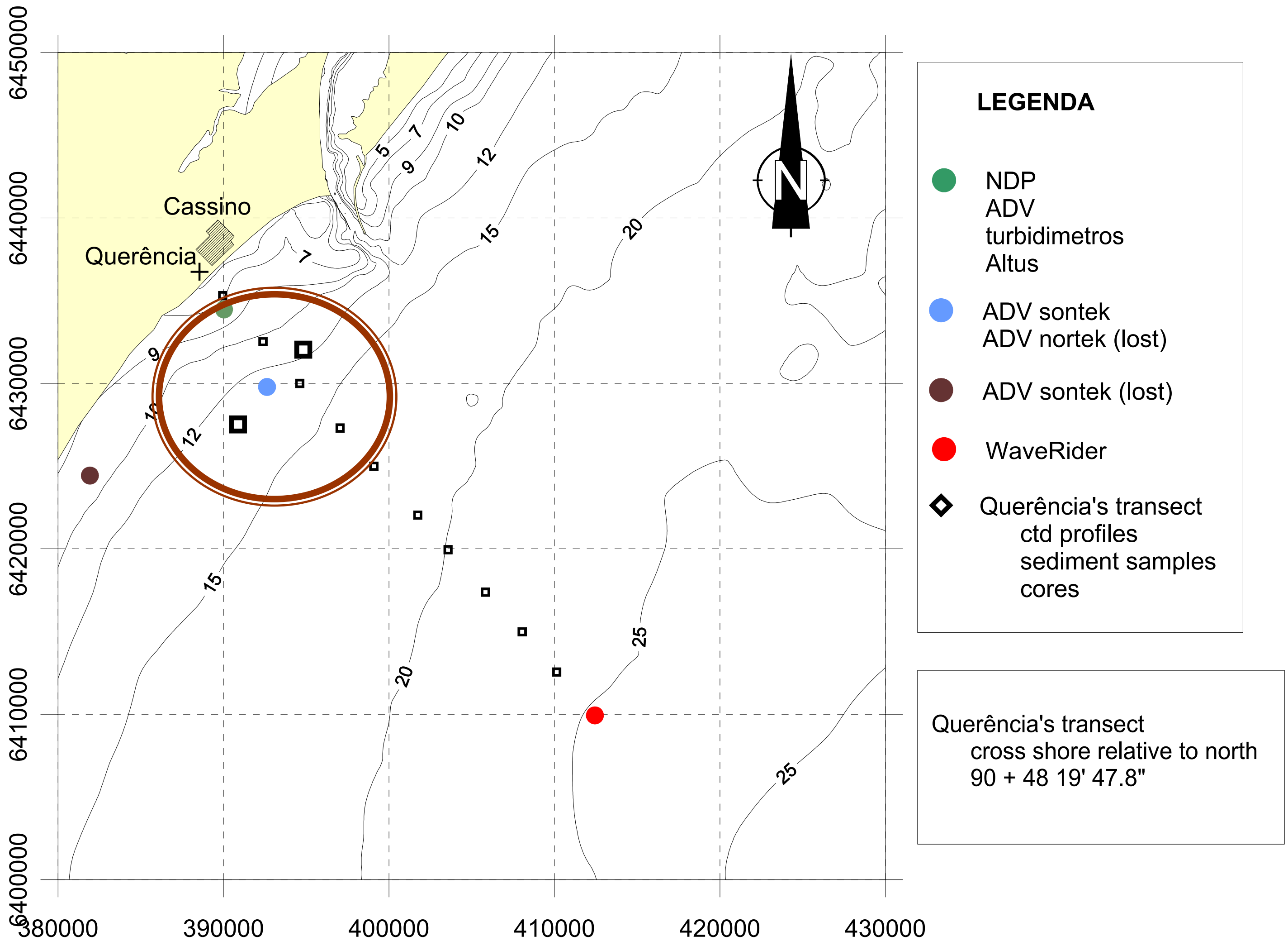


Figure 9: Bathymetry and instruments deployed in the experiment

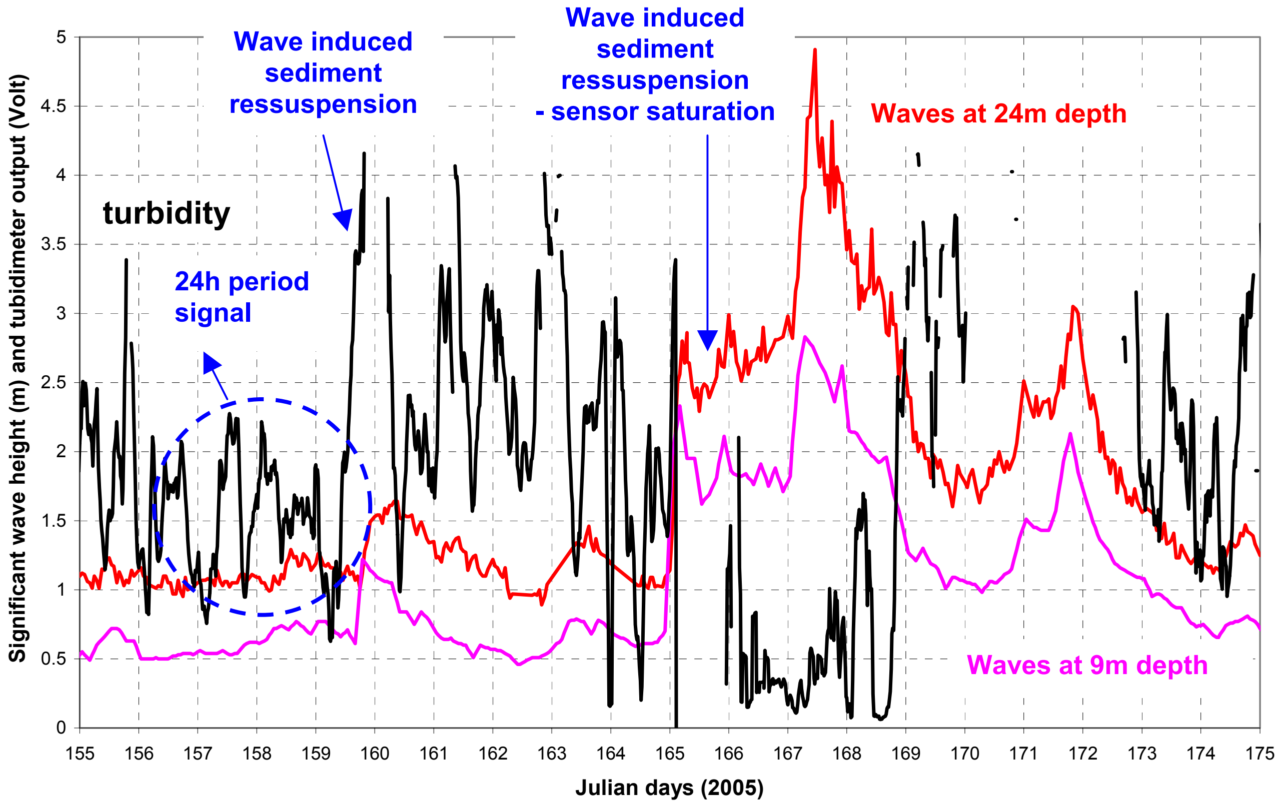


Figure 10: Significant wave height along the mud deposit and signal of turbidimeters. It is observed larger wave attenuation than could be expected for a rigid bottom and strong sediment ressuspension (indicated by the saturation of the sensors) associated to the increase in the wave energy.

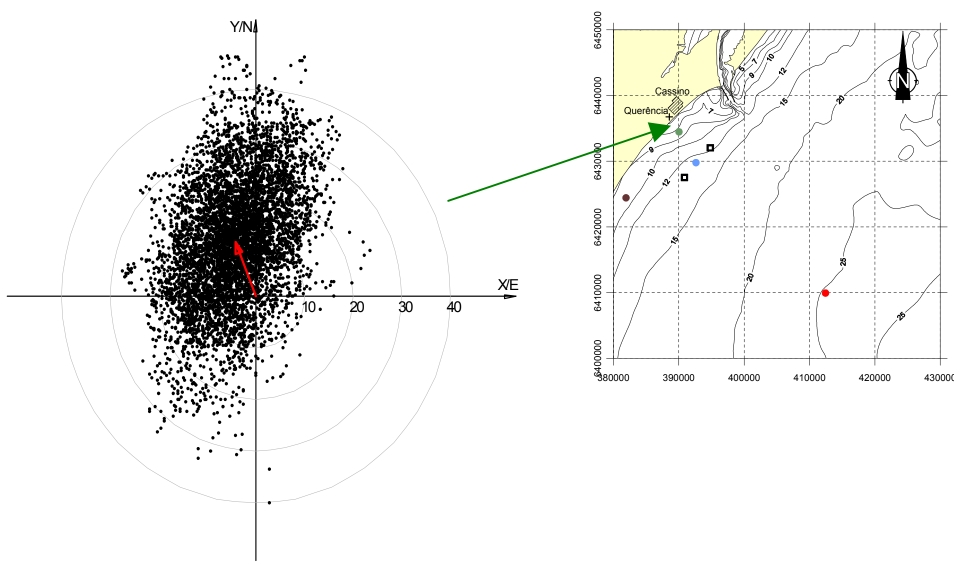


Figure 11: Scattering diagram of near bottom velocities at 9m depth station of one single record.

COLLABORATIVE PROJECTS IN THE CASSINO SHORE ZONE AREA

- **Argus Station and Shallow Water Bathymetry Surveys**

Cassino Beach area is a heterogeneous environment, and variable sediment properties are critically important to both hydrodnamics and morphodynamics. A video monitoring equipment and in-situ instrumentation has been installed to measure the temporal aspects and spatial extent of the surf zone wave damping by the mud.

