Laboratoire de Météorologie Dynamique
École Polytechnique

Sizing of a short-term wind forecasting system

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5th July 2019 - **Journée du SIRTA**

Context and motivation

Why short term wind energy forecasts ?

→ Worldwild **increasing** number of **wind farms** each years

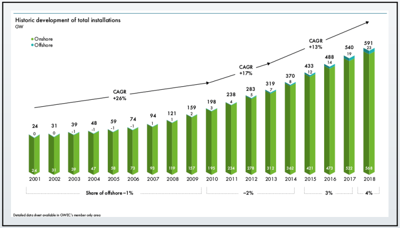


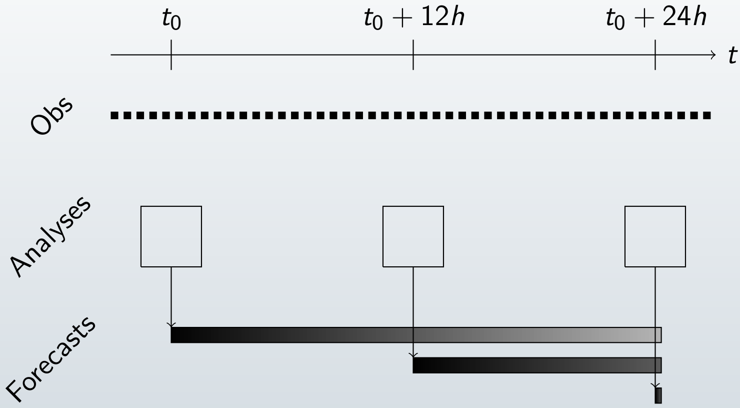
Figure: Historic development of total installation in GW. *Extracted from GWEC Report 2018.*

→ **Forecasts** on several time scales becoming **necessary** (anticipate energy production, plan maintenance operations, etc...)

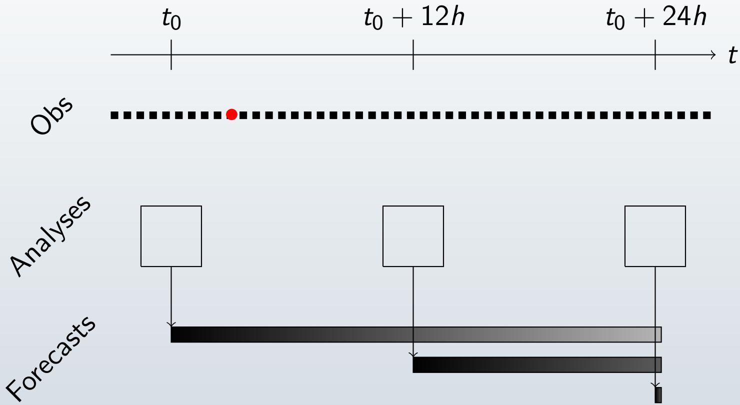
→ The end of the **feed-in tariffs** make short-term forecasts vital for wind energy **producers**

Sub-hourly forecast of averaged wind speed

Averaged wind speed forecasts



Averaged wind speed forecasts



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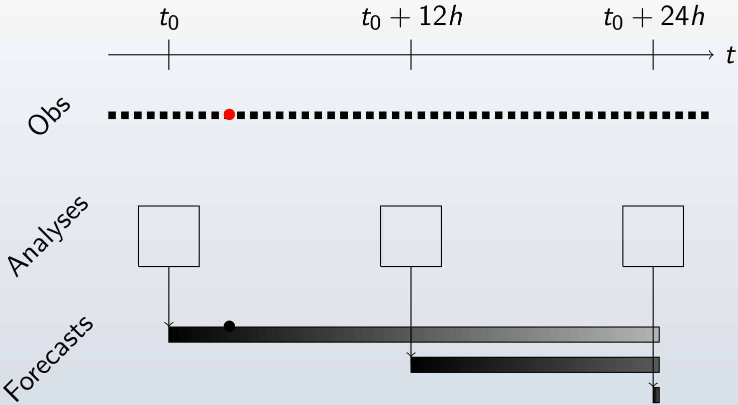

