Climate Change and the Eastern Mediterranean Precipitation Regime

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Abstract

Water is an indispensable constituent of life on Earth. However, water availability and water quality are prone to a number of external parameters, particularly climate change. In that regard, arid to semi-arid regions are particularly sensitive to changes in the water balance and to water scarcity as caused by altered climate conditions. While precipitation has always been low in the Eastern Mediterranean, the situation on Cyprus has worsened in recent years due to overexploitation of existing groundwater bodies and a steady decrease in mean annual precipitation from 530 mm for the period 1941-1970 to 460 mm for 1971-2000. An extensive program to retain precipitation in a large number of dams does not bear fruits in low-precipitation years and has lead to an increasing reliance on seawater desalination and –in the extreme- to the import of water from Greece by ship in 2008 to satisfy the demand for potable water on the island. In order to explore the prospects of future water availability in the Eastern Mediterranean, we carry out regional climate modeling, which provides (among many other quantities) scenarios of monthly mean temperatures and precipitation. After presenting results for the entire Eastern Mediterranean, more in-depth case studies for Cyprus and the Lebanon will be discussed. This will be followed by introducing a number of possible adaptation measures aimed to reduce the adverse effects of climate-change-induced water scarcity in countries of the Eastern Mediterranean.

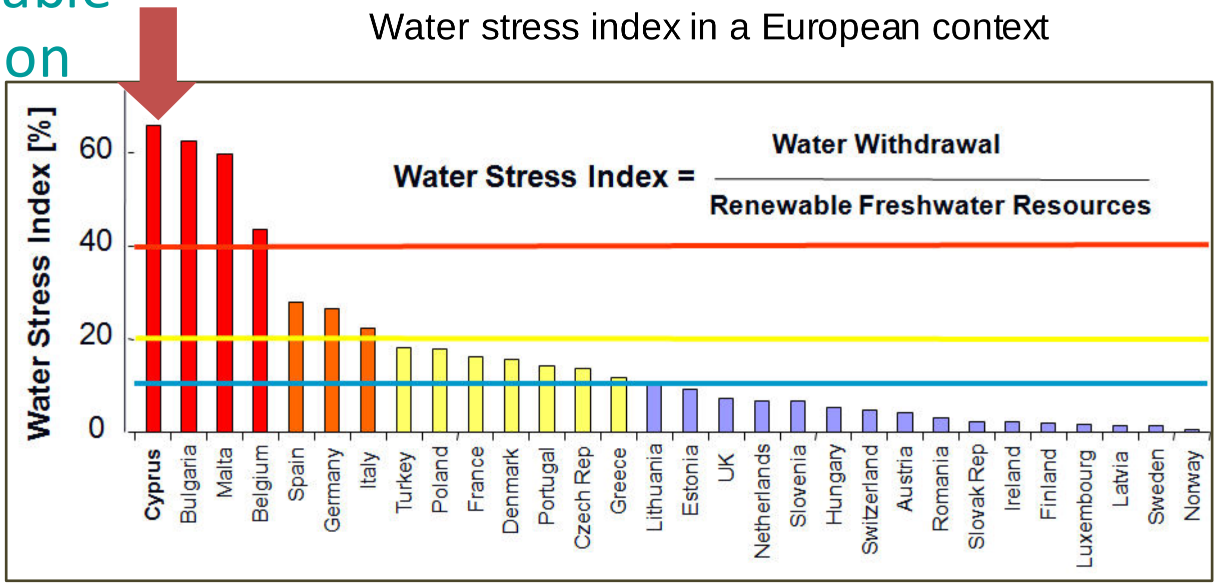
Outline

- Background and Introduction
- Regional Climate Modeling as a Tool to Assess Climate Change
- Climate Modeling Results
  - Regional
  - Case Study: Cyprus
  - Case Study: Lebanon
- Discussion and Conclusion
  - Adaptation Options/Strategies
  - The need for more research

Background and Introduction

- Water is an indispensable ingredient of life on Earth
- Arid to semi-arid regions are particularly sensitive to changes in the water balance and to water scarcity
- This situation is exacerbated on islands because:
  - no trans-boundary water exchange
  - complete reliance on precipitation for ground- and surface water recharge
- Large fraction of available water used for irrigation in the Mediterranean
- The balance between water devoted to human consumption and the environment is often skewed

Water stress index in a European context



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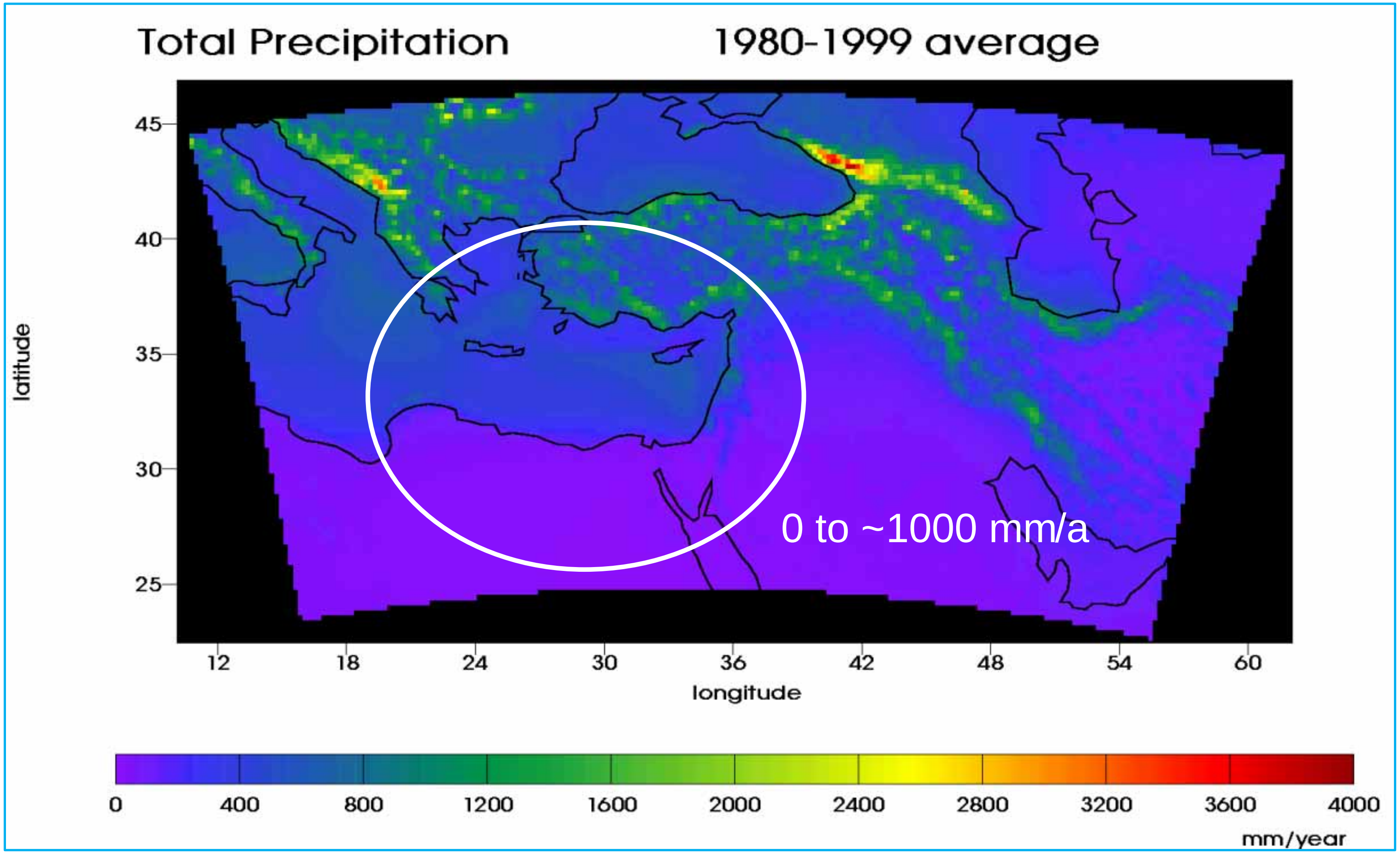
Background and Introduction

