Windblown dust deposition in solar farms

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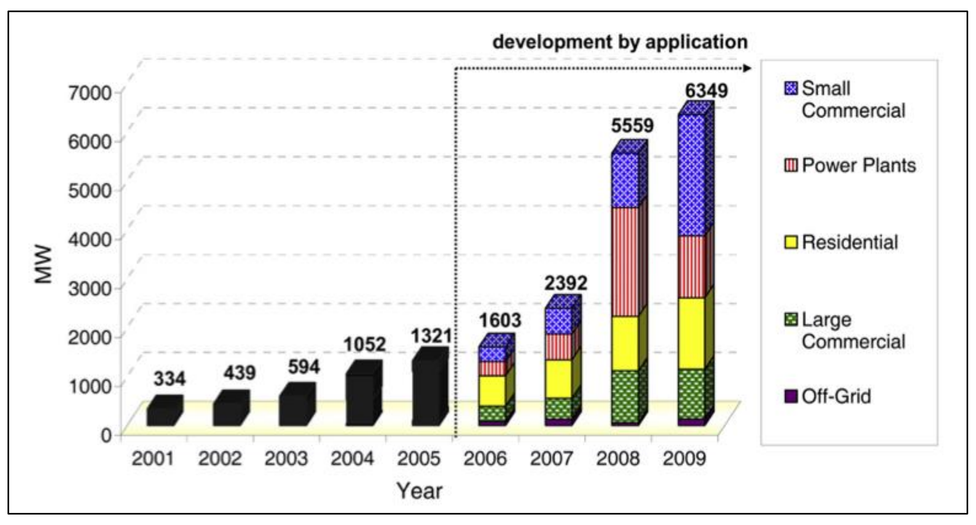
Abstract

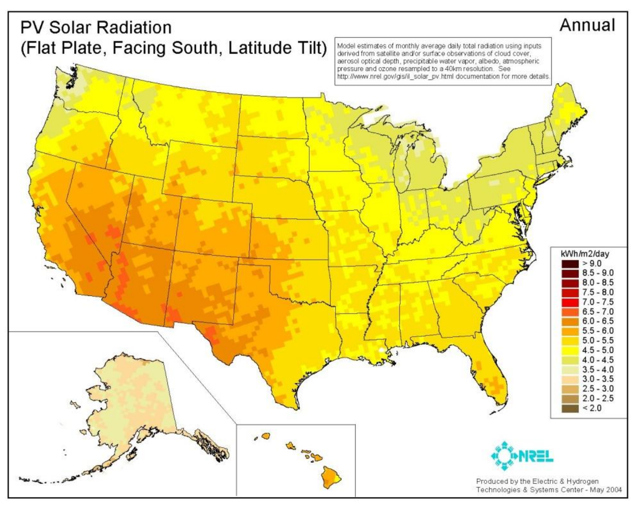
Dust accumulation on solar collectors can significantly reduce the electrical output of solar farms. The presence of solar panel array can significantly accelerate or decelerate wind speed and distort the wind velocity profiles near the ground, which leads to considerable changes in dust transportation and deposition. This work applied the Unsteady Reynolds-averaged Navier-Stokes (URANS) model to simulate the vortex shedding phenomenon over the inclined flat solar panel for a Reynolds number Re=20 000 with different angle of attack α and gap ratio G/L, the ratio of the distance from the plate to the ground (G) to the panel length (L). Vortex generation from the leading and trailing edge was captured clearly and the transportation and development of vortex structures were shown. The smaller the gap ratio is, the more the flow characteristics are affected by the ground presence. The wind speed reduction region was shown for one and two panels, with Lagrangian particle tracking method showing the tracks of particles.

