Review comments in black.

Responses in green.

The paper describes the Earth-system model CanESM5, which has performed simulations in support of CMIP6. The paper itself is very well written with very few grammatical or typographical errors. I was particularly impressed with the detailed discussion of how the model is managed with regard to the structure of the various git repositories. The improvements to model throughput are also impressive, going from 4.5 to 16 simulated years per day from the various changes described. The model itself represents some quantities well and others not so well, as might be expected in any ESM. Given the model has a relatively coarse resolution and does not represent all processes the behaviour is not unreasonable.

We thank the reviewer for their constructive comments.

Major Comments

In the Introduction the authors briefly discuss CanESM5 within the modelling system of CCCma, which includes CanRCM, CMAM, and CanSIPS. It might be helpful to describe how these are connected - are they all entirely separate, or do they share components/models?

To clarify the connection we have updated the sentence to read “CanESM, forms the basis of the CCCma modelling system, and shares components with the Canadian Regional Climate Model (CanRCM) for finer scale modelling of the atmosphere (Scinocca et al., 2016), the Canadian Middle Atmosphere Model (CMAM) with atmospheric chemistry (Scinocca et al., 2008), and the Canadian Seasonal to Interseasonal Prediction System which is used for seasonal prediction and decadal forecasts (CanSIPS, Merryfield et al., 2013).”

Figure 1 - I find this figure a little frustrating. While it is clear in naming the different component models that make up CanESM5, it does not describe how they are connected or each model’s complexity. A reader must consult Appendix A, which is somewhat technical and is still not complete for all linkages as this only discusses what goes through the coupler. As it is this figure doesn’t really show the “evolution of components” as it does not describe how complex each component model is in either CanESM2 or CanESM5, although it does show the changes to model version numbers or the change of model used.

We agree this figure was not adding much value, and have removed it in the revision. We have expanded the description of the model in Sections 2.1 and 2.6, providing the reader with more clarity on the complexity of each model component.

What I felt was missing in section 2 was a description of just how complex the atmosphere model CanAM5 is. The description is very brief and readers are directed to Cole et al. (2019), which although will also be in the same special issue as this paper, is currently still in preparation. Also, this paper describing CanESM5 should stand enough on its own such that important details regarding component models should be presented here. I suggest that the authors expand section 2.1 enough to briefly cover the complexity of the atmosphere model and what processes (or not) are represented. There is also no mention of atmospheric chemistry or the complexity of the aerosol scheme.

We have expanded section 2.1 to provide a more complete overview of the complexity of CanAM, including the treatment of aerosols and atmospheric chemistry. We have also added a new section (2.6) to describe the treatment of greenhouse gasses across the ESM components.

Added to Section 2.1.:

"Version 5 of the Canadian Atmospheric Model (CanAM5) employs a spectral dynamical core with a hybrid sigma-pressure coordinate in the vertical. The package of physical parameterizations used by CanAM5 are based on an updated version of its predecessor, CanAM4 (von Salzen et al., 2013). The physics package includes a prognostic cloud microphysics scheme governing water vapour, cloud liquid water, and cloud ice; a statistical layer-cloud scheme; and independent cloud-base mass-flux schemes for both deep and shallow convection. Aerosols are parameterized using a prognostic scheme for bulk concentrations of natural and anthropogenic aerosols, including sulfate, black and organic carbon, sea salt, and mineral dust; parameterizations for emissions, transport, gas-phase and aqueous-phase chemistry, and dry and wet deposition account for interactions with simulated meteorology. CanAM5 employs a triangular truncation at total wavenumber 63 (T63) corresponding to an approximate isotropic resolution of 2.8 degrees in both latitude and longitude. In the vertical, 49 levels are employed with layer thicknesses that increase monotonically from approximately 100 m at the surface to 2km at ~1hPa – the domain lid."

“2.6 Treatment of greenhouse gases

CanESM5 represents radiative forcing from individual greenhouse gases (GHGs). Aside from CO_2, the concentrations of all radiatively active gases are specified and transiently evolve. Of these, CH_4, N_2O, and families of CFCs are assumed to be well-mixed, while, O_3 is specified as varying spatially – typically employing that prescribed for CMIP6 (Checa-Garcia et al. 2018). CanAM5 offers two modes for modelling CO_2 concentrations - as specified time-evolving concentrations; or as a three-dimensional passive tracer driven by land/ocean surface emissions, prognostically derived through interactive coupling with biogeochemical carbon models in the land and ocean. For example, CanESM5 can be run with prognostic CO_2 in concert with specified anthropogenic fossil fuel emissions to simulate atmospheric CO_2 concentration through the historical and future periods. Wetland methane emissions simulated by CLASS-CTEM, in contrast, are purely diagnostic. While these emissions respond to changes in climate and atmospheric CO_2 concentration (through changes in vegetation productivity), they do not modify atmospheric CH_4 concentration, which are specified.”

The authors should ensure that each component model is described in sufficient detail to understand what processes it can simulate and how these models interact together in the ESM. As this is an Earth-system model, I am interested in seeing just how the component models interact. The tables in Appendix A only cover what goes through the coupler, so methane emissions that are discussed on lines 125-130 aren’t mentioned for instance - are there any others? Here what do the methane emissions do, is there a simple methane oxidation scheme, does it produce water vapour etc.?

We have expanded the description of CanAM (Section 2.1), and we now believe that each component is described in sufficient detail to understand its complexity. We have added a new section to the manuscript titled “2.6 Treatment of greenhouse gases” to specifically address the question of treatment of methane (and other GHGs).

At line 422 the authors mention “five realisations of CanESM2”, and then later discuss a 50 member large ensemble of CanESM2. Is it just that only 5 members were submitted to CMIP5? These are first mentioned on line 844. Is there a reference or more detail that can be provided?

Yes this is correct. Five realizations of CanESM2 were submitted to CMIP5. Later, the 50 member larger ensemble was created by branching those five realizations into ten each in the year 1950 (by perturbing a random seed). To clarify this we have added the text below to the start of Section 6.2, in which the CanESM2 large ensemble data are used:

“Here we make use of the CanESM2 50-member large initial condition ensemble (Kirchmeier-Young et al., 2017; Swart et al., 2018). The 50 realizations in this ensemble

were branched in the year 1950 from the five CanESM2 realizations submitted to CMIP5, and were forced by CMIP5 historical (1950 to 2005) and Representative Concentration Pathway (RCP) 8.5 (2006 to 2100) forcing. ”

Minor Comments

Out of interest, why does the numbering system go from CanESM2 to CanESM5?

To clarify this we have added the text to Section 1:

“The leap from version 2 to version 5 was a one-off correction made to reconcile our internal model version labelling with the version label released to the public.”

line 33 - I believe that “earth” should be capitalised in this context.

Changed.

line 149 - I’m not sure why “converted into ice” is in quotes here. Is there a reason for this?

The quotes have been deleted. They were used as ice mass is not explicitly tracked, as described, and hence the conversion into ice is implicit.

Section 2.3 - the way numbers and units are represented here are slightly different from other sections. The × symbol is rather large (compare to line 236), and units are given as m2/s rather than m2s−1 as is done elsewhere in the manuscript.

Changed.

line 280 - why are “bilinear” and “conservative” in quotes? I don’t think this is necessary here.

Changed.

Section 5.4 - two different ways of doing a ±symbol are used (lines 621 and 642).Given the differences in Section 2.3 (mention above) I suggest that the authors double-check how numbers and symbols are presented for consistency.

Changed.

Table B1 (versioning) - should this be “CanESM.vX.Y.Z”?

Changed.