RESEARCH AND GUIDANCE FROM HSE

Notional 2-ton pressurized anhydrous ammonia nurse tank release- Discharge and dispersion modelling in Phast.

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Health and Safety Executive (HSE)

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Research - HSE funded to provide evidence which underpins its policy and regulatory activities
Guidance - freely available to help people comply with health and safety law

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Outline

- Nurse tanks and the Beach Park ammonia incident.
- Surface roughness estimation.
- ALOHA source term.
- Set-up in Phast.
- Discharge results (release rate) - comparison with ALOHA.
- Dispersion results- centreline concentrations and isopleths of the cloud.
- Conclusions.

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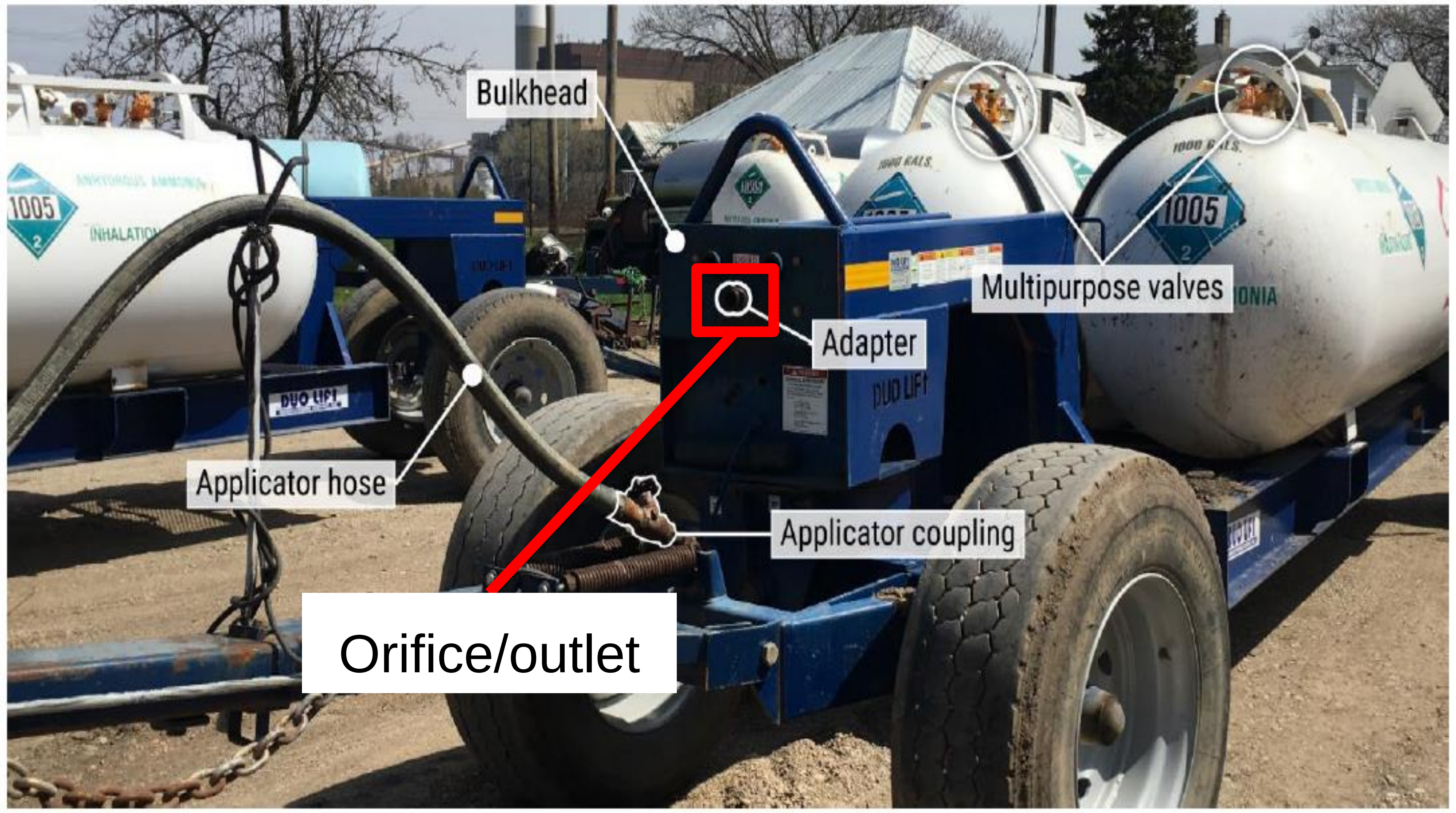
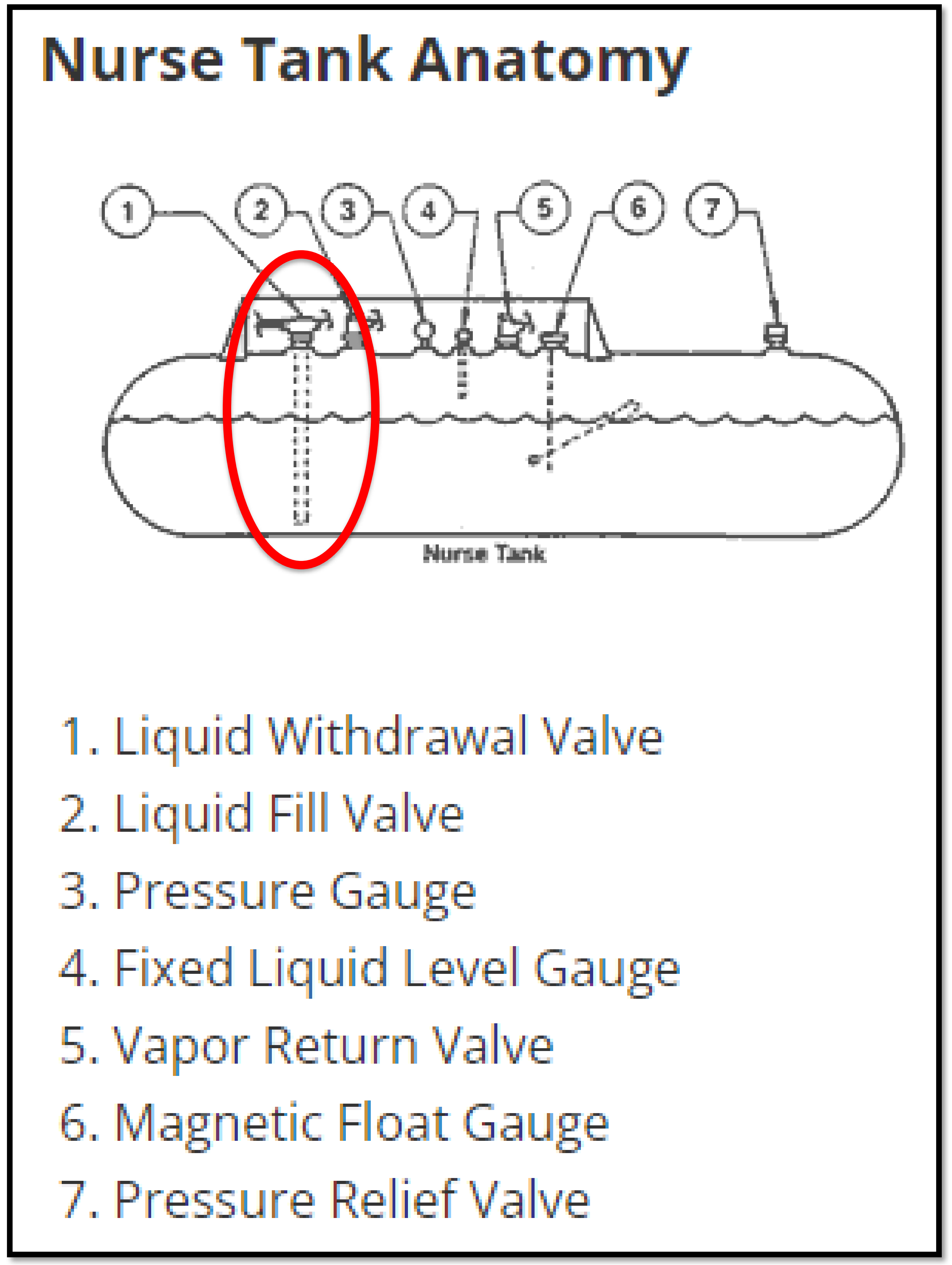
Beach Park ammonia incident

