AIR QUALITY

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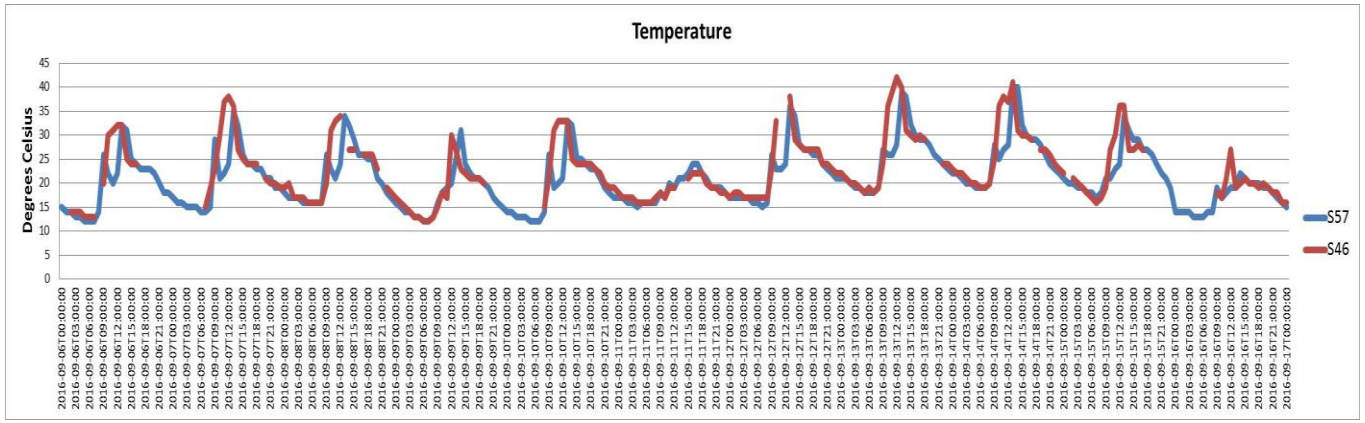
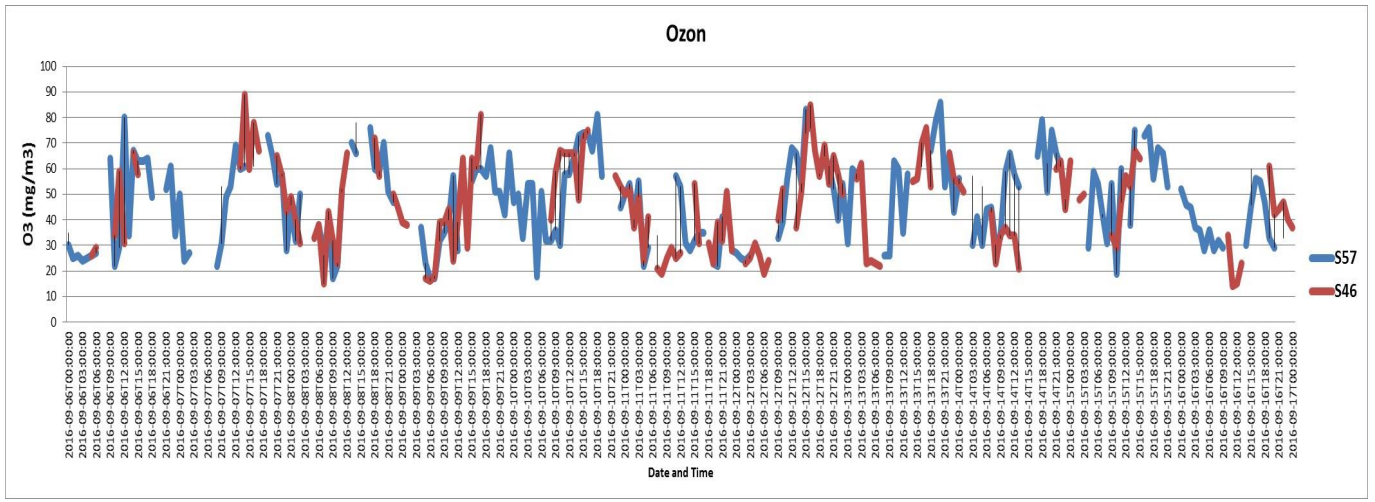
AIR QUALITY DATA ANALYSIS

- We focus on the sensor data
- We do not include data from other sources
- We cannot make inferences about causes and effects or cause-effect relations
- We identify and try to diagnose what the data "tell" us

TEMPERATURE AND OZONE





Ozone value is calibrated with help of other measurements of the sensor:

Ozone value is based on

- O3resistance
- COresistance
- NO2resistance
- Temperature.ambient
- Temperature.unit
- Barometer
- Humidity

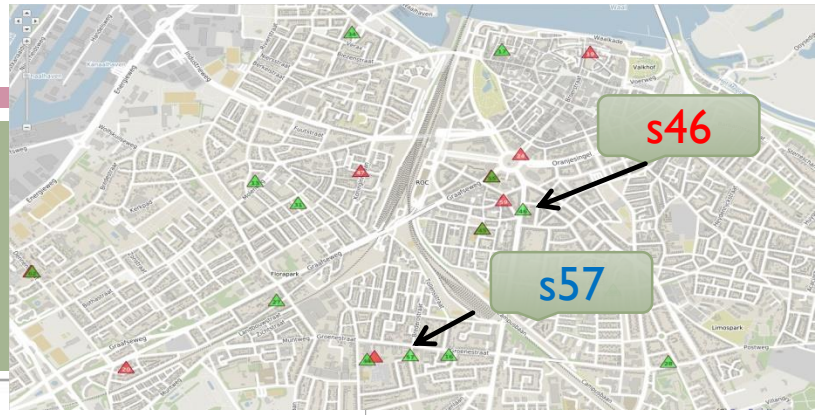
Thus, there is mutual interdependency between OzoneValue.calibrated and Temperature.

Still, for both indicators we can see a daily pattern.

Hot days seem to give higher ozone peaks.

Smart Emission

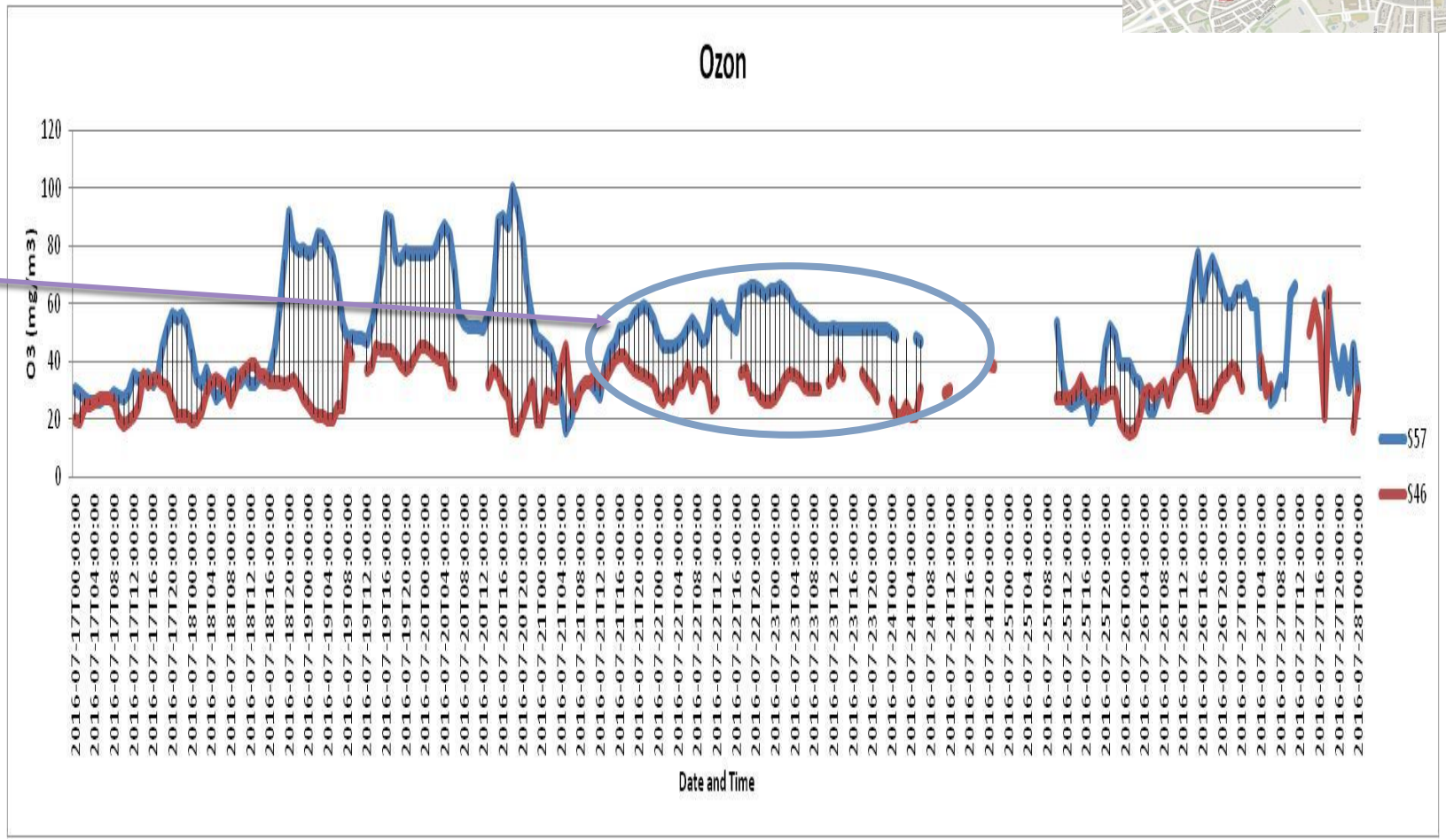
OZONE IN VIERDAAGSEFEESTEN



Different pattern than in a regular week:

Ozone **lower** than normal

on 21/7, 22/7, 23/7 which is Thursday, Friday and Saturday in the Vierdaagse week.

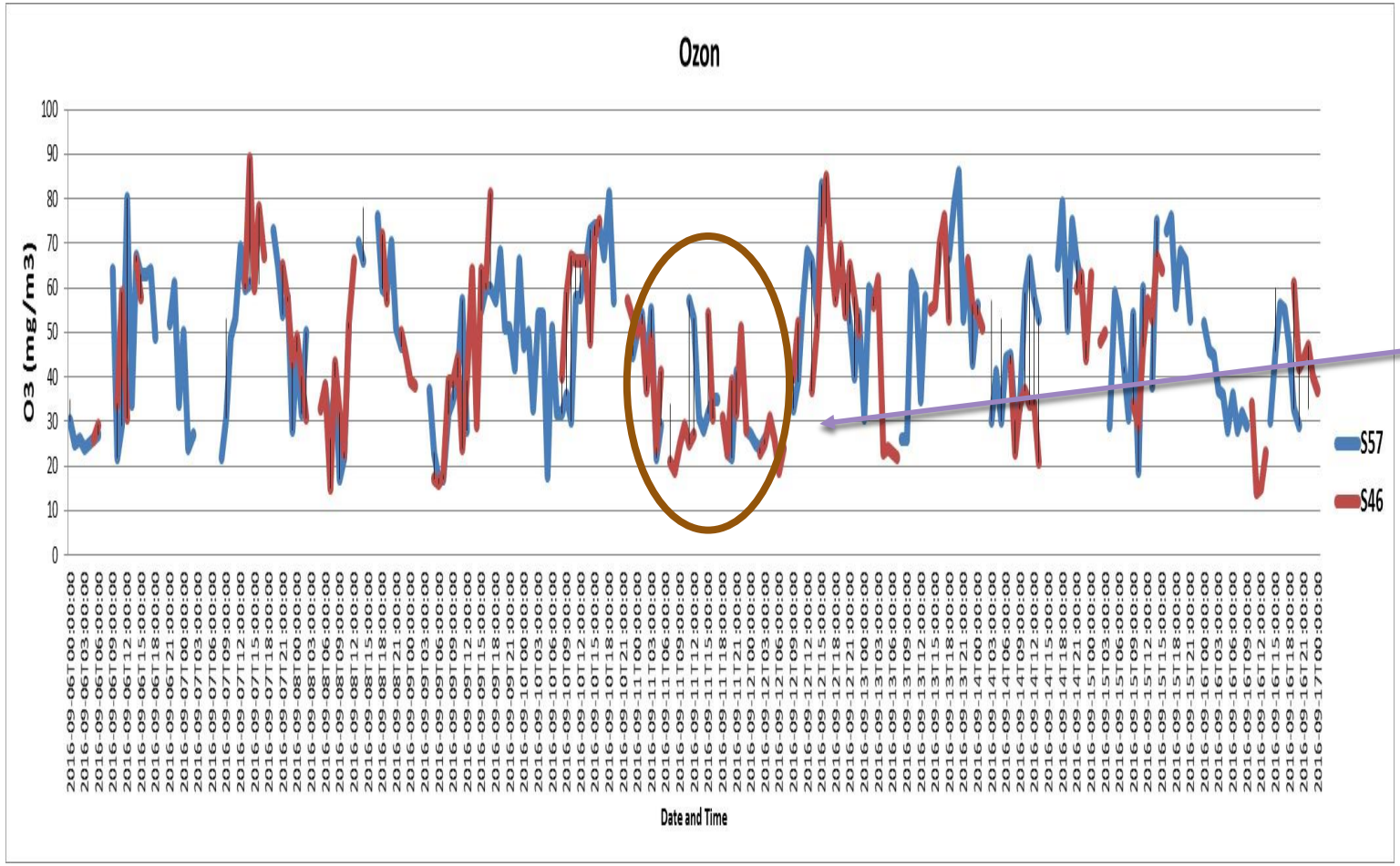


- sensor 57 (Groenestraat) higher levels of O3 than sensor 46 (Sint Annastraat).
- the highest values of O3 appears during the evening.

