Harmonization and Intercomparison of Tropospheric Ozone Climate Data Records

TOAR-II HEGIFTOM teleconference

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TOAR tropospheric ozone assessment report

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Acknowledgements

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Ozone_cci+
ProDEx TROVA-E2

BRAIN-be 2.0 TAPIOWCA

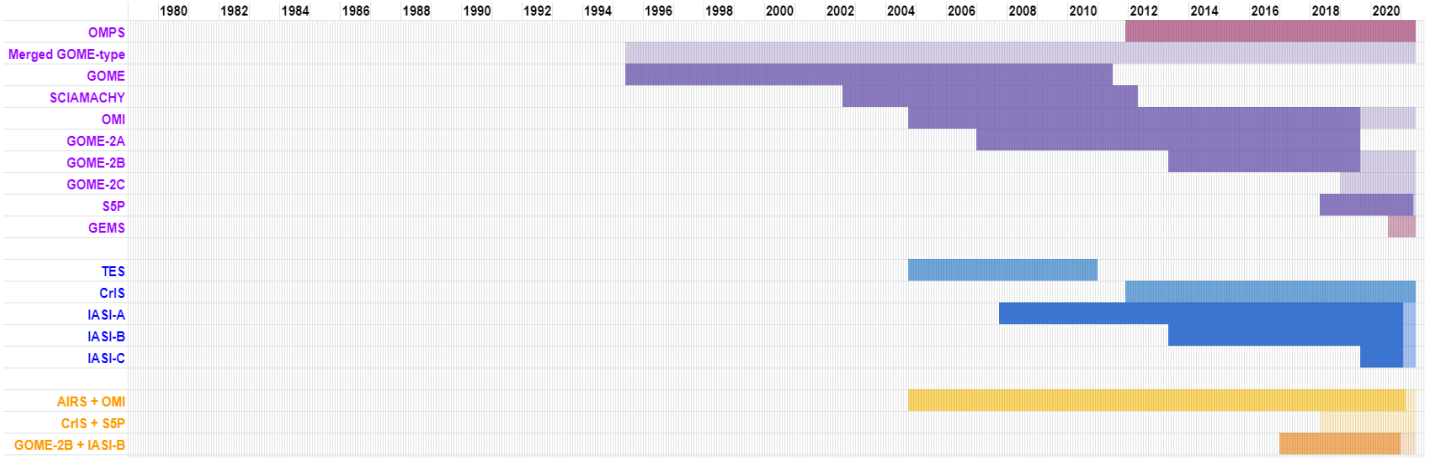
An Assessment of Ozone and Water Vapour Changes Affecting Climate and Air Quality

