INVESTIGATIVE METEOROLOGICAL REPORT

PRELIMINARY - BASED ON LIMITED DATA

Continental Flight 128 / Boeing 767-200
Turbulence near Dominican Republic
3 August 2009

4 August 2009
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The purpose of this study is to summarize a professional opinion of the most probable meteorological events. Weather Graphics neither determines nor implies liability.

Executive summary

A review of archived satellite, upper-air data, and other meteorological data holdings showed evidence that Continental Airlines Flight 128 experienced severe turbulence due to flight through a convective cell north of the Dominican Republic on August 3, 2009.

On the early morning of 3 August 2009, Continental Airlines flight 128, a Boeing 767-200 (N76156), encountered damaging turbulence at approximately 0800 UTC, about 225 km northeast of Santo Domingo, Dominican Republic. The incident was widely reported in the U.S. press, largely as a result of the highly publicized loss of Air France 447 in the Atlantic Ocean two months earlier. Reports indicated at least 4 critical injuries and 22 minor injuries.

1. Physical information

1. **Introductory information**. Continental Airlines Flight 128 was enroute from Rio de Janeiro, Brazil (SBGR) to Houston, Texas (KIAH) on an overnight flight. The press reported that at approximately "4:30 am" [EDT] (0830 UTC) and "50 miles north of the Dominican Republic", the plane encountered severe turbulence. In an interview with KHOU-TV, a passenger, Diego Saavedra, said, "All of a sudden, the plane like takes a dip and rises up and you see people going off their seats, people screaming." Passenger Celi Defaria said, "All of a sudden it came down. Everybody bumped heads twice because it came down again. It was terrifying. It happened in one fraction of a second." A passenger, Giovani Loss, said in a WSVN-TV interview, "People [were] screaming, then there was a huge silence for like 30 minutes."

2. **Establishment of time and position**. The flight plan routing for this flight was:

SBGR ANADA G449 DDP A555 IDAHO A555 ZBV FLL LBV J616 SRQ Q100 LEV WOLDE2 KIAH

A track log was obtained from FlightAware, a vendor for FAA ASDI data. Given the aircraft's location, the source data for COA128 position is believed to be the aircraft's inertial reference system uplinked to satellite. The ASDI showed the aircraft departed SBGR at 0124 UTC, flew through Brazil into the Caribbean, and reached the TJZS FIR at [0708 UTC] [15.00,-64.15]. There it appears to have been assigned a direct route to waypoint HARDY [20.01,-68.82], at the exit of the FIR, and changed course from 331°T to 318°T to proceed direct. Once at HARDY it performed another course change [0758 UTC] [20.00,-68.81] changing from 318°T to 300°T and joining A555. This crosscheck verifies that the ASDI feed appears to contain accurate location data. The plane opted to divert to Miami, where

