# EGU 2014

## CL3.1/AS1.18
## Urban climate, urban heat island and urban biometeorology

*Extraction of Urban Morphology Parameters from Generic European Datasets: A Case Study for Antwerp, Berlin and Almada*

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# NACLIM fact sheet

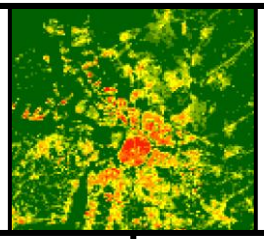
- **ECOMS** = European initiative for climate service observation and modeling
  - **NACLIM**
  - SPECS
  - EUPORIAS
- **NACLIM** = **N**orth **A**tlantic **Clim**ate
- FP7 Collaborative Project
- Project lifetime:
  - Start date: 01 Nov. 2012
  - Duration: 48 (+3) months
- Research focus:
  - Assessment of decadal climate forecasts
  - North Atlantic / European sector
- 19 research institutes
- 10 European countries
- 5 Core themes / 12 work packages
  - **WP4.2: impact on European urban societies** of predicted North Atlantic/Arctic Ocean variability
- Total budget: 11 M€
- Total EC contribution: 8.6 M€

# Impact on urban societies

**City data**

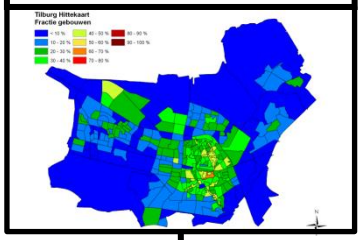
**CMIP5**

**Urban morphology**



**Observations**

**socio-economic**



**UrbClim**

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P}{\partial x}+fv-\frac{\partial}{\partial z}\overline{(u'w')}$$

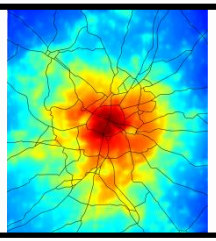
$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho_0}\frac{\partial P}{\partial y}-fu-\frac{\partial}{\partial z}\overline{(v'w')}$$

$$\frac{\partial \theta}{\partial t}+u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}+w\frac{\partial \theta}{\partial z}=-\frac{\partial}{\partial z}\overline{(w'\theta')}$$

$$\frac{\partial q}{\partial t}+u\frac{\partial q}{\partial x}+v\frac{\partial q}{\partial y}+w\frac{\partial q}{\partial z}=-\frac{\partial}{\partial z}\overline{(w'q')}$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

