Convection initiation in connection with a mountain wave episode

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1. Introduction

The initiation of **deep moist convection** (DMC) requires instability and a **lifting mechanism**, e.g. flow over orography.
Commonly, dynamically forced orographic lifting is expected on the windward side of mountains, but climatological studies of cloud-to-ground lightning reveal numerous **lee-side convective events** (Bertram and Mayr, 2004).

One **possible mechanism**:
Flow over mountainous terrain may generate gravity **waves**. Lee-side **wave updraft** or **hydraulic** jump forces conditionally unstable air to ascend over the LFC, initiating DMC.

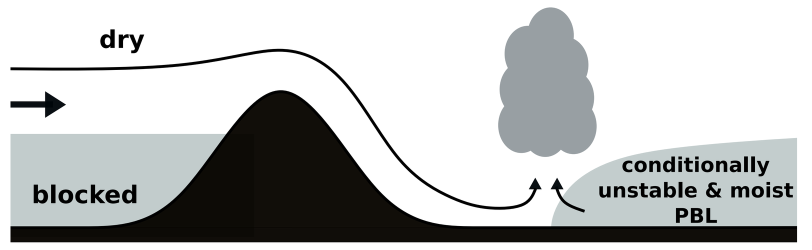

Figure 1: Possible lee-side convection initiation, favoured by large-amplitude mountain waves.

Do case studies provide evidence of convection initiation caused by large amplitude mountain waves?

2. Convection in the lee of the Apennines (Italy) on 5th July 2018

Strong south-westerly flow concurrent with **convection** along the **lee-side** of the Northern Apennines