Background

- Solar energy industry is developing fast



- Solar Energy Distribution in US



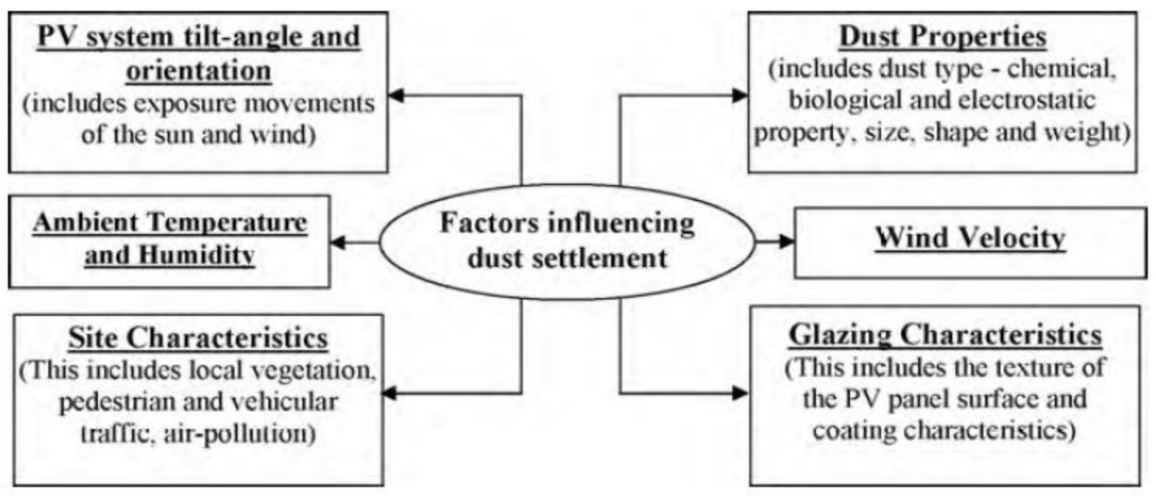
- Design of solar arrays

Dust deposition

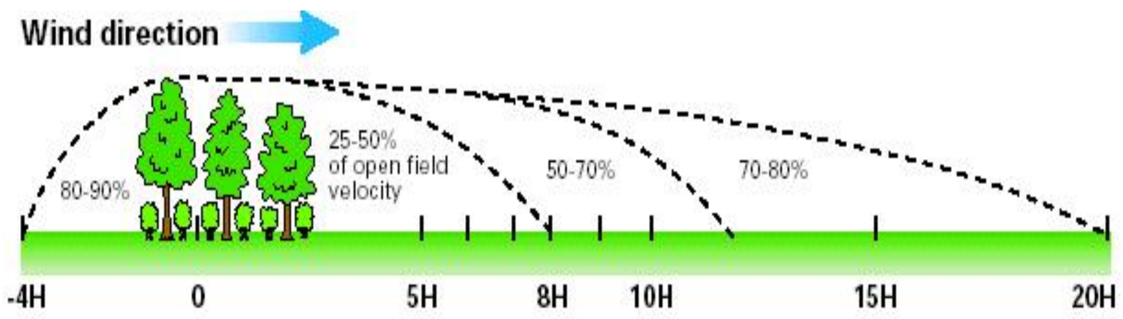
- The performance of the system is mainly influenced by the ability of the glass to transmit solar radiation. Major effects for efficient lost:

Effect	Range
Temperature	1%–10%
Angle of incidence	1%–5%
Ageing	5% over lifetime
Soil and dirt	0%–15%
Snow	Location dependent
Partial shading	Location dependent
Diodes and wiring	3%

