A Numerical Study of Snow Aggregates

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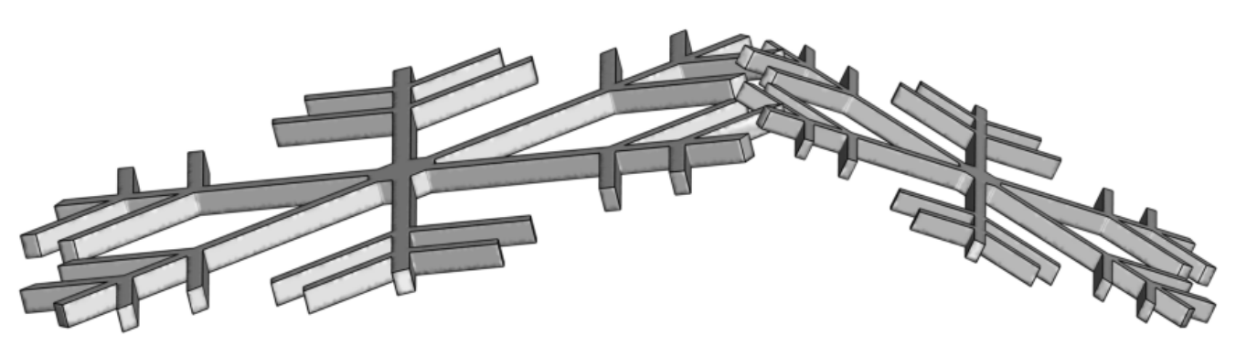
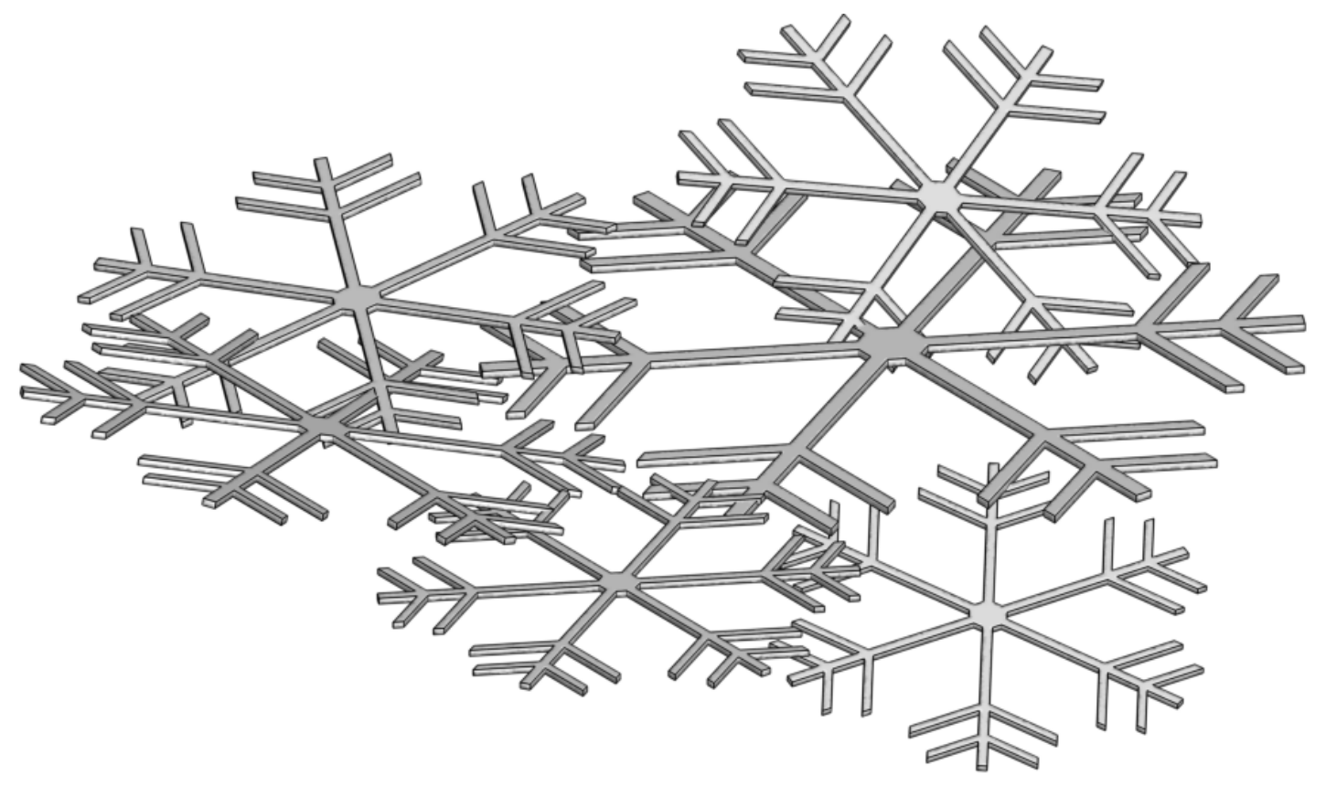
Introduction

