Total inorganic Bromine (Br_y) in the stratosphere inferred from SCIAMACHY limb measurements of BrO

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Why Br_y?

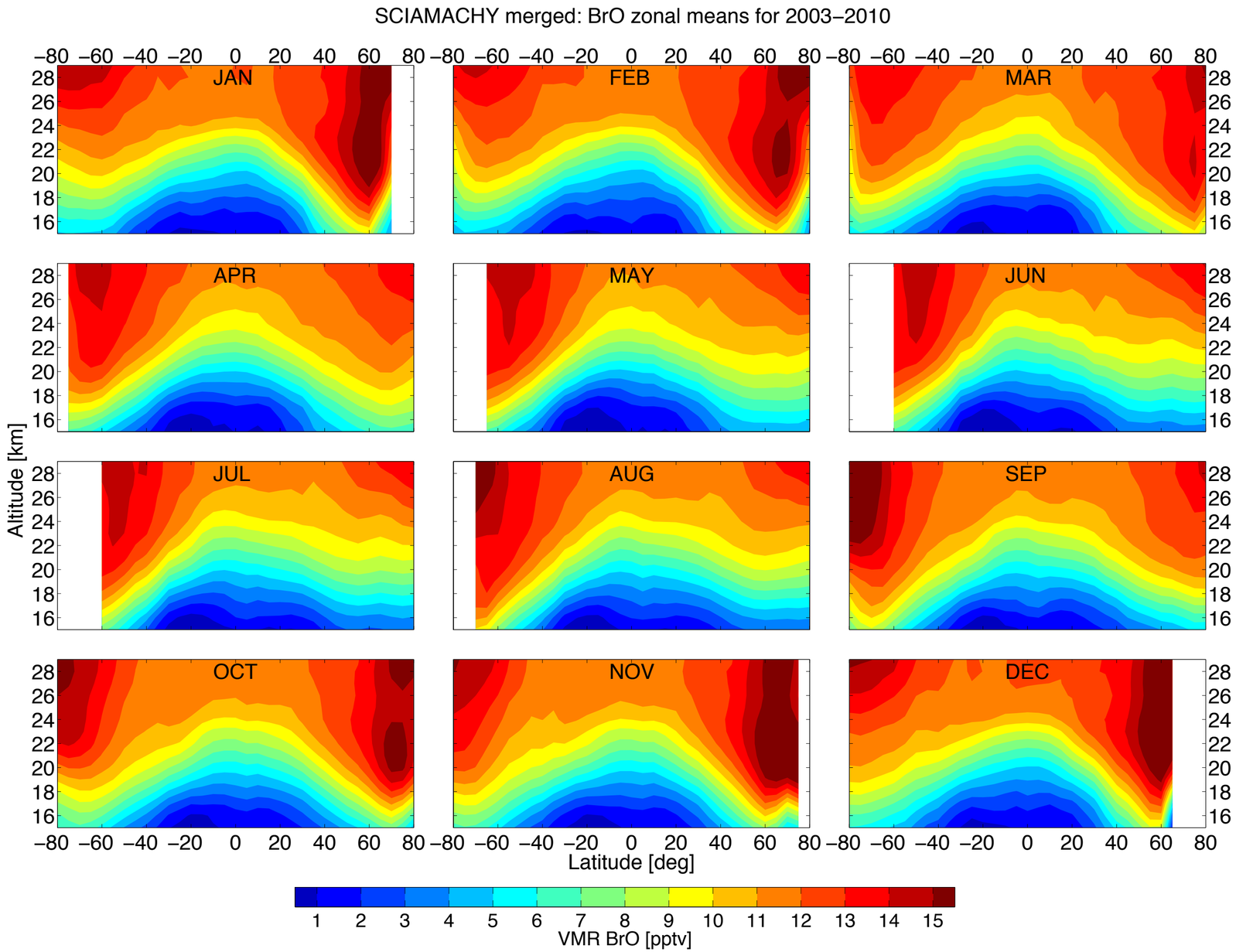
- Br plays large role in cycles destroying O_3
- Br_y budget uncertain, stratospheric abundance 15 - 25 pptv
- Emissions not fully qualified & quantified
- Contribution of VSLS to stratospheric Br budget not solved, 4 - 8 pptv

- So far two other satellite data products available:
  - AURA / MLS (e.g. Kovalenko et al., 2007; Millan et al, 2011)
  - Odin / OSIRIS, zonal mean only (e.g. McLinden et al, 2010)

SCIAMACHY Limb BrO

- BrO (O_3, NO_2) from limb available 08/2002 - 04/2012 (Rozanov et al., AMT, 2011)
- **Level 3,** gridded: lat / lon: 5° x 15° from 16 to 29 km, sampling 3.5 km (vertical resolution 3 - 5km)
- vn3.2 poleward of 40°N / S, vn3.3 in (sub-)tropics
- vn3.3 includes pointing error correction; TRUE algorithm (von Savigny et al., 2005).

SCIAMACHY Limb BrO



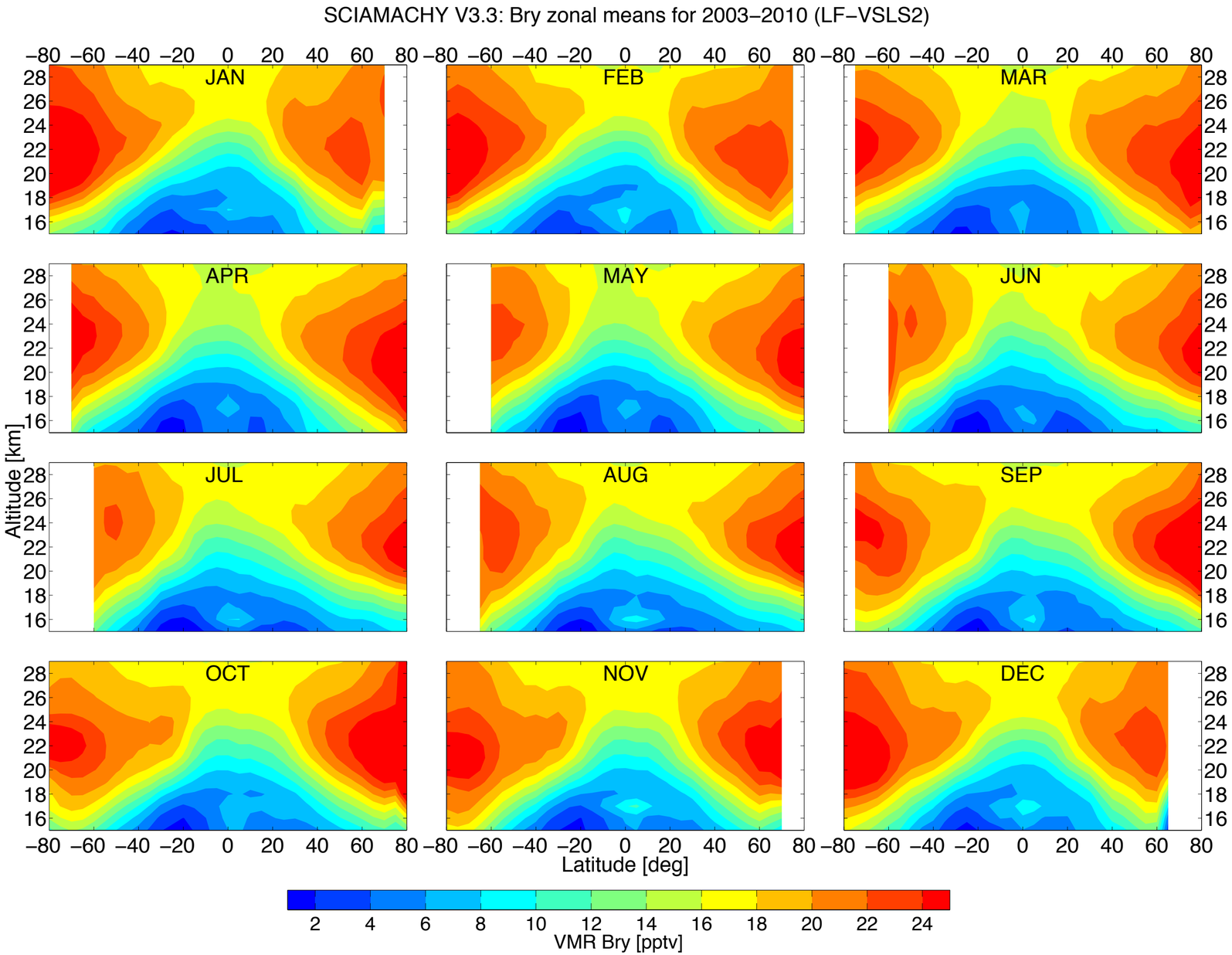
- Largest mixing ratio & highest variability in high latitudes
- Weak annual cycle in tropics
- Well validated with other retrievals (DLR, Mainz), sondes (Rozanov et al., 2011)

