# Response_to_gmd-2021-176-RC1

REB

10/19/2021

## Response

I want to thank anonymous reviewer #1 (DOI:10.5194/gmd-2021-176-RC1) for a frank and critical take on Benestad (2021). It is extremely important with discussions such as this one, even if we don't agree on the choices or methods. Because the merit of discussions potentially may be degraded by misunderstandings, a risk which can be reduced by including replicable and transparent demonstrations, I will use an R-markdown script here and its output in the PDF format. It will provide a demonstration based on the open-source `esd-package` that is freely available from https://github.com/metno/esd (documentation, help pages and demos are available on its wiki-page).

### 'Review' and lack of originality?

Reviewer #1 reads the paper as "a review of the statistical downscaling strategies followed by the author over the past decades." No. It provides an overview of our strategy, and refers to past work as examples supporting this strategy. I realise that our work to large extent has been ignored by the international downscaling community. There are indeed few other groups that have carried out similar work. This is the reason why I had to cite much of our own research to demonstrate the merit of our strategy. It would be nice to be able to refer to other examples underpinning the discussion of the overall downscaling strategy, but Reviewer #1 did not suggest any papers discussing similar strategies as Benestad (2021). A lack of suitable references can be discerned from the exclusion of other similar work in the chapter on regional modelling (Chapter 10) in the latest IPCC AR6 WG1 report from 2021. For instance, the hybrid PP-MOS type of downscaling models, that provides much of the basis for this downscaling strategy, is not included in Table 10.1 in Doblas-Reyes et al. (2021). Common EOFs are only mentioned briefly once, with a brief reference to Benestad (2011) and then mislabeled as 'PP.' It would be relevant to explain their purpose, but Doblas-Reyes et al. (2021) doesn't. Nor does the report mention them in connection with the discussion on the ability of global models to simulate large-scale indicators of climate change. None of the evaluation strategies for downscaled ensembles mentioned are discussed (they are explained in both Benestad (2021) and Benestad et al. (2016)), despite their natural place in the discussion of the overall performance in a climate change application and performance of the driving climate model ("model fitness for projections"). There is no mention in the IPCC report of the use of PCA to represent predictand and its benefit in terms of preserving the spatial consistency between sites, which naturally would fit in the chapter. These omissions can be interpreted as being exclusive since some of the authors on this chapter should have known about these topics. They also explain the difficulty to find other relevant references that Benestad (2021) could cite in order to support the choices made in the downscaling strategy.

### Dubious aspects?

Reviewer #1 claims that "reasoning concerning a few technical aspects is dubious" and that "it does not contain original model or methodological descriptions." Both are wrong and are not supported by any demonstration nor accompanied by convincing details. The good news is that most of the methods in Benestad (2021) have been demonstrated in the cited papers and a further demonstration is presented below.

When we work with the data, we can also test the assumption which the example provided shows. It is hopefully possible to resolve many different interpretations by testing claims on real data.

This is the first time we have written up a comprehensive description of our overall downscaling strategy, and I don't think there are many other similar descriptions. The fact that hardly any of this work was cited (and certainly not discussed) in Doblas-Reyes et al. (2021) shows that the work still is original from an international point of view. I will challenge Reviewer #1 to point to any published papers discussing the nine evaluation criteria that were introduced in Benestad (2021). Also, it's difficult to find other examples of downscaling that include the validation of the driving GCMs. A search within Doblas-Reyes et al. (2021) for such examples was unsuccessful. Again, if Reviewer #1 knows of any, I hope (s)he will share this information with us.

**Overview versus a forest of details**

One critical point that Reviewer #1 has on Benestad (2021) is that it "refer[s] to a list of previous papers without offering deeper insight." Again, the manuscript provides an overview of the comprehensive downscaling strategy and provides examples of demonstration to back up the choices taken. Here, the level of details was kept to a minimum to avoid getting lost in the forest of details. The cited papers should be open-access, so readers who want to delve into the details can do so by reading the cited papers. It would be no point of repeating them here, as it would introduce material that is not original - by adding such, the paper would become less original and that would give the criticism of lacking originality a little substance. Again, the purpose of this paper is to provide an overarching view and understanding of the approach to downscaling and why it differs from other similar efforts.

