Evaluating sub-kilometric simulations in the HARMONIE-AROME model on high-impact convective storms

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Case: MCS Valencia

- On 3 May 2022, a very high-impact static convective system (probably a mesoscale convective system; MCS) over south-east Spain led to heavy rainfall and flash-floods (>100 mm in 2 hours) in Valencia and its metropolitan area, beating rainfall records for May.
- This event had a very low predictability in high-resolution convective-allowing models.
- None of the national meteorological services' operational models (AROME – 1.3km, HARMONIE-AROME 2.5km, etc.) showed signals of convective system developed in the east of Spain.

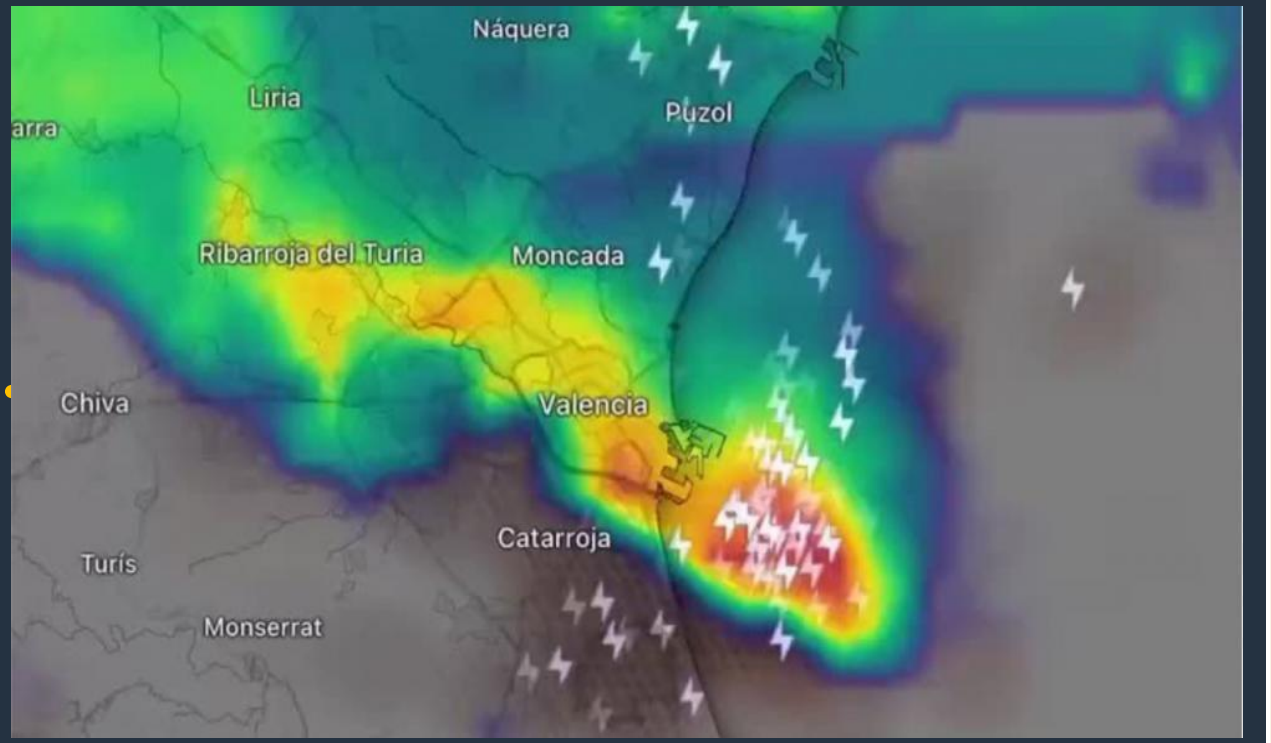
LLUVIAS TORRENCIALES

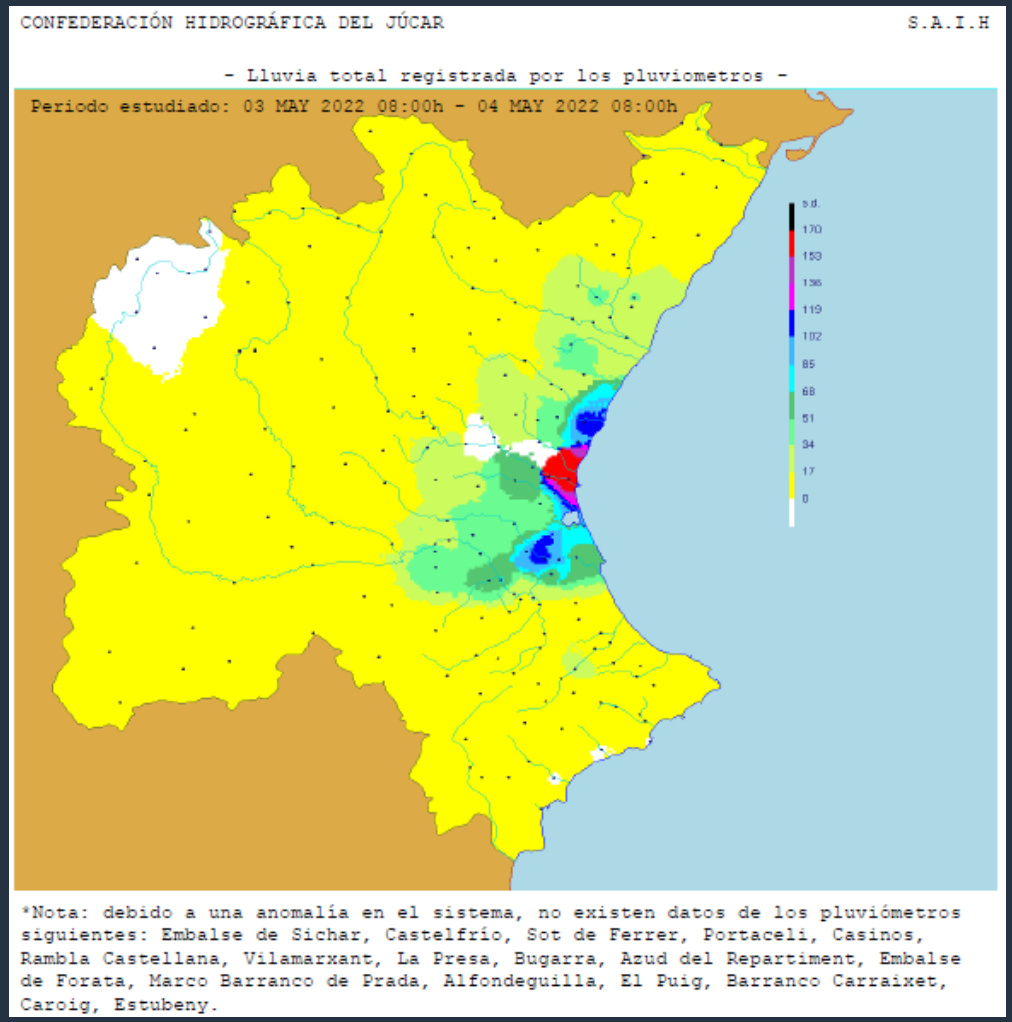
Una fuerte tormenta estática bate el récord histórico de lluvia en Valencia en el mes de mayo

La persistente tromba corta túneles, calles y líneas de metro y anega bajos en los barrios marítimos. La Politécnica suspende las clases este miércoles

Un túnel anegado de Valencia por las lluvias torrenciales de este martes, en una imagen de la Policía Local. Vídeo: EPV

Case: MCS Valencia





Synoptic climatology

- "Most torrential rainfall events in Mediterranean Spain are associated with disturbances located near or over the south of the Iberian" Romero et al (1998)

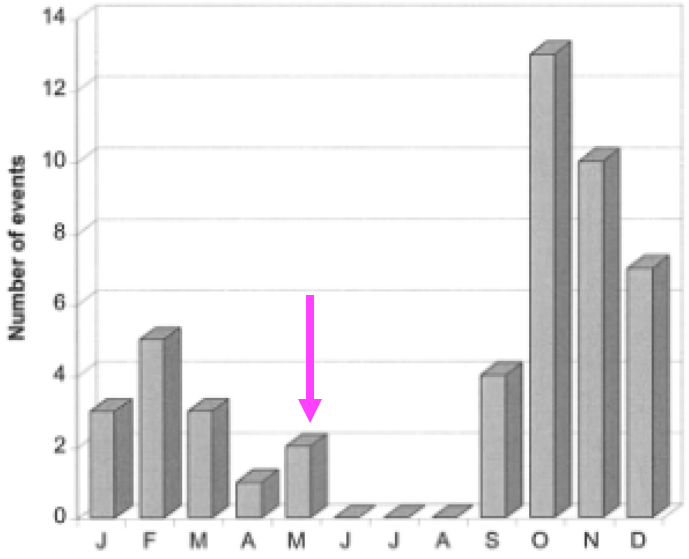
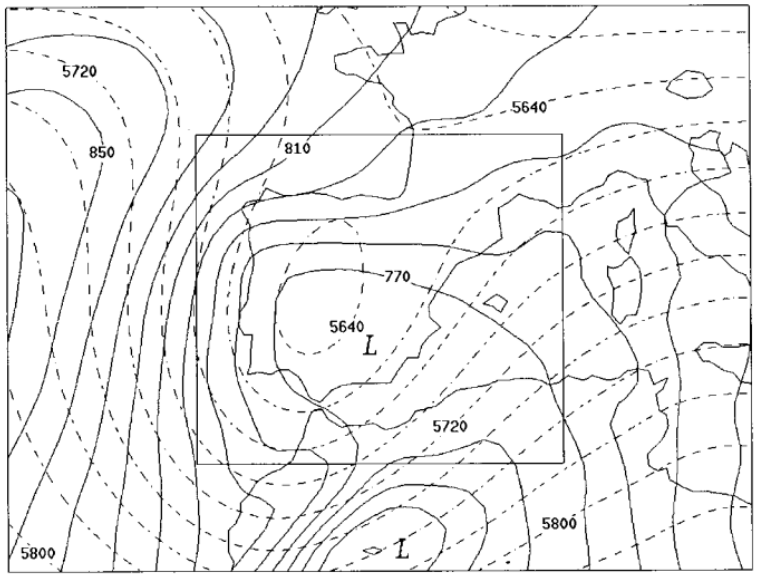
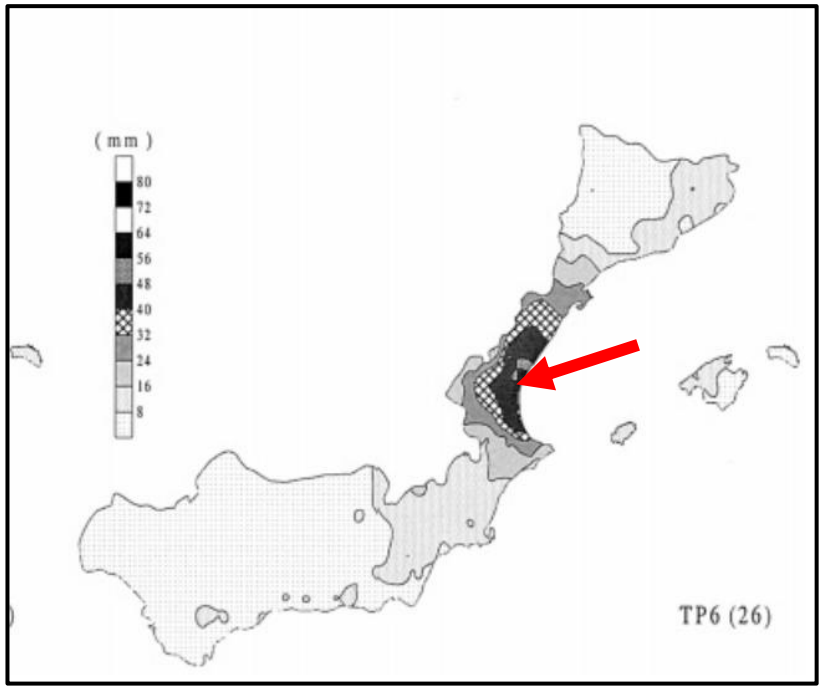


FIG. 2. Frequency and annual distribution of torrential rain events on the Spanish east coast, Valencia region (1971–95). The criterion used for selecting a rain event is a rainfall equal to, or higher than, 125 mm of precipitation in 24 h.



AP14

Geopotential 925- (solid) and 500-hPa (dash)



Daily rainfall composite (1984-93) –torrential rainfall

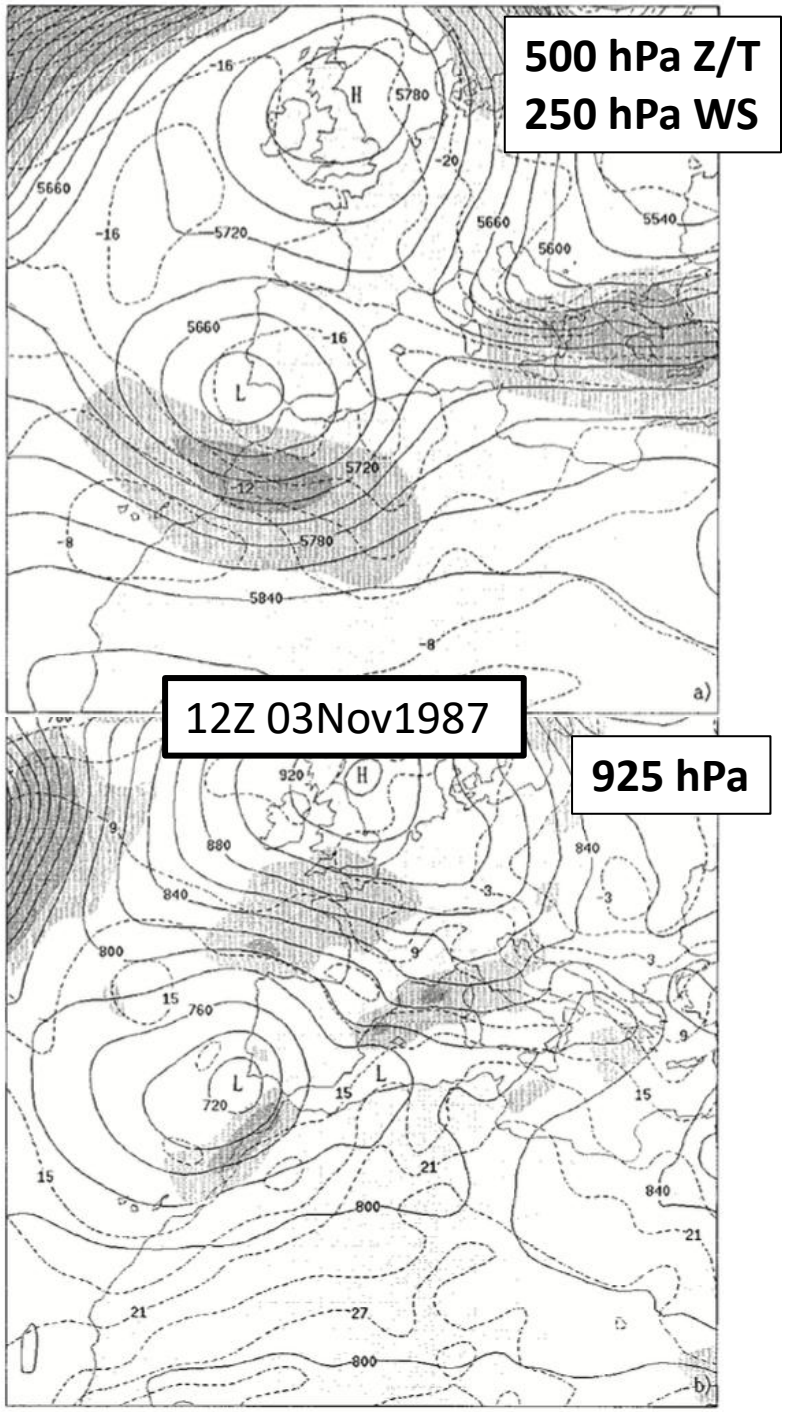
- Ingredients at synoptic scale: upward vertical motion; WV flux convergence at low levels; high values of water vapor content in atmospheric column; potential instability
- Meso-scale mechanisms: BL convergence; ageostrophic flow associated with short-wave troughs/jet streaks UL/LL coupling; orographic lifting in complex terrain; ….

