A physics ensemble of air quality-climate change projections over southwestern Europe for the 21st century

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Motivation:

One of the most important components of climate simulation models, especially of RCMs, are the parameterization schemes. When coupled to CTMs, they can provide an important source of uncertainty in air quality projections.

While multi-model ensembles of regional climate simulations have been widely performed and investigated in an attempt to evaluate and overcome intermodel-related uncertainties, few studies deal with similar multi-physics ensembles aimed at elucidating associated intramodel uncertainties (Jerez et al., 2011).

Objective:

Conduct a comparative numerical modelling study of air quality projections from a climatic perspective using a multi-physics ensemble of MM5-CHIMERE simulations.

Questions addressed in this presentation:

1. Do the multi-physics ensemble mean and associated spread change for HNDC and SCEN conditions and simulations?
2. Can we identify any leading processes?

Dynamical downscaling with MM5-EMEP-CHIMERE
Horizontal resolution: 30km; Vertical Resolution: 23 layers (100 hPa)

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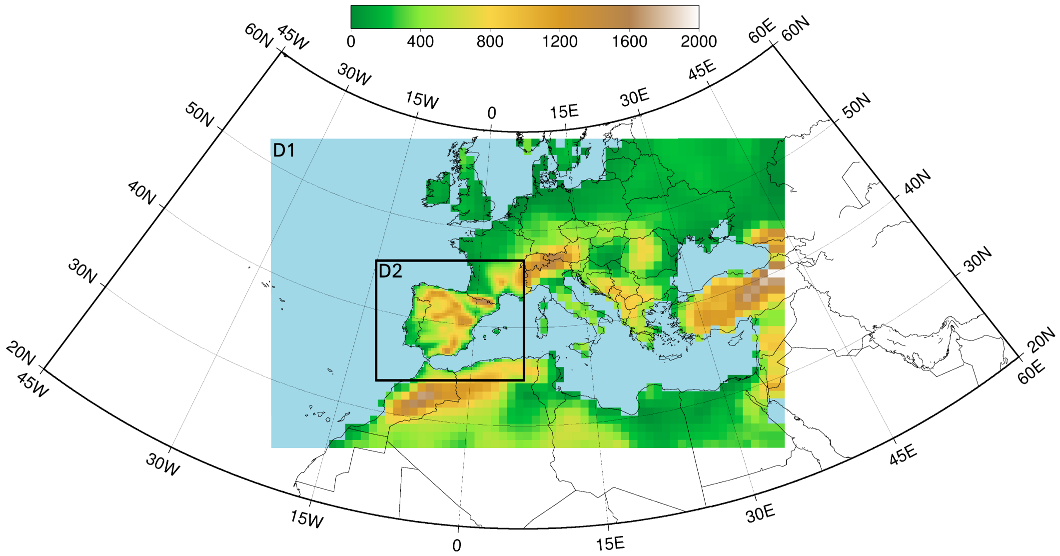
Sim.	PBL	CML	MIC
1	Eta	GR	SI
2	MRF	GR	SI
3	Eta	KF	SI
4	MRF	KF	SI
5	Eta	GR	MP
6	MRF	GR	MP
7	Eta	KF	MP
8	MRF	KF	MP



CHIMERE parameterizations:
Chemical Mechanisms → **MELCHIOR**
Aerosol chemistry → Inorganic (thermodynamic equilibrium with **ISORROPIA**) and organic (**MEGAN SOA** scheme) aerosol chemistry
Natural aerosols → **dust, re-suspension and inert sea-salt**
BC → **LMDz-INCA+GOCART**

ECHAM-5 driving conditions:
HNDC: 1971-2000
SCEN: 2071-2100, SRES A2 scenario

In order to isolate the effect of changing the physical option for a particular parameterized process, we propose a methodology based on ***subensembles*** (subgroups) of simulations. These subensembles are given by fixing the PBL, the CML or the MIC scheme to one of the two options considered. Thus, these subensembles consist of four members.

