Revista Brasileira de Geofísica
RBGf
Brazilian Journal of Geophysics

Revista Brasileira de Geofísica (2010) 28(3): 321-329

ISSN 0102-261X
www.scielo.br/rbg

HYDRODYNAMICS OF THE ITAPOCU RIVER AND THE BARRA VELHA LAGOON ESTUARINE SYSTEM, SC, BRAZIL

Cláudia França de Abreu[1], Eduardo Siegle[2], Eliane C. Truccolo[3] and Carlos Augusto França Schettini[4]

Recebido em 6 março, 2009 / Aceito em 18 maio, 2010
Received on March 6, 2009 / Accepted on May 18, 2010

ABSTRACT. A hydrodynamic characterization of the Itapocu river and Barra Velha lagoon estuarine system was carried out with the objective of evaluating how the current regime in this area is affected by astronomical and meteorological tides and the river discharge. Meteorological, water level and current velocity and direction data were gathered hourly during a twenty-day period, from 22-July until 10-August, 2004. Current meters were positioned at the inlet, at the entrance of the north and south lagoons and at the lower estuary of the river along with a tide gauge. The estuarine system showed distinct current behavior among the different sectors within the estuary, responding to the different forcings. The strongest currents were observed at the inlet while the weakest values were observed at the northern lagoon, a location that showed little dynamic. The general flow was ebb-dominated flux, in response to fluvial discharge, even during local wind water set-up event.

Keywords: circulation, hydrography, river discharge, tides, estuary.

RESUMO. Uma caracterização hidrodinâmica do sistema estuarino do rio Itapocu e Lagoa de Barra Velha foi realizada com objetivo de avaliar como o regime de correntes é afetado pela maré astronômica e meteorológica, e pela descarga fluvial. Dados meteorológicos, nível da água e correntes foram registrados em intervalos horários durante um período de vinte dias, entre 22 de julho até 10 de agosto de 2004. Os correntógrafos foram posicionados na desembocadura, nas conexões do estuário com as lagoas norte e sul, e no baixo estuário, juntamente com um marégrafo. O sistema estuarino apresentou comportamento de correntes diferenciado entre as diversas localizações, em resposta às diferentes forçantes. As correntes mais intensas foram registradas na desembocadura, e as mais fracas na lagoa norte, local que apresentou uma hidrodinâmica muito reduzida. O escoamento apresentou fluxo residual de vazante, em resposta à descarga fluvial, mesmo durante eventos de subida do nível do mar causados pelo vento.

Palavras-chave: circulação, hidrografia, descarga fluvial, maré, estuário.

---

[1] Coastal and Marine Engineering and Management, Civil Engineering Department, Delft University of Technology, CoMEM/TU Delft. Stevinweg 1, 2628 CN, Delft, The Netherlands – E-mail: cfrancadeabreu@tudelft.nl

[2] Instituto Oceanográfico, Universidade de São Paulo – IO/USP, Praça do Oceanográfico, 191, Cidade Universitária, 05508-120 São Paulo, SP, Brazil – E-mail: esiegle@usp.br

[3] Programa de Pós-Graduação em Geociências, Universidade Federal do Rio Grande do Sul – PPGGeo/UFRGS, C.P. 15001, 91509-900 Porto Alegre, RS, Brazil – E-mail: nane.truccolo@gmail.com

[4] Departamento de Oceanografia, Universidade Federal de Pernambuco – DOcean/UFPE, Av. Prof. Moraes Rego, Cidade Universitária, 50670-901 Recife, PE, Brazil – E-mail: carlos.schettini@pq.cnpq.br; guto.schettini@gmail.com

INTRODUCTION

Our ability to predict future changes in estuarine systems depends on an integrated understanding of hydrological and physical-dynamical processes (Kjerfve, 1986). For these reasons and keeping in mind that industrial complexes, fishing communities and cities often border coastal water bodies, the purpose of this paper is to characterize the hydrodynamic of the lower Itapocu estuary and Barra Velha coastal lagoon (Fig. 1) and to evaluate how the current regime is affected by the astronomical tide, river discharge and wind set-up forcing.

The Itapocu river and Barra Velha coastal lagoon estuarine system is located in the northern coast of Santa Catarina State, Brazil, between the coordinates of 26°31′56″S and 48°38′41″W and 26°37′56″S and 48°48′51″W (Fig. 1). The regional mean annual value of temperature and precipitation are 20°C and 1500 mm, respectively. The mean fluvial discharge of Itapocu river is 77 $m^3.s^{-1}$ (Schettini & Carvalho, 1998); its drainage basin occupies an area of 2930 km^2 (Gaplan, 1986). The river is formed near the city of Corupá by the confluence of a few rivers, such as the Novo river and Vermelho river, and drains out between the cities of Araquari and Barra Velha (SC).

Dionne's (1963) definition of estuary is used in this study in order to characterize the section of this estuarine system to be analyzed. Therefore, the section of the estuary studied in this system is the lower estuary of the Itapocu river and also the Barra Velha coastal lagoon, which is considered as part of the estuarine system.