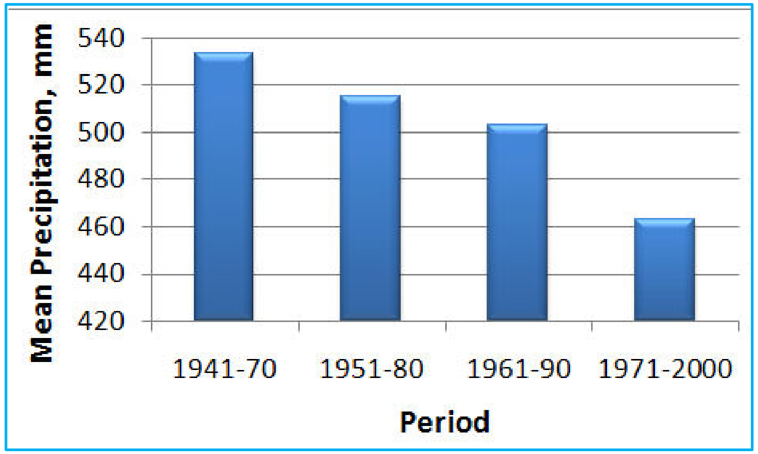
- Precipitation has always been low in the Eastern Mediterranean



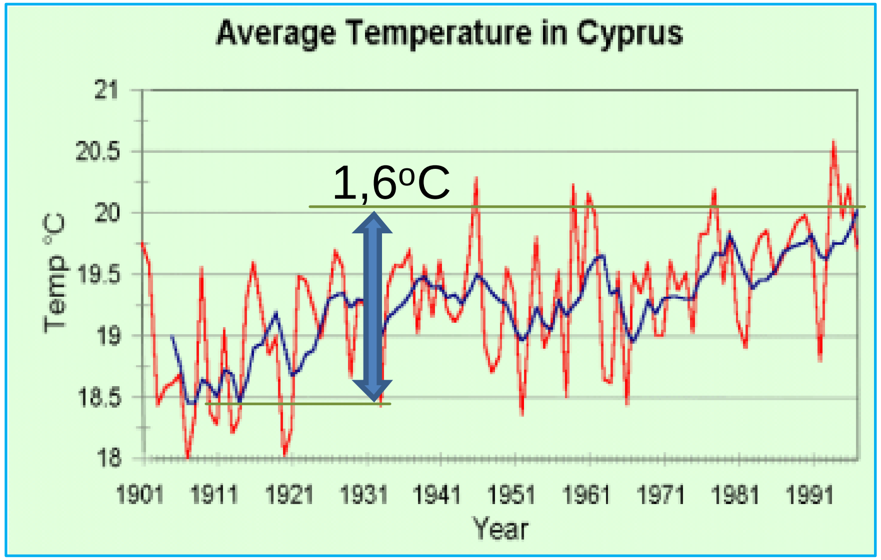
Source: Hadjinicolaou, pers. comm.

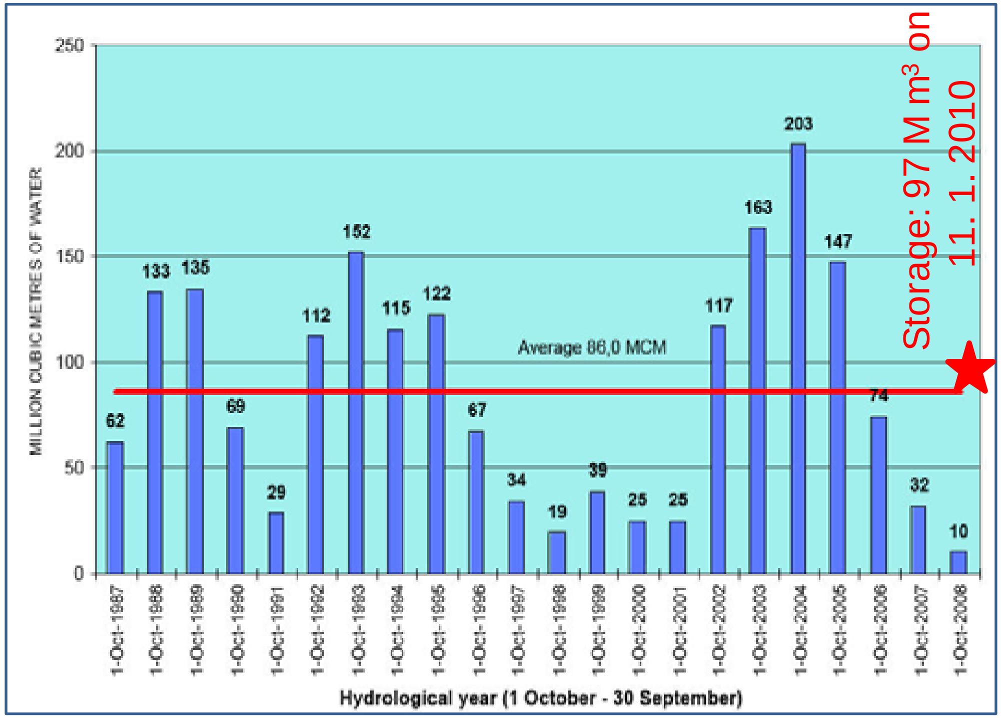
Background and Introduction

- Rising temperatures and water scarcity: common on Cyprus



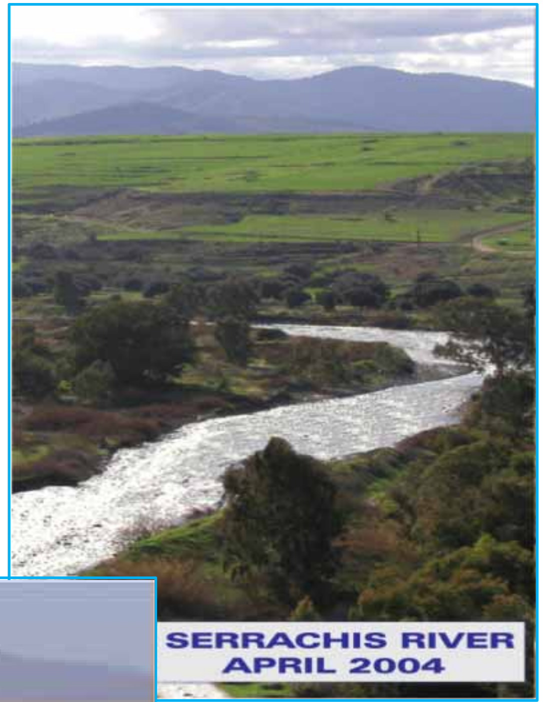
Falling mean climatological precipitation (left); mean annual temperatures for Cyprus (below left; redrawn after: Meteorological Service, Cyprus) and water storage in dams (below; source: Water Development Department, 2010)





Background and Introduction

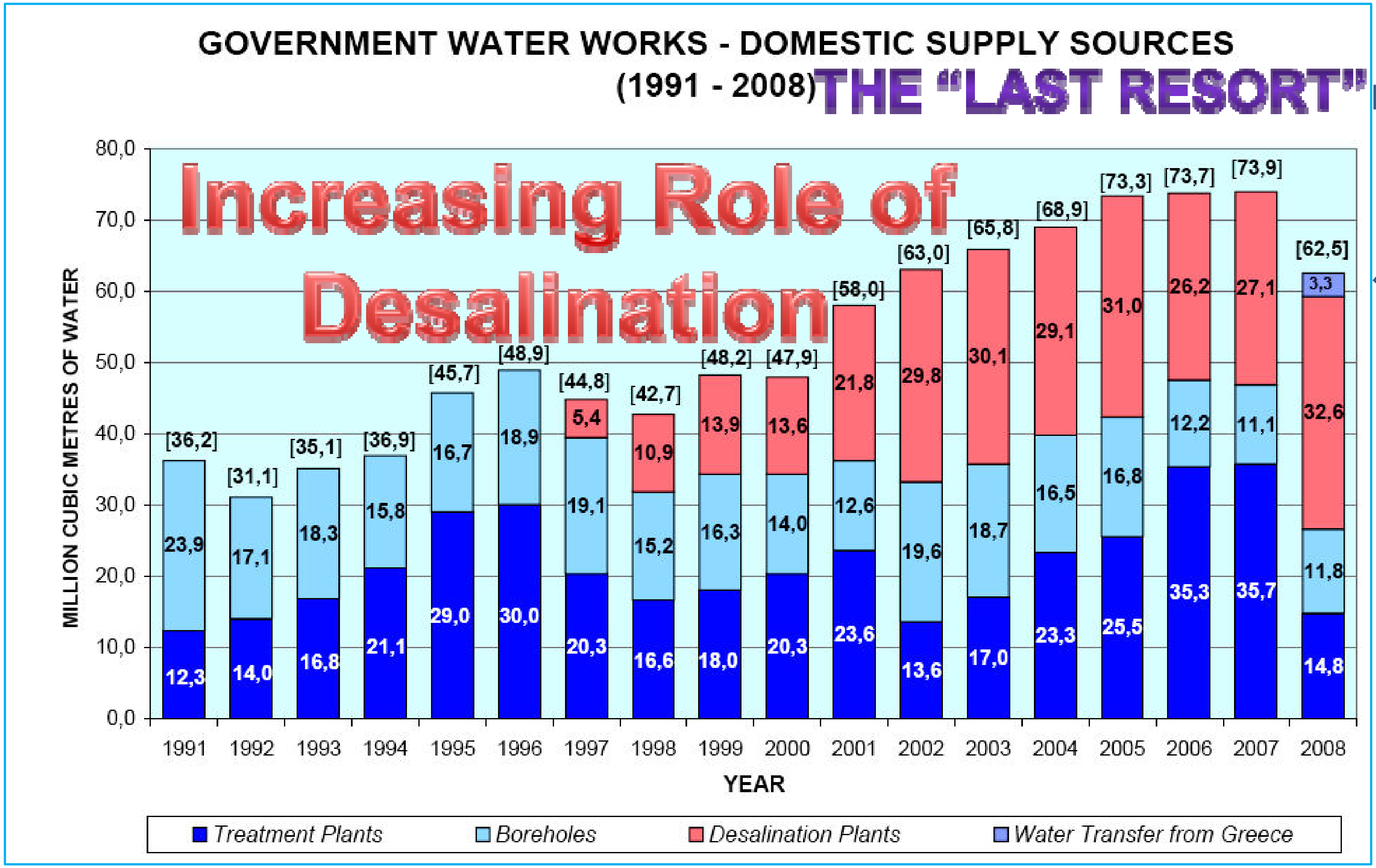
- Variability of annual precipitation
  ⇨ varying surface water reservoirs



