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Balkan rivers - Pressing environmental challenges

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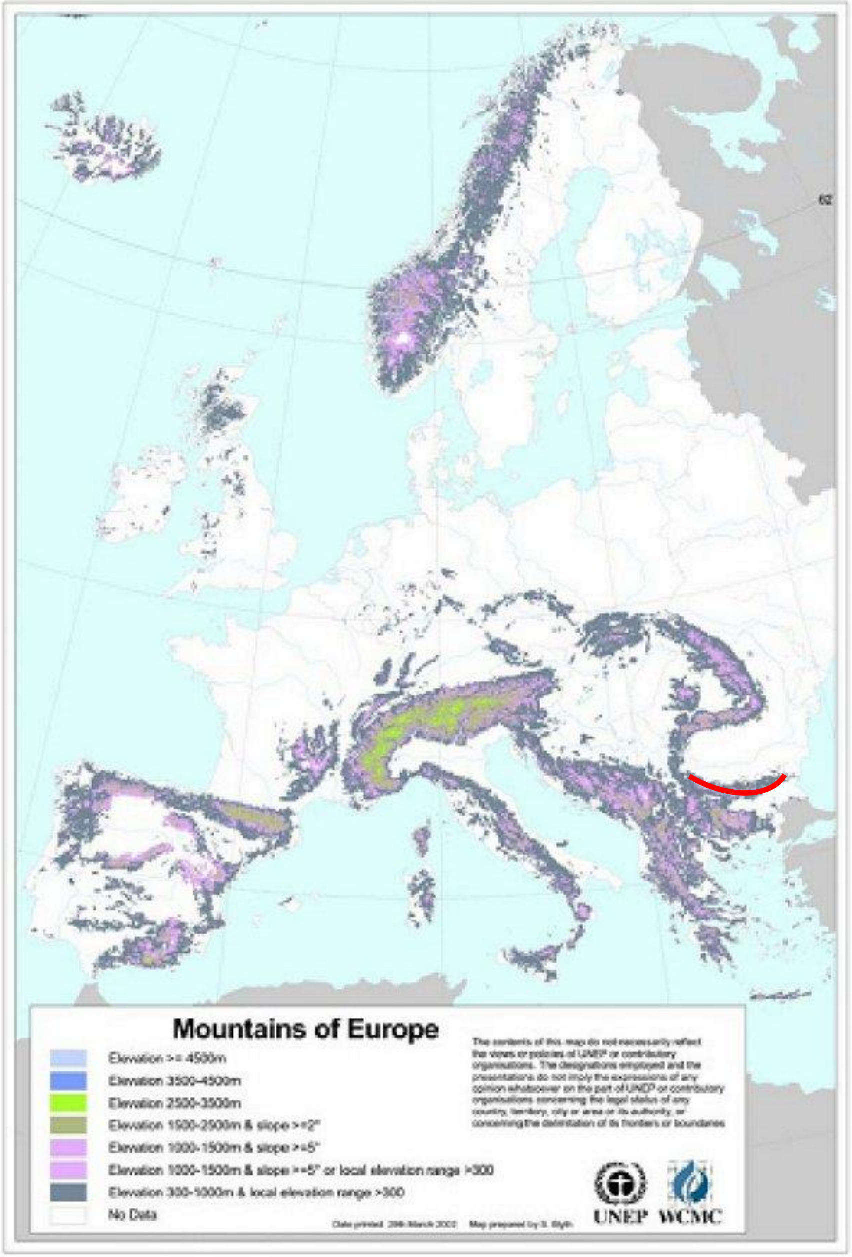
The Balkans - Introduction

The Balkan Peninsula is the historic and geographic name of southeastern Europe. The name is derived from the Balkan mountain range, the ancient *Haemos*, which divides Bulgaria and runs through eastern Serbia.

The Balkans is a mountainous area, tectonically, climatically and politically unstable.

Mountainous: Mountains cover about 27% of the Earth's surface. The Balkan Peninsula can then correctly be considered as a mountainous region, given that approximately 70% of its territory is characterized by high relief and long mountain chains (Reed et al. 2004). The name *Balkan* itself comes from a Turkish word meaning a forested mountain (Hupchick & Cox 2001).

Tectonic activity: The Balkans is a rough Alpidic orogen with large thrust sheets, ophiolites, repeated events of metamorphism and related granitic intrusions. Many areas are still tectonically active and are known for severe earthquake events and frequent landslides (UNEP 2010).



The Balkans - Intoduction

Climatically diverse: There are not many regions in the world that reveal such large temperature contrasts and climate diversity as the Balkans (Griffiths et al. 2004) with characteristic extreme events such as floods and draughts.

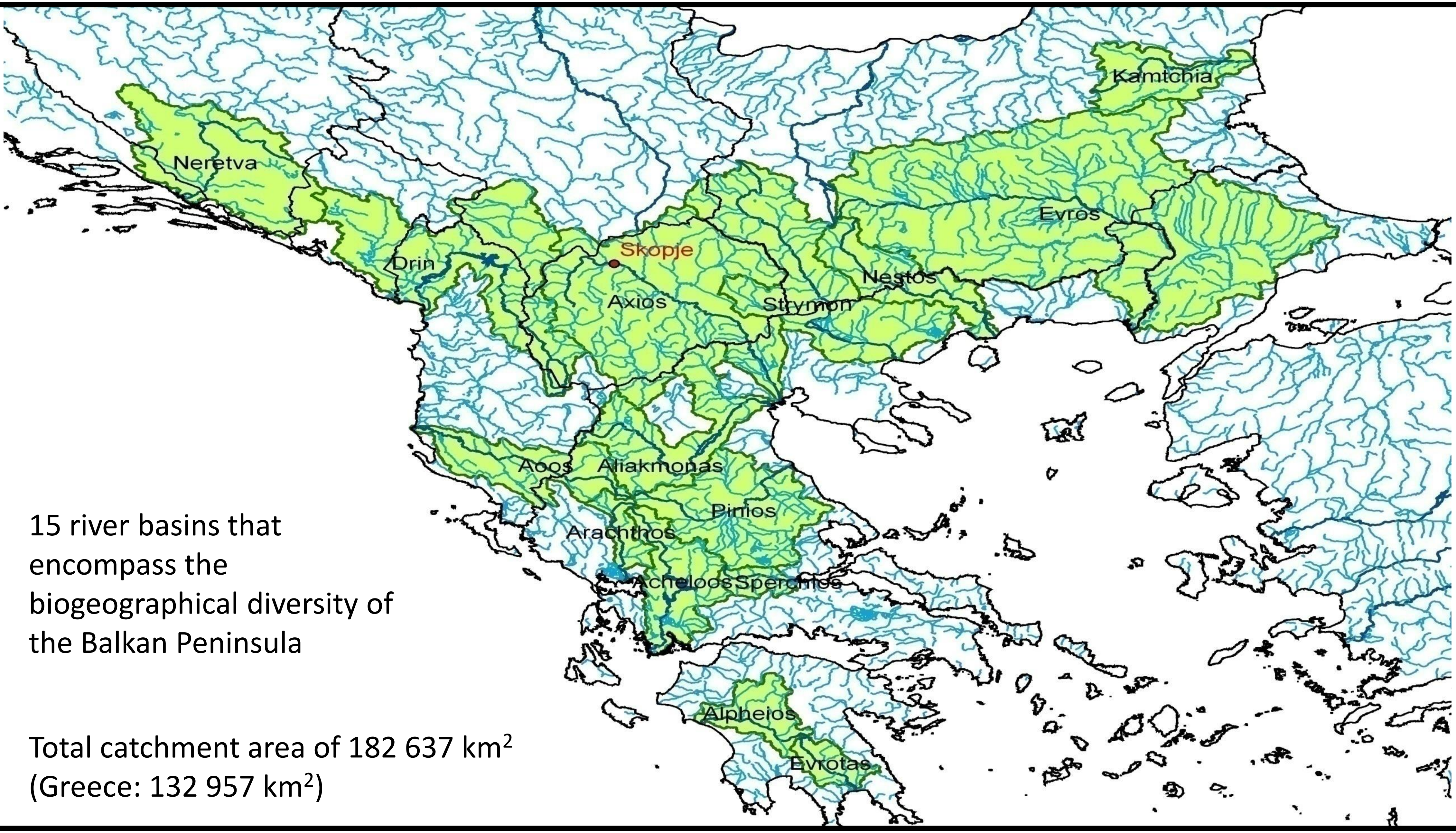
Politically unstable: Historically, the Balkan population was identified with wildness, primitiveness and violence and countries were considered wild and anarchic (the fragmentation of Yugoslavia was the result of long-standing historical divisions between religions and cultures). The Balkans were too mountainous and fragmented to facilitate a religious or linguistic homogenization without difficulty (Mazower 2000).

The Balkans - Intoduction

High biodiversity: The Balkan Peninsula is today recognized as one of Europe's "hot spots" of biodiversity and a region of global importance in regard to conservation efforts (UNEP, 2010). This is due to diversity of topography in combination with influences of both Mediterranean and continental climates and is due to its historic role of a glacial refuge for plant and animal species, and also its location at the crossroads for floral and faunal exchange between Central Europe on one side and Asia Minor on the other (Griffiths et al. 2004).

Morphological and climatic diversity created dynamic **river systems** ranging from steep gradient headwaters to braided and meandering channel types and deltaic areas.

Studied catchments



15 river basins that encompass the biogeographical diversity of the Balkan Peninsula

Total catchment area of 182 637 km^2 (Greece: 132 957 km^2)

Interregional Character

6 river basins are transboundary

The **Drin** (Drim) drains parts of Albania, Serbia, Montenegro, North Macedonia and Greece. For its relatively small size, it is among the most international rivers worldwide.

The **Neretva** flows through Bosnia & Herzegovina and Croatia.

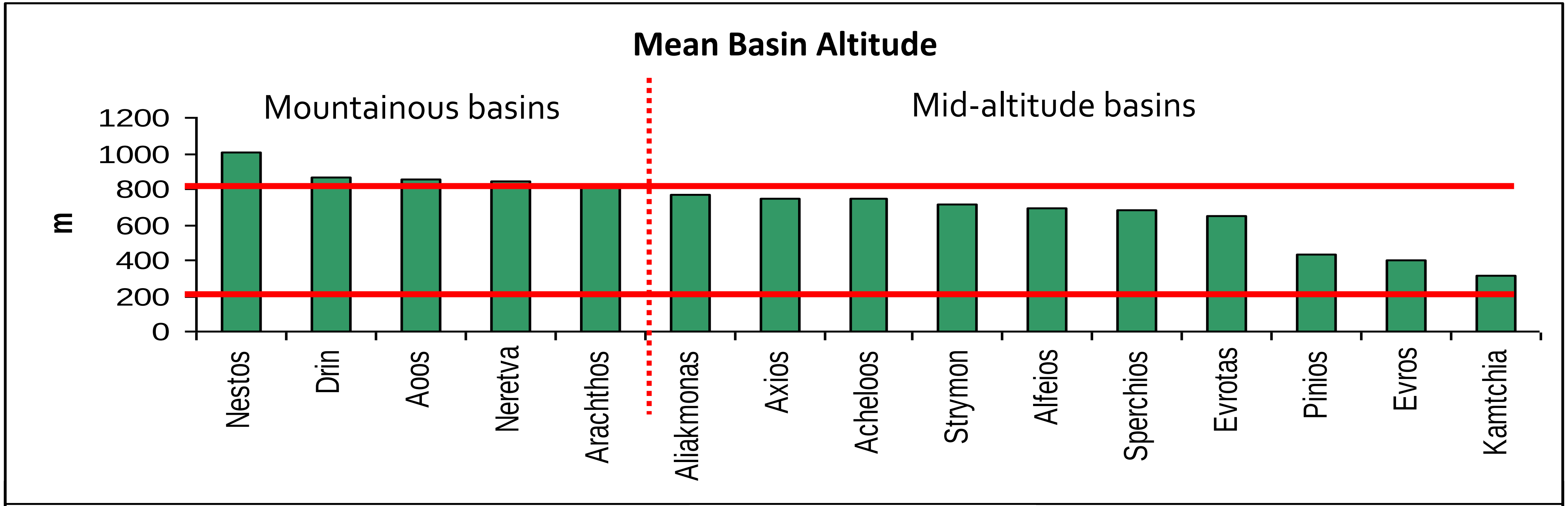
The **Evros** (Maritsa, Meric) basin is shared among Bulgaria, Greece and Turkey.

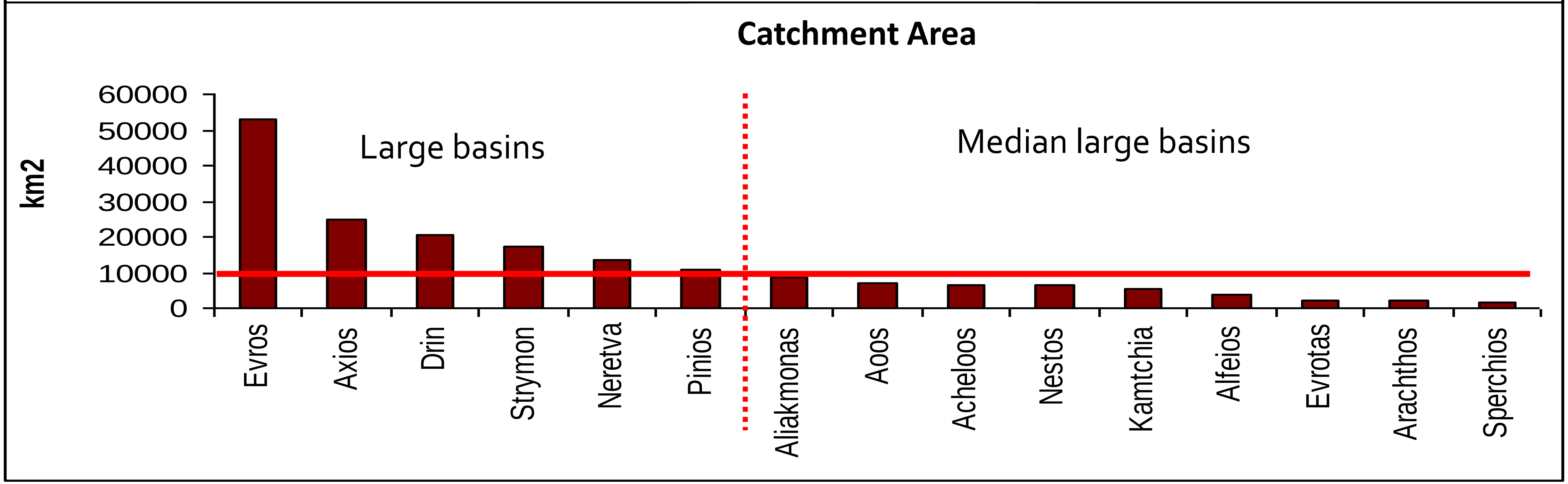
The **Strymon** (Struma) and the **Nestos** (Mesta) are shared by Bulgaria and Greece.

The **Axios** (Vardar) enters Greece from North Macedonia.

The **Aoos** (Vjose) flows from Greece towards Albania.

