# Climate and Climate Change in the Mediterranean Basin and on Cyprus

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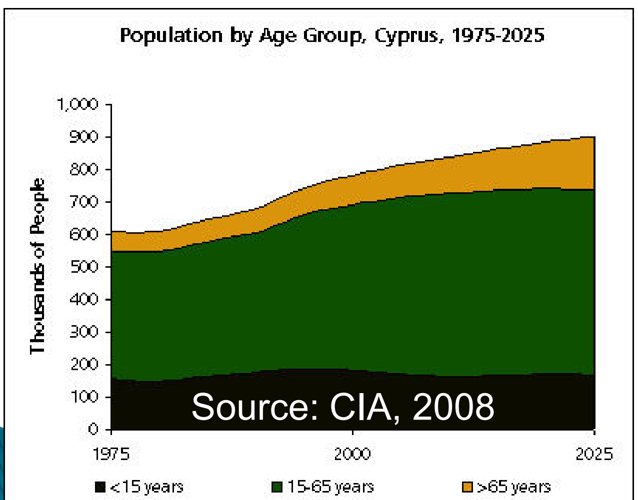
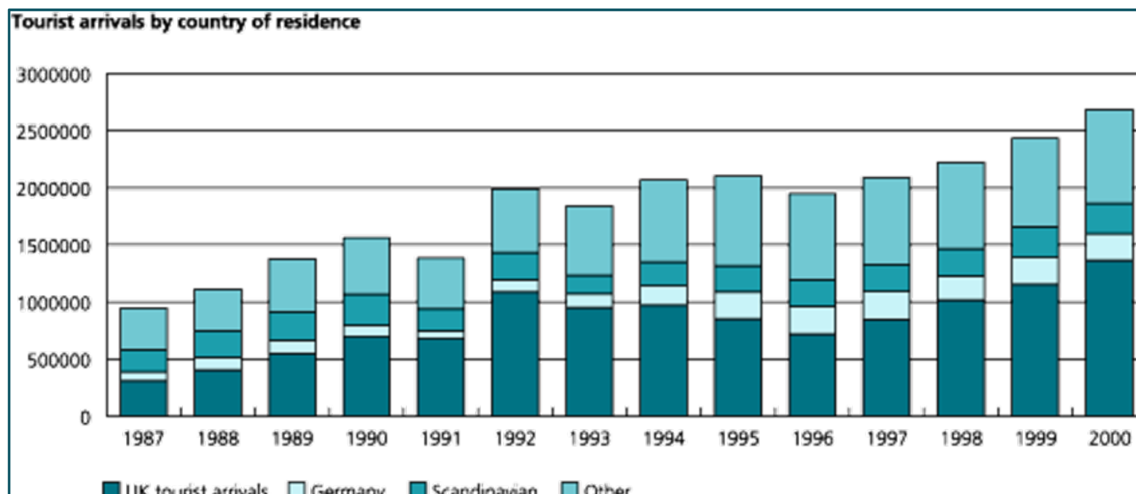
# Outline

- Background and Introduction
- Mediterranean Climate
  - Past and Current Conditions
  - Tele-Connections
- Climate Projections
  - Climate Modeling – Some Basic Facts
  - Future Climate Scenarios
- Regional Climate Projections
  - Temperature Scenarios
  - Precipitation Scenarios
- Conclusions

# Background and Introduction

- Cyprus
  - Area : 9 250 km$^2$
  - Population *) of 792 600 inhabitants + 2 to 3 Million tourists per year
  - Population expected to grow, primarily due to "retirees"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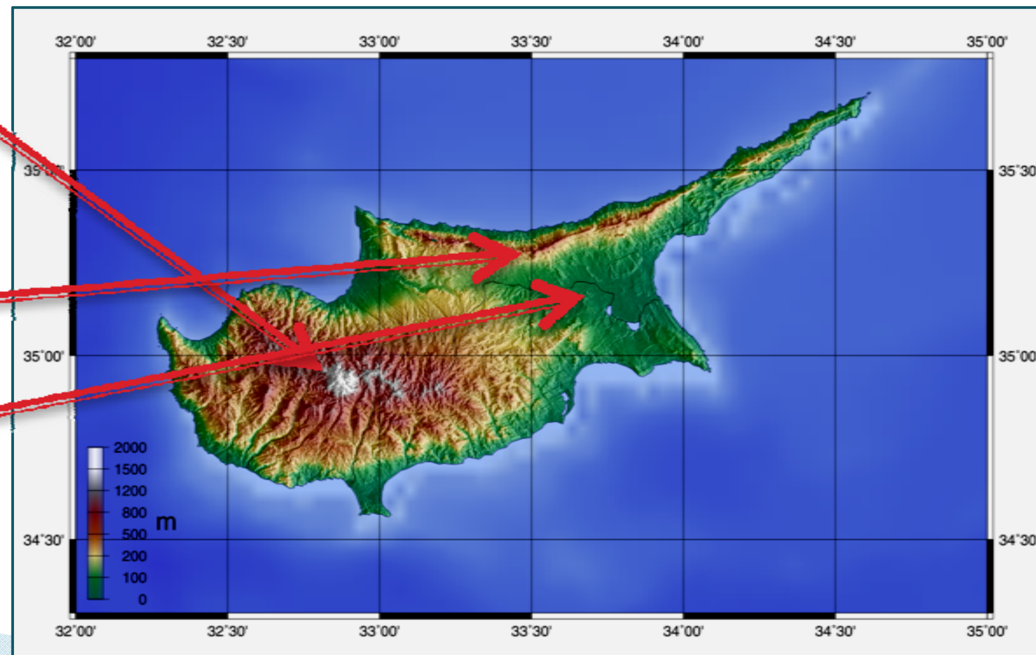
*) only Republic of Cyprus without the northern part of Cyprus

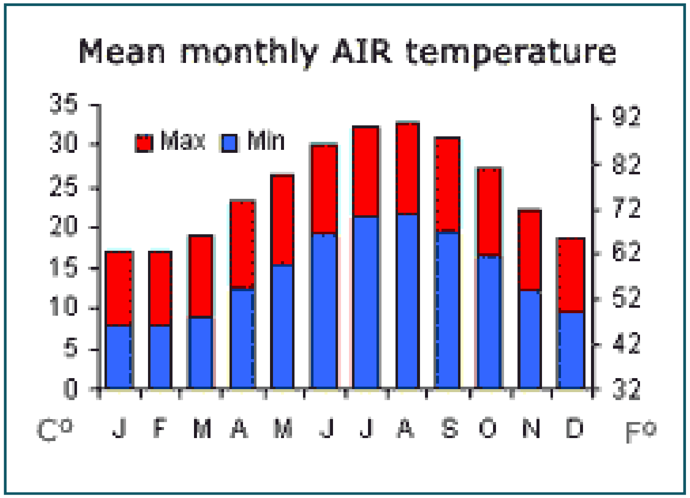
# Background and Introduction

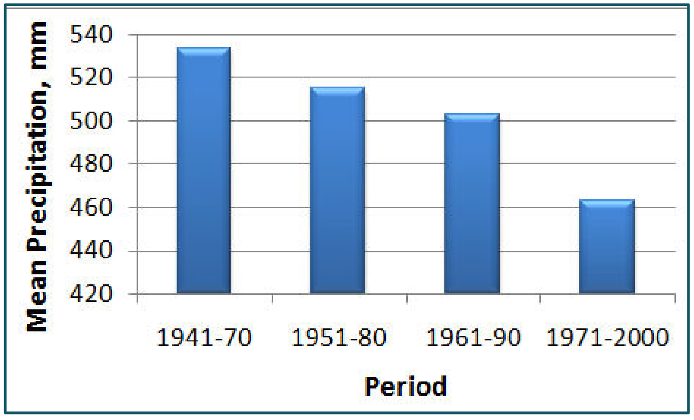
- Cyprus is...
  - the 3rd largest island after Sicily and Sardinia in the Mediterranean
  - is situated at 33°E and 35°N
  - its maximum territorial dimensions are north-south 97 km and east-west 241 km
  - 19% of the total area is forested, 47% is arable land and the remaining 34% is cultivated land
  - Geomorphology of the island is dominated by
    - two mountain ranges:
      - Troodos range, rising to 1951m and covering about 1/3 of its area and
      - the Kyrenia range at the north, rising to 1085m
    - Between the two ranges: the Mesaoria Plain



# Background and Introduction

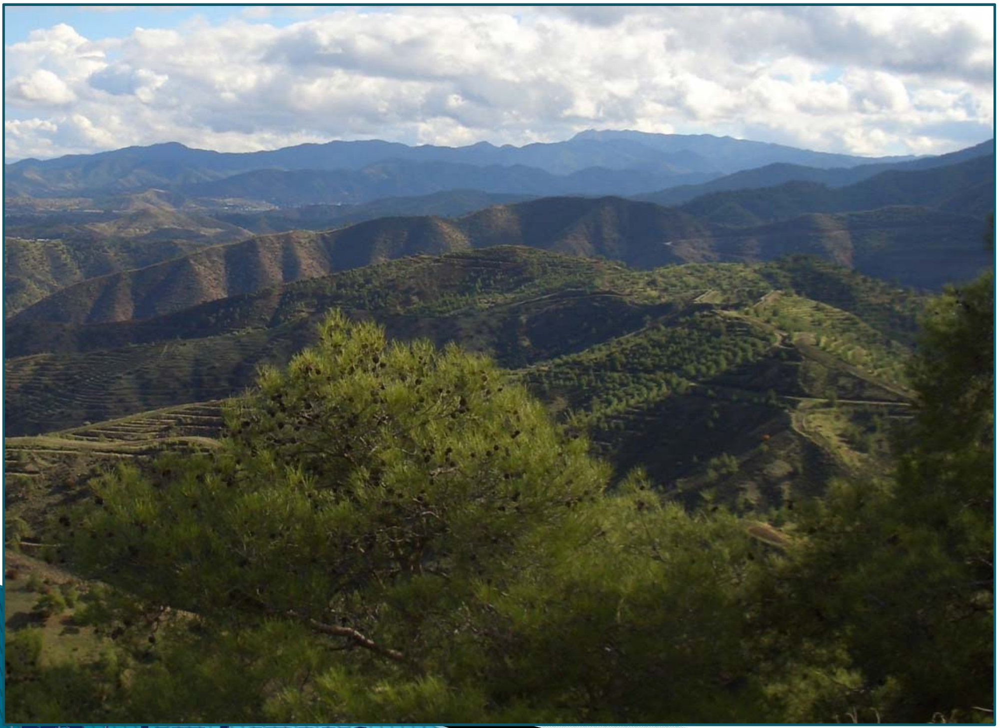
- Cyprus is characterized by a Mediterranean, semi-arid climate with
  - hot dry summers from mid-May to mid-September
  - rainy, rather changeable winters from mid-November to mid-March separated by
  - short Spring and Autumn seasons
  - mean annual precipitation of 460mm with considerable inter-annual variations
  - climatological values of precipitation have been falling over last 50 years
  - Precipitation varies from 300mm in the plains to over 1000mm on the higher parts of the Troodos range