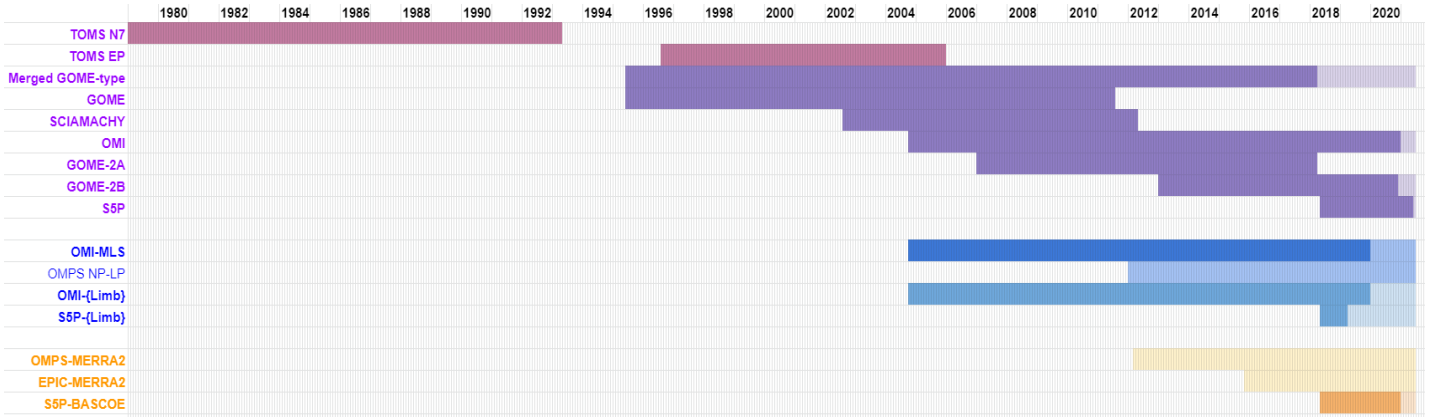
Collaborative Frameworks

AC-VC and WGCV
Joint Activity VC-20-01

Data and Expertise

Two families of tropospheric ozone measurement by satellites





Optimal Estimation retrieval

→ vertical profile at pixel level or at pixel-cluster level

- UV-VIS
- TIR
- Synergy UV-VIS+TIR

Residual techniques

→ partial column calculated as difference between total and pseudo-stratospheric columns, often gridded in time & space

- Cloud-free TC minus above Convective Cloud TC
- Nadir TC minus Limb PROF
- Nadir TC minus Reanalysis PROF

Ozone Data Harmonization Framework

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A) Harmonisation of OE-based ozone profile

Re-optimized prior matching to common prior constraints

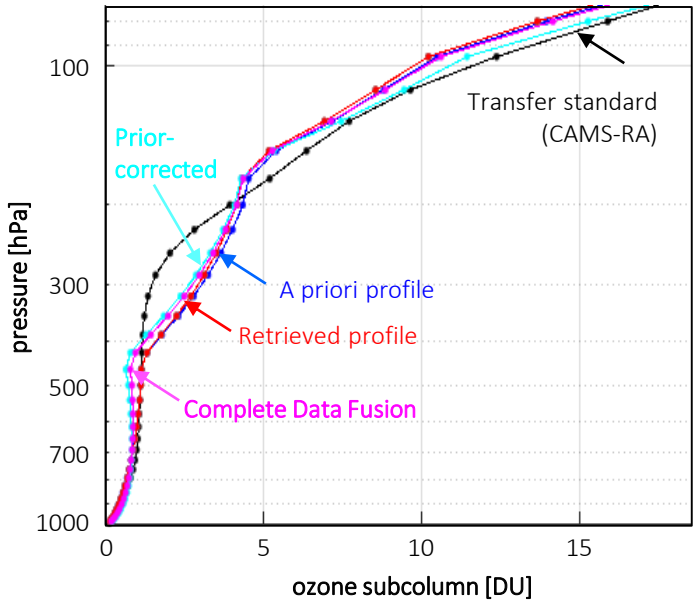
new prior

- Non-optimized prior profile harmonisation:

$$x' = x - (I - A)(x_a - x'_a)$$

- Full prior/smoothing harmonisation using Wiener deconvolution and Complete Data Fusion:

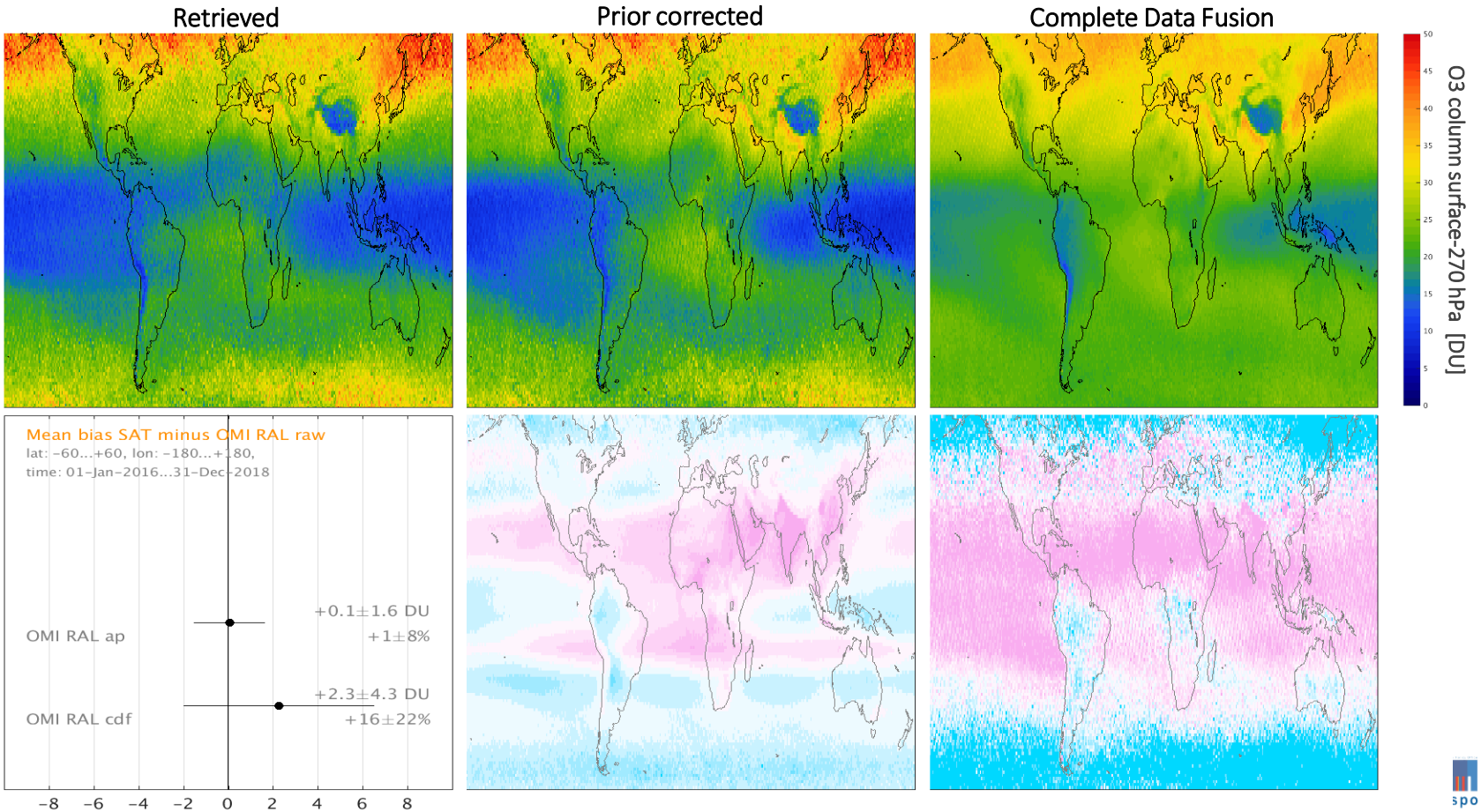
$$x' = (A^T S_x^{-1} A + S_a'^{-1})^{-1} \times (A^T S_x^{-1}(x - (I - A)x_a) + S_a'^{-1} x'_a)$$



Details in:

- Evaluation of harmonization methods: Keppens *et al.*, Atmos. Meas. Tech. (2019) https://doi.org/10.5194/amt-12-4379-2019
- CDF removal of prior information: Keppens *et al.*, Remote Sens. (2022) https://doi.org/10.3390/rs14092197

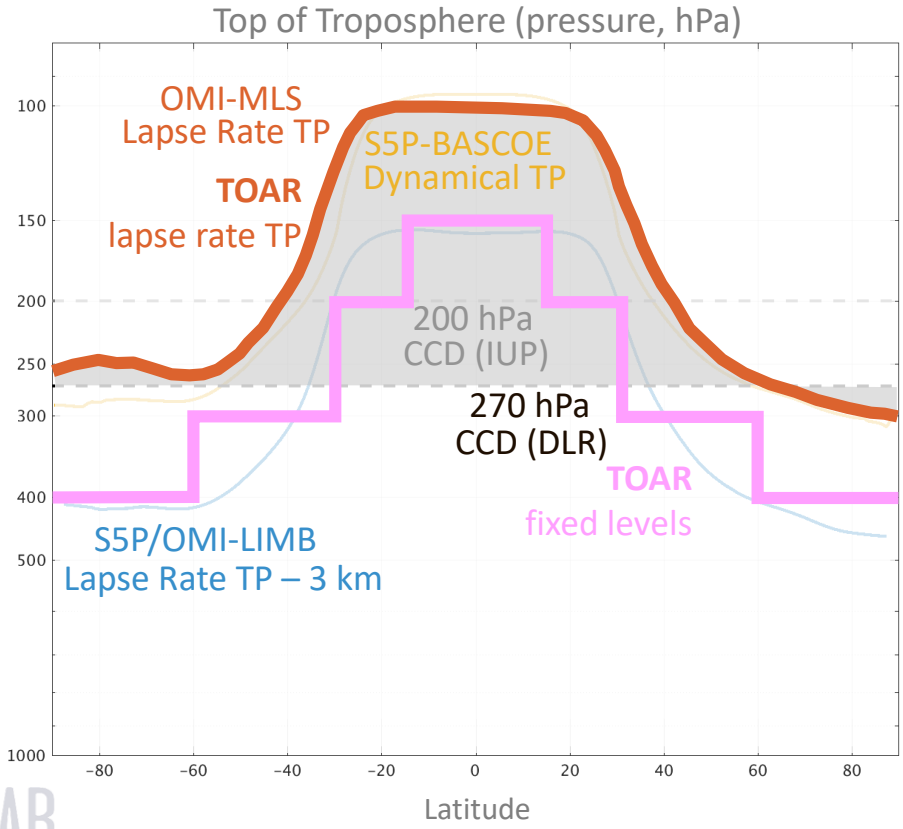
Illustration: OMI RAL ozone profile retrievals (mean 2016-2018)



