Bjerknes Centre for Climate Research

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

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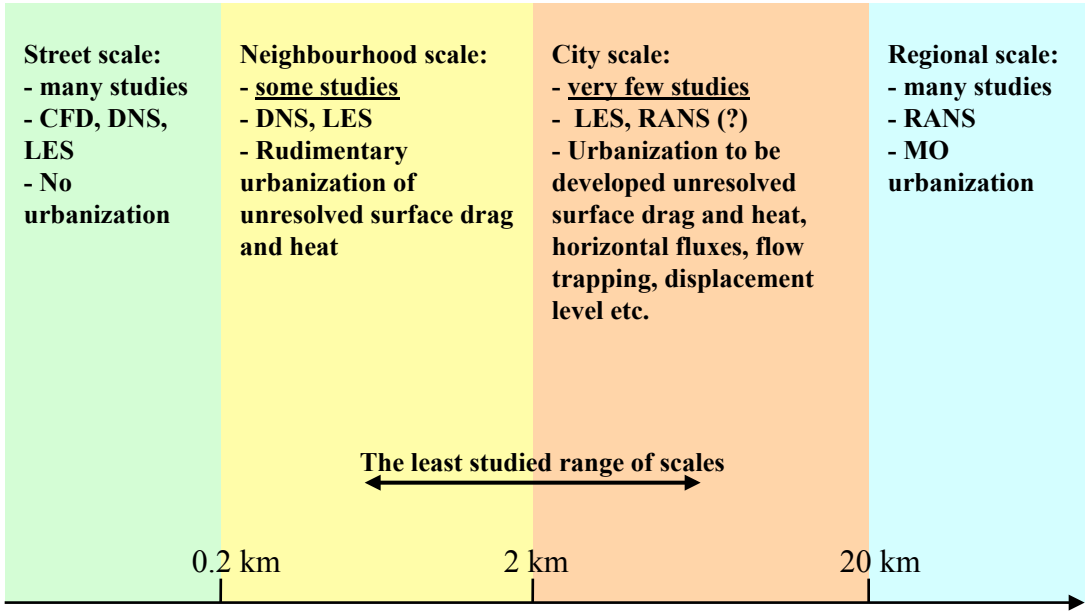
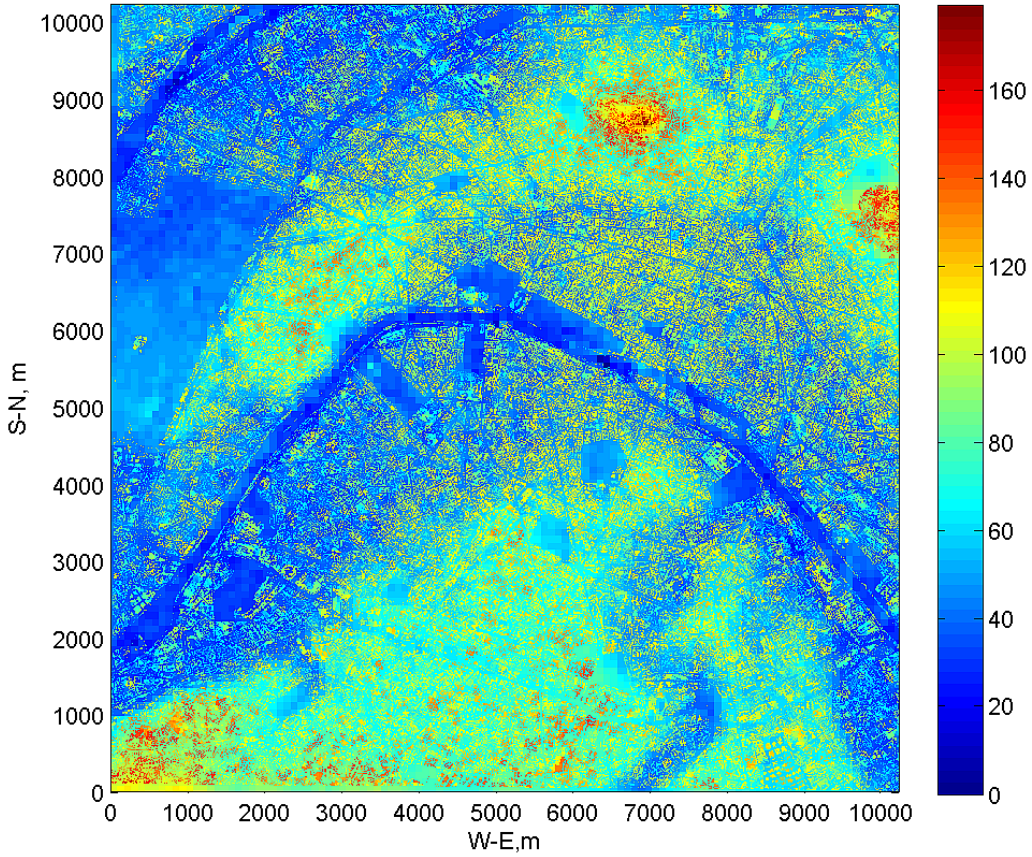
Specific problems of interest



