

Impact of assimilating ESA CCI Snow Cover on ECMWF land reanalysis

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1. Introduction

- It is important for reanalysis to ensure temporal consistency for long years.
- However, ERA5 (Hersbach et al., 2020) snow has a step-change in 2004 due to starting to assimilate the NOAA/NESDIS IMS (Helfrich et al., 2007).
- The ESA CCI Snow Cover Fraction (SCF) from AVHRR (Naegeli et al., 2022) can be used from the early 1980's, covering longer years than IMS.
- In order to improve temporal consistency in future reanalyses, the possibility of assimilating ESA CCI SCF from AVHRR has been investigated by offline land reanalysis which is cheaper and faster than coupled system.

2. Validation of snow cover products

- Before reanalysis experiments, snow cover products have been validated against in situ snow depth observations.

SCF product	In situ obs	Snow observed (SD ≥ 1cm)	Not observed (SD < 1cm)
Snow-covered (SCF ≥ 0.1)		a Hit	b False alarm
Snow-free (SCF < 0.1)		c Miss	d Correct no snow

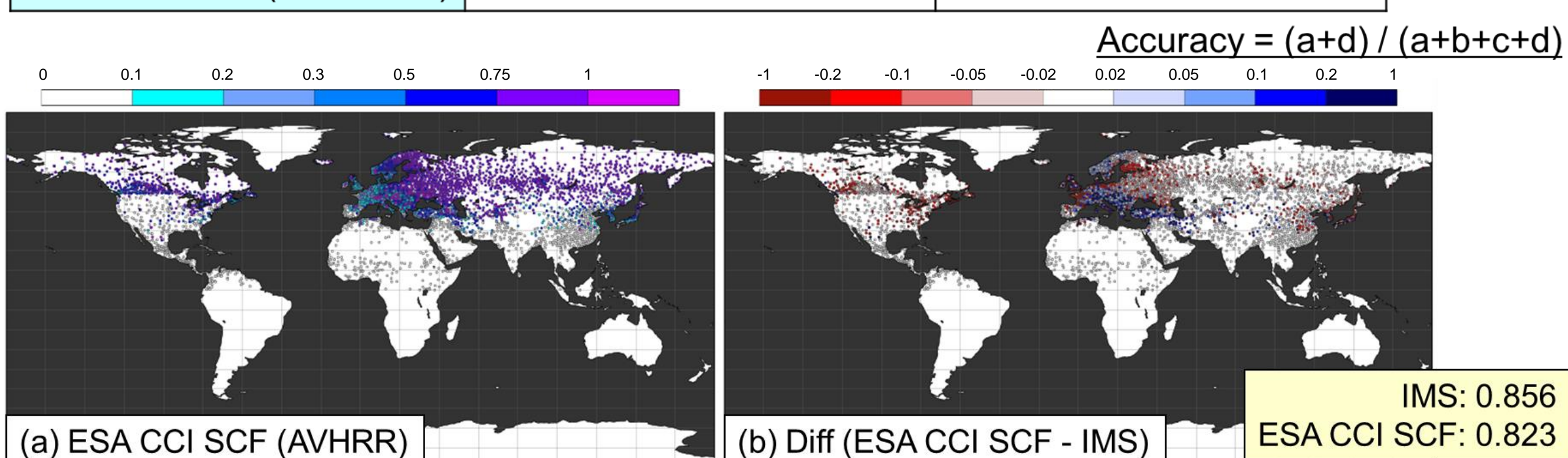


Figure. Accuracy for (a)ESA CCI SCF and (b)the differences to IMS from Sep 2004 to Jun 2018

