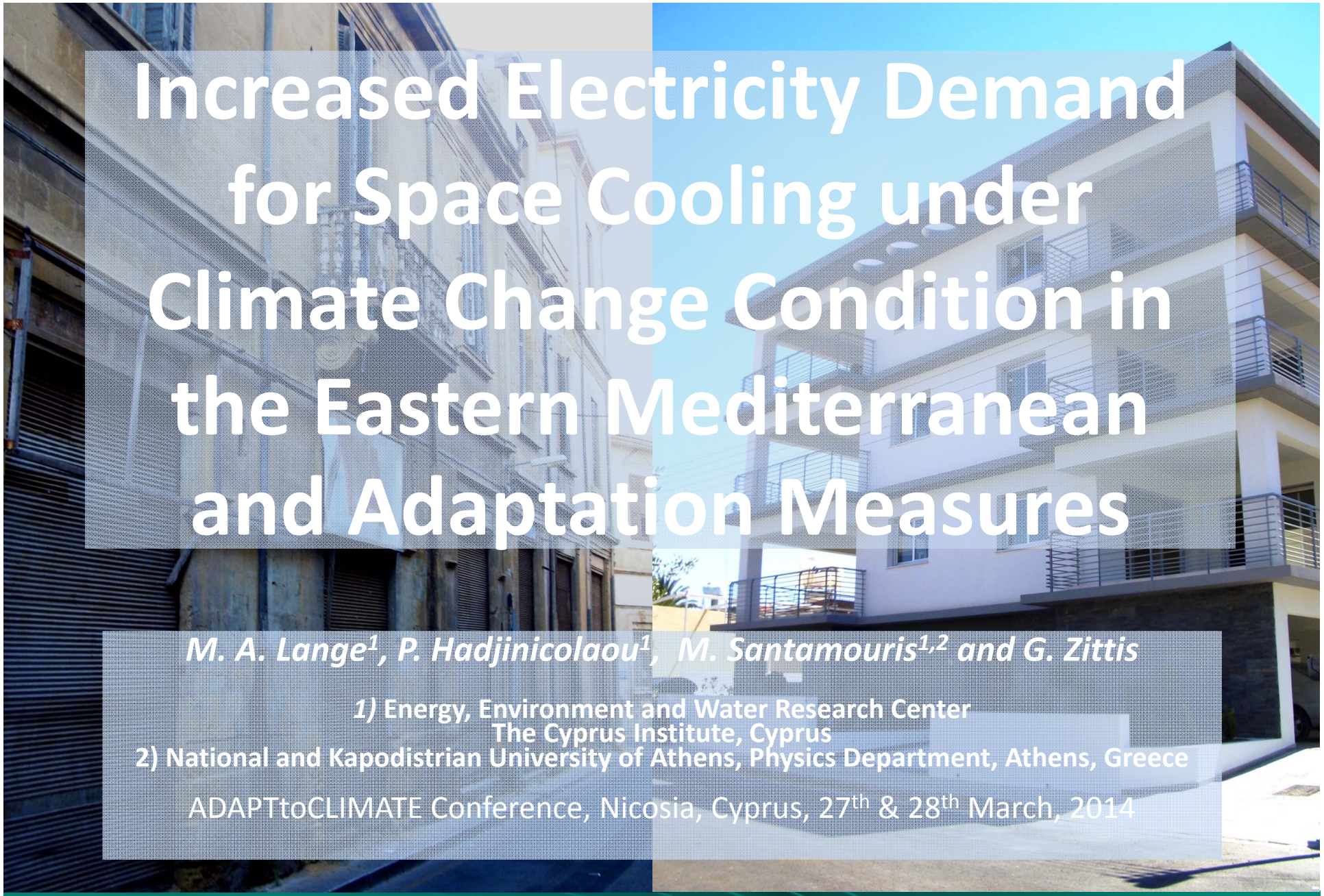

Increased Electricity Demand for Space Cooling under Climate Change Condition in the Eastern Mediterranean and Adaptation Measures

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The Cyprus Institute

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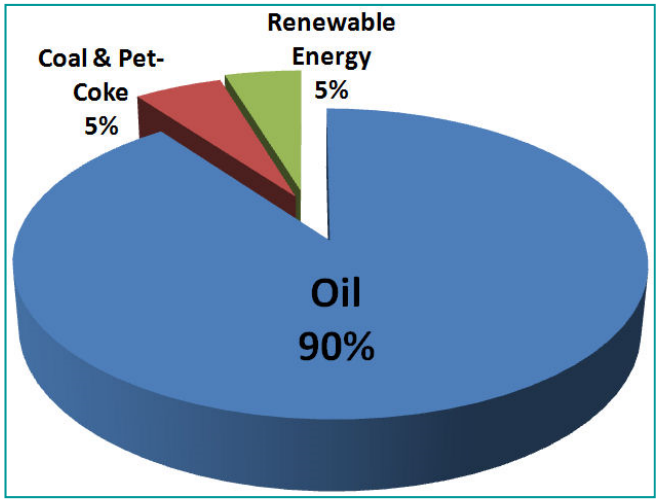
Outline