- Release of anhydrous ammonia from a nurse tank configuration, in Beach Park, Illinois, USA. 25 April 2019.
- ~1.5 tons of ammonia released.



Trailer and tank unit. Photo taken from [1].
Photograph courtesy of PHMSA.



Source: https://www.mda.state.mn.us/nurse-tank-anatomy

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Test sites and surface roughness z_0

- Analysis provided by Joe Chang (RAND).
- National Land Cover Database (NLCD) gives predominant land use type.
- EPA's AERMOD regulatory model assigns a surface roughness to land use.
- **Two surface roughness lengths used: 0.7 and 1.3 (m).**

Test site	Predominant land use	Over distance	z_0 (m)
#1	Evergreen forest	<2km	1.3
#2	Woody wetlands	<1km	0.7
#3	Evergreen forest	<2km	1.3

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ALOHA source term

Source term predicted by ALOHA for a notional 2-ton nurse tank.

- Leak from short pipe or valve in horizontal cylindrical tank.
- Flammable chemical escaping from tank (not burning).
- **Tank Diameter: 4 feet. Tank Length: 10 feet.**
- Tank Volume: 940 gallons.
- Tank contains liquid.
- **Internal Temperature: 25° C.**
- Chemical Mass in Tank: 2.13 tons (tank is 90% full).
- **Circular Opening Diameter: 1.5 inches.**
- **Opening is 0 feet from tank bottom.**
- Note: RAILCAR predicts a stationary cloud or 'mist pool' will form.
- Model Run: traditional ALOHA tank.
- **Release Duration: 5 minutes.**
- Max Average Sustained Release Rate: **471 kilograms/min** (averaged over a minute or more).
- Total Amount Released: 1,932 kilograms.
- Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

