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European Group of Territorial Cooperation

Project co-funded by European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

Understanding the patterns, trends and hotspots of Coastal Erosion and CC Vulnerability along the Coastline of Messolonghi Municipality

blending modern geodatabases in a webGIS toolkit

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TRITON – FINAL EVENT

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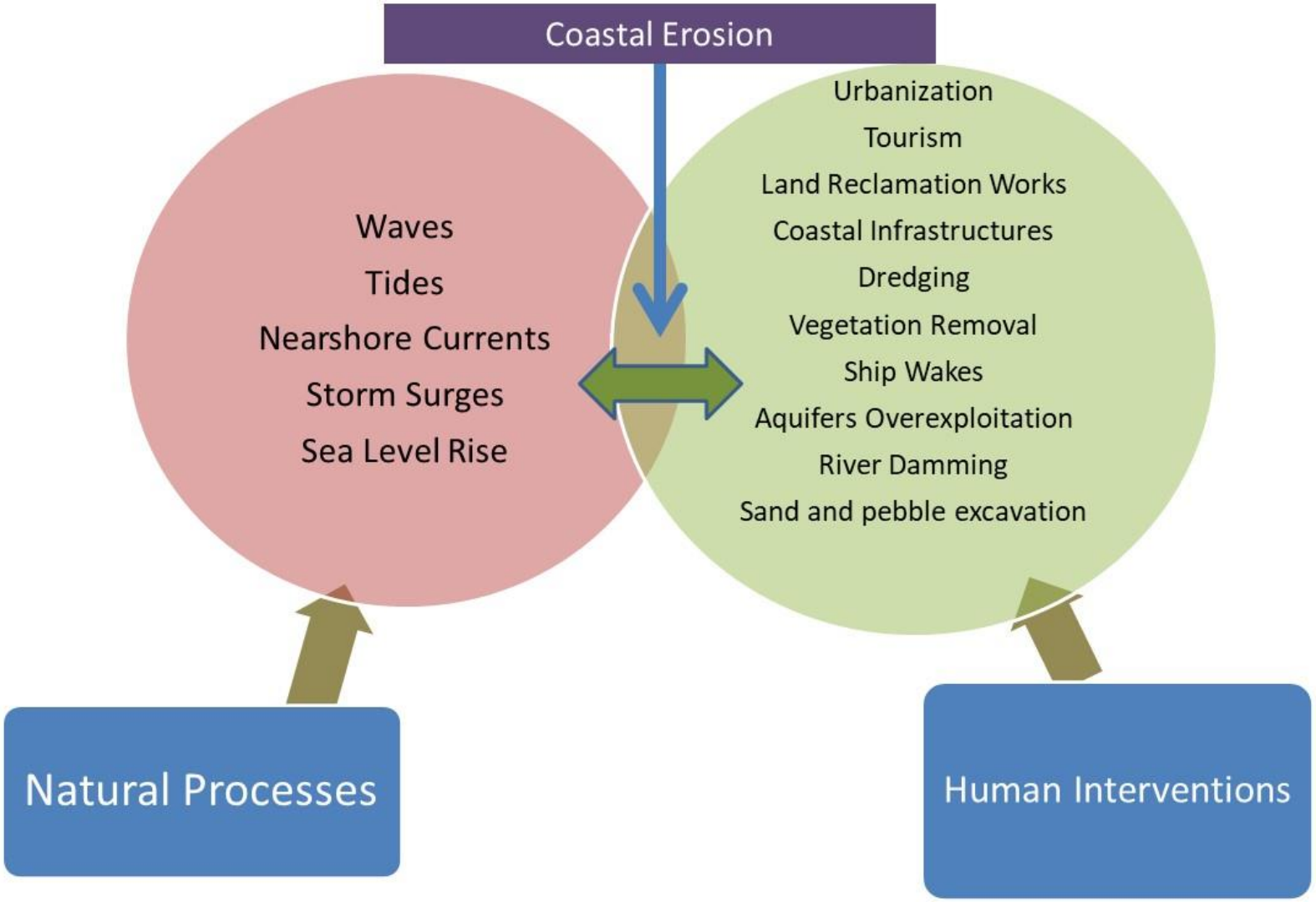
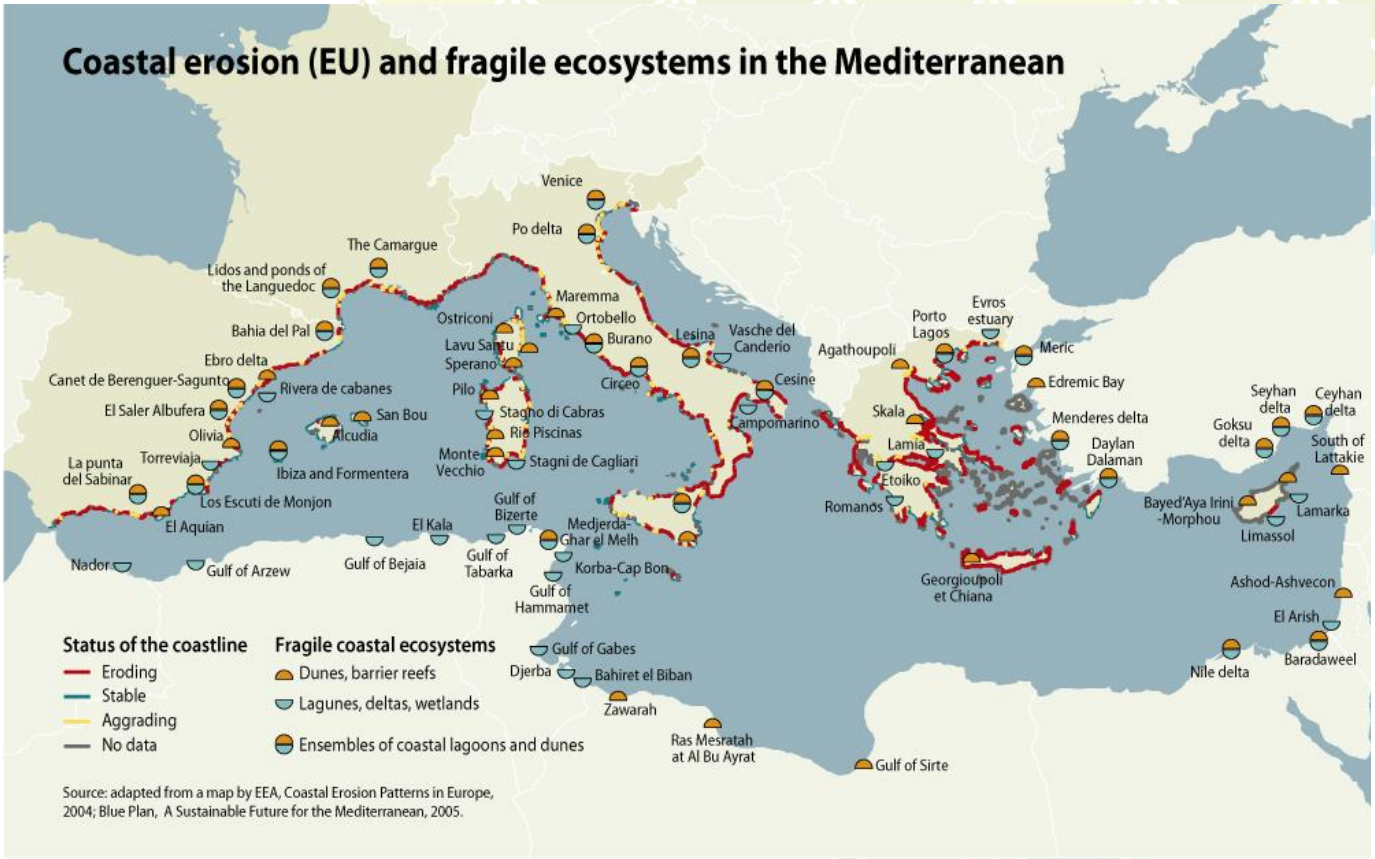
Coastal Erosion – A process with Socio-economic Impacts

