The Front

NOAA's National Weather Service June 2013

Low Level Gravity Waves Caused By Frontal Passage

Shari Mutchler, *Senior Aviation Meteorologist, Aviation Weather Center, Kansas City, MO*

The mornings of March 17-19, 2013, yielded an unusual sight in the 1 km visible satellite pictures over Texas and the Gulf of Mexico: low level gravity waves. A thin layer of low clouds, bases generally around 500 feet Above Ground Level (AGL) and tops about 2000 feet AGL, made the waves washboard appearance visible.

Typically, gravity waves emanate from the tops of thunderstorms or in the vicinity of mountains, but neither condition was applicable in these cases. These gravity waves were likely caused by a frontal passage. The surface winds from the METAR observations indicated a change in wind direction from south to north-northwest in the immediate vicinity. Strong fronts can cause gravity waves (see **Figure 1)** and therefore potential turbulence (Plougonven et al, 2007).

The METAR observations with solid blue circles indicate Marginal Visual Flight Rules (MVFR) conditions. In this case, the MVFR conditions were due to a cloud base between 1000 and 3000 feet AGL. Solid

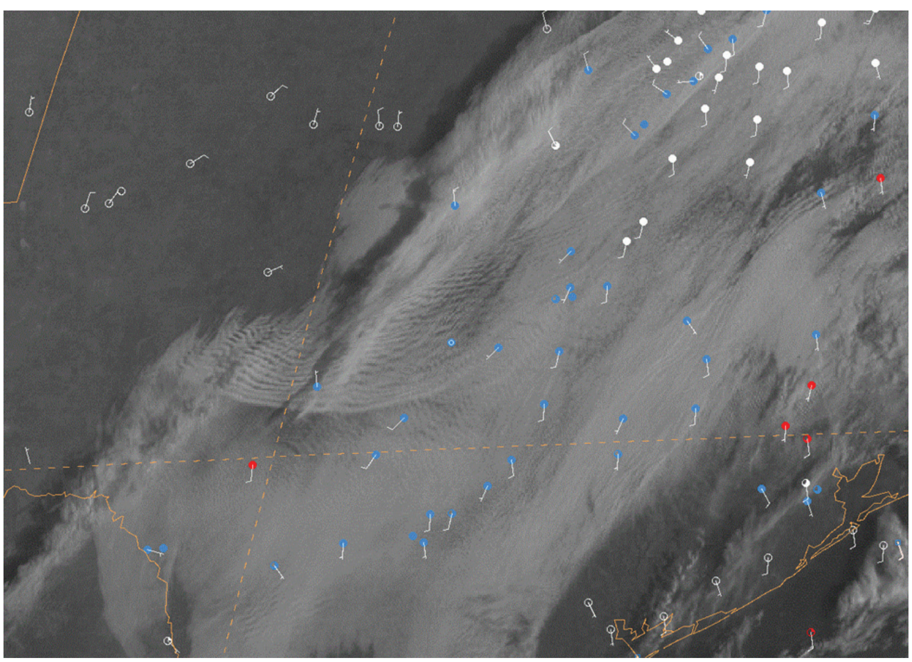

Figure 1: *1KM Vis Satellite, March 17, 2013, 14Z, courtesy of NOAA AWC*

Inside

When's the Next *Front?*

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The Front

Program Manager: Michael Graf
Managing Editor: Melody Magnus
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Mission Statement

To enhance aviation safety by increasing the pilot's knowledge of weather systems and processes and National Weather Service products and services.

red circles indicate Instrument Flight Rules (IFR) conditions. The wind barbs on the satellite picture show a wind shift from southerly to northerly. This behavior is typical of a cold front.

The effect is similar to dropping a pebble into a pond of still water. When the pebble disturbs the water's surface, it creates gravity waves that emanate away from the pebble.

Fronts demark the boundary or interface between two air masses. Those air masses are often different densities. If the density differences are great enough, the front will cause gravity waves to form.

You don't often see these gravity waves at such low levels because they are obscured by clouds. In this instance, the low stratus deck served as the stable layer, like the pond in the pebble analogy. When the front moved through, it disturbed the existing stable layer and caused gravity waves.

