School of the Built Environment
and
Department of Meteorology

University of Reading

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Modelling anthropogenic heat flux in urban climate models: capturing agency

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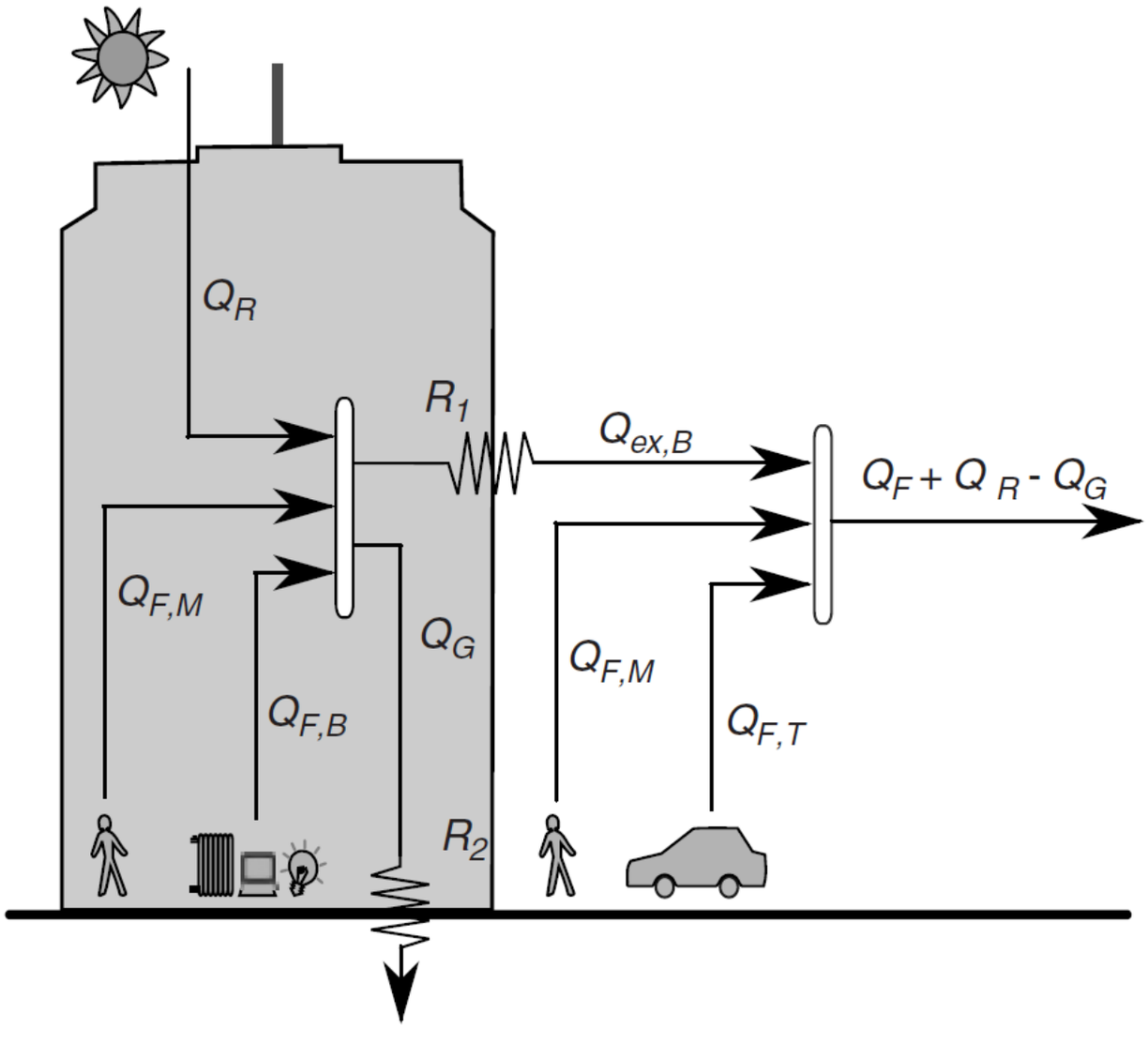
Anthropogenic Heat Flux

- Waste heat discharged by human activities



Iamarino et al. (2012) Int. J. Climatology

Sources

Q_R- short & long wave radiation received internally

$Q_{F,M}$ - metabolism
$Q_{F,T}$ – transport
$Q_{F,B}$ – buildings

Sinks

- Sensible heat
- Latent heat
- Waste water

Timing of heat release

- Instantaneous
- Lagged

Location of heat release

- Building openings: vents, windows
- Building materials: walls, roof
- Vehicles

City/ Country Goals

- Reduce carbon emissions
  - City design
    - Travel to work – can be reduced
    - Solar access
    - Building materials/standards
    - Sources of energy
    - Distance energy is transported (source/usage)

- Renewable energy
  - Requires rapid feedback
    - What can be stored
    - When is the peak demand
    - Modify energy peaks - change some behaviours

