Harmonised satellite glyoxal data records from TROPOMI, OMI and GOME-2

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[1] BIRA-IASB, [2] AWI, [3] IUP-UB, [4] DLR-IMF, [5] Chiba-U, [6] MPIC, [7] BOKU-Met, [8] IIESR; [9] IAP-CAS, [10] ESA/ESRIN

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EUMETSAT AC SAF ATMOSPHERIC COMPOSITION MONITORING

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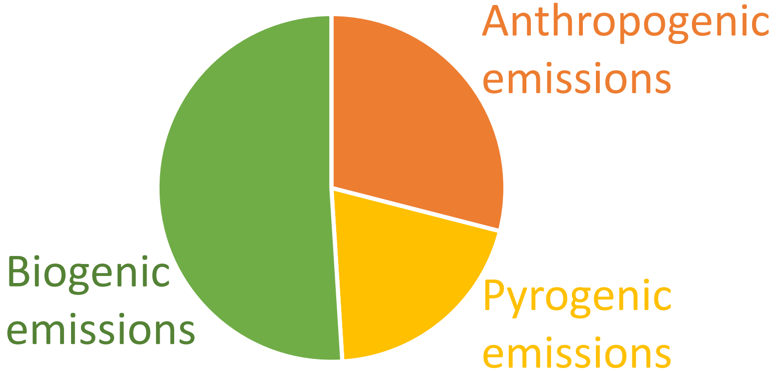
Why studying glyoxal (CHOCHO)?

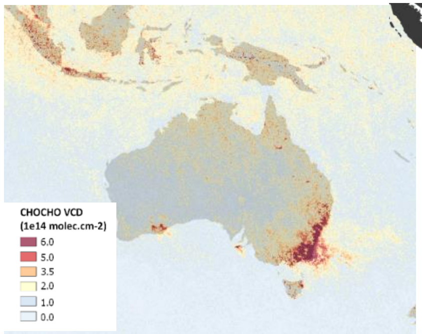
- Sources:
  - Oxidation of other NMVOCs
  - Direct emissions (combustion processes)
- Sinks:
  - Photolysis and OH oxidation
  - Dry/wet deposition
  - Conversion to SOA

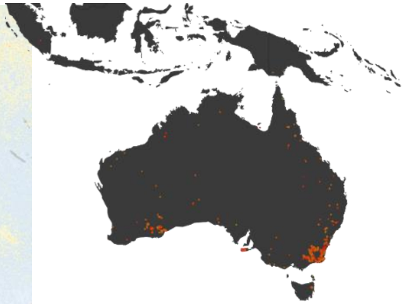
→ Information on NMVOC emissions and SOA budget.



2020 bushfires in Australia

CHOCHO VCD **VIIRS FRP**





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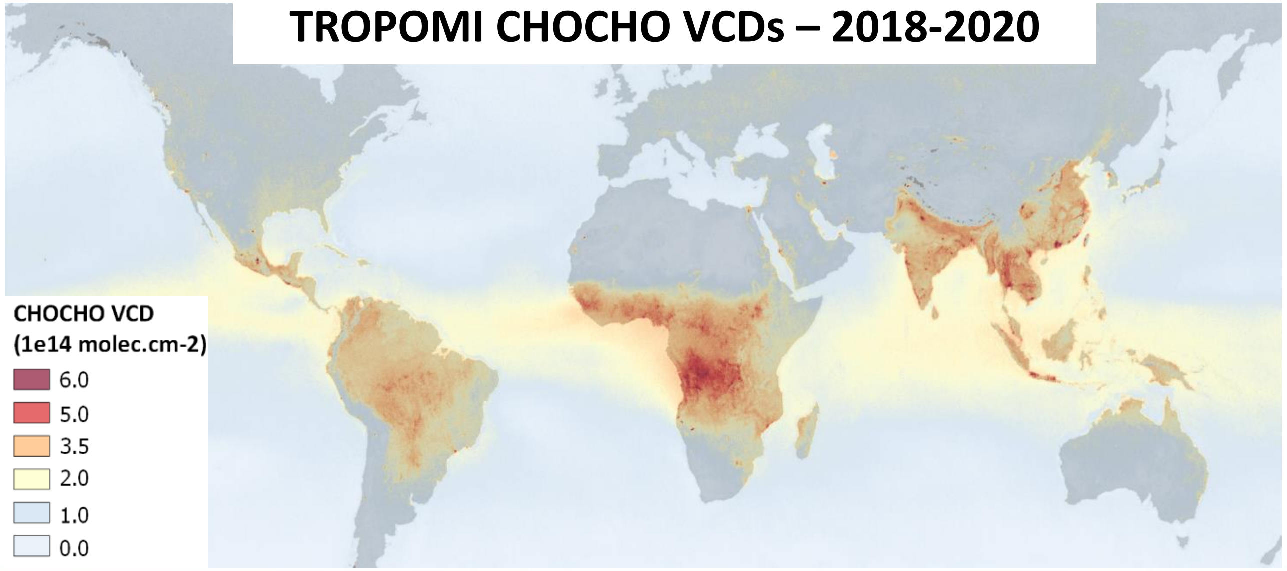
TROPOMI CHOCHO VCDs – 2018-2020



Outline

- **GLYRETRO:** One of the ESA innovation projects aiming at applying and further developing the BIRA-IASB glyoxal algorithm to TROPOMI.
- Two main project components:
  - Algorithm and product development.
  - Product characterization
    - Inter-satellite comparison
      - BIRA-IASB OMI product
      - AC-SAF GOME2A/B products (based on the BIRA-IASB algorithm)
    - Inter-algorithm comparison: IUP-UB TROPOMI product (Alvarado et al., 2020)
    - Validation: MAX-DOAS data at 9 stations