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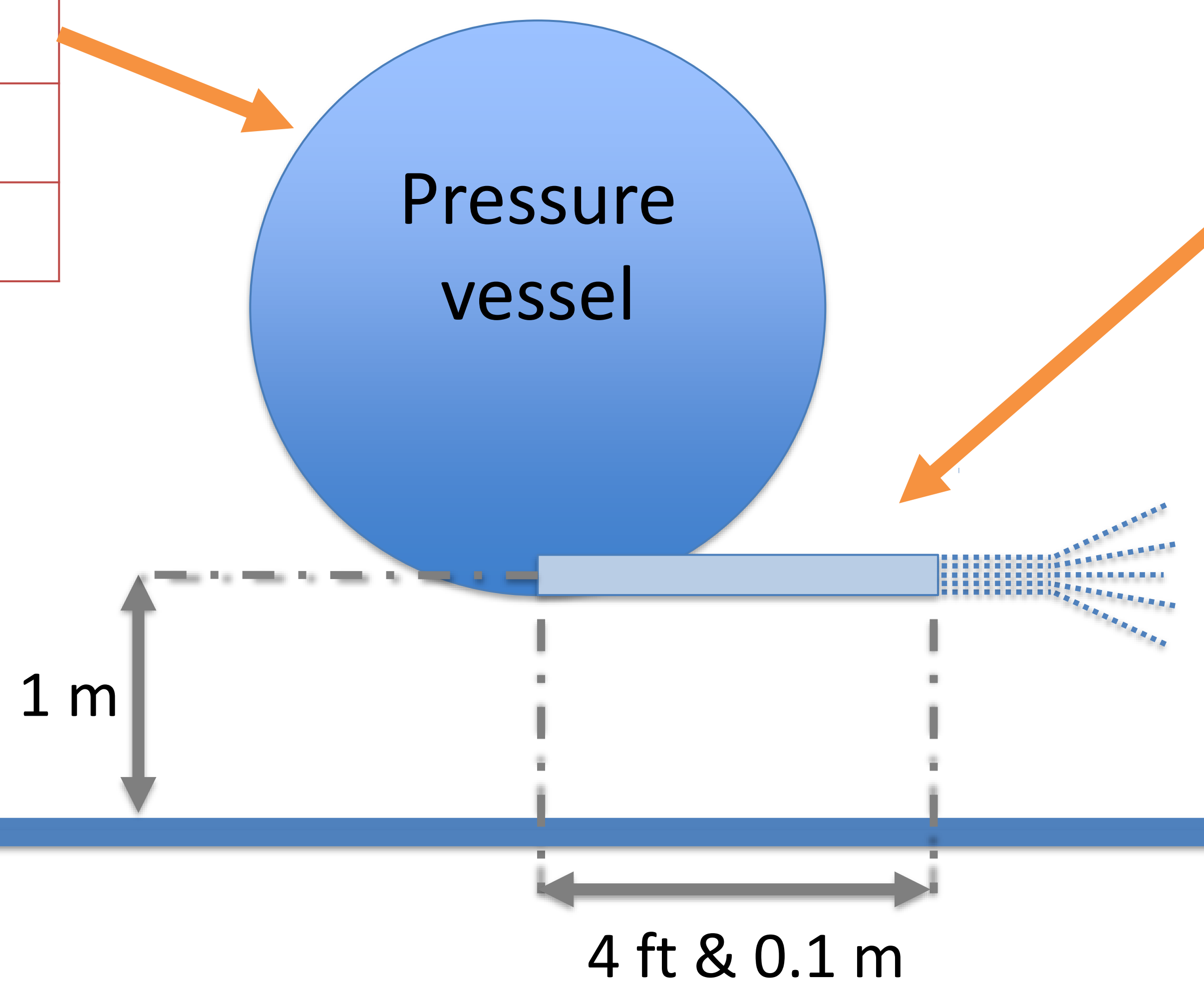
Input conditions for Phast

- Simulations ran in the Phast consequence model.
- Phast provides discharge (from the pipe connected to the vessel), in addition to downwind dispersion.

Short pipe	
Release angle	Horizontal
Release height	1 m
Internal diameter	1.5 inch
Pipe length	4 ft (base case), and 0.1 m.
Release height from vessel bottom	0 m

Inventory	
Fluid	Ammonia (liquid)
Total mass	2000 kg
Temperature	25 °C
Pressure (Psat)	10 bar (abs)



Atmosphere	
Ambient temperature	25 °C
Ambient pressure	1.01325
Relative humidity	70%
Wind speed & stability	3/D and 1.5/F
Concentration averaging time	600 s