(Source: Charis Omorphos, Water Development Department, 2009)

Background and Introduction

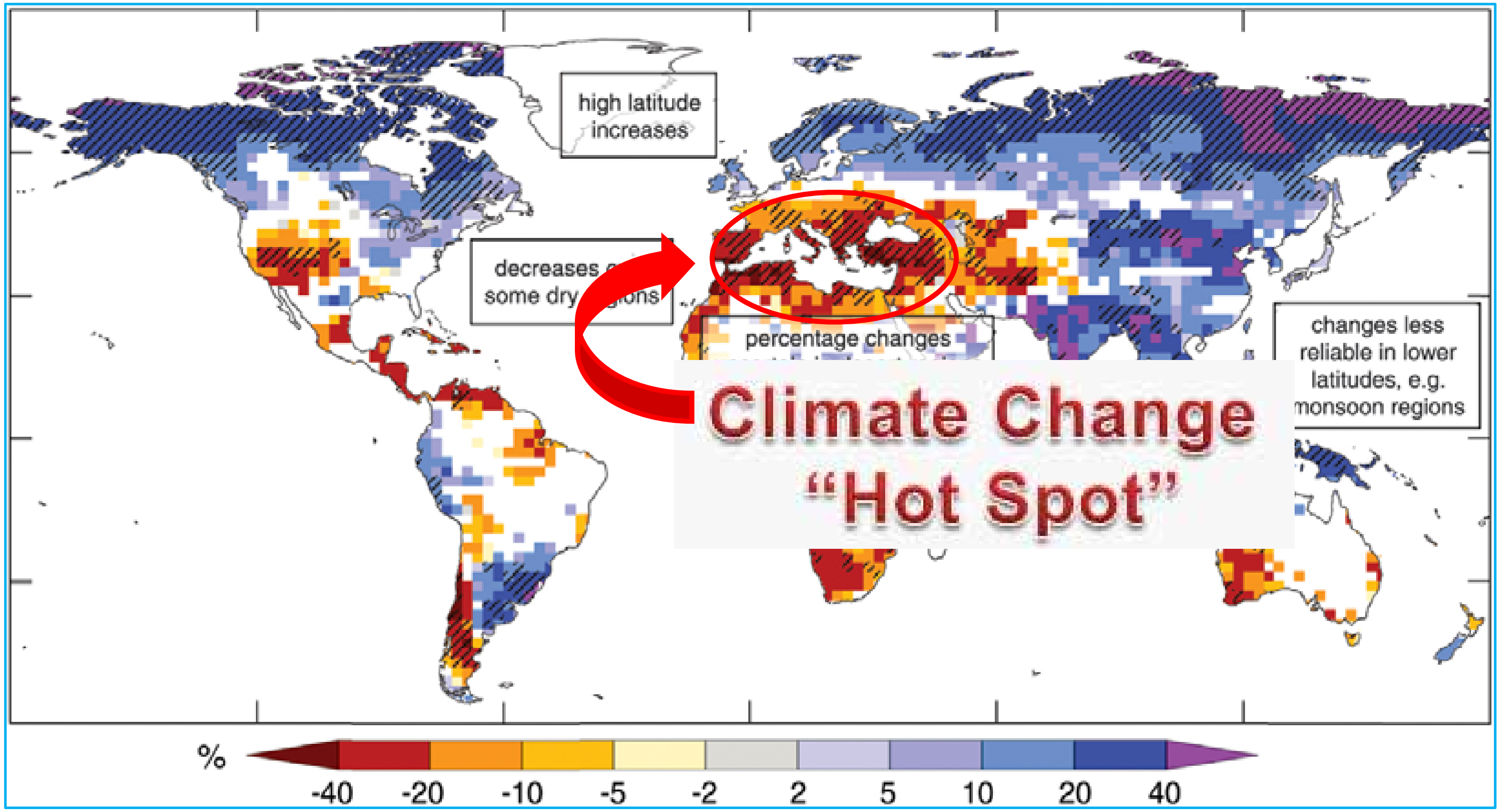
- Domestic Water Supply



Source: Water Development Department, 2009

Background and Introduction

- Anticipated change in precipitation regime: reason for concern
- We need to better understand and quantify changes in the precipitation regime and their impacts



Source: IPCC, 2007

Regional Climate Modeling

- Information on future climate development ⇨ numerical models as most reliable tool
- Global Climate Models (GCMs) have continuously been improved
- Advantages:
  - self-consistent, closed representation of global climate system
  - large body of experience
  - many groups worldwide
- Disadvantages:
  - computationally challenging
  - less satisfactory representation of smaller scale (regional) properties and processes
  - Insufficient spatial resolution of climate processes

