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Effects of released hazardous gases (EFRHA) model: development and validation

Richard Tavares and Ana Isabel Miranda

LHEEA, Ecole Centrale de Nantes
CESAM, University of Aveiro

The Problem

Introduction

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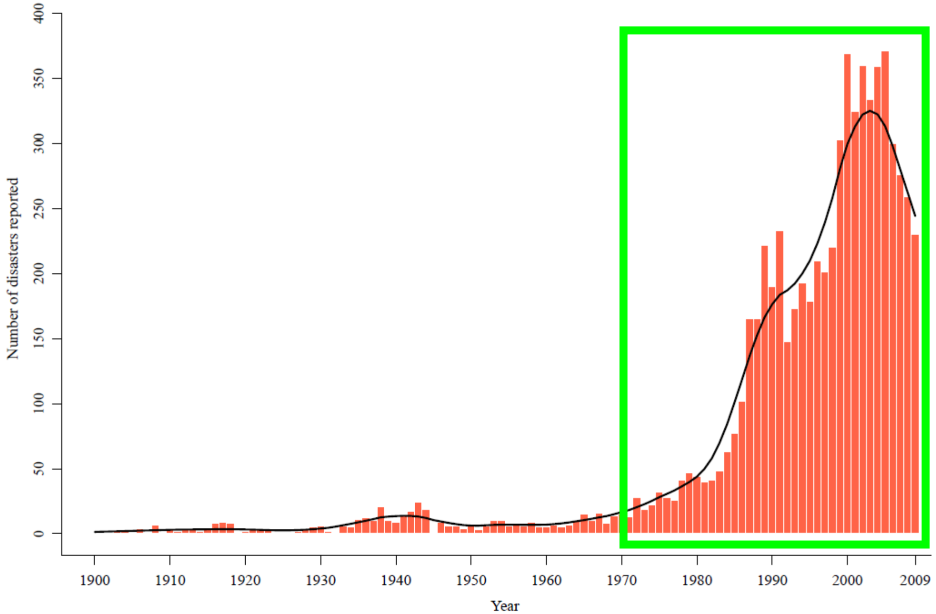
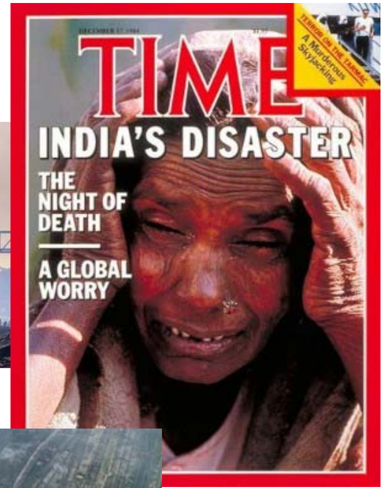
Main goal

Technological accidents



Reported Technological accidents recorded between 1900 and 2009 [*EMDAT*].



Seveso, Italy (1976)

Bhopal, Índia (1984)

Toulouse, France (2001)

Viareggio, Italy (2009)

Sendai, Japão (2011)

Prevention and Control of accidents involving the release of hazardous gases

Increased awareness of the consequences from technological accidents, in particular the exposure to hazmat gases released into the atmosphere

Development a implementation of regulatory and guidance instruments

(e.g. Consequence Analysis (CA) methodologies and studies)

Gave numerical tools (software packages or models):

- unique value to support control, training, decision, emergency response and post-events studies
- large efforts have been taken in the development and implementation of local-scale modelling tools able to predict short-term pollution episodes and exposure effects on humans and the environment

Consequence Analysis modelling tools

Despite the number and variety of existing CA modelling tools/software packages some limitations are recognized

- Number and type of accident scenarios
- Level of knowledge/experience of the user
- Computational and hardware capacity and resources

Simple modelling tools:
- Cannot properly represent the actually occurring real conditions in industrial and built-up areas

More complex modelling tools:
- Turn the tool powerless to provide fast response information

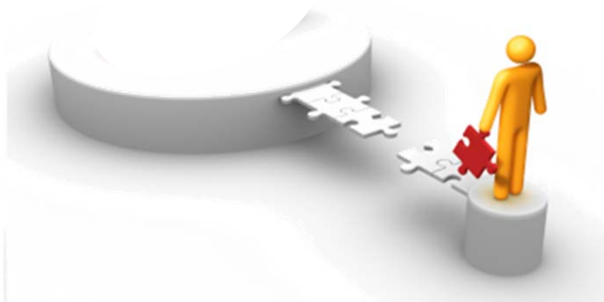
Main goal

Development and **Validation** of the **EFRHA** – '**EF**fects of **R**eleased **H**azardous g**A**ses' integrated CA modelling tool designed to:

Predict short-term pollution episodes and exposure effects on humans and the environment in case of accident with hazardous gases (hazmat),

