Evaluation of the MetOp PMAp 2 AOD Products using EMAC Model Data, AERONET Ground Station and Reference Satellite Observations (MISR and MODIS-AQUA/TERRA)

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Study Approach

We use an augmented version of the EMAC Model

Based on Abdelkader et al., 2015 and 2017 (http://www.eco-serve.de/en/Results.html) and Metzger et al., 2002, 2006, 2012, 2016 and 2018 (https://www.researchconcepts.io)

The EMAC Earth-System Model is a community modelling effort: http://www.messy-interface.org

With our augmented version being an outcome of the cooperation of the Max Planck Institute for Chemistry in Mainz and The Cyprus Institute.

The advantage of our EMAC version

Is the detailed chemical and micro-physical processes and the high resolution simulations.

EMAC (ECHAM5/MESSy 2.5.0) base model

T255-T106 L31 ($\approx$ 55–110km globally, 31 vertical levels up to 10hPa), nudged meteorology (ECWMF), state-of-the-art anthropogenic emissions, chemical aging & water uptake, online calculation of natural sea salt and dust aerosols in feedback with meteorolgy (soil moisture).

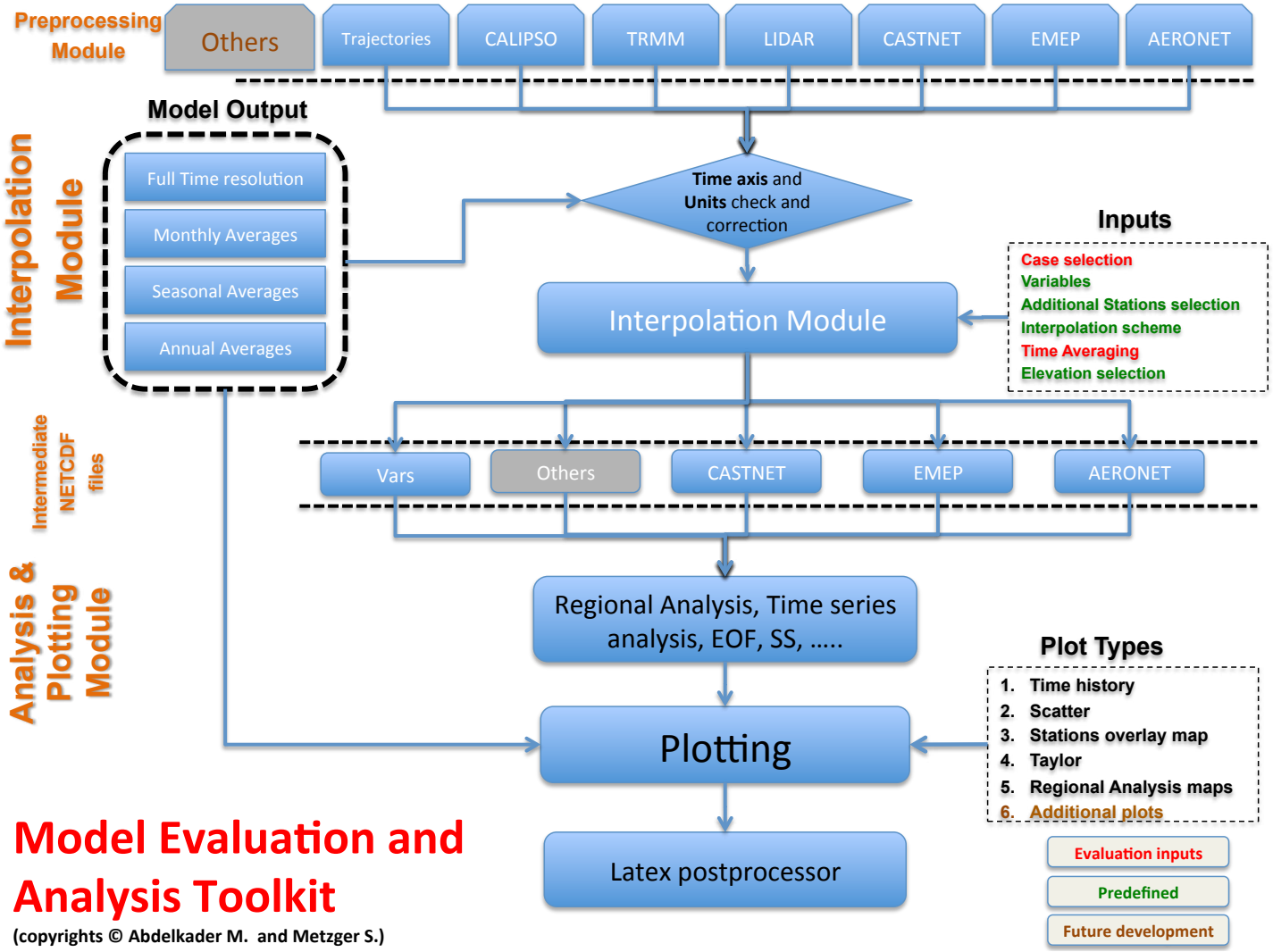
No assimilation of aerosol retrieved satellite data. To represent the actual day-to-day meteorology in the troposphere, the model dynamics are weakly nudged (Jeuken et al., 1996; Jöckel et al., 2006a; Lelieveld et al., 2007) towards the analysis data of the European Centre for Medium-Range Weather Forecasts (ECMWF) operational model data (up to 100hPa).

EMAC Model set-up

Model Features	EMAC(PMAp2 study)	EMAC(base versions)
Online calculation of natural emissions	YES	NO
(seas spray & mineral dust)	(Abdelkader et al.,2015,2017)	
Emission feedback with meteorology	YES	NO
(soil moisture & precipitation)	(Klingmüller et al., 2018)	
Chemical speciation of natural emissions	YES	NO
(e.g., $Na^+, K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-}, HSO_4^-, Cl^-$)	(Cations/Anions)	(Bulk: SS, DU, BC/OC)
Explicit & fast hygroscopic growth calculation	YES	N/A
(full & numerical efficient gas-liquid-solid aerosol partitioning)	(Metzger et al.,2012,2016)	
Aerosol-cloud clover coupling	YES	N/A
(aerosol hygroscopic growth in fog-haze and thin optical clouds)	(Metzger et al.,2006,2007)	
Consistent aerosol-cloud-radiation feedbacks	YES	Uncoupled
(driven by aerosol hygroscopic growth & water vapour uptake)	(Metzger et al.,2016,2018)	
Numerically optimized EMAC submodels	YES	NO
(computationally efficient for, e.g., day-ahead solar forecasting)	(EoCoE report, 2018)	
Output optional at local time (MetOp overpass)	YES	NO

Table: *References and results can be found at:*
`https://www.researchconcepts.io` and `http://www.eco-serve.de/en/Results.html`

Evaluation and Analysis Toolkit



Model Evaluation and Analysis Toolkit

Temporal and spatial collocation of model and observational data.

Details are given in the EUMETSAT ITT 15/210839: PMAp2 product validation report (21/12/2016, https://bit.ly/2TAuaKY.)