Smart Emission

OZONE IN SEPTEMBER- HOT WEEK

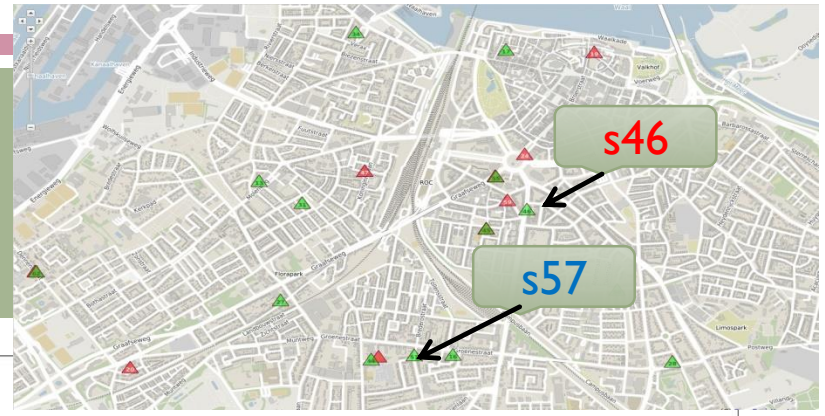
- Ozone seems to follow a specific pattern during the days.
- The level of O3 changes a lot during the day.
- Ozone increases during the hours 12:00-20:00 every day and it becomes almost double.



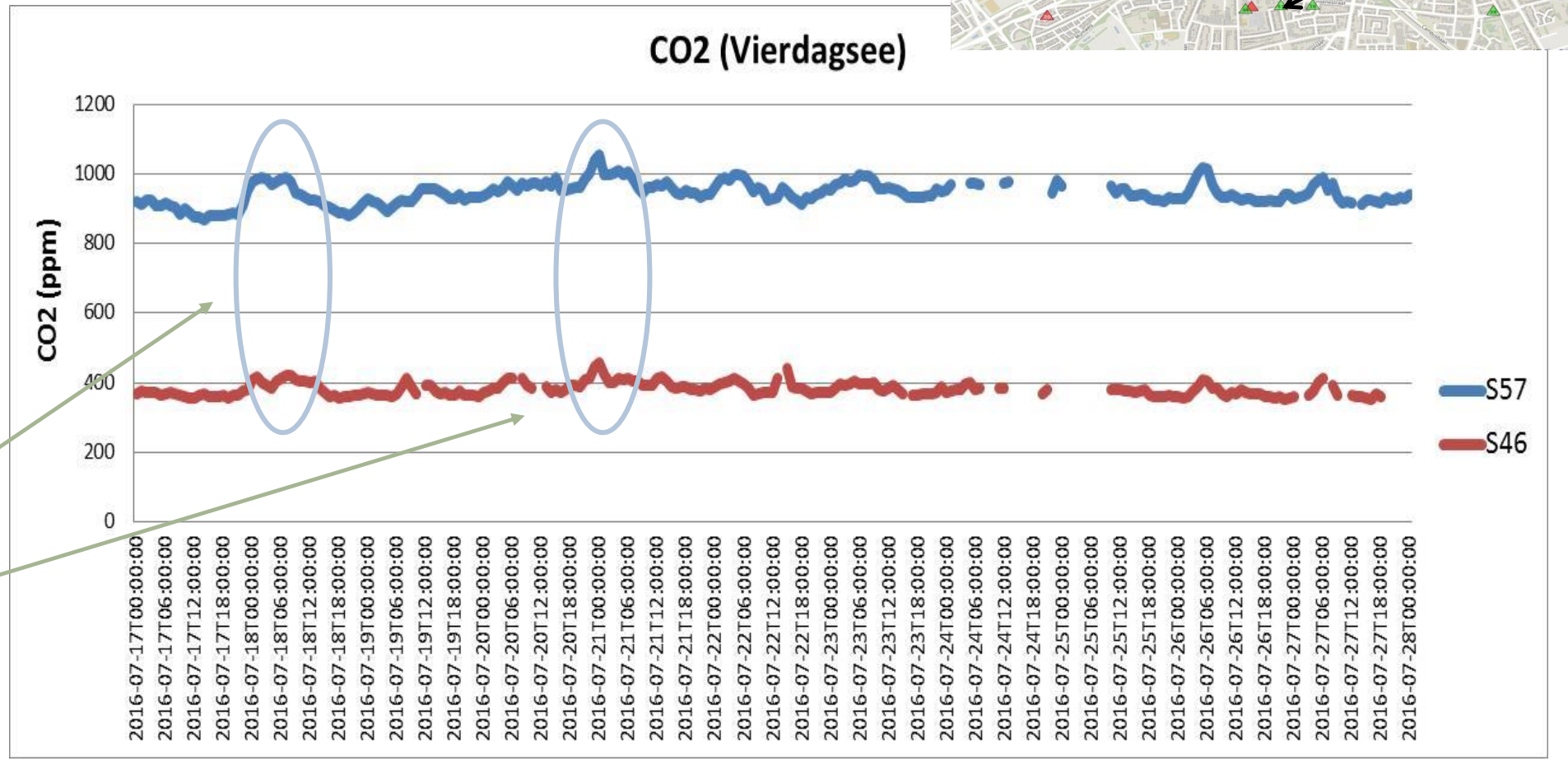
Although, ozone seems to have an important decrease on Sundays.

On this Sunday (11/9) some peak points are noticed, but they do not give as high values as on the weekdays.

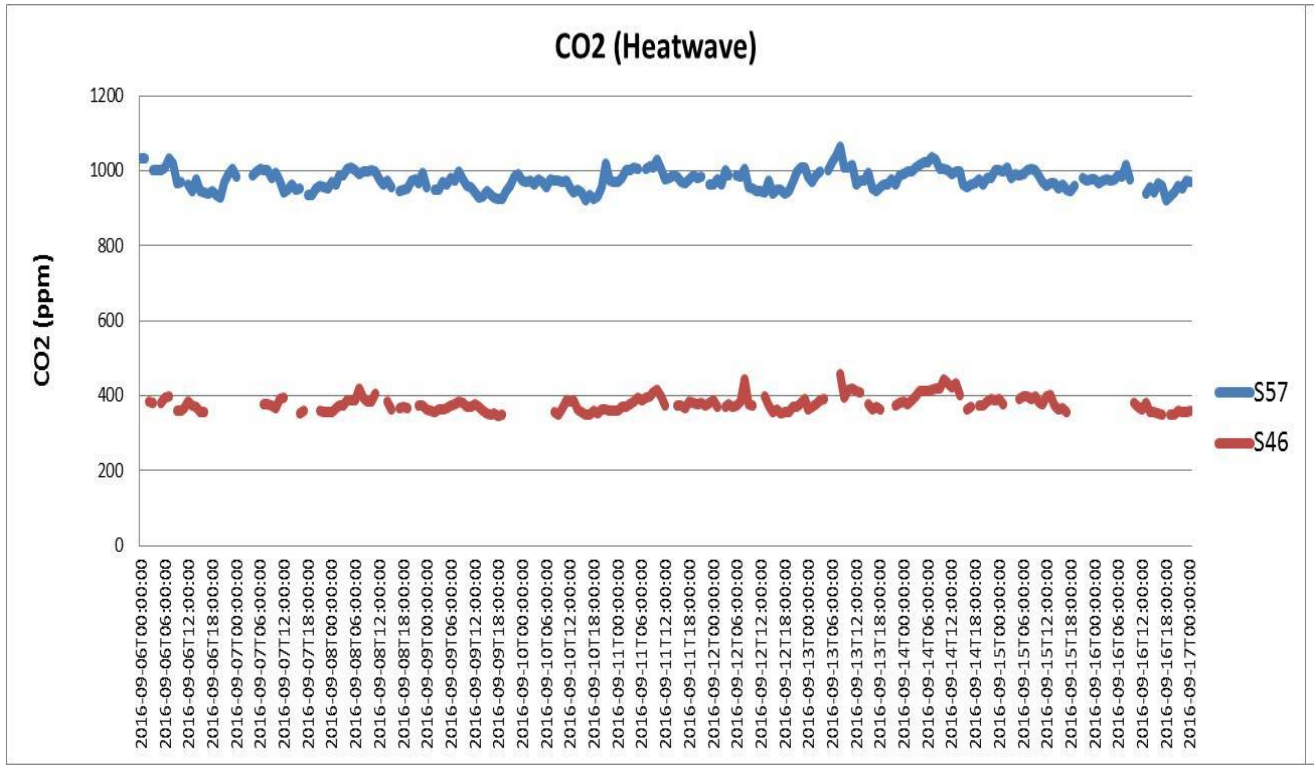
CO2 IN VIERDAAGSEFESTEN

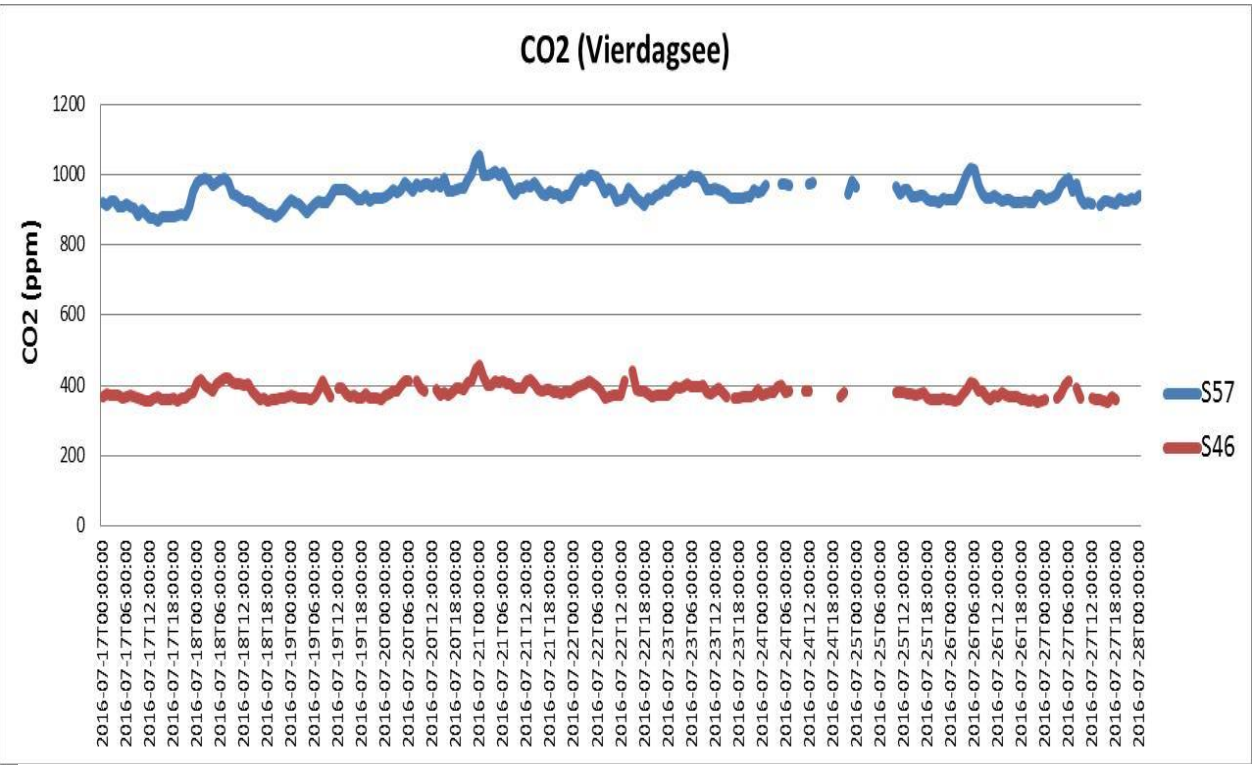


- sensor 46 (Sint Annastraat) presents lower levels of CO2 than sensor 57 (Groenestraat).
- For both sensors peak points appear at the same days and hours. For example, some peak points are noticed in the early morning hours (between 2:00 am and 9:00 am).



