Short-Term Electricity Load Forecasting: Modelling the COVID-19 Lockdown in Spain

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Electric load forecasting:

- Peculiarity of electric energy: demand = generation at all time

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Electric load forecasting:

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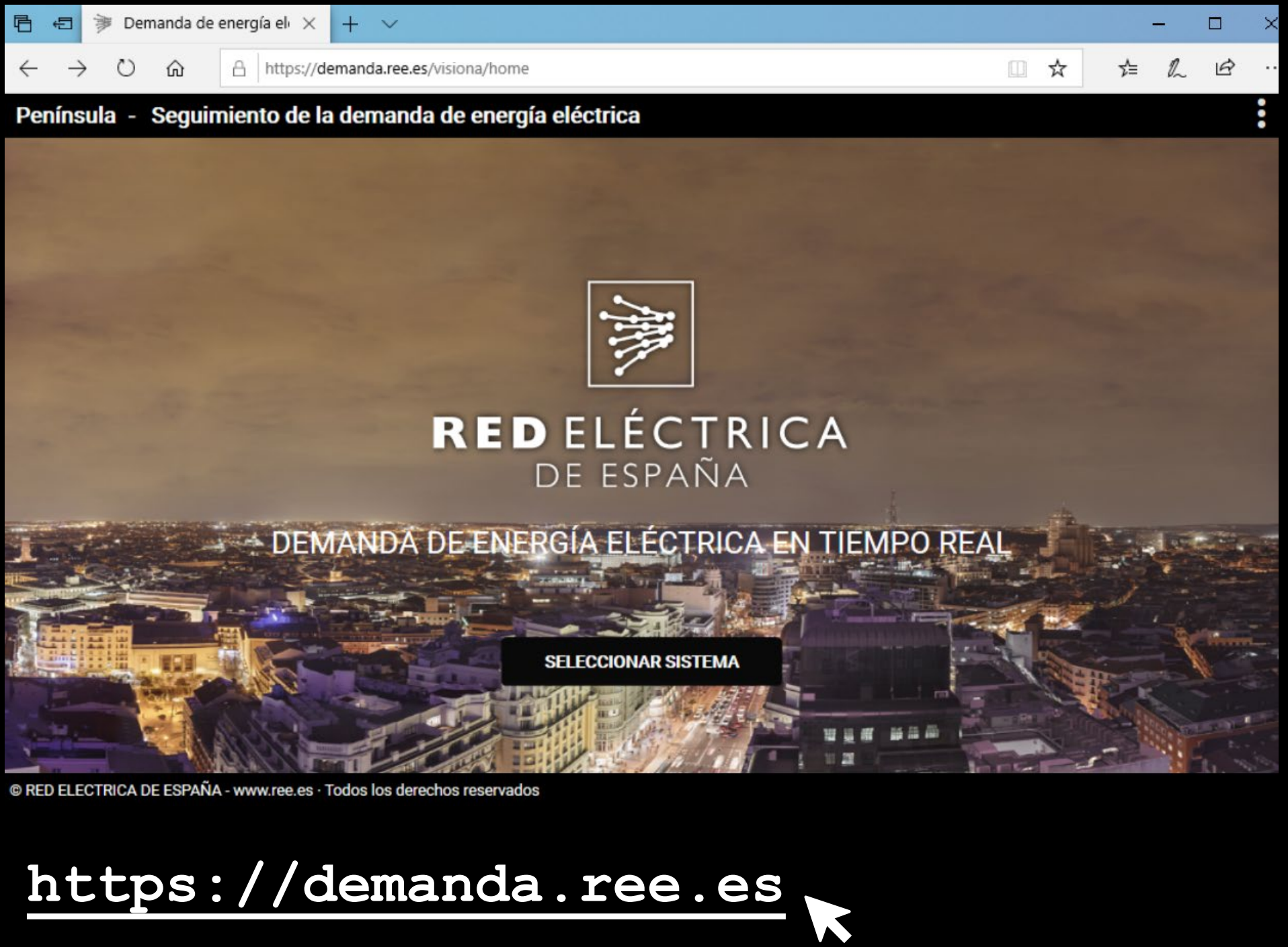
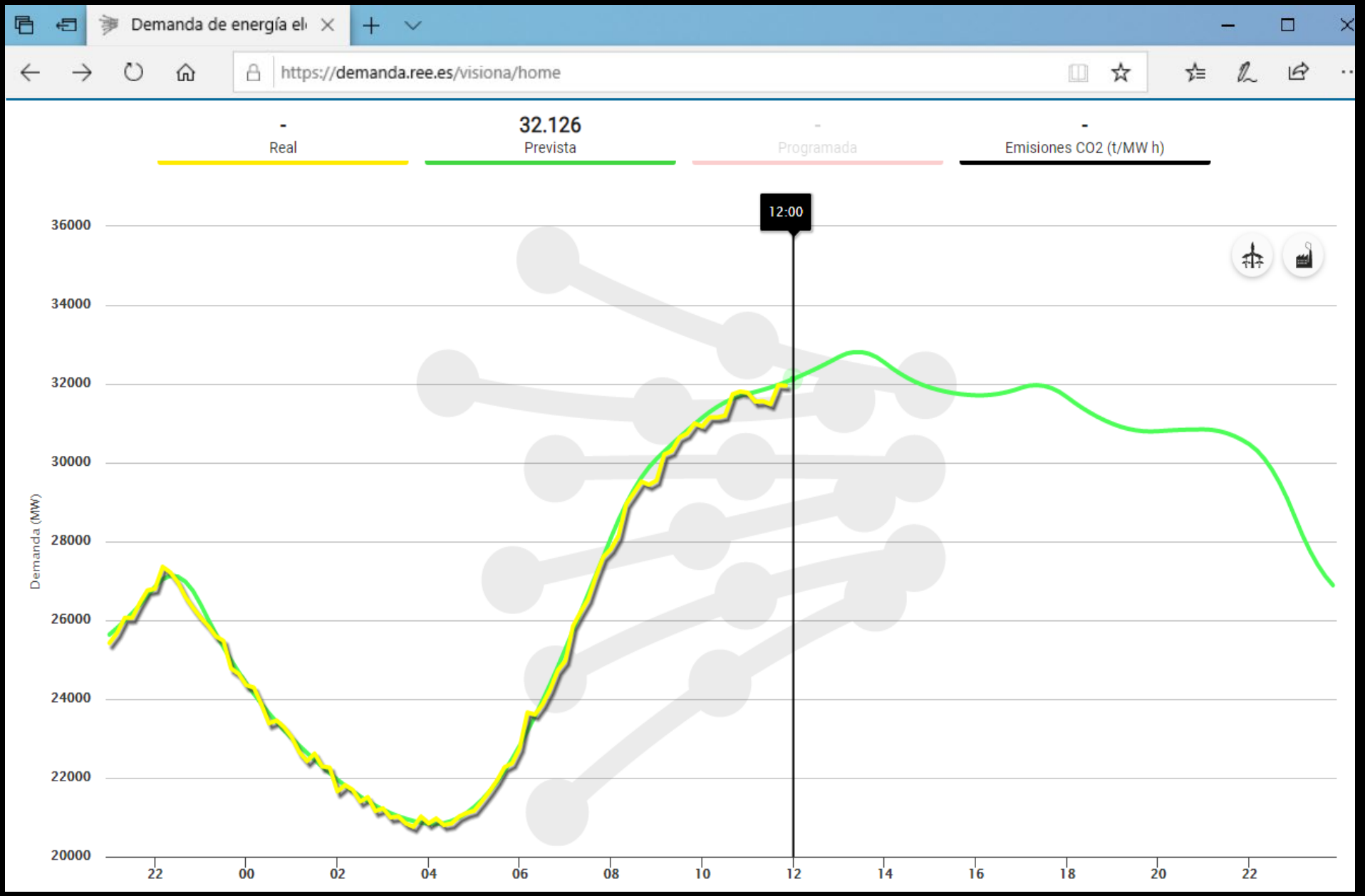
Need of accurate forecasts



https://demanda.ree.es



https://demanda.ree.es

Mathematical model:

First step: 24 hourly models:

Seasonal ARIMA with regressors

$$y_{t(h,d)} = \beta_h^T \mathbf{x}_d + z_{t(h,d)}$$

$$\phi_h(B)\nabla_{s_1}^{D_1}\nabla_{s_2}^{D_2} z_{t(h,d)} = \theta_h(B^{s_1})\Theta_h(B^{s_2})w_{t(h,d)}$$

Second step: "unifying" ARMA model

More info:

Periodically correlated models for short-term electricity load forecasting.
E. Caro, J. Juan, J. Cara. *Applied Mathematics and Computation, Vol. 363, 1 January 2020*

Forecast accuracy: **average error of 1.5%**

- Electric load forecasting
  - Temperature's influence
  - Holidays' influence
  - Solar radiation's influence
- Modelling the COVID-19 lockdown