TROPOMI DOAS glyoxal tropospheric column retrievals

1. DOAS spectral fit

1. DOAS spectral fit: SCD retrieval

↓

2. AMF computation

↓

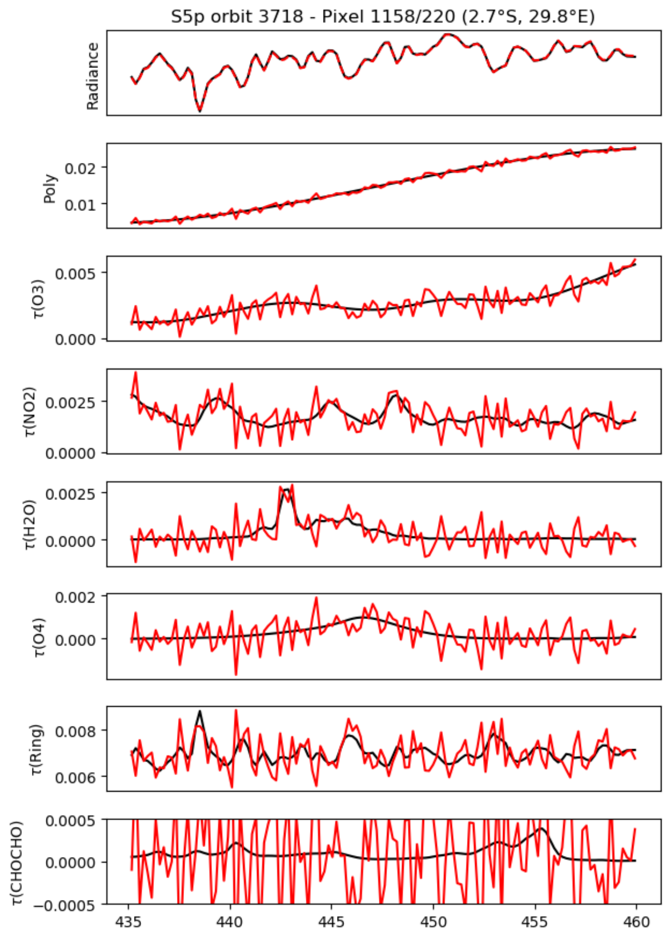
3. Background/destriping correction

CHOCHO optical depth are generally very low (<5e-4)

→ Significant noise in the retrievals.

→ Very sensitive to interferences with other spectral signatures (from other absorbers or calibration).

Fitting interval: 435-460 nm	
Absorption cross-sections:	
Glyoxal, O_3, NO_2 (2 T°), O_4, H_2O (vapour), H_2O (liquid), Scene Heterogeneity (2 XS), Ring effect	
Other parameters:	
Polynomial (3rd order), Intensity offset correction, wavelength shift	



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1. DOAS spectral fit

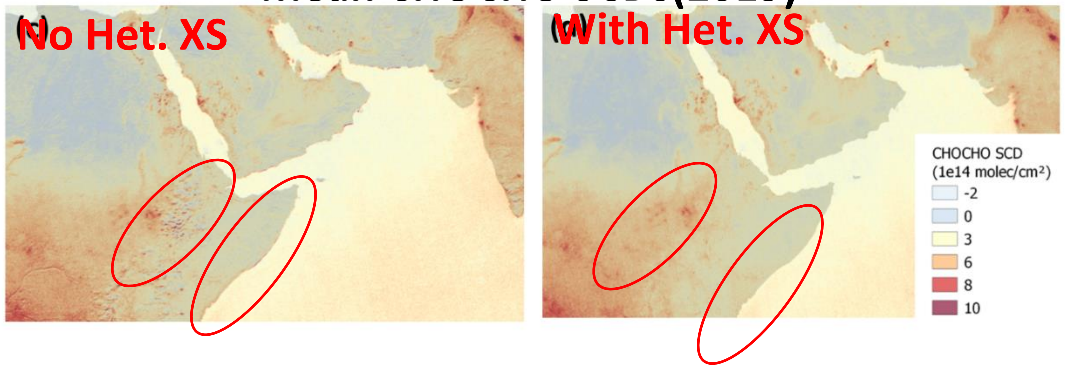
Scene Heterogeneity

- Scene brightness heterogeneity perturbs the instrumental slit function response.

→ Biases on glyoxal SCDs.

- Adding pseudo cross-sections can mitigate this effect (A. Richter et al., 2018).

Mean CHOCHO SCDs(2019)



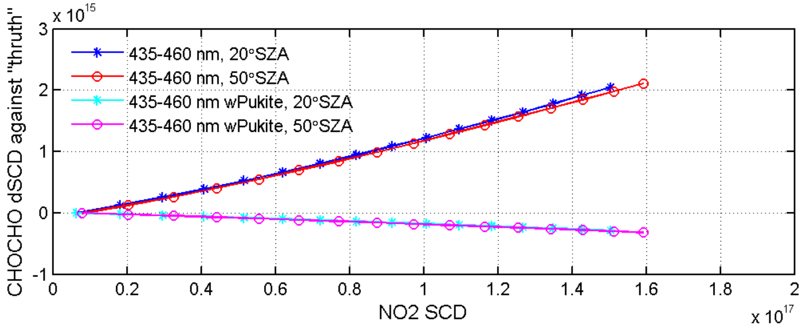
Correction for strong NO_2 absorption

- The wavelength dependence of the effective light path for strong NO_2 absorption leads to misfits.

→ Biases on glyoxal SCDs.

- An empirical correction of the CHOCHO SCDs as a function of the NO_2 SCD is applied.

