Alfred FRASHËRI*, Niko PANO*, Salvatore BUSHATI*, Neki FRASHËRI*

CLIMATE CHANGE IMPACT ON BUNA RIVER DELTA IN ADRIATIC SEA

Përmbledhje: Artikulli analizon impaktin e ndryshimeve klimatike dhe karakteristikave hidrologjike të lumit dhe detit: shkarkimi i Lumit Buna, qarkullimi i masave ujore në Gjirin e Drinit, thyerja e valëve, niveli i detit dhe dyndja e valëve të larta të baticave, akumulimi bregdetar dhe proceset erozionale etj., të cilat kushtëzojnë zhvillimet hidro-gjeomorfologjike të Deltës së Lumit Buna. Morfologjia dhe dinamikat e zhvillimeve hidro-gjeomorfologjike të Deltës së Lumit Buna kushtëzohen nga regjimi i lumit, regjimi talasografik i Detit Adriatik dhe nga ndryshimet klmatike.

Fjalë kyçe: *delta, temperatura e truallit sipërfaqësor, ndryshimet klimatike, sistemi hidrografik, Deti Adriatik*

Abstract: In the paper are analyzed impact of climate change, and hydrologic characteristic of the river and sea: Buna River run-off discharge, water mass circulation in Drini bay, wave refraction, sea level and incursion of the high tide waves, coastal accumulation and erosion processes et al, that are conditioned hydro-geomorphologic development of the delta of Buna River. The morphology and hydro-geomorphologic development dynamics of the Buna River Delta are conditioned by hydrological regime of the river, thalassographic regime of the Adriatic Sea, and climate change impact.

Key words: *Delta, Ground Surface Temperature, Climate Changes, Hydrographic System, Adriatic Sea*

INTRODUCTION

Detailed analyze of the climate change in Albania is presented in the first part of the paper (Frashëri, 1995), Frashëri *et al.*, 1999, 2002). Albania is a subtropical zone. To the east, in the mountain areas, the climate is Mediterranean mountainous. The climate in Albania varies from a region to the other. The climate change studies are based on geothermal inversion results and meteorological observation data. There

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is analyzed the ground surface history (GSH) and paleoclimate change according to the temperature recorded in the different wells in Albania. Climate changes during the last half of the XX century has been analyzed also based on the meteorological data. There are estimated continental water flow, created by atmospheric rainfalls and its impact on processes of the forming and circulation of the Adriatic Sea water mass has been analyzed. In the second part of the paper, is presented the analysis of climate change impact on Buna River Delta in Adriatic Sea.

MATERIAL AND METHODS

Climate changes are analyzed in two directions: firstly by temperature record in the deep wells and shallow boreholes, and secondly by the meteorological observations data. The ground surface temperature reconstruction for long period, about 5 centuries, has been performed by estimation of the ground surface temperature changes at the past, according to the present-day distribution of the temperature at the depth, recorded in six boreholes, which are located at the plain and mountain regions. The study of geothermal field of Albania has been carried out based on the temperature logging in the wells and boreholes (Čermak *et al.,* 1996; Frashëri *et al.*, 1995, 2004). Air and ground temperatures, total annual rainfall quantity, wind speed and wetness, which are analyzed by records in Meteorological Stations (Albanian Climate, 1978; Boriçi & Demiraj, 1990; Gjoka, 1990; Mici *et al.,* 1975, the data for 1985–2000 after Mustaqi V.).

Water potential of the Albanian Rivers System have been evaluated by a specific way (Pano, 1967, 1995, 1998), based on the multi annual archival data (Hydrometeorological Institute of the Academy of Sciences of Albania) have calculated the annual run-off discharge of the Scutary Lake-Buna River-Drini River System, according to the corresponded types of the water supply, structure of the annual discharge distribution. All modeling and calculations have been performed for the model of dry and wet characteristic years, to analyze the climate impact on Albanian Hydrographic System. Processes of the forming and circulation of the Adriatic Sea water mass have analyzed based on hydrographic data and Results of Albanian Marine Expeditions „Saranda in 1963", „Patosi in 1964" (Pano, 1967), and Italian-Albanian Expeditions „Italica I and II, 2000 and 2001" (Pano, 2008).

