

Simulating climate change in urban areas: interactions between greenhouse forcing, land surface effects and heat sources

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2nd BETWIXT workshop, Birmingham University, 13-14 May 2004



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Alternative title:

What is wrong with what we gave to
UKCIP02?



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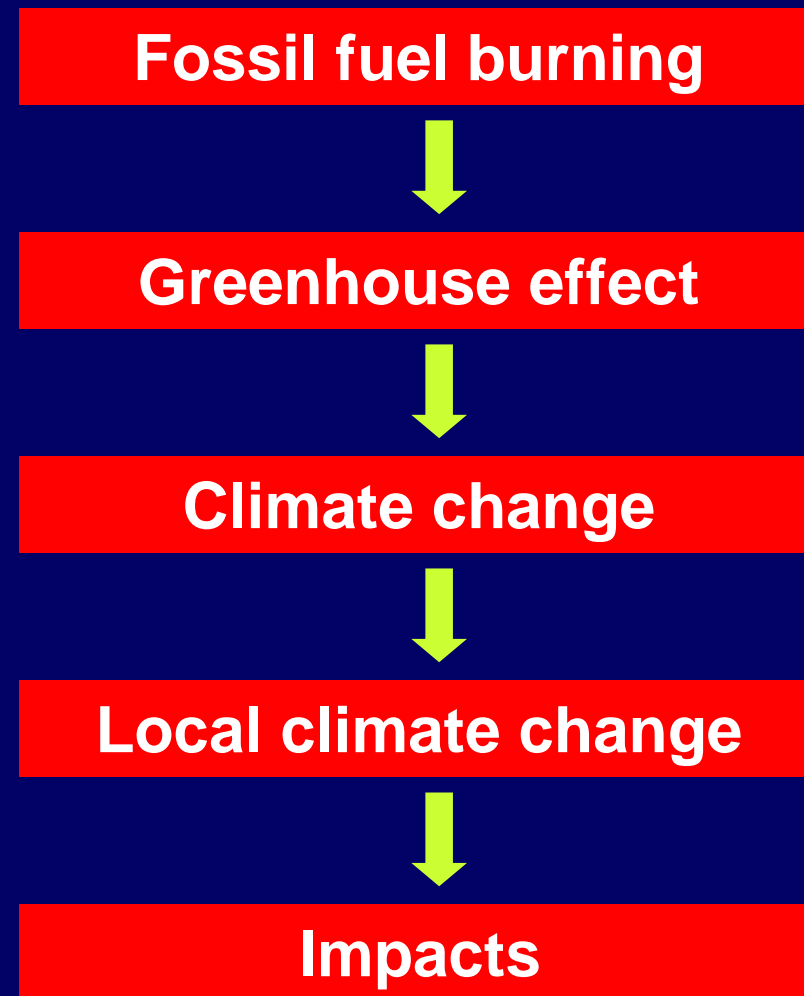
Urban heat islands

- Cities can be several °C warmer than surrounding rural areas
- Several reasons for this, including:
 - character of the land surface
 - » concrete/tarmac surface instead of vegetation
(less soil water infiltration and evaporation)
 - » heat capacity of buildings
 - sources of heat within the urban area
- Studies of climate change impacts in urban areas must take this into account



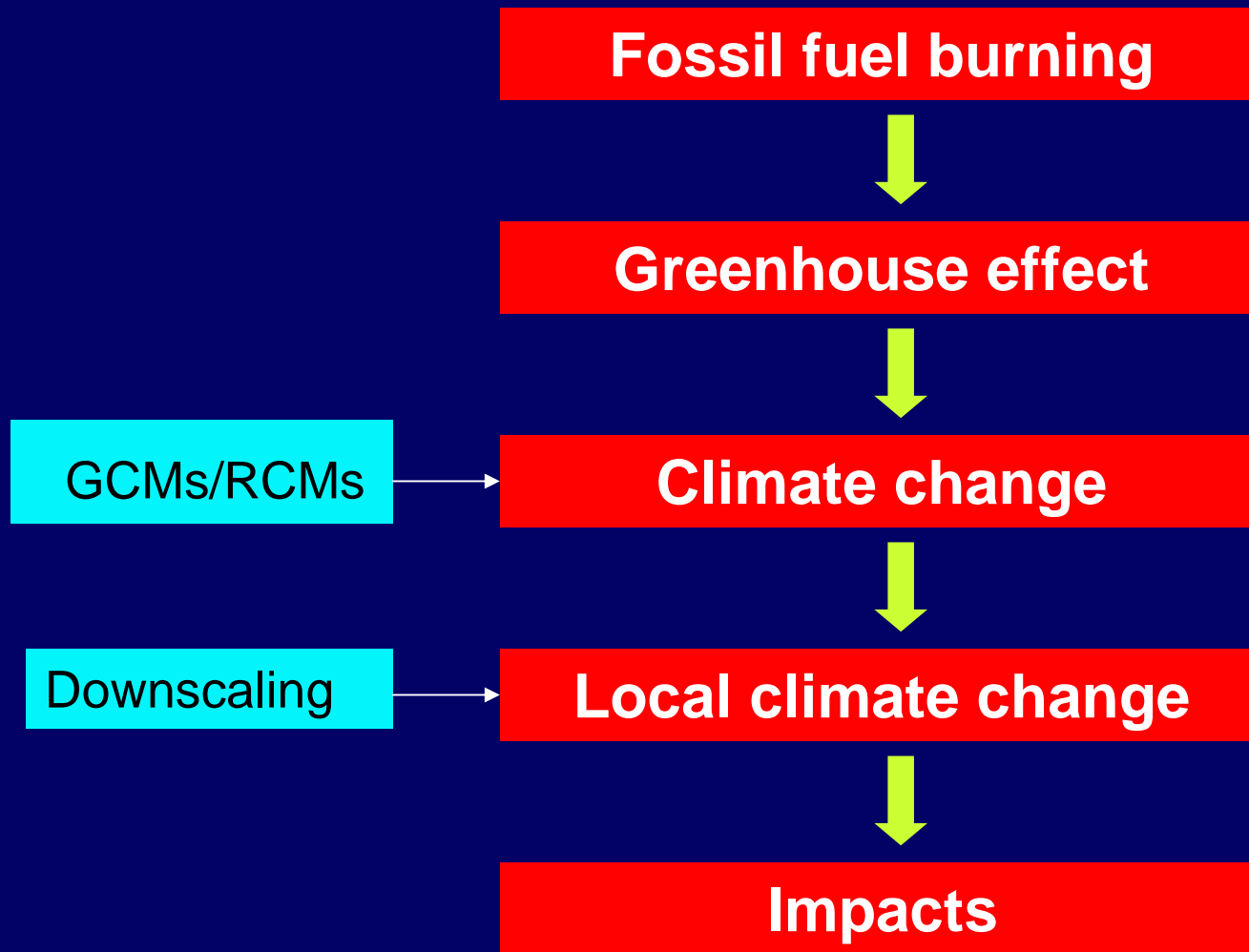
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Fossil fuel burning, climate change and its impacts



