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# Large scale urban boundary layer turbulence: An example of large-eddy simulations for a megacity

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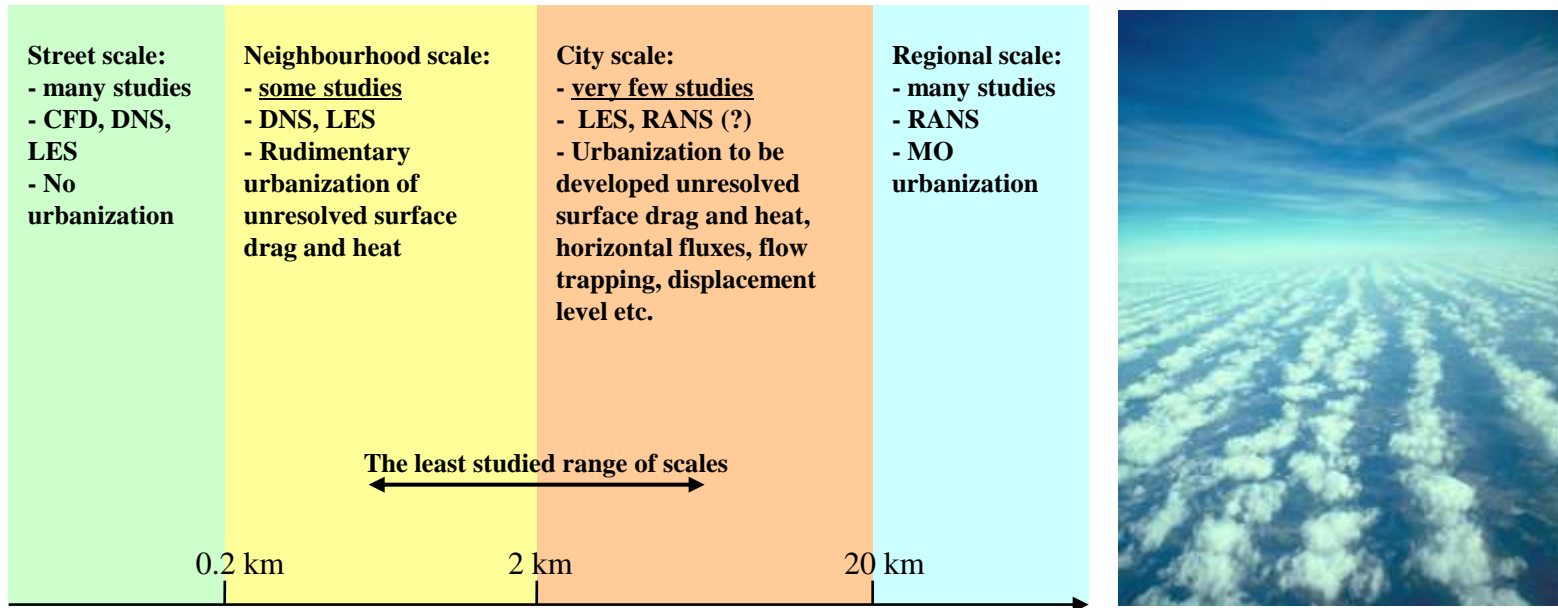
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# Contents

- Overview: specific problems of interest
- Paris surface morphology
- Urbanized LES codes PALM and LESNIC
- The finest resolution LES run for PARIS
- LES database
  - Organization and estimation of resources
  - Statistical data analysis
  - Data aggregation (mapping for meteorological modelling)
- Prospects on data assimilation into LES
- Future work on the Paris Plume Experiment



# Specific problems of interest



Very few studies dealing with  $O(10 \text{ km})$  urban domains

- Coherent structures
- Interaction of surface feature patchiness with UBL structure
- Dispersion across the UBL and into the free atmosphere
- Internal boundary layers



