ADAPTING TO WATER SCARCITY IN EUROPE

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What has been stated on water scarcity in Europe?

Conclusions:

- Southern Europe: strongest warming in winter, drier all year
- Northern Europe: strongest warming in summer, moister all year

Where will water scarcity most likely hurt?

- Agriculture (limit to rainfed agriculture)
- Hydropower (reduced water availability)
- Thermal power (reduced flow and increased water temperture)
- Transportation (reduced flow)

Water scarcity in Europe:

- Will not develop in the Northern Europe (don't think about it)
- Will increase in the South
  - will very likely severely stress existing water infrastructure
  - will be dealt with by societies, which are very experienced with water scarcity (optimistic view, still a very hard challenge)

What happens at the climatic boundary between North and South?

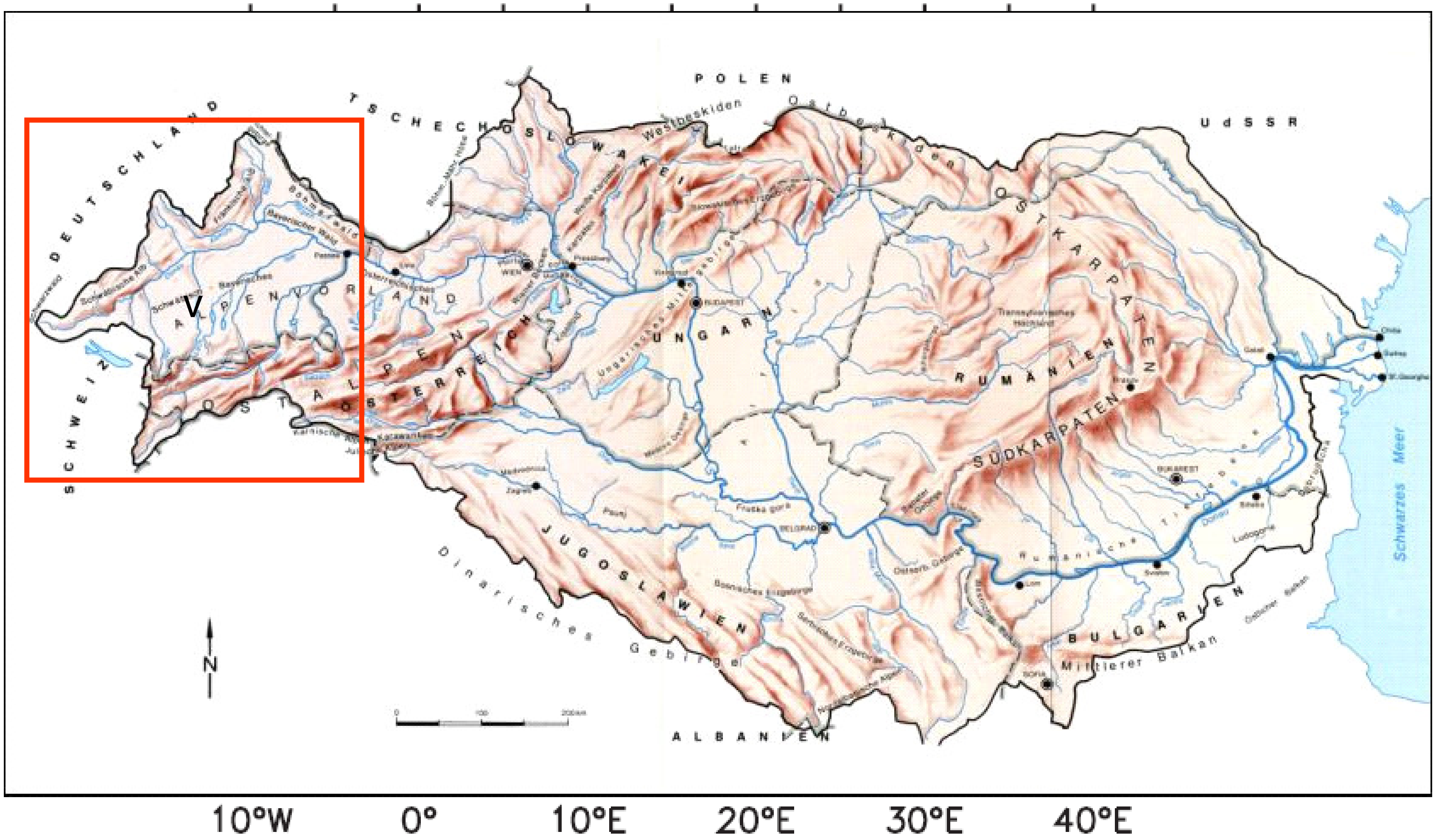
								EUROPE								
NEU	DJF	2.6	3.6	4.3	5.5	8.2	40	9	13	15	22	25	50	82	43	0
	MAM	2.1	2.4	3.1	4.3	5.3	35	0	8	12	15	21	60	79	28	2
48N,10W	JJA	1.4	1.9	2.7	3.3	5.0	25	-21	-5	2	7	16		88	11	
to	SON	1.9	2.6	2.9	4.2	5.4	30	-5	4	8	11	13	80	87	20	2
75N,40E	Annual	2.3	2.7	3.2	4.5	5.3	25	0	6	9	11	16	45	96	48	2
SEM	DJF	1.7	2.5	2.6	3.3	4.6	25	-16	-10	-6	-1	6	>100	93	3	12
	MAM	2.0	3.0	3.2	3.5	4.5	20	-24	-17	-16	-8	-2	60	98	1	31
30N,10W	JJA	2.7	3.7	4.1	5.0	6.5	15	-53	-35	-24	-14	-3	55	100	1	42
to	SON	2.3	2.8	3.3	4.0	5.2	15	-29	-15	-12	-9	-2	90	100	1	21
48N,40E	Annual	2.2	3.0	3.5	4.0	5.1	15	-27	-16	-12	-9	-4	45	100	0	46

- Mediterranean climate will shift North
- Winters will become warmer and moister
- Summers will become warmer and drier

What are the consequences for the transition regions (app.30% of EU)?