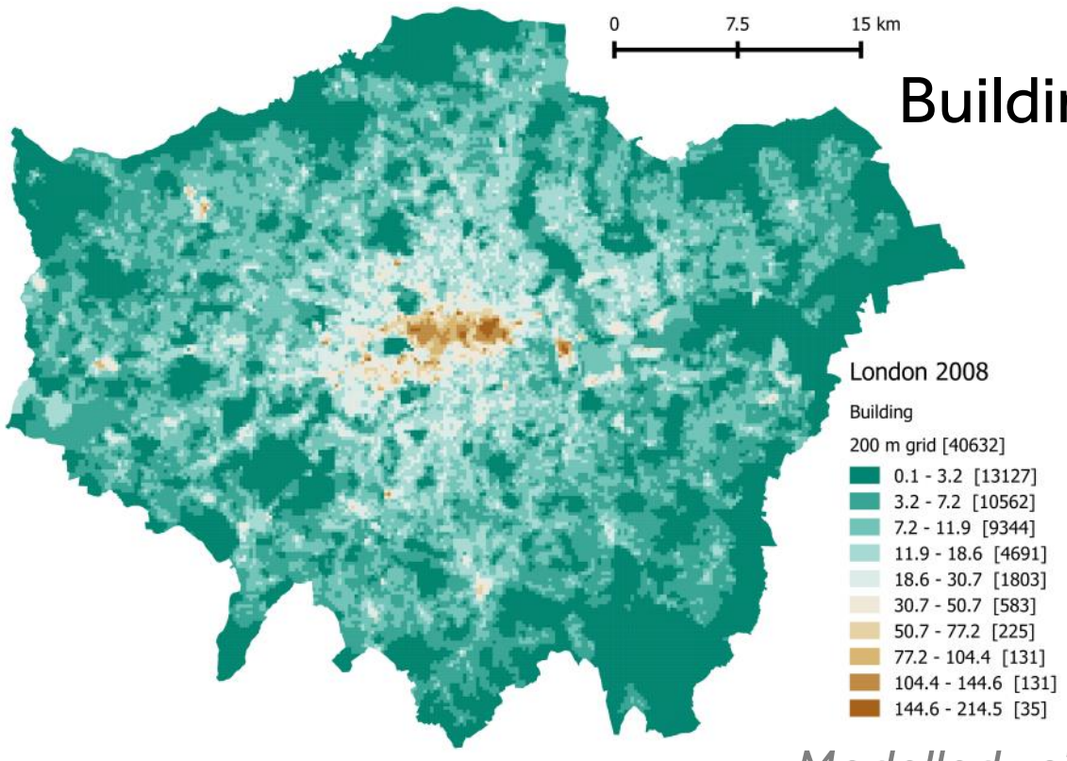
BACKGROUND

- Anthropogenic heat flux
  - Energy released from human activities
    - Buildings
    - Transportation
    - People

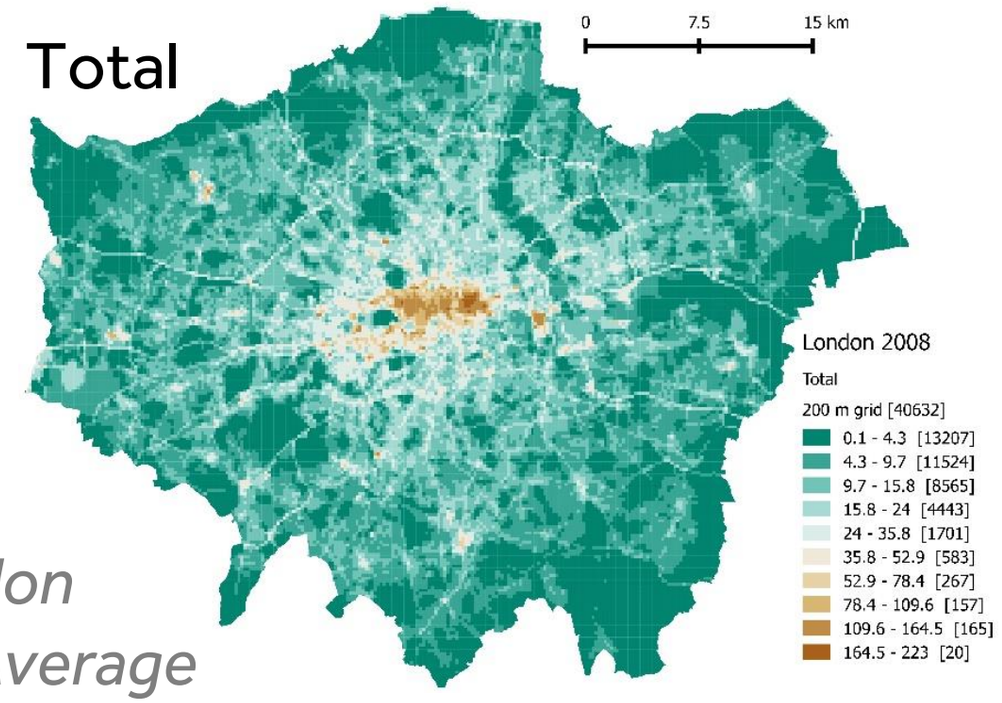
Decreasing importance/size

Flux W m^{-2} [# 200 m x 200 m grids]

Buildings



Total



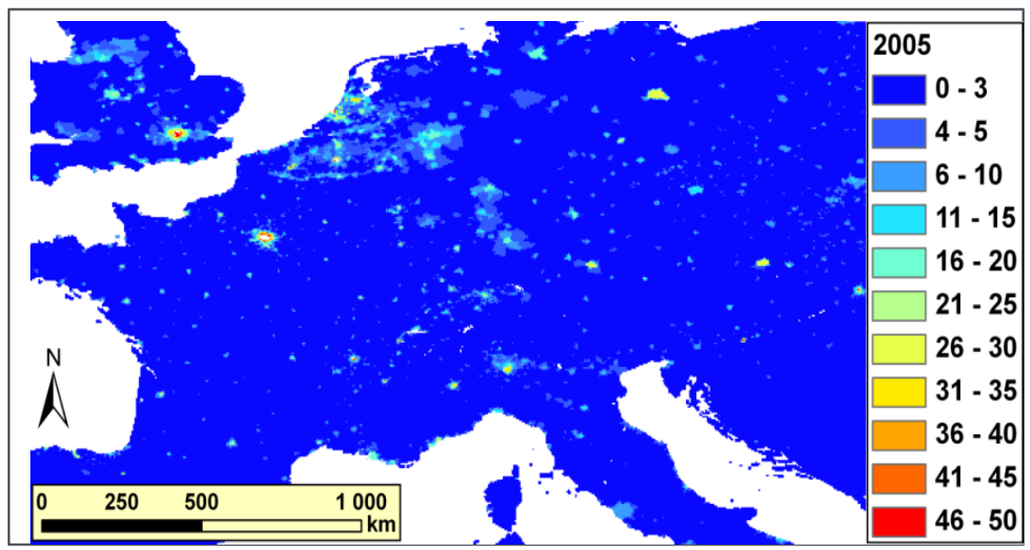
London Annual Average

Modelled using GreaterQF (Iamarino et al. 2012)

