



Assessing the Impact of Driving Bans with Data Analysis

BTW 2019, [Lucas Woltmann](#), Claudio Hartmann, Wolfgang Lehner

Motivation

STUTTGARTER-
ZEITUNG.DE

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Stuttgart Region BW Politik Wirtschaft Sport Panorama Kultur Wissen StZ Plus Reise Gen

🏠 > Stuttgart

Diesel-Fahrverbot in Stuttgart

Das hat es mit d

SWR > SWR Aktuell > SWR Aktuell Baden-Württemberg > Stuttgart



SPIEGEL ONLINE

☰ Menü | Politik Meinung

GESUNDHEIT

Nachrichten > Gesundheit > Diagnose &

Ärzte bezweifeln Sinn von Gr

Der Feinstaub-W



mdr AKTUELL
NACHRICHTEN

Startseite Politik Wirtschaft Ratgeber Vermischtes Podcast Kontak

MDR.DE > Nachrichten > Wirtschaft > Regional

Umweltministerium Vorlesen

Sächsischen Städten drohen keine Diesel-Fahrverbote

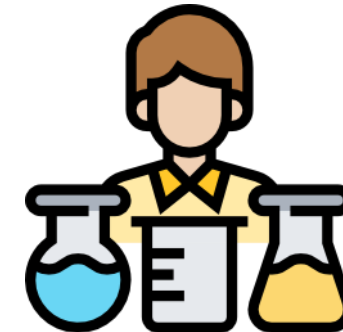
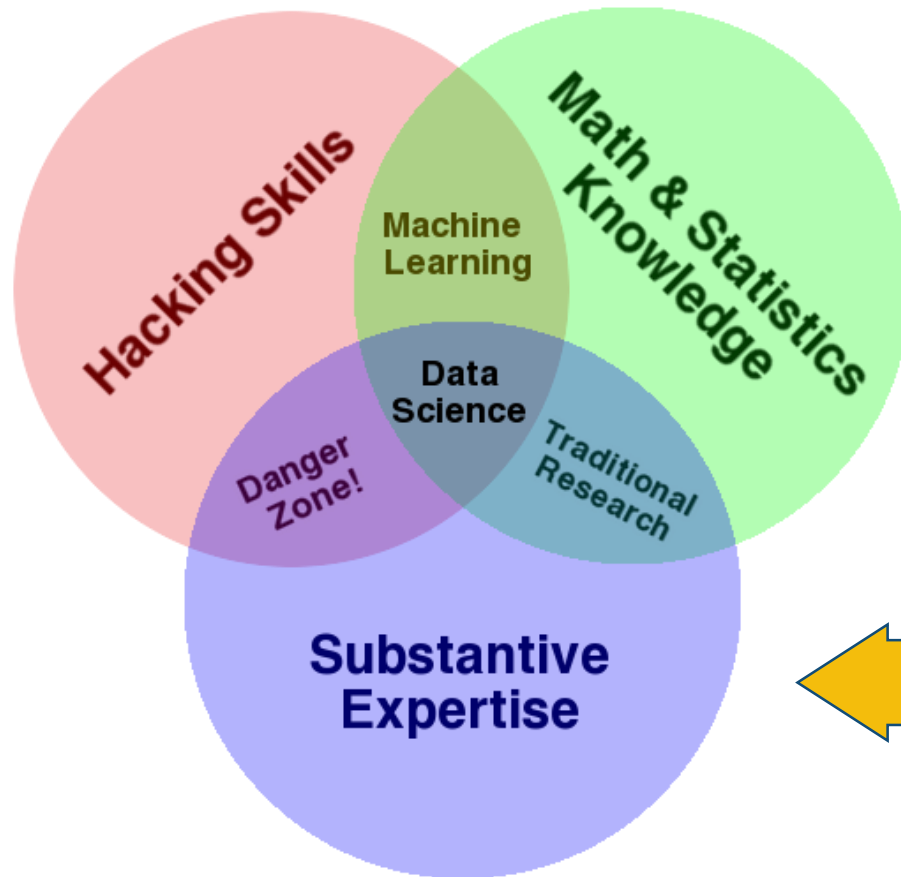
Fahrer von Dieselaautos blicken an diesem Donnerstag vor allem mit Sorge nach Leipzig. Hier berät das Bundesverwaltungsgericht, ob Fahrverbote im Kampf für eine bessere Luft in der Stadt rechtlich zulässig sind. Ein Grundsatzurteil könnte Dieselaautos aus vielen Innenstädten verbannen. Was bedeutet das für die Großstädte in Sachsen?

von Astrid Wulf, MDR AKTUELL

Fahrverbote müssen sein, denn der Feinstaub in der Luft gefährdet die Gesundheit: So argumentieren Umweltschützer und Experten. Jetzt sagen Lungenfachärzte: Das sei doch gar nicht bewiesen. Wem soll man glauben?

Motivation – Venn Diagram of Data Science

Our domain expert:

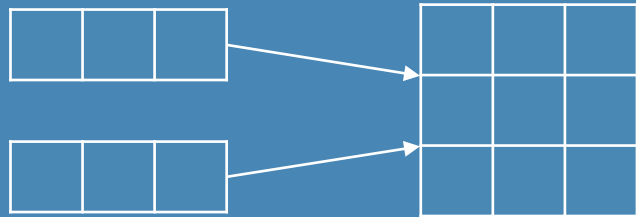


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<http://drewconway.com/zia/2013/3/26/the-data-science-venn-diagram>

Outline

Data Sets and Data Preparation



Visualizing Patterns



Time Series Forecasting

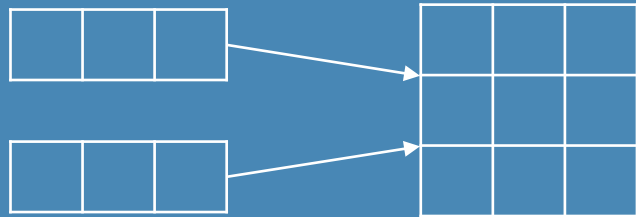


$$\hat{y}_{t+1} = \phi_1 y_t + \theta_1 x_t + c$$

No-go Areas



Data Sets and Data Preparation



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Time Series Forecasting



$$\hat{y}_{t+1} = \phi_1 y_t + \theta_1 x_t + c$$

No-go Areas



Data Sets

4 data sets from *luftdaten.info* (covering 01.2017 – 01.2019)

name	type
Dresden sds011	particle concentration (PM10)
Dresden dht22	temperature/humidity
Stuttgart sds011	particle concentration (PM10)
Stuttgart dht22	temperature/humidity

4 data sets from DWD (<ftp://ftp-cdc.dwd.de/pub/CDC/>)

name	type
Dresden F	wind speed
Dresden GS	sun intensity
Stuttgart F	wind speed
Stuttgart GS	sun intensity

Data Preprocessing

Problem 1: No concurrent time granularity in sds011 and dht22 data

Stuttgart sds011, sensor 11	
timestamp	particles [$\mu\text{g}/\text{m}^3$]
2014-09-03 12:03:07	10
2014-09-03 12:04:14	9
2014-09-03 12:04:57	8
2014-09-03 12:05:10	7

group by minute
avg(particles)

Stuttgart sds011, sensor 11	
timestamp	particles [$\mu\text{g}/\text{m}^3$]
2014-09-03 12:03:00	10
2014-09-03 12:04:00	8.5
2014-09-03 12:05:00	7

Data Preprocessing

Problem 2: Separate data set for each sensor type.

Stuttgart sds011, sensor 11	
timestamp	particles [$\mu\text{g}/\text{m}^3$]
2014-09-03 12:03:00	10
2014-09-03 12:04:00	8.5

Stuttgart dht22, sensor 65		
timestamp	humidity [%]	temperature [$^{\circ}\text{C}$]
2014-09-03 12:03:00	50	18
2014-09-03 12:04:00	52	17.8

⋈ join on timestamp (and location)

Stuttgart					
timestamp	sensor_id	particles [$\mu\text{g}/\text{m}^3$]	humidity [%]	temperature [$^{\circ}\text{C}$]	sensor_dht
2014-09-03 12:03:00	11	10	50	18	65
2014-09-03 12:04:00	11	8.5	52	17.8	65

Sensor reliability

If the humidity is over 70%, the particle concentration read cannot be seen as reliable.
(from the SDS011 Laser PM2.5 Sensor specification)



