

European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

WGs & MC Meeting at SOFIA (BG), 16-18 December 2015

New Sensing Technologies for Indoor Air Quality Monitoring: Trends and Challenges

Action Start date: 01/07/2012 - Action End date: 30/04/2016 - Year 4: 1 July 2015 - 30 April 2016

STUDY ON TCO MOX SENSORS IN OUTDOOR ODOR MONITORING



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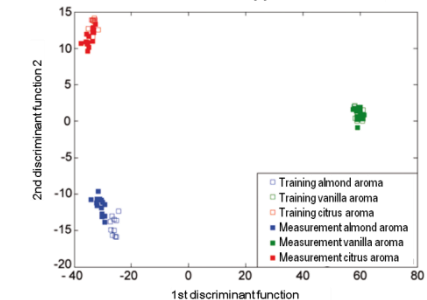
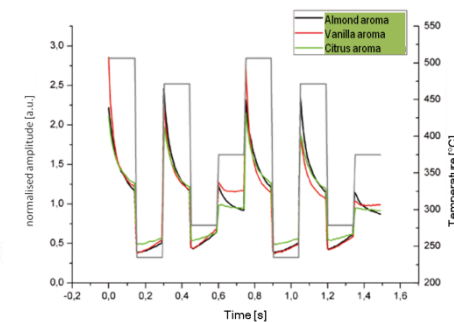
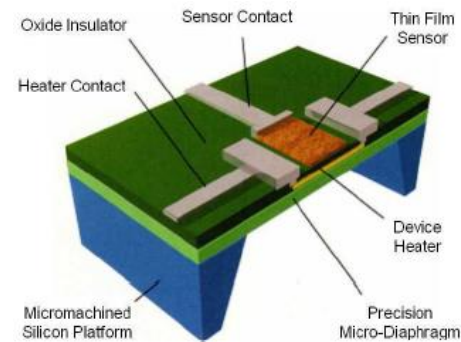
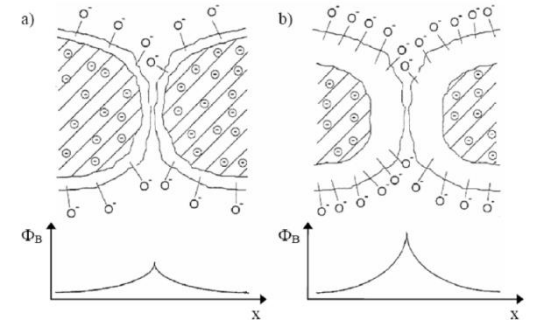
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 **cost**
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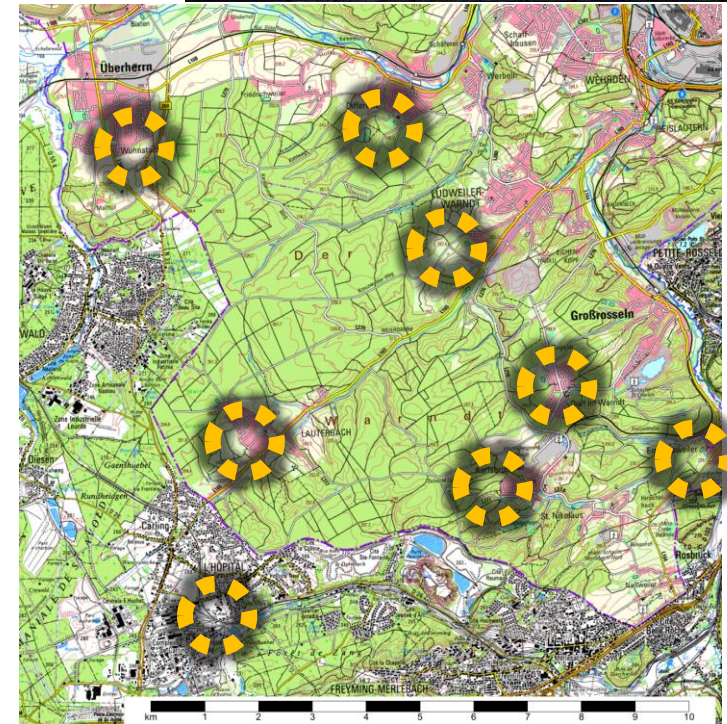
Preface: Temperature cycled MOX sensors

- Metal oxide gas sensors: working principle redox reactions with surface adsorbed oxygen
→ unspecific, **broadband** reaction
- Temperature dependency can be used for “thermal spectroscopy”
→ **selectivity**
- Transient behaviour most interesting, current research shows vast increase in **sensitivity**
- Temperature cycle results in response pattern
→ **pattern recognition** correlates reaction with substances / odours



Key question

- Can temperature cycled MOX sensors be used for odor impact monitoring?
- Odor nuisance reported by **residents**
- **Sensor network** for objective monitoring with sufficient time and location resolution
- Issues:
 - Small concentrations
 - Climatic influence
 - Strong local interference



Outdoor device prototype

- Modular electronics from IAQ

- MOX sensors:

- 1 thick film ceramic type

- 1 thin film on micromachined Si platform

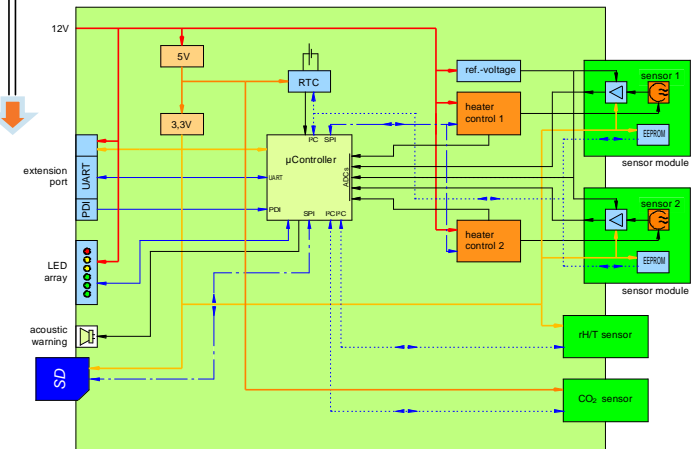
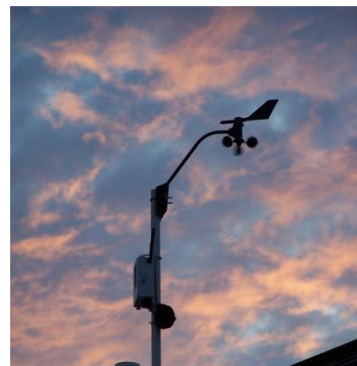
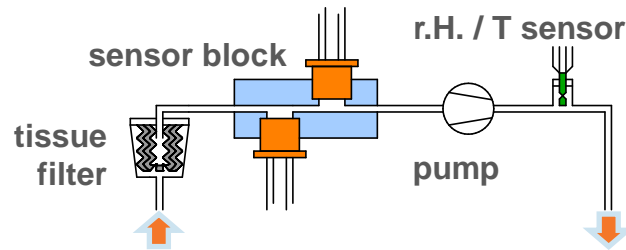
- r.H./T sensor