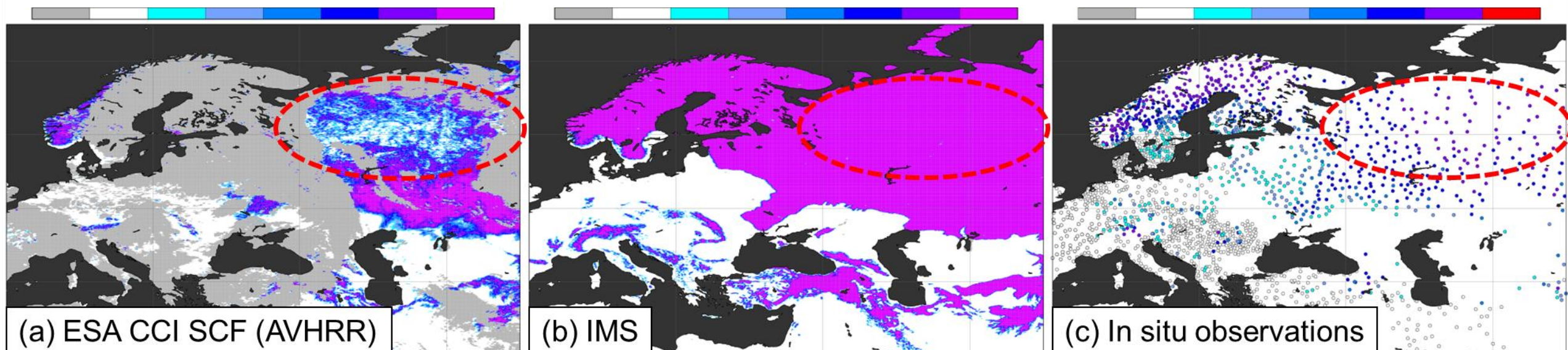


Figure. (a)ESA CCI SCF, (b)IMS and (c)in situ snow depth observations on 12th Feb 2016

- ESA CCI SCF shows good quality in most regions but sometimes worse than IMS in some regions. These results imply that additional quality control is needed not to use such SCF when it is assimilated.

