# Predicting the Impact of COVID-19 on the Emergency Departments in Lombardy, Italy

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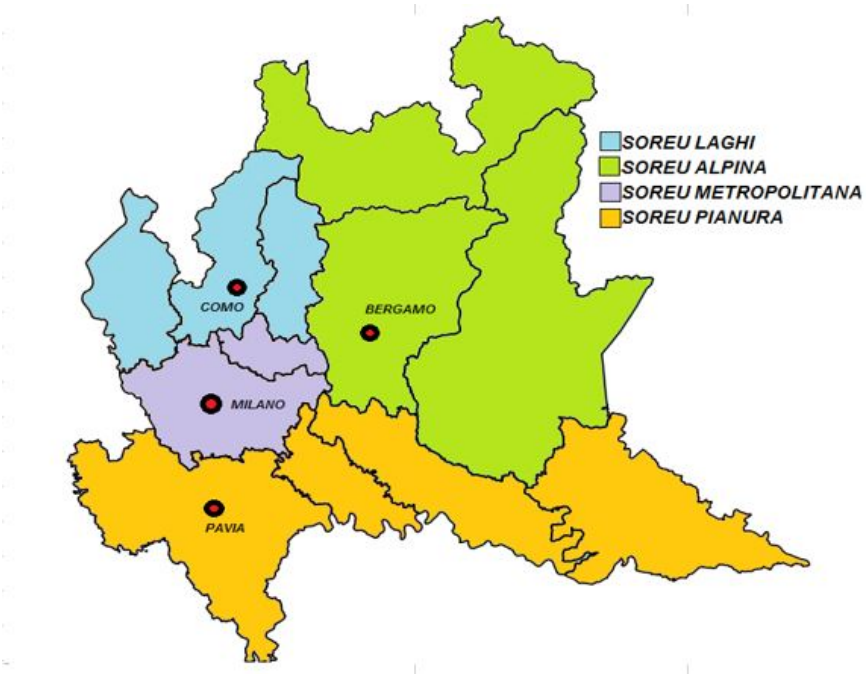
The Lombardy region in Italy relies on the emergency medical service called Agenzia Regionale Emergenza Urgenza (**AREU**).

The number and type of calls to the emergency call center changed dramatically during and after the **COVID-19** epidemic peak.

The development of a valuable **predictive model** is then crucial in this emergency period to have an accurate **organization** of the actions towards the solution of an emergency event.

**TSUNAMI PROJECT**

AREU is organized by peripheral structures called Articolazioni Aziendali Territoriali (**AAT**) and Sale Operative Regionali di Emergenza Urgenza (**SOREU**).




AREU must deals with various **factors**: daily-seasonal variations, social and demographic factors, weather circumstances, and epidemiological factors.

- **AREU data**: information about all the calls received → SOREU, Time, AAT, if the calls activated an aid, i.e., it becomes an event, etc;
- **ARPA data**: weather data collected from sensors located across the Lombardy → Temperature, rainfall, snowfall;
- **ISTAT and ISS data**: demographic and epidemiological data → Flu incidence, number of car accidents, etc.