- Outdoor adaptation

- Rugged housing

- Pumped system

- Energy and expansion options



Installations on site



Differten



Ludweiler



Emmersweiler



Überherrn



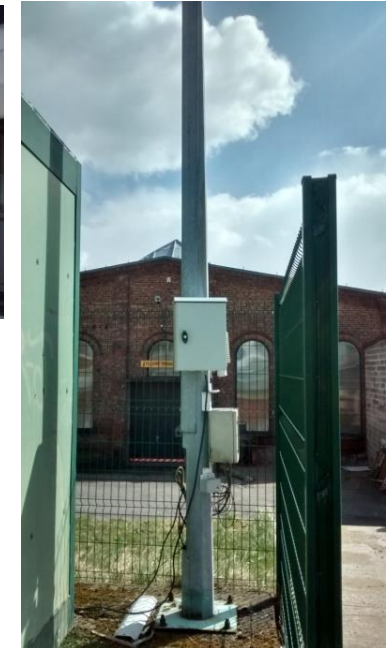
Dorf im Warndt



Lauterbach



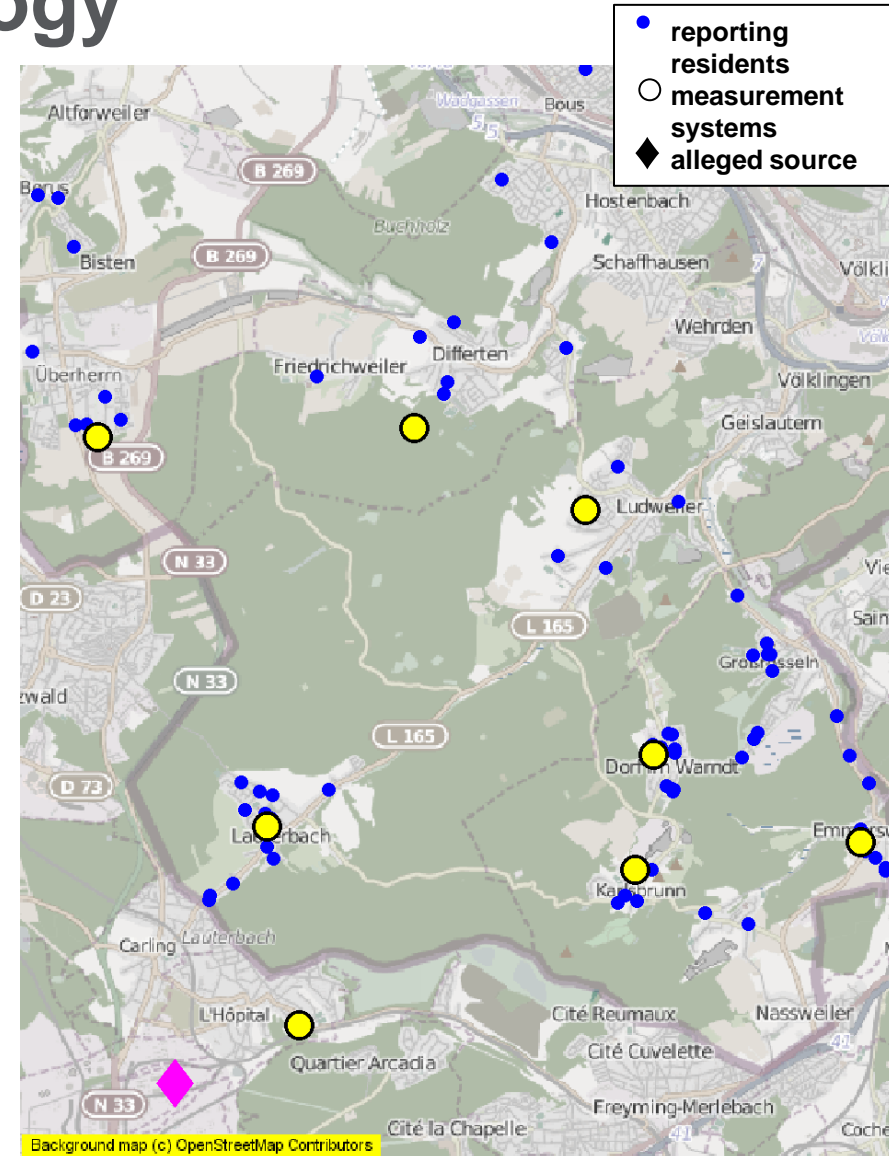
Karlsbrunn



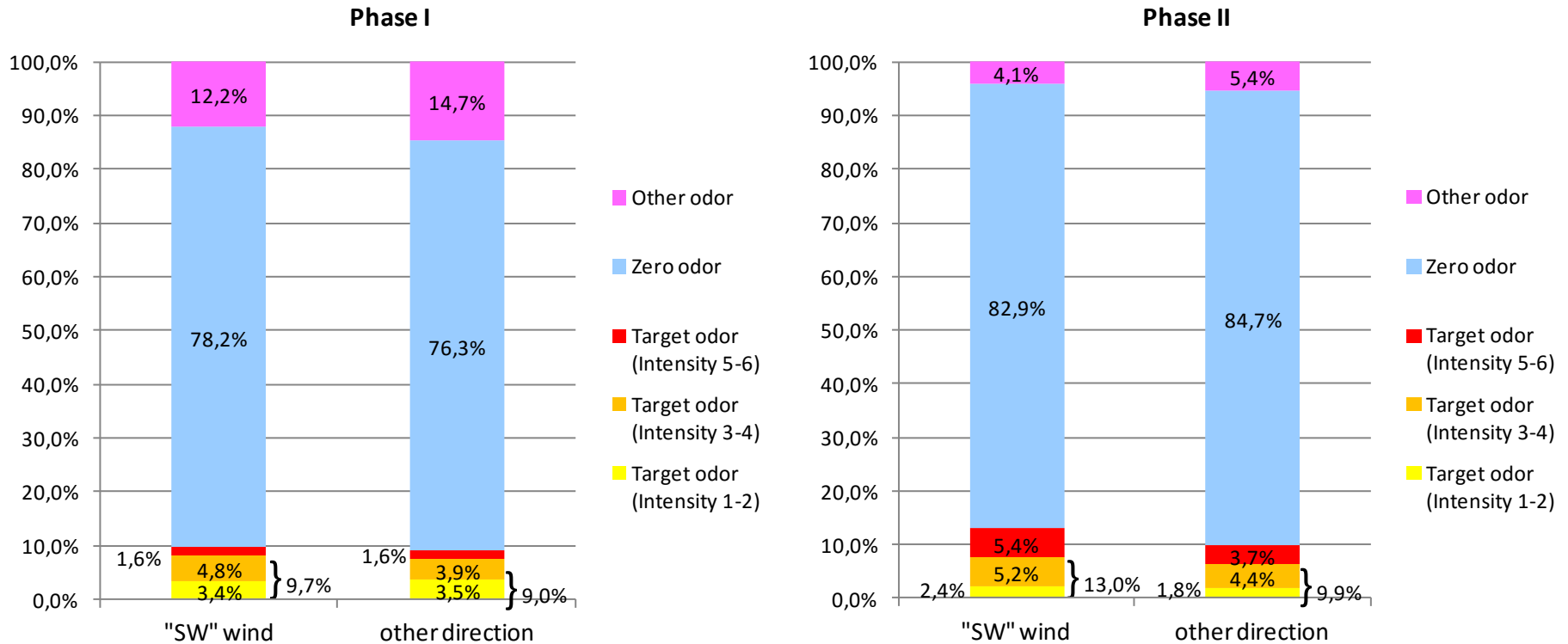
L'Hôpital

Methodology

- **Citizens network**
 - Two reporting periods
 - **Phase I** 10/2014 – 01/2015
 - **Phase II** 04/2015 – 07/2015
 - 8488 reports from 41 citizens
- **Sensor network**
 - 8 sensor system installations
- **Data processing**
 - **Validation** of citizens' reports
 - Identification of “events”
 - Supervised learning to discriminate measurements according to citizens reports
 - **Verification**

