A STUDY OF ODOUR METRICS AND MODELS USING A COMPREHENSIVE MEASUREMENT CAMPAIGN DATASET

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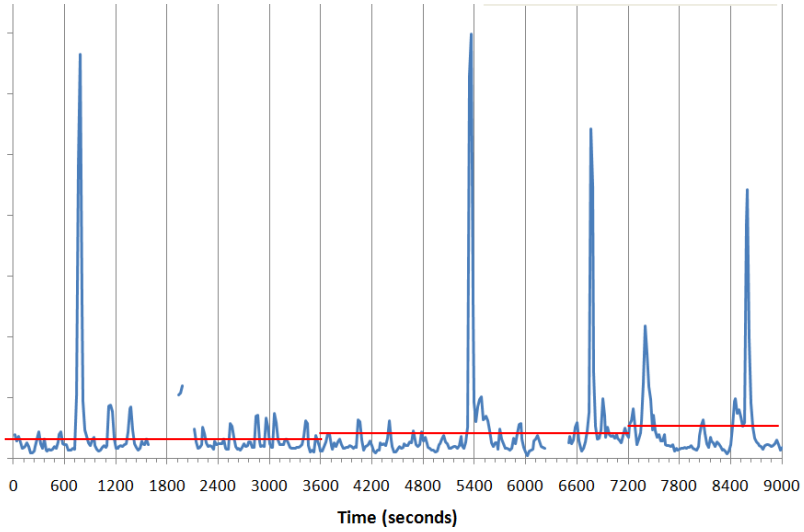
Factors that affect the impact of odours: FIDOL

Frequency	Short timescales Olfactory fatigue
Intensity	Concentrations Perception/strength of the odour
Duration	Total exposure time longer temporal patterns
Offensiveness	Human response Hedonic tone
Location	Sensitivity of receptors Land use (e.g. Urban vs rural)

- Effective odour criteria should take these factors into account
- A particular challenge in dispersion modelling is the Frequency factor

FIDOL: Frequency

- How often an individual is exposed to odour
- Duration of a single breath = a few seconds
- Olfactory fatigue / adaptation:
  - An individual can become acclimatised to the odour - unable to detect the odour after a certain period
  - But if odour has an on/off/on pattern, this is disrupted
- Assessment implications, e.g.
  - Sub-hourly averaging times
  - Fluctuating plumes
  - Intermittency
  - Peak-to-mean concentrations



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‘Percentile of hourly averages’ approach

- Used in most countries with odour criteria
- Does not directly consider the concentration frequency
- Simple concept and straightforward methodology
- Tried and tested:
  - Many studies have found good correlation between high percentile concentration results and annoyance
  - Used in many different practical situations and subjected to much legal scrutiny
- Various percentile values and/or thresholds used
  - Often the 98th percentile, but other values, and multi-percentile approach also used

‘Odour hours’ approach

- Germany and Austria (and some other countries/regions) use ‘odour hours’ approach
- Hours that have recognisable odour (above a $1ou_E/m^3$ threshold) for at least 10% of the hour (i.e. 6 minutes)
  - Equivalent to a 90^{th} percentile of ‘instantaneous’ concentrations
- Odour assessment: the percentage of occurrences of ‘odour hours’ within a year (odour frequency)
- More easily determined by field assessment than the ‘percentile of hourly averages’ approach
- Regulatory modelling in Germany uses a peak-to-mean approach to convert hourly-averaged concentrations to sub-hourly values

Peak-to-mean ratios: key questions

- What is the ‘peak’ in ‘peak-to-mean’?
  - Not standardised; definitions include
    - Various percentiles (90^{th}, 98^{th}, 99^{th})
    - Maximum (100^{th} percentile)
    - A standard deviation relationship
  - 90^{th} percentile equates to odour hour criteria (6 minutes exceed)
- Is a fixed peak-to-mean ratio acceptable?
- If so, under which conditions?
- If a fixed value is not acceptable, how should the peak-to-mean ratio be determined?

