AdriaClim

Climate change information, monitoring and management tools for adaptation strategies in Adriatic coastal areas

Activity 3.4

Integration and assessment of information of monitoring (obs/models) components for each Pilot

D.3.4.1

Report on Integration and assessment of monitoring (observations and models) components information for each Pilot

Deliverable:	D3.4.1 [Report on Integration and assessment of monitoring (observations and models) components information for each Pilot]
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Reviewers	

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1. Introduction

The main aim of this deliverable is to provide the list of quality checked information (observations and model output) available for each of the project's Pilot areas (Fig. 1). Moreover, this deliverable aims at providing an overview of the climate variability in the past/present time and in the future scenarios through the computation of specific climate indicators (e.g., trends).

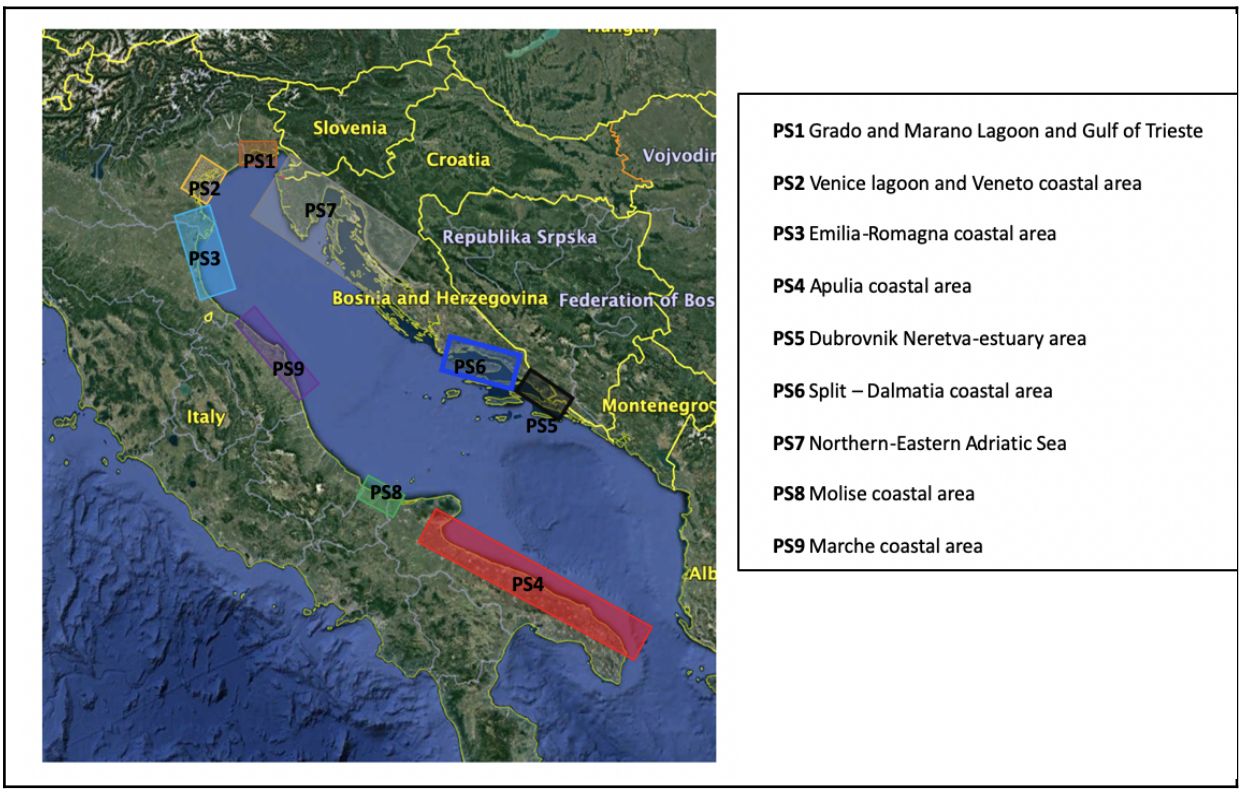

Fig. 1. The AdriaClim pilot areas in the Adriatic basin.