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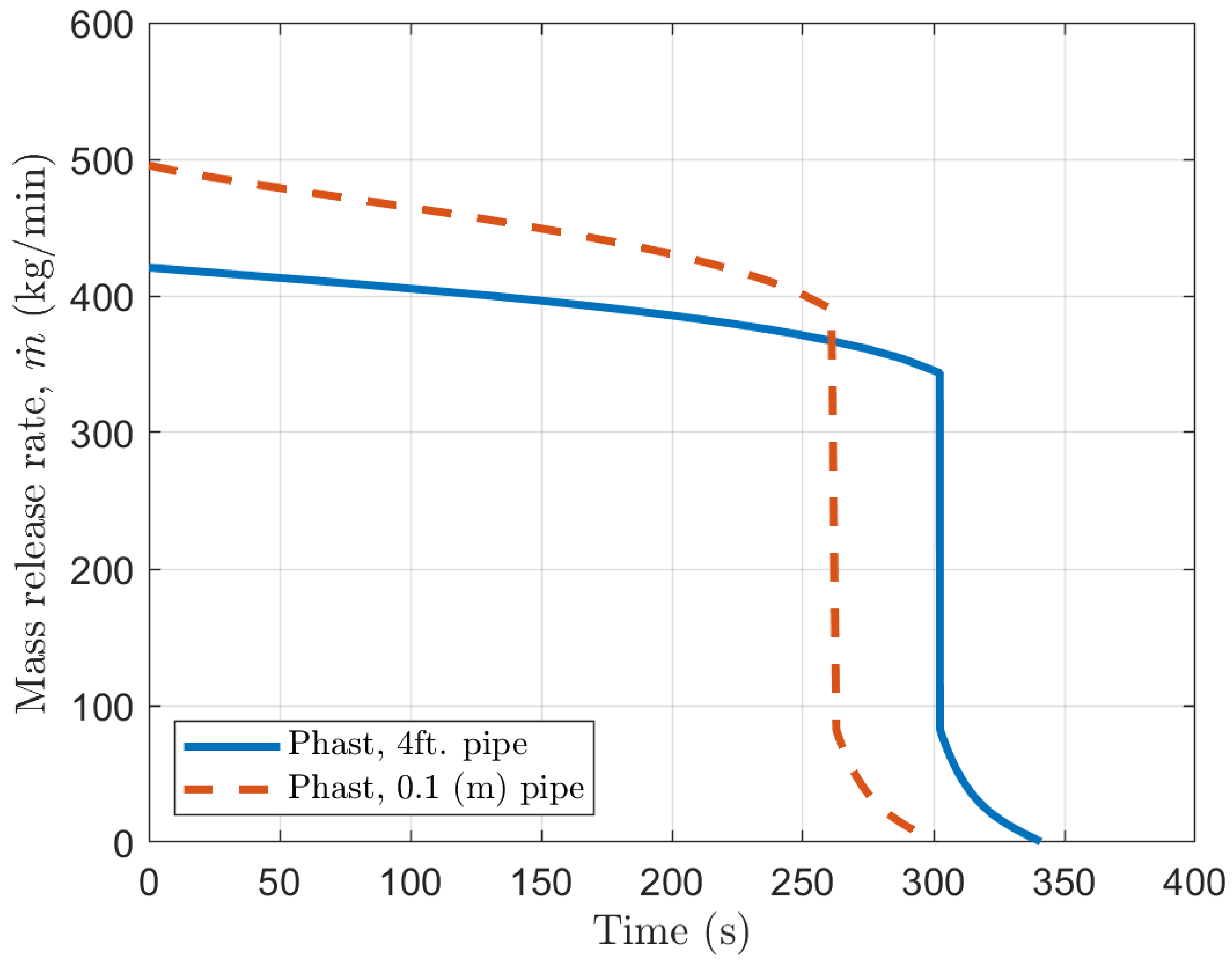
Release rate

- Model: short pipe release from a vessel.
- Pipe length set equal to tank diameter (4 foot).
- Additional run with shorter 0.1 m pipe.
- Total mass released: $\int \dot{m}\, dt = 1996$ kg.
- Increasing the pipe length from 0.1 (m) to 4 (ft) lowers the release rate, but increases the time to empty.



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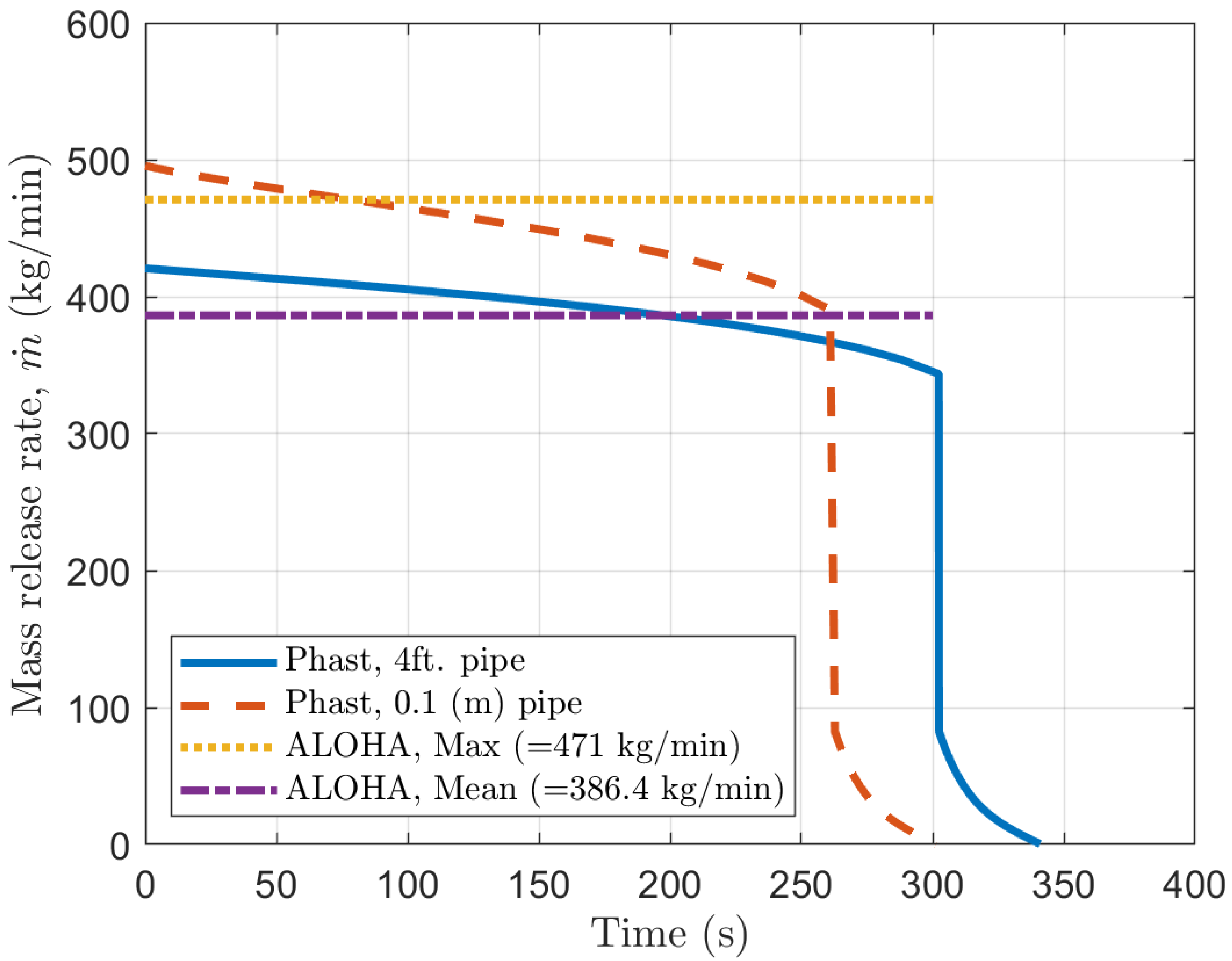
Release rate