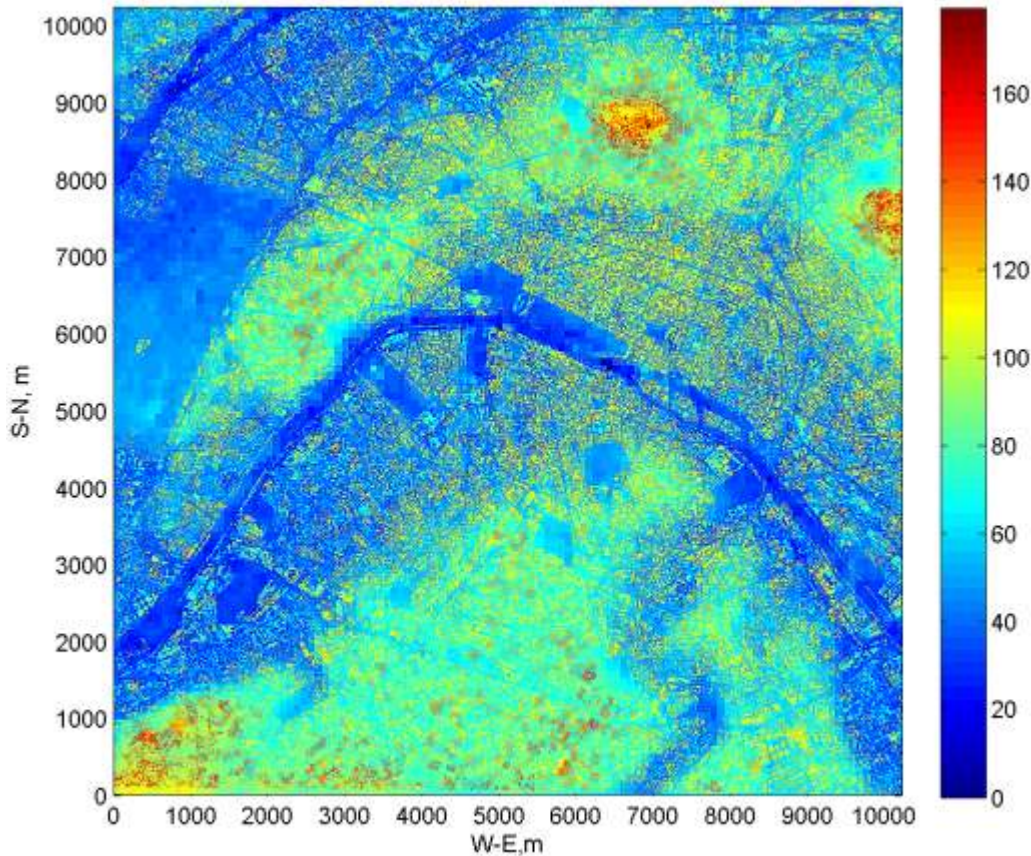
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# Paris surface morphology:

*MEGAPOLI Finnish Meteorological Institute*



- Database resolution 10 m
- Surface features (streets, etc)
- Digital Elevation Model (terrain)
- Building height (elevation data)



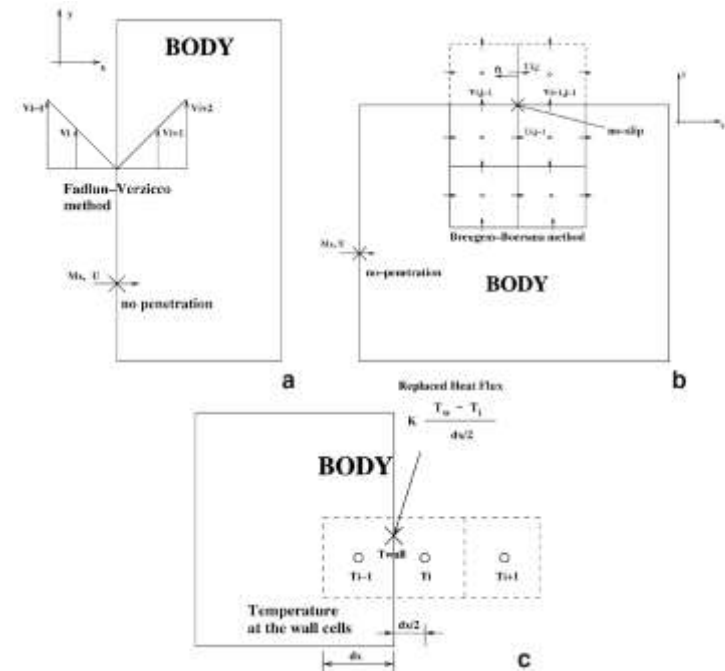
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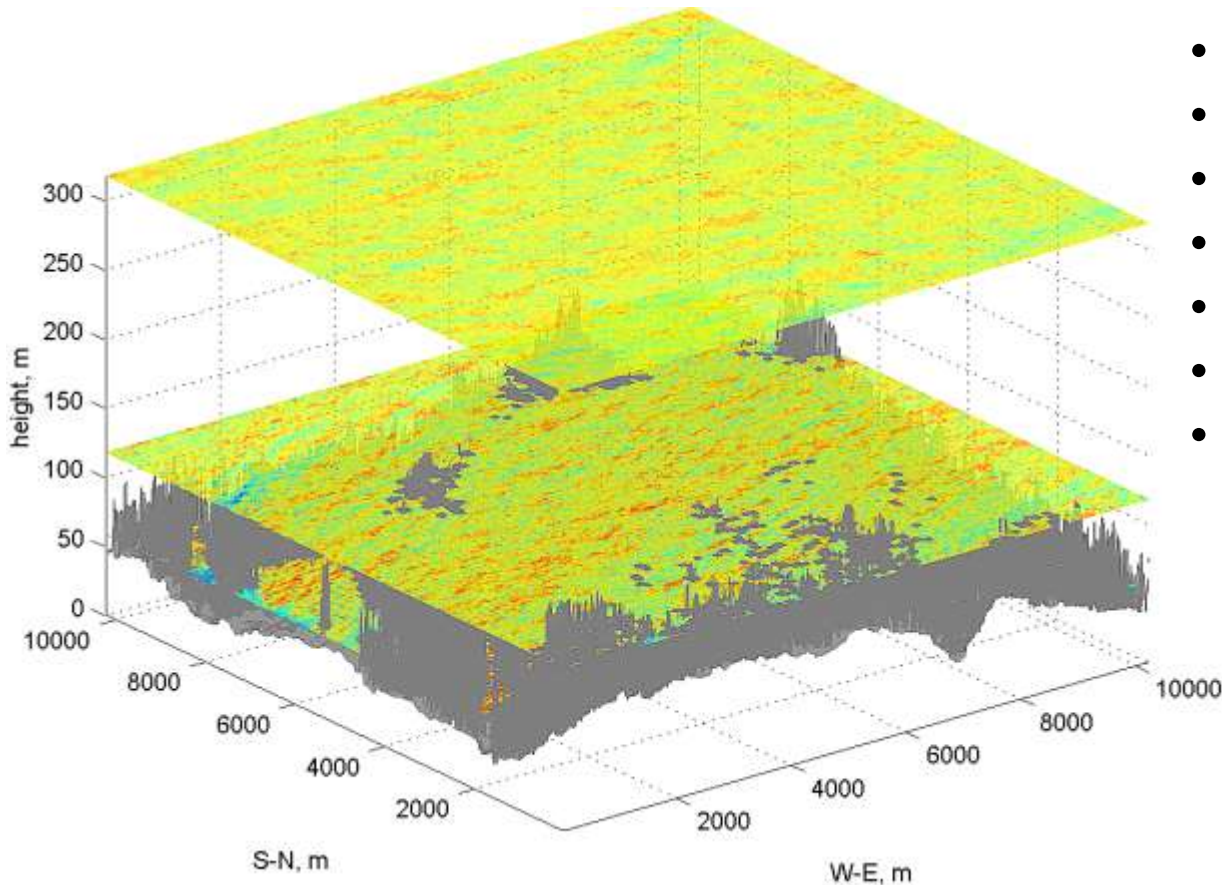
# Urbanized LES codes