The Itapocu estuary (Fig. 1) is a river dominated estuary and has been classified as a highly stratified system (Schettini et al., 1996; Schettini & Carvalho, 1998), according to Hansen & Rattray's (1966) classification (e.g. Miranda et al., 2002). Even though this estuary is strongly influenced by fluvial discharge, during low discharge periods the tide plays a relevant role. The local tidal regime is micro-tidal ($<$2 m), mixed with predominance of semi-diurnal oscillations. The tide form number is 0.4, mean tidal range is of 0.8 m, ranging between 0.3 to 1.2 m during neap and spring tidal periods, respectively (Schettini, 2002).

The Barra Velha lagoon (Fig. 1) is a coastal lagoon oriented parallel to the coast being separated from the sea by a narrow sand barrier extending for approximately 12 km along the coast. According to Kjerfve (1986) coastal lagoons are common landforms along the borders of most continents. They have restricted connections to the ocean, are poorly flushed and exhibit higher residence times. The Barra Velha coastal lagoon has only one inlet that is never closed completely due to the influence of Itapocu river discharge and tidal currents which generate strong enough flows that keep the channel open. The lagoon is approximately 2 m deep and 200 m wide.

The main aim of this study is to evaluate the hydrodynamic regime of the lower estuary of the Itapocu river and the Barra Velha coastal lagoon. The objectives are to verify the energy distribution in terms of tidal and sub-tidal frequencies and to evaluate the responses of the currents to the tides, river discharge and meteorological tide.

MATERIAL AND METHODS

The dataset used in this study was recorded in a campaign that took place between 22-July and 10-August, 2004 in the Itapocu estuarine system as a part of the "Morphodynamic and Sediment Transport in an Estuarine Inlet System – CANAIS" project. In this campaign, current speed and direction, water level, salinity, temperature and meteorological data were gathered. The sampling period covered a complete neap-spring-neap tidal cycle lasting 20 days.

Meteorological data were recorded by a Davis^{TM} meteorological station (#MS, Fig. 1) installed during the campaign. Meteorological data consisted of air temperature, humidity, wind speed and direction and barometric pressure, recorded at 30-minute intervals. Water level data was recorded by a RBR^{TM} pressure tide gauge (#TG, Fig. 1), at 30-minute intervals, time averaging over 2 minutes at 2 Hz. Currents were monitored in four different stations in the lower estuary, which were located in the inlet (#I), in the lower estuarine channel (#E), in the intersection between the estuary and South Lagoon (#SL) and in the intersection between the estuary and the North Lagoon (#NL; Fig. 1). The depth at #I was of the order of 7 m and 2 m for the other 3 stations. At each station an acoustic current meter, model 2D-ACM by Falmouth^{TM}, was moored leveled at 1 m below the surface, recording at 30-minute intervals, time averaging over 2 minutes at 2 Hz.

Daily values of water discharge data were obtained from the Environmental Resources and Hydrometeorology Information Centre – CIRAM/Agribusiness Research and Rural Extension Company of Santa Catarina – EPAGRI for the gauge station of n. 82350000. This station is located on the Jaraguá river, with catchment area of 302 km^2, which corresponds to 27% of the basin. The distance between the hydrologic station and the estuarine inlet is of 68 km, approximately.

The distinct datasets were synchronized and tabulated in a uniform matrix and visually inspected in order to check their quality and to identify spurious records, such as spikes and abrupt changes. From this database all the graphics and analysis were based on.