Modelling fluctuating concentrations

- Fluctuating concentrations are not commonly modelled
- Constraints and challenges:
  - Predicting ‘instantaneous’ concentrations is inherently difficult, especially at the right place and at the right time
  - Historically few sub-hourly concentration validation datasets
  - Many processes and source types have few datasets
  - Usually only hourly-averaged met data available
- Key questions:
  - Is it feasible and/or appropriate to model very short timescales of concentrations to assess odour nuisance?
  - Is it more feasible/appropriate in some circumstances?
  - How could it be improved?

ADMLC project

- *'Review of approaches to dispersion modelling of odour emissions and intercomparison of models and odour nuisance assessment criteria'*
- Ongoing project for the UK Atmospheric Dispersion Modelling Liaison Committee (ADMLC)
- CERC working alongside SIA Estonian, Latvian & Lithuanian Environment (ELLE), with input from RSK-ADAS
- The work described in this presentation was carried out in parallel with this project

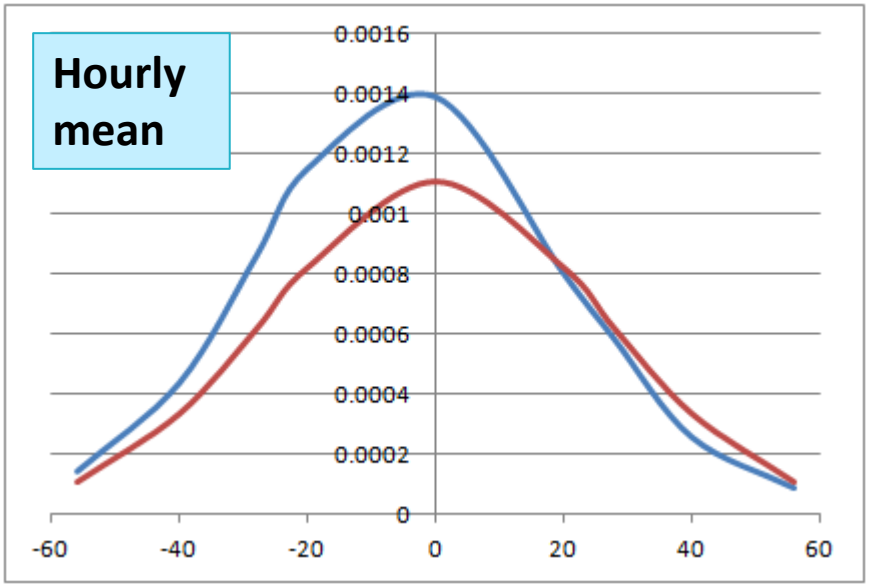
Models used in the ADMLC project (red = this presentation)

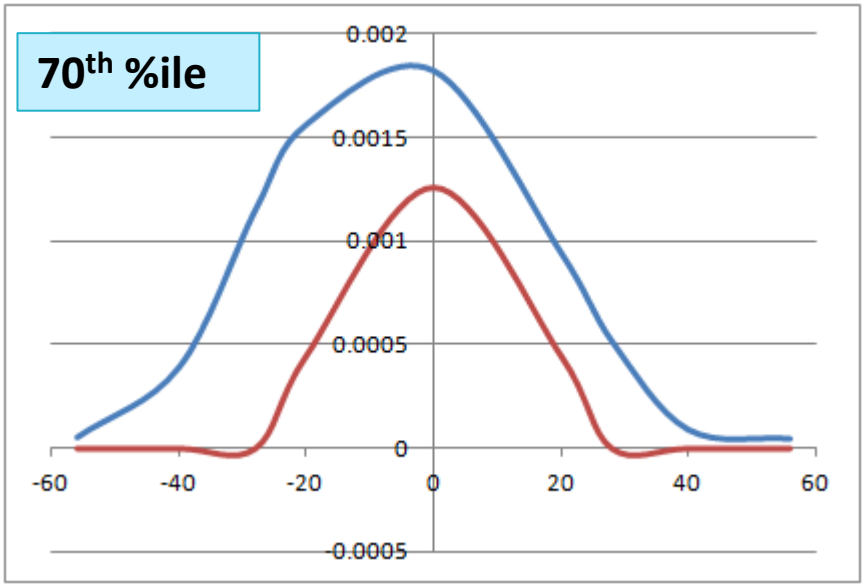
Model	Type	Calculation of odour hours
ADMS (CERC)	Gaussian plume	Fluctuations module and fixed peak-to-mean ratio
AERMOD (US EPA)		
AUSTAL2000 (Janicke Consulting/UBA)	Lagrangian particle	Fixed peak-to-mean ratio