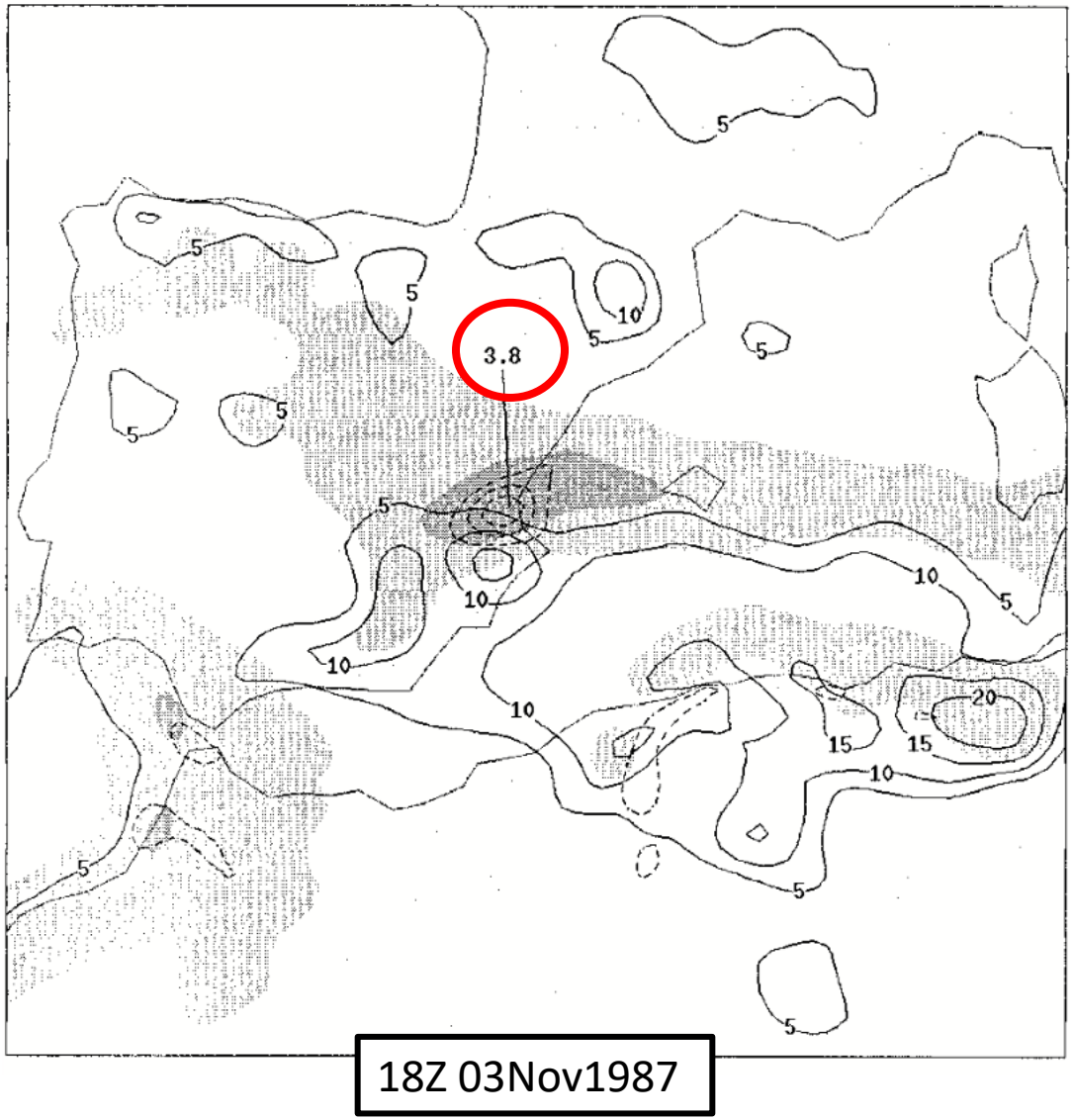
***Gandia* (Valencia) Case**
Romero et al. (2000)

1000 mm in 36h
400 mm in 6h

T (dash line)
Z (solid line)
Wind Speed (shade)

30 40 m/s
10 15 m/s

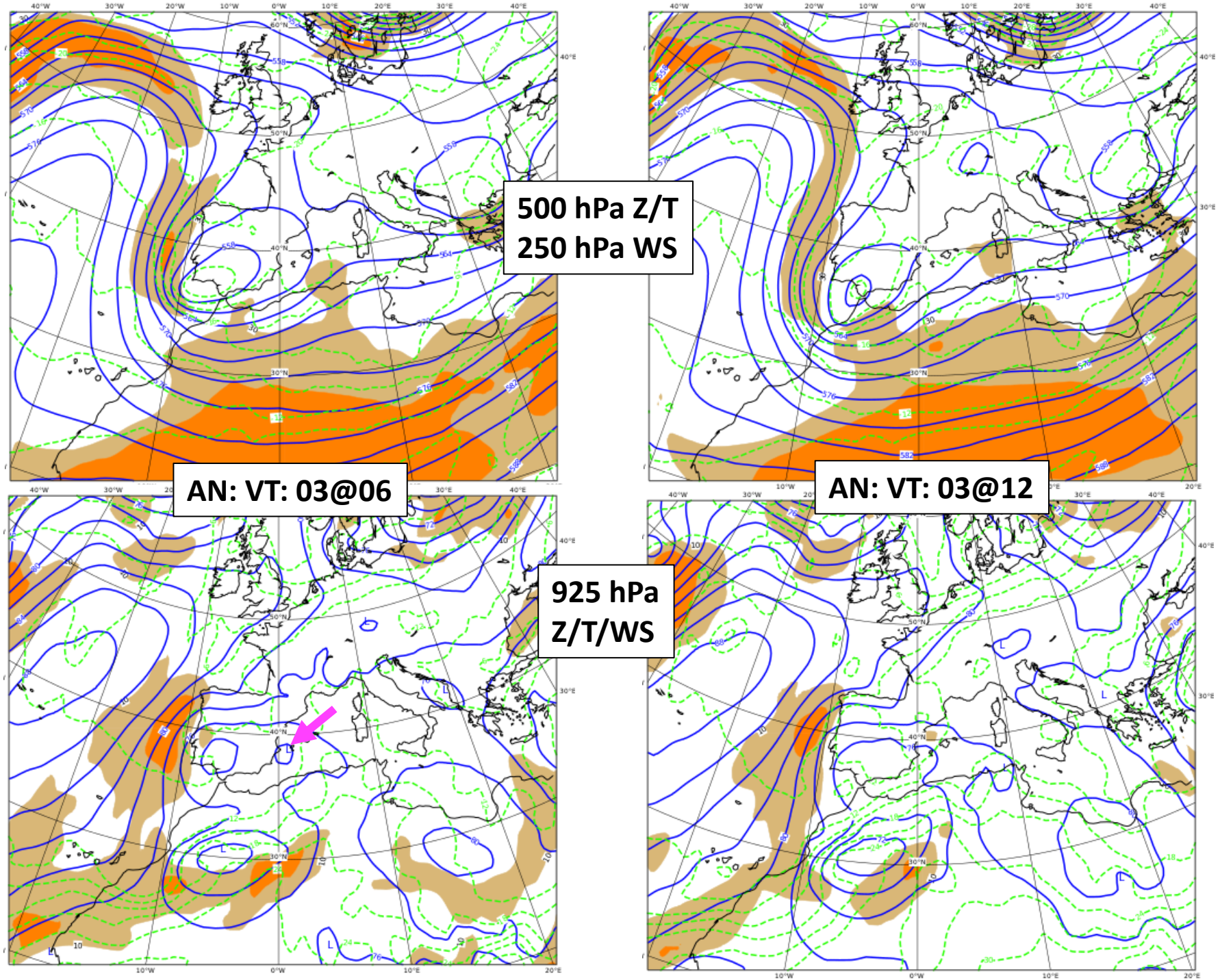




1000-850 hPa water vapor flux convergence (dash line; g m^{-2} s^{-1})

Total precipitable water (shade; mm)

32 36 mm



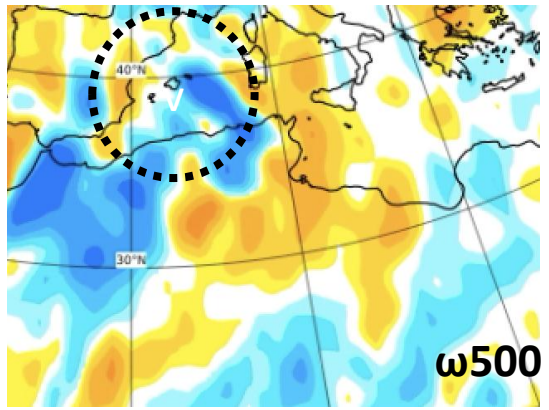
Gepotential (contour)

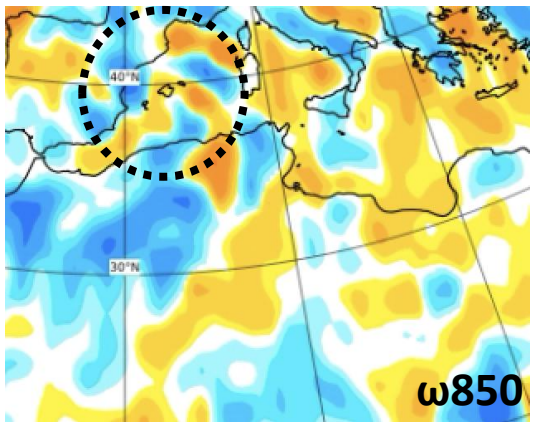
Temperature(contour)

Wind speed (shade)

250-hPa 30 40 m/s

925-hPa 10 15 m/s





Case: MCS Valencia

- **AIB_46h1_de2:**

  Same as HARMONIE-AROME operational at AEMET but cy46h1

  Warm start from IFS and data assimilation (only conventional observations)

- **VAL500m_46h1_de2:**

  Cold start from IFS with data assimilation (only conventional observations) + VHR dynamic options (cy64h1)

Case: MCS Valencia

- **AIB_46h1_de2:**

  Same as HARMONIE-AROME

  Warm start from IFS and data

- **VAL500m_46h1_de2:**

  Cold start from IFS with data *dynamic options (cy64h1)*

UNIVERSIDAD COMPLUTENSE DE MADRID

FACULTAD DE CIENCIAS FÍSICAS

Máster en Meteorología y Geofísica

TRABAJO DE FIN DE MÁSTER

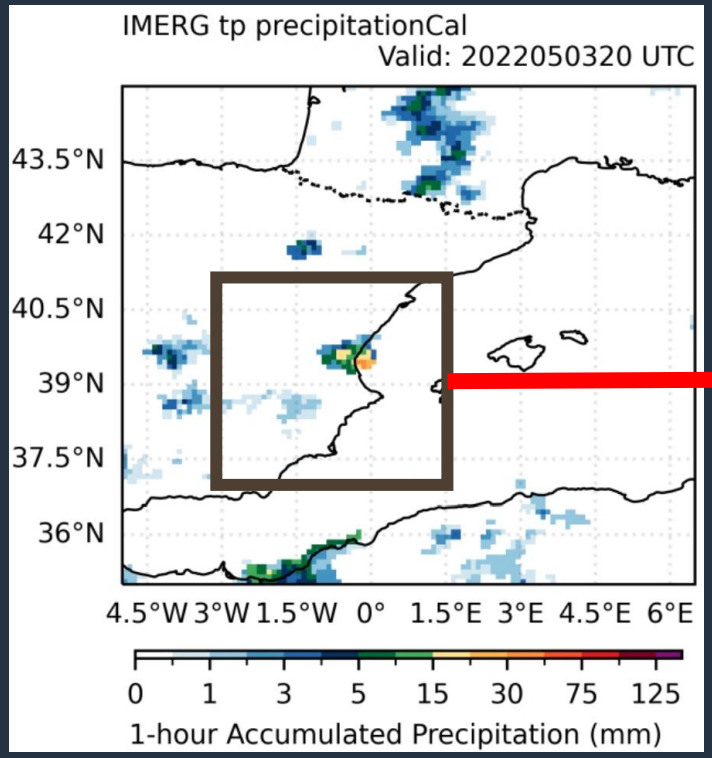
Estudio de la predicción de las tormentas convectivas en simulaciones subkilométricas con el modelo HARMONIE-AROME

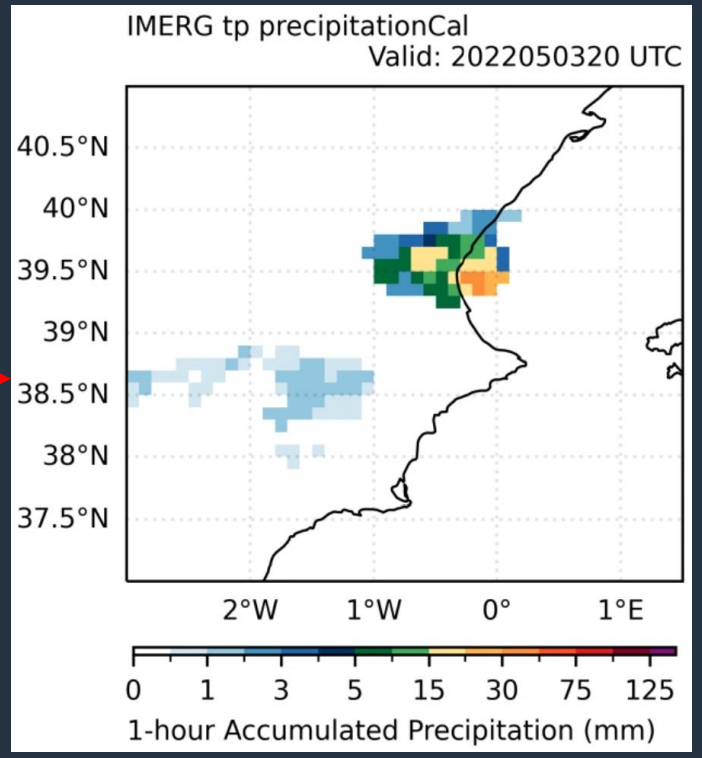
Study on the prediction of convective storms in sub-kilometric simulations with HARMONIE-AROME model

Álvaro Cano González

Case: MCS Valencia

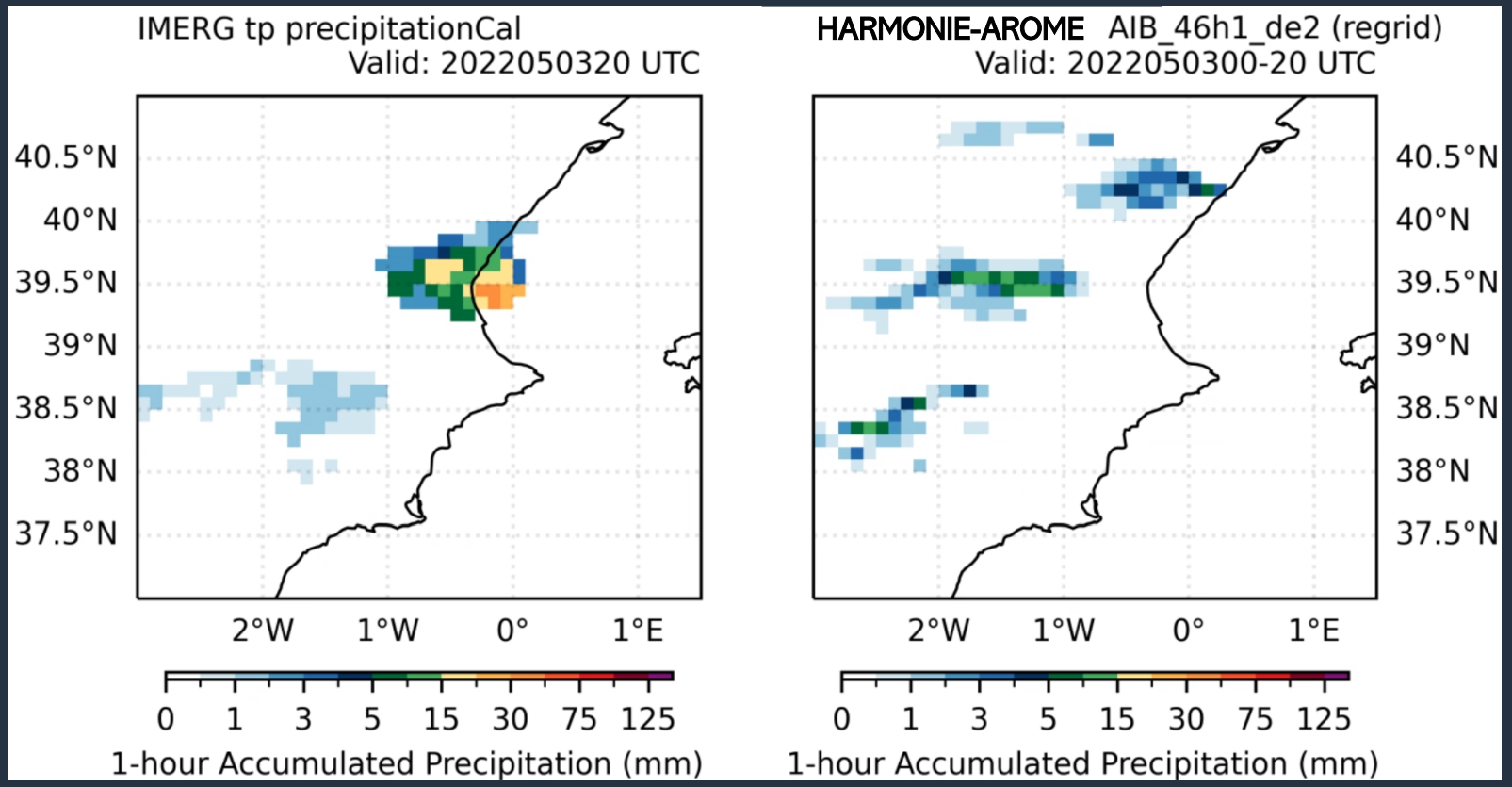
- Between 18z and 22z of day 3, there was a stationary precipitation band/patch over the coast of Valencia in the observations (IMERG-NASA precipitation), corresponding to this mesoscale convective system.
- We will use this observational dataset to compare against the model.