Very few studies dealing with O(10 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

Paris surface morphology:
MEGAPOLI Finnish Meteorological Institute



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

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

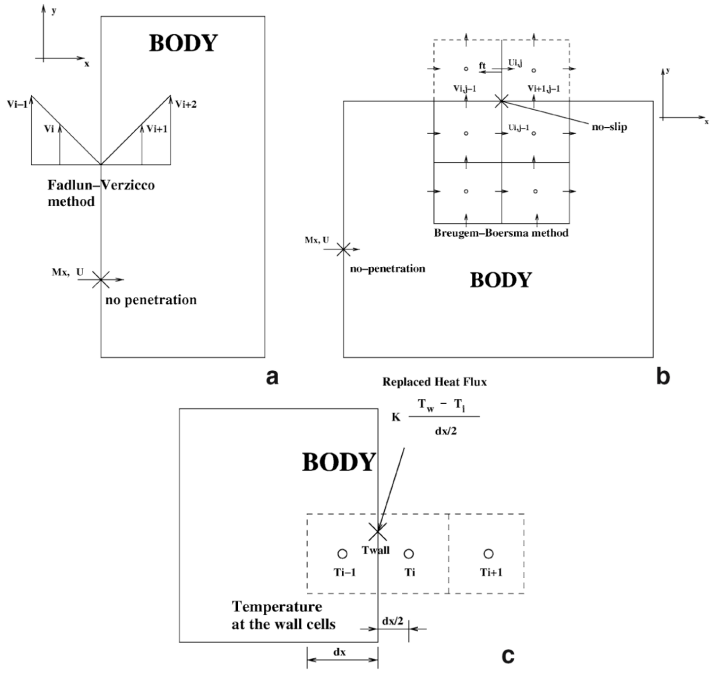
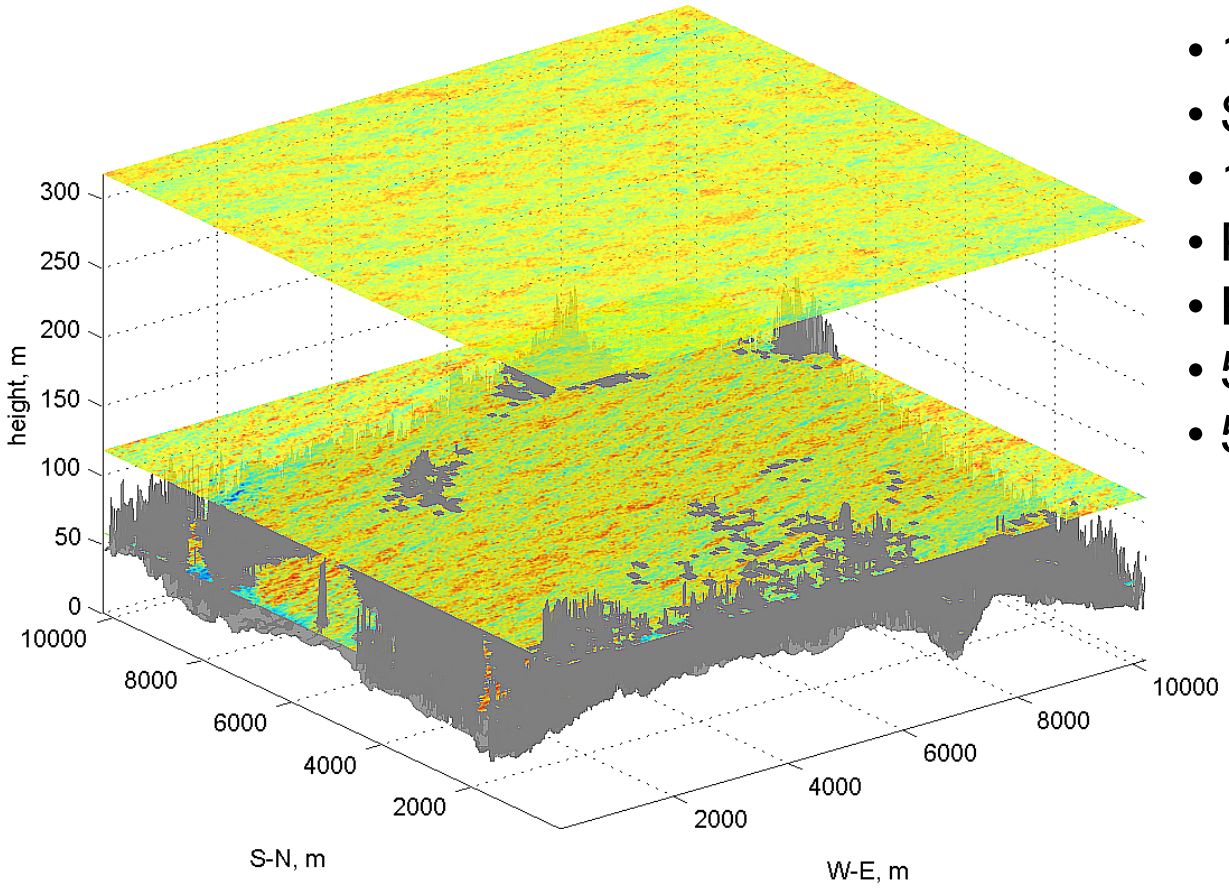


