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CONSORTIUM FOR SMALL SCALE MODELING

CALMO-MAX @ CIRA:
Sensitivity with COSMO-1 over South Italy

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Status of activities

- No new simulations with respect to those presented at COSMO GM 2018 in St. Petersburg.
- A deeper analysis has been performed using the data already available.
- Preparation of the manuscript:

E. Bucchignani, A. Voudouri, P. Mercogliano, A sensitivity analysis with COSMO-LM at 1 km resolution over South-Italy,
submitted to Advances in Meteorology (under review)

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Introduction

CIRA is working on the definition of a new COSMO-LM configuration at very high resolution, running over a domain including the CIRA facilities, where several weather instruments are currently available.

CIRA is currently involved in the PT-AEVUS, PP-CALMO-MAX and PT-CIAO for the testing of this new configuration.

The days 5-6 November 2017 Italy was affected by a strong perturbation, which caused intense precipitation and related hazards.

The period **3 to 6 November 2017** has been selected as first test case in order to test the capabilities of this COSMO-LM very high resolution configuration (also considering different settings) and its capability in reproducing weather conditions during this period.

The domain considered

The domain is centered over Campania region in southern Italy. This area includes three airports, i.e. Capua (military airport “O. Salomone”), Naples (Capodichino civil airport), and Pratica di Mare (military airport “de Bernardi”).

Pratica di Mare

Naples

CIRA

Domain:**12.22° – 14.55°E; 40.63° - 41.88° N**

Rotated North Pole: **-166°; 41°**

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Model version and set-up

- Model versions:

  - int2lm_150611_2.02

  - cosmo_171215_5.04h

- RTTOV (Radiative Transfer model for TIROS Operational Vertical sounder) libraries Version 12 have been included.

- COSMO-LM resolution: **0.009° (about 1 km)**

- Computational domain**: 260 x 138 points; 60 vertical levels, time step 10 s.**

- Time period: From 1 October 2017 onward (running with a delay of 3 days for research purposes)

- Forcing data: ECMWF IFS (resolution of 0.075°)

Parameters considered in CALMO-MAX

	Min.	Default	Max.
tkhmin	0.1	0.4	2
rlam_heat	0.1	1	2
v0snow	10	20	30
uc1	0	0.3	1
radfac	0.3	0.6	0.9
kexpdec	0	2	1
fac_rootdp	0.5	1	1.5

This is not the maximum value

parameters selected and related range of values

- uc1 is hard coded in data_constants.f90
- radfac is called now radqc_fact
- kexpdec is a number and is hard coded in sfc_terra.f90
- fac_rootdp is one of the parameters of the namelist EPSCTL

Sensitivity tests for CALMO-MAX

Simple tests

TEST	Parameter
C0	Default
C1	tkhmin at minimum
C2	tkhmin at maximum
C3	rlam_heat at minimum
C4	rlam_heat at maximum
C5	v0snow at minimum
C6	v0snow at maximum
C7	uc1 at minimum
C8	uc1 at maximum
C9	radfac at minimum
C10	radfac at maximum
C11	fac_root_dp at minimum
C12	fac_root_dp at maximum
C13	kexpdec at 0.
C14	kexpdec at 1.

