SPH numerical simulation of lift-off by impact of sand particles on flat sand bed

基于SPH方法的沙粒运动数值模拟研究

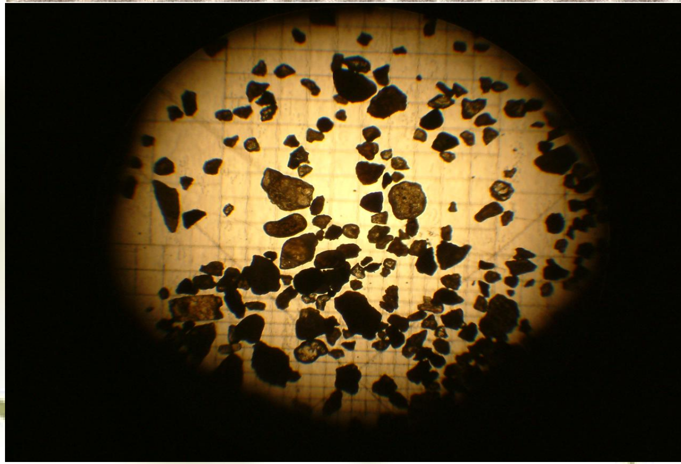
Content

Introduction

- environmental deterioration **sanstorm**

- blown sand physics
  - macrostudy
  - microstudy

- two-way coupling of sand and gas



Mathematical model

continuity equation

$$\frac{\mathrm{d}\rho}{\mathrm{d}t} = -\rho \frac{\partial u^{\beta}}{\partial x^{\beta}}$$

motion equation

$$\frac{\partial u^{\alpha}}{\partial t} + u^{\alpha} \frac{\partial u^{\alpha}}{\partial x^{\alpha}} = -\frac{1}{\rho} \frac{\partial p}{\partial x^{\alpha}} + \nu \frac{\partial^2 u^{\alpha}}{\partial x^{\alpha 2}} + f^{\alpha}$$

state equation

$$p = \rho R_{\alpha} T$$

$$p_s = p_s^k + p_s^I$$

$$p_s^k = \rho_s T_s$$

$$p_s^I = 2\rho g \left(1 + e\right) T_s$$

$$f(x) \approx \sum_{J=1}^{M} \frac{m^J}{\rho^J} f(x^J) W\left(x - x^J, h\right) + \sum_{JJ=M}^{N} \frac{m^{JJ}}{\rho^{JJ}} f(x^{JJ}) W\left(x - x^{JJ}, h\right)$$

