Computational Fluid Dynamics
or
Gaussian

Is there a right way to model gas dispersion?

Andy Stanley, Naomi Warrilow,

Dr Amita Tripathi and Dr Claude Souprayen

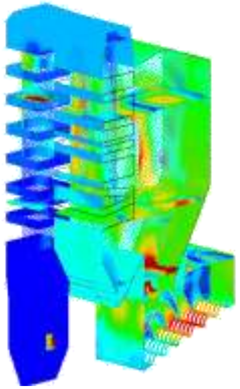
fluidyn
Multiphysics and Environmental Modelling

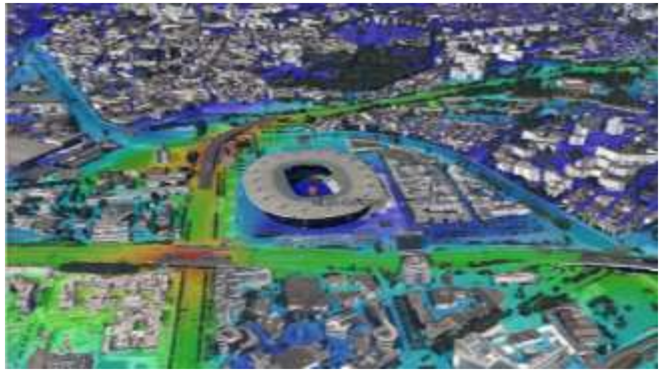
Hazards 29

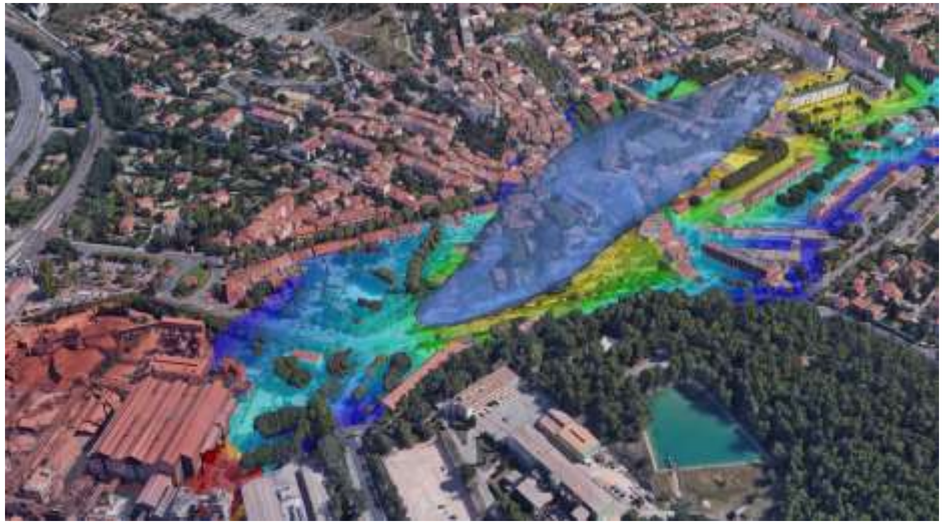
22-24 May 2019, Birmingham, UK

RAS

Fluidyn & RAS – What do we do ?







Safety Risk

Business Risk

Environmental Risk

www.ras.ltd.uk

Presentation Content

- Background
- Paper Objectives
- Gas Dispersion Overview
- Gaussian vs CFD: Mathematical Differences
- Case Studies: Gaussian vs CFD Results
- CFD Areas of Concern
- Managing Flexibility of Parameters
- Key Aspects to a Standardised Approach
- Gaussian vs CFD: Which Model?
- Summary

Background

At present there are two main approaches to modelling gas dispersion within the process safety risk assessment arena: Gaussian and Computational Fluid Dynamics (CFD).

Historically the Gaussian approach has dominated, however, with the improvement of computing power available in relatively low-cost platforms, CFD has begun to challenge that dominance.

