Snow modelling in EC-EARTH

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1. Introduction

A new snow scheme for the ECMWF land surface model HTESSEL (Balsamo et al. 2009) has been tested and validated. The snow scheme revision includes four main processes: **I)** representation of liquid water content as a diagnostic, following a similar approach applied to soil phase changes by Viterbo et al. (1999); **II)** new snow density parameterization following Anderson (1976) and Boone and Etchevers (2001); **III)**revised snow cover fraction and **IV)**revision of exposed snow albedo and new forest albedo in the present of snow adapted from Moody et al. (2007).

Offline validation (covering a wide range of spatial and temporal scales) considered site simulations for several observation locations for the Snowmip2 project (Rutter et al. 2009), global simulations driven by the meteorological forcing from GSWP2 (1986-1995) and the ECMWF ERA-Interim reanalysis (1989-2008). Validation of the hydrological cycle was achieved by comparing GSWP2 simulations with basin scale water balance data (Hirschi et al., 2006). ERA-Interim simulations are validated with remote-sensing products: snow cover fraction (NOAA/NESDIS snow cover) and surface albedo (MODIS). A detailed description of the new snow scheme and its offline validation is presented in Dutra et al. (2009).

The new snow scheme was implemented in EC-EARTH v2. Coupled IFS+NEMO and IFS only (forced with ERA40 SSTs and sea ice) simulations were performed to evaluated the impact of the new snow scheme. The IFS ran at T159 horizontal spectral resolution with 62 vertical levels, and NEMO model (version 2) with horizontal resolution of nominally 1 degree and 42 vertical levels. The sea ice model is the LIM2, and the ocean/ice model is coupled to the atmosphere/land model through the OASIS 3 coupler. Coupled simulations ran for 40 years, where the first 20 years are discarded from the analysis due to spin up; Atmospheric only simulations ran for 30 years (1970-2000).

In the following figures, CTR and NEW denote the original and new snow schemes, respectively.

2. Site validation

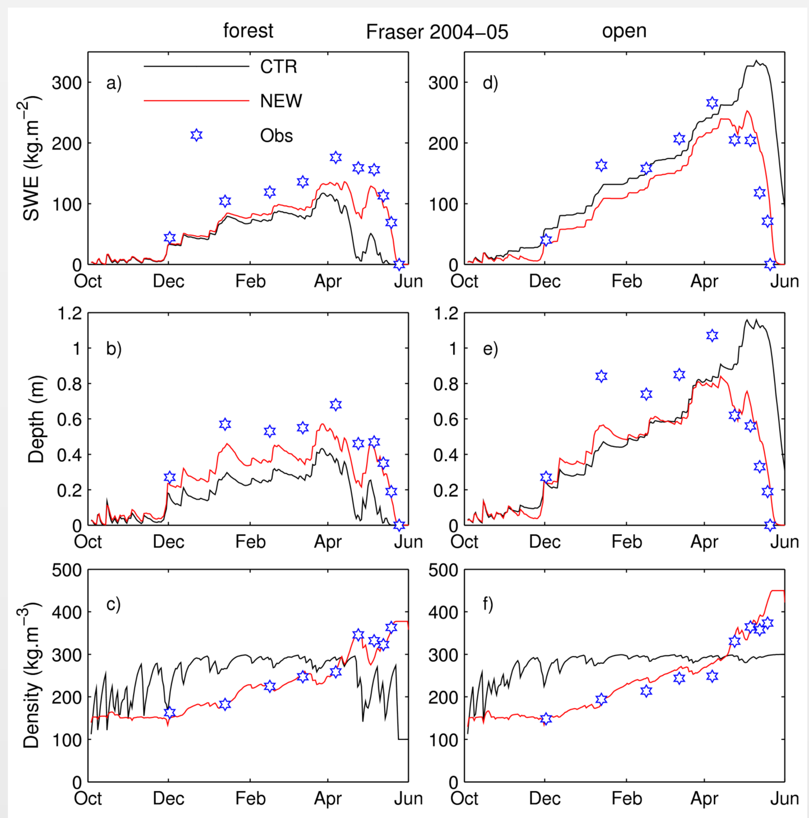

Fig.1 Simulation results for the 2004-05 winter season at Fraser forest and open sites

