Enhanced Ozone Over the North American Arctic From Biomass Burning in Eurasia During April 2008 as Seen in Surface and Profile Observations

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Summary

During April 2008, as part of the IPY, a number of ground-based and aircraft campaigns were carried out in the North American Arctic region (e.g., ARCTAS, ARCPAC). The widespread presence during this period of biomass burning effluent, both gaseous and particulate, has been reported (Warneke et al., 2009; Jacob et al., 2009). Unusually high ozone readings for this time of year were recorded at surface ozone monitoring sites from northern Alaska to northern California. At Barrow, Alaska, the northernmost point in the United States, the highest April ozone readings recorded at the surface (hourly average values >55 ppbv) in 36 years of observation were measured on April 19, 2008. At Denali National Park in central Alaska, an hourly average of 79 ppbv was recorded during an 8-hour period in which the average was over 75 ppbv, exceeding the ozone ambient air quality standard threshold value in the U.S. Elevated ozone (>60 ppbv) persisted almost continuously from April 19-23 at the monitoring site during this event. Ozone profiles from an extensive series of balloon soundings showed lower tropospheric features at ~1-6km with enhanced ozone during the times of elevated ozone amounts at surface sites in western Canada and the U.S. At two coastal sites (Trinidad Head and Vancouver Island), profiles of a large suite of gases were measured from airborne flask samples taken during probable encounters with burning plumes. These profiles aided in characterizing the vertical thickness of the plumes, as well as confirming that the plumes reaching the west coast of North America were associated with biomass burning events.

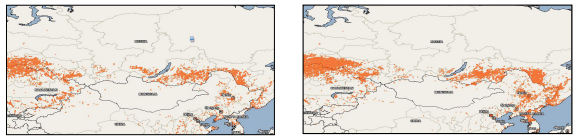


Figure 1: Fires detected by the MODIS instrument on the Aqua and Aura satellites during the period 1-10 and 11-20 April 2008.

(1)

Enhanced Ozone Over Alaska

The enhanced ozone signal was the most dramatic at Denali National Park. In the 20-yr surface ozone record, only four months experienced hourly values ≥ 60 ppbv (none in April). In April 2008 at Denali 26 hourly averages were ≥ 70 ppbv.

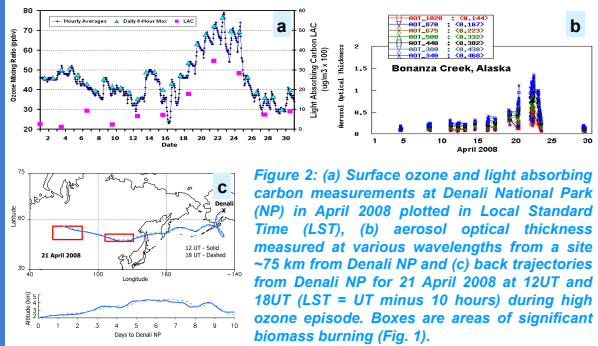


Figure 2: (a) Surface ozone and light absorbing carbon measurements at Denali National Park (NP) in April 2008 plotted in Local Standard Time (LST), (b) aerosol optical thickness measured at various wavelengths from a site ~75 km from Denali NP and (c) back trajectories from Denali NP for 21 April 2008 at 12UT and 18UT (LST = UT minus 10 hours) during high ozone episode. Boxes are areas of significant biomass burning (Fig. 1).

At Barrow the April 20 hourly averaged ozone maximum of 56 ppbv and back trajectory calculations (Fig. 3) indicate the same regions of burning identified to be responsible for the enhanced hourly averaged ozone concentrations at Denali. Highly elevated carbon monoxide, in situ aerosol light scattering, and aerosol optical depth were recorded. This provides strong confirmation that the elevated ozone amounts were associated with the biomass burning activity in Eurasia.

(2)

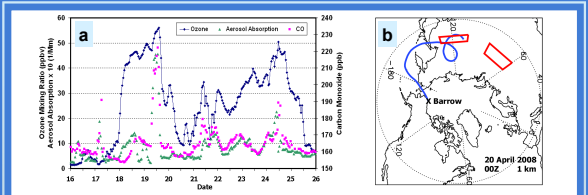


Figure 3: a) Surface ozone, aerosol absorption, and carbon monoxide at Barrow, Alaska for the period 16-25 April 2008 plotted in Local Standard Time (LST), (b) 10-day back trajectory from Barrow at 1 km at 00UT on 20 April 2008 (14 LST on 19 April).

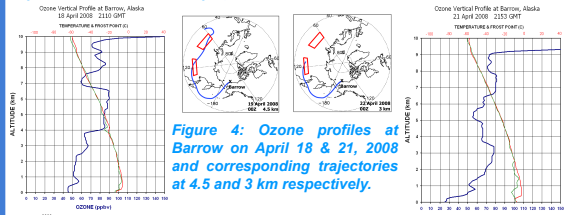


Figure 4: Ozone profiles at Barrow on April 18 & 21, 2008 and corresponding trajectories at 4.5 and 3 km respectively.

