# Results from a comparison of HCN measurements and Lagrangian back-trajectory analyses in the Asian Summer Monsoon Anticyclone

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# Motivation

- The Asian Monsoon Anticyclone (AMA) is a dominant circulation system in the Upper Troposphere and Lower Stratosphere (UTLS) in boreal summer.
- Rapid updrafts transport boundary air into AMA
- Enhanced and confined pollutants are observed in the AMA. The interaction of free stratosphere with air constrained at the top of the AMA is, however, not thorughly studied.
- The pollutants are related to the Asian Tropopause Aerosol Layer (ATAL), causing climatic feedback on the radiative budget.

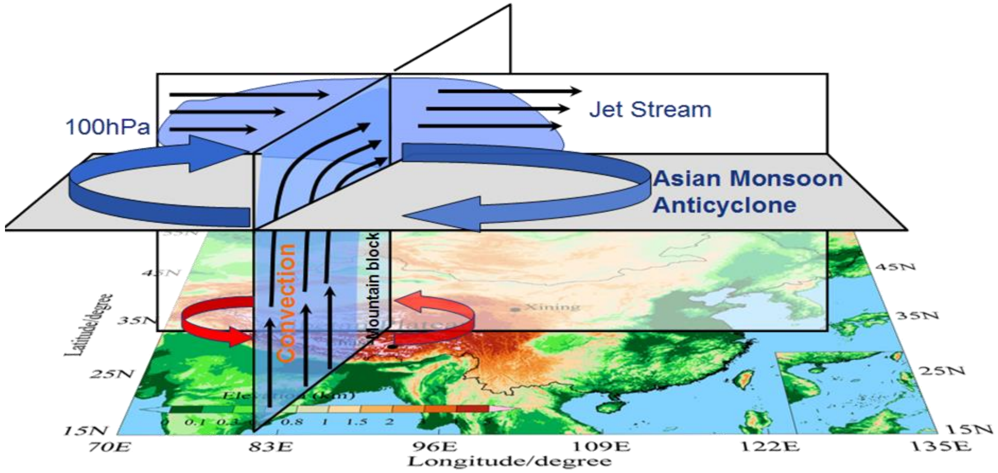
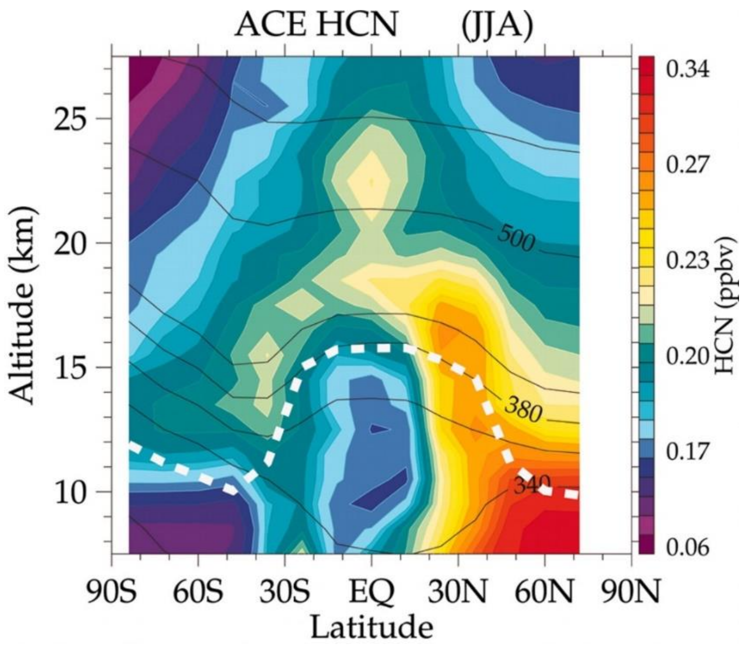



*Figure courtesy of Dr. Yong Wang*

- Relevance of HCN in the AMA

HCN: a valuable tropospheric tracer which is primarily emitted from biomass burning with a tropospheric lifetime of 4-5 months and a stratospheric lifetime of 1-2 years




