Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2019-289-AC5, 2020

Geoscientific Model Development Discussions
Open Access

Interactive comment on "The Sailor diagram. An extension of Taylor's diagram to two-dimensional vector data" *by* Jon Sáenz et al.

Jon Sáenz et al.

jon.saenz@ehu.es

Received and published: 20 January 2020

Reply to interactive comment by reviewer 2 on "The Sailor diagram. An extension of Taylor's diagram to two-dimensional vector data" by Jon Sáenz et al.

Note by the authors: The original text by reviewer is written in **boldface**

Printer-friendly version

Discussion paper

Summary comment The authors aim to propose a model evaluation method in terms of vector data. They constructed a "Sailor diagram" and claimed that this diagram is an extension of Taylor diagram. In my point of view, it is very farfetched to say the Sailor diagram is an extension of Taylor diagram. The Sailor diagram is not even like Taylor diagram. Two diagrams presents very different statistics. For example, Taylor diagram can illustrate correlation coefficient, standard deviation, and RMSE. However, the Sailor diagram shows the first and second EOF with the semi-major and semi-minor axes of ellipses, respectively.

Thank you for your comment. We understand that our work needs some clarification. Please note that:

1. All the Sailor diagrams presented in our paper show the RMSE of the vector timeseries or fields in a legend. The RMSE for two-dimensional vector data can not simply be presented as a plot if at the same time we keep the relevant information regarding the difference in orientation of the principal axes. Thus, the Sailor diagram presents the RMSE but,

Printer-friendly version

Discussion paper

additionally, it allows to identify errors in the directions and fractions of variance in models and observations.

2. Regarding the mention to correlation by reviewer 2, as we show in our manuscript (section 1, particularly page 3), there does not exist a unique definition of the correlation for two-dimensional time series. See references in our manuscript (Cramer, 1974; Crossby et al., 1993; Jupp and Mardia, 1980; Robert et al., 1985; Stephens, 1979) for further details. However, the two-dimensional correlation coefficient based in canonical correlations, which is the most widely used in the literature, is presented in Table 1 of the manuscript and can be computed with the package we present. It could also be added to the diagram by means of additional ellipses or lines, but after some previous tests at the preliminary stages, we decided to remove them, since in our view, it would not help in the interpretation of the results.

3. Regarding the semi-major and semi-minor axes, we think it is not a weakness of the diagram, but a powerful diagnostic tool in it, instead. We find a very useful contribution of this diagram the fact that the standard deviations of models and observations can be compared visually from the comparison of the

axes of the ellipses in the diagrams. These values can also be retrieved as numbers from the implementation we have developed as a R package. Thus, regarding the mention by the reviewer that we do not present standard deviations, our answer is that we present the standard deviations of the major and minor axes of the distribution of the vector field in two orthogonal directions. This is better (in our opinion) that just adding both standard deviations in a number. For us, this is a strong positive characteristic in our diagram.

4. Regarding the statement by the reviewer that our diagram does not follow the design of the Taylor diagram, we clearly stated that in the initial submission of our paper (lines 104-106): *we have decided to follow a new approximation which does not lead to the common Taylor diagram used for scalars, but gives more information about the structure of the two-dimensional errors*. Thus, we are not closely following the design of the Taylor diagram because we preferred to present the information related to errors in the direction of vectors. This information about the directionality of the vectors can not be identified in a Taylor diagram designed for scalars.

Considering the previous comments above, we think that the

Sailor diagram represents an important contribution since, to the best of our knowledge, this diagram is the only one which allows to make a full assessment of errors in the orientations and lengths of the semi-major and semi-minor axes of the horizontal distribution of vectors. We are not aware of any alternative readily available tool like the one we have developed to implement the comparison of vector fields *considering them as vectors*. It is a diagnostic tool which provides a very good capability to visually and easily compare the bias, the main directions of variability of the horizontal vectors and their relative variances.

Each ellipse represents one model or observational data, the difference between model and observation is judged visually, which is less objective.

The fundamental idea behind a diagram such as the Taylor diagram or the Sailor diagram is that they are designed to easily (visually) show the relative benefits (and also weaknesses) of different models against observations. As such, the diagram we present is designed (as it was the Taylor diagram) to allow this visual comparison, as we assert in our manuscript. However, the use of the exact RMSE errors in the legend of the diagrams in the manuscript allows a completely objective comparison of model data and observations, since the RMSE data contains an aggregated estimation of the errors due to bias and principal components as well. We carefully partition the sources of RMSE errors in bias, rotation and differences in variances. The paper presents the corresponding equations, and all of them are presented in a diagram. Besides that, they can also be retrieved numerically from the R-package we provide.