**'Project report?'**

The interpretation that Benestad (2021) 'the manuscript to [Reviewer #1] rather reads like a project report or a report of a laboratory for an external evaluation' is both strange and subjective. It shows that there are very different ways of looking at downscaling and scientific literature. I have used an R-markdown script here to demonstrate what a 'project report or a report of a laboratory' looks more like. It may even seem that Reviewer #1 is trying to exclude scientific contributions (s)he doesn't like.

**The title**

The original title of Benestad (2021) was 'The Norwegian downscaling Strategy,' but after I received some comments from Norwegian colleagues, it was changed to 'A Norwegian downscaling Strategy.' It does of course not reflect all downscaling in Norway, but nevertheless touches a large portion of it over the 23 years since the national RegClim project. Also, this approach has all the time combined both RCMs and ESD, as explained in Benestad (2021), which I have realised is not so common in other countries. And of course, our approach to ESD is very different as explained in the paper.

**The abstract**

The comment from Revewer #1 ("what is the downscaling method based? is it statistical or dynamical ?") reveals our different points of perspectives and different sets of expectations. This paper provides an overview of the comprehensive downscaling strategy that is a level above the choices of a particular downscaling method or whether it is dynamical or statistical. That would be a traditional way of writing a paper, but here we take an innovative and original look on downscaling on a higher level. The paper does present what is stated in the abstract: "... description of a comprehensive geoscientific downscaling model strategy is presented outlining an approach that has evolved over the last 20 years. ..."

**Long experience**

The work goes back to the end of the 1990s, and there were few downscaling groups then. There were some, but many of the scholars in those have since retired. Also, it predates CORDEX. The point is that the work on downscaling over many years has produced good progress that has not been recognized, as shown above where Doblas-Reyes et al. (2021) is a case in point.

**Stock-taking**

I'm certainly not representative for whole Norway, but have collaborated with largest research organisations involved in downscaling in Norway: CICERO, University of Oslo, NORCE, Norwegian Computing, and NVE. Most of these use RCMs and are well attuned to Euro-CORDEX. The paper focuses on ESD (for which I know of few other activities in Norway) and the combination of ESD and RCM.

**Bias correction**

There may be different views on bias correction, but here I want to emphasise that the merit of downscaling is to use the large-scale aspects that the GCMs are able to reproduce in a skillful way, and information about how local conditions depend on such large-scale conditions, in addition to geography, and use these additional sources of information to get a refined picture. Bias correction involves bias correction. It's legitimate to state such a point of view in a scientific paper, I think, and especially if it's controversial.

**Common EOFs**

The paper does not assume that common EOFs are superior, but cites demonstrations that show that they in fact are superior. The strange thing is that they are not recognized in Doblas-Reyes et al. (2021), but only briefly mentioned once in the passing. This is also part of the motivation behind describing the downscaling strategy that has been adopted in a Norwegian research group with long experience on downscaling. We have understood that the concept of common EOFs perhaps is a bit difficult to understand.

**Outcome**

Thanks for this question - this is explained more carefully in the revised version of the paper: "In this context, individual outcomes can be the temperature or rainfall for a random day or a particular state for a random time step when we deal with a time series."

It is true that climate downscaling is never about the prediction of individual events, and the difference between the two concepts here is in terms of how the models are calibrated: either on a time-step-by-time-step (day-by-day) basis or by estimating the dependency of the pdf parameters on large-scale conditions. This is not more carefully explained in the revised paper.

