Investigation of CO, C_2H_6 and aerosols in a boreal fire plume over Eastern Canada during BORTAS 2011

using ground- and satellite-based observations, and model simulations

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Motivation

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- These emissions can be transported thousands of miles

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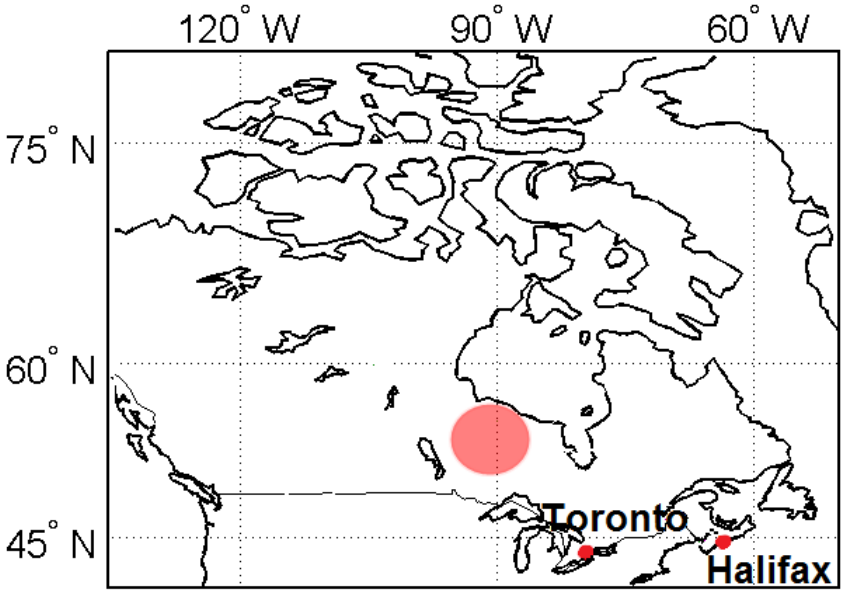
- Enhancements of CO, C_2H_6, and the fine mode aerosol optical depth (AOD) are indicators of smoke plumes
- Enhancements of the total column (TC) CO, C_2H_6 and the fine mode AOD could be seen over Halifax and Toronto 19-21 July 2011

Introduction

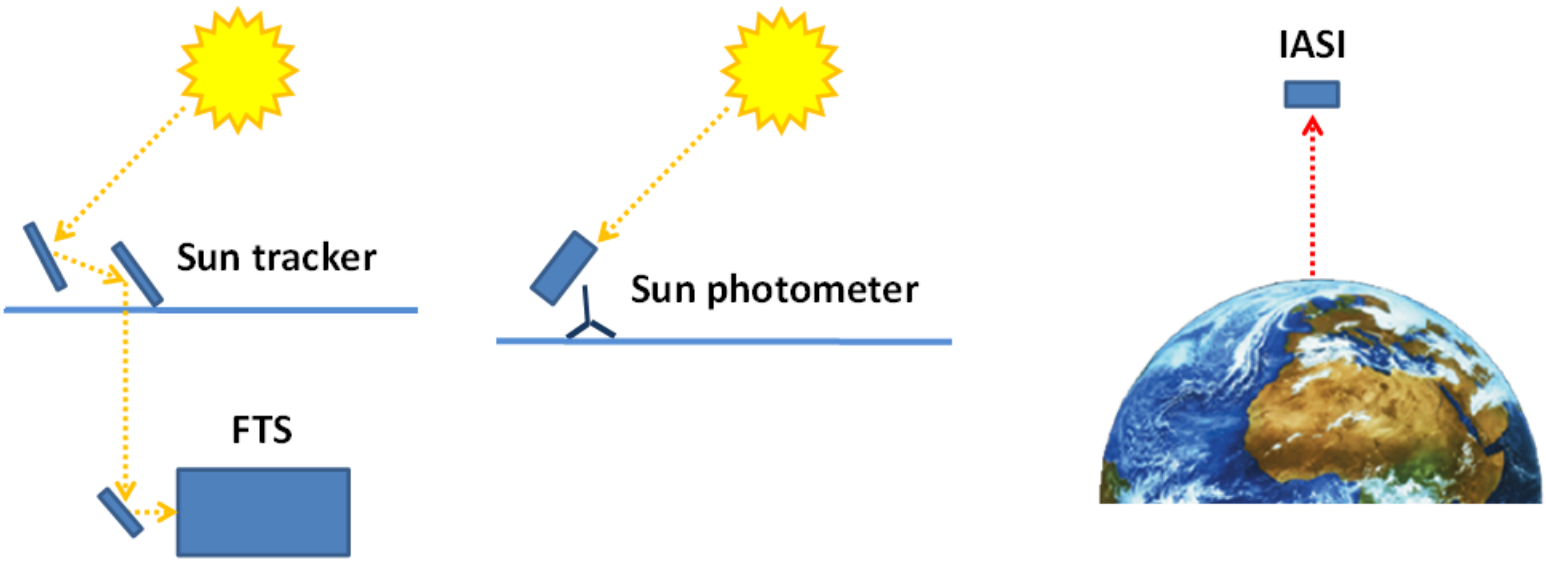


Halifax: 2 FTSs, sunphotometer
Toronto: FTS, sunphotometer
FTS = Fourier Transform Spectrometer

To examine these enhancements:

- We used: ground-based (GB) measurements (FTS, sunphotometer), satellite-borne observations (IASI) and model simulations (GEOS-Chem, FLEXPART, CMC)
- We investigated: correlation between trace gases and AOD, estimation emission ratio from GB measurements, and comparison with GEOS-Chem

Measurement principle



- DA8, and PARIS-IR FTSs: Retrieval for CO, C_2H_6 TCs is based on Optimal Estimation Method (OEM), using SFIT2 and HITRAN 2008 spectroscopic database, with NDACC recommended microwindows