COMPARISON CO2 HOT WEEK - VIERDAAGSEFESTEN

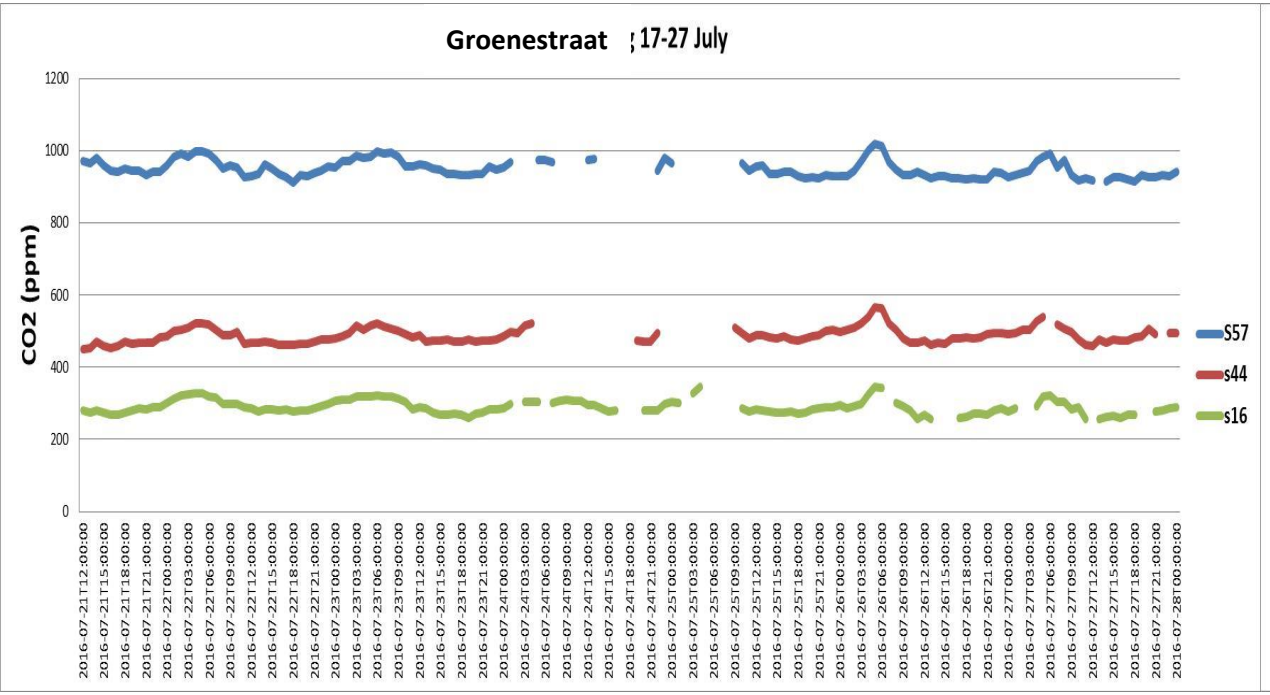


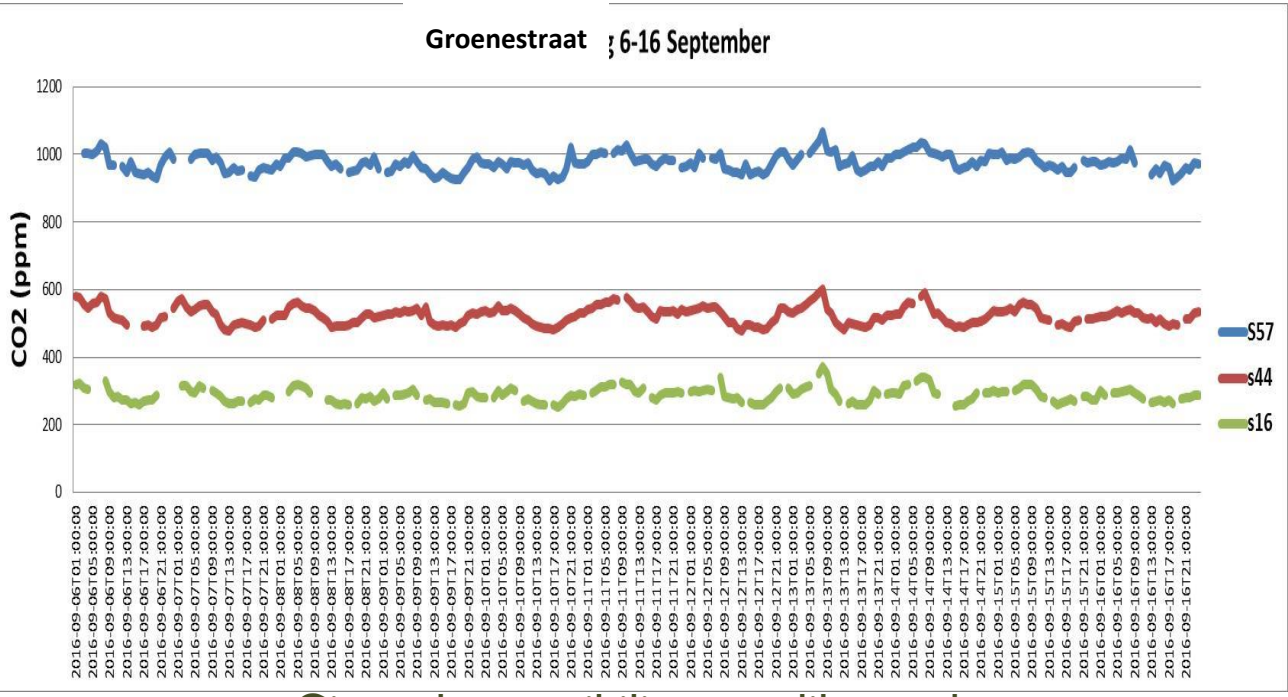


- The gas CO2 behaves 'like a heavy blanket';
  - The CO2 level does not change in time

- The average CO2 level does show significant differences **between** sensor locations. => in discussion, 24-11-16: This is recognized as a calibration problem in the Smart Emission pilot. Sensor manufacturer Intemo plans to install an automatic calibration software update, calibrating the CO2 sensing device every 4 days, to eliminate the offset of the CO2 sensor. This offset is due to internal 'pollution' on the level of the sensing device.

CO2 GROENESTRAAT





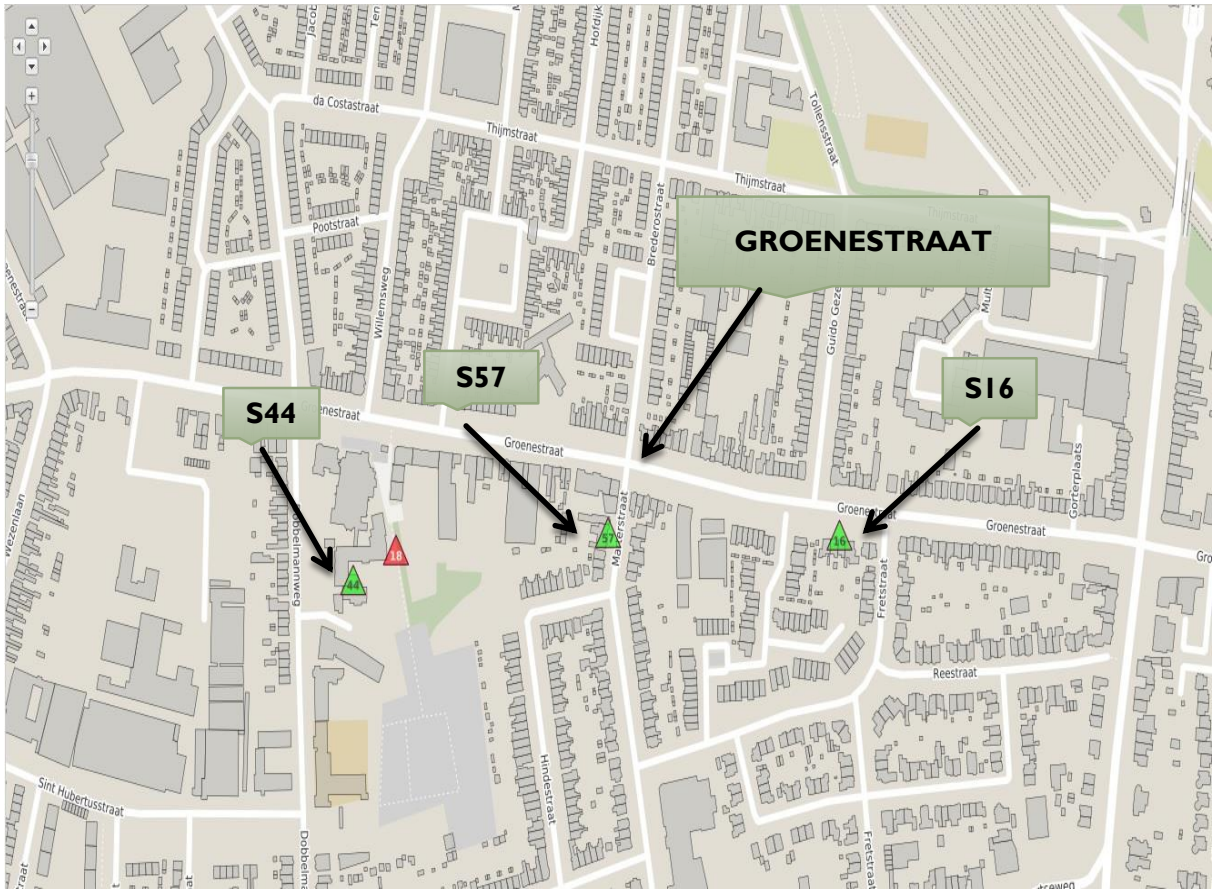
- It is clear from the graphs that these three sensors give quite different values of CO2. A round of software update per sensor, giving a software update to execute a regular automatic calibration, is envisaged to be able to eliminate the offset factor. In the current laboratory setting (outside Intemo office) this calibration has been tested. Roll-out in Nijmegen is planned to improve the CO2 measurement of the sensor network.

- Given the possibility to calibrate the sensor to eliminate the initial offset factor:
  - The values have small fluctuations during these days.
  - All sensors follow the same pattern

Smart Emission

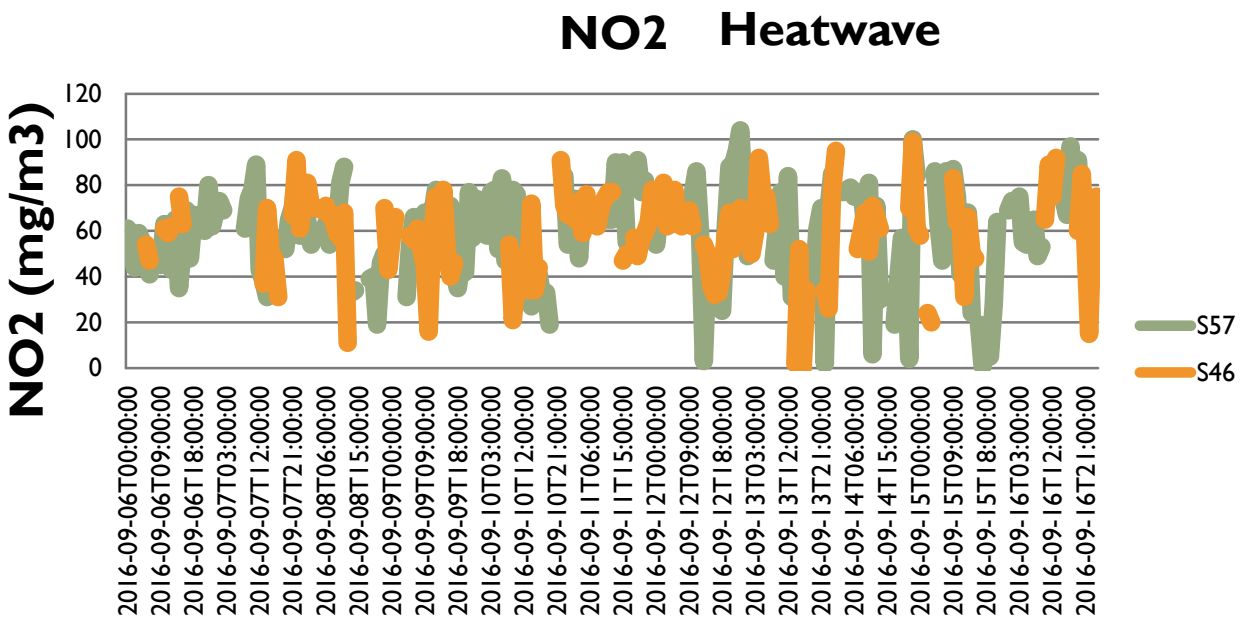
CO2 GROENESTRAAT

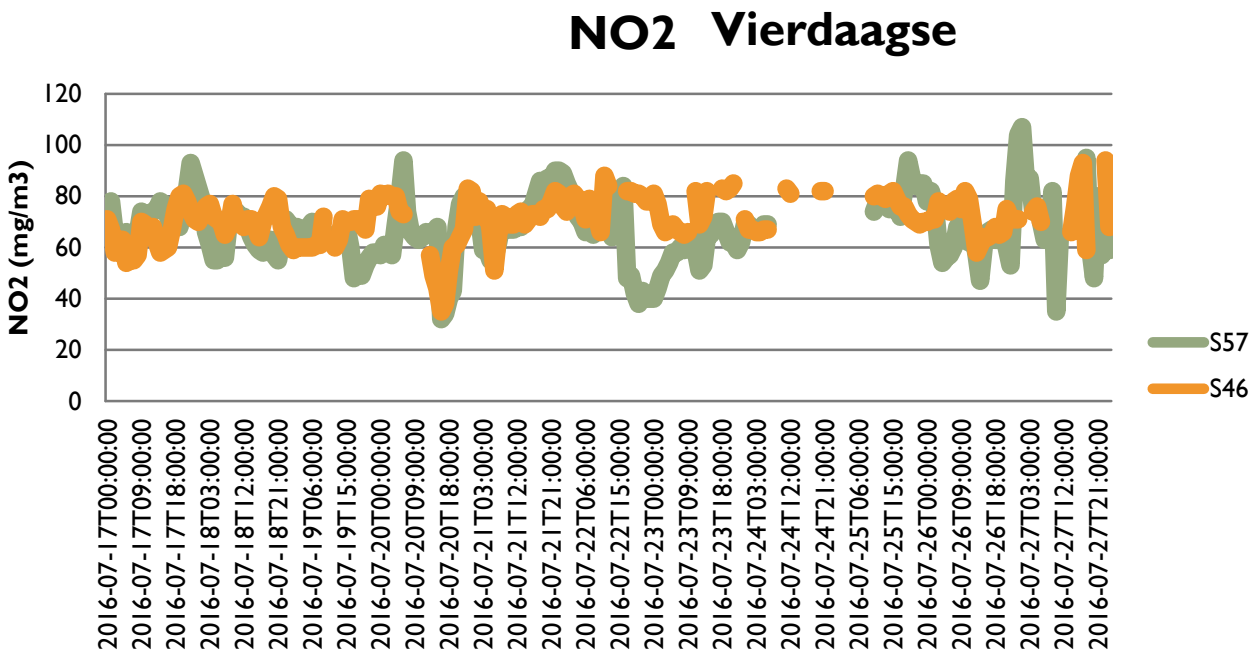
- Comparing these two graphs of Carbon Dioxide, we notice that each sensor gives almost the same values of CO2 at these two periods (ten days in July and September).