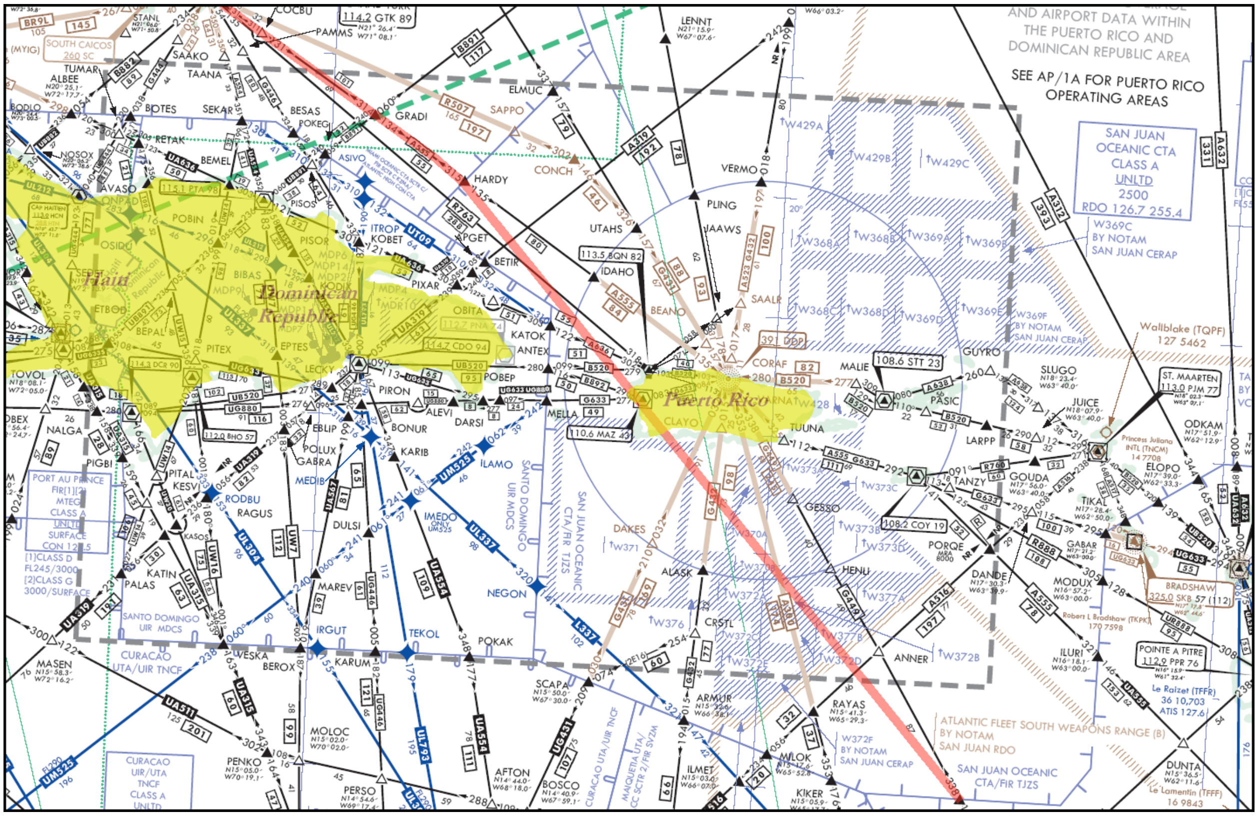

Figure 1. Navigation chart showing the route of Flight 128 through the TJSZ FIR.

it landed at 0538 EDT (0938 UTC) and was attended by emergency medical personnel.

2. **Resolution of position with media reports**. Time and position information has been rather vague and poorly sourced in most press reports. CNN reported that the incident occurred at “4:30 am” [EDT] (0830 UTC) and this appears to have been widely reproduced by news desks. There is evidence that this is based on a statement of the incident happening “about an hour” before landing in Miami. An ABC News report indicated the incident occurred “about six hours into the flight”, which would be about 0730 UTC. The media also widely refers to the incident occurring “50 miles north of the Dominican Republic”, which is highly ambiguous as the coastline is about 200 miles in length and roughly parallel to the flight route.

3. **Investigation data sources**. GOES-12 imagery was obtained from the NOAA CLASS archive and postprocessed with the McIDAS software suite. Radiance computations, where applicable, were performed in accordance with the GVAR conversions at <http://www.oso.noaa.gov/goes/goes-calibration/gvar-conversion.htm>. Radar data was obtained from the NOAA HAS server and postprocessed with Gibson Ridge GRLevel2. Surface and marine observations, if applicable, were obtained from inhouse archival of World Meteorological Organization (WMO) Global Telecommunication System (GTS) data obtained through NOAAPORT.

