Preliminary evaluation of the ARRA reanalysis over France: focus on extreme precipitation

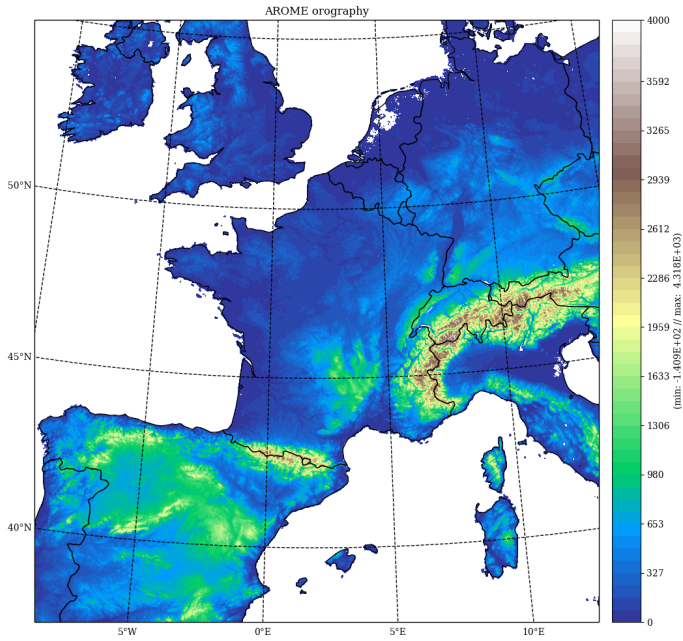
Eric Bazile[(1)], Patrick Le Moigne[(1)], Stephane Van Hyfte[(2)], Yannick Selly[(1)], Antoine Verrelle[(1)], Jean-Marie Willemet[(2)], Pauline Blanc[(1)], Diego Monteiro[(3)], Fabienne Rousset[(2)]

(1) Météo-France, CNRS, Univ. Toulouse, CNRM, Toulouse, France.
(2) Direction de la Climatologie et des Services Climatiques, Météo-France, Toulouse, France.
(3) Météo-France, CNRS, Univ. Grenoble Alpes, Univ. Toulouse, CNRM, Centre d'Études de la Neige, 38000 Grenoble, France.

26th EMS
8-12 September 2025, Ljubljana, Slovenia

ARRA in brief:

- **AROME-France domain and configuration: 1.3km, 90 vertical levels**
- **Specific changes:**
  - Dynamical adaptation with surface assimilation every 3h, with IAU (Incremental Analysis Update. Bloom et al., 1996)
  - Coupling and upper air initial condition from European reanalysis: UERRA before 1985 and CERRA after.
  - Aerosols based on CAMS and TACTIC computation from 1961 to 2020 (P. Nabat) instead of a fixed 30-year climatology
  - Solar eclipse extended to the past (Coll. J.M. Piriou and P. Descamps (IMCCE))
  - Surface observations from several data base : BDClim (France), UERRA/CERRA, AEMET (Spain), MeteoSwiss, ERA6, IRM (Belgium)
  - Daily precipitation analysis with MESCAN (Soci et al., 2016)
- **ARRA-Land** : SURFEX-offline @ 1.3km with advanced soil and snow scheme forced by ARRA and MESCAN precipitation analysis



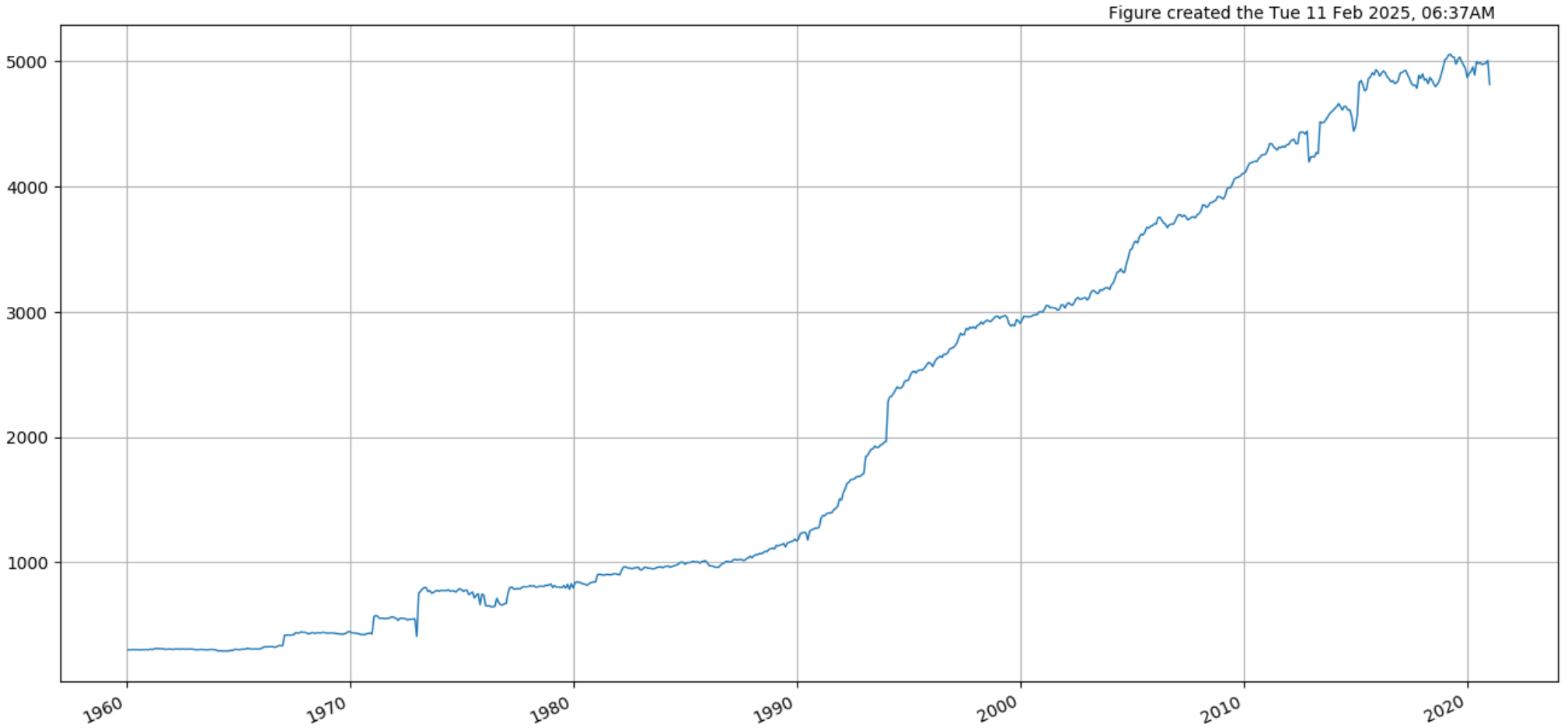
- **Total Volume for 60 years (hourly output, native grid and grib) ~13Po**
- **Production started December 2024 84 % done, will end hopefully before Christmas 2025**
- **For users: 3 NetCDF files (Surface, Pressure level, Height) Total 273To**

Observation input data:

Data from Météo-France, UERRA/CERRA reanalysis, AEMET (Spain), MeteoSwiss, IRM (Belgium) and ERA6

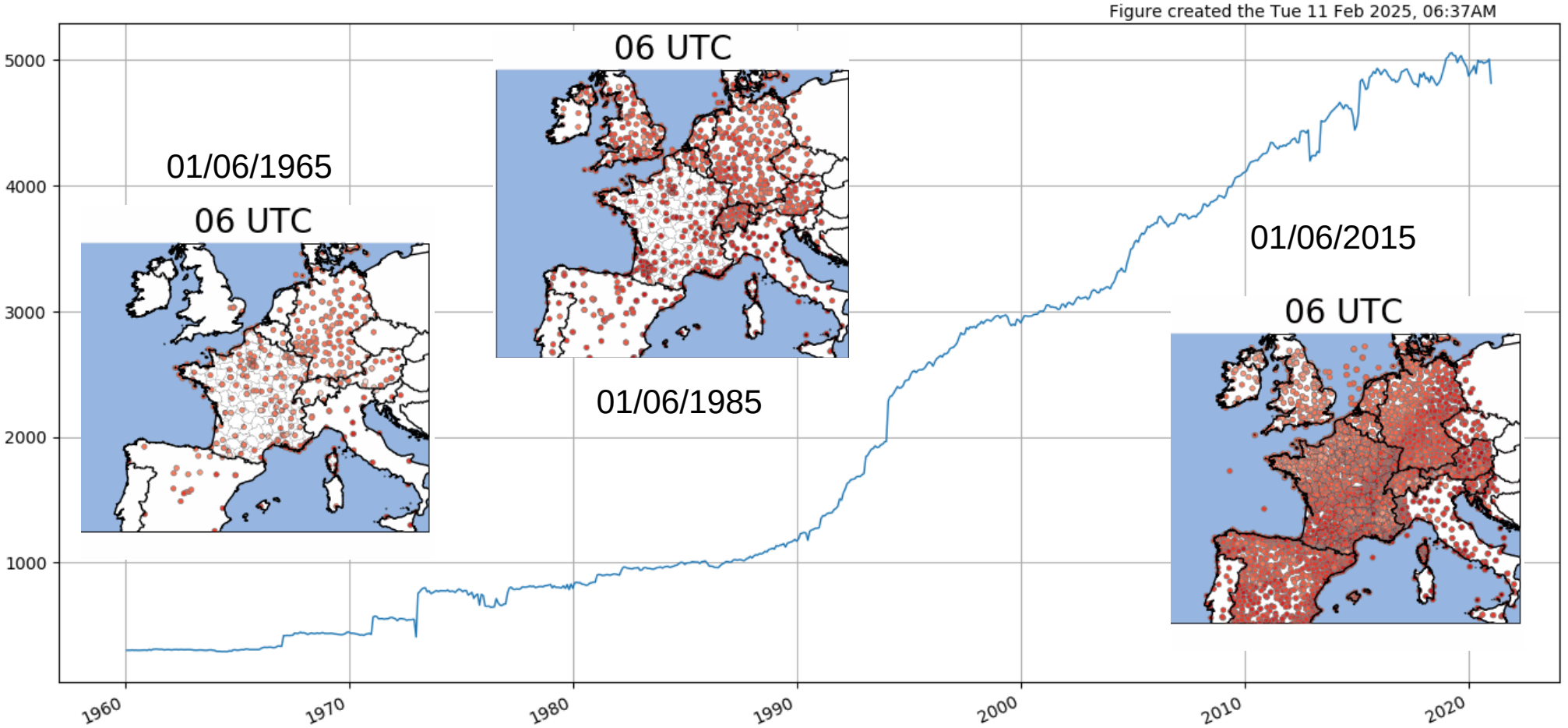
Monthly average of the number of T2M observations

