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Supplementary Files

Rational Analysis of Drag Reduction Variation Induced by Surface Microstructures Inspired by the Middle Section of Barchan Dunes at High Flow Velocity

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1. Numerical Simulation Model

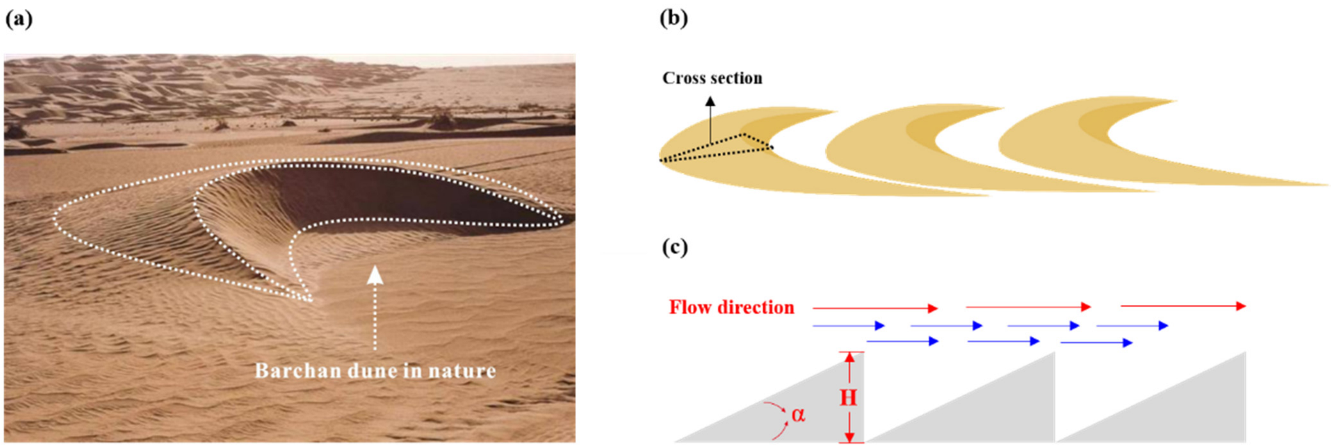

Figure S1. Illustrations of simulation model. (**a**) Barchan dune topography in nature, (**b**) typical model and cross-section parameters of a structural unit, (**c**) typical cross-section of the model.

2. Calculation Mathematical Model

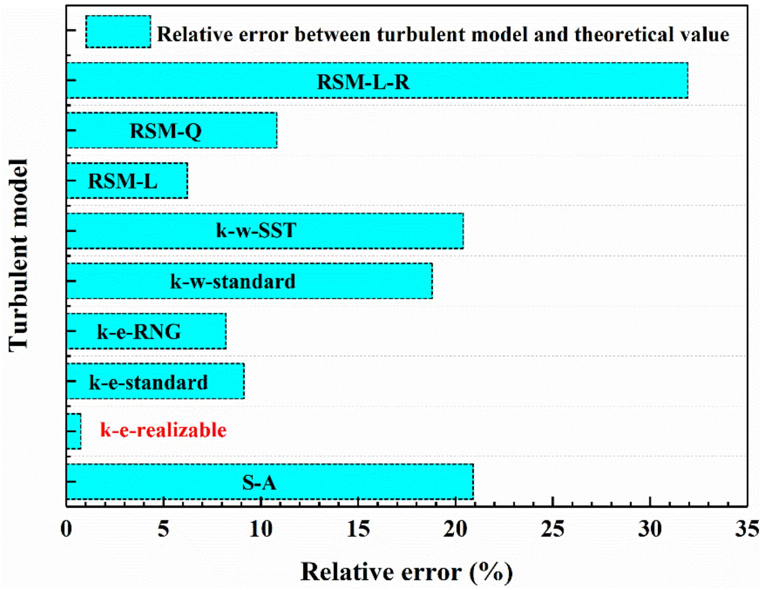

Figure S2. The comparison between the theoretical values and the calculated values under different turbulence models.

