2010
21st International Lightning Detection Conference
19 - 20 April • Orlando, Florida, USA
3rd International Lightning Meteorology Conference
21 - 22 April • Orlando, Florida, USA

CLOUD-TO-GROUND LIGHTNING IN YUKON, CANADA DURING A SEASON OF EXTREME WILDFIRE ACTIVITY

B. Kochtubajda[1], W.R. Burrows[1,2], D. McLennan[1] and D. Green[3]

[1]Hydrometeorology and Arctic Laboratory
Science Section
Meteorological Service of Canada
Environment Canada
Edmonton, Alberta, Canada

[2]Cloud Physics and Severe Weather Research Section
Science and Technology Branch
Environment Canada
Toronto, Ontario, Canada

[3]Wildland Fire Management Branch
Protective Services Section
Department of Community Services
Government of Yukon
Whitehorse, Yukon, Canada

1. INTRODUCTION

Cloud-to-ground (CG) lightning from thunderstorms initiating forest fires is a typical summer hazard in the rugged terrain of the Yukon Territory of northern Canada. The lightning season usually starts in May, peaks during July and is usually over in September. This region typically experiences 141 wildfires annually which burn over 160,000 hectares between June and August. An annual average of over 20 thousand CG flashes account for about 54% of these ignitions. During the summer of 2004, a persistent upper level ridge dominated throughout the Yukon. Maximum temperatures were above normal for much of the season and precipitation amounts were about 60% of normal. The number of CG flashes, lightning-initiated forest fires and extent of the area burned surpassed historic records. Specifically, over 40 thousand CG flashes accounted for 88% of the 282 wildfires consuming over 1.7 million hectares of the territory. (Green, 2004; WFRP, 2005). The 2004 fire season in Alaska burned about 2.7 million hectares.

Several studies have previously investigated the influence of smoke from fires on CG polarity and peak current characteristics. Large increases in the percentage and peak currents of positive CG lightning were found in thunderstorms in the central US ingesting smoke from fires in Central America (Lyons et al. 1988). Murray et al. (2000) reported peak current decreases in the negative CG flashes for the same study area. Increases in the percentage of positive CG lightning were found in the Mackenzie Basin of Canada during the 1995 fire season (Kochtubajda et al. 2002). Recently, Fernandes et al, (2006) reported decreases in negative peak currents, and increases in the peak currents and percentage of positive CG flashes in the Amazon area of Brazil.

The objective of this study is to advance our understanding of the nature of lightning during an extreme fire season. Our analyses will focus on the lightning activity during the month of July and address the following questions. What were the polarity and peak current lightning characteristics in Yukon during this extreme fire period? How different or similar were they from less extreme periods? How similar or different are the Yukon findings from those reported in southerly latitudes?

2. DATA and ANALYSIS

Cloud-to-ground lightning flash data were obtained from the Canadian Lightning Detection Network (CLDN) for the period 2002 to 2006. These data describe the location, time, polarity, first-stroke peak current and multiplicity (number of strokes) of the flash and are subject to a variety of uncertainties including measurement and calibration errors, and model limitations

(Cummins and Murphy, 2009). Figure 1 shows the location of the 7 CLDN sensors and the topography of Yukon. This 482,443 square kilometre area is a complex mixture of mountains, plateaus and river valleys. The mountain ranges run in a variety of orientations that not only border the plateaus, but sometimes cross them. There is a wide range of elevations to these mountains. The Saint Elias Mountains in south-western Yukon are the highest in Canada and have extensive icefields, while the Richardson Mountains in the northeast are low and often rounded at the peaks. Between these two ranges are numerous other ranges.

Positive flashes were reclassified according to guidelines discussed in Cummins and Murphy (2009) as a result of field campaigns described in Biagi et al. (2007). Specifically, positive events with current strength below 15 kA that were classified as CG previous to April 2006 were now classified as cloud discharges, and positive flashes with current strengths greater than 20 kA that had been classified as cloud discharges were likely to be CG discharges.

