Stratospheric HCl increasing again, caused by dynamic variability, driven by increased tropospheric wave activity

J. Notholt¹, E. Mahieu², M. Palm¹, F. Pfloeger³, M. Riese³, G. Stiller⁴, M. Chipperfield⁵, and T. Reddmann⁴

¹University of Bremen, Germany
²University of Liege, Belgium
³Forschungszentrum Jülich, Germany
⁴Karlsruhe Institute of Technology, Karlsruhe, Germany
⁵University of Leeds, United Kingdom
Ground based remote sensing in the infrared spectral region

Interferogram $\rightarrow$ FT \rightarrow spectrum

FTIR spectroscopy

NDACC: Network for Detection of Atmospheric Composition Change
HCl, O_3, HCl, ClONO_2, HF, HNO_3, NO_2, CH_2O, C_2H_6, OCS, HCN, H_2O

TCCON: Total Carbon Column Observing Network
CO_2, CH_4, N_2O
Ground-based observations by the IUP
Measurements in the infrared spectral region

Intensity

1.2 1.6 2.5

Intensity

15.69 15.74
Retrieval of trace gas concentrations (total columns)

- calculate a spectrum (assumption on concentration profiles)
- residuals = measurement – simulation
- modification of assumed concentration profiles
- minimize residuals (least square method)

⇒ best fit, result for column or concentration profile

![Graph showing transmission vs. wavenumber with peaks at 1146.0, 1146.4, and 1146.8 cm⁻¹ and labels for HDO, O₃, and N₂O contributions. The graph also depicts a best fit measurement.](image-url)
**NDACC:** Network for Detection of Atmospheric Composition Change

**TCCON:** Total Carbon Column observing Network
Jungfraujoch, Switzerland (47°N, 3850 m)

Intensität

1951

Freon-12
CCl₂F₂

wavelength (μm)

Intensity

1986

(Zander, U-Liege)
Spitsbergen (79°N)
Evolution of HCl in the Earth’s atmosphere

→ What is the reason for the HCl increase?
→ Do we have to expect a new ozone hole?
Comparison with models (SLIMCAT and KASIMA)

SLIMCAT and KASIMA: Chemical Transport Models
Source gas mixing ratios: WMO A1 emission scenario
Forcing: ERA-Interim meteorological fields from ECMWF
HCl relative rates of change for eight NDACC sites

1997–2007

2007–2011

GOZCARDS: Observations by HALOE (version 19), ACE/FTS (version 2.2), Aura/MLS

→ Observed in Northern Hemisphere since 2007
Evolution of stratospheric HCl from satellite observations (GOZCARDS)

→ Occurs in lower stratosphere (~ 46 hPa, ~ 25 km)

SLIMCAT

Δ (HCl concentration) \(10^{15} \, 10^{-3}\)

Δ (Mean age) (yr)

Approximate altitude (km)

Pressure (hPa)

Latitude

Year

Mean age (yr)

79° N

47° N

45° S
Relative decadal change of zonal mean age of air for the period 2002–2012

(Pfloeger et al., JGR, 2015)
Competition between - residual Circulation and - eddy mixing
Both driven by planetary waves
More planetary waves in NH

(Pfloeger et al., JGR, 2015)
Summary and conclusions

- HCl increasing since 2007 only in NH
- increase caused by change in transport
- not clear whether natural variability or long-term trend
- competition between residual circulation and horizontal mixing
- effect on O\(_3\) unclear, needs to be investigated by models