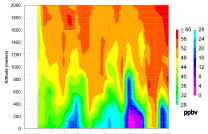


Figure 5: Cross-section of ozone mixing ratio at Barrow during the first three weeks of April 2008.

(3)

The event at Barrow was also identified in aircraft measurements (Warneke et al., 2009), where specific markers of biomass burning were measured. Daily ozonesonde measurements were made at Barrow during the first 3 weeks of April as part of ARCIONS. Spring 2008 was a very unusual year in the Arctic in that there were very few boundary layer ozone depletion events. Flow was predominantly from the Pacific sector rather than the more common flow over the Arctic Ocean. Above the boundary layer (~1000 m) ozone amounts are 40-50 ppbv, but these values were not observed near the surface until the event of April 19-20 (Fig. 5). At that time, ozone amounts were enhanced more than 5 ppbv at heights above the boundary layer and these larger amounts reached the surface. The enhanced layer extended to about 6.5 km in several of the ozonesonde profiles (Fig. 4) with corresponding trajectories reaching the biomass burning region. The vertical depth of the layer was similar to that reported in the aircraft measurements over Alaska.

Western Canada

The enhanced ozone concentrations were not confined to Alaska; they were observed at a number of locations in western Canada. At these sites the ozone enhancement was somewhat less pronounced.

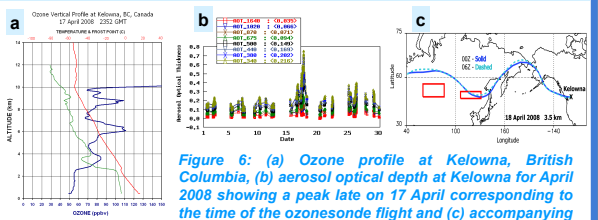
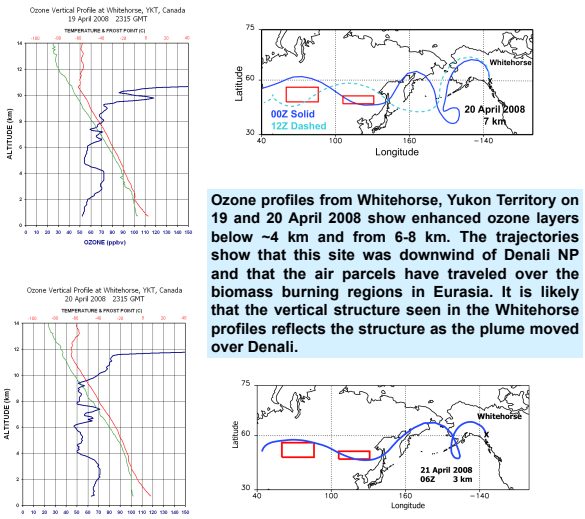


Figure 6: (a) Ozone profile at Kelowna, British Columbia, (b) aerosol optical depth at Kelowna for April 2008 showing a peak late on 17 April corresponding to the time of the ozonesonde flight and (c) accompanying trajectory for the layer at 3.5 km.

(4)



Ozone profiles from Whitehorse, Yukon Territory on 19 and 20 April 2008 show enhanced ozone layers below ~4 km and from 6-8 km. The trajectories show that this site was downwind of Denali NP and that the air parcels have traveled over the biomass burning regions in Eurasia. It is likely that the vertical structure seen in the Whitehorse profiles reflects the structure as the plume moved over Denali.

Figure 7: Ozone profiles at Whitehorse, Yukon Terr. (60N) on 19 and 20 April 2008 and accompanying trajectories for the layers at 3 and 7 km.

(5)

Discussion

A particle dispersion model (Wernli and Davies, 1997) was used to evaluate whether air parcels from biomass burning regions in Eurasia contributed to enhanced ozone over North America. Beginning 1 April particles were released from regions of biomass burning at various altitudes from near the surface to ~6km. The examples (Fig. 8) show the different transport paths at two times from the calculations plotted at 6-hour intervals throughout the period. On 18 April the influence on Alaska and the US northern Pacific coast is strongest (as also seen in the ozone measurements). On 22 April the west coast is again influenced with penetration into the northern tier of the US and Alaska is less affected. These transport patterns support the hypothesis that the observed periods of high ozone and the variability with time over western NA were influenced by Eurasian emissions and their easterly transport.

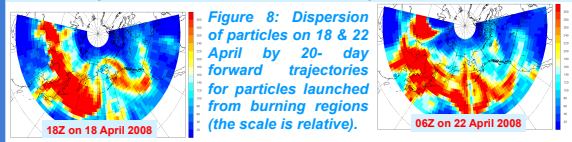


Figure 8: Dispersion of particles on 18 & 22 April by 20- day forward trajectories for particles launched from burning regions (the scale is relative).

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