*Randel et al, 2010*

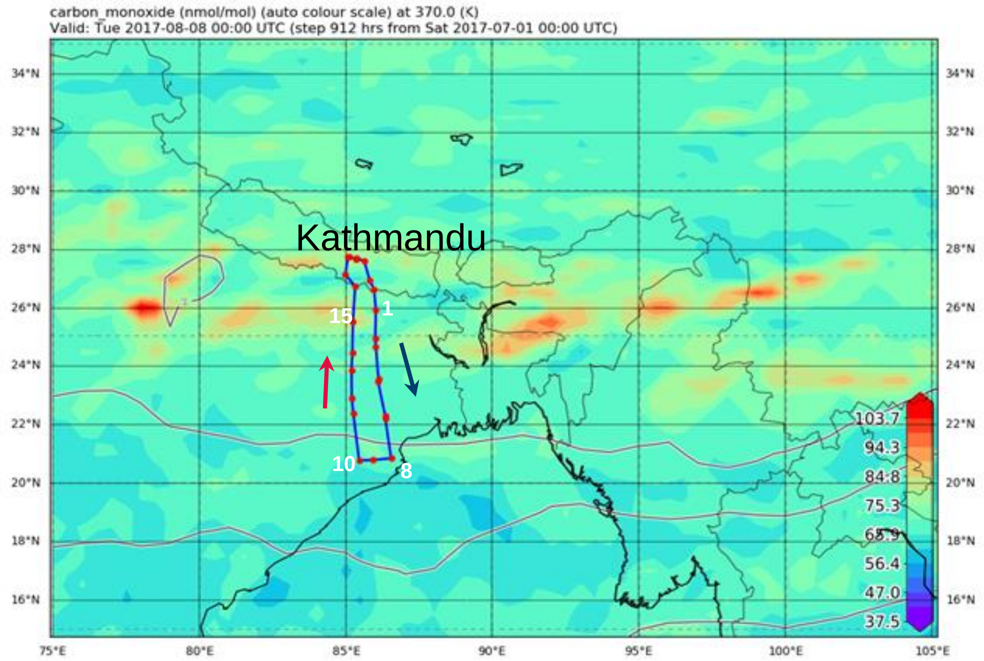
# HCN measurements

## Flight conditions

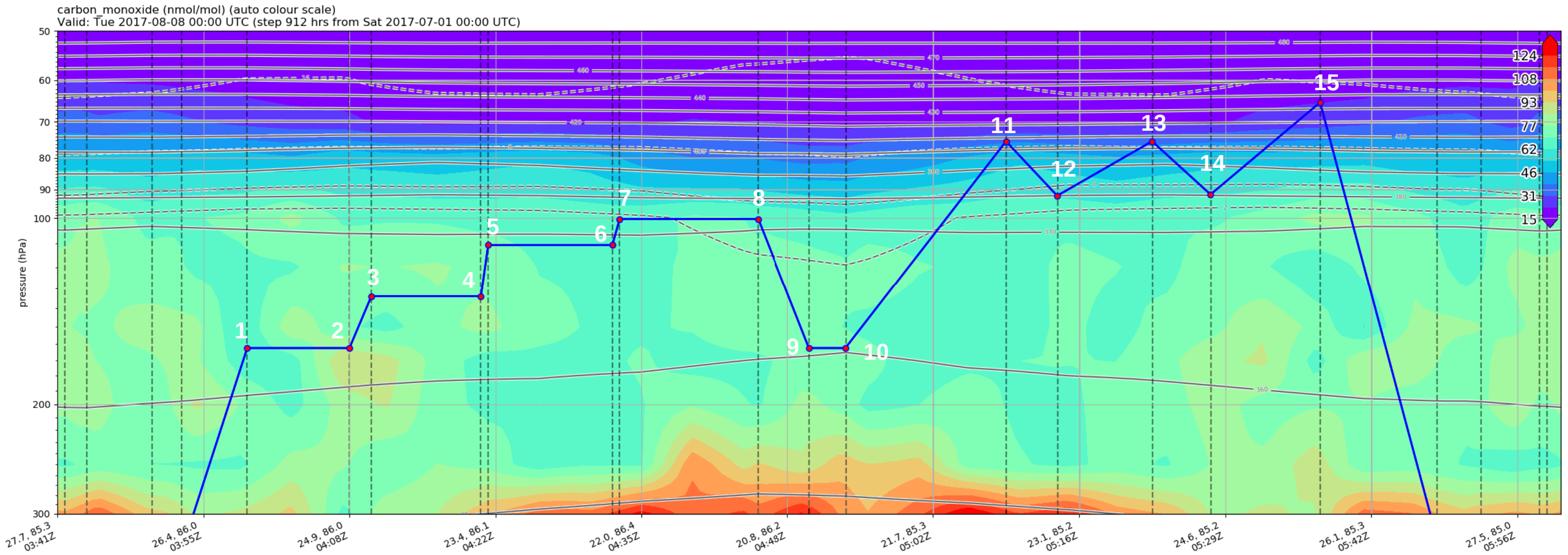
- **The Stratoclim campaign**: Kathmandu, Nepal, Jul. 21 – Aug. 10, 2017
- The platform: M55–Geophysica, max. 21 km
- Flight: **F7 on Aug. 8th —** vertical structure of the UTLS

Upper right: Horizontal CO distribution at θ = 370 K in the flight region.
The blue line shows the actual fligh path.
Black/red arrow indicates the outgoing/return flight

Lower right: Vertical gradient of CO along the flight path.



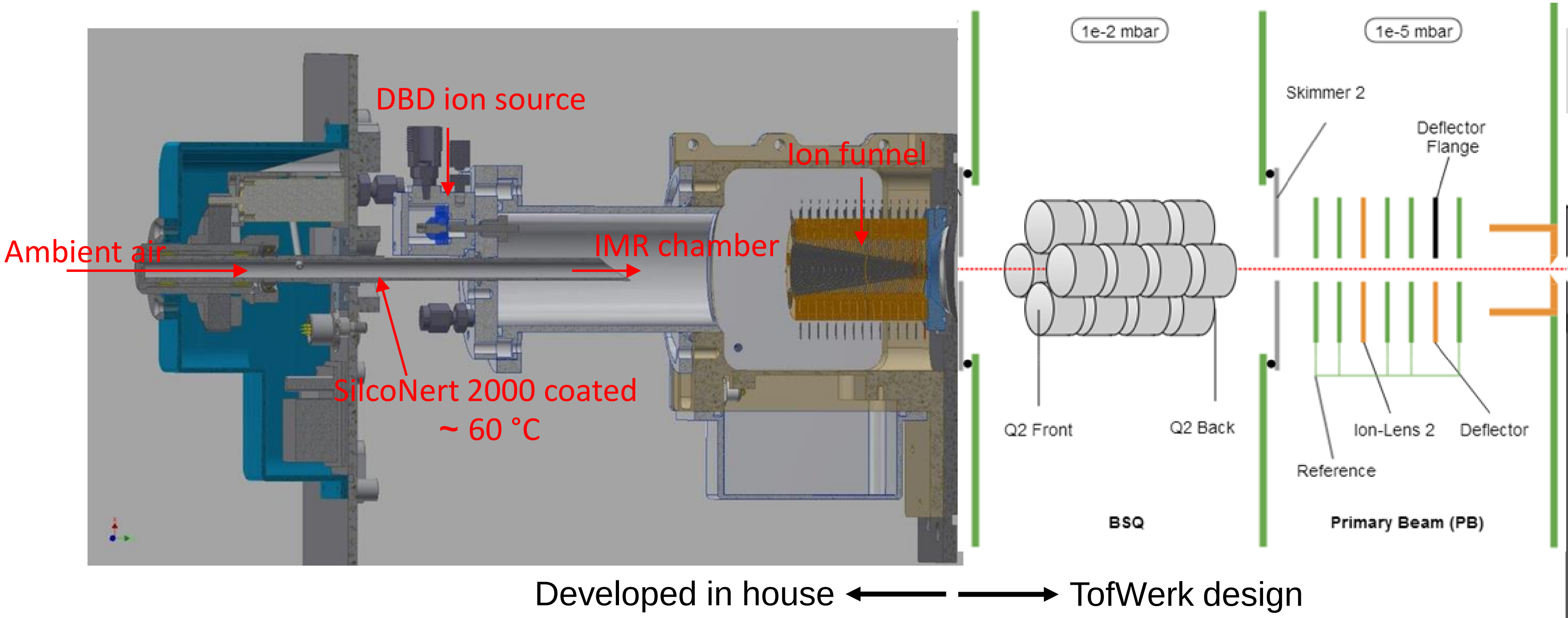

* CO mixing ratio was simulated by the Chemistry Lagrangian Model of the Stratosphere (CLaMS) initialized with CO mixing ratio on July 1, 2017 at 500 hPa measured by the atmospheric infrared sounder (AIRS)
* Actual measuring range: Amb. Press < 200 hPa

