

# ML report

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## 1 Simulation setup

Turbulent channel with constant pressure gradient (CPG).  $Re_\tau = u_\tau(H - k_{md})/\nu$ , where  $u_\tau = \sqrt{\tau_w/\rho}$  and  $\tau_w = -P_x(H - k_{md})$ .

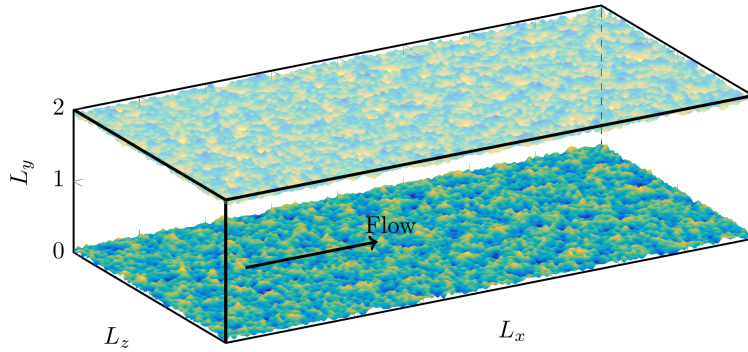


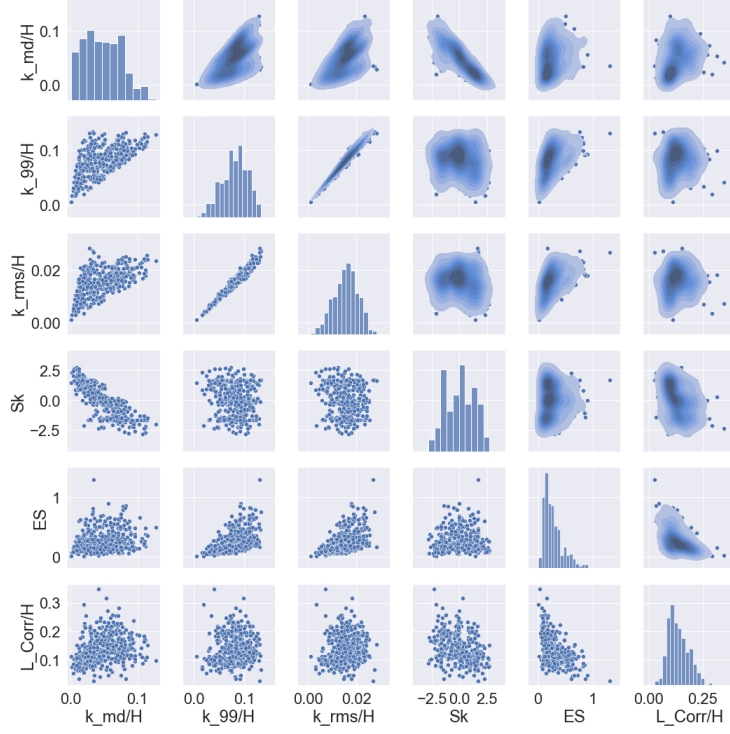
Figure 1: Schematic representation of simulation domain with an example pseudo-realistic surface mounted. Normalization of lengths with  $H$  is applied in the figure.

SurfaceID	$Re_\tau$	$L_x/H$	$L_z/H$	$N_x$	$N_z$	$\Delta_x^+$	$\Delta_z^+$	$\Delta_{y,k}^+$
0-199	500	2.4	0.8	480	160	2.5	2.5	$\approx 1.74$
200-399	500	3.0	1.0	576	192	2.6	2.6	$\approx 1.74$

Table 1: Simulation domain setup

## 2 Roughness configuration

Identical  $Re_\tau$ , varying  $k_{99} = \Phi_{0.08,0.02}$



## 2.1 PDF

Weibull:

$$f(k) = \lambda \beta^\lambda k^{(\lambda-1)} e^{-(\beta k)^\lambda},$$

Bimodal:

$$k(i) = \min\{\Phi_{0,1}(i), \Phi_{-\lambda,\lambda}(i)\},$$

Gaussian:

$$f(i) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{i-\mu}{\sigma}\right)^2}$$

## 2.2 PS

- $\lambda_0 = 0.8H$  (Surface ID 0-199),  $= 1H$  (Surface ID 200-399).
- $\lambda_1 = 0.04H$ .
- PS normalized by  $\lambda_{diff} = \lambda_0 - \lambda_1$ .
- Roll-off length:  $L_r/\lambda_{diff} = \Phi_{0.4,0.04}$ .
- PS slope:  $\theta_p = -|\Phi_{0.75,0.3}|$ .
- Randomize along PS(20):  $PS(i) - \Phi_{0,0.5*i}$ .