**UHI prediction**

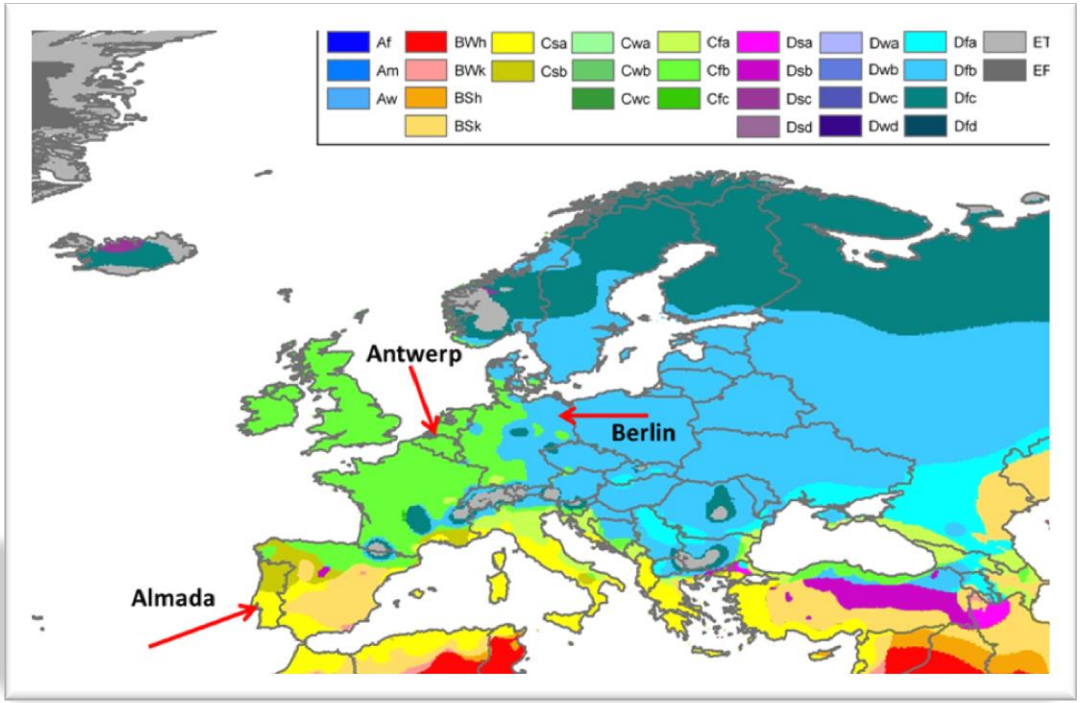


**Heat stress**
exposure maps

# Use case cities

- Different **morphologies** → density, city layout, vegetation abundance, topography, proximity to the sea, etc.

- **Almada**
  - Mediterranean
  - Köppen Csa/Csb
- **Antwerp**
  - Maritime temperate
  - Köppen Cfb
- **Berlin**
  - Warm-Summer Continental
  - Köppen Dfb

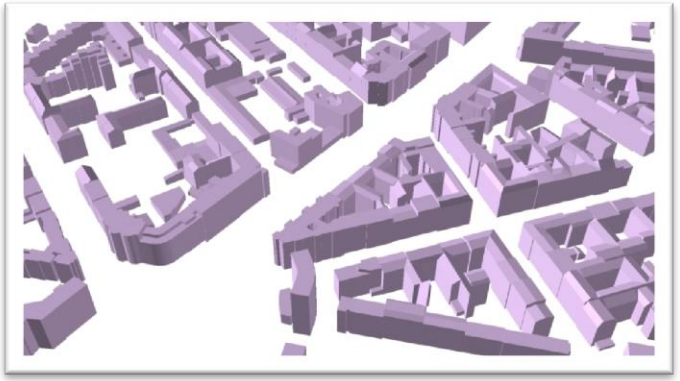


# Urban morphology indices

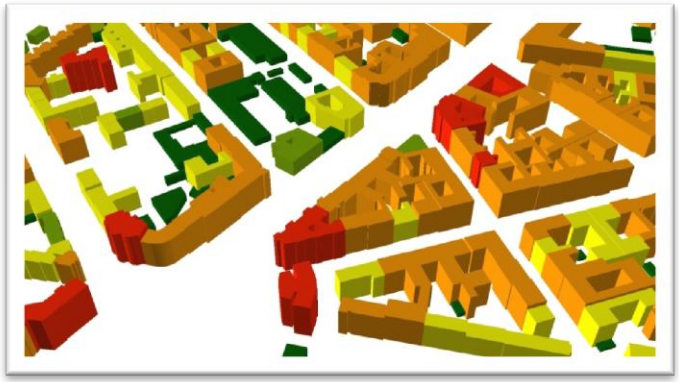
- Relevant **land surface** parameters
  - Planar area index
  - Frontal area index
  - Average building height
  - Sky view factor
  - Fraction vegetation cover
  - Vegetation type (LULC)
  - …
- Calculated on a **spatial grid**
- **PAI** - planar area index = the ratio of the plane area occupied by buildings to the total ground area
- **FAI** - frontal area index = the ratio of the frontal area (i.e. area of buildings exposed to a given wind direction) of buildings to the total ground area (averaged over all wind sectors)

# Source data

- 3D City models
  - Individual buildings → PAI
  - Building blocks → FAI
  - Conversion to 2D + attributes
  - Including / excluding roofs



3D city model (input)



Buildings (output, no roofs)

Blocks (output, no roofs)

# Methodology

- **Reference** dataset → degree of soil sealing (EEA)
- Determine area of interest (AOI) of 3D city model

- Calculations on the **analysis grid**
  - Determine optimal spatial resolution → reduce scatter & local effects
  - Calculate index (PAI / FAI) per grid cell (analysis grid)
  - Calculate average EEA SSL per grid cell (analysis grid)
  - Scatter plot & **regression between index and average EEA SSL** for all grid cells inside AOI (analysis grid)