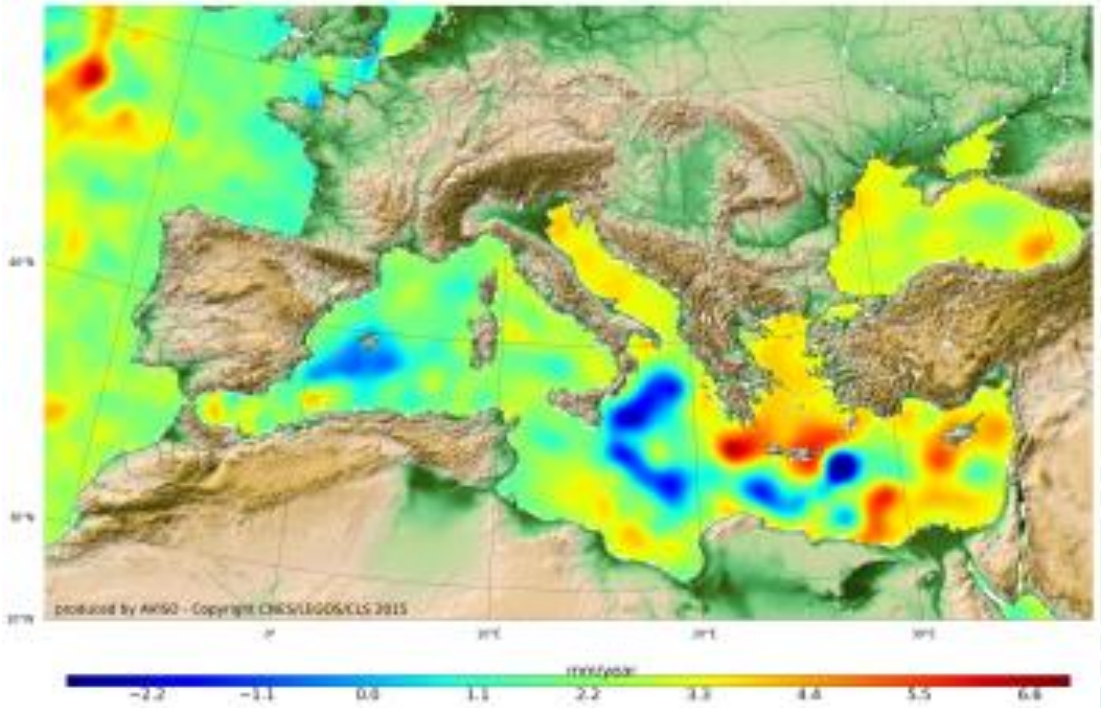
Coastal erosion is directly linked to economic losses due to coastal retreat and loss of land, ecological damage (especially of valuable coastal habitats) and societal problems.


Coastal Erosion
Waves
Tides
Nearshore Currents
Storm Surges
Sea Level Rise
Urbanization
Tourism
Land Reclamation Works
Coastal Infrastructures
Dredging
Vegetation Removal
Ship Wakes
Aquifers Overexploitation
River Damming
Sand and pebble excavation
Natural Processes
Human Interventions



- In Mediterranean, erosion threatens 1/5 of coastlines at a rate of 0.5-2.0 m/y.
- Erosion threatens high ecological valued land of 47,500 Km².
- Presently only 5% of Med coastlines is protected by hard engineering structures.

Sea Level Rise due to Climate Change



Sea level trend (mm/year) in the Mediterranean for January 1993 to June 2014 (Credits Cnes/Legos/CLS).

The sea level in the Eastern Mediterranean basin has risen significantly in recent years, apparently due to warmer water temperatures (observed by *in-situ* measurements).

The case of Greece

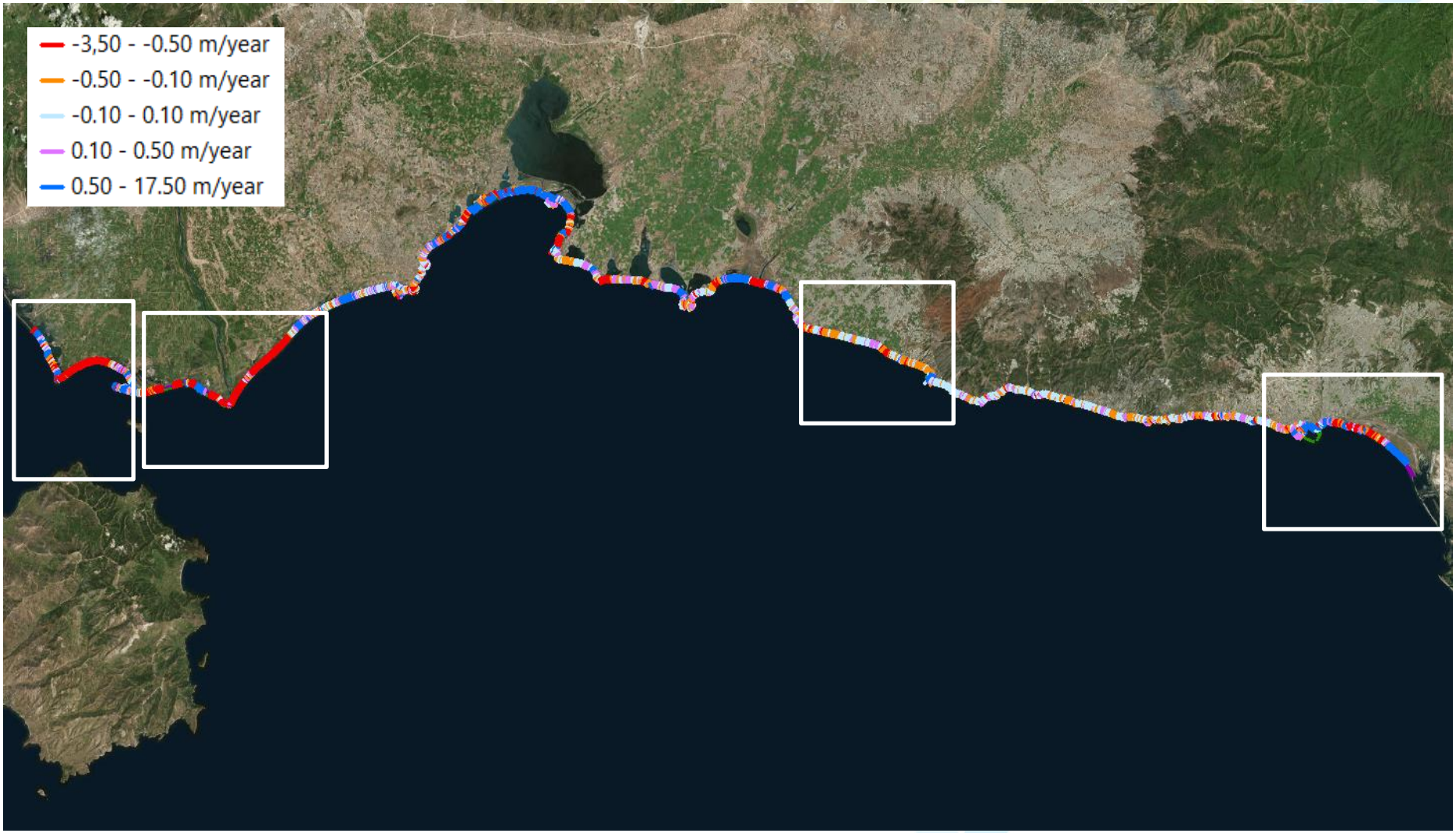
Greece is the country with the highest coastline length in EU (13,780 km). The GDP produced in coastal zones is estimated at 140 billion Euros. The population living in a distance of 50 km away from the CZ is estimated at 10.1 million. Yet, almost 30% of coasts (i.e., 3,945 km) are eroding or appear as vulnerable to coastal erosion (mostly < 10 m over time periods of 20-30 years).

Sediment supply to the coast has decreased strongly due to the construction of dams, river channelization and intense coastal development.

With respect to climate change, in the case of a sea level rise up to 1.8 mm/year almost half of the Aegean coast would be moderately vulnerable and the remaining part as highly vulnerable. For the case of a sea level rise of more than 3.5 mm/year, almost all the Hellenic Aegean coast would be highly vulnerable.