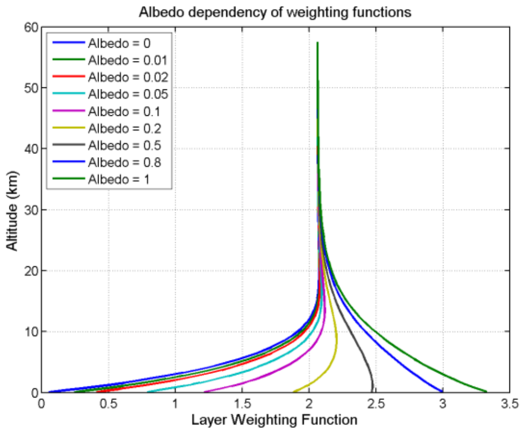
Simulated CHOCHO SCD errors asaf of NO_2 SCDs



TROPOMI DOAS glyoxal tropospheric column retrievals

2. AMF computation

- Box-AMFs W_i pre-computed with VLIDORT at 448nm asaf of geometry, scene altitude and reflectivity.

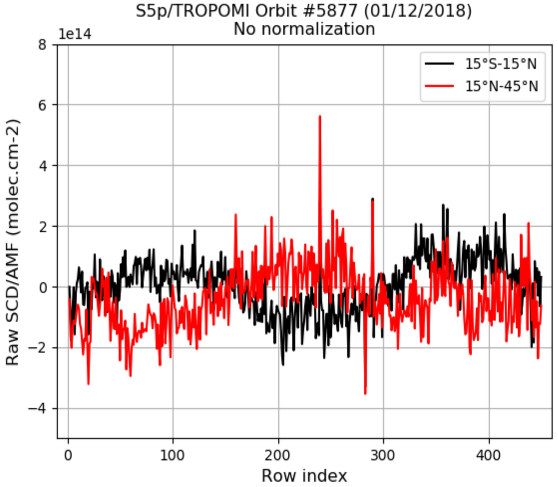


- No cloud/aerosol correction; Cloud fractions > 20 % rejected.
- A priori profile shapes:
  - **Land**: BIRA CTM MAGRITTE (run at 1°x1°) using inventories from 2018.
  - **Oceans**: Fixed airborne MAX-DOAS profile measured in the Pacific (*Volkamer et al., 2015*).

3. Background correction

- Row-dependent (destriping) correction using Pacific measurements.
- Reference value: 1×10^{14} molec/cm².

Row dependence of the uncorrected VCDs



Intersatellite comparison

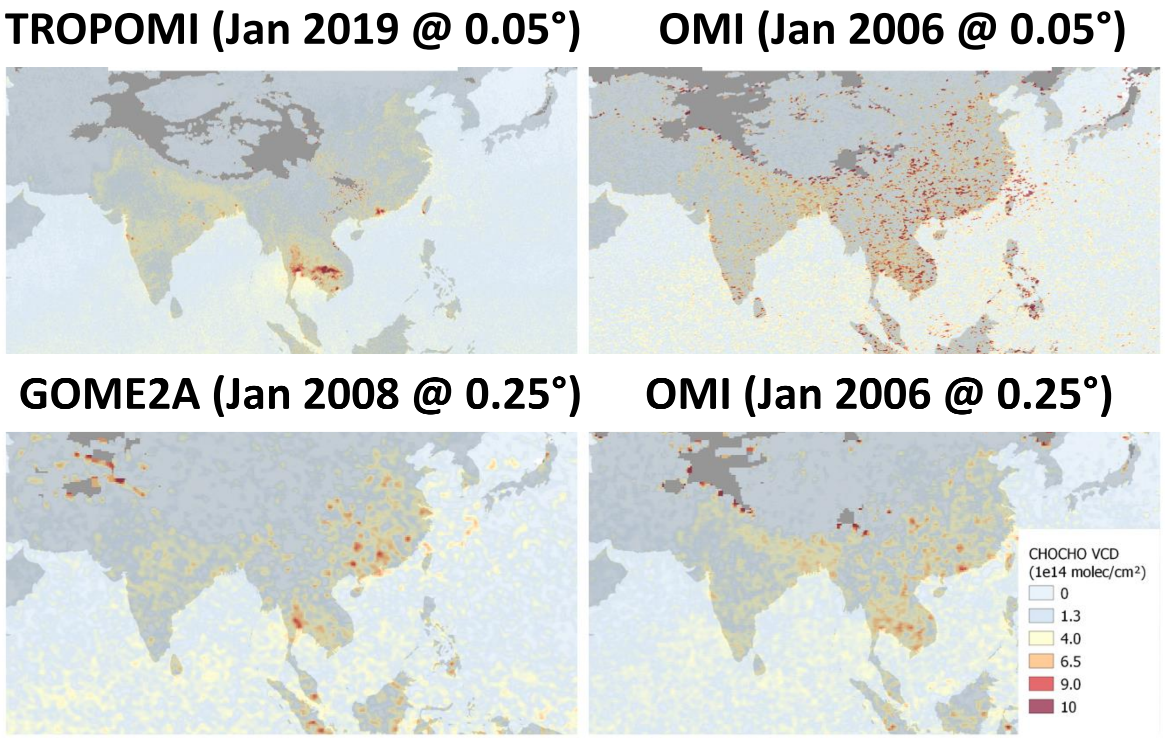
- Application of the algorithm to TROPOMI, OMI, GOME-2A and GOME-2B (AC-SAF data sets).

- GOME-2: SNR= 1000; footprint= 80x40 km².

  OMI: SNR= 500; footprint= 13x24 km².

  TROPOMI: SNR= 1500; footprint= 3.5x5 km².

➔ Much more details in the retrieved glyoxal fields at a reasonable time resolution.



