ANR SIOMRI* FIRE PLUME

Simulation numérique d'urgence de panaches incendie, de l'identification des sources à leur dispersion

* ***S**olutions **I**nnovantes et **O**pérationnelles dans la **M**aîtrise des **R**isques **I**ndustriels en milieu urbain et denses*

GDR Feux – 3 décembre 2021

B. Patte-Rouland (CORIA) et R. Baggio (SPE)

Investigation on Fire Plume Simulation Using a Meso-Scale Atmospheric Model

Présentation synthétique du programme ANR FIREPLUME

Axe scientifique ANR SIOMRI : Axe 1 Réponses d'ordre opérationnels et technologiques

Objectifs:

- Analyse et caractérisation de la source de l'incendie en termes d'émissions toxiques et la quantification de son impact **en développant une plate-forme de prévision des conséquences d'un incendie industriel et de réponse d'urgence, basée sur la simulation.**

Durée projet: Juillet 2021 – Décembre 2023 (18 mois)

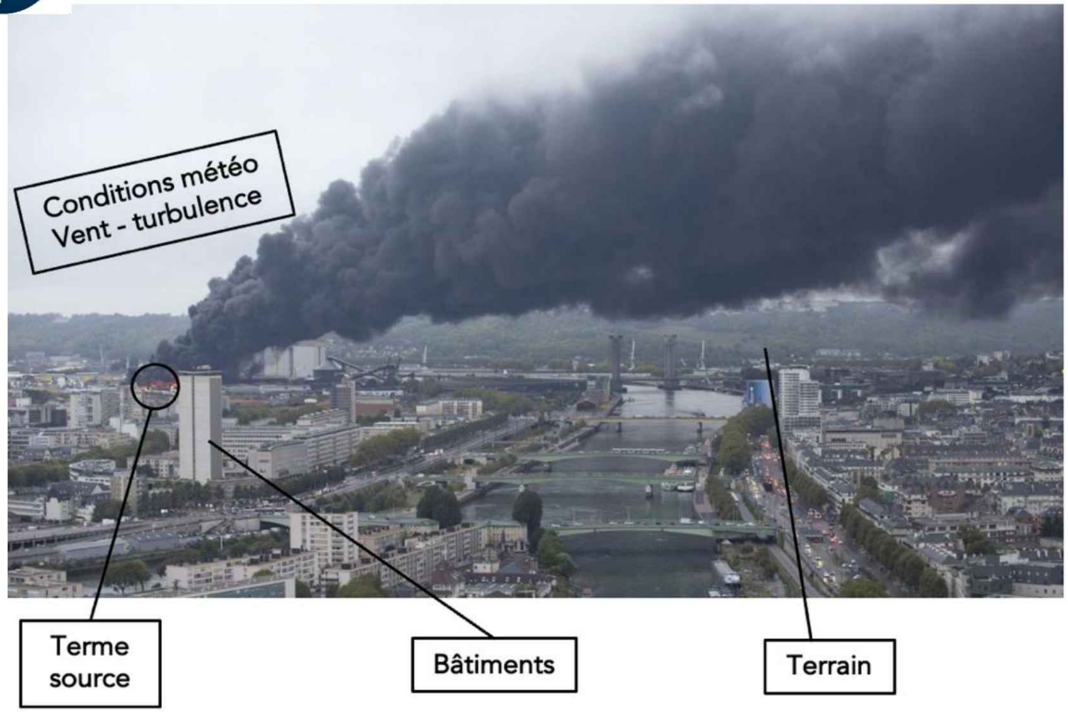
Consortium: 4 partenaires

- 4 Laboratoires de Recherche : CORIA-INERIS-LEMTA-SPE

Budget :

- Aide de l'ANR et de la Région Normandie : **144 681 euros**
- Coût complet : **391490** euros
- **45,4 Hommes-mois** : 27,4 permanent et 18 non permanent

2 post-doc : 6mois (SPE) et 12 mois (CORIA)



Les simulations pourront :

