Analysis of pollution in the neighborhood of opencast coal mine

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Introduction

Data available for the analysis

- Original data
- Partially filtered data
- Fully filtered data

Dynamics of wind flow over the opencast mine

Conclusions

Introduction

This presentation is a part of the project TA01020428:
"Investigation of possibilites of employment of physical and mathematical models in solution of dustiness in real conditions of being terrain"

A joint project of:

- **Ecoprogress a.s.**
- **Institute of Thermomechanics AS CR**
- **Czech Technical University in Prague**

Project was supported by the **Technology Agency of the Czech Republic**

The aim of the project was to develop tools and methods allowing accurately predict and efficiently reduce the airborne dust pollution. The focus is on environmental applications including large-scale mining and industrial activities.

Introduction

The project had three main parts:

1. In-situ investigation and implementation (Ecoprogress a.s.)
2. Wind-tunnel measurements (IT AS CR)
3. Mathematical modelling and numerical simulation (CTU Prague)

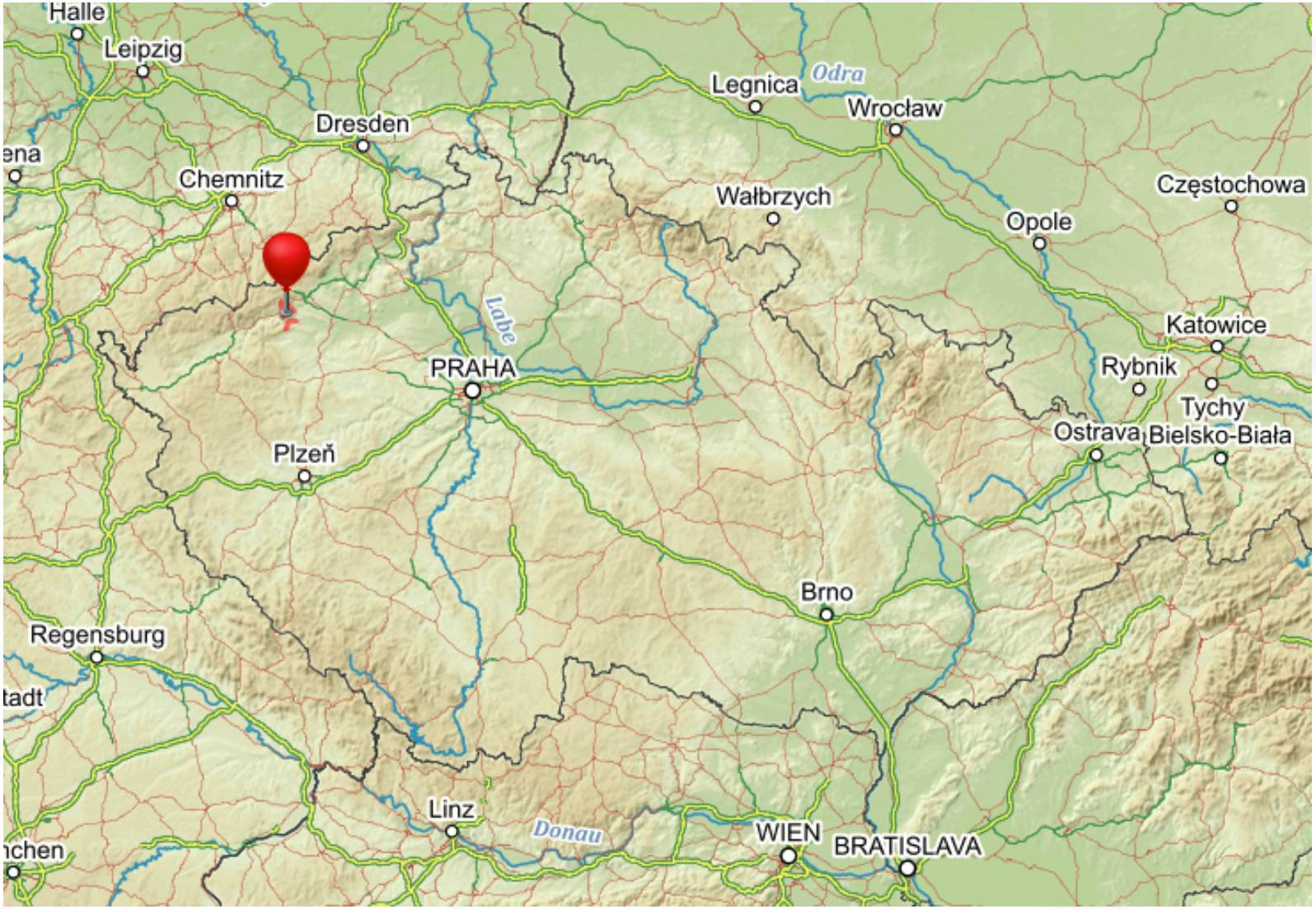
The investigation of flow and pollution dispersion in the proximity of an opencast coal mine was chosen as a test case for the tools and methods developed within this project.

As a part of the real terrain in-situ observations a long term meteorological data measurements were performed.

A huge amount of data was collected and had to be processen and evaluated.

Introduction

Map from the year 2015



Introduction

Map from the year 2015

Introduction

Map from the year 1900

Introduction

Map from the year 2002

Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Introduction

Map from the year 2006

Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Introduction

Map from the year 2012

Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Introduction

Map from the year 2013

Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

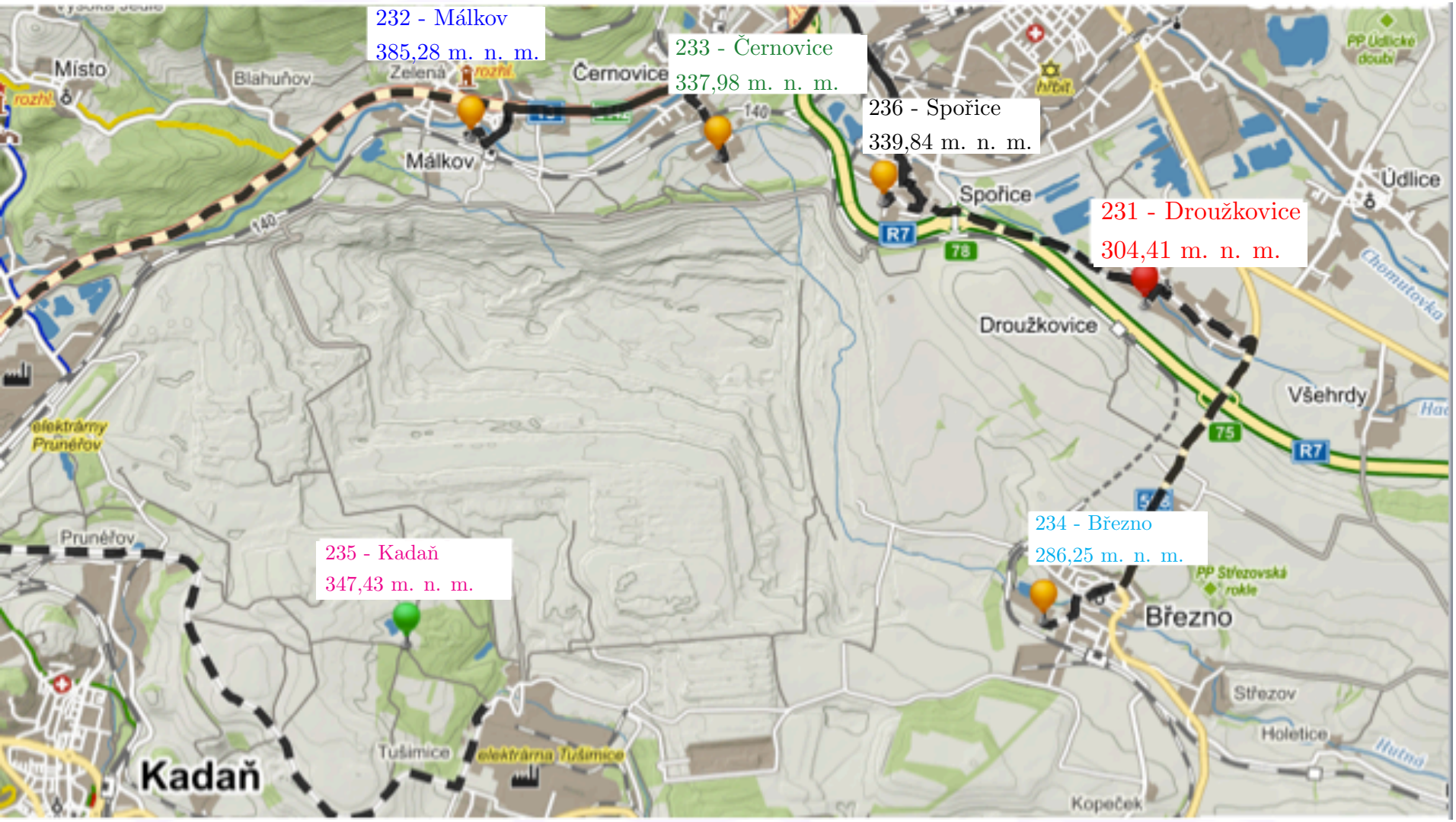
Introduction

Map from the year 2015

Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Station code	Station name	Location	Coordinates
231	Droužkovice	SW border of village, in front of gardening area, in proximity of local road crossroad.	50°25′44.118” N, 13°25′38.444” E
232	Málkov - Zelená	southern border of village, in proximity of local sport area.	50°26′35.649” N, 13°19′40.34” E
233	Černovice	SW border of village, approx. 250m from protective barrier.	50°26′31.067” N, 13°21′51.275” E
234	Březno	Area of mining water treatment, on the village boundary in the direction of opencast mine Libouš.	50°23′56.77” N, 13°24′47.85” E
235	Kadaň - výsypka	Recultivated dump Merkur, approx. 1300m west from the building of DNT main canteen.	50°23′44.46” N, 13°19′12.17” E
236	Spořice	Western border of the village, approx. 25m from local (low traffic) road.	50°35′21.162” N, 13°39′27.121” E

Map from the year 2015



Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Introduction

The first aim of the data analysis was to identify and to fix
some of the major problems contained in collect meteorological data.