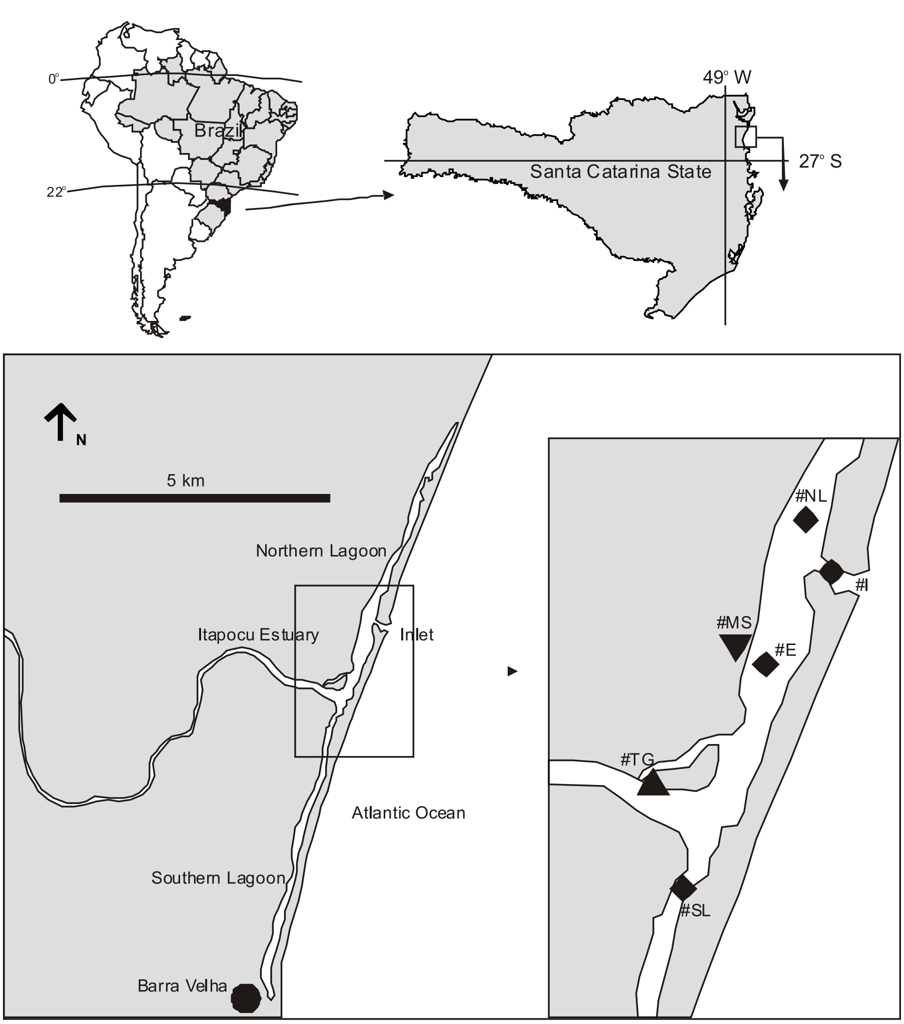

Figure 1 – Location of the Itapocu river estuary and the Barra Velha lagoon. In detail is the study area with the location of the stations: Station #I – Inlet; Station #E – Lower Estuary; Station #SL – South Lagoon; Station #NL – North Lagoon; Station #TG – Tide Gauge; Station #MS – Meteorological Station.

Current direction was firstly corrected subtracting the magnetic declination (19° for 2004) and plotted on polar diagrams in order to identify the main flow axis for each station. The decomposition of ebb/flood currents was performed in relation to the main axis based on complementary sectors, disregarding the effects of secondary circulation. The narrowness of the inlet, estuary and lagoons forces a strongly bimodal distribution in this main axis, justifying this procedure. Downstream currents were assigned as negative (out of the estuary) whereas upstream currents were assigned as positive (into the estuary). The maximum flood and ebb currents were obtained for each station.

In order to evaluate how the astronomical tide, meteorological tide and river discharge affects the currents, three 25-hour periods were selected: Period 1 (P1) at the beginning of the campaign, during neap tide conditions, high river discharge and no meteorological tide; Period 2 (P2), in the middle of the campaign, during spring tide conditions, low river discharge and no meteorological tide; and Period 3 (P3), at the end of the campaign, during neap tide conditions, low river discharge and with meteorological tide.

The current data were filtered in order to verify how the energy was distributed between tidal and sub-tidal frequencies bands. A binomial recursive filter of three elements was used, with elements weight of 0.25, 0.5 and 0.25. The time series length was preserved by re-scaling the first and last values with their neighbor with weights of 0.6 ad 0.4, respectively. The filtering efficiency was evaluated by visual inspection of the results, since the procedure is not frequency selective. The currents were also analyzed in terms of spectral analysis. The power spectral density was calculated using the Welch's averaged periodogram method with a 512-element window at a 95% confidence interval (e.g. Truccolo et al., 2006).

RESULTS

During most of the experiment winds were southward with magnitudes under 1 m.s^{-1}. However, between the days 219 to 221 strong southerly winds were recorded, reaching up to 6 m.s^{-1} (Fig. 2A).

A peak in fluvial discharge occurred at the beginning of the measuring period due to heavy rainfall on the drainage basin reaching 290 m^3.s^{-1} (Fig. 2B). After the discharge peak, it decreased rapidly to 116 m^3.s^{-1} on day 207, 24 m^3.s^{-1} on day 210, and 15.7 m^3.s^{-1} on day 222, remaining around 14.5 m^3.s^{-1} onwards.

The water level (Fig. 2C) showed a neap tide period, days 206-210, followed by a spring tide period, days 212-216, and another neap period, days 218-222. Two low frequency water level oscillations were recorded in the middle, days 212-218, and at the end, days 218-222, of the campaign, with amplitudes of 0.3 and 0.6 m, respectively. The water level variance associated with the sub-tidal frequencies accounted for 58% of the energy, whereas the tidal frequencies accounted for the remainder 42%.

Time series of the measured currents at the four sites are shown in Figure 2 (D, E, F and G). Except for Station #NL, the current regime in all other stations presented a clear semi-diurnal tidal signal. On Station #I flood currents reached a maximum magnitude of 1.57 m.s^{-1} and the ebb currents reached 1.68 m.s^{-1} (Table 1). Station #E presented maximum values of flood and ebb currents of 0.27 and 0.61 m.s^{-1}, respectively. Flood currents at stations #SL and #NL reached 0.54 and 0.2 m.s^{-1}, respectively, and 0.46 and 0.20 m.s^{-1} for the ebb currents, respectively. Residual currents were ebb-oriented for #I and #E and flood-oriented for #SL and #NL. The longitudinal axis energy represented 82, 59, 76 and 63% of the variance for the #I, #E, #SL and #NL stations, respectively.

