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Breakup of nocturnal low-level stratiform clouds during the southern West African monsoon season

Maurin Zouzoua[1], Fabienne Lohou[2], Marie Lothon[2], Paul Assamoi[1], Véronique Yoboue[1], Cheikh Dione[3], Norbert Kalthoff[4], Bianca Adler[4], Karmen Babić[4], Xabier Pedruzo-Bagazgoitia[5], and Solène Derrien[2]

[1]Laboratoire des Sciences de Structure de la Matière, de l'Environnement et de l'Energie Solaire (LASMES), Université Félix Houphouët Boigny, Abidjan, Côte d'Ivoire (pzouzoua@gmail.com)
[2]Laboratoire d'Aérologie (LAERO), Université de Toulouse 3, France
[3]African Centre for Meteorological Applications for Development (ACMAD), Niamey, Niger
[4]Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT), Germany
[5]Meteorology and Air Quality Group, Wageningen University and Research, the Netherlands

During monsoon season in southern West Africa (SWA), nocturnal stratiform low-level clouds (LLSC) frequently form over a region extending from Guinean coast to several hundred kilometers inland. The cloud deck persists at least until sunrise next day, affecting surface-energy budget and related processes. However, LLSC lifetime is underestimated by numerical weather prediction and climate models.

The DACCIWA (Dynamics-Aerosol-Chemistry-Cloud-Interactions-over-West-Africa) field campaign, in June-July 2016, paved the way for studying LLSC over SWA based on high-quality-observational dataset. The first analyzes of this data highlighted that the LLSC diurnal cycle consists of four main stages: the stable, jet, stratus and convective phases. Unlike the first three, the convective phase, which starts after sunrise and ends when LLSC breaks up, has not been well documented yet.

This study analyzes the LLSC evolution during stratus and convective phases, specifically addressing the LLSC transition toward other low-cloud types during sunlight hours. It is based on comprehensive dataset acquired during twenty-two precipitation-free LLSC occurrences at Savè (Benin) during the DACCIWA fiel campaign. The cloud-characteristics are deduced from ceilometer and cloud-radar measurements. The associated atmospheric conditions are provided by surface meteorological and energy balance stations, radiosoundings and an Ultra-High-Frequency wind profiler.

The LLSC forms (beginning of the stratus phase) decoupled from surface. In thirteen cases, the LLSC remains decoupled until the convective phase (case D). Conversely, in the other nine cases, the cloud gets coupled with surface before sunrise, within the four hours after cloud formation (case C). The coupling is accompanied by cloud base lowering and near-neutral thermal stability in subcloud-layer. Almost all cases C are observed during a period with well-established monsoon-flow over SWA. But, the weak differences of thermodynamical conditions between cases C and D

suggest that, contributions of both mesoscale and local processes are crucial for coupling LLSC to the surface before sunrise. In early morning, the macrophysical and thermodynamical characteristics of the LLSC in case C are slightly different from the case D, suggesting that, even during night, the coupling with surface impacts the cloud characteristics.

The LLSC evolution during convective phase depends upon the coupling at initial stage. In cases C, the evolution pattern is quite similar, the cloud base rises up under solar heating and shallow cumulus form when the cloud deck breaks up, around 11:30 UTC or later. For some of cases D, the LLSC couples with surface as the convective atmospheric boundary-layer grows and reaches the cloud base. The subsequent evolution and breakup time are then similar to case C. For most of cases D, LLSC remains decoupled from surface, and shallow cumulus form at the convective mixed layer top, under the LLSC deck. In this scenario, the LLSC breakup-time mostly occurs before 11:30 UTC. Thus, the coupling between LLSC and surface is a key factor for its evolution and maintenance after sunrise. Correct simulation of this feature may improve models performance over SWA. The impacts of LLSC on surface-energy budget and verical development of boundary-layer are also quantified.