SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	2018
Project Title:	High-impact precipitation events prediction with a convection-permitting model nested in the ECMWF ensemble
Computer Project Account:	SPITCAPE
Principal Investigator(s):	Valerio Capecchi
Affiliation:	LaMMA Consortium - Environmental Modelling and Monitoring Laboratory for Sustainable Development
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Simon Lang
Start date of the project:	6/October/2016 (Late Request)
Expected end date:	31/December/2018

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	3 000 000 + 3 000 000 + 1 000 000	~100%	3 000 000	2713 (June 2018)
Data storage capacity	(Gbytes)	25000 GB	10755 GB on EFS	25000 GB	20180 GB on EFS

Summary of project objectives

(10 lines max)

The rationale of the Special Project is to evaluate the accuracy of a cascade of state-of-the-art ensembles, from global-to-local, by re-forecasting past high-impact precipitation events. Starting from the recently implemented ECMWF suite of medium-range ensemble (at Tco639L91 resolution), the aim is to investigate the value of the simple dynamical downscaling approach on high-impact weather events, with a limited-area convection-permitting model directly nested in the new ECMWF global ensemble. The questions addressed in the framework of Special Project are:

1) How many days in advance a high-impact precipitation event can be foreseen by using the global state-of-the-art ensembles?

2) Which is the added value of running a regional convection-permitting high-resolution ensemble in terms of QPF (Quantitative Precipitation Forecast) with respect to global ensembles and with respect to very high-resolution deterministic regional simulation?

Three high-impact precipitation events has been selected on the basis of the pre-existing scientific literature: Cinque Terre, 25 October 2011 (study case analysed in Buzzi et al, 2014), Genoa, 4 November 2011 (study case analysed in Buzzi et al, 2014) and Genoa, 9-10 October 2014 (study case analysed in Silvestro et al, 2015)

Summary of problems encountered (if any)

(20 lines max)

The SBU requested in the SPITCAPE Special Project Request Form (submitted in October 2016) were underestimated. In fact, there was an error in the SBU requested in the first Special Project Request Form, namely SBU were under-estimated as regards ENS forecasts. The problem has been bypassed by reducing the length of the IFS forecast (forecast length up to 10 days instead of 15 days) and by running on Principal Investigator's computer facilities part of the WRF simulations initially foreseen on the ECMWF supercomputer.

Summary of results of the current year (from July of previous year to June of current year)

This section should comprise 1 to 8 pages and can be replaced by a short summary plus an existing scientific report on the project

During the second year of the SPITCAPE Special Project (hereafter SPITCAPE-SP), global and limited-area convection-permitting ensemble forecasts (ENS and WRF-ENS respectively) were performed for the Genoa 4 November 2011 study case (see [1], [2] and [3]).
During the 4-8 November 2011 period the north-western regions of Italy were hit by extensive and intense rainfalls. In particular on 4 November 2011, multiple flash floods associated to a heavy precipitation event affected the town of Genoa causing the Feregiano and Bisagno creaks to flood several areas of the town (see [5]). The area that was hit most severely is shown in Figure 1 with super-imposed 24-hour period rainfall amounts, reported by Automatic Weather Stations (AWS). Data are provided by the Italian Department of Civil Protection.
The meteorological scenario that determined the storm is very similar to the one described for the Cinque Terre event (see SPITCAPE-SP Interim Report First Year): ie it is the result of (i) a deep low-pressure system over western Europe caused by a large amplitude Atlantic trough (see Figure 2) and (ii) a convergence line between the warm and moist south-easterly low-level jet and the cold outflow from the Po Valley (occurring at meso-α and meso-β scales). The combined effect of these two factors led to quasi-stationary and back-building convective cells over the Genoa area. The rainfall intensity reached 181 mm/1-hour at the Vicomorasso rain-gauge station, while nearby rain-gauges registered total amounts exceeding 400 mm/12-hour (see [2]). The estimated 24-hour return period exceeds the 50 years (see [4]).

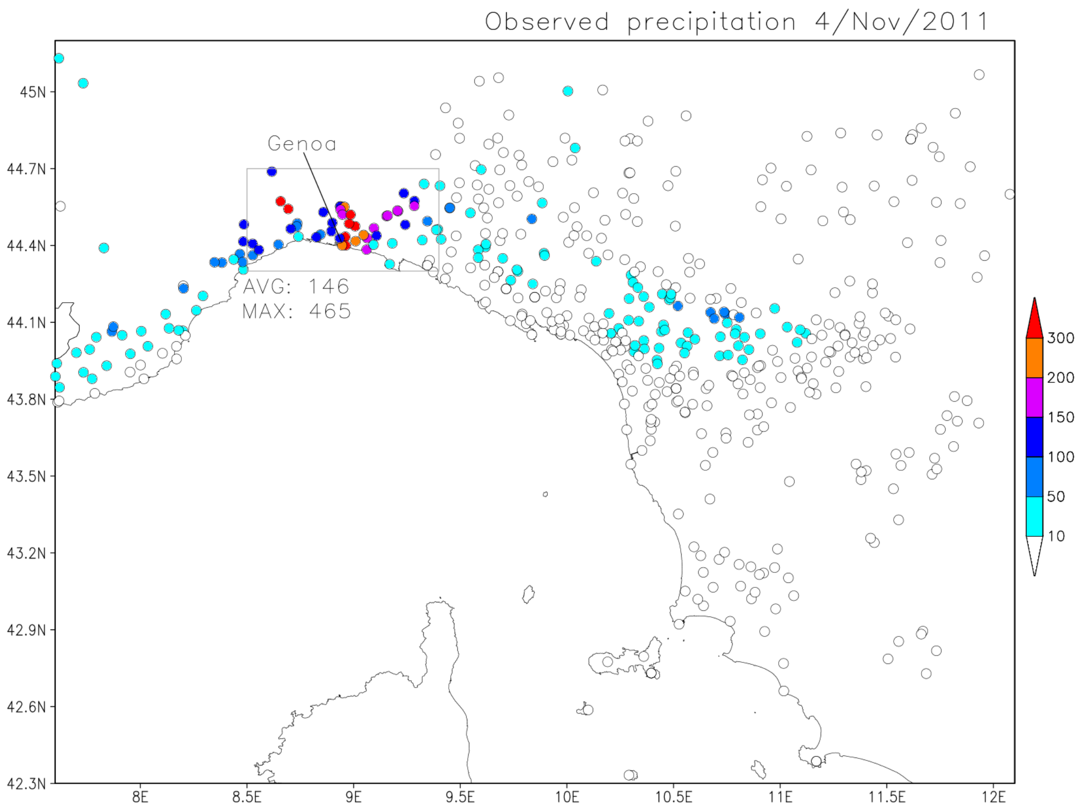


Figure 1: 24-hour observed precipitations on 4 November 2011. The average and maximum values in the inset gray rectangle are indicated.

