

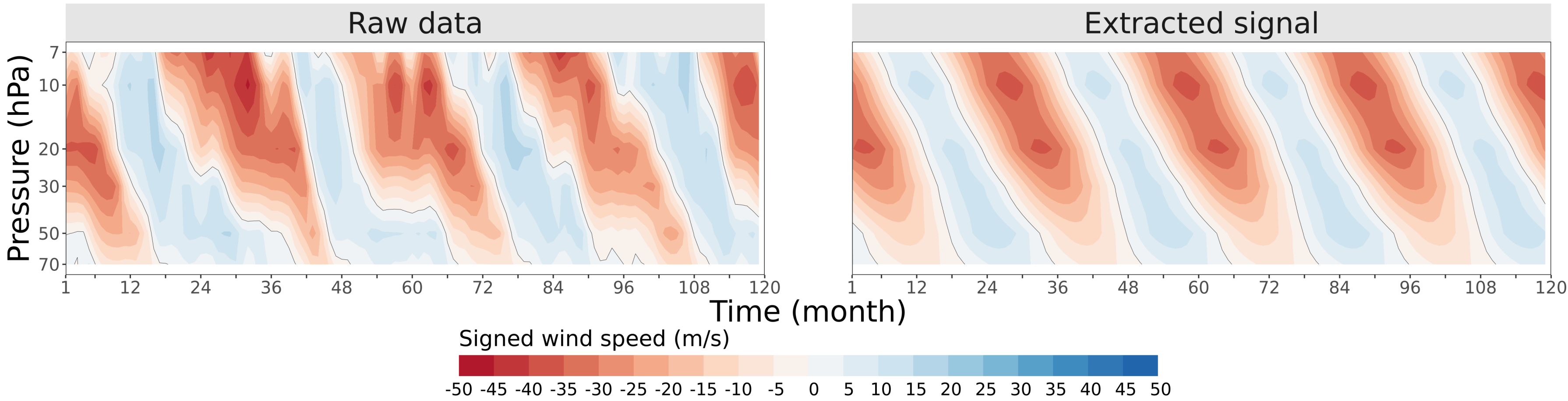


# SURROGATE-ACCELERATED MULTI-OBJECTIVE OPTIMIZATION FOR IMPROVING THE QBO

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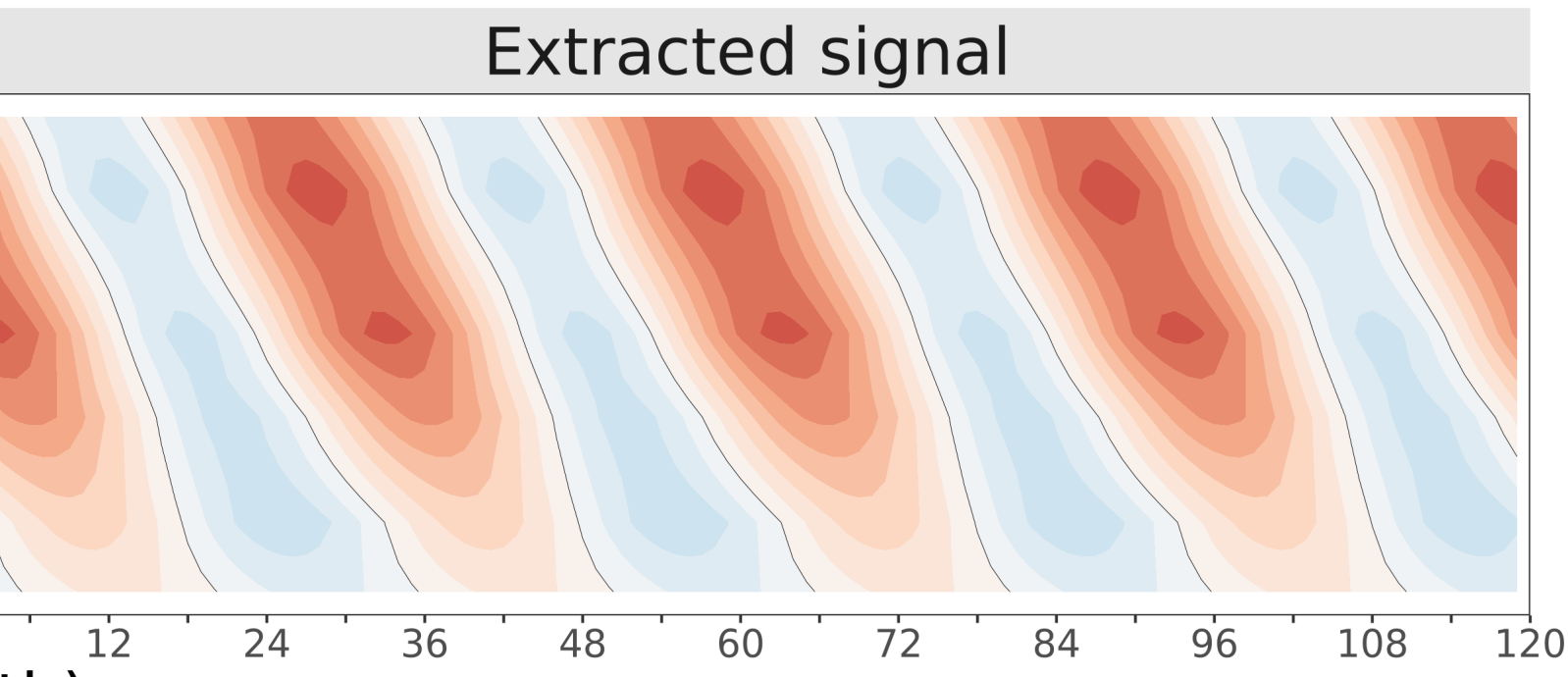
## Quasi-biennial oscillation (QBO)