RESULTS AND DISCUSSION

Buna River is important part of the hydrographic complex „Scutary Lake – Buna River – Drini River". Delta of the Buna Rives is located in Drin Bay at Adriatic Sea (Fig. 1-a-b, 2, Photo). This delta presents one of more active and interesting area of the Mediterranean Sea.

The ground surface temperature reconstructions of the thermoplots of Kolonja–10 deep wells, which are located at coastal plain region of western Albania, are shown in fig. 2. As it is seen in this figure, the GST history yielded by tighter inversion of Ko–10, presents a gradual cooling of 0.6 K, before a middle of the 19 th century. Later followed by 0.6 K warming, with a gradient 5.4 mK/years, that seems quite

Figure 1. (a, b). Satellite image of the Scutary Lake-Buna River-Drini River System, and Buna River Delta aero-photo.

reasonable and is consistent with generally accepted ideas about the climate of the last 2–3 centuries. GST history shows that warming gradient increasing is observed also at mountainous regions.

Climate changes in Albania are observed also by the hydrometeorological studies. Fig. 4, 5 present graphics of yearly average temperature of the air in Tirana and Shkodra Meteorological Stations, for the period from 1931 to 2004. In general, the end of first observes half 20 th century, a warming of climate, about 1 °C (Boriçi & Demiraj, 1990).

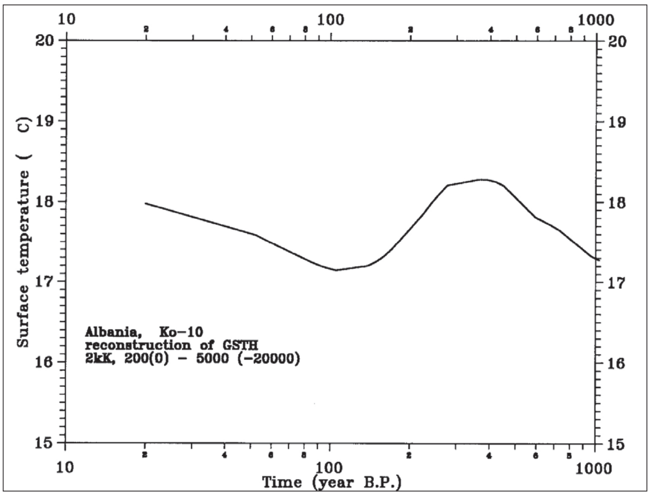

Figure 2. Ground surface temperature history according to thermoplot of Ko–10 and Arza–31 wells (According to the Šafanda, J. calculations).

Thirty quarter of 20th century is characterized by a cooling of 0.6°C, and later, up to present a warming of 1.2°C. The same climate changes are observed also at Shkodra