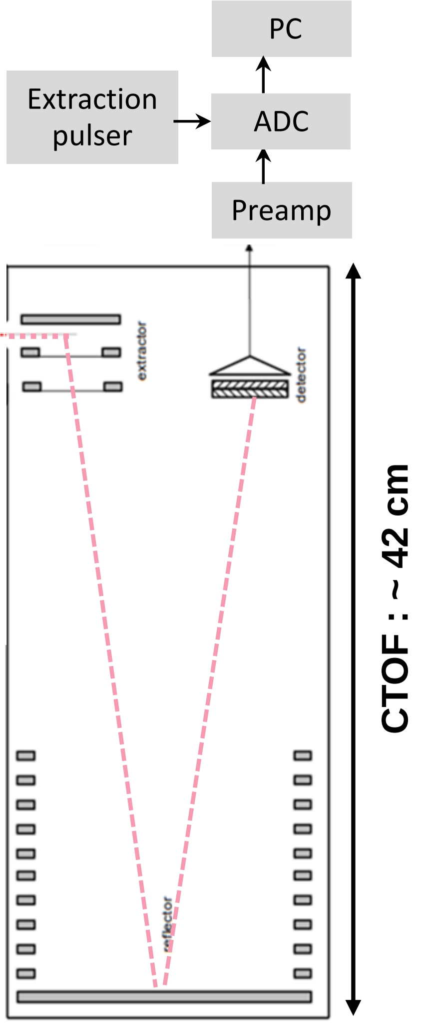


# HCN measurements

## Measuring technique

- **$CO_3^-$ Chemical Ionization Time-of-Flight Mass Spectrometry** ($SO_2$, $HNO_3$, HCN, $RO_2NO_3$)
- Detection limits with 20 s integration: **HCN**: 64 ppt, **$HNO_3$**: 0.8ppt



