

University of Stuttgart

Institute for Modelling Hydraulic and Environmental Systems



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Changes in Sediment Yield and Reservoir Sedimentation due to Global Change

The importance of snow

**Silke Wieprecht
Kilian Mouris**



Motivation Reservoirs

 Water supply

 Irrigation

 Recreation

 Flood control

 Hydroelectricity

Navigation

Fishery



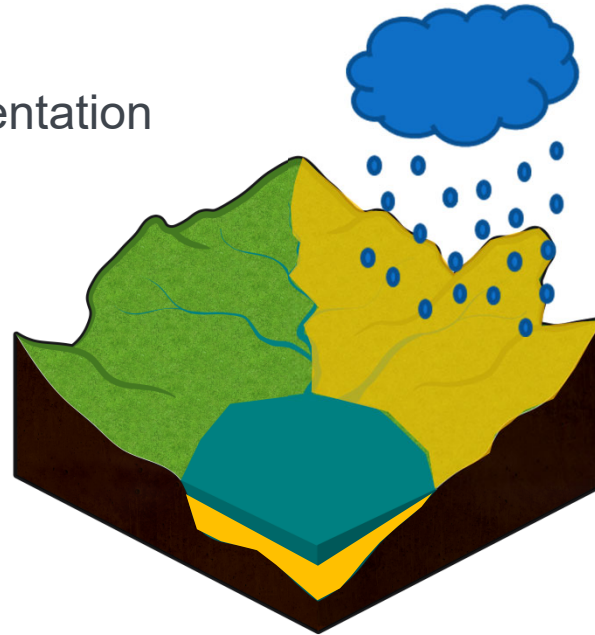
Reservoirs are large multipurpose structures



All these services are threatened by reservoir sedimentation

Motivation

Reservoir Sedimentation



Reservoir sedimentation depends on

- i. sediment yield (catchment)
- ii. reservoir characteristics

1 % of global storage volume is lost every year

→ loss not compensated by construction of new reservoirs

→ removal and remobilization of deposited sediments is expensive (every year: US\$13 -19 billion)

→ **reservoirs are not sustainable without sediment management**

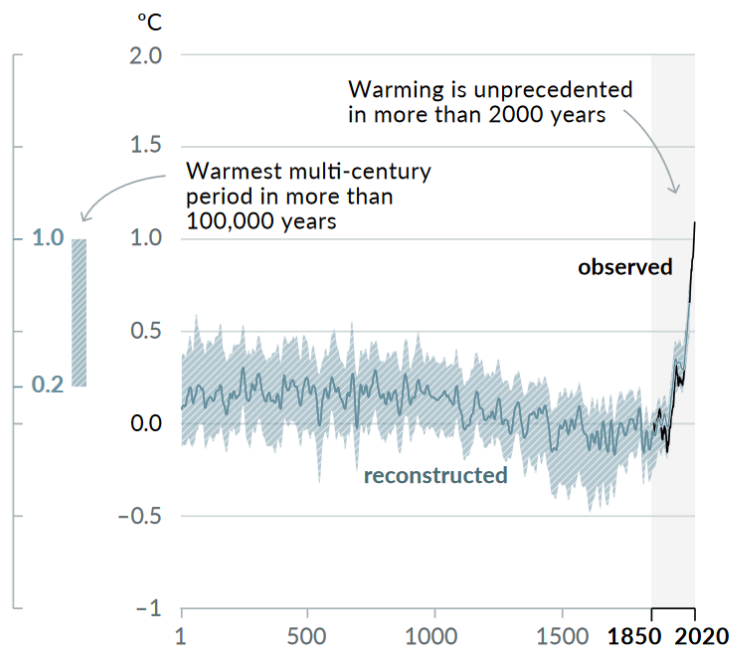
Sources: Basson (2009), Schleiss et al. (2016), Palmieri (2001)

Climate Change

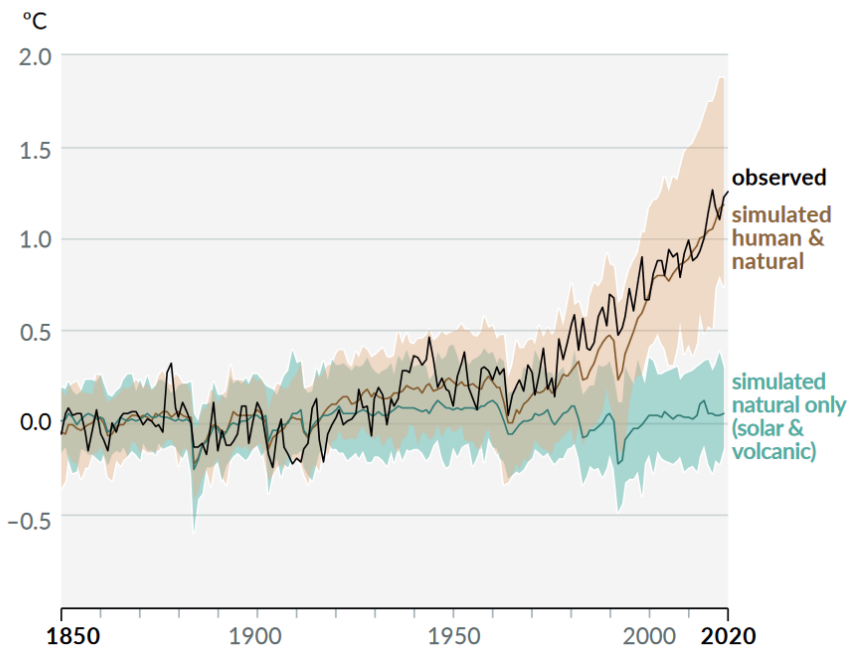
Global warming



(a) Change in global surface temperature (decadal average) as **reconstructed** (1–2000) and **observed** (1850–2020)



(b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850–2020)



