11.4 GRAVITY WAVE TURBULENCE GENERATED BY CONVECTION OVER THE BAHAMAS ON 17 JANUARY 1996

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1. INTRODUCTION

On 17 January 1996 an Airbus 300 aircraft encountered severe turbulence at about 34,000 feet over the central Bahamas, causing injuries, while en route from Miami to San Juan. Several years of litigation related to this incident recently ended. The weather conditions along the route of flight and surrounding area, prior to, during and shortly after the severe turbulence encounter were examined through satellite data and imagery, lightning data, upper air charts and soundings, and pilot reports.

2. REGIONAL WEATHER

The weather in the Bahamas was influenced by a short-wave trough traveling eastward in the middle and upper troposphere (from about 19,000 to 35,000 feet altitude). General cloudiness, with embedded widely scattered showers and thunderstorms, was generated over the central Bahamas by upward motion on the eastern side of the trough. A Meteorological Impact Statement refers to widely scattered VIP 3-4 cells with tops to 40,000 feet. An International SIGMET was issued for a portion of the area and described the thunderstorms, embedded in cirrus, as intensifying and moving north at 5 to 10 knots. Satellite images show the development and slow movement of the individual cells.

The wind at the flight level of the turbulence encounter was from the west-southwest at about 55 knots. An inversion is seen in the Miami and Nassau soundings in the layer from 31,000 to 35,000 feet, with strong wind shear and weak stratification above and below the layer. There were numerous reports of turbulence over the Bahamas and southeastward of that area on the day of the incident.

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3. TURBULENCE ENCOUNTER

The Airbus crew reported continuous light to moderate turbulence during the climb to 33,000 feet out of Miami. The turbulence during the climb occurred in an area of stratiform clouds and low Richardson number. Various flight levels were requested and assigned in an attempt to find a smooth ride. At the time of the severe turbulence encounter the crew recalls only light returns on airborne radar and no visual clues of local convective turbulence. The crew does not recall encountering a thunderstorm. The first officer recalls yellow and red radar returns to the left and right of the route at distances of at least 30 to 50 miles away and he interpreted them to be scattered thunderstorms. The incident occurred at a location beyond the reach of NWS radars in Florida. However, satellite images and lightning data tend to confirm the crew's recollections of the weather.

Various aircraft reported turbulence in and around the Bahamas on the day of the incident. Satellite images show the generation and propagation of gravity waves in cirrus as developing convective cells encountered the inversion layer. A smaller aircraft encountered severe turbulence over San Salvador at 31,000 feet as the likely result of such waves emanating from a convective cell near Rum Cay. In addition to the turbulence induced by convection, evidence for Kelvin-Helmholtz instability was present in soundings and satellite imagery.

Of particular interest to the Airbus incident is a coherent disturbance in the upper troposphere, seen in both visible and infrared imagery, that was generated in an area of strong convection well south of the route of flight. This disturbance, perhaps a solitary wave, traveled northwestward away from its source at about 42 knots for 2 hours, when it intersected the route of flight at the time of the turbulence encounter. The GOES-8 visible and infrared channel 4 images nearest the time of the incident are shown in Figures 1 and 2.

