EMPLOYMENT OF SLIDING CORRELATION METHOD IN LAKE MODELLING

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Abstract

In this study, sliding corelation method is applied to water level timeseries of Koycegiz Lake. Gauging stations were previously installed at four different locations reflecting characteristics of lake in order to observe water level changes. It was shown that stream directions and water travelling durations could be obtained using sliding corelation method. Furthermore stream directions calculated from corelations methods were compared with wind directions, wave effects from seaside and fresh water inflows. 94 of calculated 143 days matched with wind directions. 8 days matched with fresh water inflows. For 10 days, it was seen that stream directions were from seaside to lake as the effect of wind speed and fresh water are low.

Keywords

Sliding correlation, lake water level, wind direction, wave effect.

Introduction

Lagoons which are lakes joining the sea by means of a canal or a similar morphologic structure, are of great importance for the natural life. The preservation of dynamic natural balance which is affected by numerous parameters is only possible by the monitoring of the natural balance parameters.

The main parameters which determine the natural balance of a lagoon are the water cycle and the hydrodynamic characteristics related to this cycle. In general, for any lagoon, the water mass itself can be expressed by the water volume, the mean water depth and the surface area. These are functions of the time-dependent

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water level variations. As a result of the variations in the water depth of the lagoon, velocity components and other hydrodynamic characteristics within the water mass exhibit a change with time and great extent are controlled by hydrodynamic characteristics.

Water balance of the lagoons are at a great scale controlled by the water entry and exit to and from fresh water resources and sea. Freshwater originating from land are supplied mostly from rivers and some from groundwater. On the contrary, water entry from sea, which also controls the salinity of the lagoon, occurs due to effects of wave, tide and wind (determining the water level in sea medium) but its contribution to lagoon water volume is smaller compared with the fresh water entry to the lagoon. Therefore it can be said that lagoon-sea interaction has a random character related to both hydrologic properties of the rivers draining into the lagoon and the wave climate in the coastal area in the vicinity of the sea. It is possible to assume that natural dynamic balance of lagoons originates completely from this random character as mentioned by Kabdaşlı et al. (2002).

In the litearure there numerous studies about lagoon and coastal processes. Milbradt and Lehfeldt (2002) studied the littoral processes at Micro-Tidal coasts of the Southern Baltic Sea Gelen Bay. In this study German coastal regions of the southern Baltic sea can be characterized as micro-tidal regimes where shorelines are formed by wind generated waves and currents. Christiansen and Wiberg (2002) investigated the sediment deposition on a Salt Marsh Surface in Hog Island Lagoon. On the eastern shore of Virginia, they found long term deposition rates of 1-2 mm per year which have been quantified using 210_Pb dating techniques, indicating that the marshes in this area are accreting at a rate comparable to the rate of sea level rise. Smith (1999) studied the numerical circulation model of Abailang Lagoon, Kırıbati. Numerical model was applied to water level for 19 days. In conclusion, water temperatures were found to be one degree higher in the lagoon compared to open ocean waters. The effect of natural and human perturbations on the ecology of the Patos Lagoon Estuary in Southern Brazil was investigated by Seeliger et al. (2001). Rate-curve methods were based on river level data. The numeric model of circulation described the velocity fields, sea surface elevation, temperature and salinity. Kite (2000) developed a hydrologic model which can be used to explore the impacts of water management decision on levels in the Tonle Sap lake and the consequent impacts on aquatic resource production. Zaldivar et al. (2000) employed chaos theory techniques for early detection of high waters at Venice Lagoon. Time series analysis using non-linear dynamics systems theory has been applied to water level data recorded every hour at punta della salute Venice Lagoon during 1980-1994. Leidersdorf et al. (2001) investigated the nearshore processes of San Diego County's Beaches prior to the Regional Beach Sand Project.

The study comprised 5 lagoons, Aqua Hedionda, Batiquitos, San Elijo, San Dieguito and Los Penasquitos. Mohrholz and Meerswiss (1998) studied the transport and turnover processes in the Pomeranian Bight. Statistical analyses of long time series have shown that the surface current are closely correlated with the local wind. Water transport in the Odra estuary was measured and modelled for the flood period Jully/August 1997 (Rosenthal et al. 1998). In this study the Szczecin Lagoon which is an inshore water close to the Baltic Sea was investigated. Ferrati (2001) presented hydrological models of Esteros del Ibera. Correlation analysis was applied to water level data during 1968-2001.

