Smoke & Ventilation Simulation using the CHPC

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CHPC NATIONAL CONFERENCE 2019

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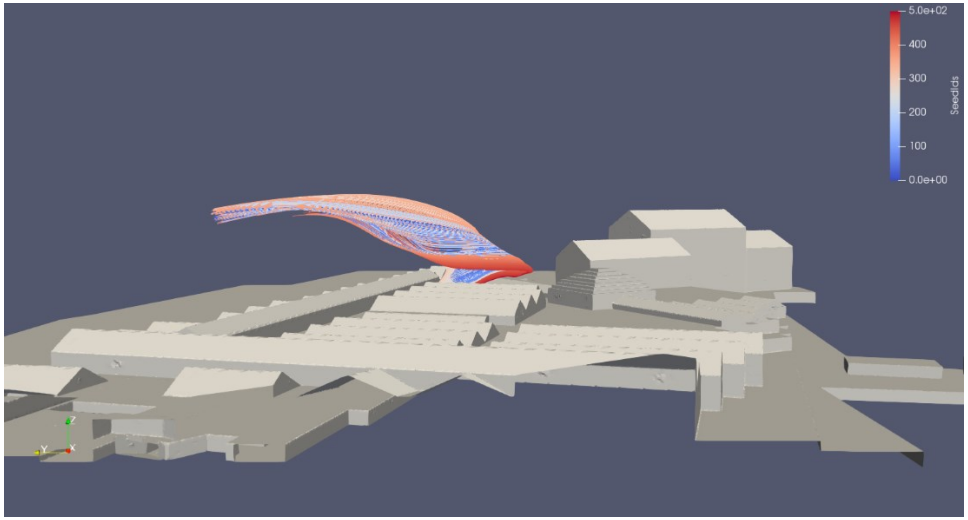
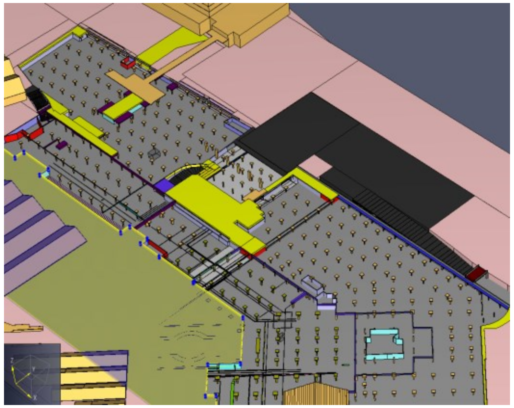


I. Project Background

- Greenplan: building thermal and fluid dynamics

This project:

- Smoke clearance & ventilation study
- Approx. 27 000 m^2 basement / parking area
- Ventilation fans, impulse fans, fire/smoke source
- Computational fluid dynamics (CFD)
- Software used:
  - Fire Dynamics Simulator (FDS) - transient
  - OpenFoam - steady-state (not CHPC)



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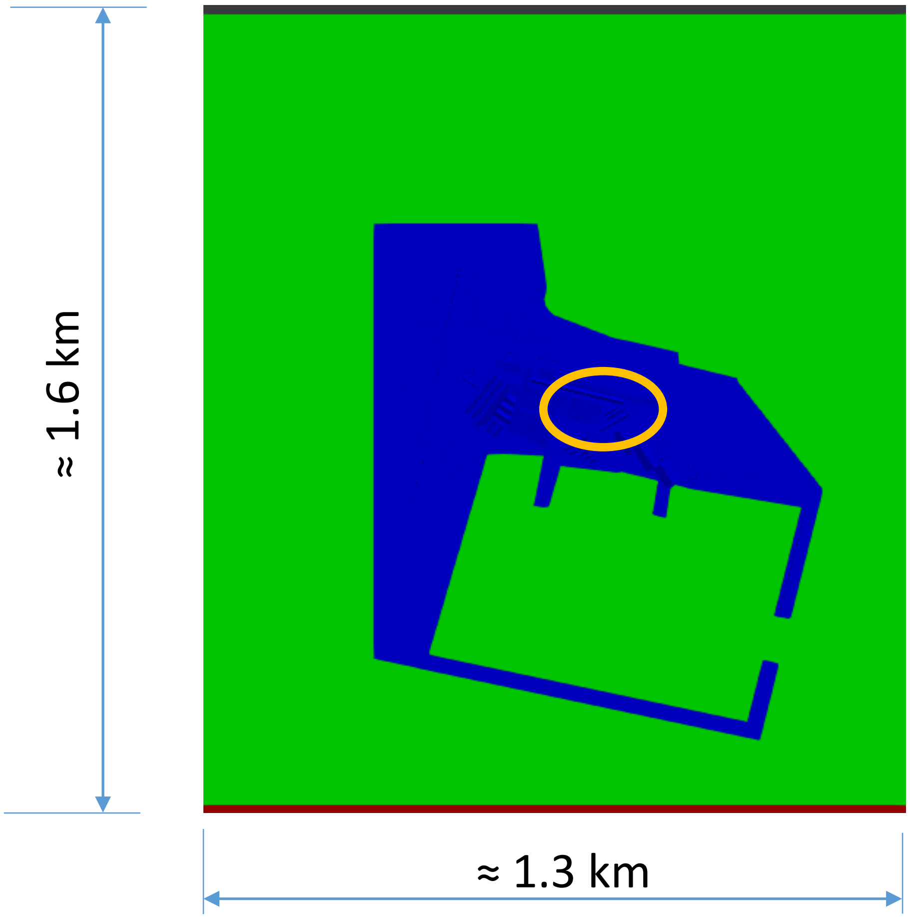
II. Model & Domain size (i)