* Data were "continuously" collected throughout the year 2012-2014
  and recorded at minute frequency.
* The whole data set contained 3 153 600 observations/year.
* Many records found in these data sets were either invalid or exceptional
  e.g. extremely distant in some sense.

Prototypes of the "exceptional" data:

* were localized in one or several neighbouring points
* quite large time intervals were affected

Such singular values were filtered out and replaced by NaN symbols,
i.e. treated as undefined in further analysis.

In some case, where only single values or short time intervals were affected,
the missing data can be substituted using interpolation from the neighboring unaffected values.

Introduction

Measured variables:

* wind velocity in $[m/s]$,
* wind direction as azimuth angle in degrees $[^\circ]$,
* pressure $[MPa]$,
* air temperature in $[^\circ C]$,
* atmospheric relative humidity in $[\%]$,
* solar radiation intensity in $[W/m^2]$,
* **atmospheric aerosol concentration** PM_{10} $[\mu g/m^{-3}]$.

EXAMPLES OF INVALID DATA

Date Time	PM10	Velocity	Direction	Temp.	Humidity	Solar rad.	Pressure
04. 12. 15:10	42.3	0.0	NaN	0.7	96.9	52.3	963.1
04. 12. 15:11	39.6	0.0	NaN	0.7	96.9	50.4	963.1
04. 12. 15:12	35.3	0.0	NaN	0.7	96.9	48.1	963.2
04. 12. 15:13	33.1	0.0	NaN	0.7	96.9	46.1	963.2
04. 12. 15:14	32.5	0.0	NaN	0.7	96.9	44.9	963.2
04. 12. 15:10	32.2	0.0	NaN	0.7	96.9	44.2	963.2
04. 12. 15:11	32.0	0.0	NaN	0.7	96.9	43.3	963.2
04. 12. 15:12	32.1	0.0	NaN	0.7	96.9	43.3	963.2
04. 12. 15:13	31.9	0.0	NaN	0.7	97.0	42.8	963.2
04. 12. 15:14	31.9	0.0	NaN	0.7	97.0	42.7	963.2
04. 12. 15:15	32.0	0.0	NaN	0.7	97.0	42.5	963.2

December 4, 2012

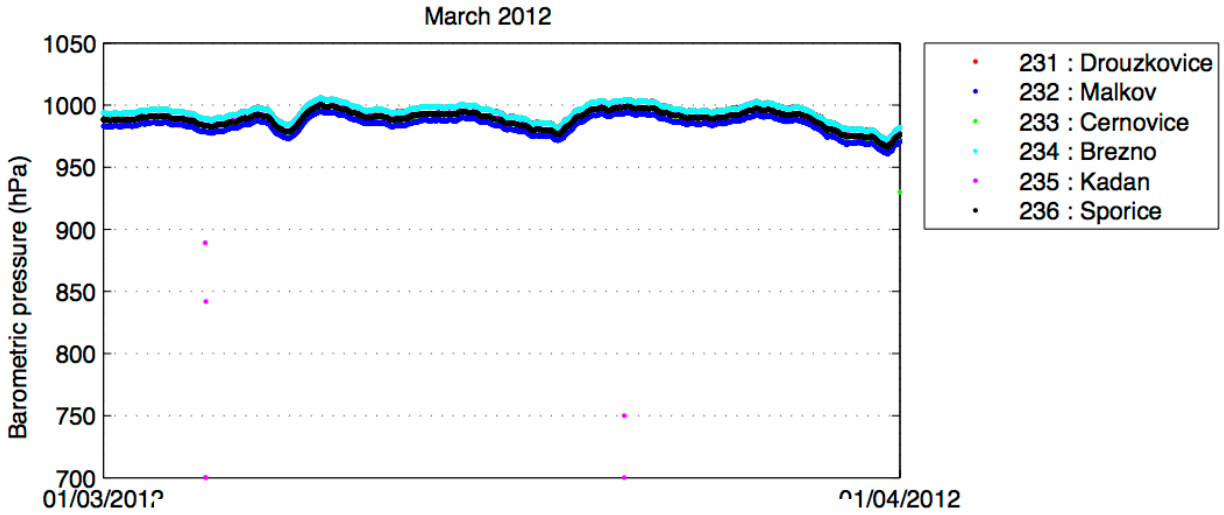
Duplicate records from measuring station *234* - Březno (5 records)

EXAMPLES OF INVALID DATA

Date	Time	PM10	Velocity	Direction	Temp.	Humidity	Solar rad.	Pressure
04. 12.	15:26	51.0	0.0	NaN	0.2	97.5	19.8	966.6
04. 12.	15:30	50.7	0.9	240	0.3	97.5	20.0	966.5
04. 12.	15:31	50.7	1.0	240	0.3	97.5	20.2	966.5
04. 12.	15:32	50.5	1.0	230	0.3	97.5	20.4	966.5
04. 12.	15:36	50.5	0.9	220	0.3	97.5	20.0	966.5
04. 12.	15:37	50.5	0.7	290	0.3	97.5	19.1	966.6

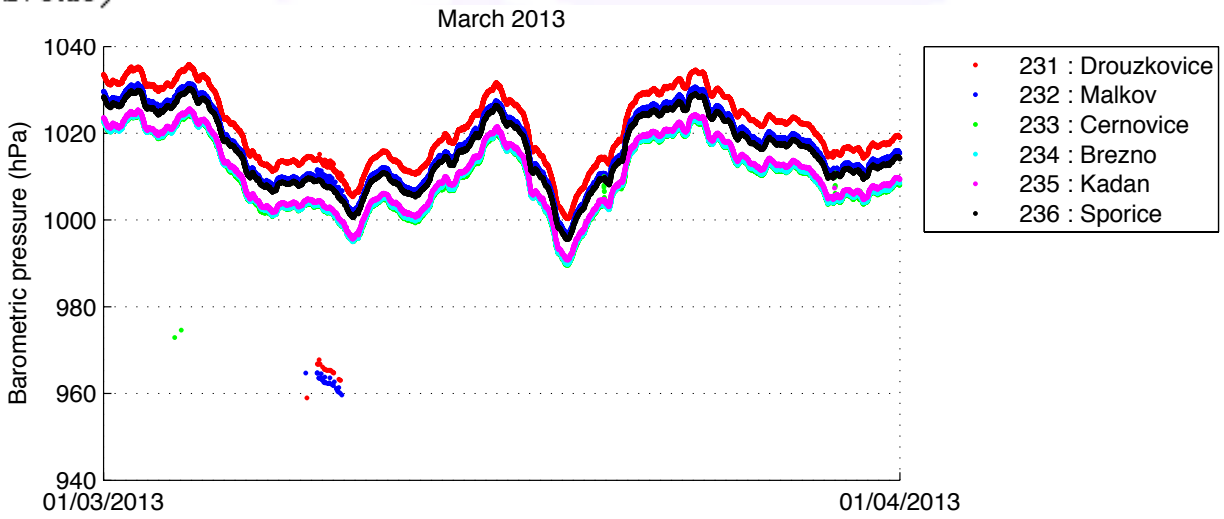
Missing records from measuring station *231* - Droužnovice (7 records)