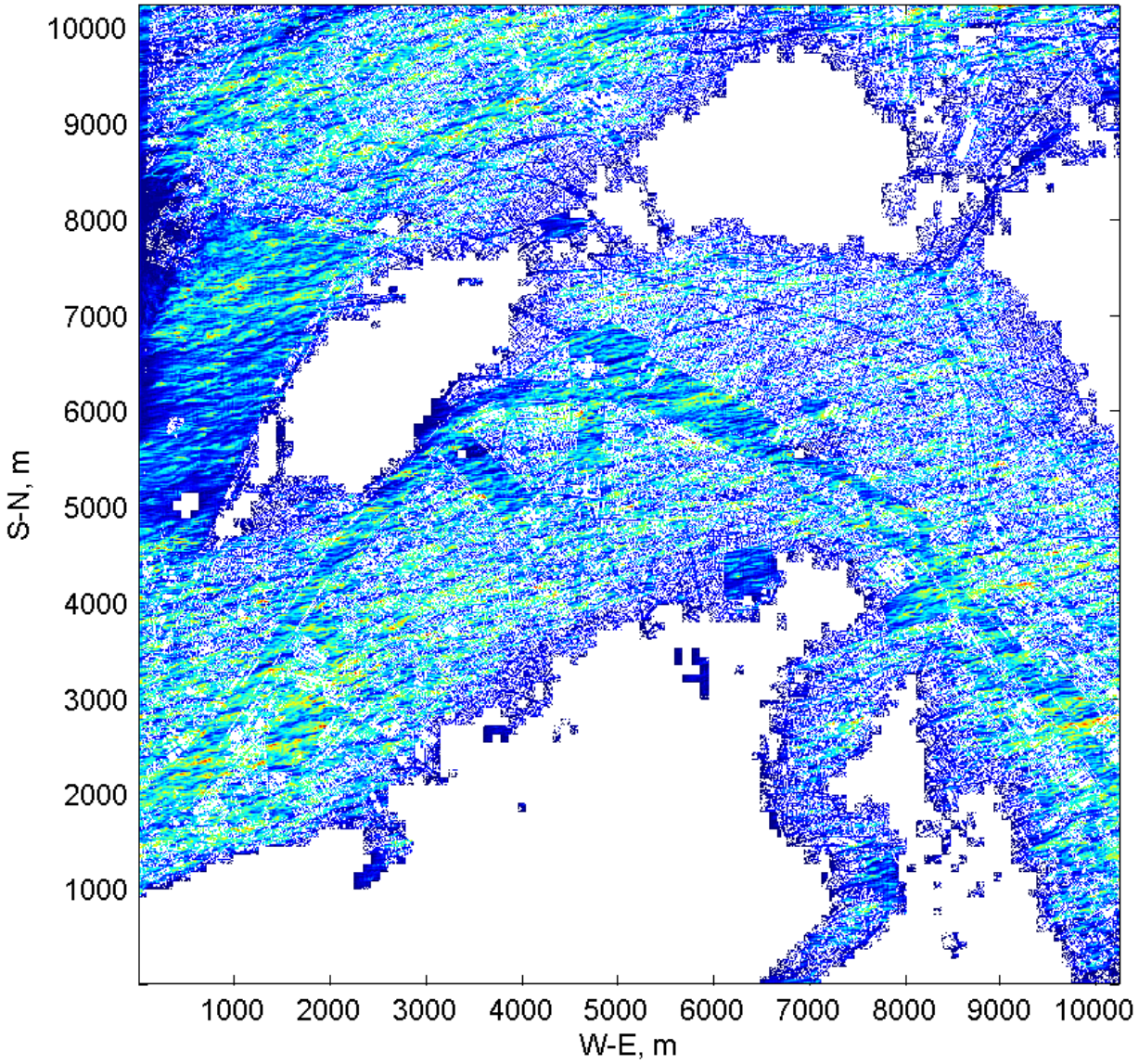
Figure 1.2.1 (from Paravento et al., 2008): (a) The Fadlun–Verzicco method; (b) The Breugem–Boersma method; (c) Temperature treatment for these methods.