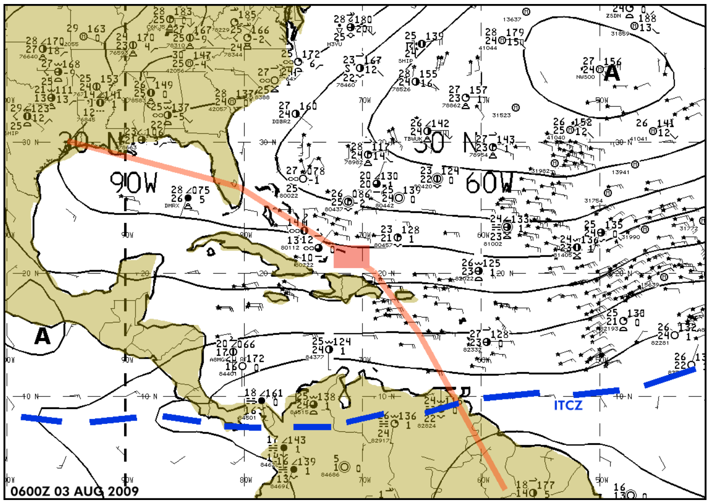

Figure 2. NCEP surface chart for 3 Aug 2009 at 0600Z showing much of the region under the influence of the Bermuda High. Solid isopleths indicate stream function, which roughly parallel the wind direction.

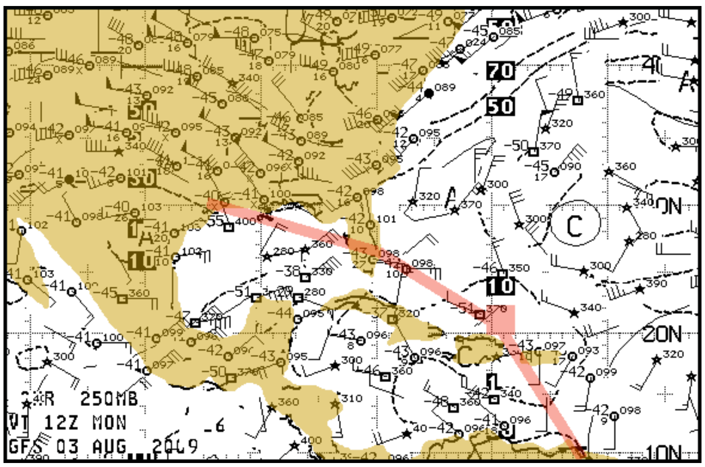

Figure 3. NCEP 250 mb chart (FL340) for 3 Aug 2009 at 1200Z. The area was in a deformation zone with relatively light winds. The area in the so-called Bermuda Triangle was under the influence of a TUTT low.

2. Meteorological discussion

1. **Surface data**. Surface charts showed the northern Caribbean basin was under the influence of a very large Bermuda high, with Puerto Rico, Hispaniola, and Cuba under the influence of extensive tropical easterlies. The intertropical convergence zone was well south of the region along the South American coast and was not a factor in any of the observed weather.

2. **Upper air data**. The nearest upper-air station was San Juan, Puerto Rico (TJSJ/78526). The sounding showed rather weak wind profiles, with easterly winds in the lower troposphere and a zone of 20 kt westerlies near the tropopause. The profile did contain a large amount of instability, with a mixed-layer CAPE of 1700 J kg^{-1}. In the mid-latitudes this is considered adequate for severe thunderstorms, but such readings are considered less significant in the tropics. Given the sounding profile, the greatest vertical velocities were realized at 26,000 to 36,000 ft, where parcel and environmental temperature differed by at least 6 Celsius degrees, and implies the potential for convective turbulence at flight level. Hodograph analysis shows the low-level to mid-level shear vector pointing eastward, owing to the westerlies aloft. This yields an environment favoring forward-propagating storms with updrafts mainly on the western sides of the precipitation cores.