TRITON

Development of management tools and directives for immediate protection of biodiversity in coastal areas affected by sea erosion and establishment of appropriate environmental control systems



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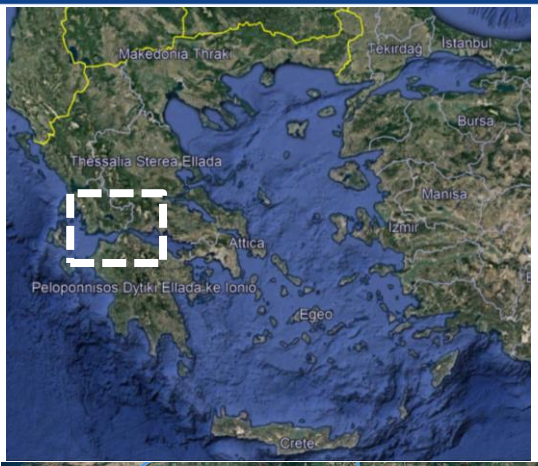
Improve our understanding on coastal erosion using data from Earth Observing Systems

Design better protection measures
Prevent from extreme events

Project co-funded by European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy



Messologhi Municipality Coastline:

i. From **R. Achelloos** to **R. Evinos**
ii. **Length**: ~ 45 km
iii. Complex Coastal **Lagoonal** System

Physical parameters affecting sediment transport are:

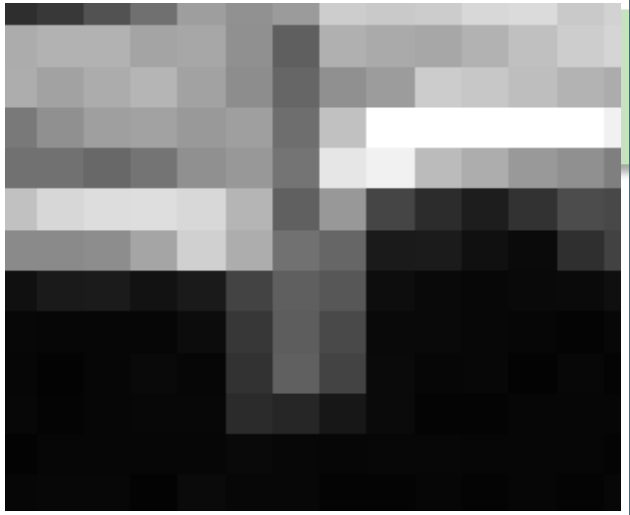
i. **Wave action** in Patraikos Gulf
ii. **Nearshore currents** induced by waves
iii. **SPM** outflux from Rivers
iv. **Influx vs Outflux** from Coastal Lagoons

Satellites - Historical imagery

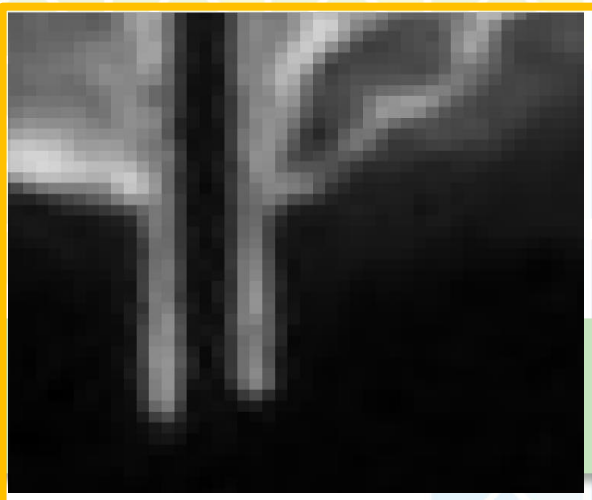
Earth Explorer

Landsat 4-5 ETM

- Spatial Resolution: 30 m
- 1985, 1990, 1995, 2000, 2005, 2009



Planet Explorer

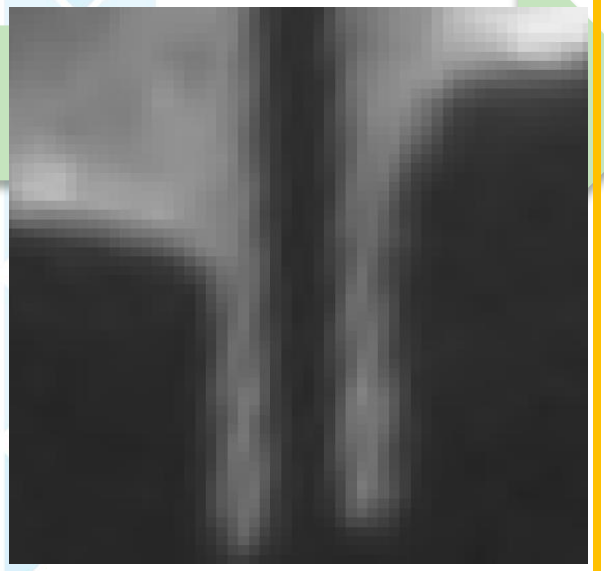


RapidEye

- Spatial Resolution 5m
- 2009, 2012, 2015

PlanetScope

- Spatial Resolution: 3.1 m
- 2018



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Satellite Imagery Selection

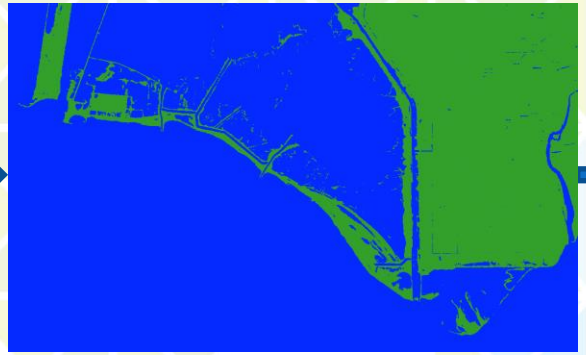
Image selection was based on:

- **Clarity** from cloud cover
- The correct **geo-reference**
- The **seasonality** (all images retrieved in the summer moths)
- Tidal effect (all images retrieved in tidal neaps)

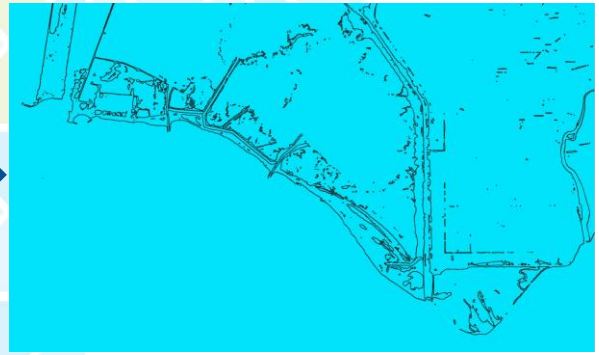
Date	Satellite	Resolution
29/07/1985	Landsat 4-5 ETM	30 m
11/07/1990	Landsat 4-5 ETM	30 m
11/09/1995	Landsat 4-5 ETM	30 m
23/08/2000	Landsat 4-5 ETM	30 m
20/07/2005	Landsat 4-5 ETM	30 m
15/07/2009	Landsat 4-5 ETM	30 m
06/06/2009	RapidEye	5 m
01/10/2012	RapidEye	5 m
28/09/2015	RapidEye	5 m
20/07/2019	PlanetScope	3.1 m

Semi-Automatic Classification Plugin (SCP) for QGIS

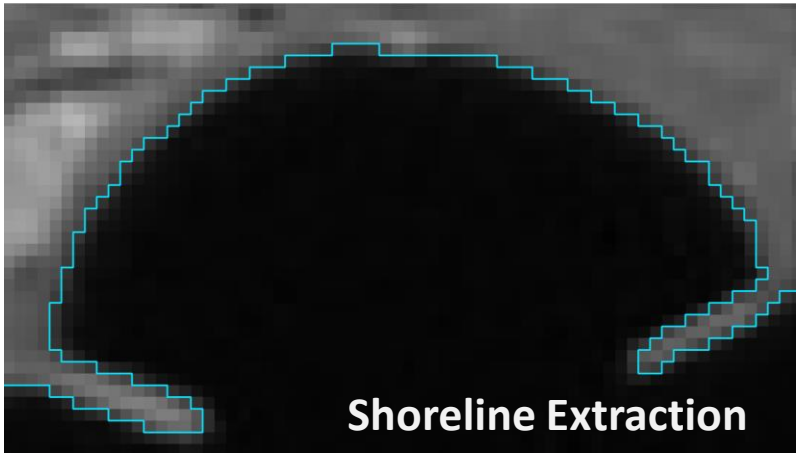
Satellite Image – Near Infrared Band

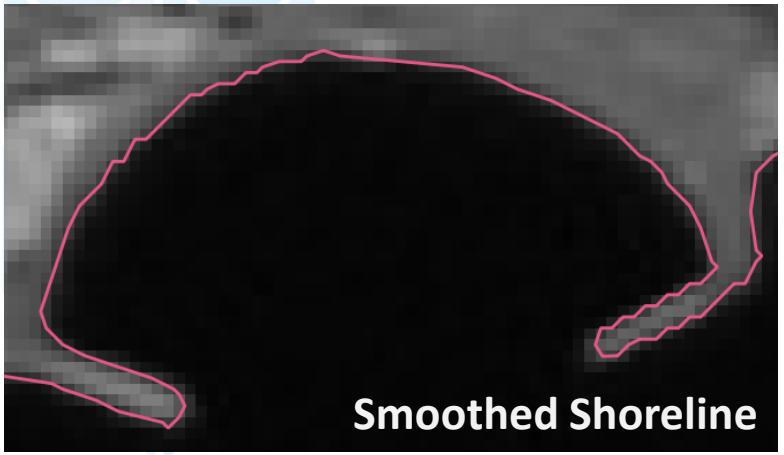


Classified Image (Land - Sea)



