Plausibility of road weather data: Methods for offline and online detection of erroneous measurements

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Critical Road Weather / surface condition

Preconditions for the **Road Weather Control Loop**

Detection by stationary sensors

precise real time detection

Well chosen thresholds

Control algorithms

Variable Message Signs: Warnings, Speed limits

Acceptance by road user!

Traffic safety and traffic flow

Authorities operating traffic management systems often have trouble with malfunctioning road weather sensors and adjustment of sensor systems, because ...

- Atmospheric conditions are because of their inhomogeneous and unsteady characteristics hardly to check in their exact value
- External disturbances (Spiders / bats, contamination)
- Inhomogeneity of meteorological situations (local detection vs. areal occurence)
- Subjectivity of occurence
- In day-to-day operations errors in environmental data acquisition were detected not at all or late respectively by random

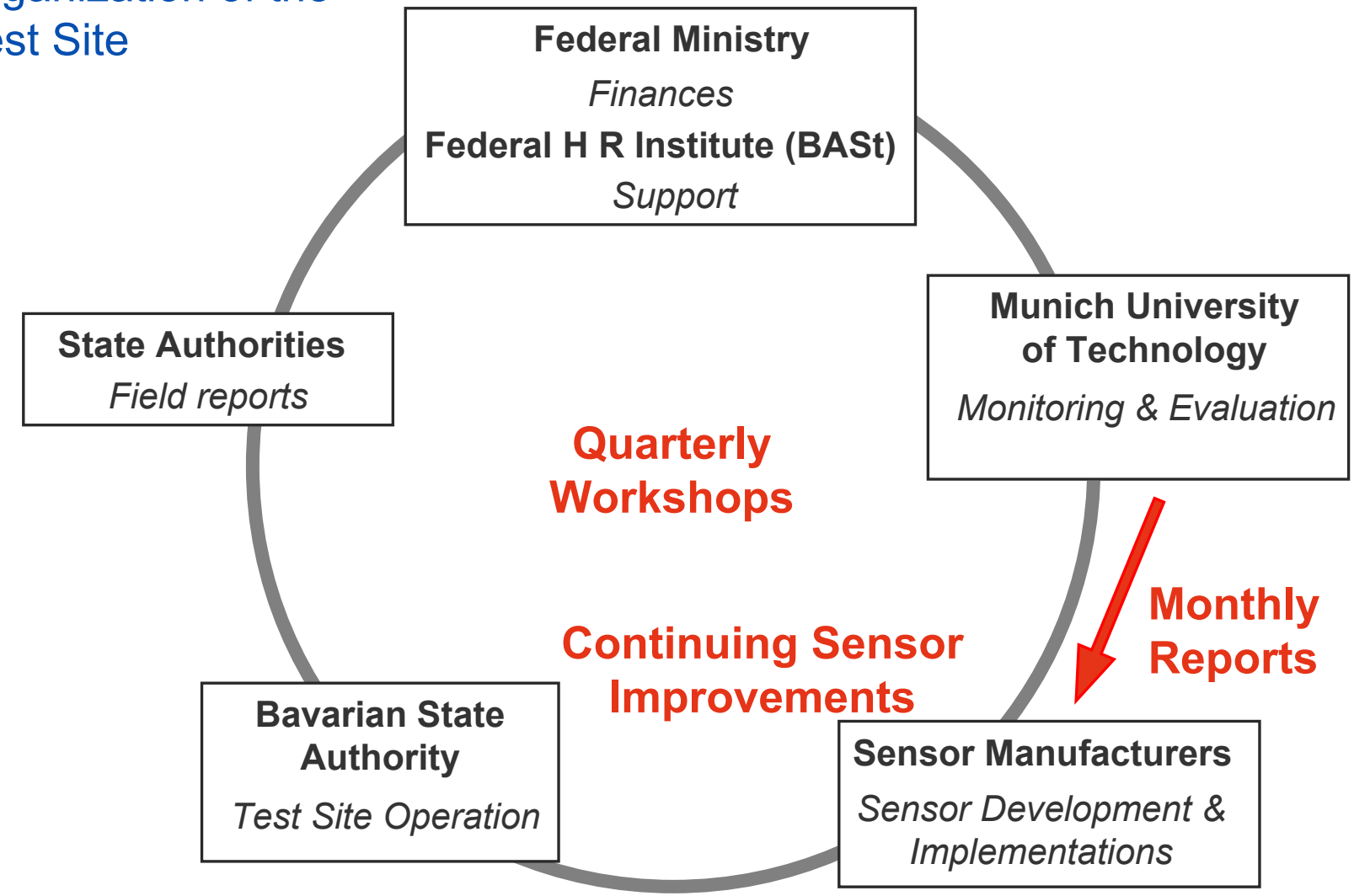
► a special test site was established

Test site “Eching Ost” for road weather and road condition monitoring

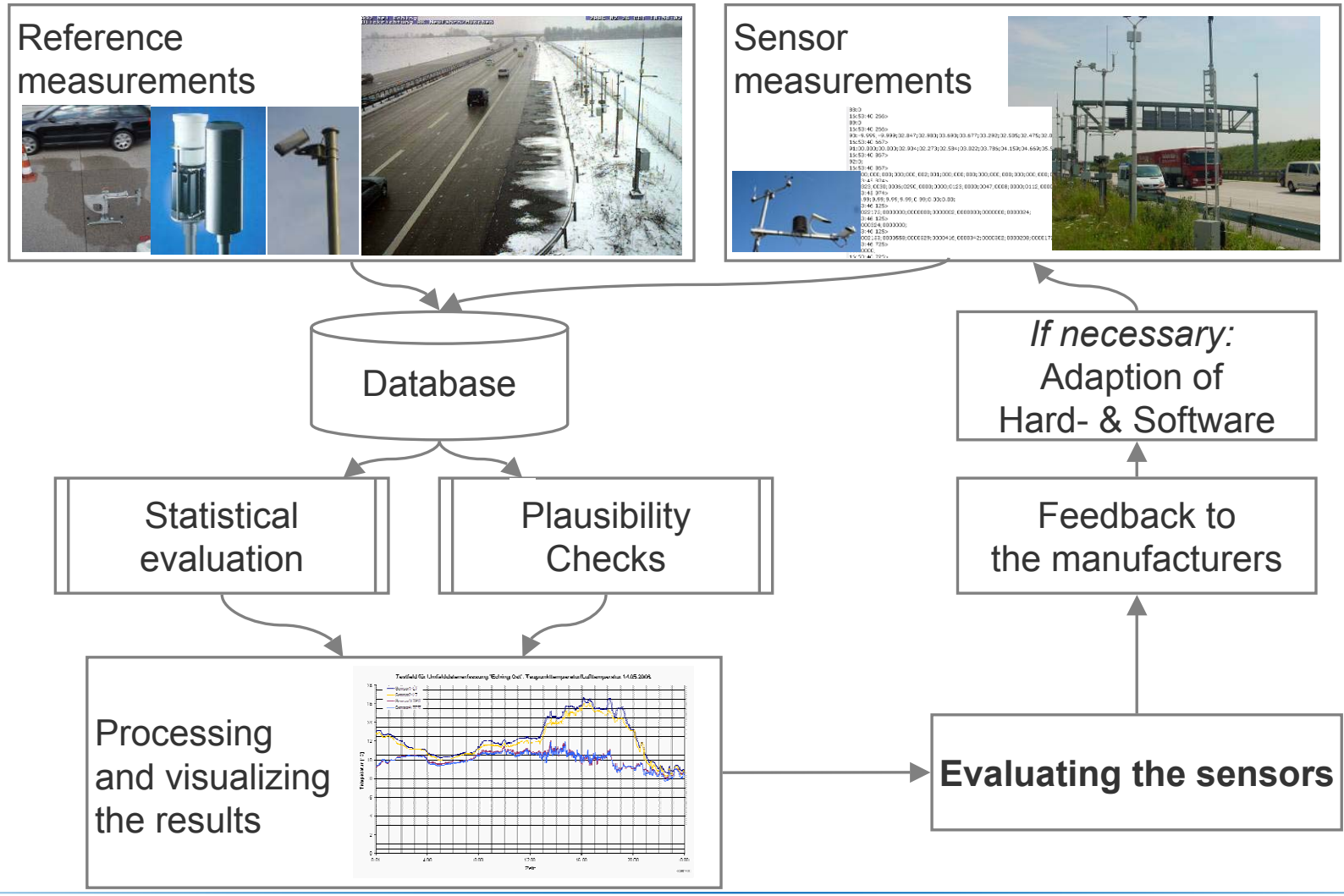
- Evaluate the plausibility of different sensors
- Find out the sensors limitations
- Compare established and new technologies
- Give Feedback to the manufacturers
- Develop methods for automatic plausibility checking
- Evaluation and classification of sensors as
  - “applicable”
  - “appropriate with restrictions”
  - “not appropriate”

