FINAL REPORT PROGRAM LEFE

Program LEFE/ action(s) AO INSU 2019	**Project Title** « Aerosol-Cloud-Precipitation interactions in a new mesoscale model (IANuP) »	**Years 2019 – 2021**

PI name, email and lab:	Contribution to
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Context:

The quantitative precipitation forecast is still an important challenge for the atmospheric community. One major problem in weather and climate models is the interactions of the cloud systems with the aerosol particles.

Objectives:

The main objective of this project is to develop a new numerical tool that considers a detailed aerosol representation and a bin microphysics approach at the mesoscale in order to improve the aerosol-cloud interactions and the precipitation forecast.

Main results:

The strategy used for this project is to couple the DESCAM (Detailed SCAvenging and Microphysics; *Flossmann and Wobrock, 2010, Atm. Res; Planche et al., 2014, QJRMS*) module developed at the LaMP to the mesoscale WRF model (Weather Research and Forecasting; *Skamarock et al., 2008, NCAR Technical report*). The DESCAM module follows the evolution of the aerosol particle, drop and ice crystal distributions. Aerosol mass in drops and in ice crystals is predicted by two distribution functions in order to close the aerosol budget (*Planche et al., 2010, Atm. Res*). This module is currently coupled with the 3D cloud scale Clark-Hall model (*Clark, 2003, JAM; Coen, 2013, NCAR Technical report*) that is no longer updated. The WRF model is a mesoscale model that not only considers the thermodynamics of the atmosphere but also treats the radiative impacts of clouds. Moreover, this model is used by a wide international community.

The first step of this project was to identify one real case to study the evolution of the cloud and precipitation microphysics with different modelling tools, e.g., with Clark-DESCAM and WRF coupled with two widely used bulk microphysics schemes (*i.e.,* the Thompson scheme: WRF-THOM, or the Morrison scheme: WRF-MORR). This case was an intense convective system observed on the 26 September 2012 (IOP7a) over the Cévennes-Vivarais region (France) during the HYMEX (HYdrological cycle in Mediterranean EXperiment) campaign (Figure 1a). Figures 1b-d represent the precipitation distribution at the surface obtained with the different modelling configurations. It shows that the Clark-DESCAM configuration provides the best results compared to observations (*Kagkara et al., 2020, NHESS; Arteaga et al., 2020, Atmosphere*). An additional sensitivity study indicated that the microphysics properties have impacted the thermodynamics and the dynamics fields in WRF-MORR and WRF-THOM during this event modifying the development of the cloud system *(Arteaga et al., 2020, Atmosphere)*.

Moreover, Kagkara's PhD thesis *(2019, Université Clermont Auvergne)*, using a comparison between in-situ airborne microphysics measurements and simulation results obtained with the Clark-DESCAM model, revealed that the ice formation processes were not well represented because the concentrations of the smallest ice crystals (*i.e.*, diameters < 900 µm) were underestimated (Figure 2), especially because the secondary ice multiplication processes were not considered. In parallel, in collaboration with the NCAR, the microphysics of the cloud ice phase of the DESCAM module has been implemented in the WRF model in an idealized framework. The COVID-19 pandemic situation in 2020 and 2021 have postponed the implementation of the DESCAM module in WRF for the real case configuration.

