A global perspective on the urban heat island effect

Lead Supervisor: Sue Grimmond, Department of Meteorology, University of Reading,
Email: C.S.Grimmond@reading.ac.uk http://www.urban-climate.net/

Co-supervisor: Robin Hogan, ECMWF, Reading, Email: r.j.hogan@ecmwf.int

Urban areas are expanding rapidly in many parts of the globe, with 70% of the world's population projected to live in towns and cities by 2050. The urban heat island effect can cause cities to be 6-12°C warmer than the surrounding rural areas, which is of great concern due to the increased fatalities associated with heatwaves, an issue that will be exacerbated by climate change. Urban areas are in the process of being introduced into the model of the European Centre for Medium-Range Weather Forecasts (ECMWF), involving a rigorous treatment of the turbulent and radiative exchanges at the principal elements of an urban area (the streets, walls and roofs). This PhD project is an excellent opportunity to be involved in this exciting work, from development of the underpinning science of modelling urban areas, through to the implementation and exploitation of this new capability in the ECMWF system to answer intriguing scientific questions on a global scale.

"Nightlight" image of Western Europe generated from cloud-cleared nighttime imagery from the DMSP-OLS satellites, highlighting the extent of urban areas on a continental scale.

It is envisaged that the PhD project would have three components involving several key scientific questions:

1. *How can we optimally represent 3D solar and thermal-infrared radiative transfer in urban areas?* A good starting point will be a new method that has recently been developed for efficiently representing the 3D interaction of radiation with randomly distributed objects, and has been successfully applied to both clouds and vegetation. What changes would be needed to adapt it for buildings? What is the impact on radiation of incorporating trees and parks into the urban landscape? How well does this approach match benchmark calculations from much more detailed (and expensive) radiation models?
2. *How well does the new urban treatment in the ECMWF model predict near-surface air temperature and surface fluxes of heat and moisture?* A systematic evaluation will be performed against existing observations from a number of contrasting cities from around the world, and possibly also using satellite

observations of skin temperature. By re-running the global land-surface module (which is fast) of the ECMWF model, the student will investigate how improvements in the treatment of urban areas in the model can improve the fit to observations.

3. Many intriguing scientific questions can then be asked using the full model. *What is the impact of urban areas globally on the weather?* Whether or not the impact is significant is a topic of controversy in the literature, but the student will be able to exploit existing ECMWF software tools to determine whether forecasts are improved downstream of cities. *What will be the impact of future increases in urban coverage, and possible mitigation efforts such as building greener cities?* By modifying the global maps of urban properties used by the model it will be possible to explore how the urban heat island effect could change in the future.

With the tools that will be available at ECMWF, the direction of the project is flexible and there are a number of avenues that the research could take depending on the interest and skills of the student.

Training opportunities:
The project would involve several placements at ECMWF in Reading, expected to amount to around 12 months in total. These would provide the student with invaluable experience of working in an operational research environment, building both team-working skills and the technical skills of modifying and running a large and complex model on a supercomputer and analyzing the large datasets produced. The student would also participate in one of the international urban physics/climate schools.

Student profile:
This project would be suitable for students with a degree in physics, mathematics or a closely related environmental or physical science.

http://www.reading.ac.uk/nercdtp