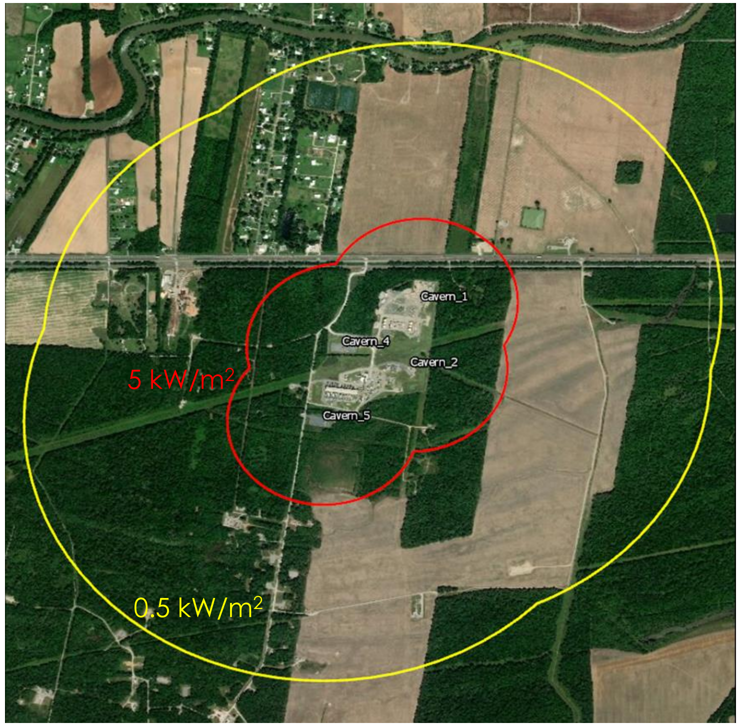
WILD WELL CONTROL

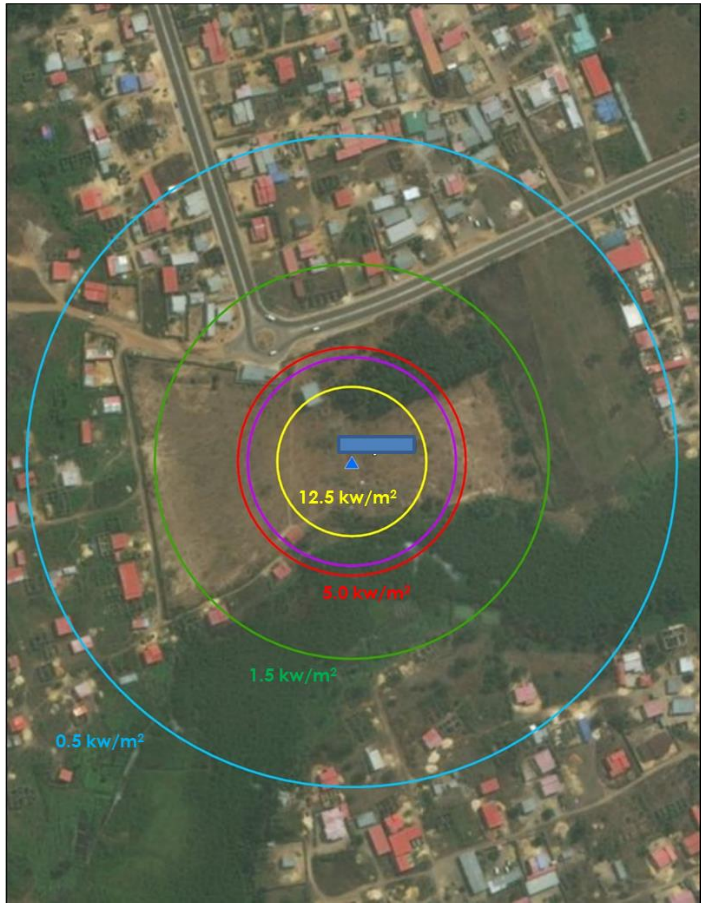
UNDERSTANDING CONSEQUENCE BY SIMULATION

Feb 2020

Why bother?



Cavern_1
Cavern_4
Cavern_2
5 kW/m²
Cavern_5
0.5 kW/m²



12.5 kw/m²
5.0 kw/m²
1.5 kw/m²
0.5 kw/m²

Gas Dispersion Analysis

– what is it?

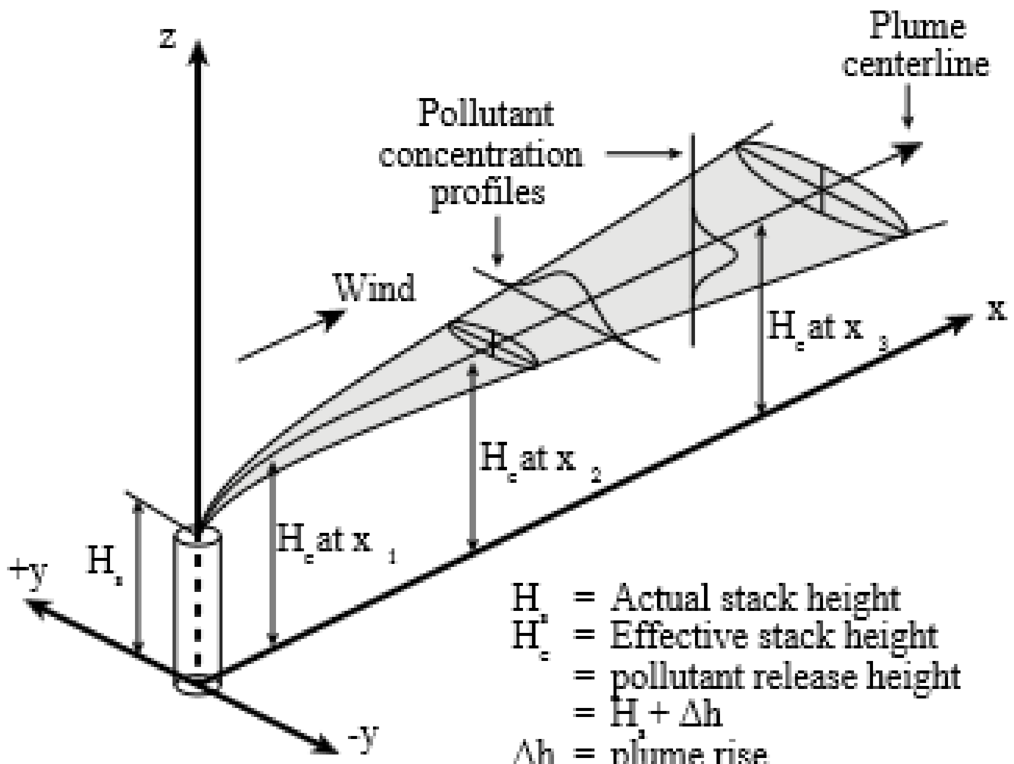
Gas dispersion analysis

- The prediction of how gas, vapor or smoke disperses in the atmosphere;
- Potential for:
  - A flammable or explosive hazard
  - A toxic hazard e.g sour gas contains H_2S – can be transported over significant distances
  - A radiant heat hazard (if a flammable cloud catches fire)
- Can impact well control response actions as well as the ***public***
- It can range from quite straight forward to very complex and hence we use different tools for different circumstances

Which tools

– when and why

Gaussian plume models



- Uses equations to determine concentration v distance

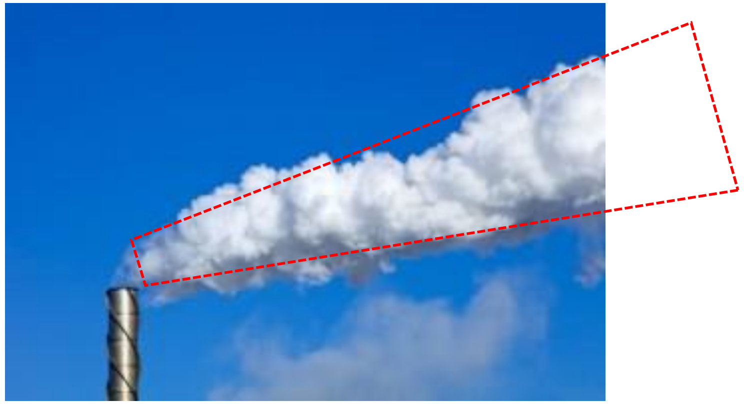
Good to use when

- High level checks are needed, e.g relief well location
- Dispersion occurs over longer distances
- When terrain is flat
- Atmospheric effects are important

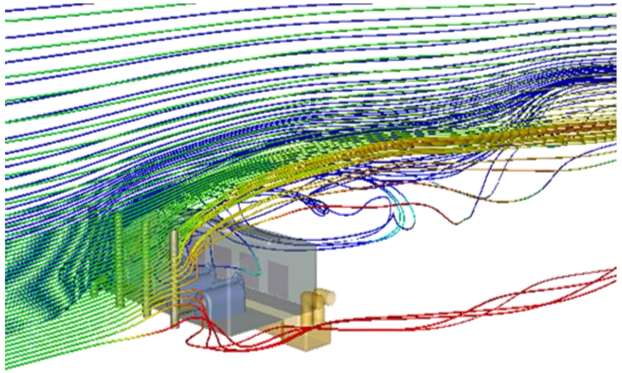
No good when

- Terrain, buildings or structures alters wind profile

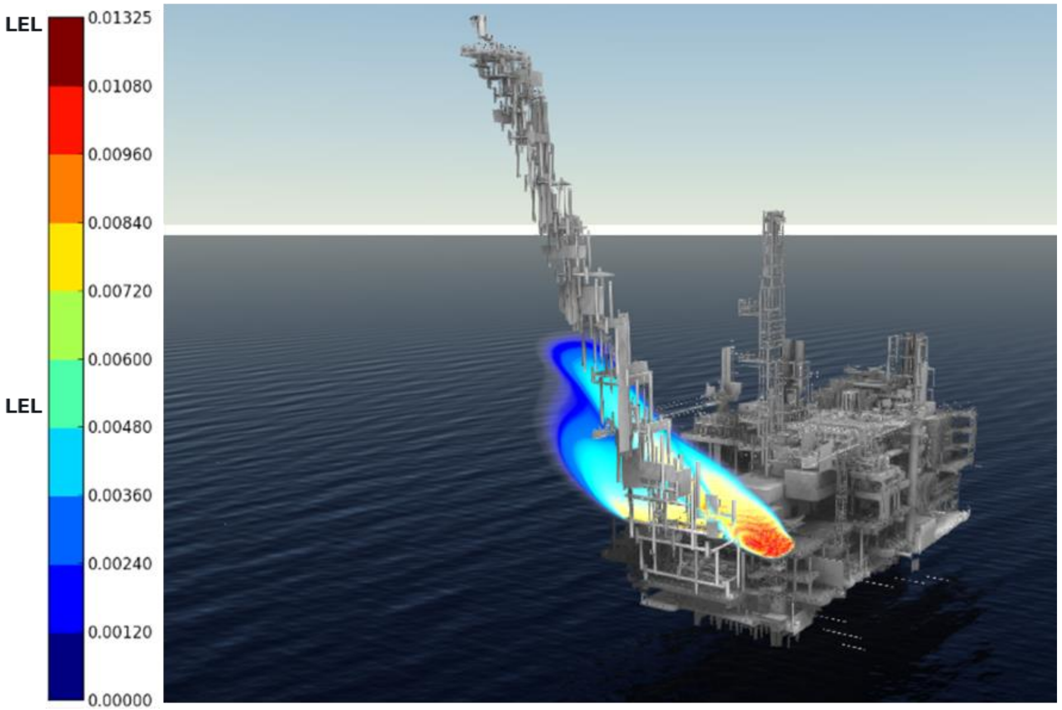
Gaussian Plume Models



Gaussian behavior



Non-Gaussian behavior



CFD dispersion models

- Uses advanced computational methods

Good to use when

- Dispersion is “near field”
- When terrain is an important consideration
- Building/structures are nearby and clearly interfere with local wind