The Upper Danube – Consequences of a shift in the Climate Boundary

JJA



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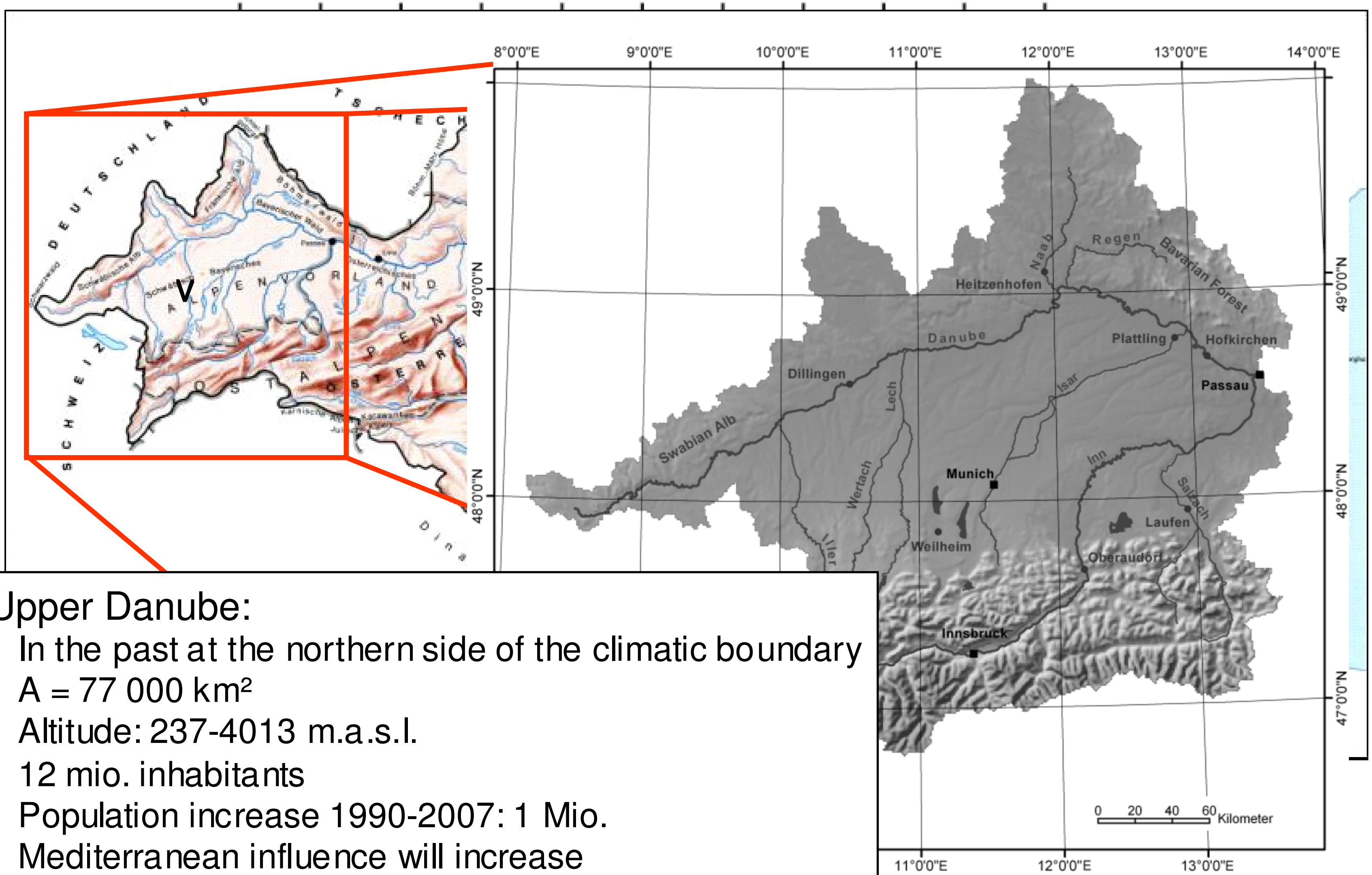
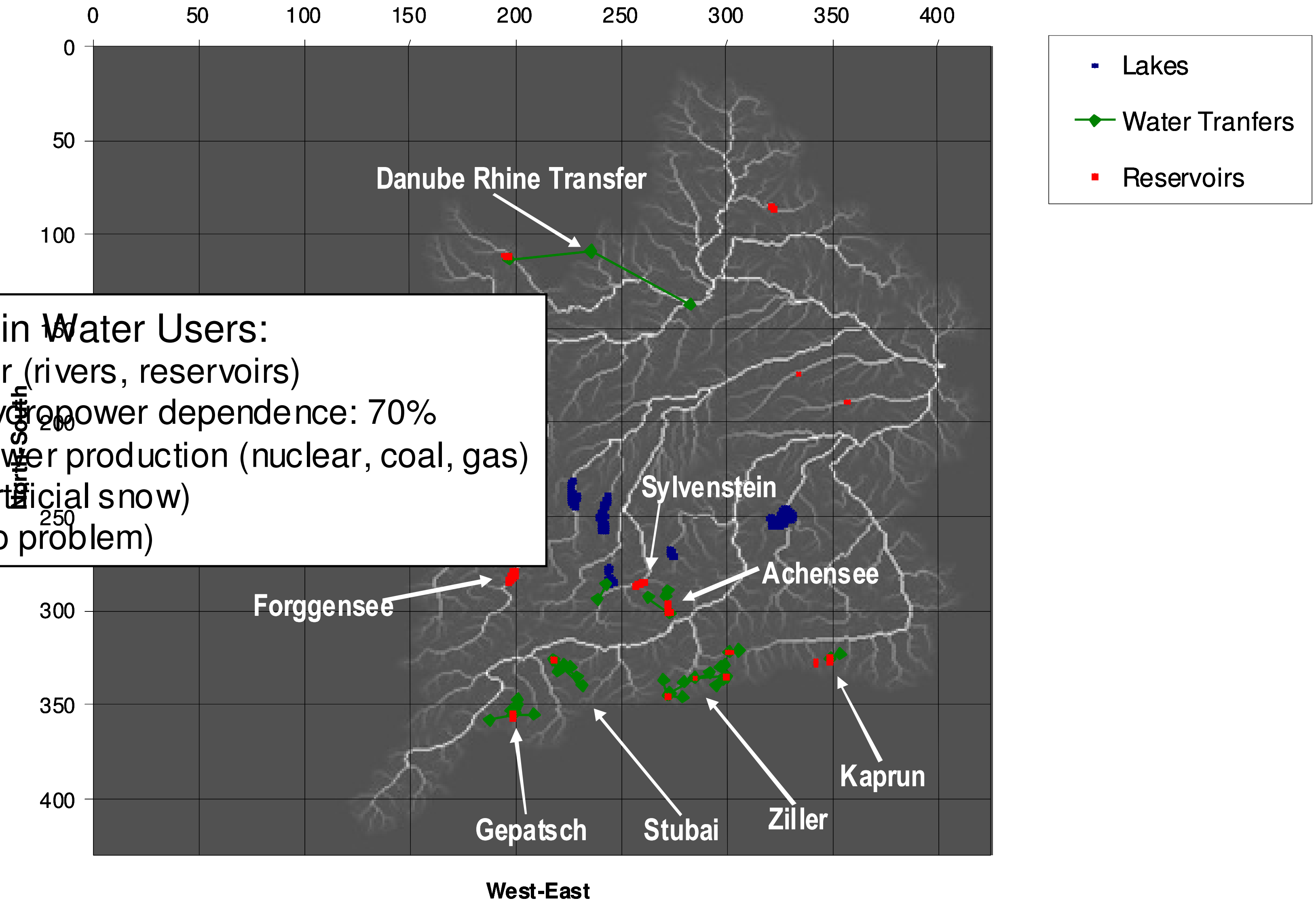


Upper Danube:

- In the past at the northern side of the climatic boundary
- A = 77 000 km²
- Altitude: 237-4013 m.a.s.l.
- 12 mio. inhabitants
- Population increase 1990-2007: 1 Mio.
- Mediterranean influence will increase