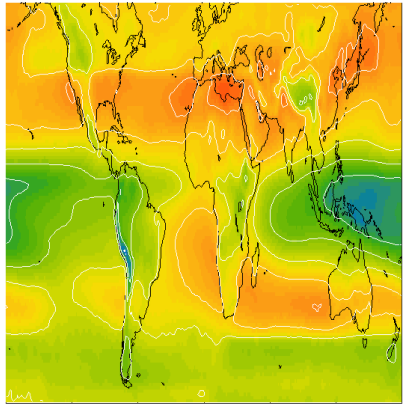
Transfer standard for ozone data harmonisation

- CAMS Reanalysis (Inness et al., 2019)
  - 60 levels (1012-0.1 hPa) of which 37 in troposphere (1012-80 hPa)
  - 0.7° latitude x 0.7° longitude (global)
  - 6 hours (2003-now)
  - assimilated ozone : total column (SCIAMACHY, OMI, GOME-2), vertical profile (MIPAS, Aura MLS, SBUV/2)
- Applied to
  - extension of tropospheric column (Residual Technique)
  - new prior information (Optimal Estimation)
  - match quantities of auxiliary data
  - (assessment of horizontal and temporal sampling differences)

B) Harmonisation of residual tropospheric column



Lapse Rate Tropopause



$$x' = x(\Delta z) + x'_a(\Delta z')$$

270 hPa

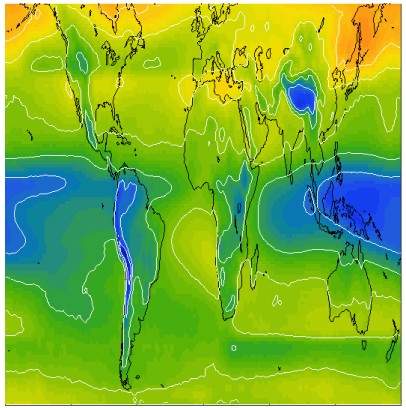
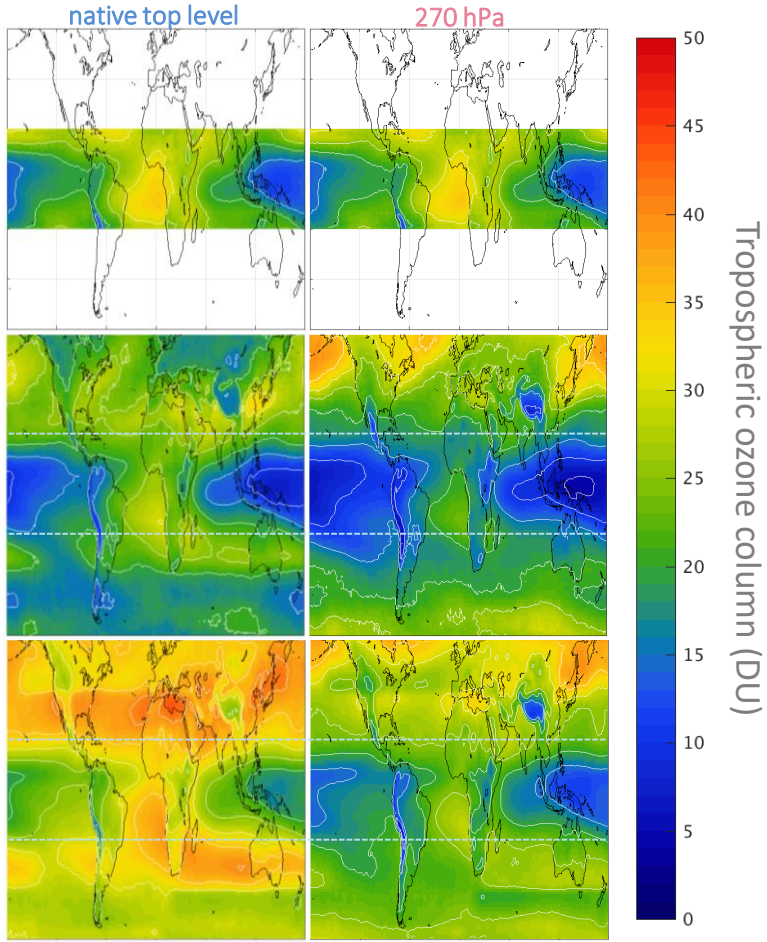
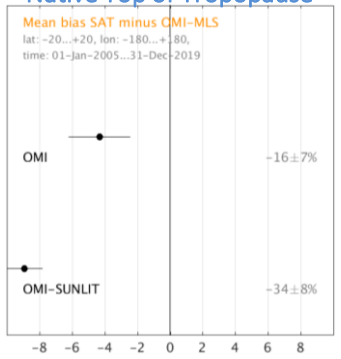


