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Sulfur containing species from the upper troposphere to the upper stratosphere: an overview on MIPAS measurements of SO2, COS and aerosol mass 2002-2012

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MIPAS products (2002-2012) by KIT

SO_2 volume mixing ratio profiles

- Retrieval from mean spectra: 13-45 km, monthly+zonal averages (18 profiles/month)

→ Höpfner et al., ACP, 2013

- Retrieval from single limb-scans: 8-20 km, high temporal and horizontal resolution (up to 2000 profiles/day)

→ Höpfner et al., ACP, 2015

OCS volume mixing ratio profiles

- Retrieval from single limb-scans: 8-35 km, high temporal and horizontal resolution (upto 2000 profiles/day)

→ Glatthor et al., GRL, 2015 (upper troposphere)

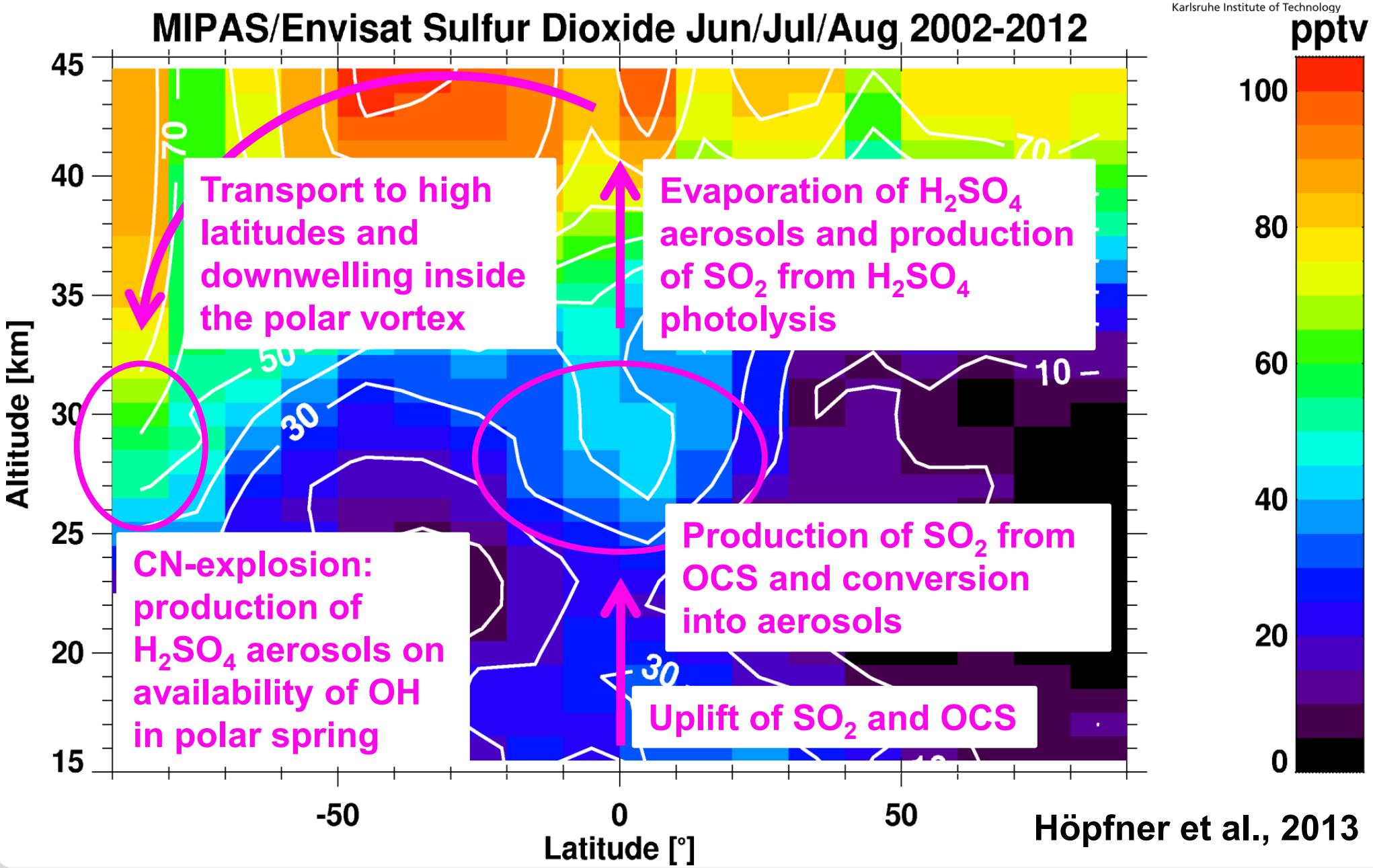
→ Glatthor et al., in prep., 2016 (stratosphere + UT biomass)

Aerosol volume density profiles

- Retrieval from single limb-scans: 8-~33 km, high temporal and horizontal resolution (up to 2000 profiles/day)

