

SWEN METZGER^{1,2} WITH SUPPORT FROM: GREGOR FEIGEL¹, BENEDIKT STEIL³, SAMUEL RÉMY⁴, ANDREAS CHRISTEN¹, SUE GRIMMOND⁵
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RESEARCH QUESTION

To which extent does aerosol hygroscopic growth influence meteorology on global and/or urban scales?

EXPERIMENTS SET-UP

Only aerosol water is switched on / off. Aerosol number concentrations and composition unchanged. Exp 1-2, stp, div, vor nudging towards ERA interim reanalysis data. No data assimilation. AOD calculation from size resolved N, PM and water.

EXPERIMENT 1 AND 2 - NUDGED TOWARDS ERAI

Exp1 with aerosol water, Exp2 without aerosol water (both T42L31, daily mean).

EXPERIMENT 3 AND 4 - ONLY SST FORCING (HADISST)

Exp3 with aerosol water, Exp4 without aerosol water (both T42L31, daily mean).

IDENTICAL EMAC SETUP OF ALL EXPERIMENTS (1 - 4) W.R.T. EMISSIONS, ETC.

All exp., identical aerosol and gas phase chemistry, emission inventory and model spin-up.

REFERENCE SIMULATIONS (HIGH RESOLUTION)

EMAC AOD vs CAMS reference simulations (REA) vs AERONET (3hr avg). CAMS REA includes AOD observations (data assimilation). EMAC does not. EMAC output regridded to CAMS grid (0.5 deg) for consistent reference model evaluation.

SATELLITE OBSERVATIONS AND GROUND STATION OBSERVATIONS (EUMETSAT ITT 15/210839)

AOD of PMAp2 (M01, M02) and MODIS (Aqua / Terra) vs AERONET (all L2, 3hr avg). 0.5 hour temporal window and 30 km radius spatial collocation relative to AERONET stations. EMAC setup and observations similar to previous PMAp study.

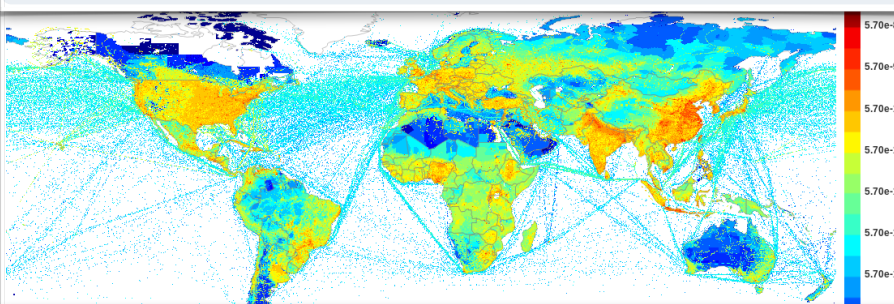


HIGH RESOLUTION RUNS - EMAC T106 / T255 + ICON

The ICON modelling framework is a joint project between the German Weather Service and the Max Planck Institute for Meteorology for developing a unified next-generation global numerical weather prediction and climate modelling system. The ICON model has been introduced into DWD's operational forecast system in January 2015 (<https://code.mpimet.mpg.de/projects/iconpublic>).

UPDATE OF EMAC EMISSION INVENTORY

Update of EMAC emission inventory based on CAMS-GLOB-ANT V4.2:
<https://eccad.aeris-data.fr/2020/04/10/cams-glob-ant-v4-2-and-v4-2-r1-1-now-available>.



SNAP SHOT

EMAC sensitivity results are preliminary and a more in-depth analysis is in progress (with T255).

TAKE HOME MESSAGE

Aerosols can affect AOD, even with unchanged aerosol composition and number concentrations.

