NUMERICAL SIMULATIONS OF BANDED OROGRAPHIC CONVECTION DURING THE VAIA STORM OVER THE EASTERN ITALIAN ALPS

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INTRODUCTION AND OBJECTIVES

Elongated and quasi-stationary convective rainbands triggered by small-scale orography and capable of producing heavy precipitation are often observed over the Italian Alps. Such features occurred in the final and most intense phase of the Vaia storm over the eastern Italian Alps, in the evening of 29 October 2018. South-east/north-west oriented bands, driven by the strong Sirocco wind, caused floods and landslides in several locations.

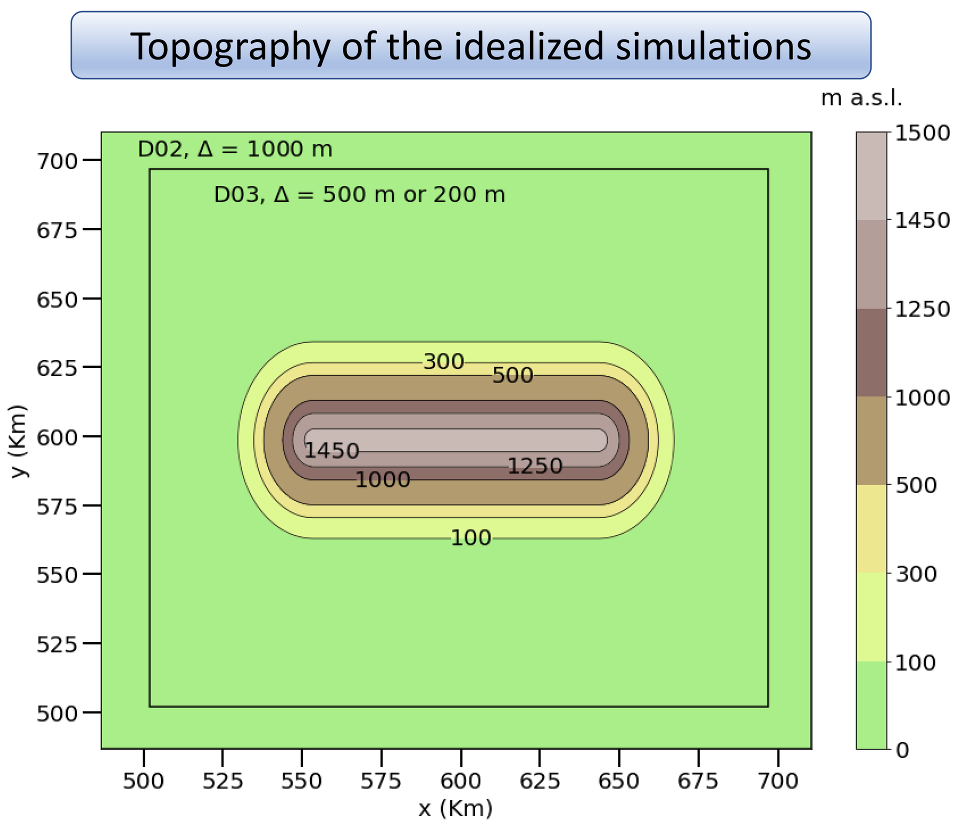
This work aims at studying the thermodynamic conditions favorable for their formation and the role played by small-scale topographic details on their development. The analysis is performed through semi-idealized numerical simulations with the WRF-ARW model. Simulations are initialized using variations of the radio-sounding data measured at Udine-Rivolto at 18:00 UTC, 29 October; the small-scale energy needed to develop convection is provided prescribing background thermal fluctuations embedded in the low-level flow or random perturbations on the background orography.

