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Hydrology and Earth System Sciences Discussions

Interactive comment on "Simulation of a persistent medium-term precipitation event over the Western Iberian Peninsula" *by* S. C. Pereira et al.

S. C. Pereira et al.

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Dear Reviewer,

We appreciate the constructive and knowledgeable comments of the Reviewer.

During the review process some Table and Figures were removed, others redone and others included. The reordered Figures and Tables are attached in the form of supplement to clarify the reading.

Anonymous Referee #2

Major comments:

C1 - Only one data point (Pousada) was used for observational nudging. This will obviously have no impact on the results some distance away from the station and therefore no large improvement can be expected. I see that the authors do not want to use all of their station data for nudging, leaving them with no data for validation, but this point should be made clear. The reader needs to grasp what can be expected from the results.

The authors found the comment relevant. One of the reasons to assimilate Pousada's weather data, besides the one pointed out by the reviewer, was the fact that this is a reference station.

A1. A paragraph at the end of section 2.3 discussing these issues was added.

"In the RunObsN simulation, a single site observation with measures of wind, temperature and humidity was available at the area of interest to nudge the model integration, at Pousadas (see Fig. 1). It is expected that, when considering all stations and at the absence of nonlinear effects, this simulation will have similar results as the RunRef simulation, however, at stations near the Pousadas site, this may have some influence that may be worth noting. The RunObsN simulation may be regarded as a weak constrain simulation, so the RunGridN experiment was performed in order to test the results of the model to a stronger constrain, where grid nudging was performed even in the D03 domain, although only six points of the GFS analysis lie inside this domain, ad two of then are over the Atlantic Ocean. This approach is different from the ones of Soares et al. (2012), Argüeso et al. (2011) and Fernández et al. (2007), who applied the model using nesting, having all performed grid nudging in the coarser domain, where they try to compromise the good representation of the large scale features in the coarser domain with the computational freedom of the innermost domains, but follows the spirit of the work of Lo et al. (2008) applying the grid nudging technique to the domain of analysis."

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C2 - Grid nudging is used in all domains, even the 1-km one, with 2-way nesting. Nudging too strongly towards coarse resolution data may overrule the benefits obtained from downscaling. This approach is likely to produce results very similar to the GFS. For this reason spectral nudging is often used, limiting the nudging only to long waves. Did you consider nudging in the outer domain only, or using the spectral nudging option in WRF? There should be some discussion on these points.

A2. Please, see previous comment.

C3 The main results seem to conclude that the timing of the precipitation occurrence was well simulated in every case, but the precipitation intensity was largely overestimated, independent on the nudging used. I think one should start with looking into the boundary conditions, is the precipitation rate overestimated in the GFS data as well? If I understand you correctly, the Dec 2009 included many frontal systems coming from the Atlantic. Were indications of such systems visible in the SLP fields, for example?

My point is, was there any improvement to expect from the downscaling if boundary conditions were wrong to begin with?

A3. The GFS data was not inspected but there are others factors that may compete to an overestimation of precipitation. The simulations show an overestimation of the 500 hPa geopotencial field averaged for the month which leads to an enhanced trough west of Portugal. This cyclonic pattern is associated with heavy precipitation.

A new section, under section 3 was introduced with an overview of the synoptic features during the 2009 December month and the evaluation of the control experiment. However, the reviewer

With the addition of the new section some paragraphs were added to the "Materials and Data" section, now renamed as "Methods and Data", to describe two observed datasets and a new measure (pattern correlation coefficient) was introduced in section "Assessment of model performance".

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Thus, the new text is as follows:

" 2.4 Rainfall measurements and Observations from Gridded Data

(. . .)

In addition to the rainfall data described in the previous section two additional datasets were used. For the temperature, relative humidity, sea level pressure and winds were used the ERA-Interim (ERA) Reanalysis project from the European Centre for Medium-Range Weather Forecasts (ECMWF, http://www.ecmwf.int/). For precipitation the E-OBS gridded data set (EOBS) from the European Climate Assessment and Dataset project (ECAD, http://eca.knmi.nl/) was used.

