Use of airborne measurements to derive emission rate estimates for black carbon from large scale surface mining facilities in the Alberta Oil Sands Region, Canada

S.-M. Li[1], P.S.K. Liu[1], K. Hayden[1], M. Gordon[1,2], A. Darlington[1], J. Liggio[1], R. Staebler[1], S. Cober[1], P. Makar[1], C. Stroud[1], A. Leithead[1], S. Mousa[1], R. Mittermeier[1], R. McLaren[2], J. O'Brien[1], J. Brook[1], and A.M. Macdonald[1]

[1]Air Quality Research Division, Environment Canada, [2]York University, Toronto, Ontario, Canada
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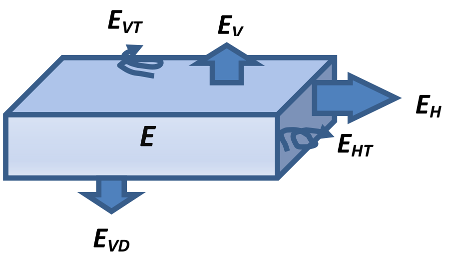
Presenting author email: shao-meng.li@ec.gc.ca

The Alberta oil sands hold a total extractable deposit of 170 billion barrels of oil. Total oil production was 1.9 million barrels/day in 2012, and continues to rise (CERI, 2014). In 2012, the Government of Canada and the Province of Alberta started a comprehensive environmental monitoring program, the Joint Oil Sands Monitoring Plan (JOSM, 2012), to determine the environment impacts of oil sands pollutants. In Aug-Sep 2013, a research aircraft equipped with an array of fast response aerosol and gas instruments was deployed in the oil sands region to measure pollutants emitted from the oil sands operations, to map out how far they are transported, and to understand how fast they are chemically converted in the atmosphere. Among the instruments, a Single Particle Soot Photometer (SP2) was used to measure refractive black carbon (rBC) mass concentrations in the air on a 1 second time resolution.

To measure pollutant emission rates from the oil sands operations, a top-down mass balance approach was used with specifically designed flight patterns that created virtual boxes or screens consisting of vertically stacked flight tracks around the surface mining facilities. The facilities are large in size, up to hundreds of square kilometres each, and include activities such as mining, transportation, separation, upgrading, and waste tailing storage all within each facility. Integrated mass fluxes across the box walls and ceilings are determined from the measurement results, and the emission rates of the measured pollutant species are derived. This approach forms the basis of the Top-down Emission Rate Retrieval Algorithm (TERRA) that was developed to determine the various terms of mass fluxes into and out of the virtual box (Gordon et al., 2015)



TERRA calculates the individual terms in the following equation to derive the emission rate:

$$E = E_H + E_{HT} + E_V + E_{VT} + E_{VD} - E_M,$$

where E is the emission rate, E_H is the horizontal advection flux term, E_{HT} is the horizontal turbulent flux term, E_V is the vertical advection flux term, E_{VT} is the vertical turbulent flux term, E_{VD} is the dry deposition, E_M is the mass change with time. Each term can be determined from air mass density, pollutant mixing ratio, wind speed, estimated diffusion coefficients, and dry deposition velocity (Gordon et al., 2015). Using the airborne measurements, the emission rates for a pollutant can be derived within uncertainties of 20% for both stack plume and surface emissions (Gordon et al., 2015).

For the 6 major surface mining operations in the Alberta oil sands region, the emission rates for rBC were obtained using the TERRA routine. The observed atmospheric rBC concentrations are clearly associated with plumes from the mining and transportation activities in each facility. By linking the emission rates of rBC to the bitumen production rates, emission factors based on the bitumen production will be derived. The rBC emission rates and emission factors calculated from this study for oil sands facilities can serve as an example of how such measurements can be used as an independent source of emission data.

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