- The values of s44 are almost the half of the values of s57
- the values of s16 are almost the one third of the values of s57
- A stable phenomenon.
- Request: Air quality experts to help interpret these data.

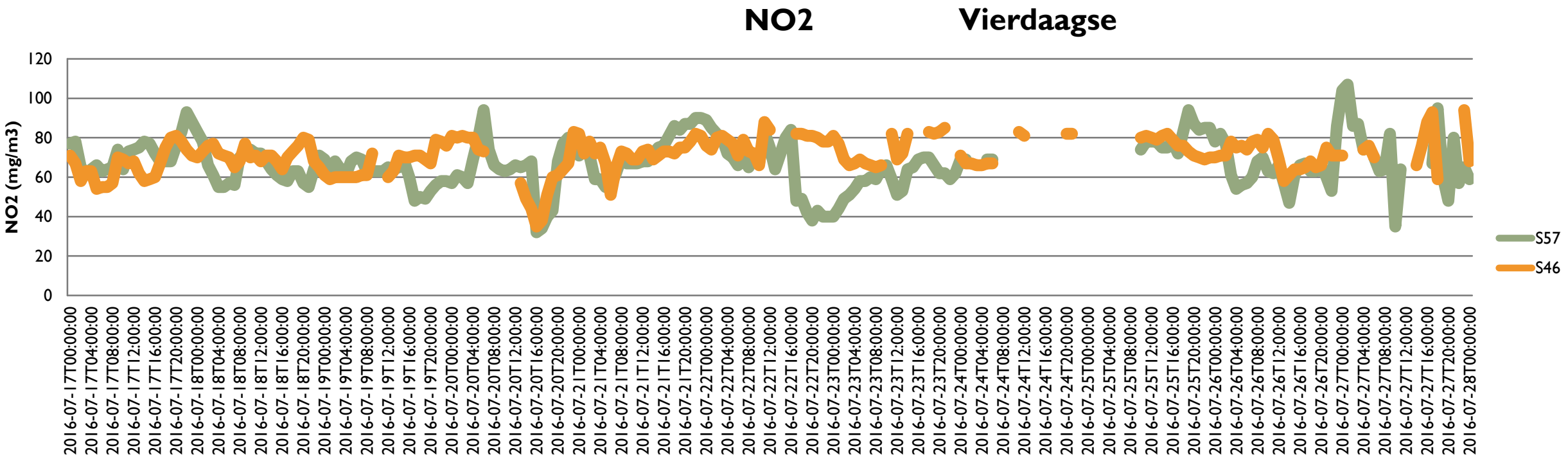
NO2 HOT WEEK - VIERDAAGSE



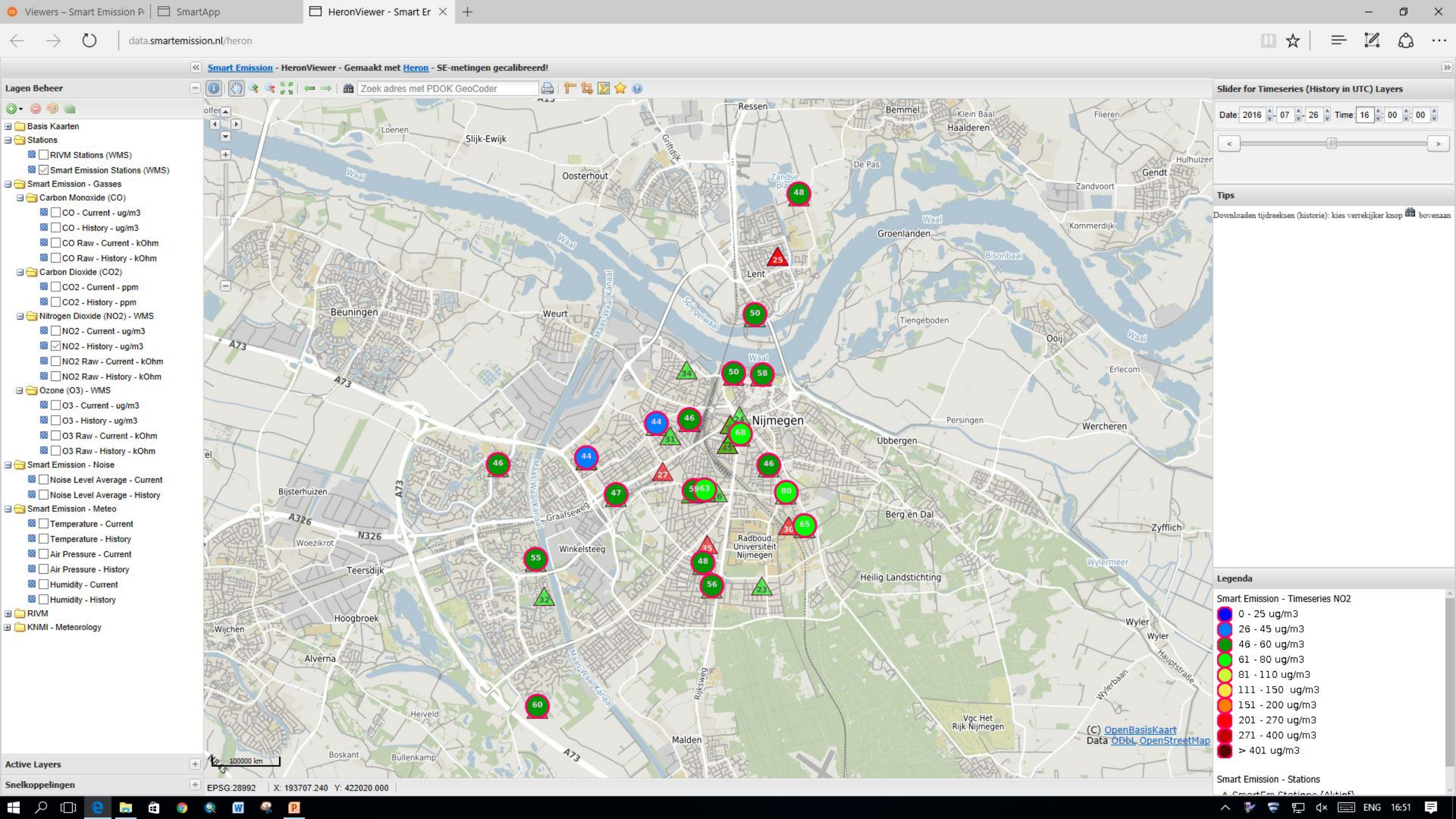


- NO2 is a gas that has big fluctuations during the day
- S57 gives higher peaks than s46

NO2 VIERDAAGSE IN JULY TIMESERIES



- NO2 levels usually between 50 and 90 mg/m3, with 3 low peaks below 40 and 5 high peaks above 90 mg/m3.
- One peak above 100 mg/m3 at s57 on 27 in the night of 26 – 27 of July (TUE-WED). At 23:00 - 0:00 midnight, the Heron viewer shows a peak in NO2 for many sensors.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SmartApp
HeronViewer - Smart Er
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Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!
Lagen Beheer
Zoek adres met PDOK GeoCoder
Basis Kaarten
Stations
RIVM Stations (WMS)
Smart Emission Stations (WMS)
Smart Emission - Gasses
Carbon Monoxide (CO)
CO - Current - ug/m3
CO - History - ug/m3
CO Raw - Current - kOhm
CO Raw - History - kOhm
Carbon Dioxide (CO2)
CO2 - Current - ppm
CO2 - History - ppm
Nitrogen Dioxide (NO2) - WMS
NO2 - Current - ug/m3
NO2 - History - ug/m3
NO2 Raw - Current - kOhm
NO2 Raw - History - kOhm
Ozone (O3) - WMS
O3 - Current - ug/m3
O3 - History - ug/m3
O3 Raw - Current - kOhm
O3 Raw - History - kOhm
Smart Emission - Noise
Noise Level Average - Current
Noise Level Average - History
Smart Emission - Meteo
Temperature - Current
Temperature - History
Air Pressure - Current
Air Pressure - History
Humidity - Current
Humidity - History
RIVM
KNMI - Meteorology
Active Layers
Snelkoppelingen
Slider for Timeseries (History in UTC) Layers
Date: 2016 - 07 - 26 Time: 16 : 00 : 00
Tips
Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan
Legenda
Smart Emission - Timeseries NO2
0 - 25 ug/m3
26 - 45 ug/m3
46 - 60 ug/m3
61 - 80 ug/m3
81 - 110 ug/m3
111 - 150 ug/m3
151 - 200 ug/m3
201 - 270 ug/m3
271 - 400 ug/m3
> 401 ug/m3
Smart Emission - Stations
Nijmegen
Lent
Ressen
Bemmel
Haalderen
Oosterhout
Slijk-Ewijk
Beuningen
Weurt
Groenlanden
Tiengeboden
Ooij
Erlecom
Persingen
Wercheren
Ubbergen
Berg en Dal
Zyfflich
Bisonbaai
Kommerdijk
Zandvoort
Gendt
Hulhuizen
Flieren
Klein Baal
De Pas
Bijsterhuizen
Woezikrot
Teersdijk
Winkelsteeg
Graafseweg
Radboud Universiteit Nijmegen
Heilig Landstichting
Wylermeer
Wyler
Hoogbroek
Wijchen
Alverna
Heiveld
Boskant
Bullenkamp
Malden
Vgc Het Rijk Nijmegen
Waal
Maas-Waalkanaal
Griftdijk
Spijkerwaal
A73
A326
N326
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Data ODbL OpenStreetMap
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100000 km
ENG 16:51

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Lagen Beheer

- Basis Kaarten
- Stations
  - RIVM Stations (WMS)
  - Smart Emission Stations (WMS)
- Smart Emission - Gasses
  - Carbon Monoxide (CO)
    - CO - Current - ug/m3
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    - CO Raw - Current - kOhm
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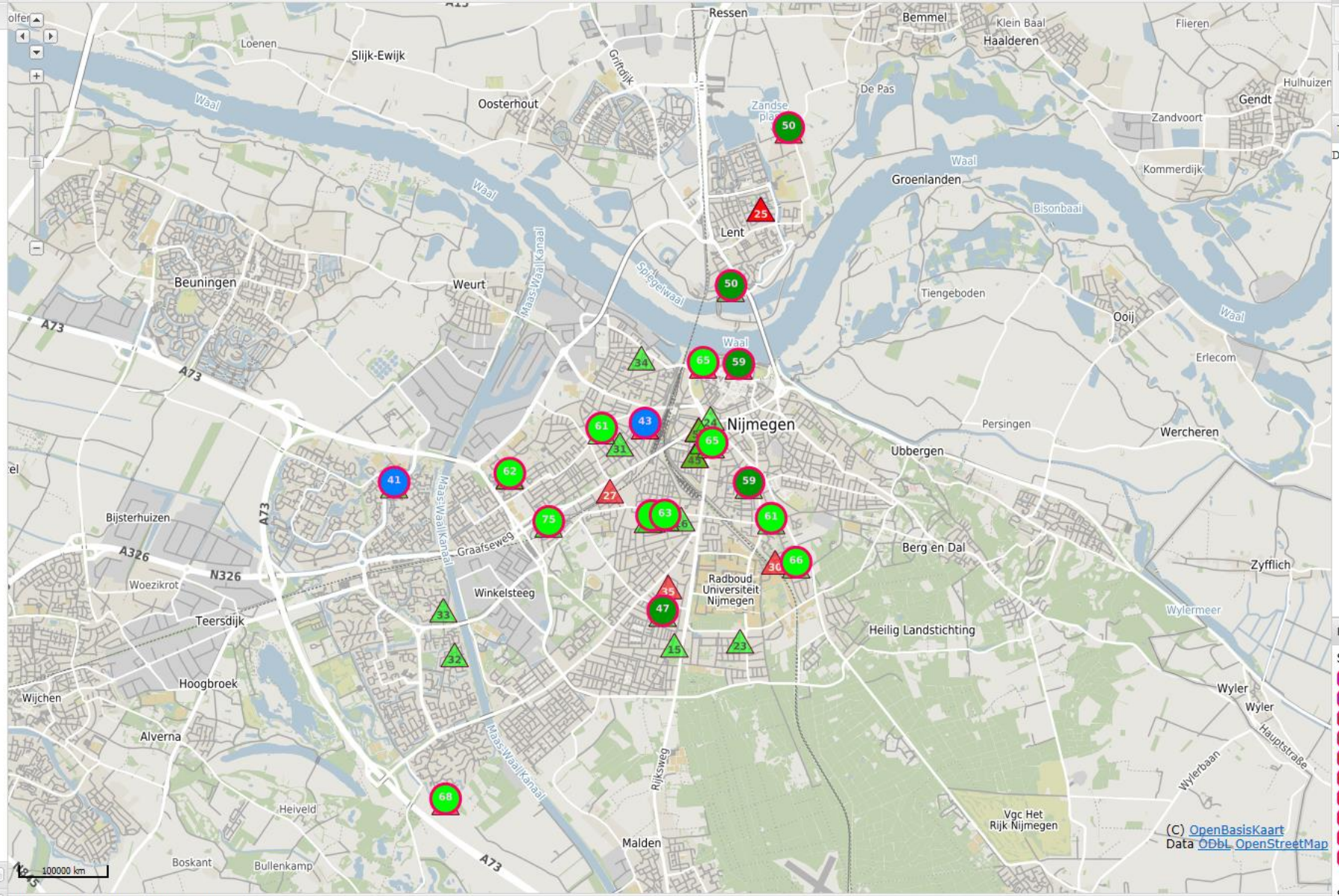
    - CO2 - Current - ppm
    - CO2 - History - ppm
  - Nitrogen Dioxide (NO2) - WMS
    - NO2 - Current - ug/m3
    - NO2 - History - ug/m3
    - NO2 Raw - Current - kOhm
    - NO2 Raw - History - kOhm
  - Ozone (O3) - WMS
    - O3 - Current - ug/m3
    - O3 - History - ug/m3
    - O3 Raw - Current - kOhm
    - O3 Raw - History - kOhm
- Smart Emission - Noise
  - Noise Level Average - Current
  - Noise Level Average - History
- Smart Emission - Meteo
  - Temperature - Current
  - Temperature - History
  - Air Pressure - Current
  - Air Pressure - History
  - Humidity - Current
  - Humidity - History
- RIVM
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



