



IMPERIAL



ICL, Dec 2025

Multiscale Physical Modelling in Urban Environment: Case study for Ningbo & Xiamen

Jie Zheng

Fangxin Fang, Linfeng Li

Multiscale physical simulations for Urban scales

PALM (Parallelized Large-Eddy Simulation Model)

PALM is a large-eddy simulation model for urban climate and environmental research.

➤ Integrated physical modules:

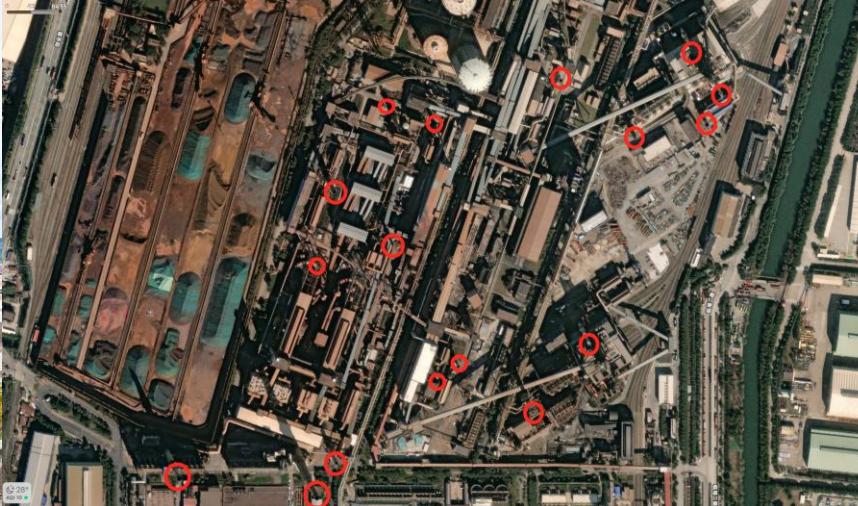
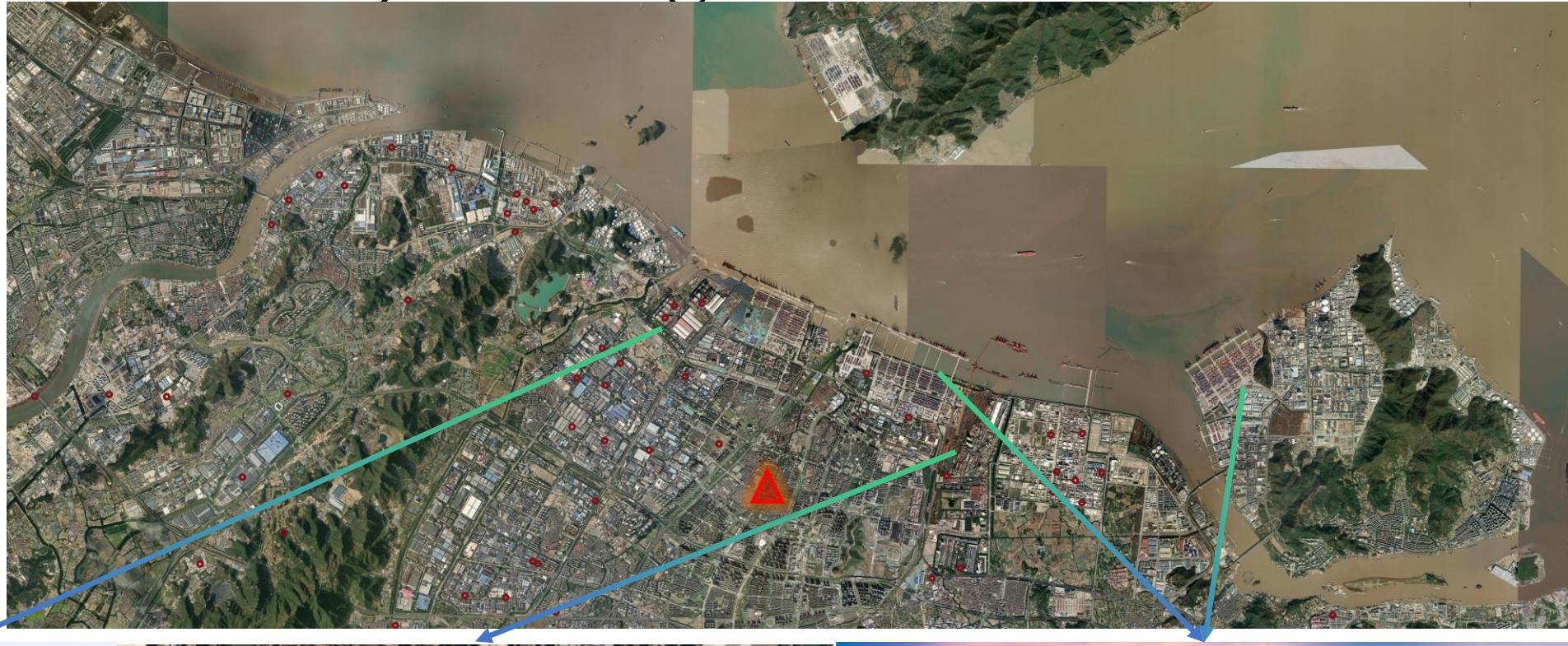
- **Radiative Transfer Module** – simulates shortwave and longwave radiation in complex urban/natural settings.
- **Land Surface Module** – represents soil–vegetation–atmosphere exchanges of heat and moisture.
- **Urban Surface Module** – captures building surfaces, walls, roofs, and their thermal dynamics.
- **Plant Canopy Module** – resolves vegetation impacts on momentum, heat, moisture, and pollutant transport
- **Indoor climate module** - Calculates temperature and other parameters inside buildings.
- **Atmospheric Chemistry Module** - Simulates the transport, chemical reactions (gas-phase chemistry), and dry deposition of air pollutants.
- **Aerosol Module** - Can be coupled to the chemistry module for a detailed description of aerosol size distribution and chemical composition.

➤ Coupling and extensions:

- Regional and mesoscale models (e.g., WRF, **ERA5**, **EAC4**) for boundary conditions.
- Time-varying emissions from traffic and other anthropogenic sources
- Energy system models, pollutant chemistry, and urban planning tools.
- High scalability for massively parallel computations on supercomputers.

Why is Ningbo

1. Port–industry–urban integration
2. Complex terrain: mountains + sea
3. High-density steel / power plants
4. Intensive port, shipping and container traffic



Case Study

- Ningbo Beilun
- Industrial Point Source
- 3 Nested Domains
 - Parent domain D01:
 - $70 \text{ km} \times 51.2 \text{ km}$
 - $\text{dx}=\text{dy}=100\text{m}$, $\text{dz} = 40\text{m}$
 - Child domain D02 :
 - $32 \text{ km} \times 12.8 \text{ km}$
 - $\text{dx}=\text{dy}= 50\text{m}$, $\text{dz} = 20\text{m}$
 - Child domain D03 :
 - $9 \text{ km} \times 6.4 \text{ km}$
 - $\text{dx}=\text{dy}= 10\text{m}$, $\text{dz} = 10\text{m}$



Static driver

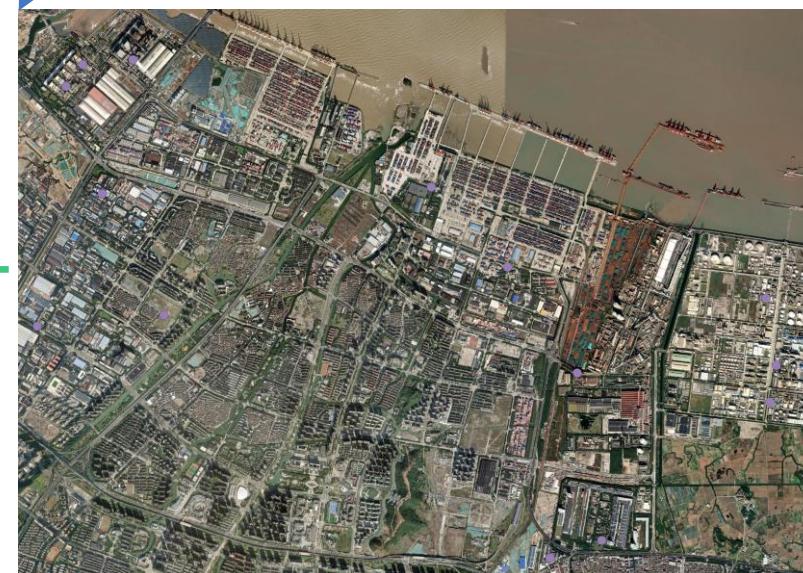
D01 Great Ningbo: regional terrain & coastline