2. Available datasets for each Pilot area

The list of available information has been derived from deliverables 3.1.1. and 3.2.1 for the observations and the model outputs, respectively. The datasets should be subjected to the quality check protocols described in deliverable 3.3.1. and distributed through the AdriaClim information system (see deliverable 4.1.1.).

It is noteworthy that the Regional Earth system Model over the Adriatic Sea area implemented in the AdriaClim project will provide atmospheric, hydrologic and oceanographic information for all pilot areas.

2.1 PS1 Grado and Marano Lagoon and Gulf of Trieste

Involved partners: ARPA FVG, UNIBO, CNR-ISMAR.

Table 1: Available observations and model results at PS1.

Type	Name	Description
Observation	ISPRA RMN Tide-gauge at Trieste	*Variables: sea-level height, water temperature, air temperature, atmospheric pressure, wind speed, wind direction, relative humidity* *Sampling frequency: 10 min*
Observation	ISPRA RMLV Tide-gauge at Grado	*Variables: sea-level height* *Sampling frequency: 10 min*
Observation	CNR tide-gauge station al Molo Sartorio	*Variables: sea-level height, atmospheric pressure.* *Sampling frequency: 10 min/ hourly*
Observation	CNR Meteorological station at Molo F. Bandiera	*Variables: 10 m air temperature and wind, sea temperature at 0.4, 2 and 6 m.* *Sampling frequency: 10 min/ hourly*
Observation	ARPA FVG coastal meteorological station at Trieste, Fossalon di Grado, Grado and Lignano Sabbiadoro	*Variables: precipitation, wind speed and direction, temperature, relative humidity and global solar radiation.* *Sampling frequency: 10 min/ hourly*
Observation	ARPA FVG open sea stations located in the Gulf of Trieste (16 stations)	*Variables: temperature, salinity, dissolved oxygen, turbidity and chlorophyll-a, dissolved nitrogen forms, dissolved phosphorus, silicate, total nitrogen and total phosphorus.* *Sampling frequency: monthly*
Observation	ARPA FVG transitional waters stations located in the Lagoon of Marano-Grado (16 stations)	*Variables: temperature, salinity, dissolved oxygen, turbidity and chlorophyll-a, dissolved nitrogen forms, dissolved phosphorus, silicate, total nitrogen and total phosphorus.*

		Sampling frequency: 10 min/ hourly
Model	SHYFEM application to the Gulf of Trieste and the Lagoon of Marano-Grado	*Variables: sea level height, current velocity, water temperature and salinity.* *Output frequency: hourly.* *Numerical domain and resolution: the numerical computation is performed on a spatial domain that represents part of the northern Adriatic Sea and the lagoon of Marano-Grado by means of an unstructured grid. To adequately resolve the river-sea continuum, the unstructured grid also includes the lower part of the other major rivers flowing into the considered system. The numerical grid consists of 33,100 triangular elements with a resolution that varies from 4 km in the open-sea to a few hundred metres along the coast and tens of metres in the inner lagoon channels.*

2.2 PS2 Venice lagoon / City of Venice / Veneto coastal area

Involved partners: Arpa Veneto, CNR-ISMAR, AUSSL3 Serenissima, ISPRA, City of Venice.

Table 2: Available observations and model results at PS2.

Type	Name	Description
Observation	*ISPRA RMLV tide-gauge and meteorological stations in the North Adriatic Sea and the Venice lagoon (26 monitoring stations)*	*Variables: sea level height and meteo-marine parameters* *Sampling frequency: 10 minutes*
Observation	ARPAV Environmental quality network of Veneto coastal and marine waters (76 sampling stations)	*Variables: multiparametric probe, nutrients, phytoplankton, chemical analysis of the water and sediment and biota matrix* *Sampling frequency: seven campaigns per year*
Observation	ARPAV Marine Strategy network	*Variables: analysis of the water, sediment and biota matrix* *Sampling frequency: six campaigns per year*
Observation	ARPAV environmental quality network of the Venice lagoon (30 sampling stations)	*Variables: ecological quality* *Sampling frequency: four campaigns per year*
Observation	ISPRA RON wave buoy Venice	*Variables: significant wave height, wave direction, wave mean period, wave peak period, wind speed, wind direction, water temperature, air temperature, atmospheric pressure, relative humidity* *Sampling frequency: 10 min/ hourly*