Inferring SCIAMACHY Br_y

Following Kovalenko et al., 2007:

$$Br_{y\ SCIAMACHY} = BrO_{\ SCIAMACHY} \cdot Br_{y\ CTM} / BrO_{\ CTM}$$

SCIAMACHY Br_y



- Minimum in tropical LS
- Maxima at mid- and high latitudes
- Pronounced annual cycle in mid- and high latitudes
- Less Br_y in winter hemispheres

➜ In contrast to BrO VMR, which is largest over poles during winter !!!!

SCIAMACHY Br_y

- Potential errors/uncertainties?
- Answer lies in understanding BrO

➡ Evaluate BrO with help of CTM against appropriate data sources

BrO Evaluation

- SCIAMACHAY limb BrO retrieval evaluated in Rozanov et al., 2011; Arctic BrO evaluated in Hommel et al. 2013 (accepted)

- CTM BrO & precursors extensively studied, e.g. in

  Sinnhuber el al., 2003; ...; Aschmann et al., 2009, 2011; Sinnhuber and Aschmann 2013; Hommel et al. 2013

  (Br chemistry, VSLS contribution, tropical uplift, Arctic vortex, ...)

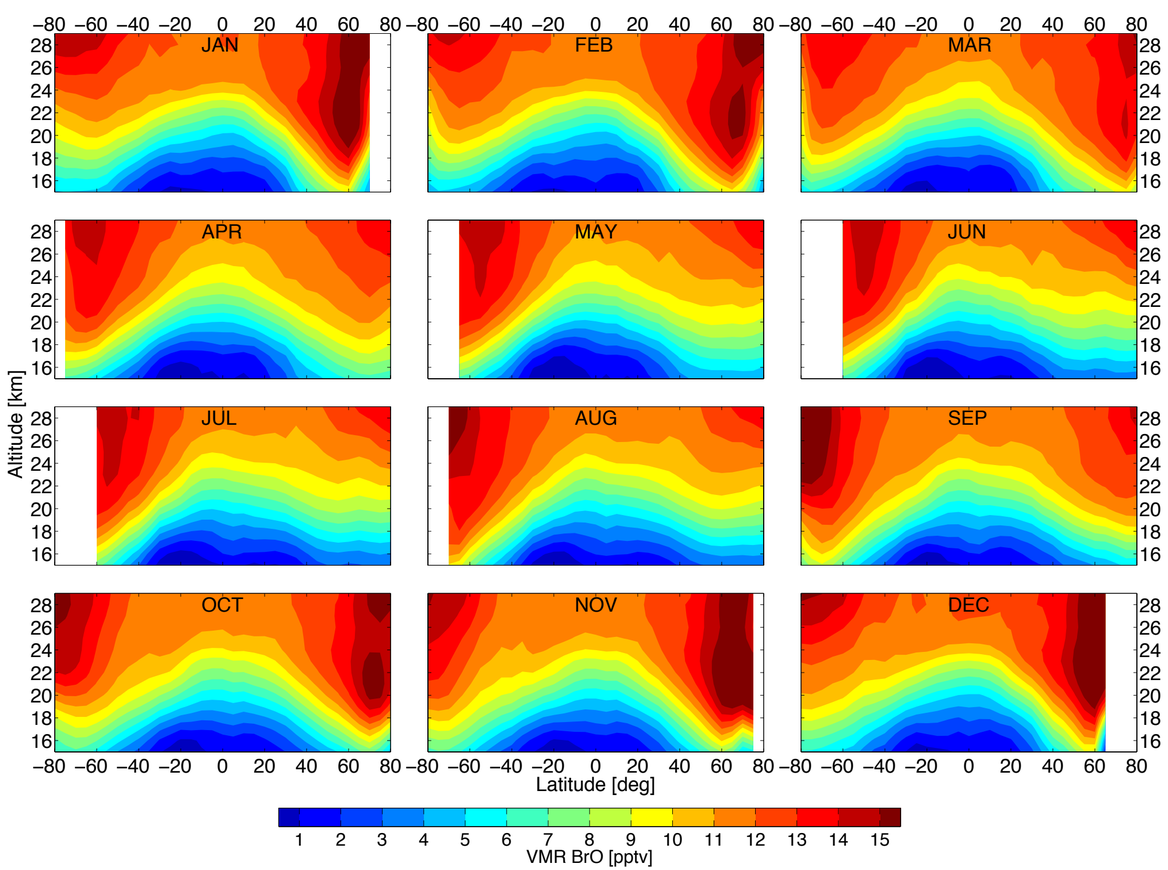
CTM

- Isentropic CTM based on SLIMCAT (Chipperfield, 1999)
- 2.5°lat / 3.75°lon, 29 theta level up to ≈1 hPa
- VSLS emissions 5 pptv as in Aschmann et al., 2011
- New climatology:
  - Initialised 1939 with perpetual 79-89 climatology ERA-Interim
  - Free running since 1979
  - ERA-Interim heating rates (all sky)

BrO Evaluation

- Pronounced annual cycle poleward of 40°N/S in SCIAMACHY (& CTM), but NOT in OSIRIS

