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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Evaluation of the vertical diffusion coefficients from ERA-40 with ^{222}Rn simulations" *by* D. J. L. Olivié et al.

D. J. L. Olivié et al.

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We thank reviewer 2 for his/her extensive, constructive and useful comments.
Please find below our detailed answer to the comments.

Answers to the general comments :

- The presentation and organization of the paper has been improved : the introduction has been completely rewritten. Sections 2 and 3 have been reorganised. We now formulated explicitly the main scientific questions. We more clearly draw conclusions from the presented material in the Conclusions. We have removed distracting comments on method, and we have separated the results and methods as suggested. The methods are now described only in Section 2 'Methods'.

- The comparison to observations has been extended. We use more ABL height measurements from the FIFE campaign : we included extra SODAR measurements. In the comparison between observations and measurements, we now distinguished between different situations : daytime and night time, and high and low wind speeds.

- We have added profiles of the time evolution of K_z for selected locations and seasons. We consider separately the distributions over sea, over land, during different seasons. We also added figures of the time evolution at 3 different locations.

- We agree that comparing averaged values does not lead to strong conclusions (except that they indicate a problem when they do not agree), and now use medians and 10- and 90-percentiles in the analysis of K_z, which yields more meaningful information. We however kept the correlation of the residue (difference between hourly value and mean daily value), comparison of the amplitude of the daily cycle, and the study of the time shift, which are informative for the shorter time scales.

Answers to detailed comments :

Abstract :

- 'instead' replaced by 'versus'

- 'by investigation of the effect' replaced by 'by examining the influence'

- We removed the 'we conclude that ...' sentence. Because the diffusion is parameterized, separate eddies are not modelled. This implies that species that are emitted from the surface and that have a short lifetime, or species that have high dry deposition rates cannot be modelled accurately. In addition, the time step of 3 (or 6) hours in the diffusion data, does not allow making a detailed description on a time

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scale much smaller than 3 (or 6) hours.

Introduction :

- We have reorganized the introduction.

- 'appeared to be ...' is replaced by 'has shown to be ...' : the transport actually is more pronounced in the non-local case.

- *Wang et al.* [1999] used ^{222}Rn and CH_4 to test the transport in the model by comparing the model results with observations of ^{222}Rn and CH_4. Later they made simulations of other species like O_3 and CH_4.

- 'Chemistry transport models ...' : we removed this paragraph.

- 'sampling interval' : The archival of meteorological fields of a Numerical Weather Prediction model with a certain frequency (every 6 hours e.g.) can be seen as sampling of the model state.

- 'The 3-hourly off-line scheme ...' : We deleted this sentence.

- 'The 3-hourly ... differences in the schemes' : By explicitly stating the research questions, and by a better organization of the paper, we state now clearly why and how we study the different diffusion sets.

Section 2 : Methods

- We reorganized this section.

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- 'where K_h is ...' : We gave units to variables when numerical values are given : in figures, tables, and in some formula's.

- The excess coefficient (dimensionless) was reduced to 2 to get a well-controlled entrainment rate and a less aggressive erosion of inversions [*Beljaars and Viterbo*, 1999].

- 'Capping inversion' is the inversion at the top of the ABL [*Stull*, 1988, page 11].

- During theERA-40 project, the ABL height is archived 3-hourly, but we only used 6-hourly values.

- Figure 1 : We have added the physical meaning of the mixing length and the asymptotic mixing length. A reference to the figure where the profiles of the mixing length and asymptotic mixing length are shown, is now put after the explanation of all the different diffusion scheme's.

- 'There is no entrainment formulation ...' : In the description of ABL processes, entrainment describes the mixing of air from the stable atmosphere above the ABL into the turbulent ABL. In the ECMWF model, this is explicitly described by the K_z at the top of the ABL. This should be distinguished from the meaning of entrainment in the context of convection. In the description of convection, updraft and downdraft plumes entrain air from some layer and transport it to other layers where the air is detrained. This kind of entrainment is accounted for in the convection-parameterization.

- '^{222}Rn : We removed the first sentence in the description of the ^{222}Rn emission scenario.

- 'generally accepted' is replaced by 'assumed' : there is a broad consensus

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about the mean emission rate of ^{222}Rn.

- 'natural and anthropogenic changes' : The TM3 model describes the composition of the atmosphere, and is driven by external forcing like the emission of gases and aerosols (fluxes), or the solar insolation. It allows us to study separately the effect of anthropogenic or natural emissions on the composition of the atmosphere.