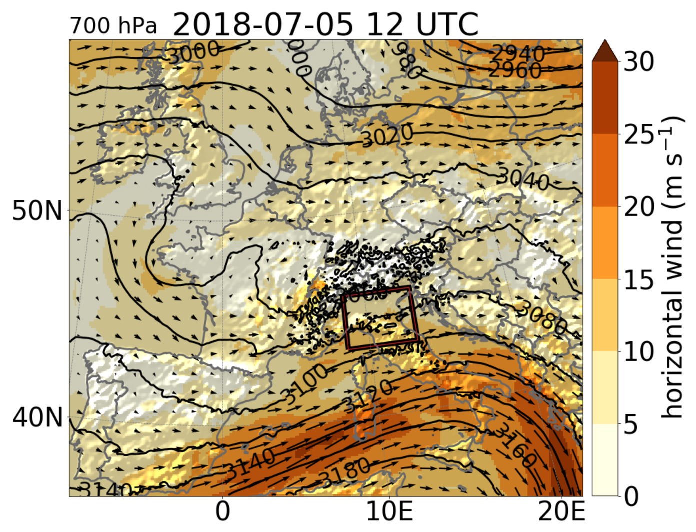

Figure 2: Geopotential and wind

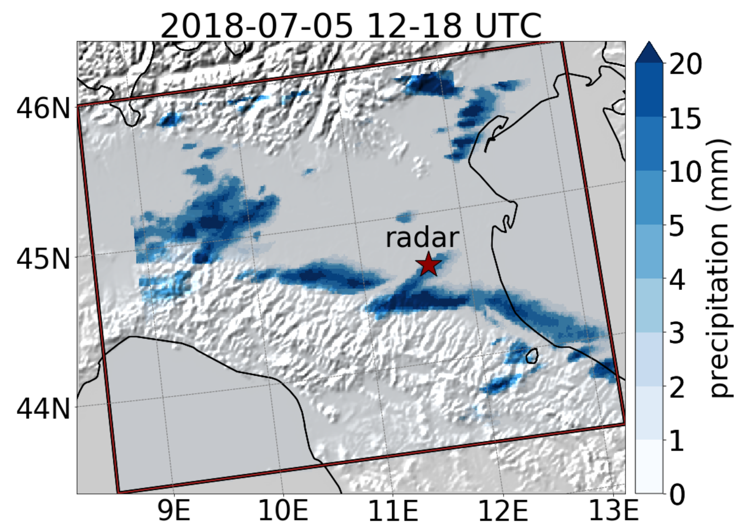

Figure 3: Radar precipitation estimates

3. Model Set-up

- WRF-ARW model

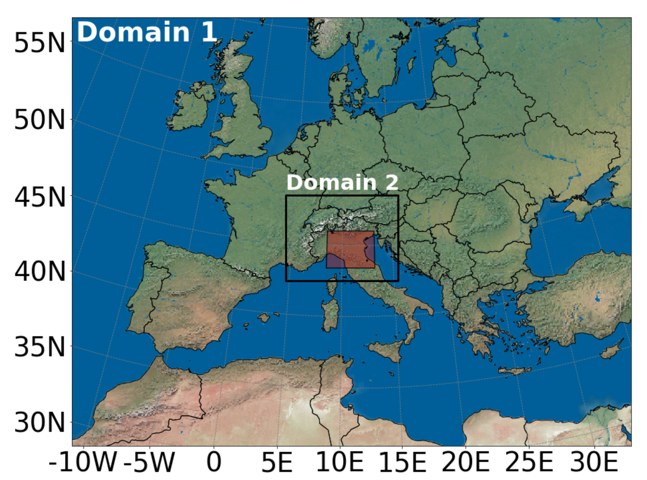

Figure 4: Simulation domains. The red area is analysed.

- **Initialized** on **4th July 2018 at 12 UTC** and **run** for **36 hours**
- Driven by **ECMWF Operational Analysis** data
- **Δx: 10 km** and **2 km** in domain 1 and 2, respectively
- **Δz: 50 - 400 m**
- **physics**: MYJ PBL, NOAH LSM, Morrison microphysics, no cumulus parametrization in domain 2

4. CAPE and precipitation

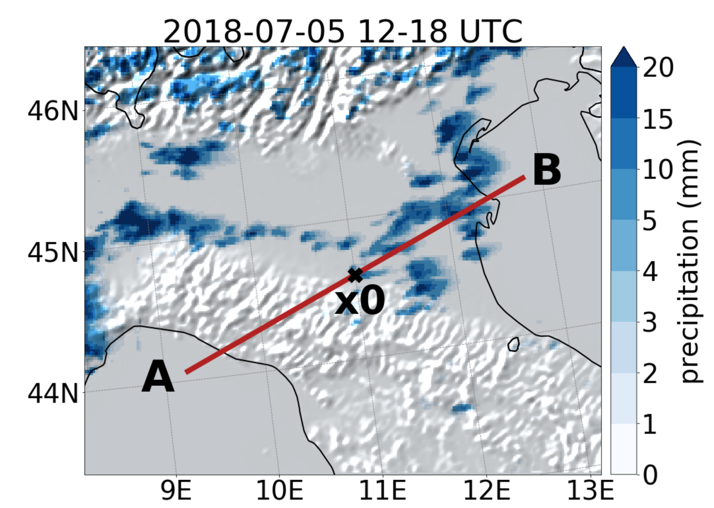

Figure 5: Simulated precipitation

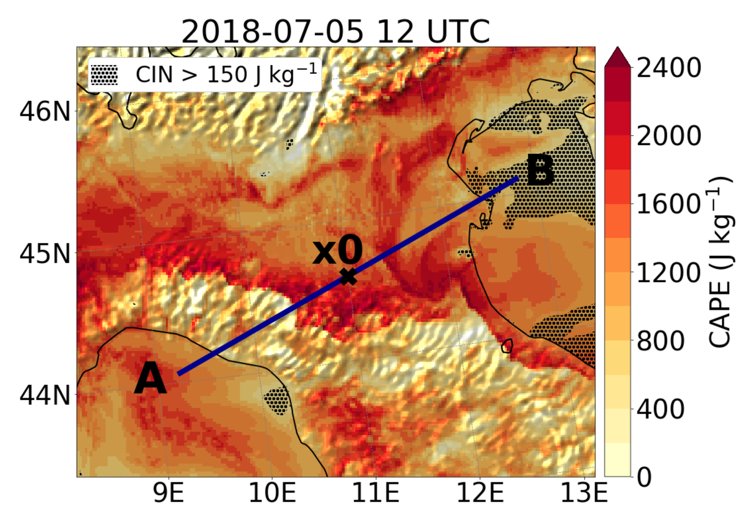

Figure 6: Simulated CAPE and CIN

- Lee-side precipitation is comparable to radar observations
- Sharp transition in CAPE along dryline