- Calculations on the urban climate **model grid**
  - Finer resolution than analysis grid
  - Typically larger extent than AOI 3D city model
  - Exact calculation of index inside AOI
  - Extrapolation outside AOI using relationships with EEA SSL

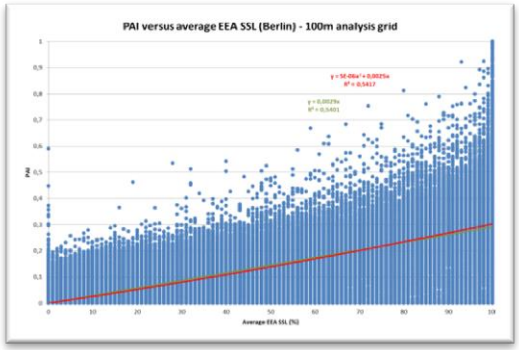
- Attention for **discontinuities** on the boundary of the AOI

# Resolution analysis grid

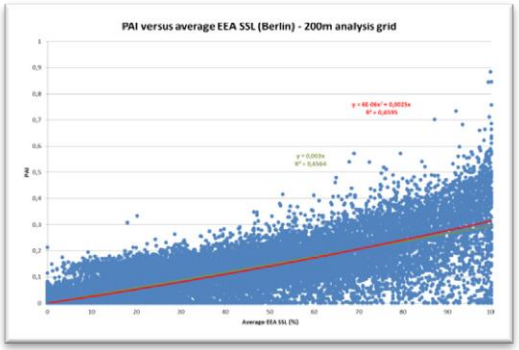
- Literature (Bohnenstengel et al., 2011)
- Reduce scatter due to local effects
- Resolution EEA SSL
- Resolution model grid
- Stable relationships
- Sample size (no. grid cells)

- Example: PAI (Berlin)
  - Coarser resolution
  - Similar fit
  - Reduced scatter
  - Increasing $R^2$

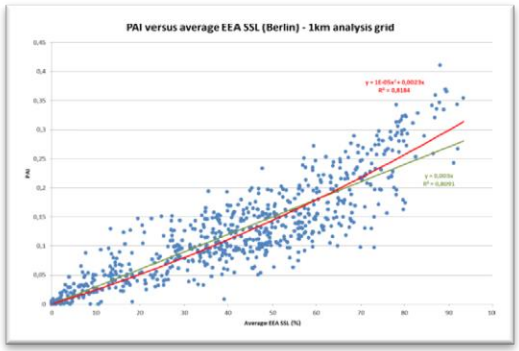
➔ Choice = 1km



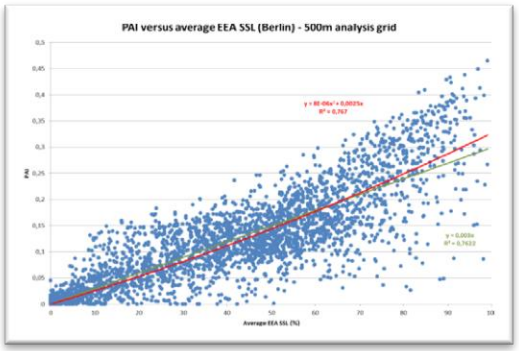

100m ($R^2_{lin}$ = 0,54)




200m ($R^2_{lin}$ = 0,66)