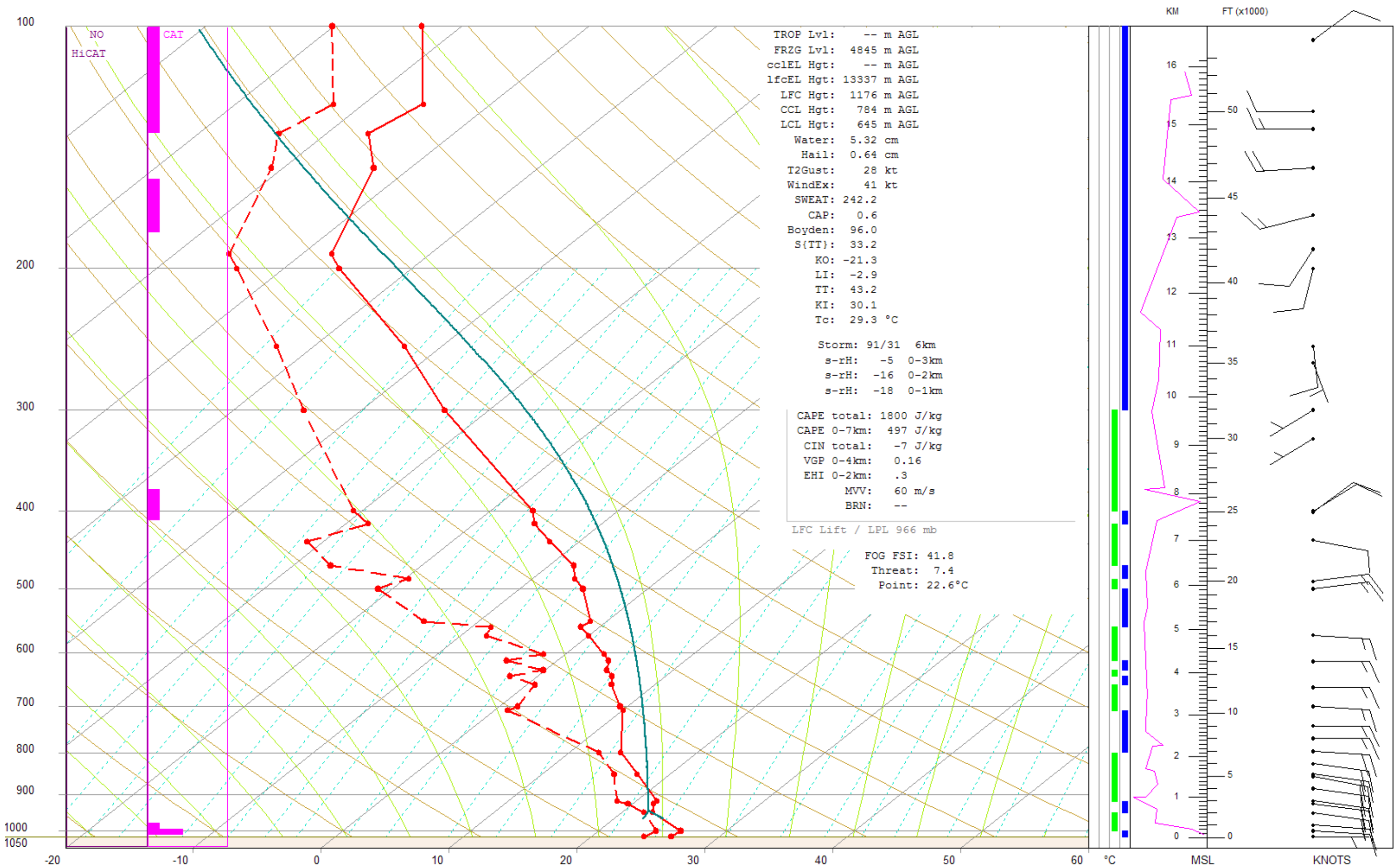

Figure 4. Thermodynamic sounding for 3 Aug 2009 at 1200 UTC for San Juan, Puerto Rico. The left two vertical tape scales indicate high-altitude CAT and FAA CAT algorithms, both of which show no noteworthy clear air turbulence potential at flight level. The right-hand line vertical graph indicates vertical shear, with minor amounts noted. However this sounding showed a conditionally unstable atmosphere with a large amount of instability.