Paper Objectives

The objectives of our paper are to:

- Explore the mathematical differences between Gaussian and CFD models
- Explore the practicalities of using CFD modelling with Process Safety Risk Assessments
- Suggest a way forward to allow CFD to become more mainstream in the UK

Gas Dispersion Overview

Gas Dispersion = Diffusion + Advection + Source/Sink

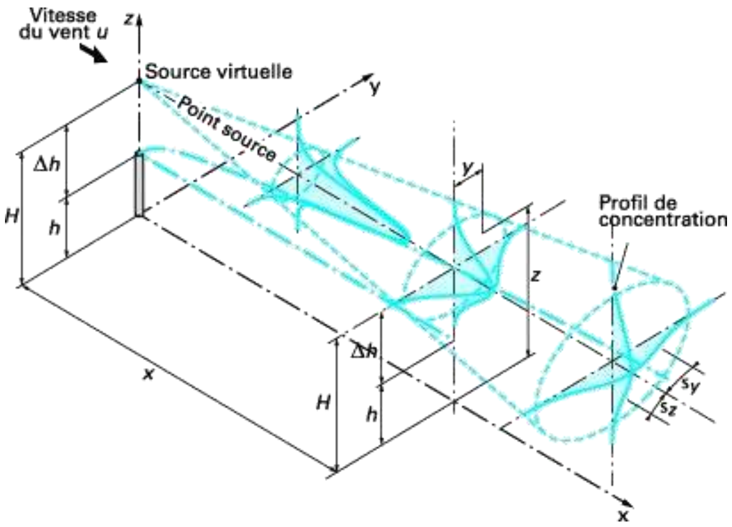
Turbulent Eddy Motion	Due to Mean flow	Deposition or Chemical reaction

Influencing factors:

- Source
- Properties of the released material
- Terrain
- Weather conditions & atmospheric stability

Gaussian vs CFD: Mathematical Differences

- Gaussian models simplify the flows using an empirical approach
- CFD models solve the physics using the Navier-Stokes Equations of flow



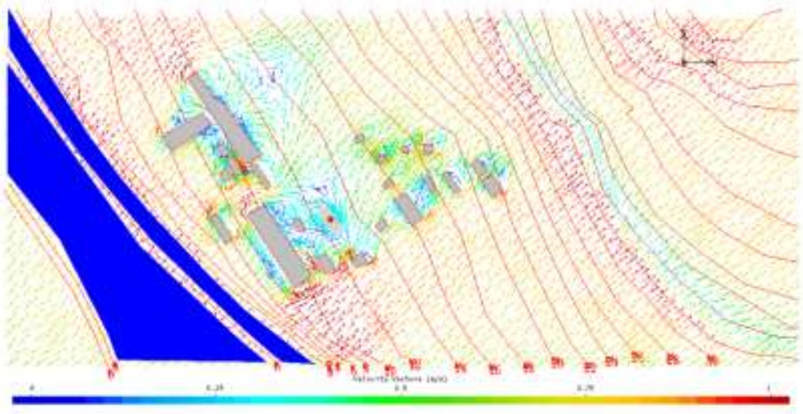


Figure 4 : Windfield for wind condition F2 – 230°N at h=1.5m

In standard Gaussian models, velocity and turbulent diffusion are assumed to be constant (in time) and uniform (horizontally) with a single vertical (assumed/empirical) variation with altitude related to the stratification of the atmosphere