The finest resolution run for PARIS



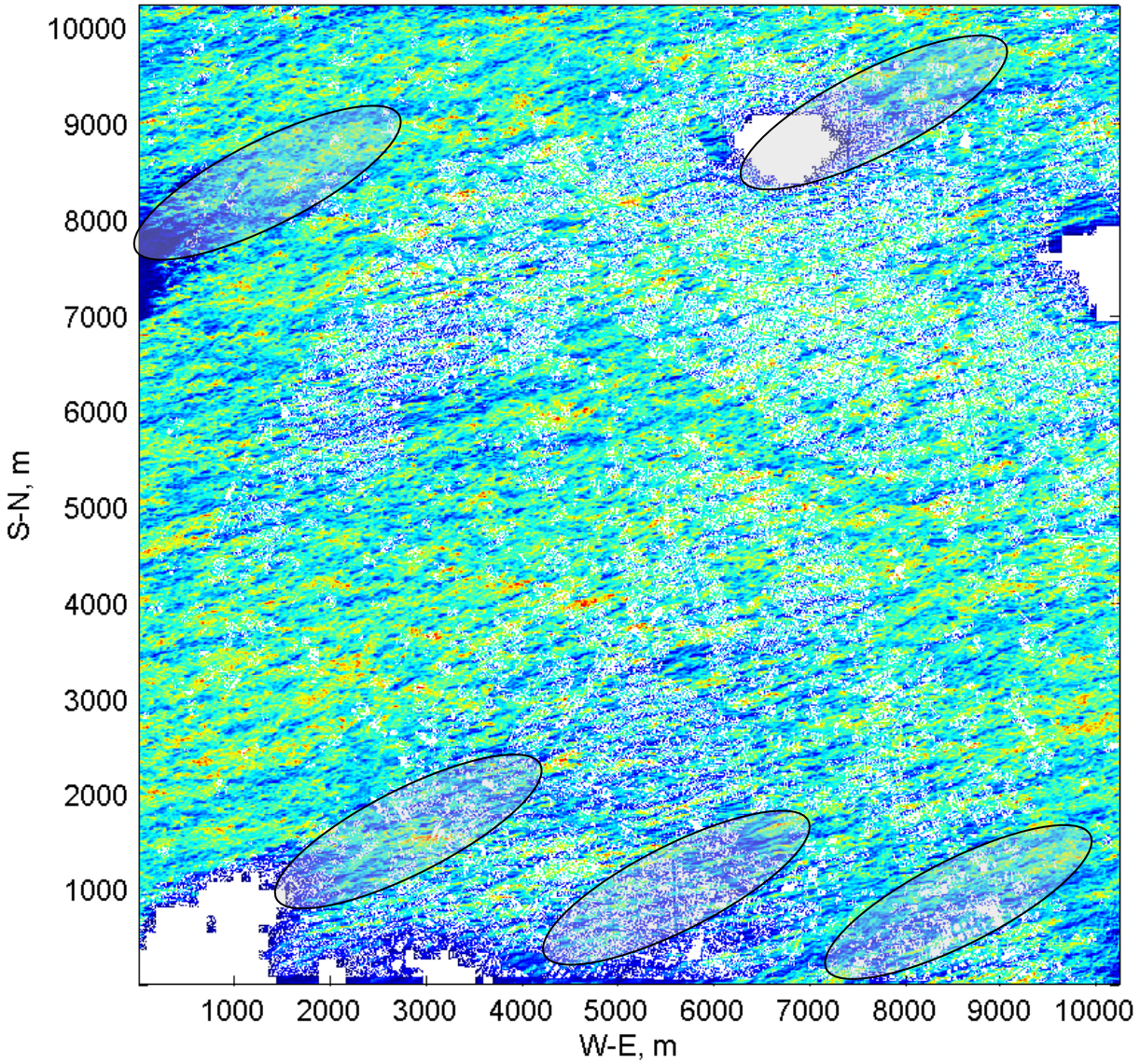
- 10 m resolution
- Spin up over rural terrain
- 1 h of urban simulations
- PALM
- Ekman UBL
- 5000 CPU hours
- 512 CPU in parallel