© DDpix <https://www.ddpix.de/wp-content/gallery/dresden-von-oben/00551.jpg>

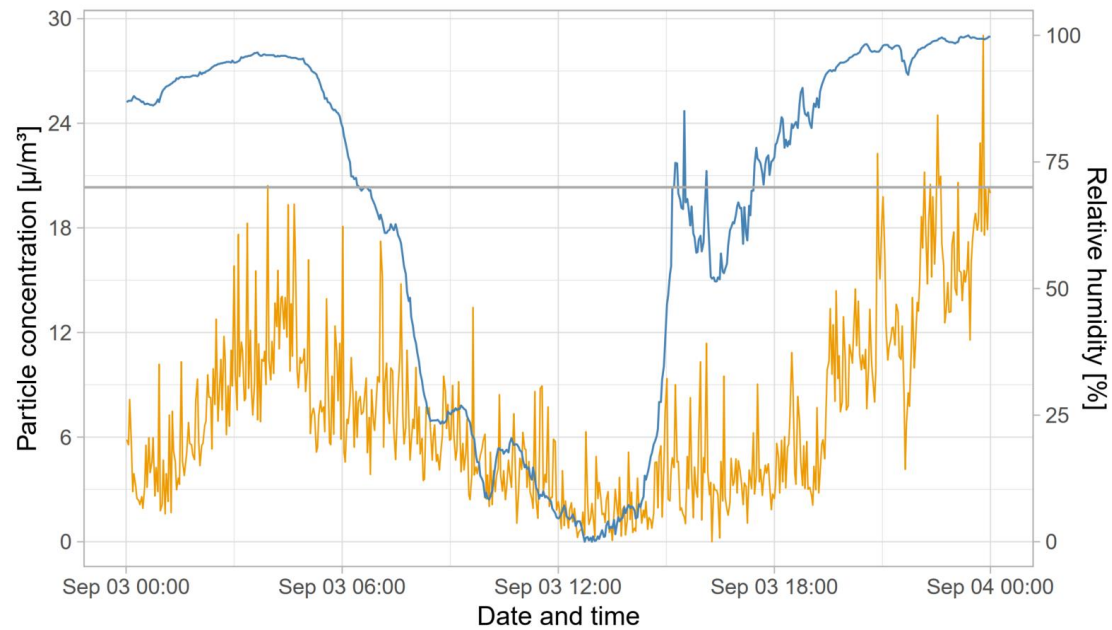


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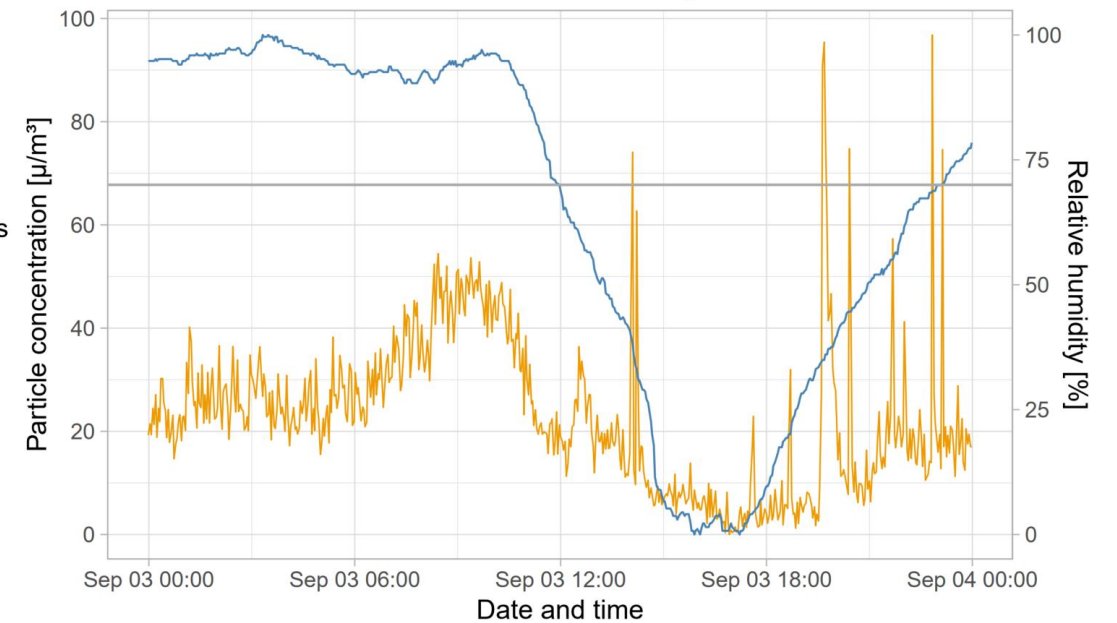
Sensor reliability



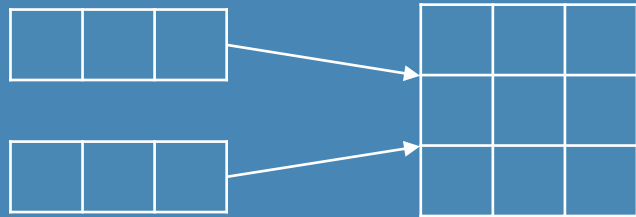
Dresden
Sensor 5301 intraday



Stuttgart
Sensor 609 intraday




Data Sets and Data Preparation



Visualizing Patterns



Time Series Forecasting



The diagram shows a white sine wave with a yellow segment at its peak, representing a forecast. To the right of the wave is the following equation:

$$\hat{y}_{t+1} = \phi_1 y_t + \theta_1 x_t + c$$

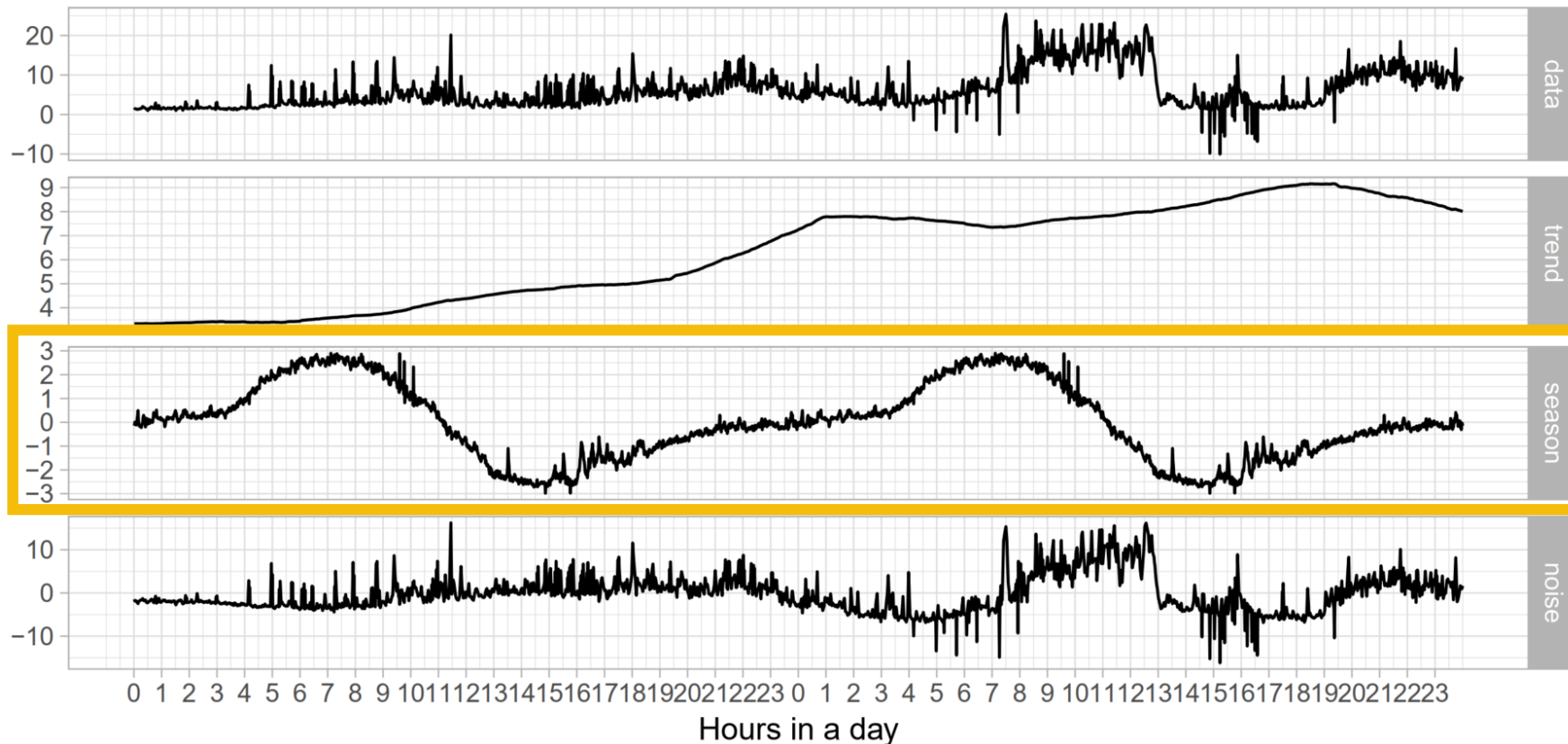
No-go Areas



Time Series Decomposition

Segment a time series into trend, seasonality, and noise [2]