D02 Great Beilun: port–industry–city corridor



3D view of buildings



D03 Main Beilun:
urban & industrial
core

Case settings

- Spatial discretisation:

	Grid size	# of grid
Parent domain D01	100m x 100m x 40m	700 x 512 x 60
Child domain D02	50m x 50m x 20m	640 x 256 x 50
Child domain D03	10m x 10m x 10m	900 x 640 x 40

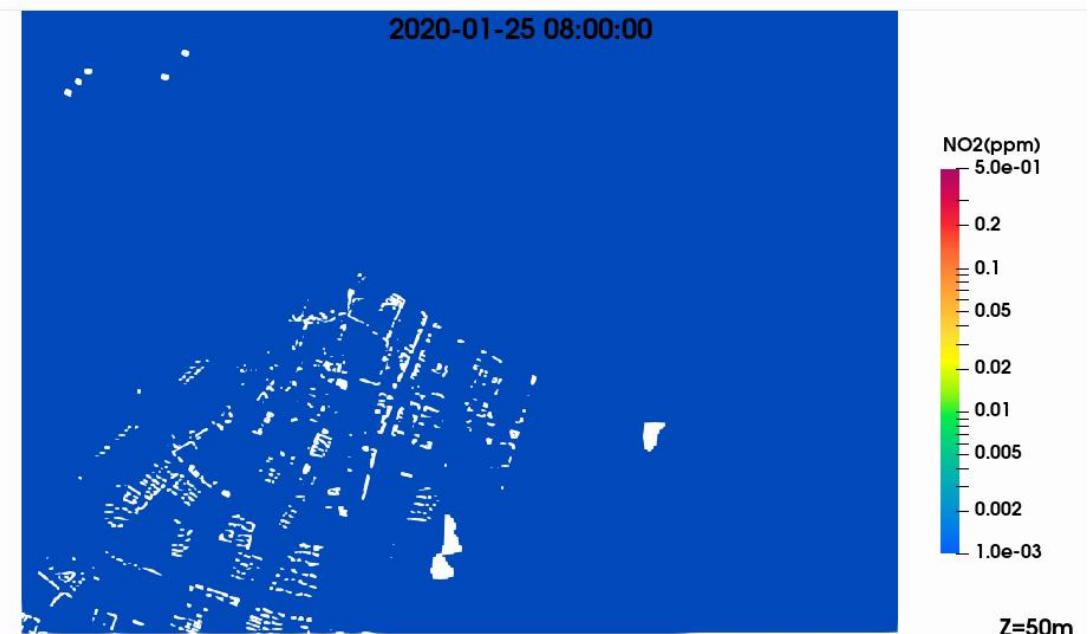
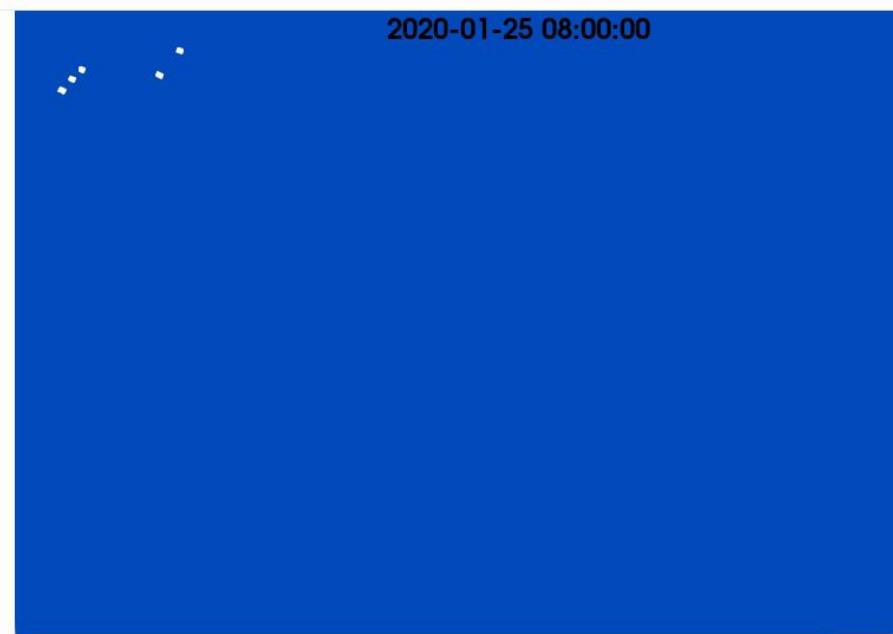
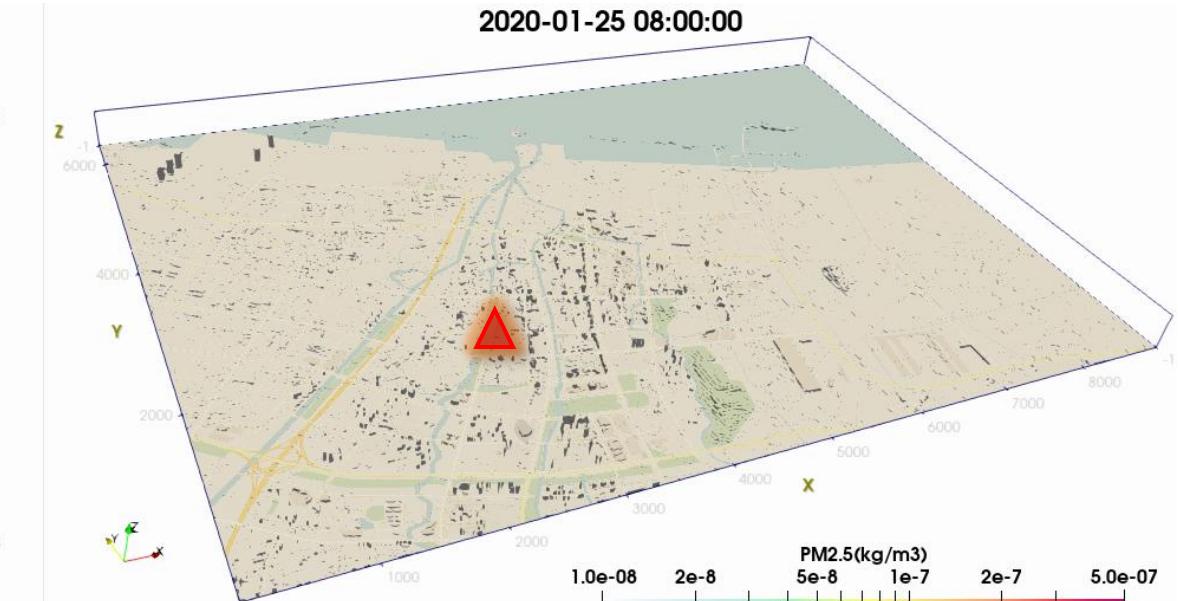
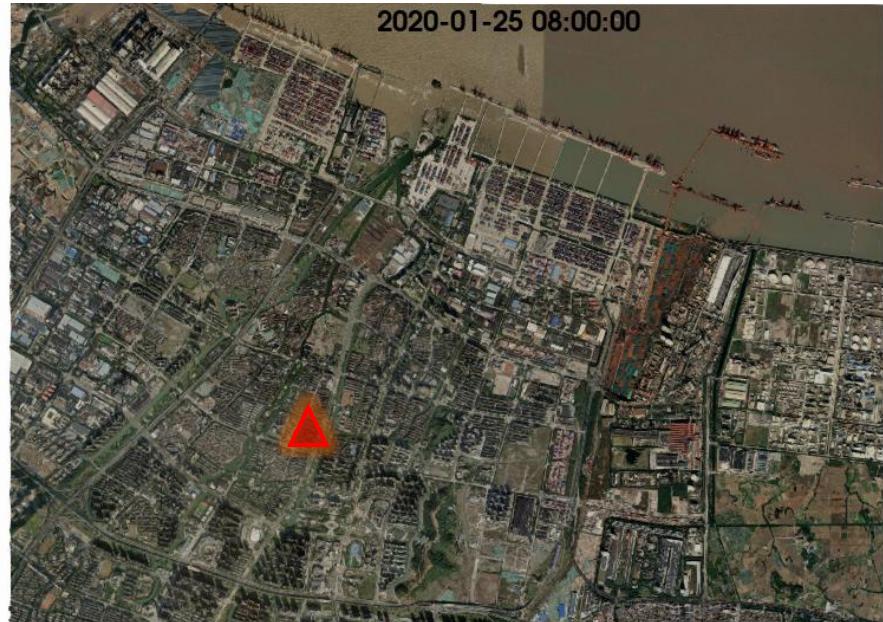
- Run on [ARCHER2](#) (UK Tier 1 HPC)
 - 8 nodes (1024 cores)
 - 13 hr CPU time for 1 day (**2020-01-25**) simulation
- Activated [physics model](#)
 - Urban surface (only in Child domain N03)
 - Radiation
 - Land surface
 - Dynamic driver([ERA5](#) reanalysis data @ 0.25 deg)

