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EMS Annual Meeting
September, 2021

Local turbulent kinetic energy modelling based on Lagrangian stochastic approach in CFD and application to wind energy

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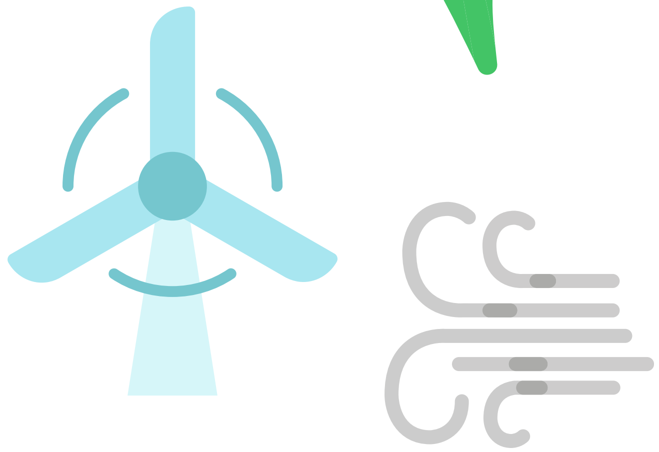
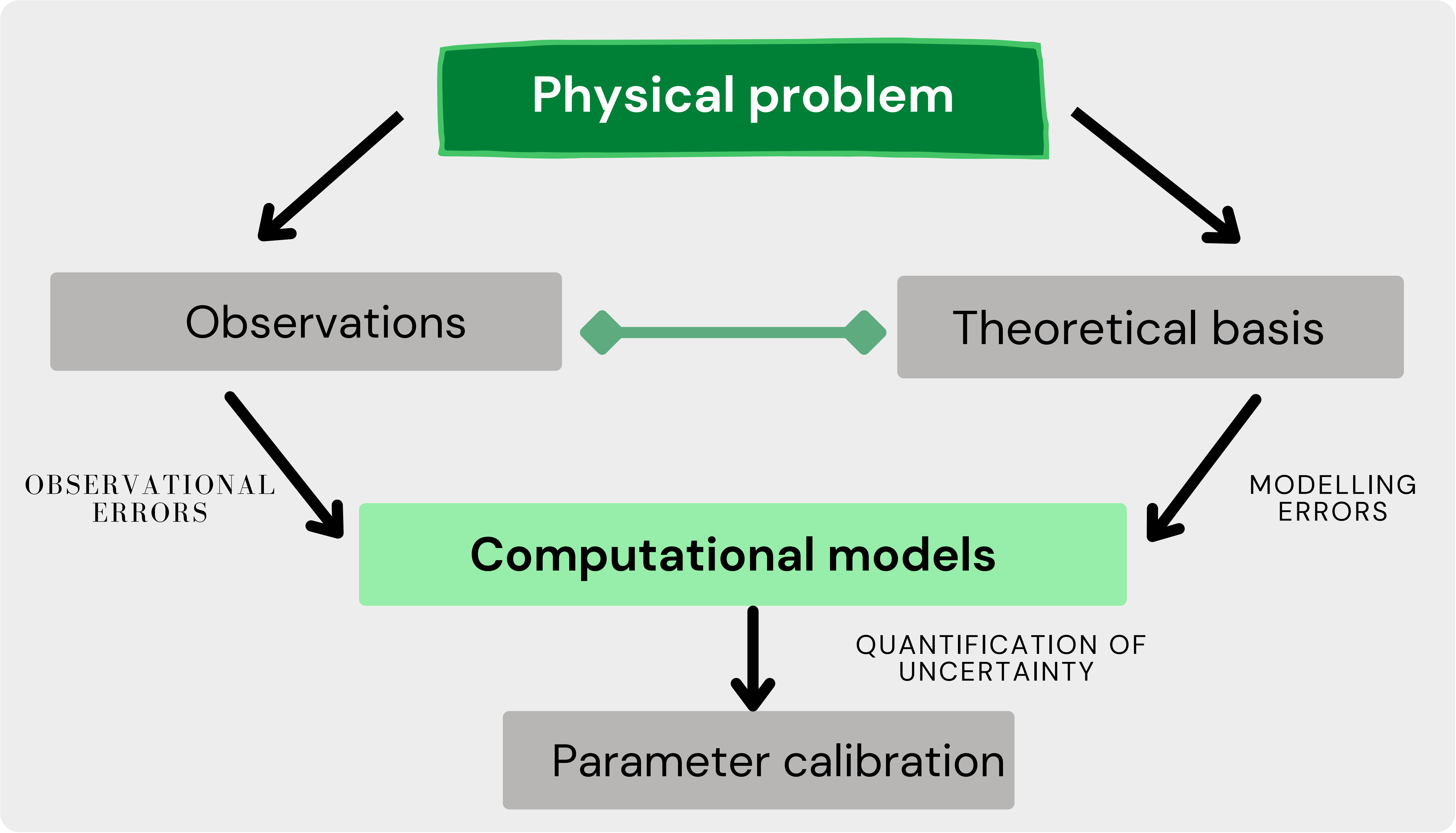
What should we do to produce accurate predictions?