Tidal frequencies accounted for nearly 65% of the current velocity variance, being the higher variance in #SL station (75%; Table 1). Sub-tidal currents are shown in Figure 3. Stations #I and #E had negative values during all monitored period, with the higher negative values during the first days of the campaign, of –0.75 and –0.5 m.s^{-1}, respectively. The currents at sub-tidal frequencies at stations #SL and #NL ranged between ±0.1 m.s^{-1}. The currents were mostly negative at #SL, while they were mostly positive at #NL.

Table 1 – Maximum ebb and flood currents for each station and their residual over the monitored period; longitudinal current variance (L.C.V.) and tidal frequency variance (T.F.V.).

Station	Ebb (m.s^{-1})	Flood (m.s^{-1})	Residual (m.s^{-1})	L.C.V. (%)	T.F.V. (%)
#I	–1.68	1.57	–0.34	82%	64
#E	–0.61	0.27	–0.20	59%	66
#SL	–0.46	0.54	+0.04	76%	76
#NL	–0.20	0.20	+0.02	63%	68

Table 2 – Tidal range (m), and maximum ebb and flood currents (m.s^{-1}) at the four stations for the three selected 25-hour periods.

Tidal Range	P1		P2		P3	
	0.27		0.90		0.30	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
#I	–0.89	0.13	–1.00	1.01	–0.98	0.66
#E	–0.43	0.06	–0.49	0.25	–0.41	0.15
#SL	–0.20	0.15	–0.26	0.19	–0.15	0.17
#NL	–0.16	0.09	–0.13	0.14	–0.19	0.05

Table 2 shows the water level variation and maximum and minimum current speeds within the 25-hour periods for P1, P2 and P3 selected periods. In P1 and P3 the ebb current speeds were significantly higher than the flood currents speeds in every station except Station #SL on P3. In P2, under spring tide conditions, the currents speed were similar between ebb and flood in stations #I and #NL and had higher magnitudes in ebb conditions on stations #E and #SL.

The current polar frequency distribution is shown in Figure 4. The energy on Station #I was concentrated along the east-west axis with most of the energy concentrated in ebb current speeds. Similar pattern was observed for #E, although there was some dispersion along the east-west direction. The energy on Station #SL showed a concentration of energy along the north-south axis and mostly on ebb-oriented current. Little energy concentration was observed along east-west direction for #NL being most of it towards west-northwest and north direction.

The energy spectrum (Fig. 5) indicates the spectral density of each forcing for each station. On stations #I, #E and #SL, the semi-diurnal (∼12 hours) and quarti-diurnal (∼6 hours) tidal frequencies were the most energetic, followed by the diurnal (∼24 hours) and terci-diurnal (∼8 hours) ones. The tidal frequencies in the Station #NL were less energetic when compared with the other stations, although the energy in the sub-tidal band was similar in all stations.