→ Günther et al., in work

First global measurements of SO_2 throughout the stratosphere



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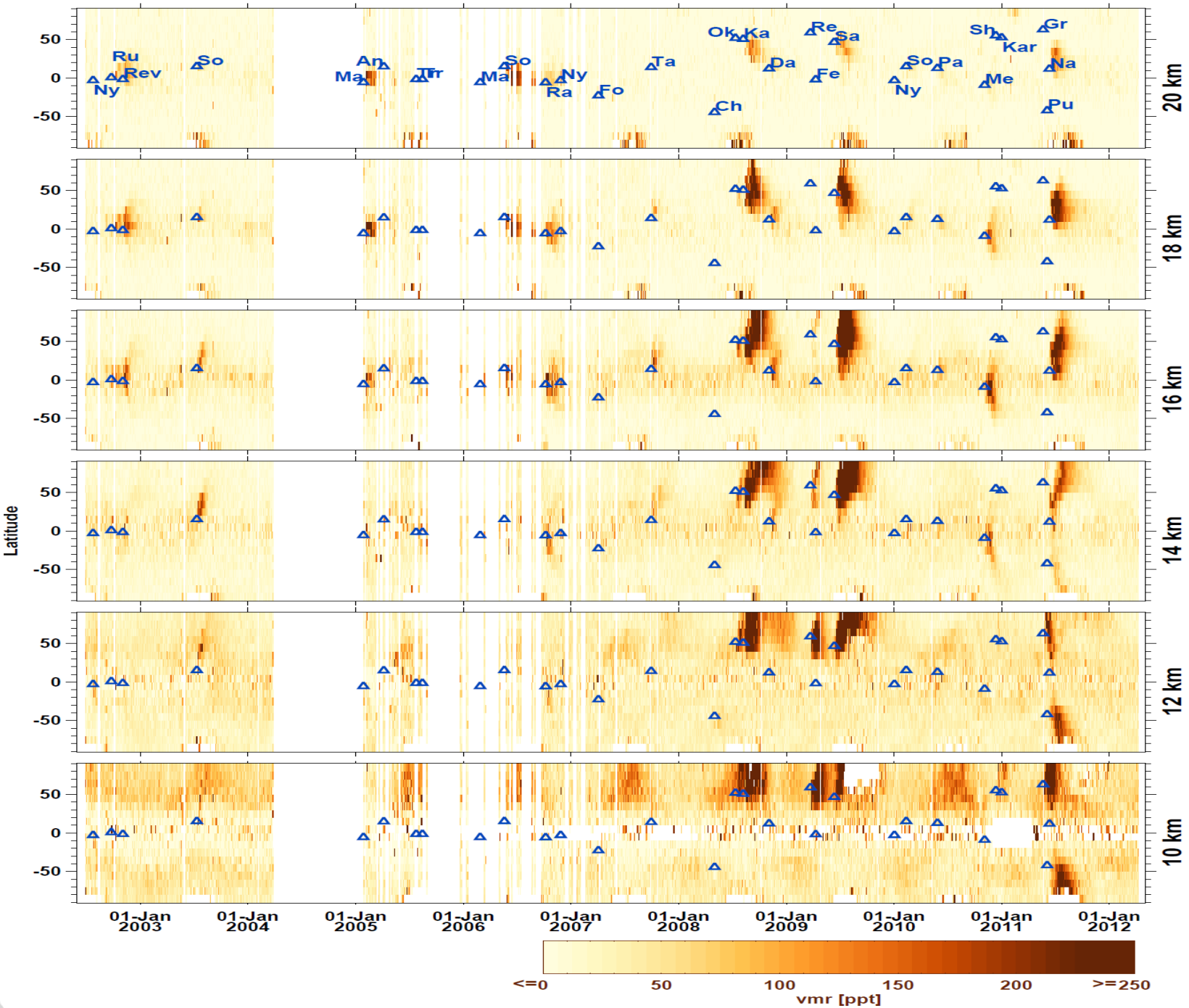

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Altitude/ latitude resolved time series:

MIPAS SO_2

Höpfner et al., 2015
Kremser et al., 2016

	Name	Eruption date	Location °N/°E	$M(t_0)$ [Gg] if present: τ [d]	$M(t_0)$ [Gg] if present: τ [d] from other sources
Ny	Nyamuragira	25 Jul 2002	−1.4/29.2	22(1)/12(1)/3(0)/**37(2)**[a]	
Ru	Ruang	25 Sep 2002	2.3/125.4	36(19)/39(9)/15(2)/**90(21)**[b]	74[1]
Rev	Reventador	3 Nov 2002	0.1/−77.7	54(47)/29(6)/12(2)/**94(47)**[b]	65–84[1]; 100[2]
So	Soufr				
Ma	Mana				
An	Anata				
Tr	Tropi				
T					
M					
S					
R					
N					
F					
T					
C					
O					
K					
D					
Re	Redoubt	23 Mar 2009	60.5/−152.7	182(10)/18(7)/–/**200(12)**[c] τ = 24(1)/22(6)/–	225–335[16]
Fe	Fernandina	10 Apr 2009	−0.4/−91.6	14(2)/11(3)/2(0)/**27(4)**[a]	
Sa	Sarychev	12 Jun 2009	48.1/153.2	888(293)/542(60)/44(4)/**1473(299)**[c] τ = 15(2)/25(1)/38(2)	1200[17]; 900[14]; 571 ± 42(> 147 hPa)[4] 1160 ± 180(> 215 hPa)[4] τ = 27 ± 2(> 147 hPa)[4]; 17 ± 3(> 215 hPa)[4]; τ = 10–11[17]; ≈10[14]
Ny	Nyamuragira	2 Jan 2010	−1.4/29.2	17(5)/3(1)/2(0)/**22(6)**[b]	
So	Soufrière Hills	11 Feb 2010	16.7/−62.2	11(3)/12(2)/5(1)/**28(4)**[b]	50[18]
Pa	Pacaya	28 May 2010	14.4/−90.6	–/10(2)/4(1)/**14(2)**[b]	20[19]
Me	Merapi	4 Nov 2010	−7.5/110.4	–/253(61)/23(7)/**276(61)**[c] τ = –/15(2)/24(7)	440[20]
Sh	Shiveluch	12 Dec 2010	56.7/161.4	18(4)/1(0)/0(0)/**20(4)**[a]	
Kar	Karymsky	1 Jan 2011	54.0/159.4	–/–/1(0)/**1(0)**[a]	
Gr	Grímsvötn	21 May 2011	64.4/−17.3	273(101)/2(0)/–/**276(101)**[a]	350–400[14]; 108 ± 11(> 215 hPa)[4]
Pu	Puyehue-Cordón Caulle	4 Jun 2011	−40.6/−72.1	185(33)/–/–/**185(33)**[c] τ = 32(3)/–/–	250[14] τ = 6.8[22]
Na	Nabro	12 Jun 2011	13.4/41.7	131(86)/343(79)/65(5)/**539(117)**[c] τ = 11(3)/23(2)/ 27(1)	1500[14]; 650(> 10 km)[21] 543 ± 45(> 147 hPa)[4] τ = 20 ± 2(> 147 hPa)[4]

