Universitat de les Illes Balears

EGU General Assembly 2020

NH1.6 – Extreme meteorological and hydrological events induced by severe weather and climate change

Ensemble generation strategies for the short-range forecast of flash floods: the 12-13 September 2019 event in Eastern Spain

A. Hermoso, V. Homar, A. Amengual

Meteorology Group, Physics Department, University of the Balearic Islands, Palma de Mallorca, Spain

alejandro.hermoso@uib.es

Introduction

- The **Eastern Mediterranean** region is frequently affected by severe weather, and especially **heavy precipitation and flash flooding**.

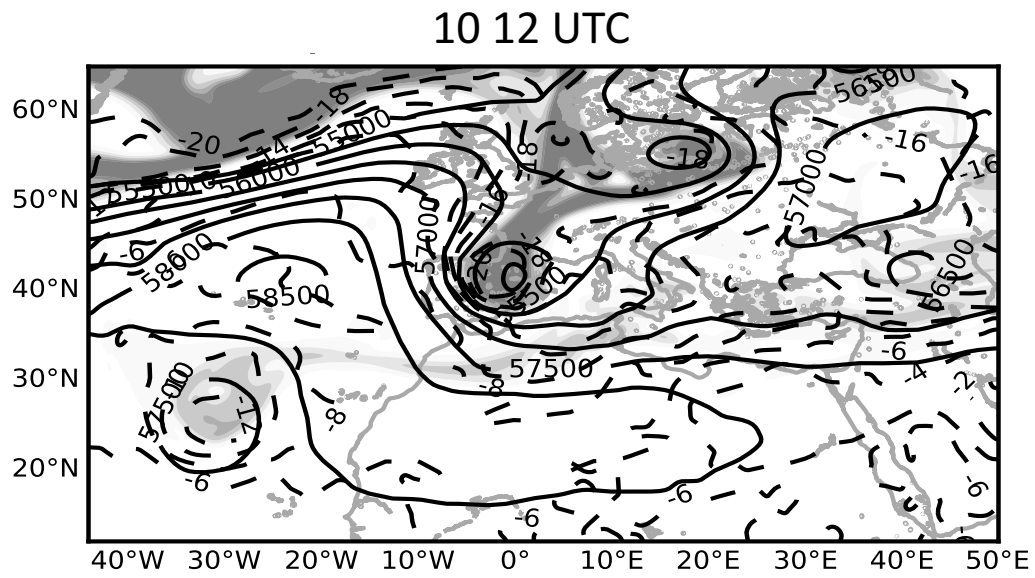
- The episode of **Valencia, Murcia and Almeria** of **11-14 September 2019** is a remarkable example for various reasons: precipitation amounts, duration and wide-spread and complex hydrological response.

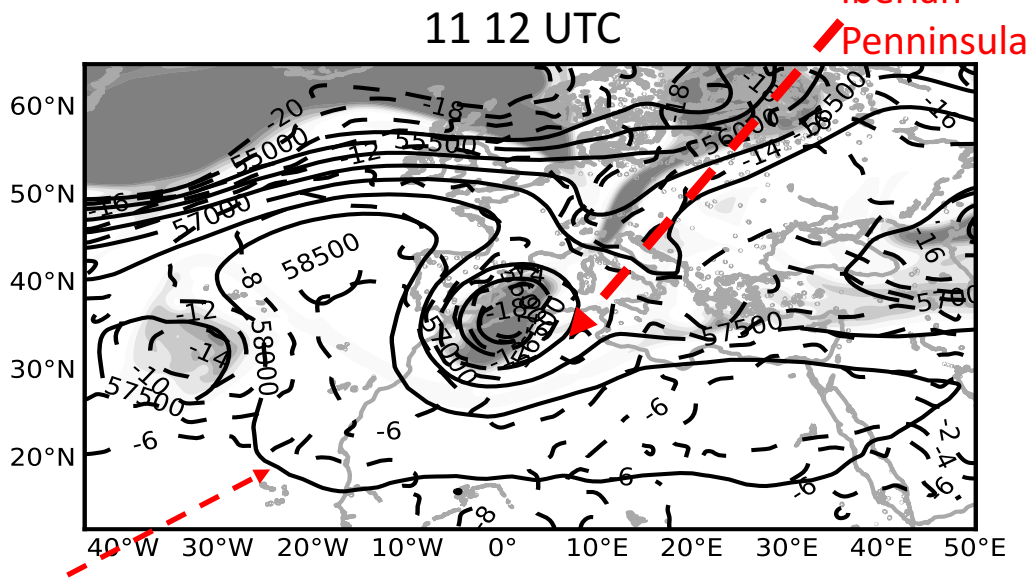
- Total accumulated **precipitation over 500 mm** in 4 days.

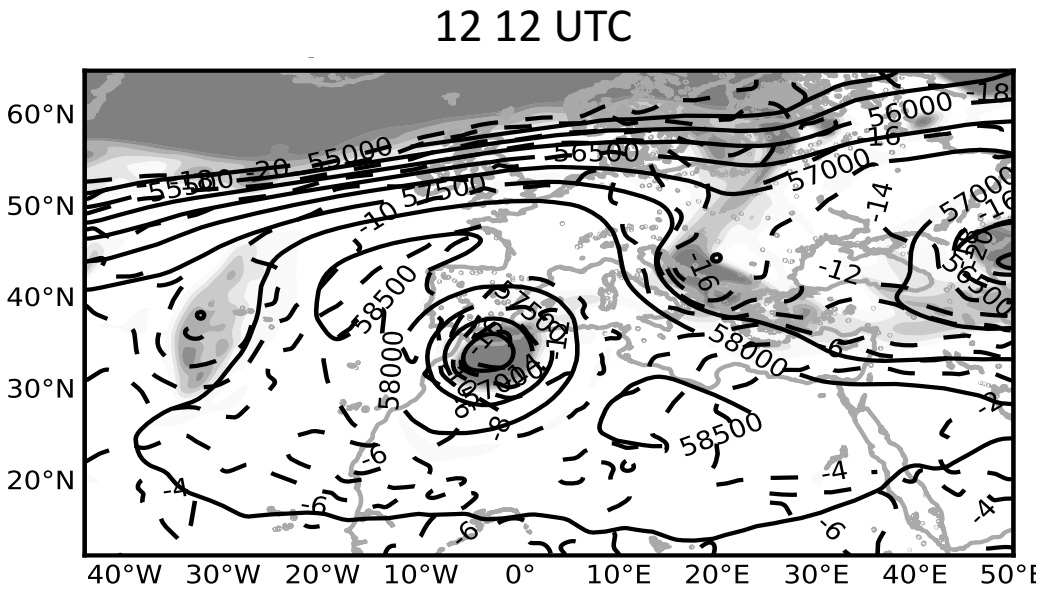
- The episode produced devastating effects including **seven fatalities** and estimated **economical losses of 200 M€**.

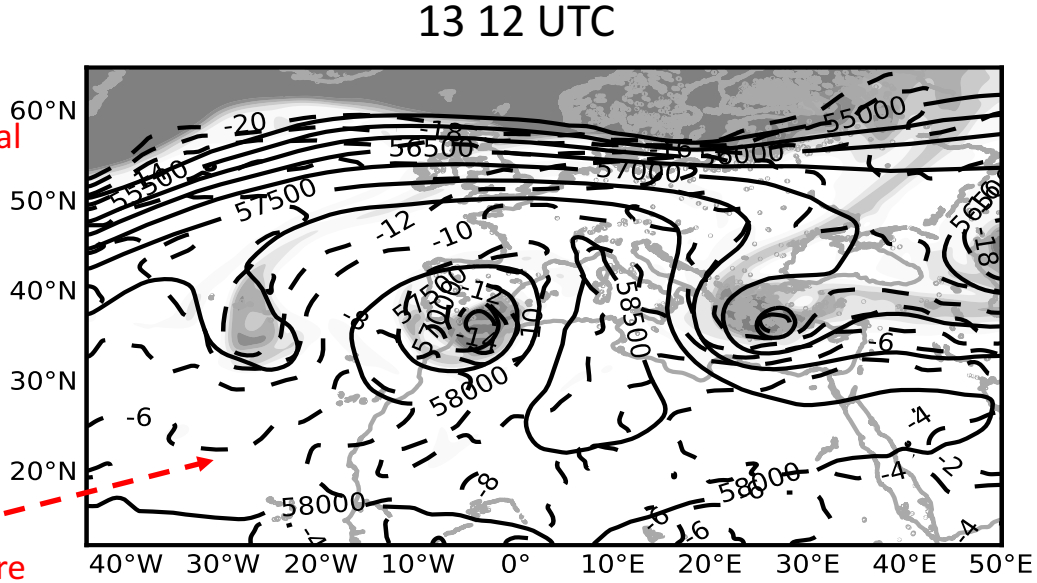
Upper levels synoptic situation

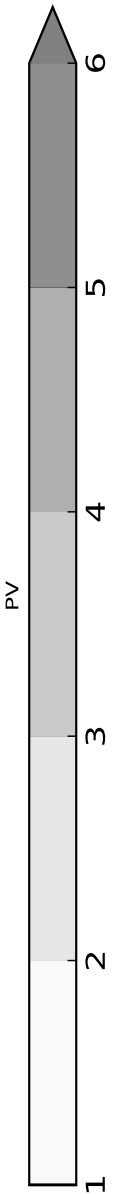
Upper level cold cut-off digging south of the Iberian Penninsula









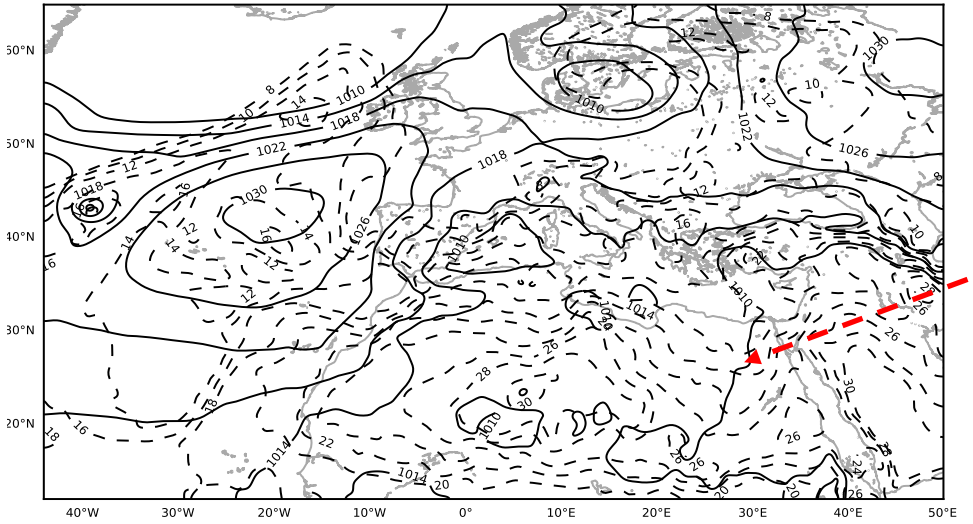


500 hPa Geopotential (solid)

500 hPa Temperature (dashed)

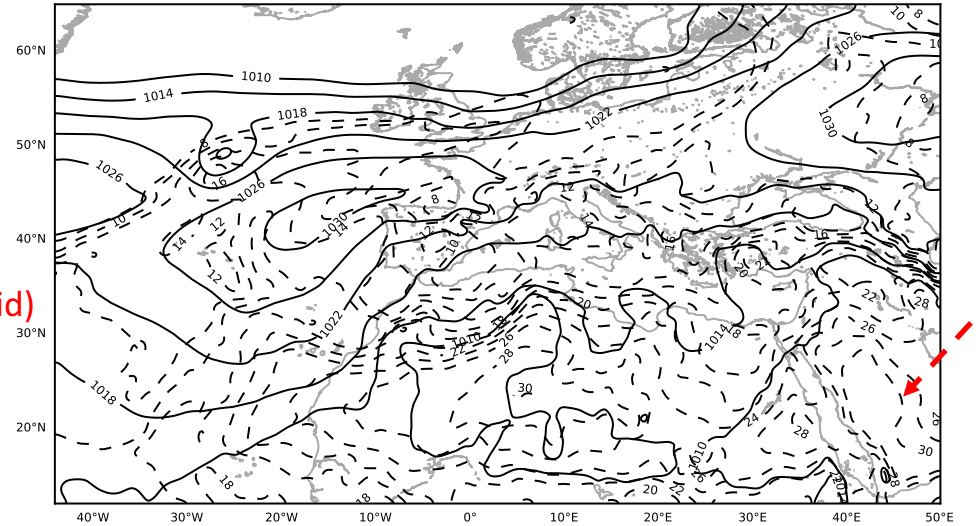
Low levels synoptic situation

10 12 UTC



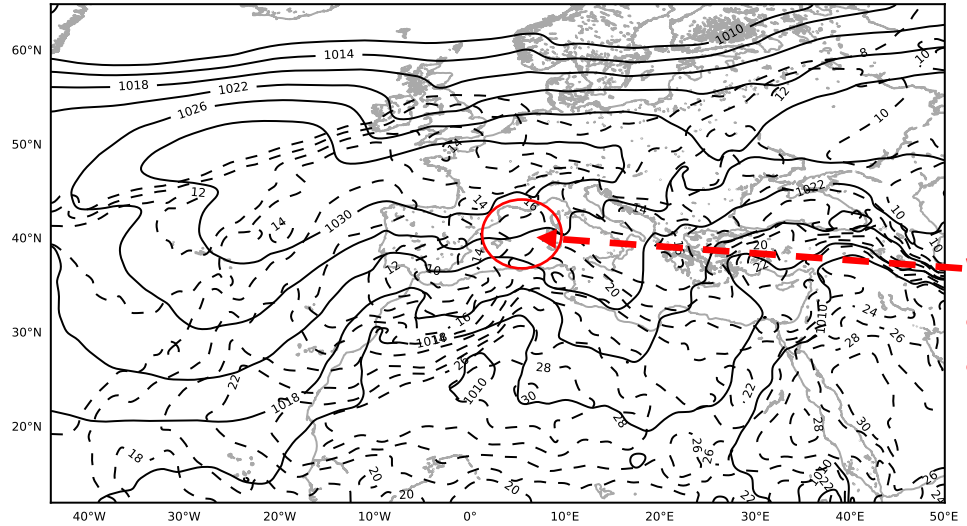
Sea level pressure (solid)

