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Nonlinear Processes
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Discussions
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Interactive comment on "Correcting for Model Changes in Statistical Post-Processing – An approach based on Response Theory" *by* Jonathan Demaeyer and Stéphane Vannitsem

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1 General comments

We thank the referee for his/her nice review. We have tried to address his/her recommendations to improve the readability of the article.

2 Specific comments

- **The information in Eq. (13)-(14) and (16)-(17) is very redundant, since one only has to exchange the parameters. I suggest to compress this a little bit.**

  We understand the comment of the referee to avoid the redundancy of equations (13)-(14) and (16)-(17). However we do believe that this redundancy is necessary at this stage of the article, such that the reader understands clearly the method proposed here (impact of model change on post-processing). It is the critical point where the design of the experiments is clarified, and we do not want to loose the reader at this stage with too compact notations.

- **The application of the concept to the OU-processes is quite helpful. I would suggest to first formulate the response theory in general, and then in a separate section apply and explain the formulas for the OU case, followed by the post-processing.**

  and also

- **The application of the response theory here is very not very clear to me, and I still do not quite see, where and how the tangent model comes into play.**

  We concur with the reviewer concerning these points, and indeed it is a good suggestion to present the response theory first. We thus added a new section to introduce this technique. We hope that it will be clearer now to a broader audience.

- **It would further be helpful to maybe see a figure of $\alpha(\tau)$ and $\beta(\tau)$.**

  We added a figure showing α and β.

- **With respect to the QG model it would be helpful to, on the one hand, see the model equations probably in the Fourier space, but, on the other hand, simplify the Fourier expansion (e.g. using complex expansion), since this is a quite standard Galerkin approach (you have to mention the boundary conditions).**

  With respect to the QG model, we prefer to follow the non-complex expansion, since it is the one used in the papers we cite, and it is also how the model was coded. We have provided information on the boundary conditions:

  > "Both fields are defined in a zonally periodic channel with no-flux boundary conditions in the meridional direction ($\partial \cdot /\partial x \equiv 0$ at $y = 0, \pi$). The fields are expanded in Fourier modes respecting these boundary conditions:..."

- **Regarding Fig. 2 (b) you may guide the reader a little bit, e.g., mention, that ψ_2 and ψ_3 represent the strength of the zonal wavenumber 1 anomalies, which are both small in the dashed line ellipse, and large in the dashed-dot ellipse, which also seems to have a strong zonal mean ψ_1 component.**

  We have added more explanations on Fig.2 according to the suggestion of the referee.

- **What is the relevance of the equilibrium ploints?**

  The equilibrium points have no other utility than to help the reader have an idea about the general structure of the global attractor.

3 Technical corrections

In general, we agree with most of the corrections proposed by the referee. However, for some corrections, we have additional comments:

p. 1, l.5 "averages involved": I only understood after reading the paper, what is meant by this.

We have replaced "averages" by "parameters". This is indeed the parameters that contain the averages of the observables.

p. 1, l. 9 What is "in a more operational environment"? Maybe "in an environment more similar to the operational environment"

We changed the sentence into:

> " The potential application in a operational environment is also discussed."

p 3., l. 17 square bracket "$\langle\rangle$" are not explained here, only later on. In general I find it confusing to refer here to averages, as these are to my understanding expectation values (which are indeed estimated via ensemble averages).

We understand your comment and the confusion that may arise, but we prefer to keep this notation as it is a traditional one in the context of stochastic process and response theory.

p. 3, l. 29 "Note that if $\kappa = 1$, the correction is perfect.": Not absolutely true, since forecast and model still differ in λ.

Thank you very much, the text has been changed to

"Note that the best correction is obtained if $\kappa = 1$."

p. 6, l. 19 "It is also assumed that there is no interference due to initial condition errors in the problem.": Please clarify, what you mean by this.

We have removed the sentence, but an explanation is now provided in the new section 2 regarding response theory:

"It is thus assumed that there is no interference due to initial condition errors in the perturbation problem, but note that the effects on the trajectories of both the initial conditions perturbation and the Ψ perturbation can be studied through this equation, by setting $\delta y(0) \neq 0$..."

Eq. (23) $f^\tau()$ is only given later and specific for the OU process. Please state here, what this is.

The definition is given just after in the text and Eq. (24). We felt that it was less artificial to introduce it right after its first appearance than before. However, the concept of dynamical system's flow is now also introduced in the new (and anterior) section 2.

Also Eq.(23) The term in the square brackes may be a scalar product in general, but as you have formulated ψ_y, it is not. Later on you use bold letters for vectors, right?

It is a simple multiplication, and thus we have removed the $\cdot$. Vectors are bold letters, as recommended by the NPG guidelines.

p. 7, l. 1 "its stochastic integrals ..." $>$ This may need some explanation.

We think that the paper is already long enough so we prefer to avoid an introduction about stochastic integrals, but we now cite there Gardiner's book which is a reference on the subject.

Eq. (28) Check formula: Isn't there missing $A(f^\tau(x_o))$ and $A(f^\tau(x_o))$ should be $A(f^\tau(x_o))$? Again is this really a scalar product?
Formula is right. This is a second-order formula in the perturbation Ψ which appears twice. On the other hand, the observable A should appears only once and the final time τ is correct. We comment on this now in a footnote. Please see Lucarini (2012) for more details. As before, you are right about the fact that it is not a scalar product and we removed the $\cdot$.

p.8, l.8+9 I assume, that the n in the sine and cosine should not be there.

n is the aspect ratio of the model domain which is $(0 \leq x \leq \frac{2\pi}{n}, 0 \leq y \leq \pi)$, it has thus to be included in the cosine and sine of x. We clarify now the domain in the model introduction:

"The horizontal adimensionalised coordinates are denoted x and y, the model's domain being defined by $(0 \leq x \leq \frac{2\pi}{n}, 0 \leq y \leq \pi)$, with $n = 2L_y/L_x$ the aspect ratio between its meridional and zonal extents L_y and L_x."

p. 12, Eq. (39) Use either scalar product or transpose ^{T} .

The transpose indicates that a row vector is used (rather than a column one), and the $\cdot$ indicates the kind of product that is being taken (here the scalar/matricial product indeed). This notation is quite standard in physics (see Gaspard (2005)), this is ultimately a matter of convention and we want to keep it the way it is.

Eq. (40) Since it is an approximation, use $\approx$ instead of $=$ here.

The referee is right that this is an approximation. But we make the quite standard abuse of notation here that δx is directly replaced by its first order approximation. We mention that it is the first order equation. With this abuse of notation, Eq. (40) is an equality and as it is an ODE, we prefer it like that.

p.21, l. 6ff Please revise paragraph.

We have changed the paragraph into:

> "To test this approach, we have focused on the EVMOS statistical post-processing method, but other methods could be considered as well. The only requirement is that the outcome of the minimisation of the cost function uses averages of the systems being considered. For instance, member-by-member methods that correct both the mean square errors and the spread of the ensemble while preserving the spatial correlation (...) could be considered. These methods generally use the covariance between the model forecasts and the observations as ingredient. Response theory can also be applied here since this covariance can be written as an average. This will be investigated in a future work, together with the applicability of the approach to parameters of probability distributions, as often used in meteorology (...)."

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