Large water infrastructure in the Upper Danube

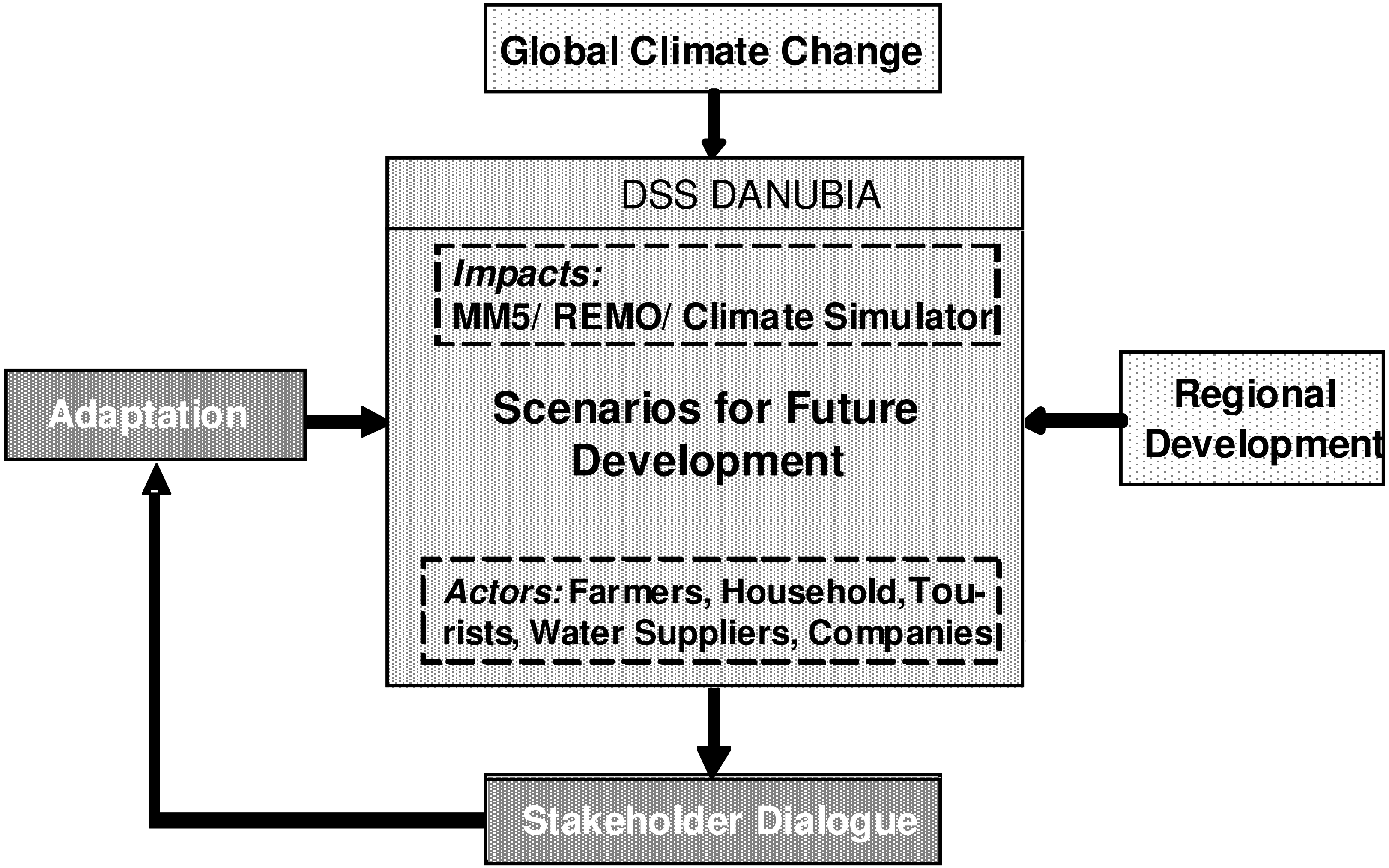


Today's Main Water Users:

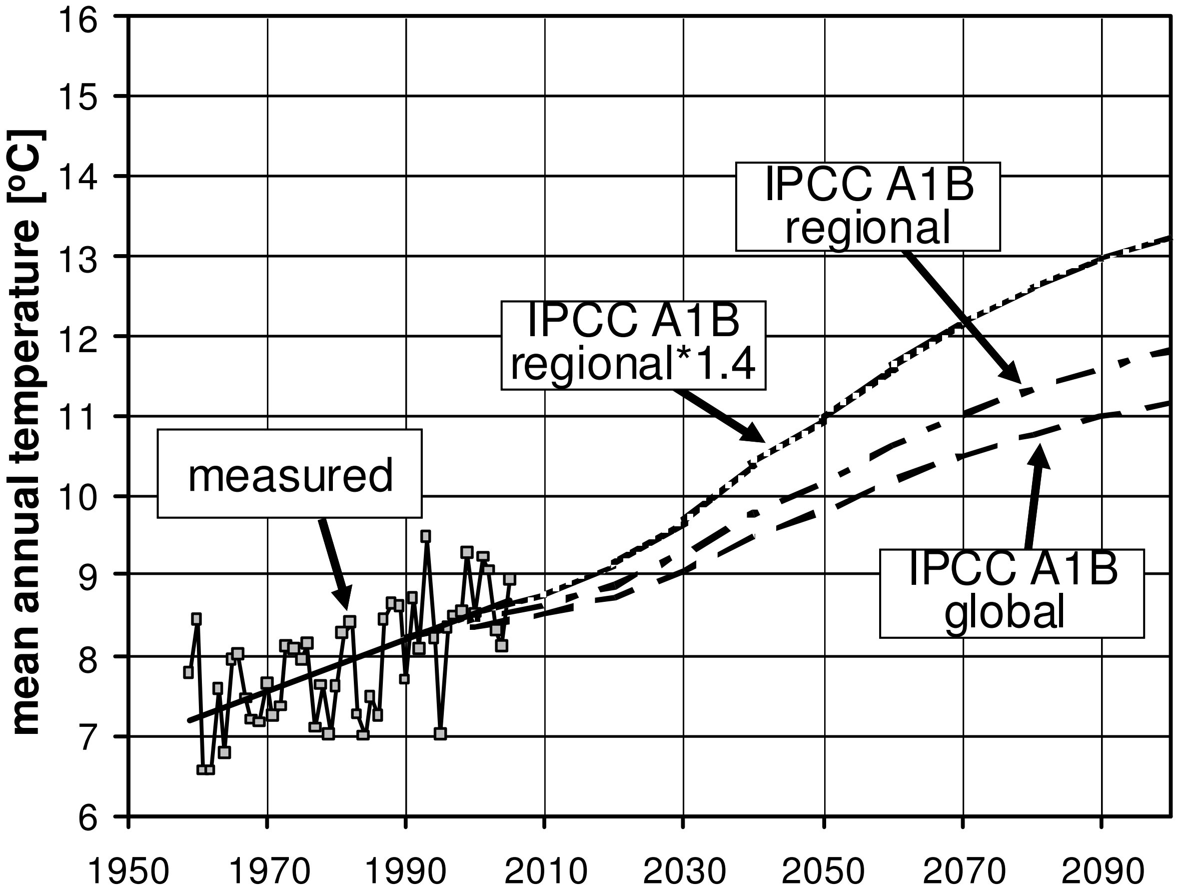
- Hydropower (rivers, reservoirs)
  Austria's hydropower dependence: 70%
- Thermal power production (nuclear, coal, gas)
- Tourism (artificial snow)
- Industry (no problem)

Large lakes, large reservoirs (> 50 Mio m³) and large transfers

GOWA-Danube – Sustainable Future Water Management in the Upper Danube



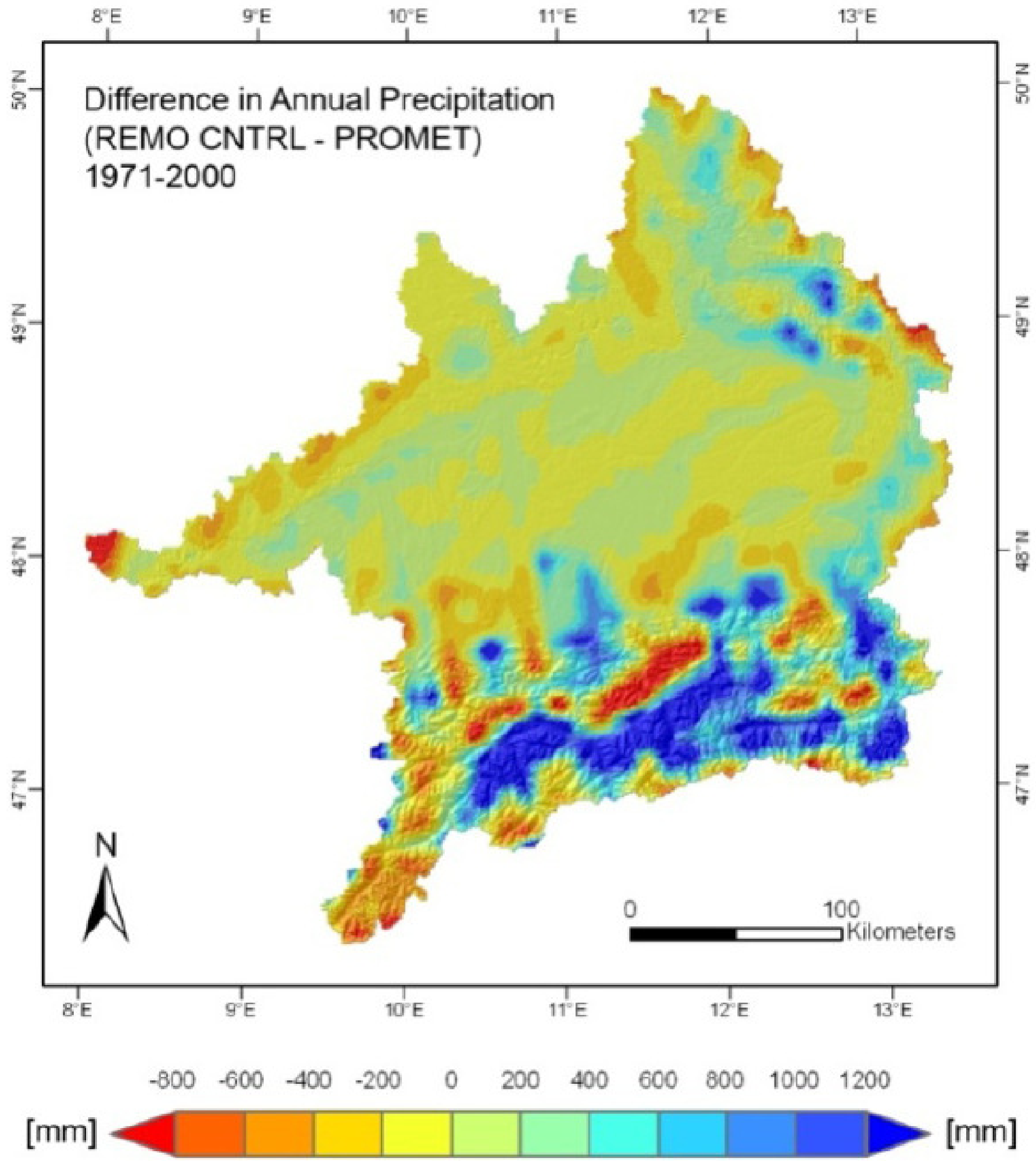
What is likely to happen? A second look at IPCC's regional climate change