Sensor 7561 decomposition



Use seasonal patterns
for analysis

[2] Cleveland et al., STL: A Seasonal-Trend Decomposition, 1990

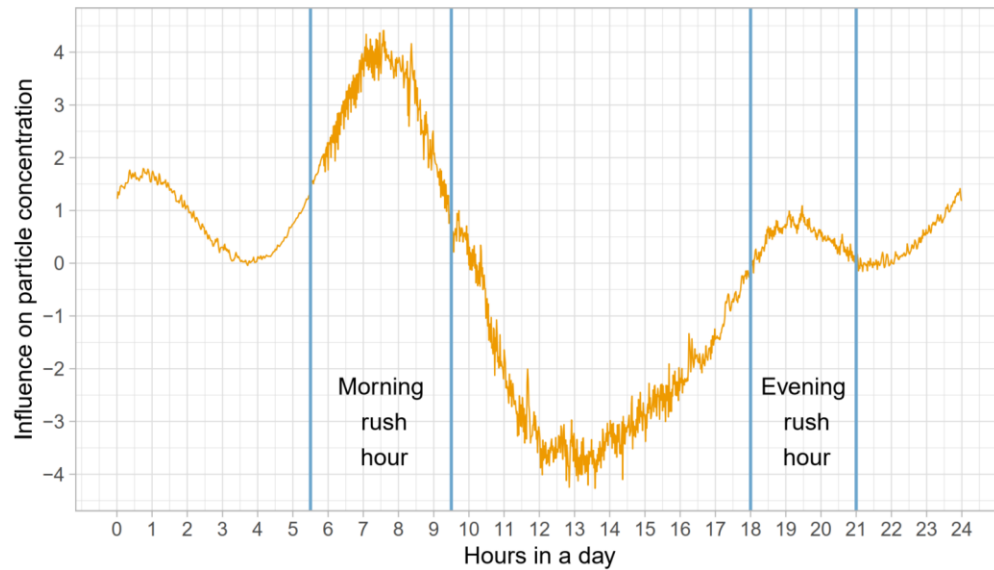
Seasonal Patterns

Differences between city centers

Dresden



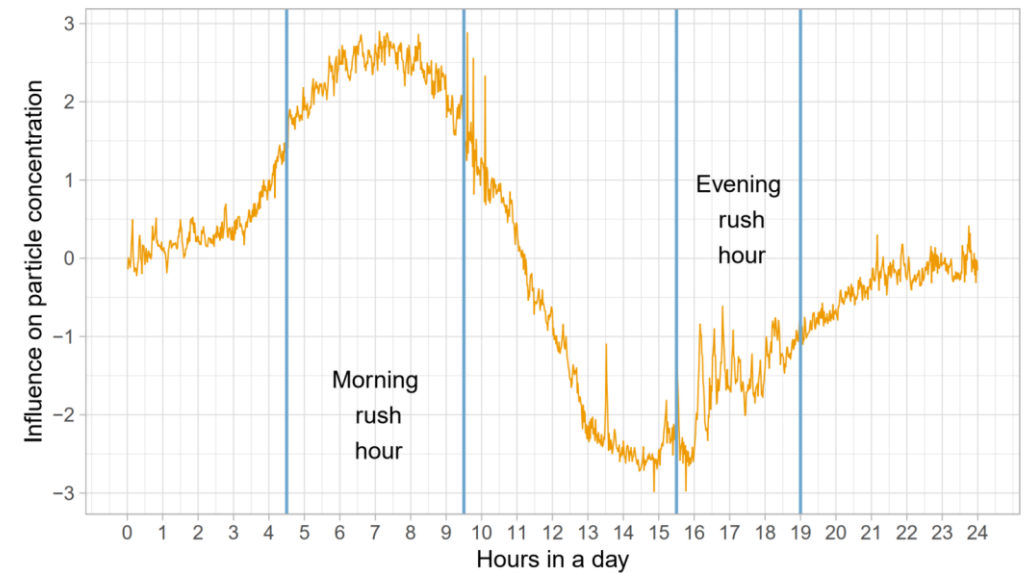
Sensor 5301 seasonality per day



Stuttgart

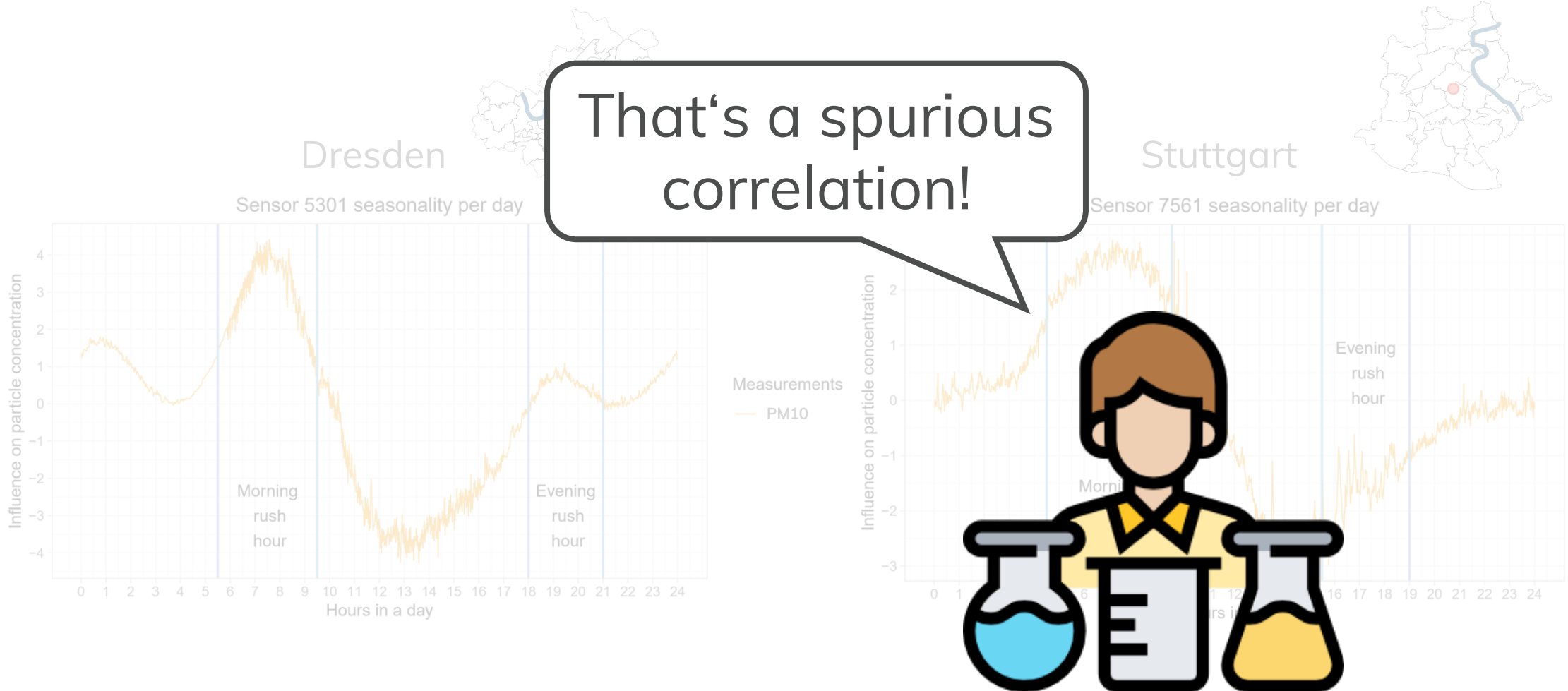


Sensor 7561 seasonality per day



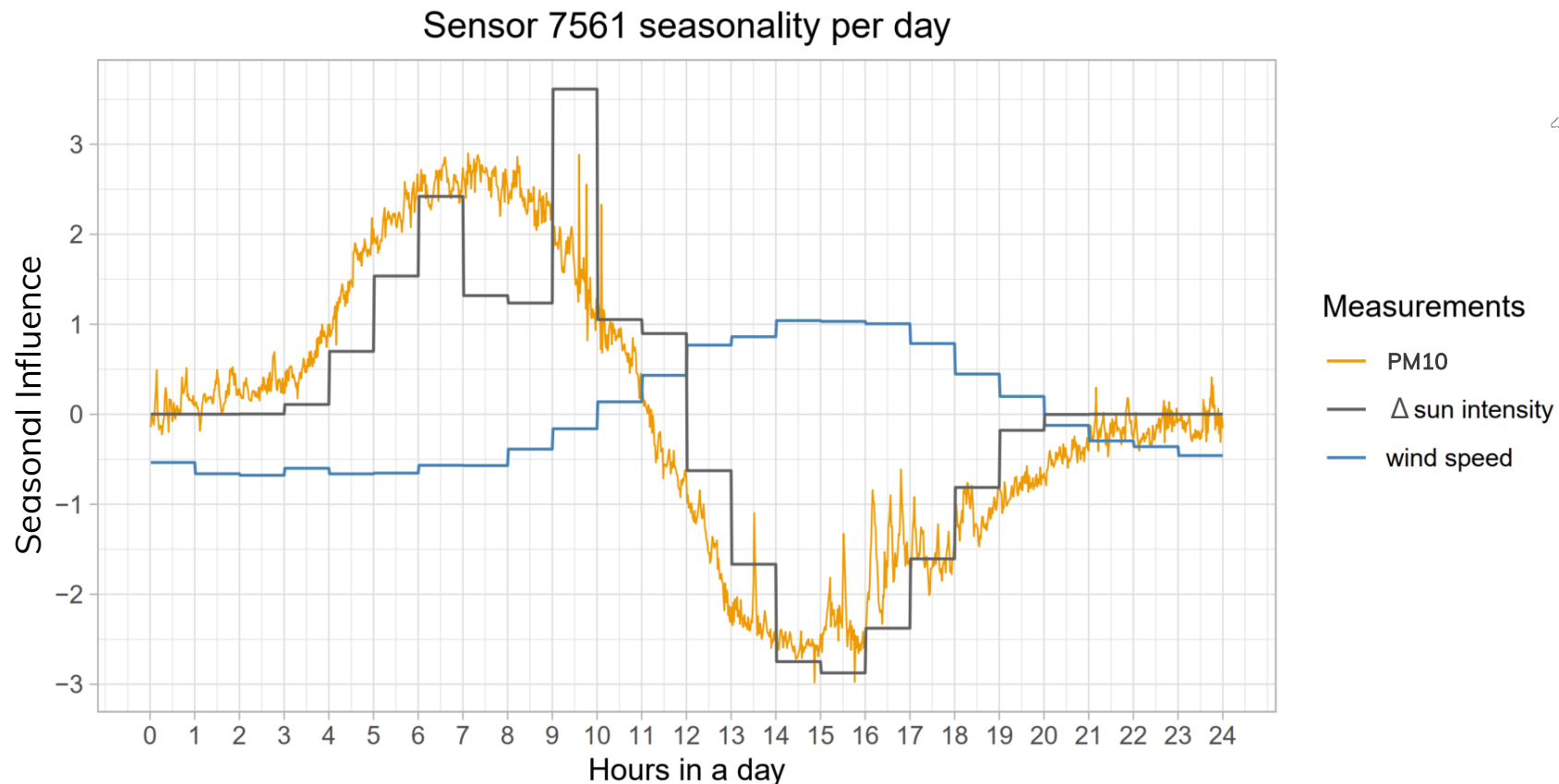
Seasonal Patterns

Differences between city centers



Expert Knowledge

The rush hour peaks are really the sun rise and sun set because PM10 directly correlates with the gradient of the global sun intensity and the wind speed [1].



[1] Klingner, Matthias; Sähn, Elke: Prediction of PM10 concentration on the basis of high resolution weather forecasting, 2008

Expert Knowledge

The time of sun rise and sun set directly influences PM10 as seen over different months