3. Experiment settings

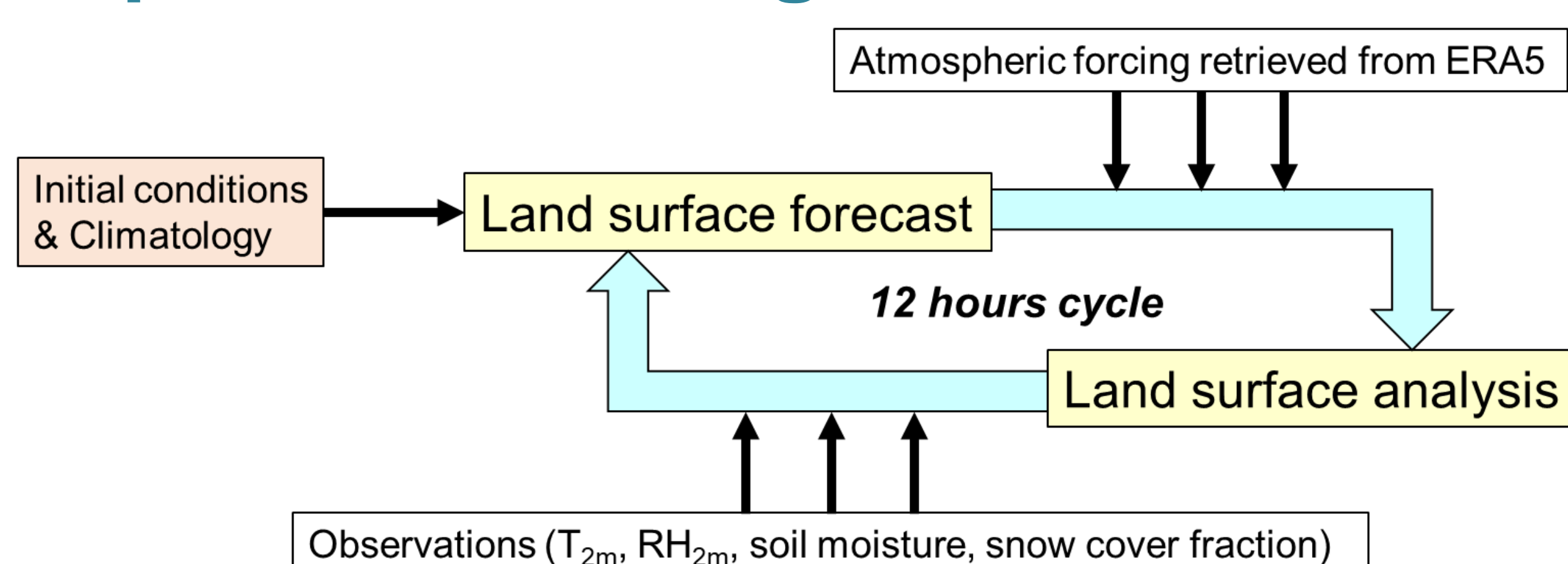


Figure. Diagram of the offline land analysis system

- The offline land analysis system consists of land surface simulations forced by ERA5 like ERA5-Land (Muñoz-Sabater et al., 2021) and soil moisture analysis (Fairbairn et al., 2019). In addition, snow depth analysis has been implemented and SCF products (ESA CCI SCF or IMS) can be assimilated.

- SCF products are assimilated into snow depth by Simplified Extended Kalman Filter (SEKF; de Rosnay et al., 2013) after converted to pseudo snow depth observations.

Model	Snow	Snow-free
SCF product		
Snow ≥0.5(IMS), ≥0.1(CCI)	Not used	Data assimilation 5cm or 1cm
Snow-free <0.5(IMS), <0.1(CCI)	Data assimilation 0cm	Data assimilation 0cm

$$\sigma_b = 3cm, \sigma_o = 4cm$$

- The quality control for snow observations is based on de Rosnay et al.(2015). In addition, ESA CCI SCF is not assimilated if $SCF_{CCI} < 0.1$ and $SCF_{clim} > 0.8$.
- Open-loop (without data assimilation) and offline land analysis experiment are conducted from Sep 1998 to Aug 2020 at a resolution of 31km (TCO319).