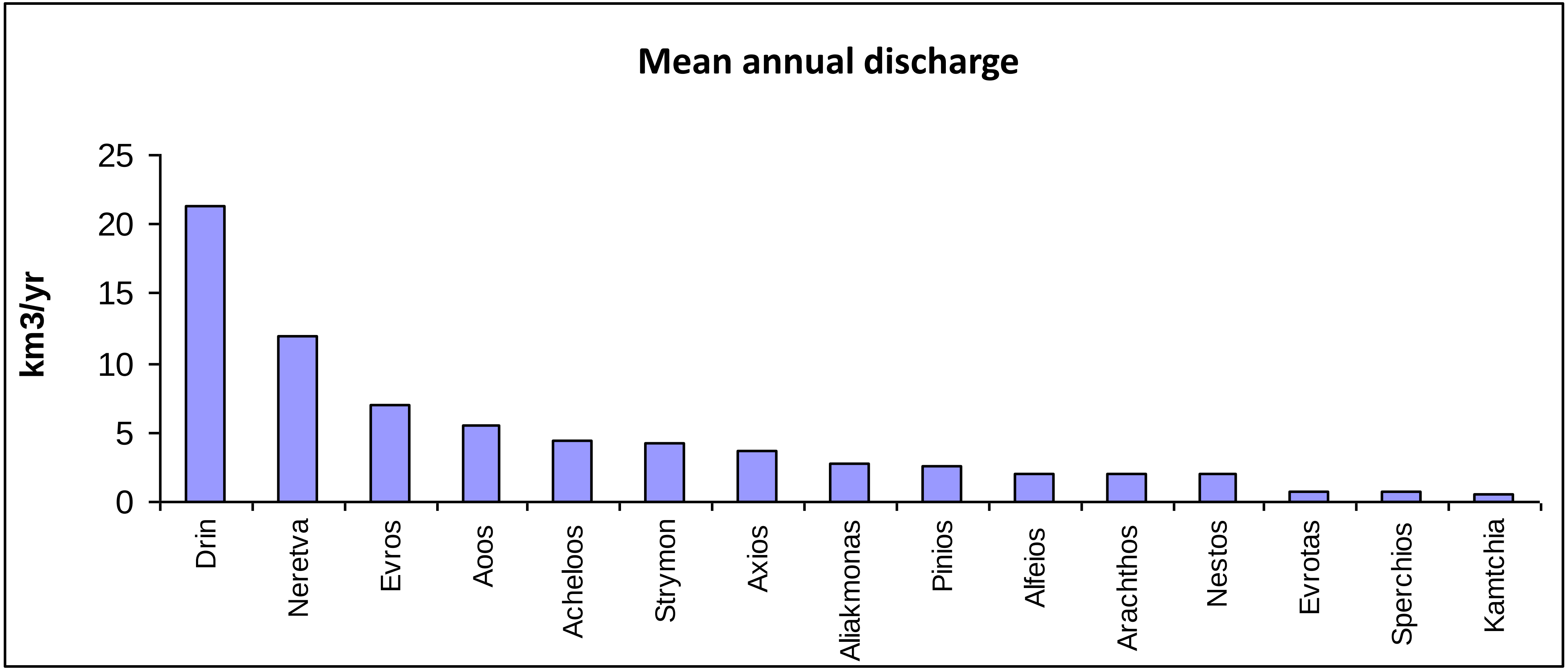
River Basin Characteristics





Hydrology – River Runoff

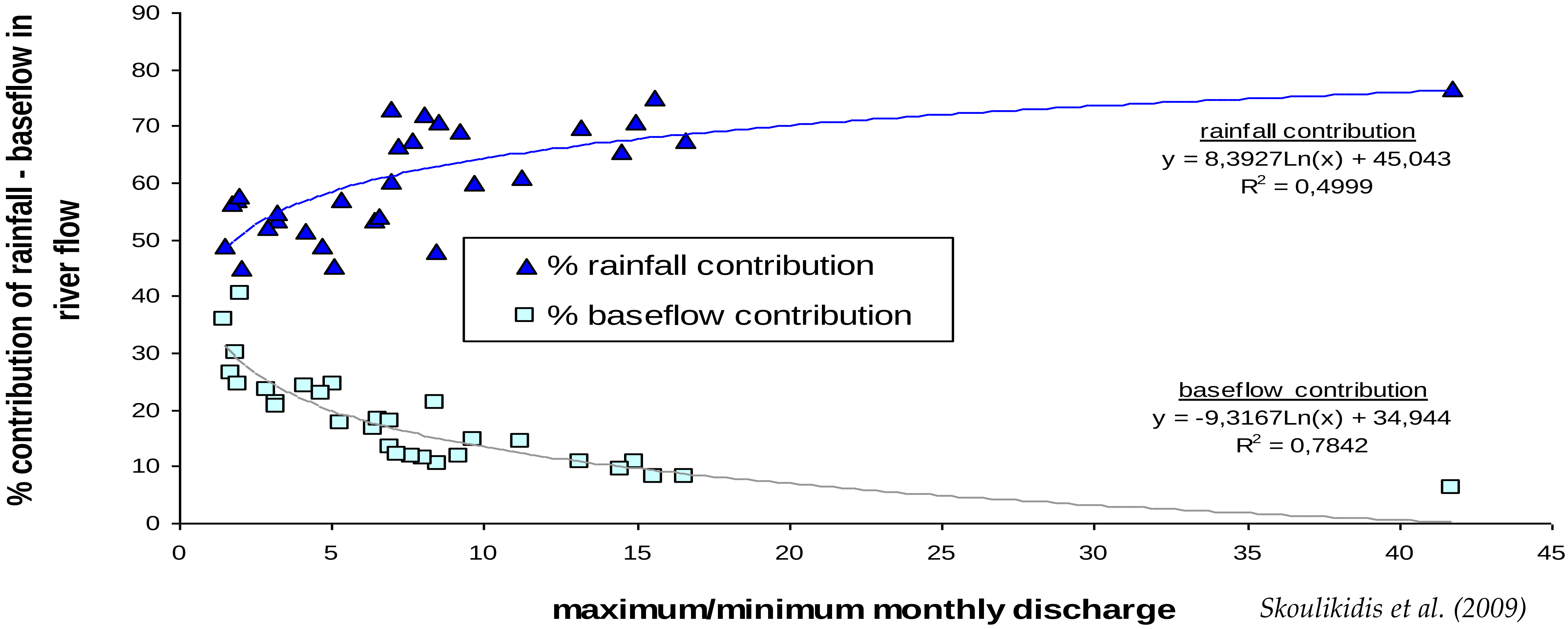
- Total European Mediterranean runoff: ~330 km^3/a
- Total Balkan river runoff: ~85 km^3/a = 26% of the European Mediterranean
- The Drin and the Neretva are ranked 3rd and 4th,respectively, after the Rhone and the Po rivers



Hydrology - Temporal variations

Monthly discharge variations increase in line with:

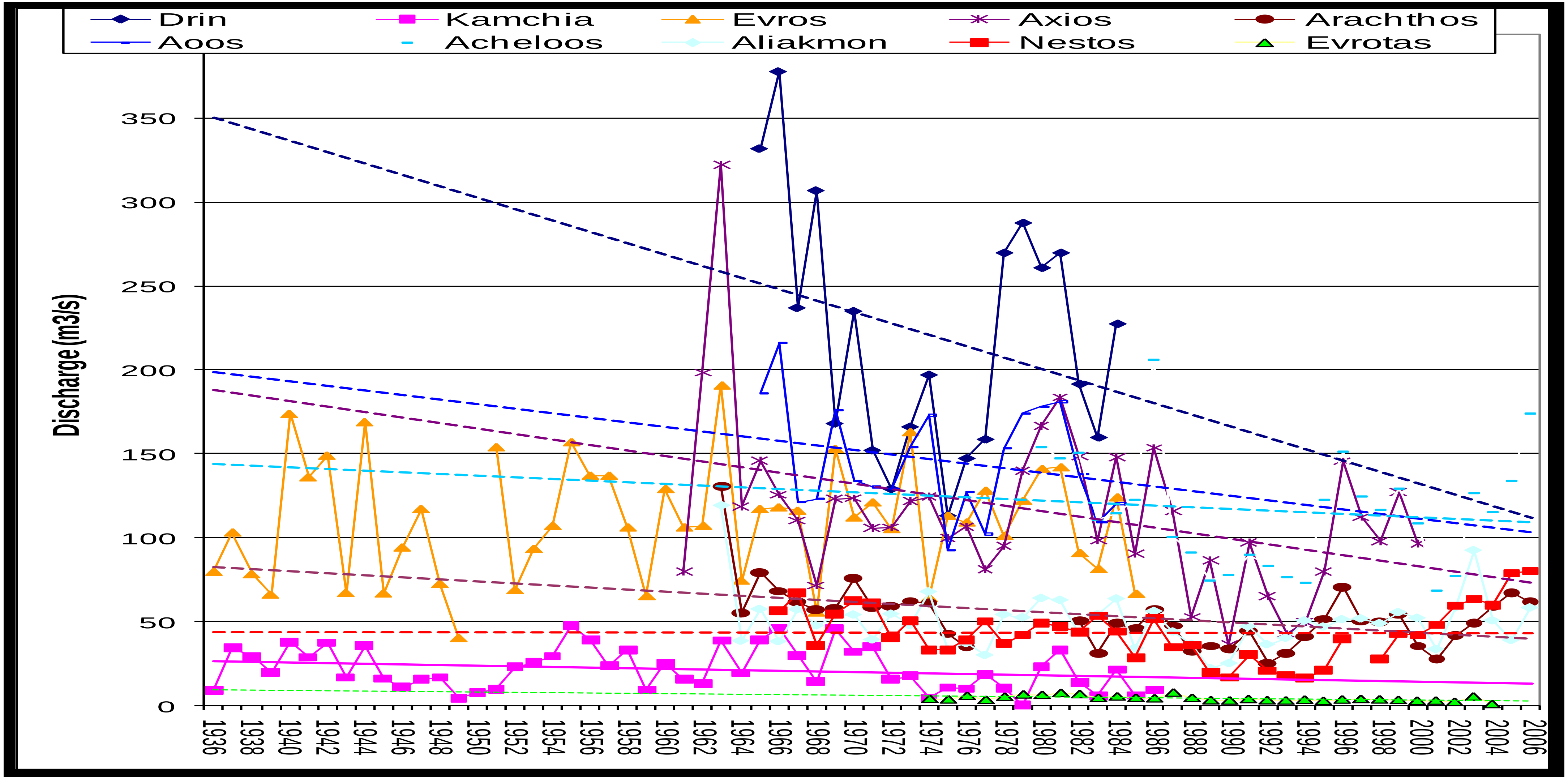
- high rainfall contribution to surface runoff
- low snow melting contribution to surface runoff
- low base flow contribution to surface runoff



Skoulikidis et al. (2009)

Hydrology - Long-term Trends

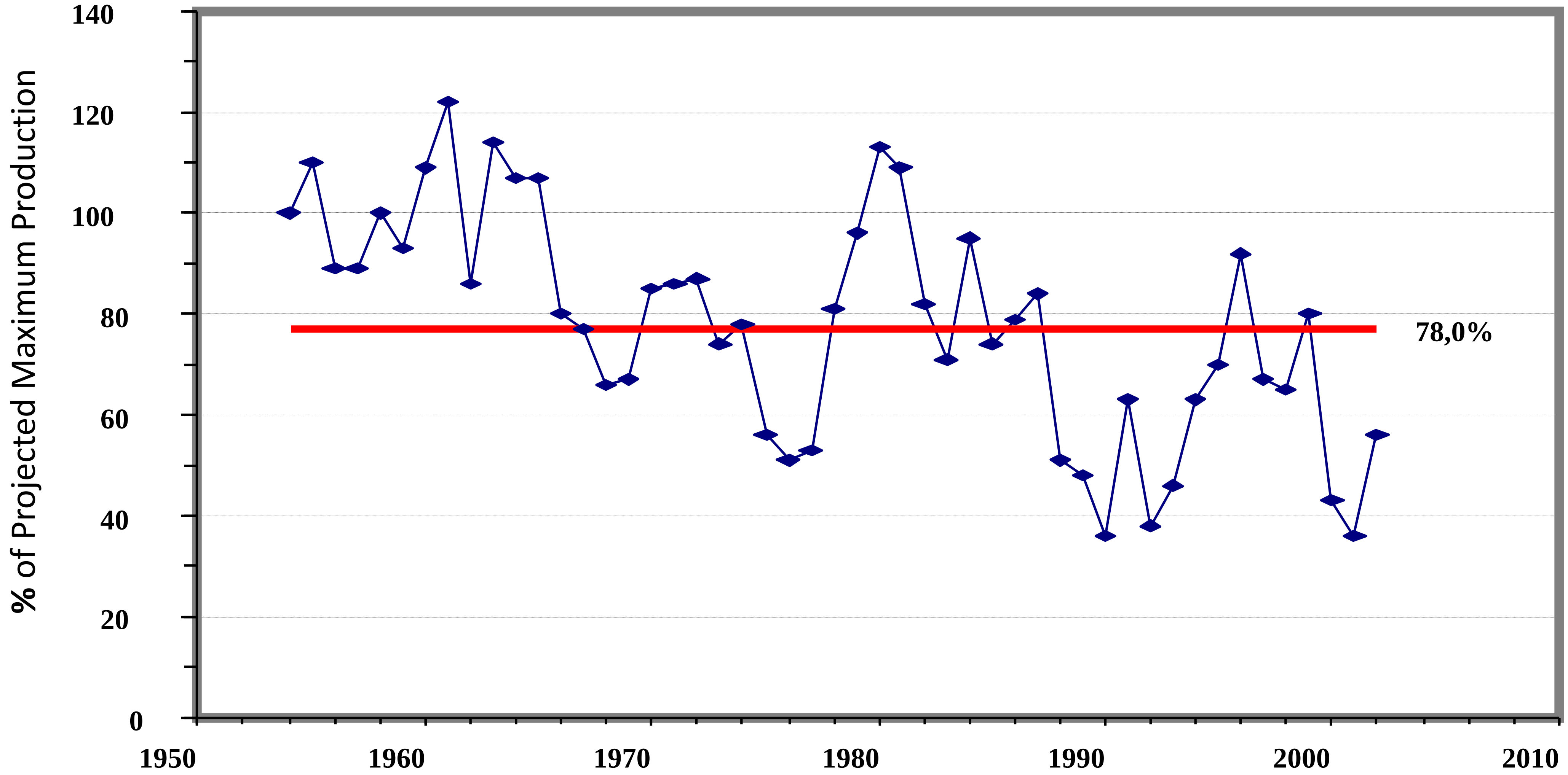
Dramatic long-term decline of river runoff in the Balkan rivers (22% average reduction of initial discharge), due to water abstraction for irrigation, climate variability/change and evaporation from reservoirs



Long-term discharge variation and trends in major Balkan rivers (Skoulikidis, 2009)

Hydrology - Impact of water use and climate change on energy production by large dams

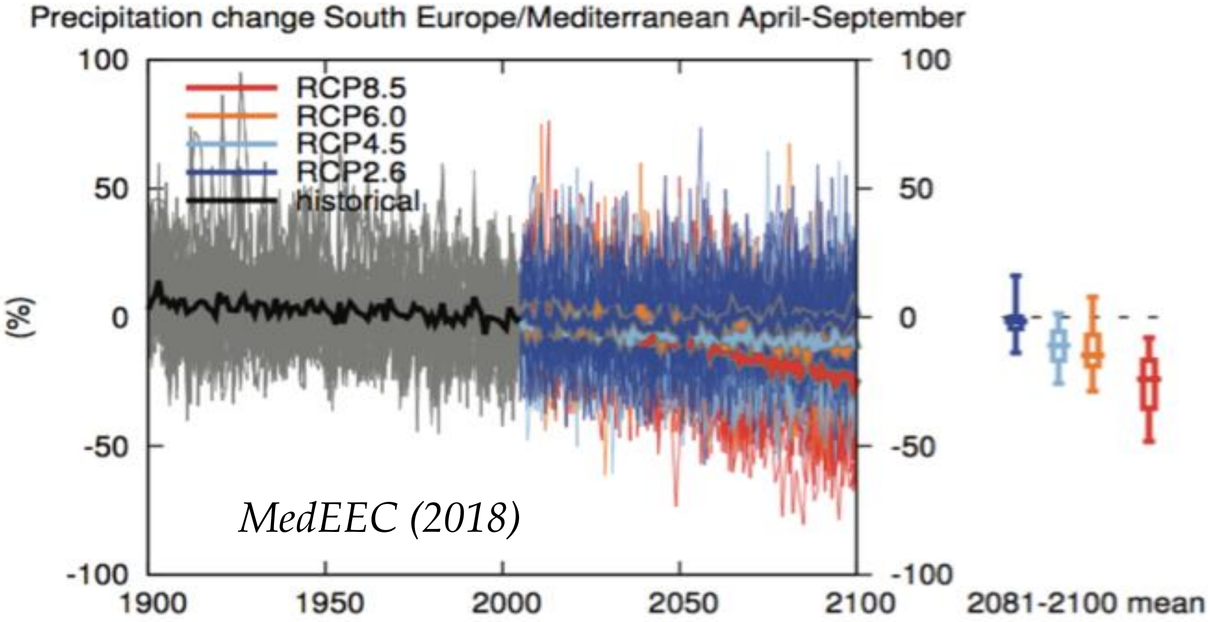
Annual energy production by large Hydros (P.P.C.)