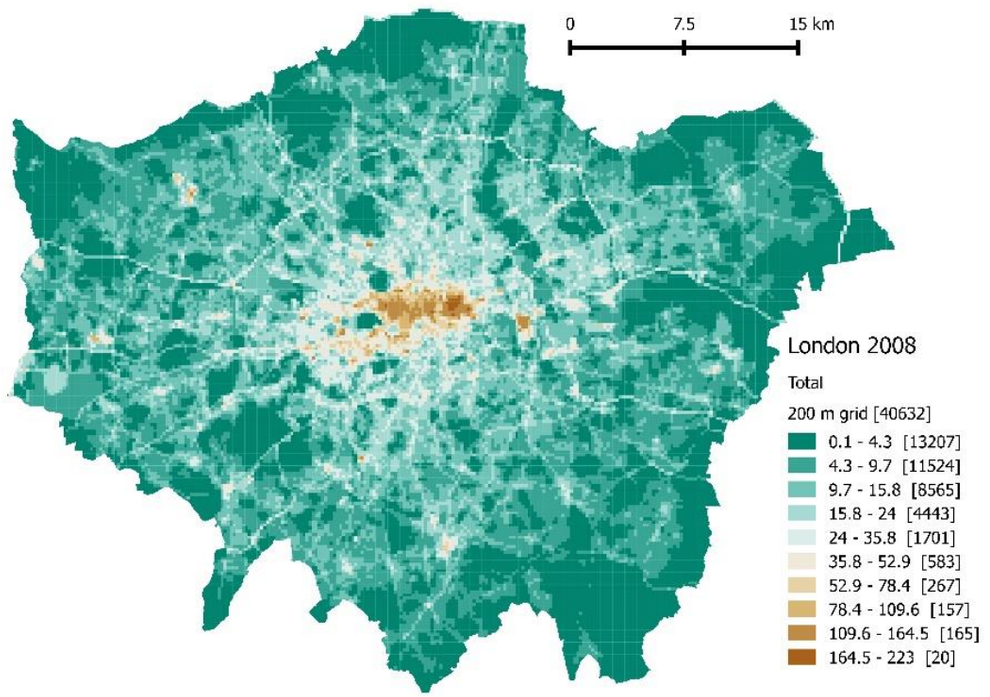
Total Anthropogenic Heat Flux

- Can vary wildly across a large city at peak hours/days
  - From < 10 W m^{-2} - residential area
  - To > 1000 W m^{-2} - in the dense central business district area

- If we consider these values with other surface energy balance (SEB) fluxes
  - Measurements (*errors, uncertainty, measurable terms*)
  - Modelling (*errors, uncertainty*)
- Can be **insignificant** to the **most significant** term
  - Summer residential vs winter time high latitude business district



LUCY
Allen et al. (2011) Lindberg et al. (2013)



Annual Average Modelled using GreaterQF (Iamarino et al. (2012) Flux W m^{-2} [# 200 m x 200 m grids]

Decisions

- **Individual** – millions made every day
  - Impact: wide range of areas
- **Daily operations**:
  - Building operations
    - e.g. closing of the conference centre
    - i.e. Work hours
    - Acceptable temperature range
  - Transport
- **Building** design decisions (*can open windows? insulation? Encourage use of stairs?)*
- **Planning** decisions (*e.g. what is within the vicinity, transport networks)*
- **City** (*e.g. resilient systems? Energy infrastructure, Business/Industries*)
- **Country** (*e.g. Carbon neutral, energy infrastructure, natural resources)*
- **International** (*e.g. EU requirements, international agreements)*

Intersection of wide range of decisions – made over a large range of time scales – influencing wide range of spatial scales

London: Anthropogenic Heat (W m^{-2}) 2005-2008

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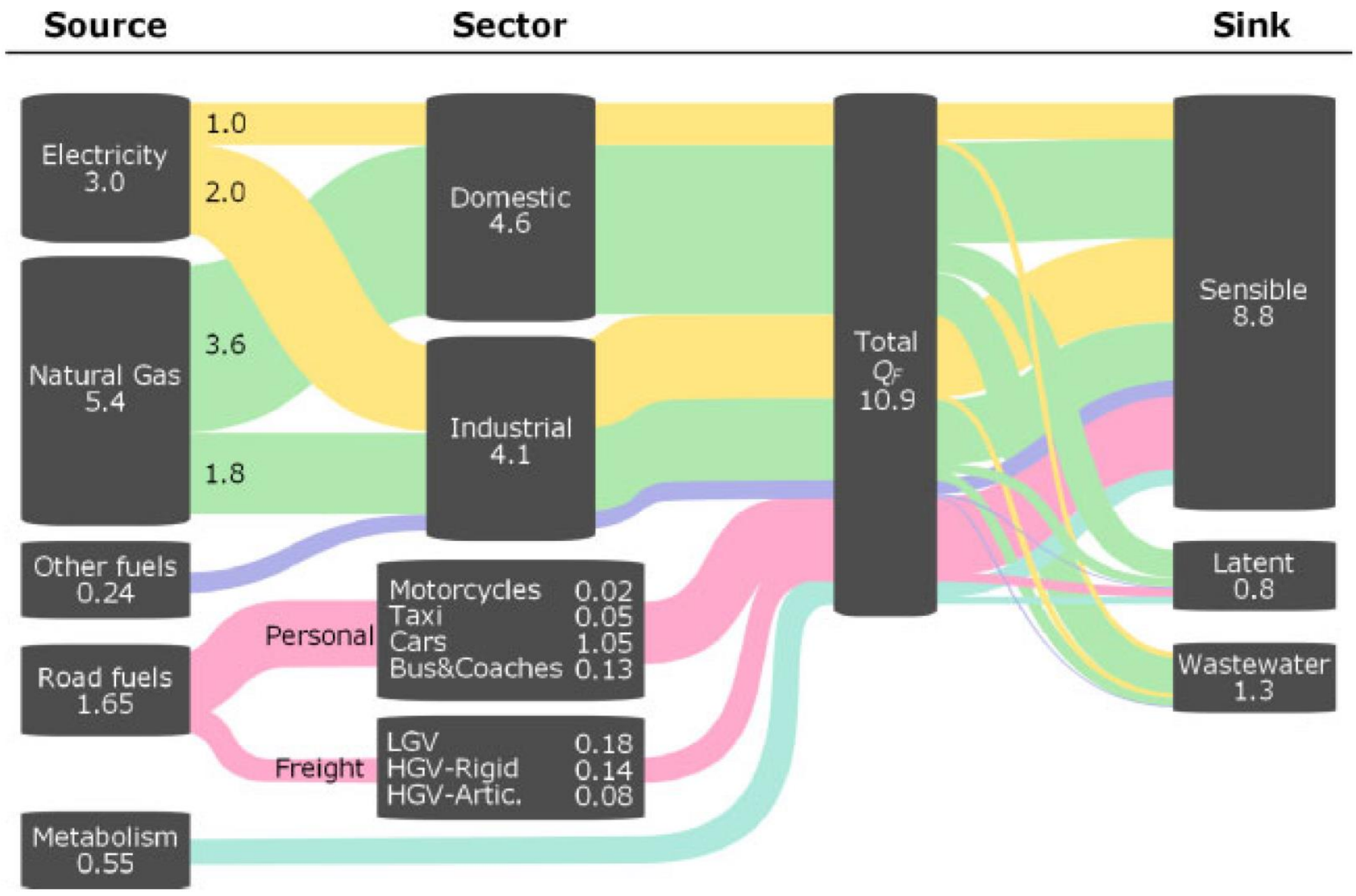
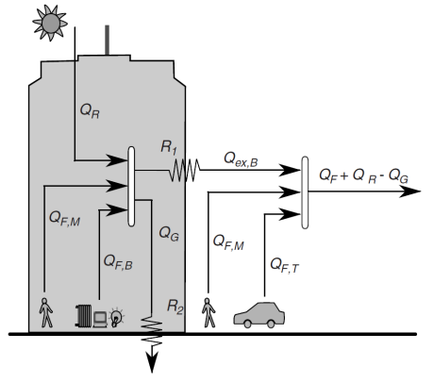