4. Results

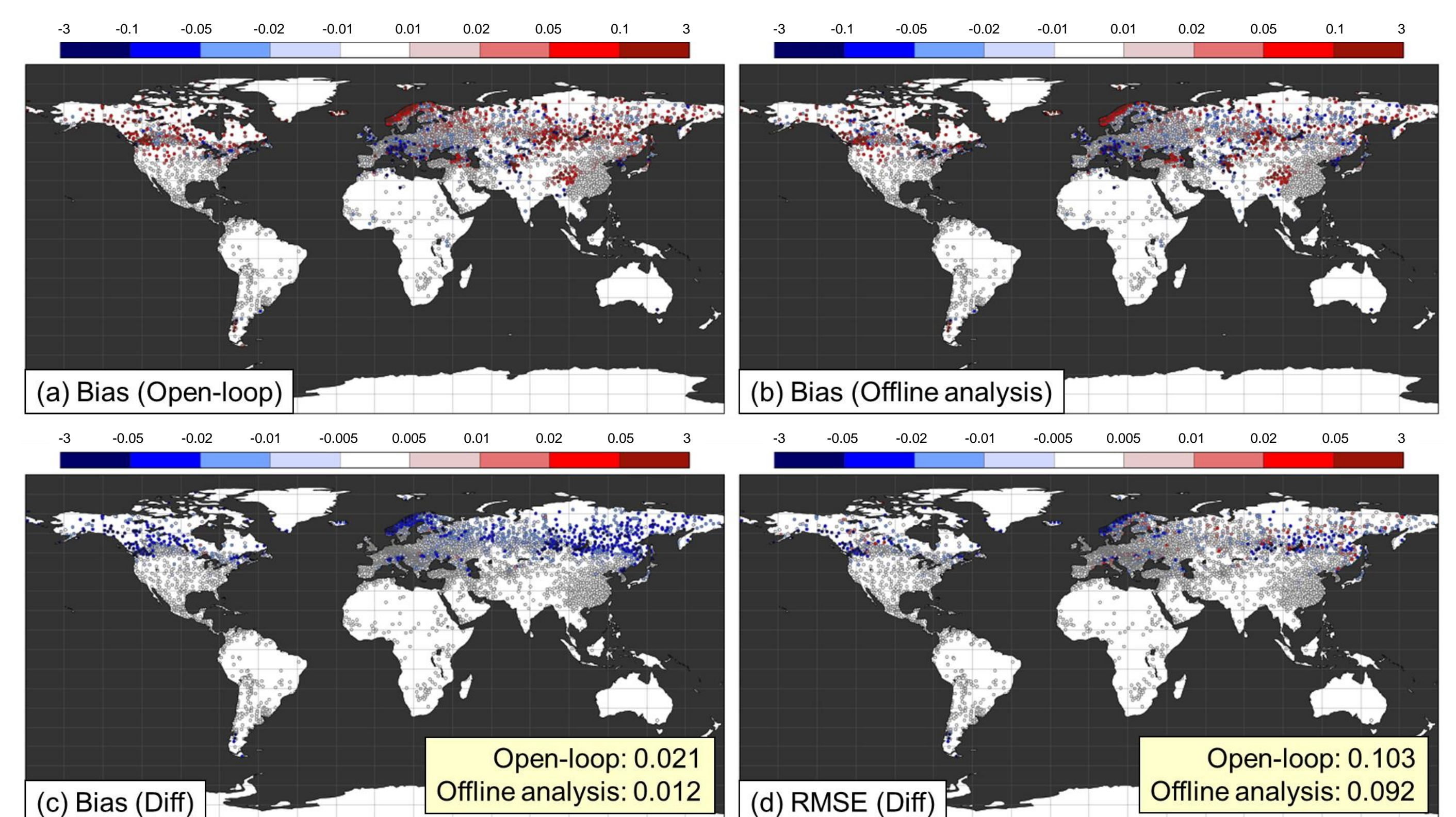


Figure. Bias of snow depth for (a)Open-loop, (b)Offline land analysis, (c)the differences, and (d)RMSE differences of snow depth in November 1998-2019 (unit: m)

- Snow depth is reduced by assimilating ESA CCI SCF (until Aug 2017) and IMS (since Sep 2017). Bias and RMSE are improved in some regions around the edge of snow-covered areas and mountainous areas.

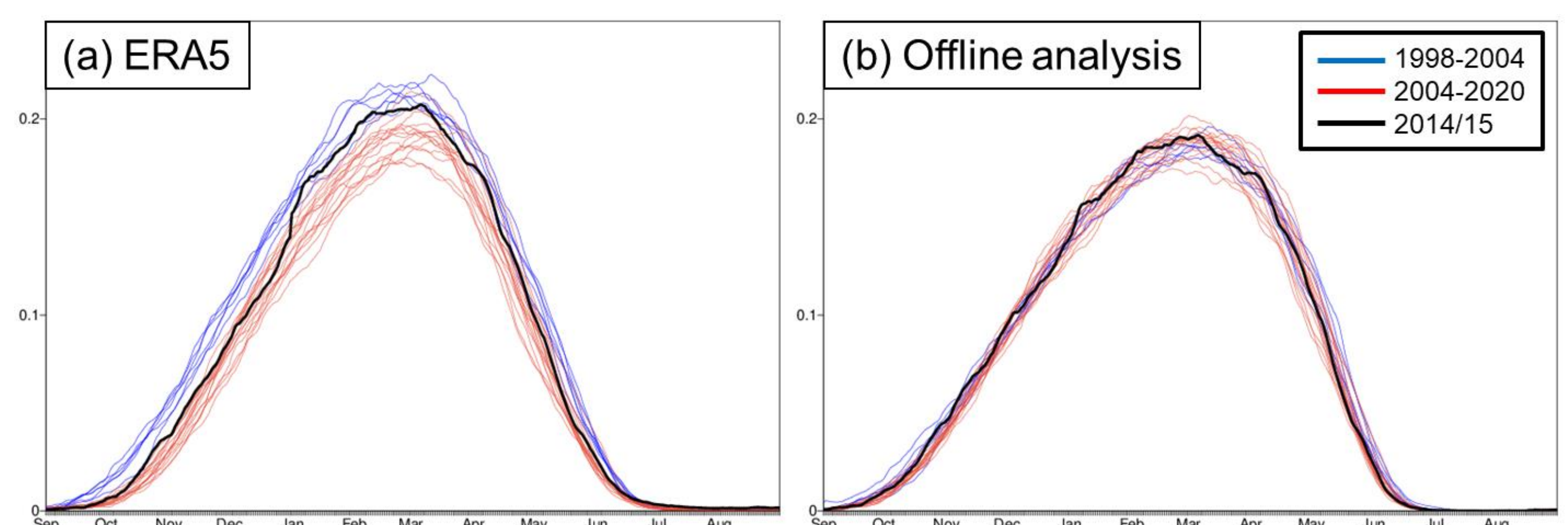


Figure. Time series of snow depth (unit: m) averaged over the Northern Hemisphere (land only, except glacier). (a)ERA5 and (b)offline land analysis.