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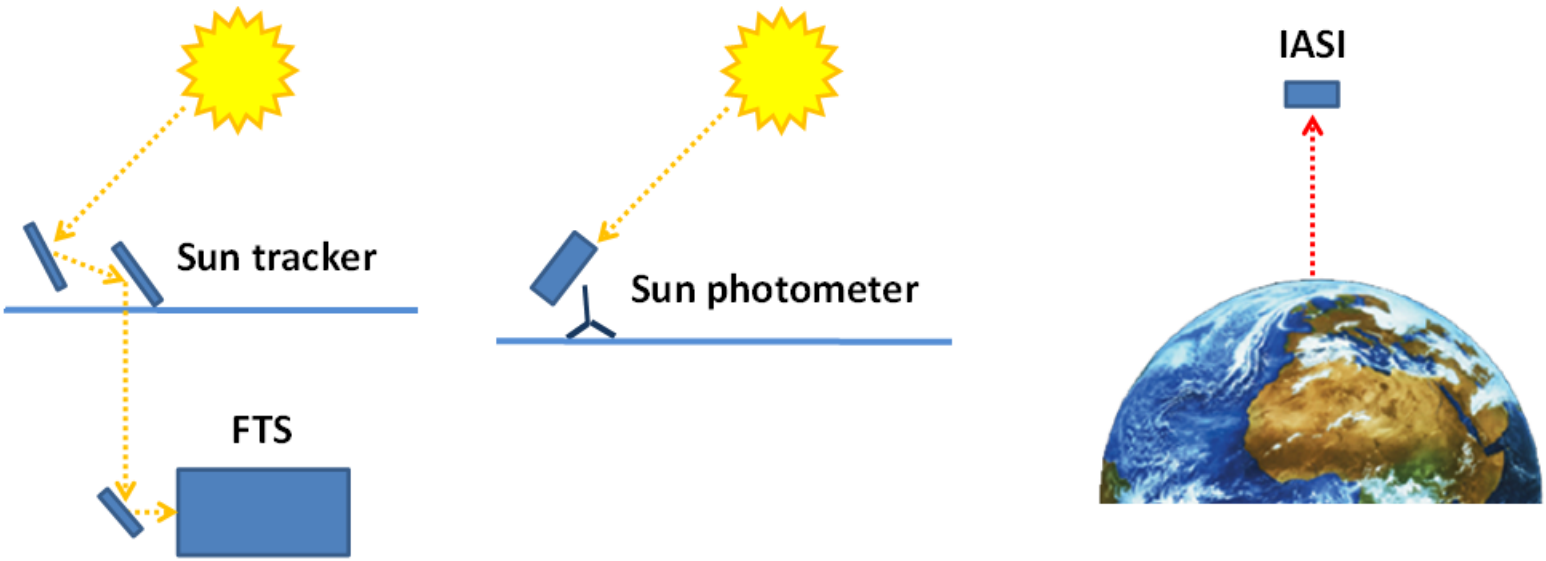

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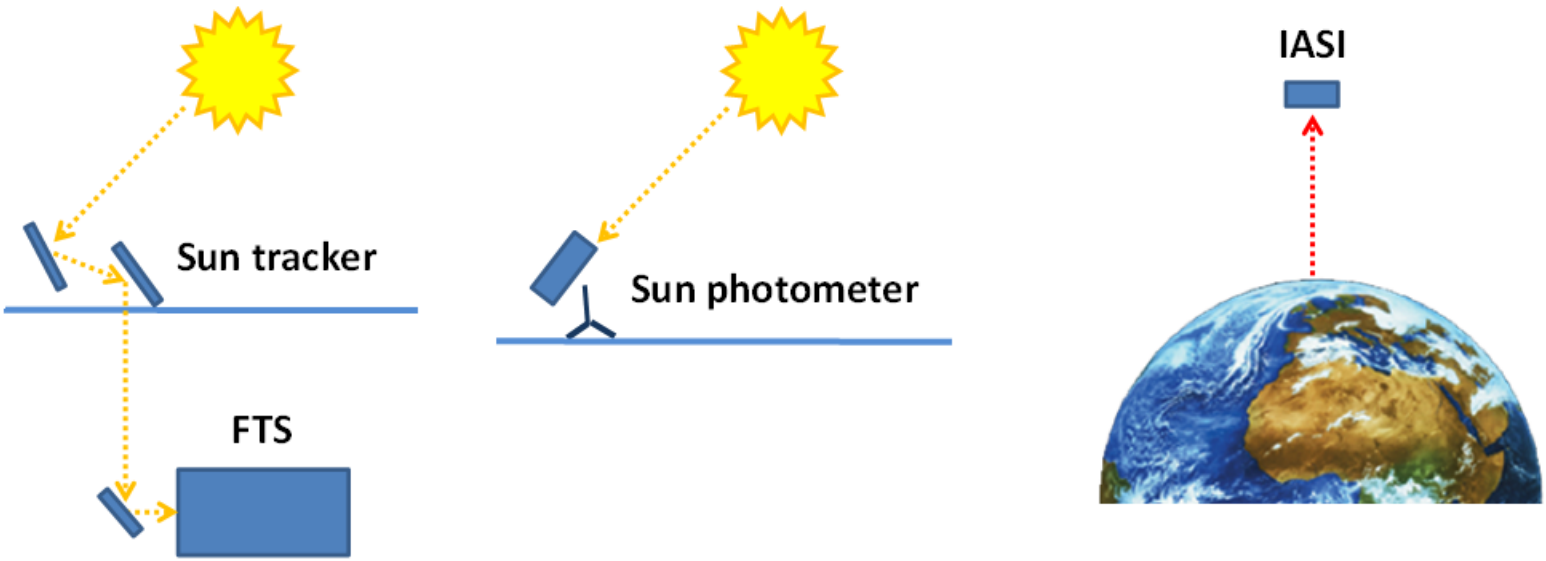