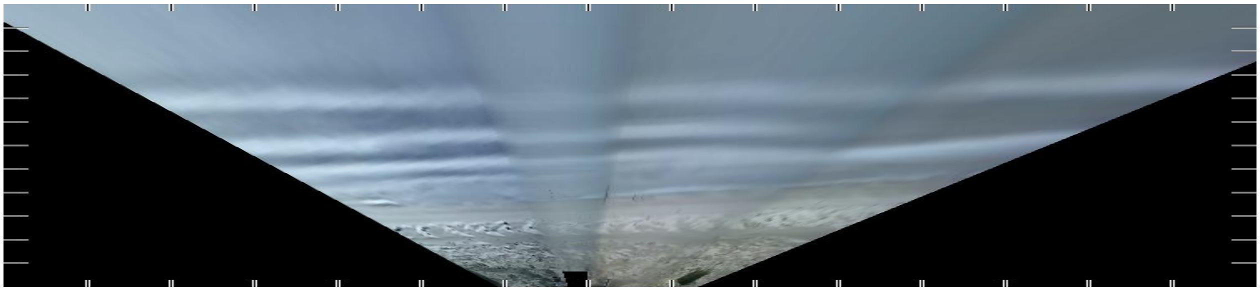
A video imaging system for monitoring nearshore processes (Holland et al. 1997) was installed at Querencia in April 2005. This system (developed in association with the Coastal Imaging Laboratory at Oregon State University) records snapshot and time exposure imagery from four cameras covering 750 m in the alongshore. Estimates of surf conditions, breaker height, period and direction are also made on an hourly interval. In addition, alongshore currents and bathymetry are inferred from pixel time series measured along a cross-shore profile. These long term measurements are critical for determining the response of the beach to mud events.

A recording fathometer was installed on a jet-ski survey system to provide measurements of nearshore bathymetry over the study region. This system utilizes kinematic GPS and acoustic measurements of depth to determine sandbars and the coastal bathymetric surface in a manner similar to Dugan et al. 2001. In addition to bathymetry, the dual frequency 50-/200 KHz system also can be used to estimate the location of differences in the acoustic return that are consistent with changes in sediment properties. These measurements (made over 3 km x 3 km region) indicated a small mud patch in the nearshore approximately 1 km offshore of the surf zone.

Holland, K.T., Holman, R.A., Lippmann, T.C., Stanley, J. and Plant, N., 1997. Practical use of video imagery in nearshore oceanographic field studies. *IEEE Journal of Oceanic Engineering*, 22(1): 81-92.

J.P. Dugan,a W.D. Morris,a K.C. Vierra,a C.C. Piotrowski,a G.J. Farruggia,a and D.C. Campiona, Jetski-Based Nearshore Bathymetric and Current Survey System, *Journal of Coastal Research*: Vol. 17, No. 4, pp. 900–908. 2001.

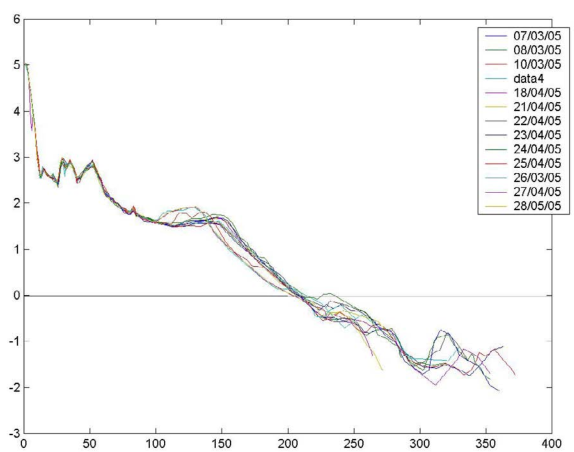
Tower with video-cameras



180º Offshore Looking Plan View (south to the left)
Merged view is 750 m in the longshore (tick spacing 50 m) and 600 m in the cross-shore.
Seam lines demarcate the visual footprint for each camera view.

Instrumented Jet-ski for nearshore surveying

Instruments for beach profile measurement and evolution of the beach and nearshore surveying



- **X-Band Radar**

Figure 1. X-band radar installed in the Cassino, Brazil (pointed by arrow).

A standard marine X-band radar is used to produce images of the sea surface to obtain wave data (e.g. wave number, period, and direction) that also can be used to estimate the nearshore and surfzone bathymetry. The X-band radar installed in Cassino Beach belongs to the Proudman Oceanographic Laboratory (UK) that is contributing to the Cassino Experiment also with other instruments, such as the millimetre wave-band radar and the ripple profiler. The X-band radar was installed in Cassino behind the dunes on the grounds of the Aquaculture Marine Station (EMA) of the Fundação Universidade do Rio Grande (FURG) at the top of a 6-m high scaffold tower (Figure 1). More than 400 h of data was collected during the field experiment from April 8, 2005 (when it was installed) to July 30, 2005 (when it was removed).

