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Organic and inorganic bromine measurements around the extratropical tropopause and lowermost stratosphere

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Contents

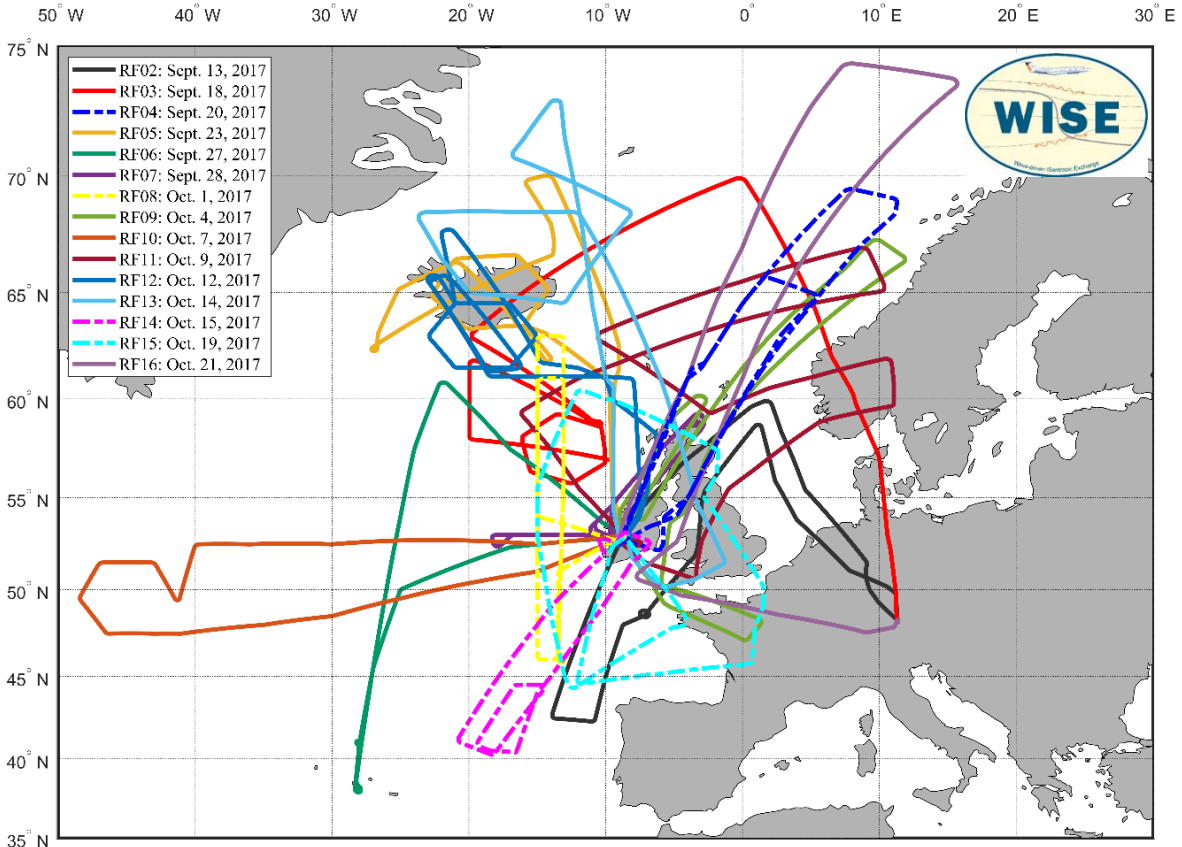
- **Airborne WISE & SouthTRAC Campaign Measurements**
- **Br^{org}, Br^{inorg}, and Br^{tot} Budget in the UTLS**
- **Summary and Outlook**

Airborne Measurements from HALO Aircraft

- **HALO: High Altitude and LOng range research aircraft**
- **Flight altitudes up to ~15km: mainly along the upper troposphere and lower stratosphere (UTLS)**
- **Campaigns: WISE → Sept. & Oct. 2017 (Northern Hemisphere) and SouthTRAC → Sept. – Nov. 2019 (Southern Hemisphere)**