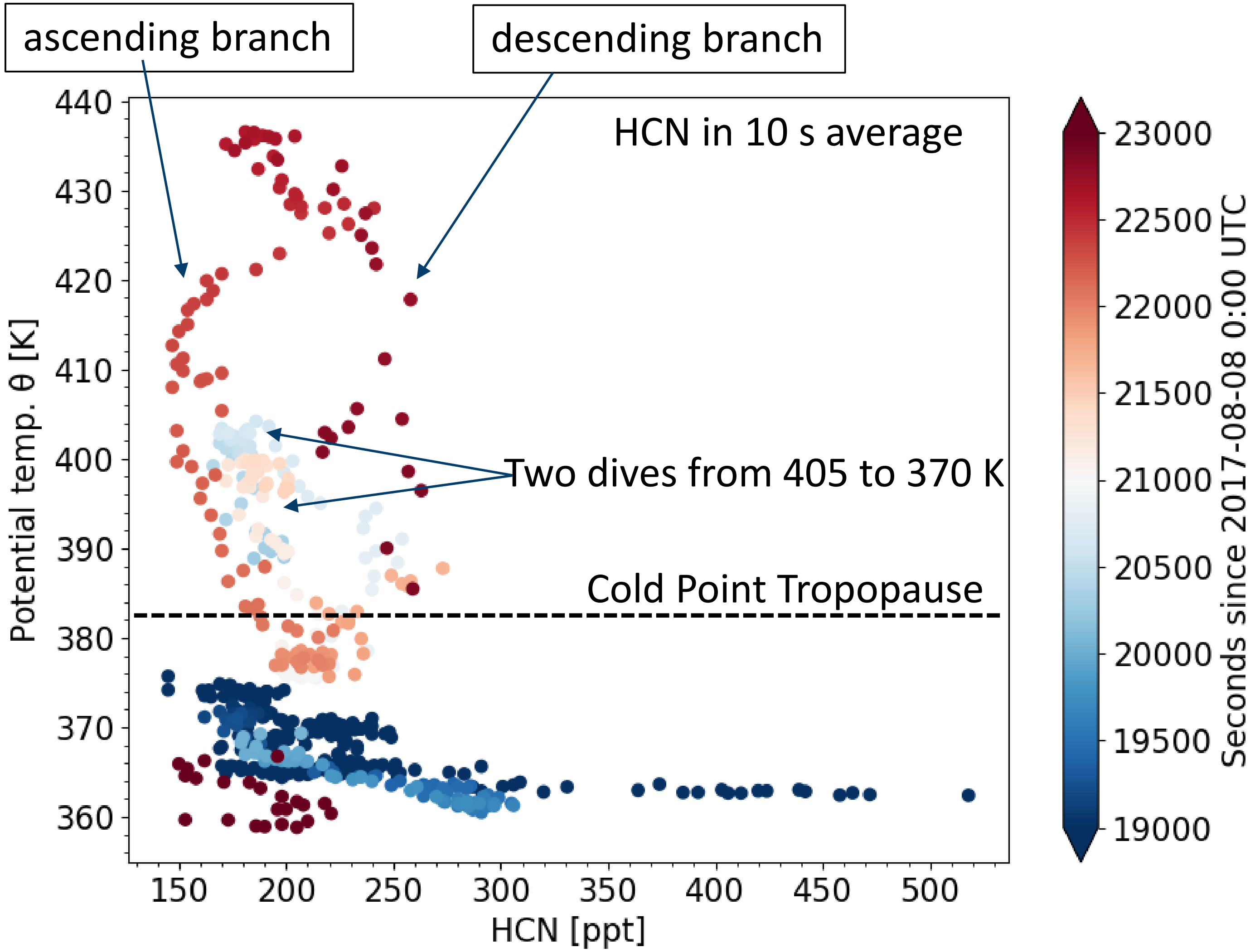




* DBD: Dielectric Barrier Discharge
IMR: Ion-Molecule Reaction

Mass resolution ~700
20 000 ex/s
Data storage 2 Hz

# HCN measurements

## Results – HCN profile



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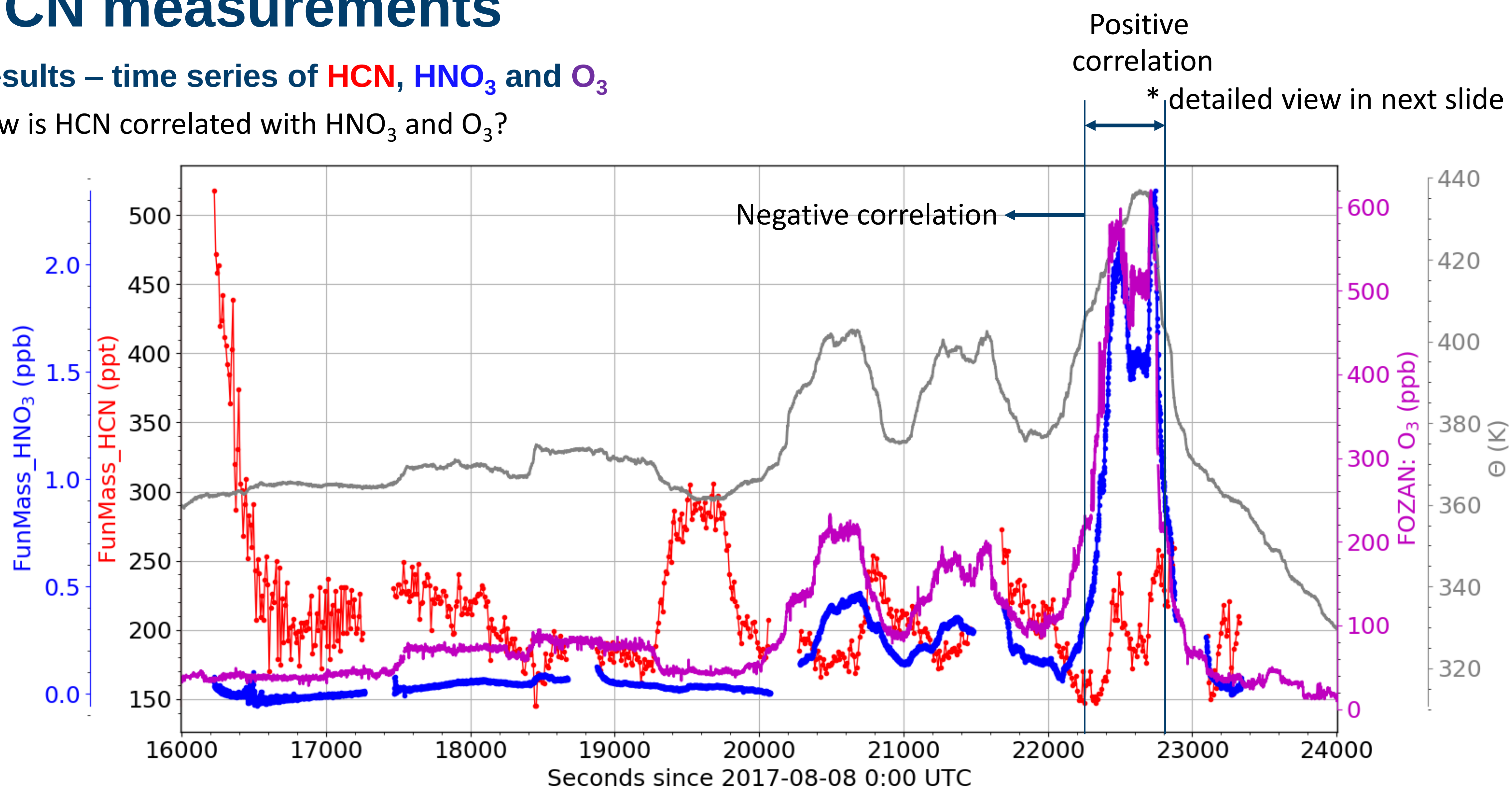
# HCN measurements

## Results – time series of HCN, $HNO_3$ and $O_3$

How is HCN correlated with $HNO_3$ and $O_3$?



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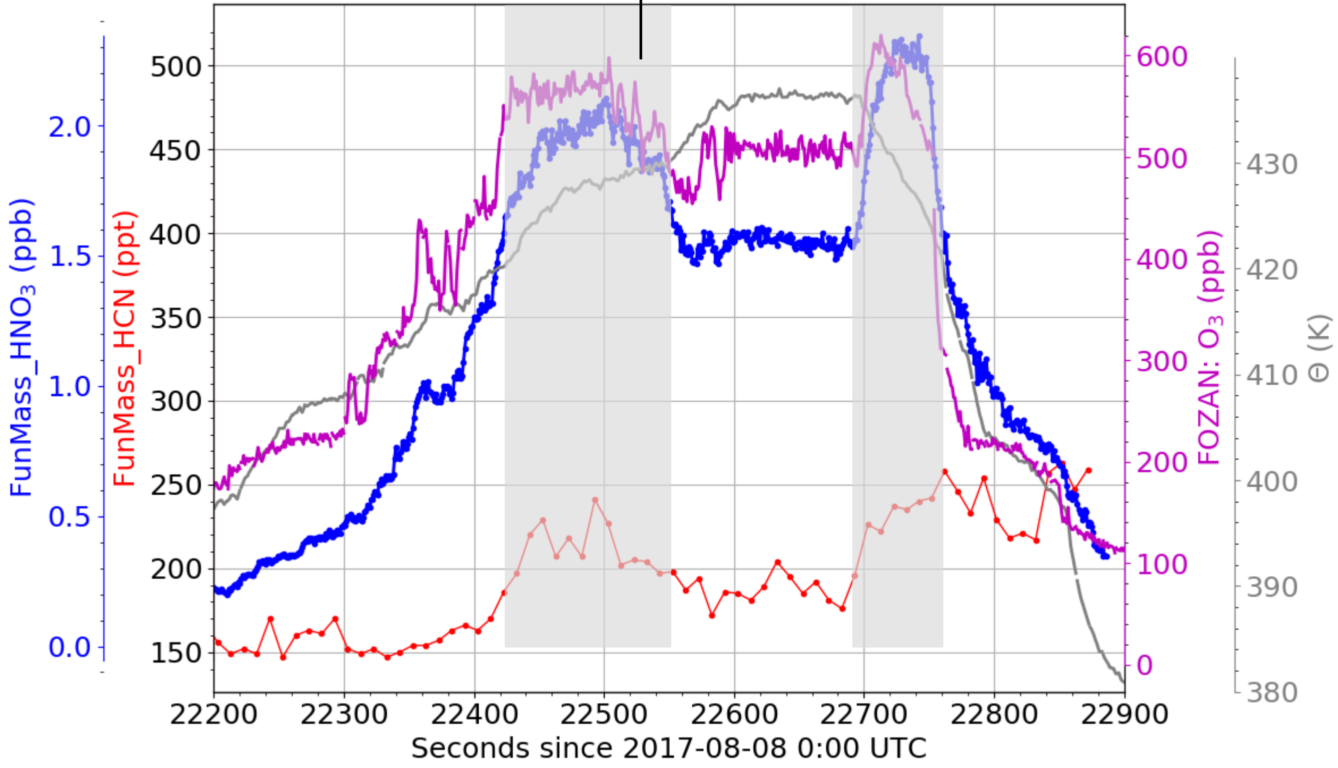
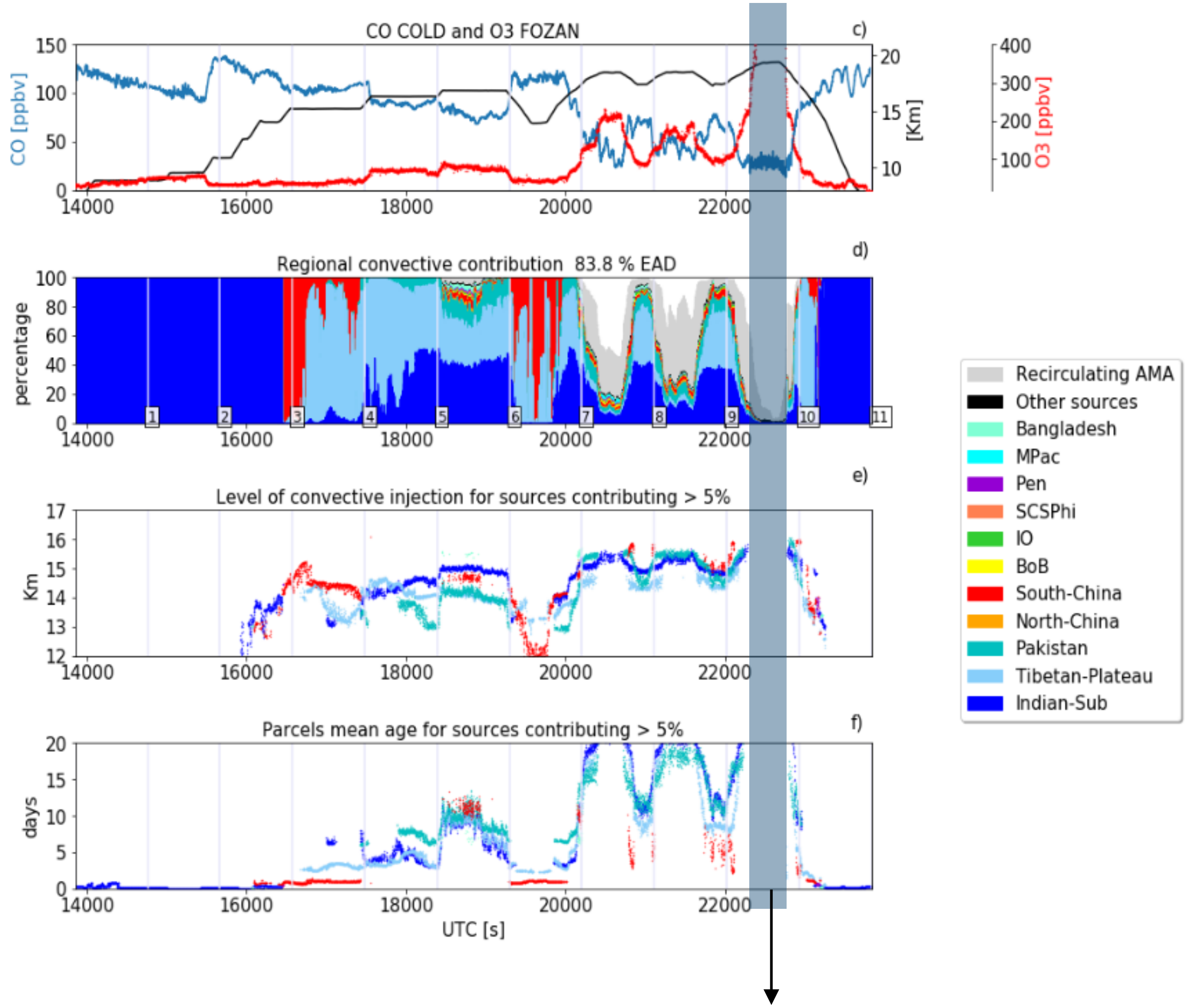
# HCN in the LS

