ML report

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June 21, 2021

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 $\tau_w = -P_x(H - k_{md})$.

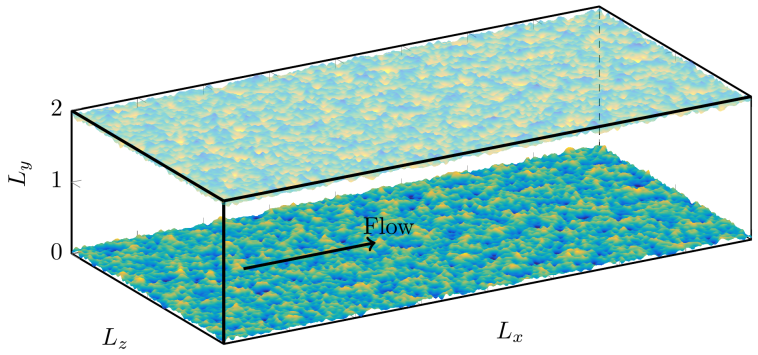


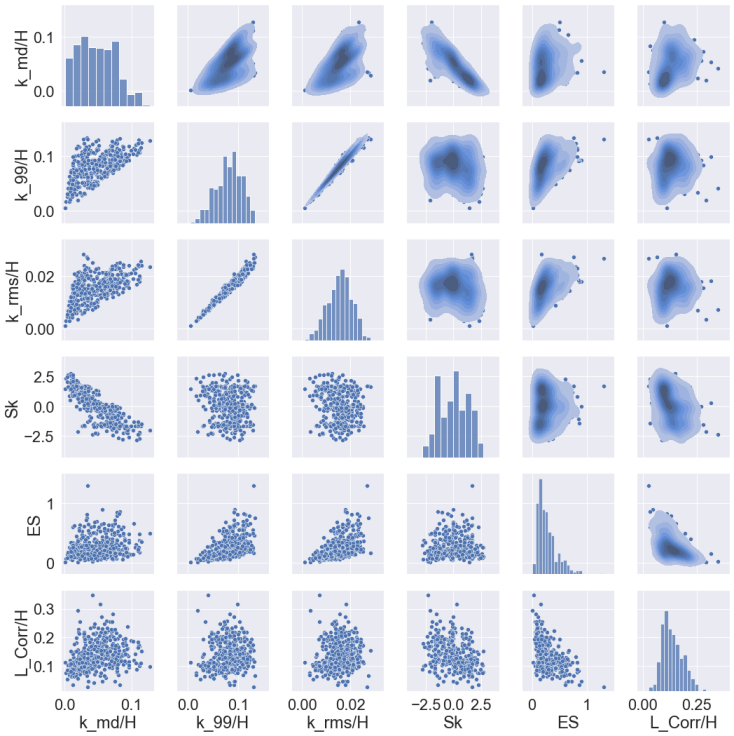
Figure 1: Schematic representation of simulation domain with an example pseudo-realistic surface mounted. Normalization of lengths with H is applied in the figure.

SurfaceID	Re_τ	L_x/H	L_z/H	N_x	N_z	Δ_x^+	Δ_z^+	$\Delta_{y,k}^+$
0-199	500	2.4	0.8	480	160	2.5	2.5	≈ 1.74
200-399	500	3.0	1.0	576	192	2.6	2.6	≈ 1.74

Table 1: Simulation domain setup

2 Roughness configuration

Identical Re_τ, variying $k_{99} = \Phi_{0.08,0.02}$



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:

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

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): $\mathrm{PS}(i) - \Phi_{0,0.5*i}$.

