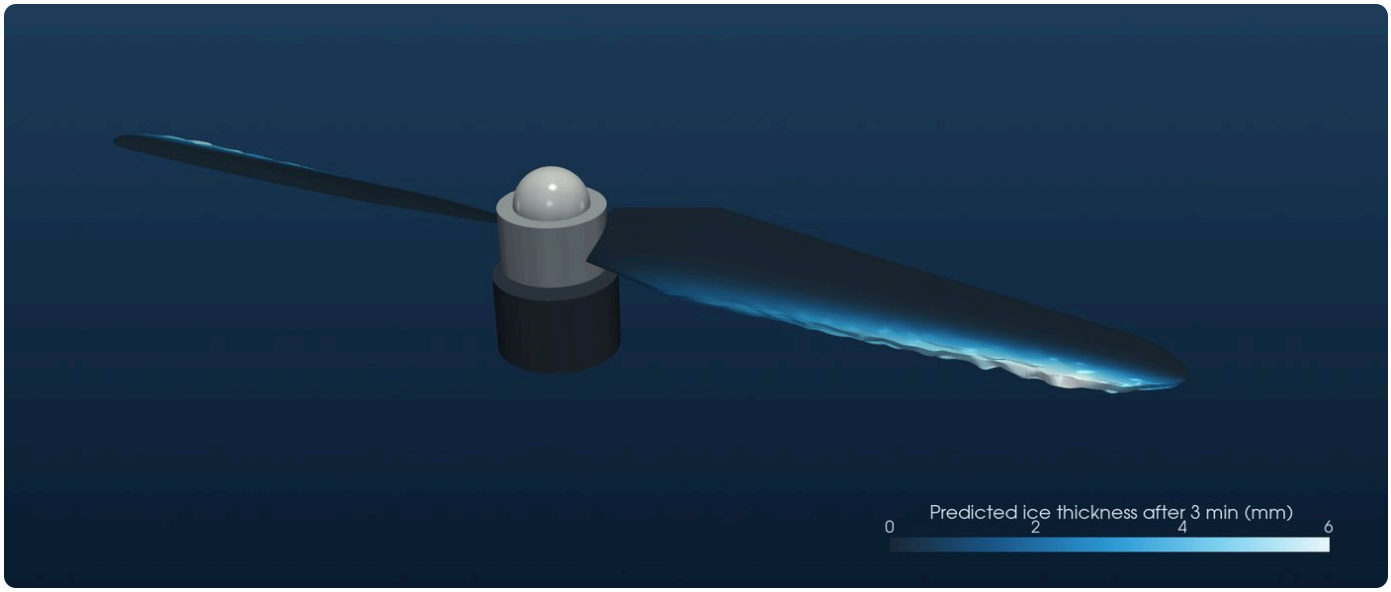
Drone propeller icing: fast, validated engineering estimates

How much ice will form on your propellers, how much stays on, and how much heater power keeps them clear, answered in days, before any icing wind tunnel campaign.



Predicted ice thickness on a 15-inch two-blade propeller after 3 minutes of hover at 6000 RPM, −5 °C, 0.3 g/m³ liquid water content and 20 µm droplets. Ice grows fastest towards the tip, where the blade speed is highest.

01 The problem

Small drones meet icing at low altitude whenever supercooled cloud, fog or drizzle is present near 0 °C. Propellers ice first and fastest: a millimetre of ice on the leading edge already costs lift, raises motor current and causes vibration when pieces shed unevenly. Most drone makers therefore simply ground their aircraft in icing conditions, which limits their market in cold climates.

Full icing CFD can answer the design questions, but it needs specialist software, meshing and computing time. In early design, engineers need quicker answers they can trust.

02 What the SOREC model does

Inputs: propeller geometry (radius, blades, chord and thickness along the span), RPM, air temperature, cloud liquid water content and droplet size, and optionally a heater layout.