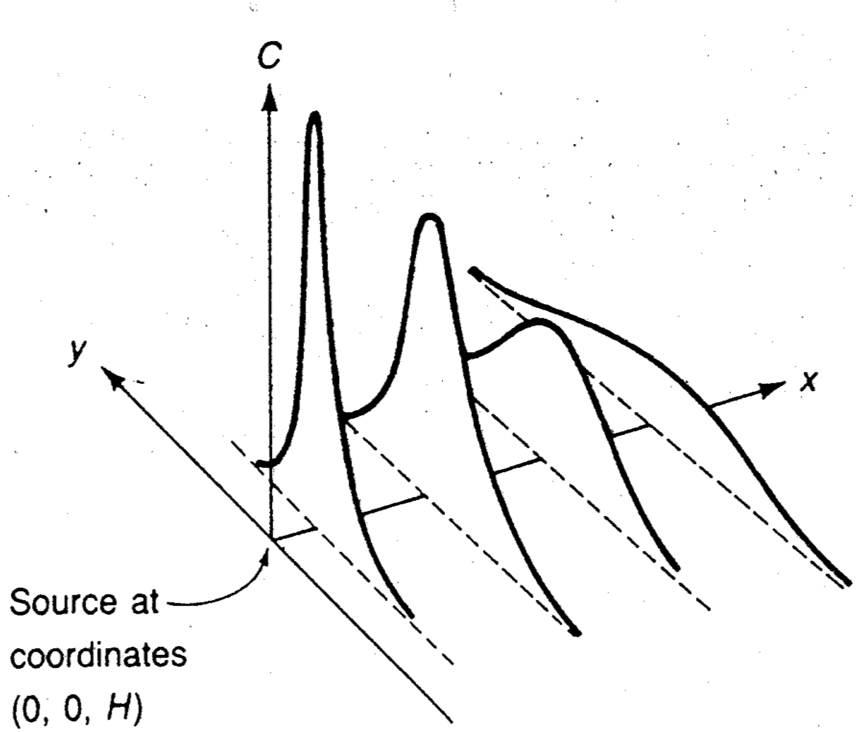
Not so good when

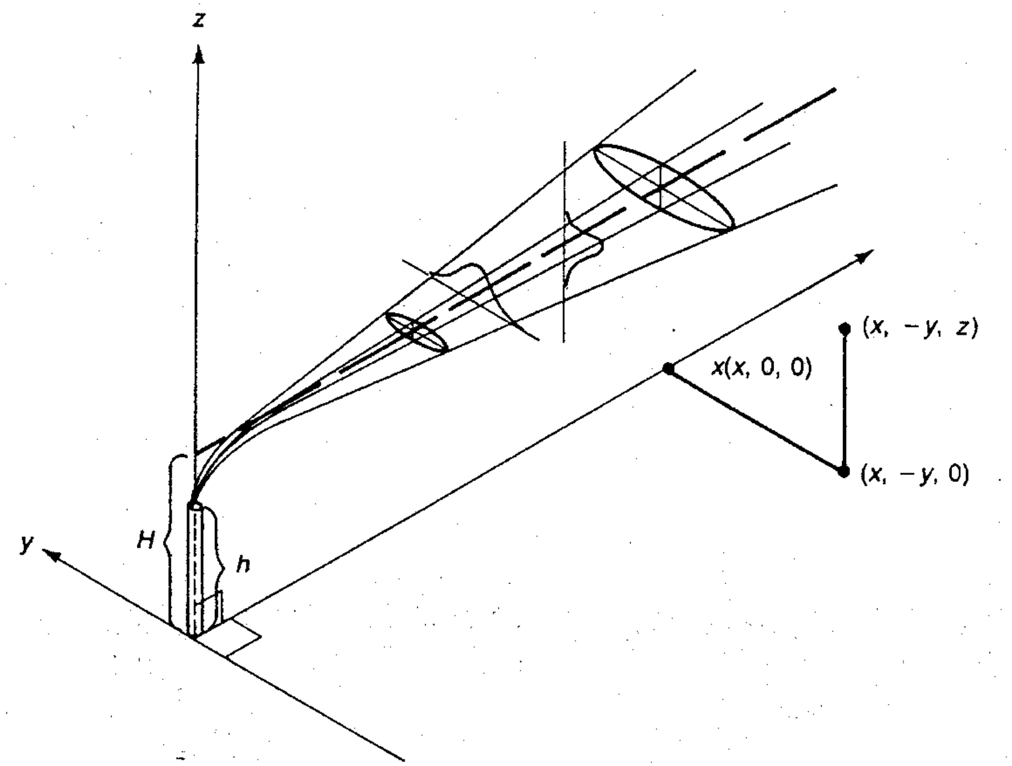
- Atmosphere is anything other than stable or neutral
- Over longer distances
- CFD dispersion models

Some physics

All Dispersion Models

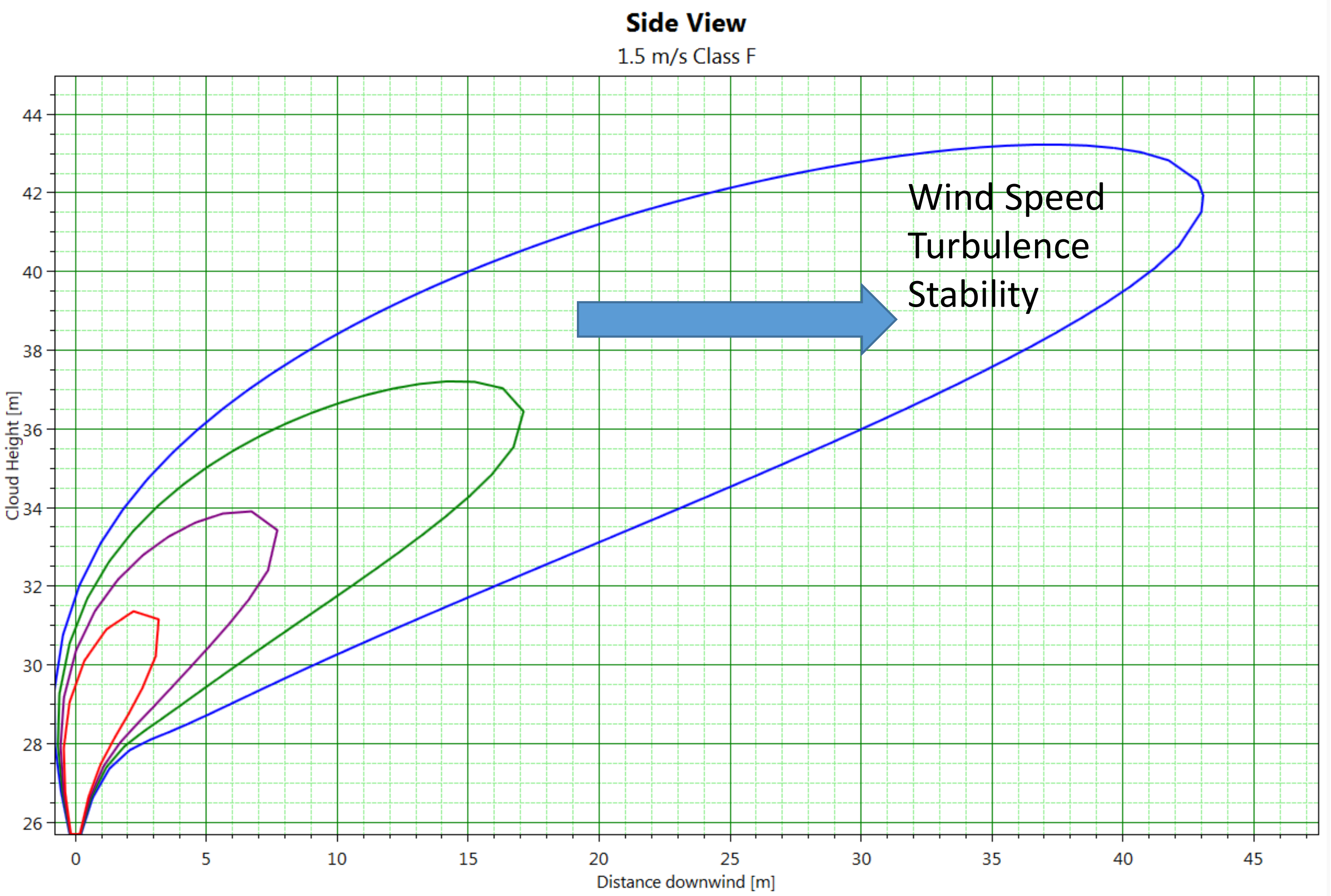
- As the gas plume is swept downwind, the concentration profile spreads out and gas concentrations reduce





All Dispersion Models

MW of Gas
Upstream P
Diameter
Temperature



Atmospheric Boundary Layer (mixing layer)