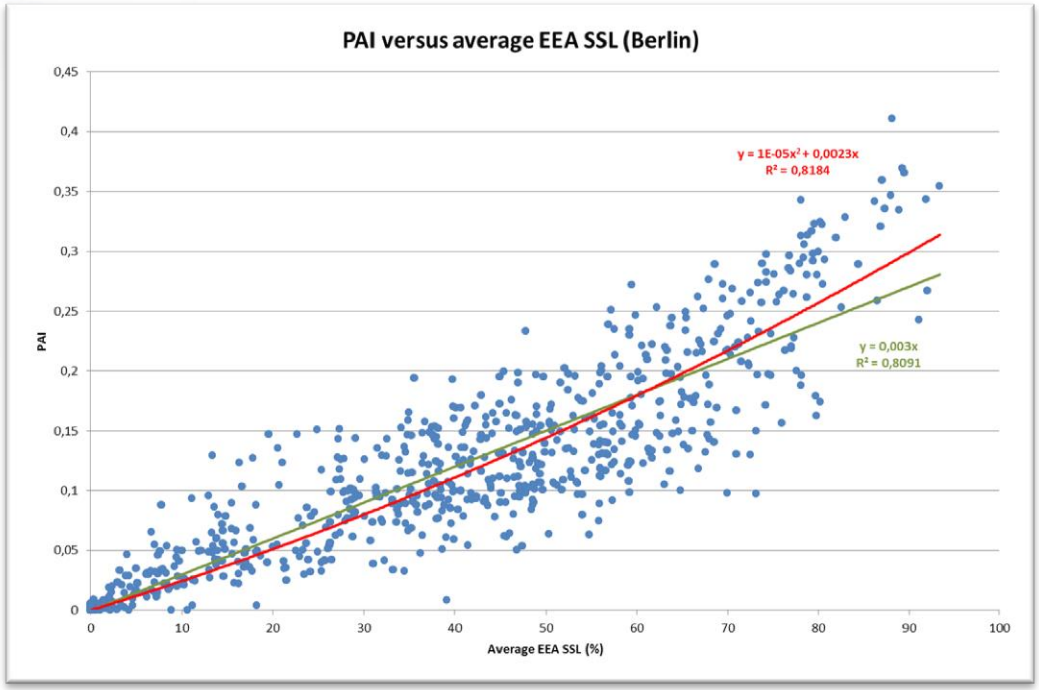

1km ($R^2_{lin}$ = 0,82)

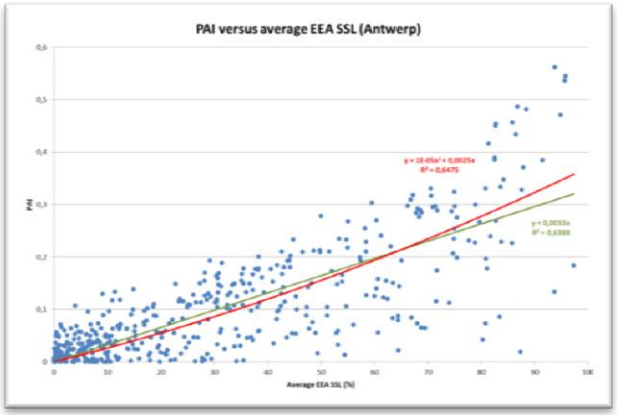


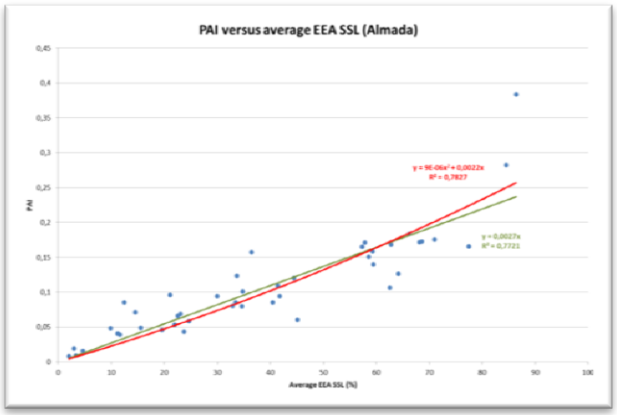

500m ($R^2_{lin}$ = 0,76)

# Planar area index (PAI)

- PAI versus average EEA SSL (1km analysis grid)