- Electric load forecasting
  - **Temperature's influence**
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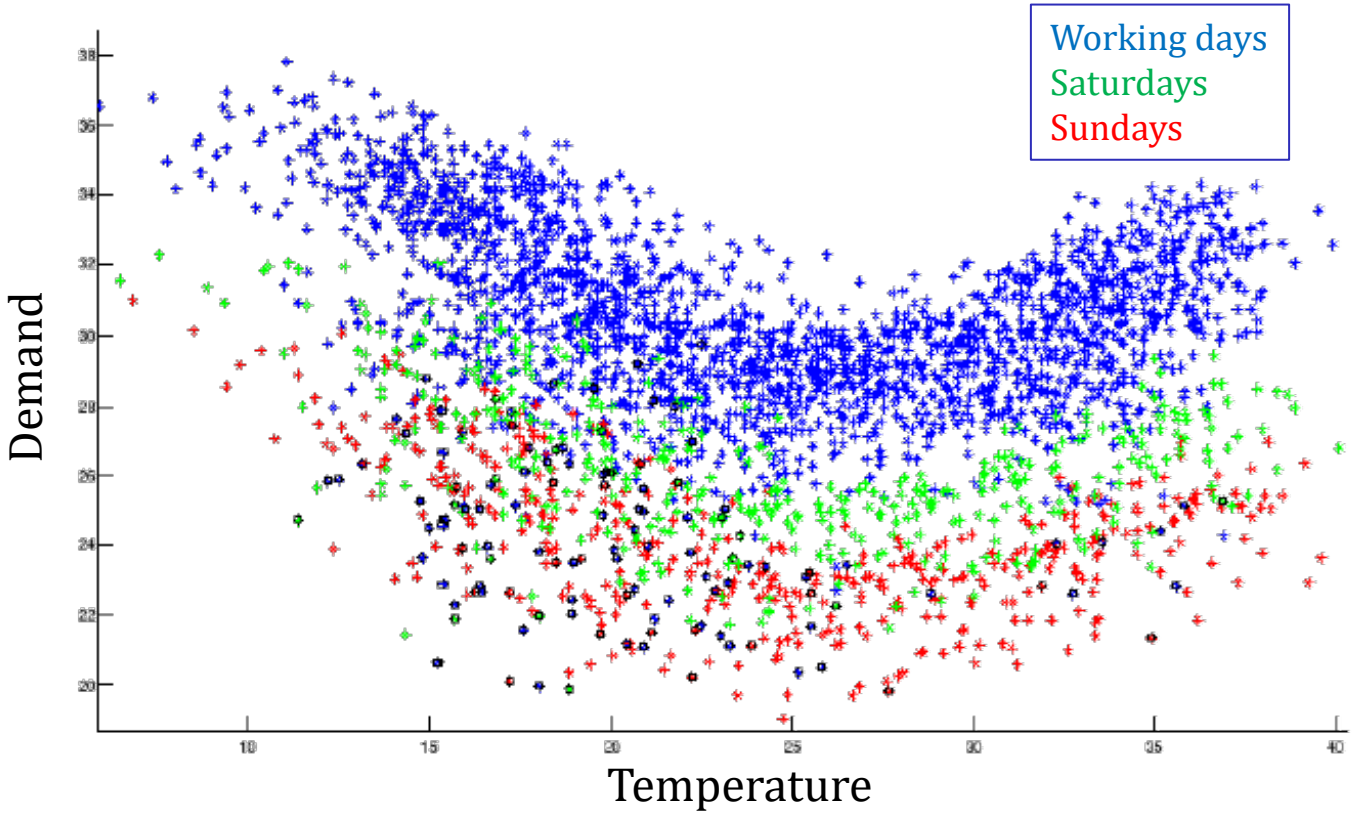
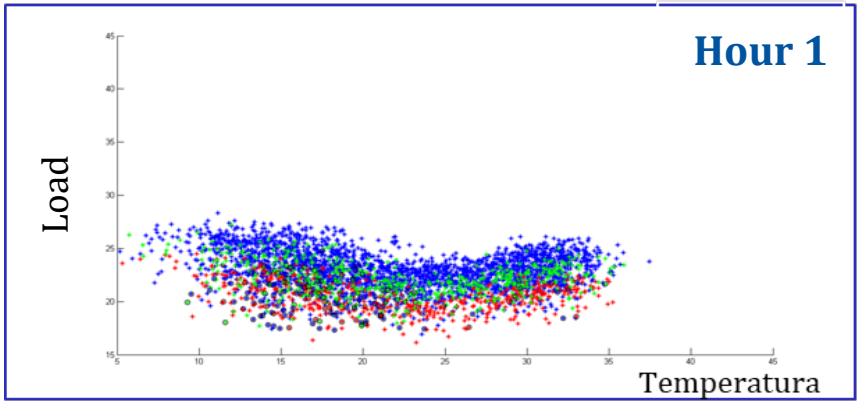
Model for the thermic effect:

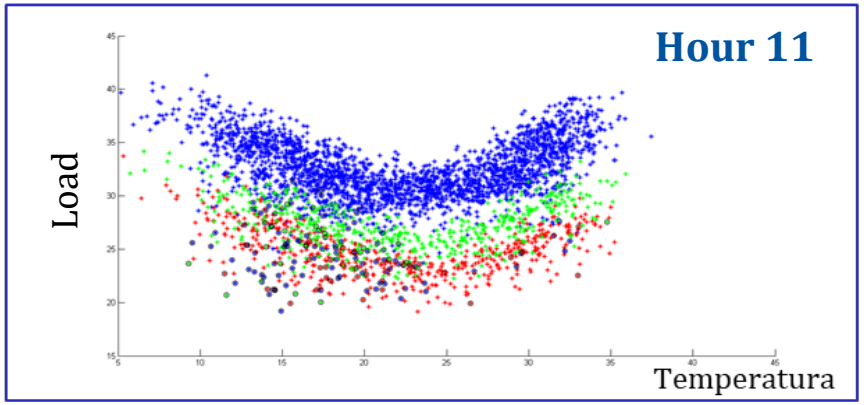
- Significant influence of the temperature
- **Non linear effect**

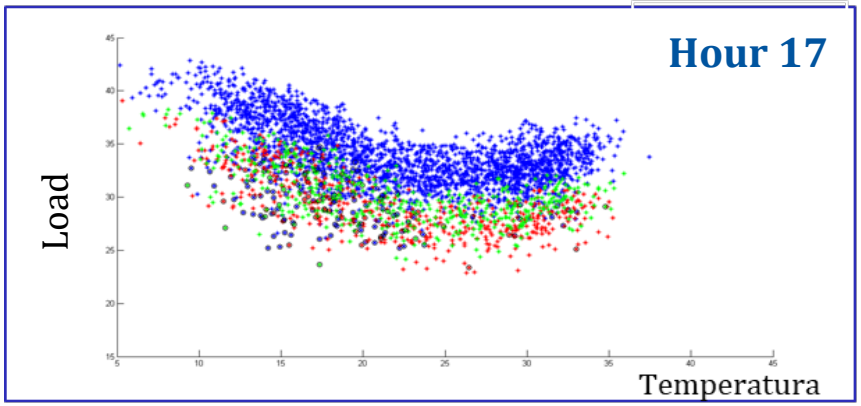


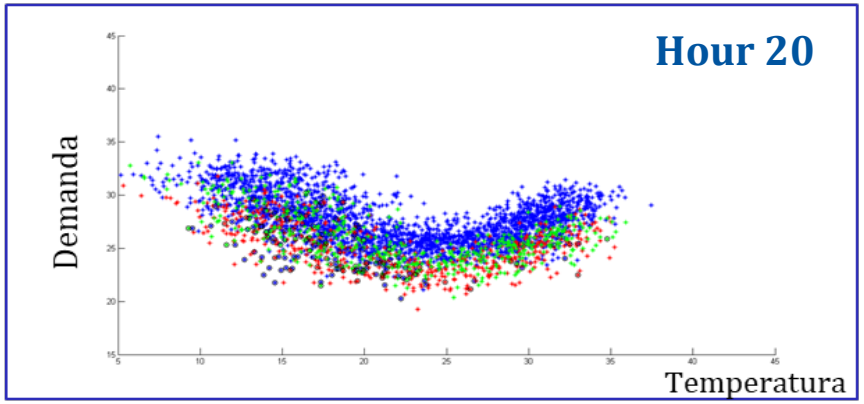
Model for the thermic effect:

- The effect depends on the hour









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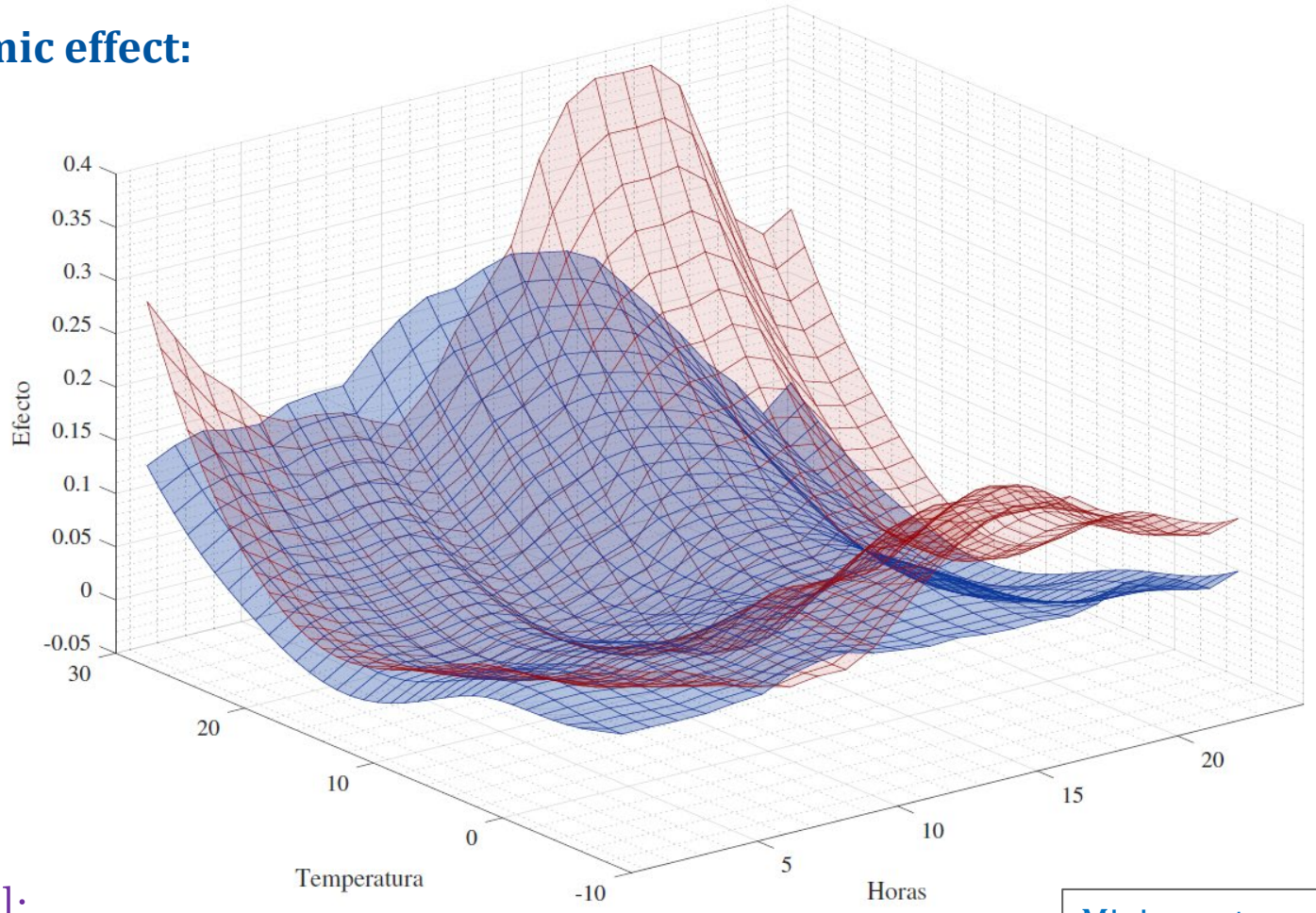
Model for the thermic effect:

- Max. and min. daily temperatures

- Working and non-working interaction

- "*d*-1", "*d*-2" & "*d*-3" temperature of previous days



Minimum temp.
Maximum temp.

Temperature model:
Aprox. 2.000 parameters to be estimated!

- Electric load forecasting
  - Temperature's influence
  - Holidays' influence
  - Solar radiation' influence
- Modelling the COVID-19 lockdown

Model for the Holidays

The Spanish working calendar considers:

- Eight National Holidays
- Several regional holidays specific for each region.