Decision/prediction

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Two-fold objective

Construct a **physical-related** stochastic model featuring the square wind speed fluctuations $\|u_t'\|^2$ at a **given location.**

Treat possible **uncertainties** within model-parameters.

On the local nature: 3d $\longrightarrow$ 0d, for instance, in the modelling of the wind speed.

On the stochastic modelling approach: several dynamical diffusion models

Bensoussan and Brouste (2016), Arenas-López and Badaoui (2020), Baehr (2010)

Turbulence models commonly use closure coefficients, for which a number of parameters appear.

Edeling, Cinnella et al. (2014)

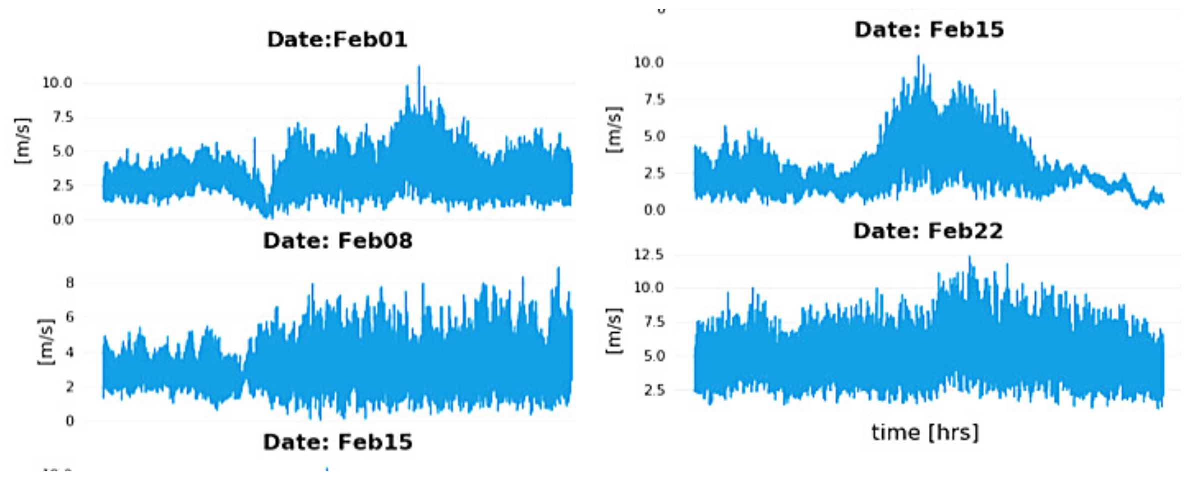
The ideas presented here can be applied with different approaches, scales and context.

Starting point:
fluid-paticle [Pope (1995)]
+ closure relation for the dissipation [Cuzart (2000)]

Derivation of the CIR-type mean-field TKE model

Data

A family of time series with velocity component:
- 10Hz at 30 meters
- 24 hours per day
- Annual (2017)



This data was obtained from SIRTA

1 Translate observations

CIR model for the instantaneous TKE

$$q_t := \|u_t'\|^2$$

$$dq_t = \Theta(C_\alpha,\gamma)\big(\mu(C_\alpha,\gamma) - q_t\big)\,dt + \sigma(\gamma)\sqrt{q_t}\,dW_t,$$

with a non-diagonal forcing term accounting for the turbulence production and physical parameter

$$C_\alpha := \frac{C_\epsilon}{l_m} \in [0.0061, 0.0259]$$

Approximation

Consider a homogeneous time step Δt and the Symmetrized Euler scheme associated with our TKE model:

$$\hat{q}_{t_{n+1}} \sim \mathcal{N}\left(\hat{q}_{t_n} + \Theta(\hat{C}_\alpha,\hat{\gamma}_t)\big(\mu(\hat{C}_\alpha,\hat{\gamma}_t) - \hat{q}_{t_n}\big)\,\Delta t, \sigma^2(\hat{\gamma}_t)\ \hat{q}_{t_n}\Delta t\right)$$