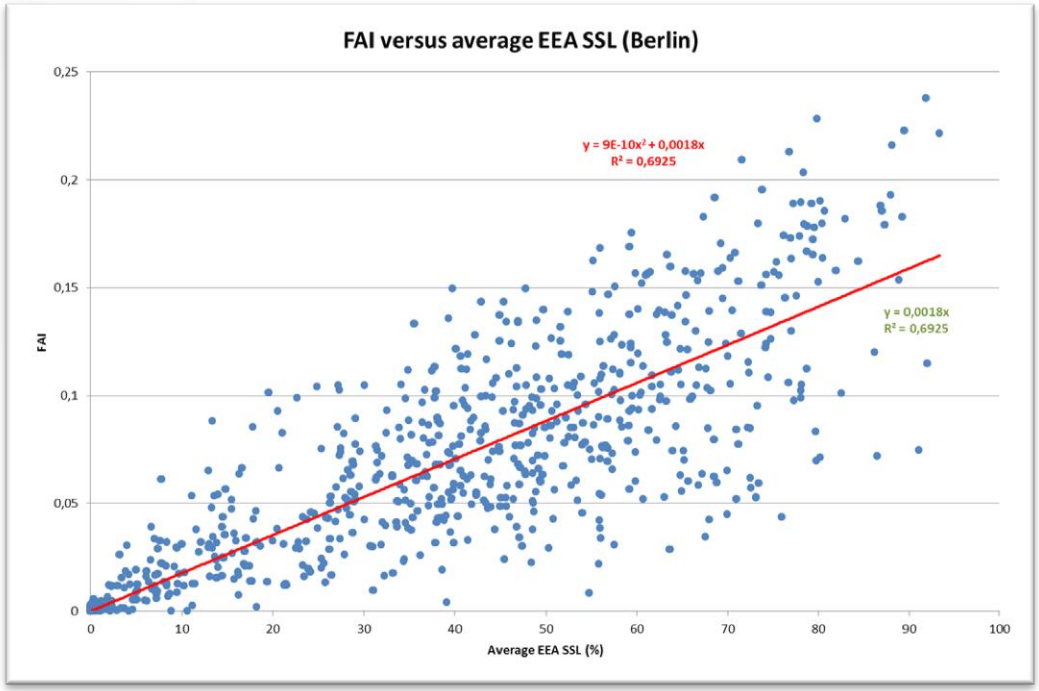



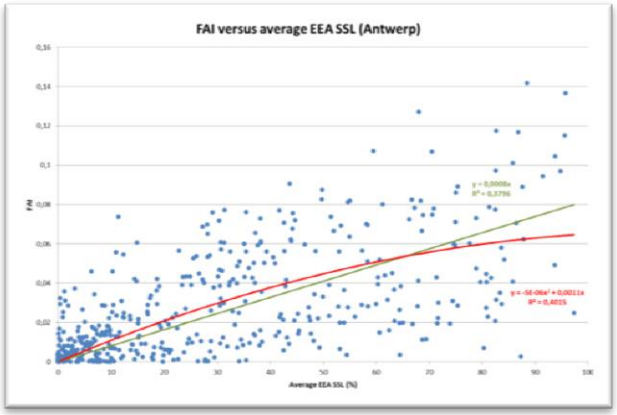
# Planar area index (PAI)

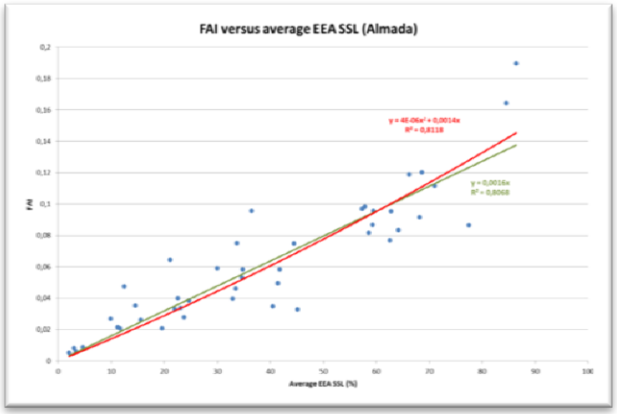
- PAI (all cities, 250m model grid)

# Frontal area index (FAI)

- FAI versus average EEA SSL (1km analysis grid)