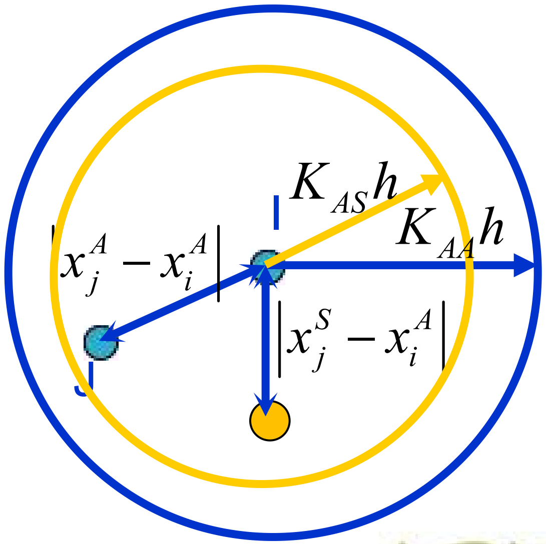
$K_{AA} = 3.0$

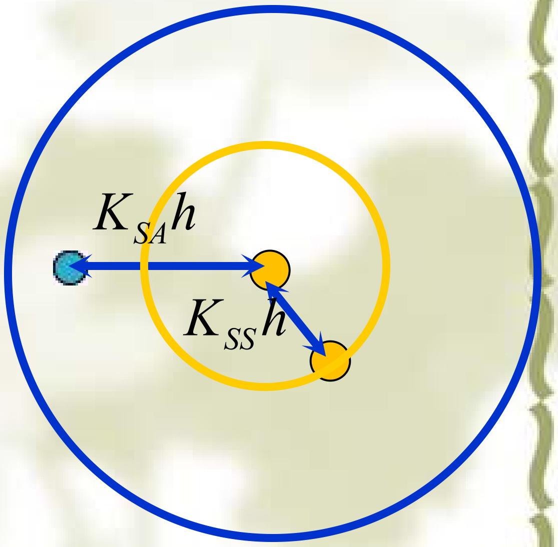
$K_{AS} = 2.5$

$$K = \begin{bmatrix} K_{AA} & K_{AS} \\ K_{SA} & K_{SS} \end{bmatrix} = \begin{bmatrix} 3.0 & 2.5 \\ 2.5 & 1.1 \end{bmatrix}$$