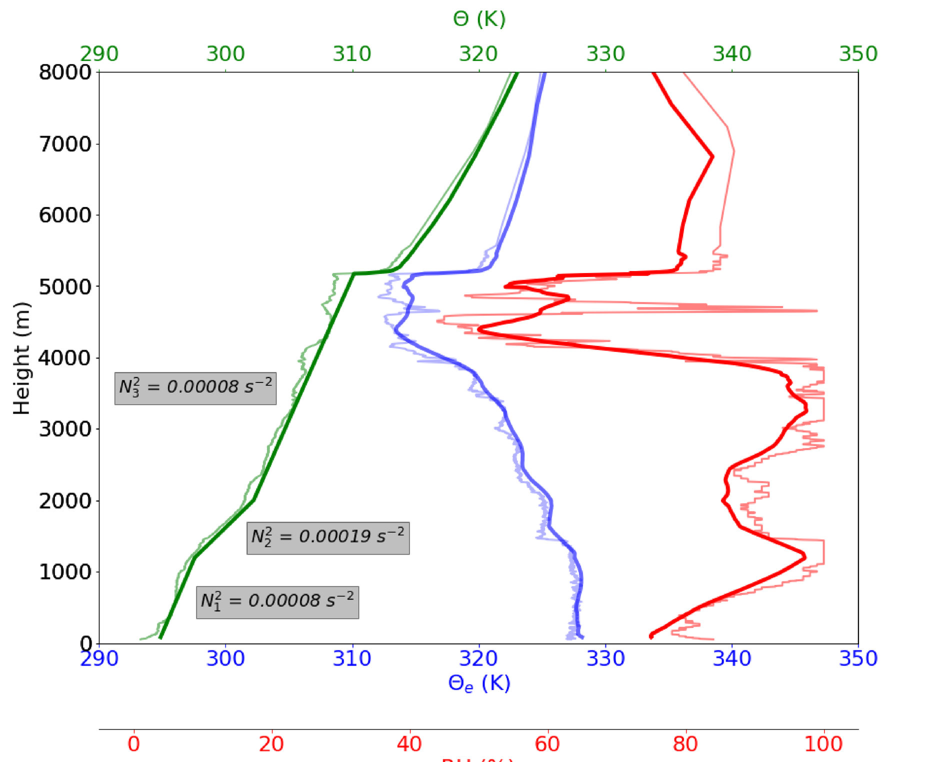
Different sensitivity analyses have been performed. Simulations initialized with a simplified smooth orography are used to demonstrate the influence of model resolution and atmospheric factors on rainbands development. The influence of orographic details on their structure and formation, is studied using different levels of topography idealization.

In this contribution, sensitivity to model resolution, atmospheric stability and small-scale orographic triggers is shown. Some of the results found with an idealized orography are confirmed performing a simulation with the real Eastern Alpine ridge.

METHODS: MODELING SET-UP AND UPSTREAM SOUNDING

Topography of the idealized simulations





Udine (lighter) and CTRL (darker) soundings

Model set-up:

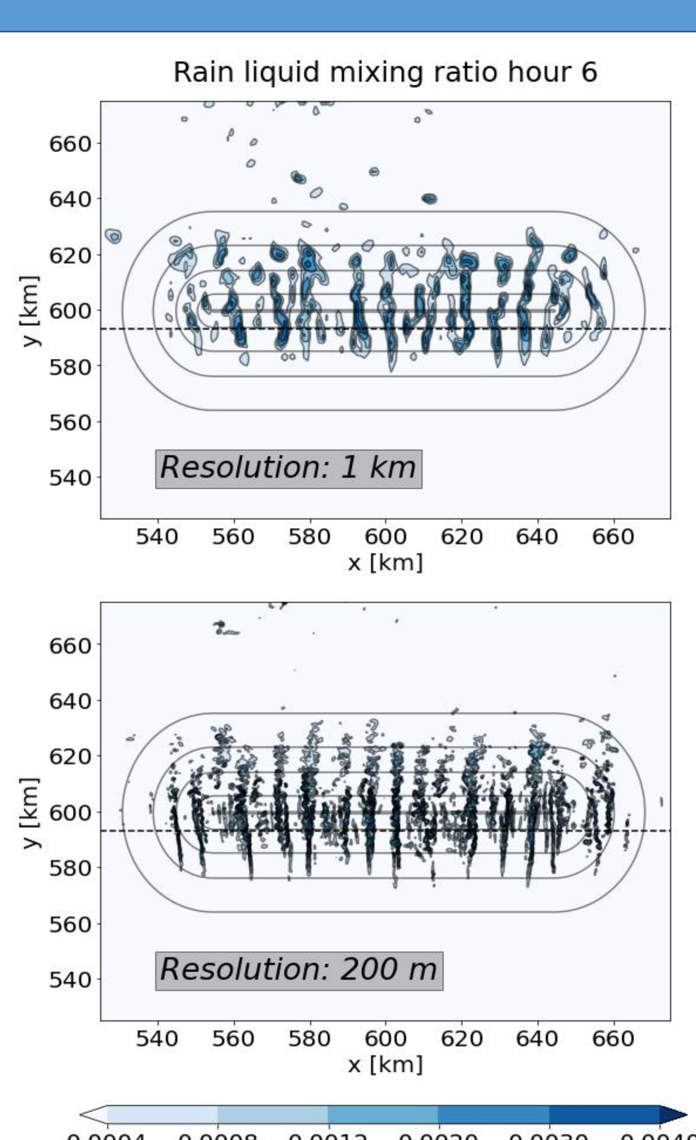
- Three nested domains
- D01: Δx = Δy = 3 km, D02: Δx = Δy = 1 km, D03: Δx = Δy = 500 m or Δx = Δy = 200 m
- D01: Δt = 9 s, D02: Δt = 3 s, D03: Δt = 1.5 s or 0.6 s
- 65 stretched vertical levels
- z_{top} = 25 km, 5 km damping layer
- Open boundary condition S-N
- Periodic boundary condition W-E
- No Coriolis force
- Simulations starts 29 October 2018 at 18:00
- Random T perturbations in range ± 0.1K for sensitivity to resolution and atmospheric stability
- P_0 = 1000 hPa
- Feedback switched off for sensitivity on resolution

Upstream Sounding:

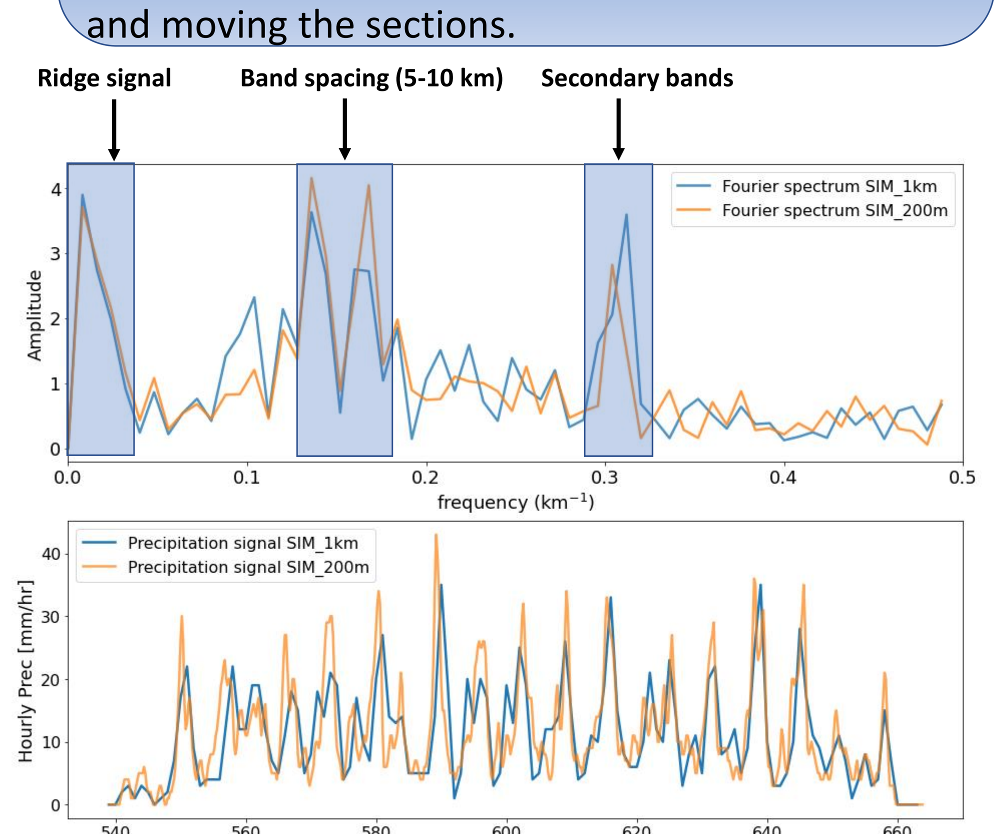
- Sensitivity to resolution is based on Udine sounding
- Ideal simplified southerly flow
- Three layer stability CTRL sounding used for the other simulations (with modifications for sensitivity to stability)
- Udine sounding: LCL = 950.7 hPa, LFC = 876.8 hPa, CAPE = 704.2 J/kg, CIN = 43.4 J/kg
- Strong low-level shear