# Background and Introduction

- The natural vegetation of Cyprus is characterized by two basic groups:
  - *Maquis*–Shrublands
    - vegetation consists mainly of tall bushes and trees
  - *Phrygana–garrigue*–Scrublands
    - vegetation consists mainly of low scrubs

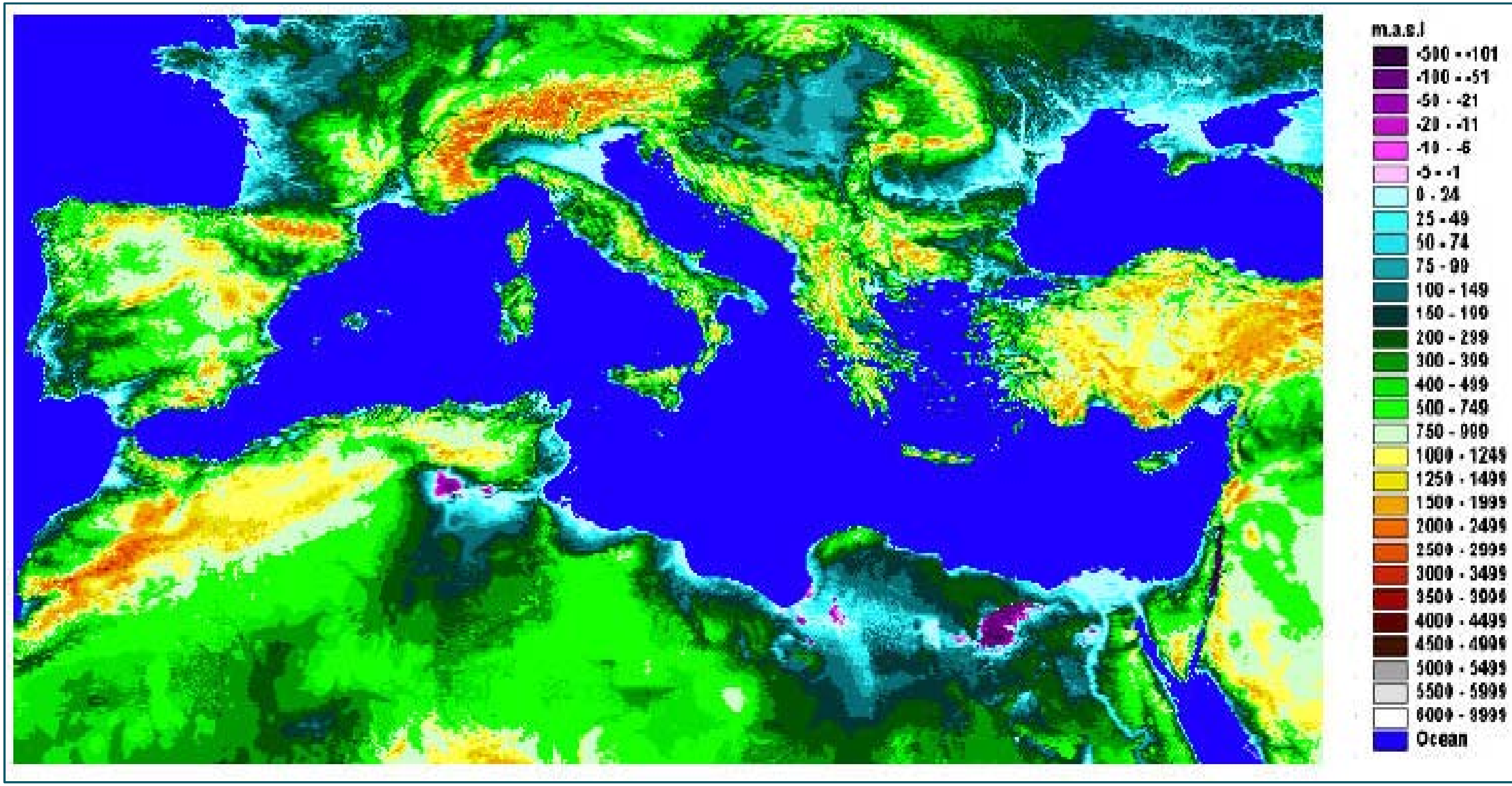


# Mediterranean Climate

- The Mediterranean Basin marks a transitional zone between the deserts of North Africa and central and northern Europe
- Mediterranean climate is exposed to
  - the South Asian Monsoon (SAM) in summer,
  - the Siberian High Pressure System in winter,
  - the El Niño Southern Oscillation (ENSO) and
  - the Arctic- (AO) and North Atlantic Oscillation (NAO)
- Main physical and physico-geographical factors controlling the spatial distribution of the climatic conditions over the Mediterranean are
  - the atmospheric circulation,
  - the latitude,
  - the altitude and
  - the orography

# Mediterranean Climate

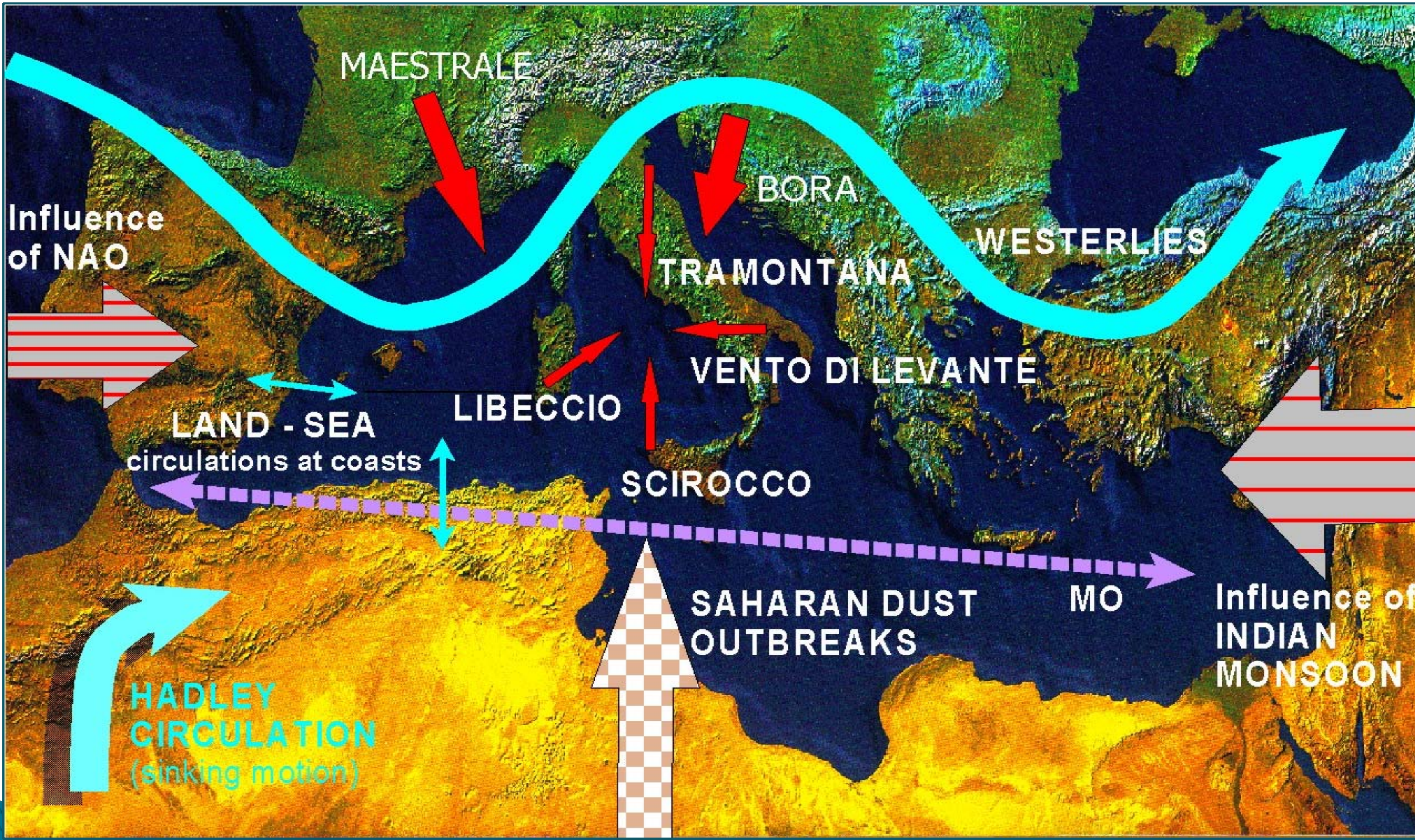
- Main Orography of the Mediterranean Basin