MODEL FEEDBACK STUDY W.R.T. STATION OBSERVATIONS OF AEROSOL OPTICAL DEPTH (AOD)

AOD change [%] - global station mean for different experiments $\Delta = (1 - \text{Exp}/\text{Ref}) \times 100$.
 Ref = reference in Δ with Exp = global AQ model type (CAMS T255 or EMAC T106 / T42), or
 Ref = obs, i.e., AERONET station observations: approx. 60 km radius (light path) with 3 hourly mean.
 AW = yes/no: refers to whether aerosol water explicitly considered in model physics and radiative forcing.
 Free = yes/no: refers to external meteorological forcing. For EMAC: yes = nudging, no = only SST forcing.
 Free = no for CAMS, since reanalysis results are shown (CAMS REA) that are based on AOD data assimilation.
 Res = horizontal model grid box resolution. CAMS (T255): approximately 55 km (with an equidistant model grid).
 EMAC (T255): 55 km, EMAC (T106): 110 km, EMAC (T42): 280 km - at the equator approx. (non equidistant).
 EMAC Exp 1-4 simulation period: 1 June - 30 September 2013, AOD output + AERONET comparison daily mean.
 CAMS and EMAC* simulation period: 1 - 30 June 2013, AOD output + AERONET comparison 4 hourly mean.
 EMAC* = EMAC output regridded to CAMS grid for AERONET station comparison and statistical analysis.

TABLE: AOD change [%] - global station mean for different experiments (see text).

Location	Global/mixed	Global/mixed	Global/mixed	Global/mixed	Global/mixed	Global/mixed
Ref	OBS - CAMS	OBS - EMAC*	CAMS - EMAC*	Exp1 - Exp2	Exp1 - Exp3	Exp1 - Exp4
Res	60 vs 55 km	60 vs 55 km	T255 vs T255	T42 vs T42	T42 vs T42	T42 vs T42
AW	yes - no	yes - yes	no - yes	yes - no	yes - yes	yes - no
Free	N/A - no	N/A - no	no - no	no - no	no - yes	no - yes
Npoints	19237	19237	19237	22277	22277	22277
Δ [%]	-8.75	16.63	23.34	19.26	-37.90	-22.73
Europe	Urban/City	Urban/City	Urban/City	Rural/Coast	Rural/Coast	Rural/Coast
Exp	Exp1 - Exp2	Exp1 - Exp3	Exp1 - Exp4	Exp1 - Exp2	Exp1 - Exp3	Exp1 - Exp4
Npoints	773	773	773	303	303	303
Δ [%]	-31.57	30.59	9.47	-31.95	29.10	0.98

SELECTION OF AERONET SITES WITHIN URBAN AREAS IN THE EUROPEAN UNION

Sensitivity study, first focus on AERONET sites located in urban areas in the European Union. Note, not all sites have data available throughout our simulation period (Jun-Sep year 2013). Results for an urban site are shown in the lower left Figure in comparison to a remote location (i.e., Hamburg vs Helsinki Lighthouse). https://aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_aod_v3 and https://en.wikipedia.org/wiki/List_of_urban_areas_in_the_European_Union.

LOCATION OF AERONET SITES WITHIN URBAN AREAS IN THE EUROPEAN UNION

Location of AERONET sites within the top 20 and top 30 urban areas by population. Note, not all sites have data available throughout our simulation period (Jun-Sep 2013). https://en.wikipedia.org/wiki/List_of_urban_areas_in_the_European_Union.

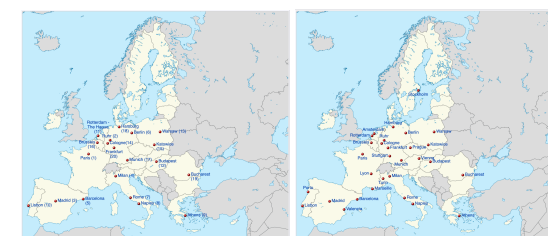


FIGURE: Top 20 (left) and top 30 (right) urban areas by population in the European Union.

Tab. 1: AERONET sites in urban areas in the European Union.

