Seismic Time Series Analysis

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June 16, 2020

Lockdown influence on seismic surveys

COVID-19 outbreak

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Belgium Lockdown
(March 14^{th}, 2020)

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Influence on background noise

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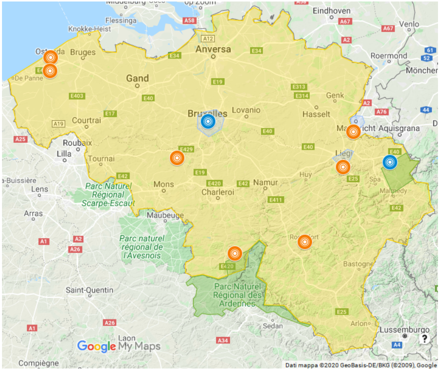
Human activity correlation

Data source

Royal Observatory of Belgium
Seismology-Gravimetry



9 stations

↓

2 selected

Uccle
in Brussels

Membach
mountain area
near a national park

Data description

(min, max) displacements	$\rightarrow$	total displacement (difference)
second precision	$\rightarrow$	hourly mean
UTC times	$\rightarrow$	legal-time conversion
missing values	$\rightarrow$	fill with weekly mean (when needed)

Dataset division

We want to be able to verify our models on pre-lockdown data

29-10-2018 28-10-2019 02-03-2020

Training set - **67%** Test set - **23%** **10%**

Fit on training → validate on test → assess lockdown influence

Seasonality - Visual inspection

Plot review

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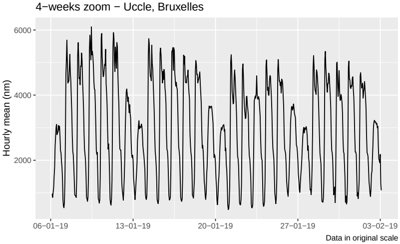
Daily and weekly seasonalities



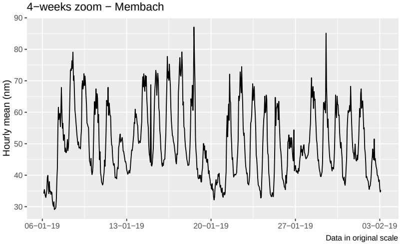


Figure: Zoom from January 6^{th} to February 3^{rd} 2019

Seasonality - Periodgram

Fourier Transform with different frequencies

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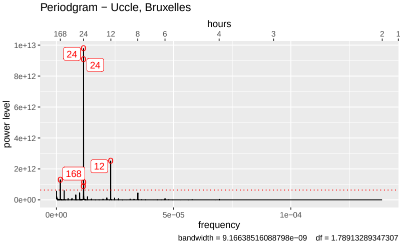
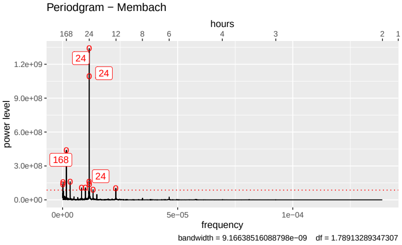
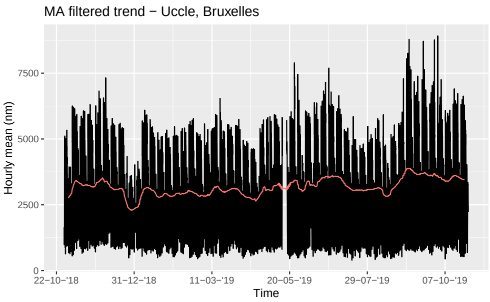
Daily and weekly seasonalities





Decomposition - Trend extraction

Tested simple, Spencer's and Moving Average filters



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Moving Average

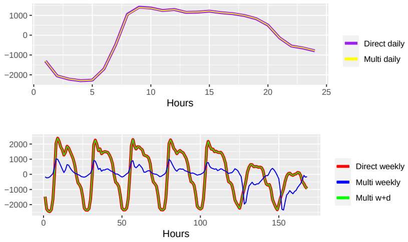
better seasonal features

Decomposition - Seasonality extraction

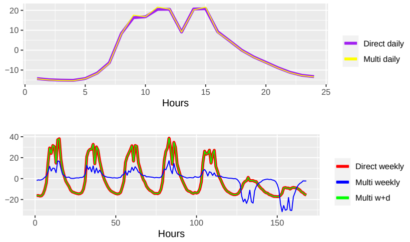
MA filter for detrending

+

local mean method



(a) Uccle, Brussels



(b) Membach

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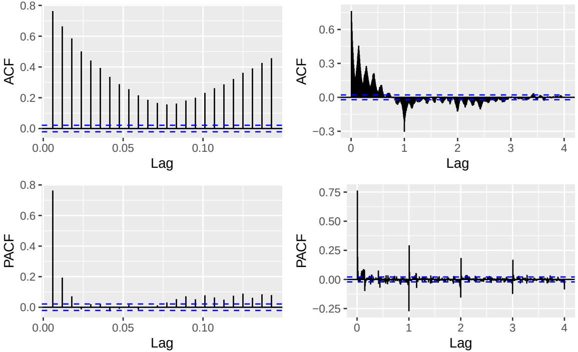
Only weekly seasonality