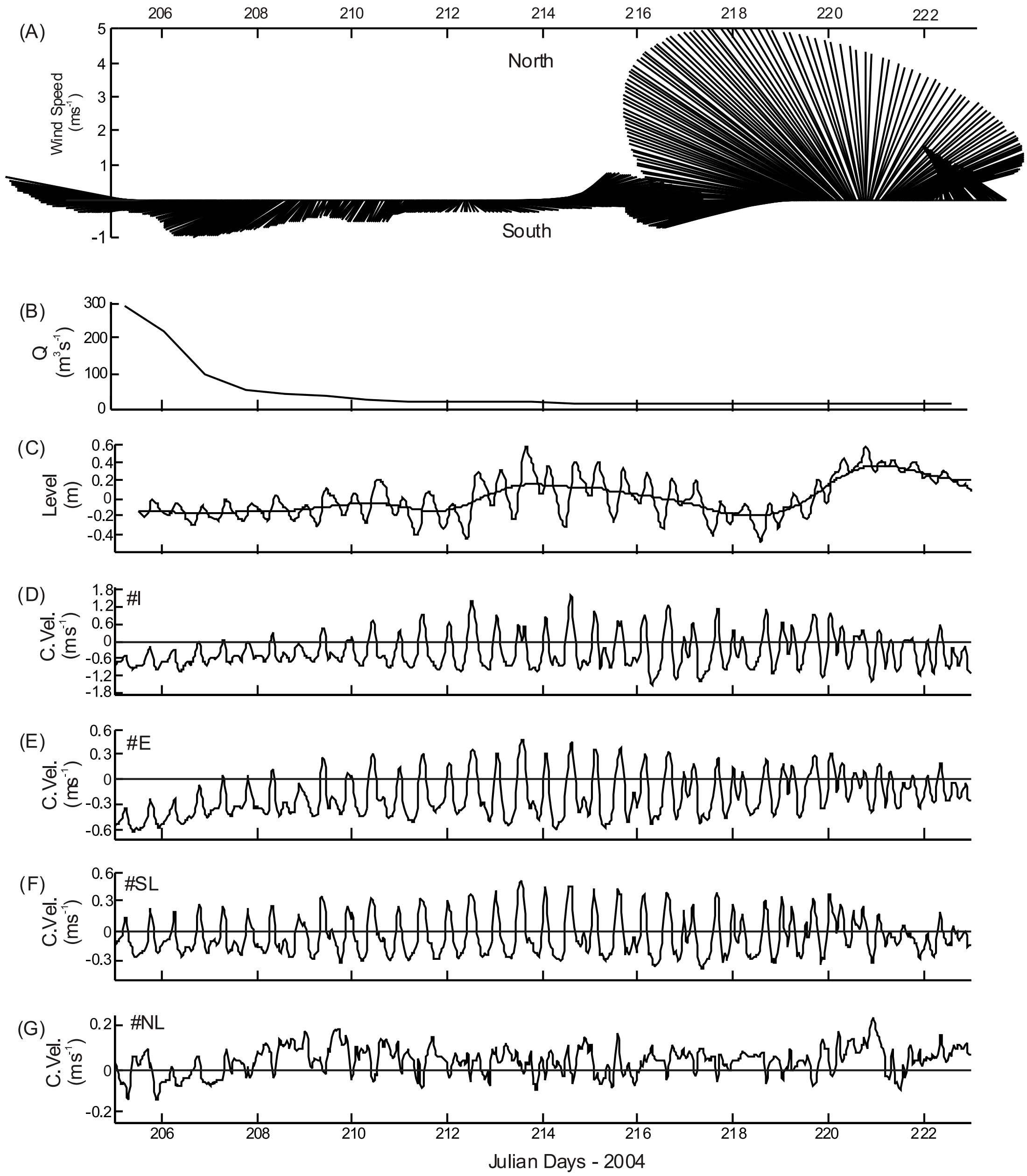

Figure 2 – Time series of wind speed (A, in vector notation), river discharge (B), water level at #TG (C) and current velocity (C.Vel.) at stations #I (D), #E (E), #SL (F) and #NL (G).

DISCUSSION

Estuaries have a wide range of morphologies, each of which developed in a specific way of interaction between fluvial and marine processes (Cameron & Pritchard, 1963; Perillo, 1995; Dyer, 1997; Miranda et al., 2002). In the Itapocu river and Barra Velha lagoon estuarine system, the estuary crosses the lagoon before it flows out to the sea, through the lagoon's only inlet. This system can be considered as composed by two restricted lagoons, according to the coastal lagoon classification (Kjerfve, 1986; Kjerfve & Magill, 1989), associated with a deltaic front estuary (e.g. Fairbridge, 1980), even though they form a single coastal water body.

Water level variability was firstly driven by semi-diurnal tidal frequencies, although, in terms of variance, the sub-tidal frequencies were not negligible, accounting for nearly 35% of the

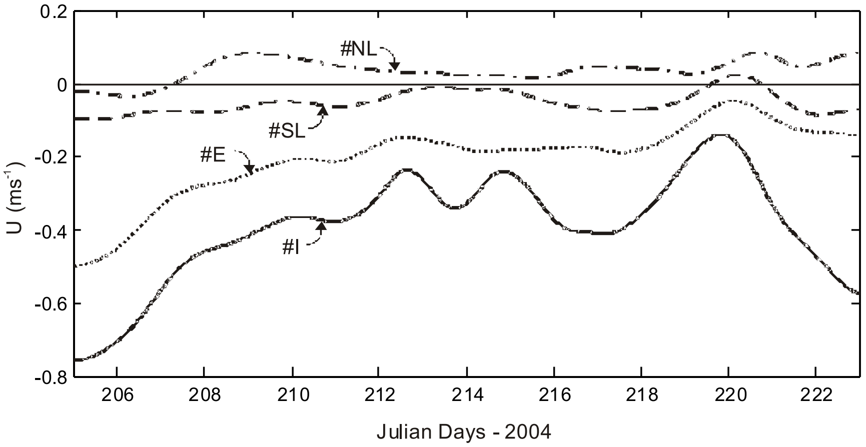

Figure 3 – Time series of sub-tidal frequency currents at the Inlet (#I), Lower Estuary (#E), South Lagoon (#SL) and North Lagoon (#NL) stations.