Illustration : OMI-based residual tropospheric ozone (mean 2005-2019)

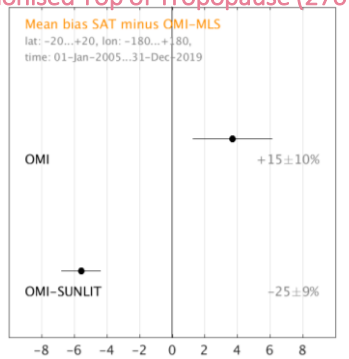


Mean bias SAT – OMI-MLS [DU] (20S-20N)

Native Top of Tropopause

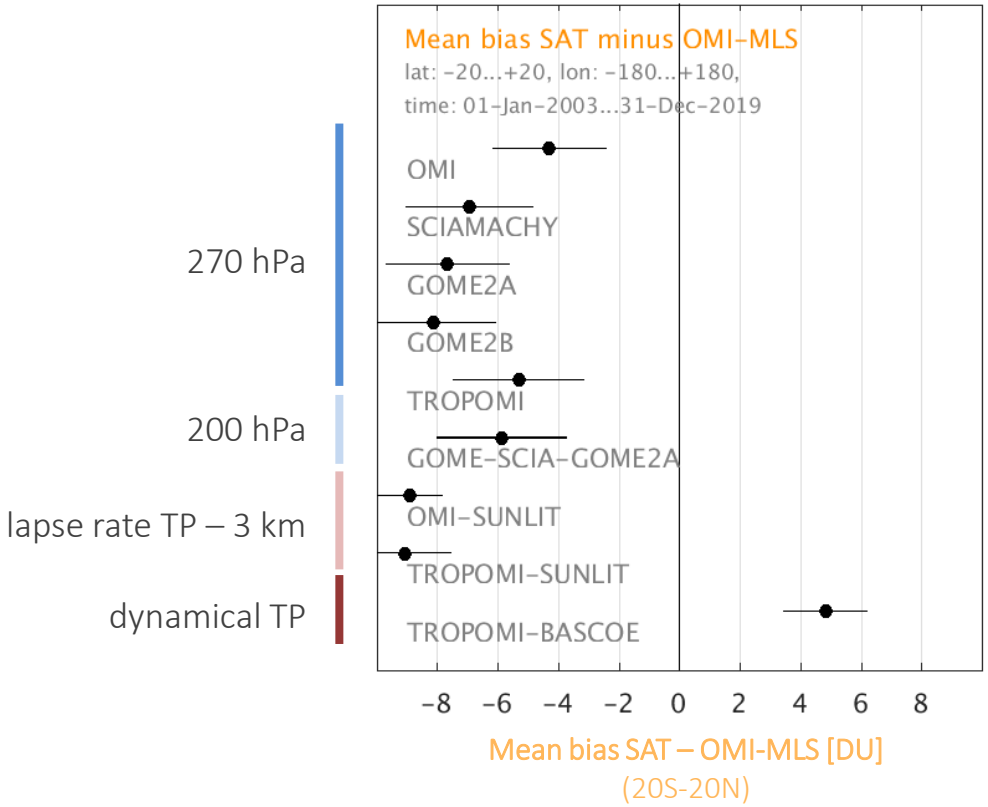


Harmonised Top of Tropopause (270 hPa)