Jan 2018

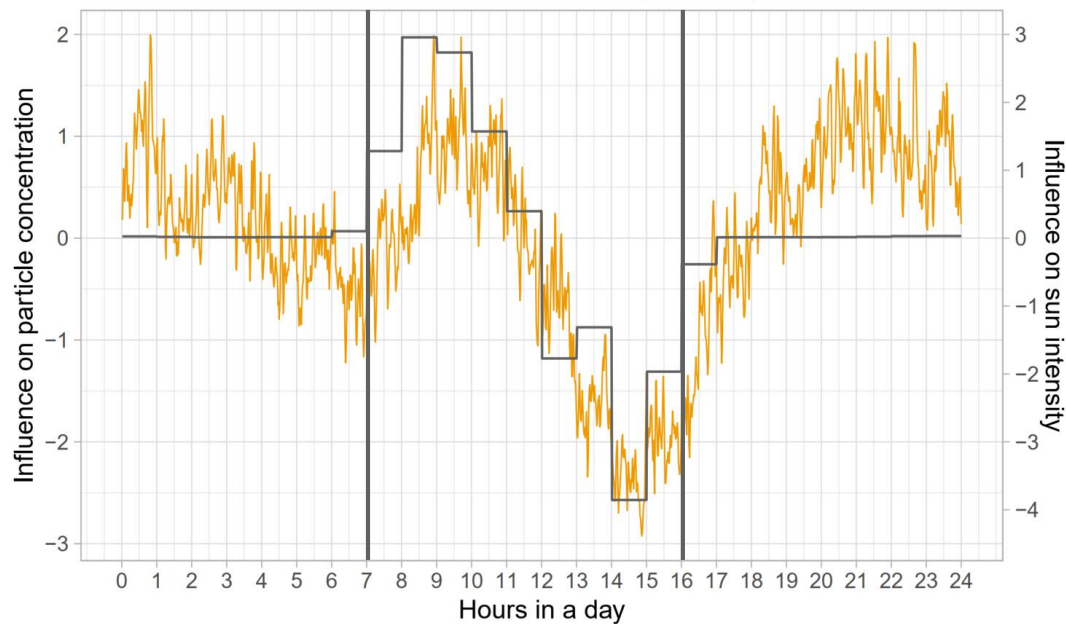


Convection

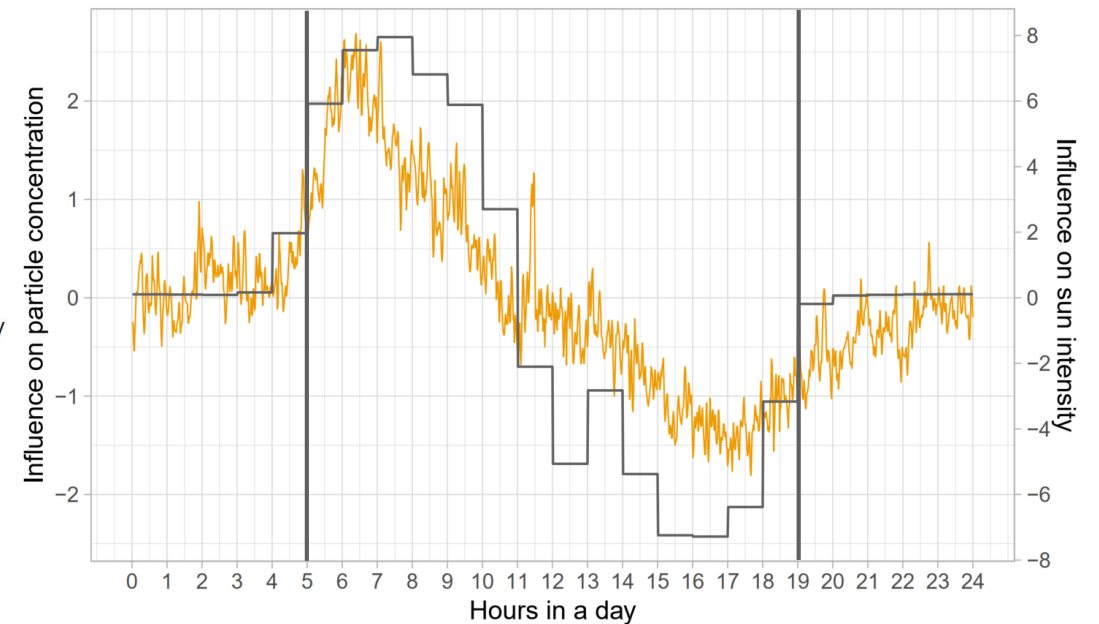


Aug 2018

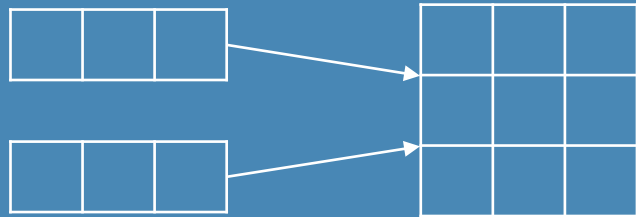
Sensor 7561 seasonality per day



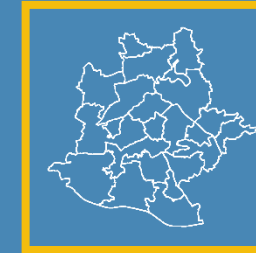
Sensor 7561 seasonality per day



Data Sets and Data Preparation



Visualizing Patterns



Time Series Forecasting



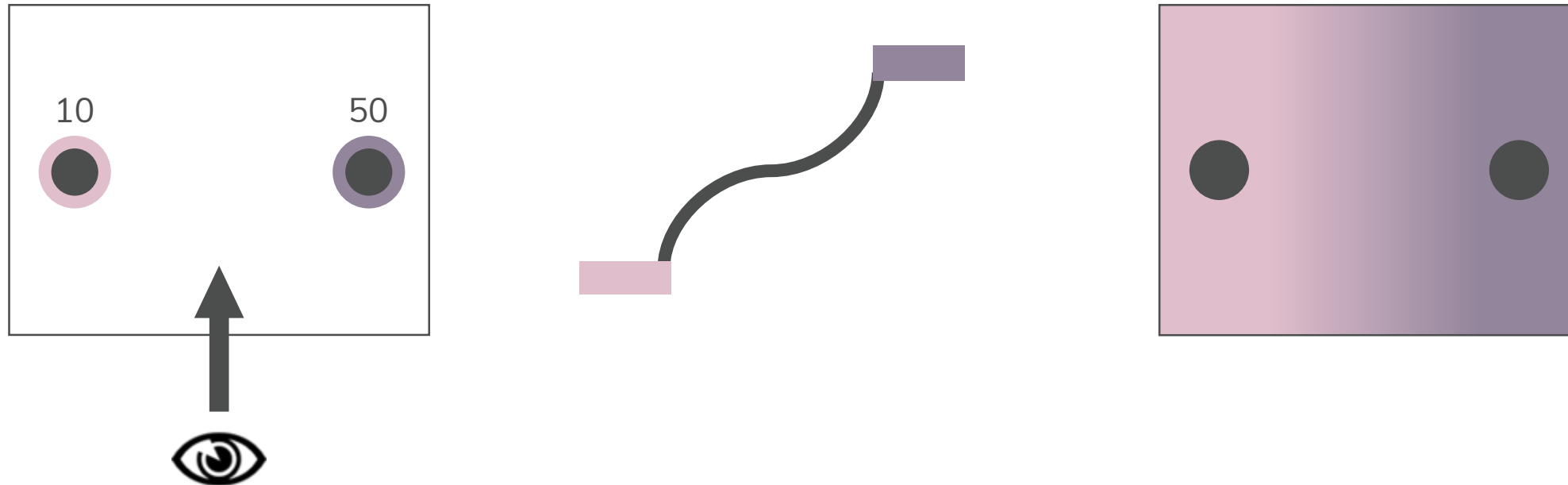
$$\hat{y}_{t+1} = \phi_1 y_t + \theta_1 x_t + c$$

No-go Areas



Graphical Interpolation of Sensor Data

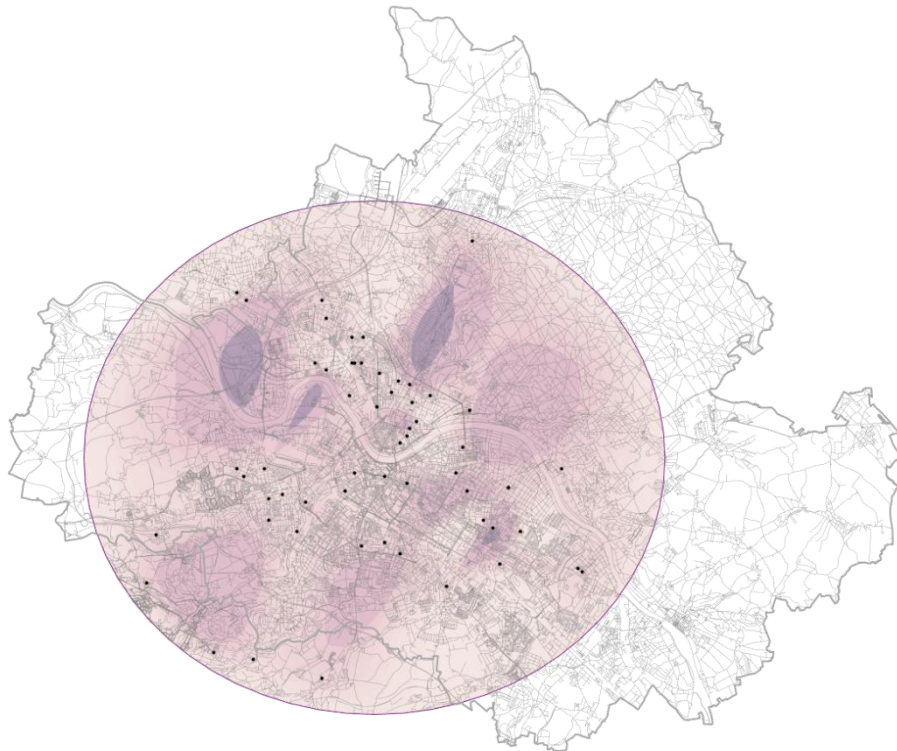
Cubic interpolation for transforming sparse 3D data to smoothed 3D data