Height:
≈ 0.1 km

Plan view of entire domain – steady state model

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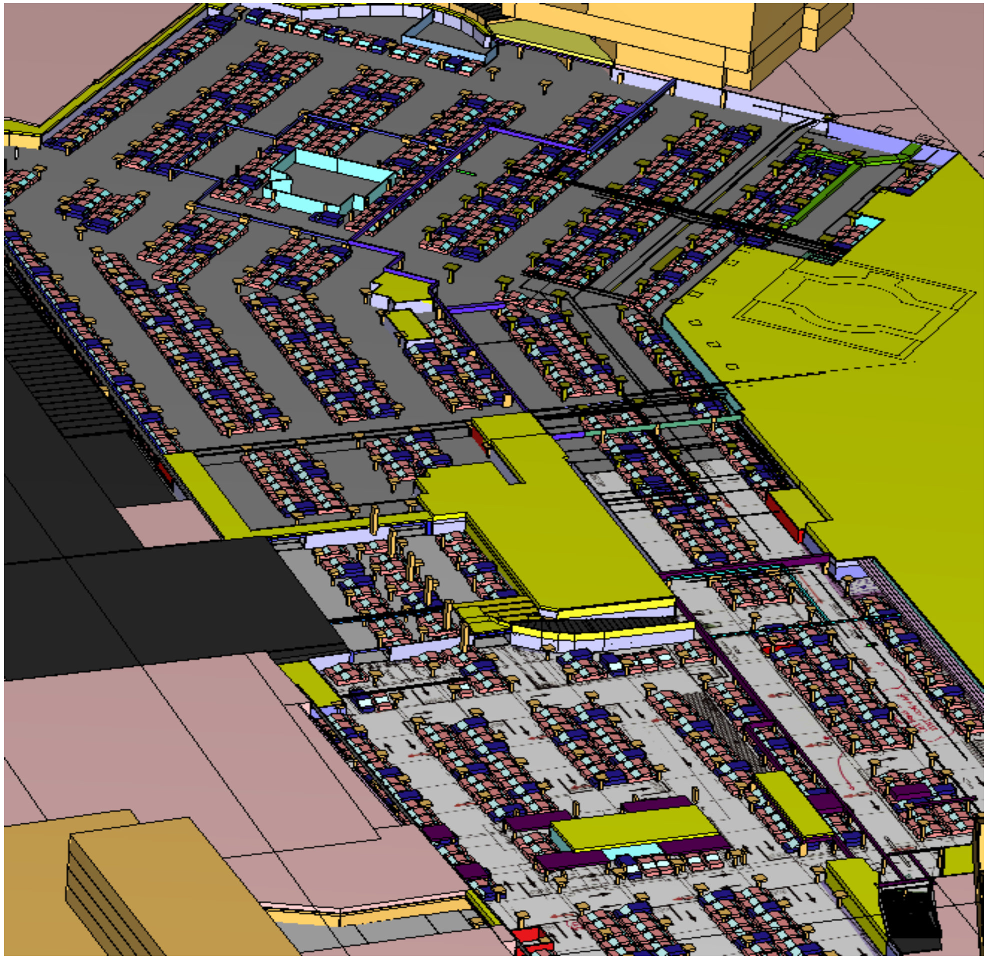
II. Model & Domain size (ii)



View below ground (layers above ghosted) – transient model

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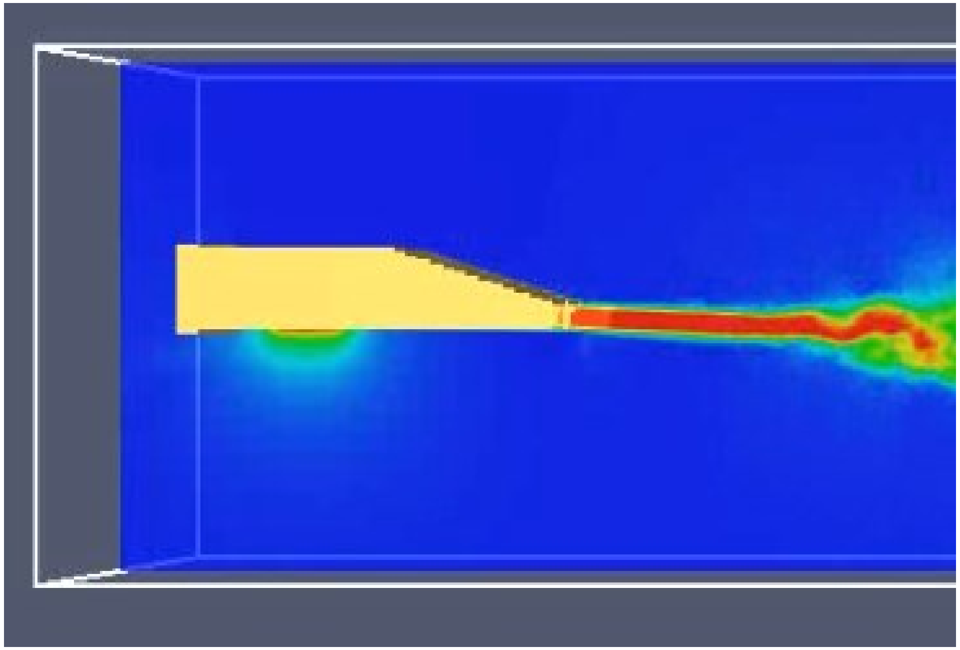
II. Model Components (i)

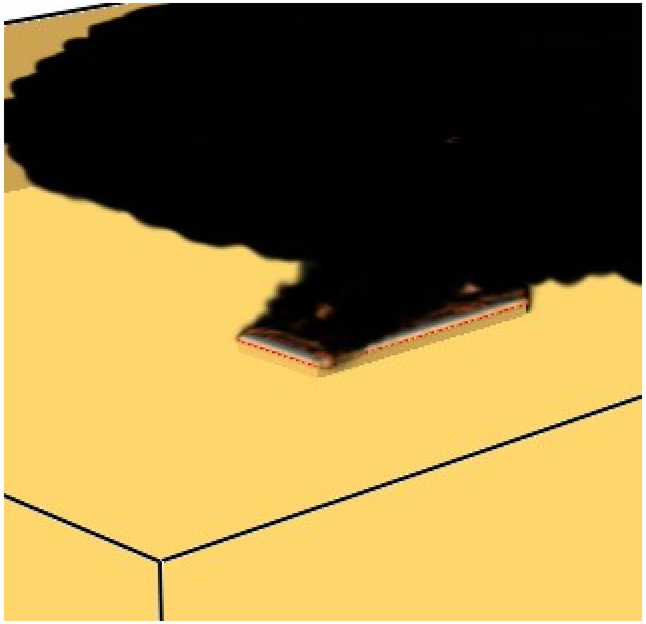


Nozzle speed:
25-30 m/s

Nozzle dimensions:
≈ 90 mm high
≈ 900 mm wide

Jet fan / impulse fan – transient model

II. Model Components (ii)



4 MW_{th} fire with and without smoke/soot visualisation – transient model

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II. Transient Simulation Overview