Temporal and spatial collocation

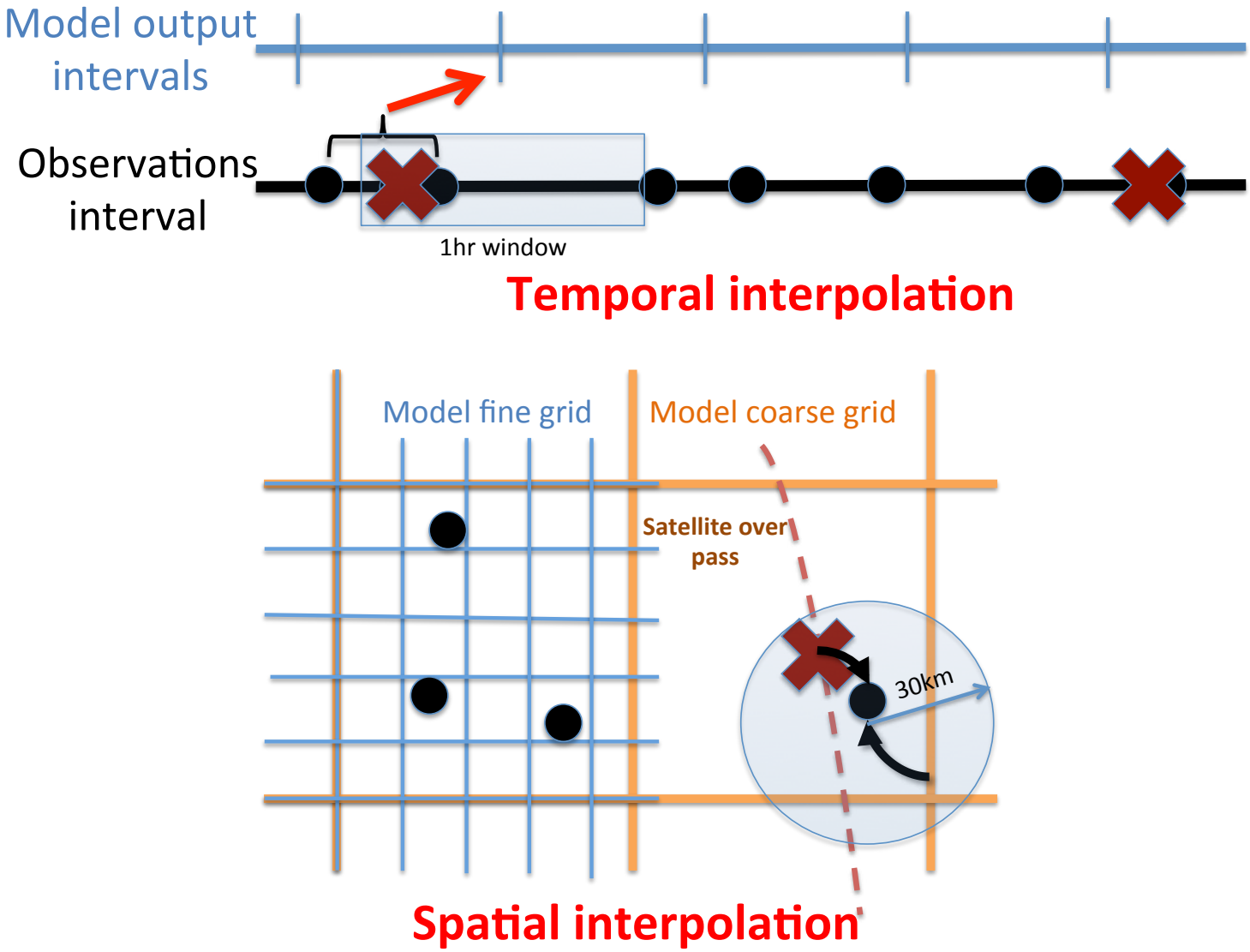


Figure: *Schematic representation of the interpolation scheme used to compare different satellite products with the AERONET station data and model results.*

Time-series of major anions (2000-2013)

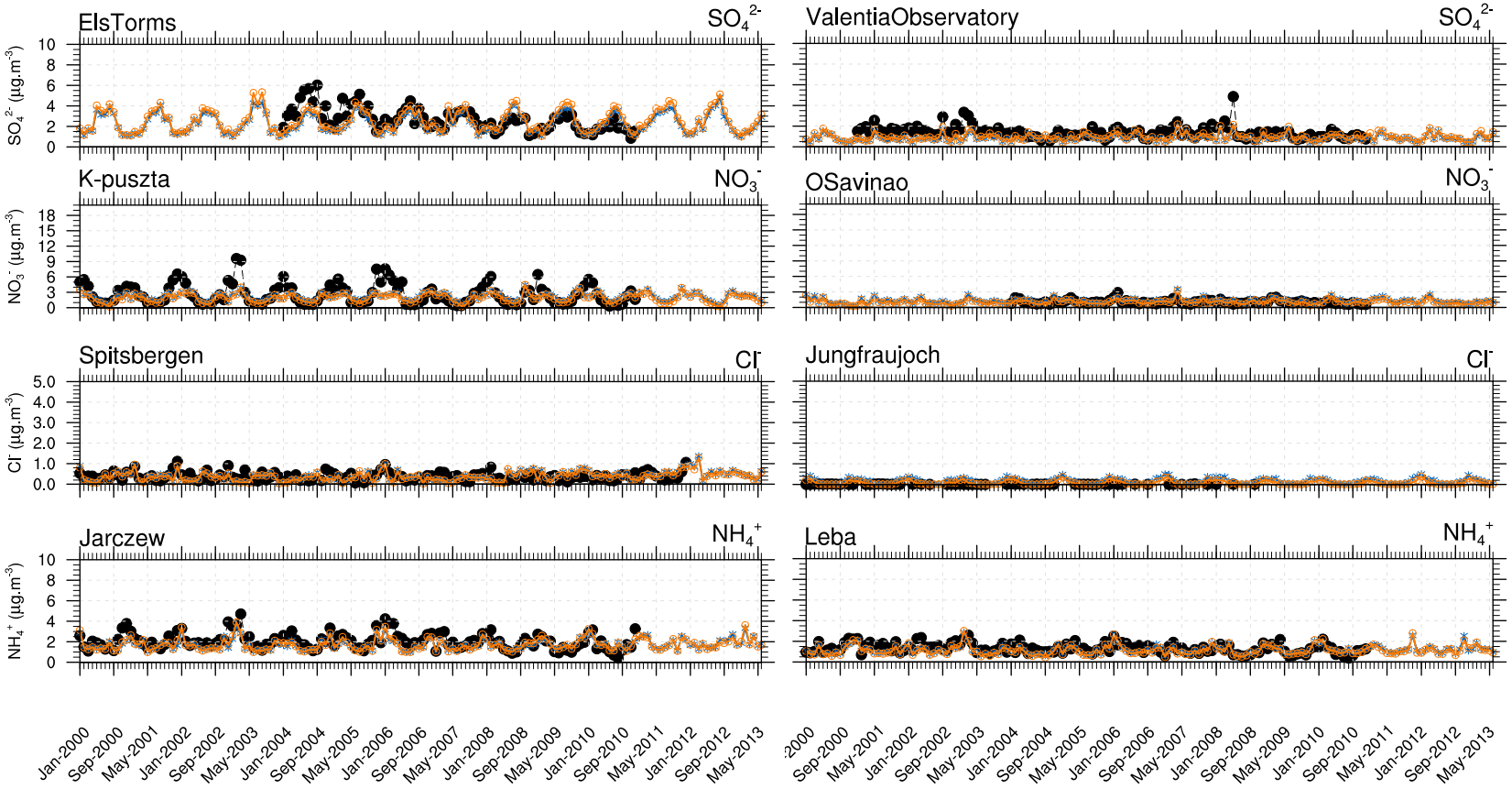


Figure: *Lumped aerosol concentrations (liquids+solids) of the EMAC simulations and EMEP observations: Sulfate (SO_4^{2-}), nitrate (NO_3^-), chloride (Cl^-), and cation ammonium (NH_4^+); each species is compared with two different station observations (left and right column, black lines); EMAC simulations based on two gas-liquid-solid partitioning schemes: ISORROPIA II (blue line, Fountoukis, C. and Nenes. A, 2007; https://doi.org/10.5194/acp-7-4639-2007), EQSAM4clim (orange line, Metzger et al, 2016, 2018, https://doi.org/10.5194/acp-18-16747-2018).*