Climate Change Consequences



Increased temperature

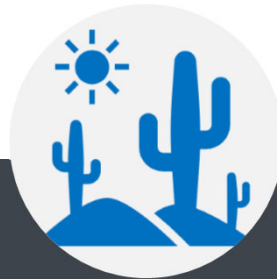


Increased evapotranspiration



Precipitation

Precipitation totals
and intensities change



Droughts

Increasing risk of
droughts



Snow and Ice

Retreat of glaciers,
snow cover and
permafrost
degradation



Floods

Increasing risk of flood
events and flash
floods



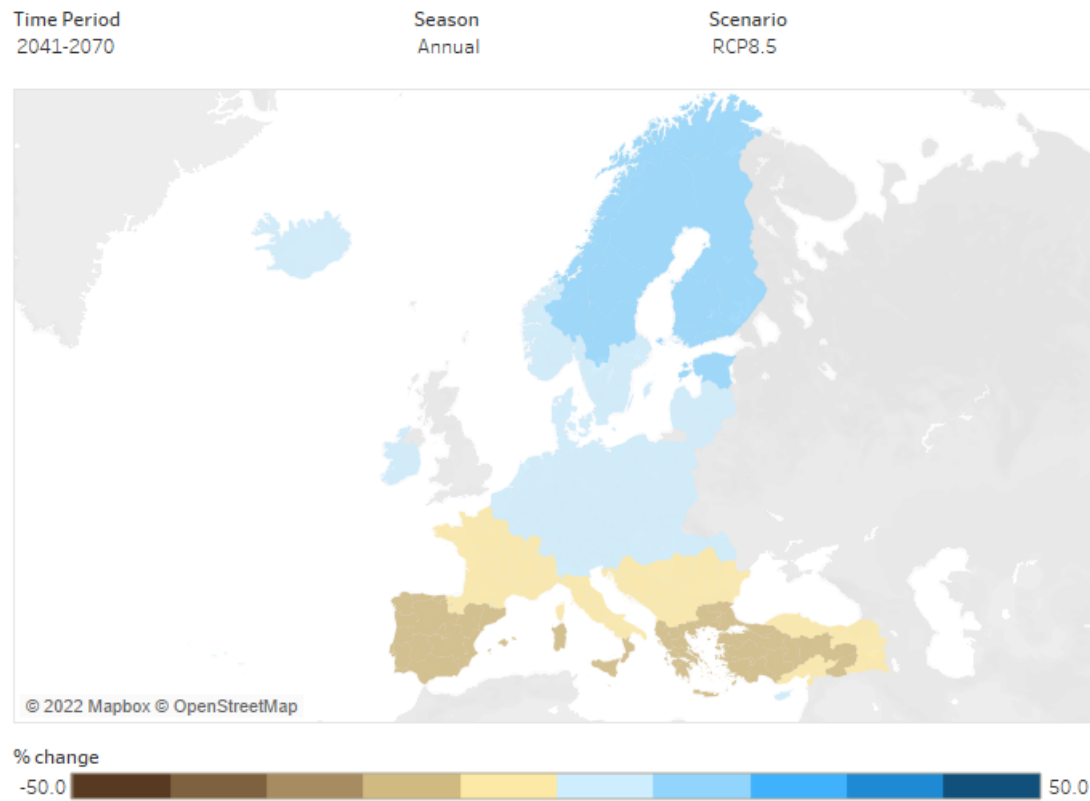
Large regional differences

Climate Change

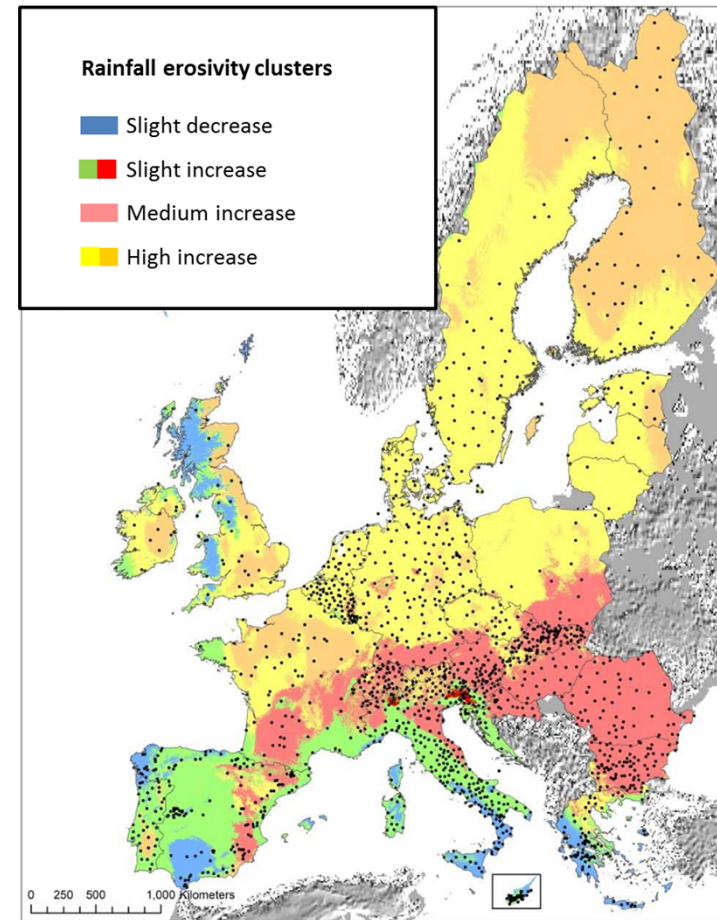
Regional differences – Precipitation & Rainfall erosivity



Projected change in precipitation sum



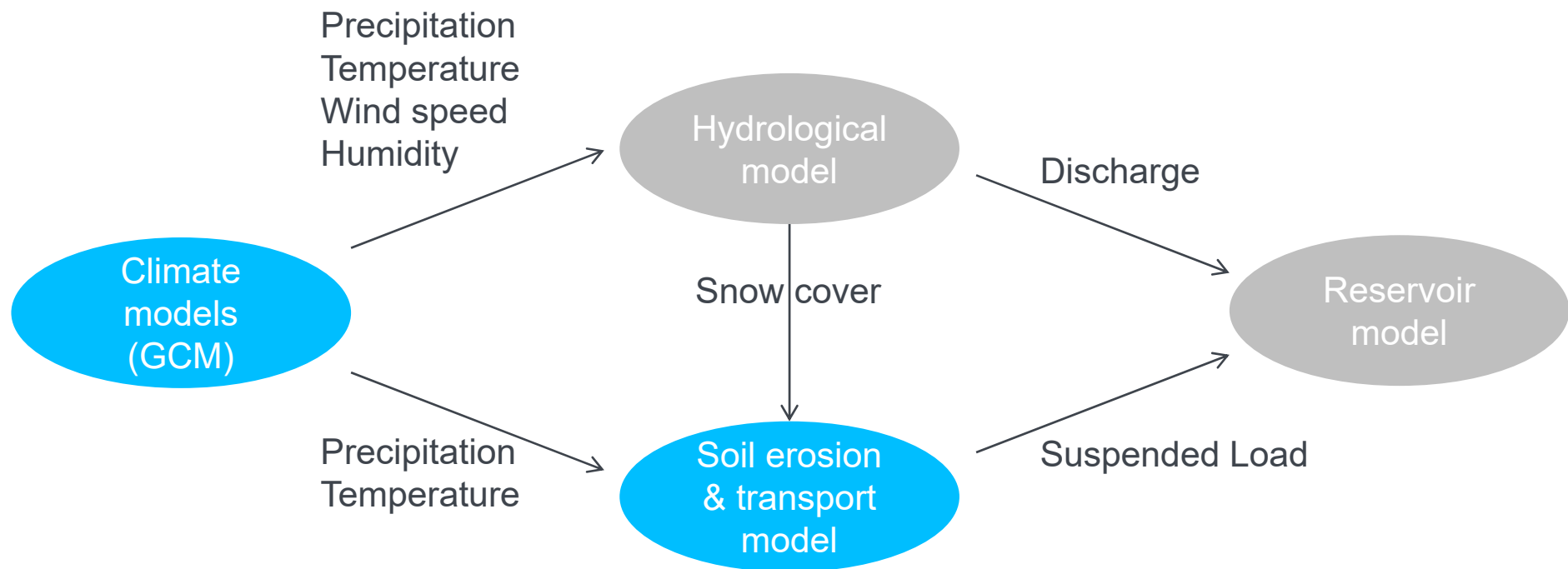
(EEA, 2022)



(Panagos et al., 2021)