RESULTS: SENSITIVITY TO MODEL RESOLUTION

Rain liquid mixing ratio hour 6

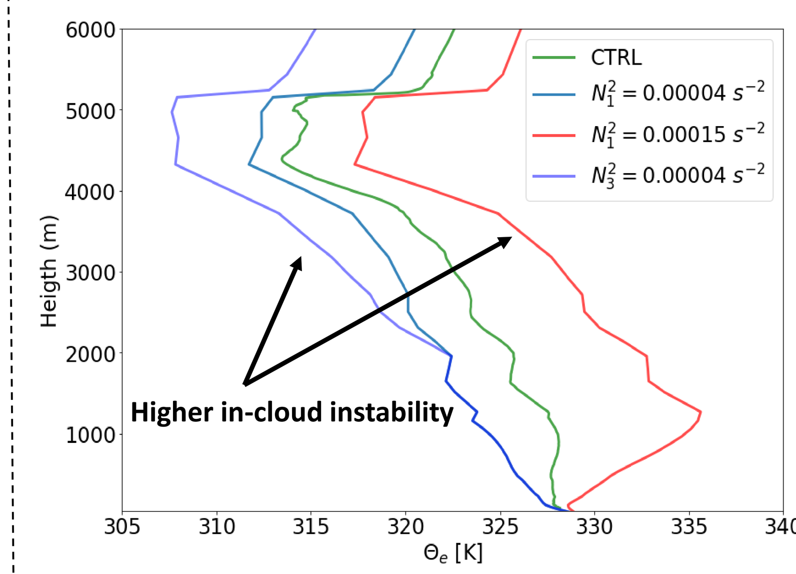


Cross sections at 2000 m of altitude of rain liquid mixing ratio from the simulations with resolution of 1000m and 200 m. Dashed lines shows the sections adopted for the Fourier analysis on the hourly precipitation signal. Similar results were found for the simulation with resolution of 500m and moving the sections.