fitting models

Uccle - ARMA orders

Figure: ACF and PACF plots after *diff* at lag 168



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non-seasonal AR order 2

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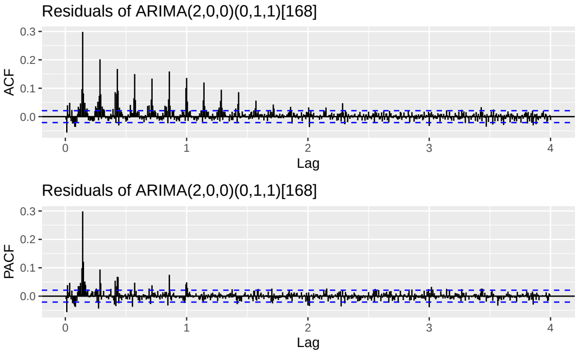
seasonal MA order 1

Uccle - Remaining seasonality

ACF and PACF plots highlight 24-hours seasonality on residuals

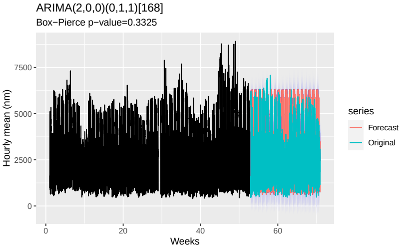


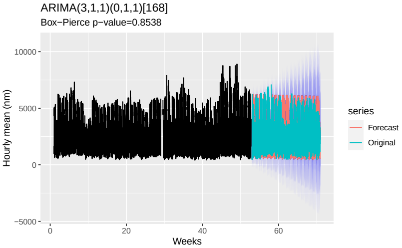
Uccle - Models comparison

ARIMA	AIC	(refit) MAPE	Box-Pierce p-value
$(2,0,0)(0,1,1)_{168}$	119700.1	5.89%	0.333
$(3,1,1)(0,1,1)_{168}$	119513.4	6.10%	0.854
$(4,1,2)(0,1,1)_{168}$	119396.9	6.13%	0.109

Other models have higher AIC and MAPE, while p-value < 0.05

Uccle - Models validation





	ARIMA	MAPE	80% CI	95% CI
accepted model $\Rightarrow$	$\mathbf{(2,0,0)(0,1,1)_{168}}$	17.48%	$\approx$ 81%	$\approx$ 91%
	$(3,1,1)(0,1,1)_{168}$	15.18%	$\approx$ 96%	$\approx$ 98%
	$(4,1,2)(0,1,1)_{168}$	14.68%	$\approx$ 98%	$\approx$ 99%

Membach - Data transformation

Spikes in data make it heavily non-Normal

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Transform using Box-Cox with $\lambda \approx -1$

Safe since all our data is positive

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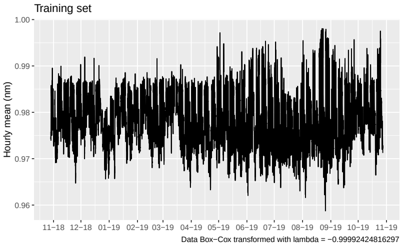
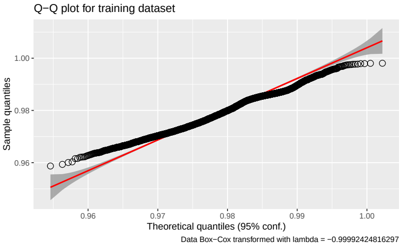
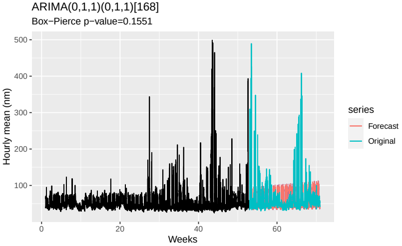
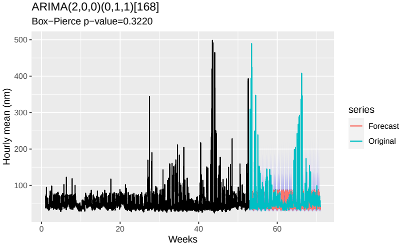