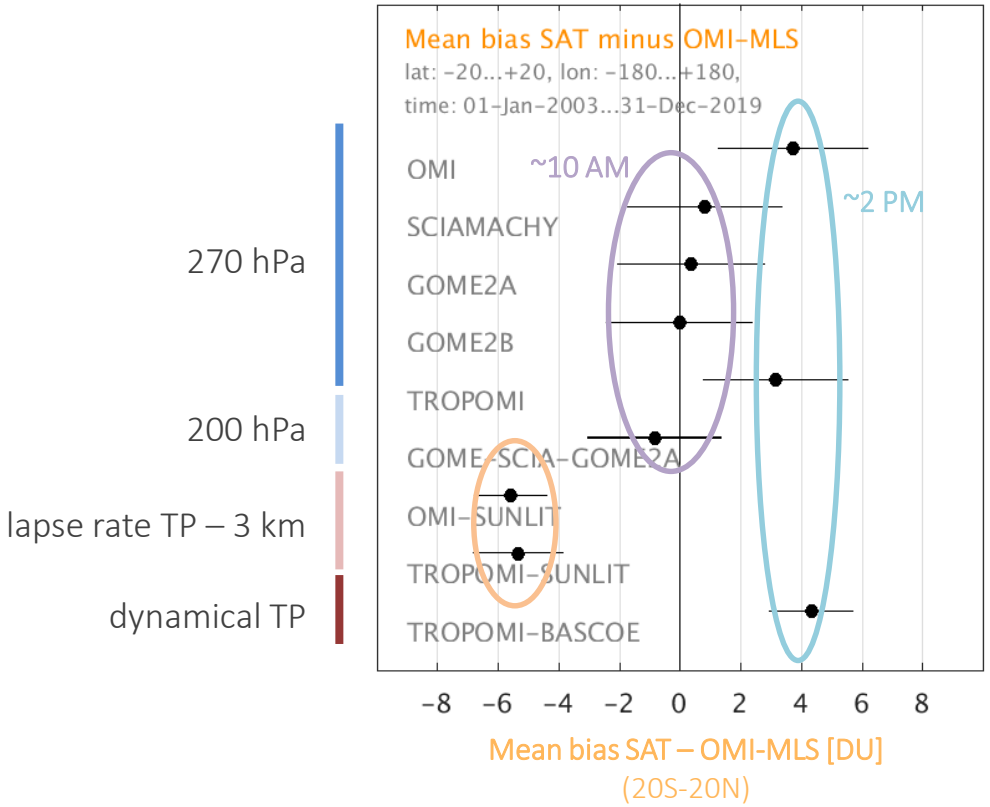
Preliminary results

Better agreement over large spatial scales



before harmonisation of top level

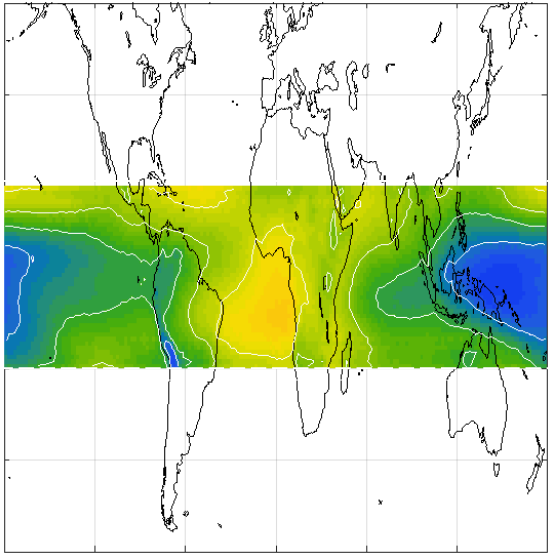
Better agreement over large spatial scales