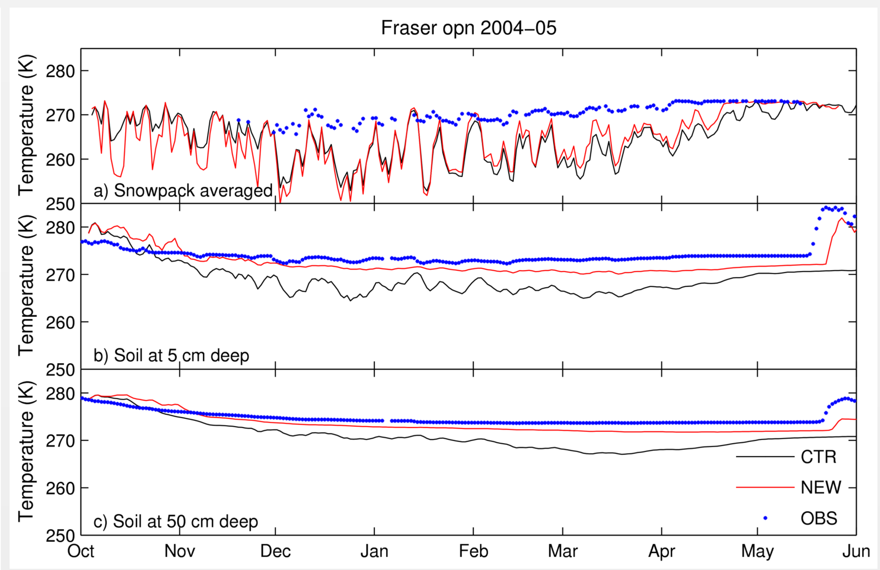

Fig.2 Mode-simulation and observations of snow temperature, and soil temperature at 5 cm and 50 cm depth. Simulations and observations represent daily means

3. Global offline validation

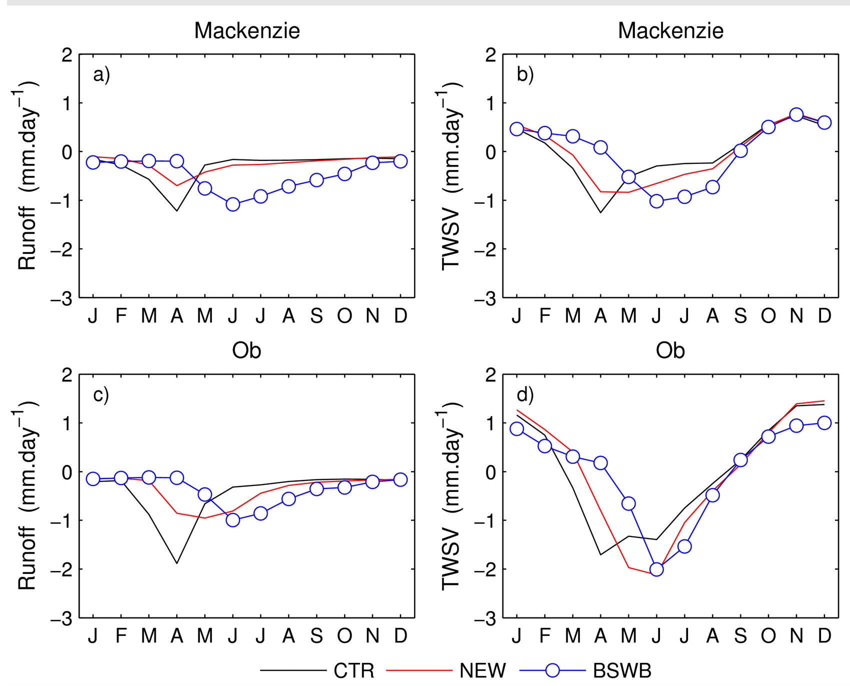

Fig.3 Mean annual cycles of runoff and terrestrial water storage variation (TWSV) in Mackenzie and Ob basins. Offline simulations forced by GSWP-2 (1986-1995) compared with basin scale water balance data (BSWB, Hirschi et al. 2006).