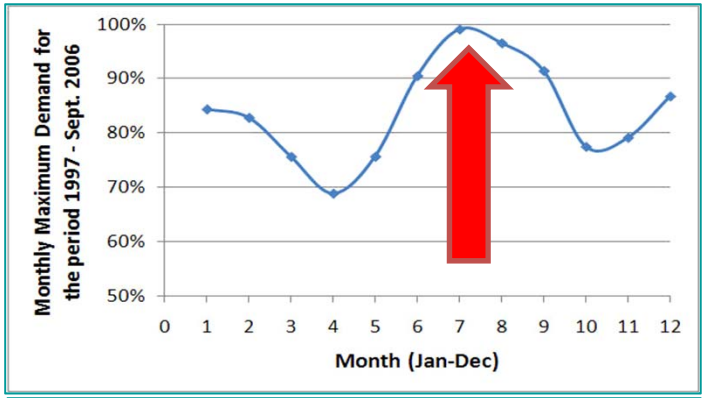
- Background: The energy and water sector in Cyprus
- Recent temperature trends and future projections
- Enhanced needs for space cooling – quantitative estimates
- Mitigation/adaptation strategies
- Conclusions

Cyprus: Energy Sector

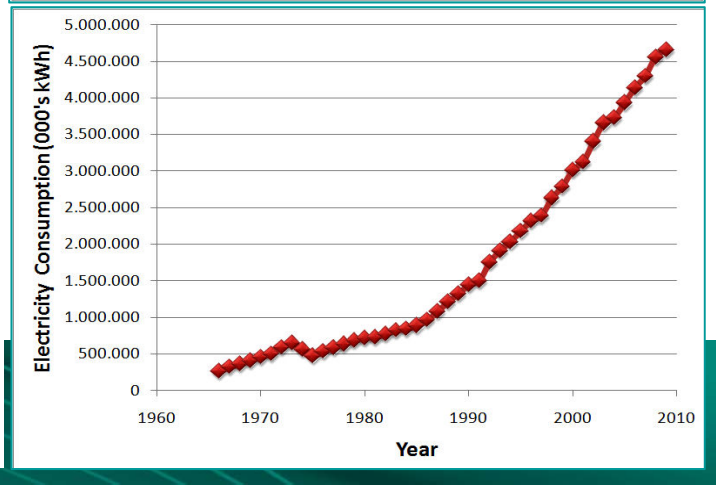
- Cyprus energy sector heavily dependent on hydrocarbon products and their imports
- Only 5% of the demand is satisfied through renewables (solar-thermal water heating)
- **Electricity consumption**
  - Steady increase since 1966
  - Summer and winter maxima
  - Domestic and commercial sectors dominate

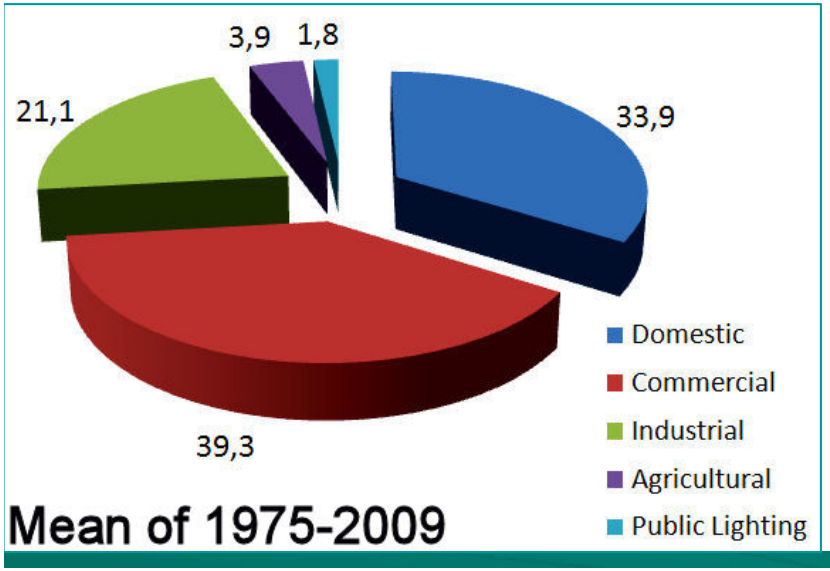


Main sources of energy in Cyprus; Kassini, 2006



Monthly maximum electricity demand (1997 to 2006; top) and increase in mean monthly electricity consumption in Cyprus (1966-2009; bottom); source: TSO (2010)