Data available from 1960-01-01 00:00:00 to 2020-12-31 21:00:00



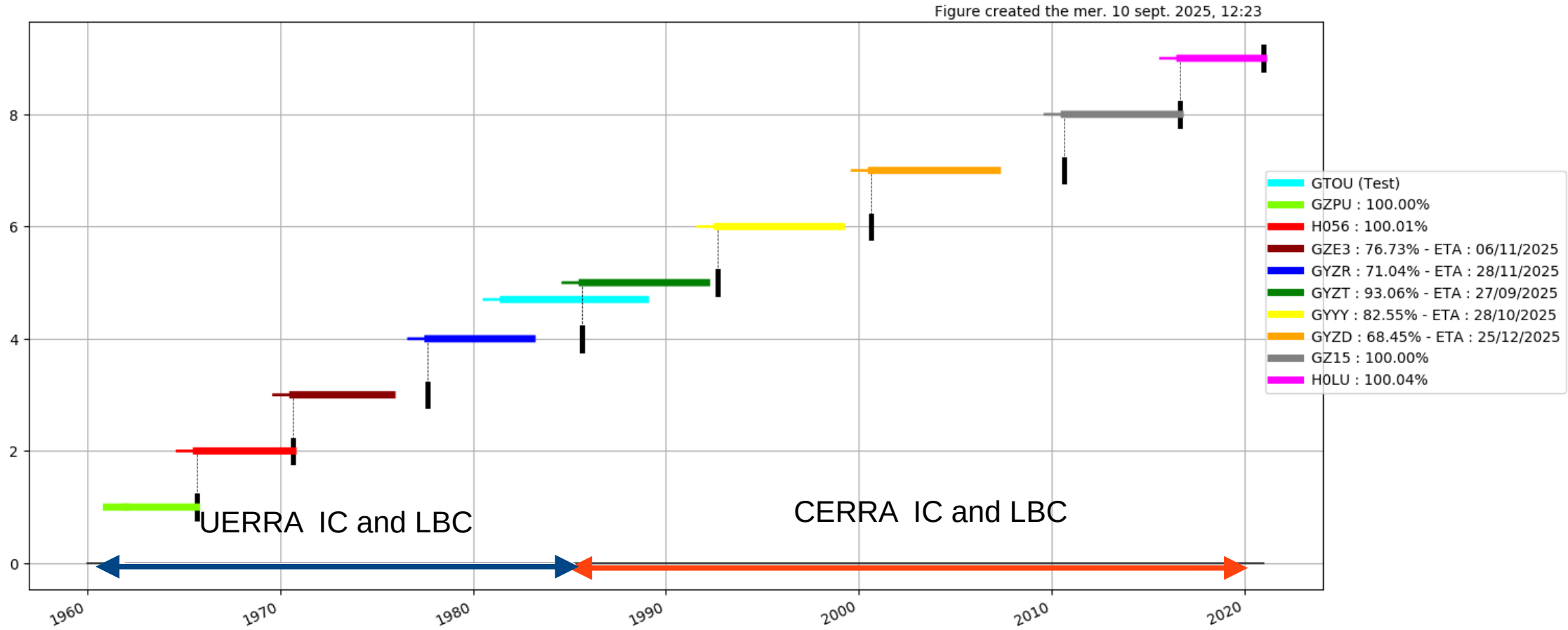
Observation input data:

Data from Météo-France, UERRA/CERRA reanalysis, AEMET (Spain), MeteoSwiss, IRM (Belgium) and ERA6



Production status: 85% done

ARRA experiments : 94.98% of the period has run !
85.15% without the spin-up

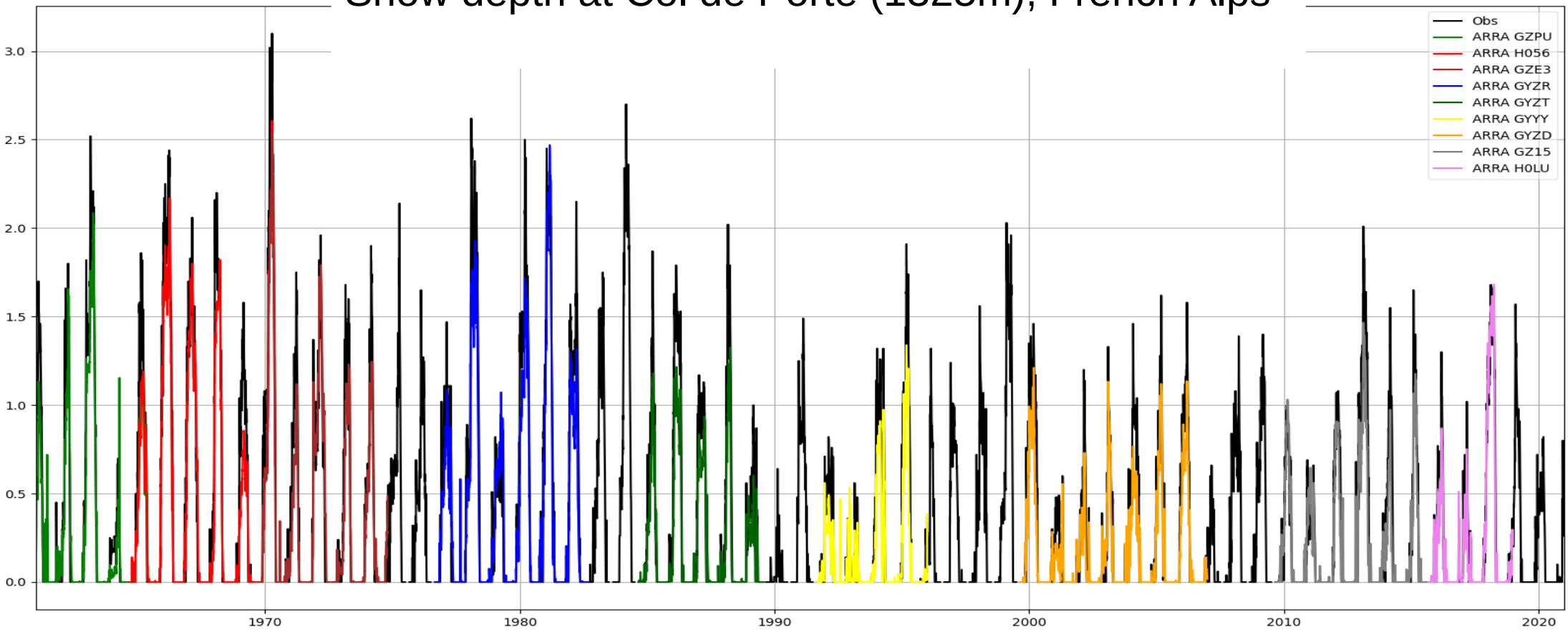


For each stream: 1 year spin-up
The production began mid-December 2024 and should be completed before Christmas 2025!

ARRA-Land production will start soon (before November, waiting for the final configuration for the precipitation analysis MESCAN)