- Parallelized PALM – IMUK, Hannover Univ., Letzel, M.O., Krane, M., Raasch, S., 2008: High resolution urban large-eddy simulation studies from street canyon to neighborhood scale, *Atmos. Environ.*, 42, 8770-8784.)
- LESNIC – NERSC, I. Esau
- Urbanization
  - immersed boundary conditions
  - regular rectangle mesh
  - staggered boundary arrangement



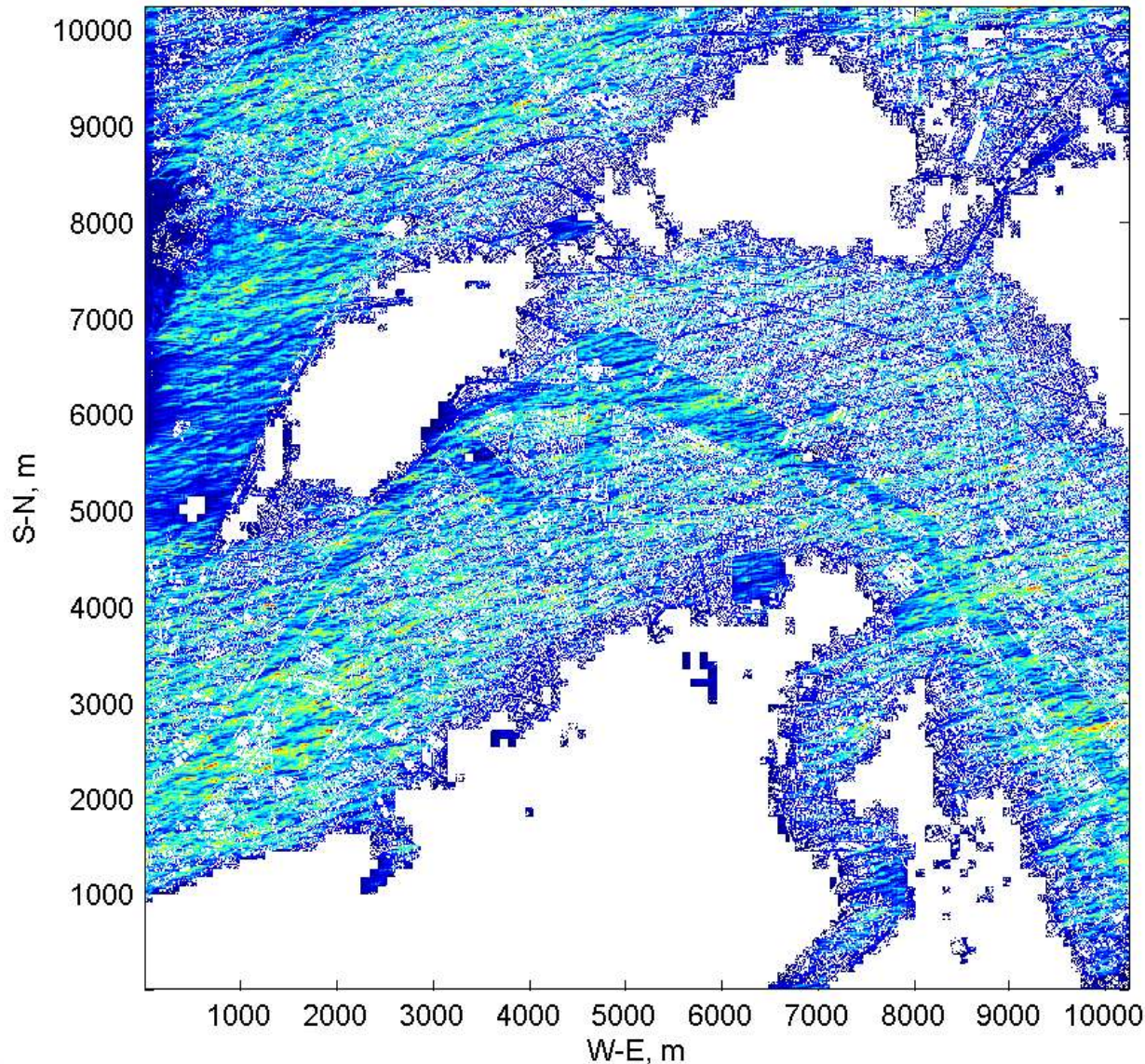
**Figure 1.2.1** (from Paravento et al., 2008): (a) The Fadlun–Verzicco method; (b) The Breugem–Boersma method; (c) Temperature treatment for these methods.