Results

Overview (D01 Great Ningbo on 20200125)

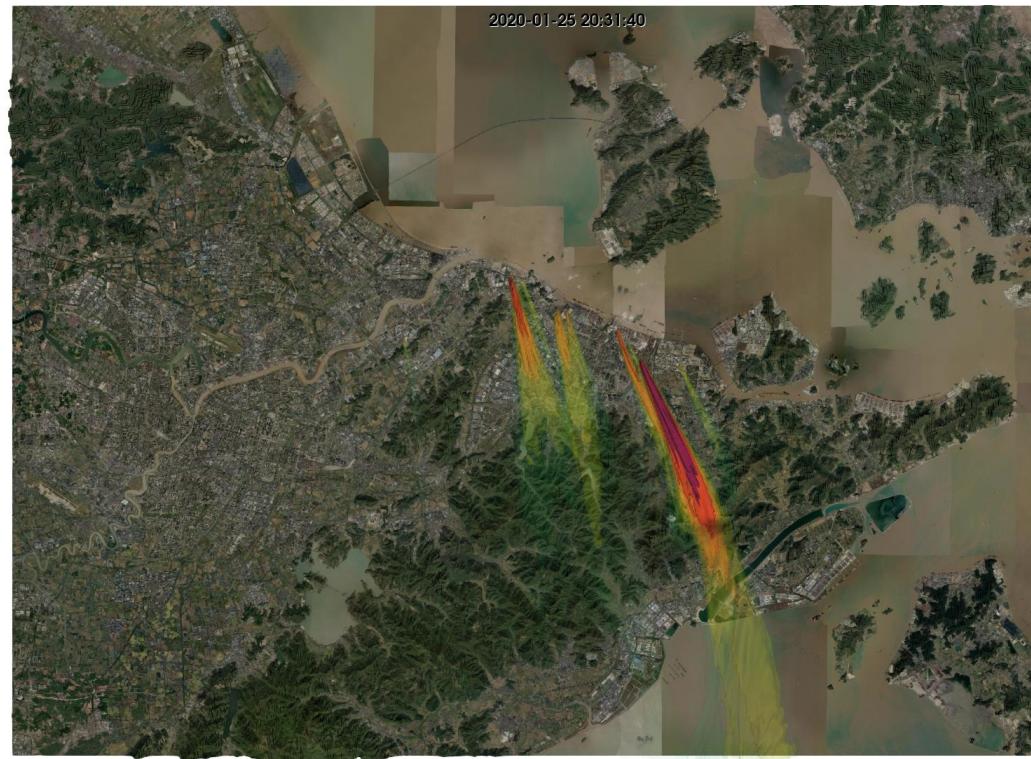


Overview (D03 Main Beilun on 20200125)