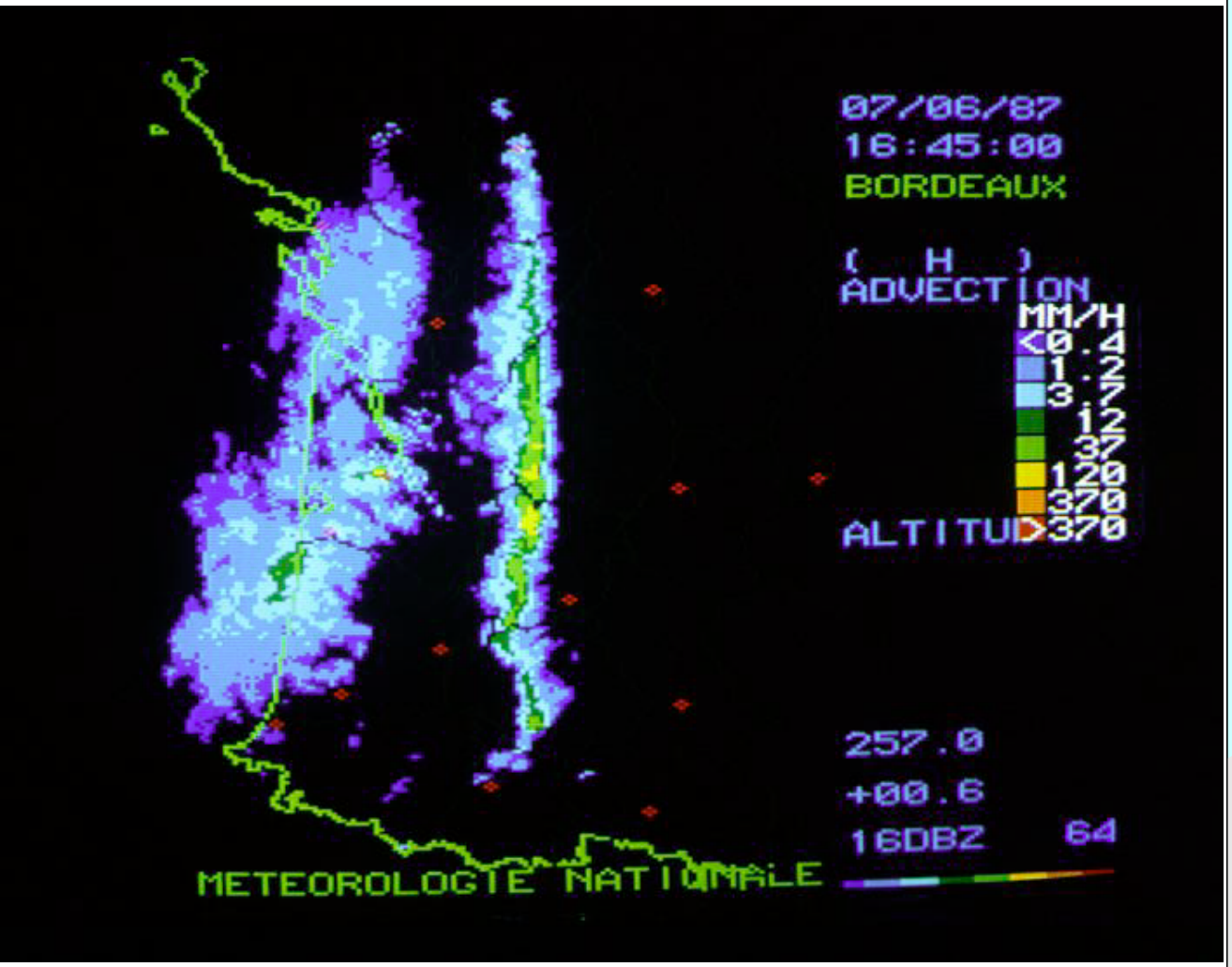
Production status: 85% done

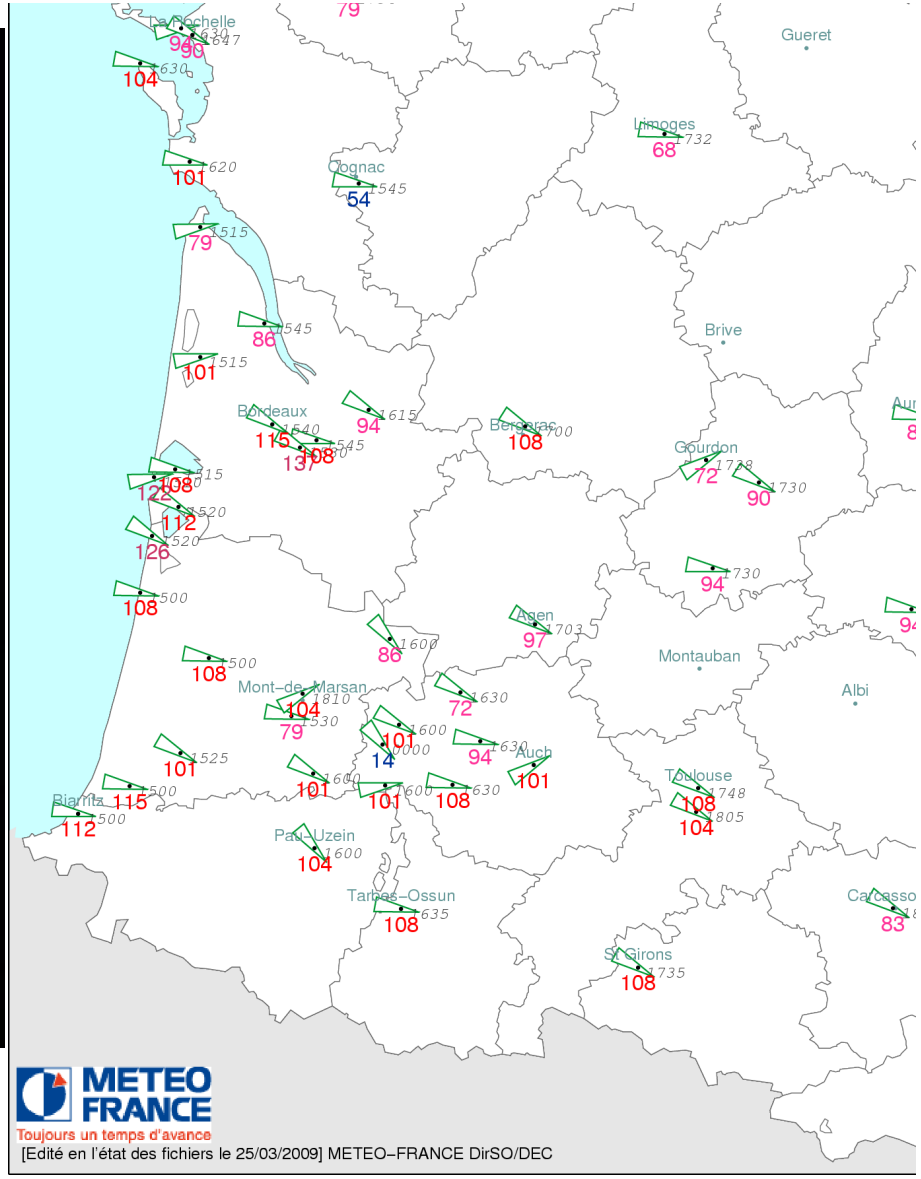
Snow depth at Col de Porte (1325m), French Alps



Good agreement with observation in black → Model precipitations are OK at least during the winter season!
For ARRA-Land, the MESCAN analysis precipitation will be used.

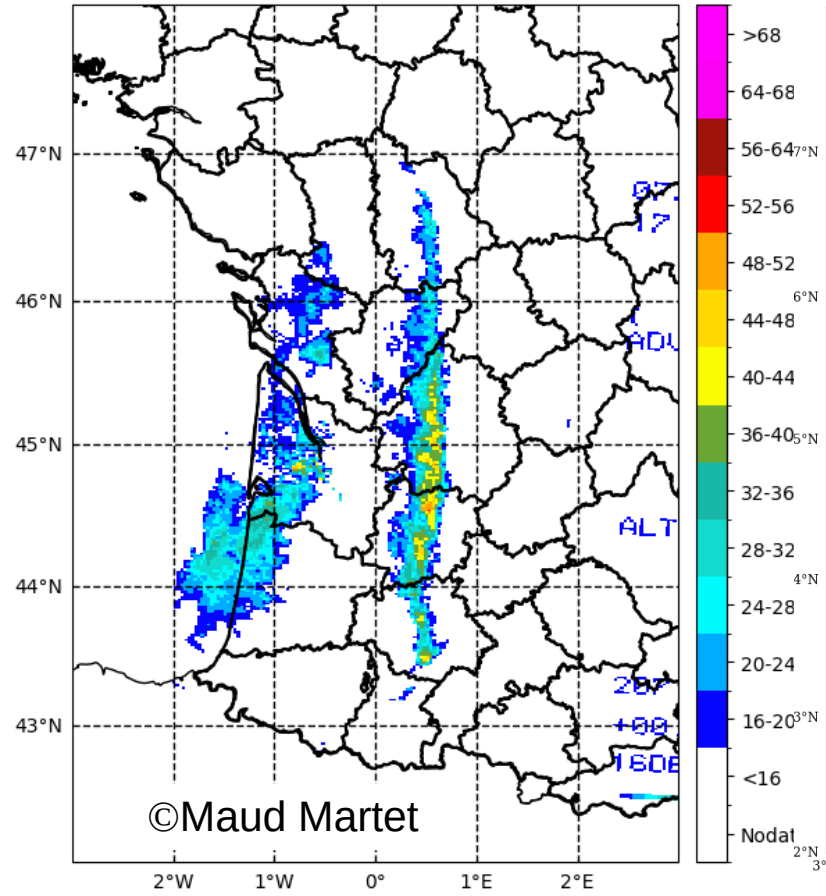
Squall line 7th June 1987



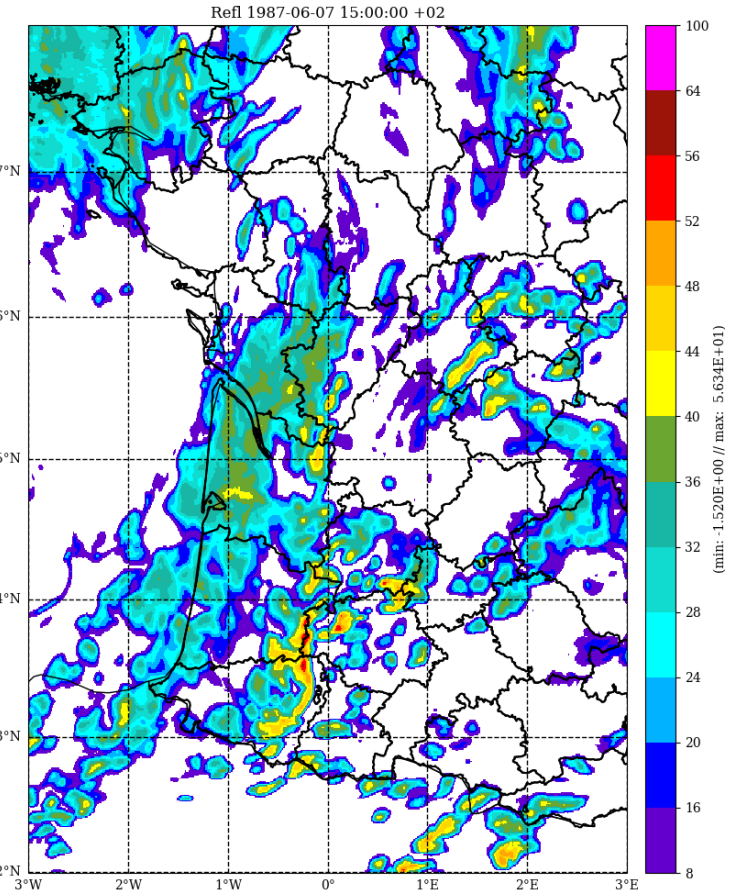


Squall line 7th June 1987

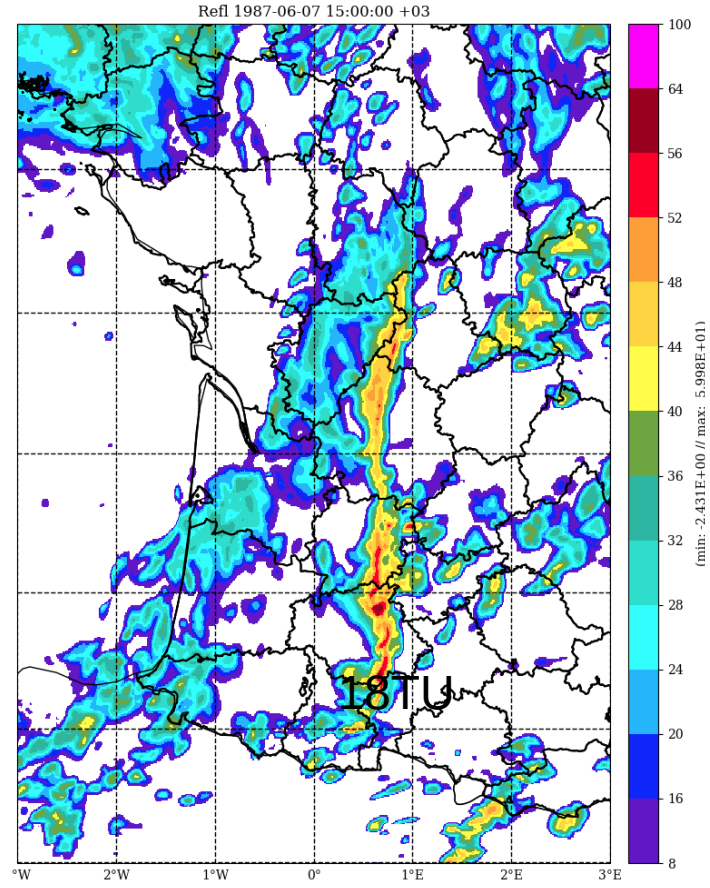
RADAR (dBZ) 17TU



ARRA Refl (dBZ) 15TU+2H



ARRA Refl (dBZ) 15TU+3H



ARRA is able to simulate the squall line! Without radar assimilation, with initial upper air field from CERRA at 5.5km (used with IAU)