Methods *(based on Jerez et al., 2011)*

The ensemble mean (EM) of a magnitude (m) is the mean value of such magnitude computed from the all values provided by every member of the ensemble (N = 8 in this case):

$$EM = \frac{1}{N}\sum_{i=1}^{N} m_i$$

We define the ensemble spread (ES) for a magnitude (m) as the maximum difference in such magnitude between whatever pair of simulations of the ensemble; and the mean ensemble spread as the mean difference in such magnitude between all the pairs of simulations of the ensemble:

$$ES = max\{|m_i - m_j|\} \; \forall i,j \text{ with } i,j = 1,...,N$$

$$\overline{ES} = \frac{1}{N(N-1)}\sum_{i=1}^{N}\sum_{j=1}^{N} |m_i - m_j|$$

The subensemble mean is analogous to the ensemble mean but considering just four members. The difference between the means of the two subensembles with different PBL schemes, for example, is called the PBL-spread:

$$\text{PBL-spread} = \left|\frac{1}{4}\sum_{i=2,4,6,8} m_i - \frac{1}{4}\sum_{i=1,3,5,7} m_i\right|$$

$$\overline{ES} = |\text{PBL-spread}| + |\text{CML-spread}| + |\text{MIC-spread}|$$

Present, future and climate change air quality ensemble means and spreads

Ensemble mean (shaded) and ensemble spread (contours) in the projected changes (SCEN minus CTRL climatologies)

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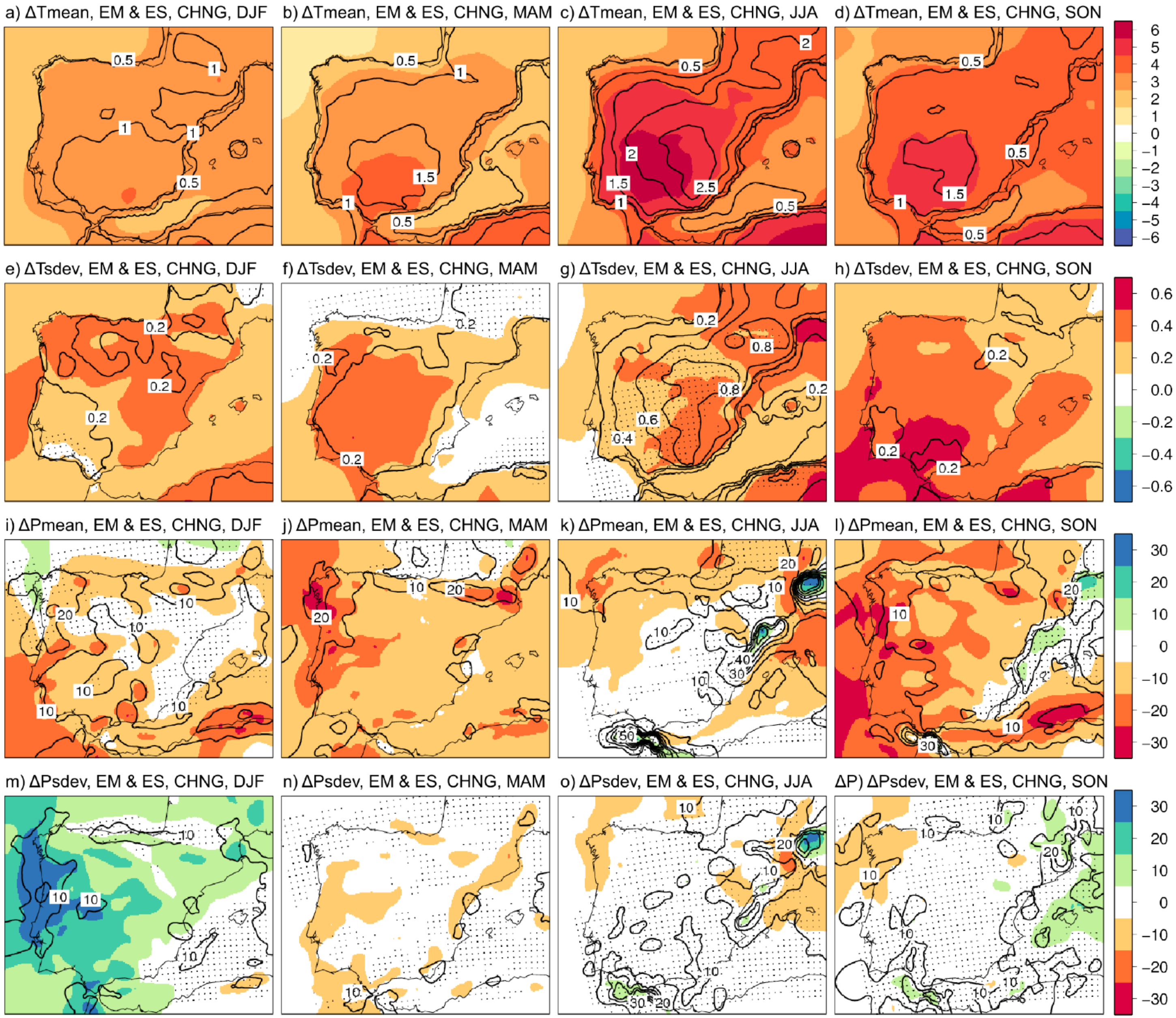