**Normal distribution according to the central limit theorem**

The reviewer points out that the notion of a normal distribution for aggregated statistics is not generally true, and in a bayesian setting the prior for variance are other types of non-normal distributions. In this case, we discuss only four different types of aggregated statistics: the mean $\overline{T}$, the standard deviation $\sigma$ for temperature, and wet-day mean precipitation $\mu$ and wet-day frequency $f_w$ for 24-hr precipitation. Fortunately, we don't need to downscale the variance. We can also carry out actual tests to see if the distribution of these variables do follow a normal distribution. Below is an example for the standard deviation $\sigma$ that has the closest connection to the variance $\sigma^2$ cited in the criticism:

```
## Test the distribution of variance in temperature
library(esd)  ## https://github.com/metno/esd
```

```
## Loading required package: ncdf4
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
## Registered S3 methods overwritten by 'esd':
##   method         from
##   subset.default base
##   subset.matrix  base
##   subset.zoo     zoo
```

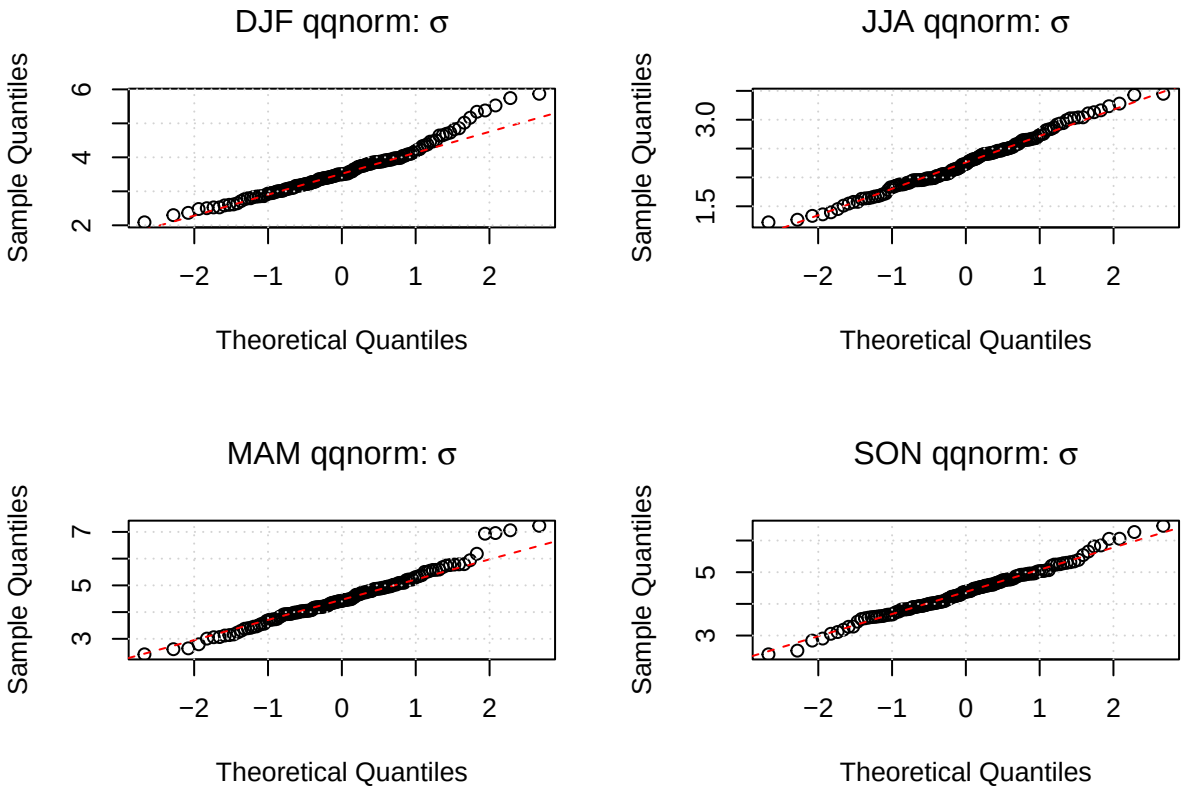
```
data(ferder)  ## This line fetches 24-hr mean temperature for Færder lighthouse south of Oslo
sigma <- as.4seasons(ferder,FUN='sd')
djf <- subset(sigma,it='djf')
mam <- subset(sigma,it='mam')
jja <- subset(sigma,it='jja')
son <- subset(sigma,it='son')

par(mfcol=c(2,2))
qqnorm(djf,main=expression(paste('DJF qqnorm: ',sigma)))
qqline(djf,lty=2,col='red')
grid()

qqnorm(mam,main=expression(paste('MAM qqnorm: ',sigma)))
qqline(mam,lty=2,col='red')
grid()

qqnorm(jja,main=expression(paste('JJA qqnorm: ',sigma)))
qqline(jja,lty=2,col='red')
grid()

qqnorm(son,main=expression(paste('SON qqnorm: ',sigma)))
qqline(son,lty=2,col='red')
grid()
```