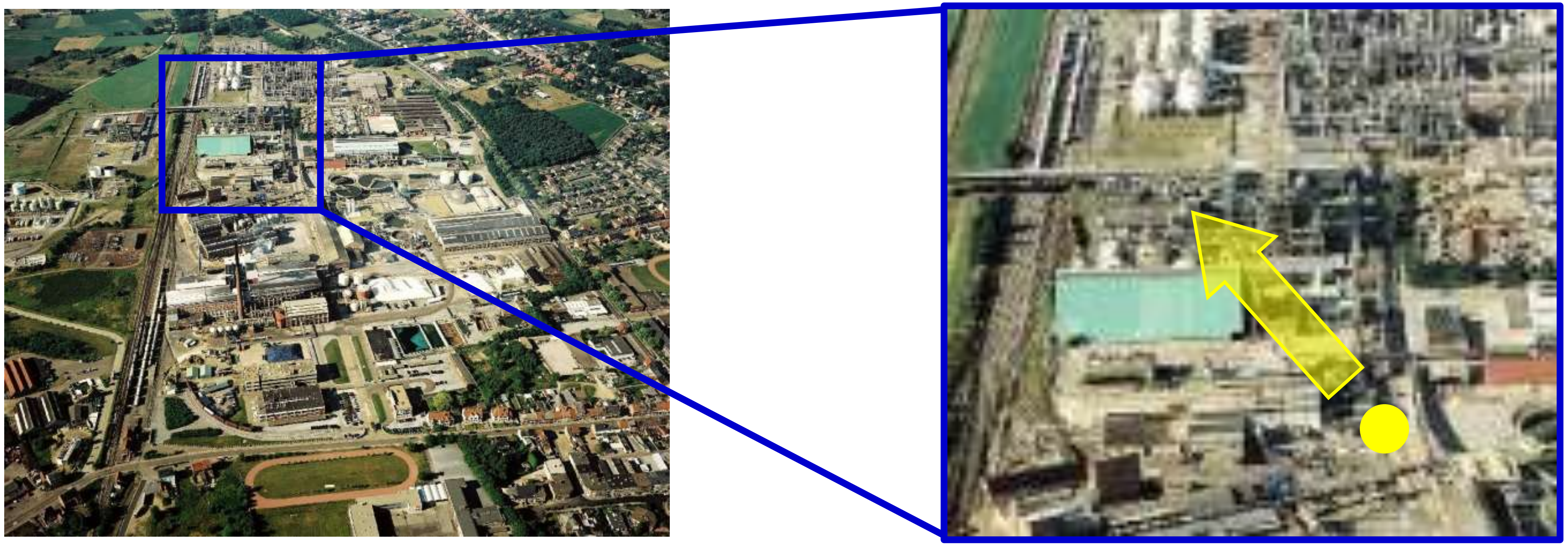
CFD approach on the other hand solves the full equation along with the relevant fluid equations (Navier-Stokes Equations) for the atmospheric flow and turbulence

Case Studies: Gaussian vs CFD Results

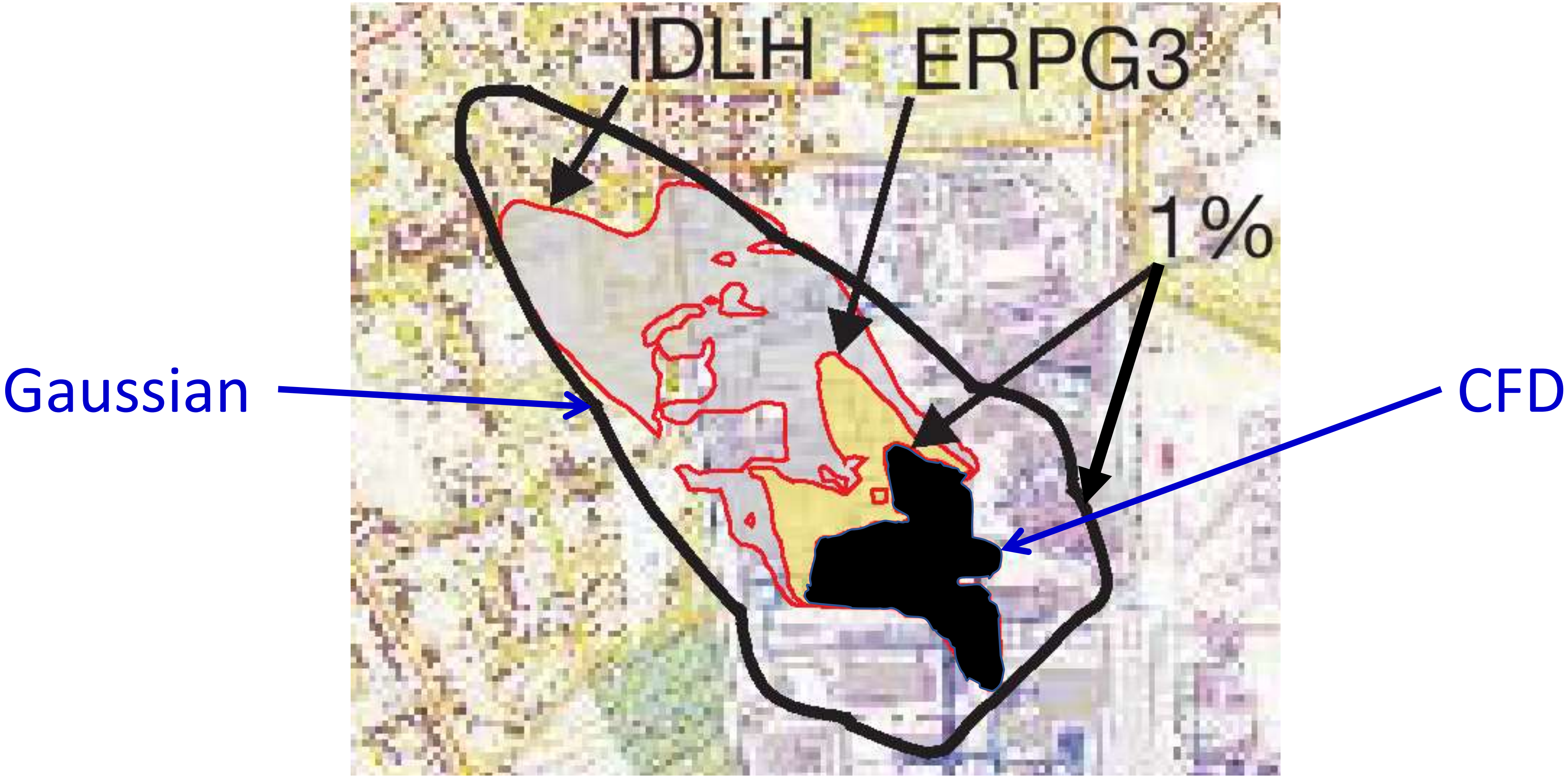
- Case Study 1: Chlorine release from a pipe manifold - very large industrial site
- Case Study 2: Chlorine release from a pipe - small industrial site in a valley with complex natural topography
- Case Study 3: Acrylonitrile dispersion from pool - complex congested industrial site with quasi flat terrain