EXAMPLES OF INVALID DATA

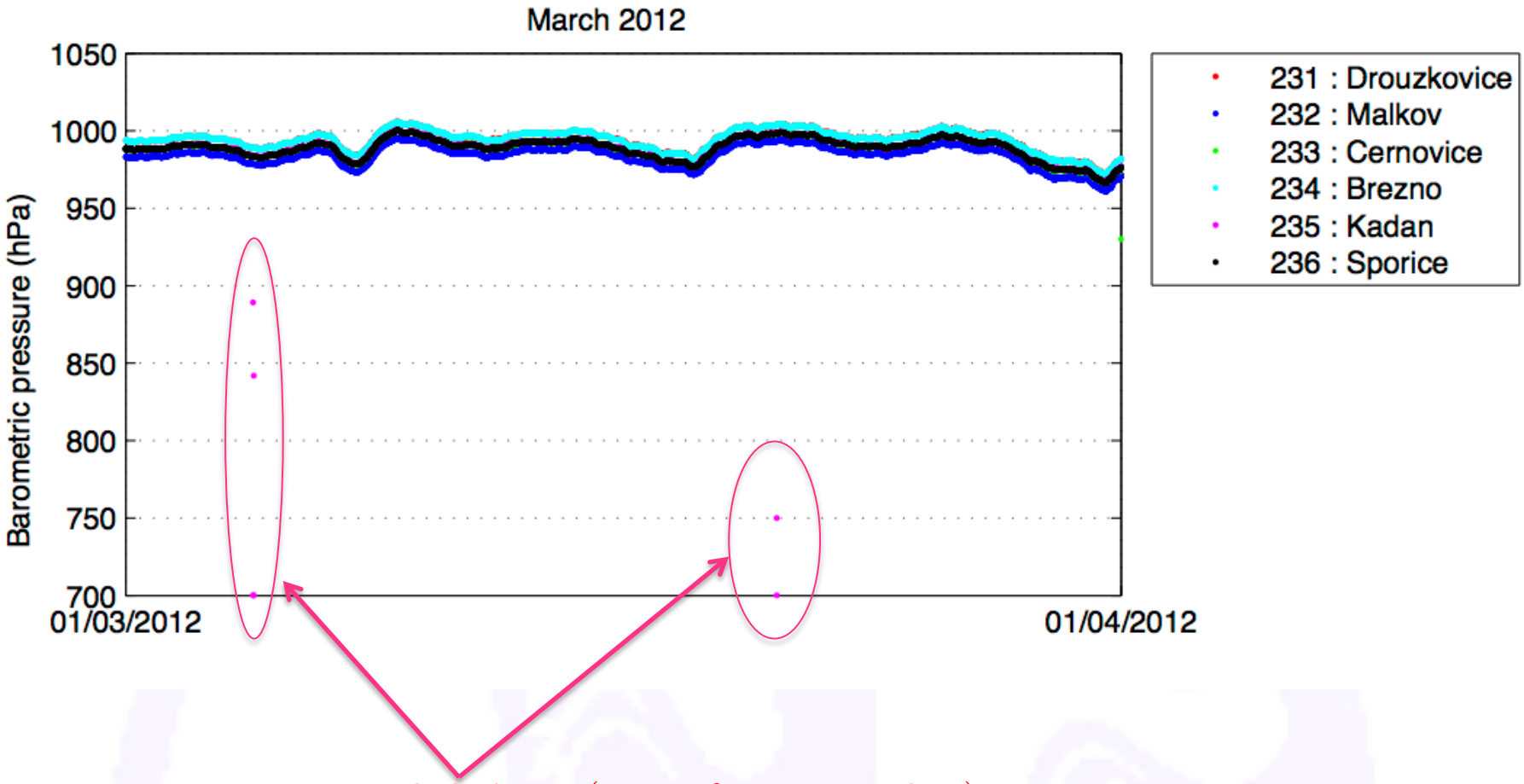


Sea–level pressure

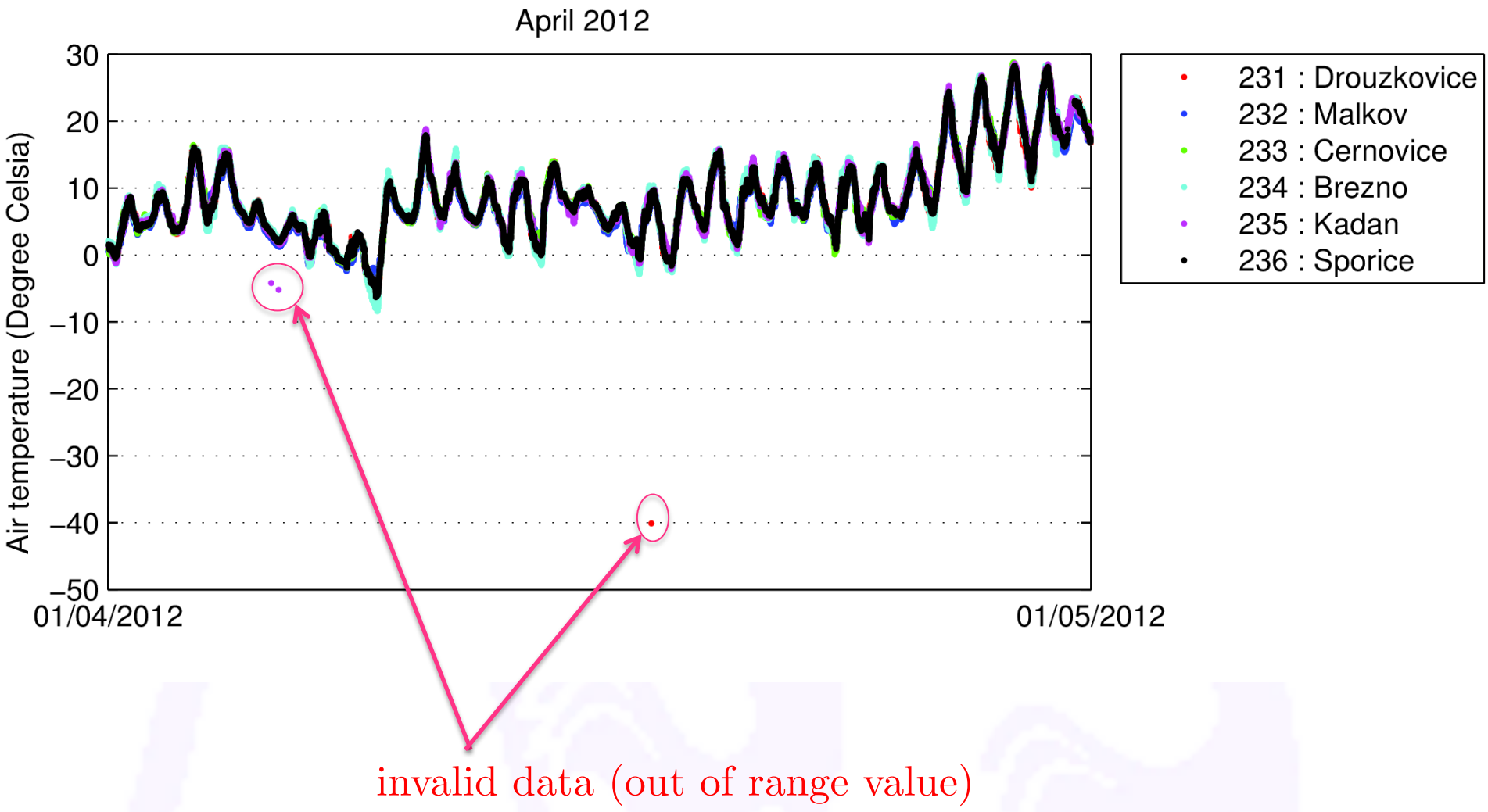
$$P_0 = P\left(1 - \frac{0.0065h}{T + 0.0065h + 273.15}\right)^{-5.257}$$



