Hydrogen cyanide emissions from Indonesia 2015 peat fire season: Satellite observations and modelling study

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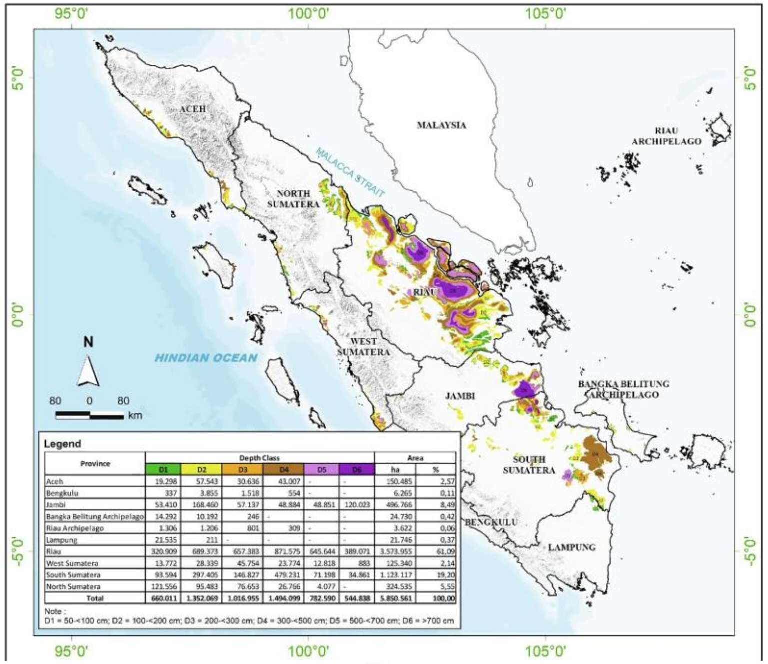
INDONESIA PEATLANDS

Indonesian land contains a high percentage of peat, a carbon-rich type of soil. The large quantity of carbon stored can be emitted as a number of compounds, mostly CO_2, CO and HCN when it burns.

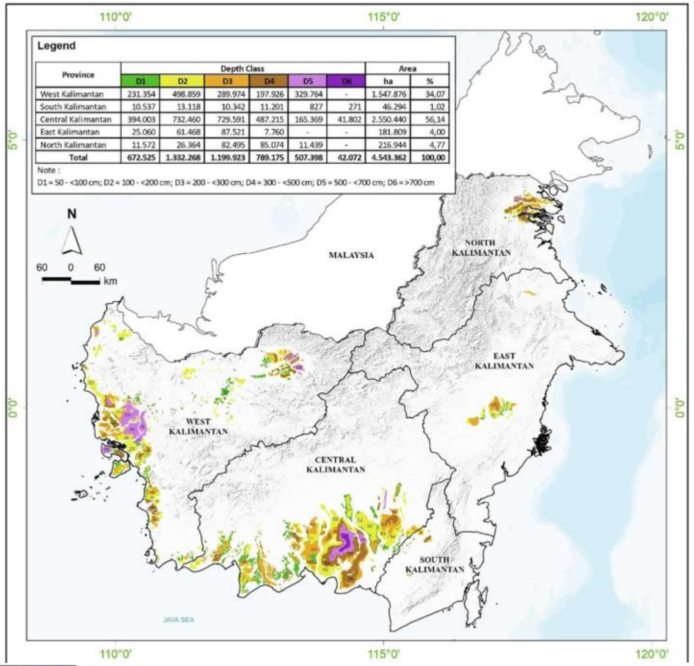
HCN is a good atmospheric tracer for peat fires due to its low chemical reactivity and long lifetime (2–5 months in troposphere many years in stratosphere).

