Precipitation frequency in Med-CORDEX and EURO-CORDEX ensembles from 0.44° to convection-permitting resolution: Impact of model resolution and convection representation.

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Motivation

Precipitation distribution is poorly represented by models even at regional scales. Convection-permitting (CP) climate simulations have demonstrated a step-change in the representation of heavy rainfall and rainfall characteristics. To better understand and model the processes triggering precipitation, in this study, we:

- ➢ use a multi-variate statistical relationship between temperature, humidity and precipitation (**Figure 1**).
- ➢ test the sensitivity of the triggering to the model resolution - from 50 to 3 km, including convection-permitting simulations

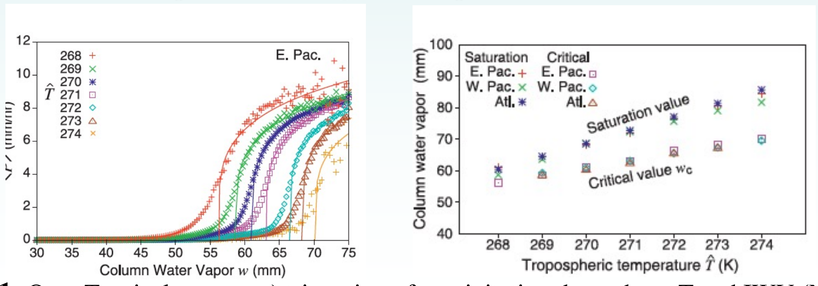

Fig. 1: Over Tropical oceans: a) triggering of precipitation depends on T and IWV (Neelin et al., 2009); b) Triggering of deep convection at high T occurs at lower Relative Humidity (Sahany et al., 2011)

Simulation and observation datasets

1 ➢ Model simulations

- **EUR-44 = 10 @ 0.44° with convection parametrized**
- **EUR-11 = 12 @ 0.11° with convection parametrized.**
- **ALP-3 = 9 @ 0.0275° with explicit deep convection**
- **ALP-11 = 9 @ 0.11° ($\in EUR-11$) father domains of ALP-3 with convection parametrized**
- **ALP3remapALP11 = 9 @ 0.11° : ALP3 remapped on ALP-11 grid. Explicit convection**

2 ➢ Observation:

- SIRTA-ReOBS for SIRTA (Chiriaco et al. 2018)
- IWV from GPS stations (Bock, 2021)
- Precipitation from EURO4M-APGD (Isotta et al 2014), SAFRAN (Quintana-Seguí et al. 2008 and Vidal et al. 2010), REGNIE (Rauthe et al., 2013)
- Tropospheric temperature from ERA5 (Hersbach et al., 2019)

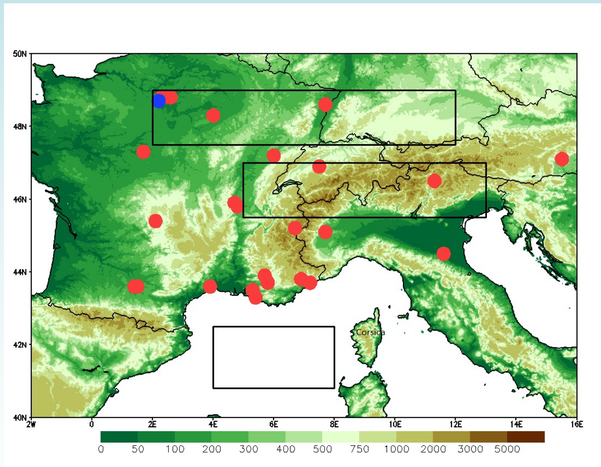

Fig. 2: Evaluation domain with the GPS locations (red points) and SIRTA stations (blue point) used for comparison with simulations. The three black boxes indicate subareas (mountains of the Alps, the Mediterranean Sea, and continental plains) analyzed in more detail in the study