Lake Koycegiz is located at south-west part of Turkey and has lagoon property as it connects to the sea through Dalyan Channel. Köyceğiz Lake is on the Aegean coast of Turkey. As a result of protected nature of lake, various plants and animals live on the area. Most popular ones are Sigla Forests and Caretta Caretta sea turtles. This area as mentioned by Güneş (2002) is separated from sea medium by İztuzu beach which is one of the 17 important nesting beaches of the Caretta Caretta throughout the Mediterranean which are now under special protection. The lake is connected to the sea via a continuously changing mouth. Gölgeli Mountains are at Lake's north-west side. Because Dalaman river is carrying alluvium to bay, bay has no connection with the Mediterranean Sea. Thermal spring in Sultaniye village and historic quay are at lake's south-west side. Lake comprises an area with 12 km length and 5 km width, and connects to sea through 10 km length Dalyan Canal. Hence this canal functions as the main canal connecting the Lagoon to the sea (Maktav and Kabdaşlı 1993, Maktav et al. 1996, Maktav et al. 1996). Fresh water resources of Köyceğiz Lagoon are mainly rivers draining into the lagoon, namely Namnam and Yuvarlakçay. In the studies made by Kabdaşlı and Maktav (1995) in Köyceğiz Lagoon, it is seen that the lake has a depth of maximum 40m and the layers below-15 m of the lake contain no oxygen. Since the channel bottom which is the outlet of the lake is at -4 m from the average water level it is concluded that the lower layer will never confront mix.The measurements made in the lake and the canal show that no salty water reaches Köyceğiz Lagoon from the sea.(Bayarı et al.1995). Mean water volume of Köyceğiz Lake is 9.37×10^6 m^3 . The active upper layer volume is 735568216 m^3.

Reedy in canal decrements volume of fresh water. On the other hand it provides protection from erosion. The changes in canal width (300-400 m) affects the incoming flow and therefore the salty water entry. At connection of sea, Iztuzu Beach has already disappeared as a result of 1m sea level rise. Low water level changes are observed at the lagoon surface. The rivers that give fresh water to the lake are Namnam, Kargacık and Yuvarlakçay. Kargacik Creek from north, Namnam Creek from north-west, and Yuvarlak Creek from north-east side inflow

to the lake. River current intensity and mass and suspended solids in water affect the water of lake. The highest flowrate is incoming from Namnam Creek. The river flows do not make significant contribution to the lake water budget. The river flows are however sudden and intensive. The fresh water input in the first three months of the next year following the month december has been effective in 1998-1999 and 1999-2000 periods.

The high rainfall amount showed a variation between 800mm and 1400mm during the time interval between 1950 and 2000 (Ertürk 2000). High rainfall effect was seen during 1999 and 2000 at december, january, and march. As a result of rainfall, freshwater discharges through river outfalls. Inside the lake coriolis force causes circular waves through coastline. Gravity is also effective as tidal force. High temperature in the year is 26,8^{0}C in July. Low temperature in the year is 7,9^{0}C in January (Üstün, 1998). Wind is a very important parameter for current direction. Wind causes wave effect depending on its direction and speed. Directions of discharge may be different and seen towards sea or lake. As inflow of freshwater rises water level at lake, sand dune is suddenly opened. Therefore reverse discharge occurs from channel to sea. As inflow of salty water is present at lake, salty water stays at deep water level. Salty water can not be discharged unless water level is very low (Maktav and Kabdaslı 1993). Salty water stays stable at low lagoon water level. But this does not cause pollution since salty water does not have a pollutant character.

In this study the a statistical approach, the sliding correlation analysis was applied to the lagoon water level time series in order find the direction of flow and the duration of flow movement. The analysis results were compared with the physical parameter measurements in the area.