When hydrometeors move in air, they generate flow fields around them. These flow fields influence many important cloud microphysical processes. For example, collision between hydrometeors may produce larger particles if they coalesce subsequently, but the major factor that determines the collision efficiency is the flow field. The flow field may prevent the collision from occurring even if the collectee particle lies in the path of the collector particle, as the hydrodynamic force of the flow may carry the collectee particle away. The details of the flow fields around falling hydrometeors are an important subject in cloud physics studies. Here, we perform numerical simulations of falling snow aggregates by allowing them to interact with their own flow field so that the aggregate may freely move sideways, and rotate in response to the hydrodynamic force of the field, as it would in the real atmosphere.





Crystal Attitudes

- Ordinary dendritic crystal (P1e) in accordance with Magono and Lee, 1966 classification scheme
- Crystal diameter and thickness determined using empirical relationships given by Auer and Veal, 1970

Table 1. Number of snow crystals per aggregate, maximum dimension (diameter), terminal velocity, drag coefficient, Reynolds number and ventilation coefficient of snow aggregates.

#	size [mm]	v_t [m s^{-1}]	c_D	N_{Re}	ventilation coefficient
2	2.1	0.24	7.8	41	1.02
6	2	0.29	4	40	-
6	15	0.96	8.4	912	1.43

Rotation and translation

- Horizontal motions and orientation of snow aggregates may have impacts on the collision efficiency and traveled distance
- Collision efficiency is defined under the assumption that a collector hydrometeor falls only vertically (Pruppacher and Klett, 1997; Wang, 2013)
- Will travel a farther distance than one falling with pure vertical motion, higher likelihood to collide with small droplets.