The example here shows that $\sigma$ doesn't follow a normal distribution perfectly, but the normal distribution is nevertheless a reasonable assumption.

It is also explained in Benestad (2021) that it's extremely important to evaluate all assumptions and all results, and also to test the downscaled results for $\sigma$ against observations to evaluate the skill of the ordinary linear model (OLM). Trend analysis over historical times and downscaled projections, however, show that $\sigma$ is not very sensitive to large-scale changes and less important than the changes in the mean $\overline{T}$. The discussion paper recommends two tests for checking whether the downscaling of any of the aggregated parameters are skillfully reproduced by the OLMs: by comparing their historical trends with the trends simulated by each ensemble member (a Chi-2 test) and whether their variance are realistic in terms of the simulated 90-percentile confidence interval. More details are provided in Benestad et al. (2016).

Another example demonstrating the point made by Reviewer #1 is that the number of e.g. heatwaves or storms in a region is expected to be Poisson-distributed, whereas the duration of heatwaves or dry spells may follow the geometric distribution as explained in Benestad et al. (2018). In other words, it is true there are some parameters used in the downscaling strategy that are not normally distributed, but Benestad (2021) already explains this quite extensively.

In this case, the point made by Reviewer #1 can be solved by inserting 'these' in the revised paper: "Since we downscale the parameters of the pdfs and the probability expressions, i.e. $[\mu_t, \sigma_T, f_w, \mu]$, we tend to use multiple regression because these parameters aggregated over seasonal scales tend to approximately follow the normal distribution according to the central limit theorem."

**The median**

The parameter of the geometric distribution is not an integer, but a rational number because it's the success probability $p$ and the mean spell length is $\overline{L} = 1/p$. With the mean duration, you can estimate the probabilities

for the different spell lengths, but it's impossible with the median which is not a rational number (it.s a mix between integers and sometimes a rational number). It's not common to use the geometric distribution to analyse duration of events in downscaling and regional climate modelling, and this is an original part of the downscaling approach described in Benestad (2021). Se e.g. https://en.wikipedia.org/wiki/Geometric_distribution for more information about the geometric distribution.

**The statistics of maxima**

The discussion about statistics of maxima is in the context of the IPCC SREX and presenting the change in annual maximum number of consecutive dry days. I have revised this part of the text somewhat to avoid confusion.

**Strategy for storing large volumes of multi-model ensemble ESD output**

The way huge volumes data is organised has an effect on their availability when it comes to climate services and use for climate change adaptation. There is to my knowledge no discussion about how to represent the information of large multi-model ensembles in ways so that relevant information can be quickly and efficiently distilled. This has become part of our downscaling strategy which is geared to providing regional climate change information for society, as explained in Benestad (2021). The details are provided in the reference cited: Benestad et al. (2017) and a demonstration is available from the cited URL. Reviewer #1 fails to see the direct link of this section to the other sections, which shows that (s)he has a different experience regarding the provision of regional climate information to society. One question is how (s)he would suggest to organise vast volumes of data from large multi-model ensembles represented on 8x8km maps for a given region (many gigabytes).