- We have limited the number of references to the TM3-model to 3.

- Section 2.4 : We postponed the comparison of the K_z-profiles until the result section.

- 'summer winter variations' : The strongest summer-winter variations can be seen in the profiles between 800 and 600 hPa.

- 'One should note that ...' : we removed this sentence.

- 'almost identical' : in the mean profiles of K_z as a function of altitude, the K_z values in the lowest 3 layers were almost identical.

- We have looked at the time evolution at many different locations during January and July 1993. The main differences in K_z have been written down in the text. We have also put short time periods of K_z in three figures.

Section 3 : Results

ABL height

- 'some days' : We used all the data that was available to us.

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- We have moved the description of all the measurements to the method section.

- 'The profiles have a resolution of ...' : The LIDAR measuring in Cabauw can work in 2 modes. In the coarse resolution mode, it can observe ABL heights up to 5 km with a resolution of 400 m. When the LIDAR works in the high-resolution mode, it can detect ABL heights only up to 2 km, but with a vertical resolution of 100 m.

- 'continuous modelled' : We have interpolated the data in time.

- 'a flat correlation curve' : We mean that there was a low correlation.

- 'due to a strong' : We have added a reference to *Bosveld et al.* [1999]. They compared observed heat fluxes in Cabauw with modelled heat fluxes in the ERA-15 data. They found that the surface heat flux during daytime in the ERA-15 data is too large at Cabauw, which can lead to too large ABL height. Because the reason for this bias (too small cloud cover, too small surface albedo) is still present in the model used in the ERA-40 data set, we might expect that also in the ERA-40 data set, sensible heat fluxes (and thus daytime ABL heights) are too large at Cabauw.

- GMT versus LT : We have omitted this remark. In general, the reconstruction of high frequent meteorological fields (like the ABL height) just needs high-frequent sampling.

- We summarized the possible short comings.

- ABL height at Cabauw : We checked the meteorological conditions at De Bilt, a meteorological observation station 30 km north east of Cabauw. It showed that on

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July 16th 1996, the weather was rather fresh and cloudy with relatively strong winds. These stronger winds can explain the higher nocturnal ABL height during the two nights 15-16 and 16-17 July, as modelled. That the ABL height observations do not agree might be related to local conditions in Cabauw.

- On August 8th 1996 in Cabauw, the duration of sunshine was short (less than 3 hours). This lower insolation has led in the model to a rather low ABL height at noon. The observed ABL height is during a relative short period much higher. This might be related to locally less cloudy conditions, leading to stronger insolation and a high ABL height.

- July 8 and 9th 1987 during FIFE : On these two days the wind was stronger and the incoming short wave radiation was weaker than on June, 30th, July 1st, 2nd, 5th, 6th and 7th. This results in less heating of the surface and lower sensible and latent heat fluxes.

- Difference between E6 and H3 : We observed in general that the daytime E6 ABL height is larger than the H3 ABL height. The smaller excess temperature coefficient used to calculate the E6 ABL height might be responsible for this.

- By using the extra Sodar measurements from the FIFE campaign in 1987, we have been able to distinguish between more cases.

- We have put the remark in the text that all measurements of ABL heights have been made in summer.

- We have omitted table 2.

- A simple sine wave for the ABL height is proposed for the ABL height at the

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FIFE site. Therefore we combined all the measurements (day, night, lidar, sodar). When we use an artificial sine wave to model the ABL height, we find a correlation with the observations of 0.715. The correlation between the E6 and observed ABL height is 0.717, and the correlation between the H3 and observe ABL height is 0.756. The H3 ABL height performs better than the sine wave, while the E6 height is only slightly better. However, when different seasons have to be modelled, the performance of the sine wave will decrease because of the lack of seasonal variation in the maximum ABL height and in the length of the daytime period.

^{222}Rn

- We moved Section 3.2 to the method section.

- The correlation of the daily mean value represents the synoptic variability. This implies e.g. the ability of the model to adequately distinguish continental air (containing high ^{222}Rn concentrations) from marine air (containing much less ^{222}Rn). The 'deviation from the mean value' is renamed as 'residue'. It is an hourly value representing the difference between the hourly value and the daily mean value of that day. It illuminates more the variation of the ^{222}Rn concentration during one day due to local mixing processes. The good correlation between the hourly values is caused to a large extent by the good representation of large-scale synoptic systems in the model.