Further details were presented by J.P. Montávez at this meeting (EMS2011-370) and are under review as Jerez et al., 2011(Clim Dyn).

HNDC spread, PM10

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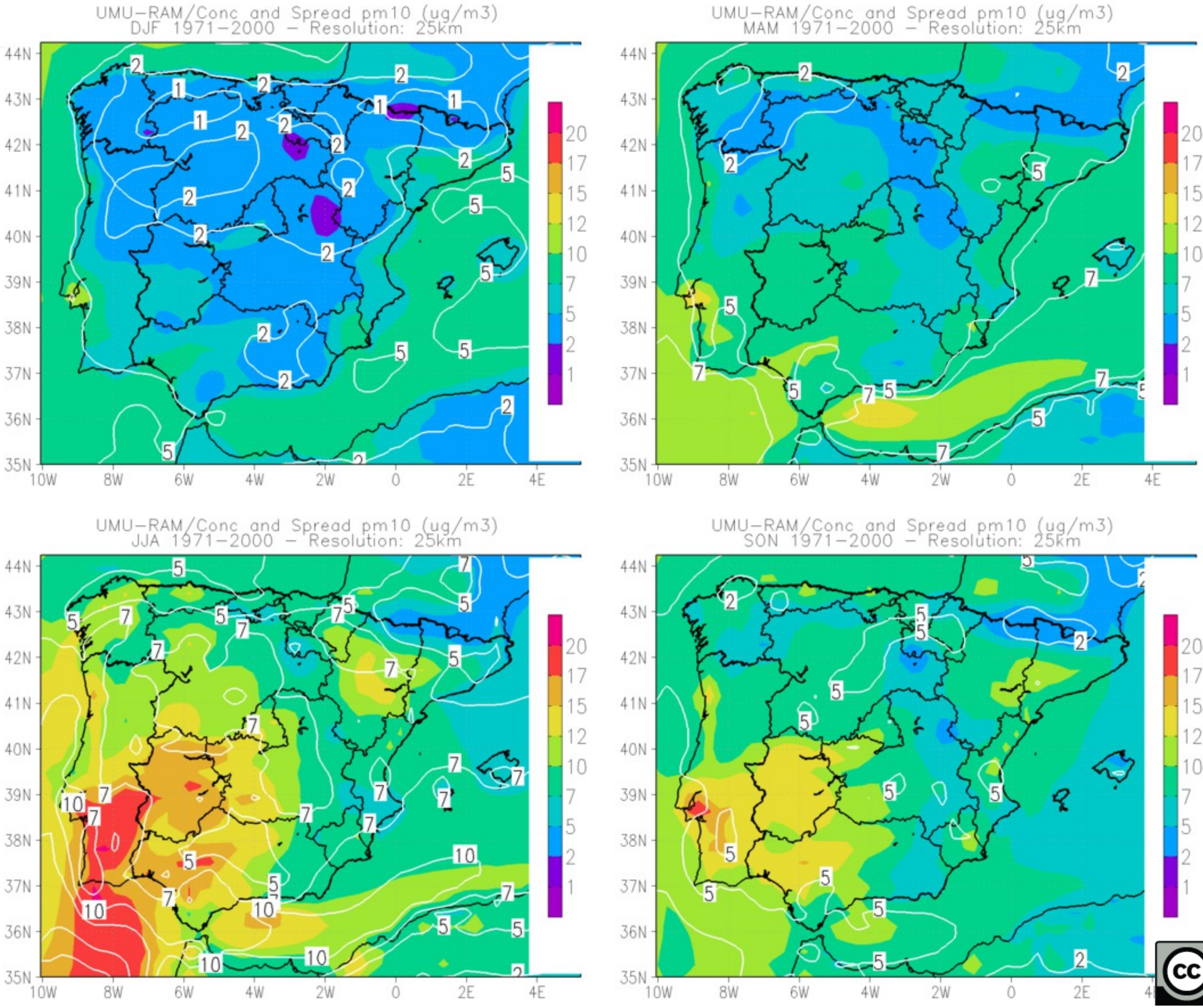