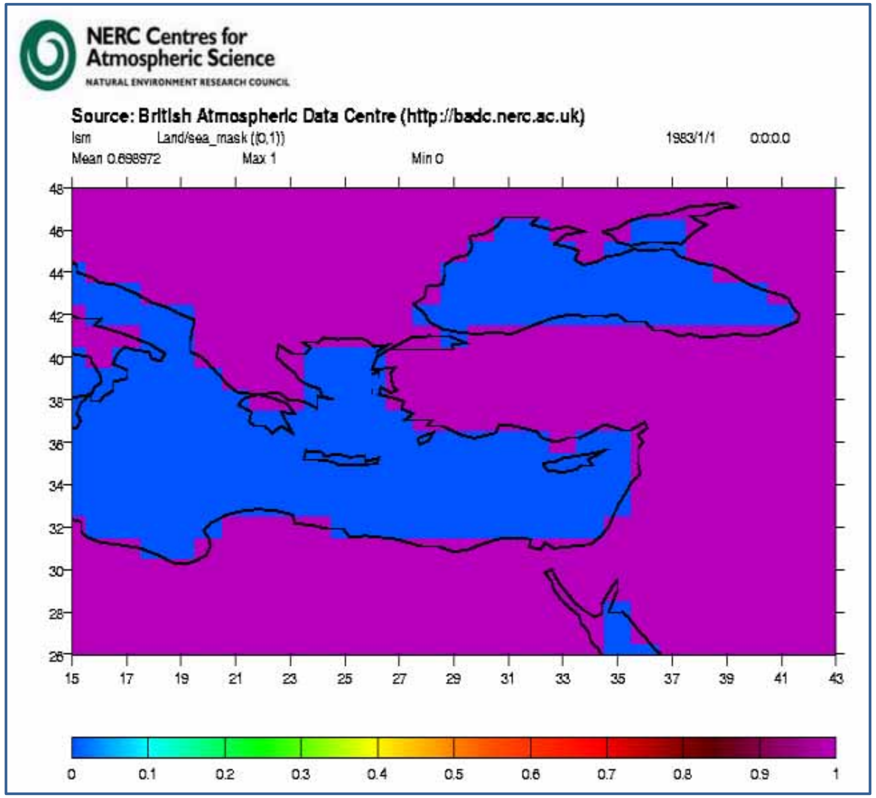
Regional Climate Modeling

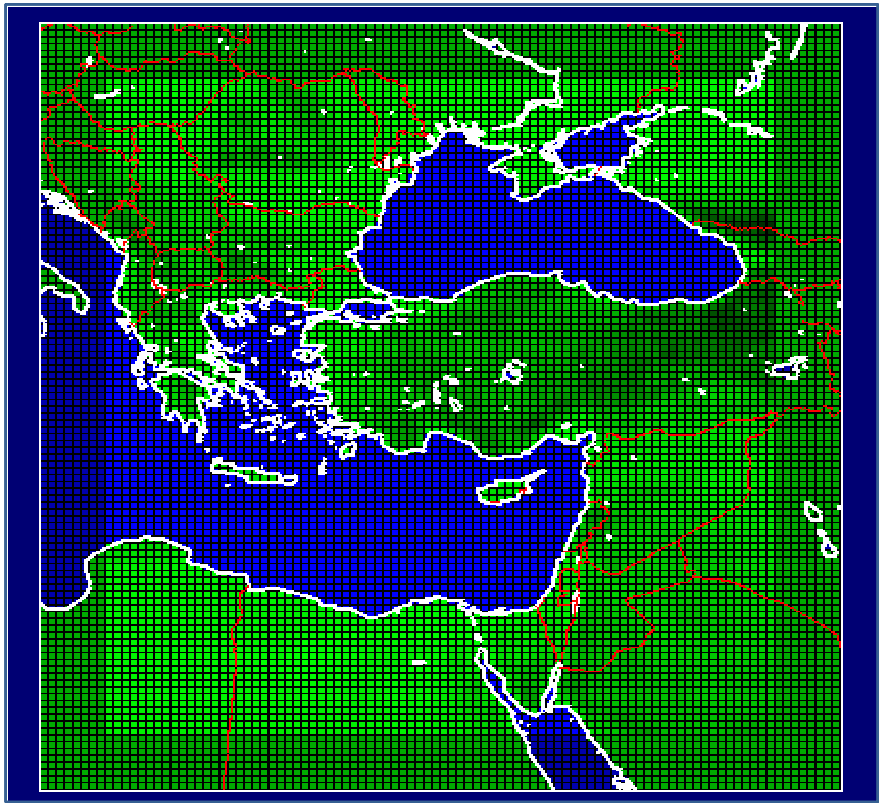
- Spatial representation ⇨ Regional Climate Models (RCMs)

GCM land-sea mask

RCM model grid

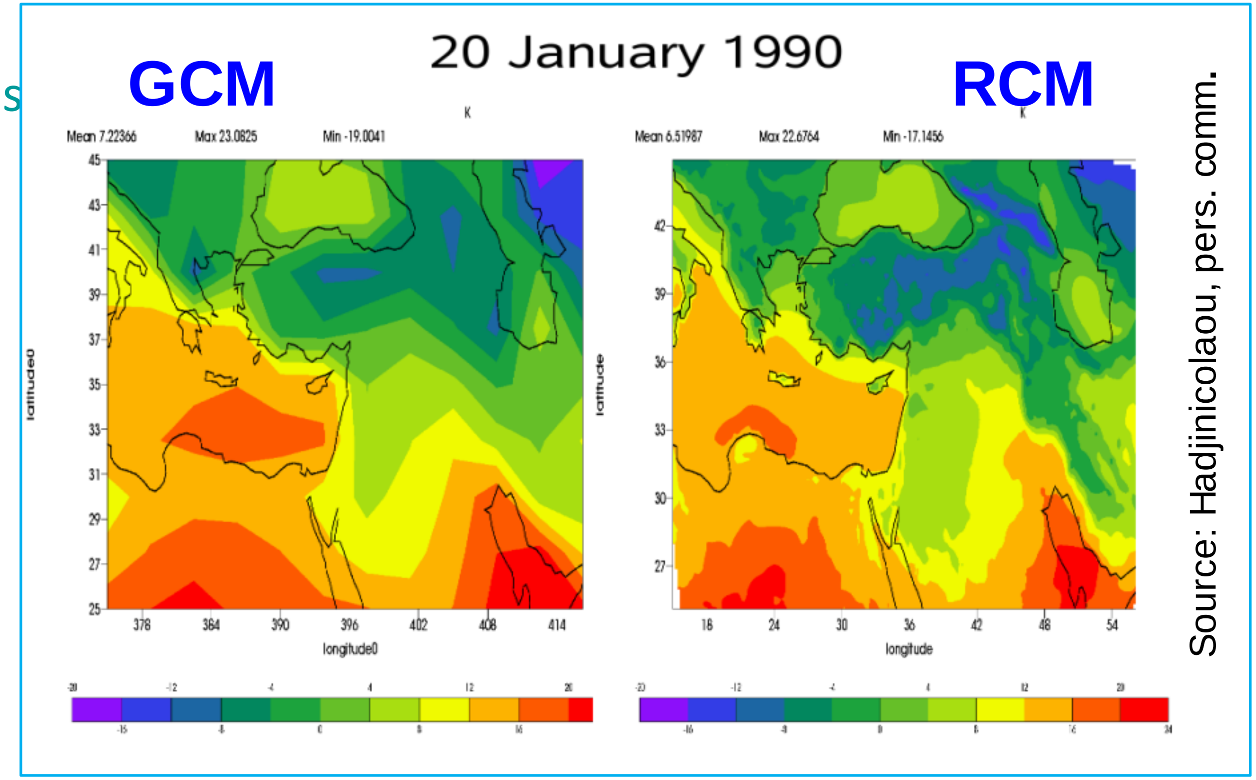
Source: Hadjinicolaou , pers. comm.





Regional Climate Modeling

- Characteristics of Regional Climate Models:
  - Better representation of regional to sub-regional properties and processes
  - Improved possibilities to address region-specific issues/questions
  - Computationally (usually) less demanding than GCMs
  - Rely on boundary conditions at the edges of the model domain
  - Usually provided through GCM output
  - „Inherit“ all uncertainties of GCMs as well as those of the underlying emission scenarios

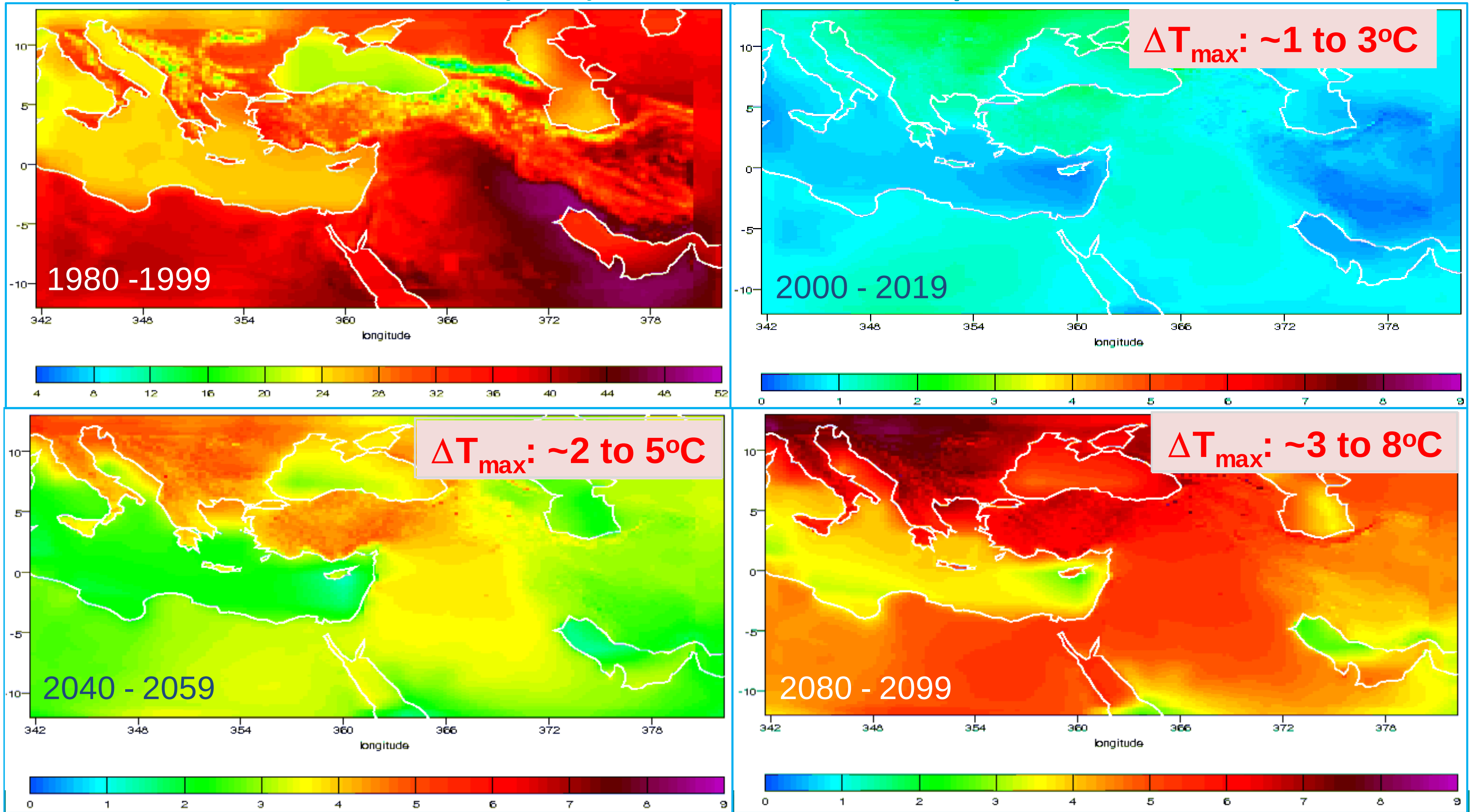


Regional Climate Modeling

- We have been using the PRECIS model (Providing REgional Climates for Impacts Studies; www.precis.org.uk)
  - spatial coverage: gridded 25 x 25 km
  - temporal frequency (separate files averaged over): decadal, yearly, seasonal, monthly, daily
  - ~ 150 variables decadal, yearly, seasonal, monthly
- Developed at the Hadley Centre of the UK Met Office; can be easily applied to any area of the globe to generate detailed climate change projections
- Application of PRECIS based on the UK Met Office HadCM3Q0 GCM
  - Coupled Ocean-Atmosphere model
  - Based on SRES A1B emissions scenario (medium)