Nîmes 3/4 October 1988

Fig.1 L'avenue G. Pompidou le 3 octobre 1988

11 casualties. Max 420mm
Estimated Cost 600M€

Source Meteo-Climat Septembre 2013 n°38

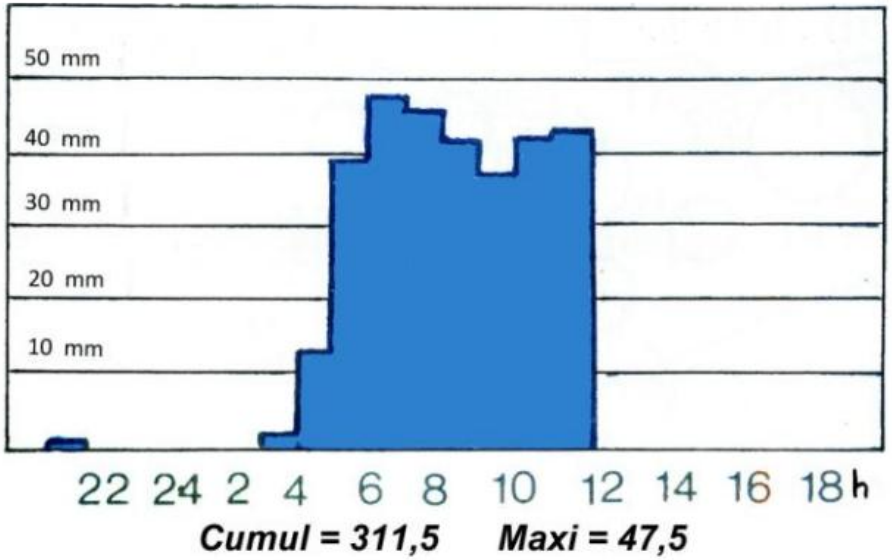
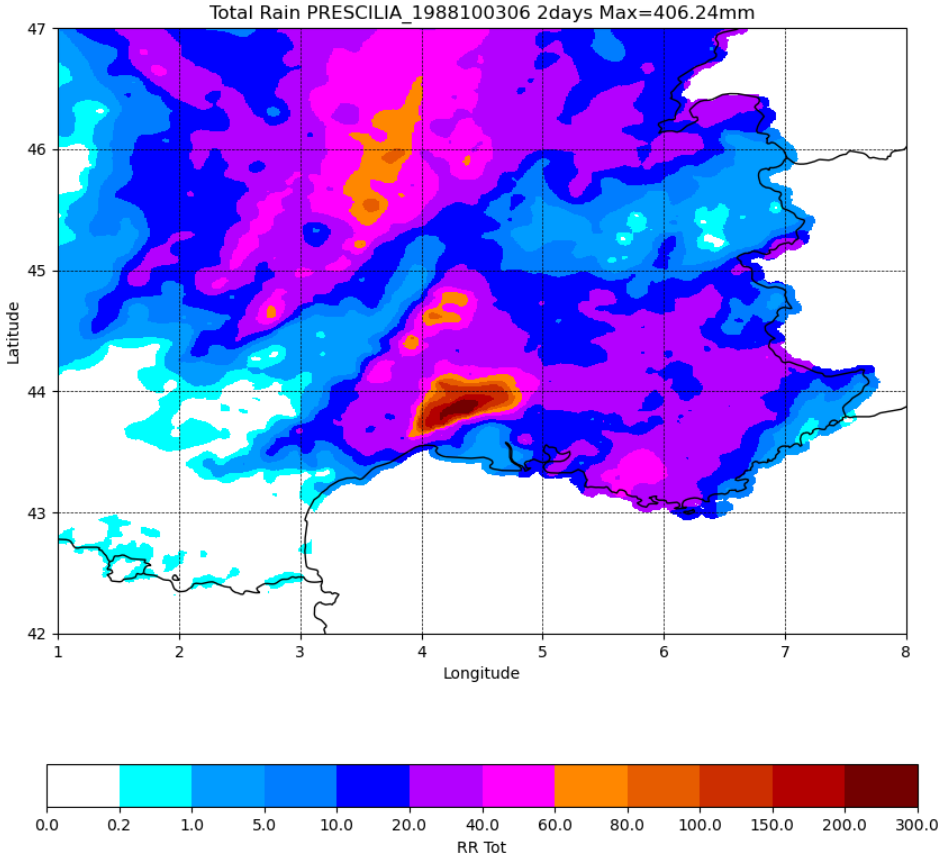
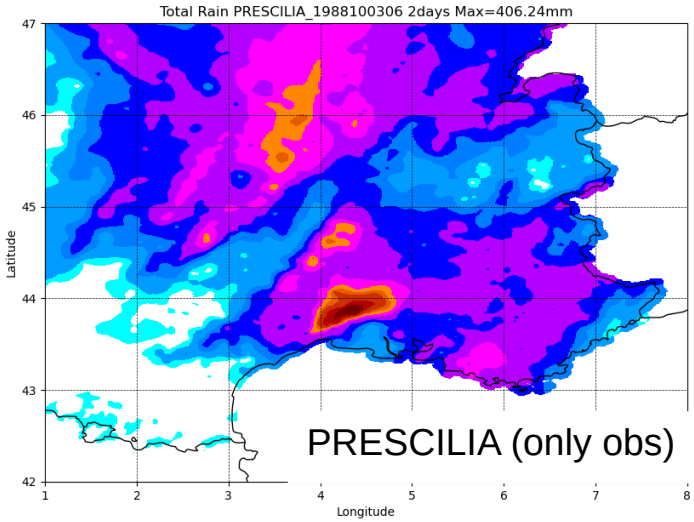


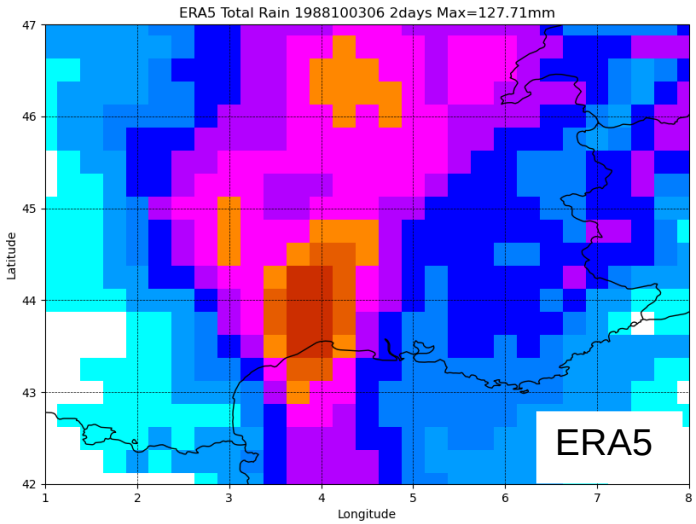
Fig.4 Précipitations horaires à Nîmes-Kennedy le 3 octobre

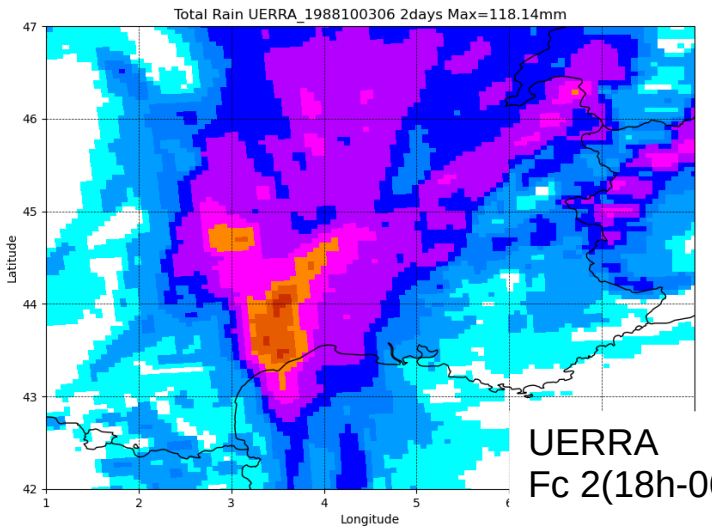


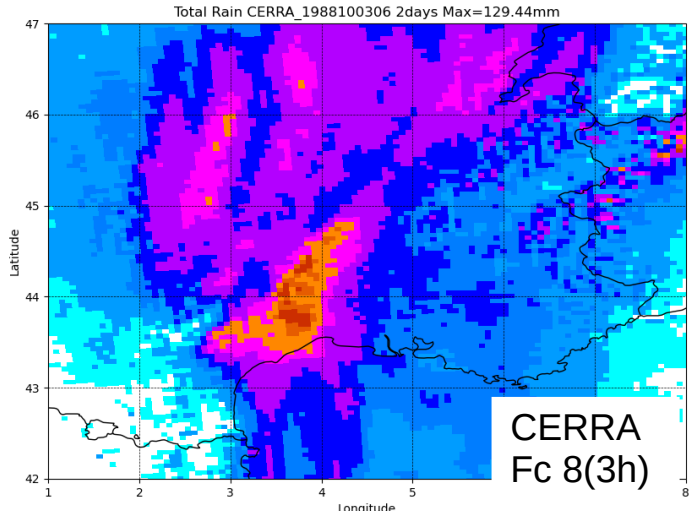
PRESCILIA: gridded observation dataset
(Lassegues P. (2016) doi:10.1007/s00704-016-1954-z)