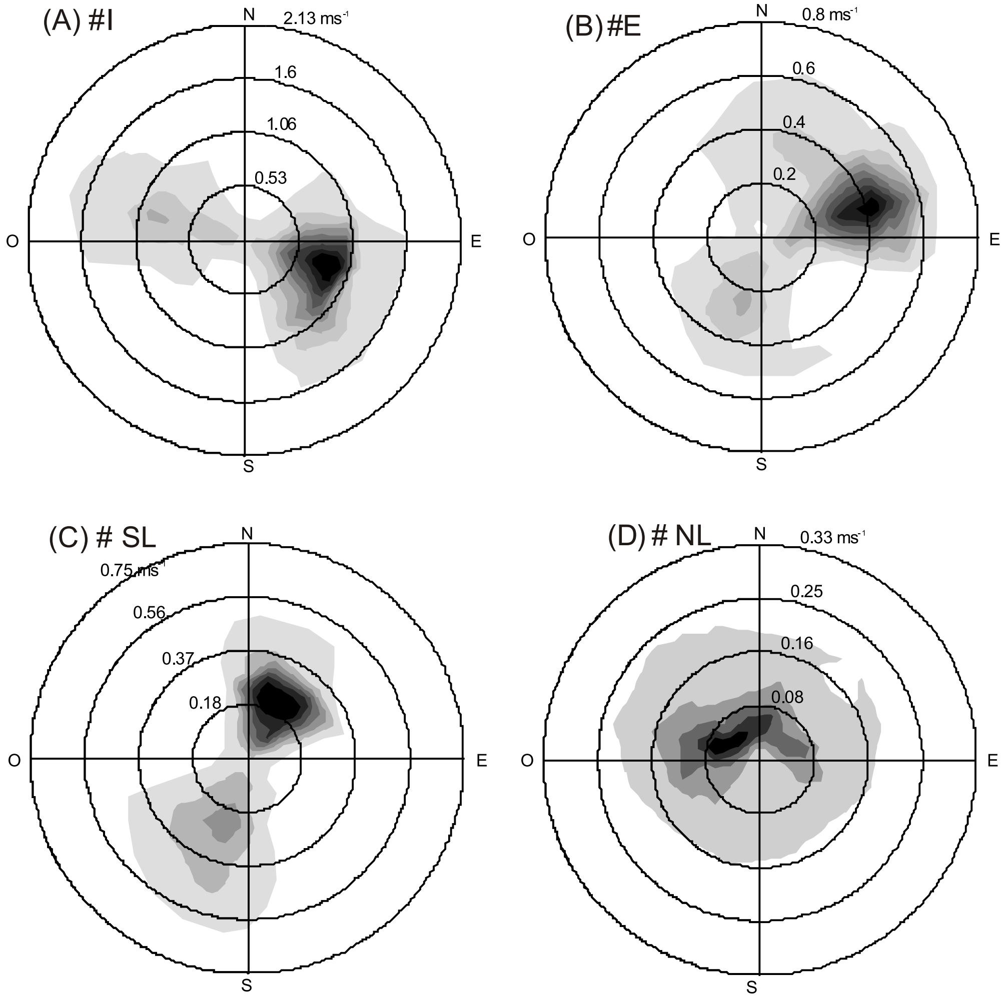

Figure 4 – Polar frequency distribution of currents of the four monitoring sites. Darker tones indicate more occurrences, while lighter tons indicate fewer occurrences. No occurrence is white. A: Station #I; B: Station #E; C: Station #SL; D: Station #NL.

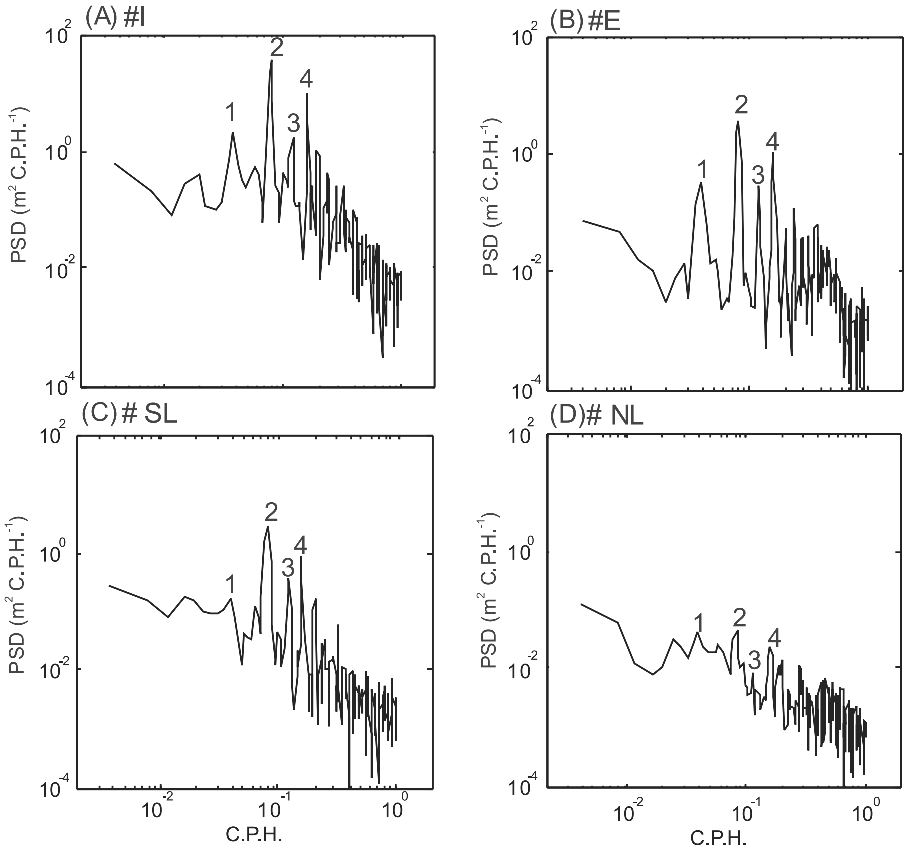

Figure 5 – Spectrograms of longitudinal currents for the four sampling sites. The numbers over the spectrum peaks indicate the tidal species (1: diurnal; 2: semi-diurnal; 3: terci-diurnal; 4: quarti-diurnal). PSD: power spectral density; C.P.H.: cycles per hour. A: Station #I; B: Station #E; C: Station #SL; D: Station #NL.

total energy. For comparison, Schettini (2002) and Truccolo et al. (2006) found energy distribution between tidal and sub-tidal frequencies of nearly 70 and 30%, respectively, from records of several months of water level in Itajaí-Açu estuary, 35 km south, and Enseada Bight, 40 km north, respectively. The energy associated with the sub-tidal frequencies for the present case can be explained due to the occurrence of a river discharge peak during the beginning of the sampling period and the meteorological tide recorded at the end of the sampling period.