- **Enhance road weather and road surface condition detection**

Organization of the Test Site



Test Site Project – Workflow



Road Weather Data

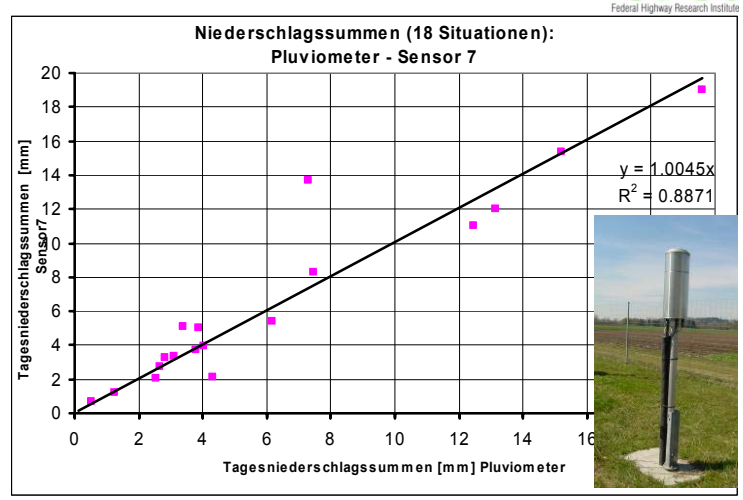
Parameter	Usage
Precipitation (intensity / type)	Direct input data for environmental control
Water film thickness	Direct input data for environmental control
Visibility	Direct input data for environmental control
Windspeed / direction	plausibility purposes
Temperature (air, road surface, freezing, melting point, ground)	plausibility purposes
Road surface condition	plausibility purposes
Relative air humidity	plausibility purposes

Offline and online evaluation

Offline evaluation

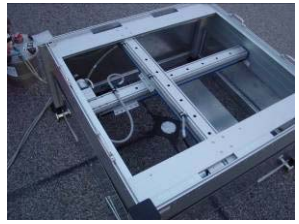
Precipitation Intensity

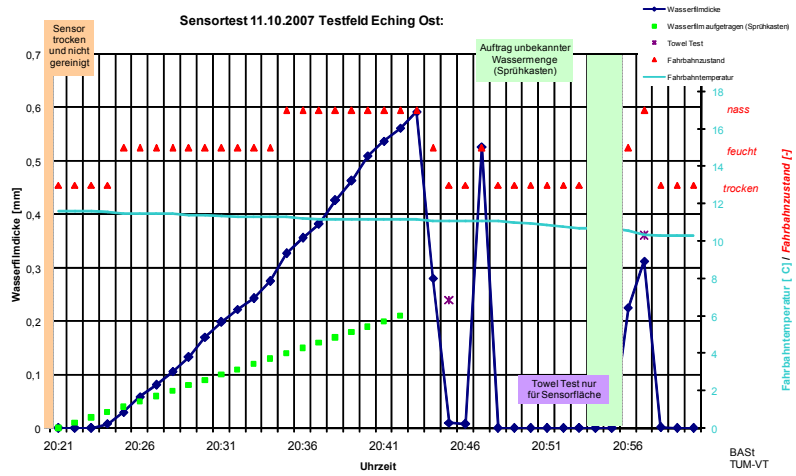
Daily precipitation sums of the sensors were compared to the daily precipitation sums of a reference system “Pluviometer”. The measurements of the Pluviometer were corrected with respect to precipitation type and wind speed.



Water film Thickness

The sensors’ measurements are compared to a known water film thickness that is brought on the sensor by the use of a “spraying box“ - a computer controlled Airbrush spray gun that gives specified amounts of water on the sensor.