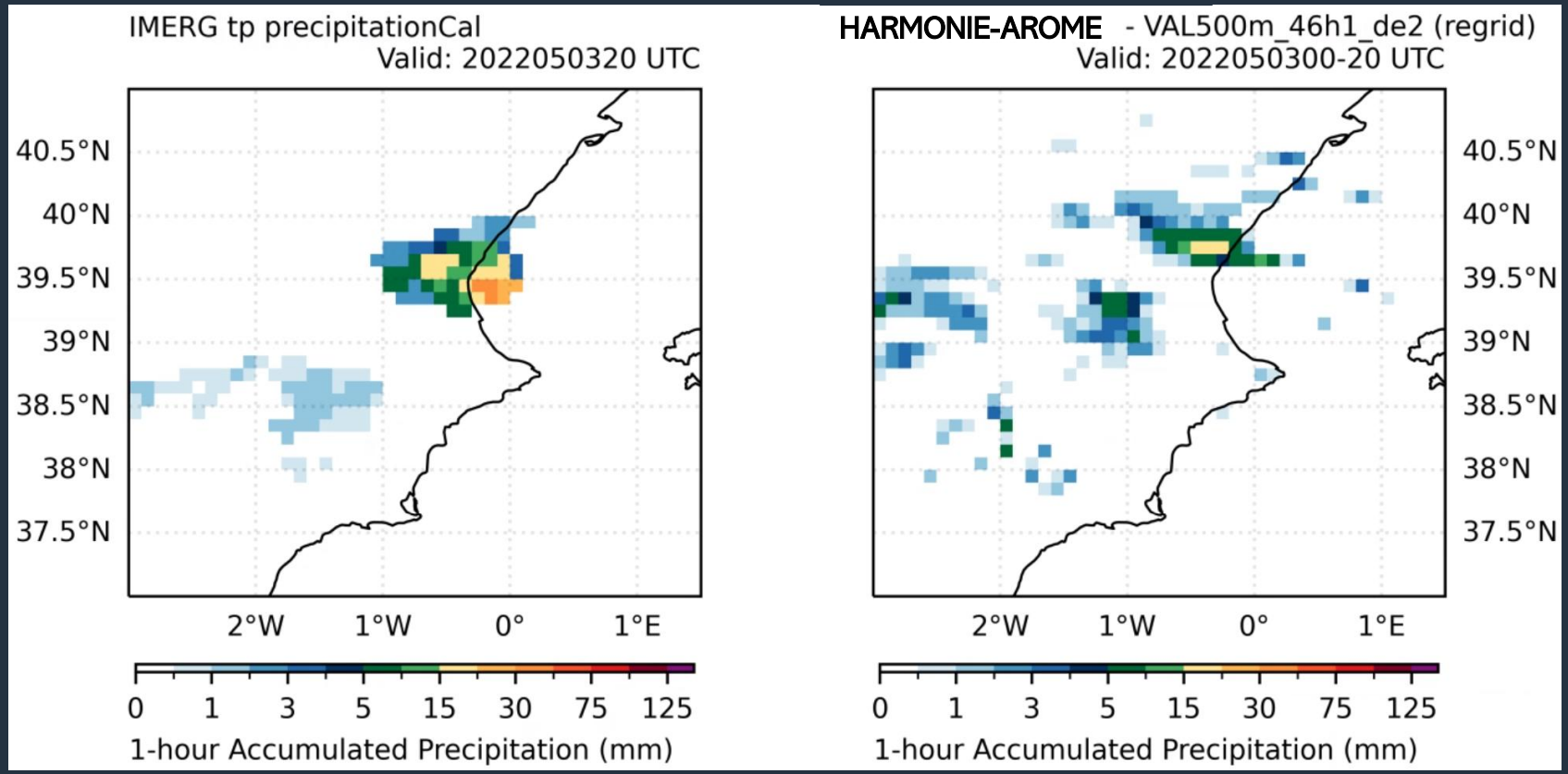
Case: MCS Valencia

- This stationary precipitation band/patch over the coast of Valencia is not present in the operational 2.5 km run. The 2.5 km run only saw convective cells being advected westward by the flow, which also left strong precipitation but not in a stationary manner as in reality.



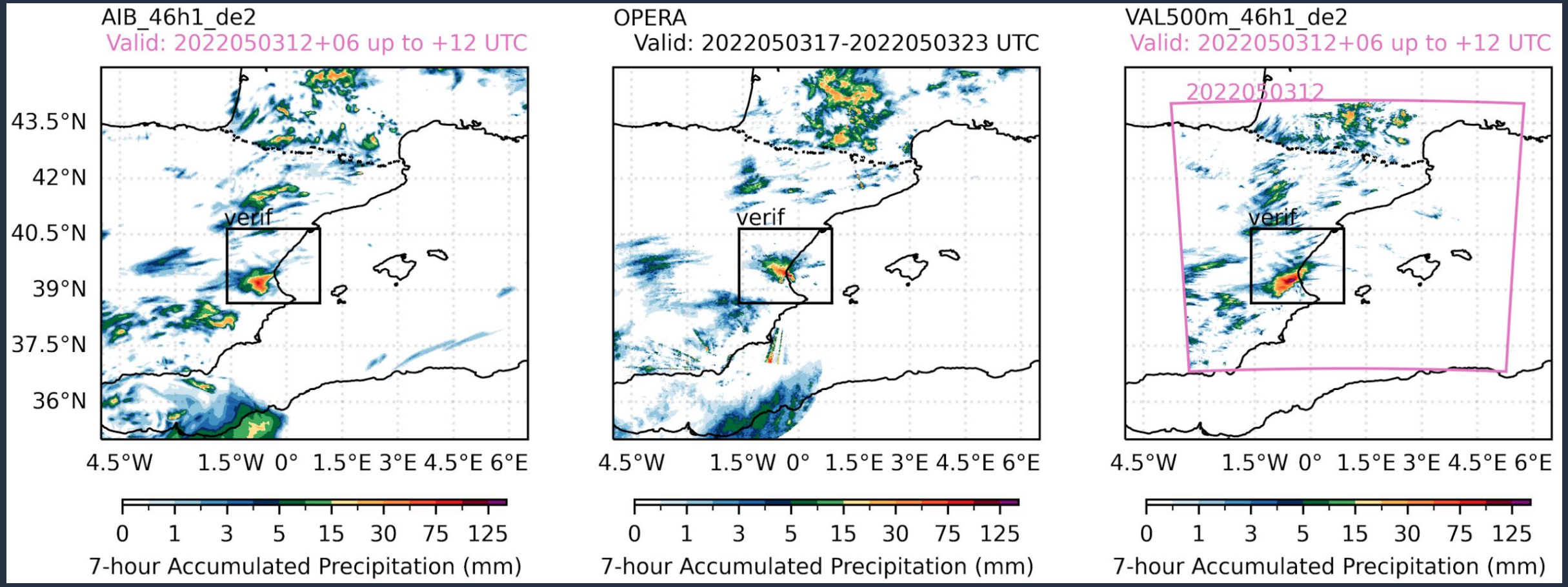
Case: MCS Valencia

- The 500 m. run start to see a stationary band of heavy rainfall, although a bit north and weaker than in the reality.



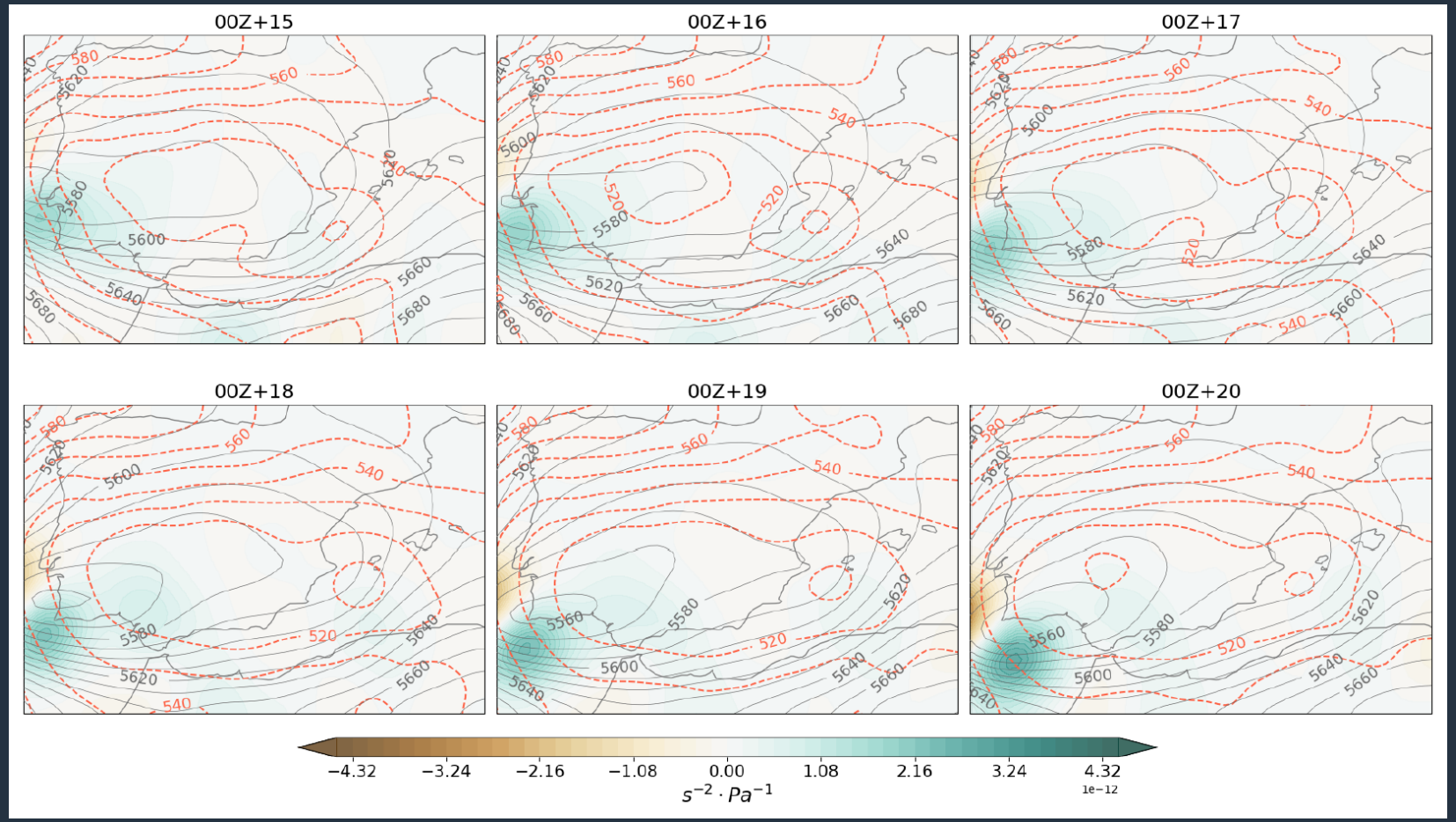
Case: MCS Valencia

- In the last initialization before the event (12z 3 May) the improvement is even better in the 500 m. run.



Case: MCS Valencia

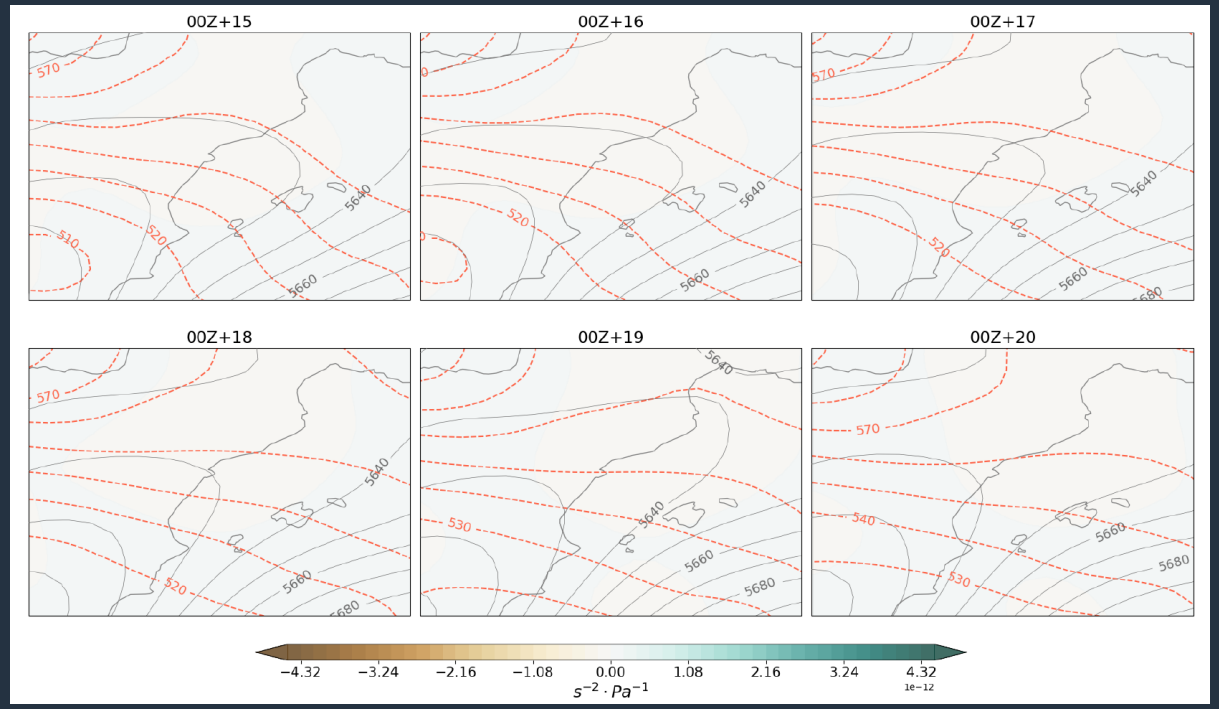
- QG forcing



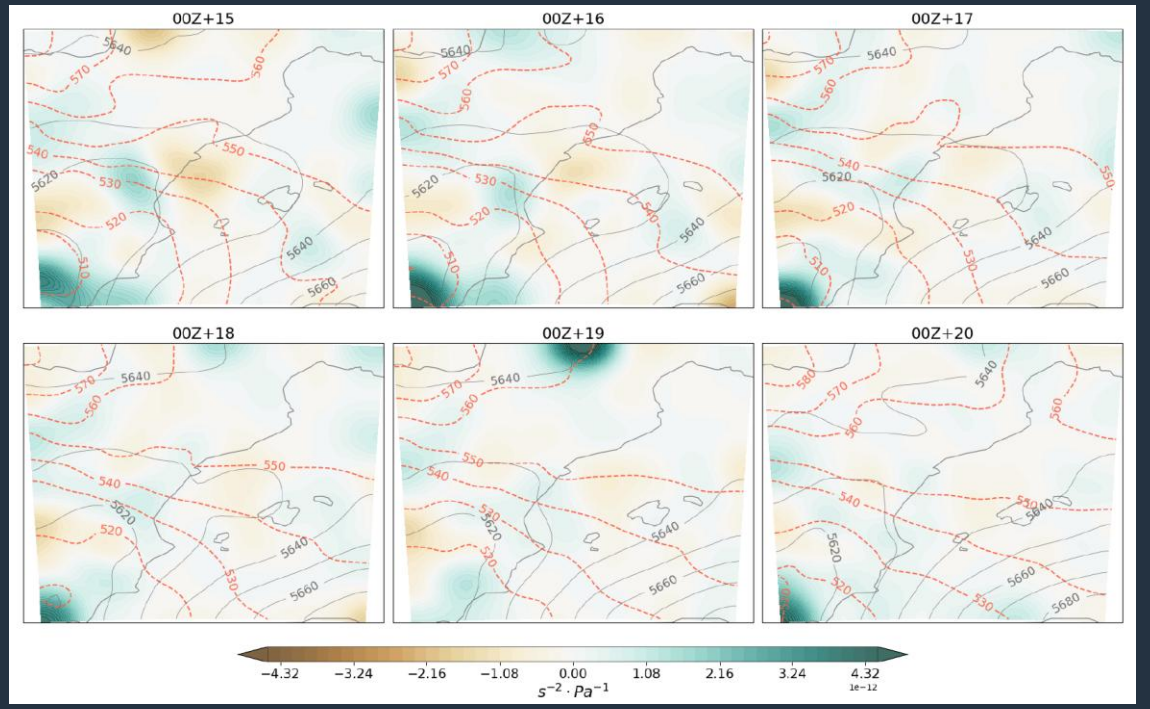
Case: MCS Valencia

- QG forcing: 2.5 km vs VHR (500 m.)