The 12z soundings from Corpus Christi and Brownsville, TX, both showed a shallow saturated stable layer from the surface to about 1500 feet AGL. At that level, above the cloud layer, the sounding showed a large inversion of warmer air (see **Figure 2**). Fluid dynamics teaches that if anything disturbs the stable layer, it can cause gravity waves (Boussinesq, 1903).

Unfortunately, there were no Pilot Reports (PIREPS) from this area when it occurred, so we do not know how the phenomena may have impacted aircraft.

Based on research (Sharman and Wurtele, 2004), we can presume light to moderate turbulence in and around the gravity wave clouds. Perceived turbulence is often inversely proportional to the size of the aircraft. In other words, the smaller the aircraft, the greater the chance you will notice turbulence (see **Figures 3 and 4**). For more on this topic, try the following Youtube Videos:

- Windows319lowgravitywaves
- gravity_waves_frontal

Boussinesq, J. "Théorie Analytique De La Chaleur Mise En Harmonie Avec La Thermodynamique Et Avec La Théorie Mécanique De La Lumière." *La Chaleur* 2.1 (1903): 1-17. Print.

Plougonven, Riwal, Snyder, 2007: Inertia–Gravity Waves Spontaneously Generated by Jets and Fronts. Part I: Different Baroclinic Life Cycles. *J. Atmos. Sci.*, 64, 2502–2520.

R. D. Sharman and M. G. Wurtele, 2004: Three-Dimensional Structure of Forced Gravity Waves and Lee Waves. J. Atmos. Sci., 61, 664-680.