- Factors influencing dust settlement

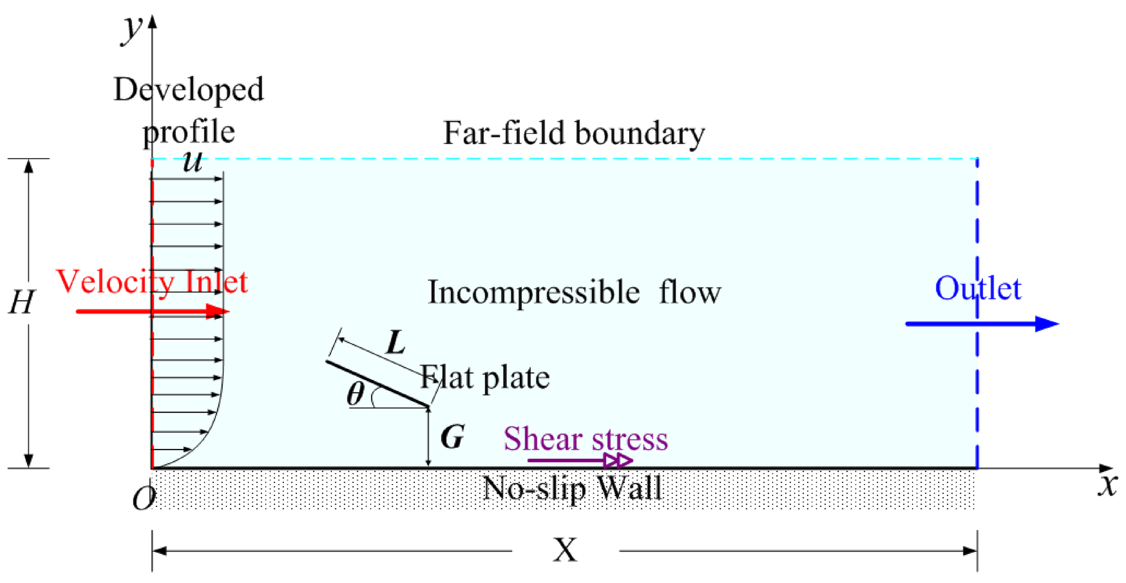


- Wind speed reduction by structures



Numerical method

- Numerical details



Geometric design for the computational domain and boundary conditions applied

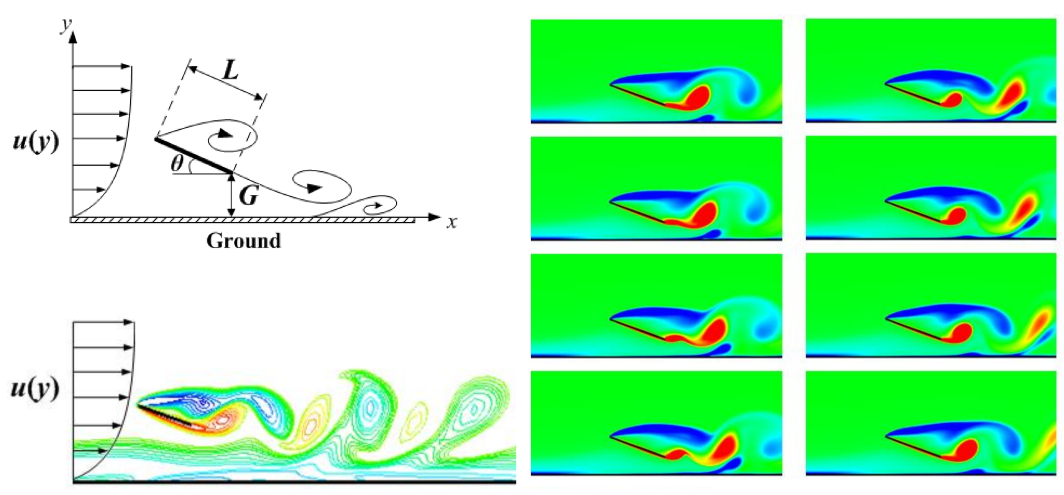
- Model validation

	Cl	Cd	St'
Coarse	1.193	0.395	0.178
Medium	1.175	0.393	0.179
Fine	1.153	0.388	0.179
Paper(DES-F)	1.153	0.389	0.189
Paper(LES-VF)	1.128	0.380	0.192
Paper(RANS-F)	1.318	0.439	-