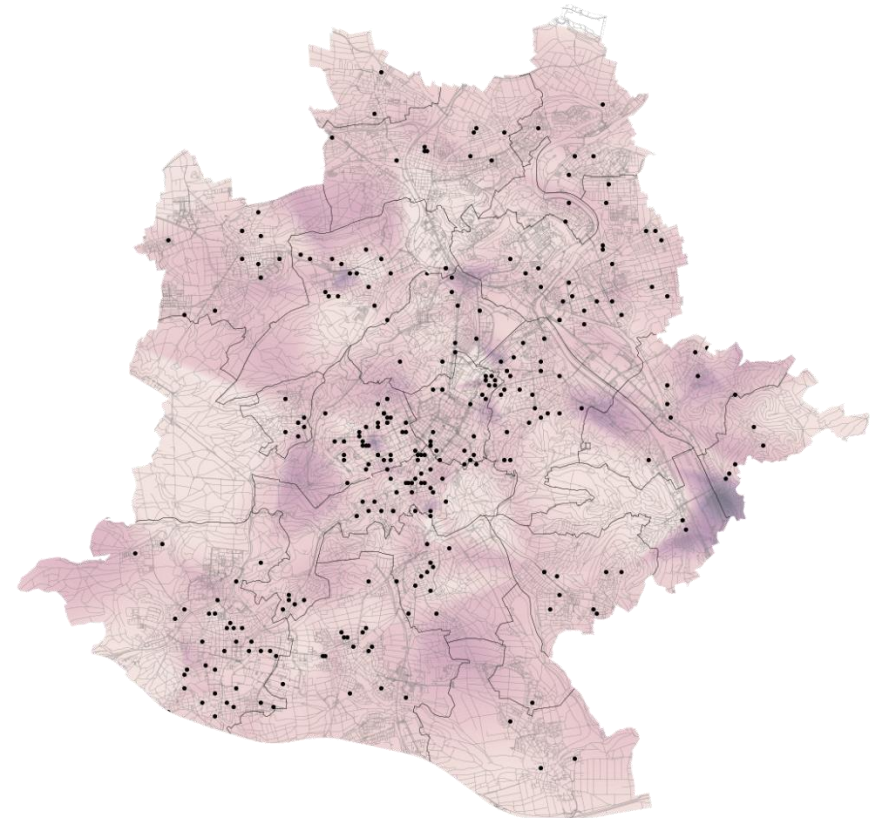
Geographical Patterns

Average particle concentration (PM10) in 2018

Dresden



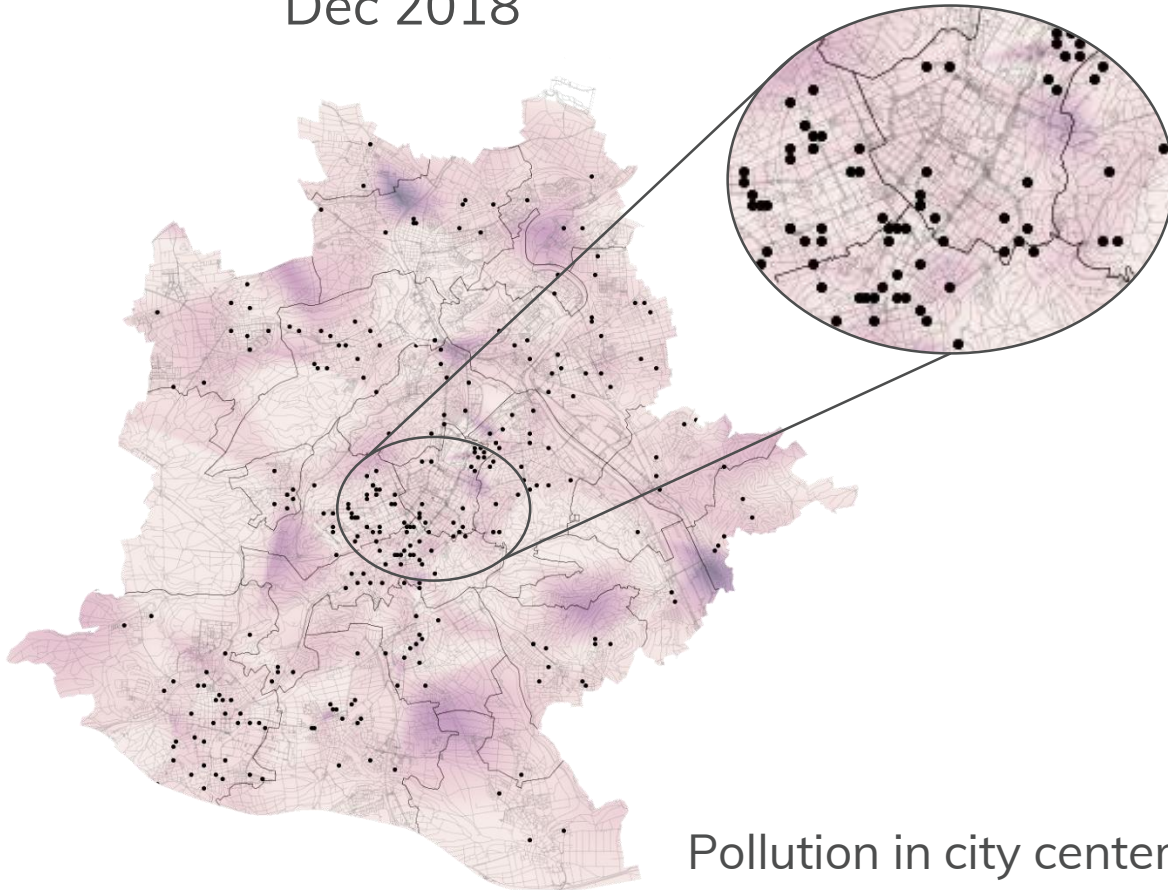
Stuttgart



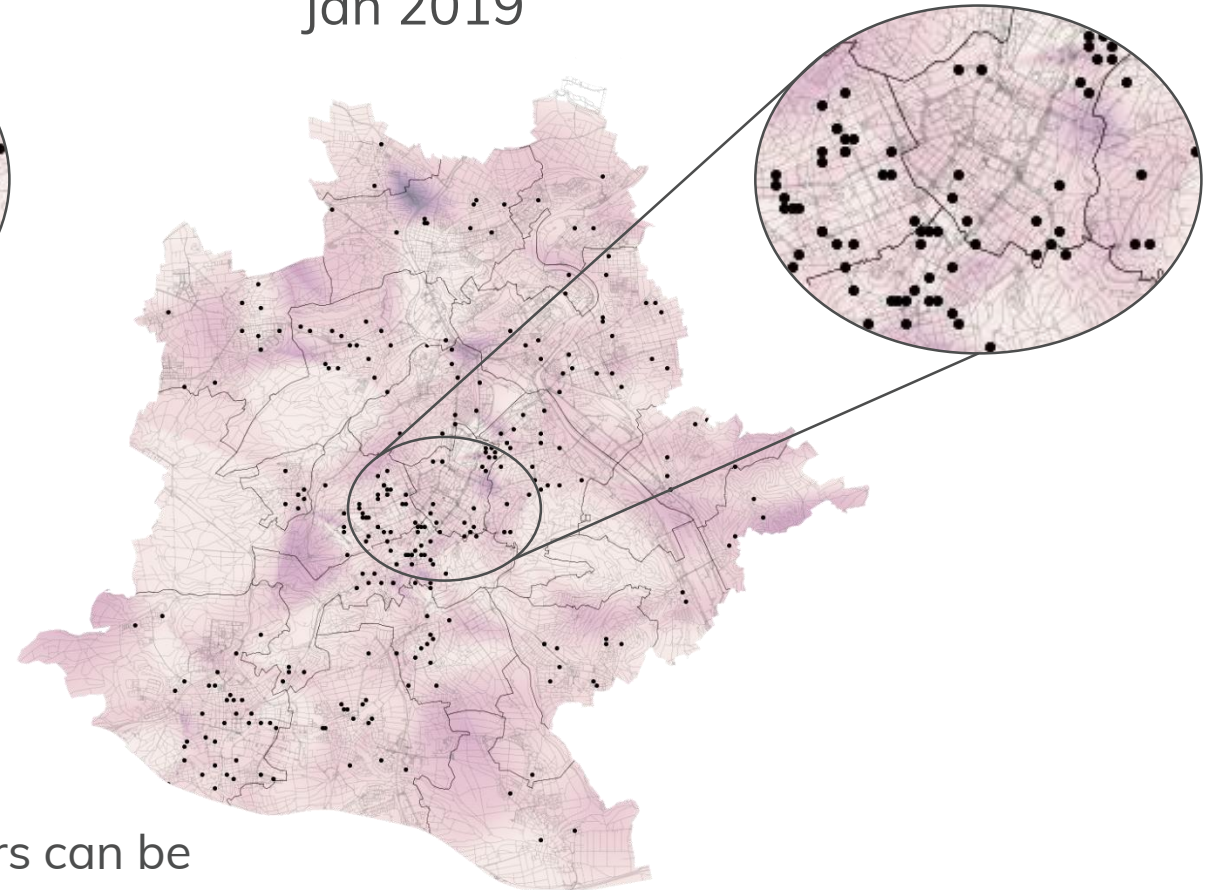
Geographical Patterns

Average particle concentration (PM10) before and after the driving ban in Stuttgart

Dec 2018



Jan 2019