Conclusion:

- contradictions between the change, that has already happened in the region and the regional predictions of IPCC can be avoided through the assumption that actual temperature increase in the region is 1.4 times stronger than the regional IPCC predictions

Regional Climate Models – still room for improvement



Creating new regional climate time series – the Climate Scenario Generator

Assuming IPCC-SRES-A1B-Scenario with a regional impact factor of 1.4 it uses a statistical approach, which re-sequences measured data from the Period 1960-2006.

13 Realisations were chosen in order to estimate the uncertainty

Reali-sation	Storyline	1% Precip. [mm] ([mm/a])	1%JJA-Temp. [°C]	Annual Rainfall [mm]
0	no temperature change until 2060			1080
1	mean annual rainfall between 2011-2035			1027
2	mean annual rainfall between 2036-2060			922
3	min. rainfall of 5 consecutive years 2011-2035	4015 (803)		
4	min. rainfall of 5 consecutive years 2036-2060	3883 (777)		
5	min. rainfall of 3 consecutive years 2011-2035	2517 (839)		
6	min. rainfall of 3 consecutive years 2036-2060	2387 (796)		
7	min. rainfall of 1 year 2011-2035	791		
8	min. rainfall of 1 year 2036-2060	762		
9	max. JJA temp.of 5 consec. years 2011-2035		20.15	
10	max. JJA temp.of 5 consec. years 2036-2060		20.35	
11	max. JJA temp. 2011-2035		21.62	
12	max. JJA temp. 2036-2060		21.71	

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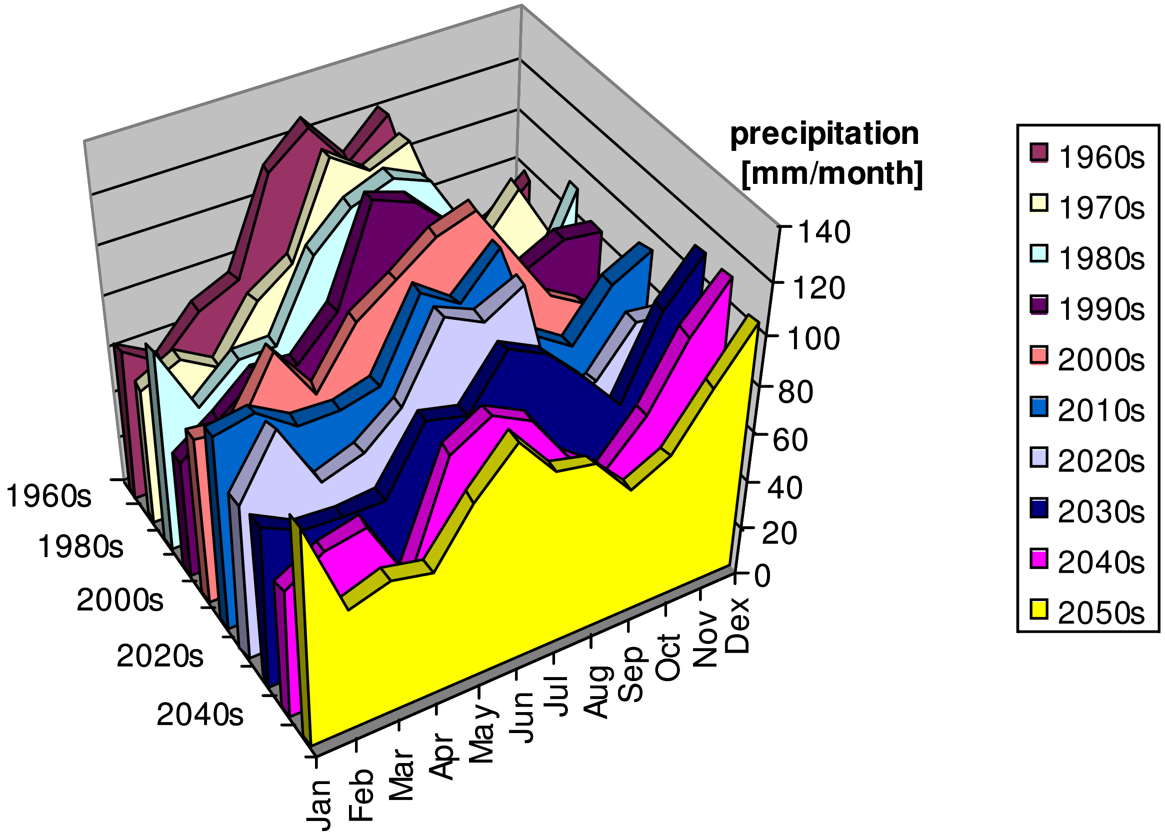
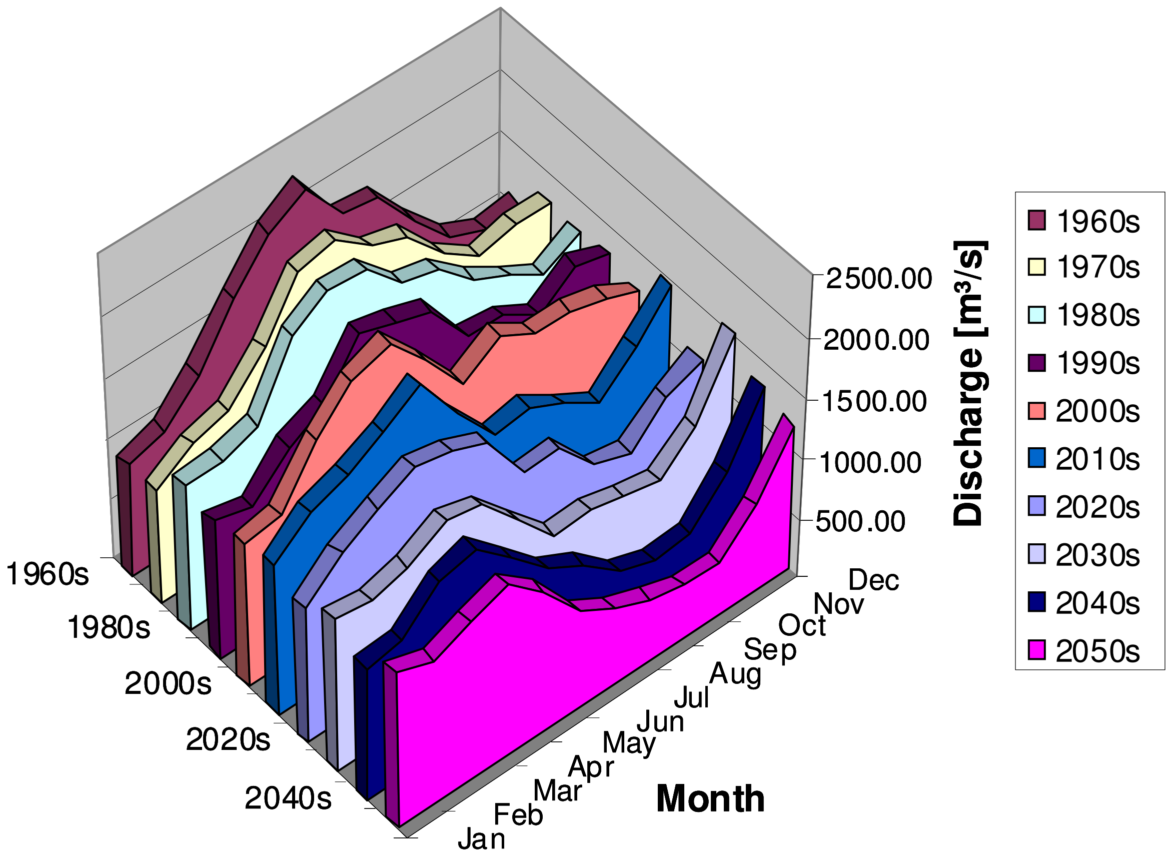
Changing rainfall