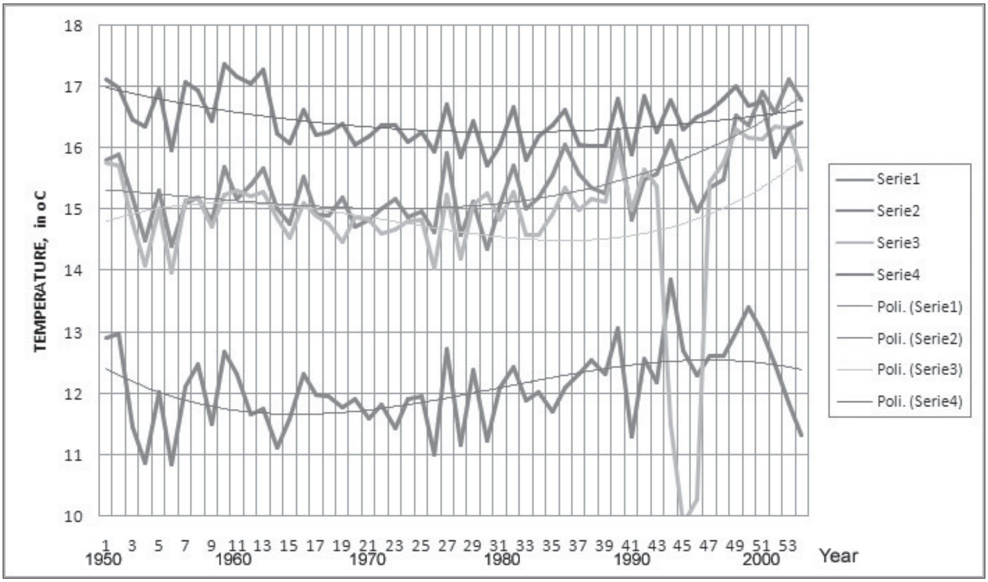

Figure 3. Air Average Annual Temperature Variation at Tirana and Shkodra Meteorological Stations (Period 1931–2004). Serie: 1- Tirana; 2- Kukës; 3- Shkoder; 4- Vlora

City. The cross correlation coefficient is $C_c = 0.78$ between variation curves of the average annual temperatures of both of these stations. Warming trend of maximum 1.2 °C, in particular after seventy years, is observed in all Albanian territory.

The meteorological data shows that the warming trend is not a monotone one. In short intervals are observed cooling and warming (Fig. 3, 4).

The warming period in Albania is accompanied with changes of the rainfall regime, wind speed and wetness. There are observed a decreasing of the total year rainfall quantity, for about 200–400 mm. (Fig. 5).

In (Fig. 6) is presented the difference of the total year rainfall quantity in the most dry and wet years, respectively 1907 and 1960.

The warming have accompanied with decreasing of the wind speed about 1.5 m/sec and 5% increasing of the wetness, during the period of 1950–1994 (Fig. 7).

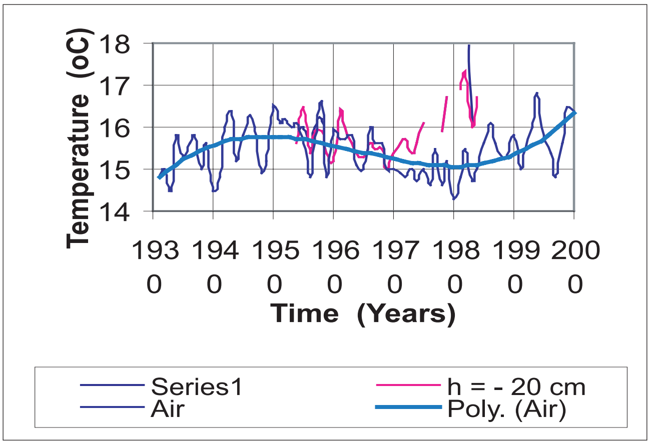

Figure 4. Air and Ground Average Annual Temperature Variation at Tirana Meteorological Station