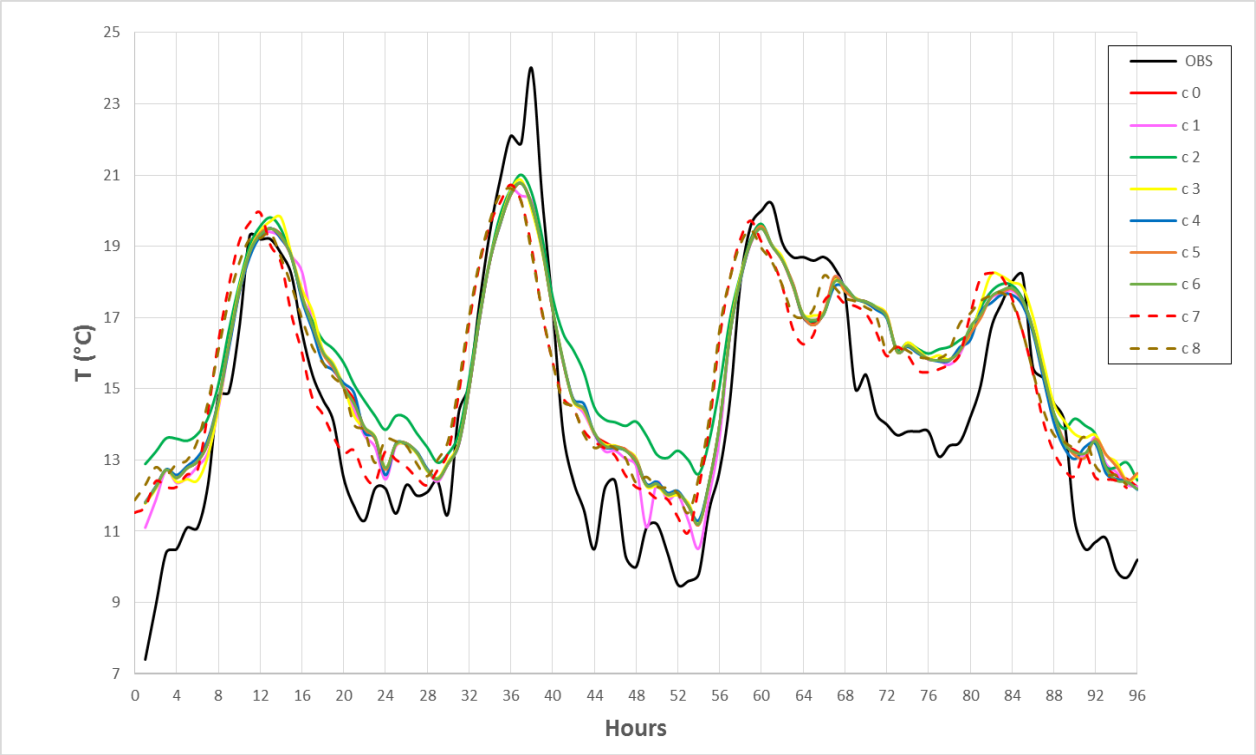
Interaction tests

TEST	Parameter
C15	rlam_heat (min) , uc1 (min)
C16	rlam_heat (min), tkhmin (min)
C17	uc1 (min), v0snow (max)
C18	rlam_heat (min), v0snow (max)

The analysis of results shows that radfac, fac_root_dp and kexpdec produce very slight (or no) modifications, so they have been neglected.

The four interaction simulations were performed considering max (min) values of rlam_heat, uc1, tkhmin, v0snow.

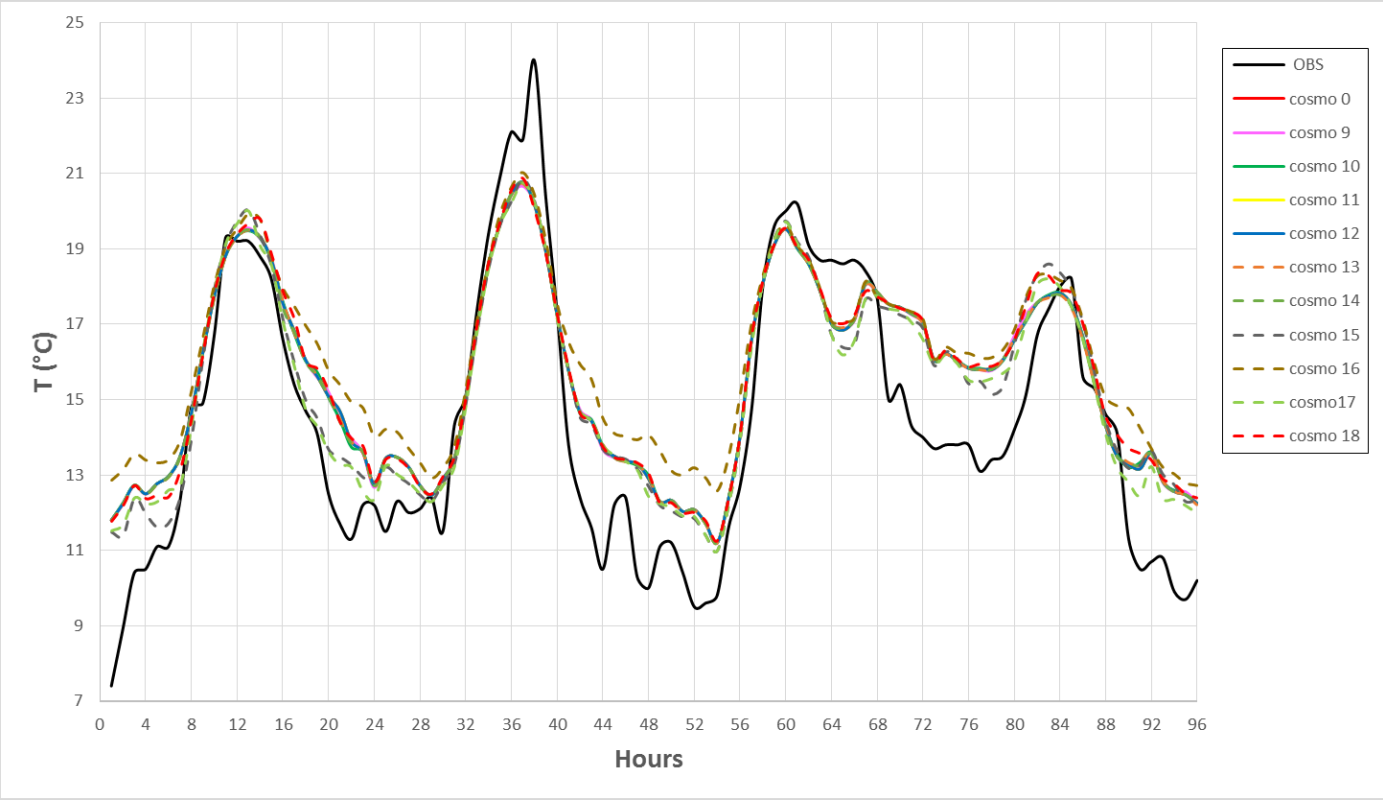
Time series of T2m at CIRA site (C0 to C8)