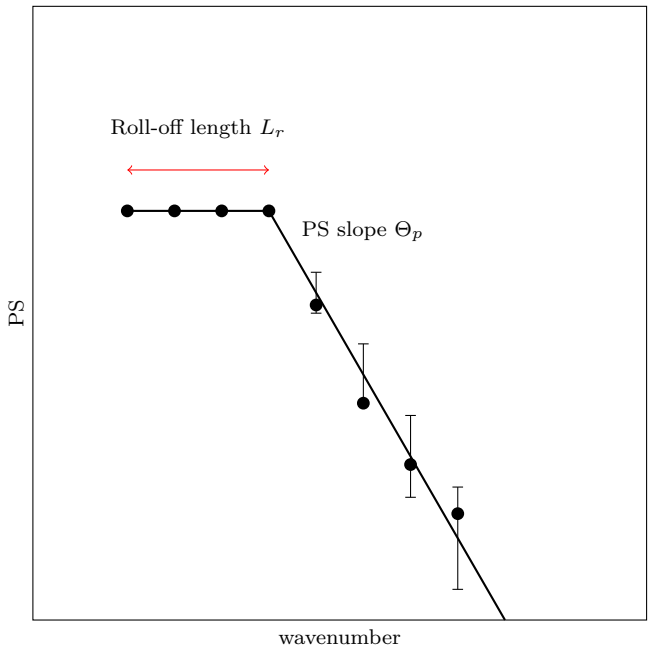


Figure 2: PS Sketch

3 Active learning

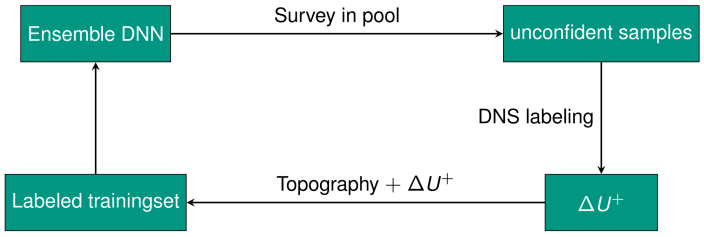


Figure 3: Flow chart of the present active learning framework

3.1 Ensemble deep neural network

Input: Discretized log(PS) and PDF/k_t, k_{99}, k_t, λ_0/k_t, λ_1/k_t.
Output: averaged prediction ($\mu_{\Delta U^+}$) & uncertainty prediction ($\sigma_{\Delta U^+}$)

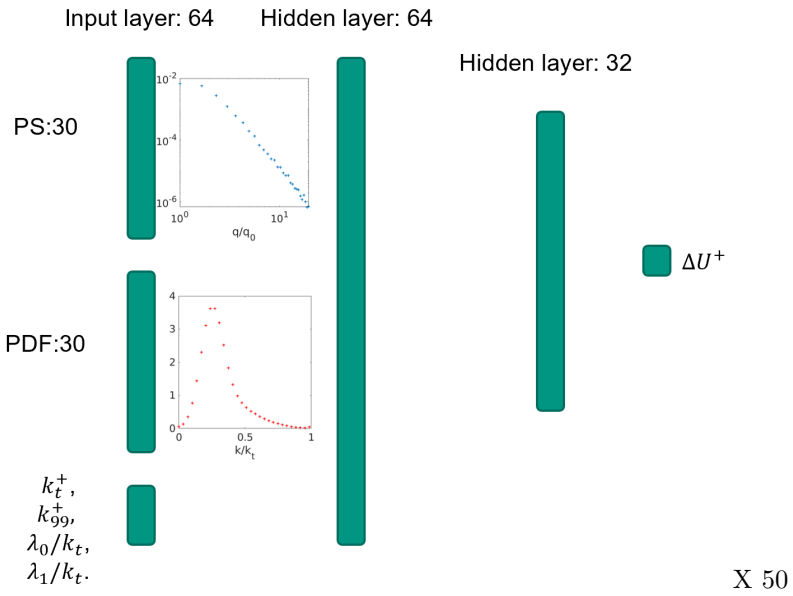
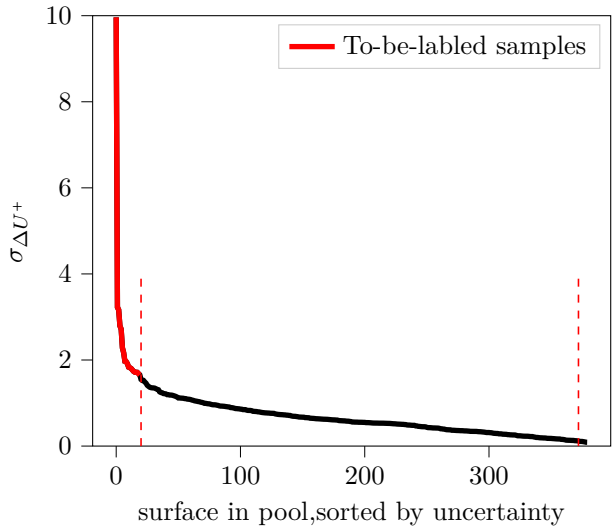
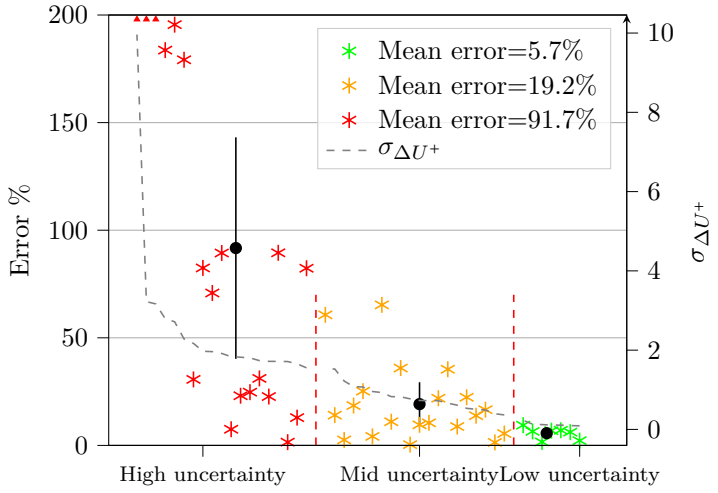