# The finest resolution run for PARIS



- 10 m resolution
- Spin up over rural terrain
- 1 h of urban simulations
- PALM
- Ekman UBL
- 5000 CPU hours
- 512 CPU in parallel

# The finest resolution run for PARIS



- Wind kinetic energy
- 58 m (urban canopy)

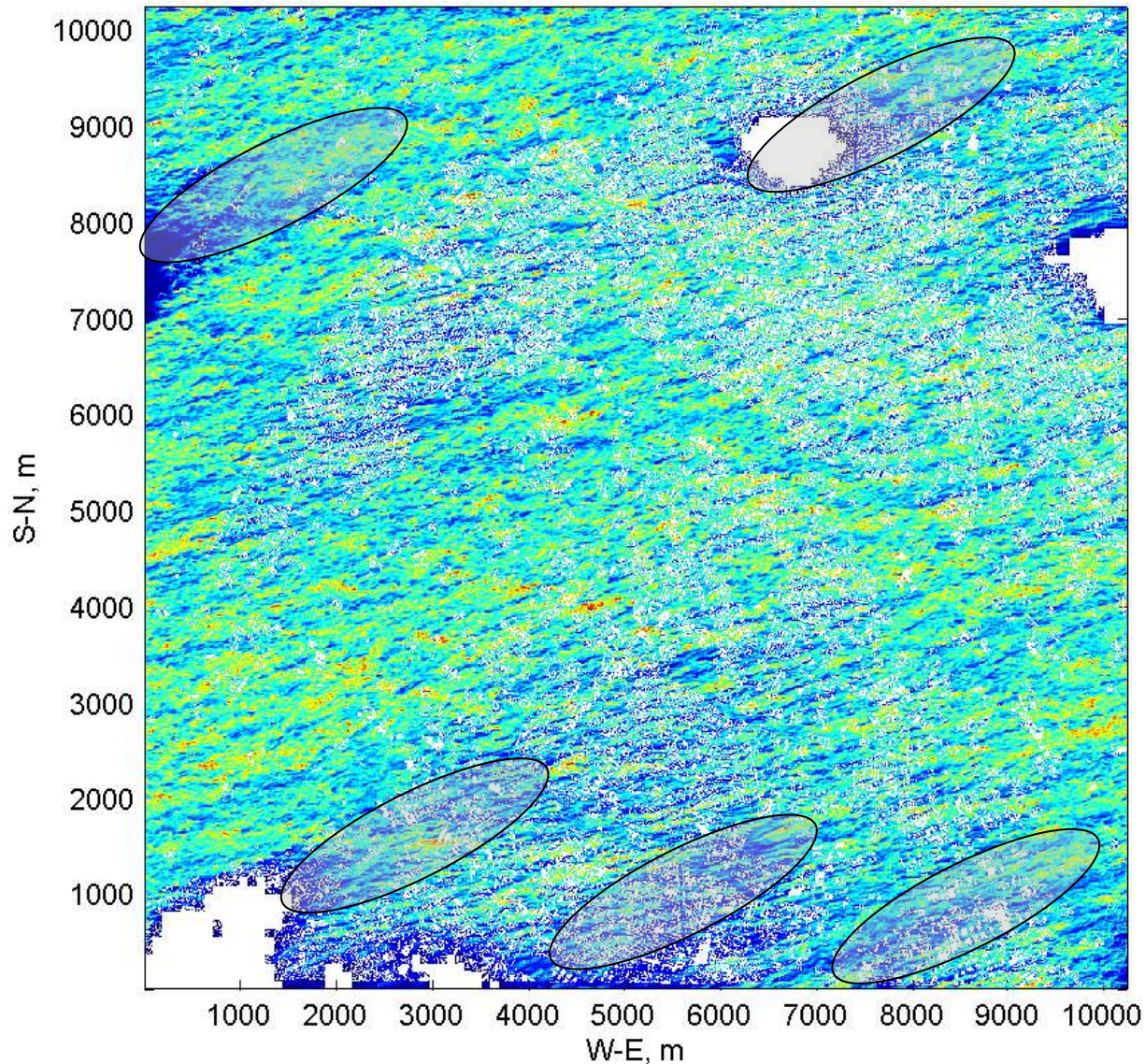


