171 Convection Diagnosis and Nowcasting System for Transoceanic Aircraft

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Introduction

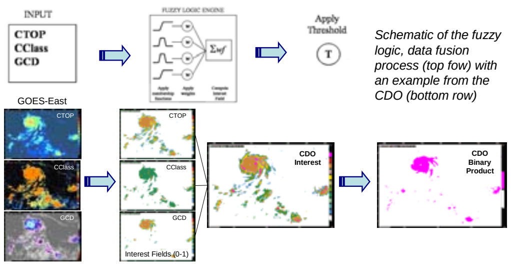
Recent oceanic aviation accidents/incidents (Air France Flight 447, Continental Flight 128, and Yemeni Airways) underscore the need for a strategic tool depicting hazardous convection to advance airline safety assurance. The Oceanic Convection Diagnosis and Nowcasting system is a potential component of such a tool and has been developed for pilots and dispatchers of transoceanic flights where aircraft fly at enroute altitudes. Using satellite remote sensing in conjunction with global numerical weather prediction, the system identifies deep convective clouds over remote, oceanic regions and produces short-term nowcasts of their future locations. These oceanic convection products are geared toward fulfillment of the Federal Aviation Administration's Next Generation Air Transportation System (NextGen) goal of a global convection product.

The Oceanic Convection Diagnosis and Nowcasting system uses geostationary satellite-based methodologies to identify convection through a data fusion of three algorithms (Cloud Top Height, Cloud Classification, and Global Convective Diagnosis). Once identified, the convection is extrapolated into the future 1-6 hours. Independent validation is accomplished with data from the Tropical Rainfall Measuring Mission satellite.

An example of a simulated cockpit display of the Cloud Top Height product is shown.

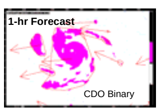
Oceanic Diagnosis and Nowcasting System

The Convective Diagnosis Oceanic (CDO) product identifies convective cells using a fuzzy logic, data fusion methodology of three satellite-based detection algorithms, the Naval Research Laboratory (NRL) Cloud Top Height (CTOP), the NRL Cloud Classification (CClass) and the Global Convective Diagnosis (GCD) algorithms. Validation of the CDO using TRMM data showed (Donovan et al., 2009) that the algorithm had good skill at identifying hazardous convection with scores for CSI=0.58 and FAR=0.26.

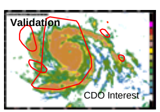


Schematic of the fuzzy logic, data fusion process (top fow) with an example from the CDO (bottom row)

The Convective Nowcasting Oceanic (CNO) product extrapolates storms identified by the CDO product using an object-tracking methodology called Thunderstorm Identification, Tracking, Analysis, and Nowcasting (TITAN) and produces polygons that locate the storm in the future (shown at right). Trends for storm growth and decay are included within TITAN but storm initiation is not.



Gridpoint-by-gridpoint validation of the 1-hr forecasts (shown at right) during a 4 day period (19-22 August 2007 during Hurricane Dean in the Gulf of Mexico) showed a CSI of 0.45, a POD of 0.69, an FAR of 0.44 and a bias of 1.23. Cai et al. (2010) has additional validation results and comparisons to other extrapolation techniques.



Air France Flight 447

In this tragic accident, the worst in French aviation history, an Air France Airbus A330-220 crashed into the ocean, killing all onboard: 216 passengers and 12 crew members. The flight originated from the Galeão International Airport at Rio de Janeiro, Brazil, taking off at 2203 UTC on 31 May 2009, with a planned destination to the Charles de Gaulle Airport in Paris, France some eleven hours later. The last contact from the pilot occurred at 0133 UTC on 1 June 2009 with the Atlantico Air Traffic Control at the edge of Brazilian radar surveillance. Between 0210-0215 UTC, twenty four maintenance messages were received from the aircraft, indicating numerous problems. The flight ended at ~0210 UTC, near the Inter-Tropical Convergence Zone (ITCZ) to the northeast of Brazil.

The aircraft was flying at FL350 (temperature ~-41°C) and intercepted a line of deep convection that was present along the ITCZ. Winds at the surface and aloft were light. Satellite analysis showed the convection was undergoing rapid development as seen in the far right figures that show the GOES-East imagery at 2230 UTC (shortly after takeoff) and at 0200 UTC (near the accident time) with cloud tops approaching the tropopause height (FL520, temperature -80°C). Flight conditions were night Instrument Meteorological Conditions. The aircraft crashed after exiting the area of strongest convection.

The French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA, Bureau of Enquiry and Analysis for Civil Aviation Safety) is the French body responsible for technical investigations into civil aviation accidents or incidents and also acts in this capacity abroad. The figure shown at the right come from the BEA's *Interim Report No. 1* (2 July 2009a). They have conducted two searches, looking for the black boxes that were onboard the aircraft, but were unsuccessful due to the large depth of the ocean at that location. A third search will commence in February 2010 (BEA 2009b). Without the black boxes, discerning the cause of the accident is nearly impossible, given the remote location, lack of radar coverage or eyewitness accounts.