2 Computational model

Calibration

stochastic model ⊕ observations

Construct a priori distribution

Bayesian inference implementing HMC methods

Informative posterior distribution

3 Parameter calibration

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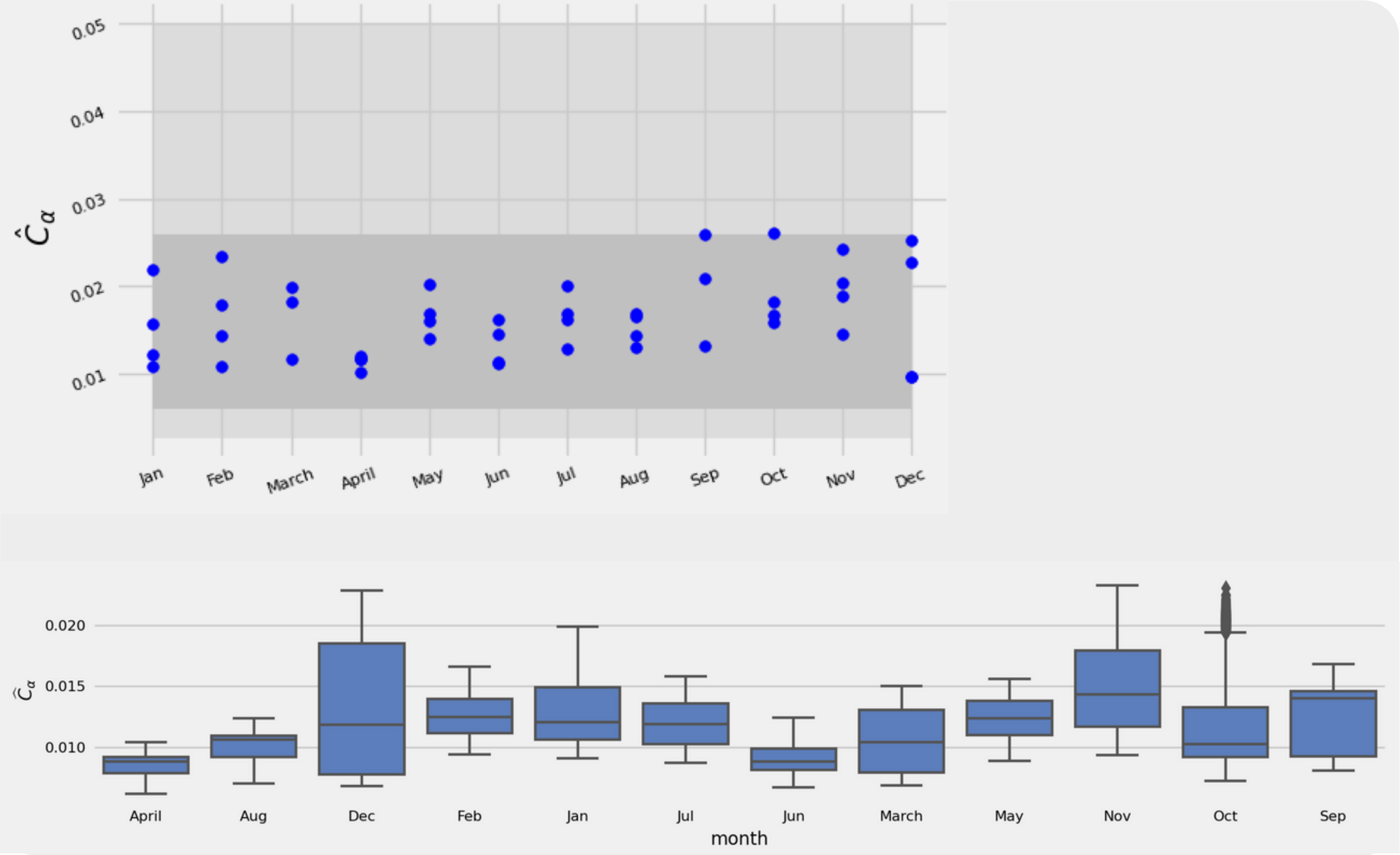
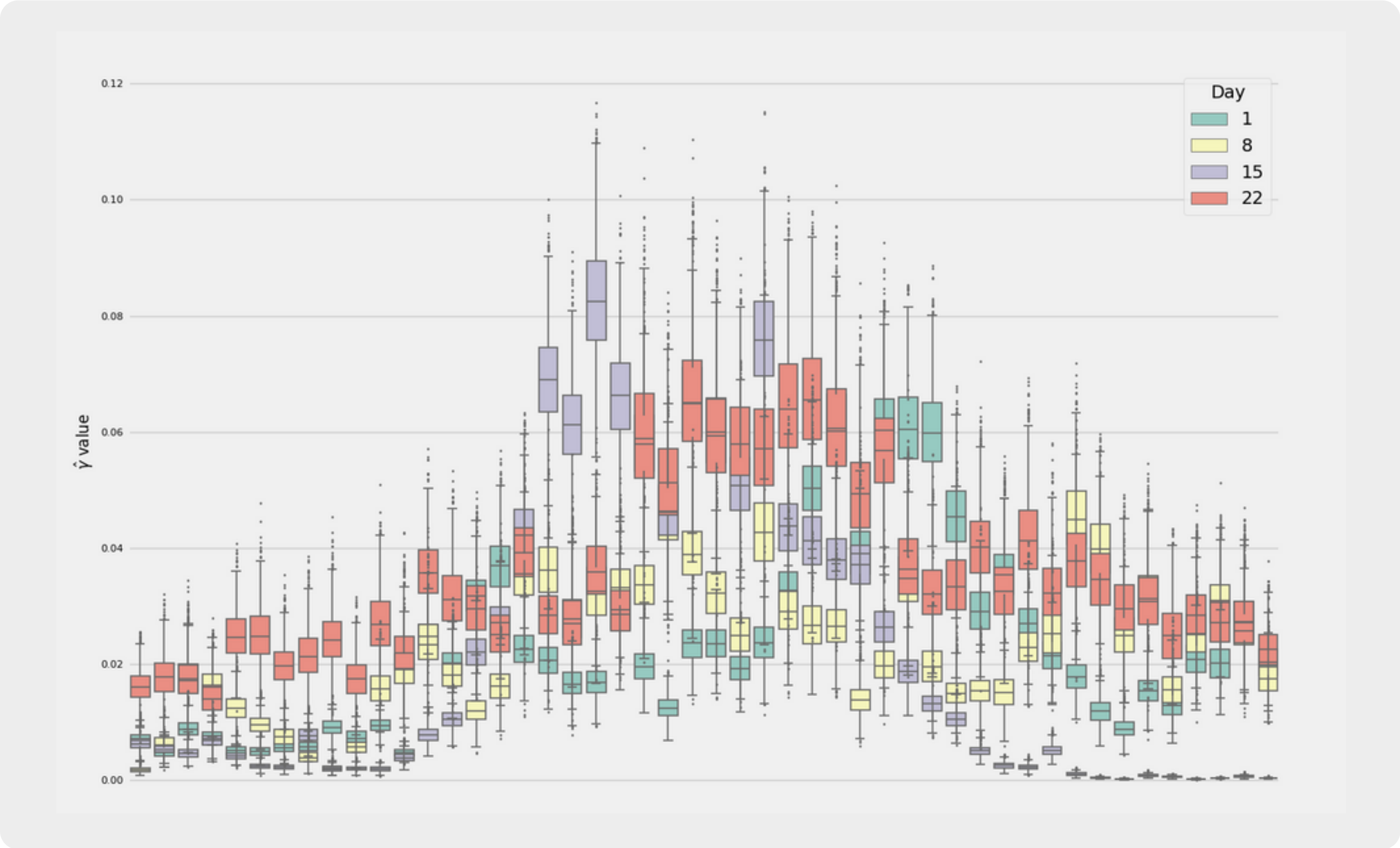
Results