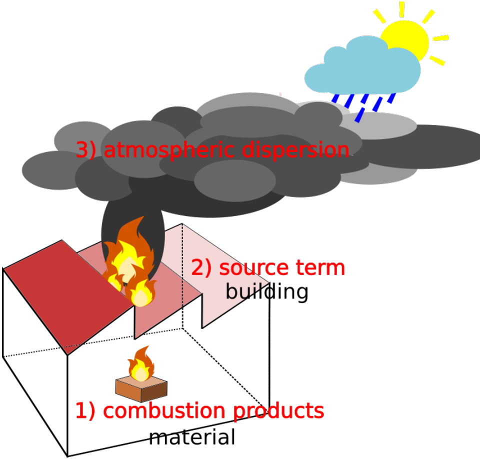
- prédire en champs proche et lointain la dangerosité de la source et sa dispersion dans l'air en fonction de la nature des produits impliqués, des caractéristiques du foyer, et des données météorologiques.
- Permettre de déterminer le dépôt et les retombés du panache de l'incendie dans le voisinage et le champ lointain.

Cet outil sera développé pour être accessible aux acteurs impliqués dans la gestion des crises (prévention ou opération) provoquées par ces grands incendies.

Investigation on Fire Plume Simulation Using a Meso-Scale Atmospheric Model

Project Goal: → development of a multi-scale modelling framework for industrial fire accidents, based on numerical simulations

- estimate of the toxic emissions
- characterization of the source term
- plume-atmosphere interaction modelling



Meso-NH Atmospheric Code

Meso-NH

mesoscale non-hydrostatic model

http://mesonh.aero.obs-mip.fr/mesonh55

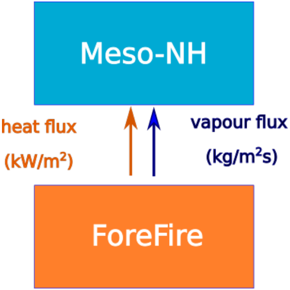
- non-hydrostatic
- broad resolution (synoptic to turbulent scales)
- advanced physical parametrizations for turbulence and cloud microphysics

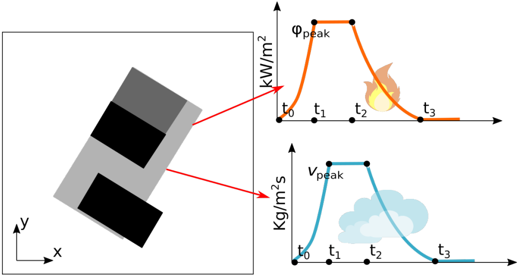
Meso-NH coupling with ForeFire:

[2011 Filippi, Bosseur, Pialat, Santoni, Stada, Mari] [2018 Filippi, Bosseur, Mari, Lac]

Solution of the convective motions caused by the interaction between the atmosphere and the released **heat** and **vapour**

Coupling with ForeFire

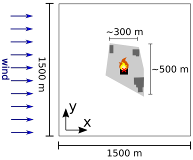


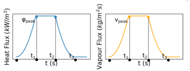


- **FuelMap**: ϕ_{peak}, v_{peak}, t_1, t_2, t_3, u_i, ...
- **Arrival Time Matrix**:

t_0^i assigned a priori,
or calculated from a fire propagation model u^i

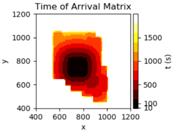
Idealized ForeFire-MesoNH simulation

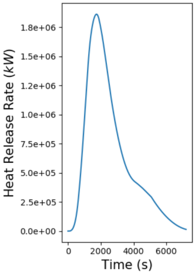


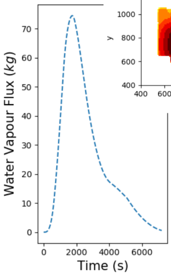


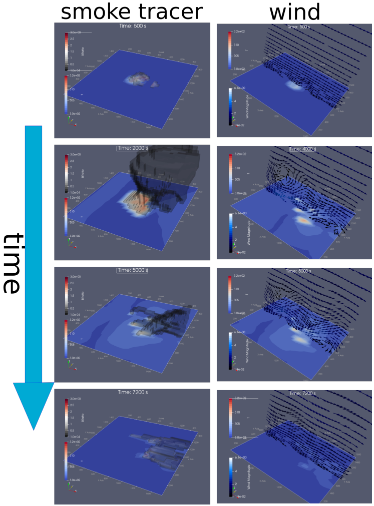
v_{peak}=4•10^{-4} Kg/m^{2}s φ_{peak}=10 kW/m^2