Pollution in city centers can be reduced with a driving ban but...

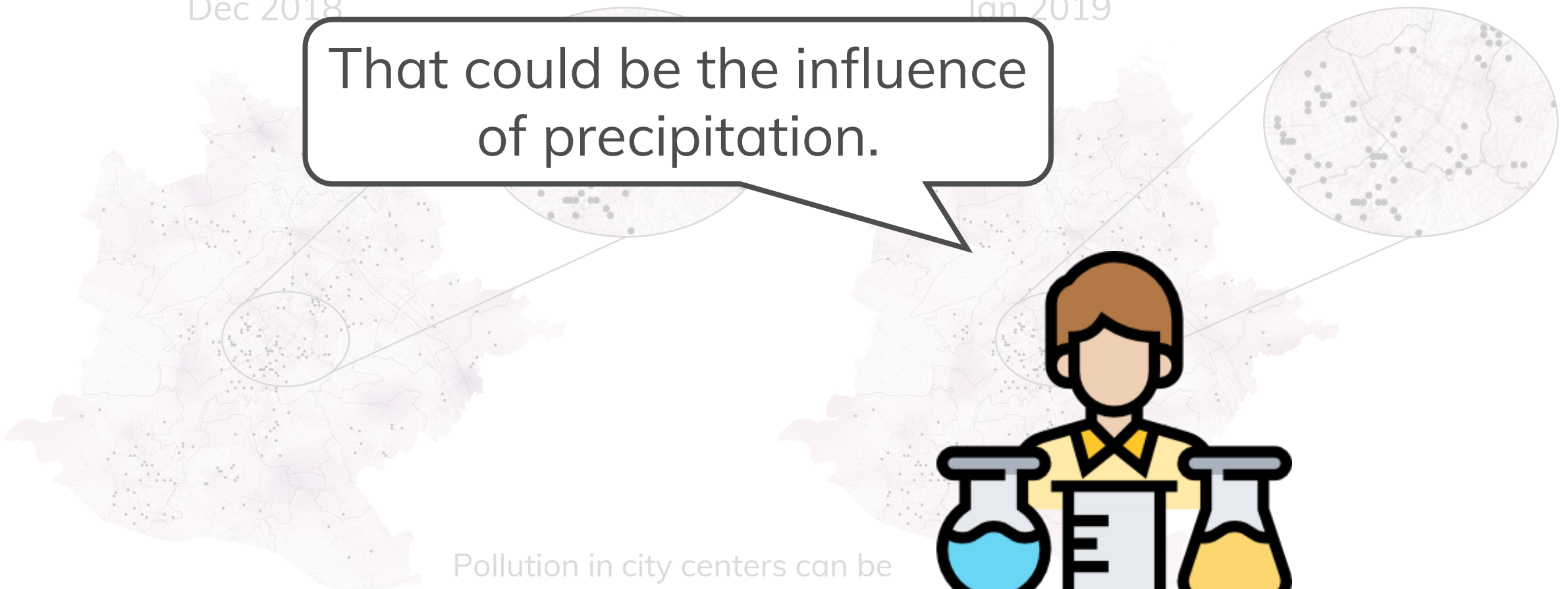
Geographical Patterns

Average particle concentration (PM10) before and after the driving ban in Stuttgart

Dec 2018

Jan 2019

That could be the influence of precipitation.

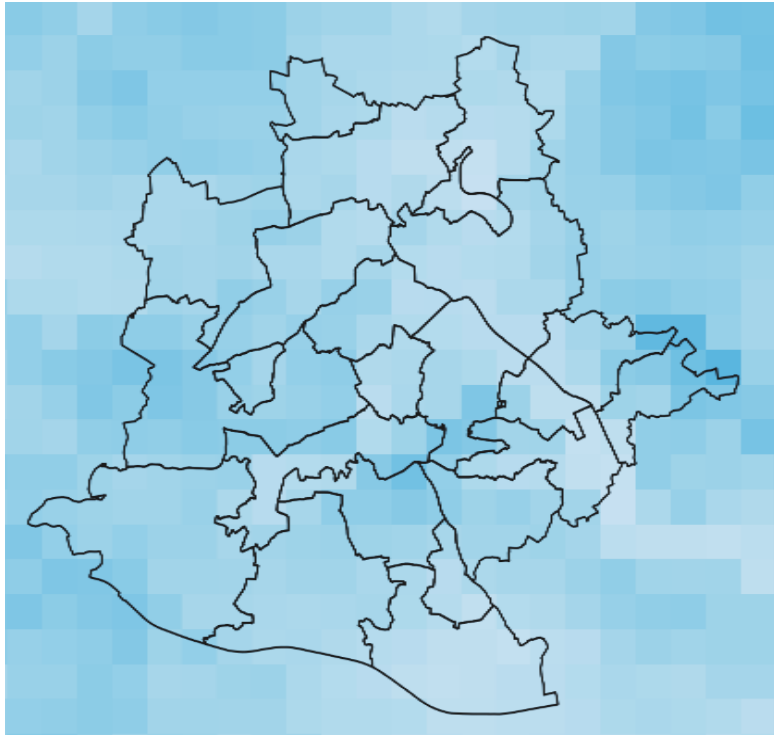


Pollution in city centers can be reduced with a driving ban but...