**RCMs and GCMs**

Yes, GCMs do strictly not represent the same aspects as those observed. But they nevertheless are able to provide useful inforation about large-scale phenomena. The downscaling strategy explained in Benestad (2021) makes use of the large-scale aspects that the GCMs are able to reproduce in order to infer local consequences.

**Using the best information the right way**

Comment: "Does this mean that the CMIP5 and CMIP6 ensemble is a 'case of not using the right information in a correct way'?" - it's better to say 'best information' and the revised paper will do that. The sentence is followed by a discussion in Benestad (2021) for why we should not use one single model, which is both obvious and a clear way of demonstrating the point. Both CMIP and CORDEX ensembles are valuable but also have limitations. We would not use any CMIP ensemble to make judgement about the fate of the Alpine snowpack, for instance, but they do a good job in terms of indicating the evolution of the global mean temperature.

**Biases in GCMs**

There are of course biases in both GCMs and RCMs, but the application of ESD bypasses them. The point is that both RCMs and ESD are needed to get the best information about the regional climate. The paper has been revised to avoid this misunderstanding.

## Wrap-up

Benestad (2021) approaches the downscaling approach with questions why, what and how, "a golden circle" inspired by the TED-talk of Simon Sinek (https://www.ted.com/talks/simon_sinek_how_great_leaders_inspire_action?language=en). This is not common in academic papers but it can make the points clearer for the reader. According to the paper's metric (2021-10-21), it has been accessed 780 times since July. This stands in contrast to the number of citations of the work connected to this strategy in Doblas-Reyes et al. (2021) and the attention received through CORDEX. Benestad (2021) can also be interpreted as a criticism against the protocol proposed by CORDEX and VALUE which possibly can have attracted interest.

Benestad (2021) provides a geoscientific model strategy description for using statistical models. It discusses new methods for assessment of models, including work on developing new metrics for assessing model performance and novel ways of comparing model results with observational data, in addition to describing new standard experiments for assessing model performance. Thus, the claim by Reviewer #1 that it is a review with no original model or methodological descriptions is unconvincing. Benestad (2021) also exposes controversial sides in the downscaling community, 'silo thinking,' and an intellectual gap between the different research groups (Reviewer #1's comments, DOI:10.5194/gmd-2021-176-RC1, also seems to support this interpretations). It begs the uncomfortable question whether some efforts are being suppressed by strong characters in important positions.

## R-markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com. The following chunk is provided to show details about the platform used in the demonstration above (e.g. versions of R and `esd`)

```
print(sessionInfo())
```

```
## R version 4.1.1 (2021-08-10)
## Platform: x86_64-pc-linux-gnu (64-bit)
## Running under: Ubuntu 18.04.6 LTS
##
## Matrix products: default
## BLAS:   /usr/lib/x86_64-linux-gnu/blas/libblas.so.3.7.1
## LAPACK: /usr/lib/x86_64-linux-gnu/lapack/liblapack.so.3.7.1
##
## locale:
##  [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C
##  [3] LC_TIME=en_US.UTF-8        LC_COLLATE=en_US.UTF-8
##  [5] LC_MONETARY=en_US.UTF-8    LC_MESSAGES=en_US.UTF-8
##  [7] LC_PAPER=en_US.UTF-8       LC_NAME=C
##  [9] LC_ADDRESS=C               LC_TELEPHONE=C
## [11] LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
## [1] esd_1.9.88 zoo_1.8-9  ncdf4_1.17
##
## loaded via a namespace (and not attached):
##  [1] lattice_0.20-45   digest_0.6.27     grid_4.1.1        magrittr_2.0.1
##  [5] evaluate_0.14     highr_0.9         rlang_0.4.11      stringi_1.6.2
```

```
##  [9] rmarkdown_2.8     tools_4.1.1       stringr_1.4.0     xfun_0.23
## [13] yaml_2.2.1        compiler_4.1.1    htmltools_0.5.1.1 knitr_1.33
```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