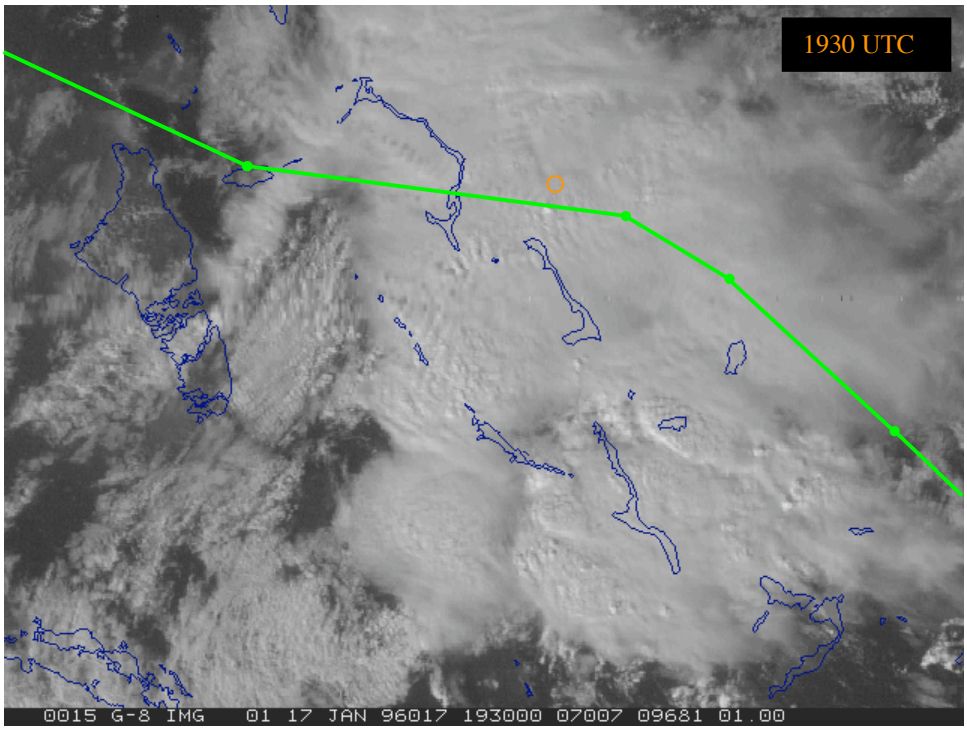

Figure 1. GOES-8 visible image, scan start time of 1930 UTC. Airway and reported location of turbulence encounter shown by line and circle, respectively.

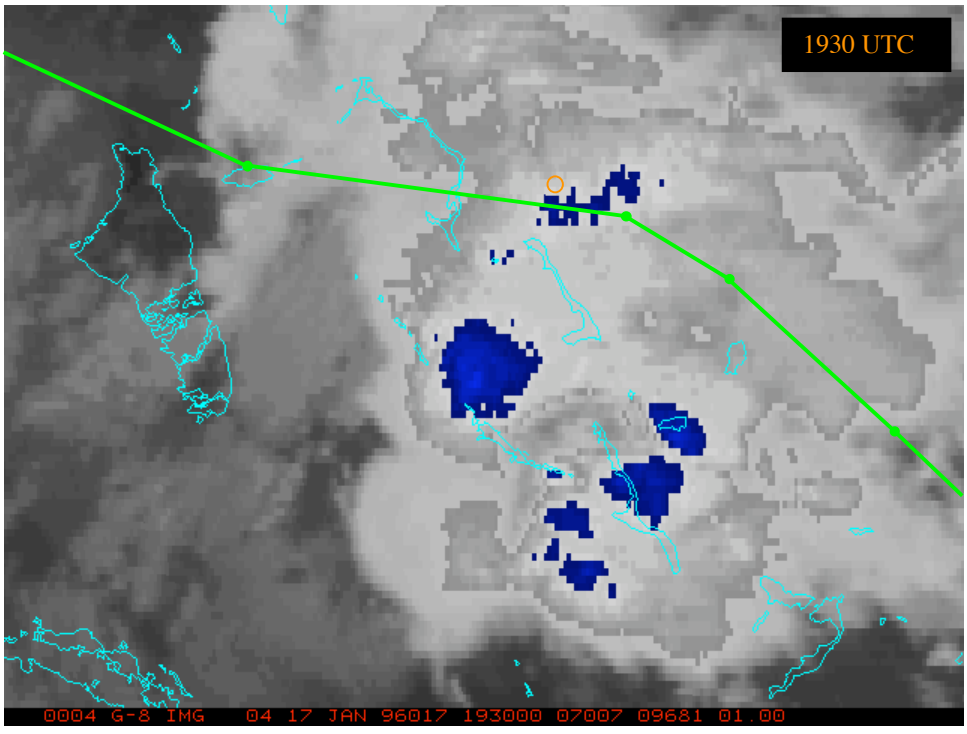

Figure 2. As in Fig. 1, except satellite image is a color-enhanced infrared channel 4 image.

An elongated area of reduced cloud top temperatures, shown in blue, with a roughly NE-SW orientation lies across the airway near the reported location of the turbulence incident in Figure 2. This disturbance propagated from an area of convection about 80 nautical miles to the southeast. Note the speckled and elongated appearance compared to the cellular and more uniform appearance of the convection to the south. In the visible image, gravity waves also appear to be emanating from the active convective cell near the center of the image.

4. CONCLUSIONS

Gravity waves generated by remote thunderstorms have been mentioned elsewhere as possible low-altitude hazards to aircraft (e.g., Miller, 1999). However, the disturbances creating severe turbulence on 17 January 1996 in the Central Bahamas appear to have been gravity waves generated in the upper troposphere as widely scattered convective cells encountered an inversion. The stratification profile was conducive to gravity-wave ducting. The gravity waves in the satellite images bear some resemblance to the convectively induced gravity waves in the numerical simulations of Lane et al. (2001) and Lane and Reeder (2001). In addition, cloud features indicative of Kelvin-Helmholtz instability capable of generating severe turbulence were also present, likely created by strong wind shear above and below the inversion layer.

The probable cause of severe turbulence experienced by an Airbus 300 was the encounter with a gravity wave disturbance that propagated from a convective cell over 80 nautical miles away. The disturbance did not appear to be the result of an outflow boundary near the surface, since a signal was seen in the upper troposphere as soon as the disturbance emerged from the parent cell.

5. REFERENCES

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