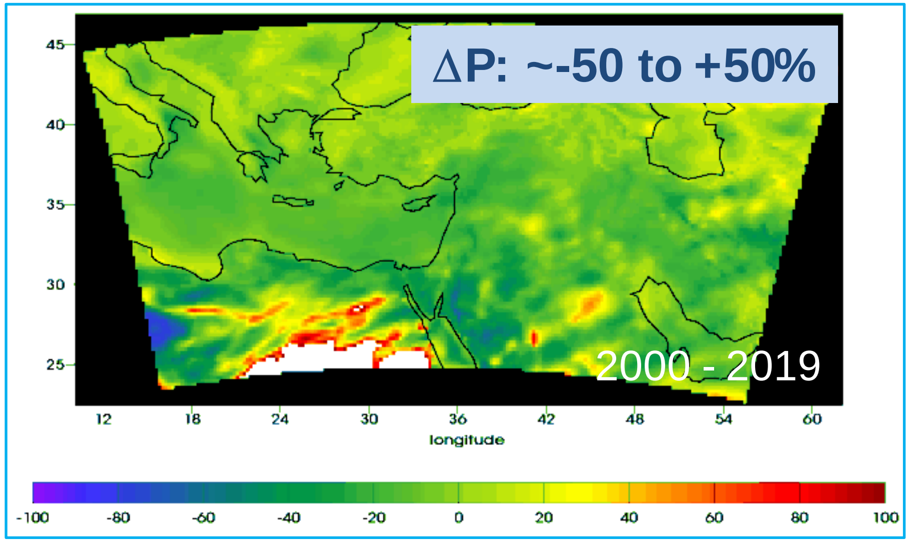
Results: Regional

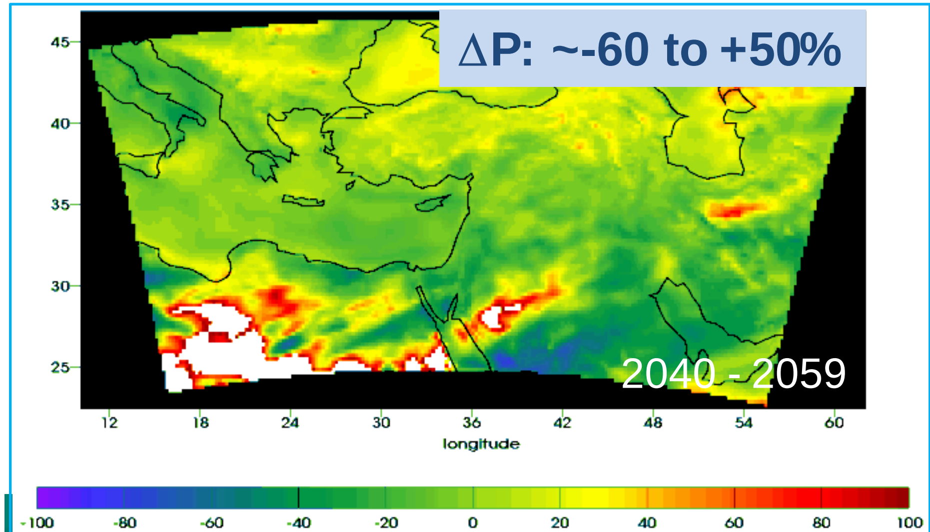
- Mean summer (JJA) maximum temperatures

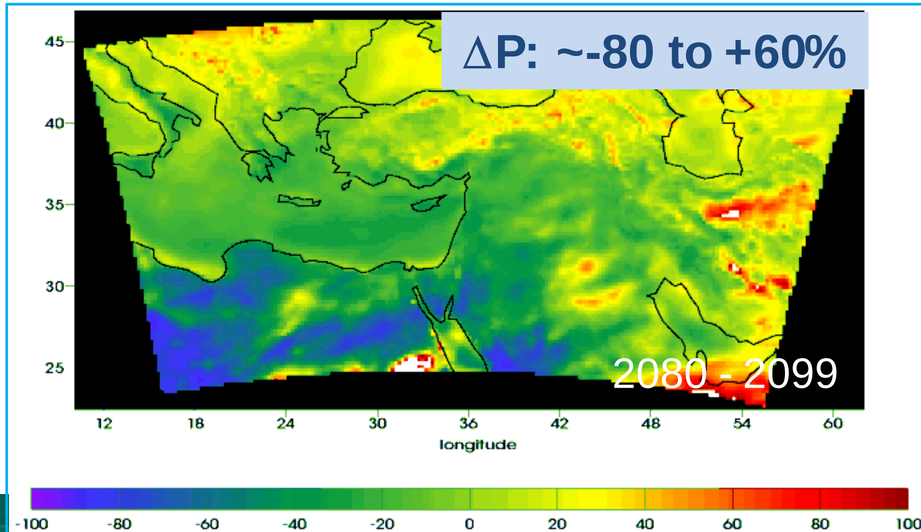


Results: Regional

- Winter precipitation (DJF)

