Global model studies on the composition and distribution of atmospheric ice nuclei

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Black carbon (BC) and mineral dust particles are among the most important atmospheric aerosol types forming ice crystals by heterogeneous nucleation (so called ice nuclei). When emitted, most BC and dust particles are externally mixed with other aerosol compounds. Through coagulation with particles containing soluble material and condensation of gases, externally mixed particles gain a liquid coating and are, therefore, transferred to an internal mixture.

This aging process is essential for the direct and indirect effect of BC and dust particles on climate, since the coating changes the radiative and hygroscopic properties of the particles and, therefore, their cloud activation ability and lifetime. Moreover, laboratory studies have shown that a liquid coating influences the freezing properties of the particles and hence their behaviour as ice nuclei [1, 2].

Due to large computational resources required, global climate models mostly parameterize the particle aging by using estimated turnover times, rather than simulating the aging processes explicitly.

In the present study, the global aerosol-climate model ECHAM5/MESSy1/MADE was extended by new aerosol modes to represent BC and dust particles and their different states of mixing as well as the relevant aging processes of externally mixed particles. The extended model setup was applied to particularly simulate the mass and number concentration as well as the composition of potential ice nuclei in the global atmosphere. Additionally, the timescales of transforming externally mixed BC and dust particles into the internal mixture was quantified.

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Asymmetry in crustal and thermal evolution of the Moon

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Understanding of lunar origin and evolution has been advanced with synergies of sample analysis and remote sensing. Apollo ferroan anorthosites (FAN) with high plagioclase abundance (>90 vol%) and low Mg/(Mg + Fe)[=mg#] ratio (typically 50–65) have been the basis of the magma ocean model, where lunar feldspathic crust formed by floated plagioclase cumulates from an evolved, Fe-enriched magma ocean [1]. Recent discovery of magnesian anorthosite (MAN) (mg#=75-77, 96.5 vol% plagioclase) and spinel troctolite (ST) (mg#=84-85, 72.0 vol% plagioclase) in lunar meteorite Dhofar 489 and paired rocks suggests a greater range of mg# in lunar feldspathic crust than previously thought. The presence of magnesian and ferroan granulites from Apollo [2], and mg# of feldspathic lunar meteorites [3] are consistent with this implication. FAN rocks are mostly noritic, whereas MAN and ST are troctolitic. The mineralogical contrast between FAN and MAN/ST further suggests a bimodal crustal composition, ferroan noritic and magnesian troctolitic.

The extremely low contents in Th, Fe, and REEs of Dhofar 489 and siblings [4, 5] indicate a probable origin of farside highland [5]. Apollo FAN from nearside highland and Dhofar MAN from farside highland imply the bimodal crust composition of the nearside and farside crust. Mineralogical and mg# distribution estimated based on Clementine ultraviolet-visible multispectral data also hints the asymmetric nearside-farside crust composition [6, 7].

MAN/ST and FAN may be products of a series of liquid line of descent during a magma ocean crystallization [8]. The crystallization sequence of olivine, anorthite, and orthpyroxene to produce ST/MAN, and following FAN requires a more Al_2O_3-rich magma composition [9] than a terrestrial mantle-like bulk-Moon composition [10]. The asymmetric crust composition might be attributed to different thermal conditions of the nearside and farside.

The composition of a magma ocean will be further constrained from the mineral distributons/compositions and thickness of the global crust by Multiband Imager and Spectral Profiler of Kaguya. The themal condition of the global crust will be defined by gravity field data of Kaguya.

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