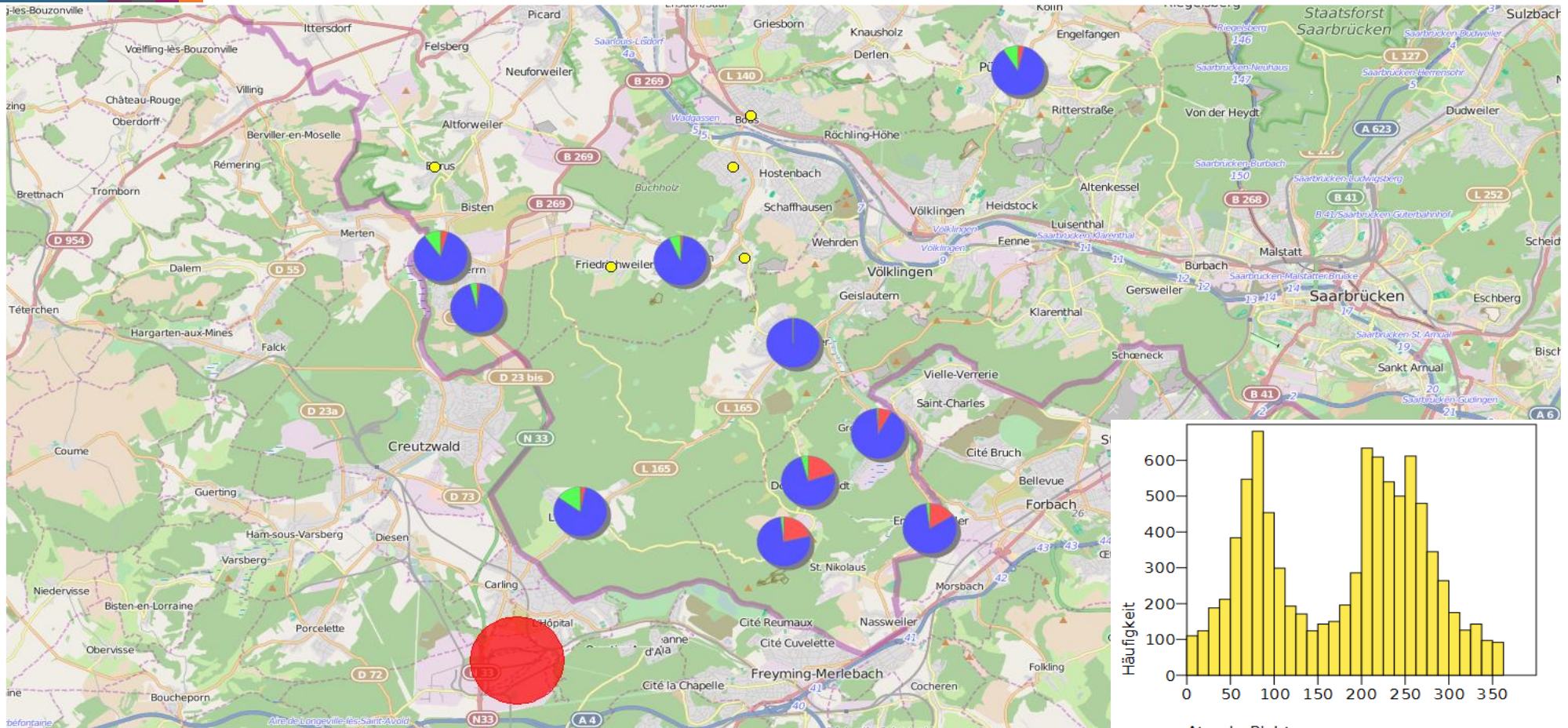


Citizens' reports



- Phase II (summer) vs. phase I (winter)
 - No significant increase in target odor fraction
 - Shift in intensity spectrum
 - Decline in „other odor“ reports
 - Increase of zero odor fraction
- Distribution effectively independent from wind direction

Localities affected by chemical odors



- Target odor cluster in Emmersweiler, Karlsbrunn, DiW, Großrosseln
- Corresponding to 200-260° peak in bimodal wind distribution

Events identified

- Event: period of plausible (wind) and consistent reports
- Target odor: pungent chemical/sweet and „plastics“
- Other odor: all other odors
- Zero odor: no perceptible odor
- Best temporal correlation of target odor reports in Dorf im Warndt, Karlsbrunn and Emmersweiler → Basis for event search

Event	Phase I	Phase II	
		raw events	selected for training
Target odor	2	32	15
Zero odor	2*	100	15
Other odor	1	4	1
	5	136	31