Iamarino et al. (2012) Int. J. Climatology

Modelling of Decisions

observed/modelled weather



Iamarino et al. (2012) Int. J. Climatology

Q_F models

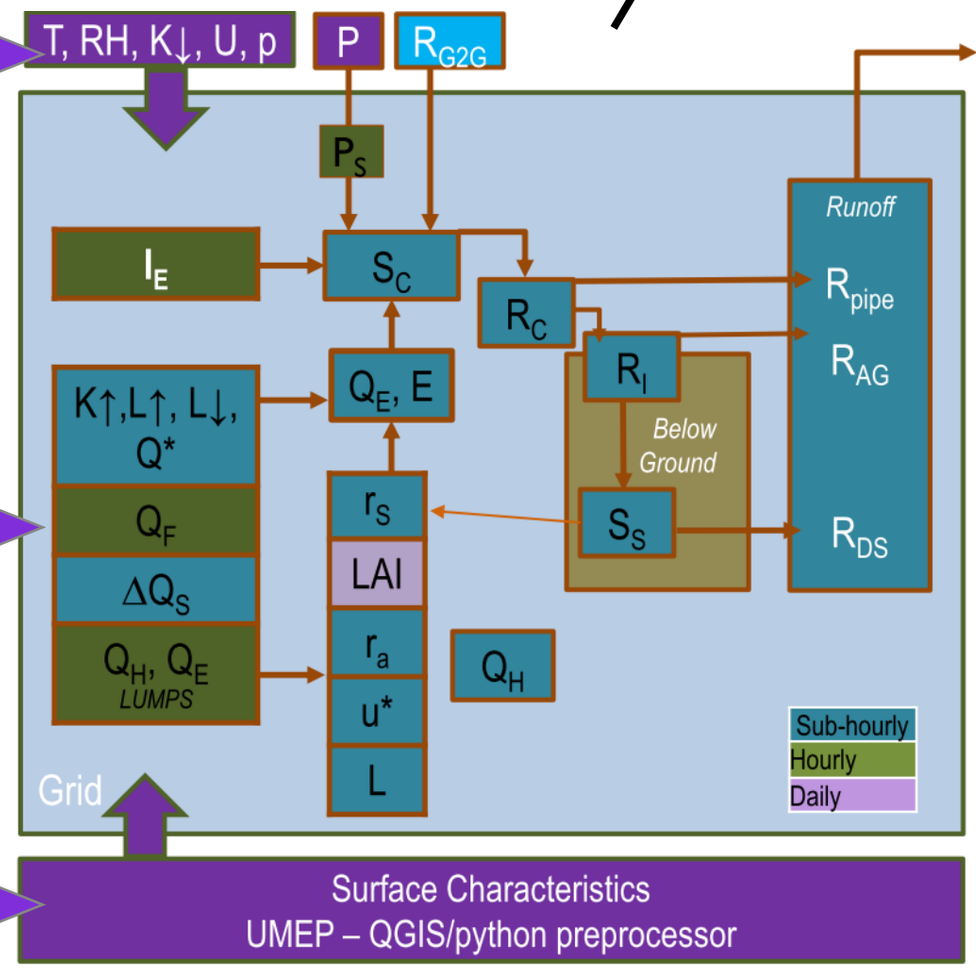
BEM* Transport Human†

Agent-Based Model

Interface - python

v2015b

SUEWS v2015a *(January 2015 status)*



Inputs	Radiation
T Temperature	K↑ Outgoing shortwave
RH Relative humidity	L↑ Outgoing longwave
K↓ Incoming solar radiation	L↓ Incoming longwave
U Wind speed	Q* Net all wave
p Station pressure	
P Precipitation	u* friction velocity L Obukhov length **r** *resistance* r_a aerodynamic r_s surface LAI – leaf area index
P_S snow processes	

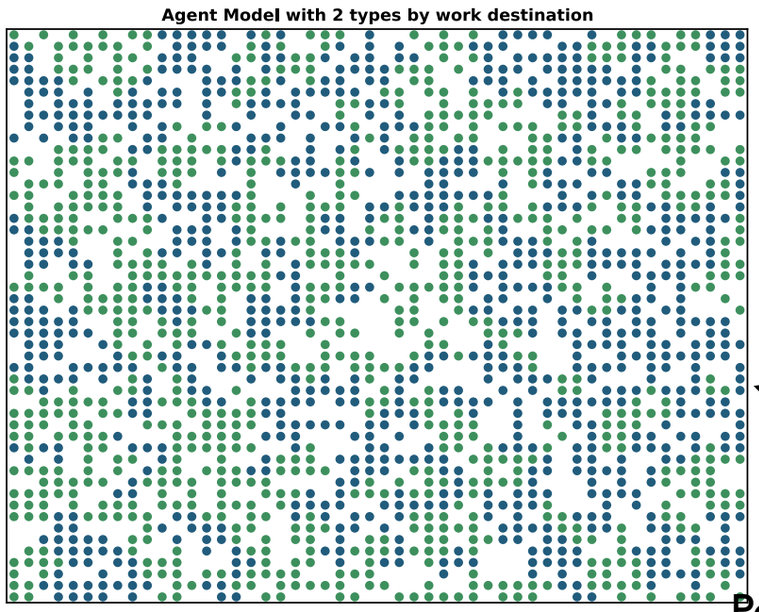
Heat fluxes	Water fluxes
Q_F Anthropogenic	I_E Piped water
ΔQ_S Storage	**S** *Change in Storage* S_C canopy S_S soil
Q_E Latent	E Evaporation
Q_H Sensible	**R** *Runoff* R_C From canopy R_I Infiltration R_{pipe} Pipe R_{AG} Above ground R_{DS} Deep soil R_{G2G} grid to grid