11 12 UTC



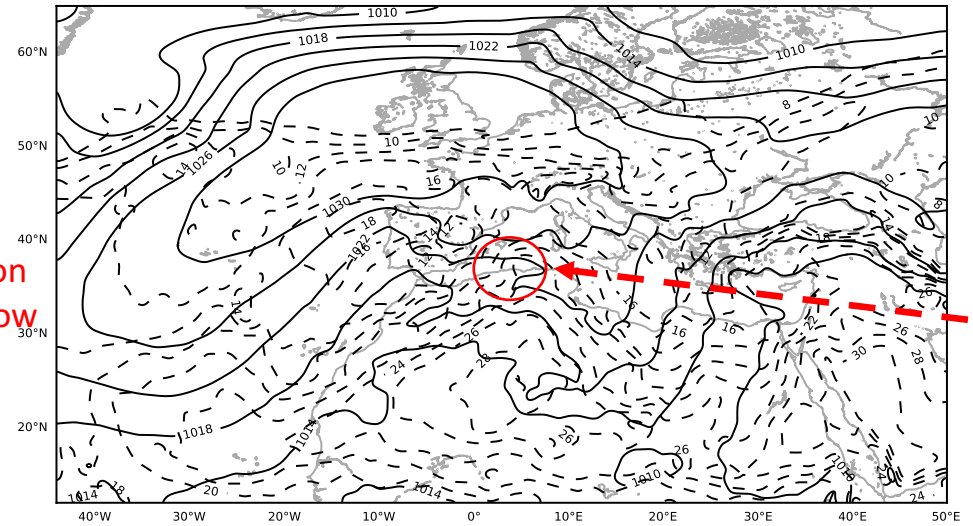
850 hPa temperature (dashed)

12 12 UTC



Warm advection and easterly flow at low levels

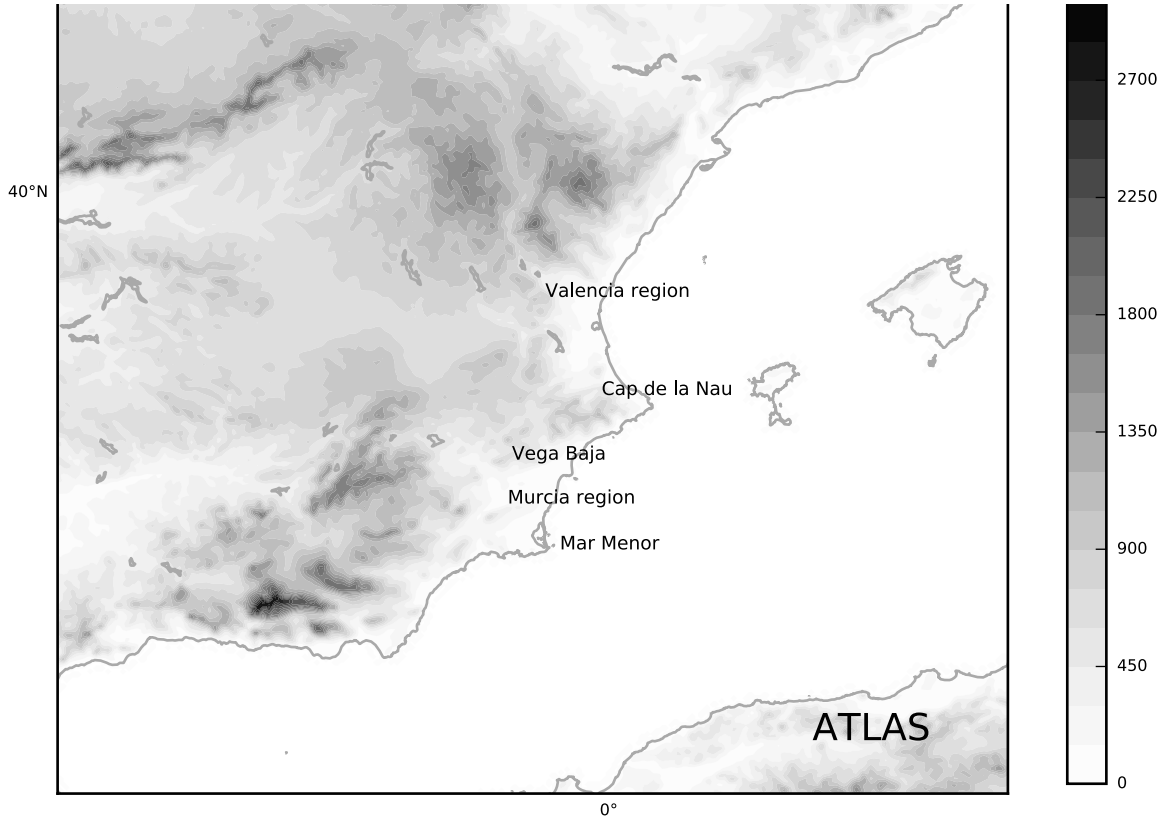
13 12 UTC



Orographic pressure perturbation

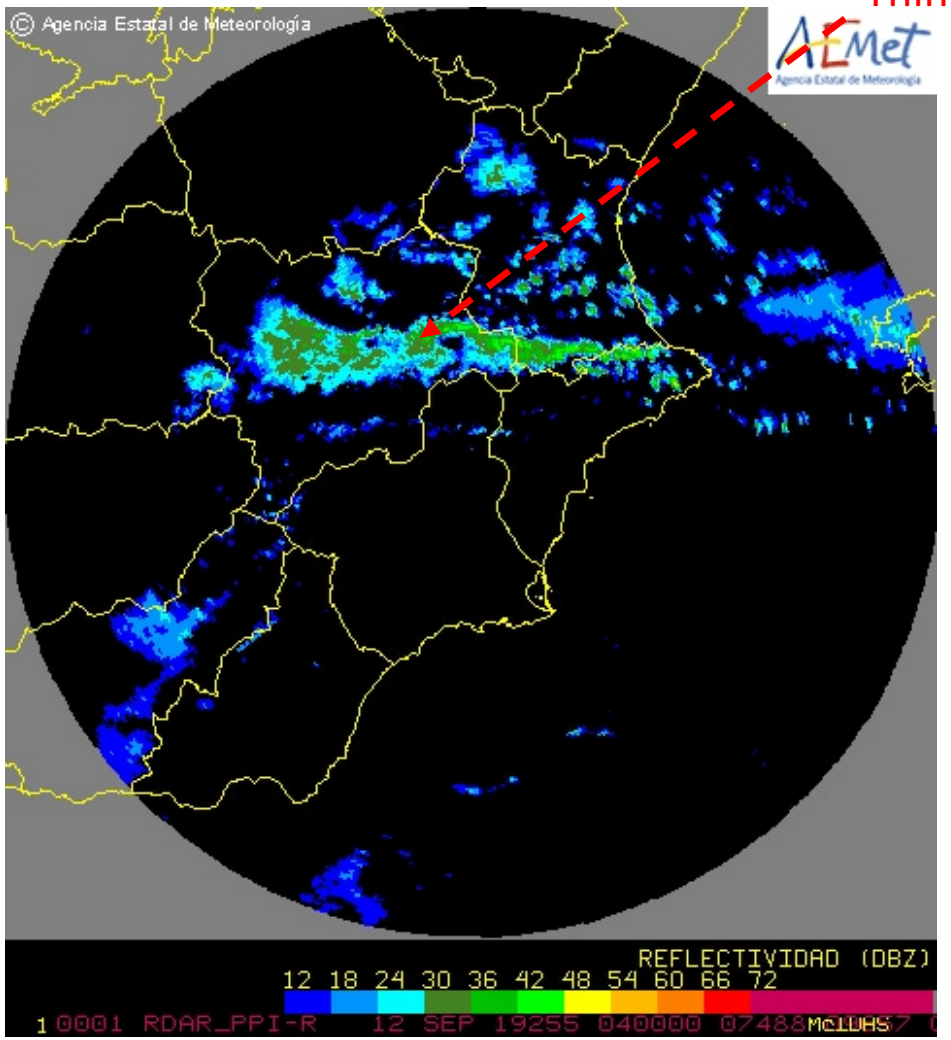
Episode phases

- The precipitation of the episode can be divided in **three phases**:
  - **Phase 1:** Thin line of convection around Cap de la Nau
    - 12 September 00-06 UTC
    - 6h precipitation accumulations > 200 mm
  - **Phase 2:** Linear precipitation structure at Vega Baja
    - 12 September 06-12 UTC
    - Precipitation accumulations > 200 mm in 2 hours
  - **Phase 3:** Precipitation associated to a mesoscale convective system in Murcia
    - 12 September 22 UTC-13 September 07 UTC
    - Hourly intensities > 100 mm