3. Calculation Mathematical Model

The realizable k-ε model:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_j) = \frac{\partial}{\partial x_i}\left[\left(\mu + \frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + G_k + G_b - \rho\varepsilon - Y_M + S_k \quad \text{(S1)}$$

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \frac{\partial}{\partial x_j}(\rho\varepsilon u_j) = \frac{\partial}{\partial x_j}\left[(\mu + \frac{\mu_t}{\sigma_\varepsilon})\frac{\partial\varepsilon}{\partial x_j}\right] + \rho C_1 S\varepsilon - \rho c_2\frac{\varepsilon^2}{k+\sqrt{\nu\varepsilon}} + C_{1\varepsilon}\frac{\varepsilon}{k}C_{3\varepsilon}G_b + S\varepsilon \quad \text{(S2)}$$

Where

$$C_1 = max\left[0.43, \frac{\eta}{\eta+5}\right] \quad \text{(S3)}$$

$$\eta = S\frac{k}{\varepsilon} \quad \text{(S4)}$$

$$G_k = \mu_t S^2 \quad \text{(S5)}$$

$$S = \sqrt{2S_{ij}S_{ij}} \quad \text{(S6)}$$

$$S_{ij} = \frac{1}{2}(\frac{\partial u_j}{\partial x_i} + \frac{\partial u_i}{\partial x_j}) \quad \text{(S7)}$$

$$Gb = -g_i\frac{\mu_t}{\rho Pr_t}\frac{\partial\rho}{\partial x_i} \quad \text{(S8)}$$

For ideal gas, the turbulent viscosity coefficient is expressed as follows

$$\mu t = \rho C\mu\frac{k^2}{\varepsilon} \quad \text{(S9)}$$

The LES model:

$$\frac{\partial\rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho\overline{u_\iota}) = 0 \quad \text{(S10)}$$

$$\frac{\partial}{\partial t}(\rho\overline{u_i}) + \frac{\partial}{\partial x_j}(\rho\overline{u_i}\overline{u_j}) = \frac{\partial}{\partial x_j}(\mu\frac{\partial\overline{u_i}}{\partial x_j}) - \frac{\partial\bar{p}}{\partial x_i} - \frac{\partial\tau_{ij}}{\partial x_j} \quad \text{(S11)}$$

Therein, the subgrid tension (τ_{ij}) is defined as:

$$\tau_{ij} = \rho\overline{u_i u_j} - \rho\overline{u_i}\overline{u_j} \quad \text{(S12)}$$

The enhanced wall treatment, which was suitable for complex flow in a high-Reynolds-number turbulence model, was used for the near-wall treatment. More specific parameters of above equations can be referred to previous studies [29,31].

4. The Independence of the Computational Grid

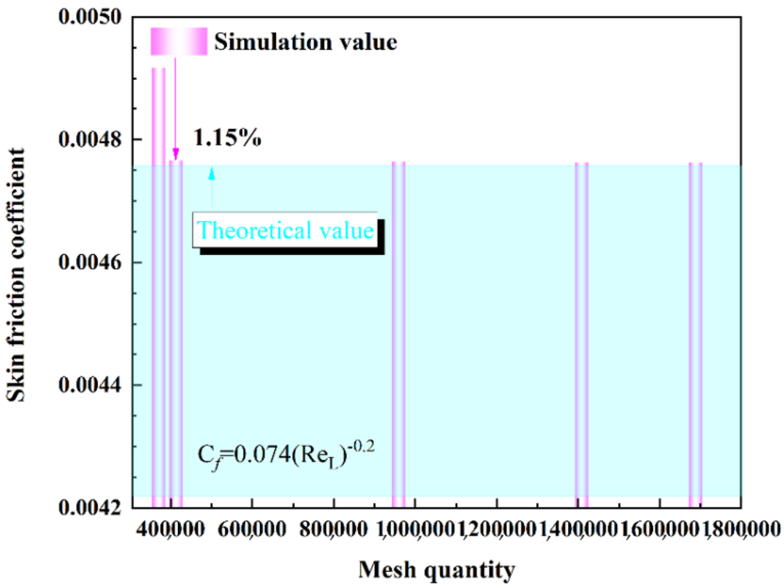

Figure S3. Validation of the grid independence.