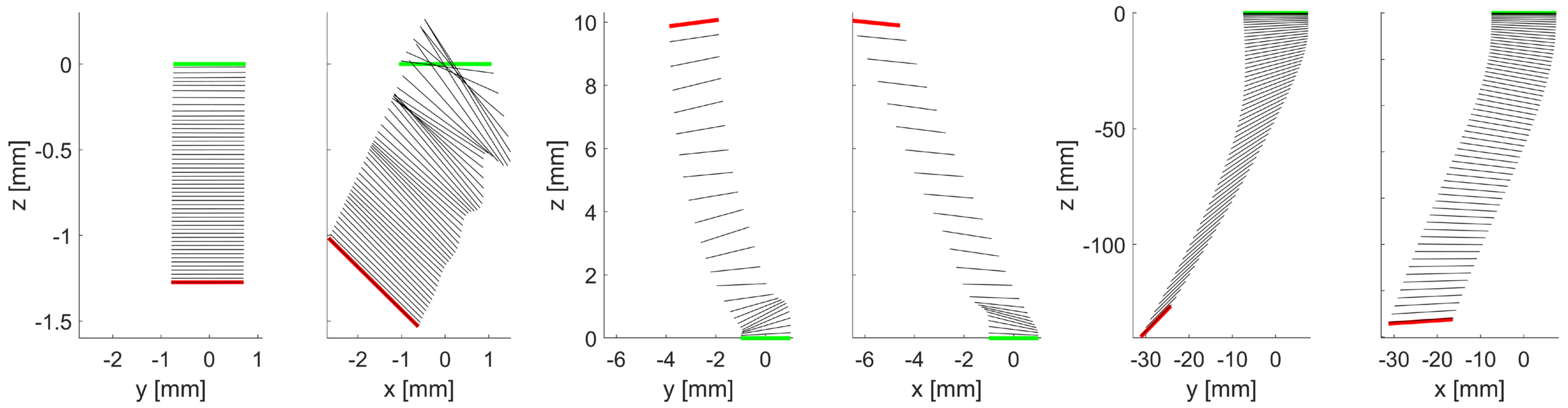


Figure 1. Trajectories of snow aggregates as shown through consecutive snapshots of the aggregate position on the x-z and y-z planes. The time interval is 0.001 s (left panel) and 0.005 s (center and right panel). The initial (final) position of the aggregate is highlighted green (red) on the projection. Left panel: 2.1 mm with 2 P1e. Center panel: 2 mm with 6 P1e. Right Panel: 15 mm with 6 P1e.

Pressure

- Pressure minimum on the upper edge of the peaks of the crystals and lends support to the observation that crystals tend to grow faster about their peaks.

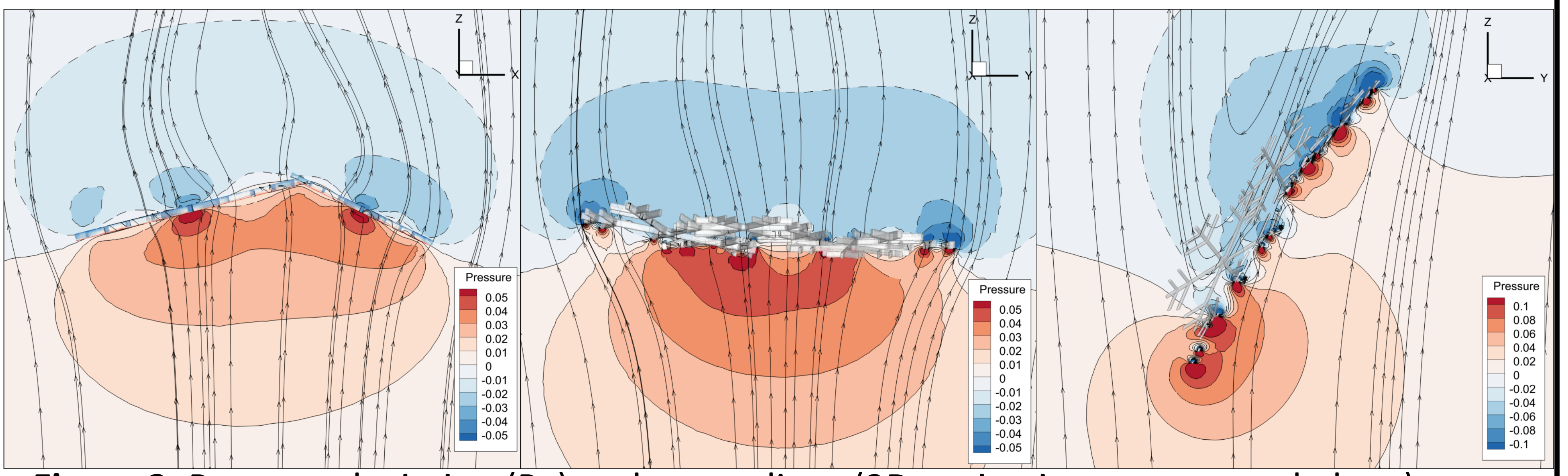


Figure 2. Pressure deviation (Pa) and streamlines (2D projection onto central plane) around snow aggregates. Left panel: 2.1 mm with 2 P1e. Center panel: 2 mm with 6 P1e. Right Panel: 15 mm with 6 P1e.

