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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Interpreting the time variability of world-wide GPS and GOME/SCIAMACHY integrated water vapour retrievals, using reanalyses as auxiliary tools" *by* Roeland Van Malderen et al.

Anonymous Referee #2

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General Comments:

In this paper an analysis of integrated water vapour (IWV) data from three different sources (ground based GPS data, GOME/SCIAMACHY/GOME-2 satellite data and ERA Interim model data) is presented. Beside intercomparisons of the three data sets major topics of the paper are the analysis of time series and the association of variabilities in IWV with 'explanatory variables', e.g. physical / dynamical processes described by teleconnection indices.

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Discussion paper

This is an interesting approach which is well presented, but some aspects need further clarifications. Especially, the method of stepwise linear regression needs to be explained in more detail. Which terms of eq. (1) are fitted in the individual steps (and in which sequence), which corrections are applied to the data sets used in each step? Especially, it should be clarified if/how e.g. seasonal variability and trends of the 'explanatory variables' is considered. Have these data been de-seasonalised before the fit? If not, how are correlations with the linear trend and seasonal terms in eq. (1) handled? It seems that e.g. linear trends are sometimes not fitted at all because they are covered by explanatory variables variations - how is this decided? Does the sequence of fitted variables matter?

Maybe it would help to add e.g. for one example a plot of the different fit steps with the different time series used in each step (not necessarily for all explanatory variables, but for the major ones); this could possibly be an extension of Fig. 8.

Another aspect is the selection of relevant explanatory variables for the fit. I would assume that many of the variables (e.g. temperature, pressure, precipitation) are strongly correlated - it needs to be explained in more detail how this is considered in the fitting procedure as well as in the interpretation of the results.

Specific Comments:

1. p. 6, l. 28–29:
   'The database has been enhanced with many observations not available in real time for operational use.'

   What is meant with this? Which database/observations do you refer to? Did you use/produce a dedicated version of NCEP/NCAR data? Please clarify.

2. p. 9, 1st paragraph:
   As I understand, the difference between lognormal and reversed lognormal distribution is that there is either a (non-zero) lower or upper limit for the IWV. Is there

a physical reason why a lognormal distribution occurs for subtropical and temperate climate and a reversed lognormal form in tropical oceanic environments?

3. p. 9, l. 10ff. and Fig. 3:
   Since the 'shouldered' lognormal distribution is a new category I suggest to add also an example plot for this in Fig. 3.

4. p. 11, l. 5–6:
   'the IWV seasonal cycle for about 15 sites in the Northern Hemisphere peaks one month later in the GOMESCIA dataset with respect to the GPS and ERA-Interim datasets'

   Is there an explanation for this?

5. p. 12, l. 7–8:
   'We calculated linear trends as the slope of the linear regression line that was fitted (by minimising the least squares) through the monthly anomaly IWV time series.'

   Please explain how these anomalies are calculated (e.g. by subtraction of harmonics or long-term monthly means).

6. p. 12, l. 16–18:
   Is here an explanation for the differences in GPS trends from this study and Wang et al. (2016a)? If the same data set is used (as stated in section 2.1), why are there differences?

7. p. 14, 1st and 2nd paragraph:
   Are seasonal variations considered in the checks for independency of explanatory variables? Where does the limit of 0.90 for the linear correlation coefficients come from (in the section on linear trends a correlation of R^2=0.66 is considered as large).

In this context, and also for the regression tests used to determine the significance of the different explanatory variables: Have the data sets been deseasonalised before the comparisons? Is the preparation of variables for this test consistent with their later use in the fit (see also general comment)? Is the fact that 'Variables with a significance level lower than 5% are discarded' the reason that in the fits instead of 100-200 variables only 6-8 (see end of this page) are considered?

Please explain.

8. p. 14, l. 17–19:
'a significant positive trend is still present in the residual time series (although the annual trend was not retained as a significant explanatory variable in the multiple linear regression).'

   This is unclear. If (as in eq. (1)) the linear trend is fitted, why is there a remaining trend in the residual?