* Here, no further events were searched for

→ Far better response from phase II: much more events

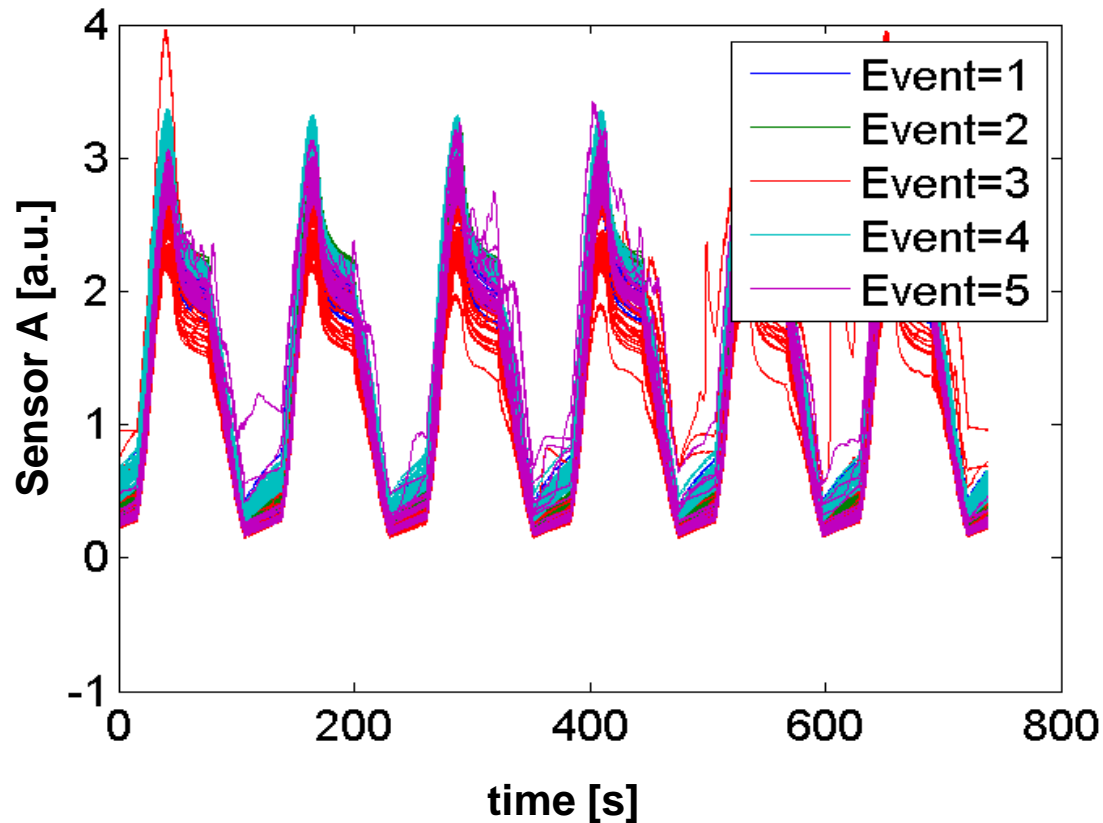
→ Reference for training

Sensor response in TCO

Example given:
Response sensor type A

Events

- 1: other odor
- 2: zero odor
- 3: target odor
- 4: zero odor
- 5: target odor



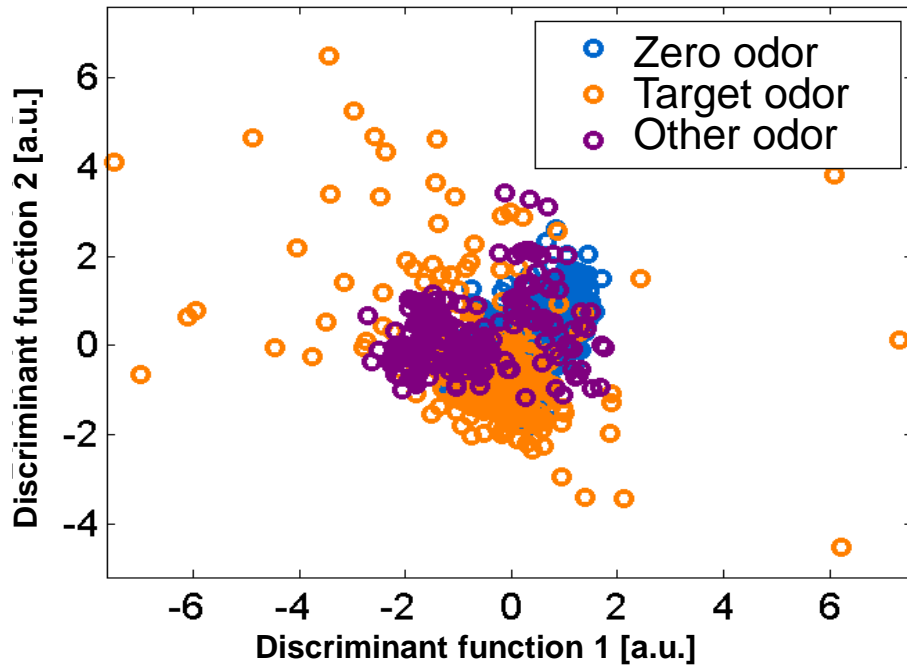
Aim:

Automated discrimination and classification of events

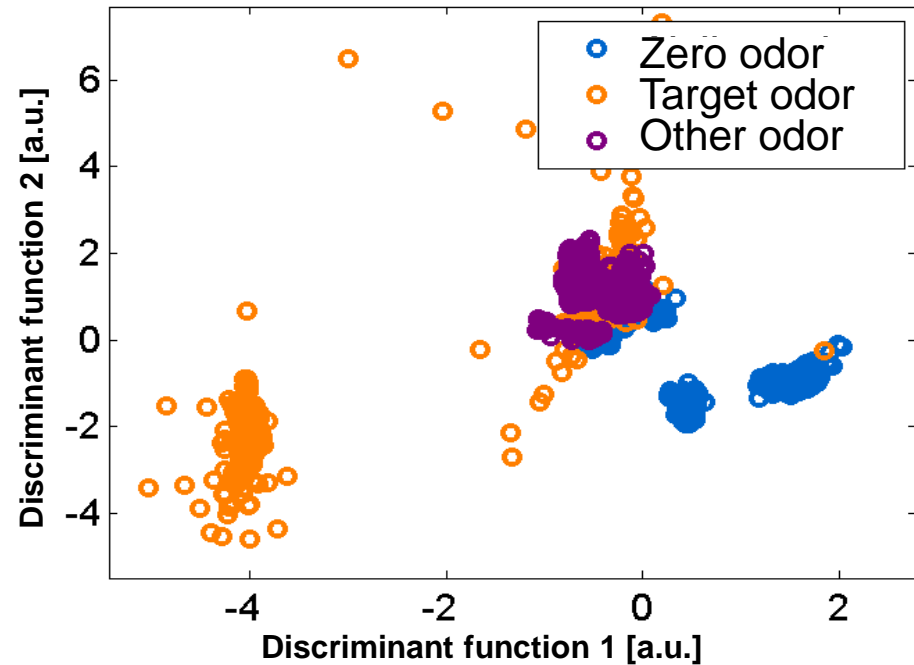
Training from phase I data

Phase I: October 2014 – January 2015

Dorf im Warndt (UST GGS 1330)



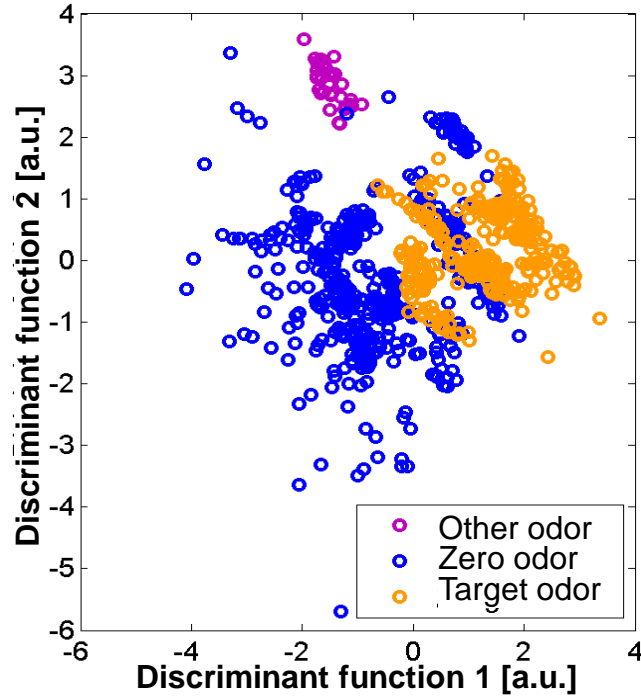
Dorf im Warndt (AS MLV)