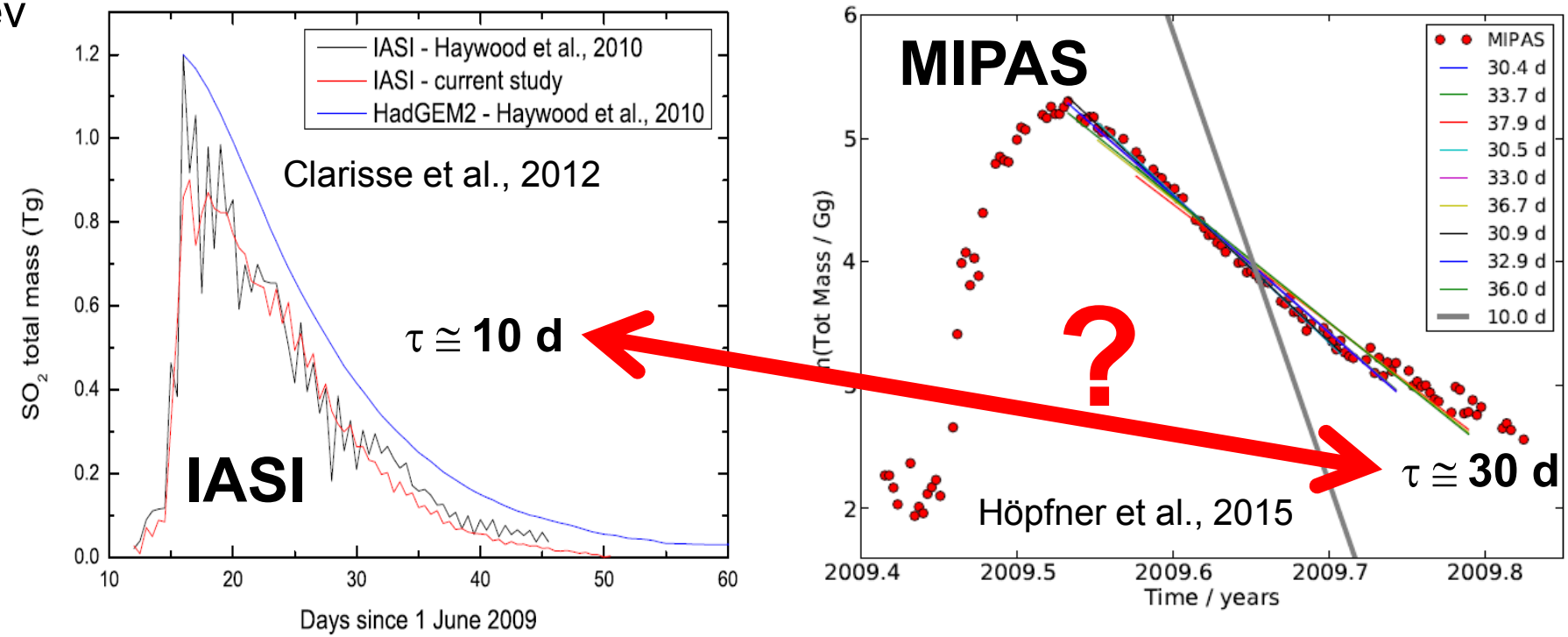
10–14/14–18/18–22/**10–22** km

888(293)/542(60)/44(4)/**1473(299)**[c]

τ = 15(2)/25(1)/38(2)