Membach - Models validation

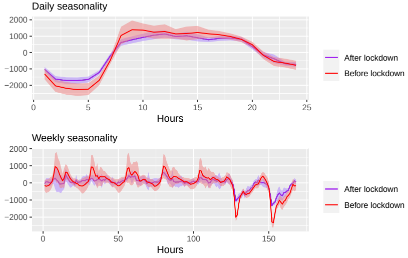




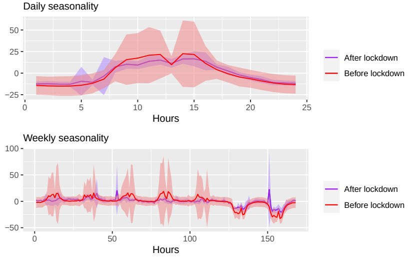
	ARIMA	MAPE	80% CI	95% CI
	$(0,1,0)(0,1,1)_{168}$	17.25%	$\approx$ 99%	100%
	$(0,1,1)(0,1,1)_{168}$	17.98%	$\approx$ 98%	$\approx$ 99%
accepted model $\Rightarrow$	$\mathbf{(2,0,0)(0,1,1)_{168}}$	16.14%	$\approx$ 73%	$\approx$ 89%

Multiple seasonalities

Seasonalities extracted together



(a) Uccle, Brussels



(b) Membach

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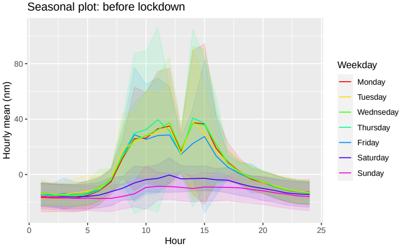
No significant difference

Weekly seasonality

Only weekly seasonality extracted



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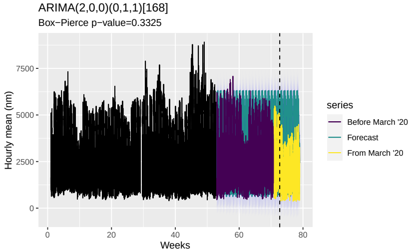
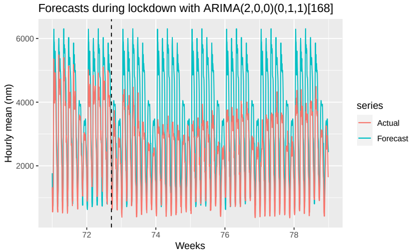
Monday to Friday lower values

Overall flattening towards 0

Forecasts assessment





Uccle, Brussels

lockdown $\rightarrow$ during lockdown

MAPE	16% $\rightarrow$ 46%
80% CI	73% $\rightarrow$ 39%
95% CI	89% $\rightarrow$ 63%

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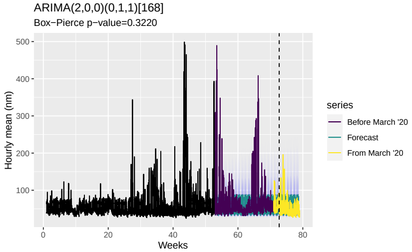
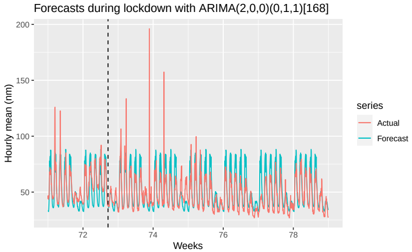
Performance degradation

Forecasts assessment





Membach

lockdown → during lockdown

MAPE 17% → 14%

80% CI 81% → 82%

95% CI 91% → 96%

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Slight performance improvement

lower peaks

Models performance

- Periodgrams and models confirm **weekly** and **daily seasonality**

- Both chosen models have **interesting forecasting power**
  Missed daily seasonality

- Models have **same number of parameters** for each component
  Membach data is transformed

- Stable **seasonality explains most of the variability**
  Membach peaks not explained

Lockdown influence

Mixed findings:

- Influence results **non-significant on seasonality**

- Influence on forecasts **depends on the station**
  Correlation with station location

Future Works

- Models with **multiple seasonality** components
  MSTL, TBATS, ARIMA with Fourier Terms, ...

- Analysis on the other **7 stations**

- Analysis when $>$ **2 years** of data available

- Different factors modify **lockdown impact**
  Location, dimension of nearest city, ...

Thank you for your attention