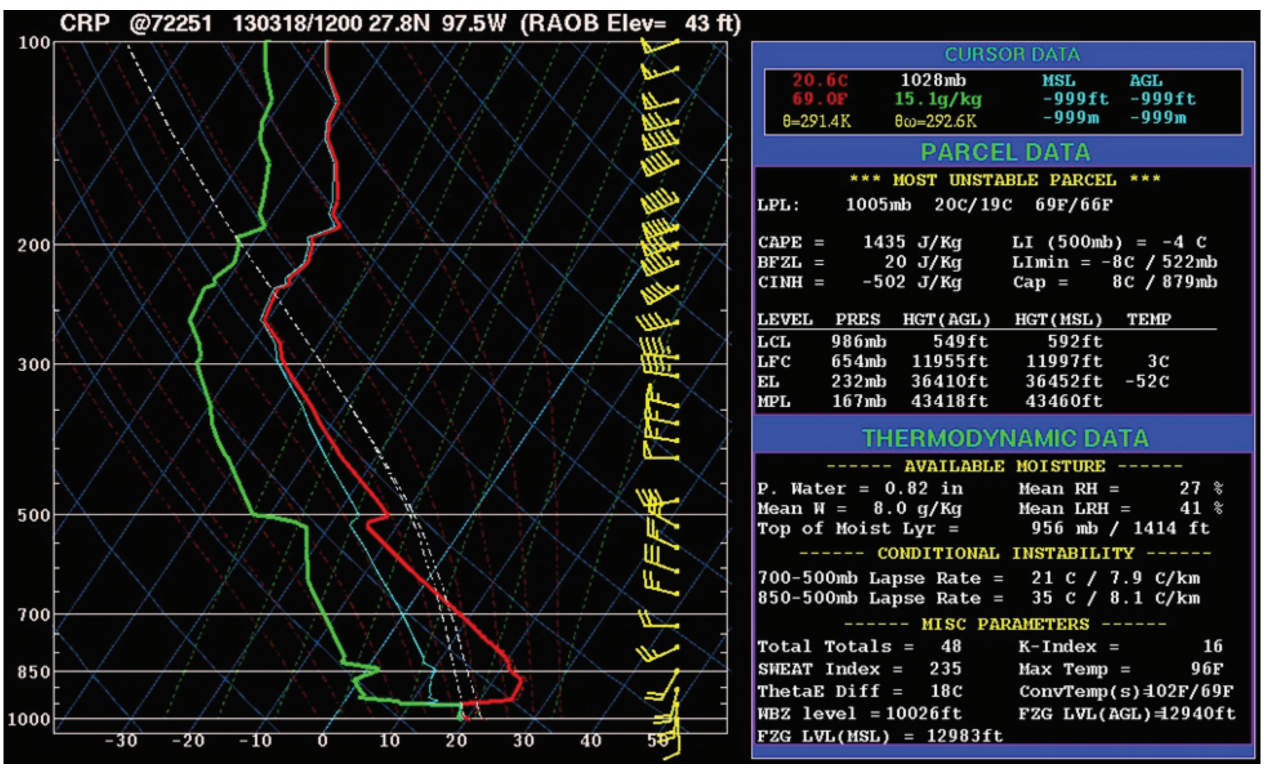

Figure 2: *Corpus Christi, TX, sounding 12Z, March 18, 2013, courtesy of NOAA AWC*