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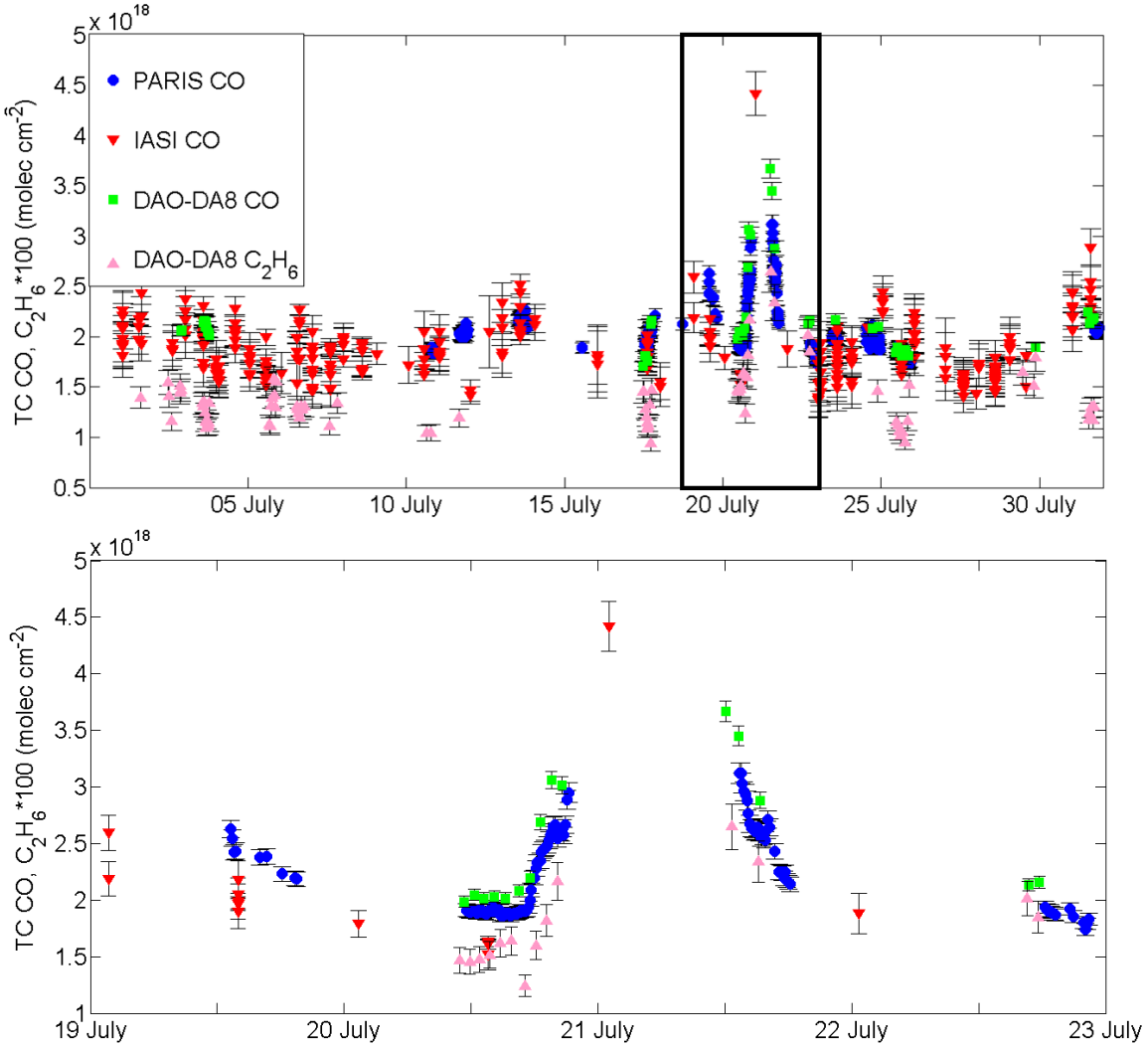
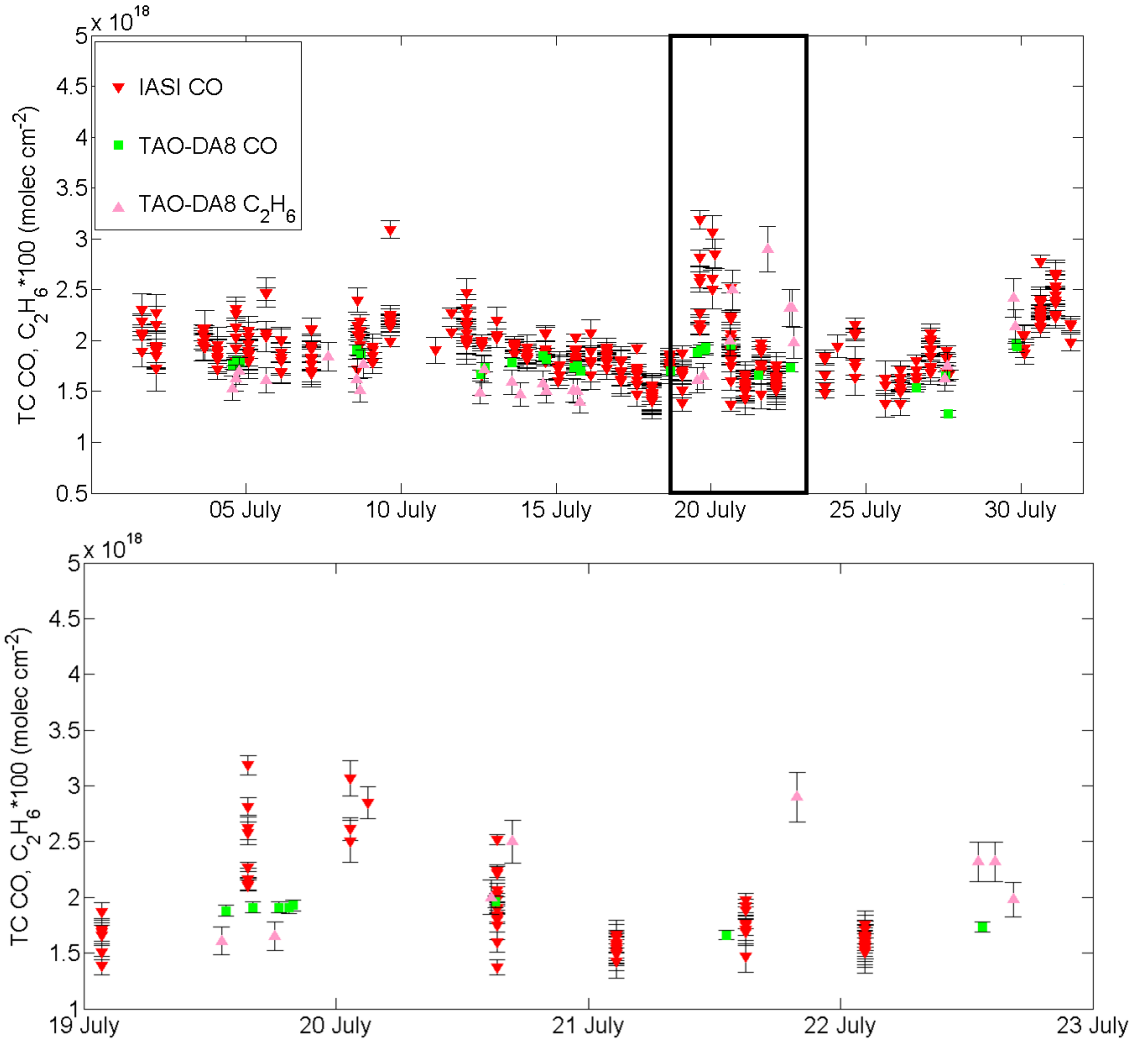
- IASI: CO TC are retrieved with FORLI-CO using OEM, for comparisons we use $\pm 0.5^\circ$ lat and long ($\sim$55 km)