2.5 km



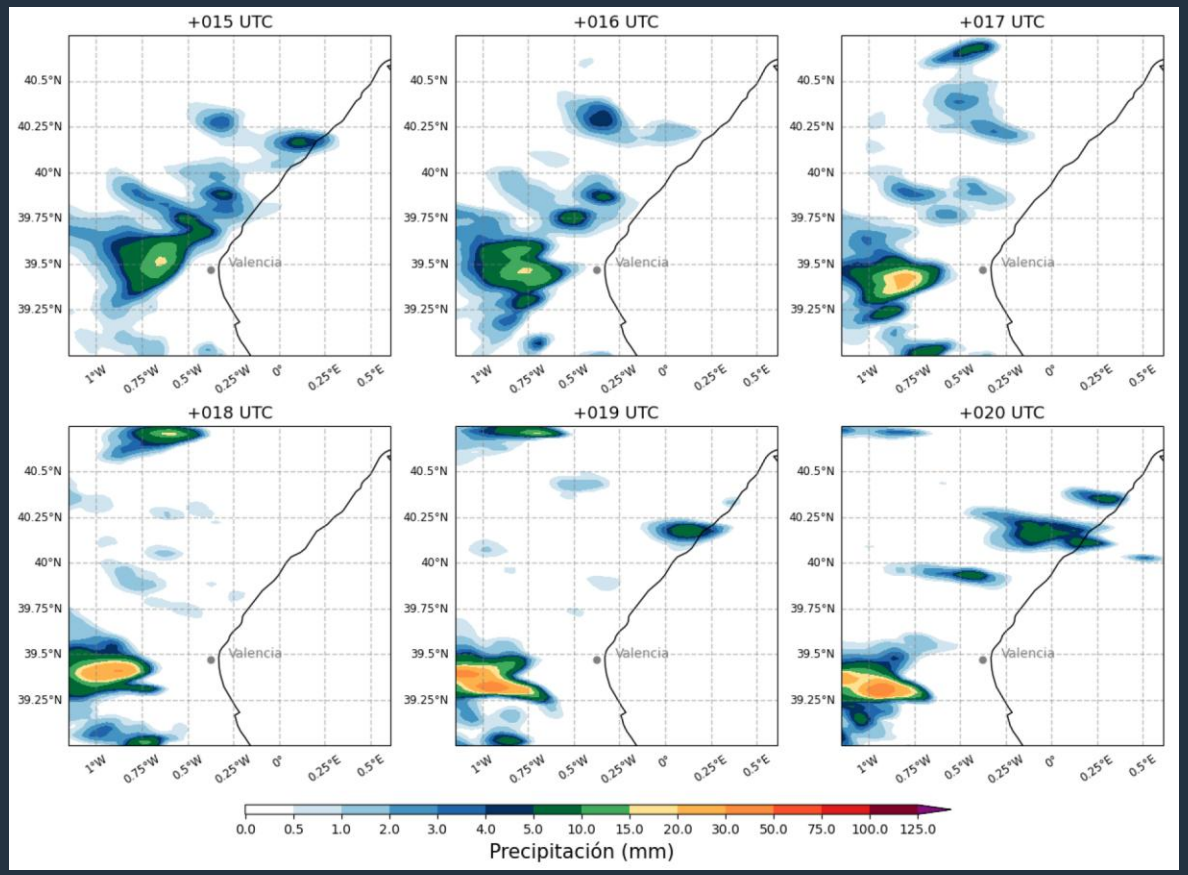
VHR/500 m.



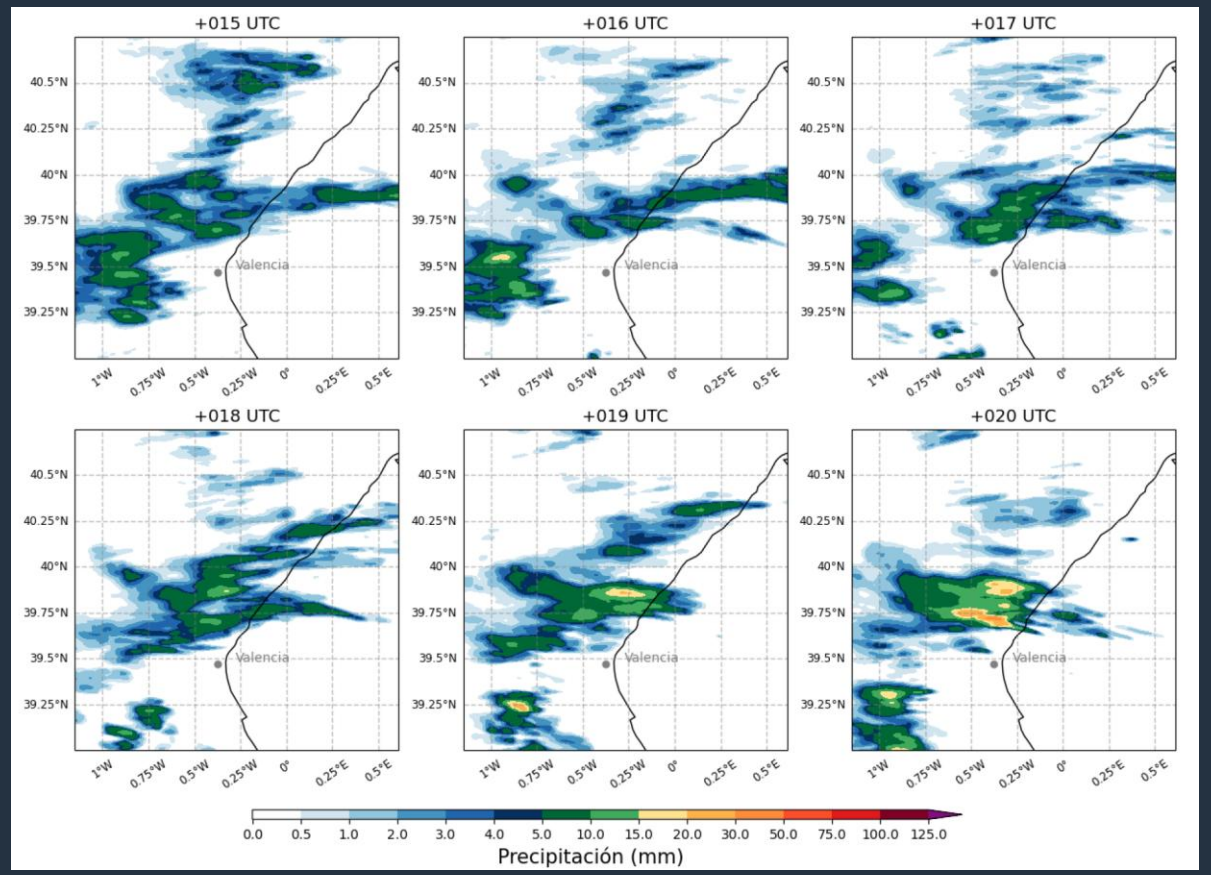
Case: MCS Valencia

- 1-hr total precipitation

2.5 km



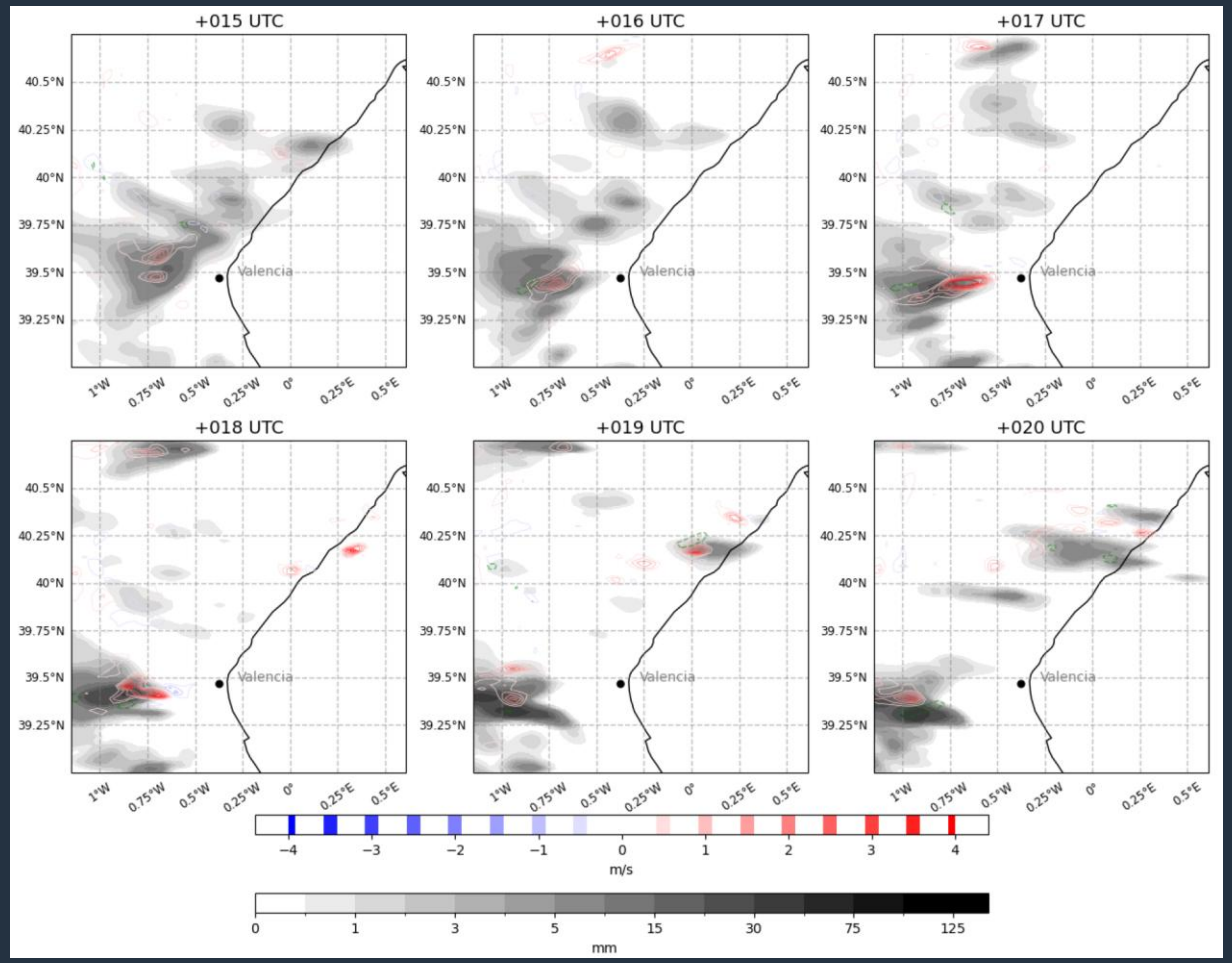
VHR/500 m.



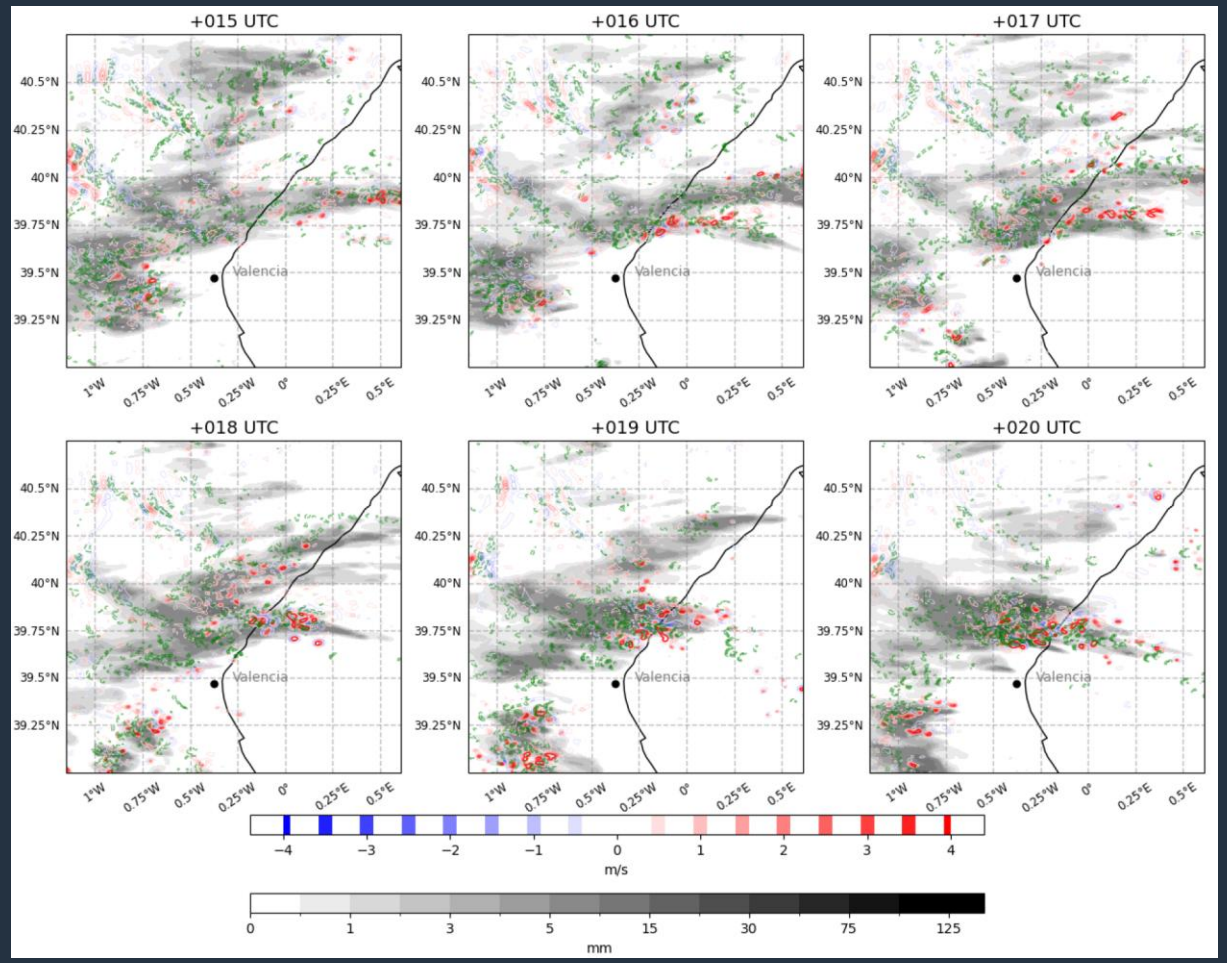
Case: MCS Valencia

- 1-hr total precipitation + w

2.5 km

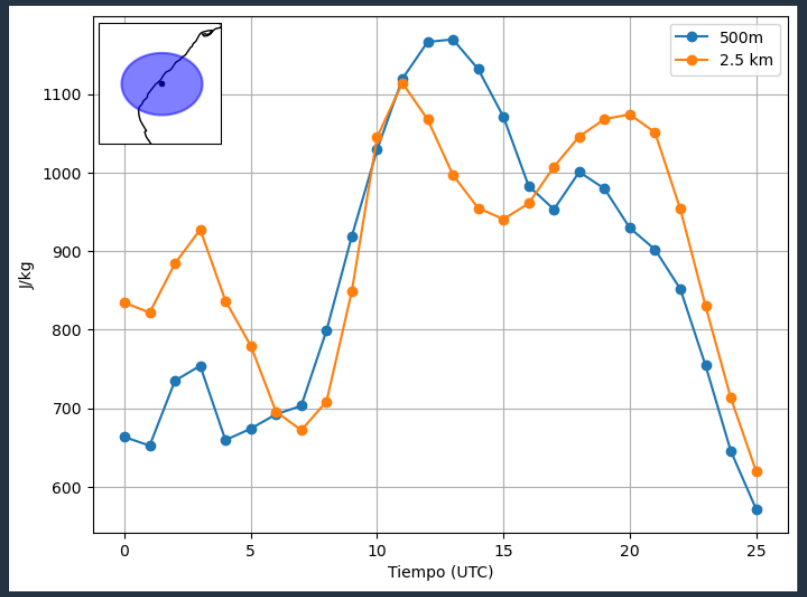


VHR/500 m.