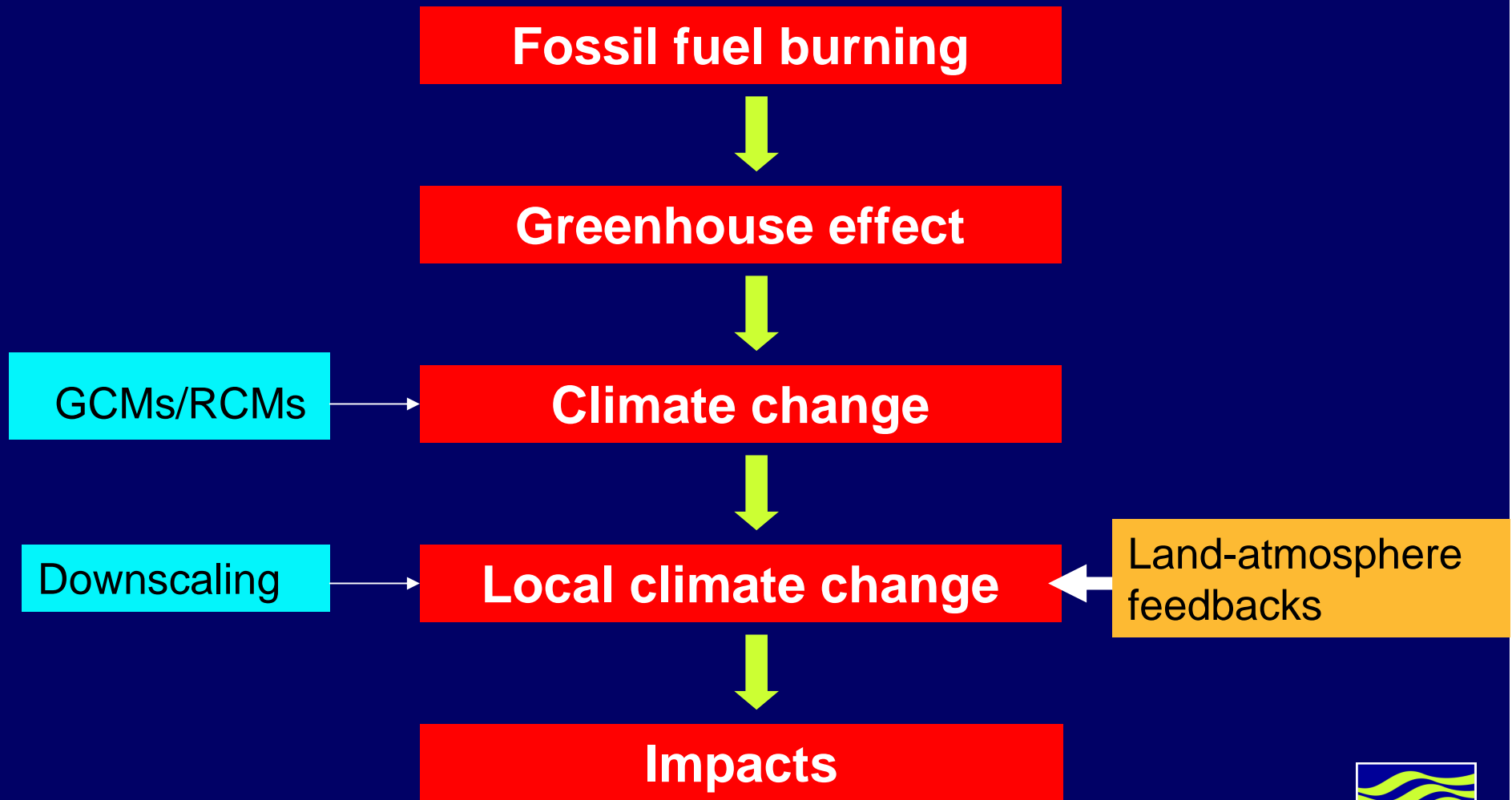
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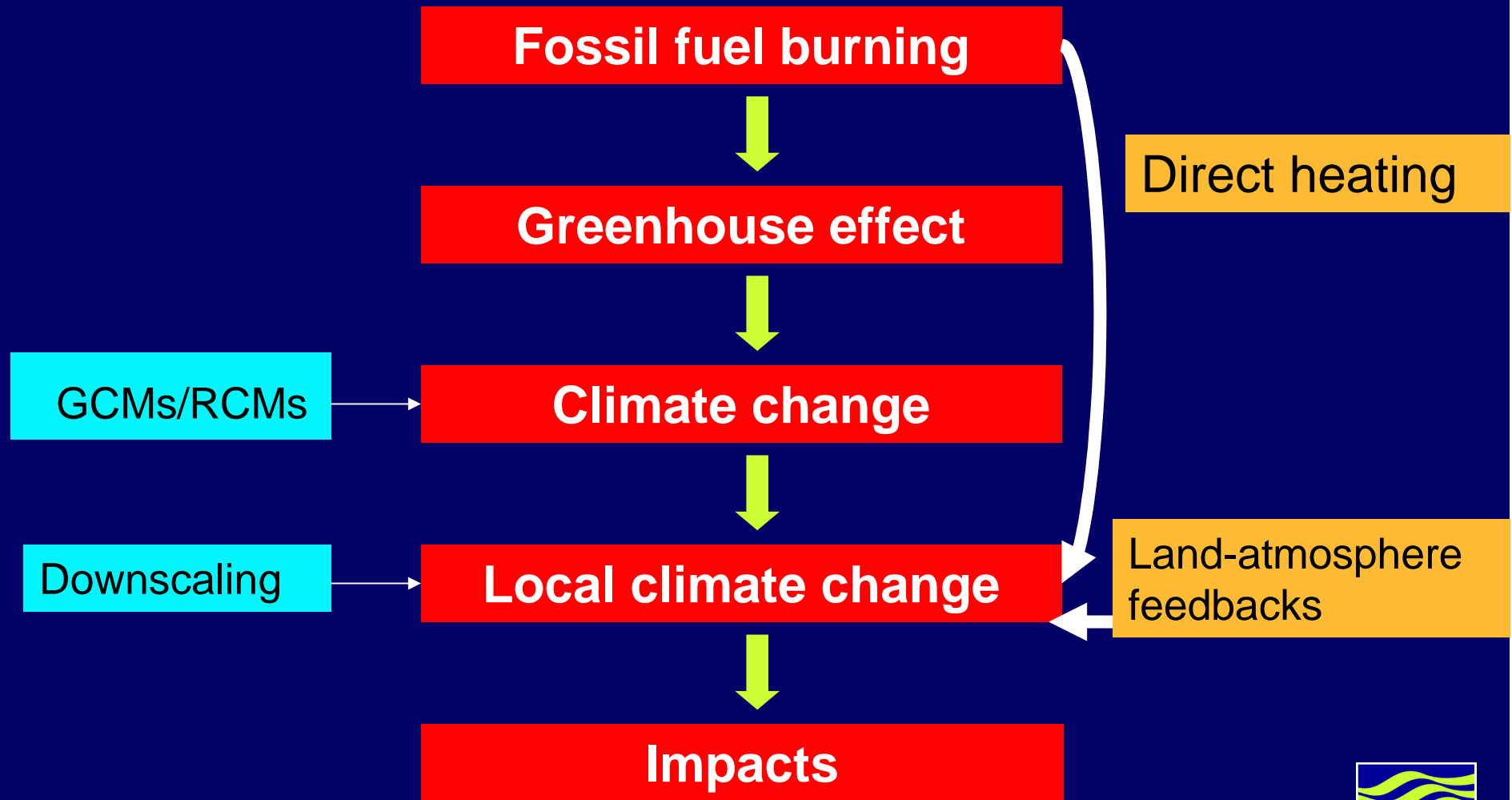
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Fossil fuel burning, climate change and its impacts



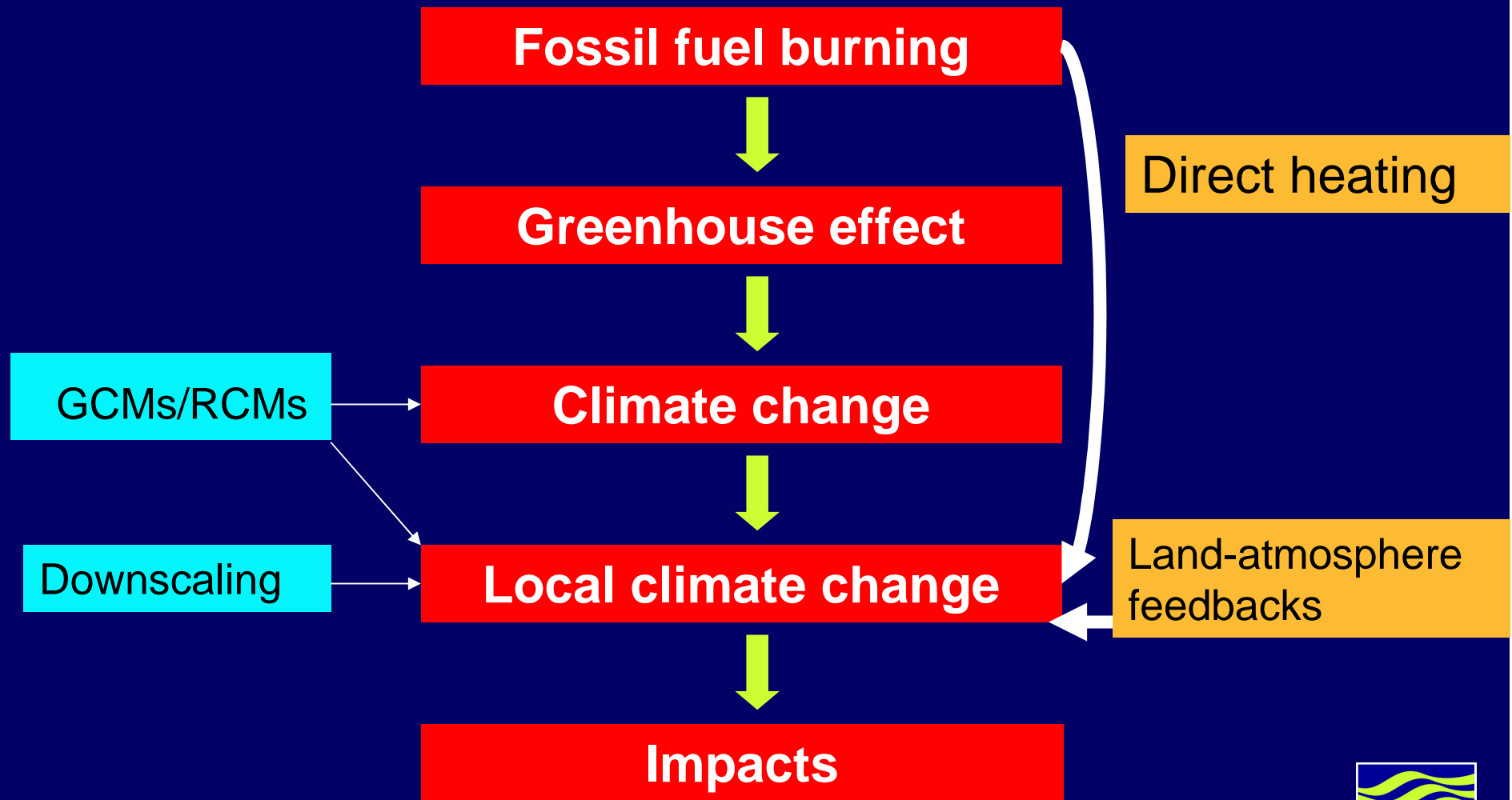
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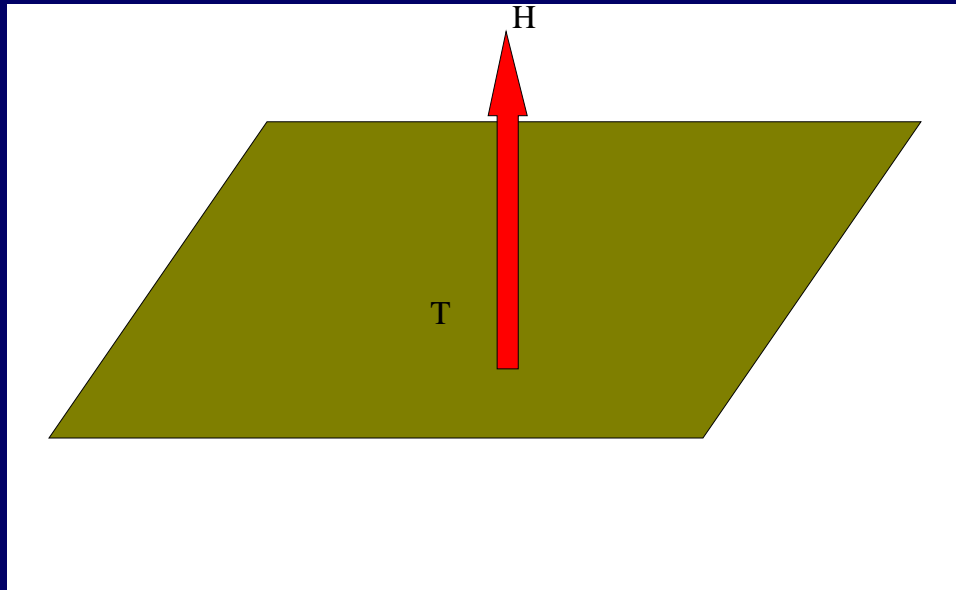
Overview