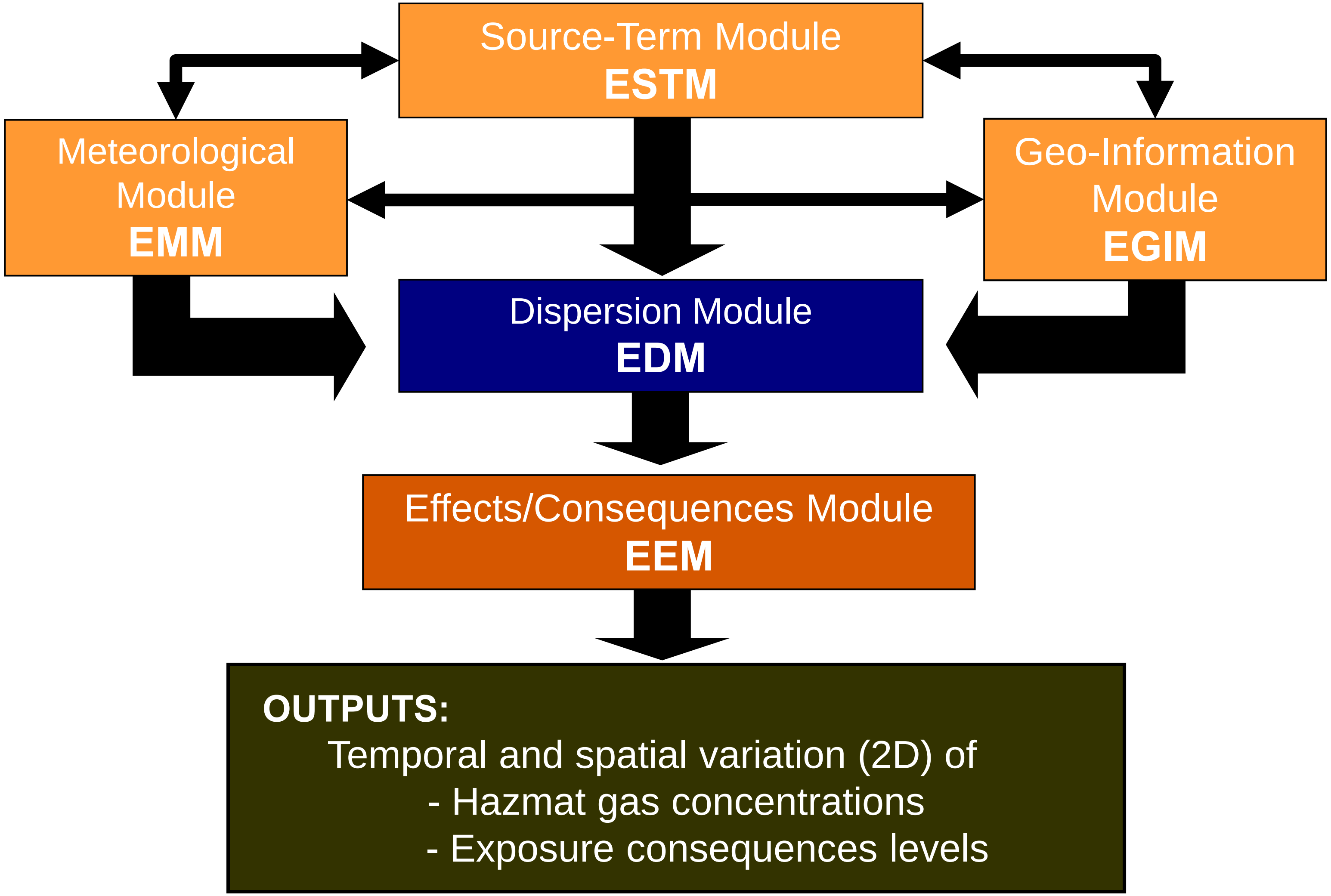
Capable to:

- Simulate the outflow and atmospheric dispersion of heavy and passive hazmat gases in complex and build-up areas,
- Estimate the exposure consequences of short-term pollution episodes in accordance to regulatory/safety threshold limits.

