3-y Ph.D. position

Location: CNRM UMR3589, Météo-France, Toulouse (France)

Topic: **Improvement of the representation of stratocumulus and cumulus clouds, as well as associated precipitation, in the AROME model**

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Doctoral School S2UDE (ED173 "Geosciences, Astrophysics, Space and Environmental Sciences")

Low clouds such as stratocumulus have an important effect on the solar radiation received at the surface (impact on photovoltaic production), on the occurrence of fog (impact on transport), on temperatures, on rainfall and thus more generally on the weather conditions felt by the population, either on the coast (marine clouds into the inner coastal areas) or on the plains.
Despite their importance and high frequency, they are poorly represented in meteorological models, whether they are climate or weather forecasting models, or global or regional models. The difficulty in representing these clouds comes from the complex interactions at play between different physical parameterizations of the models: turbulence (representation of diffuse turbulent motions), shallow convection (representation of coherent boundary layer convection motions), radiation (solar and infrared) and also cloud microphysics (set of processes representing the exchanges between the different species of hydrometeors constituting the clouds and precipitation). Moreover, numerical constraints limit the resolution of the models used and make this representation even more complex.
The AROME model (Seity et al., 2011) for regional numerical weather forecasting operational at Météo-France over metropolitan France and overseas France is not exempt from these difficulties. Deficiencies are observed over France and have been particularly documented over the Toulouse region using the Météopole-Flux station (https://www.umr-cnrm.fr/spip.php?article874) deployed by the CNRM, which brings together a large number of measurement instruments (Calvet et al, 2016 and Canut et al, 2019). Systematic biases of incident solar radiation have been highlighted and linked to a stratocumulus deficit.
Several adaptations of shallow convection schemes have been proposed to improve the representation of stratocumulus in different models. In particular, the adaptation proposed by Hourdin et al (2019) and two other adaptations performed at CNRM will have to be adjusted to the AROME model and compared between them during this thesis.
Furthermore, the interaction between shallow convection and microphysics can be improved in order to better represent stratocumulus, their transition to cumulus and precipitation under cumulus congestus (continuation of the work of Turner et al, 2012).
To do this, evaluations will first be conducted in simple settings in order to select the best approaches and to develop, tune and validate the modifications. This preliminary validation will be done using the uni-column version of the AROME model compared to existing very high resolution simulations serving as a reference (Couvreux et al, 2021 and Hourdin et al, 2021).
In a second phase, simulations will be carried out with AROME in an operational configuration on a domain covering metropolitan France in order to evaluate the performance of the modified version of the model. Particular attention will be paid to the evaluation over the Toulouse region thanks to the measurements of Météopole-Flux, as well as over situations of marine clouds affecting the Occitanie coastline.

On the one hand, the modifications made to the model will allow to improve the forecast of weather conditions, photovoltaic production and fog, in particular for the airport of Blagnac (because a deficit of Stratocumulus forecast leads to an excess of fog forecast as shown by the SOFOG3D campaign over the South-West). On the other hand, these improvements will directly benefit applications using the AROME model such as AROME-Climat, widely used for regional climate studies for urban areas, or AROME-NEMO used for the important ocean-atmosphere coupling over the Mediterranean.

Nature of the expected work and desired skills

This work will require the development of parameterizations in the AROME model. Then their adjustment will be carried out using tools comparing 1D simulations and high resolution simulations.
In parallel, 3D simulations will be carried out to evaluate the impact of the new parameterizations on case studies.
Finally, statistical evaluations over long periods will be carried out.

Profile of the candidates:

- a Master of Science degree or an equivalent qualification in atmospheric physics, oceanography, environmental physics or climate before starting the Ph. D. project
- knowledge of atmospheric physics
- good written and oral English skills to present scientific results
- good programming and data processing skills (Fortran, Shell, Python or similar)
- experience in numerical modelling

About the CNRM:

The French Centre National de Recherches Météorologiques (CNRM, www.cnrm-game-meteo.fr) is a joint research unit (UMR 3589) affiliated to Météo-France and the CNRS. It brings together 80 researchers and 150 engineers, technicians and administrative staff. Each year, the CNRM welcomes between 15 and 20 new doctoral candidates.

The PHYNH team of the CNRM is in charge of the development of physical parameterizations and process studies around the AROME and Meso-NH models at kilometre scales. In particular, the team is involved in the development and validation of radiation, shallow convection, cloud microphysics and turbulence schemes.
The proposed thesis is in line with this continuity by being at the intersection of all these fields of expertise; it will therefore benefit from numerous collaborations within the team, and more widely at CNRM.

Applications:

Candidates should send a letter of motivation, with a CV, a copy of their diplomas with the corresponding transcript of marks, a summary of the subject of their Master thesis, as well as the names of two references including their email address and telephone number.

The deadline to apply is September 23, 2022.

References :

- J.-C. Calvet et al., "METEOPOLE-FLUX: an observatory of terrestrial water, energy, and CO2 fluxes in Toulouse," in EGU General Assembly Conference Abstracts, Apr. 2016, pp. EPSC2016–2264.
- G. Canut, J.-C. Calvet, W. Maurel, and A. Paci, "Seven years (2012-2018) of continuous observation of the surface energy budget and of soil moisture and temperature profiles in a peri-urban aera" in EMS Annual Meeting Abstracts, 2019, vol. 16, pp. EMS2019–687-1
- F. Couvreux et al., "Process-Based Climate Model Development Harnessing Machine Learning: I. A Calibration Tool for Parameterization Improvement," Journal of Advances in Modeling Earth Systems, vol. 13, no. 3, Art. no. 3, Feb. 2021, doi: 10.1029/2020ms002217.
- F. Hourdin et al., "Unified Parameterization of Convective Boundary Layer Transport and Clouds With the Thermal Plume Model," Journal of Advances in Modeling Earth Systems, vol. 11, no. 9, Art. no. 9, Sep. 2019, doi: 10.1029/2019ms001666.

- F. Hourdin et al., “Process-Based Climate Model Development Harnessing Machine Learning: II. Model Calibration From Single Column to Global,” Journal of Advances in Modeling Earth Systems, vol. 13, no. 6, Art. no. 6, Jun. 2021, doi: 10.1029/2020ms002225.
- Y. Seity et al., “The AROME-France Convective-Scale Operational Model,” Monthly Weather Review, vol. 139, no. 3, Art. no. 3, Mar. 2011, doi: 10.1175/2010MWR3425.1.
- S. Turner, J.-L. Brenguier, and C. Lac, “A subgrid parameterization scheme for precipitation,” Geoscientific Model Development, vol. 5, no. 2, Art. no. 2, Apr. 2012, doi: 10.5194/gmd-5-499-2012.