The ERA dataset is a reanalysis project of the global atmosphere covering the period starting at 1979 until present day. The dataset consists in a variety of meteorological variables with different resolutions and time steps for the several vertical pressure levels and surface. A full description of the forecast model, data assimilation method, and input datasets used to produce the ERA data, as well as, the performance of the system can be found in Dee et al. (2008). A detailed description of the ERA product archive can be found at Berrisford et al. (2009). For this study the ERA data were chosen with a horizontal resolution of 0.25° x 0.25° and 6 hourly time step and with 3 hourly time step for the sea level pressure.

The EOBS dataset consists in a set of gridded daily observations for precipitation. The dataset covers the period starting at 01-01-1950 and ending up at 30-06-2012 covering the spatial region of Europe. A full description of the dataset can be found at Haylock et al. (2008). For this study it has been used the EOBS version 7 with a regular horizontal resolution of 0.25° x 0.25°.

The chosen spatial coverage for both datasets extends from latitude 34° N to 49°N and for longitudes starting at -20° W to 0.5° E. Thereby the observational grids matched the WRF coarser grid (D01 domain)."

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A new paragraph was added to L13- C1434 as follows: "2.5 Assessment of model performance

(. . .)

To validate the capability of the model in reproducing the synoptic patterns and the precipitation it was used the continuous measures MD and the RMSE. The pattern correlation coefficient (PC) was used to measure the overall agreement between the simulations and the observations grid patterns, which is expressed as:

(Equation 1 inserted as figure)

In this case the statistics were calculated for each grid point and the summations were performed for the entire grid; N stands for the total of grid points and the bar denotes spatial averaging over the grid."

"Section 3.1 Observed and Simulated Synoptic features

In this section are described the synoptic patterns over the 2009 December month over the region of analysis. The analysis follows closely the one presented by to Koo and Hong (2010). The circulation patterns were obtained from the ERA data and the precipitation from the EOBS data. Instead of analysing the mean state of the atmospheric circulation, during the time period of analysis, a variety of circulation weather types were used. These weather types describe the atmospheric circulation regime and are characteristics of a given location. The ones used in this study were produced and described by Santos et al (2005). For Portugal, five weather types were identified plus a six one derived from one of the regimes. The cyclone regime(C) associated with a high density of cyclonic features, the Westerly (W) associated with westerly and north-westerly winds (NW), the R regime linked with the negative phase of the North Atlantic Oscillation (NAO), the AA regime linked with positive phase of NAO and the Easterly regime associated with a high pressure system over the western European basin. In this study each daily circulation pattern that occurred in 2009 December was classified

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with five weather types plus a six one derived from one of the regimes (Table 5).

The most frequent regime was the cyclonic type (C) and the north-westerly (NW). In these two regimes the precipitation is linked with travelling frontal systems that extend to south covering Portugal (Fig. 5). Although the C-regime is not the most frequent it can occasionally be the dominant feature, as in the case, and can produce well-above-average rainfall probabilities throughout Portugal (Santos et al., 2005). The 2009 December observed anomalies from the mean December precipitation (PP) averaged for the time period of 1950 to 2012 show the above normal precipitation values that characterized this month (Fig. 6a).

The ERA mean 500 hPa geopotencial field represent a trough locate over sea west of Portugal indicating typical conditions for heavy induced precipitation (Fig. 6b). The mean sea level pressure pattern (Fig. 6c) is consistent with the geopotencial height: showing a low pressure region northwest of Portugal with a north south gradient. These conditions are favourable for the occurrence of precipitation as humidity advection due to south-westerly winds from North Atlantic (Fig. 6d) and along the south band of the cyclonic system which have a higher moisture content.