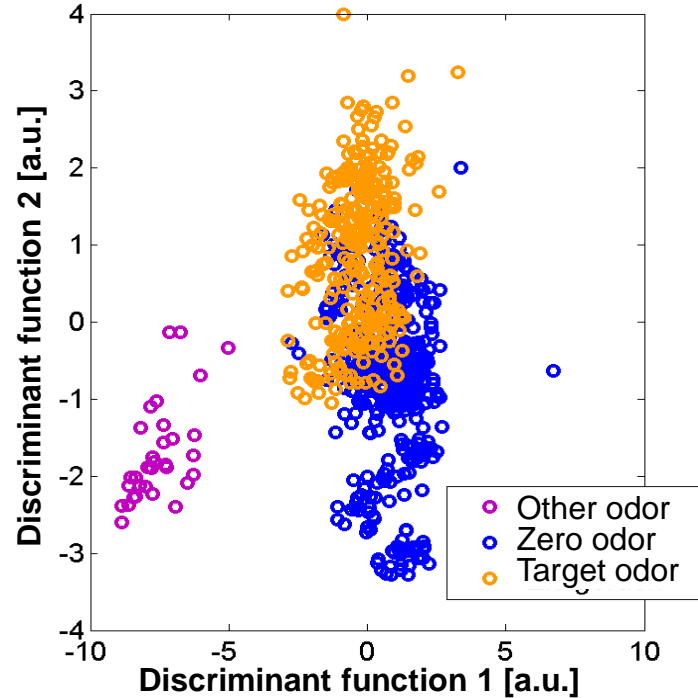
- Sensor type A (UST GGS 1330) gives no discriminable signal
- Sensor type B (AS MLV) applicable for target odor detection
- No verification possible with small number of events (training events only)