With the **default** configuration, minimum daily temperature values are overestimated, while the maximum daily values are underestimated.

- Neither of the sensitivity runs produces significant improvements in terms of daily maximum T2m.
- C7 (uc1 at minimum) allows a better representation of nocturnal values between the first and second day, while C1 (tkhmin at minimum) provides a better representation of nocturnal values between the second and third day.

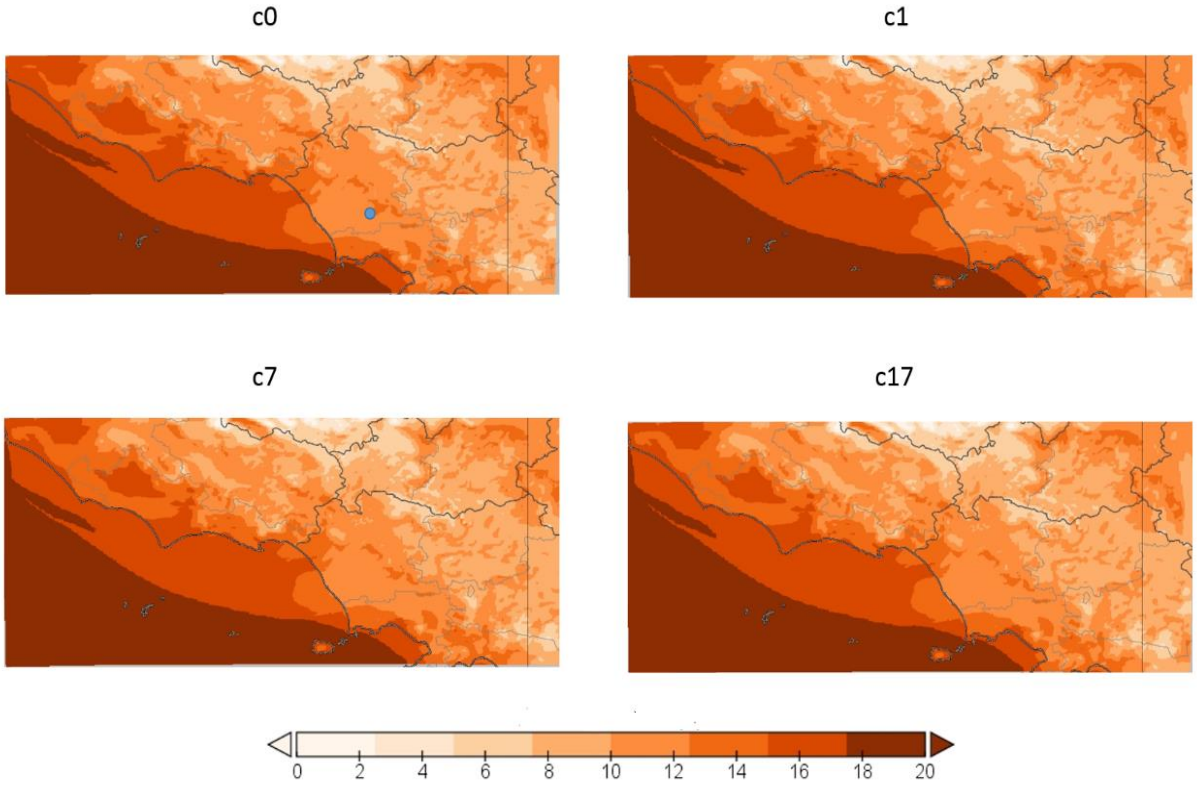
Time series of T2m at CIRA site (C9 to C18)



- Changes in radfac, fac_root_dp and kexpdec do not produce changes in the temperature values.