SCEN spread, PM10

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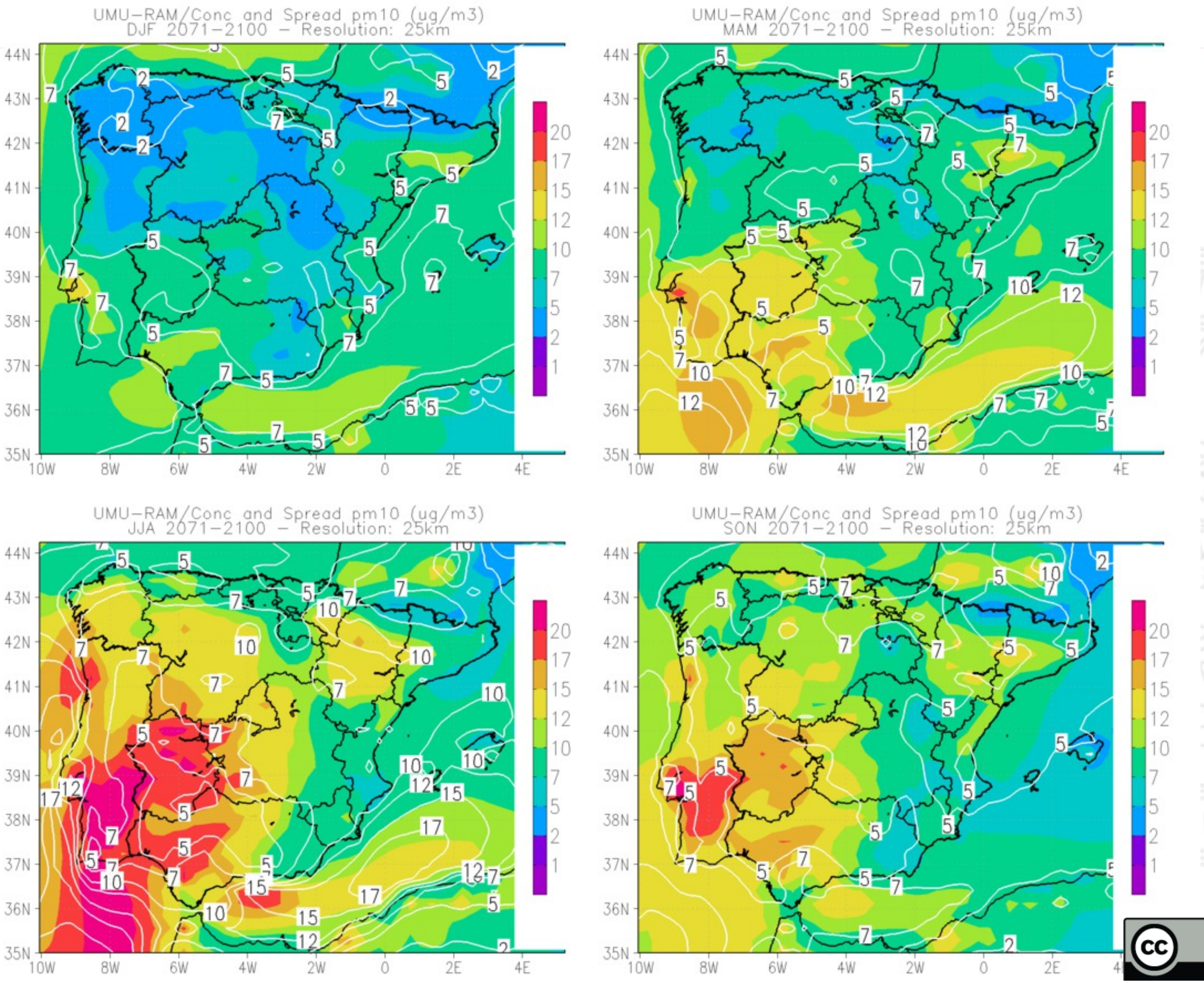

