National Aeronautics and Space Administration

The 2025 Aviation Weather Mission: Tracking Contrails with NASA and Civil Air Patrol

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Introduction

The 2025 Aviation Weather Mission (AWM) was a collaboration between Civil Air Patrol (CAP) and NASA to collect airplane and contrail information. The mission, organized by CAP, used the GLOBE Program's GLOBE Observer (GO) app to submit cloud observations and aircraft information. The GO app guides participants to collect cloud type and cover information. CAP used flight tracking programs to track commercial flights and collect altitude, direction, and aircraft registration information.

CAP is a volunteer organization and the civilian auxiliary of the U.S. Air Force. They are dedicated to emergency services, cadet development (students aged 12-20), and aerospace education (preK-12th grade STEM programs). With activities ranging from search and rescue missions to youth leadership programs, CAP provides opportunities for both adults and cadets to learn, lead, and serve in communities across the country. CAP's unique ability to organize thousands of volunteers simultaneously makes them a valuable partner for crowdsourcing the collection of specialized datasets. AWM data files are available at observer.globe.gov/get-data/clouds-data.

The GLOBE (Global Learning and Observations to Benefit the Environment) Program is supported by NASA, NOAA, NSF, and the U.S. Dept. of State, and focuses on advancing Earth systems science through data collection and analysis by volunteers.

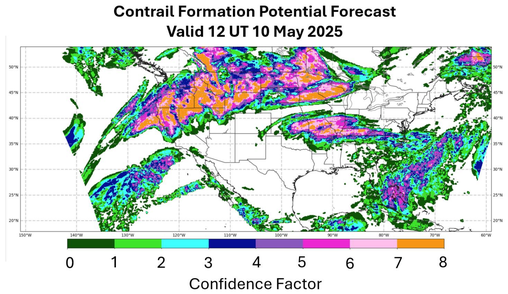
Mission Details

The mission: track aircraft and collect ground-cloud observations, particularly contrails. Over 3,800 CAP participants collected nearly 10,000 observations in 48 states, Washington, DC, and Puerto Rico, tracking more than 1,300 commercial airplanes. The AWM consisted of four 4-hour observation periods, taking place on the second Saturday from April to July 2025. CAP members collected observations from 0800 to 1200 local time. Squadrons (small groups of cadets and senior members) selected an airplane to track for 15-minute segments. During that time frame, CAP collected altitude, registration number, contrail formation if present, orientation and angle of flight in the sky with sextants, as well as cloud types and cloud cover present using the clouds tool in the GO app. After the time segment was completed, the squadron selected a different airplane in their view.

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Data & Methodology

This presentation focuses on observations collected during the May mission date, as it had the most observations. The evening before each data collection, the science team held mission briefings, where they shared mission updates and persistent contrail potential forecast maps, produced by the NASA Langley SatCORPS team.



Above: Sample contrail potential forecast valid 10 May 2025 at 12 UTC. White areas indicate models do not expect contrail formation, dark green = 1 model found conditions favorable, orange = all 8 models found conditions favorable.

Data QA/QC

After the observations were collected, CAP cadets and adult volunteers worked to fill in the missing data. They used their aircraft knowledge and research skills to correct incomplete records, such as missing aircraft type.

The corrected data file was then filtered by altitude (i.e., only considering aircraft ≥20k ft and above) and flights that satisfy the Schmidt-Appleman criterion for contrail formation within reasonable pressure levels (i.e., 300 - 175 mb). The science team compared these data points to atmospheric data to show potential correlations between contrail type and meteorology variables, including humidity, temperature, and wind.