The simulated synoptic features reproduce well the mean atmospheric conditions (Fig. 7 and Table 6) for the analysed time period. The WRF model increased the 1000-500 hPa layer (Fig. 8b) but showed a negative bias in simulating the sea level pressure, the humidity content and temperature (Fig. 7c, Fig 7d and Fig. 7f), throughout the entire domain. The highest bias values are located over land but for the central and eastern part of Iberia rather than for Portugal.

The model precipitation was overestimated mainly over the ocean and underestimated over land, with some exceptions near the north-western and south coast of Portugal. This positive bias is located in northern region and covers the area defined for the finer grid domain (Fig. 1). The excess of model precipitation can be caused by the enhanced 500 hPa geopotencial height that tends to increase the trough locate west

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of Portugal which are the typical conditions

The 200hPa winds pattern simulated by the WRF (Fig. 7e) model show a positive bias close to the borders of the domain possible caused by the interpolation to the observations grid. Overall, the upper troposphere winds are weaker than the observed. In contrast the near surface winds are zonally stronger than the observed ones (Table 6).

Overall, the WRF higher deviations from the observations (Table 6) are related to the 500 hPa geopotencial height and with the 200 hPa winds with a low pattern association."

With the new text the respective references added to "Reference" section are:

Berrisford P, Dee DP, Fielding K, Fuentes M, Kållberg P, Kobayashi S, Uppala SM. 2009. 'The ERA-Interim Archive'. ERA Report Series, No. 1. ECMWF: Reading, UK.

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N. and Vitart, F. (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q.J.R. Meteorol. Soc., 137: 553–597. doi:10.1002/qj.828

Haylock, M.R., N. Hofstra, A.M.G. Klein Tank, E.J. Klok, P.D. Jones, M. New. A European daily high-resolution gridded dataset of surface temperature and precipitation. J. Geophys. Res (Atmospheres), 113, D20119, doi:10.1029/2008JD10201 (2008)

Koo, MyungâĂŘSeo, and SongâĂŘYou Hong. "Diurnal variations of simulated precipitation over East Asia in two regional climate models." Journal of Geophysical Research: Atmospheres (1984–2012), 115.D5, (2010).

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Santos, J. A., J. CorteâĂŘReal, and S. M. Leite. "Weather regimes and their connection to the winter rainfall in Portugal."International Journal of Climatology,25.1 (2005): 33-50.

More detail comments:

C1 Abstract: I think it should be stated more clearly in the Abstract why the period of December 2009 was picked. “the heavy to extreme rainfall periods were caused by. . . “ are you referring to the period of Dec 2009 or some other periods?

A1: The sentence was rephrased and the authors believe that it is justified why December 2009 was chosen. Re-written of the phrase points that “the heavy to extreme rainfall periods were caused by. . . “ refer to the period under analysis.

Please, see comment 3.

C2 Points (1), (2) and (3): either make a sentence, including verb, of all or none of them.

A2: changed in the text. The authors decided for the maintenance of points without verbs.

Introduction C3 P. 1425, l. 11 : it looks like the abbreviation I30 is not used for anything and could be dropped.

A3: the abbreviation was removed from the text.

C4 P. 1426, l. 7-8 : “domain resolution” and later “domain”? Do you mean domain resolution horizontal resolution and size/position of domain? Please clarify.

A4: the authors believe that is now clarified.

C5 p. 1426, l. 14: “similar results. . . ” similar to what?

A5: The paragraph is now complete.

C6 p. 1426, l. 18: “precipitation integrated over time and space” I’m not sure what is

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meant here.

A6: additional information is given in the sentence to demonstrate authors' point of view.

C7 p. 1426, l. 18-22: I have trouble following this sentence. "not dependent on cumulus cell parameterisations. . . against explicit precipitation calculation".

A7: the sentence was rephrased.

C8 p. 1426, l. 22-24: same with this sentence. Perform worse than what? Either you use cumulus parametrisation, or if your grid size is fine enough, you resolve the precipitation explicitly.

A8: The sentence was rephrased and additional text was included to help clarity.

2. Materials and methods

C9 Remove "materials", to my understanding there are no materials associated with this model study.

A9: "Data" was used instead of "materials".