Raster to Vector





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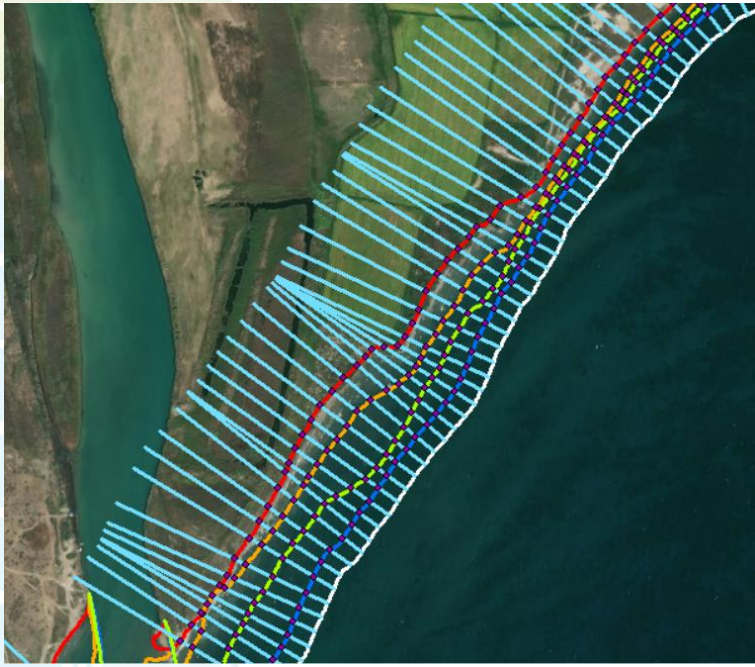
Digital Shoreline Analysis System (DSAS) by U.S. Geological Survey (USGS) in ArcMap (ESRI)

- Images imported in DSAS
- Transects every 20 m were created

- DSAS tool produces Coastal Erosion Statistics, as:
  - ✓ Net Shoreline Movement (NSM)
  - ✓ End Point Rate (EPR)
  - ✓ Weighted Linear Regression Rate (WLR)
  - ✓ Least Median of Squares (LMS)
  - ✓ Linear Regression Rate (LRR)
  - ✓ R-squared of Linear Regression (LR2)
  - ✓ Standard Error of Linear Regression (LSE)
  - ✓ Standard Error of Weighted Linear Regression (WSE)



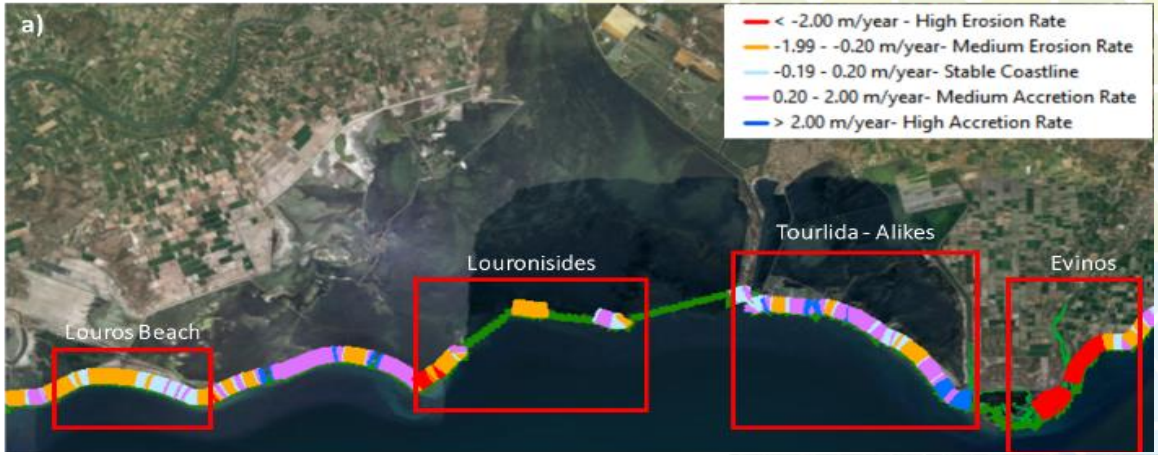
- A Python script expanded statistical analysis and grouped data into clusters according to coastal erosion statistical measures.

Descriptive statistics (Quantitative data):

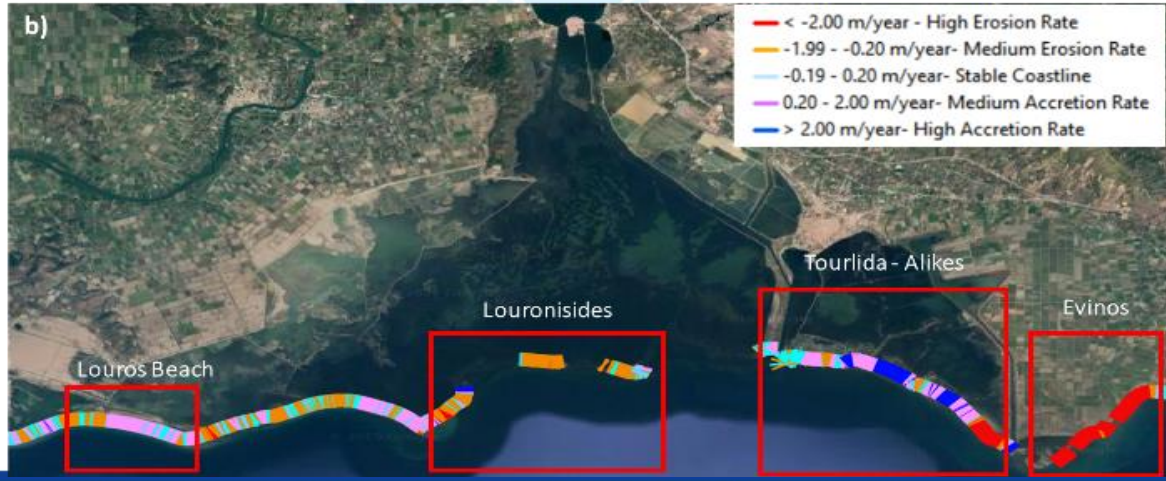
Statistical Indicator	2018-2010	2010-2004	2004 - 1985
Nbr. of observations	534	534	534
Nbr. of missing values	0	0	0
Sum of weights	534	534	534
Minimum	-15.592	-13.957	-13.470
Maximum	5.394	13.478	6.334
Freq. of minimum	1	1	1
Freq. of maximum	1	1	1
Range	20.986	27.435	19.804
1st Quartile	-0.414	0.000	-1.111
Median	0.000	0.794	-0.406
3rd Quartile	0.696	3.129	0.077
Sum	-231.196	513.782	-254.976
Mean	-0.433	0.962	-0.477
Variance (n)	9.658	12.828	4.593
Variance (n-1)	9.676	12.852	4.602
Standard deviation (n)	3.108	3.582	2.143
Standard deviation (n-1)	3.111	3.585	2.145
Variation coefficient	-7.178	3.723	-4.488
Skewness (Pearson)	-2.681	-1.256	-1.305
Skewness (Fisher)	-2.688	-1.260	-1.309
Skewness (Bowley)	0.255	0.492	-0.188
Kurtosis (Pearson)	8.155	3.742	10.487
Kurtosis (Fisher)	8.243	3.789	10.597
Standard error of the mean	0.135	0.155	0.093
Lower bound on mean (95%)	-0.697	0.657	-0.660
Upper bound on mean (95%)	-0.169	1.267	-0.295
Standard error of the variance	0.593	0.787	0.282
Lower bound on variance (95%)	8.612	11.439	4.096
Upper bound on variance (95%)	10.952	14.546	5.208
Standard error(Skewness (Fisher))	0.106	0.106	0.106
Standard error(Kurtosis (Fisher))	0.211	0.211	0.211
Mean absolute deviation	1.690	2.431	1.181
Median absolute deviation	0.550	1.448	0.603
Geometric mean			
Geometric standard deviation			
Harmonic mean			-1.605