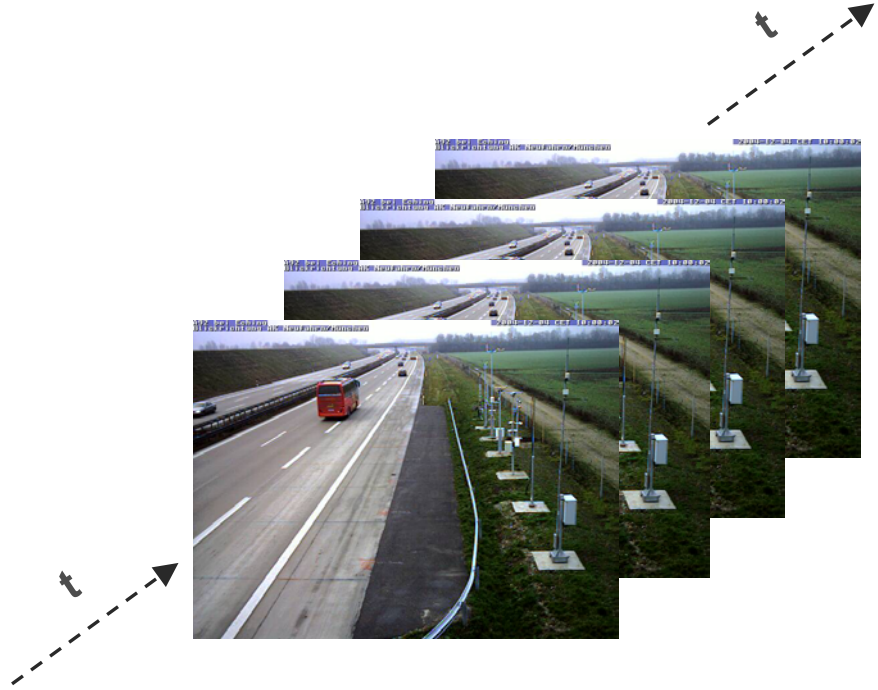


Offline evaluation Visibility

- Visibility Estimation based on WebCam Images
- Plausibility checks for Sensors
- 1 Image per Minute
- Per Day ~ 720 „usable Minutes“ (luminance)
  (x 365 Day / Year …)

→ since 2004, a lot of work…

→ Whish for Partial Automation of the evaluation



Offline evaluation **Visibility**

Visibility estimation with automatic image processing:

For each Image

1. calculation fo grey values
   (Matrix of grey values)
2. Luminance estimation
   (image usable: yes / no)

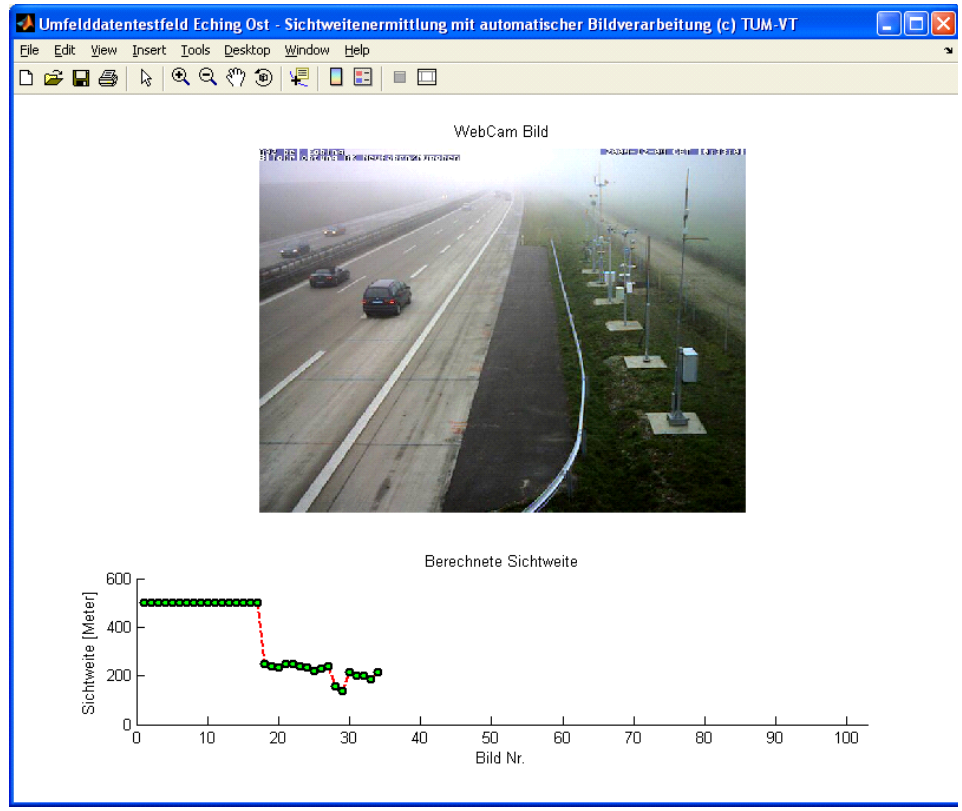
IF Image IS usable:

3. Convolution with edge detector
   (Edge-Matrix)
4. Visibility Estimation
   (*Edge Intensity (Sum, Median, Maximum)*
   Visibility in „Pixel-Rows“
   Visibility in Meters

END

Next Image

Graphical output image and calculated visibility:



Online evaluation

Time Series based (one parameter)

Does the actual measurement fall in a plausible range?

$$value_{\min} \leq measurement(t) \leq value_{\max}$$

Proposed basic provision (extract)	
Precipitation Intensity	[0, 20] mm/min
Road Surface Condition	{(adapted) WMO Code List}
Water film Thickness	[0, 3] mm
Air Temperature	[-30, 60] °C
Humidity	[10, 100] %
Visibility	[10, 2000] m
Road Surface Temperature	[-30, 80] °C
Dew Point Temperature	[-30, 30] °C
Windspeed	[0, 60] m/s
Winddirection	[0, 359] °

Online evaluation

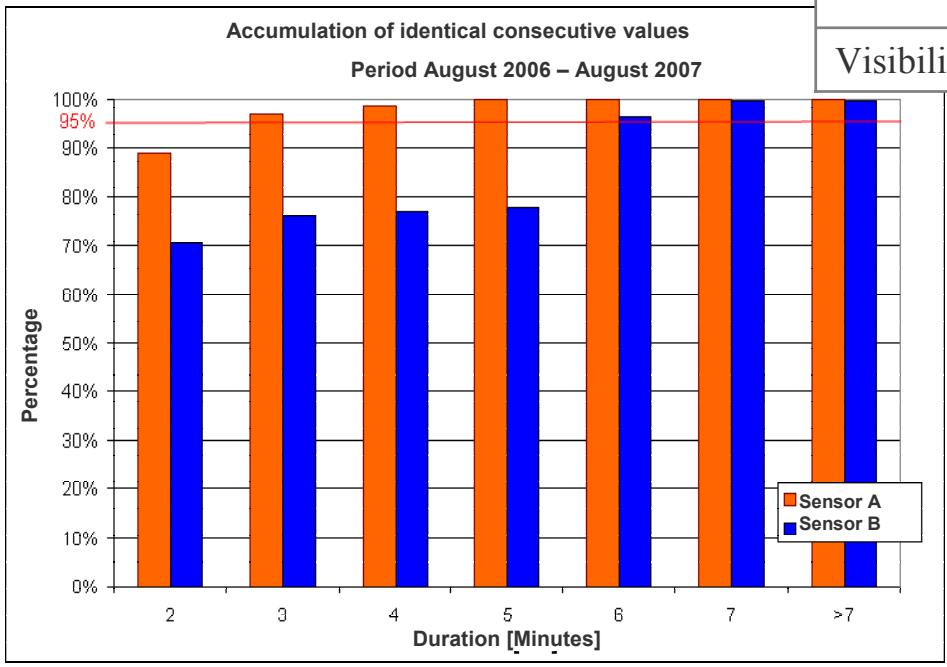
Time Series based (one parameter)

Does the time series show the expected *dynamics*?

$$measurement(t) = measurement(t-1) = \ldots = measurement(t-n)$$

e.g. proposed basic provision for visibiliy:

Parameter	Condition	Maximal duration with no change in time series
Visibility	< 500 Meter	10 minutes



Online evaluation

Time Series based (one parameter)

Is the *rate of change* not too big?

