Project period: October 2015 – September 2021

Summary for publication:

Project overview
Aerosols (i.e. tiny particles suspended in the air) are regularly transported in huge amounts over long distances impacting air quality, health, weather and climate thousands of kilometers downwind of the source. Aerosols affect the atmospheric radiation budget through scattering and absorption of solar radiation and through their role as cloud condensation and ice nuclei.

Light absorption by aerosol particles such as mineral dust and black carbon (BC; thought to be the second strongest contribution to current global warming after CO_2) is of fundamental importance from a climate perspective because the presence of absorbing particles (1) contributes to solar radiative forcing, (2) heats absorbing aerosol layers, (3) can evaporate clouds, and (4) changes atmospheric dynamics.

The overall aim of A-LIFE (https://a-life.at) was to investigate the properties of mixtures of absorbing aerosols (in particular mineral dust and BC) during their atmospheric lifetime. Special emphasis was given to the understanding of the properties and lifetime of coarse aerosol particles including processes that keep large dust particles in the air.

A-LIFE was highly successful. So far, 41 peer-reviewed papers have been published. Furthermore, a number of manuscripts are in preparation. The list of A-LIFE papers is continuously updated on the A-LIFE website: https://www.a-life.at/publications/.

Work performed from the beginning to the end of the period
A core activity of A-LIFE was an aircraft field experiment in the Eastern Mediterranean in April 2017. Several laboratory and modelling studies complemented the airborne observations. A unique data set of key aerosol parameters was collected which not only allowed to study all A-LIFE objectives, but also enables in-depth analysis of cloud properties and aerosol-cloud interactions (ongoing work).

For the A-LIFE field experiment, an extensive in situ aerosol payload including the new Cloud, Aerosol, and Precipitation Spectrometer (CAPS), a wind lidar, and meteorological sensors have been deployed on the German Aerospace Center (DLR) research aircraft Falcon, and 22 research flights (~80 flight hours) have been performed. The A-LIFE campaign included coordinated overflights of ground-sites in Cyprus, Crete, and Austria, and was carried out in close cooperation with DLR, CyCARE organized by the Leibniz Institute for Tropospheric Research, and with PreTECT (ERC project V. Amiridis).

Aerosol source apportionment was achieved with the Lagrangian transport and dispersion model FLEXPART. The airborne observations were classified into 12 aerosol types with four main types: Saharan dust, Arabian dust, and mixtures with and without coarse mode. Each of the four main types was separated into of three sub-classes (clean, moderately-polluted, polluted). For each aerosol class, microphysical and optical aerosol properties were derived. One outstanding finding of A-LIFE is that scattering properties of polluted dust mixtures do not show the typical dust signature, but rather show a wavelength-dependency of the scattering coefficient that is typical for pollution. This means that optical properties of dust mixtures are frequently dominated by the pollution – even when a significant amount of mineral dust is present. A manuscript summarizing the results of A-LIFE is in preparation (Weinzierl et al.,

2022, in prep.).

Existing airborne measurements of pure BC and mineral dust were revisited and analyzed in a consistent way. Results are published in several studies including, e.g., Weinzierl et al. (2017). The data were also used to gain new insight into the variability and distribution of BC over global scales and to refine understanding of global model ensemble performance (Schwarz et al., 2017).

Huge efforts were made to enhance capabilities for coarse particle measurements and to develop new modelling tools to study aerosol optical properties. In particular, the improvement and novel data analysis of the CAPS instrument in A-LIFE opened unique opportunities: we were invited to participate with CAPS in the NASA-lead Atmospheric Tomography Mission (ATom; https://espo.nasa.gov/atom; Thompson et al., 2021) which allowed us to acquire additional coarse mode data with global coverage for A-LIFE Task 3.3.

Combined size distributions including instrumental uncertainties and considering aerosol composition were derived for both, A-LIFE and ATom. Thereby, unique global data sets of aerosol size distributions covering the size range from 10 nm to 930 µm for A-LIFE (Weinzierl et al., 2022, in prep.), and from 3 nm to 50 µm for ATom (Brock et al., 2021) were established.

Process studies investigated aspects of absorbing aerosol layers including, e.g., particle settling in the so-called "Saharan Air Layer" and associated mechanisms keeping particles longer in the air than expected from Stokes gravitational settling (Gasteiger et al., 2017). BC lifetime in the atmosphere was shown to be shorter than predicted by most recent climate models (Lund et al., 2018).

In the A-LIFE proposal, it was not promised to study clouds. However, the "cloud indicator" algorithm – initially developed for automatically masking periods contaminated by clouds based on CAPS data – turned out to be very powerful for cloud classification (water, mixed-phase temperature regime, ice cloud) and cloud studies (Dollner et al., 2022a/b, in prep.). Our cloud analysis significantly contributed to the discovery of a new sulfur compound, hydroperoxymethyl thioformate in the atmosphere (HPMTF; Veres et al., 2020; Novak et al., 2021) which is involved in the formation process of oceanic clouds that play a crucial role in moderating climate. In a study published in Nature, a band of new particle formation at high altitude in the tropics covering about 40% of the Earth was shown to brighten lower-level clouds – a process not represented in climate models (Williamson et al., 2019). Cloud results are also part of Katich et al. (2018), Murphy et al. (2019), Brock et al. (2019), Kupc et al. (2020), Williamson et al. (2021), and Thompson et al. (2021). Combining the cloud sequences from the A-LIFE and ATom field missions, a unique global data set of cloud microphysical properties was created and is currently used to study interhemispheric differences in ice clouds, and dust impacts on clouds (Dollner et al., 2022b, in prep.). Therefore, A-LIFE also enabled a breakthrough in cloud observations.

Progress beyond the state of the art
Several highly-cited and high-impact publications as well as highly-sophisticated process studies combining modelling and measurements (see list of publications).

Novel methodologies include:
- Improved coarse mode aerosol sampling with CAPS (Spanu et al., 2020; Dollner et al., 2022a, in prep.)

- Self-consistent approach for the evaluation of calibration measurements of optical particle counters (OPCs) (Walser et al., 2017)
- Algorithm for combined parameterized size distributions (Dollner et al., 2022a, Weinzierl et al., 2022, in prep.)
- Algorithm for the automatic detection of clouds and cloud phase (Dollner et al., 2022a, in prep.)
- Algorithm for automatic aerosol type classification (Weinzierl et al., 2022, in prep.)
- Guidelines for an optimal nephelometer angular truncation depending on aerosol type (Teri et al., 2021, under review)
- MOPSMAP (https://mopsmap.net/) – an online tool for the calculation of optical properties of aerosol mixtures (Gasteiger and Wiegner, 2018; Gasteiger et al., 2022, in prep.)