Variation of peat depth in Indonesian peatlands (https://doi.org/10.1016/j.geoderma.2021.115235)



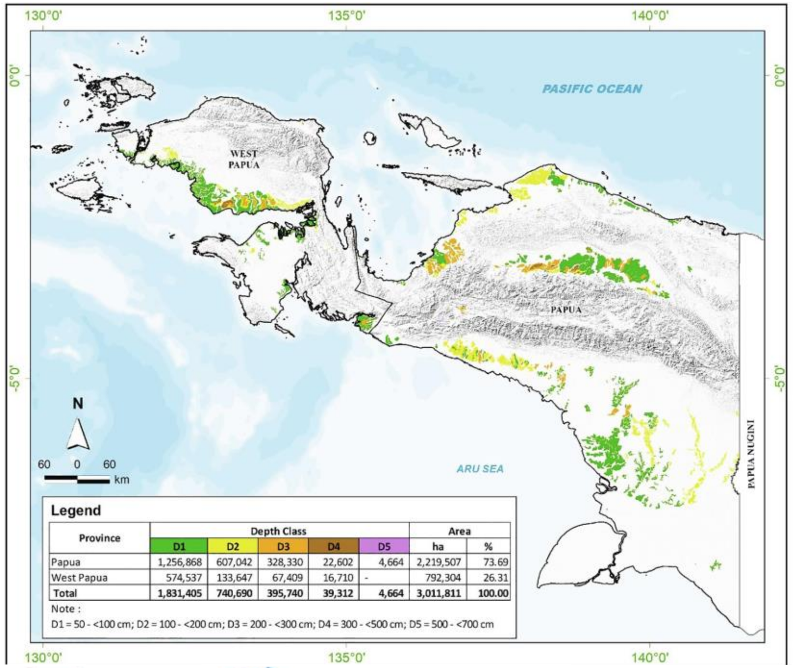
Province	Depth Class						Area	
	D1	D2	D3	D4	D5	D6	ha	%
Aceh	19.298	57.543	30.636	43.007	-	-	150.485	2,57
Bengkulu	337	3.855	1.518	554	-	-	6.265	0,11
Jambi	53.410	168.460	57.137	48.884	48.851	120.023	496.766	8,49
Bangka Belitung Archipelago	14.292	10.192	246	-	-	-	24.730	0,42
Riau Archipelago	1.306	1.206	801	309	-	-	3.622	0,06
Lampung	21.535	211	-	-	-	-	21.746	0,37
Riau	320.909	689.373	657.383	871.575	645.644	389.071	3.573.955	61,09
West Sumatera	13.772	28.339	45.754	23.774	12.818	883	125.340	2,14
South Sumatera	93.594	297.405	146.827	479.231	71.198	34.861	1.123.117	19,20
North Sumatera	121.556	95.483	76.653	26.766	4.077	-	324.535	5,55
Total	**660.011**	**1.352.069**	**1.016.955**	**1.494.099**	**782.590**	**544.838**	**5.850.561**	**100,00**

Note :
D1 = 50-<100 cm; D2 = 100-<200 cm; D3 = 200-<300 cm; D4 = 300-<500 cm; D5 = 500-<700 cm; D6 = >700 cm



Province	Depth Class						Area	
	D1	D2	D3	D4	D5	D6	ha	%
West Kalimantan	231.354	498.859	289.974	197.926	329.764	-	1.547.876	34,07
South Kalimantan	10.537	13.118	10.342	11.201	827	271	46.294	1,02
Central Kalimantan	394.003	732.460	729.591	487.215	165.369	41.802	2.550.440	56,14
East Kalimantan	25.060	61.468	87.521	7.760	-	-	181.809	4,00
North Kalimantan	11.572	26.364	82.495	85.074	11.439	-	216.944	4,77
Total	**672.525**	**1.332.268**	**1.199.923**	**789.175**	**507.398**	**42.072**	**4.543.362**	**100,00**

Note :
D1 = 50 - <100 cm; D2 = 100 - <200 cm; D3 = 200 - <300 cm; D4 = 300 - <500 cm; D5 = 500 - <700 cm; D6 = >700 cm



Province	Depth Class					Area	
	D1	D2	D3	D4	D5	ha	%
Papua	1,256,868	607,042	328,330	22,602	4,664	2,219,507	73.69
West Papua	574,537	133,647	67,409	16,710	-	792,304	26.31
Total	**1,831,405**	**740,690**	**395,740**	**39,312**	**4,664**	**3,011,811**	**100.00**