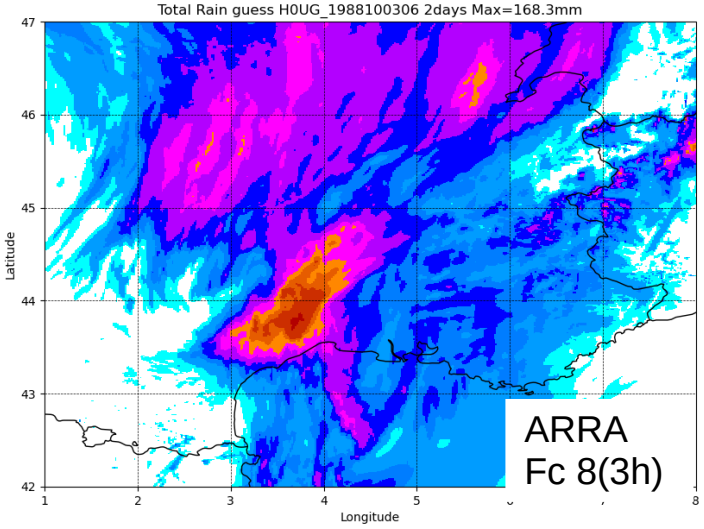
Nîmes 3/4 October 1988

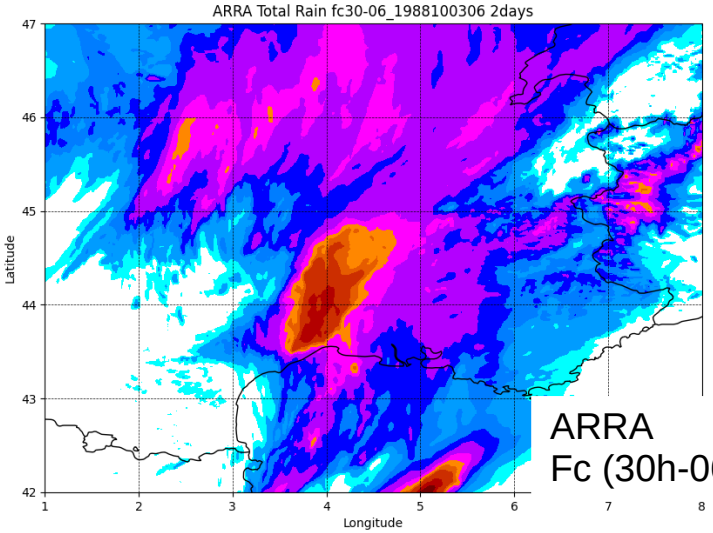






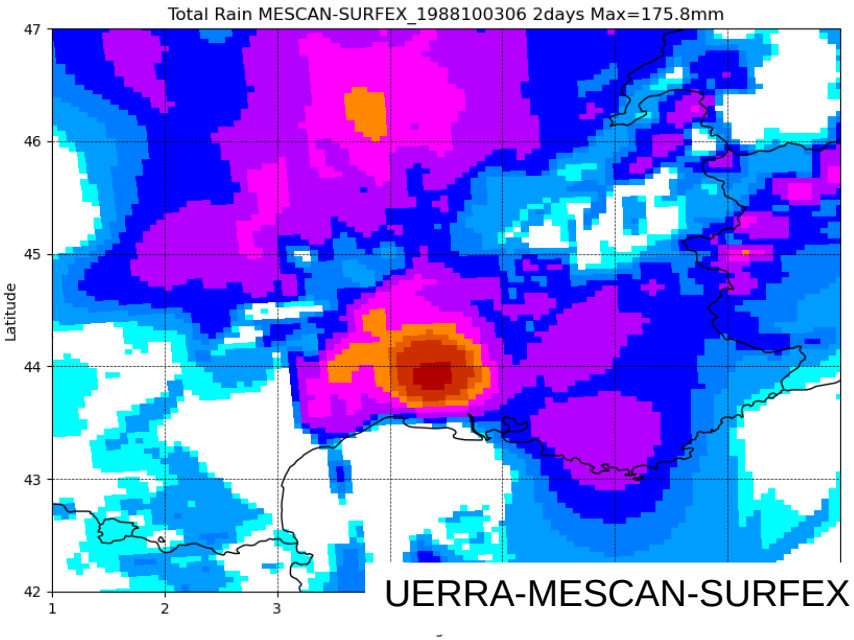




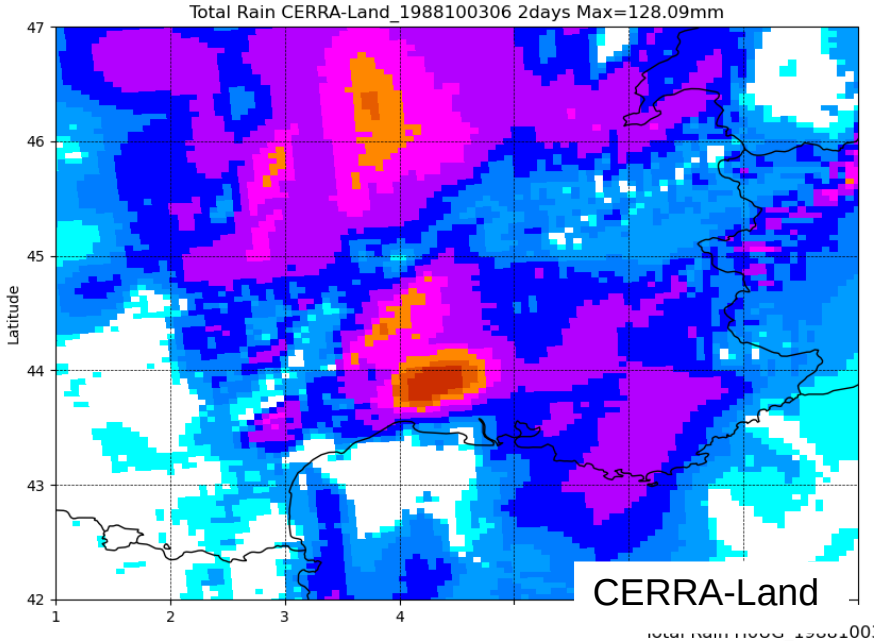


No significant improvement with ARRA (vs CERRA), however the maximum area is better localized with the 30h-06h 24h rain compared the 8 3h-forecast

Nîmes 3/4 October 1988

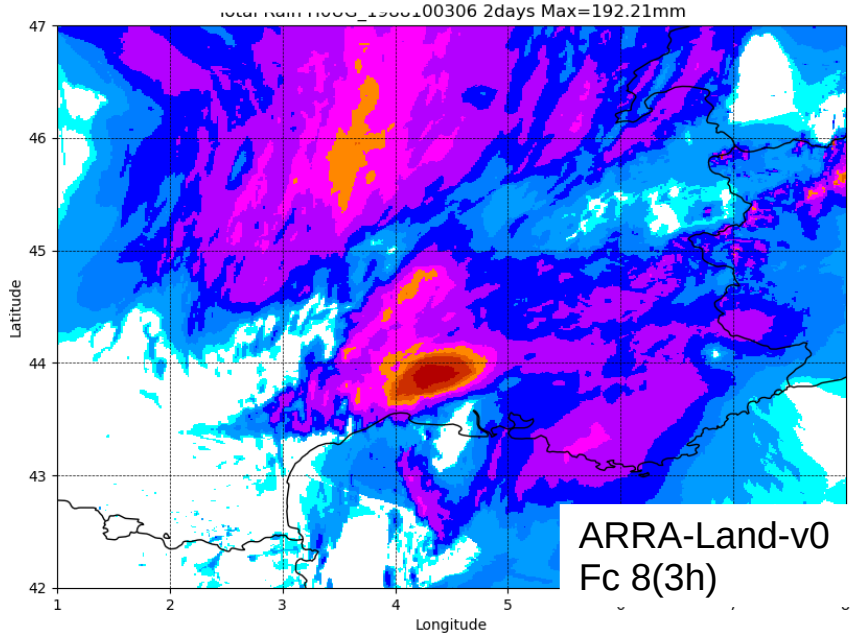


UERRA-MESCAN-SURFEX



CERRA-Land

Precipitation analysis is also improved with the increased of the horizontal resolution of the background. However, for ARRA, for this case the best background is not the 8 3h-forecast.



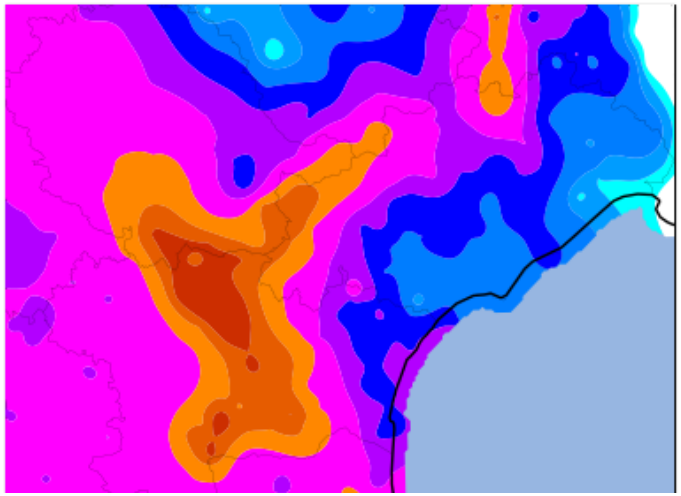
ARRA-Land-v0
Fc 8(3h)

Aude 14/15 October 2018

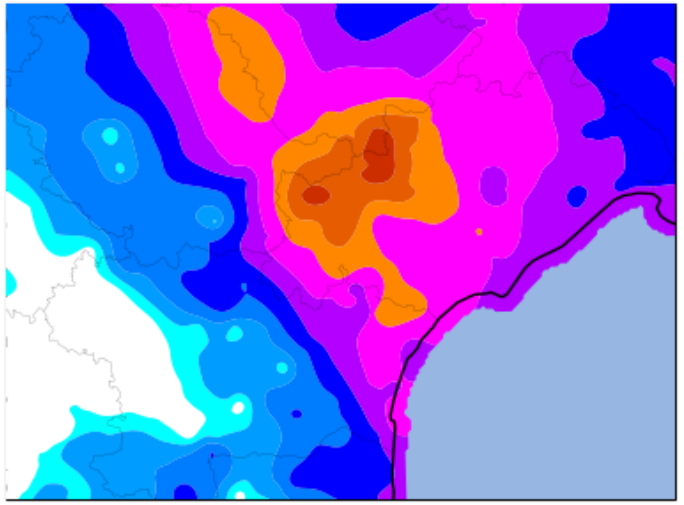
15 casualties.
Estimated Cost 256M€

PRESCILIA (only obs)