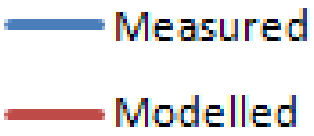
ADMS fluctuations module

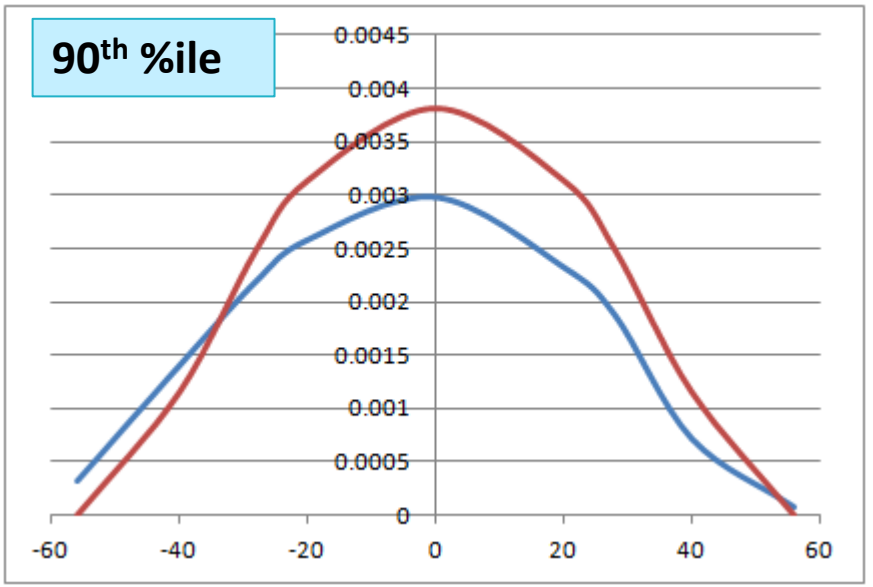
- Calculation of sub-hourly concentrations
- Also useful for applications such as toxic or flammable gases
- Based on a probability distribution of concentrations
- Accounts for variations in both meteorology and turbulence
- Inputs: averaging time (minimum = 1 second) and percentile value(s)
- CERC has recently adapted the module to generate output specifically for odour hours (yes/no for each hour)