Time-series of major cations (2000-2013)

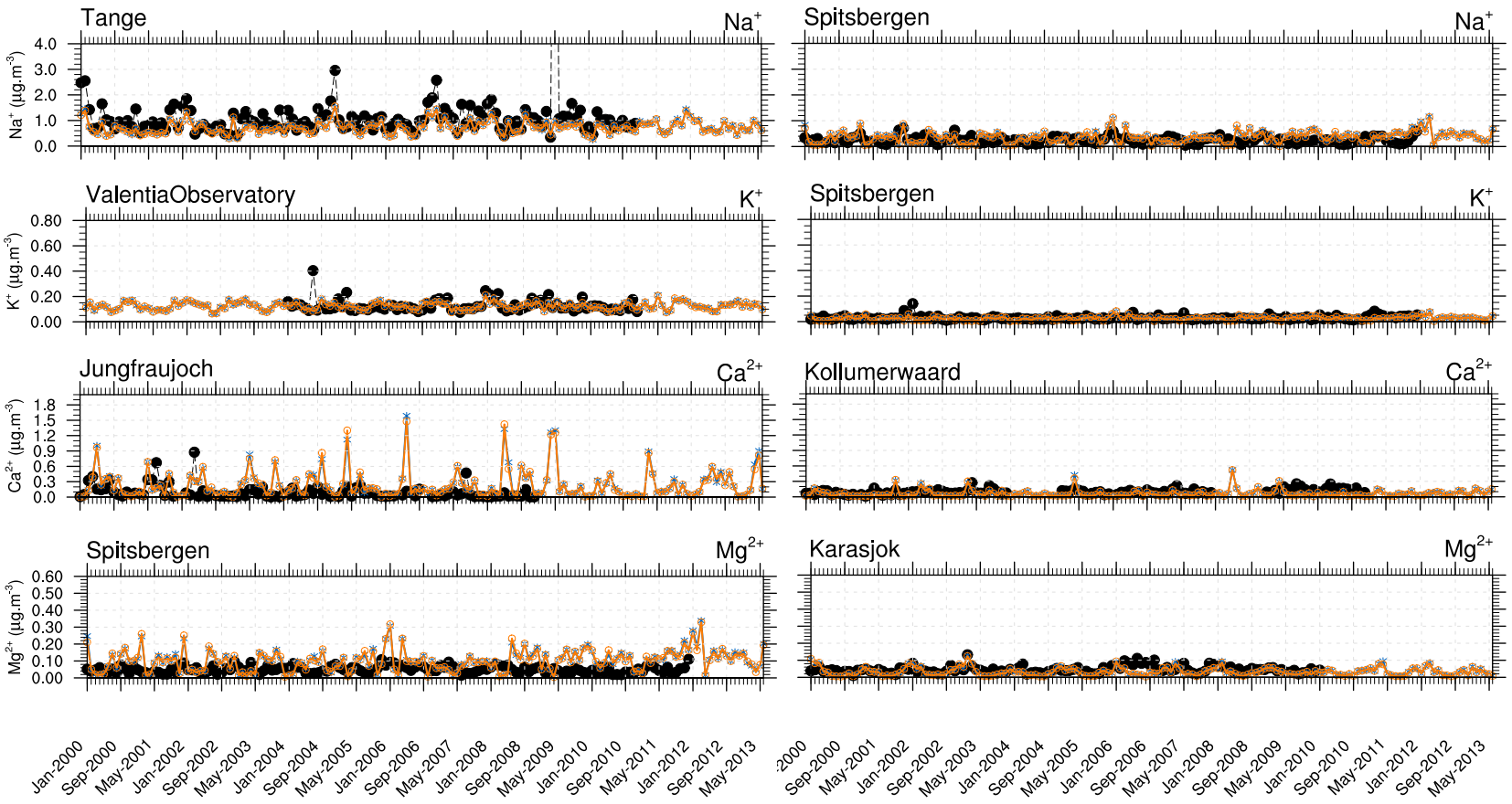
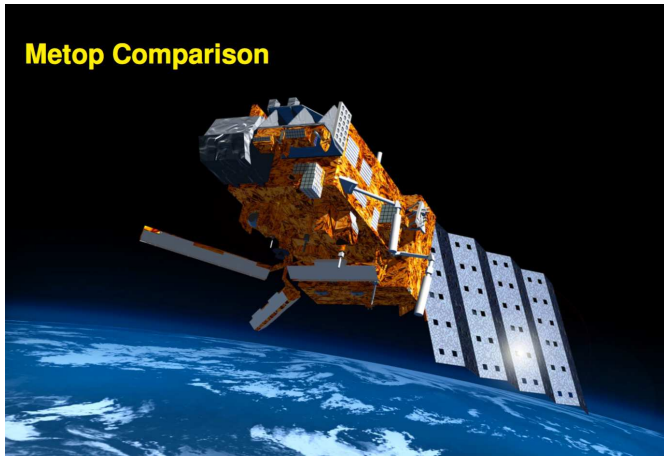


Figure: *Lumped aerosol concentrations (liquids+solids) of the EMAC simulations and EMEP observations: Sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}); each species is compared with two different station observations (left and right column, black lines); EMAC simulations based on two gas-liquid-solid partitioning schemes: ISORROPIA II (blue line, Fountoukis, C. and Nenes. A, 2007; https://doi.org/10.5194/acp-7-4639-2007), EQSAM4clim (orange line, Metzger et al, 2016, 2018, https://doi.org/10.5194/acp-18-16747-2018).*

Satellite data used for the PMAp2.x evaluation



Instrument	Platform	Data Level	Temporal resolution	Spacial resolution	Product Version
M01	MetOp B	L2	Daily	10 km x 40 km	2.10, 2.22
M02	MetOp A	L2	Daily	5 km x 40 km	2.10, 2.22
Terra	MODIS-Terra	L2, L3	Daily	10 km x 10 km	6.0
Aqua	MODIS-Aqua	L2, L3	Daily	10 km x 10 km	6.0
MISR	Terra-MISR	L3	Daily	0.5°	8.31

