# ESCAPE

## An Expert System for Consequence Analysis using a Personal Computer

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References:


- Riikonen, K. et al., 1992. Finnish Meteorological Institute,  Publ. Air Quality 13.
- http://www.fmi.fi/research_air/air_55.html



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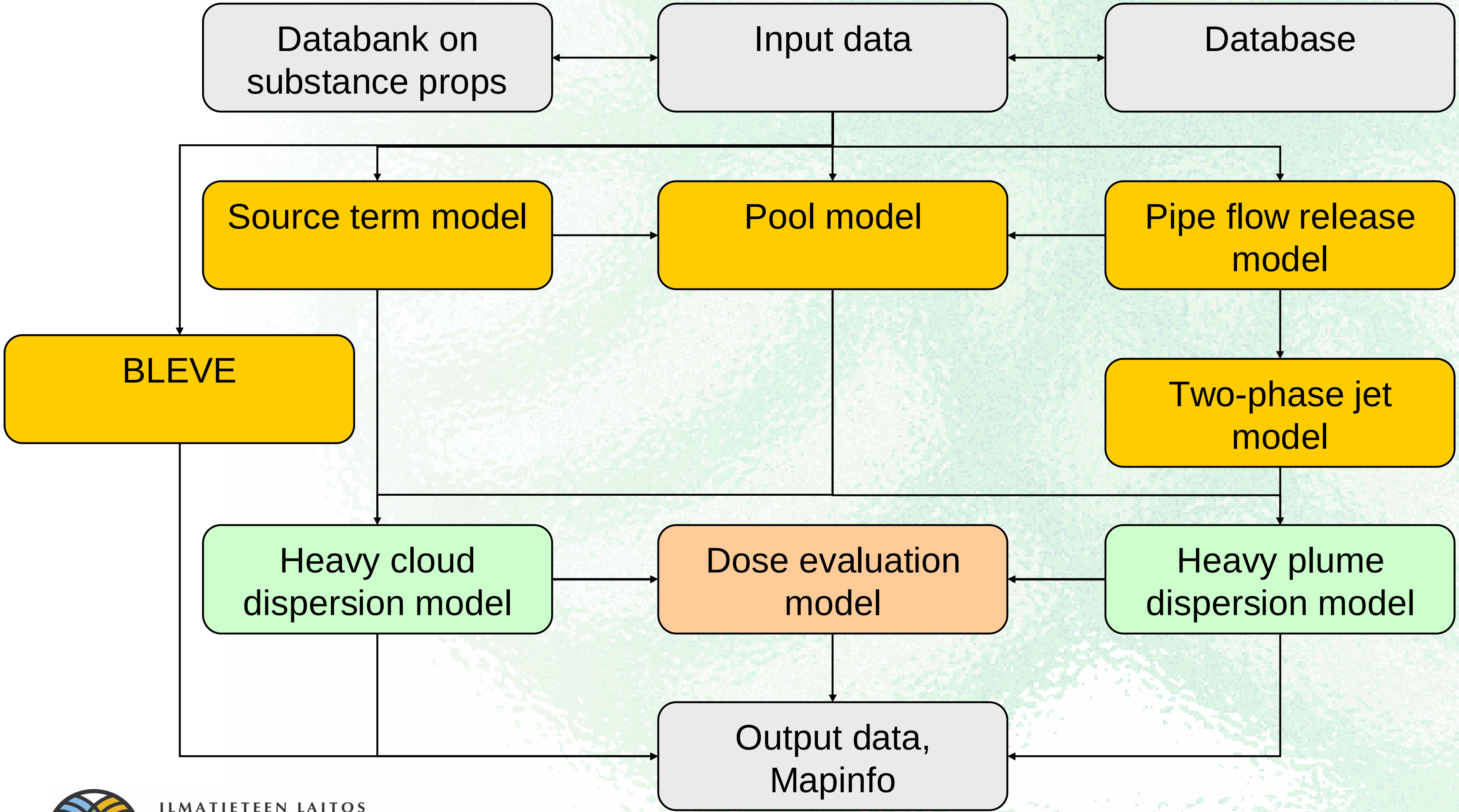
# ESCAPE



Databank on substance props
Input data
Database
Source term model
Pool model
Pipe flow release model
BLEVE
Two-phase jet model
Heavy cloud dispersion model
Dose evaluation model
Heavy plume dispersion model
Output data, Mapinfo

# The model applies for the following substances

| | | |
|---|---|---|
| Acetone | Chlorine | Methane |
| Acetonitrile | Cumene | N-butane |
| Acrylic acid | Ethane | N-pentane |
| Acrylonitrile | Ethylene oxide | Phosgene |
| Ammonia | Freon 12 | Propane |
| Benzene | Hexane | Propylene oxide |
| Bromine | Hydrogen cyanide | Sulphur dioxide |
| Butadiene | Hydrogen fluoride | Sulphur trioxide |
| Butane | Hydrogen sulphide | Toluene |
| Carbon disulphide | Iso-Butane | Vinyl chloride |
| Carbon tetrachloride | Methanol | |

# Effects of ammonia

| Concentration mg/m³ | Time of influence | Symptoms | Injurties |
|---|---|---|---|
| 3.5 - 35 | | Noticeable odour | |
| 70 | | Light irritation of nose | Irritation of mucous membrane |
| 200 - 350 | 0.5 - 1 h | Irritation of throat, eyes and nose, cough | Light injuries |
| 500 | | Flowing of tears | Rather serious injuries |
| 1200 | 0.5 h | Damages in lugn | Serious injuries |
| 2500 | 0.5 - 1 h | Swelling of the throat | May be lethal |
| 3500 - 7000 | 10 - 15 min | Swelling of the throat | Death |

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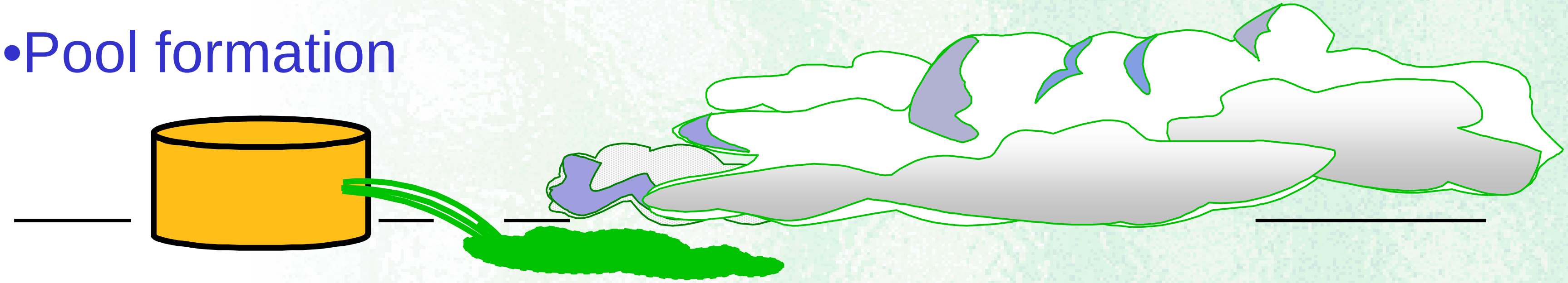
# Effects of chlorine

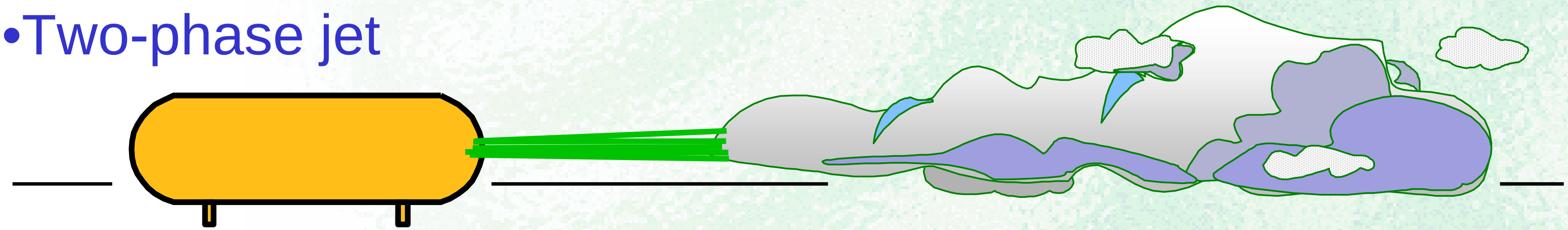
| Concentration mg/m$^3$ | Time of influence | Symptoms | Injuries |
|---|---|---|---|
| 1.5 - 9 | | Light odour | |
| 9 | 8 - 10 h | Noticeable odour | Irritation of the mucous membrane |
| 30 | 2 h | Coughing | Light injuries |
| 150 | 20 min | Suffocating cough | Rather difficult injuries |
| 300 | 10 min | Suffocation cough | Rather difficult injuries |
| 900 | 3 min | | Serious injuries |
| 3000 | | Suffocation | Death |