Data

In this study the water level measurements at 4 different stations were employed. Station No.1 was installed at the northern part where freshwater inflows (Koycegiz, Figure 1). Station No.2 is located at the connection of Dalyan Channel (Sultaniye). Station no.3 is at the middle of Dalyan Channel (Dalyan), and the fourth at the connection of the channel to the sea (Iztuzu, Figure 1). Stevens GS 93 water level monitoring system was employed for water level measurement.(Kabdaslı et al. 2000) In GS 93 the data card capacity has 120000 readings. There are gaps in water level time series, because floating part of GS 93 can move and fall in the existence of high waves. Another reason for gaps are the boats which hit the machine occasionally. Measured datas were calculated with respect to the topographical map. At 4 stations water levels are recorded instantaneously at 5 minute intervals.

The water level time series during 1998-2001 is arranged in computer. Outliers (extremely high values) in series are deleted. Time intervals for gaps are found. Datas recorded at GS 93 are raw values. Water height is calculated using machine level and lake level as equation for same nivela.



Figure 1. Locations of 4 water level measurement stations

TABLE 1. Water level – (Machine level – Lake level) = Water height

Station name	Machine level (m)	Lake level (m)
Köyceğiz (No:1)	1,695	0,049
Sultaniye (No:2)	1,419	0,056
Dalyan (No:3)	1,252	0,057
Boğaz (No:4)	1,310	0,000

Sliding correlation analysis

The dependency between the water levels of 4 stations are investigated using correlation coefficient (Pearson correlation). For the correlation analysis the common time intervals for each station pair are selected. The correlation analysis is performed for different time lags, i.e.by shifting the data of one station with respect to other station. Accordingly the cross-correlation for time lag 0 represents the correlation between the water level measurements taken at the same time for both stations. On the other hand cross-correlation for time lag 10 is computed by shifting the time series of one station by 10 values (10x5=50 minutes). The cross-correlation was computed for different sliding options and the one having the highest value was determined. Some examples for data shifting process are pre-

sented in Table 2. Here x_t and y_t represent the time series for two different measurement stations.

TABLE 2. Some examples for the data shifting (values within each rectangle are considered for cross-correlation computation)

Case 1 (no shift)		Case 2 (shift by 1 time lag)		Case 2 (shift by 2 time lags)	
x_t	y_t	x_t	y_t	x_t	y_t
x_5	y_5	x_5		x_5	
x_{10}	y_{10}	x_{10}	y_5	x_{10}	
x_{15}	y_{15}	x_{15}	y_{10}	x_{15}	y_5
x_{20}	y_{20}	x_{20}	y_{15}	x_{20}	y_{10}
			y_{20}		y_{15}
					y_{20}

The time shift providing the highest correlation value gives information about the direction and the travelling time of flows between two stations. For example if the highest correlation is obtained by shifting 2 time lags (Case 2 in Table 2) than the flow travelling time between two stations is 10 minutes. In this case, the flow direction is from station x to station y.

The sliding correlation can be formulized as:

$$r_T = \frac{1}{n-1}\sum_{i=1}^{n} \frac{X_{i+T} - \bar{X}}{S_x} \cdot \frac{Y_i - \bar{Y}}{S_y} \qquad (1)$$

where X_i and Y_i represent the water level values, $\bar{X}$ and $\bar{Y}$ the mean water levels, S_x and S_y the standard deviations of the water level series belonging to two different measurement stations. The time periods and the shifting periods for the highest cross-correlations between two measurement stations are presented in Table 3.

TABLE 3. The time periods and the shifting periods for the highest cross-correlations between two water level measurement stations

Time		Station where the flow starts	Station where the flow ends	Shifting duration (hour)	Affecting factors
Start	Finish				
24.02.2000	03.03.2000	Köyceğiz (No:1)	Sultaniye (No:2)	10	Wind
10.12.1999	12.12.1999	Köyceğiz(No:1)	Sultaniye (No:2)	280	Wind
24.02.2000	04.03.2000	Sultaniye (No:2)	Dalyan (No:3)	30	Wind
12.01.2000	14.01.2000	Sultaniye (No:2)	Dalyan (No:3)	70	Wind
03.05.1999	09.05.1999	Dalyan (No:3)	İztuzu (No:4)	60	Wind
18.11.1999	23.11.1999	İztuzu (No:4)	Dalyan (No:3)	70	-
07.04.1999	16.04.1999	Köyceğiz (No:1)	Dalyan (No:3)	90	Wind
24.11.1999	12.12.1999	Köyceğiz (No:1)	Dalyan (No:3)	450	Wind
24.02.2000	04.03.2000	Sultaniye (No:2)	İztuzu (No:4)	90	Wind
24.02.2000	03.03.2000	İztuzu (No:4)	Köyceğiz (No:1)	1120	-

Flow directions are found by considering the shifting direction. The major factors affecting the flow directions are the wind and the storm. The shifting durations (time lags for the correlation analysis) represent the flow travelling duration between two flow measurement stations.

