Fact Sheet: Aircraft Transponder Data and Detecting Cold Pools

What We Know

The Uinta Basin's winter pollution episodes happen inside a shallow pool of cold air, but no routine measurements exist of the air above ground level — no weather balloons are launched in the Basin. The Bingham Research Center is testing whether the radio signals that aircraft already broadcast, and that a receiver on the Center's Vernal campus already records, can reveal when a cold pool is present, how deep it is, and when it will break up. The work is at an early, exploratory stage.

What is a Cold Pool?

A cold pool is a layer of cold, dense air that settles into low terrain and stays there, with warmer air lying on top of it — a temperature inversion.

- In winter, cold pools in the Uinta Basin can persist for days at a time. The lid of warm air traps pollutants near the ground instead of letting them disperse.
- Trapped volatile organic compounds (VOC) and nitrogen oxides (NO_x), emitted mostly by oil and gas operations, react in sunlight reflected off snow to form the Basin's unusual wintertime ozone.
- A cold pool can be as shallow as 100–200 meters (about 330–660 feet). Weather stations measure conditions at the ground, but the layers above the surface — where the inversion actually lives — go largely unobserved.

Weather Data from Aircraft Transponders

Most aircraft carry a transponder that broadcasts Automatic Dependent Surveillance–Broadcast (ADS-B) messages about twice per second: the aircraft's position, altitude, speed, and direction of travel. The signals are unencrypted and free to receive with inexpensive equipment. The Center operates an ADS-B receiver on its Vernal campus that picks up most aircraft landing at and departing Vernal Regional Airport (KVEL) — from small training aircraft to the scheduled cargo flight that arrives each morning.

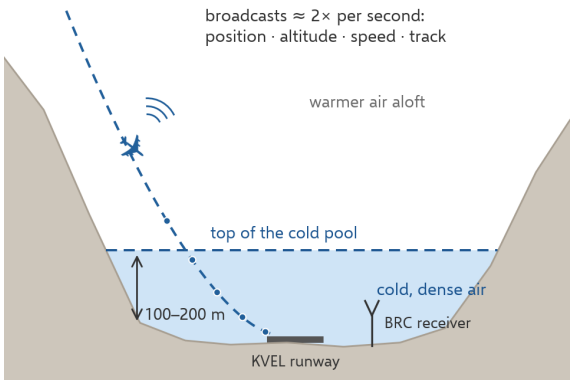


Figure 1 — an aircraft descending toward Vernal passes through the cold pool on its way down, broadcasting its position, altitude, speed, and track about twice per second.

These messages were designed for air traffic awareness, not meteorology, and most aircraft do not broadcast air temperature directly. The research question is how much weather information can be recovered from what they do broadcast. The diagram at right shows the idea: every descent into the Basin samples the atmosphere's layers on the way down.

Three Signals in the Data

1. **Wind.** An aircraft points in one direction (its heading) but moves over the ground in a slightly different one (its track), because the air it flies through is itself moving. The difference between the two puts bounds on the wind at the aircraft's altitude — including the low-level winds near the runway that signal an air-mass change.
2. **Temperature.** The speed of sound depends only on air temperature, and some aircraft report speeds measured against it. Where those reports exist they can be converted into a temperature estimate; where they do not, the broadcast speeds can still place upper and lower bounds on what the temperature could be.
3. **The cold pool's edge.** Cold air is dense air, and an aircraft's performance changes when it descends into a denser layer. If that change can be detected in the broadcast data, the point where it happens on each descent would mark the top of the cold pool — the depth measurement the Basin currently lacks.

Stacked together, the reports from one descent would form a rough vertical profile of the atmosphere — a "pseudo-sounding" — assembled without a balloon. Such profiles could also be fed into weather models to test whether they improve local forecasts.

What this Means for Air Quality Management

- ✓ **Earlier, sharper warning of ozone episodes.** Winter ozone forecasts hinge on knowing when a cold pool forms, how deep it is, and when weather will finally mix it out. Aircraft-derived profiles would give forecasters, including the Center's winter forecasts at basinwx.com, observations they currently lack.
- ✓ **Low cost, no new infrastructure.** The method uses signals aircraft already broadcast and a receiver the Center already operates. No balloons, aircraft charters, or new instruments are required.
- ✓ **A method other regions could reuse.** Many remote basins with air pollution problems lack upper-air observations but see daily air traffic. If the approach works at Vernal, it can transfer.

Limitations

This is exploratory research, not an operational product. The Center has not yet established how accurate aircraft-derived winds and temperatures are, and this sheet makes no accuracy claims until that evaluation is complete. Flights over the Basin are sparse in time and space, few aircraft transmit the data needed for direct temperature estimates, and the density-change signal may prove too subtle to detect in routine broadcasts. A viability study is in progress.

More Information

The ADS-B Meteo project is under way at Utah State University's Bingham Research Center and has not yet been published; results will appear at https://www.usu.edu/binghamresearch/papers-and-reports. A summary of all Uinta Basin air quality research is at https://www.usu.edu/binghamresearch/cumulative-research-summary, and current Basin weather and air quality are at https://basinwx.com. Contact us at john.lawson@usu.edu or visit binghamresearch.usu.edu for more information.