First-stroke peak positive and negative currents and percentage positive polarity characteristics during July 2004 were compared to the characteristics archived for July 2002-03 and July 2005-06. Spatial patterns were derived using equal-area square grid cells with 20 km sides (Burrows et al. 2002). Current strength anomaly maps were produced by subtracting the average of the July 2002-03 and 2005-06 data from the July 2004 data for each 20 km by 20 km grid cell. Difference values less than/greater than zero would show a decrease/increase in 2004, respectively. The spatial analyses were undertaken in ARCGIS and included the Spatial Analyst toolbox.

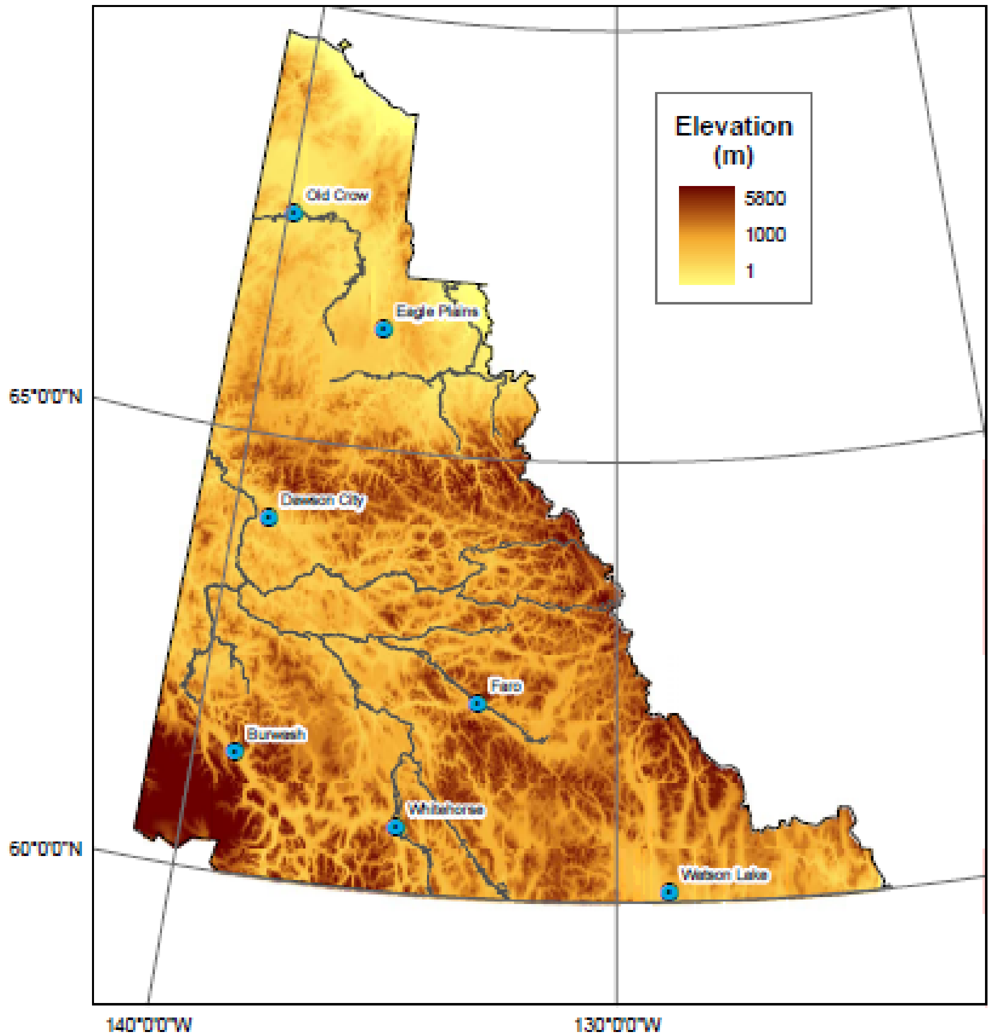

Figure 1. A map of the Yukon Territory and its topographic features. The locations of the CLDN stations are identified.