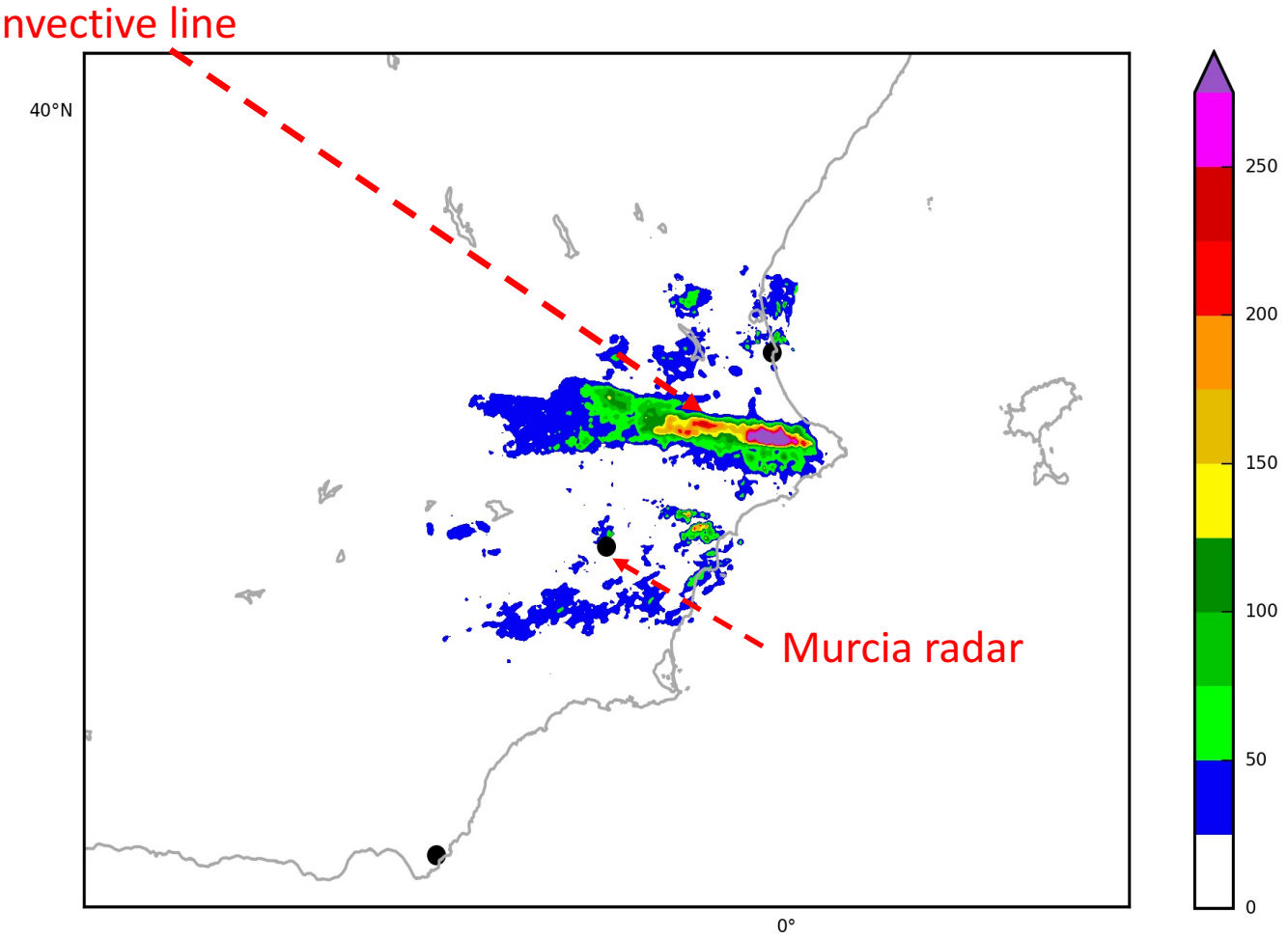


Map with geographical locations mentioned

Phase 1



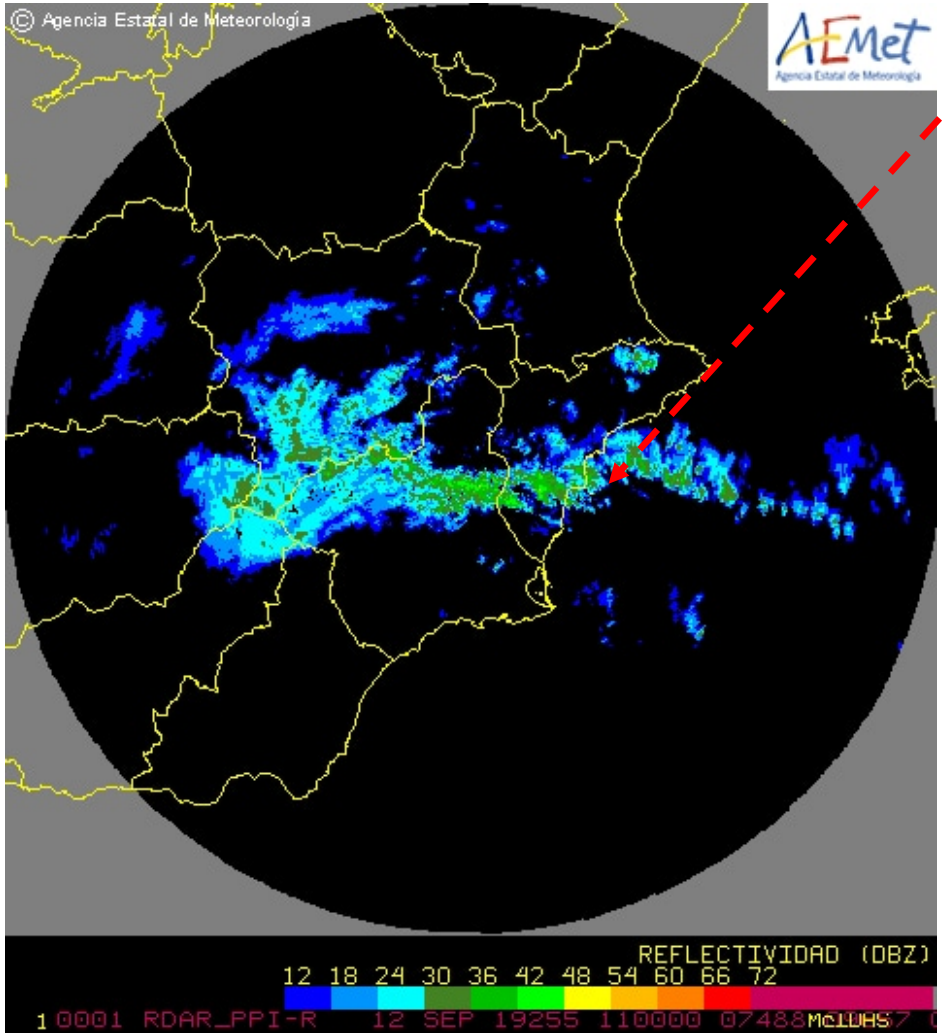
Murcia radar image
12 September 2019 04 UTC



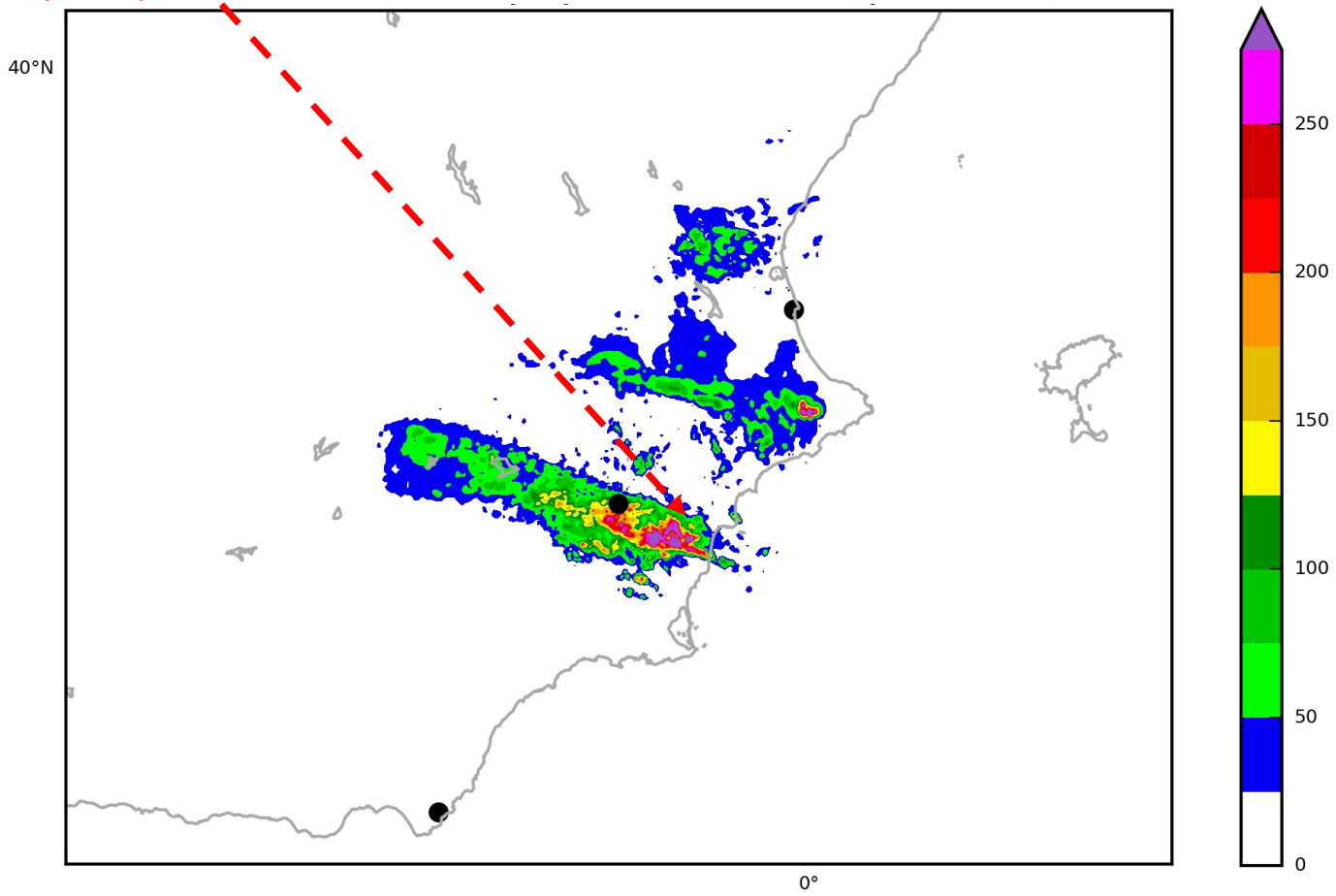
Radar estimated 12 September
00-06 UTC accumulated precipitation