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Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 26 Time: 17 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

Smart Emission - Timeseries NO2

- 0 - 25 ug/m3
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- 271 - 400 ug/m3
- > 401 ug/m3

Smart Emission - Stations

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    - NO2 - Current - ug/m3
    - NO2 - History - ug/m3
    - NO2 Raw - Current - kOhm
    - NO2 Raw - History - kOhm
  - Ozone (O3) - WMS
    - O3 - Current - ug/m3
    - O3 - History - ug/m3
    - O3 Raw - Current - kOhm
    - O3 Raw - History - kOhm
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- Smart Emission - Meteo
  - Temperature - Current
  - Temperature - History
  - Air Pressure - Current
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  - Humidity - Current
  - Humidity - History
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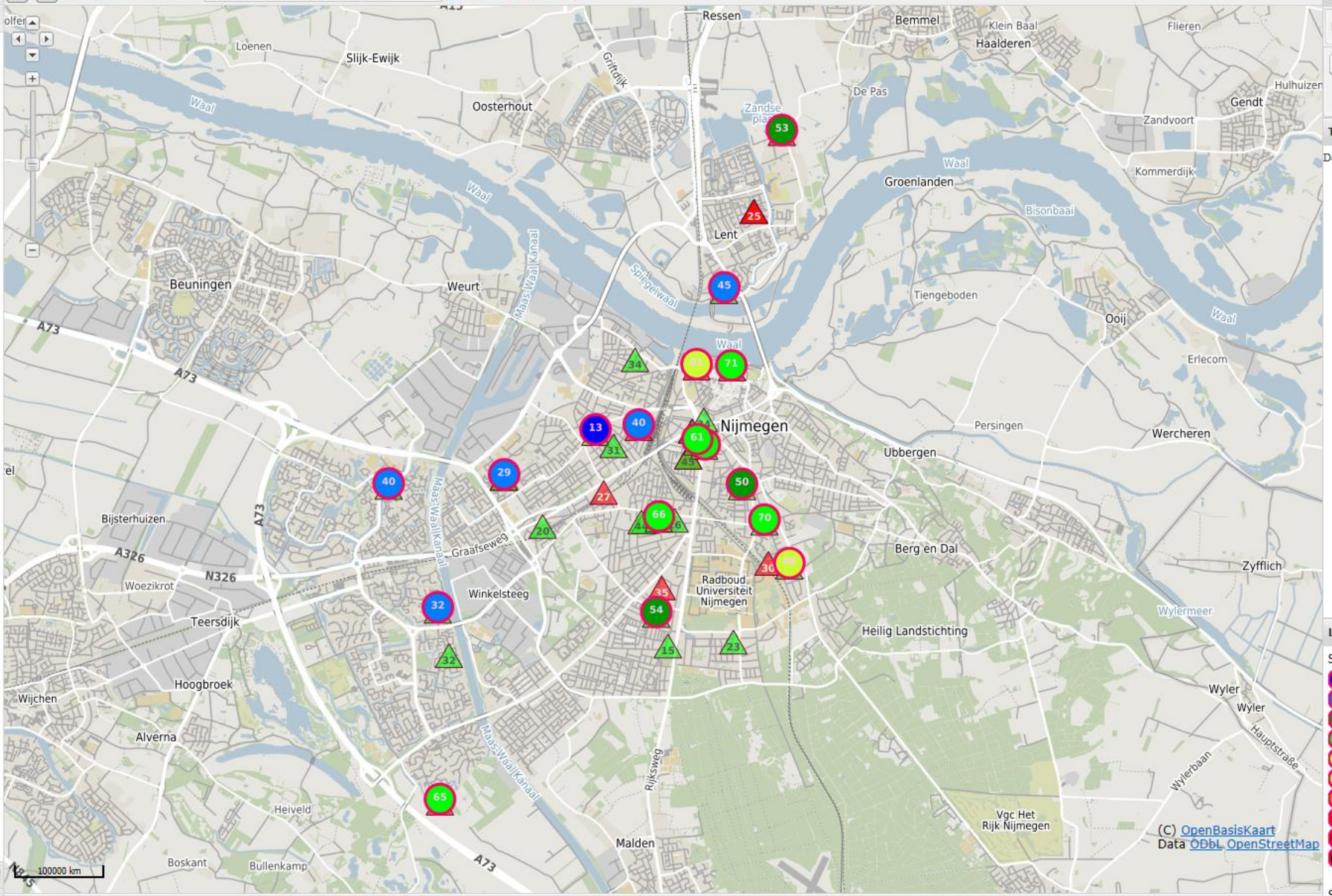
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



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Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 26 Time: 18 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

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Smart Emission - Stations

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  - Temperature - Current
  - Temperature - History
  - Air Pressure - Current
  - Air Pressure - History
  - Humidity - Current
  - Humidity - History
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- KNMI - Meteorology

Active Layers

Snelkoppelingen

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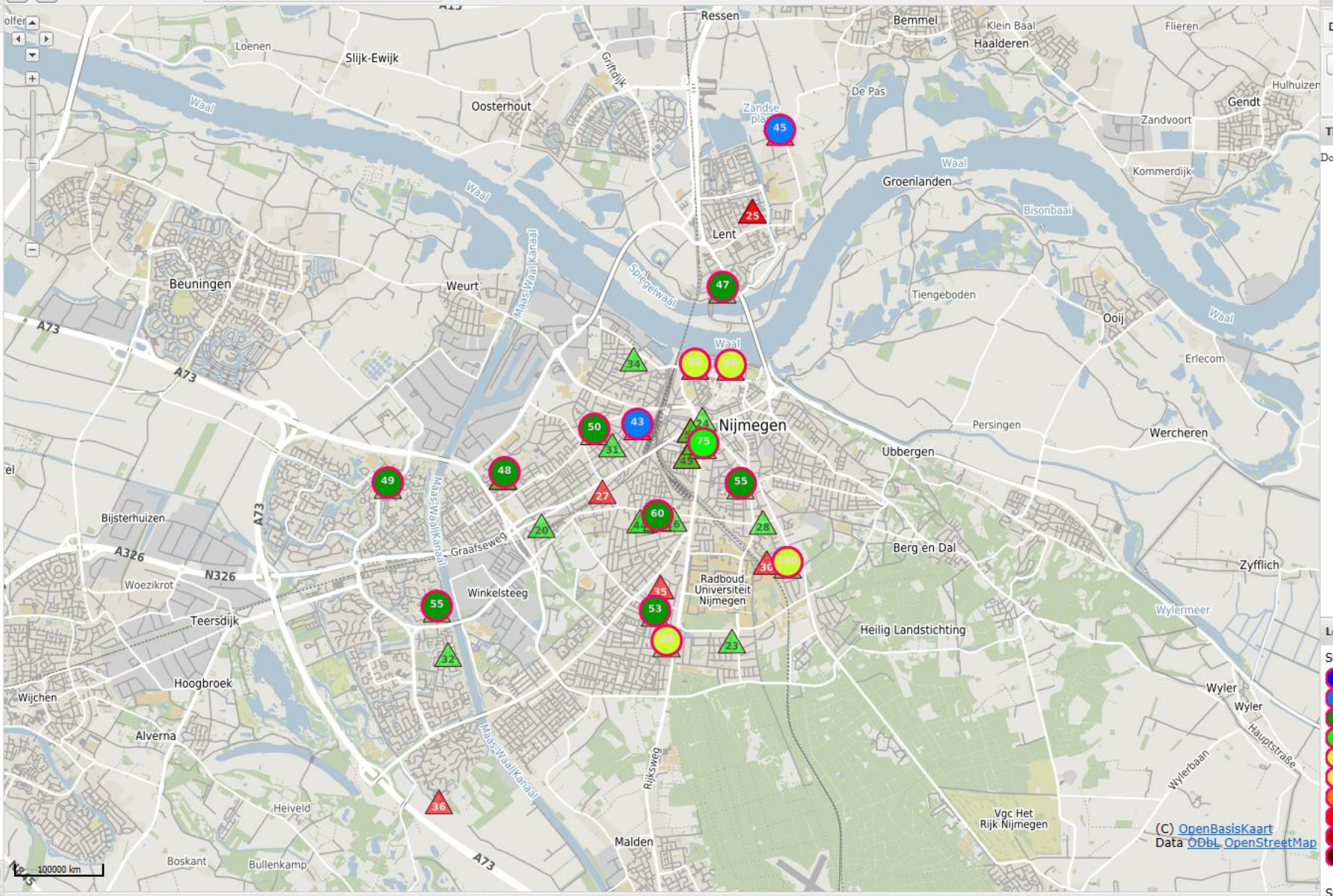

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Slider for Timeseries (History in UTC) Layers

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Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

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Smart Emission - Stations

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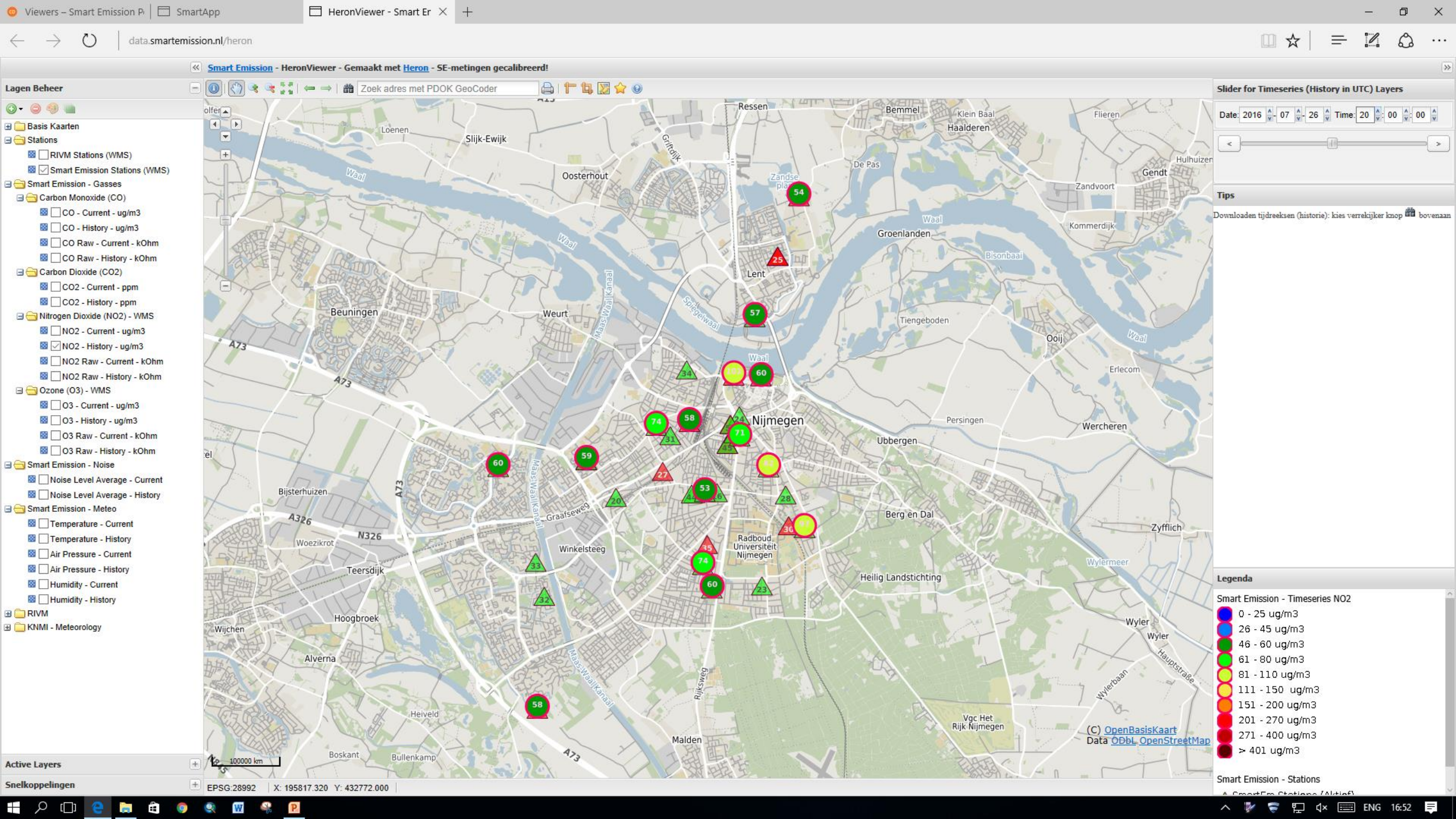
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SmartApp
HeronViewer - Smart Er
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Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!
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Slider for Timeseries (History in UTC) Layers
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Smart Emission - Stations
Nijmegen
Ressen
Bemmel
Haalderen
Klein Baal
Flieren
Hulhuizen
Gendt
Zandvoort
Kommerdijk
Groenlanden
Bisonbaai
Lent
Beuningen
Weurt
Tiengeboden
Ooij
Erlecom
Persingen
Wercheren
Ubbergen
Berg en Dal
Zyfflich
Wylermeer
Heilig Landstichting
Wyler
Radboud Universiteit Nijmegen
Vgc Het Rijk Nijmegen
Malden
Heiveld
Boskant
Bullenkamp
Alverna
Hoogbroek
Wijchen
Teersdijk
Woezikrot
Bijsterhuizen
Winkelsteeg
Graafseweg
Oosterhout
Slijk-Ewijk
Loenen
Griftdijk
Zandse plas
De Pas
Waal
Maas-Waalkanaal
Spijkerwaal
A73
A326
N326
Rijksweg
Wylerbaan
Hauptstraße
100000 km
(C) OpenBasisKaart
Data ODbL OpenStreetMap
EPSG:28992 | X: 195817.320 Y: 432772.000
ENG 16:52