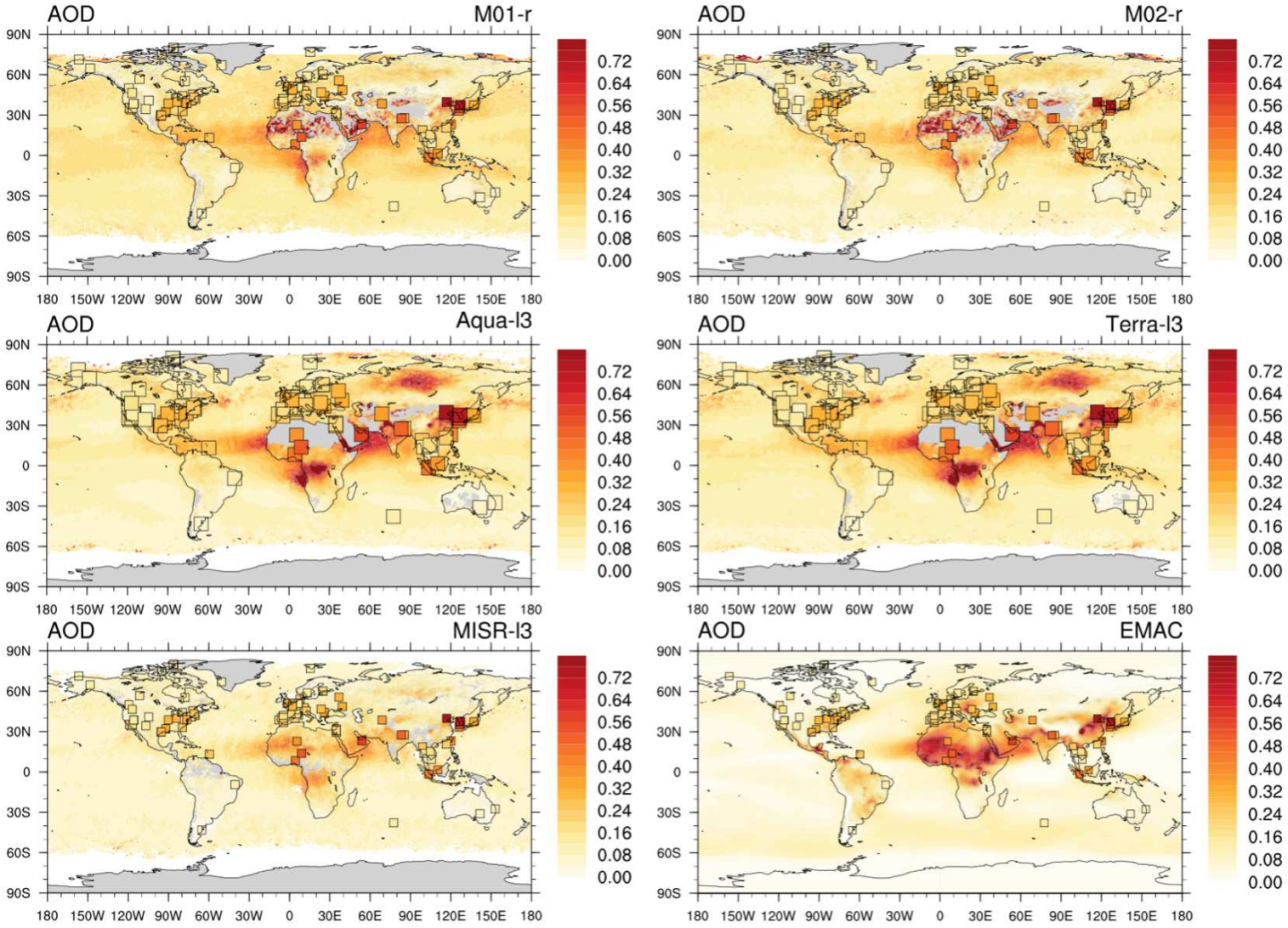


Figure: *Spacial L3 AOD distribution of the re-gridded MetOp PMAp2 AOD vs. MISR, MODIS (Aqua, Terra) and EMAC results with AERONET station observations (overlaid squares). M01=MetOp B, M02=MetOp A. All based on a four months average (June–September 2013).*

All vs AERONET observations (global mean)

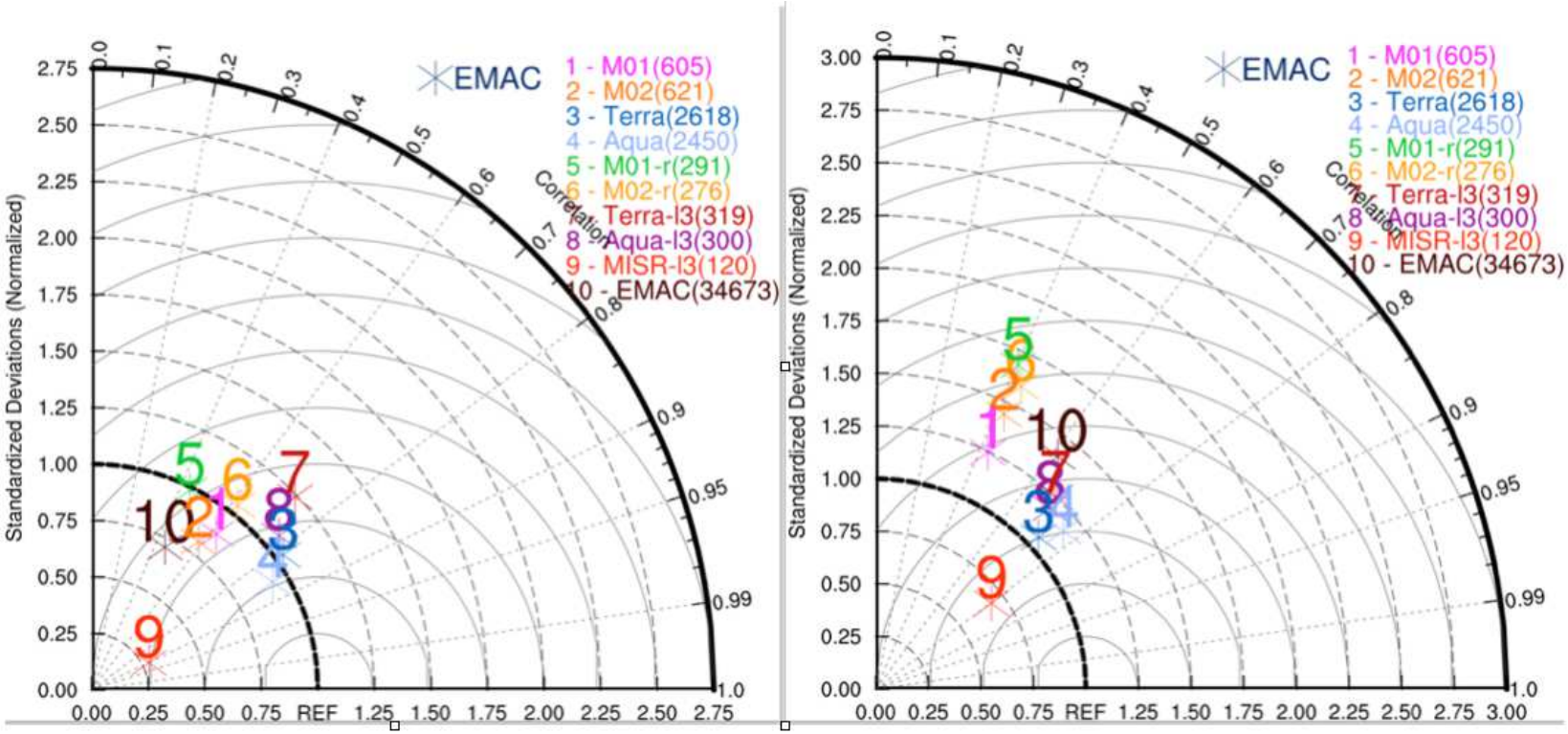


Figure: *Taylor diagram of PMAp2.1, MISR, MODIS and EMAC vs AERONET AOD. Left panel: linear-scale, right panel: log-scale. Level 2 products - number 1-4; L3 products - number 5-9. 0.5hr/30km collocation vs AERONET (based on 1hr means, February–May 2015).*

L2 AOD Products vs AERONET observations (lin log)