Phase 2

Linear precipitation structure

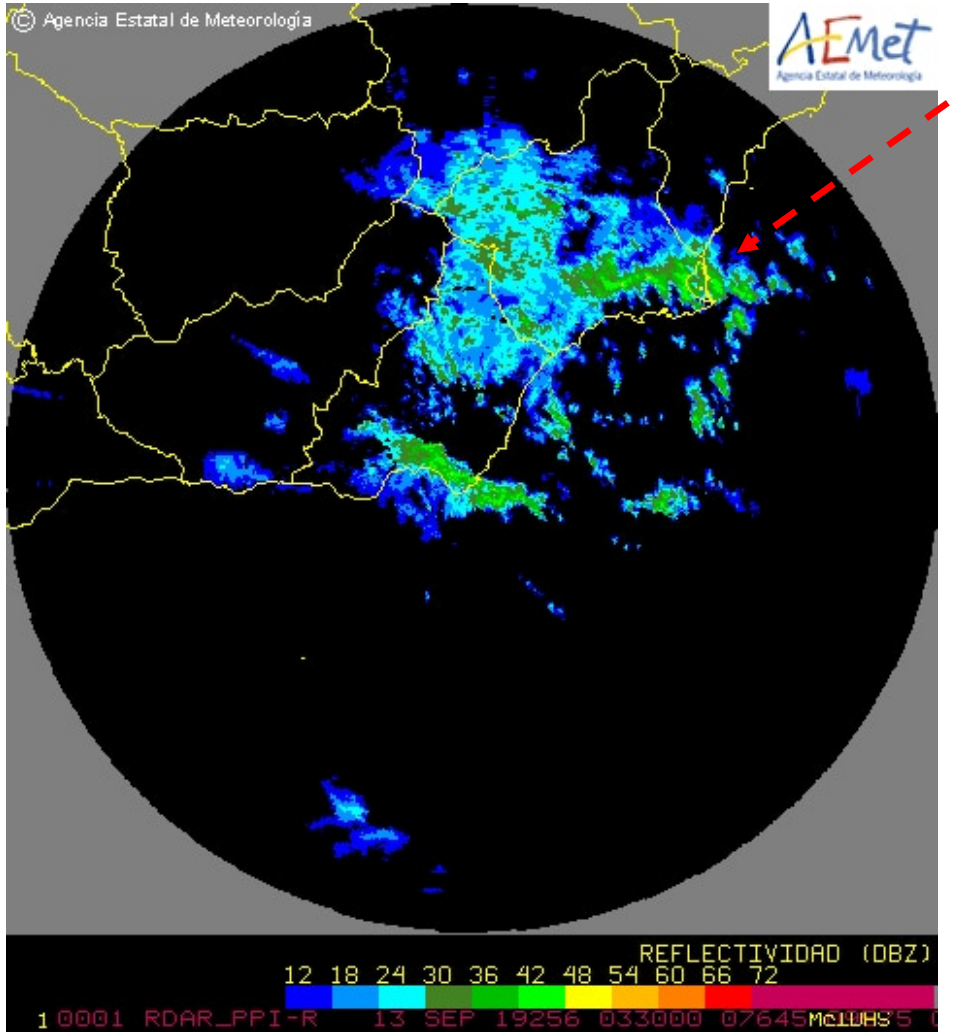


Murcia radar image
12 September 2019 11 UTC

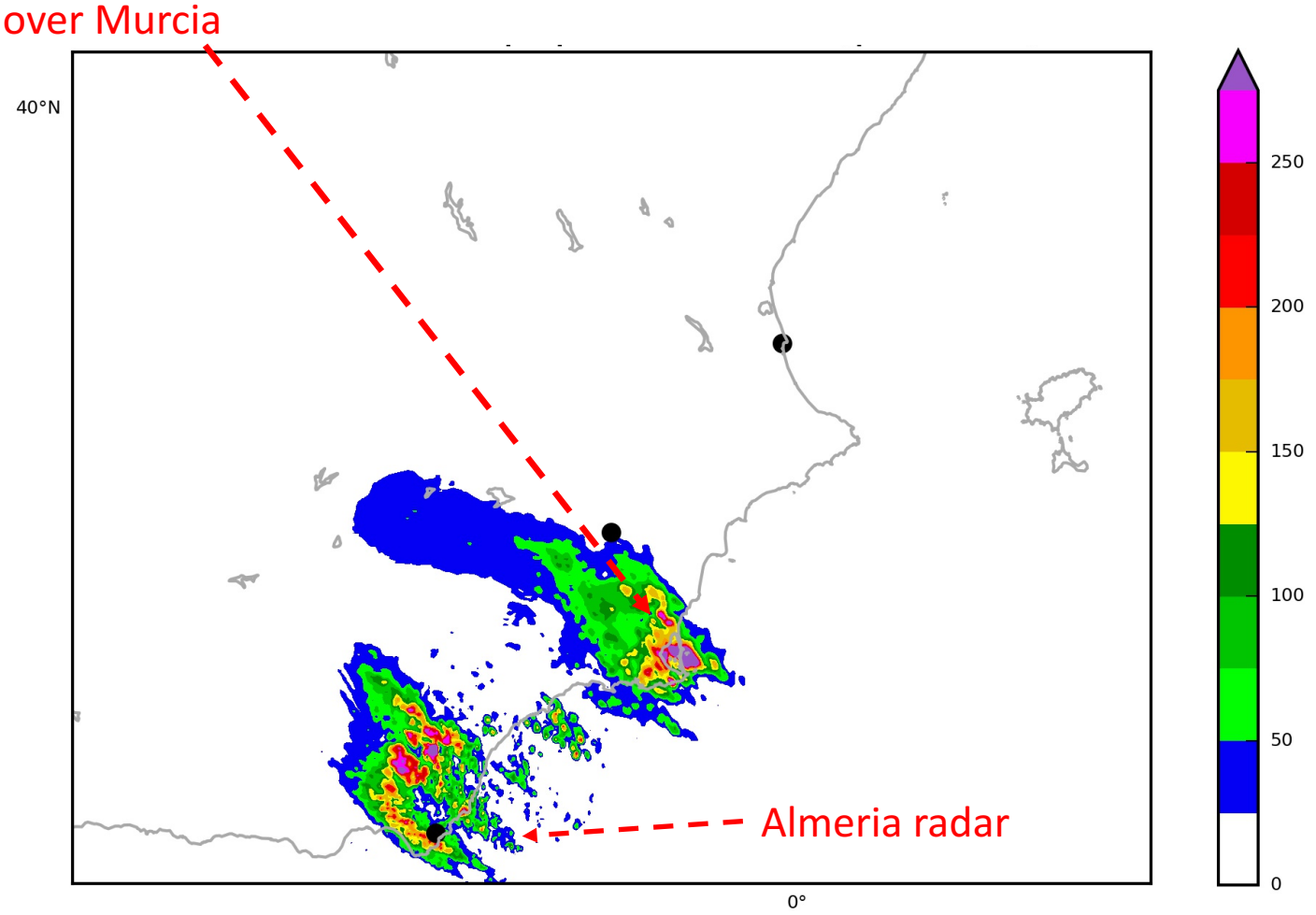


Radar estimated 12 September
06-12 UTC accumulated precipitation

Phase 3



Almeria radar image
13 September 2019 03:30 UTC



Radar estimated 13 September
00-06 UTC accumulated precipitation

Challenges for hydrometeorolgical forecasting

- Small-scale catchments in the area (100-1000 km^2) ➡ High numerical resolution required to produce accurate meteorological forecasts at catchment scale

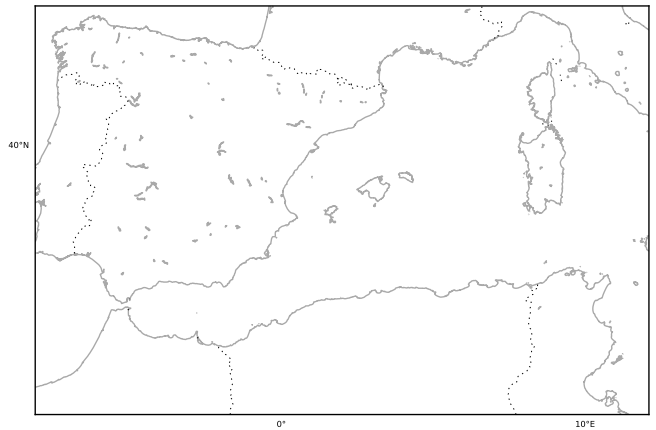
- Shorter predictability horizon for high resolutions.

- Long time span of heavy precipitation activity

- Complex convective structures linked to local factors, such as local orography (especially phases 1 and 2)

Meteorological set-up

- The model used is the WRF-ARW v3.9.1
- 2.5 km horizontal resolution and 50 vertical levels
- 30 h lead time (6 for spin-up and 24 effective)
- Initialization times: 11 September 18 UTC and 12 September 18 UTC
- 4 configurations of 50-member ensembles are designed:
  - DOWN: Downscaling of the 50 members of ECMWF-EPS (IC perturbation)
  - MPHYS: Downscaling of the 10 members of ECMWF-EPS with highest variability in the area chosen by means of a k-means clustering algorithm with different microphysics and PBL options (IC perturbation and model error)
  - SPPT: Same initial conditions of MPHYS with stochastic SPPT scheme (IC perturbation and model error)
  - BRED: Orthogonal and tailored (scale modified) bred vectors added to the unperturbed ECMWF-EPS member (IC perturbation)



Simulation domain

Precipitation verification

- Observational data provided by estimated precipitation from Valencia, Murcia and Almeria Doppler C-band radars. Data coming from 10-min reflectivity volume scans at 1 km resolution spanning and 12 elevations.

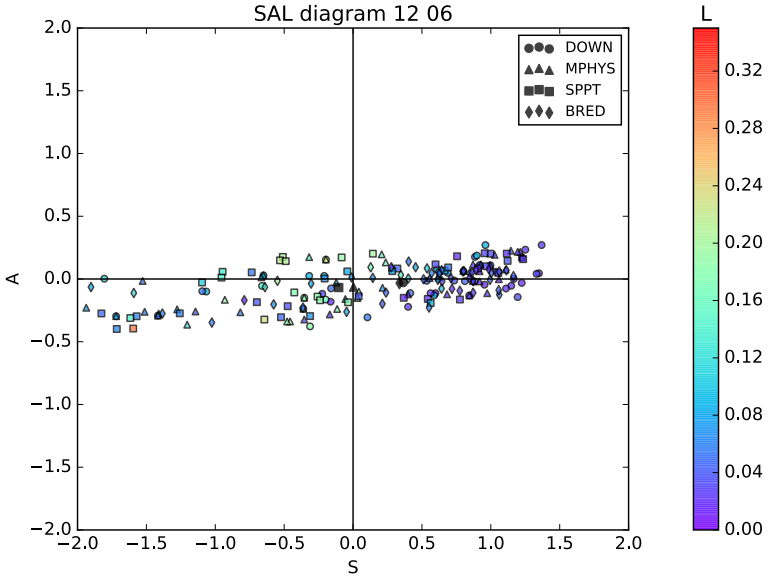
- Corrected radar errors: partial beam occlusion and signal attenuation

- Radar precipitation calibrated with rain-gauge data (369 automatic stations)

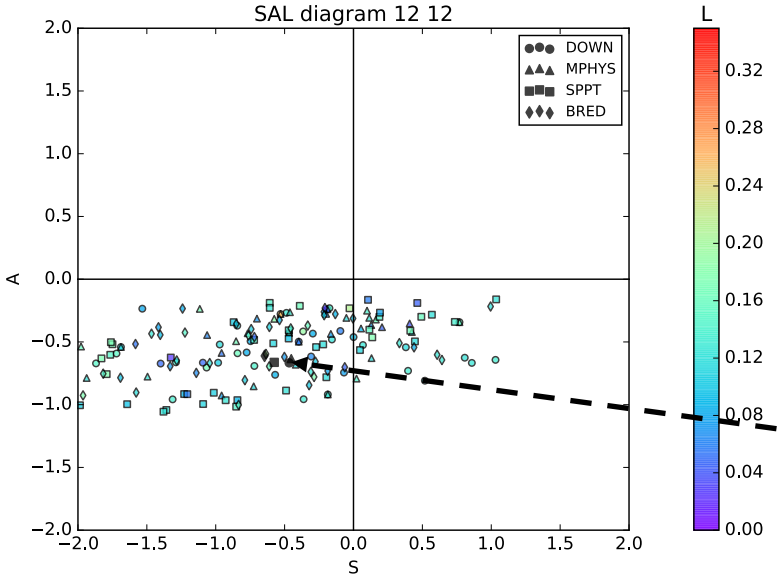
- Precipitation verification with SAL (Structure, Amplitude, Localization):

  - $S \subset [-2,2]$ $S < 0$ small or peaked objects, $S > 0$ too widespread precipitation
  - $A \subset [-2,2]$ $A < 0$ underestimation, $A > 0$ overestimation
  - $L \subset [0,2]$ Includes distance between centers of mass and distribution of objects

