

# Smart Emission

**SLIMSTE**  
**op BINNEN**  
**STAD**

Paul Geurts, Gemeente Nijmegen



# Case: Environmental health in Nijmegen



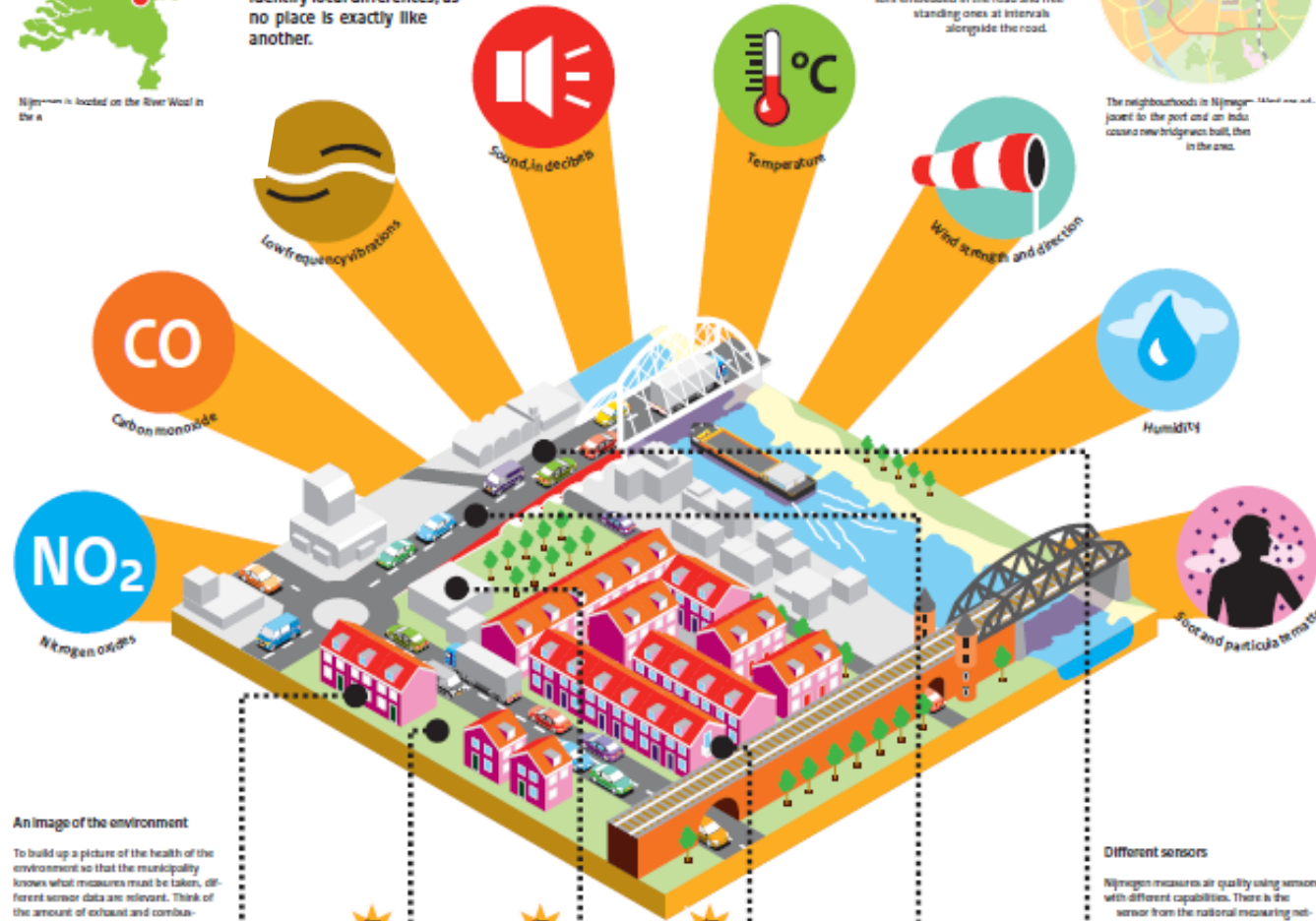
Nijmegen is located on the River Waal in the A

The environment is very important for people's health. That's why standards are set for the concentrations of pollutants. Sensors measure whether we keep within these standards using national monitoring networks. In addition, several municipalities and regions have their own sensors to identify local differences, as no place is exactly like another.

Nijmegen also monitors local environmental quality. With the advent of a new bridge and the construction of a ring road, the traffic situation in the western part of Nijmegen has changed. Developments in the port and the industrial area by the River Waal have been made, and residents in the nearby neighbourhood are worried about the health of their environment. The municipality is taking their concerns seriously and has placed sensors in the neighbourhood to measure the air quality and noise level. Nijmegen also wants to collate reports about bad odours. To monitor traffic flows, the municipality uses sensors embedded in the road and free standing ones at intervals alongside the road.

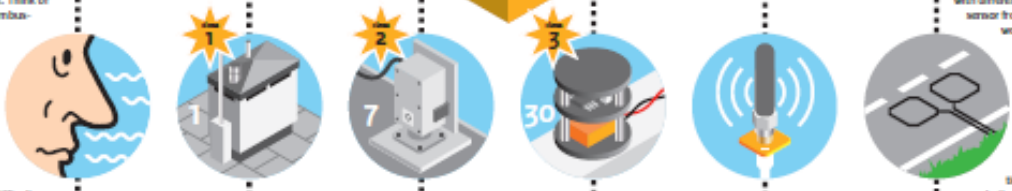


The neighbourhoods in Nijmegen adjacent to the port and an industrial area new bridges built, then in the area.



## An image of the environment

To build up a picture of the health of the environment so that the municipality knows what measures must be taken, different sensor data are relevant. Think of the amount of exhaust and combustion gases (NO<sub>2</sub> and CO), soot and particulate matter, but also the temperature, the force and direction of the wind and humidity. Sensors also measure noise, such as the number of decibels and low frequency vibrations. To measure traffic flows, there are bluetooth sensors and traffic loops.