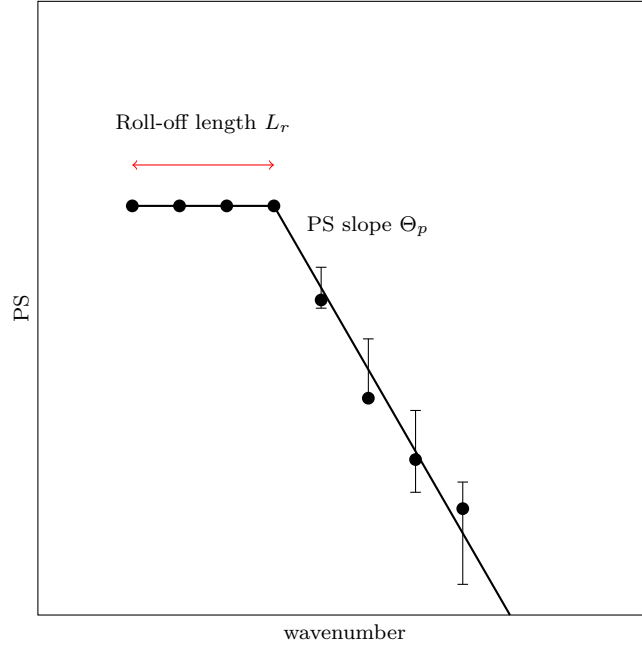


Figure 2: PS Sketch

### 3 Active learning

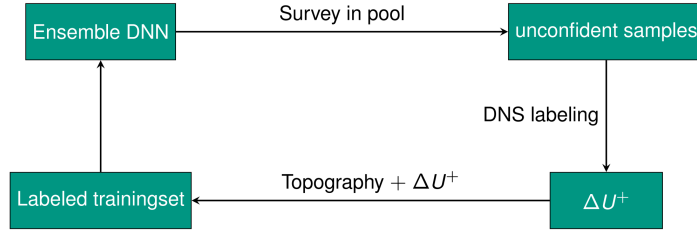


Figure 3: Flow chart of the present active learning framework

#### 3.1 Ensemble deep neural network

Input: Discretized  $\log(\text{PS})$  and  $\text{PDF}/k_t$ ,  $k_{99}$ ,  $k_t$ ,  $\lambda_0/k_t$ ,  $\lambda_1/k_t$ .

Output: averaged prediction ( $\mu_{\Delta U^+}$ ) & uncertainty prediction ( $\sigma_{\Delta U^+}$ )

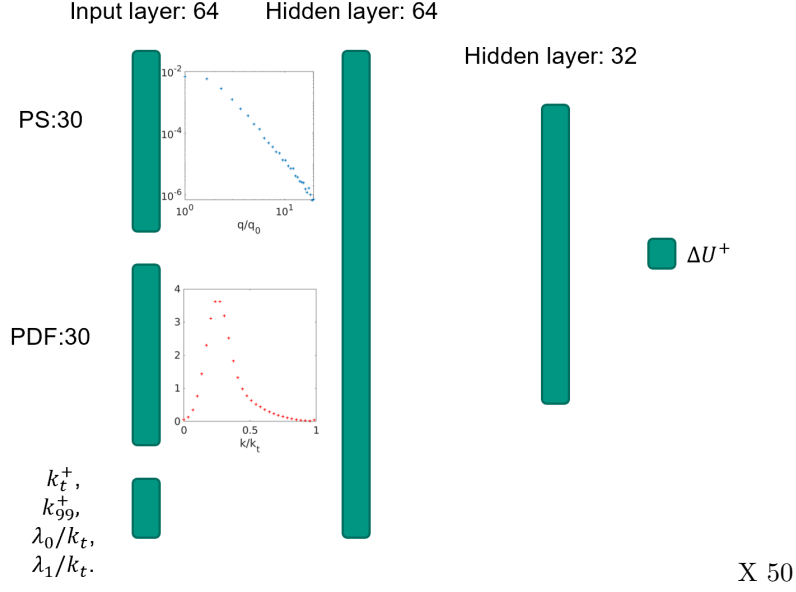
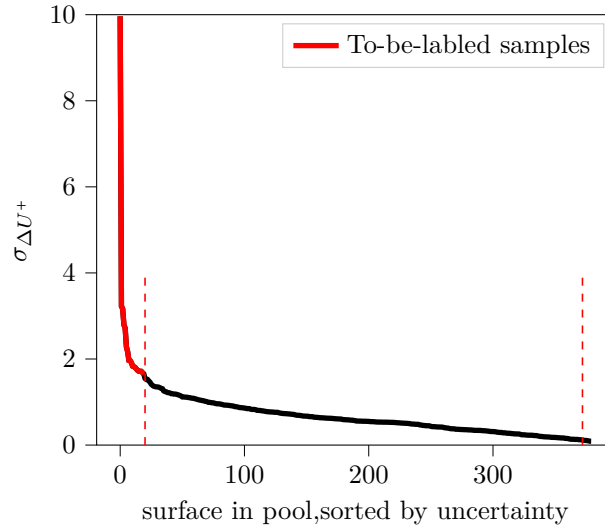
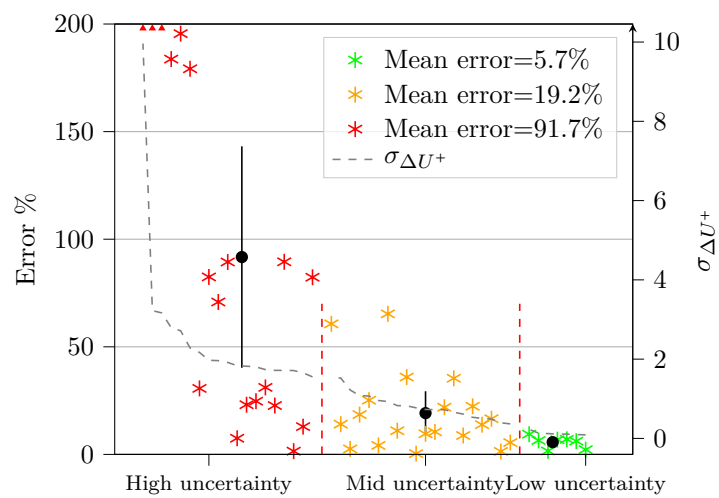