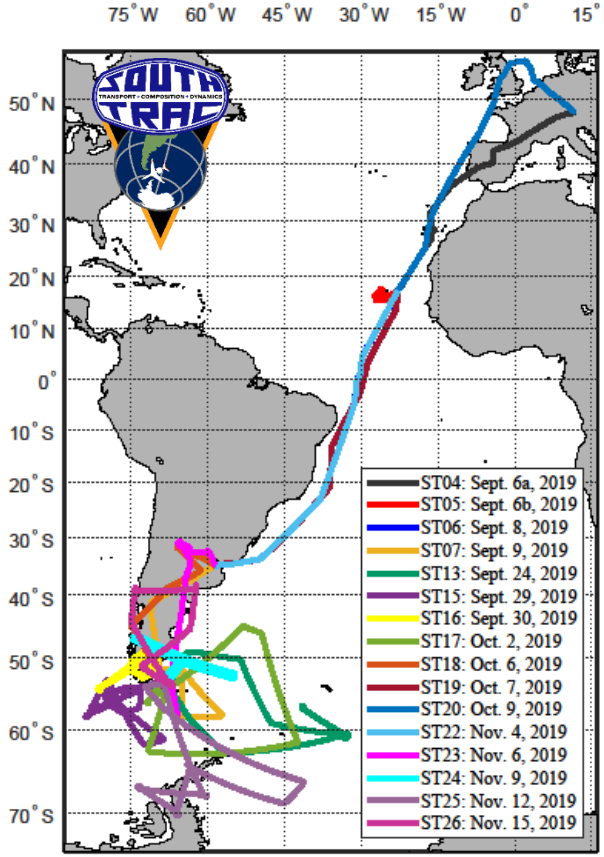
[Adopted from: http://www.gulfstream.com/special-missions/recent-programs]

Wave-driven ISentropic Exchange (WISE) 2017



[Rotermund et al. (2021), https://doi.org/10.5194/acp-21-15375-2021]

Transport and Composition in the Southern Hemisphere UTLS (SouthTRAC) 2019



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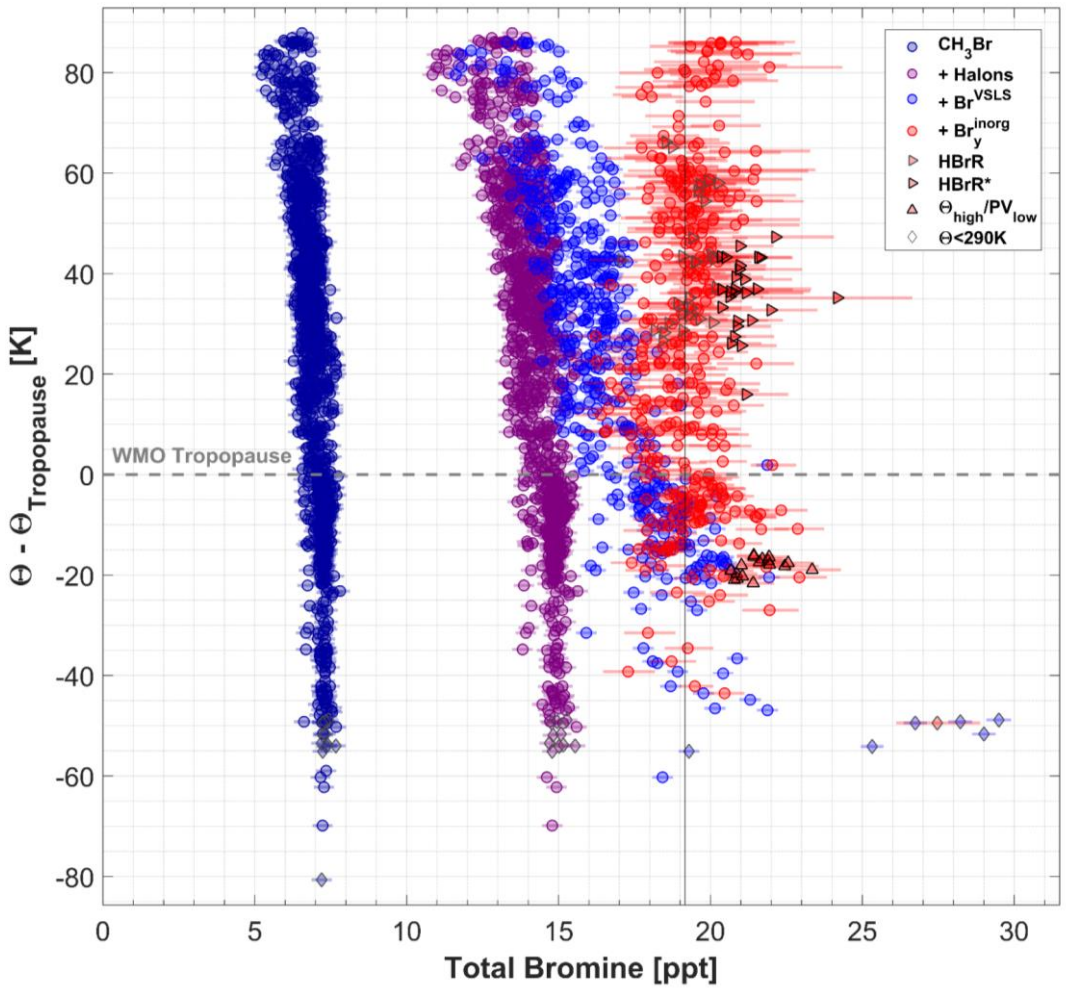
Br^{tot} as a Function of Potential Temperature Distance from the Tropopause: Northern Hemisphere WISE Campaign in Fall 2017

$CH_3Br + Halons + Br^{VSLS} + Br_y^{inorg} = Br^{tot}$



Key findings:

- **Near constant Br^{tot} throughout UTLS**
- **Lower stratospheric ($\Delta\theta$>0 K) campaign average (black solid line): [Br^{tot}] = 19.2 ± 1.2 ppt**
- **Individual regions of elevated bromine VMRs identified through air mass transport from bromine rich sources**

Legend details:

HBrR: high bromine region

Θ_{high}/PV_{low}: high potential temperature and low potential vorticity region

Θ<290 K: at/near ground measurements

[Rotermund et al. (2021), https://doi.org/10.5194/acp-21-15375-2021]

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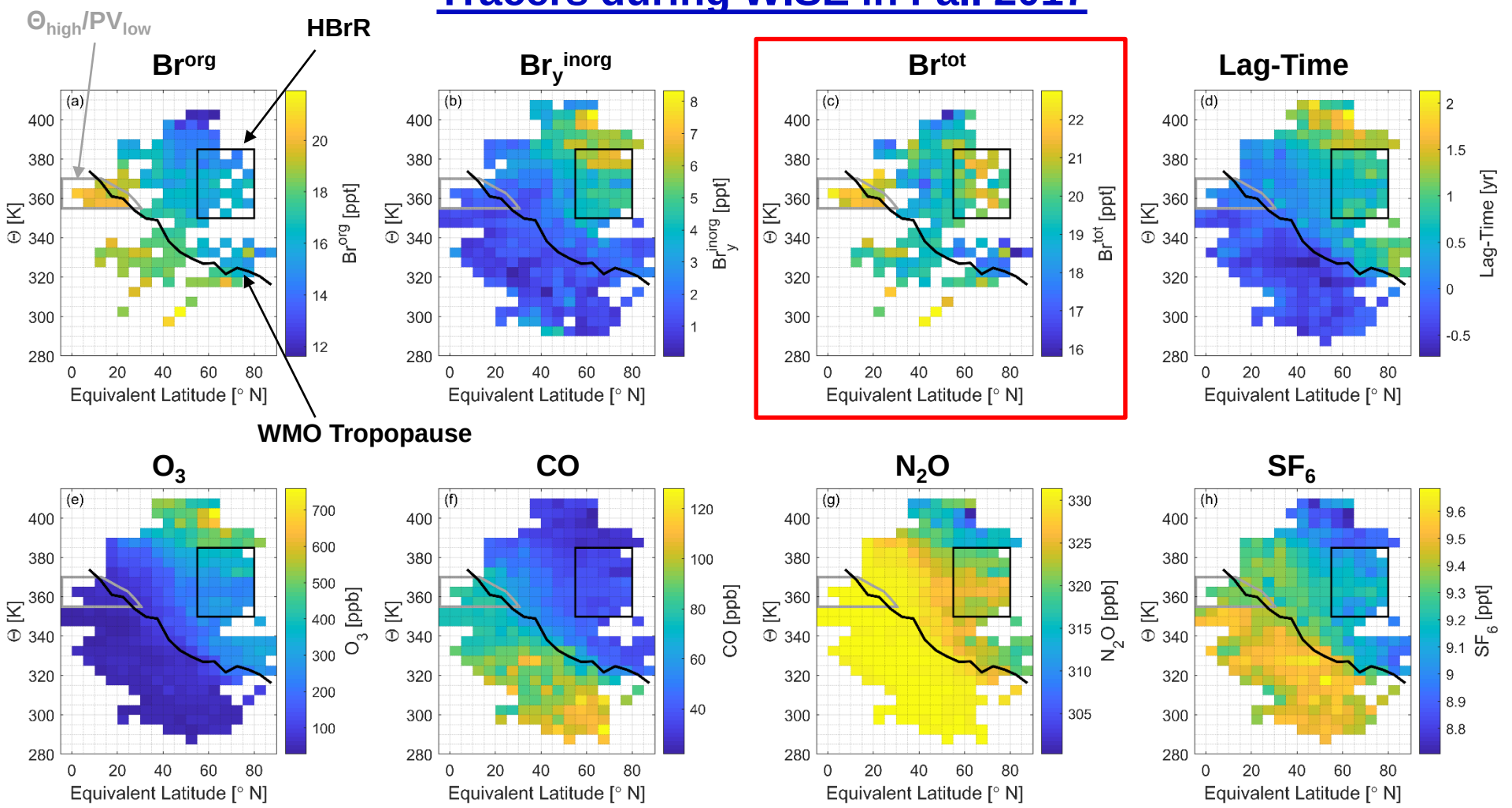
Latitudinal Distribution of Br^{org}, Br_y^{inorg}, Br^{tot} and Air Mass Transport Tracers during WISE in Fall 2017



[Rotermund et al. (2021), https://doi.org/10.5194/acp-21-15375-2021]