## Positive correlations of HCN with $HNO_3$ and $O_3$

A filament of enhanced HCN, $HNO_3$ and $O_3$ at the same time between 425 – 430 K.




No fresh convective input during the high-altitude flight segment

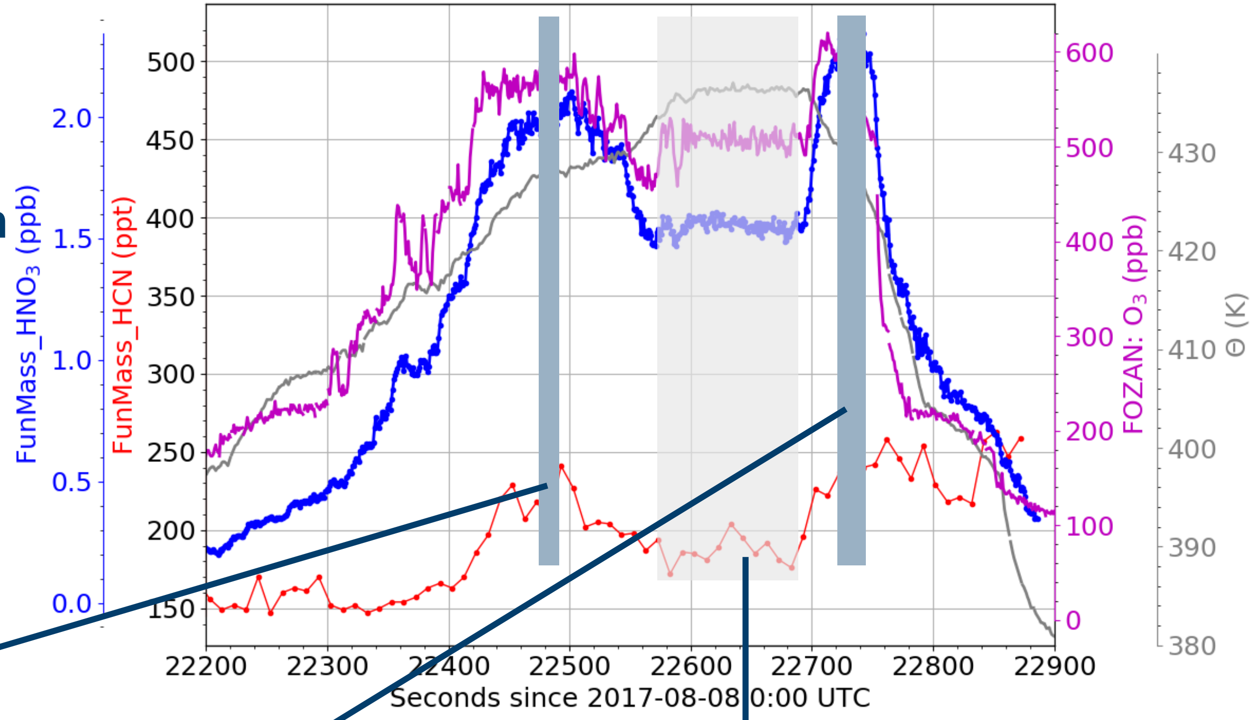
More details are shown in Bucci et al, ACPD, 2020 and the presentation by Silvia Bucci from the same session

# HCN in the LS

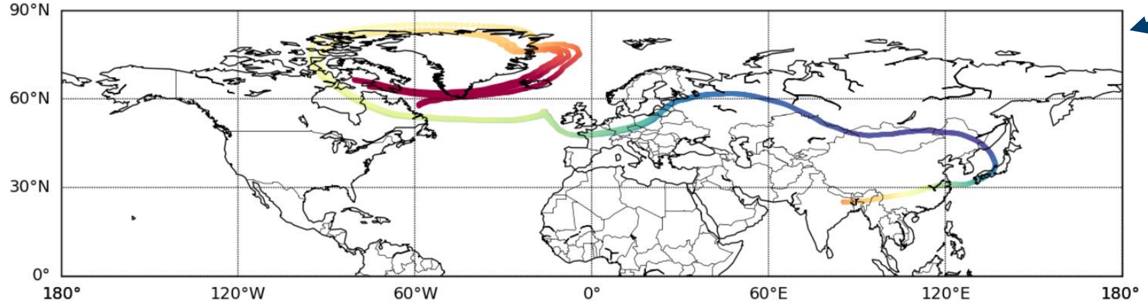
## Back-trajectory study using The Chemical Lagrangian model of the Stratosphere (CLaMS)