- It is true that averaging dampens the variability. However it still shows the characteristic effects of different K_z data on the daily cycle of ^{222}Rn.

- 'some deviation' : This would suggest that during daytime in the models the lowest layers are vented too much.

- The model and measurements are sampled on the same time and day.

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- Figure 8 : One can observe the times when the meteorological fields are update best in the daily JJA-cycle in Freiburg. E.g., the L6 K_z has 4 updates per day : around 3h00, 9h00, 15h00, 21h00. At 9h00, the low K_z value is replace by a high K_z value, leading to a fast decrease of the ^{222}Rn concentration in the lowest layer. E.g., the E6 K_z has also 4 updates per day : around 0h00, 6h00, 12h00, 18h00.

- 'high frequency variability' in Figure 8 : The term 'high frequency' is used for variation on a time scale shorter than a day.

- 'influence of ABL turbulence in JJA' : In JJA the ABL height is in general higher than in winter (except for the case of extreme winds). The will allows signals from the surface (like ^{222}Rn concentrations) to penetrate higher in the troposphere.

- amplitude : Maxima in Schauinsland are underestimated because the maxima are caused by fluctuations in the concentrations on time scales smaller than 3 hours (e.g. thermals bringing surface air to higher altitudes). Minima at Schauinsland can be over-estimated because large horzontal gradients cannot adequately be represented due to the coarse horizontal resolution.

- The correlation are r-values. We added the sample sizes.

- time shift : A simple remedy is not easy to suggest. In the morning, the K_z should be shifted forward in time, in the evening they should be shifted backward. High frequency sampling is the best remedy.

- ratio : The station of Freiburg and Schauinsland are close to each other (12 km). The ratio of the ^{222}Rn concentration in Freiburg (300 m above sea level) and Schauinsland(1200 m above sea level) is assumed to be less sensitive to errors in the ^{222}Rn

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emission and to influence of large-scale transport (synoptic variability), and might therefore give a good indication of the vertical mixing.

- 'We would certainly advise ...' : We deleted this sentence.

- 'a large drop' : This indeed means that the ratio should go to one.

- 'climatological sense' : These ^{222}Rn measurements are made between 1959 and 1963. There are almost no meteorological data sets available for this period to drive CTMs, which prohibits a direct comparison between modelled and these observed ^{222}Rn concentrations.

- 'seems to be' is replaced by 'is'.

- an observed morning peak concentration : We mean the very high ^{222}Rn concentration in the morning in the observational data. We skipped the term 'peak'.

- 'seems to fail' replaced by 'fails'

- Measurements are only available as monthly mean daily cycles.

- 'The effect of diffusion is such that ... ' is replaced by 'Diffusion leads to ...'

- 'effect or influence' : we choose 'influence'

- 'If the diffusive transport changes' : The TM3 model does not calculate its own physics : the air mass fluxes due to convection and advection are fixed. All the transport processes induce mixing on shorter (vertical diffusion, convection) or longer

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(synoptic scale) time scales. Switching off one of the transport processes results in larger concentration gradients, which then increases the effectiveness of the remaining transport processes.

Conclusions

- We did not include a counter-gradient term because it was not present in the ECMWF-model that generated the ERA-40 data.

References

- accents on letter eś : the online version of the text gives problems with the é, è, while the off-line processing of the text in our institute gives no problems with these accents. We will try to solve it.

Tables

- Table 2 : We have skipped this table.

- Table 3 : We added standard deviation.

- Table 5 : We added the sample size N for all these sets.

- Table 6 : For the period November 1958 until 1963, we did not perform E3-simulations. This is mentioned in the experimental setup. We added the standard deviation.

- Table 7 : We added the standard deviation.

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Figures

- We now use colours in the Figures.

- Figure 1 : We added the interpretation of the mixing length in the text.

- Figure 4 and 5 : We kept the size of these figures.

- Figure 8 : We did not contract the y-axis, because the standard deviation is now added.

- Figure 9 : We corrected the panel numbering.

- 407 or 409 meter : In TM3 hybrid σ-pressure levels are used. This implies that the pressure and height of the model level boundaries depend on the surface pressure. Changes in the surface pressure will give changes in the pressure of some model level boundaries. The height of the model level boundaries is moreover also sensitive to variations in temperature.

- Figure 12 : We included a 1-on-1 line.

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