SPECIAL PROJECT PROGRESS REPORT

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

Reporting year	2020
Project Title:	SPHERA (Special Project: High rEsolution ReAnalysis over Italy)
Computer Project Account:	SPITCERE
Principal Investigator(s):	Ines Cerenzia, Tiziana Paccagnella
Affiliation:	ARPAE Emilia-Romagna, SIMC, Viale Silvani, 6 Bologna, Italy
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Andrea Montani
Start date of the project:	01/01/2018
Expected end date:	31/12/2020

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)	14.340.000	14.577.184 (101%)	38.550.000	13.068.638 (34%)
Data storage capacity	(Gbytes)	78.000	78.393	132.200	86.418

Summary of project objectives (10 lines max)

The SPHERA special project aims at developing a high resolution atmospheric regional reanalysis over Italy (convection permitting resolution of 2.2km), performed with the COSMO non-hydrostatic Limited Area Model. SPHERA is performed by means of a dynamical downscaling of the ERA5 global reanalysis and by employing the observational nudging during the model integration. Three-dimensional hourly model output are produced. At the end of the project, SPHERA will cover 25 years, from 1995 to 2020. The main purposes of SPHERA are:

- to provide a high resolution, space and time consistent, description of the past decades climate (statistics for extreme events, specific-site series, application in scenarios)
- to provide a COSMO model validation based on long term performance, to be used as a reference for the operational forecast and to calibrate the COSMO based forecasting systems.

Summary of problems encountered (10 lines max)

During 2019 and 2020 no problems have been encountered.

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

The production of the SPHERA reanalysis is currently ongoing and within the end of 2020, it should be performed for the entire archive extent, from 1995 to 2019.
At the same time with the production, the assessment of the SPHERA performance will be continued as well. The comparison of the surface and near surface variables with the in-situ observations will be performed with the verification tool box (configured ad hoc in 2018). Moreover, an intercomparison study with other high resolution reanalyses covering the Italian domain is currently ongoing and it will be extended to several near surface variables and several years. It aims at analyzing pros/drawbacks of different reanalysis archives, all driven by ERA5, but based on diverse limited area models, using different assimilation methods.

List of publications/reports from the project with complete references

2019/09 Oral presentation with title: " SPHERA (High Resolution REAnalysis over Italy): development and first assessment" (Ines Cerenzia[1], Tiziana Paccagnella[1], Andrea Montani[2], 1. Arpae-Emilia Romagna, HydroMeteoClimate Service, Bologna, Italy, 2. ECMWF Reading, UK) presented at the AISAM (Italian Association for Atmospheric Science and Meteorology) Annual Congress

2019/09 Oral presentation with title: "La rianalisi meteorologica in Italia: confronto tra i dataset disponibili" (Simone Sperati1, Matteo Lacavalla1, Riccardo Bonanno1, Ines Cerenzia2, Tiziana Paccagnella2,Andrea Montani2,3, Bernardo Gozzini3,4,Francesco Pasi4, Valerio Capecchi4, 1. RSE SpA, Milano, 2. ARPAE-SIMC, Bologna, 3.ECMWF, Reading, UK, 4.Consorzio LaMMA, Sesto Fiorentino FI) presented at the AISAM (Italian Association for Atmospheric Science and Meteorology) Annual Congress

2019/09 Poster with title: "Intercomparison of three regional reanalysis datasets over Italy based on ERA5" (Ines Cerenzia 1* , Matteo Lacavalla 2 , Simone Sperati 2 , Riccardo Bonanno 2 , Valerio Capecchi 3, Tiziana Paccagnella 1 , Andrea Montani 1,4 , Bernardo Gozzini 3,4 , Francesco Pasi 3. 1. Arpae-Emilia Romagna, HydroMeteoClimate Service, Bologna, Italy, 2. RSE S.p.A (Ricerca sul Sistema Energetico S.p.A), Milano, Italy, 3. Consorzio LAMMA, Sesto Fiorentino, Italy, 4. ECMWF, Reading UK) presented at the EMS Meeting