The low frequency sea level oscillations play an important role along the Santa Catarina coast, as it is under a micro-tidal regime (<2 m; Truccolo et al., 2006). These fluctuations are generated mostly by meteorological events and the wind accounts for 90% of the variance whereas the remaining 10% are explained by atmospheric pressure (Truccolo et al., 2006). The influence of meteorological processes on the mean sea level is very important for local coastal dynamics since the water level can be raised up to 1 m above the astronomical tides (Schettini et al., 1996), generating currents and influencing mixing processes. The importance of meteorological events on coastal water bodies was effectively verified in this study. Water level set-up at the end of the campaign (Fig. 2), at neap tide conditions, occurred due to intense southerly winds that reached speeds of up to 10 m.s^{-1} (the wind vectors in Figure 2 were filtered to minimize noise, though masking wind peaks). Truccolo et al. (2006) demonstrated that there is a phase lag between the wind stress and water level of around 10 hours for the coastal region of São Francisco do Sul, located to the north of the study area. The winds that lasted for approximately 3 days starting at day 219, were strong enough to push and accumulate water against the coast and lagoon generating the water level raise.

The hydrodynamic regime for the Itapocu river estuary and Barra Velha coastal lagoon estuarine system presented ebb-dominated flows during all recorded period: under wind set-up conditions, neap and spring tides and high and low discharge conditions (Fig. 3), in agreement with Siegle et al. (2007). Current direction almost always followed the tidal pattern, with flood currents occurring synoptically with high tides, and the ebb currents coinciding with the low tides; therefore, the higher magnitudes were always recorded during ebb phase.

Although the tidal frequencies exhibit higher energy concentration both in the spectrum and in the energy variance, the highest current speeds and dominant flux were associated with increased river discharge, which is made clear by the flux rate values (e.g., Dyer, 1997). The flux rate, FR, weights the relative volume contributions of river discharge and tides, by

$$FR = \frac{\int_0^{6.2} Q dt}{Ah} \tag{1}$$

or, the river discharge, Q in $\text{m}^3.\text{s}^{-1}$, integrated over half semidiurnal tidal period, divided by the tidal prism. The latter is the product of the estuarine surface area, A in m^2, and the tidal height, h in m. The FR was calculated using a 12.4-hour running window over the dataset (Fig. 6). Values of FR equals to one mean that river and tide equal volume contributions, whereas higher FR value indicates the dominance of river discharge. According to Dyer (1997), when $FR > 1$ there is river dominance and the estuary is highly stratified.

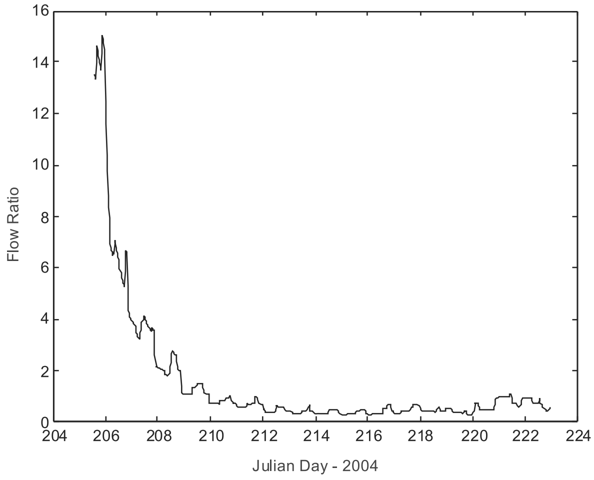

Figure 6 – Time series of the flow ratio during the sampling period.

During the first third of the experiment FR values were much higher than unity, reaching up to 15, directly related to the river discharge peak. During the second third, under spring tide conditions, FR ranged between 0.3 and 1.5 indicating that during low tide the volume of river water is greater than the tidal prism and during high tide the tidal prism dominates over the river discharge. During the last third of the campaign FR varied between 1 and 2, also demonstrating the dominance of river discharge over tidal prism.

CONCLUSIONS

The observations of wind speed, water level and currents in the lower Itapocu estuary and lagoons during a limited time period (15 days), during which a river discharge peak and a meteorological tide were recorded, allow one to depict some important characteristics of this system. Each current measurement station has a current pattern that responds in different ways to tides and river discharge. It was observed that in general the flux direction switches between ebb and flood due to the tidal variation, being more perceptible during spring tide condition, when the tidal range is larger.

In this estuary the ebb currents had a higher frequency and intensity for the entire campaign period. The magnitude of the fluxes and their resultant direction were forced by the low frequencies, mostly by the action of the river discharge, causing the dominance of the ebb currents during most of the campaign.

The highest speeds were measured at the inlet (#I), due to its constricted form and because it is the only water connection to the ocean; and the lowest current speed values were recorded in the north lagoon (#NL), showing it to be the location where the lowest dynamics occurs in this estuarine system.