Leading mode of variability in the tropical stratosphere that **influences weather and climate patterns globally**



## Fundamental frequency model

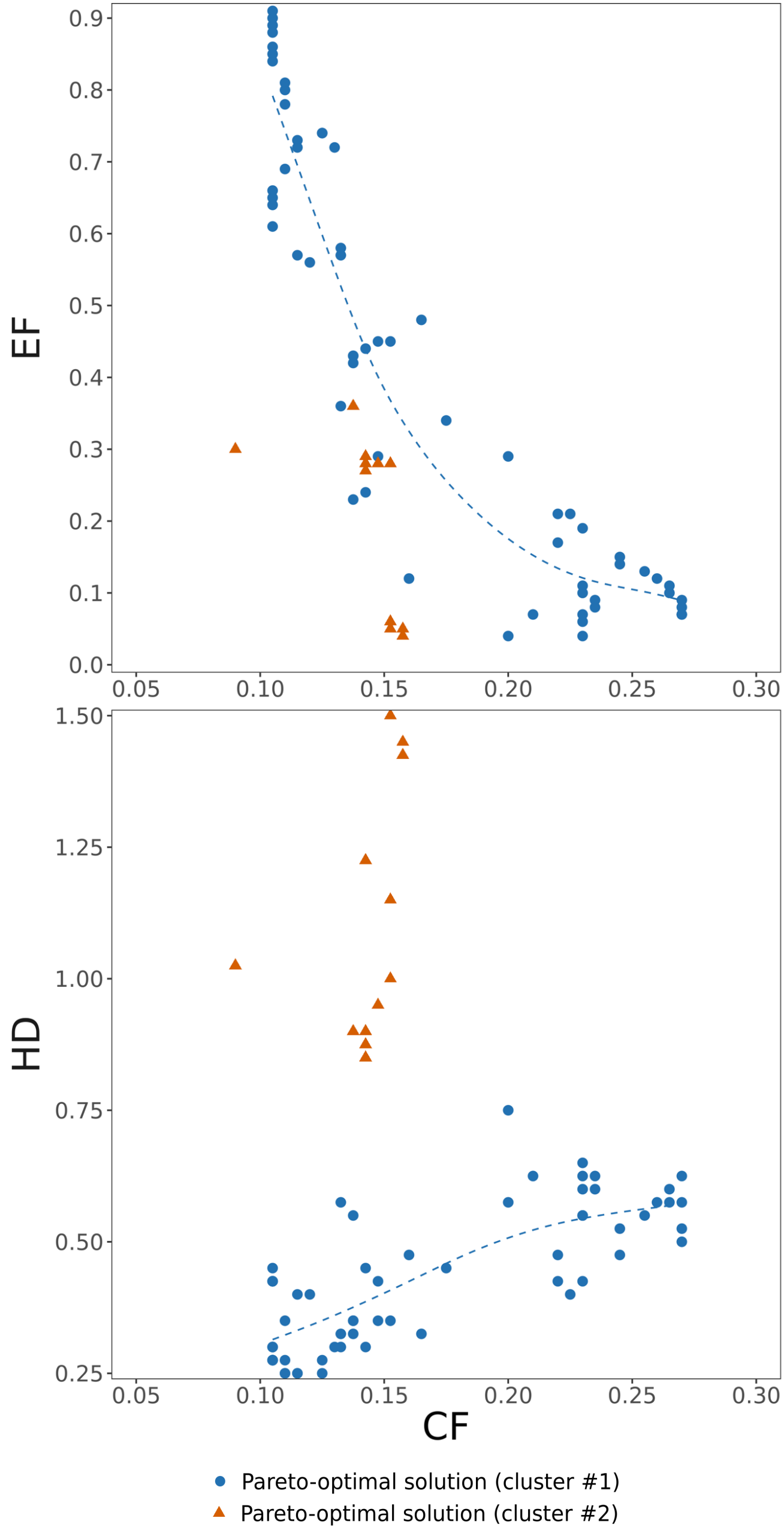