Topographic Map of the Mediterranean Basin, Xoplaki, 2005

# Mediterranean Climate

- Major climate elements of the Mediterranean




Major elements influencing the climate of the Mediterranean Basin, Bolle, 2003

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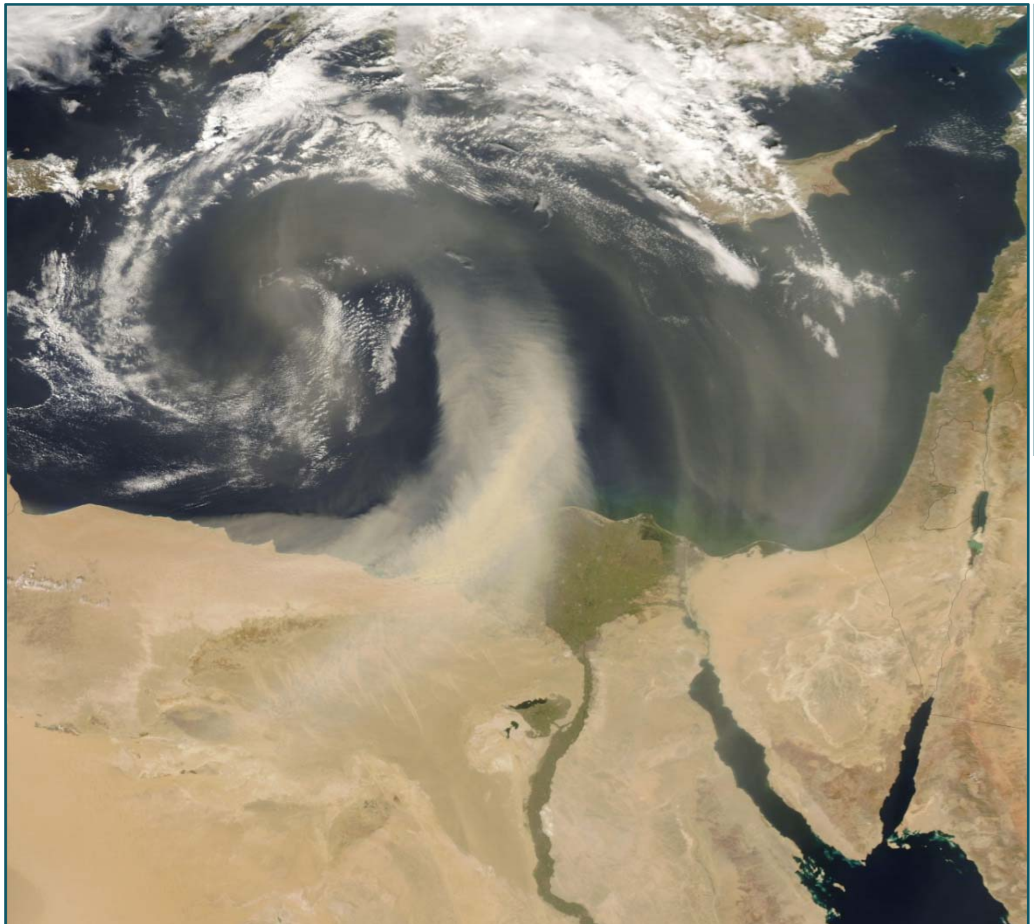
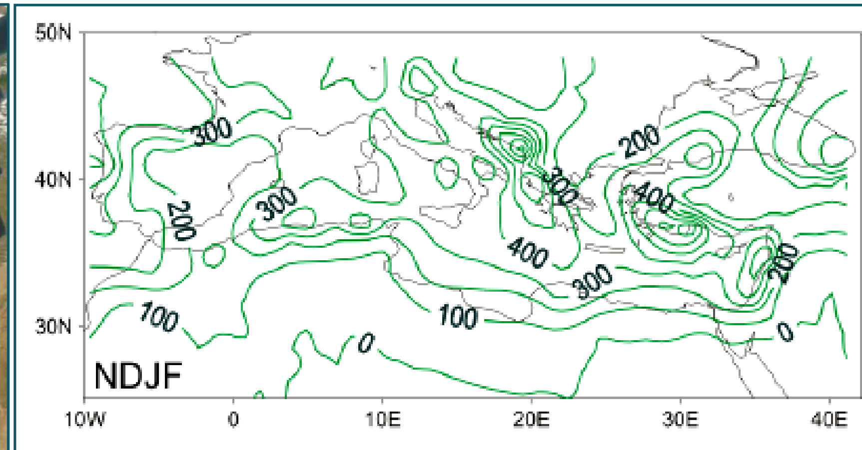
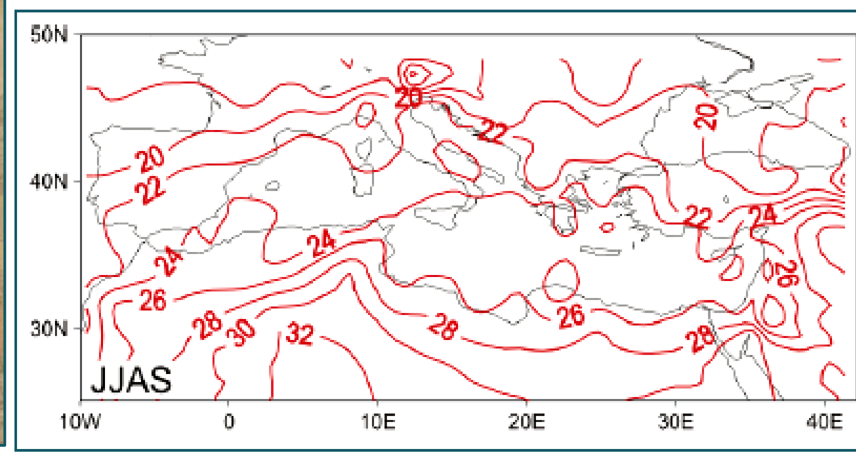
# Mediterranean Climate

- Current climatic conditions of the Mediterranean



Dust storms, originating over the north-eastern Sahara are a frequent phenomenon in the eastern Mediterranean Basin, NASA Quickbird, 26.9.2008




Winter (NDJF) mean precipitation (mm; top) and summer (JJAS) mean temperatures ($^{o}C$; bottom) for 1930-1999 for the larger Mediterranean Basin, Xoplaki, 2005

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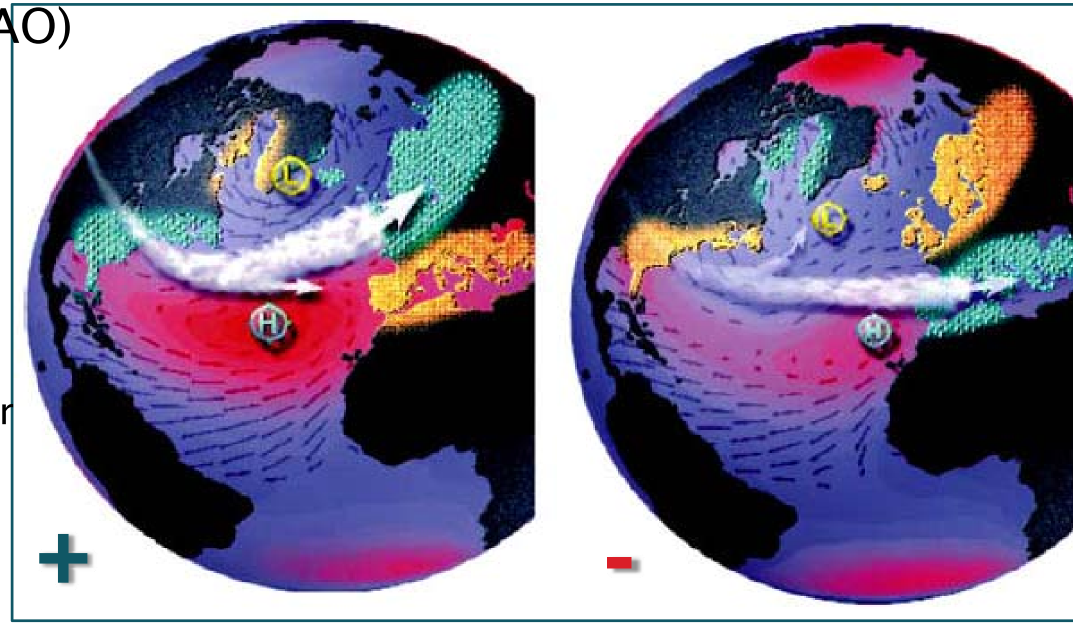
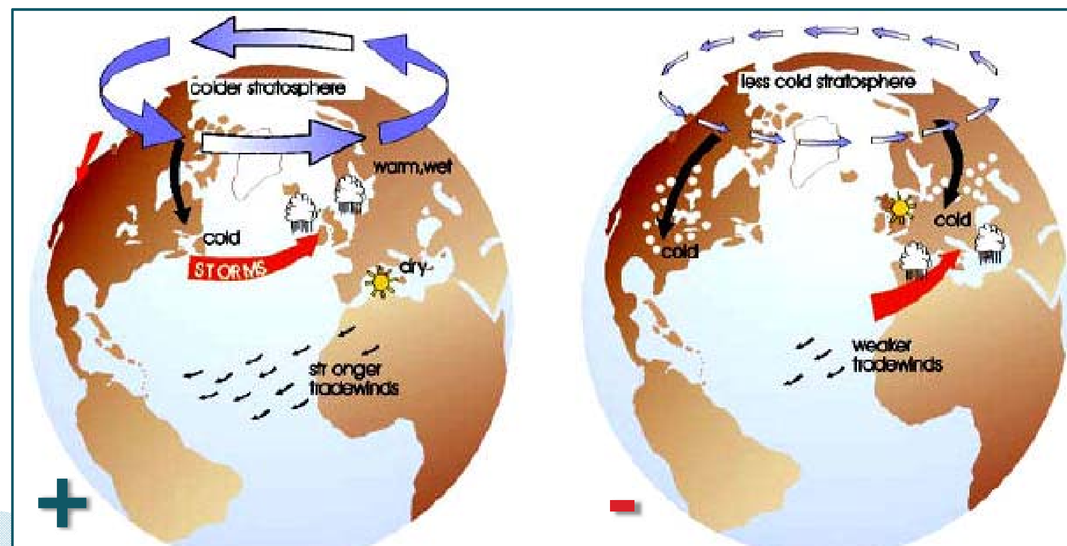
# Mediterranean Climate

- Tele-connections affecting Mediterranean climate
  - North Atlantic Oscillation (NAO)
    - most important large-scale mode of climate variability in the Northern Hemisphere
    - significant fluctuation of atmospheric  air masses
      - Positive NAO: warm and wet winters for Europe, less rain for Mediterranean
      - Negative NAO: more rain for Mediterranean