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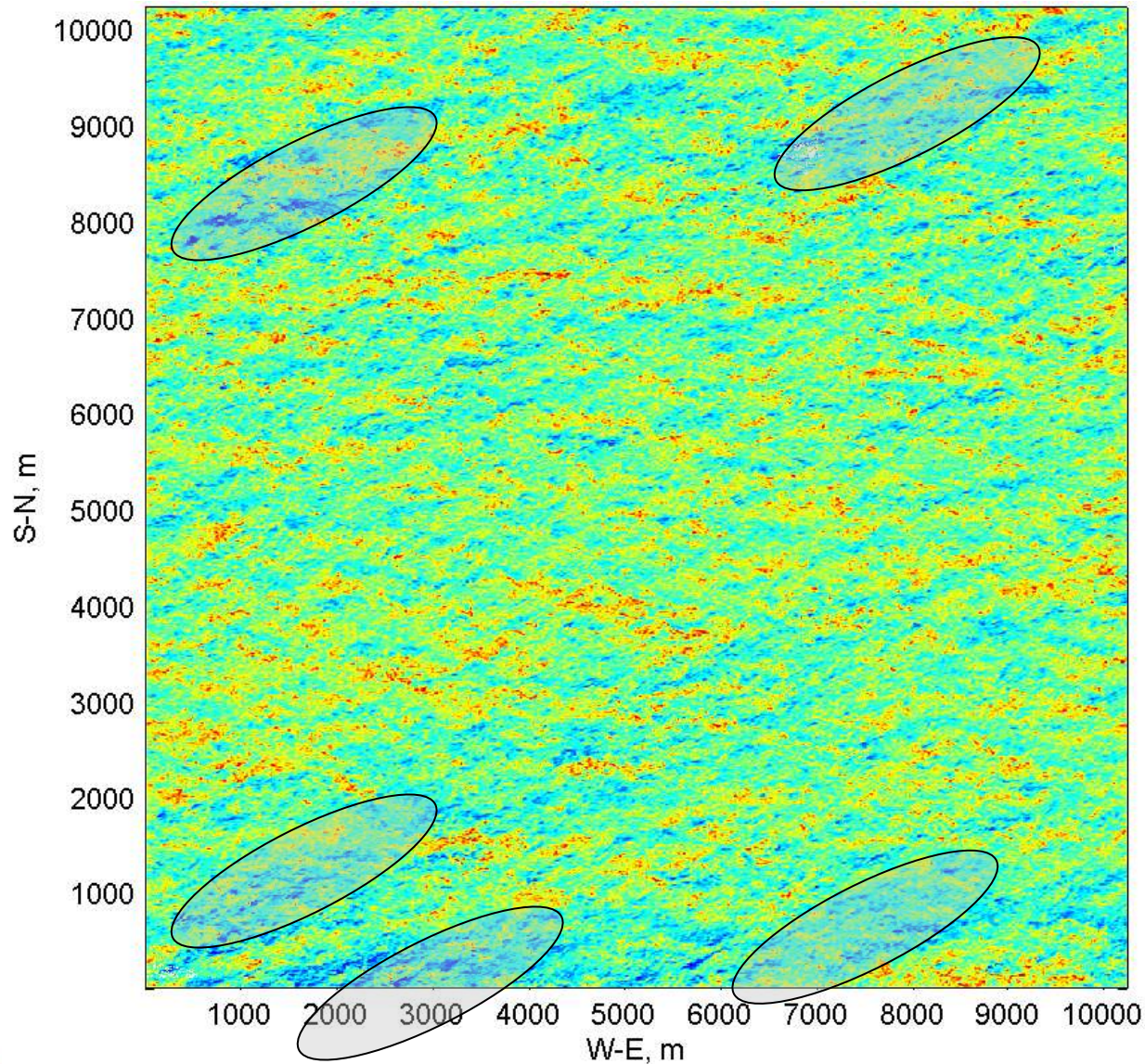


# The finest resolution run for PARIS



- Wind kinetic energy
- 118 m (tallest buildings and “valleys”)

# The finest resolution run for PARIS



- Wind kinetic energy
- 158 m (roughness layer)