Coastal Erosion Analysis

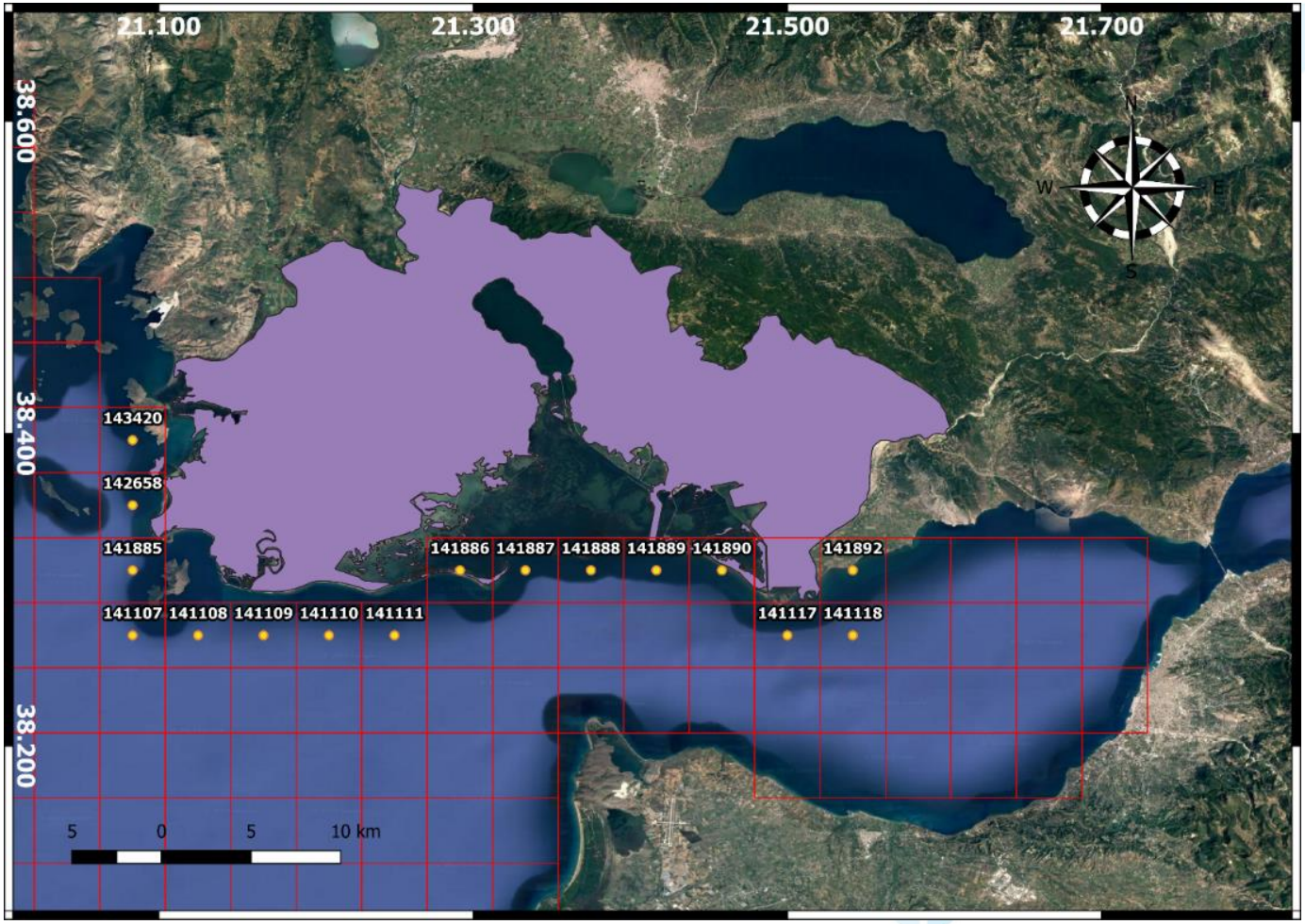
Shoreline change from 1985 till 2009



…and from 2009 till 2019



CMEMS Wave Database Retrieval and Analysis



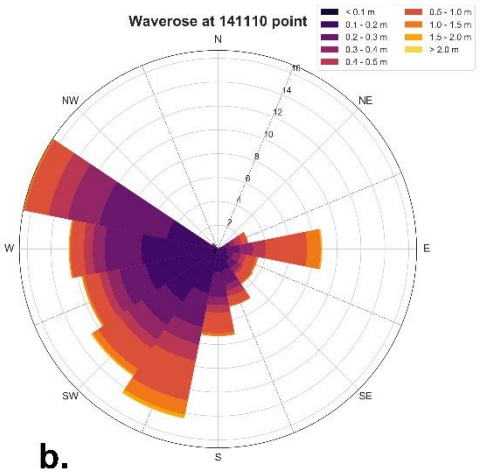
Louros Beach

1985-2009

- **Mean Shoreline Retreat -0.2 m/y**
- **Western Coastline: Erosion / Eastern Coastline: Accretion**

2009-2019

- **Western part: Retreat up to -0.5 m/y**
- **Eastern part: Deposition up to 0.9 m/y**
- **Longshore transport from Waves incident from SW to NW directions**



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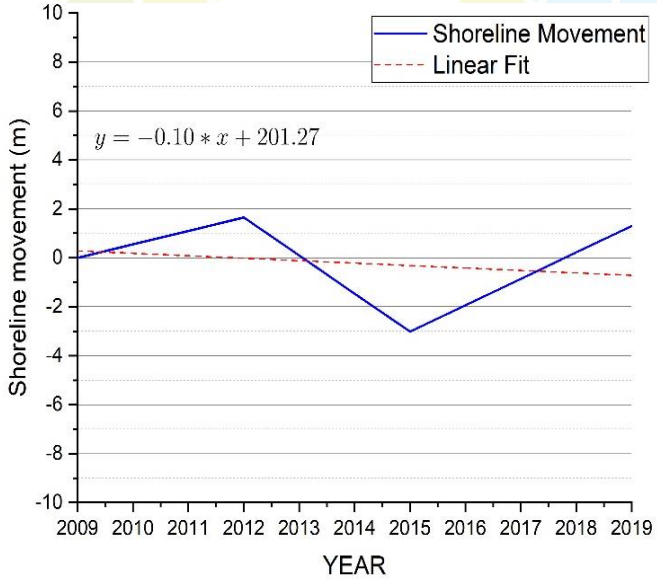
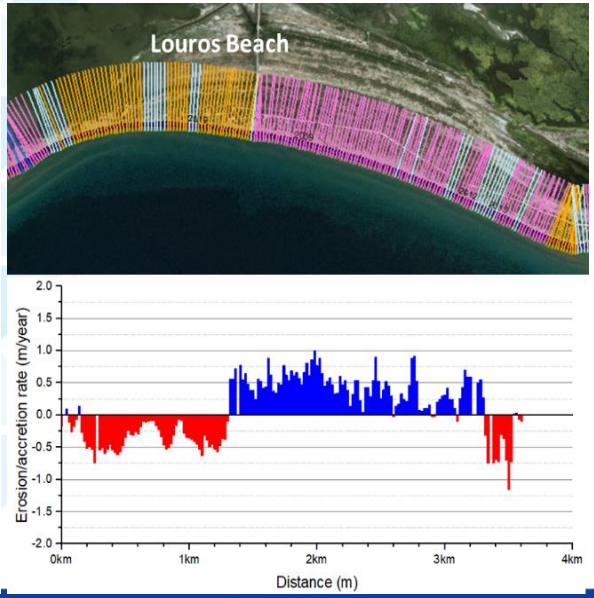




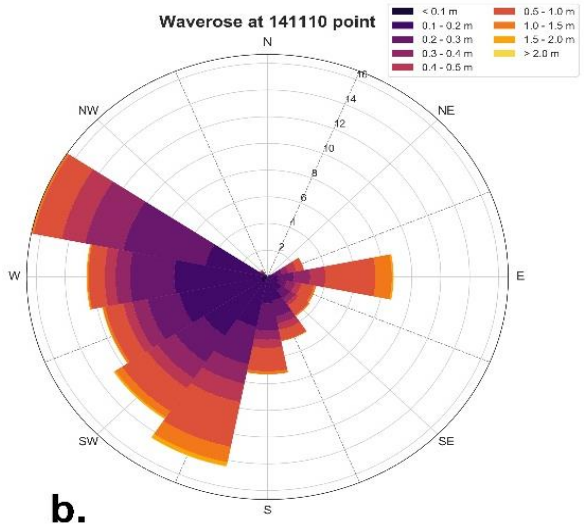
Louronisides (Prokopanistos, Schinias, Komma)

1985-2009

- **Mean Shoreline Retreat -0.9 m/y**

2009-2019

- **Dominant Incident Wave Direction from SW to NW**
- **Mean Wave Height: 0.25 m**
- **Max Wave Height up to 1.7 m**
- **Mean Erosion Rate: - 0.50 m/y**