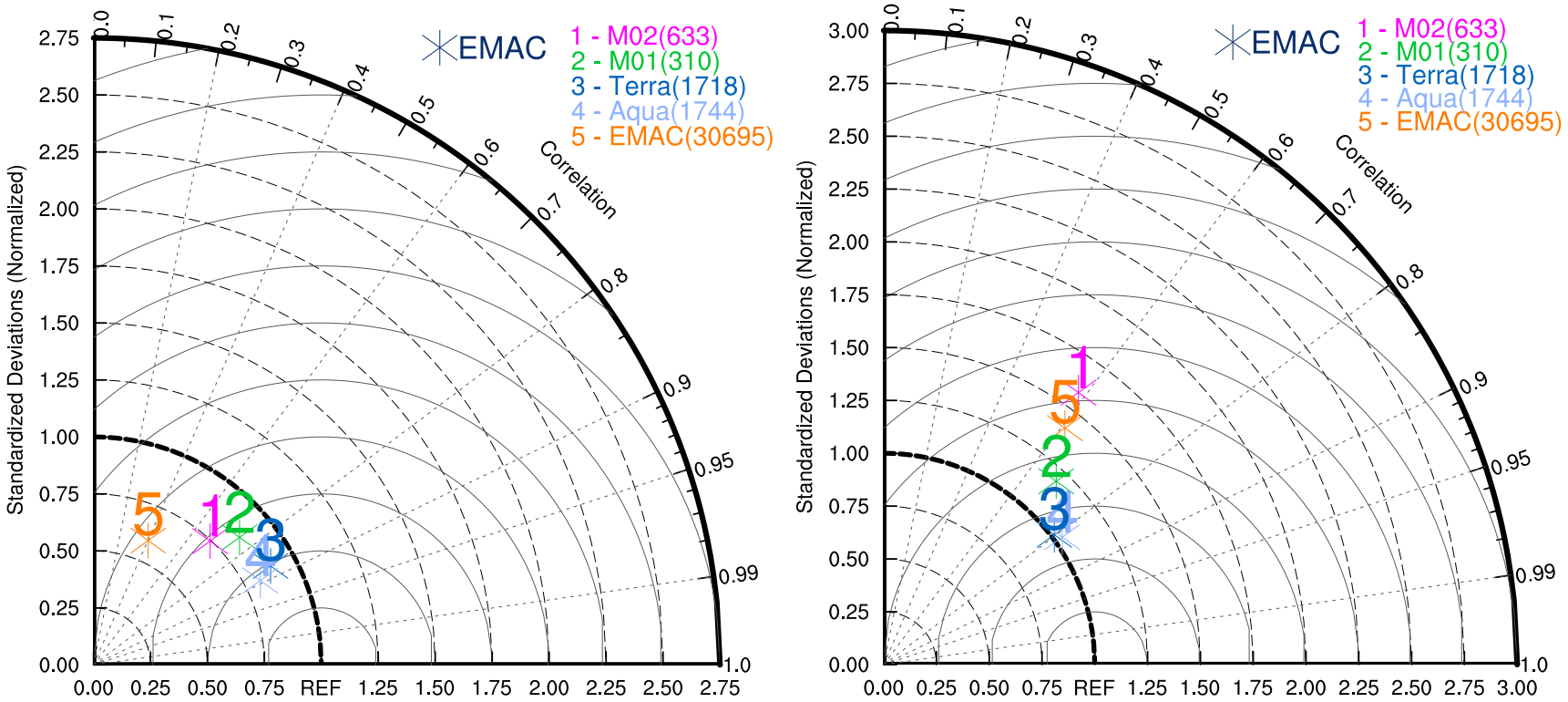


Figure: *Taylor diagram of L2 PMAp v2.2.2 (M01 = Metop B, M02 = Metop A), MODIS (Aqua/Terra) and EMAC vs AERONET AOD. Left panel: linear-scale, right panel: log-scale. 0.5hr/30km collocation vs AERONET (based on 1hr means, February–May 2015).*

Selected Aeronet stations

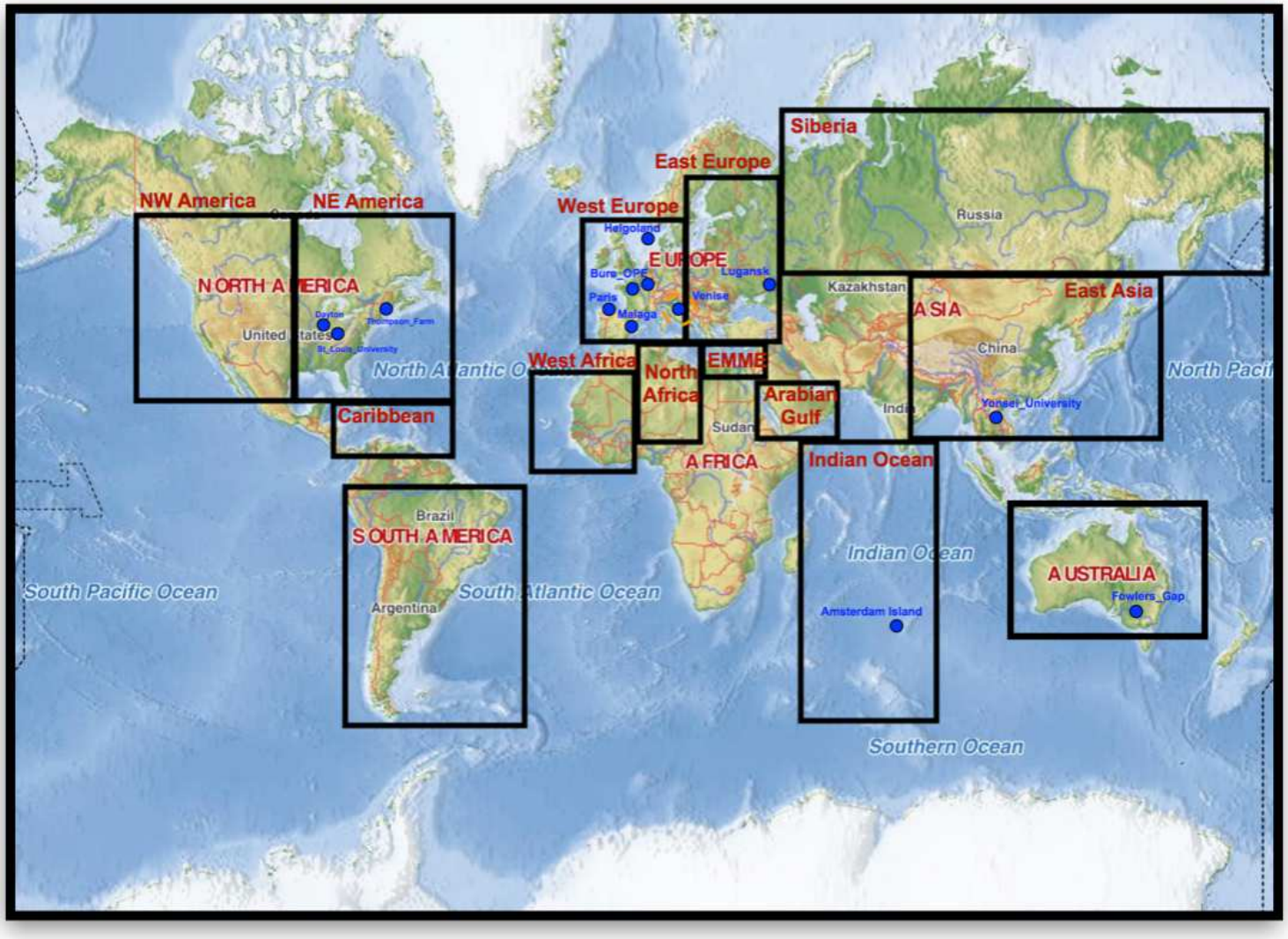


Figure: *Selected Aeronet station locations and region definition.*

All products vs AERONET observations (2015 linear)

