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MITIGATING THE IMPACT OF OCEANIC WEATHER HAZARDS ON TRANSOCEANIC FLIGHTS

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1. INTRODUCTION

Air traffic control over the oceanic airspace is less stringent than that over the continental U.S. as the aircraft are not on radar for most of the transit. As a result, much greater separation between aircraft is required because the only positional information available to air traffic control is via low quality, infrequent high frequency voice position reports from the aircraft. Transoceanic flights will increase significantly in the next decade and to efficiently manage this increased demand for capacity while maintaining safety, the Federal Aviation Administration (FAA) is investigating whether or not the separation minima normally used between aircraft transiting oceanic regions can be reduced both horizontally and vertically.

However, in implementing reduced separation standards, the hazard of encountering convective weather over oceanic routes must be considered, as aircraft would have less airspace to maneuver for convective weather avoidance. And, given the difficulty of oceanic communications, more time would be needed for coordination between operational decision-makers (i.e., controllers, dispatchers, and pilots) for altitude and/or routing changes. To facilitate this coordination, current and forecast oceanic weather products not only need to be improved, but must be disseminated to these personnel near simultaneously.

2. NEW EXPERIMENTAL PRODUCTS

Operational decision-makers need to know the location of oceanic convective activity for routing/re-routing of aircraft. However, they are hampered in that the only weather data consistently available is from satellite imagery, which alone cannot reveal areas of convection that would impact aviation operations and influence routing/re-routing decisions. To aid this effort, the FAA and National Weather Service (NWS) are developing oceanic convective products.

The NWS' Aviation Weather Center (AWC) created a new product that identifies thunderstorms by exploiting the output from different satellite imagers (Mosher, 2001). The technique uses the difference between the 11-micron infrared (IR) channel and the 6.7-micron water vapor channel. It also employs a stability index filter to eliminate non-convective areas. In addition, the global Aviation forecast model (AVN), 4-layer Lifted Index is used in the algorithm to eliminate areas not associated with convection. Since these two channels are on all geostationary weather satellites, this product has the potential for thunderstorm detection on a global scale. While this technique is presently considered experimental, it is routinely used by AWC forecasters in conjunction with other data sets, such as the long-range lightning data from oceanic regions. The validity of this new technique is being established and is planned for inclusion on the AWC experimental web site in the near future.

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The National Center for Atmospheric Research (NCAR) has also developed a new product that maps cloud top temperatures derived from IR satellite imagery and converts them to aircraft flight levels. This product also incorporates a correction for non-standard atmosphere lapse rates [temperature and pressure] to make the depiction of cloud tops more precise. NCAR utilizes commercial communications and display capabilities to simultaneously present selected graphical displays of oceanic traffic (current and projected positions) with an updated depiction of oceanic convection. This product has been made available to controllers and the Central Weather Service Unit (CWSU) meteorologists at the FAA's Air Route Traffic Control Center (ARTCC) in Oakland, CA, airline dispatchers and forecasters. In addition, the depiction of areas of convection relative to the flight path has been displayed on flight decks crossing the Pacific Ocean. Future improvements include diagnostics and/or cloud classification algorithms that more precisely differentiate convective from non-convective clouds.

3. RESULTS FROM AN OCEANIC CONVECTION DEMONSTRATION/VALIDATION (DEMVAL)

In 1998, the AWC Aviation Support Branch, with support from Global Atmospherics, Inc. (GAI), developed an experimental maritime lightning product. This maritime, or Long Range (LR), lightning product was superimposed (or overlaid) onto IR satellite imagery over various oceanic regions (i.e., Atlantic, Pacific, and Tropical Atlantic/Pacific). These LR lightning data nominally represent the detection of groundstrokes associated with convective activity from very long distances. This product has proven invaluable to AWC forecasters as the Center's forecasting responsibilities extend out into the oceanic regions, well beyond the range of land-based weather radars, aiding forecasters in generating international Significant Meteorological Information (SIGMET) products for oceanic regions.