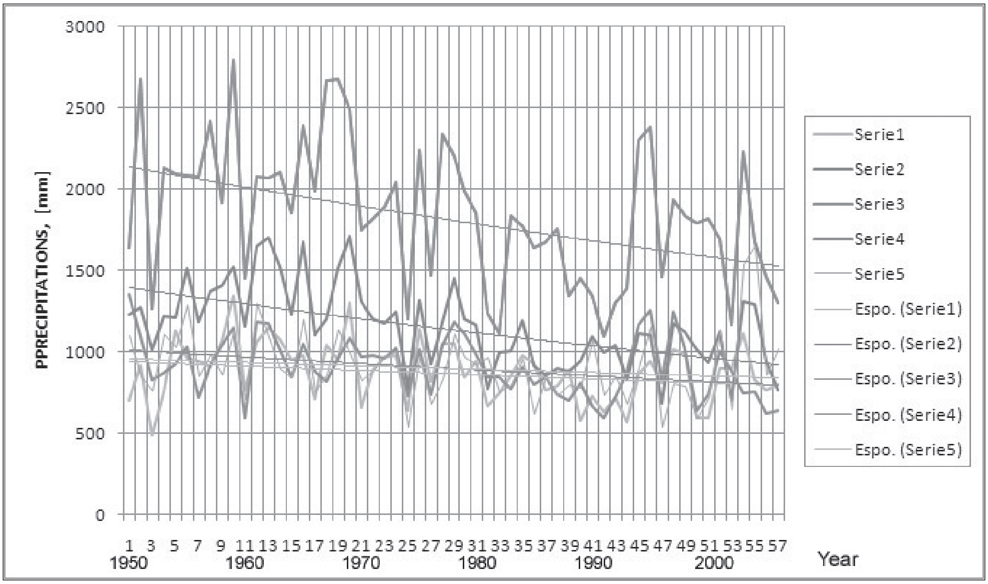

Figure 5. Total year rainfall quantity of the Tirana and Shkodra Meteorological Station (Period 1930–2007). Serie: 1 – Kukës; 2 – Tirana; 3 – Shkodër; 4 – Ersekë; 5 – Vlora.

This warming is part of the global Earth warming during the second half of XX century. Its impact has been observed on water systems and water resources. Inland water resources change has its impact also on the hydrographic regime of the Adriatic Sea (Pano, 1984, 1994, 2008). There are great impacts of the specific natural conditions of the Albanian Hydrographic System catchment in particular of the Scutary Lake-Buna River-Drini River System.

Buna River maximal flow (respectively discharge ($QM_{p\%}$) and volume ($WM_{p\%}$) for different probabilities (p=0,01; 0,1; 1; 2; 5; 10, 20 %) is presented in the Table 1, Fig. 8 a, b, c.

Maximal flow with a probability p=1% (one in 100 years) has the discharge $QM_{p=1\%} = 6680\ m^2/s$ and a volume $WM_{p=1\%} = 2870.10^6\ m^3$.

The average annual sea level is H=0,12 m on the 0” absolute level. In

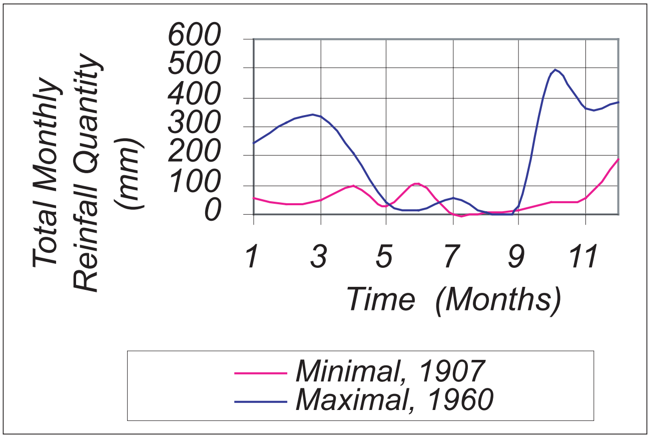

Figure 6. Total Year Rainfall Quantity in the most dry and wet year, respectively, of the Shkodra Meteorological Station (respectively 1907 and 1960 years).