3. **Satellite data**. The highest resolution satellite data available was the GOES-12 infrared satellite images. The images showed that the flight, as given by ASDI data, penetrated a convective cell at about 0754 UTC. The cloud tops of this cell showed a radiance temperature of 232K, corresponding to a height of 36,000 ft. This is with 4 km resolution sampling, so smaller cores may be contaminated by warmer cloud material and may actually be much higher than this value

4. **Radar data**. The area north of Hispaniola was within range of the 240 nm sweep of the San Juan WSR-88D. Level II radar data confirmed the presence of several small convective cells along the route northwest from Puerto Rico. Due to large beam width and vertical distance between radar elevations at this extreme range it was not possible to accurately determine maximum thunderstorm tops along the route, but appearance on the 1.4-degree elevation at 170 nm suggests tops at least to 36,000 ft.

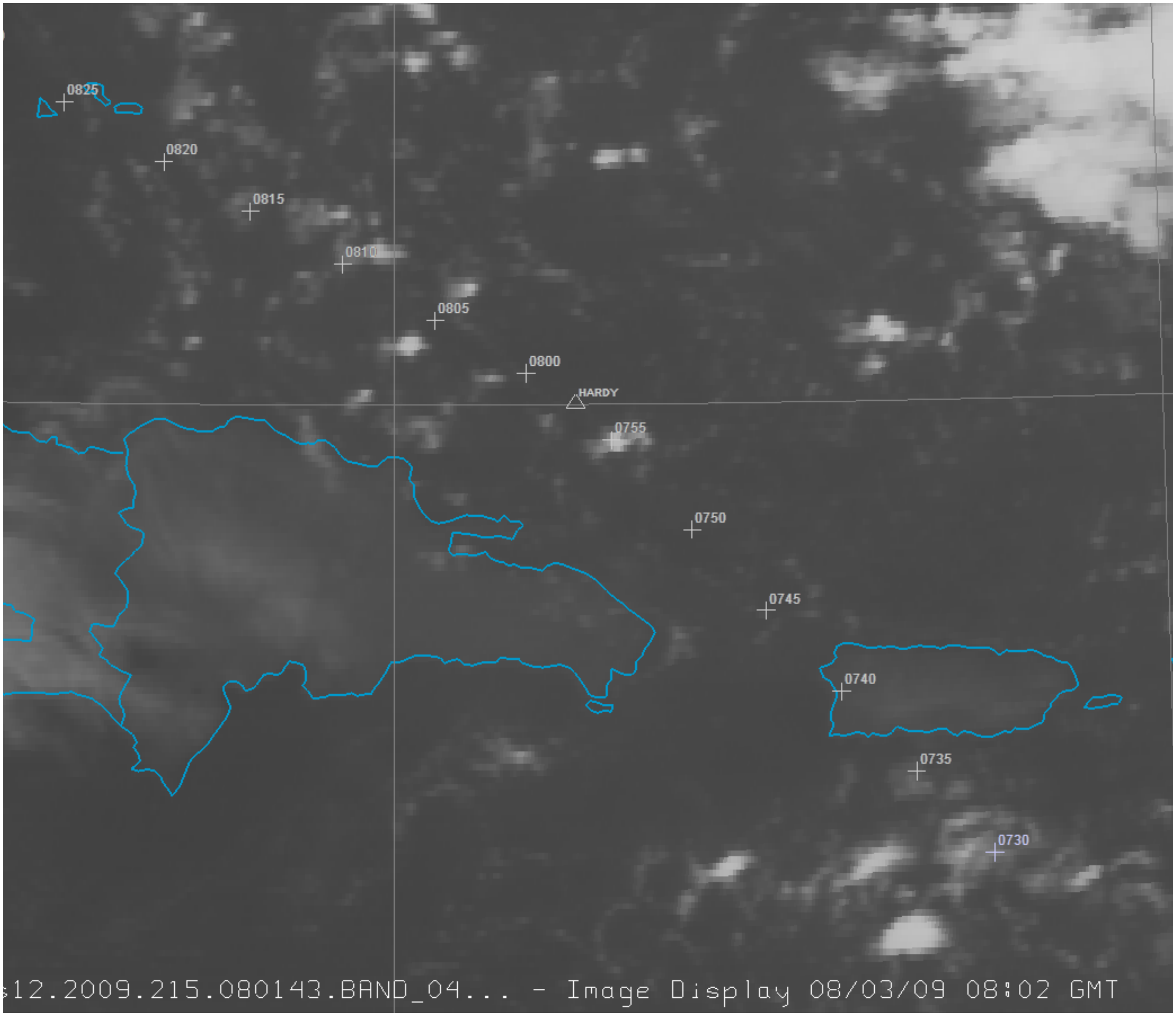

Figure 5. GOES-12 infrared satellite imagery for 3 Aug 2009 at 0802Z, with the ASDI flight track superimposed at 5-minute intervals. This indicates that the flight skirted a convective field south of Puerto Rico. This area was probably enough to put the flight crew on guard. The plane then penetrated a cumulonimbus cloud at 0755 UTC north of the Dominican Republic. Cell movement was westward at about 10 kt.

