Simulation of the atmospheric tape recorder signal in HCN

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❶ Abstract

We present a simulation of the HCN (hydrogen cyanide) "tape recorder" signal first observed by *Pumphrey et al.* (2008). We reproduced the HCN "tape recorder" signal by a simulation with the Chemical Lagrangian Model of the Stratosphere (CLaMS, *McKenna et al.*, 2002a,b; *Konopka et al.*, 2007) using only emissions from Indonesian fires as boundary conditions at the ground. This confirms one of the suggestions by *Pumphrey et al.* (2008) that the stratospheric HCN "tape recorder" signal is driven by inter-annual variations in biomass burning in Indonesia. A trajectory study shows an irregular cycle rather than the two-year cycle assumed by *Pumphrey et al.* (2008).

❷ Motivation

In the past the atmospheric "tape recorder" has been observed in several species (H_2O, CO_2, CO) as a phenomenon with an annual cycle (*Mote et al.*, 1996; *Andrews et al.*, 1999; *Schoeberl et al.*, 2006). Recently, based on Microwave Limb Sounder (MLS) and Atmospheric Chemistry Experiment (ACE) satellite measurements, a tape recorder signal has been observed for HCN, but with an exceptionally period of approximately two years (*Pumphrey et al.*, 2008). *Pumphrey et al.* (2008) suggested among others that this signal might be connected to inter-annual variations in biomass burning in Indonesia and the surrounding region.

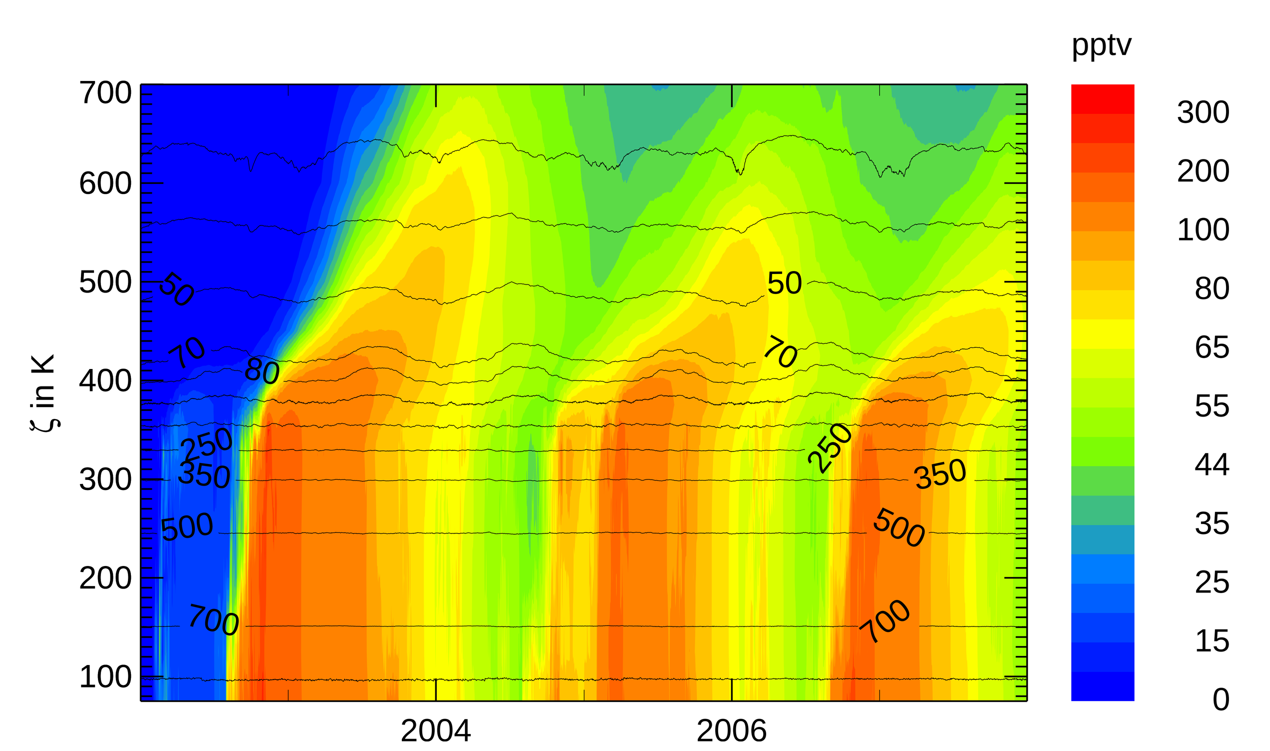
The arising questions were:

- **Is it possible to reproduce the pattern of the HCN "tape recorder" by using HCN emissions only from Indonesia?**
- **What causes the two-year cycle?**