2019/09 Oral presentation with title: "SPHERA a convection-permitting reanalysis over Italy" (Ines Cerenzia 1, Tiziana Paccagnella 1 , Andrea Montani, 1,2 ,Matteo Lacavalla 3 , Riccardo Bonanno 3 , Simone Sperati 3 , Valerio Capecchi 4. 1. ARPAE-Emilia Romagna SIMC, Bologna, 2. ECMWF, Reading UK, 3. RSE S.p.A, Milano, 4 Consorzio LaMMA, Sesto Fiorentino FI) presented at ClimRisk 2019

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.

1. Production of SPHERA

SPHERA is performed by means of a dynamical downscaling of ERA5 global reanalysis and by employing observational nudging during the model integration. Details about the SPHERA model setup and its preparation are reported in the progress report 2018 and 2019 of this special project. For simplicity, the simulation is organized in a sequence of 24h-long runs: at the first day (the real start of the model integration), the initial fields are interpolated from ERA5, while afterwards warm initialization is applied (the 24h forecast is used as initial condition for the following run) in order to reproduce a continuous run. The lateral boundary conditions are updated every hour and the sea surface temperature is updated (interpolated from ERA5) every day.

The production period (1995-2019) was sliced in six production trances of 4 years each (Figure 1), which could run independently. Each trance was preceded by 6 months of rerun needed for the soil spin-up. As reported in the production advancement in Figure 1:

- the trances for 2003-2006, 2007-2010 and 2011-2014 have been completed (partly in 2019 taking advantage of the accorded additional resources and partly in 2020)

- the trance for 2015-2018 is almost completed and the last period (one year: 2018) will be produced in the second half of 2020,
- the trances for 1995-1998 and 1999-2001 are currently in production and they will be completed in the second half of 2020.
- the production of the last trance (2015-2018) will be extended of one year, in order to cover 2019. However, only the first part of this year will be actually produced in 2020 within the present special project, due to the unavailability of the deep soil temperature used as bottom boundary condition to the COSMO model. Indeed this field is generated by applying a temporal delay to the three-years running mean of the deepest soil temperature of ERA5 (details reported in the progress report 2019 of this special project). Due to the operation applied and to the latency by which ERA5 is published, the deep soil temperature for ERA5 is available with a delay of about 1.5 year with respect to the real time. The last part of 2019 and 2020 (i.e. the last year foreseen in SPHERA archive) will be completed in the next years, on behalf of a new special project and in case it will be approved.