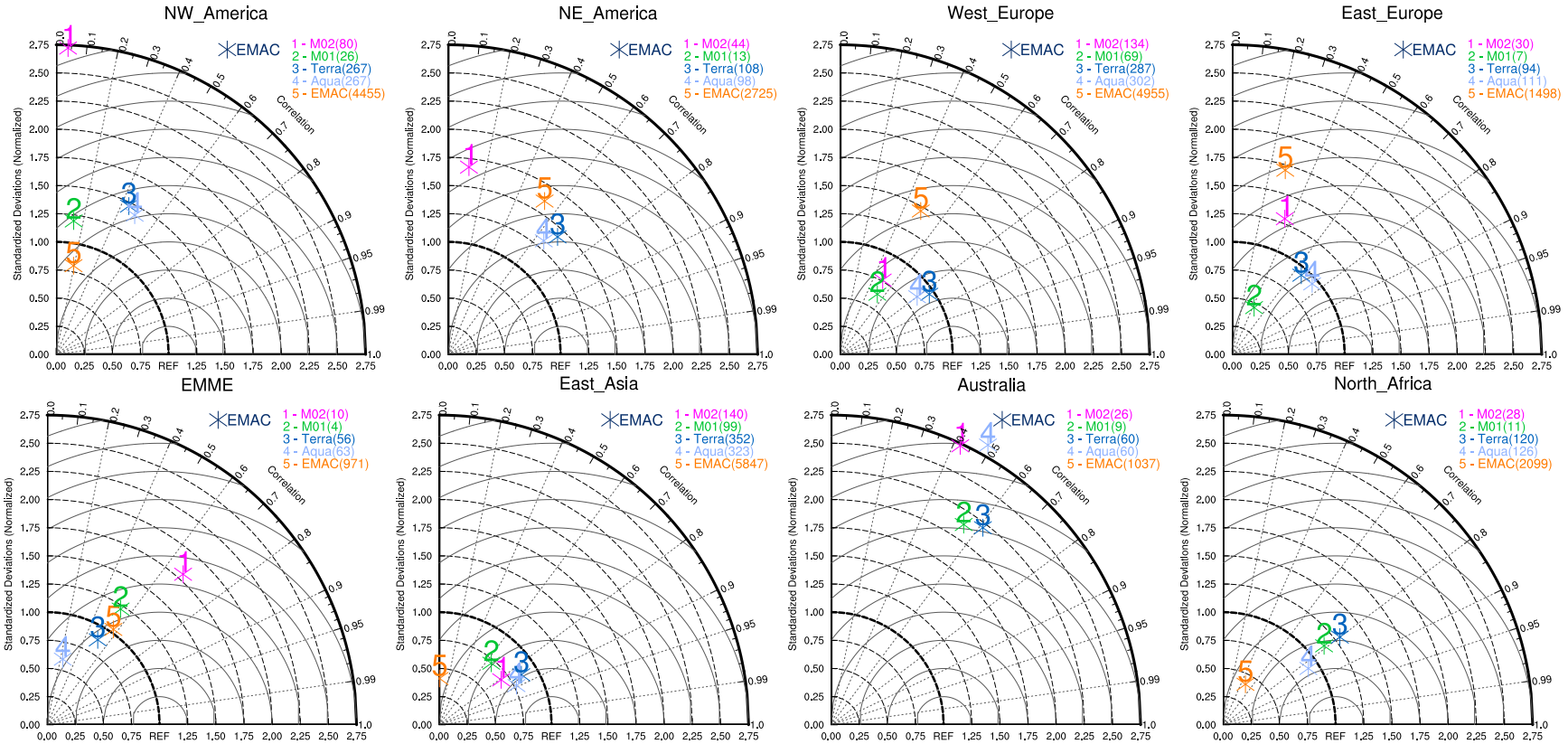


Figure: *Taylor plots of L2 MetOp PMAp v2.2.2 (M01 = Metop B, M02 = Metop A), MODIS (Aqua, Terra) and EMAC AOD products versus AERONET observations (February–May 2015 avg; linear scale). Note that not all cases give a robust statistics.*

All products vs AERONET observations (2015 log)

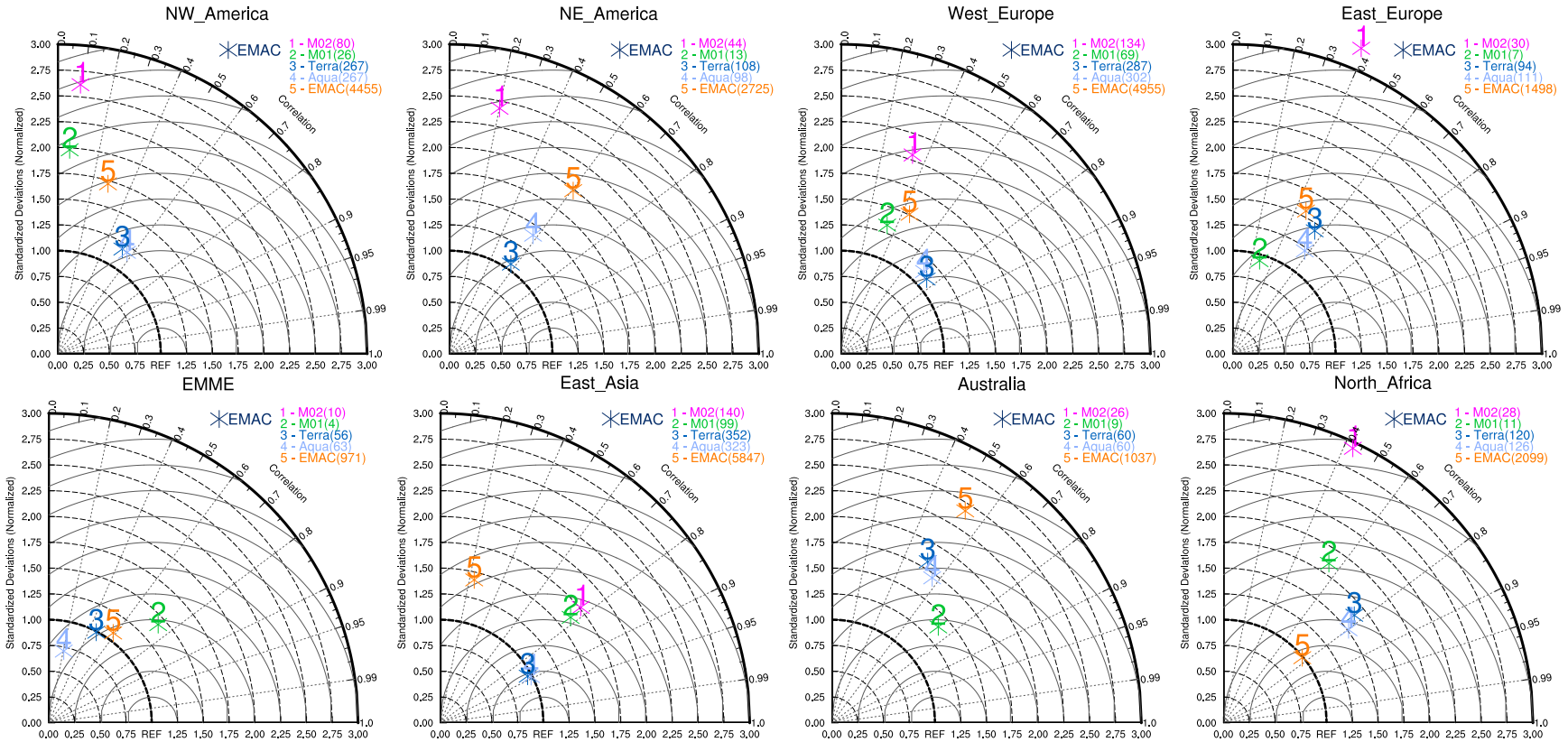


Figure: *Taylor plots of L2 MetOp PMAp v2.2.2 (M01 = Metop B, M02 = Metop A), MODIS (Aqua, Terra) and EMAC AOD products versus AERONET observations (February–May 2015 avg; log scale). Note that not all cases give a robust statistics.*