A Occurrence of precipitation

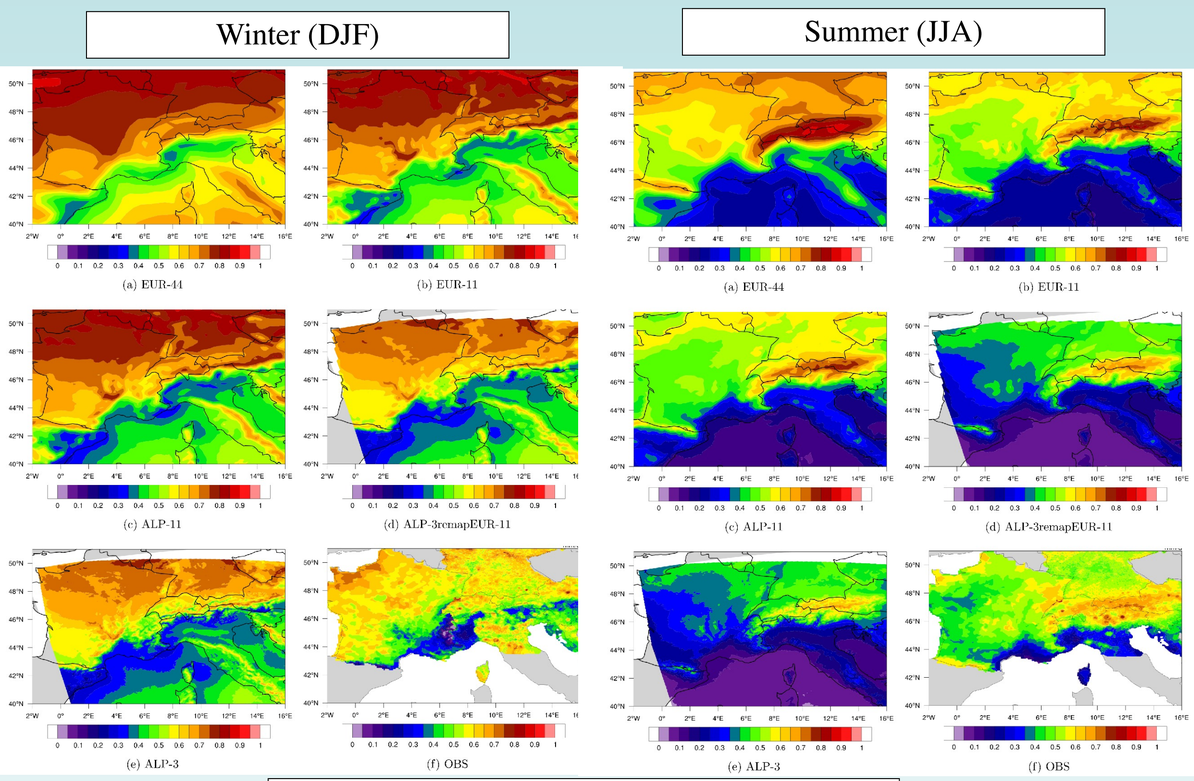

Fig.3 Precipitation frequency

- With a higher resolution, precipitation frequency reduces over high mountain and the Mediterranean in the winter and all sub-areas in the summer
- When the convection parameterization is switched off, the occurrence is reduced stronger over the entire domain, and they even underestimate the occurrence compared to observations (as notice in Ban et al. 2021)

