Evaluation of numerical weather prediction model precipitation forecasts forshort-term streamflow forecasting purpose

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We sincerely thank the reviewer for his thorough reviews and constructive suggestions. We have carefully revised the manuscript to address his comments and suggestions. Our responses to the comments are in blue font, updated text in manuscript in red font.

M. Zappa (Referee)

General remarks:

This paper is a nicely prepared exercise of NWP quantitative precipitation fore-casts (QPF) using only partly state-of-the-art verification methods and considering hydrological boundaries (analysis at catchment scale). Some specific QPF verification methods are not discussed (see comments below).
While in the title "streamflow-forecasting" takes a prominent role, no quantitative streamflow simulation is presented in the whole manuscript. Some speculative arguments concerning propagation of precipitation by streamflow forecasting are declared in the conclusions. But in the whole manuscript we obtain no information about the structure, name and configuration of an hydrological model having being forced by the presented QPF.

This study is the first part of a research program to support the production of ensemble streamflow forecasts by the Australian Bureau of Meteorology. The forecasting service seeks to produce ensemble streamflow forecasts out to 10 days using continuous hydrological modelling and NWP rainfall forecasts. This study mainly focuses on evaluation of NWP model precipitation forecasts for short-term streamflow forecasting purpose. The results from this study are going to be used for streamflow forecasting study. Future work is planned to assess the benefits of using the NWP rainfall forecasts for short term streamflow forecasting. This was explicitly mentioned in the abstract and conclusions of the original version of the paper. However, it seems that the title is somehow misleading as the streamflow forecasting results are not presented. We explicitly mention this also in introduction section of the revised paper and change the title to "Evaluation of numerical weather prediction model precipitation forecasts for short-term streamflow forecasting purpose"

The last paragraph of the introduction section now reads

This study is the first part of a research program to support the production of ensemble streamflow forecasts by the Australian Bureau of Meteorology. The forecasting service seeks to produce ensemble streamflow forecasts out to 10 days using continuous hydrological modelling and NWP rainfall forecasts. The main objectives of this study are to i) compare the skill of NWP models with different spatial resolutions at station locations and at the catchment scale, ii) to evaluate the impact of lead time, precipitation accumulation period, and precipitation threshold values on forecast skill, and iii) to investigate the effect of diurnal cycle and sampling uncertainty on forecast skill. The contribution and benefit of NWP model rainfall forecasts for use in streamflow forecasting will be presented in a subsequent paper. In comparison with previous studies, the main contributions of this study are to i) evaluate the quality of the ACCESS model suite which is the latest generation Australian NWP model, ii) use both continuous and categorical evaluation scores, iii) analyse the evaluation scores of precipitation forecasts at multiple sub-daily temporal resolutions out to longer forecast lead times, iv) investigate diurnal cycle and uncertainty analysis of the evaluation scores. The Ovens catchment in southeast Australia is selected to evaluate the skill of the precipitation forecasts from ACCESS models.

We removed arguments concerning the streamflow forecasting from the revised manuscript.

I find also a bit a pity, that the verification and results almost solely focus on the coarse ACCESS-G product, while for the high resolution ACCESS-VT and ACCESS-A models only one figure is given.

We deliberately removed skill of higher resolution models from Figure 6 onwards, because as mentioned in the manuscript that they only provide forecasts up to 72 hours. Figures will be messy with additional three lines and their uncertainty bounds. However, considering the reviewer feedback, we have added the skill of high resolution models in only Fig 6 of the revised manuscript as the conclusions drawn are not different than those obtained from all remaining figures.

My judgement as a reviewer is that this paper might be adequate for final publication in HESS after addressing some issues presented below.
The paper is written in fluent English by native English speakers. As a non-native English person it was no problem for me to read it.

Major issues: Page (line)

P 12572-12575: While I find the general declaration of the used scores well formulated, I was a little bit surprised, that I was not able to find in the whole manuscript any reference to the SAL (for structure (S), amplitude (A), and location (L) of the precipitation field) verification method proposed by Wernli et al. (2008). Have you considered this method and then decided to disregard it? Would the SAL approach suit to evaluate your data?

We have seen other object oriented based approaches (e.g., Ebert and McBride, 2000). We have not considered such method in the study as catchment area selected is much smaller than the area required by such method to get reliable results. Furthermore, our focus is to evaluate rainfall forecasts from hydrological perspective where the rainfalls outside the boundary of the catchment do not contribute to the streamflow forecasts to the catchment of the interest. The location error of rainfall is crucial for hydrological application as an error of a few kilometres can lead the precipitation in the wrong catchment (Habets et al., 2004). Whereas for object oriented verification approach, this is only location error and magnitude of the forecast is still considered to be right.

P 12582: You don't show many results on the verification of the high resolution ACCESS-VT and ACCESS-A models. I would welcome in a revised manuscript to give more weight on results for all models.

Please see the earlier response in this page.

P 12586 (8-11): You write: “The catchment average precipitation is used as the input to lumped hydrological models when forecasting streamflow. Furthermore, the sensitivity of the streamflow forecasts to the errors in catchment average precipitation is higher than to the stations precipitations because of a smoothing effect.”
First issue: From the manuscript we don’t learn any details on which kind of hydrological models are used (or planned to be used). As you average precipitation for sub-catchments one might expect that you use lumped models, but there is enough literature also on the use of distributed models for hydrological forecasting.