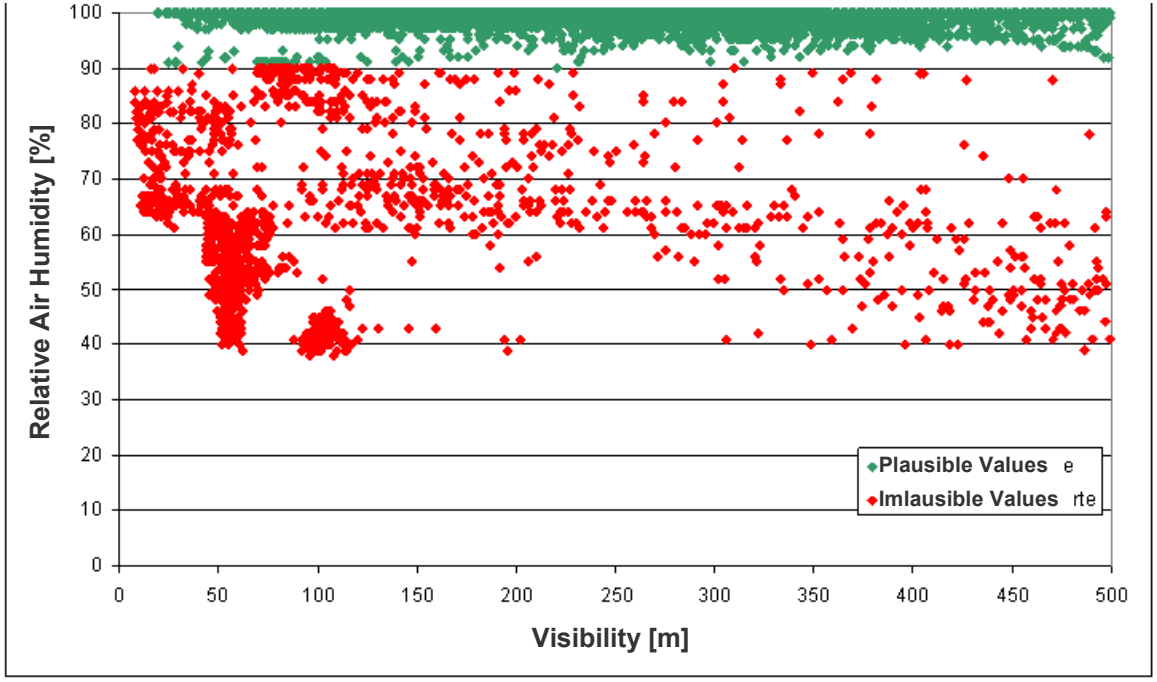
$$\left|measurement(t) - measurement(t-1)\right| \leq \Delta r_{\max}$$

Proposed basic provision (extract)	
Parameter	**Maximal rate of change (per minute)**
Water film Thickness	+/- 2 mm
Air Temperature	+/- 2 °C
Humidity	+/- 10 %
Road Surface Temperature	+/- 7 °C
Temperature in Depth 1	+/- 0,5 °C
Dew Point Temperature	+/- 1 °C
Windspeed	+/- 15 m/s