Projected changes and spread, PM10

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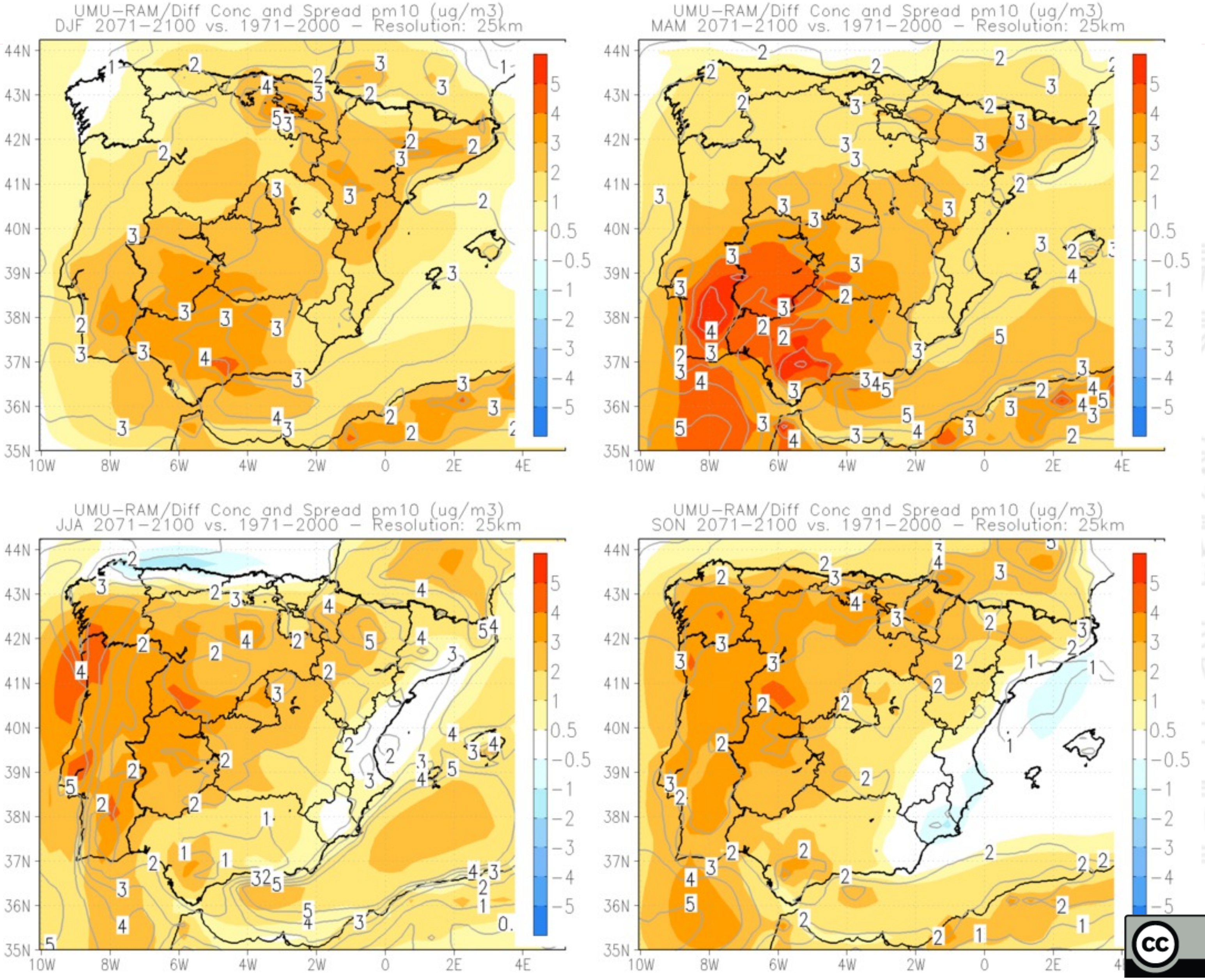

Spread of projected changes

Spreads present different patterns for HNDC and SCEN (and also different to the spread of the future variation of PM10 levels) and appear much more in the spring and summer season, when they represent above 100% of the ensemble mean-projected change for PM10. This spread also indicates a high uncertainty in the sign of the projected change.

But which scheme is responsible for the projected spread?