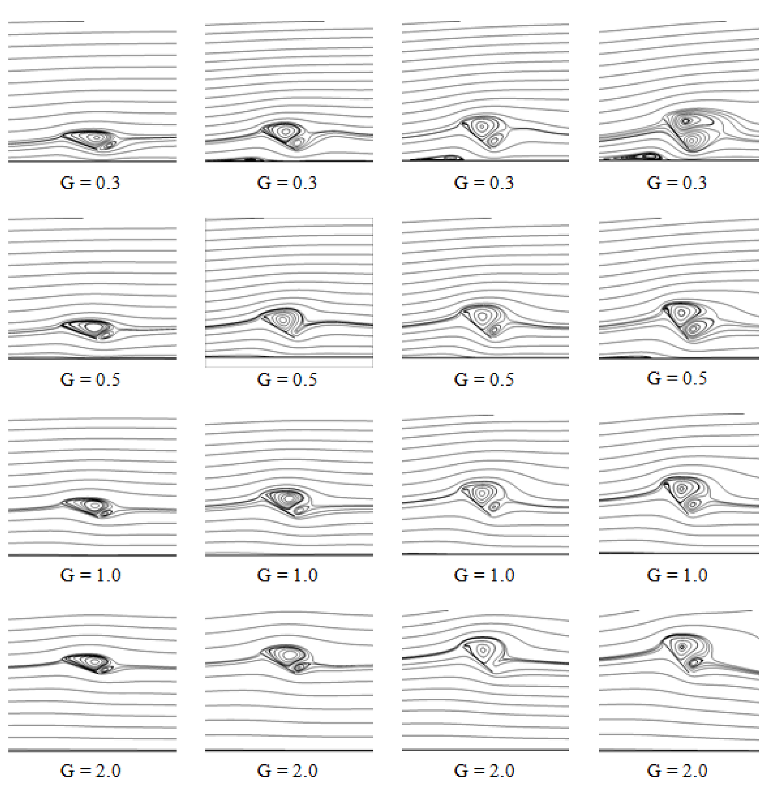
The comparison of results including the drag/lift coefficients (Cd, Cl) and Strouhal number with Breuer's paper[5] using coarse, medium and fine meshes

Flow structures around panel

- Instantaneous and time-averaged data



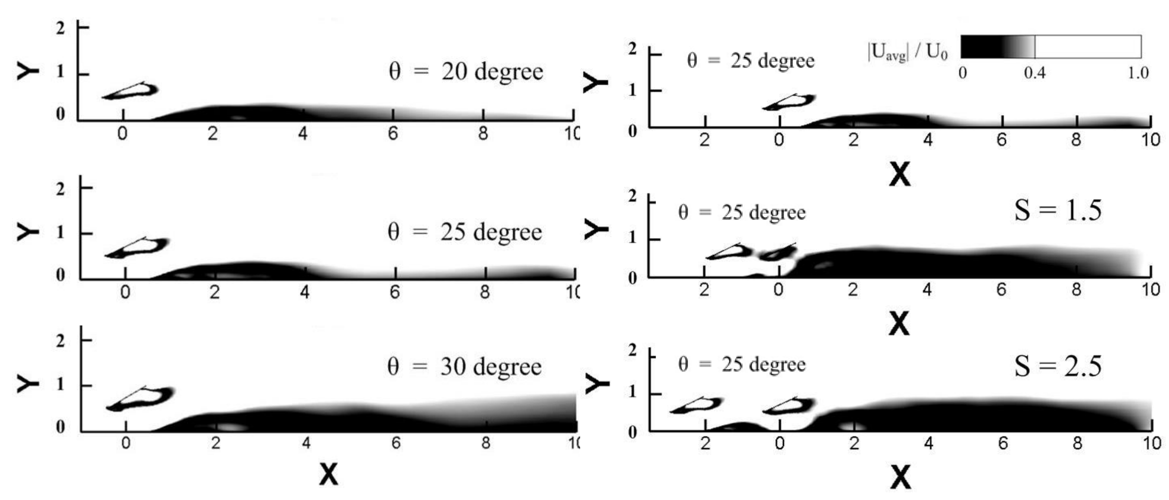
Instantaneous vortex shedding structures (left) and frames for one whole period (right)