# Various source terms

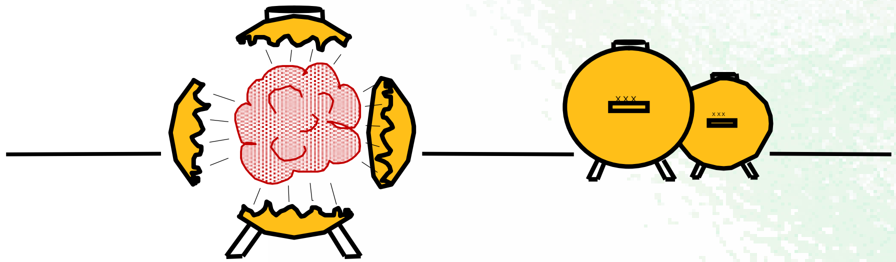
•Pool formation



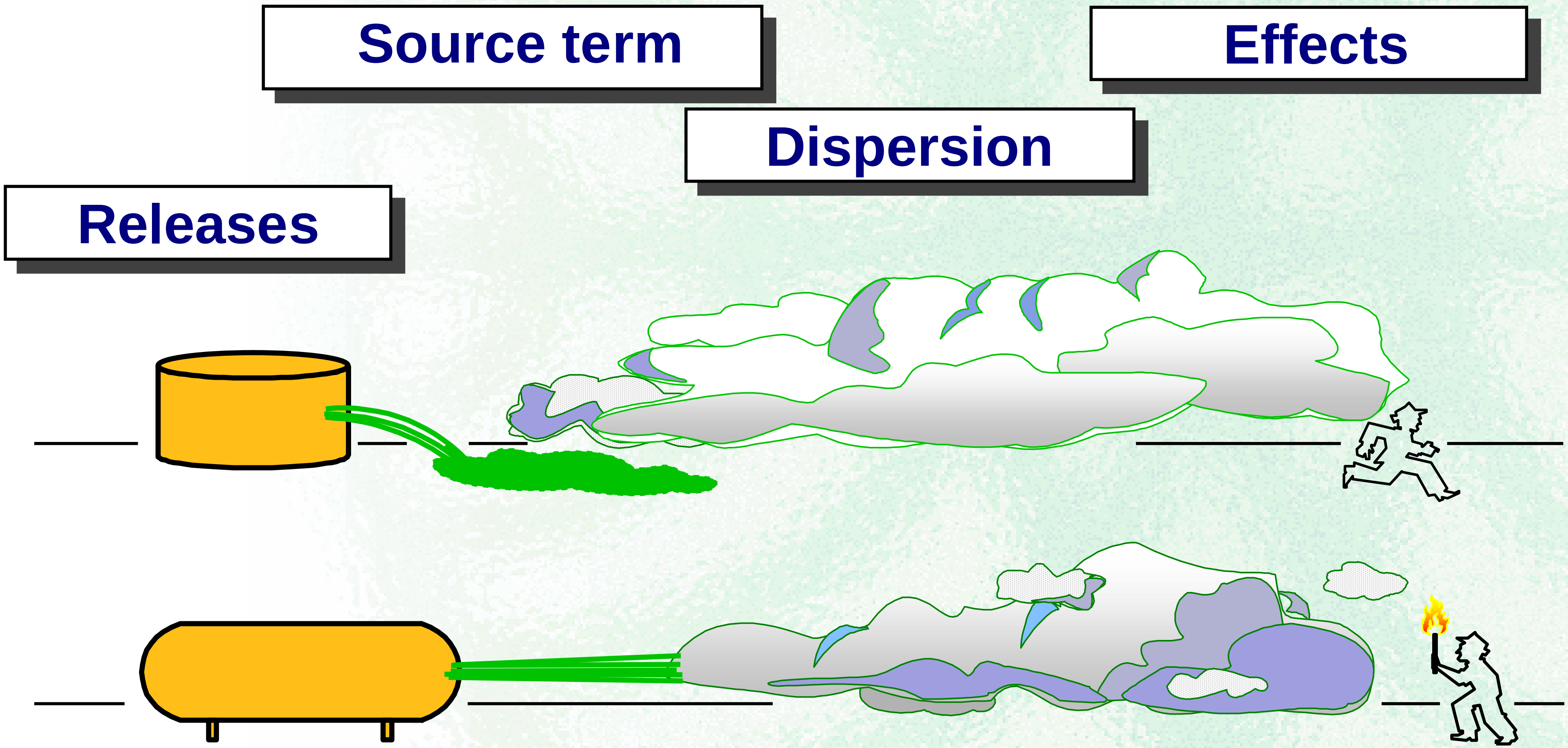
•Two-phase jet



•Catastrophic failure



Ref.: Webber, 1992




The model ESCAPE evaluates releases, atmospheric dispersion and consequences of chemical accidents (Fig.: Webber, 1992).

The propability of accident

↓

Consequence analysis

Release

↓

Source term

↓

Atmospheric dispersion

↓

Consequence

↓

Risk

# Application of models and numerical results

- emergency response planning
- hazard and risk analysis
- inspection and surveillance of industrial installations
- analysis of past accidents

The model results are most useful in preparing in advance for accidents.

# The state-of-the-art of source term models

1. Liquid pool models
   - fairly good models available
2. Two-phase jet models
   - reasonably good models available
3. Source terms of catastrophic releases
   - the few suggested models not realistic
4. "Semi-instantaneous" releases
   - no models available

# The state-of-the-art of heavy gas dispersion models

The atmospheric dispersion of a one-phase gas cloud over flat terrain in terms of time-averaged concentrations is generally well understood.

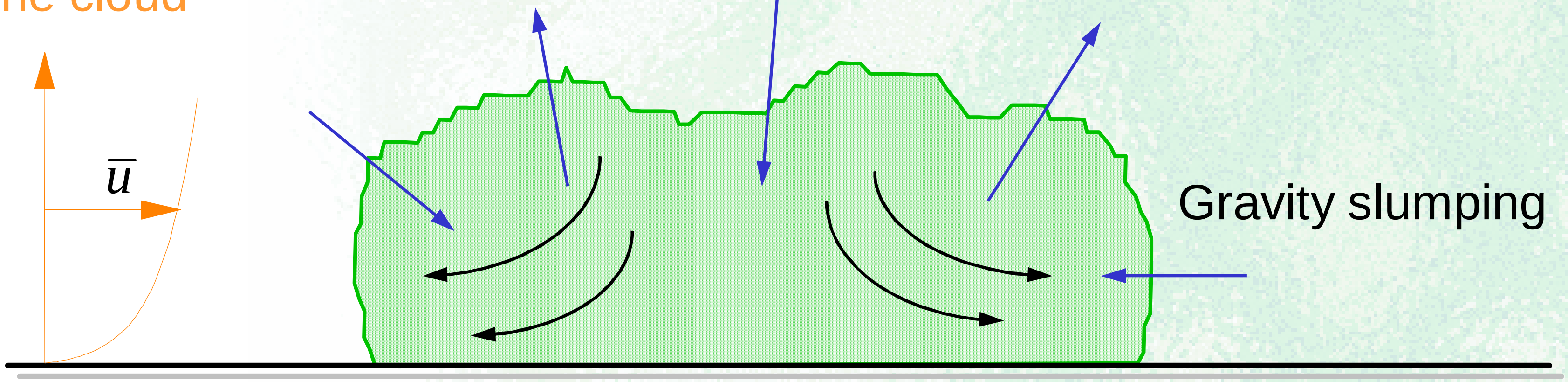
Predictive techniques are sufficiently accurate for hazard assessment purposes.

# HEAVY GAS DISPERSION MODEL

Entrainment of air:

- atmospheric turbulence
- internal turbulence of the cloud
- mechanical entrainment

Transport of the cloud




Thermodynamical effects:

- phase transitions
- heat flux from the ground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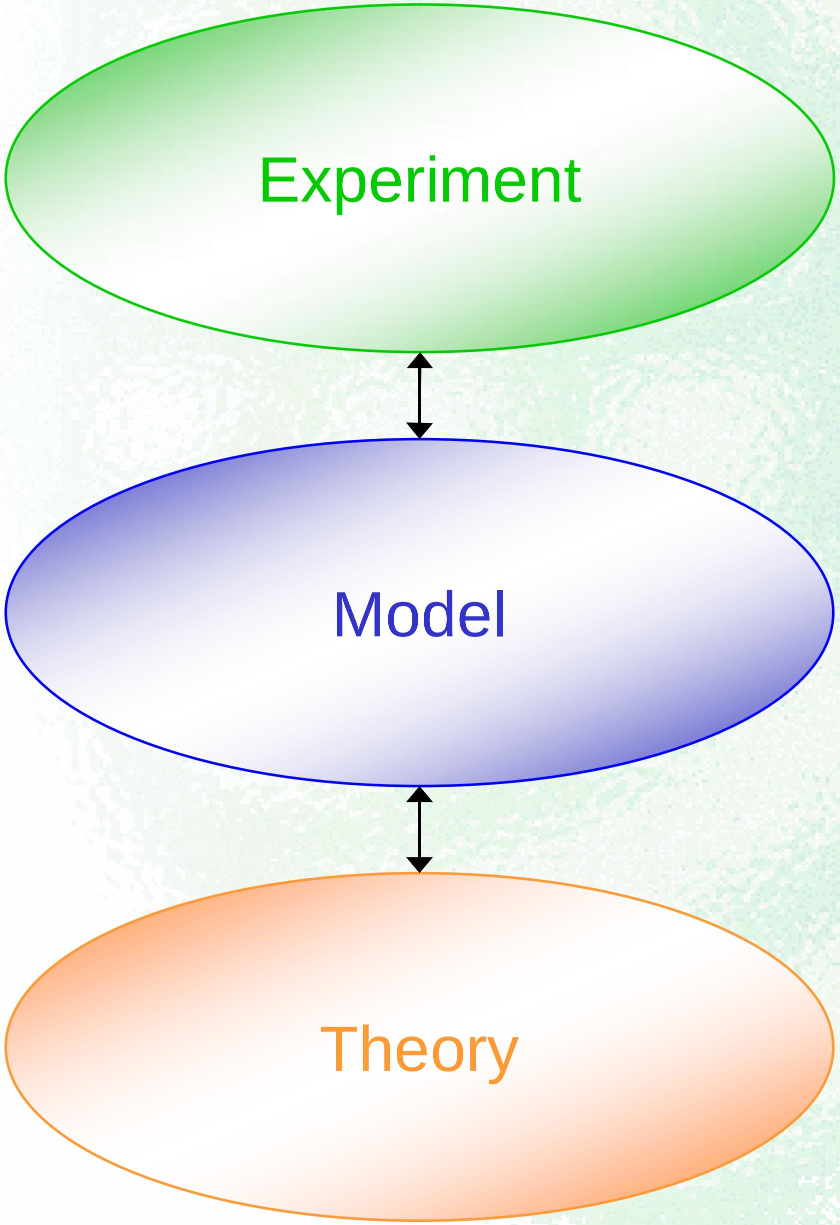

