REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: ITALY…………………….……………………………

Principal Investigator[1]: Stefano Federico (cm4)………

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Project Title: Study of different configurations of the RAMS model for precipitation and lightning forecast over Italy at high horizontal resolution. ……………………………………………………………….………

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** __________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2018-2020: (To make changes to an existing project please submit an amended version of the original form.)	**2018**	**2019**	**2020**
High Performance Computing Facility (SBU)	6,000,000	6,000,000	6,000,000

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Accumulated data storage (total archive volume)[2]	(GB)	4TB	7TB	9TB

An electronic copy of this form must be sent via e-mail to*:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

……………………………………………

Continue overleaf

Principal Investigator: ……Stefano Federico (cm4)…………
…………………………

Project Title: …… Study of different configurations of the RAMS model for precipitation and lightning forecast over Italy at high horizontal resolution.
……………………………………………………………

Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests will be evaluated by ECMWF as well as the Scientific and Technical Advisory Committees. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Large requests asking for 10,000,000 SBUs or more will receive a detailed review by members of the Scientific Advisory Committee.

All accepted project requests will be published on the ECMWF website.

Abstract

In recent years (2009-2016) several improvements and new parameterizations have been implemented into the RAMS (Regional Atmopheric Modeling System). Some of them have been introduced by the PI of this project at ISAC-CNR in Rome, and some others have been introduced at the Colorado State University (Fort Collins, Colorado) by the Professor Sue van den Heever's research group.

The improvements introduced at ISAC-CNR have been discussed in few publications (Federico et al., 2014; Federico, 2016; Federico et al., 2017), and are based on case studies approach. The improvements made at Colorado State University, in addition to publications, are also documented in web pages (http://vandenheever.atmos.colostate.edu/vdhpage/rams.php) . Hereafter we will distinguish the two models calling: RAMS the model developed at ISAC-CNR, and CSU-RAMS the model developed at Colorado State University.

It is important to assess the differences (strength and weaknesses) of the model to different physical parameterizations. **In particular, the aim of this special project is to test the model performance for the one-day precipitation and flashes forecast with different microphysics and radiative parameterization schemes available in the code.**

Two different microphysics and radiative schemes will be considered for each model. For the RAMS model the microphysics schemes are: the single moment WSM6 scheme (Hong and Lim, 2006), recently implemented in RAMS (Federico, 2016) and the Thompsom (Thompson et al., 2008) microphysics scheme, whose implementation is in progress and a beta version of the code exits. For the CSU-RAMS model the microphysics schemes are: a single moment scheme (Walko et al., 1995) and a double moment scheme (Meyers et al., 1997). It is important to note that several improvements were added to the microphysics scheme, both one- and two-moments, at the CSU compared to the version documented in the abovementioned papers (see Igel et al., 2014 and references therein).

Two radiative schemes will be considered for both RAMS and CSU-RAMS: the Chen and Cotton scheme (Chen and Cotton, 1983) and the Harrington scheme (Harrington, 1997). The Chen-Cotton radiative scheme, used for both short-wave and long-wave radiation, accounts for the total condensate in the atmosphere but not for the specific hydrometeor type. In particular, the scheme has an "effective emissivity" for cloud layers, where the cloud emissivity is parametrized empirically from observations. The "effective emissivity" is a function of the total condensate water path, computed summing all hydrometeors mixing ratios for each model

level (liquid, i.e. cloud and rain, solid, i.e. ice and snow, and mixed phase, i. e. graupel) and integrating over the cloud-layer (Chen and Cotton, 1983).

Numerical and observational experiments show that the impact of the water phase is significant for the computation of the radiative transfer because the absorption and emissions are largely reduced in ice compared to liquid path with the same water path. The Harrington scheme, which considers both short wave and long wave components of the radiation, takes into account for the optical properties of the hydrometeors but it is slower that the Chen and Cotton scheme. Moreover, the Harrington radiative scheme has been coupled at the CSU with an aerosol module to simulate the impact of the aerosols on both radiation and microphysics (Saleeby and van den Heever, 2013).