- C15 (rlam_heat min + uc1 min) provides an improvement (increase) of the maximum temperature, and a slight reduction of the minimum and mean values. Currently, this is the best configuration for temperature.

T2m distribution (°C) related to 5th November at 6.00 (hour 54)



C1 (tkhmin at minimum) and C17 (uc1 min, v0snow max) provide lower values not only over CIRA site, but also over mountain areas (eastern part of the domain), while with C7 (uc1 at minimum) reductions are confined to smaller areas.

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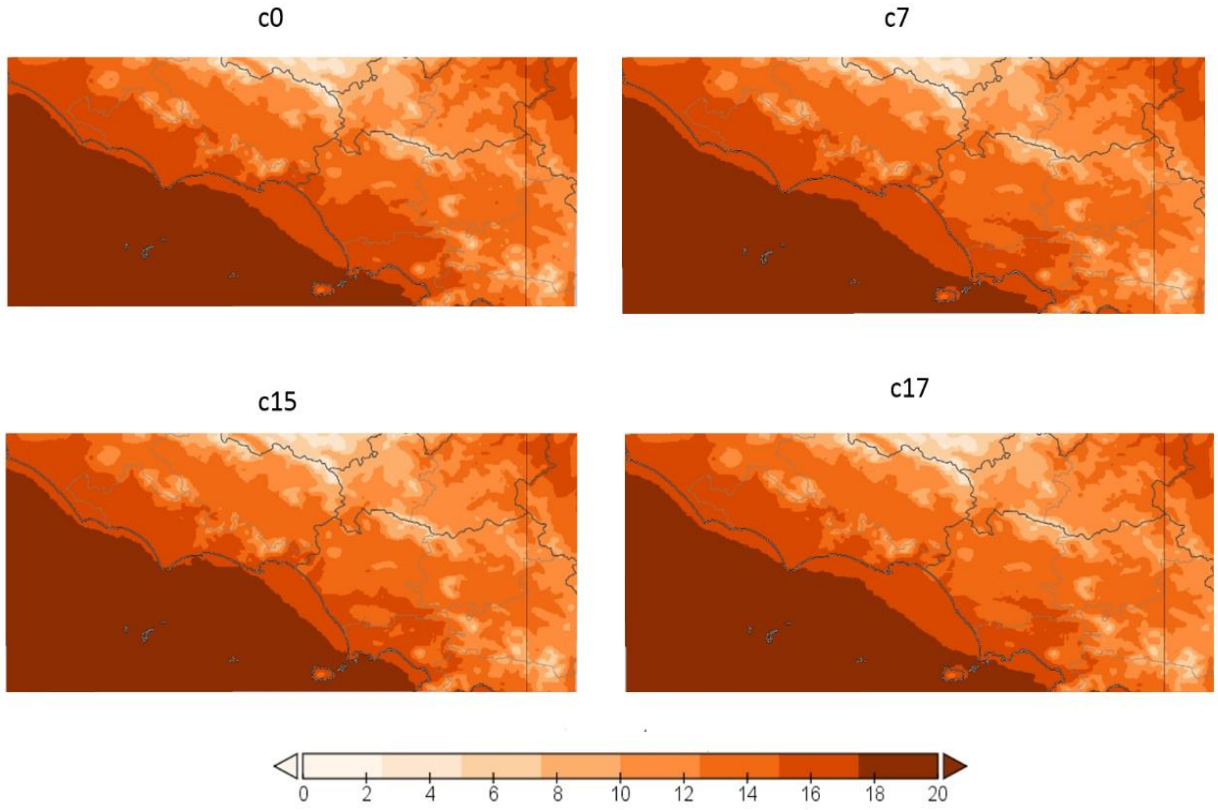
T2m distribution (°C) related to 3rd November (mean value)



C0 overestimates the mean value of about 1.2°C at CIRA site; the other three configurations are able to reduce significantly this bias (of about 0.5°C). A general temperature reduction is observed over the whole domain with respect to C0.

