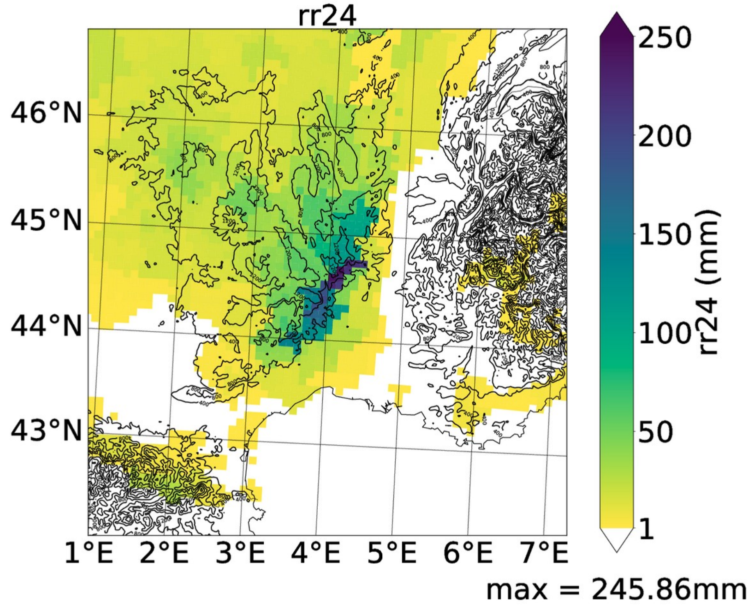
Assessing the **role** of **sub-grid scale orography** in the representation of a **heavy precipitating event** by CNRM-ALADIN63



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AMA, 2021

Context

- **Heavy Precipitating Events (HPEs) are likely to increase** in intensity and frequency of occurrence **in the future in southeastern France** (e.g., Blanchet et al., 2018; Ribes et al., 2019; Drobinski et al., 2018; Tramblay and Somot, 2018)

- **Intensity of HPE is underestimated** by most **Regional Climate Models (RCMs)** using **parameterized convection** (~10-50 km) (Khodayar et al., 2016)

- Convection-permitting models generally show better performance, but are particularly expensive

- Representation of **HPEs in RCMs** is mor **sensitive** to model physics, especially **convection parameterization**, than to other model configuration such as resolution or coupling (Cavicchia et al., 2016)

- **Importance of orography in the triggering and intensity** of HPEs (Davolio et al., 2009)

- Consideration of **'sub-grid' orography** has already been shown to **improve prediction** of orographic waves or precipitations (Leung and Ghan, 1995 ; Lott and Miller, 1997; Lee et al., 2015; Garner, 2018)

Objectives and method

- **Evaluation of the CNRM-ALADIN63 (Nabat et al., 2020) convection scheme**

- Better **understanding of processes** leading to convective rain

↳ Evaluation of the role of **small-scale features of the regional topography** in triggering and maintaining convection

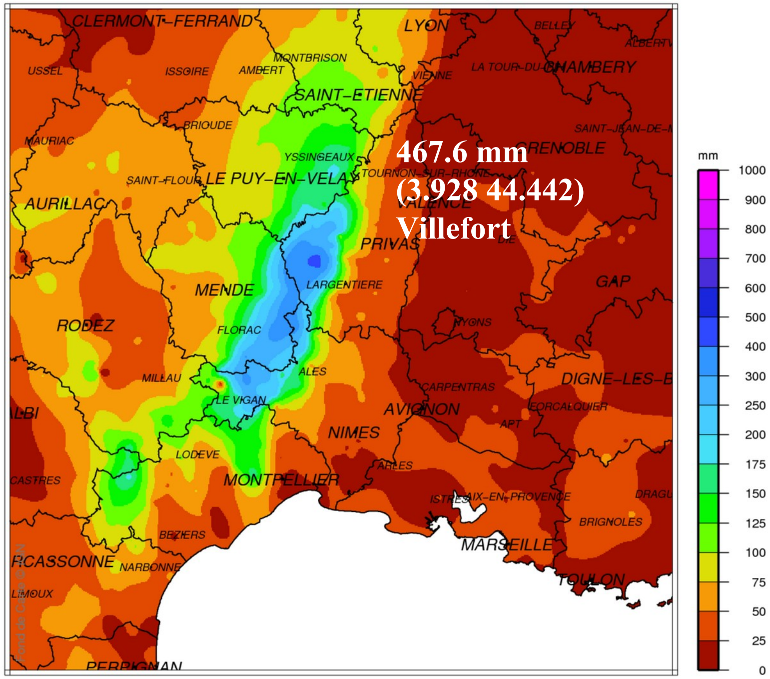
- Provide guidance in the development of a **specific parametrization** to account for the **role of subgrid-scale orography**

1. Focus on one **typical** HPE over the Cévennes with a moist large-scale flow directly impinging the mountains (**no cold pool**)