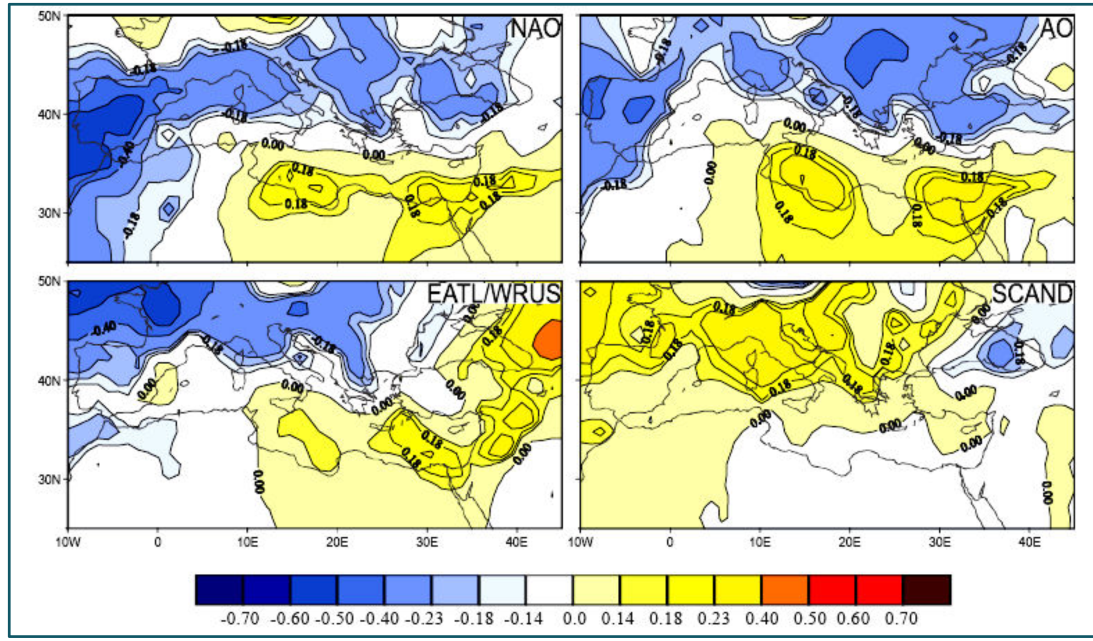



  - Arctic Oscillations (AO)
    - dominant pattern of non-seasonal sea level pressure
    - (SLP) variations north of 20°N vs 37°N-45°N
      - Positive AO dry, sunny, weak inflow
      - Negative AO: wet, cloudy, strong inflow

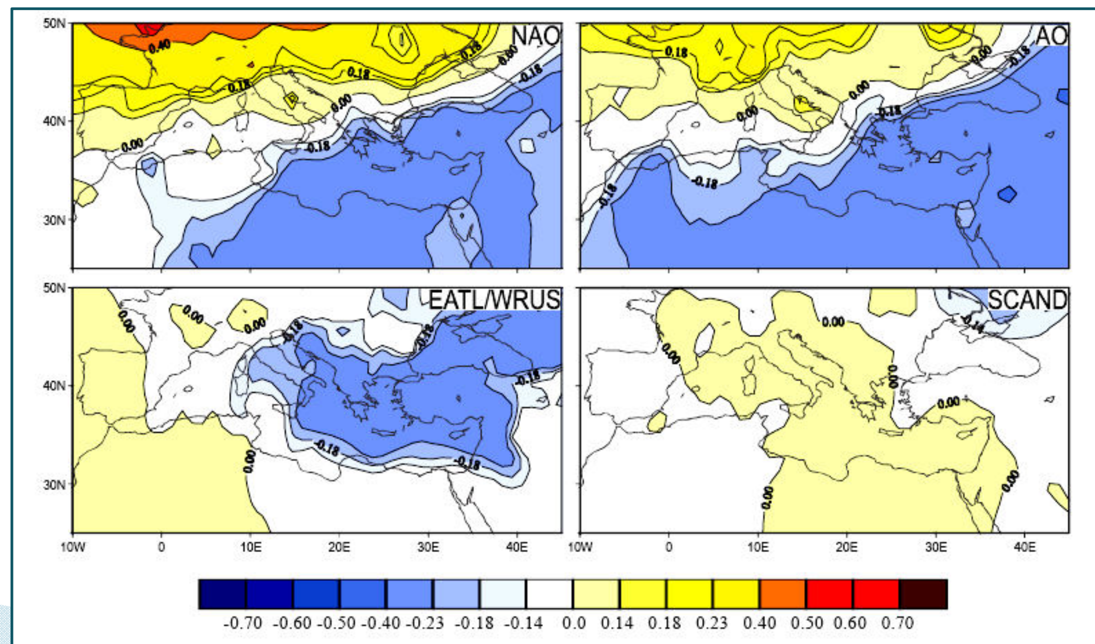


# Mediterranean Climate

- Tele-connections: Mediterranean climate and major oscillations
  - Precipitation
  - Temperatures




Spatial correlation between tele-connection patterns and winter (NDJF) mean precipitation (mm) for 1950-1999 for stations in the larger Mediterranean Basin, Xoplaki, 2005




Spatial correlation between tele-connection patterns and summer (JJAS) mean temperatures ($^oC$) for 1950-1999 or stations in the larger Mediterranean Basin, Xoplaki, 2005

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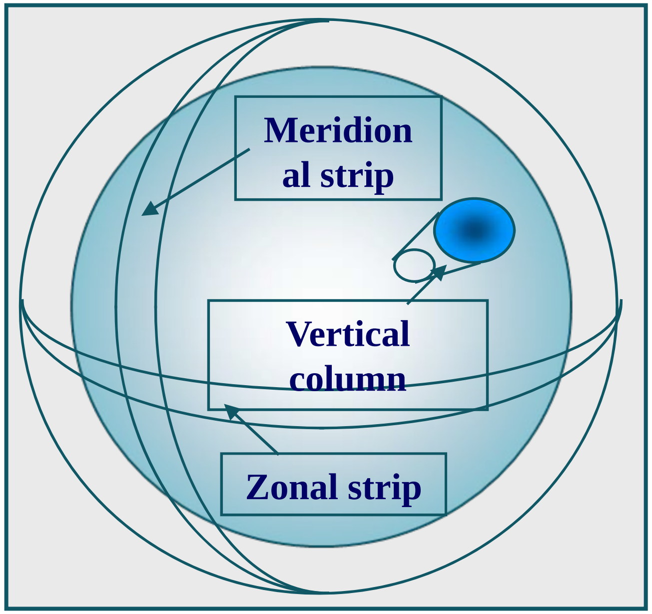
# Climate Projections

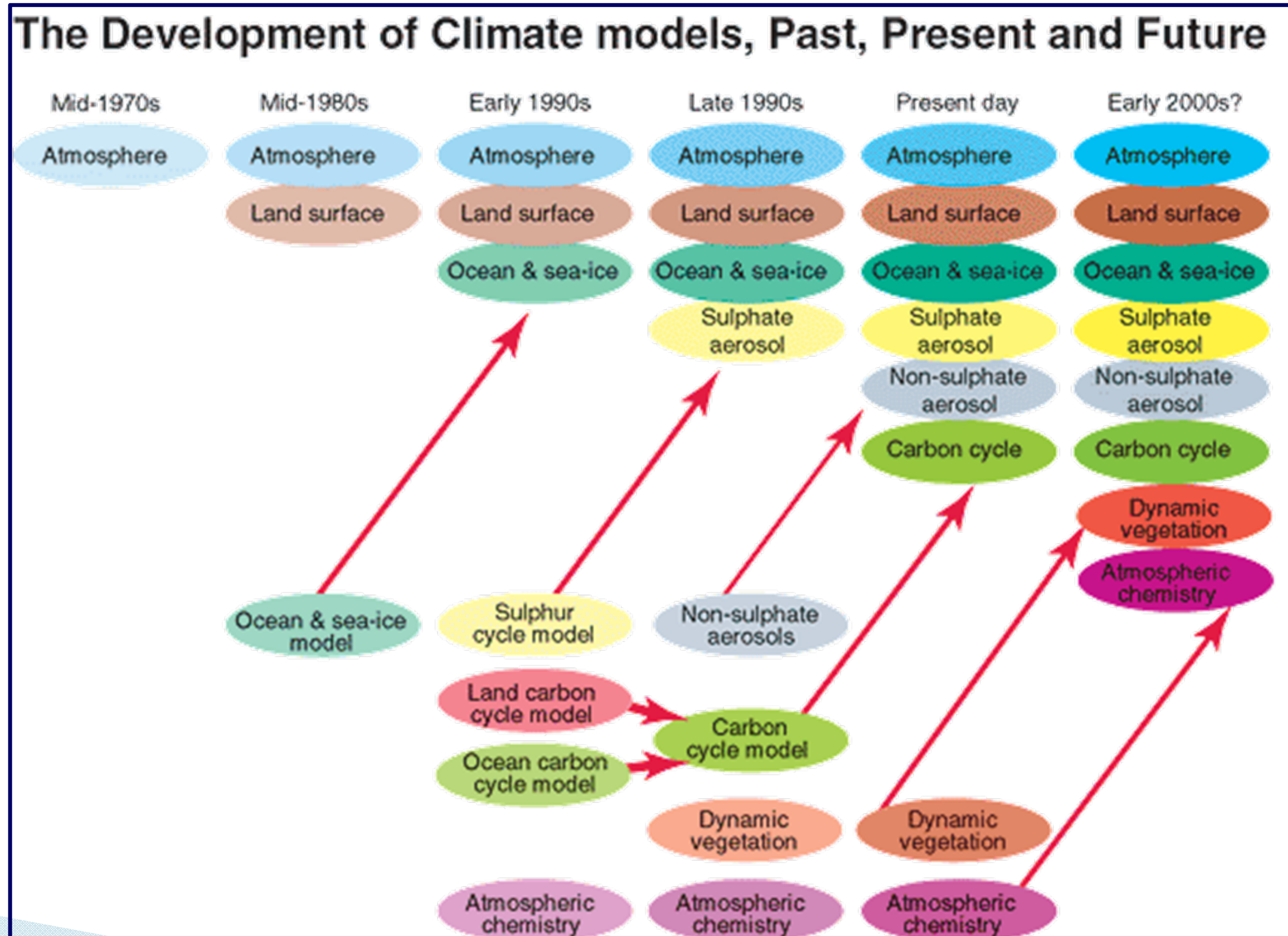
- The climate of the future cannot be assessed through measurements ⇨ numerical climate modeling
- Climate models
  - are ‚long-term versions‘ of weather prediction models
  - are in accordance with the First Principle of Thermodynamics and the radiation laws and a number of additional equations:
    - Three equations of motion: meridional, zonal, vertical movements/transports based on Newton‘s 2. Law (conservation of momentum)
    - In addition, the rotation of the Earth has to be accounted for through a *Coriolis term*
    - An equation of state for ideal gases
    - The continuity equation (conservation of mass)




Basic concepts of the meridional, zonal and vertical approach to climate characteristics