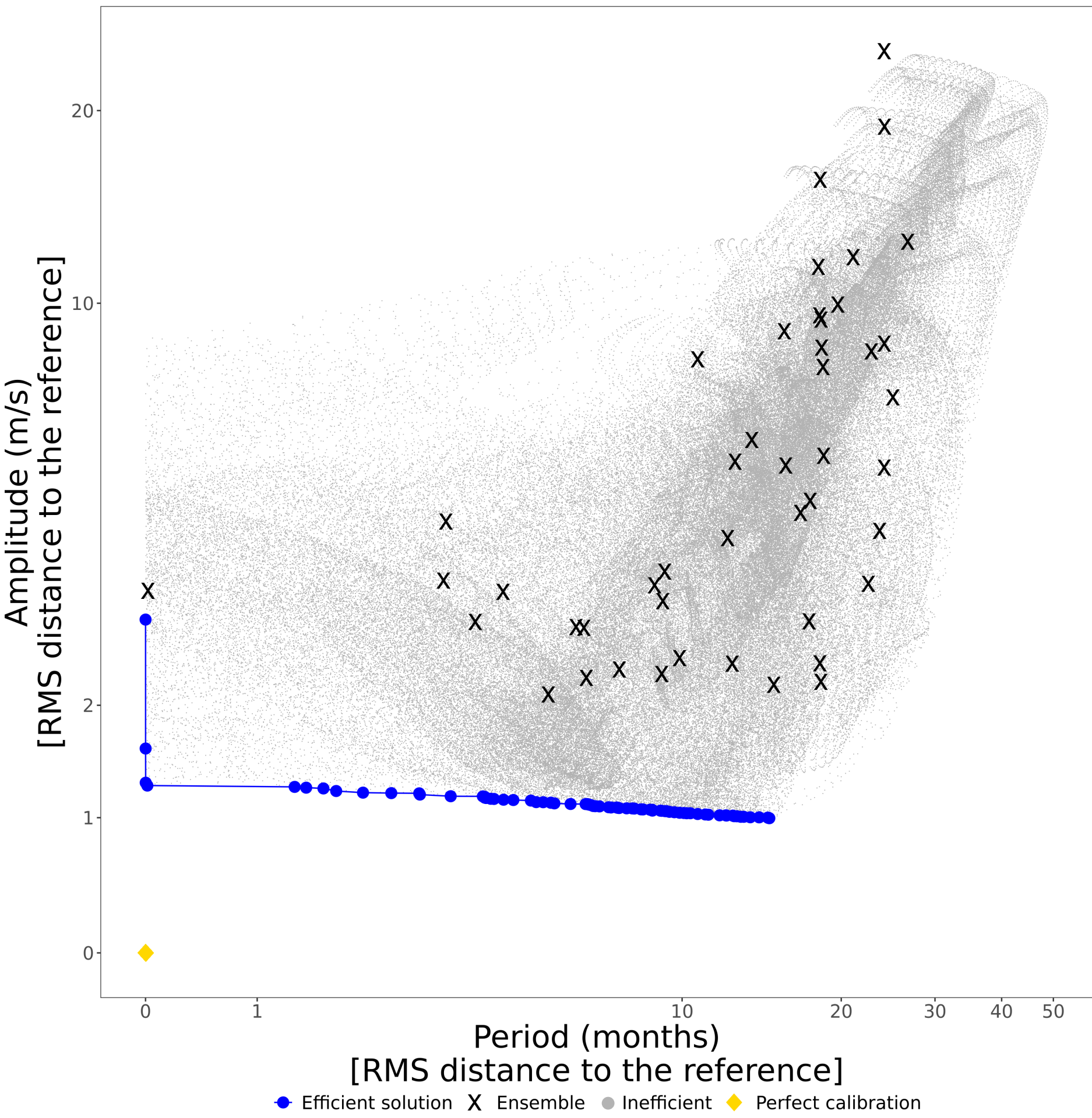
**Domain-knowledge informed** compressed representation of high-dimensional spatio-temporal dense wind fields



