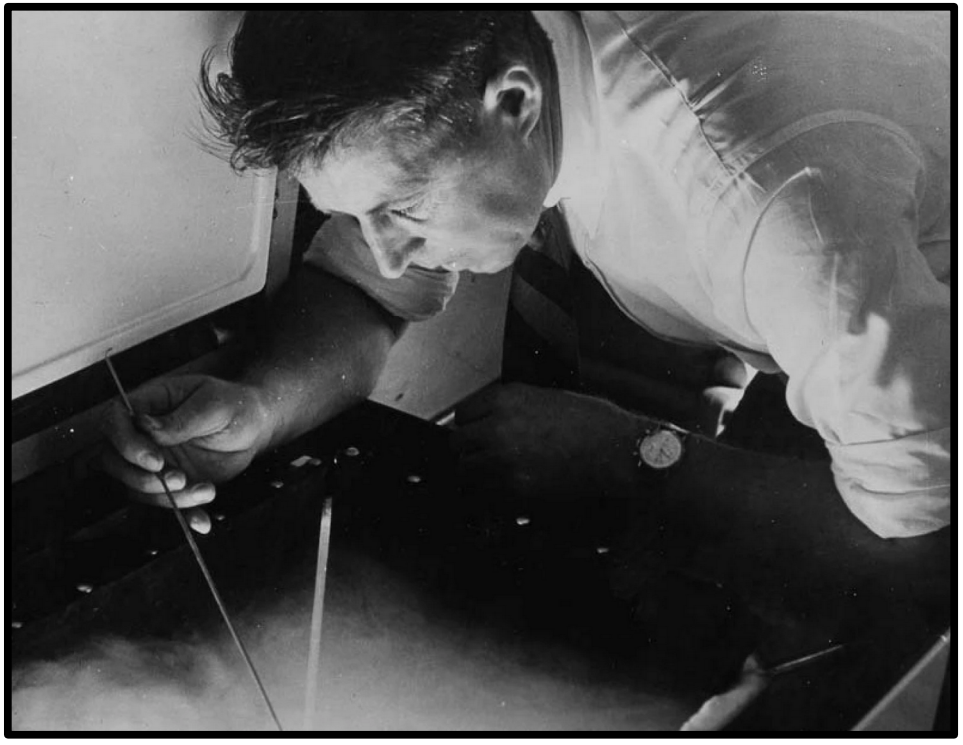
Dry Ice as Cloud Seeding Agent

What is Dry Ice?

- Frozen carbon dioxide, also know as solid CO_2.
- Does not melt into a liquid, but evaporates directly into a gaseous form by sublimation.
- Liquid carbon dioxide is only found at much higher pressures than exists in the Earth's atmosphere.
- Carbon dioxide is the gas that we exhale during breathing and the gas that plants use in photosynthesis.
- Soda Water= Water + CO_2

History of Dry Ice as Seeding Agent

- Dry Ice has been used as a seeding agent since Schaefer fell upon the idea while trying to lower the chamber temperature.
- Birth of cloud modification started on November 13, 1946.
- Schaefer dumped 3 lbs of dry ice pellets from an aircraft in a racetrack pattern.