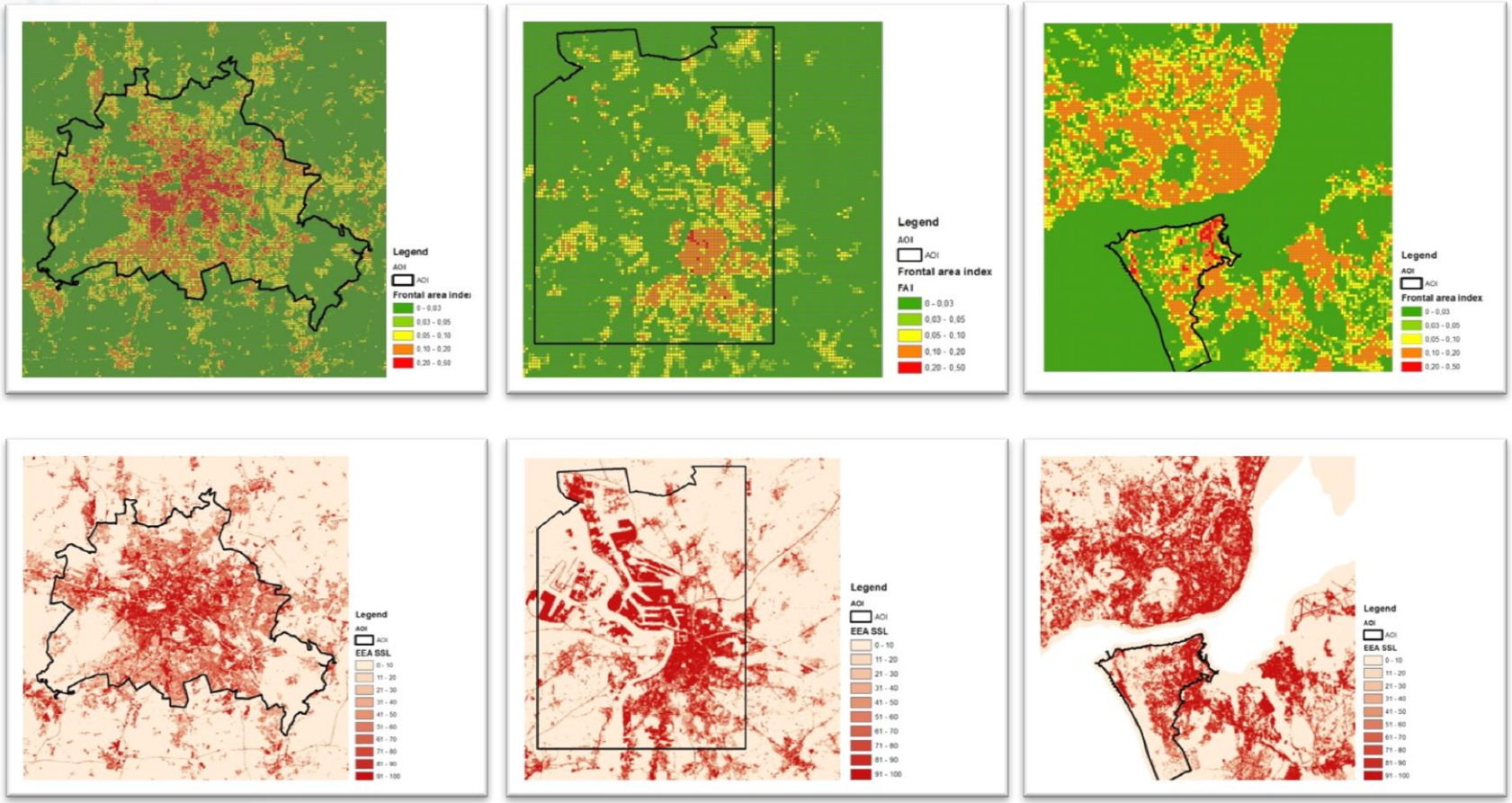


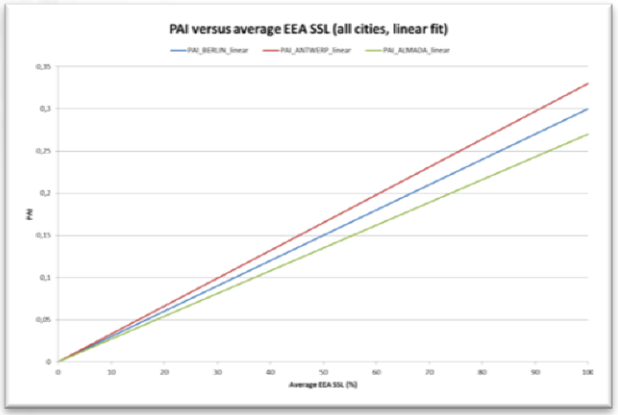
# Frontal area index (FAI)

