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Interactive comment on "The impact of a forest parametrization on coupled WRF-CFD simulations during the passage of a cold front over the WINSENT test-site" *by* Daniel Leukauf et al.

Anonymous Referee #3

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General comment

This paper describes the impact of a forest parameterization on coupled WRF-CFD simulations over complex terrain for a cold front case study. Simulation results are compared to met-mast observations and UAV measurements. The test of a forest parameterization in WRF is interesting and relevant for the model community. The results are, however, described very qualitatively and the main findings should be communicated more exactly. Too often flow situations are described, which are not relevant for the main results of the paper and make the paper difficult to read. It should be focused on important results and it should be quantified what the benefit of coupling WRF with

the CFD model is. Is it really necessary to run a CFD with 5 m horizontal resolution and how much better is it compared to WRF? WRF results with a spatial resolution of 90 m are mentioned, but not shown. They should be included in the manuscript and compared to observations and CFD simulations. Further, I think that the UAV observations should be included/used in a better way to quantify the model errors. In the manuscript they are only used to describe the situation qualitatively. I suggest major revision for the submitted manuscript.

Major comments

1. You are running WRF with a horizontal resolution of 12.120 km in the outer domain, which is coarser than the ECMWF data (mesh size of 9km) that is used as initial and boundary conditions. Why did you use this coarse resolution in the outer domain? This means that the flow is upscaled when interpolating from the 9 km ECMWF grid to the coarser WRF grid? Meteorological fields and synoptic events like cold fronts are strongly smoothed, which also influences the results of the inner WRF domains. Typically, mesoscale simulations are started with the same or higher grid resolutions than the driving model. I suggest that you rerun the WRF simulation by starting with domain 2 as outer domain. This should improve your results. Can you also add more information to the model setup section 2.1 about the date and time period, which is simulated: how many days were simulated, what was the time step and output interval, why was this event chosen? Why is the passage of the cold front important? What tree height did you use in the forest parameterization and where did you get the tree height from? What was the real tree height at the test site?

2. The comparison of model results with UAV measurements has to be improved. You only use data from the met-mast to quantify the model error, whereas data from UAV flights are just used for qualitative comparisons. Model data should be interpolated in space and time to the measurement points of the UAV flights and should then be compared directly to observations. I suggest to plot correlation scatter plots (observation versus simulation) to get an impression if wind speeds are over- or underestimated.

Biases, mean errors and correlation coefficients should be computed for the met-mast (already done for WRF and WRF-F) and UAV observations for all simulations: WRF, WRF-F, OF(WRF), OF(WRF-F), OF-F(WRF), OF-F(WRF-F). The description of the results is generally were qualitatively done and the effect of the forest and the coupling of WRF with CFD has to be quantified. Is it necessary to run a CFD with 5 m horizontal resolution? The UAV also measured TKE: please compare it to simulated TKE of all simulations.

3. You mention the WRF run with 90 m horizontal resolution, but don't show the results. These simulations should be included in the paper and compared to OF simulations. All simulations have to be compared quantitatively to both met-mast and UAV observations.

4. Some figures should be left out: Figs. 7 and 11 don't add additional value to the manuscript and corresponding passages in the text are difficult to read and understand, as they only describe meteorological situations in a qualitative way and try to explain how the flow situation was in some valleys (e.g. Simonsbach valley), whose location is not clear/described. As observations were only available at the WINSENT test site the description of the flow should focus on that location. It's also not necessary to show 3 hours of streamline plots in Fig. 4, as streamlines in two different levels are confusing. Please only show streamlines on the lower level for one hour (e.g. 14 UTC). The streamline plots in Fig. 12 can be left out as it is nearly impossible to detect differences between OF and OF-F. Correlation plots should be included for all model runs instead, which make clear how much wind speeds are over- or underestimated. These numbers have to be summarized in a respective table.

Minor comments

1. P2L41: Please add: . . . and the CFD model in the order of tens of meters...

2. P2L47: Can you add an overview of the paper like: "The paper is organized as follows: section 2 describes the used methods..."

3. P3L55: Can you please add the mesh sizes of all model domains. D1 has 12150m, D4 450m and D5 150m resolution. What about D2 and D3? Probably 4050m and 1350m as you use a factor of 3? Please add this to the text.

4. P3L55: Why do you use such a coarse horizontal resolution of 12.125 km for domain D1? You are initializing WRF with ECMWF, which has a horizontal resolution of 9 km. This means that you strongly smooth ECMWF data in space before they are used in WRF.