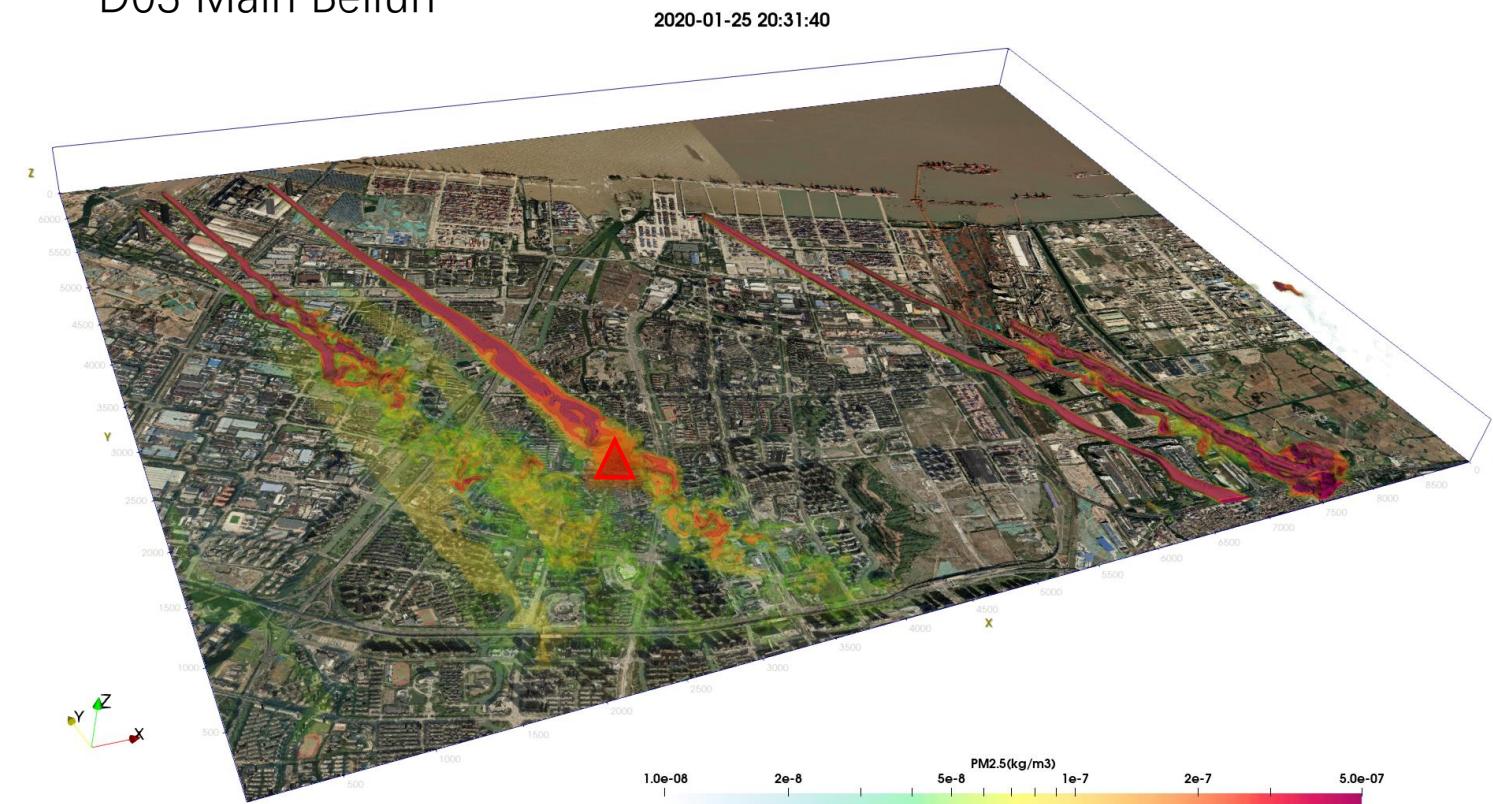


Northwest Wind Simulations

D01 Great Ningbo

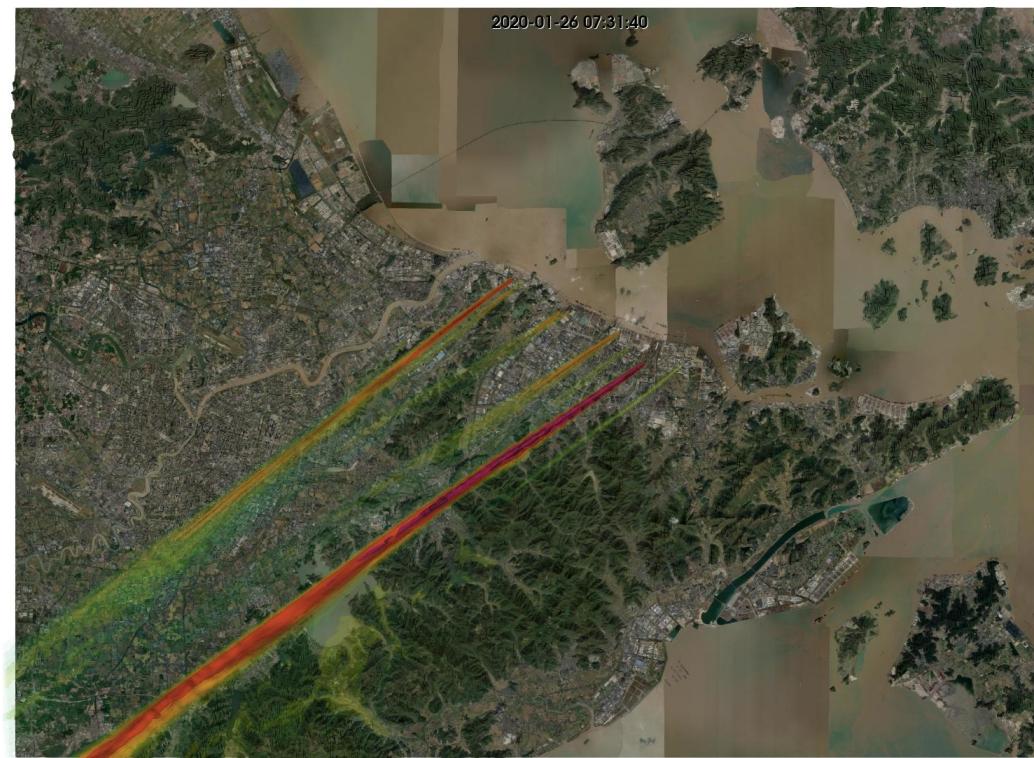


D03 Main Beilun

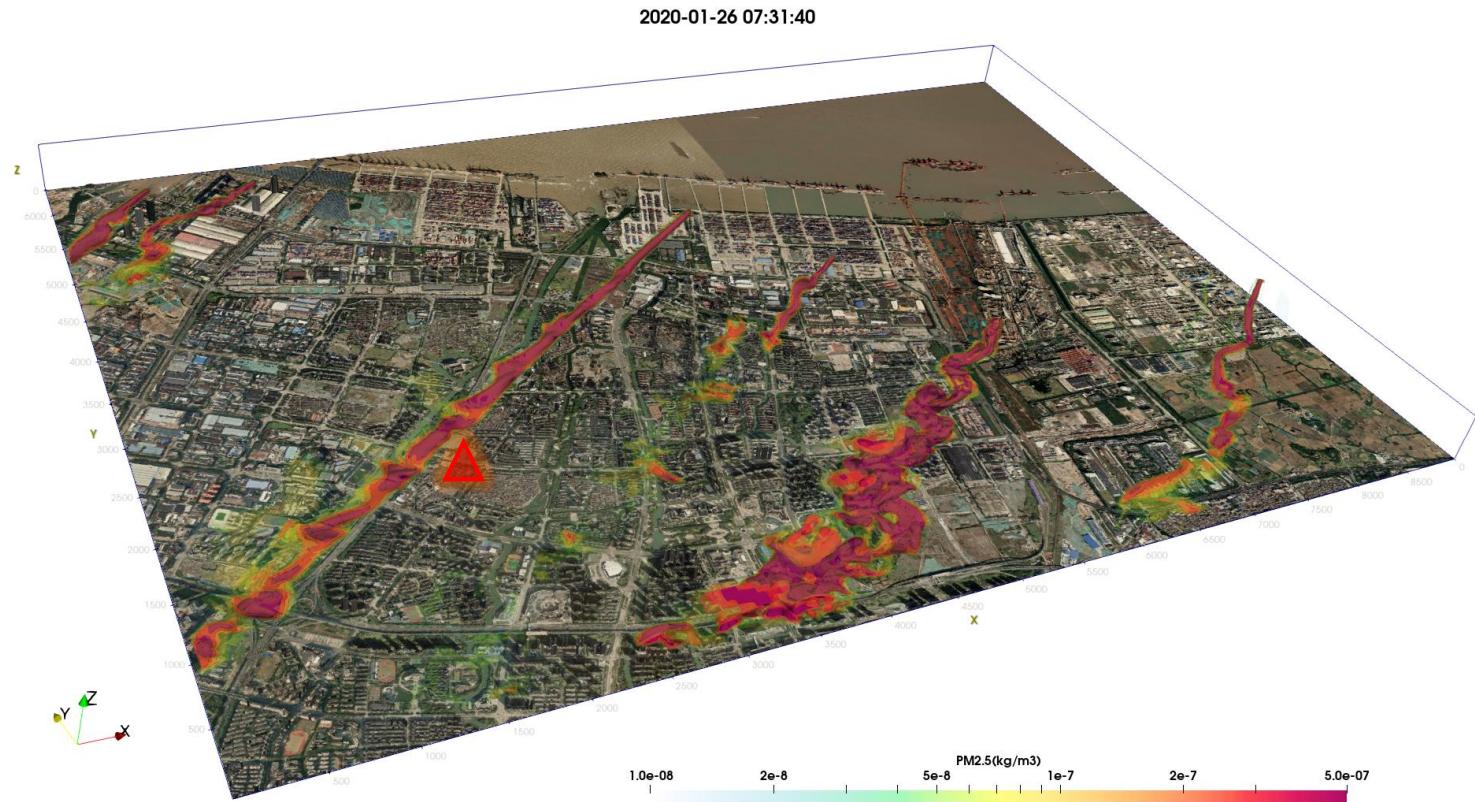