Predicted Changes not dramatic, but:

- Increase in Winter
- Decrease in Summer

may change the runoff regime!!

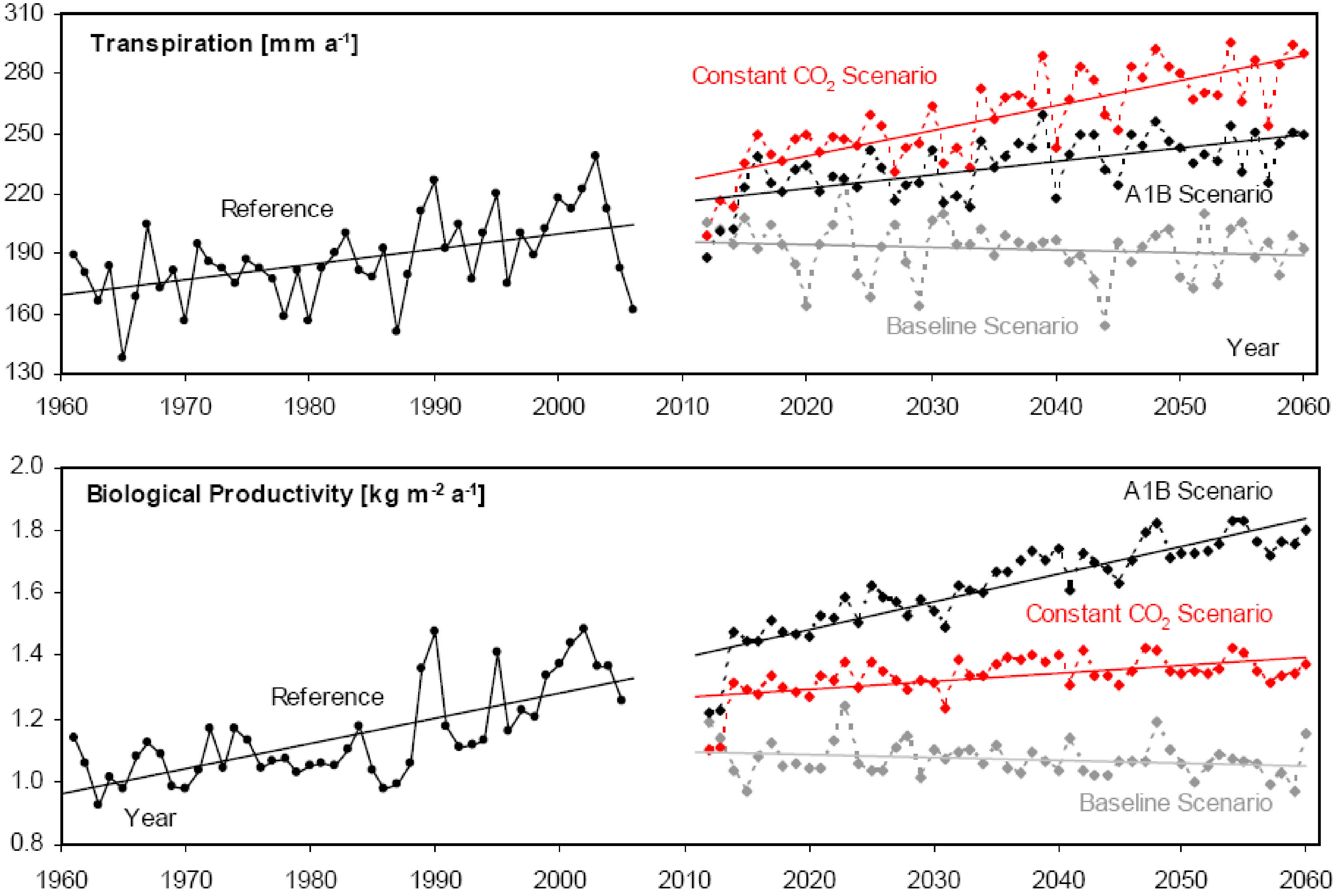


Predicted changes quite large:

- Reduction much larger than precipitation reduction (increase in evapotranspiration)
- Change from a summer peak (snow in the Alps) to a Winter peak (rain in the Alps)