The lake flow process between stations 4 and 3 (İztuzu and Dalyan stations, respectively) for the time period 18-23 November 1999 is graphically explained in Figure 2. Shifting duration is 72 minutes. The flow direction is from station 4 to 3. The flow direction can be explained by the high water level of İztuzu discharged towards Dalyan.

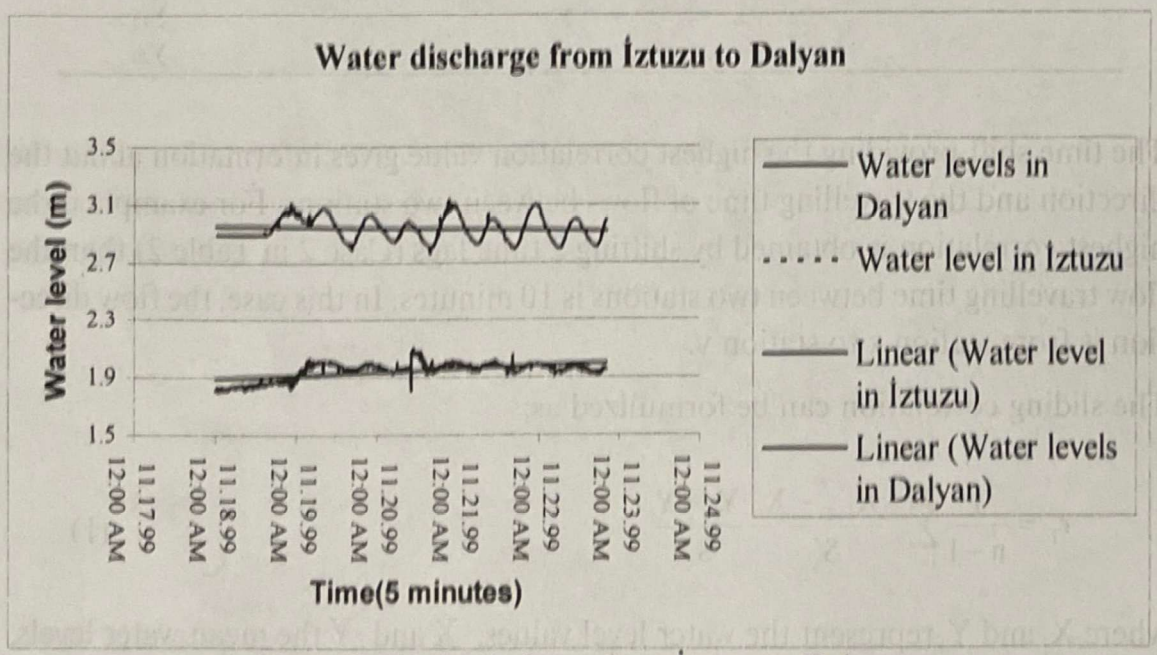


Figure 2. Water discharge from İztuzu to Dalyan

The comparison and interpretation of the contemporary correlation calculations

The flow directions for different station pairs are tabularized for a selected time period (Table 4, November-December 1999). It is seen that the flow directions are the same for the last days of November 1999. It is detected that there is flow from İztuzu to Dalyan and from Dalyan to Köyceğiz. The data of 1st station is not recorded between the dates 19-24 November. As a result of storms there has been floods from the rivers on 15, 16, 19, 21, 24 and 25th November. This is the explanation of the flow direction from station 1 to 3 for 24th and 25th November.