2. Comparisons with the **Convection Permitting** Model Méso-NH through **conditional sampling of updrafts**

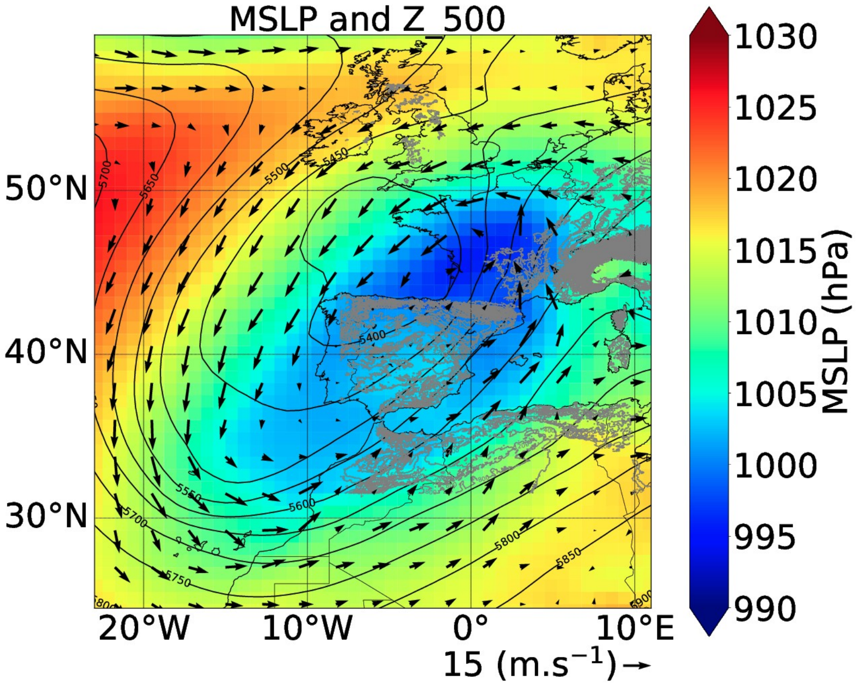
3. Diagnostics of relevant sub-grid-scale elements favorable to convection

Focus on **01-02/11/2008** High Precipitation Event



Accumulated precipitation on 01-02/11/2008 as measured by the Météo-France's rain-gauge network.

01 November 2008 06:00 UTC



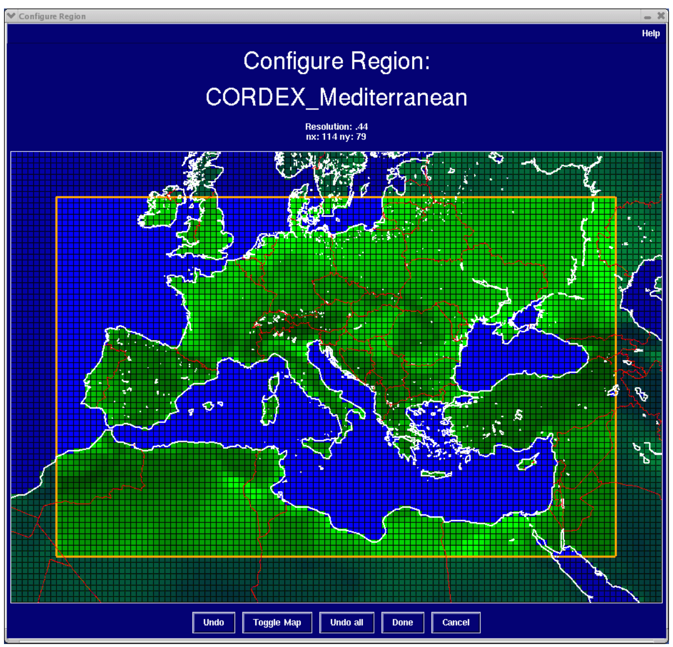
ERA-Interim 500-hPa geopotential height (contours, in m), mean sea-level pressure (colors, in hPa) and 925-hPa wind (vectors, in m.s-1

- From 10:00 UTC on 01/11/2008 to 06:00 UTC on 02/11/2008
- **Typical HPE situation** (Nuissier et al. 2008),
- **Classic synoptic situation** (Cyclonic South Westerly, Nuissier et al. 2011)
- **Already studied by Duffourg et al. (2011) with Méso-NH**
- **No cold pool**

Setup for the CNRM-ALADIN63 (50 km) and the convection-permitting model Méso-NH (2.5 km)

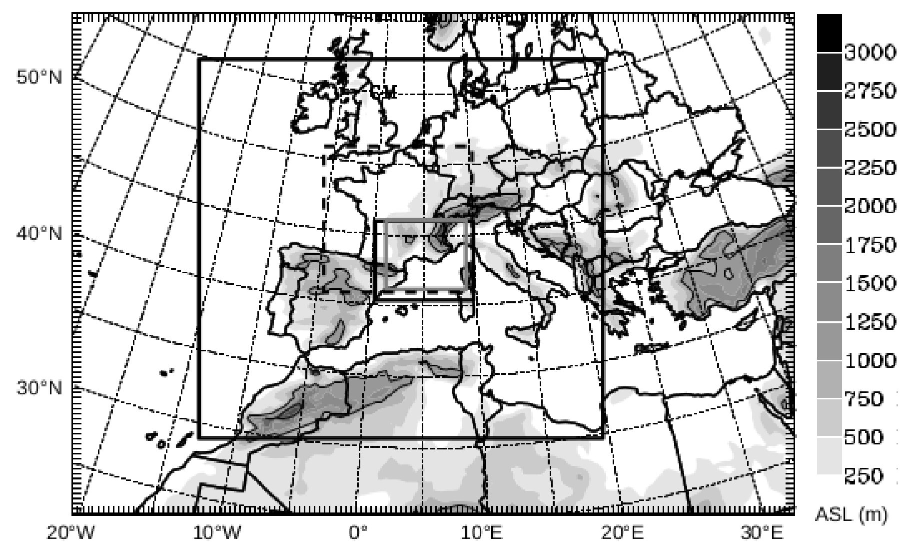
CNRM-ALADIN63

- MED-CORDEX domain
- Initialization on 31/11/08 at 18:00 UTC
- Forced by ERAI
- Spectral Nudging