# Climate Projections

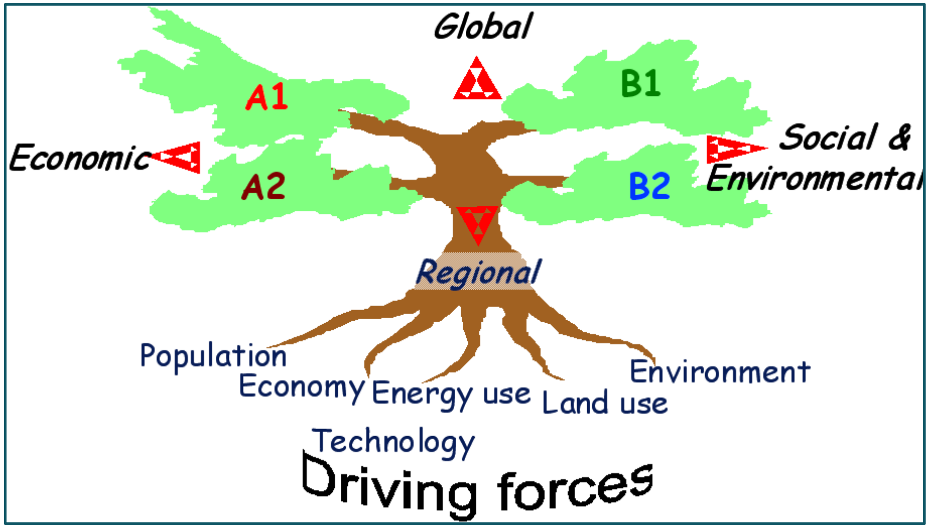
- Climate modeling has seen significant development
  - more processes
  - More powerful computers



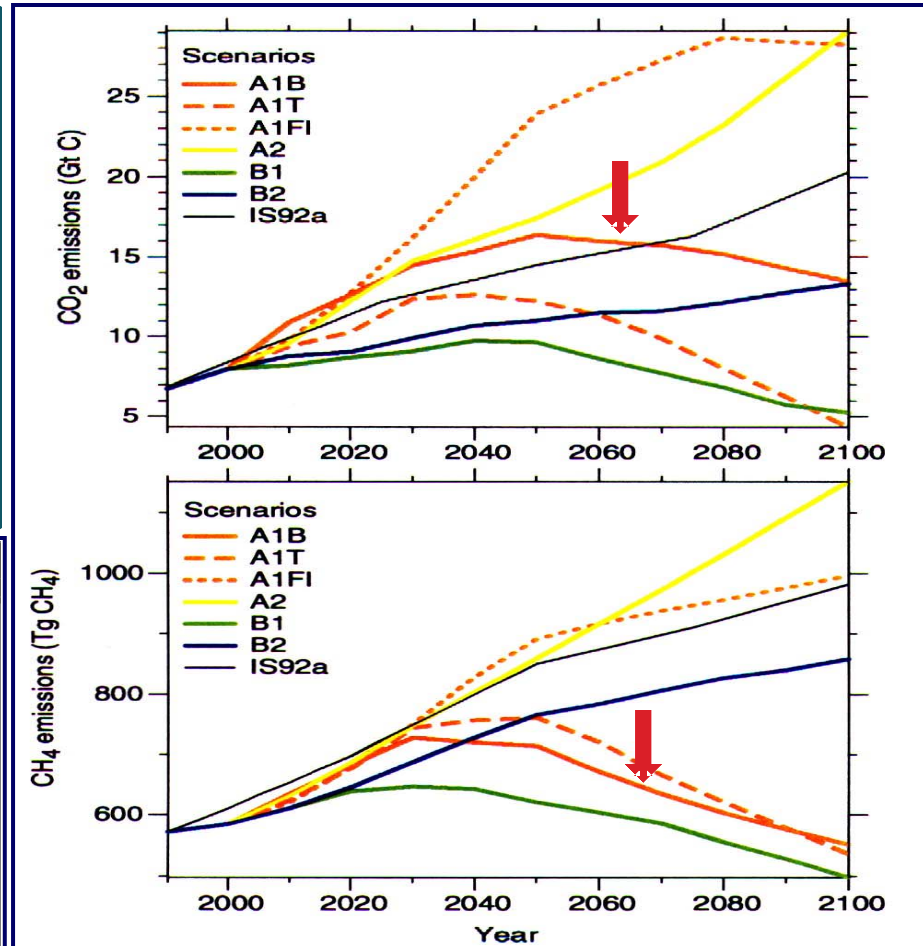

Climate models and their evolution [Source: IPCC-TAR, 2001]

# Climate Projections

- Models need greenhouse gas emissions scenarios



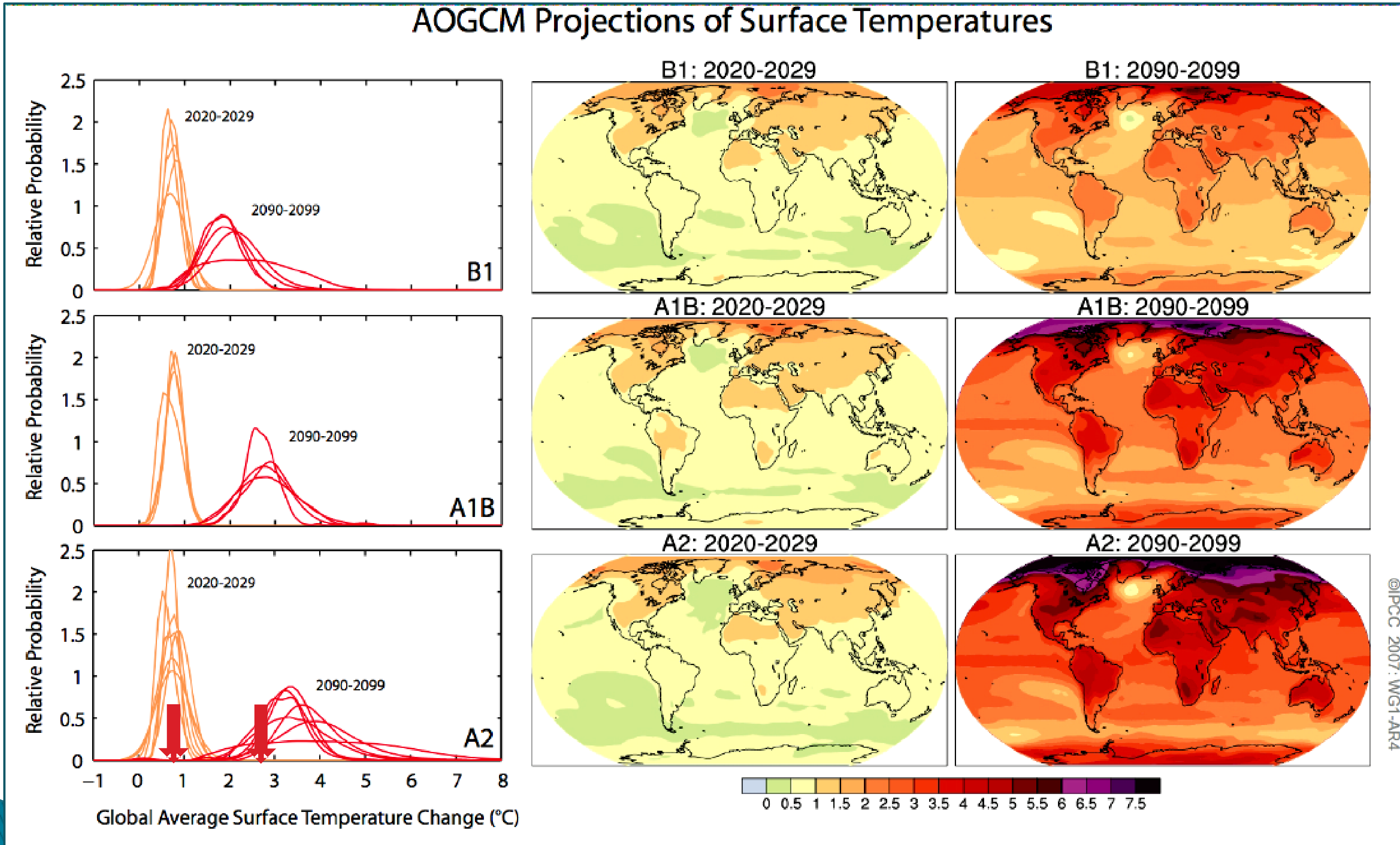

| Scenario | Population | Economy | Environment | Equity | Technology | Globalization |
|---|---|---|---|---|---|---|
| A1FI | ↗↘ | ↗ | ↘ | ↗ | ↗ | ↗ |
| A1B | ↗↘ | ↗ | ↗ | ↗ | ↗ | ↗ |
| A1T | ↗↘ | ↗ | ↗ | ↗ | ↗ | ↗ |
| B1 | ↗↘ | ↗ | ↗ | ↗ | ↗ | ↗ |
| A2 | ↗ | ↗ | ↘ | ↘ | ↗ | ↘ |
| B2 | ↗ | ↗ | ↗ | ↗ | ↗ | ↘ |




Specific families of emission scenarios to be used in climate modelling, their underlying basic determinants and resultant emissions of $CO_2$ and $CH_4$ [Source: IPCC-SRES; IPCC-TAR, 2001]

