9.11 Using Satellite-based Lightning Products to Enhance Aviation Decision Support Systems: A Feasibility Study

Cathy Kessinger, Wiebke Deierling, John K. Williams, Robert Sharman, Nancy Rehak and Jason Craig

National Center for Atmospheric Research – Research Applications Laboratory

Introduction
Predicting the intensity, location and timing of convection initiation and extratropicalization of existing storms is a difficult endeavor over oceanic regions that are far-removed from land and have few surface-based observations. Geostationary and Low Earth Orbit (LEO) satellites can be the primary and sometimes exclusive source of observations. The feasibility of improving the diagnosis and nowcasting of aviation hazards related to deep convection (oceanic or continental) is examined using the National Aeronautics and Space Administration (NASA) satellite measurements of brightness temperatures, total lightning and ice water path. Further, inferring lightning estimates are examined as a diagnostic tool. Data from the Defense Meteorological Satellite Program (DMSP) satellites will be used in the future.

The presence of lightning indicates that a storm has attained at least the minimum updraft strength to be an aviation hazard. Strong updrafts imply that aviation hazards such as heavy turbulence, wind shear and icing may be present. Brightness temperatures and ice water path are derived from instruments onboard the Tropical Rainfall Measuring Mission (TRMM, Bhlyth et al., 2001; Peterson et al. 2005) are uniquely related to total lightning activity and can be used as input to improve convection diagnosis and nowcasting results. Investigation into potential relationships between cloud-to-ground (CG) lightning measurements and convectively-induced turbulence are examined to determine their potential use for global turbulence detection.

Case Study Data – 28 May 2008
A case study from 28 May 2008 is selected to examine the relationships between lightning and aviation hazards. The NEXRAD radar mosaic (Fig. 1) shows convection is present along a frontal boundary located across the southeastern United States. The domain for the case study of interest is at the westernmost portion of the convective system (red box). The 1800 UTC (all times UTC) NEXRAD overlaid swath is shown by the Visible and Infrared Scanner (VIRS) image that underlays the reflectivity.

The NEXRAD mosaic is shown for four times (Fig. 2) that bracket various stages of convective development of the selected portion of the convective system. In Fig. 2a, the first radar returns from a cell (labeled “A”) are seen at 1520. An hour later at 1620 (Fig. 2b), the first cloud-to-ground lightning flash is observed. The National Lightning Detection Network (NLDN). At 1800 UTC (Fig. 2c), the convective system has continued to evolve and numerous NLDN flashes are observed within the convective cells. Also at this time, the TRMM overflight occurs over the area. By 1925 (Fig. 2d), the convective system has expanded to trend towards the west with convective cores producing numerous lightning flashes.

Using Derived Lightning Groups within Oceanic Convection Diagnostic
A fuzzy logic, data fusion technique, described in Kessinger et al. (2010), diagnoses the presence of deep convection using geostationary satellite imagery over oceanic regions where ground-based data systems are limited. While not fully described here, this technique is augmented with 37 and 85 GHz TRMM lightning groups (Fig. 5) for the purposes of illustrating how these fields may assist in better pinpointing regions of convective hazards.

Briefly, the Convective Diagnosis Oceans (CDO) technique combines multiple, scaled input fields in a weighted summation and is then normalized. The output is an interest field (values between 0 and 1) that indicates the likelihood of convection with values 0.5 to 0.55 indicating deep convection. Several configurations of the CDO are run for concept testing. In Fig. 6a, the CDO is computed using inputs from geostationary satellite imagery. In Fig. 6b, the CDO includes the 37 GHz derived lightning group as an input field. Likewise, in Fig. 6c, the CDO inputs the 85 GHz derived lightning group. Each CDO configuration is compared (Fig. 7) with corresponding composite reflectivity and NLDN flashes (Fig. 7a) and the reflectivity at 5.5 km (Fig. 7b). Results some improvement is realized in CDO performance with the addition of these two lightning groups. Additional work is planned to validate these preliminary results.

Summary and Future Work
A case study has illustrated the use of advanced satellite and lightning products to better understand and detect hazardous convection. If a relationship between lightning and turbulence production is found and is found to be generally applicable, the launch of the Global Lightning Mapper (GLM) on GOES-R could provide an important diagnostic tool for locating regions of convectively-induced turbulence over the hemisphere and could vastly improve pilot awareness and avoidance of hazards. Use of GLM total lightning will be examined in the future with proxy data sets.

These preliminary results are promising but additional cases must and will be examined to ascertain the applicability of the results. Both oceanic and continental storms will be examined, although the NEXRAD mosaics are currently limited to the contiguous United States. Further, construction of a “hazard map” will be undertaken since that aviation hazards associated with convection can be summarized on one chart.

References