SAL 6h precipitation accumulations 12 September forecast

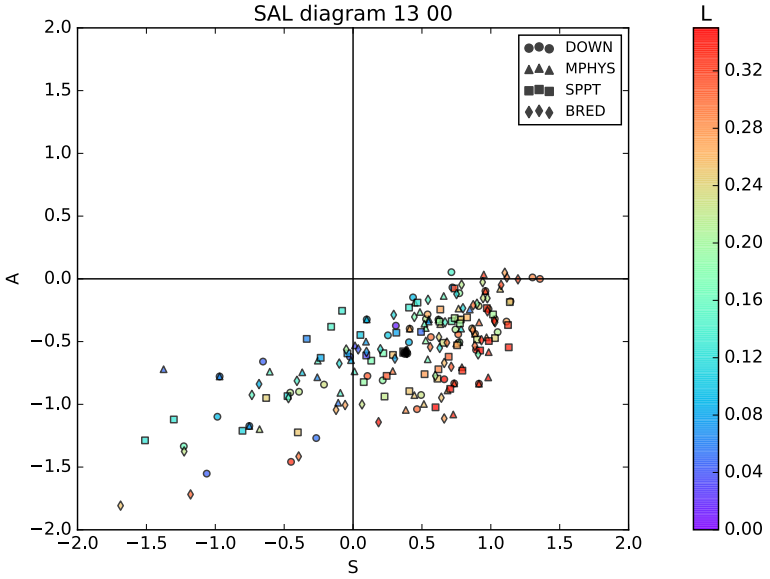


Phase 1



Phase 2

Ensemble means of S and A



Initial Phase 3

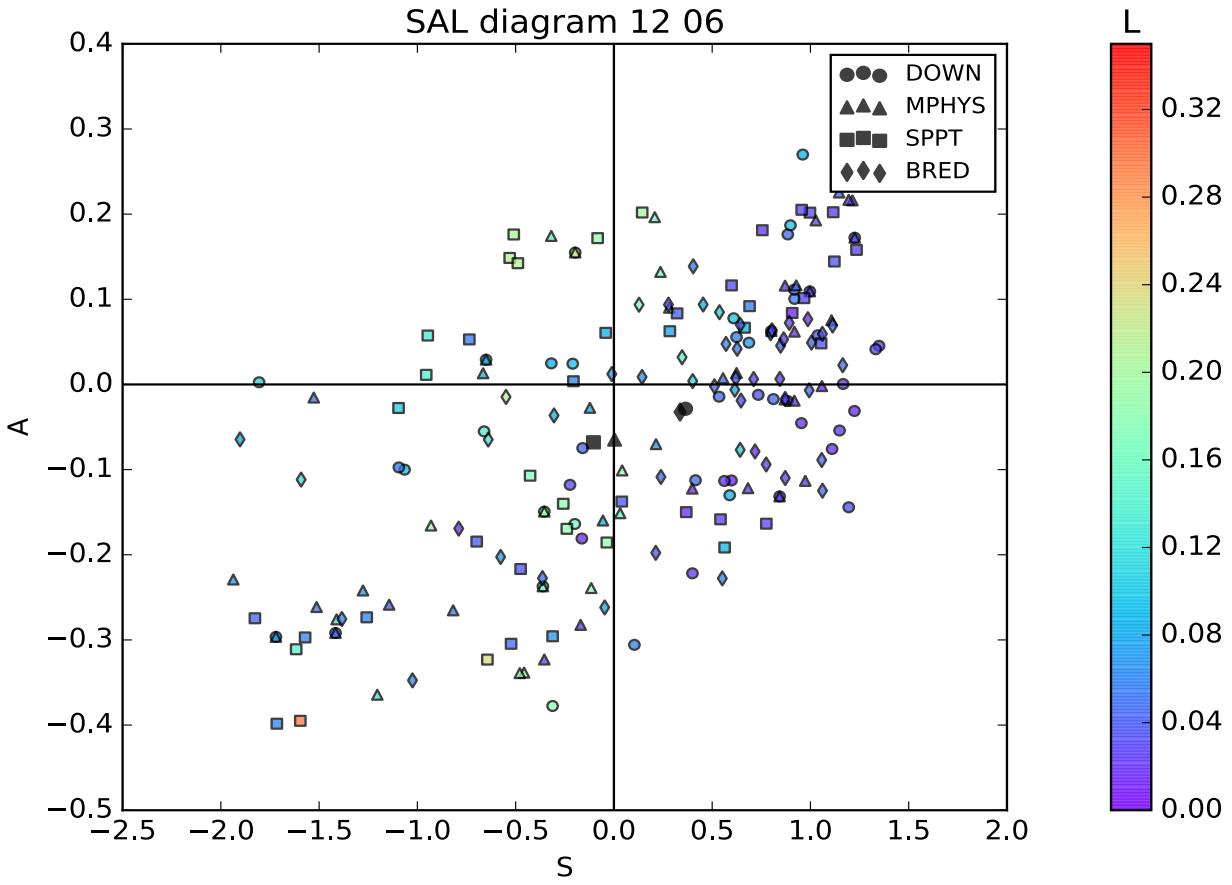
Loss of localization with lead time

Underestimation for phases 2 and 3

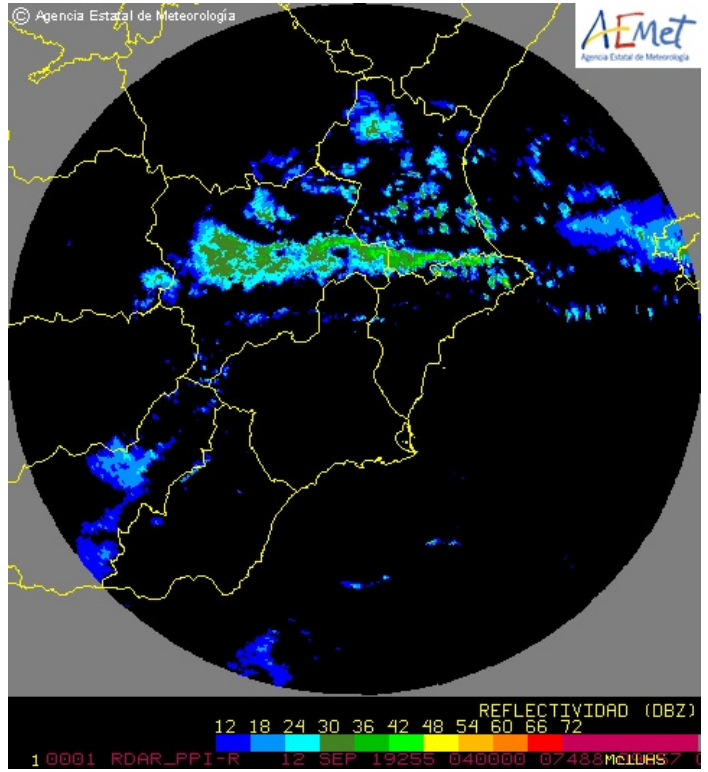
More widespread precipitation for phases 1 and 3

Similar performance of different ensembles

SAL 6h phase 1

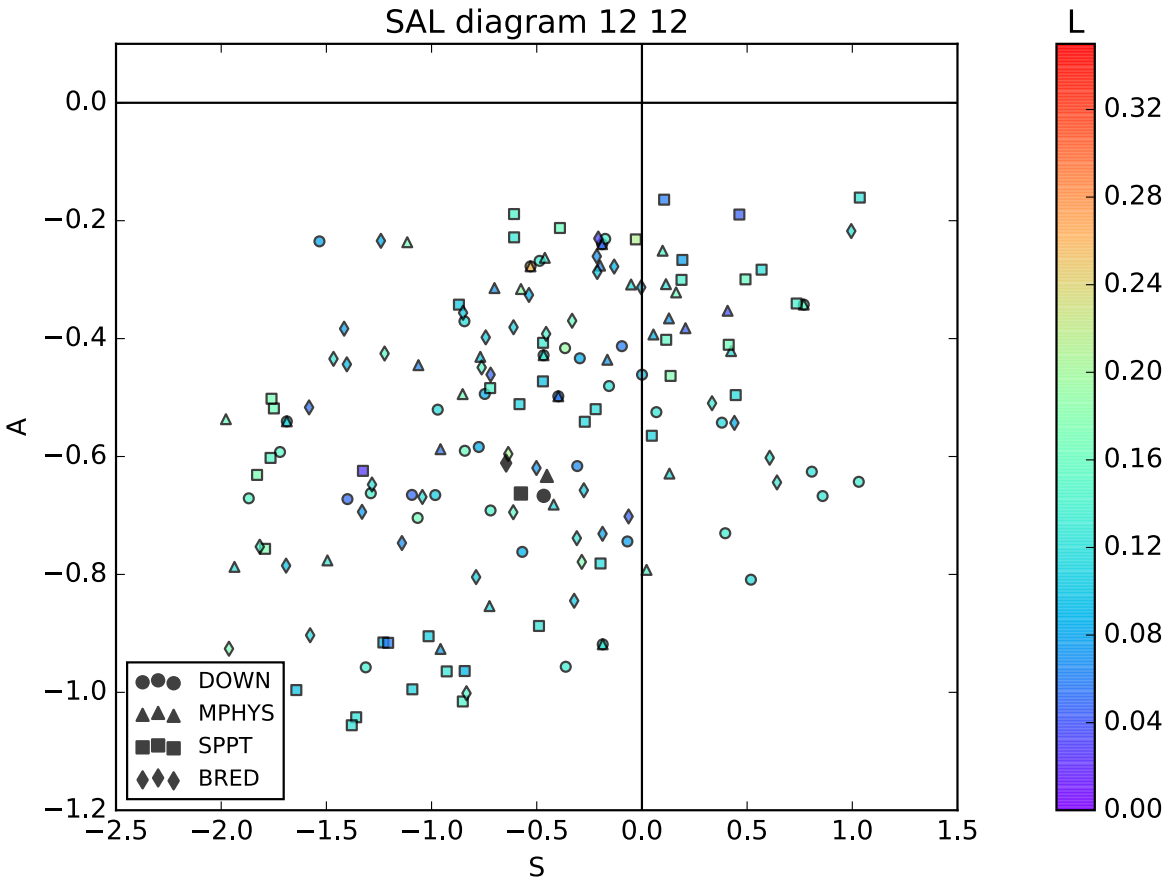


Good localization and
amplitude for most members



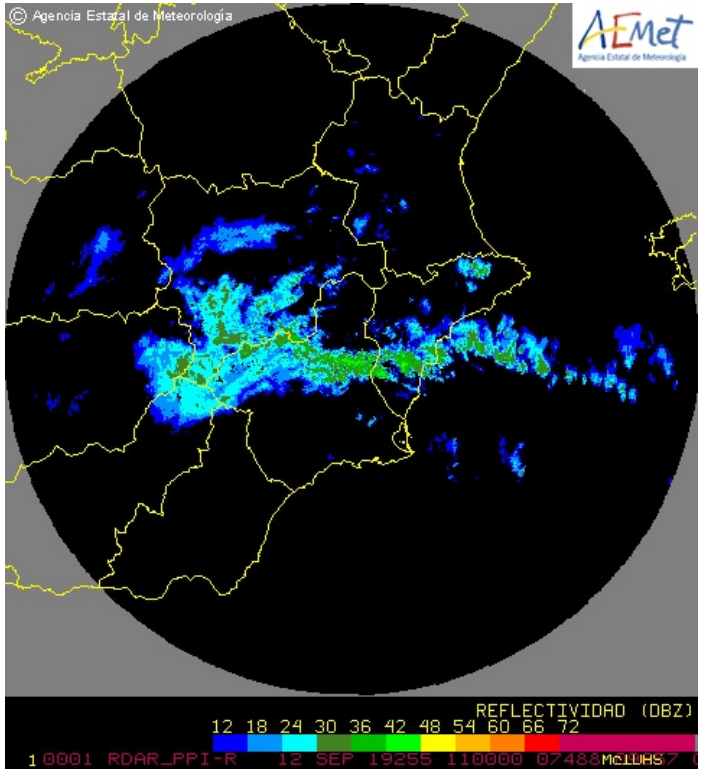
High values of structure
(thin line is not accurately simulated)

SAL 6h phase 2



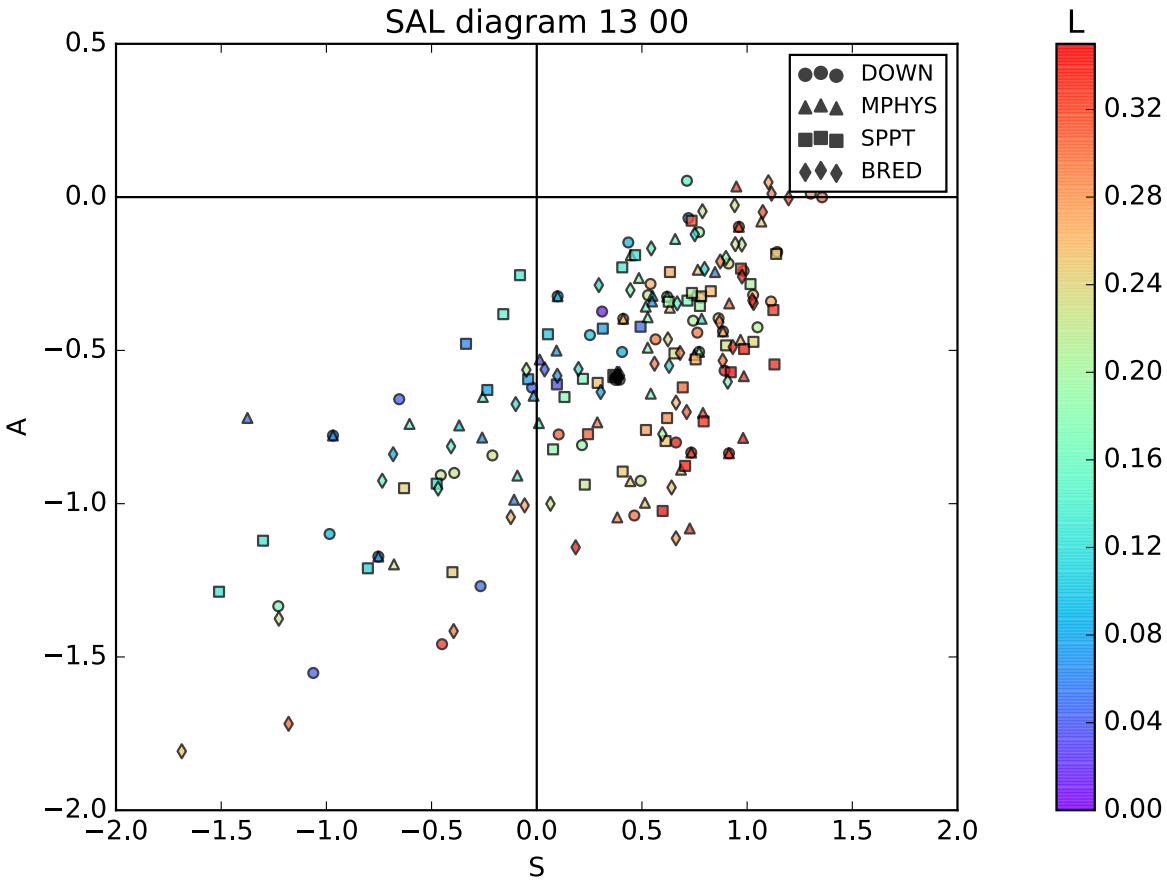
Poor performance of all ensembles

Underestimation of all ensemble members and high localization error



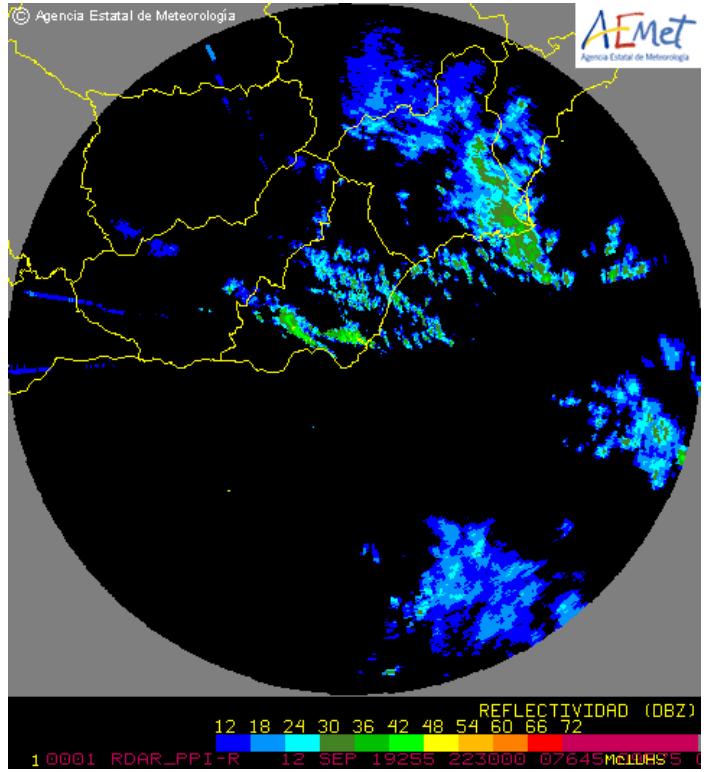
Loss of predictability for this phase after 18 h lead time