Note :
D1 = 50 - <100 cm; D2 = 100 - <200 cm; D3 = 200 - <300 cm; D4 = 300 - <500 cm; D5 = 500 - <700 cm

INDONESIA FIRES

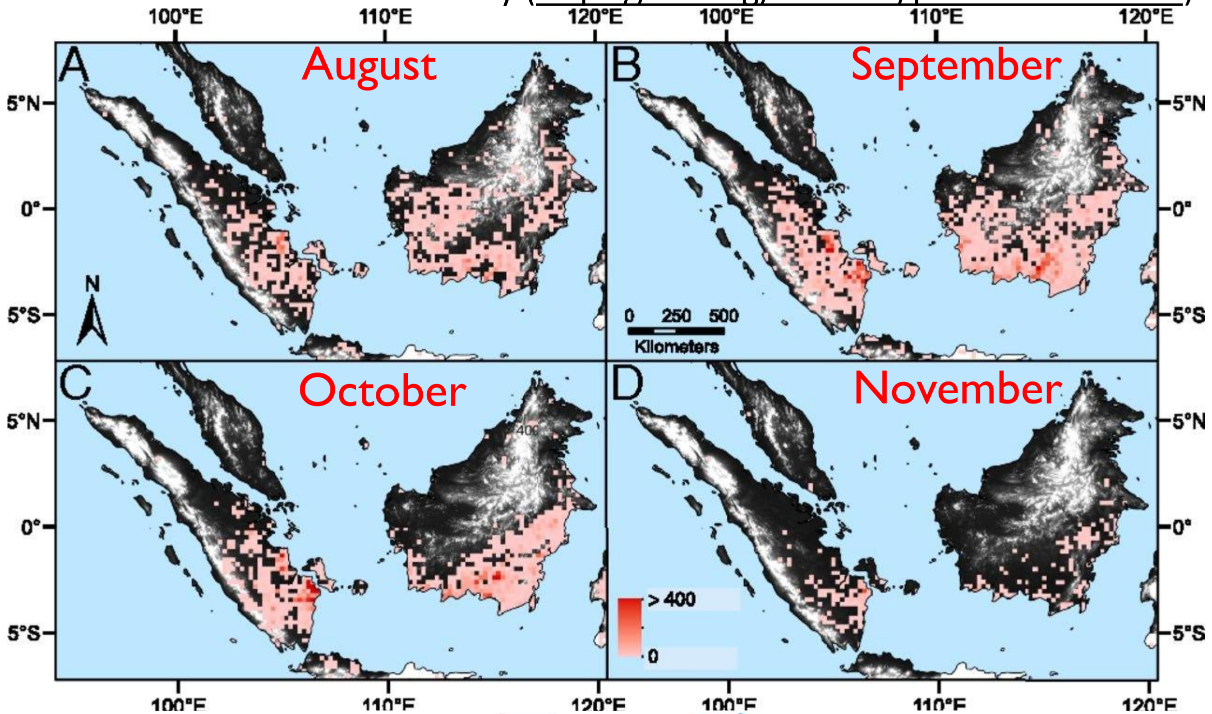
Wildfires in Indonesia are seasonal events regulated mainly by the agricultural practice of land clearing in order to prepare the soil for the new planting season.

El Niño exacerbates the extreme weather conditions of the Indonesian fire season, making burning events difficult to control, as they were towards the end of 2015.

In 2015, over 100,000 land and forest fires burned, covering 2.6 million hectares. The air quality was extremely affected across SE Asia.