SCIAMACHY



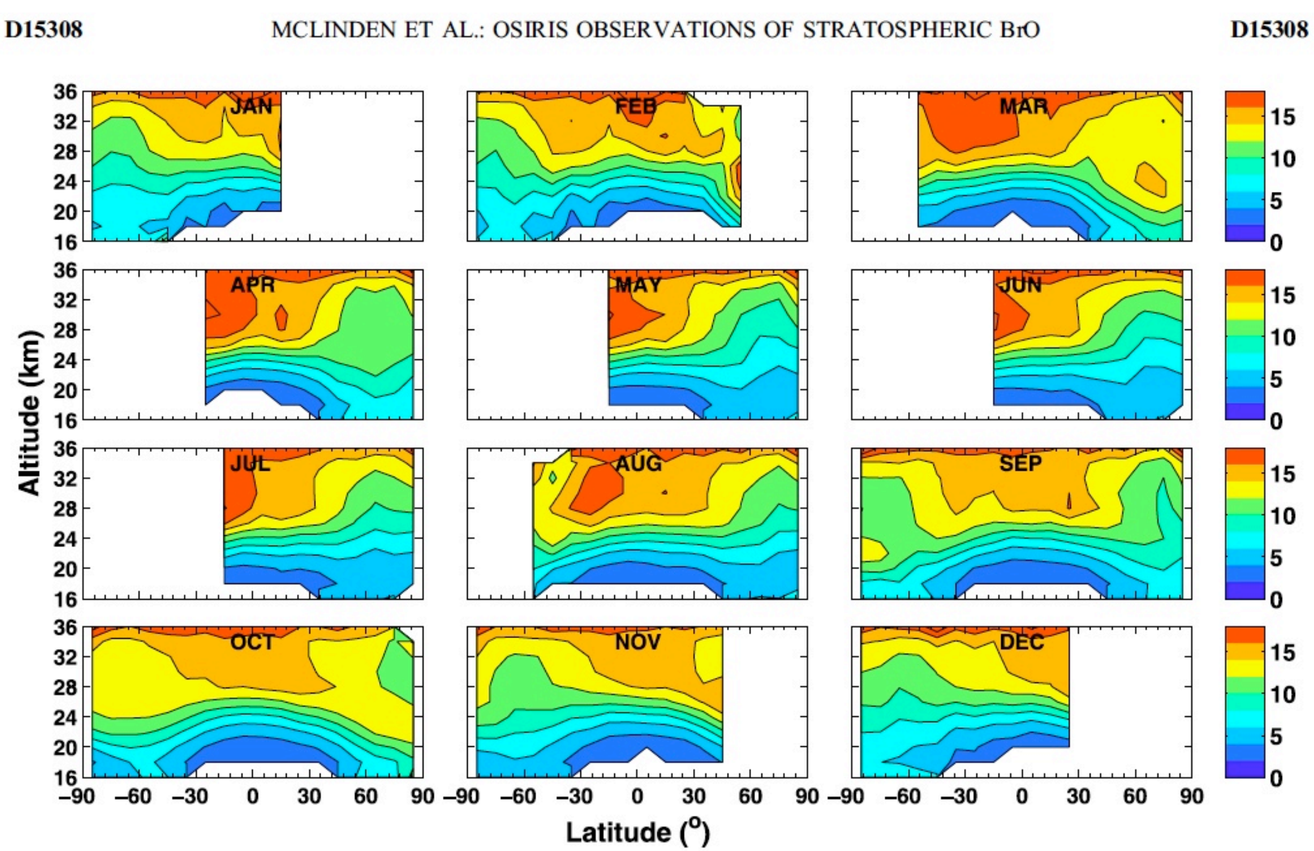
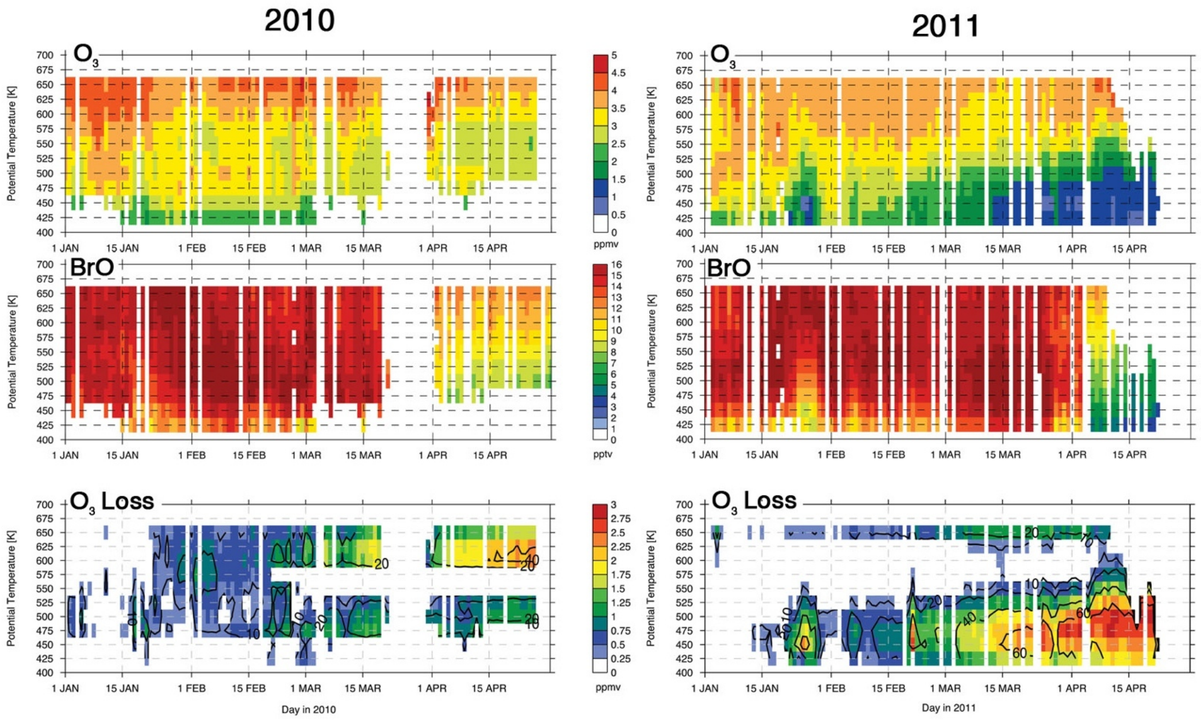


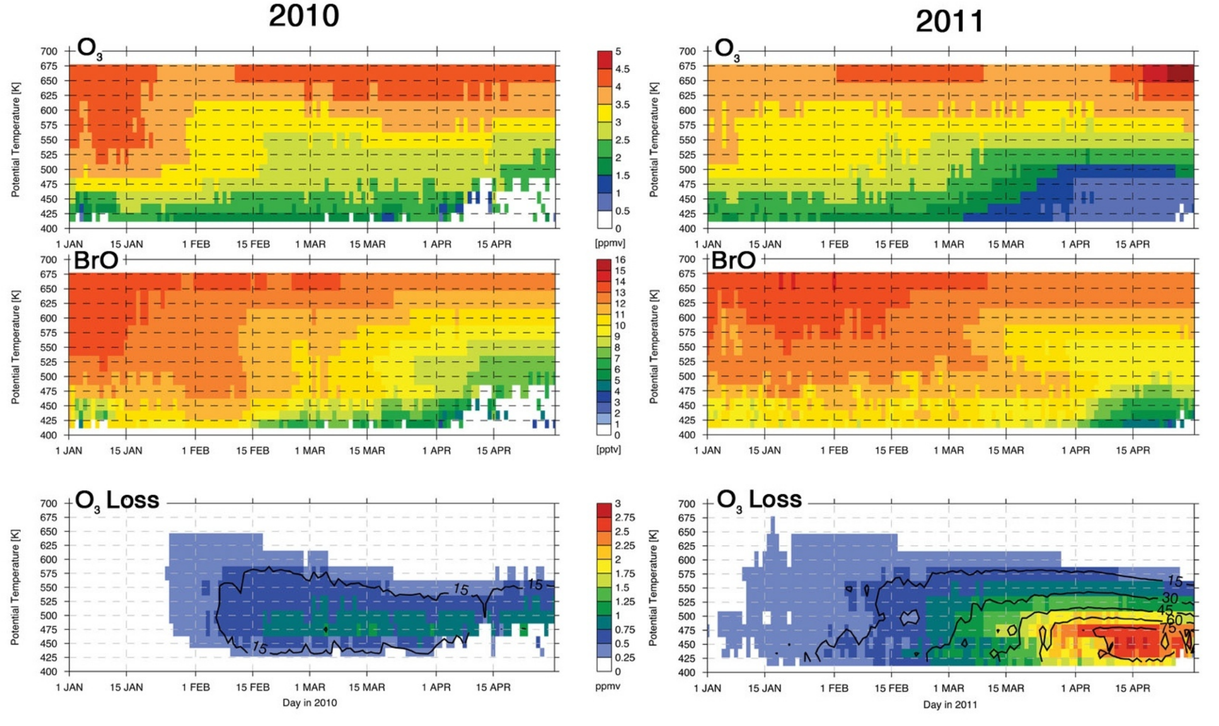
Figure 8. OSIRIS monthly mean descending node (AM) BrO mixing ratio (in pptv), averaged over November 2001 to December 2008.