It was observed that the storm on 12 December1999 caused a high increase in the water level of 1st station. The storm on 19 November1999 seems to have caused a similar water level increase due to the storm intensity. On the other hand the wind

direction for the time period between 24 November 1999 and 12 December 1999 agrees with the sliding correlation analysis results verifying the flow direction from station 1 to 3 and from station 1 to 2. There has been fresh water input between the dates 25. November 1999 and 12 December 1999 resulting in a flow direction from the 1st station to the 3rd. The same explanation is holding for the flow directions from 2nd station to 3rd one and from 1st station to 2nd one. But the flow direction from 4th to 2nd station and from 4th to 3rd station for this time period can be attributed to the wave action from the sea towards the lagoon. The water levels for this time interval are plotted in Figure 3 for all 4 stations.

TABLE 4. Flow directions for station pairs for a selected common time period (18.11.1999-12.12.1999)

Station pairs	Time																							
	November 1999													December 1999										
	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11	12
1. ve 2.																							→		
1. ve 3.	—						→																		
2. ve 3.																							→		
1. ve 4.	—													←											
2. ve 4.																							←		
3. ve 4.	←													←											

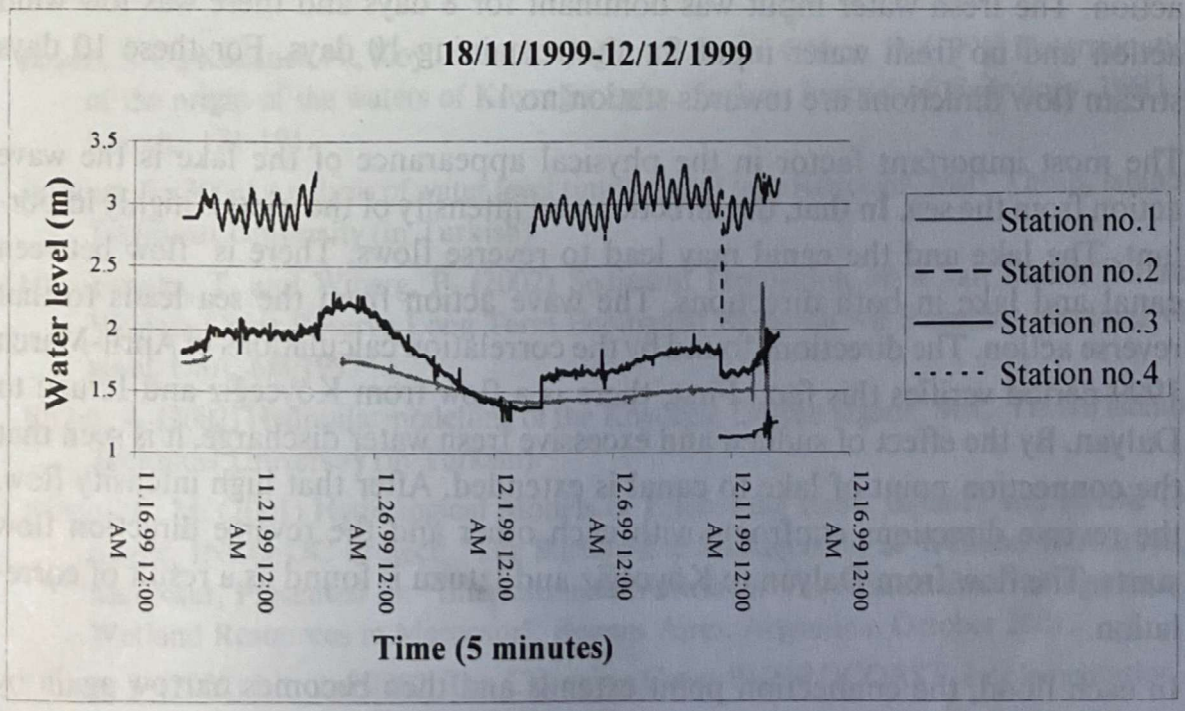


Figure 3. Water levels for all 4 stations for the time period 18.11.99-12.12.1999

Considering the water levels at measurement stations the flow direction is expected to be from sea to lake. However the movement of upper layer in the form of waves occurs frequently. It is found that for the period of February-March 2000 the flow direction from lake to sea is the same for all stations (Table 5). The intense storms in January, February and March 2000 have been effective in the flow direction from Köyceğiz to İztuzu. No explanation, however, could be found for the flow direction from 4th station to the 1st one.