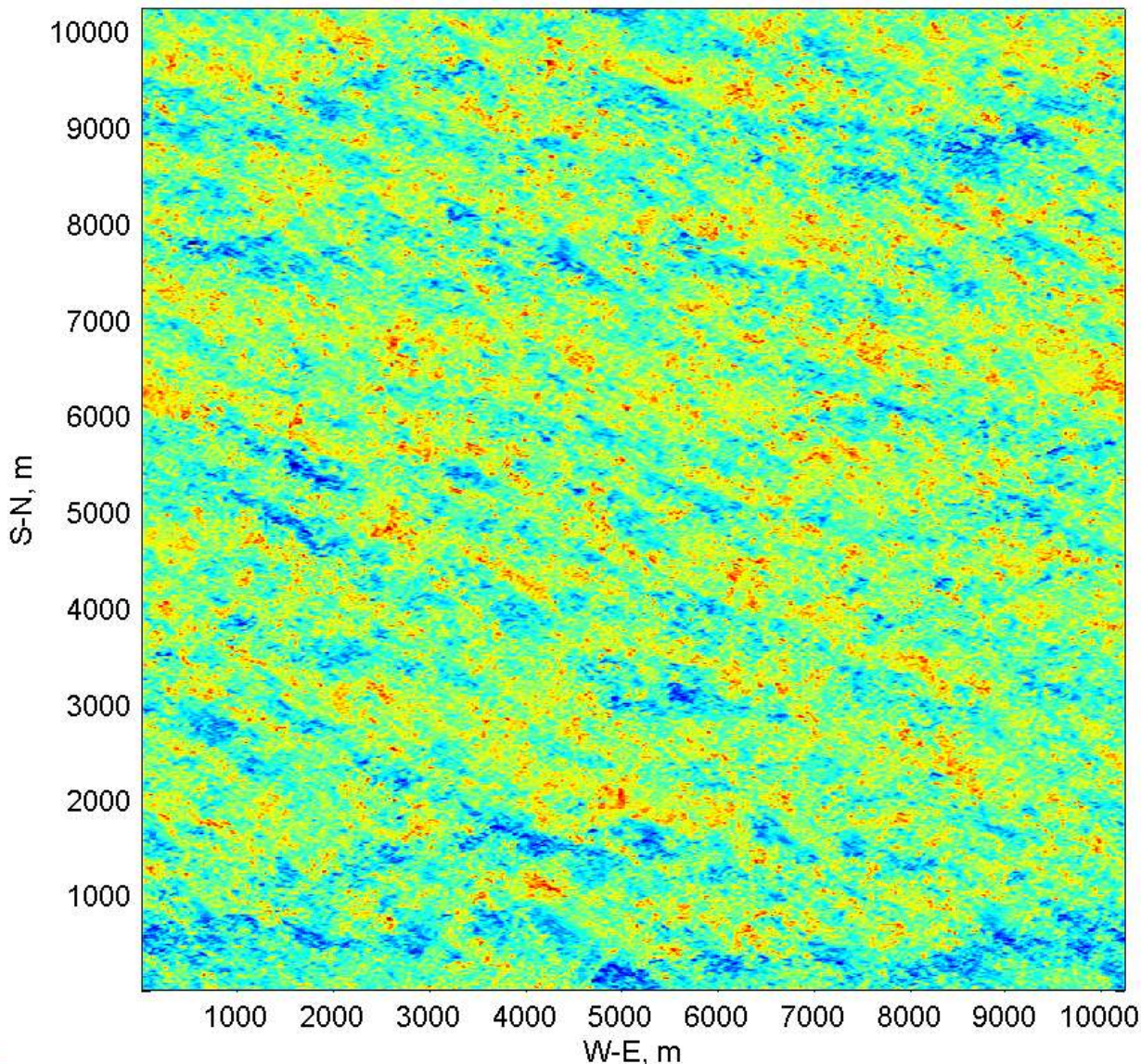


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# The finest resolution run for PARIS



- Wind kinetic energy
- 478 m (UBL above blending height)