Observation	CNR-ISMAR Acqua Alta oceanographic platform	*Variables: wind speed and direction, air temperature, humidity, solar radiation, precipitation, sea temperature, sea level, ADCP currents, waves* *Sampling frequency: 10 min/ hourly*
Observation	ARPAV meteorological network	*Variables: meteorological parameters* *Sampling frequency: 10 min/ hourly*
Model	SHYFEM application to the Venice Lagoon and Veneto coast	*Variables: sea level height, current velocity, water temperature and salinity.* *Output frequency: hourly.* *Numerical domain and resolution: the numerical computation is performed on a spatial domain that represents the entire Lagoon and its adjacent shore. The numerical grid consists of about 32,000 triangular elements with a resolution that varies from 2 km in the open-sea to a few hundred metres along the coast and tens of metres in the inner lagoon channels.*

2.3 PS3 Emilia-Romagna area

Involved partners: ARPAE, RER, UNIBO, CNR-ISMAR, CMCC, ISPRA.

Table 3: Available observations and model results at PS3.

Type	Name	Description
Observation	ISPRA RMN Tide-gauge at Ravenna	*Variables: sea-level height, water temperature, air temperature, atmospheric pressure, wind speed, wind direction, relative humidity* *Sampling frequency: 10 min*
Observation	ARPAE real time coastal and marine network (four stations in the Goro and Sacca di Goro Area and other four located in the Valli di Comacchio)	*Variables: Dissolved oxygen, pH, salinity and temperature* *Sampling frequency: hourly*
Observation	ARPAE monitoring in the Sacca di Goro (20 stations)	*Variables: Dissolved oxygen, pH, salinity and temperature* *Sampling frequency: undefined, only from June to September*
Observation	ARPAE Integrated station of Porto Garibaldi	*Variables: sea level, water quality, air temperature and humidity, wind direction and velocity, atmospheric pressure, pluviosity, vertical land movement parameters* *Sampling frequency: hourly*

Observation	ARPAE Nausicaa buoy	*Variables: sea temperature, significant wave height, wave direction, wave mean period, wave peak period* *Sampling frequency: hourly*
Observation	ARPAE idro-meteo monitoring network	*Variables: Rain gauges (233), hydrometric levels (182), temperature (176), relative humidity (67), wind (36), solar radiation (27), snow depth (18), radars (2), and an automatic radio sounder (1)* *Sampling frequency: hourly*
Observation	ARPAE Daphne Oceanographic Structure (35 sampling stations located along eight transects perpendicular to the coast)	*Variables: sea temperature, salinity, dissolved oxygen, pH, chlorophyll-a, nutrients (nitrate, phosphate and silicate) and phytoplankton communities.* *Sampling frequency: two times a month (weekly from June to September)*
Observation	ARPAE Environmental and sanitary monitoring network of shellfish production areas of Emilia Romagna (61 sampling stations)	*Variables: salinity, oxygen, pH, water and air temperature, toxic phytoplankton, heavy metals, PAHs, PCBs, dioxins, faecal bacteria (e.g. Escherichia coli; Salmonella spp.), viruses, biotoxins* *Sampling frequency: weekly/monthly/yearly*
Observation	ARPAE Daphne Oceanographic Structure for shellfish life and productions (most of the 35 sampling stations for the classification of the trophic status of coastal marine waters)	*Variables: pH, T°, oxygen, salinity, suspended solids, colour, metals, hydrocarbons, organ halogenated substances, faecal coliforms and saxitoxin and other substances which can influence the flavour of shellfish* *Sampling frequency: unknown*
Model	SHYFEM-BFM application to the Emilia Romagna coast	*Variables: sea level height, current velocity, water temperature, salinity, biogeochemistry.* *Output frequency: hourly.* *Numerical domain and resolution: the numerical computation is performed on a spatial domain that represents the Emilia-Romagna coast and its adjacent shore. The numerical grid consists of 15,392 triangular elements with a resolution that increases towards the coast.*

2.4 PS4 Apulia region

Involved partners: Apulia region, CMCC.