- **Model formulation & experimental design**
- **Heat island due to land surface effects**
 - current climate
 - doubled-CO₂ climate
- **Effect of land-atmosphere feedbacks on changes in heat island under doubling CO₂**
 - can we assume heat islands remain unchanged?
- **Effect of direct heat sources on heat island**
 - comparison with doubled-CO₂ warming

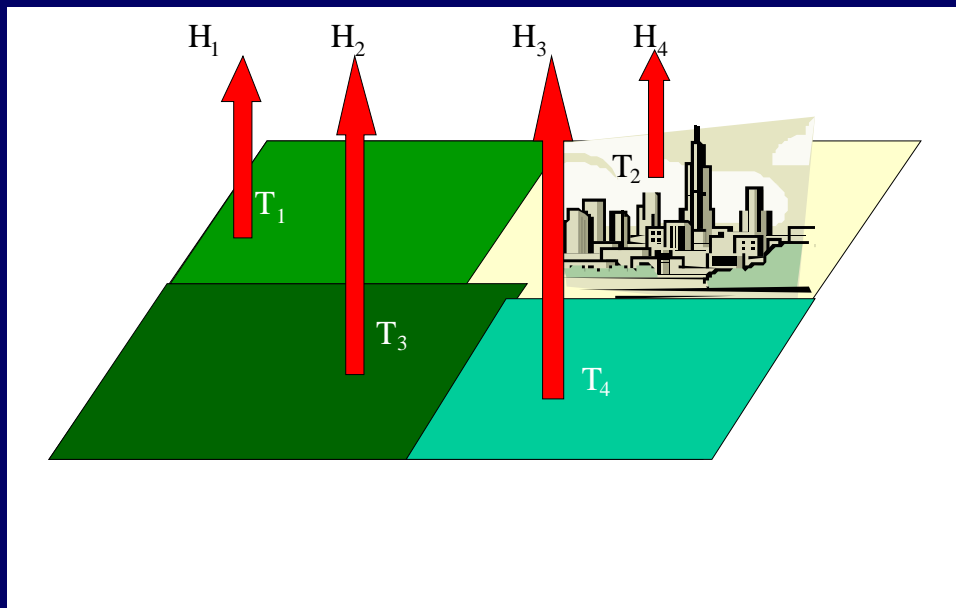


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Representations of sub-gridscale land surface heterogeneity



“Effective parameters”
(HadCM3 / AM3 / RM3,
used in UKCIP02)

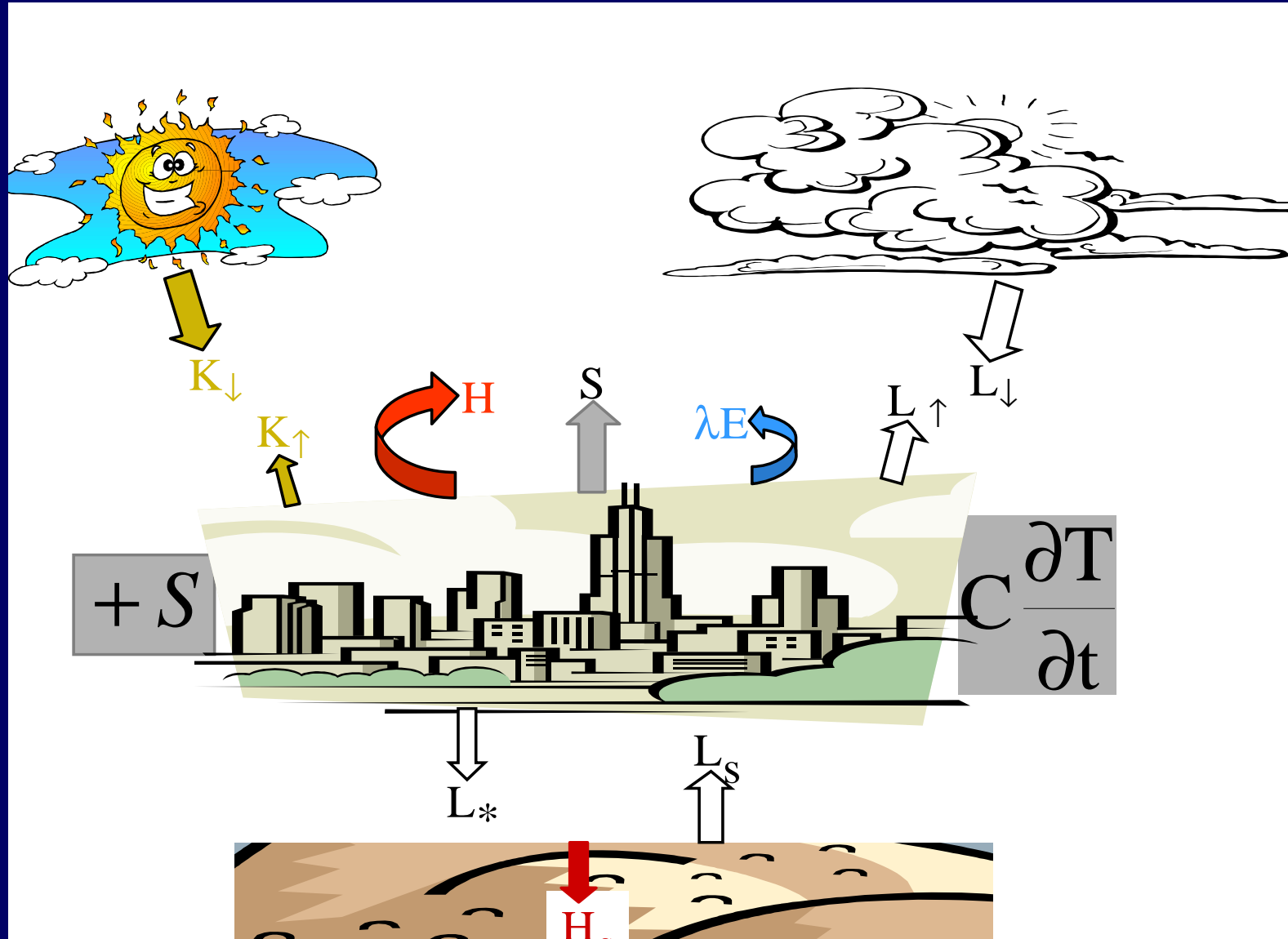


“Tiles”
(HadCM3-MOSES2
& new model HadGEM1)



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Urban areas and anthropogenic heat source in model surface energy budget