- Reported ALOHA source term results:
  - Max average sustained release rate: 471 kg/min (averaged over a minute or more).
  - Average release rate: 386.4 kg/min (averaged over 5 minutes).
- **386.4 kg/min** used in SLAB to predict downwind dispersion.
- Release rate from 4ft pipe in Phast (averaged over first 5 mins): **393.9 kg/min**.
  - Comparable to ALOHA's time-averaged release rate.
- The 4 ft pipe model is used in subsequent analysis.



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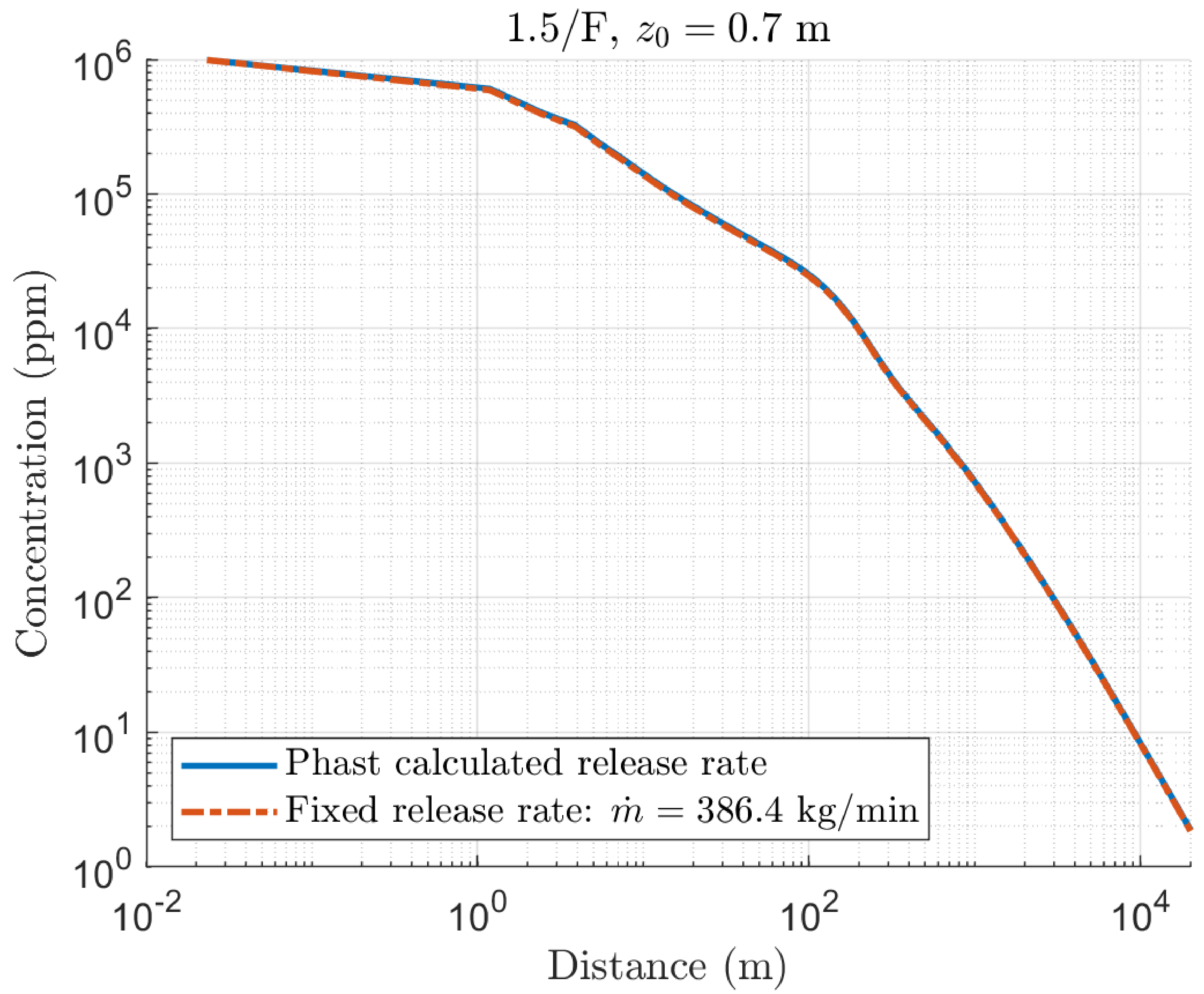
Matching release rates to ALOHA

- Phast calculates the discharge conditions as input to the dispersion model. SLAB is using the inputs generated by ALOHA.
- Does this make a difference to the downwind dispersion?
- Fix release rate in Phast to match that of ALOHA (386.4 kg/min).
- No significant difference seen in the downwind dispersion.



