We would like to thank both reviewers for their valuable comments and suggestions our manuscript. Please find our responses and relevant changes (*italic*) to comments (**bold**) below.

Referee #1:

General Comments:

This paper uses WRF regional atmospheric model coupled with the CMB climatic mass balance model to simulate the climatic mass balance of Svalbard glaciers over a ten-year period. The paper provides an extensive but concise evaluation of the simulations through comparison with AWS data, stake data, GPR data and satellite altimetry data and demonstrates that the modelling scheme has good skill (in most regions) in calculating the climatological mass balance. The paper also investigates the impact of WRF horizontal resolution using both the 9 km outer grid, the 3 km inner grid and a special 1 km grid for a one-month test. The paper is clearly written and concise.

Specific Comments:

1. Abstract and elsewhere. I suggest keeping the same units when reporting mass balances. At the moment mm w.e. y-1 and m w.e. y-1 are both used.

Thank you for this comment. We now only use mm w.e. y^{-1}.

2. I would like to see more details on the WRF model set up.

a. More information on how the ERA –Interim is used for lateral BCs. Is there a nudging or relaxation scheme used at the edges of the 9 km domain? If so, how is this applied? What is the time frequency of the ERA Interim dataset.

b. What is the vertical resolution? Is it the same on the 9/3/1 km domains?

We have now included this information in the model description section:

As boundary conditions for this domain we use the ERA-Interim reanalysis (Dee et al., 2011) with a 6-hour temporal resolution. We employ the default boundary configuration in WRF, with the outermost grid-point specified, followed by a four-grid-point relaxation zone.

And:

All three model domains use the same vertical resolution (40 eta layers up to a model top of 25 hPa) and physical parameterizations, with the exception of the cumulus convection scheme that is only employed in the outer (9-km) domain.

3. At the end of section 2.2 the authors point out an issue with some grid cells giving unrealistic sub-surface melting in the climatic mass balance (CMB) model, but do not provide any reasons for this. This is problematic and casts doubt on the integrity of the CMB simulation. I suggest that the authors do some debugging and testing to determine why this error is occurring. (I would not insist that the redo their entire simulation – just that they provide an explanation or the error and demonstrate that it is not impacting their simulation in a significant way.

After further testing and debugging, we found that the unrealistic sub-surface melt was related to small oscillations in the Crank-Nicolson (CN) scheme used to solve the heat equation in the CMB model. This commonly used scheme can result in small (decaying) oscillations (e.g. Østerby 2003). For most applications, the issue is not very problematic. However, for an ice field at melting point, these oscillations were enough to result in sub-surface melt even when there was no external forcing to heat the ice below the surface. Through isolated testing of this scheme in MatLab, we found that the magnitude of these oscillations was sensitive to the number precision. The WRF model normally uses single precision numbers (i.e. an accuracy of 7-8 digits), which contributed to making this problem significant in these simulations.

The main solution to this problem was therefore to introduce double precision numbers in the subsurface module of the CMB code, which removed the unrealistic sub-melt pattern seen in the previous results. By comparing the calculated sub-surface melt with the penetrating solar radiation (QPS), we confirmed that this largely solved the problem. There were, however, still some instances where some overestimation of sub-melt occurred. To further mitigate this problem, we therefore repeated the calculation of the CN solution twice in the timesteps when the issue arose and used the average of the solutions. As the CN oscillations are alternating around the true solution, this approach has been suggested as a method to reduce their impact (Østerby 2003). Each of these two changes reduced the problem with approximately 1-2 order of magnitude, to the point where the sub-melt exceeding the heating from penetrating solar heating (QPS) was reduced to less than 0.01 mm w.e. yr^{-1} on average. This we consider to be insignificant in the context of this study.

Test simulations with these modifications indicated that the main conclusions would not be changed. However, the effect on the total net mass balance (as the difference between large positive and negative terms) was larger than previously thought, and we therefore decided to redo the entire simulation. Before redoing the simulation, we also incorporated a bug fix to WRF code, namely a change to the lateral boundary specification. Originally, the lateral boundary conditions in WRF were calculated based on tendencies rather than the actual numbers, which for long simulations resulted in round-off errors. This could be seen as noise along the boundaries, which propagated into the interior of the domain. This correction also contributes to altering the new results compared with the original simulation, with the mean annual b_n changing from -167 to -257 mm w.e. yr^{-1}. The test simulation without the boundary condition update, covering only the first year, differed only with about 30 mm w.e. yr^{-1}.

4. The authors use a modified version of the CMB model from Molg et al (2008,2009). It would be helpful if they could briefly describe how CMB differs from the land surface schemes that are part of the normal WRF model.