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Lagen Beheer

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  - Smart Emission Stations (WMS)
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  - Noise Level Average - History
- Smart Emission - Meteo
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  - Air Pressure - Current
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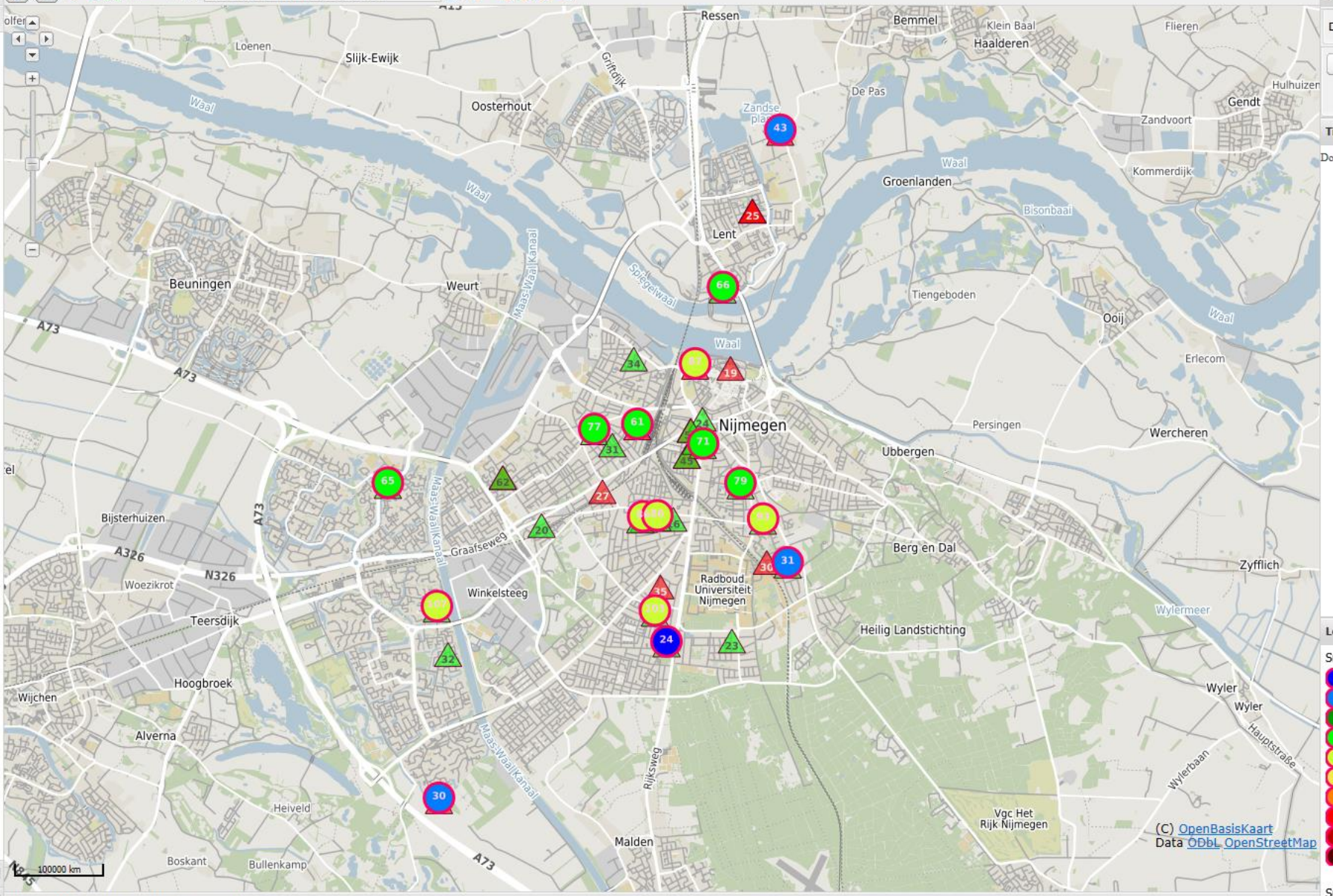
  - Humidity - Current
  - Humidity - History
- RIVM
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



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Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 26 Time: 21 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

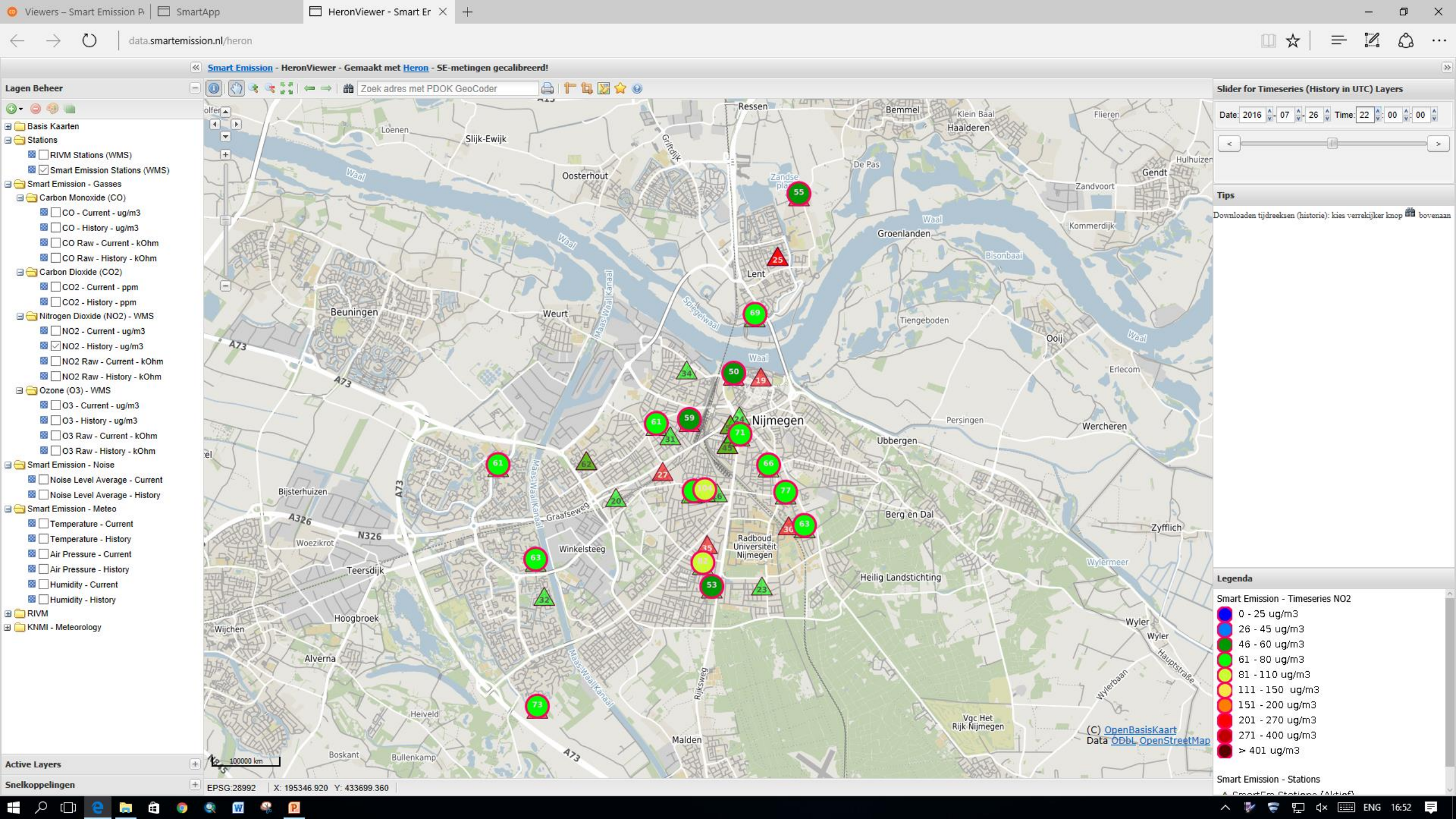
Legenda

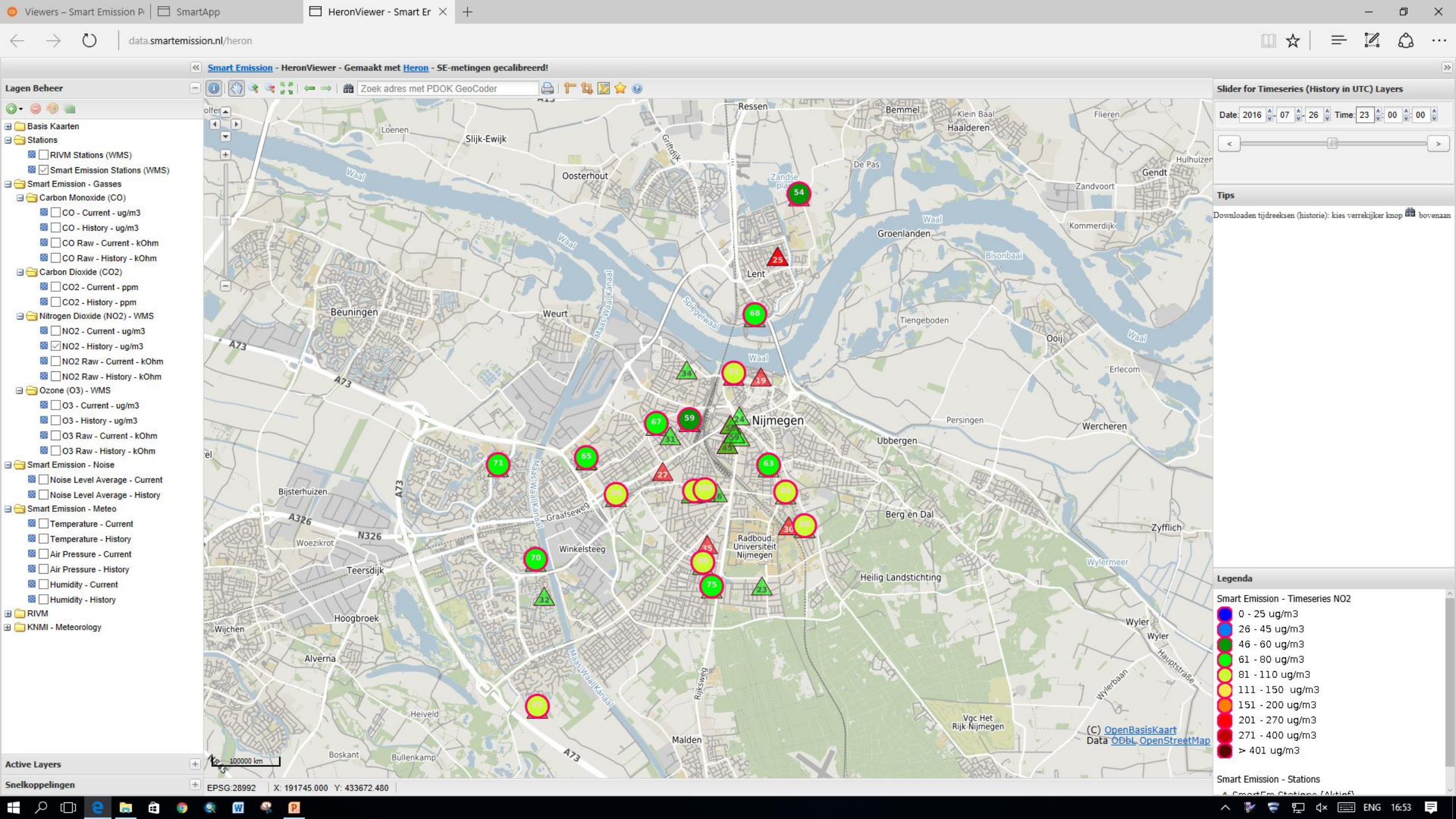
Smart Emission - Timeseries NO2

- 0 - 25 ug/m3
- 26 - 45 ug/m3
- 46 - 60 ug/m3
- 61 - 80 ug/m3
- 81 - 110 ug/m3
- 111 - 150 ug/m3
- 151 - 200 ug/m3
- 201 - 270 ug/m3
- 271 - 400 ug/m3
- > 401 ug/m3