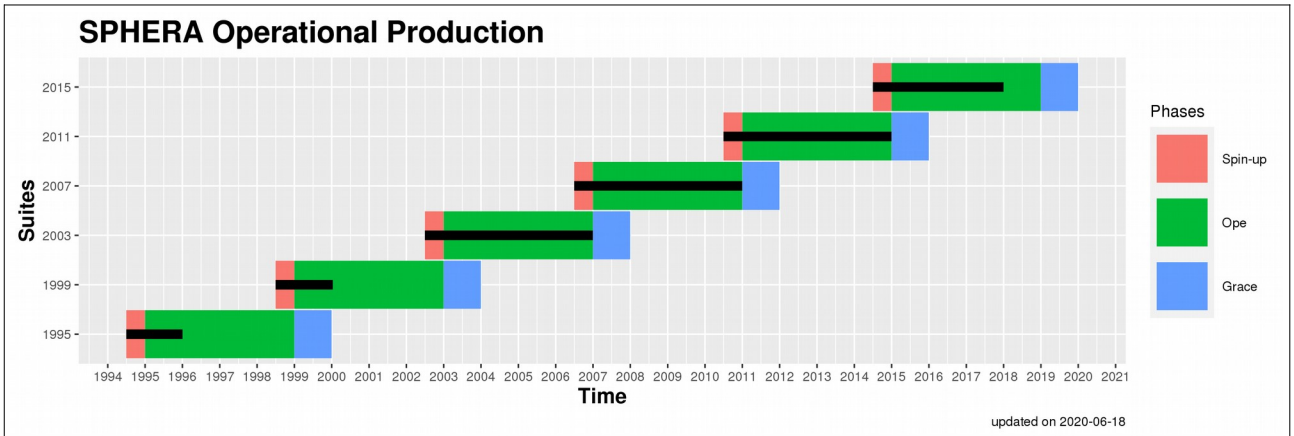

Figure1. Production advancement for the SPHERA dataset updated at 18/06/2020. Black line indicates the periods already produced, while the other colors represent the production phases ('Ope' stays for operational and indicates the production of final data, 'spin-up' indicates the initialization period, while 'Grace' indicates an optional rerun, only for comparison purposes).

In addition the XCDP monitoring screenshot, a monitoring tool has been prepared to routinely check up the production advancement and the status of the data assimilation. Everyday an informative mail reports the updated plot of the production advancement (as Figure 1) and the number of days simulated by each production trance in the last 24hours. Regarding the monitoring of data assimilation, it considers the number of observations assimilated during each simulation (24hours-long) subsetted per observation type. Details are reported in the progress report 2019 of this special project.

2. Performance assessment

A potentially critical issue on long continuous simulations is the development of unrealistic temporal trends. The presence of time trends during the production trances was verified in detail in the progress report 2019.

The performance assessment herein reported regards the verification of the daily accumulated precipitation against surface observations over two of the production trances (2011-2014 and 2015-2017). Backward extension is currently ongoing. Verification of the temperature at 2m and wind components at 10m will be accomplished in the next months.

The verification of precipitation was performed over 0.25°x0.25° boxes covering the Italian domain and comparing the maximum of the daily accumulated precipitation in each box between model and observations. Notice that the observations used in this phase (from the Italian Civil Protection network, http://www.mydewetra.org/) had not been ingested into the data assimilation procedure.

For brevity, the results are reported only in terms of the Threat Score (TS). The TS is useful to measure the accuracy of a forecast and is defined as the number of correct "yes" forecasts divided by the total number of occasions on which that event was forecast and/or observed:

$$TS = hits/(hits+misses+falseAlarms) = (1/POD + 1/(1-FAR) - 1)^{(-1)}$$

It can be viewed as a representation of the correct forecasts for the quantity, after removing correct "no" forecasts from consideration. The worst possible threat score is zero, and the best possible threat score is one. It is a non-linear combination of the Probability Of Detection (POD) and False Alarm Rate (FAR) and compared to them is less sensitive to the horizontal resolution of the model verified. For this reason, it is a useful score to fairly compare SPHERA and ERA5, which have horizontal resolutions of respectively 2.2km and 31km.

Regarding TS, SPHERA performs better than ERA5 in any season for daily precipitation thresholds higher than 50mm (Figure 1). The improvement is particularly large during winter and spring months. For the precipitation threshold of 25mm, the two models present similar performances in terms of TS, with SPHERA behaving better in winter. For lower precipitation thresholds, generally ERA5 reports a greater TS than SPHERA, except for some summer seasons: i.e. 2011-2013-2015, which are characterized by strongly negative precipitation anomalies over Italy.