A sequence of radar images was recorded at intervals corresponding to the antenna rotation rate of about 2.4 seconds. For the Cassino Experiment, the X-band radar was set to record 256 images in a 10-minute interval every hour, starting to record at the beginning of the hour. The X-band radar collected information of waves in a 4-km range as can be seen in figure 2. Forecast of wave heights for deep waters (NOAA WWatch) during most of the experiment is presented in figure 3. Differences in wave conditions from snapshots shown in figure 2 can be observed in figure 3. A more detailed image showing a range of 1.5 km around the X-band radar allows identification of individual waves at the nearshore and surf zone, the shoreline, and other features on the beach (Figure 4). Dark regions correspond to strong radar echos and are identified in the image.

Mean images of the 10-minute recording were produced to enhance strong reflection features such as breaking waves. The average images can be used to identify areas where waves are breaking, which are related to the location of submerged sand bars. As a result, the movement and morphological evolution of the sand bars can be followed through time.

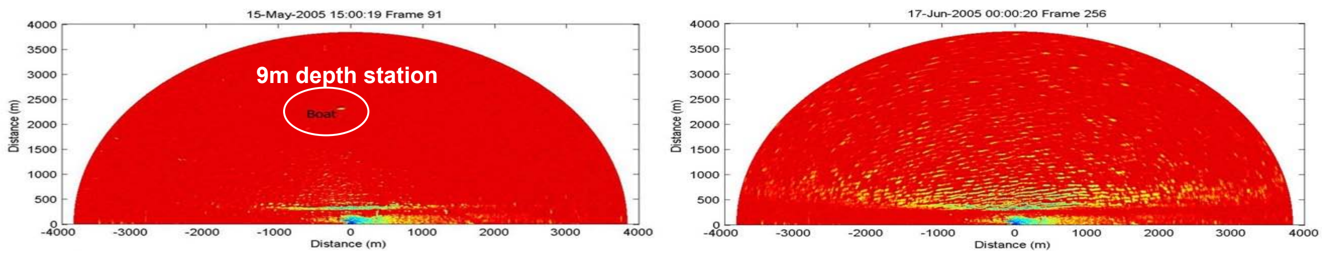


Figure 2. X-band radar images showing calm wave conditions (left) and storm conditions. The radar position is marked by the dark blue color at 0 m distance, bright blue and yellow are strong reflections and identify wave crests. In the left figure, the position of the boat used to deploy the ADV/ADCP close to the inner margin of the mud deposit is identified. The instrumented 9m station is in the coverage area.

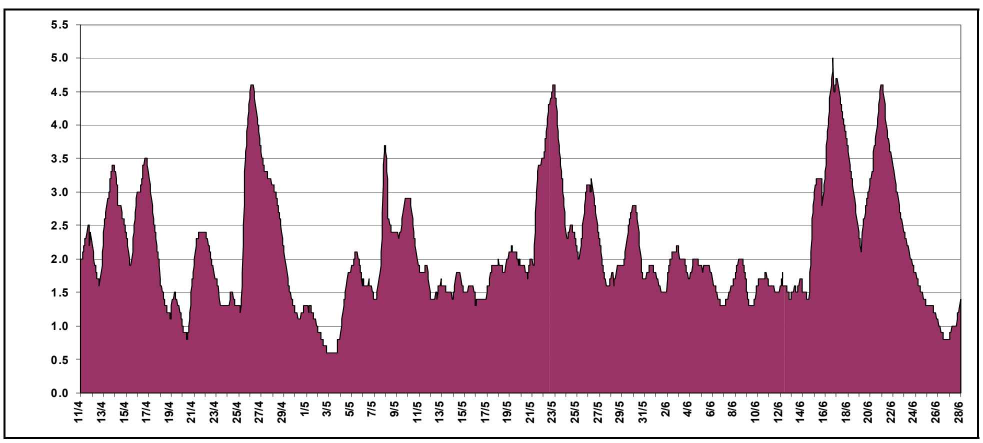


Figure 3. Forecast of wave heights for deep waters adjacent to Cassino Beach obtained from NOAA WWatch for the time interval of the Cassino Experiment.

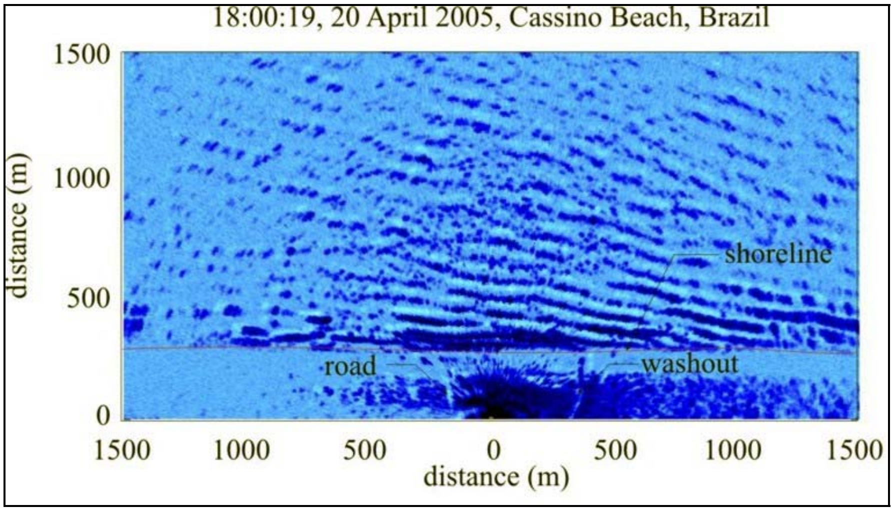


Figure 4. Detail of a X-band radar image showing waves at the surf zone and nearshore and other features at the beach (as labeled). The dark blue identifies strong reflection and the associated white areas are their shadows.