They require a specific model:

- The influence depends on the hour
- The influence depends on the day of the week
- The influence affects the previous/following days

Model for the Holidays

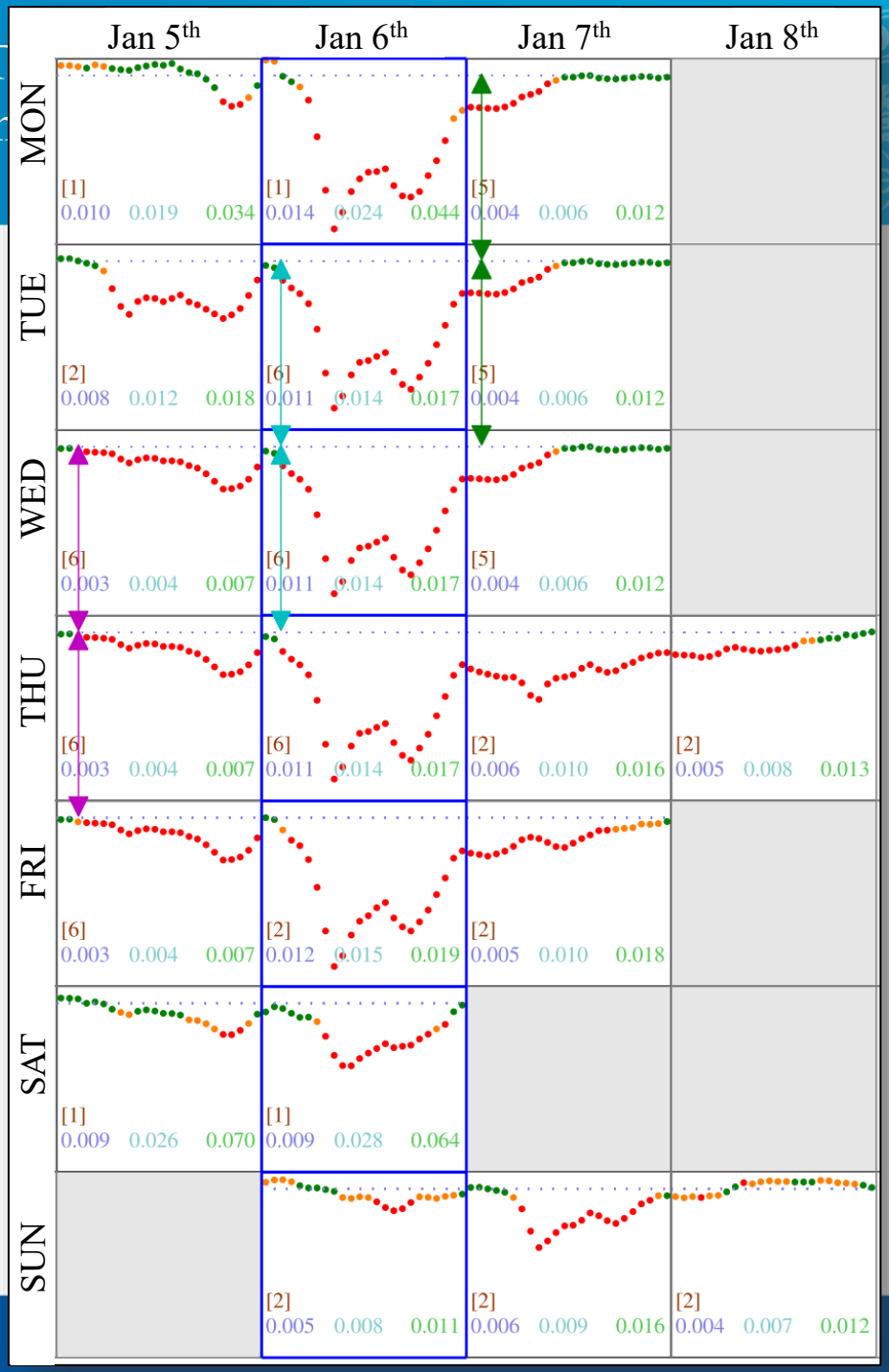
$$y_h = \beta_0 + \beta_1 \cdot x_1 + \ \ldots + \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{MON}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{TUE}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{WED}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{THU}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{FRI}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{SAT}$$
$$+ \ \beta_{30Apr} \cdot x_{30Apr} + \beta_{1May} \cdot x_{1May} + \beta_{2May} \cdot x_{2May} + \ \ldots \quad \textbf{SUN}$$

Model for holidays:
More than 5.000 parameters to be estimated!

Short-T
Modelling th

Model for the Holidays

Influence of the
National Holiday
January 6th
over the demand



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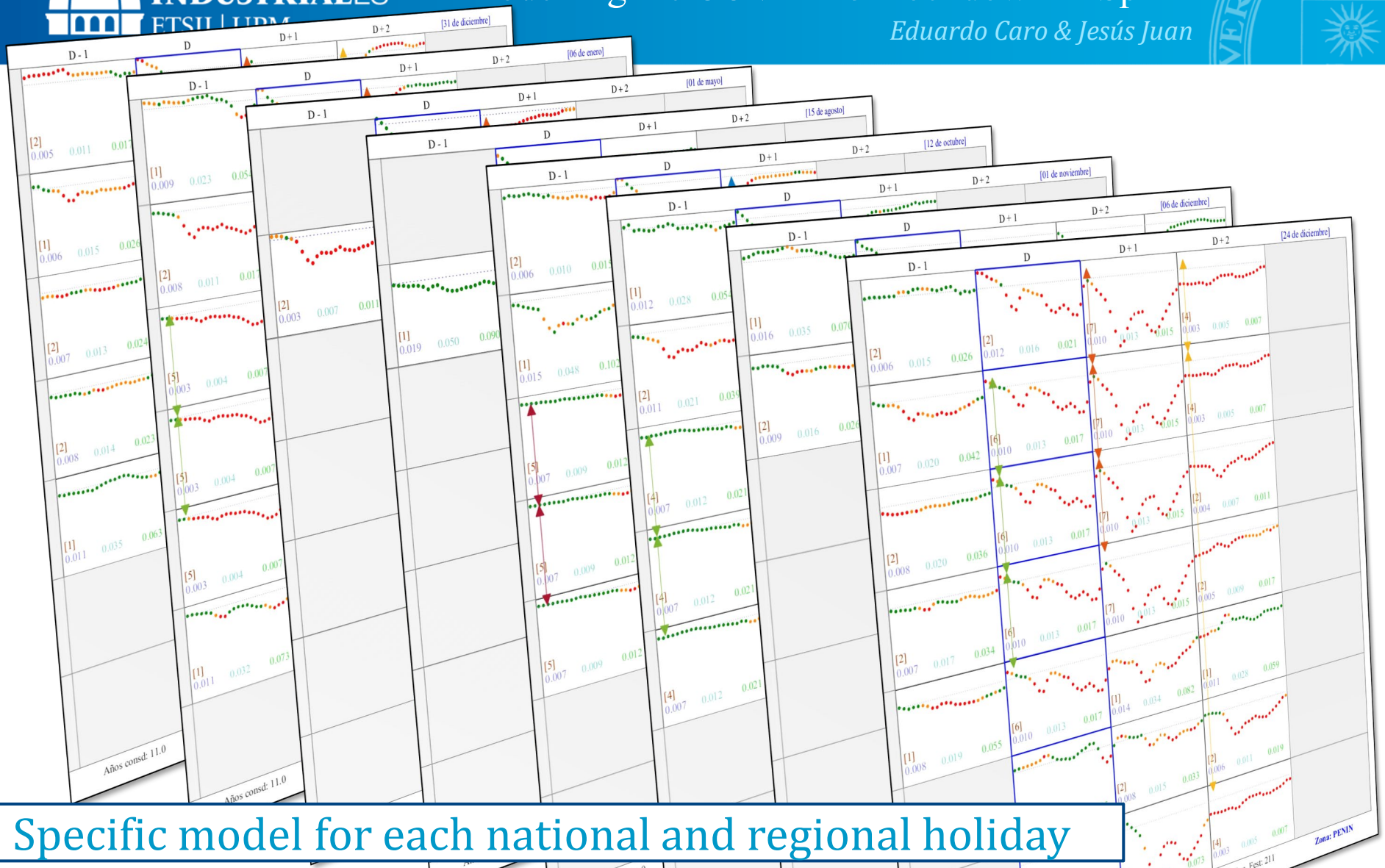