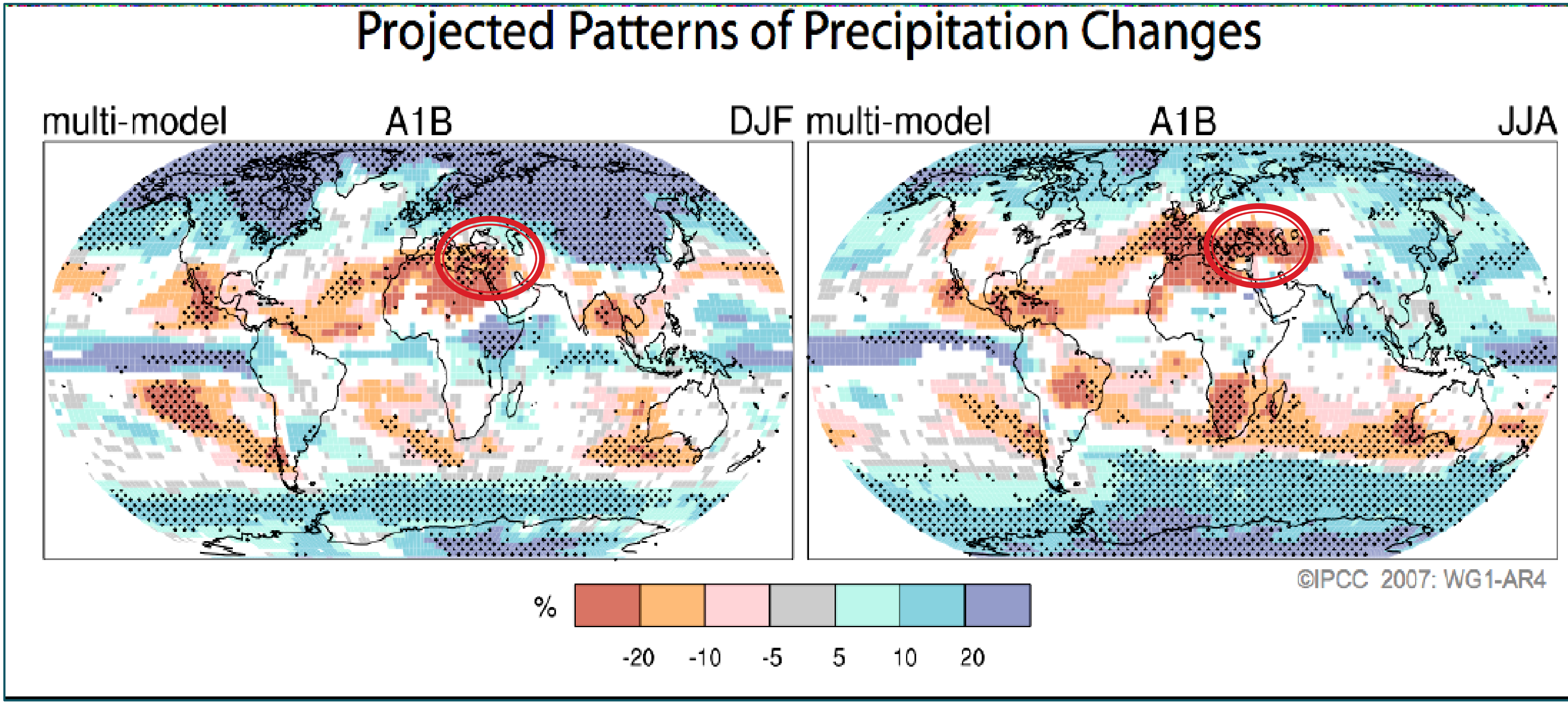
# Climate Projections

- Results: mean annual temperatures



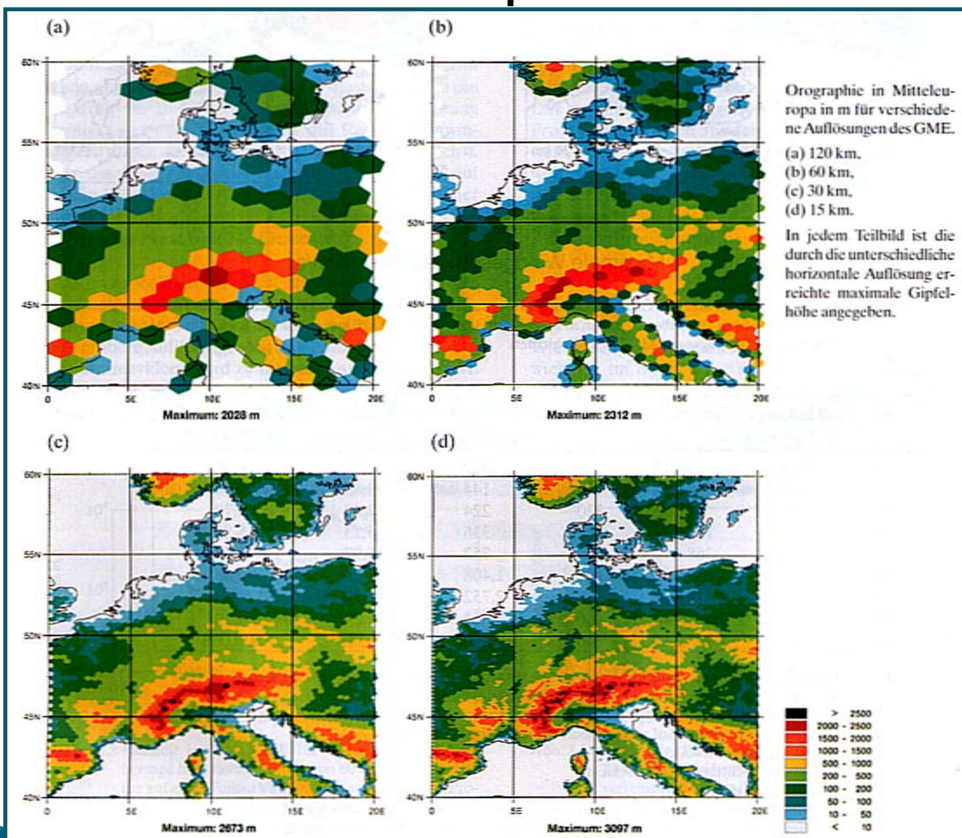
# Climate Projections

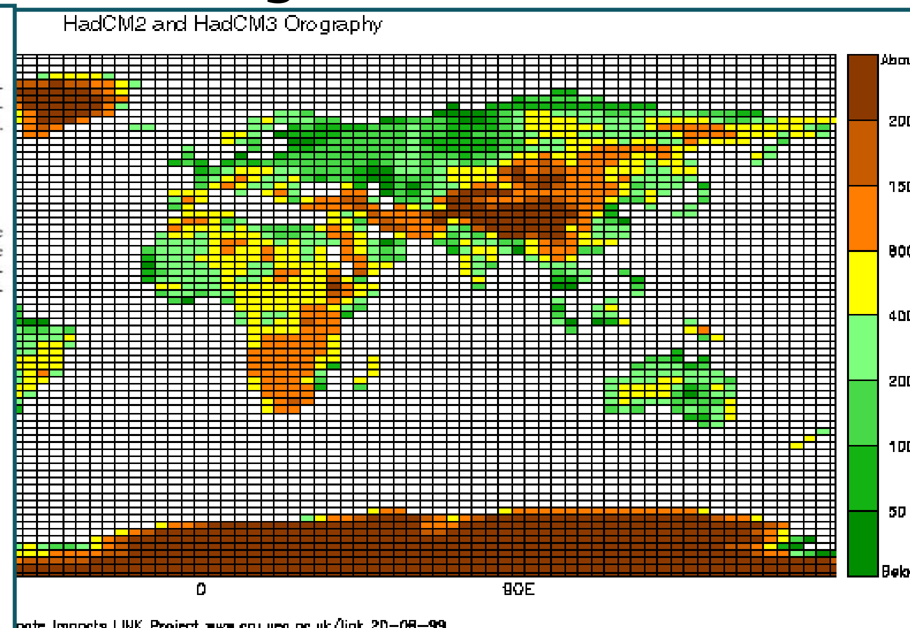
- Results: mean seasonal precipitation



# Regional Climate Projections

- Regional climate modeling: rationale
  - Need for finer scale spatial resolution
  - Inclusion of processes on GCM sub-grid scales




Representation of the global topography in a general climate model and of the European topography in model grids of varying resolution:; T21≈5,6°, T30≈3,5°, T42≈2,8°, T106≈1,1° (left; Source: Hadley Centre, UK)

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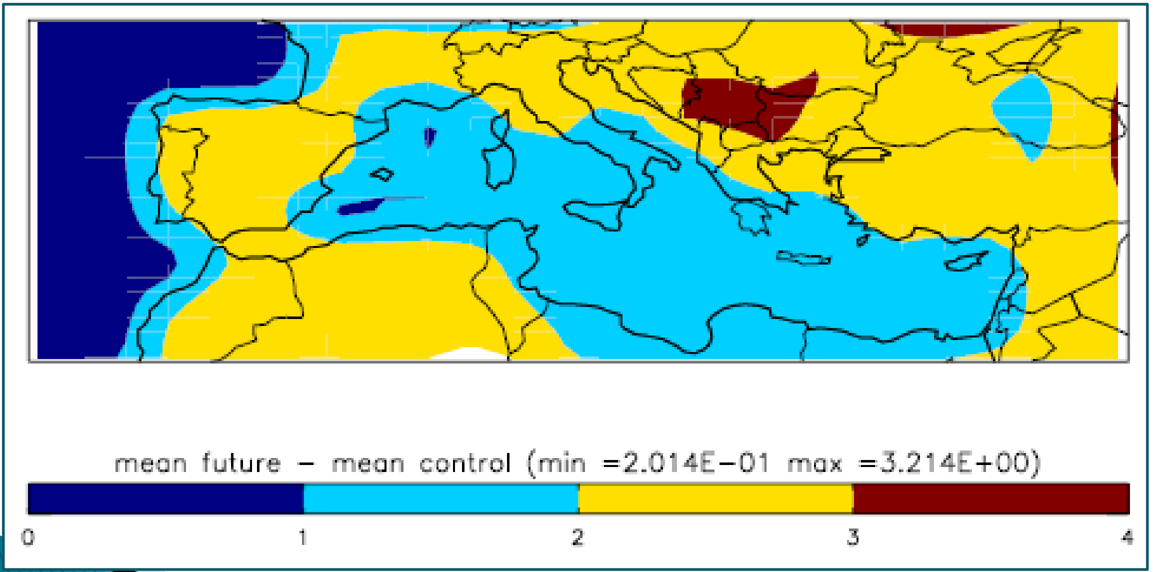
# Regional Climate Projections

- Downscaling of GCM Results: Temperature
  - GCM: ECHAM5; A1B SRES emission scenario
  - RCM: RACMO2 regional climate model developed at KNMI, Netherlands in the framework of EU-ENSEMBLES
  - Horizontal resolution: $25 \times 25 km^2$, 40 vertical layers
  - Control run: 1961–1990; two time slices: 2021–2050 and 2071–2100