SAL 6h initial phase 3



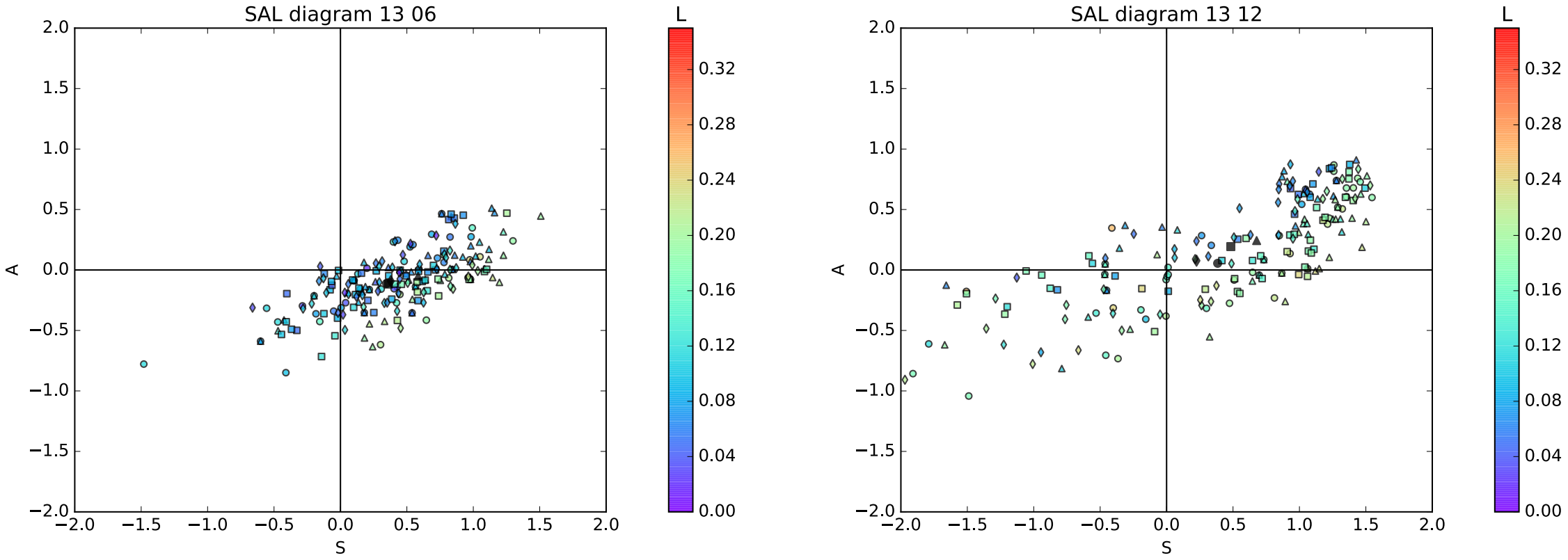
High localization errors

Underestimation of most ensemble members



Good performance of some individual members in terms of localization/structure or amplitude

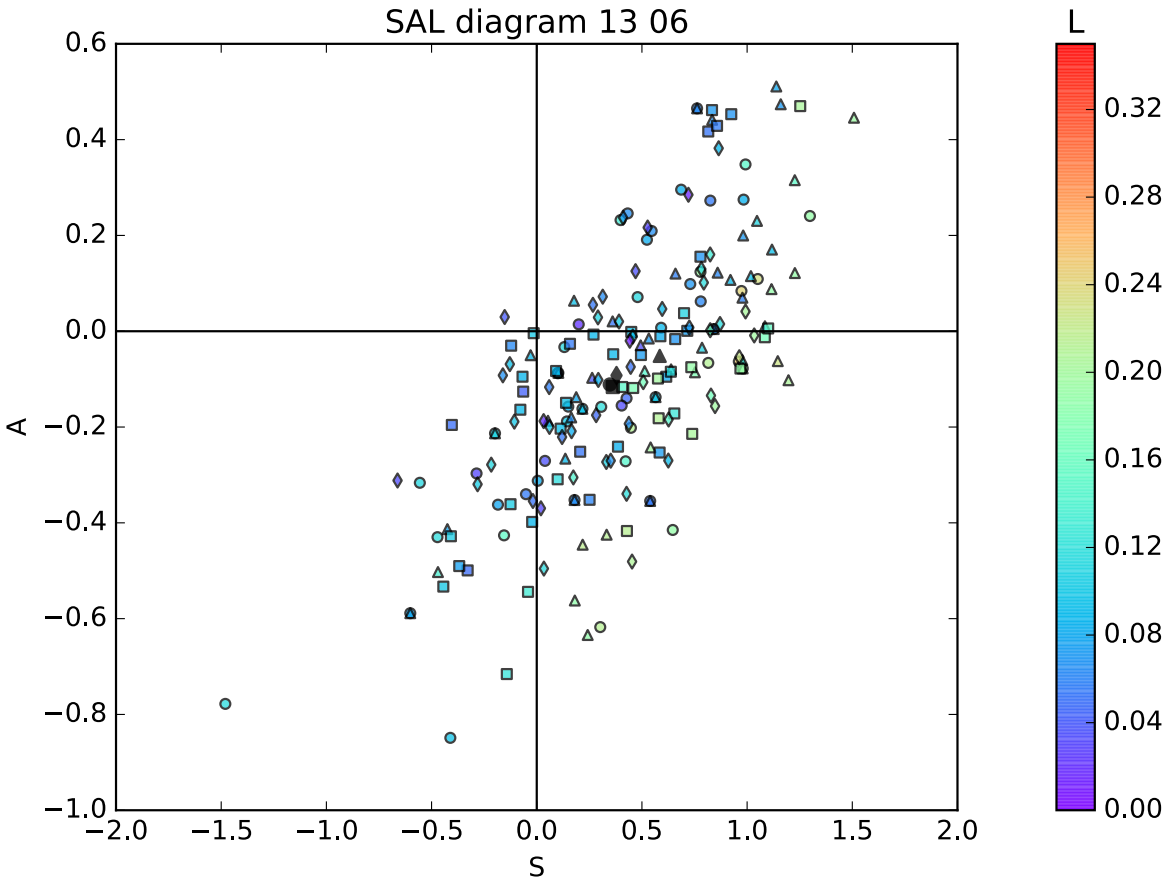
SAL 6h precipitation accumulations 13 September forecast (continuation of phase 3)



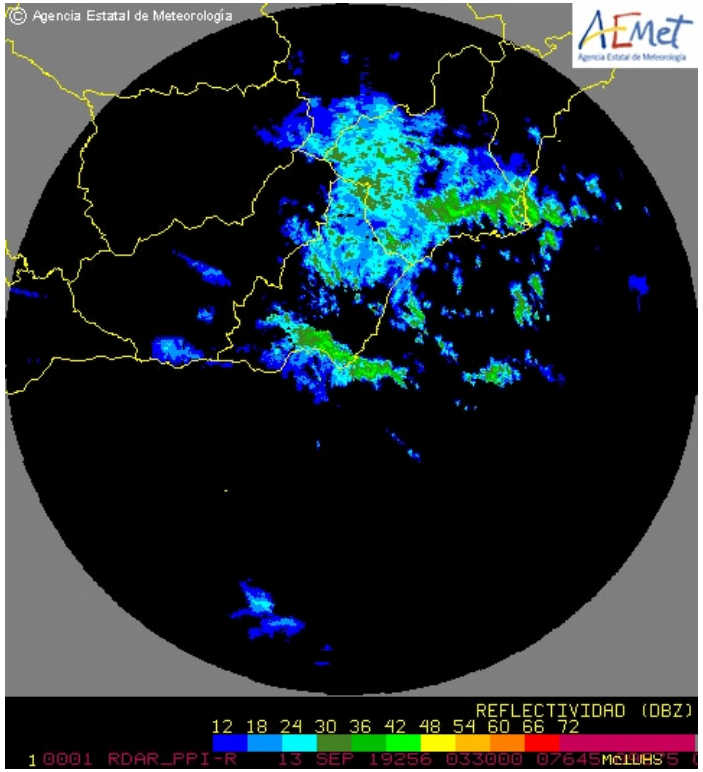
Accurate forecasts in terms of structure and amplitude

More extended precipitation structures are more accurately predicted than smaller structures (phases 1 and 2)