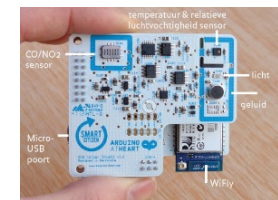
## Different sensors

Nijmegen measures air quality using sensors with different capabilities. There is the sensor from the national measuring network coordinated by the National Institute for Public Health and the Environment, there are seven specific particulate matter sensor units and, as part of a research project, the Radboud university has distributed a 'swarm' of thirty simple sensors among residents. One of the questions posed by this research is



# Sensoren en kwaliteit

Prijs en kwaliteit



Dichtheid van sensoren





# Specs Josene sensor Intemo

## Outside unit WiFi

*Base unit for Beta-test outdoor air quality*

1. Light intensity
2. Light reflection
3. Light (air) color
4. Earth vibration
5. Carbon monoxide
6. Nitric oxide
7. Ozone
8. hydrogen
9. Carbon dioxide
10. Pressure
11. Temperature (Unit / environment)
12. Humidity
13. Noise load dBm / Laeq (per 500Hz linof log.)
14. Time / Date
15. Location (GPS)
16. Communications (WiFi / USB)
17. Memory + Multi Color Display Ring
18. Electricity, USB phone adapter

Lichtintensiteit bovenzijde	1 ~ 64000 lux
Lichtintensiteit reflectie	1 ~ 64000 lux
Luchtkleur	weertype detectie
Trillingsmeter	0 ~ 2G/4G x-y-z
Koolmonoxide	1~1000ppm
Stikstofdioxide	0.05 ~ 10ppm
Ozon	10 ~ 1000 ppb
Waterstofsulfide	
Kooldioxide	
Luchtdruk	500 ~ 1100 hPa
Unit binnentemp. (compensatie)	-40 ~ 85°C
Unit buitentemp. (bij USB ingang)	-40 ~ 85°C
Luchtvochtigheid	0 ~ 100 %RH
Geluidsdruk	dBm
Geluidsdruk	Laeq
Tijd	12:34:56 + SoD
Datum	01-02-15 + DoW
Locatie via GPS	✓
Communicatie via WiFi	✓
Communicatie via USB	✓
EEPROM	256kb ~ 2Mb
Multikleuren indicator ring	RGBA
Backup batterij	✓
Voeding lokaal	Usb Adapter



# Data



# Data.smartemission.nl

## Smart Emission - Data Platform

Dit is het Smart Emission Data Platform. Deze levert toegang tot de data uit de Smart Emission sensoren via web services (web APIs) en een aantal apps. Deze site en onderliggende diensten zijn ontwikkeld door [Geonovum](#) en draait binnen het [Firmware Lab NL](#). De algemene Smart Emission website vind je op [www.smartemission.nl](http://www.smartemission.nl)

*"Het Smart Emission project draait om het in kaart brengen van luchtkwaliteit, geluid, trillingen en meteorologische indicatoren in de stad op een fijnmazig schaalniveau, door inwoners met zogenoemde burger-sensor-netwerken."* (Bron: [SE-Website](#))

## Apps

- [SmartApp](#) - voor Mobiel/Tablet
- [Heron App](#) - voor Desktop
- [SOS Viewer \(52North\)](#) - Timeseries, Charts, Download History

## APIs

- [SOS REST API](#) - JSON/HTML REST API alleen voor laatste waarden
- [SOS API - 52North](#) - full SOS API voor alle (historische) waarden - ([docs](#))
- [SOS REST API - 52North](#) - 52North SOS REST API voor alle (historische) waarden - ([docs](#))
- [WMS API](#) - WMS including WMS-Dimensions for Time
- [WFS API](#) - WFS, e.g. for Download Timeseries

## Download Timeseries


Download of refined (validated, calibrated, aggregated) and raw timeseries (history) data is possible in various ways. Apart from the SOS/WMS/WFS APIs above data can be downloaded via the Viewers.

### 52North Viewer (SOS)

See the [SOS Viewer \(52North\)](#). When viewing the Chart, click in "I" (Info) button on the right under each component. NB: there is a [known bug in the 52North Viewer](#): the download button disappears when changing the color of the indicator/component.

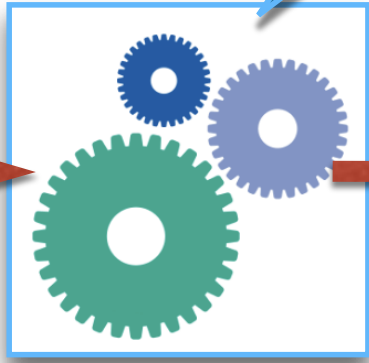
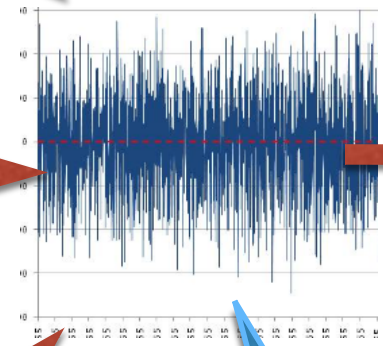
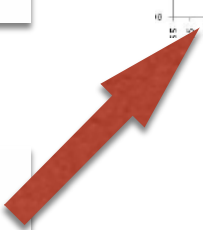
### Heron Viewer (WFS)

Download as CSV and other formats via WFS using the [Heron Viewer](#):

- Choose the *Binoculaires*  icon within the top-toolbar
- A search form window pops up
- Choose Station and Component
- press the "Zoeken" button. Searching may take some time...be patient
- A result table-grid appears. Choose "Download" and choose download format, e.g. CSV, Excel, GML etc



# Datastream



“Raffinere  
n”



