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-deploying hazardous convection to advance air safety. 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 remote 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., 2003) that the algorithm had good skill at identifying hazardous convection with scores for CSI=0.58 and FAR=0.26.

The Convective Nowcasting Oceanic (CNO) product projects developing 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.

On 3 August 2009 at 0755 UTC, Continental Flight 128 was enroute to George Bush International 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, Fort Lauderdale, Florida, due to severe turbulence, 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 that the tops of the convective clouds were ~34Kft. The Cloud Top Height product estimated the storm height at ~34Kft. The NTSB classified this as an incident.

Acknowledgments

This work is funded by the NASA Research Opportunities in Space and Earth Sciences (ROSES) 2005 grant NNX05DA20A/NSC30862: Decision Support through Early-Stage Research for NNA07CN14A: Oceanic Convective Weather Diagnosis and Nowcasting

Weather in the Cockpit

One of the Next Generation Air Transportation System (NextGen) goals is to provide weather hazard information for pilots within the cockpit to improve situational awareness and reduce safety concerns related to hazardous weather encountered during flight. The recent Air France Flight 444 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 the plot) with the convective complex. Deep convection was clearly present and, with sufficient information for pilots to divert and avoid 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 0123456789 (simulated) and produced polygons that locate the storm in the future (shown at right) during a 4 day period (19-22 August 2007 during Hurricane Dean in the Gulf of Mexico) showed aCSI of 0.45, a POD of 0.69, an F1 score of 0.64 and a bias of 1.23. Cai et al. (2010) has additional validation results and comparisons to other extrapolation techniques.

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.

References