ADMS fluctuations module: example









- Transect (arc) concentrations
- Percentiles: 1-second averaging time

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Peak-to-mean ratios

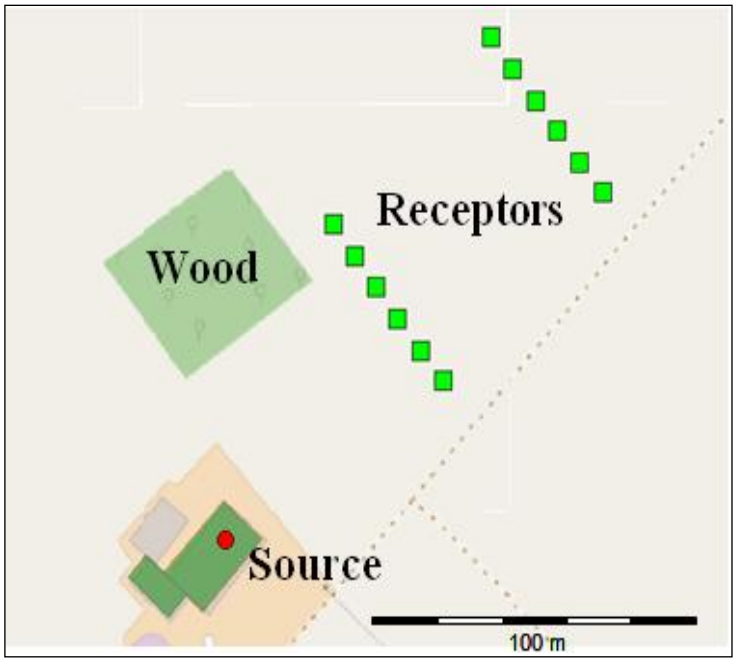
- AUSTAL: A fixed peak-to-mean ratio of 4 is applied in the model as a proxy for the 90th percentile of instantaneous concentrations
  - In practice, the hourly average value is simply compared with a threshold of 0.25 ou_E/m^3
- ADMS: A fixed peak-to-mean ratio of 4 was simply applied to the hourly average concentrations as a post-processing step