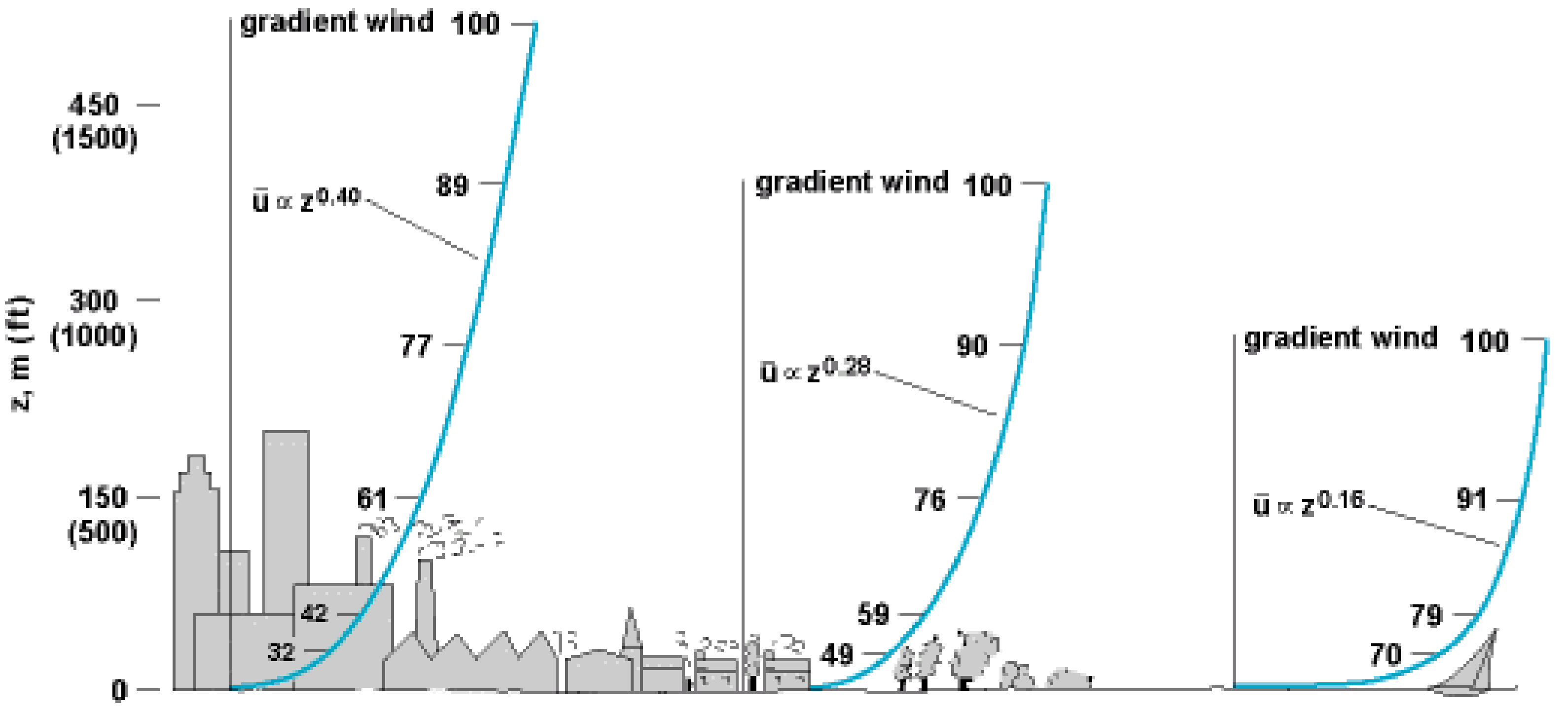
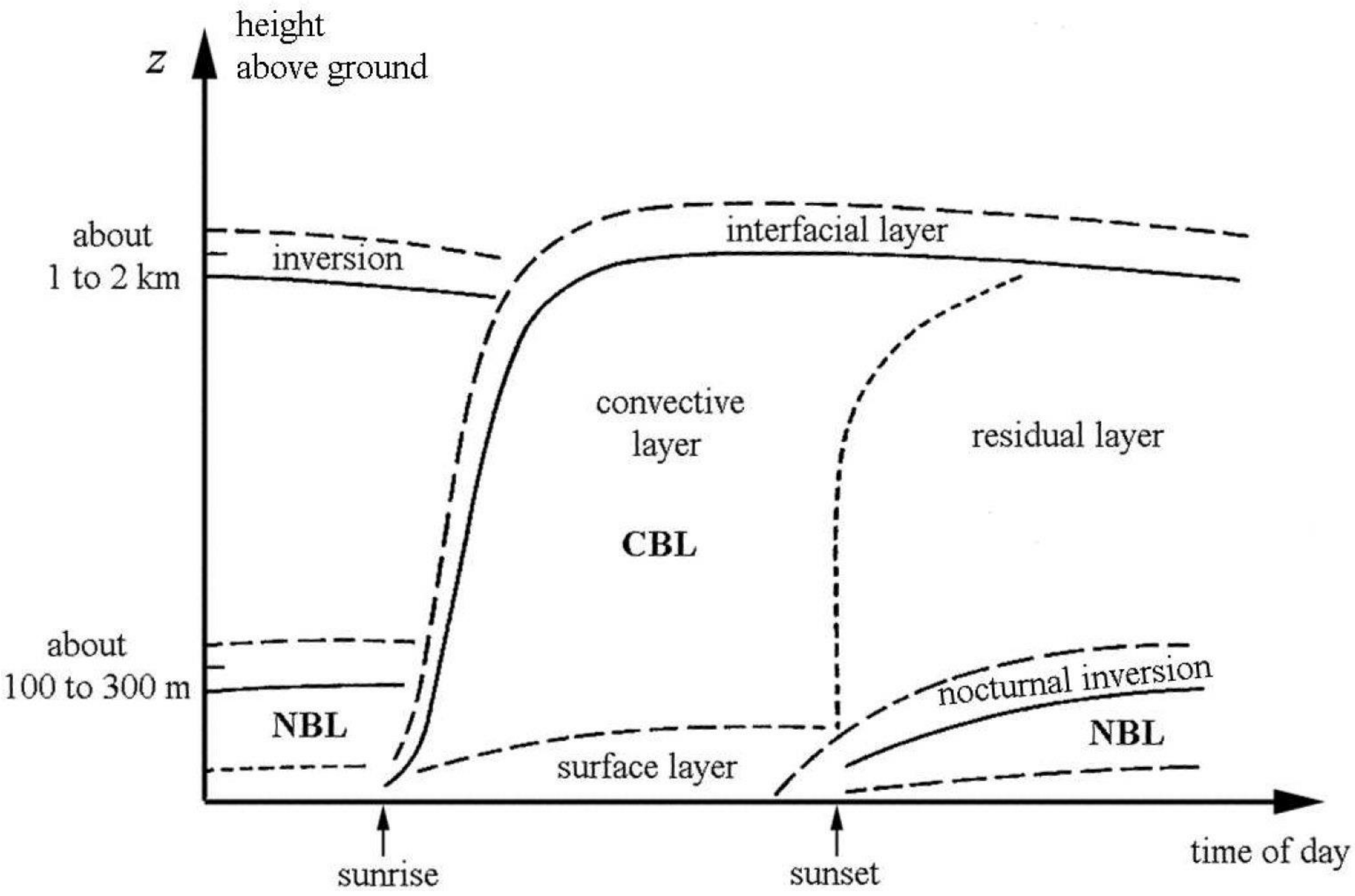


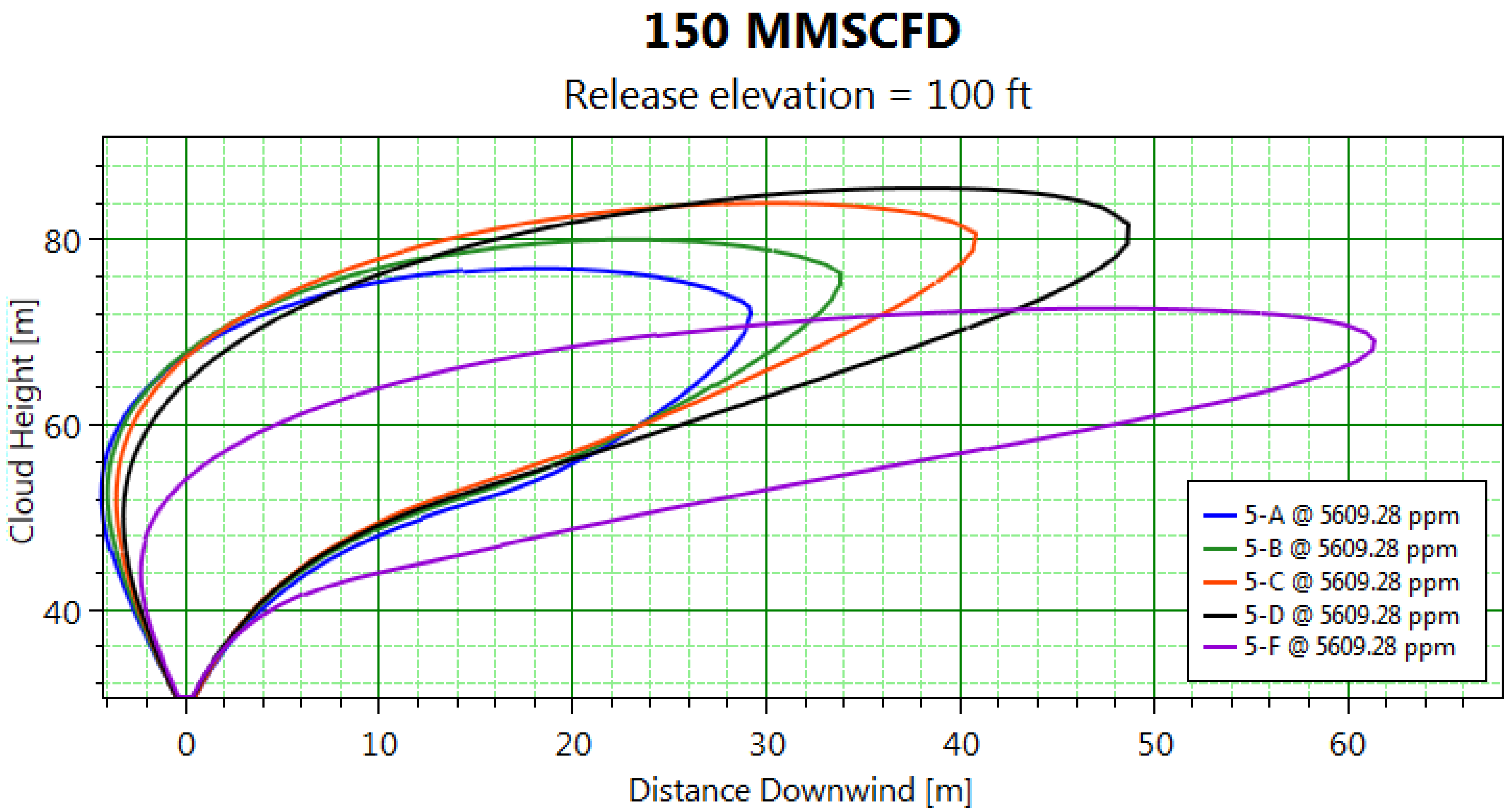
Fig. 3 Atmospheric boundary-layer profiles (plots of average wind speed *u* versus height *z*) over different terrains. Wind speeds are expressed as percentages of the upper level wind (referred to as the gradient wind) above the boundary (or surface) layer.
(After E. J. Plate, Aerodynamic Characteristics of Atmospheric Boundary Layers, AEC Critical Review Series, U.S. Department of Energy, 1971)

Credit: Ali Fazeli egeology.blogfa.com

Atmospheric Boundary Layer (mixing layer)