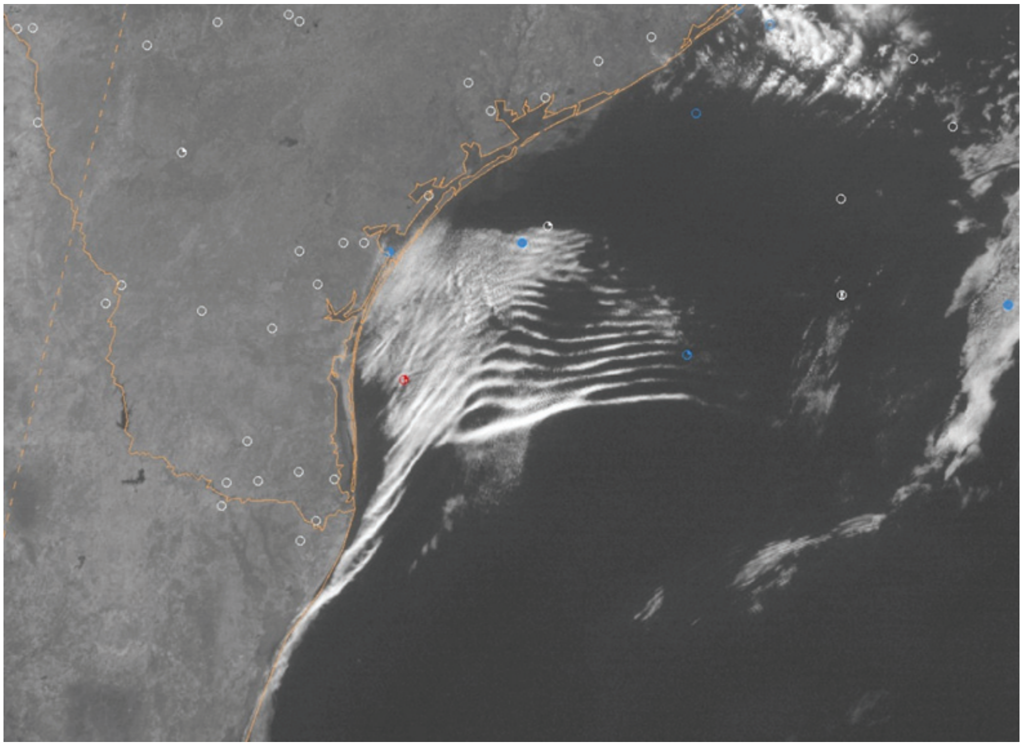

Figure 3: *March 18, 2013, 1402Z, courtesy of NOAA AWC*

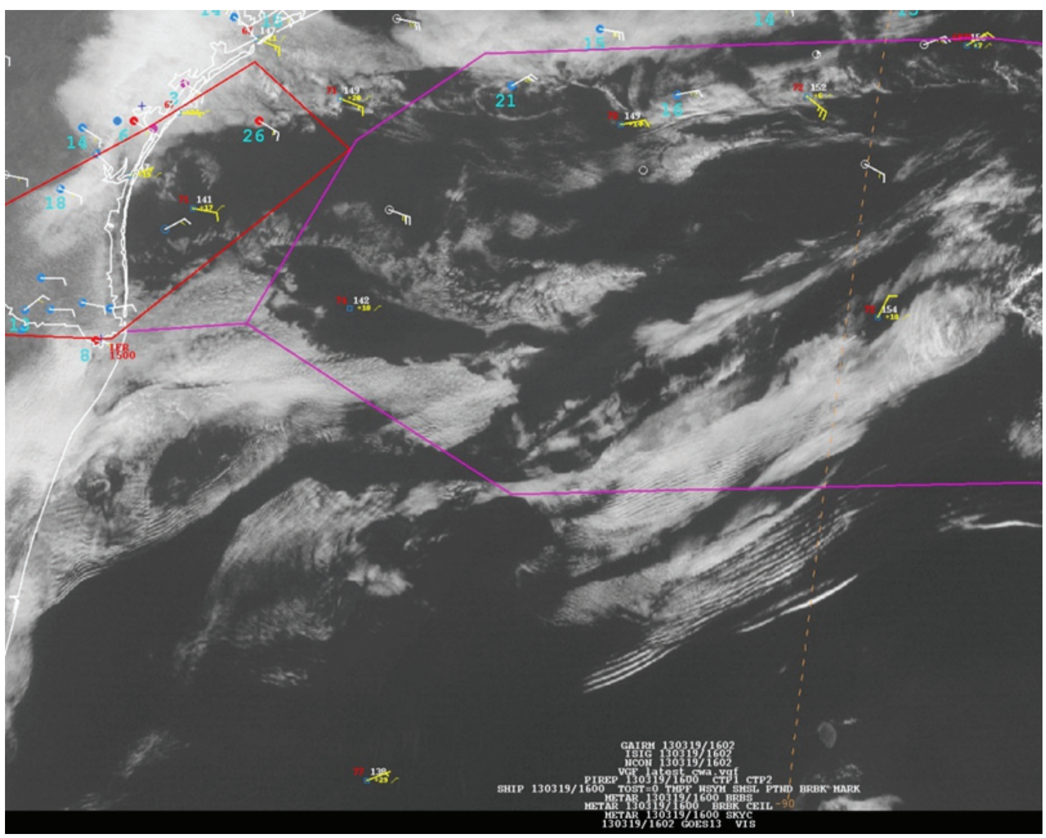

*Figure 4***:** *March 19, 1604Z, 1Km Vis Satellite, courtesy of NOAA AWC*

Inadvertent IFR: New Weather Data and Tools to Help Avoid a Deadly Trap

Paul Herzegh, Project Scientist and Arnaud Dumont, Software Engineer
National Center for Atmospheric Research, Boulder, CO

The safety statistics for general aviation operating in instrument meteorological conditions (IMC) paint a troubling picture. According to the National Transportation Safety Board (NTSB), ceiling and visibility (C&V) hazards, which by definition accompany IMC, are the second leading cause of weather-related aircraft accidents.

An FAA study of NTSB data showed Part 91 (general aviation) operations account for about 93% of these accidents. About 72% of Part 91 C&V accidents result in fatalities, with an average of 1.5 fatalities per incident. Surprisingly, a pilot's instrument rating was not a major factor in these accidents. Of pilots in Part 91 accidents, 56% held an instrument rating.

The details of these statistics yield an overarching message: thousands of Part 91 pilots are not proficient enough or adequately equipped to survive IMC, making *avoidance* of IMC the most potent strategy they can follow. Failing that, IMC *escape* is their best step toward safety.