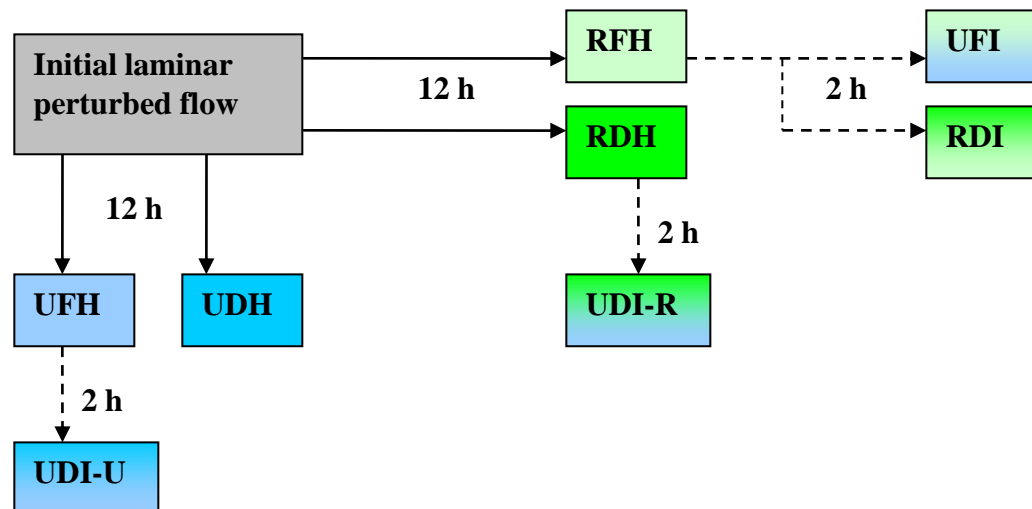
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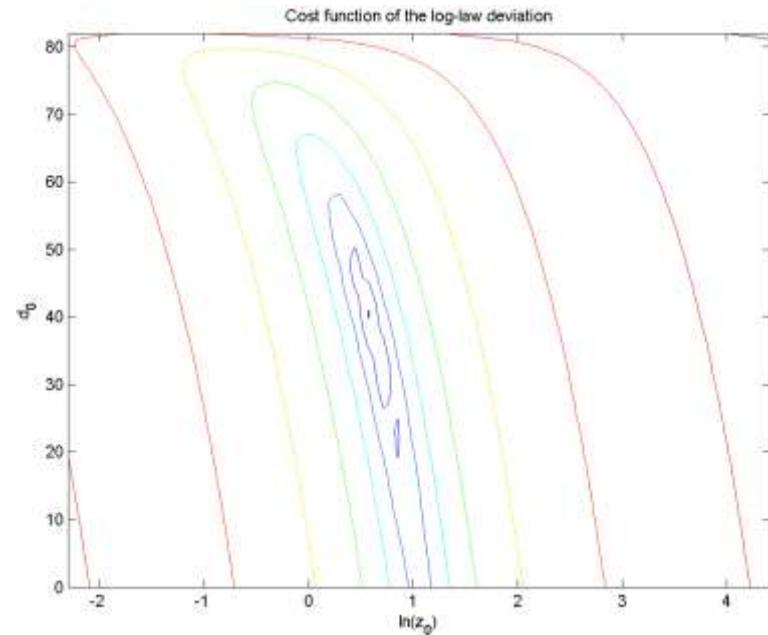
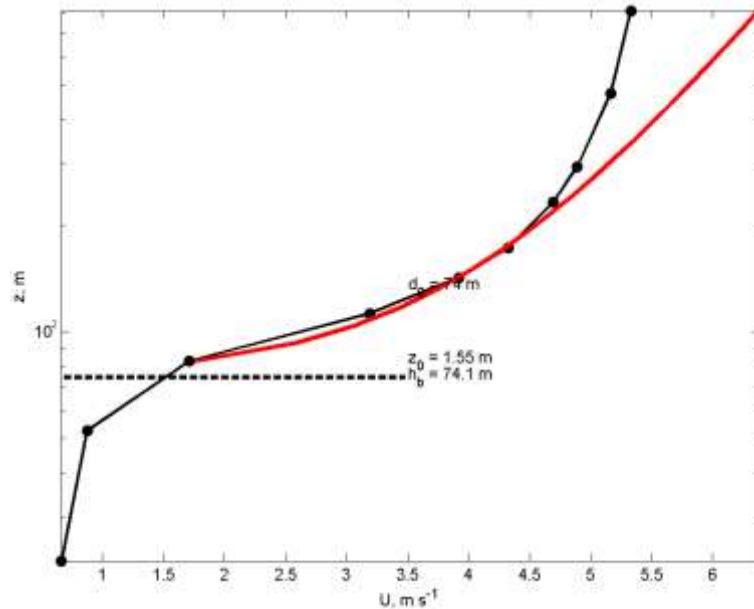


# LES database

- Fine resolution LES on city scale are now feasible but require enormous resources
- Applications and research require a database of LES runs: **What will be an optimal compromise?**



# Statistical data analysis



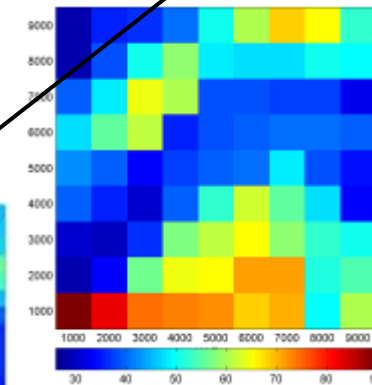
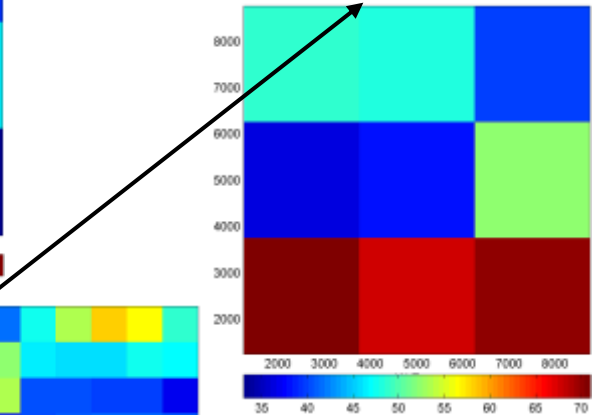
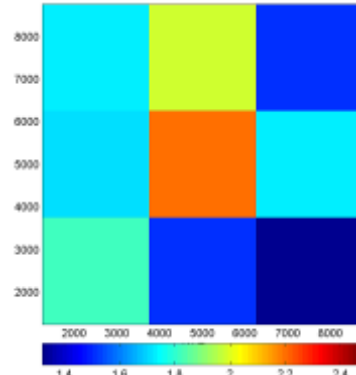
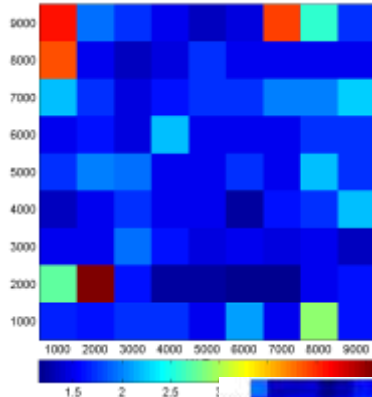
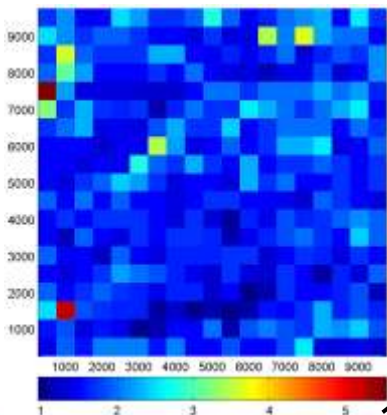
# Data aggregation: *mapping for meteorological modelling*