The reader is referred to [4] for a deeper analysis of the event both at synoptic and meso scales and for a discussions about precipitation patterns.

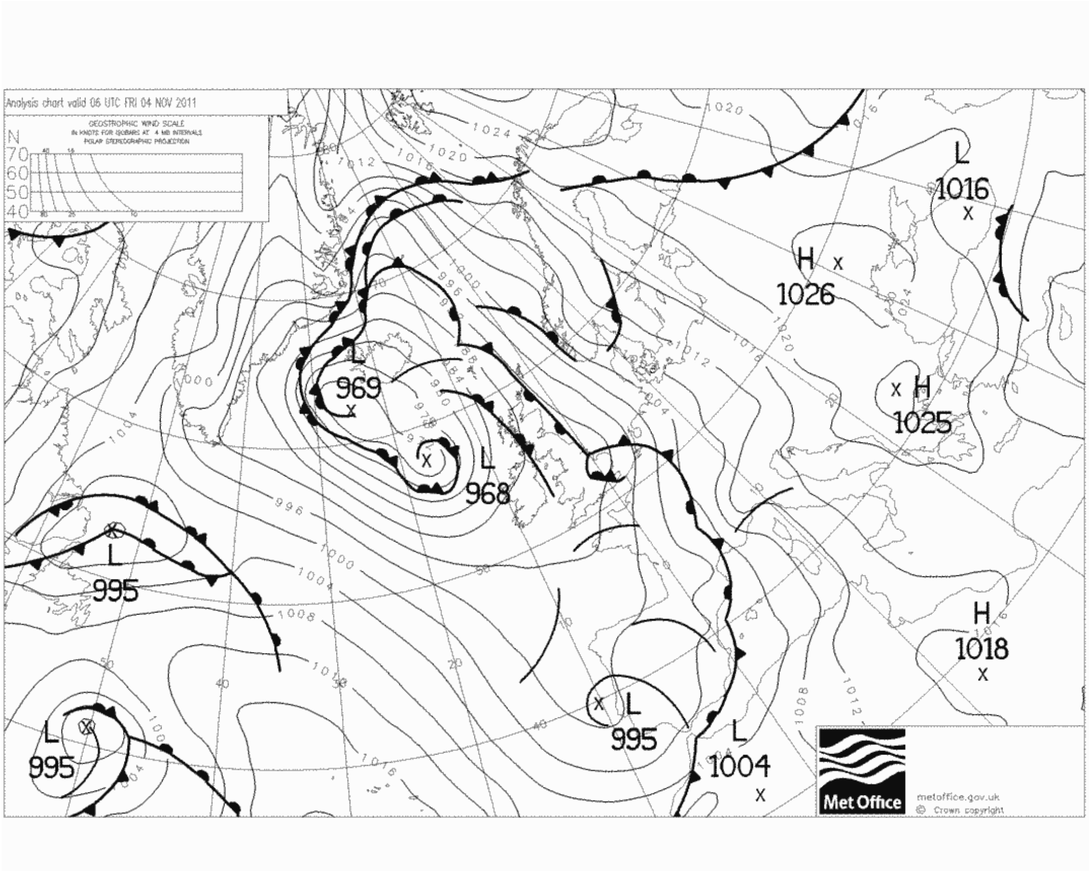
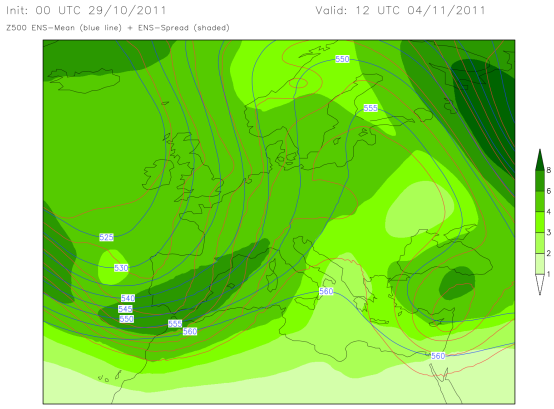


Figure 2: Synoptic analysis over Europe on 4 November 2011 at 6 UTC drawn by the UK Met Office. The Figure illustrates a trough in the Ligurian Sea and a blocking ridge over the Balkans (1025 hPa).

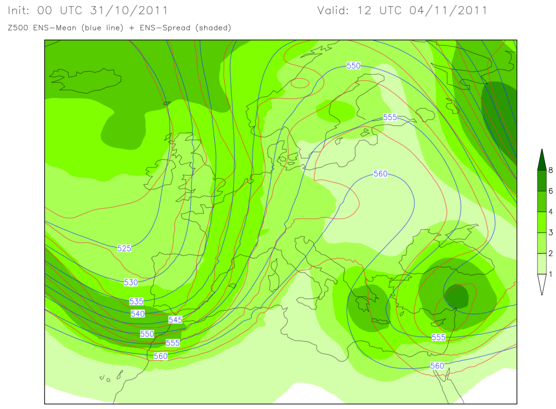
As regards the ENS forecasts, the settings used to produce the data are identical to those used for the Cinque Terre Case (see SPITCAPE-SP Interim Report First Year). Model cycle is 41r2.
As regards the WRF-ENS forecasts, no changes were made to the configuration used during the first year of SPITCAPE-SP. Here we briefly recall some basic characteristics of the model set-up:

- WRF model, Version 3.8.1 (August 2016)
- horizontal resolution 3 km
- 60 vertical levels
- time step 15 sec
- no parametrisation for convection

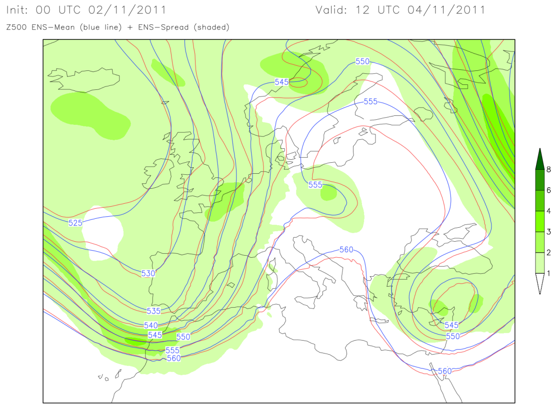
To answer to the first question raised in the Scientific Plan of the SPITCAPE-SP Request Form, namely, "How many days in advance a Mediterranean HPE (Heavy Precipitation Event), can be foreseen by using the global state-of-the-art ensembles?", the geopotential height at isobaric level 500 hPa of the ENS forecast has been plotted for different starting dates. As motivated in the Second (October 2017) and Third (December 2017) Request for additional resources Form, due to an under-estimation of the SBU needed to run the ENS forecast, this analysis is limited to forecasts initialised one to ten days prior the rainfall event. Moreover due to the low predictability of the event, only the results regarding forecasts initialised about six to one days prior the rainfall event are shown. Figure 3 illustrates the ENS ensemble mean and spread (defined as the ensemble standard deviation) values of the geopotential height at isobaric level 500 hPa for different forecast lengths. The verification time is 4 November 2011 at 12 UTC. As expected, the shorter the forecast length, the smaller the green shaded area.



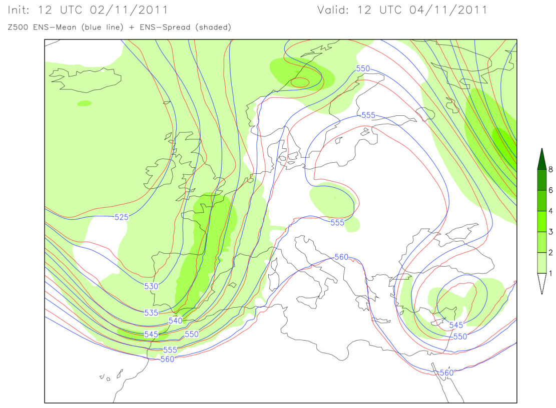
(a) 29/Oct/2011 00:00 UTC + 156 hours



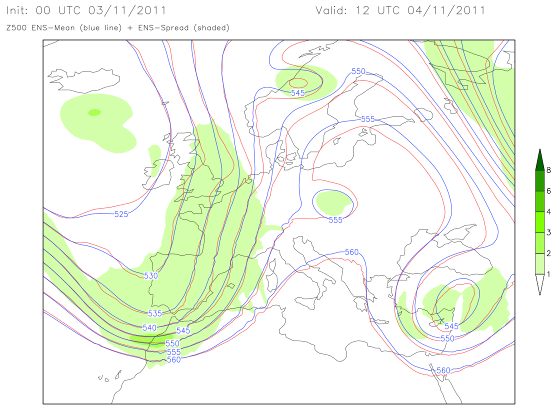
(b) 31/Oct/2011 00:00 UTC + 108 hours



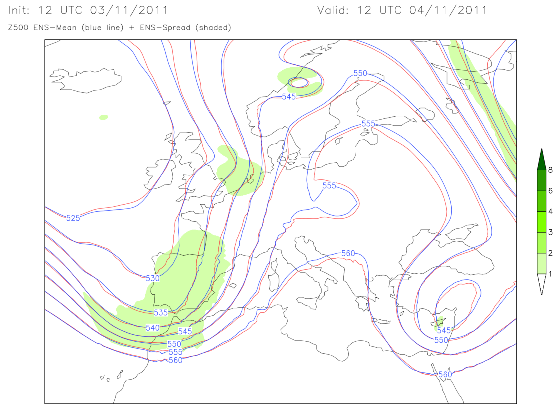
(c) 2/Nov/2011 00:00 UTC + 60 hours



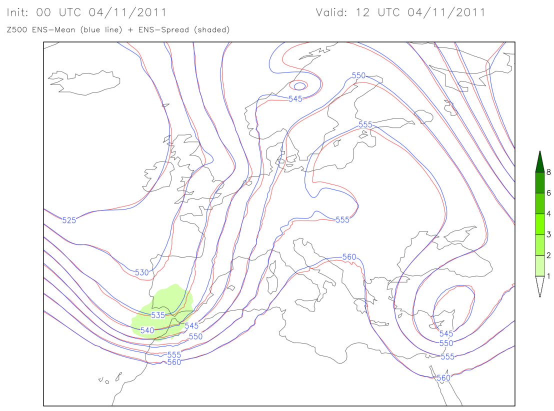
(d) 2/Oct/2011 12:00 UTC + 48 hours



(e) 3/Nov/2011 00:00 UTC + 36 hours



(f) 3/Nov/2011 12:00 UTC + 24 hours



(g) 4/Nov/2011 00:00 UTC + 12 hours

Figure 3: 500 hPa geopotential height ensemble mean (blue line) and spread (green shades) for different starting dates for ENS data. Verification time is 4 November 2011, 12 UTC. The analysis (ERA5 data) is shown with the red line.

