Investigating HCN and CO emissions of biomass burning in the Earth system

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1. Introduction

Carbon monoxide (CO) and hydrogen cyanide (HCN) are pyrogenic species that can be used as atmospheric tracers for biomass burning. In particular, HCN is an important tracer of peat fires, but there are significant uncertainties in the HCN atmospheric budget, especially its photochemical and ocean sinks. We used the TOMCAT model and satellite measurements to study global atmospheric HCN distributions and significant peat fires over Indonesia during 2015, associated with a strong El Nino event.

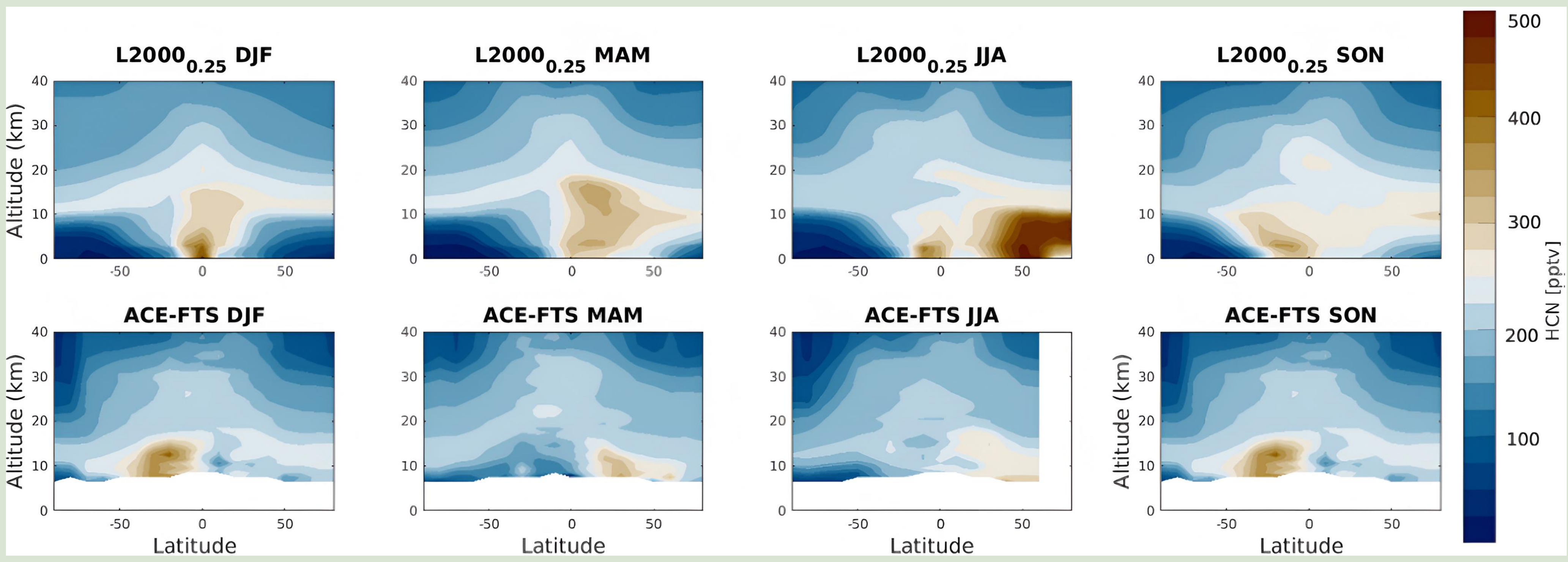
2. TOMCAT model

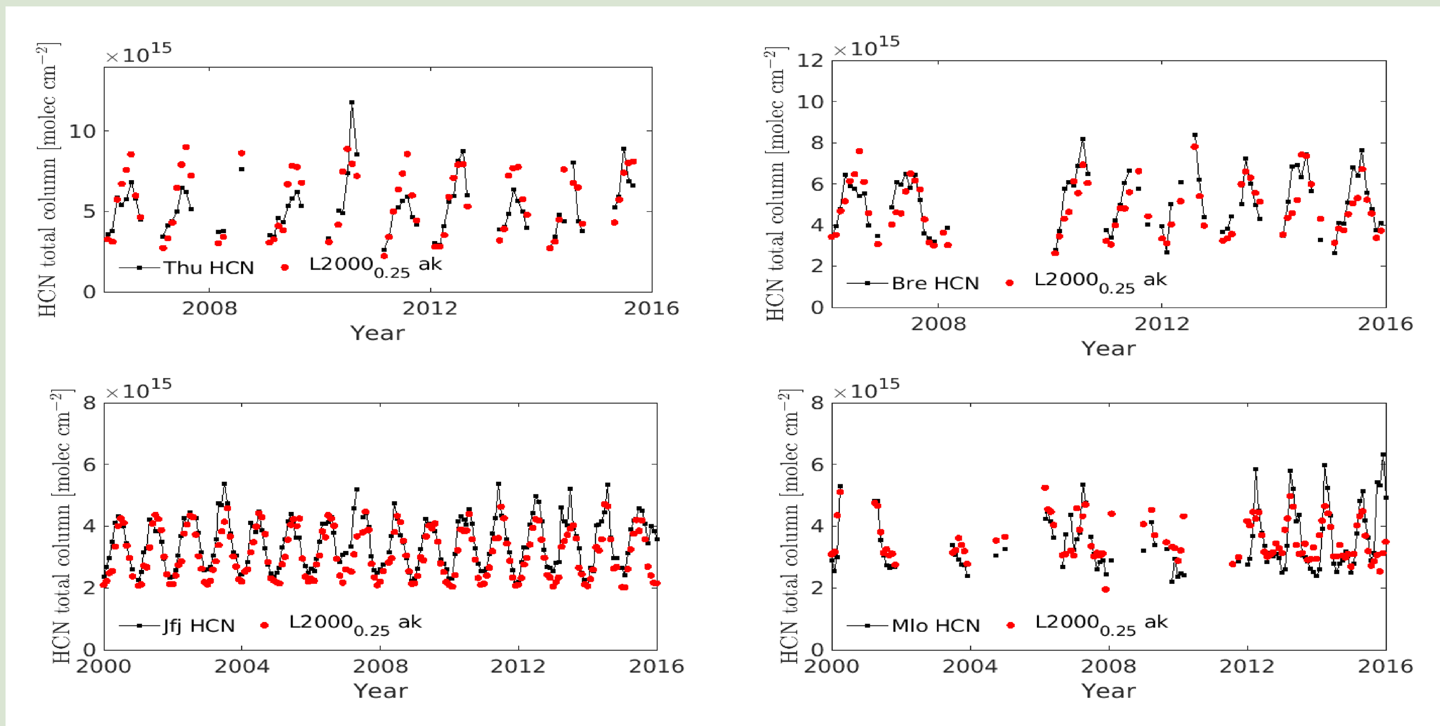
- The TOMCAT 3-D chemical transport model (CTM) uses Global Fire Emissions Database (GFED) v4.1 inputs for HCN biomass burning emissions to simulate global atmospheric HCN distributions.
- The model is run using the ocean sink from Li et al (2000) scaled by 0.25, and the reaction rates for HCN+OH and HCN+O(1D) from Kleinböhl et al. (2006).