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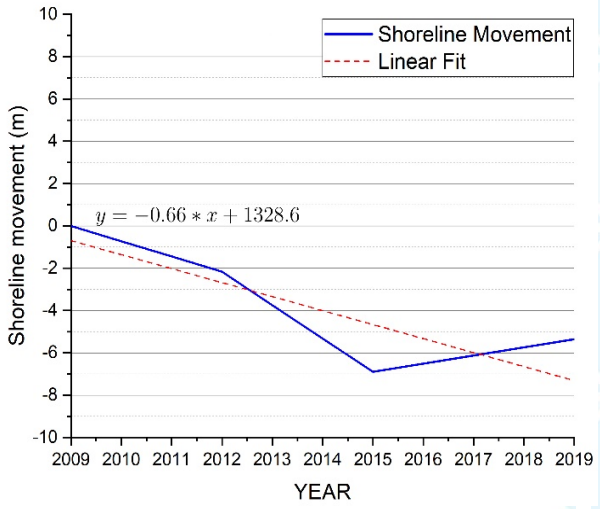
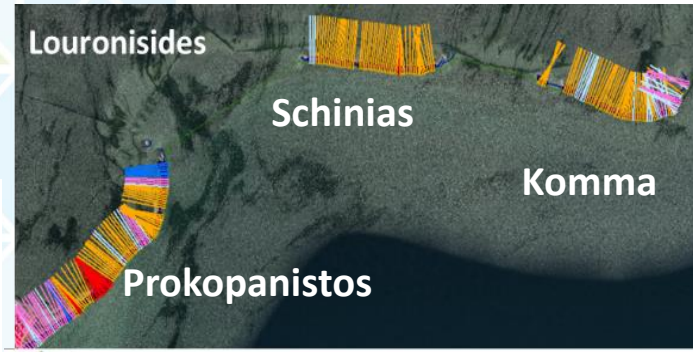
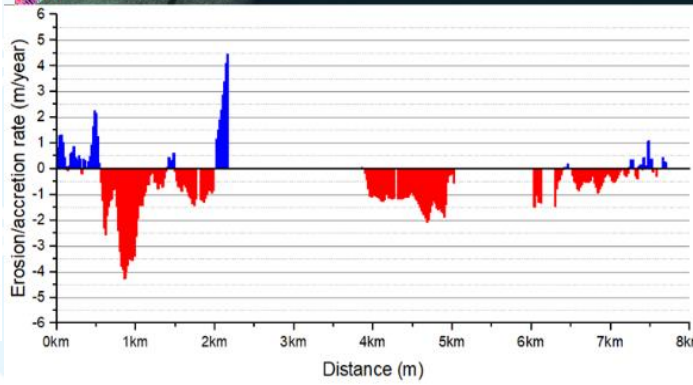






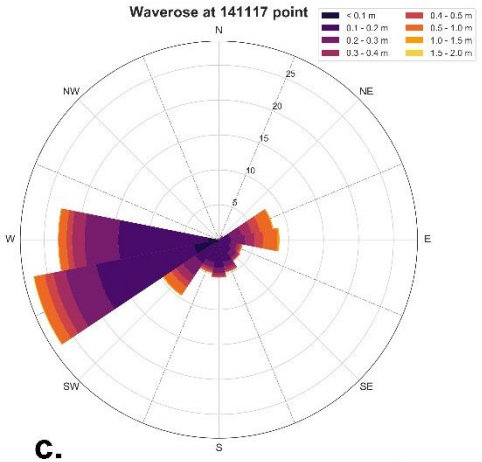
Alikes – Mpampakoulia Zone

1985-2009

- **Mean Deposition Rate +1.2 m/y**
- **Sediment Accumulation in Mpampakoulia Canal**

2009-2019

- **South-Eastern part (Mpampakoulia): Retreat up to 14 m/y**
- **Eastern part: Deposition up to 8 m/yr**
- **Dominant Incident Wave: from WSW direction**



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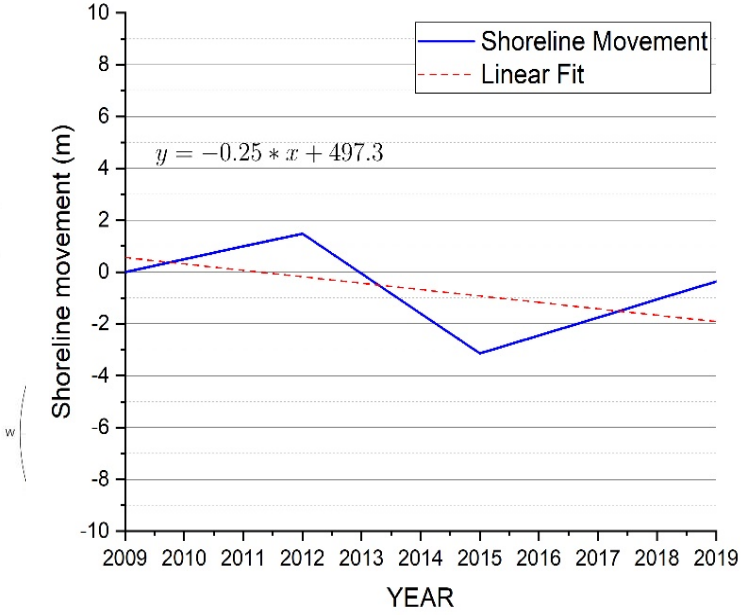
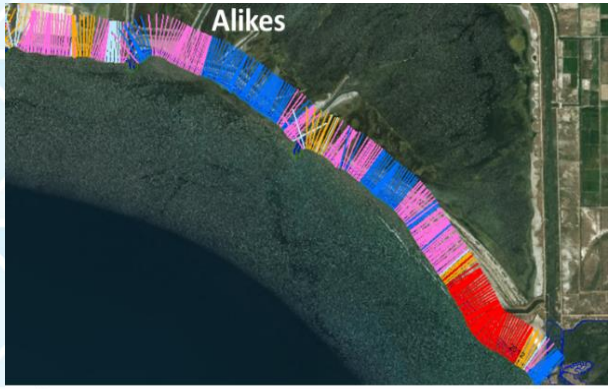
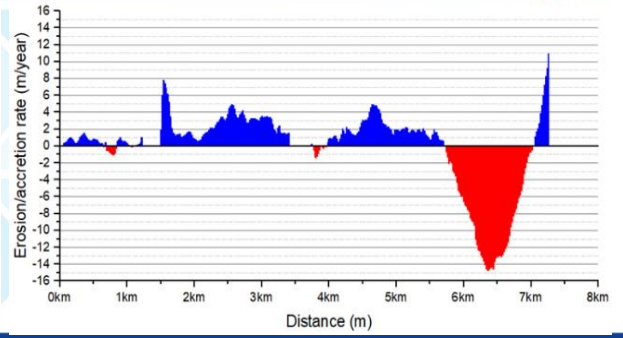






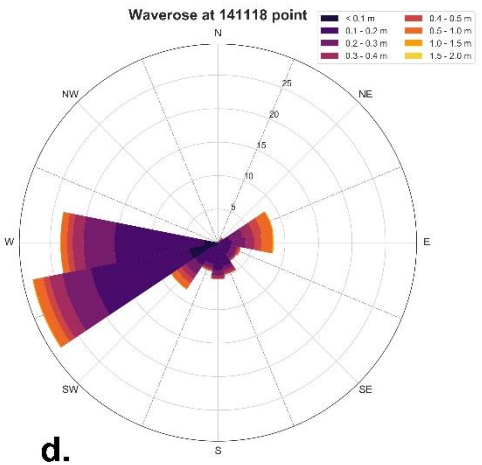
Evinos Deltaic Zone

1985-2009

- **Mean Erosion Rate up to -10 m/y**

2009-2019

- **Steadily reduced Evinos River discharge**
- **SW part: Huge sediment loss – land retreats up to -125 m**
- **Dominant Incident Waves: WSW direction**
- **Mean Wave Height: 0.25 m**



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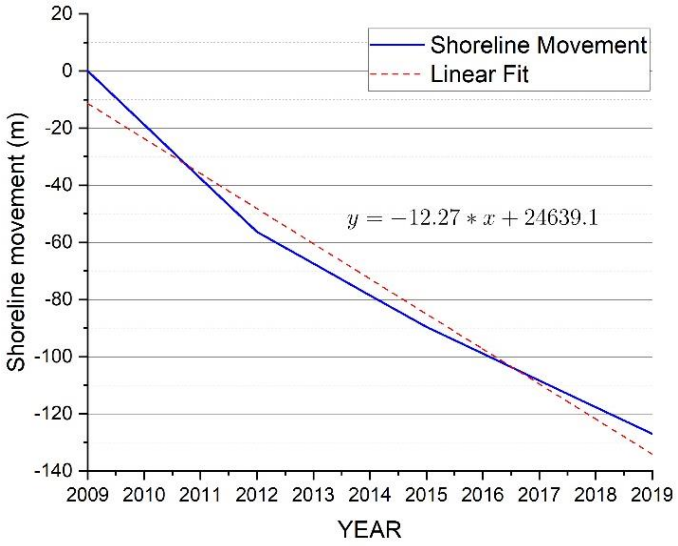
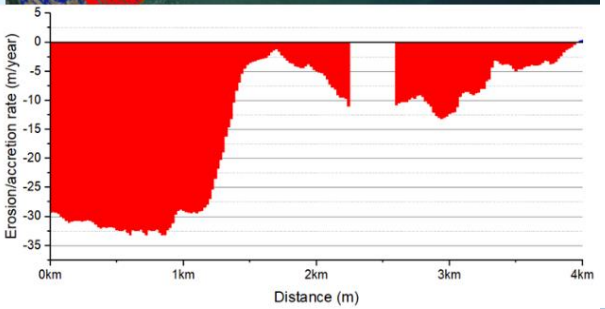




Extreme Wave Analysis per Grid Point

Table 1. Wave analysis results for the coastal zone of the Municipality Ieras Poleos Messolonghiou.