❸ Methods

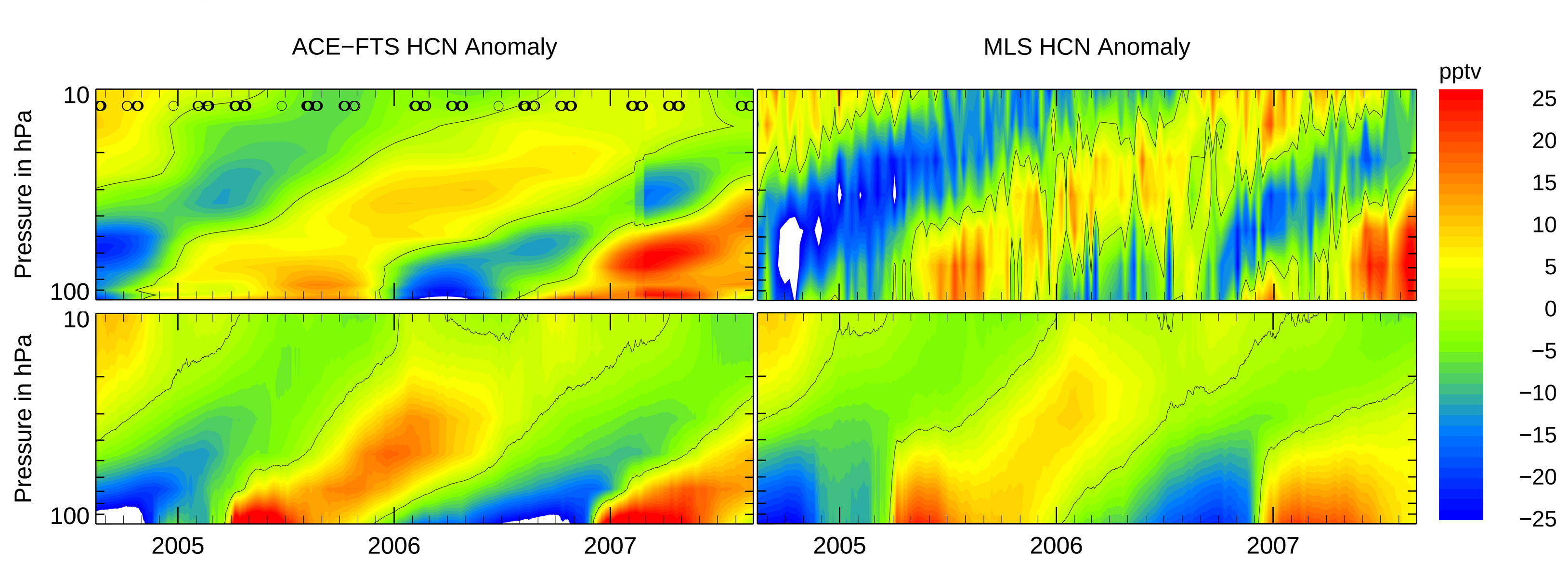
We performed a multi-annual model run with the Chemical Lagrangian Model of the Stratosphere (CLaMS, *McKenna et al.*, 2002a,b; *Konopka et al.*, 2007). As boundary condition we used emissions from the region of Indonesia as source of HCN. The dominant sink for HCN is uptake by the ocean (*Li et al.*, 2000). We adjusted the loss rate to the ocean such that a mean atmospheric residence time of HCN of ≈5 month emerges according to *Singh et al.* (2003). The chemical loss of HCN is represented by reaction with OH and $O(^1D)$. We compared our results with data from MLS-Aura and ACE-FTS to validate our simulation. We performed a trajectory study to investigate the reason for the two-year cycle of the HCN "tape recorder" signal. The question is, how strong is the influence of the upwelling air on the one hand and the influence of the emissions of HCN on the other hand.

❹ Simulation



The result of the multi-annual model run. These are the zonal mean values of the mixing ratio of HCN from the simulation with CLaMS. The black lines are isolines of pressure.