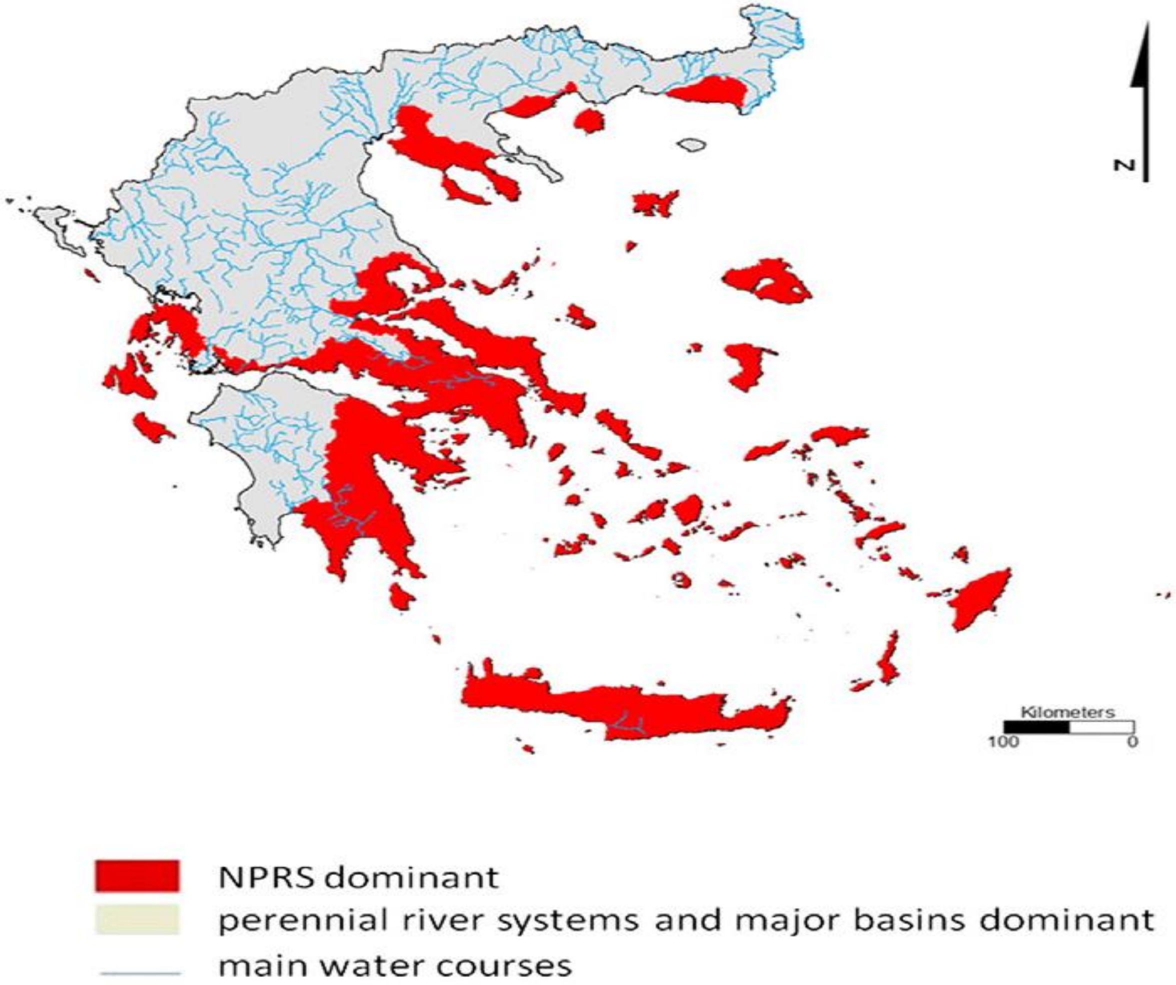
Hydrology – Non Perennial Rivers

In Greece, river basins with temporary flow cover ~40% of the country's surface area.

The temporary river Anapodaris in Crete



MedEEC (2018)

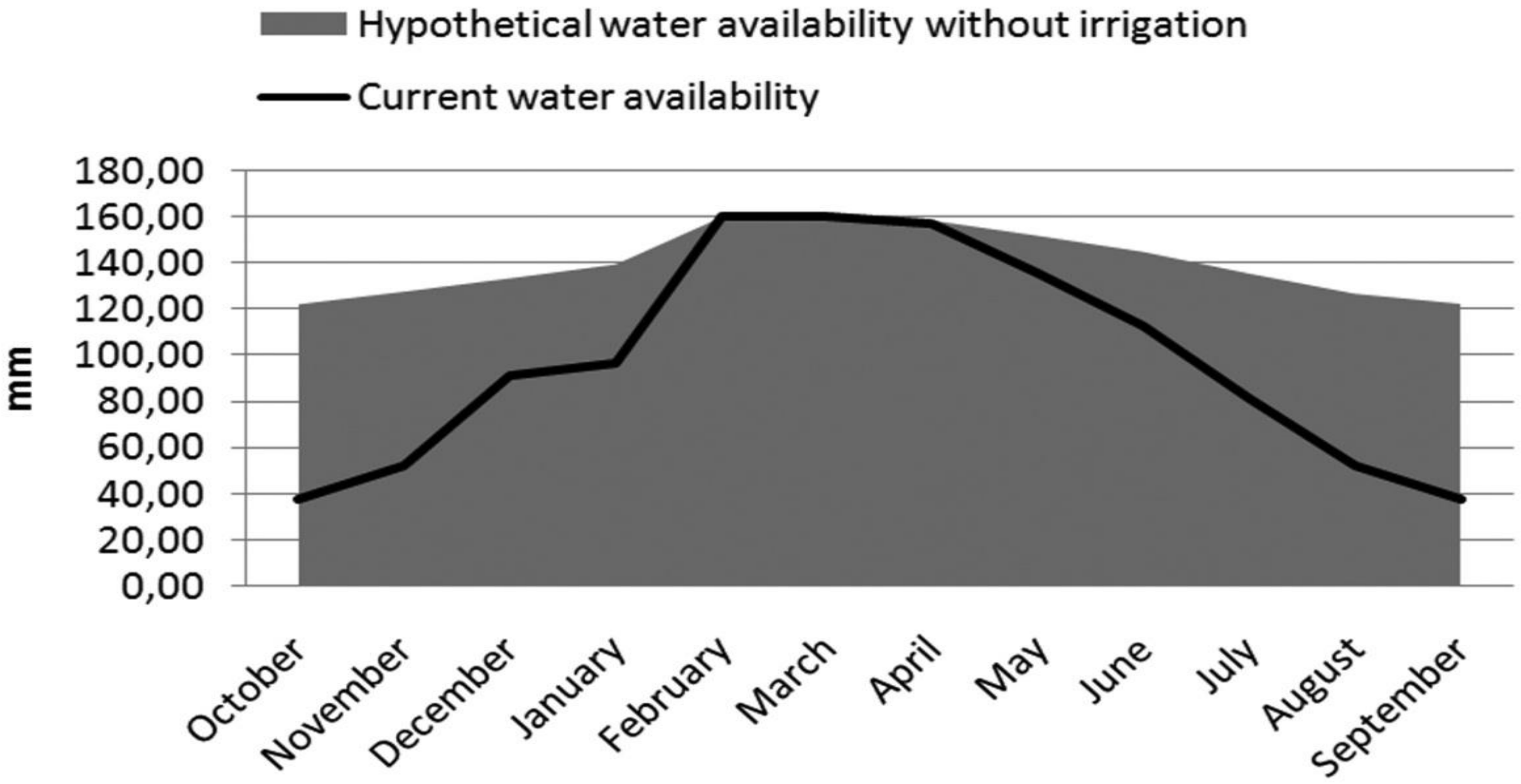


Distribution of temporary river basins in Greece
(Skoulikidis et al., 2016)

Hydrology – Artificial Desiccation

It has been estimated that if the irrigation of olive groves in Evrotas River basin stops, then the discharge at the downstream of the river during the irrigation period will **triple** and bring about a major halt to the artificial desiccation of river reaches (Skoulikidis et al., 2011).

Massive fish deaths of endangered endemic fish in Evrotas River (summer 2007)



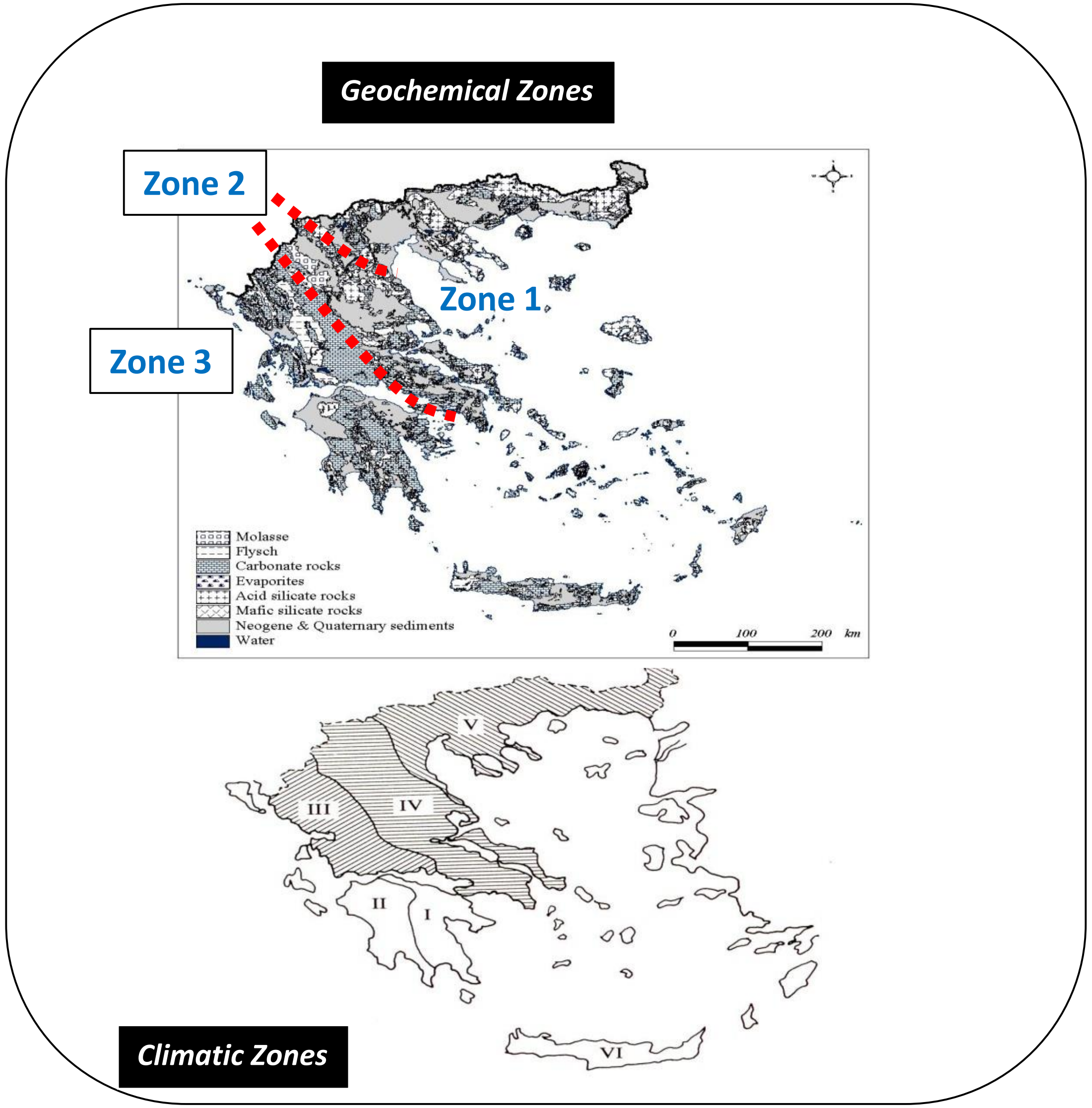
Monthly discharge variation in Evrotas River with and without olive tree irrigation (Skoulikidis et al., 2011)

Geological/Climatic Zonation

The Balkan Peninsula may be divided into three geological and climatic zones:

Geotectonically, **zone 3**, extending along the Adriatic and Ionian Seas, belongs to the External Dinarides/Hellenides which were subject to the Alpine orogenesis. This zone reveals a rather simple geotectonic structure made up of sedimentary sequences, predominately flysch and carbonates, imprinted by karstic features, and may be termed as a "*carbonate type zone*". This zone receives maximum precipitation, particularly in the north.

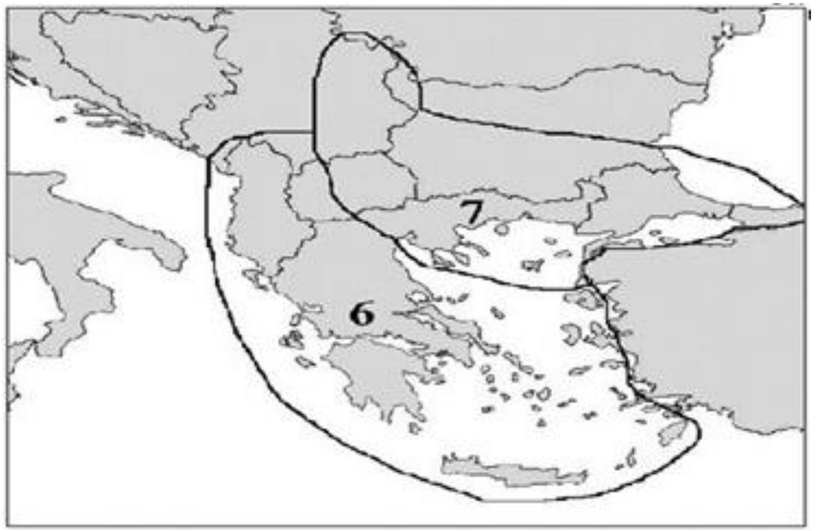
Situated east of the Pindos Mt. range, **zones 1** and **2** fit in the Internal Balkanides, which were additionally affected by older orogenetic movements, and reveal a complex geotectonic structure, dominated by metamorphic massifs, plutonic and volcanic intrusions and ophiolite suture zones.

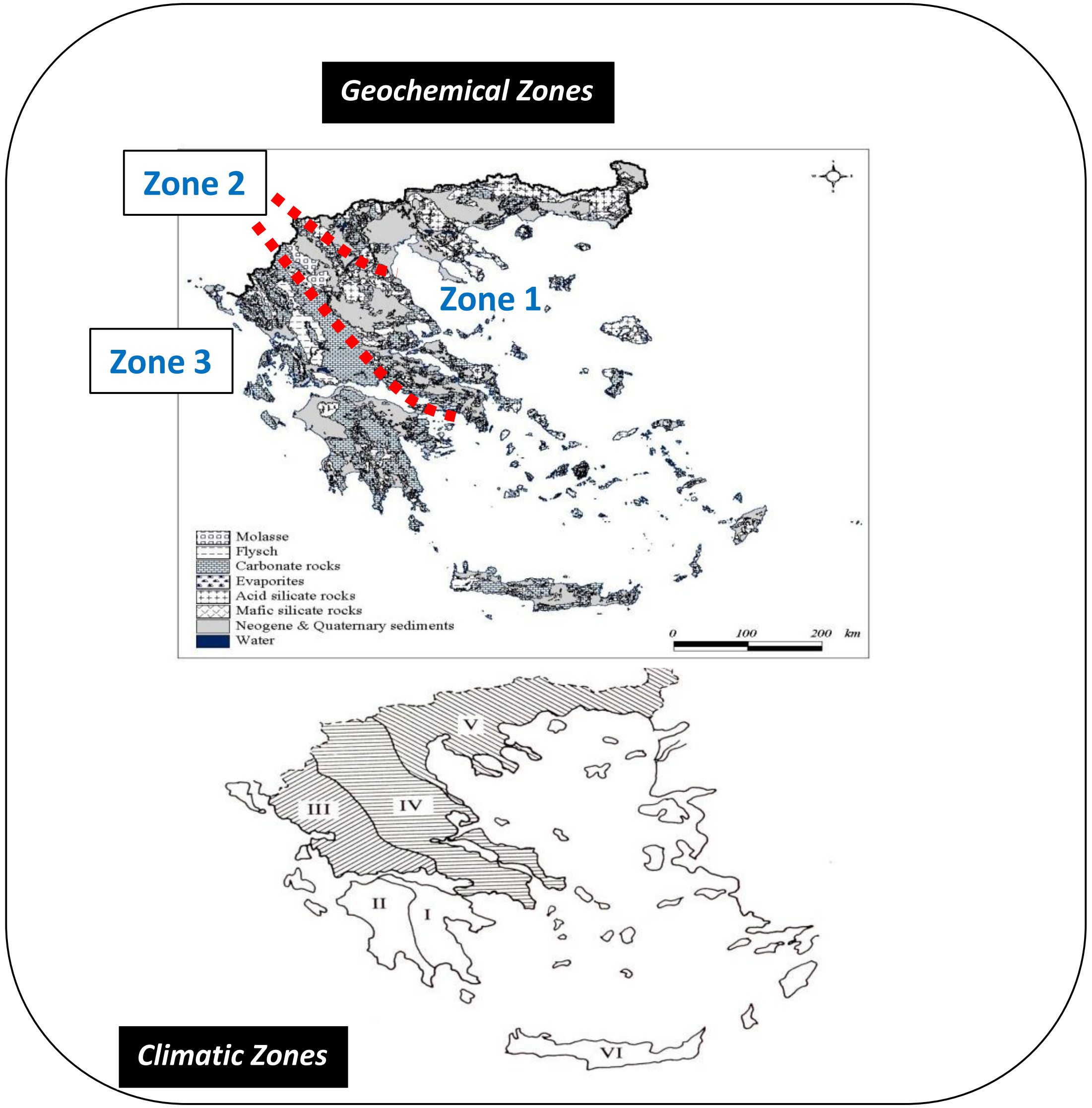


Geological/Climatic Zonation

Geochemically, **zone 1** belongs to an acid silicate type and presents minimum precipitation, while **zone 2** is characterized by a mixture of carbonate rocks and silicate rocks, mainly of magmatic origin, and shows intermediate precipitation and minimum air temperature.

In addition, the boundary between zones 1-2 and zone 3 is identical with the boundary of Illes **ecoregions** 6 and 7.