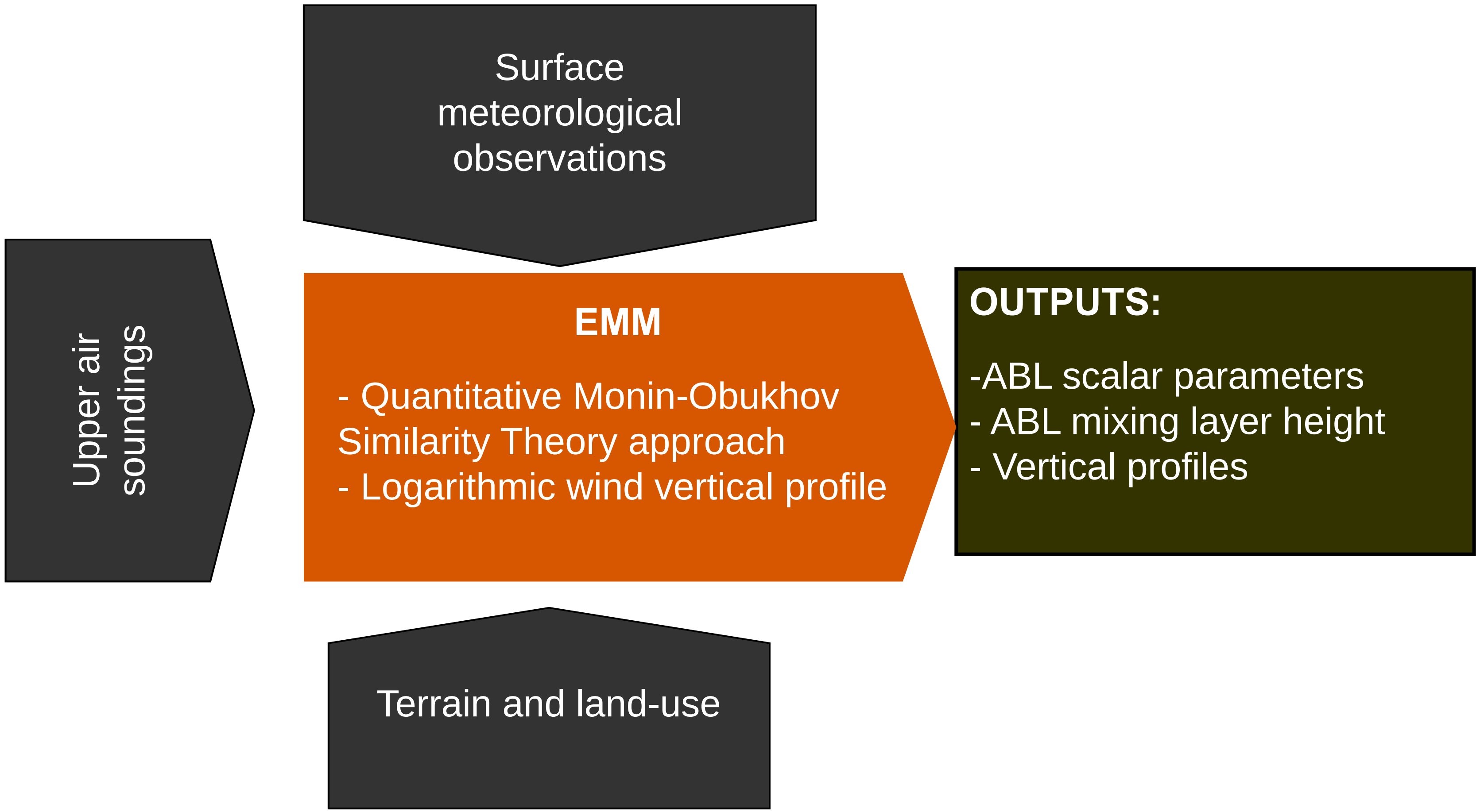


Overview of the CA integrated EFRHA model

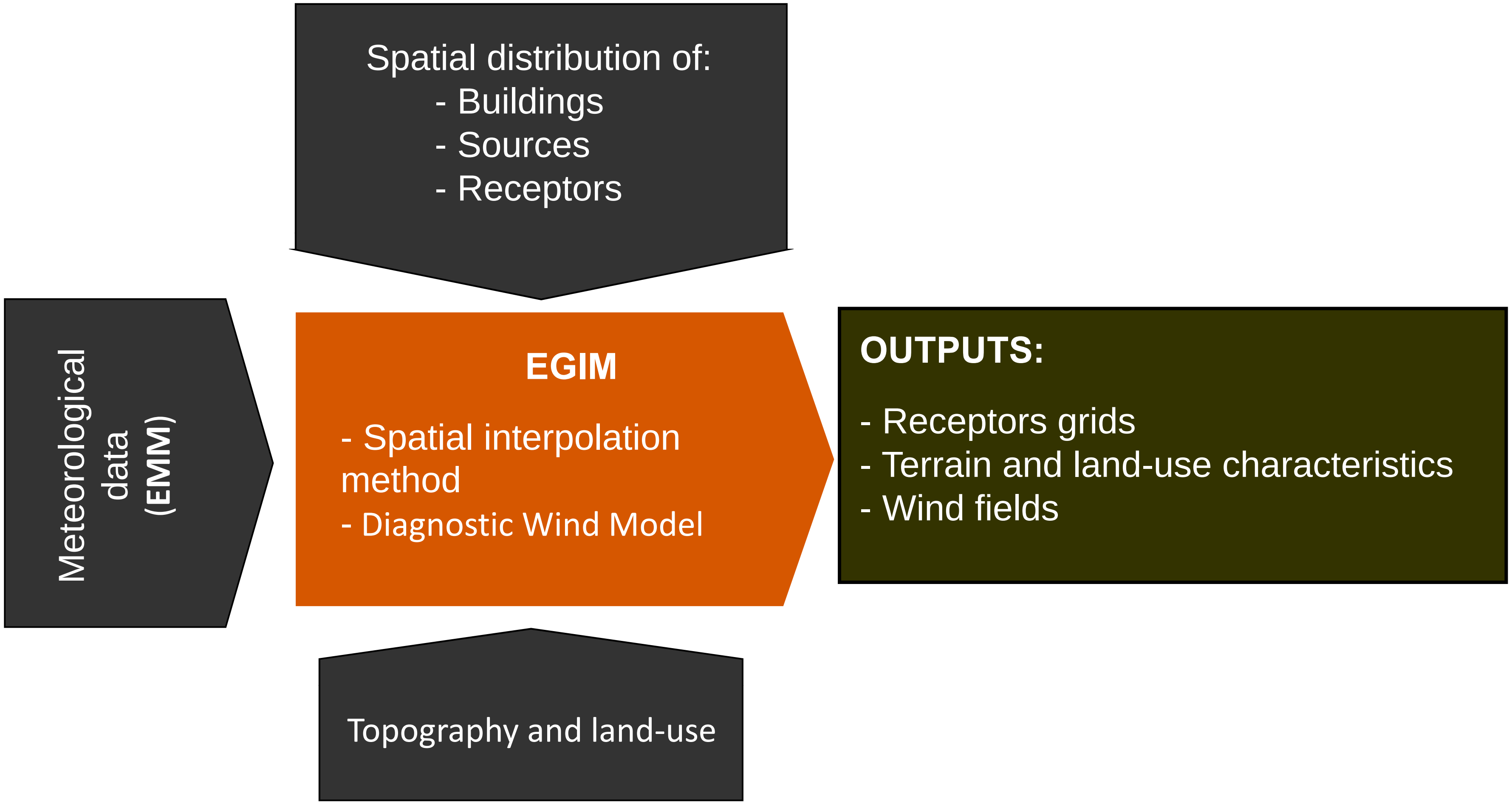
EFRHA model Main Structure



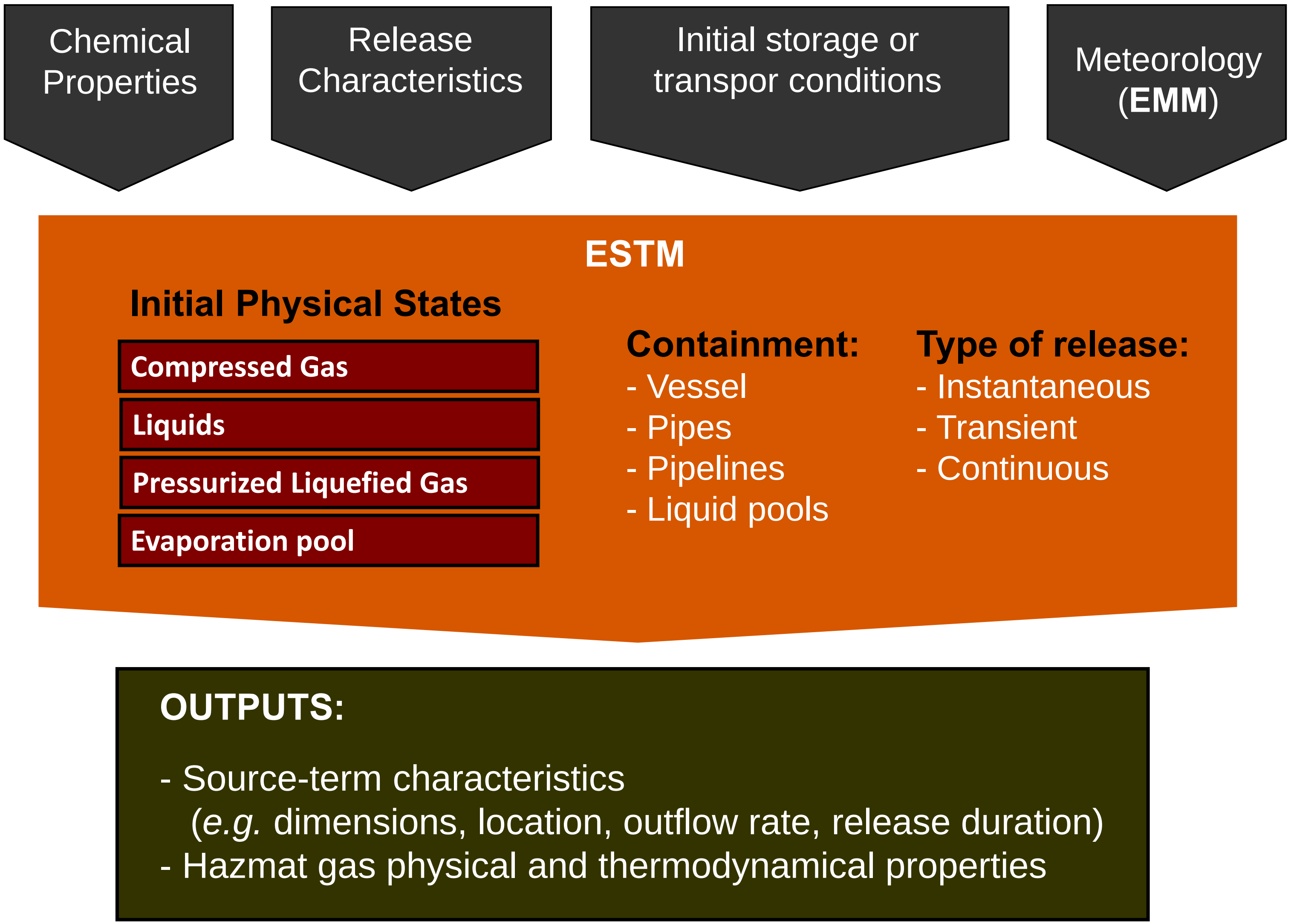
EFRHA model – EMM



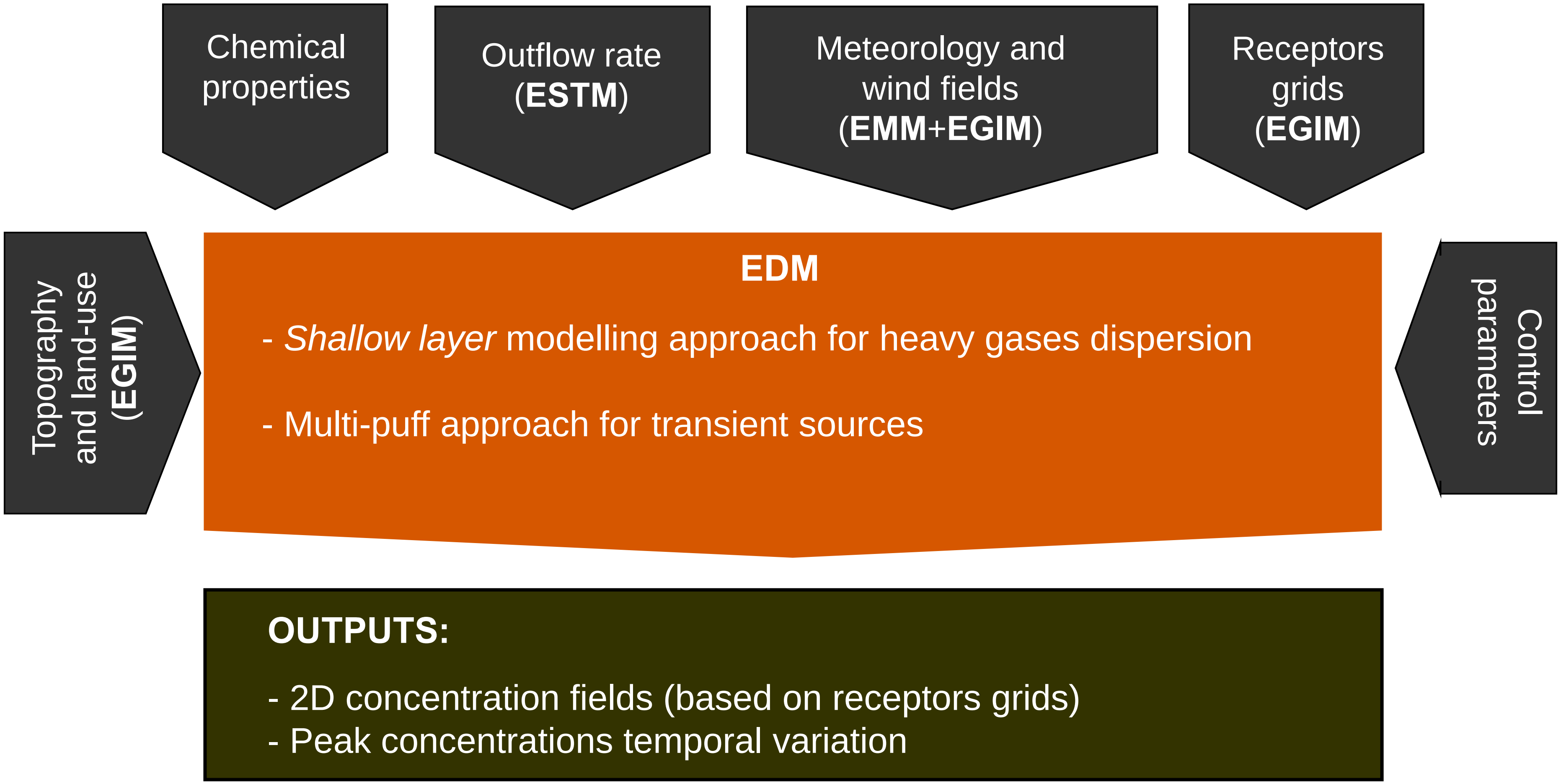
EFRHA model – EGIM



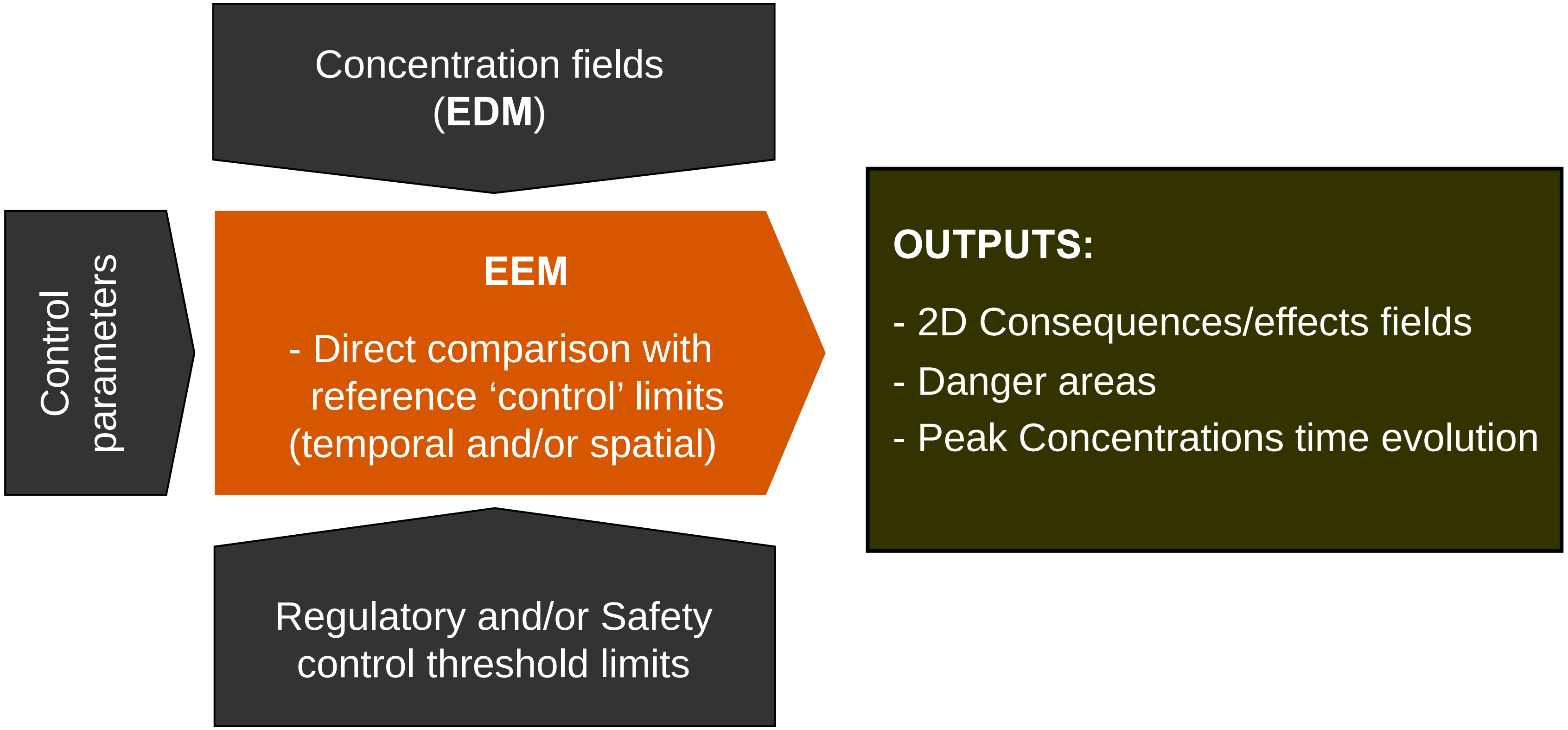
EFRHA model – ESTM



EFRHA model – EDM



EFRHA model – EEM



Validation of EFRHA model

EFRHA model Validation

Validation Exercise:

- *Qualitative* and *quantitative* analyses validation techniques suggested in the COST Action 732 ***Model Evaluation Guidance Protocol*** (*Britter and Schatzmann, 2007*)
    - Graphical comparisons of measured VS modelled concentrations
    - Estimation of quality metrics

EFRHA model validation in its entire scope

- Direct comparisons of modelled and measured peak concentrations from well-established full-scale field test trials

concentration fields were estimated between 0.4 and 1.5 m high from the ground level to maintain a somewhat consistency with measurements, but also, for corresponding to 'normal heights of exposure to hazmat gases'.

