NTNU AMOS
Centre for Autonomous Marine Operations and Systems

# Icing Protection Systems for Unmanned Aerial Vehicles (UAVs) in the Arctic

CIRFA
Centre for Integrated Remote Sensing and Forecasting for Arctic Operations

*Richard Hann – Arctic Change 2018*

## Motivation

In recent years, there has been a strong development and an increased utilization of unmanned aerial vehicles (UAVs) all around the globe. Automated drones are suitable for a wide range of applications and are used in many different industry or science areas today. In the Arctic, fixed-wing UAVs are well suited for remote sensing operations in isolated and harsh areas. However, cold climate conditions impose special challenges for UAVs, effectively limiting their operational envelope. This poster highlights the various applications for UAVs in the Arctic, the current limitations due to the environmental conditions and the state of ongoing research.

Figure 1: X8 ready for flight in Ny-Ålesund, Svalbard. Photo: Kim Sørensen, NTNU

## Opportunities

UAVs are versatile platforms that are mainly used for remote sensing applications and for gathering aerial imagery data. Autonomous drones have several advantages compared to traditional aircrafts. They are low-cost, low-maintenance and can be operated in conditions that may be unsafe for regular aircrafts. They can be fit with various sensors, such as optical, infra-red, hyperspectral or radar. Ideally, drones are used in combination with conventional remote sensing tools (satellites and aircrafts) in order to obtain high quality remote sensing data. Today, the main research focus of UAV applications in the Arctic is in the following fields:

- Sea ice monitoring
- Oil spill detection
- Search and rescue
- Ship-based iceberg detection
- Wildlife and vegetation surveying
- Terrain mapping
- Glaciological surveying
- Avalanche forecasting
- Transportation of small urgent goods (e.g. medical supplies)
- General surveilling and remote sensing
- Border patrol

## Challenges

There are three main challenges when operating UAVs in cold climate conditions: extreme temperatures, high winds and atmospheric icing. Very **low temperatures** can have a negative impact on electronics and mechanical systems. Moreover, the capacity of batteries is severely reduced in low temperatures. For electrically driven drones this will significantly limit their maximum range and endurance.

In the Arctic and in marine environments, UAVs often encounter **harsh winds** and gusts. Small-scale UAVs typically operate at flight velocities between 10-20m/s. It is not uncommon to encounter winds speeds of the same magnitude in arctic environments. This means that either faster drones have to be utilized (which are bigger, heavier and more expensive) or that the UAVs can't operate during periods of high wind velocities. In addition, strong gusts are a challenge for the stability of the aircraft and require special design. Stable flight conditions are especially important when conducting surveying and mapping operations. Extreme gusts can also potentially lead to complete flight instability and consequent crash.

Both aforementioned challenges can be overcome comparatively easy by selecting temperature resilient electronics and larger UAVs. The actual main problem for fixed-wing UAVs in cold climate conditions is **atmospheric icing** [1]. This type of icing occurs when super-cooled cloud droplets collide with the leading-edge of the aircraft and form ice, Figure 2 & 3. These ice accretions are considered to cause a significant degradation in the aerodynamic performance [2] [3], and have been attributed as the main reason for UAV losses in cold climate regions such as the Arctic.