3. RESULTS

a. <u>Percent positive CG flashes</u>

The spatial pattern of the average percentage of positive CG lightning for July 2002, 2003, 2005 and 2006 is shown in Figure 2. The Yukon typically detects about 20-30% positive flashes. However, there are some areas that experience more positive flashes. The band of positive CG flashes >80% along the St. Elias Mountains in the south west corner of the Yukon may reflect sensor bias or topographic influences as weaker flashes may not be detected due to the distance or range from the nearest sensor. The spatial pattern of percentage positive CG lightning detected in July 2004 (figure 3) is significantly different from the 4-year average. A large area of the Yukon Plateau was found to have 2 to 5 times more positive lightning.

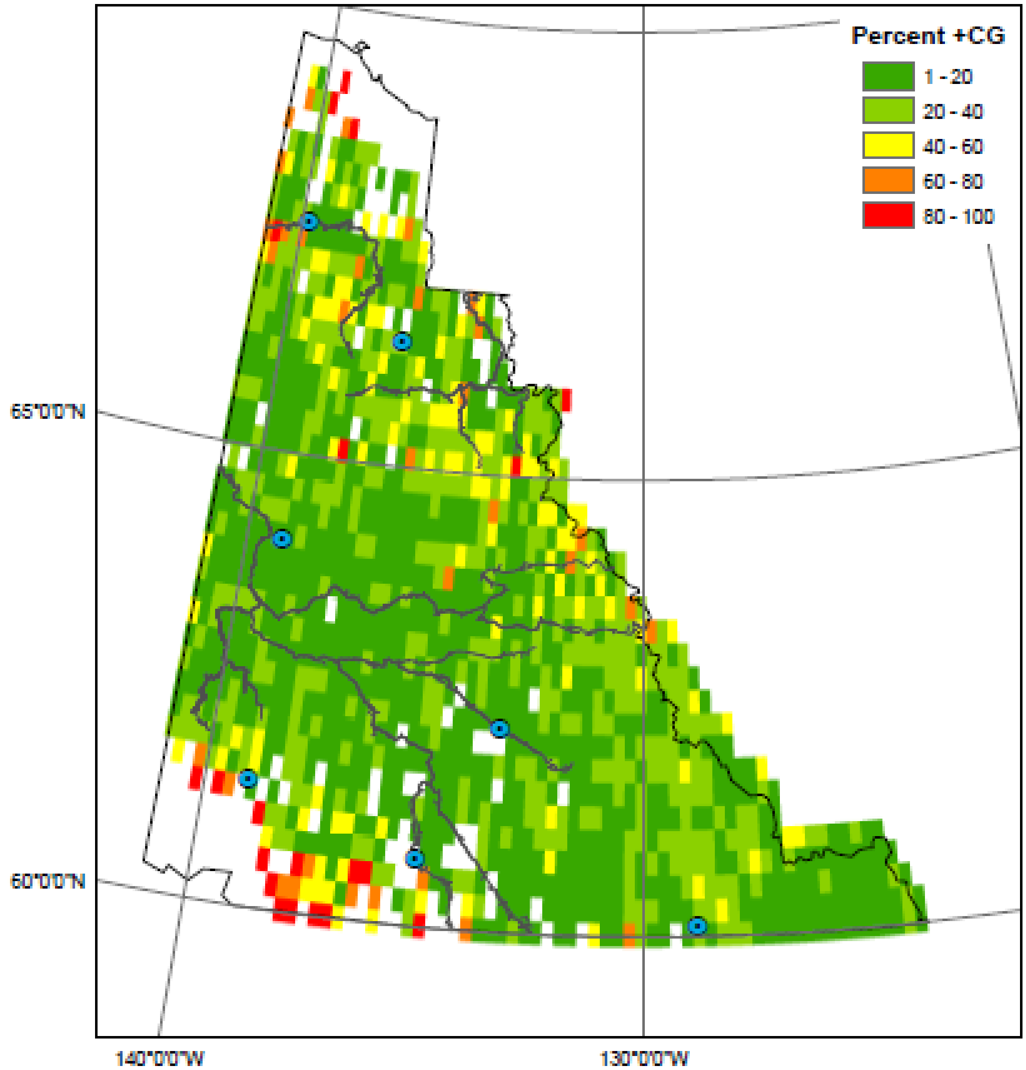

Figure 2. The spatial distribution of the percentage of positive flashes in July [averaged for 2002, 2003, 2004, 2005]. The locations of the CLDN sites are superimposed.

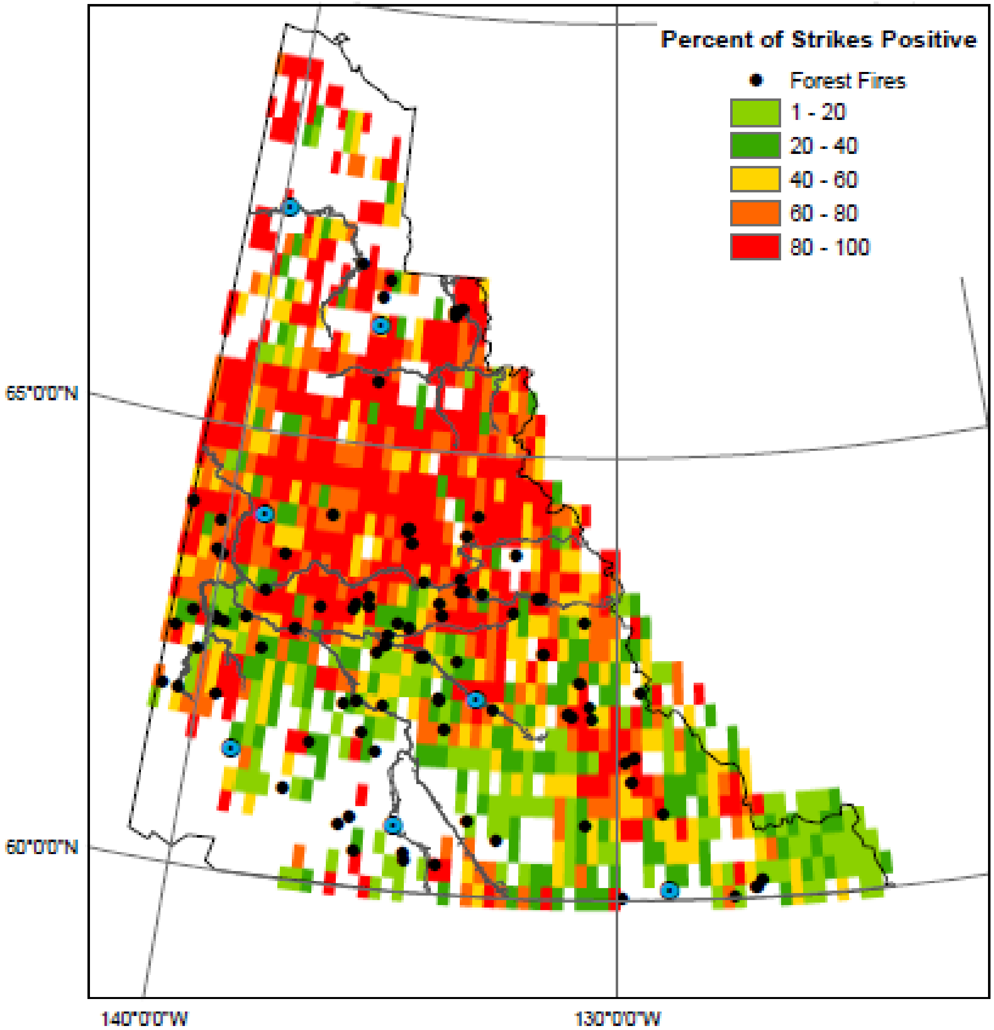

Figure 3. The spatial distribution of the percentage of positive flashes in July 2004. Locations of the CLDN sites (blue) and the lightning-initiated fires during the month are superimposed (black).