**BUT** also COVID-19 related factors.

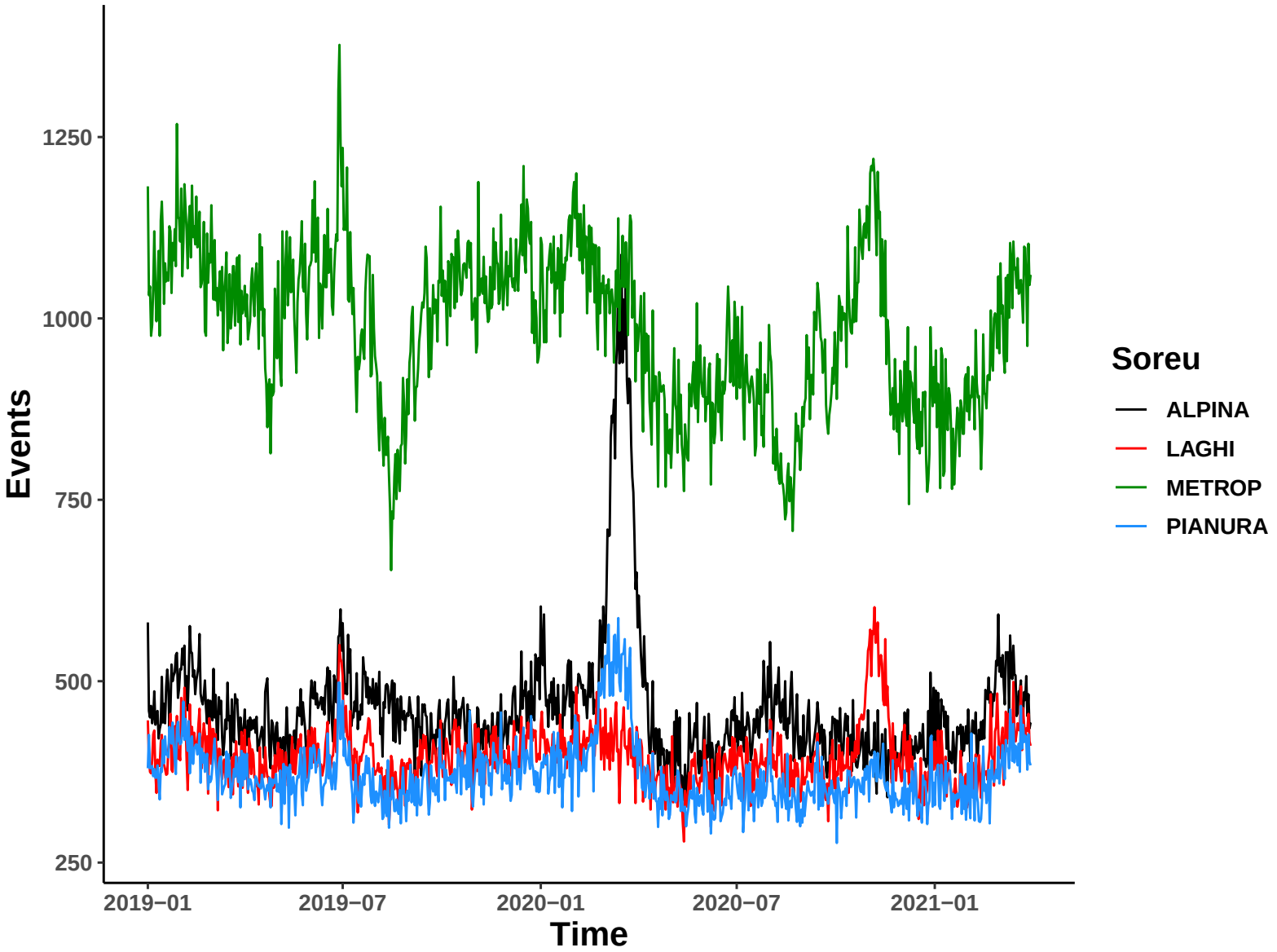
- **Dipartimento della Protezione Civile data**: number of hospitalized patients with symptoms, swabs, etc.

Here, we computed the **reproduction number** $R_t$ based on the number of

1. the total amount of positive cases;
2. and total hospitalized patients

considering a daily and weekly window. The computation of these $R_t$ follows the one used by the ISS.

# DATA


1250
1000
750
500
250
Events
2019−01
2019−07
2020−01
2020−07
2021−01
Time
Soreu
ALPINA
LAGHI
METROP
PIANURA

Here, we talk about the model to predict **events**, i.e., dispatch of transport and equipment until the rescue is completed, for the SOREUs **Pianura** and **Metropolitana**.

- We used a **Generalized Additive Model** (GAM) with **negative-binomial** family to deal with over-dispersed count data and no linear relationship between dependent and independent variables;
- The data were aggregated at **hour** and **SOREU** levels;
- However, the final predictions (one day ahead) were aggregated at the **day** level.