The finest resolution run for PARIS



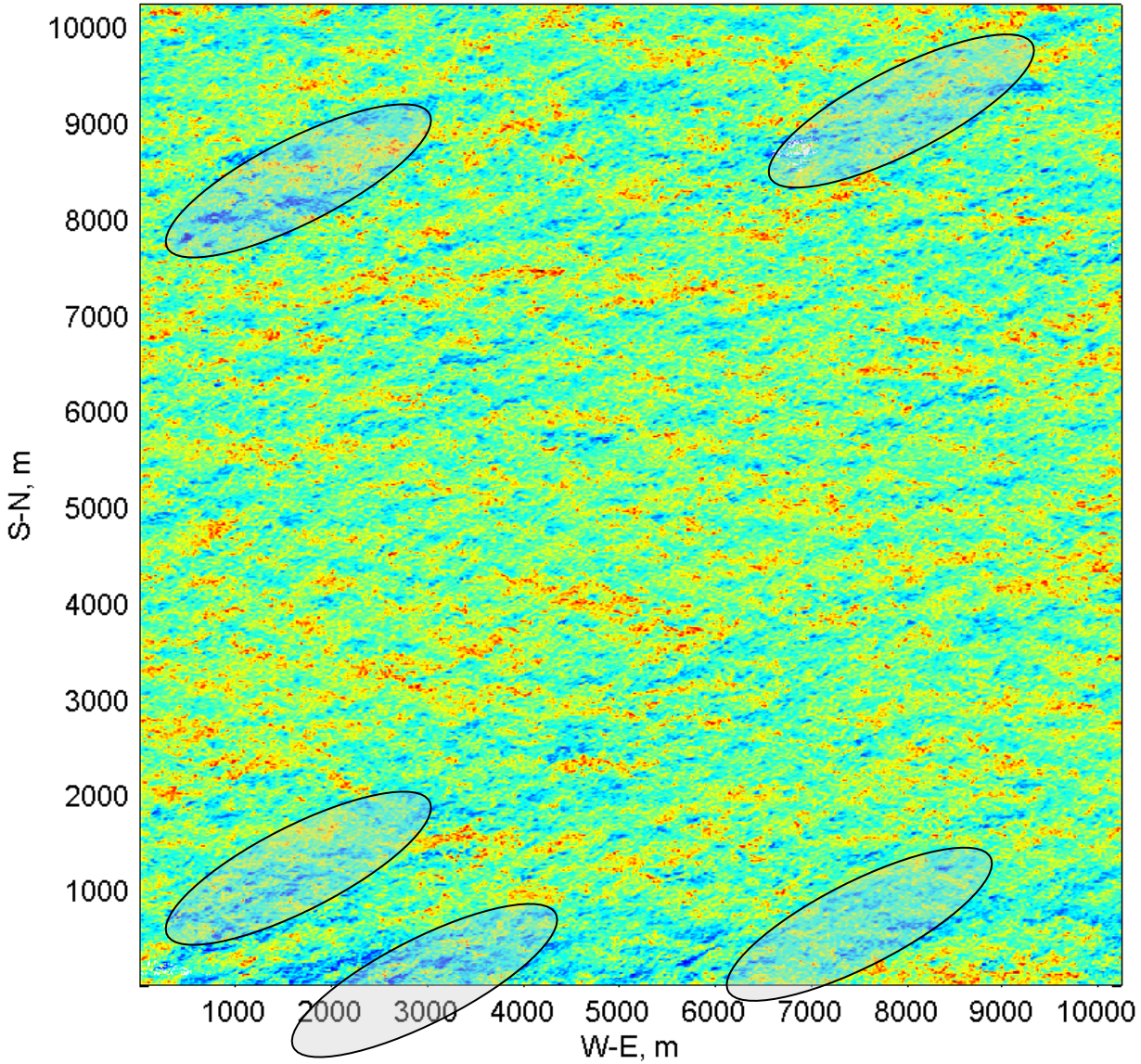
- Wind kinetic energy
- 58 m (urban canopy)

The finest resolution run for PARIS



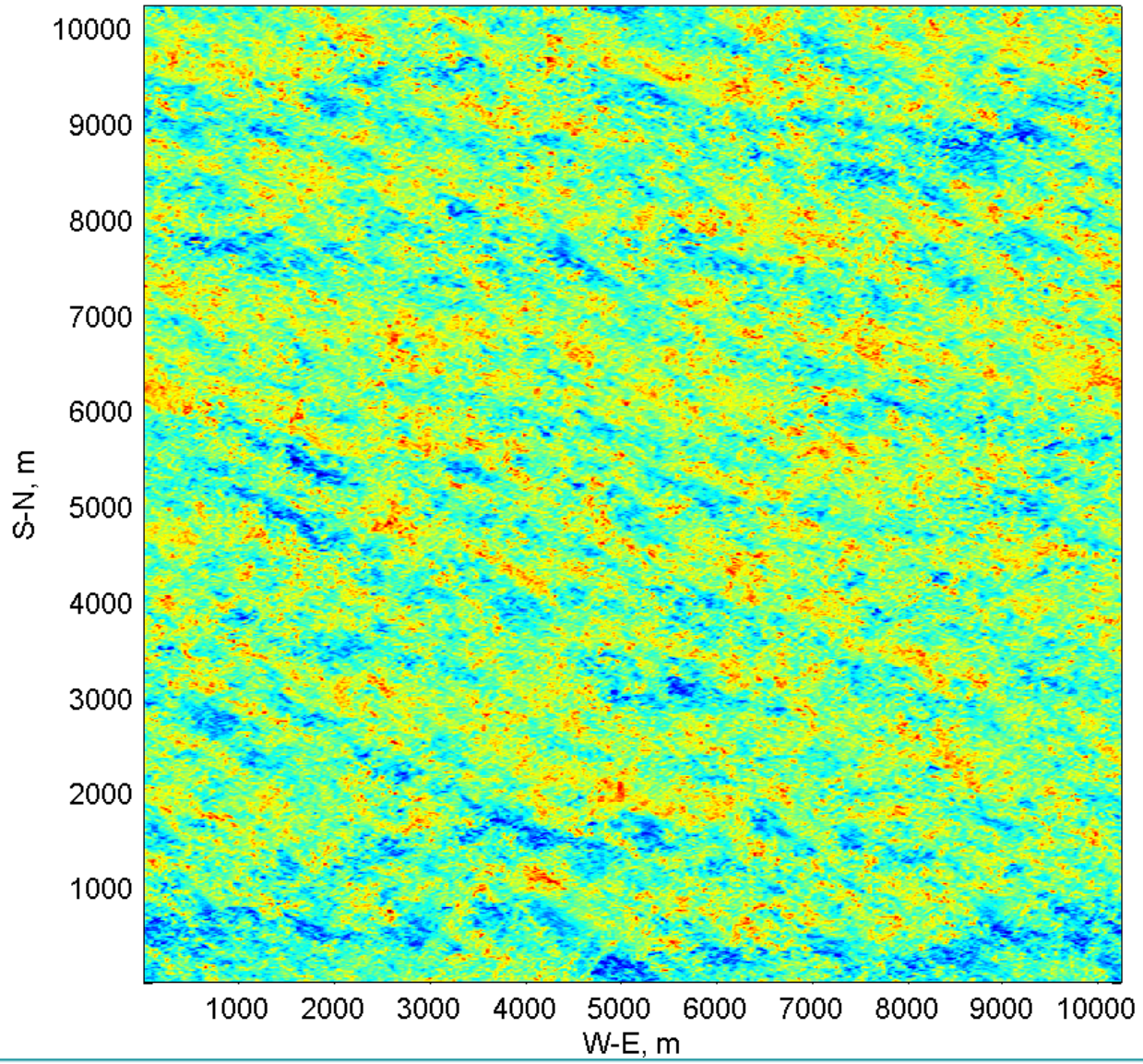
- Wind kinetic energy
- 118 m (tallest buildings and “valleys”)