Datasets used in the ADMLC project (red = this presentation)

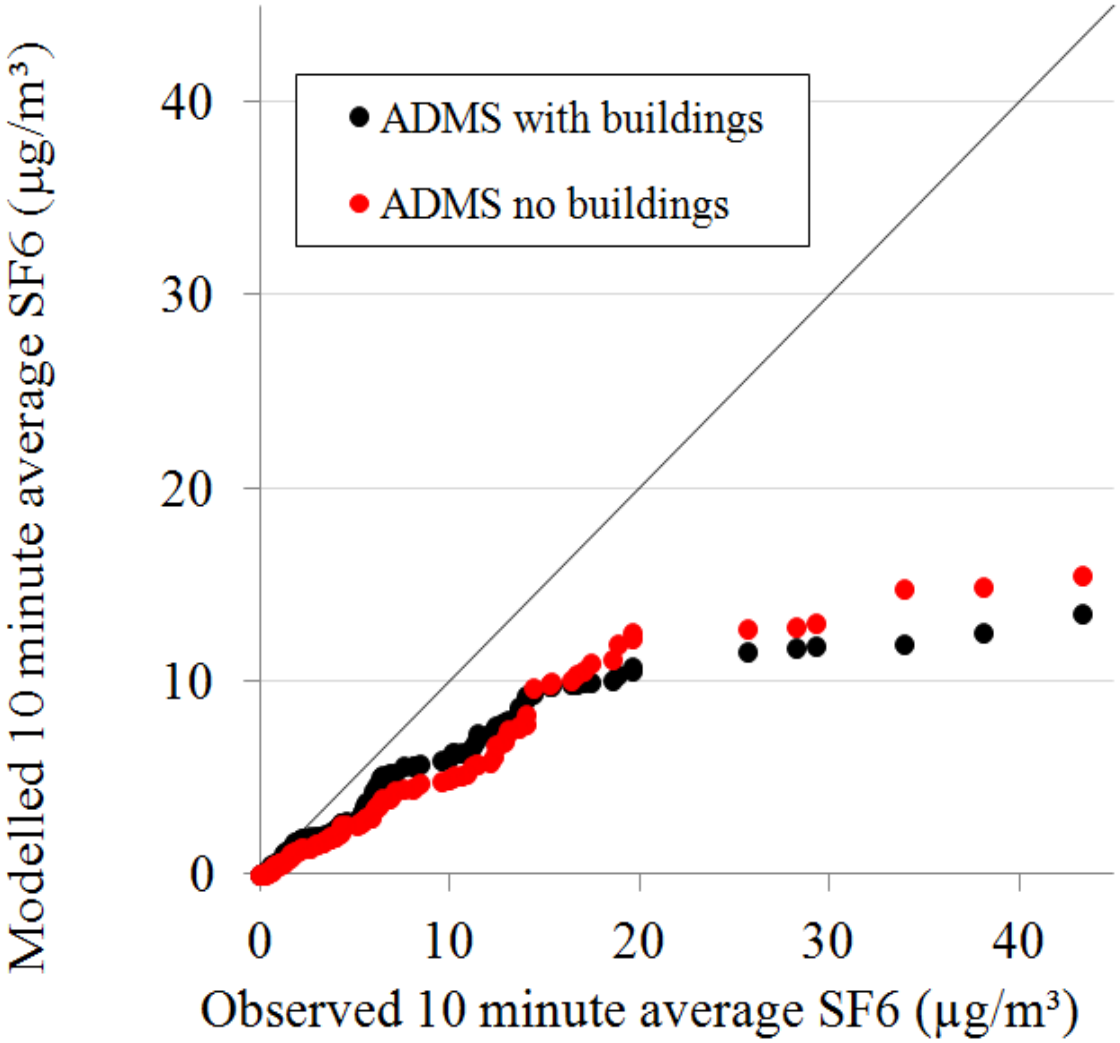
- OROD
  - Field experiments at a pig farm with SF_6 tracer and odour measurements
  - 10-minute and some shorter (10-second) measurements
- CEDVAL
  - High frequency wind tunnel measurements, based on the OROD dataset
- Port
  - Continuous electronic nose measurements at three locations, 1-minute averages
- Pig farm in Austria
  - Field experiment with odour measurements