2018-10-14 06:00:00

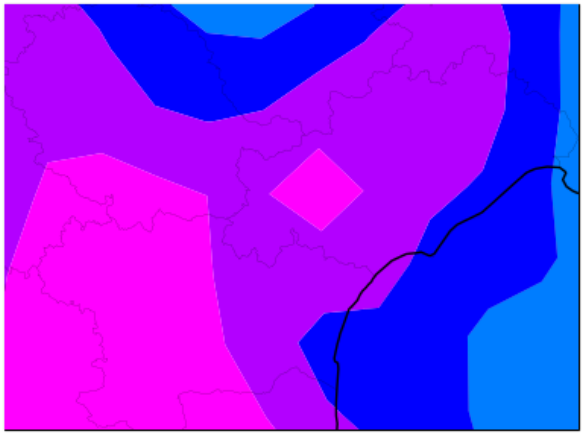


2018-10-15 06:00:00

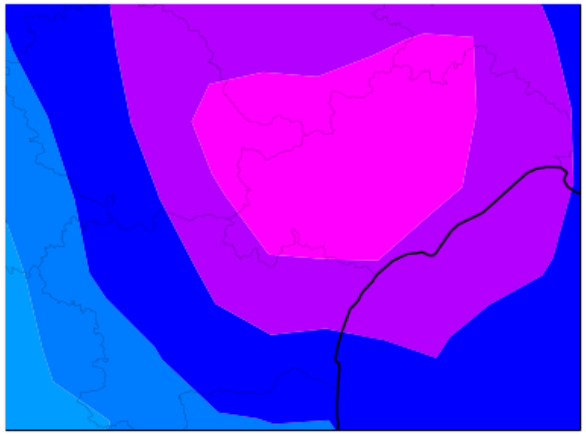


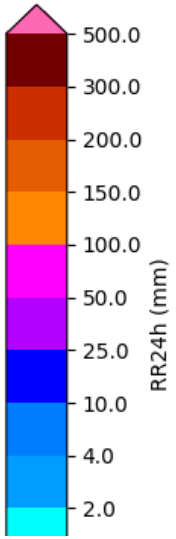
ERA5

2018-10-14 06:00:00

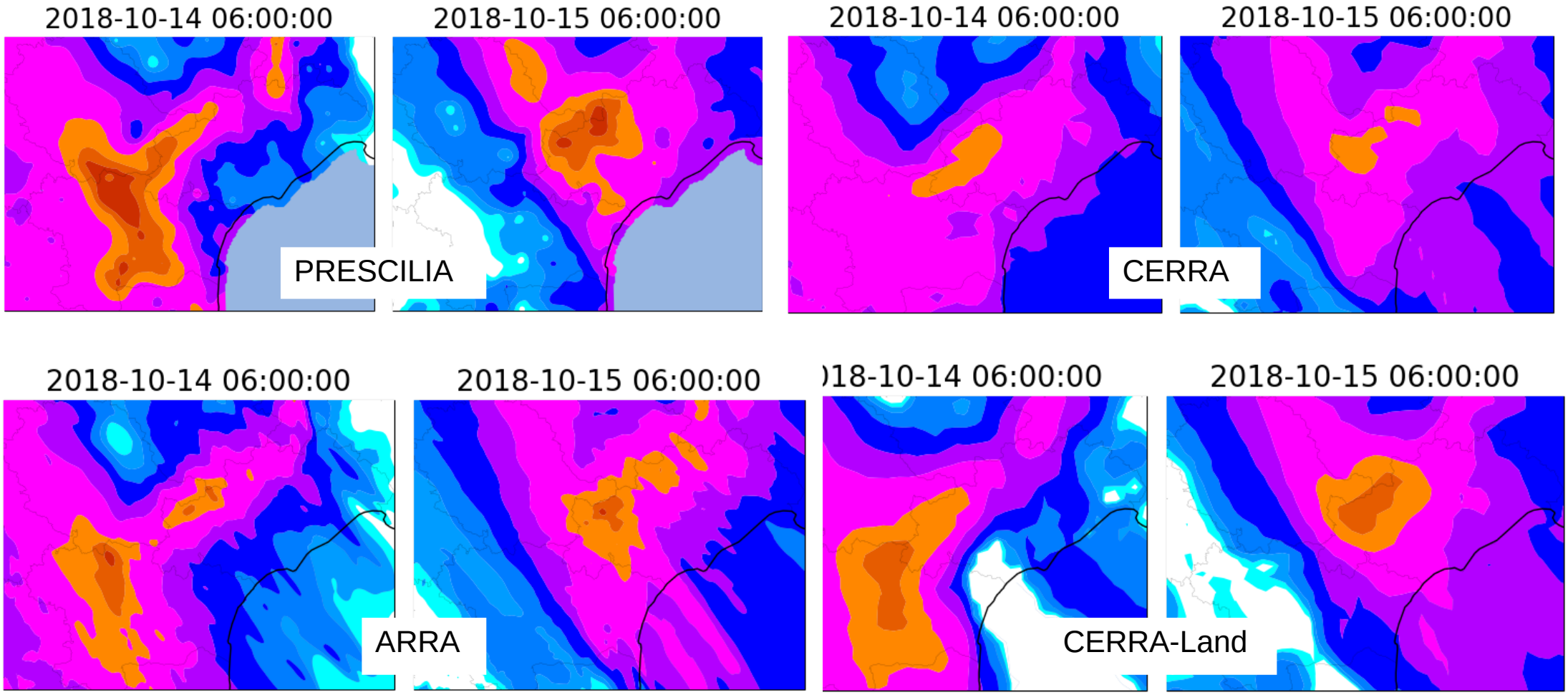


2018-10-15 06:00:00



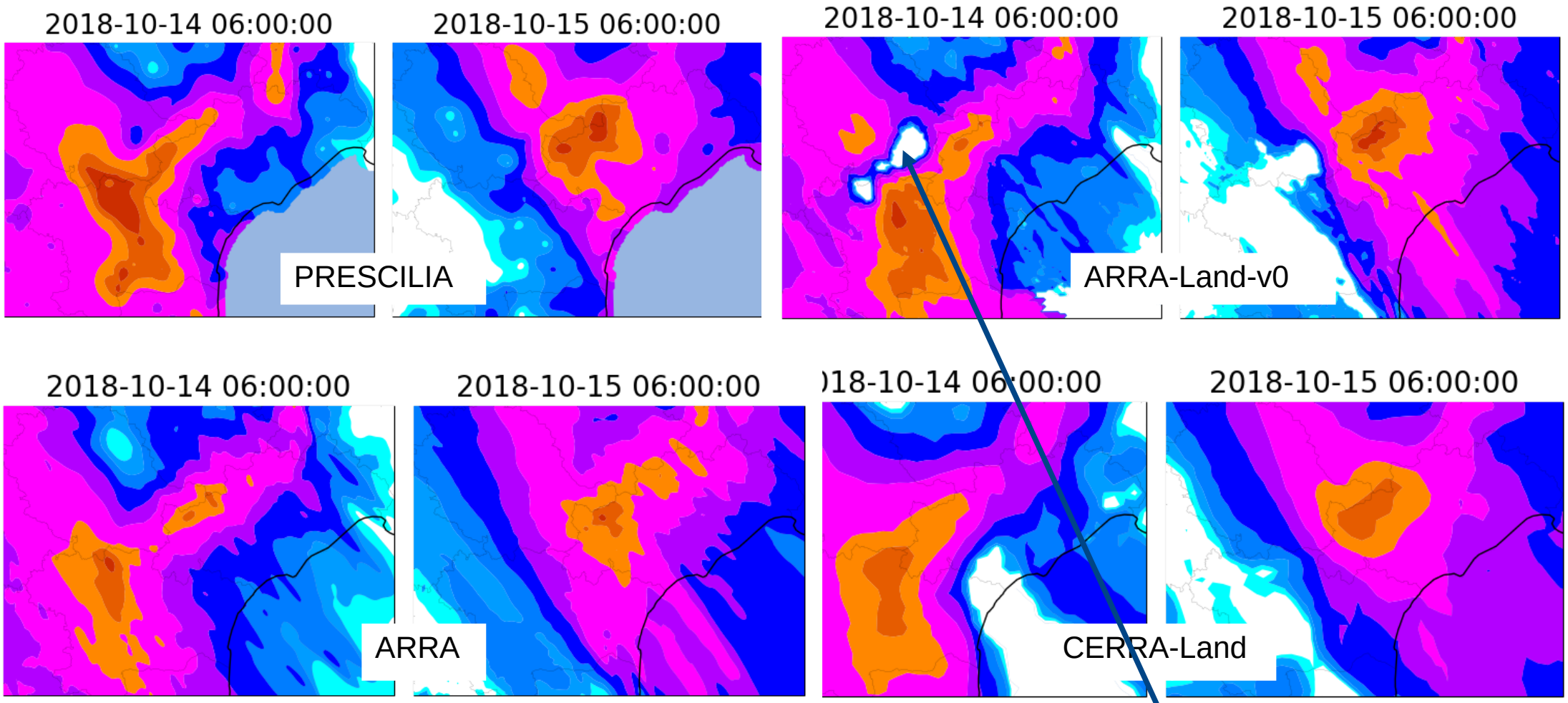


Aude 14/15 October 2018



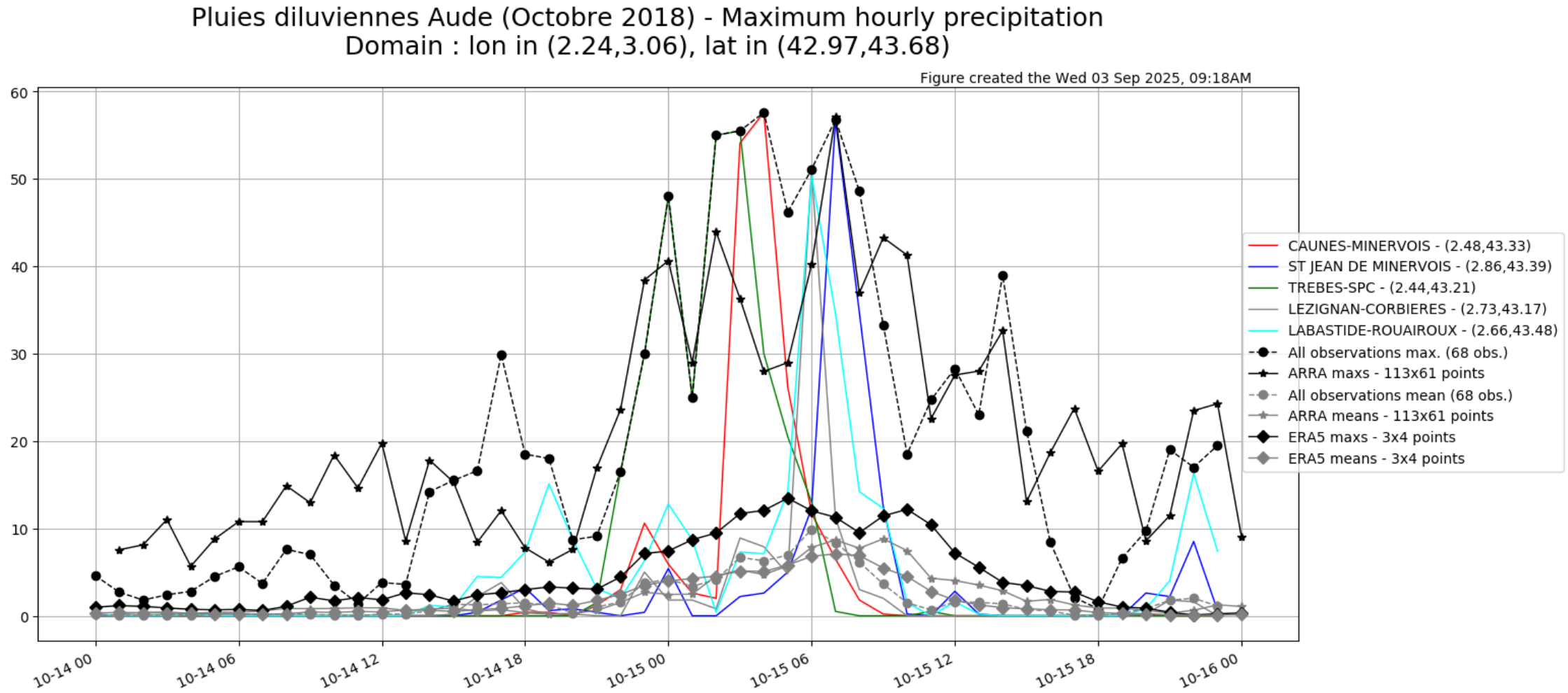
Clear improvement with ARRA for the model accumulated precipitation thanks to the kilometric scale.
ARRA is almost better than CERRA-Land (precipitation analysis ~ 5km)