“Verfijnde  
”  
Data

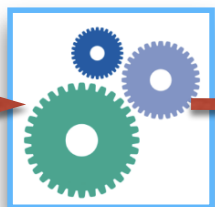
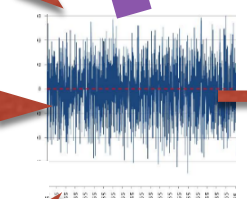
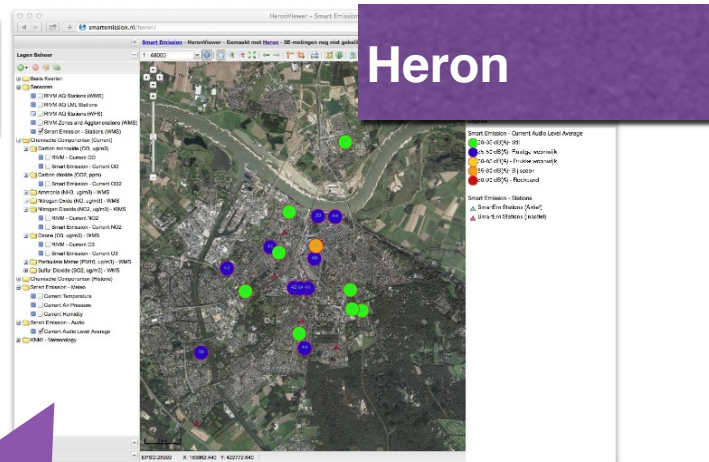
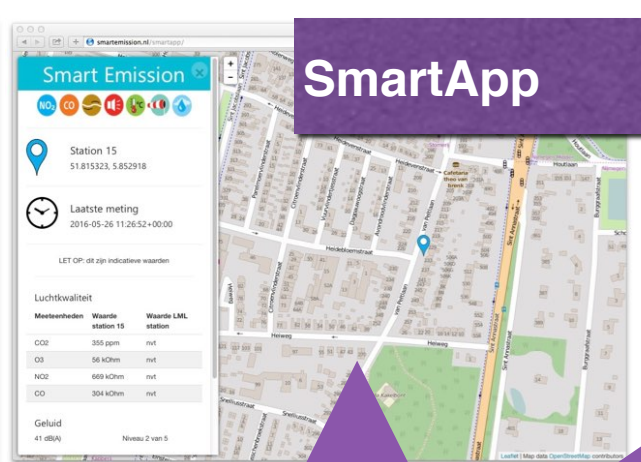
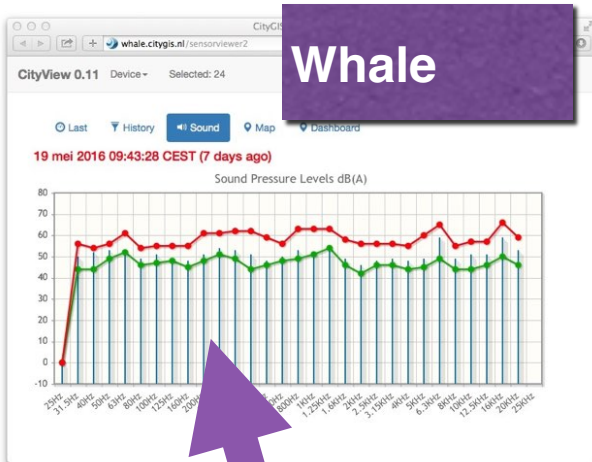
Ruwe Data



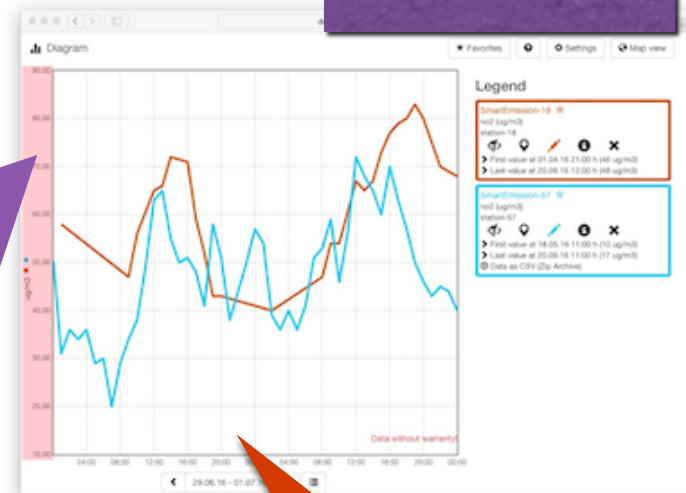
# Viewers







“Verfijnde” Data



NIEUW



# Smart Emission



Station 57  
51.830536, 5.851028



Laatste meting  
2016-09-20 13:39:25+02:00

LET OP: dit zijn indicatieve waarden

## Luchtkwaliteit

Meeteenheden	Waarde station 57	Waarde LML station
CO	16 ug/m3	nvt
CO2	937 ppm	nvt
CORaw	286 kOhm	nvt
NO2	26 ug/m3	nvt
NO2Raw	812 kOhm	nvt
O3	79 ug/m3	nvt
O3Raw	72 kOhm	nvt

## Geluid

42 dB(A) Niveau 2 van 5

## Meteo

Meeteenheden	Waarde station 57
Luchtvochtigheid	43 Procent
Luchtdruk	1016 HectoPascal
Temperatuur	25 Celsius



# SmartApp



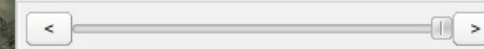
Lagen Beheer

1 : 48000



Slider for Time Series Layers

Date: 2016-05-26 Time: 11:00:00



Legend

Smart Emission - Current Audio Level Average

- 20-35 dB(A)- Stil
- 35-50 dB(A)- Rustige woonwijk
- 50-65 dB(A) - Drukke woonwijk
- 65-80 dB(A)- Bij spoor
- 80-90 dB(A) - Rookband

Smart Emission - Stations

- SmartEm Stations (Aktief)
- SmartEm Stations (Inactief)

- Basis Kaarten
- Sensoren
  - RIVM AQ Stations (WMS)
  - RIVM AQ LML Stations
  - RIVM AQ Stations (WFS)
  - RIVM Zones and Agglomerations (WMS)
  - Smart Emission - Stations (WMS)
- Chemische Componenten (Current)
  - Carbon monoxide (CO, ug/m3)
    - RIVM - Current CO
    - Smart Emission - Current CO
  - Carbon dioxide (CO2, ppm)
    - Smart Emission - Current CO2
  - Ammonia (NH3, ug/m3) - WMS
  - Nitrogen Oxide (NO, ug/m3) - WMS
  - Nitrogen Dioxide (NO2, ug/m3) - WMS
    - RIVM - Current NO2
    - Smart Emission - Current NO2
  - Ozone (O3, ug/m3) - WMS
    - RIVM - Current O3
    - Smart Emission - Current O3
  - Particulate Matter (PM10, ug/m3) - WMS
  - Sulfur Dioxide (SO2, ug/m3) - WMS
- Chemische Componenten (Historie)
- Smart Emission - Meteo
  - Current Temperature
  - Current Air Pressure
  - Current Humidity
- Smart Emission - Audio
  - Current Audio Level Average
- KNMI - Meteorology



# Heron

Active Layers

Bookmarks

EPSG:28992 | X: 183862.440 | Y: 422772.640

## Lagen Beheer

Basis Kaarten

Stations

Zoeken: Download Historie/Tijdreeksen

Station: 57

Component: Stikstofdioxide (NO2 mg/m3)

