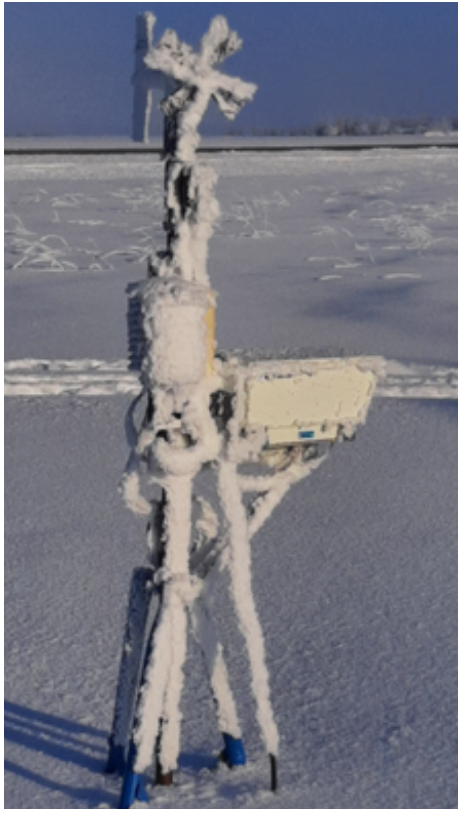
Assessing the Usage of Unmanned Aircraft Systems (UASs) for Conducting Cloud Seeding for Fog Abatement

Left: Images showing ice on plates of octocopter UAS after a super-cooled fog flight in March 2023 at Ice Crystal Engineering.

Left: Images showing the TIMMS in March 2023 at Ice Crystal Engineering.

Right: Images showing ice on the TIMMS after fog event taken on in March 24 2023 at Ice Crystal Engineering.



Definition of Mist and Fog

- An assortment of small hydrometeors suspended at the Earth's surface that reduces horizontal visibility.
  - Mist results in visibility of between 7 statute miles (11.2 km) and 5/8 statute miles (1 km)
  - Fog results in visibility below 5/8 statute miles (1 km).

Images showing fog on May 8, 2023 outside of East Grand Forks, MN. Courtesy of David Delene.

Hazards of Fog

- Fog causes 38,700 vehicle crashes annually, with 16,300 injuries and over 600 fatalities. (U.S. Department of Transportation 2022)
- The transportation (land, sea, air) economic losses for fog are similar to those of severe weather. (Gultepe et al. 2007)
- Visibility reductions is responsible for majority of weather-related aviation accidents. (Gultepe et al. 2007, 2017)
- Of fatal weather-related aviation accidents, fog and low ceilings are the most prevalent factors. (Capobianco and Lee 2001)

Images showing a multi-car wreck near Jamestown. Photo courtesy of North Dakota Highway Patrol and the Jamestown Sun.

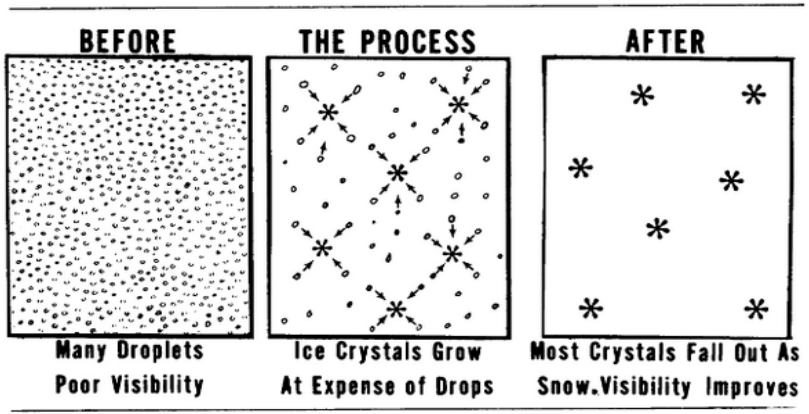
Types of Fog Dispersal (Abatement)

-40 °C | -20 °C | 0 °C

Ice Fog | **Ice and Supercooled Fog** | **Supercooled Fog** | **Warm Fog**

Stable | Metastable | Metastable | Stable

- Dispersal largely preventative.
- Conventional aircraft downwash has limited effectiveness.
- Success is limited to transportation of anthropogenic vapor sources.



Credit: Lease and Zeigler (1972)

Least common, most accomplished dispersal operationally.

