A look back at 25 years of atmospheric CFD and field campaigns: from Thorney-Island to Jack Rabbit II

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Sciences de l'environnement

Flixborough, 1974

estimated : ~ 30t cyclohexane

before

after

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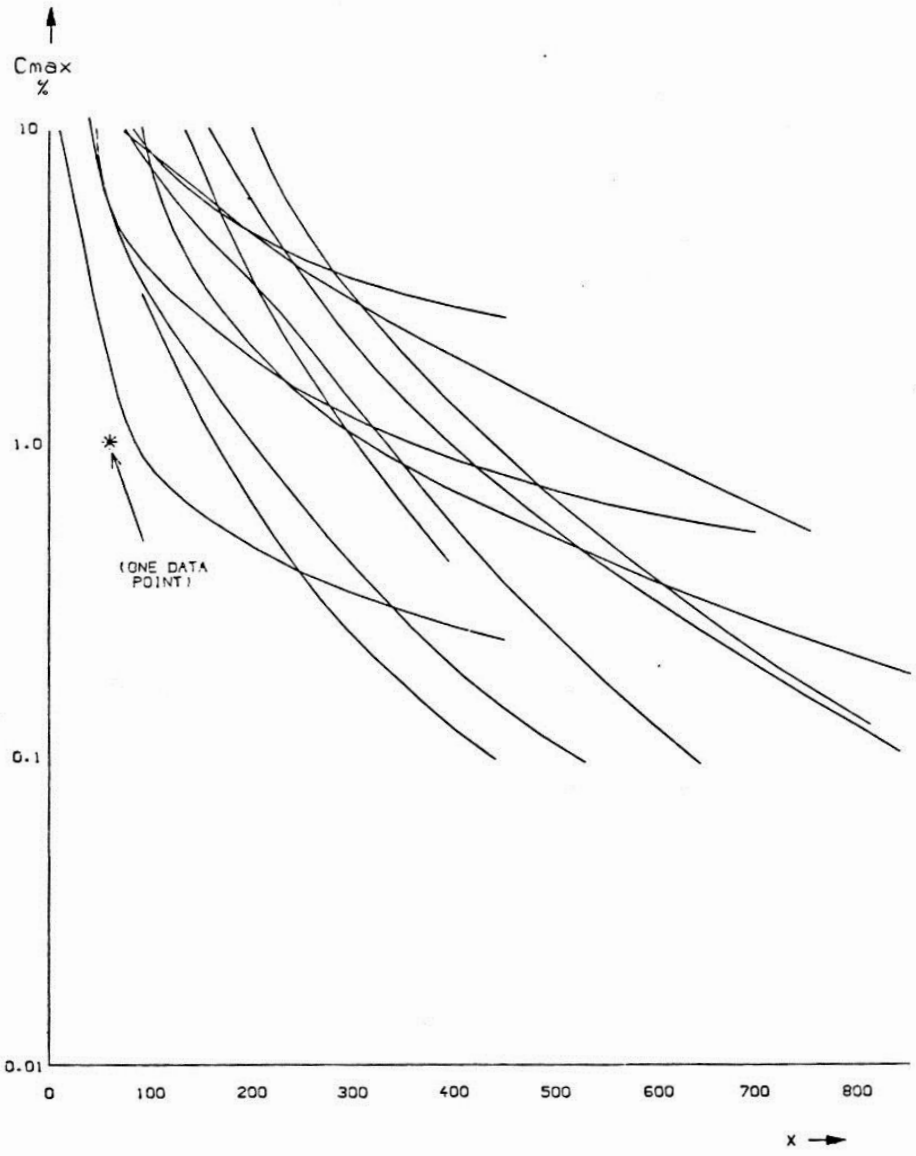
Consequences …

- Flixborough (1974) and Seveso (1976)… (+Bhopal 1984) prompted :
  - EEC directives (e.g.“Seveso I & II”)
  - + sponsored research :
    - model developement, validation, improvement, intercomparison and QA
    - field trials and other laboratory studies
    - ➔**Thorney Island Field Trials**

Intercomparison of box models with data (before Thorney Island ;-)