Start datum: 29 Jun 2016

Eind datum: 01 Jul 2016

Downloaden tijdreeksen (historie)  
Kies station nummer, dan component, dan evt tijdspanne.  
Klik op "Zoeken" knop. Zoeken kan even duren...geduld...Dan rechtsboven in resultaat tabel  
Download en formaat, bijv CSV, kiezen

Zoeken voltooid: 49 Resultaten

Stop Zoeken

&lt; Zoeken

Resultaat &gt;

Smart Emission - Meteo

 Temperature - Current Temperature - History Air Pressure - Current Air Pressure - History Humidity - Current Humidity - History

Active Layers

Snelkoppelingen

EPSG:28992 | X: 187014.671 | Y: 427927.956

Castellatoren

Castellastra

de Ruyter


# Heron

**NIEUW:  
Downloads**

## Slider for Timeseries (History in UTC) Layers


Date: 2016 09 20 Time: 10:00:00

## Tips

Downloaden tijdreeksen (historie): kies verrekijker knop  bovenaan

## Legenda

Smart Emission - Stations

 SmartEm Stations (Aktief) SmartEm Stations (Inactief)

(C) [OpenBasisKaart](#)  
Data [ODbL](#) [OpenStreetMap](#)

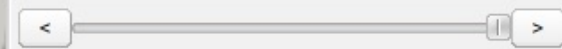
Lagen Beheer

- Basis Kaarten
- Stations
  - RIVM
  - Sm
- Smart Em
  - Carbo
    - 
    - 
    -
  - Nitrog
    - 
    -
  - Ozon
    - 
    - 
    - 
    -
  - Smart Em
    - No
    - No
  - Smart Emission - Meteo
    - Temperature - Current
    - Temperature - History
    - Air Pressure - Current
    - Air Pressure - History
    - Humidity - Current
    - Humidity - History

Zoek adres met PDOK GeoCoder

Slider for Timeseries (History in UTC) Layers

Date: 2016 09 20 Time: 10:00:00



Tips

Downloaden tijdreeksen (historie): kies verrekijker knop bovenaan

Legenda

- Smart Emission - Stations
  - SmartEm Stations (Aktief)
  - SmartEm Stations (Inactief)

Zoeken: Download Historie/Tijdreeksen

49 Resultaten

Gid_r...	Insert_time	Device_id	Name	Label	Unit
59619	2016-07-27T03:20:10.679	57	no2	NO2	ug/m
59620	2016-07-27T03:20:10.945	57	no2	NO2	ug/m
59621	2016-07-27T03:20:11.202	57	no2	NO2	ug/m
59622	2016-07-27T03:20:11.417	57	no2	NO2	ug/m
59623	2016-07-27T03:20:11.662	57	no2	NO2	ug/m
59624	2016-07-27T03:20:11.941	57	no2	NO2	ug/m
59625	2016-07-27T03:20:12.186	57	no2	NO2	ug/m
59626	2016-07-27T03:20:12.486	57	no2	NO2	ug/m
59627	2016-07-27T03:20:12.744	57	no2	NO2	ug/m
59628	2016-07-27T03:20:13.018	57	no2	NO2	ug/m3
59629	2016-07-27T03:20:13.25	57	no2	NO2	ug/m3
59630	2016-07-27T03:20:13.519	57	no2	NO2	ug/m3
59631	2016-07-27T03:20:13.823	57	no2	NO2	ug/m3

als Comma Separated Values (CSV)  
 als Excel (XLS)  
 als GML v2  
 als Esri Shapefile (RD)  
 als Esri Shapefile (WGS84)  
 als OGC GeoPackage (RD)  
 als OGC GeoPackage (WGS84)  
 als GeoJSON  
 als Well-known Text (WKT)