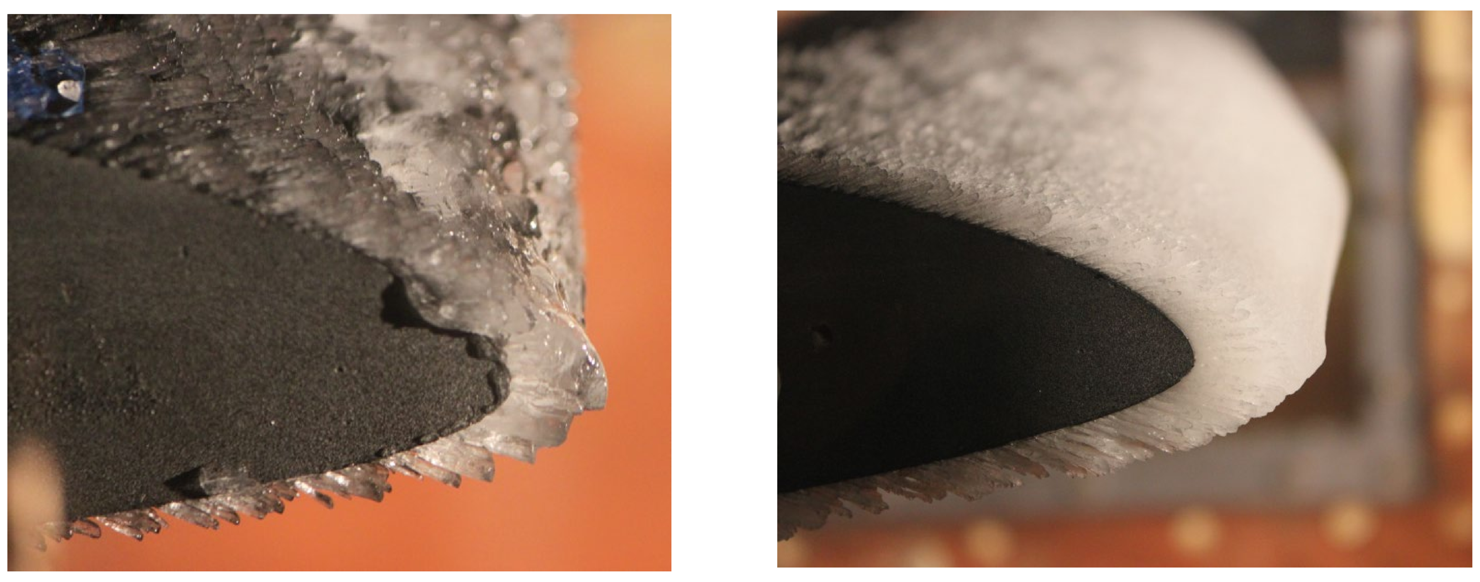

Figure 2: Glaze ice (left) & rime ice (right). Photo: Richard Hann, NTNU

## Research on UAV Icing & Icing Protection

Atmospheric icing is not an issue only affecting UAVs. It is also relevant for general aviation, wind turbines and building structures (e.g. power lines or masts). As such, there has been significant research performed on the topic, with the main focus being on aircraft icing. Transferring results from (commercial or military) aircrafts to UAVs is not a trivial task for a number of reasons. The main is the difference in the Reynolds (Re) number regime between the two applications. Aircrafts are typically operating at relatively high Reynolds numbers $Re=[1..10\times10^6]$. Due to their smaller size and generally lower velocities, UAVs operate in the low-Reynolds number regime $Re=[1..10\times10^5]$.

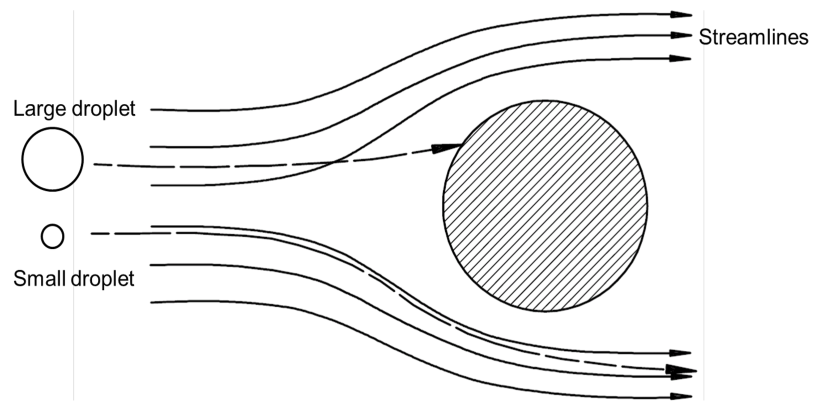


Figure 3: Atmospheric icing

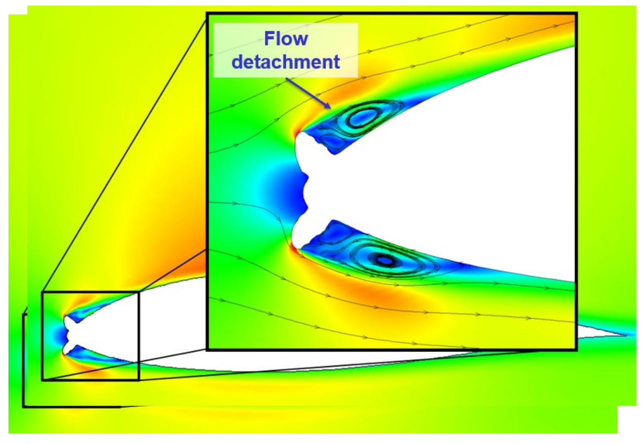


Figure 4: CFD results for icing

There are several numerical tools and methods available to **simulate** icing and icing mitigation on aircrafts [4, 5]. In particular, computational fluid dynamics (CFD) have been proven useful in both predicting ice shapes as well as determining the aerodynamic performance degradation of UAVs, Figure 4.

Currently, we are working on developing an **icing protection system** (IPS) for UAVs using electro-thermal heating [6]. The system will enable UAVs to operate safely during icing conditions and hence offer increased efficiency and availability.

In the scope of this study an electro-thermal system IPS is considered, see Fig. 5. This type of system provides heat to specially coated areas on the wing via electric currents. Such systems are well-suited for UAVs, as they are light-weight and require only electrical power, which is often easily available – although often limited in amount. Generally, there are two different kind of IPS. **Anti-icing systems** continuously supply heat in order to avoid ice accretion on critical surfaces. Such systems are called **fully evaporative** if the provided heat is sufficient to evaporate the incoming liquid water within the impingement zone. The advantage of such a system is that it has no risk for runback icing and the area to be protected is limited. On the draw-back, such systems require high heat fluxes and may result in very high surface temperatures. An anti-icing system is considered to be **running wet** when it is providing just enough heat to prevent super-cooled droplets from freezing on the surface. Running wet anti-icing systems typically require a larger area to be heated, but with lower heat fluxes and lower surface temperatures. The resulting water film from a running wet system may freeze downstream of the heated areas and form runback ice that can have severe effects on the aerodynamics. **De-icing systems** allow uncritical amounts of ice to build up which are removed periodically short bursts of high heat release. Characteristically such systems have a substantially lower energy requirements than an anti-icing system but may not offer the same level of safety.


Figure 5: Anti-icing system in operation with partially unheated zones. Photo: R. Hann

## Conclusions

- The Arctic offers many opportunities for UAVs in the field of remote sensing, monitoring, surveying and search & rescue missions.
- Today, the operational envelope of UAVS in the Arctic is mainly limited by atmospheric icing conditions.
- Icing degrades the aerodynamic performance by increasing drag and decreasing lift, leading to reduced range, shorter endurance and risk for loss of aircraft.
- An icing protection system for UAVs is currently being developed and tested at NTNU (www.d-ice.tech).

## References

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