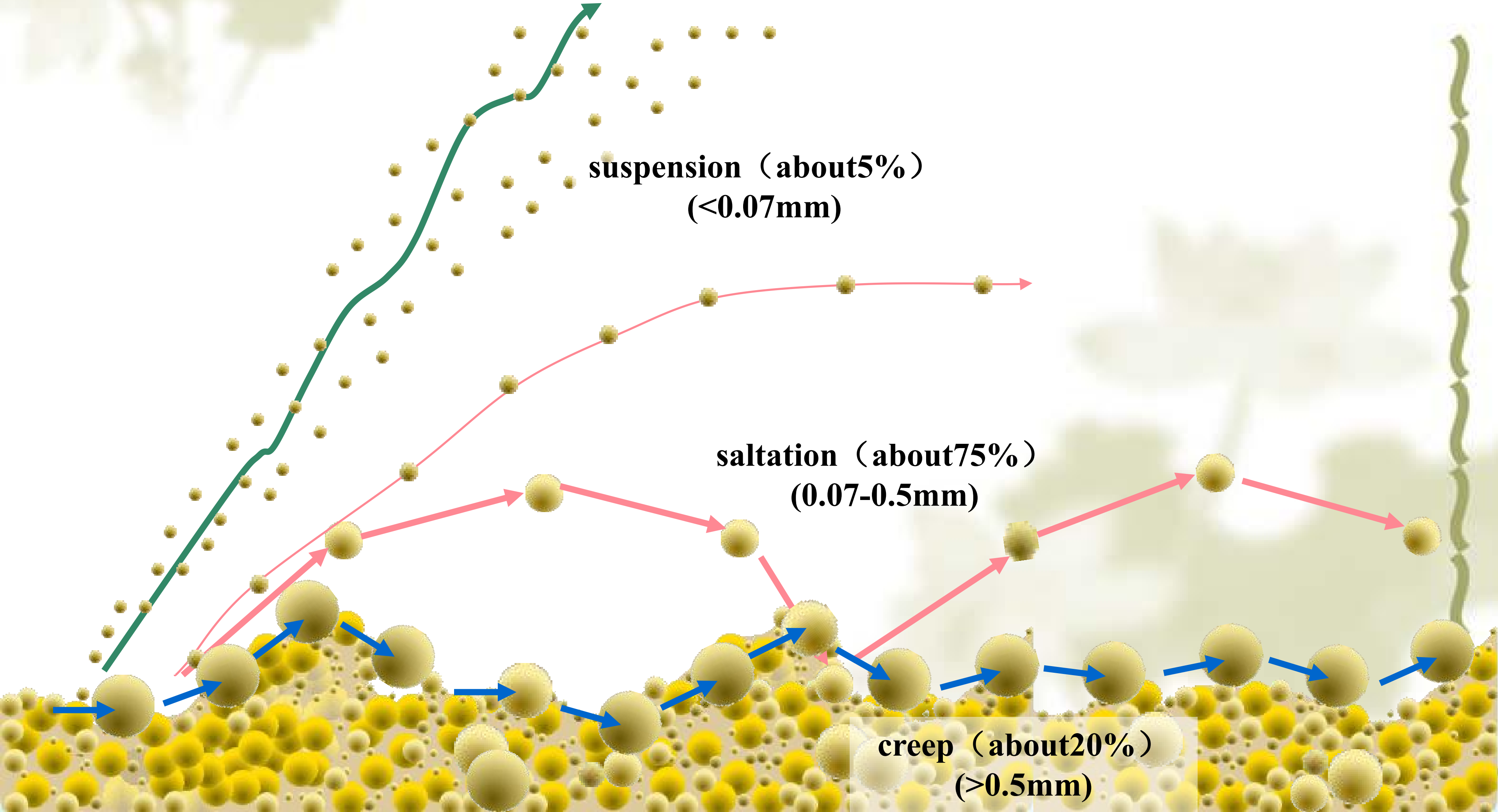
$K_{SA} = 2.5$

$K_{SS} = 1.1$

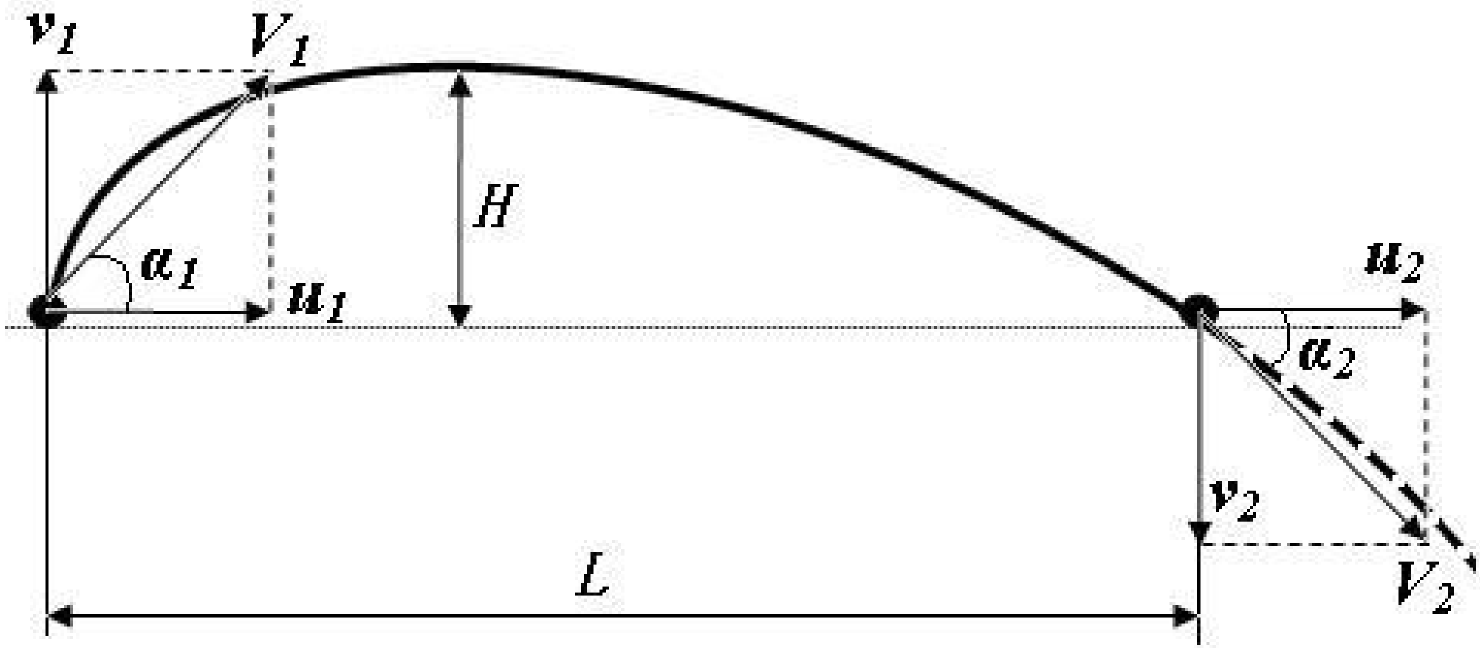




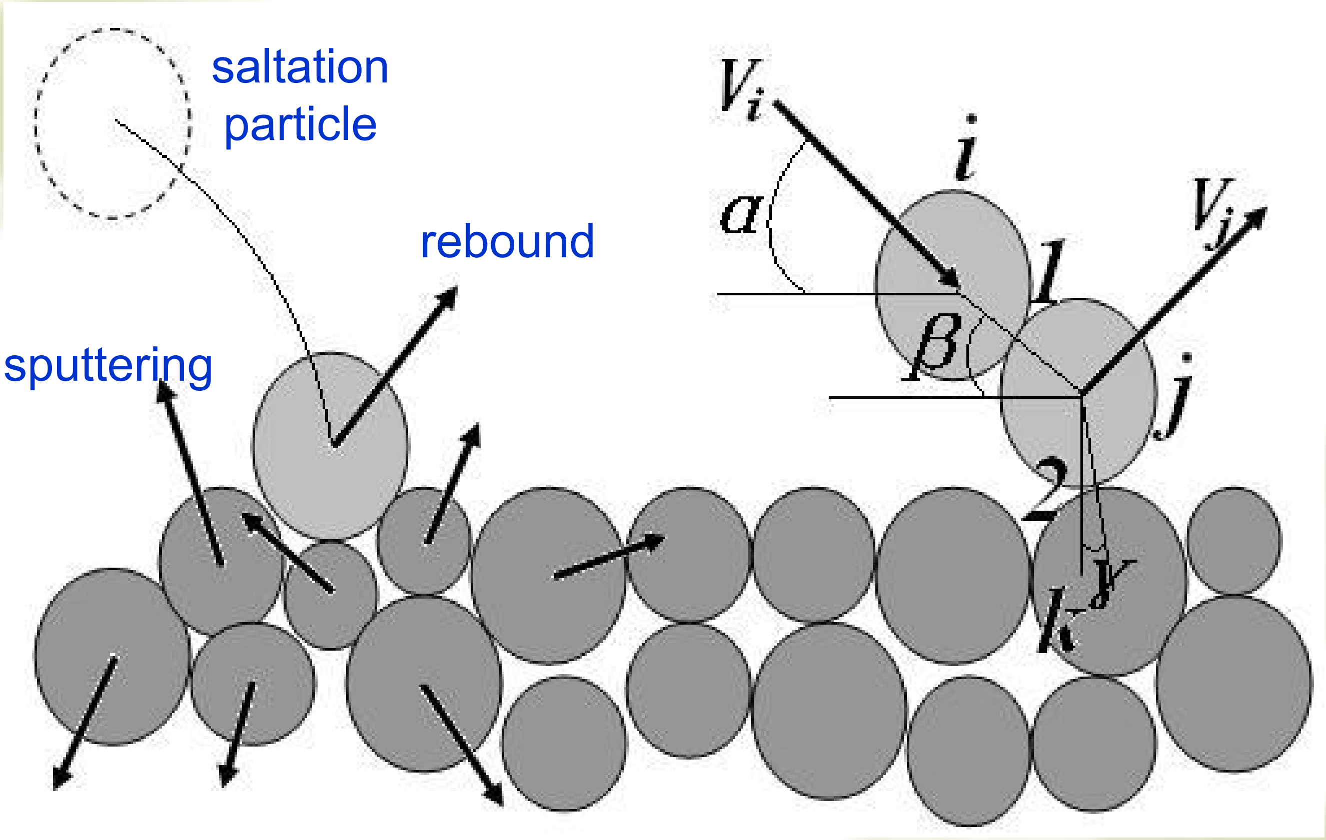
Simulation conditions



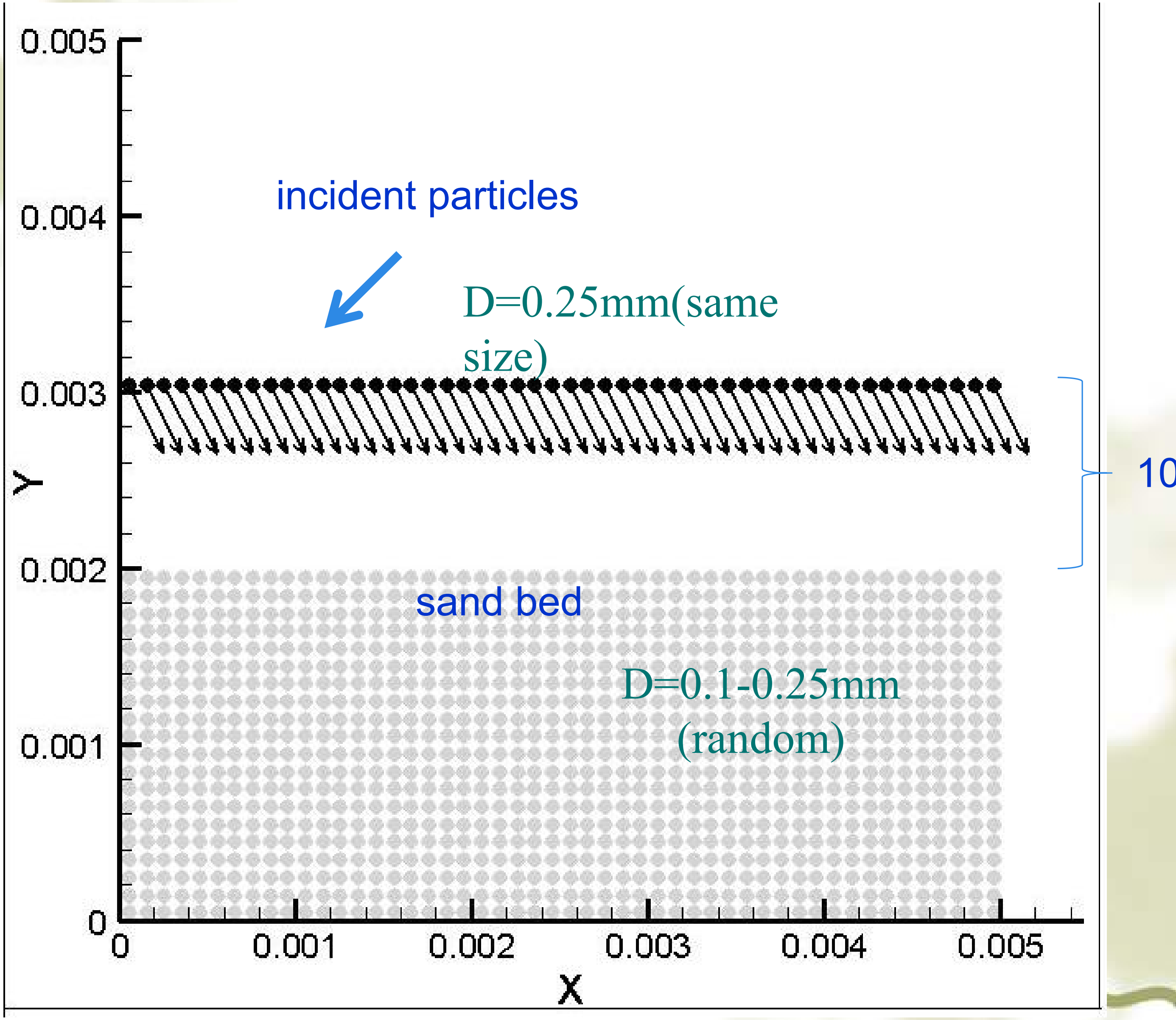
Trajectory of saltaion particle

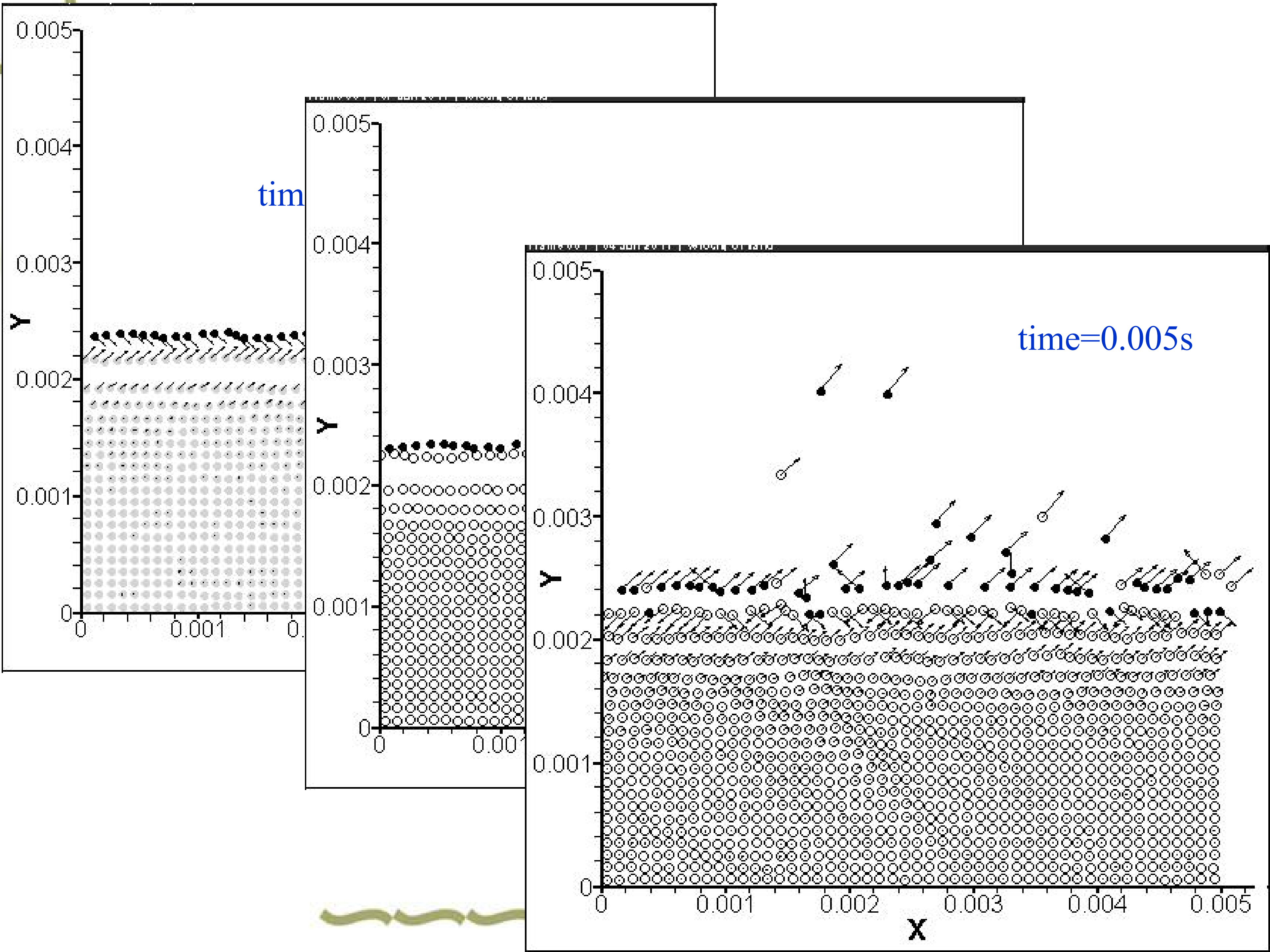


Collision model



Initial setting of simulation





tim