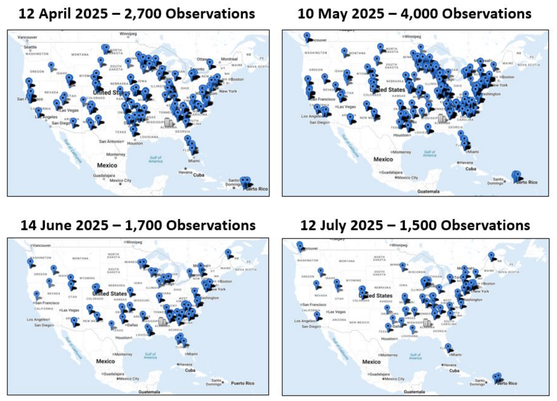
Observation Type	Description	Notes
Airplane, altitude, registration number, aircraft type	CAP members selected a commercial airplane to observe every 15 min. Altitude, registration number, and aircraft type were obtained using flight tracking software.	Only commercial airplanes above 20k ft were selected
Cloud cover & types, including contrails	Observations of percent cloud cover and cloud types entered through the GO app. Contrails were classified as short lived, persistent nonspreading, or persistent spreading.	CAP used the GO app clouds tool to report clouds (Colón Robles et al., 2020)
Latitude, longitude, azimuth	CAP practiced basic orienteering to collect their coordinates; azimuth was measured for the tracked airplane.	Latitude and longitude are measured automatically by the GO app; sextants were used to measure direction and angles
Sky photographs	In addition to sky photographs taken through GO app, CAP took photos of the sky every 5 minutes while tracking an airplane to record any sky changes, particularly regarding contrails.	The GO app guides users to take photos in each cardinal direction at a 15-degree angle

Citations

Colón Robles, M., et al., (2020). Clouds around the world: How a simple data challenge became a worldwide success. Bull. Amer. Meteor. Soc., 101, E1201–E1213, https://doi.org/10.1175/BAMS-D-19-0295.1.

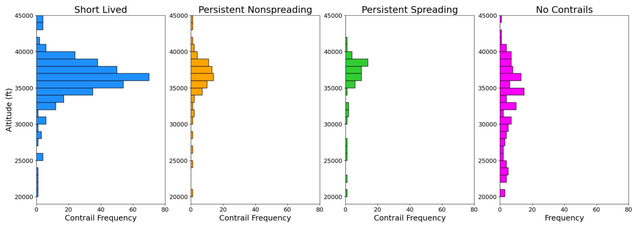
National Academies of Sciences, Engineering, and Medicine. 2025. Developing a Research Agenda on Contrails and Their Climate Impacts. Washington, DC: The National Academies Press. https://doi.org/10.17226/29073.

Results



Above is the monthly breakdown of total CAP observations. Of the 4,000 May observations, there were:

- 103 unique locations
- 73 unique locations that reported contrails
- 769 unique aircraft registrations
- 502 aircraft that produced contrails
- 95 aircraft recorded by 2+ CAP squadrons
- 35 aircraft that produced more than 1 contrail type

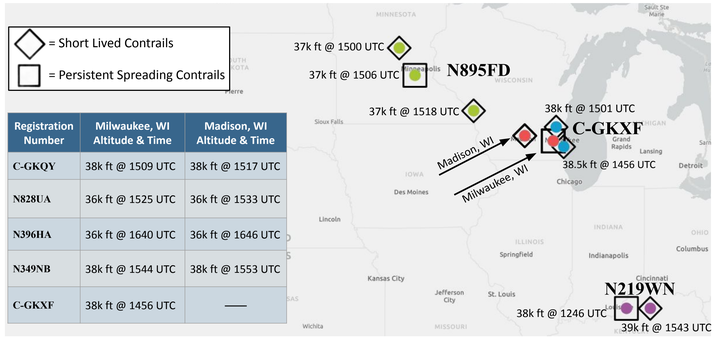


Above: Altitude histograms from 10 May 2025 for where each type of contrail was observed, as well as where aircraft did not form contrails. The majority of contrails were short-lived, defined as contrails that dissipate within a few seconds after being produced.

Further Engagement: Cadet Micro-Internships

To help with data QA/QC, CAP chose several cadets to participate in micro-internships. These cadets were given a list of data issues identified by the science team, as well as recommended tasks and steps to correct them.