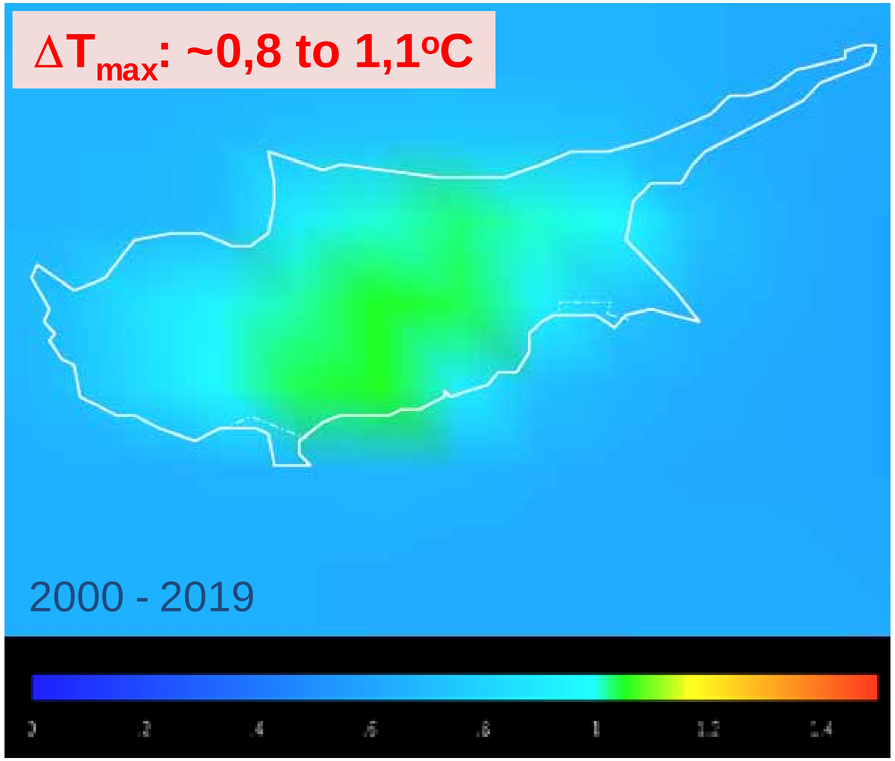


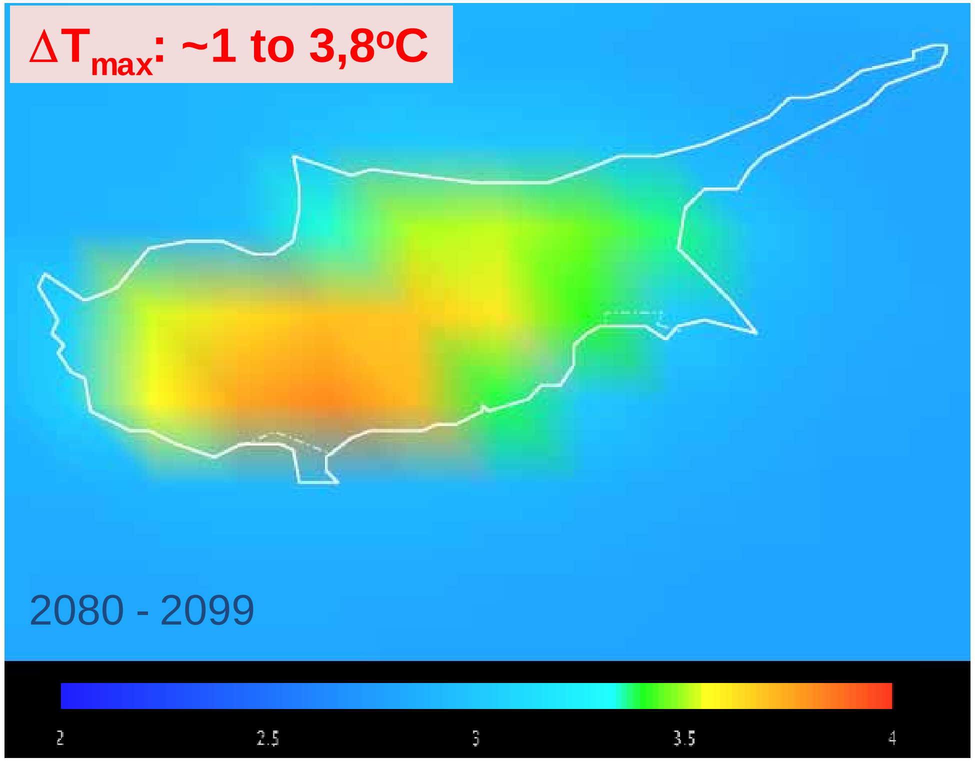




Results: Case Study - Cyprus

- Mean summer (JJA) maximum temperatures (rel. to 1980-99)





Results: Case Study - Cyprus

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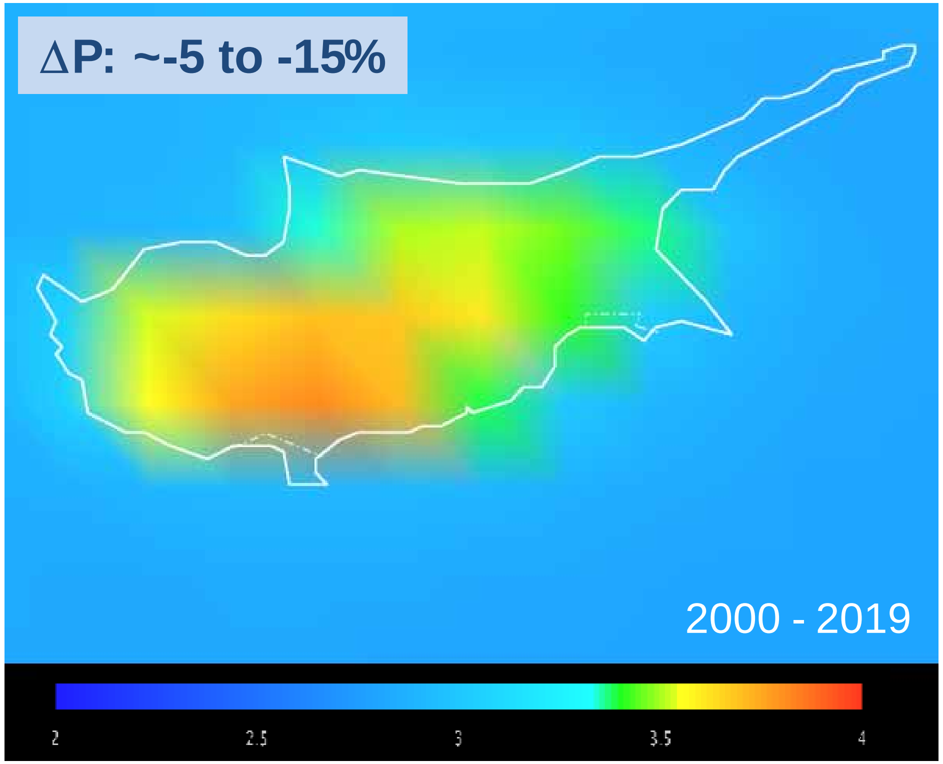
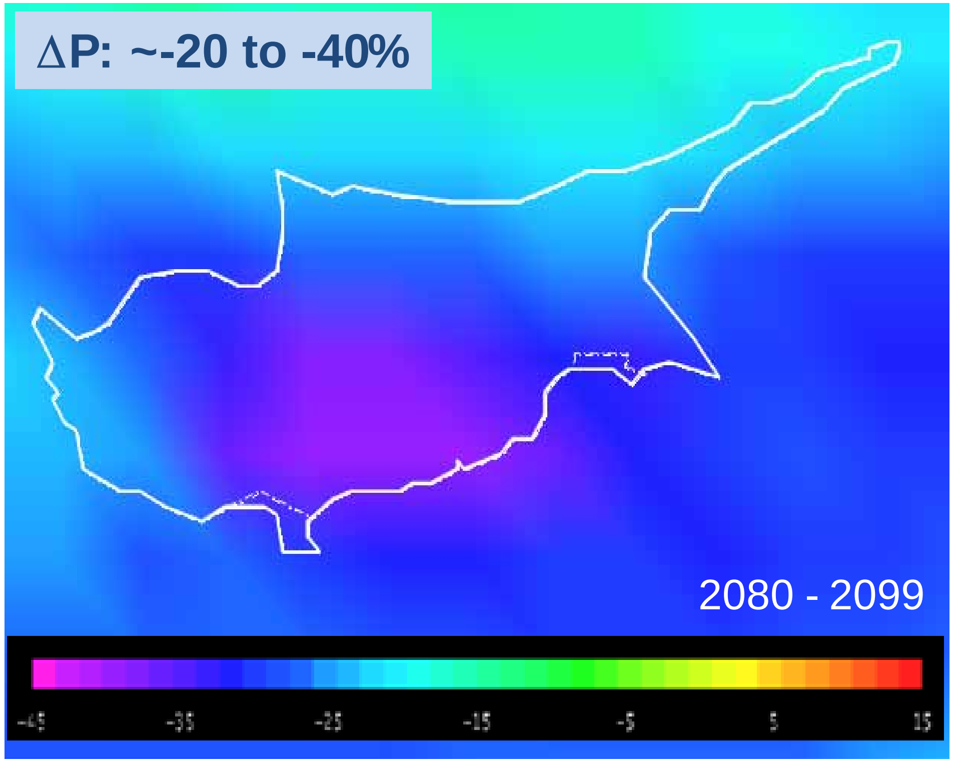
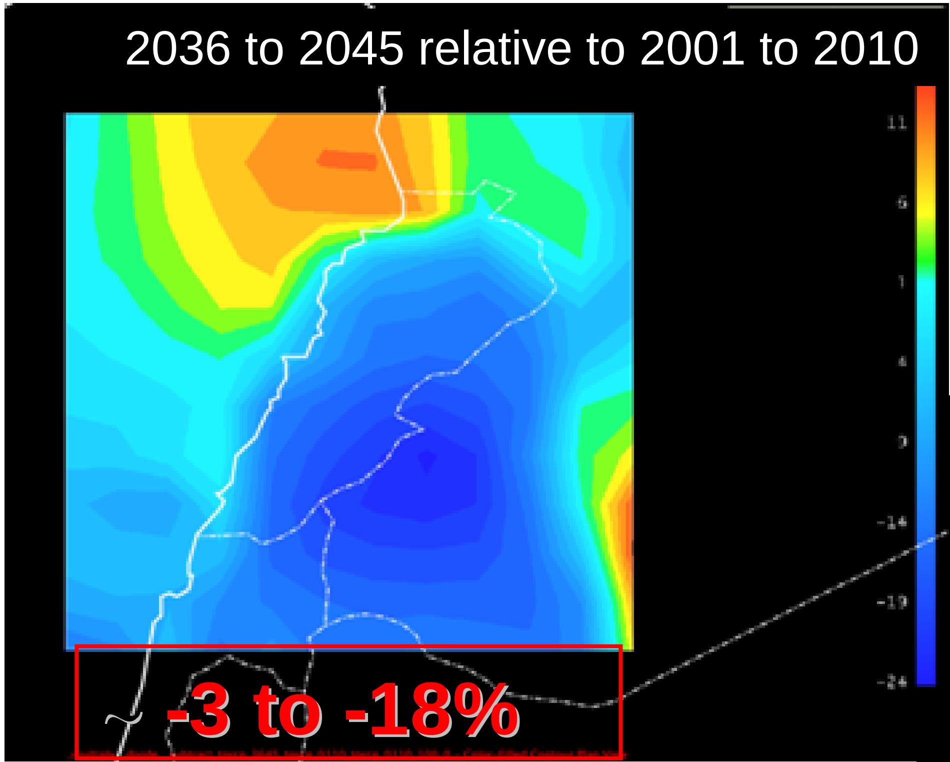
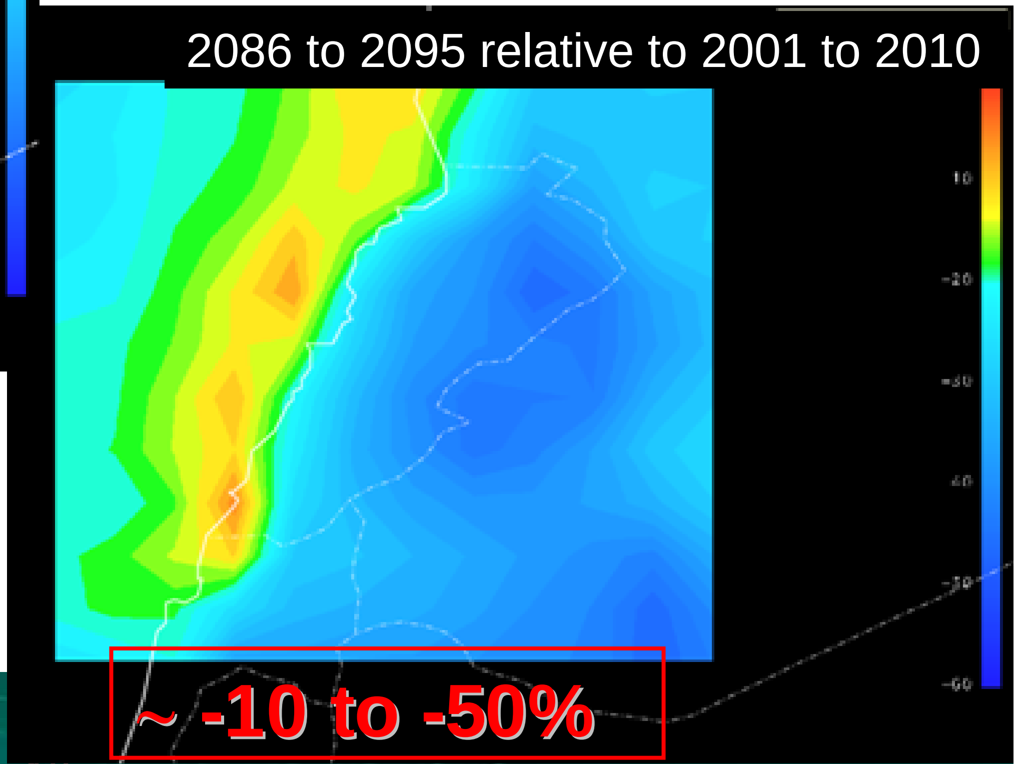