SUEWS	Surface Urban Energy and Water Balance Scheme
UMEP	Urban Multi-scale Environmental Predictor
QGIS	Quantum GIS http://www.qgis.org/en/site/
LUMPS	Local scale urban parameterization scheme

*BESTEST - TRNSYS, but can change as modular code

†Comfort and activity as drivers by population type

Dynamic nature of Q_F

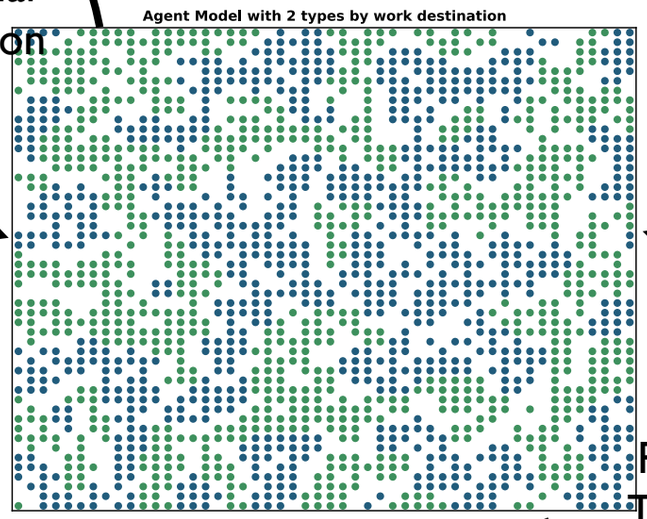


High Activity

Low Activity

Negligible Activity

Potential Transition



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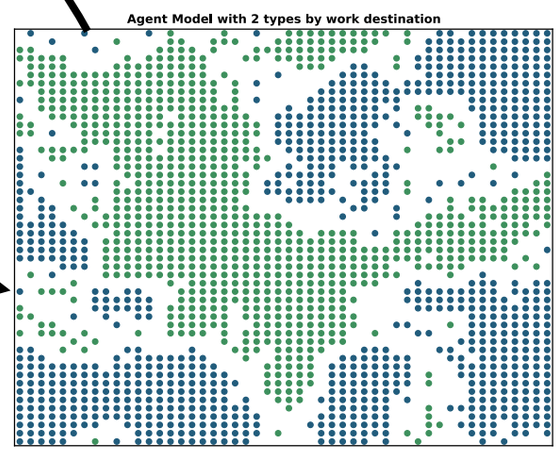

Influential factors

- Work place expectations
- Family structures
- Combination of travel decisions also influence the other two Q_F components
  - How long energy remains high in the central city
  - When residential use start to increases

Urban Energy – Water - Carbon

How to observe Q_F - model comparison?

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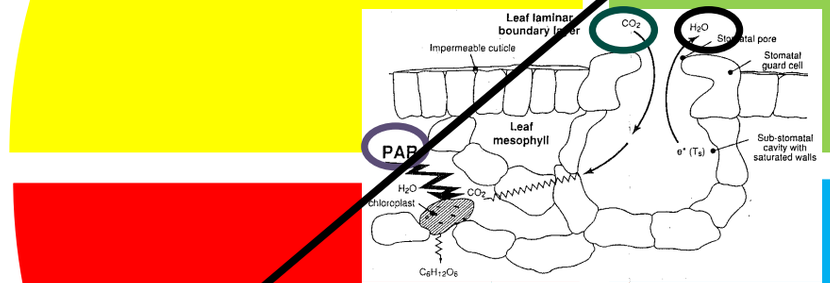
$$Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow$$

PAR

$$F_{CP} + F_{CF} = F_{CR} + F_{CM} + \Delta S_C$$

Radiation

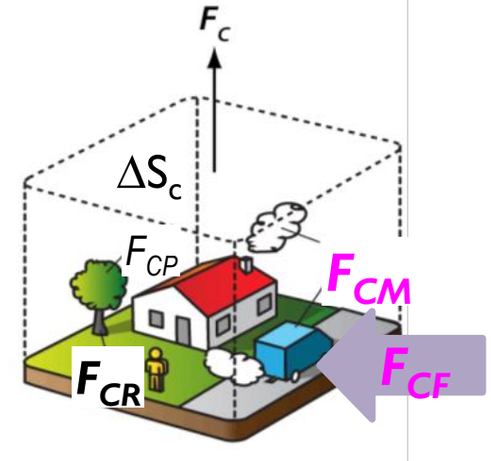
Carbon

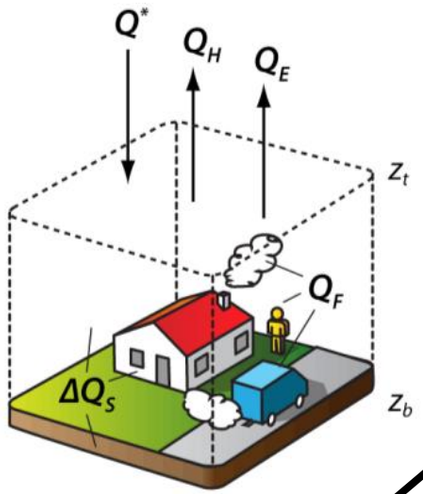


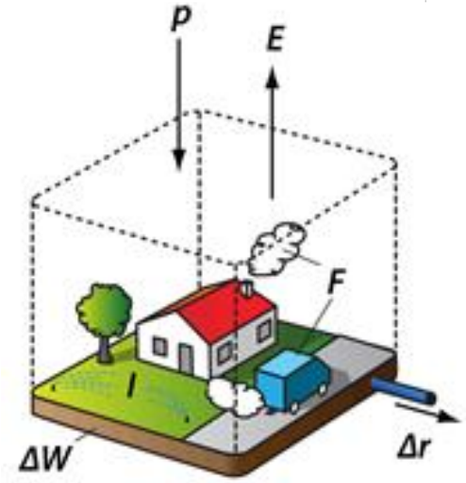
Energy Heat

Water

Oke 1987







Feigenwinter et al. (2012)

