Representing Urban Vegetation in Weather and Climate Models

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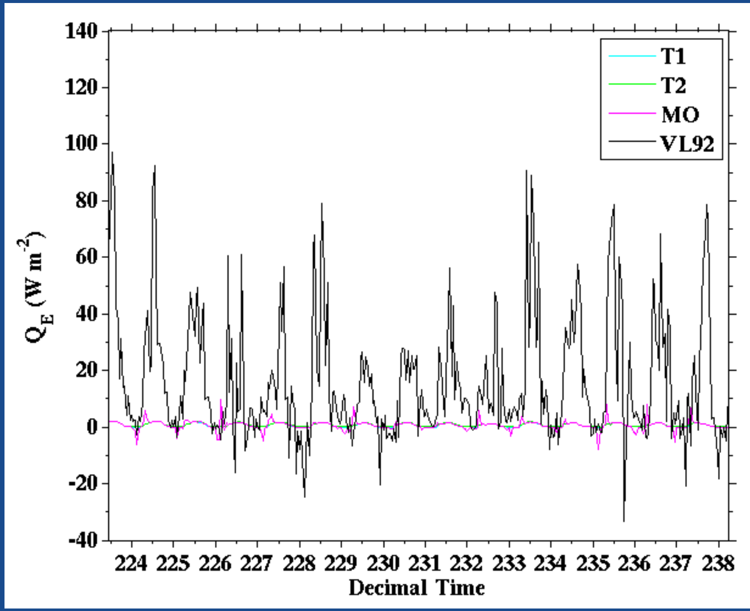
30 June 2014

1: Introduction

- High resolution mesoscale models now operational (~10^3 m) – Urban areas now resolved
- Urban schemes not fully capturing magnitude, partitioning and diurnal variability of the Surface Energy Balance (SEB)
- Moisture fluxes poorly modelled (Grimmond *et al.* 2010; 2011)



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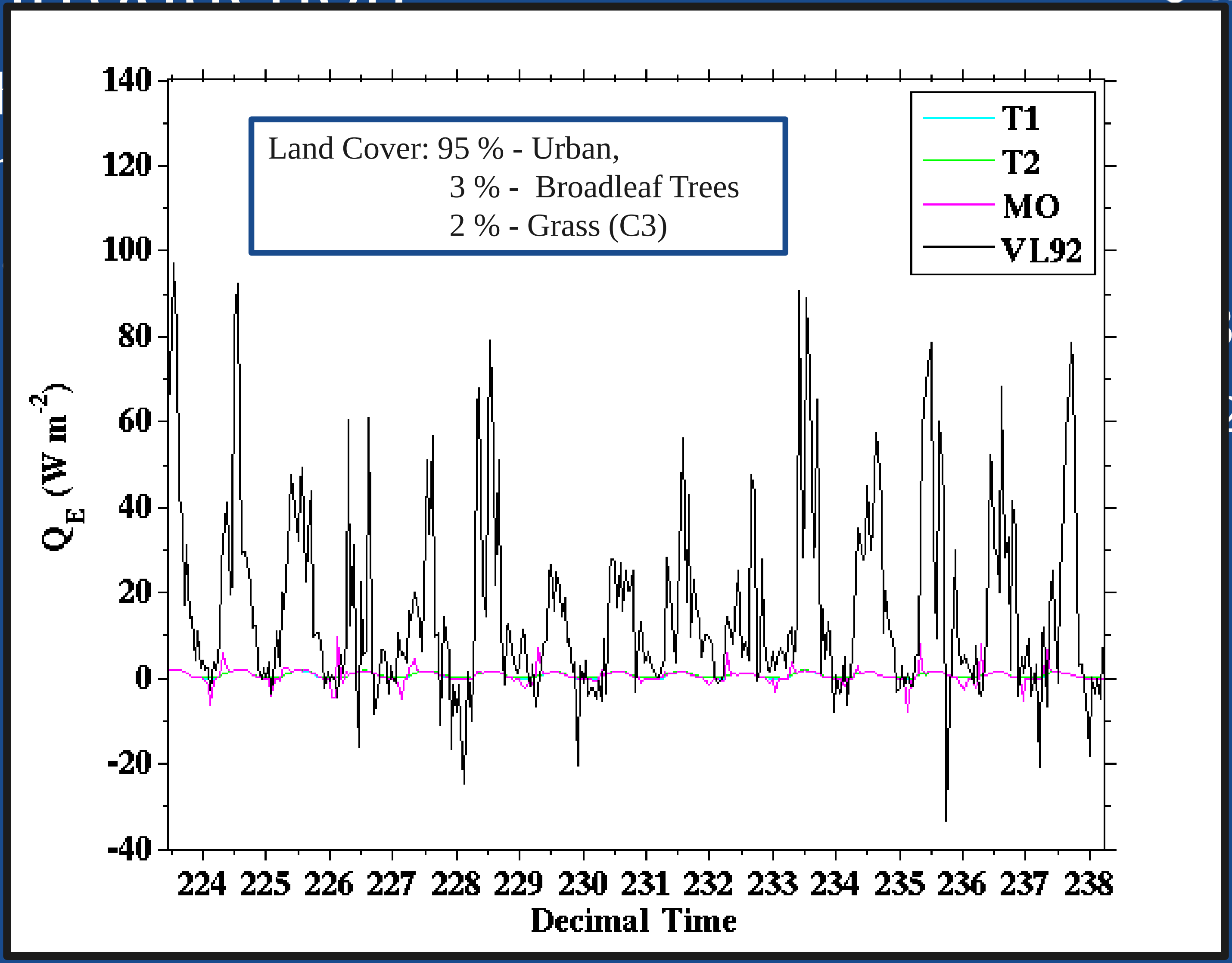