Urban area	State	elevation [m]	lat	lon
Aachen HOPE RWTH	Germany	230	50.7777	6.0606
Barcelona	Spain	125	41.38925	2.11206
Bari University	Italy	12	41.18833	16.88288
Berlin FUB	Germany	80	52.4575	13.31033
Brno Airport	Czech Republic	238	49.19447	16.63333
Brussels	Belgium	120	50.78333	4.35
Bucharest Ince	Romania	89	44.34333	26.02805
Corsica	Spain	67	43.303	-8.4288
Granada	Spain	680	37.364	-3.695
Hamburg	Germany	120	53.56933	9.973333
Helsinki	Finland	52.8	60.20273	24.90605
Karlsruhe	Germany	140	49.0903	8.4279
Leipzig	Germany	125	51.3525	12.46258
Lille	France	60	50.61167	3.11667
Madrid	Spain	680	40.4159	-3.72205
Malaga	Spain	56	36.71524	-4.478153
Marseille	France	34	43.2924	5.39317
Munich	Germany	520	48.309	11.258
Munich University	Germany	533	48.148	11.573
Nantes	France	60	47.469	-1.5707
Paris	France	50	48.8488	2.335589
Rome La Sapienza	Italy	75	41.9017	12.51577
Rosario Tar Vergata	Italy	130	41.83055	12.64753
Santa Cruz Tenerife	Spain	52	28.47253	-16.23736
Thessaloniki	Greece	60	55.63	22.96
Toulon	France	50	43.12506	6.099444
Toulouse	France	150	43.51772	1.37889
Toulon MF	France	160	43.57261	1.37432
Valladolid	Spain	705	41.6636	-4.76563
Valladolid Sci	Spain	701	41.6562	-4.7148
Vienne DORJE	Austria	266	48.23796	16.33161
Vienne UNIVIE	Austria	225	48.22867	16.35583
Warsaw UW	Poland	117	52.23093	20.98264
Zaragoza	Spain	200	41.6334	-0.85235

ACKNOWLEDGEMENTS

This work used resources of the Deutsches Klimarechenzentrum (DKRZ) granted by its Scientific Steering Committee (WLA) under project ID bb1195. This work was partly funded through the urbisphere project (ERC-2019-SyG Grant agreement: 855005) and ResearchConcepts Io GmbH (<https://www.researchconcepts.io>) through CAMS.43 (which is funded through ECMWF).

Relevant EMAC Publications

- Abdelkader, et al., Dust-air pollution dynamics over the eastern Mediterranean
<https://acp.copernicus.org/articles/15/9173/2015>, 2015.
- Abdelkader, et al., Sensitivity of transatlantic dust transport to chemical aging and related atmospheric processes
<https://acp.copernicus.org/articles/17/3799/2017>, 2017.
- Klingmueller, et al., Revised mineral dust emissions in the atmospheric chemistry-climate model EMAC
<https://gmd.copernicus.org/articles/11/989/2018>, 2018.
- Metzger et al., New representation of water activity based on a single solute specific constant to parameterize the hygroscopic growth of aerosols in atmospheric models, ACP,
<https://doi.org/10.5194/acp-12-5429-2012>, 2012.
- Metzger et al., Aerosol Water Parameterization: A single parameter framework, ACP,
<https://doi.org/10.5194/acp-16-7213-2016>, 2016.
- Metzger et al., Final Report EUMETSAT ITT 15/210839, 2016 (<https://www.eumetsat.int/PMaP>).
- Metzger et al., Aerosol water parameterization: long-term evaluation and importance for climate studies, ACP, <https://doi.org/10.5194/acp-18-16747-2018>, 2018.

EMAC vs CAMS - REFERENCE SIMULATIONS

CAMS REA closer to AERONET globally, but EMAC superior for some dust locations.

MODIS vs AERONET - REFERENCE OBSERVATIONS

AERONET station SEDE BOKER (Israel), MODIS AOD - CAMS REA issue? Dust aging issue?

EMAC vs SATELLITE AOD

EMAC AOD within the range of satellite AOD of MODIS (Aqua/Terra) and of PMAp v2.2.2, i.e., recent version of the Polar Multi-sensor Aerosol product of the Meteorological Operational Satellites (MetOp) on MetOp-B platform number 1 (M01), MetOp-A platform number 2 (M02).



EXP2 vs EXP1 AND EXP4 vs EXP3

Aerosol water effect on AOD noticable for nudged and free running EMAC versions.

EXP4 vs EXP1 RELATIVE TO EXP3 vs EXP1

Aerosol water effect on AOD larger for free running EMAC versions (Exp4 vs Exp1). Effect is evident for several AERONET sites, e.g., Hamburg, Karlsruhe, Thessaloniki, Zaragoza.

REMOTE VS URBAN REGIONS

Aerosol water effect on AOD larger for urban regions due to moisture feedback with air pollution. This effect is most pronounced for the free running EMAC model. Exp1 - Exp4: $\Delta(\text{urban})=9.47$ [%] vs $\Delta(\text{rural})=0.98$ [%].