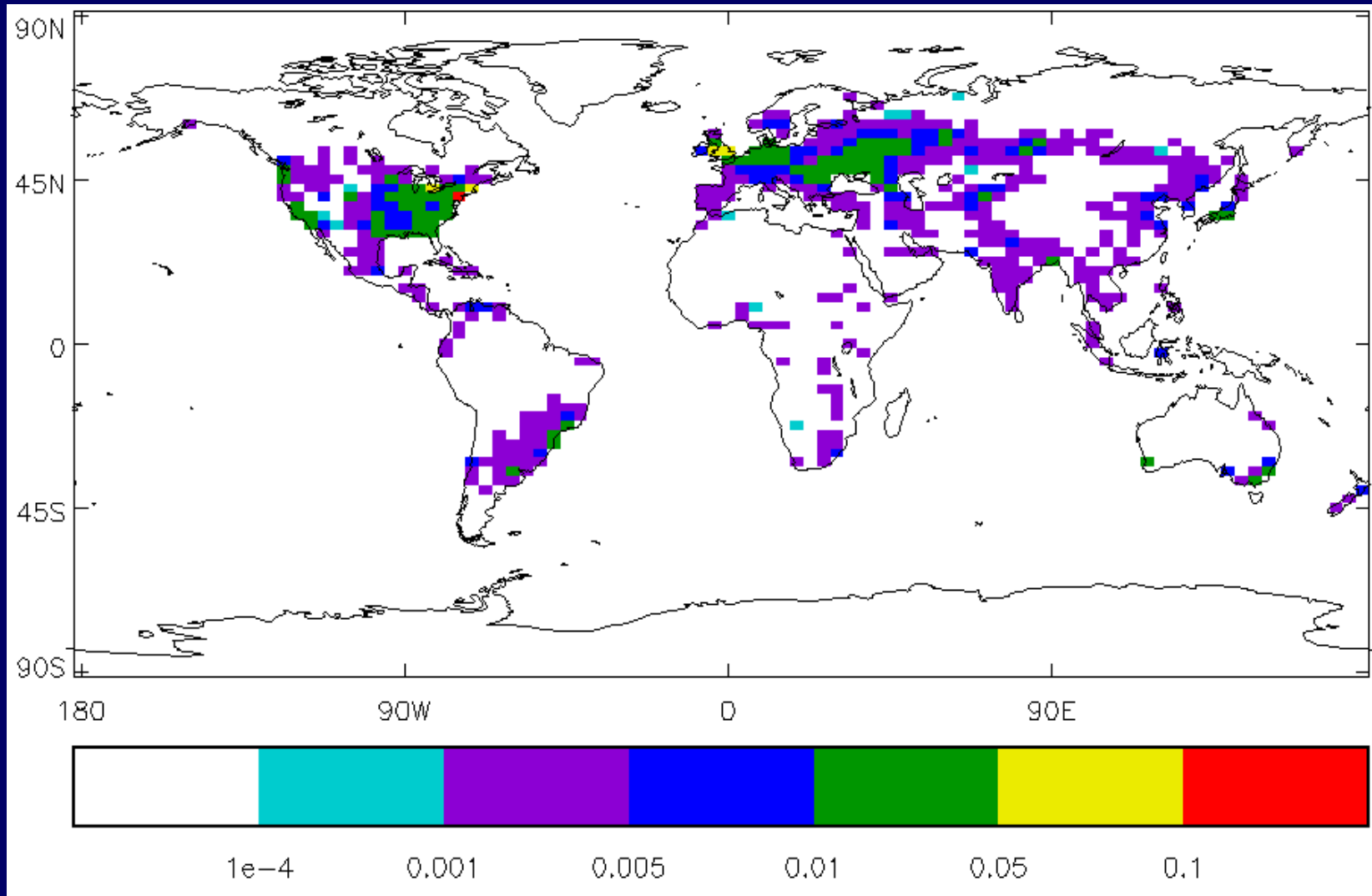
Experimental Design

ID	Urban	CO ₂	Heat
N1N	No	1x	None
N2N	No	2x	None
U1N	Yes	1x	None
U2N	Yes	2x	None
U1C	Yes	1x	Current
U2C	Yes	2x	Current
U2F	Yes	2x	Future



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Fraction of GCM gridbox specified as urban land



Horizontal resolution: $2.75^\circ \times 3.75^\circ$



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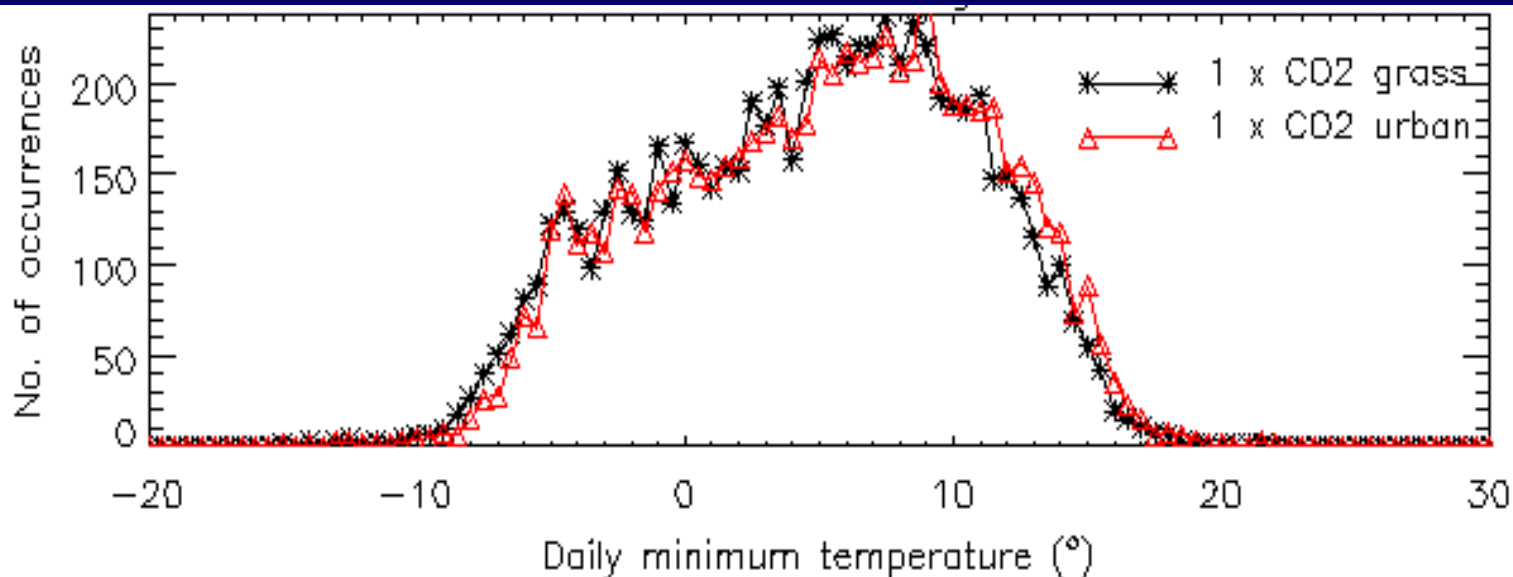
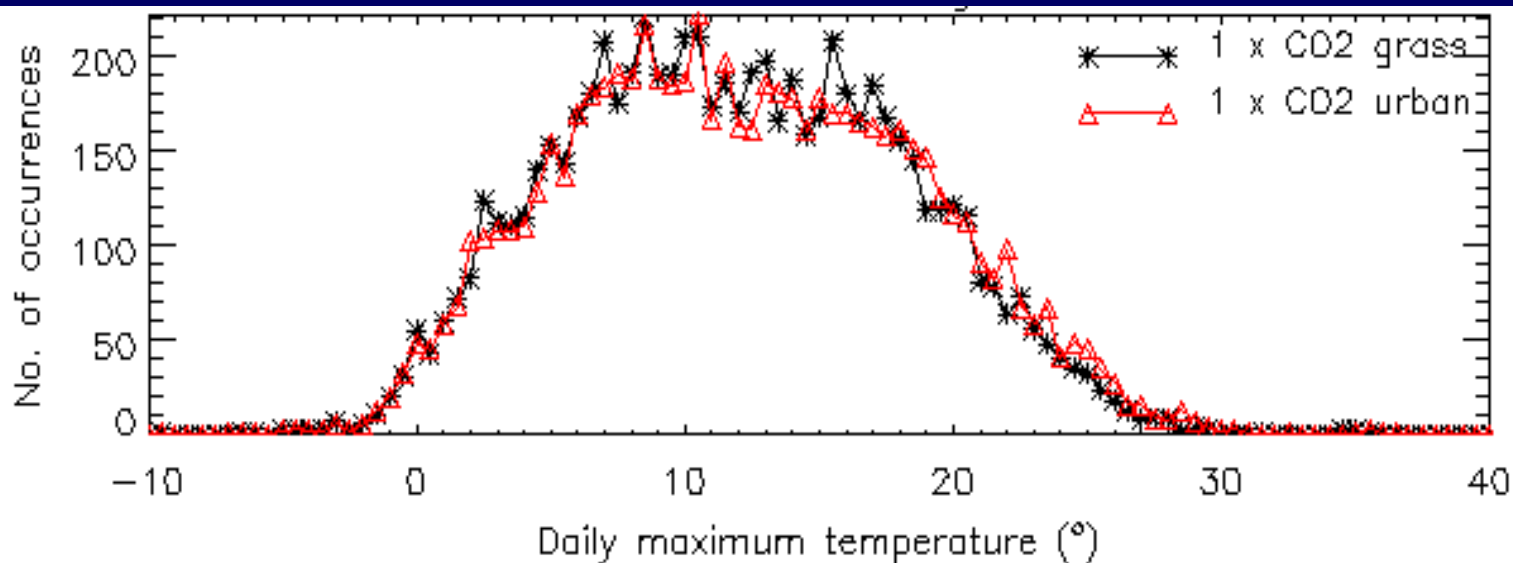
Comparing climate change in urban and non-urban areas (no additional heat sources)