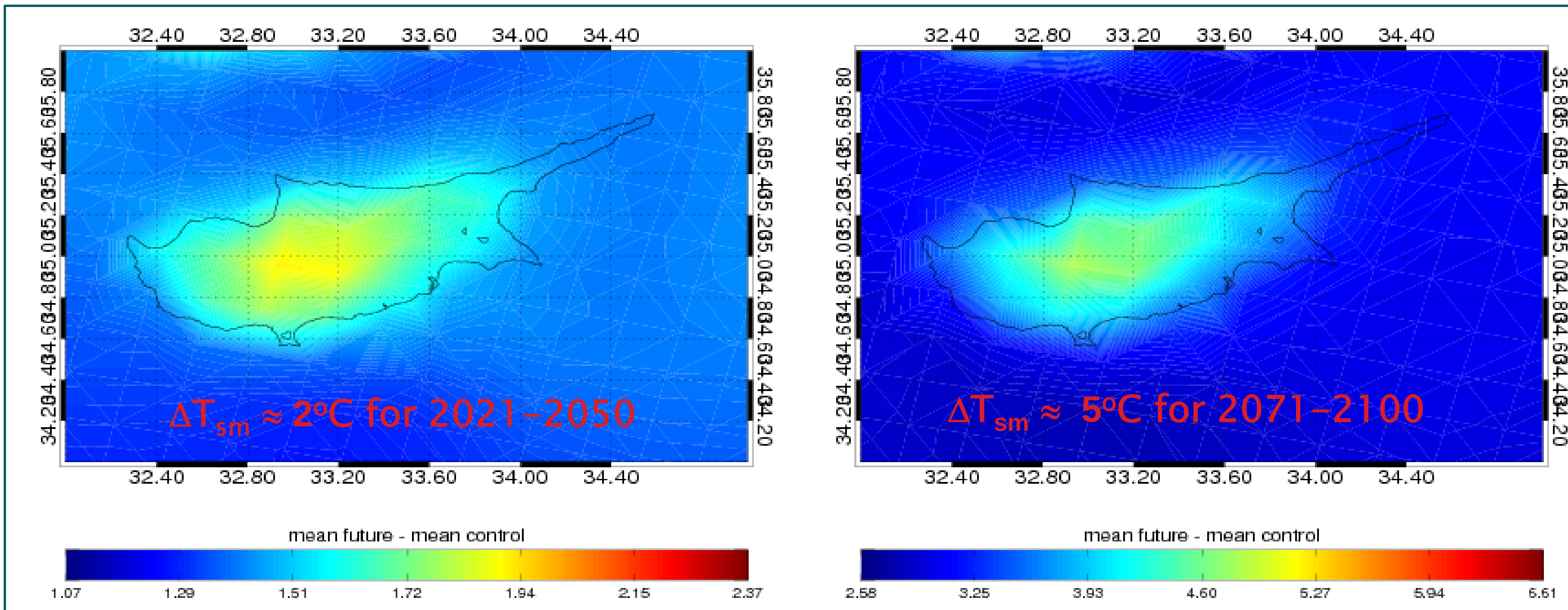



GCMs do not provide sufficient detail on the scale of countries (e.g., Cyprus)

Average annual temperature changes from ECHAM5 for the Mediterranean relative to reference; source: Giannacopoulos et al., 2008

# Regional Climate Projections

- RCM provides significantly more details
- Maximum summer temperatures
  - will be significantly higher than reference
  - particularly pronounced in Trodoos region




Average change in **summer maximum temperatures** ($\Delta T_{sm}$) relative to reference value of ~34$^o$C; source: Giannacopoulos et al., 2008

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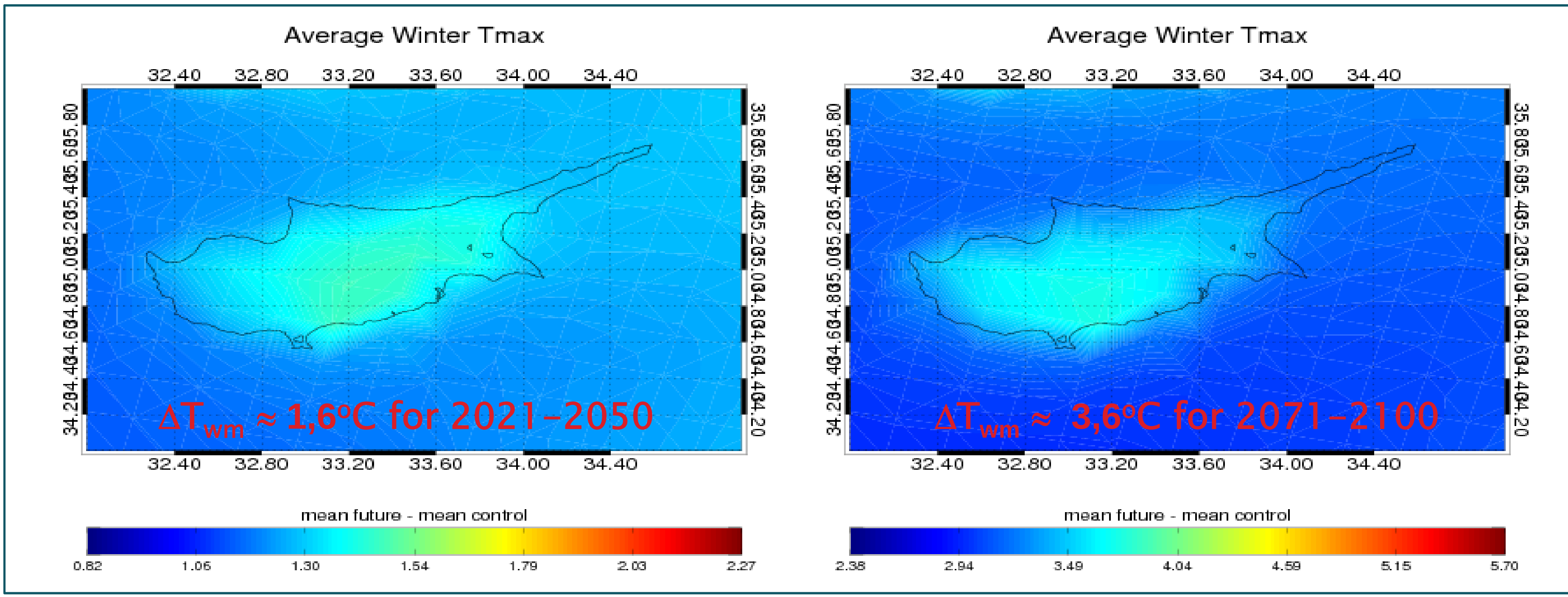
# Regional Climate Projections

- Rise in average winter maximum temperatures
  - less severe than for summer maximum temperatures
  - Slightly more pronounced in inland part of the island




Average change in **winter maximum temperatures** ($\Delta T_{wm}$ ) relative to reference value of ~15$^o$C; source: Giannacopoulos et al., 2008

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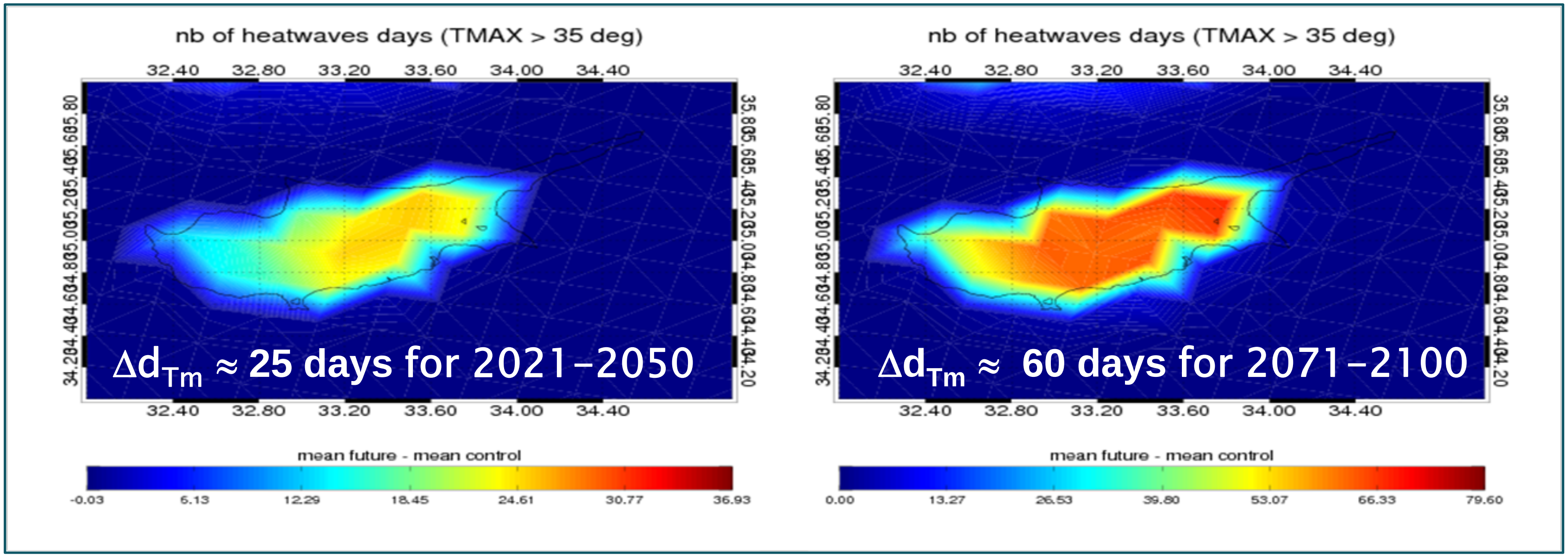
# Regional Climate Projections