- Most common in the mid-latitudes.
- Physical Removal
  - Sound waves
  - Sprays
  - Air-mass Removal
- Evaporation
  - Heat
  - Hygroscopic Materials

Conceptual Model for Supercooled Fog Dispersal

Supercooled Fog Formation

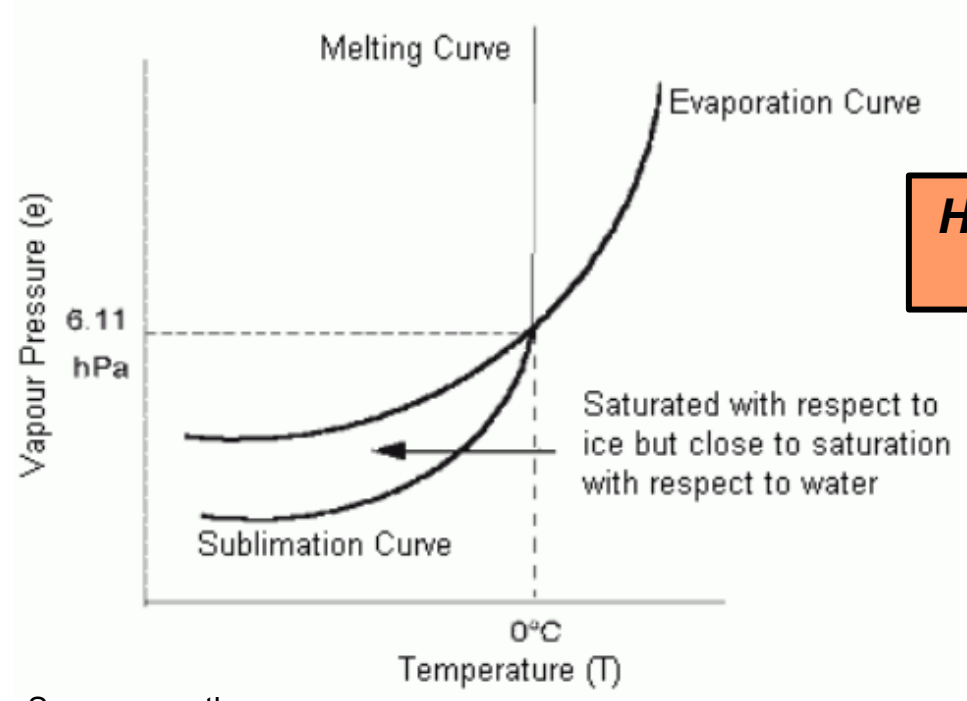
Ice crystal growth potential via Wegener-Bergeron-Findeison process

Heterogeneous Nucleation

Homogeneous Nucleation

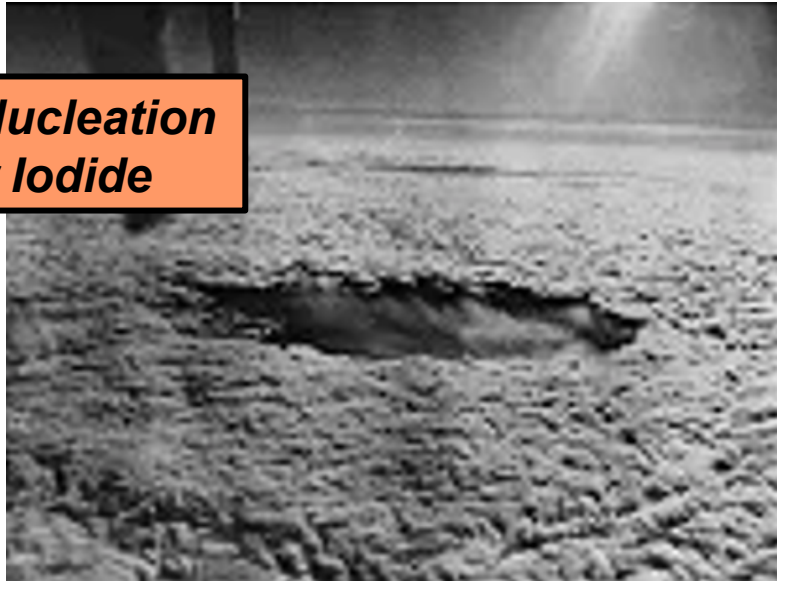
Gravity-induced Fallout

Increasing visibilities, dispersal



Source: weather.gov.

