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Implications of aerosol growth mechanics and aerosol-cloud interaction to the sun-cloud-climate hypothesis

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Observations as well as proxy-data indicate a substantial variability of the cosmic rays induced ionisation of the terrestrial atmosphere, and several theories have been postulated that link atmospheric ionisation to global climate. Recently, evidence suggesting a direct link of the cosmic rays flux to the cloudiness of the marine boundary layer was produced, and it is presumed that secondary aerosol formation and its interaction with cloud microphysical properties acts as explanatory mechanism.

In this study the dynamical properties of the aerosol, cloud droplet and raindrop system are explored with a 1-D model of the marine boundary layer with respect to their implications to the above theory. A linear relationship between the secondary nucleation rate and the atmospheric elementary ion number concentration, as implied by the classical nucleation theory, is assumed. Ultrafine secondary aerosol growth to cloud nuclei size is represented by a state of the art formalism of aerosol mechanics that takes into account their interaction with background aerosol and locally produced sea salt particles. The interaction of the aerosol and cloud properties is represented on a novel unified platform of interstitial and activated aerosol particles that is based on the monitoring of the solute content rather than the water content of the cloud droplets. Doing so the activation properties of the aerosol, and thus the time dependence of the critical activation radius may be represented with higher accuracy, and cloud droplet coalescence may be assessed explicitly according to a statistical size distribution for each particle bin. The unified formalism of the aerosol population allows reproducing key features of the marine aerosol such as its bimodality resulting from aerosol activation. The resulting cloud droplet population shows a distinct sensitivity to cloud dynamical conditions, such as the relevant updraft velocity, and allows reproducing the typical pattern of nocturnal drizzle in marine stratocumulus clouds.

Results show a remarkable tendency of the Aitken mode to a very limited sensitivity to the ionisation rate due to particle-particle interaction. Although not self-preserving an analogous stiffness of the cloud droplet number with respect to the nucleation rate may be observed due to both effective scavenging of interstitial particles and cloud droplet coalescence. Further, a variation of the yield of condensable tends not to result in a relevant variation of the Aitken particle number. However, the consequent variation of the growth velocity of the interstitial aerosol may effectively vary the number of cloud droplets. This effect is more or less pronounced depending on whether secondary particles originate in the boundary layer or the free troposphere and on whether the variation of the condensable yield applies to both of these. As a conclusion the present study indicates that due to aerosol and cloud droplet dynamical phenomena a mere limited variation of the nucleation rate is not sufficient to a significant variation of the cloud droplet number. An additional variation of the condensable yield, however, potentially alters the cloud droplet number via its strong enough effect on the continuous activation flux of Aitken mode particles.