BRIEFING NOTES ON THE CIRCE URBAN CASE STUDIES: ATHENS

Summary

The city of Athens, capital of Greece, will be studied as an urban case study. Athens is a large metropolitan city, with a densely populated urban area and few green open spaces (Figure 1).
The topography of the city, surrounded by mountains, favours the formation of air pollution episodes during periods of anticyclonic circulation. The city is prone to summer heatwaves and floods during heavy precipitation events. Impacts of temperature extremes and air pollution on human health, tourism, energy demand and peri-urban forest fire risk will be examined in this case study.

1. Physical and socio-economic characteristics

Geography:
Athens sprawls across the central plain of Attica and is identified by the geographical coordinates of 37° 58' N and 23° 43' E (Figure 2). Several mountains surround Athens; Aegaleo in the west, Parnitha in the north, Penteli in the northeast and Hymettus in the east. Most consist of limestone or marble, from which the ancient buildings of the city were constructed. The plain on which the city is built contains isolated limestone hills, including Lycabettus, which rises 339 m above the sea, and the flat-topped Acropolis (156 m high) around which the

Figure 1: View of northeastern Athens towards Mount Lycabettus showing the densely built inner urban area

city grew. The inner city has a land area of 39 km^2, while the urban conurbation of Athens spans 412 km^2. The metropolitan area of Athens has a population of around 3.8 million people, with an estimated population density of 9,137 inhabitants per km^2.

Climate:
Athens enjoys a typically Mediterranean climate of cool, rainy winters and hot, dry summers. The topographic conditions as described above cause the Athens weather to be warmer than would be expected from a city surrounded by water.
Athens has one of the driest climates of Mediterranean Europe.
The clear light-blue skies, characteristic of Athens, are due to the low humidity levels. The location of Athens in a mountain basin causes a temperature inversion during anticyclonic conditions, and is partly responsible for the air pollution problems the city faces. Winter in Athens is typically mild, with temperatures mainly dropping at night.
Precipitation during this season is usually in the form of short-lived heavy rainfall events. Snowfall occurs on an almost yearly basis, but rarely remains on the ground. Summer can be particularly hot and at times prone to smog and pollution episodes. The average summer daytime maximum temperature is 32°C and during the months of July and August, heatwaves occur when hot air masses move across Greece from the south or southwest and temperatures soar above 40°C. The all-time maximum temperature record for the metropolitan area of Athens is 45°C (as recorded at the National Observatory of Athens), while the respective minimum temperature record is -6°C. Figure 3 shows the mean monthly temperature, sunshine duration, precipitation amount and the number of wet days in Athens.

Figure 2: Satellite map of the Attica peninsula showing the topography and the urban expansion of the Greater Athens area (courtesy of Dr Adrianos Retalis, National Observatory of Athens)

Economy:
Greece has a mixed capital economy with a large public sector that accounts for about half of the GDP which was $305.595 billion in 2006. It is an agricultural country (with agricultural products including: wheat, corn, barley, sugar beets, olives, tomatoes, tobacco, potatoes, beef, dairy products and wine) and 20% of the workforce is employed in this sector. The principal economic activities include tourism and shipping industries. For the prefecture of Attica (in which Athens lies), the GNP (gross national product) has been steadily increasing since 1993 as shown in Figure 4.

2. Justification

This case study will examine possible impacts of climate change on heat stress, human discomfort and disaster preparedness. The high den-

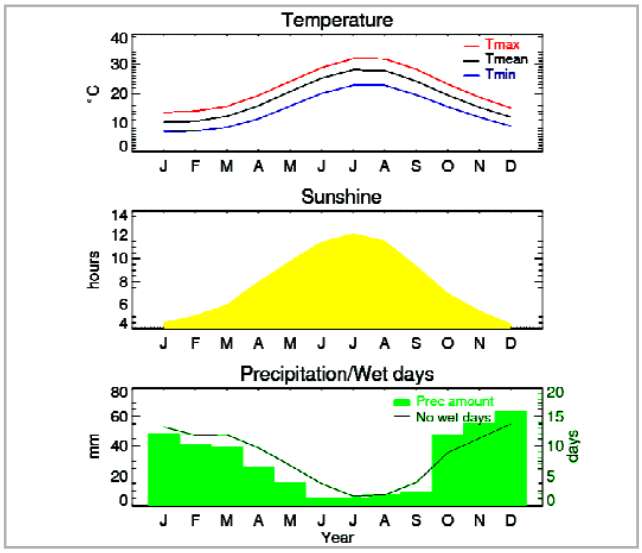

Figure 3: Mean monthly temperature (Tmean, Tmax, Tmin), sunshine duration, precipitation amount and number of wet days for Athens averaged over the period 1961-1990