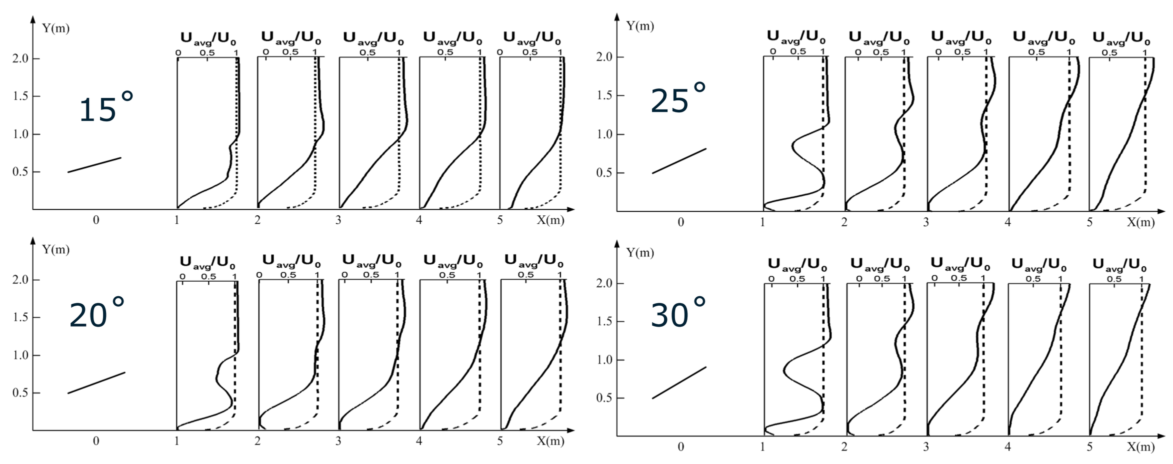
Streamlines of time-averaged flow around the inclined flat plate and the ground, for α = 20, 30, 40, 50 (from left column to right)

Results for dust deposition

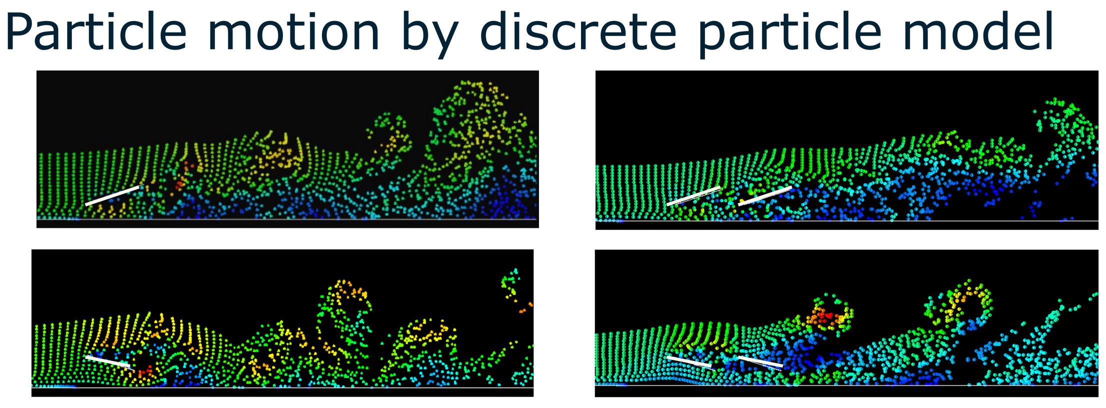
- Wind reduction region by one and two panel



- Time-averaged wind speed in downstream



- Particle motion by discrete particle model



Contour color shows the velocity magnitude of particles

Conclusions

❑Vortex shedding is clearly captured by URANS model

❑Wind speed in the downstream near the ground can be reduced by single panel

❑Two panels will reduce the wind speed in the downstream for 10 times length of panel length

Future work:

❑Unsteady RANS simulation for multiple panels

❑Simplified model for large-scale solar arrays

References

(1) J.K.Kaldellis, A. Kokala, Energy (2010) 4862-9.

(2) M. Mani, R. Pillai, Renewable & Sustainable Energy Reviews 14 (2010) 3124-3131.

(3) M.S. Elshobokshy, F.M. Hussein, Solar Energy 51 (1993) 505-511.

(4) G. M. Burdick, N. S. Berman, S. P. Beaudoin, Thin Solid Films 488 (2005) 116-123.

(5) M. Breuer, N. Jovičić, and K. Mazaev, International journal for numerical methods in fluids 41 (2003) 357.