- The modelled HCN distribution is validated with version 4.1 Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS) HCN satellite observations, which provide profiles up to around 42 km, and with ground-based column measurements from the Network for the Detection of Atmospheric Composition Change (NDACC).

Table 1: Comparison between the global burden, budget terms, and atmospheric lifetimes from literature and from the TOMCAT model.

Parameters	$L2000_{0.25}$	Li et al. (2000)	Li et al. (2003)	Singh et al. (2003)
Atmospheric burden (Tg N)	0.55	0.50	0.426	0.44
Emissions (Tg N yr^{-1})	2.42	1.4-2.9	0.83	1.1
Ocean uptake (Tg N yr^{-1})	2.38	1.1-2.6	0.73	1.0
Reaction with OH (Tg N yr^{-1})	0.12	0.3	0.1	–
Reaction with $O(^1D)$ (Tg N yr^{-1})	1.9×10^{-3}	0.3×10^{-3}	–	–
Atmospheric lifetime (months)	2.6	2.1-4.4	6.2	5

Figure 1: (Left panel) Seasonal mean latitude–height zonal mean cross sections from December 2008 to November 2009 of HCN zonal means in 10° latitude bins for TOMCAT HCN and ACE-FTS measurements. Figure 2: (Right panel) HCN total column time series (molec. cm^{-2}) measured at four NDACC stations (Thule (Thu), Bremen (Bre), Jungfraujoch (Jfj), and Mauna Loa (Mlo); black lines) and modelled by the $L2000_{0.25}$ (red dots) (with averaging kernels applied; ak). Note the different time periods at the different stations.