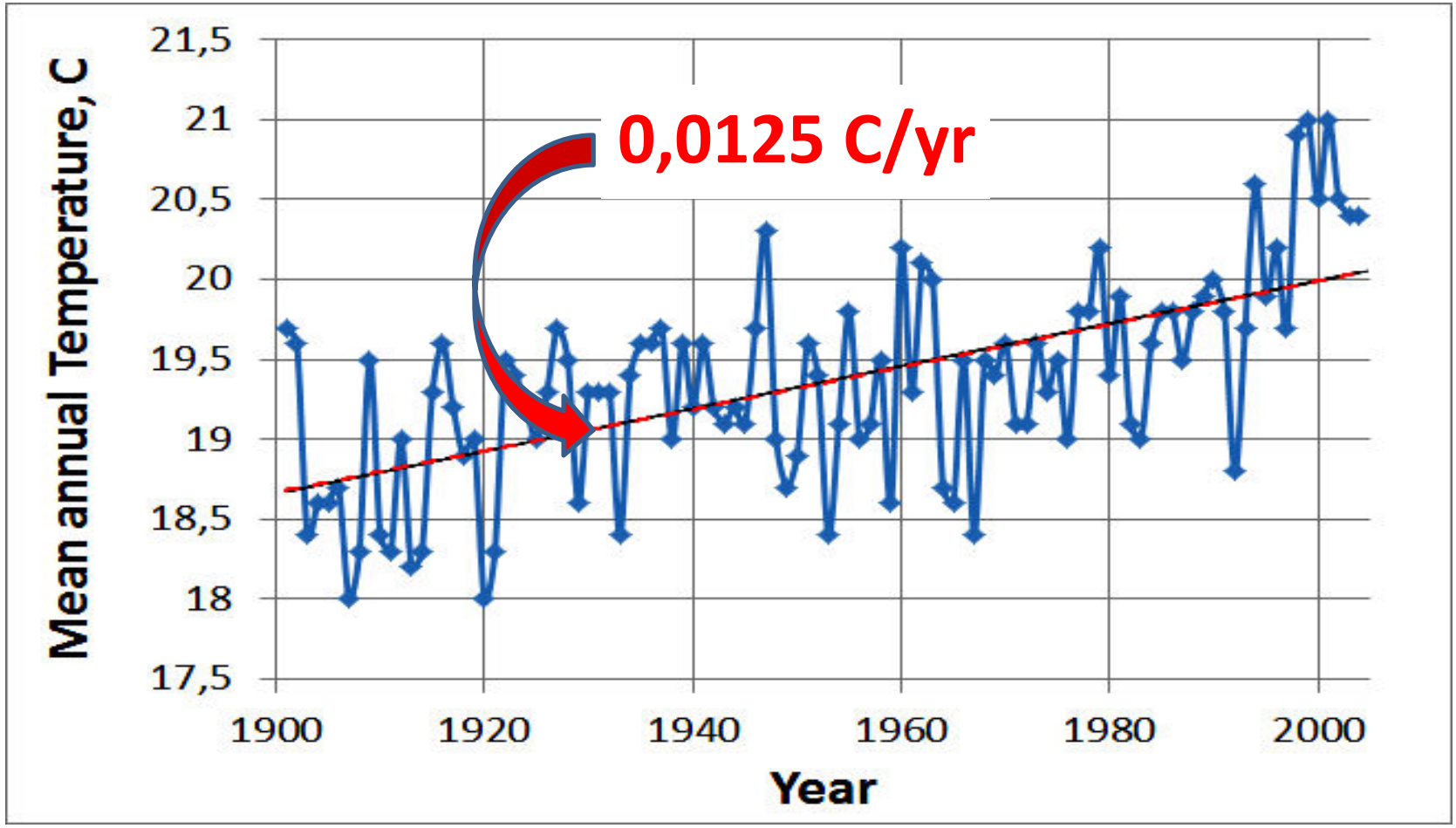




Final energy consumption in Cyprus; after Kassini, 2006

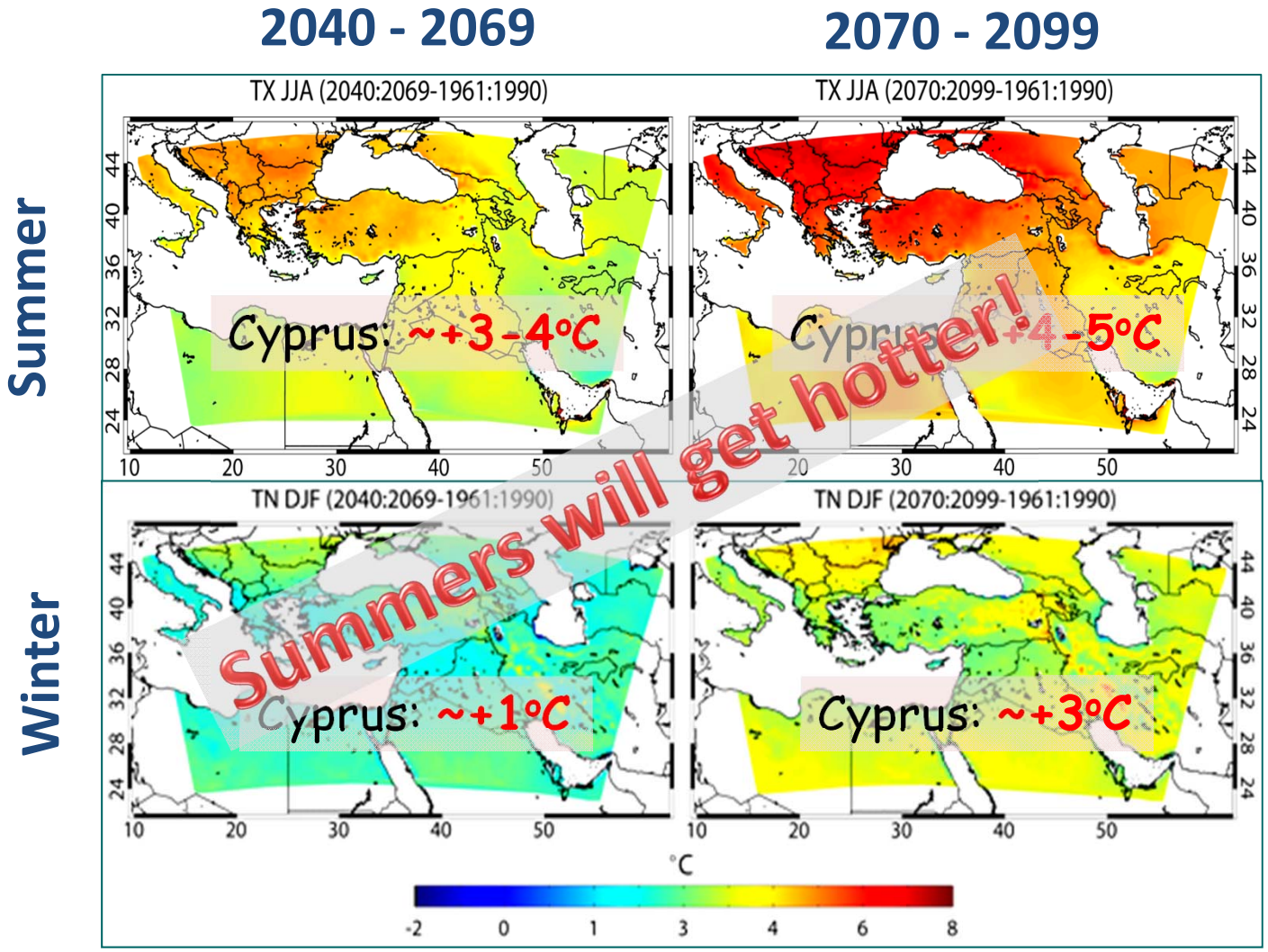
Recent Temperature Trends

- Significant temperature increases locally (Nicosia)