Time series over Halifax



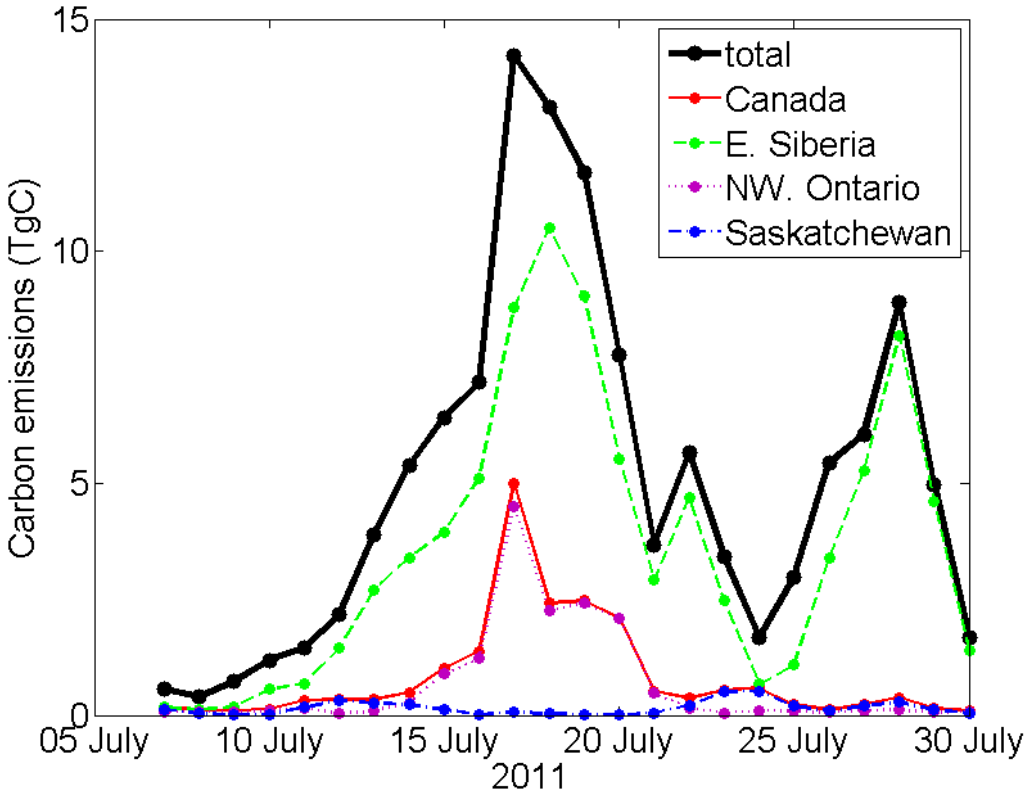
- Ground-based measurements from PARIS-IR and DAO-DA8 (FTSs), and satellite-borne observations (IASI)
- Enhancement of TC CO and C_2H_6 between 19-21 July
- Vertical sensitivities:
  PARIS-IR: 0-10 km
  DA8: 0-15 km
  IASI: 5-15 km

Time series over Toronto



- Ground-based measurements from TAO-DA8 (FTS), and satellite-borne observations (IASI)
- Enhancement of TC CO and C_2H_6 between 19-21 July
- Enhancements are not as large in Toronto as observed in Halifax