Training from phase II data

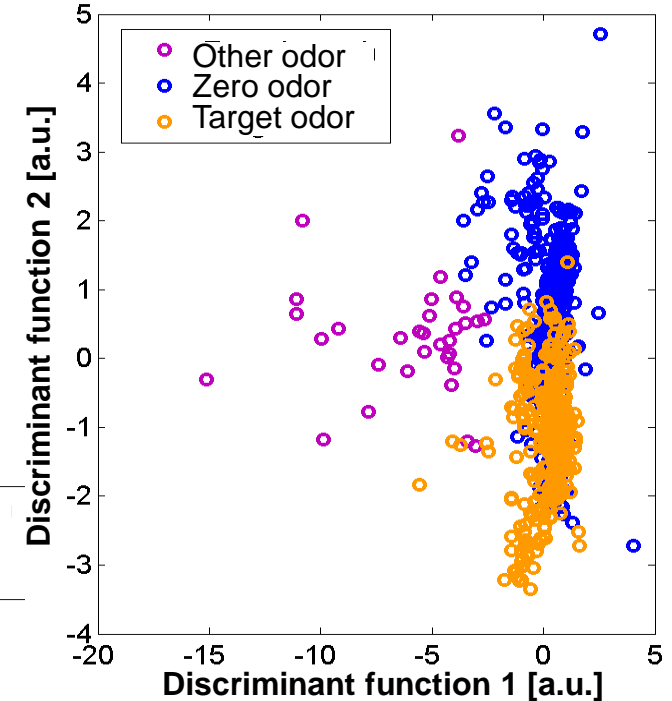
Dorf im Warndt 01.04. – 13.07.2015



Karlsbrunn 01.04. – 13.07.2015

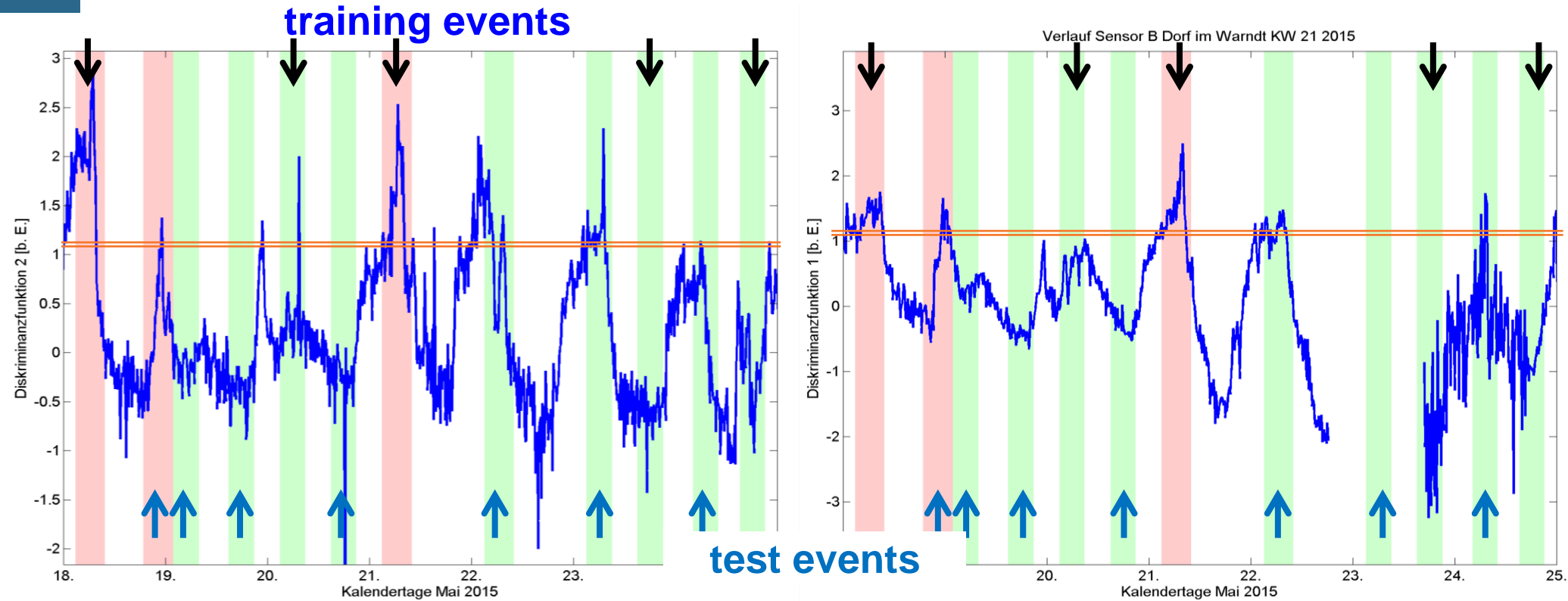


Emmersweiler 01.04. – 13.07.2015



- Only sensor B (AS MLV) has been evaluated
- Visible overlap of target odor and zero odor projections
→ Limit of sensitivity reached
- → Amalgamation of target odor and non-target odor within „event“ period
- Aim: **Output signal** „odor intensity“ over time
 - Separation for Dorf im Warndt along DF1
 - Separation for Karlsbrunn along DF2

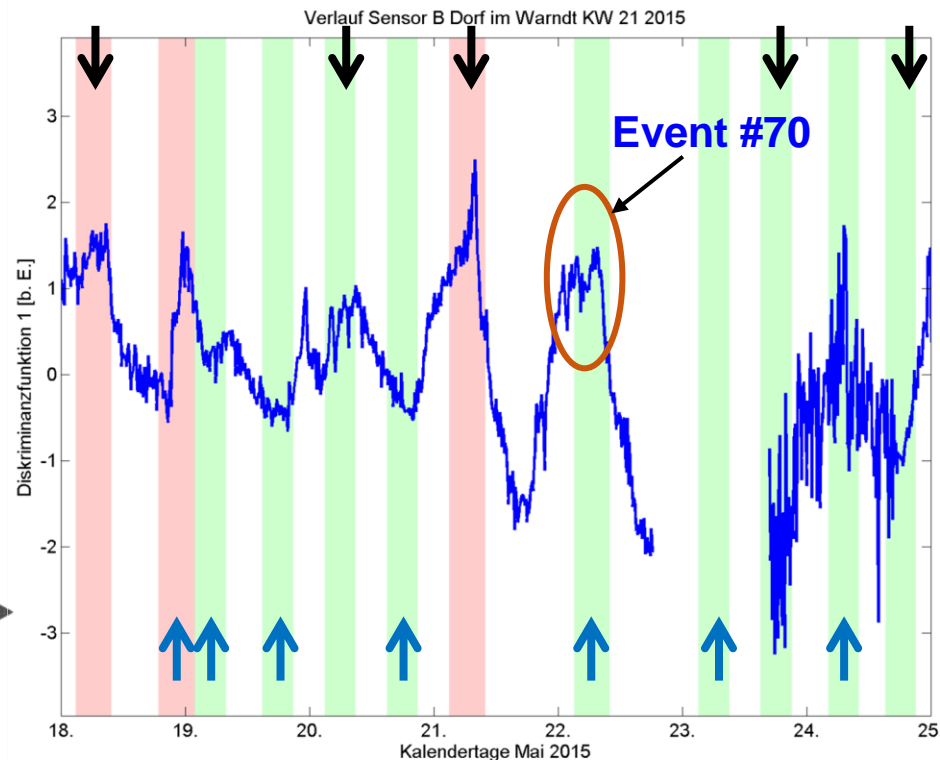
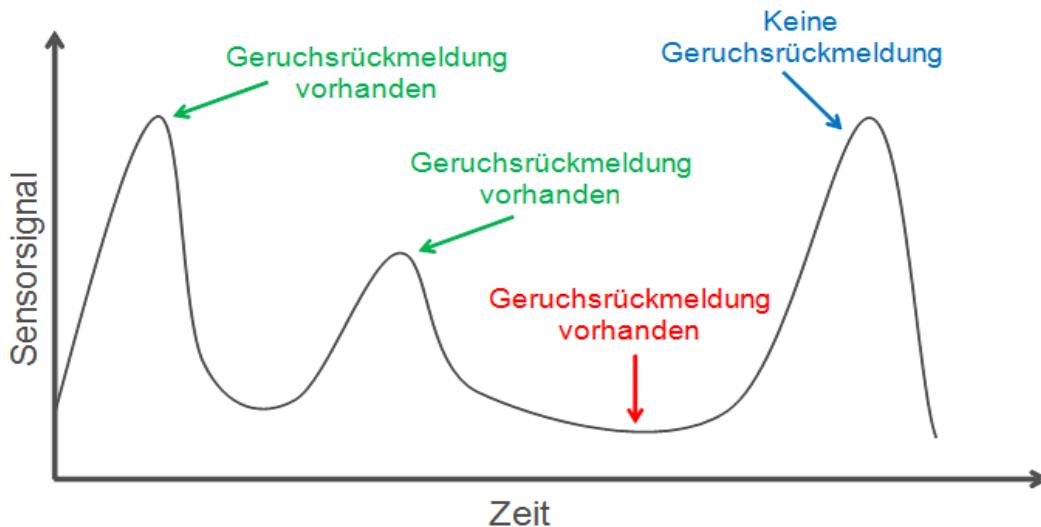
Verification



red: target odor event, green: zero odor event, white: unclear situation

- ◆ Discriminant functions give local maxima over time
- ◆ However: No simple threshold applicable for „odor“ identification
- ◆ Various interfering influences (climate, insolation, time of day)