Méso-NH

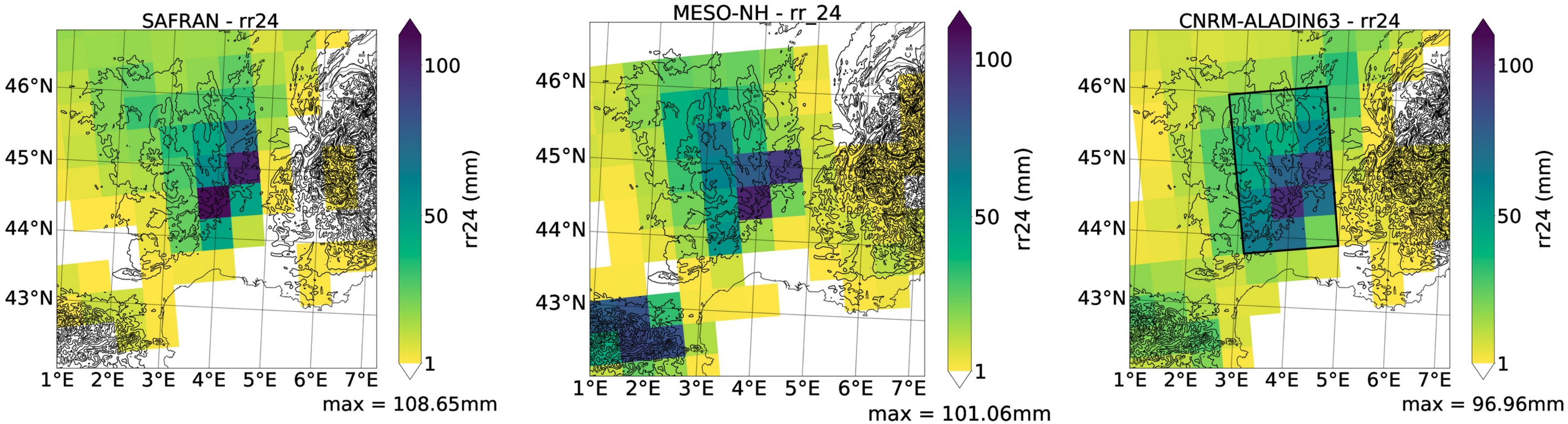
- Two-way nested simulations ; 40 km (4 days before) ↔ 10 km ↔ 2.5 km (1 day before : 31/10/08 at 18:00 UTC)
- Forced by ERAI



Domains of the 40 km simulations, 10 km (in solid black) and 2.5 km (smaller rectangle in solid black). Duffourg et al. (2011).

Precipitation intensity and location

01 November 2008



OBS

(Safran product regridded to CNRM-ALADIN63 50 km grid)

MÉSO-NH

(regridded to CNRM-ALADIN63 50 km grid)

CNRM-ALADIN63

→ CNRM-ALADIN63 : - more spread around the peak of precipitation
- slight understimation on the Cévénnes area
- overestimation on the foothills

Evaluation of **CNRM-ALADIN63 convection scheme PCMT** (Pirou et al., 2007, Guérémy et al., 2011)

➢ **Mass flux scheme** (Mc=ρ*w*alpha)

→ **Updrafts velocity** (prognostic equation ; advection, buoyancy and entrainment)
→ **Updrafts area fraction**, alpha (CAPE relaxation closure)

→ **Triggering on w > 0 m/s** (both flux levels surrounding the top variable level)

➢ **Diagnostic of updrafts** with Méso-NH

Conditional sampling of convection updrafts:

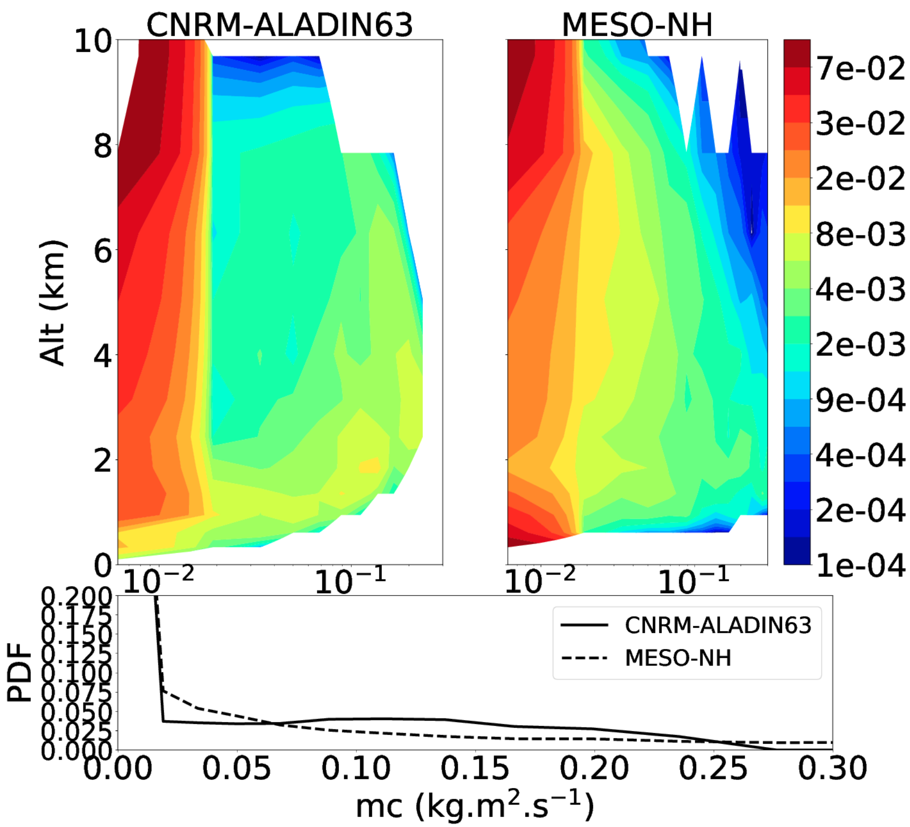
- *Derbyshire et al. (2004):* ***w>0 m/s and ql >0 g/kg***
- *Khairoutdinov et al. (2009):* ***w>1 m/s (core)***
- *Lemone and Zipser (1980):* ***w>0.5 m/s (draft)*** ***w>1m/s (core)***

1. w > 0 m/s and (ql+qi) > 0
2. w > 0.5 m/s and (ql+qi) > 0 (DRAFT)
3. **w > 1 m/s and (ql+qi) > 0 (CORE)**

→ Threshold on ql+qi to limit the inclusion of orographic waves

Convection scheme evaluation using Méso-NH

- **Bivariate PDF** of the **altitude** and the **updraft mass flux** as identified from the Méso-NH simulation using conditional sampling and the CNRM-ALADIN63 50 km grid.
- Calculated on the Massif central area over 00:00 – 24:00 UTC on 01 November 2008

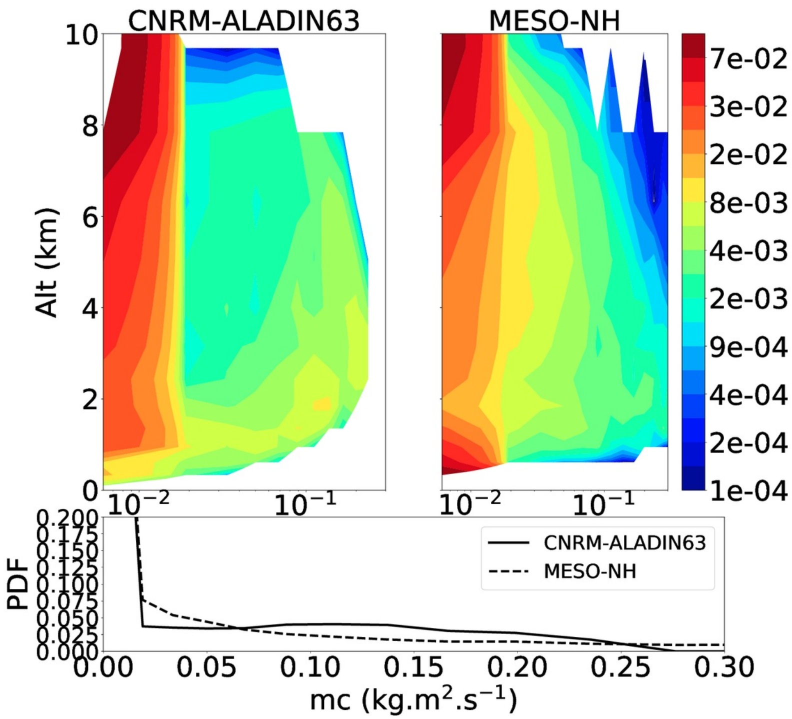


→ 2 modes in ALADIN, while Meso-NH show more continuity
→ High values of mass flux systematically underestimate (at all levels)

→ Weakly sensitive to the conditional sampling criteria

Convection scheme evaluation using Méso-NH

- Bivariate PDF of the altitude and the **updraft mass flux** (= *-α*ω/g*), the **updraft vertical velocity** (-ω) and the **updraft area fraction** (α)
- Calculated on the Massif central area over 00:00 – 24:00 UTC on 01 November 2008



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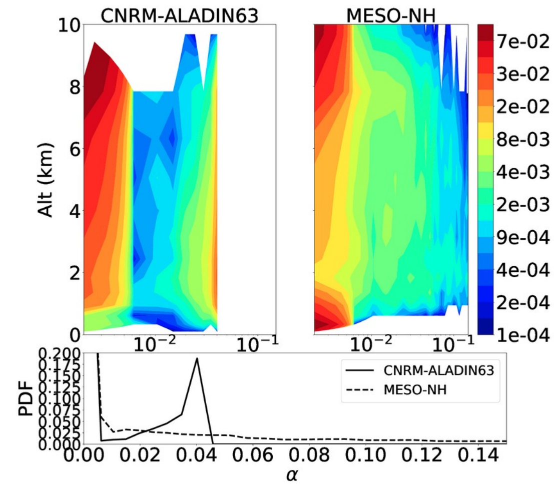