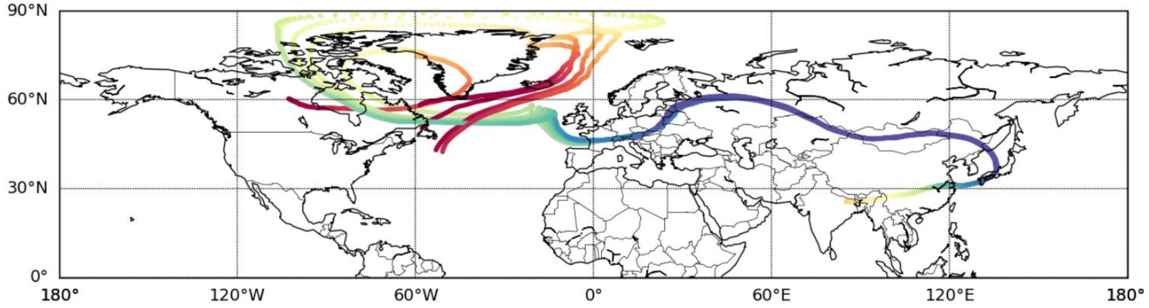
40-day back-trajectories driven by ERA-Interim met. fields

1 trajectory lauched at the flight position every second



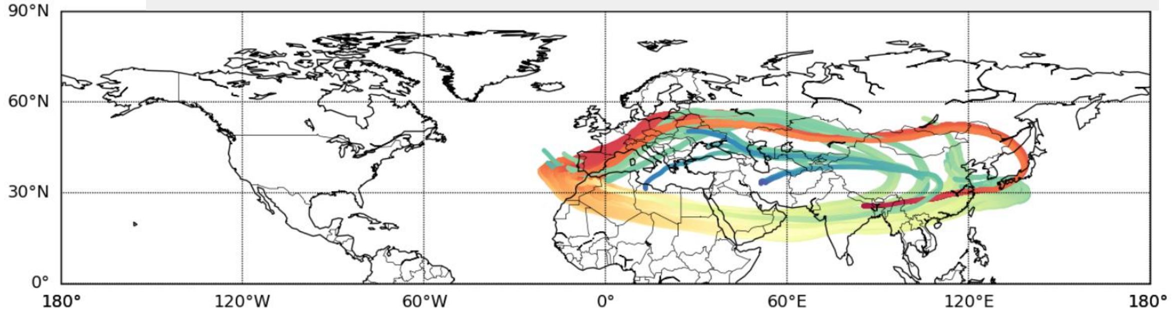

Stratospheric air (high $O_3$ and $HNO_3$, high HCN — could be remainings from 2015 —2016 peat fire) transported from the mid-latitudes likely causes the filament.

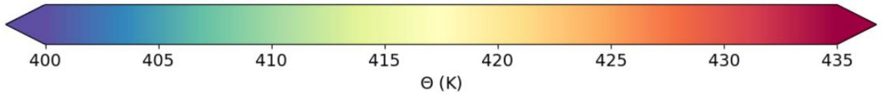




Air ascent from the AMA (Vogel et al., ACP, 2019) with less HCN, $HNO_3$ and $O_3$