BrO Evaluation

- Arctic Winter 2011: severe O_3 losses well reproduced by CTM (Hommel et al., ACPD, 2013, accepted)

➡ But: CTM shows systematic low bias in polar BrO by 2 - 4 pptv

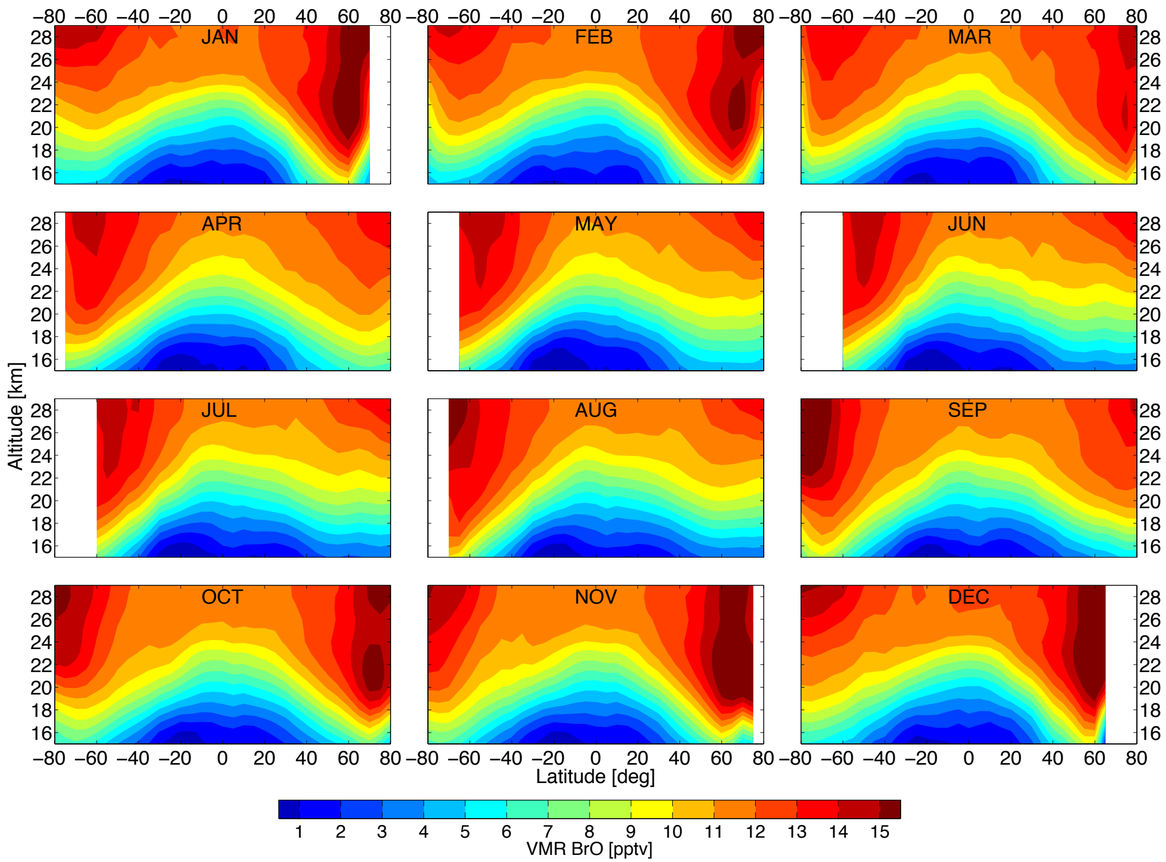




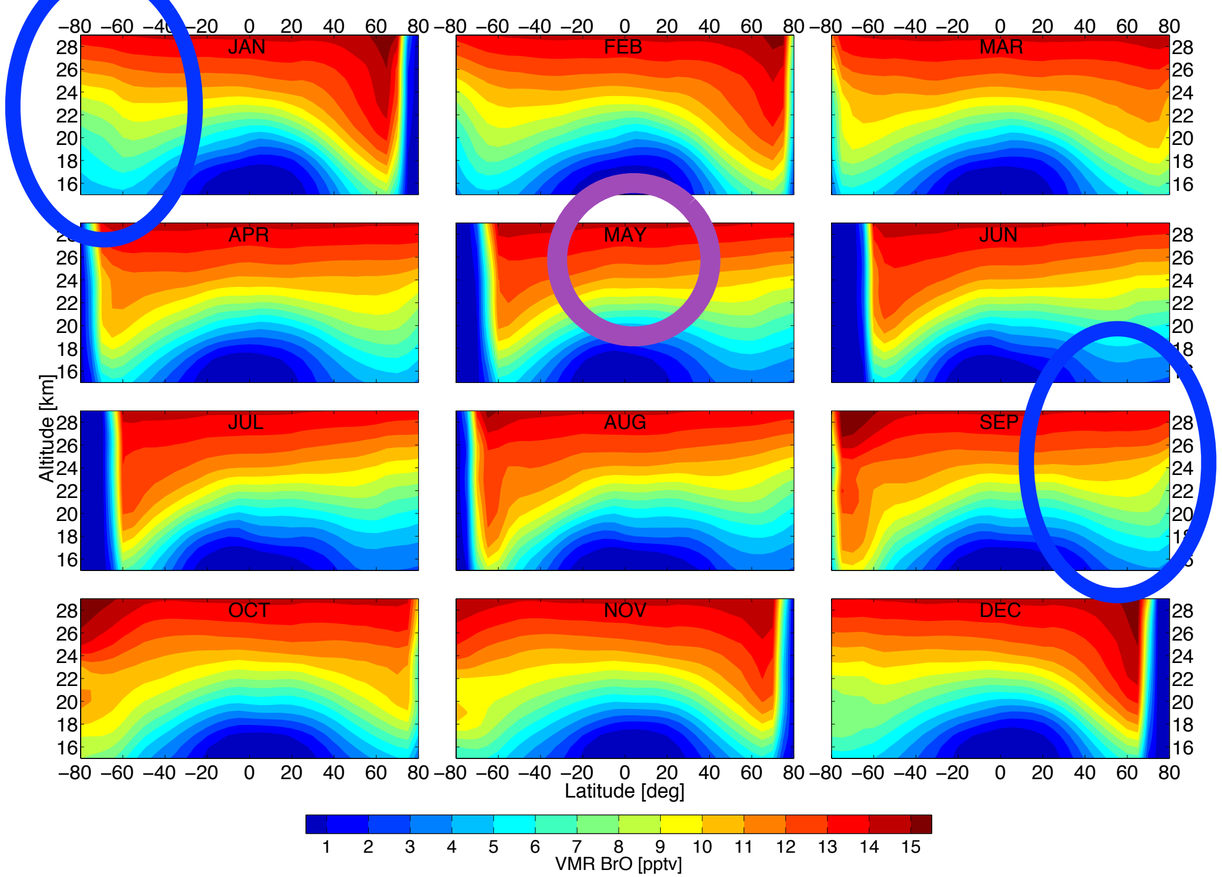
BrO Evaluation

- CTM underestimates (late) summer hemispheric BrO
- CTM overestimates BrO in tropics at higher altitudes