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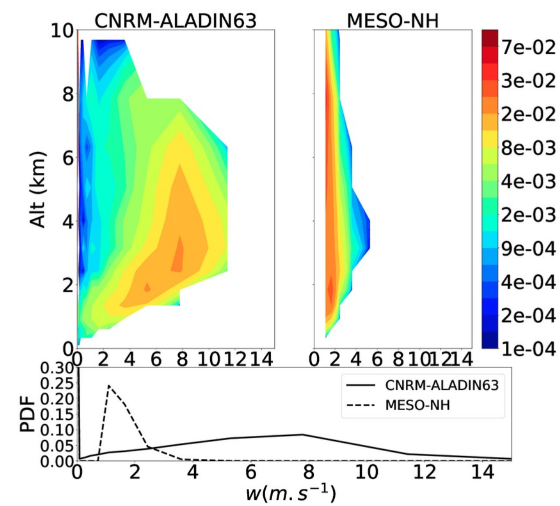


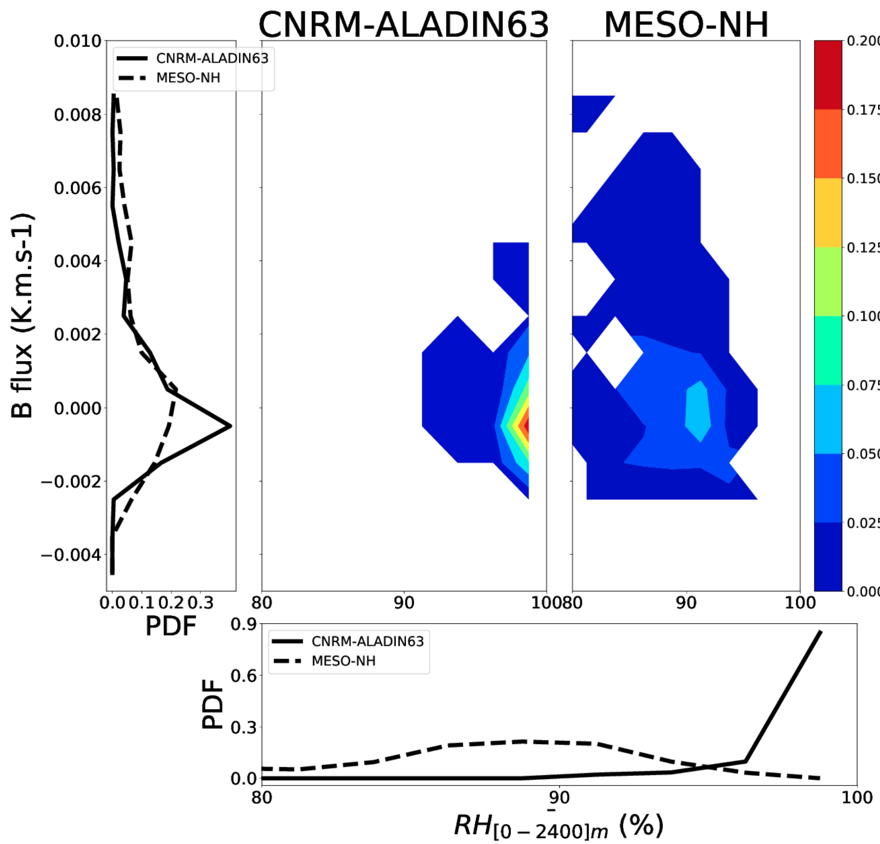
→ Compensating errors:

- strong overestimate of updraft vertical velocities
- strong **underestimate of the area fractions covered by updrafts**

Processes responsible for **convection activities** in CNRM-ALADIN63

➢Bivariate PDF of surface buoyancy flux (B flux) and relative humidity (RH) **when convection is active**

➢Calculated on the Massif central area over 00:00 – 24:00 UTC on 01 November 2008



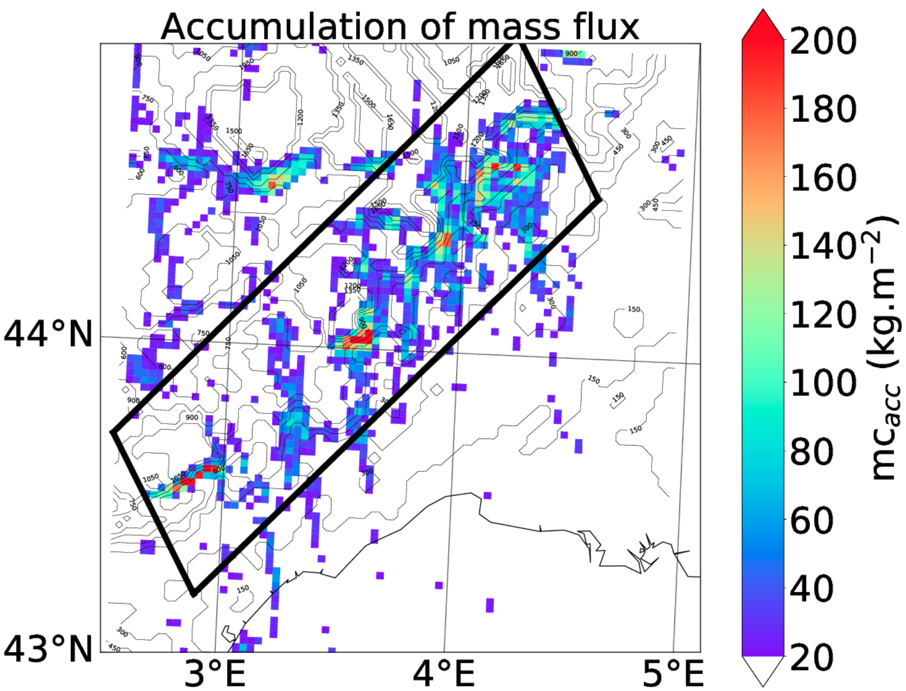
In Méso-NH, we set that convection is active when an updraft occurs at ***2400 m***