The finest resolution run for PARIS



- Wind kinetic energy
- 158 m (roughness layer)

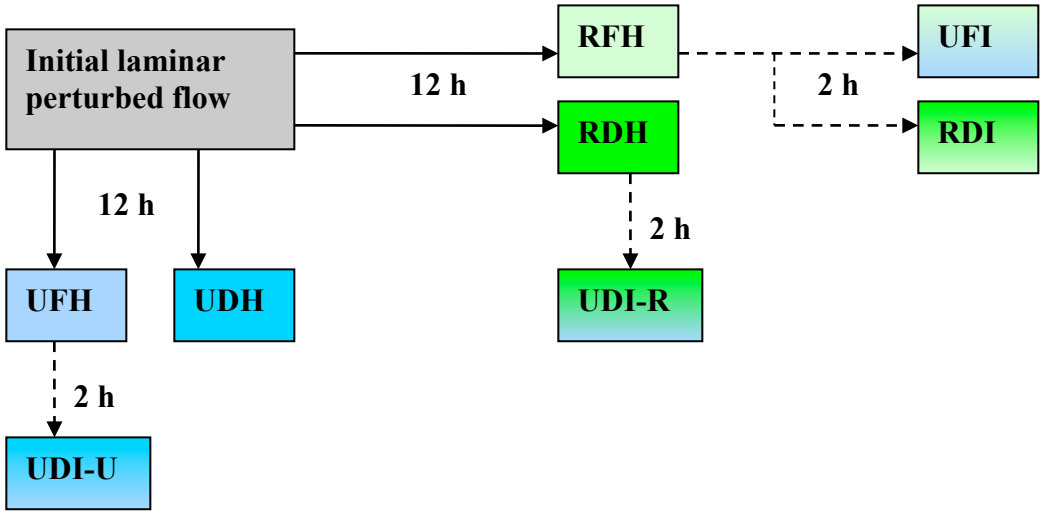
The finest resolution run for PARIS



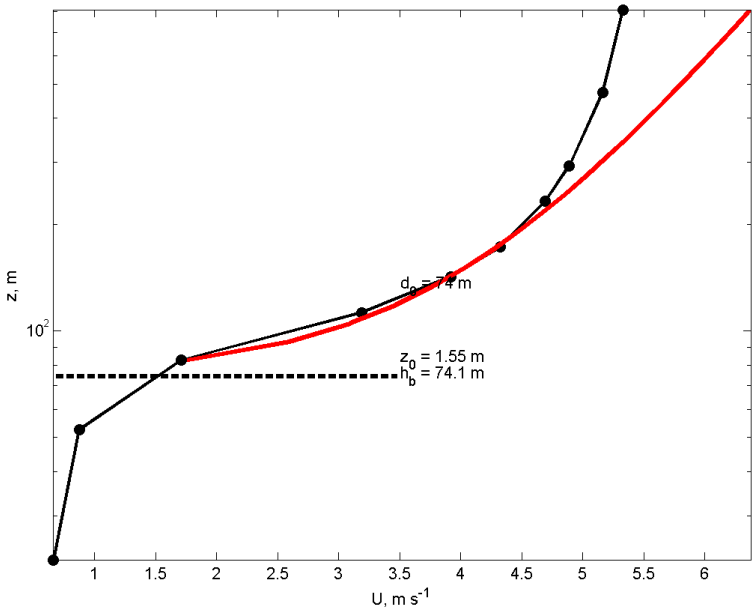
- Wind kinetic energy
- 478 m (UBL above blending height)