Case	x_{AEGL-3} (m)	
	Phast $\dot{m}$ calculated	Fixed $\dot{m} = 386.4$ (kg/min)
1.5/F, $z_0 = 0.7$	425	419

Distance to AEGL-3 (x_{AEGL-3}), 2700 ppm, 10 min exposure.

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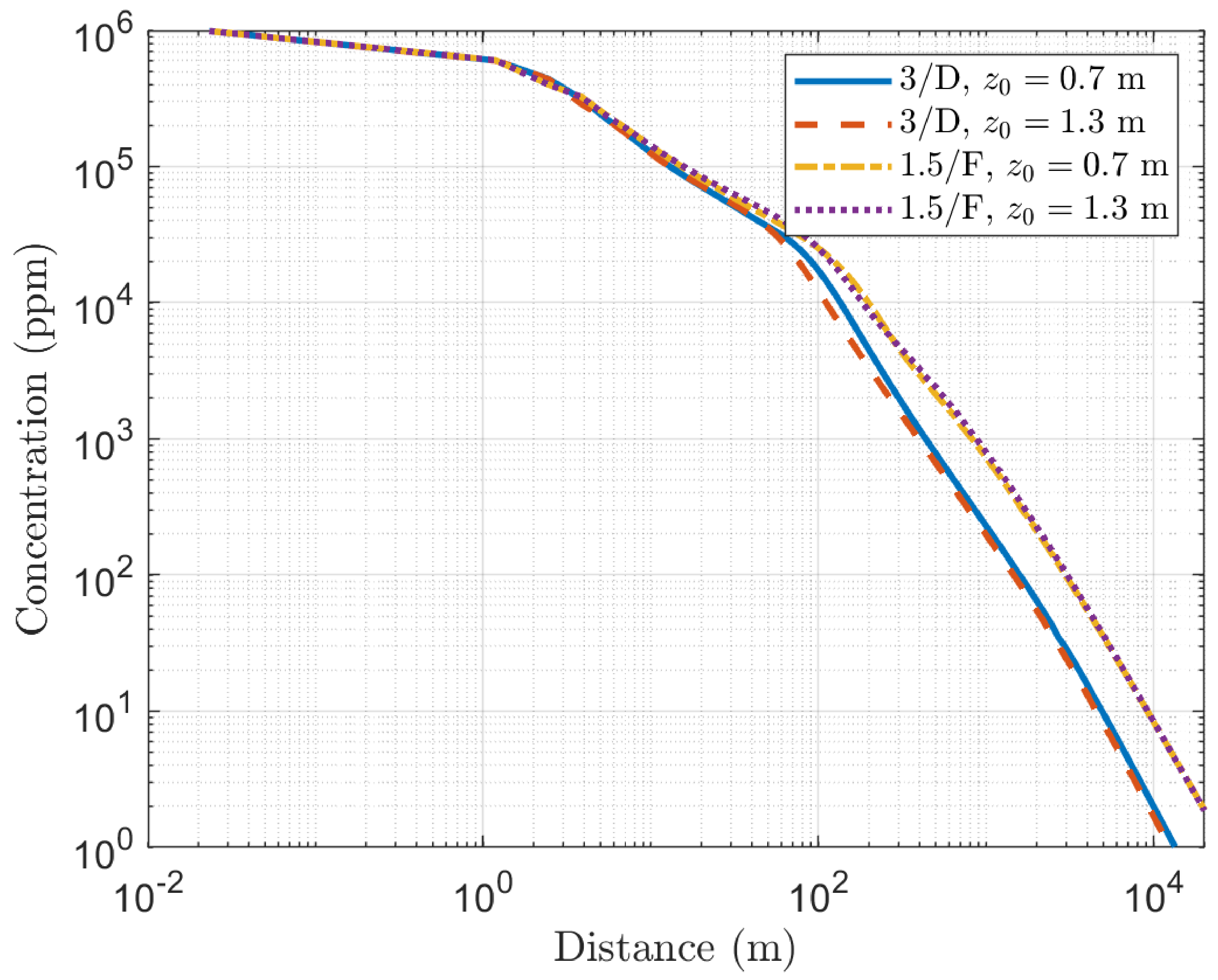
Centreline concentrations

- Effect of varying wind/stability versus roughness length.
- Slight difference in concentration profiles for a change in z_0.
  - For 3/D, increasing z_0 results in a 13% **reduction** in x_{AEGL-3}.
  - For 1.5/F, increasing z_0 results in a 8% **increase** in x_{AEGL-3}.
- Change in weather scheme more significant.
  - Changing from 3/D to 1.5/F increases x_{AEGL-3} by 65% ($z_0 = 0.7$ m), and 103% ($z_0 = 1.3$ m).
- x_{AEGL-3} is within a factor of two between Phast and SLAB.