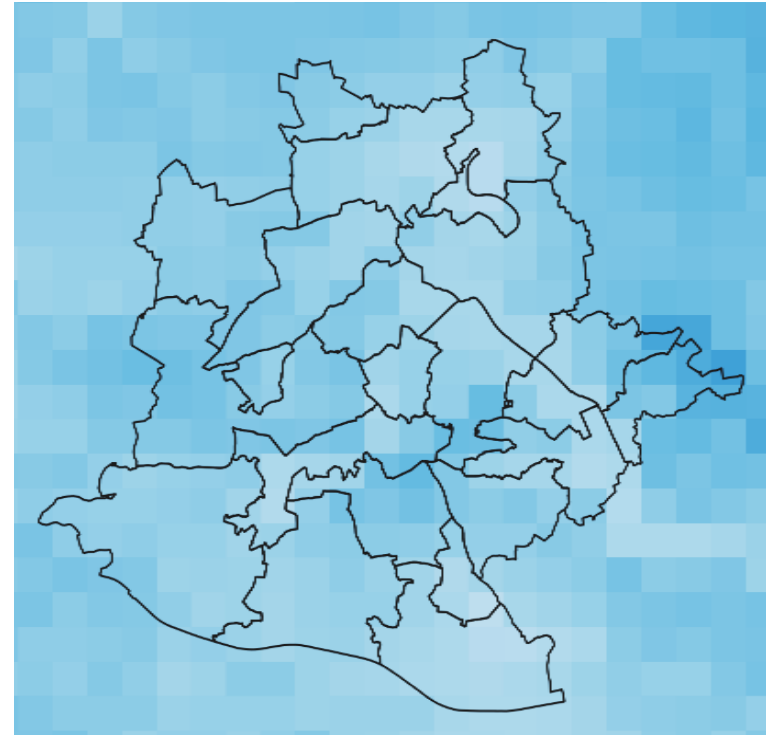
Expert Knowledge

Precipitation rate times number of rainy days in Stuttgart

Dec 2018

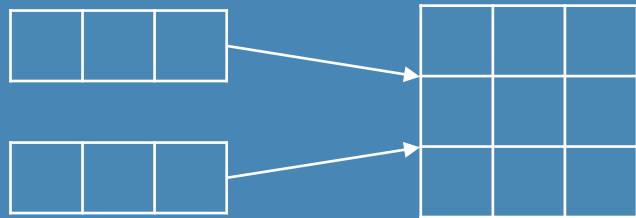


Jan 2019



Data: DWD ftp://ftp-cdc.dwd.de/pub/CDC/grids_germany/monthly/precipitation/

Data Sets and Data Preparation



Visualizing Patterns



Time Series Forecasting



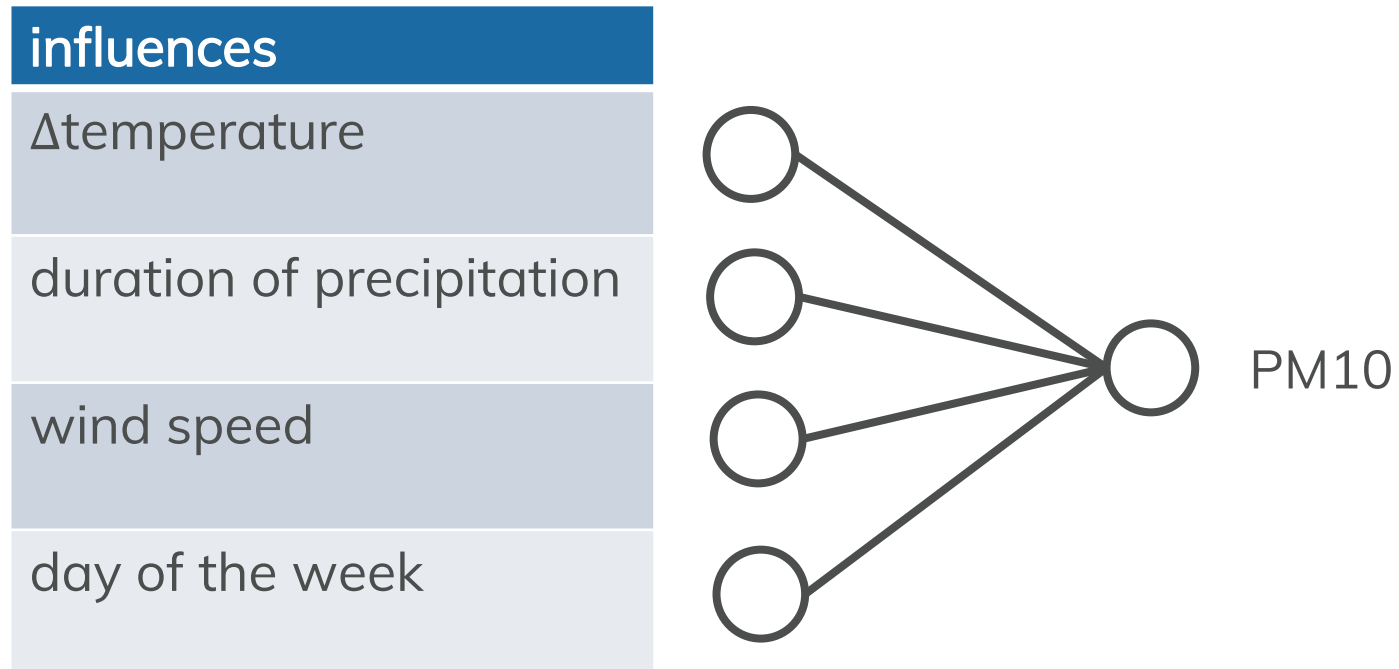
$$\hat{y}_{t+1} = \phi_1 y_t + \theta_1 x_t + c$$