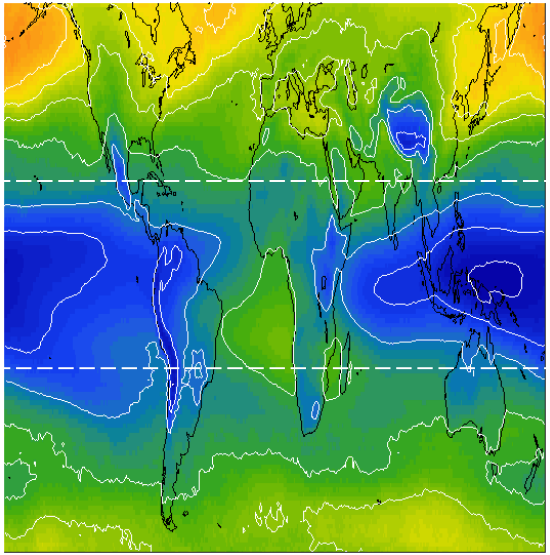
after harmonisation of top level

… and at small spatial scales

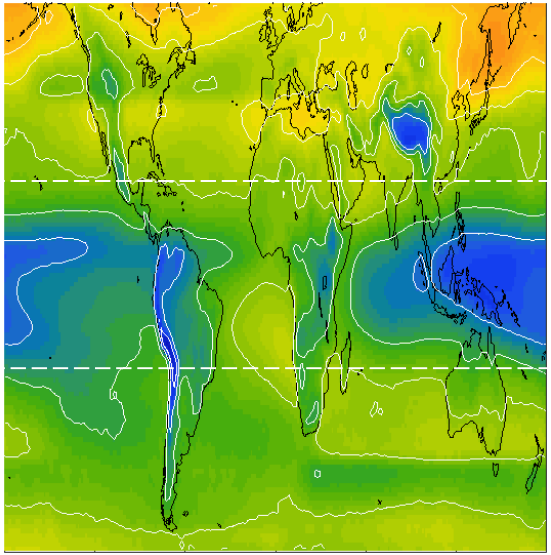
OMI CCD



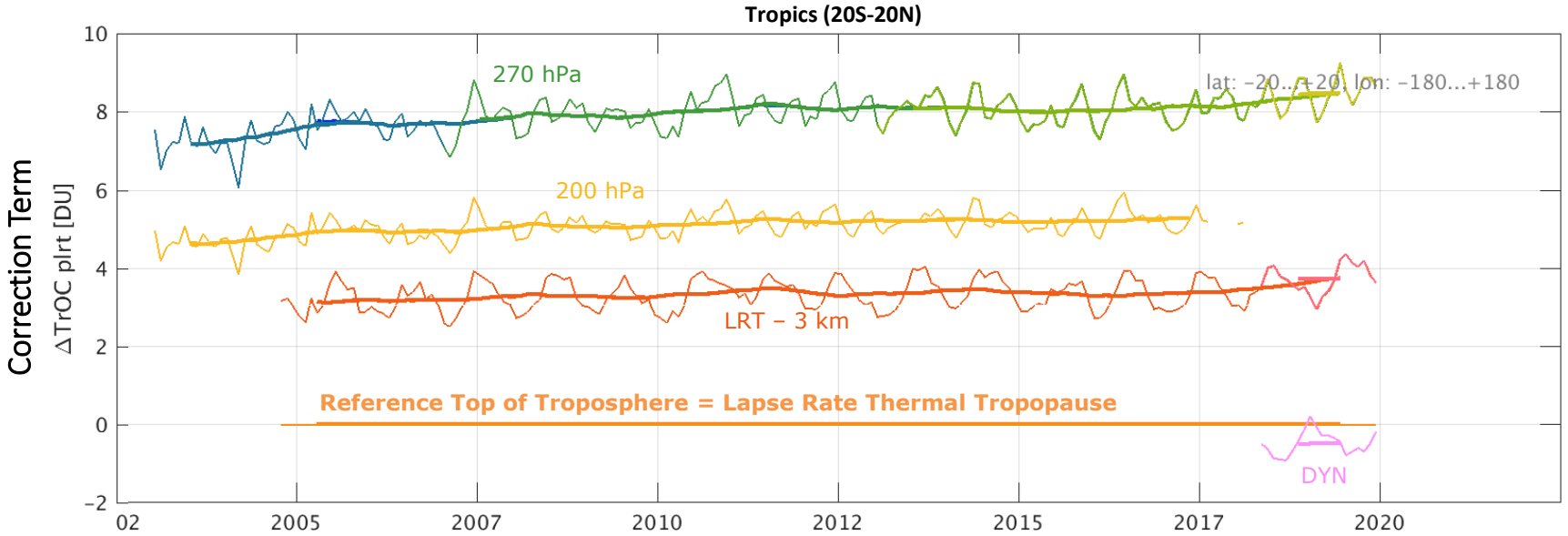
OMI-SUNLIT



OMI-MLS



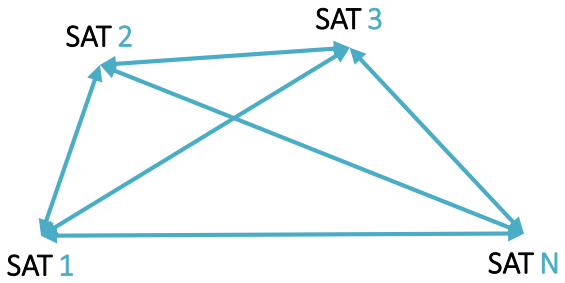
Harmonisation alters temporal structures (variability, trends)



Next steps

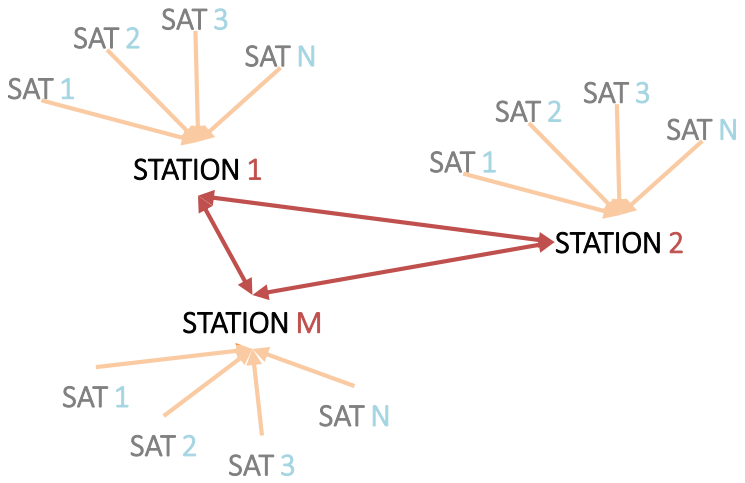
Planned analyses & feedback to TOAR II

Consistency of satellite data records (SOWG, CEOS)



- Complementary techniques, spectral range, sensors…
- Ensemble of satellite CDRs allows to identify issues in single records, between measurement techniques…
- Analysis of dis/agreement of spatial distributions and long-term changes

Consistency of ground-based data records (HEGIFTOM)



- Use satellite ensemble as a transfer standard to estimate bias and dispersion of data at each ground-based station
- Investigate inhomogeneities in time and across network(s)
- Focus first on ozonesonde network
- If HEGIFTOM provides ozone column data (surface to lapse rate TP, surface to fixed level) from other instruments these might be considered as well.

Conclusions & perspectives

- Framework to harmonise tropospheric ozone Climate Data Records from satellites
  - Harmonisation of ozone profiles using Complete Data Fusion
  - Harmonisation of tropospheric columns with vertical correction for tropopause definition
  - CAMS reanalysis used as a transfer standard
- Harmonisation generally improves the agreement between
  - Residual tropospheric column CDRs,
  - OE-based profile CDRs,
  - Residual and OE-based CDRs,
  - Spatial distributions and temporal evolution.
- Next steps
  - Further sensitivity studies and refinement of harmonisation
  - Characterise remaining discrepancies between ozone CDRs after vertical harmonisation
  - Investigate underlying causes of differences → interaction with data providers (CEOS, networks, TOAR…)
  - Establish confidence in available tropospheric ozone CDRs → climate monitoring & climate research community

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