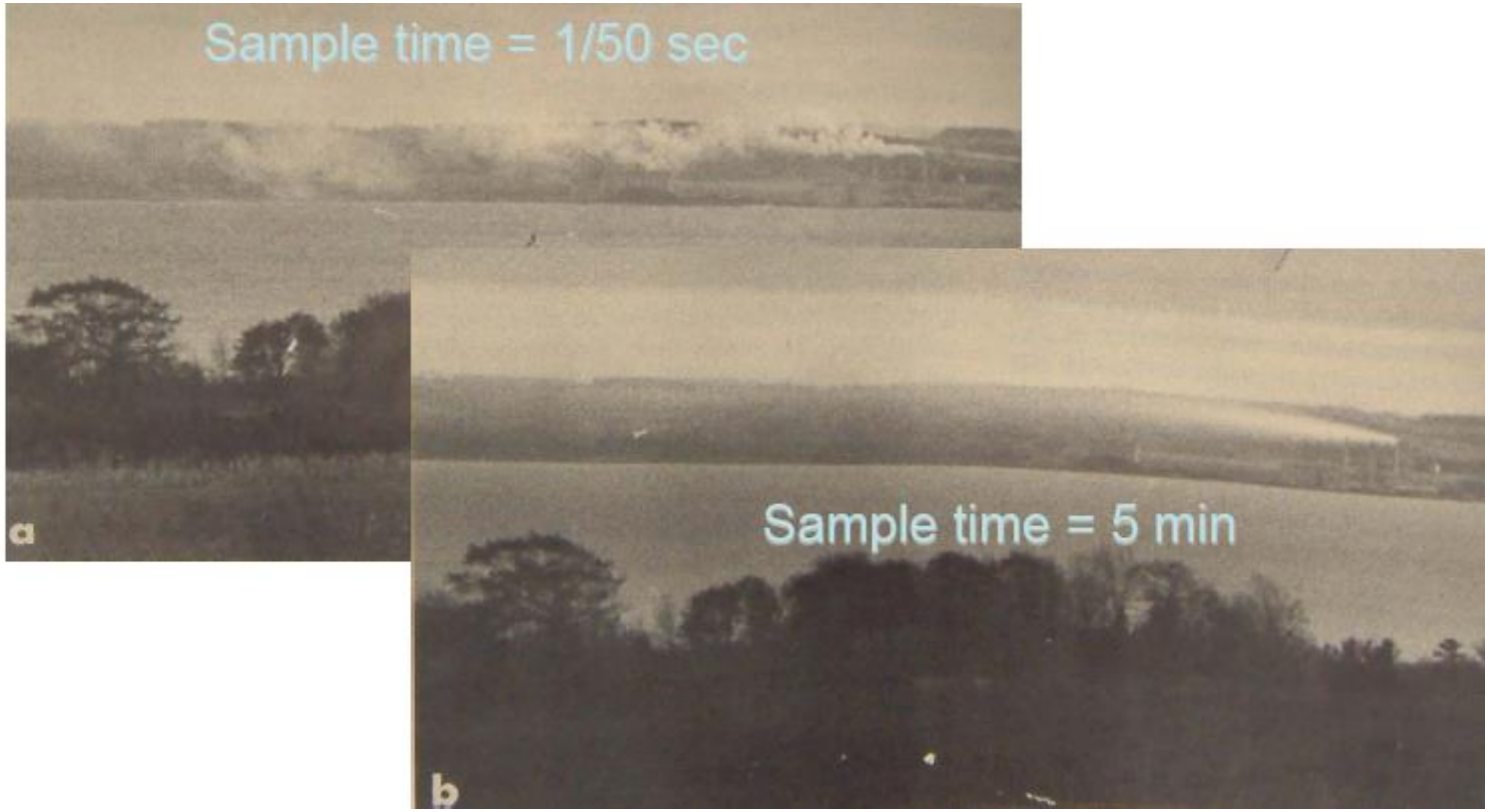


Atmospheric Stability



Stable v unstable

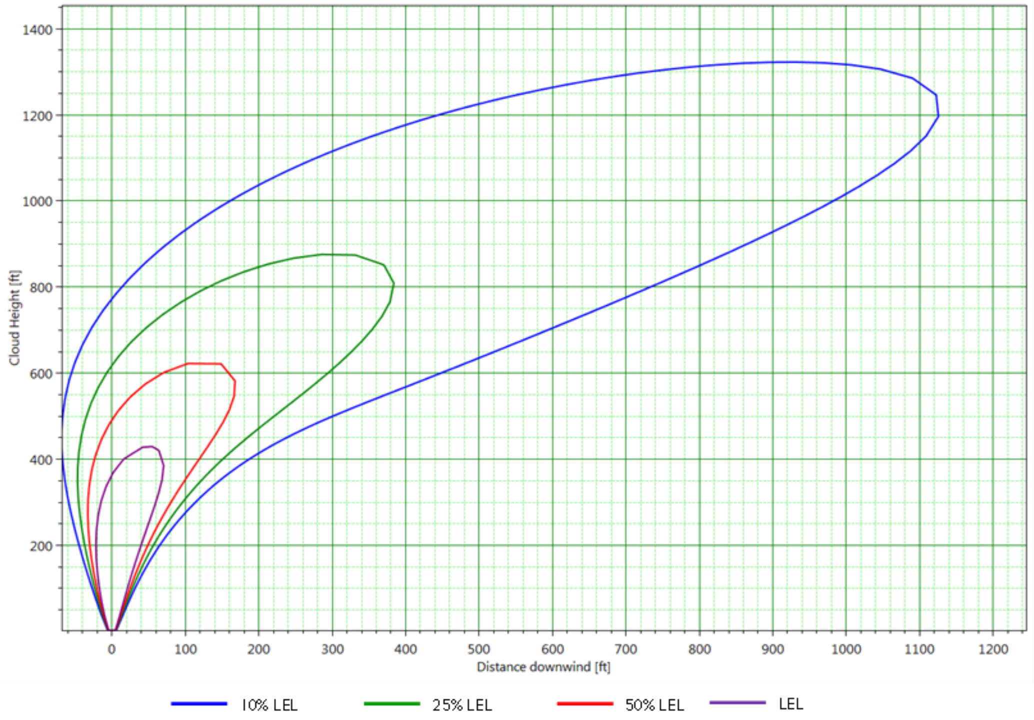
Plume meandering – averaging time



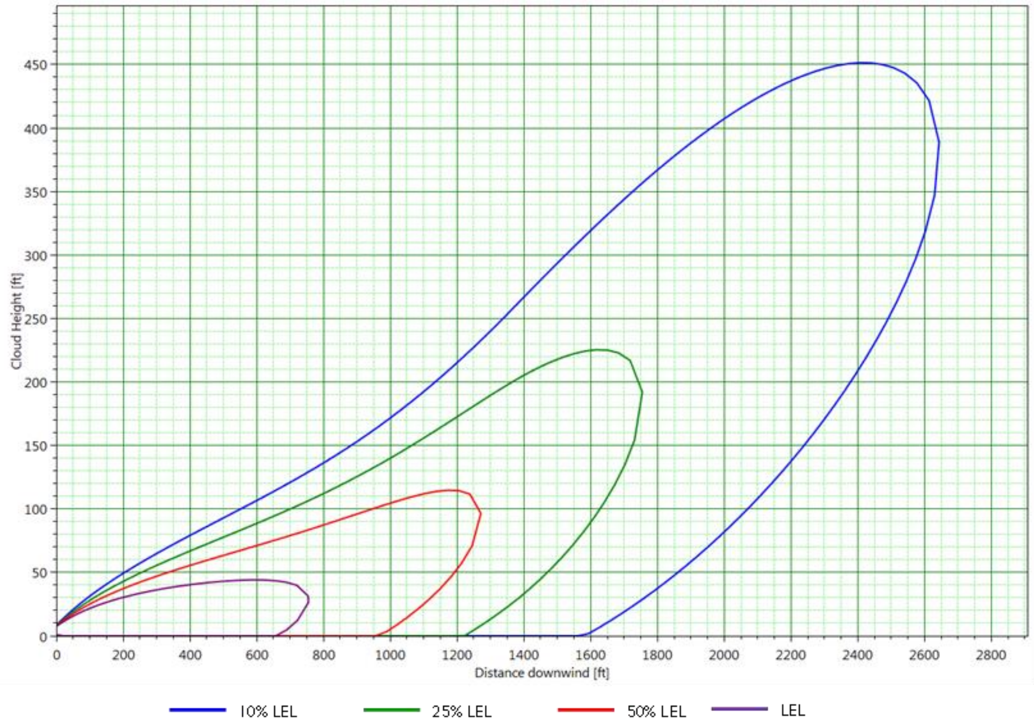
Release orientation

Release orientation

- Vertical release

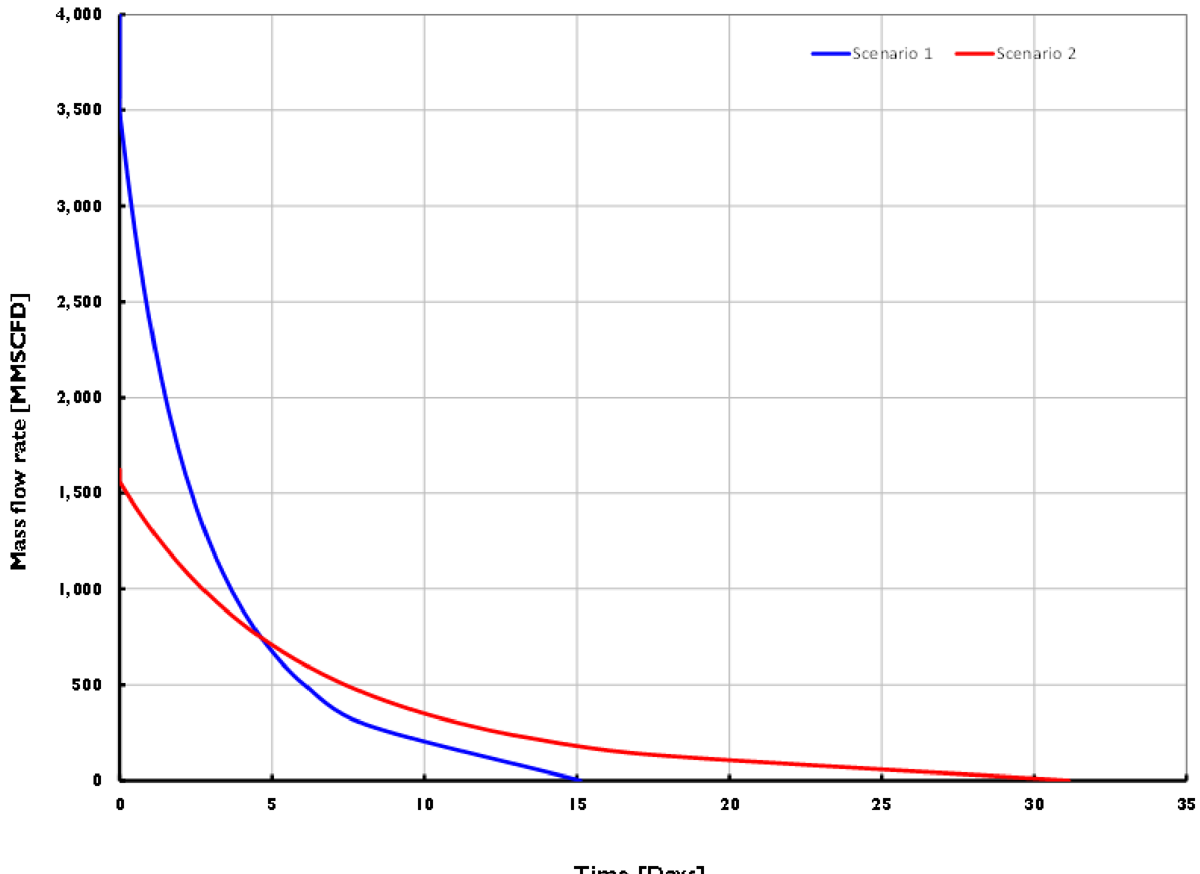


- Horizontal release

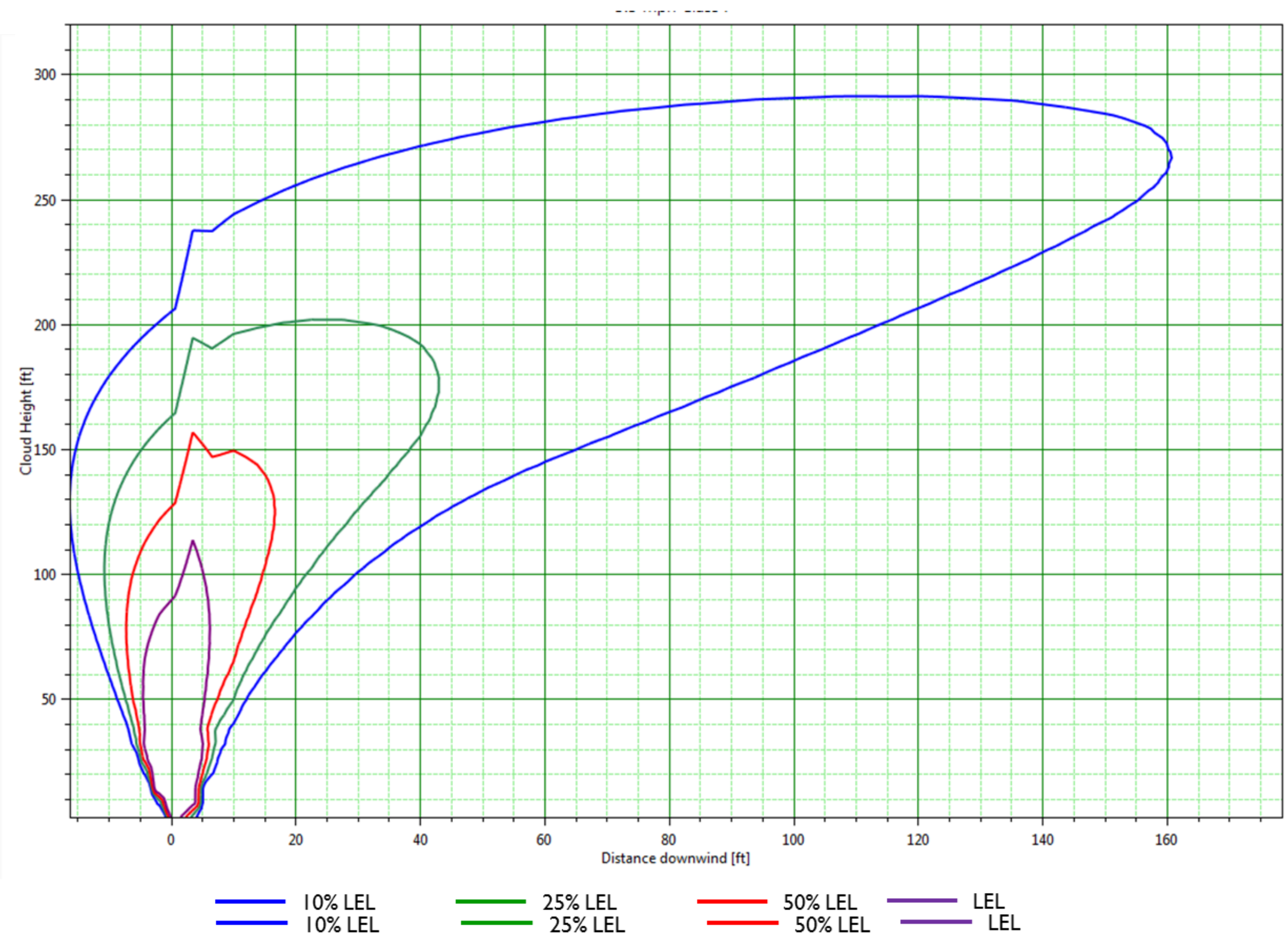