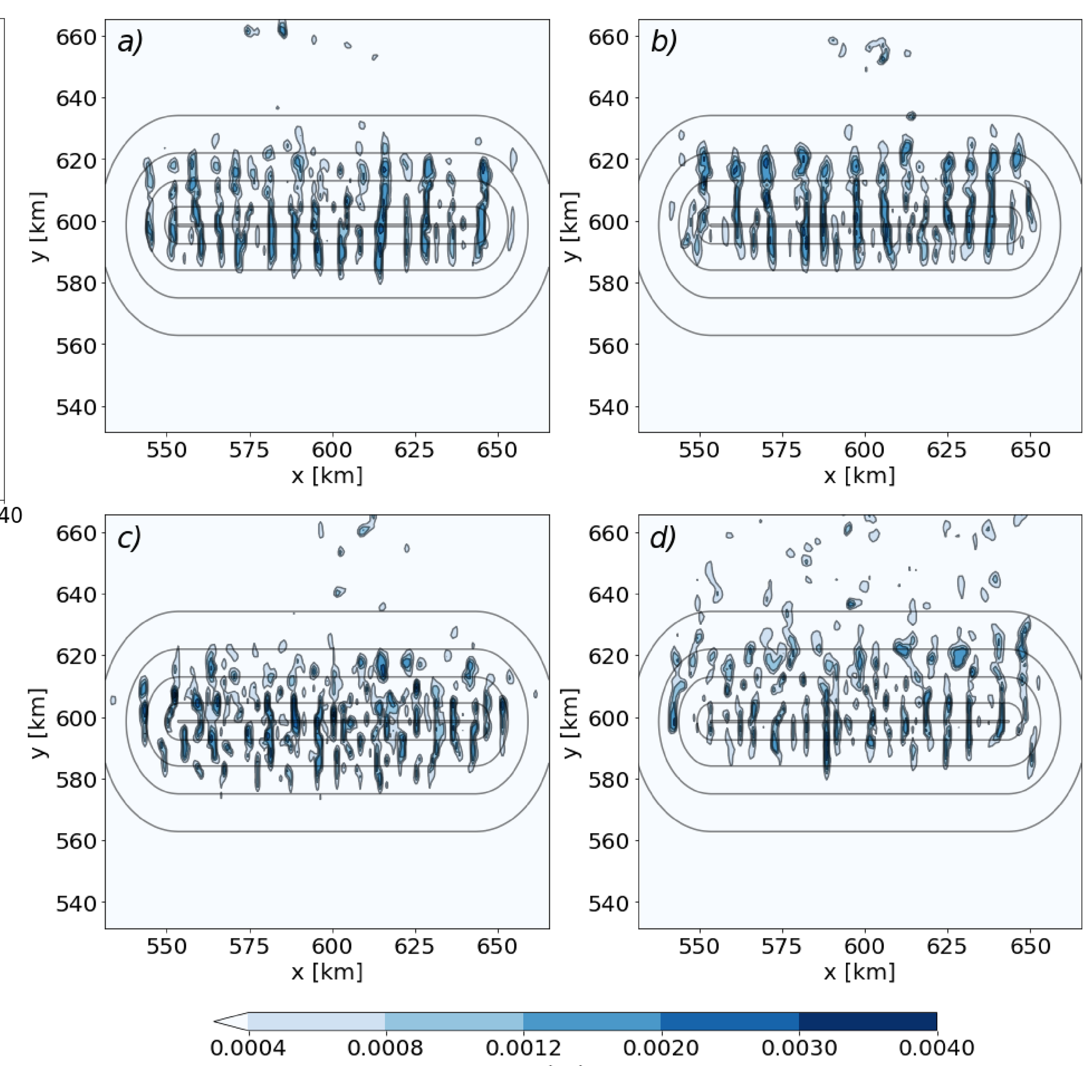
RESULTS: SENSITIVITY ON ATMOSPHERIC STABILITY

Sensitivity to atmospheric stability has been studied varying the dry Brunt Vaisala frequency N of layers 1 or 3 of the CTRL sounding, keeping the RH constant. Less band-shaped convective organization is observed as instability increases in the cap cloud, causing more cellular convection because of stronger updrafts.