We have updated the first paragraph of section 4.6 and now it reads as

Previous sections presented the evaluation scores of the ACCESS model precipitation forecasts at point scale (i.e. at rain gauge station). For hydrological applications the localisation of precipitation is important at the catchment scale so that it is useful to evaluate precipitation forecasts on catchment averages (e.g., Oberto et al., 2006; Rossa et al., 2008). We are using lumped model GR4J (Perrin et al., 2003) for each sub-catchment and the flow from each sub-catchment is routed to the outlet of the catchment using Muskingum channel routing algorithms. Thus average precipitation over sub-catchment is used input to the GR4J model for hydrological forecasting. Australian Bureau of Meteorology currently uses the event-based model URBS (Malone, 1999) for real time flood forecasting in Australia. URBS is a lumped model which uses a single catchment average forecast rainfall as compared to sub-catchment average rainfall for the GR4J model. Bureau is planning to use continuous modelling with semi distributed lumped model (connected lumped model) for real time flood forecasting services in Australia.

Second issue: How can you conclude on the sensitivity of the streamflow fore-casts? You should carefully revise the paper in order to eliminate any speculation on streamflow-forecasts. I have the impression that you have already the results of the streamflow forecasts and that you plant to present them in a follow-up paper. No problem with this, as long as you avoid making conclusions and interpretation of streamflow forecasts in this manuscript.

We agree with the reviewer. As mentioned before, indeed we are planning to present streamflow forecasting results in a subsequent paper and have removed the texts related to streamflow forecasting in the revised manuscript.

Minor comments: Page (line):

P 12564 and 12565: I would expect some citation to support the general affir-mations of the first paragraph of the introduction. E.g. for the intercomparison of NWP models you could refer to Rotach et al.(2009).

We have added references Rotach et al. (2009) and Cuo et al. (2011).

P 12565: There is a recent review paper by Rossa et al. (2011) on propagation of uncertaintiy from NWP into hydrological models. P12567: You might be eventually also interested in the paper by Ament et al. (2011).

These references are also added to the revised manuscript.

P12568-12569: Is this the first study using the ACCESS model suite? If yes I would expect more information on the model and its relation to other similar model suites (e.g. COSMO). If other studies have been already published, then you should cite them.

This is first study using the ACCESS model suite and we have explicitly mentioned this in the revised manuscript. A detailed description of the ACCESS models is given in section 2.1 of the revised manuscript.

P 12570: Can you give some information on how you estimated potential evapotranspiration?

The potential evapotranspiration came from the AWAP project data (Raupach et al., 2008) which is based on Priestley-Taylor evaporation rate. The reference is added to the revised manuscript (section 2.2).

P 12571, lines 9-18: This paragraph is formulated in a not very scientific way (e.g. "suspicious data"). Can you re-elaborate this in give some information on how you detected the suspicious data, how many data (in percent) were "suspicious" and how many needed to be "infilled" (and how . . .)

We have revised second last paragraph of section 2.2 with some information on how we detect outliers (suspicious data). This paragraph now reads

Observed precipitation data were collected from 33 measurement stations that are used for operational forecasting in the Ovens catchment (Table 2). The measurement stations are reasonably distributed across the catchment and surroundings as shown in Fig. 3. Some stations at high elevation have heated rain gauge to measure snow fall. Careful preparation of the precipitation observations was necessary and included removal of outliers and infilling of missing values. Data which are significantly different from the neighbouring stations and gridded daily precipitation data or previous time step are marked as missing. A visual inspection of the precipitation hyetograph and corresponding observed streamflow hydrograph was also used to identify outliers in the precipitation. We believe such data are resulted from human error, and there are a few such data records in the evaluation period. The infilling process related daily precipitation totals at the measurement stations to gridded daily precipitation data from the Australian Water Availability Project (Jones et al., 2009) and disaggregated the daily total using the concurrent temporal pattern from the nearest available station. The percentage of missing data is given on Table 2.

Figure 3: Can you assign a colour to the area of the Wangaratta basin?

Done.

References:

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Rotach MW, Ambrosetti P, Ament F, Appenzeller C, Arpagaus M, Bauer HS, Behrendt A, Bouttier F, Buzzi A, Corrazza M, Davolio S, Denhard M, Dorninger M, Fontannaz L, Frick J, Fundel F, Germann U, Gorgas T, Hegg C, Hering A, Keil C, Liniger MA, Marsigli C, McTaggart-Cowan R, Montani A, Mylne K, Ranzi R, Richard E, Rossa A, Santos-Muñoz D, Schär C, Seity Y, Staudinger M, Stoll M, Volkert H, Walser A, Wang Y, Wulfmeyer V, Zappa M. 2009. MAP D-PHASE: Real-time Demonstration of Weather Forecast Quality in the Alpine Region. Bulletin of the American Meteorological Society. 90. Pages 1321-1336. doi:10.1175/2009BAMS2776.1

Wernli, Heini, Marcus Paulat, Martin Hagen, Christoph Frei, 2008: SALâ TA Novel Quality Measure for the Verification of Quantitative Precipitation Forecasts. Mon. Wea. Rev., 136, 4470–4487. doi: http://dx.doi.org/10.1175/2008MWR2415.1
Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 12563, 2012.

Added references

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