To further answer to the question raised above, stamp plots were produced with accumulated precipitation predicted by all the members of ENS (plots not shown here). For sake of simplicity, we report in Table 1 the maximum and mean values, averaged among the 50 members of ENS, of the rainfall in the inset rectangle of Figure 1, as a function of the starting date. These values should be compared with the observed ones reported in the last row of Table 1 (and in Figure 1). As shown

Starting Date	**Forecast length**	**Mean/Maximum values** (mm)
29/Oct/2011 at 00:00 UTC	168 hours	34/67
31/Oct/2011 at 00:00 UTC	120 hours	58/108
2/Nov/2011 at 00:00 UTC	72 hours	64/121
2/Nov/2011 at 12:00 UTC	60 hours	58/118
3/Nov/2011 at 00:00 UTC	48 hours	67/121
3/Nov/2011 at 12:00 UTC	36 hours	63/125
4/Nov/2011 at 00:00 UTC	24 hours	61/118
Observed values		**146/465**

Table 1: Mean and maximum values of rainfall accumulated in the 24-hour period ending on 00 UTC 5 November 2011 and predicted by the ENS members in the inset rectangle of Figure 1, as a function of the starting date. The last row contains the observed values.

in Table 1, predicted mean and maximum values largely under-estimate observed precipitations. Forecasts with lead time equal or lower than 72 hours (ie initilised on 2 November at 00 UTC or later) provide similar results for what concerns both the mean and maximum values.
Figures 5 to 8 illustrate the Probability of Precipitation (hereafter PoP) exceeding the 50-mm and 100-mm thresholds in the 24-hour period ending on 00 UTC 5 November 2011 to investigate the probability of potential severe weather with several days in advance. Comparing these results

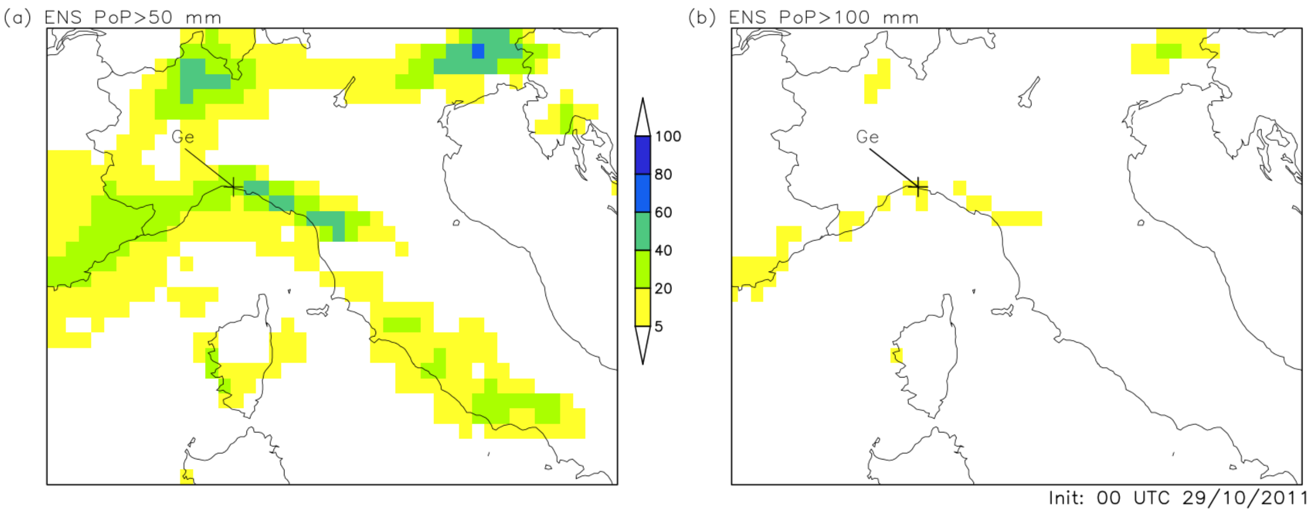


Figure 4: ENS Probability of Precipitation. Starting date is 29/Oct/2011 00:00 UTC

with those obtained for the Cinque Terre case (see SPITCAPE-SP First Year Interim report), the uncertainty for the Genoa 4 November case is lower. In fact, PoP values (both for the 50-mm and 100-mm threshold) are higher in the area close to the city of Genoa, where intense precipitation was observed. However ENS data fail to reproduce rainfall amounts close to observed ones (ie average and maximum values in the target rectangle are lower than observations, see Table 1). It has to be considered in fact, that during the event, the convection is dominant (see [4]) and that the horizontal resolution of the ENS data is relatively coarse (about 18 km).

To answer to the second question raised in the Scientific Plan of the SPITCAPE-SP Request Form, namely "Which is the added value of running a regional convection-permitting high-resolution ensemble in terms of QPF (Quantitative Precipitation Forecast)?", in Table 2 we show the same

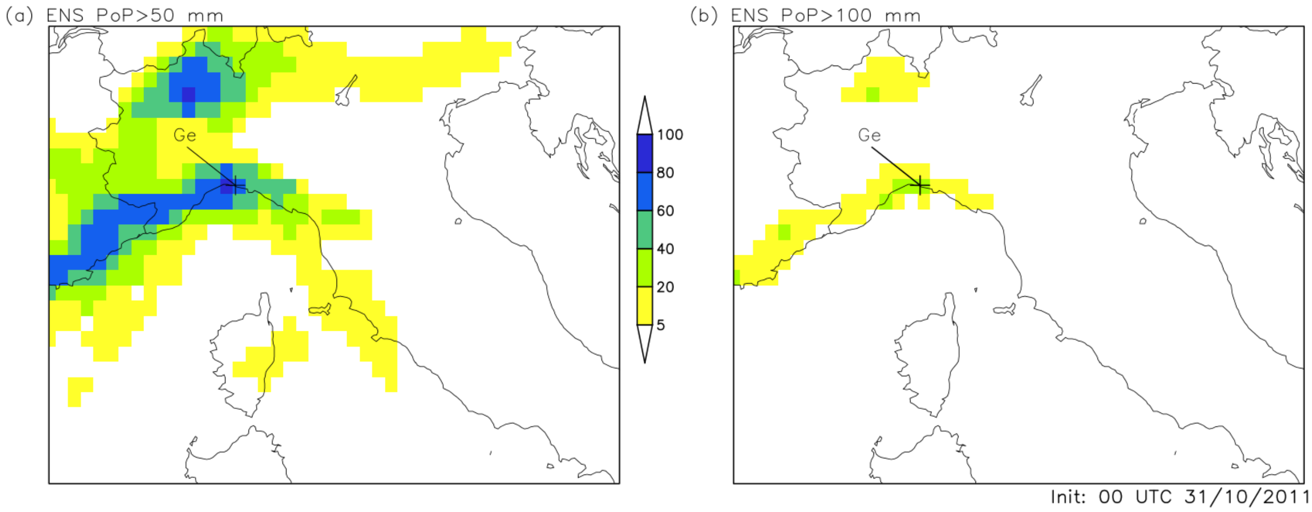


Figure 5: ENS Probability of Precipitation. Starting date is 31/Oct/2011 00:00 UTC