Table 4: Available observations and model results at PS4.

Type	Name	Description
Observation	ISPRA RMN Tide-gauge at Bari	*Variables: sea-level height, water temperature, air*

	and Otranto	*temperature, atmospheric pressure, wind speed, wind direction, relative humidity* *Sampling frequency: 10 min*
Observation	ISPRA RON wave buoy at Monopoli	*Variables: significant wave height, wave direction, wave mean period, wave peak period, wind speed, wind direction, water temperature, air temperature, atmospheric pressure, relative humidity* *Sampling frequency: 10 min/ hourly*
Observation	CMCC buoy at Torre Guaceto Marine Protected Area	*Variables: unknown* *Sampling frequency: unknown*
Model	SHYFEM application to the Apulia coast	*Variables: sea level height, current velocity, water temperature and salinity.* *Output frequency: hourly/daily.* *Numerical domain and resolution: the numerical computation is performed on a spatial domain that represents the southern Adriatic Sea surrounding the Apulia coastline*

2.5 PS5 Dubrovnik Neretva area

Involved partners: DUNEA, IOF, CMCC, CNR-ISMAR.

Table 5: Available observations and model results at PS5.

Type	Name	Description
Observation	Slano bay monitoring network (3 stations)	*Variables: salinity, temperature and bacterial (Escherichia coli, Enterococcus)* *Sampling frequency: unknown*
Observation	Permanent national oceanographic monitoring	*Variables: unknown* *Sampling frequency: unknown*
Observation	Regular Neretva estuary monitoring by a research vessel BIOS DVA	*Variables: sea temperature, Salinity, Transparency, Oxygen, Copper, Zinc, Phytoplankton pigments, Phytoplankton species, Nutrient salts, pH, DOC (Dissolved organic carbon), Priority substances in water, biota and sediment, Microalgae, Microzooplankton, Mesozooplankton, Marine seagrass, Benthic invertebrates* *Sampling frequency: unknown*
Model	ROMS-Ichthyop application to the Dubrovnik Neretva area	*Variables: sea level height, current velocity, water temperature, salinity and dispersion of passive particles.* *Output frequency: hourly.* *Numerical domain and resolution: the model domain*

		covers the Neretva estuary and adjacent coastal sea with horizontal resolution of 200 m.

2.6 PS6 Split – Dalmatia area

Involved partners: RERA, IOF, RB, CMCC, CNR-ISMAR

Table 6: Available observations and model results at PS6.

Type	Name	Description
Observation	IOF T/S long-term monitoring at Split-Vis transect and at Stončica station	*Variables: water temperature and salinity* *Sampling frequency: monthly*
Observation	IOF plankton monitoring at Stončica and Kaštela Bay stations	*Variables: water temperature, salinity, chlorophyll-a concentration, picoplankton, phytoplankton and zooplankton community* *Sampling frequency: monthly or seasonally*
Observation	Sediment monitoring in Split-Dalmatia	*Variables: grain size composition, the content of organic matter (loss of ignition) and carbonates were determined at all stations, while the content of N and P in surface subsamples 2 cm thick and the content of org C* *Sampling frequency: monthly or seasonally*
Observation	Tide gauge at Jurana	*Variables: sea level height* *Sampling frequency: hourly*
Model	ROMS-Ichthyop application to the Split-Dalmatia area	*Variables: sea level height, current velocity, water temperature, salinity and dispersion of passive particles.* *Output frequency: hourly.* *Numerical domain and resolution: the model domain covers the middle Adriatic coastal area with a horizontal resolution of 165 m in the E-W direction and 231.5 m in the N-S direction.*

2.7 PS7 Northern-Eastern Adriatic Sea

Involved partners: IRB

Table 7: Available observations and model results at PS7.

Type	Name	Description
Observation	IRB Center for Marine Research (CMR) oceanographic buoys	*Variables: unknown* *Sampling frequency: unknown*

2.8 PS8 Marche area

Involved partners: Regione Marche.

Table 8: Available observations and model results at PS8.