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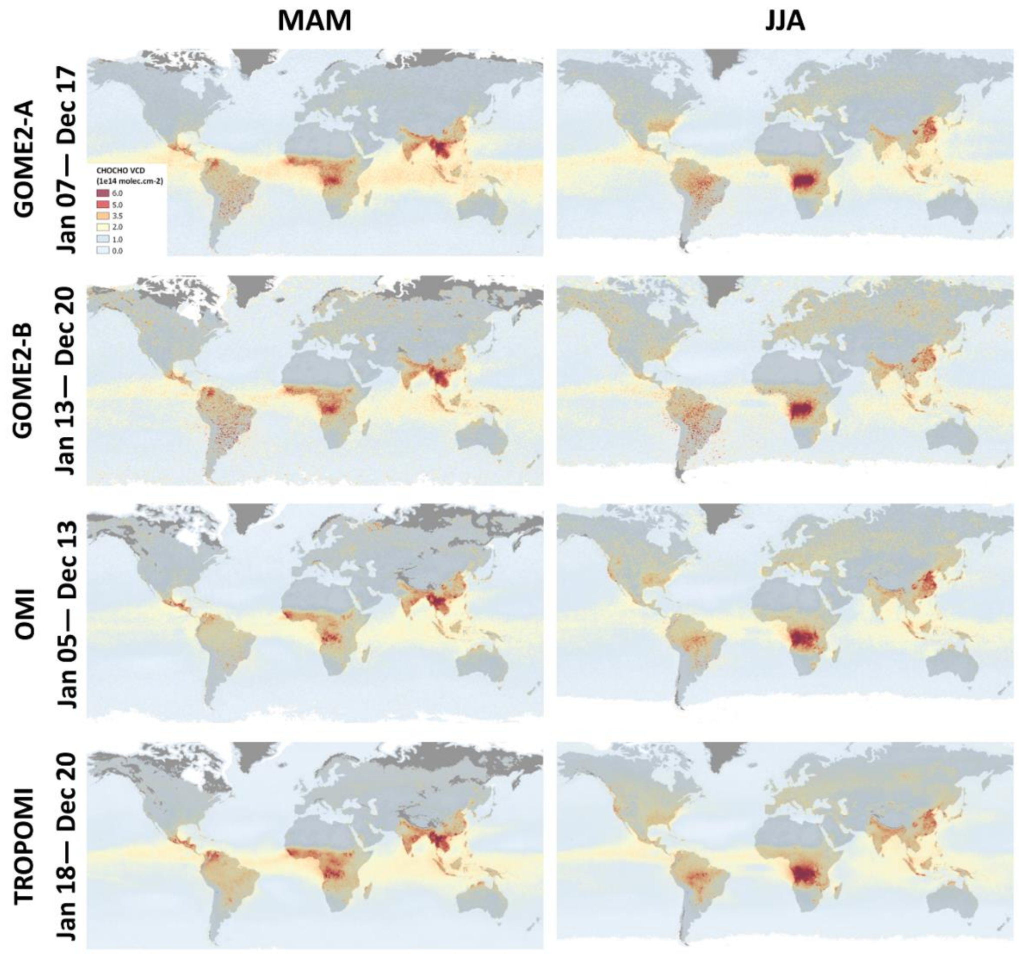
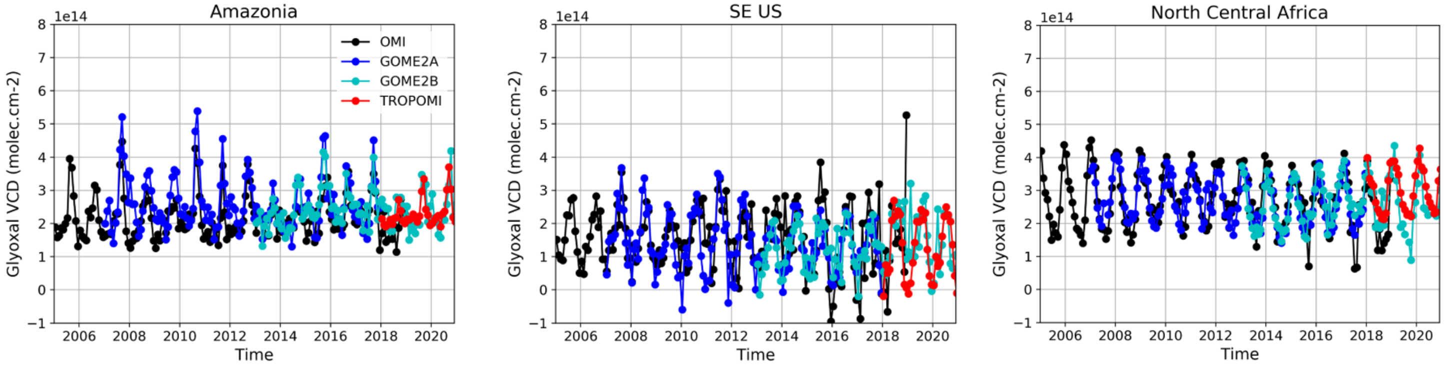
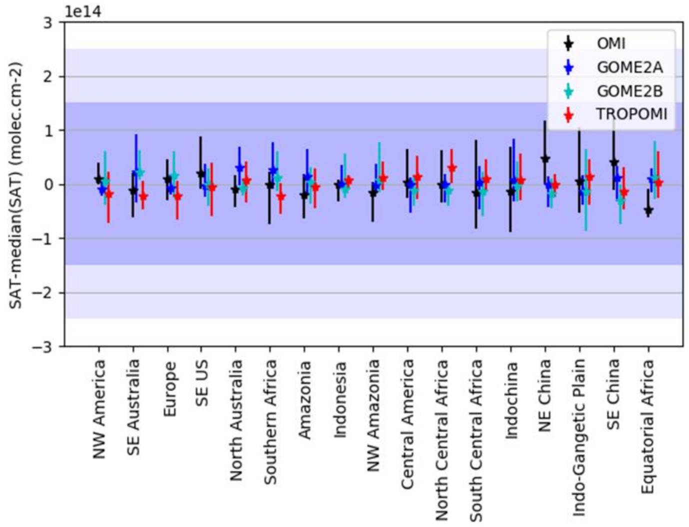