SO_2-lifetime: differences between nadir and limb

Sarychev



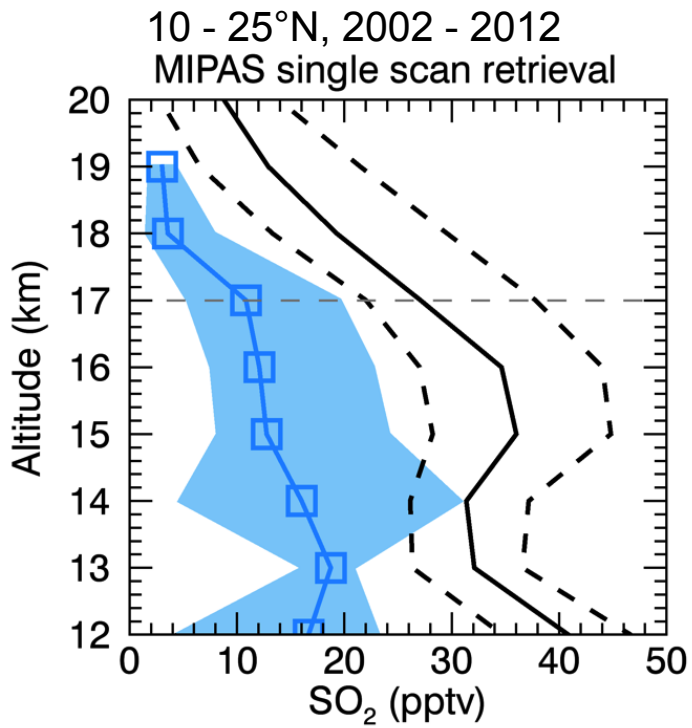
+ MIPAS results are consistent with MLS (Pumphrey et al., 2015)

Nadir sounders underestimate the lifetime of SO_2 in the UTLS:

- **Detection-limit of nadir sounders (global dillution of SO_2, Haywood et al., 2010)?**
- **Combination of lower SO_2-lifetime at lower altitudes and nadir averaging kernels?**

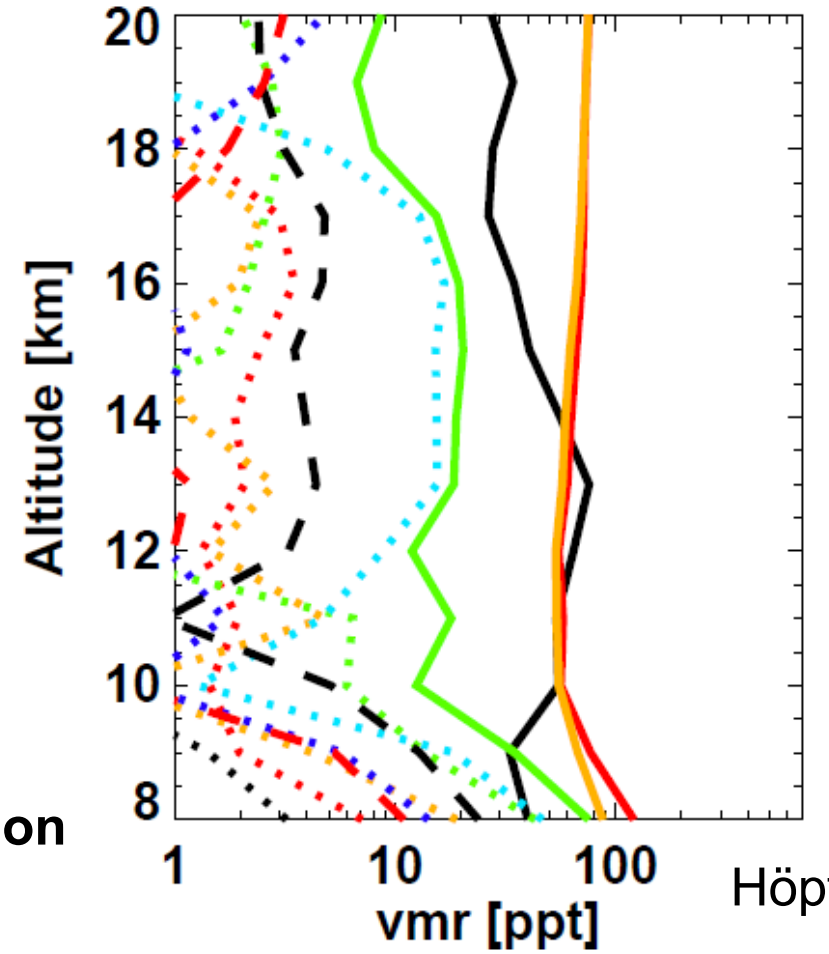
‚Features' of the SO2 dataset (1)

Bias of MIPAS (tropical) SO2 background?



Talk by Andrew Rollins et al.