SAL 6h continuation phase 3

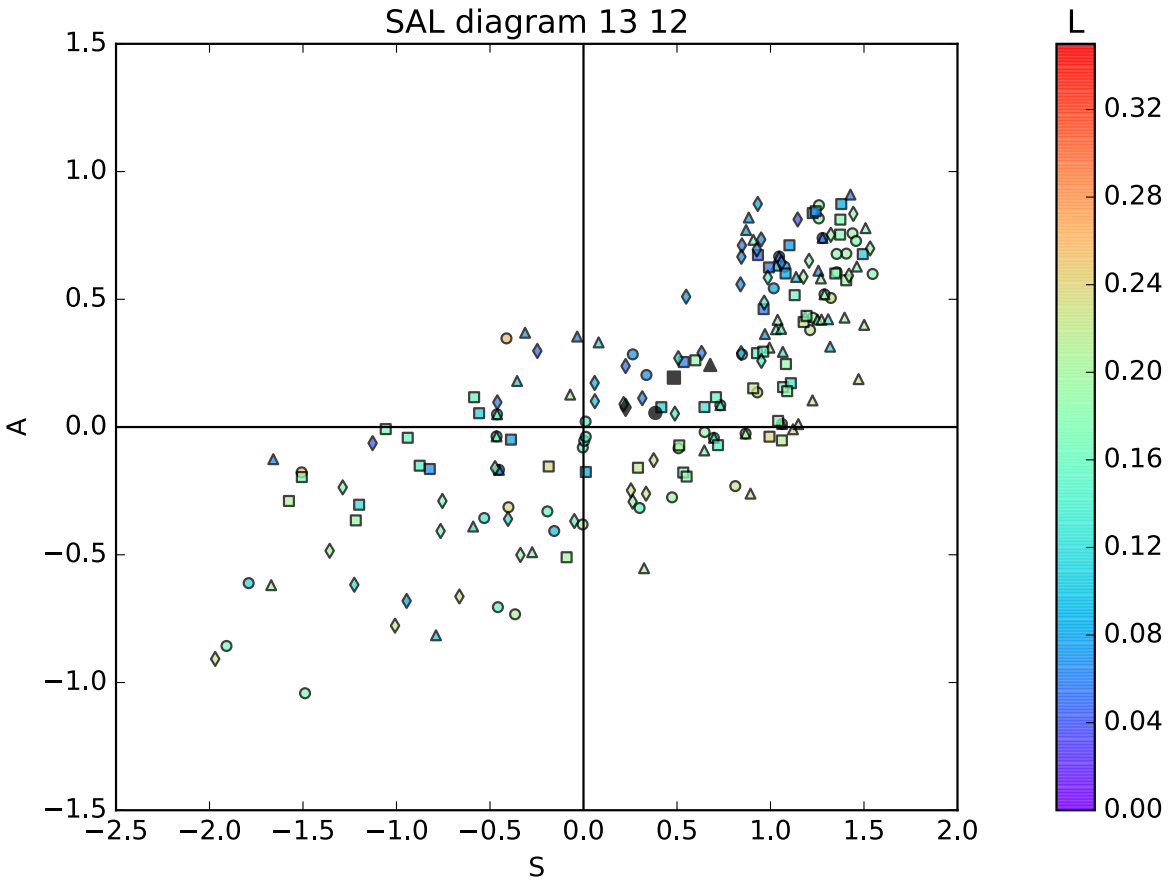


Small errors at short lead times

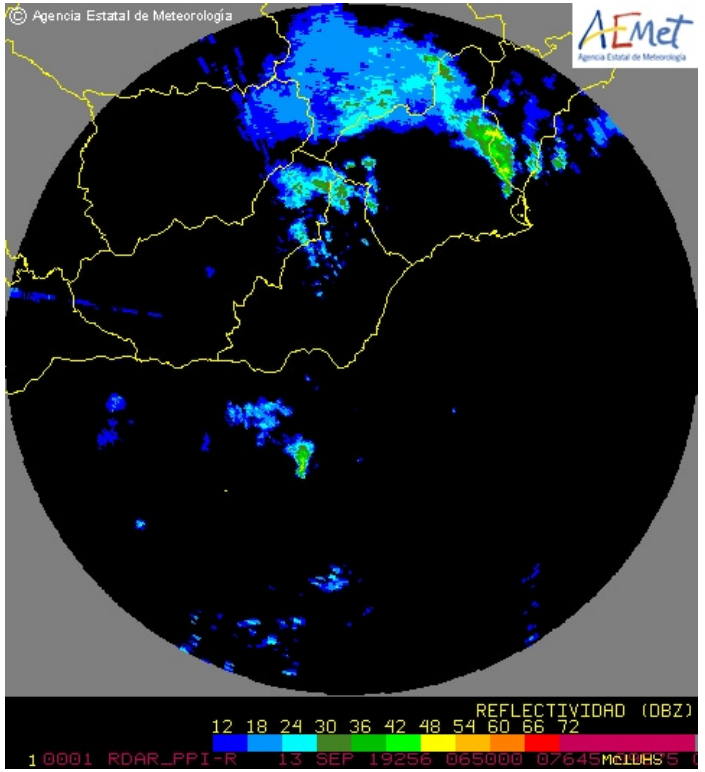


Most members of all ensembles predict precipitation field features accurately

SAL 6h continuation phase 3

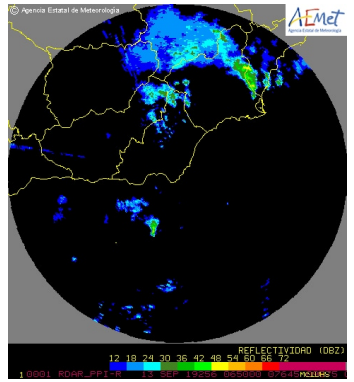


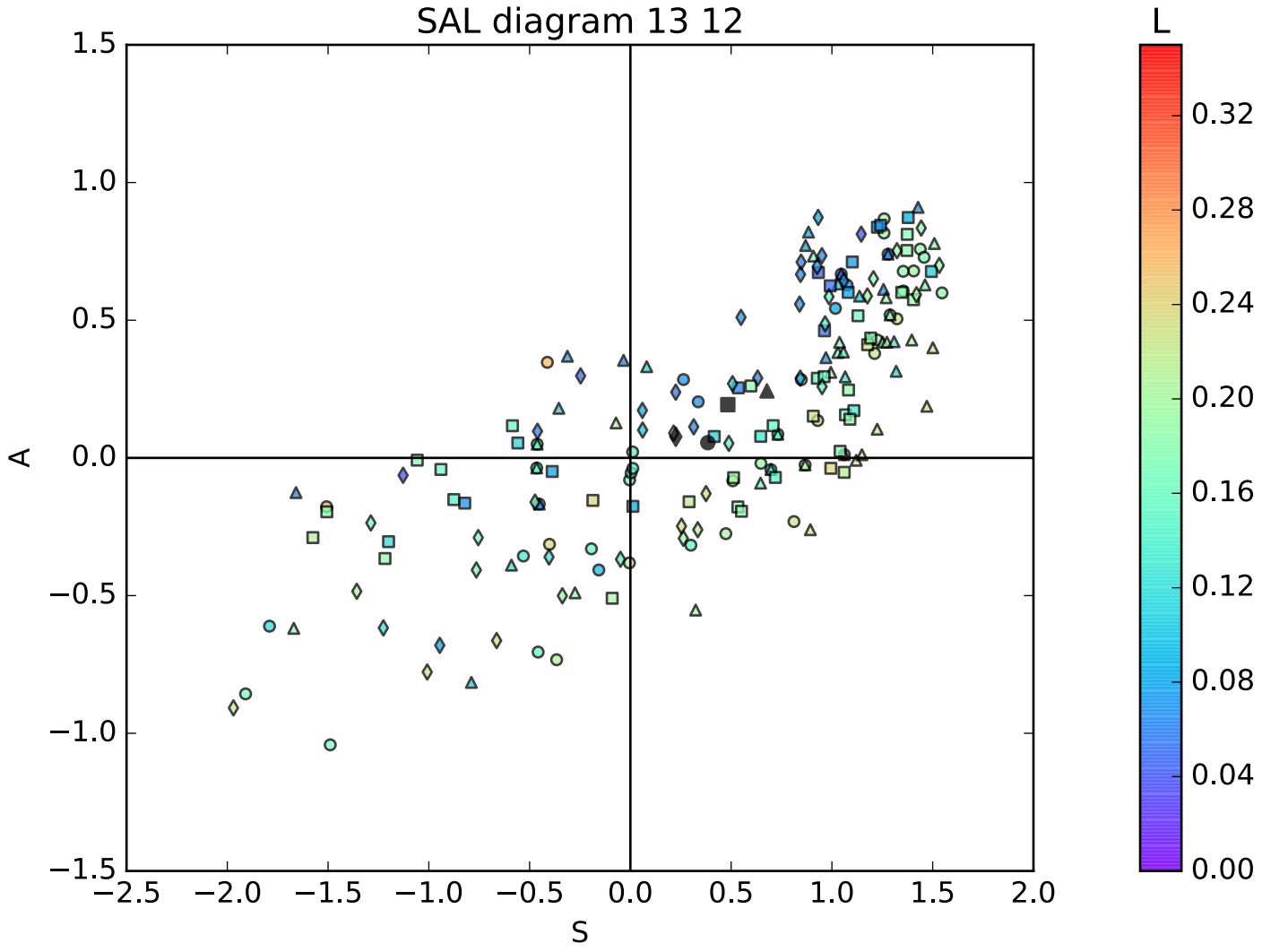
Larger localization errors for longer lead time



Simulated precipitation structures more widespread than observed (similar to phase 1)

SAL 6h continuation of phase 3

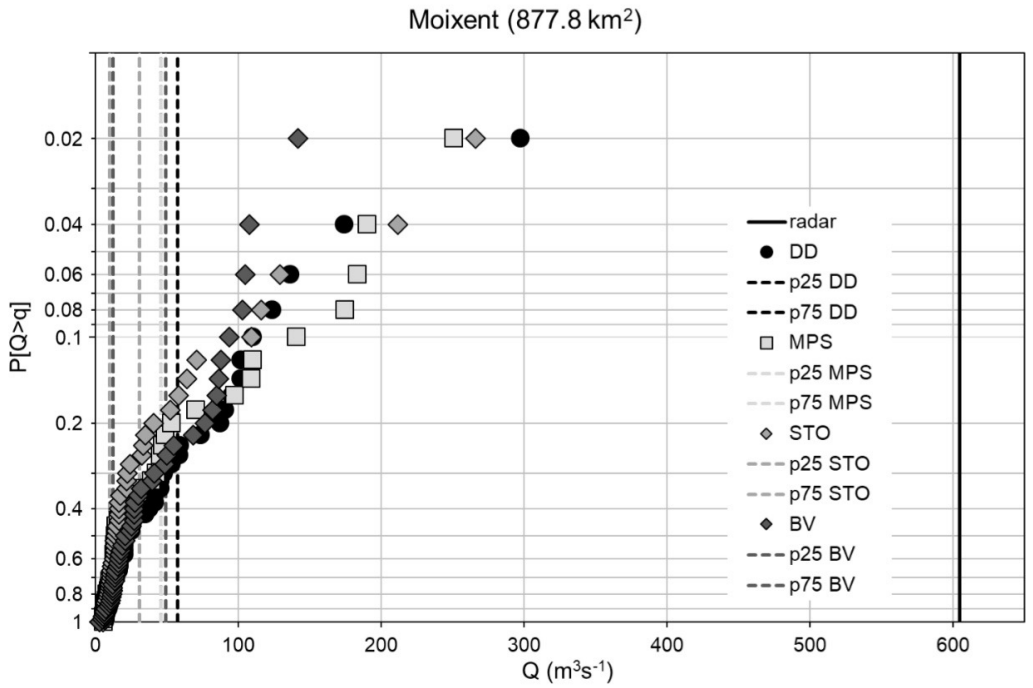




Hydrological set-up

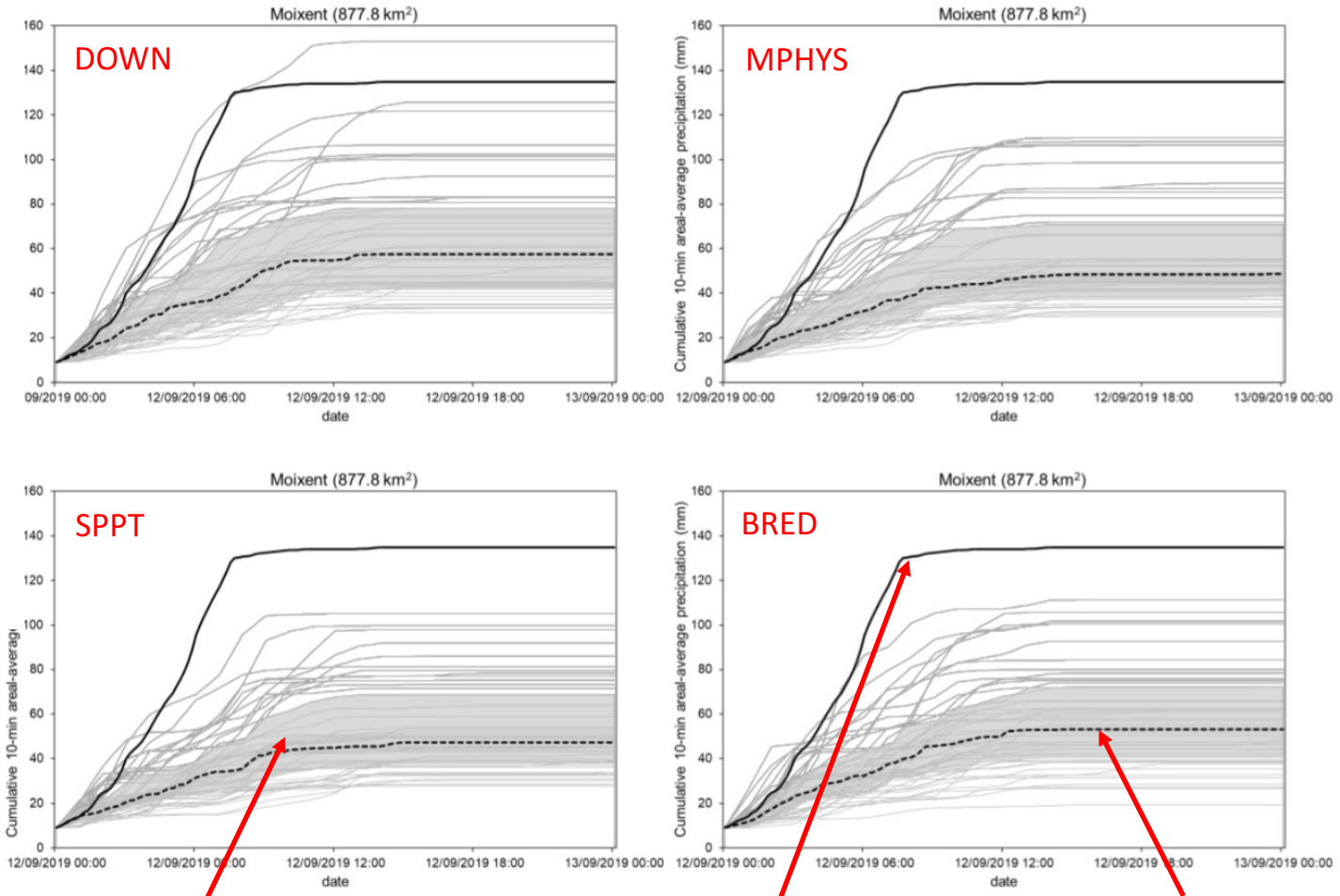
- The Kinematic Local Excess Model (KLEM) hydrological model is used
- Hydrological model forced by 10-min radar accumulations during spin-up periods
- Model forced by hourly accumulated forecast precipitation after spin-up period
- Hydrological simulations are used as an advanced probabilistic quantitative precipitation forecast verification technique
- It also assesses the potentialities of flash-flood forecasting associated to this heavy precipitation episode for small basins

Catchment accumulated precipitation 12 September (phase 1)

