Doctorate Contract for Emerging Exploratory Projects at the University of Grenoble Alpes

Year 2026

Project	PreVerS
Title	**Pré**servation des **Ver**gers de **S**avoie face aux gelées printanières. Rôle du vent catabatique sur le processus de gelée radiative en coteau. Protecting Orchards from Spring Frosts: The Role of Katabatic Winds in Radiation Frost Processes on Slopes
Contact	Brun christophe : christophe.brun@univ-grenoble-alpes.fr
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Starting grant	1 October 2026
Ecole doctorale pressentie	ED STEP - Sciences de la Terre, de l'Environnement et des Planètes

Subject: Field study of the physical processes involved in spring frost events. The role of katabatic winds in the process of radiative frost on hillsides.

Context : The PhD will focus, on the one hand, on the in situ observation and study of radiative frost events, and, on the other hand, the analysis of technological methods to combat the effects of these frosts in order to characterize their effectiveness, propose avenues for optimization, and devise viable solutions that are financially accessible to fruit growers and universal—and thus applicable to similar situations encountered in vineyards. Among the methods used to combat frost, four stand out (Bureau Interprofessionnel des Vins de Bourgogne 2018): water spraying to protect the buds, the circulation of warm air using a booster, an anti-freeze mixing tower, or even a helicopter to warm the ambient air and mix the warmer air stagnating above orchards or vineyards, protection via candle heating or gas burners, and finally the generation of smoke by burning straw to reduce radiative heat exchange with the ground. Among all these methods, which draw on very different physical concepts combining fundamental processes of heat transfer, phase change, scalar transport, turbulent mixing, and combustion, we will focus on the most natural and easiest to implement. In particular, we will evaluate the passive mixing effect generated by the interaction of the descending katabatic wind and the presence of low walls or hedges transverse to the flow. Another avenue of investigation will be to examine the source of surface radiative cooling by assessing the impact of injecting a water vapor mist at the orchard scale and its ability to inhibit radiative exchange with the atmosphere by reducing its emissivity. These processes must be identified and analyzed in detail to characterize their effectiveness in homogenizing ambient air temperature for the purpose of protecting the fruit. This study will be conducted under real-world conditions of thermal inversion in a natural wind tunnel in the Belledonne massif and in situ in the orchards of Savoie.

Methodology : The study will focus on two avenues with high innovative potential but which have rarely been implemented due to the complexity of the physics involved: passive mixing generated by a low wall or hedge at the base of a slope in the presence of a downslope wind, and the inhibition of radiative cooling of the ground through the generation of a water vapor mist. All of these solutions can be used simultaneously. The thesis program will follow three complementary approaches:

In situ observation in orchards of a spring frost event. Based on the preliminary campaign in April 2022 (M. Giannoni's M2 internship) a measurement campaign will be conducted in response to a weather alert,

involving temperature measurements using a tethered balloon up to 30 m above the ground, measurements of nocturnal surface radiative flux, turbulence measurements, and wind speed and air temperature profiles at the height of the orchard. The influence of slope winds on the event will be characterized.

Measurements in a natural wind tunnel of the turbulent mixing effect of fractal wall and hedge models (Meneveau, "Modeling Turbulent Flow over Fractal Trees," J. Comp. Phys. 2007) and of the radiative loss reduction effect (vapor cloud generator) under thermal inversion conditions. We will utilize LEGI's expertise to plan and analyze in situ experiments on an alpine slope during an anticyclonic winter episode (Charrondière et al. BLM 2022). We will use 3D velocity probes, thermocouples, and radiative probes to characterize katabatic wind profiles and their transformation, on the one hand, by the effect of obstacles (synthetic fractal wall and hedge models) and, on the other hand, by the reduction of radiative fluxes from the cold surface (injection of water vapor clouds). The purpose of this test phase is to simulate a natural situation of surface radiative cooling in a stable stratified boundary layer—a scenario well-documented in two previous PhD—and to quantify the modifications that an artificial system can introduce into it.

Field application in orchards of a technological system combining a passive mixing system (low walls and synthetic or natural hedges) with a water vapor cloud generator, a prototype of which will be installed in the SCEA orchards in Savoie, in order to quantify the system's effectiveness in terms of the heat balance at the tree level, under various conditions of thermal stratification and radiative balance. The measurement campaign will be conducted in response to weather alerts each spring.

Prerequesite The PhD student hired for the three-year project will have a background in atmospheric geophysics and/or fluid mechanics and will be responsible for setting up, conducting, and analyzing in situ measurements of spring frost events in the hillside orchards of Savoie. He or she will participate in the research and scientific validation of solutions to combat frost. He or she will also have expertise in the properties and processes of turbulence in fluids, particularly in geophysical flows.