■ v=1 m/s	t_1=1200 s	t_2=5040 s	t_2=7200 s
■ v=0.5 m/s	t_1=1200 s	t_2=3600 s	t_2=7200 s
■ v=0.2 m/s	t_1=600 s	t_2=1200 s	t_2=3600 s





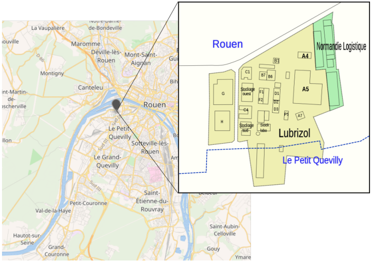




Lubrizol Industrial Fire

26th September 2019:

The Lubrizol chemical plant in Rouen takes fire



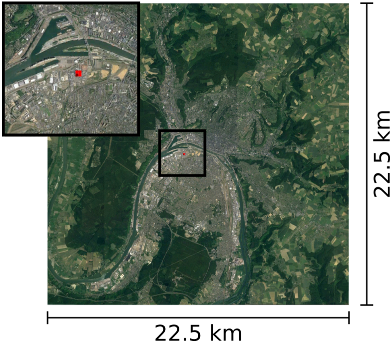
≈ 02.30 h 00.30 UTC	02.30 UTC	15.30 UTC
PROBABLE STARTING TIME	FIRE SPREADS OUT OF CONTROL	FIRE IS DEFINITELY EXTINGUISHED

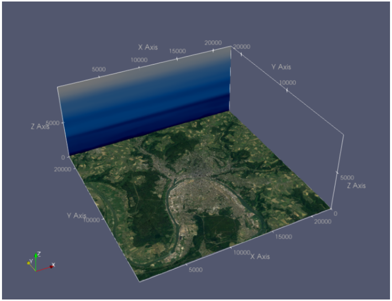
$\approx$ 9500 t burned products (mineral oils), fire area $\approx$ 20 000 m^2

Lubrizol Industrial Fire: Meso-NH simulation

Simulated Domain:

22500 m × 22500 m × 9750 m



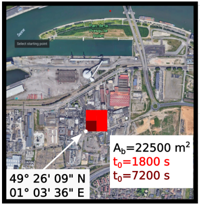


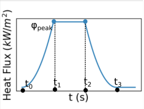
$$\Delta x = \Delta y = 75\ m,$$

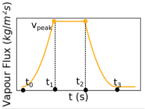
$$\Delta z_{bot} = 75\ m \qquad \Delta z_{top} = 250\ m$$

Lubrizol Industrial Fire: Meso-NH simulation

Implemented Source Terms:







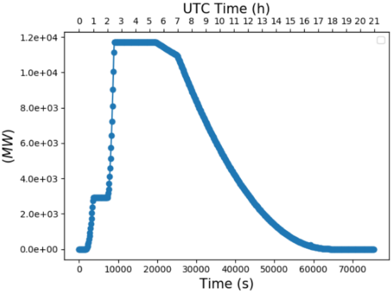
φ_{peak}=520 kW/m^2

v_{peak}=1.7•10^{-2} Kg/m^{2}s

t_1=30 min + t_0

t_2=5 h + t_0

t_3=16 h + t_0



Total Released Power: $97.5\,GWh$

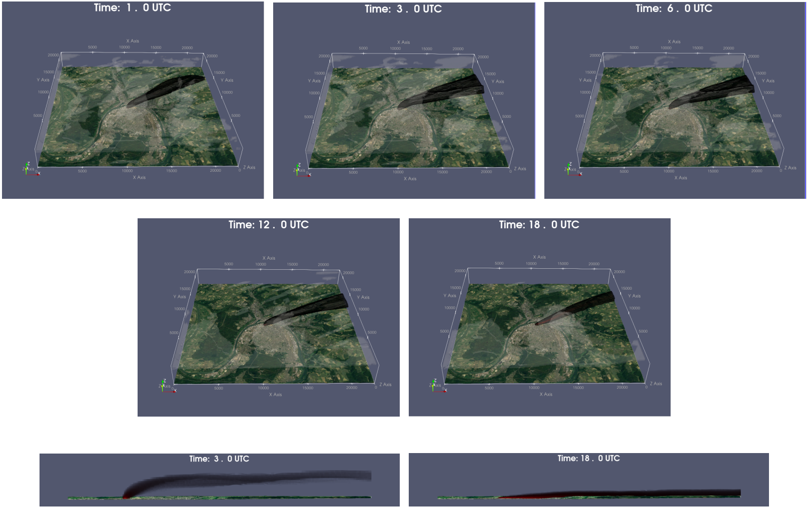
$\longrightarrow 3 \cdot 10^7 \frac{j}{kg} \times 10^7\,kg = 83.3\,GWh$

Total Released Vapour: $11\,500\ t$

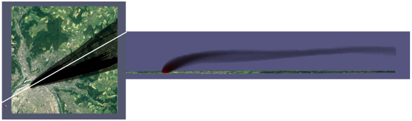
$10^7\,kg$ mineral oil $\rightarrow 10\%\ H\ 10^6\ kg\ H + 8 \cdot 10^6\ kg\ O_2 = 9 \cdot 10^6\ kg\ H_2O$

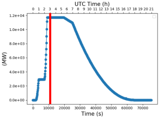
Lubrizol Industrial Fire: Meso-NH simulation

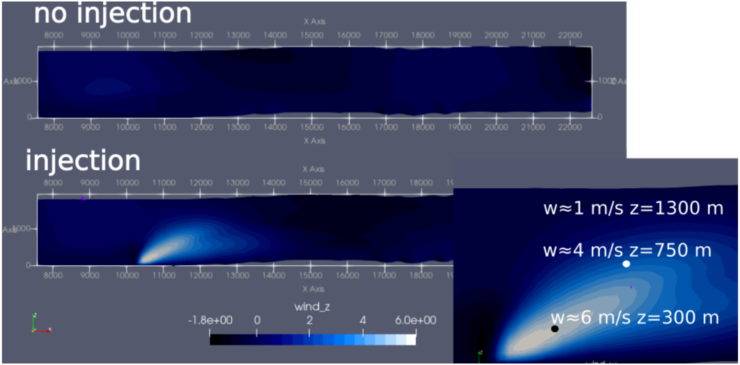
evolution of the smoke tracer:



Lubrizol Industrial Fire: Meso-NH simulation

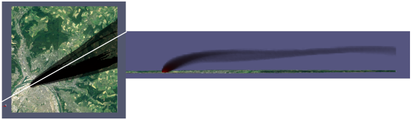


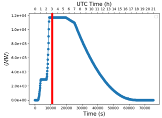


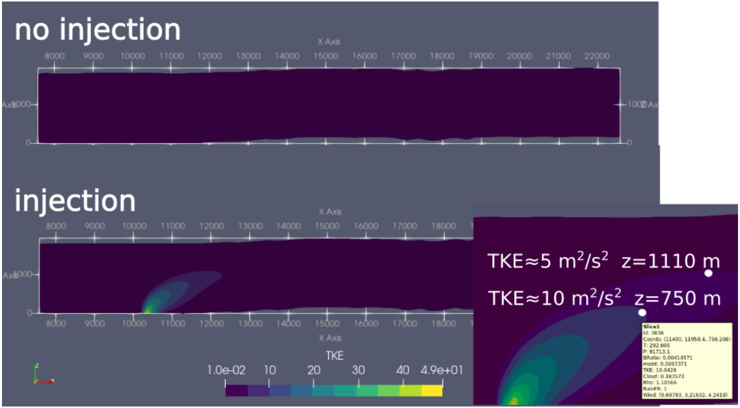


vertical wind component at 03.00 UTC

Lubrizol Industrial Fire: Meso-NH simulation

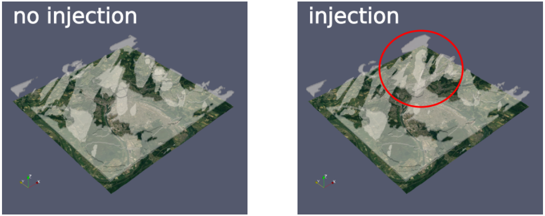


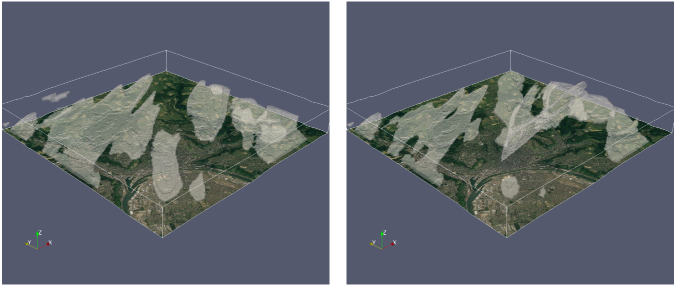




turbolent kinetic energy at 03.00 UTC

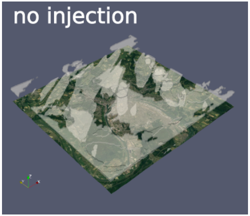
Lubrizol Industrial Fire: Meso-NH simulation

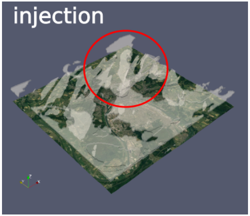


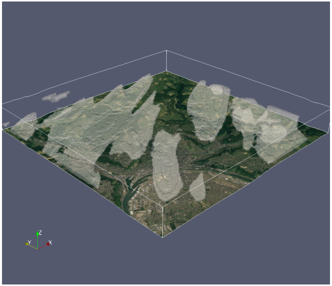


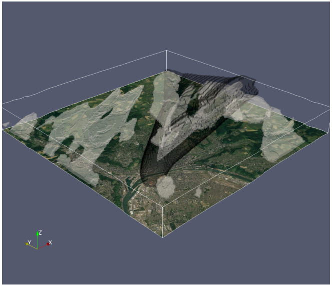
cloud fraction at 03.00 UTC

Lubrizol Industrial Fire: Meso-NH simulation





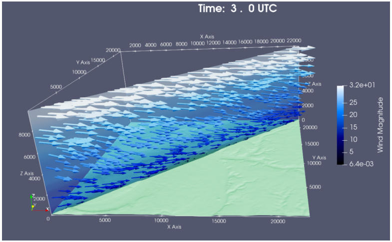




cloud fraction at 03.00 UTC

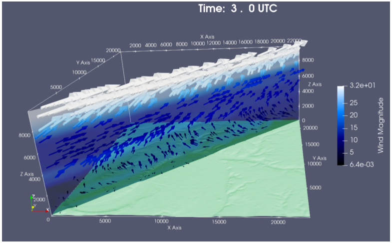
Alternative Scenario

26th September 2019



- uniform/strong horizontal ground wind speed
- wind speed increases rapidly with height and its direction is constant

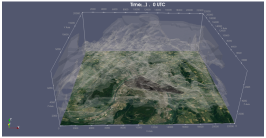
10th June 2019

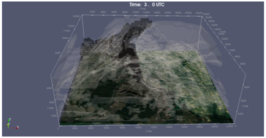


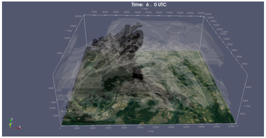
- low ground horizontal wind speed, convective motions
- wind speed increases slowly with height and has a jump for $z \approx 9km$