3. IASI measurements during Indonesia 2015 wildfire season

- The University of Leicester IASI retrieval scheme (ULIRS) is used to perform retrievals of global CO partial/total column and HCN total column from IASI spectra.
- Large differences between the observed and modelled averaged total column time series over Indonesia during 2015.
- Different time evolutions for both HCN and CO, and an overestimation of HCN amount during the fire season.

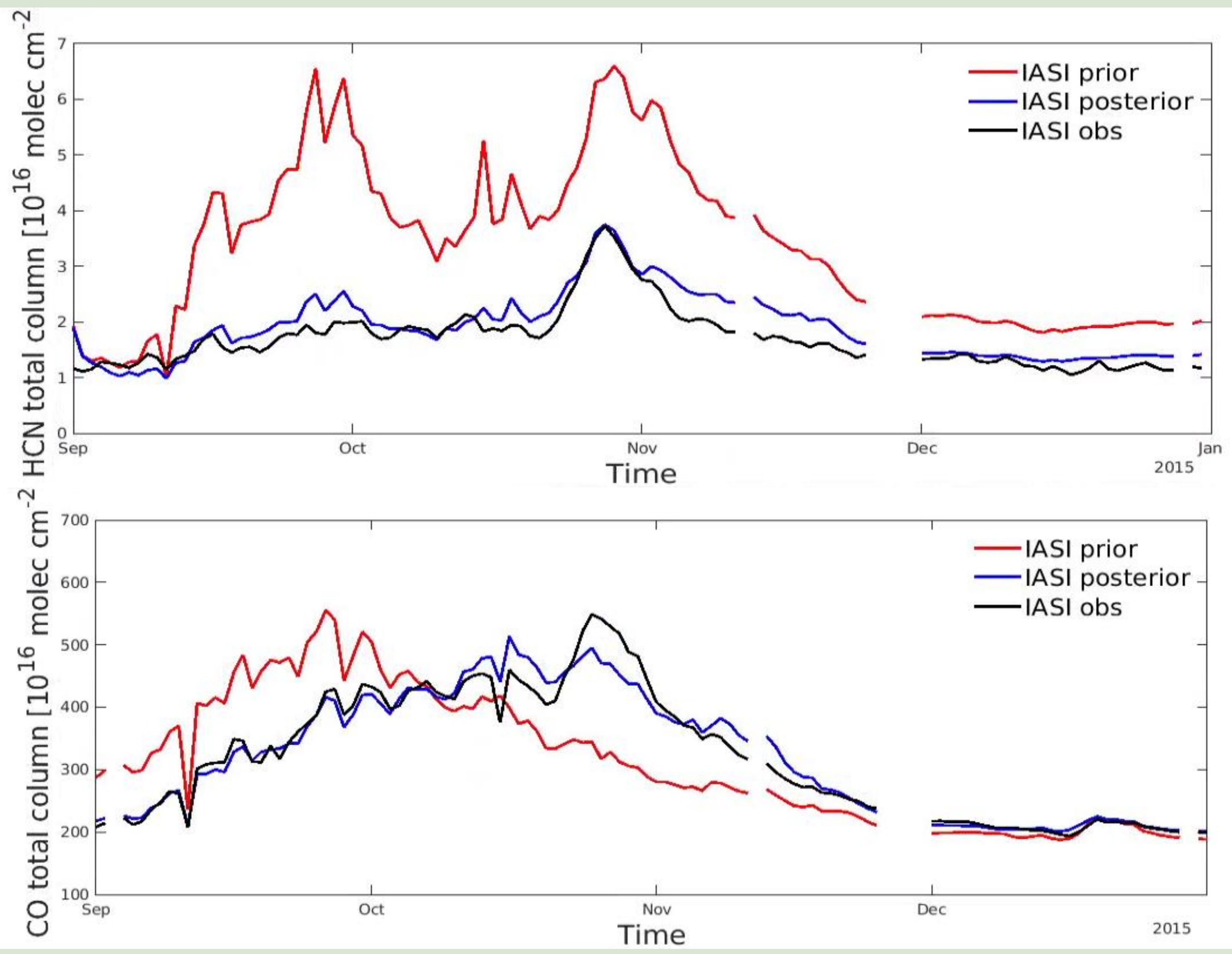


Figure 3: Measured daily averaged IASI HCN (top panel) and CO (bottom panel) columns (black lines, 10^{16} molecules cm^{-2}) over Indonesia compared with the prior modelled by TOMCAT using GFED (blue lines) and the posterior IASI inversions (red lines).

4. Inversion model

- The INVICAT inversion is used to optimize the CO and HCN emissions from the GFED database during the Indonesian fires by directly assimilating IASI measurements.
- Assimilating satellite measurements leads to a significant improvement in the agreement between model and observation.