Northeast Wind Simulations

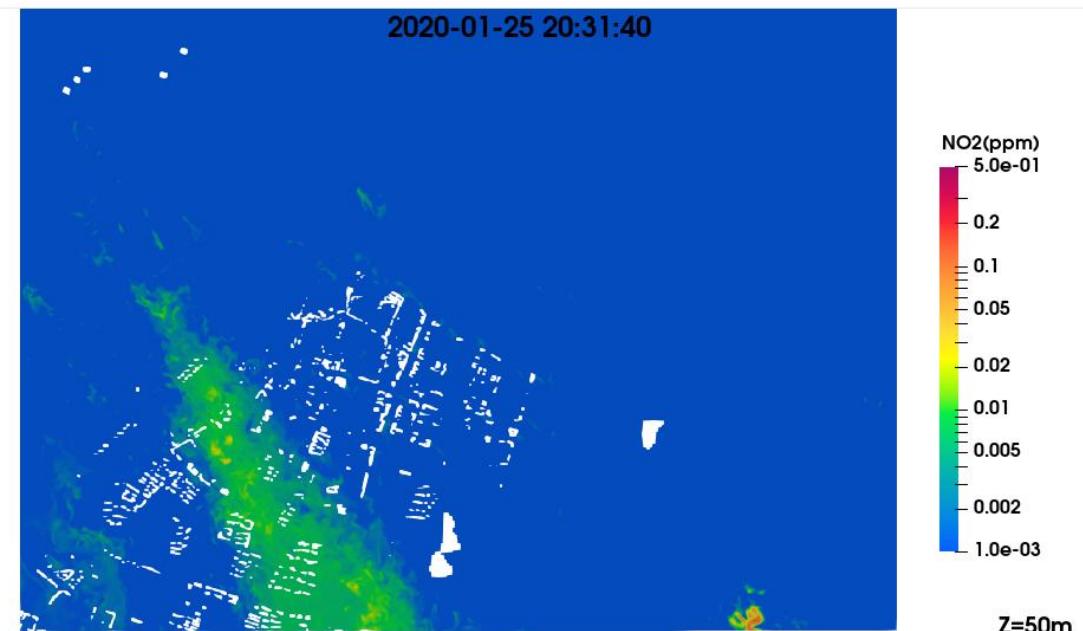
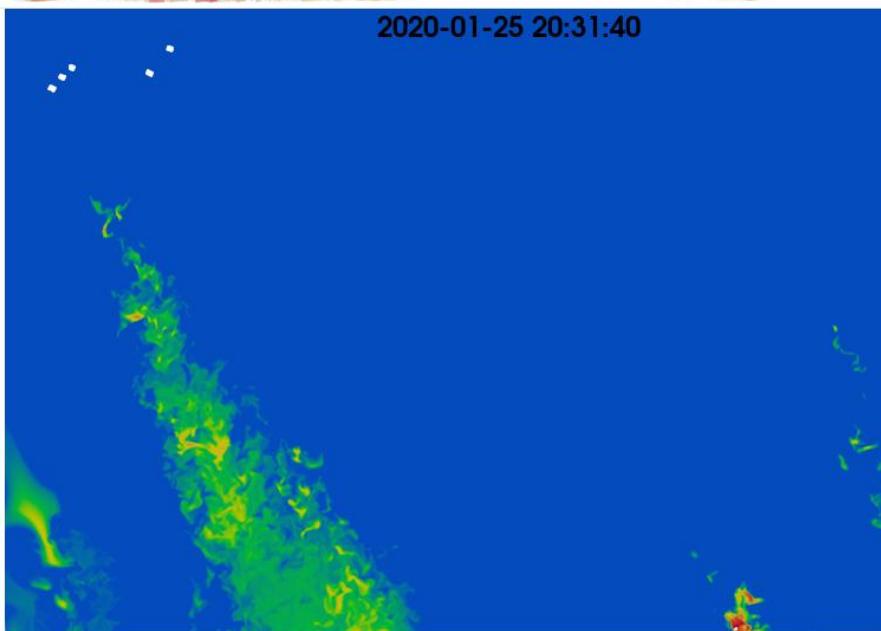
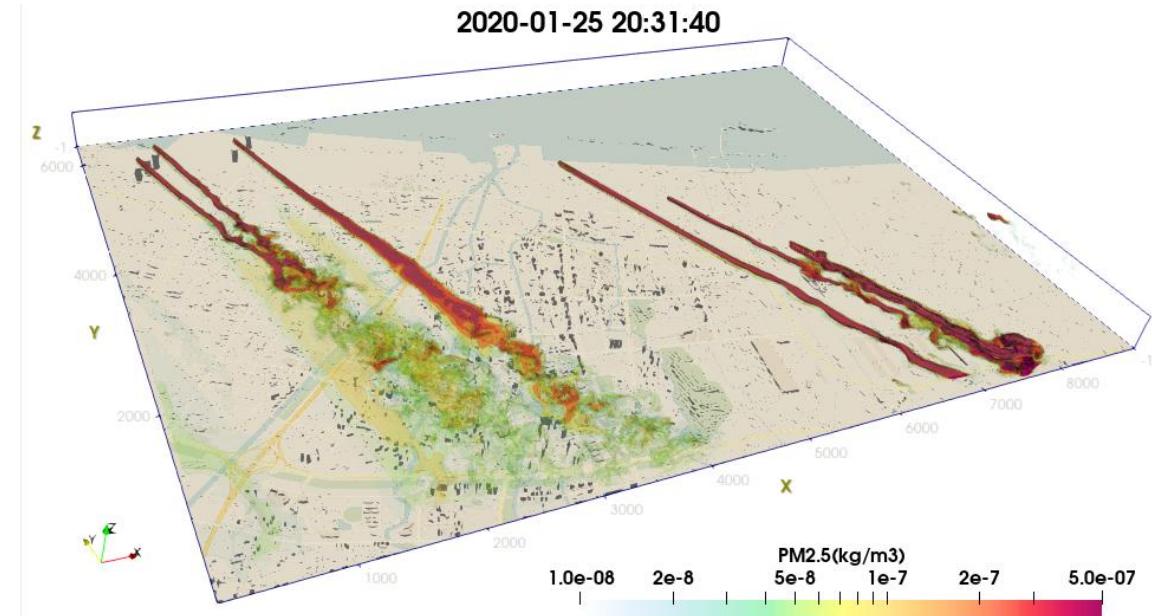
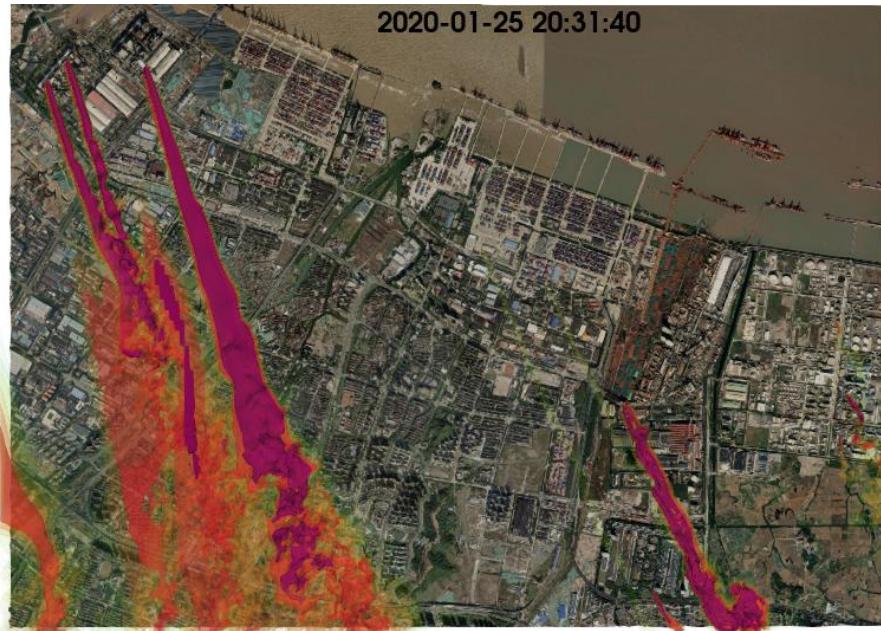
D01 Great Ningbo