## Multi-objective optimization

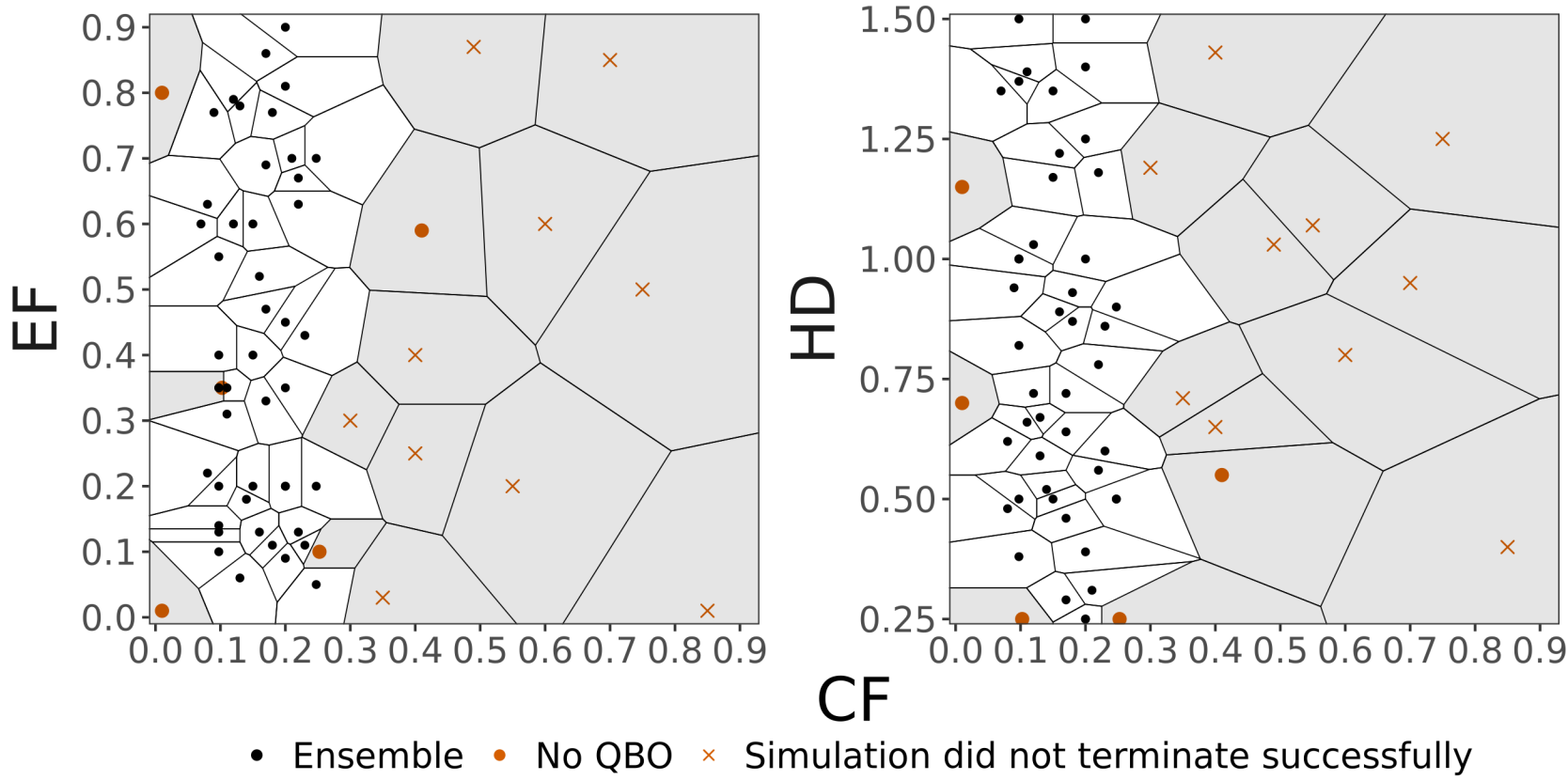
No single solution, but a set of efficient solutions that trade off period for amplitude