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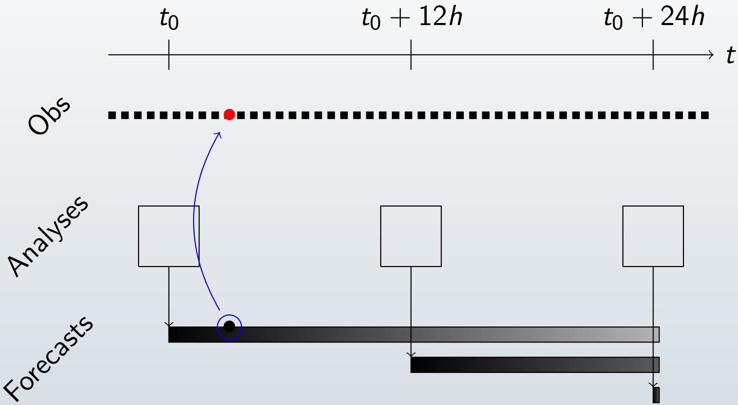

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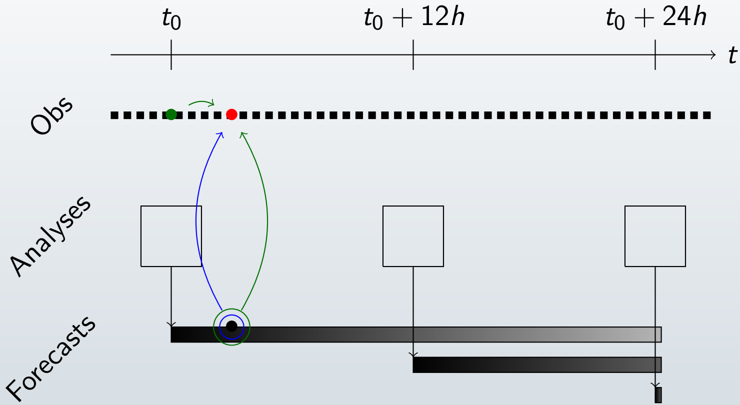


Data and methodology

Linear regression over N explanatory variables extracted from **ECMWF hourly forecasts**:

$$\widehat{y}_t = \alpha_0 + \sum_{i=1}^{n_1} \alpha_i X_i + \varepsilon, \quad n_1 = N$$

➙ Among the explanatory variables, some provide **less information** and some may be **correlated**

➙ A **variables selection algorithm** is useful to keep only the most **important** variables

$$\widehat{y}_t = \alpha_0 + \sum_{i=1}^{n_2} \alpha_i X_i + \varepsilon, \quad n_2 \ll N$$

Results

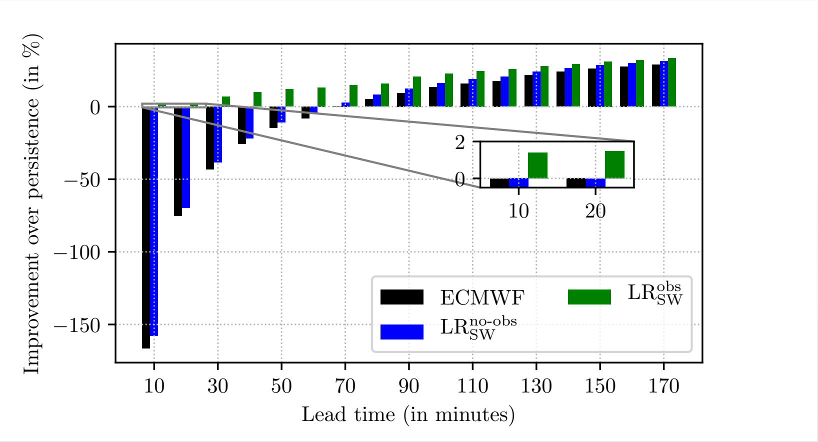
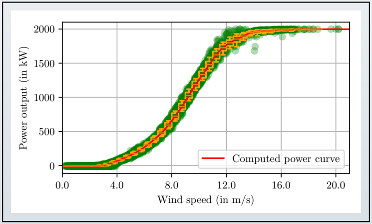