We evaluated a set of negative-binomial GAM models cross-validating across 4 periods of time in 2020 and 2021 using as performance metric the mean absolute error. The **prediction error** requested by AREU is defined as

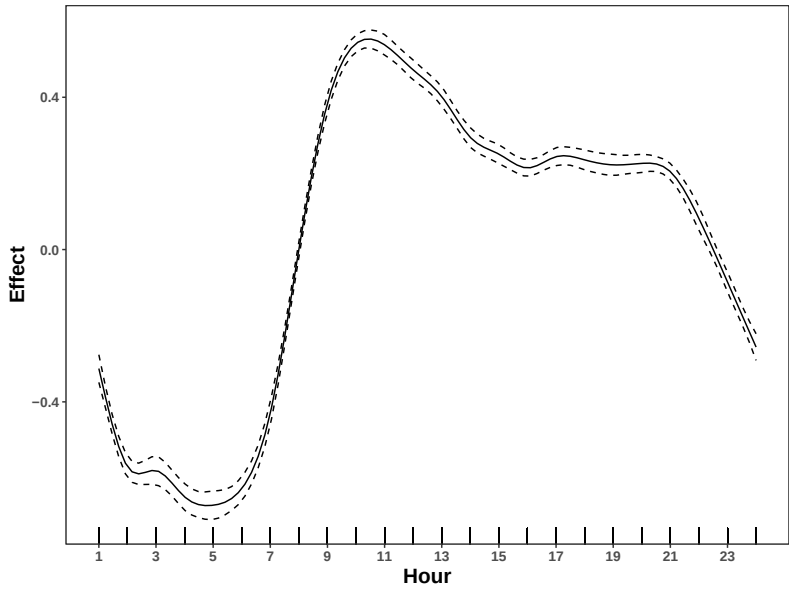
$$E_i = \frac{\hat{y}_i - y_i}{y_i},$$

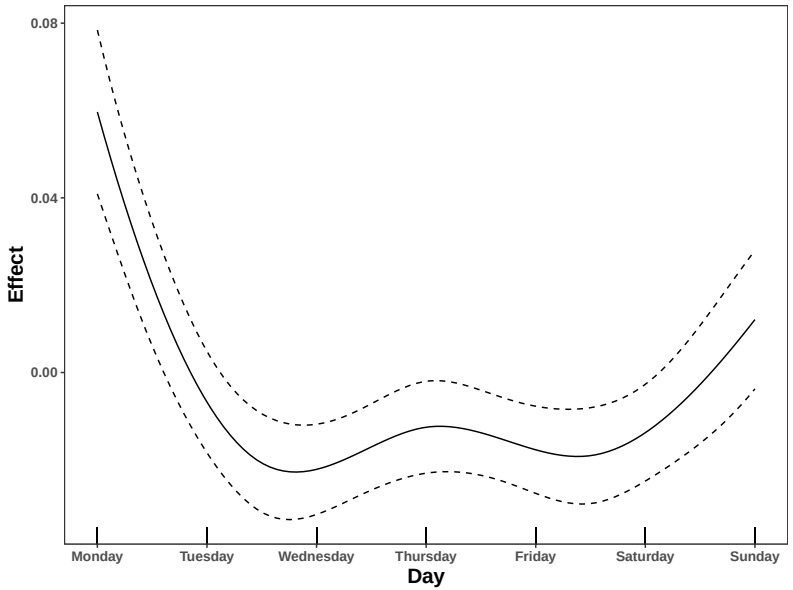
where $y_i$ is the observed value and $\hat{y}_i$ the predicted one at day $i$ level.

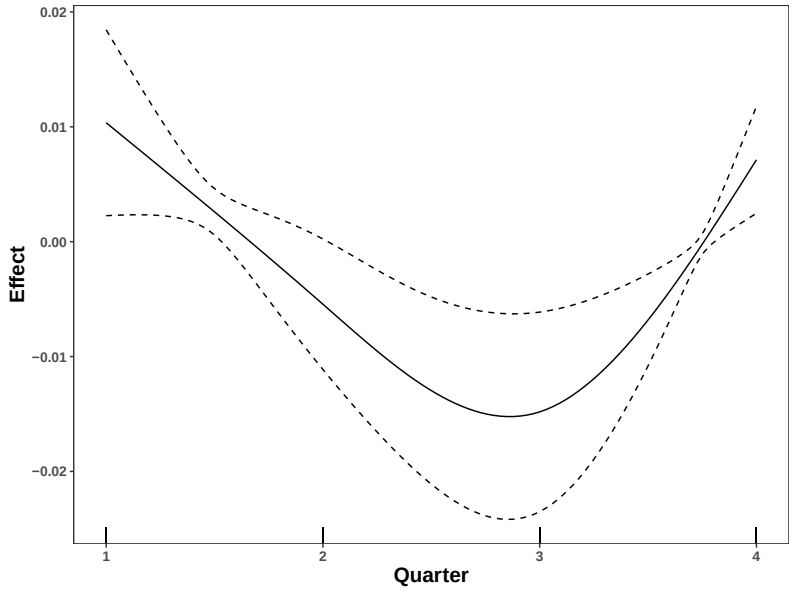
The following covariates were then selected:

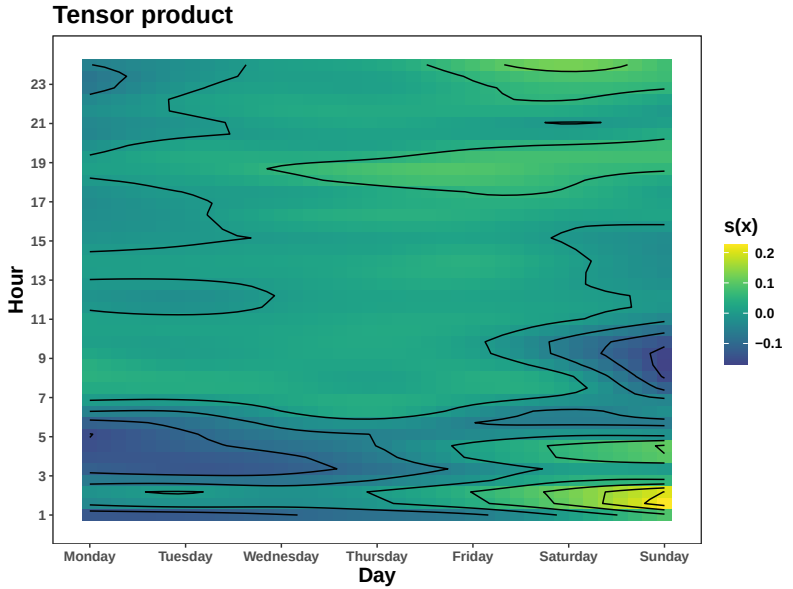
- cubic regression spline for **Hours** with 24 basis;
- cubic regression spline for **Quarter** with 4 basis;
- P-spline for **Day** with 7 basis;
- Tensor product smooths between **Day** and **Hour**;
- **Temperature** lagged one day;
- **Events** of the day before lagged 1-2-3 by hour;
- **Events** aggregated by day and lagged 1, 2 and 7 days;
- $R_t$ lagged one day;
- **Flu** incidence lagged one day.