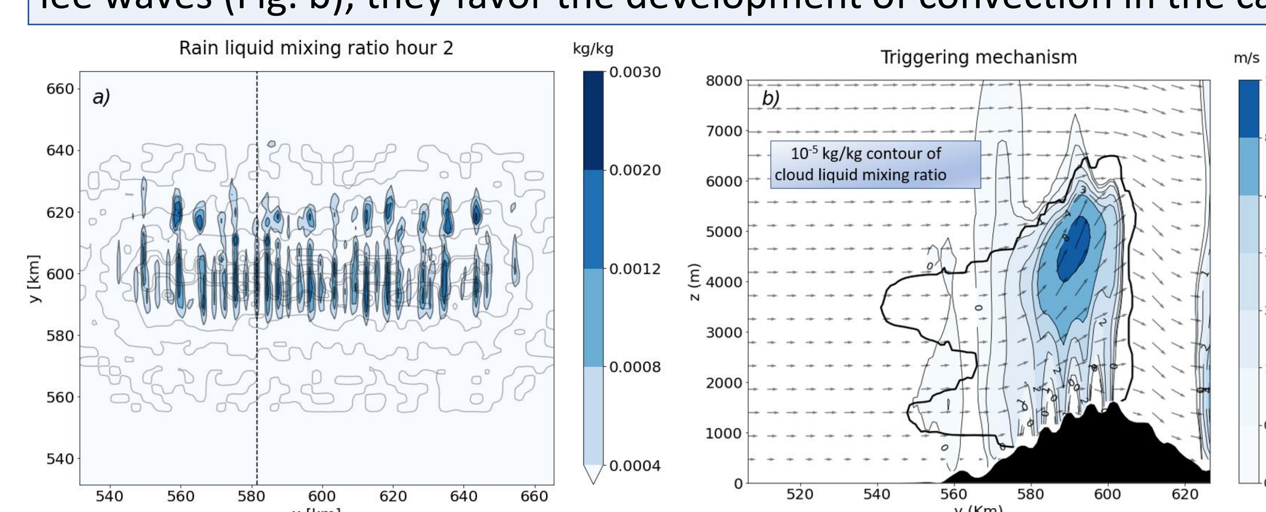
Rain liquid mixing ratios at 2000 m of altitude for:

- CTRL sounding (a)
- $N^2 = 0.00004\ s^2$ in layer 1 (b)
- $N^2 = 0.00015\ s^2$ in layer 1 (c)
- $N^2 = 0.00004\ s^2$ in layer 3 (d)



RESULTS: SENSITIVITY ON SMALL SCALE TOPOGRAPHIC DETAILS

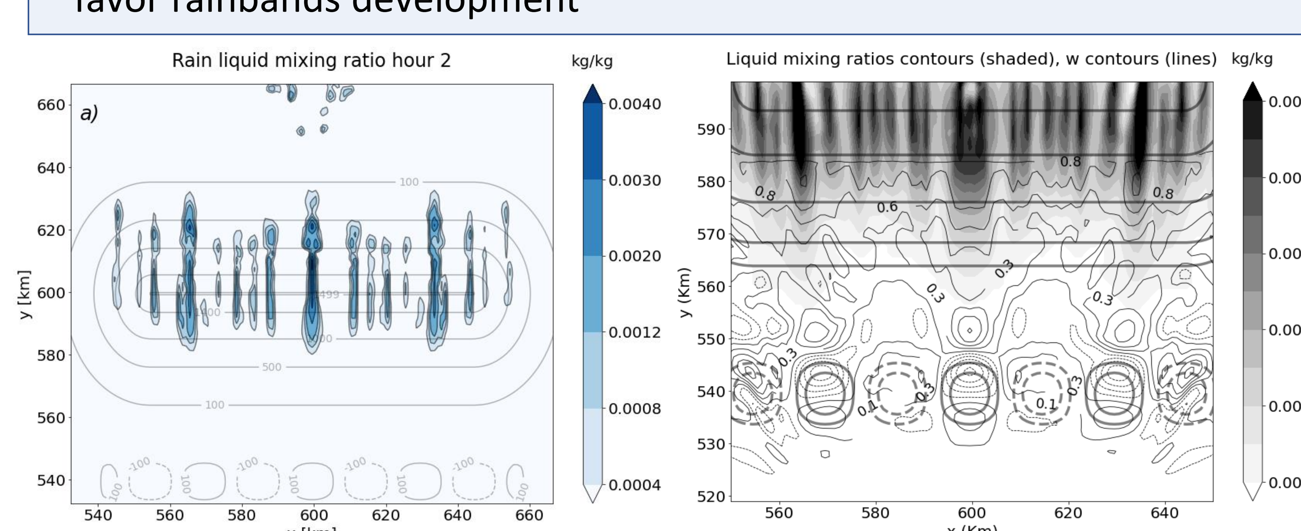
The effect of small scale topography is studied applying random perturbations to the background orography, or defining individual bumps and holes before the main smoothed ridge. The CTRL sounding has been used. Random perturbations make the rainbands stationary and enhance the spatial difference in total precipitations, if their influence is strong enough. Acting as a trigger for lee waves (Fig. b), they favor the development of convection in the cap cloud.