- RAM requirement: ≈ 100-150 GB
- Nodes used: 10-15
- Cores used: 240-360
- Simulated time goal: 2 minutes
- Multiple wind conditions and fan layouts
- Total cells: max of 70-80 million

II. FDS Particulars (I)

- FDS: LES or DNS transient simulations
- LES & DNS - computationally intensive!
- Customised for fire/smoke simulation
- Very flexible (fans, ducts, control, etc.)
- Can use OpenMP threads
- Can run in parallel (MPI)
- NB: first MPI process does all output/file writing
- Input geometry and boundaries – created with

PyroSim

II. FDS Particulars (II)

- Challenges with FDS:
  - Rectilinear grid mesh – manually specified
  - Rasterised objects to fit grid
  - Multiple meshes required to run in parallel – at least one mesh per MPI process
  - One large grid built up from smaller meshes
  - Manual mesh construction - not necessarily balanced
  - Can’t remove cells embedded in solid walls etc.

Whole grid

Individual mesh

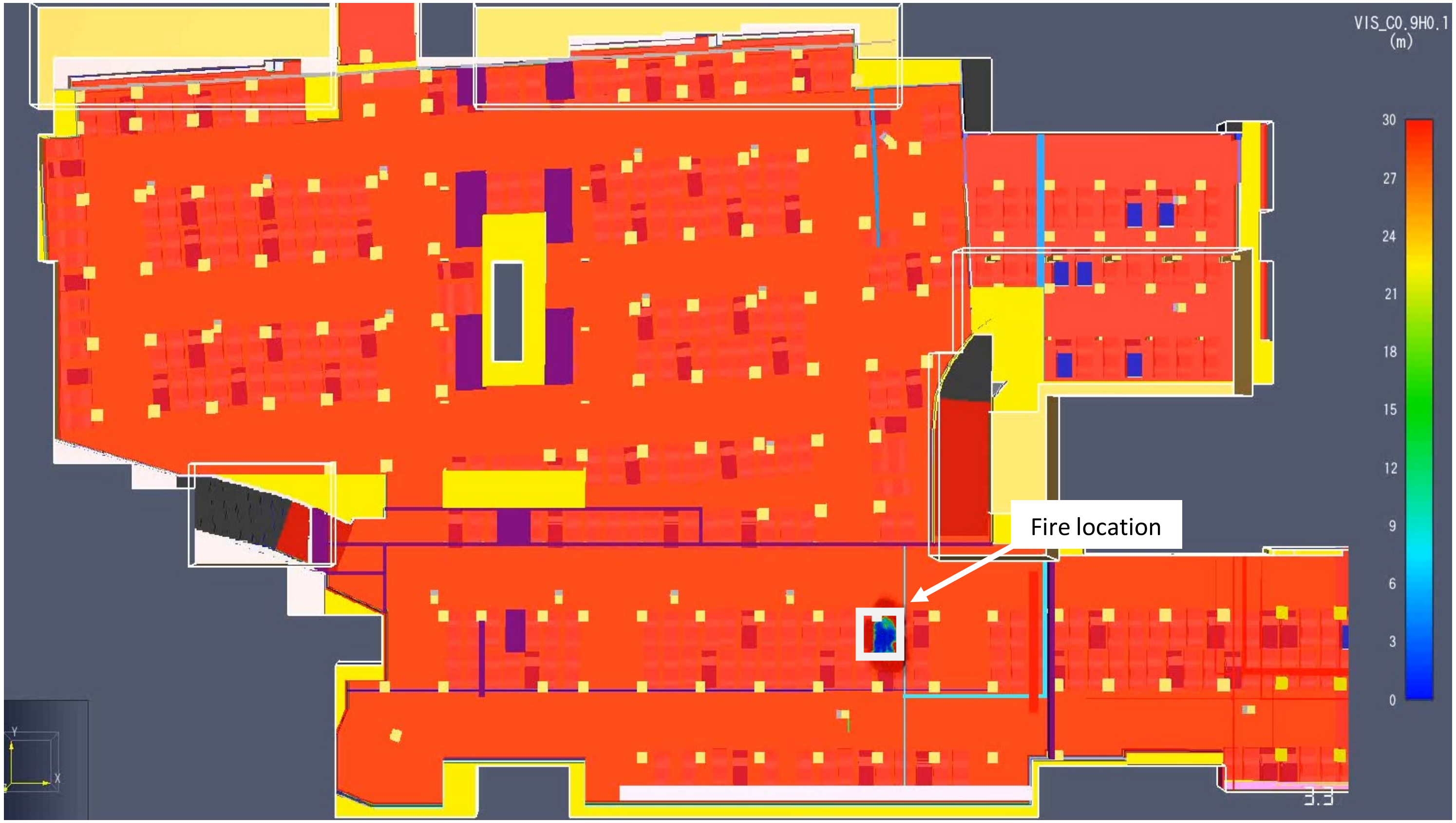
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24

III. Accessing Results

- Data quantity per full simulation (100-200 GB)
- Initially from an LTE office network
  - Too costly to download
  - Too slow
- Collected most data via hard drive
  - Worked well – except for some incompatibility with Linux & Windows not recognising the drive
- Later had access to uncapped fibre – ideal!
- Some issues with download speed from CHPC
  - May 2019: ≈ 10 kB/s (exceptional circumstances)
  - Generally achieved 100-500 kB/s per file