5. Mountain wave and lee-side convergence

Control run

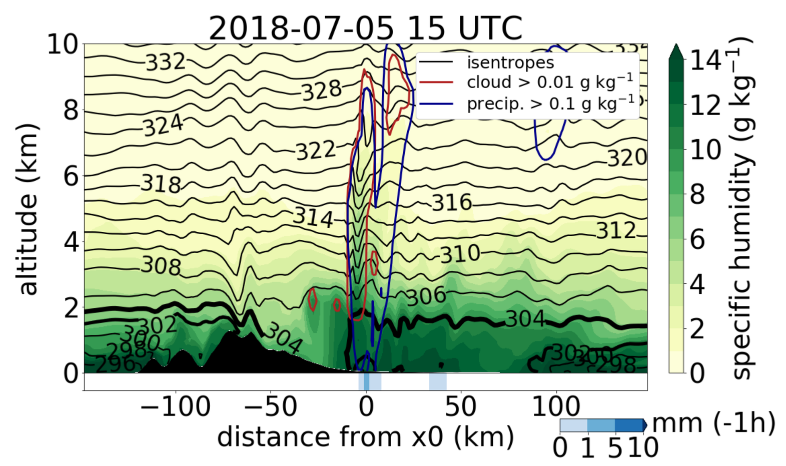

Figure 7: Cross section along A-B

- Non-dimensional mountain height $\frac{Nh}{U} = 7$ implies upstream blocking and generation of large-amplitude waves.
- Isentropes indicate wave pattern
- Convection close to dryline/ hydraulic jump