1 C_α-calibration



2 γ-calibration



We observed a connection between the production term and the turbulence intensity, and, considering a stationary regime, we deduce the relation:

$$\gamma_t = \frac{C_\alpha}{\sqrt{2}} \langle \|U\| \rangle^3 I_t^3 3^{3/2}.$$

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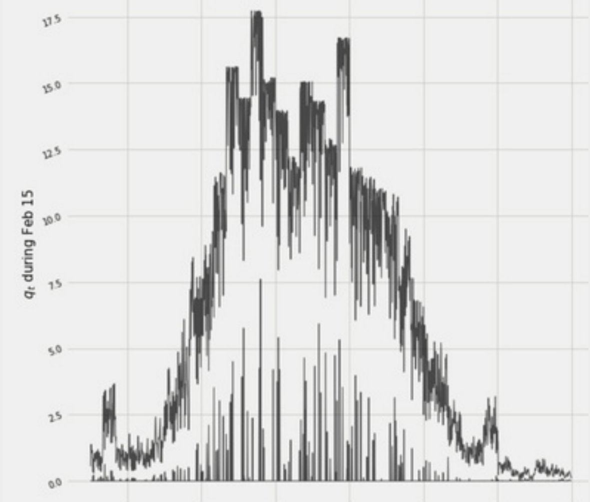
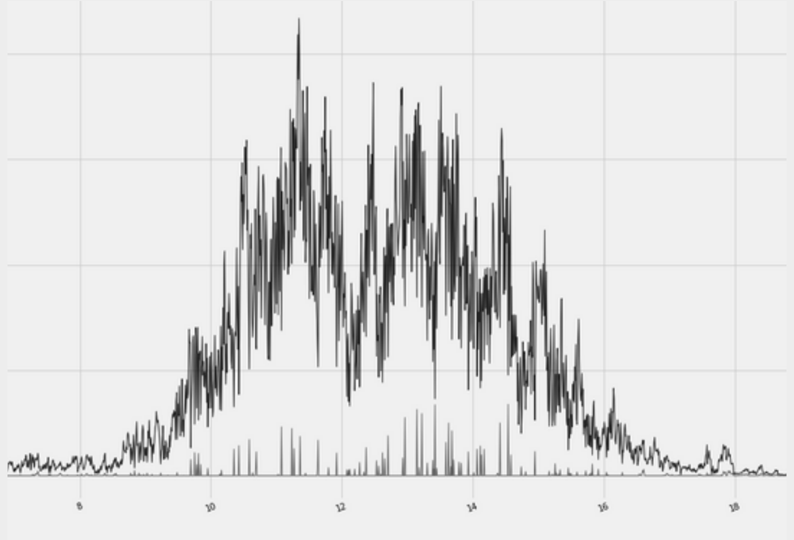
Results

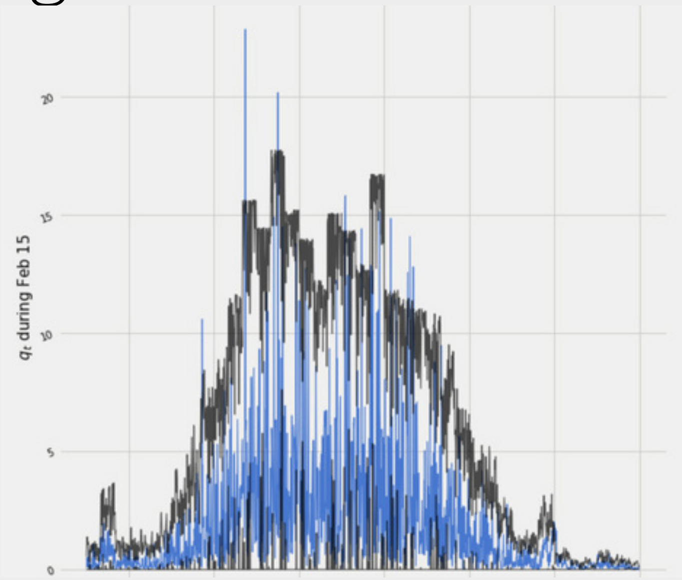
3 Replication of the observations

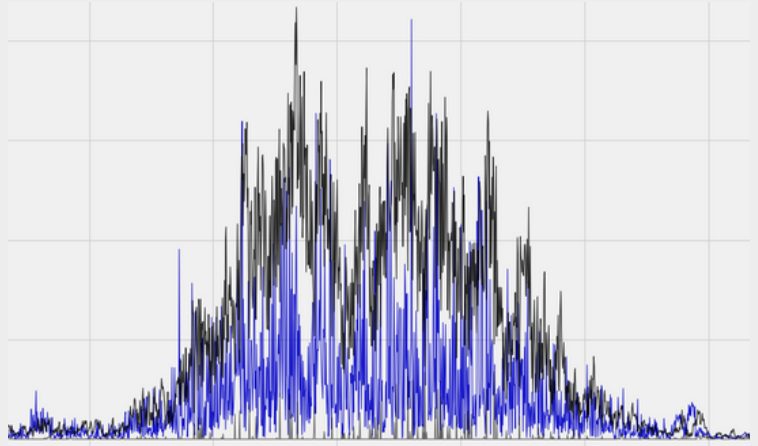
By means the numerical approximation and calibrated parameters, we construct a 95% confidence interval





and then we compare against the observations





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Following step?

Extract information from the theoretical model to

- **predict/ improve predictions of the TKE itself,**
- **validation/tuning of parameter in online predictions,**
- **quantify the probability of a gust,**
- **and many other possibilities.**

Thank you for your attention.