- The posterior CO results show a better comparison with the satellite data than the prior. The optimized emissions show a similar time evolution with the main peak in late October.
- Despite the overestimation of the HCN amount in the prior, the preliminary results of the HCN inversion scheme considerably improves the agreement with the satellite observations over Indonesia and correctly reproduces the peak in late October.

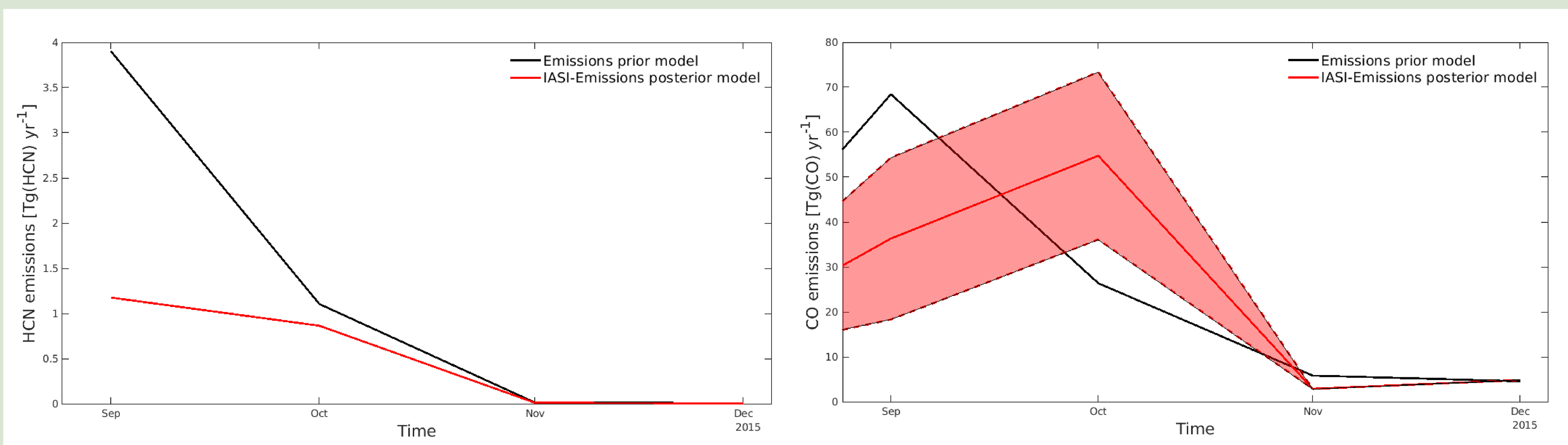


Figure 4: Prior (black line) and posterior (red line) emission evolution in time during September-December 2015 over Indonesia for HCN (left, units Tg(HCN) yr^{-1}) and CO (right, units Tg(CO) yr^{-1}).

5. Conclusions

- We have demonstrated improvements in modelling the atmospheric HCN abundance, obtaining an excellent comparison with independent observations both from satellite and ground.
- The inverse modelling approach is a useful technique to validate fire emission inventories and improve our understanding of fire processes.

6. References

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