Experiment
Model
Theory

# Refinement of the model

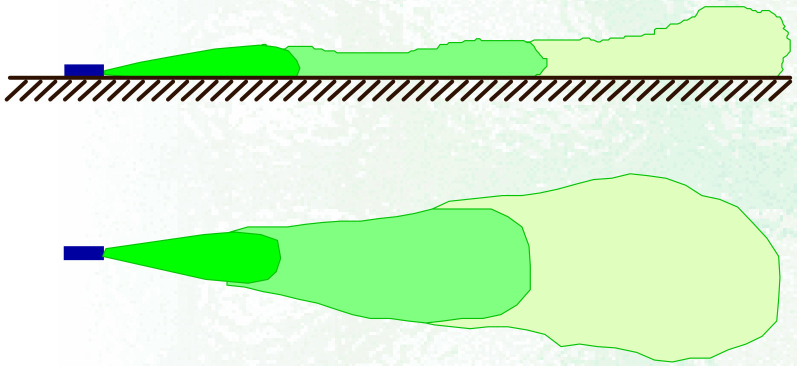
- including a databank of the physico-chemical properties of substances
- an easy-to-use introduction of new substances into the model
- refinement of heavy gas dispersion models
- improvement of the flexible and versatile use of the model
- improvement of graphical output
- further validation against experimental data

# Future research on heavy gas dispersion modelling

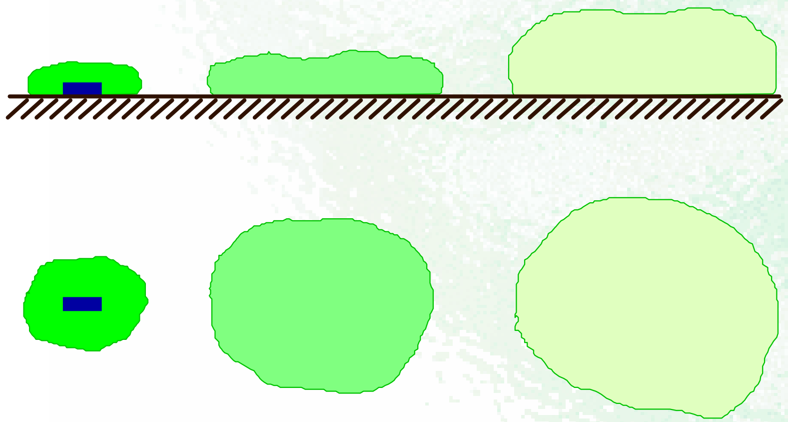
- thermodynamical effects
- the influence of complex terrain and obstacles
- statistical fluctuations
- time-dependent releases

<u>Validated tools of assessment</u> are also needed for non-expert users.

## Plume



## Cloud



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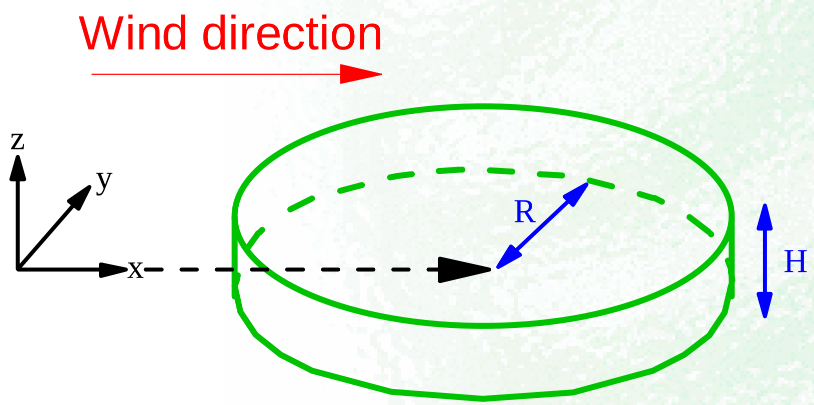
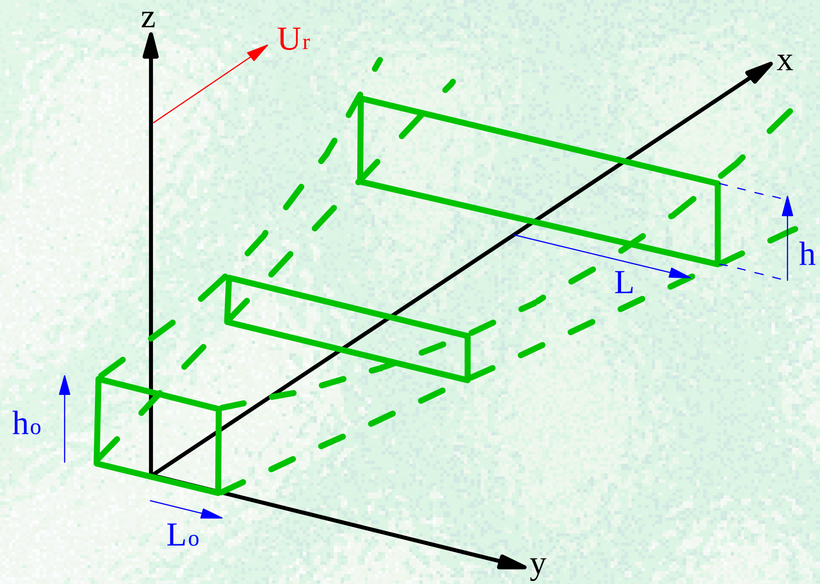
# Box model cloud representation




Cloud shape for instantaneous release

Plume shape for continuous release

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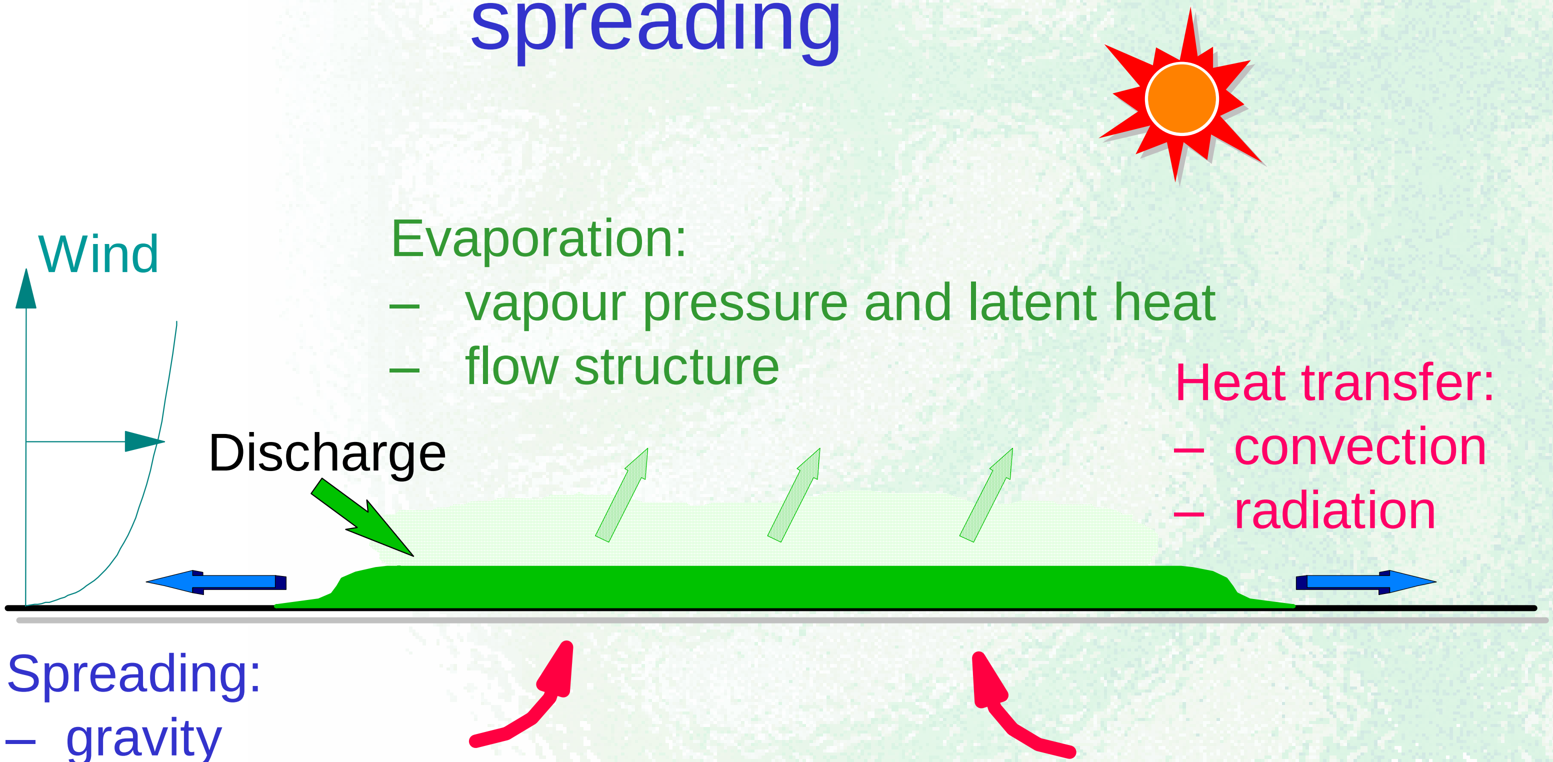
# A model for liquid pool evaporation and spreading