Aude 14/15 October 2018



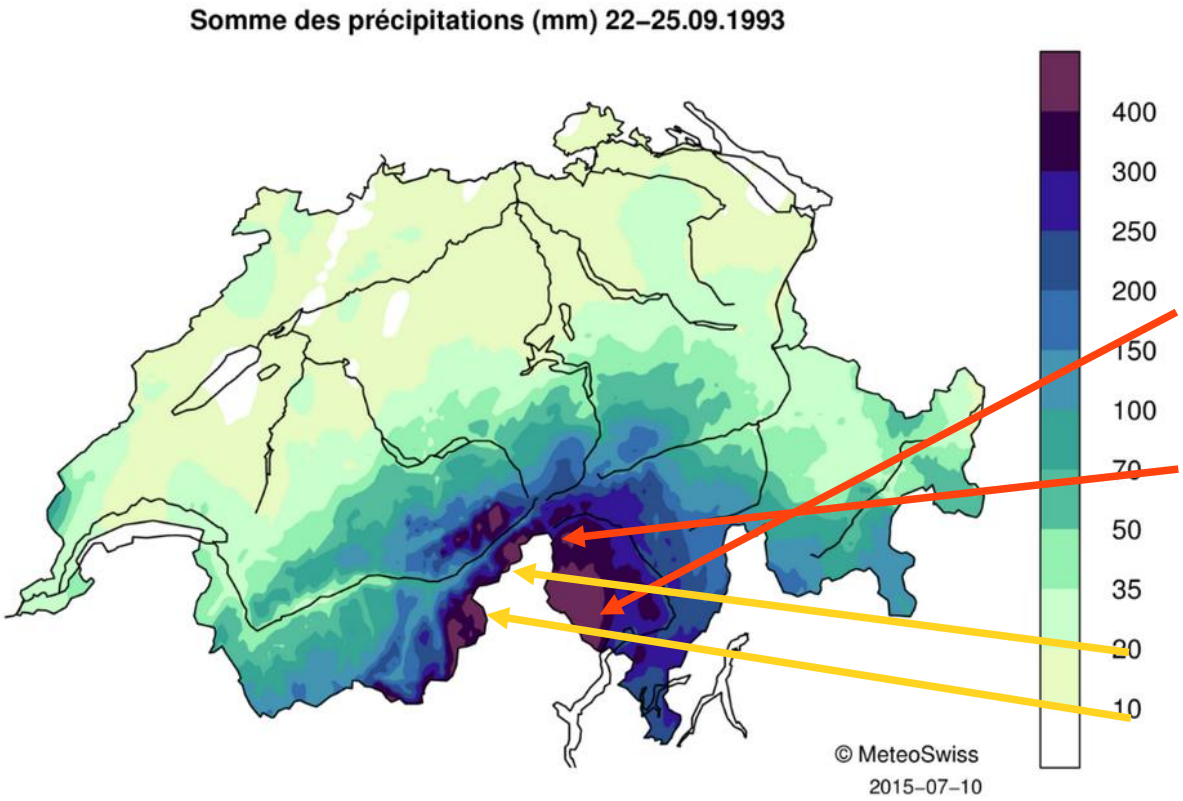
Clear improvement with ARRA for the model accumulated precipitation thanks to the kilometric scale
ARRA-Land-v0 is better than CERRA-Land (precipitation analysis ~ 5km)
However, QC for the rain gauge must be improved especially to remove the clogged one

Aude 2018



Rainfall intensity significantly improved with ARRA in good agreement with observations

Extreme precipitation in Switzerland 22-25 September 1993

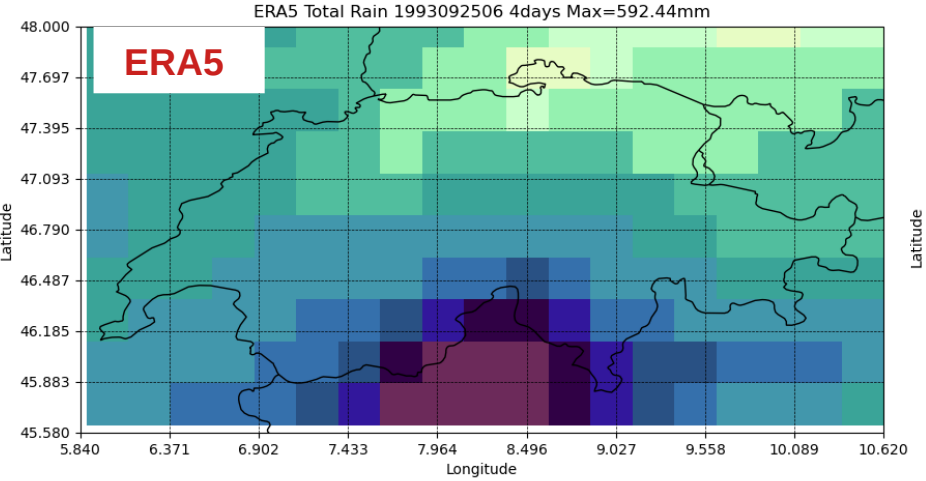


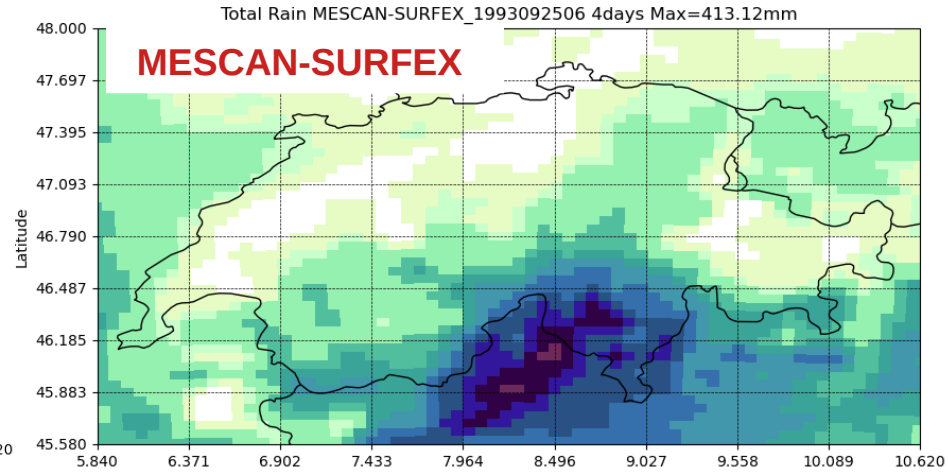
Cumul des précipitations sur 4 jours entre le 22 et le 25 septembre 1993

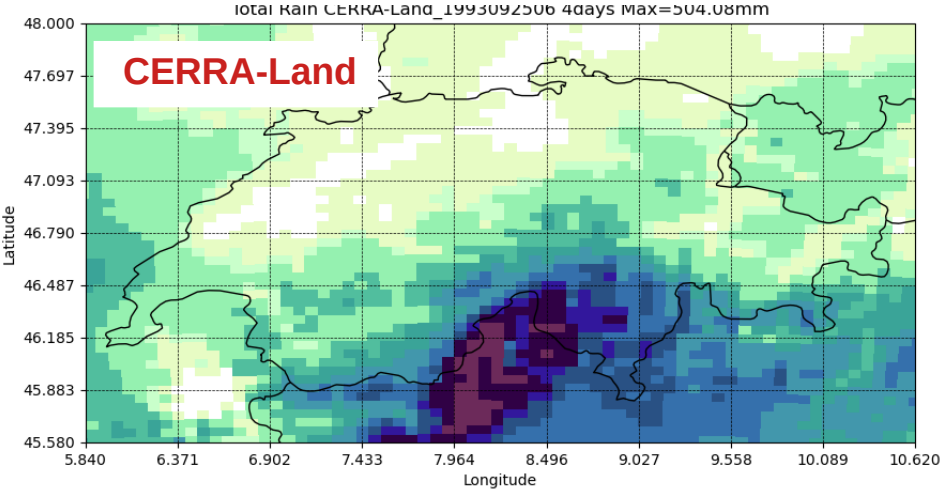
Station	Area	Acc. 4 days
Mosogno	Tessin	544.3
Càmedo	Tessin	543.8
Cevio	Tessin	478.6
Bosco-Gurin	Tessin	445.1
Binn	Haut-Valais	381.4
Simplon-Dorf	Haut-Valais	374.8