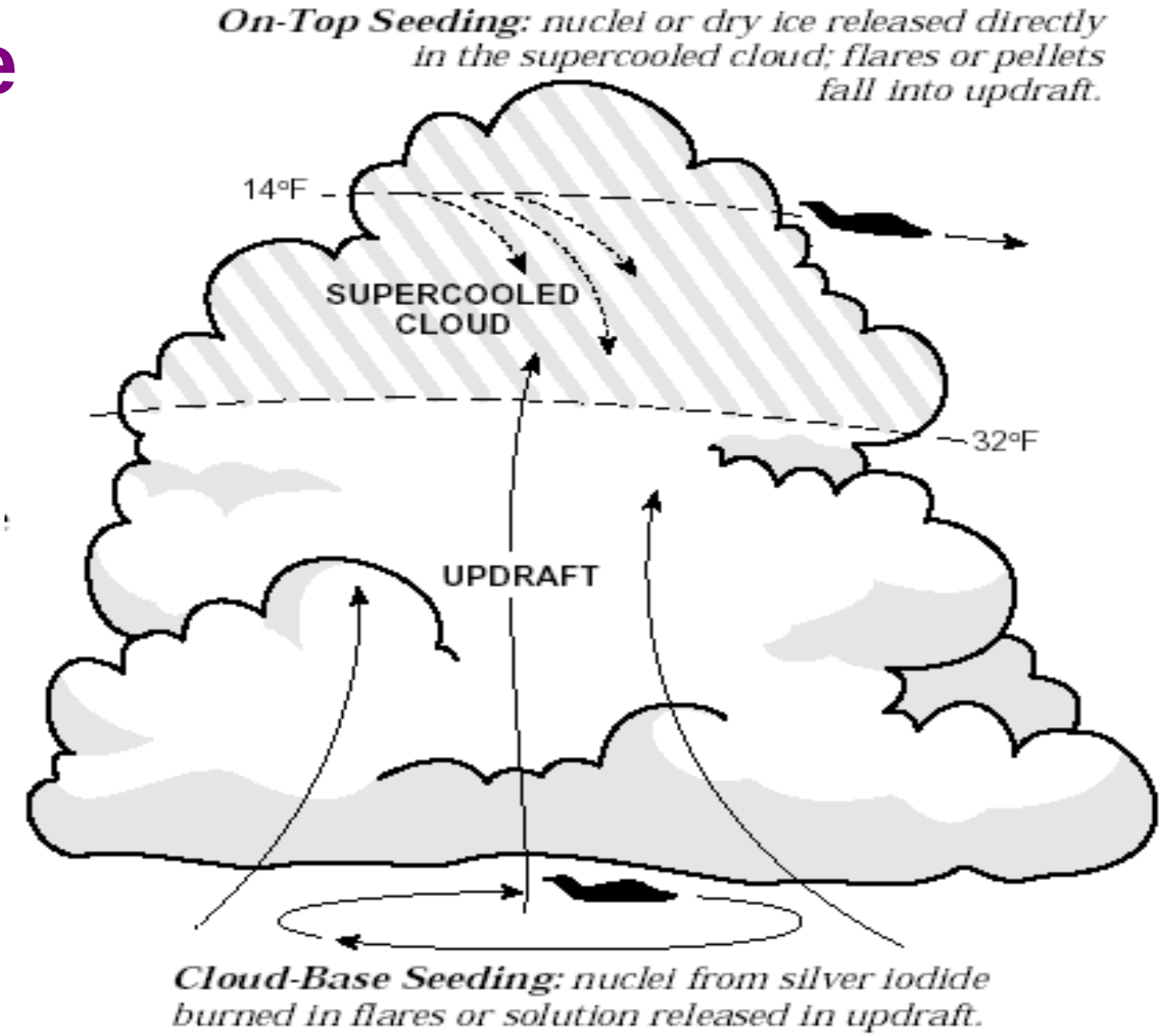
Vincent Schaefer

How does Dry Ice Work?

- Glaciation forms ice crystals by cooling water droplets below -40 °C (**Homogeneous Nucleation**).
- Temperature of a falling dry ice pellet is cold enough to super-cool the cloud in its vicinity.
- Freezing cloud droplets, even in the absence of ice nuclei.
- CO_2 pellets are not themselves nuclei, but start the rapid development of large numbers of small ice crystals.
- Water droplets evaporate and ice crystals grow larger, until large enough to fall. (cold rain process)

Where is Dry Ice Dispensed?

- Dry Ice pellets are dropped into the upper regions of the clouds.



When to use Dry Ice?

- Direct-injection seeding- aircraft penetrate at or near cloud top.
- Target clouds growing through -10 °C level.
- Seeding Agents are placed into the supercooled cloud where nucleation is desired.
- Updrafts provide a continuing source or condensate, not used to transport the seeding agent upward from cloud base.

What amount of Dry Ice to use?

- Amount is proportional to liquid water concentration and updraft strength.
- The dry ice hopper can dispense up to a rate of 40 lbs/min, but the preferred rate is about 5 oz/sec.

What amount of Dry Ice to use?

- Production of ice crystals by dropping dry ice pellets through supercooled clouds is i**ndependent of cloud temperature**, unlike various AgI Compounds.

- Dry ice seeding experiments show an average output between 10^{11} or 10^{12} crystals per gram of dry ice.

Handling of Dry Ice?

- Extremely cold temperature (-78.5 °C or -109.3 °F).
- Ice can cause damage to the skin if handled.
- Use tongs, or insulating gloves, and protective goggles.
- Dry Ice will sublimate at five to ten pounds every 24 hours in a typical ice chest.

Preparing Dry Ice for Cloud Seeding

- Before a launch is called, dry ice pellets should be sifted through ¼ inch hardware cloth to remove the water ice (snow) prior to being loaded in the hoppers.
- Don’t load hopper until launching.
- Bad insulation and an open bottom in the plane will cause deposition of water
- Ice may freeze the dry ice into clumps. Bad for dispensing.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Storage of Dry Ice During Operations

- Dry Ice is stored on the ground in storage boxes with the lids kept tightly sealed and only opened when necessary.
- Mosquitoes can be an issue with the storage box.

Advantages of Using Dry Ice

- Works immediately.
- Requires less anticipation.
- Creates high concentrations of crystals.
- Works at any temperature colder than 0 °C.

Dry ice dispenser on King Air C90 aircraft (N709EA in 2022.

- Smaller (warmer) clouds can be treated more effectively with dry ice than with ejectable flares.

Experiments Seeding of Supercooled Clouds

- Procedure: Refrigerating chamber (-15 °C).
- Breath into chamber (produces thick, grey, supercooled fog).
- Scratch some dry ice into cloud (dense streaks resembling condensation trails. These contain thousands of tiny ice crystals).
- Ice crystals disperse through chamber. Super cooled water droplets evaporate and vapor will deposit on ice crystals.

Sources of Material

- North Dakota Cloud Modification Project Operations Manual
- http://www.swc.state.nd.us/arb/ndcmp.html
- http://www.weathermod.com
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- Bohren, Craig, Clouds in a Glass of Beer