B1 Precipitation enhancement

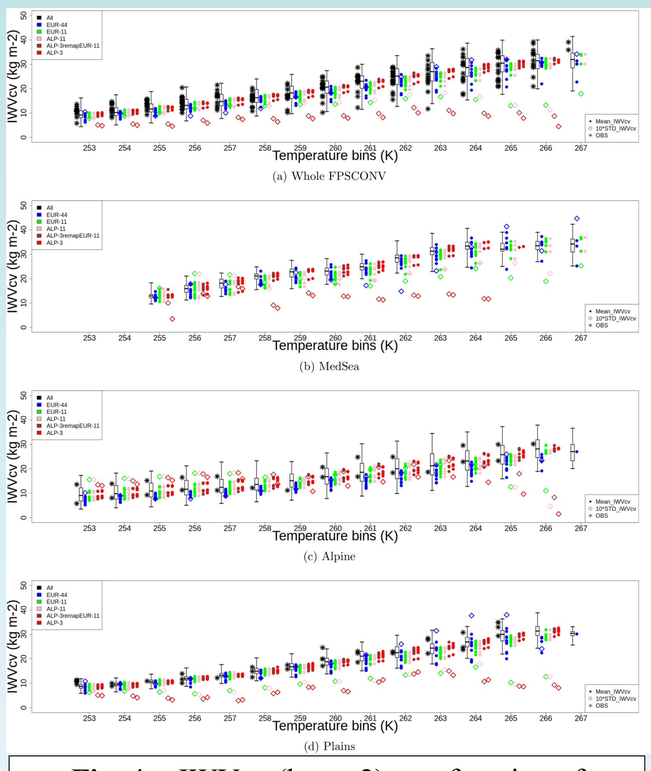

Fig. 4: : IWVcv (kg m-2) as a function of tropospheric temperature

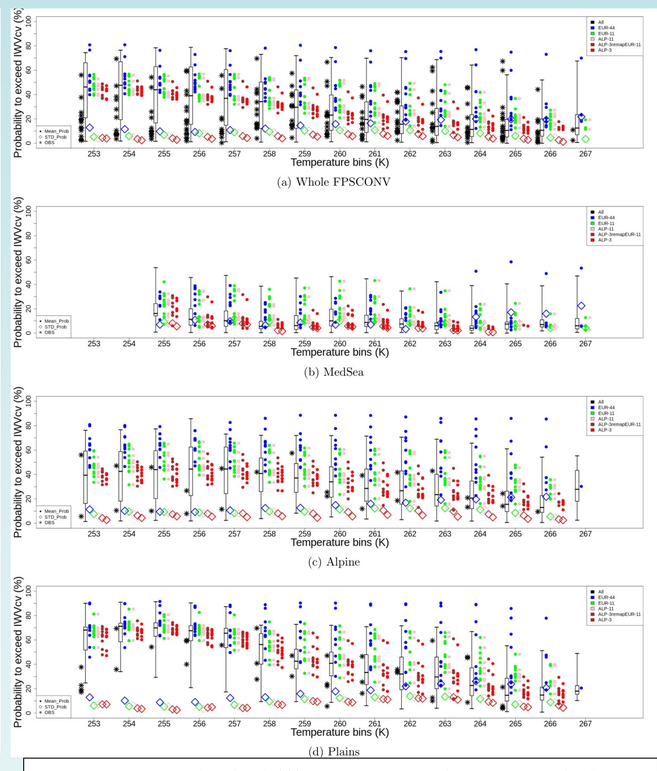

Fig. 5: : Probability to exceed IWVcv (%)

- IWVcv increases with tropospheric temperature and stops to increase at a certain temperature, while the probability to exceed IWVcv decreases.
- With higher resolution, the spread between simulations is reduced
- With CPM simulations, IWVcv increases, probability to exceed IWVcv decreases and the spread between simulations is reduced.
- Over the sea, since lifting is produced by large scale convergence, the probability to exceed IWVcv does not depend on temperature and model resolution does not impact a lot the results
- Over the plains, both model resolution and convection representation affect the precipitation triggering while over the mountain resolution mostly impacts because of orography-induced triggering processes

B2 Distribution of occurrence of IWV

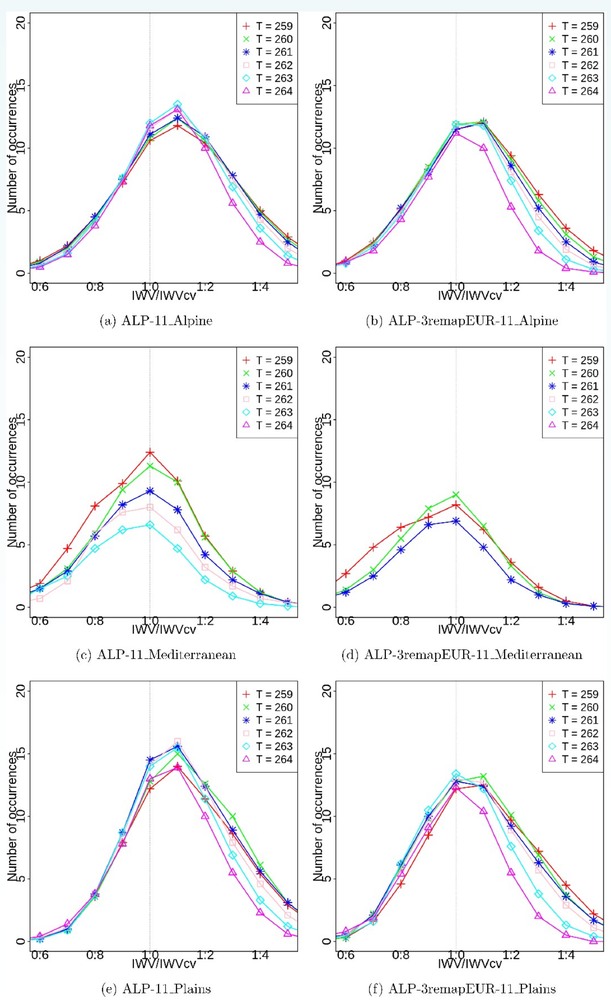

Fig. 6: : Number of occurrence of IWV rescaled by the corresponding onset threshold values IWVcv for precipitating days for ALP-11 (left), ALP3remapEUR-11 (right) over the Alpine mountain (a, b), Mediterranean (c, d) and plains (e, f), respectively.