$$\operatorname{argmin}_{x^* \in X} \begin{cases} \left( \frac{\hat{q}_1(x^*) - q_1^{REF}}{q_1^{REF}} \right)^2 & (\text{period}) \\ \sum_k \left( \frac{\hat{q}_{2,k}(x^*) - q_{2,k}^{REF}}{q_{2,k}^{REF}} \right)^2 & (\text{amplitude}) \end{cases}$$



## Simulation ensemble

Sequential design to fill the param. ranges

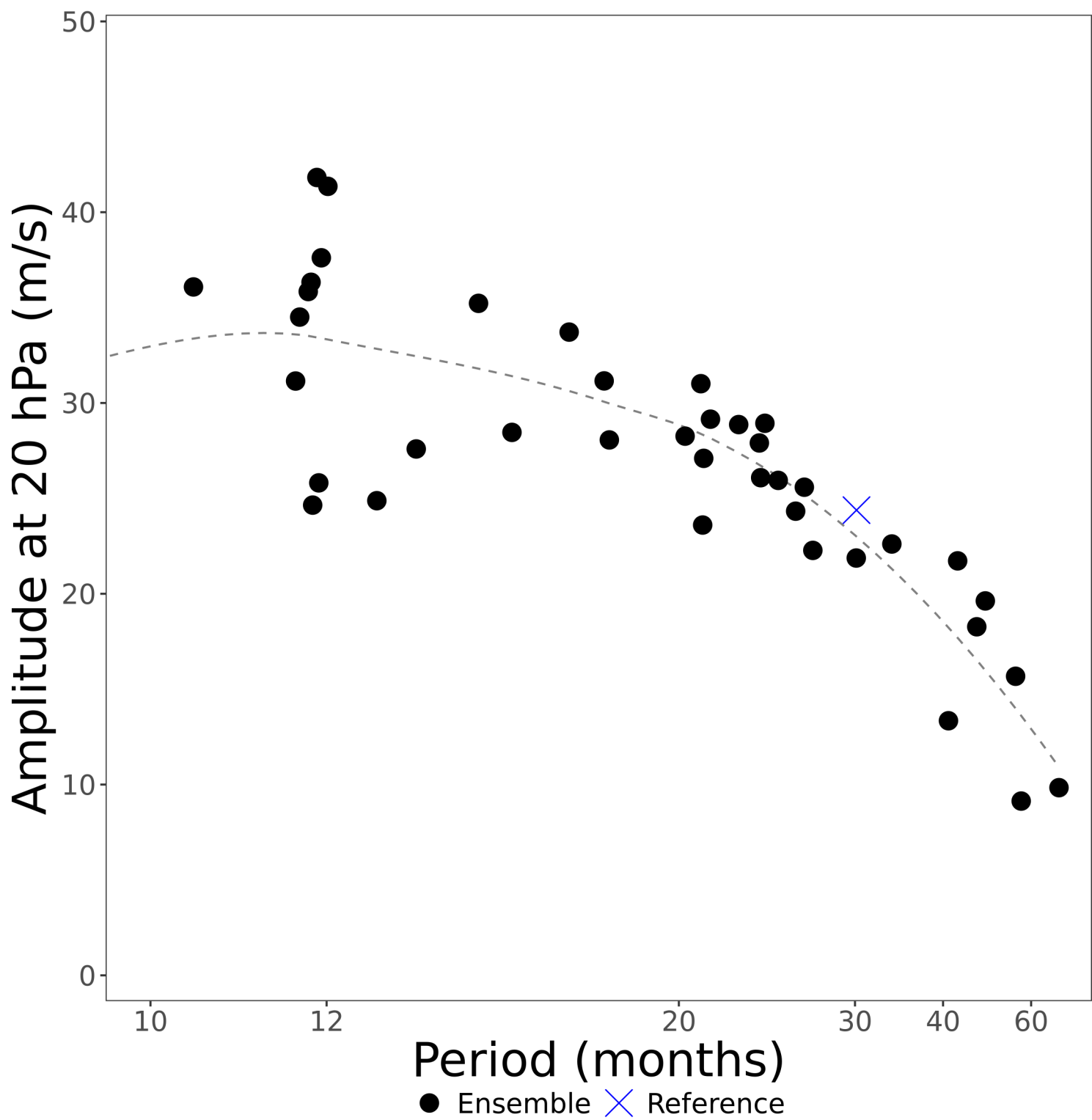
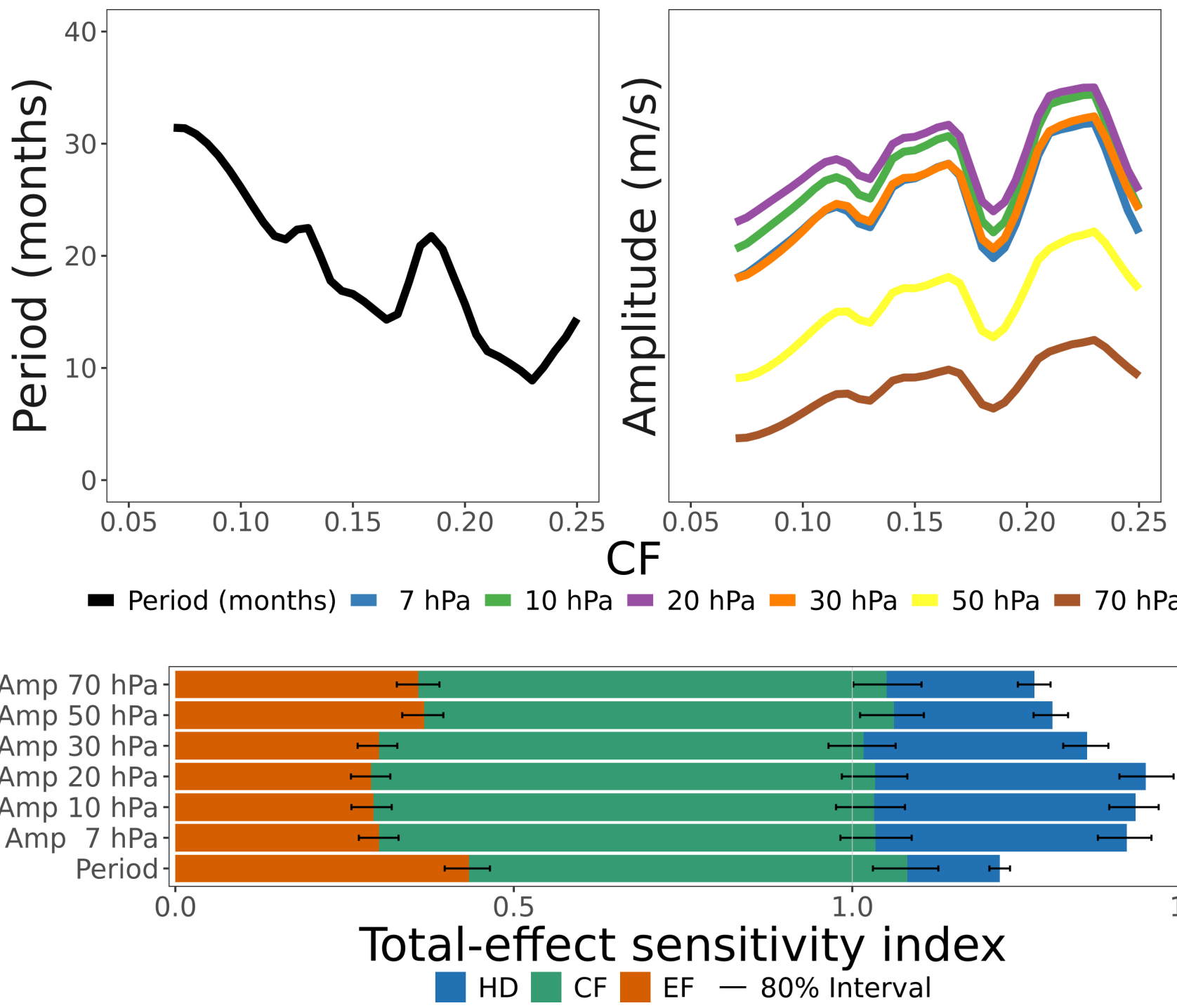