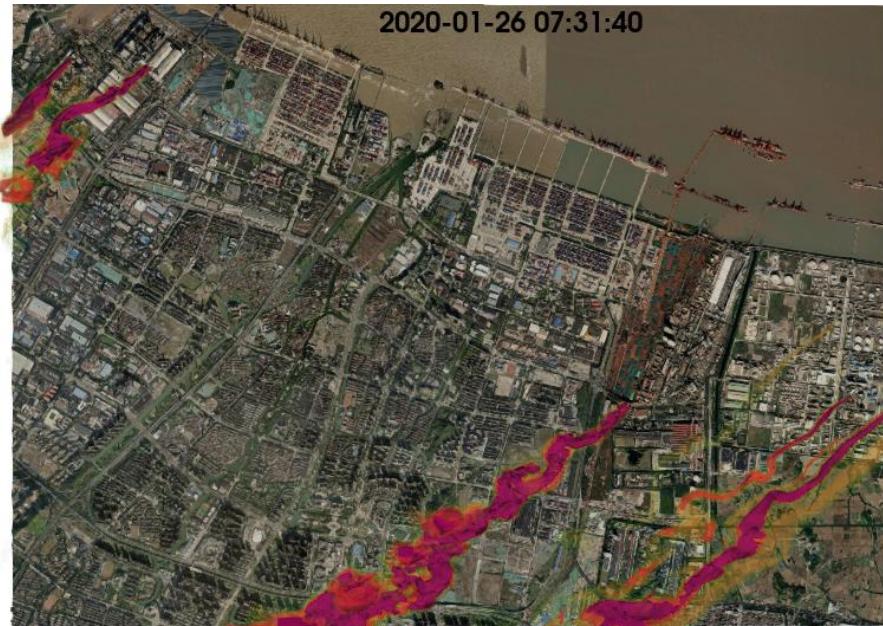
D03 Main Beilun



Northwest Wind Simulations

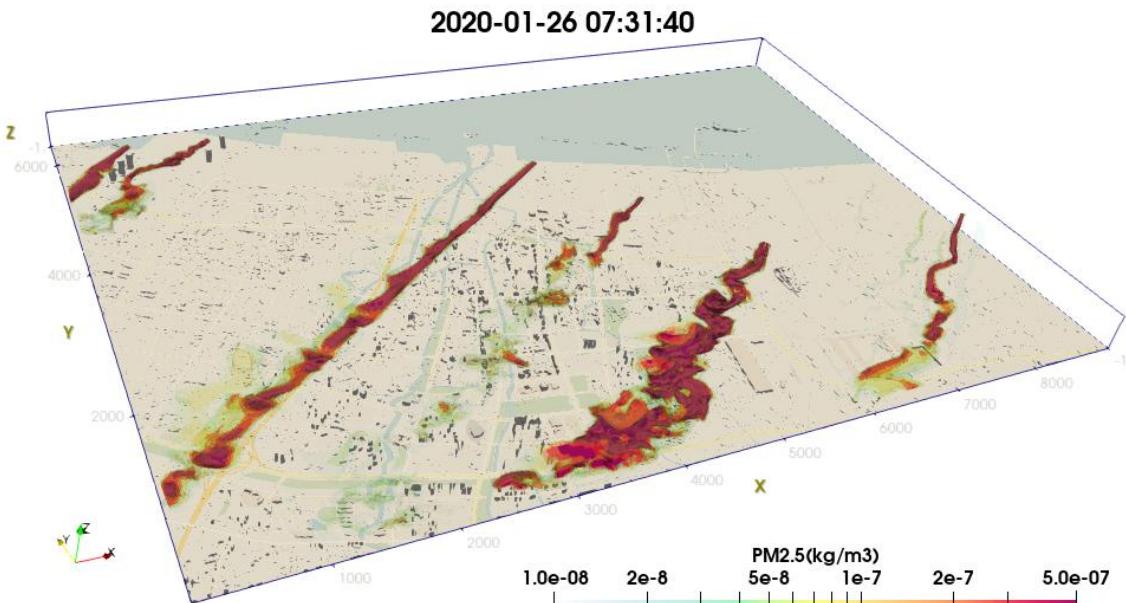


Northeast Wind Simulations



NO(ppm)

5.0e-01
0.2
0.1
0.05
0.02
0.01
0.005
-
-1.0e-03



PM2.5(kg/m³)

1.0e-08 2e-08 5e-08 1e-07 2e-07 5.0e-07



NO₂(ppm)

5.0e-01
0.2
0.1
0.05
0.02
0.01
0.005
0.002
1.0e-03



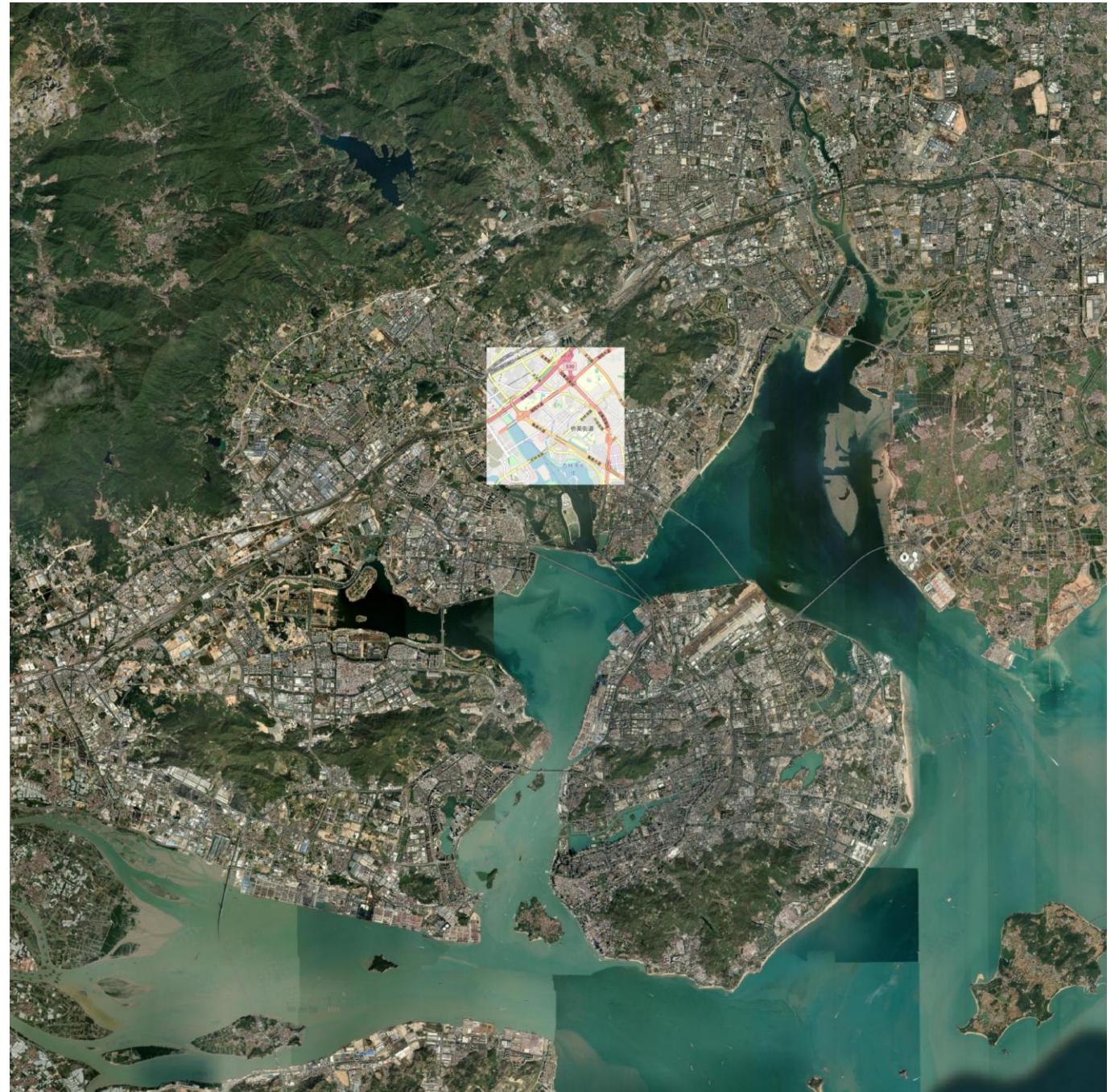
NO₂(ppm)