Mean annual temperatures in Nicosia/Athalassa, 1901-2004; source: Meteorological Service Cyprus

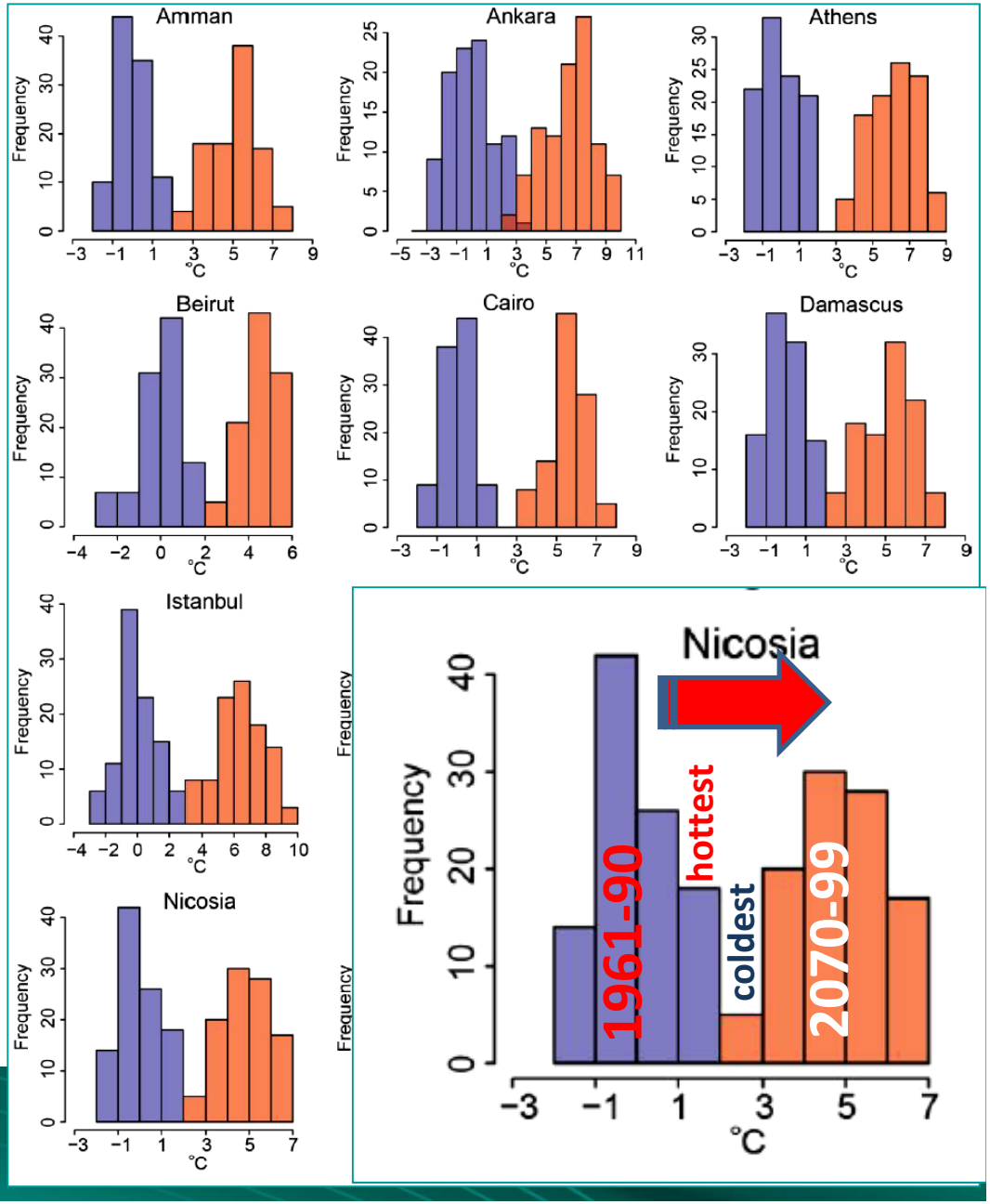
Numerical Climate Model Projections



Patterns of changing mean summer maximum (JJA) and mean winter minimum (DJF) temperatures, TX (top) and TN (bottom), respectively, calculated from PRECIS output. The left panels show the mean changes for 2040-2069 and the right panels for 2070-2099 relative to the 1961-1990 control period; source: Lelieveld et al, 2012

Heat Waves in Urban Settings

- Climate models project particularly severe warming in large cities in the Eastern Mediterranean