In summary, the following model configurations will be compared in this project: RAMS with the WSM6 microphysics scheme and Chen-Cotton radiative scheme (R_W6_CC), RAMS with the Thompson two-moments microphysics scheme and the Chen-Cotton radiative scheme (R_TH_CC), RAMS with the WSM6 microphysics scheme and the Harrington radiative scheme (R_W6_HA), RAMS with the Thompson two-moments microphysics scheme and the Harrington radiative scheme (R_TH_HA), CSU-RAMS with the single moment microphysics scheme and the Chen-Cotton radiative scheme (CSU_SM_CC), CSU-RAMS with the single moment microphysics scheme and the Harrington radiative scheme (CSU_SM_HA), CSU-RAMS with the two-moments microphysics scheme and the Chen-Cotton radiative scheme (CSU_TM_CC), CSU-RAMS with the two-moments microphysics scheme and the Harrington radiative scheme (CSU_TM_HA).

For each model configuration, a set of twenty case studies will be run, using as initial and boundary conditions the 12 UTC operational assimilation/forecast cycle of the IFS (Integrated Forecasting System) of ECMWF (European Centre for Medium Weather range Forecast). The RAMS horizontal grid resolution cannot be definitively clarified at this stage, because it depends on the specific implementation that will be done at ECMWF supercomputer, however it will be between 2 and 4 km, while it will use 35-40 vertical levels. Each simulation will last 36 h, the first 12 h being spin-up time and the second 24 h being the forecast for the following day. This (daily) precipitation will be compared against raingauges data over Italy,

A second subject that will be investigated in this project is the test of two parameterization schemes for the forecast of the electric activity over Italy. These schemes are based one on the methodology of Dahl et al. (2011), already implemented in RAMS, and the other on the computation of the integrated ice water path (Barthe e t al., 2010). The two methods will be used to simulate the lightning for the twenty case studies using the best RAMS configuration, i.e. the model configuration, among the eight tested, that shows the best performance for the daily precipitation forecast.

An important aspect of this project is to have a reliable verification database to compare the model output. For the precipitation, we will use the dataset of the Italian Civil Protection Department (DPC). This network has more that 2900 raingauges over Italy and gives the opportunity to verify the precipitation forecast at high horizontal resolution over the whole country. A free dataset of this network is available for the HyMeX-SOP1 (HYdrological cycle in the Mediterranean Experiment – first special observing period) occurred between 5 September and 6 November 2012. The dataset can be found at: http://mistrals.sedoo.fr/?editDatsId=1282&datsId=1282&project_name=MISTR&q=DPC .

HyMeX (Drobinski et al., 2014; Ducroq et al., 2014) is an international experimental program that aims to advance scientific knowledge of water cycle variability in the Mediterranean basin. This goal is pursued through monitoring, analysis, and modelling of the regional hydrological cycle in a seamless approach. In HyMeX special emphasis is given to the topics of the occurrence of heavy precipitation and floods, and their societal impacts, which were the subjects of the SOP1 (first special observing period).

During HyMeX-SOP1 several weather systems passed over Italy causing widespread convection and precipitation. Few of them are well known and have been already studied by several authors. In particular, Federico et al. (2017) selected twenty cases of widespread convection over Italy with moderate to heavy precipitation. These cases will be considered in this project.

Scores (Bias, POD, FAR, ETS) computed from 2 by 2 contingency tables (dichotomous case), and quantitative scores (QB, MAE and RMSE) will be considered to evaluate and compare the performance of different model configurations. The main focus will be on the daily precipitation forecast, but shorter scales could be also considered.

For the verification of the lightning forecast we will use the data of the LINET network (Betz et al., 2009). LINET is a European lightning location network for high-precision detection of total lightning, cloud to ground (CG) and intra cloud (IC) lightning, with utilization of VLF/LF techniques (in range between 1 and 200 KHz). The network has more than 550 sensors in several countries worldwide, with very good coverage over central Europe and central and western Mediterranean (from 10° W to 35° E in longitude and from 30° N to 65° N in latitude). The lightning three-dimensional location is detected using the time of arrival (TOA) difference triangulation technique (Betz et al., 2009). For the verification of the lightning forecast, scores (Bias, POD, FAR, ETS) computed from 2 by 2 contingency tables (dichotomous case) will be used for different lightning thresholds.