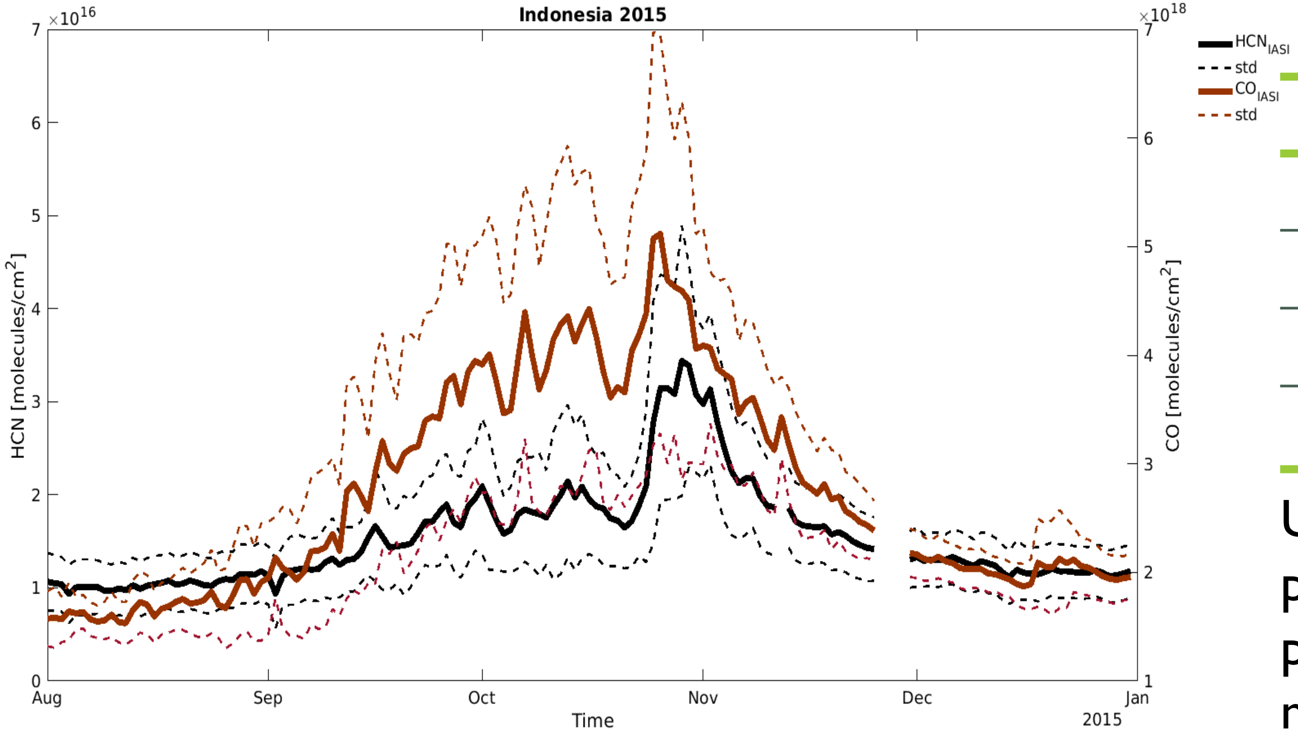
Unprecedented amounts of HCN have been observed emitted from Southeast Asia during September–November 2015.

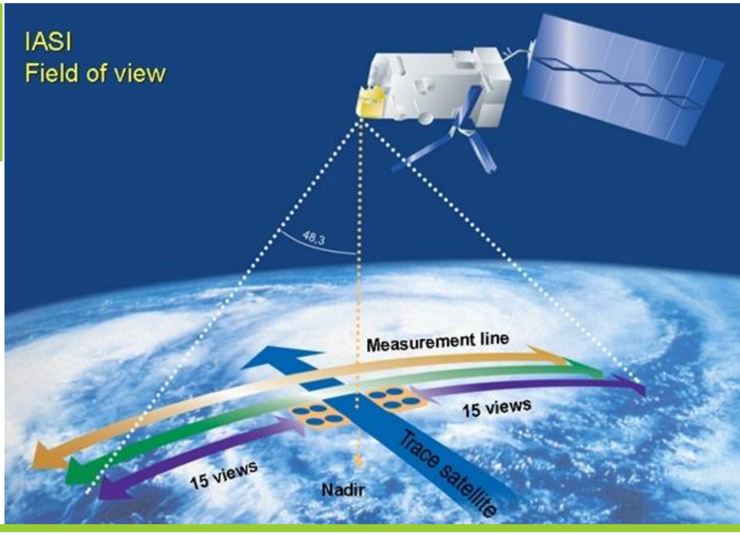
2015 MODIS active fire density (https://doi.org/10.1073/pnas.1524888113)