Case Study 1: Chlorine release from a pipe manifold

- Downward release from pipe on a central position on plant
- Complex obstacles within site
- Patchwork of surrounding surface types including open flat vegetation and built up residential zones



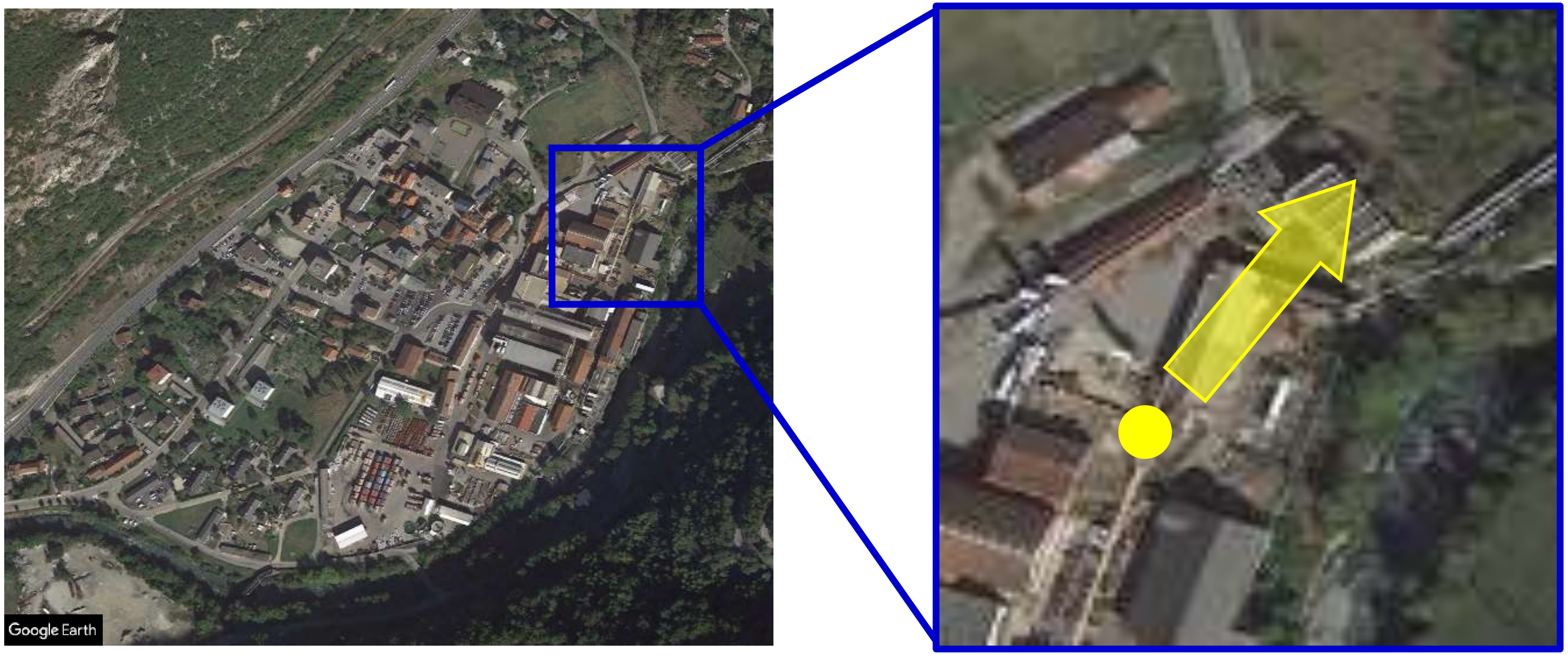
Case Study 1: Chlorine release from a pipe manifold