Points from West to East	Threshold (m)	No. of Waves over Threshold	Maximum Wave Height (m)	Mean Wave Height (m)
143420	1.04	146	2.33	0.35
142658	1.22	99	2.37	0.38
141885	1.34	83	2.46	0.40
141107	1.52	73	2.58	0.45
141108	1.14	211	2.53	0.42
141109	1.16	157	2.41	0.39
141110	1.15	138	2.24	0.37
141111	0.95	181	2.17	0.35
141886	0.78	147	1.52	0.24
141887	0.82	139	1.70	0.25
141888	0.74	169	1.69	0.25
141889	0.69	186	1.64	0.24
141890	0.70	146	1.57	0.23
141117	0.77	134	1.61	0.25
141118	0.88	57	1.53	0.24
141892	0.51	259	1.47	0.21

Wave Characteristics at Breaker Zone

- **Historic offshore wave time-series** data at **fourteen** data points, were retrieved from the reanalysis product of the **Copernicus Marine Environmental Monitoring Service (CMEMS)**
- Wave data comprised of **daily time-series** of the spectral significant **wave height (Hmo)**, the **zero up-crossing wave period (To2)** and the **wave direction relative to the north (ϕ_o)**.
- A **simple wave-ray model** was used to transform the **offshore wave** characteristics into the **wave characteristics at the breaker zone**.
- A list of wave parameters was estimated, following the equations described by the **CEM (2008)**, as:

  a) the wavelength [m],
  b) the wave celerity [m/s],
  c) the wave group celerity [m/s],
  d) the breaker zone, e) the significant wave height [m],
  f) the breaker was computed, g) the shoaling coefficient,
  h) the refraction coefficient,
  i) the wave dispersion coefficients at offshore and breaker zones,
  j) the wave direction at the breaker zone,
  k) the longshore wave-induced current, Vlong [m/s],
  l) the incident wave energy at the breaker zone [J $m^{-1}s^{-1}$],
  m) the longshore sediment transport on annual basis [m^3 yr^{-1}].

Nearshore Wave Characteristics along the Messologhi Municipality Shoreline

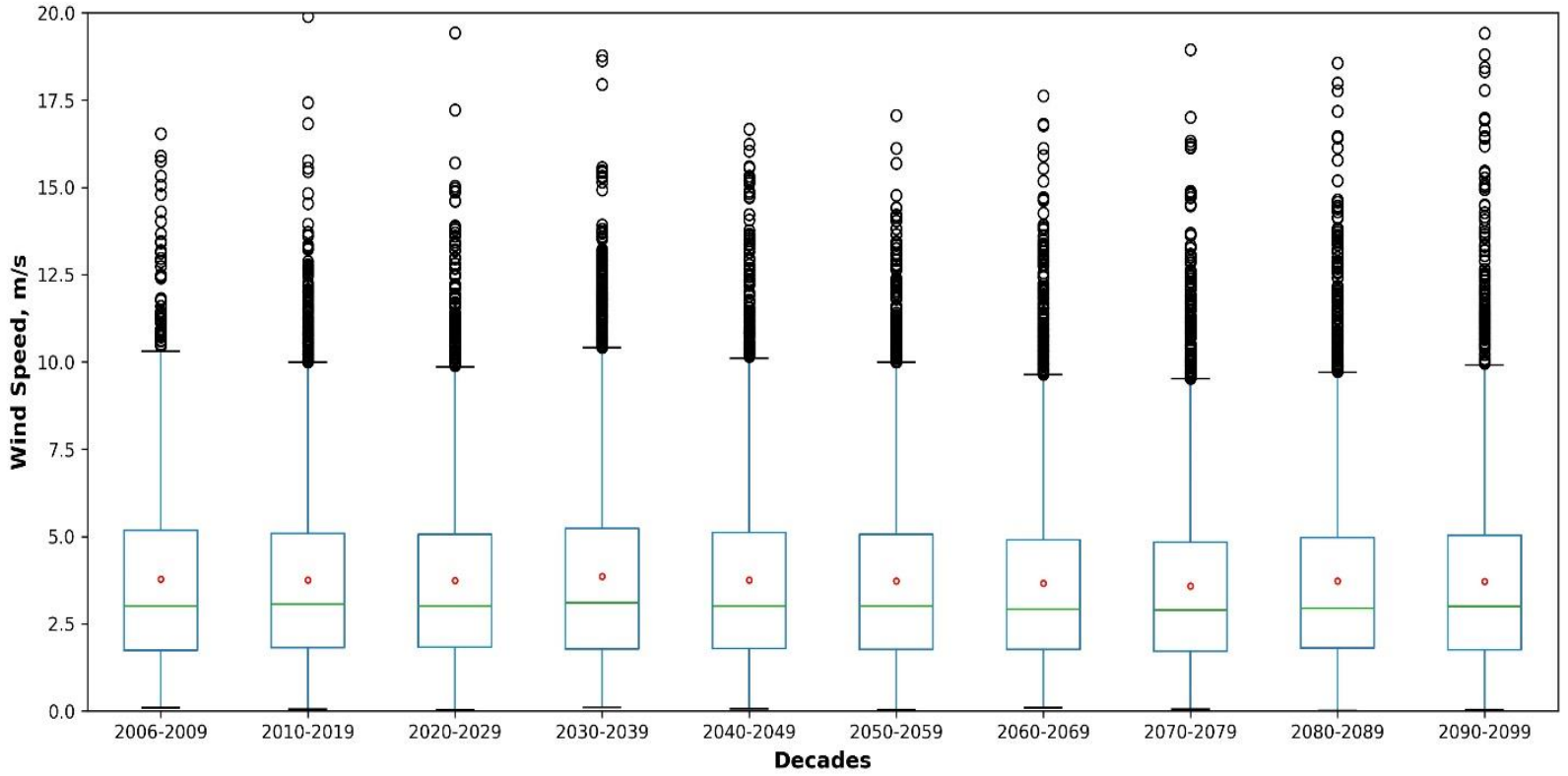
Table 4. Wave characteristics analysis results for the coastal zone of the Municipality Ieras Poleos Messolonghiou.

Period	Erosion	Longshore Wave Power	Theoretical Sediment Longshore flux	Wave Induced Longshore Current
	(m/y)	*(J $m^{-1}s^{-1}$)*	*(m^3 s^{-1})*	*(m s^{-1})*
2009 – 2012	-0.8	63.8	304.1	0.21
2012 – 2015	-1.7	79.2	381.0	0.17
2015 – 2019	0.2	21.4	85.2	0.08

- Results of the wave energy model indicate that the 2012-2015 was the most energetic period with mean wave energy incident on the coast of 79.2 J $m^{-1}s^{-1}$
- Increased incident wave energy is directly linked to an increase in the mean erosion rate along the coast
- In most areas, longshore sediment transport is favored, transporting sand from west to the east.
- The highest incident wave energy was found in Louros Beach (158.1 J $m^{-1}s^{-1}$) and in Prokopanistos Beach (85.9 J $m^{-1}s^{-1}$) correlated to erosion rates of about -1.8 m/y

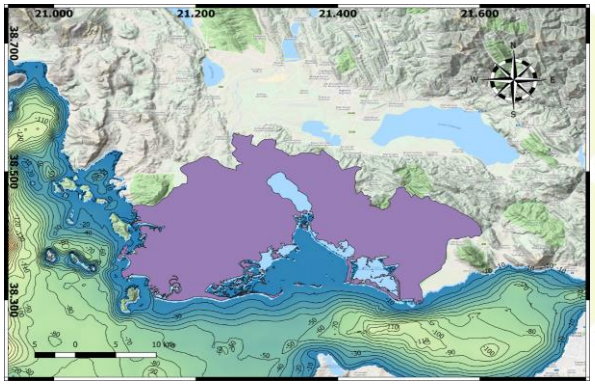
CC Scenarios Analysis

boxplot for wind speeds over 2006-2099

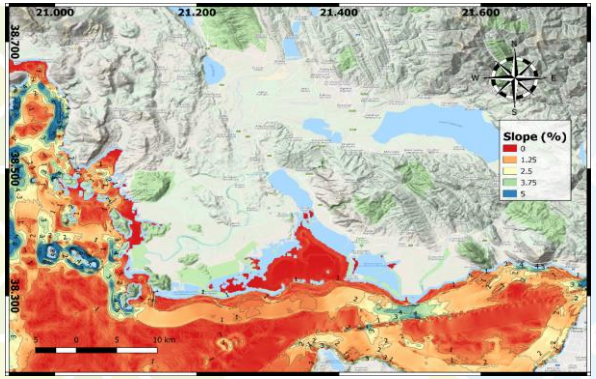


- **Storm events of the order of 18-20 m/s might prevail in the area, more dominant at the latest two decades**