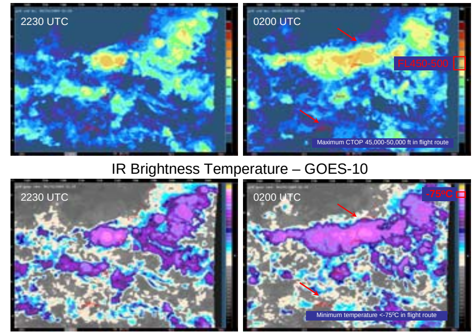
Flight Chronology (BEA, 2009a):

- 2229 – take off
- 224526 – Curitiba ATC
- 225541 – Brasilia ATC
- 231927 – Recife ATC
- 013325 – Atlantico ATC
- 013515 – passed INTOL waypoint (Atlantico)
  - Estimated 0148 SALPU
  - Estimated 0200 ORARO
- 013546 - Atlantico asked them to maintain FL350 and give estimated time at TASIL
- 013553-013614 - Atlantico asked 3 times for TASIL estimate; no response
- 0210-0215 – 24 maintenance messages received

Depiction of the flight chronology is shown above with a map of the flight path. The last contact with the crew and the last known position are indicated with red arrows. Figure from BEA (2009a).

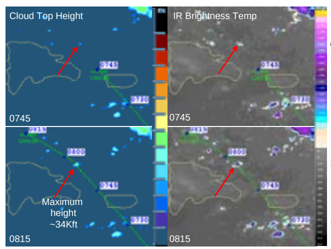
Cloud Top Height – GOES-10

IR Brightness Temperature – GOES-10



The GOES-10 NRL Cloud Top Height product (top row) and the longwave infrared brightness temperature (bottom row) are shown at 2230 UTC on 31 May 2009 (left column) and at 0200 UTC on 1 June 2009 (right column). The expected flight path of the aircraft is show by the red line. Red arrows indicate the last contact with the crew near the Intol waypoint (bottom arrow) and the last known position of the aircraft (top arrow; BEA 2009a). The 2230 UTC images were taken shortly after takeoff while the 0200 UTC images are near the accident time.

Continental Flight 128



The NRL Cloud Top Height product and the GOES-East infrared brightness temperature is shown in the left and right columns, respectively, at 0745 UTC (top row) and 0815 UTC (bottom row). The aircraft flight path is indicated by the green, cross-hatched line with time stamps at the blue triangles. The location of the turbulence incident and the storm position indicated by the red arrows.

On 3 August 2009 at 0755 UTC, Continental Flight 128 was enroute to George Bush Intercontinental Airport in Houston, Texas, after taking off from the Galeão International Airport at Rio de Janeiro, Brazil, when severe turbulence occurred as the aircraft flew over the top of a developing cumulus cloud near the Dominican Republic, indicated by the red arrow in the above figure. Two jolts of severe turbulence occurred within ~5 seconds. The pilot said that it was dark, there was no lightning, no radar echoes and no indication of clouds. The flight diverted to Miami International Airport. Four people required hospitalization, 22 had minor injuries. Damage to the inside of the aircraft occurred.

The Boeing 767-200 aircraft was at FL360. The 12 UTC sounding from San Juan, Puerto Rico showed the tropopause was at ~42Kft. The Cloud Top Height product estimated the storm height at ~34Kft. The NTSB has classified this as an incident.

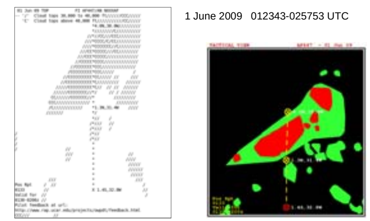
Weather in the Cockpit

One of the Next Generation Air Transportation System (NextGen) goals is to provide weather hazard information for pilot use within the cockpit to improve situational awareness and reduce safety concerns related to hazardous weather encountered during flight. The recent Air France Flight 447 accident has focused attention to the need for additional, aircraft-specific weather information in the cockpit, particularly for transoceanic flights.

The figure to the right shows a reconstruction of the NRL Cloud Top Height product that could have been uplinked to the Air France Airbus A330-220 at the INTOL waypoint (shown as an "X" in the bottom center of each panel), prior to the aircraft encounter with the mesoscale convective complex. Deep convection was clearly present and, with sufficient warning, the pilot could have diverted and thus avoided the area of cloud top heights in excess of 40Kft. Two versions of the display are shown: an ASCII graphic suitable for printing on cockpit printers and a color graphical version that could be used in Electronic Flight Bags.

In 2006, a prior Federal Aviation Administration Aviation Weather Research Program (AWRP) effort with selected transoceanic United Airlines flights successfully demonstrated the usefulness of this product. An ASCII character display was sent to Boeing 777 aircraft onboard line printer when a significant amount of deep convection existed along the flight route, giving the pilots up to 2 hours of warning. Similarly, the AWRP Turbulence Product Development Team has successfully demonstrated a look-ahead turbulence severity product into the cockpit of selected CONUS United Airlines flights.

1 June 2009 012343-025753 UTC



Graphical depiction of the GOES-East derived cloud top heights (30Kft and 40Kft contours) from 1 June 2009 at 0115 UTC via an ASCII, line printer graphic (left) and a color-coded graphic (right) relative to the last known position of Air France Flight 447 (bottom center). The 30Kft contour is represented by a "/" and green shading; the 40Kft contour by a "C" and red shading The images are drawn relative to the expected flight route over the next 2 hours.

Summary

Transoceanic aircraft are particularly vulnerable to convective weather hazards, given their remote location and lack of timely, aircraft-specific weather information. The technology exists today to improve this situation.

Acknowledgements

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