5. P3L59: What is the vertical level distance of the coarser domains? I guess dz=15m at 10m above ground level is valid for the LES domains?

6. P3L63: I think this is wrong: "subgrid-scale turbulence is parameterized using the revised MM5 surface layer scheme." Subgrid-scale turbulence is parameterized by the Deardorff TKE scheme. The MM5 surface scheme parameterizes the exchange processes at the surface. Please correct this in the text.

7. P3L68: What time step do you use? Do you use adaptive time stepping? In Fig. 4 and 5 you say 10 minute averages are shown. Are these really averages or snapshots? What's the time interval used for averaging over 10 minutes? Every time step?

8. P3L70: Please add an article: ..."the ASTER topography data set..."

9. P4L74: Please change to: "... were initialized at ..."

10. P4L74: Please change the time format: "...21 September 2018, 00:00 UTC"

11. P4L74: Please change to: "... considered as model spin-up..."

12. P4L81: I think the formulas for LAD are taken from Lalic and Mihailovic (2004). Please cite this paper, when you describe the formulas

13. P4L82: Where do you have the formula for Lm=LAI(0587h-0.124) and hm=0.6m from? Please cite the corresponding paper. I guess it should be 0.587h in the brackets?

14. L4P84: I don't understand the sentence: "... are classified as forest and lie below the maximum tree height". What does this mean? Which tree heights do you use? What is the real tree height in your modelling domain?

15. L4P85: Change "lowest 2-3 data points" to "lowest 2-3 model levels"

16. P5L88: Add a reference to the dashed white box in Fig. 1b): "... along the borders of a 10x10x2.5km large box (see dashed white box in Fig. 1b)."

17. P5L89: Can you add the dates and time intervals that will be simulated with WRF and the CFD model? The simulation started at 21 September 2018 at 00:00 UTC. When did it finish? What was the output interval? When was the CFD model started/finished?

18. P5L93: Please add the acronym URANS: "An unsteady Reynolds Averaged Navier-Stokes (URANS) approach..."

19. P5L103: I think it should be: "Vegetation is discretized into finite..."

20. P5L108: Can you explain what a PIMPLE algorithm is?

21. P5L112: In line 88 on page 5 you say that the domain size of the CFD model is 10x10x2.5km? Which altitude is correct (here you say it's 2km)?

22. P5L114: What does "finer near the ground" mean? Can you add the vertical mesh size near the ground?

23. P5L115: Does "conforming to the site orography" mean a terrain following vertical coordinate?

24. P6L118: Which roughness length did you use for forested areas when no forest parameterization was used?

25. P6L131: Typo: "an inertial navigation..."

26. P6L130: When did the UAS measurements take place (at which time)?

27. P6L140: Please change the date format.

28. P7L47: Typo: "is characterized"

29. P7L158: Can you add a reference for the used boundary layer height definition?

30. P8L171: Change the synax: "At 12 UTC the average wind speed...". What does "over forest mean? Why don't you compare wind speeds at the location of the met-mast?

31. P8L175: I don't understand this sentence: "Thus, the impact of the topography on the flow is stronger due to the strong correlation of the land use categories with the terrain." As I understand land use categories are arbitrary numbers/classes that cannot correlate with terrain. Can you explain this differently?

32. P8L165: Why do you show streamlines in 58.5m and 190m AGL in Fig. 4 (by the way in the caption of Fig. 4 you say it's 187m AGL)? Wouldn't it be better to use 100m, which is the height of the met-mast? Is it necessary to show 3 hours of streamline plots in Fig.4? To me it would be more interesting to show the plot at 14:00 UTC and one after the passage of the front at 17:00 UTC. As the flow is not very different in 190m AGL for the WRF and WRF-F run I suggest to plot streamlines only at one altitude, as it's difficult to distinguish between all these lines.

33. P8L175-L180: It's difficult to understand what you want to explain here, as the location Simonsbach is not shown in Fig.4. Are these explanations relevant? To me this passage can be left out.

34. P10L182: Add: "... a northern wind component..."

35. P10L206: You mention the effect of the forest on the vertical wind component. Can you plot w in Fig. 5 as additional contour plot?

36. P10L210: Improve the syntax in: "The geostrophic wind at 5km height is with values..."

37. P11L221: You say that the increase in wind speed during the frontal passage was not observed. As I can see there is a strong increase in wind speed in Fig.6at about 17 UTC on 21 September (blue curve). Can you please correct this in the text?