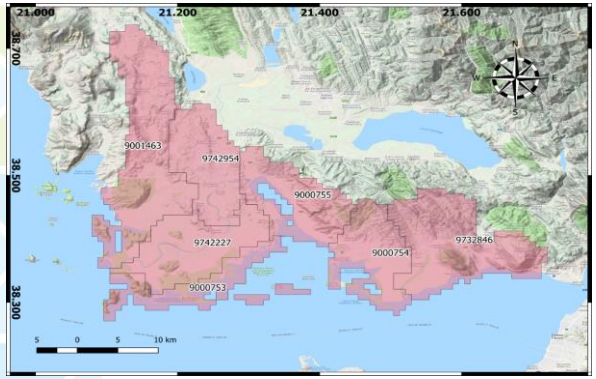
Data Collection from Geo-databases



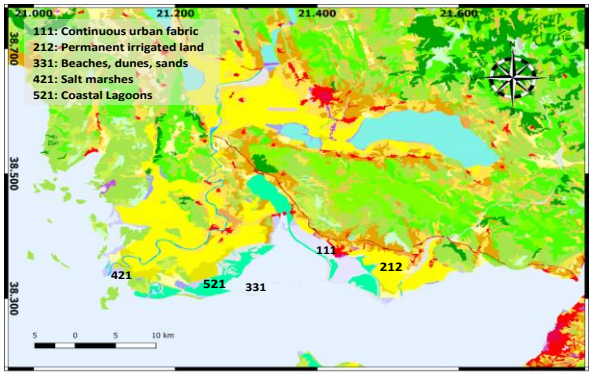
Bathymetry (GEBCO)



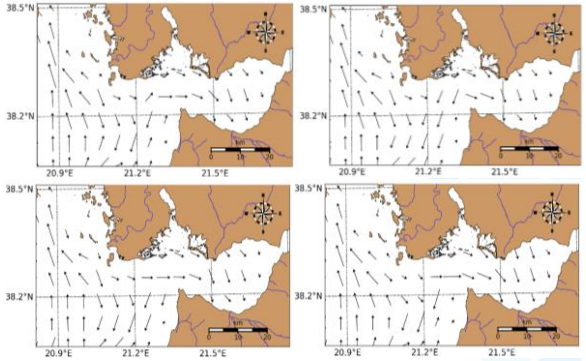
Sea bed Slope (GEBCO)



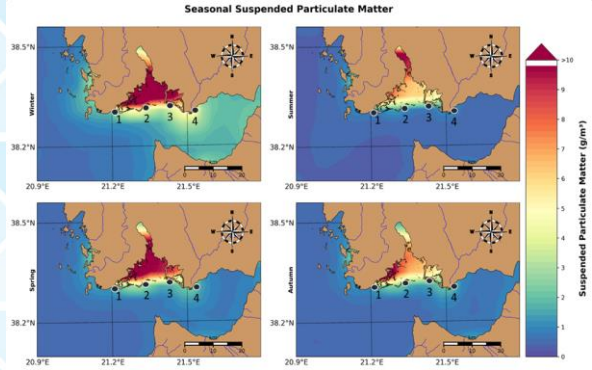
River Fluxes (e-Hype)



Land uses (CORINE 2018)

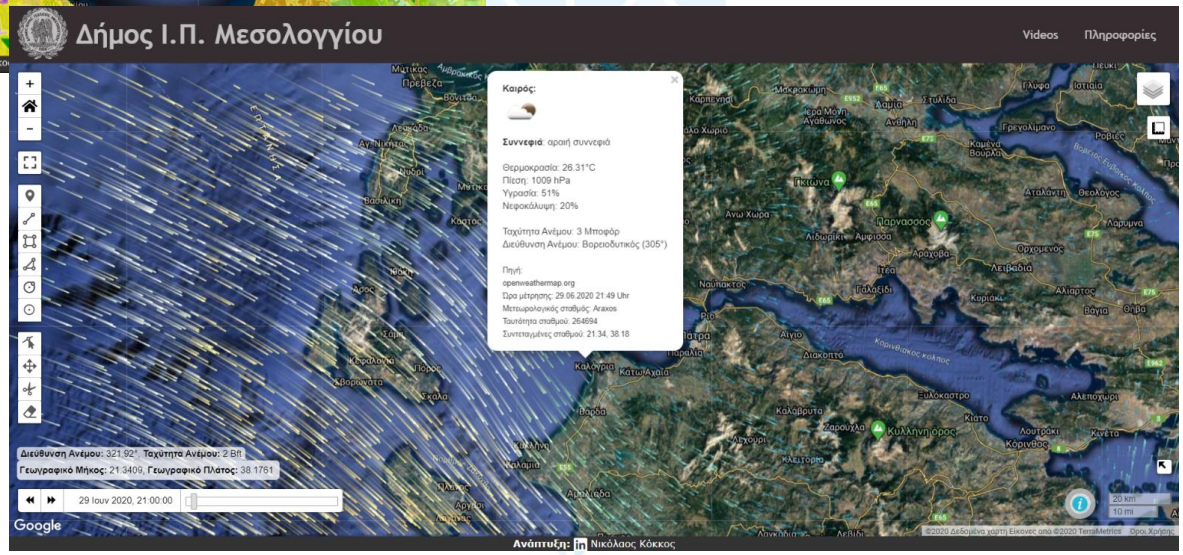


Sea surface currents (CMEMS)

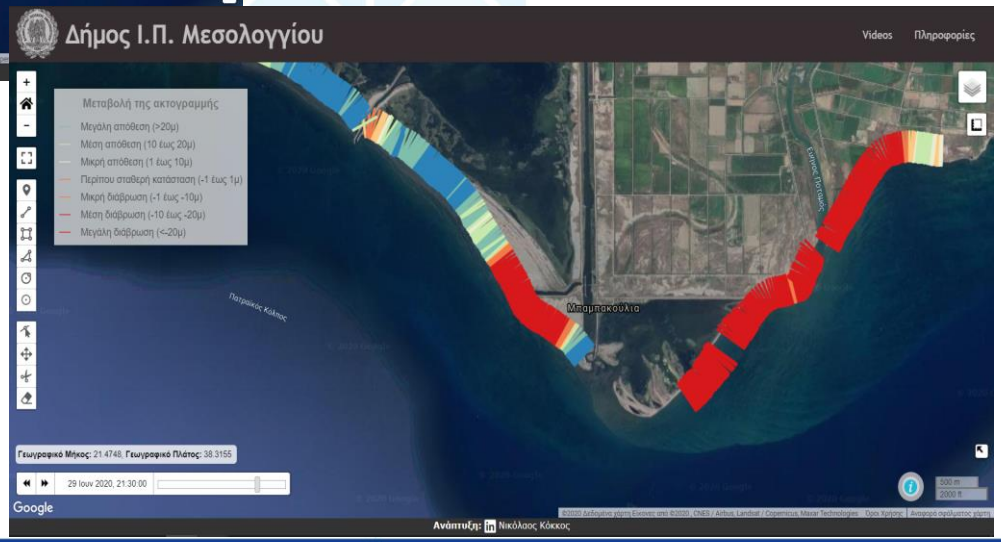


SPM (CMEMS)

TRITON web-GIS toolkit



TRITON web-GIS toolkit



http://labecolftp.env.duth.gr/TRITON/

Project co-funded by European Union, European Regional Development Funds (E.R.D.F.) and by National Funds of Greece and Italy

Conclusions

- Messologhi Municipality coastline is exposed to intense coastal erosion phenomena, especially in the area of Louronisides and Evinos deltaic zone.
- Evinos River discharge reductions led to the gradual decrease in SPM outflux which affects directly the coastal erosion processes in the area.
- Extreme weather events enhance the coastal erosion processes
- CC Scenario analysis explains that in future such extreme events might increase in frequency and intensity – the western coastlines and Louronisides will be the most vulnerable
- **We propose to clean canals transporting sediments to lagoons from accumulated sand and use this sand to nourish Louronisides, thus reducing costs and efforts of beach restoration**

Thank you for your attention

Enjoy responsibly Greece !

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