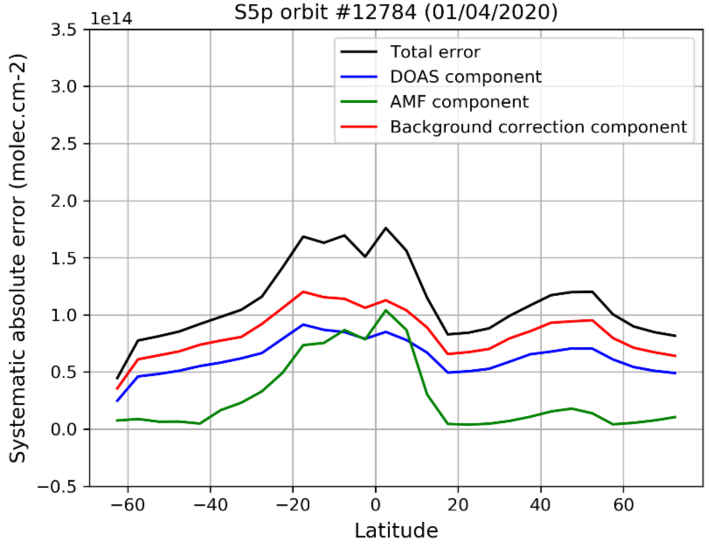


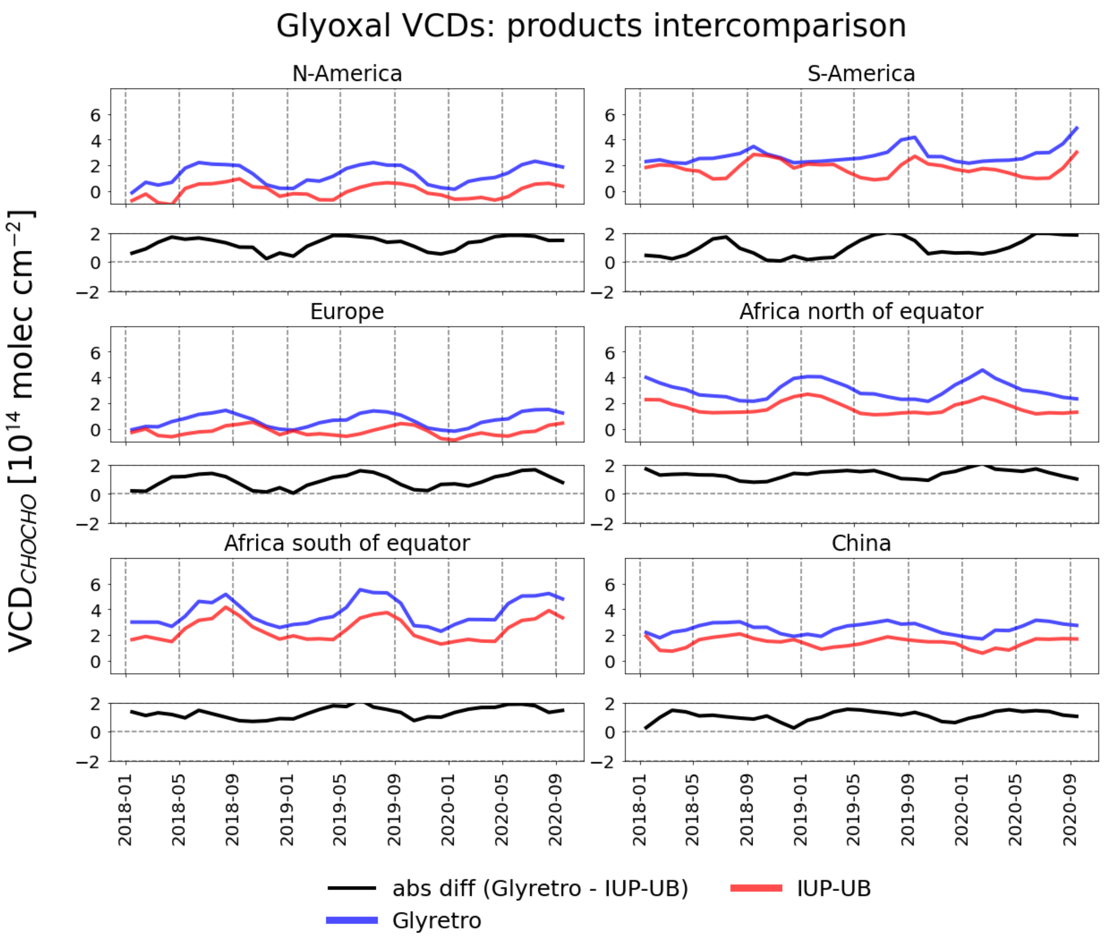


Overall four satellite consistency within 5e13 molec/cm² (<20%)

Interalgorithm comparison (BIRA/IUP)

- Main algorithmic differences:
  - Reference values in background correction.
  - Different a priori profiles.
  - Small differences in DOAS settings (e.g. fit window, polynomial)