L2 products vs AERONET observations

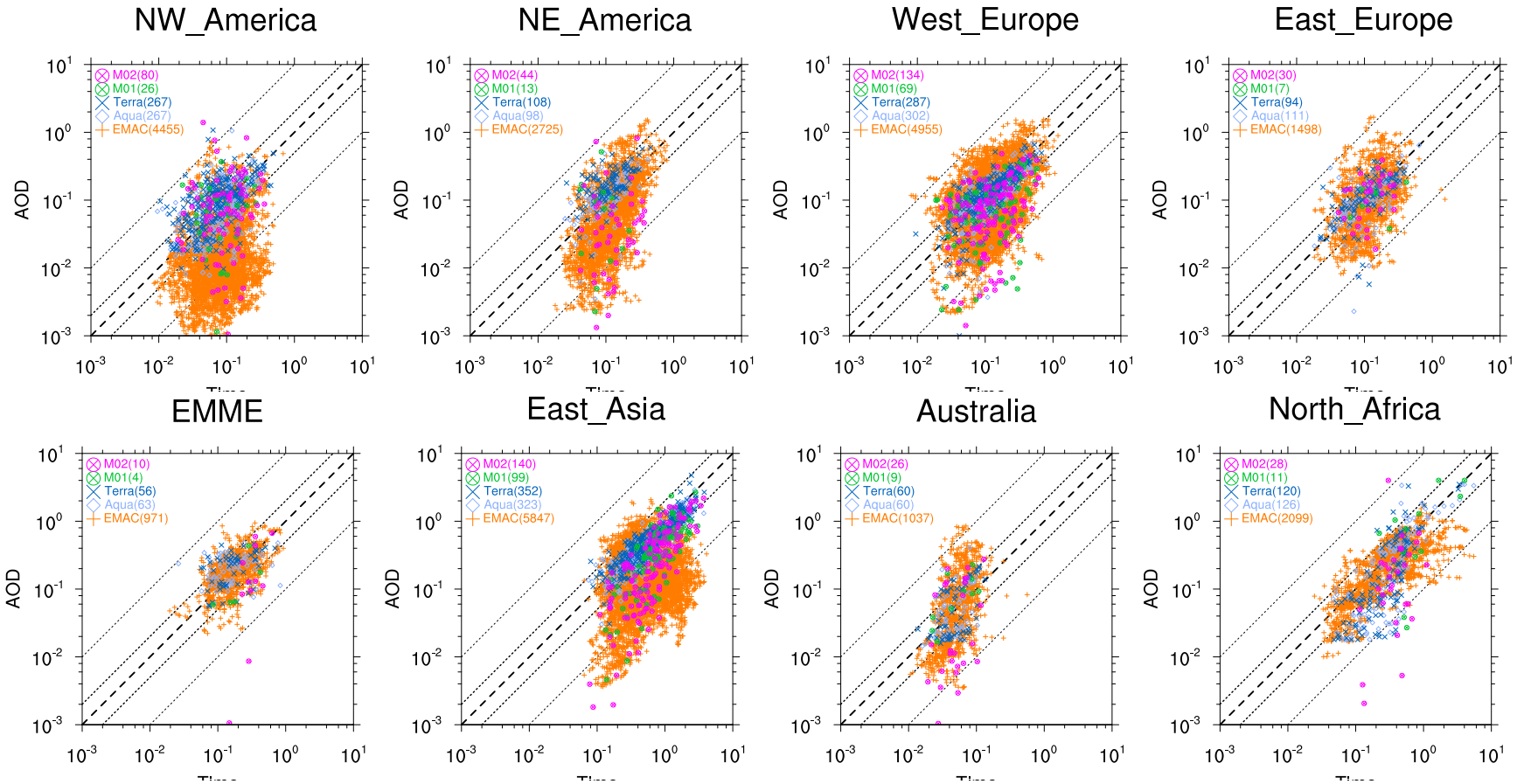


Figure: *L2 MetOp PMAp2.2.2, MODIS (Aqua, Terra) and EMAC AOD products versus AERONET observations (February–May 2015 avg; log scale).*

Top: Jun - Sep 2013 – Bottom: Feb - May 2015

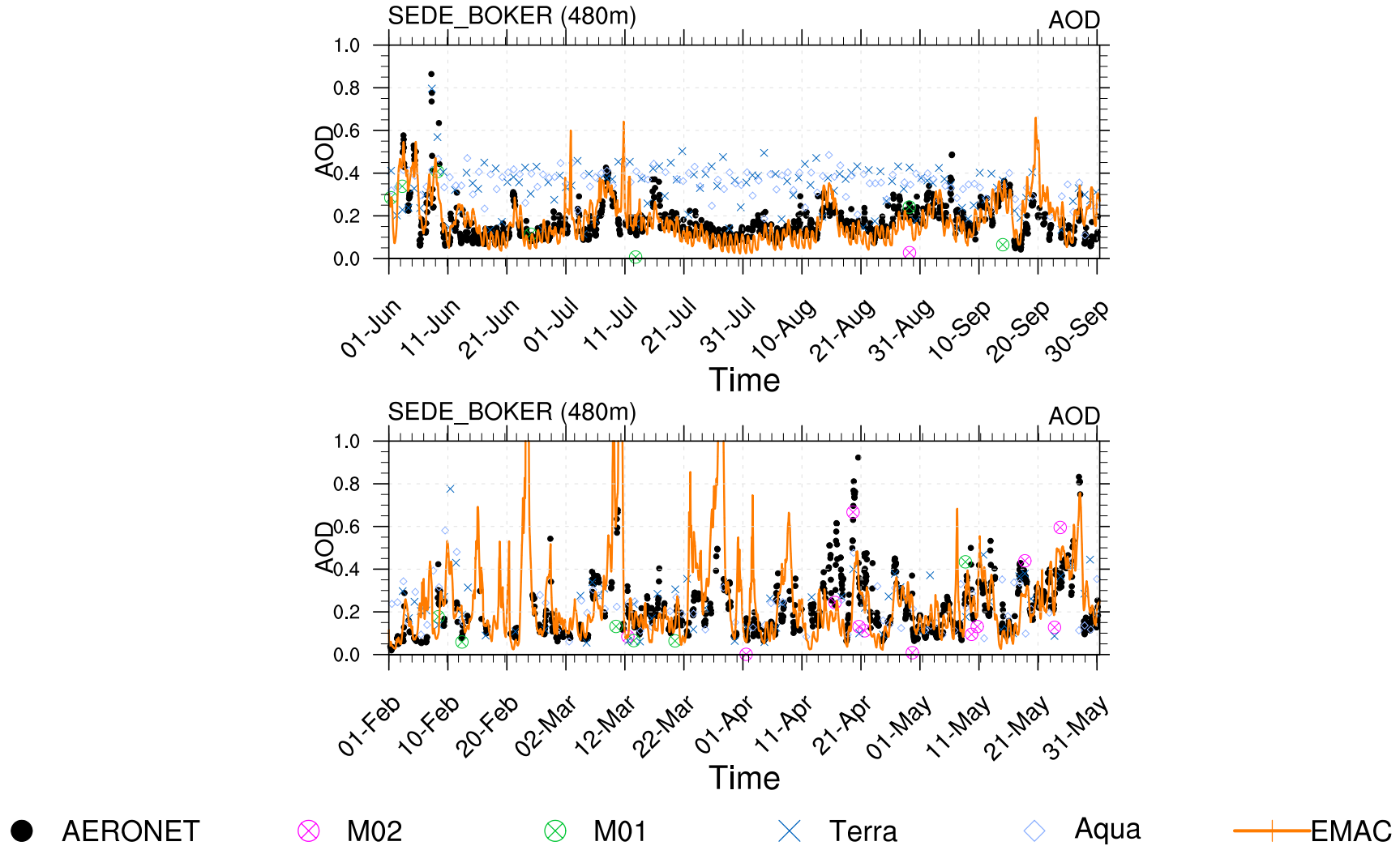


Figure: *AOD time series of PMAp2.2.2, MODIS (Aqua/Terra) and AERONET (all L2). M01 = Metop B, M02 = Metop A, EMAC model results orange line, AERONET black dots.*