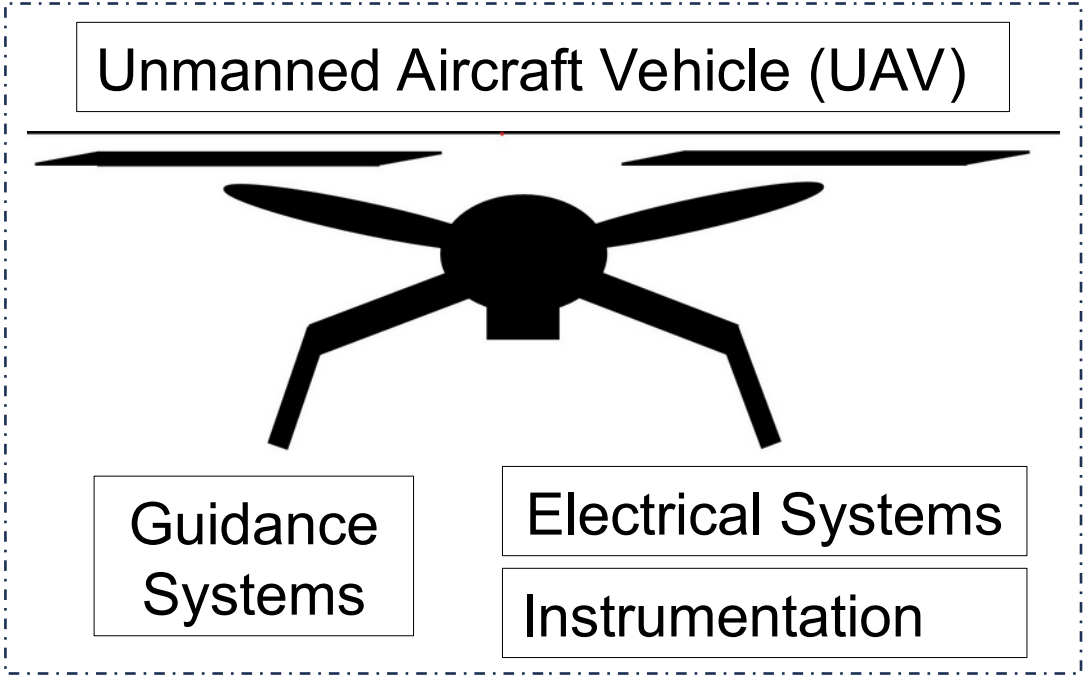
Heterogeneous Nucleation through Silver Iodide



Source: Bulletin of the American Meteorological Society 1965, Volume 46, Issue 6

Unmanned Aircraft System (UAS) Platform

- Existing dispersal methods have used tethered balloon or conventional aircraft.
- Near-surface restrictions constrain conventional aircraft.
- Unmanned Aircraft Systems (UAS) is a promising platform for operation within the boundary layer.
  - Swarming UAS