HNDC leading scheme, PM10

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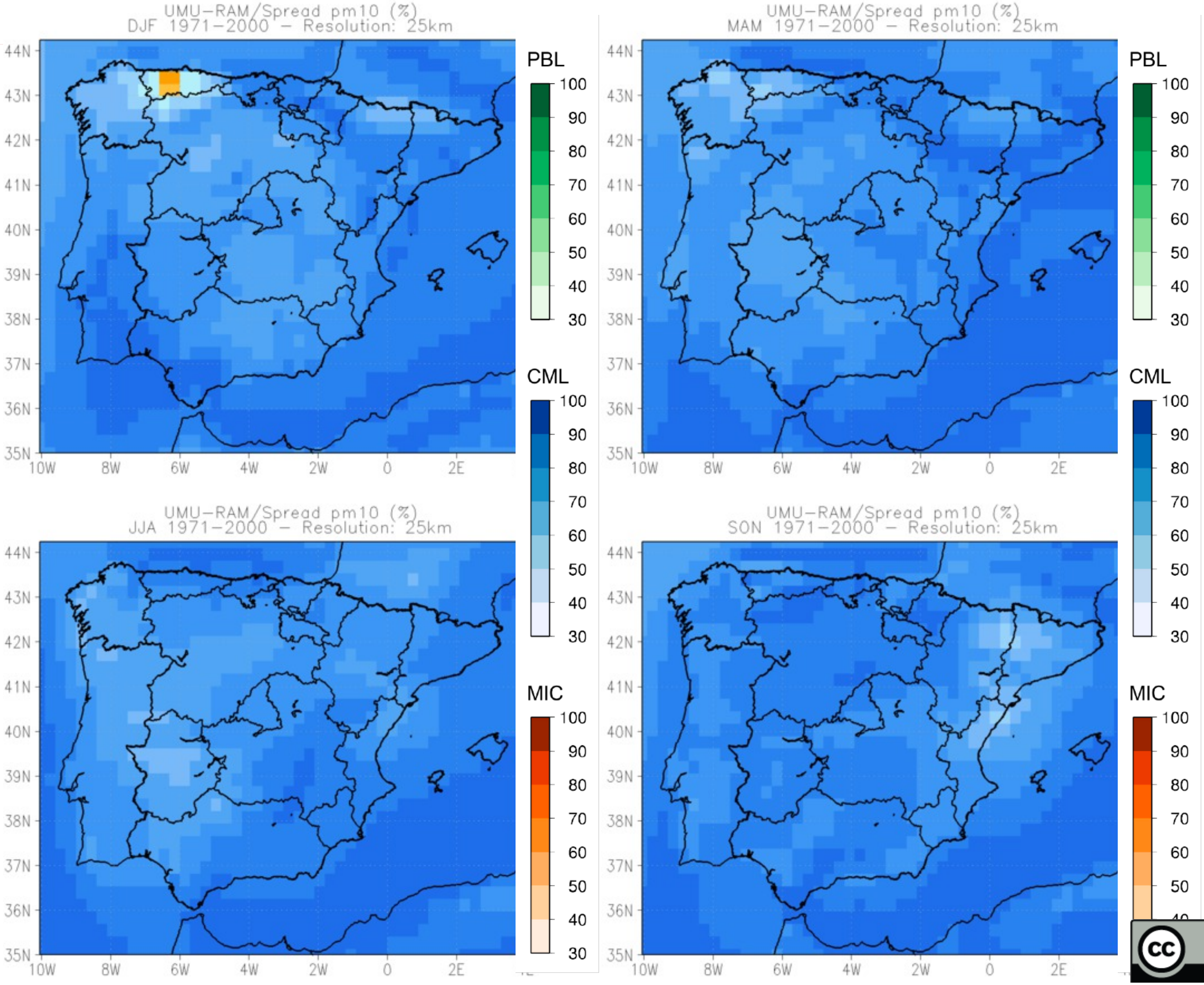
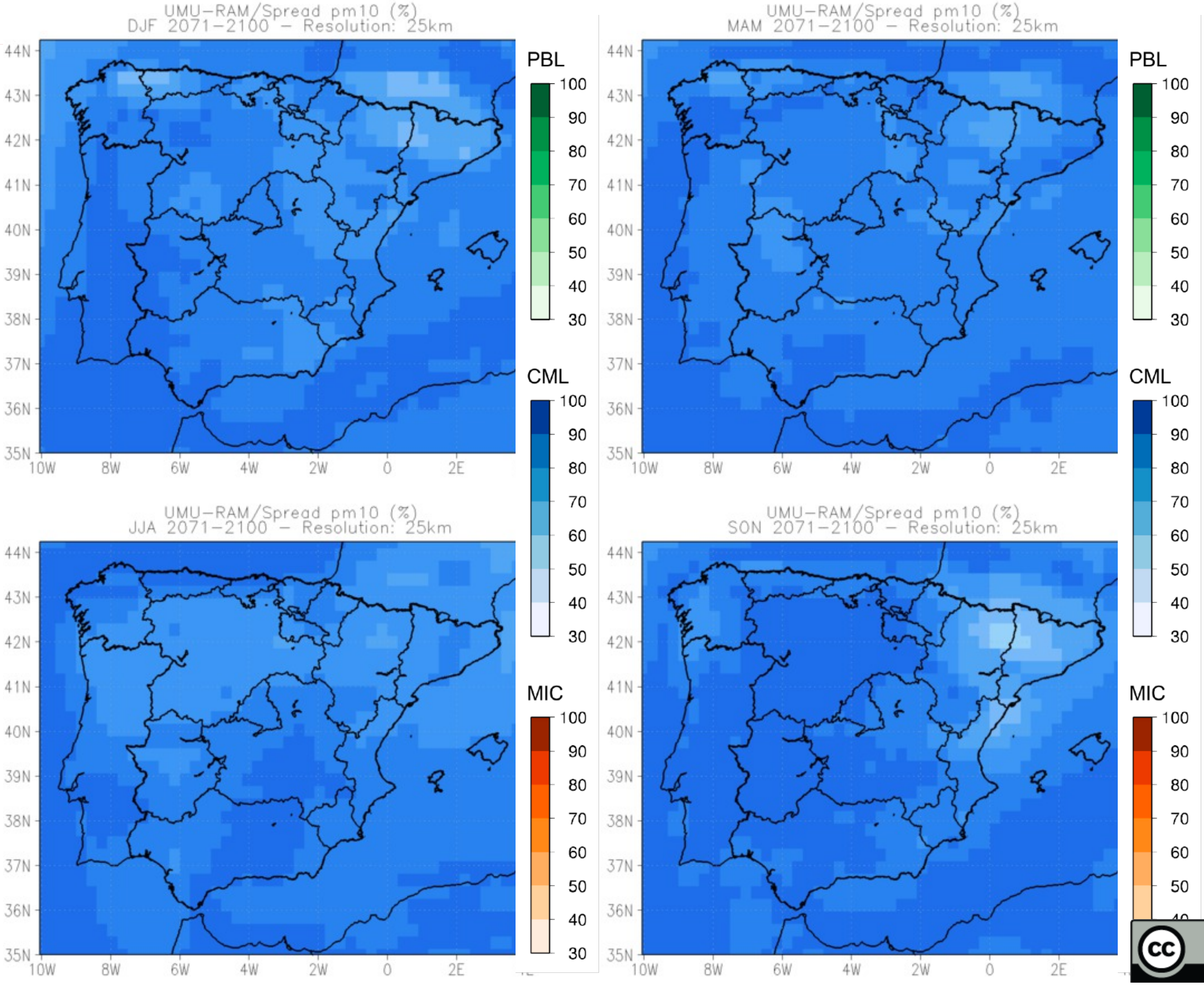