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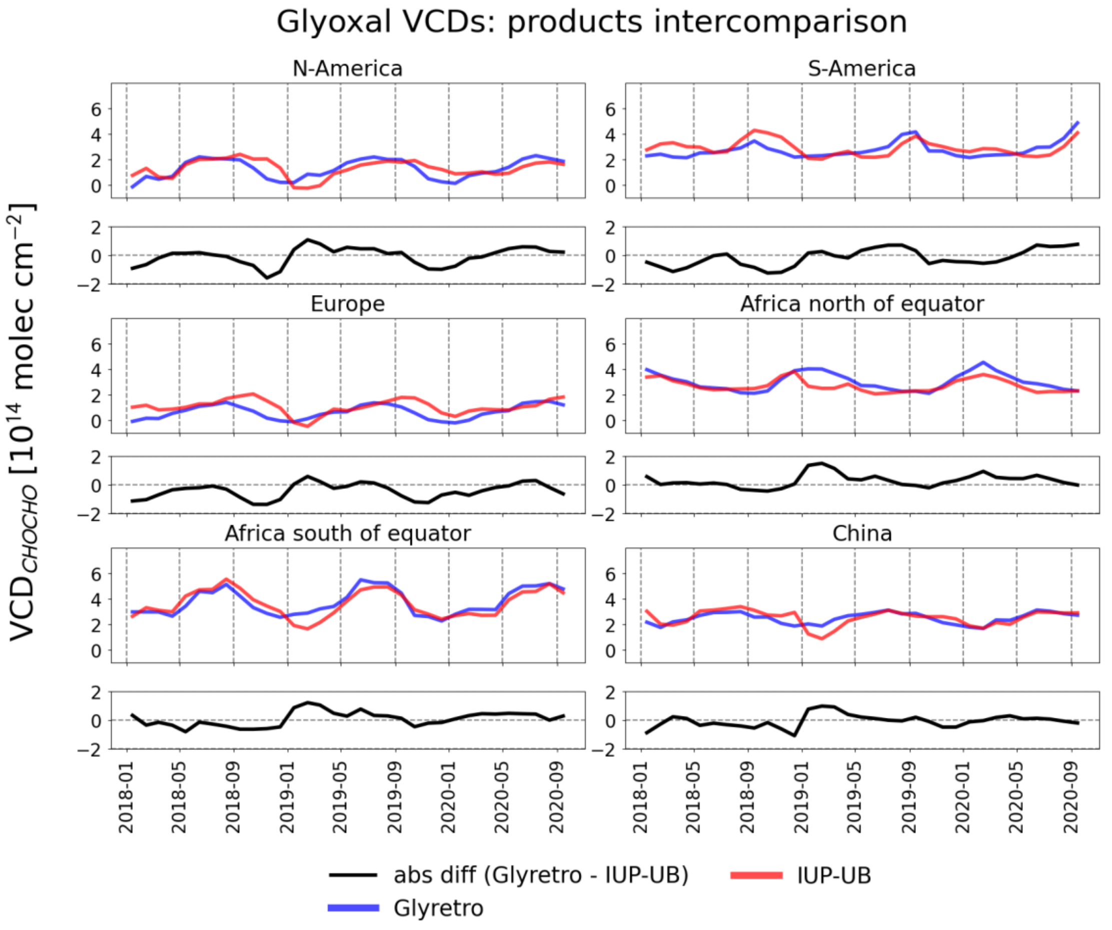
- Using similar reference Pacific columns, both product agree reasonably well and present similar spatio-temporal CHOCHO variability.



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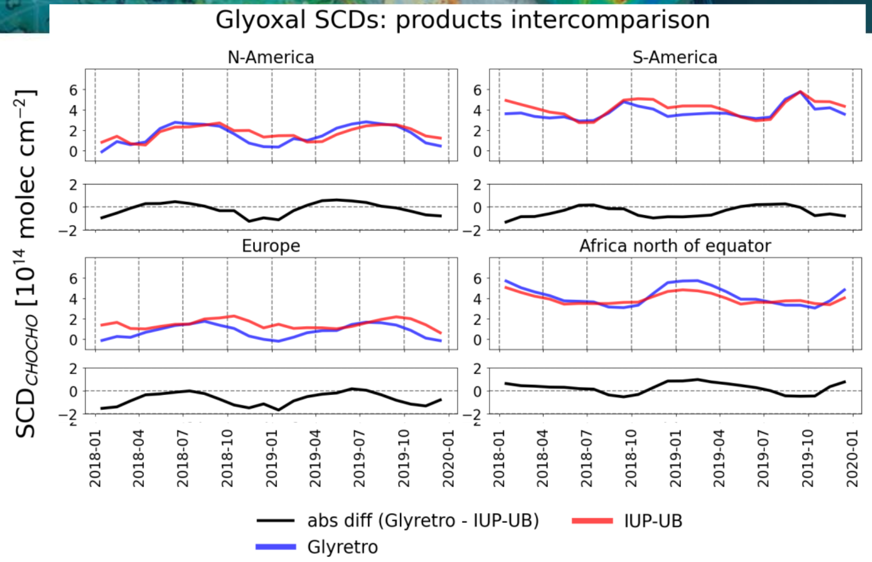
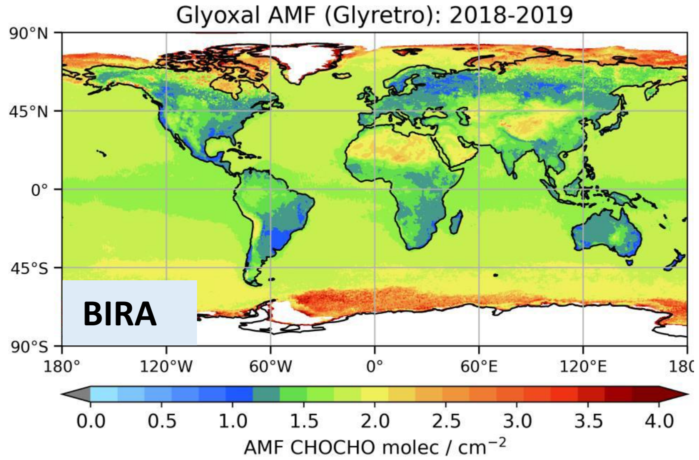
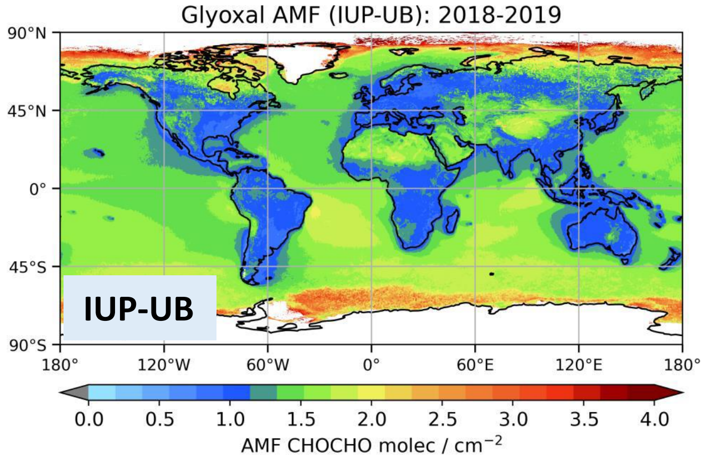
- Remaining differences originate from the DOAS fits and from the AMFs.