CFD predicts shorter hazard ranges due to large downstream buildings and obstacles

Case Study 2: Chlorine release from a pipe

- Downward release from a pipe
- Tall buildings in vicinity of release
- Complex surrounding terrain, with site located in a valley.



Case Study 2: Chlorine release from a pipe

Gaussian

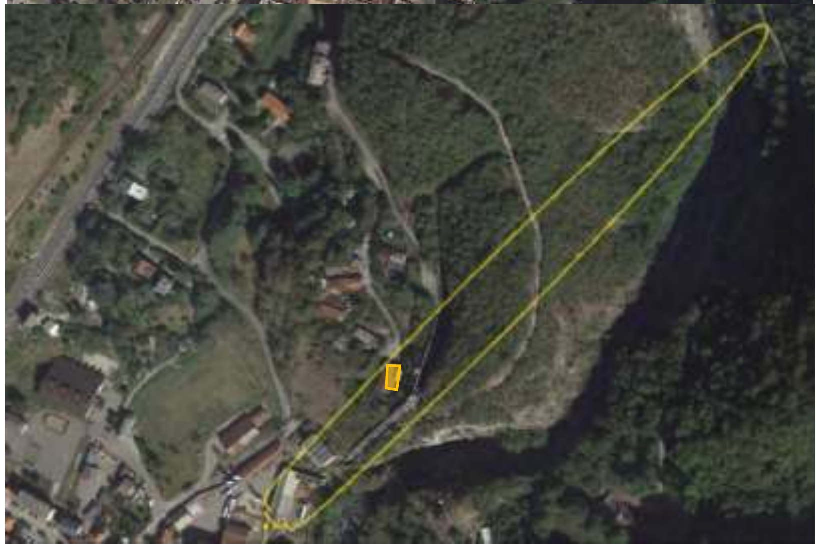
The CFD modelling predicts shorter hazard ranges due to the large building and topography downwind, with a steep hill