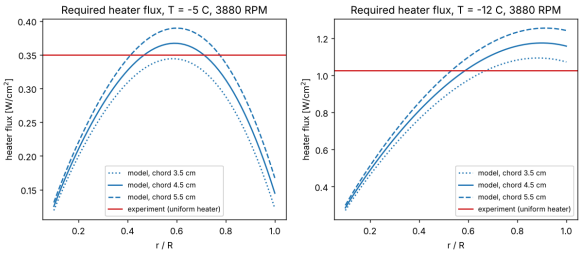
Physics: droplet collection on the blade (Finstad / ISO 12494), the Messinger heat balance with rime and glaze regimes, stagnation and flat-plate heat transfer, and centrifugal ice shedding.

Outputs, along the blade:

- ice type (rime, glaze or none) and growth rate
- ice mass collected and ice retained after shedding
- heater power needed for running-wet anti-icing
- total heater power and the flight-time penalty

03 Heater power: four-blade rotor in an icing wind tunnel

The model was compared with published icing wind tunnel tests of a 0.66 m, four-blade drone rotor at 3880 RPM in a dense icing cloud (6.3 g/m³, 120 µm droplets), with the heater power needed to keep the blades ice-free as reported in [1]. We compare the peak heat flux our model requires along the blade with the measured uniform heater flux at the same conditions. For reference, the reduced-order model in [1] overestimated the −5 °C flux by about 50 %.

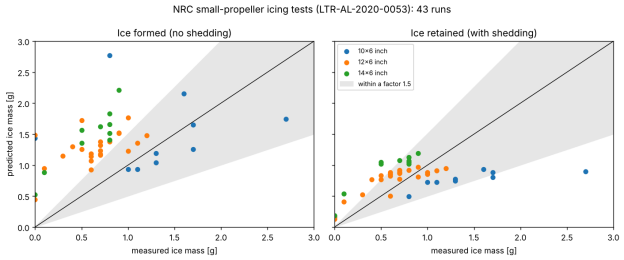


Temperature	Measured heater flux	Predicted peak flux	Difference
−5 °C	0.35 W/cm²	0.34 – 0.39 W/cm²	−2 % to +11 %
−12 °C	1.03 W/cm²	1.09 – 1.25 W/cm²	+7 % to +22 %

The ranges cover the uncertainty in the blade chord (3.5 to 5.5 cm), which was not published. The model tends to be slightly conservative, which is the safe side for heater sizing.

04 Ice mass: 43 runs on 10- to 14-inch propellers

Against 43 icing tunnel runs on small commercial propellers at 8000–9000 RPM [2], we compare the ice mass weighed on the propeller after each run. *Ice formed* is all ice that freezes on the blades; *ice retained* subtracts what centrifugal force throws off once it outgrows its adhesion strength. Accounting for shedding cut the root-mean-square (RMS) error from 0.79 g to 0.44 g, against a mean measured mass of 0.78 g; most runs fall within a factor of 1.5. The adhesion coefficient (17,800 Pa/K) was fitted to these runs.



05 Known limits

The model treats each blade station separately and does not resolve 3D flow or heat conduction into the hub, so it is less accurate near the root than near the tip. Without exact blade geometry it misses part of the trend between propeller sizes, and near 0 °C it predicts a little ice where none was measured. A client study uses the real blade geometry and, where needed, a CFD check of the critical cases.

A SOREC icing study for your aircraft uses your propeller geometry and flight envelope: ice growth and shedding along the blade, heater power and layout, and the flight-time cost, at a fixed price. Icephobic coatings and textured surfaces can be compared on the same blade.
Try the free calculator at soreclabs.com/icing.html · Contact sorecllc@gmail.com

[1] A. Samad, E. Villeneuve, F. Morency, M. Béland, M. Lapalme, "A Preliminary Approach towards Rotor Icing Modeling Using the Unsteady Vortex Lattice Method", *Drones* 8 (2024) 65, doi:10.3390/drones8020065 (experimental anti-icing heat fluxes for the APT70 rotor). [2] A. Benmeddour, "Investigation of tolerance for icing of small UAV rotors/propellers: phase 2", National Research Council Canada, Aerospace, report LTR-AL-2020-0053 (2020), doi:10.4224/40002002.