9. p. 14, l. 23–25:
'part of the seasonal behaviour present in the time series still has to be explained by other variables, especially by the surface temperature and precipitation time series'

   As mentioned in the general comments, it has to be clarified how seasonal variations are considered in each of the fitted time series and how this is in line with the seasonal terms in eq. (1).

10. p. 14, l. 23–25:
'the NAO index is present in only one third of the sites as explanatory variable, although its relationship with precipitation is well established in Europe'

    If NAO index and precipitation are closely related, why can these be considered as independent explanatory variables?

11. p. 18, l. 26:
‘we do not expect an effect of IWV on precipitation’

Why not? Please explain.

12. p. 18, l. 10–13:
‘Moreover, whereas the majority of the sites have positive trends in their IWV time series, especially for the GPS and ERA-Interim datasets (see Sect. 6.1), the residual time series after applying the multiple linear regression show an equal amount of positive and negative trends (GPS and ERA-Interim) or even a higher amount of sites with a negative trend (GOMESCIA).’

Obviously, there are different ways to determine trends. As I understand, trends from section 6.1 originate from a simple linear regression (and probably a to be defined seasonal correction, see above). It seems that the multiple linear regression trends mentioned here are those remaining after subtracting the effects of explanatory variables without a linear trend fit (although a linear term is given in eq. (1)). This should be clarified.

13. p. 19, l. 25–27:
‘the linear trend sign of the explanatory variable’s term (coefficient multiplied with its time series) is in agreement with the linear trend sign of the IWV time series of the same site’

It is not clear what is meant with ‘trend sign of the explanatory variable’s term‘ and how this is derived. Do you fit a linear trend to the explanatory variable’s term? Please explain.

14. p. 20, l. 25–27:
‘the precise identification of the main contributor to the IWV trend is almost impossible’

This sounds rather pessimistic. In most cases there will not be one single contributor to the IWV trend. The analysis presented in this paper at least shows for certain regions the main contributors, and this is a very useful result which could possibly even be the basis for further investigations (see suggestion below).

15. p. 22, l. 14:
The 'meteorological station' is only introduced in the next paragraph, should be explained before.

16. p. 22, l. 14:
'the slope of the linear regression (with correlation coefficient 0.84) between the Ps and IWV biases between the different corresponding datasets for the 40 IGS stations is equal to the -0.34, confirming the acceptable data quality of the pressure observations at the retained stations.'

    It is not fully clear to me what has been done here and how the derived numbers are to be interpreted. Do you refer here to the begin of the appendix 'a 1 hPa change in Ps gives an IWV change of 0.36 mm'? Table A1/A2 list three different Ps sources - to which do you refer here?

17. Table A1:

    (a) Please define "abs bias" and "abs trend". Probably these are the bias and trend of the absolute differences? Why are these absolute numbers relevant in relation to the interpretation of the multilinear fit?

    (b) What exactly is meant with case a)? Is this a comparison between the IGS and the ERA Interim IVW data?

    (c) What is meant with 'the two different databases of the meteorological variable whose impact on the IWV is studied'? For example, I interpret case b) as a comparison between IWV results based on Ps from ERA Interim and

Ps from synoptic stations (this should be the non-italic numbers). What are the italic numbers in this case?

18. Figure 4:
Why do you only show Classification for GPS (a) and GSD for ERA Interim data (b)? I assume these plots should be available for both data sets.

19. Figure 8:
It should be clarified that no linear trends are fitted, only proxies (if this is the case here).

Technical Corrections:

1. p. 2, l. 16:
differntial → differential

2. p. 2, l. 20:
An inventory many of → An inventory of many of

3. p. 7, l. 18:
Antarctic (AO) → Antarctic (AAO)

4. p. 11, l. 21:
statistical significant → statistically significant

5. p. 16, l. 30:
our sample our located → our sample are located

6. Caption Figure 3:
with its contribution lognormal distributions → with its contributing lognormal distributions

Suggestion:

The current work is limited to the geographical sampling of the GPS stations. I suggest to perform (outside the scope of this paper) a similar multiple linear regression analysis for global time series (e.g. from ERA Interim and/or GOMESCIA). This could help to identify reasons for IWV variations on a regional scale.

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