No-go Areas



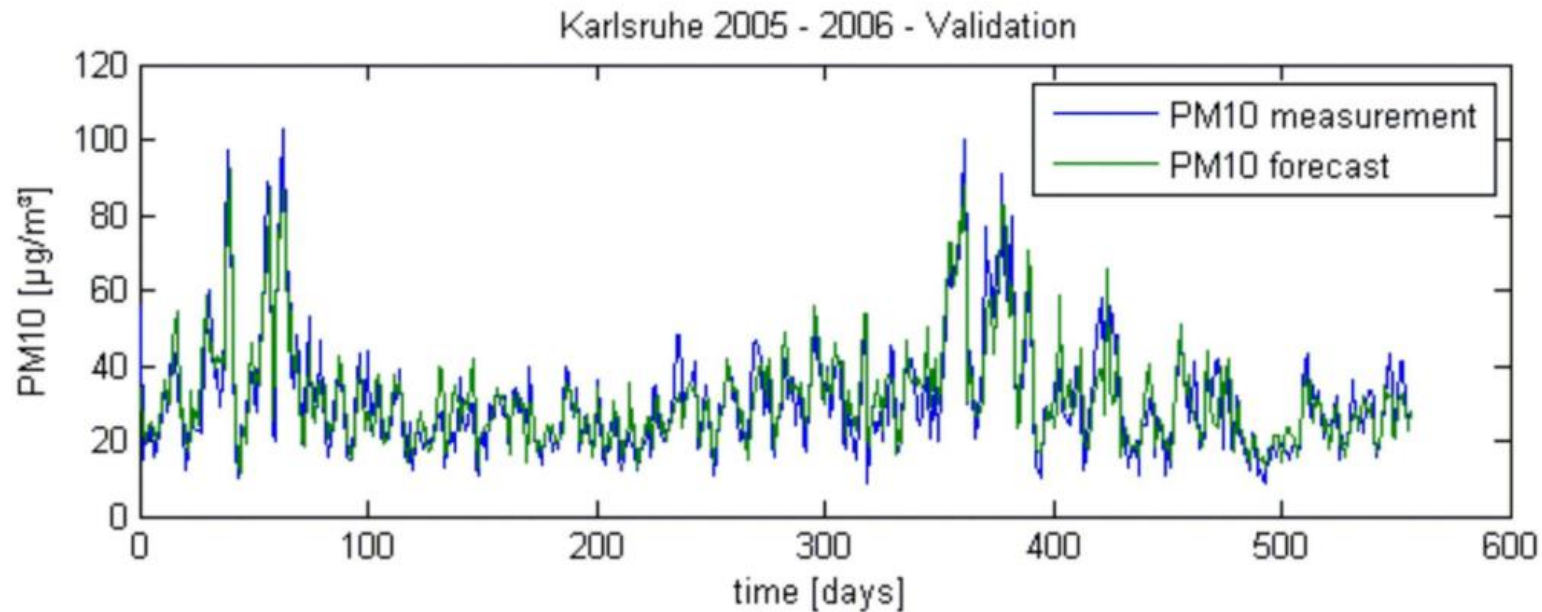
Forecasting with Neural Networks

Modeling external influences to predict PM10 concentration



Forecasting with Neural Networks

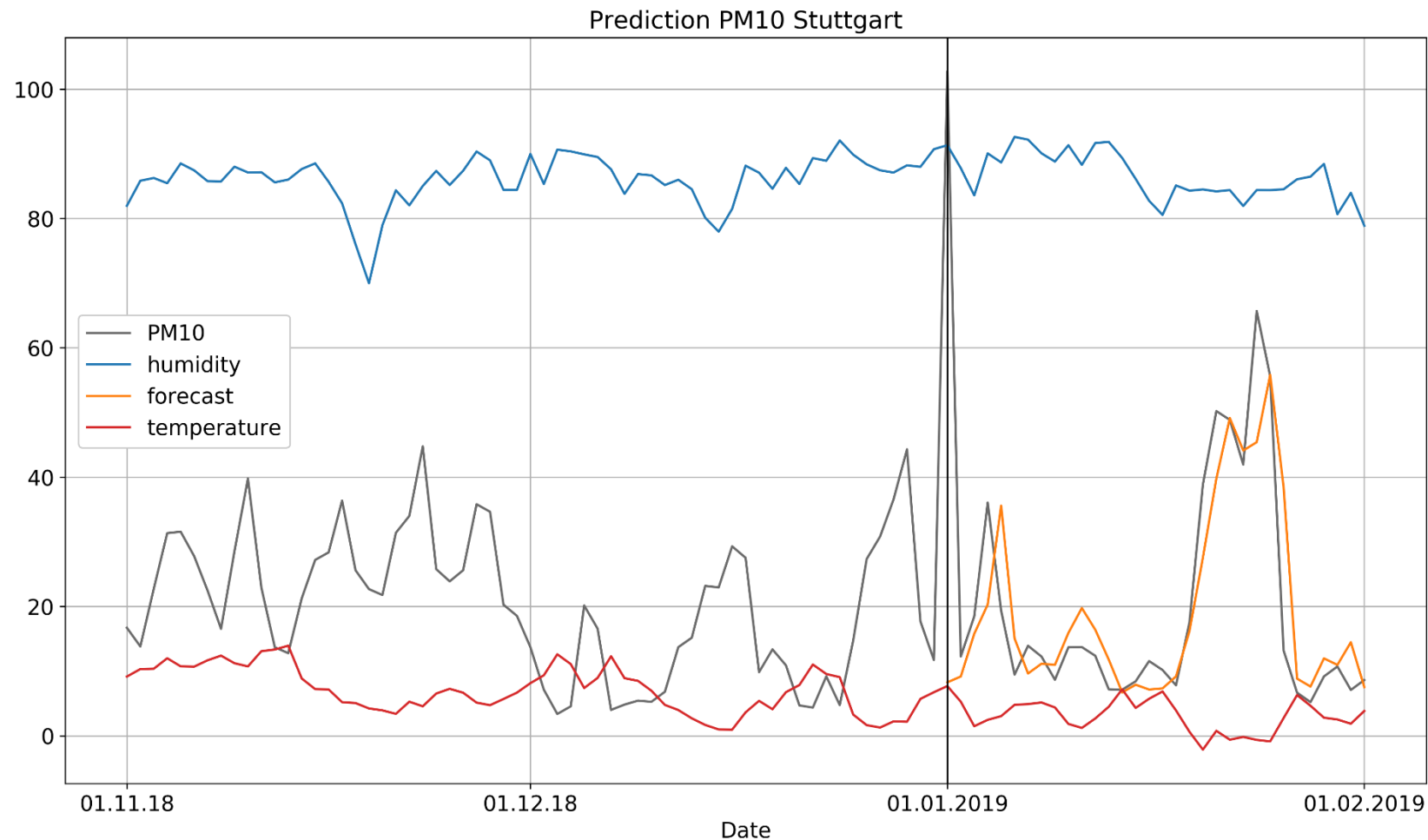
Prediction of PM10 concentration with multi-layer perceptron.



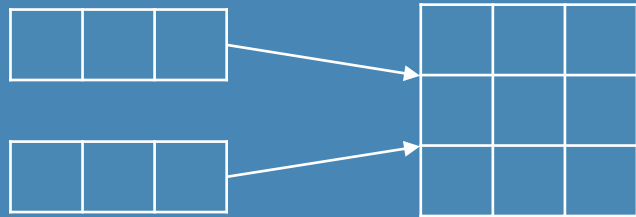
[1] Klingner, Matthias; Sähn, Elke: Prediction of PM10 concentration on the basis of high resolution weather forecasting, 2008

Long short-term memory (LSTM)

Prediction of PM10 with humidity and temperature with lag 1



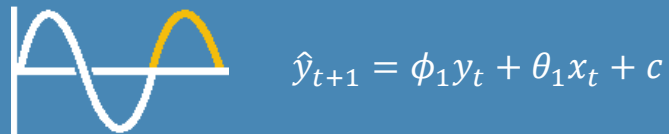
Data Sets and Data Preparation



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No-go Areas



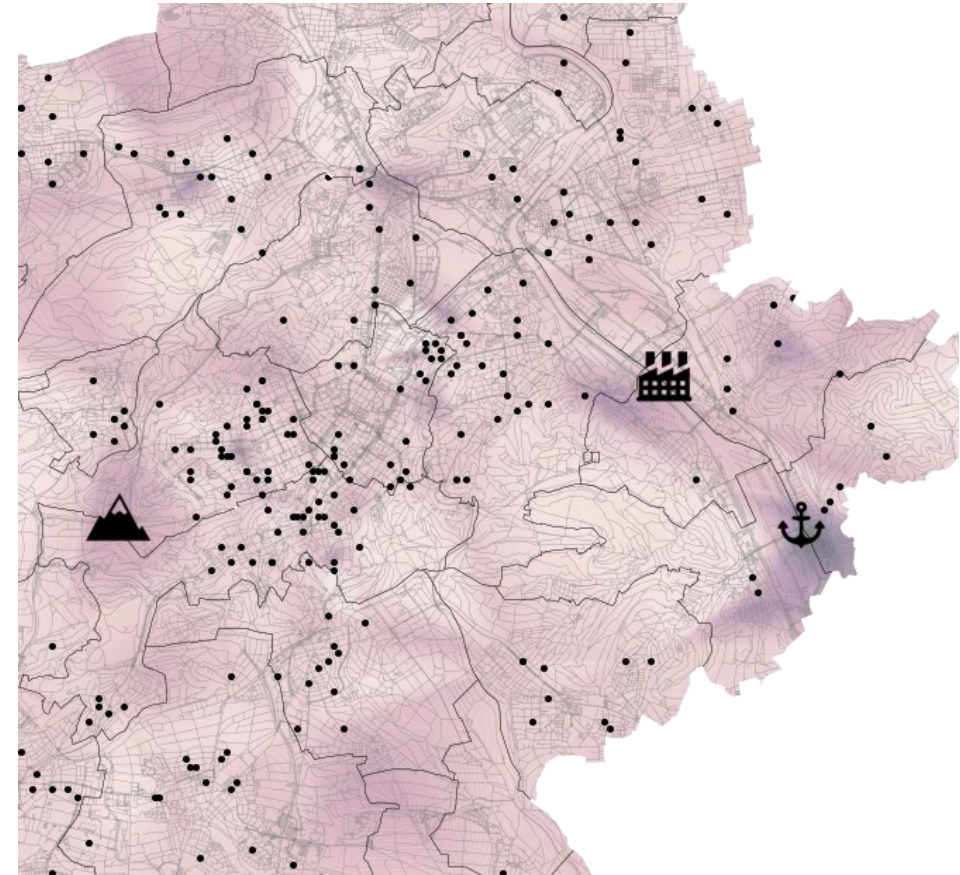
Geographical Patterns

Average particle concentration (PM10) in 2018

Dresden



Stuttgart



Geographical Patterns

Average particle concentration (PM10) in 2018

Dresden



Conclusion

Summary

- What seems to be rush hours are spurious correlations
- External influences other than traffic have a more significant impact on the particle concentration
- No measurable impact through driving bans on particle concentration due to the strong influences of weather and other factors
- Always ask an expert!

Outlook

- Standardized sensor network
- Identification of other external factors (environmental/human)
- Research on better data preparation to get exact anthropogenic influence
- Combination of other analysis techniques