Production and Transport of Ozone from Boreal Forest Fires

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1. Introduction

The Quantifying the impact of BOReal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites (BORTAS) mission was planned by several universities and government agencies in the United Kingdom, Canada, and USA, and was funded by the UK Natural Environmental Research Council, with meteorological field support from the UK Meteorological Office and Environment Canada. It was conducted in two phases: July and August 2010 (BORTAS-A) and 2011 (BORTAS-B). The main goal of the campaign was to better understand the chemical evolution of plumes emitted from wildfires in boreal regions, with a particular emphasis on the net production of tropospheric ozone and downwind impacts on air quality.

2. Forest Fires

- 2010 was an exceptional year for Canadian boreal fires. The burned area in Saskatchewan in 2010 is 6 times larger than the 10-year mean (Figure 1) .
- MODIS (Moderate Resolution Imaging Spectroradiometer) satellite fire count data show large fire events in Saskatchewan on several days in July (Figure 1).

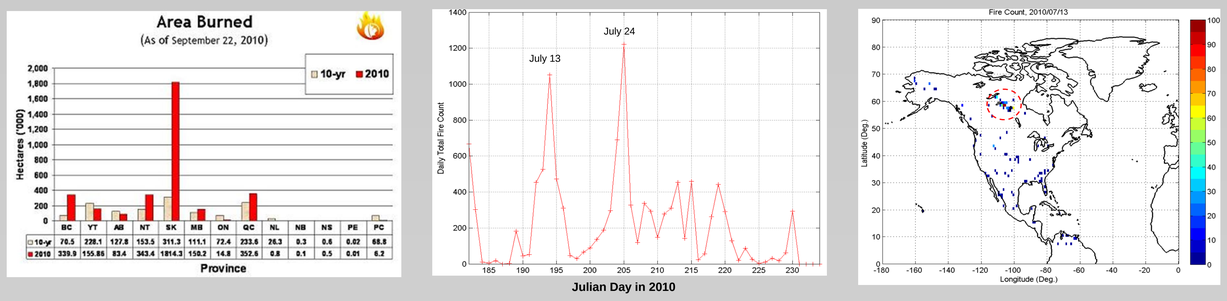

Figure 1. Comparison of the burned area in 2010 in province Saskatchewan (SK) with the 10-year mean (left panel). (Source: Canadian Forest Service). Fire evolution in Central Canada (55-65ºN, 120-90ºW), July- August, 2010 (middle panel) and the large fire location on July 13 (right panel, in red circle) as from the MODIS Fire count data.

3. Ozonesonde Measurements and Trajectories

- Layers of elevated ozone mixing ratio are detectable in ozonesonde profiles downwind at several sites, following days with large fire activity (Figure 2, red circles).
- Back-trajectories with HYSPLIT suggest the elevated ozone in the profile is traceable to the fires in Saskatchewan (Figure 3).

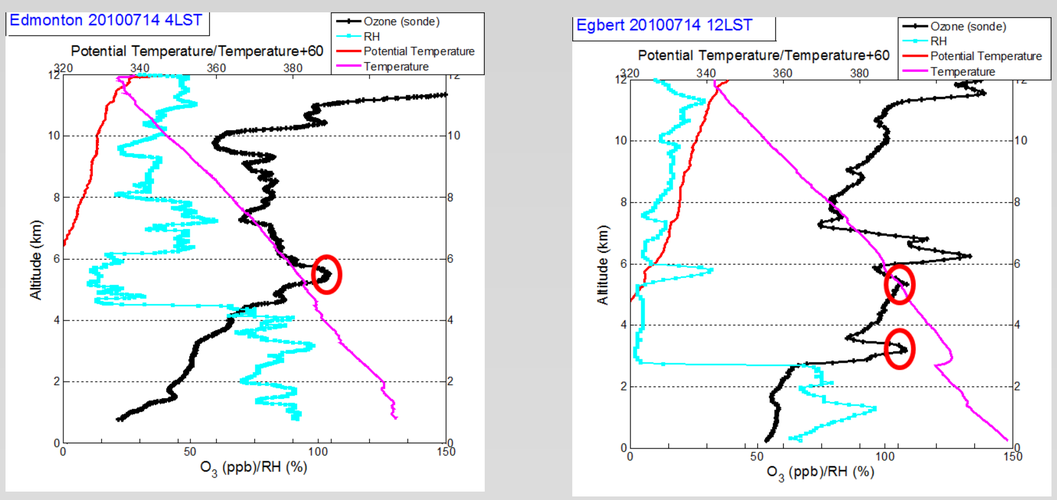

Figure 2. Significant ozone enhancement is observed on July 14 at a station nearby the large fires (Edmonton, left panel) and at a station in distance from the fires (Egbert, right panel).