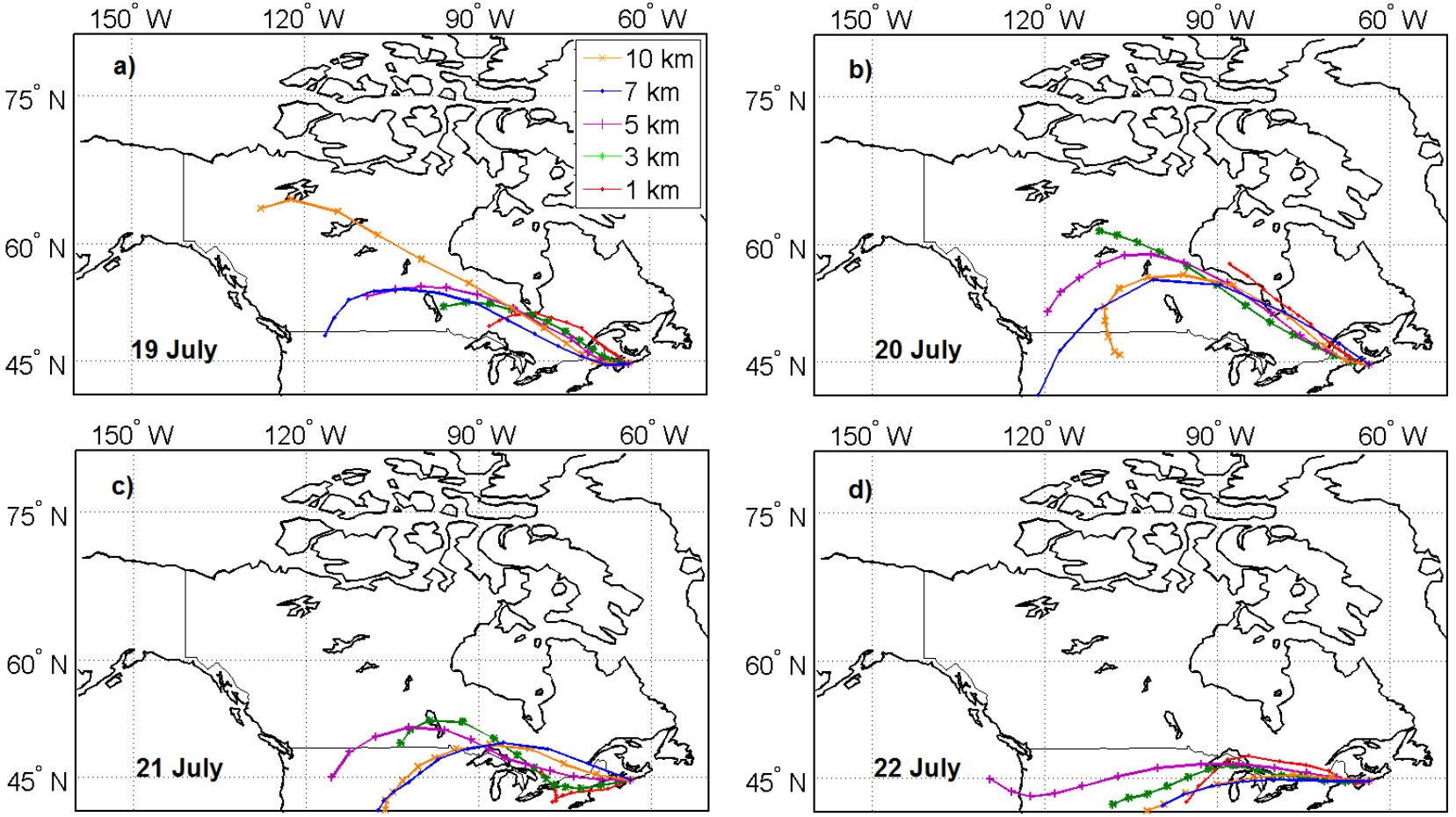
Fires during BORTAS 2011



- Daily total carbon emitted from boreal fire regions
- MODIS and GOES (both satellites) data used for the FLAMBE inventory