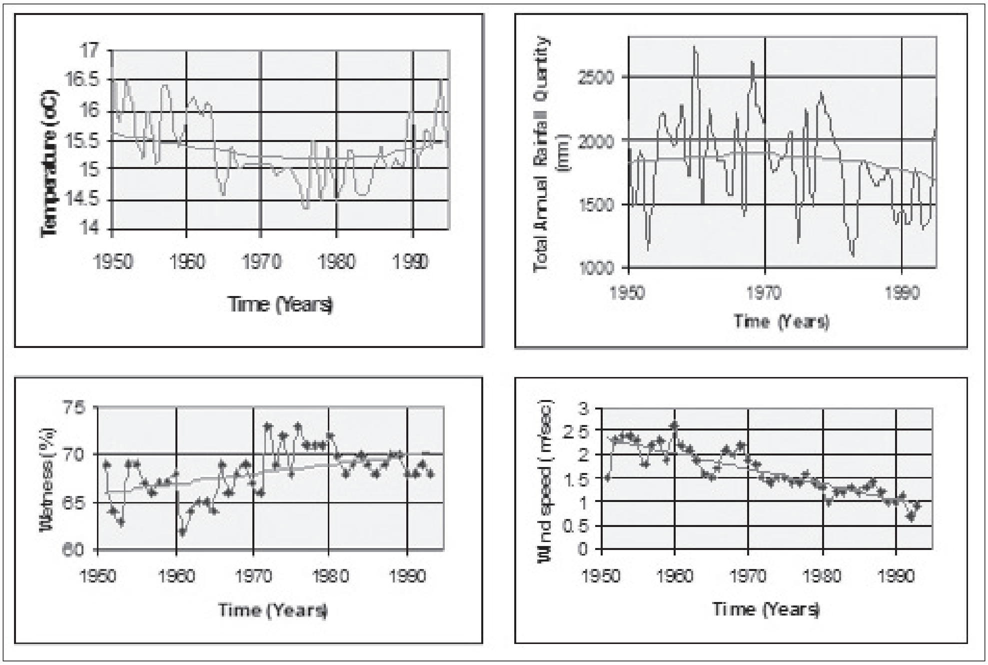

Figure 7. Air Average Annual Temperature, Total Year Rainfall Quantity, Wind Speed and Wetness Variations, at Shkodra Meteorological Stations (Period 1950–1994).

the multi annual period the maximal level with the probability of p=1% on the Albanian offshore is H_{max}= 1,2 m on the 0” absolute level, while the minimal level is H_{min}=-0,5 m Abs. as the results the maximal amplitude of the sea level during the multiannual period is $\Delta H=(H_{max} - H_{min})$=1,62 m. The most eventual waves observed during the year in the Drini Bay are h=0,6–1 m (33% of the cases). Same important ones are also the following: h=1,6–3,1 m (20% of the cases). The one of the h=3,5 m have are not observed very often, about 0,3%. Their principal directions are S, SW, NW, and S. The maximal waves in marine shelf: height h=5,10 m, length L=80,6 m, velocity C= m/sec and period τ=7,2 sec.

Table 1. Maximal flow, Buna + Drini River-Dajç

Nr.	River	Elements	Index	Units	Parameters			Probability, [%]						
					R 0	Cv	Cs	20	10	5	2	1	01,	0,01
1	Buna-Drini Dajç	Discharge	Q_0	m^3/s	4010	0,22	0,88	4690	5210	5680	6220	6680	7860	9020
		Volume	W_0	$.10^6\ m^3$	1367	0,34	1,36	1700	1980	2270	2610	2870	3700	4520

Minimal discharge is 700–800 m^3/s for the hydrological dry years of low precipitation, up to maximal values 1900–2200 m^3/s for the hydrological wet years of high precipitation.

Buna River is one of the most important rivers of the Mediterranean Basin. This river, together with Po River in Italy, is determinant in the water balance of the Adriatic Sea.

Climate change and variation of the discharges have its impact on the marine water mass flows and solid material transport in the time, velocity and locations, and also on the wave regime (Fig. 8-b Pano, 1995; Simeoni *et al.*, 1997). Consequently, in the Buna delta during the short period for about 37 years (1972–2009) are developed intensive erosion, and in the both side of the coastline an accumulation process (Fig. 8-c). In the Buna River Delta actually is formed a marine spit (Fig. 9).

Ecosystems, and biodiversity, in the particularly in the water's flora and fauna have an important influence from climate change. Temperature augmenting has caused increasing of the evaporation in the water systems. Consequently in the river system, reservoirs, wetlands, lakes and lagoon system has been observed thermal stress. In very beautiful ecosystems of Albanian lagoon as Kune-Vaini in Lezha region etc. thermal stress has its impact, first of all on the biodiversity. This stress is extended also in the shallow coastal waters; consequently there are observed diminution of the fish quantity.