5.0e-01
0.2
0.1
0.05
0.02
0.01
0.005
0.002
1.0e-03

Z=50m

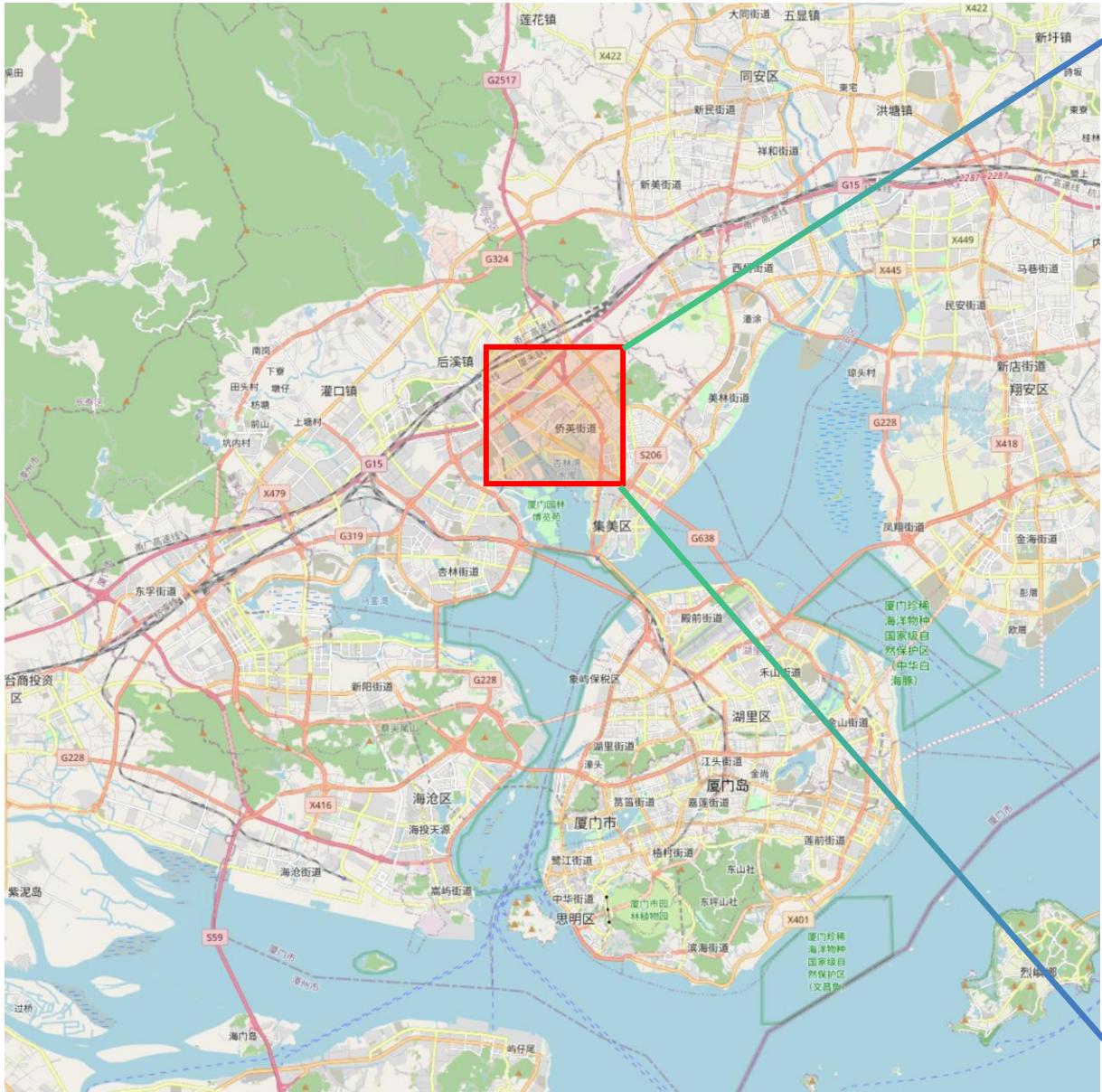
Case Study

- Xiamen Jimei
- Traffic Sources
- 2 Nested Domain
 - Parent domain D01:
 - $40 \text{ km} \times 40 \text{ km}$
 - $\text{dx}=\text{dy}=100\text{m}$, $\text{dz} = 50\text{m}$
 - Child domain D02 :
 - $5 \text{ km} \times 5 \text{ km}$
 - $\text{dx}=\text{dy}= 10\text{m}$, $\text{dz} = 10\text{m}$

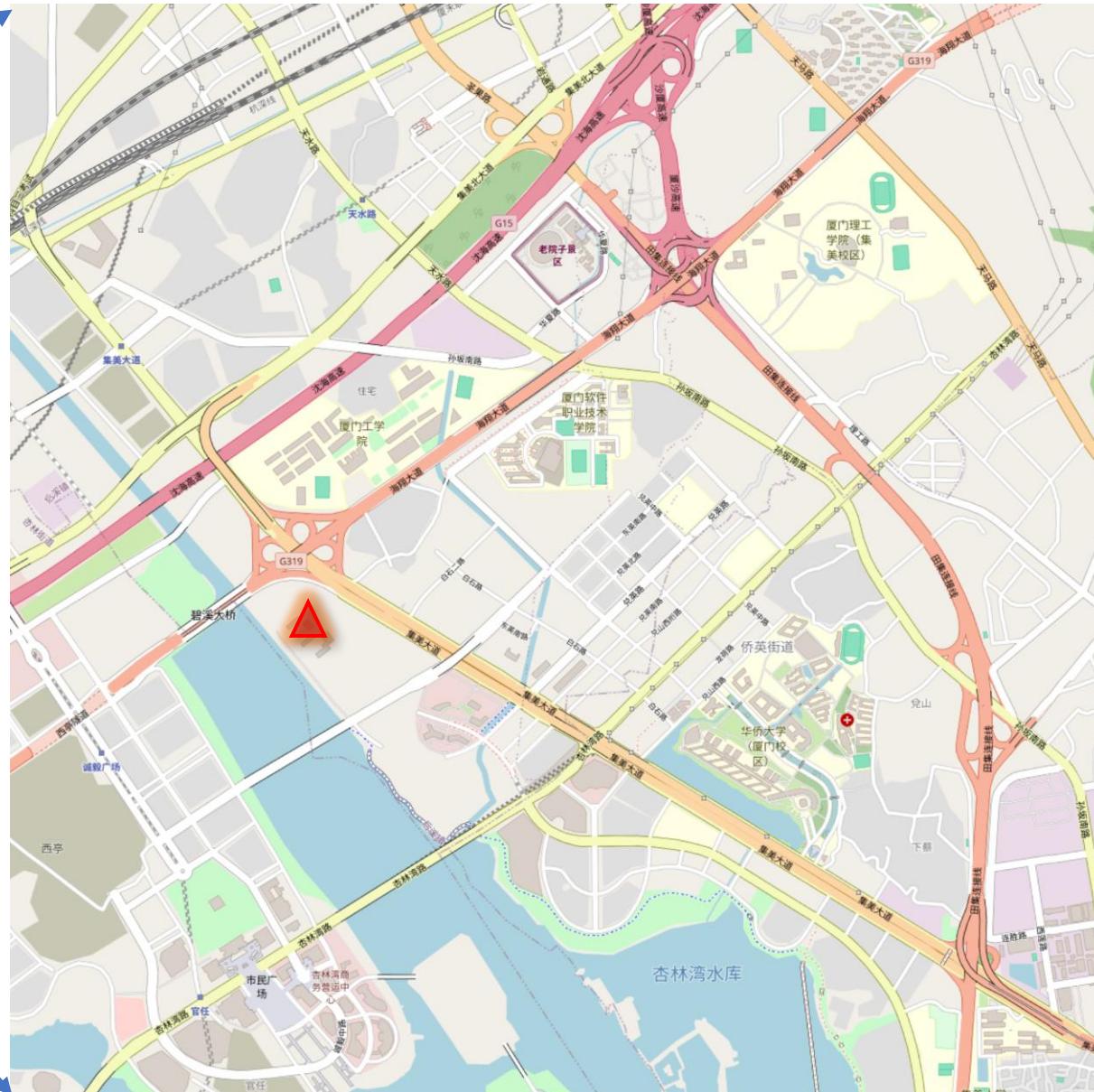


Static driver

D01 Xiamen



D02 Jimei



Case settings

- Spatial discretisation:

	Grid size	# of grid
Parent domain D01	100m x 100m x 50m	400 x 400 x 50
Child domain D02	10m x 10m x 10m	500 x 500 x 50