Specific model for each national and regional holiday

- Electric load forecasting
  - Temperature's influence
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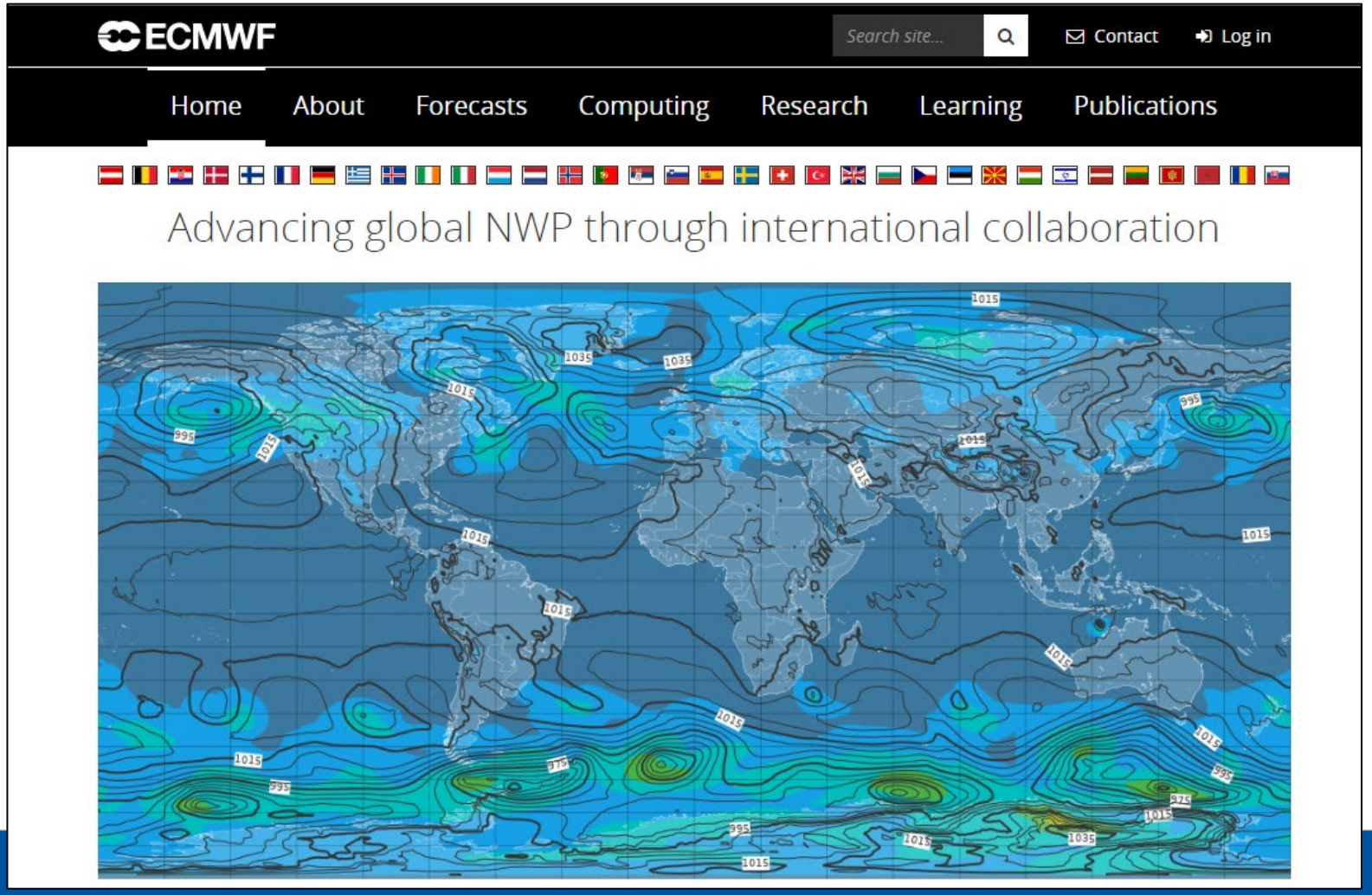
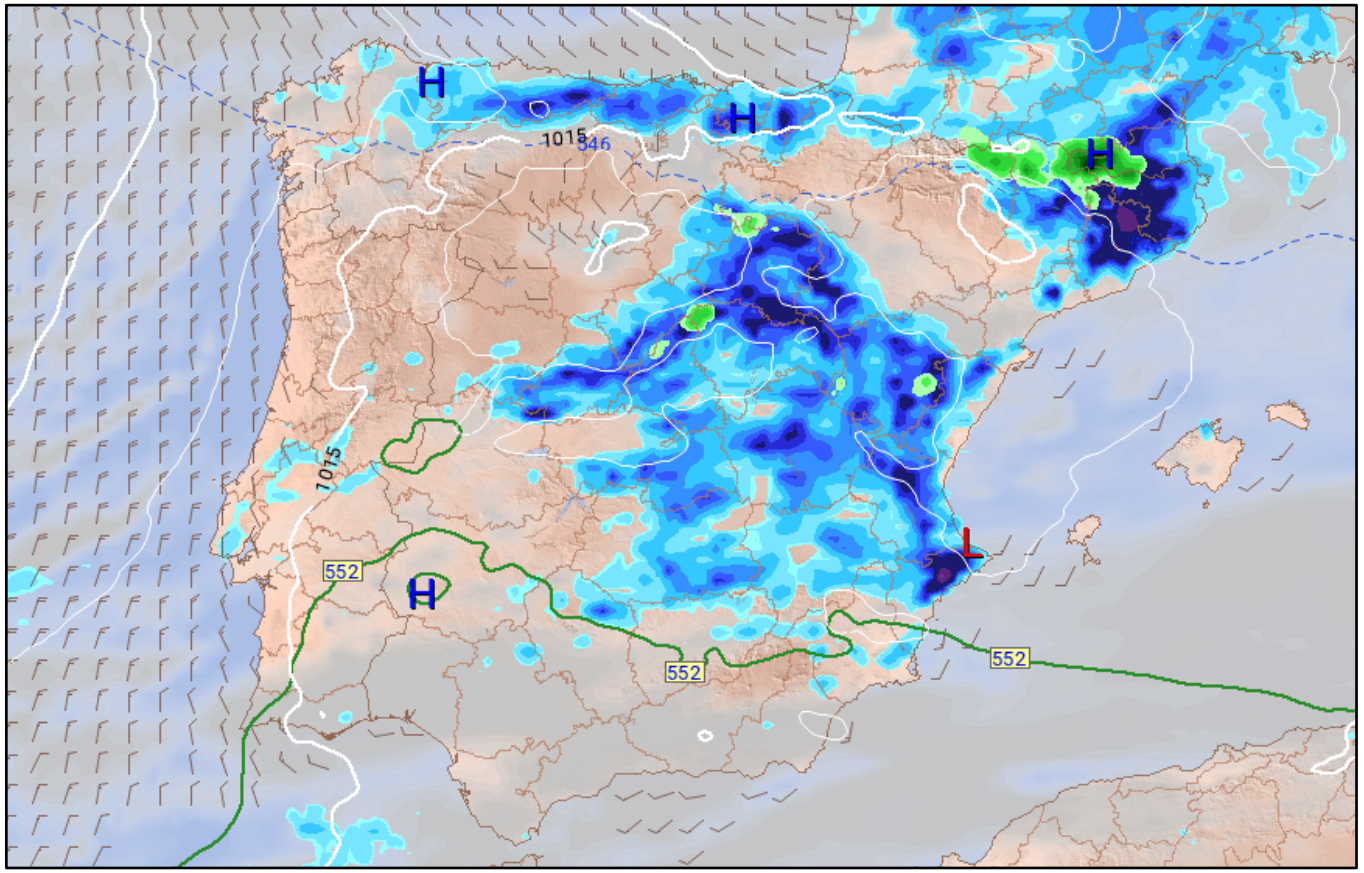
Model for additional meteorological variables

ECMWF - *European Centre for Medium-Range Weather Forecasts*



Model for additional meteorological variables



Grid resolution: ~ **9 km**

Data size: 7 years of historic --> several **dozens of Gb** of compressed files!

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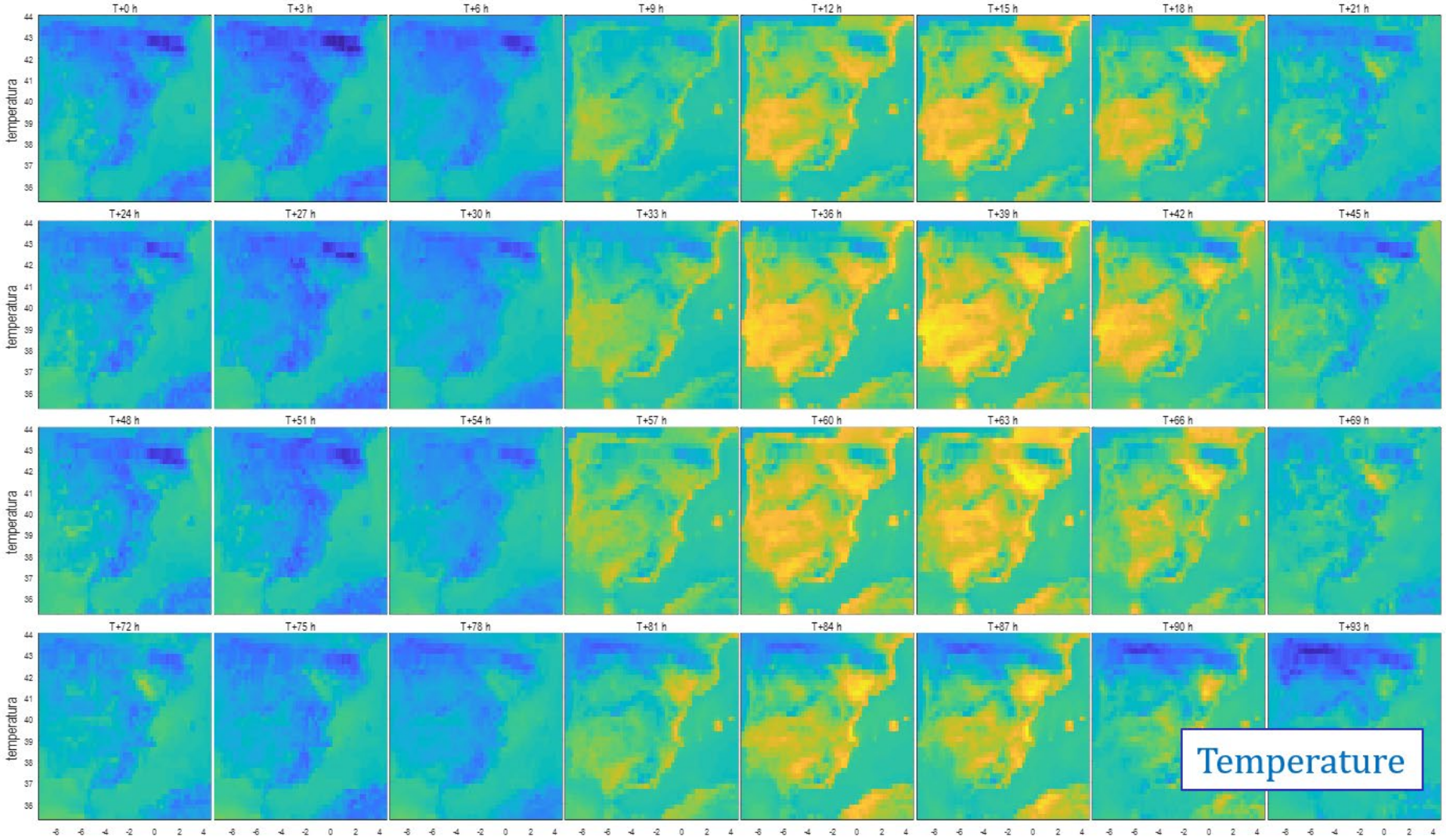

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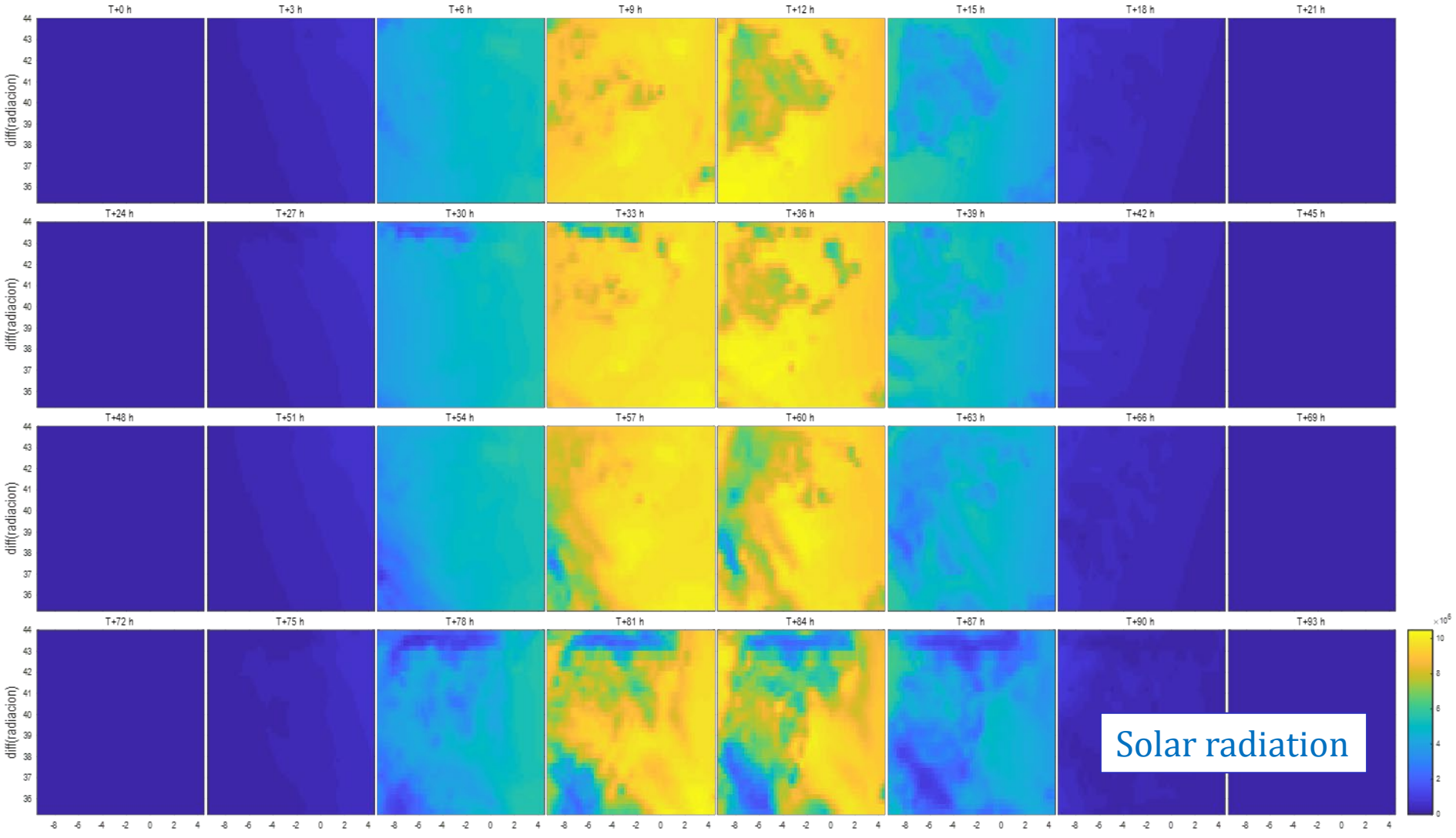