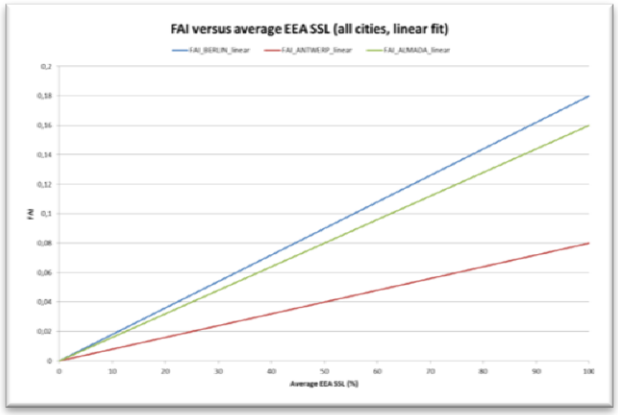
- FAI (all cities, 250m model grid)

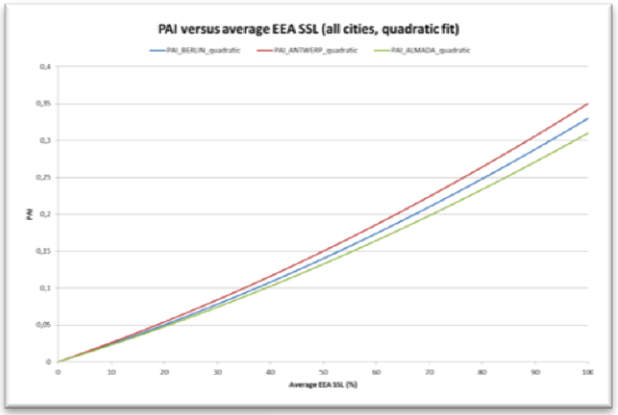


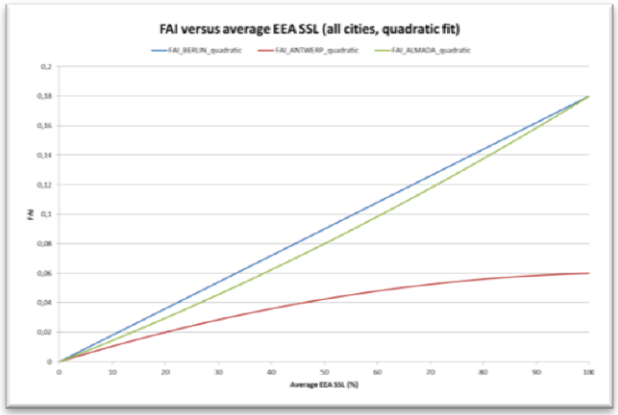
# Transferability equations

- PAI / FAI versus average EEA SSL (all cities, linear / quadratic fit)



# Conclusions

**Technical**

- **Good correlation** between PAI / FAI and average EEA SSL at 1km scale
- Best relationships found for **PAI** (all cities): **$R^2$ = 65% → 80%**
- PAI → **stable** relationship (all cities)
- **FAI** → more **variation** in relationships across cities → Antwerp versus Berlin & Almada

**Practical**

- Promising results to extract **urban morphology indices** from generic European datasets in absence of detailed city models
- Modelling community → **access** to relevant model input parameters for all cities in Europe
- **Flexible** approach
  - Exact calculation when 3D city models are available → **calibration** on local data
  - **Extrapolation** / estimation from average EEA SSL for other regions
- Possibility for **downscaling** urban climate simulations to higher resolution

# Future / ongoing research

- Other urban morphology **parameters**
  - Mean and standard deviation building heights
  - Fraction vegetation cover
  - Fraction urban land use
  - Sky view factor
  - Indices extracted from satellite imagery (e.g. SST, reflectivity)

- Optimal **AOI** for establishing relationships
  - Urban centre only
  - Buffered zones around urban centre
  - Effect on quality relationship

- Multiple **explaining variables** for relationship with indices
  - Average EEA SSL
  - Average EEA SSL within a given search radius → morphological zones

- Other **cities** (size, structure, etc.)

# Questions?

Don’t hesitate to ask us!

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The research leading to these results has received funding from the European Union 7th Framework Programme (FP7 2007-2013), under grant agreement n.308299

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