Smart Emission - Stations

ENG 16:52


Viewers – Smart Emission P
SmartApp
HeronViewer - Smart Er
data.smartemission.nl/heron
Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!
Lagen Beheer
Zoek adres met PDOK GeoCoder
Basis Kaarten
Stations
RIVM Stations (WMS)
Smart Emission Stations (WMS)
Smart Emission - Gasses
Carbon Monoxide (CO)
CO - Current - ug/m3
CO - History - ug/m3
CO Raw - Current - kOhm
CO Raw - History - kOhm
Carbon Dioxide (CO2)
CO2 - Current - ppm
CO2 - History - ppm
Nitrogen Dioxide (NO2) - WMS
NO2 - Current - ug/m3
NO2 - History - ug/m3
NO2 Raw - Current - kOhm
NO2 Raw - History - kOhm
Ozone (O3) - WMS
O3 - Current - ug/m3
O3 - History - ug/m3
O3 Raw - Current - kOhm
O3 Raw - History - kOhm
Smart Emission - Noise
Noise Level Average - Current
Noise Level Average - History
Smart Emission - Meteo
Temperature - Current
Temperature - History
Air Pressure - Current
Air Pressure - History
Humidity - Current
Humidity - History
RIVM
KNMI - Meteorology
Active Layers
Snelkoppelingen
Slider for Timeseries (History in UTC) Layers
Date: 2016 - 07 - 26 Time: 22 : 00 : 00
Tips
Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan
Legenda
Smart Emission - Timeseries NO2
0 - 25 ug/m3
26 - 45 ug/m3
46 - 60 ug/m3
61 - 80 ug/m3
81 - 110 ug/m3
111 - 150 ug/m3
151 - 200 ug/m3
201 - 270 ug/m3
271 - 400 ug/m3
> 401 ug/m3
Smart Emission - Stations
Nijmegen
Lent
Beuningen
Weurt
Oosterhout
Slijk-Ewijk
Ressen
Bemmel
Haalderen
Groenlanden
Tiengeboden
Ooij
Erlecom
Persingen
Wercheren
Ubbergen
Berg en Dal
Zyfflich
Wylermeer
Heilig Landstichting
Radboud Universiteit Nijmegen
Bijsterhuizen
Winkelsteeg
Teersdijk
Woezikrot
Hoogbroek
Wijchen
Alverna
Heiveld
Boskant
Bullenkamp
Malden
Vgc Het Rijk Nijmegen
Wyler
Zandvoort
Gendt
Kommerdijk
Bisonbaai
Waal
Maas-Waalkanaal
Graafseweg
Rijksweg
A73
A326
N326
(C) OpenBasisKaart
Data ODbL OpenStreetMap
EPSG:28992 | X: 195346.920 Y: 433699.360
ENG 16:52


Viewers – Smart Emission P
SmartApp
HeronViewer - Smart Er
data.smartemission.nl/heron
Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!
Lagen Beheer
Zoek adres met PDOK GeoCoder
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Smart Emission Stations (WMS)
Smart Emission - Gasses
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Carbon Dioxide (CO2)
CO2 - Current - ppm
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Nitrogen Dioxide (NO2) - WMS
NO2 - Current - ug/m3
NO2 - History - ug/m3
NO2 Raw - Current - kOhm
NO2 Raw - History - kOhm
Ozone (O3) - WMS
O3 - Current - ug/m3
O3 - History - ug/m3
O3 Raw - Current - kOhm
O3 Raw - History - kOhm
Smart Emission - Noise
Noise Level Average - Current
Noise Level Average - History
Smart Emission - Meteo
Temperature - Current
Temperature - History
Air Pressure - Current
Air Pressure - History
Humidity - Current
Humidity - History
RIVM
KNMI - Meteorology
Active Layers
Snelkoppelingen
Slider for Timeseries (History in UTC) Layers
Date: 2016 - 07 - 26 Time: 23 : 00 : 00
Tips
Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan
Legenda
Smart Emission - Timeseries NO2
0 - 25 ug/m3
26 - 45 ug/m3
46 - 60 ug/m3
61 - 80 ug/m3
81 - 110 ug/m3
111 - 150 ug/m3
151 - 200 ug/m3
201 - 270 ug/m3
271 - 400 ug/m3
> 401 ug/m3
Smart Emission - Stations
Nijmegen
Ressen
Bemmel
Haalderen
Klein Baal
Flieren
Hulhuizen
Gendt
Zandvoort
Kommerdijk
Groenlanden
Bisonbaai
Lent
Beuningen
Weurt
Tiengeboden
Ooij
Erlecom
Persingen
Wercheren
Ubbergen
Berg en Dal
Zyfflich
Wylermeer
Heilig Landstichting
Wyler
Bijsterhuizen
Woezikrot
Teersdijk
Winkelsteeg
Graafseweg
Radboud Universiteit Nijmegen
Hoogbroek
Wijchen
Alverna
Heiveld
Boskant
Bullenkamp
Malden
Vgc Het Rijk Nijmegen
Loenen
Slijk-Ewijk
Oosterhout
Griftdijk
Zandse plas
De Pas
Waal
Spijkerwaal
Maas-Waalkanaal
Rijksweg
A73
A326
N326
N325
100000 km
(C) OpenBasisKaart
Data ODbL OpenStreetMap
EPSG:28992 | X: 191745.000 Y: 433672.480
ENG 16:53

Viewers – Smart Emission P | SmartApp | HeronViewer - Smart Er

data.smartemission.nl/heron

Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!

Lagen Beheer

- Basis Kaarten
- Stations
  - RIVM Stations (WMS)
  - Smart Emission Stations (WMS)
- Smart Emission - Gasses
  - Carbon Monoxide (CO)
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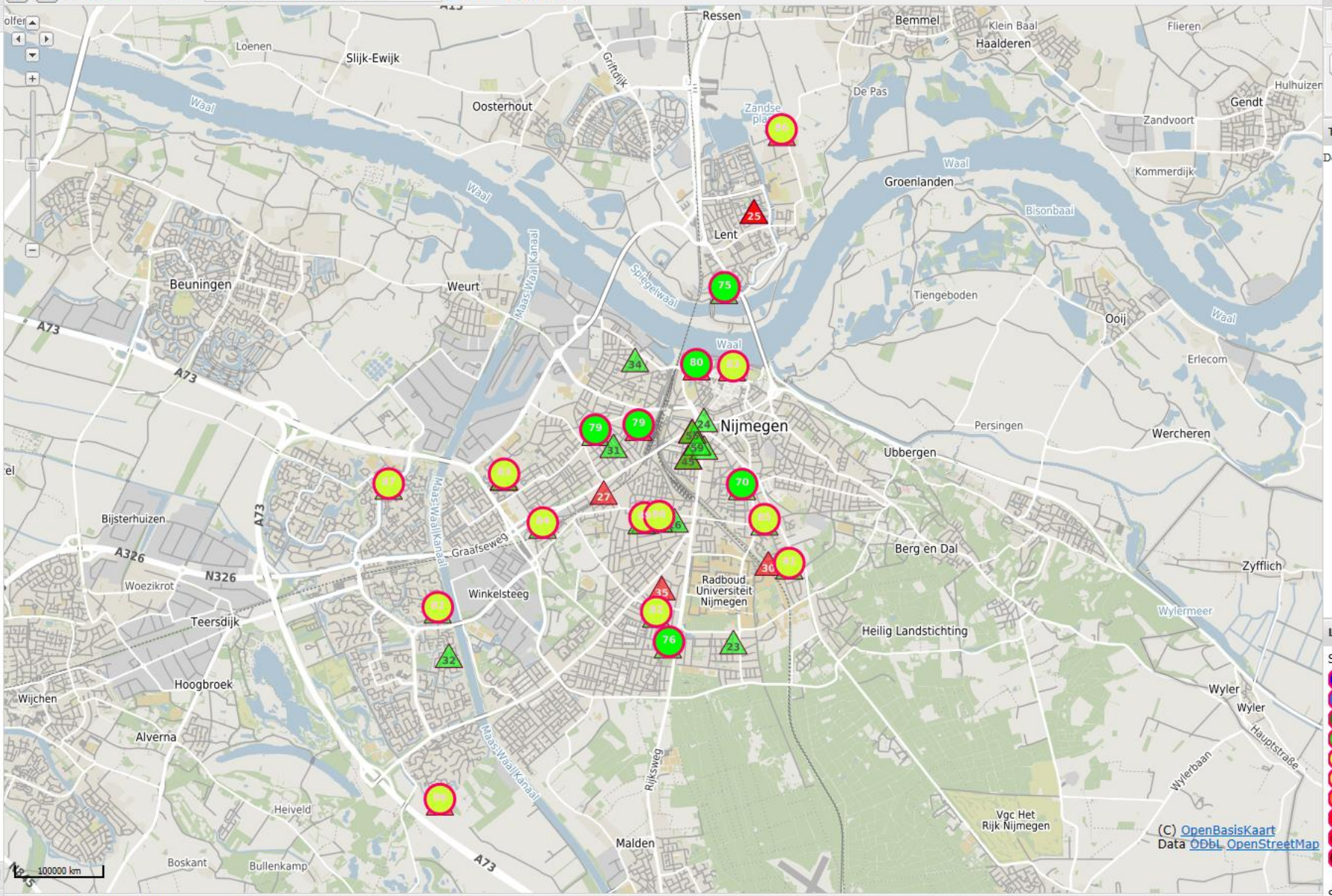
    - CO2 - Current - ppm
    - CO2 - History - ppm
  - Nitrogen Dioxide (NO2) - WMS
    - NO2 - Current - ug/m3
    - NO2 - History - ug/m3
    - NO2 Raw - Current - kOhm
    - NO2 Raw - History - kOhm
  - Ozone (O3) - WMS
    - O3 - Current - ug/m3
    - O3 - History - ug/m3
    - O3 Raw - Current - kOhm
    - O3 Raw - History - kOhm
- Smart Emission - Noise
  - Noise Level Average - Current
  - Noise Level Average - History
- Smart Emission - Meteo
  - Temperature - Current
  - Temperature - History
  - Air Pressure - Current
  - Air Pressure - History
  - Humidity - Current
  - Humidity - History
- RIVM
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



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Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 27 Time: 00 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

Smart Emission - Timeseries NO2

- 0 - 25 ug/m3
- 26 - 45 ug/m3
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Smart Emission - Stations

ENG 16:53

Viewers – Smart Emission P | SmartApp | HeronViewer - Smart Er

data.smartemission.nl/heron

Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!

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    - NO2 - History - ug/m3
    - NO2 Raw - Current - kOhm
    - NO2 Raw - History - kOhm
  - Ozone (O3) - WMS
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    - O3 - History - ug/m3
    - O3 Raw - Current - kOhm
    - O3 Raw - History - kOhm
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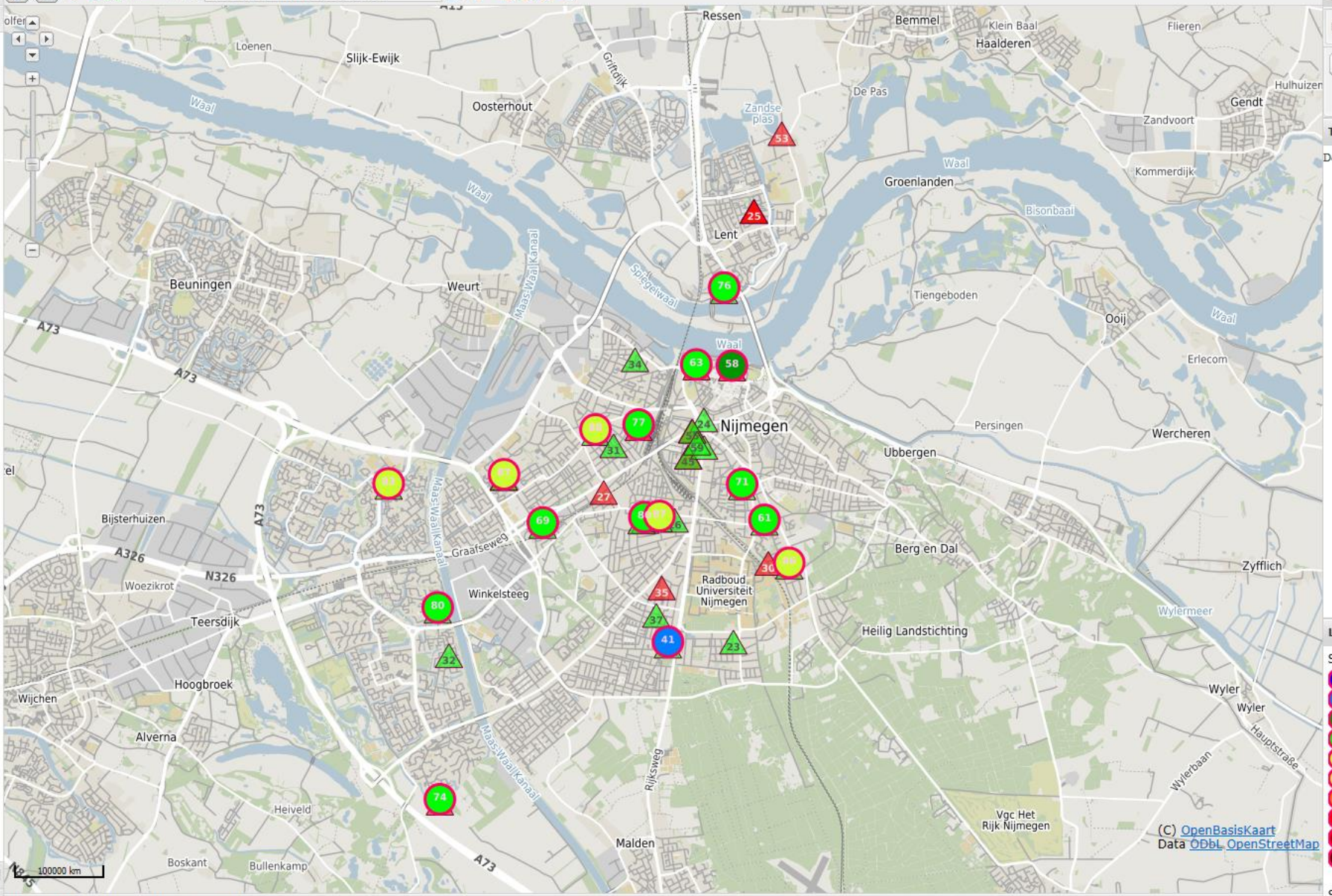
  - Noise Level Average - Current
  - Noise Level Average - History
- Smart Emission - Meteo
  - Temperature - Current
  - Temperature - History
  - Air Pressure - Current
  - Air Pressure - History
  - Humidity - Current
  - Humidity - History
- RIVM
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



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Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 27 Time: 01 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

Smart Emission - Timeseries NO2

- 0 - 25 ug/m3
- 26 - 45 ug/m3
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Smart Emission - Stations

ENG 16:53

Viewers – Smart Emission P | SmartApp | HeronViewer - Smart Er

data.smartemission.nl/heron

Smart Emission - HeronViewer - Gemaakt met Heron - SE-metingen gecalibreerd!