Model chain

Overview

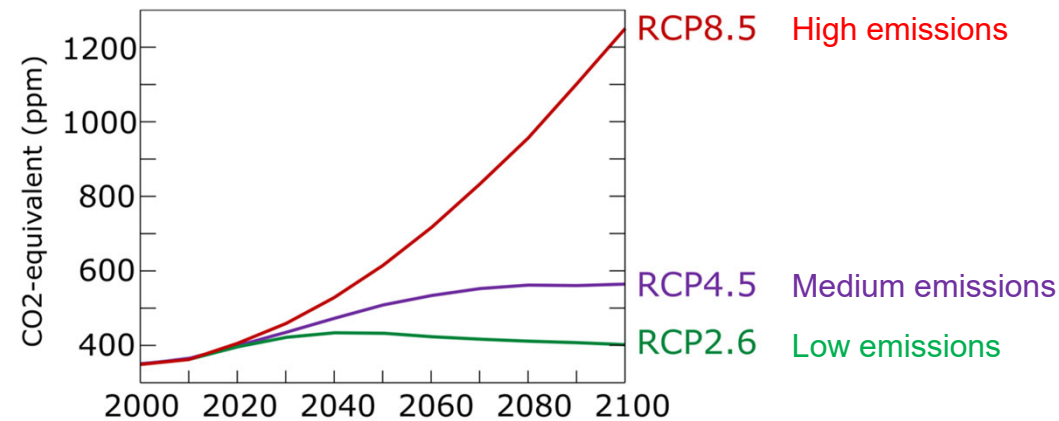


Model chain

Climate Models



- Three different general circulation model (GCM) were applied
 - EC-Earth Global Climate Projections (EC-Earth)
 - Max-Planck-Institute Earth System Model (MPI-ESM)
 - Hadley Centre Global Environment Model v2 (HadGEM2)
- Analysis of three Representative Concentration Pathways (RCPs):
Reference period: 1981-2010



Model chain

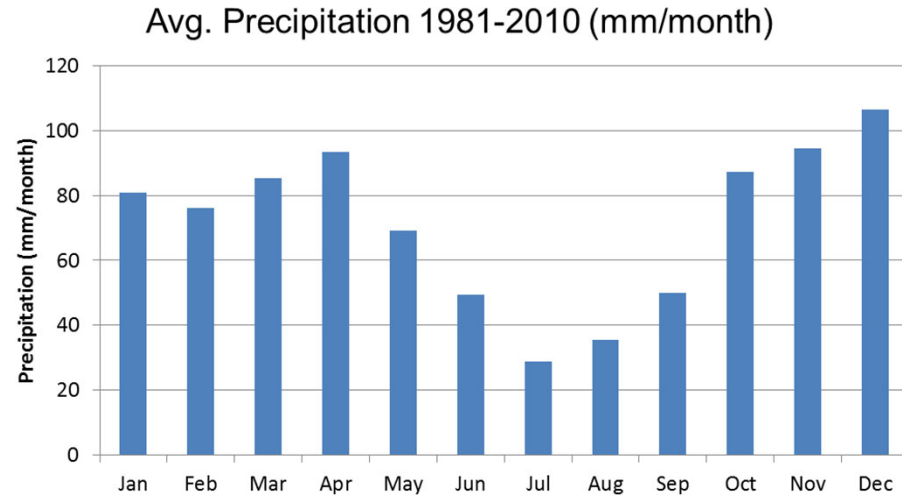
Soil Erosion and transport modeling

- Revised Universal Soil Loss Equation - RUSLE (Renard et al., 1997)
- Sediment Delivery Distributed model – SEDD (Ferro and Porto, 2000)
- Input data for precipitation and temperature:
 - Climate reanalysis for calibration
 - Climate models for predictions
- Calibration **uses** monthly suspended sediment loads
 - 10 months with continuous data (WL > 1 m)

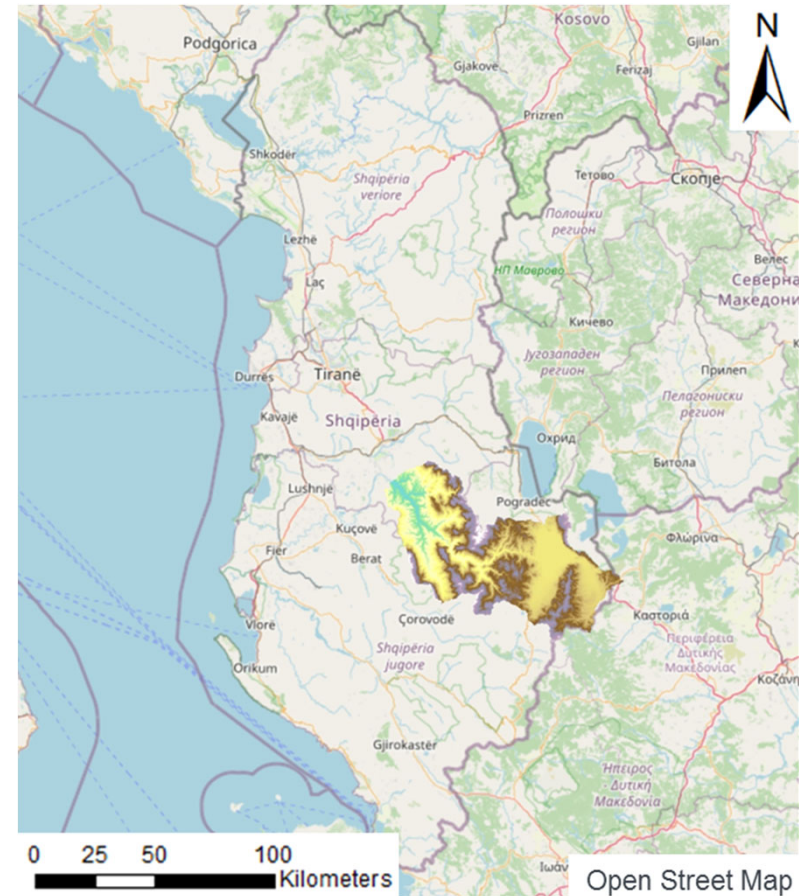
Study area

Location

- Southeast Albania
- Mediterranean Climate
- Dry summers and wet winters
- Frequent snowfall in high elevations

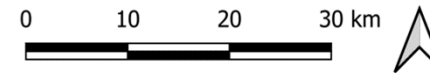


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Study area

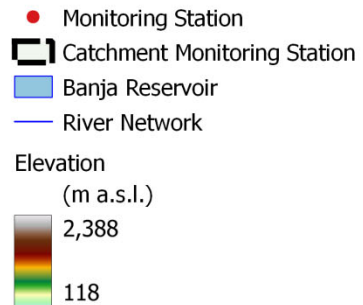
Topography & River Network



Statkraft



Aleixo et al.



EU-DEM V1.1

Study area

Sedimentation at the head of the reservoir



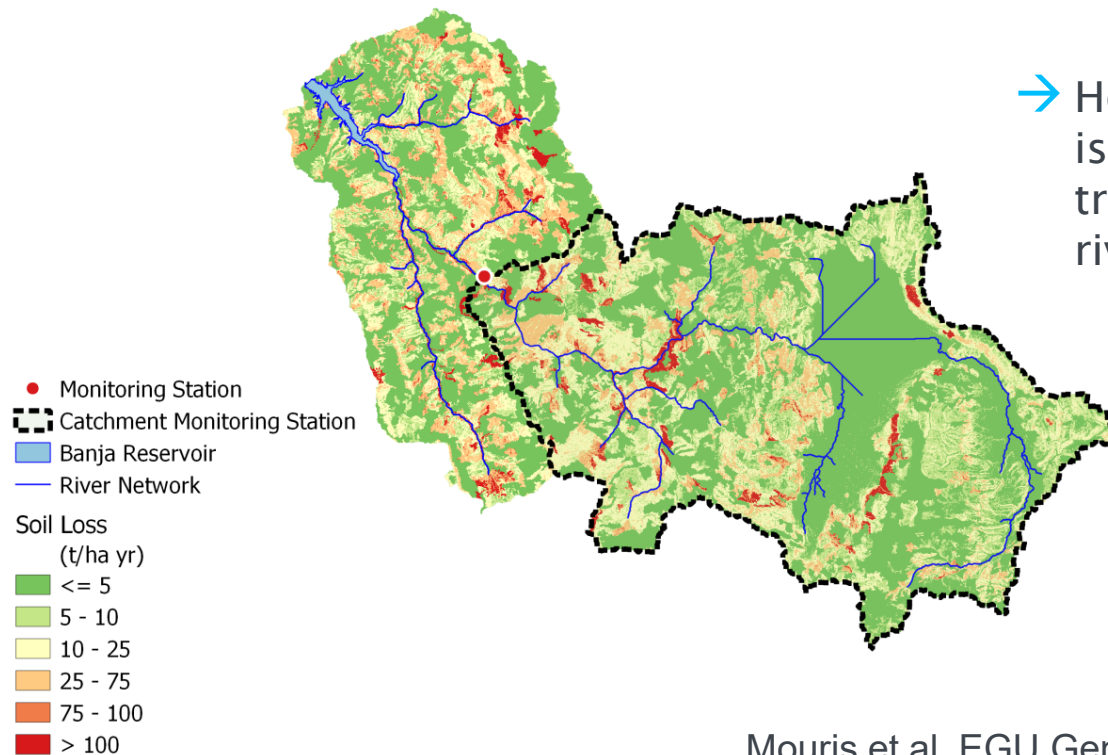
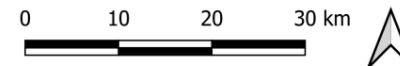
Study area