McQuaid & Roebuck, 1985

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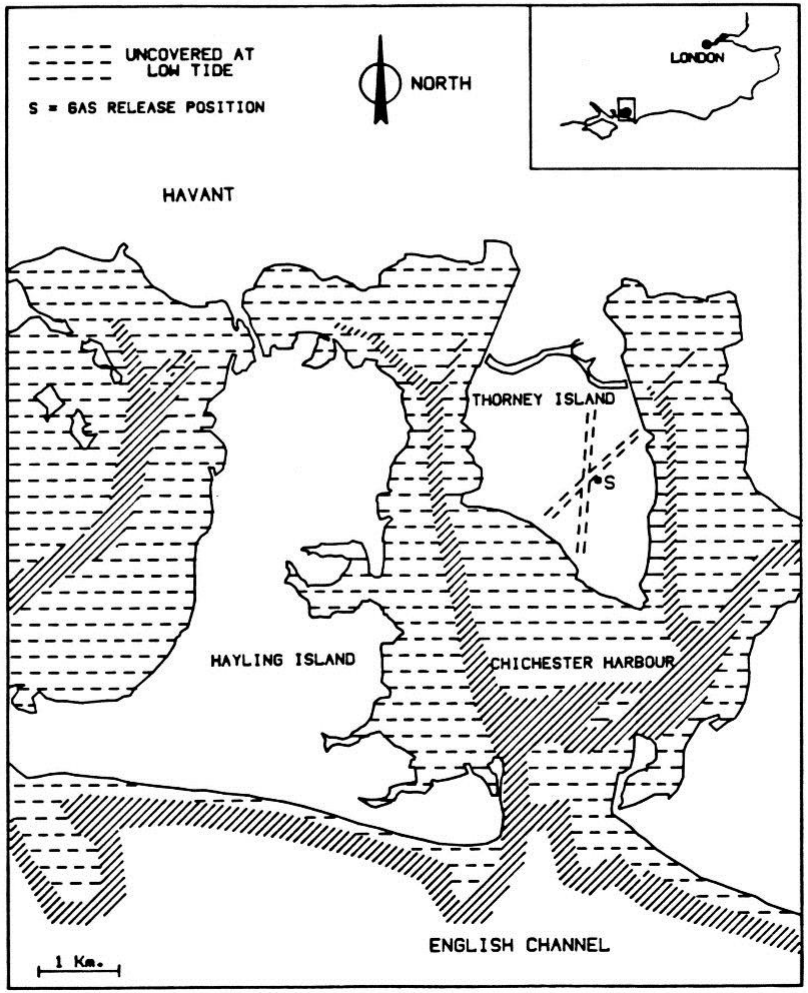
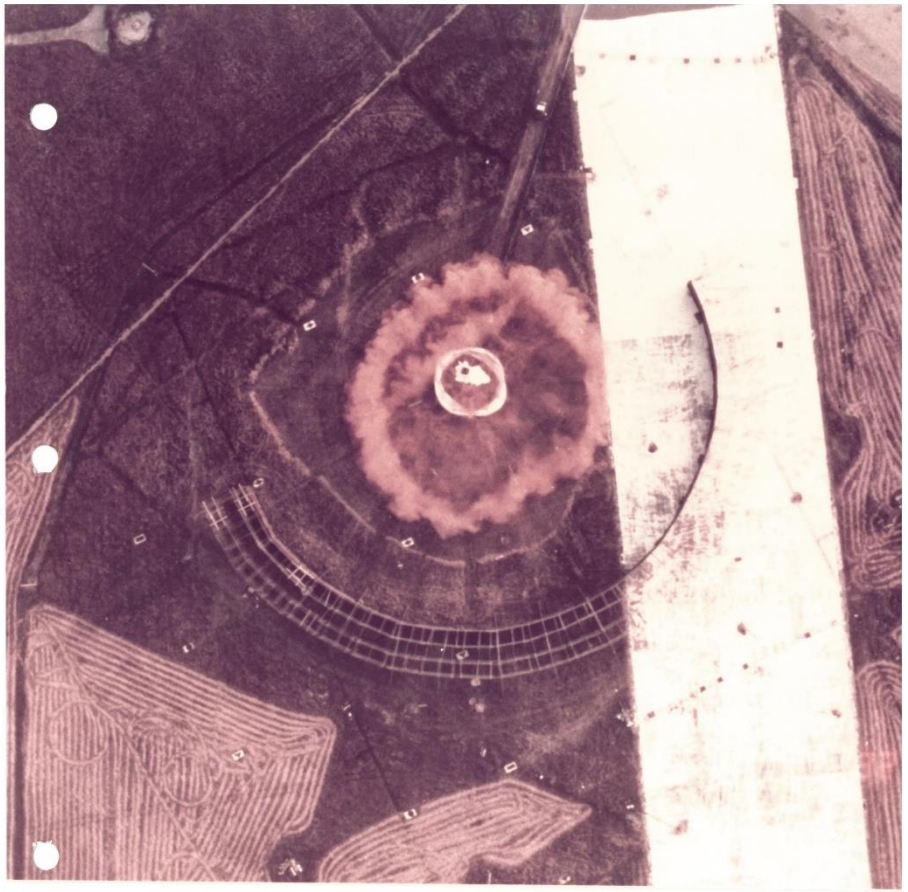
Thorney Island



- 2000 m3 of Freon mixture +colorant
- Varying heavy gas densities
- Different atmospheric stabilities
- Phase I : without obstacles
- Phase II : with semi-circular wall
- ….

McQuaid & Roebuck, 1985

Fig. 8.5 The fully erected gas container



Helicopter view of gas cloud about 6s after release in Trial 021 on 15th July 1983. The collapsed gas container is within the cloud and the cloud front is approaching a semi-circular wall of 50m radius. The white rectangle is the airfield runway.

McQuaid & Roebuck, 1985

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Thorney Island release : side view

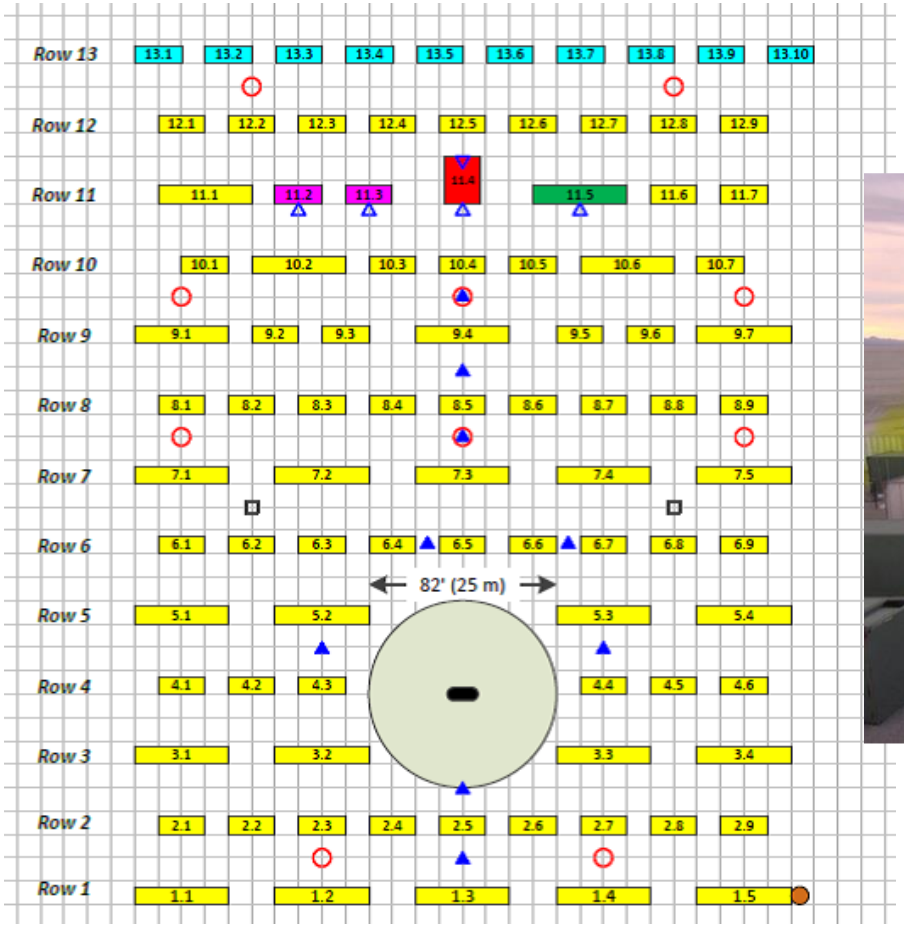
Jack Rabbit I Cl_2 Field Study
Dugway Proving Ground, Utah, 2010

