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 temperature)
• 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?

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

JJA

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
• Mediterranean influence will increase
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

Global Climate Change

DSS DANUBIA

Impacts: MM5/REMO/Climate Simulator

Scenarios for Future Development

Actors: Farmers, Household, Tourists, Water Suppliers, Companies

Adaptation

Stakeholder Dialogue

Regional Development
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.

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

Transpiration [mm a⁻¹]

Biological Productivity [kg m⁻² a⁻¹]
Impact on Agriculture – increased water use efficiency

The role of the increase in CO2-concentration
Impact on Agriculture – nevertheless, when to introduce irrigation?

![Water Stress Days (d a⁻¹)]

- Std. Dev. (+)
- Std. Dev. (-)
- W. Stress (Reference)
- W. Stress (Scenario)
- Moving Average (10a)
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 resources?
What does that mean for winter tourism?

23.7.08 EXPO Zaragoza
Impact on large Alpine reservoirs

Storage [Mio m³]

2012 2020 2035 2045 2060

Danube River

Lakes

Water Transfers

Reservoirs

Forggensee

Achensee

Kaprun

Gepatsch

Stubai

Ziller

West-East

North-South

23.7.08

EXPO Zaragoza
Ensemble of low-flow developments at the outlet

- Measured past
- Modelled past
- No further climate change
- Realisation 1
- Realisation 2
- Realisation 3
- Realisation 4
- Realisation 5
- Realisation 6
- Realisation 7
- Realisation 8
- Realisation 9
- Realisation 10
- Realisation 11
- Realisation 12
Impact on Danube low-flow

Danube Rhine Transfer

Lakes
- Water Transfers
- Reservoirs

Discharge [m³/s]
- Measured past
- Modeled past
- Mean of ensemble
- Mean - one sigma
- Mean + one sigma

North-South

Kaprun

West-East

1960 1980 2000 2020 2040 2060

0 50 100 150 200 250 300 350 400

0 50 100 150

200

600

400

200

0

800

300

0

100

1000

250

350

400

300

400

0

1200

200

300

400

500

0

200

400

600

800

1000

1200

300

200

100

0

1960 1980 2000 2020 2040 2060
Change in storage operation rules

Today’s operation rules:
Winter low-flow augmentation

Proposed 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 other:
  - 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!