SCEN leading scheme, PM10



Leading schemes for for the projected changes (SCEN minus CTRL climatologies).

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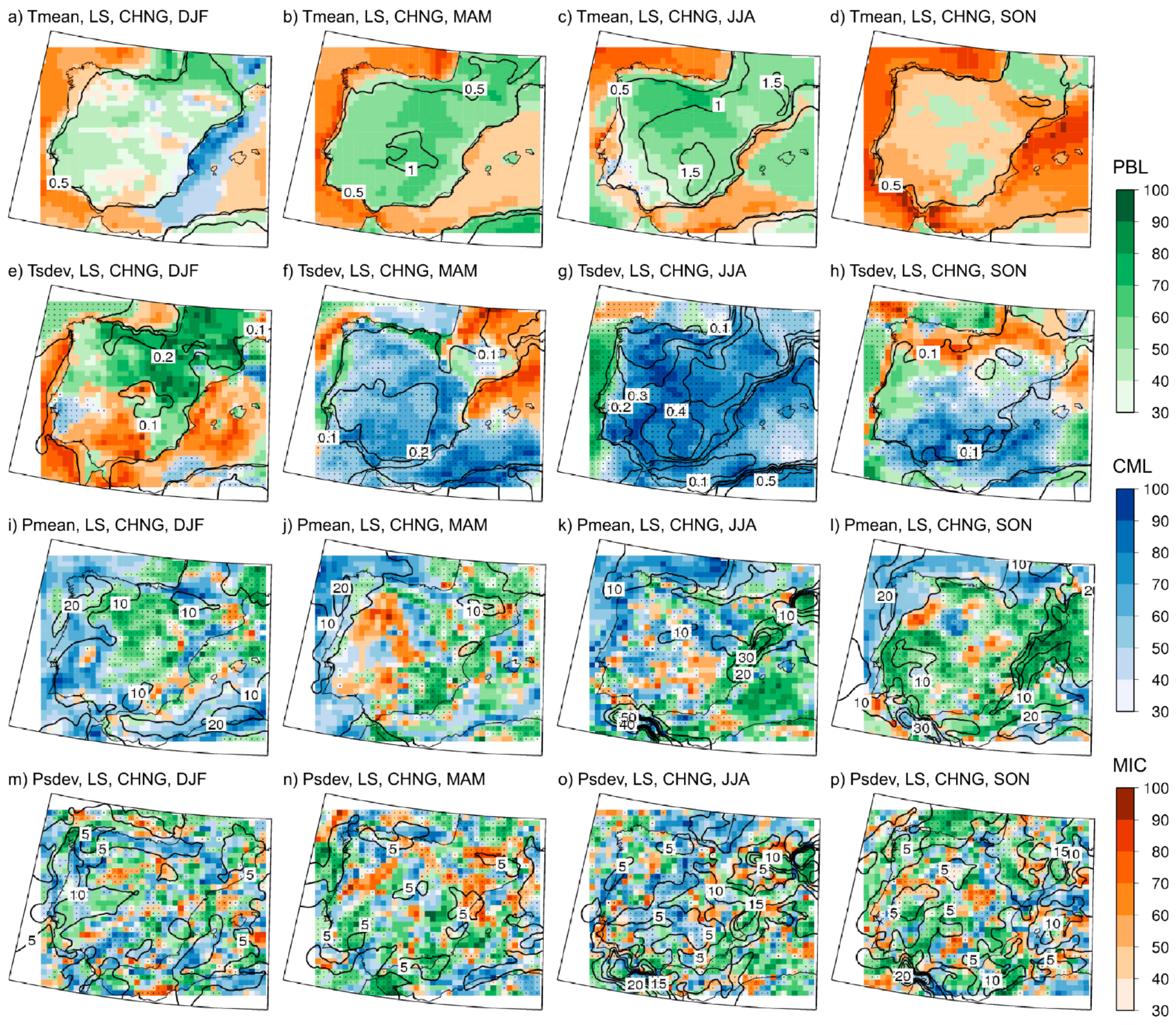

The results (from Jerez et al., 2011) indicate that for 2-m temperature the spread observed in the simulations is caused by changes in the PBL scheme. The precipitation spread is caused both by the selection of the PBL scheme and the CML parameterization

Conclusions: what have we learnt?

1. Climate change impacts gas-phase compounds and aerosols. This increase may be driven by an enhanced secondary production as a consequence of the temperature increase, the changes in precipitation patterns, the decrease of the mixing heights hampering the dilution of pollutants and the stagnant conditions.

2. Spreads look quite different in the HNDC and SCEN ensembles, meaning that air quality patterns show a great sensitivity to the physical configuration of the RCM model. So, the future-minus-present approach for characterising the changes in air quality under future scenarios should be carefully taken.

3. Moreover, we found that the leading schemes for HNDC and SCEN simulations are similar in the case of aerosols (CML schemes), while the PBL and MIC schemes add importance under future simulations for gaseous pollutants (not shown).

4. Therefore, although some processes could deserve little attention when simulating the climatology of a given period, their influence gains relevance when projecting future climate changes.

Questions that are currenly being addressed by the G-MAR group at the University of Murcia:

Do these results change under different global-driving models or scenarios (e.g. B2)? Is the magnitude of these spreads comparable to the magnitude of the spreads obtained in multi-model ensembles?

Is the behaviour analized here particular for the Iberian Peninsula? Or does it change in different European regions?

Thank you for your attention

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