



Quantifying the impact of BOREal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites: An overview of the BORTAS project

Mark Parrington¹, Paul I Palmer¹, Stephan Matthiesen¹, Peter F Bernath², Alastair C Lewis³, James D Lee³, Andrew Rickard⁴

¹School of GeoSciences, University of Edinburgh, UK; ²Department of Chemistry, University of York, UK; ³National Centres for Atmospheric Science, Department of Chemistry, University of York, UK; ⁴National Centres for Atmospheric Science, Department of Chemistry, University of Leeds, UK



1. Introduction

Boreal forest fires are a significant source of atmospheric trace gases and aerosols and consequently play an increasingly important role in the chemical state of the atmosphere and global climate. Accurately estimating the impact relies on understanding the connection between measurements over the source region and downwind, involving uncertain atmospheric chemistry. In particular, there are serious gaps in our understanding of NO_y and organic chemistry within biomass burning plumes.

BORTAS is a 3-year multi-national project, led by the University of Edinburgh, with the overall goal of quantifying the connections between the composition and the distribution of pollutant outflow from boreal forest fires, ozone production and loss within that outflow, and the resulting perturbation to oxidant chemistry in the troposphere. To achieve this, the main objectives of BORTAS are to:

1. Measure biomass burning outflow from boreal North America using satellite, aircraft and surface instruments.
2. Describe observed chemistry within plumes with models of atmospheric chemistry and transport.
3. Quantify the impact on tropospheric oxidant chemistry by combining measurements and models.

2. Satellite data

Data from a variety of satellite instruments will be used in BORTAS to (1) statistically determine boreal biomass burning plumes; (2) analyse characteristic tracer-tracer correlations along plume trajectories; (3) test consistency between ground-based and aircraft measurements, and model simulations. Table 1 shows some of the key data pertinent to BORTAS. During July 2010, TES will also provide high density step and stare observations over the North Atlantic region as shown in Figure 1.

Instrument (Limb/Nadir)	Products pertinent to BORTAS
ACE-FTS (L occultation)	NO, NO ₂ , HNO ₃ , PAN, CH ₄ , C ₂ H ₂ , C ₂ H ₄ , C ₂ H ₆ , HCHO, HCOOH, CH ₃ OH, H ₂ O ₂ , CH ₃ C ₂ H ₅ , CH ₃ COCH ₃
GOME-2 (N)	O ₃ , HCHO, NO ₂
IASI (N)	O ₃ , CO, HNO ₃
MIPAS (L)	CH ₃ COCH ₃ , PAN
MLS (L)	HCN, CO, ice water content
MODIS (N)	Land-surface properties, aerosol optical properties
MOPITT (N)	CO
OMI (N)	HCHO, NO ₂ , aerosol optical properties
SCIAMACHY (LIN)	NO ₂ , CO, CH ₄
TES (N)	HNO ₃ , CO, O ₃

Table 1. Satellite data relevant to BORTAS.

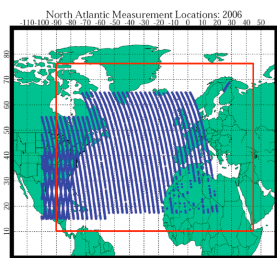


Figure 1. TES step and stare observation locations over the North Atlantic.

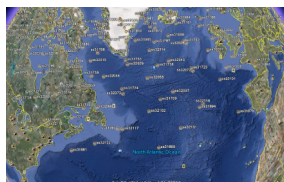


Figure 2. Measured ACE occultations over the North Atlantic, July 2009.



http://www.faam.ac.uk/

The FAAM146 can operate up to approximately 10.7 km with an endurance of 5-5½ hours depending on payload. The species measured by the aircraft are listed on the right.

The 2004 ITOP measurement campaign made a serendipitous discovery that O₃ production within biomass burning plumes was sensitive to the speciation of NO_y. To learn more about this we include an instrument to measure the speciation of NO_y within biomass burning plumes compared to air immediately outside of the plumes.

Complimentary data in BORTAS from ozonesondes and ground-based instruments (FTIR and lidar) will allow us to measure the chemical evolution of the plumes along their trajectories. Measurements will also be made from the Mt. Pico observatory in the Azores to further analyse the plumes impact on tropospheric chemistry. Figure 3(b) shows a map of the surface measurements available during BORTAS.