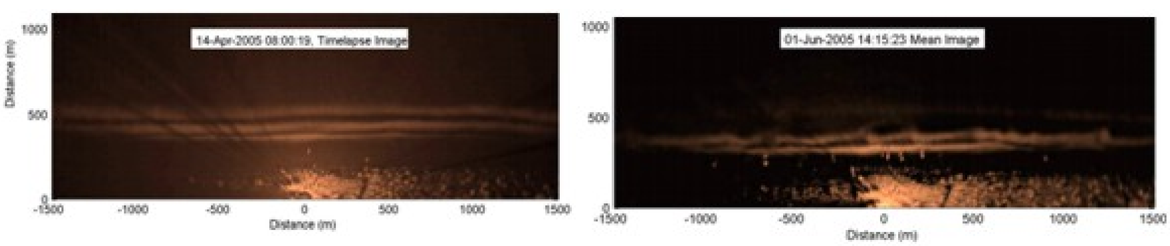


Figure 3. Mean images of two 10-minute sets, showing different morphology of the sandy bars.

The analysis of the radar images consists of several steps, including:

- Conversion from the polar coordinates in which the data is recorded to a georeferenced Cartesian grid.

- A Fourier transform is applied to each pixel through time in the sequence of images to isolate individual wave frequencies.

- All images recorded in a 10-minute interval are averaged to cancel out noise signals and enhance persistent targets, as seen in figure 5.

- Wave and bathymetry: The image sequences can be analyzed to produce maps of wavelength, celerity (wave speed) and direction. The changes in the wave behavior caused by shoaling as the waves move into shallow water are used in a wave inversion algorithm to produce an estimated map of the water depth causing that wave behaviour. Bathymetric maps can be produced, as presented in figure 6.

The products that can be obtained from the X-band radar data are:

- Two-dimensional wave spectra.

- Wave transformation over heterogeneous bottoms: The radar data is useful to help interpolate wave conditions in areas between measurements were obtained.

- Bathymetric maps.

- Changes in the morphology of sandy bars in the surf zone during the passage of storms: the radar images show the evolution of surf zone bars and can help quantify sediment transport during storms.

RELATED ARTICLES

Bell, P.S., 1999. Shallow water bathymetry derived from an analysis of X-band marine radar images of waves. Coastal Engineering, 37(3-4): 513-527.

Bell, P.S.; Williams, J.J.; Clark, S.; Morris, B.D. & Vila-Concejo, A., 2004. Nested radar systems for remote coastal observations. Journal of Coastal Research, SI 39 (Proceedings of the ICS 2004): in press.

Borge, R.-C.N.; Reichert, K. & Dittmer, J., 1999. Use of marine radar as a wave monitoring instrument. Coastal Engineering, 37(3-4): 331-342.

Wolf, J. & Bell, P.S., 2001. Waves at Holderness from X-band radar. Coastal Engineering, 43: 247-263.

- **MUDEX Project**

The experimental objectives are to measure directional wave spectral transformation over heterogeneous sediments, to determine dissipation due to wave interaction with a muddy bottom, and to measure longshore currents and sediment transport. To meet these objectives, waves and velocities were measured in two cross-shore arrays transecting the surf zone, one transect within the muddy region and a second, simplified transect over the homogeneous sandy beach outside the muddy region. The surf zone array is located shoreward of the offshore wave array installed by the offshore group so wave transformation can be studied from deep water through the surf zone.

Deploying instrumented tower in the surf-zone

SYMPOSIUM

In order to discuss the results of the project a symposium is being organized. The first announcement below was given at INTERCOH 2005, the 8th International Conference on Cohesive Sediment Transport, held in Saga, Japan, 20-23 September 2005.

First announcement for
International Symposium on the Dynamics of Muddy Coastal Areas
November 13-17, 2006
Porto Alegre, Brazil

Scope:

Mud deposits are found in coastal areas throughout the world. The deposits may stay permanently submerged, may migrate eventually to the coast or may form mud beaches. Mud coasts can be found from (semi-)arctic environments, such as found in Alaska, to temperate climate zones, as in North-West Europe, to tropical environments, as in Brazil. These environments yield permafrost mud deposits, salt marshes, and mangrove, respectively. Muddy coasts have very important ecological functions, as their biological production is high and they form nurseries for many species. Moreover, mud deposits in coastal areas often form important natural sea defenses as the mud damps waves efficiently.