More importantly, why are the first and second EOFs useful and what is the implication of the EOFs in terms of climate model evaluation? The EOFs between model and observation may represent different patterns. In this case, the comparison between model and observation can give wrong conclusions. These questions were not clearly interpreted (addressed) in the manuscript.

We find the EOFs are fundamental in the identification of the errors in direction between modelled and observed winds. Perhaps the reviewer is considering here that we are applying EOFs in the traditional space-time decomposition of fields as follows:

$$A(\mathbf{r},t) = \bar{A} + \sum_k \lambda_k p_k(t) A_k(\mathbf{r}),$$

where $\mathbf{r}$ represents the grid points, $p_k(t)$ the k–eth principal component, λ_k the k–eth standard deviation and $A_k(\mathbf{r})$ the k–eth empirical orthogonal function. However, in our methodology, we are just using EOFs to identify the main directions of variability of the two-dimensional time-series/spatial fields in order to be able to describe the matching in direction of model data with observations.

The enclosed figure explains with the help of a scatterplot the derivation of the ellipses and their relationship with EOF analysis and the standard deviations mentioned by the reviewer before. We think that, if the editor and reviewers agree, it could be added to the manuscript as Figure 1 since this was also requested by Reviewer 1. It would help in the interpretation of the paper, and it would lead to a better version of it.

In this figure, panel top left (a) presents the scatterplot which can be constructed with one year (2018) of surface wind in front of Los Angeles. It is the same reference dataset we have prepared for Reviewer 1. The red ellipse corresponds to the eigenvectors (major and minor axes, matrix $\mathbf{E}_u$ in equation 5 of our original submission) and eigenvalues (semiaxes of the ellipses, matrix $\mathbf{\Sigma}_u$ in equation 4 in our initial submission) from a EOF decomposition of the two-dimensional covariance matrix, computed from the zonal and meridional components of the observed wind (reference dataset, $\mathbf{U}$). The red point represents the mean of the wind ($\bar{\mathbf{U}}$ in our submission, zonal and meridional components), also indicated by the horizontal and vertical lines passing through it. The ellipse represents the conic section expressed by equation (2) in our submission.

The top-right panel (b) presents the same representation for the reference dataset together with a similar scatterplot (grey colour) representing model MOD1 that we prepared in our answer to Reviewer 1 by adding a constant bias $\mathbf{b} = (4.8, -6.8)$ m/s. The dark brown ellipse represents the major axes of variability of MOD1, their standard deviations centered on its mean (elements $\mathbf{E}_v$, $\mathbf{\Sigma}_v$ and $\mathbf{V}$ in our submission). Since MOD1 only involves the addition of a constant bias, both ellipses are of the same dimensions and are oriented similarly. Panel c) shows in a similar way (scatterplot plus ellipses) a comparison of the reference dataset (black) and a second model MOD2 (grey) which has been calculated by rotating the observed winds counter-clockwise by 30°. The brown ellipse shows that the major and minor axes of the ellipse (eigenvectors) are rotated accordingly. However, their standard deviations are the same, because the difference between both datasets is limited to an orthonormal transformation (rotation). Panel d shows the behaviour of the data in model MOD3, in which a resampling in time of the same wind vectors as the ones in the reference dataset is performed. By means of this operation, the average wind doesn't change, and the major and minor axes are also the same. However, the correlation of the zonal/meridional components of wind must be close to zero. These results are correctly represented in the Sailor diagram, when the RMSE component is reported. Panel e represents a comparison of the reference data and model MOD4, which has been built by multiplying the reference data by 2. This implies that the average changes and the standard deviation along the major and minor axes doubles, as correctly represented in the diagram. Panel f is similar to the sailor diagram in the sense that the previously shown scatterplots are removed in order to allow an easy comparison of the main components of the errors (bias, rotation and standard deviations along the major and minor axes). Centered and uncentered versions of the Sailor diagram for these synthetic datasets are shown in the reply to Reviewer 1. Authors appreciate this constructive suggestion by both reviewers (build an easy example to illustrate the diagram), since it will lead to a better paper.

We hope that this new figure clarifies the way we compute the EOFs and the important role played by these ellipses in the Sailor diagram. They represent the standard deviations along the main orthogonal directions of variability of the horizontal vectors.