CFD

195 m

61 m

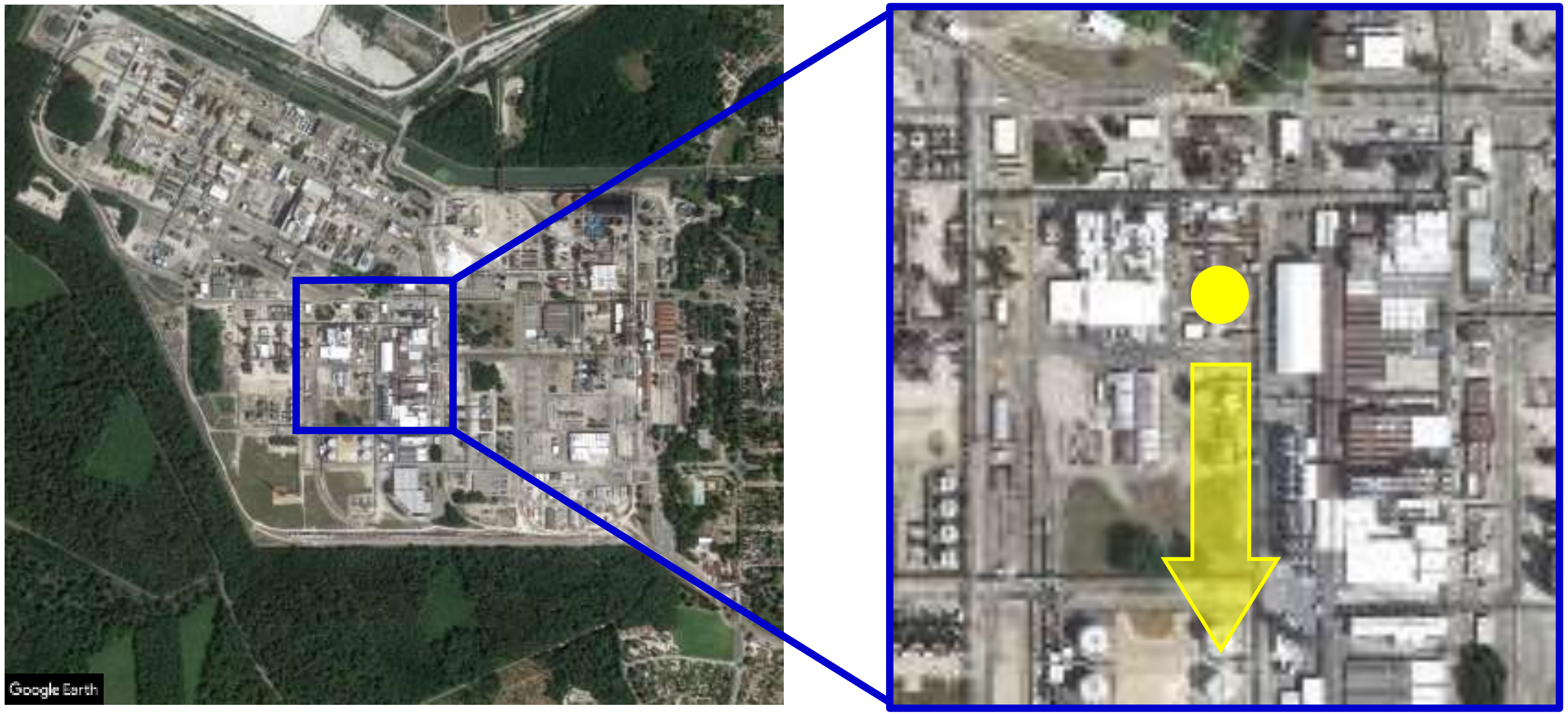
608 m



135 m

Case Study 3: Acrylonitrile Dispersion from Pool

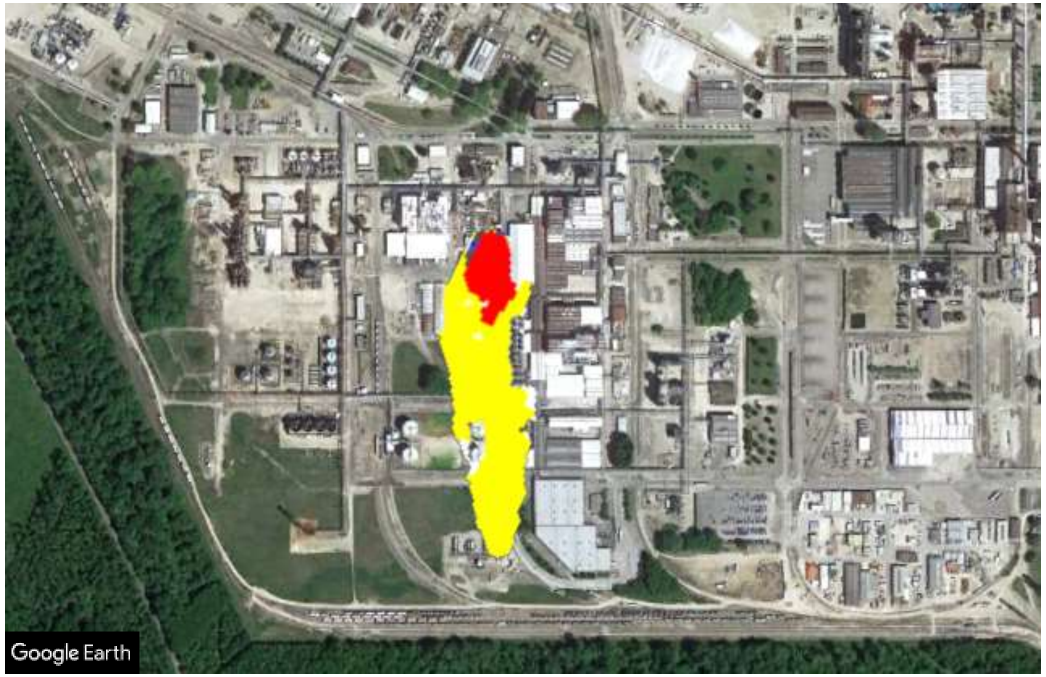
- Dispersion from pool, with wind towards the south
- Relatively flat terrain
- Complex series of obstacles on site, but area surrounding release and in wind direction relatively sparse



Case Study 3: Acrylonitrile Dispersion from Pool

Gaussian

CFD



Gaussian and CFD dispersion predictions are very similar due to the lack of large buildings and flat topography in immediate vicinity downwind.

CFD Areas of Concern

Area of Concern	Gaussian Models	CFD Models
Conformity between models	Little evidence of comparisons.	Literature studies suggest large inconsistency.
Software user competence	Often user-friendly interfaces, but can be misused as user can be given false sense of ease of use without understanding limitations or mathematics of the model.	Often user interface is complex, so unlikely to be used by analysts that do not appreciate the development of the model.
Validation and verification	Validation is often for narrow area of use, however the models are used beyond this.	Large amount of effort in validation and verification, however this varies between model providers, in particular in how forthcoming they are with evidence.
Time and Cost	Low cost, short time to run simulations.	Higher cost and longer time to run simulation, but increasing access as technology advances.
Flexibility of parameters	Simplification may be made to reduce the choice for users, but there are differences between the representative parameters. E.g. representation of Pasquill stability classes varies between commonly used models.	Flexibility in choice of parameters, if not set by rules.

Managing Flexibility of Parameters

Flexibility of parameters is the main concern for CFD and needs to be managed to ensure confidence in CFD.