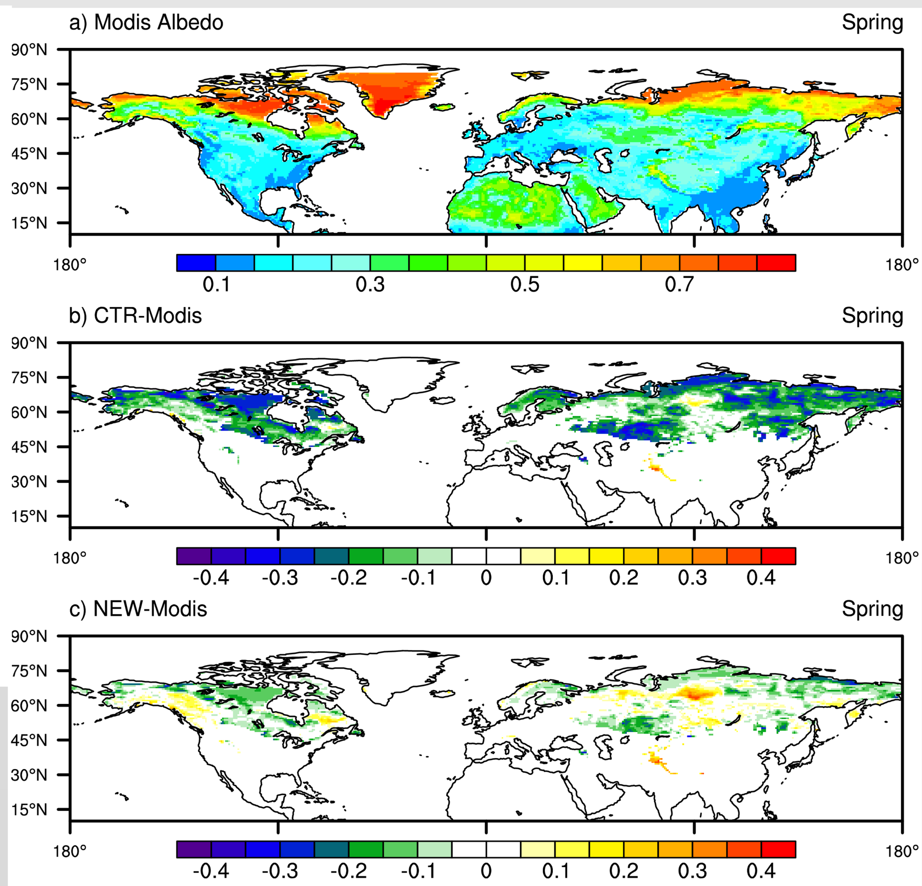

Fig.4 Mean observed maps of MODIS spring albedo for the period 2000-2008 (top) and differences between simulated albedo and MODIS for CTR(middle) and NEW (bottom). Offline simulations forced by ERA-INTERIM (2000-2008). The difference panels show only snow-covered grid-boxes with less than 50% missing MODIS data.

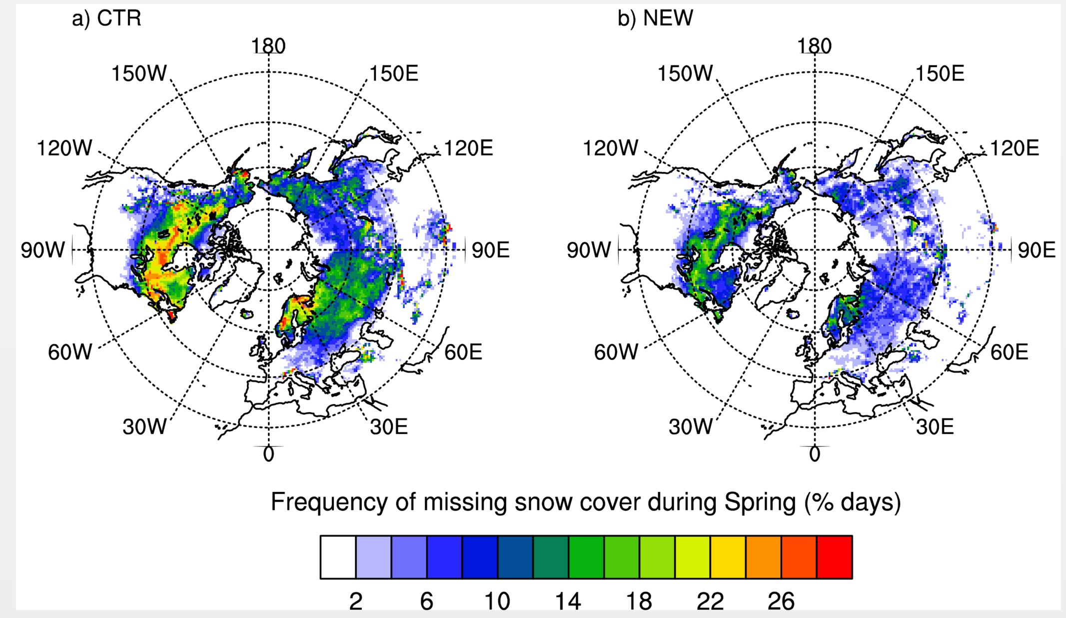

Fig.5 Frequency of occurrence of snow-covered NESDIS data and simulated snow-free during spring for global 2001-2008 simulations forced by ERA-Interim. The number of days in each grid box is normalized by the total number of days of the season.