IASI - MetOp-B

- Spectra: sampling 0.25 cm^{-1}, resolution 0.5 cm^{-1}, TIR range – 645 to 2760 cm^{-1} (15.5 to 3.62 μm)
- 15 orbits/day in a polar sun-synchronous orbit, local time ~09:30
- Global daily coverage due to large 2200 km swath





IASI properties

IFOV	14.65 mrad	
IFOV shape	circular	
Nadir size	12 km	
Edge size	39 km (across track)	20 km (along track)

ULIRS: full optimal estimation method used to perform global total column and concentration profile retrievals from IASI spectra, each measurement has errors and sensitivity profiles.

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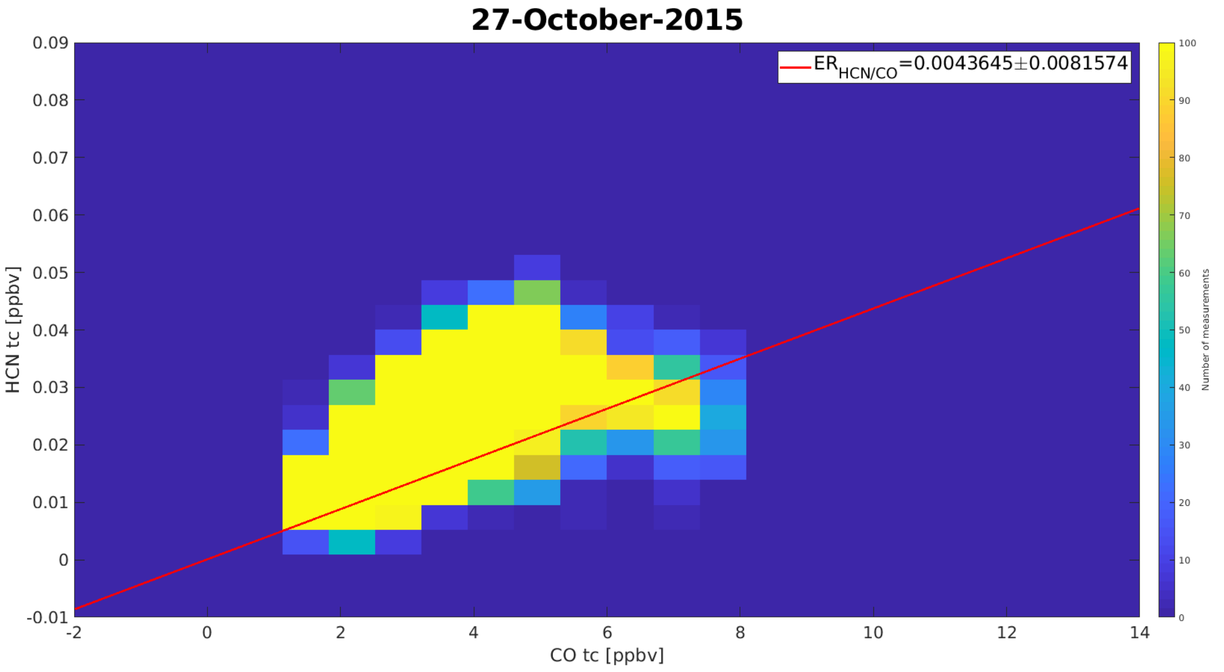
EMISSION FACTORS

- **Enhancement ratios**

$$ER_{\mathrm{HCN/CO}} = \frac{[HCN]_{smoke} - [HCN]_{ambient}}{[CO]_{smoke} - [CO]_{ambient}}$$