# Heron

**NIEUW:  
Downloads**

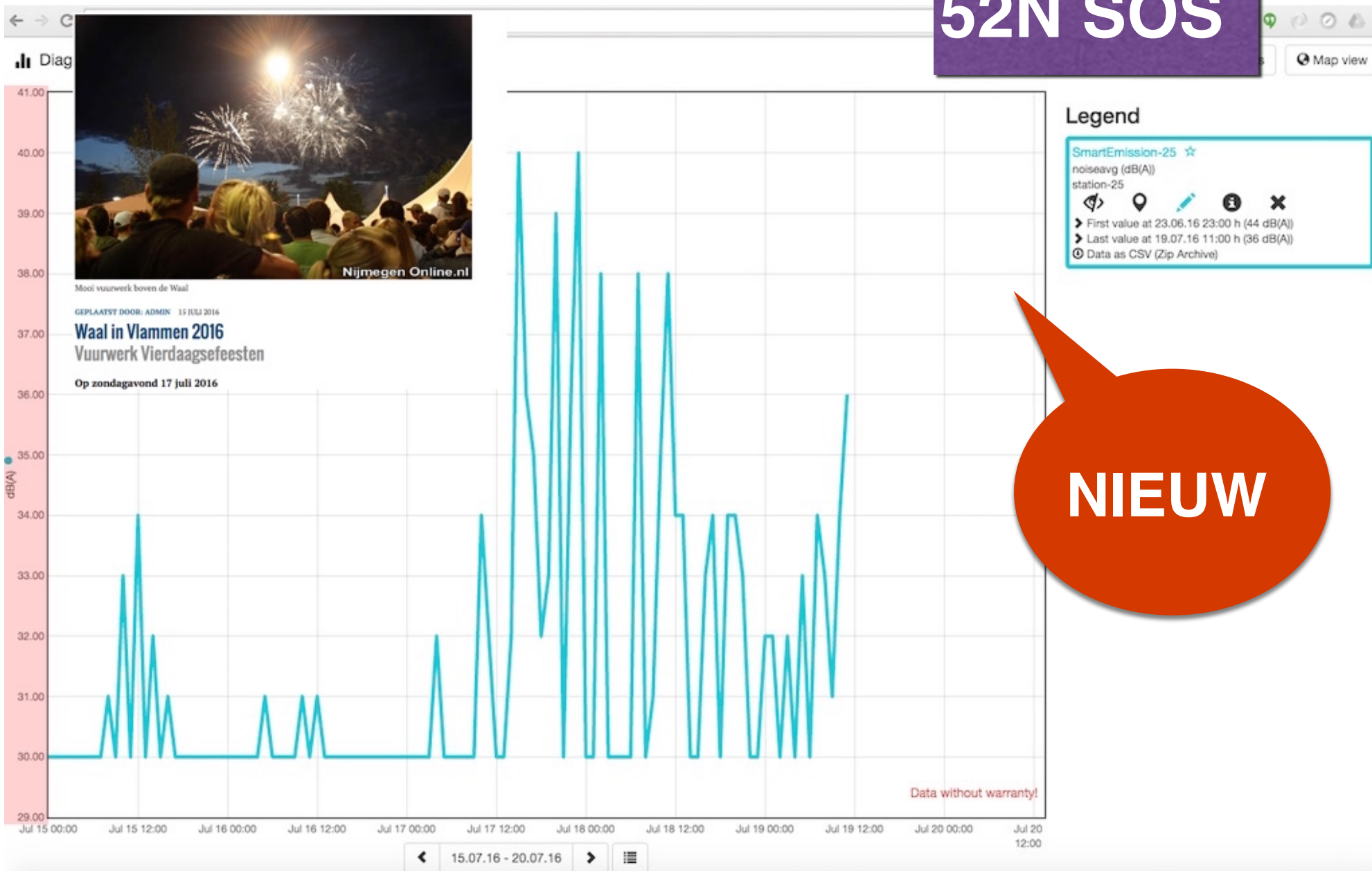
OpenBasisKaart  
Oa ODbL OpenStreetMap

Active Layers

Snelkoppelingen

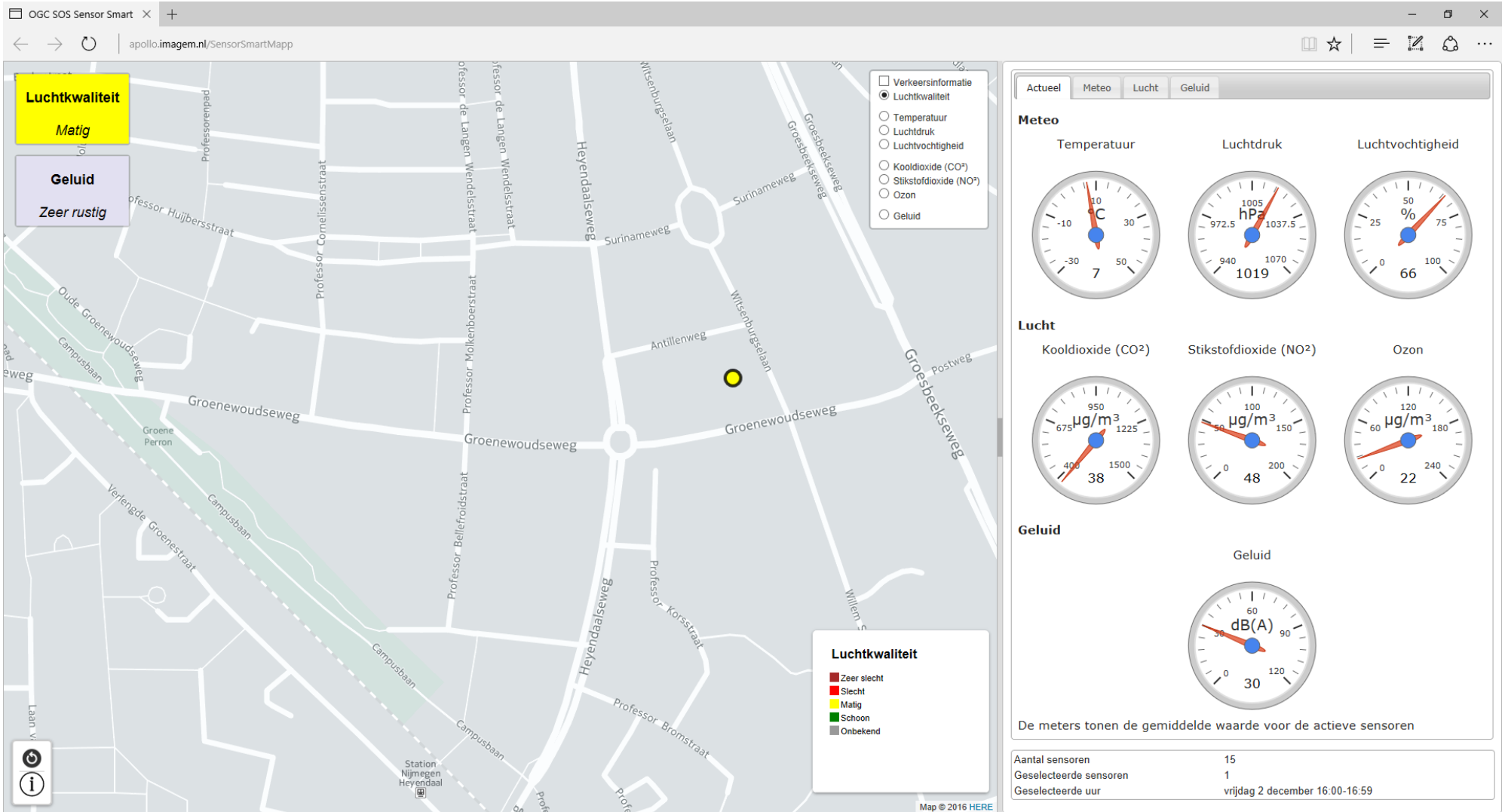
EPSG:28992 | X: 187077.461 | Y: 427812.876

# 52N SOS



**NIEUW**

<http://data.smartemission.nl/sos52n/static/client/jsClient/index.html>



# Statistieken op 20 sept 2016

- **Historie: start 25 april 2016**
- **Stations: 46, actief (laatste 2 uur) 33**
- **Indicatoren: 12 (meteo 3, geluid 2, gas 7)**
- **Metingen (ruw):**
  - 10GB JSON “harvested” (whale API)**
  - plm 10 miljoen metingen**
  - plm 70 indicatoren (sensors)**
  - plm 200 per station/per uur**
  - ~ 8000 metingen per/uur**
  - ~ 20000 metingen per dag**
  - database opslag plm 15GB, plm 5GB p/maand**
- **Metingen (geaggregeerd uurbasis)**
  - totaal 888636**
  - database opslag 150MB plm 15MB p/maand**