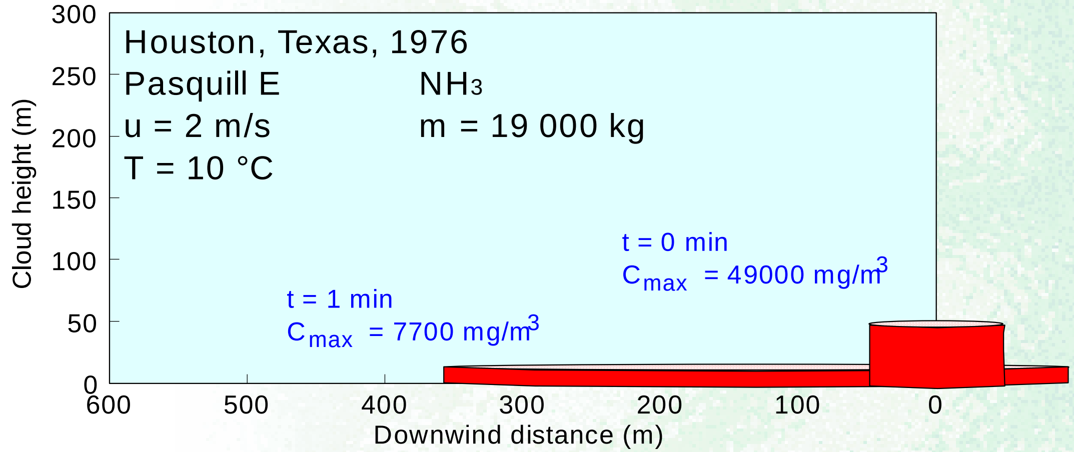

Evaporation:
– vapour pressure and latent heat
– flow structure

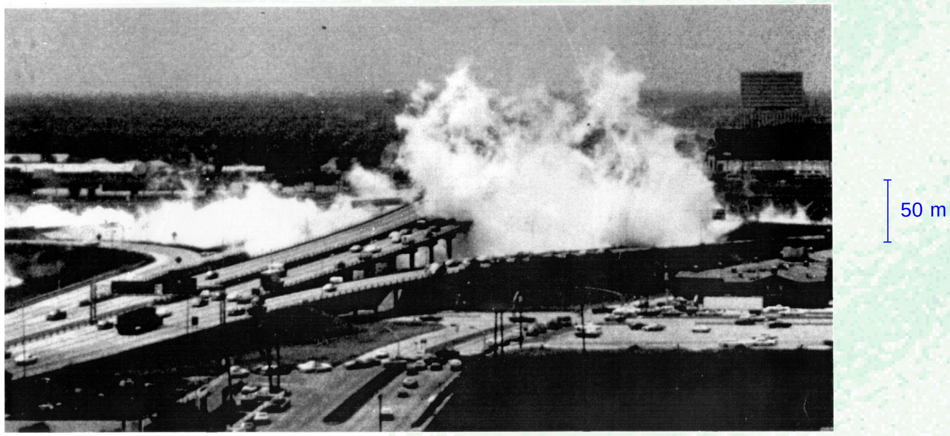
Heat transfer:
– convection
– radiation

Spreading:
– gravity
– resistance

Heat transfer:
– conduction
– convection

# Comparison of the predictions of ESCAPE and the visual observations




A photograph taken about one minute after the Houston tanker crash (Fryer and Kaiser, 1979).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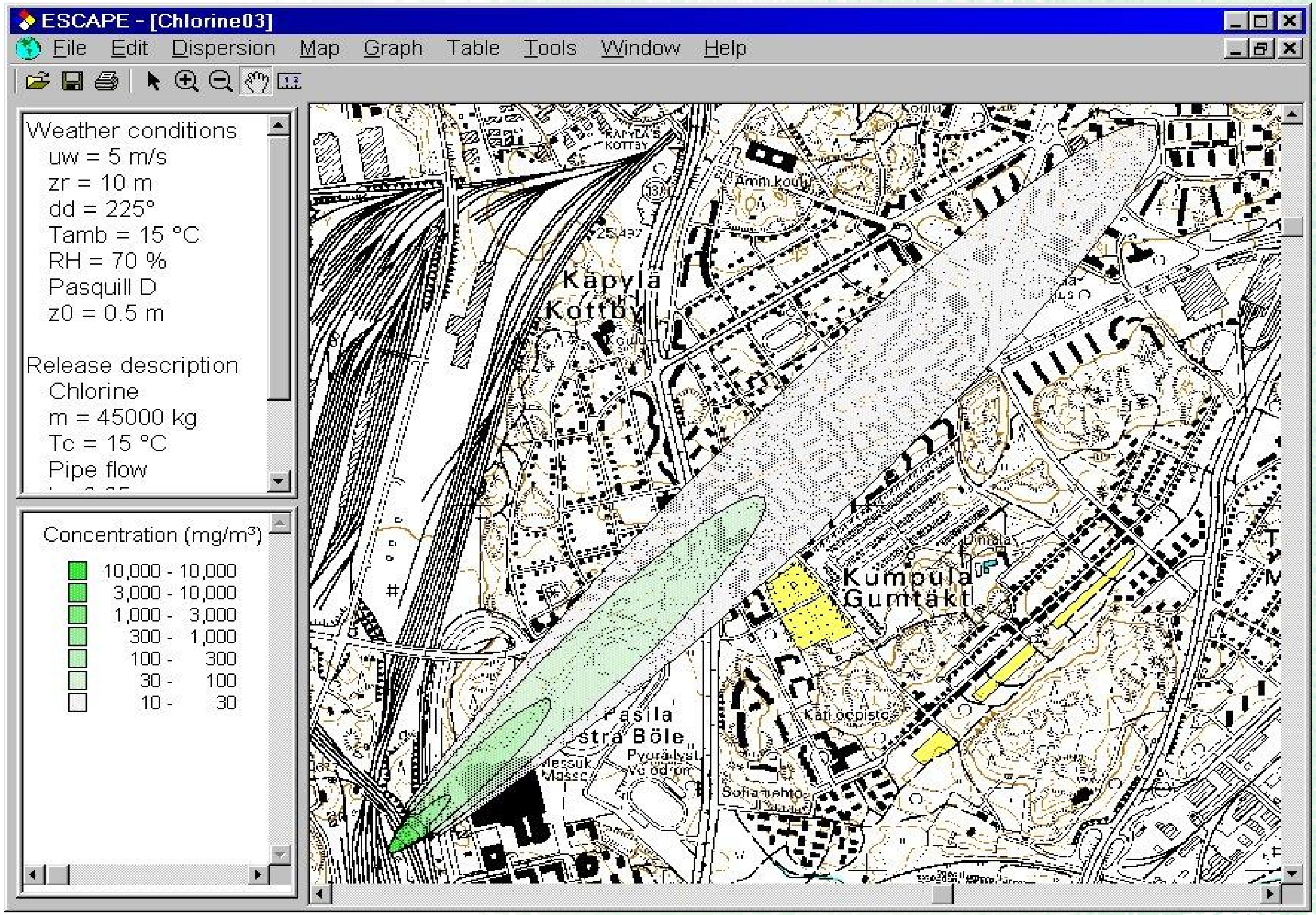
# The results of ESCAPE

- Dispersion diagram
- The height of gas cloud or plume
- The average concentration
- The temperature of gas cloud or plume
- The density of gas cloud or plume
- Tabulated results of concentration
- Total dose
- Dose in a minute
- Tabulated results of doses
- Toxicology and flammable levels
- BLEVE (blast wave dispersion diagram)




Example output of ESCAPE. (map (©) Genimap Oy).

