## Ecole Doctorale des Sciences Fondamentales

**Title of the thesis: Study of water vapour - clouds - precipitation interactions**

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**Summary:**

The atmosphere of the Earth, and more particularly the troposphere, presents conditions of temperature and pressure that allow water to coexist in its three phases: liquid, solid and gas.

Water vapour is one of the main natural greenhouse gases present in the atmosphere (Kiehl and Trenberth, 1997). It is an important tracer of stratospheric intrusions into the troposphere (D'Aulerio et al., 2005). Due to its role in the formation of stratiform and convective clouds (Van Baelen et al., 2011) this gas also has an indirect climatic effect. In fact, in its condensed phase (solid and / or liquid), the radiative impact of atmospheric water depends on the characteristics of clouds (macroscopical properties: altitude, optical thickness, and microphysical composition). In addition, when the cloud droplets reach a critical size (larger than 0.1 mm), they can sediment and cause precipitation (Glickman, 2000). The life cycle of the cloud droplets is therefore largely influenced by water vapour and by many microphysical processes occurring within clouds (Pruppacher et al. 1998).

Atmospheric water vapour has an important spatial and temporal variability under the effect, among other, of privileged transport zones called atmospheric rivers (Zhu and Newell, 1998). This high variability can locally have an impact on the formation and evolution of precipitating cloud systems. Recently, studies highlighted climatology and long-term trends of water vapour over the ClermontFerrand region (Hadad et al., 2018). In this context, it is therefore important to understand the variations of the three different water phases in the atmosphere at different temporal and spatial scales, but also to understand the interaction between the three different water phases and the dynamic processes at the origin of these variations and interactions, especially in the current context of climate change.

The objective of this thesis is therefore to characterise the interactions between the water vapour, clouds and precipitation from a climatological point of view but also in terms of case studies, and to well identify the impact of the dynamic processes such as atmospheric rivers, stratospheretroposphere exchanges, and/or Foehn effect on water vapour distribution, clouds and precipitation formation.

This study should be based on:

- The use of in-situ and remote sensing observations from the CO-PDD instrumented site,
- The use of satellite products (COSMIC-FORMOSAT, AURA-MLS, AQUA-AIRS, CALIOP, CloudSATCALIPSO ...).

The development and use of lagrangian (CAT, Baray et al., 2020) and eulerian (ECMWF ERA-5, Hoffmann et al., 2019; WRF, Skamarock et al., 2008) modelling codes available at LaMP.

The Cézeaux-Aulnat-Opme-Puy de Dôme instrumented site (Baray et al., 2020) is ideally located and equipped to document water vapour - clouds - precipitation interactions with a set of remote sensing instrumentation including a multi wavelength lidar, rain radars, wind profilers, and the in-situ measurement station of puy de Dôme which is in cloudy conditions 60% of the time in winter and 24% of the time in summer (Baray et al., 2019). Other ACTRIS (Aerosol Cloud and Trace gases Research Infrastructure) research infrastructure sites also offer potentially useful datasets to document this research topic.

In addition, satellite products will allow provide the properties of water vapour over larger regions but at specific time steps (depending on the orbit of the satellite considered). Finally, numerical models will be used to determine the transport of water vapour and its role in the formation of precipitating cloud systems observed over the Clermont region. The models used will then be different depending on the spatial and temporal scale analysed.

The thesis will take place at the Laboratory of Physical Meteorology, Clermont Auvergne University. It will be part of the ACTRIS research infrastructure and the CNES EECLAT (Expecting Earth-Care, Learning from A-Train) project. It could be supported by the LEFE-CHAT CANDY-CLOUD project (PI Laurent Deguillaume) whose objective is to characterize the chemical composition of the aqueous phase of clouds. Scientific collaborations with researchers from other French laboratories which manage other instrumented sites of the ACTRIS network could also be considered.

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