Geological/Climatic Zonation

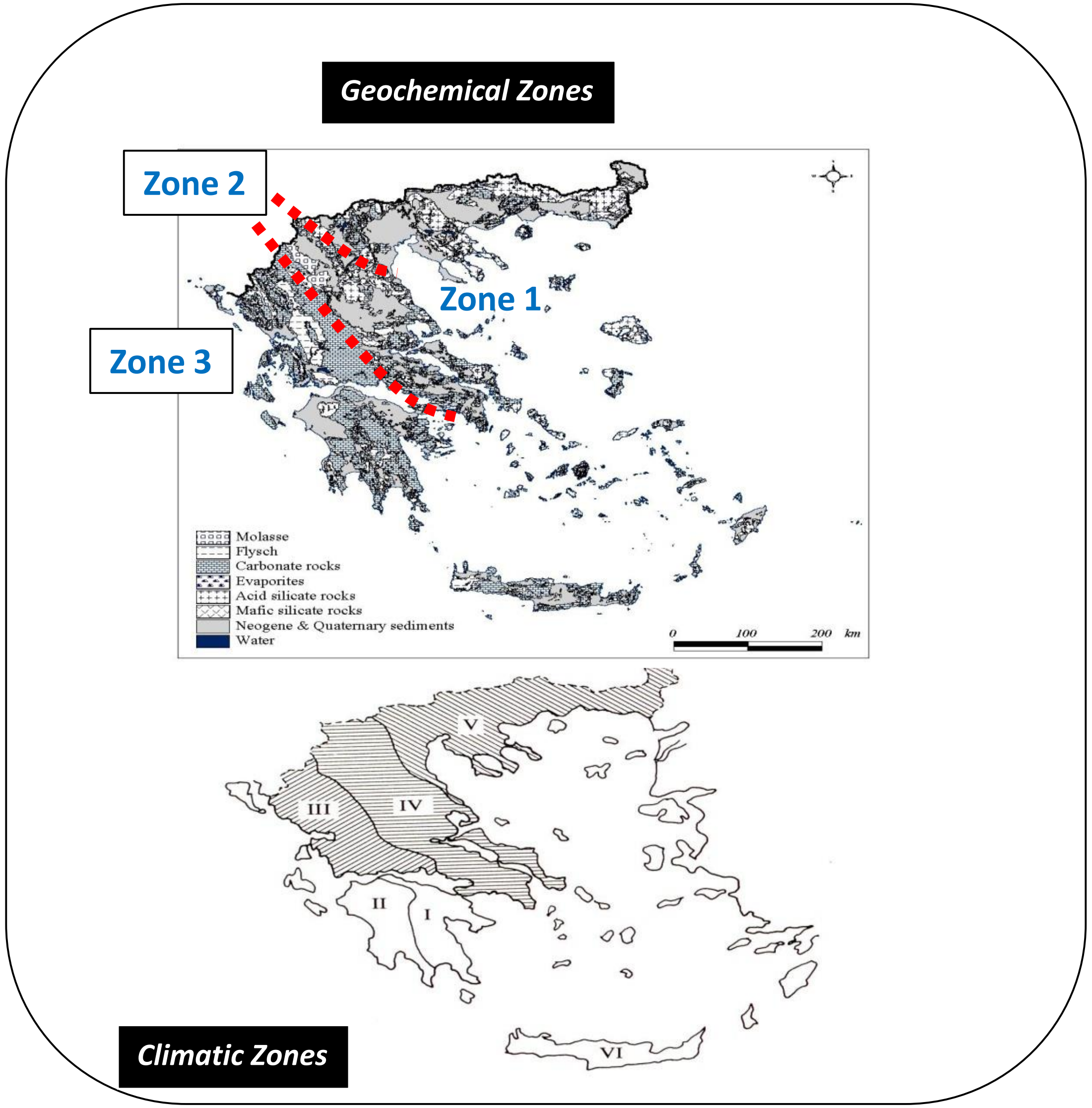
Morphological features

River basin geological and climatic characteristics shape morphological features of river reaches:

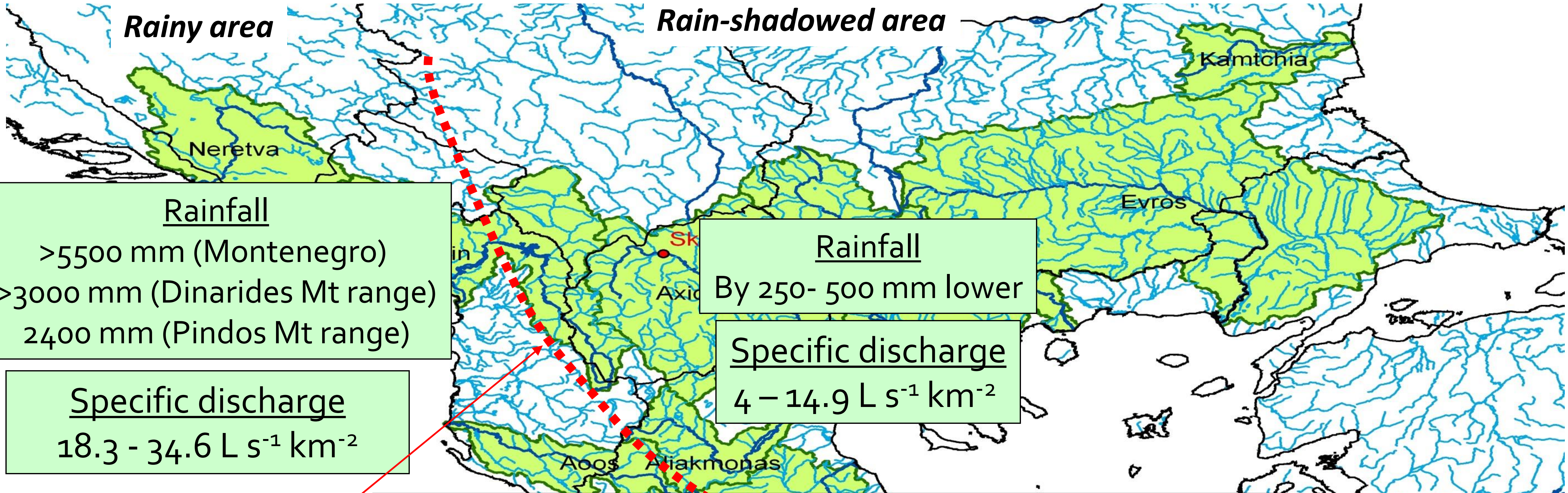
Zone 1 is dominated by U-shaped valley forms and wide floodplains but narrow and shallow riverbeds as a result of highly impermeable rock formations that dominate this zone.

In zone 2, V-shaped valleys, and riverbeds with medium width and depth predominate.

In zone 3, V-shaped valleys with narrow floodplains and deep and wide riverbeds characterize the calcareous river basins.



Hydrological Zonation



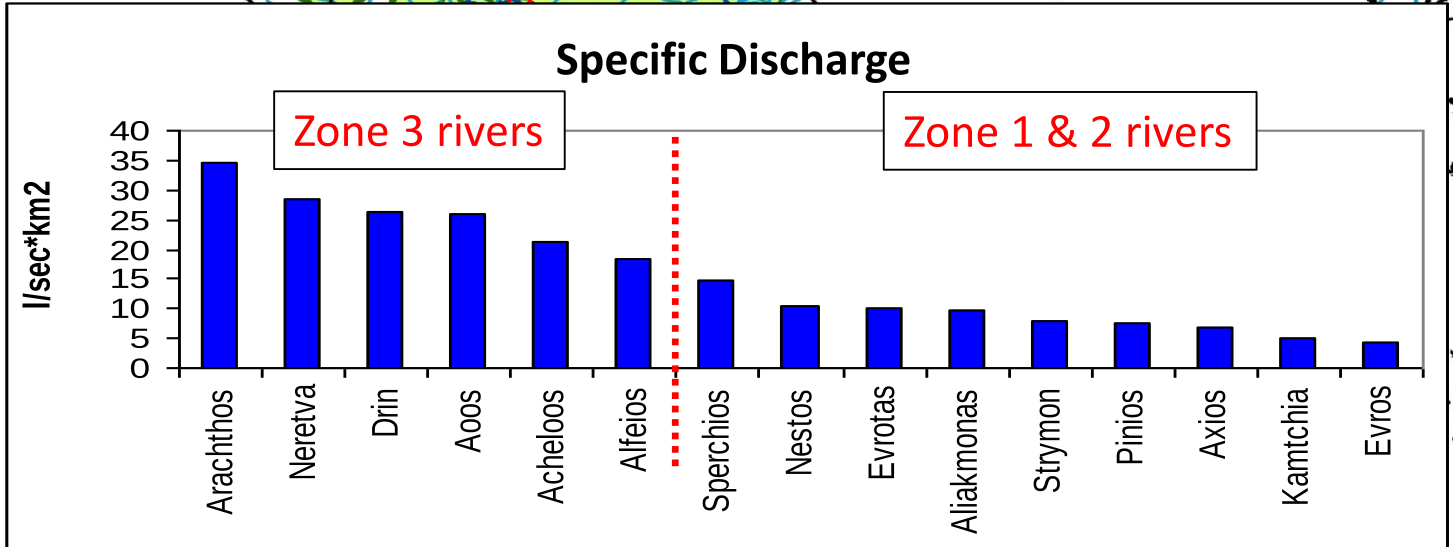
Rainfall
>5500 mm (Montenegro)
>3000 mm (Dinarides Mt range)
2400 mm (Pindos Mt range)

Specific discharge
18.3 - 34.6 L s^{-1} km^{-2}

Rainfall
By 250- 500 mm lower

Specific discharge
4 – 14.9 L s^{-1} km^{-2}

Dinarides-Hellenides Mt range



Hydrochemical Zonation

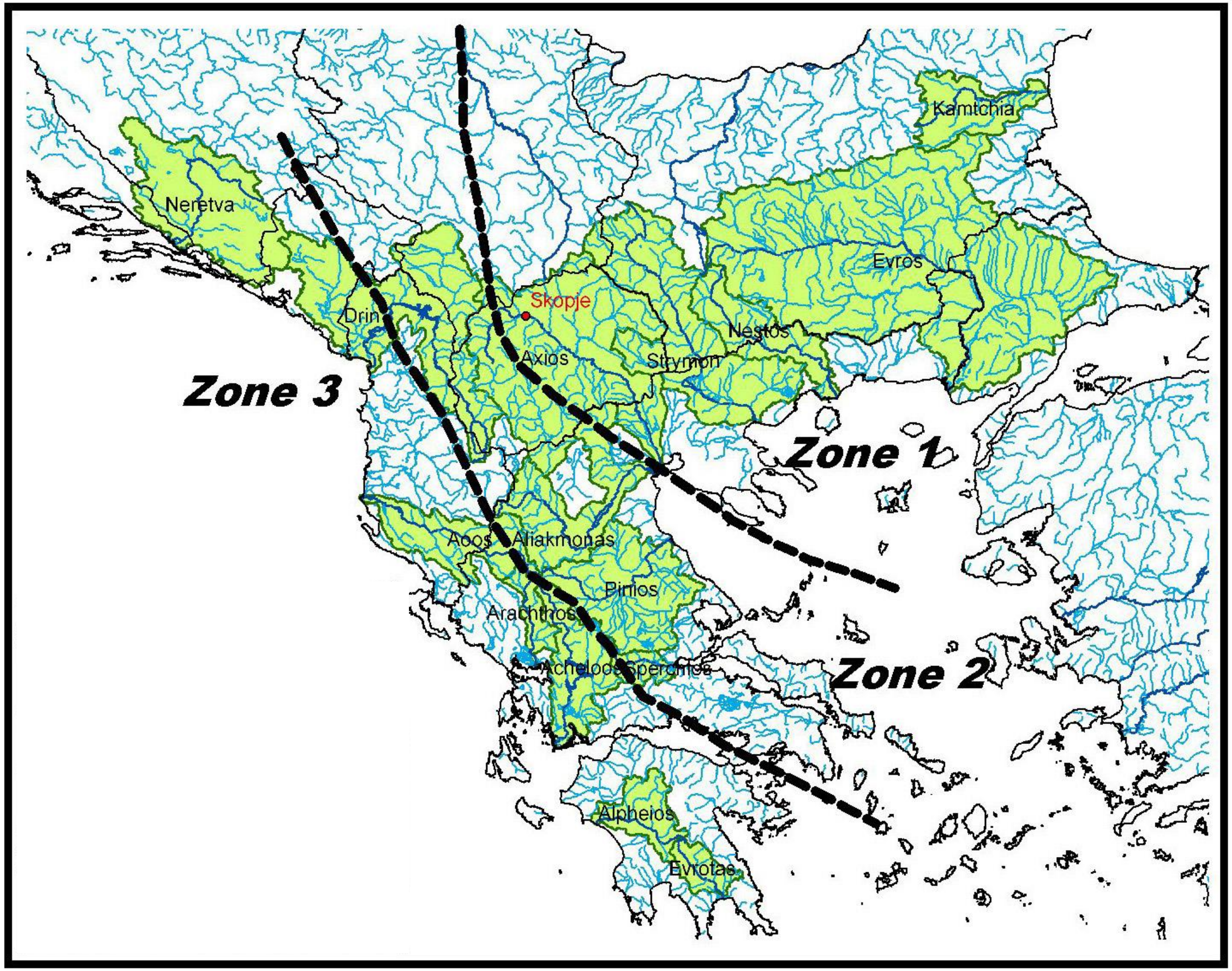
Geology and climate are the main drivers of the hydrochemical regime of rivers (Skoulikidis et al. 2018).

Within Greece, the three zones are characterized by rivers with differences in water temperature, conductivity, and major ion concentrations (Skoulikidis et al. 2006).

Zone 3 shows maximum **water temperature** and minimum **P** due to its karstic nature, and, despite elevated precipitation, high **mineralization**.

Zone 2 shows maximum **SiO_2** concentration and maximum **Mg** portion as a result of ophiolite weathering.

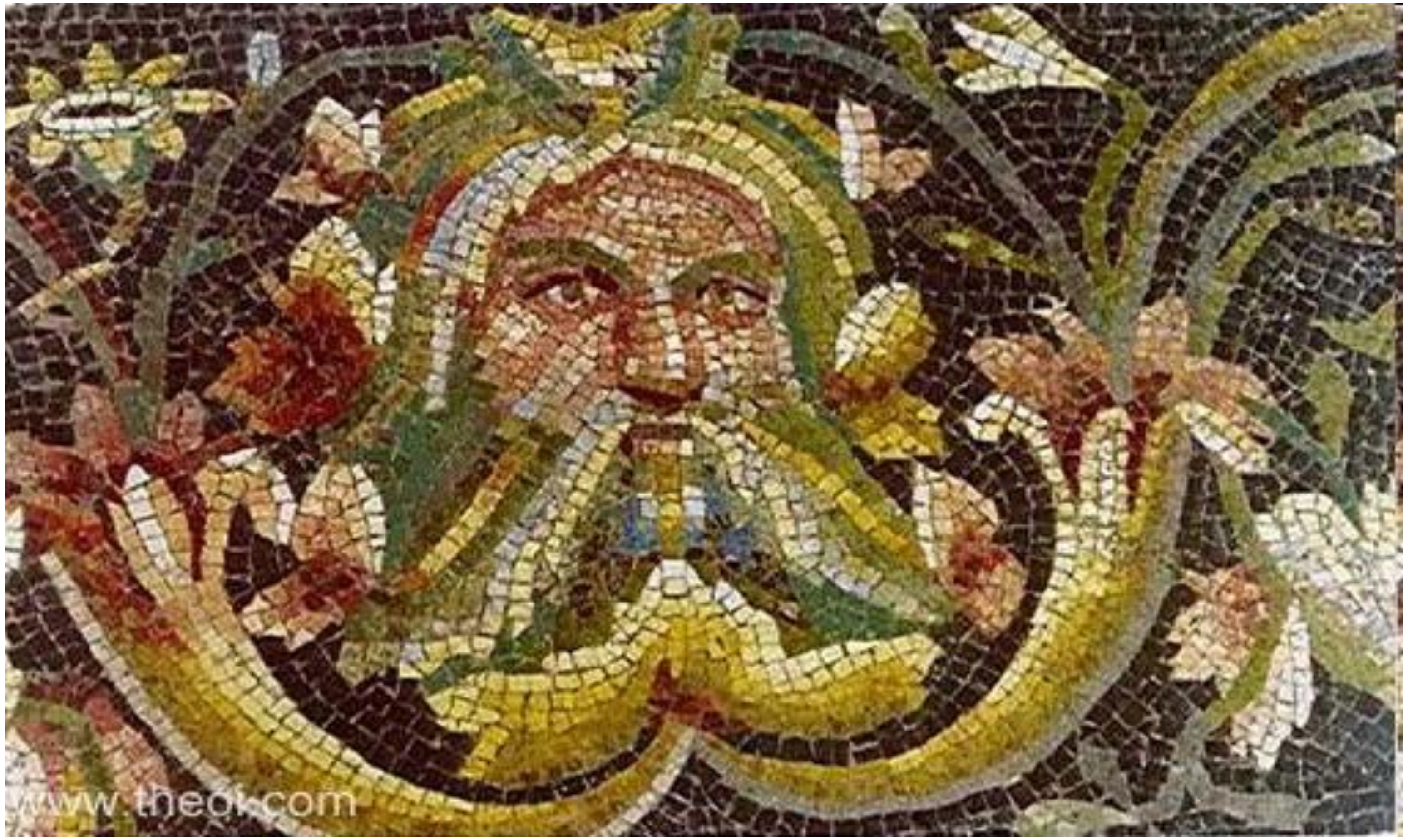
Zone 1 is characterized by maximum **SO_4** concentration due to the dissolution of pyrite ores (followed by zone 3 which is affected by evaporite dissolution), high **SiO_2** and maximum **K** concentrations due to acid silicate rock weathering.