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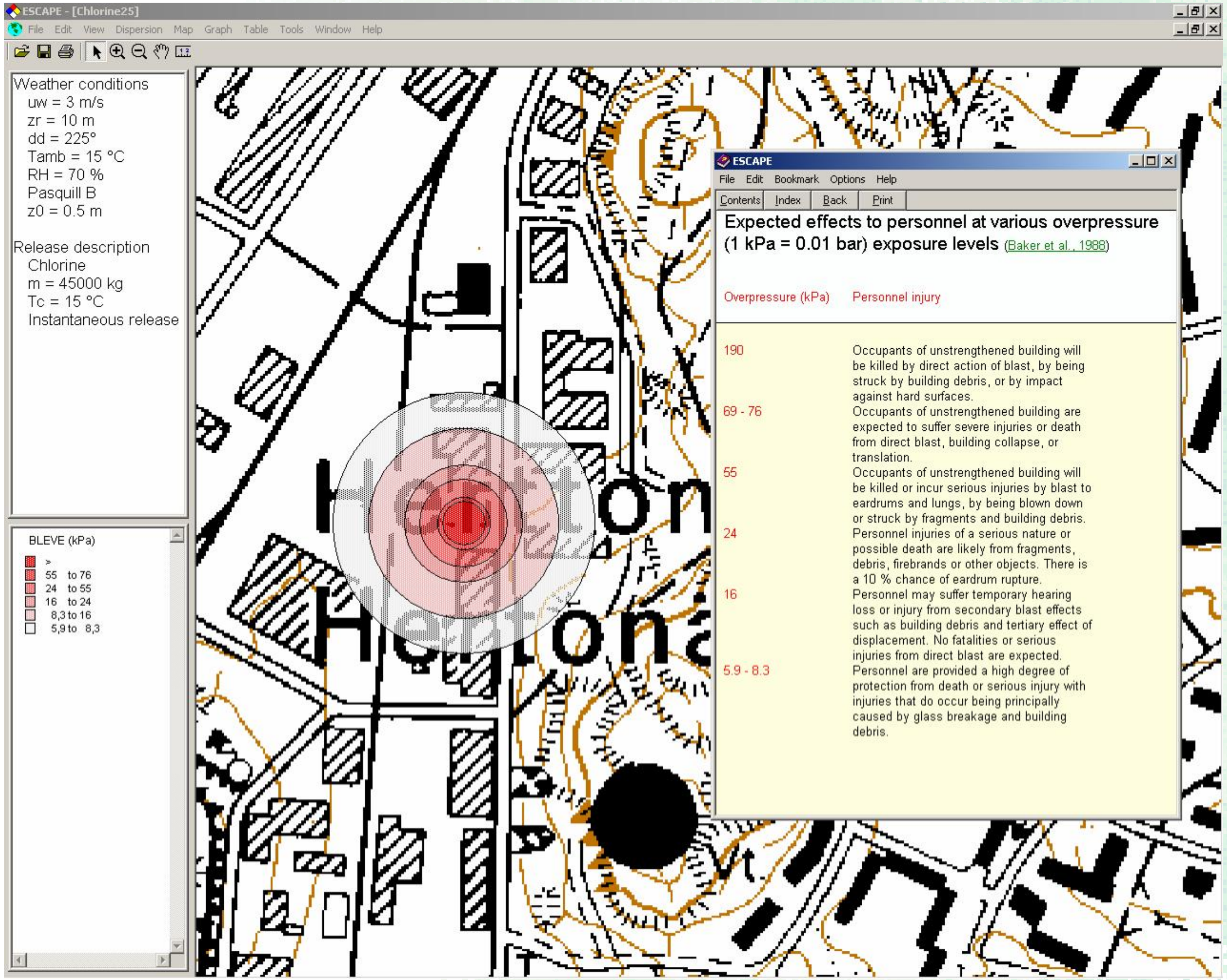


Example results of the Win - ESCAPE application: BLEVE formed in a conceived container breakage of liquified chlorine (map (©) Genimap Oy).

# ESCAPE Users

City of Helsinki Environment Centre, Finland
Ekokem, Finland
Environment Protection Agency, Lithuania
*Finnish Meteorological Institute (FMI)
*Inspecta, Finland
Institute of Physics of Vilnius, Lithuania
*Ministry of the Interior, Finland
- Rescue services (22)

Neste, Finland
Radiation and Nuclear Safety Authority (STUK), Finland
State Pollution Control Authority (SFT), Norway
The Finnish Defence Forces
Toray Plastics Malaysia Sdn. Bhd.
University of Applied Sciences (EVTEK and HAMK), Finland
University of Hamburg, Germany



*financier

# More information

- http://www.fmi.fi/research_air/air_55.html

- Download: http://escape.fmi.fi/
  (license required!)

Thank you for your attention !

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# Model equations (POOL)

Volume discharged: $\frac{dV_d}{dt} = S$

Pool volume: $\frac{dV}{dt} = S - WA$

Pool temperature: $c\rho V \frac{dT}{dt} = A\{Q - \rho WL\} + \{T_s - T\}c\rho S$