38. P14L235-L250: It would make more sense to interpolate both WRF and WRF-F data in space and time to the UAV measurement points and plot them the same way as the observations are shown in Fig. 8. instead of comparing observed snapshots with WRF data averaged over 1.5 hours.

39. P14L245: WRF data have to be interpolated in space and time to the flight tracks of the UAV. These data can then be compared directly with UAV observations. Can you change Fig. 9 and make a scatter correlation plot by plotting observed versus simulated wind speed and wind direction. This would give a better impression if wind speeds are over- or underestimated. What is the bias and correlation between simulations and UAV observations? Please add this information to Table 1.

40. P15L266-P16L271: This discussion including Fig. 11 should be left out as it is just a qualitative comparison. Can you please quantitatively compare WRF, WRF-F, OF-F and OF simulations driven by either WRF or WRF-F to show what is qualitatively the impact of the forest and the different boundary conditions? Please interpolate all the simulations to the flight track of the UAV and compare with these observations.

41. P16L272-P17L283: The streamline plots in Fig. 12 are difficult to interpret and differences are hard to see. The comparison is too qualitatively done and the simulation results should be quantified by computing correlations and biases.

42. P17L279: Where is Simonsbach valley and why is this location important? It's not shown anywhere in the plots.

43. P19L285: Wrong section reference.

44. P19L300: Which resolution? Probably horizontal mesh size? Why don't you show these results?

45. P19L304-L311: You only show qualitative comparisons. Please quantify the model errors for both WRF and OF. What is the benefit of OF?

46. P19L314: "The model indicates...". Which model do you mean? WRF or OF?

47. P19L316: You have to interpolate model data in space and time to the flight track and can then compare simulated with observed values.

48. P20L319: Can you plot measured turbulence of the UAV and compare it to simulated TKE?

49. P20L323: Typo: "even further"

50. P20L329-L330: I don't understand this point. Why does the forest drag prevent upper level winds from disturbing lower level winds?

51. P20L331: Where can I see this? Please confirm your conclusion by quantifying model errors.

52. P20L339: Quantify your conclusions.

53. P20L342: You say that the flight legs should be over the slope. According to Fig. 8 the flight legs were over the slope and I don't understand what you want to explain here.

Figure comments

1. Fig. 1: Caption: Please change "Setup of ..." to "Model domains of the WRF simulations...". The green dot in b) for the met-mast ist hard to see. Can you change the colour maybe and make the dot larger?

2. Fig. 2: Can you add the dot of the met-mast in both figures, please? Can you increase the axes and colorbar labels? Can you add a grid to the right figure showing the OpenFoam landuse? To me it would make more sense to plot the forest distribution in the left Figure instead of the CORINE land cover classes.

3. Fig. 3: Please add the date that is shown (21 September 2018).

4. Fig. 4: Please add the date that is shown (21 September 2018). Can you increase the dot and the flight path of the UAS?

5. Fig. 5: Can you add the date that is shown. What is the "first day“? Can you change the range of wind direction from 0 to 360 degrees, which is the common meteorological range of wind direction. Please include contour lines of potential temperature.

6. Table 1: Please add units for bias, MAE and r.

7. Fig. 7: I think this figure brings no additional value and can be left out.

8. Fig. 8: Please add the date. Why don't you show results for the WRF run? Can you interpolate the WRF and WRF-F data in space and time to the measurement points of the UAV and plot these data the same way as it is done for the UAV? This would make more sense than comparing the UAV observations with 1.5 hour averages of WRF simulations. Can you change the range for wind direction to 0 to 360 degrees and increase the contour interval for both wind speed and wind direction, as the gradients can be better seen, when the contour interval is coarser.

9. Fig. 9: Interpolate WRF data to the flight track and compare profiles directly with observations. I would suggest to make a scatter plot (observation versus simulation) instead/in addition to the profiles.

10. Fig. 10: Caption: the description of used colors is wrong: "... taken directly from WRF (dashed black;+) and WRF-F (dashed red)...“. Please add the date.

11. Fig. 11: This figure should be left out, as it does not show any relevant information. Can you instead make a correlation plot, which shows the benefit of the OF-F simulation compared to WRF simulations and the impact of WRF and WRF-F boundary conditions?

12. Fig. 12: This figure can be left out, as differences between simulations are hard to

see and the model comparison should be done in a more quantitative way.

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