Rivers in the Mythology

According to the Cosmogony of Hesiod, rivers where worshiped as mail gods, offsprings of Titan Ocean (son of Gaia and Uranus) and Tethys.

River god and Nymph (4th century B.C.)



The river god Efratis in Mesopotamia

The Alpheios river god and Nympf

Rivers in the Modern World - Environmental Pressures

Rivers were the primal highways of life. From the crack of time, they have borne men's dreams, and in their lovely rush to elsewhere, fed our wanderlust, mimicked our arteries and charmed our imaginations in a way that the static pond or vast and savage ocean never could. Now, full of dams and contamination, they reflect on the modern man his foolish image, and go on singing the world's inexhaustible song (Tom Robins).

Rivers and streams, together with most natural resources, are exploited for human “welfare” (= over-consumption), and are even used, locally, as waste pipes.

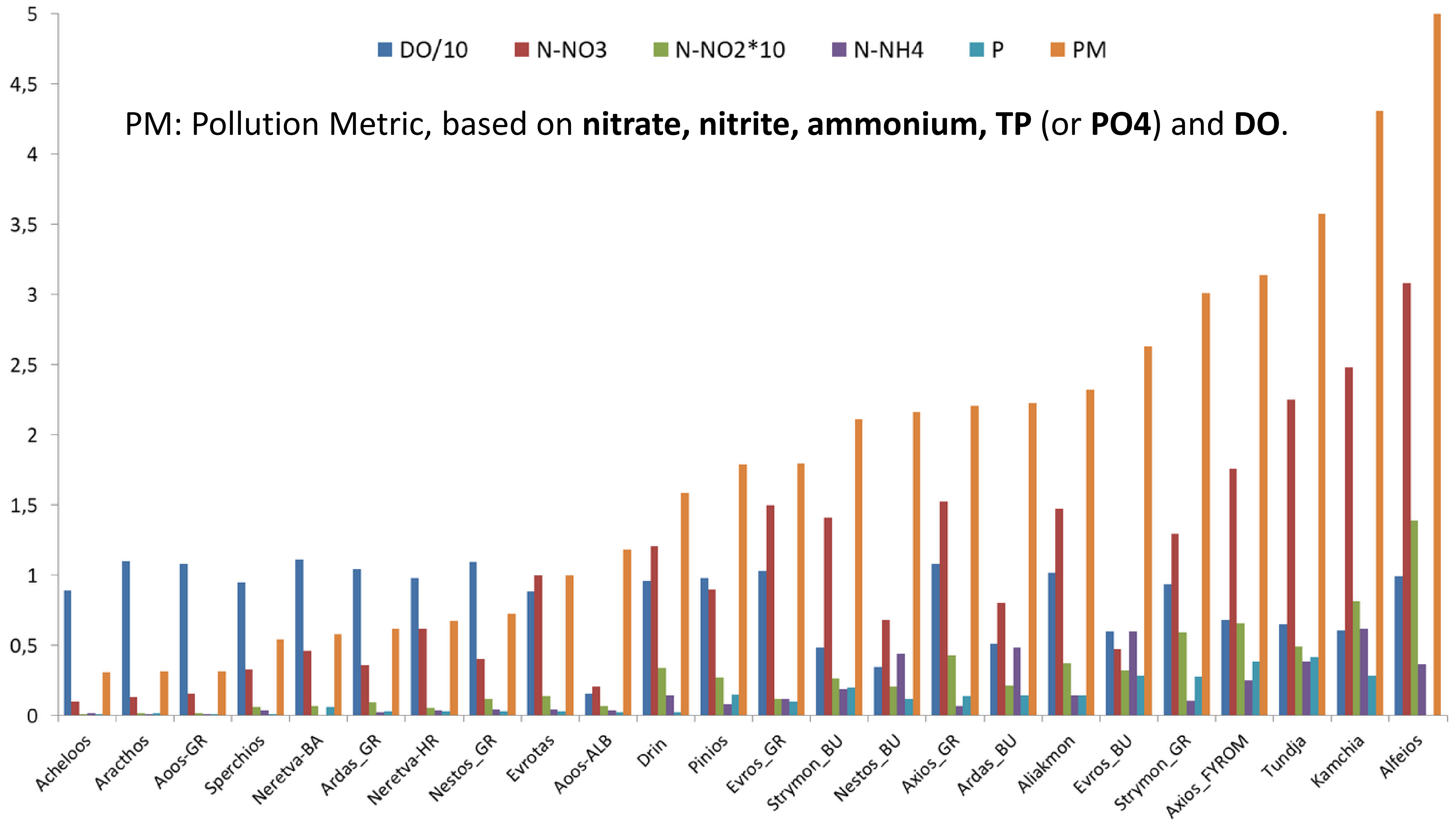
In the Balkans, pollution from municipal, industrial and agrochemical sources remains a major threat to freshwater ecosystems.

Environmental pressures differ among regions; **mining** effluents affect mainly Bulgarian and Albanian rivers, **industrial** pollution is important in Bulgaria, Northern Macedonia and Bosnia & Herzegovina, **agricultural** pollution is widespread in Greece, Bulgaria and Albania, while **urban** pollution prevails in all countries while in Greece is evidence of inadequate operation of WWTPs.

Today, the aquatic and riparian fauna and flora in many Balkan river basins is at risk. Lowland sections are at greatest risk due to changes in agricultural practices, industrialization and tourism. **However, the recent rapid development and installation of renewable energy technologies seriously threaten mountain ranges and headwater streams, even in Natura 2000 protected areas**.

Qualitative Issues

Ranking major Balkan rivers according to a Pollution Metric



Skoulikidis et al. (2019). Rivers of Europe, 2nd edition

Qualitative Issues

However, river basins that meet **reference conditions for all nutrients and dissolved oxygen** still exist. These are the **Acheloos**, the **Arachthos** and the **Greek sub-basin of the Aoos** (all mountainous and situated in Zone 3).

The **Mesta**, **Struma** and **Marica** (including the Arda), and the **Kamchia** exhibit **critical DO concentrations**. The same basins show elevated **ammonium** (0.62 - 0.19 mg/L $N\text{-}NH_4$) and **TP** (0.42 - 0.20 mg/L P) concentrations, reflecting impacts of organic waste discharges (municipal and/or industrial). However, the **highest ammonium** concentration is found in the **Alfeios** (0.87 mg/L $N\text{-}NH_4$). High **TP** concentrations are found in the **Vardar** (0.38 mg/L P) and high **orthophosphate** concentrations in the **Strymon Axios**, **Pinios** and **Aliakmon** (0.28 - 0.14 mg/L $P\text{-}PO_4$).

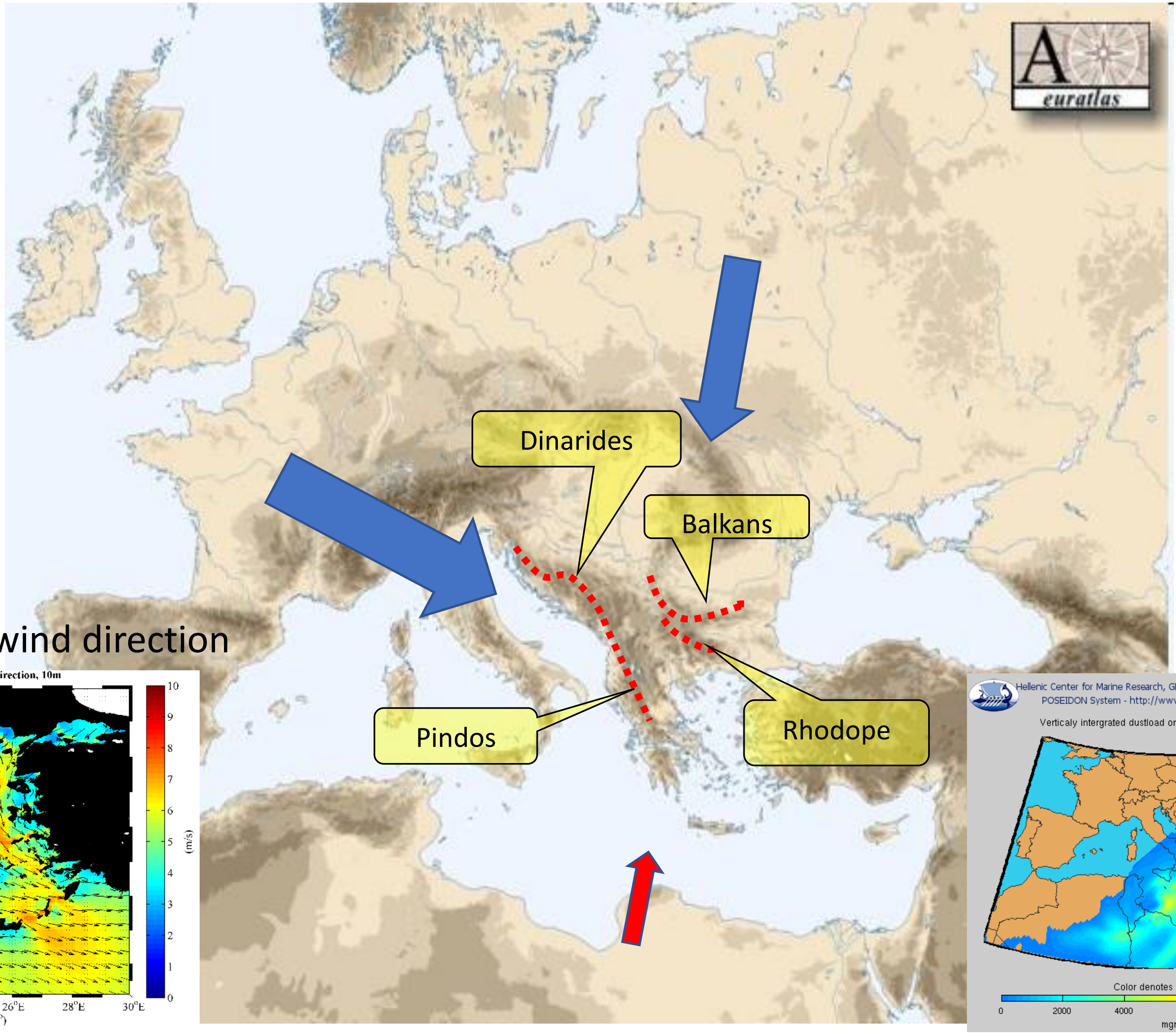
Concerning **pesticides**, the Greek rivers follow similar concentration levels and patterns as reported in most European countries, the levels of some compounds decreased with time mainly due to a ban or the implementation of good agricultural practices, whereas in areas with intense agricultural practices, the concentrations of pesticides are in non-compliance with the environmental quality standards (Lambropoulou et al. 2018).

Several **PCBs** compounds were detected in the **Drin** and, especially in the **Buna** (Dano et al. 2016). In the **Neretva**, maximum concentration was substantially lower than quality standards (Djedjibegovic et al. 2010).

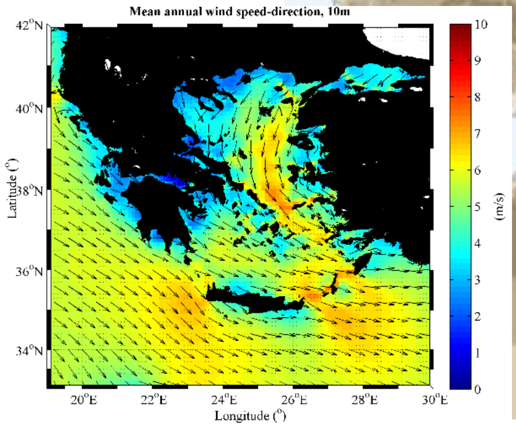
Regarding **pharmaceutically active compounds** a recent study carried out in the **Evrotas** showed that the diuretics and the analgesics/anti-inflammatory class were the most abundant, followed by antihypertensives, psychiatric drugs, β-blocking agents and antibiotics as a result of WWTP discharges (Mandaric et al. 2019).