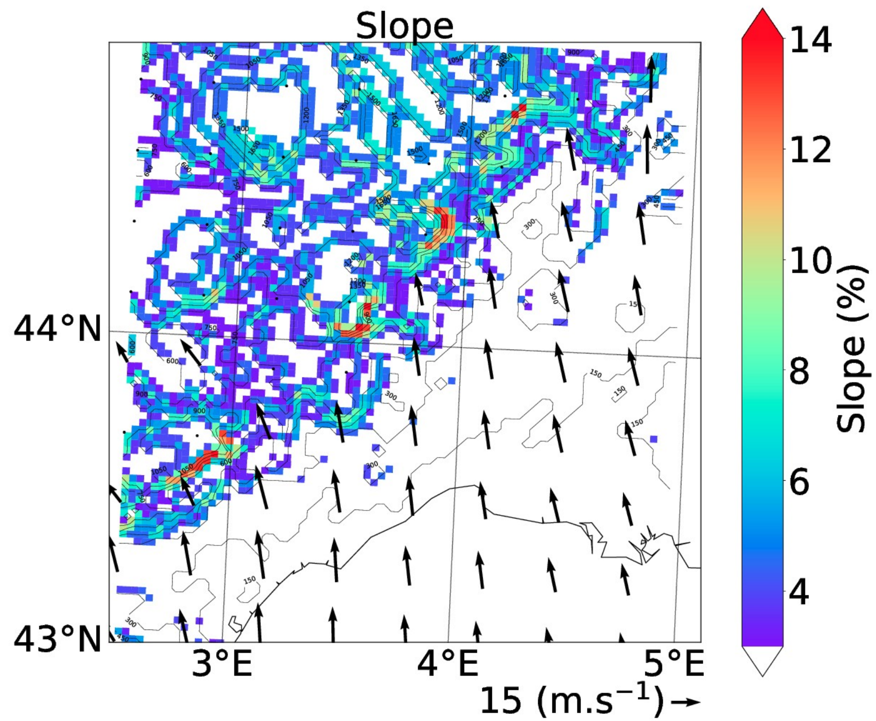
→ High sensitivity of **CNRM-ALADIN63** activity to **thermodynamic** (surface buoyancy flux and saturation in the lower troposphere).

→ **Different** behavior in **Méso-NH.**

Favorable **locations** for **convection activity** in Méso-NH

➢Méso-NH **mass flux accumulated** over 00:00 – 24:00 UTC on 01 November 2008 on [0 - 2400] m.