T2m mean (°C) values over 3-6 November 2017

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T2m mean values

		DEF	TKHMIN		RLAM_HEAT		V0snow		UC1		RADFAC		FAC ROOTDP		KEXPDEC		INT1	INT2	INT3	INT4
	OBS	cosmo0	cosmo1	cosmo2	cosmo3	cosmo4	cosmo5	cosmo6	cosmo7	cosmo8	cosmo9	cosmo10	cosmo11	cosmo12	cosmo13	cosmo14	cosmo15	cosmo16	cosmo17	cosmo18
03-nov	14.6	15.8	15.7	16.3	15.8	15.8	15.8	15.8	15.3	15.9	15.8	15.8	15.8	15.8	15.8	15.8	15.3	16.4	15.3	15.8
04-nov	15.3	15.7	15.7	16.3	15.8	15.7	15.7	15.7	15.7	15.8	15.8	15.8	15.7	15.7	15.8	15.8	15.7	16.2	15.6	15.8
05-nov	15.9	16.5	16.4	16.8	16.5	16.5	16.5	16.5	16.3	16.6	16.5	16.5	16.5	16.5	16.5	16.5	16.3	16.8	16.3	16.5
06-nov	13.6	15.1	15.1	15.4	15.4	15.0	15.2	15.1	15.0	15.2	15.1	15.1	15.1	15.1	15.1	15.1	15.2	15.7	14.9	15.3

T2m average bias values

03-nov	14.6	1.2	1.1	1.7	1.2	1.2	1.2	1.2	**0.7**	1.3	1.2	1.2	1.2	1.2	1.2	1.2	**0.7**	1.8	**0.7**	1.2
04-nov	15.3	0.4	0.4	1.0	0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.4	0.9	**0.3**	0.5
05-nov	15.9	0.6	0.5	0.9	0.6	0.6	0.6	0.6	**0.4**	0.7	0.6	0.6	0.6	0.6	0.6	0.6	**0.4**	0.9	**0.4**	0.6
06-nov	13.6	1.5	1.5	1.8	1.8	1.4	1.6	1.5	1.4	1.6	1.5	1.5	1.5	1.5	1.5	1.5	1.6	2.1	**1.3**	1.7

Observational values provided by the ground station installed at CIRA:
The nearest grid point is considered. The first three hours of every day have been neglected.

uc1 at minimum (C7) provides the best improvements, even in interactions simulations, combined with rlam_heat at minimum (C15) and v0snow at maximum (C17).

T2m max-min (°C) values over 3-6 November 2017

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Max daily T2m values

		DEF	TKHMIN		RLAM_HEAT	V0snow		UC1		RADFAC		FAC ROOTDP		KEXPDEC		INT1	INT2	INT3	INT4
	OBS	cosmo0	cosmo1	cosmo2	cosmo3	cosmo4	cosmo5	cosmo6	cosmo7	cosmo8	cosmo9	cosmo10	cosmo11	cosmo12	cosmo13	cosmo14	cosmo15	cosmo16	cosmo17	cosmo18
03-nov	**19.3**	19.5	19.4	19.8	19.8	19.5	19.5	19.5	19.9	19.4	19.5	19.5	19.5	19.5	19.5	19.5	20.0	19.9	20.0	19.8
04-nov	**24.0**	20.8	20.5	21.0	20.8	20.7	20.7	20.7	20.7	20.6	20.6	20.7	20.8	20.8	20.7	20.7	20.9	21.0	20.7	20.9
05-nov	**20.2**	19.5	19.5	19.6	19.5	19.5	19.5	19.5	19.7	19.4	19.5	19.5	19.5	19.5	19.5	19.5	19.8	19.6	19.7	19.5
06-nov	**18.2**	17.8	17.7	17.9	18.2	17.6	17.8	17.8	18.2	17.7	17.8	17.8	17.8	17.8	17.8	17.8	18.6	18.3	18.2	18.3

Max T2m average bias values

03-nov	**19.3**	0.2	**0.1**	0.5	0.5	0.2	0.2	0.2	0.6	**0.1**	0.2	0.2	0.2	0.2	0.2	0.2	0.7	0.6	0.7	0.5
04-nov	**24.0**	-3.2	-3.5	**-3.0**	-3.2	-3.3	-3.3	-3.3	-3.3	-3.4	-3.4	-3.3	-3.2	-3.2	-3.3	-3.3	-3.1	-3.0	-3.3	-3.1
05-nov	**20.2**	-0.7	-0.7	-0.6	-0.7	-0.7	-0.7	-0.7	-0.5	-0.8	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	**-0.4**	-0.6	-0.5	-0.7
06-nov	**18.2**	-0.4	-0.5	-0.3	**0.0**	-0.6	-0.4	-0.4	**0.0**	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	0.4	0.1	**0.0**	0.1