There is some existing guidance available:

- The Atmospheric Dispersion Modelling Liaison Committee (ADMLC)
- The NAFEMS (National Agency for Finite Element Methods & Standards) has a CFD working group, which includes members from industry, academics and consultants.
- French working group resulted in 10 best practices including atmospheric profiles, mesh sensitivity with respect to solvers, validation regarding site based and/or wind tunnel experiments.

Managing Flexibility of Parameters

This could be managed through some rules for a standard approach, which would:

- Avoid the issue of too many variables, reducing the chance for inadvertent error
- Enable repeatability and comparability between people using these models

Key Aspects to Standardised Approach

- Computational domain
- Floor geometry
- Obstacle geometry
- Boundary conditions
- Input/weather conditions
- Mesh
- Model resolution
- Initial wind conditions
- Post processing & results analysis
- Model validation

The industry, regulators and modellers need to agree a set of rules to ensure a standardised approach to CFD.

Rule sets need to be developed for specific applications, such as atmospheric dispersion discussed here.

Gaussian vs CFD: Which Model?

Key questions to consider when choosing which model to use:

- What is the purpose of the modelling ?
- What level of understanding is required for that purpose ?
- What is in the vicinity of the release ?

In other words the ‘right’ modelling approach varies from case to case

Summary

- The use of Gaussian vs CFD depends on user needs
- CFD can give extra resolution that is needed for making complex decisions
- Historical concerns of cost and time are no longer prohibitive
- Biggest concern remaining is flexibility of parameters
- Joint industry guidance and rule setting can address this