Odor alarm interpretation



- False positive (false alarm):
 - System gives odor signal, citizens network does not
 - Event #70: 0 target odor reports, 14 zero odor, 2 other odor
- False negative (missed alarm):
 - System does not indicate odor in contrast to citizens' report
 - No *false negatives* within the period evaluated (regarding minima resp. adapted threshold)

Results

- Evaluation of citizens' reports
 - No significant correlation between odor and wind direction
 - Reference times for training (“events”)
- Sensor systems
 - 250 GB of raw data collected
 - No electronics or sensor failure from 10/2014 until 12/2015
- Data analysis
 - Toolchain for **citizens-to-system training** scenario implemented
 - Individual training for each system necessary (sensor-to-sensor variation)
→ No inter-system „master fingerprint“ for target odor
 - Local maxima of trained DF indicate odor events
 - Prone to **false alarms** for target odor identification
(small concentrations, complex environmental influences)

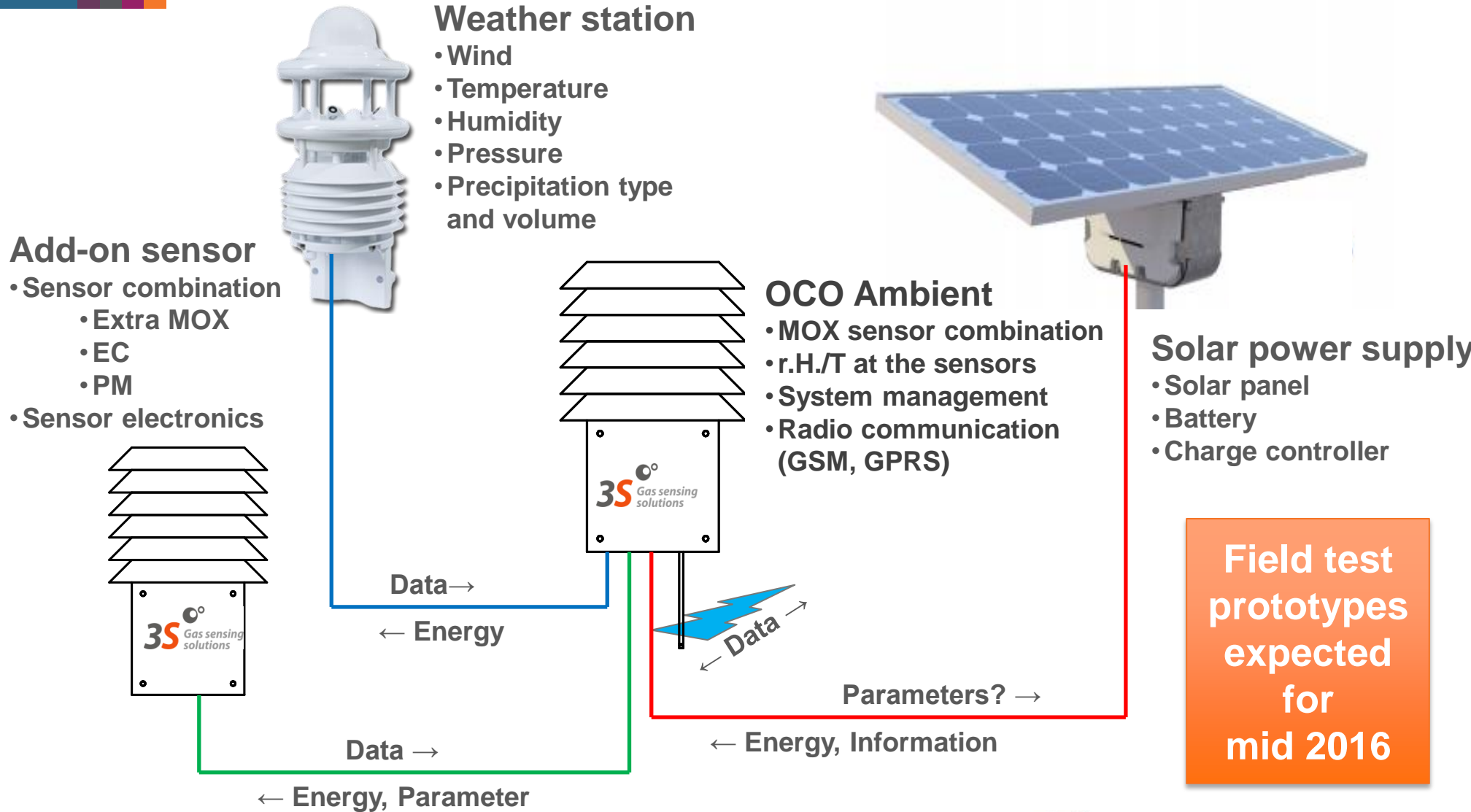
Official report on the project (in German):

http://www.saarland.de/dokumente/thema_immissionsschutz/2015-10-19_Abschlussbericht_Warndtmessungen_FINAL.pdf

What's next?

- **Commercialisation** of outdoor odor monitoring systems
 - Three variants for source, fenceline and residential scenarios
 - Field testing with research partners and pilot customers
- Improvement on **sensitivity**
 - Sensor selection
 - Pre-treatment of gas atmosphere
- Interdisciplinary complexity calls for a **structural model**
 - Identification of interfaces
 - Complete coverage of problem areas
 - (Gas) Sensor System Interchange Model

OdorCheckerOutdoor “Ambient”



Field test prototypes expected for mid 2016

Sensor System Interchange Model

(first draft)

- **Inspiration**
ISO-OSI reference model
- **Motivation**
Complexity of application-ready (gas) sensor systems
- **Current issue**
Sustainable and complete vertical implementation
- **Example challenges**
 - **Calibration** (lab-to-field, cross-device)
 - **Data aggregation**