Min daily T2m values

	OBS	cosmo0	cosmo1	cosmo2	cosmo3	cosmo4	cosmo5	cosmo6	cosmo7	cosmo8	cosmo9	cosmo10	cosmo11	cosmo12	cosmo13	cosmo14	cosmo15	cosmo16	cosmo17	cosmo18
03-nov	**10.5**	12.5	12.3	13.5	12.4	12.6	12.5	12.5	12.2	12.6	12.5	12.5	12.5	12.5	12.5	12.5	11.6	13.3	12.2	12.4
04-nov	**10.0**	12.4	12.4	12.9	12.5	12.4	12.4	12.4	12.3	12.5	12.4	12.4	12.4	12.4	12.5	12.5	12.3	12.9	12.3	12.5
05-nov	**9.5**	11.2	10.5	12.6	11.2	11.3	11.2	11.2	10.9	11.5	11.2	11.2	11.2	11.2	11.2	11.2	11.0	12.6	11.0	11.2
06-nov	**9.7**	12.2	12.2	12.4	12.4	12.2	12.4	12.2	12.2	12.3	12.2	12.2	12.2	12.2	12.2	12.3	12.3	12.7	12.0	12.4

Min T2m average bias values

03-nov	**10.5**	2.0	1.8	3.0	1.9	2.1	2.0	2.0	1.7	2.1	2.0	2.0	2.0	2.0	2.0	2.0	**1.1**	2.8	1.7	1.9
04-nov	**10.0**	2.4	2.4	2.9	2.5	2.4	2.4	2.4	**2.3**	2.5	2.4	2.4	2.4	2.4	2.5	2.5	**2.3**	2.9	**2.3**	2.5
05-nov	**9.5**	1.7	**1.0**	3.1	1.7	1.8	1.7	1.7	1.4	2.0	1.7	1.7	1.7	1.7	1.7	1.7	1.5	3.1	1.5	1.7
06-nov	**9.7**	2.5	2.5	2.7	2.7	2.5	2.7	2.5	2.5	2.6	2.5	2.5	2.5	2.5	2.5	2.6	2.6	3.0	**2.3**	2.7

tkhmin and uc1 at minimum provides a slight improvement for min T2m, while rlam_heat and uc1 at minimum provide an improvement for max T2m.

Analysis of sensitivity for temperature

- A reduction of tkhmin causes a decrease of minimum and mean T2m. Stratification is made more stable, leading to decrease of night air temperature. On the other side, its increase causes a general increase of temperature, especially the minimum value (up to 1.5°C). In fact, an increase of tkhmin implies that the turbulent kinetic energy is maintained in stable conditions, eliminating strong inversions.
- A reduction in rlamheat causes a slight increase of T2m, while its increase does not modify the values of temperature with respect to C0. Generally, an increase of rlam_heat will increase the heat fluxes upward from the warm surface, leading to a larger heating of the lower atmosphere.
- Variations in v0snow do not have relevant effects on T2m.
- A reduction in uc1 causes an increase of the maximum temperature and a reduction of the minimum, while an increase causes a slight reduction of the maximum temperature and a slight increase of the minimum.
- Variations in radfac, fac_root_dp and kexpdec produce very slight (or null) modifications of T2m values.

Precipitation (mm) values over 5-6 November 2017

Nearest grid point

		DEF	TKHMIN		RLAM_HEAT		V0snow		UC1		RADFAC		FAC ROOTDP		KEXPDEC		INT1	INT2	INT3	INT4
	OBS	cosmo0	cosmo1	cosmo2	cosmo3	cosmo4	cosmo5	cosmo6	cosmo7	cosmo8	cosmo9	cosmo10	cosmo11	cosmo12	cosmo13	cosmo14	cosmo15	cosmo16	cosmo17	cosmo18
05-nov	**33.15**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
06-nov	**21.3**	0.2	0.2	1.4	3.7	0.0	0.8	1.4	0.3	0.3	0.6	0.2	0.2	0.2	0.2	0.2	2.9	5.4	1.5	2.2

Bias - Nearest point

05-nov	**33.15**	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2	-33.2
06-nov	**21.3**	-21.1	-21.1	-20.0	-17.6	-21.3	-20.6	-19.9	-21.0	-21.0	-20.7	-21.1	-21.1	-21.1	-21.1	-21.1	-18.4	**-15.9**	-19.8	-19.1

- On 3rd and 4th of November precipitation value is almost zero, and this null value is well reproduced by all the configurations.
- On November 5th and 6th, high precipitation were observed
- On 5th November, a null precipitation value is provided by all the configurations, while on 6th November, the almost null value provided by C0 is slightly improved with different settings, but in any case largely underestimated
- Similar low precipitation values have been recorded even considering 3x3 and 5x5 grid point boxes centered over CIRA site (instead of considering the nearest grid point).