- Bulldozed basin is 50 m in diameter and 2 m deep
- Release valve is 2 m above ground, and two-phase jet is directed downwards
- 1 or 2 tons of pressurized liquefied gas in tank, which empties in 30-60 s
- Cloud hold-up in basin for 30+ minutes for u < 3 m/s

Releases Jack Rabbit 2 : 2015 - 2016

Source : Hanna 2014

Jack Rabbit II



Layout 1

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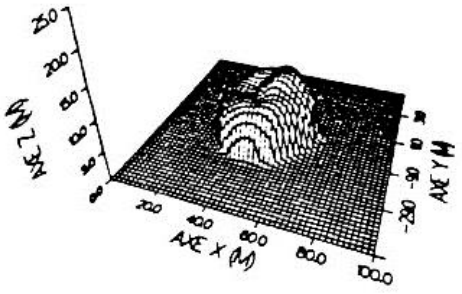
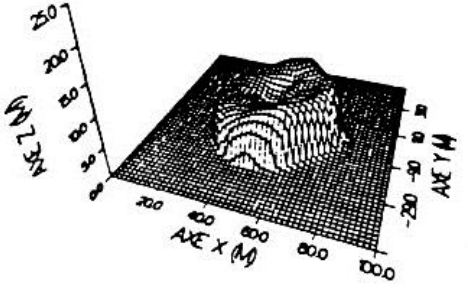
Simulation Results

Thorney Island simulations with MERCURE GAZ LOURD (Riou, 1988)

Temps écoulé depuis le début du rejet : 6.s

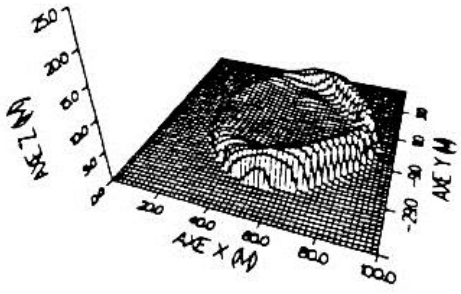


Temps écoulé depuis le début du rejet : 9.s



Temps écoulé depuis le début du rejet : 12.s

Temps écoulé depuis le début du rejet : 14.s
Isoconcentration 5 %



Temps écoulé depuis le début du rejet : 14.s
Isoconcentration 10 %

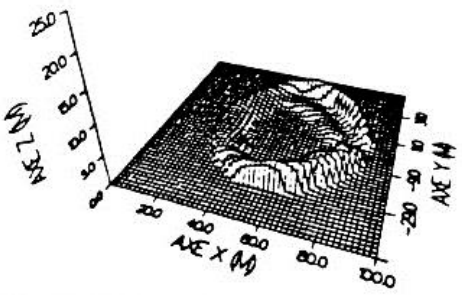


Figure 35. — Vues tridimensionnelles de différentes isoconcentration du nuage essai de Thorney Island n° 08 — Modèle MERCURE-GAZ LOURDS.

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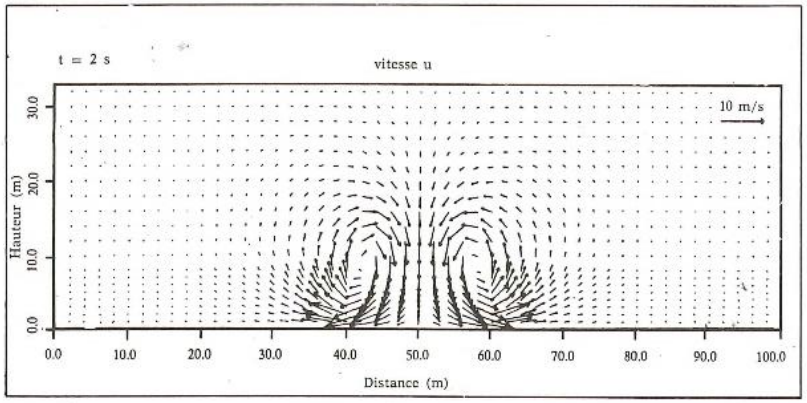
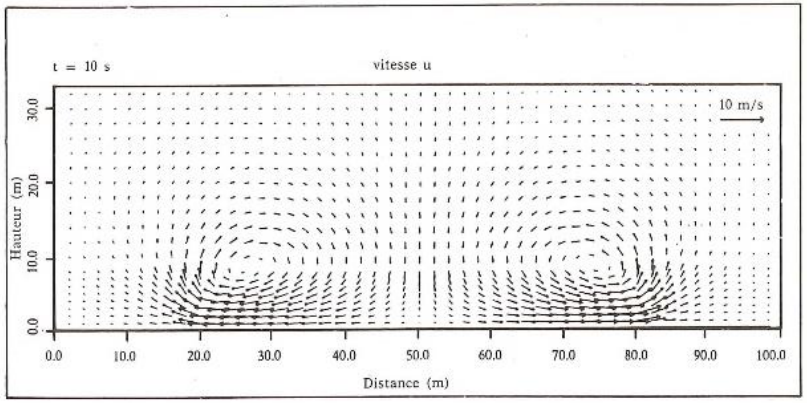
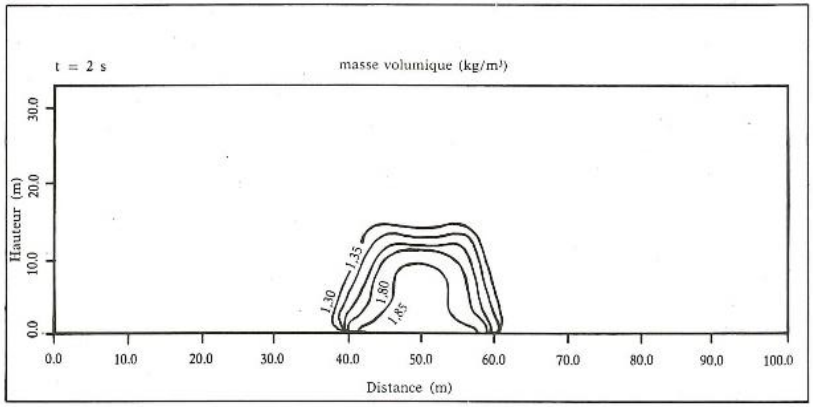
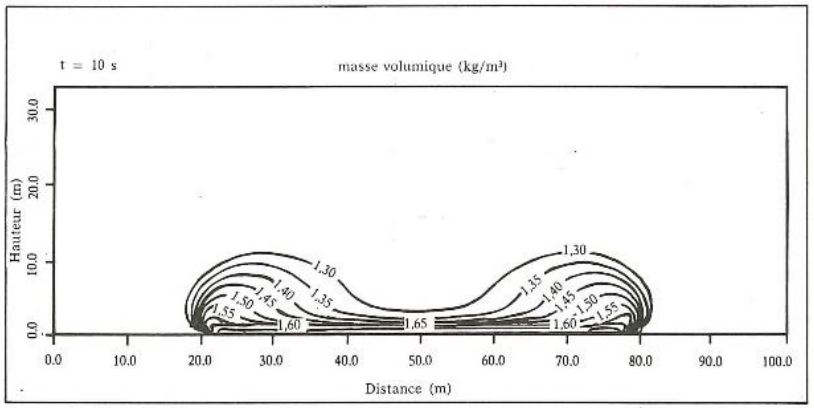
Thorney Island simulations with MERCURE GAZ LOURD (Riou, 1988)