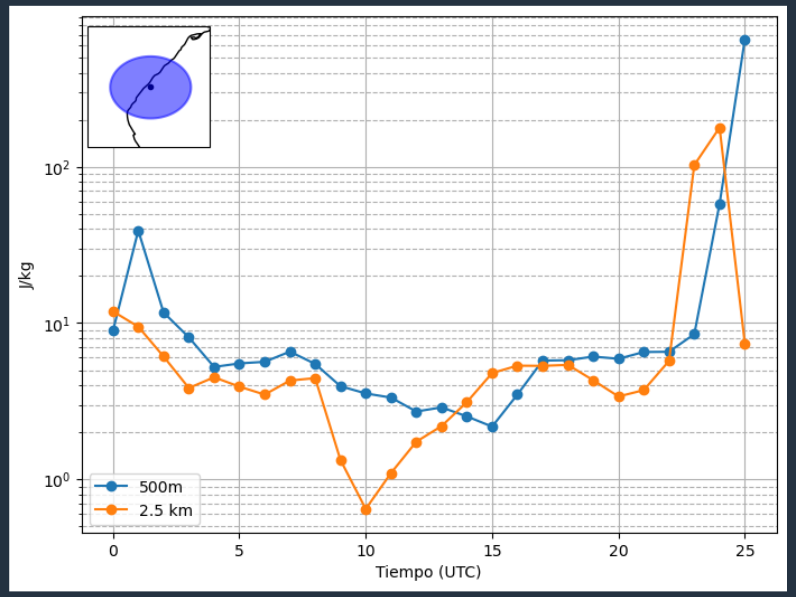


Case: MCS Valencia

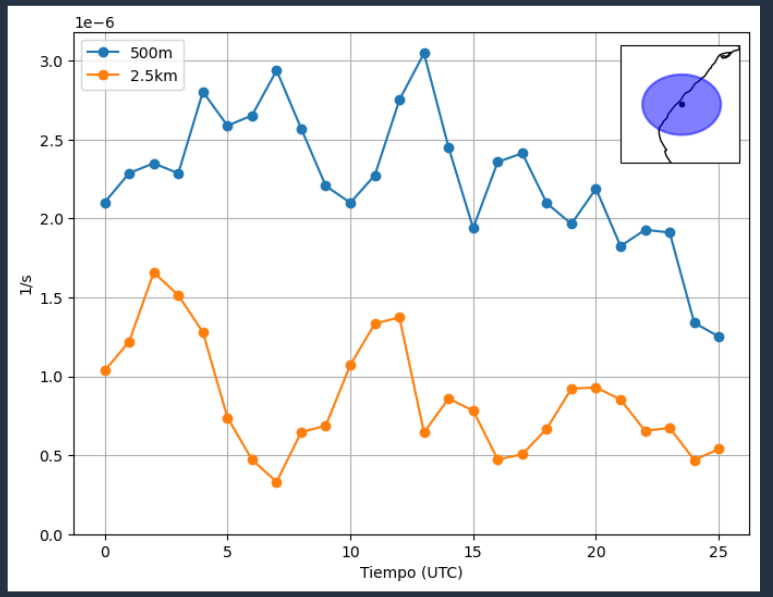
CAPE



CIN



MFD

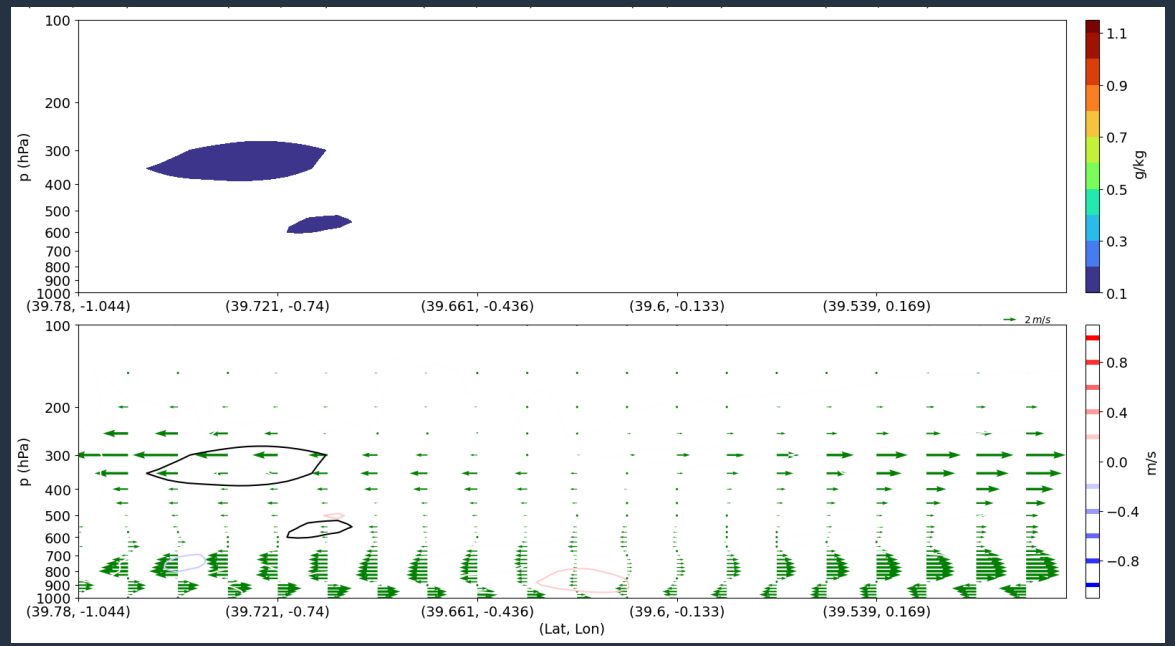


MFD = Moisture Flux Divergence

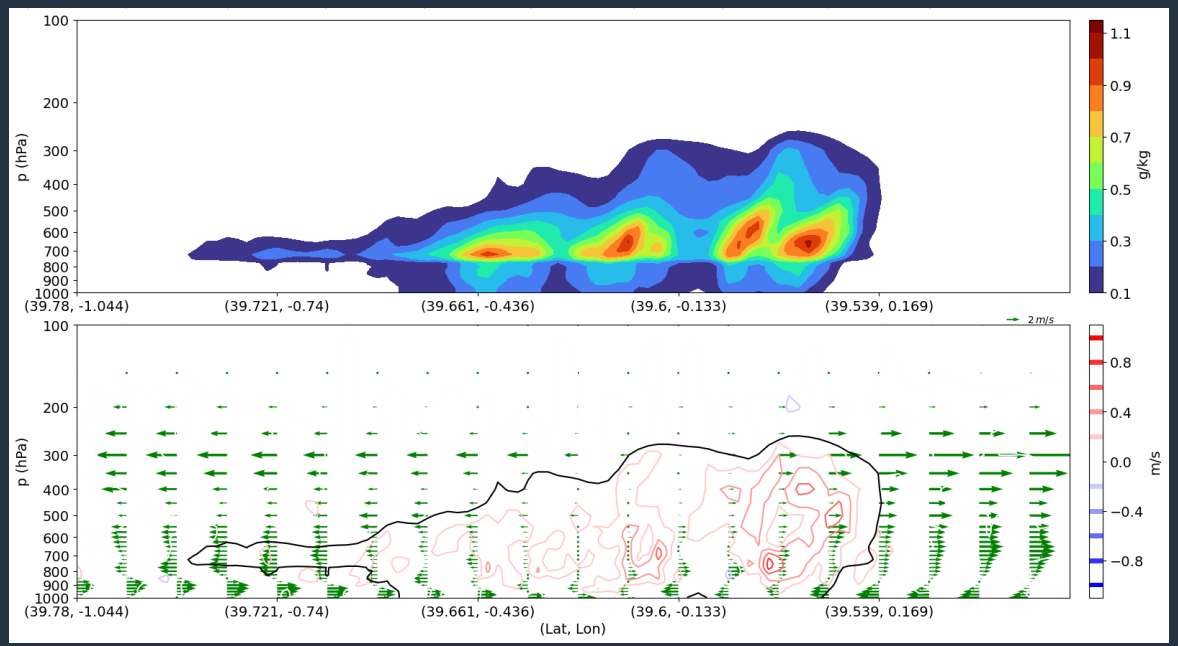
Case: MCS Valencia

- Clouds + vertical motion

2.5 km



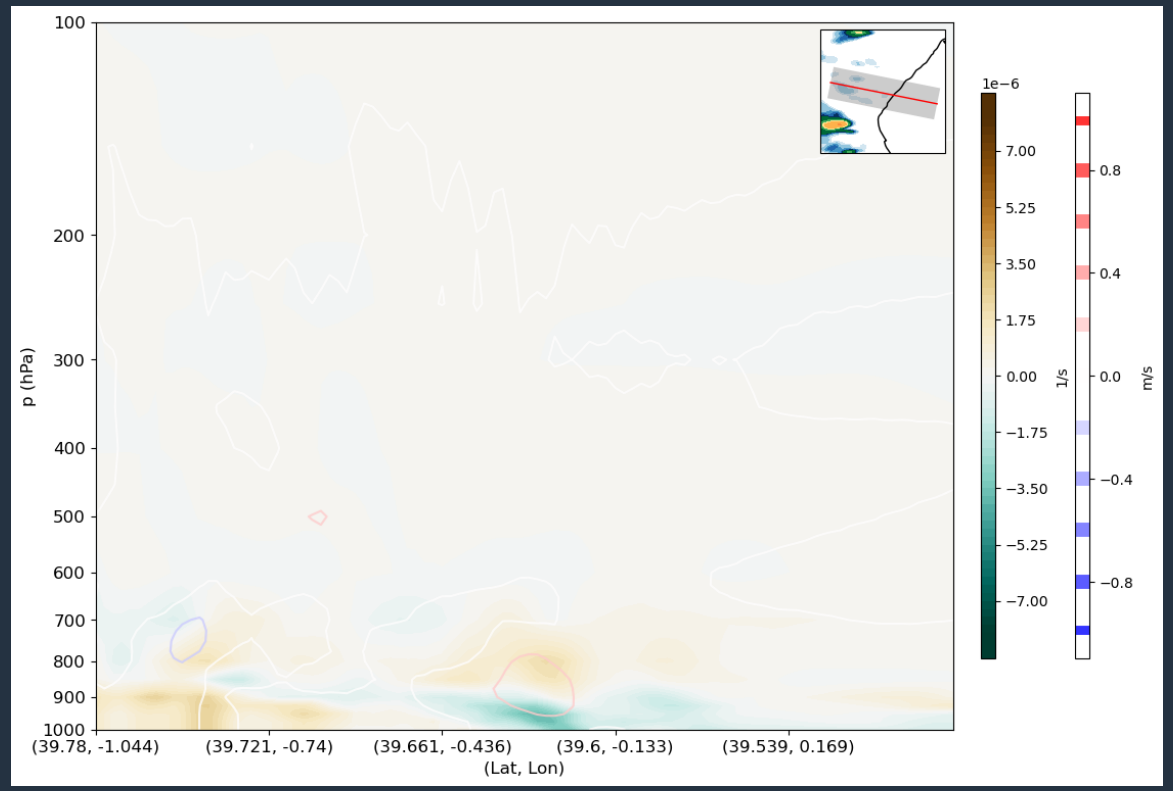
VHR/500 m.



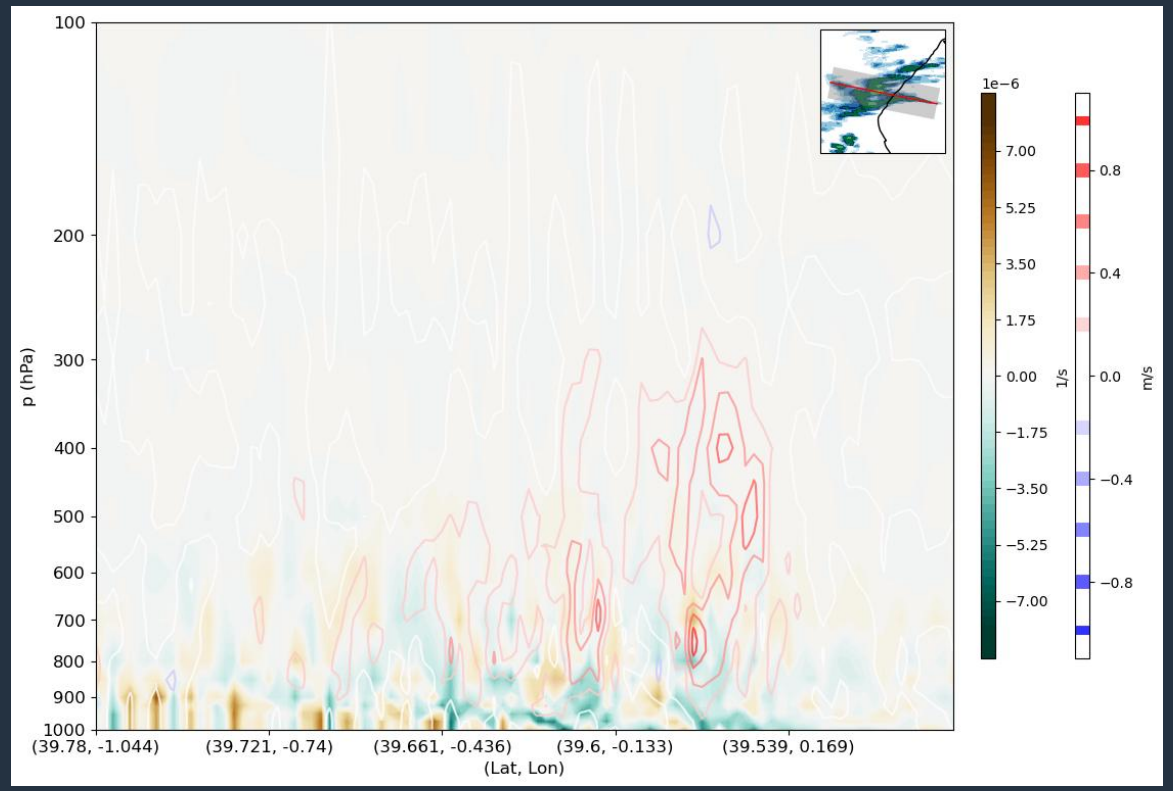
Case: MCS Valencia

- MFD + vertical motion

2.5 km

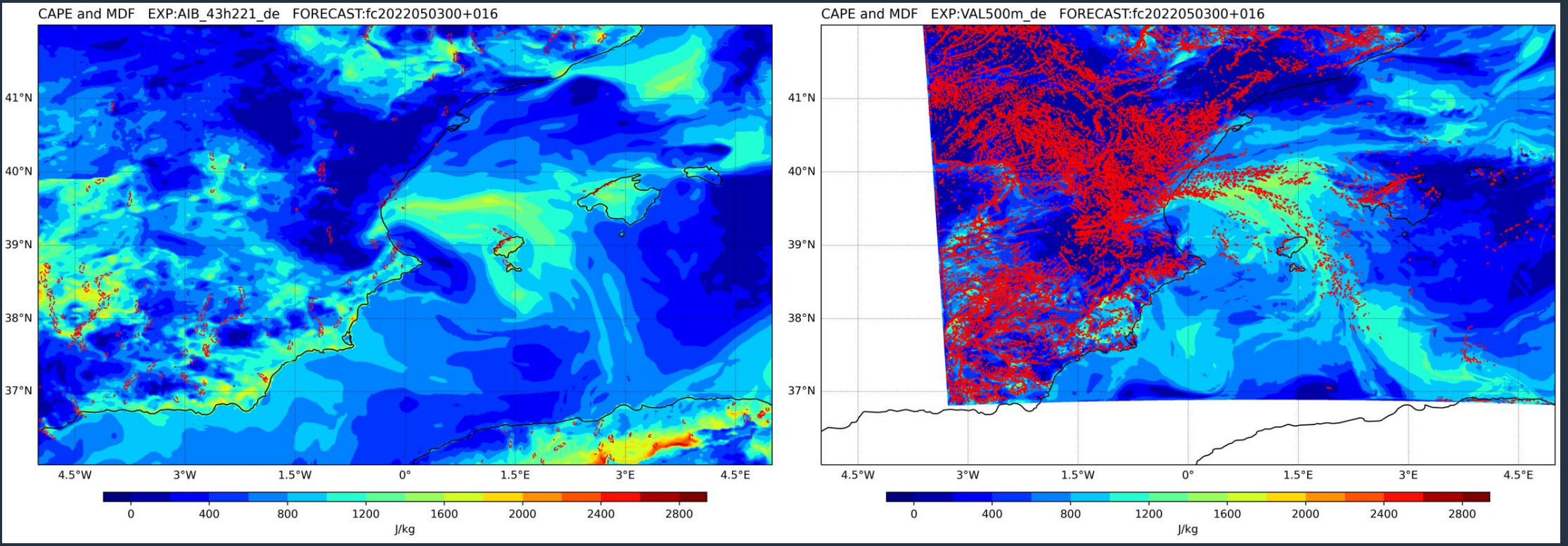


VHR/500 m.



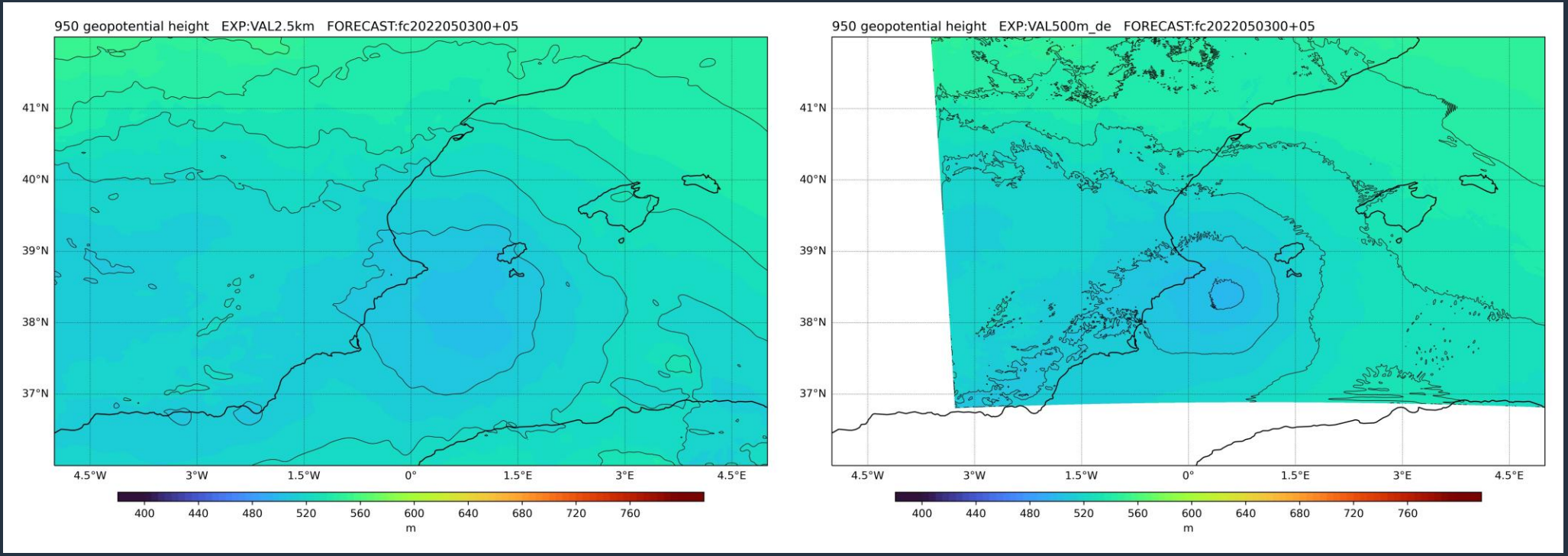
Case: MCS Valencia

- This stationary precipitation band/patch in the 500 m. run was due to the presence of a moisture flux convergence (red) line in presence of high instability (CAPE; shaded). This convergence line was not present in 2.5 km.
- Instability (CAPE) seems to be similar in both runs, although in 500 m it gets further into the coast.