Mass vaporised: $\frac{dM}{dt} = \rho WA$

$A = \pi r^2$

$\rho W = \mathrm{X}(T)u_* \hat{W}(u_* z_o/\nu, Sc, R/z_o, p_s(T)/p_a)$

$Q(T,t) =$ conducted + convected + radiated

$W$ = evaporation rate

$A$ = area of pool

$c$ = spec. heat capacity of contaminant

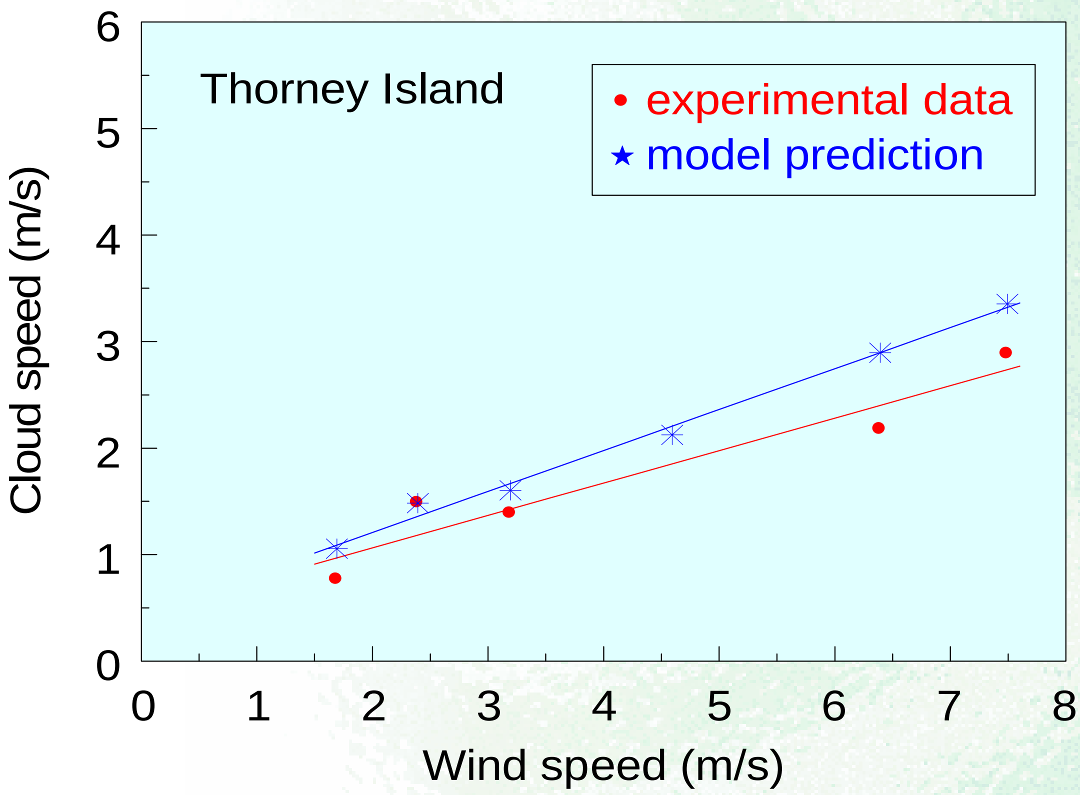
$r$ = liquid density of contaminant

$Q$ = heat flux density into the pool

$L$ = latent heat of evaporation

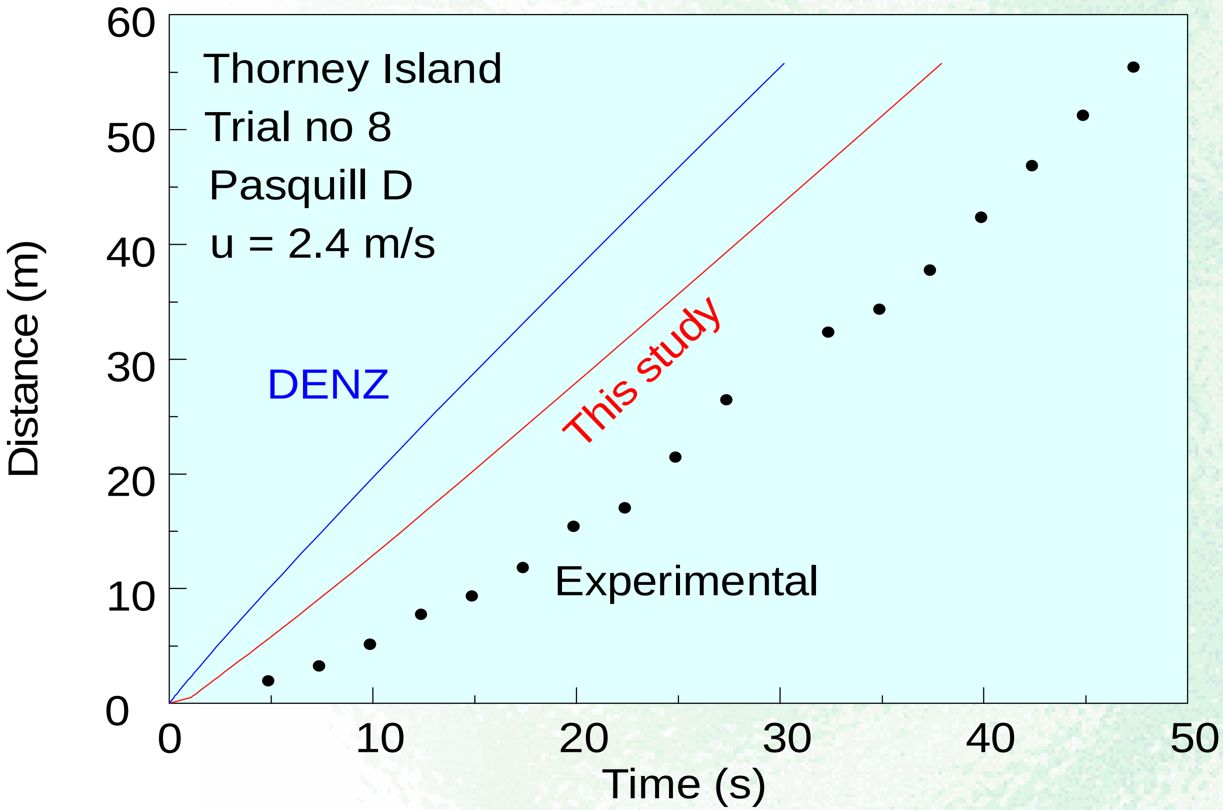
$T_s$ = temperature of source discharge

# Validation of DENZ model (4/4)



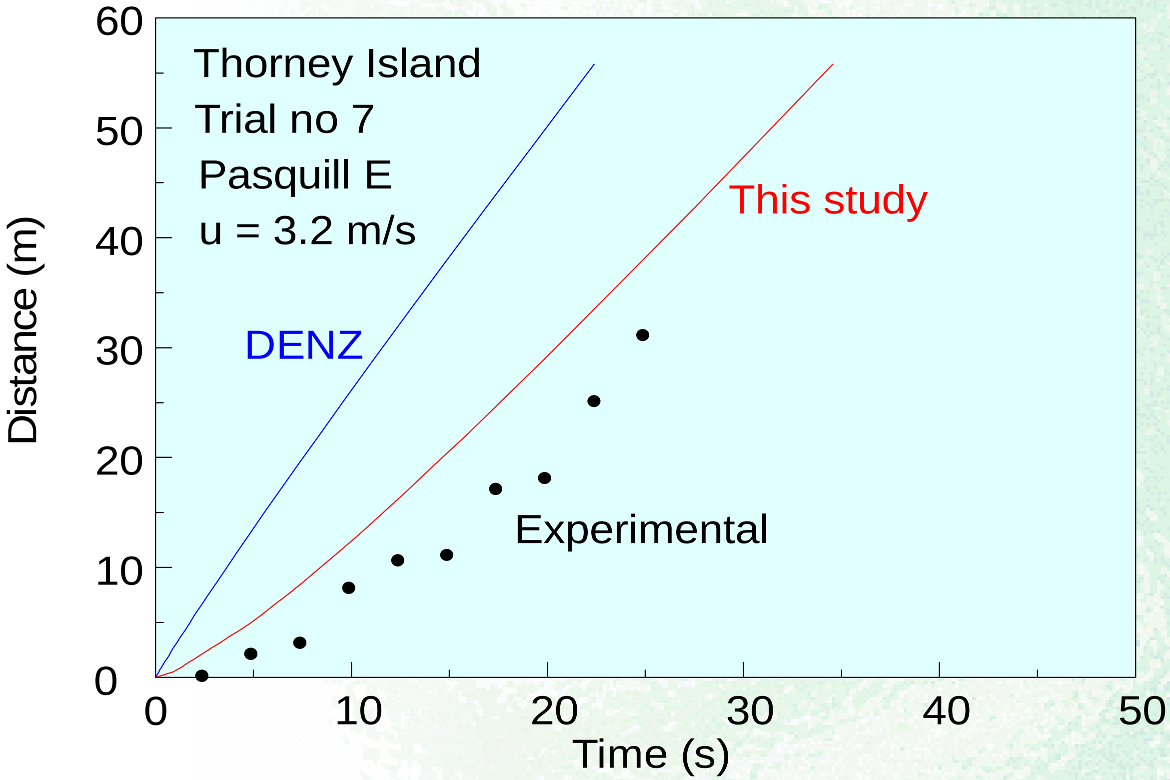

The computed and measured cloud speeds against the measured wind speed at 10 m height (Kukkonen and Nikmo, 1992. J.Hazard.Mater. 31, 155-176).

# Validation of DENZ model (3/4)




The distance of the cloud centroid from source against time (Kukkonen and Nikmo, 1992. J.Hazard.Mater. 31, 155-176).