OROD (BWPLUS) dataset

- 14 field experiments at a pig farm
- Some have two receptor arcs, others a single arc
- All points: 10-minute odour and SF_6
- At two points for each experiment , 10-second odour and SF_6 also measured
- The subjects recorded their odour perceptions as a value from 0 (no odour) to 6 (extremely strong odour), with 1 = a very faint odour
- Followed VDI Guideline 3940

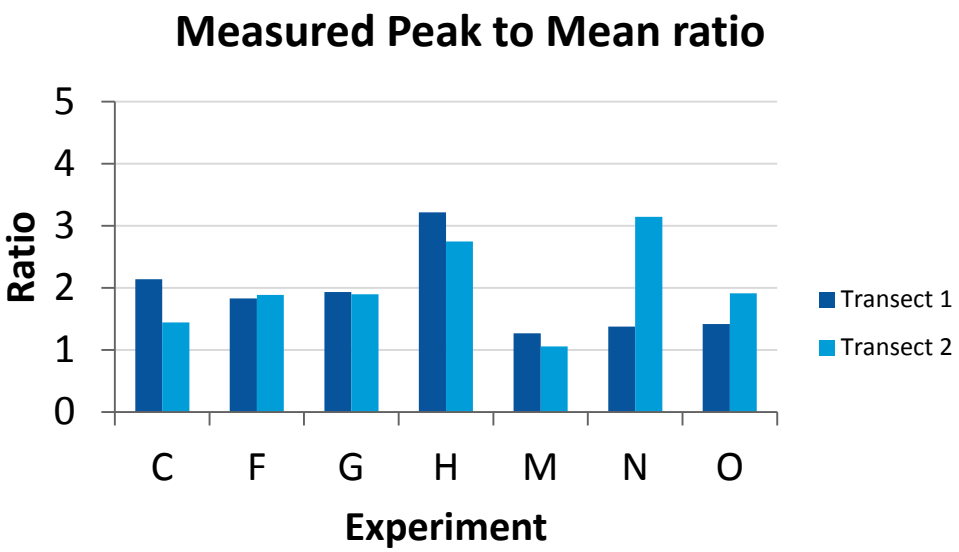


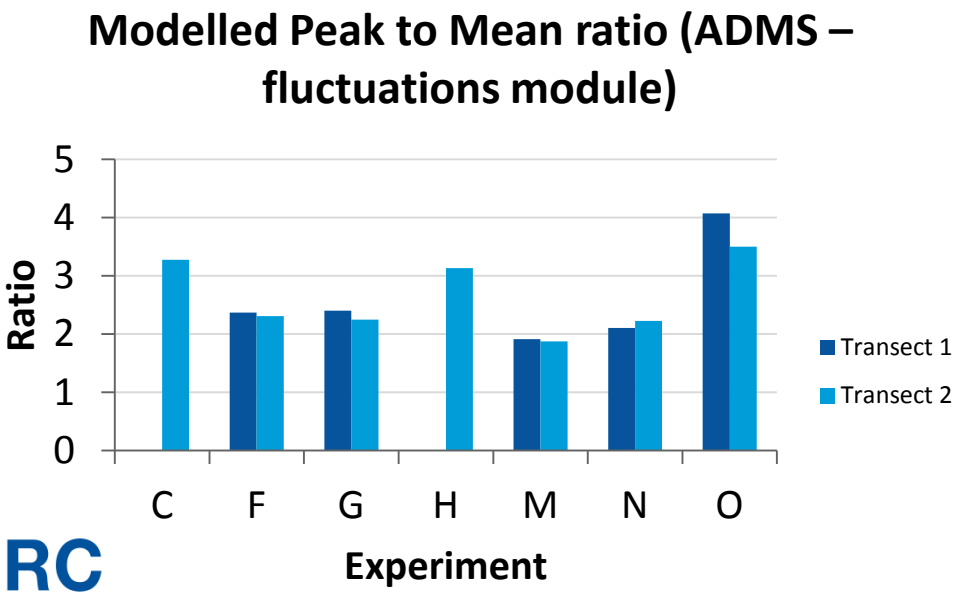
OROD dataset: 10-minute average SF_6

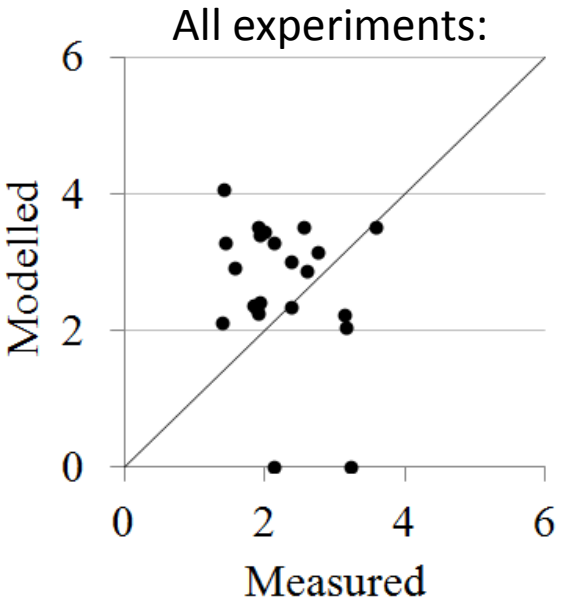


- Quantile-quantile plot over all experiments
- Shows ADMS data (without fluctuations module)
- Have also run with AUSTAL

OROD dataset: 10-second average SF_6 (ADMS fluctuations)