Substantial revision is needed before the manuscript can be considered for publication in GMD. Detailed comments are listed below.

1. The title of the manuscript is misleading and should be changed because the Sailor diagram is totally different from the Taylor diagram. Two diagrams present very different statistics and have different implications. For example, Taylor diagram presents correlation coefficient, standard deviation, and RMSE. However, the Sailor diagram was constructed based on the EOF of vector data, which does not explicitly include correlation coefficient and standard deviation. Two diagrams do not look like each other, either.

As we stated before, the Sailor diagram effectively shows the standard deviation of each dataset (axes of ellipses) and the RMSE in the legend of the plot. However, it can not show the correlation because there is not a universally accepted definition of correlation in two dimensions. Besides that, it also shows the errors in direction and the bias component of the error. Thus, we find it is a very efficient and objective way of comparing model results to observations. Thus, we find "Sailor diagram" is a good way of defining it, as also acknowledged by Reviewer 1. We insist in keeping this name (easy to remember, much better than any acronym we could imagine, and culturally neutral). Besides that, in our view, for the sake of coherence, the name sailor must be kept, since the sailoR package[1] that we distribute in CRAN is also called that way.

2. Section 2 introduced five different vector datasets using 3 pages. It's not necessary to use so much dataset and can be reduced since they are all vector data. Only one or two of them should be enough to interpret the diagram.

Thanks for this suggestion. We have decided to reduce the

[1] `https://cran.r-project.org/package=SailoR`

number of observational datasets included in the final version of the manuscript since both reviewers agreed on this. Our intention was to show that the diagram can be applied for many different variables in many different fields of study.

In contrast, methodology (section 3) is the key part of the manuscript which should clearly interpret and explain the method. However, the methodology was not well interpreted and hard to follow.

We are a little bit surprised by this comment, since Reviewer 1 found the description of the methodology very clear. However, we hope that the addition of Figure 1 as shown in this reply will improve the understanding of the methodology. It will also be added in the final version of the manuscript if the editors and the reviewers agree on including it there.

I suggest that the authors interpret the methodology using an example data. Eu, Pu, and EOFs can be illustrated by using the example data to help readers to understand the method.

We agree with the reviewer in this point, and as we already showed in the reply to Reviewer 1, we will include an initial figure built by using synthetic datasets with the aim of describing the main characteristics of the diagram. The Figure that we have prepared for this reply would be Figure 1 in this document. It is an extension of the one we prepared in the answer to Revgiewer 1's comments. Thus, we hope that the methodology is clearly explained now and that we meet the requirements by both reviewers with this new figure.

The method and its application should be clearly interpreted in terms of model evaluation. In addition, section 3.1 and 3.2 generally present the same equations and can be merged.

We accept that section 3.2 it is a little bit repetitive, but we found it was interesting, particularly because section 3.3 is an important part of the description of the diagram, as it justifies the errors due to rotation of the model data with respect to observations. We will make an effort in making it shorter without penalizing the interpretation of the methodology. Removing it completely would probably make difficult to understand the role played by the relative rotation matrices, so we would prefer not to remove it completely from the manuscript. At least some of the equations must be kept.

3. Line 49-51 and 78-80: This is not true. The Taylor diagram can be extended to two (even more) dimensional vector data evaluation directly by using a set of statistical quantities defined by Xu et al. (2016). This paper was also cited by the authors. Line 99-101, 109-112: To my knowledge, Xu et al. (2016) did normalize various statistics but no approximation was applied.

It was not our intention to demean Xu et al. (2016) paper when we mentioned the word "approximation". In fact, we also used the word "clever" when we referred to it. We just noticed that in some cases (see, for example their equation 9 or their section 3), the Cauchy-Schwartz inequality was used. That means that the norms of some of the vectors presented are actually upper bounds of the true norms and equation 9 is a good example. But we insist that it was not our aim to demean that paper, so that in the final submission we will just remove these mentions to the paper by Xu et al., which we consider a very good paper.

The author argued that the merit of the Sailor diagram is that no approximation is needed. However, Sailor diagram illustrate the first two EOFs. Each EOF can only explain part of the variability of the original data.

As we wrote in lines 241 and 266 of the initial submission, the covariance matrix that we use is the one built using the zonal/meridional components at each time-series or the spatial distribution of an averaged wind field. This is hopefully better illustrated in Figure 1 added to this reply. Thus, this covariance matrix is a rank 2 matrix. The only exception to this would be the case of a completely degenerated and physically unrealistic flow (laminar). Therefore, the covariance matrix in equations 4 and 12 is representing a full-rank matrix for all sensible cases. We hope that the interpretation will be clear now with the addition of Figure 1 .