Case: MCS Valencia

- Why 500 m is the one able to get a convergence line?
- Probably due to a better representation of the low and stronger pressure gradient with the anticyclonic region to the northeast, which promotes convergence?



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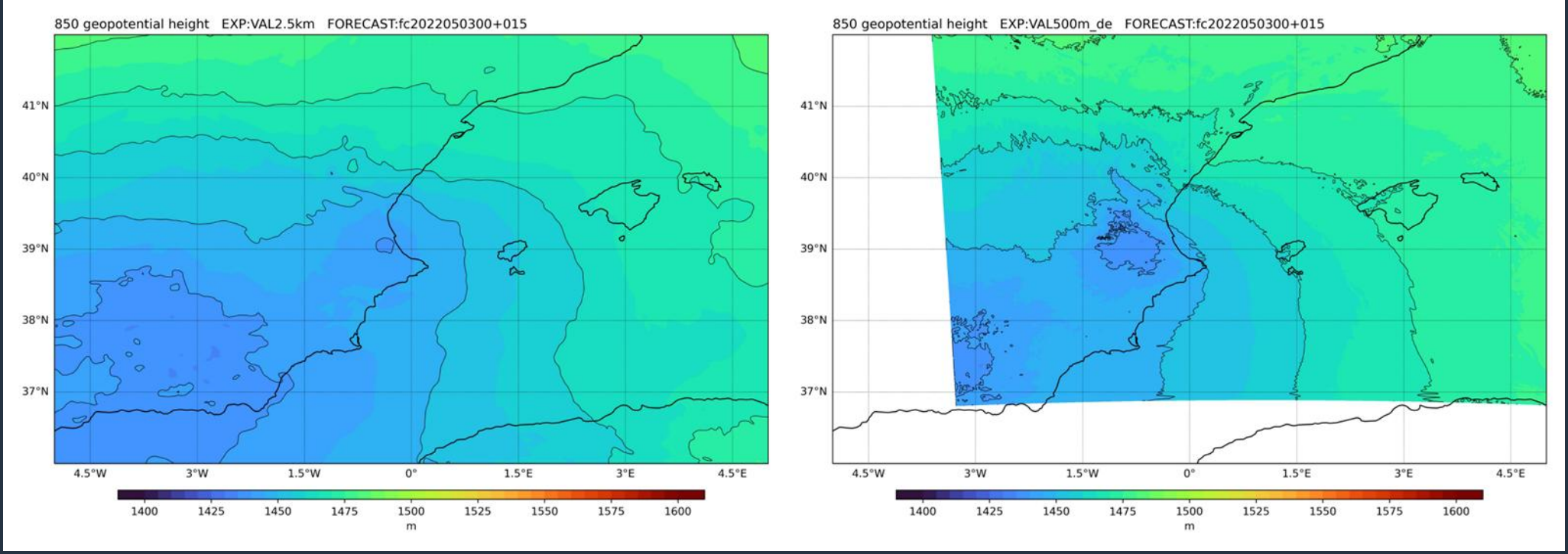
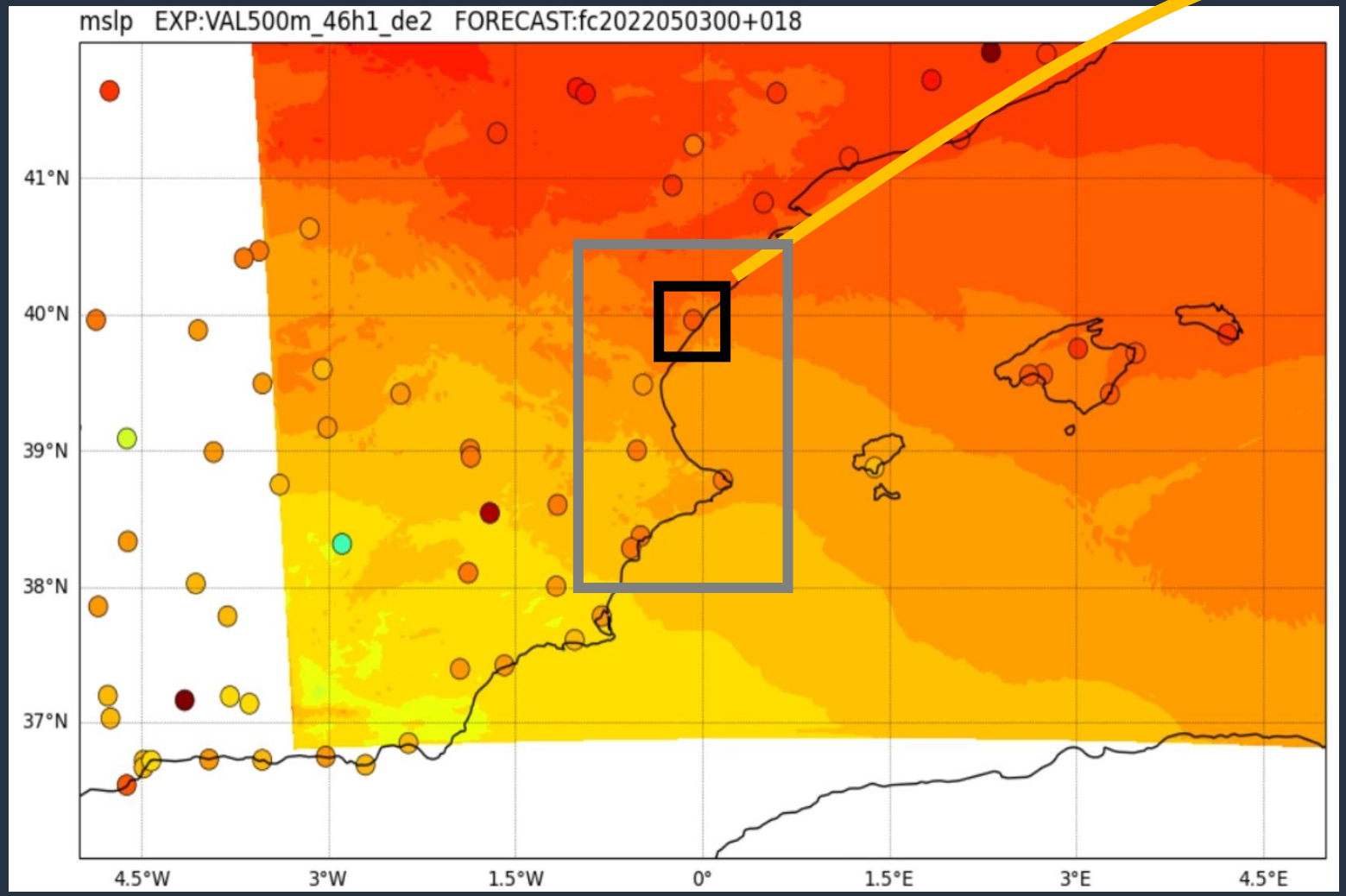
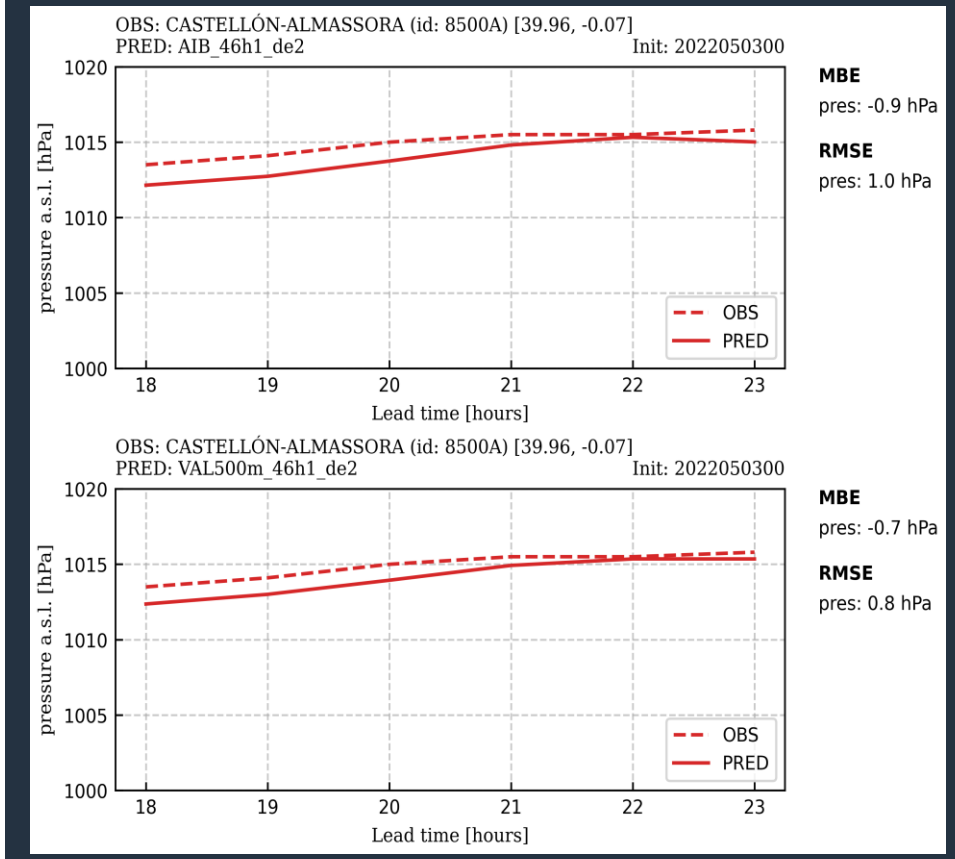
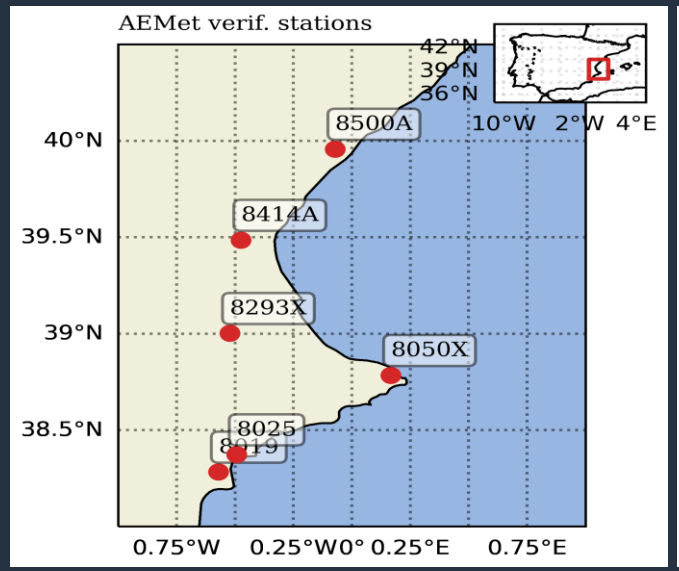