Type	Name	Description
Observation	SPCSL meteorological network	*Variables: precipitation, temperature, humidity, wind, air pressure, hydrometric level of watercourse* *Sampling frequency: hourly*
Observation	ASSAM meteorological network	*Variables: precipitation, temperature, humidity, wind, air pressure* *Sampling frequency: hourly*
Observation	ISPRA RMN Tide-gauge at Ancona and San Benedetto del Tronto	*Variables: sea-level height, water temperature, air temperature, atmospheric pressure, wind speed, wind direction, relative humidity* *Sampling frequency: 10 min*
Observation	CNR-IRBIM Meda Senigallia	*Variables: air temperature, humidity, wind, air pressure, sea level height, current speed and direction, significant wave height, mean wave period, mean wave direction, chlorophyll a, turbidity, sea temperature, salinity, dissolved oxygen,* *Sampling frequency: hourly*
Observation	ARPAM Algal surveillance monitoring (35 stations)	*Variables: sea temperature, salinity, pH, dissolved oxygen, concentration of chlorophyll-a, reactive silica and transparency, phytoplankton component (composition, density, reporting of blooms of potentially toxic species), nutrients (soluble inorganic nitrogen and total phosphorus)* *Sampling frequency: monthly*
Observation	ARPAM Monitoring of coastal marine water bodies (12 transects, each consisting of 2 stations)	*Variables: sea temperature, salinity, pH, dissolved oxygen, chlorophyll a, reactive silica and transparency, phytoplankton component (composition, density, reporting of blooms of potentially toxic species), nutrients (soluble inorganic nitrogen and total phosphorus), macrobenthonic component* *Sampling frequency: monthly*

2.9 PS9 Molise area

Involved partners: Regione Molise.

Table 9: Available observations and model results at PS9.

Type	Name	Description
Observation	Civil protection hydro-meteorological monitoring network	*Variables: equivalent precipitation, hydrometric level, air temperature, relative humidity of the air, wind speed and wind direction, solar radiation, the height of the snow cover, normalised pressure at sea level.* *Sampling frequency: 10 min*

3. Assessing climate variability for each Pilot areas

The objective of the second part of this study is to identify useful statistical indicators from measured and modelled datasets for assessing the climate variability in the investigated pilot area. The climate variability trends have been computed applying time-series analysis methodologies to selected monitoring variables, here grouped in three main categories: 1) physical and chemical marine variables (sea temperature, salinity, sea level, wind-wave energy and height, oxygen, nutrients), 2) atmospheric and hydrological variables (air temperature, wind speed, mean sea level pressure, precipitation, river discharge), 3) biotic variables (chlorophyll-a and phytoplankton) (Chust et al., 2022).

Traditionally, time series methods decompose the temporal data into the following components: cyclical fluctuation, trend, and random error (Mudelsee, 2019). For the present study, we suggest using the non-parametric Mann–Kendall test to assess the significance of trends in the climate data on monthly, seasonal, and annual scales. The null hypothesis in the test is that there is no significant trend within the time series and when this hypothesis is rejected it indicates a trend, which can be either positive or negative as described by its score.

The analysis will be performed for investigating:

- changes in the mean values of the variable;
- changes in extreme events; here an appropriate metric needs to be defined (e.g., intensity, duration or frequency of the event) before the trend analysis.
- changes in seasonality, which in classical decomposition methods is assumed to be constant over the years.

Data have been firstly decomposed to remove seasonal effects using LOESS (Cleveland et al., 1990). For the purpose of the AdriaClim project, we decided to limit the trend analysis to the 30-year periods considered in the model simulations: 1991-2020 and 2021-2050 for the historical and climate change scenarios, respectively. In table 10, we listed the trend analyses to be applied to the measured timeseries and to model output timeseries extracted at site-specific monitoring station locations. Some of the computed trends overlap with the indicators for changes in the climate systems proposed within Activity 3.5. The trends will be computed with the software developed in Activity 4.2.

Table 10: List of variables and analyses to be performed on the timeseries.