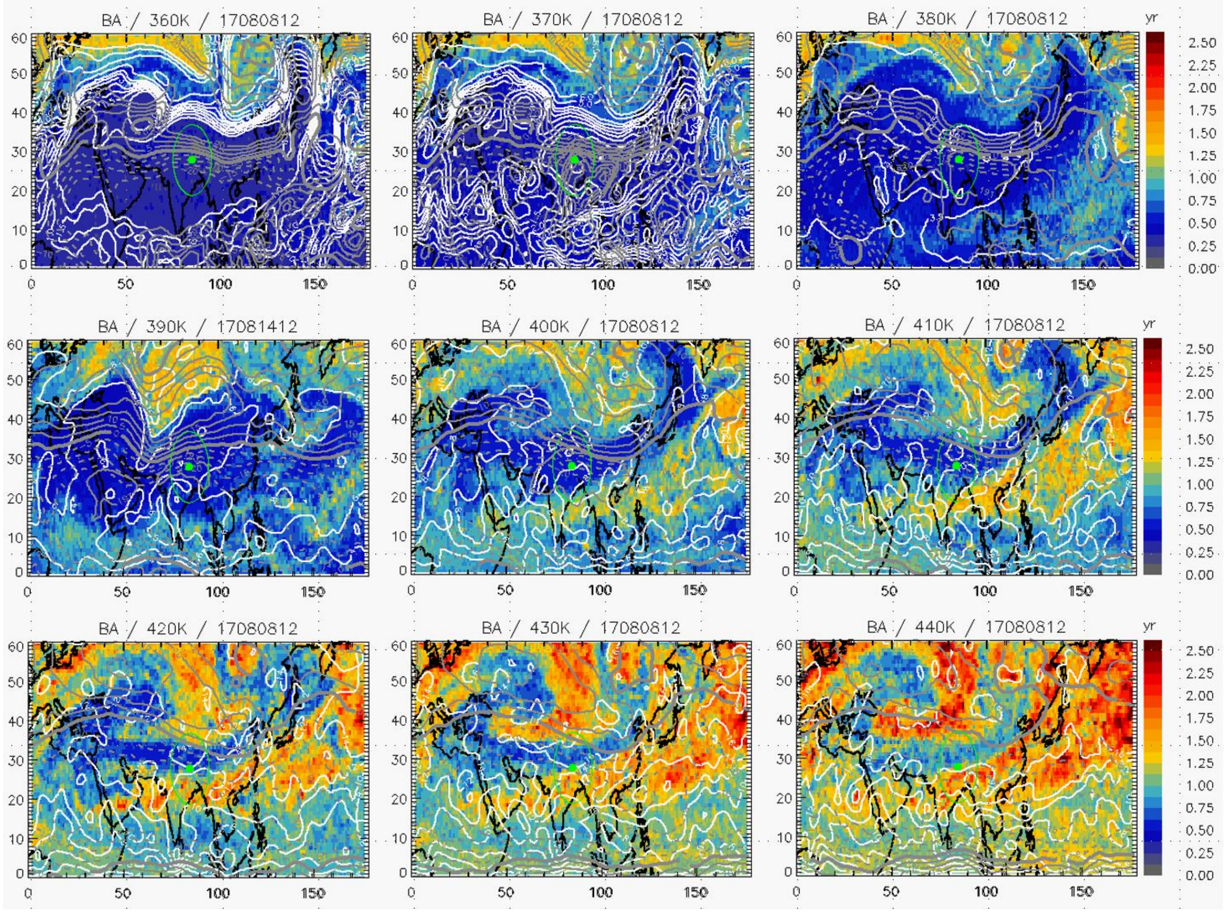


# Stratospheric intrusion into the AMA

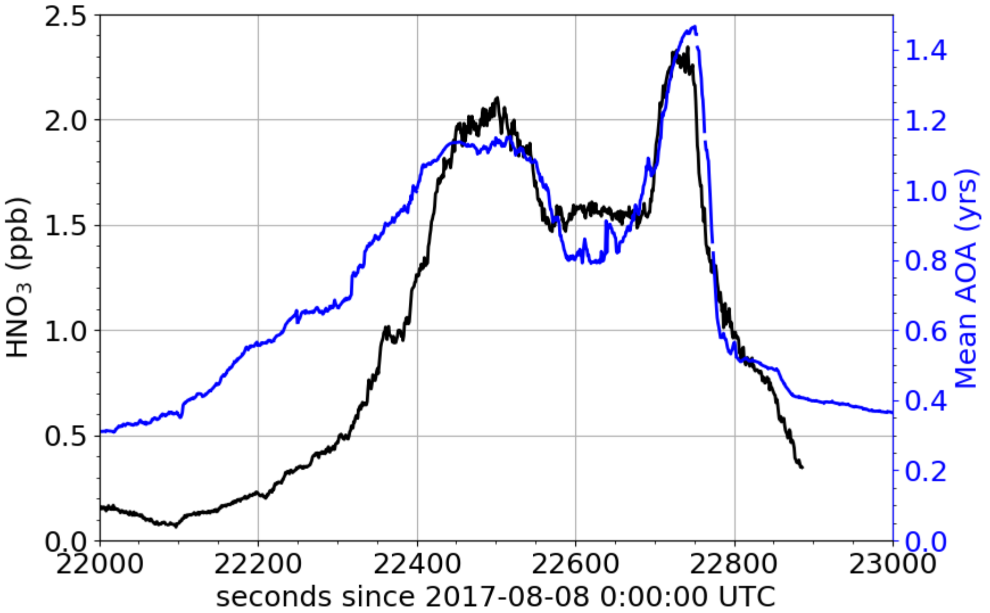
Mean Age of Air (AoA) calculations using CLaMS driven by ERA-Interim winds and total diabatic heating rates.

Mean AoA in the AMA at different isentropic levels




The green dot: location of Kathmandu. The green circle: 1000 km around Kathmandu.
White contour: potential vorticity. Grey contour: zonal wind (solid: westerly, dashed: easterly)
Flight direction: towards to the south part of the circle

Mean AoA in the high-altitude flight segment

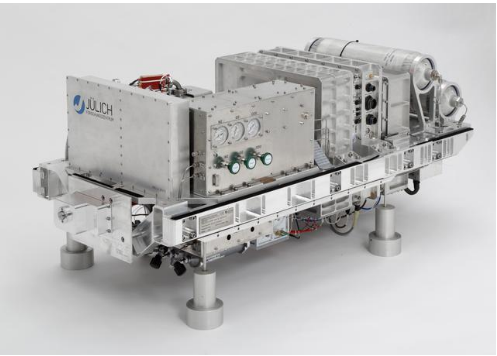


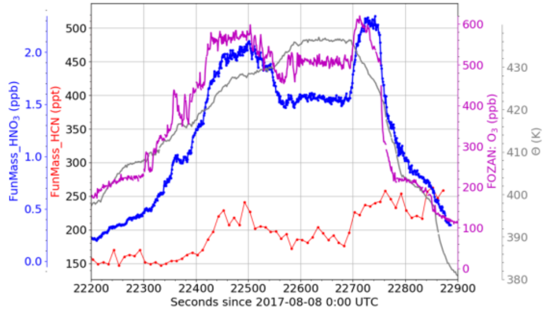

The observed filament feature could be resulted from intrusion of mid-latitude stratospheric air rich in $HNO_3$, $O_3$ and HCN into the AMA lower stratosphere.

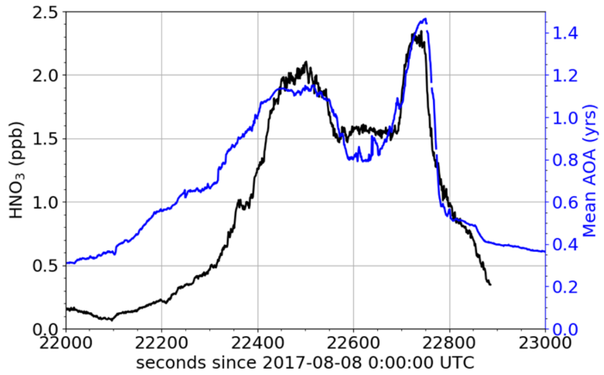
# Summary

- HCN was measured in the AMA with the $CO_3^-$ Chemical Ionization Time-of-Flight Mass Spectrometer on board of the high-altitude research aircraft M55-Geophysica, based on the Stratoclim Campaign in the summer 2017.
- An altitude profile of HCN was determined from in-situ measurement. A comparison of HCN with parallel measurements of $HNO_3$ (FunMass) and $O_3$ (FOZAN) show a positive correlation between tropospheric origin tracer HCN and stratospheric origin tracers $HNO_3$ and $O_3$ in the AMA lower stratosphere.
- A filament of enhanced HCN, $HNO_3$ and $O_3$ was observed between 420 – 430 K in the AMA lower stratosphere.
- Back-trajectory calculations conducted with CLaMS driven by ERA-Interim met. fields indicate that air masses with enhanced HCN, $HNO_3$ and $O_3$ could originate from mid-latitude stratosphere.
- Mean age of air calculations with CLaMS by ERA-Interim met. fields show an increasing trend from θ = 420 K to 440 K (covering the high-altitude flight segment) that old air from mid-latitudes intruded into the AMA. In the AMA lower stratosphere air masses were a mixture of old mid-latitude stratospheric air and younger air ascent from the anticyclone.

❖ Acknowledgement to the European Commission for funding the StratoClim project within the framework program 7 ENV. 2013.6.1-2, Grant agreement No. 603557