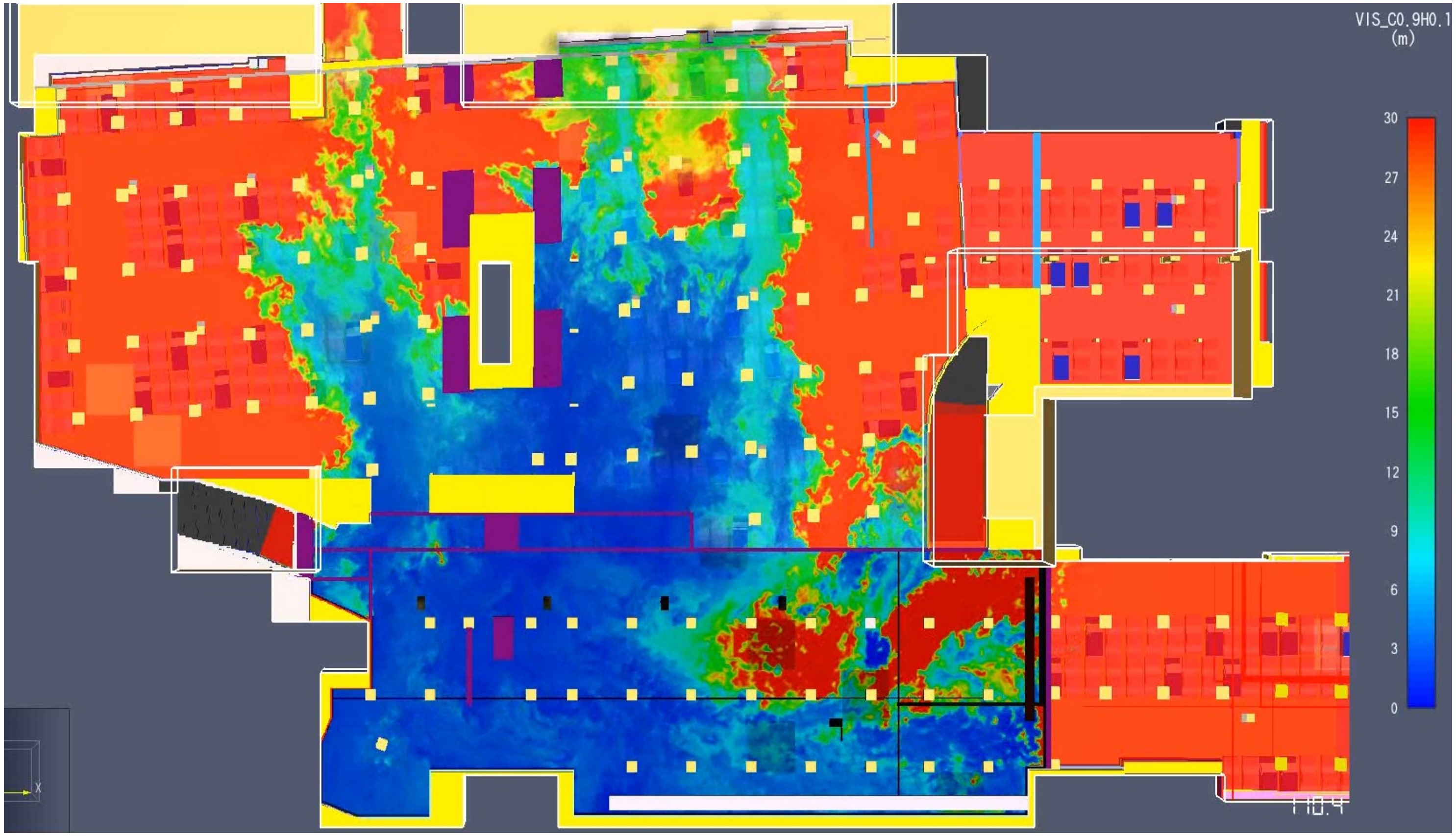
III. Results – Sample (i)

- Visibility just after fire ignition:



III. Results – Sample (ii)

- Visibility after 110 s:



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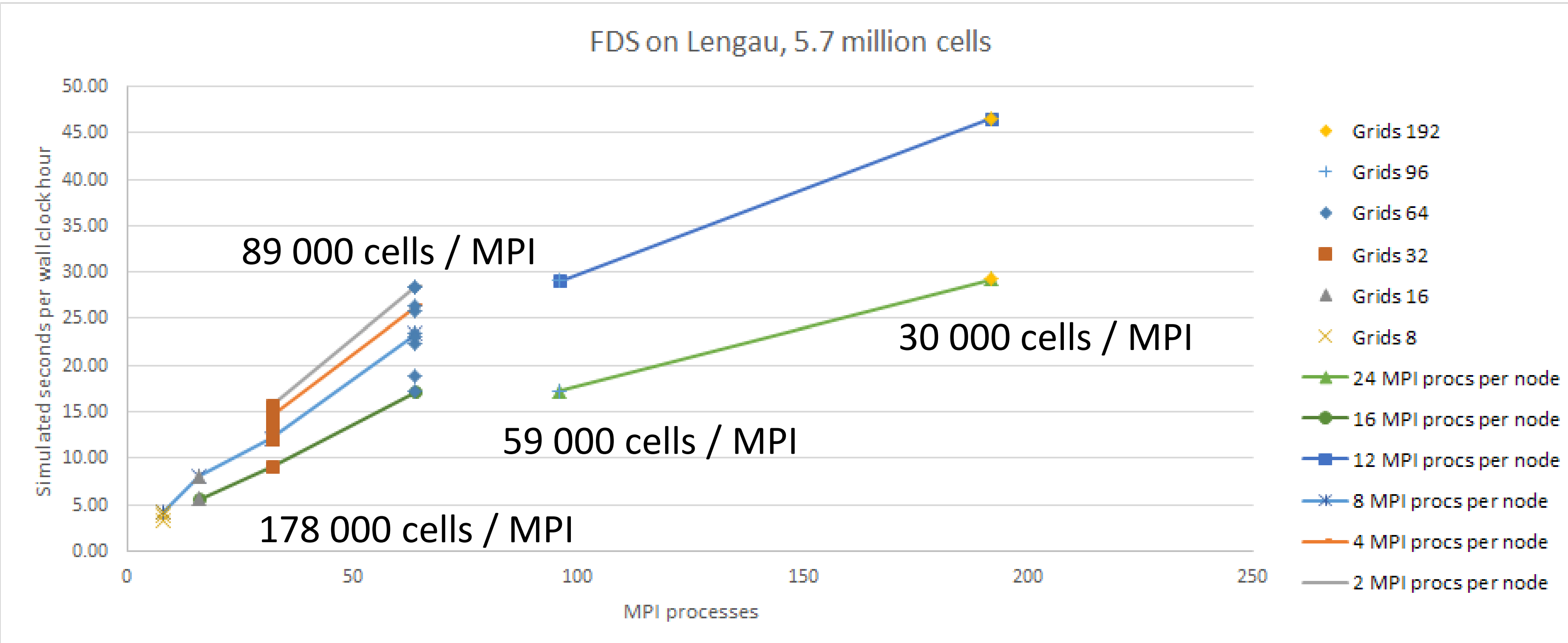
IV. Scaling & Speed (i)