Sedimentation at the head of the reservoir



Soil Erosion and transport modeling

Soil Loss (05/2016 – 04/2018)

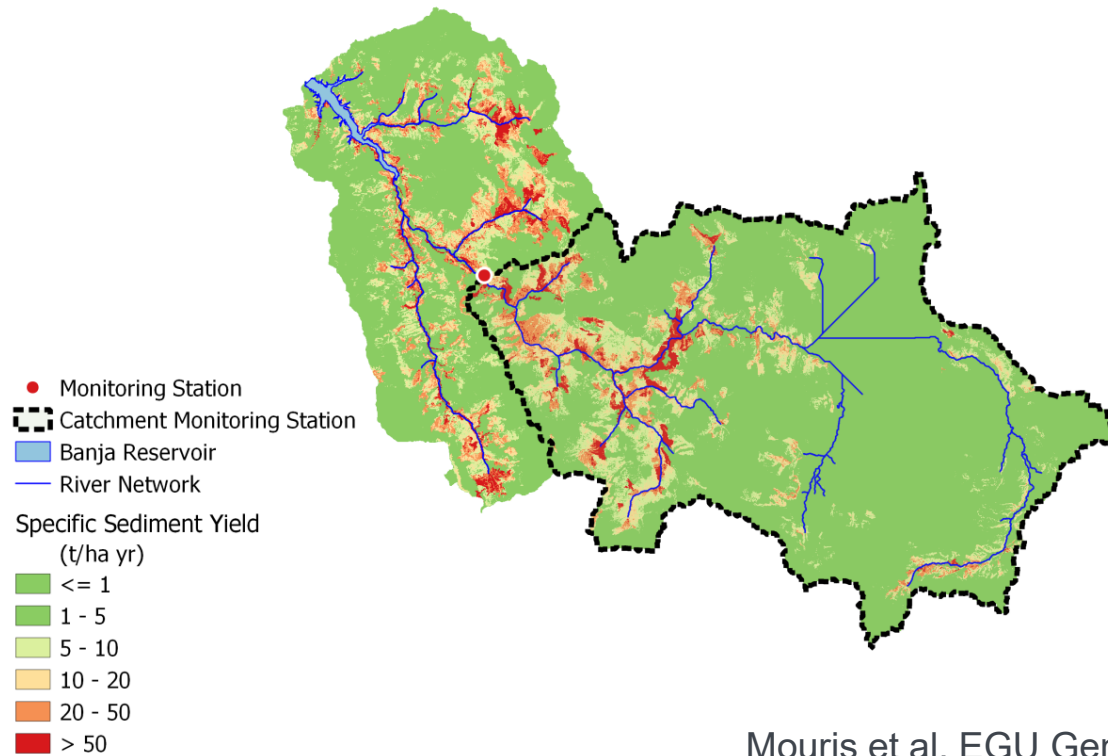
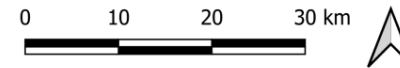


→ How much sediment is actually transported to the river network?

Mouris et al. EGU General Assembly 2021

Soil Erosion and transport modeling

Sediment Yield (05/2016 – 04/2018)