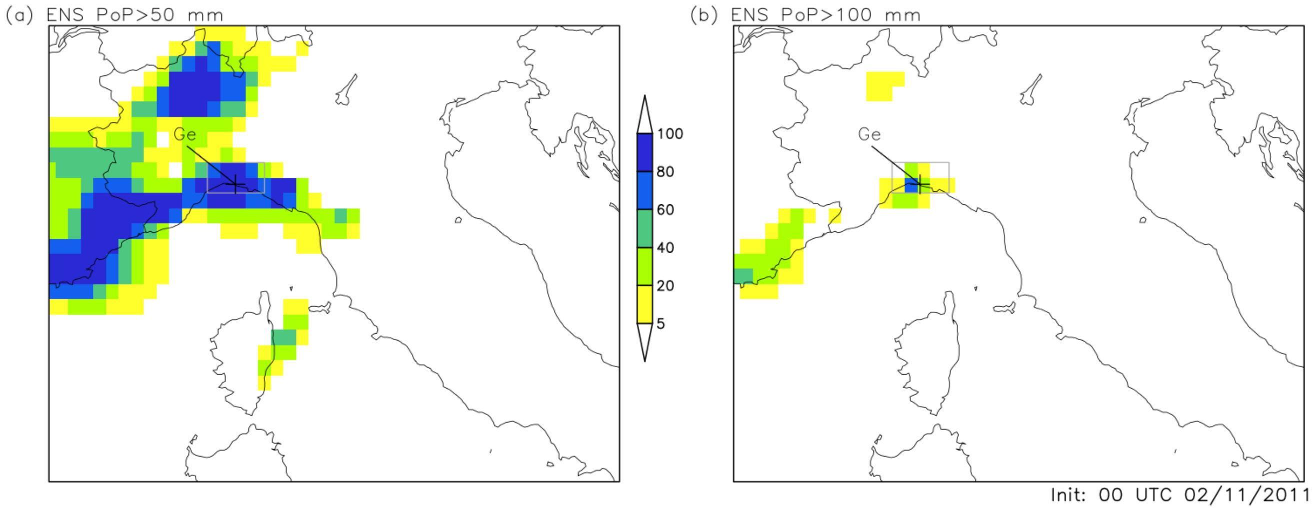


Figure 6: ENS Probability of Precipitation. Starting date is 2/Nov/2011 00:00 UTC

statistics shown in Table 1 but for WRF-ENS forecasts. WRF-ENS results outperform ENS ones for what concerns the maximum values predicted in the target area. On the other hand mean values are similar to those provided by the ENS forecasts. Figures 9 to 13 illustrate the PoP for 50-mm,

Starting Date	**Forecast length**	**Mean/Maximum values** (mm)
2/Nov/2011 at 00:00 UTC	72 hours	66/264
2/Nov/2011 at 12:00 UTC	60 hours	57/257
3/Nov/2011 at 00:00 UTC	48 hours	64/224
3/Nov/2011 at 12:00 UTC	36 hours	73/241
4/Nov/2011 at 00:00 UTC	24 hours	56/192
Observed values		**146/465**

Table 2: As in Table 1 but for WRF-ENS forecasts.

100-mm, 150-mm and 200-mm thresholds for the WRF-ENS system to further answer the second questions raised above. As regards the WRF-ENS PoP plots (Figures 9 to 13), the higher values are located north of the area where maximum precipitation was observed. Further investigations are needed to understand the motivation of such results.

In conclusion to partially address the two main questions raised in the SPITCAPE-SP Request Form, namely:

1. How many days in advance a HPE (Genoa 4 November 2011) can be foreseen by using the

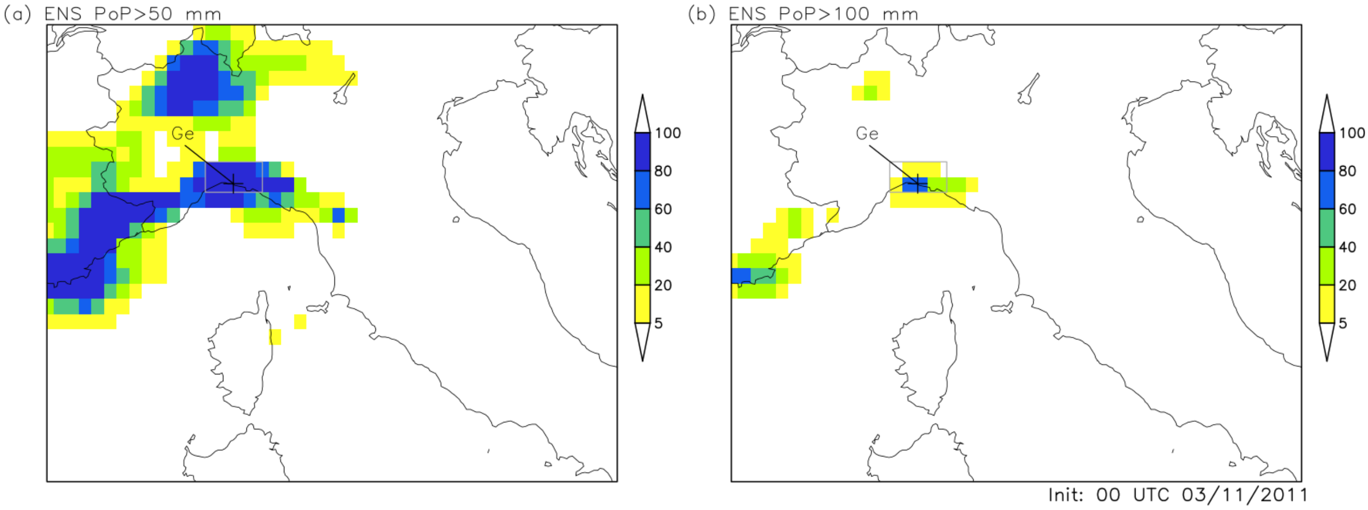


Figure 7: ENS Probability of Precipitation. Starting date is 3/Nov/2011 00:00 UTC