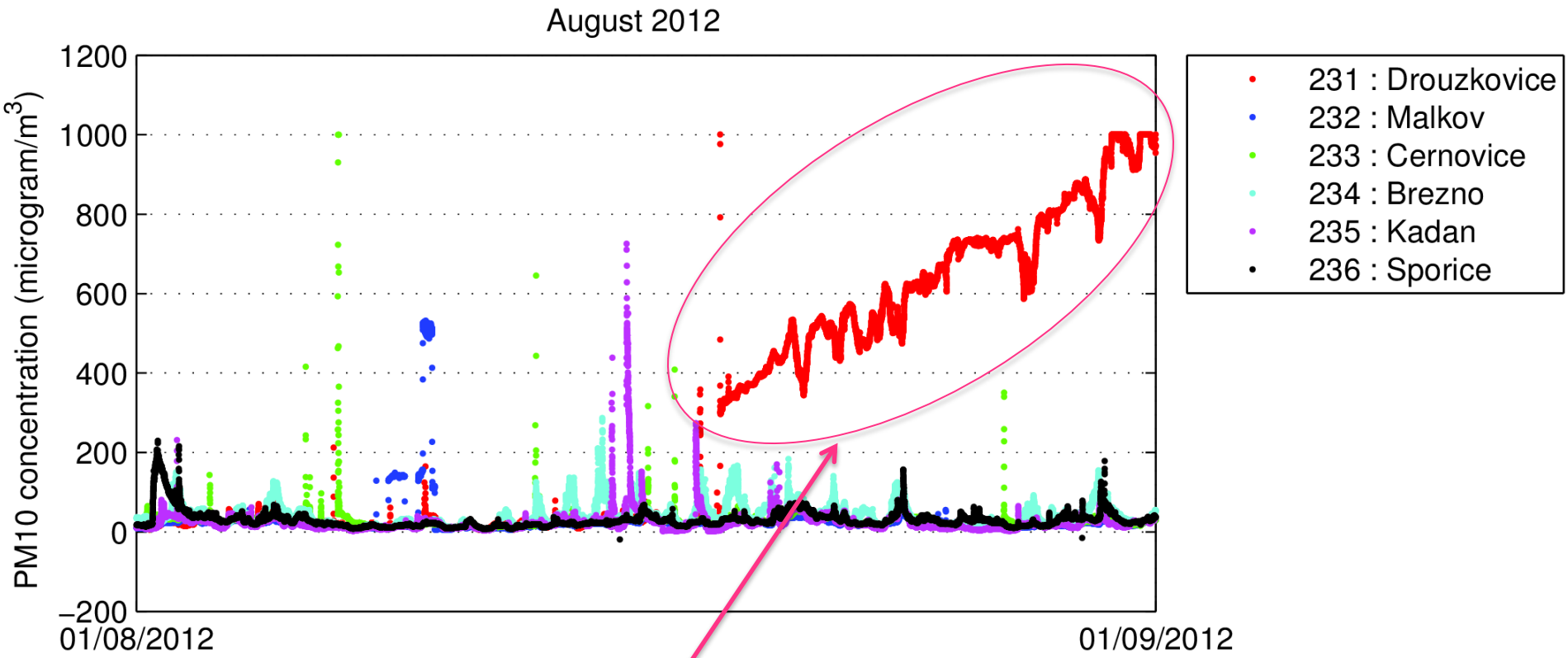
EXAMPLES OF INVALID DATA



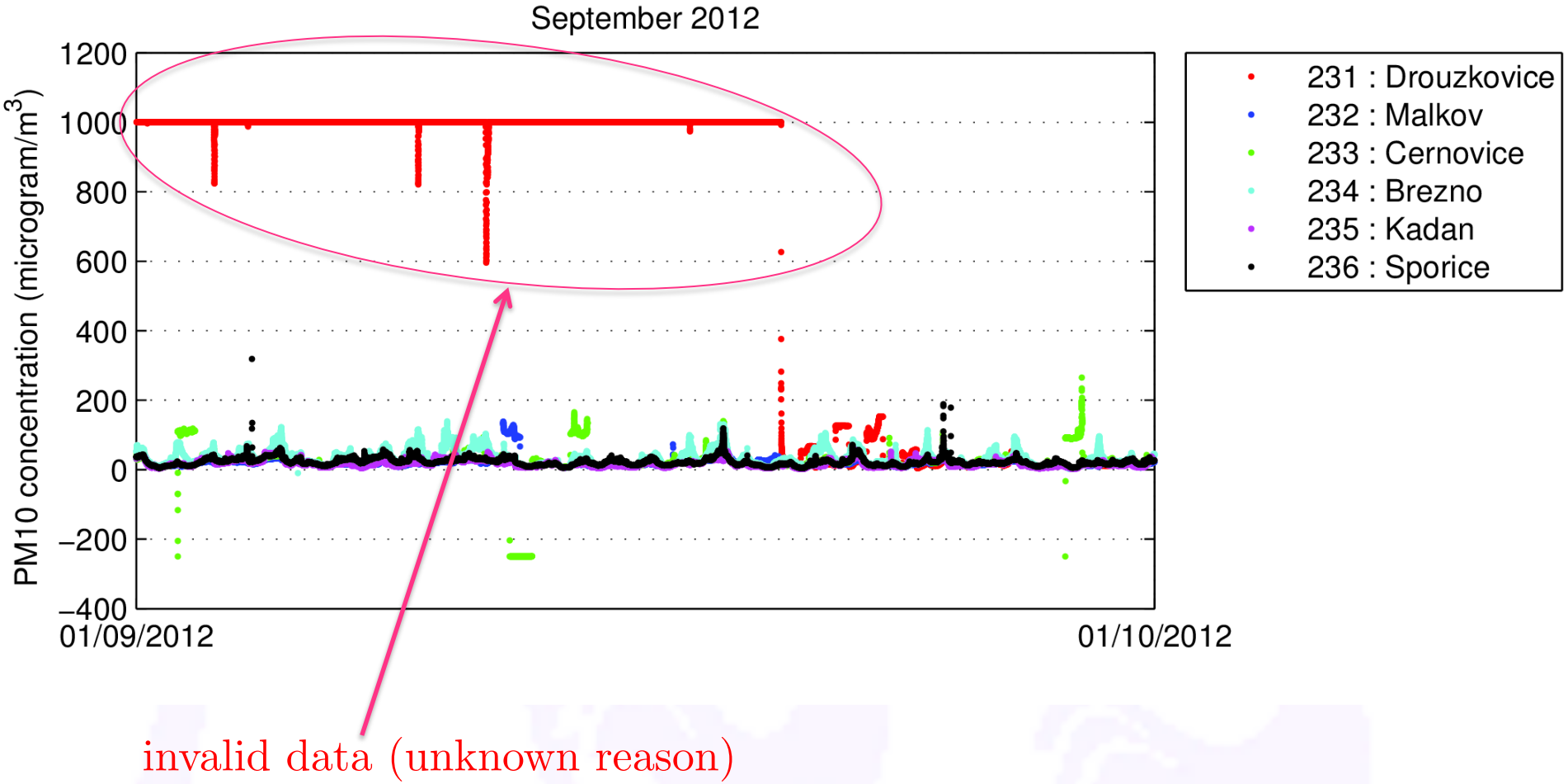
EXAMPLES OF INVALID DATA



EXAMPLES OF INVALID DATA



EXAMPLES OF INVALID DATA



EXAMPLES OF INVALID DATA

	Station	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.
MIN	*231*	-250	-0.0	0	**-40.1**	**0**	-4	**700.1**
MIN	*232*	10	-0.0	0	-17.3	29.3	**-11.6**	943.5
MIN	*233*	-249.8	**-0.1**	0	-18.4	30.4	10.0	951.6
MIN	*234*	**-252.7**	0	0	**-40.1**	**0**	-0.9	965.6
MIN	*235*	-251	-0.0	0	**-40.1**	**0**	-1.9	**700.1**
MIN	*236*	-251.9	-0.0	0	**-40.1**	**0**	-0.5	**700.1**

Example of extremal values from stations *231* - *236*

EXAMPLES OF INVALID DATA

	Station	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.
MIN	*231*	-250	-0.0	0	**-40.1**	**0**	-4	**700.1**
MIN	*232*	10	-0.0	0	-17.3	29.3	**-11.6**	943.5
MIN	*233*	-249.8	**-0.1**	0	-18.4	30.4	10.0	951.6
MIN	*234*	**-252.7**	0	0	**-40.1**	**0**	-0.9	965.6
MIN	*235*	-251	-0.0	0	**-40.1**	**0**	-1.9	**700.1**
MIN	*236*	-251.9	-0.0	0	**-40.1**	**0**	-0.5	**700.1**
MAX	*231*	**1001**	19	350	38.4	98	1199.5	**1006.2**
MAX	*232*	539	18.7	350	36.9	97	**1200**	995.3
MAX	*233*	946.9	12.8	350	30.8	95.1	**1200**	998.2
MAX	*234*	959.9	30	350	**39.2**	98.1	**1200**	1000.9
MAX	*235*	999.3	**23.4**	350	39	97.4	**1200**	1000.5
MAX	*236*	370.6	9.7	350	37.8	**99.3**	**1200**	1000.4

Examples of extremal values from stations *231* - *236*

PARTIALLY FILTERED DATA

The invalid data records had to be filtered out from the data files and excluded from further processing.

The following data were assumed to be invalid and have been excluded from the original raw data sets:

* Negative concentrations of aerosol concentrations $PM_{10}[\mu g/m^3]$.
  In total 5 822 data records were excluded.
* Negative values of wind speed $[m/s]$.
  In total 63 937 records were excluded.
* Negative values of solar radiation intensity $[W/m^2]$.
  In total 308 305 records were excluded.
* Extremely low barometric pressure values $< 940\ hPa$.
  In total 65 records were excluded.

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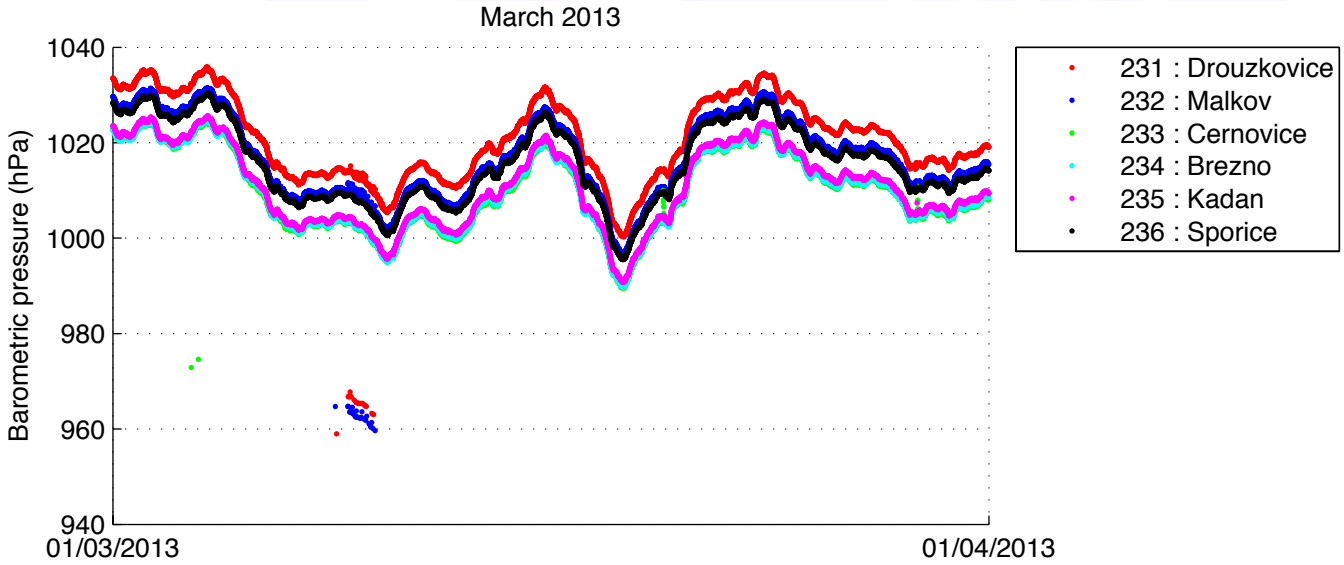


PARTIALLY FILTERED DATA

Date Time	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.	Station
12. 7. 13:44	-199.5	0.2	230	-28.1	19.8	249.0	812.4	*234*
4. 3. 23:12	-249.8	0.1	NaN	-40.1	0.0	3.2	700.1	*235*

Example of negative values of PM10 concentrations (5 822 values)

Date Time	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.	Station
5. 3. 23:11	43.2	-0.2	NaN	-0.4	93.7	3.5	986.5	*233*
8. 3. 00:04	65.3	-0.2	NaN	0.7	69.7	3.4	979.1	*233*

Example of measured negative wind velocity (63 937 values)

Date Time	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.	Station
12. 7. 13:44	-199.5	0.2	230	-28.1	19.8	249.0	812.4	*234*
4. 3. 23:12	-249.8	0.1	NaN	-40.1	0.0	3.2	700.1	*235*

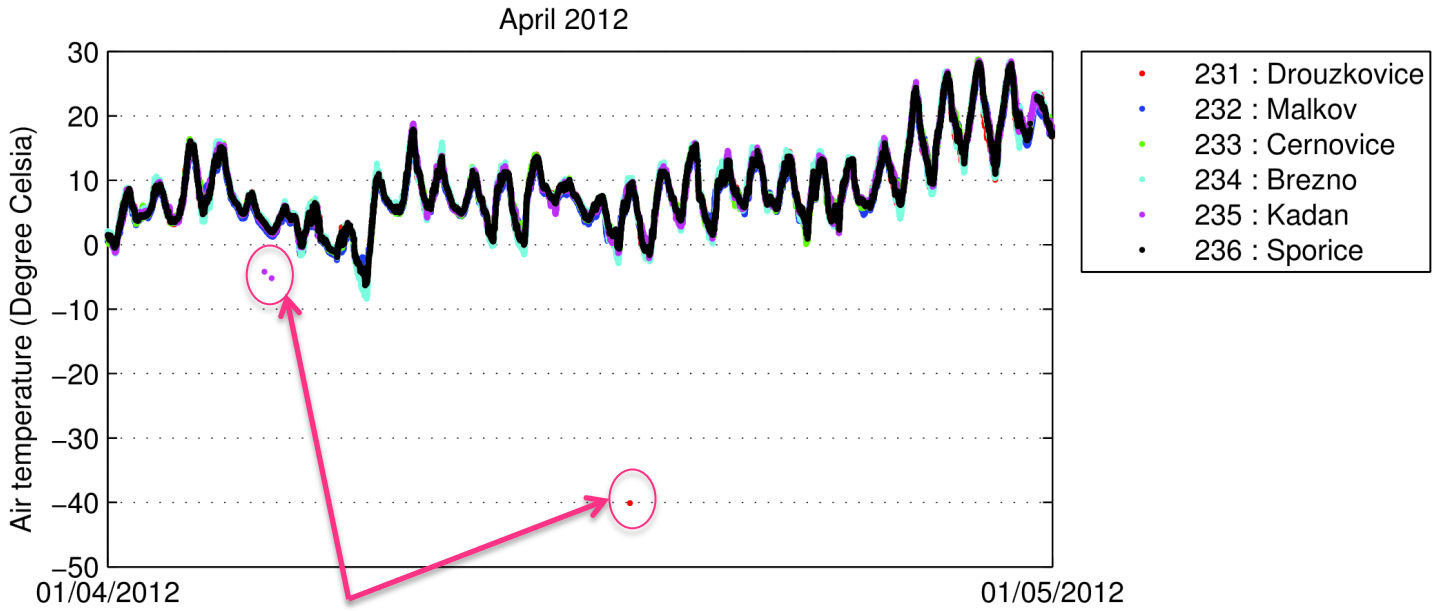
Example of extremely low barometric pressure values < 940 hPa (65 values)