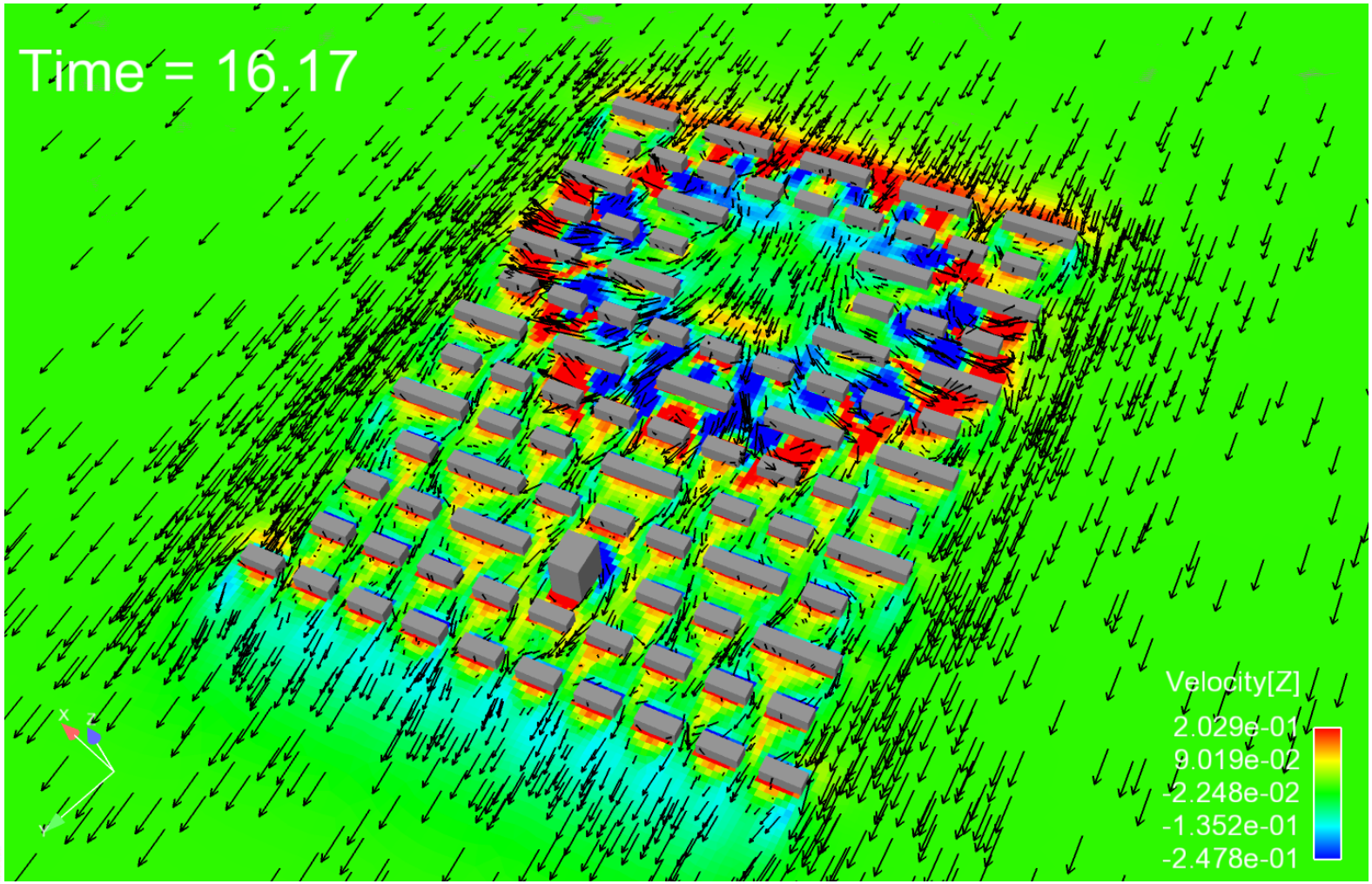




Jack Rabbit 2 preliminary simulation with *Code_Saturne*

(www.code-saturne.org)

velocity field (arrows), vertical velocity (color)