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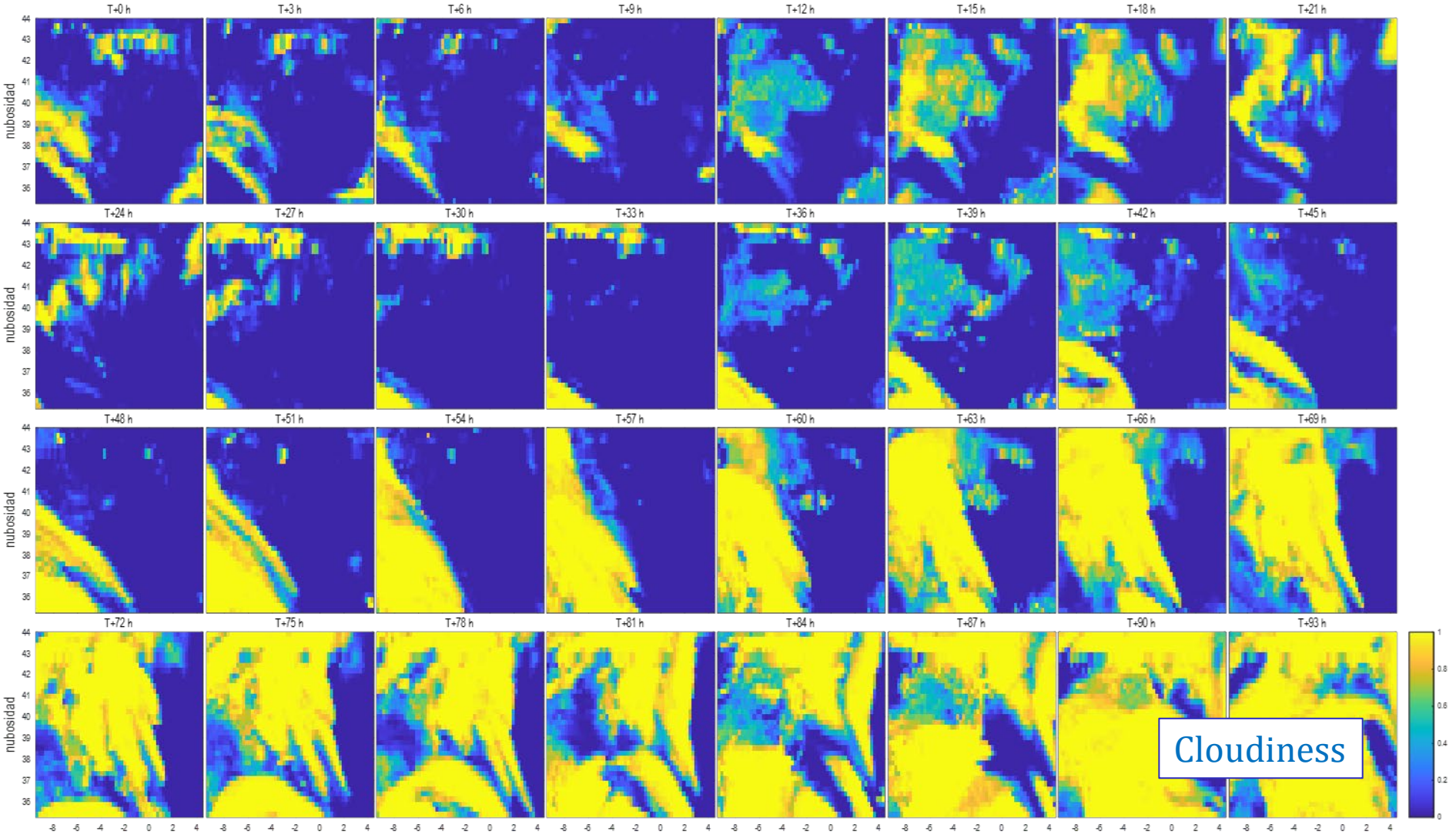

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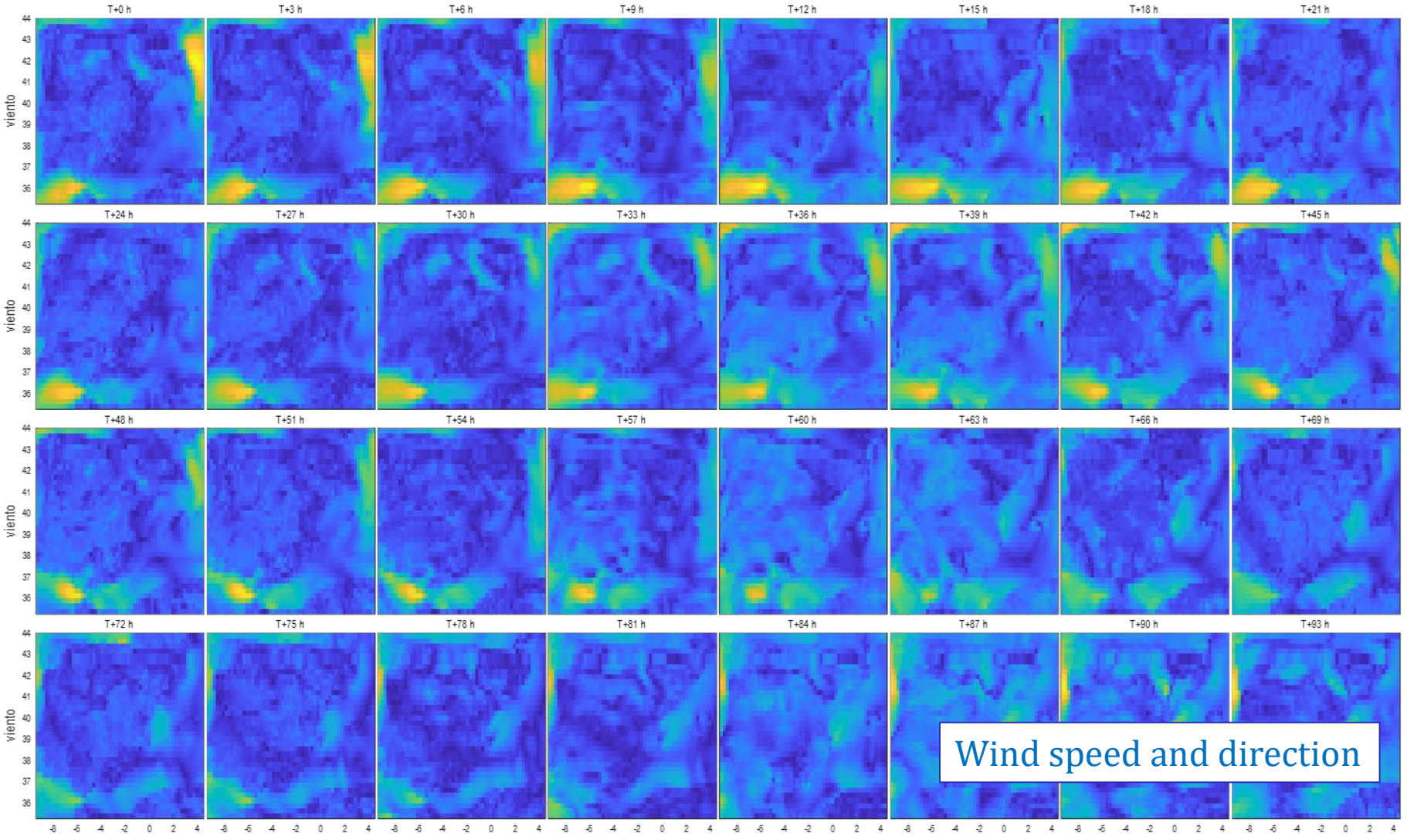
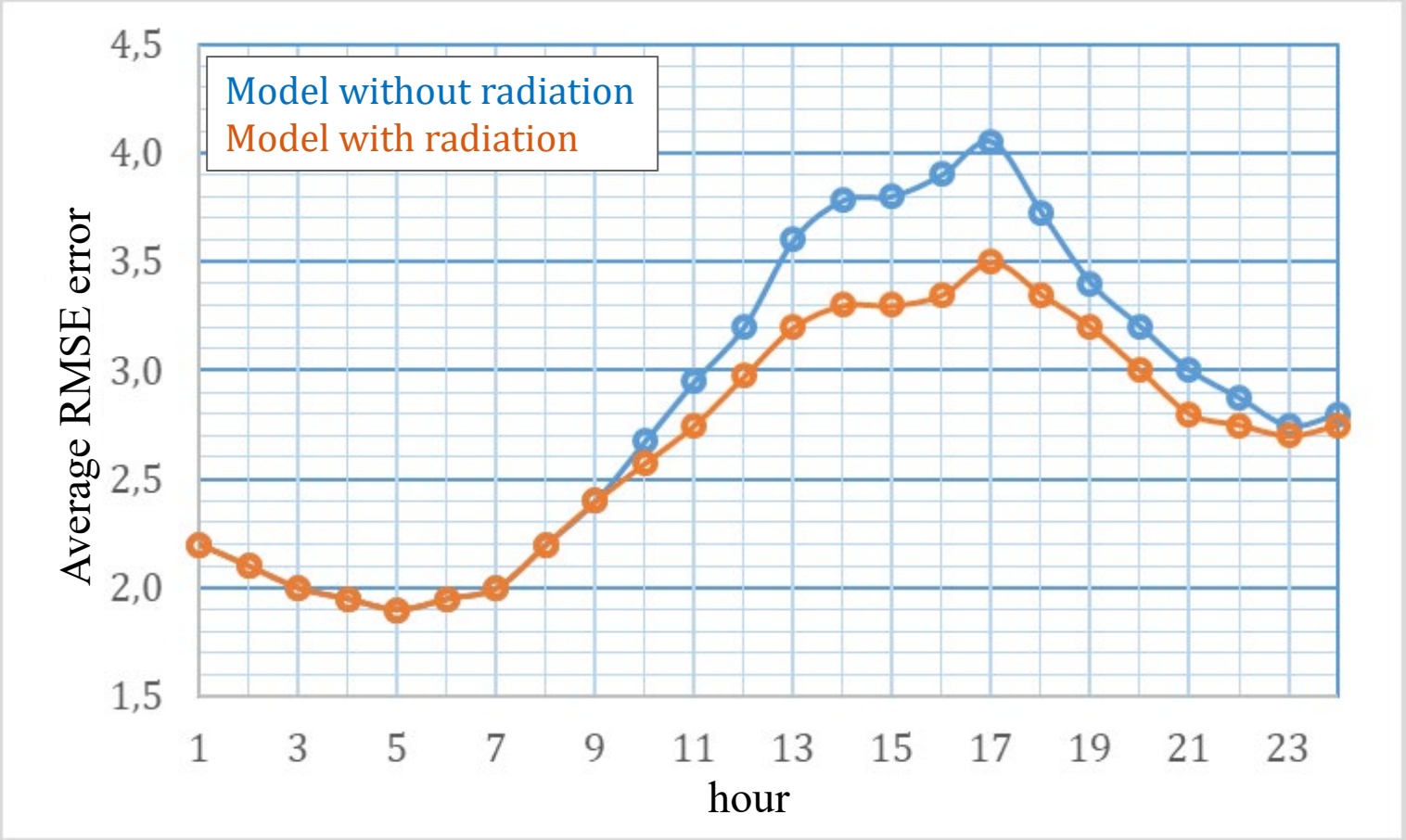