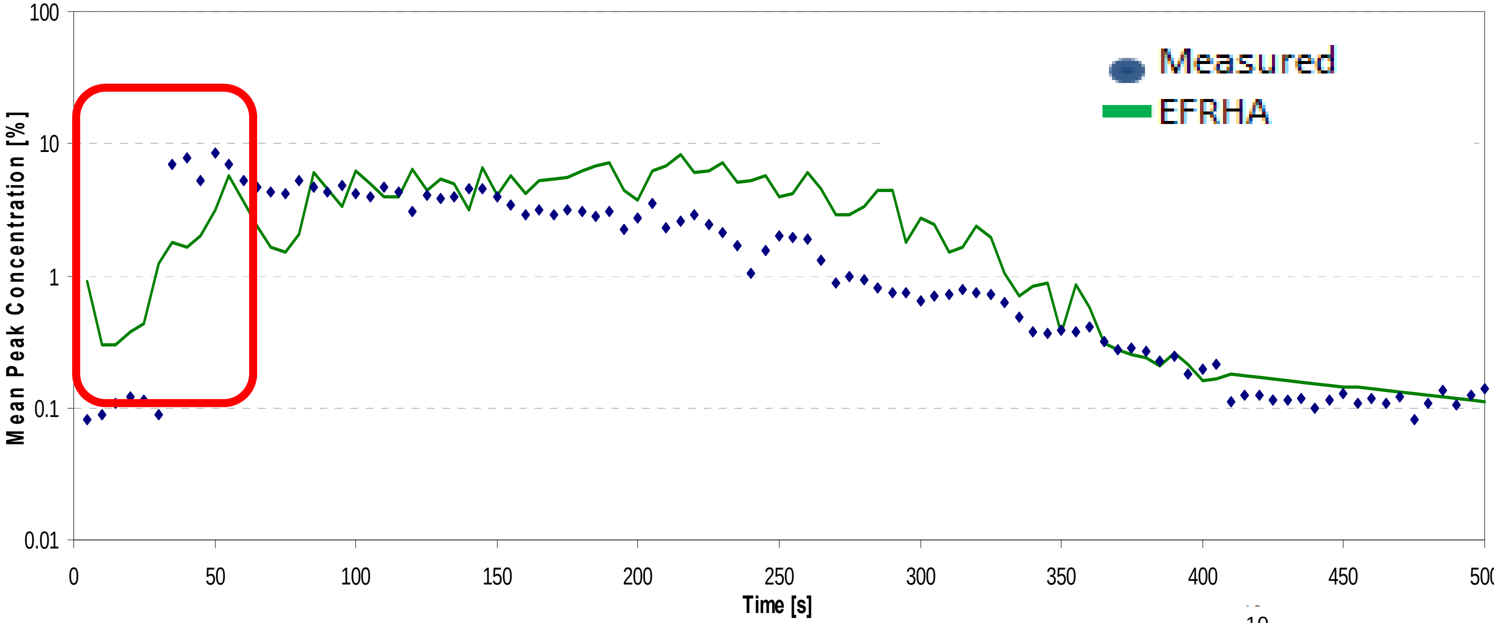
EFRHA model Validation

Set of full-scale field experimental set-ups test trials simulated

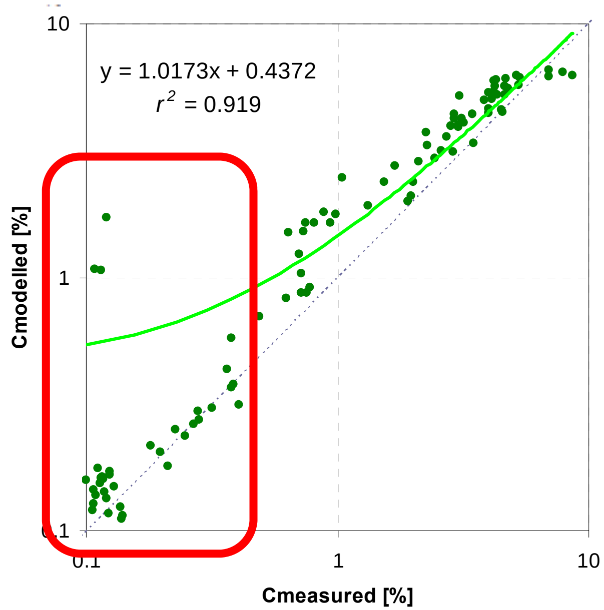
ID	Test Trial	Substance	Spill Flow (kg/s)	Duration (s)	Release Type	Meteorological Conditions
VT1	TI 8	Freon 12-N_2	3967.0	1.0	**Instant. Puff**	T_a = 17.2 ºC P = 1 bar u_{ref} = 2.4 m/s class D
VT2	B 3	LNG	88.0	167.0	**Evapo. Pool**	T_a = 33.8 ºC P = 0.94 bar u_{ref} = 5.4 m/s class B
VT3	DT 3	Ammonia	133.0	166.0	**Continuous Jet**	T_a = 17.2 ºC P = 1 bar u_{ref} = 2.4 m/s class D

