Remote sensing of trace gases and aerosols in biomass burning plumes over Eastern Canada during the 2011 BORTAS field experiment

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1. Introduction

Biomass burning is a significant source of carbonaceous aerosols and trace gases to the atmosphere. During the summer of 2011 an international effort, led by the University of Edinburgh, aimed to evaluate the chemistry and dynamics of Boreal forest fire smoke through aircraft, satellite, and ground-based measurements [1]. The Dalhousie Ground Station (DGS), located in Halifax, Nova Scotia (44.63N, 63.59W), was organized to provide multiple remote sensing measurements of both particulates and trace gases.

July 2011 saw a significant number of lightning sparked wildfires located Southwest of Hudson Bay. Those fires detected by the MODIS instruments aboard the Aqua and Terra satellites between 17 and 20 July are shown above [2]. Remote sensing instruments at the DGS (purple diamond) detected two distinct biomass burning plumes originating from this region that followed very different trajectories to the coast.

2. Dalhousie Ground Station (DGS) Remote Sensing Instruments

2.1 Fourier Transform Spectrometers

A pair of Fourier Transform Spectrometers (FTS) were operating from the DGS during the BORTAS campaign.

The Dalhousie Atmospheric Observatory DAB is a newly commissioned high spectral resolution spectrometer that continuously make daily solar absorption measurements from Halifax. PARIS-IR is a lower spectral / higher temporal resolution FTS that was temporarily installed at the DGS for the BORTAS campaign.

Both instruments measured the solar spectrum between 750 and 4000 cm⁻¹. The different sensitivities of these two instruments enabled us to better understand the distribution of trace gases above Halifax.

2.2 Sun/Star Photometers

Aerosol optical depth measurements were provided by two photometers co-located with the FTS instruments. The CIMEL sun photometer has been operating in this location since 2002, while the star photometer from Université de Sherbrooke was installed temporarily for the BORTAS campaign.

Fine mode (sub-micron) aerosol optical depths were derived using a spectral decomposition algorithm [3].

3. Observations & Simulations

A major biomass burning event arrived at the DGS on the evening of 20 July 2011 and continued through the following day. DAB and PARIS-IR retrievals of CO agree after smoothing DAB data with PARIS averaging kernels (see right).

Throughout much of the campaign AOD measurements followed the total column of CO. However, at 1300 UTC on 20 July the DAB detected an additional plume of CO that was not associated with aerosols (green band).

This low-AOD plume was not detected by PARIS-IR. The higher spectral resolution of the DAB provides it a greater sensitivity to CO in the mid-upper troposphere than PARIS-IR (above, left plot) suggesting that this plume is at a higher altitude than the major event that arrived at 2000 UTC.

HYSSPLIT (left) and FLEXPLAT (not shown) trajectories ending at 8km above the DGS on 1300 UTC on 20 July suggest that these air parcels were associated with the fire region 60 hours prior and then underwent significant lofting over Northeast Manitoba on 19 July. Once lofted, the air parcels were efficiently transported to the DGS.

4. Precipitation

Ground observations are quite sparse in Northeastern Manitoba, but GOES-East infrared images (not shown) indicate that a significant convective event transited this region during the early hours of 19 July.

Clouds associated with this system are clearly visible in the MODIS images from Terra taken before and after the lofting event (right, HYSSPLIT positions marked in red). Cloud tops on 19 July were measured at 11 km by CALIPSO. Biomass burning smoke is evident throughout. Scattered ground stations report significant precipitation during this time, which supports the theory that rain-out was responsible for the trace-gas / aerosol anomaly observed above Halifax.

5. Conclusions

- The clustering of remote sensing instruments enabled us to successfully detect a variety of biomass burning plumes passing above the DGS at multiple altitudes.
- A high-altitude plume of CO not associated with aerosols was detected by the DAO-DAB at 1300 UTC on 20 July.
- Ground and satellite observations, supported by trajectory models, strongly suggest that a rain-out event is responsible for the observed trace gas / aerosol discrepancy.
- Observations of the early dynamics of forest fire plumes are critically important for properly understanding later radiative forcings.

References & Acknowledgements

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