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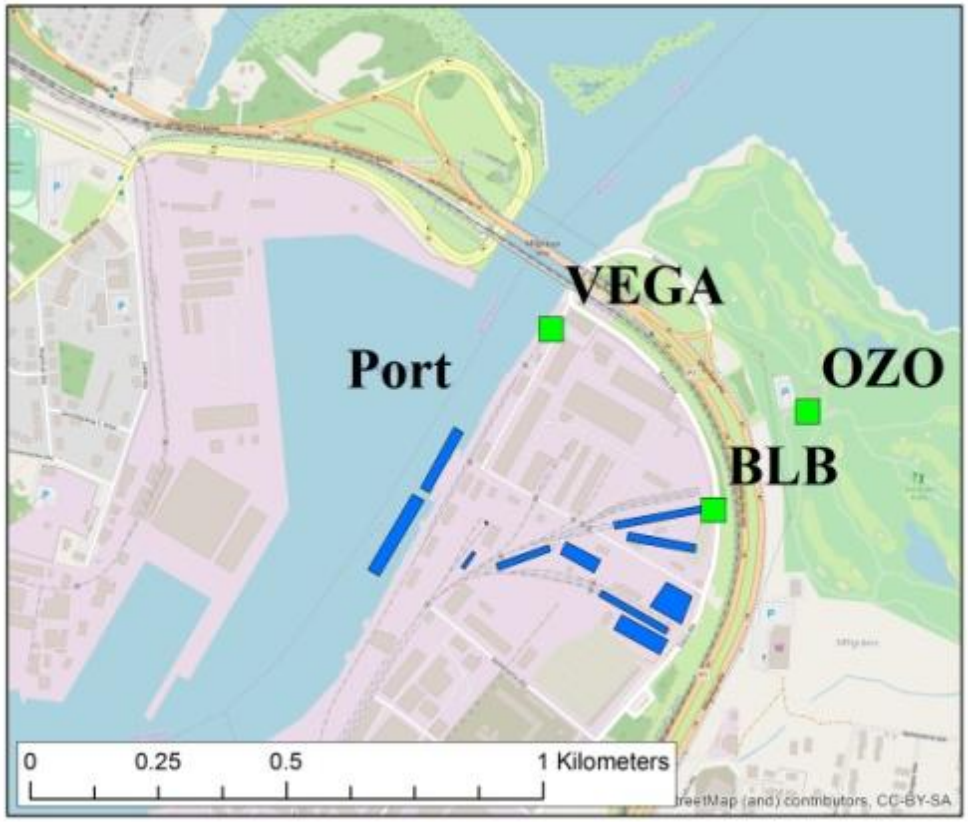
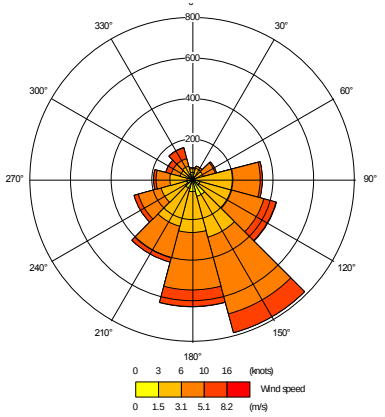
Port dataset

- Terminal in Riga, Latvia
- Main activities: unloading, short-term storage and loading of oil
- Continuous electronic nose monitoring at 1-minute intervals
- Several years of data
- Monitors allow operator to monitor odour trends in real time