- Initial CHPC tests by C. Crosby with 5.7 million cells



- Ideal cell distribution per mesh; no jet fan

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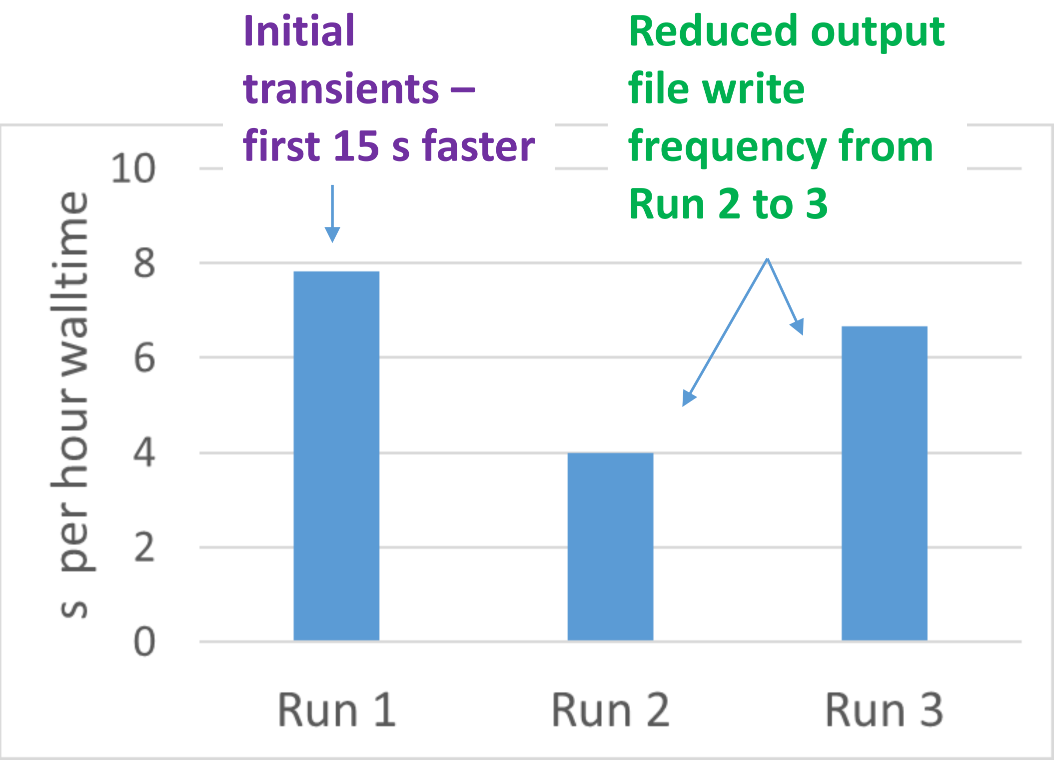
IV. Scaling & Speed (ii)

- Western half of basement – model A:
  - ➢ 15 nodes / 360 cores (approx. 10^5 cells/MPI)
  - ➢ Varying simulation speed – same model:

Run 1: 0-40 s
Run 2: 40-80 s
Run 3: 80-120 s
Avg: 5.7 s/hr

Model with wind:
Avg 3.8 s/hr



… But there is possibly more to it than just these factors

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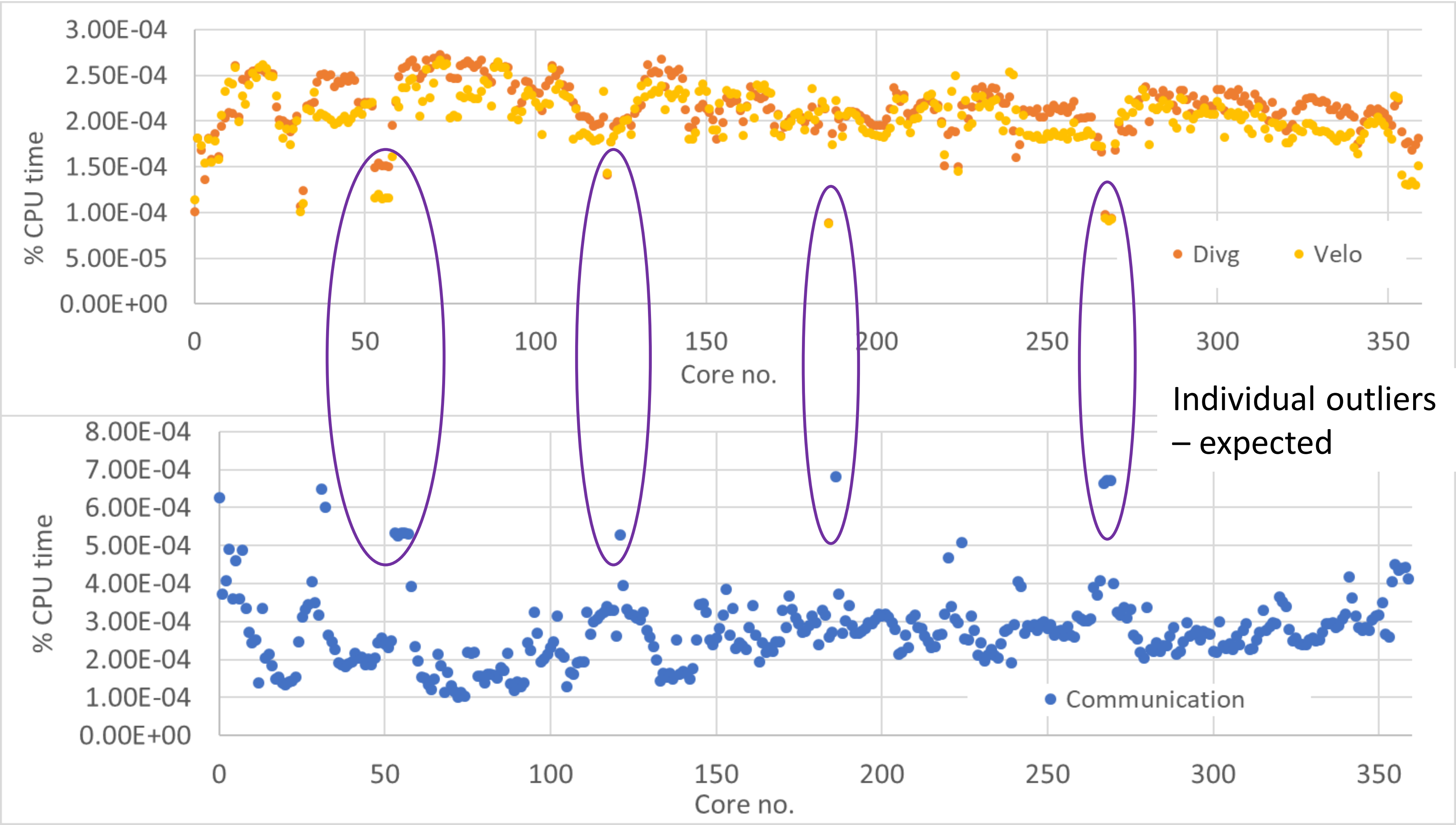
IV. Scaling & Speed (iii)