Lagen Beheer

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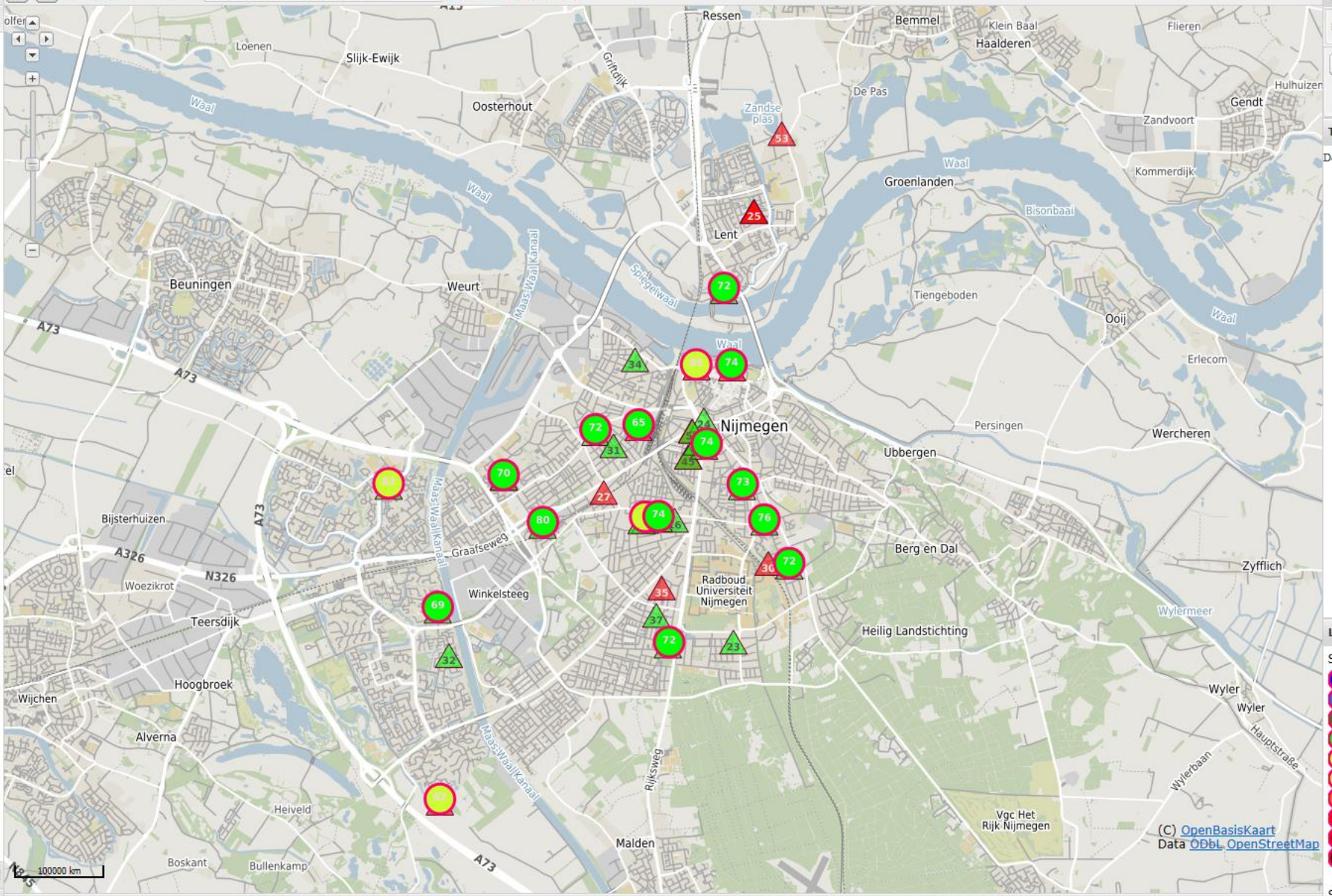
  - Humidity - Current
  - Humidity - History
- RIVM
- KNMI - Meteorology

Active Layers

Snelkoppelingen

Zoek adres met PDOK GeoCoder



EPSG:28992 | X: 195696.360 Y: 433685.920

Slider for Timeseries (History in UTC) Layers

Date: 2016 - 07 - 27 Time: 02 : 00 : 00

Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

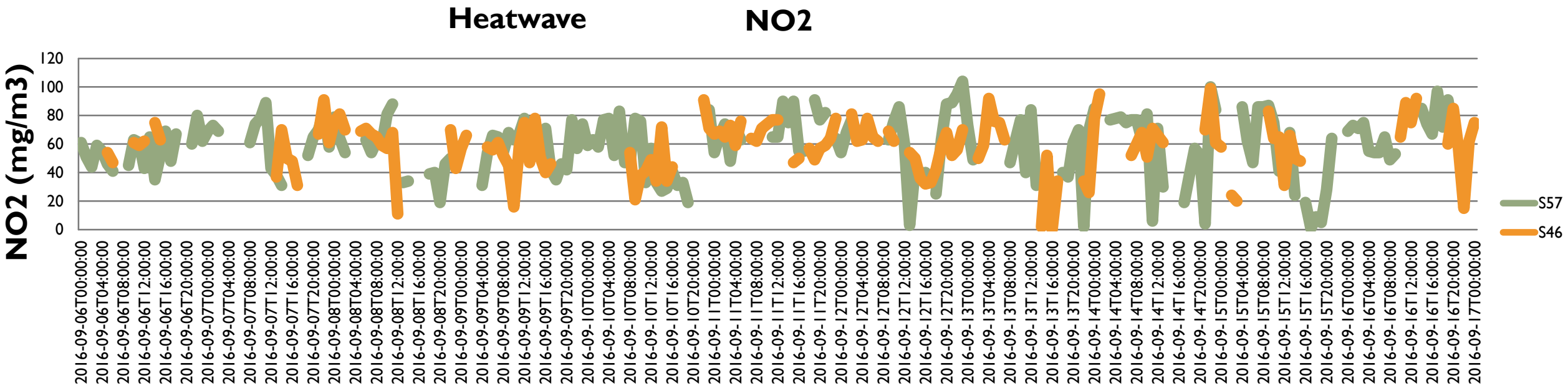
Smart Emission - Timeseries NO2

- 0 - 25 ug/m3
- 26 - 45 ug/m3
- 46 - 60 ug/m3
- 61 - 80 ug/m3
- 81 - 110 ug/m3
- 111 - 150 ug/m3
- 151 - 200 ug/m3
- 201 - 270 ug/m3
- 271 - 400 ug/m3
- > 401 ug/m3

Smart Emission - Stations

ENG 16:53

NO2 HOT WEEK IN SEPTEMBER TIMESERIES



- NO2 level usually between bandwidth of 40-80 mg/m3. Some low and higher fluctuations between 20 and 90 mg/m3.
- 6 very low peaks at s46, 1 very low peak at s57 (Question for air quality expert: can sensor be right, and NO2 level below 10 mg/m3?)
- 2 peaks above 100 mg/m3, around 20:00 hour on 12 and 14 Sept.

CONCLUSIONS AND FURTHER STUDY

Proof of concept: The citizen sensor network can be used to signal space-time increases of emissions or noise.

- **The basic concept is applied in and has showed to be working in practice, as envisaged in theory.** The sensors now are created, implemented in the field, the data is processed through a spatial data infrastructure that makes use of spatial data standards, and the data can be viewed and analyzed by both experts and citizens, available as Open Data. Further study is considered, both in improving the application, organizing the maintenance, and create technical improvement as well as calibration improvement and measurement continuation (some sensors have downtimes, 'the data timeseries show holes in the data').
- **Sensors:** As this is a first-design sensor, a second-design version could be further optimized. Further improvement is possible in many aspects; technical, organizational, maintenance. Further study seems promising; For example on the dimension of government-citizens cooperation, accuracy and calibration process, sensor data visualization, use practices and applications (measuring in specific locations in the city, specific events, monitoring for smog, monitoring during festivals in the city like the Zevenheuvelenloop, Velo-City week, etc).
- **Participation results;** active citizens have asked for these Evening Lectures to learn about Noise and Emissions in the City, and how to measure and interpret collectively with citizens and experts, applying collective sense-making in practice on these intangible qualities of the urban environment (furthermore, see other presentations by Ellen Klein Gunnewiek, Cécile Kerssemakers and Linda Carton)

CONCLUSIONS AND FURTHER STUDY

The O3 emission data seems to give significant results:

- O3 calibration seems to be successful.
- Ozone seems to follow a specific pattern during the days. Ozone increases during the hours 12:00-20:00 every day and it becomes almost double.
- Ozone seems to have an important decrease on Sundays. A data analysis of ozone layers during other weeks of the year, will give a clear view of these "ozone patterns" and of the ozone layers on Sundays.

CONCLUSIONS AND FURTHER STUDY

Traffic related, air quality observations:

- **Additional analysis of traffic:** Looking at the sensor data, there seems to be increased traffic to the city center in the evenings on the days Thursday, Friday and Saturday. Additional information about traffic and festivals like the Vierdaagse, Zevenheuvelenloop (etc.) in combination with tracing the noise and emission timeseries of the sensor data in these periods (relative to 'average days/weeks patterns') could shed more light on the use of the city.
- **Dynamics close to and in City center:** More sensors in the city center would help to get a clearer picture of city-center activities and its effects on noise and emissions. This is a suggestion for further study.
- **Hypothesis:** In heavy-traffic streets like Groenestraat emissions (ozone) seems related to vehicle traffic flows. Combining counts of vehicle traffic data with sensor data may validate this claim, and give improved understanding of the vehicle-flow and emission pattern in particular city streets that are of specific interest. For instance because citizens in these busy streets are concerned about the emissions and their daily air quality, or because of specific activities (for instance scooter shops, garages, etc).

CONCLUSIONS AND FURTHER STUDY

- **Based on discussion on calibration** (based on P. Marsman):
  - O3 calibration seems to be successful.
  - NO2 calibration not so successful. More data calibration and data analysis for NO2. Notes discussion: Consider another, more costly NO2 sensing device for the next generation of Jose sensors. NO2 gas most difficult to measure due to many cross-sensitivities. (NB. According to a specialist in NO2 measurement data this gas gives a bigger uncertainty in data than other gases, because of the nature/behavior of this gas; it is said that also the national station measurements are less accurate for NO2 than for other gases).
  - CO2 shows similar patterns observed by sensors, but currently there is an offset per sensor, that can and should be eliminated. Sensor manufacturer Intemo proposes a calibration procedure with the CO2 sensing device, installing this calibration software in each sensor, to calibrate every 4 days. This seems a worthwhile procedure to improve the CO2 measurements to similar, calibrated values. Current sensor-tests are promising. A software update is planned for.
  - **Suggestion for further research:**
    - Calibrate in 4 seasons, thus continue the calibration process to reach a one-year cycle of measurements included.
    - Add a number of higher-quality air quality measurement boxes at a few places that are of special interest, like Groenestraat.

CONCLUSIONS AND FURTHER STUDY

Suggestion for further study:

- **Citizen organization:** It is envisaged to organize a working group of citizens who will continue to monitor with the Smart Emission sensor network, after the project has finished. A public-private partnership with city-government, knowledge institutes and organized citizen-working group will continue to use and maintain the citizen-sensor-network. The municipality will extend the number of sensors, and experiment with new applications like monitoring at schools, with school children. The knowledge institutes will look for additional funding to continue the innovation and learning process that has been working over the course of the project.
- **Coverage:** More sensors in the city center would help to get a clearer picture of city-center activities and its effects on noise and emissions.
- **Visualization:** It could be worthwhile to make a spatial interpolation of emission levels across the city, to find out if we can indeed visualize the dynamic peaks and the 'heavy blanket' behavior of gases (CO2) and see how this blanket is "drapped over the city", with its spatial variations and dynamics in time.
- **Data**: The Open Data approach and standardized Sensor Data Infrastructure (using formats like the SensorThings API) invites more options in data presentation.
- **Data science:** Possible future avenue for calibration research, for instance with longer timeseries for neural network training, and combination of data in spatial network approach: Possibility to use '2nd order data' of additional measurement boxes like Osiris for validating the '3rd order data' of the many small sensors, using RIVM LML-stations as 1st order reference base. (Idea for data scientists and measurement-validation research, using 1st, 2nd and 3rd order data for a network-analysis approach using sensing data of different sources.)

Smart Emission

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Thank you

Suggestions for further analysis…?