Solar radiation effect for an Spanish island:

- Hourly average errors



- Electric load forecasting
  - Temperature's influence
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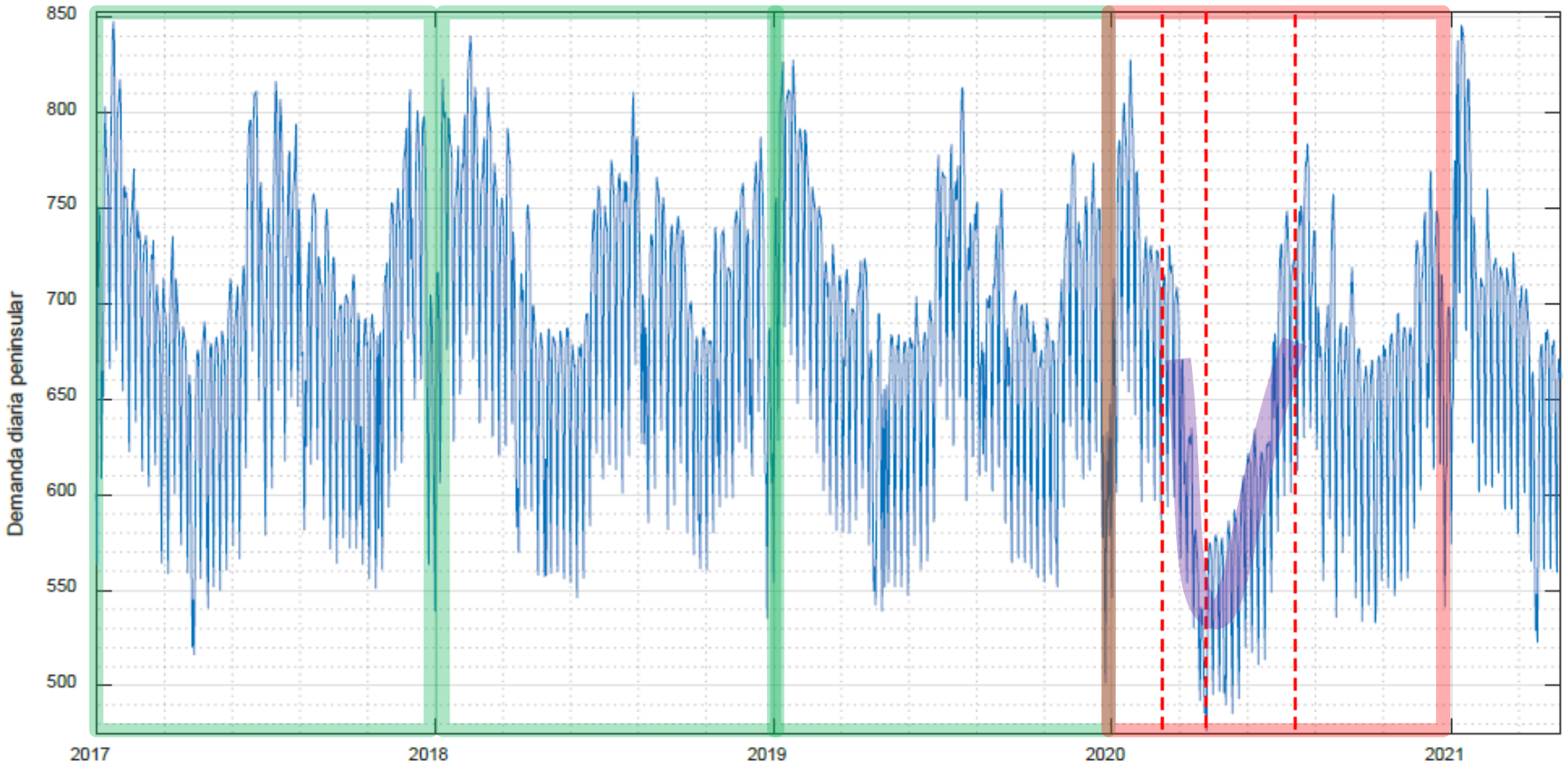
- **Spanish daily demand**



Peninsular daily demand since 2017.
Two stages are observed in 2020: decreasing and then increasing trend.

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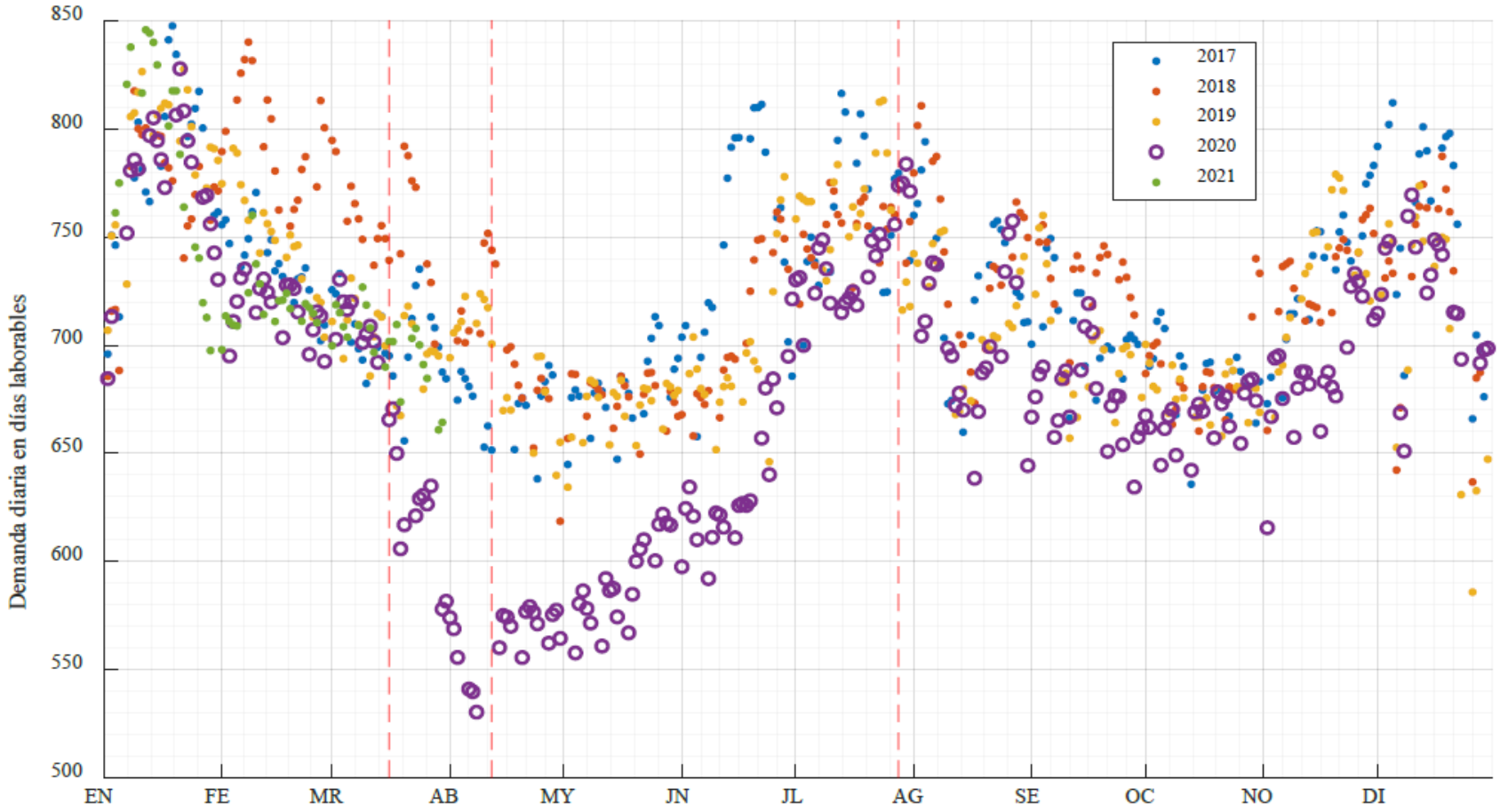
- **Spanish daily demand**



Peninsular daily demand since 2017 for weekdays.