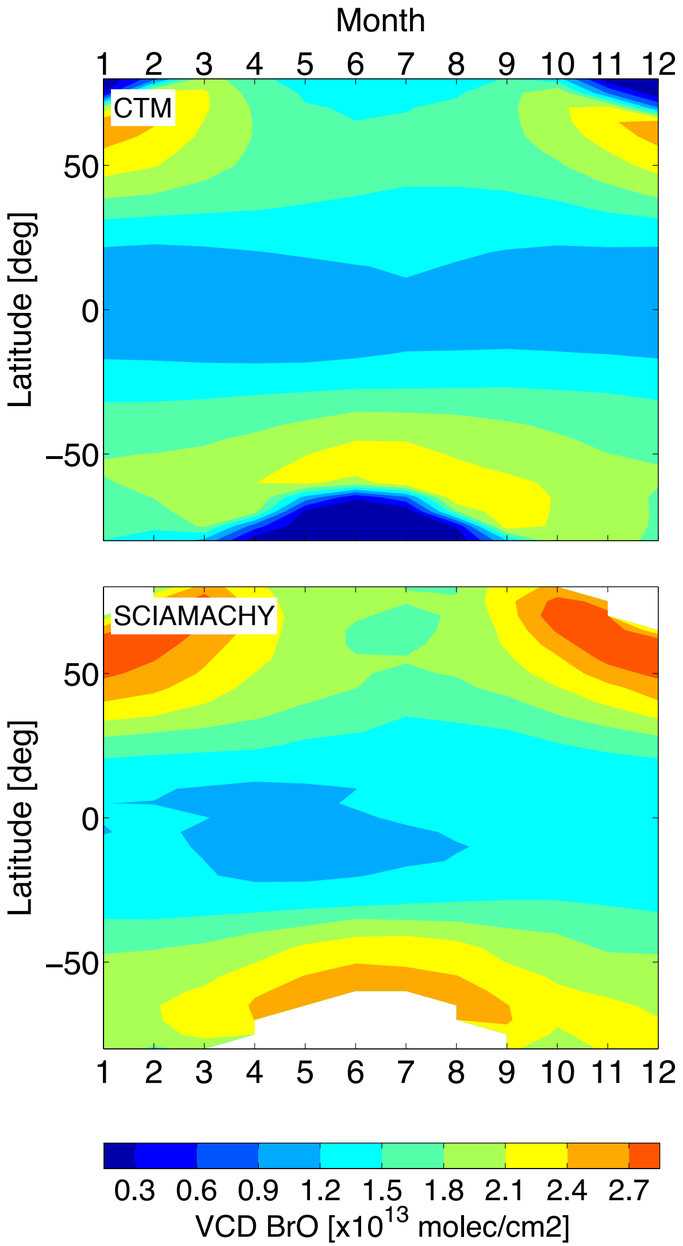
SCIAMACHY

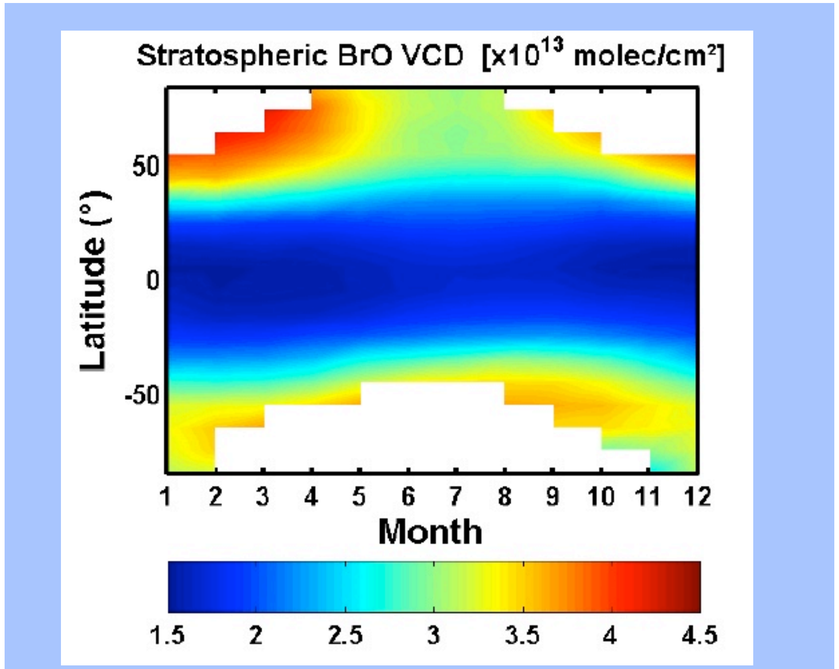


IUP Bremen CTM



BrO Evaluation





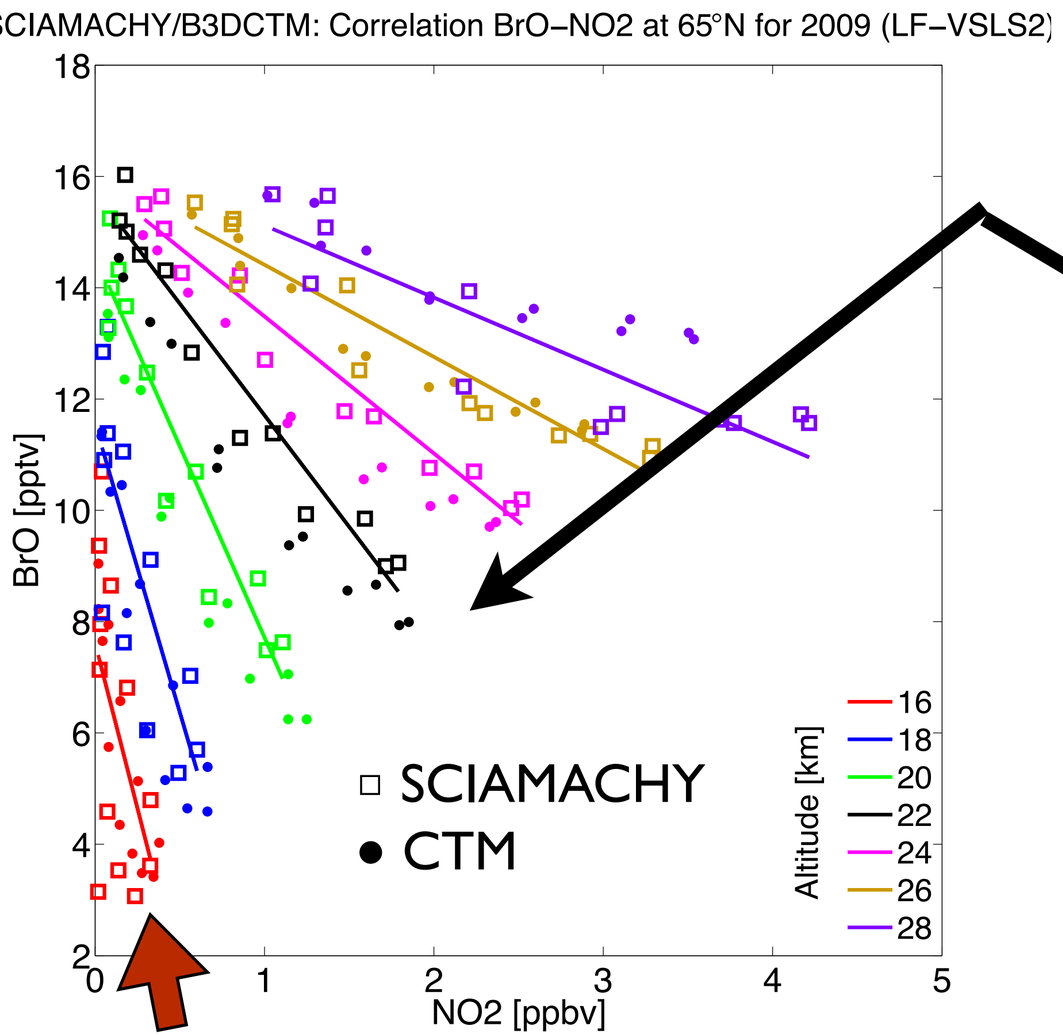
BASCOE CTM (Theys et al, 2009)