Case	x_{AEGL-3} (m)		Ratio Phast/SLAB
	Phast	SLAB	
3/D, $z_0 = 0.7$	258	143	1.8
3/D, $z_0 = 1.3$	225	172	1.3
1.5/F, $z_0 = 0.7$	425	273	1.6
1.5/F, $z_0 = 1.3$	457	238	1.9

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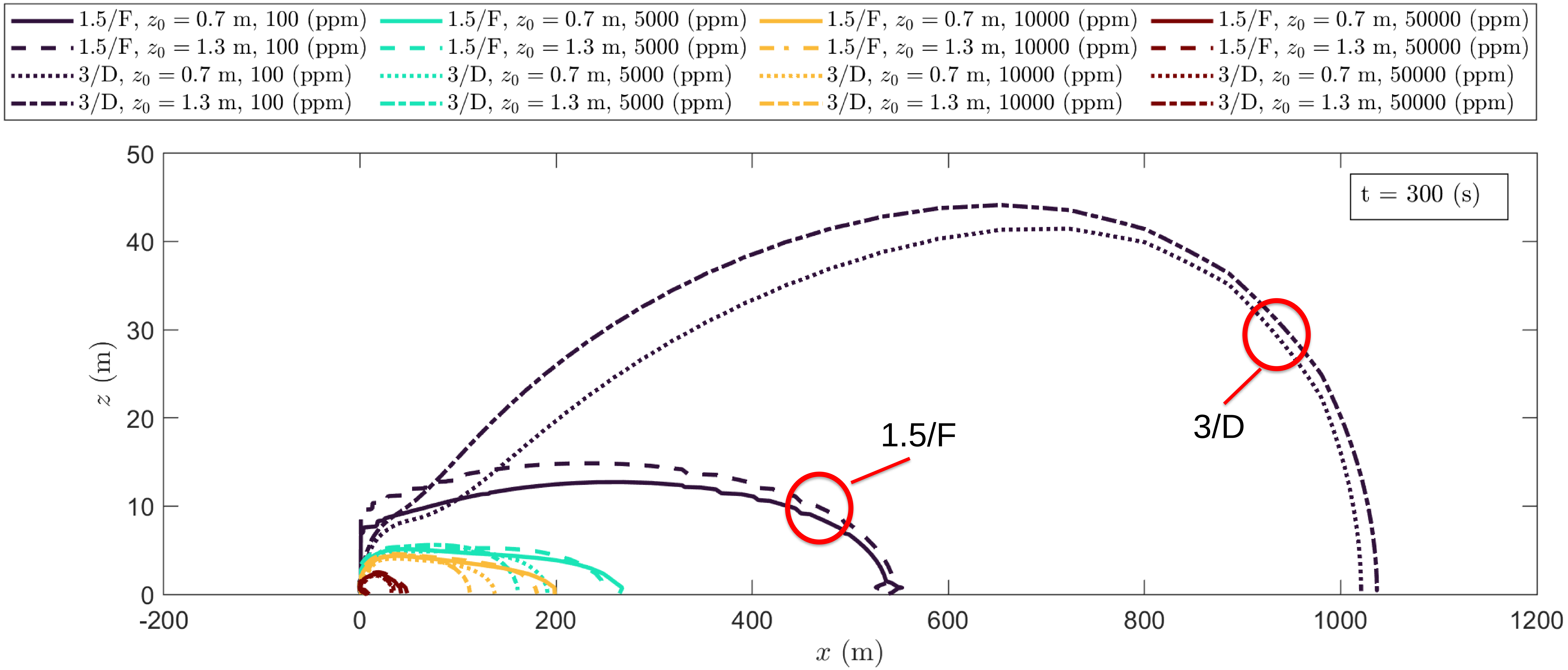
Cloud side view

- Snapshot of cloud (side view) at 300 s.
- Isopleths of 100, 5000, 10000, and 50000 ppm.



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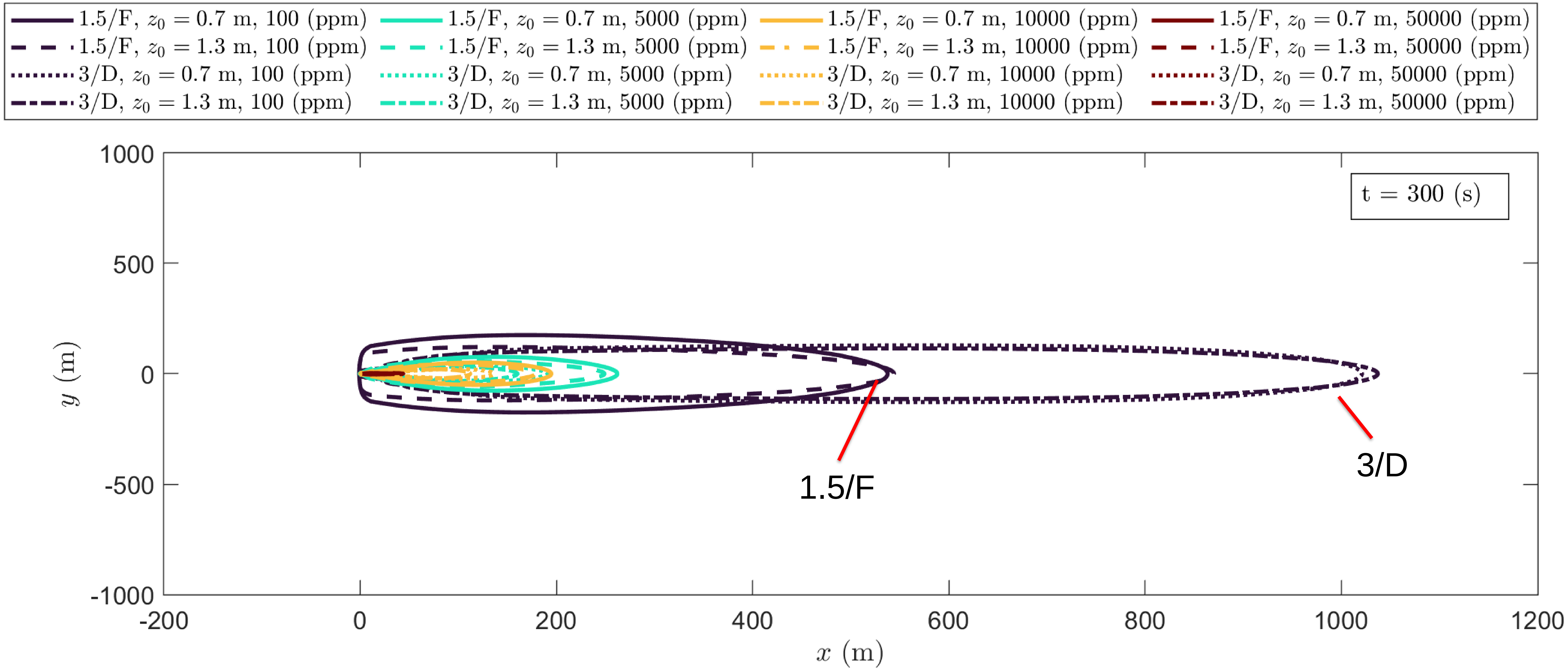
Cloud footprint