b. <u>First-stroke peak current</u>

The first-stroke mean peak current strength anomaly maps for negative and positive CG flashes are shown in Figures 4 and 5, respectively. Negative mean peak current strengths during July 2004 were generally weaker over much of the Yukon. The peak-current strengths decreased by as much as 20 kA in some regions of the Yukon. Conversely, positive mean peak current strengths were generally stronger over the area. In some areas, the peak-current strengths increased by 40 to 50 kA.

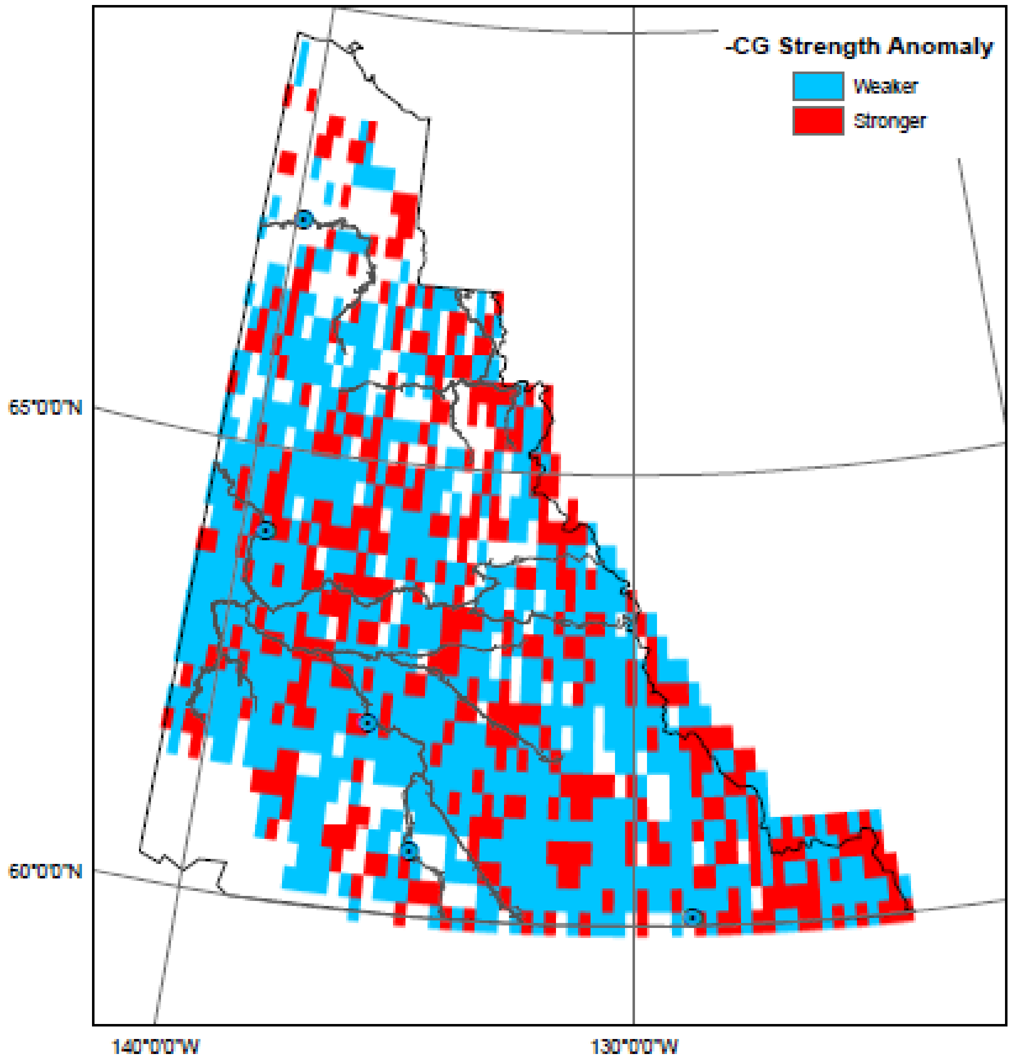

Figure 4. Anomaly map of negative flash peak current. Difference was determined by subtracting the mean of July 2002, 2003, 2005 and 2006 data from the July 2004 data for each bin.