- 1×CO₂ simulation with urban areas
 - compare temperature on urban and non-urban tiles
- 2×CO₂ simulation with urban areas
 - compare temperature on urban and non-urban tiles

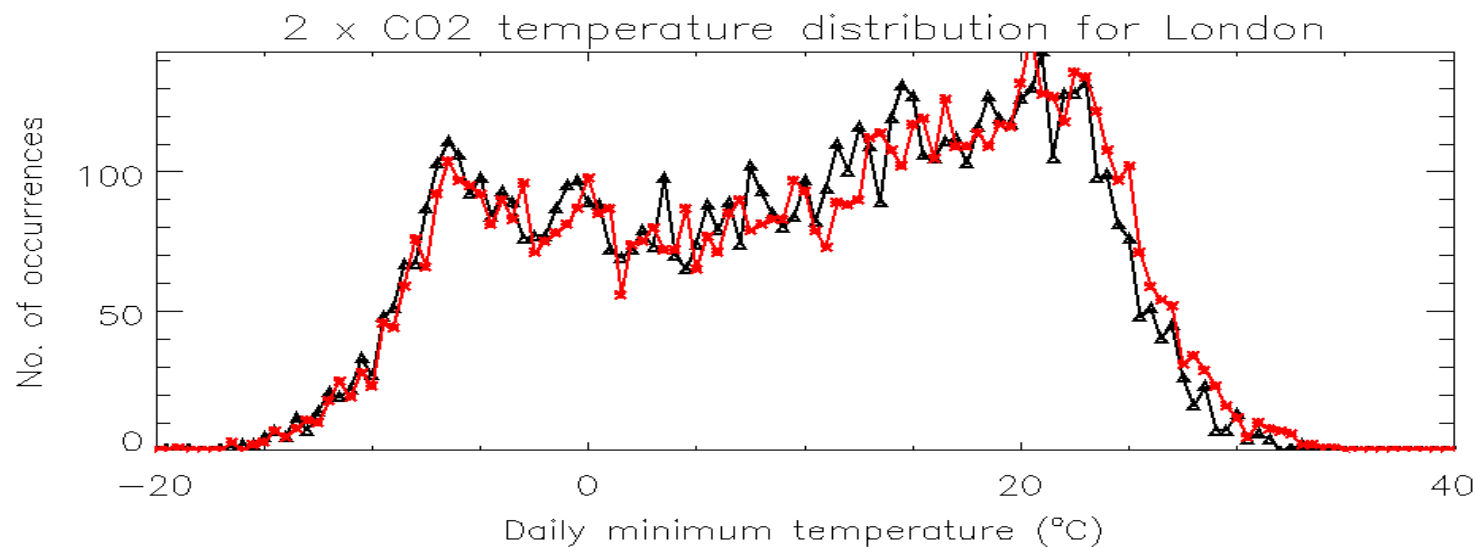
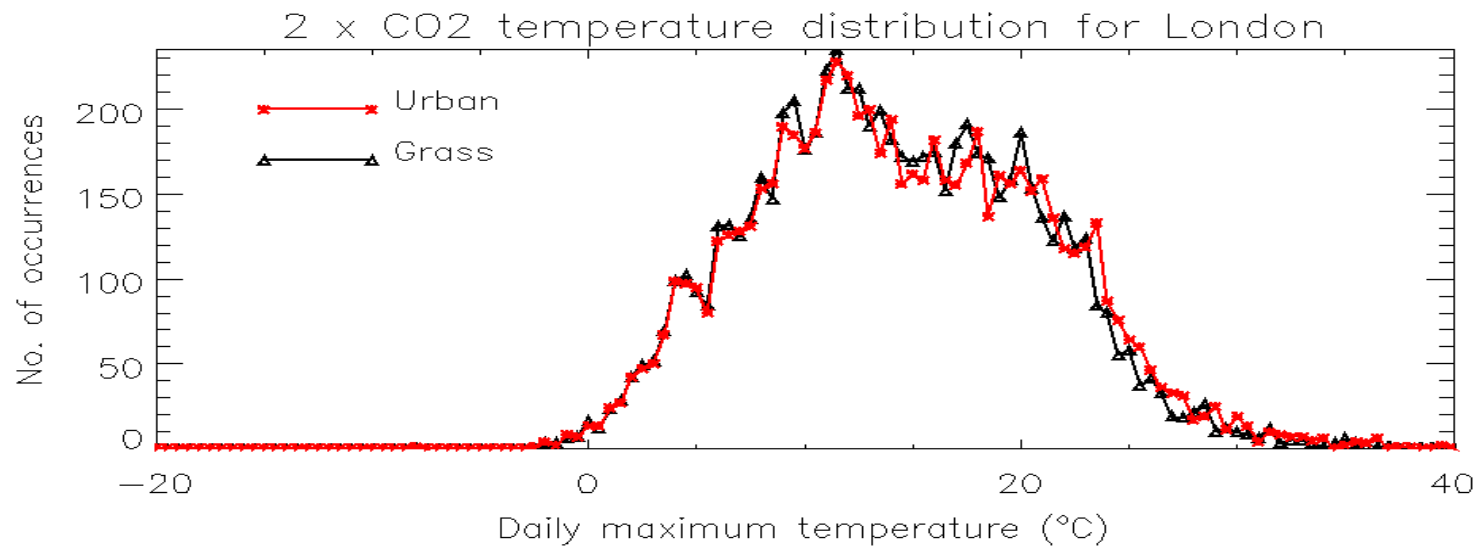


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Simulated present-day distributions of daily maximum and minimum temperatures: London gridbox



Simulated distributions of daily maximum and minimum temperatures under doubled CO₂: London gridbox



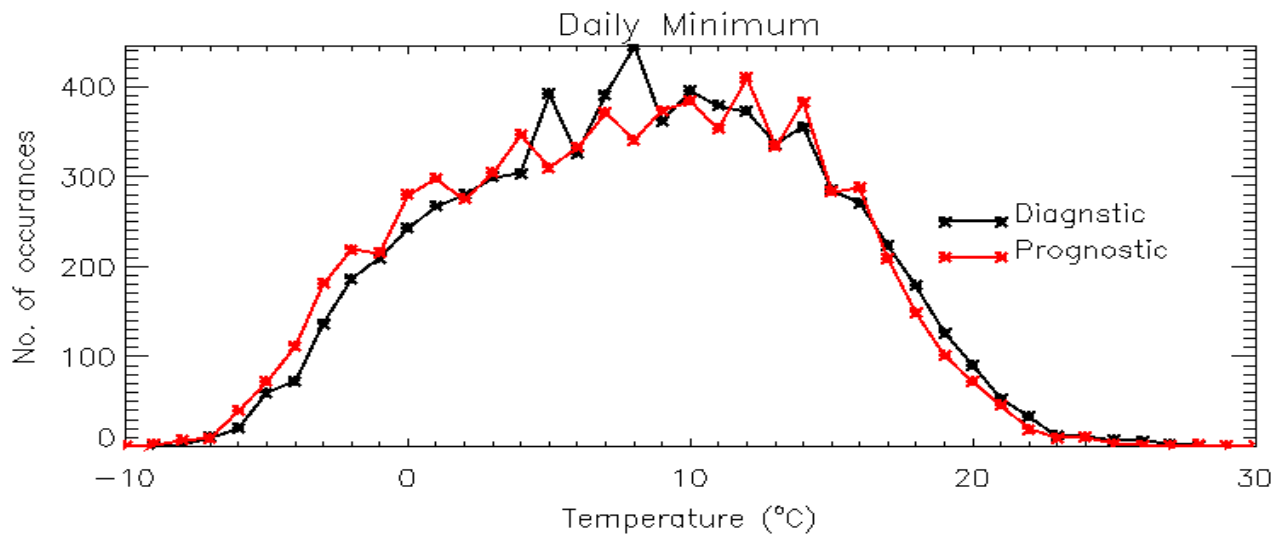
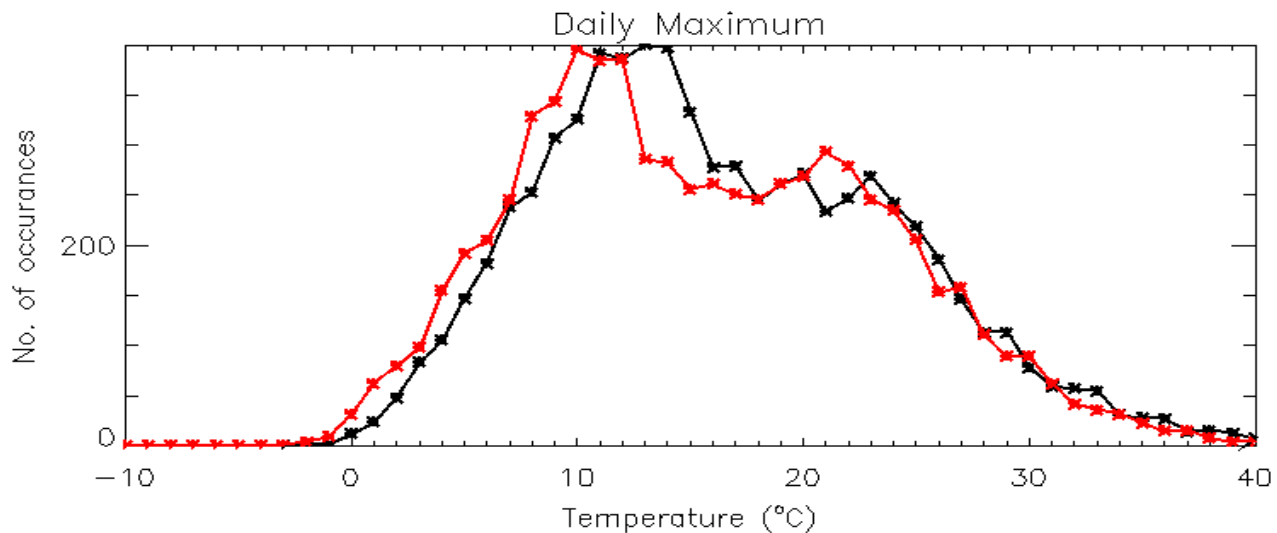
Do we need to model the urban heat islands, or can we just add on present-day climate patterns to standard modelled climate change?