5. Line 220-223: It is confusing that the authors use "U" to

represent observation and "V" to represent model because U and V were usually used as the zonal and meridional component of wind. I suggest the authors replace "U" with "O" and "V" with "M" or other appropriate notation to avoid confusion.

We, sincerely, do not see any possible confusion, as the matrices $\mathbf{U}$ and $\mathbf{V}$ are typed using bold font. They are, thus, matrices, and the text clearly states their dimensions (rows and columns). We would prefer to keep the current notation, which has been defined as clear by Reviewer 1. Besides that, the current notation is the one used in the R package for the Sailor diagram already distributed by CRAN. This way, the paper using the current notation serves as an additional documentation file for the package. However, if we receive any indication from the editor indicated that we must change the notation, we will do it.

6. Line234: How are the principal components of the data standardized?

They are not standardized. The fact that they are not standardized allows us to make a full analysis of the RMSE error of the original fields. Perhaps we didn't make that clear enough, but we will clarify it in the final version of the manuscript by explicitly asserting they are not standardized.

7. Line 360-361: What is the implication of the relative rotation between EOFs from observations and simulations? Why is it important to model evaluation?

The EOFs of an anemometer/vane represent an orthogonal basis in the horizontal plane. If this basis is different for model and observations, this difference means that the distribution of the horizontal wind in the zonal/meridional plane from model and observations is different (see the case of the Reference dataset and MOD2 in the Figure enclosed to this reply). Thus, changes in rotation of the EOFs imply that there is an error in the directionality of the simulated data. The reviewer has to keep in mind that we are applying the EOFs to the time-series (or spatial distribution) of a 2x2 covariance matrix. Thus, the spatial/temporal variability of the field is not being analysed. We hope this is clear now with the new figure we provide.

8. Line 361-363: Why the variance explained by each EOF is important in terms of model evaluation?

It is important because the horizontal distribution of the zonal/meridional components in the horizontal plane defined by the zonal and meridional components must be as close as possible for the simulated wind fields. We stress again that our EOFs analyse the structure of a two-dimensional covariance matrix.

What if the EOFs between model and observation represent different patterns?

In that case, the agreement in terms of the RMSE (as described by equation 22) will be lower, as correctly shown in Figures 3b and 4 from the manuscript. We stress again that our EOFs are computed in a two-dimensional covariance matrix both for model data and for observations. We hope that the new figure makes this clear.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2019-289,

2019.

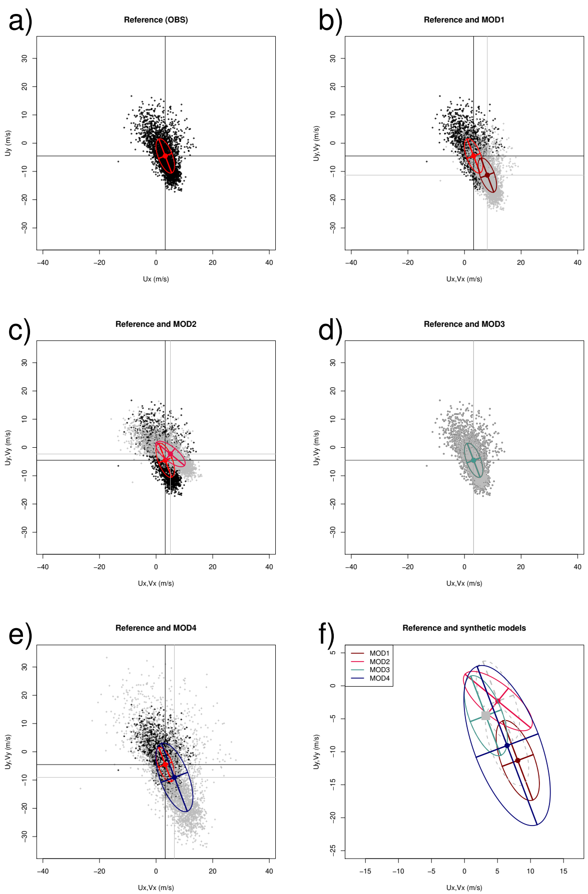

Fig. 1.

Printer-friendly version

Discussion paper