Online evaluation

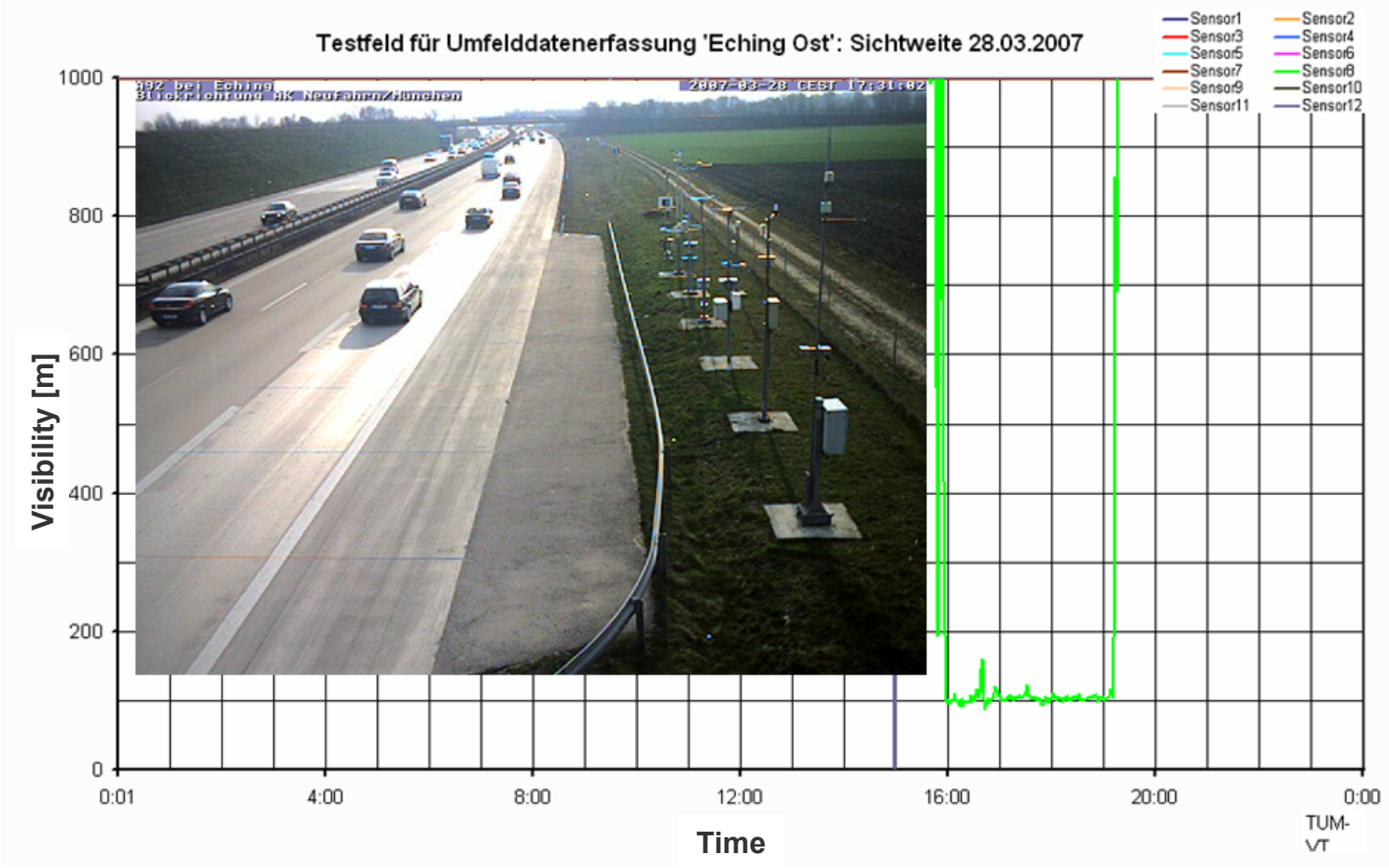
Cross Correlations (extract)

First Check	Second Check	Plausible value	Implausible value
Visisbility $\leq$ Visisbility^{max} (500 Meters)	Precipitation Type = „None“ AND Humidity < Humidity$_{dry}^{max}$ (60%)		Visibility



Online evaluation

Cross Correlations: Example Visibility

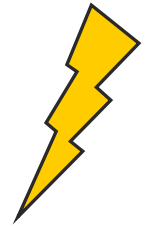


Online evaluation

Cross Correlations (extract)

First Check	Second Check	Plausible value	Implausible value
Precipitation Intensity > 0,5 AND Water film Thickness = 0	ΔTDry > 3 Minutes AND Humidity < Humidity dry max (60%)	Water film Thickness	Precipitation Intensity

Date	Precipitation intensity	Precipitation Class	Relative humidity	Waterfilmthickness
11.09.2006 18:30	0	0	51.8	0
11.09.2006 18:31	0	0	51.9	0
11.09.2006 18:32	1.077	Rain	51.8	0
11.09.2006 18:33	0.604	Rain	51.9	0
11.09.2006 18:34	0.715	Rain	52.3	0
11.09.2006 18:35	0.527	Rain	52.2	0
11.09.2006 18:36	0.624	Rain	52.6	0



Result:

- Water film thickness plausible
- Precipitation implausible

Online evaluation

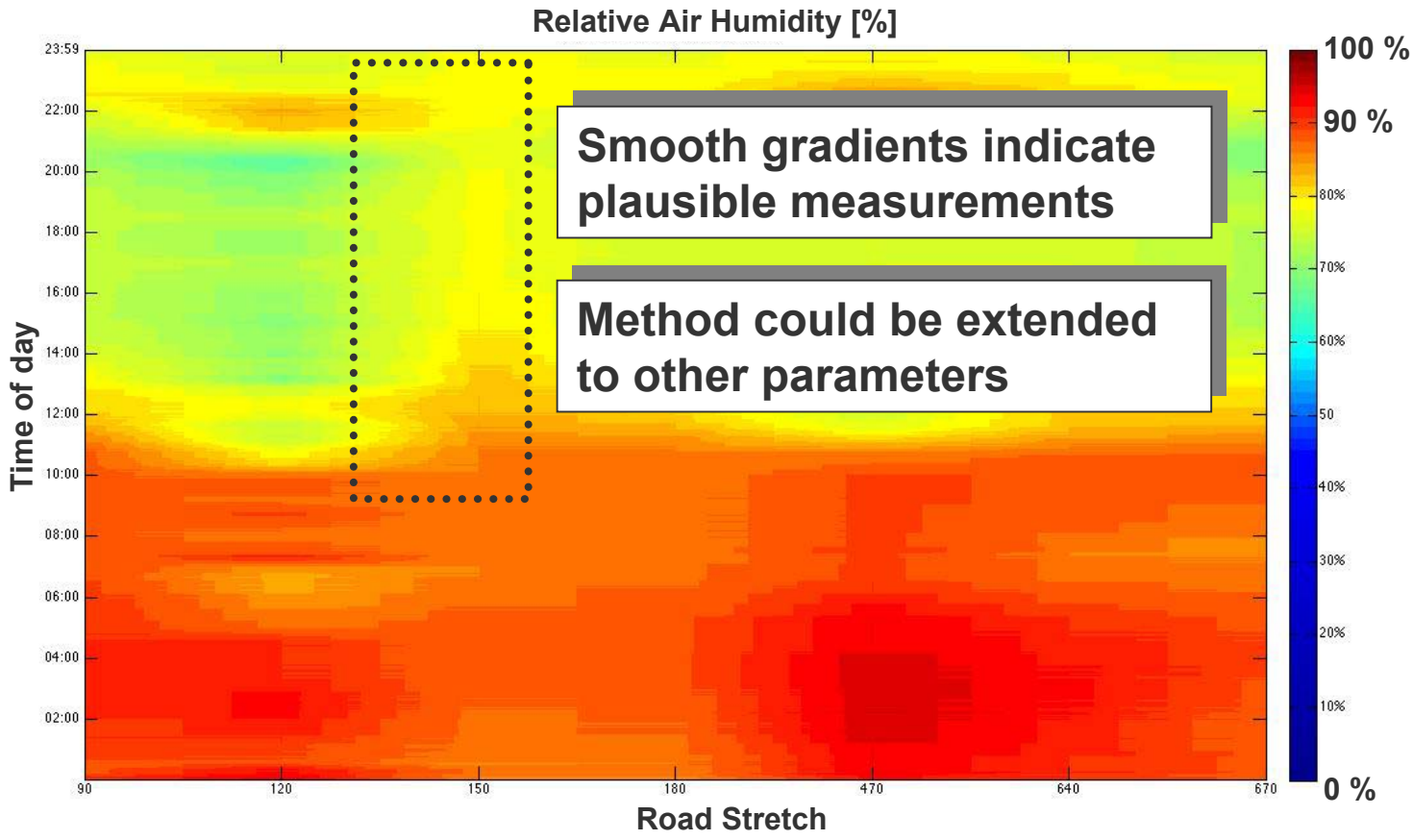
Long Term Cross Site based Plausibility Checks

Observations and comparisons between several sites can reveal systematic errors.
The results have to be evaluated carefully and with respect to local meteorological and topological characteristics.
The following parameter can be evaluated in this manner:

- Precipitation Sum
- Average Air Temperature
- Visibility
- Precipitation Type

Online/offline evaluation

Cross Site based Plausibility Checks – Visualization Example



Publications

- Huge database with matching observations
  - Used for development and
  - Application

    of plausibility checks

  Plausibility checks will be published:
  FGSV AK 3.2.1. 2008. Merkblatt „Umfelddatenerfassung in Verkehrsbeeinflussungsanlagen“. Köln. draft version.
- Evaluation and classification of sensors is published:
  Dinkel, A., Leonhardt, A. and Busch, F. 2007. Umfelddatenerfassung in Streckenbeeinflussungsanlagen. Testfeld „Eching Ost“ des Bundes, Abschlussbericht 2. Testphase. issued by Bundesministerium für Verkehr, Bau und Stadtentwicklung.

Questions, Comments …?

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