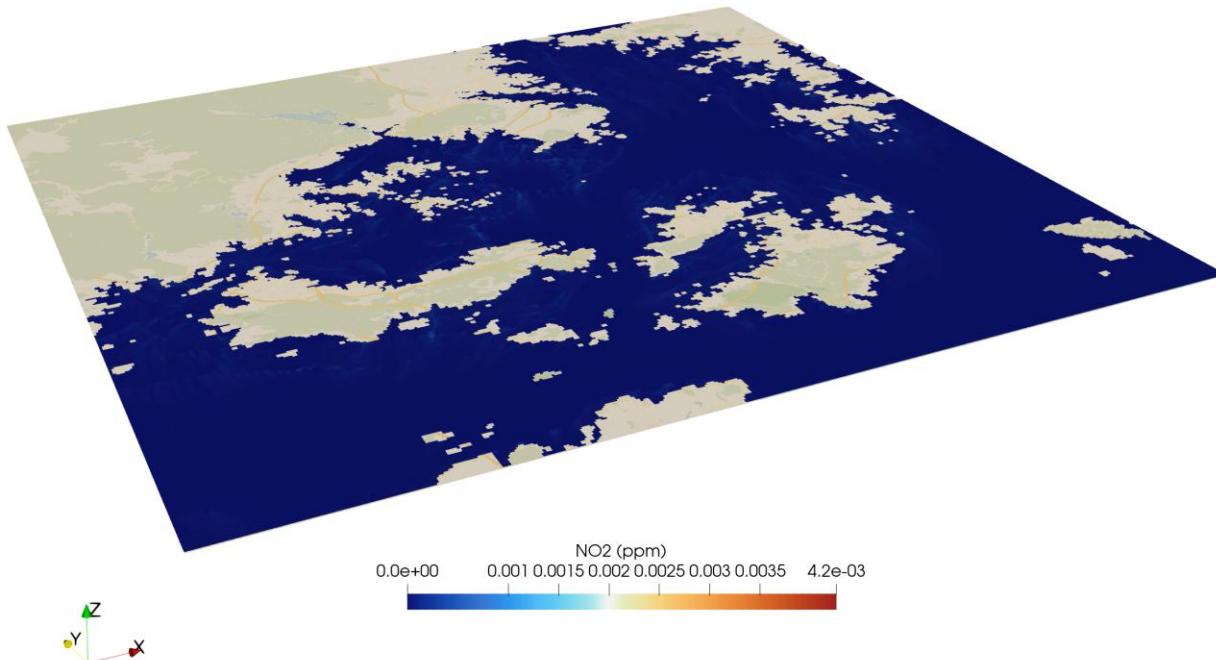
- Run on [ARCHER2](#) (UK Tier 1 HPC)
 - 8 nodes (1024 cores)
 - 5 hr CPU time for 1 day (**2020-01-25**) simulation
- Activated [physics model](#)
 - Urban surface (only in Child domain N02)
 - Radiation
 - Land surface
 - Dynamic driver(**ERA5** reanalysis data @ 0.25 deg)

Results

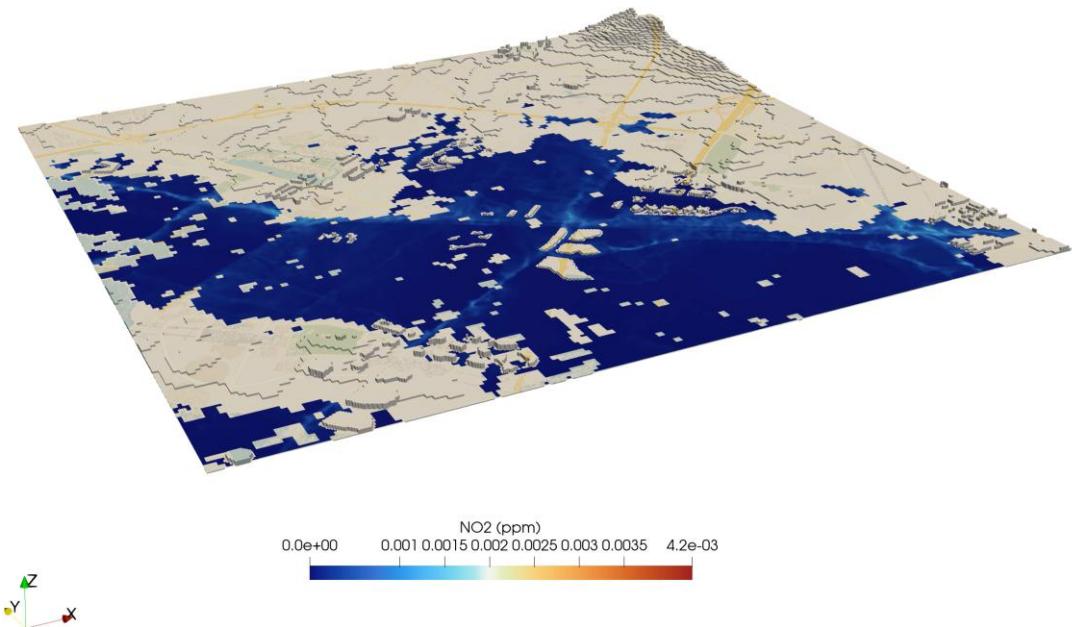
Multiscale physical simulations

Case study: Xiamen nested grid schemes

2020-01-24 08:30:10



2020-01-24 08:30:10



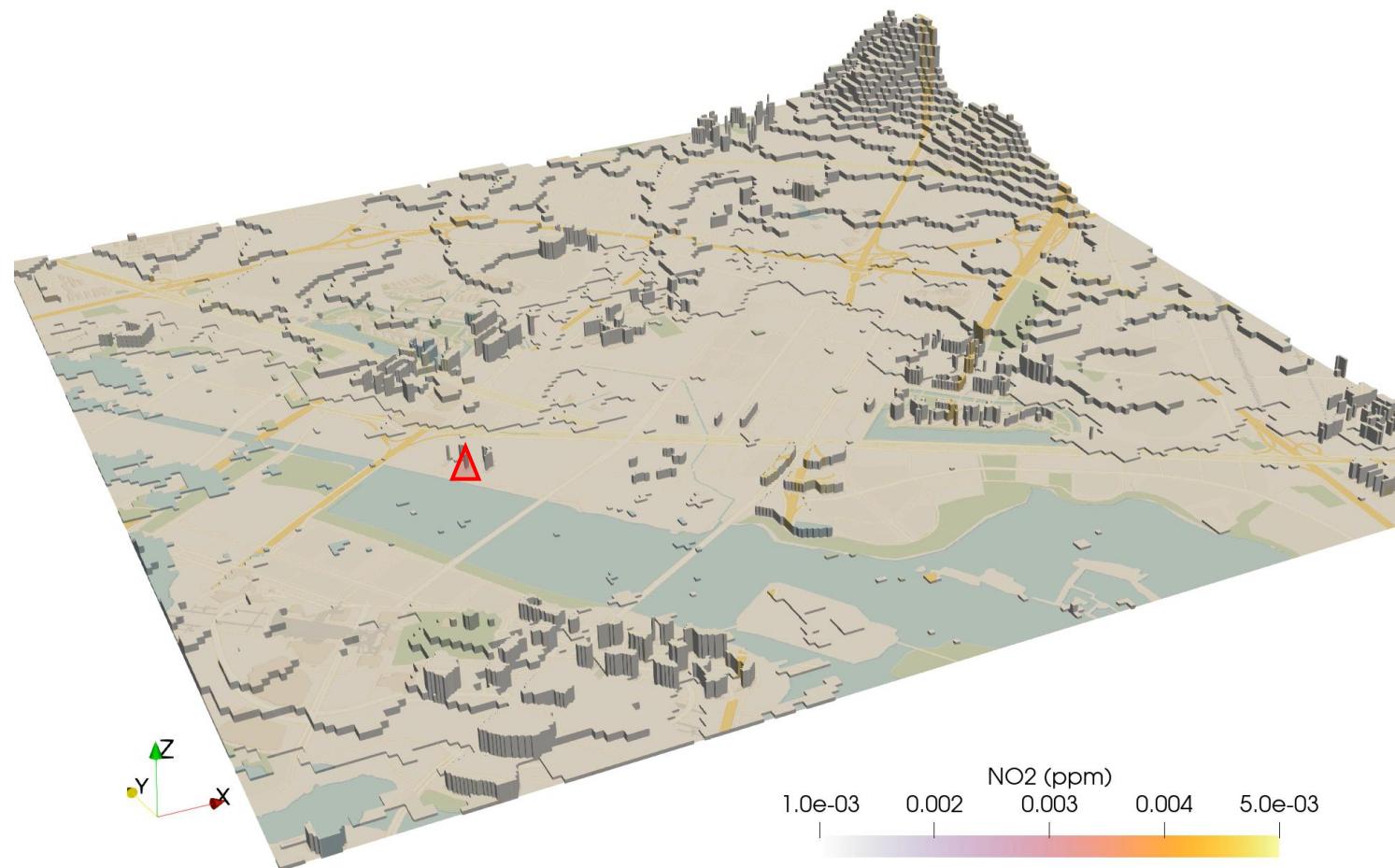
Large area: 40km x 40 km in horizontal and 2500m high
Mesh resolution: 100m x 100m in horizontal and 50m in vertical

Small area: 5km x 5km in horizontal and 500m high
Mesh resolution: 10m x 10m in horizontal and 10m in vertical

Multiscale physical simulations

Case study: Xiamen nested grid schemes

2020-01-24 08:30:10





IMPERIAL



IC, Dec 2025

Thank you !

Jie Zheng

Fangxin Fang, Linfeng Li