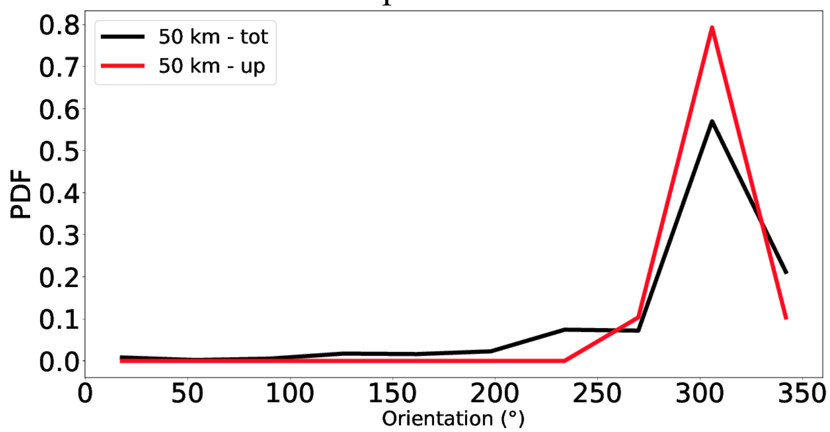
Wind at 925 hPa on 12 UTC 1 Nov

→ Convection activity preferably occurs on **high slope before crests**

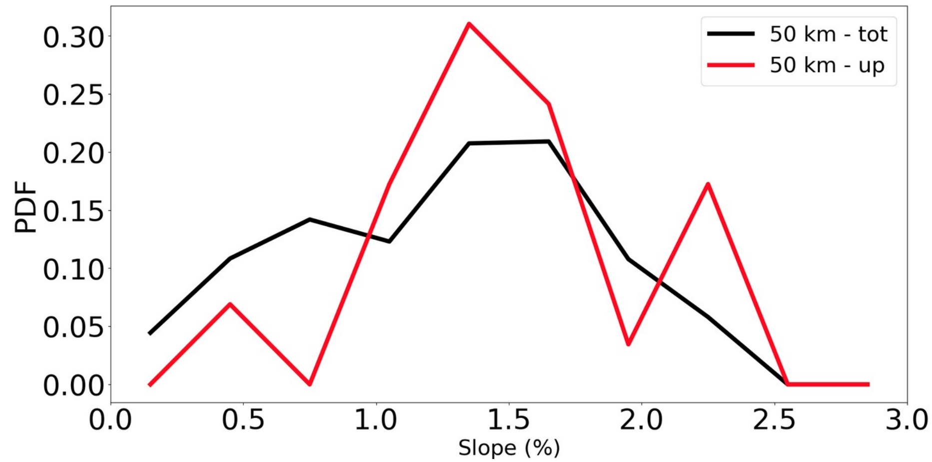
Favorable conditions of convection activation in Méso-NH **orography and details needed**

➢Méso-NH **PDF of updraft and all meshes** characteristics over 00:00 – 24:00 UTC on 01 November 2008. Méso-NH regridded by moving average on 50 km (CNRM-ALADIN63 meshes) on Massif Central area.

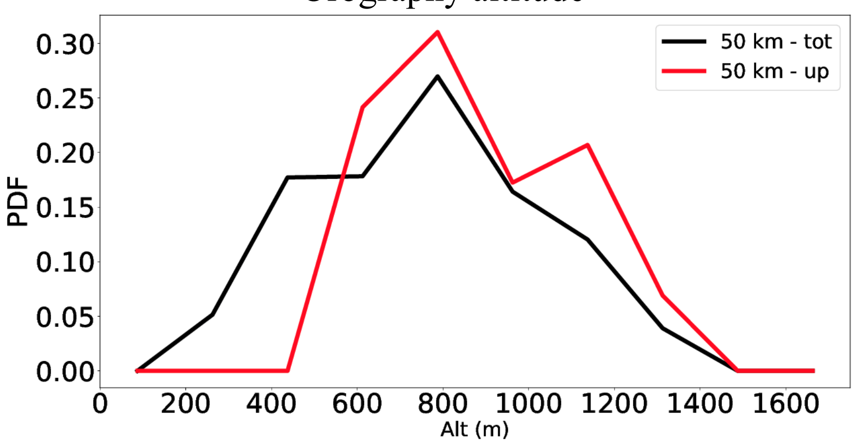
Slopes orientation



Slopes intensity



Orography altitude

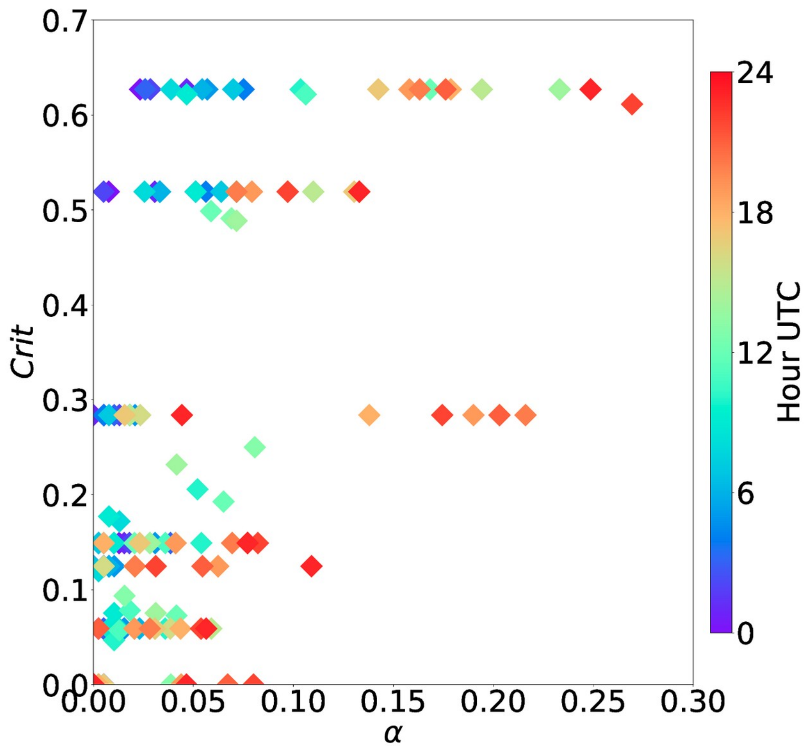


→ Convection activation depends on altitude, slope and slope orientation: **dynamical forcing**

First step toward a **parametrization of sub-grid orography** for convective closure

➢ **Scatterplot of α** at 2400 m over 00:00 – 24:00 UTC on 01/11/2008 **function of percentage of orographic criteria in a CNRM-ALADIN63 mesh**. Méso-NH regridded by moving average on 50 km (CNRM-ALADIN63 meshes) on Massif Central area.