- Over the land, in ALP-11, the peak of distribution points is at IWV/IWVcv > 1, while in explicit convection, it points around 1.
- After the highest frequency reached, IWV occurrence decreases sharper in ALP3remapEUR11 than in ALP-11 simulations => weaker dissipative effects when convection is parametrized (Holloway and Neelin, 2009).
- Over the Mediterranean, more precipitation occurs in lower IWVcv because precipitation triggering is determined by large-scale dynamics operating on longer time scales over the sea (Xoplaki et al, 2004; Trigo et al, 2006).

Conclusion and perspectives

(Ha-Truong et al., under review)

- ➢ Less frequent occurrence of precipitation in CPM can be explained by a higher IWVcv and a lower probability of exceeding this critical value.
- ➢ In CPM simulations, it is shown that the occurrence of precipitation is more peaked around the critical value, indicating stronger dissipative effects than when convection is parametrized
- ➢ The spread between models in simulating IWVcv and its exceedance probability is reduced at high temperature in the ensemble of models with explicit convection over land, when convective precipitation becomes more important.
- ➢ Model resolution has a larger impact over high mountain in simulating IWVcv because dynamical processes linked to orography play an important role in triggering convection.
- ➢ In contrast to the land, over the sea, model resolution does not impact a lot the results because precipitation triggering depends on large scale convergence.

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Future works

Explicit convection at coarser resolutions

- CPMs have both higher resolution and explicit convection => we cannot disentangle what difference comes from the resolution and what comes from the convection representation.
- With the suggestion from Vergara-Temprado et al (2020), a collaborative effort in the framework of FPSCONV has been conducted to test the use of explicit convection at 12km resolution. There are 3 standard experiments in the project:
  i) run with deep and shallow convection parameterized (standard);
  ii) run without deep convection parameterization, using a shallow convection scheme;
  iii) run without any convection parameterization at all; no deep and no shallow convection
- 3 simulations from IPSL and UCAN with the WRF model and from SMHI using HCLIM model are chosen to investigate the impact of deep convection (Fig. 7 and Fig. 8). Results show that at low temperature (< 257 K), the 12-km ensemble without parameterization of convection behaves similarly to the 12-km ensemble with parameterization, while the triggering is reduced in the ensemble at high resolution. At higher T, the two ensembles without parameterization present consistent behaviors despite different resolutions, while the ensemble with paramererization shows different results.

Evolution of precipitation triggering in a warming climate

To investigate the evolution of these convective transition processes and of precipitation distribution in a warming climate, we collected FPSCONV simulations for historical and in the end of 21st century uder RCP8.5 scenario. The results show an increase in the value of IWVcv, but the probability to exceed it is already low and does not seem to decrease more.

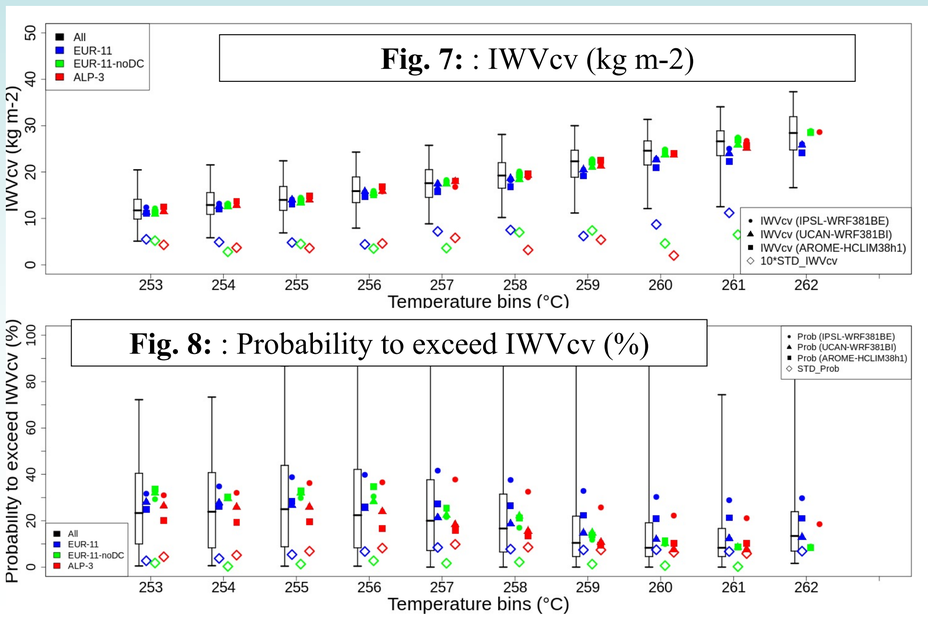

Fig. 7: : IWVcv (kg m-2)

Fig. 8: : Probability to exceed IWVcv (%)