Origin of the plume

CMC back-trajectories from Halifax, starting at 18:00 UTC on each day

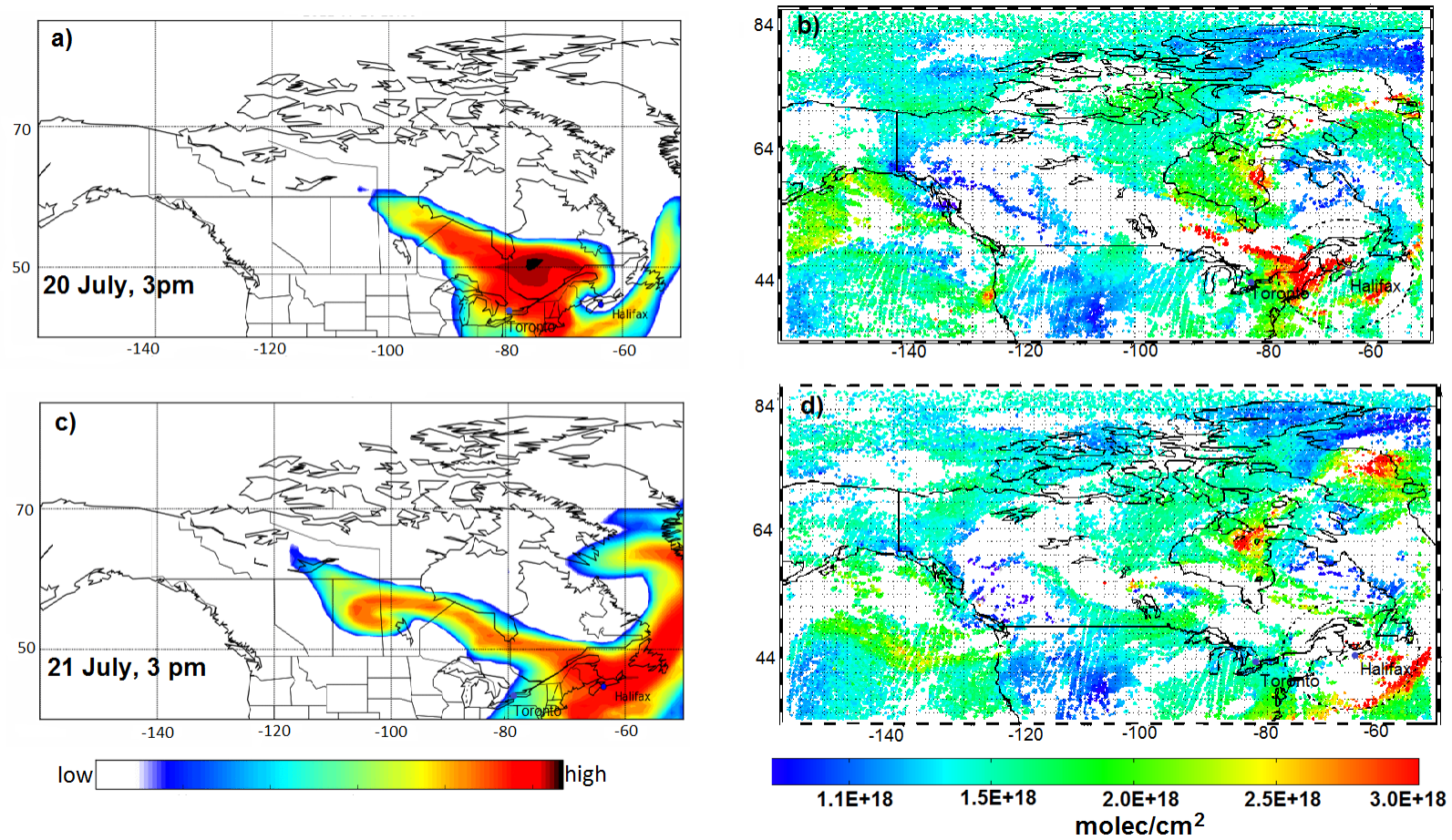


The markers indicate the location every 6 h over a 72 h period

$\Rightarrow$ it took approx. 36 h$\pm$ 6 h from the fire region to Halifax

Origin of the plume

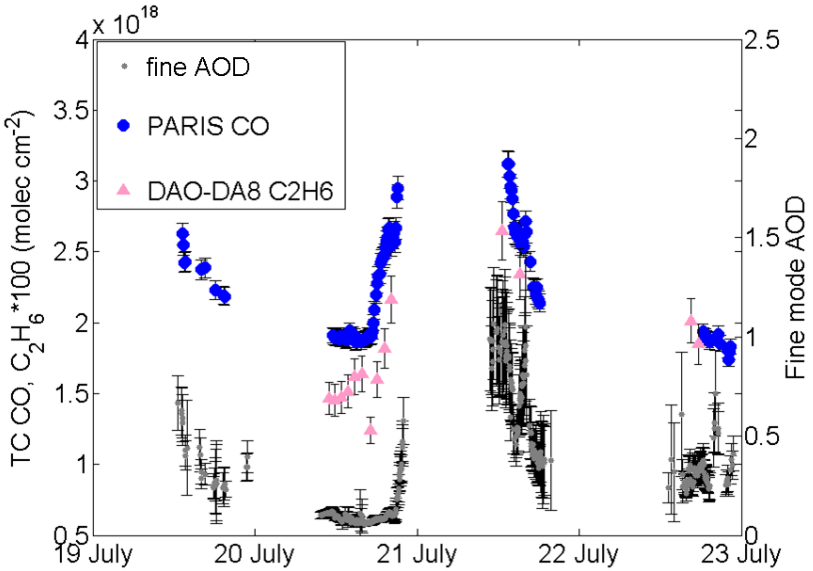
FLEXPART forward-trajectories and IASI CO (TC)

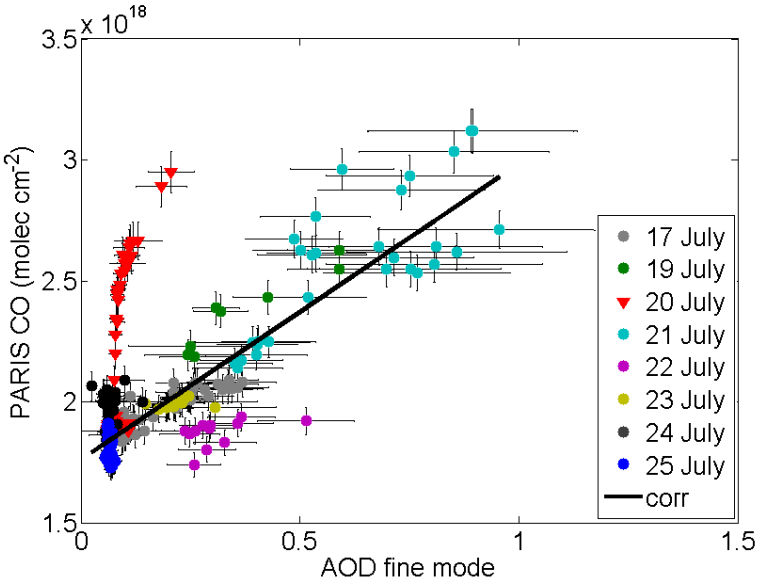


FLEXPART simulation for a particle release starting on 17 July at 12 UTC

$\Rightarrow$ The simulated trajectories agree well with IASI overpass ($\sim$14 UTC)