TABLE 5. Flow directions for station pairs for a selected common time period (24.02.2000-10.03.2000)

Station pairs	Time													
	February 2000					March 2000								
	24	25	26	27	28	1	2	3	4	5	6	7	8	9	10
1. ve 2.	→	→	→	→	→	→	→								
1. ve 3.	→	→	→	→	→	→	→	→							
2.ve 3.	→	→	→	→	→	→	→	→	→						
1. ve 4.	←	←	←	←	←	←	←								
2. ve 4.	→	→	→	→	→	→	→	→	→						→
3. ve 4.	→	→	→	→	→	→	→	→	→	→	→	→	→	→	

The comparison of flow directions with other parameters measured at the same times is also investigated. These parameters are wind, wave and water input. A comparison with the wind direction is done for more than half of the time periods included in the study. The movement of lagoon water with wind action is observed. It is seen that for 94 out of 143 days the flow direction was affected by wind action. The fresh water input was dominant for 8 days and there was low wind action and no fresh water input for the remaining 10 days. For these 10 days stream flow directions are towards station no.1.

The most important factor in the physical appearance of the lake is the wave action from the sea. In that, the direction and intensity of the wind is highly important. The lake and the canal may lead to reverse flows. There is flow between canal and lake in both directions. The wave action from the sea leads to that reverse action. The directions found by the correlation calculations in April-March 1999 period verifies this fact. First, there is a flow from Köyceğiz and İztuzu to Dalyan. By the effect of sudden and excessive fresh water discharge, it is seen that the connection point of lake to canal is extended. After that high intensity flow, the reverse directions confronts with each other and the reverse direction flow starts. The flow from Dalyan to Köyceğiz and İztuzu is found as a result of correlation.

In each flood, the connection point extends and then becomes narrow again by sand filling. In general, as the water level in lagoon increases, the lagoon borders

extend. During the flood, the lagoon tends to protect its borders by extending the canal. It was seen that freshwater inflows changed stream direction towards sea during November-December1999 period. Although stream direction was initially from Köyceğiz towards the lake, it was changed towards the sea. But current direction at station 4 is not affected by freshwater inflow because of the low freshwater quantity. The direction was from Köyceğiz to Dalyan. The stream flow was directed from Köyceğiz towards the Iztuzu according to the computed sliding corelation for February-March 2000 time interval as mentioned by Bozkurt (2003).

Conclusions

The presented study comprised the application of the sliding correlation method to lake flows. The method provided information about the flow directions and the flow movement duration between different water level measurement stations on the lagoon. The flow directions computed by the method were compared with the measurements of physical parameters such as wind, wave action from the sea, storms, floods, groundwater, evaporation and the tides. It was seen that the computed directions agreed well with the wind measurements, wave directions and river water inflows. In other words, the presented statistical approach shed light to the physical nature of the water flow movement on the lagoon. This kind of ingormation can be quite useful for the times when physical parameter measurements are not available.

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PREFACE

The fourth issue of the International Black Sea Conference on Environmental Protection Technologies for Coastal Areas, traditionally organized by the Bulgarian National Association on Water Quality and supported by IWA and EWA will gather from 9 to 11 June 2004 in Varna researchers, experts, practitioners and managers from Bulgaria, Turkey, Austria, Germany, Belgium, Denmark, Japan, Czech Republic, Greece, Iran and USA.

The Black Sea is a unique natural phenomenon in respect to its specific morphological, hydrological and environmental conditions. Many big European and Asian rivers drain in it huge heavily populated territories effluents, while the only outlet the Bosphorus channel, mostly separates from, than connects the Black Sea to the Mediterranean Sea and the global ocean water motion. This situation makes the Black Sea very sensitive to anthropogenic impacts and particularly to water pollution.

The papers presented for the conference and published in this Proceedings cover five main topics:

- Environmental Monitoring and Identification of Pollution Sources
- Legislation on Sea Water Quality, the Black Sea Strategic Action Plan
- Wastewater Treatment Technologies in Coastal Areas
- Impact of Danube River to the Pollution of the Black Sea
- Integrated Coastal Zone Management

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The Local organizing committee members and the Conference Secretariat worked with perseverance for the compilation of these proceedings and for the success of the conference.

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BOOK OF PROCEEDINGS

ENVIRONMENTAL PROTECTION TECHNOLOGIES FOR COASTAL AREAS

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