MIPAS Error estimation

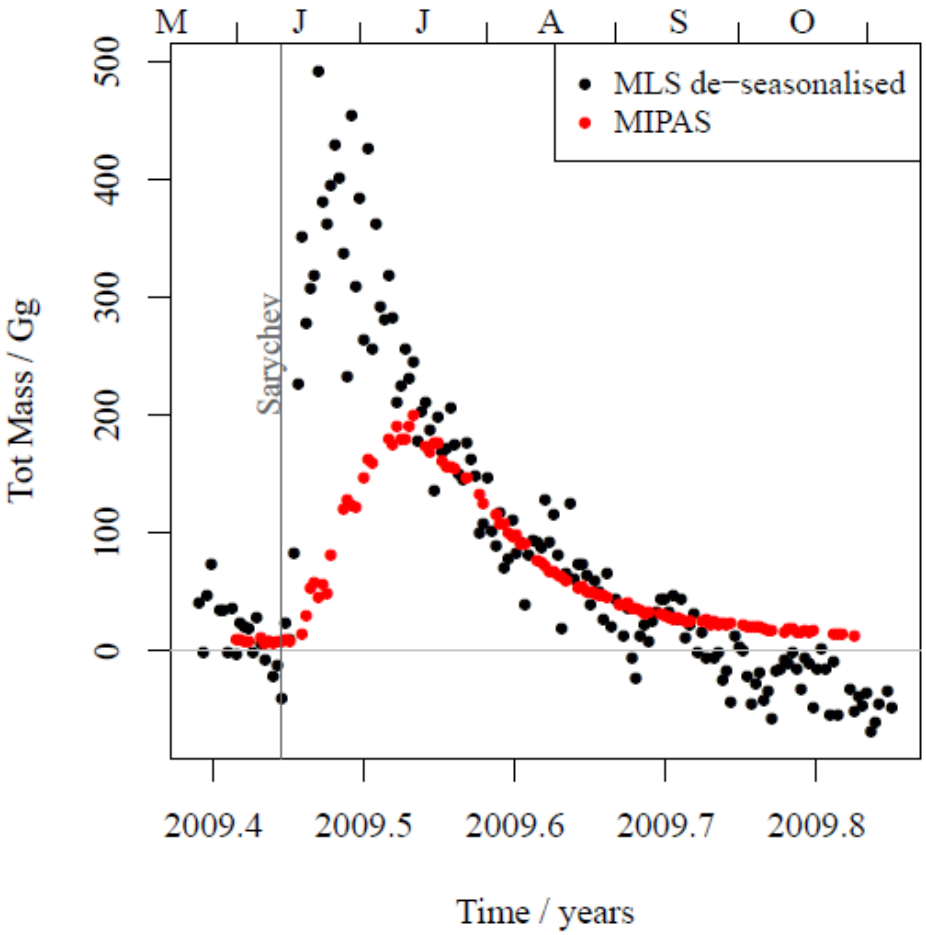


Höpfner et al., 2015

Differences within MIPAS estimation of possible systematic errors

(MIPAS might still be contaminated by smaller volcanic eruptions)

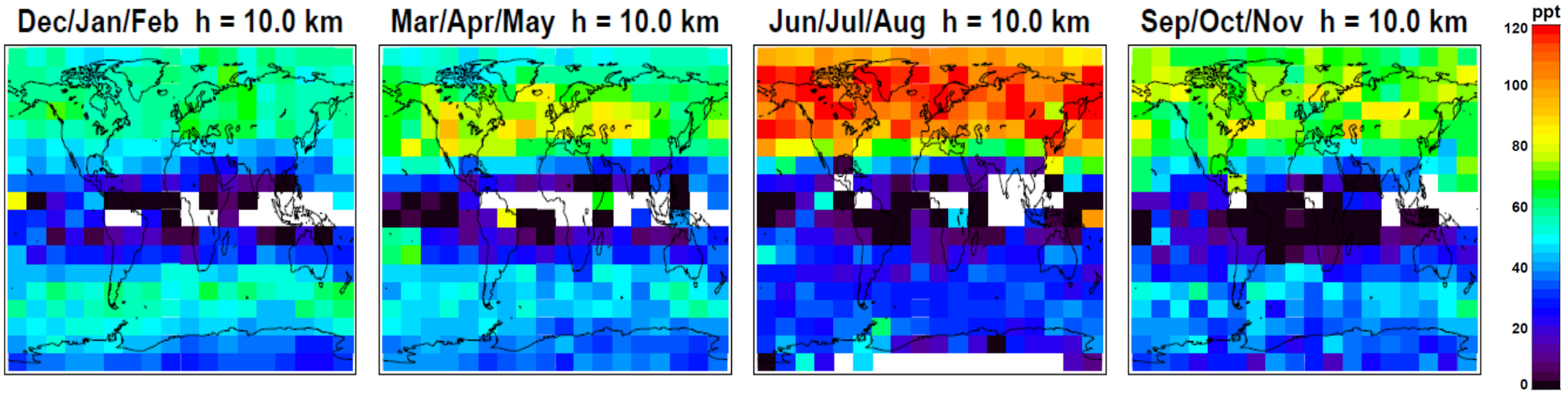
‚Features' of the SO2 dataset (2)



2-3 weeks after strong eruptions:
Underestimation of the SO2 mass

Höpfner et al., 2015

Non-volcanic SO2 background at lowest retrieval altitudes



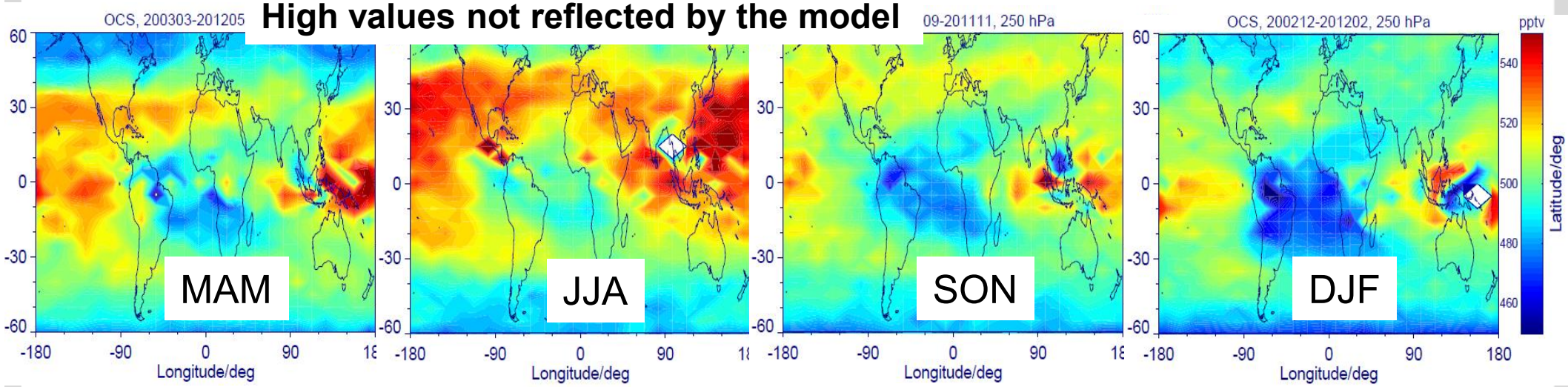
Strong annual cycle of SO2 in the mid/high latitude upper troposphere?
→ To be confirmed/refuted by independent observations