Blow Down – how long with the problem last!

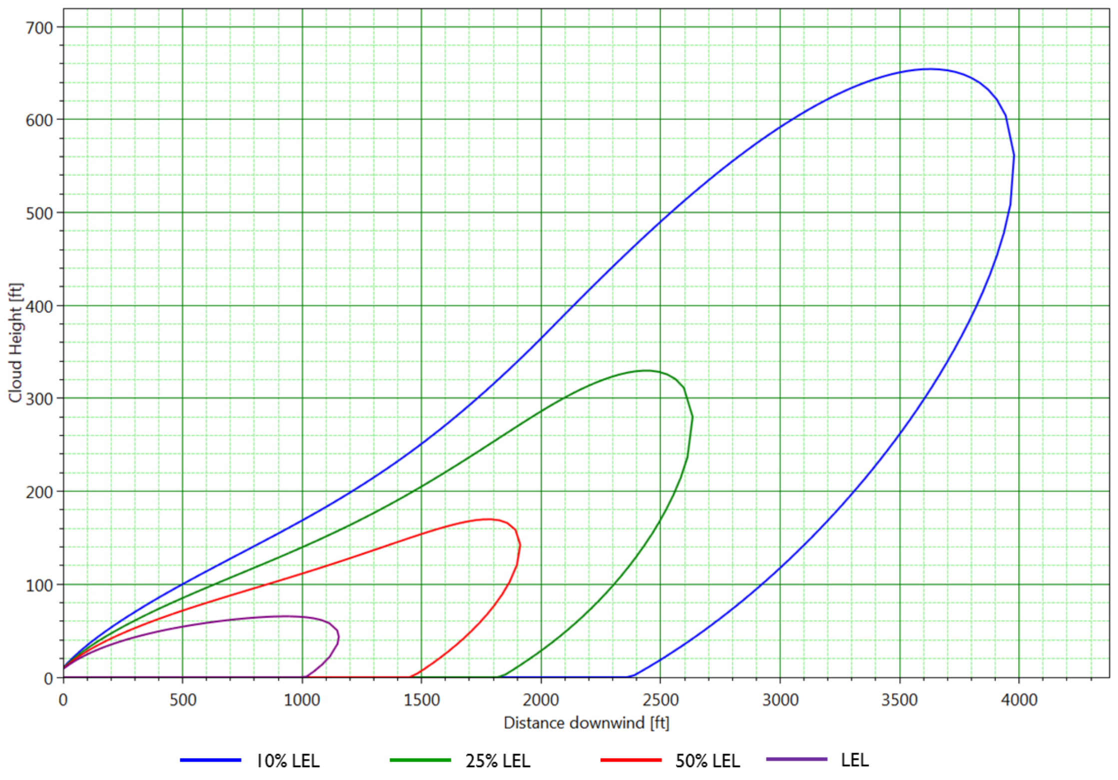
- Depending upon the release scenario the blow out can take days to subside:
  - Reservoir
  - Cavern
  - Release scenario

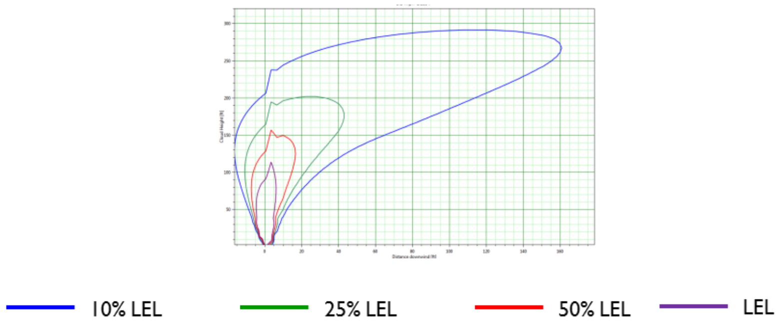


Reservoir or Cavern



Storage specific scenarios



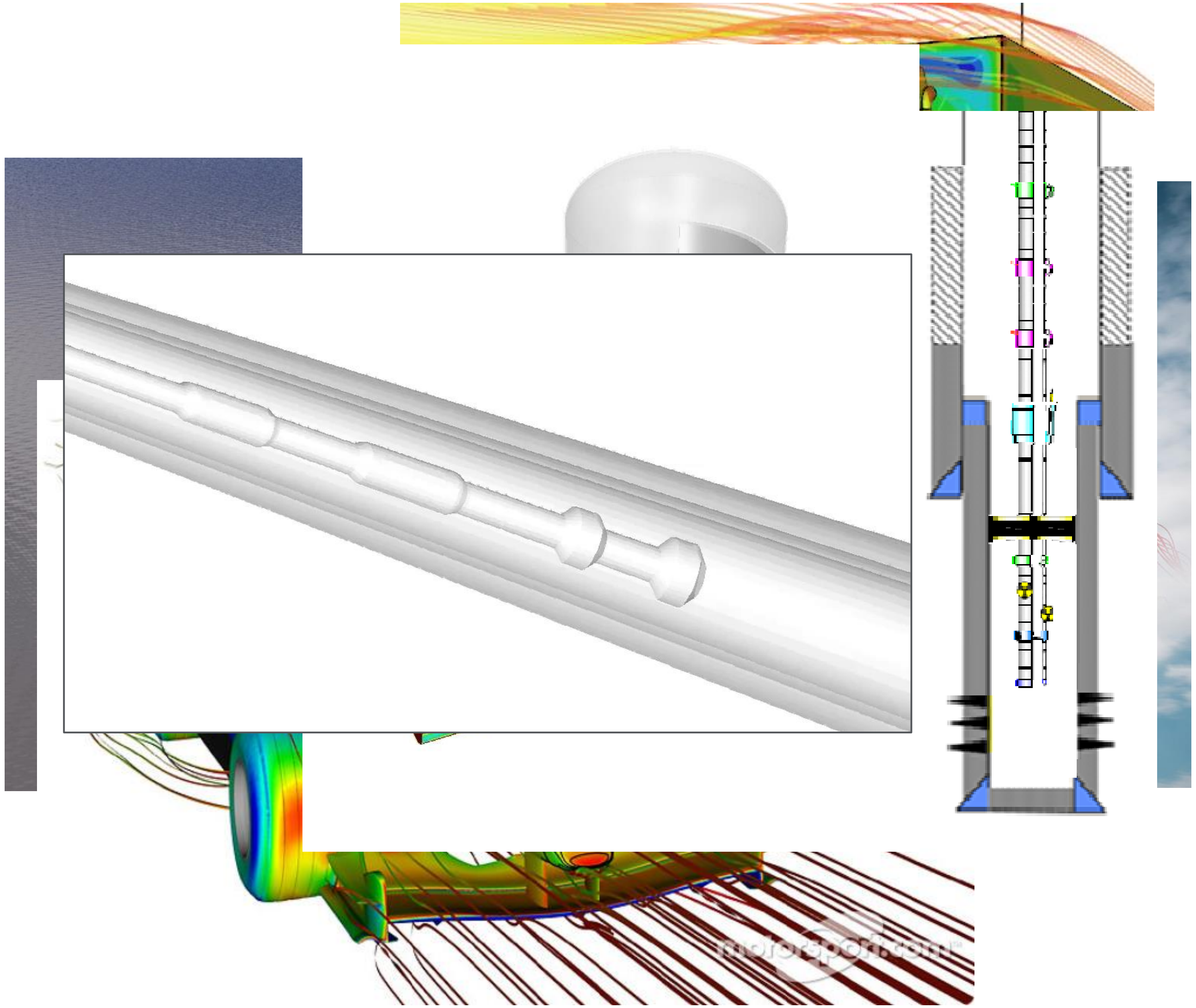


CFD

What, when and why?