Scientific Plan

Months 1-6: Implementation of the codes, both RAMS and CSU-RAMS, at the ECMWF supercomputer. In this part of the project, in addition to the technical settings, a case study of HyMeX-SOP1 will be selected (likely 15 October 2012, which is a well-known case study) and used to check the correct installation of the codes. These tests will also give a qualitative comparison of the output of the different model configurations.

Months 7-23: Simulations for the twenty case studies of the HyMeX-SOP1 for different model configurations. The following table clarify the simulations that will be performed during this period:

ACRONYM	Model configuration	Simulations
R_W6_CC	RAMS with WSM6 microphysical scheme and Chen-Cotton radiative scheme.	20 cases of HyMeX-SOP1
R_W6_HA	RAMS with WSM6 microphysical scheme and Harrington radiative scheme.	20 cases of HyMeX-SOP1
R_TH_CC	RAMS with Thompson microphysical scheme and Chen-Cotton radiative scheme.	20 cases of HyMeX-SOP1
R_TH_HA	RAMS with Thompson microphysical scheme and Harrington radiative scheme.	20 cases of HyMeX-SOP1
CSU_SM_CC	CSU-RAMS with single moment microphysical scheme and Chen-Cotton radiative scheme.	20 cases of HyMeX-SOP1
CSU_SM _HA	CSU-RAMS with single moment microphysical scheme and Harrington radiative scheme.	20 cases of HyMeX-SOP1
CSU_DM _CC	CSU-RAMS with double moment microphysical scheme and Chen-Cotton radiative scheme.	20 cases of HyMeX-SOP1
CSU_DM _HA	RAMS with double moment microphysical scheme and Harrington radiative scheme.	20 cases of HyMeX-SOP1

Table 1: model simulations.

Two reports will be prepared in this period, one report at the end of each year of project, showing both the project evolution and the performance of the different model configurations.

At the end of this activity (second year) the “best” model configuration will be determined and used for the forecast of the electric activity.

Months 16-24: Implementation of the schemes for lightning simulation in the best model configuration (the Dahl methodology is implemented only into RAMS at the time of writing). In this part of the project new parameterizations to simulate the electric activity will be implemented and tested for one of the 20 cases of the HyMeX-SOP1 (likely 15 October 2012). This activity will be shown in the project report at the end of the second year.

Months 25-34: At the end of the second year, the "best" model configuration will be defined; this configuration will be used to test the lightning schemes for all the twenty cases of the HyMeX-SOP1. In particular, all the cases will be simulated with the two lightning schemes and the performance of each scheme will be evaluated comparing the forecast with the LINET observations.

Months 34-36: Preparation of the final report.

Technical aspects

The RAMS model is written in Fortran with few routines in C. The model uses the hdf5 library (the CSU-RAMS uses the parallel version of the library) and MPI (Message Passing Interface). The model will be run between 2 and 4 km horizontal resolutions and the final resolution will be chosen in the first part of the project (Months: 1-6). The model takes about 12 h to simulate one day at 2.5 km horizontal resolution over Italy (37 vertical levels up to the 23000 m) using 108 cores (3 full nodes) of the ECMWF supercomputer cca. Using this configuration, which represents a good horizontal resolution, and considering also the initial and prost-processing, each simulation takes about 50,000 SBU. In view of this time, and considering that several experimental tests need to be done (20 experiments for each of the RAMS configuration plus 20 experiments for each configuration using lightning; a total of 200 experiments, i.e. 10,000,000 SBU, excluding numerical experiments for the set-up of the model and development of the code), we request a total of 18,000,000 SBU over the three years and the possibility to use three full nodes in order to experiment resolutions higher than 2.5km for specific cases. Also, an adequate storage is requested to maintain a copy of most of the simulations and to perform the post-processing on ecgate.

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