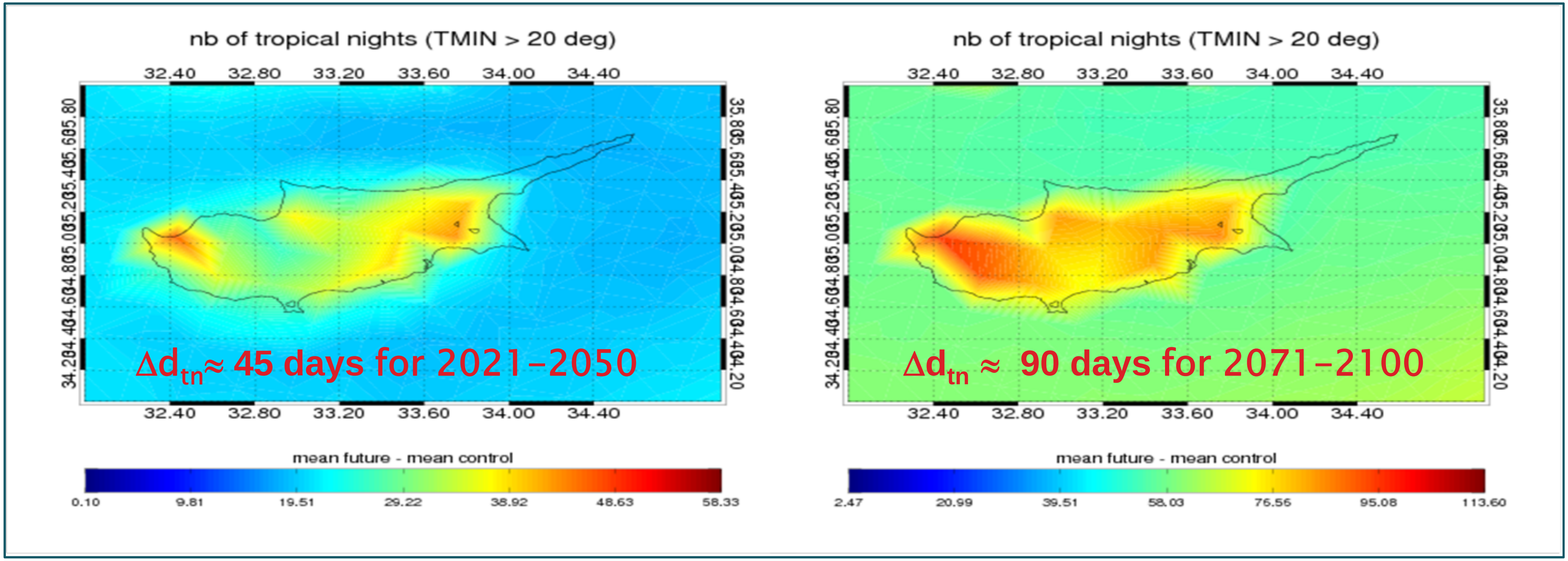
- Number of days with $T_{max} > 35^oC$
  - changes are more pronounced in the central eastern part of the island




Increase of days with $T_{max} > 35^oC$ ($\Delta d_{Tm}$) relative to reference($d_{Tm}$ =~ 60 days); source: Giannacopoulos et al., 2008

# Regional Climate Projections

- Number of tropical nights with $T_{min} > 20^oC$




Increase of days with tropical nights $T_{min} > 20^oC$ ($\Delta d_{tn}$) relative to reference($d_{ttn}$ =~ 75 days); source: Giannacopoulos et al., 2008

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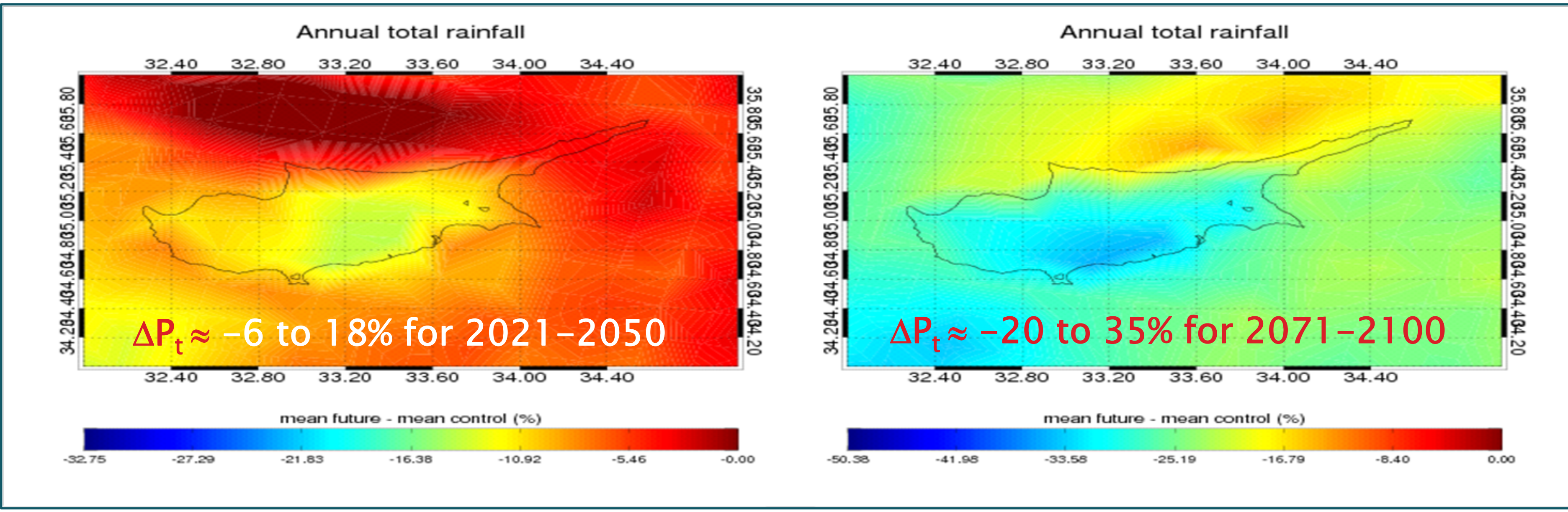
# Regional Climate Projections

- Downscaling of GCM results: precipitation
- Annual total precipitation
  - Strongest decrease in central-southern part of the island




Average change in **total precipitation** ($\Delta P_t$) relative to reference; source: Giannacopoulos et al., 2008

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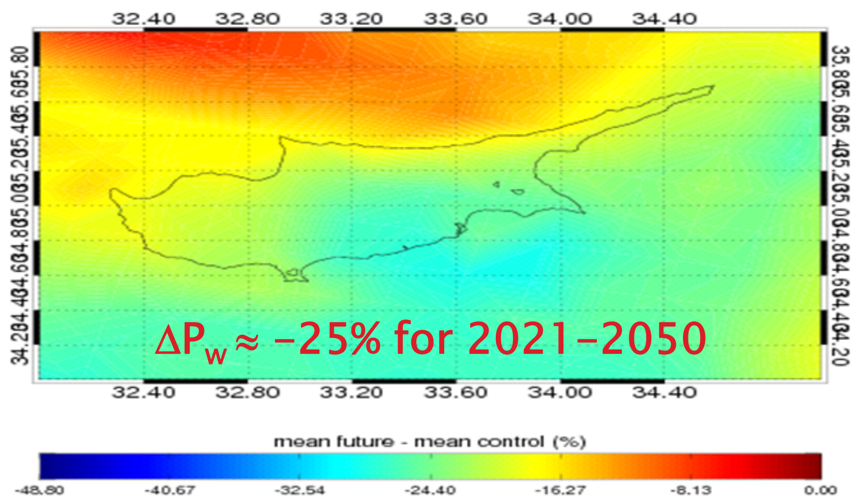
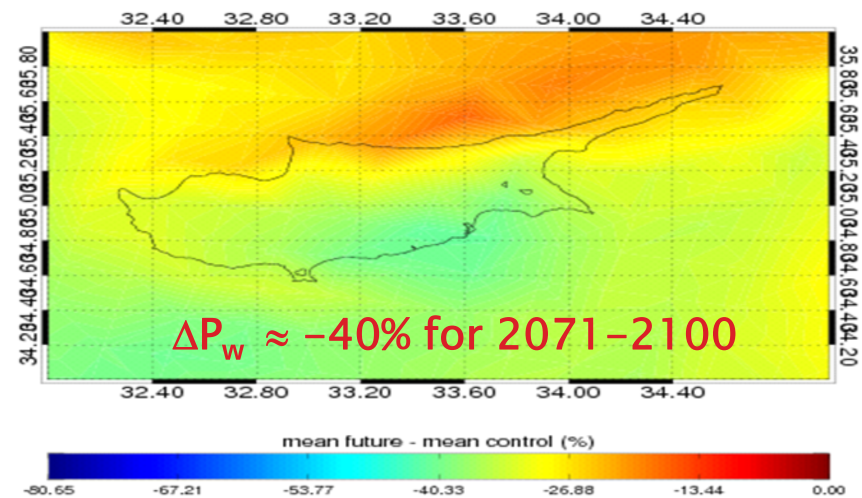
# Regional Climate Projections

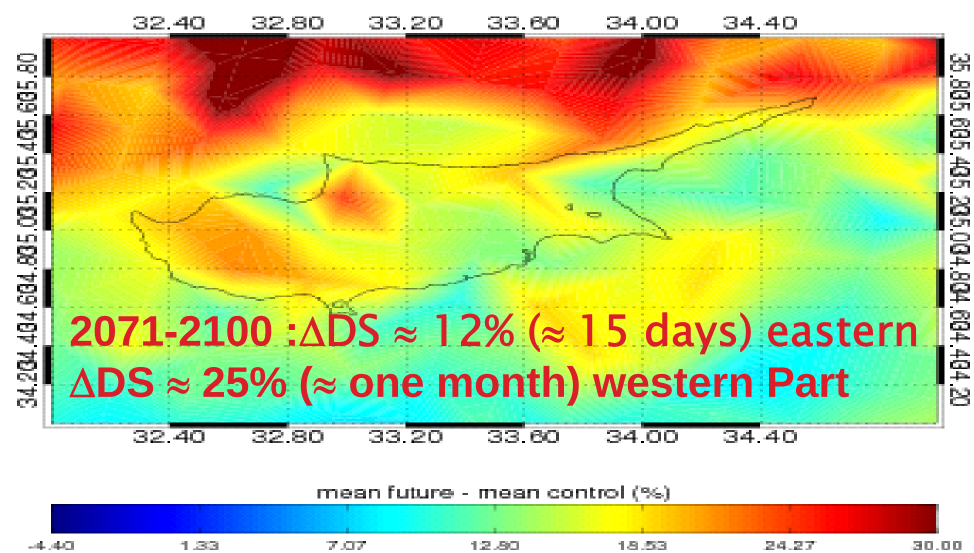
- Annual total winter precipitation & dry spells




Average change in **total winter precipitation** ($\Delta P_w$) relative to reference; source: Giannacopoulos et al., 2008

Average change in length of **dry spells** ($\Delta$DS) in summer relative to reference; source: Giannacopoulos et al., 2008



# Conclusions

- Mediterranean climate characterized by large variability, increasing temperatures and decreasing precipitation
- Tele-connection pattern and dust events exert strong effects on Mediterranean climate
- Future climate projections highlight Mediterranean as "hot spot"
- Future climate of Cyprus will be characterized by very warm and dry summers and milder winters
- There will be an enhanced scarcity in available water and an increasing trend towards desertification of the island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