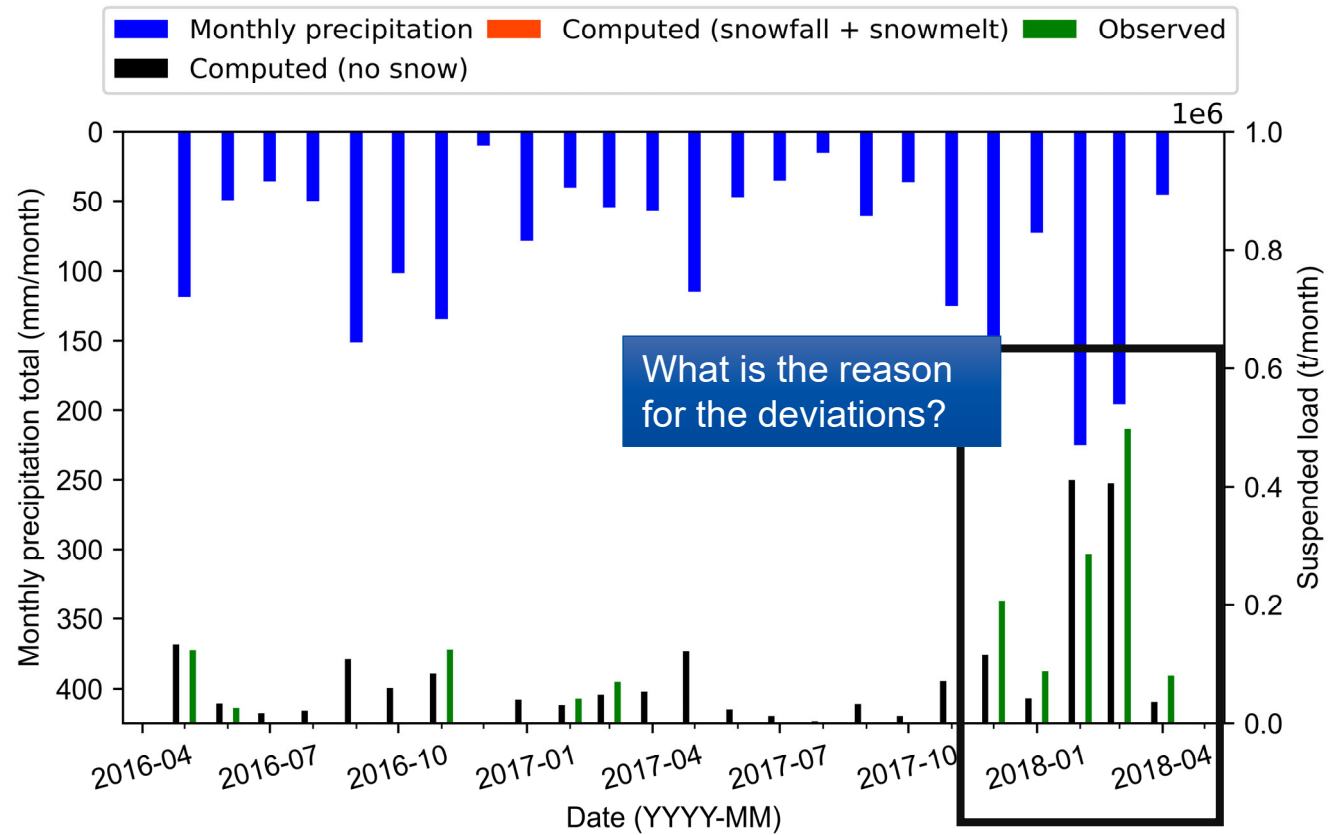
Mouris et al. EGU General Assembly 2021

Soil Erosion and transport modeling

Computed and observed sediment loads



NSE = 0.79
r = 0.91



Soil Erosion and transport modeling

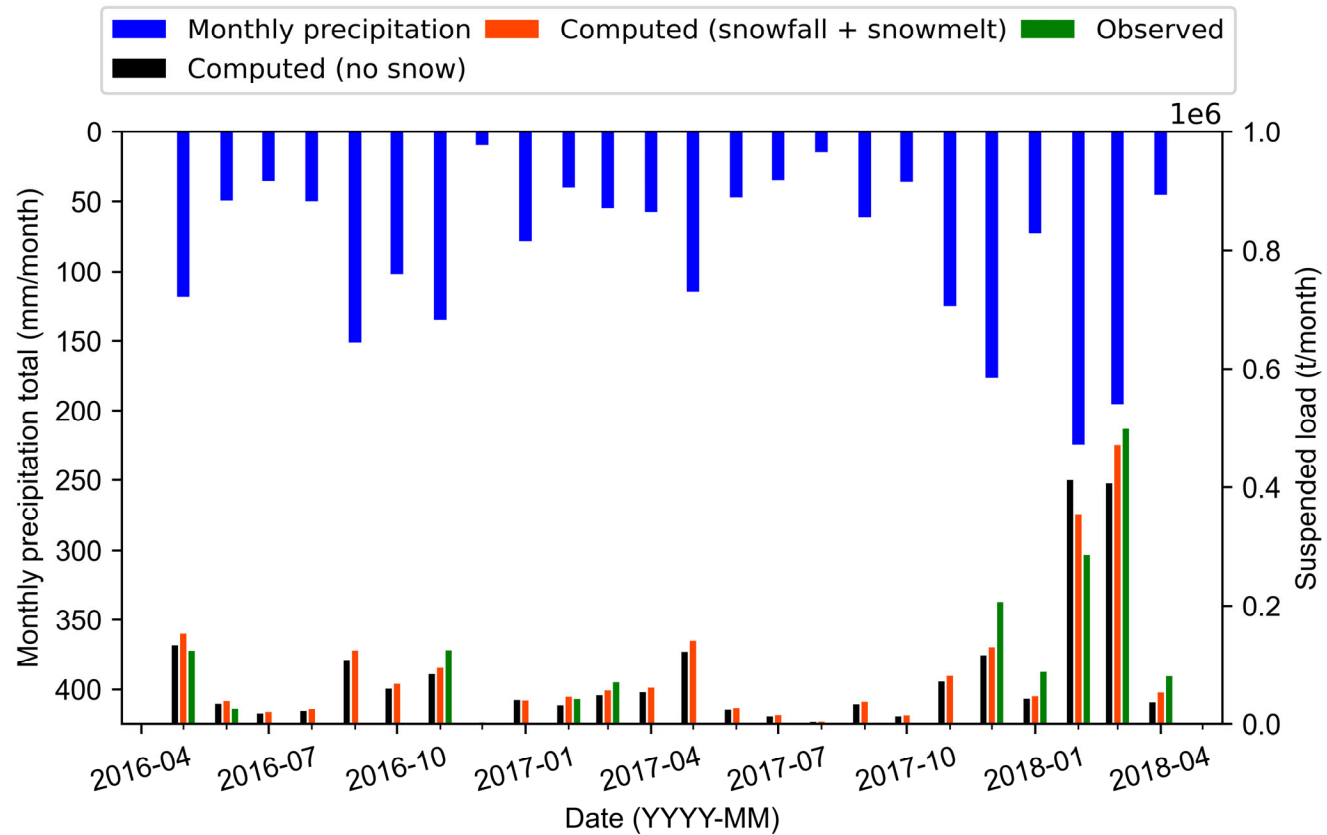
Computed and observed sediment loads



NSE = 0.79
r = 0.91



NSE = 0.92
r = 0.96



Soil Erosion and transport modeling

Consideration of snow & snowmelt

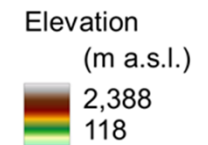
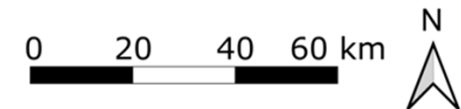
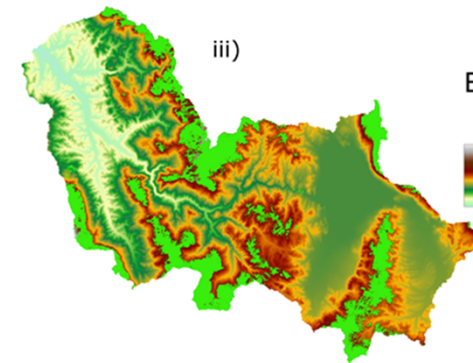
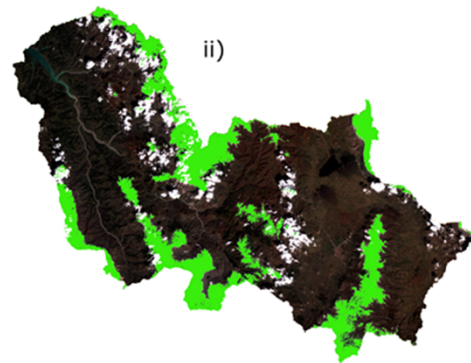
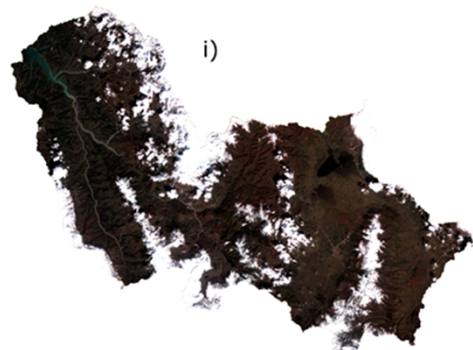