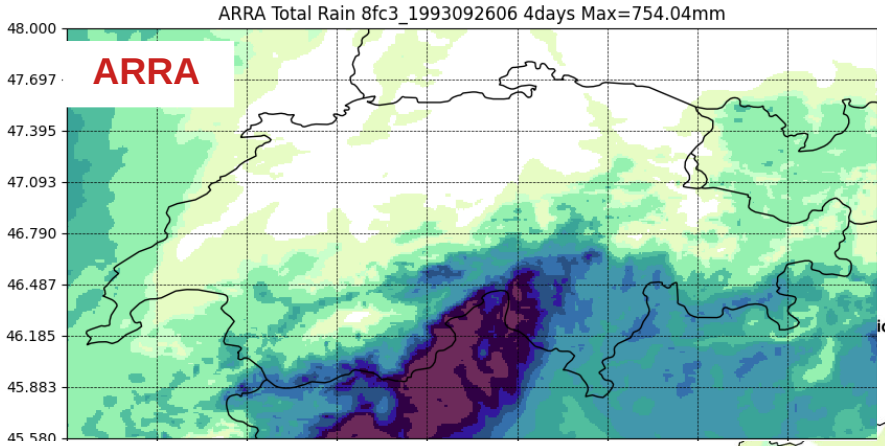
Source : www.meteosuisse.admin.ch

Extreme precipitation in Switzerland 22-25 September 1993

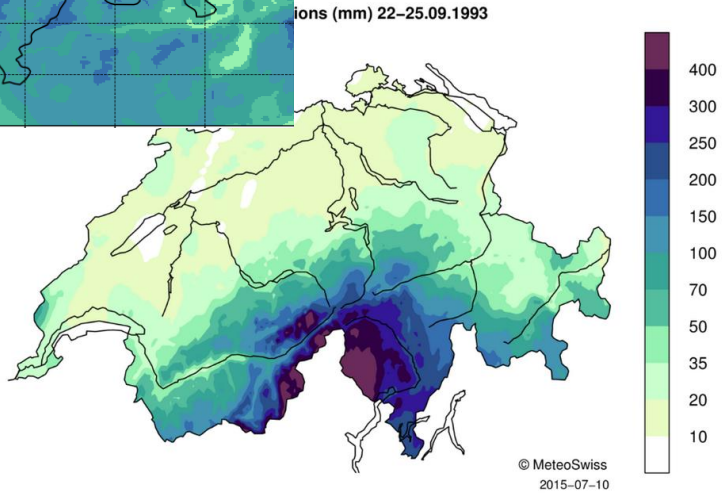






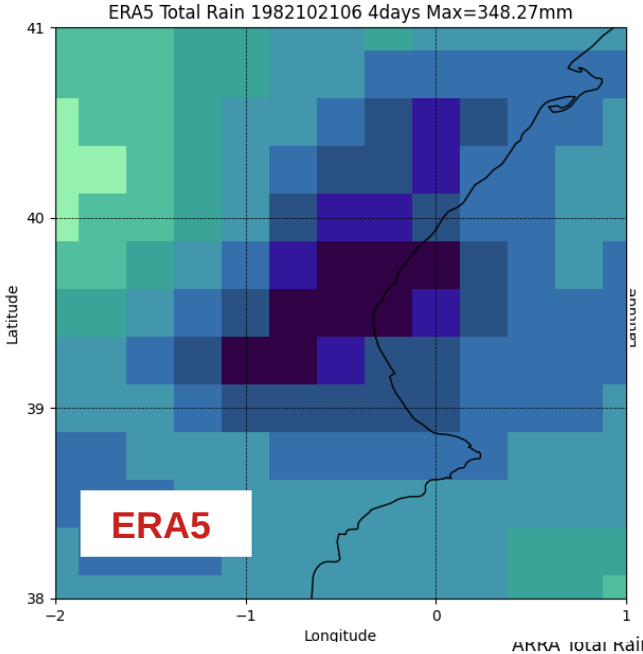


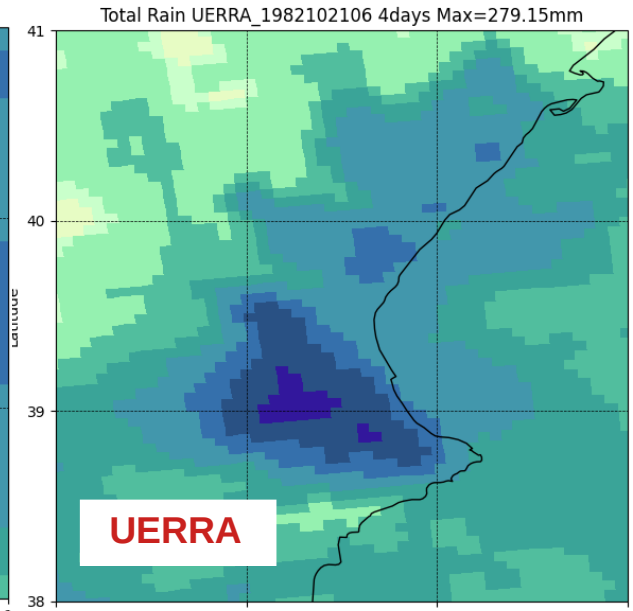
Higher precipitation with ARRA may be overestimated but no observations in the Italy side ..

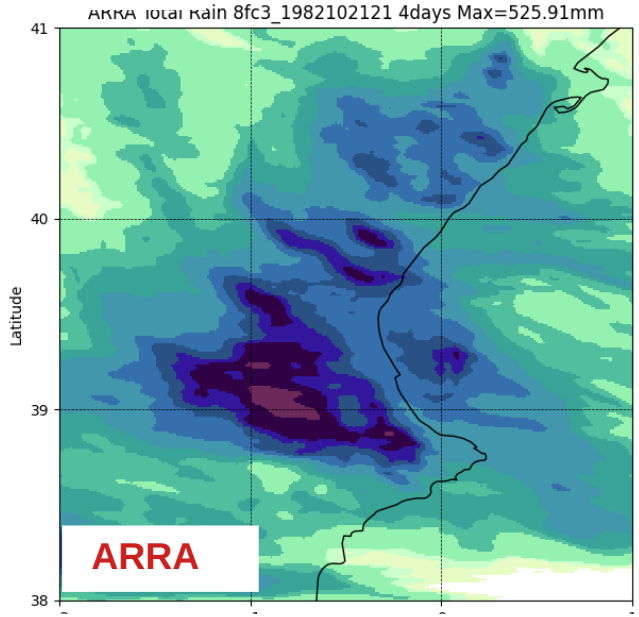


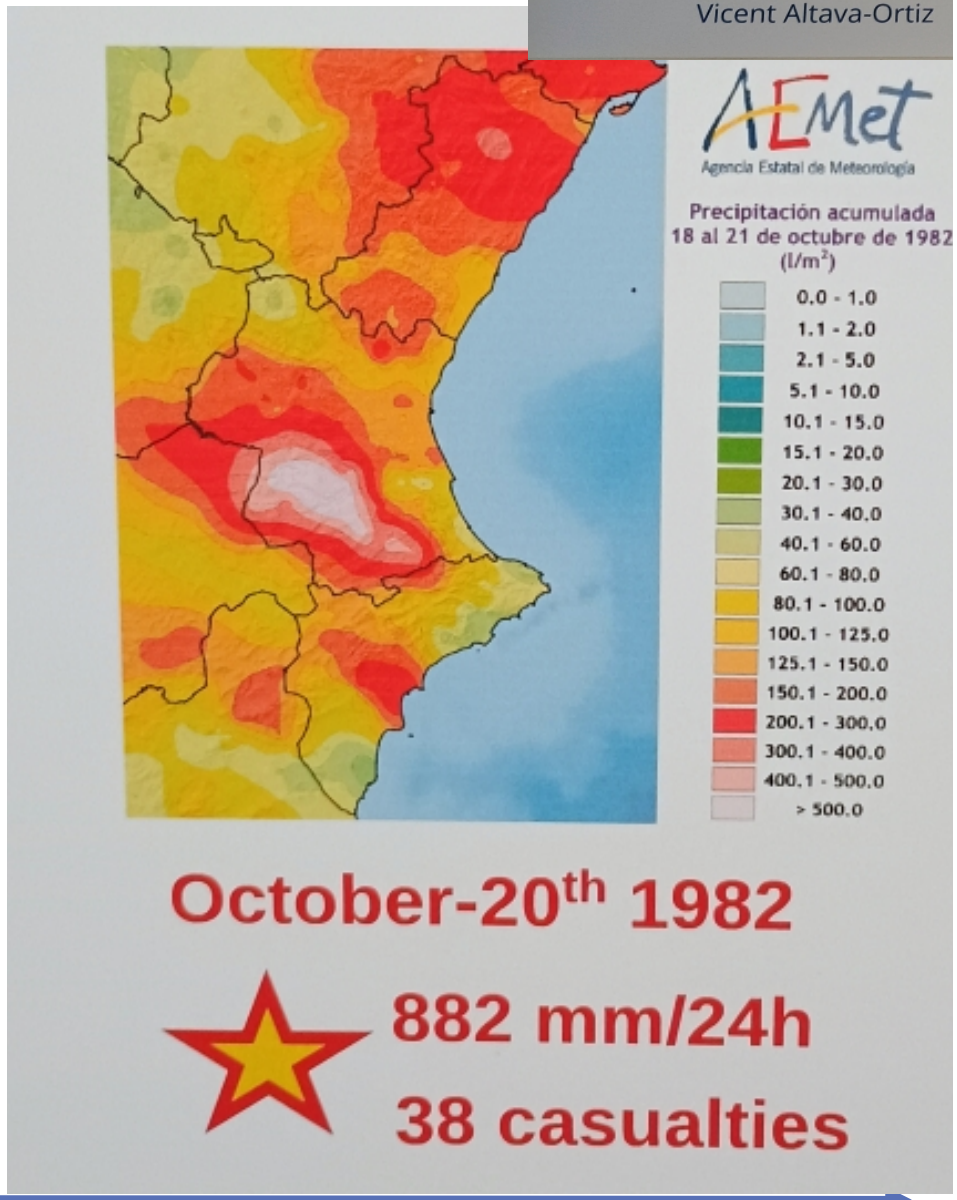
Cumul des précipitations sur 4 jours entre le 22 et le 25 septembre 1993

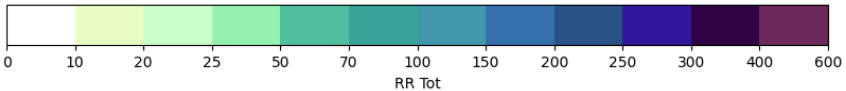
Extreme case in Spain: 20th October 1982











Conclusions:

ARRA

- Clear added value of the kilometric ARRA reanalysis (without radar nor upper air assimilation) for several extreme precipitation cases, as expected because AROME resolves explicitly convection. More extreme cases to be studied.

- ARRA is able to simulate accurate extreme intensity rainfall:
  - Is it confirmed along the 60-yr reanalysis time period?
  - Is there an increase in the frequency of such events?

- ARRA reanalysis is already used at Meteo-France for kilometre-scale AI applications

ARRA-Land

- Daily precipitation analysis: preparation of the 24h accumulated background field (choice of the best option for the background field)
- Offline land surface model SURFEX configuration is ready:
  - Advanced physics: ISBA soil diffusion scheme, explicit snow scheme, 12 patches, TEB, FLake
- Production will start in November and will be finished mid-2026 (one stream from1/1/1961)

ARRA and ARRA-Land production will continue to catch up with near real time thanks to the continuation of the CERRA reanalysis (CERRA-TU C3S project) up to mid 2027