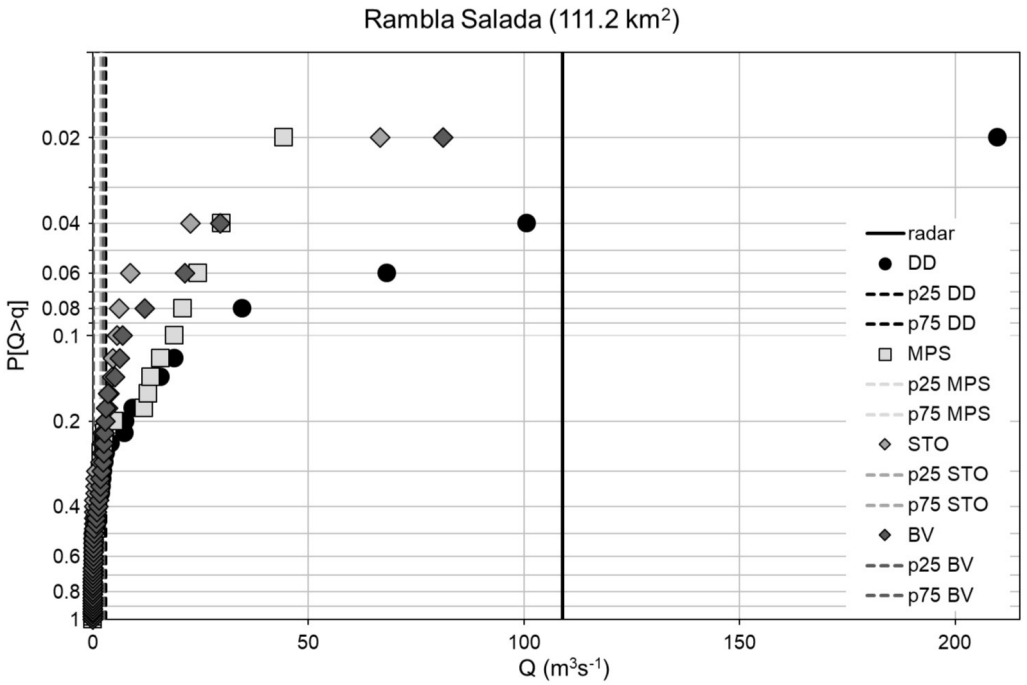


Probability of peak discharge exceedance (Moixent, 877.8 km²)

- None of the ensembles simulates accurate precipitation and estimates in this phase (thin linear structure)
- Small differences between ensembles
- Some members of DOWN ensemble reproduce the precipitation in the catchment

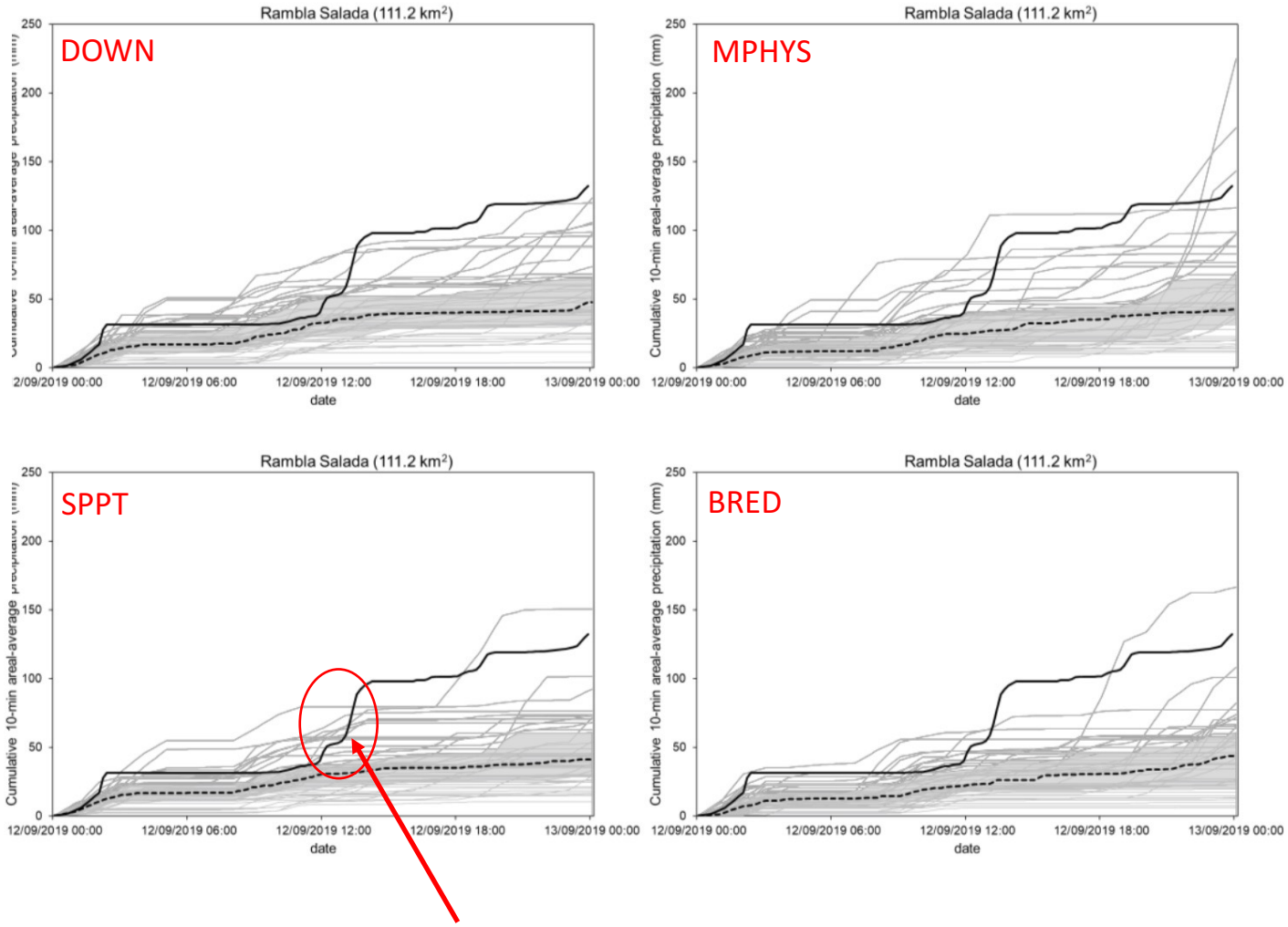


Catchment accumulated precipitation 12 September (phase 2)

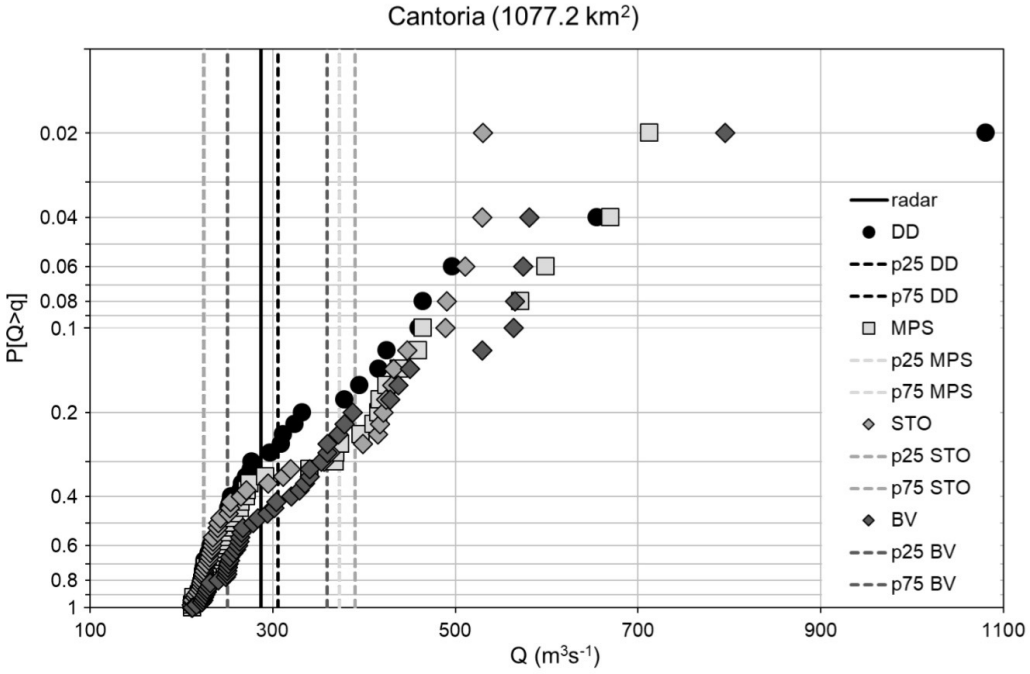


Probability of peak discharge exceedance (Rambla Salada, 111.2 km²)

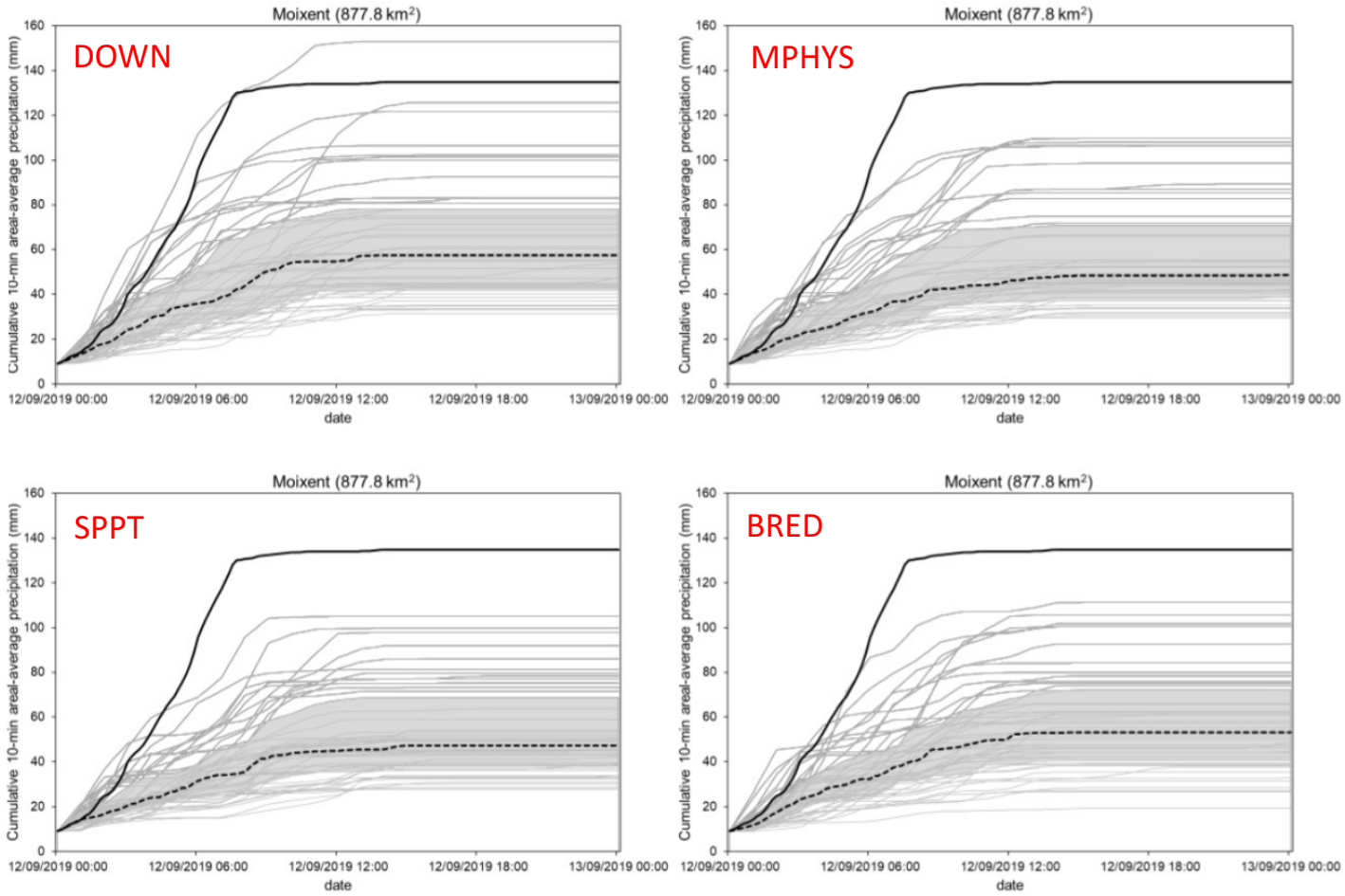
- Simulations do not reproduce the precipitation of phase 2
- The loss of predictability at small scales after 18h lead time could explain the poor performance



Catchment accumulated precipitation 13 September (phase 3)



Probability of peak discharge exceedance (Cantoria, 1077.2 km²)



- All ensembles capture the precipitation in the catchment
- Introducing model error improves ensemble performance: Persistent convective activity in this phase
- BRED ensemble adequately reproduces the evolution with less spread

Preliminary conclusions

- The 12-13 September 2019 episode consisted of wide-spread heavy precipitation and flash flooding. It is an extremely challenging case for hydrometeorological forecasting

- The highly localized convective structures observed in the first phases of the episode are not adequately reproduced due to the small spatial scale at which develop

- The inclusion of model error improves ensemble performance in the last phase of the episode due to the intense and persistent convection activity.

Acknowledgments

- COASTEPS CGL2017-82868-R
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- AECT-2019-3-0012
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- Rain gauge data provided by AEMET, CHJ, CHS and Hidrosur

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