time=0.005s
Y
X
0.005
0.004
0.003
0.002
0.001
0
0.001
0.002
0.003
0.004
0.005

	Incident sand particle size (mm)	Incident velocity (m/s)	Incident angle (°)	Rebound velocity (m/s)	Rebound angle (°)	Rebound/ Incident（velocity）
Rice et al.	0.15-0.25	3.85	10.85	1.99	44.63	0.52
		3.78	10.24	2.13	38.03	0.58
		3.74	10.45	2.16	37.85	0.58
Anderson &Haff 1991	0.32 (same size)	1-8	11.5	0.6-4.9	42-48	
Li 2007	0.32 (mix size)	1-8	11.5	0.6-4.8	47	0.6-0.65
Our study	0.25	2.24	30	1.4-1.9	26-49	0.6-0.8
		1.41	45	0.8-1.1		
		2.07	15	1.2-1.7		

Study	Incident sand particle size (mm)	Sputtering velocity(m/s)				Sputtering/ incident (velocity)
		0.425-0.6	0.3-0.355	0.15-0.25	all	
Rice et al. 1995	0.425-0.6	0.2134	0.2537	0.2335	0.243	0.09
		0.2574	0.2402	0.2418	0.2422	0.09
		0.2381	0.2548	0.2521	0.2522	0.09
		0.2708	0.2878	0.2398	0.2637	0.09
	0.3-0.355	0.2253	0.2839	0.2268	0.2544	0.08
		0.2051	0.2686	0.2416	0.2520	0.08
		0.2584	0.2716	0.2506	0.2607	0.08
		0.2730	0.3117	0.2848	0.2950	0.09
	0.15-0.25	0.2011	0.2669	0.2914	0.2757	0.07
		0.1736	0.2299	0.2946	0.2566	0.07
		0.1956	0.2905	0.2736	0.2773	0.07