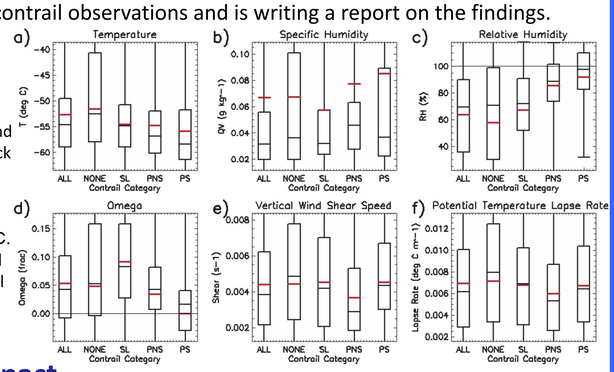
Cadets and Senior Members Who Worked on Data QA/QC		
C/Lt Col Mark McManaman North Carolina	C/SMSgt Ben Hiu National Capital	Lt Col CJ Muncy Virginia
C/2nd Lt Shalom James New York	C/MSgt Thomas West New Mexico	Capt Blanche Cohen Colorado
C/Lt Col Alexander Morgan Louisiana	C/SSgt Justin Betz California	Capt Brechen Caruso Kansas
C/1st Lt Shreya Sulgham Pennsylvania	C/SrA James Fennessey Connecticut	Capt Dave Drainer Arizona
C/CMSgt Jayden Shokrgozar Nebraska	C/Amn Jaxon Black North Carolina	1st Lt Gary Fox New York
C/SMSgt Emma Anderson Colorado	C/Amn Leo Gobel Colorado	1st Lt Kristin Garrison Arkansas



Registration Number	Milwaukee, WI Altitude & Time	Madison, WI Altitude & Time
C-GKQY	38k ft @ 1509 UTC	38k ft @ 1517 UTC
N828UA	36k ft @ 1525 UTC	36k ft @ 1533 UTC
N396HA	36k ft @ 1640 UTC	36k ft @ 1646 UTC
N349NB	38k ft @ 1544 UTC	38k ft @ 1553 UTC
C-GKXF	38k ft @ 1456 UTC	—

Above: Map of 10 May 2025 identifying locations where squadrons recorded the same registration, denoted by point color and label, and the type of contrail they observed, denoted by outline shape (diamond = SL, square = PS). Flight altitudes and observation times are included. The map specifically shows only aircraft that were reported to produce both SL and PS contrails, of which there were 7. The inset table displays times and altitudes for aircraft that were all seen at the same location (Milwaukee, WI & Madison, WI – indicated with the arrows).

In the above map, registrations C-GKQY, N828UA, N396HA, and N349NB were all recorded in the same areas, with the same contrail types in each area (i.e., all 4 planes produced SL contrails in the same location and PS in the same location). Similar patterns are seen throughout the dataset. By having the same aircraft tracked in multiple locations, the aircraft variables are removed, allowing the science team to better correlate contrail formation with atmospheric data. The science team used ERA5 data to examine variables relevant to contrail formation. Below are boxplots of select variables for the whole dataset. As expected, RHI is greatest for PS contrails. These findings hold true when looking at the specific flights in cases such as those in the map above. RHI ≥100% is required for persistent contrails, which is inconsistent with the boxplot – likely due to model limitations (spatial resolution & prediction capabilities). The science team continues to compare atmospheric variables with contrail observations and is writing a report on the findings.



Right: 6 boxplots for ERA5 variables colocated with CAP data at flight level and time. Thin black (thick red) lines represent the median (mean). RH is represented as RHI for temps ≤-23°C. Plot F was calculated for half a model level above and below flight level.

Societal Impact

This AWM produced a first-of-its-kind dataset, where aircraft were tracked and contrails were reported across the country along with local weather conditions. It provides opportunities to increase contrail knowledge and improve models, as well as contribute to research on overall aviation weather and its forecasting.

The National Academies Press recently released "Developing a Research Agenda on Contrails and Their Climate Impacts" (2025), highlighting the importance of contrail research and the special role that volunteer ground observations holds. GLOBE is identified as a reliable database, especially with its support from NASA. This AWM emphasizes how GLOBE can be utilized for research projects on a national scale and be compared to validated datasets, such as model or satellite data, to provide a more complete picture of the atmosphere.