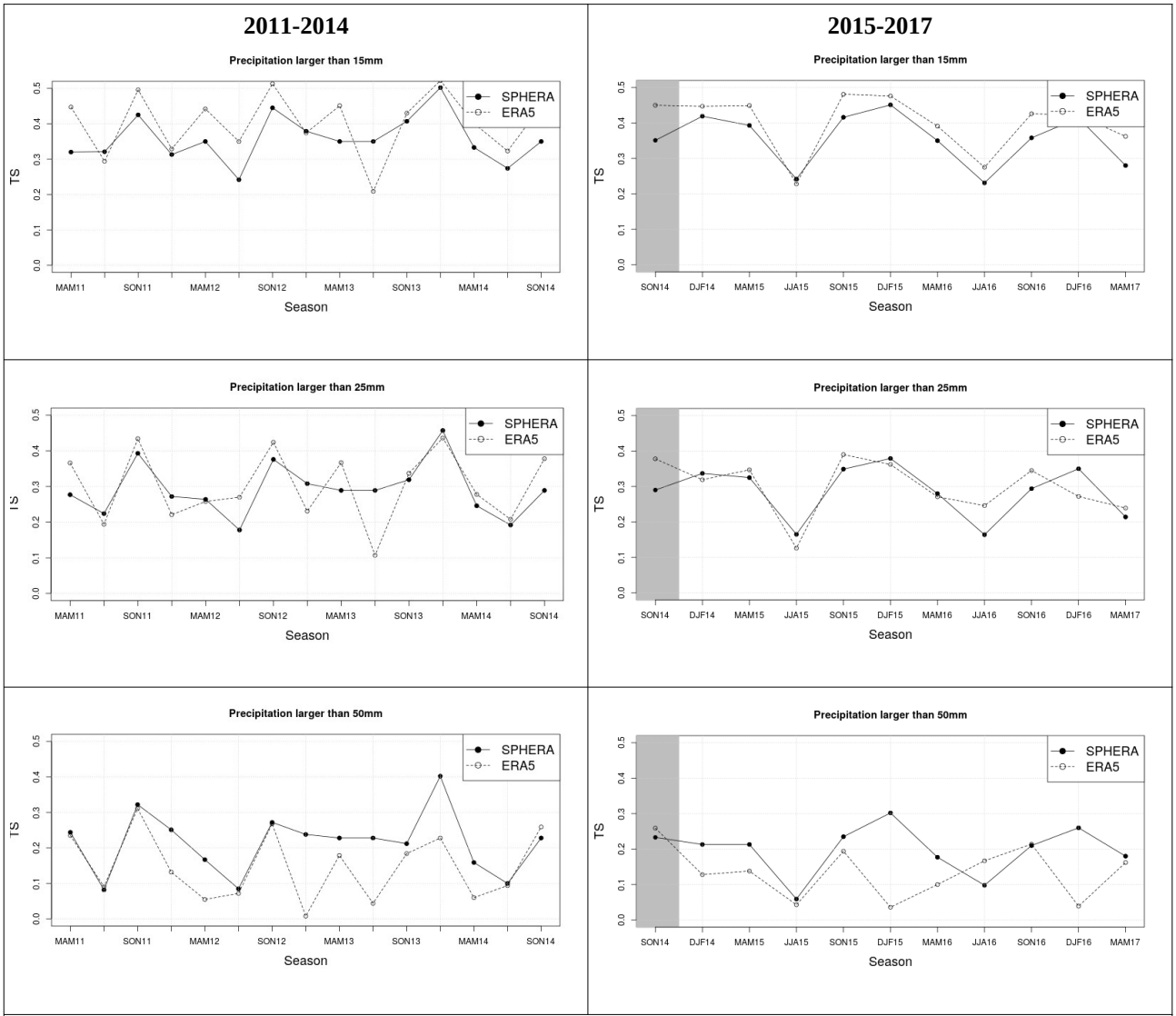

Figure 1. Threat Score (TS) of the daily accumulated precipitation reported by SPHERA and ERA5 during two of the

production trances of SPHERA (2011-2014 and 2015-2017)

The seasonal average of TS confirms that the larger advantage of SPHERA versus ERA5 is during the winter months, when higher scores are reported for daily accumulated precipitation amounts greater than 15 – 20 mm (Figure 2). During spring, the value at which SPHERA starts to improve compared to ERA5 is between 25 and 30 mm, while in fall this limit is larger, being at approximately 50 mm. In summer the TS is very variable: the average of the period 2011-2014 evidences an improvement starting from 15 mm, while the average of the trance 2015-2017 does not show an advancement until precipitation are larger than 50 mm. A longer verification period is necessary to better define the precipitation performance during summer. As a general remark, the scores reported in Figure 2 further confirm that SPHERA has a higher ability that ERA5 to reproduce the daily accumulated precipitation in all seasons for thresholds greater than 50 mm and that ERA5 misses (or underestimates) the majority of these occurrences.