# Validation of DENZ model (2/4)

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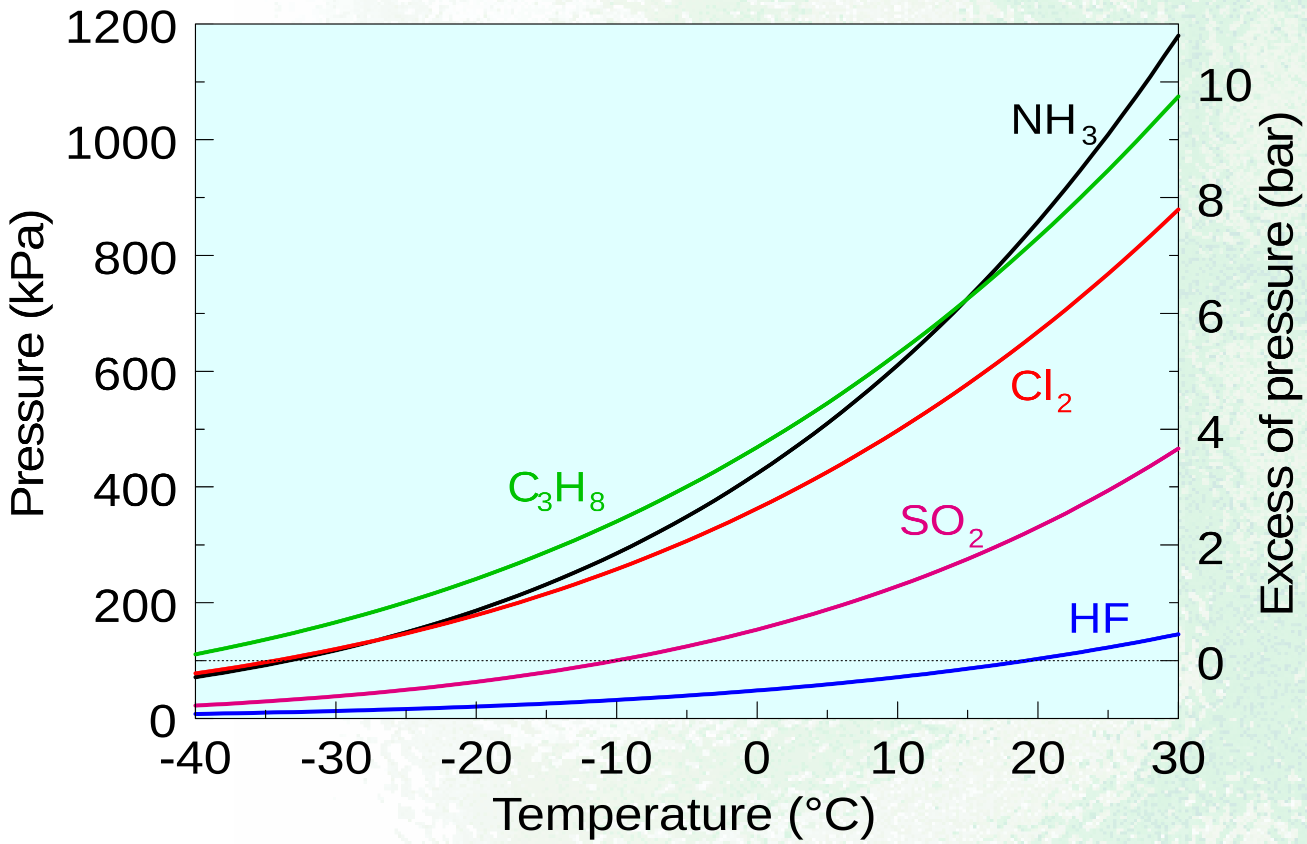
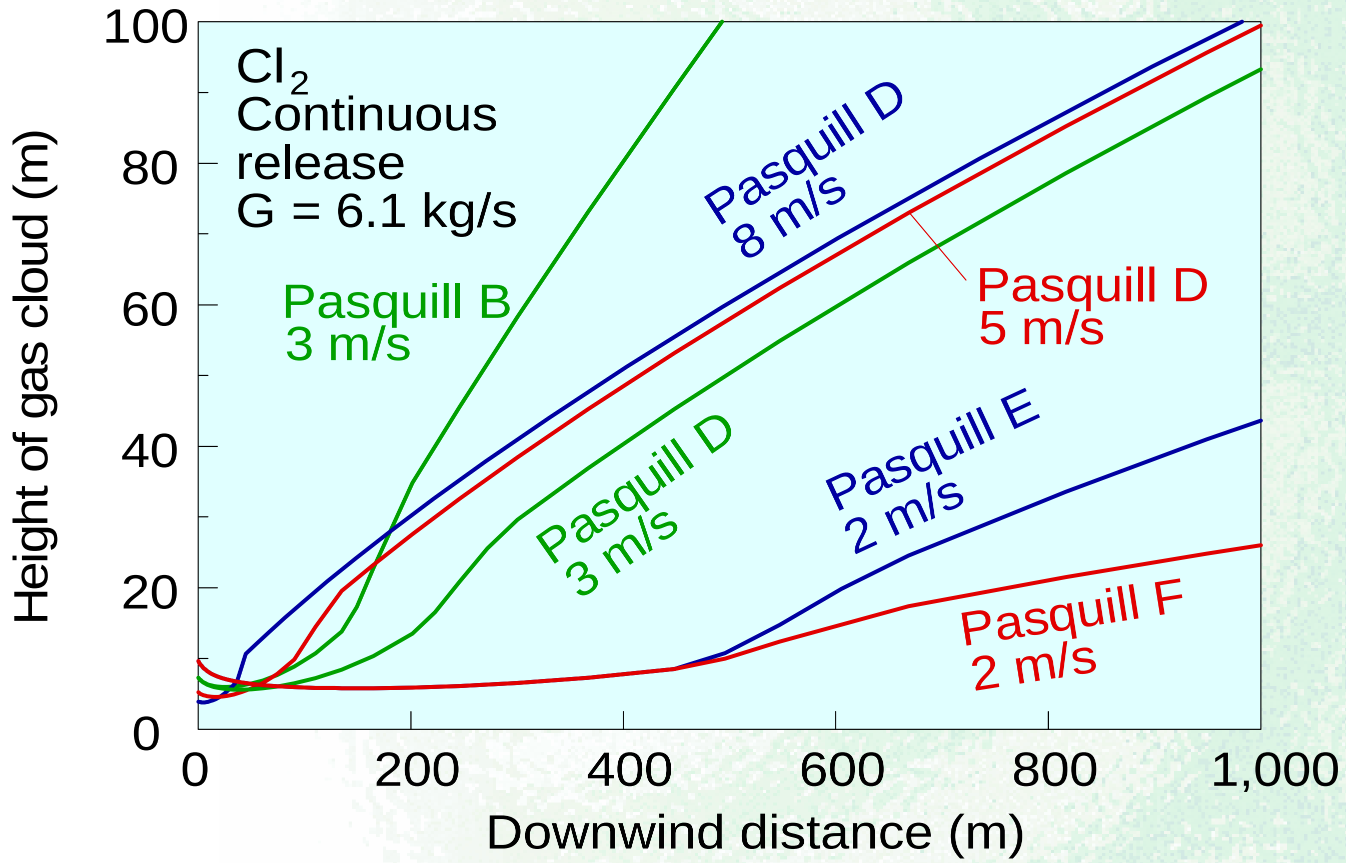
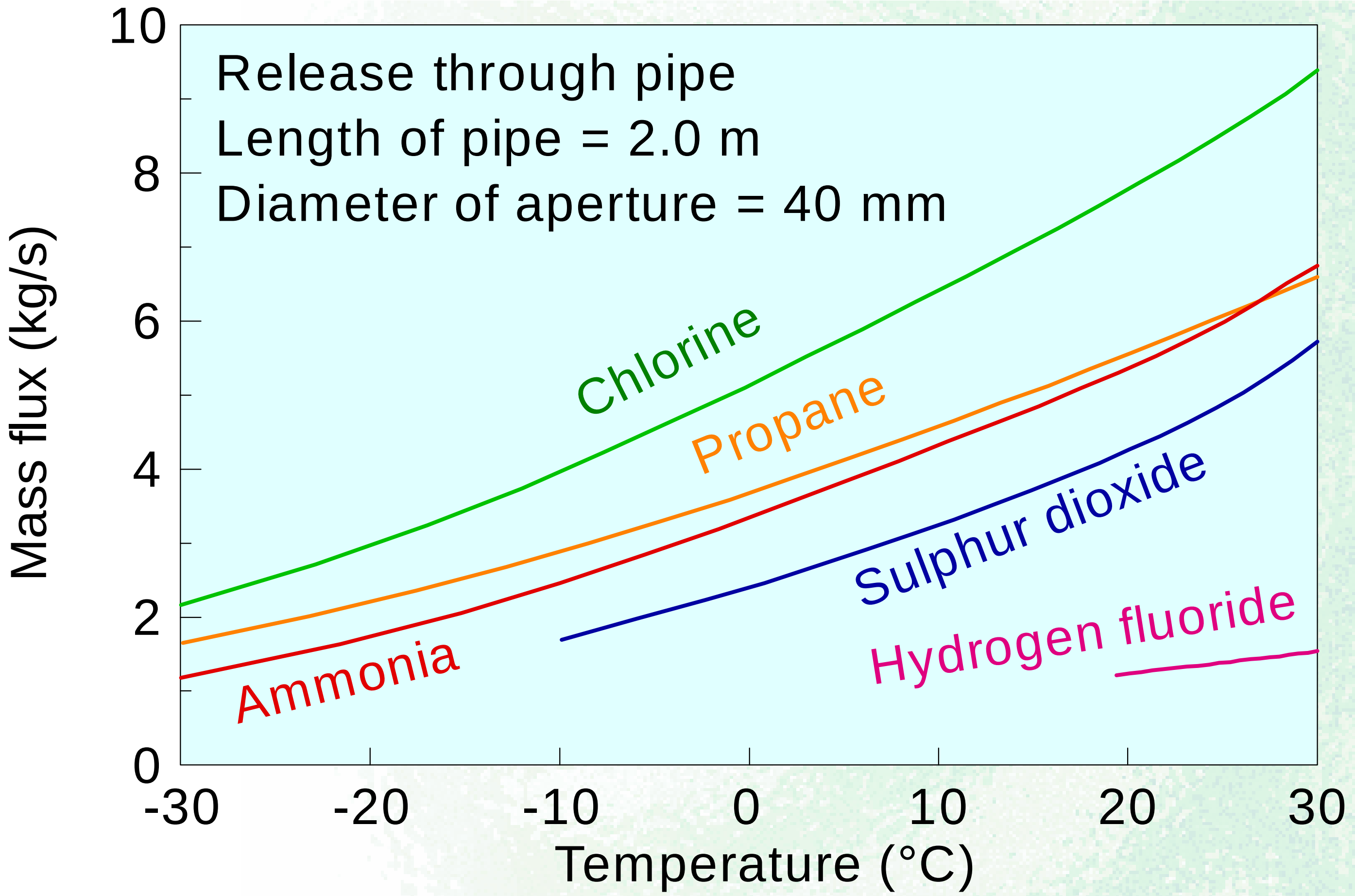