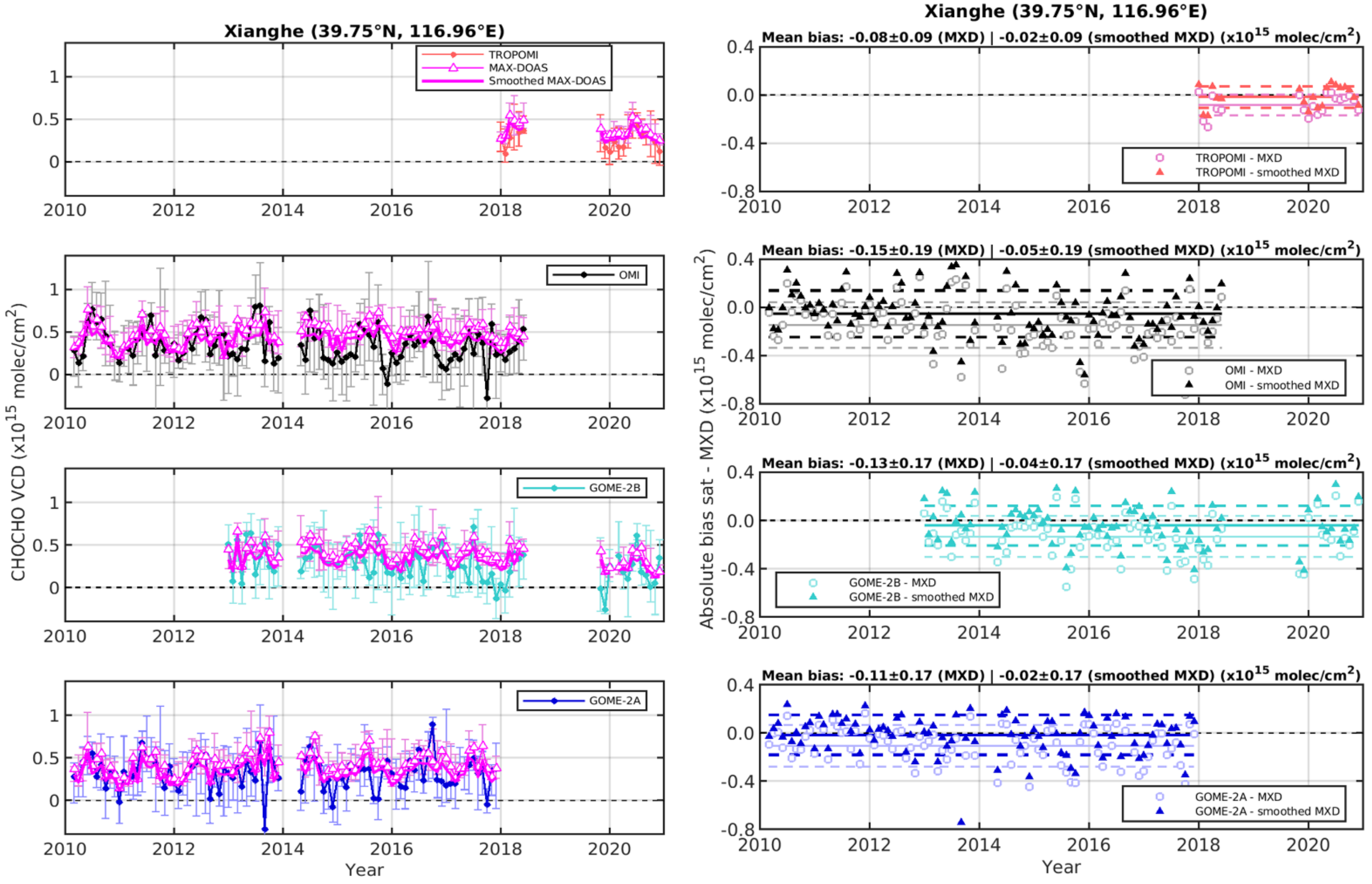
Validation

- MAX-DOAS validation based on 9 stations in Asia and Europe.
- Overpass radius: 20 km for TROPOMI, 100 km for others.
- MAX-DOAS data within 1.5h of the satellite overpass selected.
- The exercise would benefit from a further homogenization of MAX-DOAS retrievals.