proxy

$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S$$

$$P + I + F = E + R + S$$

Swindon:
Estimate of anthropogenic emissions

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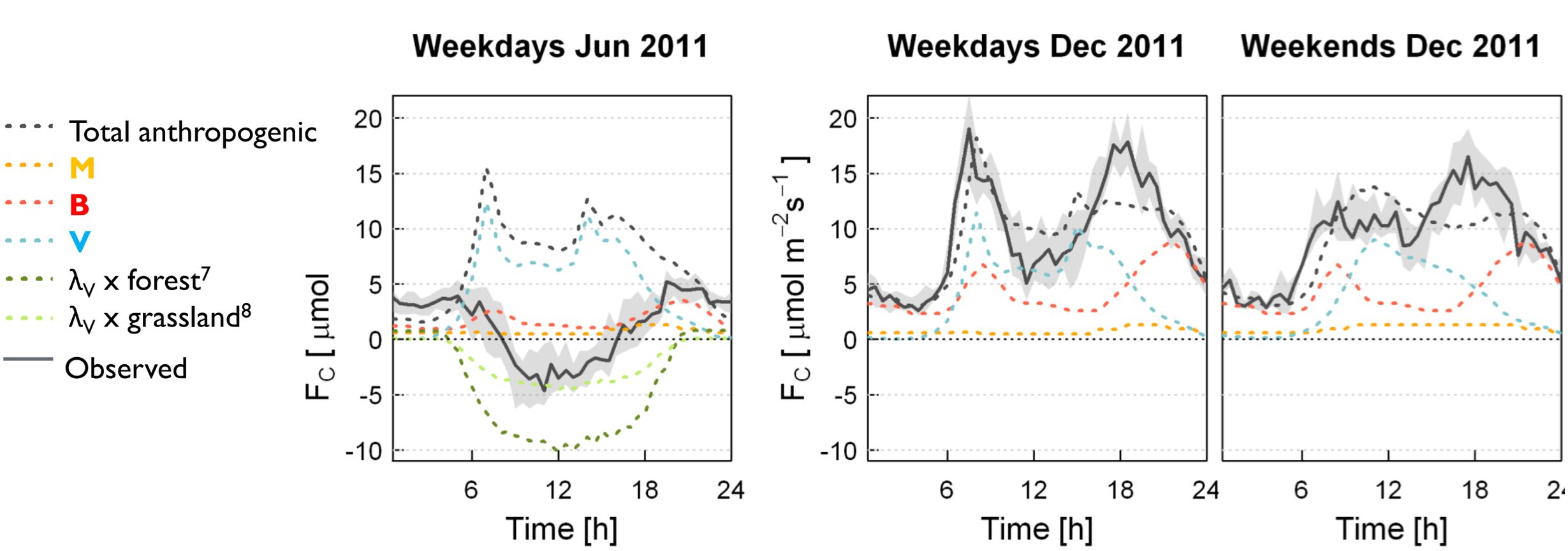
M Human metabolism Population data[1] Per capita emissions[2,3]

B Building energy use UK fuel Consumption[5] Emission factors[2] Diurnal profile[4]

V Vehicles Vehicle km in UK[6] Emission factors[2,3,5] Diurnal/weekly profiles[6]



[1]ONS; [2]Moriwaki & Kanda (2004) JAM; [3]Sailor & Lu (2004) AE; [4]Hamilton et al. (2009) B&E; [5]DECC; [6]DfT; [7]Schmid et al. (2000) AFM; [8]Flanagan et al. (2002) GCB

Ward et al. ACP 2013

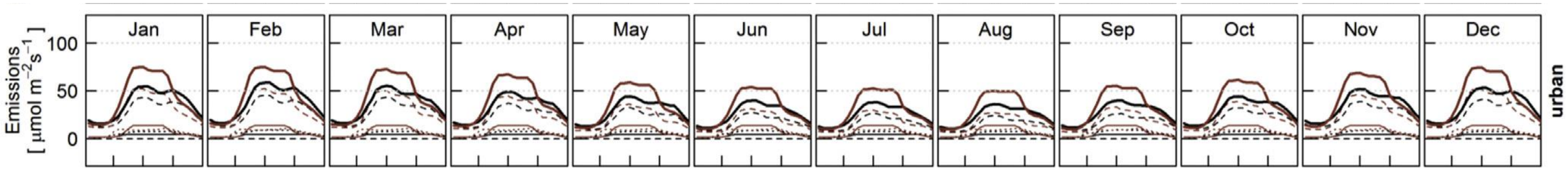
Emissions Workdays/non-Workdays

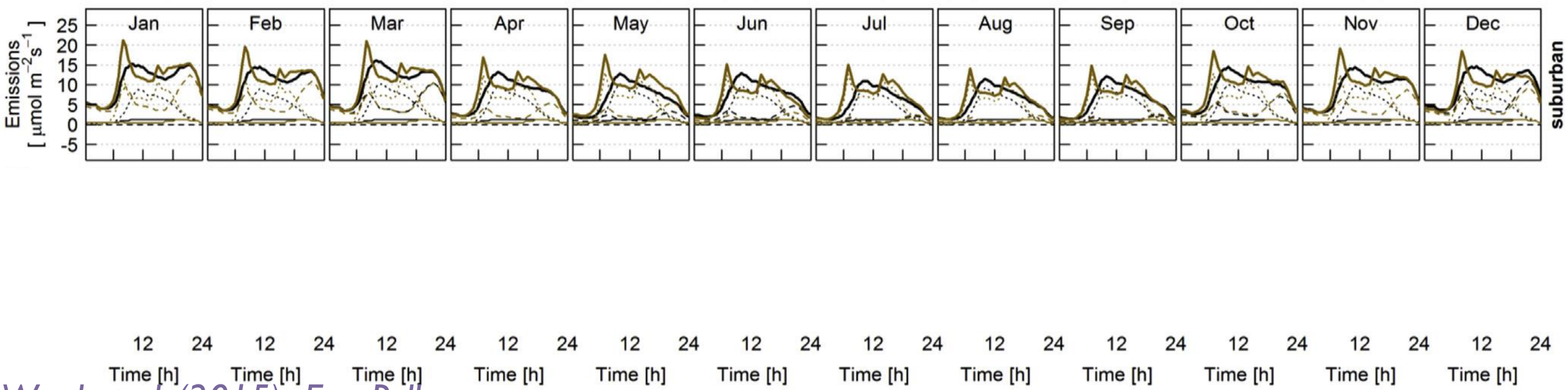
Jan Mar May July Sep Nov

Traffic

Building heating

building heating, traffic and human metabolism combined





Ward et al. (2015) Env. Poll.