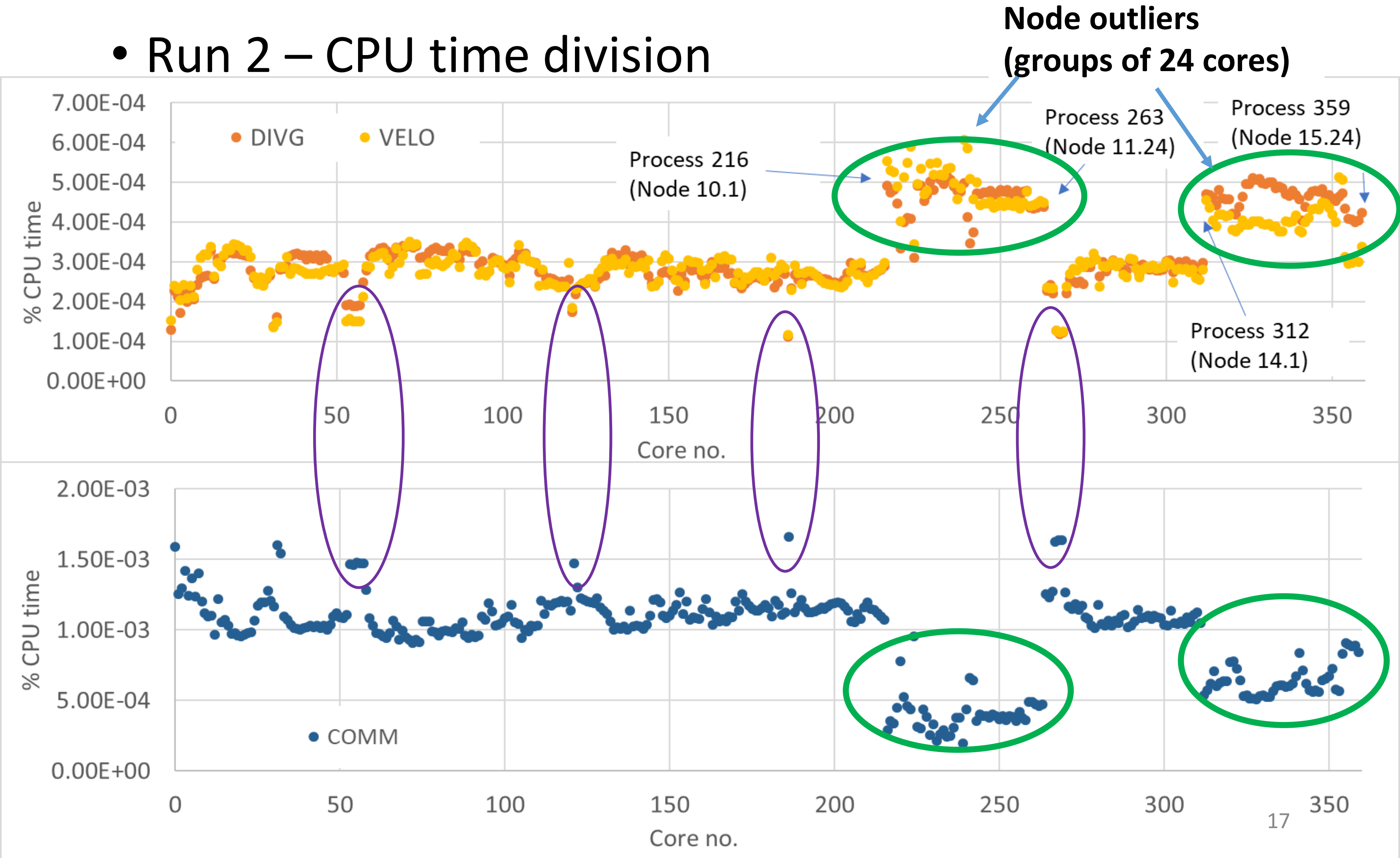
- Run 1 – CPU time division



Individual outliers – expected

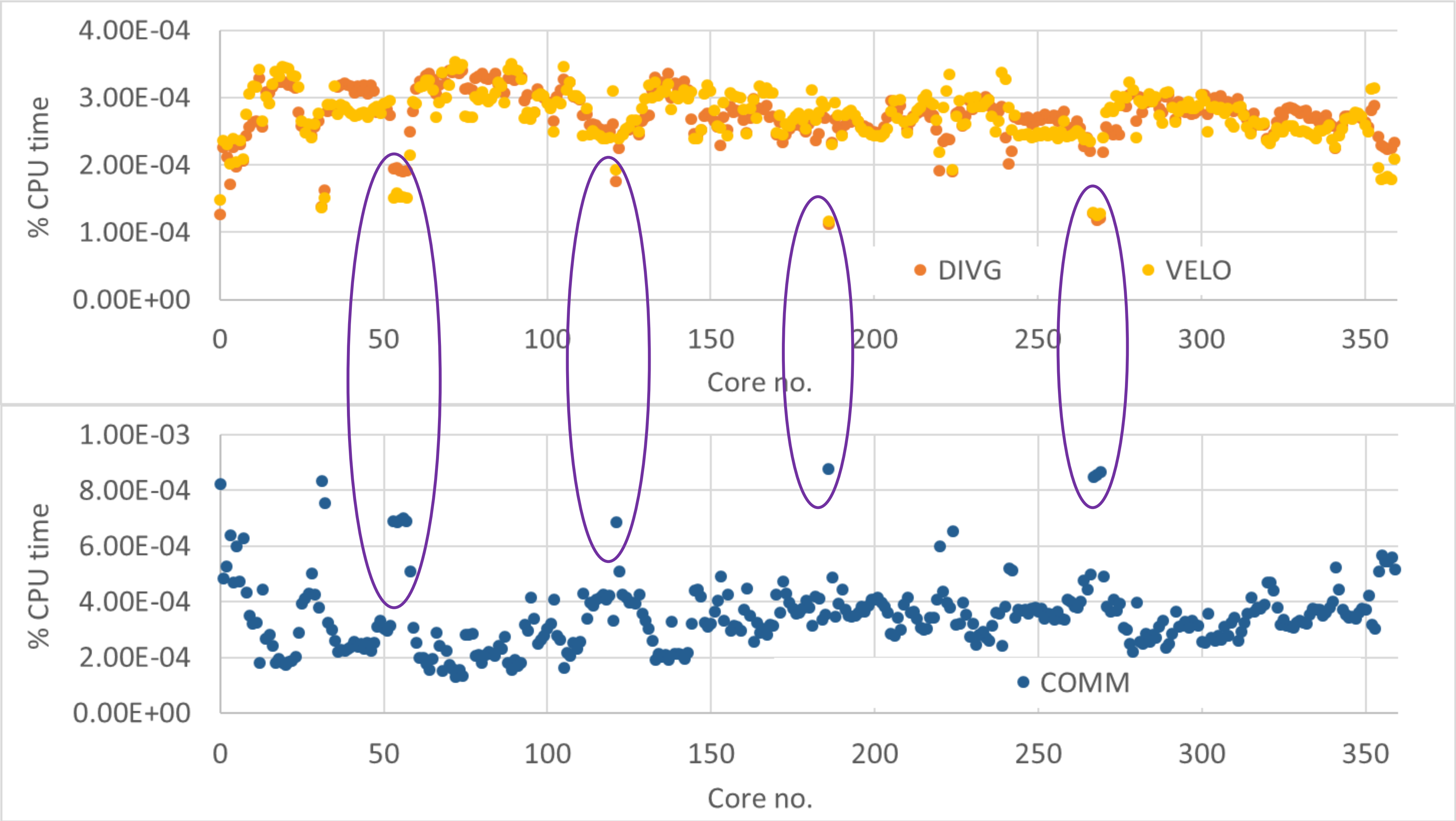
IV. Scaling & Speed (iv)

- Run 2 – CPU time division



IV. Scaling & Speed (v)

- Run 3 – CPU time division

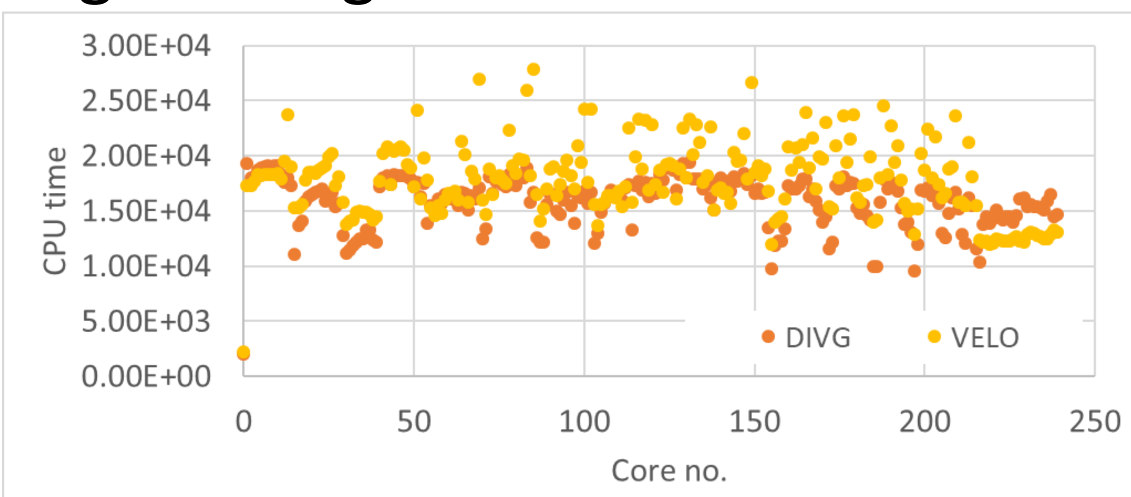


IV. Scaling & Speed (vi)

- Later simulations – similar tendency with nodes
- What is the cause? – Don't know
- One possibility – ghost processes (confirmed once)
- Second possibility – CHPC architecture?
  - ➢ 8 nodes grouped together
  - ➢ Interconnection between groups of 8 nodes
  - ➢ Bottleneck due to blocking ratio (1 to 3)
  - ➢ i.e. when you run outside a group of 8 nodes?
  - ➢ PBS assigns nodes automatically (not user) so no control

IV. Scaling & Speed (vii)

- Last model – experimented:
  - Fewer nodes - limited to 10
  - Higher total cell count ($\approx 7 \times 10^7$)
  - Higher cell per mesh/core ($\approx 3 \times 10^5$)
  - 3 consecutive runs (avg 2.3 s/hour walltime)
- No node outliers – only individual cores
- Not enough testing to draw a conclusion



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IV. Scaling & Speed (viii)

- OpenMP versus MPI: which is more effective?