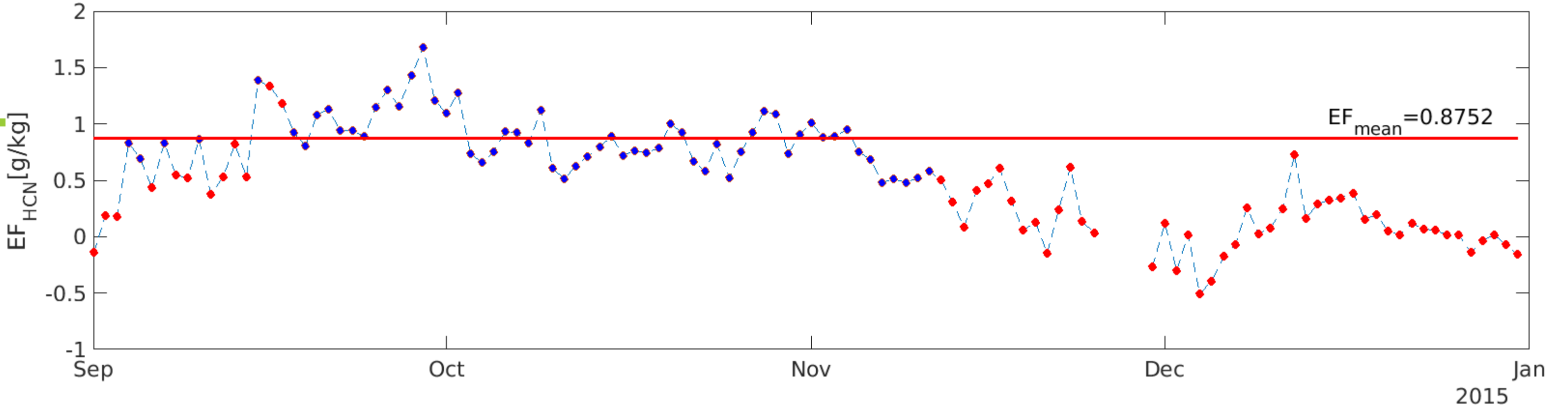
- **Emission factors**

$$EF_{\mathrm{HCN}} = EF_{\mathrm{CO}} \frac{M_{\mathrm{HCN}}}{M_{\mathrm{CO}}} ER_{\mathrm{HCN/CO}}$$



GFED BB EF_{HCN}

	Peatlands HCN EF (g kg^{-1})
Akagi et al. 2011	5.00 (4.93)
Andreae 2019	4.40 (1.20)
Stockwell et al., 2016	5.75 (1.60) (Kalimatan)
Smith et al. 2017	3.79 (1.97) (Malaysia)



HCN MODEL

The HCN lifetime in the troposphere is 2–5 months, but much longer (many years) in the stratosphere. Atmospheric HCN has been modelled by the 3D Chemical Transport Model TOMCAT at a spatial resolution of 2.8° × 2.8° and 60 levels (surface to ~60 km).

Sources

- Biomass burning (main) – monthly means from GFED inventory
- Anthropogenic sources (minor)
  - Industry
  - Transport