Results: Case Study - Lebanon

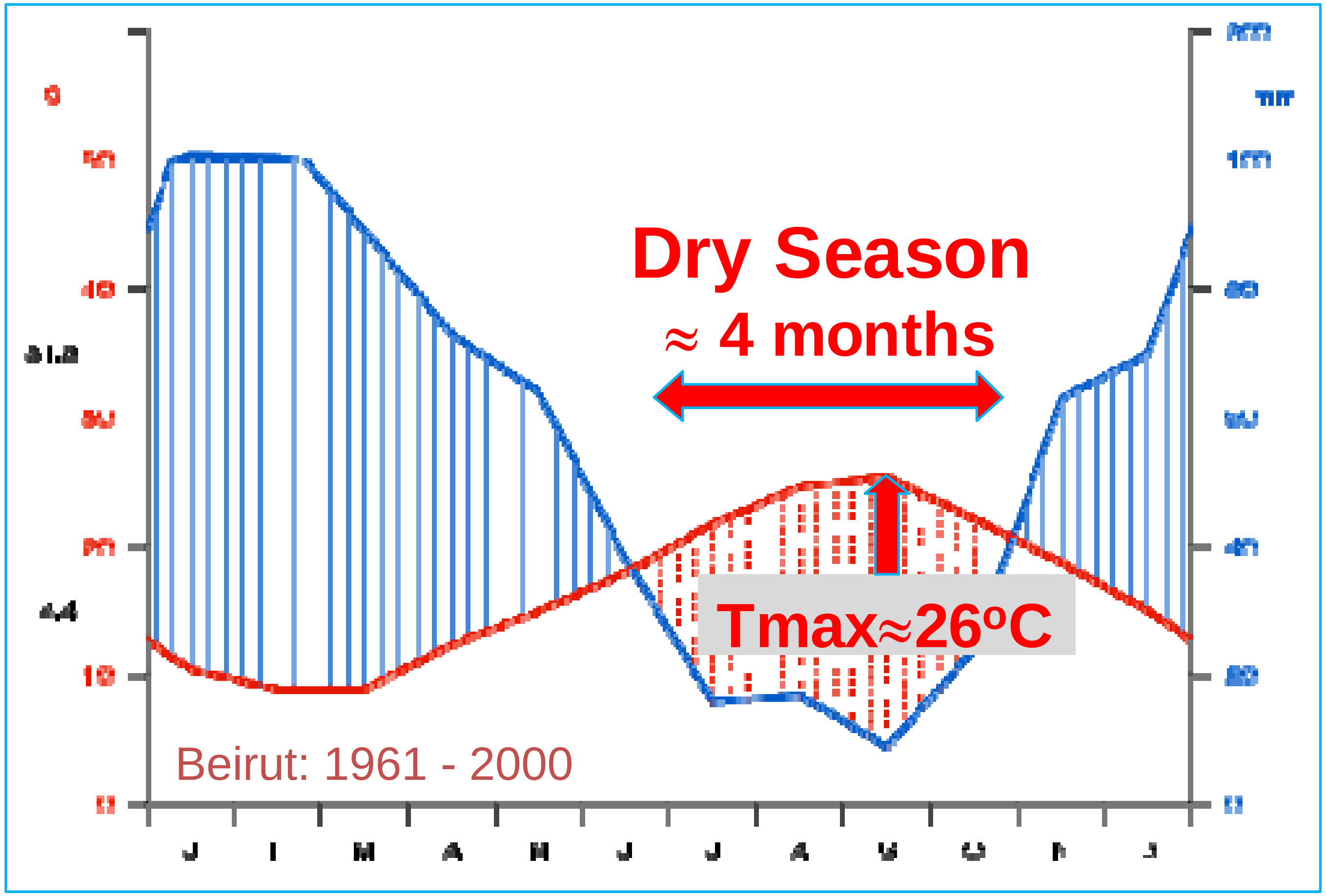
- Winter precipitation (DJF)