Objectively aggregated  $Z_0$  has little resemblance to the surface morphology map

$Z_0$  on 0.5 km

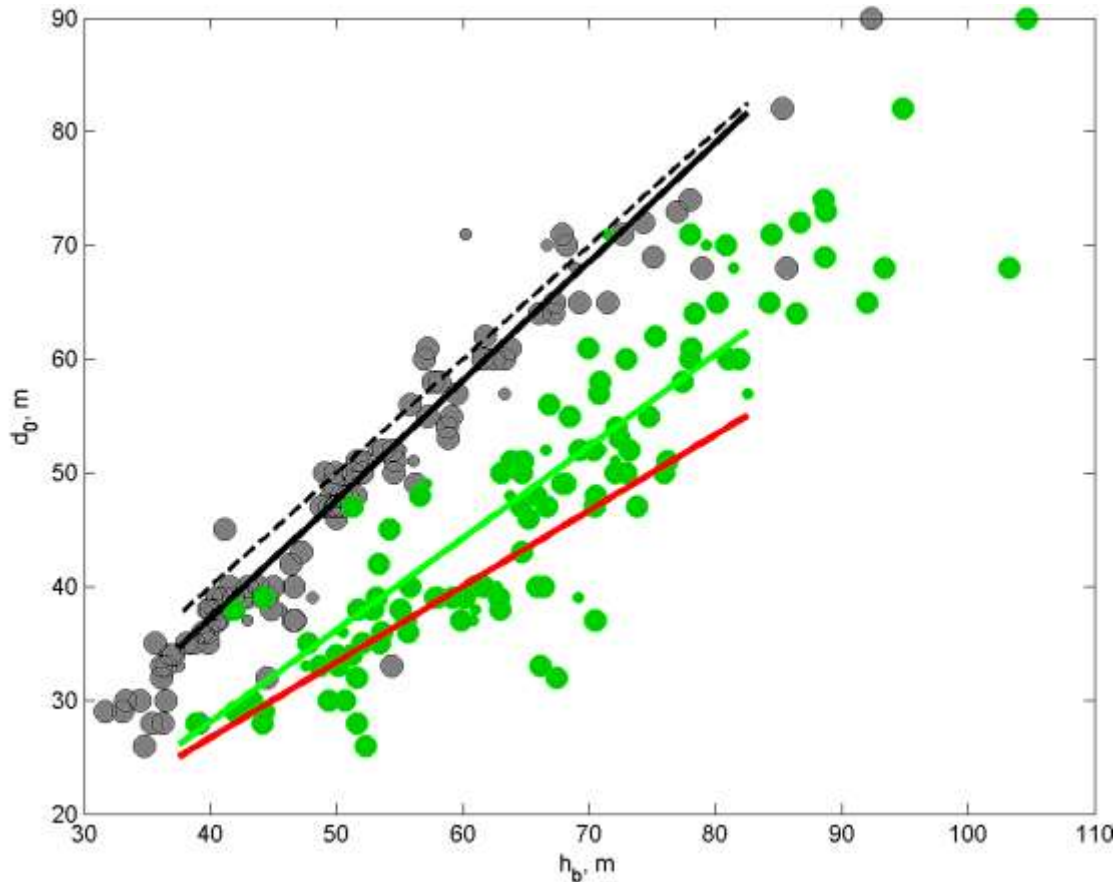
1.0 km

2.5 km



Objectively aggregated  $d_0$  shows direct proportionality to the surface morphology map

# Data aggregation: *mapping for meteorological modelling*



**Figure 2.4:** Validation of Garratt (1992) parameterization for the displacement height on basis of the run A and AUL simulations (code PALM, 10 m resolution mesh). Large dots correspond to 1000 m aggregation (averaging over 10,000 profiles in the area 1 km<sup>2</sup> for each dot); small dots – 2500 m aggregation (averaging over 62,500 profiles in the area 6.25 1 km<sup>2</sup> for each dot). Rural simulations (run A with the Paris DEM but without buildings) are depicted in grey. Eq. (6) with the optimal fitting  $Ad = 1.08$  is given by the black solid line. The black dashed line represents  $Ad = 1.0$ . Urban simulations (run AUL) are depicted in green. Eq. (6) with the optimal fitting  $Ad = 0.79$  is given by the green solid line. The red line represents the Garratt's  $Ad = 0.75$ .

# Future Work

- Accumulate database of Paris LES runs for cross-scale studies of the EBL
- Complement database with stratified and transport runs – dispersion studies, urban heat island
- Complete LESNIC urbanization
- Runs for the intercomparisons study
- Assimilation of Paris Plume field campaign data into LES runs