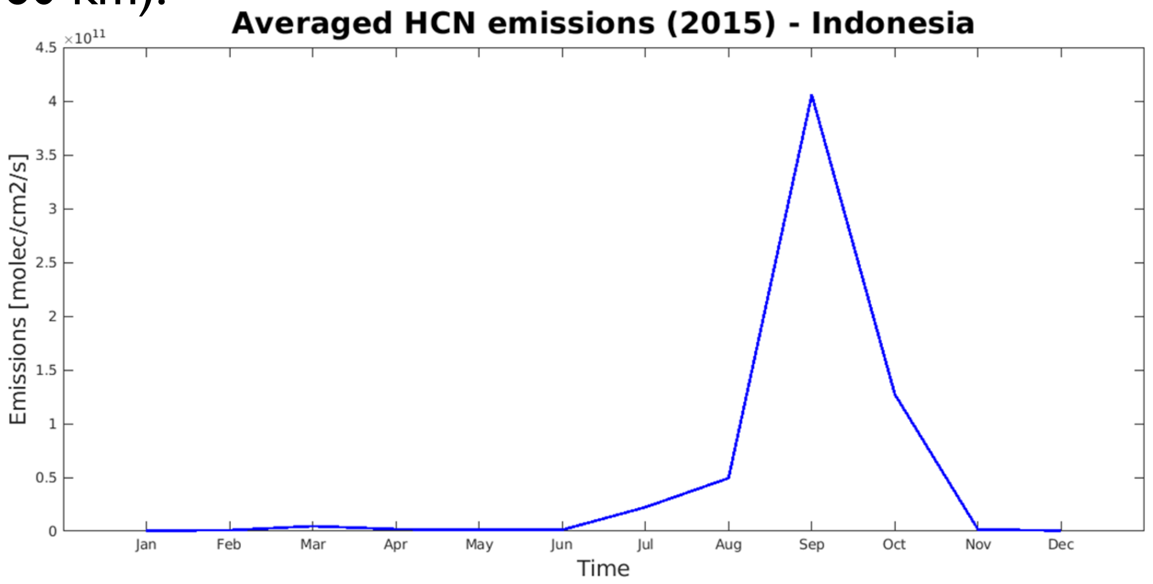
Sinks

At the surface level:

- Ocean uptake (main)
  - *Li et al. 2003*
  - *Li et al. 2000 x 0.25*

In the stratosphere:

- Oxidation by OH - *Kleinboehl et al. 2006*
- Oxidation by $O(^1D)$ - *Kleinboehl et al. 2006*
- Photolysis (negligible)



Surface emissions of HCN:

- GFEDv4.1s biomass burning emissions – monthly mean
- CMIP6 anthropogenic emissions
- CCMI annually fixed biogenic emissions
- CMIP6 annually fixed ocean natural emissions