TI – *Thorney Island* full-scale experimental trials
B – *Burro* Test full-scale experimental trials
DT – *Desert Tortoise* full-scale experimental trials

EFRHA model Validation – Qualitative Analysis



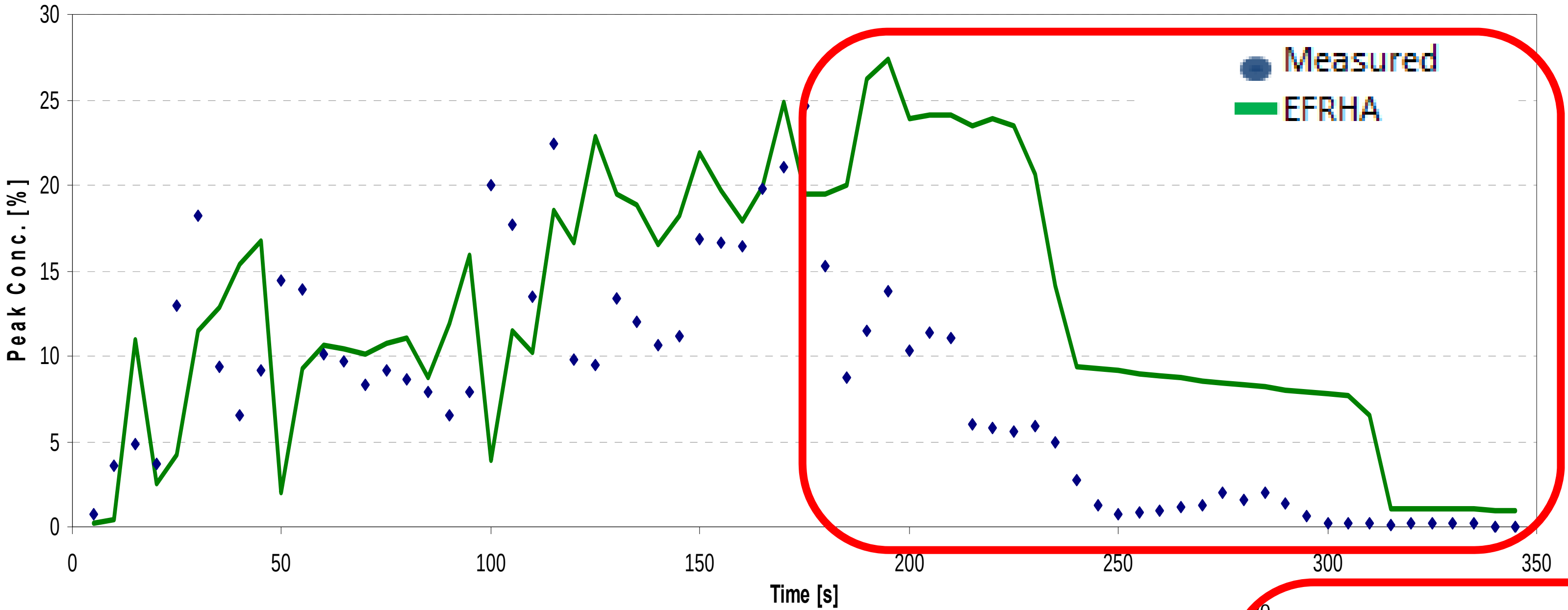
Peak concentration temporal evolution until 500 s after the release



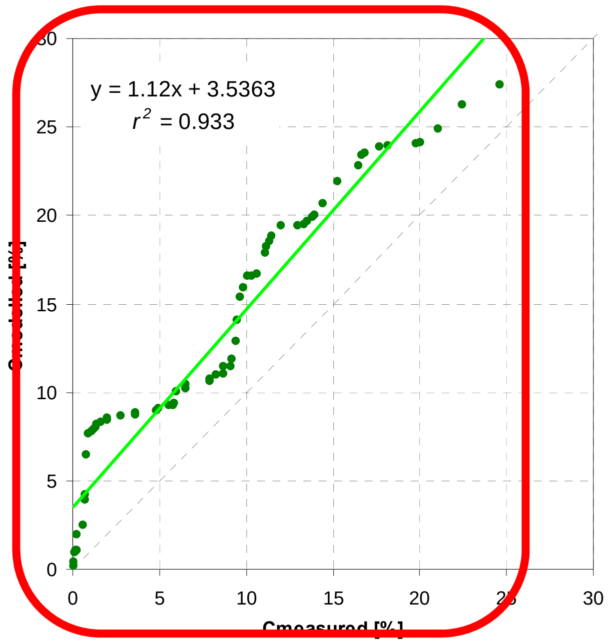
Measured VS Simulated Peak concentration q-q plot