Category	Variable	Units	Analysis description
Physical and chemical marine	Sea temperature	°C	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile)*
Physical and chemical marine	Salinity		*Trend in daily/monthly/yearly mean values*
Physical and chemical marine	Sea level	m	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile); Trend in number of peaks over site-specific threshold per year*
Physical and chemical marine	Significant wave height	m	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile)*
Physical and chemical marine	Dissolved oxygen	mg l^{-1}	*Trend in monthly/yearly mean values*
Physical and chemical marine	Nutrients (NH4, PO4, NO2, NO3, SiO4)	mg l^{-1}	*Trend in monthly/yearly mean values*
Atmospheric and hydrological	Air temperature	°C	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (10th and 90th percentiles); Trend in number of days with T over/below threshold (25°C for warm and 0°C for cold days) per year*
Atmospheric and hydrological	Wind speed	m s^{-1}	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile)*
Atmospheric and hydrological	Mean sea level pressure	mbar	*Trend in daily/monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile)*
Atmospheric and hydrological	Precipitation	mm day^{-1}	*Trend in annual accumulated values; Trend in yearly extreme values (90th percentile); Trend in number of days with P over threshold (10 mm/day); Trend in number of days without precipitation*
Atmospheric and hydrological	River flow	m^3 s^{-1}	*Trend in monthly/yearly mean values; Trend in monthly/yearly extreme values (90th percentile)*
Biotic	Chlorophyll a	mg l^{-1}	*Trend in monthly/yearly mean values*
Biotic	Phytoplankton	mg m^{-3}	*Trend in monthly/yearly mean values*

3.1 PS1 Grado and Marano Lagoon and Gulf of Trieste

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Table 11: Trends computed for PS1 from observations (Obs 1991-2020), reanalysis scenario (REA 1991-2020), historical climate scenario (Hist 1991-2020) and climate change RCP85 scenario (RCP8.5 2021-2050).

Station	Variable	Trend (units/year)				
		Description	Obs 1991-2020	REA 1991-2019	Hist 1991-2020	RCP8.5 2021-2050
Trieste	Sea surface temperature (˚C)	*Trend in monthly mean values*	*0.037 ± 0.000*	*0.041 ± 0.000*		
		Trend in monthly extreme (p95) values	*0.033 ± 0.000*	*0.048 ± 0.000*		
	Surface salinity	*Trend in monthly mean values*	-	*0.016 ± 0.000*		
	Sea surface height (mm)	*Trend in monthly mean values*	*3.38 ± 0.03*	*3.55 ± 0.03*		
		Trend in monthly extreme (p95) values	*3.59 ± 0.05*	*3.47 ± 0.05*		
		Trend in number of peaks over threshold (XX m) per year				

3.2 PS2 Venice lagoon / City of Venice / Veneto coastal area

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Table 12: Trends computed for PS2 from observations (Obs 1991-2020), reanalysis scenario (REA 1991-2020), historical climate scenario (Hist 1991-2020) and climate change RCP85 scenario (RCP8.5 2021-2050).

Station	Variable	Trend (units/year)				
		Description	Obs 1991-2020	REA 1991-2020	Hist 1991-2020	RCP8.5 2021-2050
AAOT	Sea surface temperature (°C)	*Trend in monthly mean values*	-	*0.040 ± 0.000*		
		Trend in monthly extreme (p95) values	-	*0.044 ± 0.000*		
	Surface salinity	*Trend in monthly mean values*	-	*no*		
	Sea level height (mm)	*Trend in monthly mean values*	*5.14 ± 0.04*	*3.69 ± 0.03*		
		Trend in monthly extreme (p95) values	*5.38 ± 0.04*	*3.90 ± 0.04*		
		Trend in number of peaks over threshold (XX m) per year				
Venice Punta della Salute	Sea surface height (mm)	*Trend in monthly mean values*	*4.94 ± 0.03*			
		Trend in monthly extreme (p95) values	*4.43 ± 0.04*			
		Trend in number of peaks over threshold (XX m) per year				

3.3 PS3 Emilia-Romagna area

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3.4 PS3 Emilia-Romagna area

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3.5 PS4 Apulia region

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3.6 PS5 Dubrovnik Neretva area

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3.7 PS6 Split – Dalmatia area

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3.8 PS7 Northern-Eastern Adriatic Sea

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3.9 PS8 Marche area

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3.10 PS9 Molise area

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4. References

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