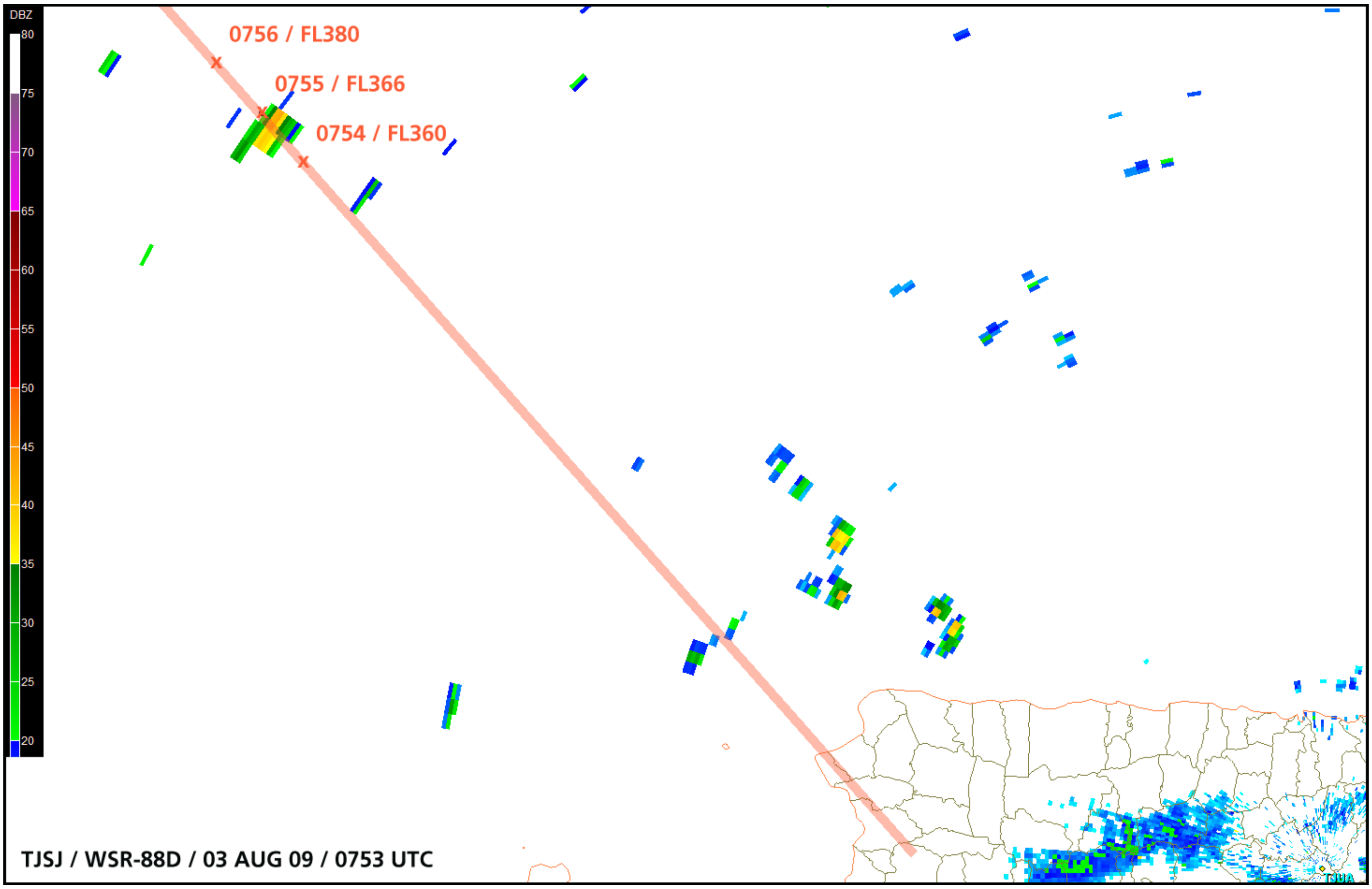

Figure 6. San Juan PR WSR-88D weather radar for 3 Aug 2009 at 0753 UTC with flight track superimposed. This showed fairly conclusive evidence that the flight passed through a convective cloud. The radar reflectivity here shows 43 dBZ being returned in a volume between FL220 and FL380. The echo was also detectable at the 1.4 deg elevation, encompassing a bin between FL 360 and FL530. Variations in the refractive index may add further uncertainty to estimated heights.

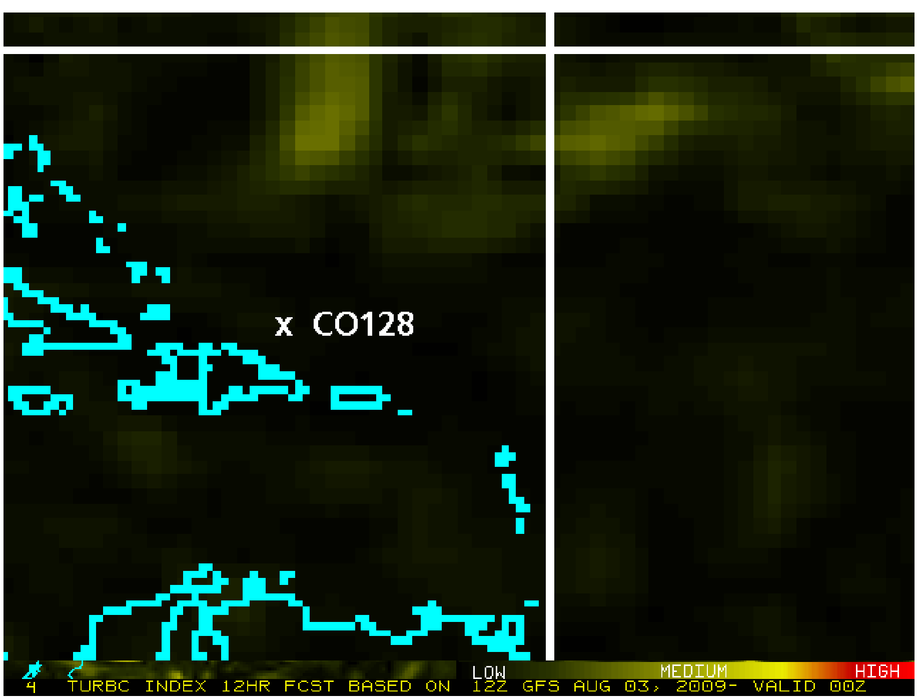

Figure 7. NCEP clear air turbulence product valid 3 August 2009 at 0000 UTC. It shows CO128 in the Dominican Republic area to be in an area with no clear air turbulence risk. The TUTT low well north toward Bermuda does show some evidence of moderate turbulence potential, but this is several hundred miles distant.

5. **Clear air turbulence**. Clear air turbulence is caused by breakdown of gravity waves in the upper atmosphere into smaller scales of motion. This requires a strong vertical shear profile and is usually seen only during the winter months in temperate latitudes. National Centers for Environmental Prediction forecasts for clear air turbulence indicated negligible deformation-vertical shear index (DVSI) values in and around the flight track from South America to Florida. This is confirmed by the weak wind profiles indicated on the San Juan upper air profile. Furthermore, the eyewitness reports of the turbulence being extremely brief in duration is not consistent with the mesoscale or synoptic scale extent of clear air turbulence fields. It appears that the media reports of "clear air turbulence" affecting COA128 are misleading and downplays the inherent risks associated with deep convective clouds.