Vorticity

- Structure of the wake and downstream flow, illustrated here using vorticity, may influence the collection of cloud droplets and scavenging of aerosol particles by ice crystals.

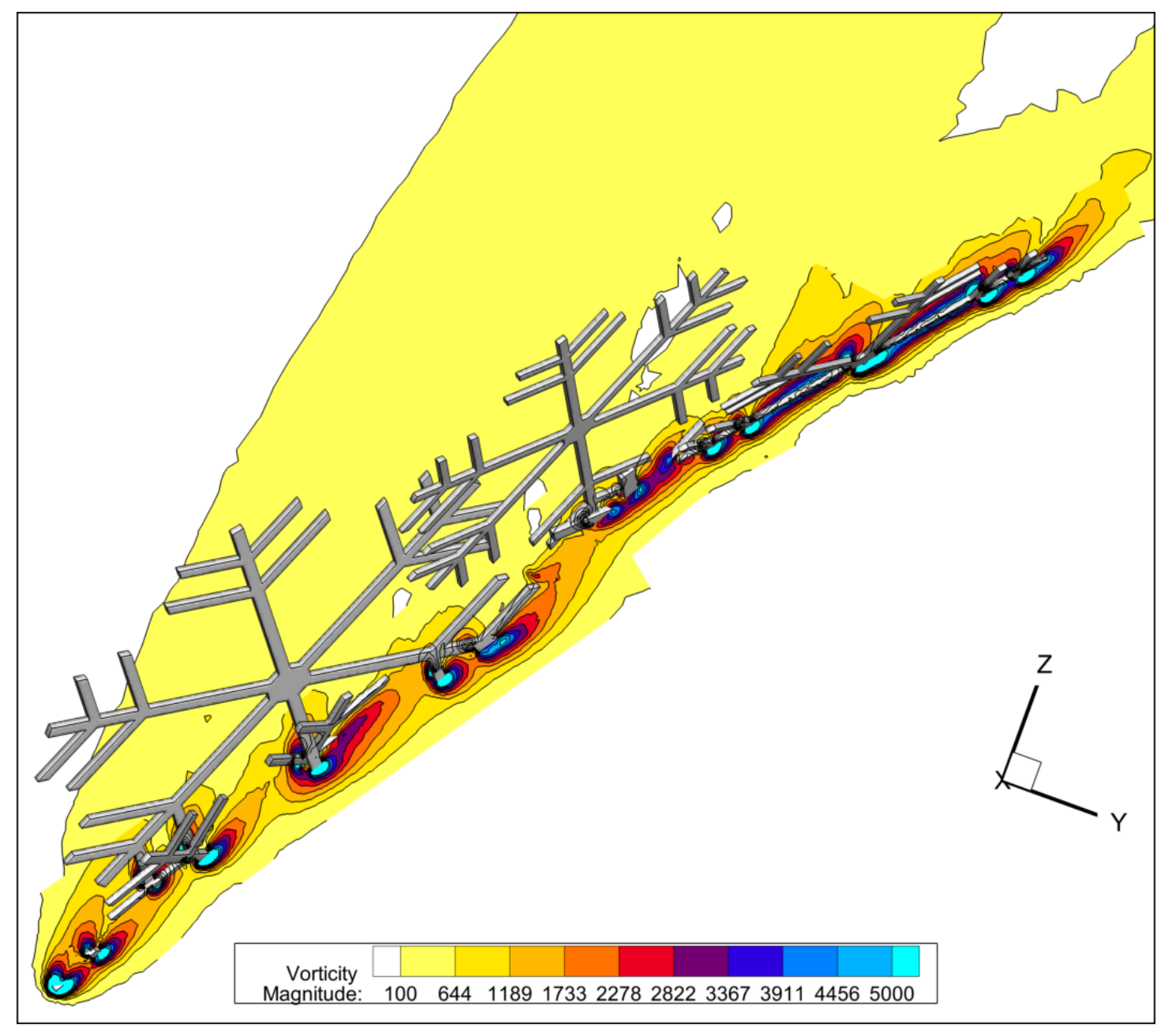


Figure 3. Vorticity distribution (s^{-1}) around a 15 mm snow aggregate.