Though mud coasts are fairly resilient to natural forces, today they are under great pressure as a result of human exploitation, agriculture, pollution or just poor management. Proper measures for maintenance, mitigation and compensation are difficult to design as our knowledge on the functioning of these systems is still poorly developed.

The 2006 International Symposium is meant to advance our understanding of the physical aspects of the dynamics of mud deposits in coastal areas. We aim to host a meeting of no more than about 80 scientists, so no parallel sessions are necessary and ample time for discussion is available. Some of the more pertinent scientific topics of interest include nearshore hydrodynamics, geomorphology, sediment transport, and coastal erosion. The symposium will be integrated with the final workshop of the Cassino Beach project.

The Cassino Beach project is a multi-national project in the southern part of Brazil, near Rio Grande and Porto Alegre, in which scientists from Brazil, USA, UK and the Netherlands are cooperating. The study is financed largely by the US Office of Naval Research and the Naval Research Laboratory. The aim of the study is to understand the mechanisms that drive episodic mud bank attachments to the sandy shore, and the interaction of these banks with the flow and waves. The study contains a field campaign, analysis, and numerical modeling.

Time schedule:

September 2005	first announcement
December 2005	second, final announcement; launching of symposium web-site
March 31, 2006	deadline for submitting abstracts
June 30, 2006	notification of acceptance of abstracts
November 13-17, 2006	international symposium
February 28, 2007	deadline for submitting manuscripts

Proceedings

The proceedings of the conference will be published in a special issue of a well-known journal. All manuscripts submitted will be reviewed by at least two independent reviewers. Final editing will be done by Prof. Susana Vinzon, Dr. Todd Holland and Dr. Han Winterwerp.

Scientific Committee

The following Scientific Committee has been appointed. This committee is responsible for the scientific quality of the symposium contributions:

Prof. Lauro Caliari (FURG, Brazil)

Dr. Elisa Fernandez (FURG, Brazil)

Dr. Todd Holland (NRL, USA)

Prof. Ed Thornton (Naval Postgraduate School, USA)

Prof. Susana Vinzon (chair, UFRJ, Brazil)

Dr. Han Winterwerp (Delft Hydraulics, Netherlands)

PUBLICATION PLAN

The results of the project will be published in the proceedings of the Symposium according the following plan:

Title: The "Facies Patos".An overview of the nearshore and inner shelf sediment deposits and its effect in the coastal zone adjacent to the Patos Lagoon estuary.

Summary: This paper presents an update of the sedimentology and recent processes associated with the deposition of fine sediments on the inner shelf and shoreface of the area of influence of the Patos Lagoon. Previous and new data related to bottom types found in the area. (grab samples) as well as core samples in terms of sand/silt/clay ratio are gathered in order to characterize the vertical sedimentary features of the shoreface, and inner shelf. Bathymetry and seismic interpretation of the echosounder and shallow seismic records as well analysis of the "equilibrium profiles" prior obtained for the inner shelf adjacent to the area. Review of characteristics and processes related to the last events of mud deposition at Cassino beach. It is expected to obtain an update of the “Patos Facies”, characterization of the environment deposition and associated processes. Define the limits of occurrence of fluid mud versus more consolidated mud.

Expected Collaborations: FURG, UFRJ, Delft Hydraulics, UERJ, USP, NRL

Title: Beach profile mobility during the Cassino experiment.

Summary: In this work an analysis of high frequency (daily) beach profiles at Querência beach are analyzed. Beach profiles are analyzed and interpreted using empirical orthogonal functions (EOF), associating the beach profiles with the wave data (visual and measured). The beach profiles are going to be compared with ARGUS data. Analysis of High frequency (daily) beach profiles (single) at Querência beach will be done, as well as some specific days analysis of a grid of beach profiles. It is expected to characterize the mobility of Querência beach during the experiment under different hydrodynamic conditions, to obtain ground truth for bar mobility at Argus site during the Cassino Experiment and to quantify the rate of bar migration inshore and offshore during the experiment

Expected Collaborations: FURG, NRL and NPS

Title: Determination of the wave climate for the sourthn Brazilian Shelf

Summary: The association between the wind acting on the water surface and the atmospheric regime produce disturbances (waves) in the ocean which present great spatial and temporal variability. Gravity waves are the main and more constant source of energy in the sea. They play a fundamental hole in the formation of coastal features, and affect several recreational and economical activities (e.g. sailing, harbor operations, oil extraction), highlighting the importance of developing mechanisms to predict the wave climate. Throughout the Brazilian coast, however, observational data on the wave climate are sparse. Especially regarding the Southern Brazilian Shelf (SBS), a systematic study of the wave climate does not exist, although some local efforts were done in order to characterize certain areas. These studies were based on several sources of data, which include field measurements and observations, historical data from opportunity ships, and remote sensing. Thus, the objective of this study is the characterization of the wave climate in the SBS based on published and unpublished data.

