Stratospheric lifetime ratio of CFC-11 and CFC-12 from satellite and model climatologies

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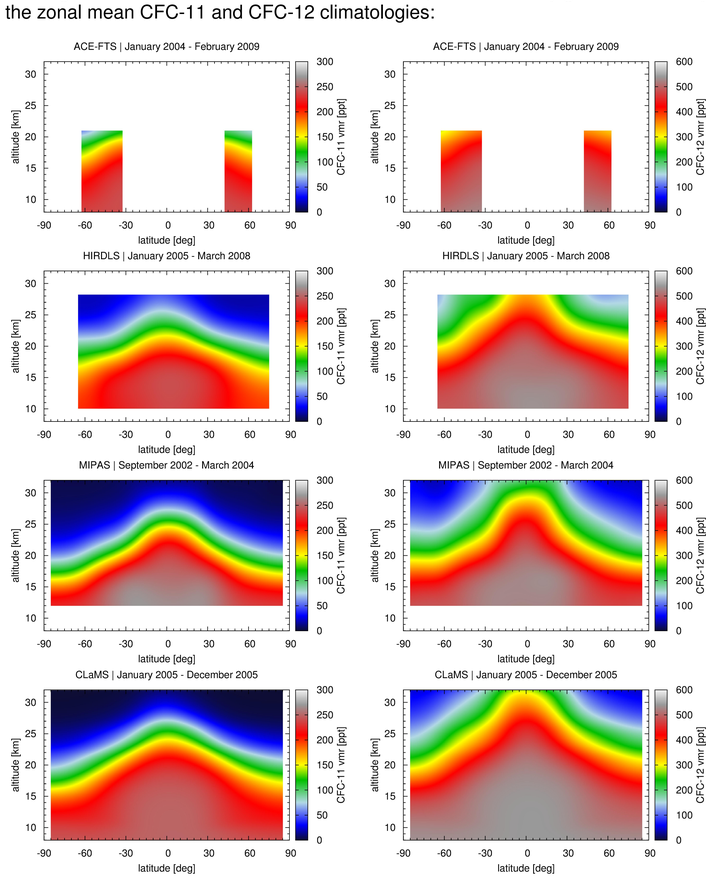
CFC-11 and CFC-12 satellite and model data

- Chlorofluorocarbons (CFCs) play a key role in stratospheric ozone loss and are strong infrared absorbers that contribute to global warming. The stratospheric lifetimes of CFCs are a measure of their stratospheric loss rates that are needed to determine global warming and ozone depletion potentials.
- We estimated the stratospheric lifetime ratio of $CFCl_3$ (CFC-11) and CF_2Cl_2 (CFC-12) from three satellite climatologies (ACE-FTS, HIRDLS, and MIPAS).
- Satellite observations were also used to validate first results from the new EMAC/CLaMS coupled model system, which integrates a Lagrangian chemistry transport model into a climate model (Hoppe et al., 2014).
- Although the data sets cover different time periods, there is mostly good consistency of the zonal mean CFC-11 and CFC-12 climatologies:



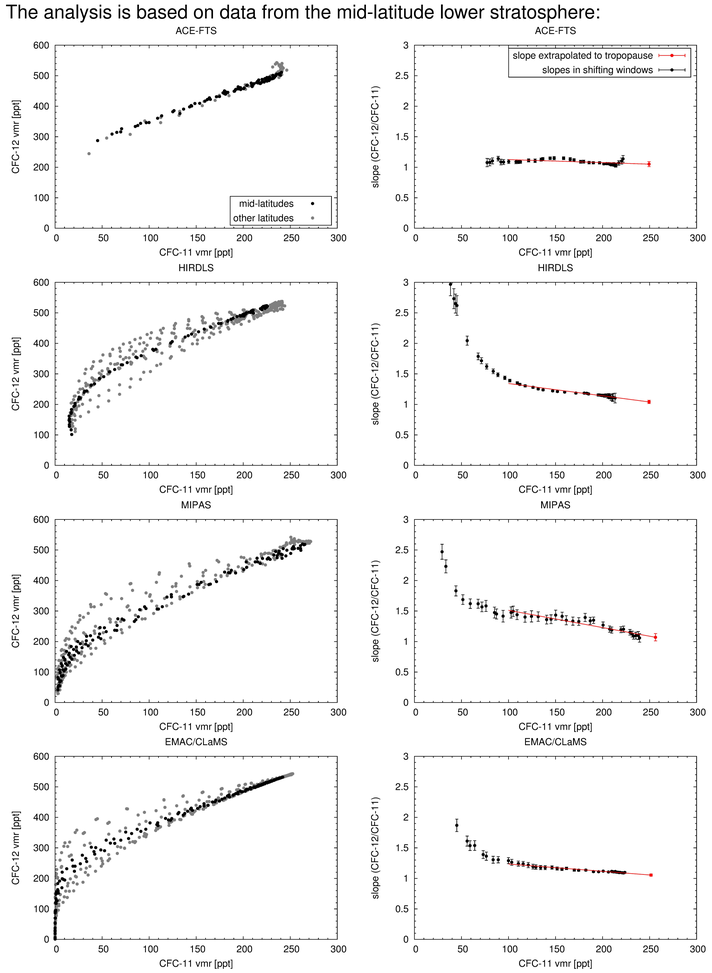
Tracer-tracer correlations and estimation of lifetime ratios