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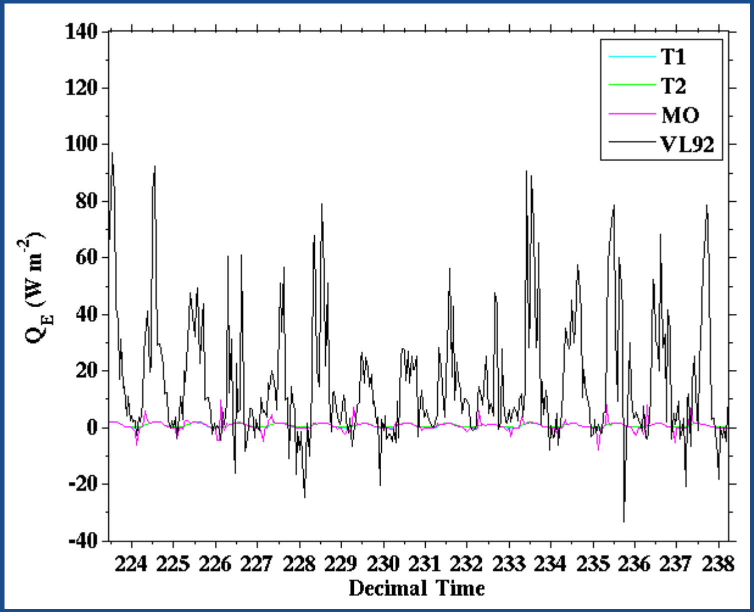
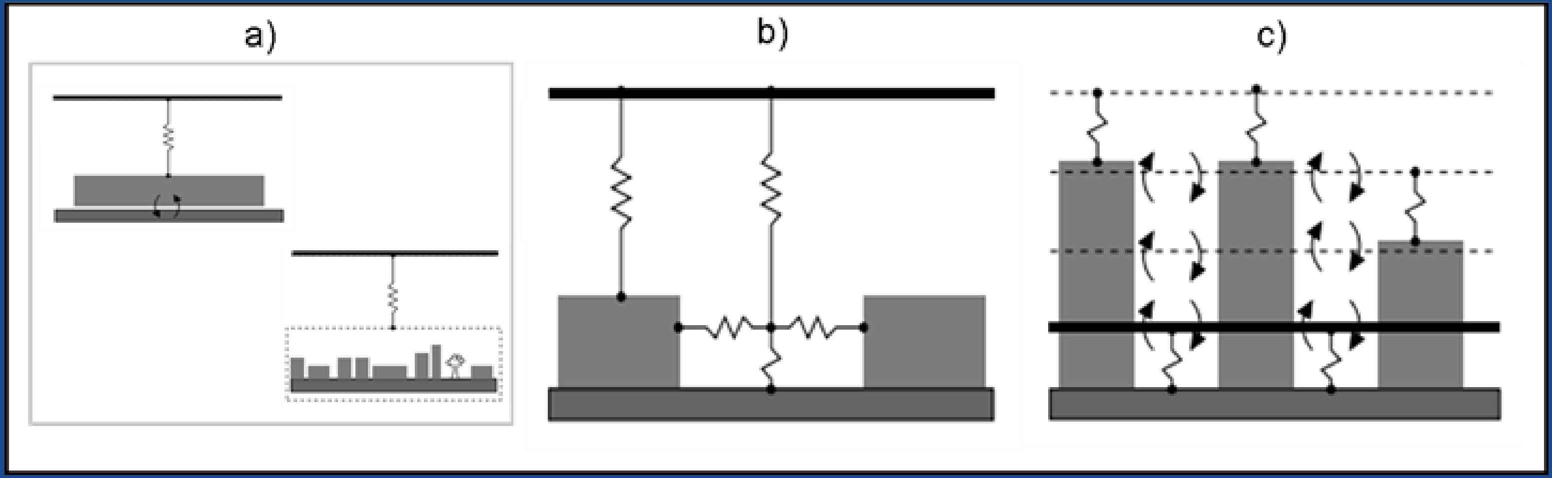
  – Urban areas now resolved
- Urban schemes not fully capturing magnitude, partitioning and diurnal variability of the Surface Energy Balance (SEB)
- Moisture fluxes poorly modelled (Grimmond *et al.* 2010; 2011)
- More than half the worlds population live in urban areas (United Nations, 2011)
- Number or extreme heat events expected to increase (IPCC, 2013)
- Test mitigation strategies and improve model forcing