The next step of this work is to use these information to set-up numerical experiments to study the generation and propagation of waves from deep to shallow waters in the SBS, focusing on the wave attenuation over the mud deposits observed in the area.. The SWAN model will be used. SWAN is a 3rd generation numerical model of high resolution, developed to calculate realistic estimates of marine agitation. The processes described by the model include wave propagation, associated as refraction and shoaling, with the spatial variations in bottom topography and currents; generation and dissipation associated as winds, by whitecaping, by bottom friction and wave-wave interactions. The model is currently being implemented for the SBS, and data collect during the Cassino Project will be used to validate the numerical experiments.

Expected Collaborations: FURG, DHN, UFSC

Title: Modelling the hydrodynamics of the Southern Brazilian Shelf

Summary: Continental shelves are among the most productive and diverse environments of our planet. However, they are also one of the most human-impacted environments, serving as the ultimate collector for sediments and disposals of the human population concentrated in coastal areas. The shelf circulation is certainly an important factor determining the equilibrium of these systems.

Modelling studies in the Southern Brazilian Shelf (SBS) are rare and either lack in space-time resolution or do not include the adequate forcings needed for a realistic simulation of the coastal circulation. Thus, the objective of this study is to investigate the response of the SBS to the main physical forcings observed in the area, namely the tides, the winds, the western boundary and buoyancy driven currents, providing an insight on the hydrodynamics over the mud deposit areas under investigation on the CASSINO Project.

Two- and three-dimensional modelling experiments for the SBS are being carried out using the TELEMAC model, a flow model based on finite element techniques, developed by Laboratoire National d'Hydraulique (EDF, France) to simulate the flow in estuaries and coastal zones. The modelling domain extends from 28^{o}S to 35^{o}S, including the Patos Lagoon and extending seawards to the 100 m isobath. The resulting finite element mesh has 23.419 triangles, with a spatial resolution varying from 100 m (near the coast) to 9000 m (deeper areas). The boundary conditions for the model include time series of sea surface elevation measured in the upper (Torres) and lower (Chuí) limits of the domain, the major tidal constituents, time series of wind speed and direction and mean freshwater discharge on the top of the Patos Lagoon.

This work represent a contribution for the understanding of the general characterization of the shelf hydrodynamics in the area, considering the large scale circulation over the coast, strongly influenced by the meteorological forcings. It is thus expected to provide further insights on the barotropic circulation over the coast and thus on the sediment transport and mud deposit formation, assessing the influence of the jetties.
Expected Collaborations: FURG, UNIVALI, UFRJ

Title: Tidal and sub-tidal oscillations along the Rio Grande do Sul Coast

Summary: The aim of this paper is to investigate the basic tidal components in the astronomic and meteorological time scales, assessing the propagation of shelf waves along the coast. It will be analyzed for this purpose sea level time series from Chui, Cassino and Torres. Current data off Cassino, wind data from Chuí and Santa Marta Navy stations. Tidal harmonic analysis will be used to identify the astronomical tidal constituents and time series analysis on the time and frequency domain to identify patterns and delays between the stations, and the effects of local wind on the sea level. The expected results are to identify the energy associated with astronomical and meteorological events on the sea level along the coast. To evaluate the local generation and propagation of trapped shelf waves, and how they affect the hydrodynamics nearby Cassino beach.

Expected Collaborations: UNIVALI, UFRJ

Title: Fine sediment dynamics off Cassino Beach

Summary: This work intends to investigate the transport of fine sediment off Cassino beach, and how it is related to the current and wave action. Time series of ADCP (currents, wave, pressure and acoustic back scatter) and turbidity data acquired off Cassino Beach will be analyzed for this purpose. Statistical and time series analysis will be used to identify relationship between wave and current yield shear stresses and the concentration of particulate suspended matter along the water column, and EOF analysis to identify modes of transport. The expected results is to quantify the cross and along shore fine sediment transport associated with different scenarios (wave action; astronomical tides; meteorological tides; low and high Patos Lagoon runoff)

Expected Collaborations: UNIVALI, UFRJ

Title: Geoaccoustics of an inner shelf fluid mud deposit in Cassino Beach, South Brazil

Summary: An integrated geophysical survey with high resolution seismic (HRS) and high precision depth recorder (HPDR) was conducted along the Cassino´s Beach inner shelf, South Brazil, in order to map its fluid mud deposit. In this survey we have used a DGPS satellite system for positioning the high frequency sub-bottom profiler (2-16 kHz) and the high precision echosounder (200 kHz). Thirteen geophysical lines (80 km) were obtained along the Cassino´s Beach inner shelf, southward of the Rio Grande Jets. The fluid mud seismic echo-character was almost transparent along the deposit with exceptions where very fine sands were mixed with the mud. The echosounder characteristic was a double-trace type (bottom/sub-bottom) where the fluid mud occurs and a single-trace type where the very fine sand is presented. However the mean thickness of the fluid mud registered in the seismic and in the echo bathymetry was significantly different varying from 1.0 meter to 0.5 meter respectively. Also we have noticed that the absolute depth of the mud seismic horizons and the echobatimetric ones are not the same. In this paper we discuss the implications of these observations for mapping fluid mud deposits in the inner continental shelf.