First global distributions of OCS: tropical sink

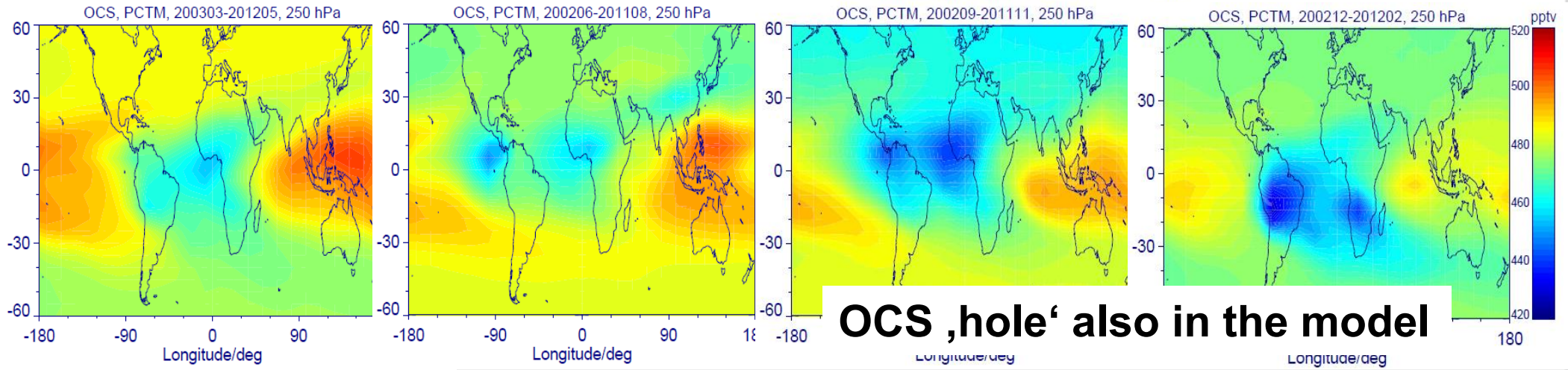
250 hPa

MIPAS measurements

High values not reflected by the model



Model: Berry et al., 2013

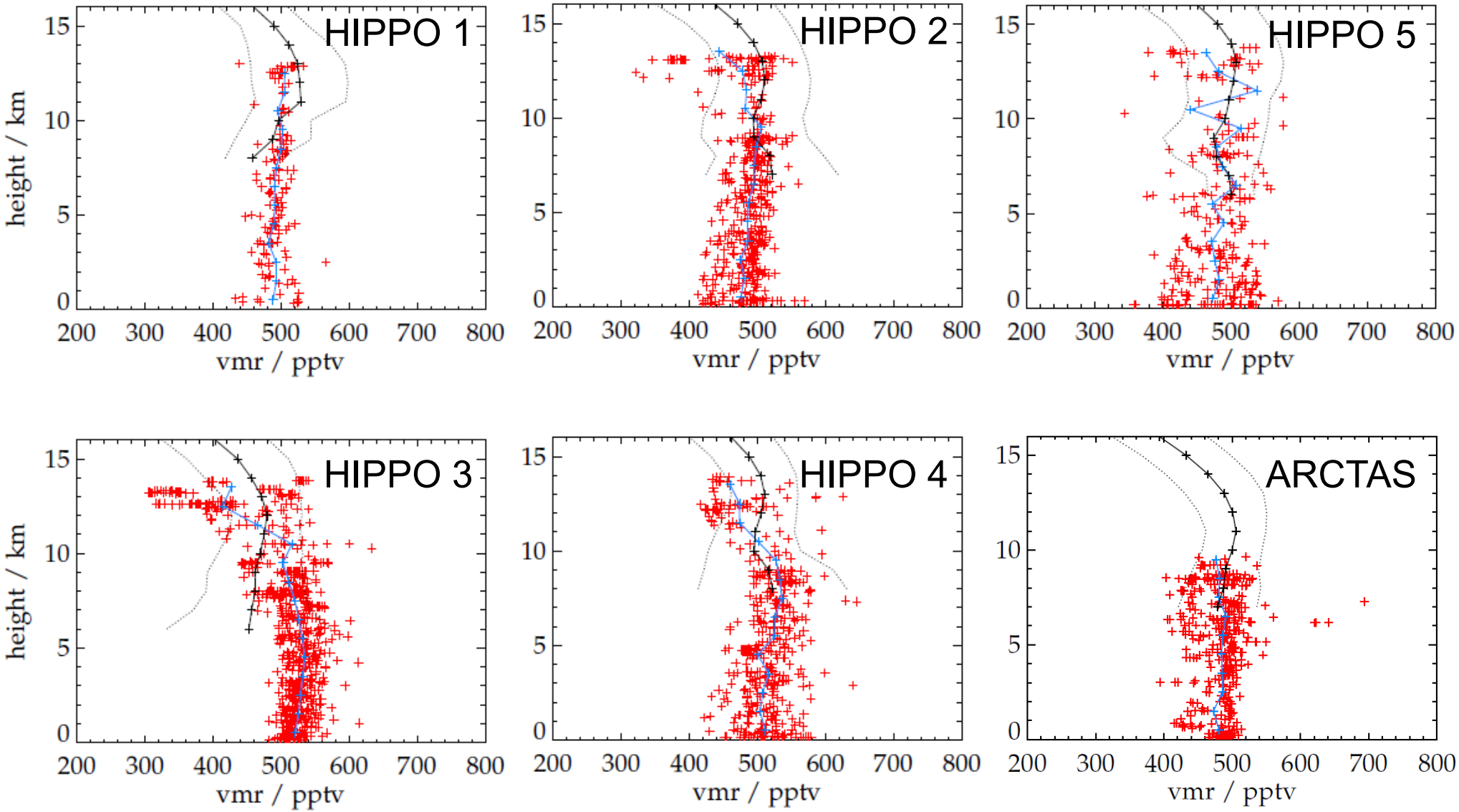


OCS ‚hole' also in the model