Receptor

Odour Source



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Port dataset

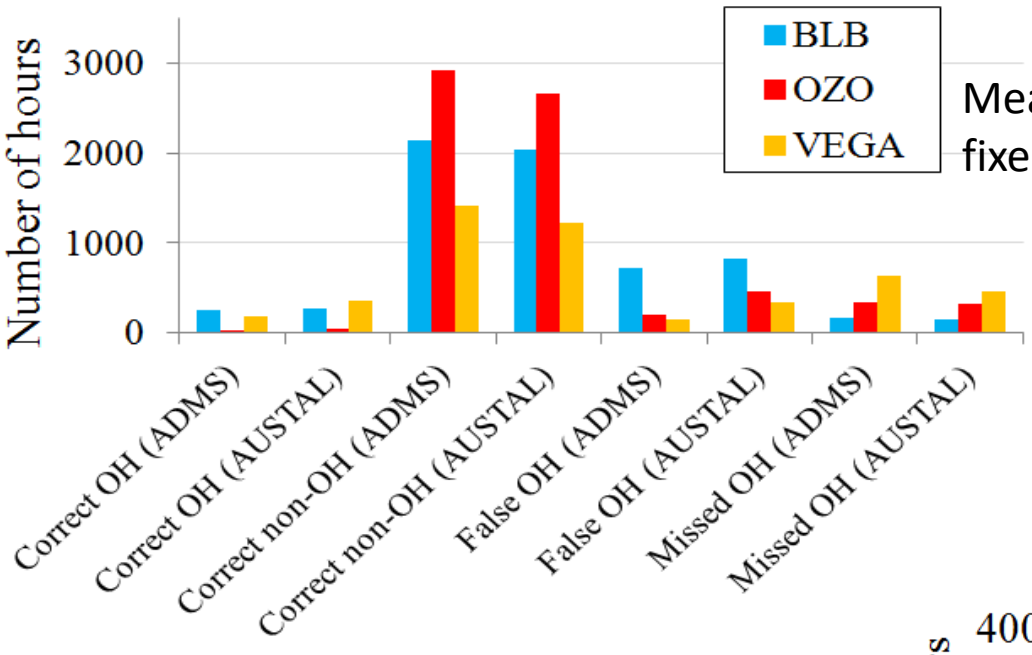
- 98th percentile of hourly averages

Monitor	Measured	ADMS	AUSTAL
BLB East	7.1	12.0	10.2
OZO	9.7	4.3	4.3
VEGA	20.2	5.4	17.0

- Odour hours prediction (threshold = 5 ou_E/m^3) (%)

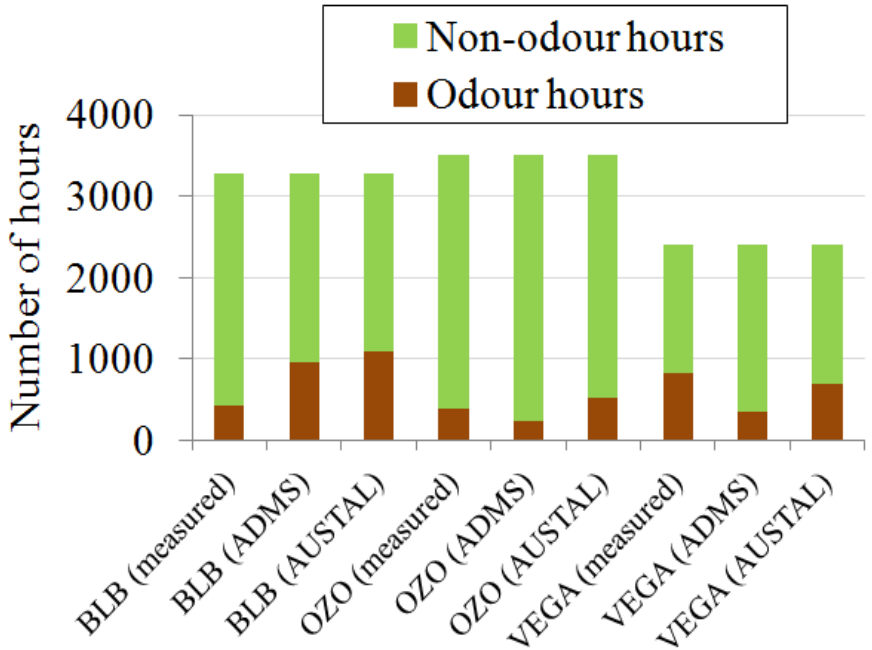
Monitor	'Correct' odour hour (ADMS)	'Correct' non-odour hour (ADMS)	'Correct' odour hour (AUSTAL)	'Correct' non-odour hour (AUSTAL)
BLB East	59	75	66	71
OZO	10	93	12	85
VEGA	22	90	43	78

Port dataset: prediction of odour hours



Measured and modelled odour hours: values fixed in time and space ←

Measured and modelled odour hours: no temporal dependence →



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Conclusions

- Evaluation of ADMS and AUSTAL2000 for odour assessment using two datasets:
  - Field campaign at a pig farm
  - Continuous monitoring at a port
- Fixed peak-to-mean and fluctuations modelling assessed
- ADMS and AUSTAL2000 perform similarly in predicting odour hours (fixed peak-to-mean)
- The ADMS fluctuations module can be used to model sub-hourly concentrations to assess the odour hour criteria
- Further work ongoing to assess the relative merits of fixed peak-to-mean and fluctuations modelling approaches

Many thanks for your attention