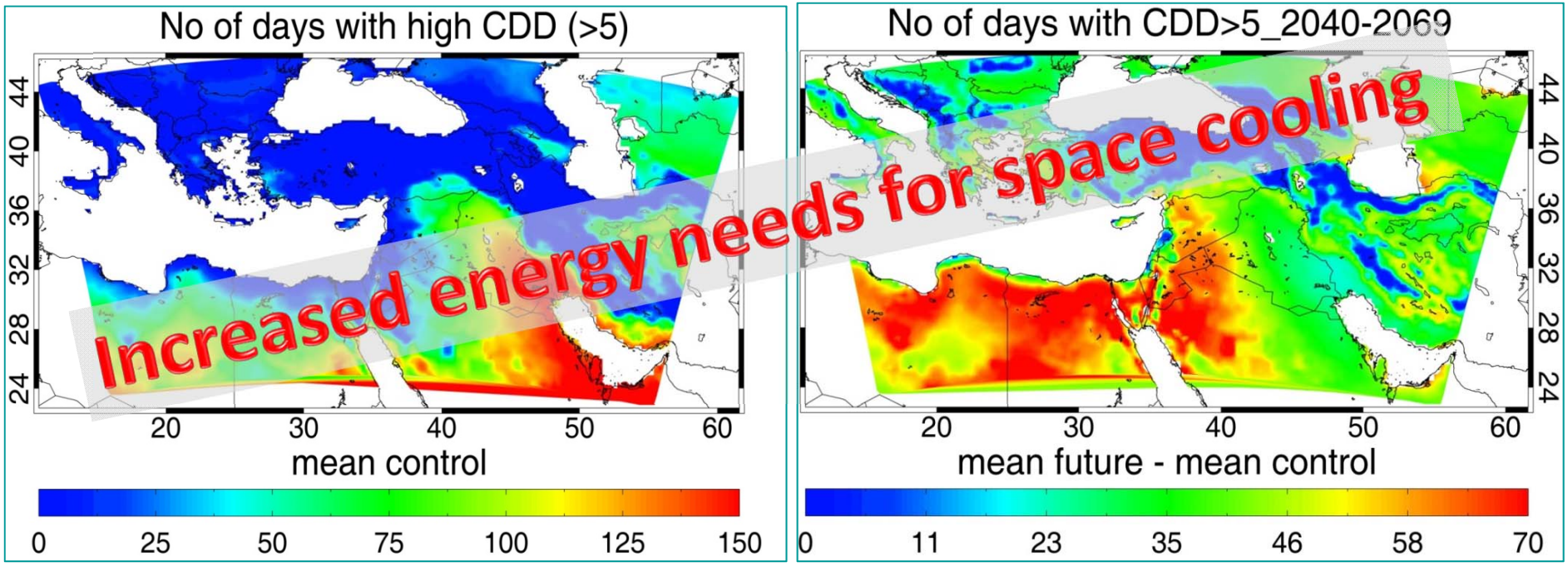
Recent and end-of-century temperature anomalies. Model calculated frequency histograms (%) of summer (JJA) daytime maximum temperature (TX) anomalies relative to the period 1961-1990, based on the A1B scenario. Blue is for the period 1961-1990 (hence cantered around 0°C) and red for the period 2070-2099.; Source: Lelieveld et al., (2012) Extreme heat in the eastern Mediterranean and Middle East. Regional Environmental Change (submitted)

Impacts on Required Space-Cooling

- Increased summer heat enhances need for space cooling
- This can be captured by the Cooling Degree Day index **CDD_i**:

  $CDD_i = \max(T_i - T^{**}, 0)$

  – with T^{**}=25°C; T_i=mean daily temperature summed over a certain time period



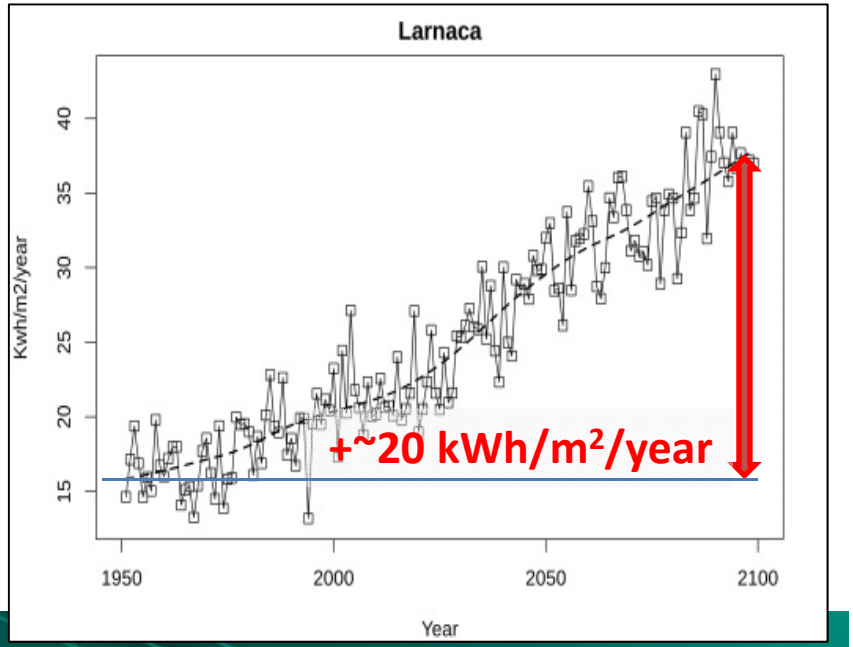
Patterns of mean number of heavy cooling degree days/year (CDD>5°C) for the control period 1961-1990 (left) and additional CDD>5°C days for the period 2040-2069 (right), calculated from PRECIS output;
source: Lelieveld et al., 2012