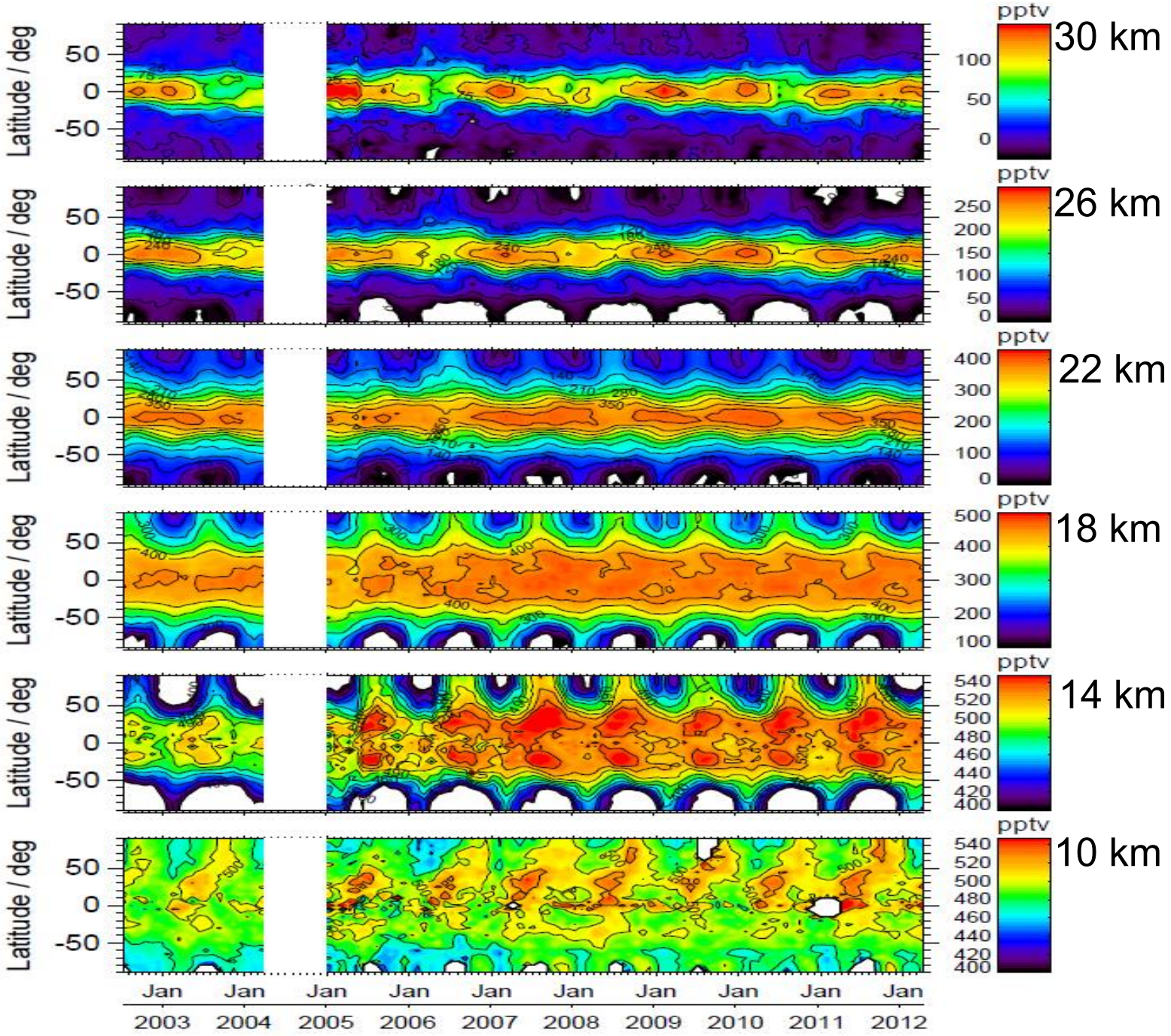
Glatthor et al., GRL, 2015

Comparison MIPAS OCS vs. airborne in-situ

black: MIPAS, red/blue: in-situ



Glatthor et al., GRL, 2015 (suppl. mat.)



MIPAS OCS time series

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Glatthor et al., in prep.