2: Urban Surface Schemes

- Three types of urban representation within schemes
  - Slab/Bulk (e.g. Best, 2005; Grimmond & Oke, 2002)
  - Single Layer (e.g. Masson, 2000; Porson *et al.*, 2010)
  - Multi-layer (e.g. Martilli et al., 2002)
- Within JULES three urban scheme options available
  - 1 tile, 2 tile & MORUSES (Best *et al.*, 2011, Porson *et al.*, 2010)



After Harman, 2003

3: Vegetation in Urban Schemes

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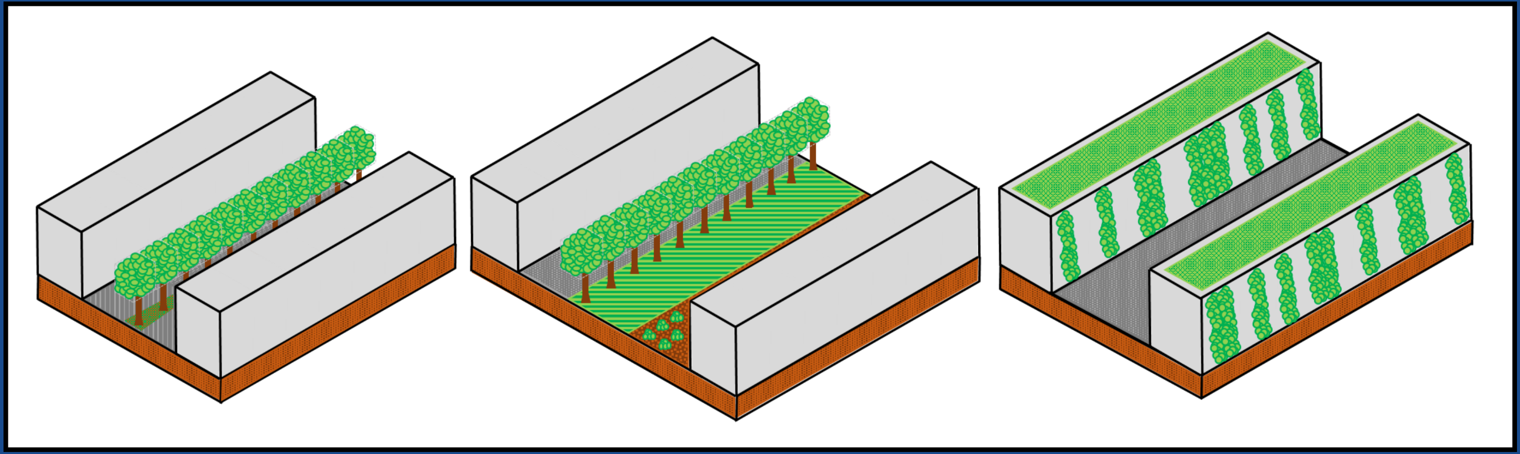
- Vegetation on the whole not included explicitly within urban schemes
  – No representation – non-natural impermeable surfaces
  – Vegetation tiles within the scheme
  – Vegetation tiles independent of the scheme
- Urban impact on vegetation physiology/dynamics not represented
- Few schemes have represented vegetation explicitly. Show improvement, but constrained by existing model frameworks (e.g. Lee, 2011; Lemonsu *et al.*, 2012; Krayenhoff *et al.*, 2014)

4: The Plan

- Single layer vegetated urban canyon scheme
- Urban vegetation represented in a integrated and physically sound manner
- Evaluate the performance of the new scheme against observations and existing schemes
- Apply a version within JULES – New urban tile(s)
- Applications: UHI mitigation, CO_2 budgets, forecasting



5: Questions Posed

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Does the inclusion of vegetation within a single layer urban street canyon model improve the modelling of urban latent heat flux?