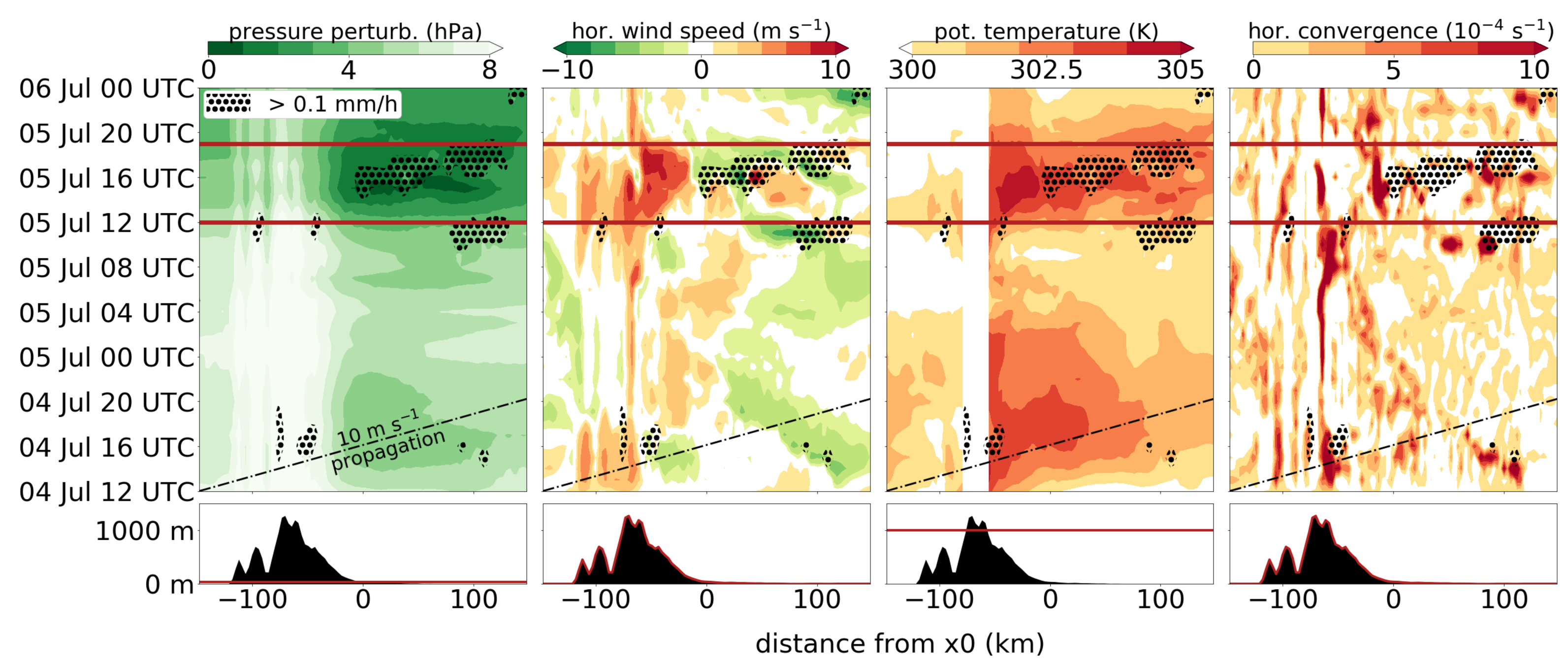

Figure 8: Hovmöller diagrams along A-B cross section.

- Afternoon of 05 July 2018 shows wave induced patterns such as
  - A distinct lee-side pressure minimum ($p' = p - p_{min}$)
  - Increased downslope winds
  - Positive potential temperature anomaly due to adiabatic compression
- Convection occurs at the **convergence line**, downstream of the strongest anomalies

Key findings and outlook

- **Wave induced pressure minimum** generates low-level **convergence** and compensating updrafts, favouring the initiation of **DMC**
- Low-level **convergence** line is anchored to the **mountains**
- Are **thermal processes** like mountain-plain circulation/ thermal updrafts, besides mountain waves, also crucial for DMC in this event?

Future activities:

- Test sensitivity to model physics and increase resolution
- Idealized simulations to
  - separate thermal and dynamical processes
  - determine the range of conditions that allow this mechanism to happen

6. The role of the topography

Sensitivity run: Apennines replaced by **flat** terrain

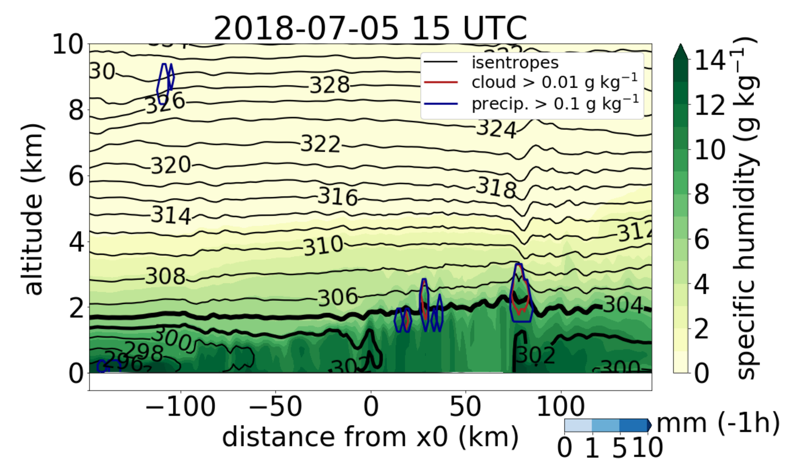

Figure 9: Cross section along A-B

- No blocking of low-level air (compare 302 K isentrope)
- No distinct wave pattern
- Isentropes at crest level (compare 304 K isentrope) are not descending
- No dryline at the surface
- **No DMC**