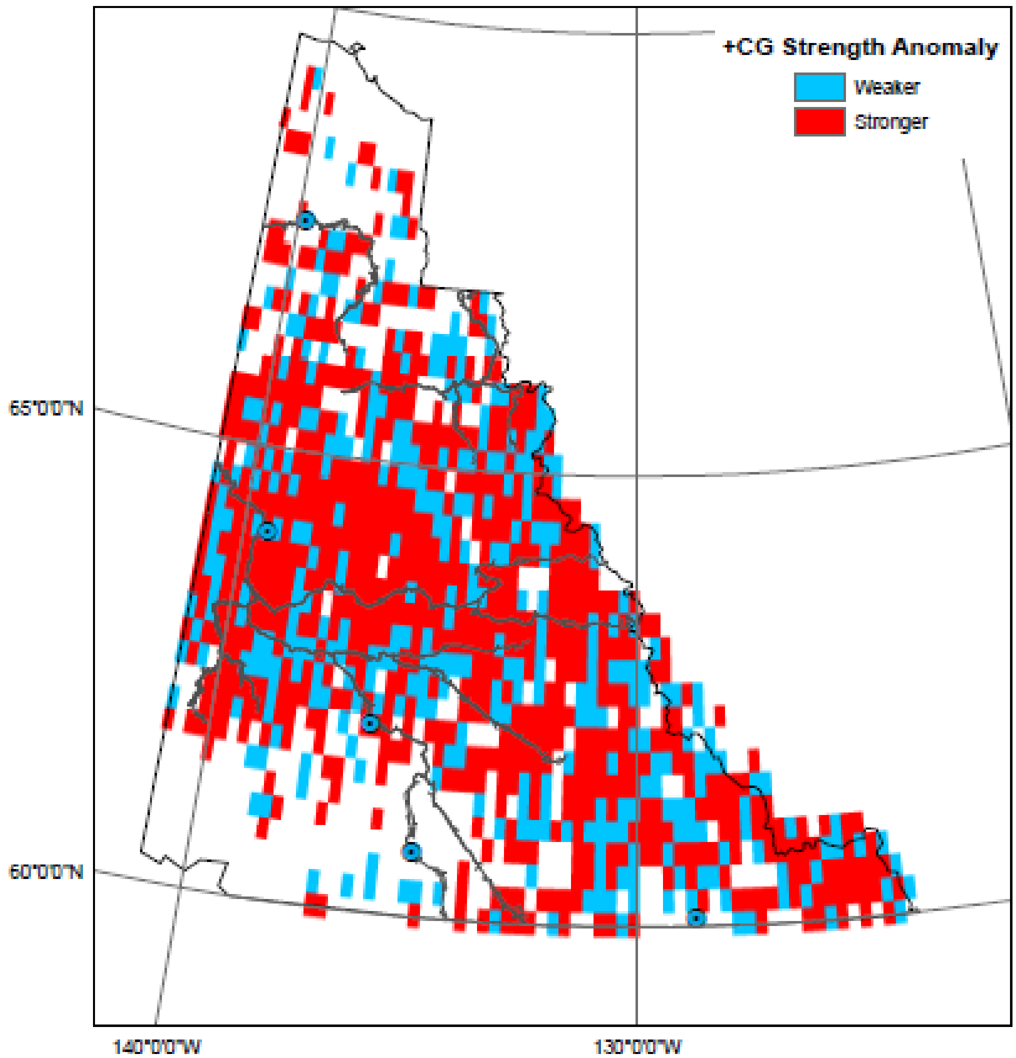

Figure 5. Anomaly map of positive flash peak current. Difference was determined by subtracting the mean of July 2002, 2003, 2005 and 2006 data from the July 2004 data for each bin.