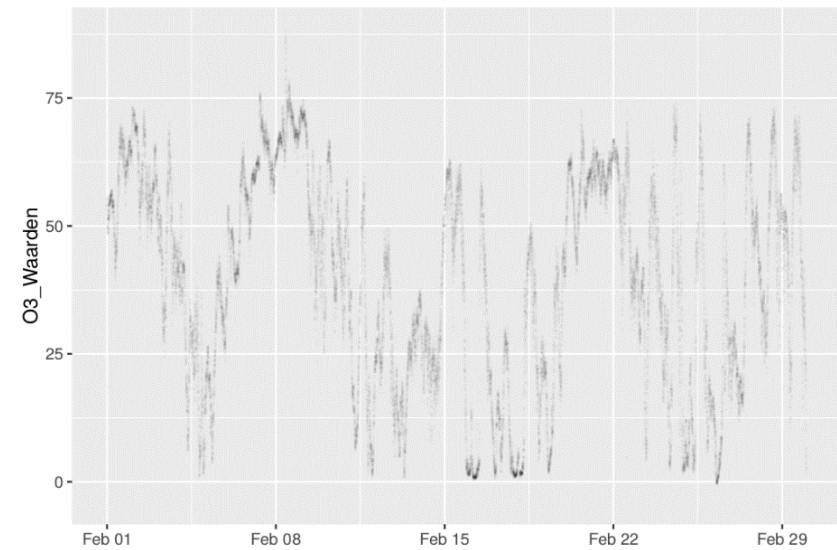
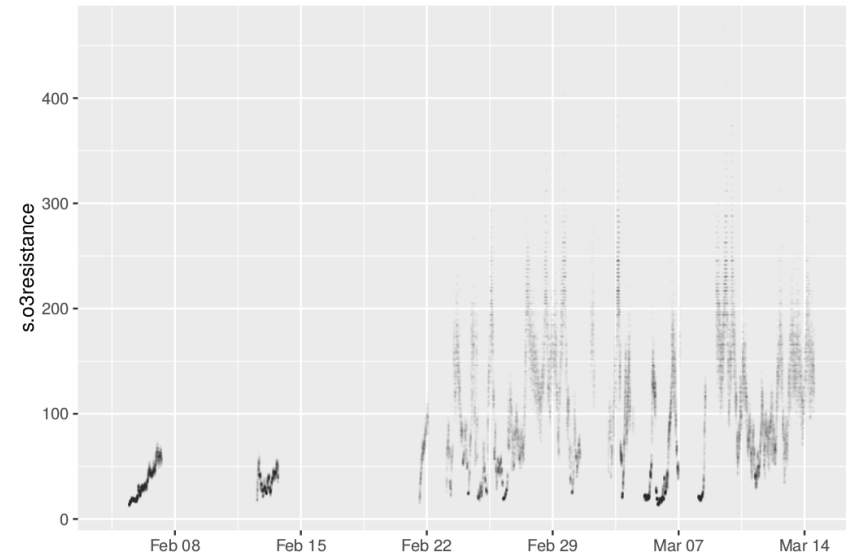


# DataScience voor kalibratie

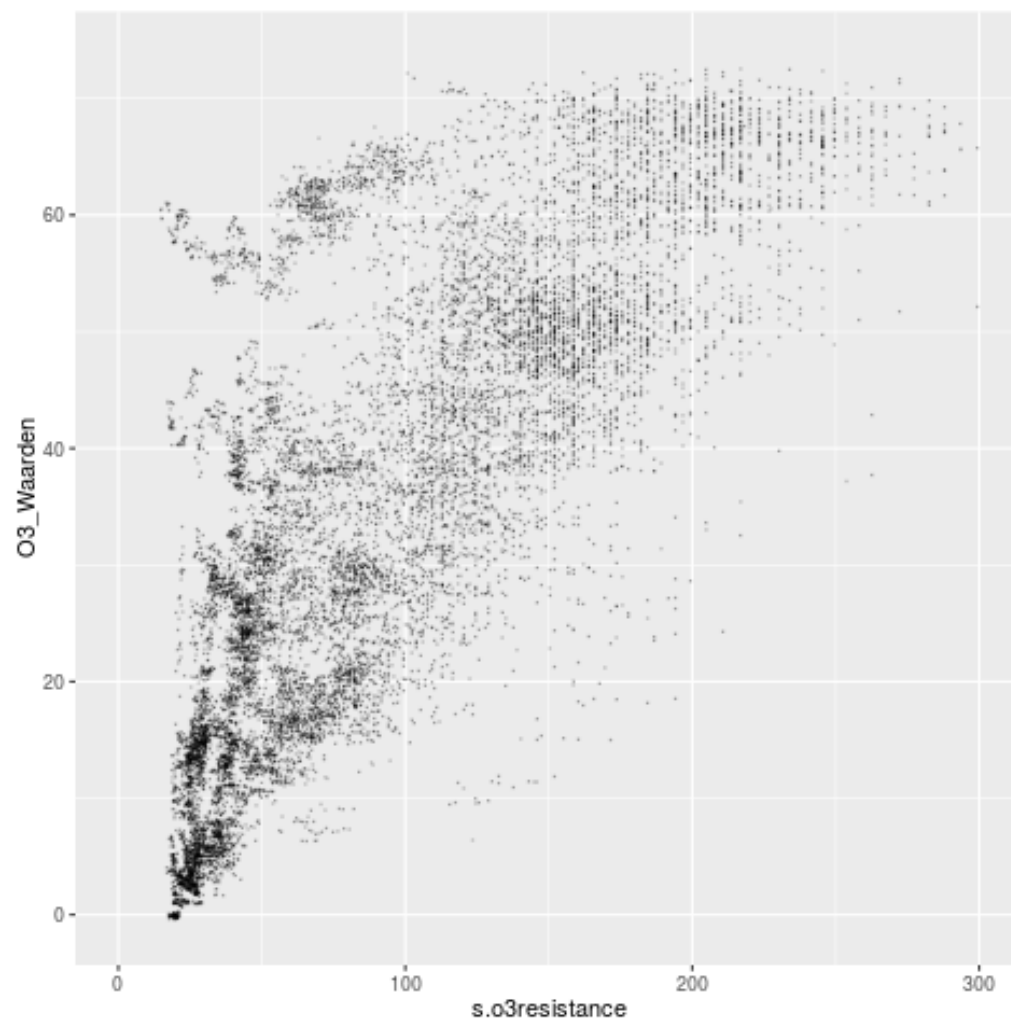


# Waarop letten?

- (Type)relatie
- Ruis
- Verschillen tussen sensoren
- Versturende effecten
- Missende waardes
- Sensor karakteristieken