- We use the tracer-tracer approach of Plumb and Ko (1992), Plumb (1996), and Volk et al. (1997) to estimate stratospheric lifetime ratios of long-lived species.
- For any two species with local lifetimes longer than quasi-horizontal transport time scales the ratio of lifetimes is given by

$$\frac{\tau_1}{\tau_2} = \frac{B_1}{B_2}\frac{d\chi_2}{d\chi_1}\frac{C_2}{C_1}, \qquad (1)$$

with global burdens B_i (from NOAA/ESRL surface measurements), tracer-tracer slope $d\chi_2/d\chi_1$ (from the satellite and model data), and transience correction factors C_i (from Brown et al., 2013).

- The tracer-tracer slope needs to be determined very carefully to avoid systematic errors. The analysis is based on data from the mid-latitude lower stratosphere:



Comparison of CFC-11/CFC-12 lifetime ratios

- Th CFC-11/CFC-12 lifetime ratios and CFC-12 lifetimes (based on a reference lifetime of 52 yr for CFC-11) found in this study are in good agreement with other work:

Reference	Data source	Method	τ(CFC-11) [yr]	τ(CFC-12) [yr]	Ratio
this study	ACE-FTS	rel	52	112^{133}_{96}	$0.47^{0.54}_{0.39}$
	HIRDLS	rel	52	113^{134}_{97}	$0.46^{0.54}_{0.39}$
	MIPAS	rel	52	114^{136}_{98}	$0.46^{0.53}_{0.38}$
	EMAC/CLaMS	rel	52	110^{129}_{95}	$0.48^{0.55}_{0.40}$
SPARC (2013)	various	both	52^{67}_{43}	102^{122}_{88}	$0.51^{0.76}_{0.35}$
Brown et al. (2013)	ACE-FTS	rel	52	131^{161}_{110}	$0.40^{0.47}_{0.32}$
Chipperfield et al. (2014)	model results	abs	55	95	0.58
Laube et al. (2013)	aircraft data	rel	52	87^{97}_{77}	$0.60^{0.67}_{0.54}$
McGillen et al. (2013)	model results	abs	58	–	–
Minschwaner et al. (2013)	ACE-FTS	abs	46^{65}_{36}	105^{139}_{84}	$0.44^{0.77}_{0.26}$
	CLAES	abs	–	108^{140}_{88}	–
	CRISTA-1	abs	53^{75}_{41}	–	–
	CRISTA-2	abs	61^{86}_{47}	–	–
	MIPAS	abs	36^{50}_{28}	108^{151}_{83}	$0.33^{0.60}_{0.19}$
	combined	abs	45^{58}_{36}	107^{130}_{90}	$0.42^{0.64}_{0.28}$
Rigby et al. (2013)	AGAGE	abs	54^{61}_{48}	111^{132}_{95}	$0.49^{0.64}_{0.36}$
	NOAA/ESRL	abs	52^{61}_{45}	112^{136}_{95}	$0.46^{0.64}_{0.33}$
WMO (2011)	various	both	45	100	0.45
Douglass et al. (2008)	model results	abs	60^{64}_{56}	106^{110}_{101}	$0.57^{0.63}_{0.51}$
Volk et al. (1997)	aircraft data	abs	41^{53}_{29}	77^{103}_{51}	$0.53^{0.76}_{0.3}$
		rel	52	99^{112}_{87}	$0.52^{0.59}_{0.45}$

- Having smaller uncertainties than the results from several other recent studies, our estimates can help to better constrain CFC-11 and CFC-12 lifetime recommendations in future scientific studies and assessments.
- Closely reproducing the satellite data, the new EMAC/CLaMS model will likely become a useful tool to assess the impact of advective transport, mixing, and photochemistry as well as climatological variability on the stratospheric lifetimes of long-lived tracers.

References

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