- Modification of RUSLE to consider snowfall and snowmelt

→ Distinguish between non-erosive snowfall and erosive rainfall

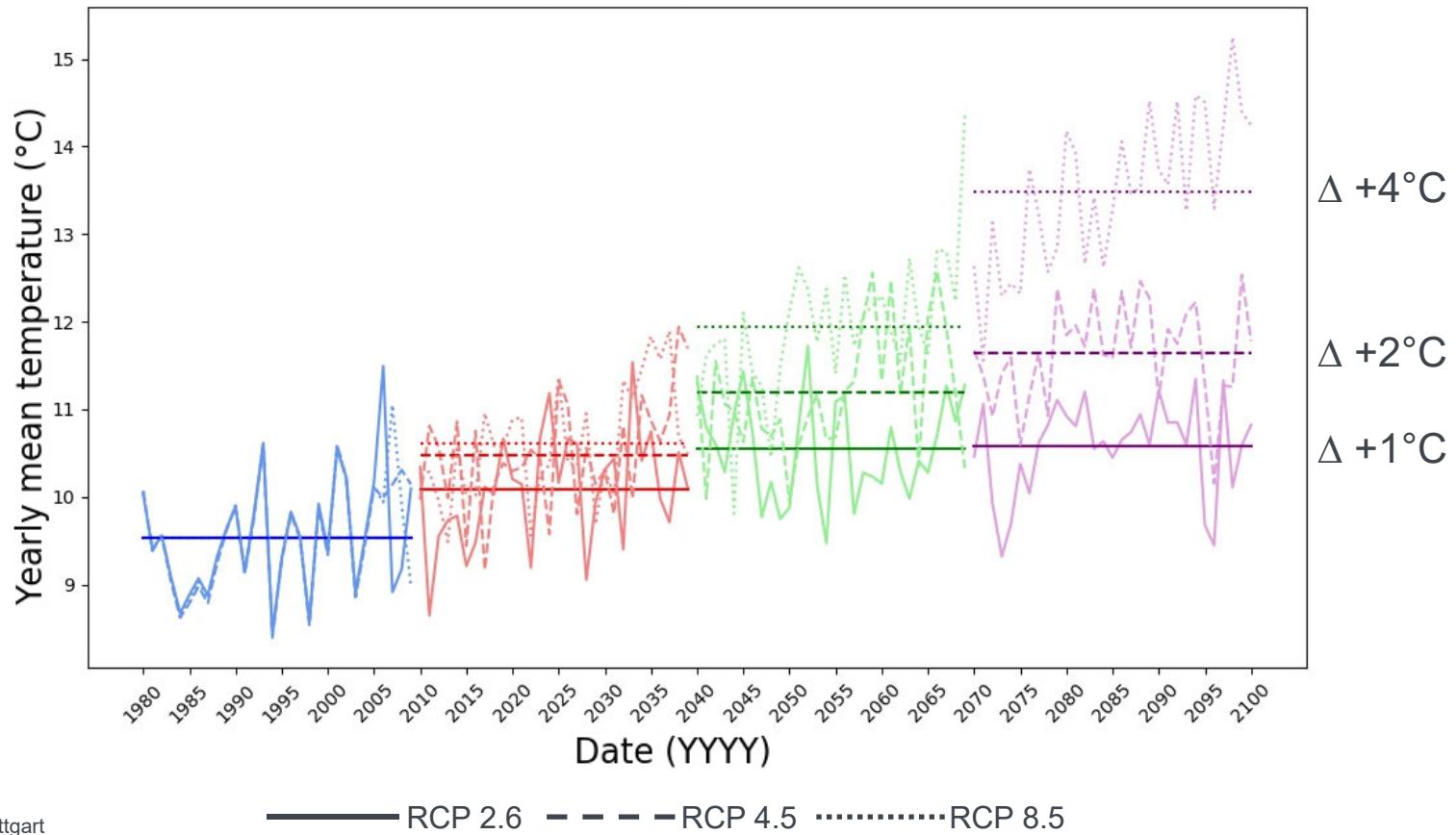
→ Snow becomes erosive **when** it melts

→ Snow cover detection accounts for snowmelt from satellite imagery



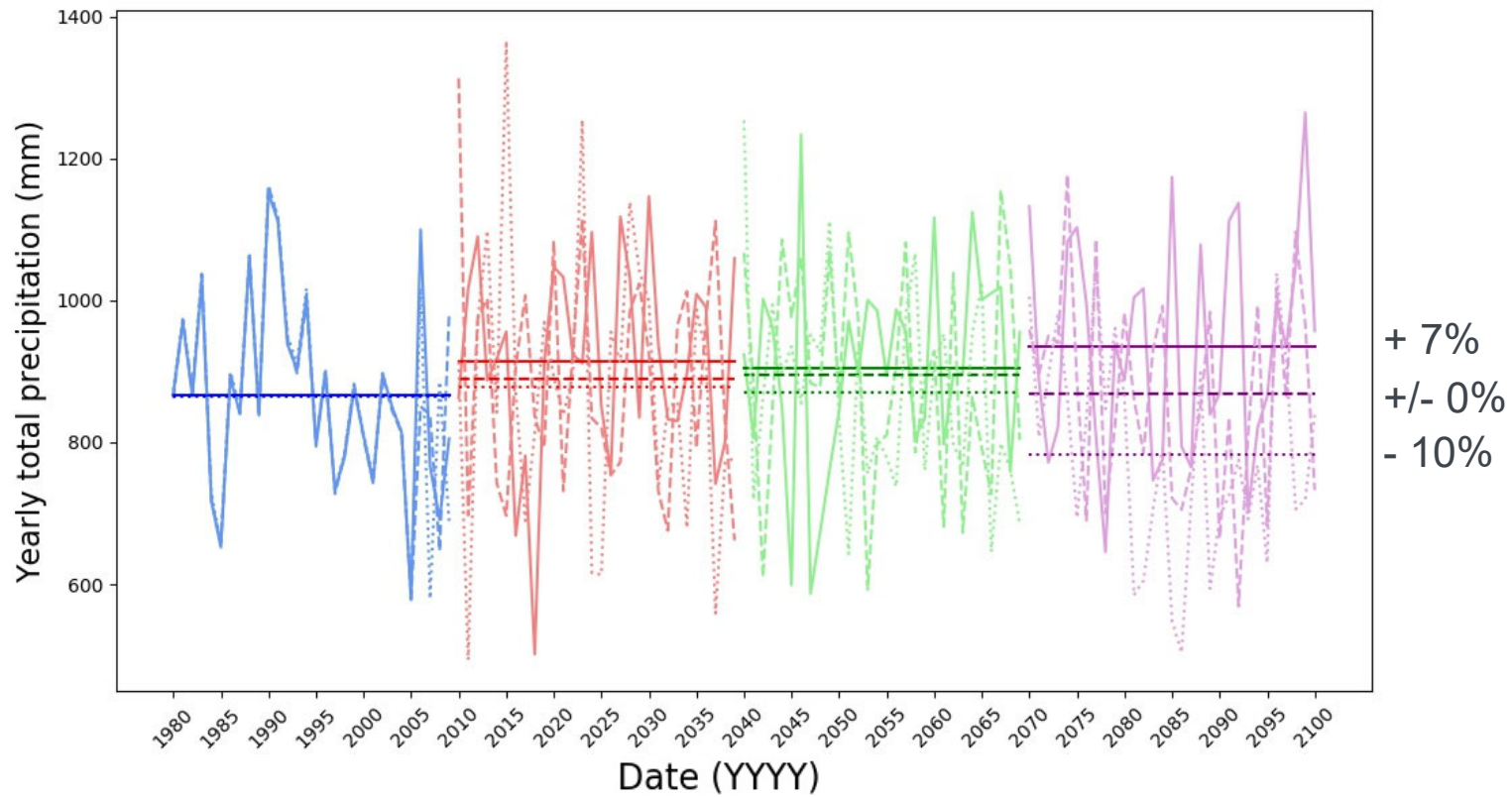
Climate projections for southeast Albania