Our experience –

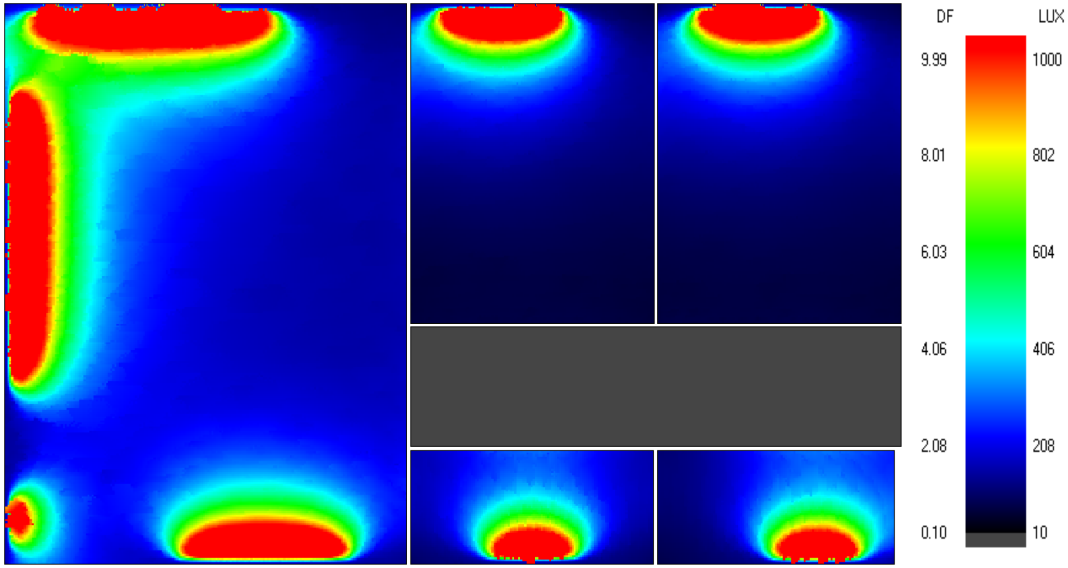
- OpenMP set to 2 and 12 MPI per node:
  - Little better than 24 MPI <u>with half the no. of nodes </u>(!)
- OpenMP set to 1 and 12 MPI per node:
  - Also poor performance (relatively)
- OpenMP set to 1 and 24 MPI per node:
  - Generally best performance
- Trends not thoroughly tested but recommend MPI only with full use of node

V. Conclusion

- CHPC essential for this type of work
- No compatibility issues with FDS
- System in general worked very well
- Scope for exploring the outlier node effect
- Computational cost - good value for money
- Highly competent support

Please feel free to contact us with any queries:

www.greenplan.co.za



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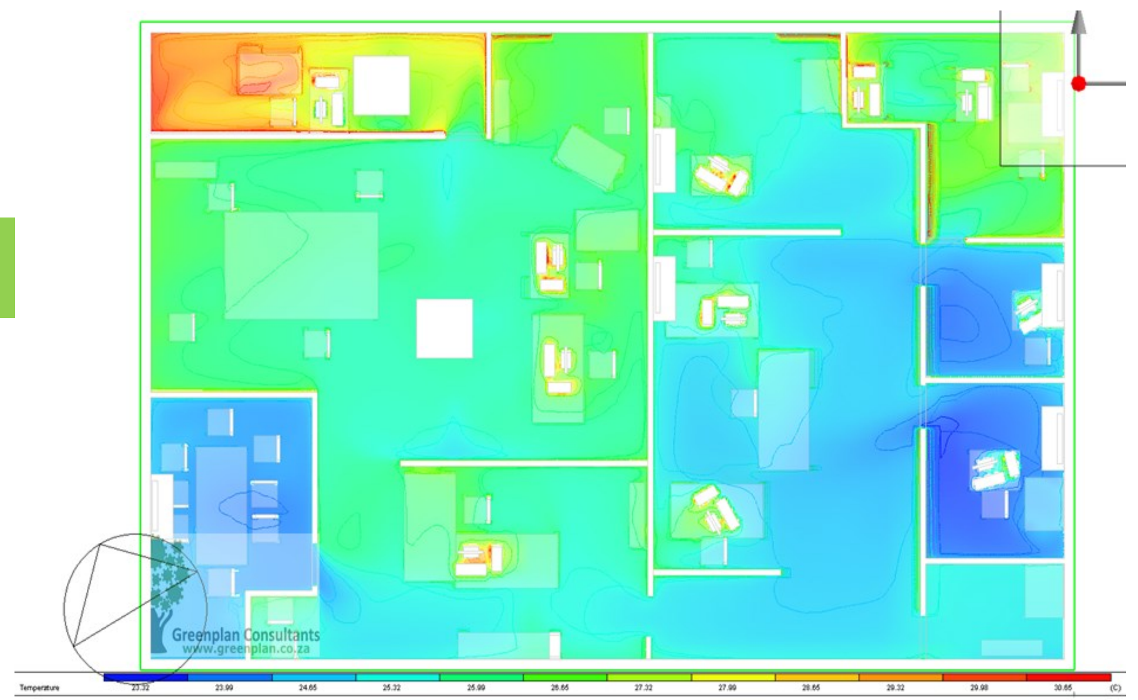

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