- **Calendar of political decisions:**

  Two stages:

  - State of alarm and confinement
  - De-escalation (or *return to normality*)

Mes	Lu.	Ma.	Mi.	Ju.	Vi.	Sá.	Do.
Mar. 2020	2	3	4	5	6	7	8
	9	10	11 Suspensión docencia	12	13	14	15
	16 Comienzo estado de alarma	17	18	19	20	21	22
	23	24	25	26	27	28	29 Cambio de hora
	30 Suspensión de actividad no esencial	31	1	2	3	4	5
Abr. 2020	6	7	8	9 Jueves Santo	10 Viernes Santo	11	12
	13 Reanudación de actividad no esencial	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	1	2	3

Stage 1: State of alarm and confinement

Stages 2: return to normality

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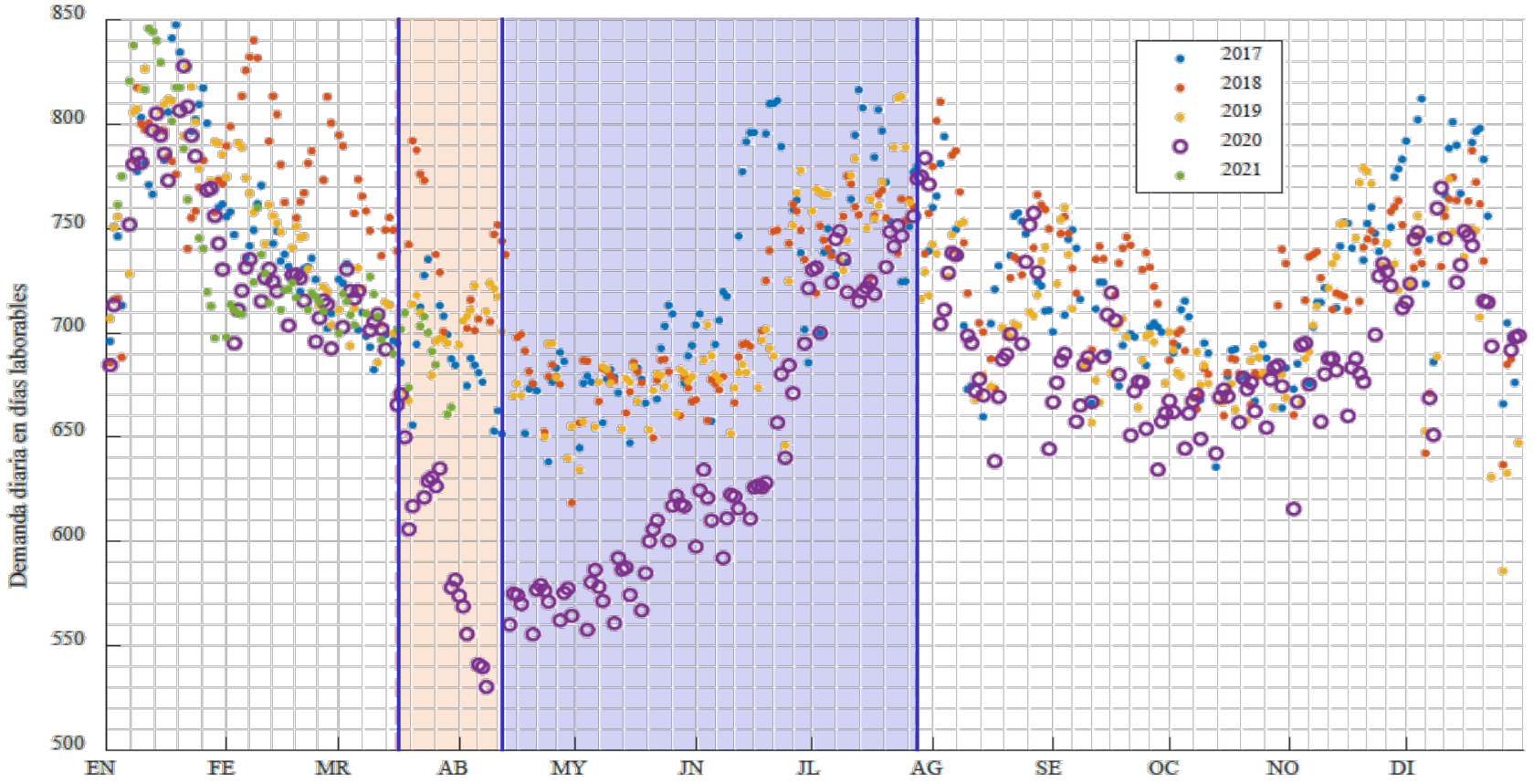
- **Confinement & de-escalation effect: two-phase modeling**



Containment phase: 16/March/2020 to 12/April/2020

De-escalation phase: from 13/April/2020 to 28/June/2020

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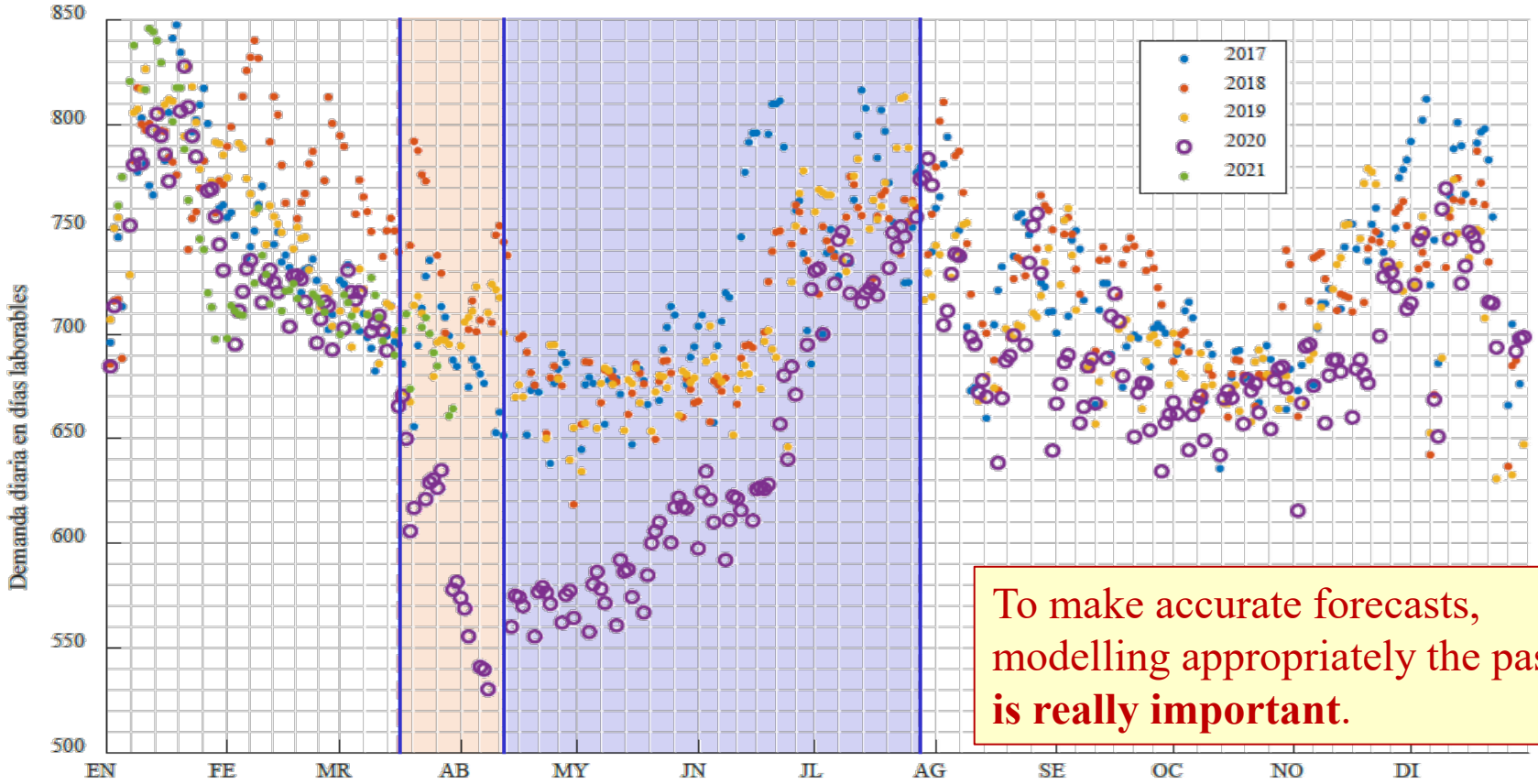
- **Confinement & de-escalation effect: two-phase modeling**



To make accurate forecasts, modelling appropriately the past **is really important**.

Containment phase: 16/March/2020 to 12/April/2020

De-escalation phase: from 13/April/2020 to 28/June/2020

- **Confinement & de-escalation effect:** Proposed mathematical model

- ***Model for the confinement phase***

  - Parameter date_1 = 16/March/2020
  - Parameter date_2 = 12/April/2020

$$x_{1,d} = \begin{cases} 0 & d < \text{date}_1 \\ 1 & \text{date}_1 \le d \le \text{date}_2 \\ 0 & \text{date}_2 < d \end{cases}$$

$$x_{2,d} = \begin{cases} 0 & d < \text{date}_1 \\ \dfrac{d - \text{date}_1 + 1}{\text{date}_2 - \text{date}_1 + 1} & \text{date}_1 \le d \le \text{date}_2 \\ 0 & \text{date}_2 < d \end{cases}$$

- ***Model for the de-escalation phase***

  - Parameter date_1 = 13/April/2020
  - Parameter date_2 = 26/July/2020

$$x_{3,d} = \begin{cases} 0 & d < \text{date}_1 \\ 1 & \text{date}_1 \le d \le \text{date}_2 \\ 0 & \text{date}_2 < d \end{cases}$$

$$x_{4,d} = \begin{cases} 0 & d < \text{date}_1 \\ \dfrac{d - \text{date}_1 + 1}{\text{date}_2 - \text{date}_1 + 1} & \text{date}_1 \le d \le \text{date}_2 \\ 0 & \text{date}_2 < d \end{cases}$$

$$x_{5,d} = \begin{cases} 0 & d < \text{date}_1 \\ \dfrac{(d - \text{date}_1 + 1)^2}{(\text{date}_2 - \text{date}_1 + 1)^2} & \text{date}_1 \le d \le \text{date}_2 \\ 0 & \text{date}_2 < d \end{cases}$$

- *Effect of laborality:*

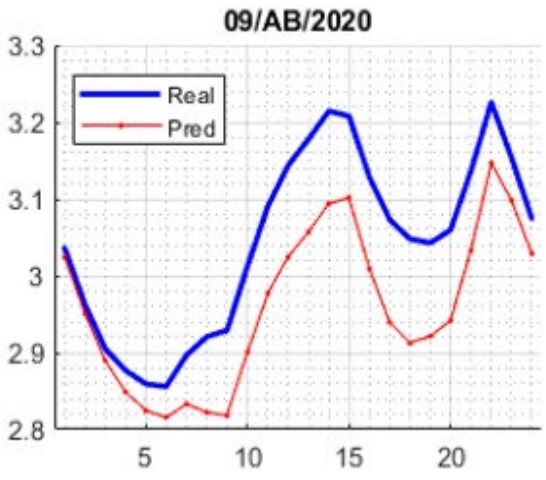
$$\sum_{i=1}^{5} z_{labor} \cdot \beta_{i,labor} \cdot x_{i,d} + \sum_{i=1}^{5} (1 - z_{labor}) \cdot \beta_{i,fest} \cdot x_{i,d}$$

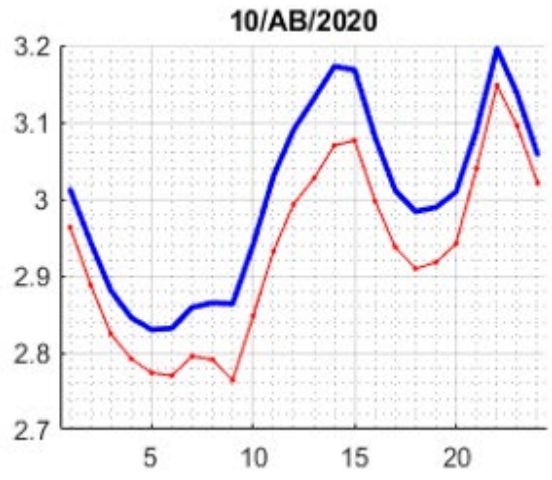
- **Second effect observed: influence over holidays**
  - Effect of COVID on holidays:

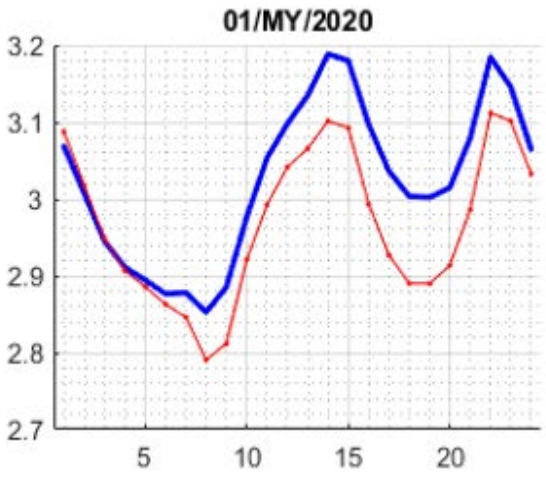
    On several occasions, for national holidays,

    predictions were **much lower** than actual demands.