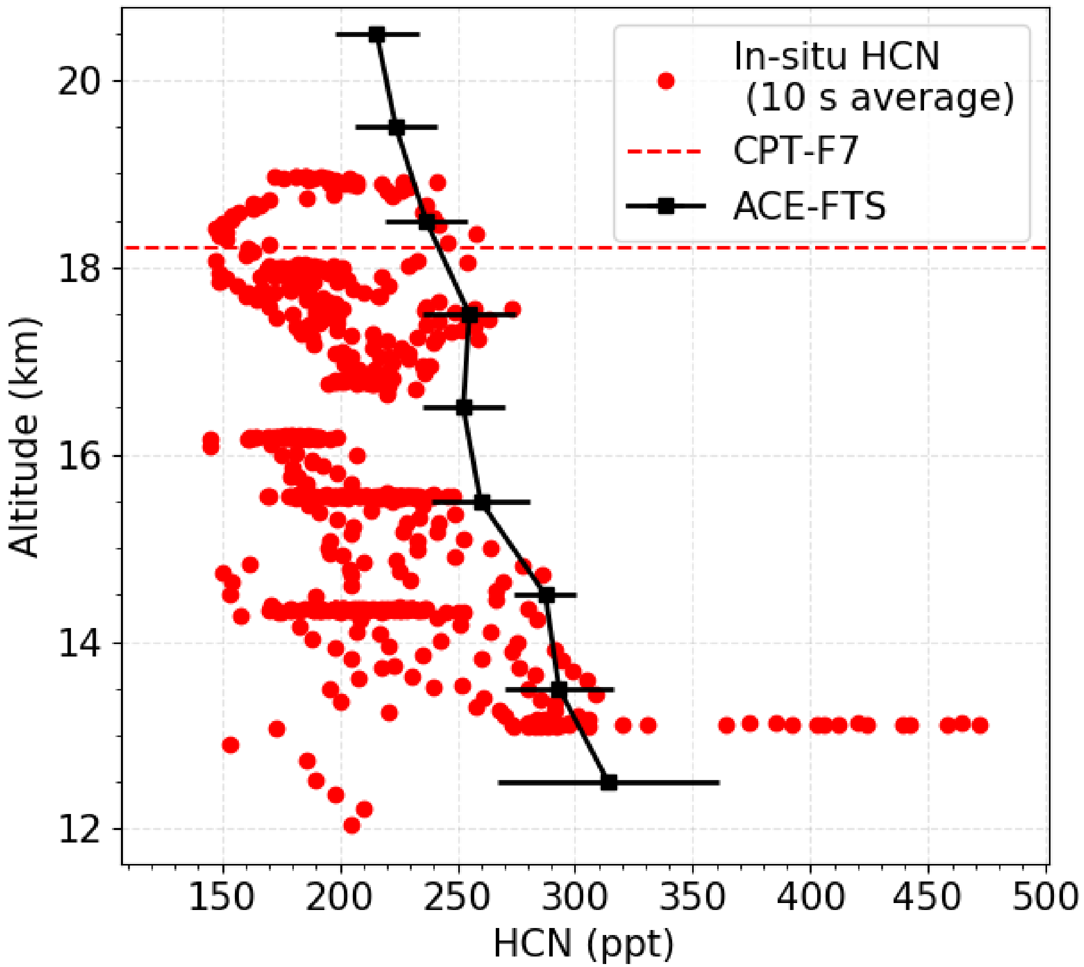


# HCN measurements

## HCN profile in comparison with ACE-FTS mean profile

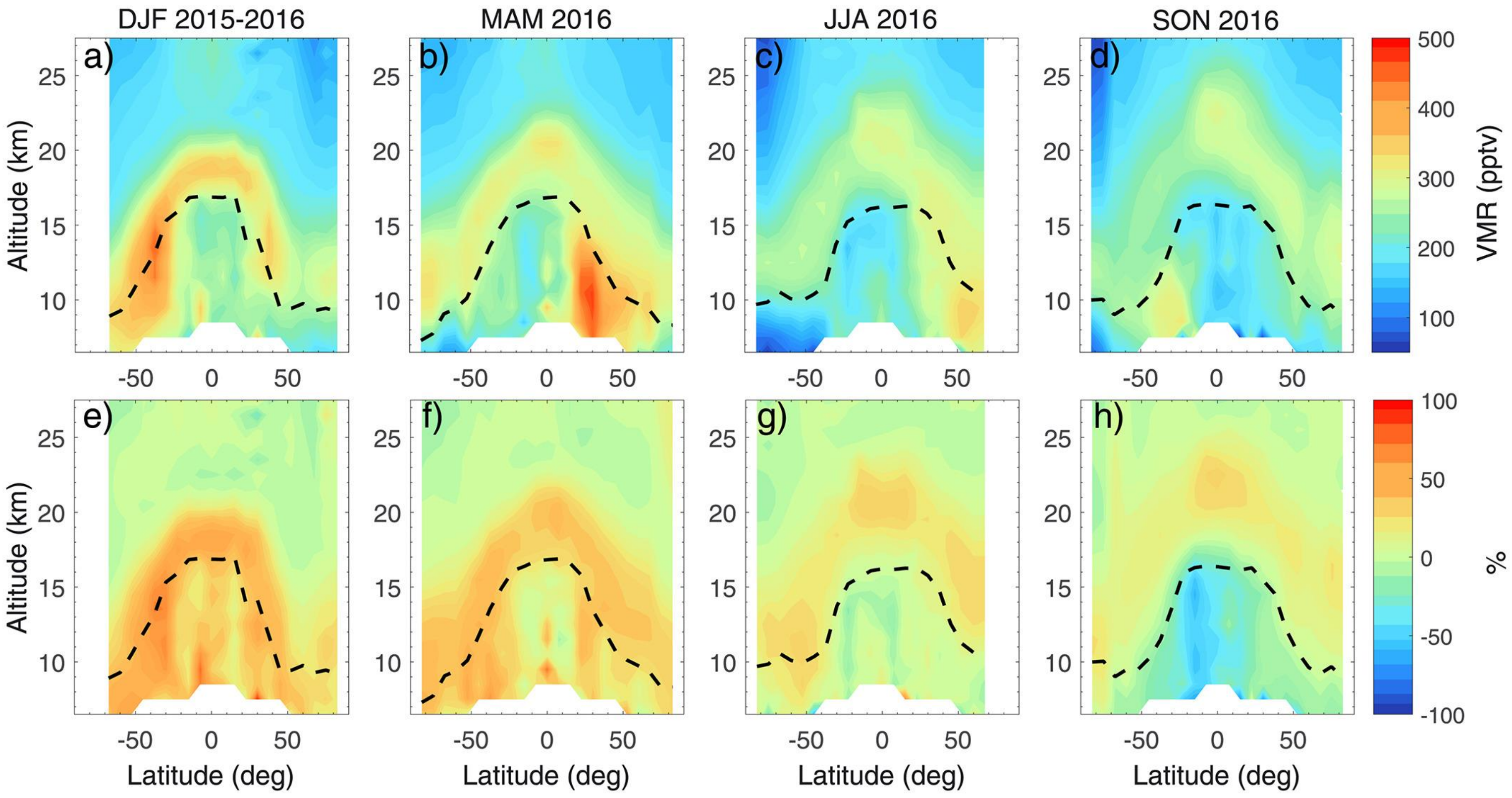



ACE-FTS Data averaging region:

15 – 35° N, 80 – 110° E from Aug. 6 – Aug. 10, 2017

* Error bars show the  mean error of HCN mixing ratio at correspoinding altitude

## **A global enhancement of HCN thoughout 2016** (Sheese et al., GRL, 2020)




(a–d) Seasonal latitudinal cross sections of zonal mean HCN profiles for Dec. 2015 to Nov. 2016.

(e–h) Latitudinal cross sections of percent deviations of seasonal zonal mean HCN from the 2004–2014 climatological means.

Data are averaged in 5° latitude and 1 km altitude bins



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