4. EC-EARTH runs

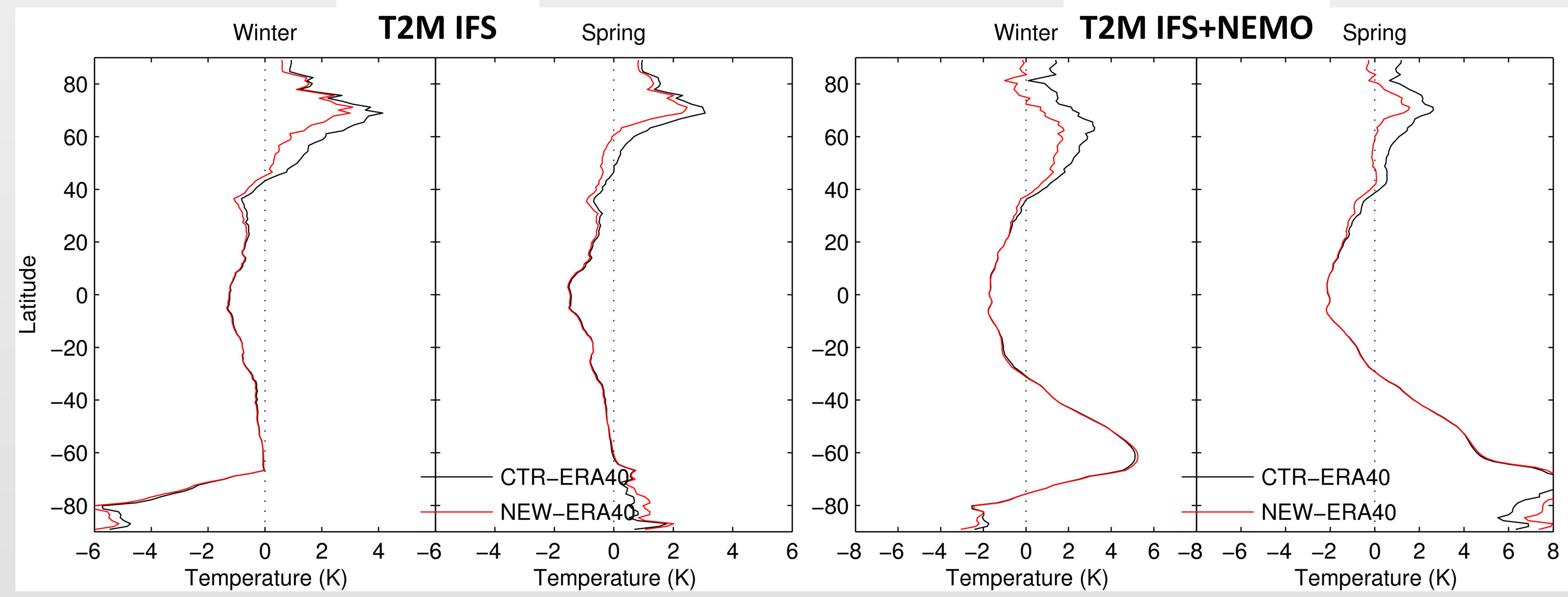

Fig.6 Zonally averaged simulated 2 metre temperature bias for winter and spring (with respect to ERA40). Left: Atmospheric only 30 years runs 1970-2000(IFS+SSTs/sea ice from ERA40). Right: Coupled (IFS+NEMO) 40 years runs (20 year spin-up)