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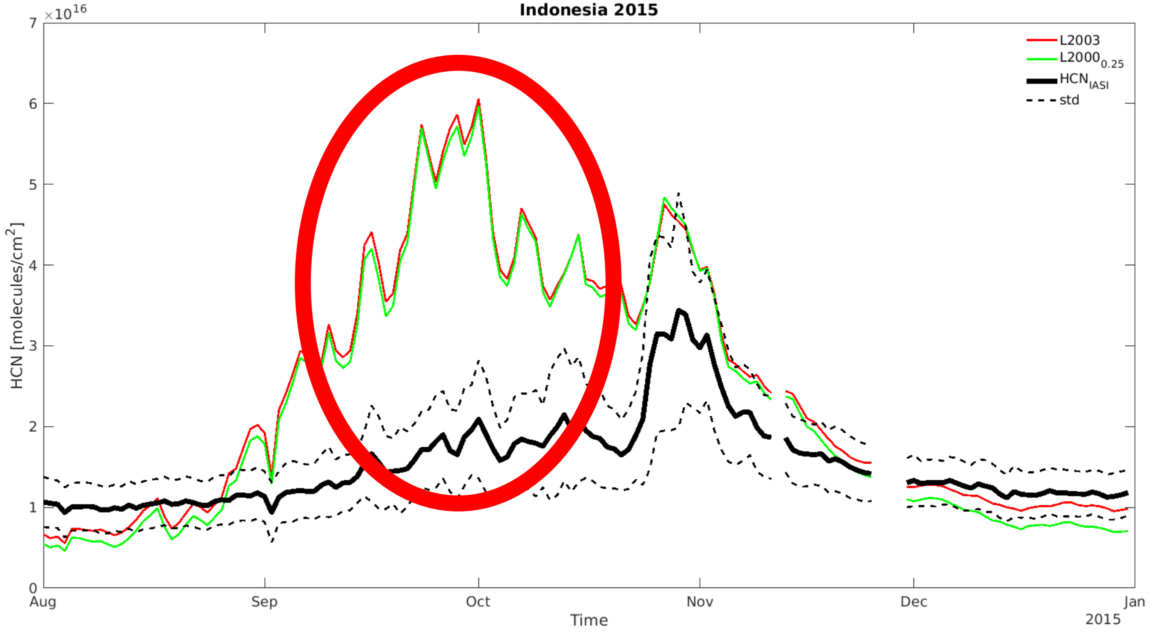
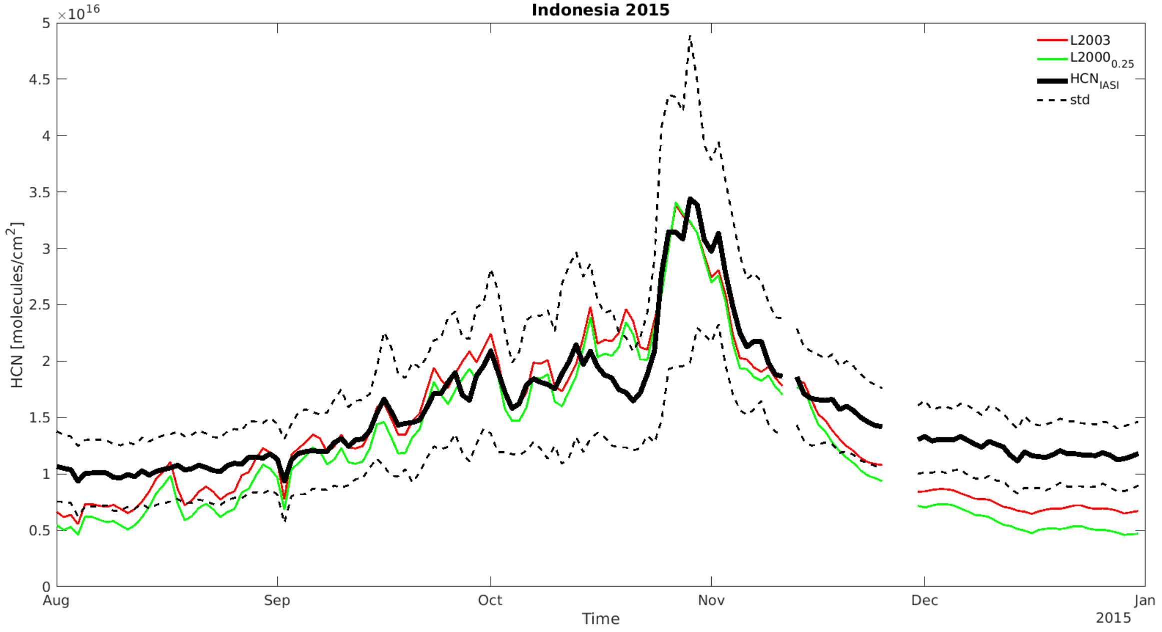
MODEL SIMULATIONS: HCN204





	HCN204		HCN204 0.25 Sep	
	L2000_0.25	L2003	L2000_0.25	L2003
SLOPE	1.3362	1.6292	0. 8651	0. 93122
R^2	0.4352	0.4616	0.7846	0.8216
RMSE	1.07e+16 molec./cm2	1.12e+16 molec./cm2	3.30e+15 molec./cm2	2.87e+15 molec./cm2
Max corr.	0.69	0.69	0.93	0.93
Max corr. lag	1 day	1 day	0 days	0 days

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CONCLUSIONS

- Our first estimations of EF_{HCN} do not match with the EFs used to calculate GFED emissions from Akagi (2011). Further investigation on box choice, plume origins and age are necessary to improve our estimation.
- At the initial stage of the wildfire season the HCN concentrations in Indonesia measured by IASI are substantially different from that modelled using the Global Fire Emissions Database (GFEDv4.1s) emission inventory, highlighting uncertainties in its estimates on HCN emissions.
- Using only the 25% of the GFED HCN emissions during September 2015 produced a more realistic result in comparison to the satellite measurements.
- IASI-based fire emissions capture observed variations more accurately, thus atmospheric composition satellite observations have a high potential to constrain the actual emission inventories whose estimates are based only on fire information such as fire counts, fire radiative power and burned area.

Next step

- Satellite observations can be used to estimate HCN fire emissions using the INVICAT inverse modelling framework.