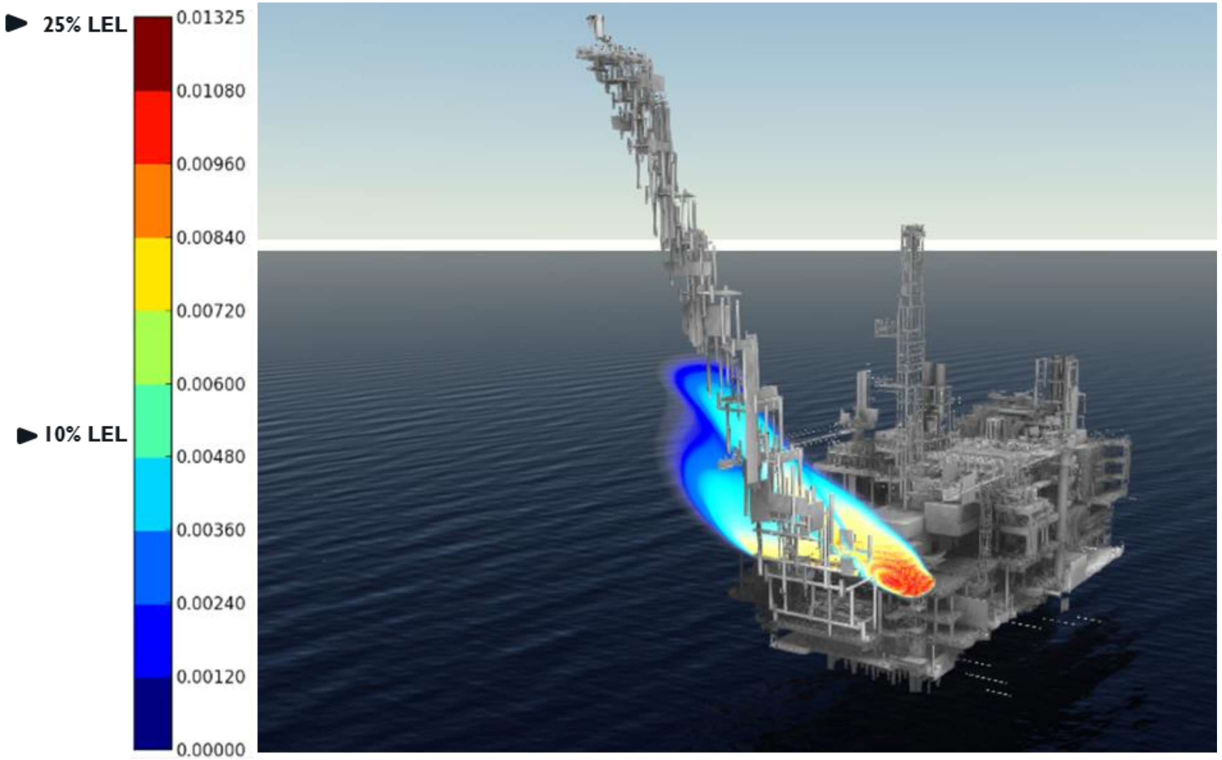
Computational ***F***luid ***D***ynamics

- CFD is a well established analysis tool used across various industries including:
  - Automotive
  - Aerospace
  - Oil and gas
- CFD enables engineers to simulate, visualise and understand complex fluid flows
- WWC use CFD to study the effects of multiphase mixing, separation studies, gas dispersion, plume analysis, fire and blast modelling – see later



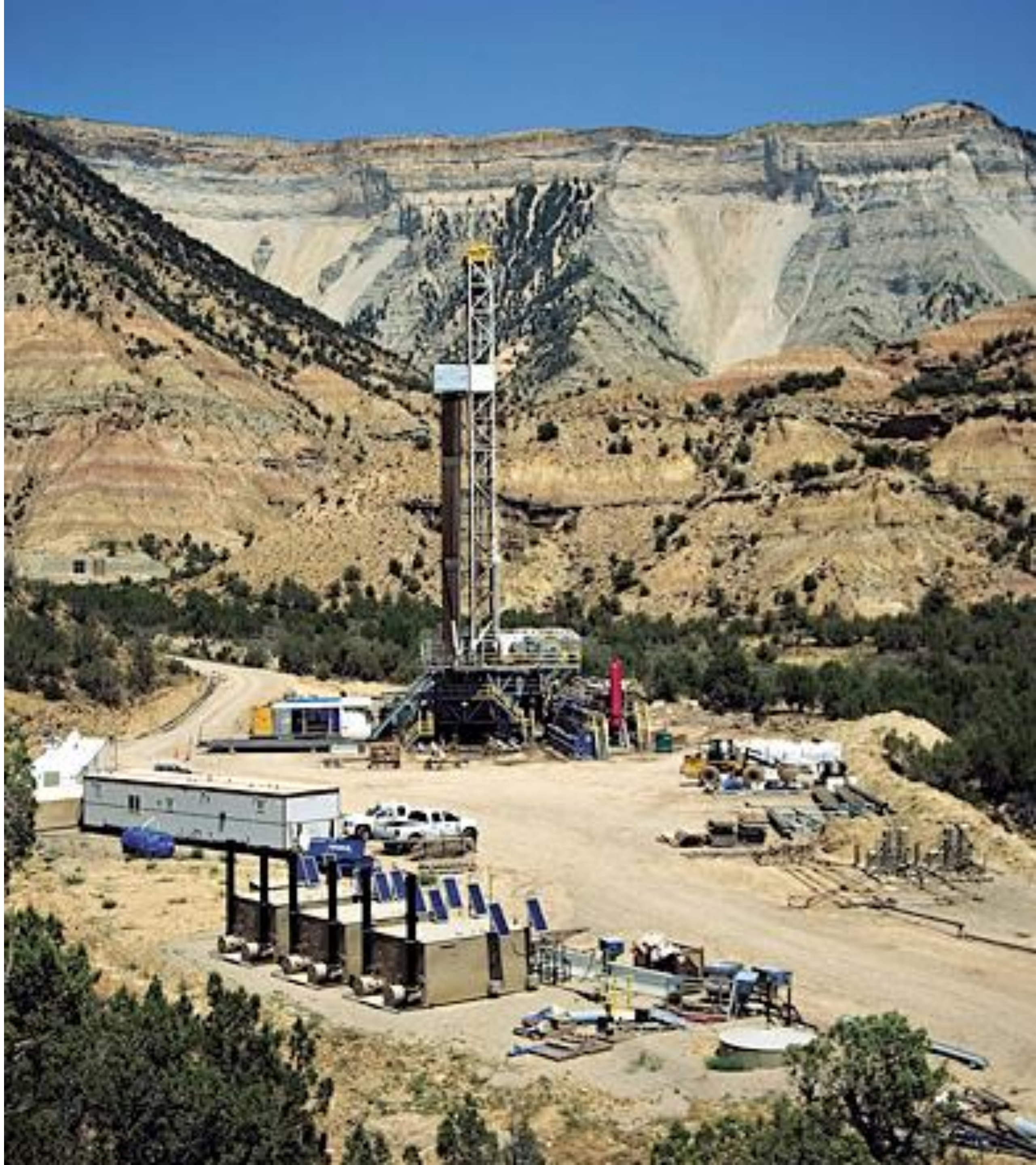
Computational **F**luid **D**ynamics

- Needed for gas dispersion when non-Gaussian behavior dominates
- When well site is surrounded by significant terrain or infrastructure



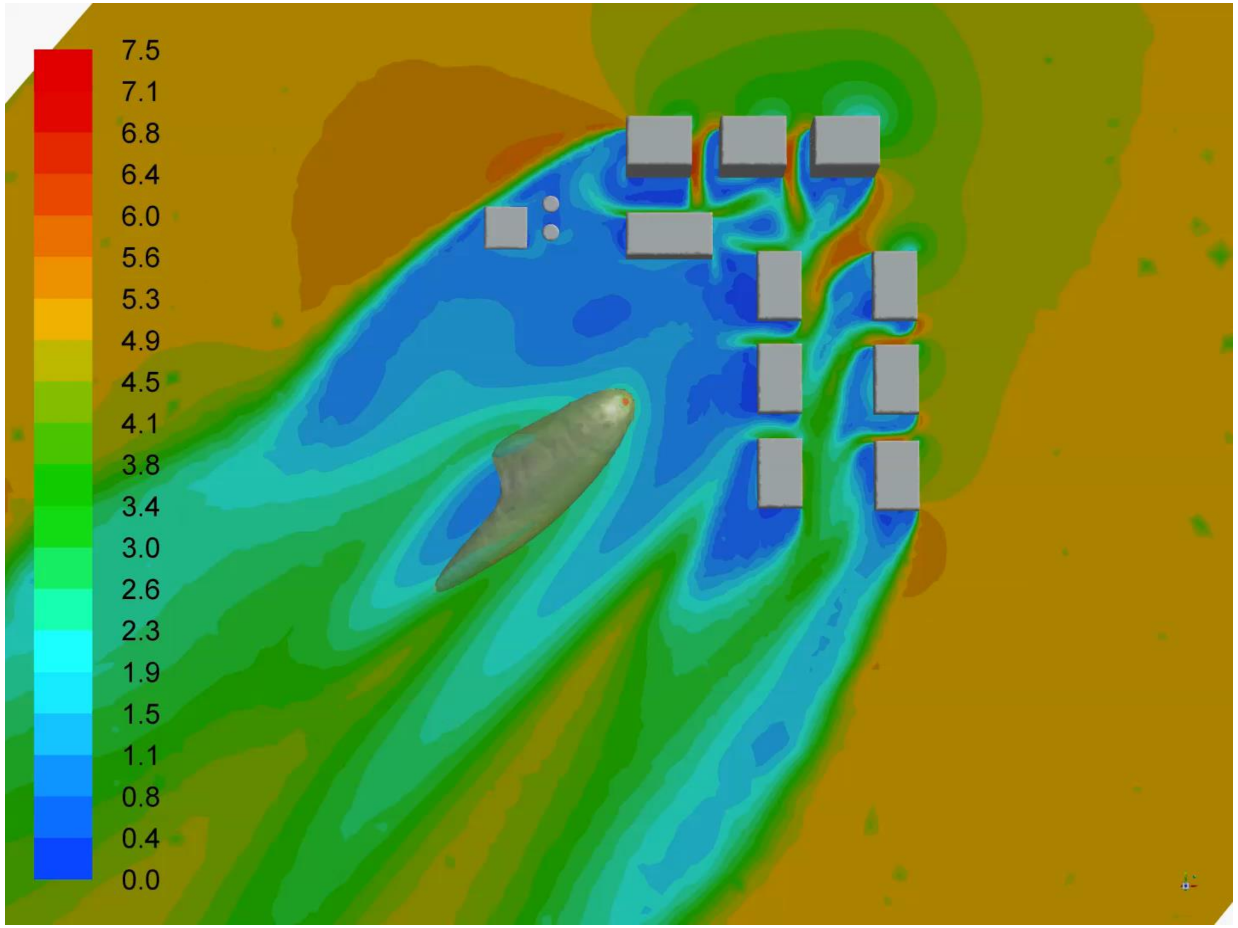
Terrain effects

- Needed for gas dispersion when non-Gaussian behavior dominates
- When well site is surrounded by significant terrain or infrastructure