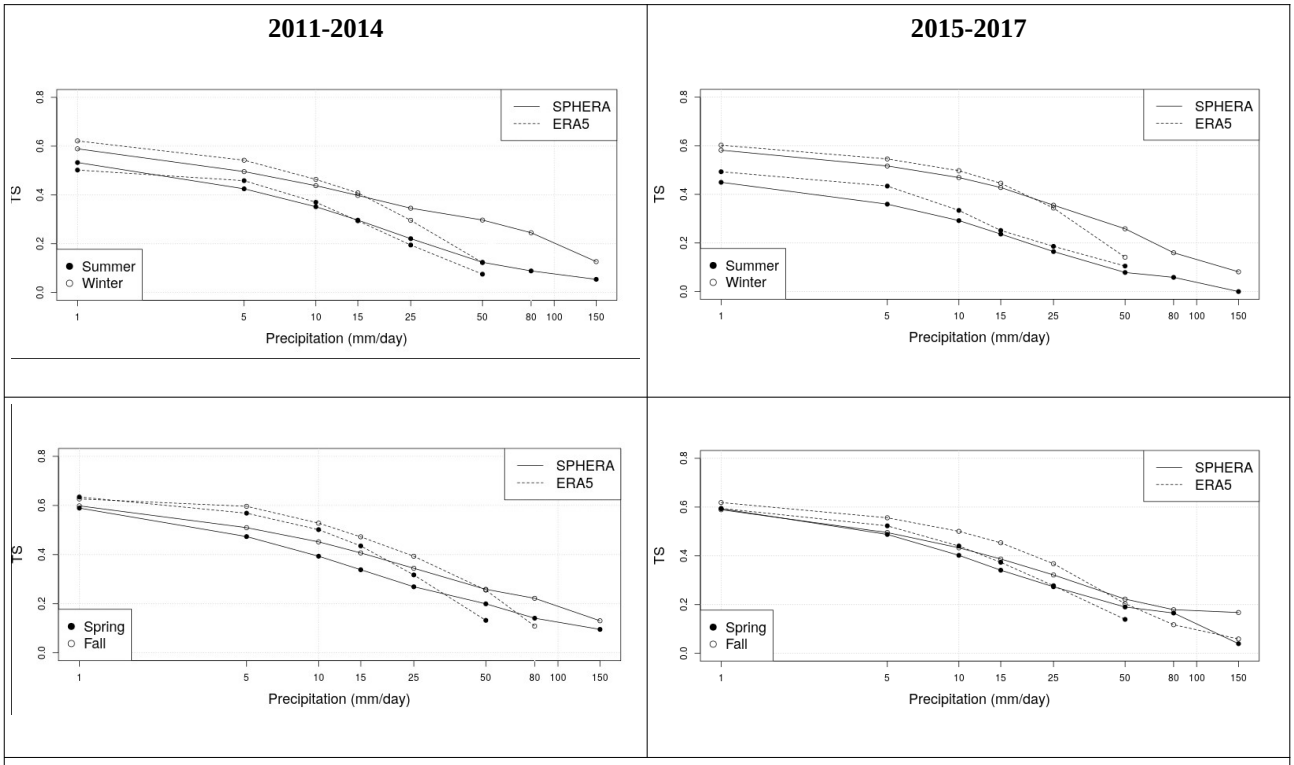

Figure 2. Seasonal average of the Threat Score (TS) of the daily accumulated precipitation as a function of the precipitation threshold reported by SPHERA and ERA5 during two of the production trances of SPHERA (2011-2014 and 2015-2017)