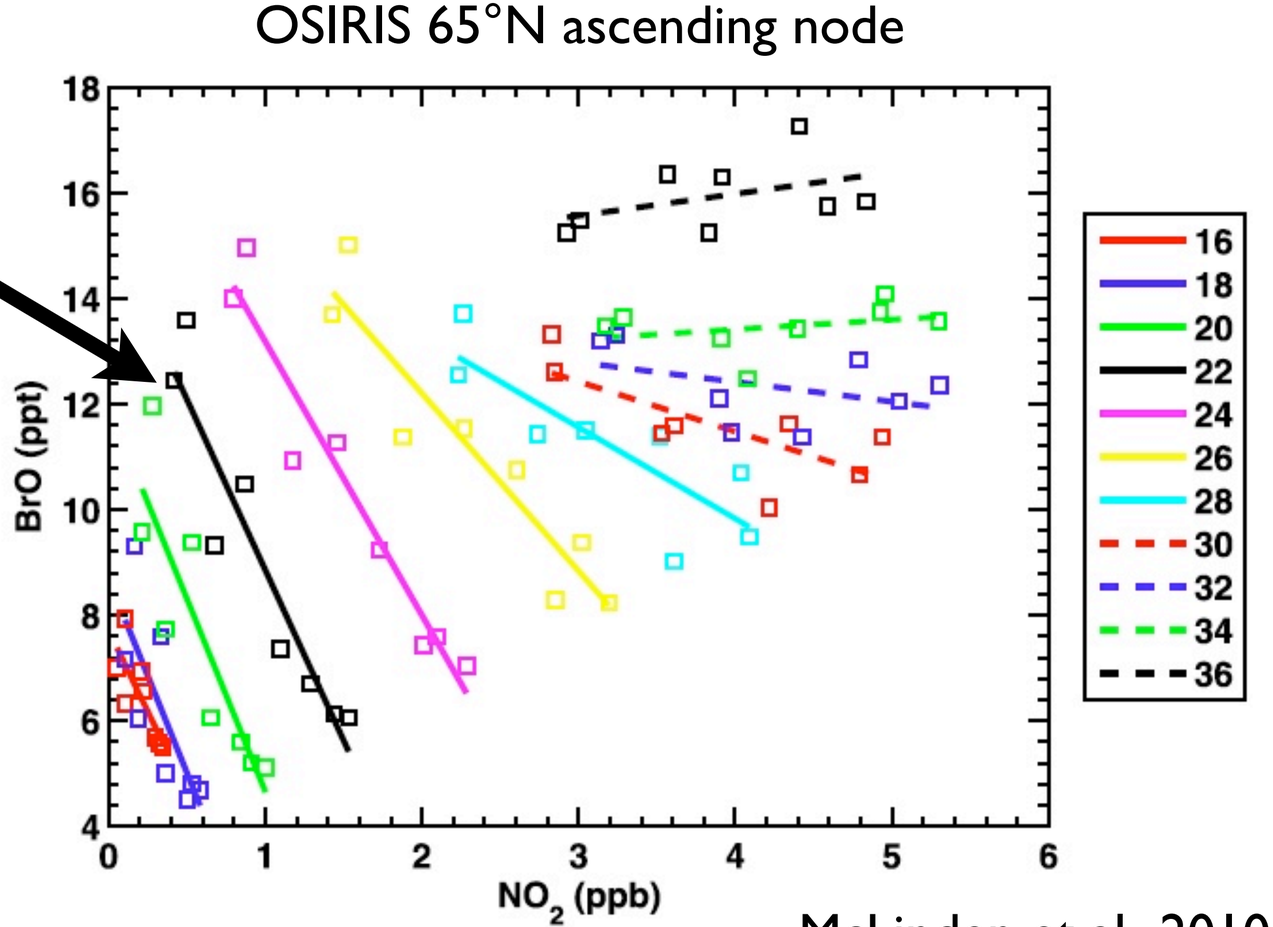
➡ Low bias in CTM BrO

- Larger BrO VCD also in BASCOE CTM
- Similar annual cycle in both CTMs

BrO - NO_2 Correlation

- SCIAMACHY & CTM show larger BrO at 65°N than OSIRIS
- NO_2 in good agreement with BASCOE CTM & SCIAMACHY limb (Bauer et al., 2012; Hilboll PhD thesis)