FULLY FILTERED DATA

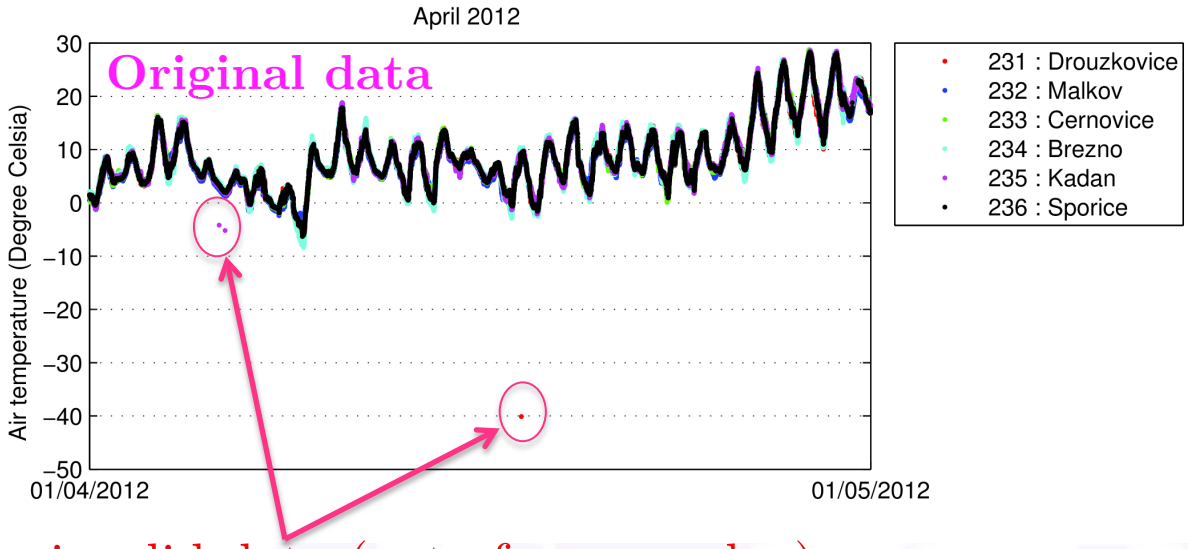
Some further data filtering was applied to *pressure*, *temperature* and *humidity*.

Date Time	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.	Station
4. 5. 14:17	-251.9	0.1	NaN	-40.1	0.0	7.0	700.1	*236*
17. 6. 7:53	-162.6	0.5	30	-30.4	11.0	81.2	747.7	*235*

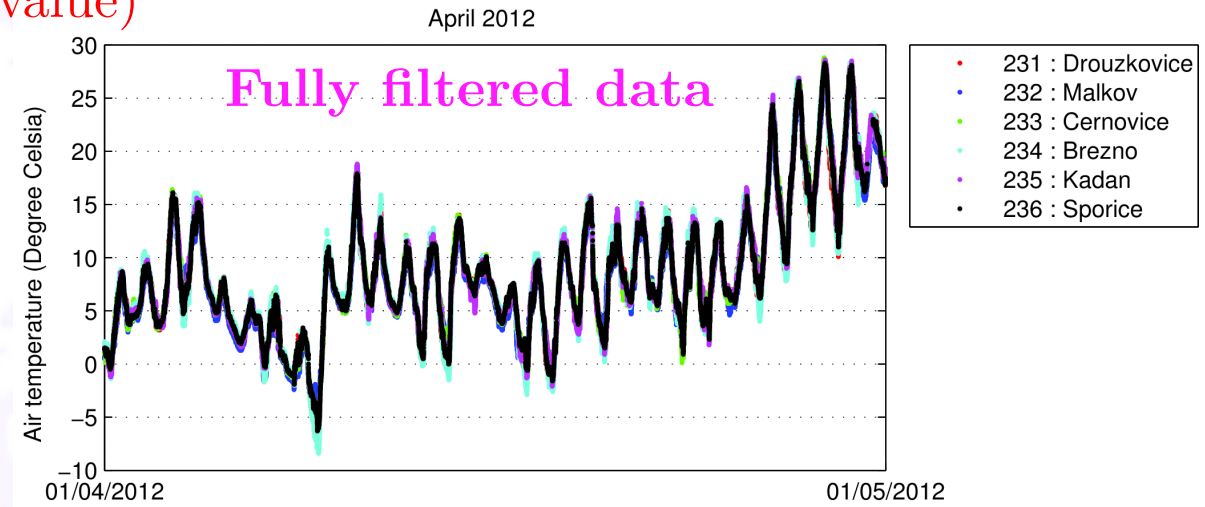
Example of invalid data replaced by NaN value.



invalid data (out of range value)



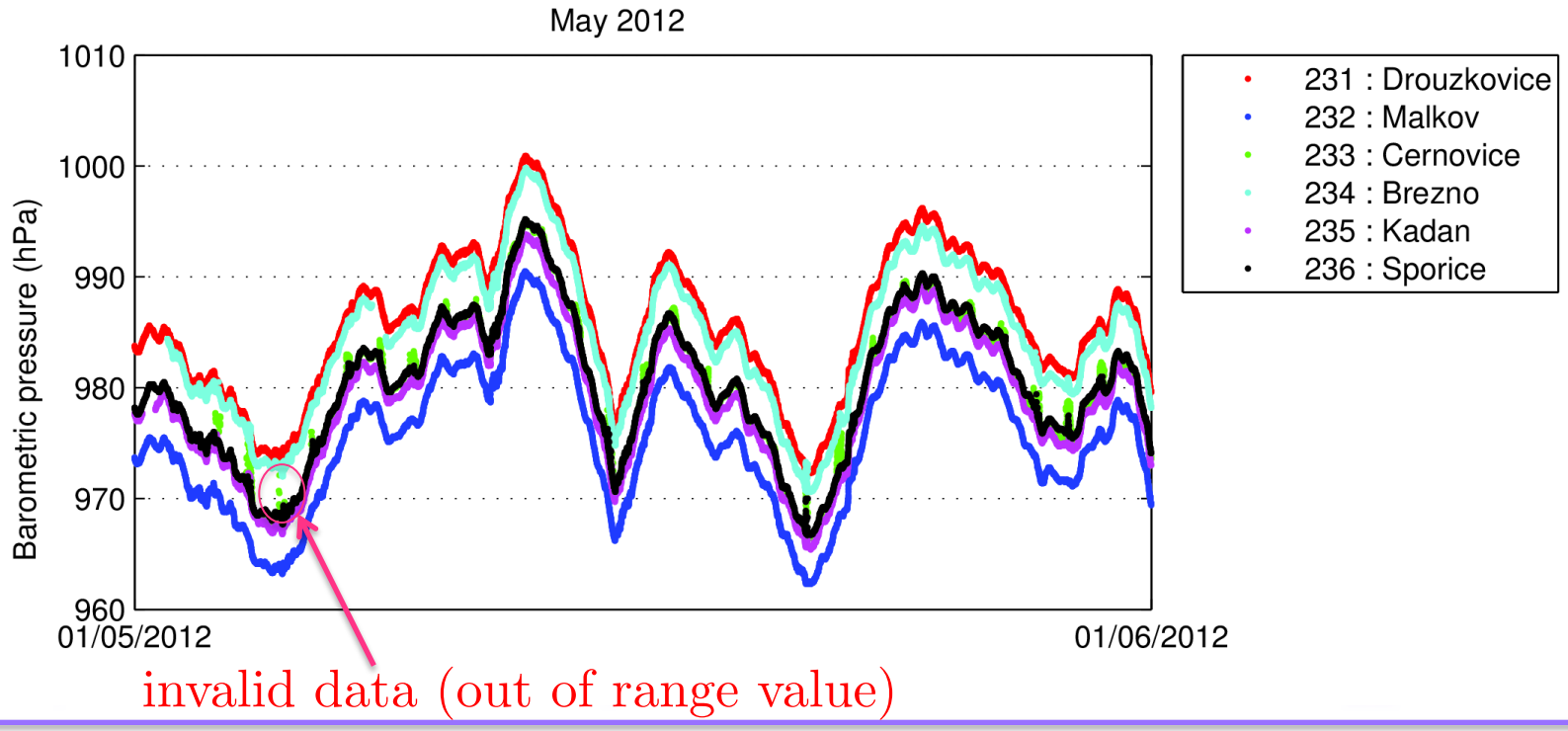
invalid data (out of range value)