3. Summary

1. **Conclusion**. Inspection and analysis of meteorological data holdings showed that Continental Flight 128 penetrated a convective cell at [0755 UTC] [19.73,-68.54]. The data strongly suggests that the flight entered the top of a cumulonimbus cloud and was subject to brief periods of severe turbulence. The main contributing factors to the turbulence were normal for convective clouds, including some combination of shear in and near a buoyant updraft and significant evaporation of supercooled water and ice particles in the cloud which generated dense downdrafts. This report was not able to determine why this particular turbulence episode was stronger than those encountered by aircraft in other tropical convective clouds.

2. **Reconstruction of events**. The Houston Chronicle reported that the turbulence incident occurred "about an hour after the pilot announced possible turbulence". This is consistent with satellite imagery. It appears the captain initiated precautionary cabin preparation at about 0710 UTC as the flight approached the convective field south of Puerto Rico and began detecting it on the airborne radar. According to press reports, most passengers were sleeping during the minutes leading up to the incident. At about 0755 UTC, CO128 penetrated the hot tower shown on satellite imagery and it was likely at this time that damaging turbulence occurred. The incident was brief. The Houston Chronicle reported "Passengers estimated the ordeal lasted about five seconds, with two big jolts punctuating the bouncing and shaking". This is consistent with passage through a single small cumulonimbus tower and is not consistent with any form of clear air turbulence. Whatever happened at 0755 UTC coincided precisely with the beginning of a climb from FL360 to FL380. Altitude climbs are common in commercial jets to "find smooth air" and to avoid icing and stronger turbulence in lower portions of thunderstorms. This study did not explore whether the climb could have been a precautionary or a reactionary measure, and there may not be sufficient temporal resolution to determine this.

3. **Forecast aspects**. No exceptional meteorological indications were noted on any of the products, suggesting that this incident may have been unavoidable and unforecastable. It also occurred on an exceptionally small scale scale (about 200 m to 2 km; in the five-second duration ascribed to the event the aircraft traverses 1.2 km). Anomalies at this scale

in data-poor regions are often not possible to adequately resolve and are far beyond the capability of operational numerical prediction models, so forecasting techniques can only address environmental factors that favor the appearance of anomalies which may pose a risk to flight. It is not clear which factors allowed portions of this cumulonimbus cloud to develop strong motion, and whether (1) these motions are highly typical for tropical convection but are confined to extremely small areas where they are rarely traversed; (2) were augmented by unique in-cloud processes (e.g. evaporation of ice and supercooled water that are configured in an unusual way in certain tropical clouds), or (3) were enhanced by mesoscale and synoptic-scale factors such as a mesoscale maxima of dry air aloft.

Further work is needed to assess the turbulence potential in tropical hot towers, as currently most work into tropical convection focuses on heat budget and modelling issues. Topics relating to instability and motion are scarce. In this case it is probable that airborne radar signatures may have been sufficient to warrant a course deviation, but it cannot be assumed that the radar showed any of the indications outlined here as radar is inherently not a turbulence dectector but a precipitation detector, and not always a reliable one at that. It is also clear that some sort of analysis and recording capability of off-the-shelf flight weather radar with incident timelines and FDR data would serve a constructive purpose and help meteorologists reconcile airborne radar signatures against (1) the growing network of high-resolution radar and satellite data and (2) the growing body of detailed, accurate conceptual models of deep convection. Much of this, however, will probably not be forthcoming in the years ahead due to liability concerns and corporate opacity.

4. **Accuracy**. This is only a preliminary report based on the best available data 48 hours after the incident and without any privileged access to information. **Findings and conclusions are subject to change**.

4. References and further reading

Turbulence slams Continental jet, at least 26 hurt
A post by "JAC" on canetalk.com with other related weather products.
<http://www.canetalk.com/2009/08/1249326204.shtml>