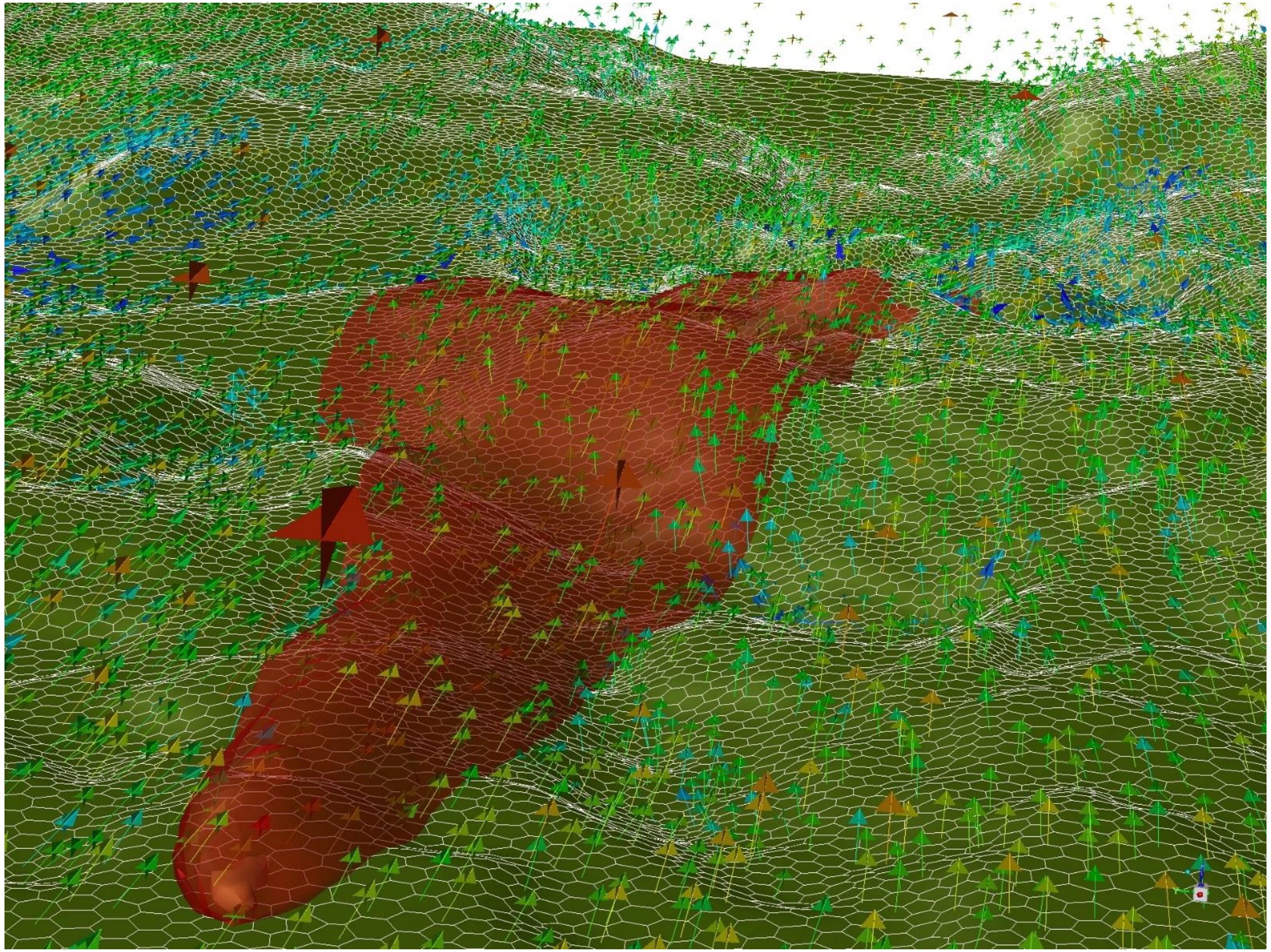


Terrain effects

- Wakes are unstable chaotic structures
- In general the additional turbulence is a good thing as it help disperse the gas
- But building wakes are 3D and include downwash
- This can negatively impact plume position

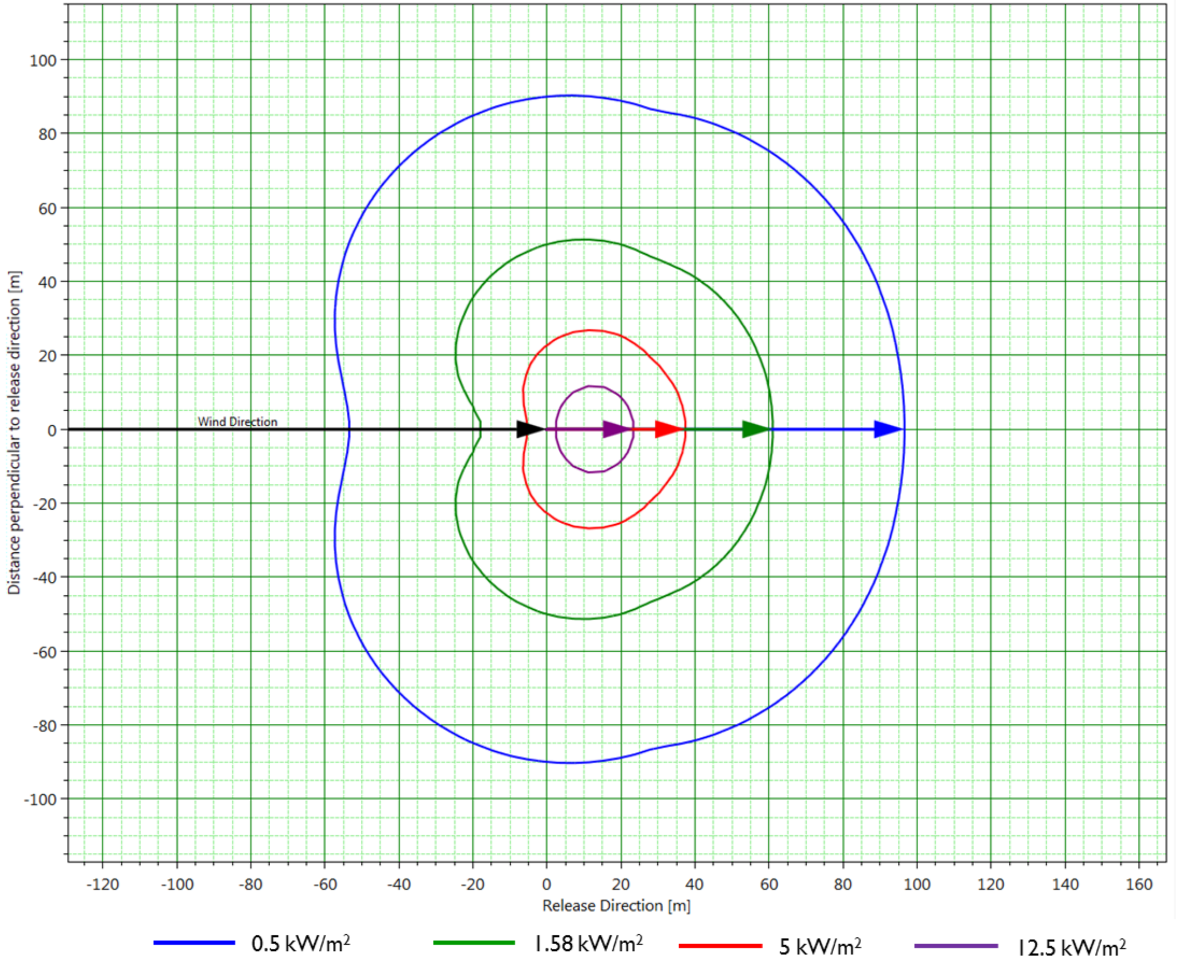


Terrain effects



Radiant Heat & Explosion

Radiant heat effects



Radiant heat effects

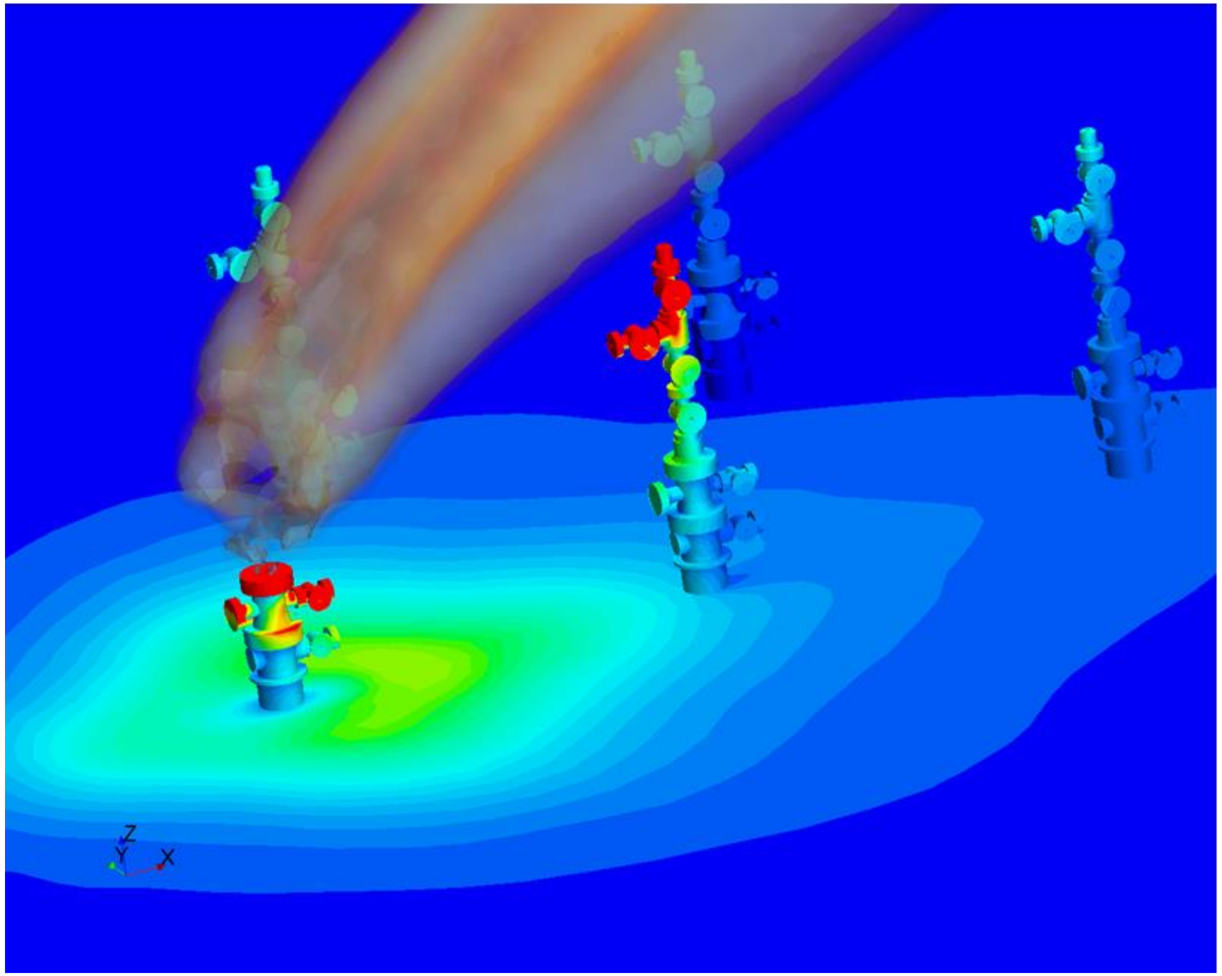
12.5 kW/m^2 (4000 BTU/hr/ft2)
Lethal in 30 s

5 kW/m^2 (1500 BTU/hr/ft2)
Pain threshold limit in 16 s
Minimum lethal flux in 60 s

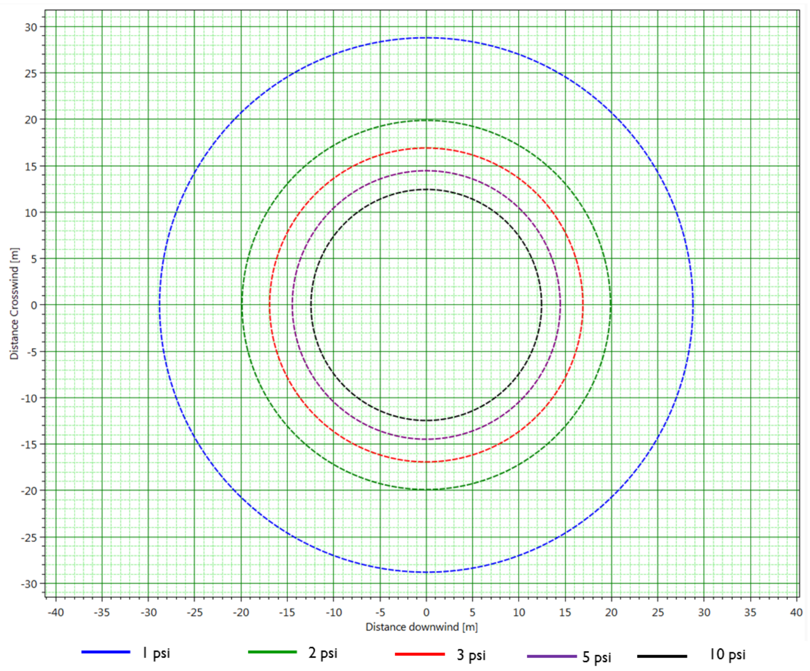
1.58 kW/m^2 (500 BTU/hr/ft2)
Maximum radiant heat intensity at any location where personnel with appropriate clothing can be continuously exposed