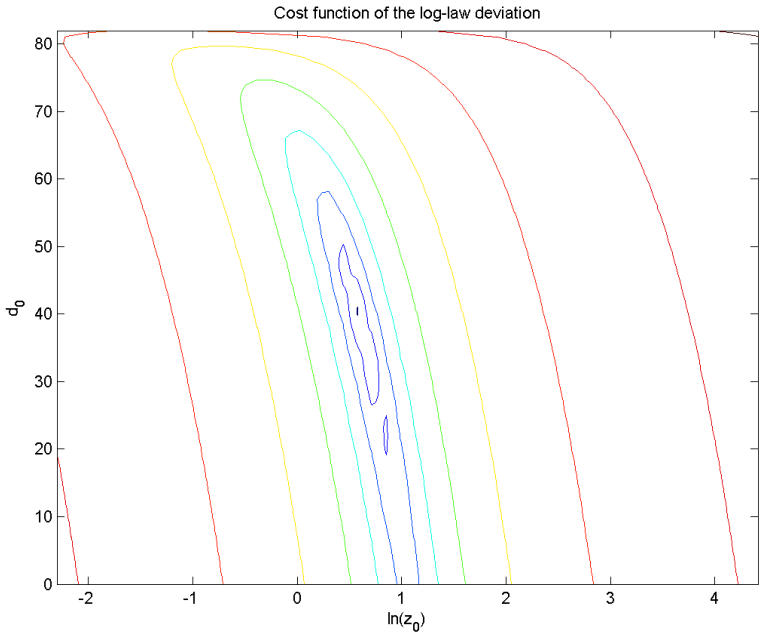
LES database

- 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?