Actual demand and forecast demand for Holy Week (Thursday-Friday) and May 1st





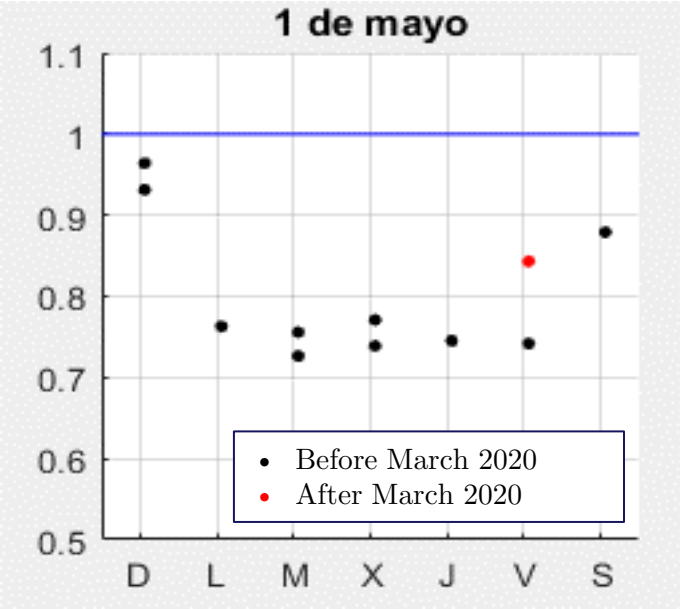


- The "diminishing" of the festive effect has been studied.

Let's imagine that I want to study the variation caused by "Friday, May 1, 2020".

I compare it with the demand of the previous and subsequent Friday I calculate the "variation".

$$variation = \frac{\text{demand(May } 1^{st}\text{)}}{0.5 * \text{demand(May } 1^{st} - 7 \text{ days)} + 0.5 * \text{demand(May } 1^{st} + 7 \text{ days)}}$$



If we analyze the last "1-May", usually this holiday caused a 25% decrease in demand.

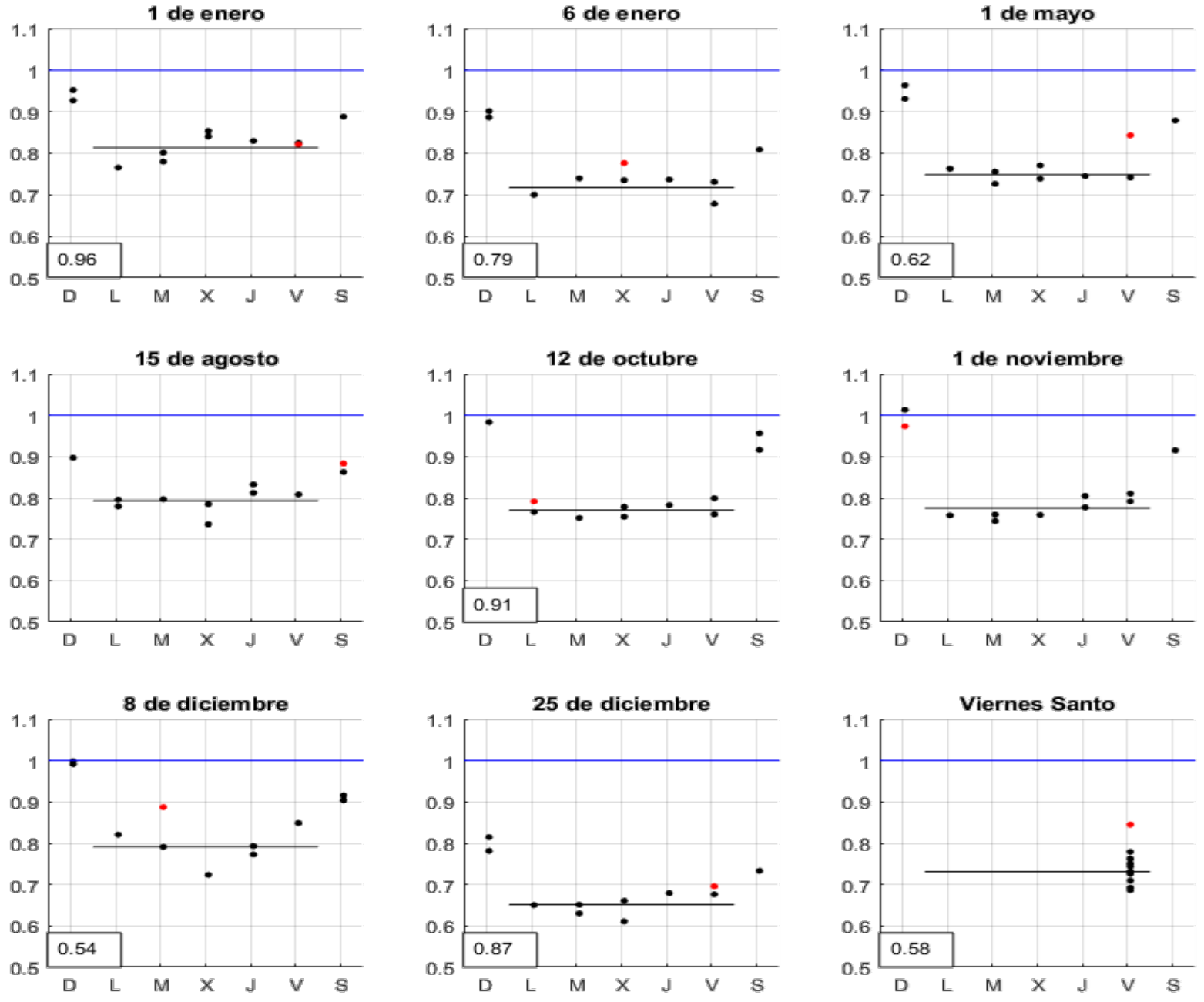
However, in 2020 demand dropped by 15%.

It was due to "confinement + de-escalation".

Therefore, our intervention in the program during 2020 and 2021 has been to "de-escalate" the effect of the holidays.

Even in 2021, this effect will be maintained, due to the increase in teleworking..

The holidays that have occurred during the pandemic have been analyzed in detail.



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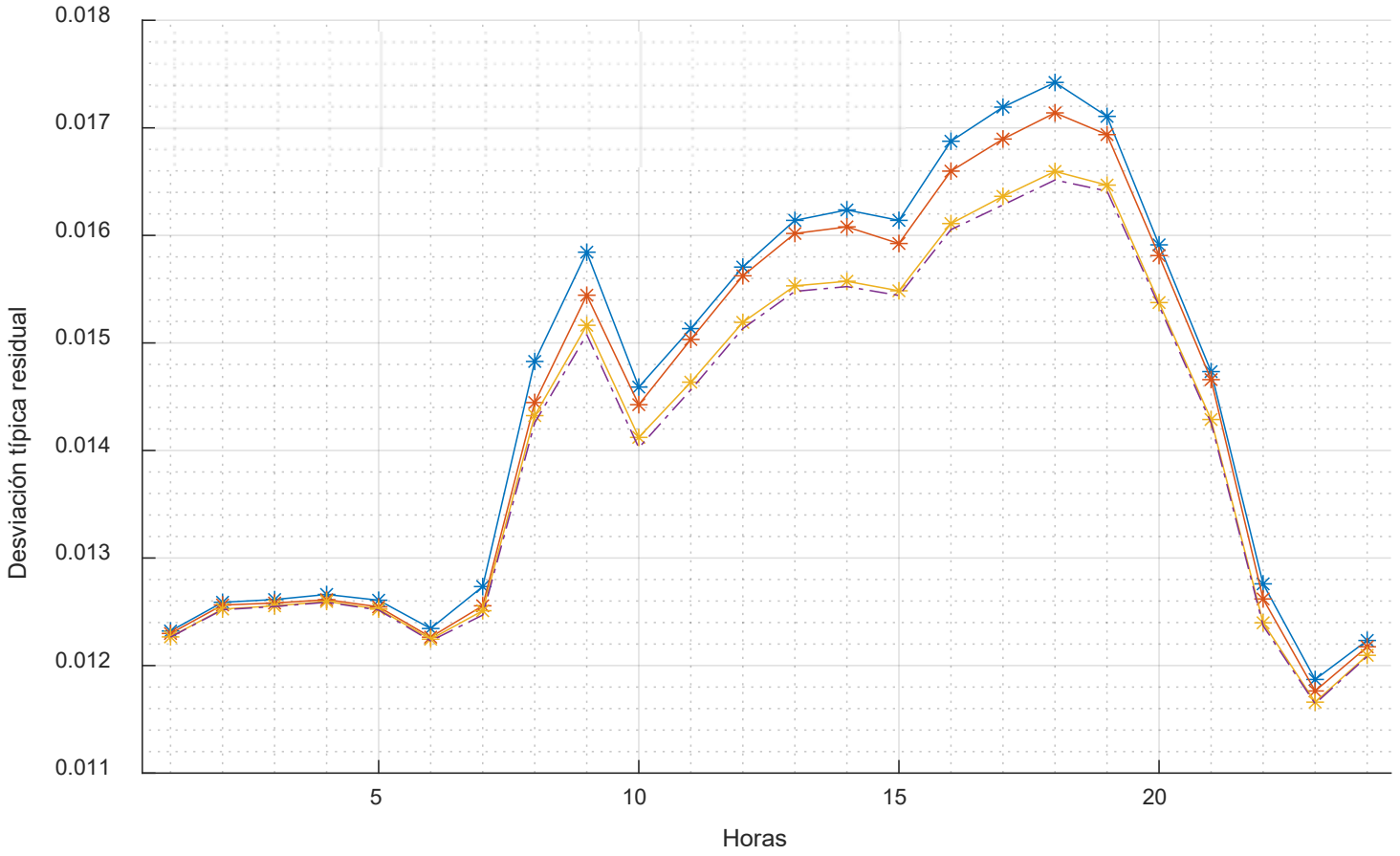
- Results:
  - Baseline model (without any intervention).
  - Baseline + confinement/de-escalation (8 regressors)
  - Benchmark + confinement/de-escalation (8 regressors) + "holiday effect" (0 regressors)



Conclusions:

- The impact of COVID-19 lockdown over the Spanish electricity demand has been studied.
- A model for the COVID-19 lockdown's impact over the electric load has been proposed.
- The proposed model improves the forecasting accuracy.


Thank you for your attention!