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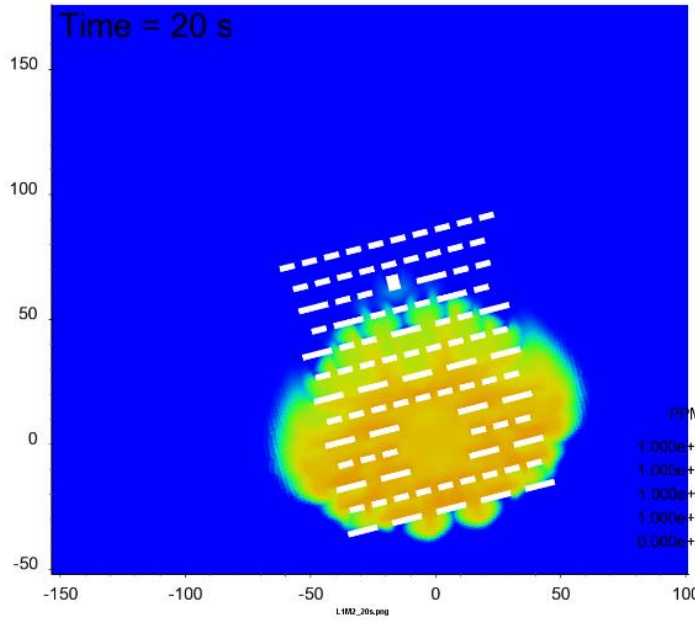
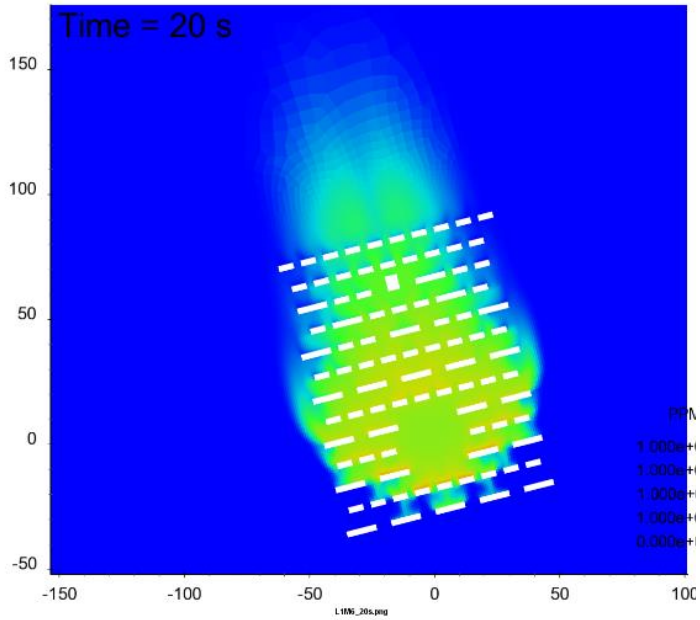
Jack Rabbit II : *Code_Saturne* simulations