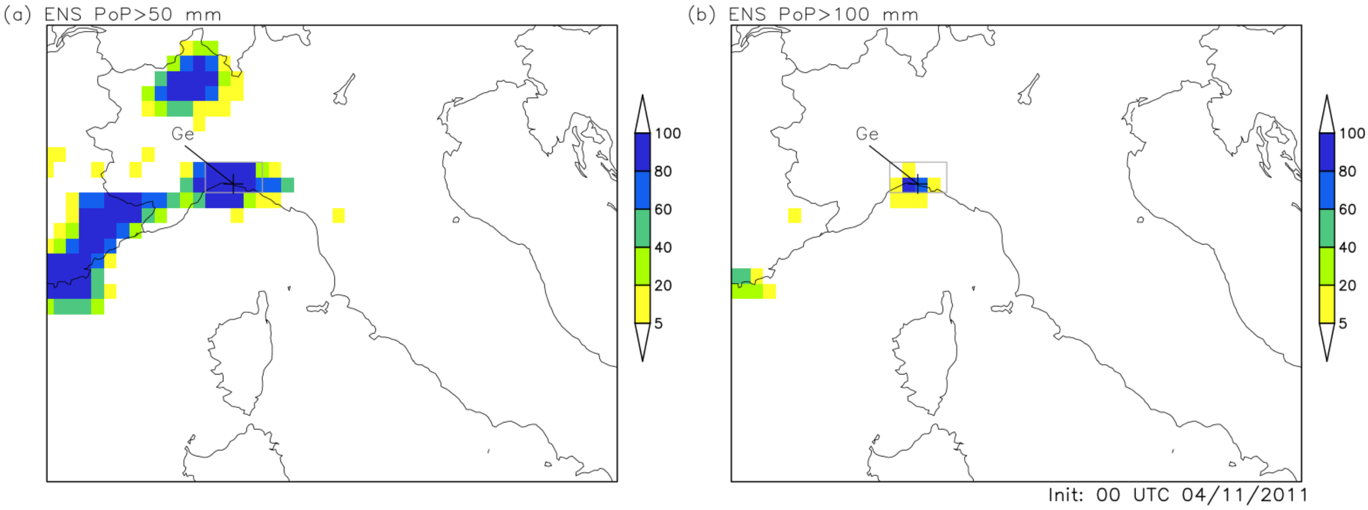


Figure 8: ENS Probability of Precipitation. Starting date is 4/Nov/2011 00:00 UTC

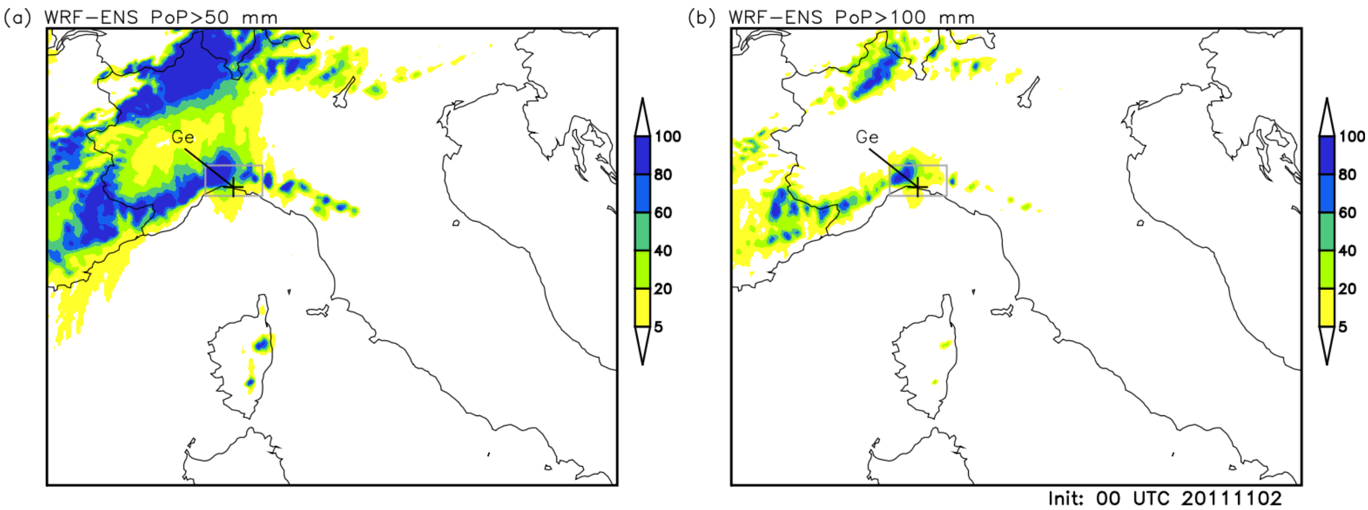


Figure 9: WRF-ENS Probability of Precipitation. Starting date is 2/Nov/2011 00:00 UTC