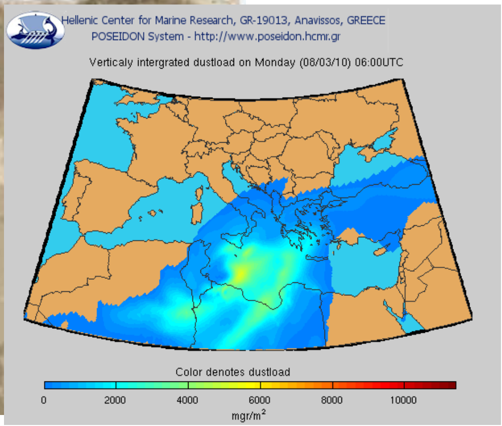
Qualitative Issues

Atmospheric Inputs



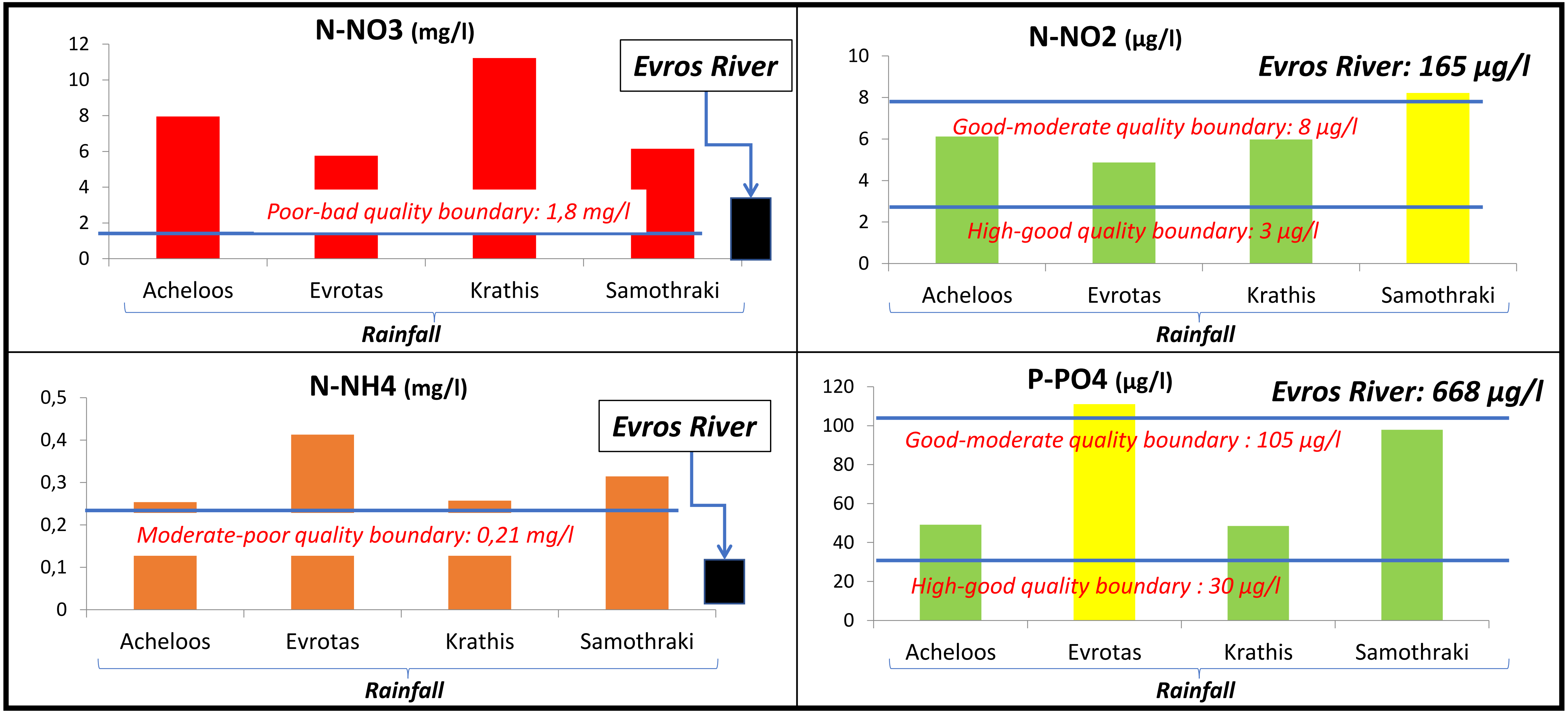
Mean annual wind direction





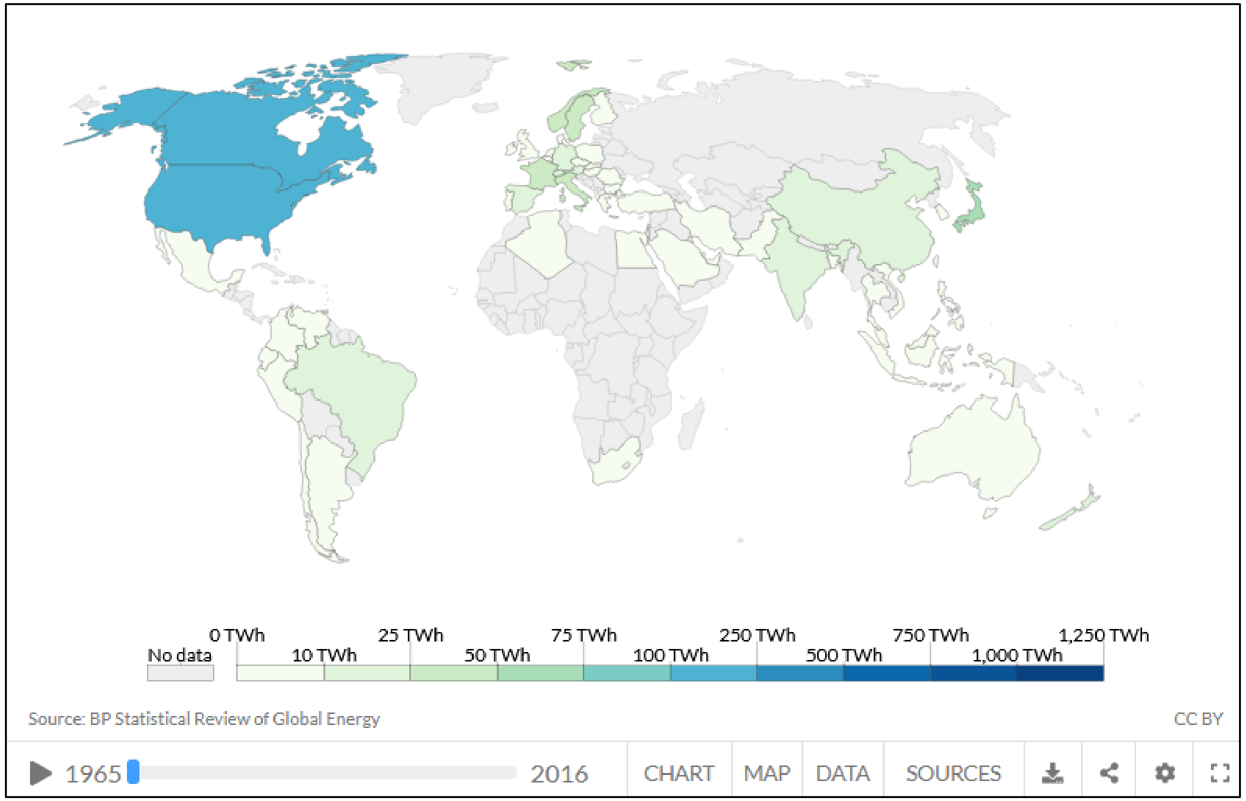
Qualitative Issues

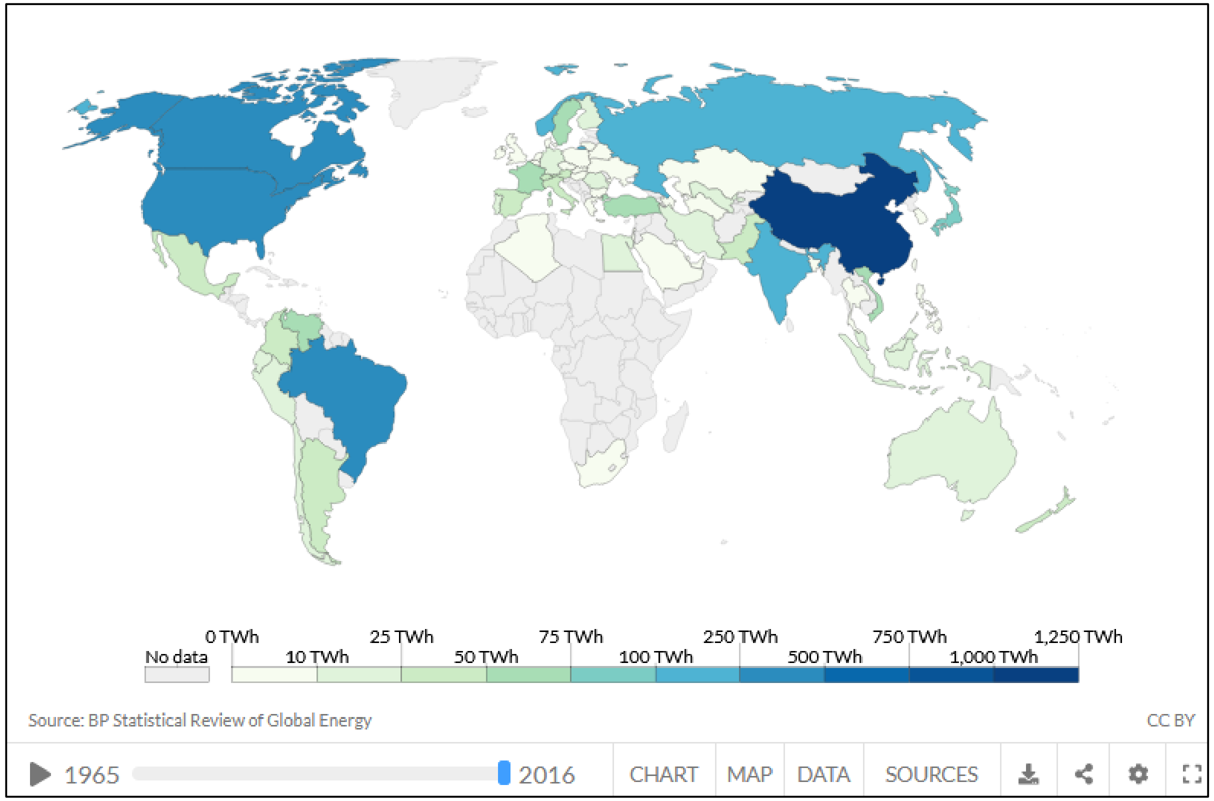
Atmospheric Inputs



Nutrient quality of rain water in 4 Greek river basins [according to the Greek Nutrient Classification System (Skoulikidis et al. 2006)] – Comparison with polluted Evros River (data from: Skoulikidis 2018)

Hydromorphological Issues – River Fragmentation

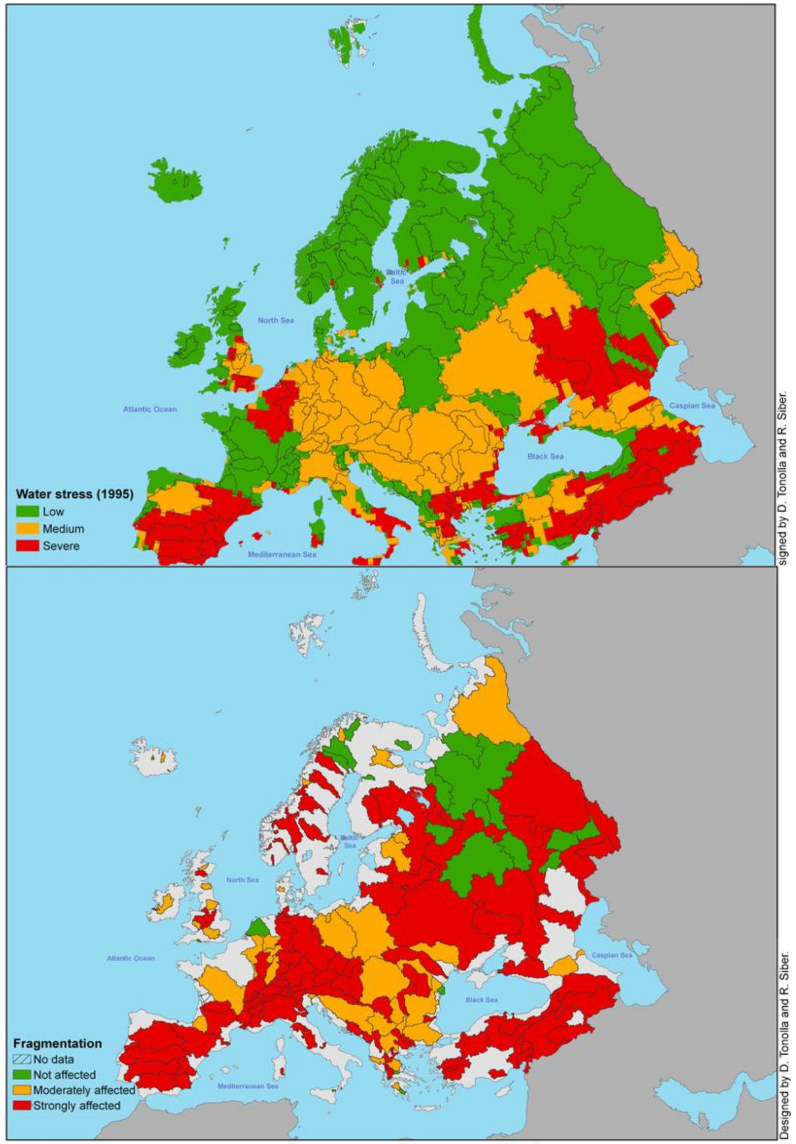




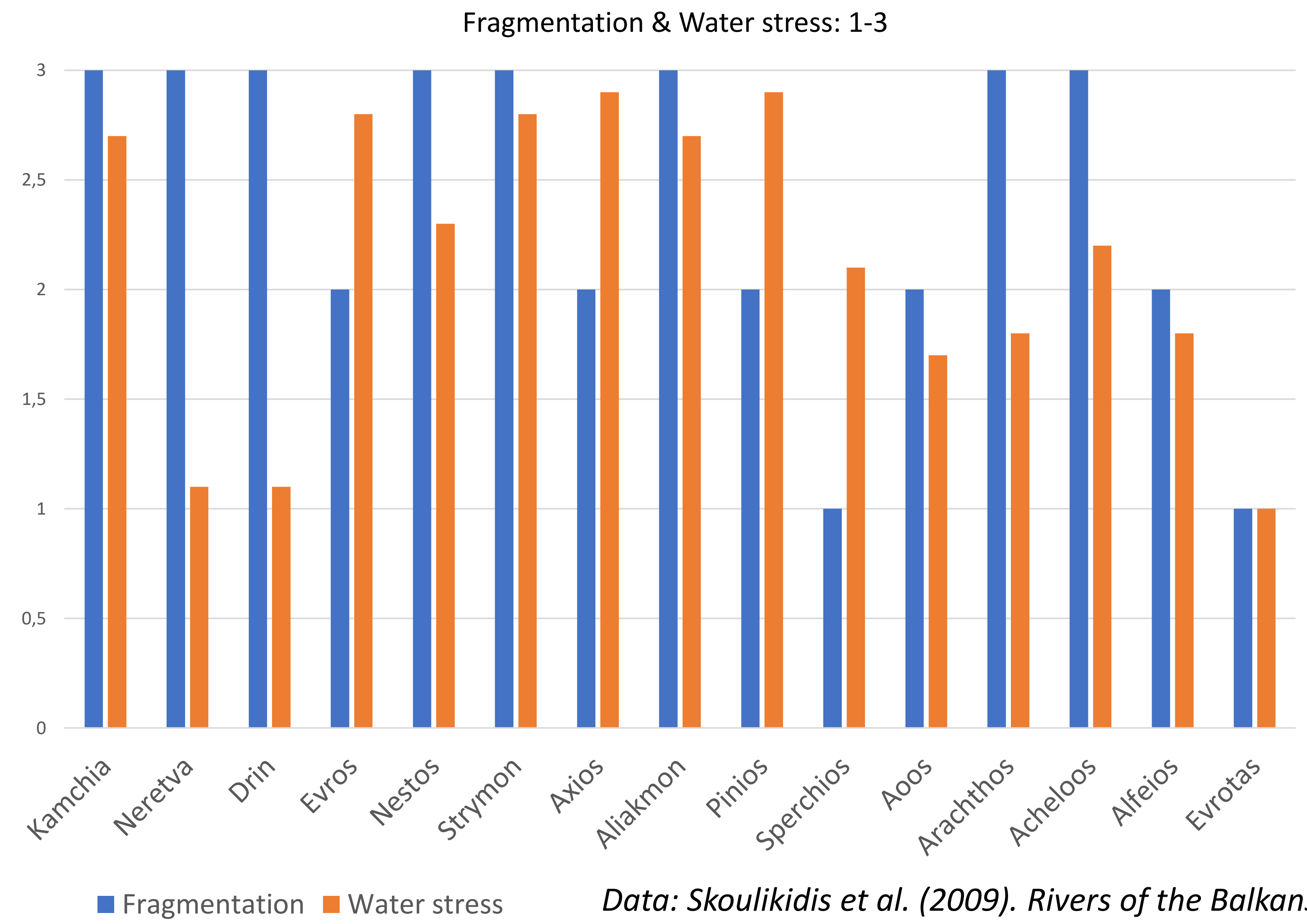
Annual Hydropower consumption (Our World in data: https://ourworldindata.org/renewable-energy)

Hydromorphological Issues - Fragmentation and Water Stress

According to EEA (2018), the main significant pressure on surface water bodies is the hydromorphological one (40 %).



