All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2025…………………………………………………….……
Project Title:	Future Weather: weather predictions of rainfall extremes in past, present and future climate conditions…………………………………………………
Computer Project Account:	spnllend ……………………………………………………….……
Principal Investigator(s):	Geert Lenderink, Christiaan van Dalum, Hylke de Vries, Bert van Ulft and Erik van Meijgaard ……………….……
Affiliation:	KNMI…………………………………………………
Name of ECMWF scientist(s) collaborating to the project (if applicable)	……………………………………………………….…… ……………………………………………………….……
Start date of the project:	1-1-2025
Expected end date:	31-12-2027………………………….……

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)	-	-	60,000,000	9,500,000
Data storage capacity	(Gbytes)	-	-	3000	1500

Summary of project objectives (10 lines max)

In this project we run continuous forecasts to past, present and future climate conditions. The aim is to establish the influence of climate change on our weather. This can be used in attribution studies, to construct counterfactual climate, and to study processes in a changing climate, for instance related to cloud dynamical changes in rain events. The aim of this special project is running a convection permitting model (HCLIM) embed in coarser resolution (12km) modelling results using RACMO.

Summary of problems encountered (10 lines max)

A scripting system to run the convection permitting model HCLIM within RACMO has been setup, and is now in testing phase. However, we still have problems with finetuning HCLIM to perform longer continuous forecasting cycles. During longer simulations with HCLIM it turned out that surface scheme related problems (too much evaporation leading to too dry soil in summer and too high temperatures) prevented us to do the continuous cycles. Further finetuning of the model is still required. We aim to solve these problems early autumn and start the reforecast of this year. The reason of underspending of the computing resources is also related to the fact that a continuous forecasting cycle is not useful at the moment.

Summary of plans for the continuation of the project (10 lines max)

As stated above, we will start a reforecast of the current year (2025) in autumn (and depending on available resources extending to2024). If the model performance is good, we will continue this forecast cycle for present-day, past and future climate conditions on a daily basis up to the end of this year. If not, we will first need to improve the model, and start a reforecast. More continuous forecast cycles are planned for 2026 and 2027.

List of publications/reports from the project with complete references

We published a recent paper describing the method:

Lenderink G, Vries H de, Meijgaard E van, et al (2025) A pseudo global warming based system to study how climate change affects high impact rainfall events. Weather and Climate Extremes 49:100781.
https://doi.org/10.1016/j.wace.2025.100781

Note, al runs performed in this paper were done before this special project. This special project builds upon the infrastructure and methodology described and developed in this paper.

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Within this project we aim to develop a high-resolution storyline based system to attribute the influence of climate changes on recent flood events in Europe. Besides attribution, it is also important to understand physical changes that lead to these flood events. Our main assumption is that current attribution statements strongly underestimate the actual changes to flood risks. In the first half year we published a paper describing the system (Lenderink et al, Weather and Climate Extremes, 2025). Besides describing the technical setup of the system we also discussed the strengths and weaknesses of the system in comparison to more traditional methods. We also applied the system to a number of recent flood events in Europe. For these cases, we found that traditional attribution methods strongly underestimate change to local flood risk, as they are typically based on rather coarse-scale statistical metrics. Multiday rainfall over a 10^4 km^2 area, for instance, is often limited in underlying data. We show that changes in peak amount, falling locally within shorter time spans (for instance sub-daily) can be substantially higher. For a case study in Italy (May 2023) we show that while mean accumulated rain of a large area only increases at a rate of 3-7% per degree global warming, the actual peak amounts increase at rates of 10-17% per degree warming. This could lead to substantially larger impacts despite relative modest rainfall over larger areas.