Carbon Dioxide Fluxes and Emissions

Central London – Residential Swindon - Forest

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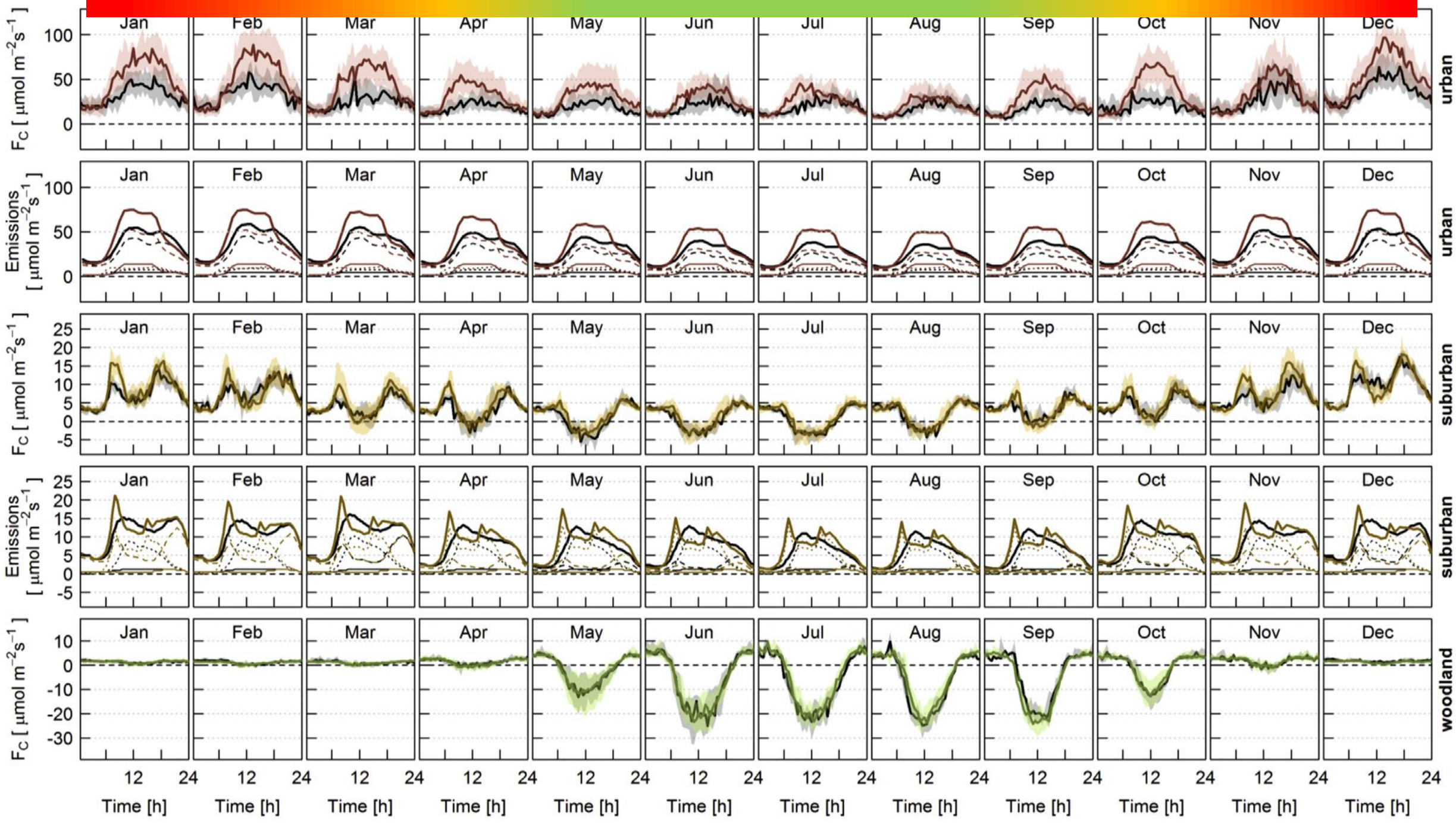
Jan Mar May July Sep Nov