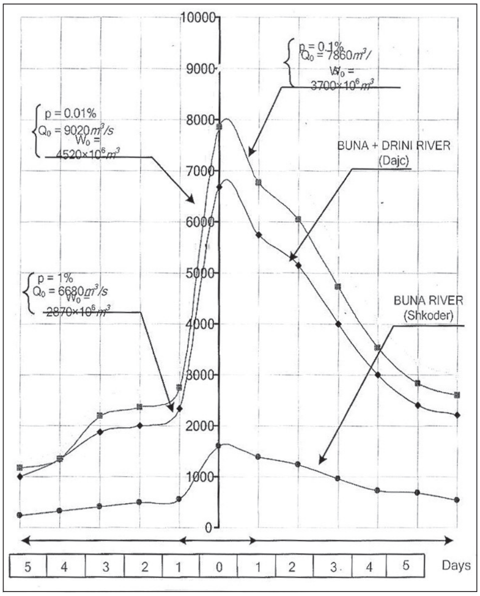

Figure 8 a. Maximal flow, Buna + Drini River-Dajç

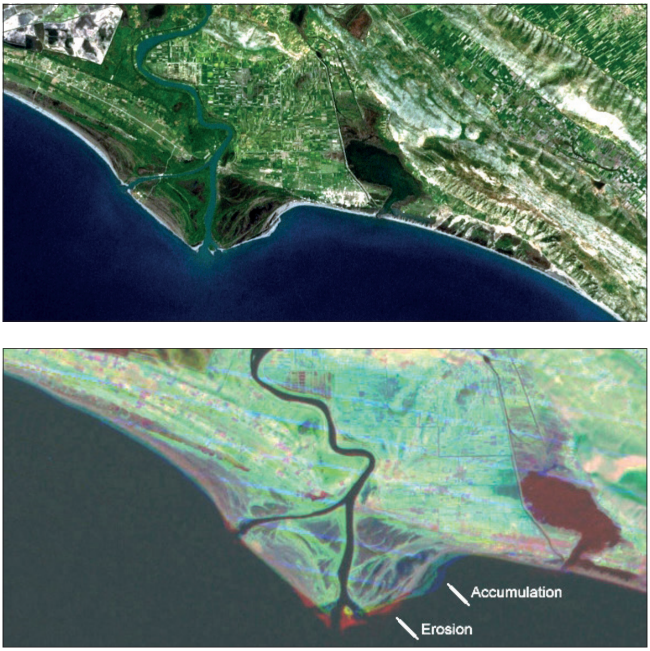

Figure 8 b, c Marine flows, solid sediments materials (b), and the geomorphologic development of the Buna River Delta area for the period 1975.2009, according to the satellite images NIR analyze (c).

Figure 9. Marine spit in Buna River Delta

CONCLUSIONS

1. The climate at coastal plain region of Western of Albania was cooled of. 6 K before of middle of 19th century. Later a warming of 0.6 K occurred, from last quarter of 19th until present-day. Temperature records in northwestern mountainous region of Albania confirmed also a climate warming of 0.6 K during 20th century. Warming, mainly during the last quarter of the 20th century, is demonstrated also by meteorological data.

2. Warming has caused its impact on country climate and ecosystems. There is observed a decreasing of the water resources of the country, and thermal stress in the wetlands, lagoons and lakes of Albania. Impact it is observed first of all on the biodiversity.

3. The rainfall regime changes have their consequences in the fresh water resources of the country, of surface's and underground waters.

4. In the Buna delta during the short period for about 37 years (1972–2009) are developed intensive erosion and in the both side of the coastline an accumulation process.

5. Geomorphologic change of the coastline it is necessary to evaluate during the urban planning of the coastline.

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