ACKNOWLEDGEMENTS

We would like to thank Santa Catarina's Research Support Foundation – FAPESC for the financial support and everyone that had a participation in the Morphodynamic and Sediment Transport in an Estuarine Inlet System – CANAIS, project; we are grateful to the anonymous reviewers for its valuable contribution improving the manuscript. CNPq Grants No. 306217/2007-4 and 308303/2006-7.

REFERENCES

CAMERON WM & PRITCHARD DW. 1963. Estuaries. In: HILL MN (Ed.). The sea. New York, Wiley Interscience. p. 306–324.

DIONNE JC. 1963. Towards a more adequate definition of the St. Lawrence estuary. Zeitschr. F. Geomorph., 7(1): 36–44.

DYER KR. 1997. Estuaries: a physical introduction. 2nd ed. New York, John Wiley and Sons, 195 p.

FAIRBRIDGE RW. 1980. The estuary: its definition and geodynamic cycle. In: OLAUSSON E, CATO I. (Eds.). Chemistry and biogeochemistry of estuaries. New York, John Wiley and Sons, p. 1–35.

GAPLAN. 1986. Atlas do Estado de Santa Catarina. Gabinete de Planejamento e Coordenação Geral, Florianópolis, 173 p.

HANSEN DV & RATTRAY JR M. 1966. New Dimensions in estuary classification. Limnology and Oceanography, 11: 319–326.

KJERFVE B. 1986. Comparative Oceanography of Coastal Lagoons. In: WOLFE DA (Ed.). Estuarine variability. New York, Academic Press. p. 63–81.

KJERFVE B & MAGILL KE. 1989. Geographic and hydrodynamic characteristics of shallow coastal lagoons. Marine Geology, 88: 187–199.

MIRANDA LB, CASTRO BM & KJERFVE B. 2002. Princípios de Oceanografia de estuários. São Paulo, EdUSP, 411 p.

PERILLO GME. 1995. Geomorphology and Sedimentology of Estuaries. New York, Elsevier Science, 471 p.

SCHETTINI CAF. 2002. Caracterização física do estuário do rio Itajaí-Açu. Revista Brasileira de Recursos Hídricos, 7(1): 123–142.

SCHETTINI CAF & CARVALHO JLB. 1998. Hidrodinâmica e distribuição de sedimentos em suspensão dos estuários dos rios Itapocu, Tijucas e Camboriú. Notas Técnicas da Facimar, 2: 141–153.

SCHETTINI CAF, CARVALHO JLB & JABOR P. 1996. Comparative hydrology and suspended matter distribution of four estuaries in Santa Catarina State – Southern Brazil. In: Workshop on Comparative Studies of Temperate Coast Estuaries, Bahía Blanca. Proceedings, p. 29–32.

SIEGLE E, SCHETTINI CAF & TRUCCOLO EC. 2007. Balanço dinâmico em desembocaduras durante marés meteorológicas. In: Congresso Latino-americano de Ciências do Mar – XII, 2007. Florianópolis. CD-ROM.

TRUCCOLO EC, FRANCO D & SCHETTINI CAF. 2006. The low frequency sea level oscillations in the northern coast of Santa Catarina, Brazil. Journal of Coastal Research, 39(SI): 547–552.

NOTES ABOUT THE AUTHORS

Cláudia França de Abreu. Undergraduate in Oceanography by the Universidade do Vale do Itajaí (2007). Actually is graduate student in Coastal and Marine Engineering and Management (CoMEM), Erasmus Mundus Program, Delft University of Technology – The Netherlands. The main interests are coastal hydrodynamics and morphodynamics.

Eduardo Siegle. Undergraduate in Oceanography by the Fundação Universidade do Rio Grande (1996), Master in Geosciences by the Universidade Federal do Rio Grande do Sul (1999) and Doctor in Marine Sciences by the University of Plymouth (2003). Actually is Lecturer in the Instituto Oceanográfico of the Universidade de São Paulo. Has experience in oceanography, with emphasis in Coastal Environmental Morphology, acting mainly in the subjects: coastal morphodynamics, estuarine and coastal processes, sedimentology, coastal dynamics, numerical modeling, and remote sensing. Has CNPq Research Grant since 2007.

Eliane Cristina Truccolo. Undergraduate in Oceanography by the Fundação Universidade do Rio Grande (1993), Master in Environmental Engineering by the Universidade Federal de Santa Catarina (1998) and Doctor in Geosciences by the Universidade Federal do Rio Grande do Sul (2009). Actually has pos-doc scholarship in the Instituto de Ciências do Mar of Universidade Federal do Ceará. The main interests are physical oceanography, sea-atmosphere interactions, and sea-level analysis.

Carlos Augusto França Schettini. Undergraduate in Oceanography by the Fundação Universidade do Rio Grande (1991), Master in Geosciences by the Universidade Federal Fluminense (1994) and Doctor in Geosciences by the Universidade Federal do Rio Grande do Sul (2001). Lecturer in the Instituto de Ciências do Mar of the Universidade Federal do Ceará. The main interests are estuarine and coastal physical oceanography and fine sediment dynamics. Has CNPq Research Grant since 2005.