# Results - Pianura



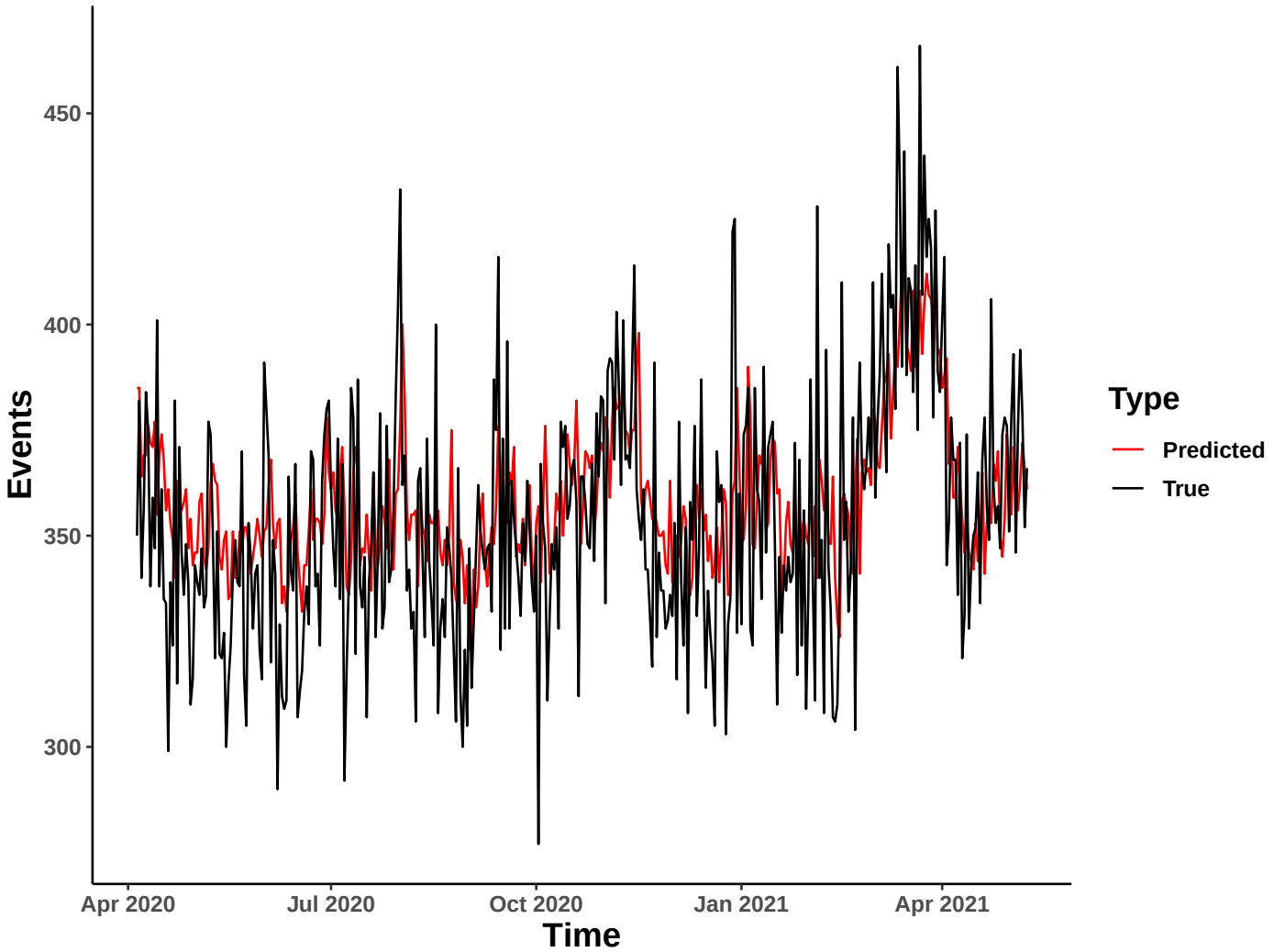



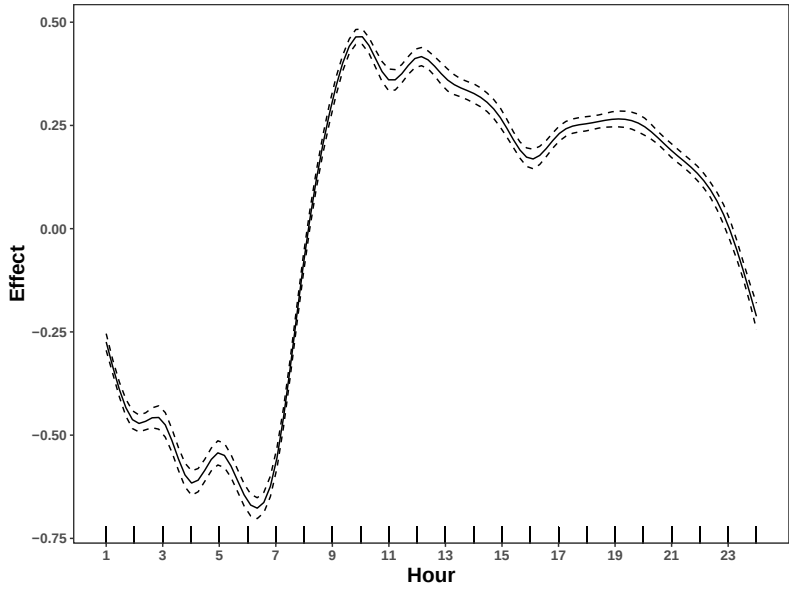
# Results - Pianura

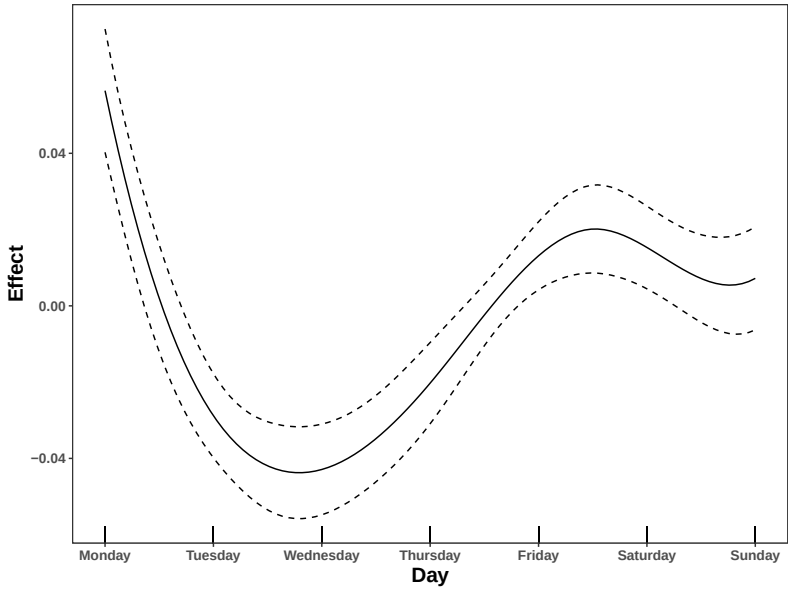
| Month | Year | MAE | MeAE | MaxAE | MinAE | RMSE |
|---|---|---|---|---|---|---|
| 1 | 2021 | 5.471 | 4.638 | 16.129 | 0.562 | 6.856 |
| 2 | 2021 | 7.161 | 5.478 | 20.561 | 0.279 | 9.409 |
| 3 | 2021 | 5.343 | 5.651 | 15.401 | 0.783 | 6.189 |
| 4 | 2021 | 4.528 | 3.804 | 14.286 | 0.265 | 5.907 |
| 5 | 2021 | 4.394 | 3.989 | 7.868 | 1.366 | 4.817 |
| 4 | 2020 | 7.269 | 6.823 | 20.736 | 0.267 | 8.666 |
| 5 | 2020 | 5.550 | 3.846 | 17.000 | 0.590 | 6.887 |
| 6 | 2020 | 6.036 | 4.907 | 21.724 | 0.526 | 7.527 |
| 7 | 2020 | 5.994 | 5.325 | 22.260 | 0.000 | 7.812 |
| 8 | 2020 | 7.451 | 7.055 | 16.340 | 1.153 | 8.581 |
| 9 | 2020 | 4.498 | 3.789 | 13.003 | 0.275 | 5.780 |
| 10 | 2020 | 5.146 | 3.352 | 28.881 | 0.272 | 7.696 |
| 11 | 2020 | 5.507 | 4.596 | 13.174 | 0.820 | 6.451 |
| 12 | 2020 | 6.827 | 5.307 | 18.152 | 0.299 | 8.450 |