FULLY FILTERED DATA

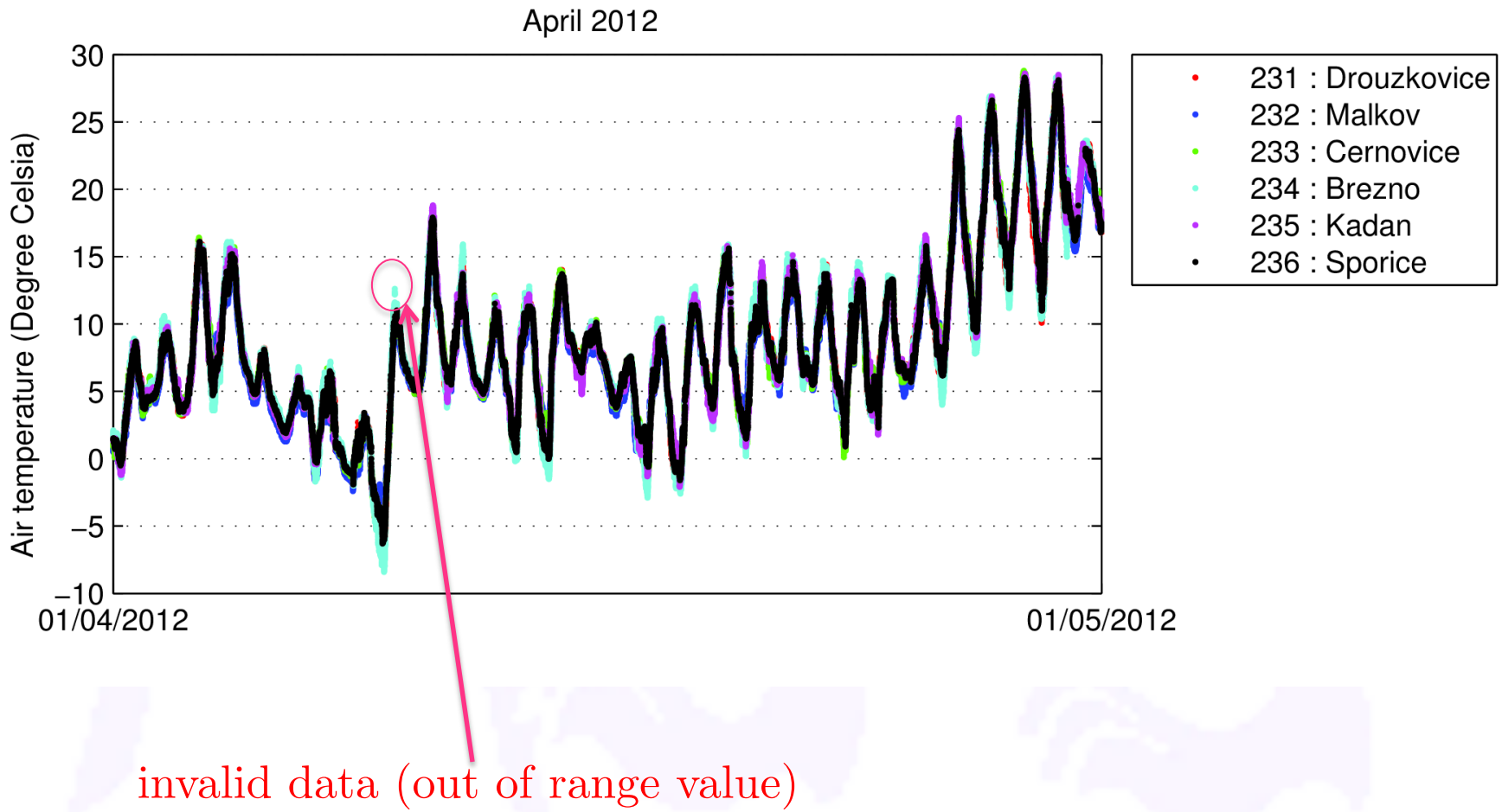
Date Time	PM10	Velocity	Direct.	Temp.	Humidity	Solar rad.	Press.	Station
22. 04. 11:28	7.1	7.4	20	11.4	51.8	1142.0	973.9	*233*
22. 04. 11:26	7.1	7.8	20	11.6	52.4	1166.2	974.6	*233*

Example of exceptional singular values that were replaced by NaN value.

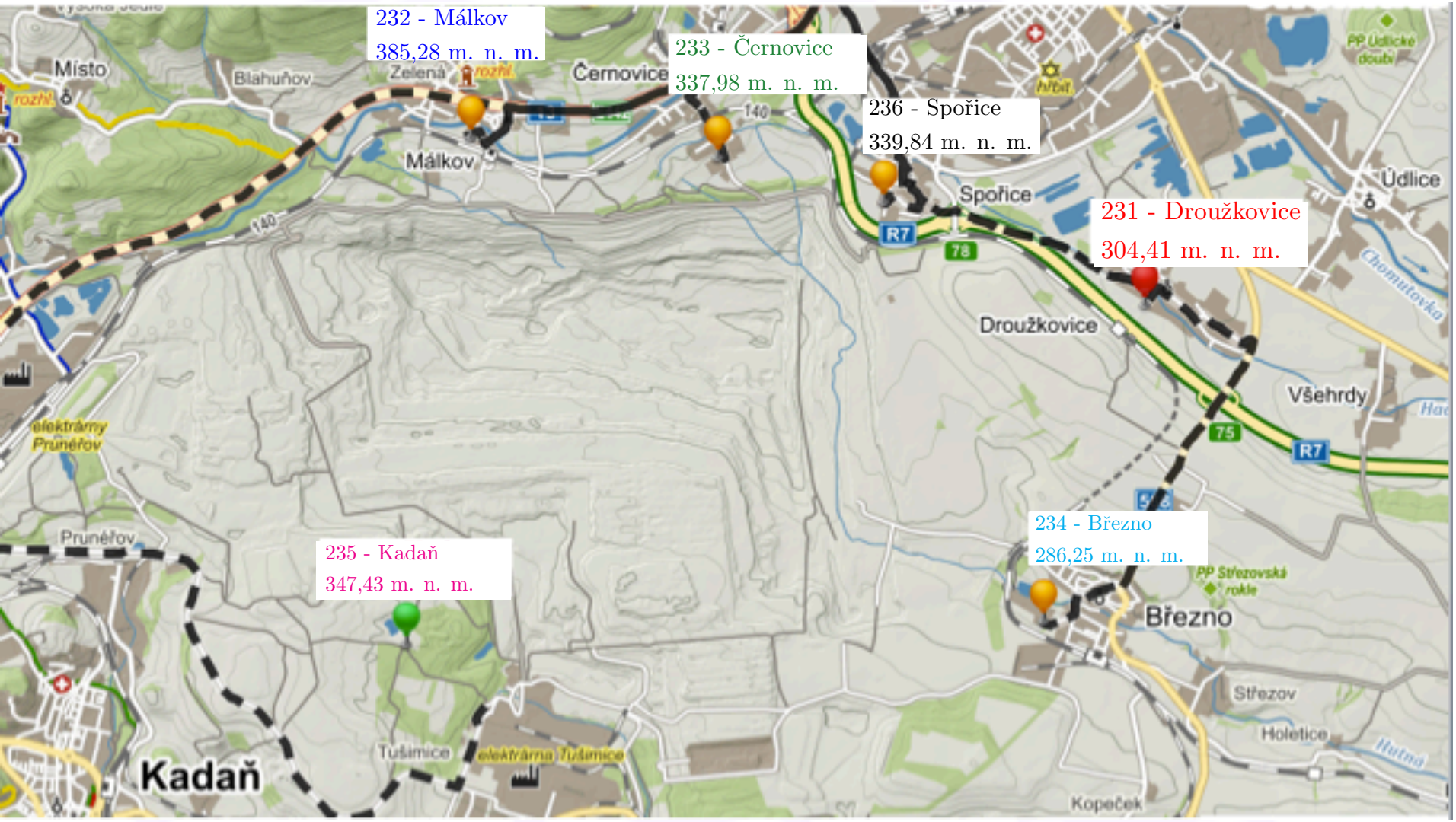


FULLY FILTERED DATA

Example of exceptional singular value was replaced by NaN value.