2 m/s

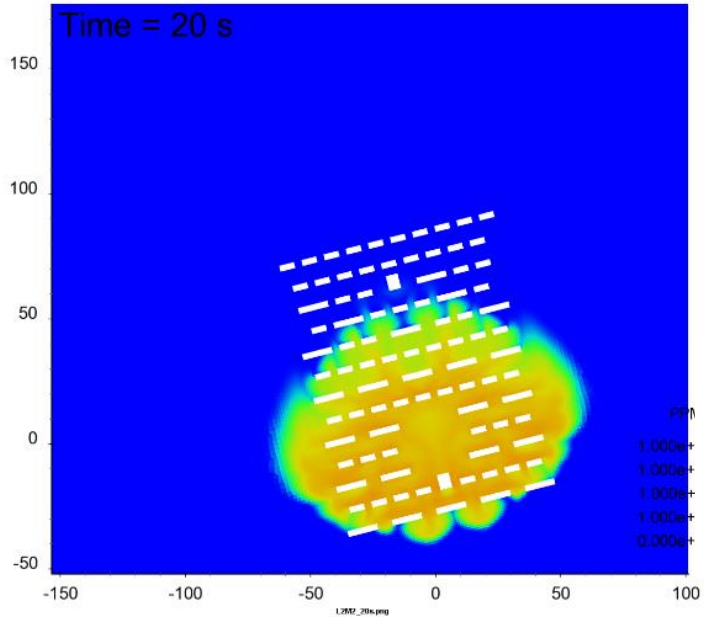
6 m/s

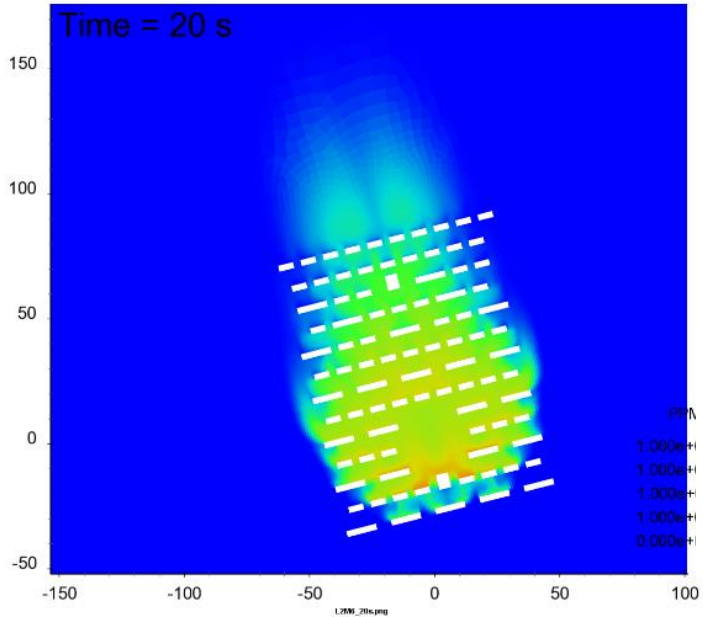
Layout 1





Layout 2





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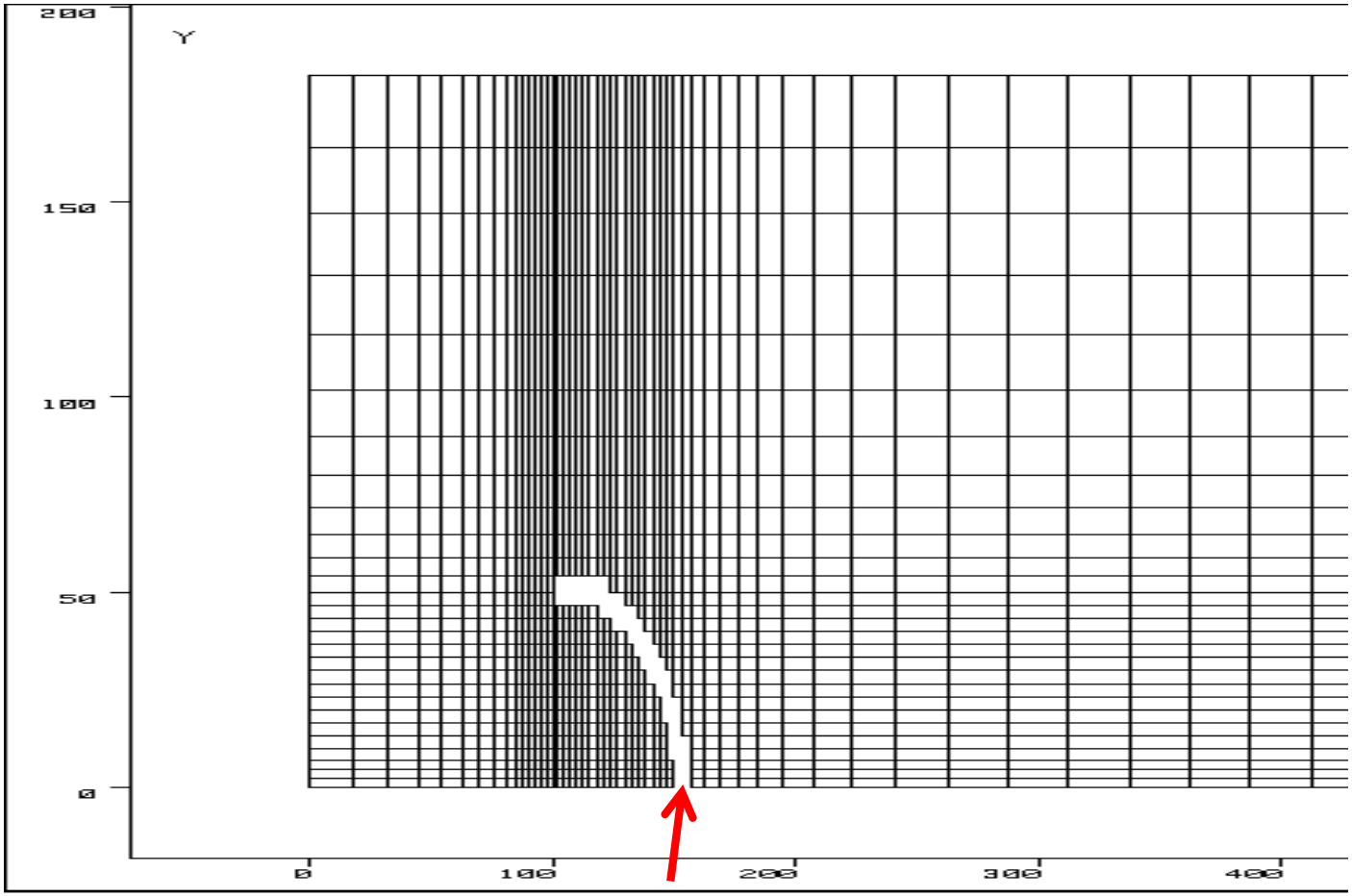
Mesh comparisons

Thorney Island structured grid : horizontal section (half domain + symmetry)



Semi-circular wall

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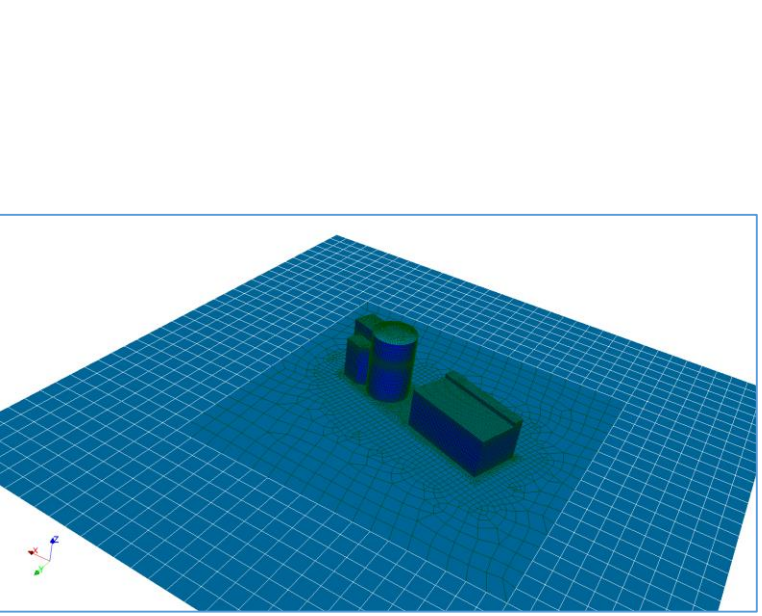
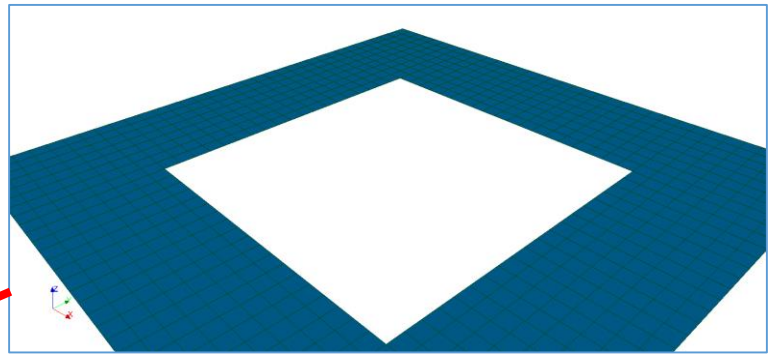
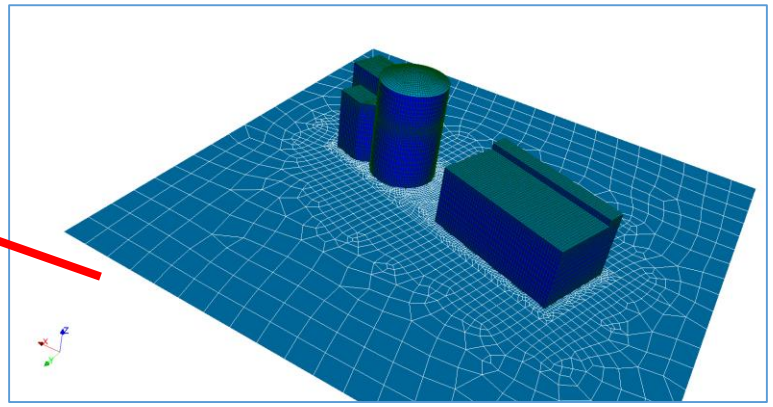
Unstructured grid construction principle