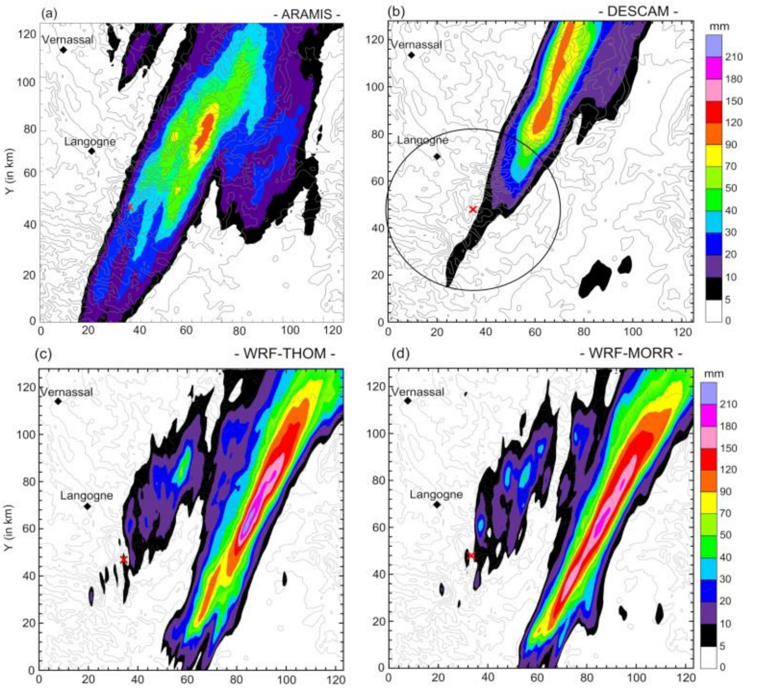

Figure 1: 12-h cumulative rainfall retrieved from the ARAMIS radar network (a) and simulated with Clark-DESCAM (b), WRF-THOM (c) and WRF-MORR (d) for the innermost domain. The topography is represented from sea level to 2400 m height every 200 m.

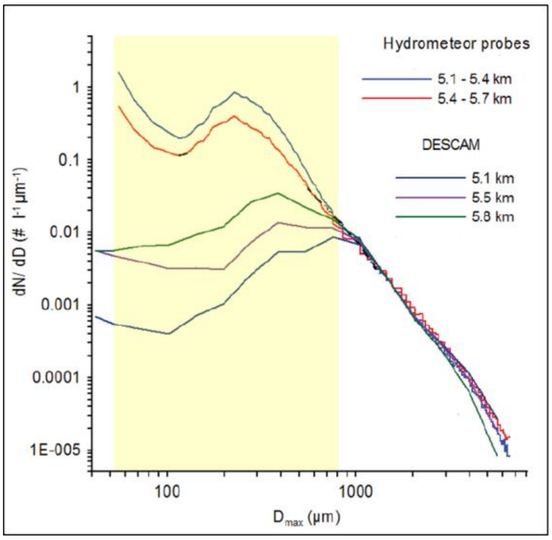

Figure 2: Mean ice particle size distribution (PSD) observed by in-situ airborne microphysics probes and simulated with Clark-DESCAM for the IOP7a HYMEX case.

Future of the project:

In the future, the coupling between WRF and DESCAM will be done with an extended version of the ice microphysics, *i.e.,* with the implementation of the secondary ice multiplication processes. This new numerical tool will be used in an idealized framework and then for real study case (such as the IOP7a HYMEX case) in order to better understand the aerosol-cloud-precipitation interactions. Also, the comparisons between different bulk microphysics schemes in the WRF-DESCAM model will provide insights of the impact of the cloud microphysics representation that is used.

Publications:

D. Arteaga, C. Planche, C. Kagkara, W. Wobrock, S. Banson, F. Tridon, A. Flossmann. 2020. Evaluation of two cloud-resolving models using bin or bulk microphysics representation for the HyMeX-IOP7a heavy precipitation event. Atmosphere, 11(11), 1177. DOI:10.3390/atmos11111177.

C. Kagkara, W. Wobrock, C. Planche, A. I. Flossmann. 2020. The sensitivity of intense rainfall to aerosol particle loading - a comparison of bin-resolved microphysics modelling with observations of heavy precipitation from HyMeX IOP7a. Nat. Hazards Earth Syst. Sci., 20, 1469-1483. DOI:10.5194/nhess-20-1469-2020.

Presentations :

C. Planche, W. Wobrock, A. Flossmann. Impact of ice splintering on a convective cloud system observed during the HyMeX campaign in France. *3rd Atmospheric Ice Nucleation Conference, Boston, MA, USA, 10 - 12 Janvier 2020.* (Oral presentation).

C. Planche, F. Tridon, S. Banson, G. Thompson, A. Battaglia, W. Wobrock. Evaluation of the rain microphysics representation in the WRF model with ARM multifrequency radars observations. *27th IUGG General Assembly, Montreal, Canada, 8 - 18 Juillet 2019*. (Oral presentation).