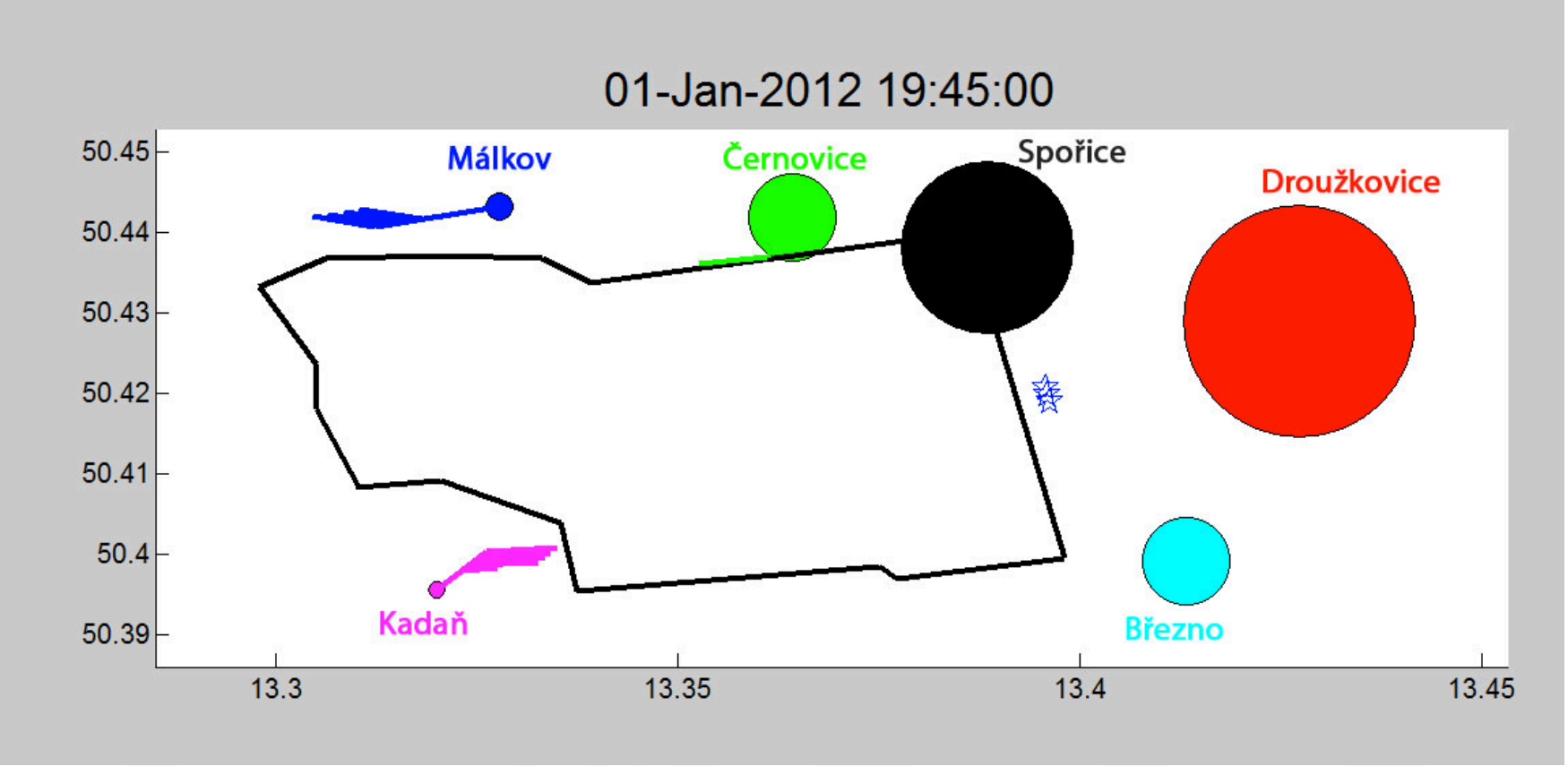


Map from the year 2015



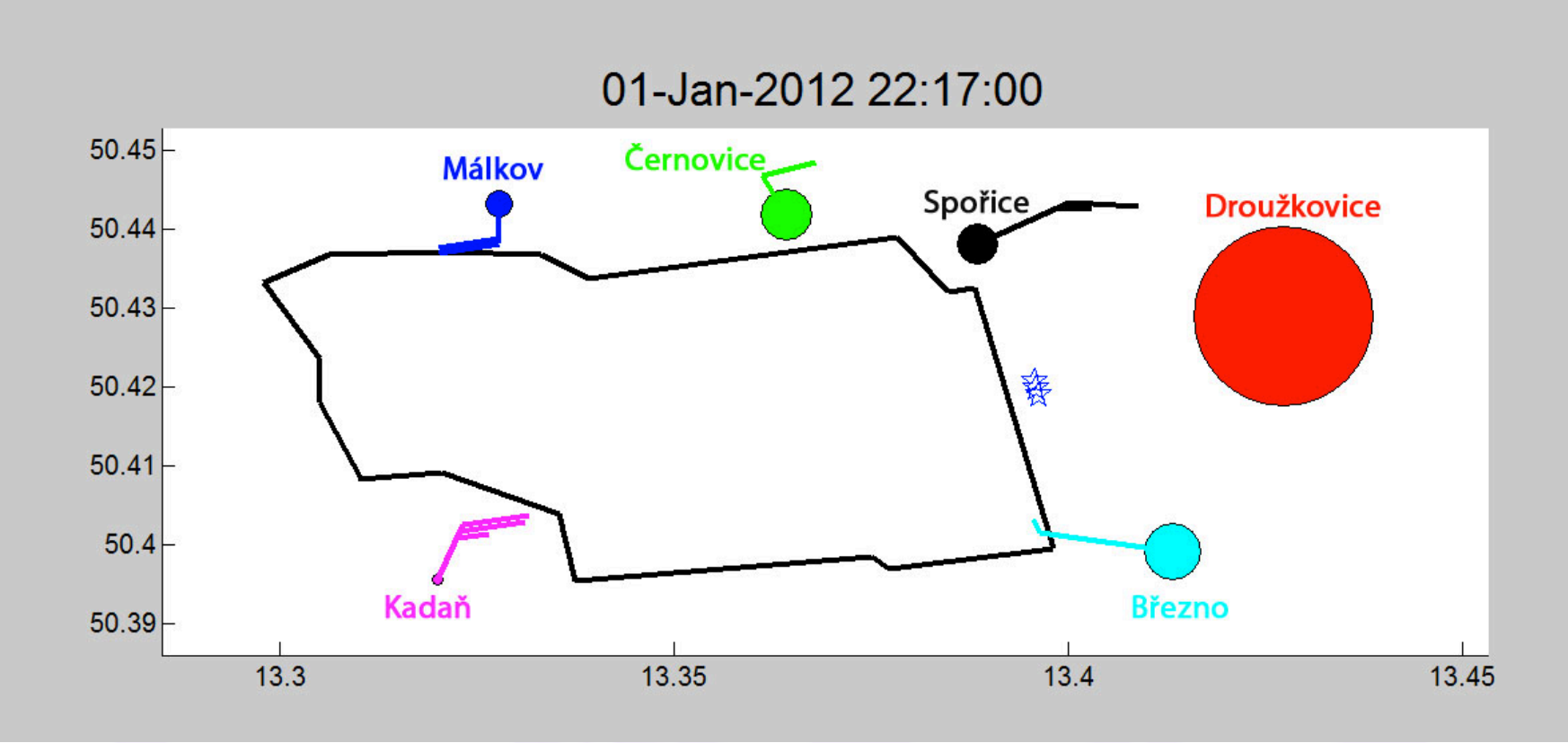
Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

Degree of pollution



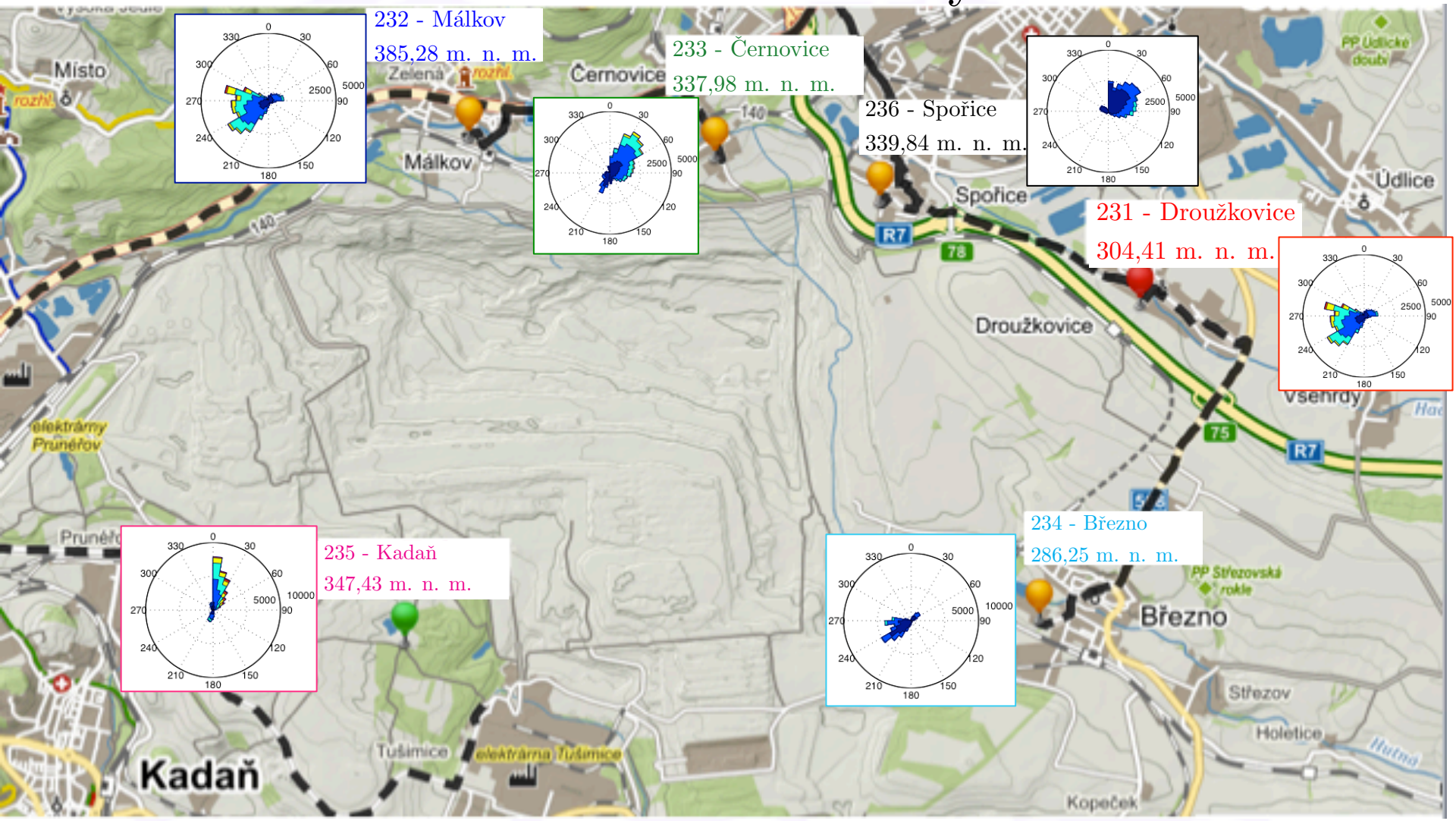
Map of wind flow over the opencast mine from 1. 1. 2012 19:45

Degree of pollution



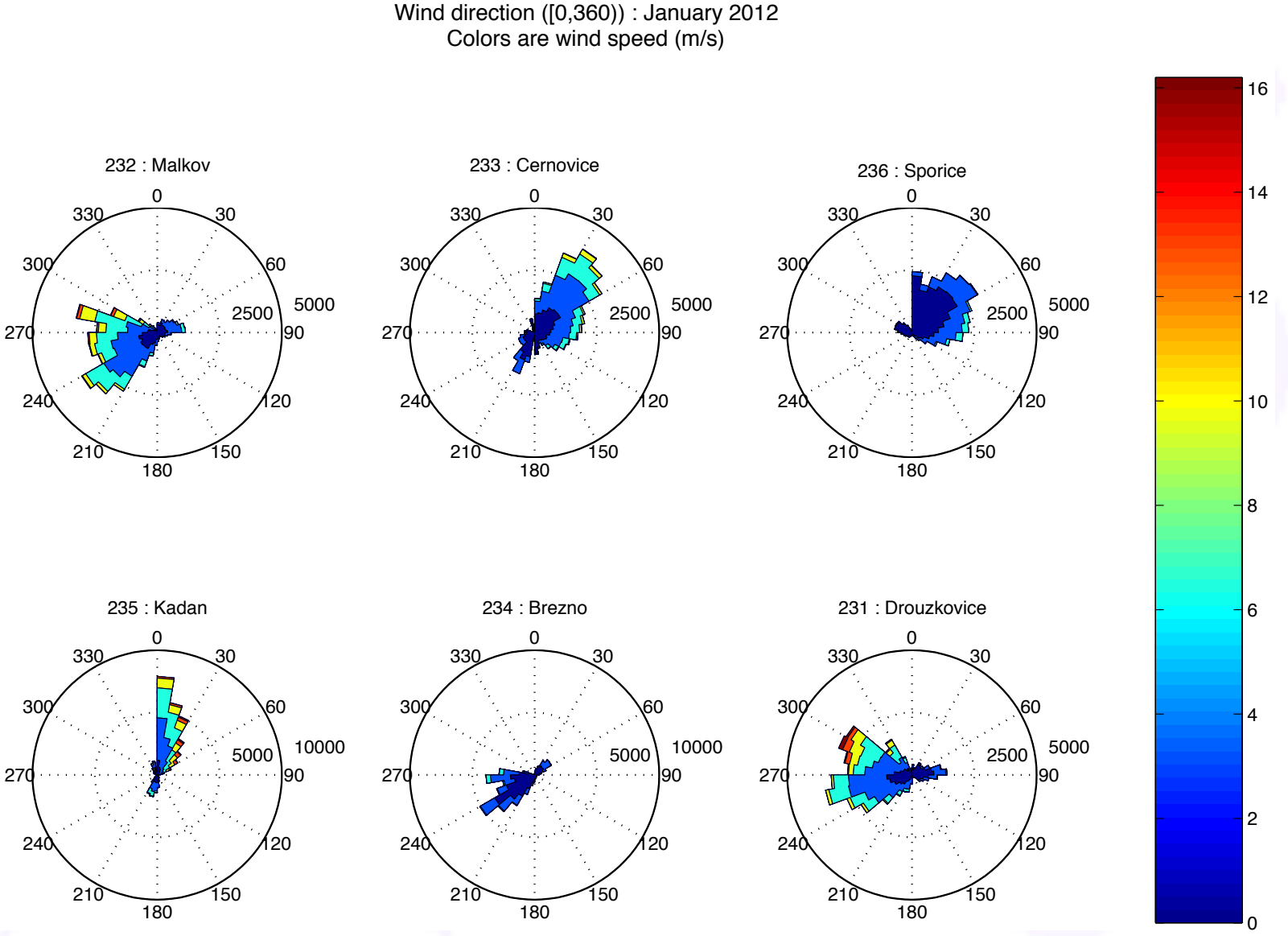
Map of wind flow over the opencast mine from 1. 1. 2012 19:45