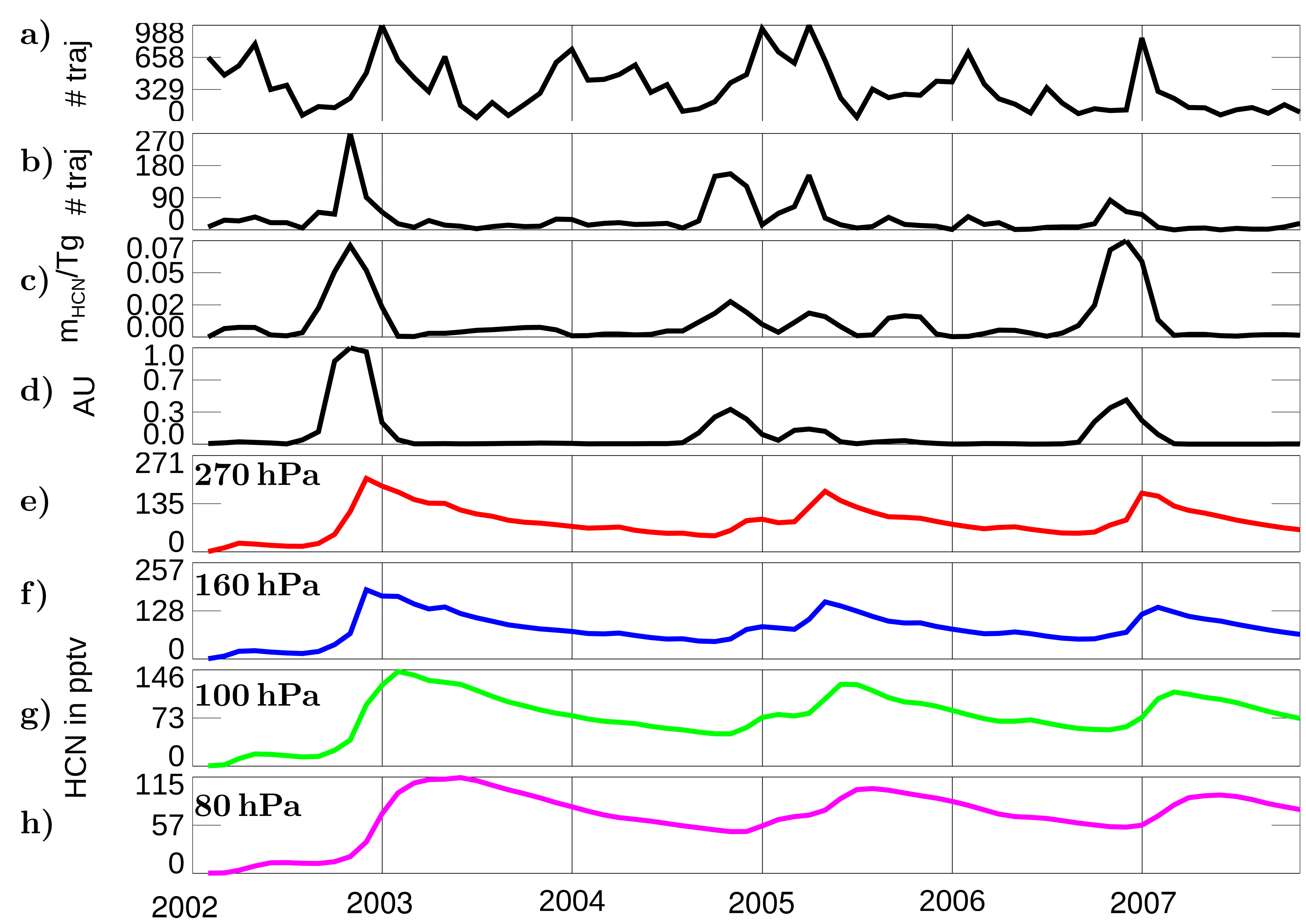
❺ Comparison with satellite data



These plots show the good agreement of the simulation results, which are transformed to the field of view of the respective instrument, in comparison to the satellite measurements of ACE-FTS **(left)** and MLS **(right)**. This leads to the conclusion that the signal of the measured HCN "tape recorder" is mainly caused by emissions from Indonesia. Now the question is, whether the cycle of upwelling air masses or the cycle of biomass burning causes the signal of the HCN "tape recorder".

❻ Trajectory study

To investigate which way the air takes from Indonesia into the region of the Tropical Tropopause we performed a trajectory study. Panel **a)** shows the number of trajectories which reached the region of the Tropopause ($\theta \approx 350$ K) monthly. This shows the well known annual cycle of upward transport of air masses. It seems to be necessary to focus on places, from where HCN could be transported. Panel **b)** factor therefore only trajectories that started from areas with emissions of HCN. Panel **c)** shows the monthly total mass of emitted HCN. The normalized product of the number of the trajectories potential carrying HCN and the emitted HCN is shown in Panel **d)**. The lowest four panels show the signal of the simulated HCN "tape recorder" in four heights: **e)** ≈ 270 hPa **f)** ≈ 160 hPa **g)** ≈ 100 hPa, **h)** ≈ 80 hPa, by means to picture heights below, midst and above the TTL.



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❼ Summary

We performed a multi-annual model run and reproduced the observed two-year cycle of the HCN "tape recorder" in the time range of mid-2004 to end-2007. The model result agrees well with the satellite measurements. To answer the question, whether the upward transport of air masses in the tropics or the temporal cycle of biomass burning in the region of Indonesia causes the two-year cycle, we performed a trajectory study.

We propose on the basis of our results that there is an irregular cycle rather than a two-year cycle of the HCN "tape recorder", because the cycle of the upward transport in the tropics and the cycle of biomass burning in Indonesia influences the cycle of the HCN "tape recorder".