Temperature EC-Earth



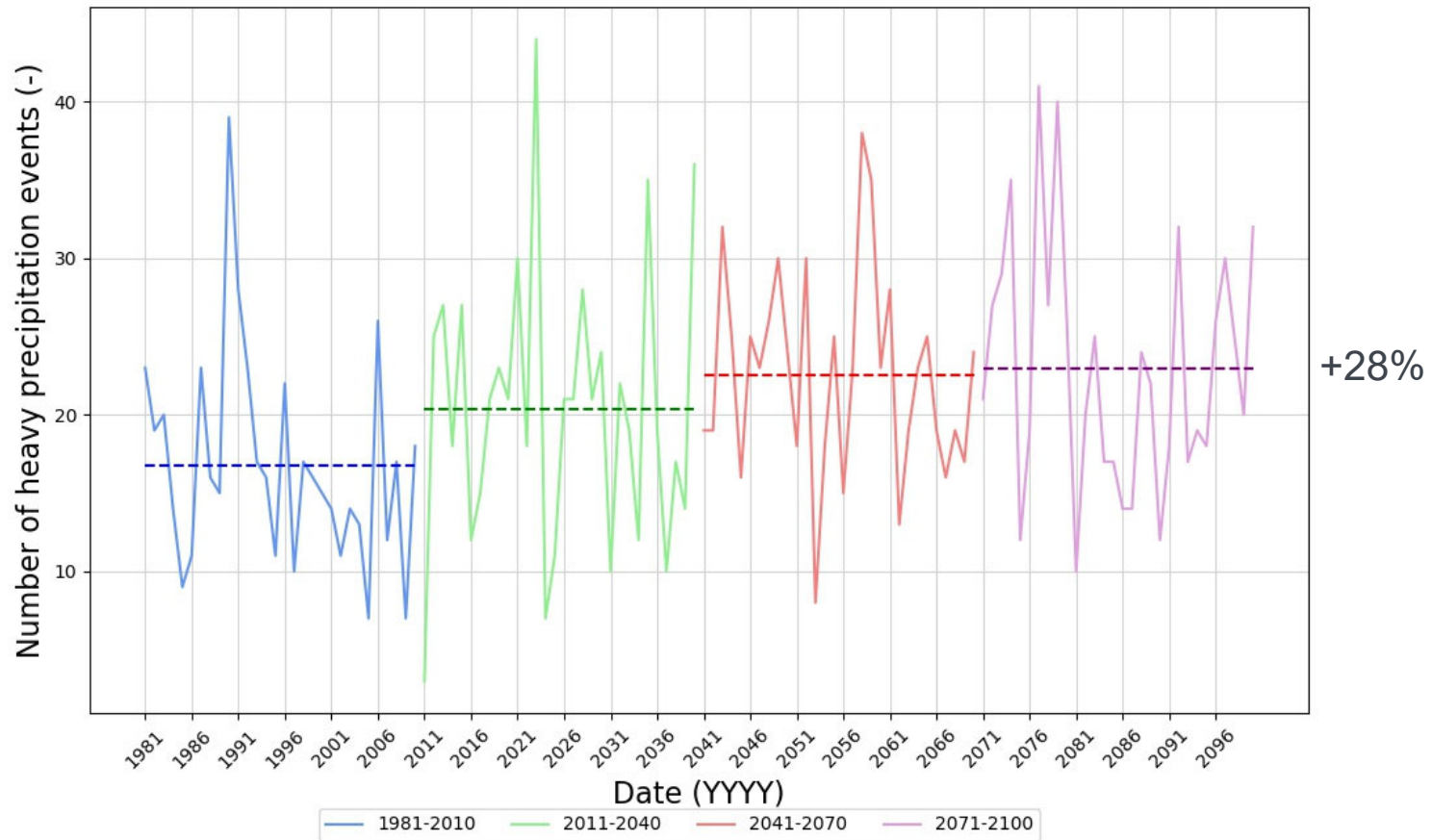
Climate projections for southeast Albania

Precipitation EC-Earth



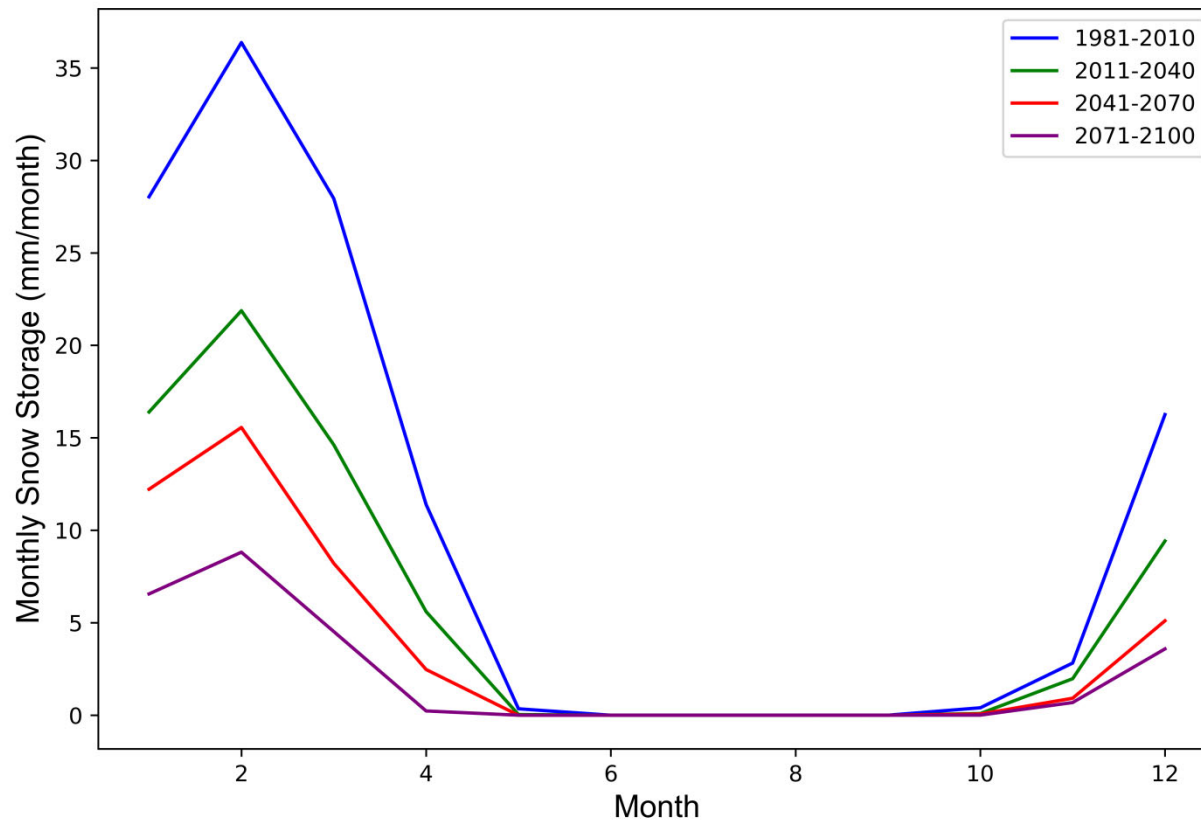
Climate projections for southeast Albania