Figure 4: Sketch of ensemble DNN, output: averaged prediction ($\mu_{\Delta U^+}$) & uncertainty prediction ($\sigma_{\Delta U^+}$)

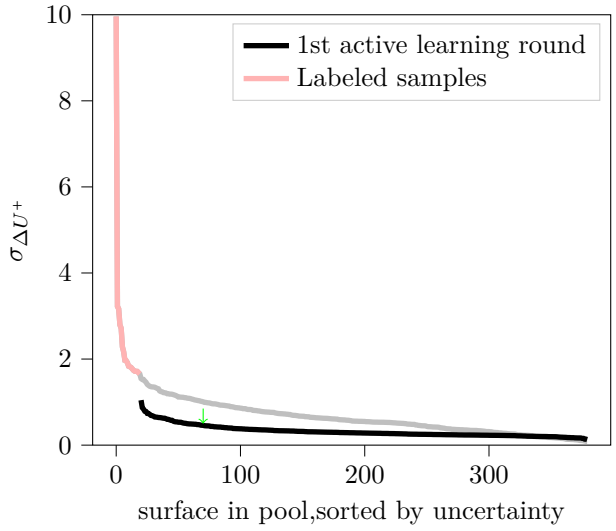
4 Results

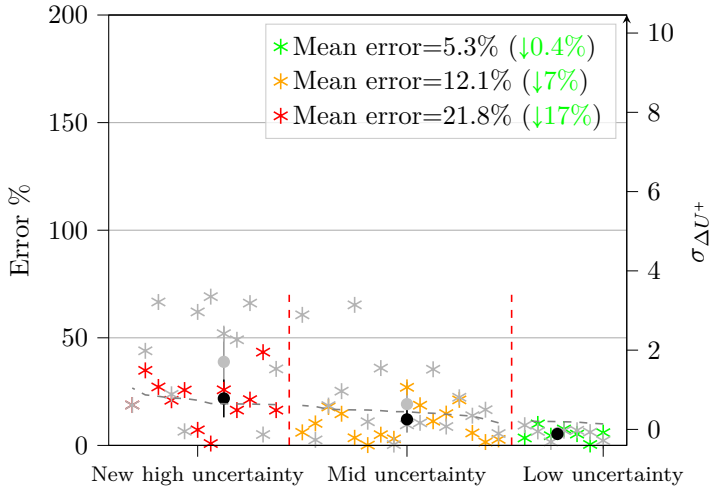
4.1 0th round




Mean error=5.7%
Mean error=19.2%
Mean error=91.7%
$\sigma_{\Delta U^+}$
Error %
$\sigma_{\Delta U^+}$
200
150
100
50
0
10
8
6
4
2
0
High uncertainty
Mid uncertainty
Low uncertainty

4.2 1st round


1st active learning round
Labeled samples
$\sigma_{\Delta U^+}$
10
8
6
4
2
0
0
100
200
300
surface in pool,sorted by uncertainty



4.3 Prediction of realistic surfaces

Surface	ΔU^+_{DNS}	ΔU^+_{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%