- Extract urban heat island from present-day simulation
- Simulate doubled-CO₂ climate change without urban areas included
- Add on present-day urban heat island
- Compare urban temperatures with those simulated in 2×CO₂ run including urban areas



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Effect of feedbacks on urban temperatures under doubled CO₂



“Prognostic” (red):
urban
temperatures
simulated within
GCM

“Diagnostic”
(black): doubled-
CO₂ climate +
present-day heat
island



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How important are direct heat sources for urban climate change?

- Consider 3 cases:
 - No direct heat source
 - Estimated present-day heat source
 - Extrapolated heat source for time of doubling of CO₂



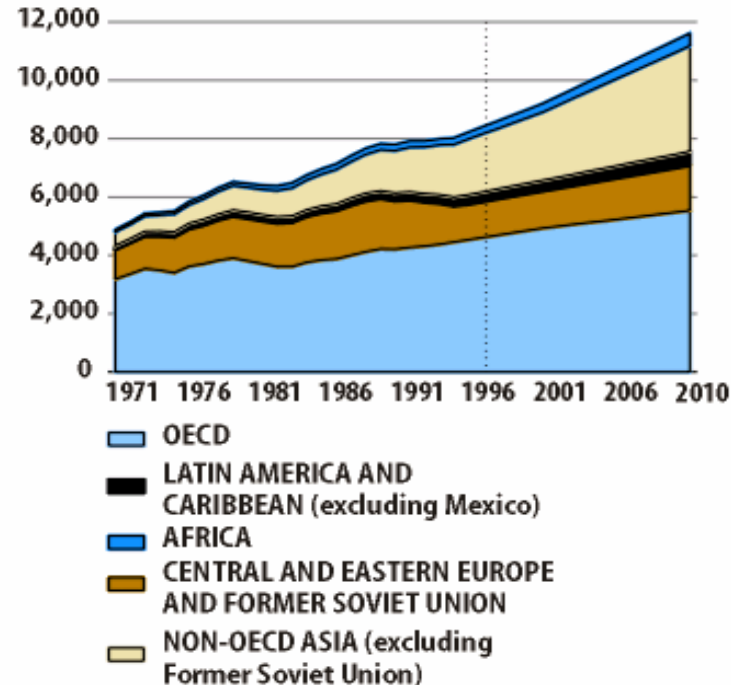
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Determining the Heat Source

Global Energy Use is Projected to Rise

Past and Projected Trends in Energy Demand, 1970-2010a

(million metric tons of oil equivalent)



Source: International Energy Agency, *World Energy Outlook 1996*, (OECD, Paris, 1996), pp. 237-285; International Energy Agency, *Energy Statistics and Balances*, on diskette (OECD, Paris, 1997).

World Resources Institute

www.wri.org/trends/emission2.html

1 Tonne of Oil Equivalent = 41.868 GJ

Global Energy Use $\approx 335 \text{ EJ}$ (10^{18})

Distributed Globally = 0.02 Wm^{-2}

Distributed Over Land = 0.06 Wm^{-2}
(Land = 35% of Globe)

Distributed Over Cities = 45.8 Wm^{-2}
(Cities = 0.046% of Globe
= 0.14% of Land)

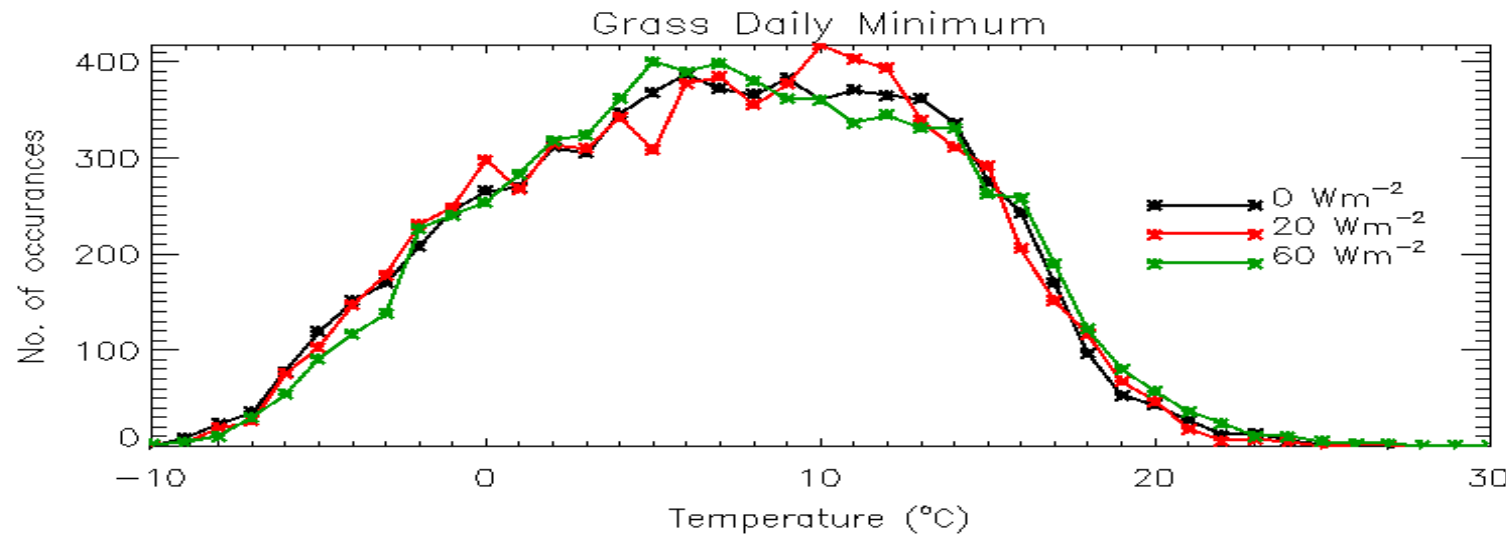
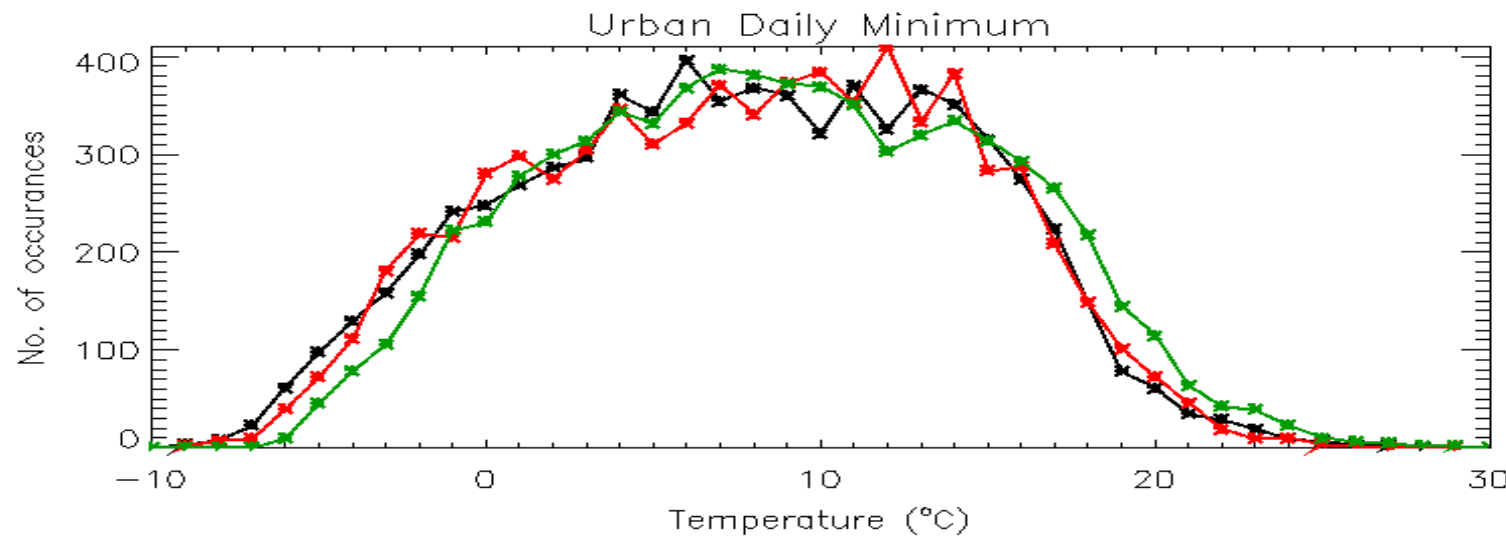
Current Day Anthropogenic
Heat Source = 20 Wm^{-2}