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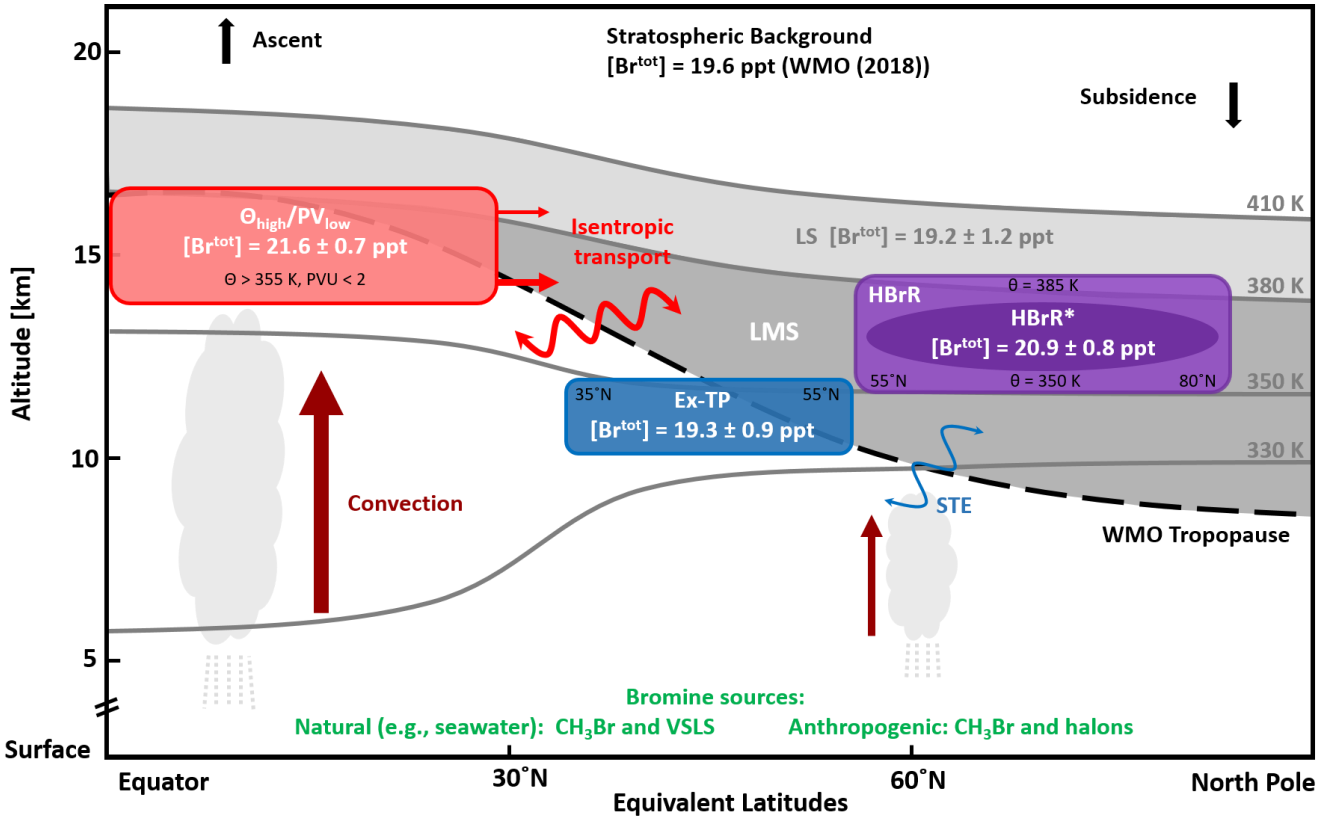
Transport Pathways of Br^{tot} during WISE in the NH during Fall 2017

In the lowermost stratosphere, a high bromine region (HBrR) is observed due to additional influx of tropospheric air masses compared to surrounding lower stratosphere

- **Main source: isentropic transport of bromine-rich air masses from south - eastern Asia.**
- **2nd smaller source: stratospheric–tropospheric exchange (STE) across the tropopause in mid-latitudes.**

Former tropical upper tropospheric air masses (Θ_{high}/PV_{low}) with observed elevated bromine:

- **From south - eastern Asia via convection associated with the Asian monsoon anticyclone.**
- **From Central America transported by remnants of hurricanes Maria and Ophelia.**



[Rotermund et al. (2021), https://doi.org/10.5194/acp-21-15375-2021]