Quantification of Cooling Energy Needs

- Based on numerical model projections of temperatures in individual cities in Cyprus (Kyrenia, Nicosia, Pafos, Larnanca) Cooling Degree Days (CDD) and the Warm Spell Duration Index (WSDI) has been calculated for each city throughout the 21st century
- **WSDI** = Annual count of days with at least 6 consecutive days when Tmax > 90th percentile (Fisher et al., 2010; Lelieveld et al., 2013)

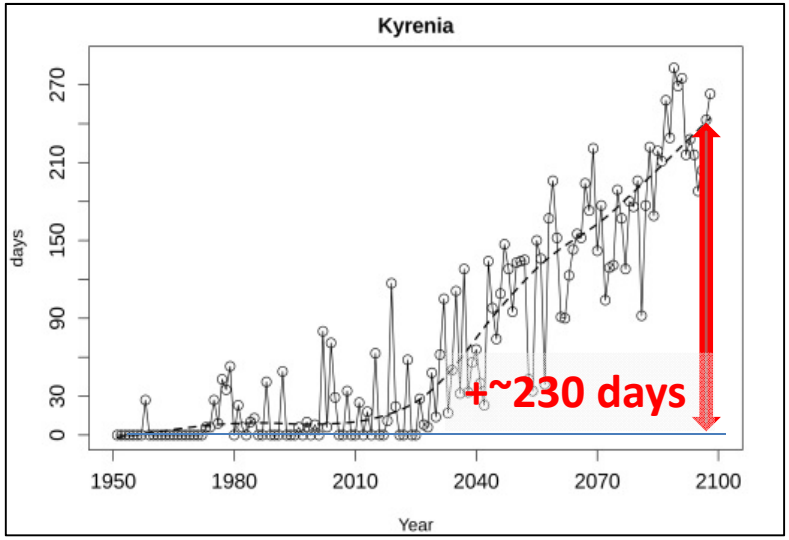
Quantification of Cooling Energy Needs

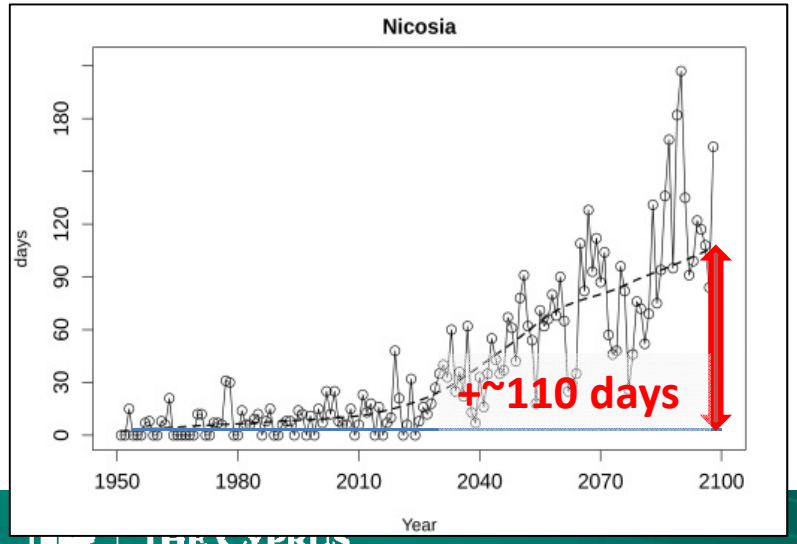
- In order to reach/maintain acceptable indoor comfort, space cooling (air conditioning) has to be employed
- The increasing/additional energy demand needed for space cooling **CLOAD** has been computed for each city
- CLOAD = (1W/m^2/K * CDD*U * 24h)/1000
  units of kWh/m^2/year; U=overall heat transfer coefficient (=1)
- In addition, we calculated the cooling load of each year divided by cooling load of the reference period 1951-2000 mean for each city: **ratio**
- ratio = Cooling load of each year divided by mean cooling load of reference period 1951-2000