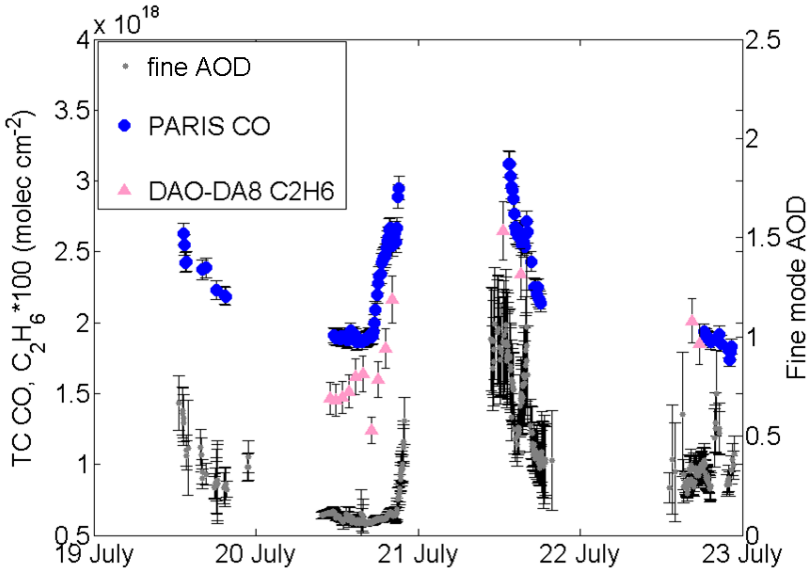
Fine mode AOD vs CO (TC)

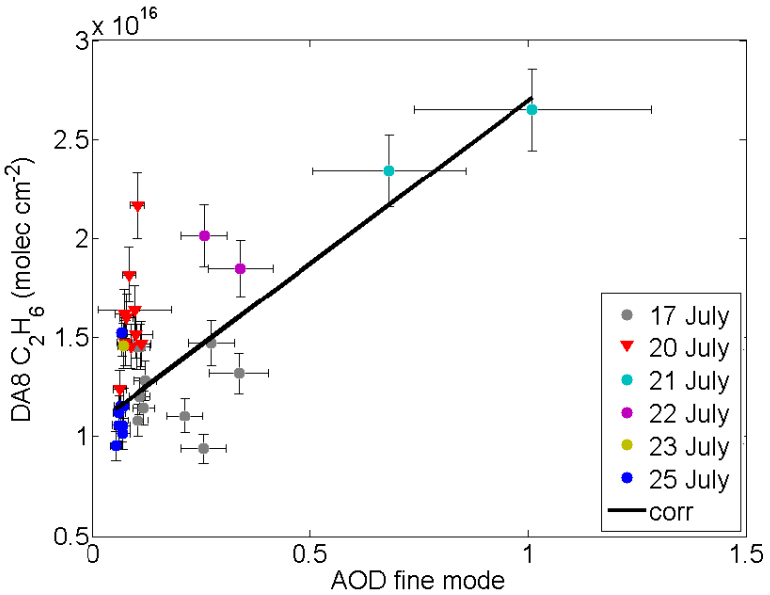




- Exceptional behaviour on 20 July, likely precipitation event (see Franklin et al. at poster session)
- Highly correlated with $R^2 \approx 0.8$ (without 20 July) for coincident measurements ($\Delta t \leq 5$ min)
- Slope: $(1.22 \pm 0.04) \times 10^{18}$ molec cm^{-2} per unit incr. in fine mode AOD
- Intercept: $(1.76 \pm 0.01) \times 10^{18}$ molec cm^{-2}

Fine mode AOD vs C_2H_6 (TC)





- Same exceptional behaviour on 20 July, as for CO
- Well correlated with $R^2 \approx 0.7$ (without 20 July) for coincident measurements ($\Delta t \leq 5$ min)
- Slope:
  $(1.6 \pm 0.2) \times 10^{16}$ molec cm^{-2}
  per unit incr. in fine mode AOD
- Intercept:
  $(1.0 \pm 0.1) \times 10^{16}$ molec cm^{-2}

Emissions of C_2H_6 (EF_{C2H6}) during biomass burning

The emission factor EF is used to quantify the amount of trace gas emitted from the fire

Fire area	EF_{C2H6}	Results from
Extra-tropical	0.60 ± 0.15 g/kg	Andreae and Merlet (2001)
Tropical	$0.5 - 1.9$ g/kg	Andreae and Merlet (2001)
Australia	0.26 ± 0.11 g/kg	Paton-Walsh et al. (2005)
Savannah	0.21 ± 0.12 g/kg	Sinha et al. (2003)
Boreal	1.79 ± 1.14 g/kg	Akagi et al. (2011)
Temperate	1.12 ± 0.67 g/kg	Akagi et al. (2011)

Estimation of emission ratio ER and factor EF

$ER_{C2H6/CO}$ is the excess amount of C_2H_6 over the excess amount of CO:

Type of measurement	$ER_{C2H6/CO}$	Results from
Ground-based	$(10.0 \pm 6.0) \times 10^{-3}$	this study
Airborne	$(5.1 \pm 0.4) \times 10^{-3}$	Lewis et al. (2013)
Satellite-based (ACE)	$(6.8 \pm 1.1) \times 10^{-3}$	Tereszchuk et al. (2012)