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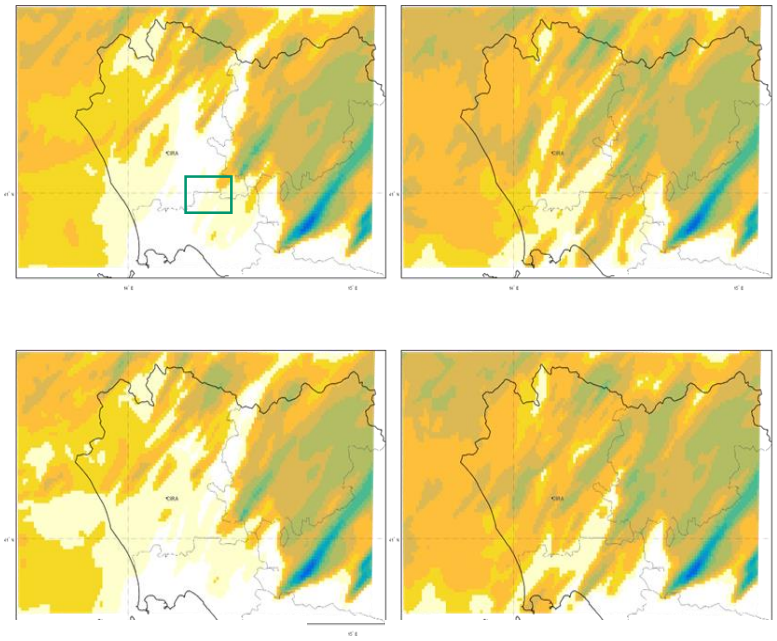
Analysis of sensitivity for precipitation

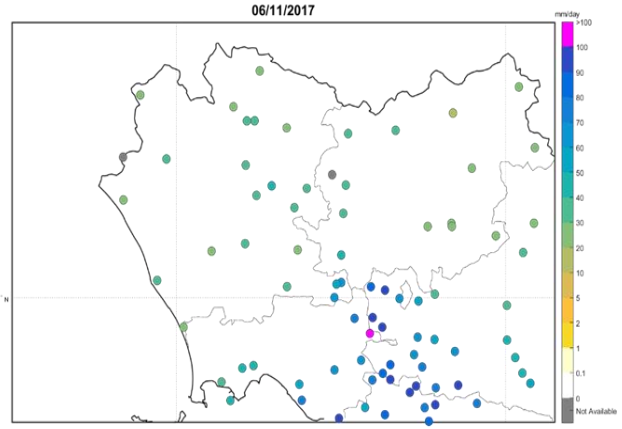
- A reduction of tkhmin does not cause variations, while its increase causes a growth of precipitation, since it increases the small convective cloudiness.
- A reduction in rlam_heat causes the largest increase of precipitation, while its increase causes a reduction. In fact, the reduction of this parameter causes an increase of instability, leading to more precipitation.
- A reduction in v0snow does not modify the values of precipitation, while its increase causes a modest increase of precipitation.
- Variations in uc1, radfac, fac_root_dp and kexpdec produce very slight or null modifications.
- All the interaction simulations are able to increase precipitation. In particular, c16 (rlam_heat min and tkhmin max) appears to be the best configuration for precipitation.

Precipitation maps 6th November 2017

C0

C3 (rlam_heat min)





C5 (v0snow min)

C16 (rlam_heat min + tkhmin min)

- In order to avoid the limitation of analysis related to a single spatial point, the effects of the sensitivity have been investigated over a wider area, comparing daily model data with observational data provided by ANCE Campania for a network of stations.

- It is worth noting that C3 is able to increase the average precipitation values in an area including CIRA (indicated by a box) with respect to C0, but not exactly at the CIRA grid point. Similarly, C16 performs in a similar manner, even with greater strength, but not at the CIRA site.