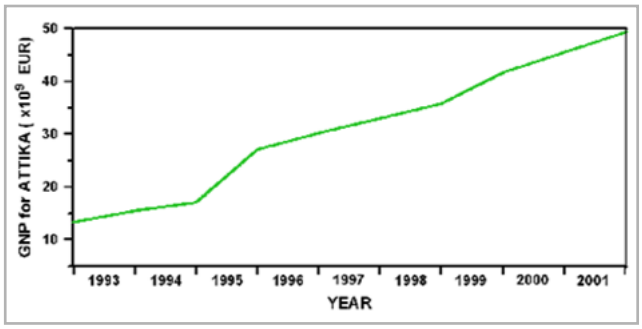

Figure 4: Gross National Product (GNP) for the prefecture of Attica from 1993 to 2001

sity of buildings in the urban sprawl, with few open spaces, is prone to floods in present and future climate.
Furthermore, with heatwaves becoming more common it is anticipated that human discomfort and associated health impacts will increase. Hospital admissions related to heat extremes and air pollution events will be examined.
Moreover in a hotter future, energy suppliers may face serious problems since they may not be able to meet the increasing demand for energy, mainly for air conditioning (Giannakopoulos and Psiloglou, 2006). Impact sectors will be examined together with potential adaptation measures for the area. For information on data availability and access to policy makers refer to Sections 5 and 6.

3. Key Research Issues

Climate issues:
Energy use, air quality, thermal comfort and related health issues, water supply and demand are major concerns for urban areas. A detailed assessment of extreme climate events using selected indicators will be conducted. Previous work over the wider eastern Mediterranean region (Kostopoulou and Jones, 2005) revealed a significant positive trend in the number of very warm days in summer, and positive trends across a range of precipitation indices, such as precipitation intensity and amount. Analysis of the 100-year surface air temperature record of the National Observatory of Athens (Founda et. al., 2004) revealed a tendency towards warmer years. Moreover, this study demonstrated a significant increase in the number of hot days, as well as in the frequency of occurrence and duration of warm events during the last decade. Here, research will focus on temperature extremes and heatwave episodes, and precipitation extremes for determining the probability of drought occurrence, as well as intense precipitation events capable of causing damaging floods.

Environmental issues:
Athens is prone to air pollution formation when stagnant air masses dominate synoptic conditions. This occurs mostly in the transition seasons of spring and autumn. Air pollution levels for ozone and nitrogen oxides and for the more 'modern' pollutants such as benzene can far exceed the EU-imposed limits and pose a threat to human health. Air pollution events will be examined in relation to human health (see social issues below) and to climate parameters. Hot and long periods of dry weather can also pose a threat to peri-urban forest areas, which have air cleansing mechanisms that are very important to the city's ventilation. Forest fire risk for present and future climate will be evaluated for the Greater Athens area.

Social issues:
Hospital admissions associated with hot weather and air pollution will be examined. In a hotter future, additional energy demands (mainly for air conditioning) could present serious problems to energy suppliers.

Increasing trends in the number of hot days and heatwave events affects key sectors of the Greek economy such as the tourism industry.
Heatwaves not only cause power outages, but under hot and dry weather conditions peri-urban forest fires can break out across the Mediterranean. For instance, in July 2007, fires destroyed vast tracts of the pine-covered Parnitha range. The blazes not only intensified the heat but have also been blamed for soaring pollution levels, and authorities reported hundreds of patients in hospital with respiratory problems. Potential adaptation measures for each impact sector will be assessed. Increasing summer temperatures are likely to result in increasingly uncomfortable conditions in the summer months. Using a human comfort index it is possible to assess how atmospheric conditions will evolve for a range of climate change scenarios.

4. Key areas of integration

The Athens urban case study has been chosen since it provides excellent opportunities for using an integrated approach across multiple temporal and spatial scales and sectors. In the spatial dimension, work will extend from the inner city boundaries to the surrounding mountains and forests. In the temporal dimension, research will range from the current observed time period (using available meteorological and sector data) to future time periods using data from several climate change projections. In addition, a multi-sector approach to climate change impacts will be adopted. Impacts sectors covered will range from direct climate impacts on natural ecosystems (such as flash floods and forest fire risk) to indirect impacts resulting from combined climate-social-economic linkages (such as energy demand, tourism and health). Furthermore, the dy-