Future Anthropogenic
Heat Source = 60 Wm^{-2}



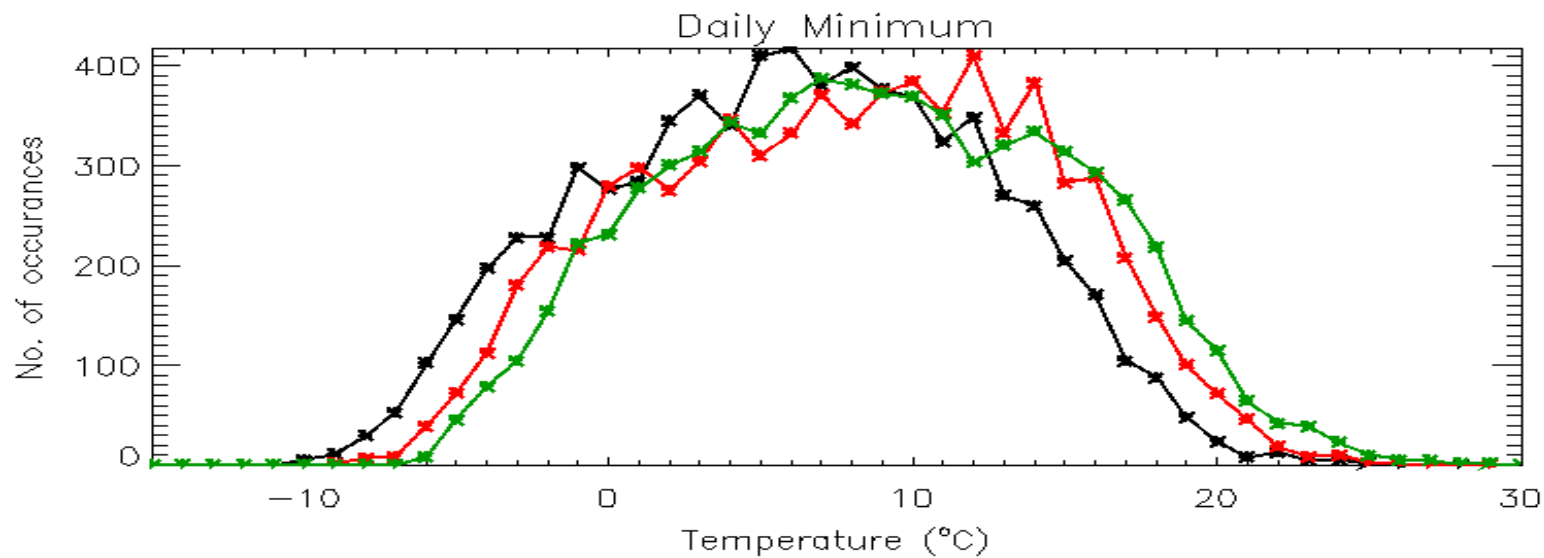
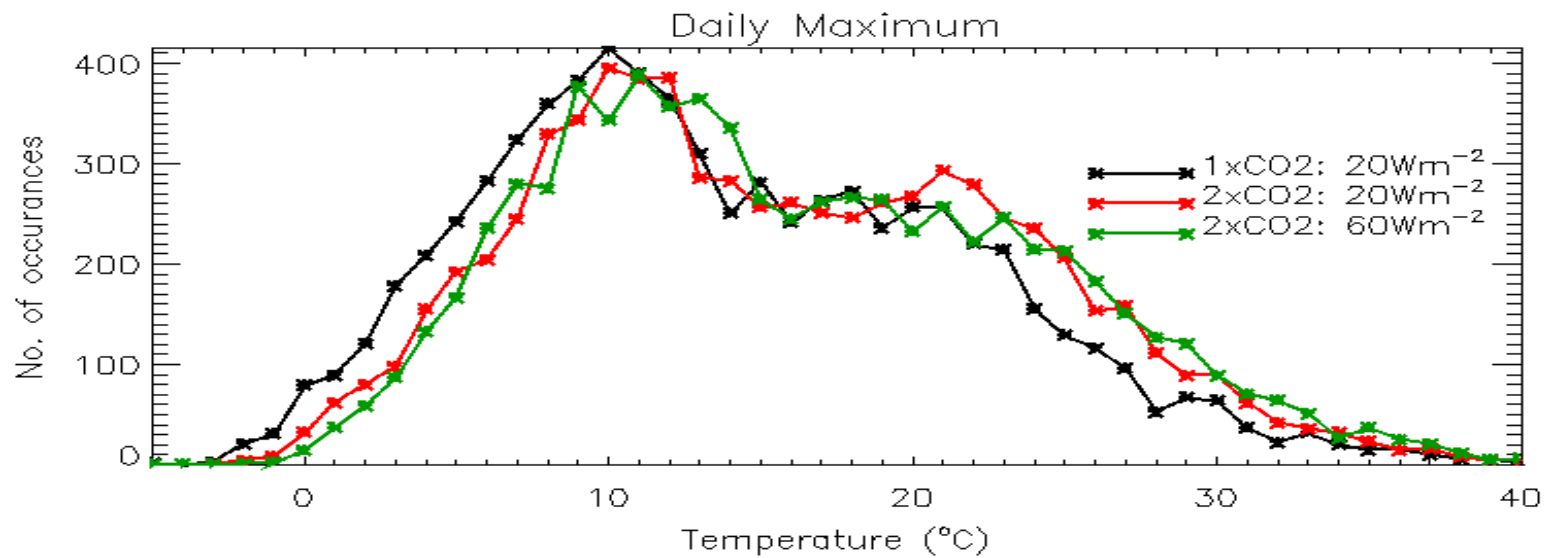
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Impact of direct anthropogenic heat source on simulated doubled-CO₂ temperatures

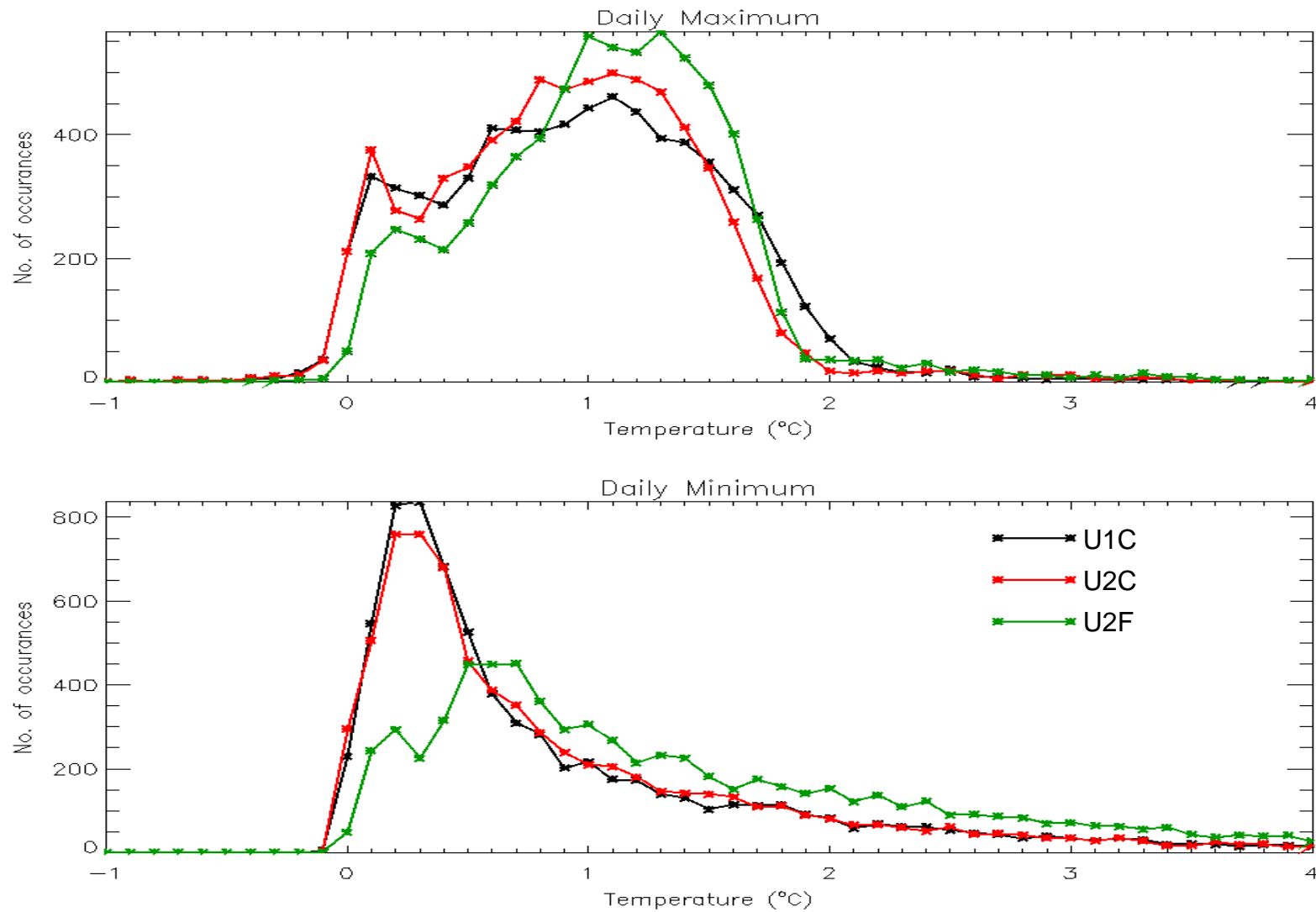


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Relative impact of heat source and doubling CO₂ on urban temperatures