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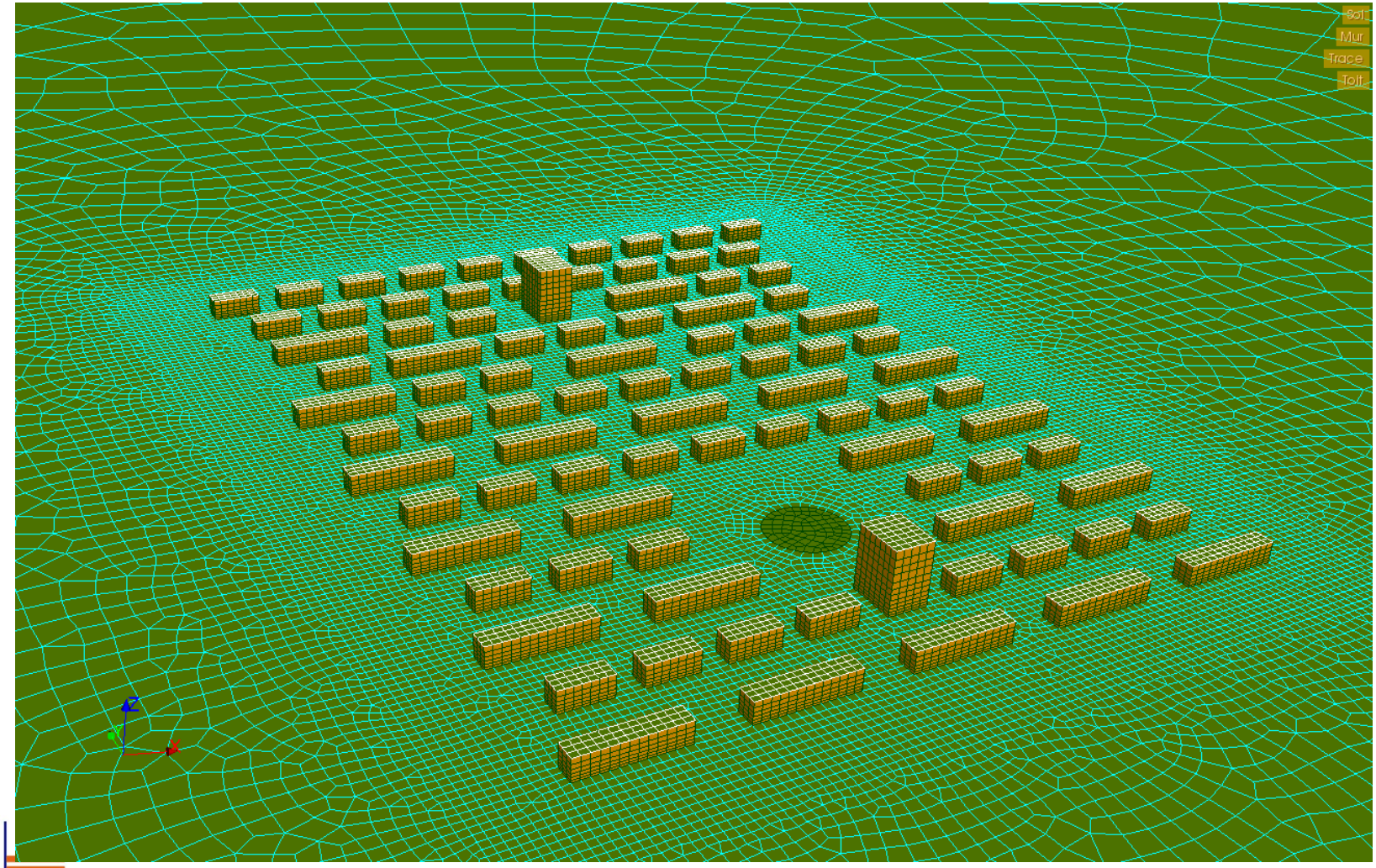
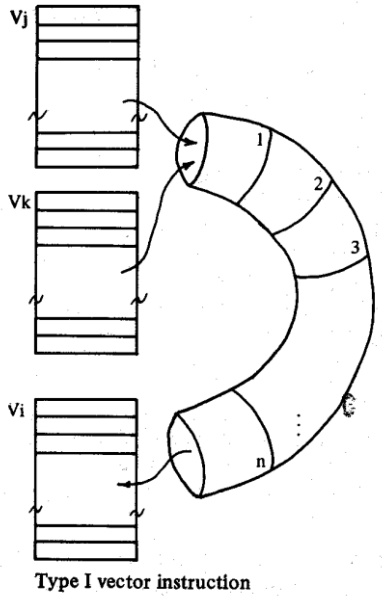
Grid view for Jack Rabbit 2 simulations with *Code_Saturne*



Computer architecture and CPU comparisons

CRAY computer principle : pipe the data in the vector processing unit

DO 10 I = 1, N, 3
Z(I) = X(I) * Y(I)