Realizing the potential usefulness of this lightning-augmented product for oceanic routing and hazardous weather avoidance, the FAA and NWS promoted an evaluation of this experimental product in 1999. The primary purpose of this evaluation was to determine whether LR oceanic lightning data had the potential to aid in convective oceanic forecasting. CWSU meteorologists and other ARTCC personnel also found these data beneficial in monitoring convective storm development over the Gulf of Mexico (GOM) and the Caribbean (Nierow, 2000). Subsequent results from the evaluation confirmed that NWS and ARTCC meteorologists would find lightning data to be quite useful in their operations of issuing SIGMETs for convection. Air traffic managers stated that, "When the tracks/routes that were designed hours before becoming effective (in use), the real-time lightning data can allow controllers to slightly alter the routings if needed, and keep the traffic flowing smoothly" (Nierow, 2000*)*. Since the LR data provided information not available from other sources, it demonstrated a potential to improve safety, increase air traffic flow efficiency and realize fuel cost savings over data-sparse oceanic regions. ARTCC/NWS meteorologists and Air Traffic managers stated that the availability of LR lightning data enhanced weather briefings to traffic management specialists and aided in making operational decisions. Likewise, the Department of Defense (DoD) forecasters stated these data were helpful in pre-flight briefings to aircrews.

4. INCORPORATING LIGHTNING DATA IN DEVELOPMENTAL PRODUCTS

Figure 1 depicts lightning measurements taken with a satellite-borne Optical Transient Detector (OTD) and illustrates that there are significant/frequent occurrences of lightning over the GOM, Western Atlantic, Caribbean, Central America, and South America. In addition, a study from Chang et al. (1999) showed that there is frequent wintertime convection associated with cold fronts and East Coast storms over the GOM and out into the western Atlantic Ocean. However, Figure 1 also shows that there is little lightning associated with the Inter-Tropical Convergence Zone, Western Pacific, and Eastern Atlantic. Lightning requires a mechanism for charge separation. A primary mechanism for this in a thunderstorm is grapel/ice crystal/liquid water interaction. In order to obtain charge separation, the vertical motion in the cloud must reach approximately $7ms^{-1}$ (Zipser, 1994). Since turbulence in thunderstorms is related to strength of the updraft, the hazard to transiting aircraft is greatest for those systems that are generating lightning.

Figure 1 also reveals that lightning occurs less frequently over the oceans in comparison to land. Presently, land-based lightning detection systems are the only method to determine which oceanic storms pose a significant hazard for aircraft. Additional research is in progress and attempting to characterize the relationship of lightning to maritime convective processes.

The FAA and NWS intend on developing a 0-6 hour (or longer) forecast of oceanic convection incorporating AVN model fields and trend data, satellite-based observations of convection to define current conditions, and LR lightning data. The results from the DEMVAL and Figure 1 support the implication that LR lightning data can be utilized to differentiate between thunderstorms and non-thunderstorms, especially over active lightning areas (e.g., the GOM, Western Atlantic, South America, and Caribbean regions). Since the occurrence of lightning over the ocean is acknowledged as a potentially important parameter in developing future oceanic convective products, several government agencies are advocating research and development efforts to develop a satellite or global land-based lightning observing system.