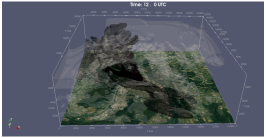
Alternative Scenario: Meso-NH simulation

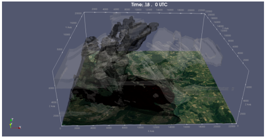
evolution of the smoke tracer:

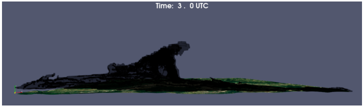


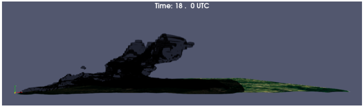




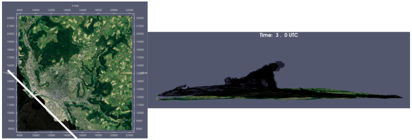


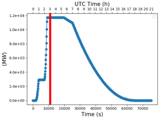


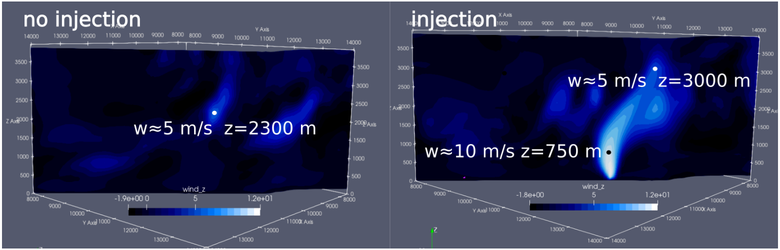




Alternative Scenario: Meso-NH simulation

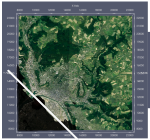


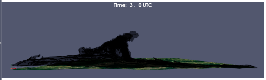


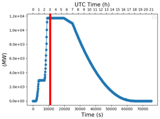


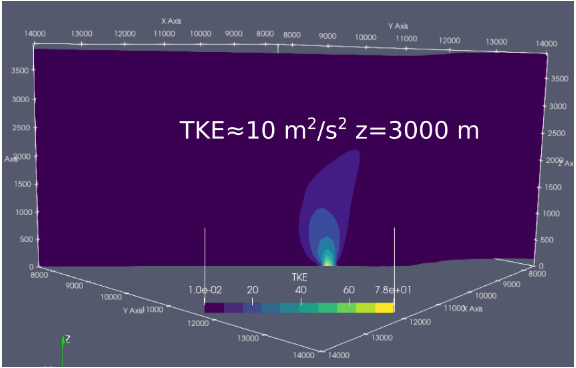
vertical wind component at 03.00 UTC

Alternative Scenario: Meso-NH simulation



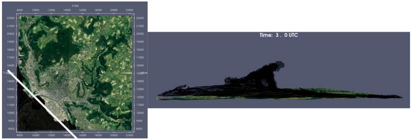


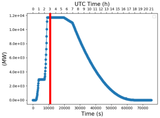


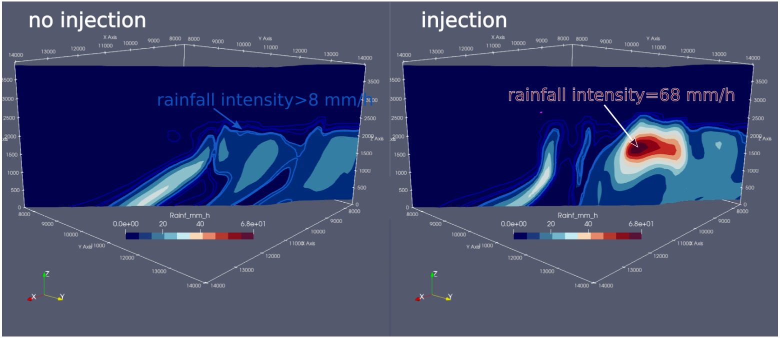


vertical wind component and TKE at 03.00 UTC