Intense storm events per year EC-Earth RCP 8.5



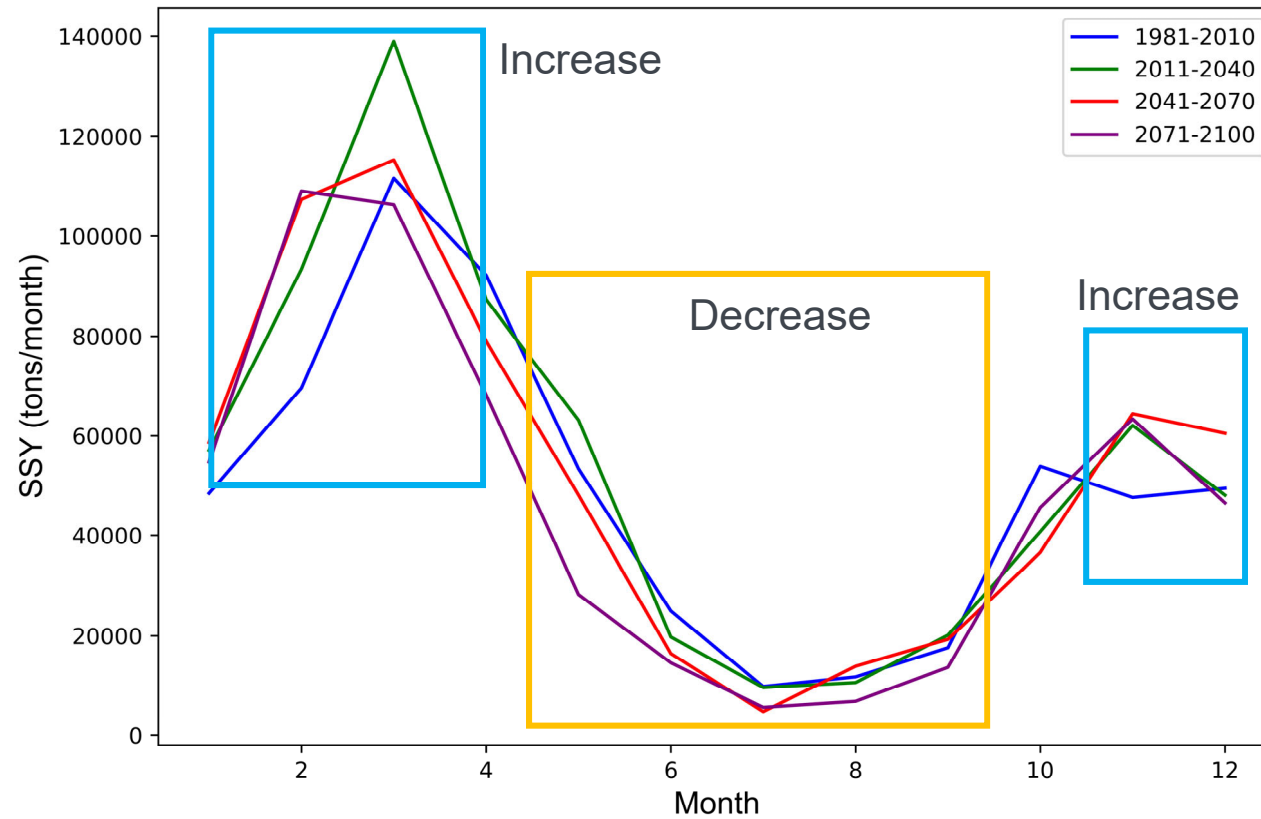
Modeling results for southeast Albania

Snow storage EC-Earth RCP 8.5



Modeling results for southeast Albania

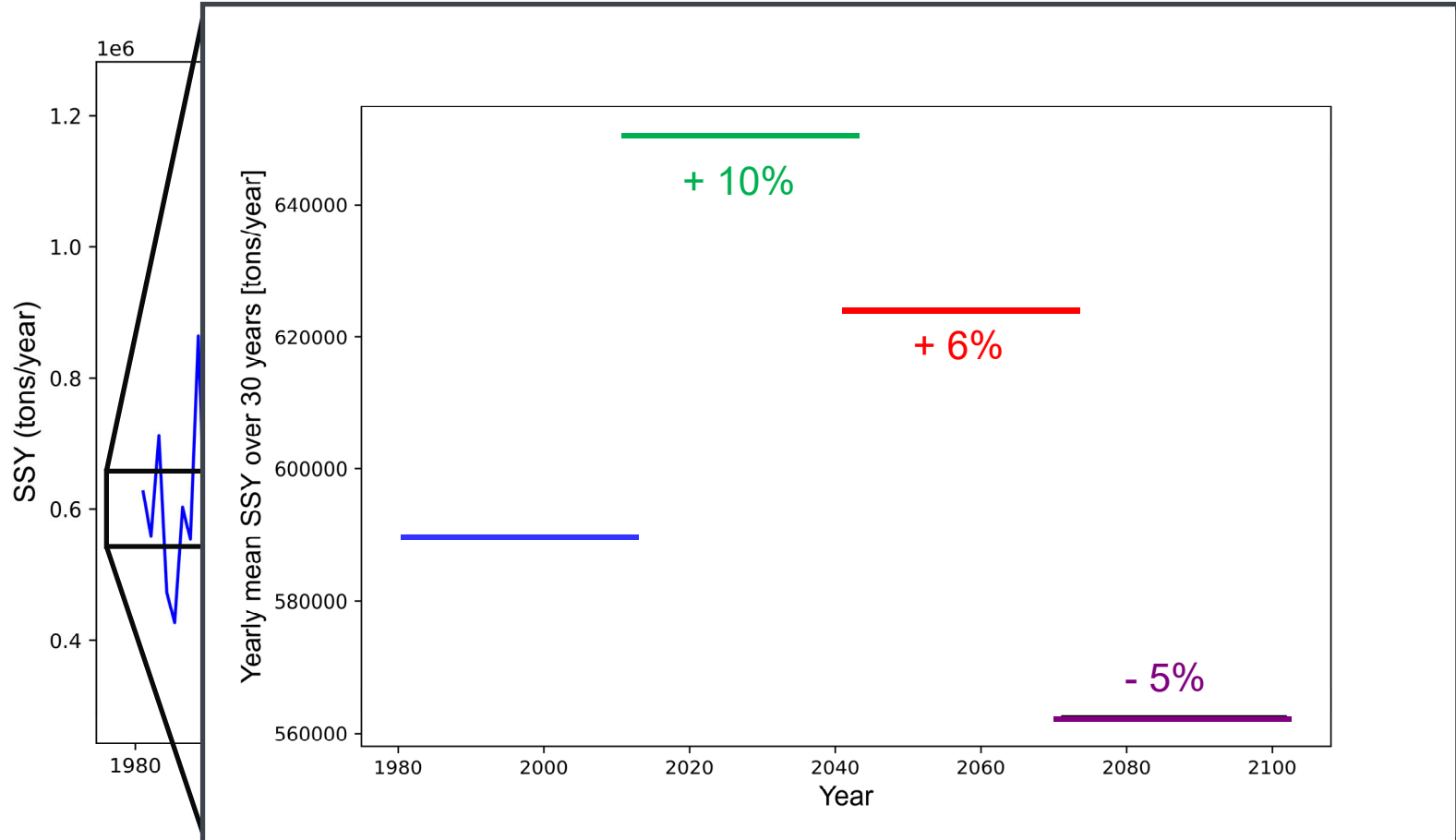
Seasonal changes – RCP 8.5



Modeling results for southeast Albania



Yearly SSY - EC-Earth RCP 8.5



Take-home messages



- Significant seasonal and regional differences
→ detailed analysis of catchment is necessary
- Less snowfall in winter leads to higher SSY in winter and lower SSY in spring
- SSY is sensitive to both climate models and emission scenarios
→ recommended to analyze various input data sets
→ results should be ranges rather than exact values
- Approach is transferable to other case studies

Take-home messages

What can be expected for France?



- Decrease of annual precipitation, especially in Southern France (up to 20%)
- Retreat of glaciers and snow cover
- Increase of precipitation in winter (10%)
- Increase of rainfall intensity

- Similar effects are expected; even a greater impact on glacial systems and snowfall than in Albania
- Higher sediment concentrations
- Annual: Needs further analysis
- Seasonal: Increase in winter and decrease in spring and summer

Outlook

Long-term reservoir sedimentation modelling

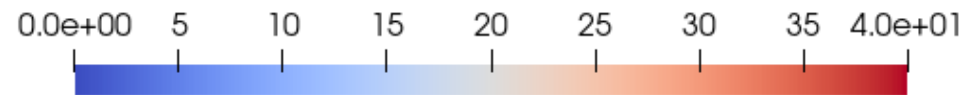


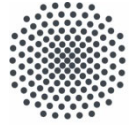
Start (2016)

After 50 years



Depth (m)





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Thank you



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