McLinden et al., 2010

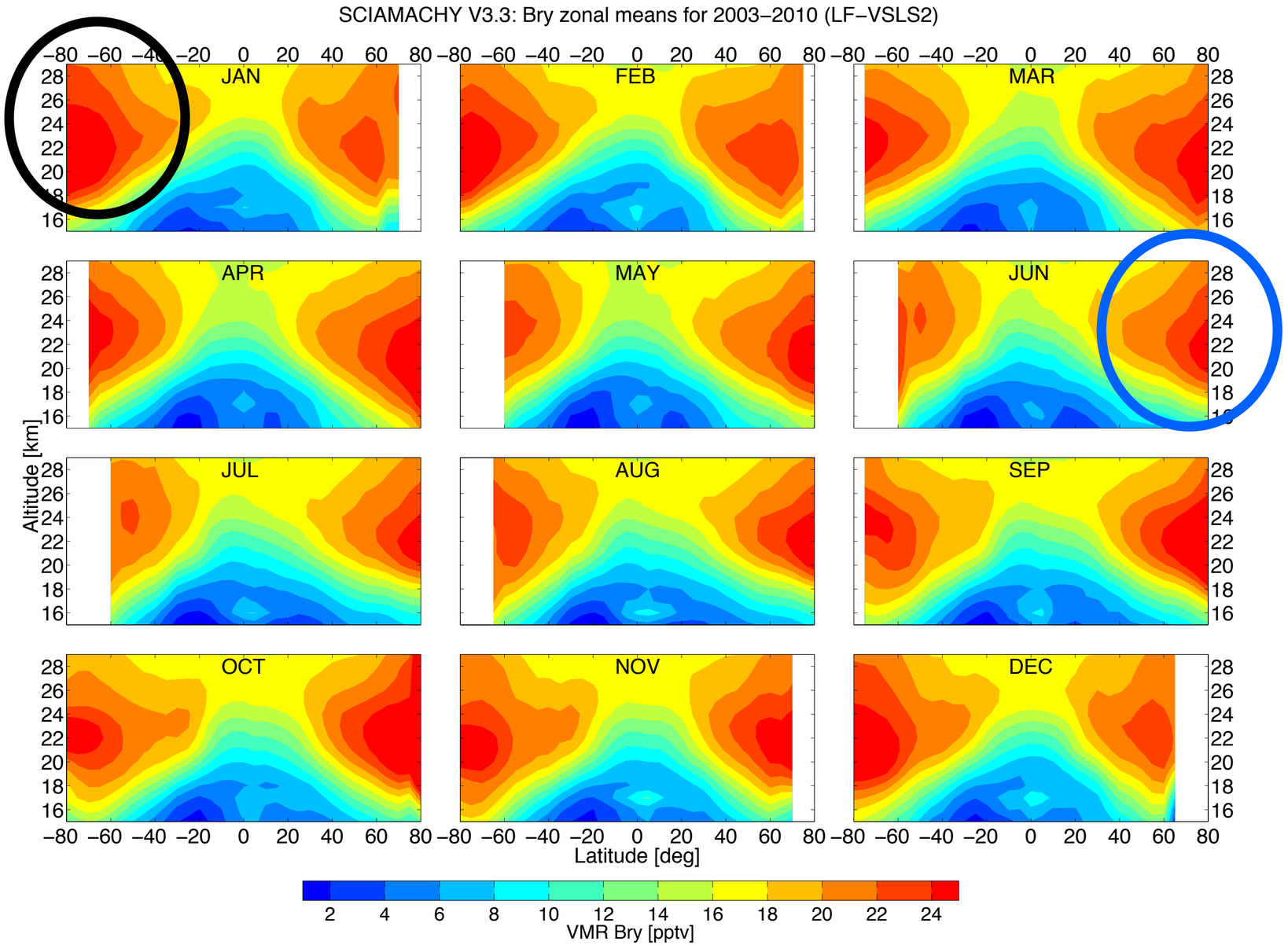
Assessing Quality Br_y SCIAMACHY

- SCIAMACHY:
  - Too low Br_y in winter hemispheres ? ... because BrO VMR is largest over poles during winter
  - Or do we infer too much Br_y in summer ? ... because extratropical BrO is low during summer
- CTM, that determines the scaling factor:
  - meridional gradient weak in summer hemisphere → BrO underestimated in summer

→ Leads to conclusion, $Br_{y\ SCIAMACHY}$ is rather biased high in summer in mid- & high latitudes

... instead of being low in winter (as suggested at the beginning)

Assessing Quality Br_y SCIAMACHY



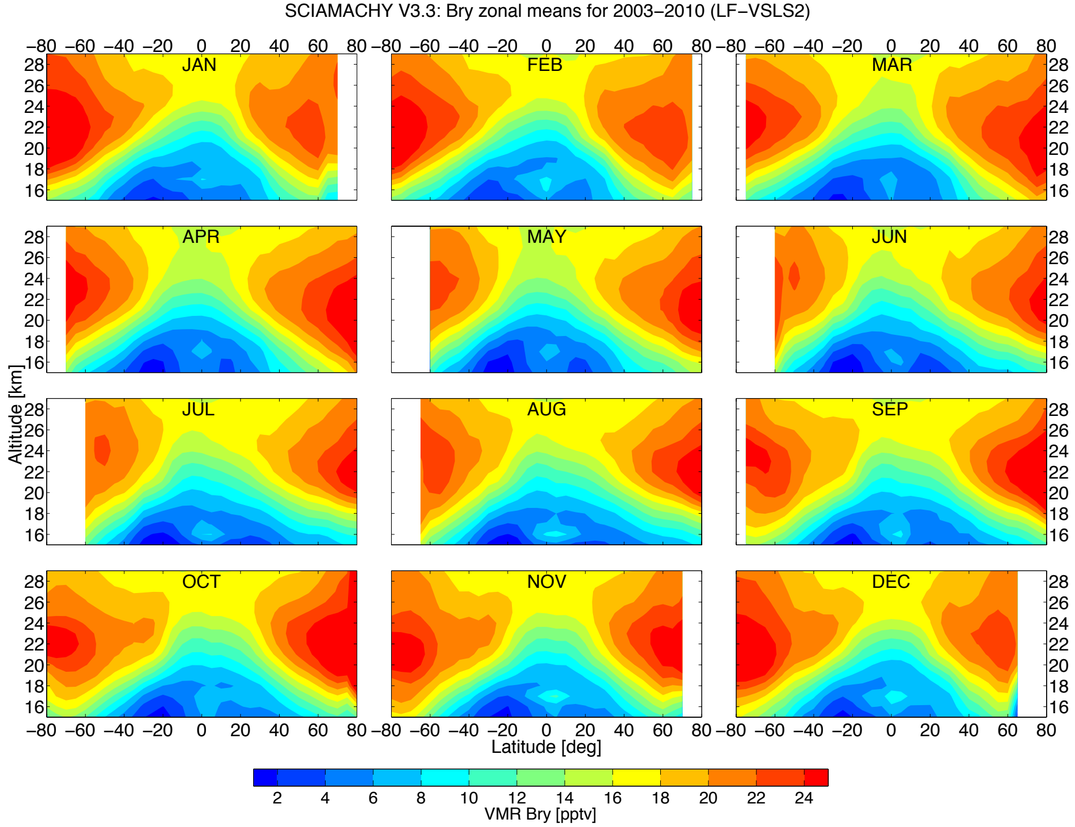
➔ Br_y in winter hemispheres <u>not</u> underestimated

➔ overestimation of SCIAMACHY Br_y in mid-, high latitudes during summer by 5 - 10 pptv

Br_y Comparison to OSIRIS

- SCIAMACHY Br_y minimum in tropics !

  ... because BrO weak annual cycle in tropics & pronounced annual cycle poleward of 40°N/S (SCIAMACHY & models)