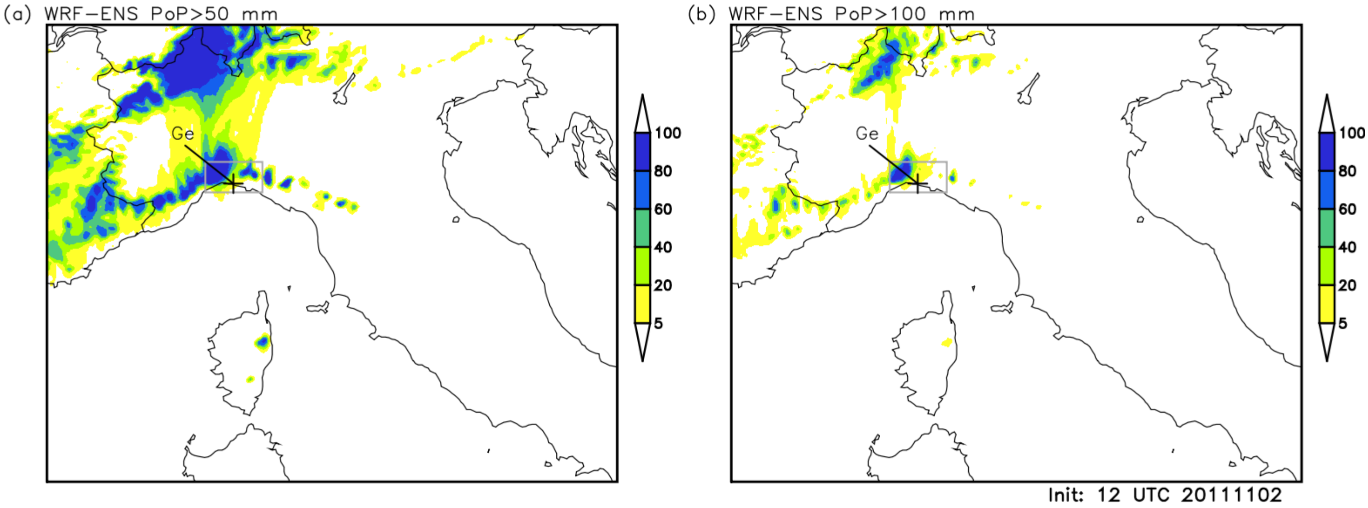


Figure 10: WRF-ENS Probability of Precipitation. Starting date is 2/Nov/2011 12:00 UTC

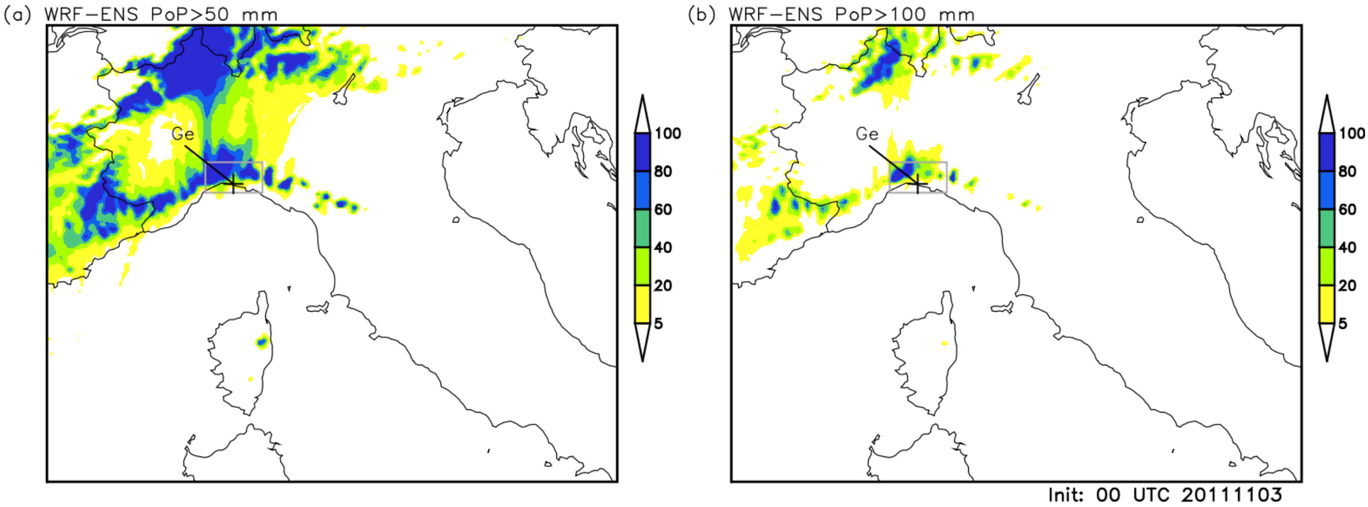


Figure 11: WRF-ENS Probability of Precipitation. Starting date is 3/Nov/2011 00:00 UTC

