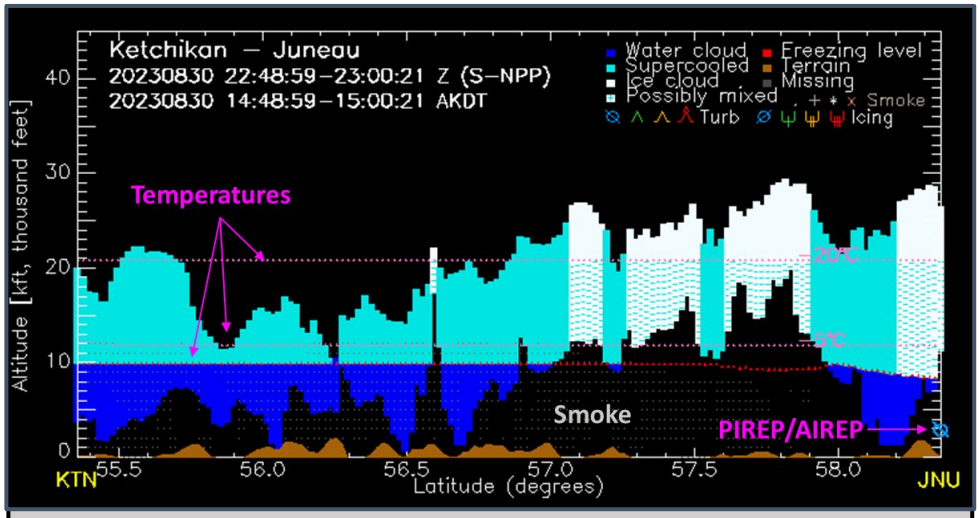
Satellite Cloud Vertical Cross-section (CVC)

Quick Guide

What is the cloud cross section product?

This ***experimental*** product is part of a 3D, satellite-based cloud height field that displays where clouds are present in a vertical column of the atmosphere. Information on 3D cloud structure is important for the aviation community. The cloud cross section is computed along flight routes from cloud products derived from operational NOAA satellites, including *Cloud Top Height (CTH)* and *Cloud Base Height (CBH)*, and is supplemented with additional data useful for aviation (e.g., temperature, PIREPs, and the presence of smoke). These data sets are interpolated to a common grid in order to provide cloud vertical structure information along flight paths.



Sample CVC between Ketchikan (KTN: PAKT) and Juneau (JNU: PAJN) over Alaska. CVC shown in thousands of feet [kft] above MSL for aviation purposes and colored by cloud top phase; water (blue), supercooled water (cyan), ice (white), missing data (gray), and possibly mixed phase at lower levels (white+cyan). **Terrain**, temperatures (0°C: red, -20°C and -5°C isotherms: pink), PIREPs (turb/icing: negligible/light/moderate/severe) & **smoke** included.

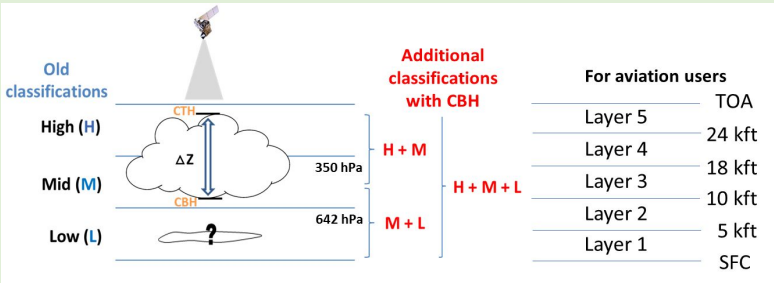
How is the product created?

The product is generated by extracting information from several data sources, which are combined and displayed along flight routes with a 1000 ft vertical resolution. The product incorporates CTH data (derived from infrared observations) along with an estimate of CBH, and is categorized by cloud top phase (also from infrared observations). Cloud top phase retrievals are combined with temperature (derived from satellite data called NUCAPS or from the GFS numerical weather prediction model) to determine cloud phase below the cloud top (e.g., "possibly mixed"). Cloud bases (CBH) are estimated with input from cloud tops (CTH) and cloud water data from a statistical approach based on satellite radar and lidar sensors. When satellite input data is not available, GFS numerical weather model data is used as supplementary input. This process has been applied to NOAA polar orbiting satellites (JPSS VIIRS) for Alaska, and GOES geostationary satellite data was added for CONUS.

Impact on Operations

Applications:

Aviation: Vertical cloud structures from satellite data (applicable to both polar and geostationary sensors) provide information for aviation weather applications in combination with numerical weather models. Users can infer areas of potential icing and turbulence as well as smoke over the U.S.



3D cloud product improvement: CTH and CBH information is used to compute the cross section and Cloud Cover Layers (CCL) products. CBH introduces additional cloud coverage at lower levels, typically hidden under cloud top.

Limitations

Dependency on cloud optical properties:

The cross-section product relies on inputs from both cloud top and base products. CBH performance is highly dependent on the accuracy of cloud top and water path data. Regions designated as "missing" indicate suitable data is not available.

Multi-layer clouds: Determining the cloud base from satellites is still challenging due to inherent limitations of passive sensors. The algorithm is optimal for single layer clouds such as boundary layer clouds, thin cirrus clouds, and deep convection cells. This may limit the accuracy of the product for satellite observations consisting of multiple cloud layers.

Nighttime observations:

Nighttime performance may be degraded due to missing low cloud layers and difficulty in determining cloud water path at night. CVC should be used with caution at night.