$$y_{tk} = \beta_{0k} + \beta_{1k} \sin(2\pi t/P - h_k) + e_{tk}$$
$$h_k = \alpha_0 + \alpha_1 \log_{10}(\text{pressure}_k)$$

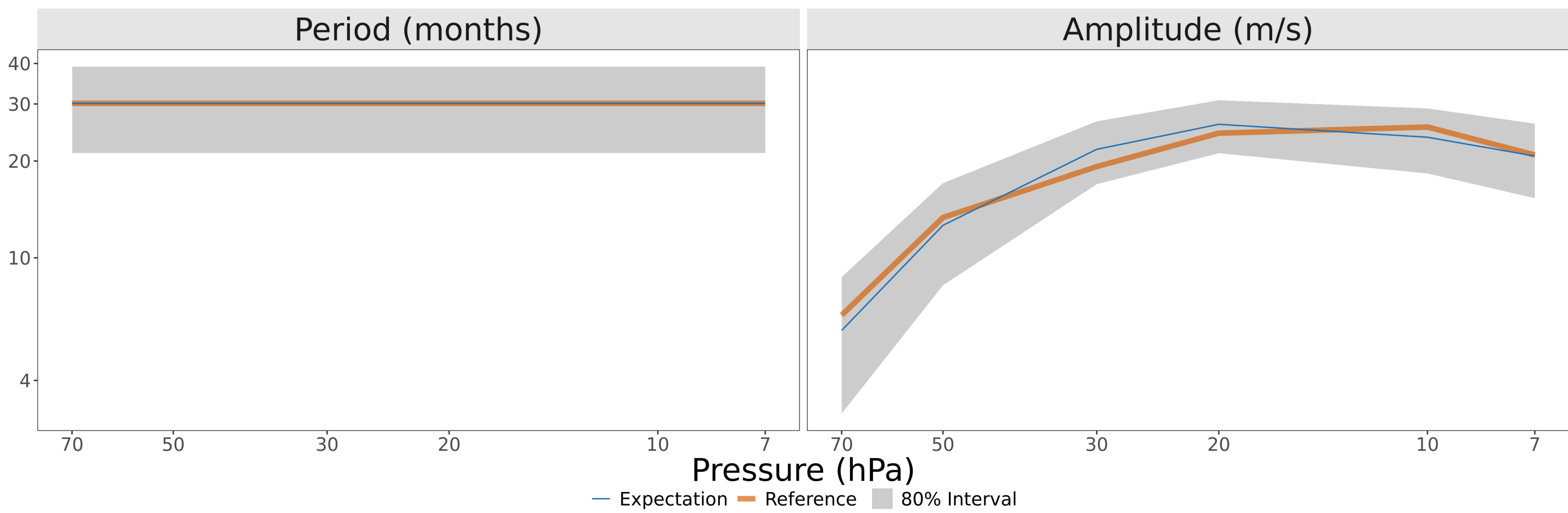
$y_{tk} \in \mathbb{R}$  is the signed wind speed,  $\beta_{0k} \in \mathbb{R}$  is the E/W balance,  $\beta_{1k} \in \mathbb{R}^+$  is the **QBO amplitude**,  $P \in \mathbb{R}^+$  is the **QBO period**,  $h_k \in [0, 2\pi]$  is the phase shift,  $e_{tk} \sim N(0, \sigma_{ek}^2)$  is an additive noise,  $\alpha_0, \alpha_1 \in \mathbb{R}$  are the linear propagation coefficients,  $t$  and  $k$  are indices

## Surrogate

Gaussian process & Karhunen-Loève expansion for rapid interrogation (KLGP)



## An optimal solution



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