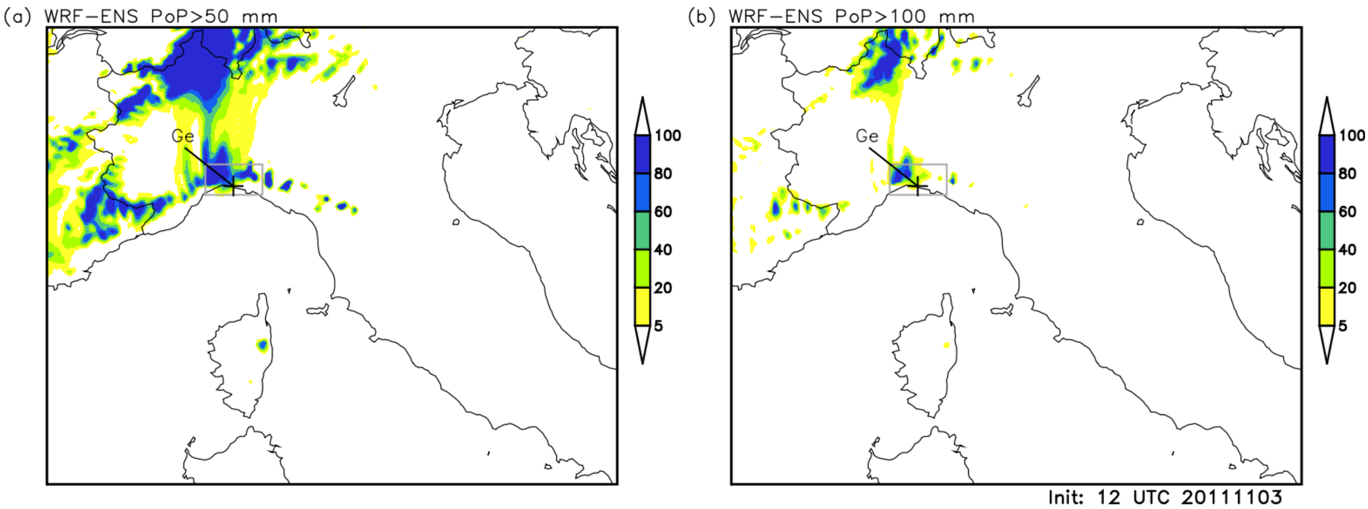


Figure 12: WRF-ENS Probability of Precipitation. Starting date is 3/Nov/2011 12:00 UTC

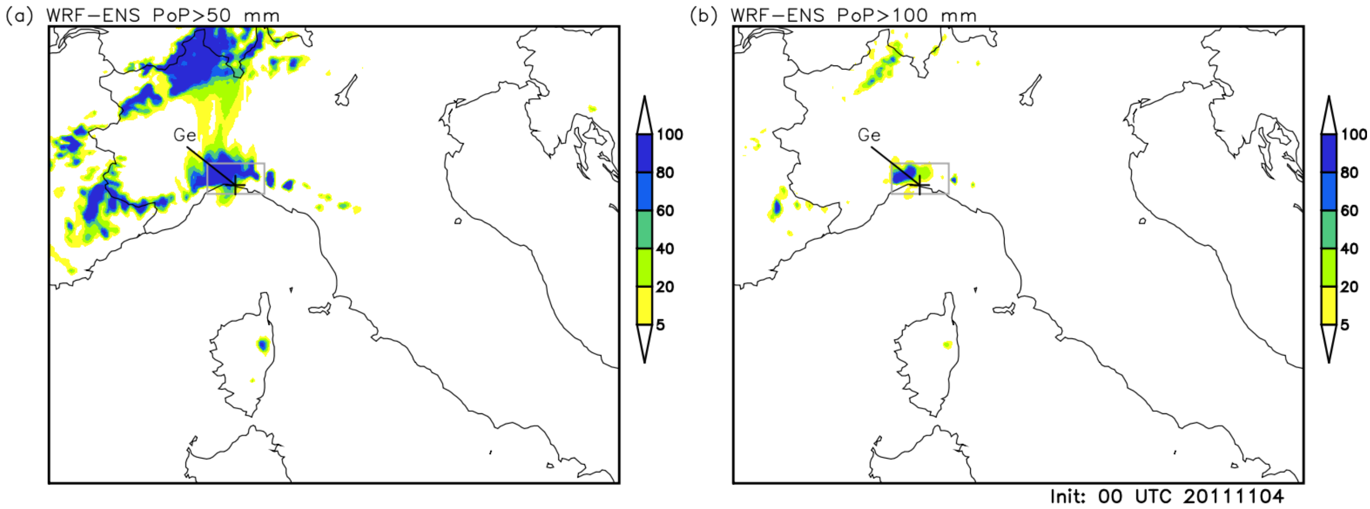


Figure 13: WRF-ENS Probability of Precipitation. Starting date is 4/Nov/2011 00:00 UTC

global state-of-the-art ensembles?

2. Which is the added value of running a regional convection-permitting high-resolution ensemble in terms of QPF (Quantitative Precipitation Forecast)?

we can state that for the Genoa 4 November 2011 case:

1a. ENS forecasts largely under-estimates accumulated rainfall in the target area (see Table 1)

1b. Figures 4 to 8 illustrate how high values of ENS PoP are located in the area where maximum precipitation was observed. This is true in particular for forecast lenghts equal or lower than 72 hours

2a. as regards the rainfall maxima in the target area, WRF-ENS forecasts predict higher values compared to ENS ones (see Table 2). However, the location of such WRF-ENS rainfall maxima are located north of the area where they were observed (see Figures 9 to 13)

2b. further investigations are needed to understand if a different set-up of the WRF model could reproduce better precipitation patterns.

References

[1] A Buzzi, S Davolio, P Malguzzi, O Drofa, and D Mastrangelo. Heavy rainfall episodes over liguria in autumn 2011: numerical forecasting experiments. *Natural Hazards and Earth System Science*, 14(5):1325–1340, 2014.

[2] F Cassola, F Ferrari, and A Mazzino. Numerical simulations of mediterranean heavy precipitation events with the wrf model: a verification exercise using different approaches. *Atmospheric Research*, 2015.

[3] E Fiori, A Comellas, L Molini, N Rebora, F Siccardi, DJ Gochis, S Tanelli, and A Parodi. Analysis and hindcast simulations of an extreme rainfall event in the mediterranean area: The genoa 2011 case. *Atmospheric Research*, 138:13–29, 2014.

[4] N Rebora, L Molini, E Casella, A Comellas, E Fiori, F Pignone, F Siccardi, F Silvestro, S Tanelli, and A Parodi. Extreme rainfall in the mediterranean: what can we learn from observations? *Journal of Hydrometeorology*, 14(3):906–922, 2013.

[5] F Silvestro, S Gabellani, F Giannoni, A Parodi, N Rebora, R Rudari, and F Siccardi. A hydrological analysis of the 4 november 2011 event in genoa. *Natural Hazards and Earth System Sciences*, 12(9):2743, 2012.

List of publications/reports from the project with complete references

None

Summary of plans for the continuation of the project

(10 lines max)

The plan is to simulate the second Genoa case (9-10 October 2014). Results are going to be produced shortly and will be analysed and post-processed, as done for the other study cases, to be able to draw more statistically sound conclusions.

A new Request for additional resources Form is likely to be forwarded to in the next months to get the SBUs necessary to perform a full numerical experiment with ENS and WRF-ENS ensembles.