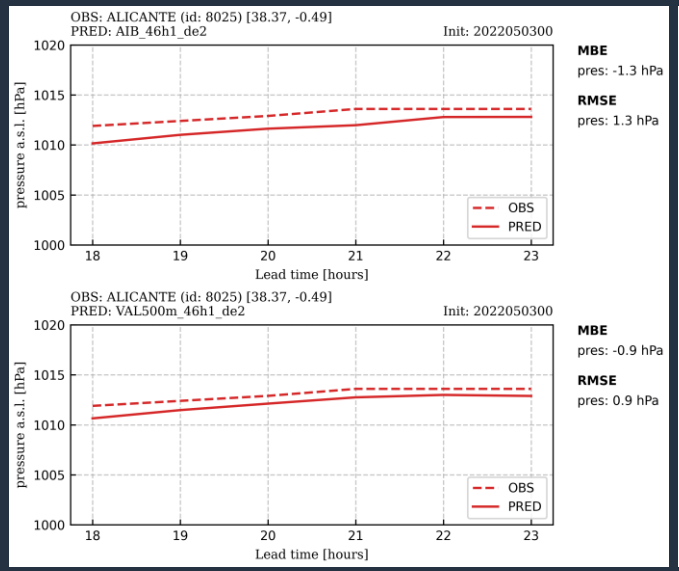
Case: MCS Valencia

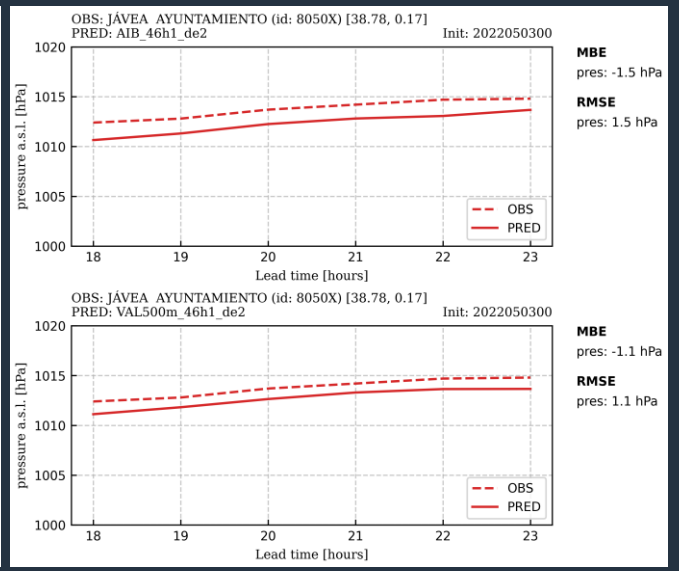


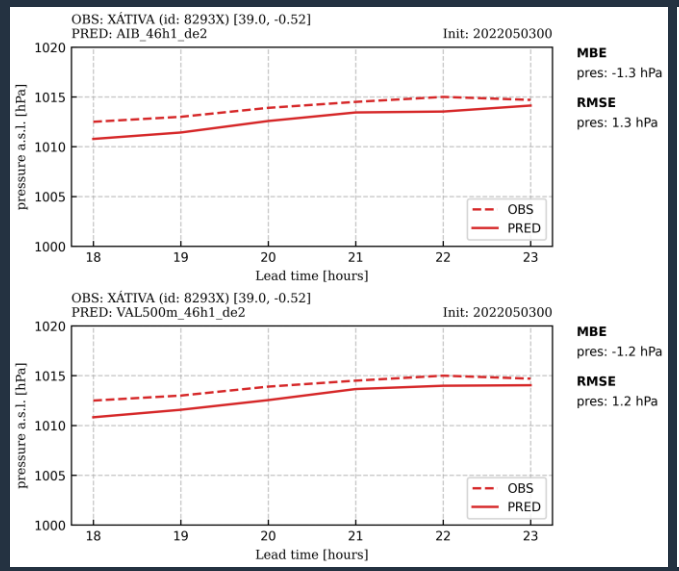


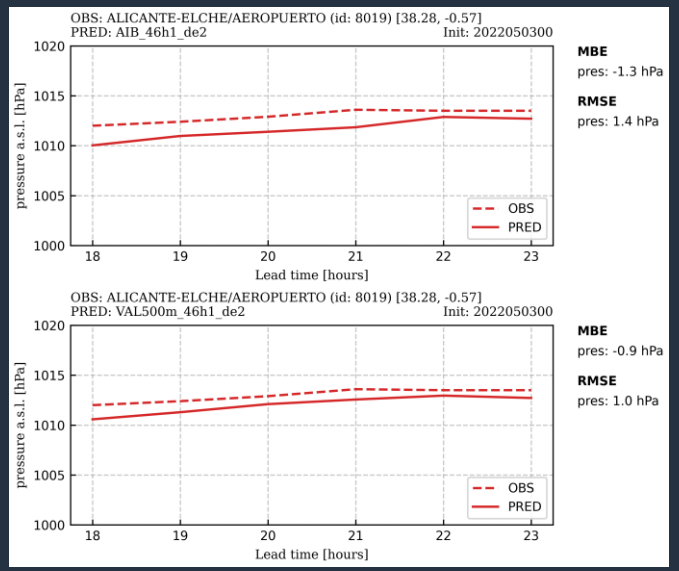
Case: MCS Valencia

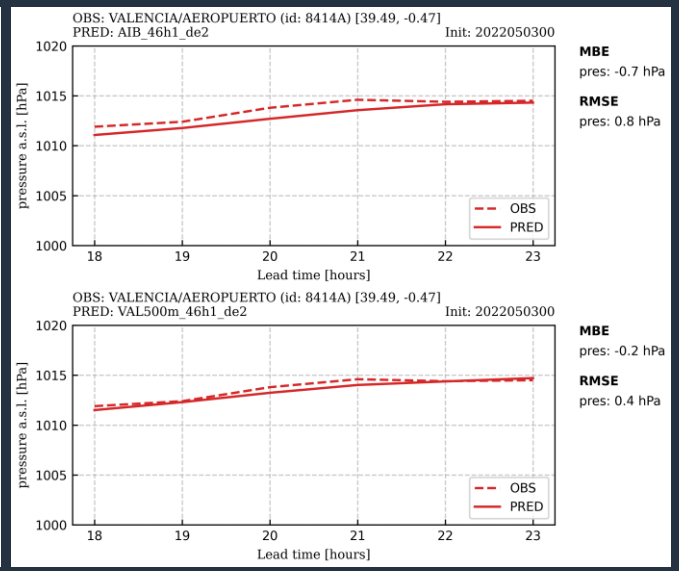






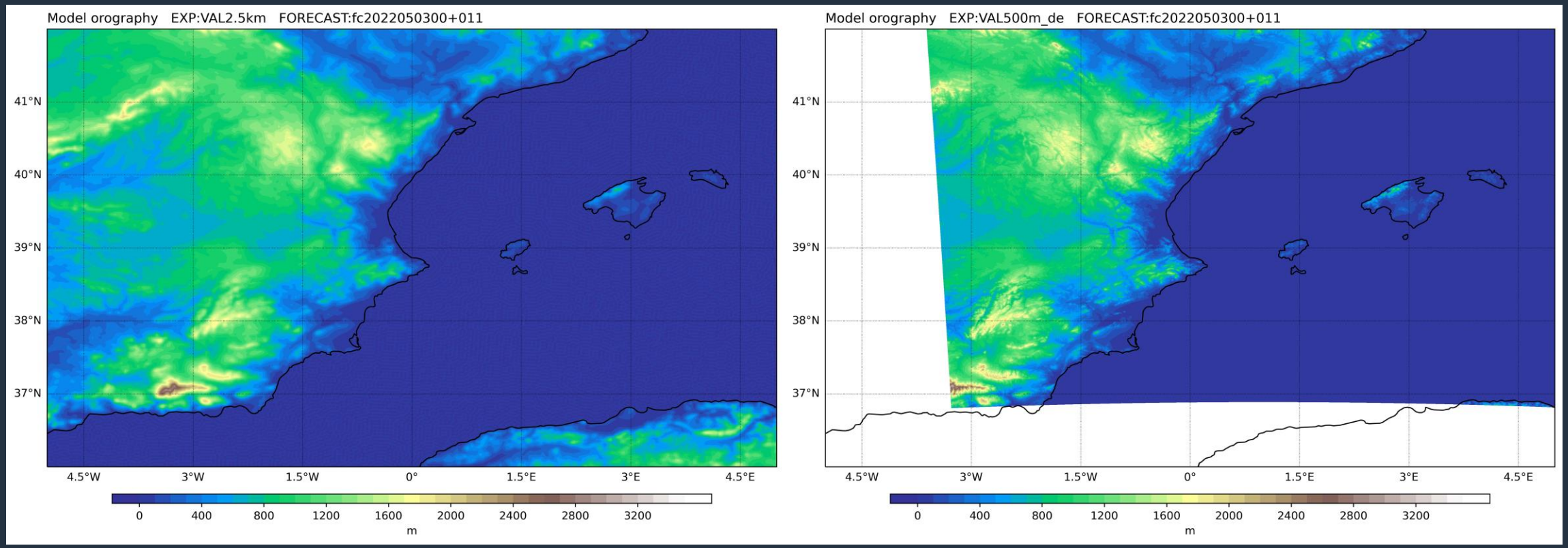






Case 2: MCS Valencia

- Orography is not necessarily playing a crucial role, as the gradient is stronger not only because of the low and the anticyclone to the north. Although the low deepens further in 500 m once it enters the coast?



Case: MCS Valencia

Conclusions:

- Operational runs at 2.5 km were not able to simulate the deep convective system that left heavy rainfall over Valencia.
- Sub-kilometric resolution simulations are able to simulate the system, although it is not totally clear regarding the intensity and structure. Further analysis needed.
- The key differences are related to the well represented low-level moisture flux convergence line over the coast that does not occur in the reference run.

Case: Convective storms in the Canary Islands

Case: Convective storms in the Canary Islands

- **AIC:**

  HARMONIE-AROME operational at AEMET in the Canary Islands (cy43)

- **CANs500_46h11_ifs:**

  Domain over the Canary Islands with cold start from IFS without data assimilation + VHR dynamic options; cy46h11

Case: Convective storms in the Canary Islands

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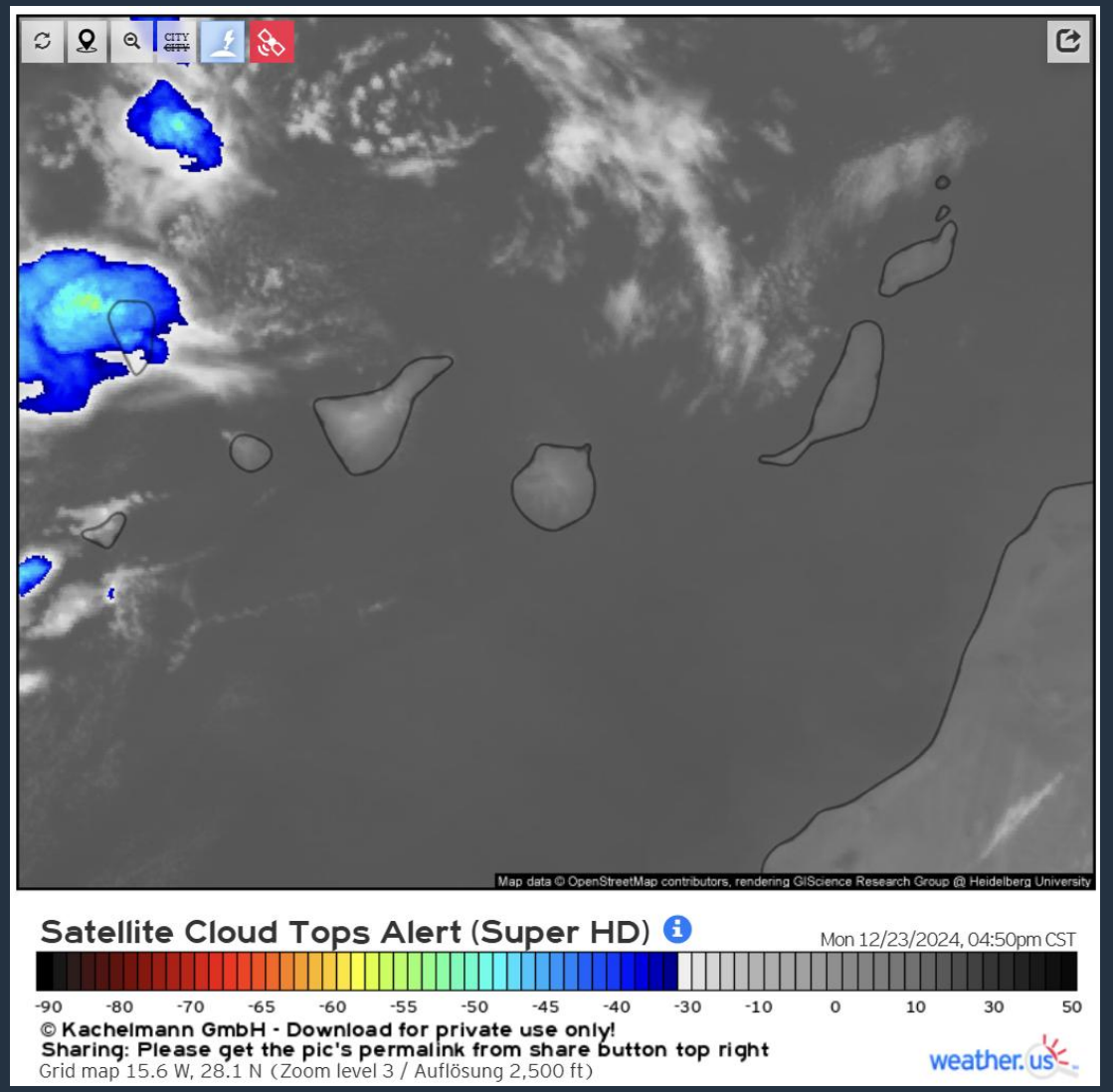

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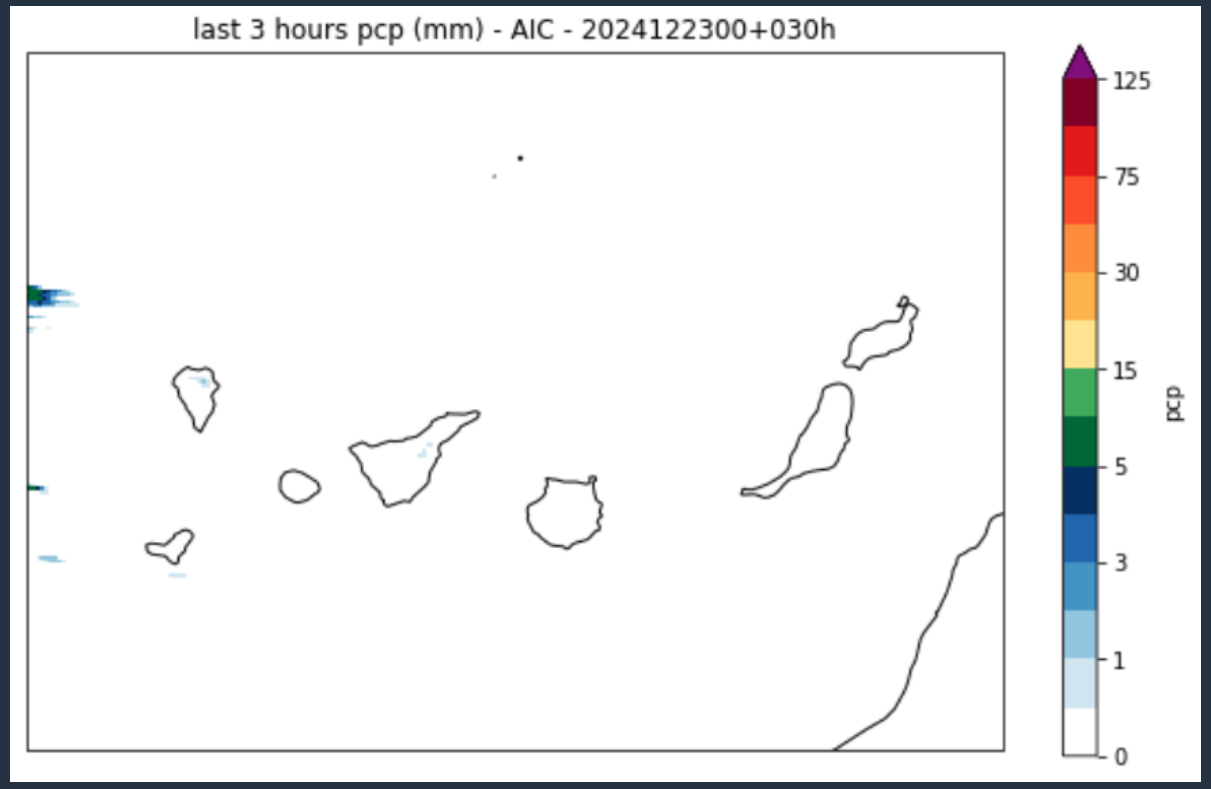
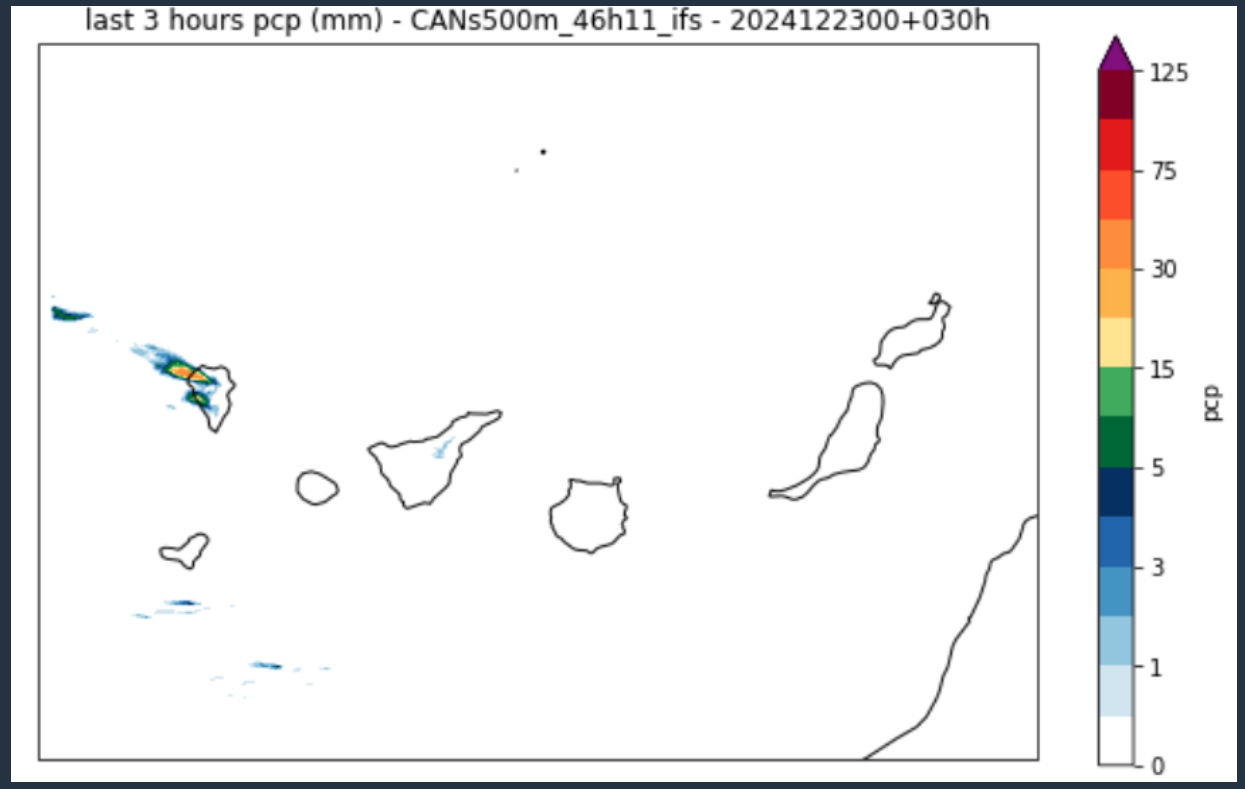
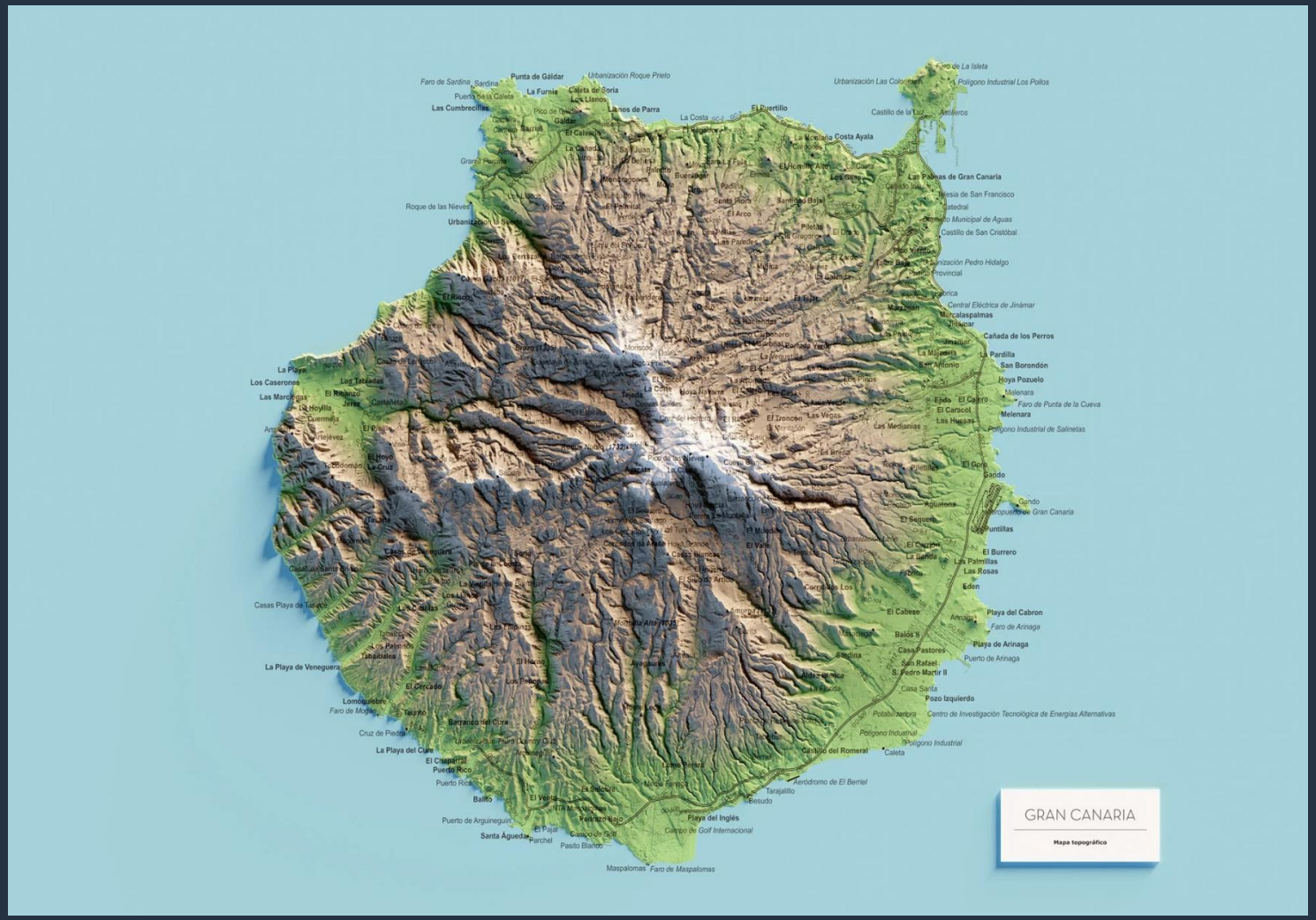