# Relatie tussen weerstand en werkelijk waarde



# Wat heeft invloed ?

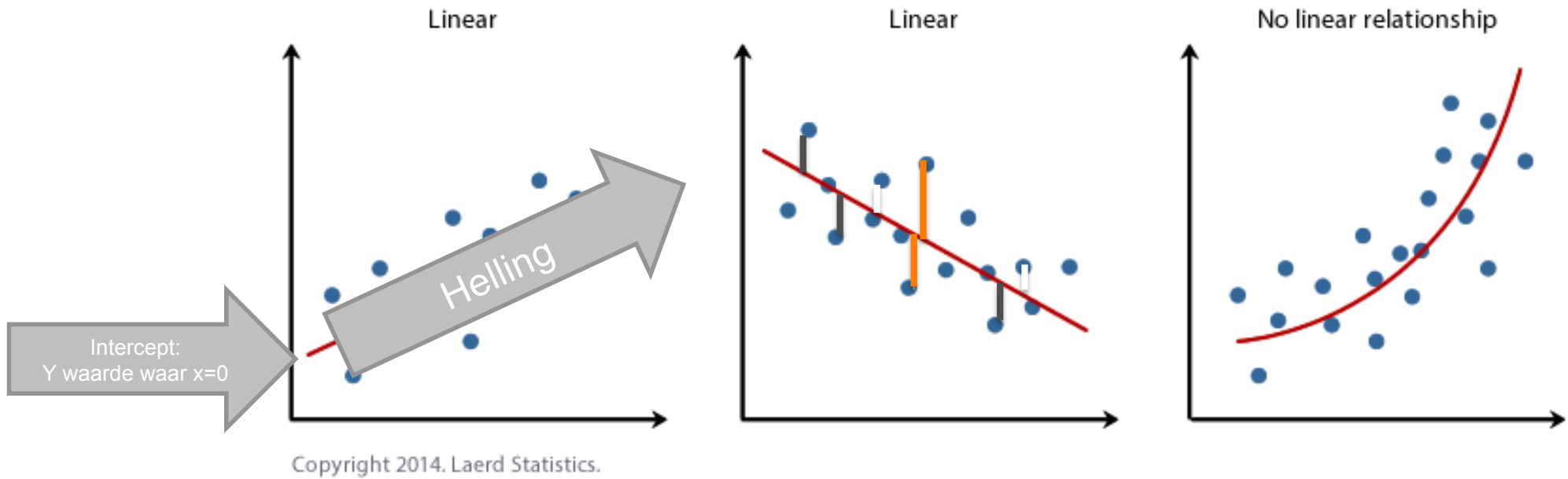
datetime  
p.base.timer  
p.co.heater.mode  
p.co.heater.value  
p.error.base irq.service.stopped  
p.error.booting  
p.error.configuration  
p.error.memory  
p.error.sensor  
p.error.wifi.connection  
p.no2.heater.mode  
p.no2.heater.value  
p.power.aux\_power.input.active  
p.power.charged  
p.power.charging  
p.power.co2.sensor.on  
p.power.co.heater.on  
p.power.energy.harvesting.standby  
p.power.error  
p.power.gauge.ok  
p.power.h2s.sensor.on  
p.power.harvest.input.active  
p.power.mains.input.active  
p.power.nh3.sensor.on  
p.power.no2.heater.on

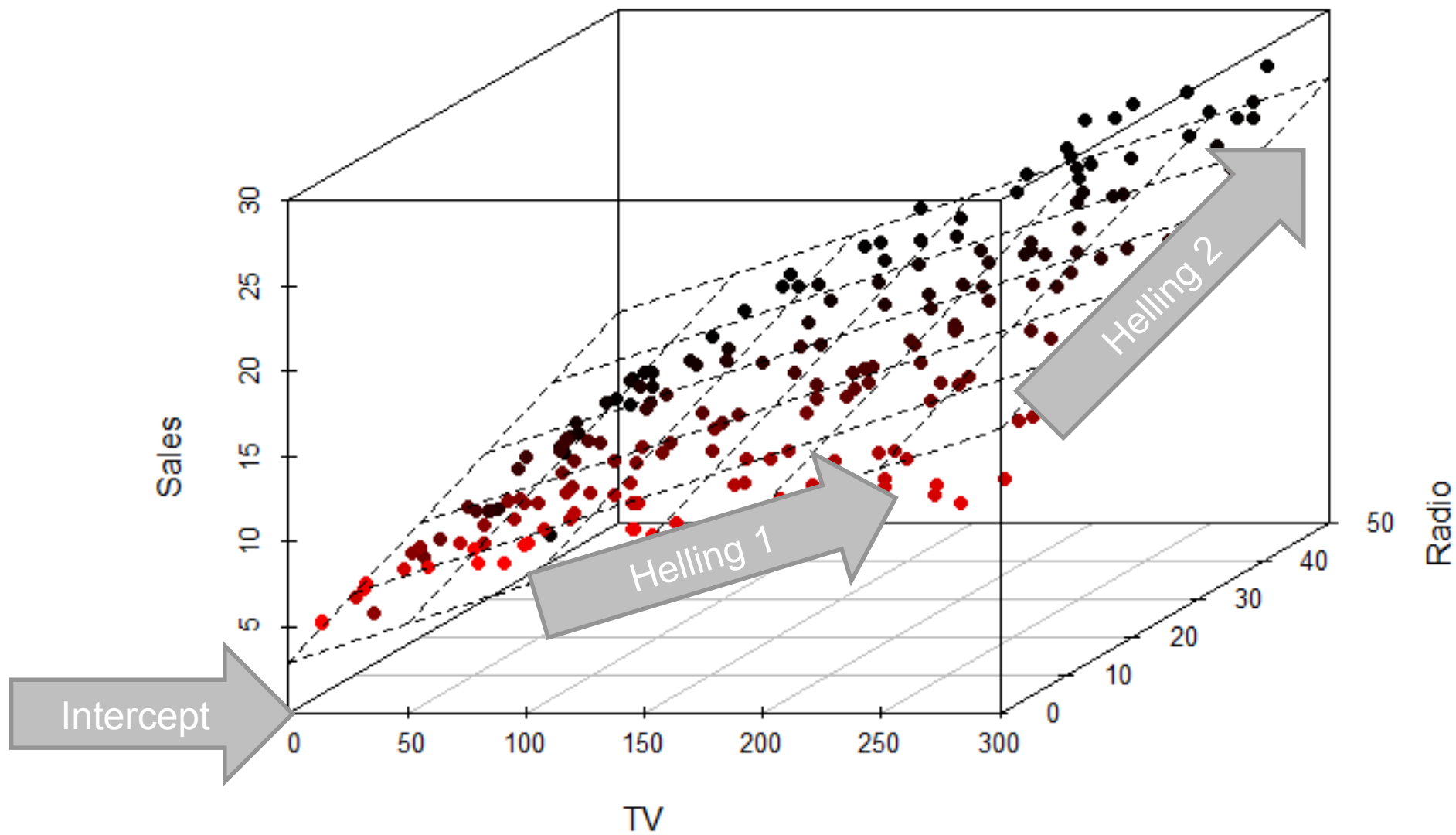
p.power.no.battery  
p.power.o3.heater.on  
p.power.pm.sensor.on  
p.power.usb.input.active  
p.session.up.time  
p.total.up.time  
p.unit.serial.number  
p.unknown.17  
p.unknown.18  
p.unknown.19  
s.accelero.x  
s.accelero.y  
s.accelero.z  
**s.barometer**  
s.co2  
**s.coresistance**  
**s.humidity**  
s.latitude  
s.light.sensor.blue  
s.light.sensor.bottom  
s.light.sensor.green  
s.light.sensor.red  
s.light.sensor.top  
s.longitude