4. DISCUSSION

The 2004 wildfire season and associated lightning activity in the Yukon Territory of northern Canada was unusual in many aspects. Our preliminary observations of the CG flash characteristics during July 2004 in the Yukon appear to confirm the previous findings of Lyons et al. (1998), Murray et al. (2000) and Fernandez et al. (2006). We found increases in the peak currents and percentage of positive CG flashes and decreases in negative peak currents.

Smoke transported from the fires in Alaska is also likely to have influenced the electrical characteristics of CG lightning in the Yukon. It would be interesting to examine how aerosols might affect lightning. Although there is no known source of direct aerosols data for the Yukon, an inter-comparison of satellite-derived aerosol optical depths from the MODIS instrument onboard the EOS -Terra satellite and CG lighting may provide additional insight. Recently, Lang and Rutledge (2006) have suggested that changes in +CG production in thunderstorms may be linked to drought environments. Further studies will also be undertaken to determine whether/how these changes in lightning characteristics may be related to the drought conditions prevalent in 2004.

5. ACKNOWLEDGEMENTS

Vaisala Inc. of Tucson, Arizona, USA processes the CLDN data and provides telecommunication services to Environment Canada. The data are the property of Environment Canada.

6. REFERENCES

Biagi C.J.; K.L. Cummins, K.E. Kehoe and E.P. Krider. 2007. National Lightning Detection Network (NLDN) performance in southern Arizona, Texas and Oklahoma in 2003-2004. *J. Geophys. Res.* **112**, D05208, doi:10.1029/2006JD007341.

Burrows, W.R., P.King, P.J. Lewis, B. Kochtubajda, B. Snyder, and V. Turcotte, 2002: Lightning occurrence patterns over Canada and adjacent United States from lightning detection network observations. *Atmosphere-Ocean*, **40 (1)**, 59-81.

Cummins, K.L. and M.J. Murphy. 2009. An overview of lightning locating systems: history, techniques and data uses, with an in-depth look at the U.S. NLDN. *IEEE Trans. Electromagn. Compat.*, **51**, No.3, 499-518.

Fernandes, W.; I.R.C.A. Pinto, O.Pinto Jr., K.M. Longo and S.R.Freitas. 2006. New findings about the influence of smoke from fires on the cloud-to-ground lightning characteristics in the Amazon region. *Geophys. Res. Lett.*, **33**, L20810, doi:10.1029/2006GL027744.

Green, D., 2004. End of year report: 2004 fire weather. Government of Yukon Community Services / Yukon Wildland Fire Management . 11pp.

Kochtubajda, B. , R.E. Stewart, J.R. Gyakum, and M.D. Flannigan, 2002: Summer convection and lightning over the Mackenzie River Basin and their impacts during 1994 and 1995. *Atmosphere-Ocean*, **40(2),** 199-220.

Lang, T.J. and S.A. Rutledge. 2006. Cloud-to ground lightning downwind of the 2002 Hayman forest fire in Colorado. *Geophys. Res. Lett.,* **33**, L03804, doi:10.1029/2005GL024608

Lyons, W.A.; T.E. Nelson, E.R. Williams. J.A. Cramer and T.R. Turner, 1998. Enhanced positive cloud-to-ground lightning in thunderstorms ingesting smoke from fires. *Science*, **282**, 77-80.

Murray, N.D.; R.E. Orville and G.R. Huffines, 2000. Effect of pollution from Central American fires on cloud-to-ground lightning in May 1998. *Geophys. Res. Lett.,* **27**, 2249-2252.

Wildland Fire Review Panel. 2005. 2004 Wildland fire review – Final Report. http://www.community.gov.yk.ca/pdf/Panel_Review_Report_June_7_2005.pdf