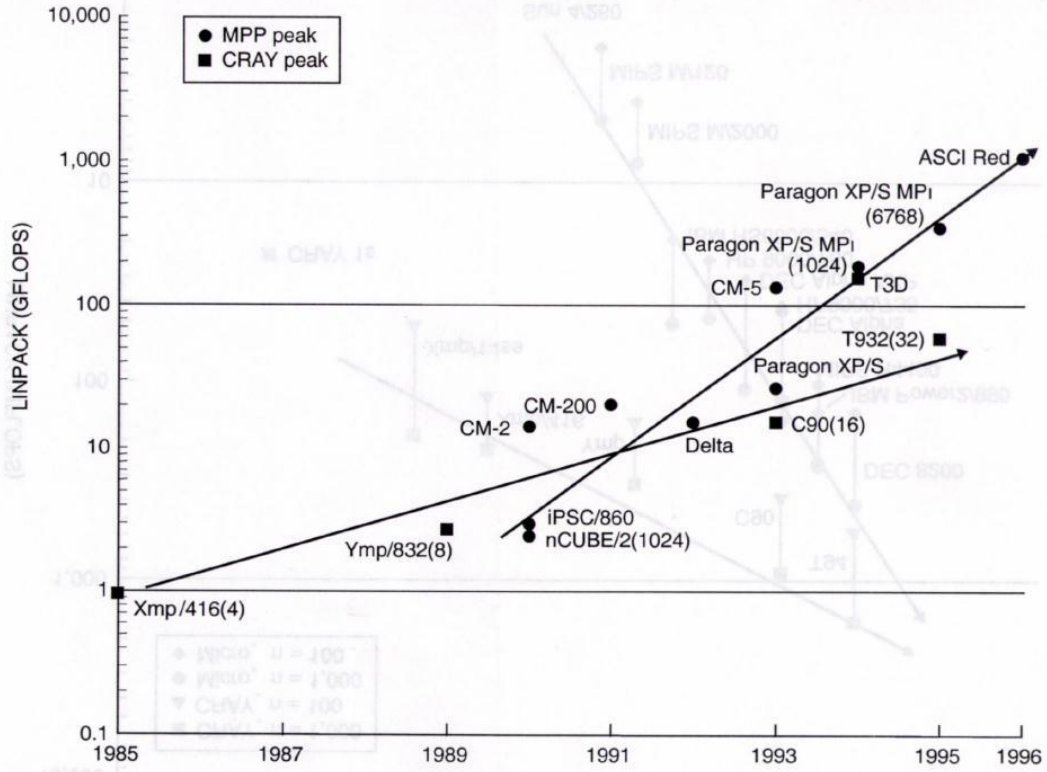


Type I vector instruction

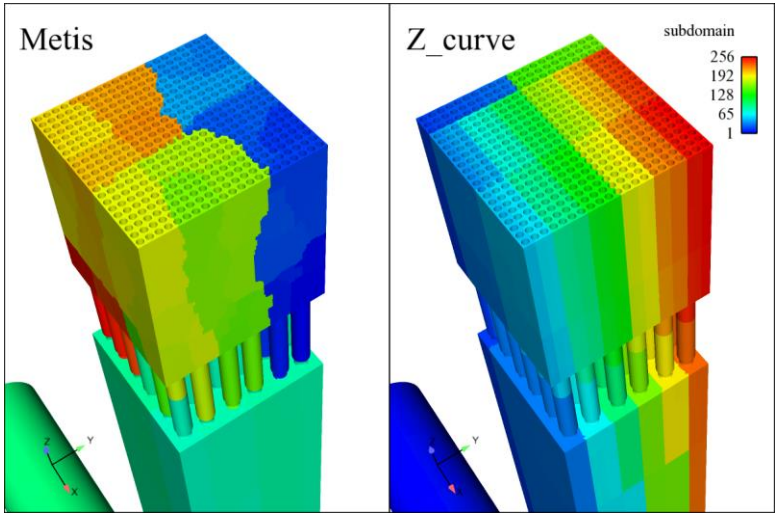
… architecture evolution …

Distributed memory, massively parallel processing (ex: modern HPC cluster)

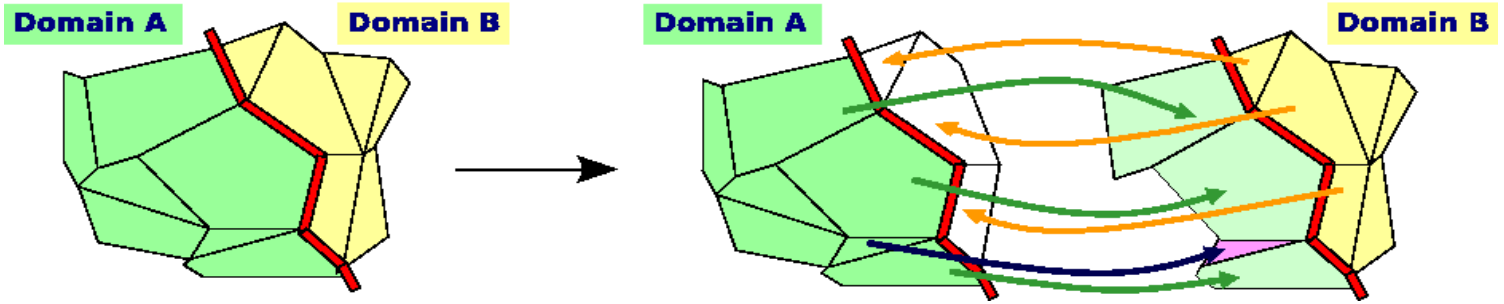
Shared memory, vector computers, multi-processor (ex: CRAY)



Parallelism on distributed memory



- **Classical « domain partitioning » using MPI**
  - Partitioning using METIS, SCOTCH
    or internal Morton space-filling curve
  - Classical « ghost cell » method for
    both parallelism and periodicity
    - Most operations require only ghost cells sharing faces
    - Extended neighborhoods for gradients also require ghost cells sharing vertices



- Input output is partition independent

CPU performance evolution in 25 years

Thorney Island MERCURE-GL	**ncell**	**T_{CPU}/dt/100 000cell (s)**
CRAY vector	43 500	4,02
workstation 1 proc.	43 500	22,30
Jack Rabbit II *Code_Saturne*		
workstation 8 proc.	721 000	0,12
Cluster 64 proc.	5 000 000	0,03

Conclusions /perspectives

- Huge change in computing power in 25 years
- Change in computer architecture ➔ change in code
  - MERCURE : structured grid, shared memory
  - Code_Saturne : unstructured grid, distributed memory
- Scalability (currently 10 billion cells, 1 million core)
- Adaptation to mixted clusters (CPU/GPU)
- Change in code paradigm : SPH (Smooth Particle Hydro.) , Lattice Boltzmann…