Alternative Scenario: Meso-NH simulation



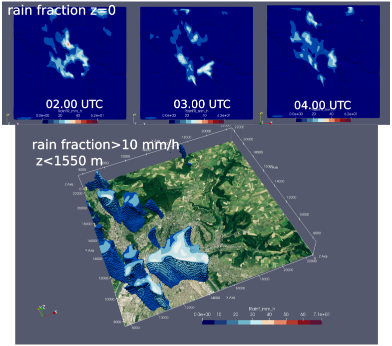




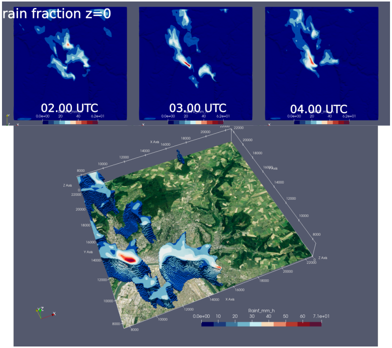
rainfall intensity at 03.00 UTC

Alternative Scenario: Meso-NH simulation

★ no injection:



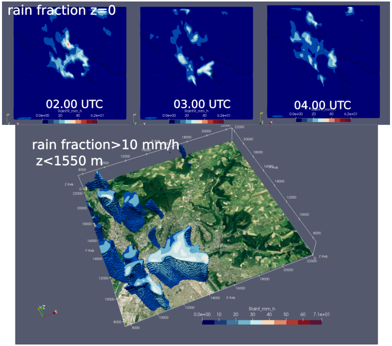
★ injection:



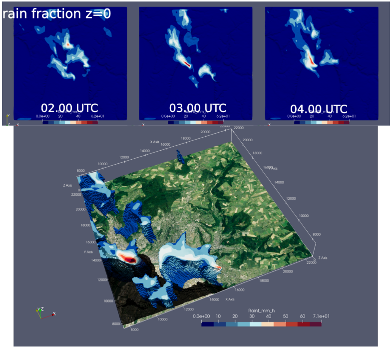
rainfall intensity at 03.00 UTC

Alternative Scenario: Meso-NH simulation

★ no injection:

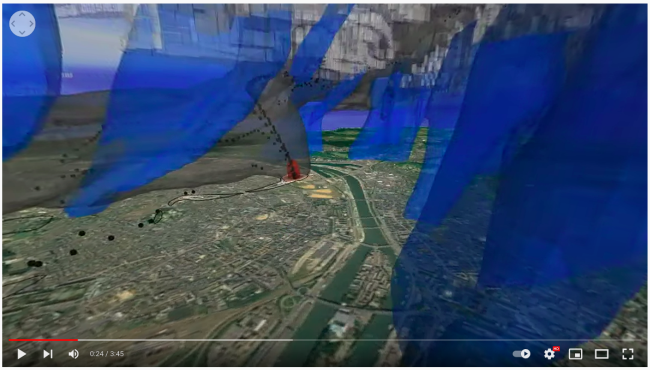


★ injection:



rainfall intensity at 03.00 UTC

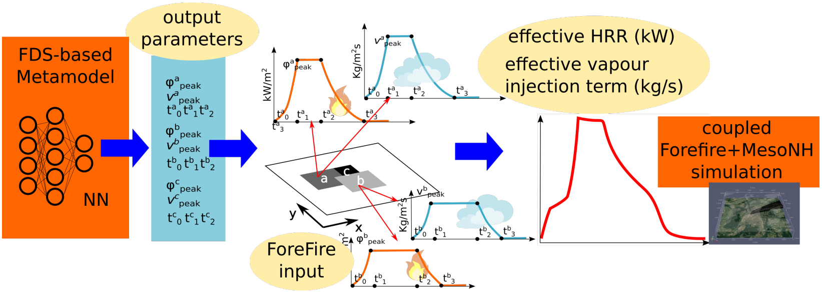
Alternative Scenario: Meso-NH simulation



3D video available at: https://tinyurl.com/fplume

Perspectives

- embedded simulation of the Lubrizol accident (up to $\approx 1000\ km$)
- systematic comparison with existing models
- more realistic source terms



thank you for your attention!