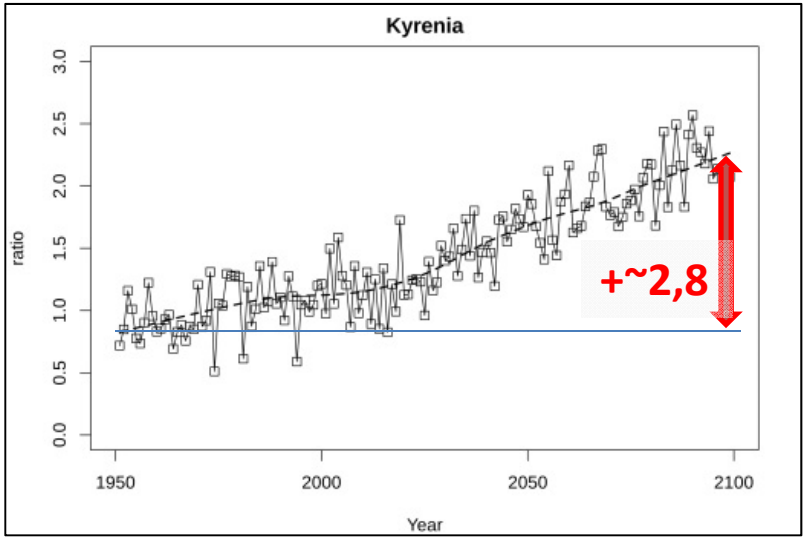
Quantification of Cooling Energy Needs

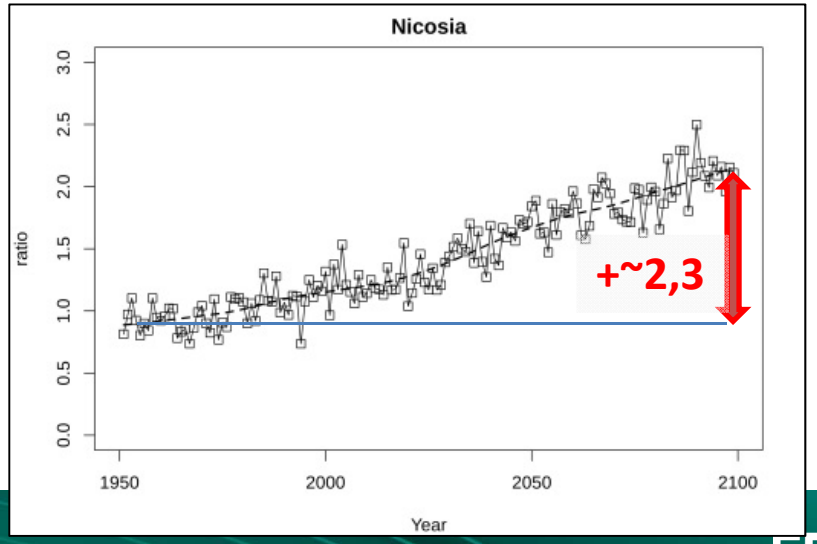
WSDI





ratio



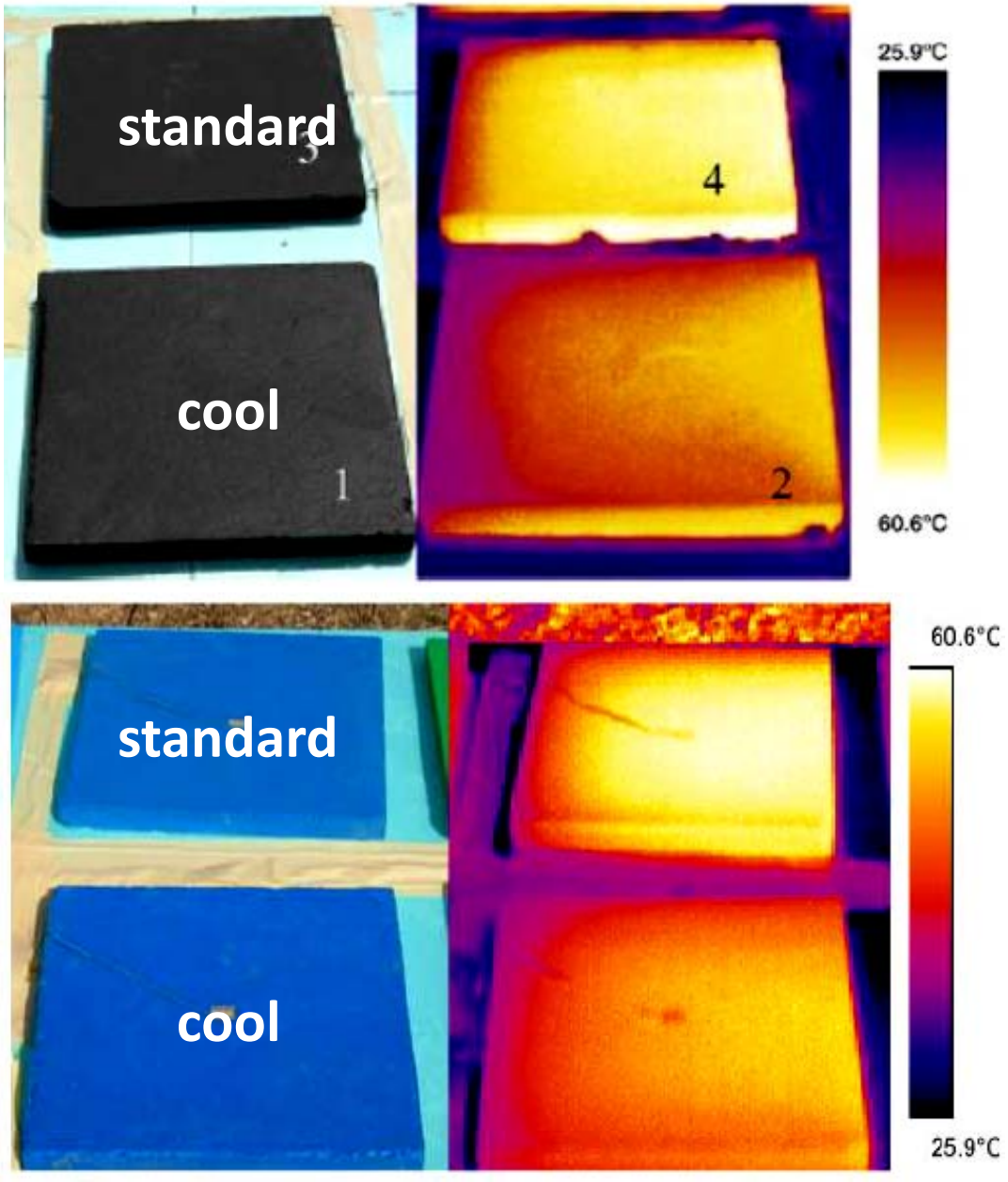


Adaptation/Mitigation Strategies

- The expected increase in summer peak temperatures will have adverse health effects on urban populations
- These impacts will hit lower-income households disproportionally hard
- Enhanced space cooling –aside from being costly- will cause positive feedbacks to climate change due to higher CO_2 emissions
- Current urban built environment ill-prepared for such impacts
- We need innovative mitigation and adaptation strategies, including:
  - an enlargement of green areas,
  - **the use of "cool" materials, in particular of highly reflective and low absorptive coatings and pavements,**
  - shading and the orientation of buildings and windows,
  - the use of cool sinks for heat dissipation,
  - appropriate layout of urban canopies involving the use of solar control,
  - techniques to enhance air flow/ventilation in buildings