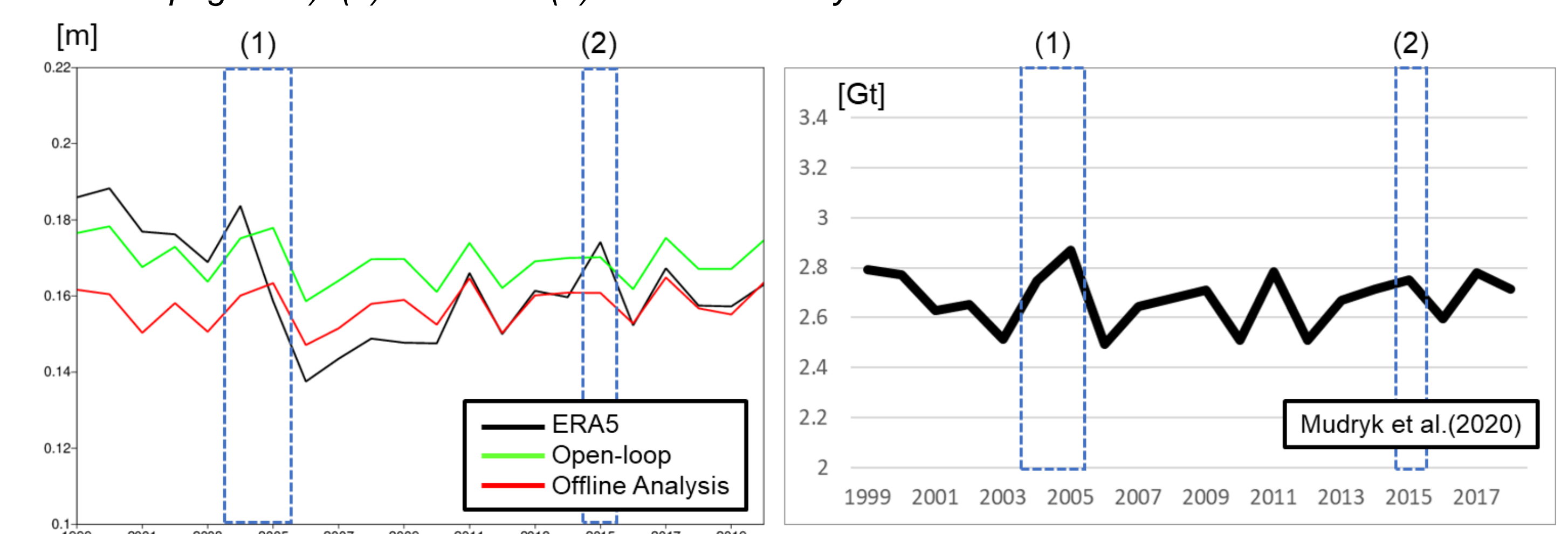


Figure. Time series of (left) snow depth averaged over the NH in January and (right) total snow mass over the NH retrieved from the multi-dataset historical snow water equivalent by Mudryk et al.(2020)

- ERA5 shows inconsistency (1) around 2004 due to IMS assimilation and (2) between 2014 and 2015 due to different streams.
- Offline land analysis is more consistent for longer years and shows similar interannual variability to the multi-dataset SWE by Mudryk et al.(2020).

5. Summary and future works

- The ESA CCI SCF from AVHRR makes it possible to enhance temporal consistency of climate reanalysis for longer years.
- The impact will be further investigated for the entire period after 1982 towards next reanalyses and next seasonal prediction system.

References for data used in this study

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