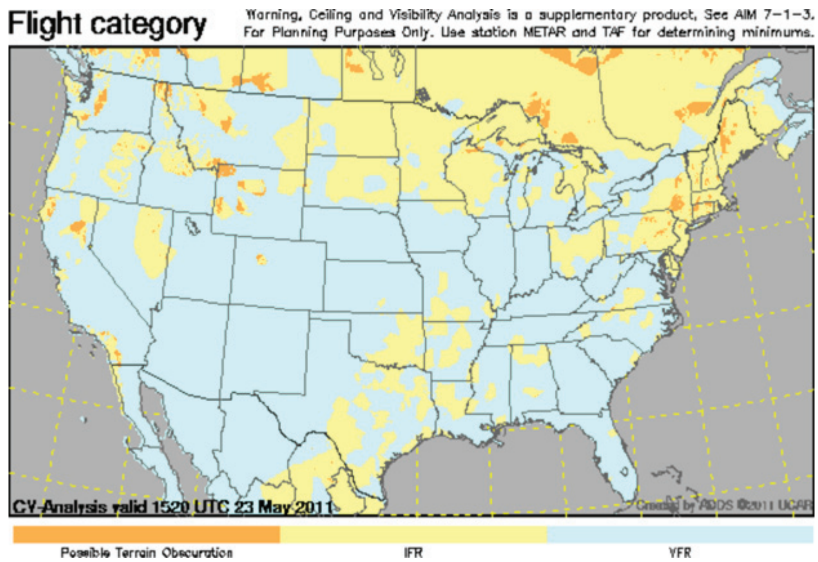

Figure 1. *CONUS-scale view of CVA's flight category display for 1520 Z on 23 May 2011. While most of the country shows VFR conditions, portions of the northeast and the northern and southern great plains show IFR conditions. Regions where ceiling height is less than 200' AGL are shown in orange to warn of possible terrain obscuration.*

A New Aid to IMC Avoidance and Escape

In 2012, the AWC Aviation Digital Data Service (ADDS) Website added an operational FAA-funded real-time analysis of current C&V conditions across the continental United States (see **Figure 1).**

This product is intended to aid flight planning, particularly for the VFR-only general aviation pilot who must avoid IMC; however, a Ceiling and Visibility Analysis (CVA) quick-glance overview is useful to pilots and those involved in flight planning or weather briefing.

First, all CVA users involved in flight operations should review METARs, Terminal Aerodrome Forecasts (TAF), Airman's Meteorological Information (AIRMET), Area Forecasts and other weather information before making flight decisions.

Inside CVA: Interpolating METARS

The CVA ceiling in feet AGL and visibility in statute miles (SM) are derived through nearest-neighbor interpolation of METAR data. The assigned ceiling value is the observed ceiling at the nearest METAR site, corrected for any terrain height difference between the two points. The assigned visibility is simply the visibility at the nearest METAR without alteration.

Flight category is derived from interpolated ceiling and surface visibility values according to the FAA definitions given in **Table 2**.

CVA also warns of regions where the ceiling is expected to be less than 200 feet AGL. These areas are shown in orange and bear the label "Possible Terrain Obscuration."

The interpolation process described above, in effect, stretches limited-area METAR observations across the broader domain between stations and accounts for terrain effects on ceiling height.

Table 1: Overview of CVA Features and Characteristics

General Features	♦ Automated displays of ceiling, surface visibility, possible obscuration, and flight category ♦ Ongoing 5-minute update rate 24/7 ♦ 5-km horizontal resolution, uses NWS NDFD grid
Data Inputs	♦ Current reports from ~1800 METAR sites across the United States and on the border regions of Canada and Mexico ♦ GOES East and West visible and IR observations for information on cloud coverage ♦ Terrain height at each map gridpoint
Product Output	♦ Available at www.aviationweather.gov/adds/cv ■ CONUS-scale view (Figure 1) ■ Eighteen selectable regional-scale views (Figure 2a) ■ Images from preceding 2 hours at 5-minute frequency ♦ Available at weather.aero/tools/weatherproducts/cva ■ Same as above plus mouseover magnified window viewer ♦ Available at weather.aero/tools/desktopapps/hemstool ■ GIS-enabled view using the experimental HEMS Tool (Figure 2b) ♦ Available from AWC: GRIB2 files containing ceiling, visibility and flight category
Operational Use	♦ For flight planning purposes only; should always be used in combination with ceiling and visibility information from official sources such as METARs, AIRMETs, TAFs and Area Forecasts ♦ The HEMS tool viewer is approved for use by Emergency Medical Services personnel by Operational Specification A021

Table 2: Flight Category as Determined from Ceiling and Visibility

Flight Category	Ceiling Condition (AGL)		Visibility Condition (SM)
Visual Flight Rules (VFR)	Greater than or equal to 1000	and/or	Greater than or equal to 3
Instrument Flight Rules (IFR)	Less than 1000	and/or	Less than 3

The resulting fields help to visualize the *likely* conditions at range from METARs; however, the reliability of these fields degrades as distance from a METAR site increases. Be cautious when using this tool. Use judgment in considering the representativeness of the product as the distance from a METAR site increases.