Figure: Improvements over persistence for ECMWF, $LR_{SW}^{no\text{-}obs}$ and LR_{SW}^{obs}

From wind speed to wind energy forecasts

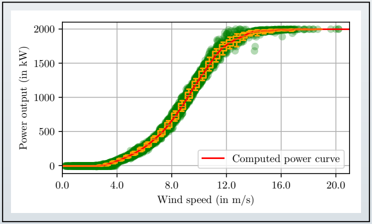
Computed power curve



External effects that need to be taken into account:

1. Wind direction
2. Air density

Computed power curve



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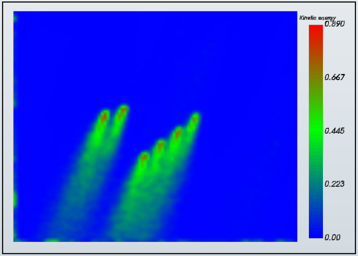

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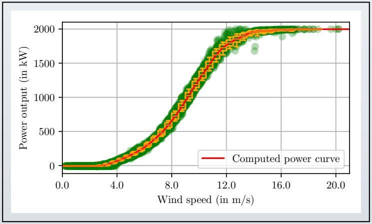

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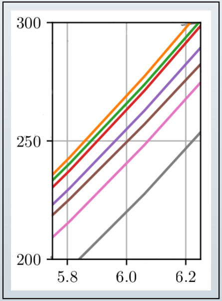

How to manage the lack of instrumentation ?

$$\rho = \frac{MP}{RT} = \frac{M}{R}\frac{(P_0 + P')}{(T_0 + T')} = \underbrace{\frac{MP_0}{RT_0}}_{\rho_0}\left(1 + \frac{P'}{P_0}\right)\left(\frac{1}{1 + T'/T_0}\right)$$

Pressure, temperature and density measured at **SIRTA**	MAE (in %)
$\tilde{\rho} = \rho_0\left(\frac{1}{1 + T'_{\text{OBS}}/T_0}\right)$	1.37
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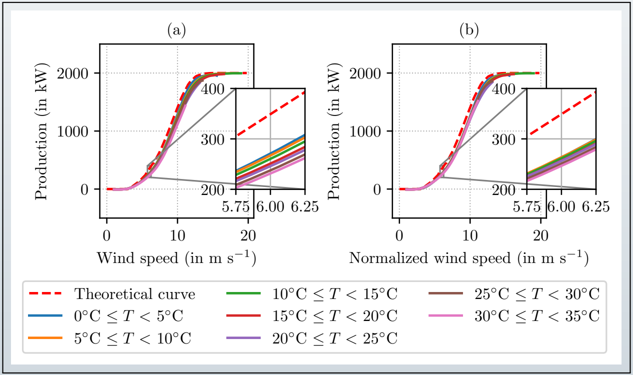
Air density: application to wind energy modeling

$$U_n = U_t \left(\frac{\rho_t}{\rho_0} \right)^{1/3}$$

➙ *Cf. IEC 61400-12-1, 2005*



Results

		MAE (in %)
$T \leq 5°C$	$U_n = U_t$	27.66
	$U_n = U_t \left(\frac{\rho_t}{\rho_0} \right)^{1/3}$	18.36
$T \geq 25°C$	$U_n = U_t$	24.09
	$U_n = U_t \left(\frac{\rho_t}{\rho_0} \right)^{1/3}$	14.51

Table: BIAS, MAE and NRMSE between the measured and modeled wind energy production for temperatures lower than 5°C and higher than 25°C.

General conclusion

- ➙ A **linear regression** using Numerical Weather Prediction model outputs to forecast the **wind speed** improve persistence **after 70 min** from 2.9% to 31.3% at 170 min
- ➙ Adding the last **measurement** as explanatory variable improves persistence **from 10 min**. The improvement goes from 1.4% to 33.3% at 170 min
- ➙ Taking into account the **air density** variations improves the **wind energy** modeling up to **39.8%**

Thank you for your attention !