C10 p. 1427, l.26: is there no influence of the Atlantic on the climate? P. 1430, l13, states that the western boundary is important for the model to capture the dominant atmospheric circulation patterns.

A10: In this particular sentence, the authors wish to name the climate class to which this region belongs. According to the Köppen climate classification the region is classified as having Mediterranean climate, with Ocean influence. (Csa/Csb, Csb is the dominant class over the domain of interest).

http://www.hydrol-earth-syst-sci.net/11/1633/2007/hess-11-1633-2007.pdf

C11 p. 1428, l.25: "IDF long-term IDF curves in the dataset". Please explain IDF and double check the sentence.

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A11: IDF is shortly explained and the sentence was checked.

C12 p. 1429, l.16: Andaluzia -> Andalucia

A12: Written in the correct form.

C13 p. 1429, l.22: “on the winter modeled precipitation. . .” -> “on the modeled precipitation in winter than in summer” or similar.

A13: changed accordingly to the indications given.

C14 p.1430, l. 16: are 27 vertical levels enough for 1-km resolution?

A14: The authors believe that this is enough since WRF is a non-hydrostatic model and the first layer is 55 m thick. It is not straightforward that increasing horizontal resolution leads to an increase of the vertical resolution. The authors have some experience in manipulating the number of vertical levels in WRF, and depending on the type of weather system to be simulated; increasing vertical resolution may pose additional problems on numerical stability.

C15 p.1430, l. 28: was the convective parametrisation used even in the 1-km domain? Probably p. 1426 lines 18-24 justified this somehow but it was hard to follow.

A15: As the referee mentioned, the introduction section gave a justification for the use of cumulus parameterisation in the finner grid domain. However, in the end of this section, a paragraph was added refering a sensibility test that was performed about the use of the Grell-Devenyi cumulus scheme in the 1 km domain.

Section 2.3:

C16 My comments 1)-3) regarding nudgig could be discussed here.

A16: A paragraph was added at the end of this section discussing the nudging methodology. Section 2.5

C17 If metrics used are standard statistical measures it may not be necessary to write them here, just refer to a text book.

A17. The metrics for basic statistic were removed from the text and presented as Appendix.

C18 P. 1432, l14: add a comma before "namely" and remove –ly from "spatially"

A18: The text was changed according to the given indications.

C19 p. 1435, l15: remove comma after "Meaning"

A19: The text was changed according to the given indications.

C20 p. 1435, l17: "rather rescaled or transformed", what do you mean by that?

A20: It means that model results were used "as it is". Sometimes, for application of theoretical probability distributions data bust be transformed (e.g. of an highly used is the log transformation) or rescaled in order for data to better fit the theoretical probability distribution. It was not the case here.

C21 Table 4: perhaps the errors could be given relative to the mean, or % to be able to intercompare the numbers.

A21: Hourly precipitation series have many zero or near zero values. Small variations in the numerator may arise in huge differences expressed in percentage or even in relation to the mean value. Due to this fact, errors and not signal.

C22 p. 1436, l.24 why do you think these stations behave differently, are they located in a similar area?

A22. One possible explanation is that are facing the south side of the mountain within a valley. These valleys opens to the Ocean humid air masses channelling the flow, their location may be more favourable to record the precipitation that forms.

C23 p., 1437, l. 3: remove "of"

A23: The text was changed according to the given indications.

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C24 p.1437, l 3-7 & Figure 2: the figure is barely readable in my copy of the manuscript. Its size needs to be increased. Why do you expect all grid points in the domain to corral ate with any given station? My suggestion would be to show the correlation-nearest grid point at the location of the station to see how the model performance varies spatially, with three figures, one for each run. A24. This figure was removed from the manuscript. The pattern correlation coefficient was used to establish the agreement between observed and simulations pattern. Please see comment 3.

C25 p. 1437, l.9 “+3” add unit, is it 3 hours?

A25: The text was changed according to the given indications.