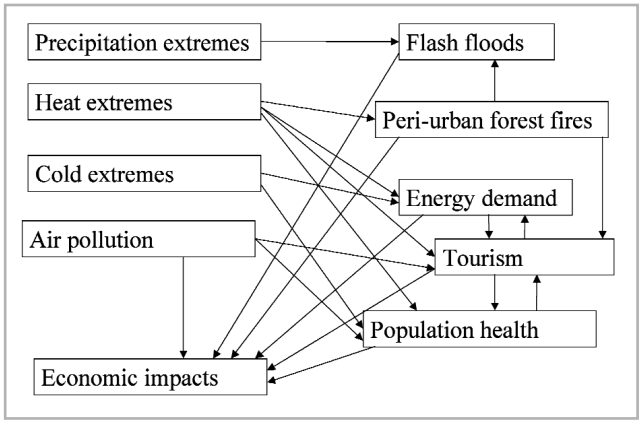

Figure 5: Conceptual framework for the integrated assessment of the impacts of climate change in the Athens case study

namics of the climate system will also be examined in an integrated fashion. Climate indicators specific to Athens will be chosen and will cover both temperature and rainfall-related extremes. Figure 5 illustrates the conceptual multi-sector approach, and includes climate system dynamics, natural / social / economic impact sectors and their interlinkages.

Case-study work on impact sector risk to climate change will be of particular interest to relevant policy makers and stakeholders, with whom contacts have been established from the early stages of the project. Stakeholder consultation will be advantageous to the selection of indicators of climate change for specific economic sectors. Discussion of impact sector risks and adaptation measures can also be exploited. For example, the construction of energy efficient buildings which have adequate insulation and the design of green roofs on city blocks of flats will help to counteract the damaging effects of heat extremes.

5. Regional stakeholders, policy makers, institutions

Energy officials and hospital medical staff will be among the stakeholders involved in this case study since they will be the main data providers. In addition, officers from the Greek Civil Protection Bureau will be contacted, since they are the main decision makers in terms of forward planning and protecting against various types of natural disasters.

Officers from the Environment and Tourism Ministries will be contacted as the main decision and policy makers for this sector.

6. Data availability

Meteorological data for Athens are readily available from a central site operated by the National Observatory of Athens since the year 1900. In addition, energy demand data for the city are available from the Greek Public Power Corporation.

Contacts with this institution were established during the EU-project MICE. Cardio-respiratory patient admissions to major hospitals within Athens will also be obtained. Contacts with chief doctors are already underway as part of the EU-project ENSEMBLES, and data will soon be available. Air pollution data, including measurements of ozone, nitrogen oxides and other particulates, will be available from the Greek Ministry of the Environment who routinely record air pollution measurements in the city of Athens and its suburbs. Data for forest fires in the areas around Athens will be provided by the Forest Fire Research Institute of Athens. A range of climate projections will be available as output from other CIRCE research lines, together with data from other projects such as ENSEMBLES.

Downscaling methods for the Greater Athens area will provide scenarios of what the climate of the city will look like in years to come. These scenarios will help identify future energy demand, forest fire risk and health impacts (Giannakopou-

los et al., 2005).

Acknowledgements

CIRCE (Climate Change and Impact Research: the Mediterranean Environment) is funded by the Commission of the European Union (Contract No 036961 GOCE) http://www.circeproject.eu/.
This briefing note forms part of the CIRCE deliverable D11.3.1.

▶ Final version, January 2008

References

▶ Founda D., Papadopoulos K.H., Petrakis M., Giannakopoulos C. and Good P., 2004: Analysis of mean, maximum, and minimum temperatures in Athens from 1897 to 2001 with emphasis on the last decade: trends, warm and cold events. *Global and Planetary Change*, 44, 27-38. http://dx.doi.org/10.1016/j.gloplacha.2004.06.003

▶ Giannakopoulos C, Bindi M., Moriondo M., LeSager P. and Tin T., 2005: *Climate change impacts in the Mediterranean resulting from a 2°C global temperature rise*, Report published in July 2005 by WWF, the global conservation organization, Gland, Switzerland, available from: http://assets.panda.org/downloads/medreportfinal8july05.pdf

▶ Giannakopoulos C. and Psiloglou B.E., 2006: Trends in energy load demand for Athens, Greece: Weather and non-weather related factors, *Climate Research*, 13, 31(1), 97-108 (MICE special issue) doi: 10.3354/cr031097

▶ Kostopoulou E. and Jones P.D., 2005: Assessment of climate extremes in the Eastern Mediterranean. *Meteorology and Atmospherics Physics*, 89(1-4), 69-85. doi:10.1007/s00703-005-0122-2

Authors

▶ Christos Giannakopoulos and Effie Kostopoulou, National Observatory of Athens, Institute for Environmental Research & Sustainable Development, Metaxa & V. Pavlou, GR-152 36 Palaia Pendeli, Athens, Greece.
Email: giannak@meteo.noa.gr,ekosto@meteo.noa.gr.
Tel: +30-210-8109128, +30-210-8109151
• Fax: +30-210-8103236

Editors

▶ Maureen Agnew (m.agnew@uea.ac.uk) and Clare Goodess (c.goodess@uea.ac.uk)
Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, UK