Expected Collaborations: UERJ, FURG, UFRJ

Title: On the physical, spatial and temporal scales of the larger Patos Lagoon – Cassino Beach system

Summary: This paper gives a phenomenological description of the physical processes relevant for hydrodynamics and transport processes of fine sediment in Patos Lagoon and adjacent coastal area, amongst which Cassino Beach. We will discuss the role of astronomical and meteorological tides on the water movement in Patos Lagoon and its tidal inlet, and the remobilization of fine sediment from the lagoon's bed by local wave activity and its subsequent transport through the lagoon and towards the coastal zone. We discuss the influence of the tide, the meteorological effects and the fresh water input on the horizontal and vertical salinity distribution within the lagoon, its tidal inlet and the coastal zone. We argue why fine sediment deposits are mainly found in the foreshore south of the lagoon's tidal inlet and discuss the interaction between these deposits and the hydrodynamics, in particular with the waves, including the effects of fluid mud induced wave damping. We make an estimate of the mobility and residence time of the fine sediments in the foreshore region and the role of wave-induced mud bank migration. In these discussions we recognize a number of spatial and time scales, establishing yearly and seasonal variations and shorter time scales, related to the cycles of depressions in the area.

Expected Collaborations: Delft Hydraulics, FURG, UFRJ

Title: Modeling of mud deposition on the open coast of the larger Patos Lagoon – Cassino Beach system

Summary: This paper describes the modeling of the transport and fate of fine suspended sediment originating from Patos Lagoon in the Patos Lagoon – Cassino Beach coastal system. Emphasis is paid to the conditions under which mud deposits are formed and their locations and eventual thickness. The work is carried out with the DELFT3D software system, modeling (part of) the Patos Lagoon and the larger Patos Lagoon – Cassino Beach coastal system in three dimensions. The water movement is driven by the tide and by meteorological effects, the latter are probably the more important.

Expected Collaborations: Delft Hydraulics, UFRJ

Title: Modeling of the fluid mud induced wave damping in Cassino Beach coastal area

Summary: Waves entering the Cassino Beach area are damped by viscous dissipation in the soft, c.q. fluid mud layers on the sea bed. Though wave damping may be most profound when mud banks attach to the coast, it is expected that wave damping is also observed when the mud deposits are found further off-shore.

Wave damping over fluid/soft mud will be modeled with the third generation wave model SWAN in which the effects of viscous dissipation are implemented. The modeling domain will be limited to a coastal stretch of the larger Patos Lagoon – Cassino Beach coastal system.

Expected collaborations: Delft Hydraulics, FURG, ONR/NRL

Title: Modeling of the mud bank migration in Cassino Beach coastal area.

Summary: It has been observed that under specific conditions mud banks migrate towards the coast. The driving force is most probably streaming, i.e. the effects of wave-induced Reynolds stresses (radiation stresses) on the mud layer. We will derive the relevant mathematical-physical descriptions, including the effects of wave damping described in the third paper.

These formulations will be implemented in the two-layer fluid mud model that is part of the DELFT3D-system. The model will be coupled with SWAN to account for the wave-mud interactions.

Expected collaborations: Delft Hydraulics, ONR/NRL, UFRJ

Title: Fine sediment transport in Dos Patos Lagoon and adjacent coastal area

Abstract: This paper presents a modeling exercise assessing the main features of the fine sediment transport in Dos Patos Lagoon and adjacent coastal area, in order to explain the formation of a mud deposit in front of Cassino Beach, RS, Brazil.

In this work a 2DH modeling approach is used in order to highlight the main forcings of the system and the conditions for the delivery of sediments to the coastal zone.

Expected collaborations: UFRJ, FURG

TEAM

The following researchers participated in the meetings and different activities of the project:

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1- Federal University of Rio de Janeiro (UFRJ) / Laboratory for Dynamics of Cohesive Sediments, Susana B. Vinzon, Raphael Miguez Nogueira, Carla D'Aquino

2- University Foundation of Rio Grande (FURG) / Geological Oceanography Laboratory,Lauro Calliari, Elisa Fernandes, Debora Cuchiara, Luciana Estevez, Cláudio Dias, Marina, Antonio H. da Fontoura

3- Argentinean Oceanographic Institute (IADO), Gerardo Perillo

4- State University of São Paulo / Oceanographic Institute, Moyses Tessler

5- Brazilian Navy / Directorate of Hydrography and Navigation / Navy Hydrographic Center, Rodrigo Obino, Antonio Garcez

6- University of the Vale do Itajaí (UNIVALI), Carlos Augusto Schettini, Rodrigo Zaleski, João Luiz Carvalho

7- State University of Rio de Janeiro (UERJ) / GPOG, Josefa Varela Guerra, Marcelo Sperle, Monia Reich, Marcelo Azevedo

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From Naval Posgraduate School, US: James MacMahan, Mark Orzech, Ed Thornton, Timothy Stanton, James Stockel, Thomas Keefer

From Proudman Oceanographic Laboratory, UK,: Jon Williams and Paul Bell.

From Delft Hydraulics, Netherlands, Han Winterwerp
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