How Callendar can accurately predict weather-related outage at nuclear plants?

The challenge

In France, more than two thirds of electricity come from nuclear reactors. This production is frequently disrupted by heatwaves or droughts.

Such disruptions have material impacts on electricity markets: on July 25, 2019, for example, heat-related outages on 9 reactors caused the spot electricity market to spike above 70€/MWh, one of the highest prices in 2019.

The issue

One of the major factors in these outages is river water temperatures. When the temperature upstream is too high, power plants can not use it to cool their turbines while complying with maximum downstream temperature regulation and are forced to reduce load or shut down. As a result, accurate water temperature data are key to predict weather-related nuclear reactors outages.

Unfortunately, it is difficult to create accurate water temperature models because publicly available data are biased compared to the EDF's measurements. As a result, a model trained or calibrated on these data cannot correctly predict the operator decisions, like shutting down or reducing load.

Our solution

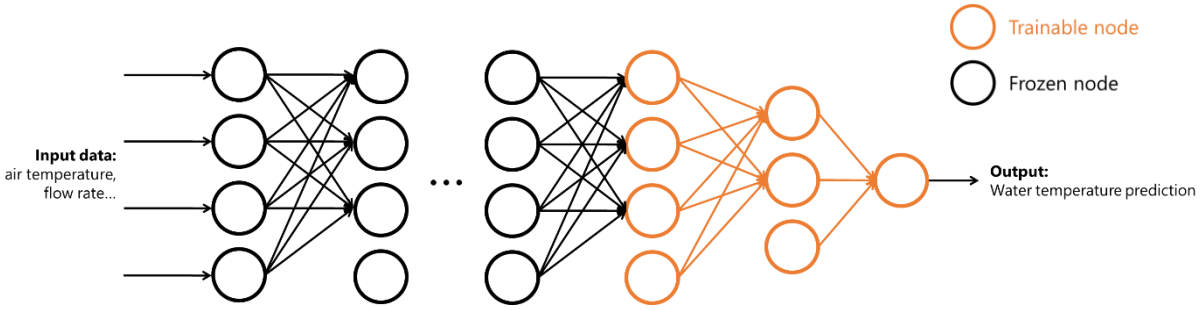
Callendar developed an innovative solution for uniquely accurate prediction of water temperature:

1. First, we **train a deep neural network on publicly available water temperature data**. The goal of this first training is to learn the general physics of the river: how does the water temperature react to variation of air temperature, river flow, etc.

Initial training: all nodes in the neural network are trained

2. We **use data mining to collect water temperature measured by the plant operator**. EDF does not regularly publish those data but by analyzing various sources (environmental reports, newsletter, press release…) we can assemble a small dataset of an unbiased water temperatures.

3. We then **use transfer learning**: we retrain the last layers of the neural network using unbiased data.



Transfer learning: the first layers of the neural network are frozen before it is retrained with unbiased data, only the last nodes are optimized

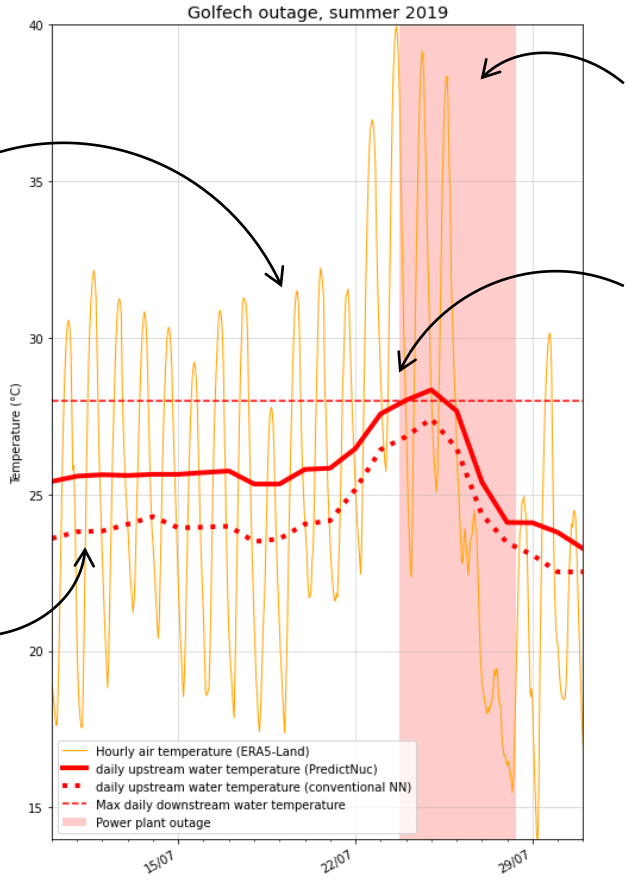
This approach allows us to reproduce past outages with far better performances both in precision and recall.

An illustration

In the summer of 2019, Golfech power plant in the south-west of France was shut down during a heatwave.

Starting on July 20, air temperature increases sharply in Golfech area.

A conventional machine learning model outputs a water temperature following similar trend but lower and fails to predict the outage.



From July 23 to July 28, Golfech was completely shut down.

Our model correctly predicts that upstream water temperature reaches 28°C, the maximum temperature allowed downstream, on July 23.