- What impact does a tree located within an urban canyon have on the radiation balance? How can we model this?
- How does urban vegetation effect flow within a street canyon and what implications does this have on the SEB?
- Is the parameterisation of urban canyon hydrology the missing link in improving the modelling of urban moisture?
- What impacts do urban areas have on vegetation physiology?

6: Radiation

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What impact does a tree located within an urban canyon have on the radiation balance? How can we model this?

- Reduced solar radiation receipt on urban surfaces
- Longwave radiation trapping within the canyon
- Surface and canyon emissivity and albedo altered

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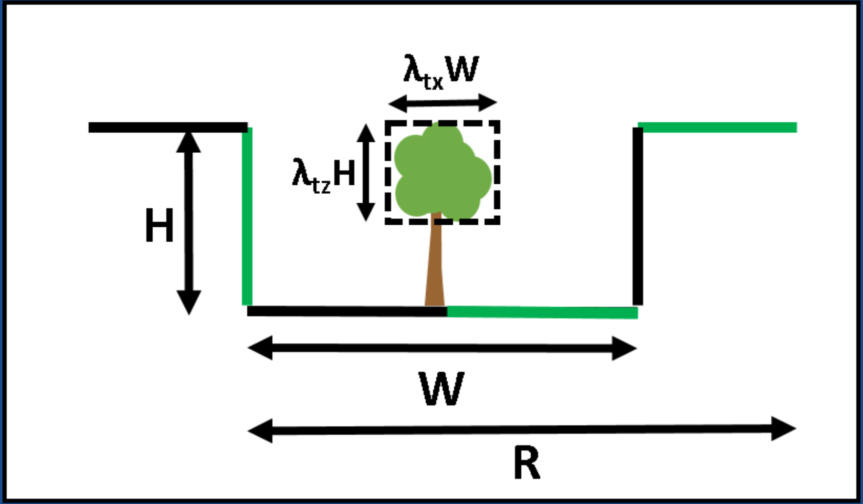
Radiation Model

- Diffuse radiation exchange model (Harman *et al.*, 2004)
- Facet radiation balance using shape factors
- Tree canopy radiation



7: Flow and Surface Exchange

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How does urban vegetation effect flow within a street canyon and what implications does this have on the SEB?

- Increased canyon surface roughness due to vegetation
- Disruption of circulation patterns – stagnation
- Turbulent fluxes are likely to be reduced (Harman *et al.* 2004)

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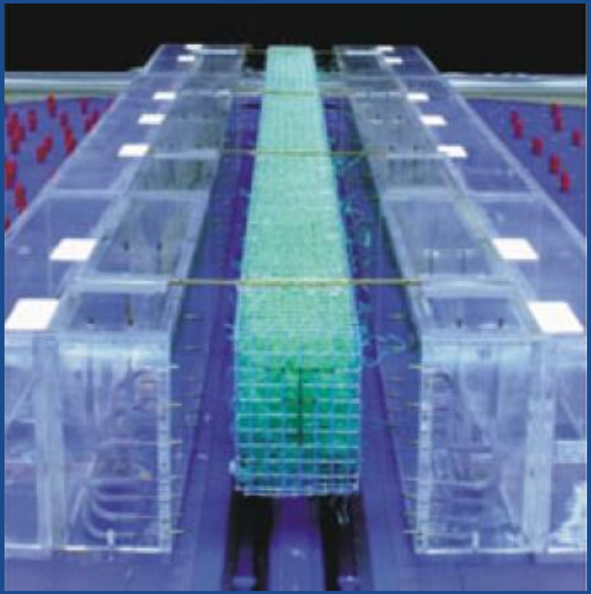
Flow & Flux Representation

- Canyon flow parameterised
- Fluxes from bulk form using resistance network analogy
- Investigate impact of vegetation on flow (e.g. Gromke & Ruck, 2012)



Gromke & Ruck, 2012

8: Canyon Hydrology

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Is the parameterisation of urban canyon hydrology the missing link in improving the modelling of urban moisture?