Adaptation/Mitigation Strategies

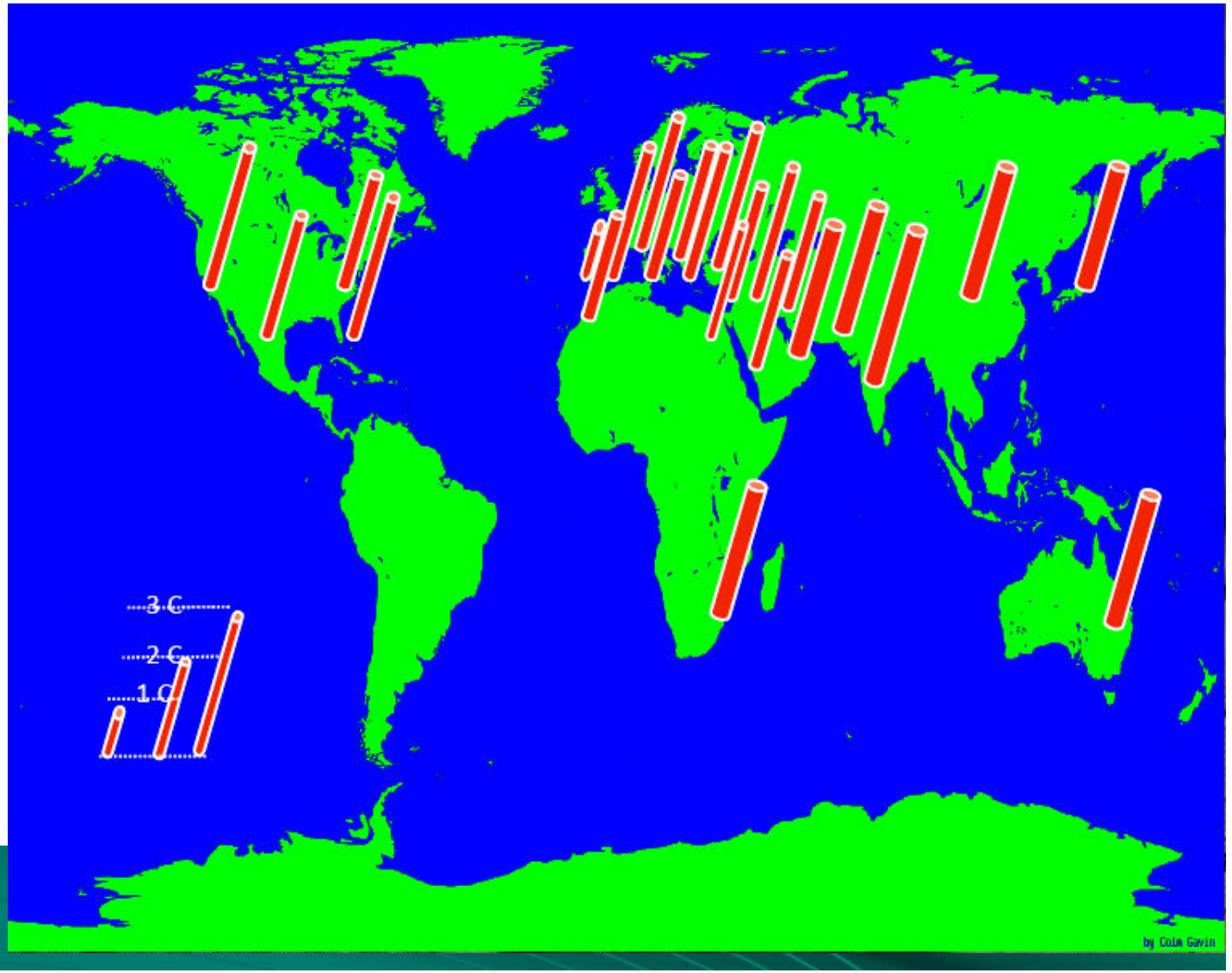
- At the University of Athens high-reflective “cool” coatings have been compared to similarly colored standard coatings
- Differences in mean daily surface temperature during the month of August between cool and standard color-matched coatings amounted to 5.2 and 4.7°C for black and blue coatings, respectively



Distribution of temperatures on surfaces with „cool“ and standard coatings; source: A. Synnefa, M. Santamouris and K. Apostolakis : On the development, optical properties and thermal performance of cool colored coatings for the urban environment, Solar Energy 81 (2007) 488–497

Adaptation/Mitigation Strategies

- Reflective coatings have a significant influence on indoor temperatures
  ⇨ improved indoor comfort



Reduction of indoor temperatures as a result of reflective coatings of external surfaces in residential buildings at various locations; source: A. Synnefa, M. Santamouris and H.Akbari: Estimating the effect of using cool coatings on energy loads and thermal comfort in residential buildings in various climatic conditions, Energy and Buildings, 39,11, 1167-1174, 2007

Conclusions

- Temperatures in the MENA region and Cyprus have been strongly increasing
- Climate projections 21st century: hot summers, mild winters
- Severe warming in urban settings ⇨ enhanced space cooling
- Quantification of warm spells and of addional energy needs for space cooling in selected Cypriot cities for the 21st century underline severe adverse consequences
- Adaptation/Mitigation strategies: use of “cool” materials
- Such materials exist and have been proven to be highly effective in reducing heating loads on buildings


Thank you
for your attention