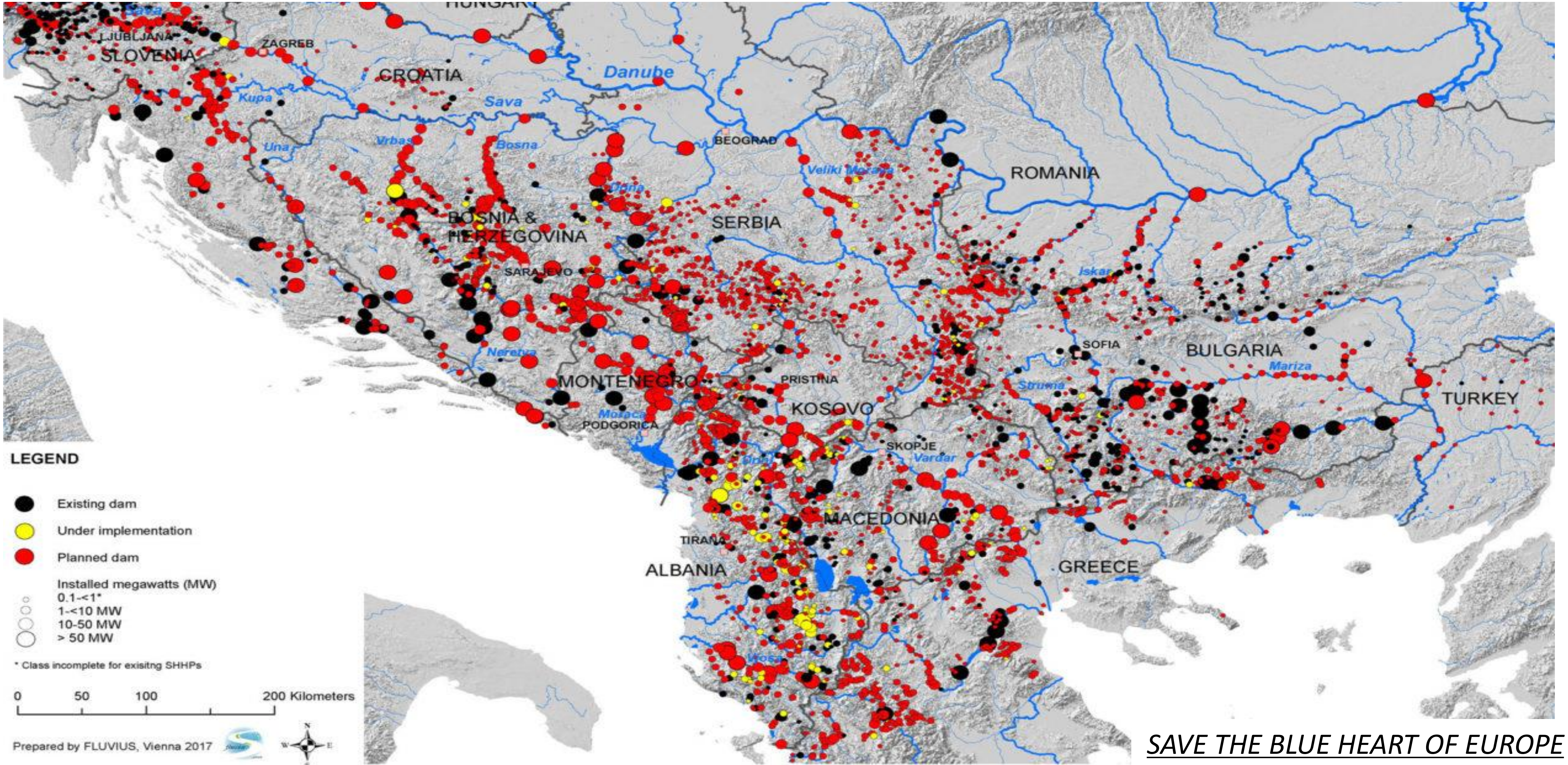
Tockner et al. (2009). Rivers of Europe



Data: Skoulikidis et al. (2009). Rivers of the Balkans

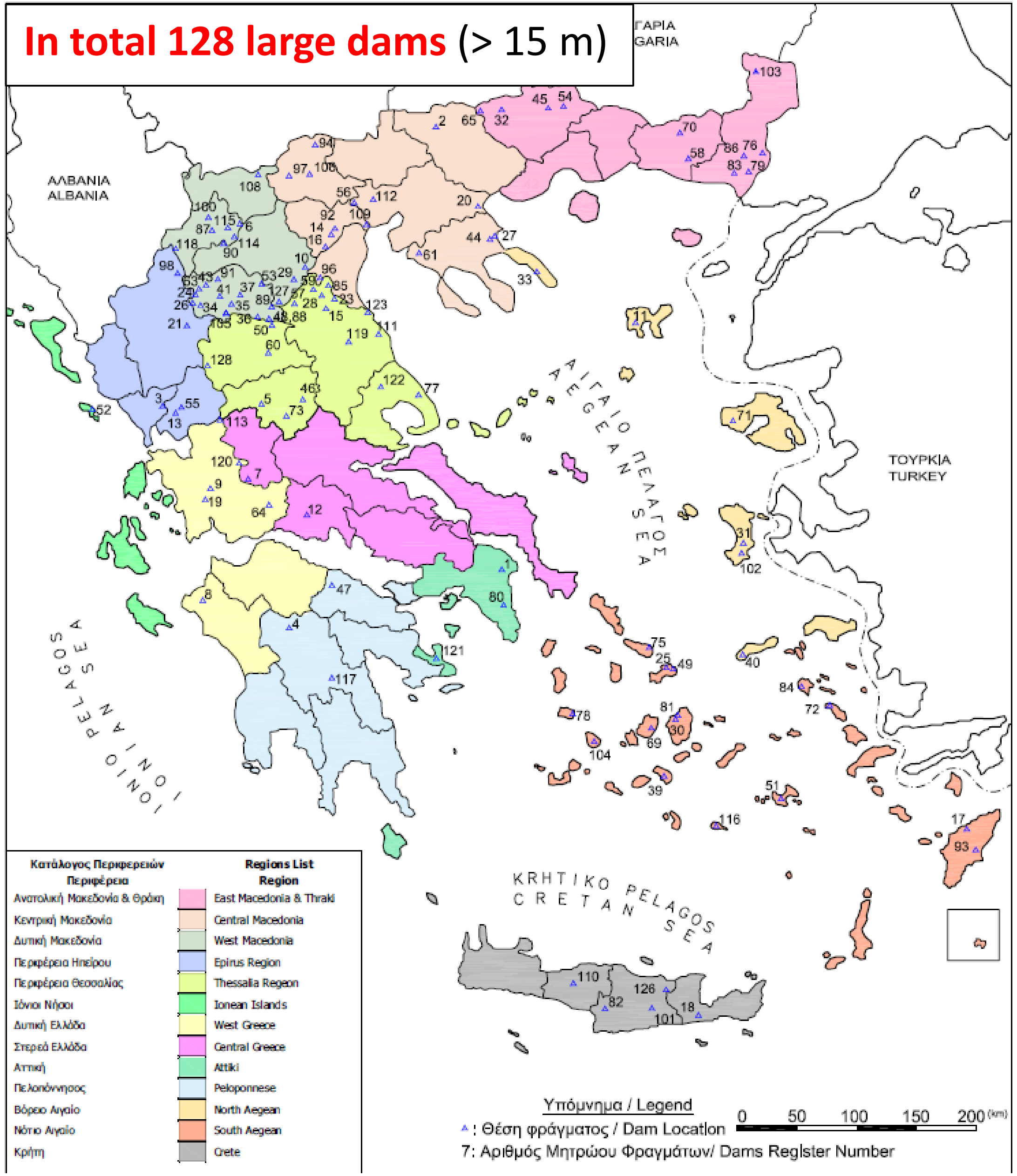
Hydromorphological Issues – River Fragmentation

Throughout the Balkan region, some 2,700 hydropower plants are currently under construction (yellow)



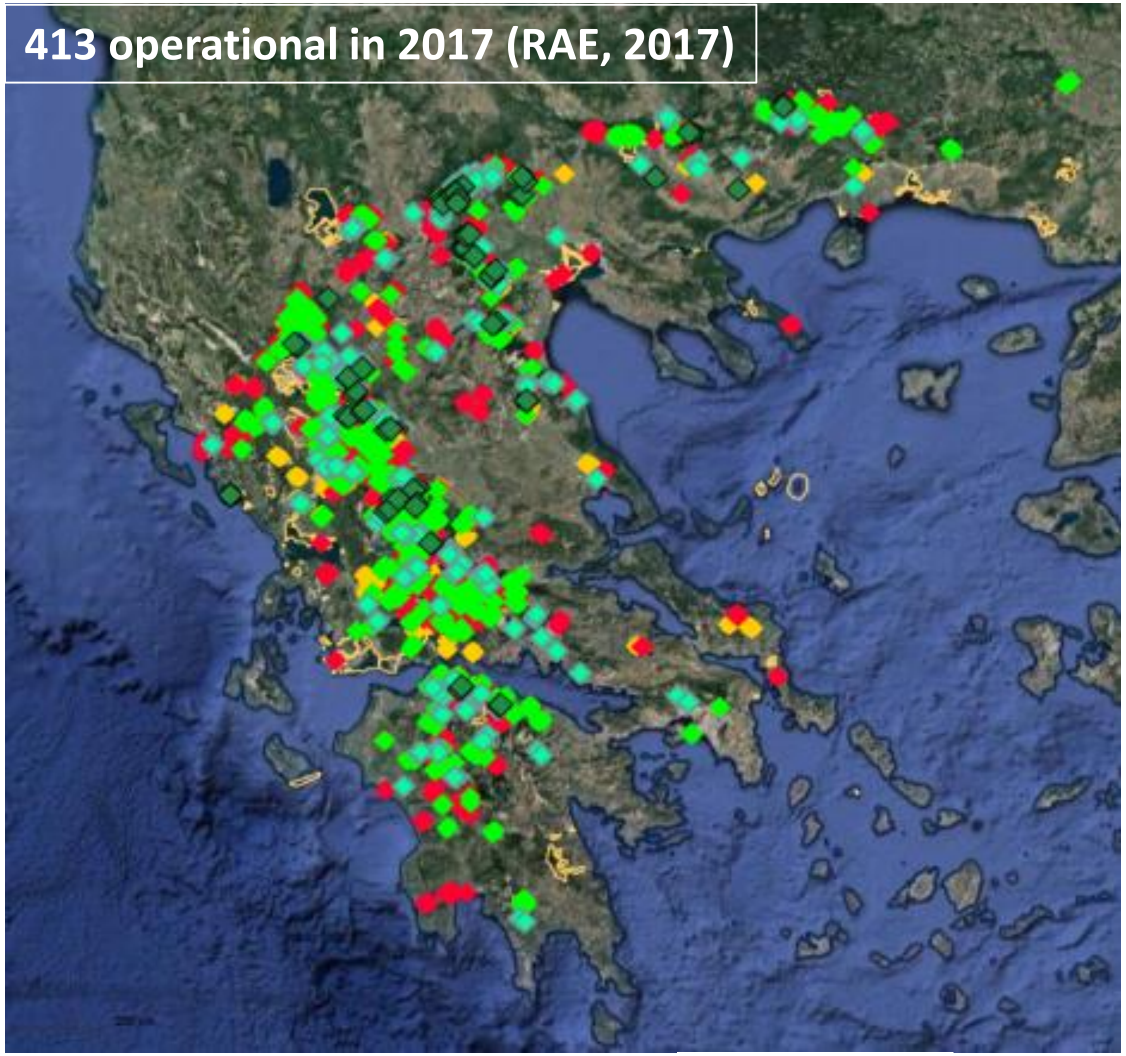
SAVE THE BLUE HEART OF EUROPE

Large Hydros (P.P.C.)



Greek Committee on Large Dams (2013)

Small Hydros (mainly private)



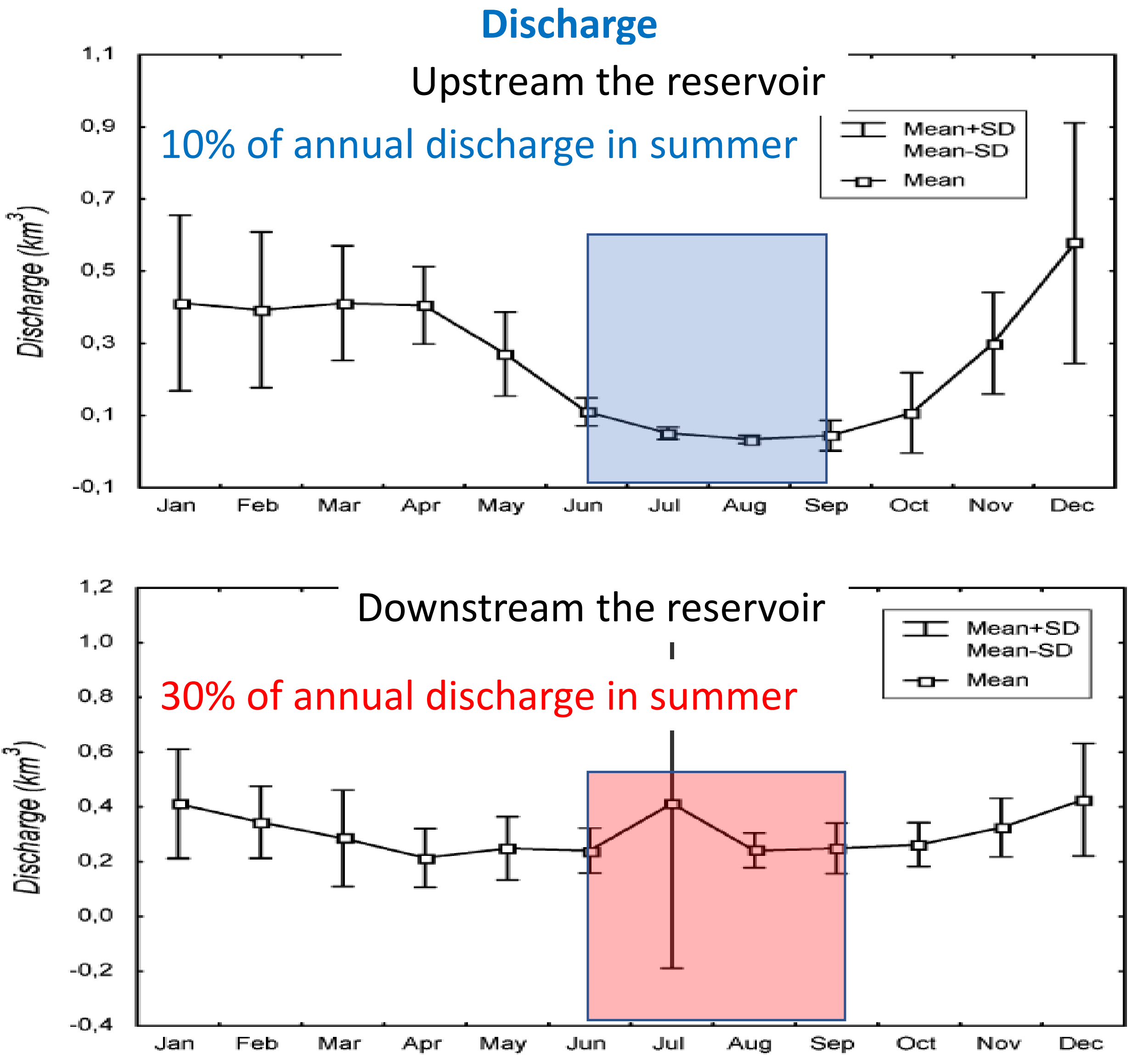
Installation License — Authorised

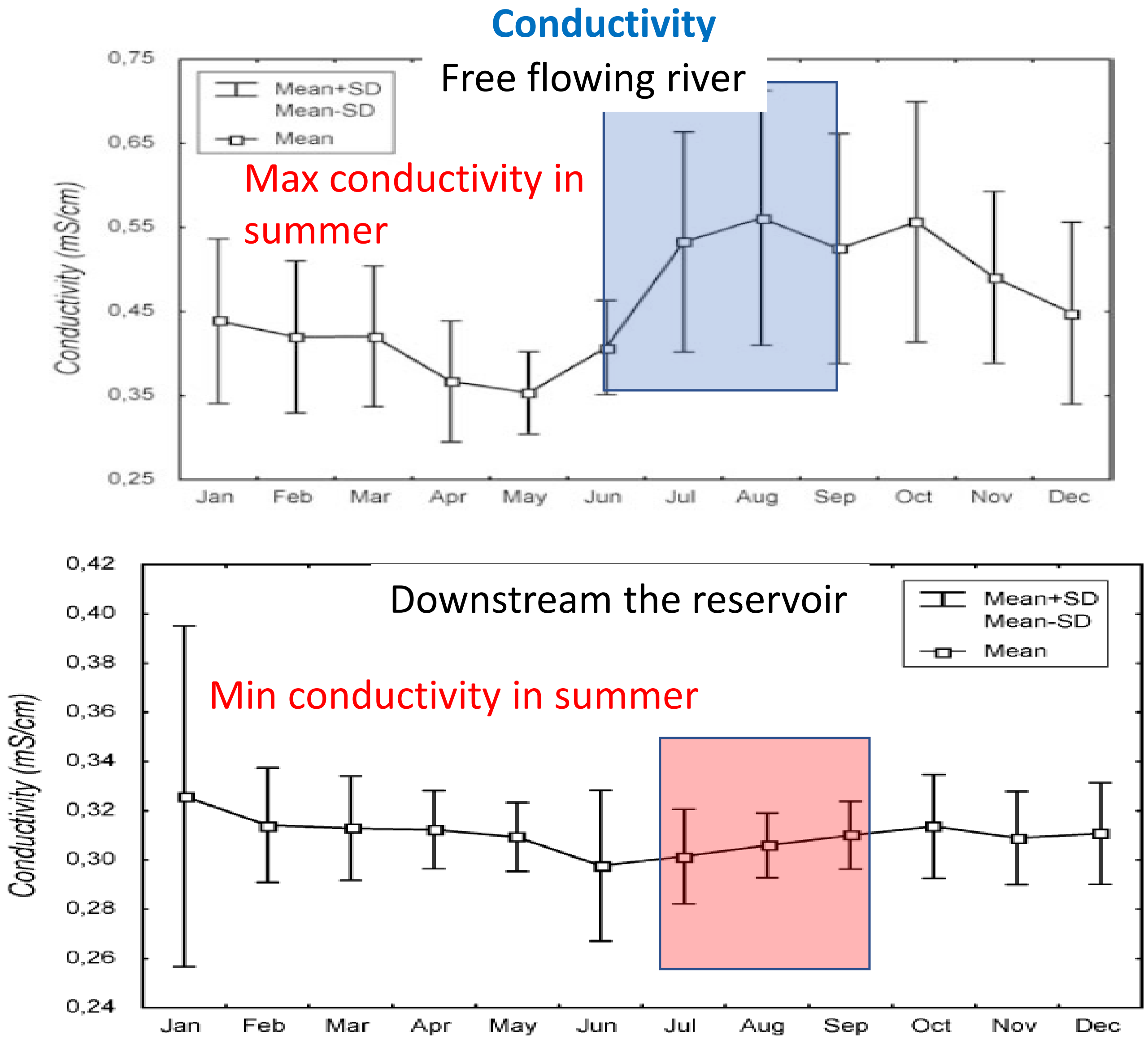
Production License — Rejection Decision

In Evaluation — Protected areas

Reservoir impacts

Dam operations smooth seasonal variations and result in a downstream **modification of the hydrological regime**. The Acheloos, Nestos and Aliakmon now present high to maximum discharge in July due to peak hydropower production.