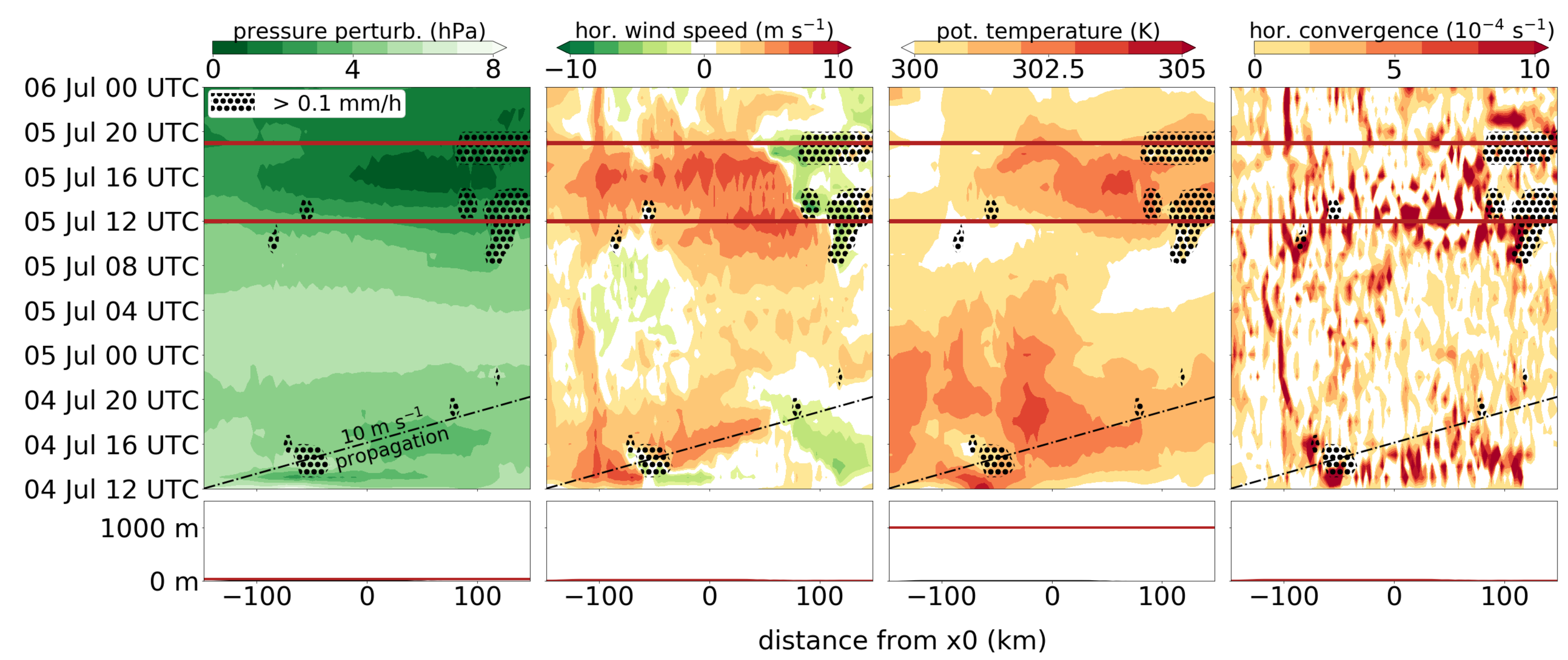

Figure 10: Hovmöller diagrams along A-B cross section

- Convergence and precipitation occur at at sea-breeze front, about 80 km to the east compared to the control run

References:

Bertram I. and G. J. Mayr, 2004: Lightning in the eastern Alps 1993 – 1999 , Part I : Thunderstorm tracks. *Nat. Hazards Earth Syst. Sci.*, **4**, 501–511.

Acknowledgements:

Ongoing project funded by the Austrian Science Fund (FWF): P30808-N32. Numerical simulations were run on the HPC infrastructure LEO3E of the Univ. of Innsbruck. Radar data was provided by courtesy of Pier Paolo Alberoni.