We added to the manuscript:

The land surface schemes in WRF have become more advanced in terms of representing snow processes in recent years, but still only simulate a few snow layers (up to three for NoahMP). They therefore have limitations when it comes to simulating the development of deep multiyear snow packs in the accumulation area of Svalbard glaciers, as well as realistically representing different glacier facies (snow, firn and ice) during the ablation season. We therefore used a modified version of the glacier climatic mass balance (CMB) model of Mölg et al. (2008, 2009) to simulate glacier grid cells.

5. Section 3.1 compares the simulation output with weather station data. Many atmospheric parameters, like temperature, depend strongly on altitude, but the WRF surface elevation and actual (AWS) surface elevations were not reported. Was there any difference between the WRF surface elevation and the actual surface elevation at the AWS locations? Was any adjustment made to account for this difference?

The model grid points were 44 m and 29 m lower than the AWS elevations at Kongsvegen and Etonbreen, respectively. We made no corrections based on this, as these deviations are relatively small. We included these numbers in the text:

Note that the model grid points are 44 m and 29 m lower than the station heights at these two locations, respectively.

6. Page 5787 line 22: change "(Fig. 5b)" to "(Fig. 5c)" (I think this is a typographical error)

This has now been corrected. Thank you for pointing this out.

7. Section 3.4 – comparison with Satellite altimetry. You note that geodetic mass balance does not include glacier dynamics, however in Table 4 you only include mean elevation changes for whole glaciers. Is it possible that glacier dynamics "cancels out" at this scale of analysis (in other words emergence in some areas offsets submergence in others)?

The model does not include the glacier dynamics, whereas the geodetic measurements do. For land-terminating glaciers, the flux divergence terms cancels when integrating over the entire glacier area, but this is not the case for tidewater glaciers where the mass-flux over the glacier boundaries causes a gap between the area-averaged CMB and the geodetically observed volume change. Many, and especially the largest glaciers on Svalbard, are tidewater glaciers (see Nuth et al., 2012). This is why the text focuses on the overall agreement between the sign and magnitude of the surface height changes in the different regions, rather than the exact values. However, we now include also an estimate of the mass flux from calving for comparison:
The mass loss from calving flux has been estimated to be 6.75 km3 yr-1 (w.e.) for the years 2000-2006 (Blaszczyk et al., 2009), which corresponds to an additional lowering of about 0.2 m yr-1. This suggests that the model in general simulates too much surface lowering in this period. However the time periods are different and the estimate of Moholdt et al. (2010) does not include the effect of retreat or advance of the calving front. One must therefore still be cautious when comparing these numbers.

8. Figure 7 should include a scale indicating the correspondence between colours and topography.
This is now included.

9. Blowing snow is not accounted for. How important is this likely to be? Only at Hansbreen?
There are few studies that quantify the effect of this on Svalbard, and they only cover limited regions. Jaedicke (2002) estimated that only 0.2 % of the annual precipitation in a valley on the west coast of Spitsbergen was lost to sea due to wind redistribution, even though the wind was blowing out of the valley 80% of the time. However, a model study of Vestfonna ice cap indicated that ~ 10-20% of the accumulated snow at the highest elevations was lost to other regions of the ice cap due to wind (Sauter et al. 2013). We focus on this effect mainly on Hansbreen, where it is known to be an important process, but mention it now also for the other glaciers:
However, resolution alone does not explain the large b_w bias at Hansbreen. Instead it is likely that processes like wind drift and snow redistribution are important for the accumulation pattern on this glacier. <u>These processes likely also affect the accumulation at the other glaciers, however their influence is largely unconstrained.</u>

10. In Figure 8, comparing October precipitation at the three model resolutions, are observational data available for comparison too? If so, it would be interesting to include that as a fourth profile line.
Unfortunately, we do not have precipitation estimates from these glaciers on sub-seasonal time scales.

11. In Figure 10 – define all the terms in the energy balance and mass fluxes.
This is now included in the figure caption.

References:

Jaedicke, C.: Snow drift losses from an Arctic catchment on Spitsbergen: an additional process in the water balance, Cold regions science and technology, 34, 1-10, 2002.

Sauter, T., Moller, M., Finkelnburg, R., Grabiec, M., Scherer, D., and Schneider, C.: Snowdrift modelling for the Vestfonna ice cap, north-eastern Svalbard, Cryosphere, 7, 1287-1301, 2013.

Østerby, O.: Five ways of reducing the Crank–Nicolson oscillations, BIT Numerical Mathematics, 43, 811-822, 2003.