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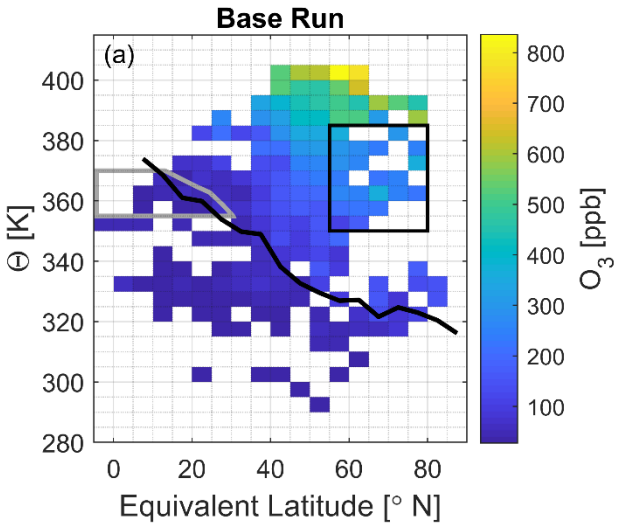
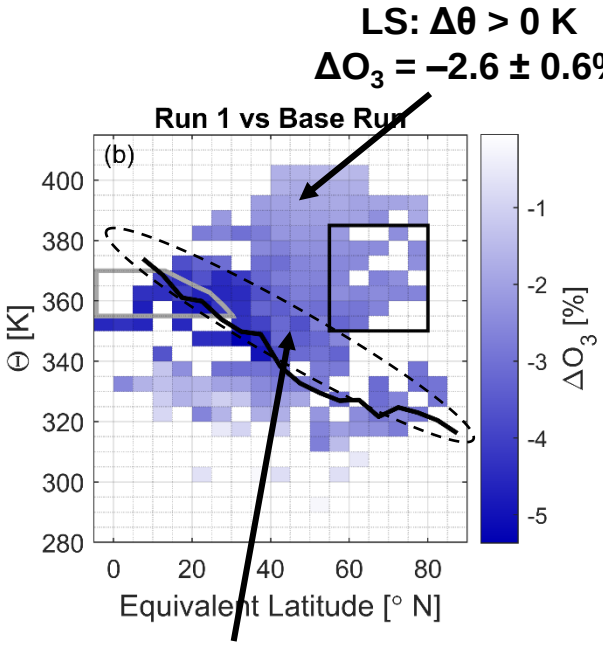
O_3 Loss due to Elevated Br^{tot} in UTLS during WISE in Fall 2017

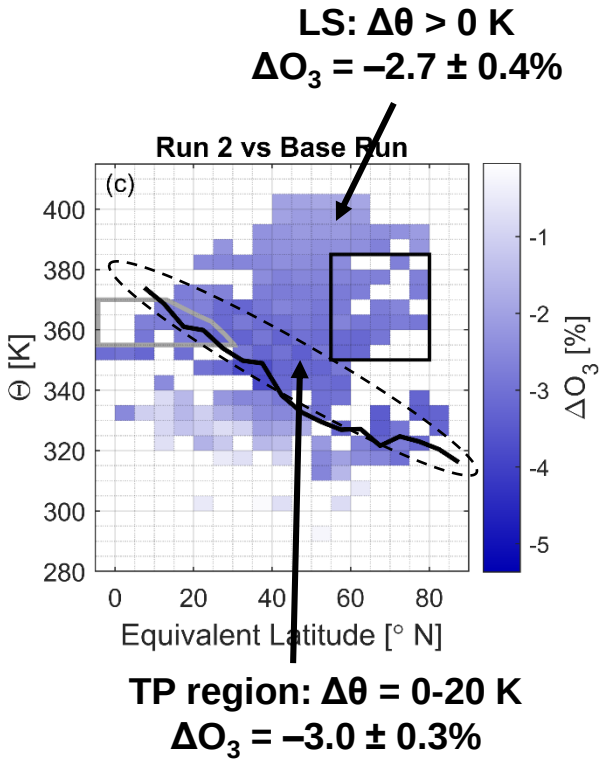
Run	Region	CH_3Br	Halons	Br^{VSLS}	Br_y^{inorg}	Br^{tot}
Base	Ex–TP	7.25 ± 0.16 ppt [1a]	7.80 ppt [2]	3.06 ± 0.56 ppt [1b]	1.44 ± 0.53 ppt [1b]	19.6 ± 0.8 ppt
Run 1	TTL	7.25 ± 0.16 ppt [1a]	7.80 ppt [2]	3.12 ± 0.47 ppt [3]	2.63 ± 1.04 ppt [4]	20.8 ± 1.2 ppt
Run 2		7.25 ± 0.16 ppt [1a]	7.80 ppt [2]	5.00 ± 0.54 ppt [1c]	1.69 ± 0.54 ppt [1c]	21.7 ± 0.8 ppt

[1a] Current study all data at the TP: $\Delta\Theta = -10$ K to WMO TP
[1b] Current study Ex–TP: eq. latitude from $40-60°$ N, $\Delta\Theta = -10$ K to WMO TP
[1c] Current study tropical UT/TTL: eq. latitude from -5 to $30°$ N, $\Theta = 355-380$ K
[2] from WMO (2018) and cited by Keber et al. (2020)
[3] Navarro et al. (2015) average from East and West Pacific
[4] Werner et al. (2017) and Koenig et al. (2017)

TOMCAT Simulations:







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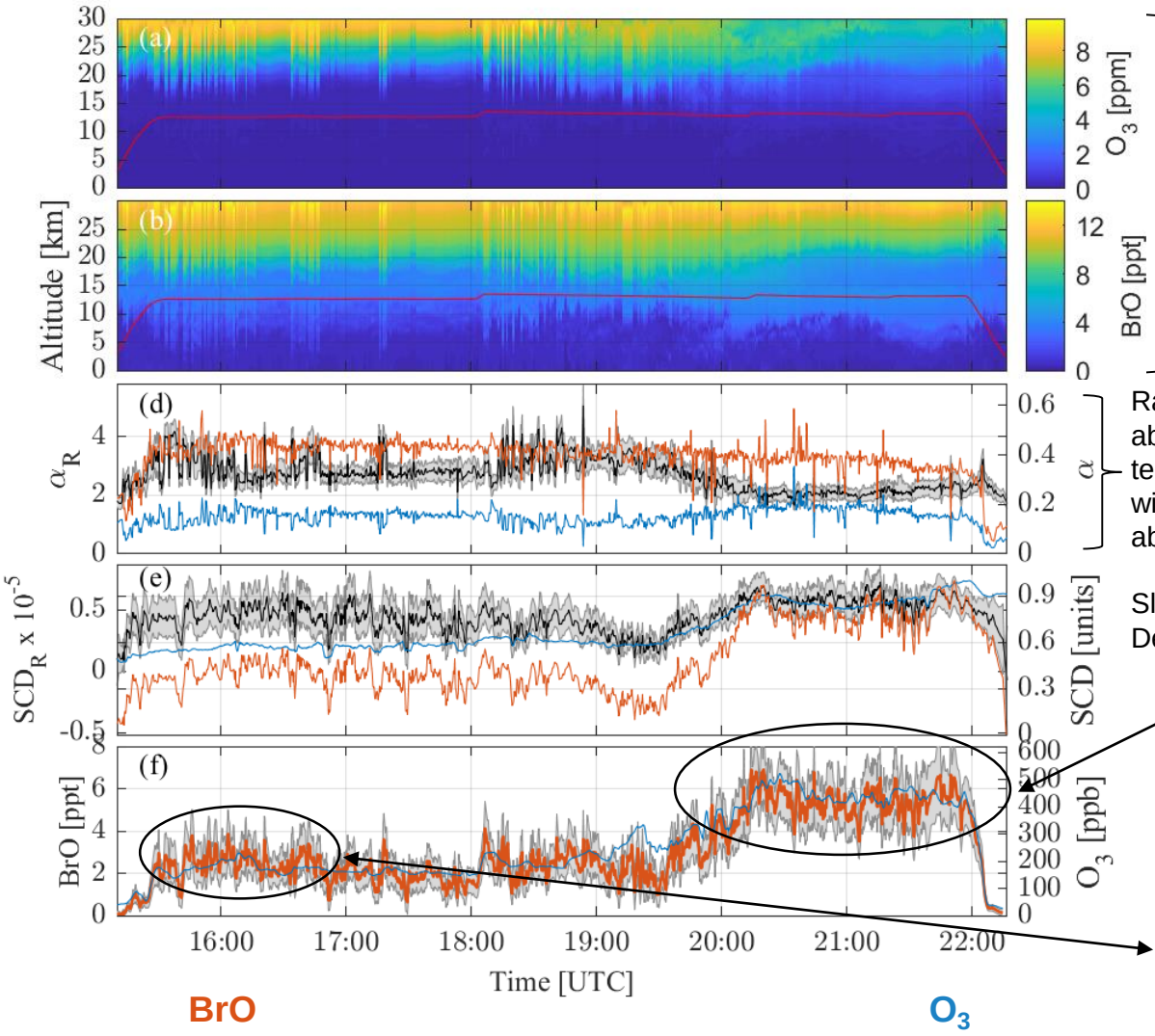
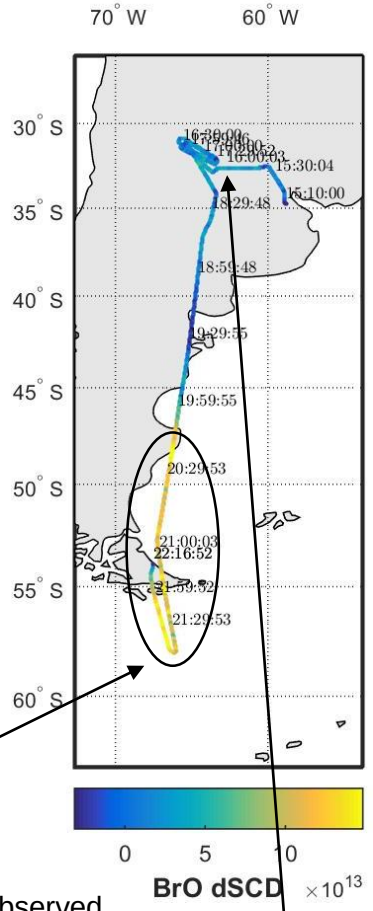
Sample SouthTRAC flight on Nov. 6, 2019:

mini-DOAS remote sensing spectrometer preliminary analysis of BrO





Elevated BrO VMRs observed over the southern Argentina in the stratosphere.