Results: Case Study - Lebanon

- Summer temperatures and the length of the dry season



Results: Case Study - Lebanon

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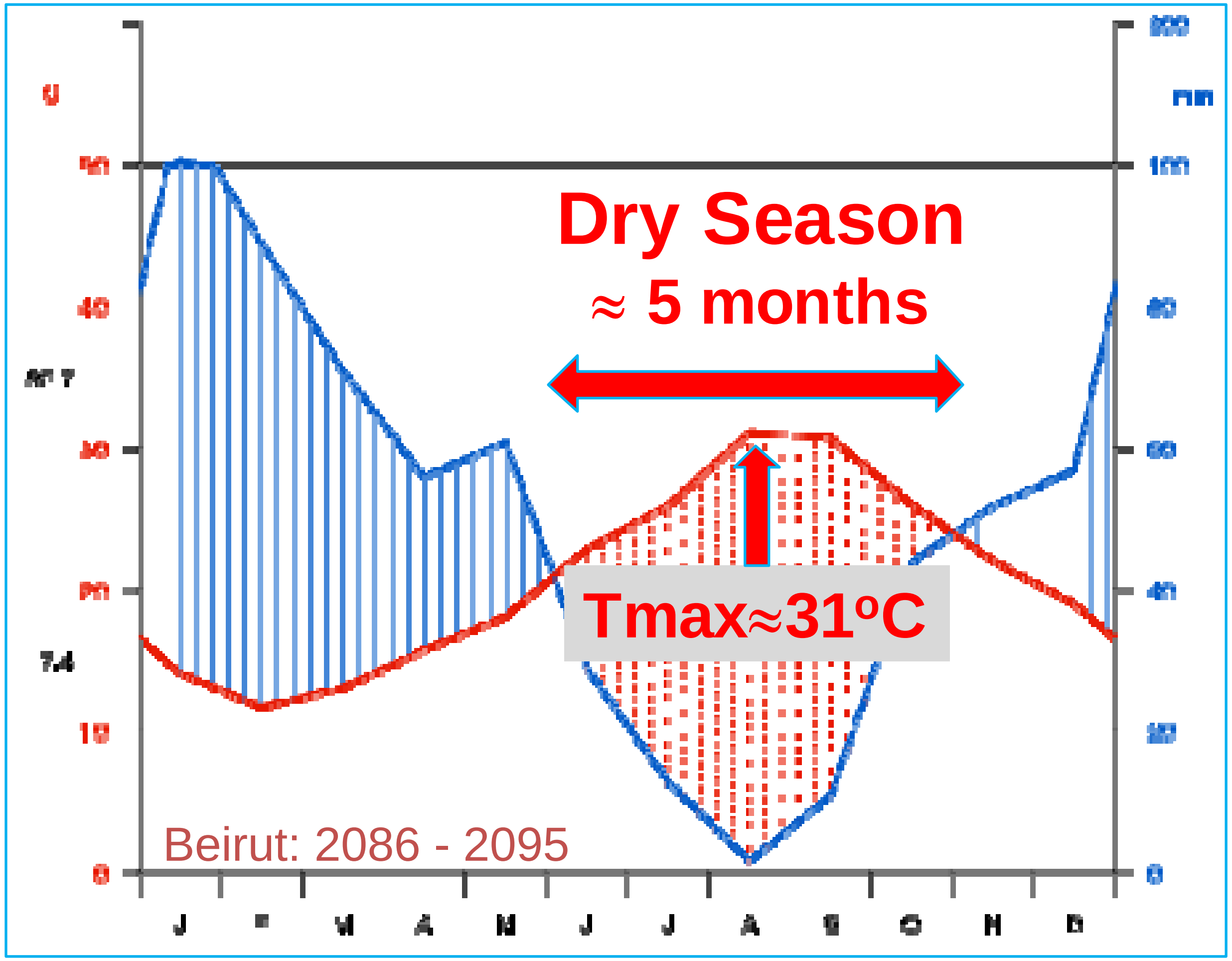


Discussions and Conclusions

- „Take-home-messages“ (up to now)
  - Global model results highlight the Mediterranean Basin as a climate change “hot spot“
  - Global climate change will lead to significant regional manifestations and resultant impacts
  - Regional climate modeling required to enable adequate representation of properties and processes on sub-GCM-grid-scales
  - RCM results give uniform and successively higher temperature rises in the Eastern Mediterranean throughout the 21st century
  - Precipitation changes more varied but successively larger decreases
  - Expected changes for Cyprus: significant sub-regional variations, but uniformly higher temperatures and lower precipitation
  - Expected changes for Lebanon : significant sub-regional variations, but increasingly higher summer temperatures, lower precipitation and lengthening of the dry season
  - We need to devise effective adaptation options/strategies

Discussions and Conclusions

- Adaptation Options/Strategies include (but are not limited to):
  - Planning for extremes (droughts), such as safeguarding domestic water supply through increased desalination
  - Planning for extremes (floods): modeling and mapping flood extends and hazards
  - Artificial recharge of groundwater resources by reservoirs and check dams
  - Recharge of groundwater in severely depleted aquifers by tertiary-treated sewage water
  - Integrated modeling, management and cost recovery of groundwater use, under Water Framework Directive
  - Improving rainfall-runoff management and use in urban areas, such as water harvesting for landscaping and groundwater recharge
  - Improved leakage detection in urban water distribution systems


Flood-induced road destruction in Badia, Syria; source: Bruggeman

Discussions and Conclusions

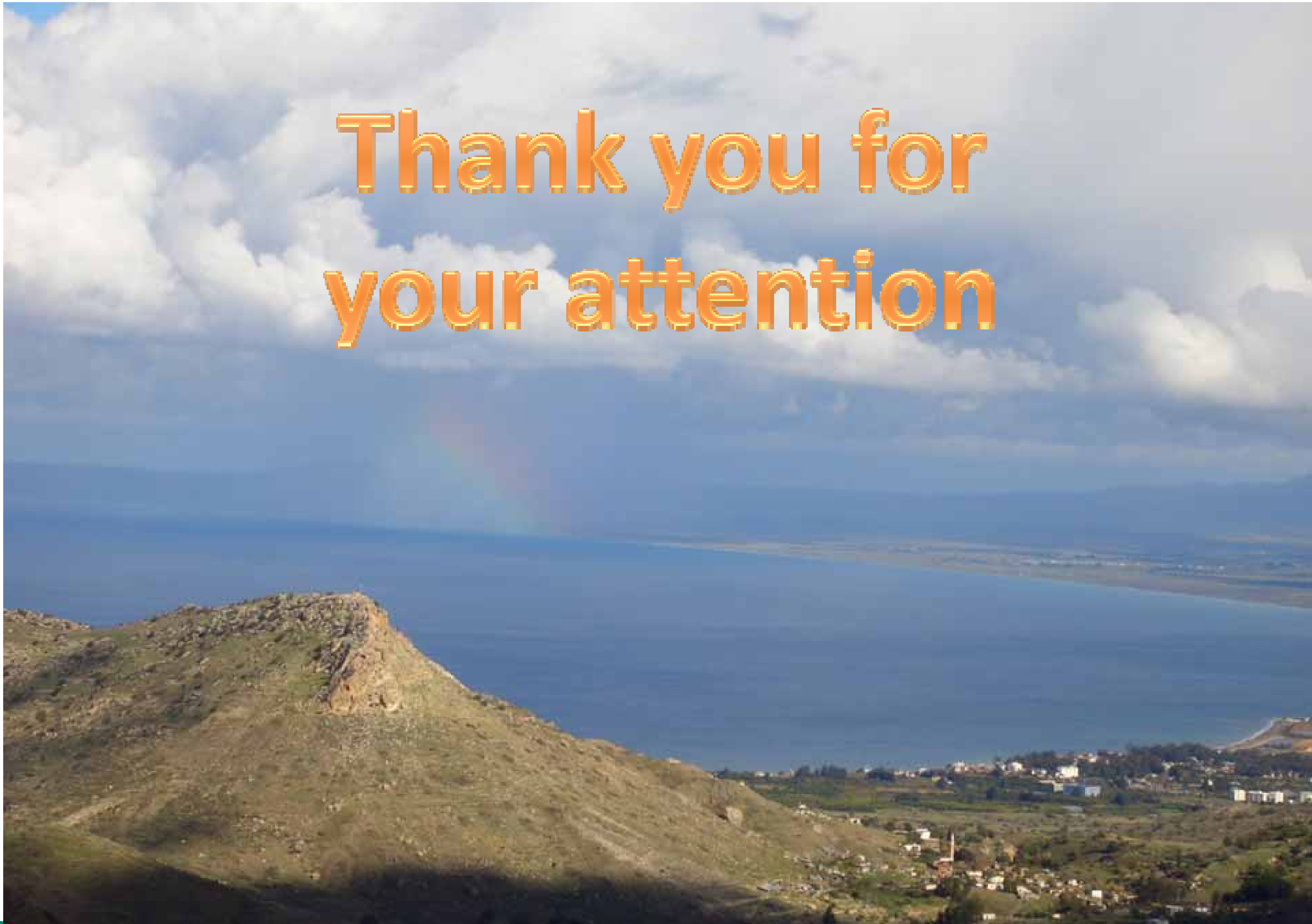
- Adaptation Options/Strategies include (but are not limited to):
  - Drought tolerant crops and natural vegetation, such as olives, barley, and Atriplex shrubs
  - Supplemental irrigation of rain-fed winter crops instead of full irrigation of summer crops
  - Irrigation of selected crops with treated sewage water
  - Rainwater harvesting
  - Reforestation of marginal, abandoned agricultural lands
  - Analysis of environmental flow requirements and options
  - Policies to reduce water demand, such as subsidies and extension support for modern irrigation systems

Drought-tolerant olive tree, Idalion, Cyprus; source: Bruggeman

Rainwater harvesting, Ierapetra, Crete; source: Lange

Discussions and Conclusions

- There is a clear need for more research, which includes (but is not limited to):
  - Improved RCMs with higher spatial resolution and more appropriate parameterization of various climate relevant processes
  - Increased spatial resolution (decreased grid-size) of GCMs
  - Better integration of hydrological/water-management models into RCMs or high-resolution GCMs
  - Truly integrated impact assessments that do not „only“ deal with individual sectors or compartments (e.g., water)
  - Holistic adaptation strategies aiming to „optimize“ measures for various economical and societal sectors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