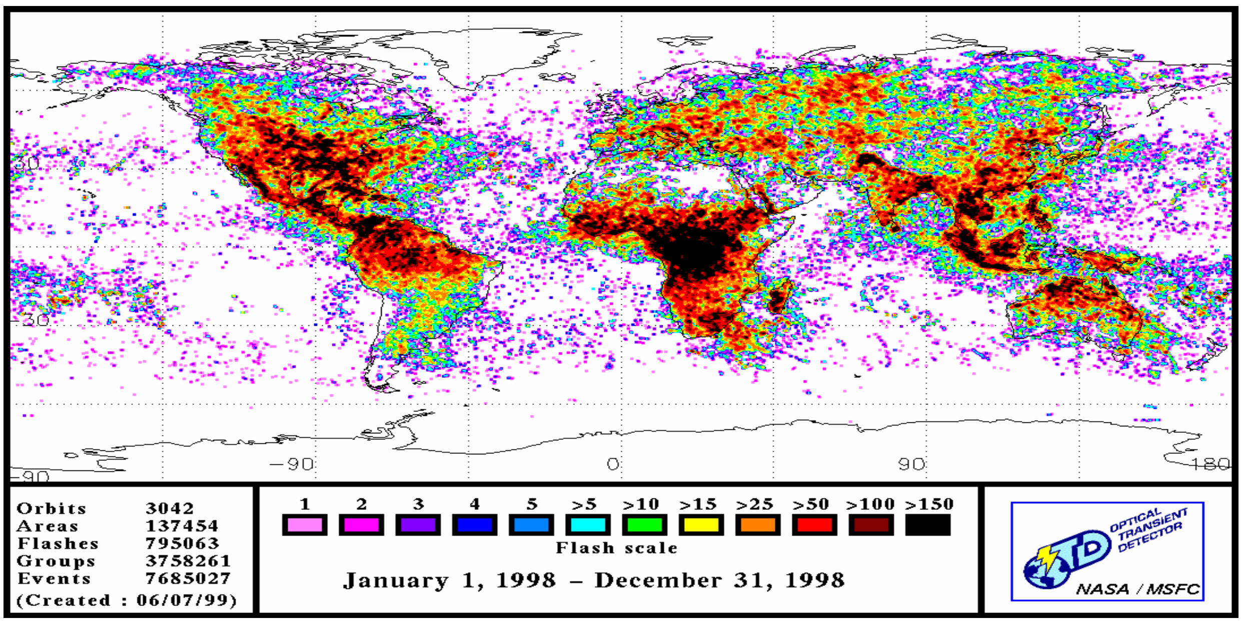

Figure 1. Cumulative lightning data for 1998 from the OTD systems (NASA/MSFC)

5. POTENTIAL AVIATION BENEFITS FOR THE OCEANIC REGIONS

Numerous National Transportation Safety Board studies have documented the existence of upper-level turbulence in the form of Clear Air Turbulence. This type of turbulence over the North Pacific is related to a jet or ridge. However, new evidence has shown that approximately half of the turbulence encounters were likely associated with convective activity (Lindholm, 2002). This phenomenon, called Convectively-Induced Turbulence (CIT), can occur quite a distance away from thunderstorms. The FAA Oceanic Weather Product Development Team (PDT) summary (November 2001), mentions that North Atlantic reports of turbulence are related to embedded convection within baroclinic systems rather than thunderstorms, while turbulence over the GOM is presumably related to thunderstorms (convective systems). In addition, this summary found that from a preliminary survey of pilot reports from routes over the western North Atlantic and to a lesser extent the GOM regions, encounters constituted a significantly higher fraction of moderate or greater turbulence than those over the Pacific. A detailed investigation using archived satellite data and Flight Data Recorder data is attempting to confirm the percentage of turbulence encounters associated with CIT.

Oceanic convective/turbulence nowcasting and short term forecasting products would have a significant impact on flight operations since they would depict possible locations of turbulence and wind shear associated with thunderstorms. These products would also enhance airspace capacity by enabling the FAA to decrease oceanic aircraft separation standards while maintaining safety. The desired result is to reduce the incidences of non-coordinated deviations (due to unexpected encounters with severe weather) through greater situational awareness and more time for coordination. By avoiding areas of convective activity and associated turbulence over oceanic regions, these products have the potential to not only improve safety of flight but increase efficiency (e.g., facilitate routing/re-routing resulting in smaller flight track deviations and reduced fuel costs) over the oceanic regions as well.

6. SUMMARY AND CONCLUSIONS

Future products will consist of not only a very short term forecast (nowcast) of convection, but also a time-phased 'snapshot,' which will eventually evolve to a 6-hour forecast. These products will employ more sophisticated algorithms from FAA-sponsored weather research and development efforts enabling the integration of satellite imagery, model data, and ultimately lightning data. When convective and turbulence products become operational, they could play a significant role as well in supporting the demand for increased airspace capacity over oceanic regions, enhancing both safety and efficiency. In addition, ARTCC/NWS meteorologists, Air Traffic managers, airline dispatchers, and DoD forecasters would be able to provide enhanced weather briefings to traffic management specialists and flight crews that would aid them in making operational decisions.

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