GOES Satellite Cloud Detection

There are large areas within CONUS not well represented by METAR observations due to the broad spacing of observing sites. It is important to augment observations in these regions however possible. CVA uses GOES-East and GOES-West cloud detection capabilities to discriminate between cloudy regions, where a ceiling may exist below 12K feet, and cloud-free regions, where there is unambiguous indication that *no ceiling exists*. The latter indication, no ceiling, is used in CVA to avoid interpolating low-ceiling observations too broadly across the regions between METAR sites.

Regional-Scale Displays

Most users want to see as much detail as possible in a METAR. To accommodate this preference, the ADDS Website provides 18 additional views focusing on smaller regions of the CONUS.

These views also incorporate an overlay of abbreviated data from the METAR sites in the area (see **Figure 2**).

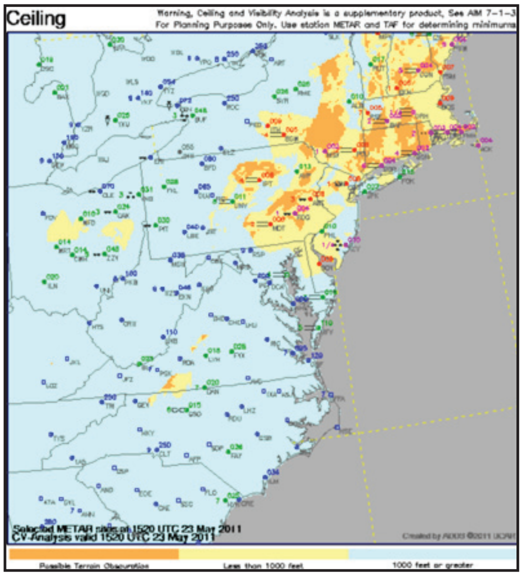

Figure 2a: Regional-scale display of CVA ceiling on ADDS including overlay of METAR ceiling and visibility observations.

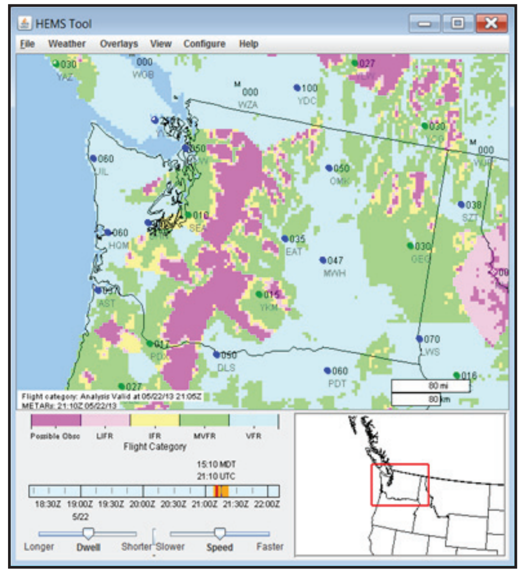

Figure 2b: HEMS Tool display of flight category including overlay of observed ceilings.

HEMS Tool

Under funding from the Federal Aviation Administration, the National Center for Atmospheric Research created a tool specifically designed to show weather conditions for short-distance and low-altitude flights common for the helicopter emergency medical services (HEMS) community.

The HEMS Tool has been designed to meet the needs of low-altitude VFR emergency first responders. It runs as a desktop application for maximum performance. A sample HEMS display of ceiling and visibility is shown in Figure 2. HEMS does the following:

- Overlays multiple fields of interest: ceiling, visibility, flight category, winds, relative humidity, temperature, radar (an experimental display of base and composite reflectivity), AIRMETs, SIGMETs, METARs, TAFs, and PIREPs
- Interpolates all three-dimensional data to AGL altitudes and slices it horizontally at 500 ft. intervals up to 5000 ft.
- Can animate all data through time
- Provides high-resolution base maps, including streets, hospitals, and heliports for the entire United States; detail is revealed by zooming in
- Saves preferred views for quick recall

A video demonstrating the power of the HEMS Tool and the many data sets it displays is available on YouTube.

We hope that you will get the most out of CVA, the HEMS Tool, and all the aviation products available on the ADDS Website as you plan your next flight. Stay safe!

This research is in response to requirements and funding by the FAA. The views expressed are those of the authors and do not necessarily represent the official policy or position of the FAA.