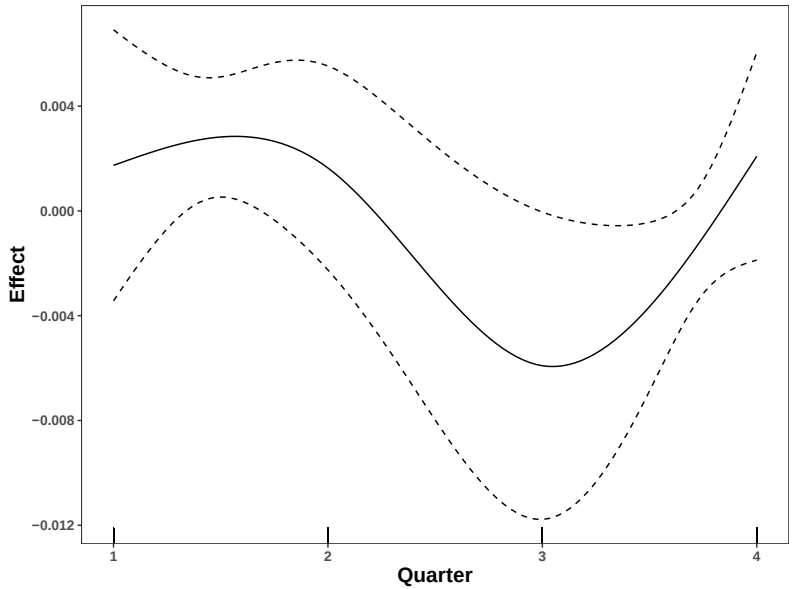
# Results - Pianura

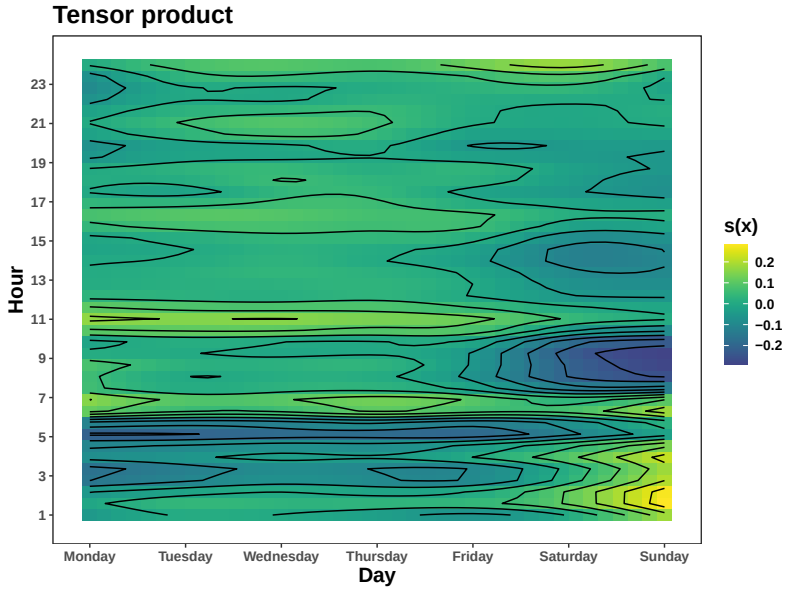


# Results - Metropolitana



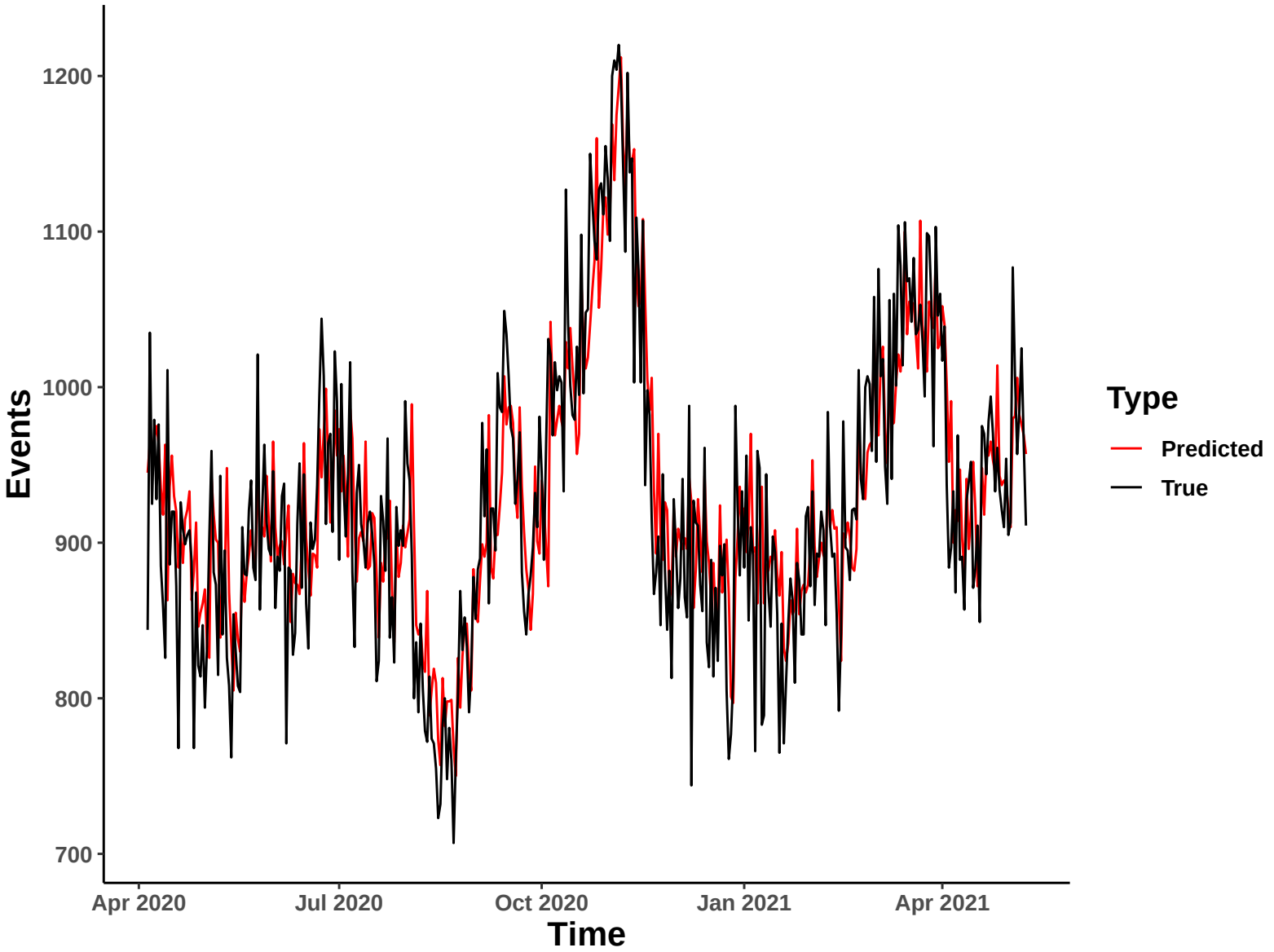



# Results - Metropolitana

| Month | Year | MAE | MeAE | MaxAE | MinAE | RMSE |
|---|---|---|---|---|---|---|
| 1 | 2021 | 5.441 | 4.430 | 19.540 | 0.224 | 7.040 |
| 2 | 2021 | 3.175 | 2.670 | 8.712 | 0.110 | 3.888 |
| 3 | 2021 | 3.317 | 2.678 | 9.944 | 0.097 | 4.230 |
| 4 | 2021 | 3.911 | 3.489 | 10.479 | 0.096 | 4.639 |
| 5 | 2021 | 3.295 | 2.679 | 9.006 | 0.305 | 4.302 |
| 4 | 2020 | 5.706 | 4.475 | 16.586 | 1.087 | 7.399 |
| 5 | 2020 | 4.607 | 3.322 | 14.770 | 0.114 | 5.850 |
| 6 | 2020 | 4.597 | 3.771 | 17.769 | 0.000 | 5.749 |
| 7 | 2020 | 4.495 | 3.386 | 10.489 | 0.111 | 5.496 |
| 8 | 2020 | 4.534 | 3.415 | 13.750 | 0.236 | 5.720 |
| 9 | 2020 | 4.115 | 3.907 | 14.053 | 0.346 | 5.186 |
| 10 | 2020 | 4.172 | 3.175 | 15.422 | 0.360 | 5.157 |
| 11 | 2020 | 4.198 | 2.496 | 14.955 | 0.090 | 5.678 |
| 12 | 2020 | 5.383 | 3.395 | 24.462 | 0.669 | 7.197 |

# Results - Metropolitana



# Take home messages and Further Directions

- We proposed a valuable model to predict the number of events occured on the SOREU **Pianura** and **Metropolitana**;
- capturing the **daily** and **seasonal** variation and incorporating **epidemiological** aspects as well as **weather** information.

Further direction would be applying

- the **Generalized Additive Mixed Models** to better deal with the data autocorrelation structure;
- a **Bayesian extension** assigning appropriate Markov random field priors with different forms and degrees of smoothness to deal with the trend and seasonal components.

Thanks to the amazing TSUNAMI group that worked on this project and thanks for your attention!

You can find the full analysis on `https://github.com/angeella/Tsunami_project`.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