1.00 kW/m^2 (316 BTU/hr/ft2)
Sunshine at the equator

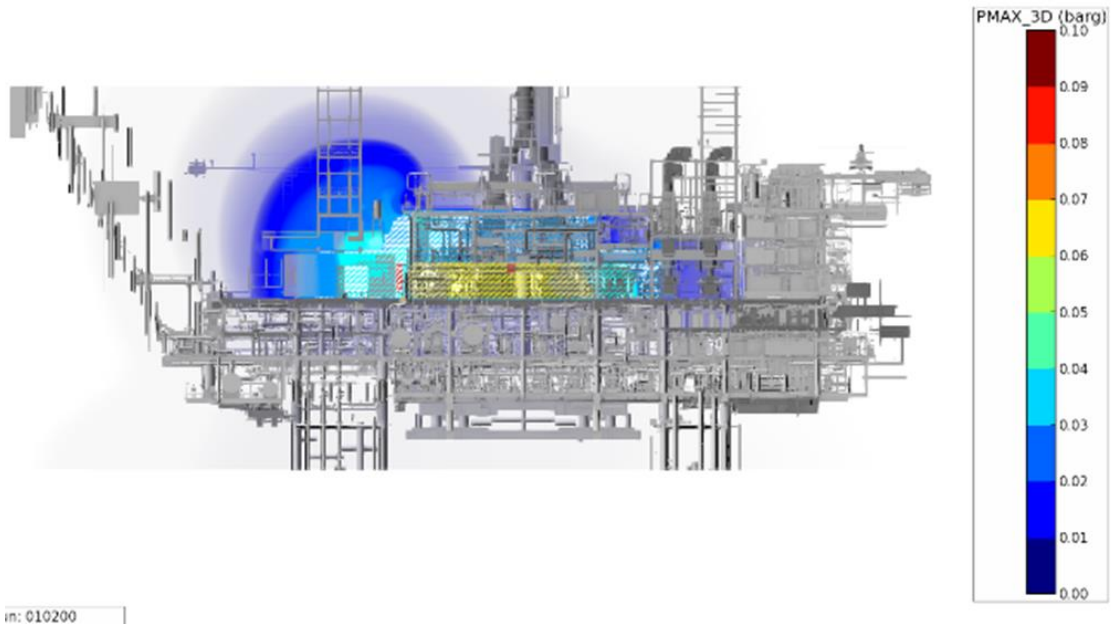
Radiant heat effects



Explosion

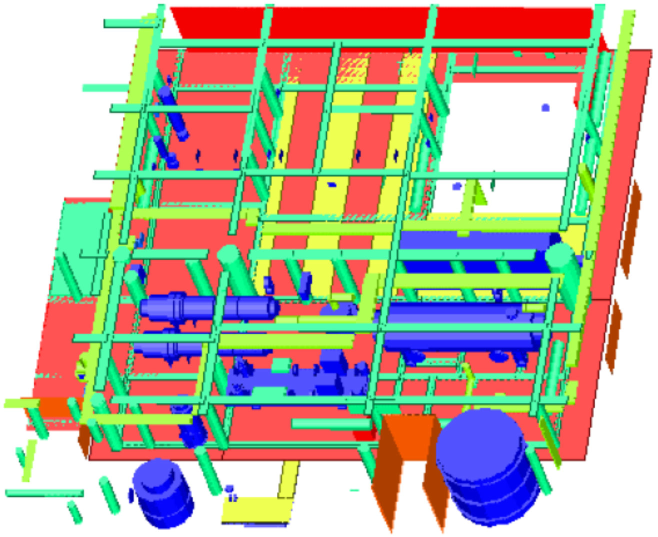


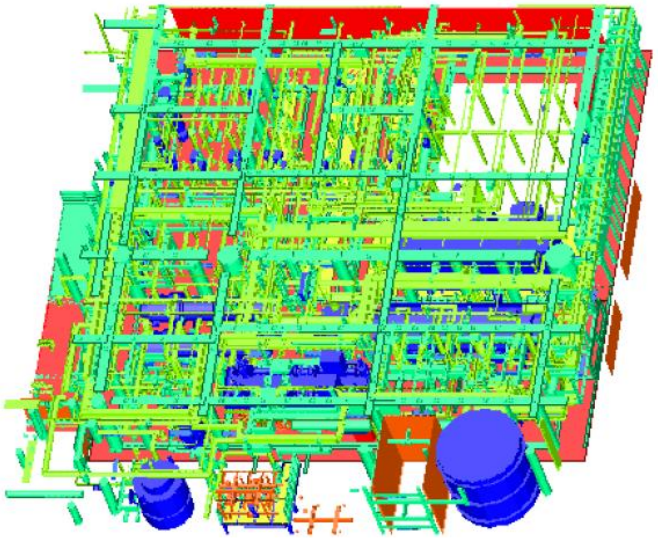
Distance Crosswind [m]
Distance downwind [m]
1 psi
2 psi
3 psi
5 psi
10 psi

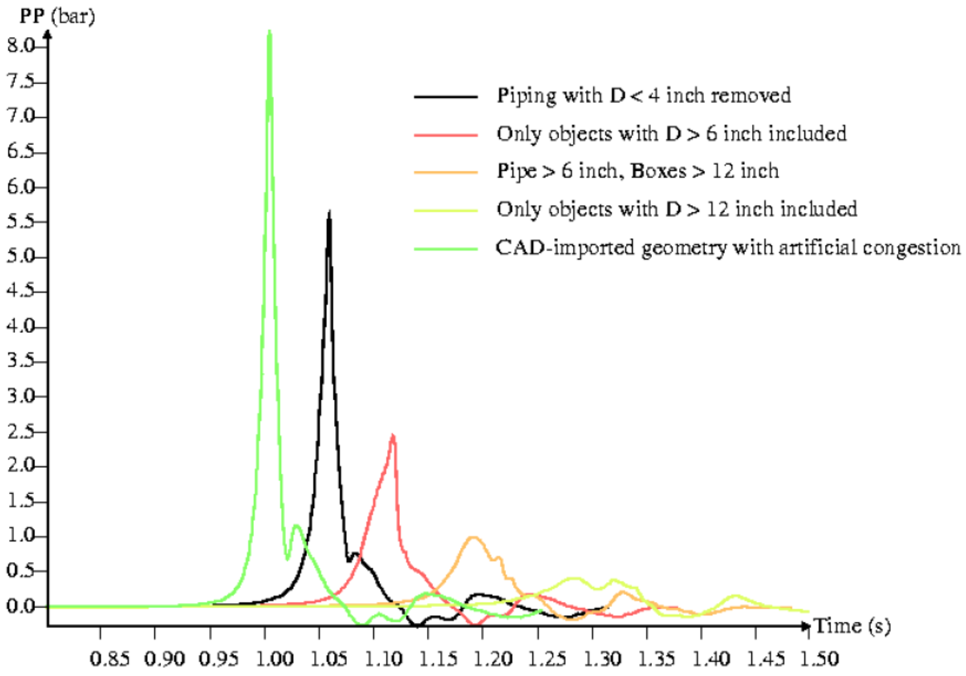


PMAX_3D (barg)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00

Explosion

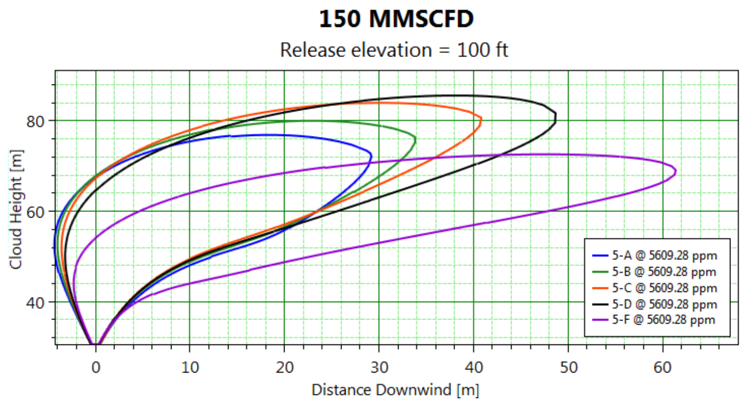


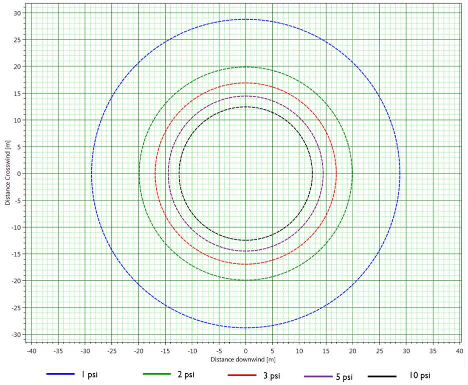




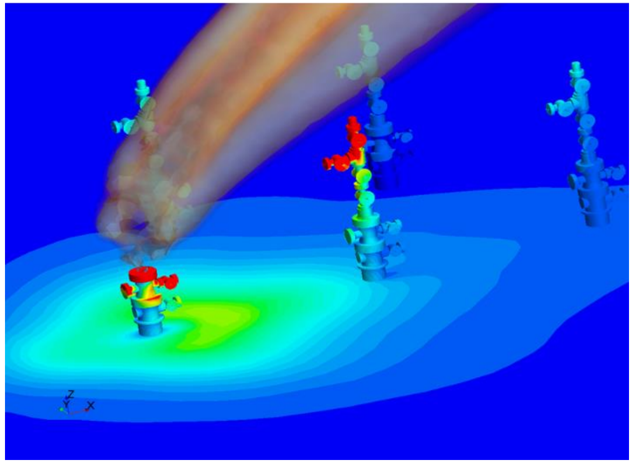
PP (bar)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Piping with D < 4 inch removed
Only objects with D > 6 inch included
Pipe > 6 inch, Boxes > 12 inch
Only objects with D > 12 inch included
CAD-imported geometry with artificial congestion
Time (s)
0.85 0.90 0.95 1.00 1.05 1.10 1.15 1.20 1.25 1.30 1.35 1.40 1.45 1.50

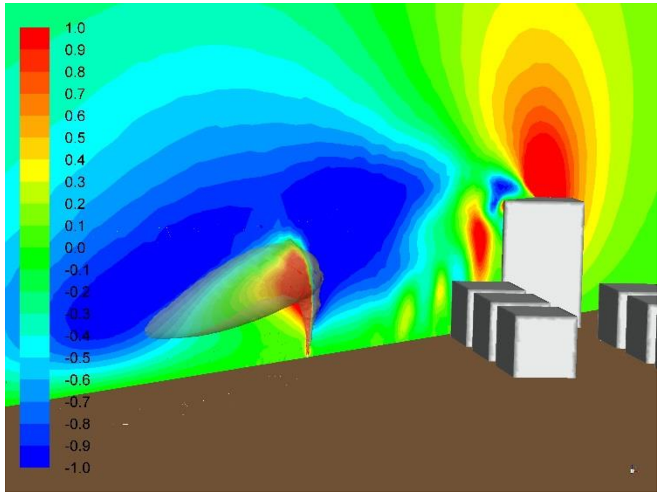
Summary





Start simple high level …. progress to complex





Thank you, any questions

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