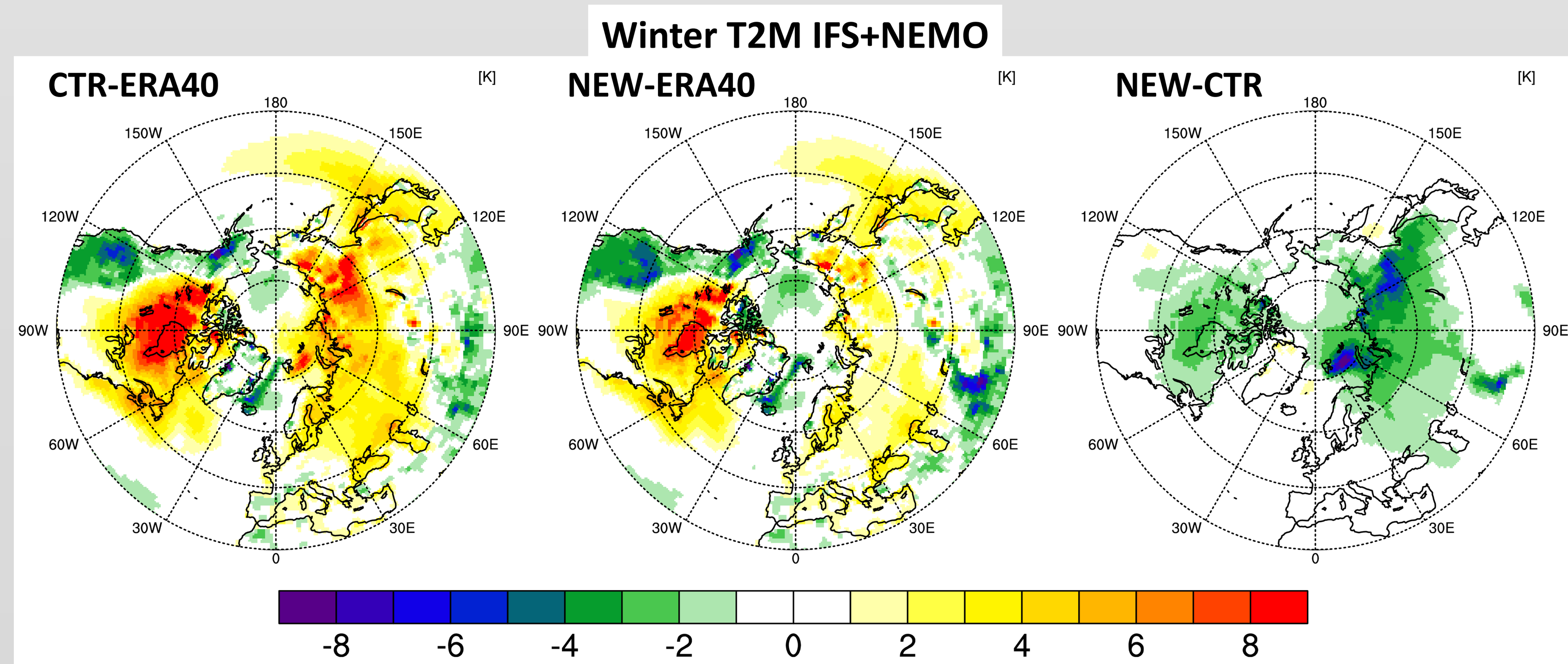

Fig.7 Coupled IFS+NEMO simulated winter 2 metre temperature differences: CTR-ERA40(left), NEW-ERA40(middle), NEW-CTR(right). Coupled 40 years run (20 years spin-up)

5. Summary and Discussion

SnowMIP2 simulations revealed that the original snow scheme had a systematic early and late prediction of the final ablation in forest and open, respectively. The NEW scheme reduces the negative timing bias in forest plots from 15 to 1 day and the positive bias in open plots from 11 to 2 days. The new snow density parameterization in NEW has a good agreement with observations, resulting in an augmented insulation effect of the snowpack. There is a reduction of the basal heat flux, resulting in less cooling of the underlying soil, which is warmer in NEW than in CTR during the cold season. Reduced soil freezing decreased the surface runoff and increased soil water storage. In ten Northern hemisphere basins, there is an average reduction of the monthly runoff RMSE from 0.75 to 0.51 mm day^{-1} when comparing CTR and NEW, respectively. These results highlight the importance of the snow insulation on the hydrological cycle, even at regional scales. On a hemispheric scale, the new snow scheme reduces the negative bias of snow-covered areas, especially during spring. On a daily scale, using NOAA/NESDIS snow cover data, the early ablation in CTR is reduced by a factor of two in some regions over the Northern Hemisphere. The new scheme reduced the albedo bias, resulting in better radiative fluxes at the surface in October to May over snow covered areas, with averaged surface net shortwave radiation bias of 7.1 W m^{-2} in CTR to -1.8 Wm^{-2} in NEW. Coupled EC-EARTH IFS+NEMO and IFS only simulations, showed significant improvements in the near surface temperature fields during winter and spring. In both simulations, there is a reductions of about 50 % of the 2m temperature cold bias, a known problem in the model. The coupled results are coherent with the offline tests, showing the importance of snow insulation in the model climate.

6. References

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