Impact on Agriculture – increased water use efficiency

The role of the increase in CO2-concentration



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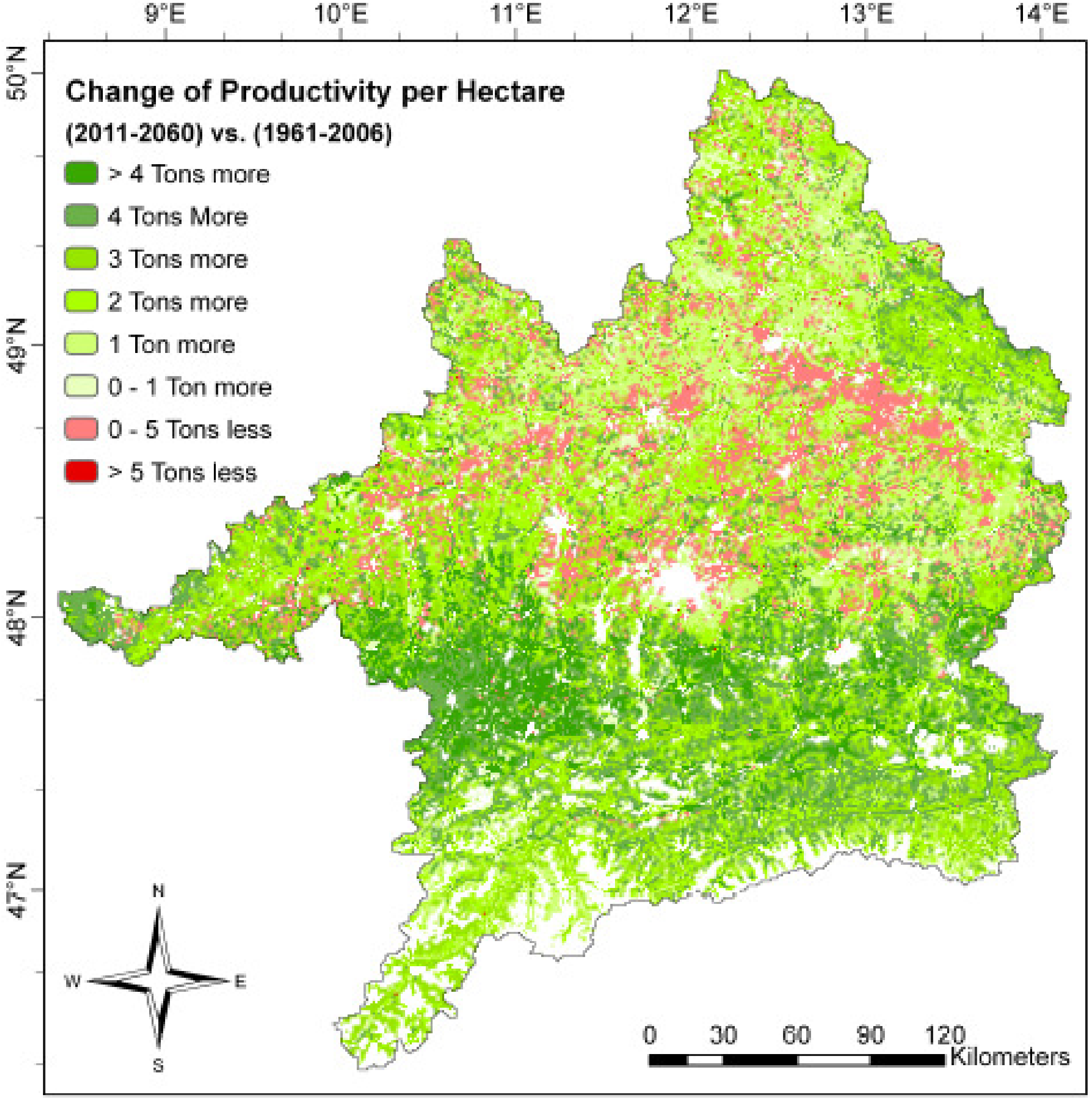
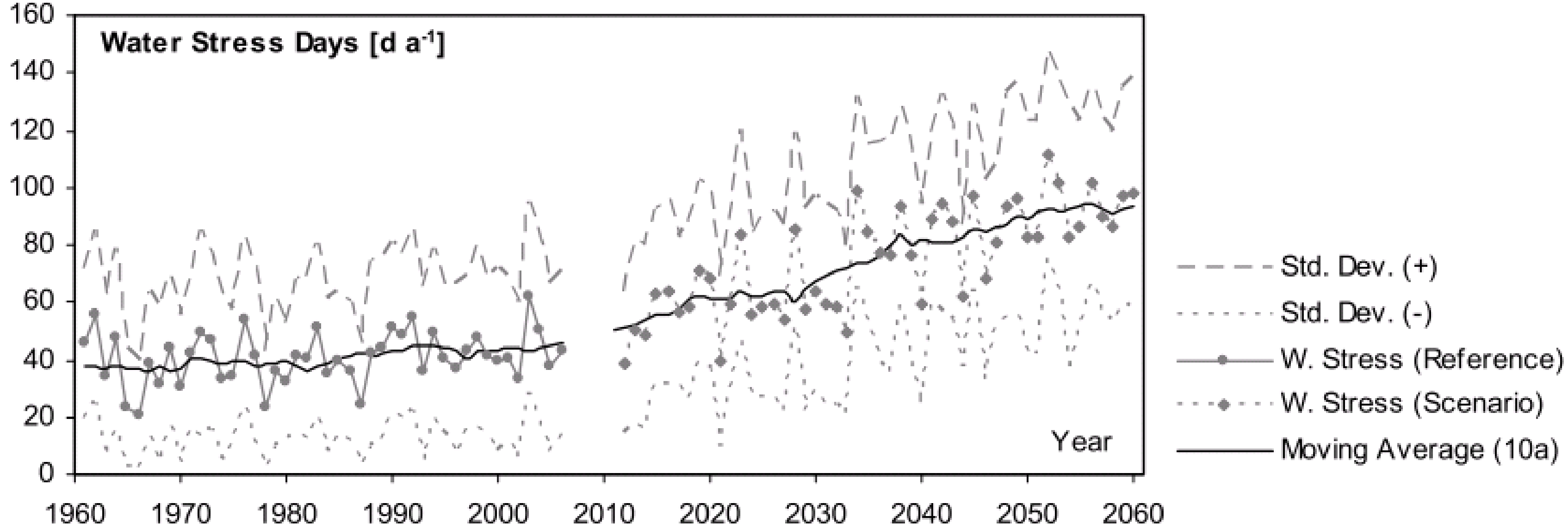
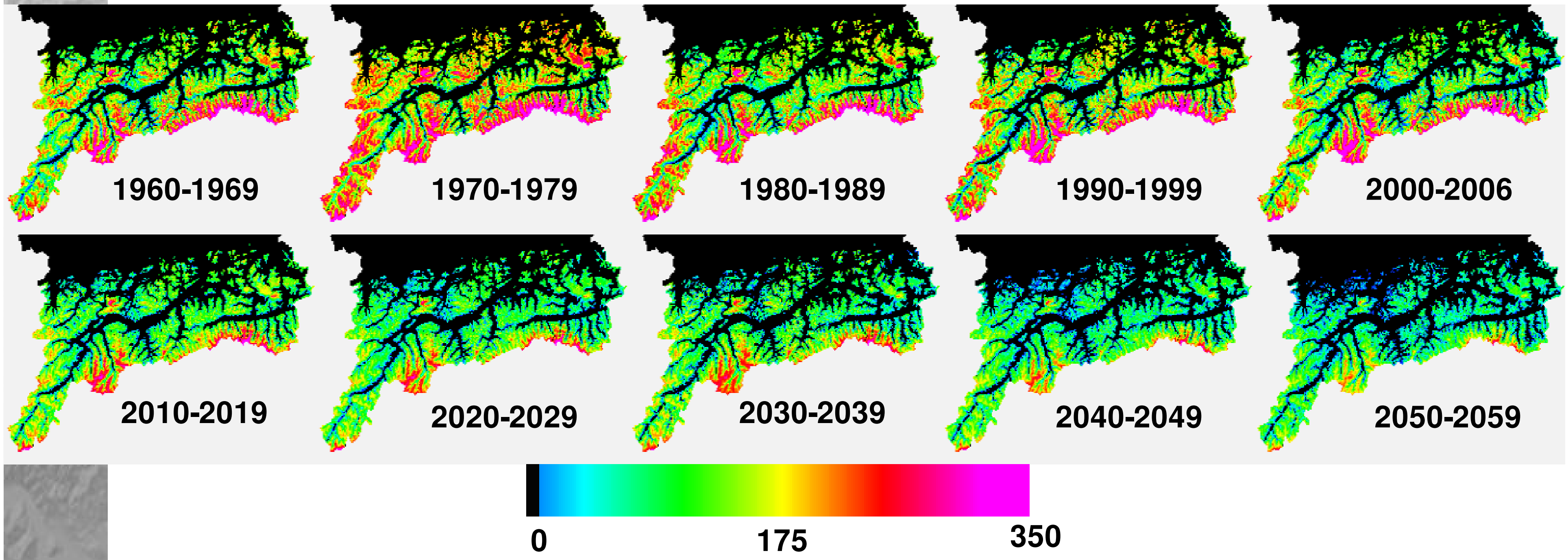


Impact on Agriculture – nevertheless, when to introduce irrigation?