Conceptual Model for UAS Operations

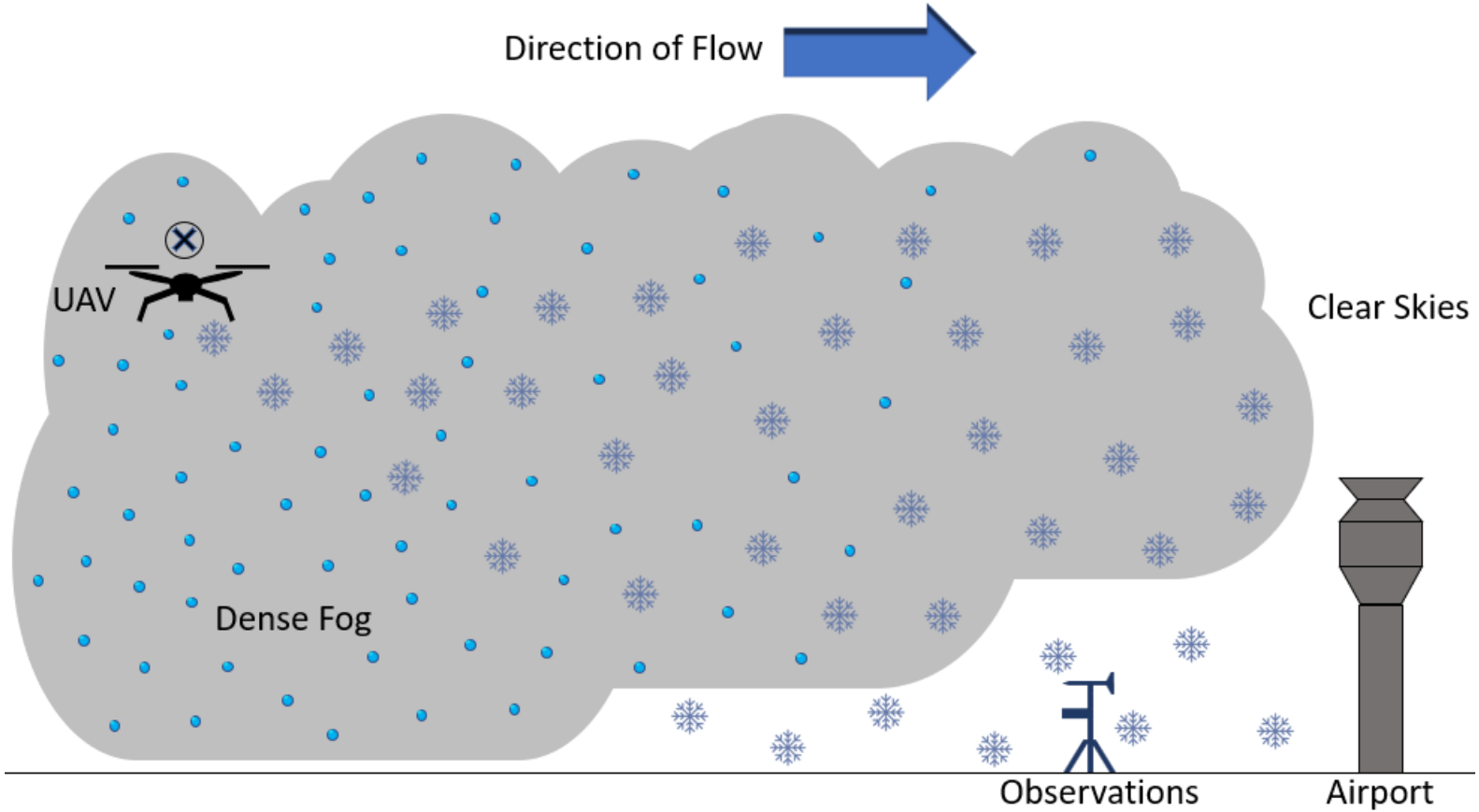
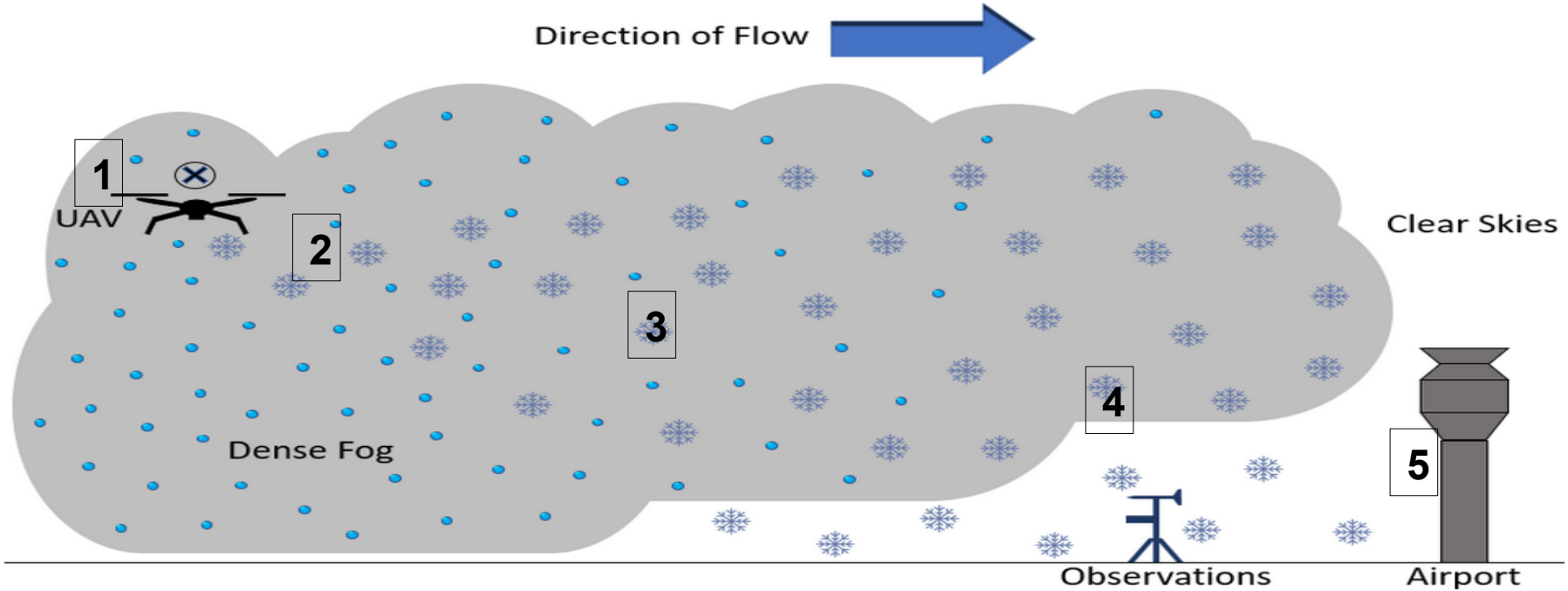


Image illustrating the conceptual model for using Unmanned Aircraft Systems (UASs) to conduct cloud seeding for fog abatement.

Conceptual Model for UAS Operations



1. UAV flies upwind of airport runway, just below top of fog layer.
2. UAV releases seeding material, instigating ice crystal growth.
3. Ice crystals grow at expense of droplets.
4. Ice crystals fall through the extent of cloud.
5. Cloud bases rise, dispersal commences.