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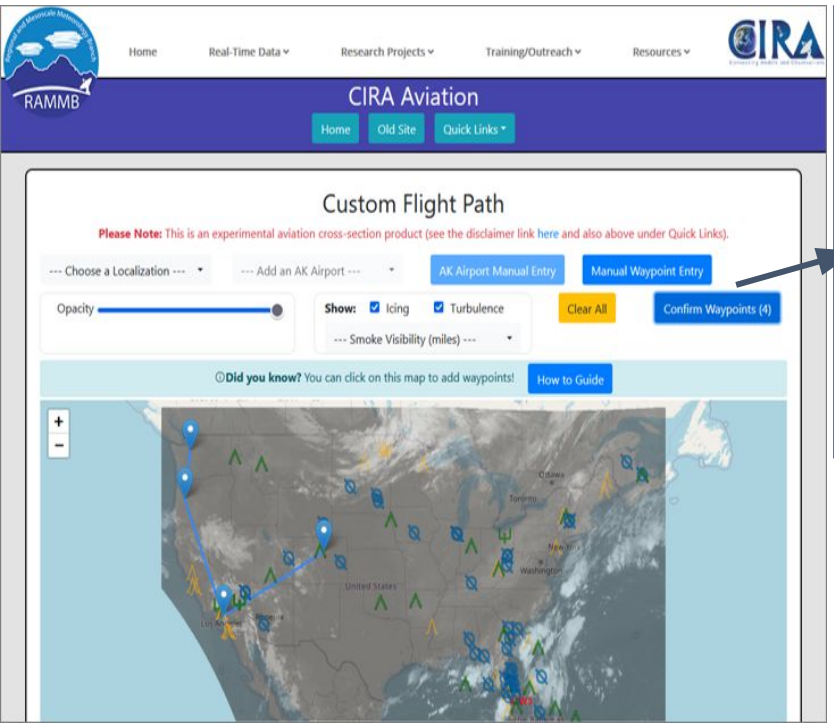
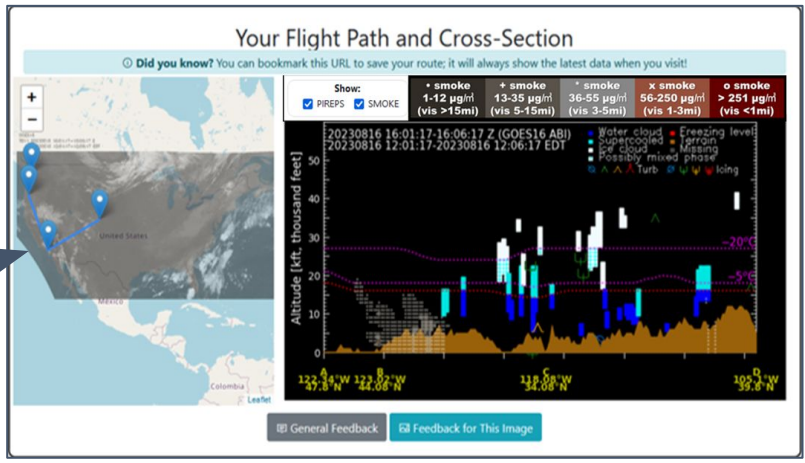




Custom cross-sections can be created along selectable flight paths at CIRA's website, https://aviation.cira.colostate.edu. Users can toggle on/off smoke (gray-brown) and PIREP data layers when generating their own CVCs. A 4-day image archive is accessible for pre-selected flight paths between major airports in Alaska and CONUS by selecting the "Old Site" menu.

How to Create Your Own Cross-section?

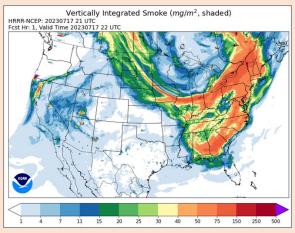
A user interface that enables custom CVCs along user-defined flight paths is now available at CIRA's aviation website. For flight paths, click on each point along your flight path, or select an airport from the drop-down list, then click "Confirm Waypoints" and then "Generate Cross-Section" to produce a cross-section for your flight path. If you need to start over, click "Clear All". Users can provide feedback and find documents (quick guide and user survey) on the website. The experimental CONUS domain is available with geostationary satellite data (updated hourly).

Custom Cross-sections: Data Processing and Level-2 Cloud Properties with Smoke Data

Data Processing and Latency:

To enable custom cross-sections, a fully gridded 3D data set is required. To do this, multiple satellite cloud data are combined with supplementary data (temperature, PIREPs, terrain information, and smoke data) into one 3D data field using various interpolation methods. Due to the latency of satellite data delivery (55 min−1.5 hr for JPSS polar-orbiting satellites, 20−25 min for geostationary satellites - GOES-16) and additional 3D data processing time, use for real-time decision making requires caution. However, the product can still provide additional information about broad-scale cloud structure, supporting situational awareness.

HRRR-Smoke Data:



The NOAA High-Resolution Rapid Refresh (HRRR) weather model forecasts wildfire smoke concentrations that travel across the U.S. The data is generated on 3-km horizontal grids with 50 hybrid vertical levels and is available every 3 hours for Alaska and hourly for CONUS. Smoke data (1-3 hr forecast fields close to the satellite overpass times) are extracted, and interpolated into satellite-based 3D cloud data grids (currently 0.02 x 0.02 degrees per 1000 ft, up to 50,000 ft), and displayed in CVCs.

Resources

CIRA Aviation website: https://aviation.cira.colostate.edu, **NOAA HRRR smoke model:** https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/
NOAA NESDIS STAR: Enterprise Cloud Algorithm Theoretical Basis Documents (ATBD)
Journal publications: Development of a statistical cloud base height retrieval algorithm, Satellite-based 3D cloud data
Smoke and Visibility: Oregon Wildfire Response Protocol for Severe Smoke Episodes www.oregon.gov/deq/FilterDocs/WFresponse.pdf

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