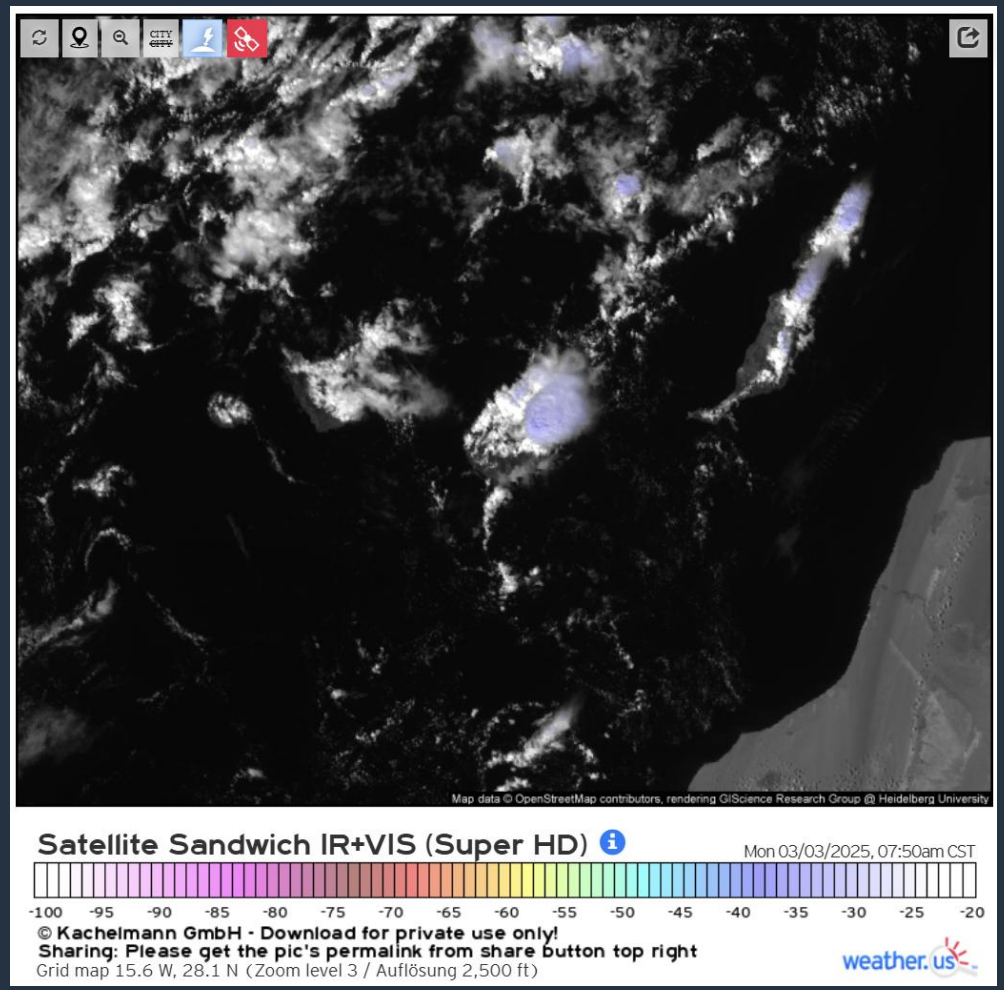


Case: Convective storms in the Canary Islands



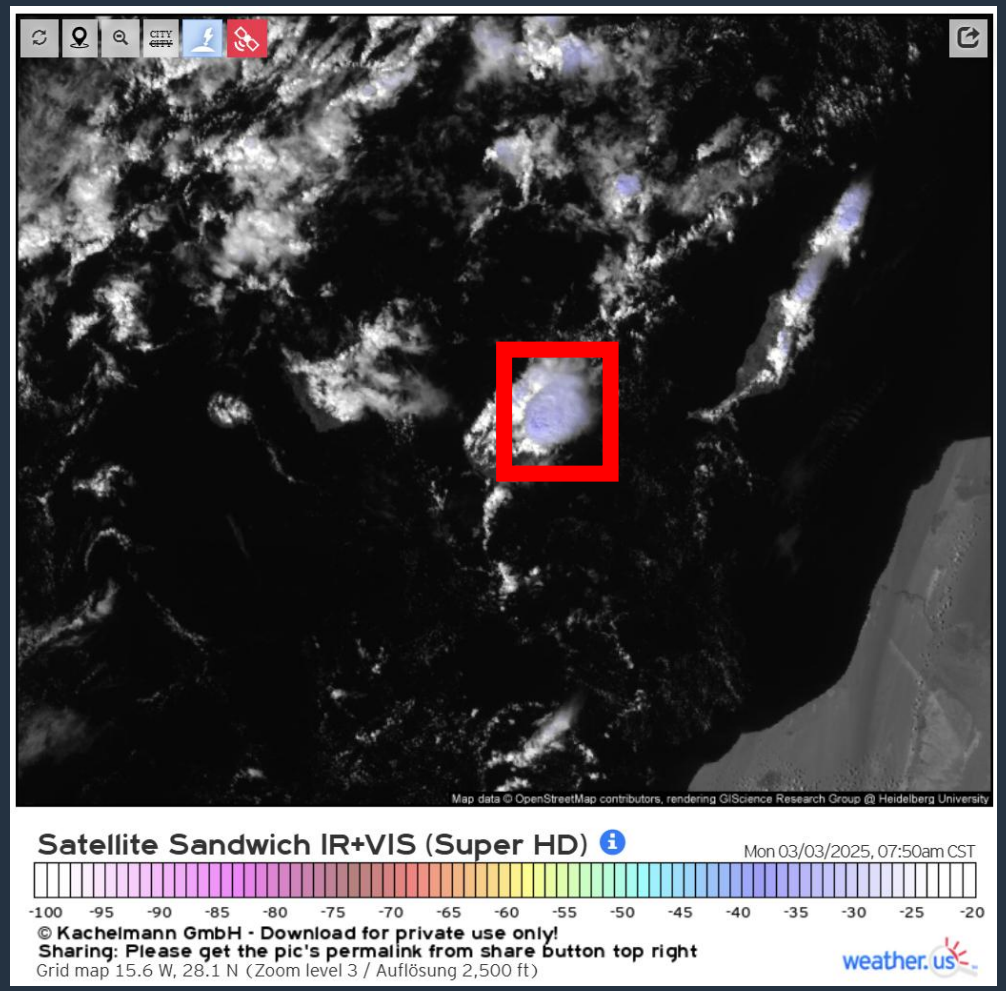
Case: Convective storms in the Canary Islands

https://weather.us/satellite/156-w-28l-n/sandwich-ir-vis-10m-superhd/20250303-1350z.html



Case: Convective storms in the Canary Islands

https://weather.us/satellite/156-w-28l-n/sandwich-ir-vis-10m-superhd/20250303-1350z.html



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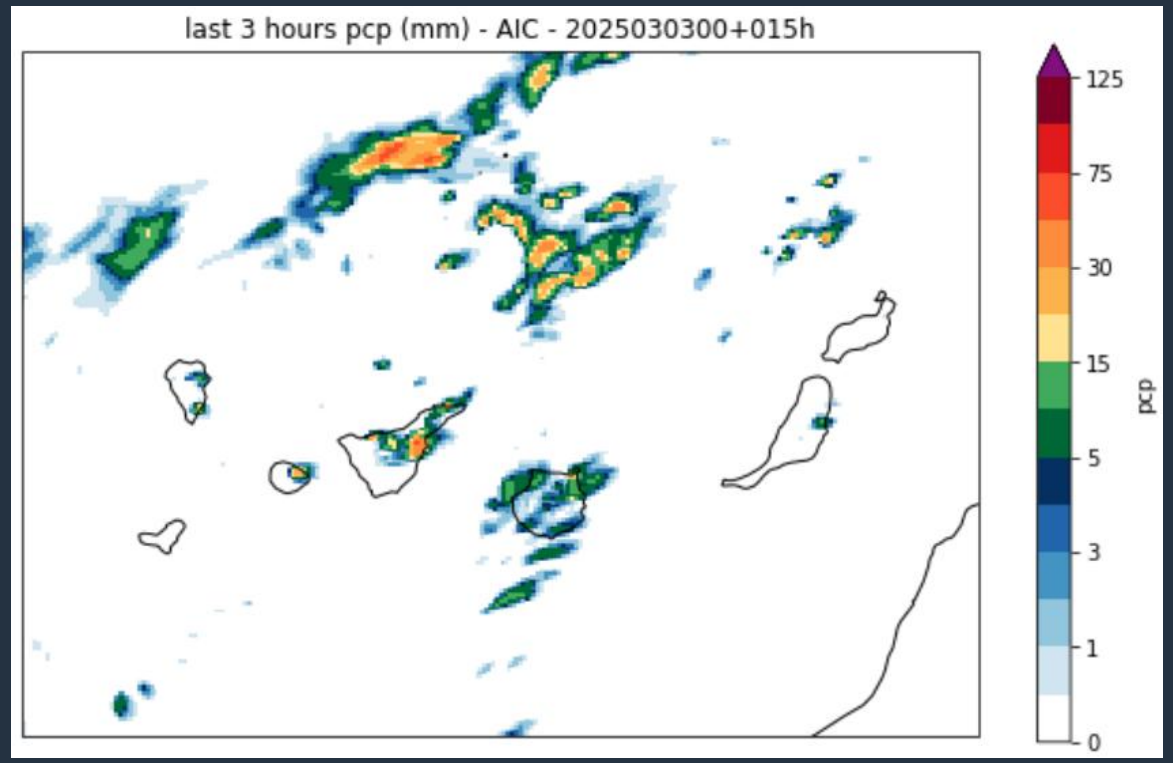

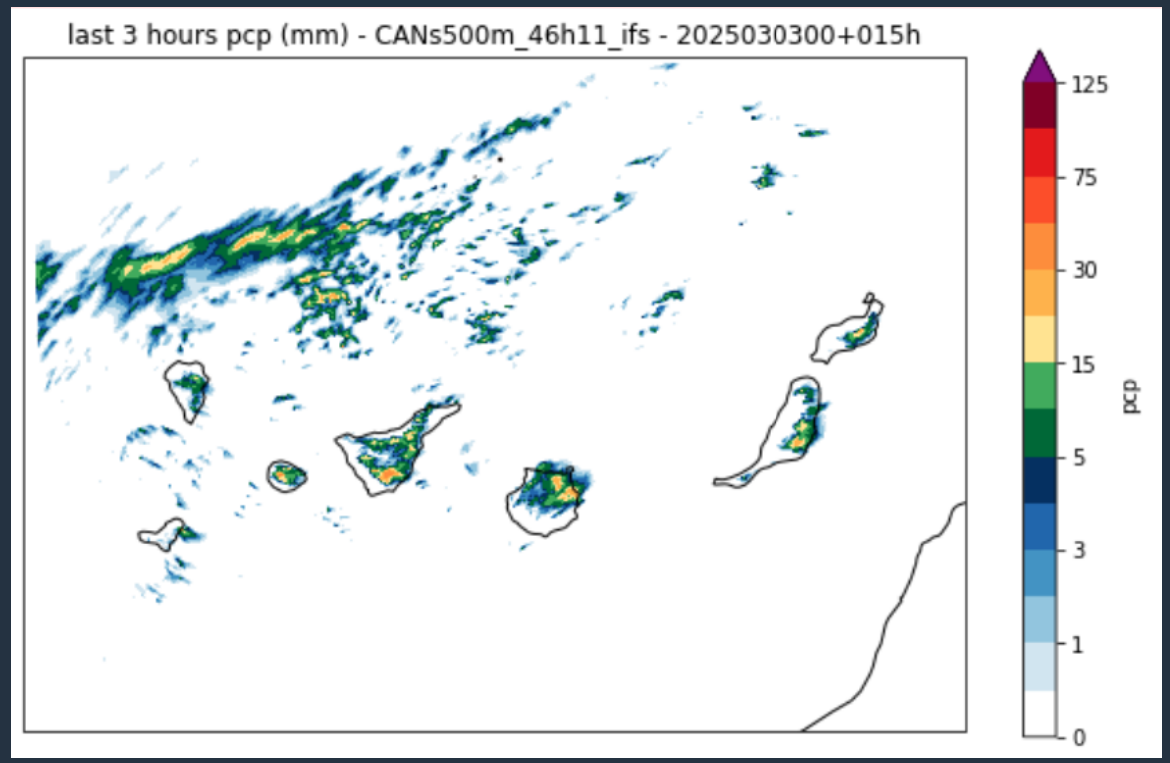

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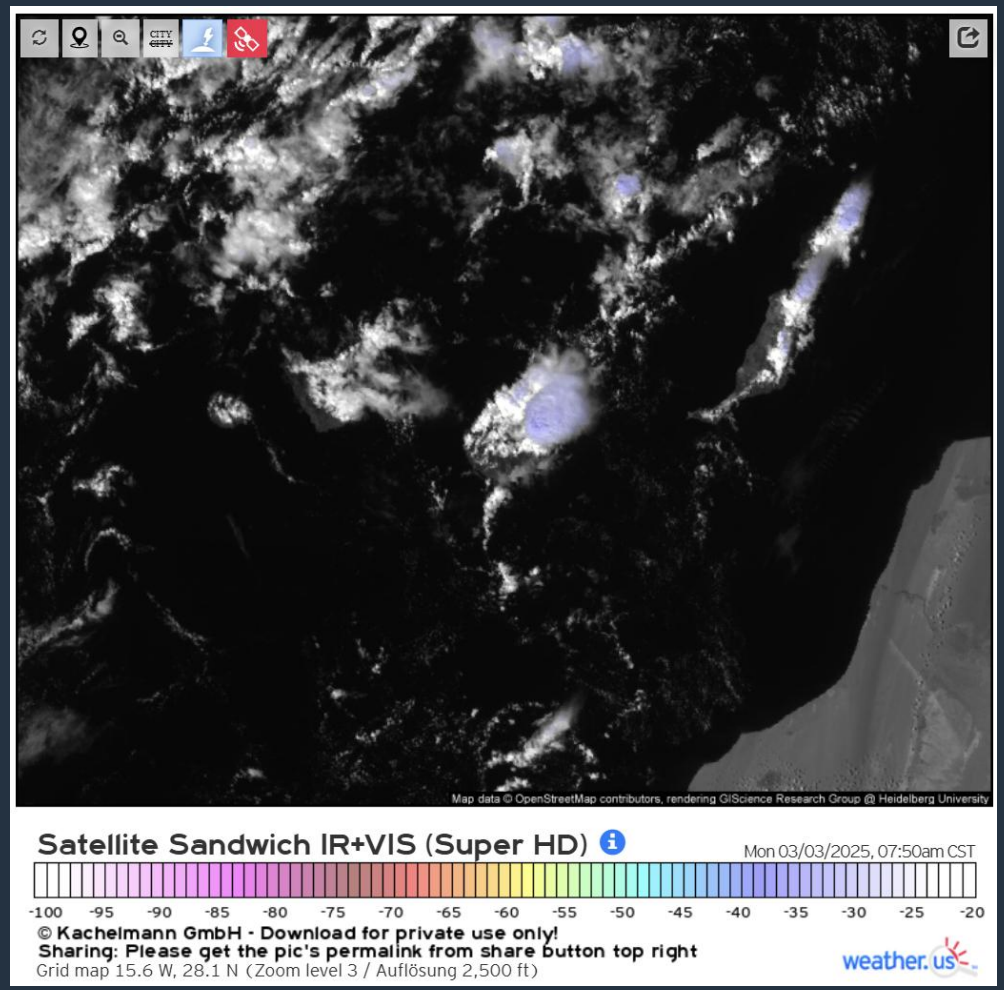

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