**s.no2resistance**  
**s.o3resistance**  
s.rain.backside.left  
s.rain.backside.right  
s.rain.frontside.left  
s.rain.frontside.right  
s.rgb.color  
s.satinfo.dilution  
s.satinfo.fix  
s.satinfo.num  
s.second.of.day  
**s.temperature.ambient**  
s.temperature.unit

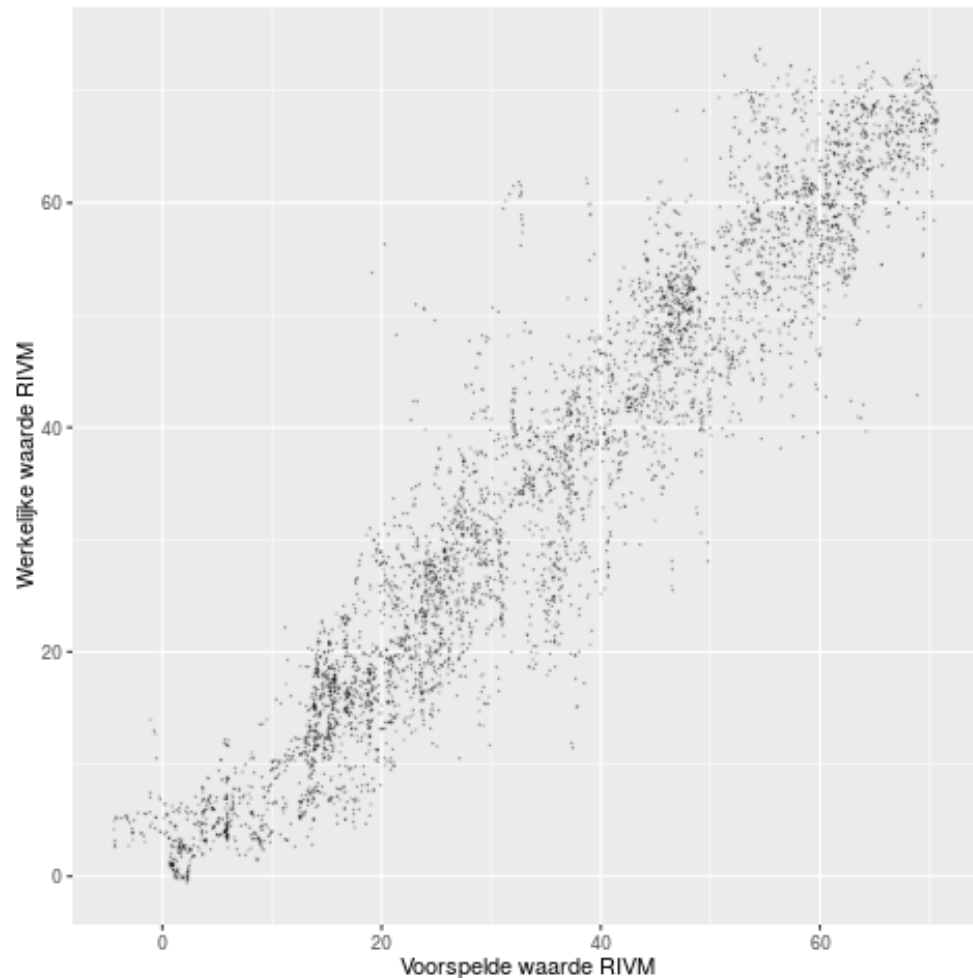


# Lineaire regressie





# Voorspellen van de werkelijke waarde



$$\begin{aligned} O_3 = & 89.1177 \\ & + 0.03420626 * s.coresistance * \log(s.o3resistance) \\ & - 0.008836714 * s.light.sensor.bottom \\ & - 0.02934928 * s.coresistance * s.temperature.ambient \\ & - 1.439367 * s.temperature.ambient * \log(s.coresistance) \\ & + 1.26521 * \log(s.coresistance) * \sqrt{s.coresistance} \\ & - 0.000343098 * s.coresistance * s.no2resistance \\ & + 0.02761877 * s.no2resistance * \log(s.o3resistance) \\ & - 0.0002260495 * s.barometer * s.coresistance \\ & + 0.0699428 * s.humidity \\ & + 0.008435412 * s.temperature.unit * \sqrt{s.no2resistance} \end{aligned}$$



# Lessen tot nu toe

- Goedkope sensoren zijn in te zetten voor kwalitatieve metingen van voldoende niveau, door gebruik te maken van datascience en referentiestations van het RIVM.
- De sensoren moeten stabiel zijn in hun metingen, niet gaan “drijven”
- De sensor moet zo goed zijn dat installatie en beheer minimaal is.
- Beheer van sensoren door specialisten (lucht en geluid) van de gemeente.
- Data infrastructuur opzetten is complex. Het gaat over erg veel data.
- Kalibratie is een voortdurend proces.
- Kalibratie hangt van verschillende meetwaarden van verschillend sensoren aan elkaar.