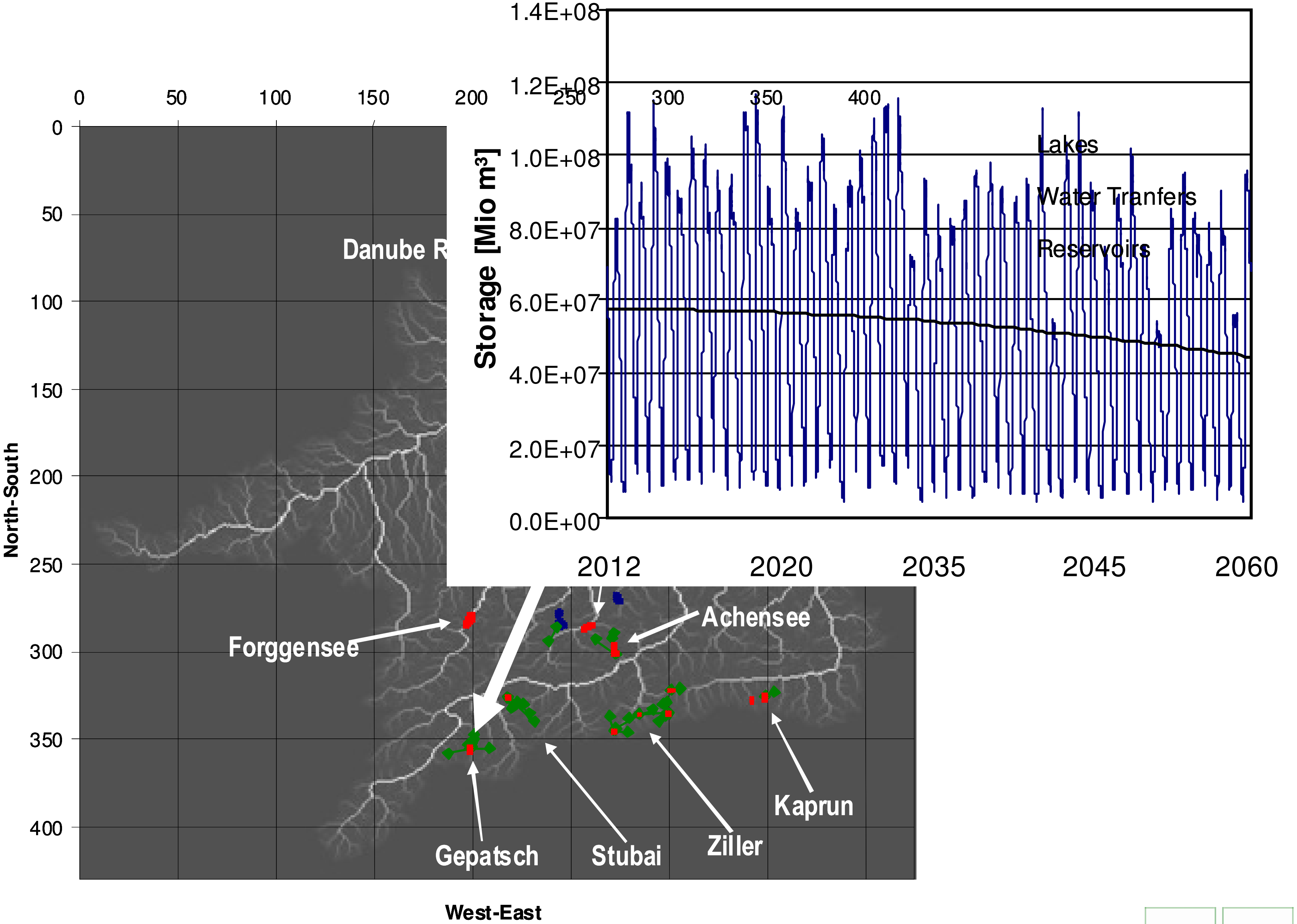


Climate Change impact on snow storage

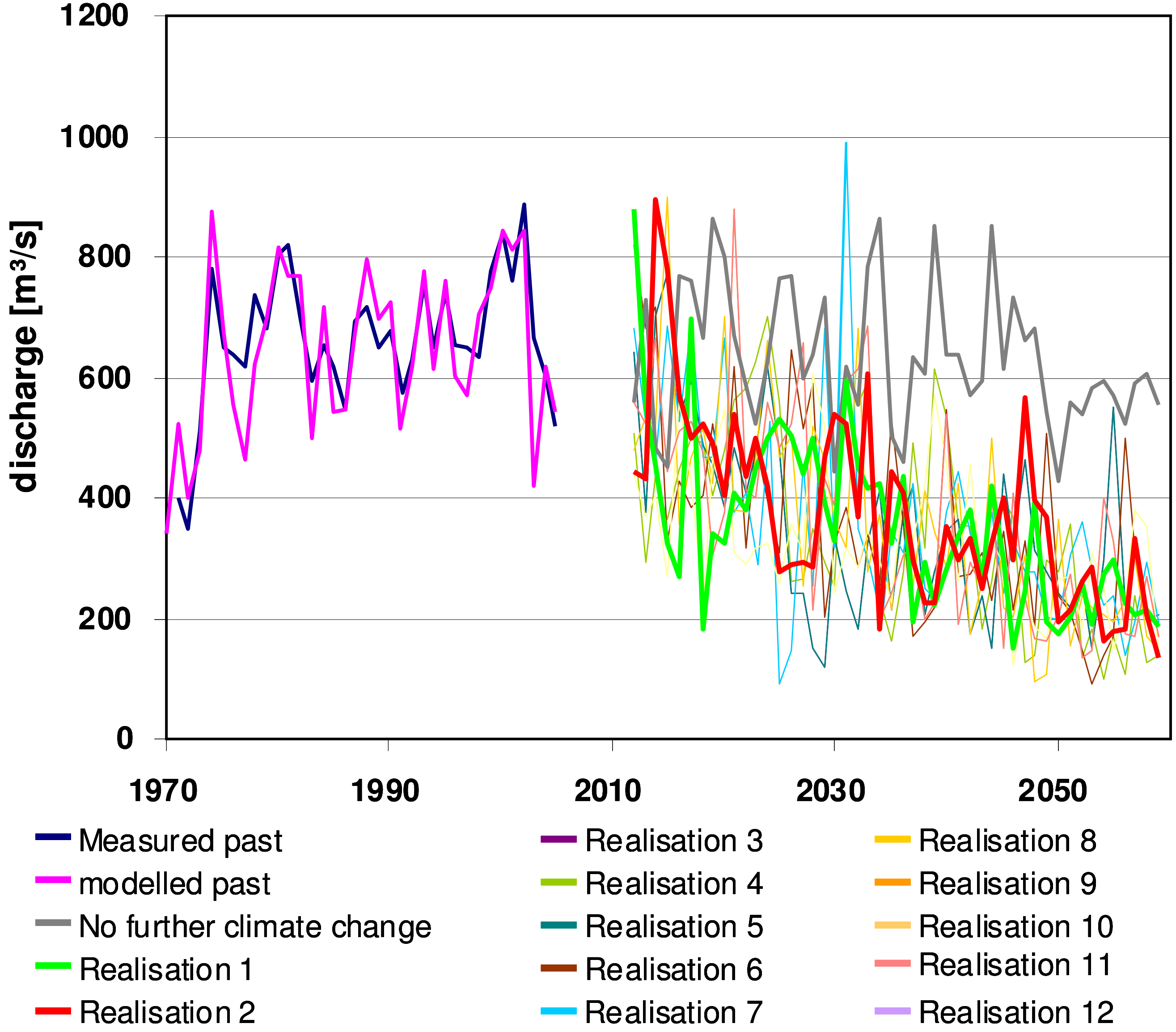


Today's snow conditions at 700 m elevation in 2050 will appear at 1200 m!
What does that mean for the water ressources?
What does that mean for winter tourism?