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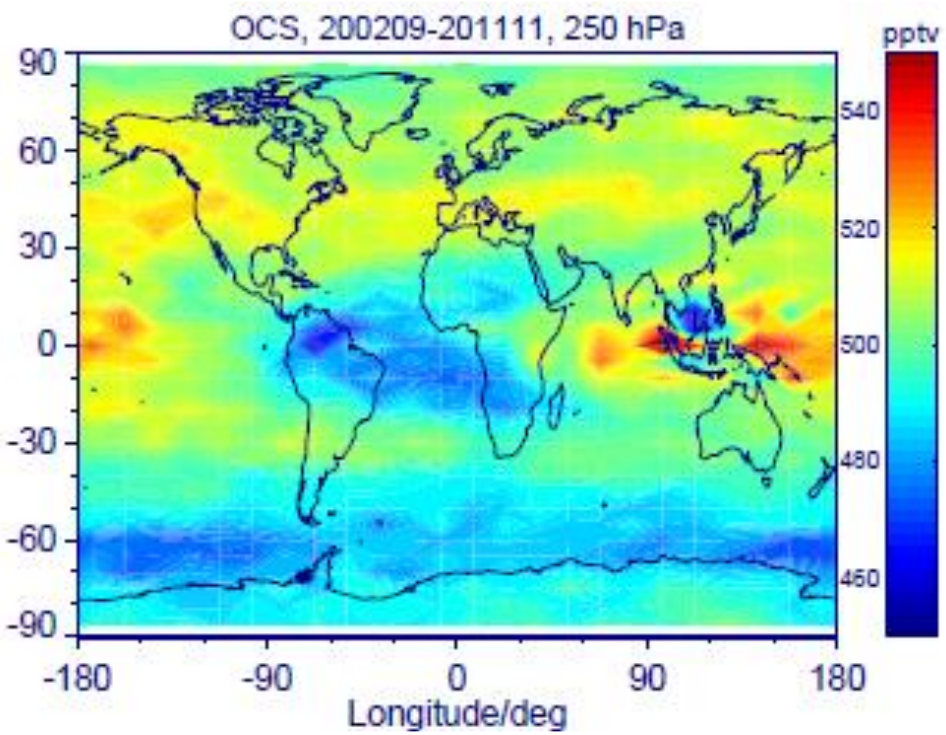
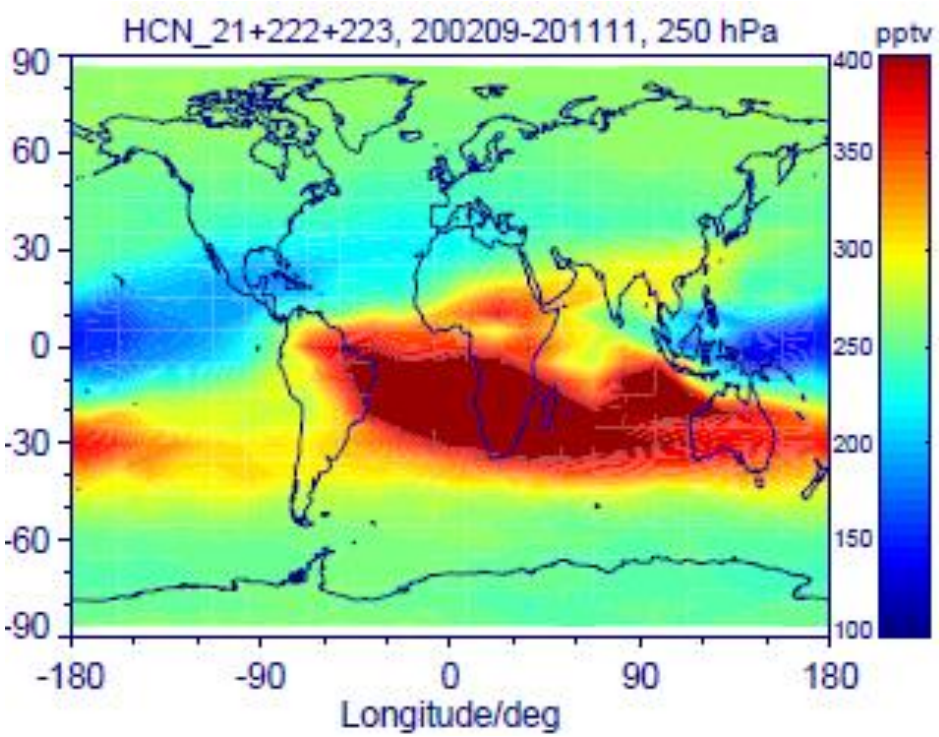
OCS source by biomass-burning

Biomass burning tracer HCN





No obvious enhancement of OCS due to biomass burning

Summary

MIPAS SO_2 (single retrievals)

- Height-resolved SO_2 masses and lifetimes for ~30 volcanic eruptions reaching stratospheric levels
- Nadir instruments seem to underestimate SO_2 lifetimes in the UTLS
- Enhanced values in monsoon regions (not shown here)
- Open data issues:
  - 10-20 ppt positive bias (background, tropics)?
  - Underestimation of SO2 mass directly after strong eruptions
  - Strong seasonal variability @10 km northern mid+high latitudes

MIPAS OCS

- First global distributions of OCS including observation of tropical sink: need of much larger vegetation uptake in models
- Strong source over W-Pacific in spring: not well captured by models
- Biomass burning cannot be identified as a strong source of OCS
- Hemispherically different stratospheric trends
- Enhanced values in monsoon regions (not shown here)

Future

- GLORIA limb-imaging instrument on HALO + Geophysika (StatoClim): direct comparison with in-situ