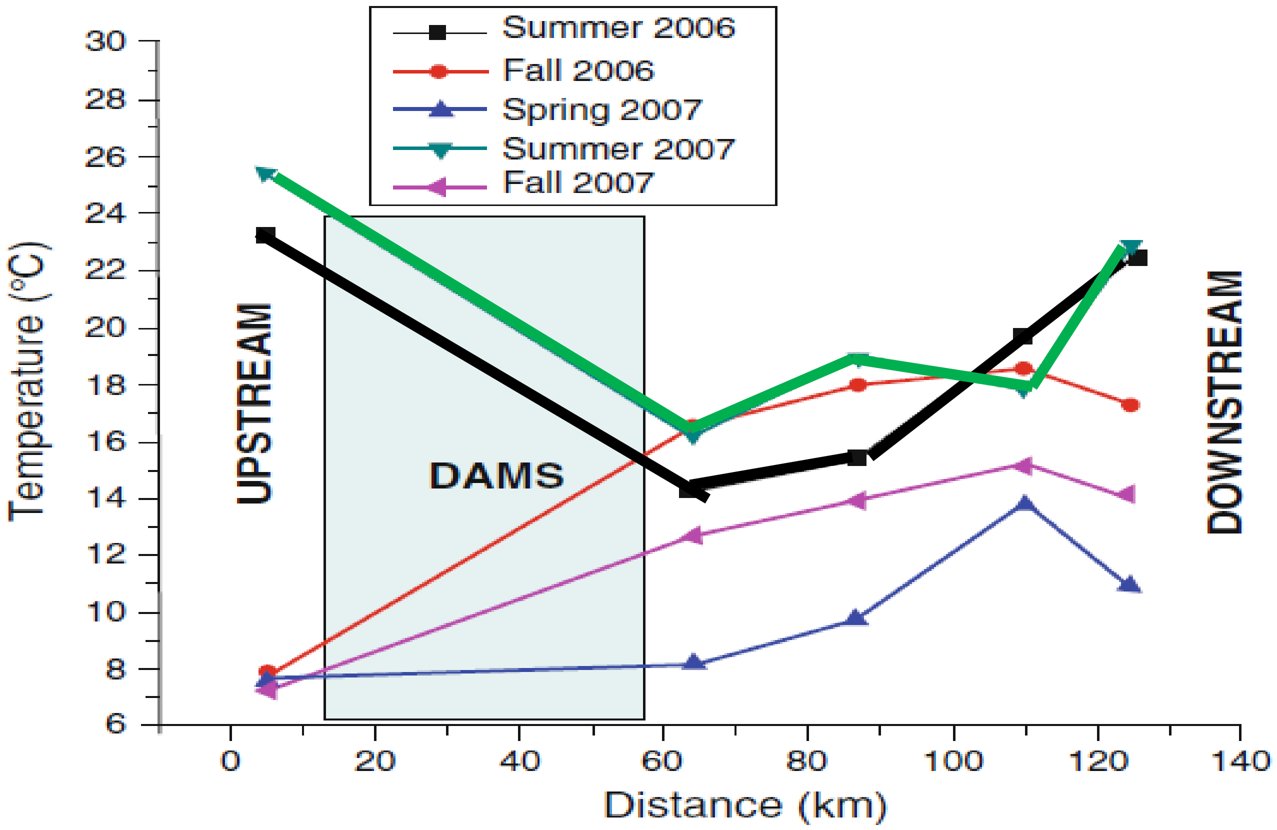
Monthly variation of discharge and conductivity upstream/downstream of reservoirs (Skoulikidis, 2002)

Reservoir impacts

Dramatic cooling of downstream waters in summer

Up to 11°C downstream Nestos R. reservoirs

Due to the release of cold hypoliminion waters



Water temperature change downstream of Nestos R. reservoirs (Sylaios & Kamidis, 2018)

Downstream change of N:P ratio due to P retention in the reservoirs
(Sylaios & Kamidis, 2018)

Upstream N/P: 4-5
N limited photosynthesis

Downstream N/P: 25-30
P limited photosynthesis

Heavy metal accumulation
in Nestos R. reservoirs due to transboundary pollution
(Sylaios & Kamidis, 2018)

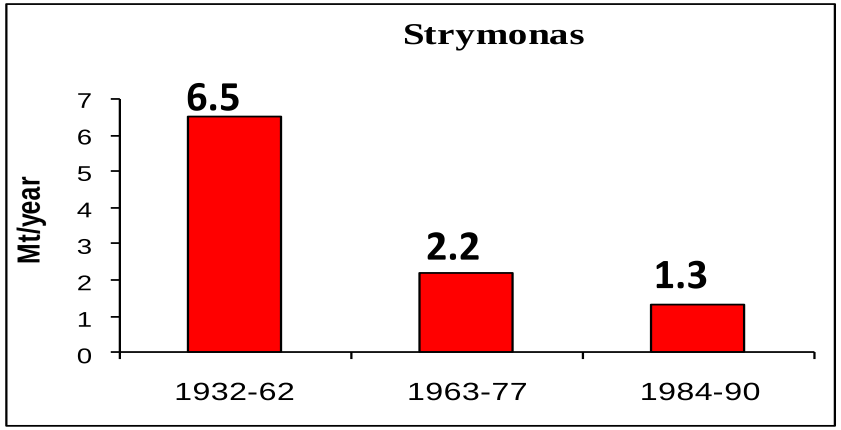
Reservoir impacts

Dramatic sediment retention and Hydro-peaking impacts

Long-term decrease in sediment loads entering the sea due to trapping of ≥ 80% river sediments behind dams, and long-term discharge diminishing.

Diminishing of sediment loads

In **Strymon** R. by 80% within 40 years (data from: Psilovikos et al., 1994; Criveli et al., 1995). The **Drin** R. experienced a 13-fold sediment reduction compared to pre-industrial rates (REAP, 2006).



Decline in Delta evolution and land mass losses (which will further increase due to global sea level rise)

In **Evros** R. (with no dams along its main course) the Delta evolution declined by 50% within 55 years (Kanelopoulos et al., 2006).

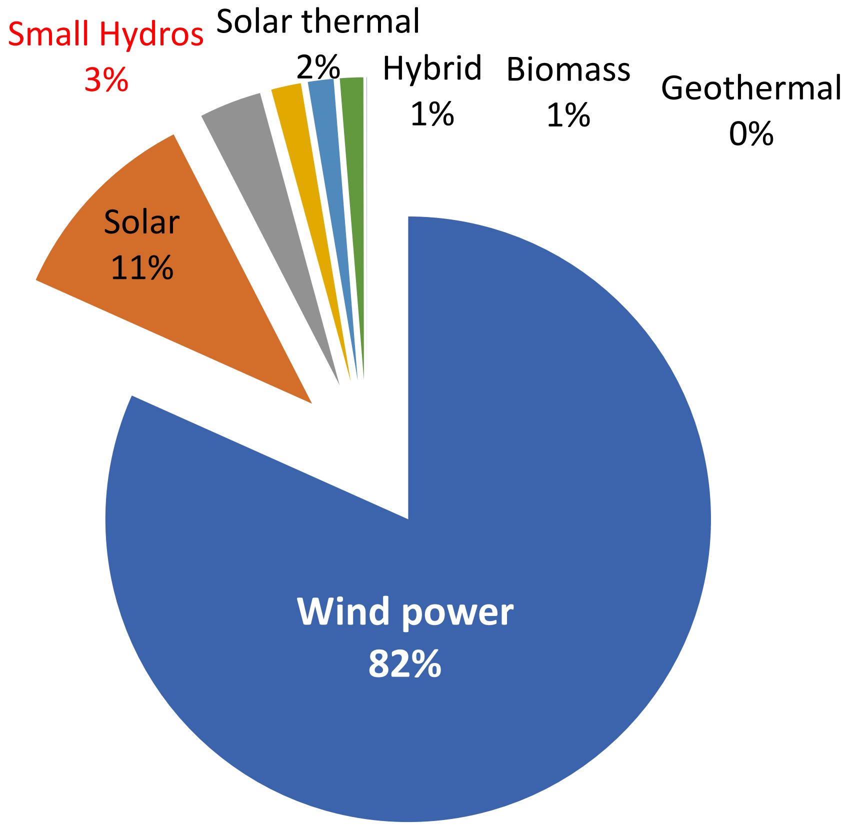
The **Nestos** R. Delta diminished by 0.22 km^2 (Tsihrintzis et al., 2008) and Acheloos R. Delta (Bouzos et al., 1994).

Hydropeaking

Besides the adverse effects of **hydropeaking** on river habitats, fauna and flora, it may also cause severe floods. In the **Evros** basin for example, hydropeaking causes, besides water quality and biodiversity issues, catastrophic floods (Dimitriou et al. 2012)

Not only Dams but also Wind Power Plants threaten our Mountains

Share of renewable energy technologies in energy production in Greece for 2017



Greek Regulatory Authority for Energy (RAE) (2017)

Case Study: Samothraki Island – Northern Aegean Sea

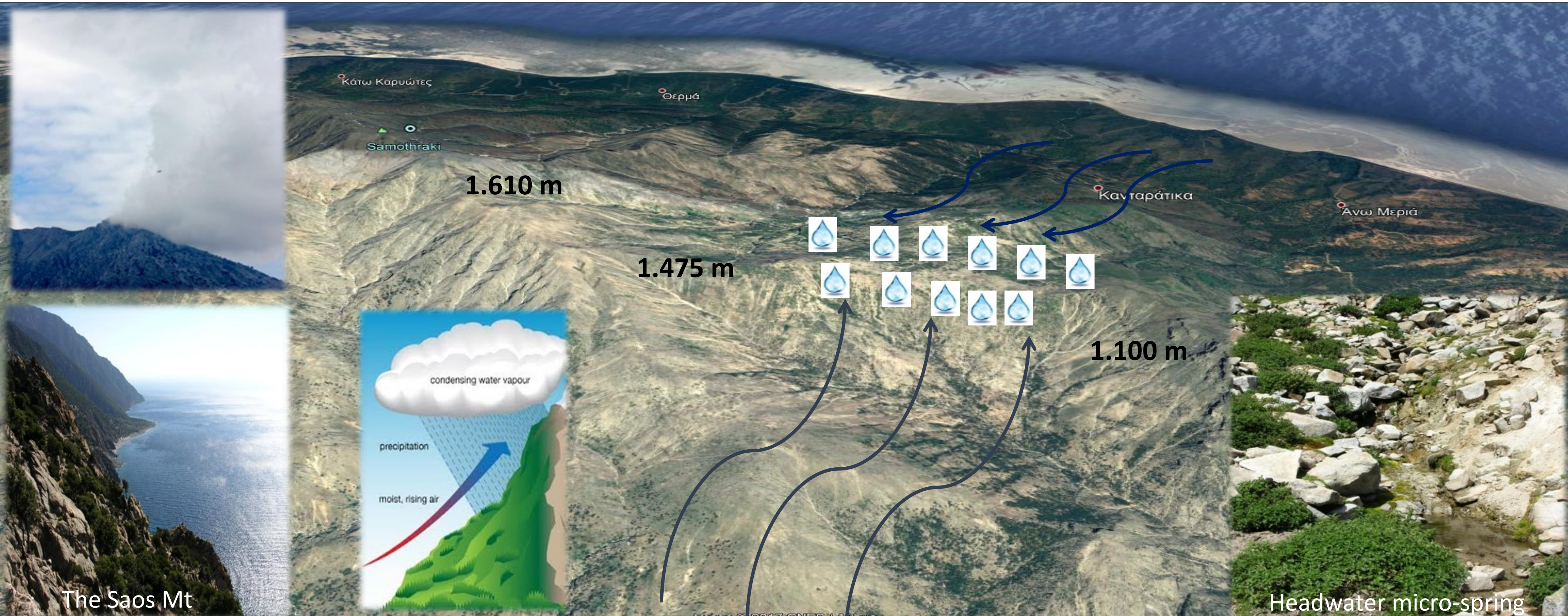
Samothraki Island

NATURA area – MAB/UNESCO candidate

RAE initially approved the siting of two hybrid industrial wind power plants (WPPs) with 39 windmills (77 m height each, total capacity 110.5 MW) on the top of the island's mountain ranges.

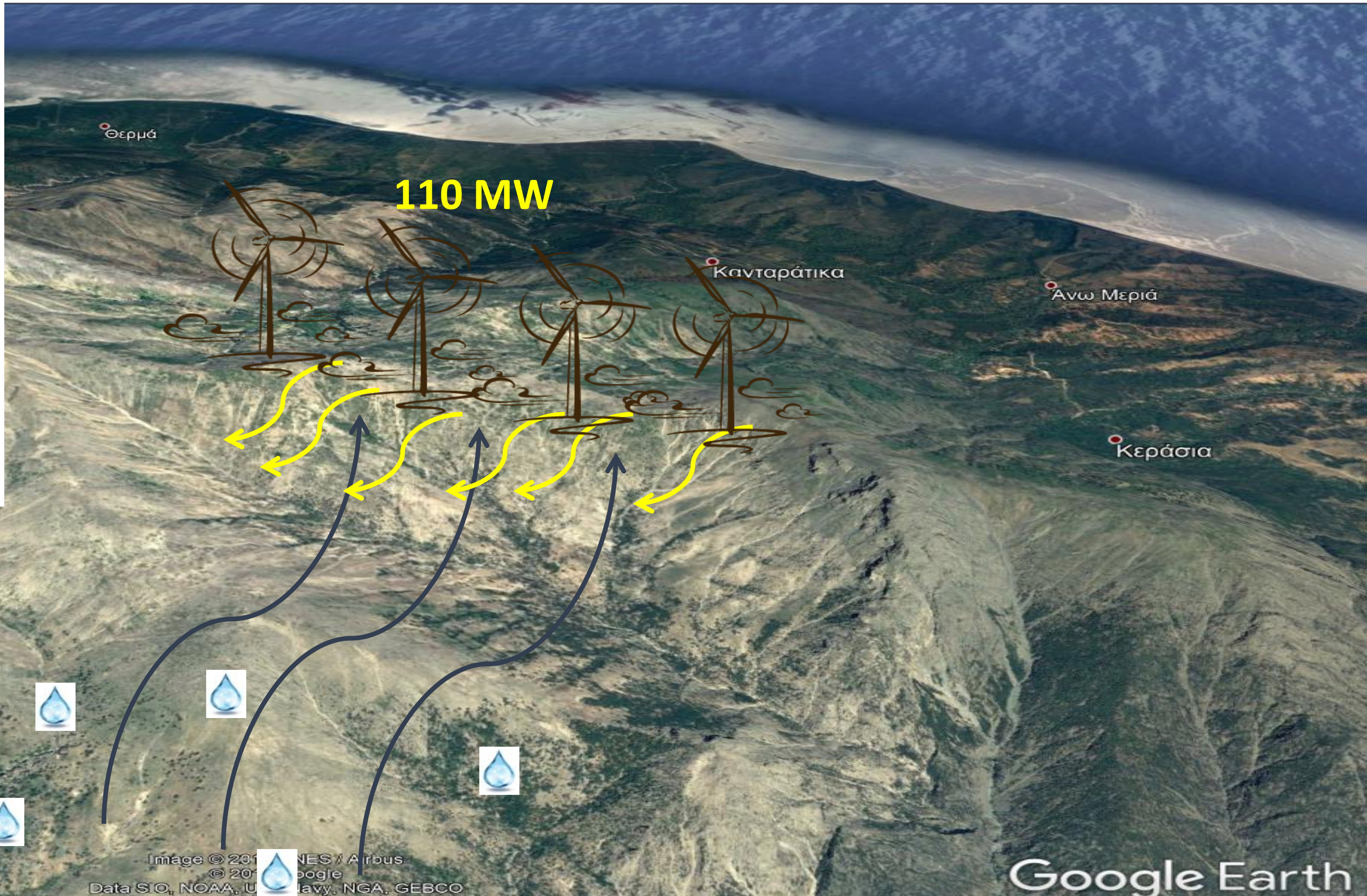
Impacts of Wind Power Plants placed on Mountain Peaks

Vapor condensation (VC) is an important mechanism for water formation in mountain areas. Particularly in Samothraki, VC formed on Saos Mt. contributes to the presence of numerous mountainous perennial *micro-springs* with restricted aquifers, that feed perennial streams and supply the exceptionally (compared to the other Greek islands) high surface runoff of the island.



Impacts of Wind Power Plants placed on Mountain Peaks

As numerous literature sources indicate, WPPs affect microclimate in their wider area of installation and cause intense mixing of air masses by altering the temperature and humidity near the surface of the soil, resulting in heating and drying of the near ground air masses. This may cause the interruption of VC process and the evaporation of water from the small aquifers, thus **reducing flow or even causing the desiccating of headwater springs and streams**.



Outlook: Renewable Energy and EC prescriptions

The recent rapid development and installation of renewable energy technologies, in the name of climate change mitigation, seriously threatens mountain ranges and headwater streams

According to Article 6 of the Habitats Directive, in exceptional circumstances, **a derogation may be invoked to approve a project having an adverse effect on the integrity of a Natura 2000 site if it can be demonstrated that there is an absence of less damaging alternatives** (!) and the project is considered to be necessary for **imperative reasons of overriding public interest**. In such cases, adequate compensation measures will need to be secured to ensure that the overall coherence of the Natura 2000 network is protected.

The competent authority can only agree to the project if, based on the findings of an appropriate assessment, it has ascertained that it **will not have an adverse effect on the integrity of the site**. But what means a "***significant negative effect***"?

To avoid the high level of subjectivity in the assessment of significance of effects, there is a need for a European Guidance to provide scientifically sound rules, methods and conventions for all valuable and endangered habitat types and species that occur in Europe.


Thank you !