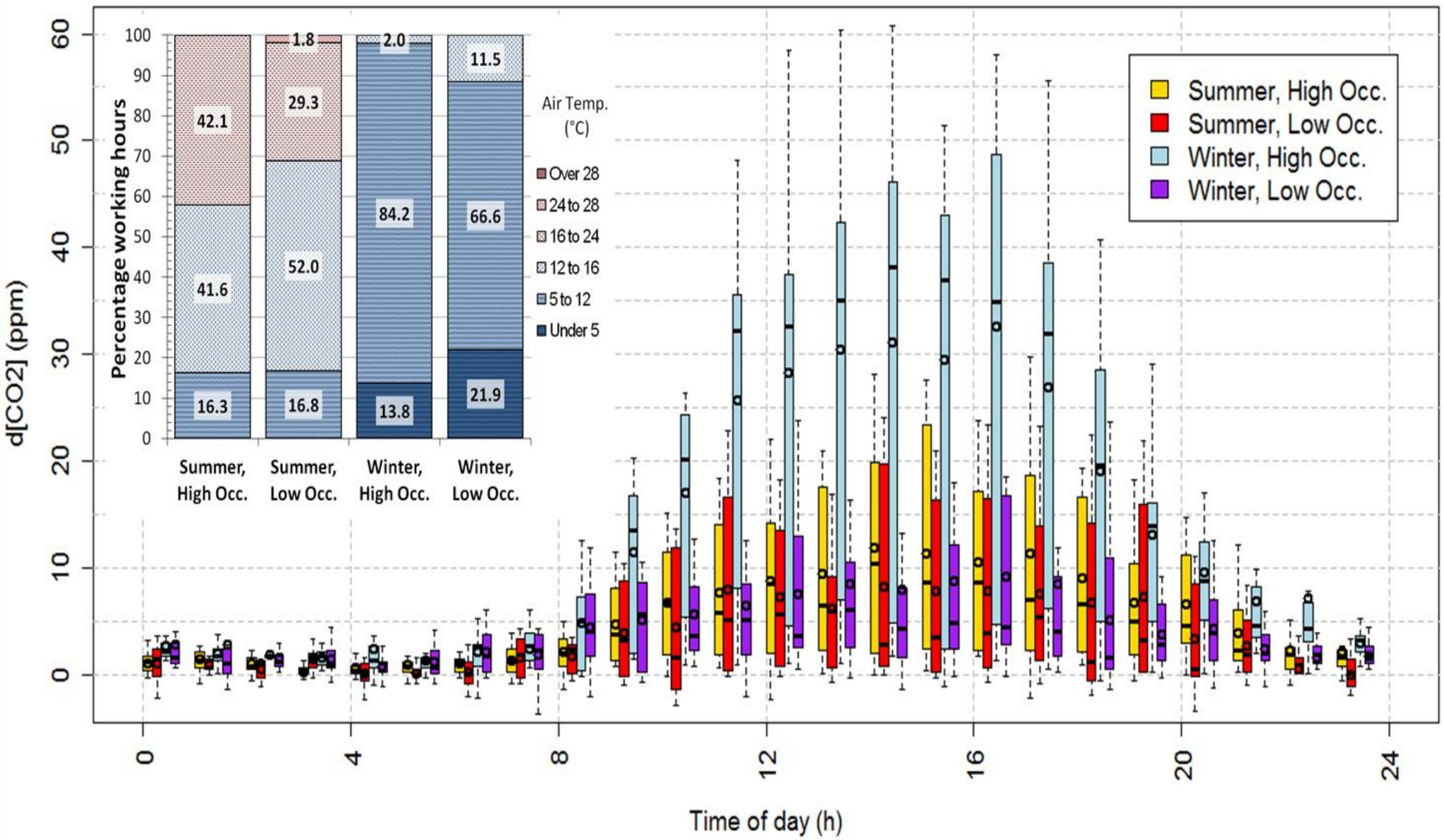
Ward et al. (2015) Env. Pollution

Building Sources Summer/Winter

Occupancy: High/Low High / Low

$\Delta[CO_2]$ = Building vent - Tower top

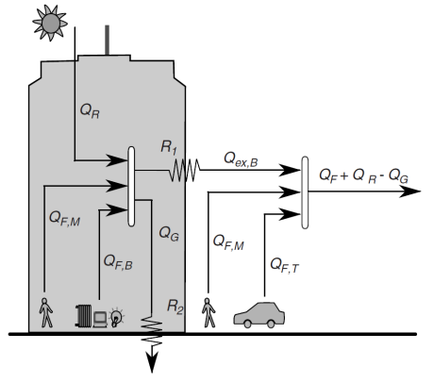
London



Bjorkegren & Grimmond

Final Remarks

observed/modelled weather



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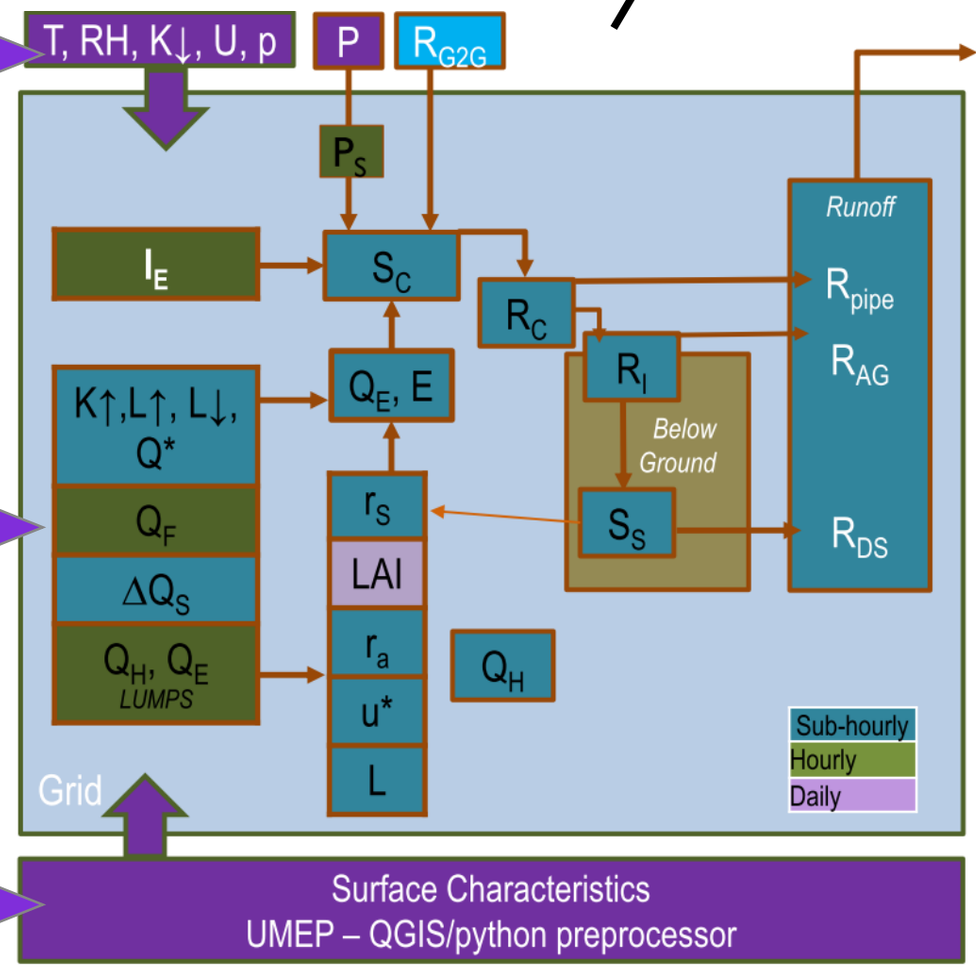

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Data Led Process

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Two PhD positions available
(UK - / EU –if been in UK for 3 + years)