Direction of the wind - January 2012

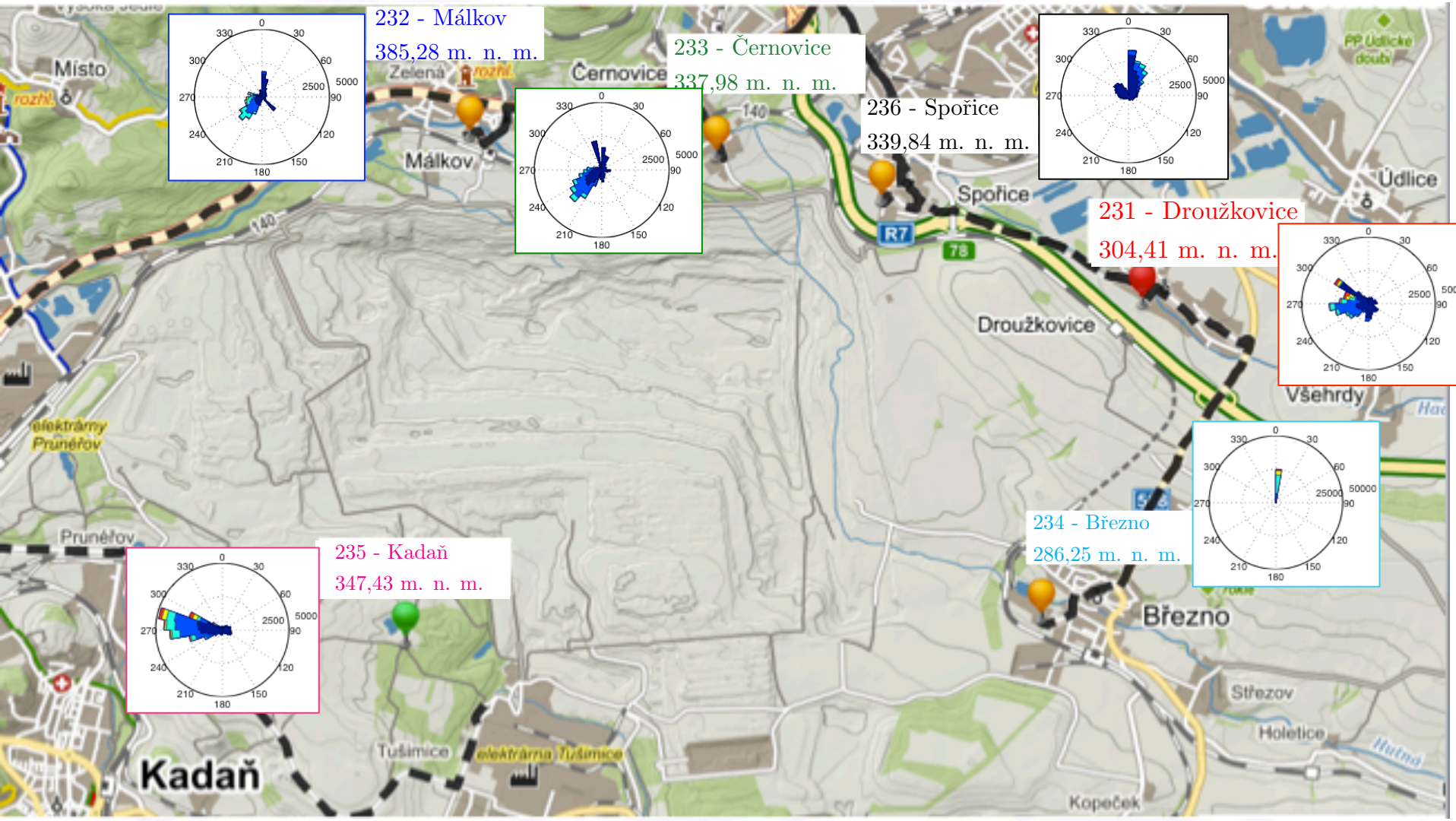


Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

WIND FLOW OVER THE OPENCAST MINE

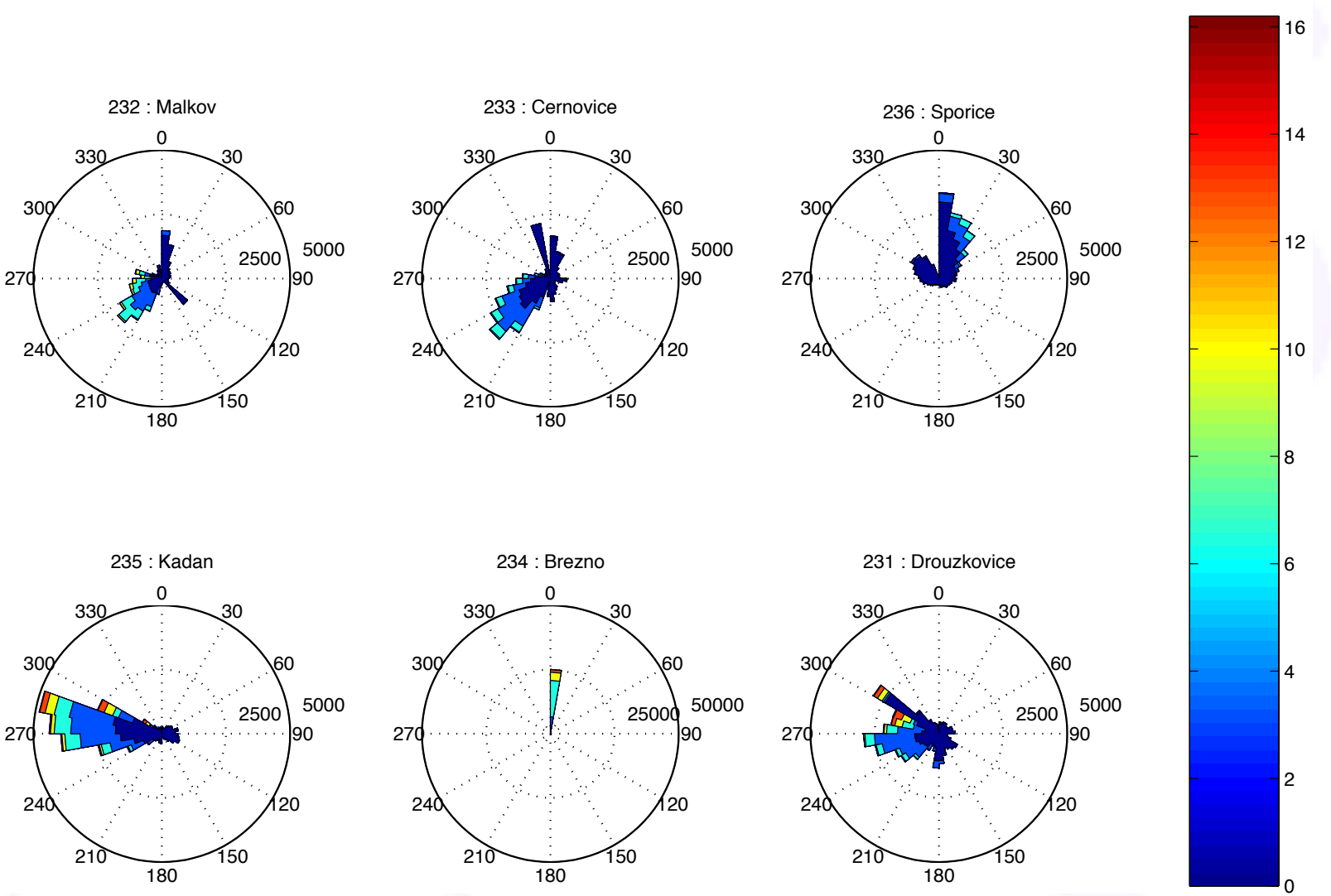


Direction of the wind - December 2013



Map of the opencast mine Libouš - Tušimice (Severočeské doly, a.s.)

WIND FLOW OVER THE OPENCAST MINE



Conclusions

Despite of the above mentioned problems it can be concluded that the data, provided some a-priori filtering and pre-processing will be applied, can be used for the analysis of pollution dispersion conditions and other meteorological phenomena in the area of the opencast coal mine.

* This preliminary data exploration discovered many problems in acquisition and storage of the data.
* These problems are mainly of technical origin and have to be resolved before undertaking any further steps in analysis of the data.

References

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[4] L. Matějíček, T. Bodnár, Š. Nosek, and E. Gulíková. Processing of environmental data for air dispersion numerical models and aerodynamic research in wind tunnels. *Proceedings - 7th International Congress on Environmental Modelling and Software: Bold Visions for Environmental Modeling, iEMSs 2014*, 4:2301–2308, 2014.

[5] L. Matějíček, Z. Jaňour, L. Beneš, T. Bodnár, and E. Gulíková. Spatio - temporal modelling of dust transport over surface mining areas and neighbouring residential zones. *Sensors*, 8(6):3830–3847, 2008.