- Band spacing reduced to 3 km (frequency of perturbations)
- Spacing independent on resolution
- Fig. (b) shows contours of w (m/s) along the cross section shown in Fig. (a)

Simulations with individual bumps or series of bumps and «valleys» before the main ridge show that:

- their effect on rainbands development is strictly related to their position
- the generated lee wave pattern has to be in phase with the uplift generated by the main ridge to favor rainbands development

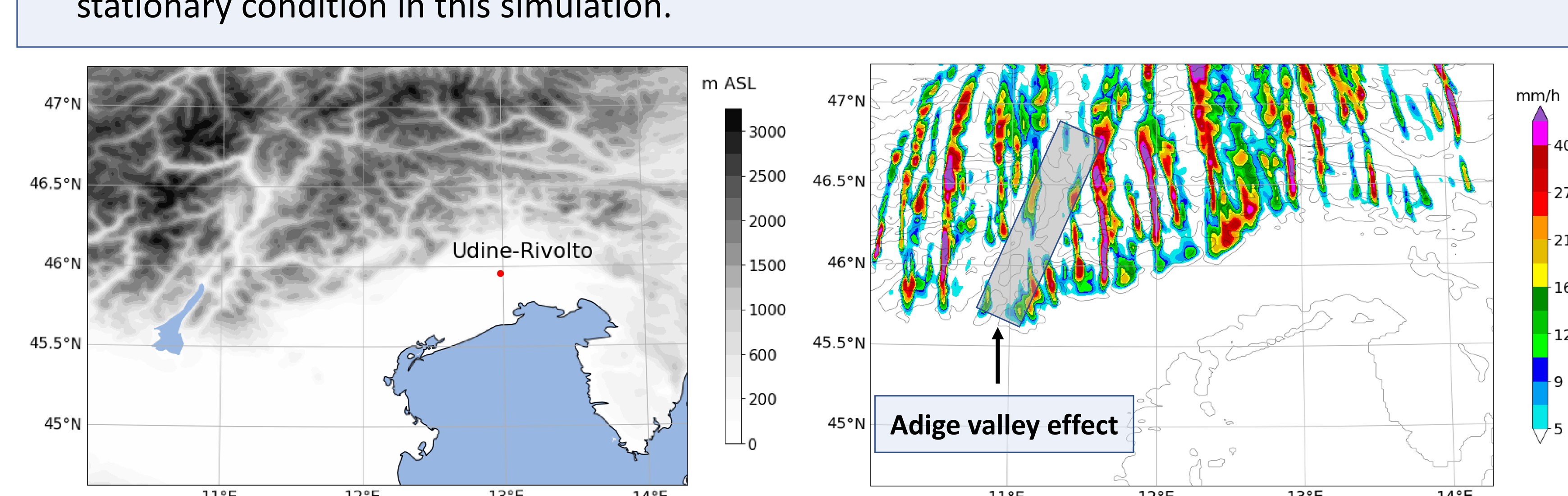


The wave generated by the bumps are in phase with the uplift generated by the ridge and favor the development of three stronger rainbands. Valleys create a shadow effect.

RESULTS: SIMULATION WITH REAL OROGRAPHY

A simulation initialized with the real orography and the CTRL sounding (keeping the directional shear with altitude) shows that bands are well-captured by the model.

- Bands are characterized by strong stationarity, in agreement with idealized simulations
- Their position is strictly related to the underlying topography
- Subsidence induced by deeper valleys (as the Adige valley) creates shadow regions and disorganization of convective rainbands
- The spacing is increased to 10 -15 km. A probable cause is the lower value of RH reached as quasi-stationary condition in this simulation.



WRF terrain for the pseudo-real simulation and hourly precipitation after 9 hours