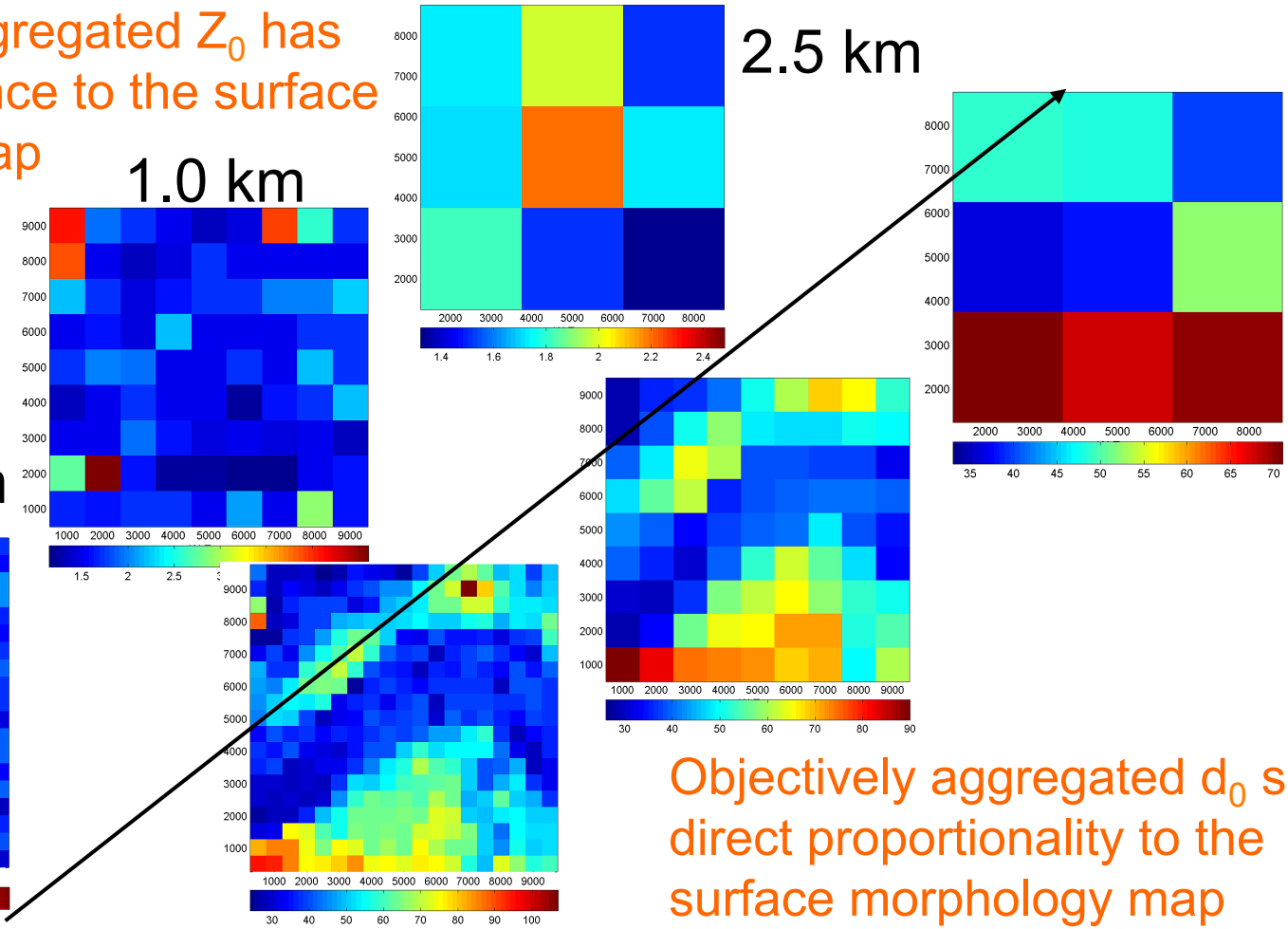
Statistical data analysis





Data aggregation:
mapping for meteorological modelling

Objectively aggregated Z_0 has little resemblance to the surface morphology map



Objectively aggregated d_0 shows direct proportionality to the surface morphology map

Data aggregation:
mapping for meteorological modelling

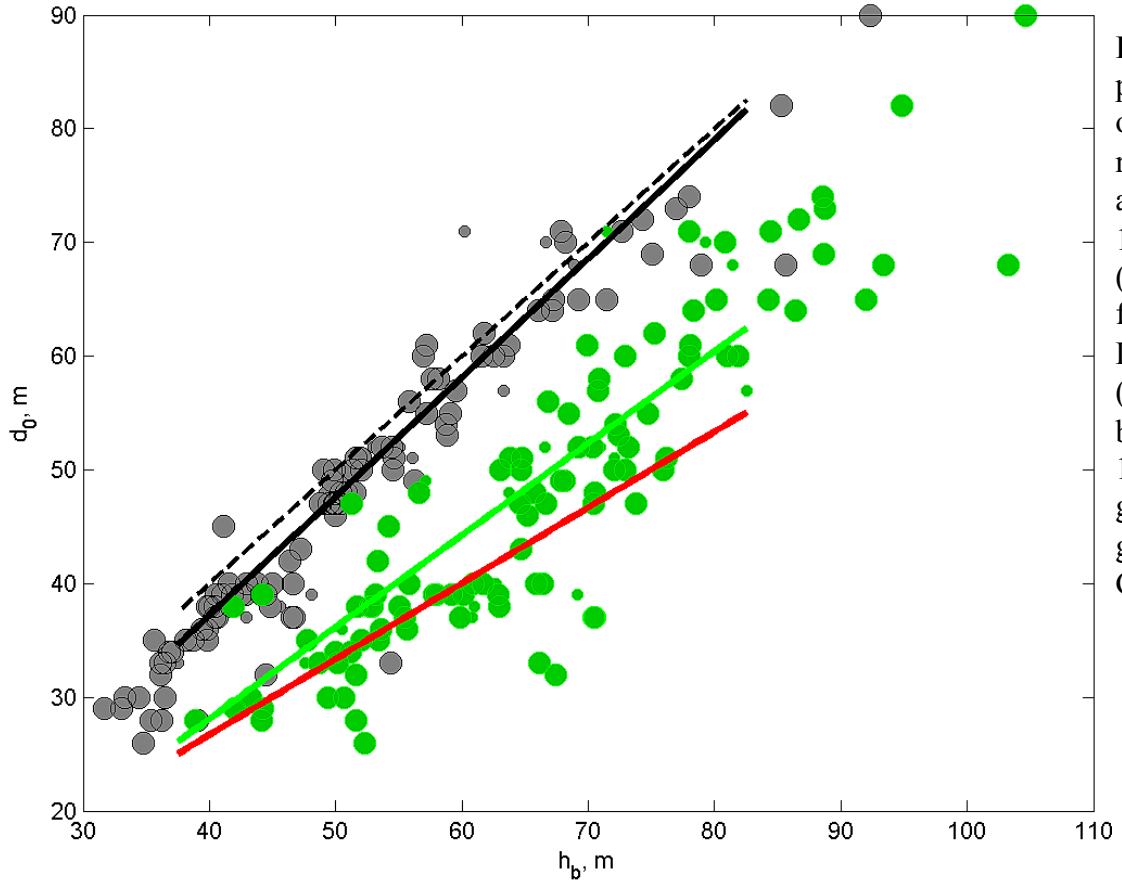


Figure 2.4: Validation of Garratt (1992) parameterization for the displacement height on basis of the run A and AUL simulations (code PALM, 10 m resolution mesh). Large dots correspond to 1000 m aggregation (averaging over 10,000 profiles in the area 1 km^2 for each dot); small dots – 2500 m aggregation (averaging over 62,500 profiles in the area 6.25 1 km^2 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