- Urban hydrology represented crudely (Wang *et al*. 2014)
- Evaporation limited to a time after precipitation or dewfall
- Anthropogenic moisture sources not represented (e.g. irrigation and combustion)

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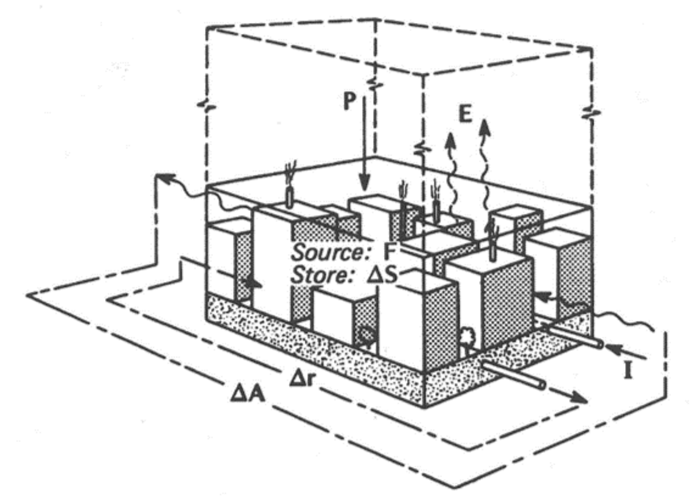
How to represent canyon hydrology?

- Urban Water Balance
- Surface to sub-surface moisture flow
- Urban soil scheme?



Oke, 1987

9: Urban Vegetation Physiology

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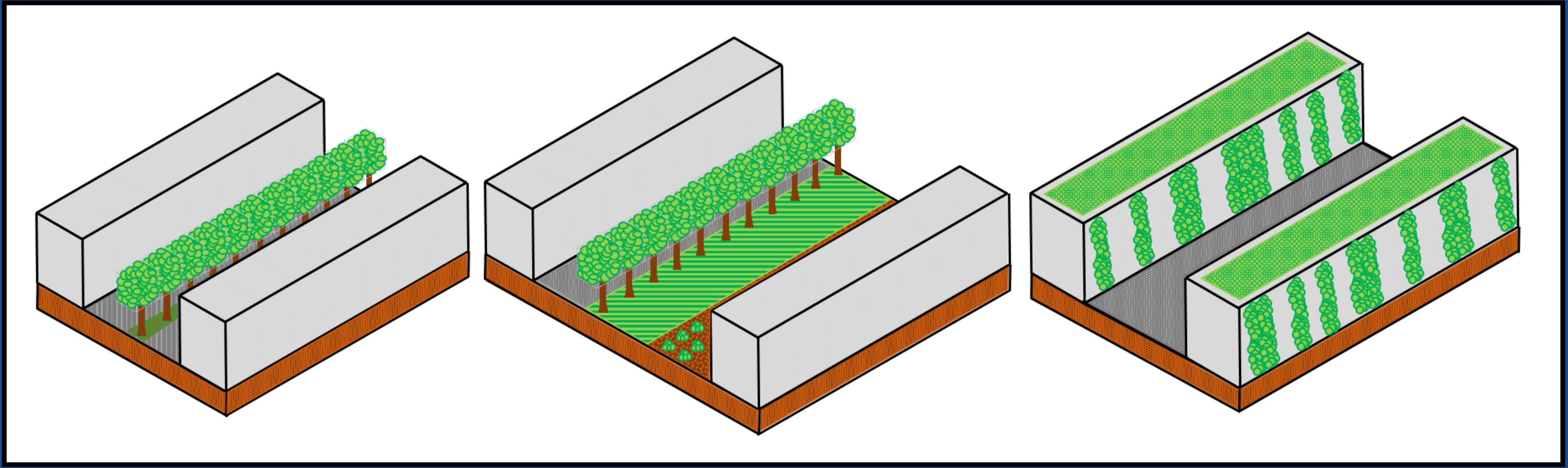
What impacts do urban areas have on vegetation physiology?

- Implement and adjust existing JULES vegetation physiology parameterisations (Clark *et al.*, 2011)
- Capture impact of urban areas on vegetation dynamics
  - Leaf temperature
  - Photosynthesis and Respiration
  - Stomatal resistance
  - Phenology
- Suggestions? Any thoughts and discussion on this welcome

Conclusion

- Single layer vegetated urban canyon scheme for three urban representations
- Focus on physical representation of radiation, canyon flow, fluxes of heat and moisture, urban hydrology and plant physiology
- Version of the model implemented as new tile(s) in JULES



Thank you for listening
Comments & Questions?

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