Approx. 3ppt BrO (ie. Br_y^{inorg} up to ~5ppt) observed in the upper troposphere over northern Argentina: slightly larger than during other upper tropospheric flight sections (see next slide: pink data points around $\Delta\Theta$ = - 40 K).

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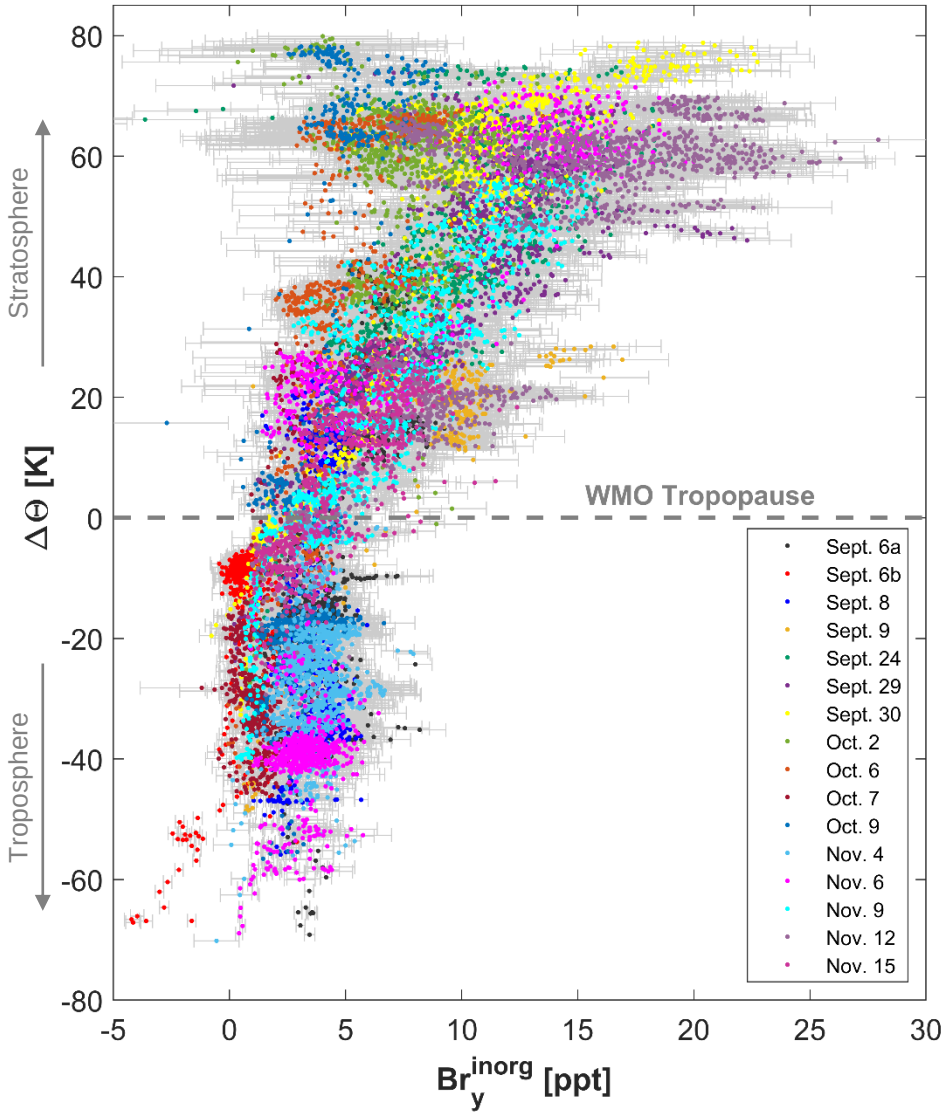
Southern Hemispheric preliminary Br_y^{inorg} VMR:



SouthTRAC 2019

Ongoing work:

- Inferred Br_y^{inorg} measurements: from mini-DOAS remote sensing spectra → preliminary analysis of BrO along 16 SouthTRAC flights and scaled by BrO/Br_y^{inorg} partitioning from the CLaMS model
- **General expected trend of low tropospheric Br_y^{inorg} and increasing VMRs into the stratosphere (+ΔΘ) are observed**
- Elevated stratospheric Br_y^{inorg} around ΔΘ = 60 K is observed over the Antarctic Peninsula (flight Nov. 12th)
- Individual flight sections with elevated tropospheric Br_y^{inorg} (e.g. Sep. 8th, Nov. 4th and 6th) from tropical/subtropical regions need to be further investigated