3. Measurement campaign

We will conduct a measurement campaign with the UK FAAM146 research aircraft (pictured) during the last 3 weeks of July 2010. The campaign will be based in Halifax, Nova Scotia in order to best sample the outflow from North American biomass burning.

- CO
- O₃
- NO, NO₂
- Total NO_y (speciated)
- CO₂, CH₄
- PAN
- Isoprene, MEK, MVK, acetonitrile
- NMHCs, oVOCs
- H₂O vapour
- CN, black carbon
- Aerosol size number distributions and composition

4. Modelling and data analysis

Modelling of atmospheric chemistry and transport is an integral component of BORTAS, for flight planning and data analysis.

For flight planning during the measurement campaign, we will use a boreal biomass burning tracer, from the NASA Global Modeling and Assimilation Office GEOS-5 forecast system, at a horizontal resolution of 1/2 degree latitude x 2/3 degree longitude. The GEOS-Chem chemical transport model will be used in BORTAS to:

- 1) perform near real-time simulations (tagged CO and full chemistry) throughout the measurement campaign;
- 2) evaluate chemistry in biomass burning plumes using a reduced chemical mechanism, which has traceability to the Master Chemistry Mechanism (MCM);

Difficult → Complexity → Simple

MCM:
7000 reactions,
2500 chem. species.

CRI:
1191 reactions,
442 chem. species

GEOS-Chem:
310 reactions,
~90 chem. species

- 3) 'scale up' the BORTAS measurements to analyse the impact of biomass burning plumes on tropospheric chemistry in conjunction with ground-based and satellite data.

For all model simulations, we will use a nested grid covering the North Atlantic region similar to that defined by the TES step and stare measurements shown in Figure 1.

5. Preliminary analysis

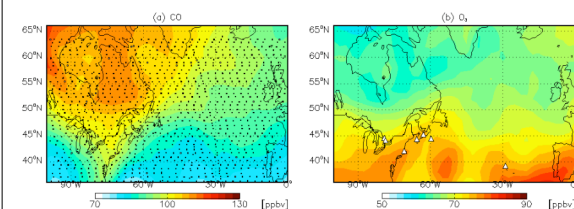


Figure 3. July 2008 monthly mean modelled (a) CO, and (b) O₃ at 5 km. The black squares in plot (a) represent the TES global survey observation locations from July 2008. The white triangles in plot (b) highlight some of the surface measurement sites available throughout the BORTAS measurement campaign:

- Halifax, NS^{1,2}
- Toronto, ON³
- Egbert, ON^{2,3,4}
- Sable Island, NS⁴
- Yarmouth, NS⁴
- Narragansett, RI⁴
- Mt. Pico, Açores³

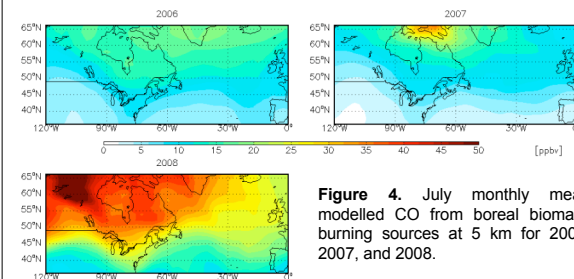
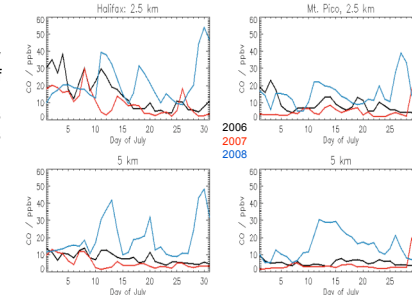


Figure 4. July monthly mean modelled CO from boreal biomass burning sources at 5 km for 2006, 2007, and 2008.

Figure 5. July timeseries of modelled CO from boreal biomass burning sources over Halifax and Mt. Pico at 2.5 and 5 km for 2006, 2007, and 2008.



Preliminary analysis of CO from boreal (Siberia, Canada and Alaska) biomass burning sources performed with GEOS-Chem (v8-02-01) tagged CO simulations with Flambe fire emissions.

Boreal biomass burning can contribute between 10 and 30 ppbv, on average, across the North Atlantic region with large inter-annual variability.

Timeseries of the model output sampled at Halifax and Mt. Pico indicate that the BORTAS data will provide valuable constraints for evaluating the chemical evolution of biomass burning plumes.