C26 P 1437, l.9-10: “the association among series was. . .” I do not understand, what kind of association do you mean?

A26: The authors meant correlation but the text was changed. Please, see comment C24.

C27 P 1437, l.9-12: “slightly worst” sounds strange.

A27, It was removed because is not adding any value to this discussion. Referee #1 also pointed this sentence on his comments and text was changed according R#1 indications.

C28 P 1437, l.9-13: What is mode?

A28: mode is the central tendency statistical measure, like the median or the mean, it is the value with the highest frequency in the data set.

C29 p. 1347, l. 24: “week” -> “weak”

A29: text was changed according to the given indications.

C30 p. 1347, l. 27: “this result was not detected in the ME”, why not? If the mean values are too high, shouldn’t that be seen in the ME? C30. C31 p. 1438, l. 4: “ the frequency distributions are very typical for rainfall (see Wilks, 2006, for example) A31: The sentence was completed.

C32 p. 1438, l. 7-8: what is "the three times the IQR area"?

A32: "area" was removed since IQR implies already a range.

C33 p. 1438, l. 18: There are three experiments: one free run and one with observational nudging on one single point, which is likely to produce similar results to the free run outside of the (small) area influenced by the obs. Nudging. Then ther's the very strongly nudged RunFridN which is likely to produce very similar results to GFS, and different from the two other experiments. This is mainly what you see but the background for it should be made clear in the manuscript.

A33: There is a discussion at the end of section 2.3 about the nudging methodologies used. However, the authors do not believe that the RunGridN experiment is strongly nudged through the analysis fields. In fact, domain D03 is a very small domain, in which only six points of the analysis fields lie inside the domain, being two of them over the ocean. Table 4 shows that, for the higher stations, the mean absolute deviation is lower in the RunGridN than in the other simulations, meaning that the model is resolving the topographic features in precipitation.

C34 p. 1438, l. 20: slight -> slightly

A34: text was changed according to the given indications.

C35 p. 1438, l. 21: "this characteristic is more pronounced", please be more explicit. The RunGridN results perform better for the ... thresholds, or similar. The fact that the grid nudged experiment performs well in reproducing low precipitation values is not surprising because it is forced towards the coarse resolution GFS data, which is probably averaging out the high precipitation events due to reduced orography and coarser time resolution. A35: text was changed according to the given indications.

C36 p. 1439, l. 11: Remove comma after "study"

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A36: The text was changed according to the given indications.

C37 p. 1439, l. 17: “WRF model” -> WRF model’s or the WRF model

A37: It is written “the WRF model”.

C38 p. 1441, l. 10-14: I guess which scheme works best depends on the typical weather regimes and the time of the year you’re simulating. Simulating areas with high convection is typically a hard task and would probably lead to better agreement with observations in winter. Therefore comparing various cases studies in different regions is difficult.

A38: The referee points an important issue. However, the references are in the text to emphasize the importance on conducting sensitivity studies over the regions of interest. Model results will experience different errors according to the parameterisations, season, and type of weather systems favouring precipitation. Due to interest on filling precipitation gaps on a time series, sensitivity of model results on other meteorological variables were not attempted. In this case, it is not a general rule that errors will be smaller in winter time. This will depend on the variable and the horizontal scale under analysis (ex: Awan et al., 2011)

4 Conclusions

C39 Mention the period of the study right in the start.

A39: The text was changed according to the given indications.

C40 p. 1441, l. 18: “measured gaps” -> gaps can not be measured, do you mean gaps in measurements or similar?

A40: The text was changed according to the given indications.

C41 p. 1441, l. 24: explain abbreviations in “Conclusions”

A41: The text was changed according to the given indications.

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C42 p. 1442, l. 9: introduce classes rather than use abbreviations. A42: The text was changed according to the given indications.