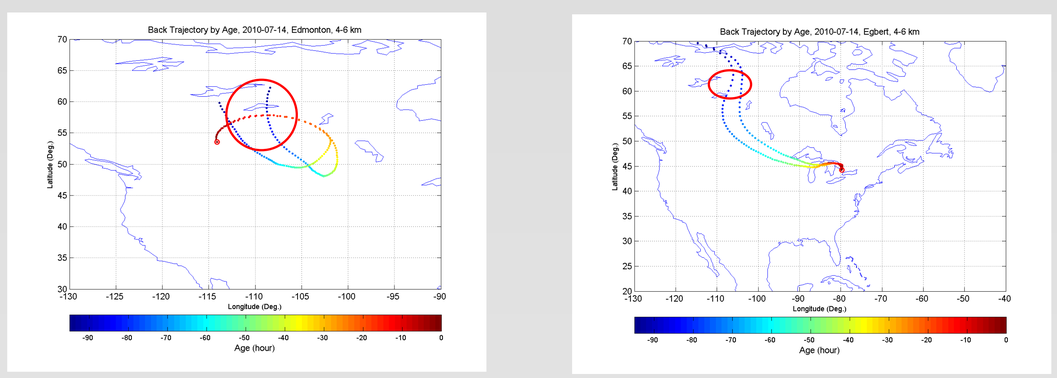

Figure 3. Back-trajectories for Edmonton (left panel) and for Egbert (right panel). Red circles indicate the area with large forest fires.

4. Chemical Conditions

- High amounts of NO2 close to the large fires are observed from OMI satellite data (Figure 4).
- Associated with the fires, large amounts of CO, another precursor of ozone, are observed in MOPITT (Measurements Of Pollution In The Troposphere), AIRS and TES (Tropospheric Emission Spectrometer) satellite data in the middle to upper troposphere (Figure 4).
- These chemical conditions can produce ozone in sunny weather.

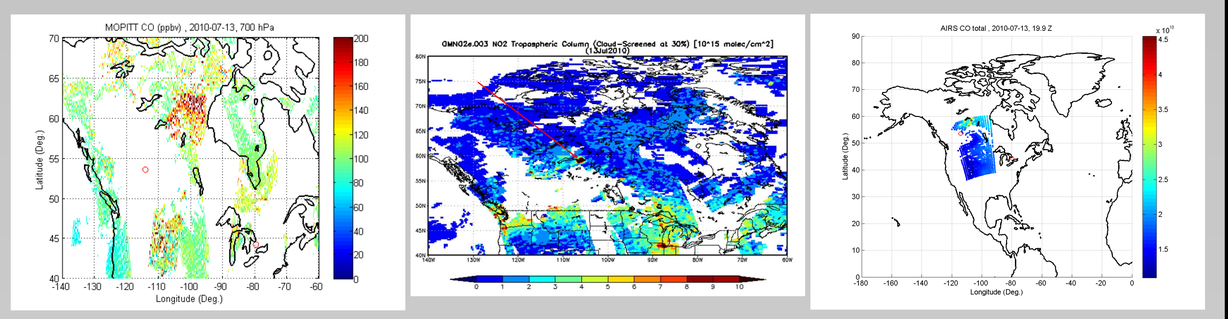

Figure 4. Carbon monoxide (CO) from MOPITT on July 13 at 700 hPa (left panel) and from AIRS on July 13 (right panel), NO2 from OMI on July 13 (middle panel).

5. HYSPLIT Trajectory Calculations

- Trajectory calculations for all profiles for two months (July and August) in 5x5 degree longitude and latitude grid cell show that the average ozone content of the air parcels traceable to the fires is 10 to 30% larger than the average of parcels at the same height which are not traceable to the fires (Figure 5).