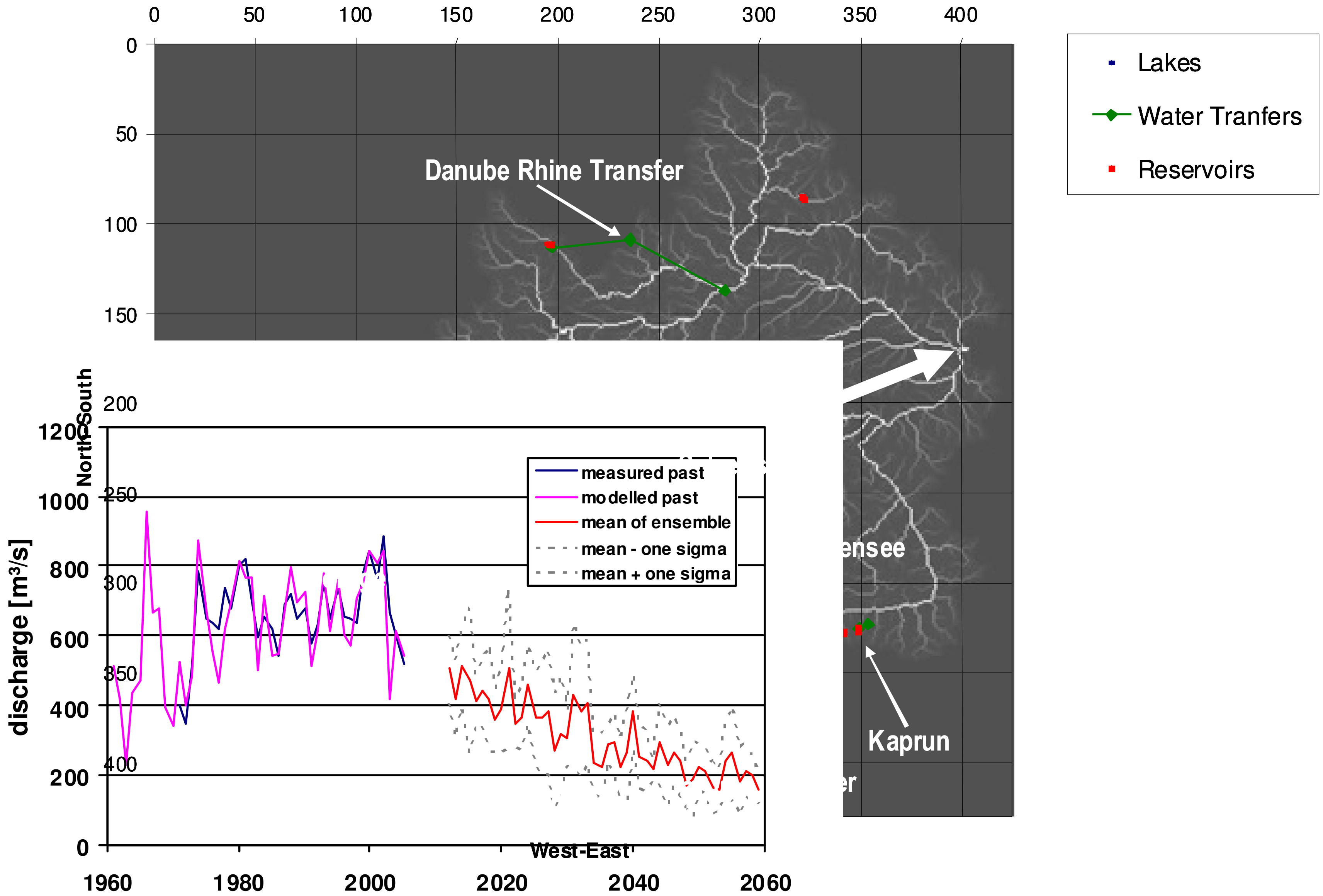
Impact on large Alpine reservoirs



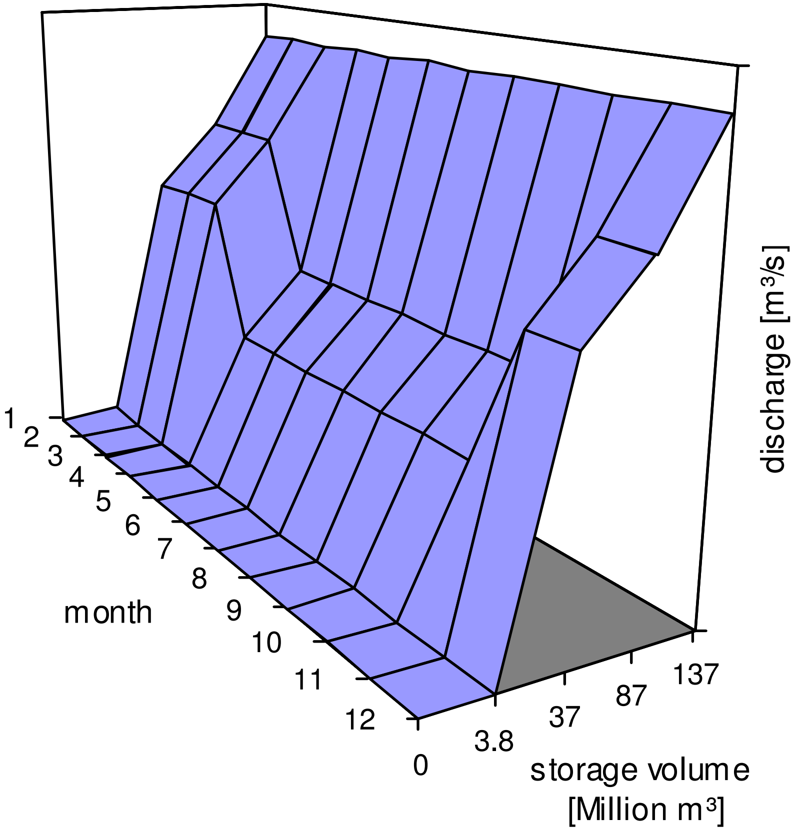
Ensemble of low-flow developments at the outlet



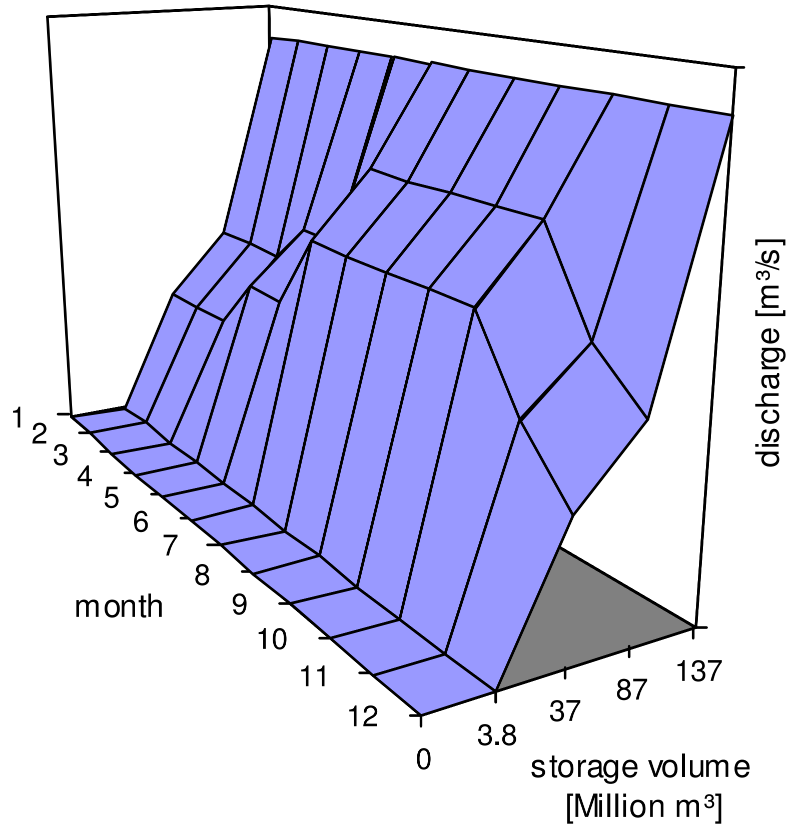
Impact on Danube low-flow



Change in storage operation rules



Today's operation rules:
Winter low-flow augmentation



Porposed future operation rules:
Summer low-flow augmentation

Conclusions

- Hydrologic changes in the European climatic border regions may be serious, they may include a complete regime change from winter low-flows to summer low-flows

- Reasons are coupled and often amplify each others:
  - -> reduced rainfall, increased temperature
  - -> increased radiation input
  - -> increased evapotranspiration
  - -> decreased snow-storage
  - -> decreased soil-moisture

Conclusions

- all important water related sectors are affected by CC and have to adapt:
  - **Hydropower** (change operations, increase storage, build new reservoirs)
  - **Transportation** (change low-flow augmentation
  - **Thermal power** (switch to more expensive evaporative cooling)
  - **Agriculture** (introduce irrigation)
  - **Winter Tourism** (artificial snow production will fail, no chance in lower regions, retreat to today's glaciers)
- It is not at all clear, which adaptation strategy will be most beneficial from an overall point of view. Alternatives should carefully be analysed using integrative tools, which cover all affected sectors before society is approached with new technology or sociology fixes (see biofuel)
- Results suggest that the amount and seasonal distribution of water delivered downstream may change significantly.
- Important transboundary questions arise within EU:
  - **Sensitive and complex question to the EU:**

    is it better to introduce irrigation in Germany (transferring water into the atmosphere) or to let it flow down the Danube, improve transportation and use it downstream to irrigate agriculture in Eastern Europe?

Thank you!