<u>Orographic criteria :</u>
Slope > 1 %
Alt > 0.6 km
270° < Orientation < 360°



⟶ Relationship between α (closure term) and orographic criteria become strongest with HPE blocking

Orographic criteria explain the largest α

Summary

- Evaluation of the CNRM-RCM convection scheme by comparisons with the Convection Permitting Model Méso-NH on a mountainous area trough a conditional sampling of updrafts

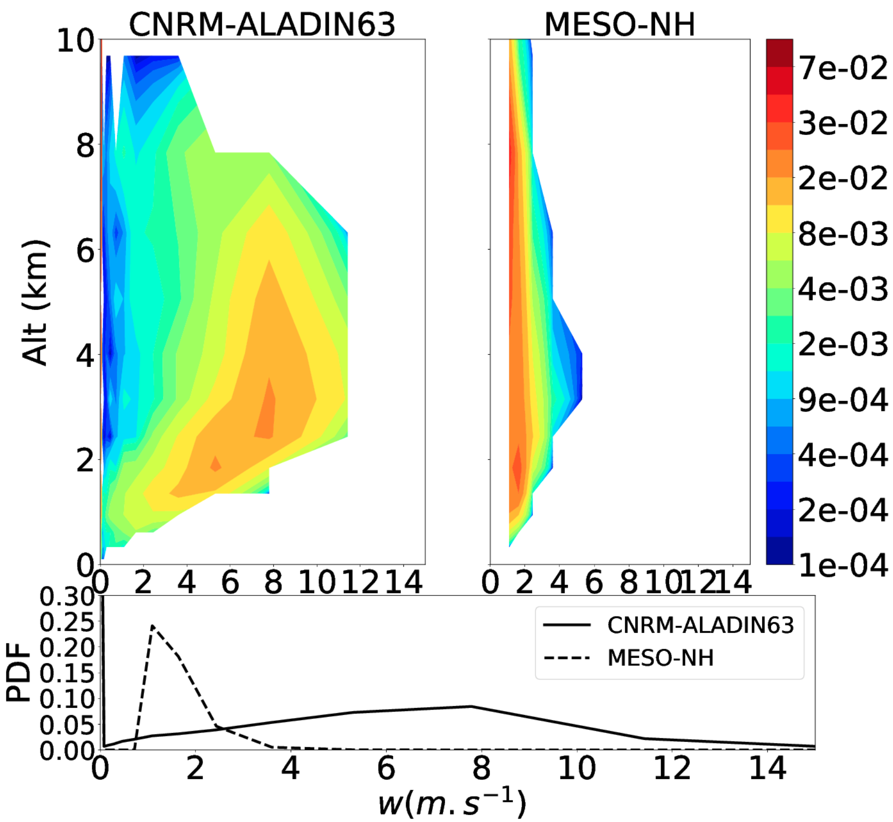
- **CNRM-ALADIN63 underestimate the updraft mass flux** with two compensating errors : Overestimate of updraft vertical velocities and **underestimate of area fraction covered by updrafts**

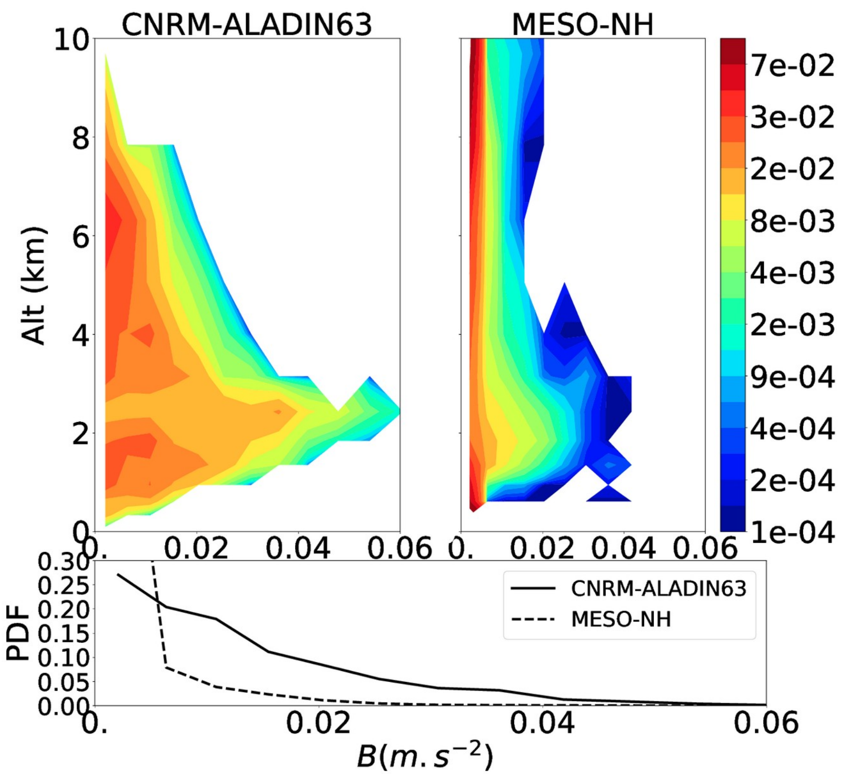
- **CNRM-ALADIN63 activities areas** are highly sensitive to **thermodynamics conditions** such as surface buoyancy flux and saturation in the lower troposphere

- **Diagnostic of relevant sub-grid-scale elements favorable to convection** show that: **Méso-NH activities areas** are highly sensitive to **dynamical forcing induced by orography** (altitude, slop, slope orientation)

- **Some predictive potential of updraft area (convection scheme closure conditions) could be obtained with sub-grid-scale orographic features**

→ **Updrafts velocity** (prognostic equation ; advection, buoyancy and entrainment)





Lack of dilution in updrafts ?