VT 1

EFRHA model Validation – Qualitative Analysis



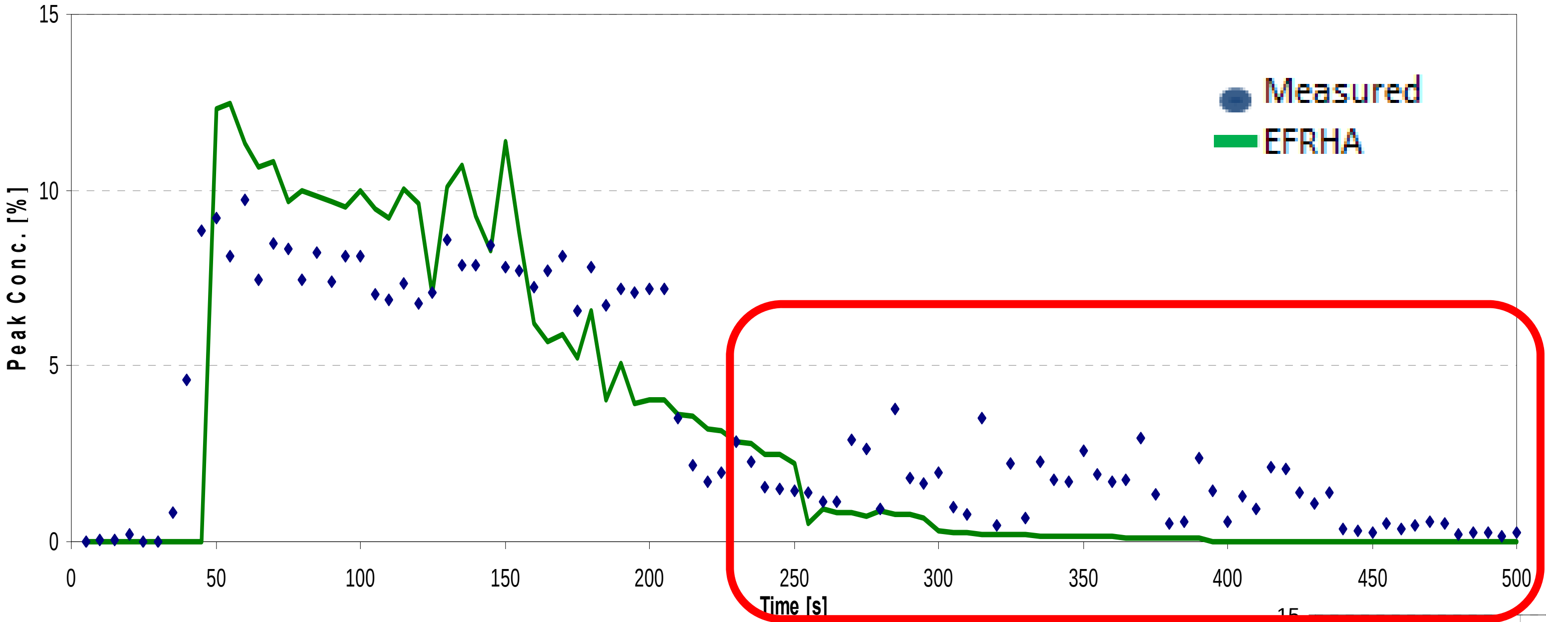
Peak concentration temporal evolution until 350 s after the release



Measured VS Simulated Peak concentration q-q plot

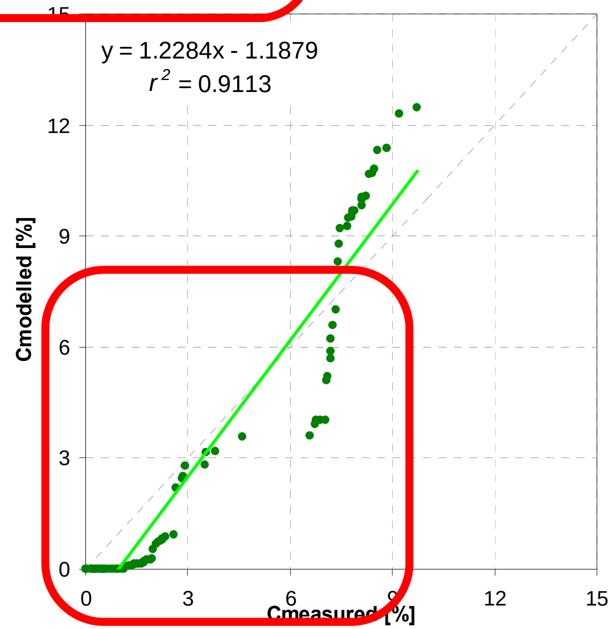
VT 2

EFRHA model Validation – Qualitative Analysis



VT 3

Peak concentration temporal evolution until 500 s after the release



Measured VS Simulated Peak concentration q-q plot

EFRHA model Validation – Quantitative Analysis

Quality metrics estimated using the statistical BOOT Software [*Chang and Hanna, 2004*]

Run ID	FB |FB| < 0.3	FAC2 FAC2 > 0.5	NMSE NMSE < 1.5	r r ≈ 1	MG 0.7<MG<1.3	VG VG < 4	SB -	SDSD -
VT 1	-1. 340	**0.570**	**0.95**	0.57	0.70	**2.03**	0.592	0.130
VT 2	**-0.240**	**0.506**	**0.66**	0.56	0.43	8.71	0.170	0.100
VT 3	**0.121**	0.450	**0.36**	**0.84**	1.95	**2.72**	0.160	0.810

FB *Fractional bias*
FAC2 *Factor of 2*
NMSE *Normalized mean squared error*
r *Pearson correlation coefficient*
MG *Geometric mean bias*
VG *Geometric variance*
SB *Squared bias*
SDSD *Standard deviation of modelled results and observations*

Main Conclusion

Main Conclusions

- Consistent description of ambient conditions and reasonable prediction of hazmat gas release and dispersion,

- *Shallow layer* based dispersion approach can be considered a plausible alternative to integral and CFD approaches for intermediate/operational CA modelling tools,

- EFRHA can be used as a straightforward tool to support CA studies in case of hazmat gas accidental release in industrial and/or urban areas,

- Need to develop and/or improve integrated CA modelling tools to support decision and emergency response in case of hazmat gas accidental release and dispersion in obstructed areas.

Thank You !

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Richard Tavares
(richard.tavares@ec-nantes.fr**)**