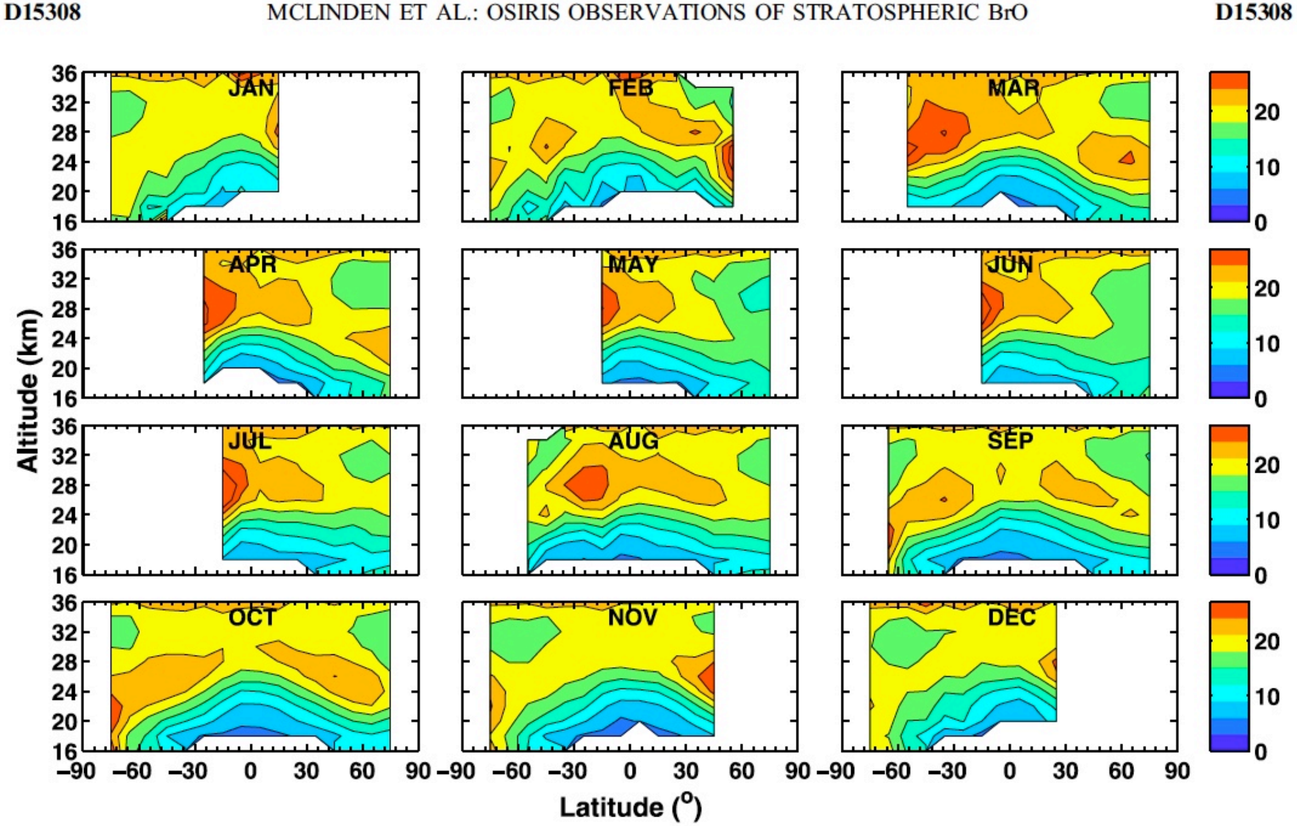
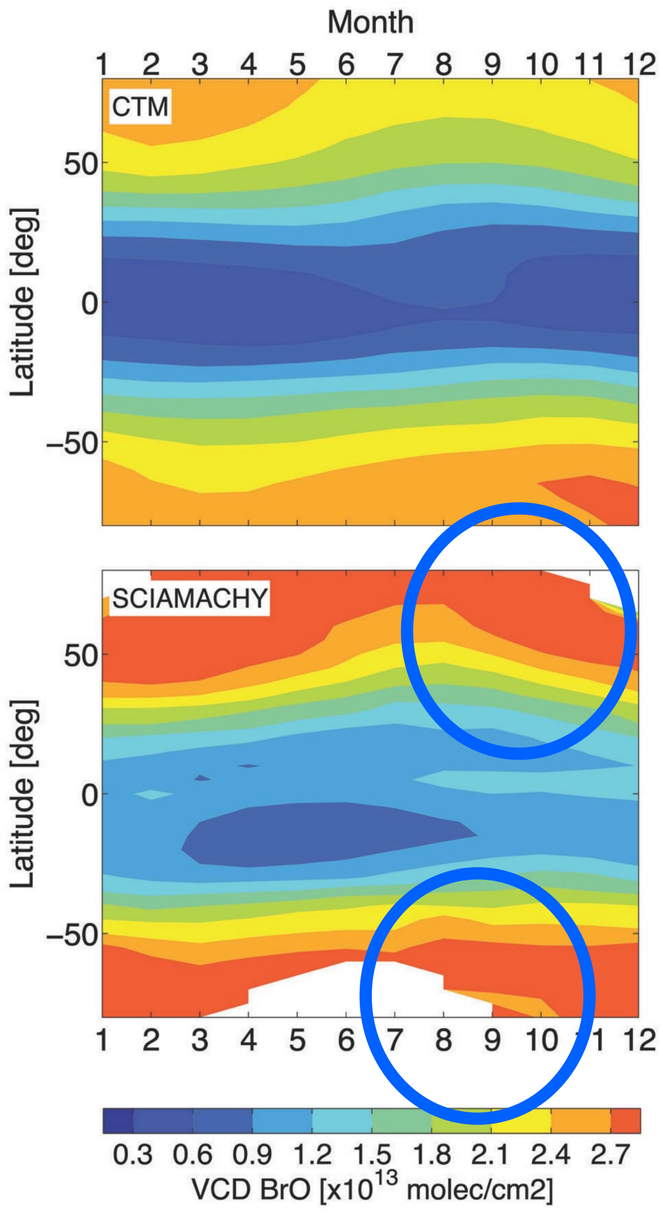
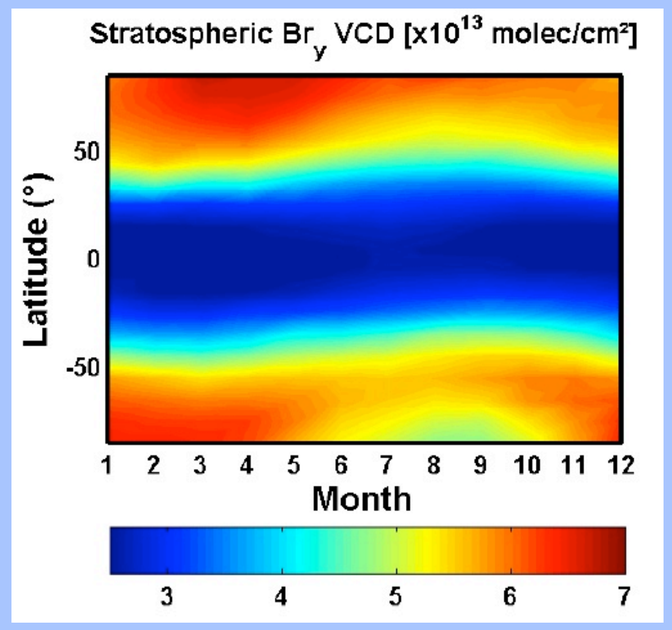


Figure 16. OSIRIS monthly Br_y (in pptv) calculated from descending node (AM) monthly mean BrO shown in Figure 8.

Br_y Comparison to CTMs





BASCOE CTM (Theys et al, 2009)

- BASCOE CTM shows larger VCD Br_y
- Qualitatively annual cycle in CTMs in agreement
- some differences remain

Summary

- 3-D SCIAMACHY BrO and Br_y climatologies 08/2002 - 04/2012 on the base of monthly means (note, OSIRIS is 2-D !)
- Our Br_y is 2-3 pptv lower than **earlier** estimates from **other** groups
- **In agreement** with other works!
- Distinct differences in spatial structures of zonal mean BrO & Br_y compared to OSIRIS - also in variability?
- Few remaining details under investigation, e.g.
  - Contribution of "minor" VSLS 1-2 pptv (e.g. C_2H_5Br; Hossaini et al., 2012) ... partitioning not linearly (Aschmann et al., 2011; Aschmann & Sinnhuber, 2013)
  - Variability of lower stratospheric Br_y in high latitudes
  - Quasi-biennial oscillation not seen in SCIAMACHY BrO
  - If Br_y is in agreement, but BrO_{CTM} is low, re-investigate CTM Br partitioning

Acknowledgements

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