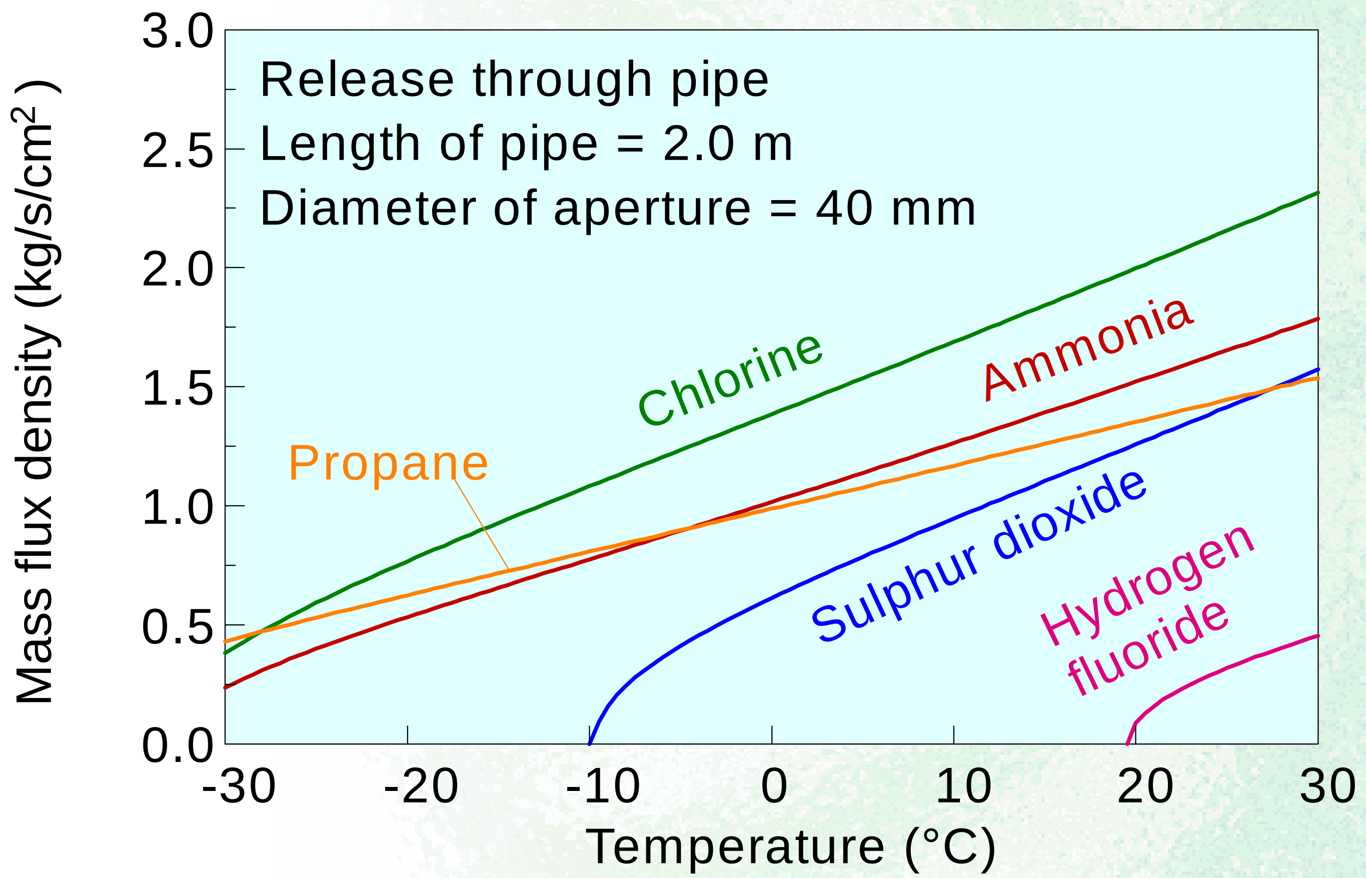

The saturation vapour pressure for some toxic and flammable substances.




The predicted height of the gas cloud in varying meteorological conditions (Kukkonen and Savolainen, 1988. Publ. on Air Quality 4, Finnish Meteorological Institute).




The mass flux through a pipe from the liquid space of the container against the storage temperature (Kukkonen, 1990. Dissertationes No 34, The Finnish Society of Sciences and Letters).

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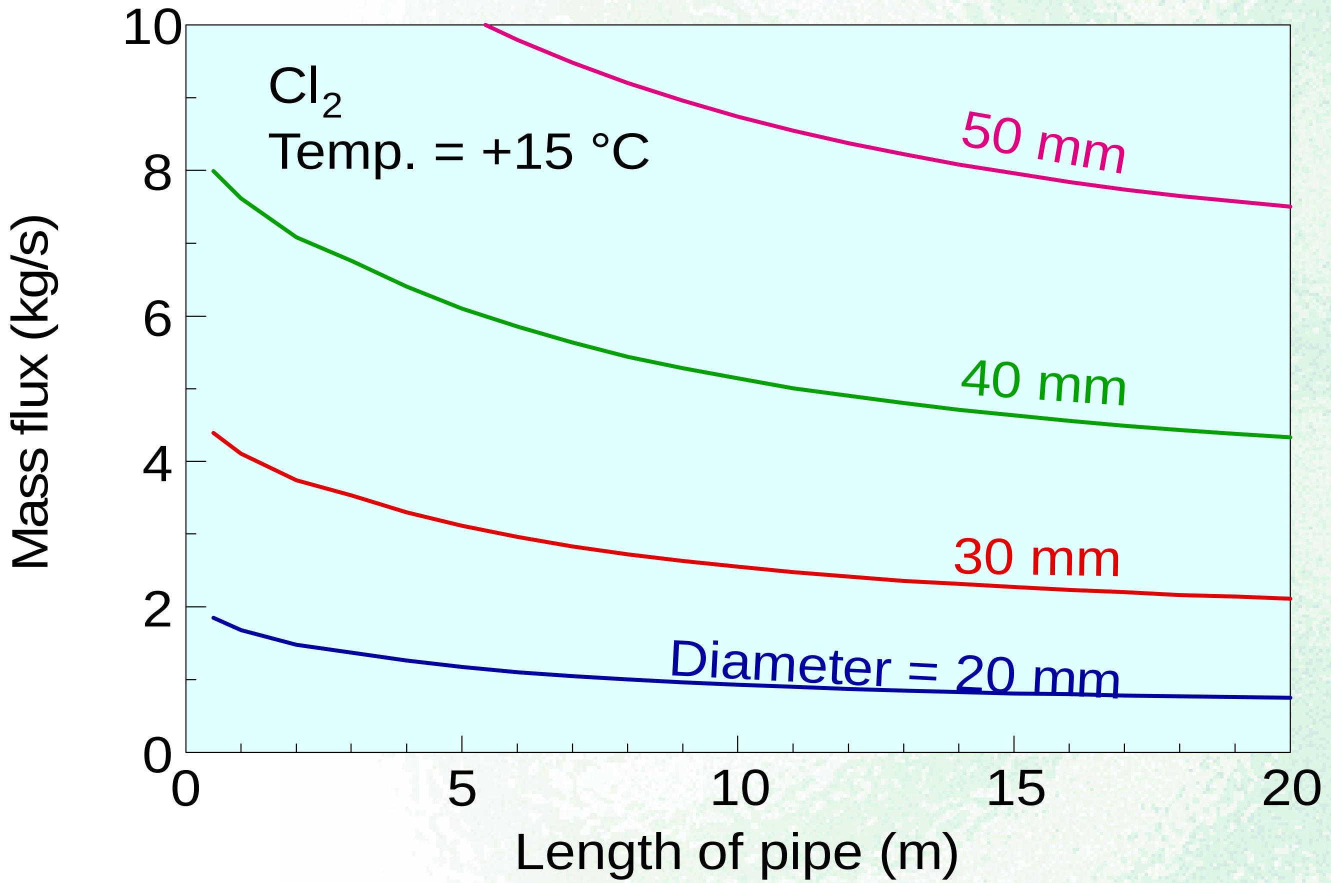
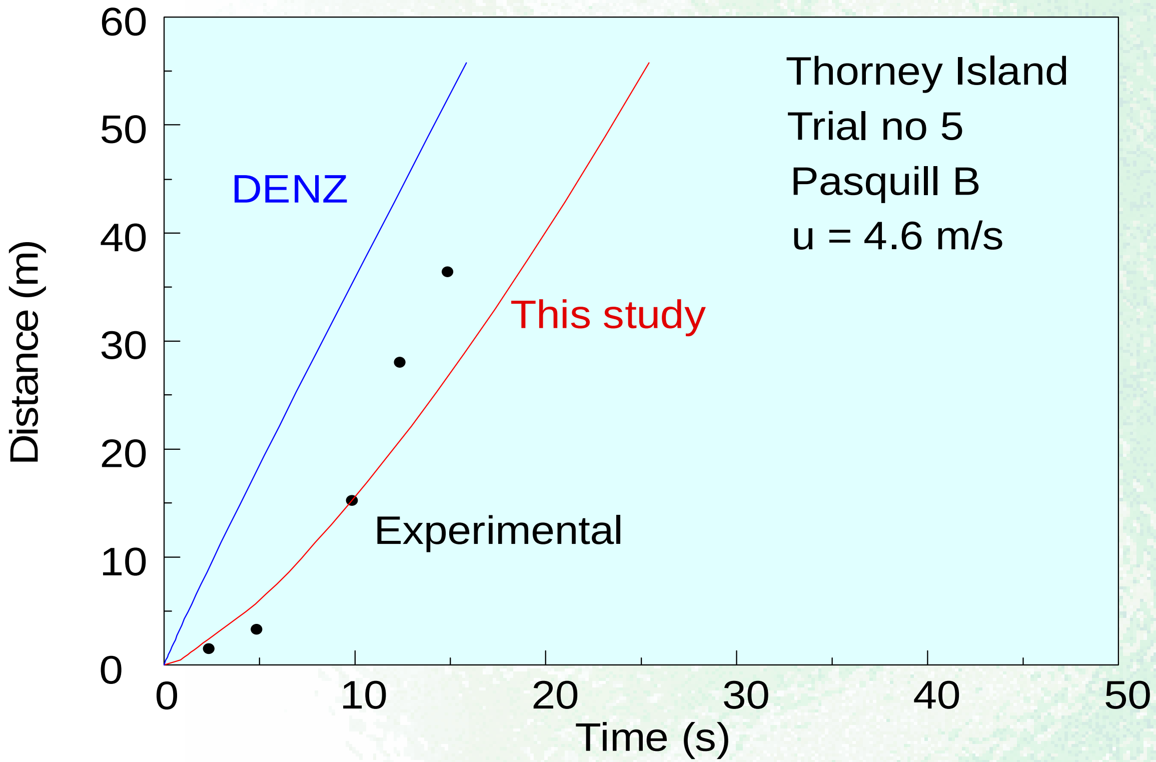



The mass flux through pipe from the liquid space of the container against the length of pipe (Kukkonen, 1990. Dissertationes No 34, The Finnish Society of Sciences and Letters).

# Validation of DENZ model (1/4)




The distance of the cloud centroid from source against time (Kukkonen and Nikmo, 1992. J.Hazard.Mater. 31, 155-176).