C43 p. 1442, l. 11-15: What kind of skill are you referring to? The very coarse vertical resolution versus fine horizontal one might cause problems, especially in complex terrain. What were the resolutions studied in Liu et al., 2011? In your case the precipitation rates are overestimated throughout the region so too large spatial scatter doesn't seem to be the reason for the discrepancy. It should be easy enough to assess by looking at 2d fields whether these problems arise from too much spatial noise. In mountainous areas the use of a coarse resolution will lead to an underestimation of the orography and orographic precipitation, so concluding that the best results are achieved with a coarse resolution probably won't hold. I think a starting point would be to increase the vertical resolution. Then apply spectral nudging and perhaps try reducing the down-scaling ratio to 3 between the domains.

A43: The skill measured is the SS – skill score. Liu et al., 2012 performs the model runs with 28 vertical levels. The suggestions are interesting. In a step forward work we should assess model results under the suggested configuration.

C44 p. 1442, l. 19: You mention that your model reproduces the timing correctly?

A44: The authors didn't mention that the model reproduced the time correctly. What the paragraph is saying is that although the time reproduction on hourly basis is not appropriate, daily values may be used on daily applications since the events were detected and ME is low for this purpose. The authors think that more aspects either than resolution may be analysed. A fixed set of physical choices to run the model under different precipitation driven processes over the same terrain may introduce the different skills.

C45 p. 1442, l. 25: RUNGridN -> RunGridRun

A45: The text was changed according to the given indications.

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C46 Tables 1 and 4 are very small

A45: In the original manuscript the tables are at normal size. Probably the resizing happened during edition by HESS.

C47 Increase the size of the text in figures 1, 3, 4, 5, 6 and 7.

A47: The text size in the figures was changed but figure 3 that was removed and the figures 6 and 7 were presented as bar plots.

C48 Figures 2, 6 and 7 are nearly impossible to read.

A48: Figure 2 was removed and figure 6 and 7 are now bar plots.

C49 table 4: better to show the errors in %

A49. Please, see comment 21.

C50 Table7 : the title says “RunObsN” instead of RunGridN

A50: The change was made.

C51 A comment to tables 5-7. The correlation coefficients are surprisingly low. Looking at figure 3 the model seems to capture the timing of the events quit well. What is the reason for this?

A51: The authors believe that the main reason relies on the small features that the model is not resolving, see for instance the beginning of the second precipitation period in Figure 3, or that is resolving in different times for some stations (last period of precipitation, mainly in stations C1, where precipitation is produced by the model but not detected by this stations.)

C52 Table 8? What is “mode”?

A52: mode is the central tendency statistical measure, like the median or the mean, it is the value that repeats more times in the data set.

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C53 Figure 1 caption: D03 frame marks. . . I think the triangle marking Pousadas is red "area of. . . " perhaps rather give the dimensions of the domain in X km x X km which is easier to grasp.

A53: The figure caption was changed .

C54 Figure 3: the titles say RunObs-OBS suggestion we're seeing the difference. However, the caption simply states "precipitation series". "second" and "third experiment are confusing, simply use the abbreviations RunRef etc.

A54: The caption was changed to clarify the figure interpretation (it is the difference between simulations and observations)

C55 Figure 5: what is IQR? Cannot it be expressed in percentiles for consistency? I would call this plot a frequency distribution to be consistent with the terminology used in the text.

A55: The caption was changed.

C56 Figure 6 caption:. 2negative values of the measurement", do you mean negative difference from measurement, i.e. model underestimates observation?

A56: The figure was replace by a bar plot.

C57 Figure 7: this figure requires more explanation. What are the blue, green, orange bars representing? What is "PC measurement?? Perhaps draw a line at 1 or whatever is the perfect measure to be able to assess the errors.

A57: The figure was replace by a bar plot.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C1072/2013/hessd-10-C1072-2013-supplement.pdf

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$$PC = \frac{\sum_{n=1}^{N} (y_i - \bar{y}_i)(o_i - \bar{o}_i)}{\left[\sum_{i=1}^{N} (y_i - \bar{y}_i) \sum_{i=1}^{N} (o_i - \bar{o}_i))\right]^{1/2}}$$

Fig. 1. Eq. 1

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