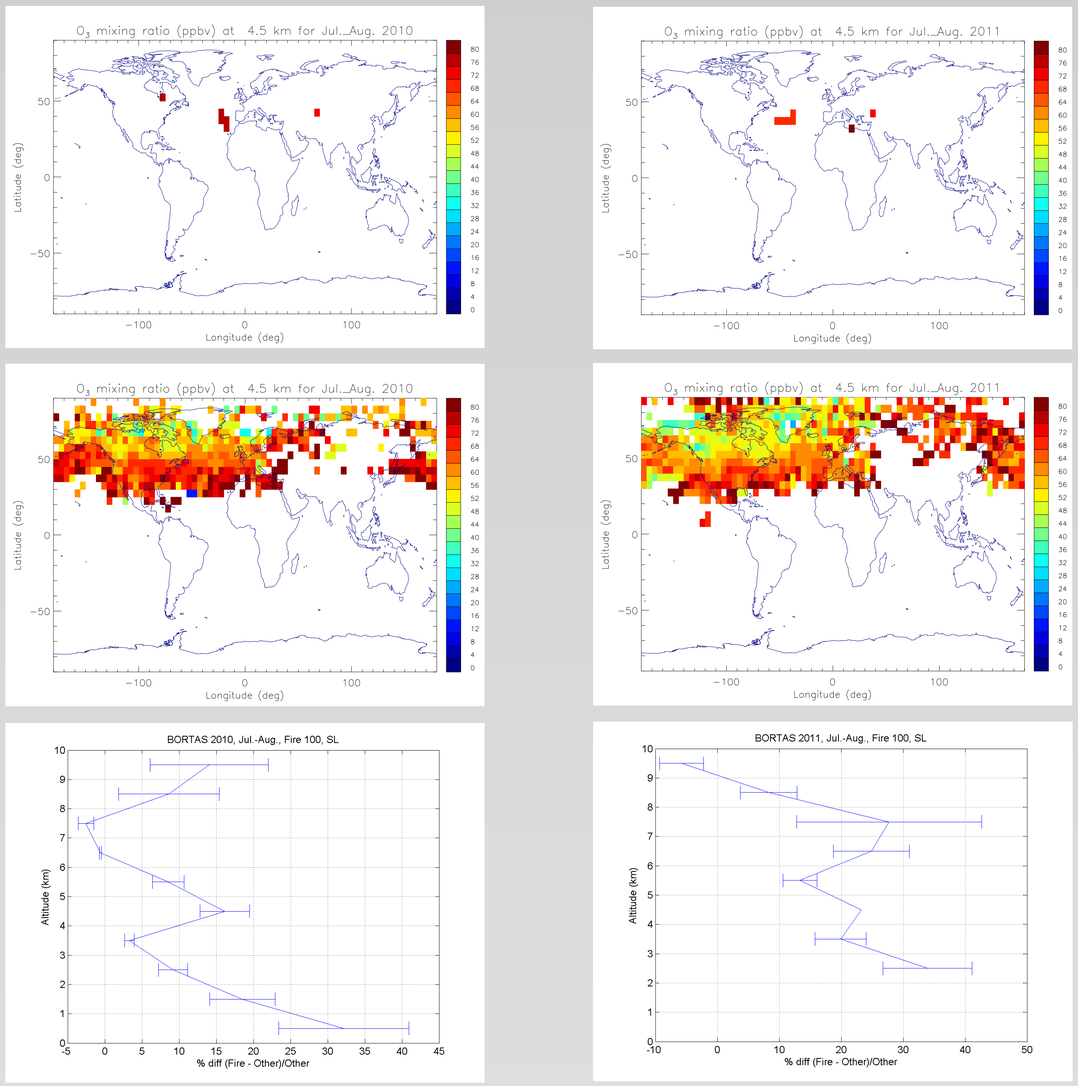

Figure 5. Average ozone content of the air parcels traceable to the fires (top) and of those which are not traceable to the fires (middle) for two months (July and August) in 5x5 degree longitude and latitude grid cell for 2010 (left) and 2011 (right). Difference in percentage (bottom).

6. Conclusions

- Elevated ozone is observed in ozone profiles at stations nearby or in distance of large boreal forest fires.
- High amount of NO2 close to the large fires is observed from OMI satellite data, indicating that not all NO2 is converted to PAN. High CO, another precursor of ozone, is observed in MOPITT, ARIS and other satellite data.
- Back-trajectories can trace the elevated ozone in the profiles to the forest fires.
- Some layers of high ozone are associated with low humidity, which suggest the possibility of entrainment of stratospheric air.
- The average ozone content of the air parcels traceable to the fires is 10 to 30% larger than the average of parcels at the same height which are not traceable to the fires.