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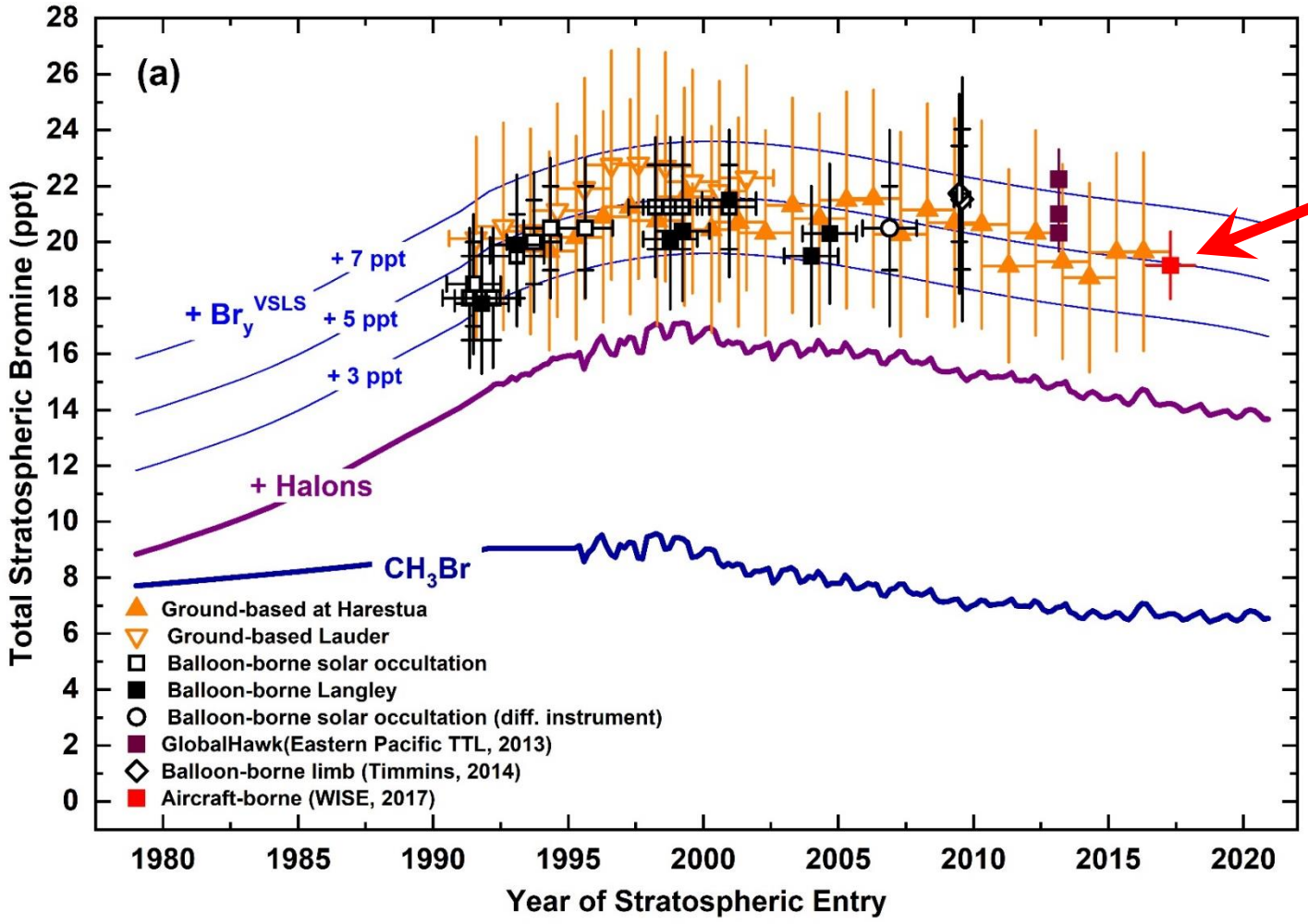
Updated Trend in Stratospheric Bromine (to be included in 2022 WMO Ozone Assessment Report)



The WISE campaign lower stratospheric mean total bromine: [Br^{tot}] = 19.2 ± 1.2 ppt

- **Agrees well with previous stratospheric bromine data**
- **Smaller uncertainty!**

Next: further update trend with SouthTRAC campaign (2019) data point.

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Summary & Outlook

Completed:

Northern Hemisphere WISE 2017 campaign analysis for Br^{org}, Br_y^{inorg}, Br^{tot}, bromine transport pathways, source regions, and consequences on UTLS ozone

- **Published in ACP: Rotermund et al., (2021) https://doi.org/10.5194/acp-21-15375-2021**
- **To be included in 2022 WMO Ozone Assessment Report**

Ongoing:

Southern Hemisphere SouthTRAC 2019 campaign preliminary retrievals of Br_y^{inorg}, Br^{org} and Br^{tot} for 16 flights

Outlook:

Finalizing SouthTRAC Br^{tot} analysis and interpretation of bromine rich air mass transport using CLaMS transport model

Thank you!

EGU22-9685:

Rotermund et al.

https://doi.org/10.5194/egusphere-egu22-9685