

# Review of "Exploration of diverse solutions for the calibration of imperfect climate models" by Peatier et al. (2023)

## 1 Summary

This is the second review of the manuscript by Peatier et al. 2023.

In this study, the authors propose a method to calibrate a climate model, taking into account the model uncertainty due to input parameters. For this purpose, they propose the use of emulator (statistical model) to sample the input parameters space and select sets of parameters values that lead to similar results than a reference. In order to build the emulator, they reduce the dimensionality of the model output by using Empirical Orthogonal Function analysis. To select the candidates, a k-medians clustering method is employed. Furthermore, to better analyse the model error, a decomposition according to the parametric and non-parametric error is analysed spatially.

The manuscript has been improved from the last version. The last version really suffered of its structure. But, this new version is better structured and the main major comments have been answered. Furthermore, the methodology used is more convincing. For this reason, I accept the publication but only, if the following minors comments are taking into account. They mainly concern the structure or the explanation, not the scientific results.

## 2 Minor comments

### Title

I find that the title of the manuscript is still very vague. It's not about diverse solutions for calibration, but rather about a single method allowing for diverse calibrations of the same model, taking into account the inherent uncertainty of the model. I suggest a title such as 'Addressing discrepancy in the calibration of a climate model'.

### Abstract

I would add few sentences to describe the method succinctly. For example, 'A meta-model, simulating the outputs of a climate model, reduced through principal component analysis, is used to sample the degrees of freedom of the model. Thus, a subset of input parameter values yielding results similar to a reference simulation is identified.'

### Introduction

- L. 14: Maybe add references for your sentences 'It is an important [...] quantify their uncertainties'
- L. 15: 'atmospheric convection or clouds' is quite redundant as, generally, atmospheric convection refer to convective clouds. I suggest 'radiation or turbulence or clouds'.
- L. 29-30: 'In particular, the potential [...] future climate evolution'. I think this sentence is not completed.
- L.50: I don't agree. There are different studies that have conduct sensitivity analyses to quantify uncertainty even for atmospheric model. See for example (for limited area model):  
Di, Z., Q. Duan, W. Gong, C. Wang, Y. Gan, J. Quan, J. Li, C. Miao, A. Ye, and C. Tong (2015), Assessing WRF model parameter sensitivity: A case study with 5 day summer precipitation forecasting in the Greater Beijing Area, *Geophys. Res. Lett.*, 42, 579–587, doi:10.1002/2014GL061623.  
Wimmer, M., Raynaud, L., Descamps, L., Berre, L. and Seity, Y.(2022) Sensitivity analysis of the convective-scale AROME model to physical and dynamical parameters. *Quarterly Journal of the Royal Meteorological Society*, 148, 743, 920– 942, doi:10.1002/qj.4239  
And even for ARPEGE-Climat, see works done by Laurent Descamps (not published, personal documentation).

- L. 89: Add a reference to section 2: "The approach, presented in Section 2, is used as a practical..."

## Methods

- L. 97: I would suggest to create a new paragraph to present the PPE.
- L. 99-102: This is a long sentence to describe the LHS. Please reformulate to make it clearer.
- L. 102: I suggest: 'we consider the annual means averaged over the whole 1979-1981 period as model outputs'
- L. 106: 'the simulated spatial climatology' -> 'ARPEGE-Climat' or 'GCM'
- L. 191: Maybe define  $\hat{\theta} = (\hat{\theta}_1, \dots, \hat{\theta}_m)$
- L. 182: 'objective function' -> 'multi-variate spatial error'
- L. 183: Maybe define here  $\theta_0$ .
- L. 183: It is not necessary to define again the reference simulation here.
- L. 198-202: It is redundant to write twice 'The selection of candidate [...] are shown in Section'. Maybe write only: 'The selection of candidate calibrations is detailed in Section 2.6, the results for the application to surface temperature are shown in Section 3 and for the multi-variation application, in Section 4.'
- L. 204: I suggest to keep a general view and to consider  $\hat{\theta}$  instead of  $\hat{\theta}_{tas}$  and  $\hat{\theta}_{tot}$  for the whole section.
- L. 204: To make it clearer, I suggest: 'we aim to identify  $k$  solutions among  $m$  configuration, which explore...'
- L.204-226: I think the explanation in Appendix is quite good and should be put in the manuscript. Furthermore, there are redundancy in this section. This section must be reformulated.

## First application: surface temperature error

- Figure 1: As previously, I still suggest to switch the left and right panel, as you firstly describe the right panels in the manuscript.
- L. 261: I would add: 'averaged over the PPE members, according to Figure 1b.'
- L. 263: I suggest to better clarify that  $q = 5$  is an example and add 'For example, for a truncation of  $q = 5$ , ...'
- All along the Section 3.2 section, you refer to  $\theta$ ,  $c$ , ... and not  $\theta_{tas}$ ,  $c_{tas}$ , ... I suggest to use the 'tas' abbreviation in the whole section.
- L. 300: delete 'includes 10 atmospheric simulations [...] but different initial conditions'
- L. 301: I suggest this: 'to compute their associated parametric errors (yellow in Figure 2.b)'
- L. 308: 'This emulator is then optimized to find an example' -> 'This emulator is then used to optimized and thus find an example ...'
- L. 343: 'have to have' -> 'must have' ?
- L. 376: Can you justify these 4 candidates ? Why these 4 ones and not the others ?

## Second application: multi-variate error

- Section 4.3: Why do you present candidate 6 in Figure 8 and not candidate 9 that you discuss more in the section? I would suggest to discuss and present only the best and worst candidate (1 and 5). This is sufficient. You can still discuss to the other candidates, but I think it is better to put candidates 6 and 10 in appendix.

## Conclusion

- I would suggest to review the structure of the conclusion. I mean it is better to summarise the study firstly (paragraph L. 540-547), and then present the main results (paragraph L.530-539).
- L. 578: A missing word ? 'we did not [consider?] the observational uncertainty' ?

### 3 Technical corrections

- L.73: "perturbed parameter ensemble" -> " PPE"
- L.84: order in the references: "Peatier et al. 2022, Hourdin et al. 2023"
- L. 97: 'A PPE of this model f is created', correct the typology of '*f*'.
- L. 98: 'amip' -> 'AMIP'
- L.146: add a space between 'Rougier (2007)' and 'and'
- L. 233: '(Salter et al. 2019)' -> 'Salter et al. (2019)'
- L. 234: ' $y_j$ ' -> ' $z_j$ '
- L. 243: '(Salter et al. 2019)' -> 'Salter et al. (2019)'
- L. 270: 'Section 14' ?
- L.309: 'for' repeated twice
- L. 350; add space in '2,4 and 5'.
- L. 505: 'an d' -> 'and'
- L. 540: 'Rougier et al. (2007)' -> '(Rougier et al., 2007)'
- L. 570: 'Williamson et al. (2013), Hourdin et al (2023)' -> '(Williamson et al. (2013), Hourdin et al (2023))'
- L. 575: '(Salter et al. 2019)' -> 'Salter et al. (2019)'
- L. 577: '(Howland et al, 2022)' -> 'Howland et al. (2022)'