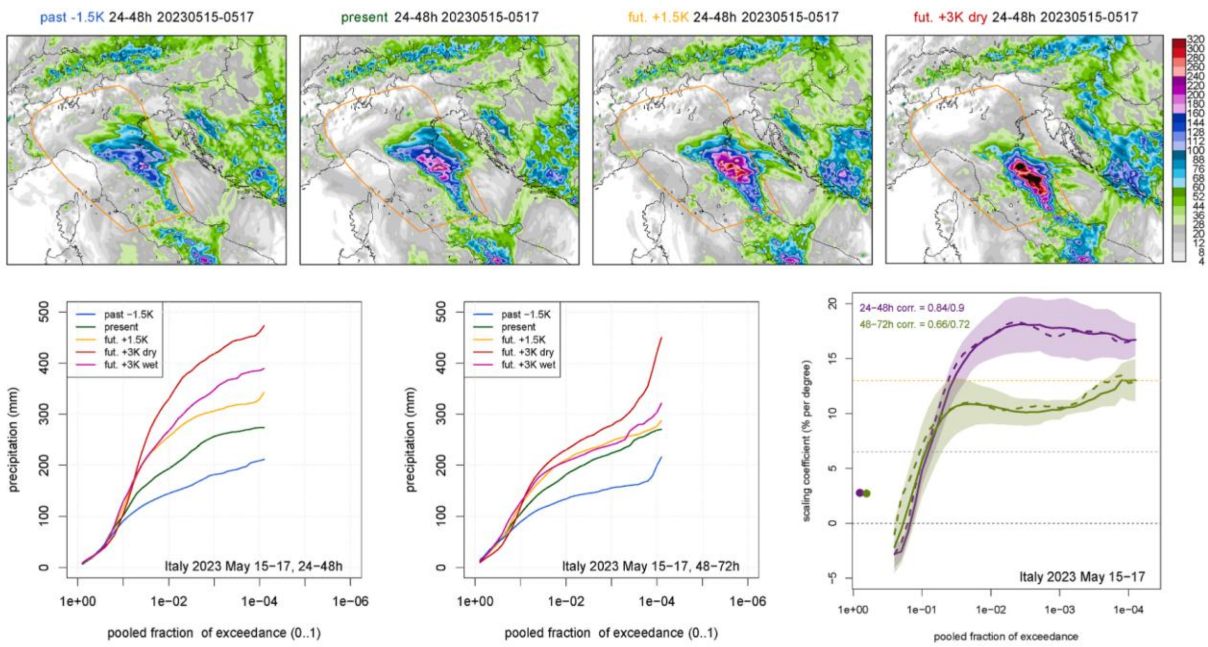

Figure 1. Top panels: Ensemble maximum (max of 3 simulations with different initial conditions) of accumulated rainfall 15 to17 May 2023 at different warming levels, from left to right -1.5, 0, 1.5 and 3 degrees compared to present. For the 3 degrees warming level we only show the dry11-based simulation. Results are for the accumulation from 24-48h of the forecasts. Bottom panels: The distribution of rainfall amounts within the orange polygon area (including sea points) as a function of pooled fraction of exceedance, left are 24-48h accumulations (as shown in the maps), middle the 48-72h accumulations. Right-hand panel. The sensitivity per degree global warming, mean (solid), the ensemble max results (dashed), and uncertainty band given by the +/- the standard deviation between 6 estimates. The dots represent the mean precipitation change over the orange polygon (details in Lenderink et al. WACE, 2025)

The above results have been obtained before starting this special project (runs performed in 2024). We are now extending to other recent flood events. Reruns of storm Boris (October 2024) have been performed as a test case of the implementation of the system. A preliminary analysis of the results revealed similar findings a s above. Depending on actual events happening over western Europe this year we can run the system to assess the impact of climate change. In addition, we also updated the HCLIM version to Cy46, and test runs for Boris are currently underway.

In addition, we aim to run continuously, so that an assessment can already be made before the actual events happens. As discussed earlier, problems with the surface scheme of HCLIM prevents us from performing these longer continuous simulations. With longer simulations we can also better assess the statistical properties of the system, and compare with other methods.