Simulation of the Aerosol-Atmosphere Interaction in the Dead Sea Area with COSMO-ART

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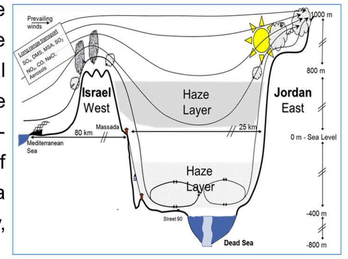
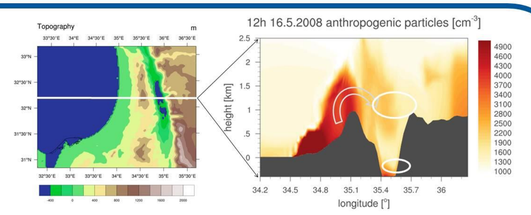
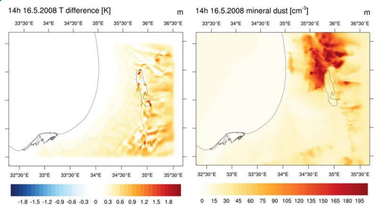
The Dead Sea region and the ambient Eastern Mediterranean coastal zone provide a natural laboratory for studying atmospheric processes ranging from the smallest scale of cloud processes to regional weather and climate. The virtual institute DESERVE is designed as a cross-disciplinary and cooperative international project of the Helmholtz Centers KIT, GFZ, and UFZ with well-established partners in Israel, Jordan and Palestine. One main focus is the role of aerosols in modifying clouds and precipitation and in developing the Dead Sea haze layer as one of the most intriguing questions. The haze influences visibility, solar radiation, and evaporation and may even affect economy and health.



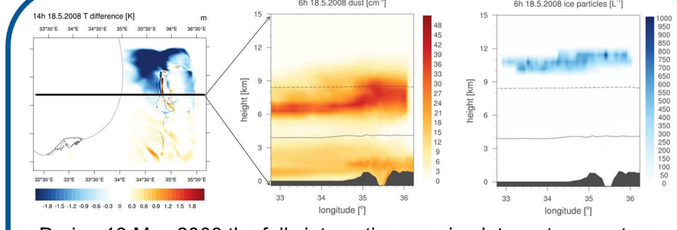
We carried out sensitivity runs for a three days period in May 2008 with 2.8 km horizontal resolution. Scenario A takes into account the complete feedback mechanisms between aerosols, clouds, and radiation. Scenario B gives the results for prescribed and constant background aerosol.



Direct emissions of soot and gaseous precursors of secondary aerosol particles in the Eastern Mediterranean are transported to the Dead Sea area by the westerly flow. Inside the Dead Sea Valley the westerly flow is superimposed by secondary flow systems as land sea breeze and upslope and down slope winds. The interaction of these flow systems finally leads to the formation of the two haze layers (white circles) similar to those measured by Levin et al. (2005).



During cloud free conditions especially mineral dust leads to an increase of the temperature close to the surface.



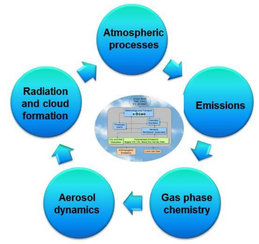
During 18 May 2008 the fully interactive run simulates a temperature decrease of up to -2 K in the northern part of the model domain. This temperature decrease is caused by high ice clouds that are initiated by an elevated layer of mineral dust.

Summary:

- Anthropogenic aerosol and the complex flow system create two seperated haze layers in the Dead Sea valley.
- Absorbing aerosol (anthropogenic and mineral dust) heats the boundary layer during cloud free conditions.
- An elevated dust layer creates ice clouds reducing temperature at the surface by up to 2 K.

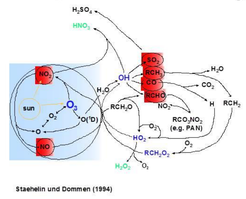
The model system COSMO-ART

In order to quantify the feedback processes between aerosols and the state of the atmosphere on the continental to regional scale the fully online integrated model system COSMO-ART with two-way interactions between different atmospheric processes was developed (Vogel et al., 2009; Knote et al., 2011; Bangert et al., 2012). The operational weather forecast model COSMO of the Deutscher Wetterdienst (Baldauf et al., 2011) was extended to treat secondary aerosols as well as directly emitted components like soot, mineral dust, sea salt and biological material and their feedback with radiation and clouds.



The online regional scale model system COSMO-ART

Gas phase chemistry



The gas phase chemistry module (RADMKA) is based on RADM2 and includes several improvements. We updated rate constants according to IUPAC, updated the mechanism concerning biogenic VOCs, made extensions for the hydrolysis of N_2O_5, and included new sources for HONO. The KPP mechanism can be used for a flexible modification of the chemical mechanism.

Treatment of aerosols

Interaction of five modes:

- Two modes for SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, internally mixed
- One mode for pure soot.
- Two modes for SO_4^{2-}, NO_3^-, NH_4^+, H_2O, SOA, and soot internally mixed.

Condensation of SO_4^{2-}, $NH4^+$, $NO3^-$, SOA

coagulation

Three modes for **mineral dust** particles + **Three** modes for **sea salt** particles + **Pollen**

COSMO-ART uses the modal approach to describe the size distribution. New particles can be formed by nucleation of sulfuric acid. The processes condensation, coagulation, sedimentation and washout are taken into account. A volatility basic set approach is used to describe the secondary organic aerosol (Athanasopoulou et al., 2012). The thermodynamic module ISORROPIAII (Fountoukis et al., 2007) is applied.

Treatment of clouds

Two Moment cloud microphysics (Seifert and Beheng, 2006)

- number and mass concentration of all hydrometeors

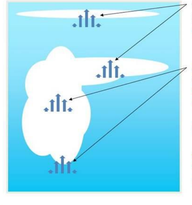
Six hydrometeor classes

- water droplets
- ice crystals
- rain droplets
- snow flakes
- graupel
- Hail

Parameterization of cloud optical properties

- function of cloud droplet and ice crystal number concentration
- long and short wave (Hu & Stamnes 1993, Ackerman and Stephens 1989, Edwards et al. 2007)

Aerosol activation



Ice Nucleation
(Barahona and Nenes 2009)

- competition of heterogeneous freezing involving dust with homogenous freezing of droplets

Aerosol Activation
(Kumar et al. 2009, Barahona et al. 2010)

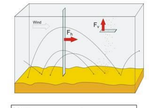
- adsorption activation of dust particles
- competition of the different aerosol particles for water vapor
- considering all simulated aerosol properties

Distribution of subgridscale updrafts

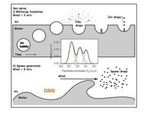
- mean = grid scale updraft
- standard deviation $= \sqrt{TKE}$

Natural emissions

Emissions of mineral dust are calculated at each grid point and each time step for three individual modes, depending on the simulated frictions velocity and surface parameters (Stanelle et al., 2010).



Emissions of sea salt are calculated at each sea grid point and each time step for three individual modes, depending on the simulated wind speed and the sea water temperature (Lundgren et al, 2013).



Anthropogenic emissions

- NO, NO_2, SO_2, CO, NH_3
- VOC's
- EC, OC, PM

prescribed

Biogenic emissions

- VOC's

online calculated: f (T, S)

Biomass burning

- CO
- VOC's
- EC

prescribed