Relative impact of heat source and doubling CO₂ on urban heat island (urban - grass temperatures)



Conclusions

- **Urban land warmer than non-urban land both at present-day and under doubled CO₂**
- **Even with no change in heat source, character of urban heat island changes under doubling CO₂ due to land-atmosphere feedbacks**
- **Tripling of heat source source significantly changes character of urban heat island**
- **Tripling heat source has smaller impact than doubling CO₂ concentration, but still significant**

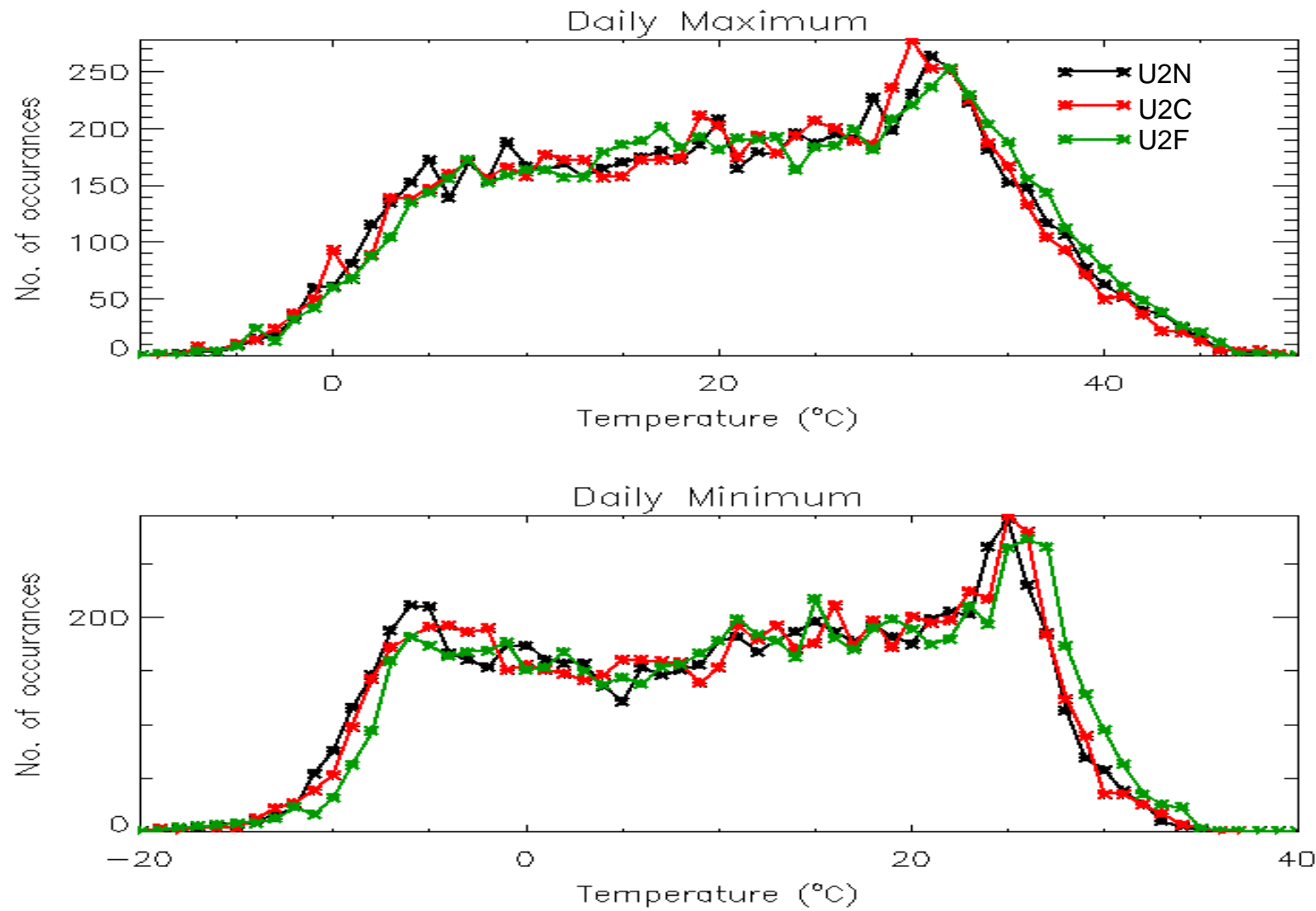


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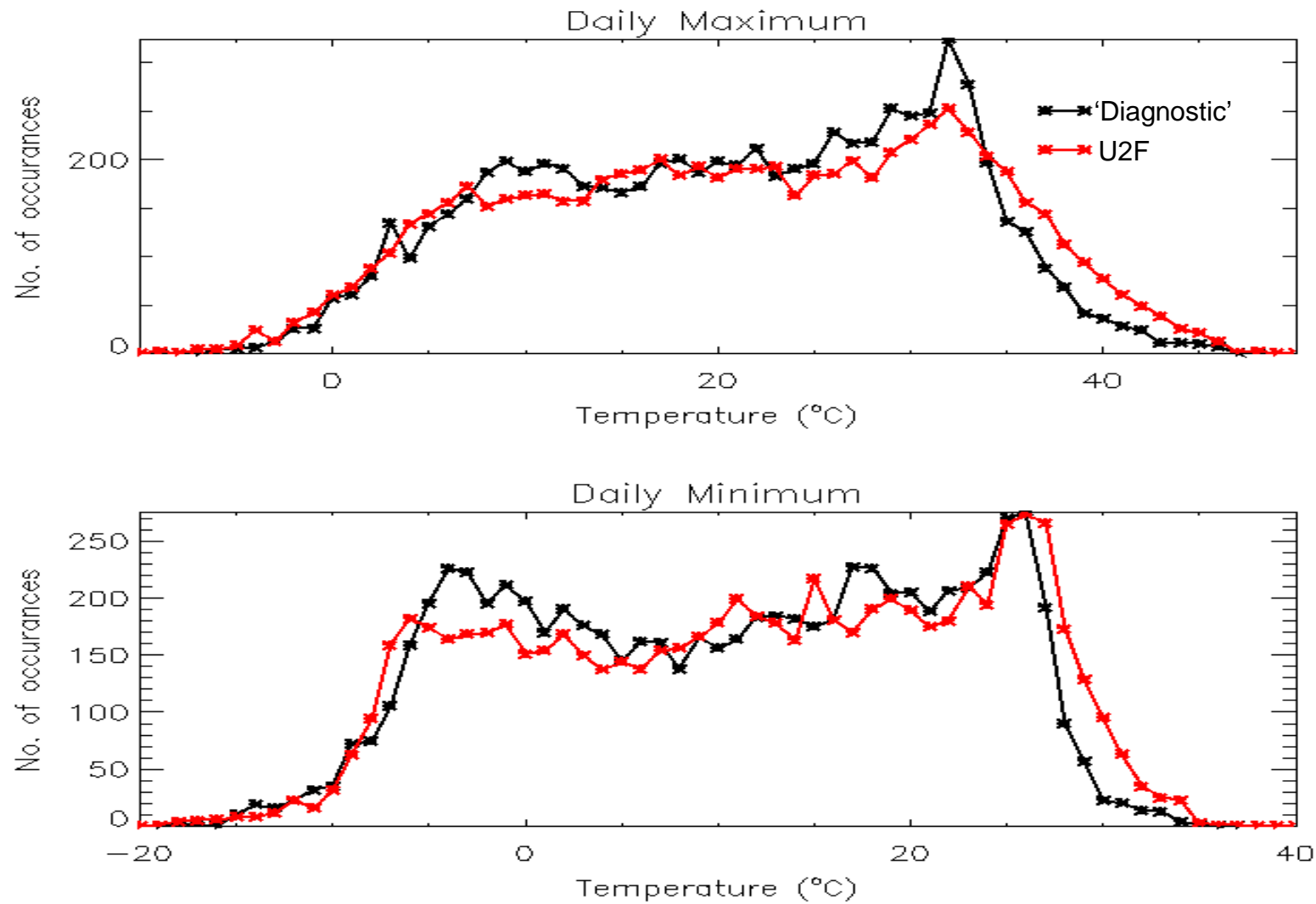


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Impact of Heat Source



Including Urban Areas



Relative Impact of Local Source