Vapor density distribution

- The enhancement of the diffusional growth/evaporation rate of cloud and precipitation particles due to movement relative to the flow, is due to the enhancement of the vapor density gradient around a falling hydrometeor compared to a stationary one.

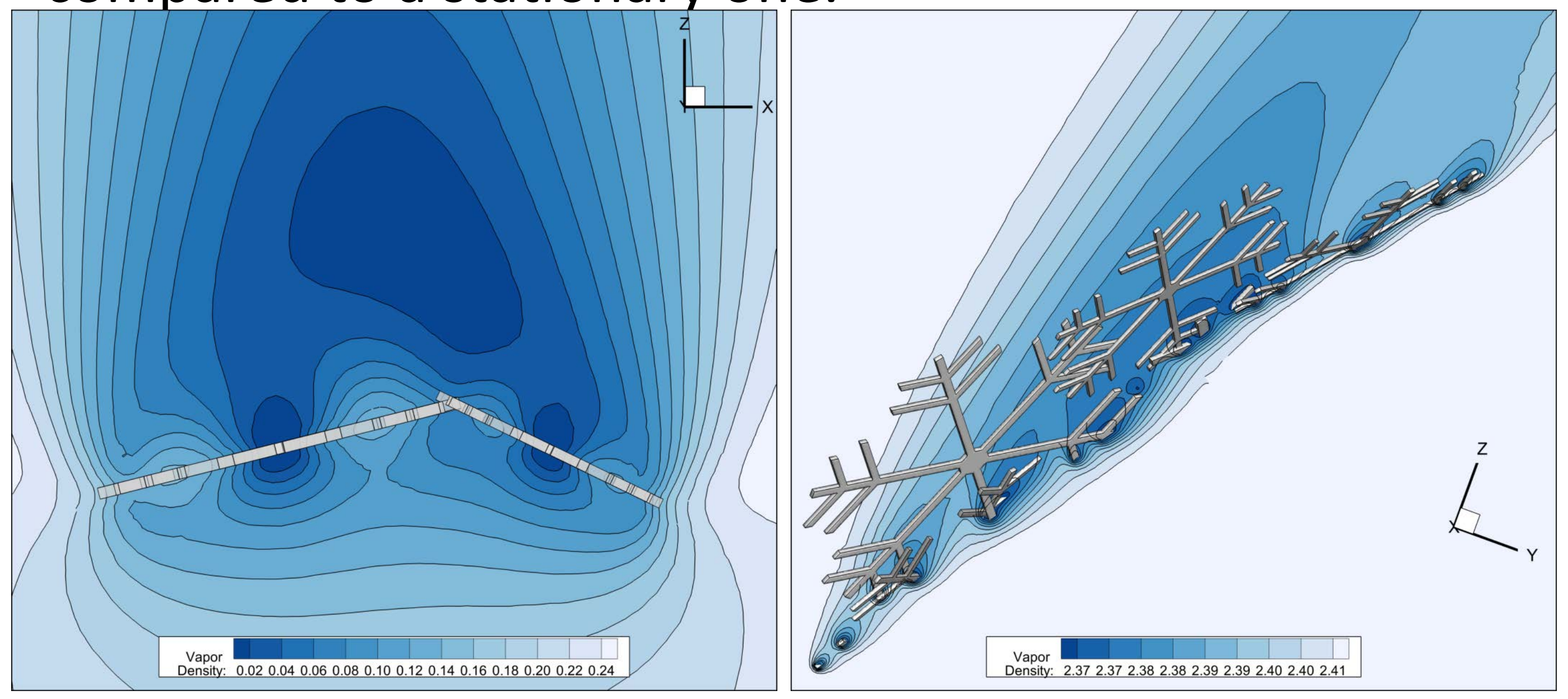


Figure 4. Vapor density distribution (g m^{-3}) around snow aggregates with diameters of 2.1 mm (left panel) and 15 mm (right panel).

References

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