Column 1-2: Jun - Sep 2013 – Column 3-4: Feb - May 2015

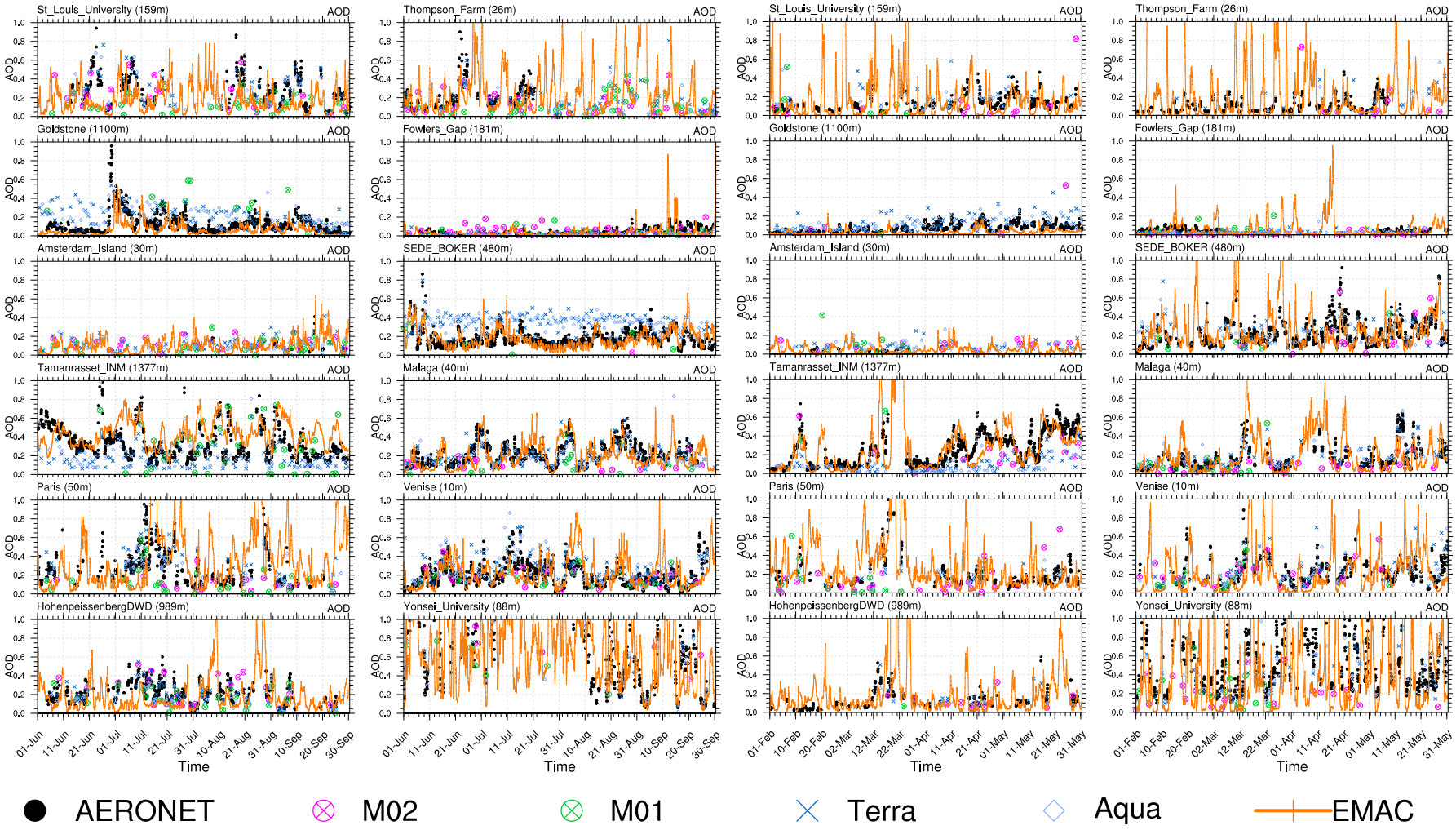


Figure: *AOD time series of PMAp2.2.2, MODIS (Aqua/Terra) and AERONET (all L2). M01 = Metop B, M02 = Metop A, EMAC model results orange line, AERONET black dots.*

PMAp2.10 and v2.22 AOD (L2) products (Metop A and B)

have been thoroughly evaluated versus model results (EMAC), other satellite products (L2 and L3) and AERONET observations.

Available L3 satellite products (e.g., MODIS, MISR)

generally show a higher correlation compared to AERONET observations than level 2 products.
Level 2 satellite products, which are more difficult to process are, however, required for a fair comparison.

The PMAp2 products nicely compare for many AERONET stations

with the ground observations, model results and even with widely available level 2 and 3 satellite products.

Differences between the AOD time-series

are most likely caused by cloud-masking. Still, most AOD time-series are generally supported by the EMAC model results.

Aging on primary aerosols (DU/OC/BC) appears to be of crucial importance

Water vapor uptake on (usually assumed) dry particle surfaces can regionally significantly increase aerosol mass/radius and hence AOD, but in turn also increases wet scavenging & dry deposition, thus decreasing aerosol lifetime and transboundary transport.

Limitations of this validation

The amount of AERONET operational stations over ocean is limited so that the AERONET comparison might be biased.
On the other hand, the EMAC model results may not show the truth over the oceans either, but provides a global coverage.

Thank you for your attention

EUMETSAT ITT 15/210839 Final Acceptance Review (FAR) presentation:

Metzger, S.; About the Validation of the Polar Multi-Sensor Aerosol product (PMAp) – http://bit.ly/2QObx8V.

Dust–air pollution dynamics over the eastern Mediterranean

Abdelkader, M., Metzger, S., Mamouri, R. E., Astitha, M., Barrie, L., Levin, Z., and Lelieveld, J.; Atmos. Chem. Phys., 15, 9173–9189, 2015 – https://doi.org/10.5194/acp-15-9173-2015.

Sensitivity of transatlantic dust transport to chemical aging and related atmospheric processes

Abdelkader, M., Metzger, S., Steil, B., Klingmüller, K., Tost, H., Pozzer, A., Stenchikov, G., Barrie, L., and Lelieveld, J.; Atmos. Chem. Phys.,17, 3799–3821, 2017 – https://doi.org/10.5194/acp-17-3799-2017.

Revised mineral dust emissions in the atmospheric chemistry–climate model EMAC

Klingmüller, K., Metzger, S., Abdelkader, M., Karydis, V. A., Stenchikov, G. L., Pozzer, A., and Lelieveld, J.; (MESSy 2.52 DU_Astitha1 KKDU2017 patch), Geosci. Model Dev., 11, 989-1008, 2018 – https://doi.org/10.5194/gmd-11-989-2018.

Aerosol Water Parameterization: A single parameter framework

Metzger, S., Steil, B., Abdelkader, M., Klingmüller, K., Xu, L., Penner, J.E., Fountoukis, C., Nenes, A., and Lelieveld, J.; Atmos. Chem. Phys., 16, 7213–7237, 2016 – https://doi.org/10.5194/acp-16-7213-2016.

Aerosol water parameterization: long-term evaluation and importance for climate studies

Metzger, S., Steil, B., Abdelkader, M., Klingmüller, K.; Atmos. Chem. Phys., 18, 16747–16774, 2018 – https://doi.org/10.5194/acp-18-16747-2018.