Figure 4: Sketch of ensemble DNN, output: averaged prediction ( $\mu_{\Delta U^+}$ ) & uncertainty prediction ( $\sigma_{\Delta U^+}$ )

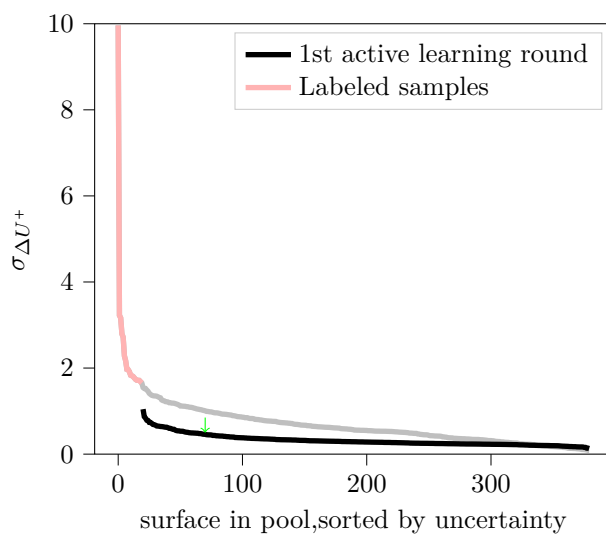
## 4 Results

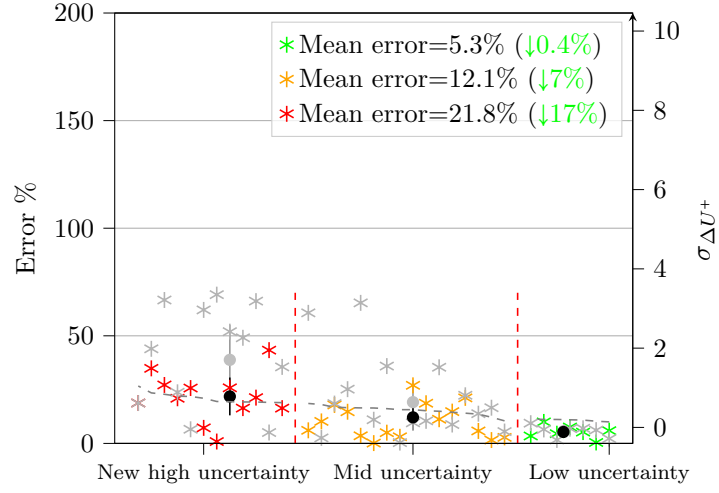
### 4.1 0th round





## 4.2 1st round





### 4.3 Prediction of realistic surfaces

Surface	$\Delta U_{DNS}^+$	$\Delta U_{DNN}^+$	$\sigma \Delta U^+$	error%
Ice 1	4.84	4.47	0.44	7.6%
Ice 2	2.15	2.13	0.24	1.0%
Ice 3	3.76	3.70	0.40	1.6%
Sandpaper	5.36	5.37	0.39	0.4%
IC 1	8.76	8.12	1.36	7.3%

## 5 Next steps