Conclusions

- Good improvement (0.5°C) in terms of temperature bias, but no significant improvement in terms of precipitation.
- The analysis of the results show that the parameters that have influence on this test case are: tkhmin, rlam_heat, v0snow, uc1.
- radfac, kexpdec, fac_rootdp have almost no impact on the solution, so the number of parameters could be reduced to 4.
- Analyzing the whole set of simulation performed, it results that the best improvement for the representation of the mean T2m is achieved with uc1 at minimum (c7), even better when combined with rlam_heat at minimum (c15). A slight improvement for the minimum T2m is achieved with uc1 at minimum, while rlam_heat at minimum provides the best improvement for the maximum T2m.
- Precipitation are largely underestimated by the reference configuration, being these biases partially due to shortcomings of the model in simulating some climate features of the area considered.
- Improvements can be achieved by setting the factor for laminar resistance for heat at its minimum value, even if further adjustments are needed in order to improve the spatial distribution of precipitation.

Future work

- The minimum number of simulations required by MM is: *2 N + 0.5 N (N-1) +1* so in the present case (*N = 7*) it is 36 (too high).
- Assuming N=4, the minimum number of simulations is 15.
- Is it necessary to perform additional interaction simulations ?
- **Is it possible to run the MM metamodel in order to define an optimal set of values for these key parameters, based on the output of these 18 simulations?**
- Observational data: Hourly data provided by the CIRA weather station (single point) and daily data over several stations in Campania region provided by ANCE data (Associazione Nazionale Costruttori Edili)

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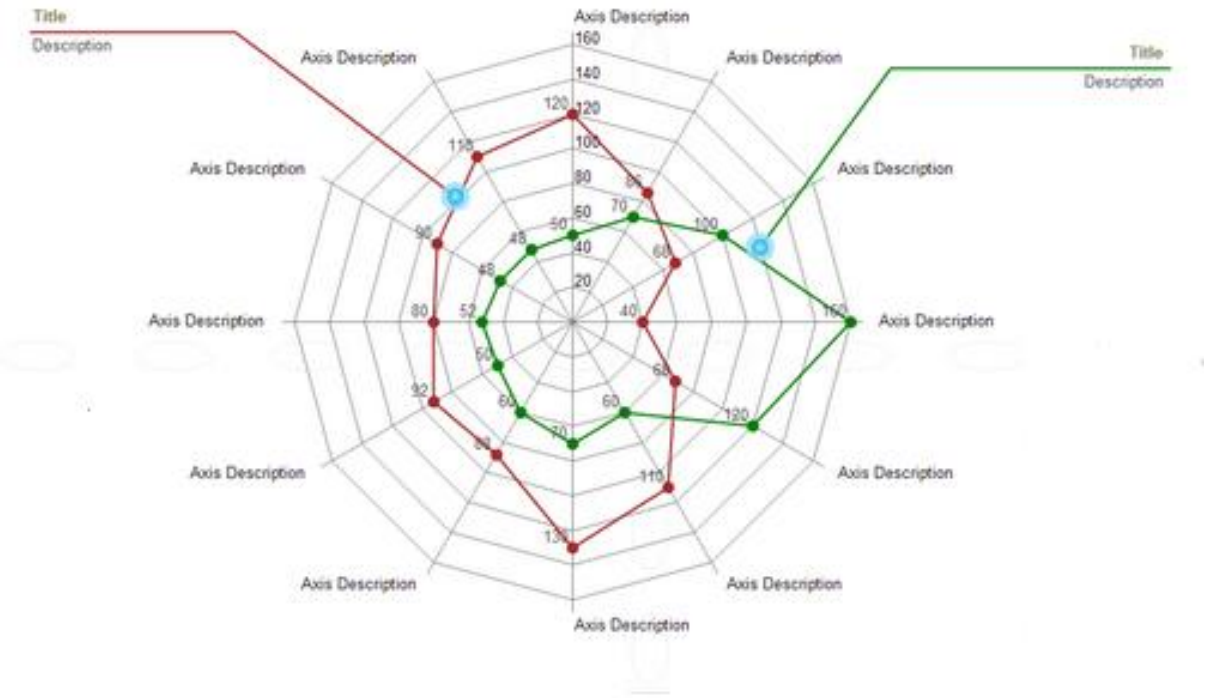
Future work

- Usage of spider charts. Is it possible to use the software of Euripides ?



- Problems of manpower and cpu time limitations.
- Wind .
- Time step of radiation (order of 1 min) . Domain too small.

THANKS !