Station (coordinates) Time range	Institution PI	Retrieval Approach and fit interval	Reference
Xianghe/China (39.75°, 116.96°E) 2010-2020	BIRA-IASB	Profile retrieved using Optimal Estimation 436-468 nm	(Clémer et al., 2010; Hendrick et al., 2014)
Uccle/Belgium (50.78°N, 4.35°E) 2017-2020			
Chiba/Japan (35.63°N, 140.10°E) 2012-2020	CERES	Profile retrieved using a parametrization approach 436–457 nm	(Hoque et al., 2018; Irie et al., 2011)
Phimai/Thailand (15.18°N, 140.10°E) 2014-2020			
Pantnagar/India (29.03°N, 79.47°E) 2017-2020			
Mohali/India (30.67°N, 76.73°E) May 2019 - 2020	MPIC/IISERM	Profile retrieved using a parametrization approach 400-460 nm	(Beirle et al., 2019; Kumar et al., 2020)
Athens/Greece (38.05°N, 23.80°E) 2018-2020	IUP-UB	Columns retrieved using the Geometrical Approximation 436-468 nm	(Gratsea et al., 2016; Schreier et al., 2020)
Vienna/Austria (48.18°N, 16.39°E) 2018-2020			
Bremen/Germany (53.11°N, 8.86°E) 2018-2020			

Validation

- Long Xianghe time series allows validating all sensors.
- Satellite and MAX-DOAS seasonal cycles agree well. Degradation appears for OMI/GOME-2 data after a few years.
- Reduced scatter for TROPOMI clearly visible.
- Reduction of small negative biases when applying the sat. averaging kernels to MAX-DOAS data.

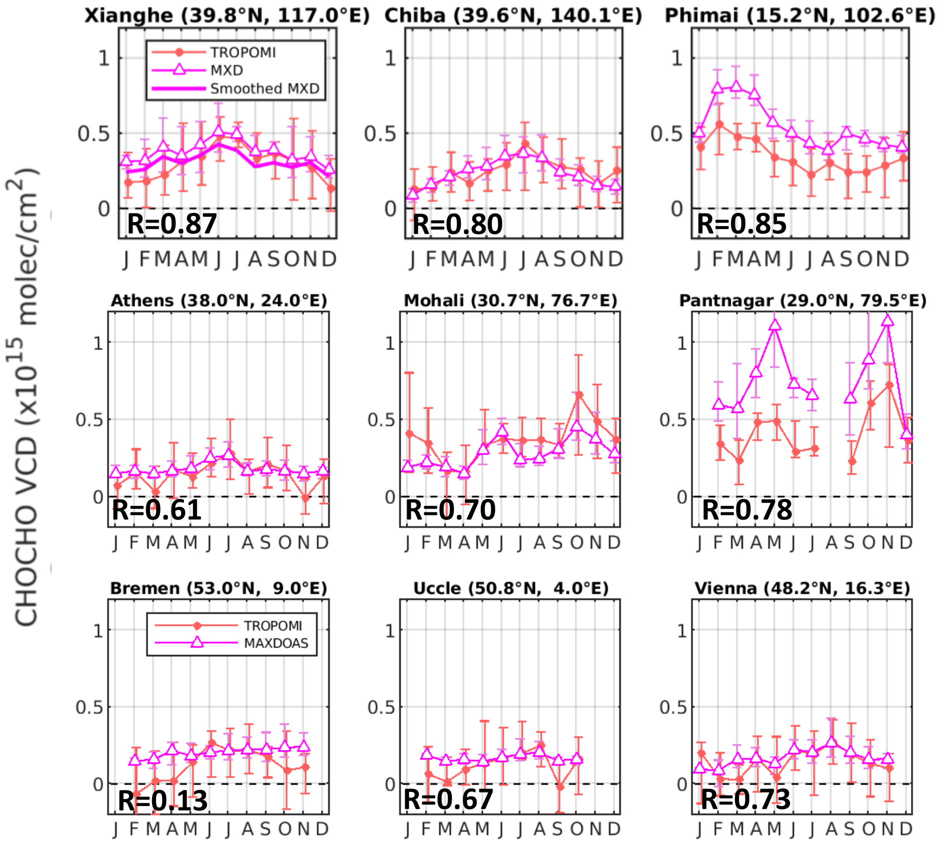


Validation

- Overall, consistent TROPOMI and MAX-DOAS seasonal cycles.
- Large biases in Phimai and Pantnagar not fully understood, especially as not identified in Mohali.
- Indication for a negative bias during wintertime at mid/high latitude (e.g. Bremen).

Sat./MAX-DOAS correlation coefficients

	Xianghe	Chiba	Phimai
TROPOMI	0.87	0.80	0.85
OMI	0.70	0.32	N/A
GOME-2B	0.37	0.66	0.88
GOME-2A	0.92	0.58	0.86



Summary

- Consistent glyoxal fields are obtained from TROPOMI, OMI, GOME2A/B with the BIRA-IASB algorithm. TROPOMI provides much more details. The OMI and GOME-2A/B data sets become less stable after a few years of operation.
- Validation of the satellite glyoxal retrievals based on 9 MAX-DOAS sites showed:
    - Seasonal cycles observed from space and ground in good agreement.
    - A low bias in satellite data during winter for mid/high latitude stations.
    - Significant unexplained biases at 2 sites. They may originate from the satellite a priori profiles, neglect of aerosols, but also from MAX-DOAS data themselves. It would be beneficial to homogenize the MAX-DOAS glyoxal retrievals.
- Comparisons with the IUP-UB product allowed to quantify the impact of choices made at every step of the algorithm.
- The glyoxal signal over oceans remains largely unexplained and should be cautiously interpreted because of the high sensitivity to the DOAS settings.
- TROPOMI glyoxal data are accessible via the glyretro website (https://glyretro.aeronomie.be).
- More details in Lerot et al., accepted for AMT.