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Real Case Simulations of Aerosol-Cloud Interactions in Ship Tracks over the Bay of Biscay

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The impacts of aerosol perturbations on cloud microphysical structures and the cloud radiative response (aerosol-cloud interactions) have been studied intensively since the mid 20th century and yet remain one of the largest uncertainties of climate sensitivity. Ship tracks, which are characterized by recurring streak-line patterns of increased cloud albedo under certain environmental conditions are often used as an illustrative example for such aerosol-cloud interactions. They are predominantly observed in stratocumulus regions with relatively shallow boundary layers. Although the radiative effect of ship emissions on a global scale is still under debate, they indeed provide an ideal test bed for studying aerosol-cloud interactions of warm clouds.

This work will focus on a case study from the 26th – 28th of January 2003 in and around the Bay of Biscay. During this time period ship tracks were observed in a region influenced by high-pressure subsidence, followed by a cold front propagating through the domain from the Atlantic towards the European coast. MODIS observations of cloud optical thickness are used for model evaluation.

For these studies we use the limited-area model COSMO, maintained and developed by the COSMO consortium, with extensions from Zubler et al. (2011). The aerosol and cloud microphysics are based on the M7 aerosol microphysics scheme following Vignati et al. (2004) and the two-moment cloud microphysics scheme by Seifert and Beheng (2006). Results will be shown for simulations with 2-km horizontal resolution nested into a 12-km simulation, that in turn was driven by ERA-interim at the lateral boundaries.

In this framework the meso-scale aerosol-cloud interactions due to shipping emissions (implemented as moving sources) are studied and evaluated. In particular changes in the horizontal cloud distribution, vertical extent, cloud optical thickness, drizzle rates and cloud microphysical properties were compared between clean conditions without shipping emissions and pristine aerosol concentrations as low as 20-50cm^{-3}, and polluted conditions with shipping emissions. Model evaluation shows a satisfactory representation of the synoptic-scale environment including the simulation of very sharp inversions (Possner et al. 2014, in press). More importantly we are able to simulate track-like structures of decreased effective radius and increased cloud optical thickness. Due to the large uncertainties with respect to the emission mass flux and size distribution, differently aged plumes with differently scaled mass fluxes are emitted to estimate the sensitivity of the cloud response with respect to emission uncertainties.