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Calculation of EF

$$EF_{C2H6} = ER_{C2H6/CO} \cdot MW_{C2H6}/MW_{CO} \cdot EF_{CO}$$

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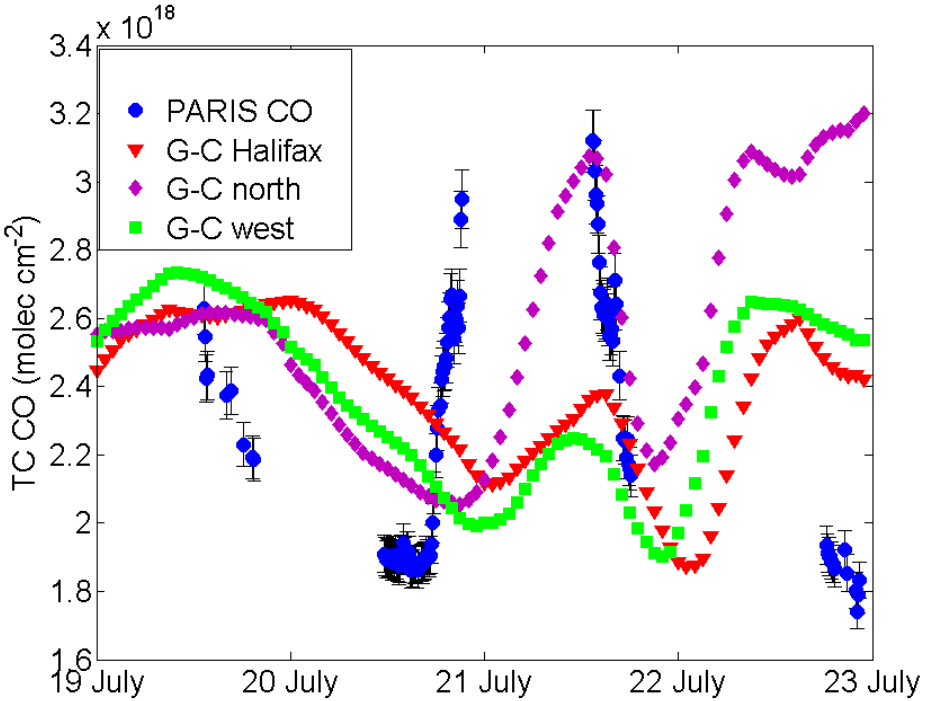
$$EF_{C2H6} = ER_{C2H6/CO} \cdot MW_{C2H6}/MW_{CO} \cdot EF_{CO}$$

$\Rightarrow$ with $EF_{CO} = 122 \pm 45$ g/kg (Akagi et al., 2011):

$$EF_{C2H6} = 1.35 \pm 0.51 \text{ g/kg}$$

Comparison with GEOS-Chem

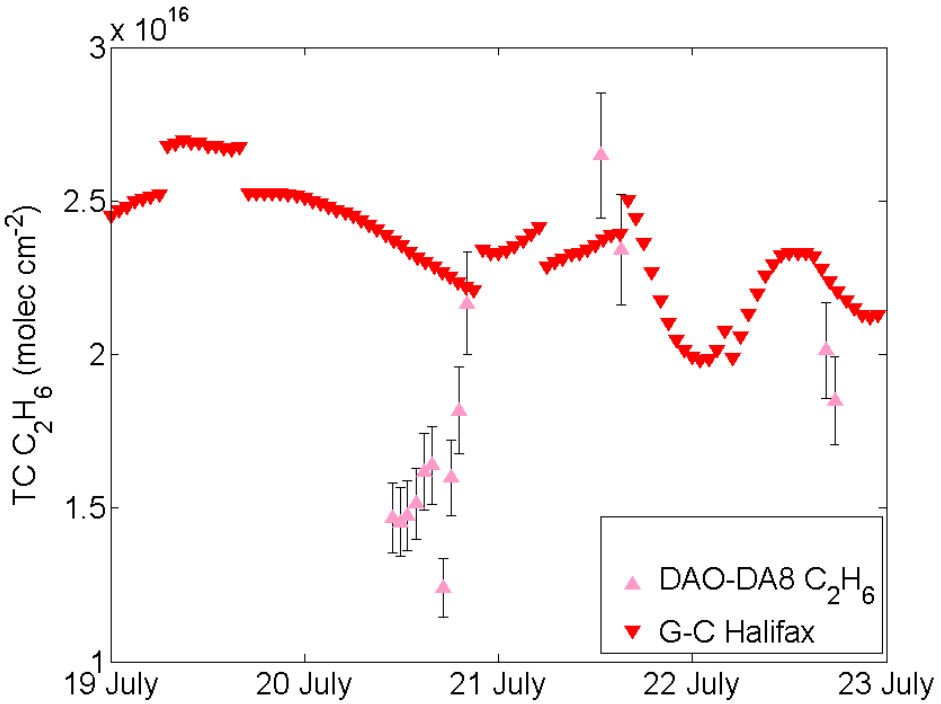
For total column CO over Halifax



- v8-02-04 of GEOS-Chem, with a resolution of 2° lat. × 2.5° long., using the FLAMBE fire inventory
- TCs have been calculated from GEOS-Chem profiles, different sensitivities have been accounted for by smoothing with PARIS-IR averaging kernel
- The magnitude of the modelled CO enhancement compares well with the measurements on 21 July; best for the grid box north of Halifax

Comparison with GEOS-Chem

for total column C_2H_6 over Halifax



- No significant difference between different grid boxes was found
- $ER_{C2H6/CO} = 5.6 \times 10^{-3}$, employed in GEOS-Chem, is similar to the emission ratio obtained in this study from FTSs
- Peak value obtained in model agrees with measurements
- GEOS-Chem TCs are also enhanced on 20 July

Summary and conclusion

- Enhancements of the TC CO, C_2H_6 and the fine mode AOD could be seen over Halifax and Toronto on 19-21 July 2011
- We identified the source of the trace gas enhancements to be boreal fires in Northwestern Ontario, using CMC back-trajectories and FLEXPART forward-trajectories
- Our estimated emission ratio and emission factor for C_2H_6 ($ER_{C2H6/CO} = (10 \pm 6) \times 10^{-3}$, $EF_{C2H6} = 1.35 \pm 0.51$ g/kg) for the boreal fire in Northwestern Ontario are consistent with other studies
- CO and C_2H_6 emitted by the fire in Northwestern Ontario could be simulated reasonably well by GEOS-Chem; we found that the grid box north of Halifax represents the observations best

Acknowledgements

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- We would like to further acknowledge the LATMOS research group for providing the Level 2 IASI CO data
- We are also very grateful to AEROCAN (Environment Canada and the Université de Sherbrooke) and AERONET (NASA / GSFC) for their support
- Thanks to David Waugh and Jacinthe Racine for providing CMC back-trajectories