- Snapshot of cloud from above at height of 1 m ($t = 300$ s).
- Isopleths of 100, 5000, 10000, and 50000 ppm.



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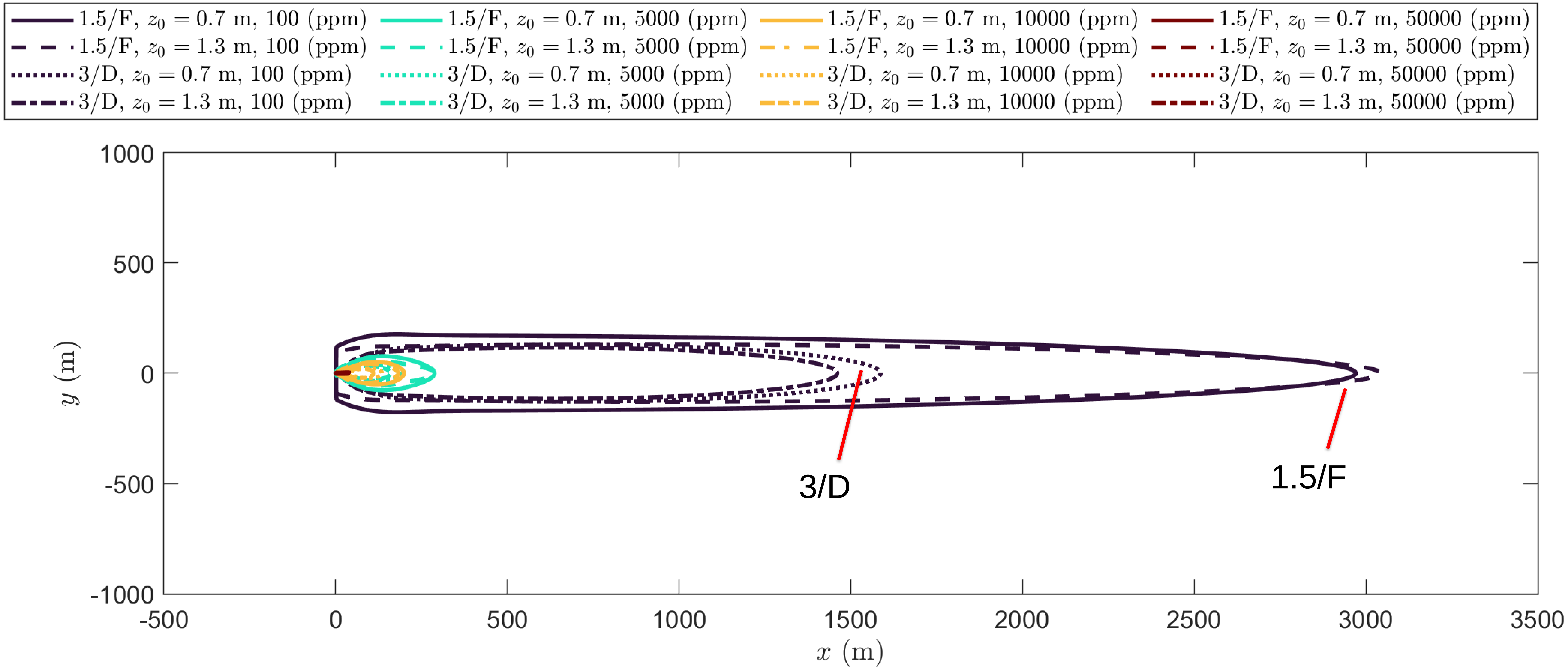
Max Footprint

- Maximum footprint (all times) of the cloud from above, at height of 1 m.
- Max footprint- low-level concentration isopleths of 100 ppm extend further.



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Conclusions

- Release of anhydrous ammonia from a 2-ton nurse tank has been simulated using the Phast dispersion model.
- Results from Phast compared to results from SLAB (ran by Joe Chang).
- Release rate is in good agreement to ALOHA (which is used as input to SLAB).
- Isopleths of varying concentrations (100, 5000, 10000, 50000 ppm) are generated for the cloud footprint and side view.
- Distances to AEGL-3 reported from Phast are greater than SLAB. However, results are within a factor of 2.
- Distances to AEGL-3 from Phast range from 225 m to 460 m in D3 and F1.5.

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Thank you

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- Contact: rory.hetherington@hse.gov.uk.
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