Study	Incident sand particle size (mm)					Sputtering velocity(m/s)	Sputtering/ incident (velocity)
Anderson& Haff 1991	0.32 (same size)	Incident angle	8	Incident velocity	1-8	0.27-0.47	
			11.5				
Li 2007	0.32 (mix size)		8		<3	0.18-0.26	0.1-0.2
			11.5		≥3	0.26-0.38	0.05-0.1
Our study	0.25		30		2.24	0.35-0.43	0.17-0.3
			45		1.41	0.46-0.52	
			15		2.07	0.28-0.36	

<table>
<tr><th rowspan="2">Study</th><th rowspan="2">Incident sand particle size (mm)</th><th colspan="7">Sputtering angle (°)</th></tr>
<tr><th colspan="2">0.425-0.6</th><th colspan="2">0.3-0.355</th><th colspan="2">0.15-0.25</th><th>all</th></tr>
<tr><td rowspan="12">Rice et al. 1995</td><td rowspan="4">0.425-0.6</td><td colspan="2">48.32</td><td colspan="2">50.39</td><td colspan="2">50.58</td><td>50.36</td></tr>
<tr><td colspan="2">44.76</td><td colspan="2">51.83</td><td colspan="2">47.36</td><td>49.27</td></tr>
<tr><td colspan="2">46.86</td><td colspan="2">54.37</td><td colspan="2">54.31</td><td>53.77</td></tr>
<tr><td colspan="2">37.41</td><td colspan="2">48.82</td><td colspan="2">51.49</td><td>49.34</td></tr>
<tr><td rowspan="4">0.3-0.355</td><td colspan="2">47.75</td><td colspan="2">54.05</td><td colspan="2">66.41</td><td>59.03</td></tr>
<tr><td colspan="2">52.89</td><td colspan="2">52.74</td><td colspan="2">54.35</td><td>53.57</td></tr>
<tr><td colspan="2">36.31</td><td colspan="2">59.09</td><td colspan="2">62.09</td><td>59.47</td></tr>
<tr><td colspan="2">47.40</td><td colspan="2">52.56</td><td colspan="2">53.02</td><td>52.50</td></tr>
<tr><td rowspan="4">0.15-0.25</td><td colspan="2">32.28</td><td colspan="2">56.14</td><td colspan="2">60.07</td><td>56.57</td></tr>
<tr><td colspan="2">41.21</td><td colspan="2">55.07</td><td colspan="2">56.13</td><td>54.58</td></tr>
<tr><td colspan="2">42.88</td><td colspan="2">55.47</td><td colspan="2">55.73</td><td>55.00</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td rowspan="2">Anderson& Haff 1991</td><td rowspan="2">0.32 (same size)</td><td rowspan="7">Incident velocity</td><td rowspan="2" colspan="2">1-8</td><td rowspan="7">Incident angle</td><td>8</td><td rowspan="2" colspan="2">67-76</td></tr>
<tr><td>11.5</td></tr>
<tr><td rowspan="2">Li 2007</td><td rowspan="2">0.32 (mix size)</td><td rowspan="2" colspan="2">1-8</td><td>8</td><td rowspan="2" colspan="2">63-69
mean=66</td></tr>
<tr><td>11.5</td></tr>
<tr><td rowspan="3">Our study</td><td rowspan="3">0.25</td><td colspan="2">2.24</td><td>30</td><td rowspan="3" colspan="2">35-89</td></tr>
<tr><td colspan="2">1.41</td><td>45</td></tr>
<tr><td colspan="2">2.07</td><td>15</td></tr>
</table>

Conclusion

- Establish the coupling between sand phase and gas phase
- Simulate the process of wind-blown sand movement based on SPH
- Help to explain the mechanism of wind-blown sand movement

THE END