# Impact of revised snow cover on NWP and plans for ERA6

Kenta Ochi, Patricia de Rosnay, Gabriele Arduini, Gianpaolo Balsamo, David Fairbairn, Ewan Pinnington, Dinand Schepers and many others



ESAS Monthly Update Meeting, 24th November 2023

#### Outline

- Impact of revised snow data assimilation and snow cover parameterization
  - Implemented in the CY49R1
- ESA CCI snow cover assimilation for reanalysis
  - Plans for snow data assimilation in ERA6
- Other work on snow data assimilation in 2 years

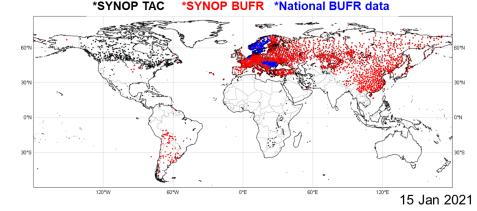
# **Snow data assimilation at ECMWF**

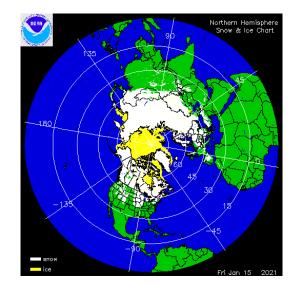
#### Observations:

- Conventional snow depth data: SYNOP and National networks
- Snow cover extent: NOAA NESDIS/IMS daily product (4km)
  - Available daily at 23 UTC, assimilated in the next analysis at 00UTC
- Data assimilation:
  - Optimal Interpolation (OI)
    - Based on horizontal and vertical structure function in Brasnett (1999)
  - The result of the data assimilation is used to initialize NWP

#### • One of current issues:

- IMS is assimilated at the grids lower than 1500m, leading to excess snow depth on high mountains
- Especially on the Tibetan Plateau (Orsolini et al, 2019)



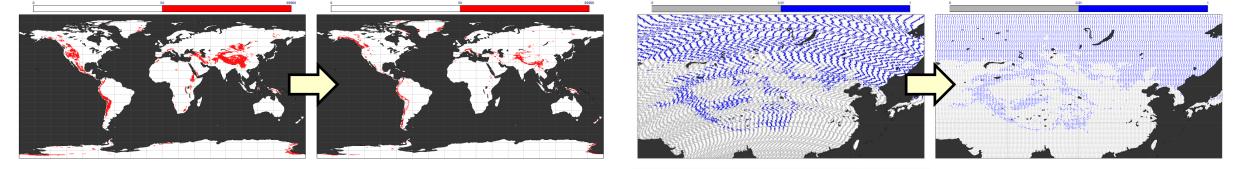


## **Revised snow DA for the CY49R1**

	Current system (CNTL)	Revised snow DA (TEST)
IMS assimilation area	Altitude < 1500m	SDFOR < 250m
IMS thinning	Select 1 from every 36	Select closest 1 to a gaussian grid of 40km
Condition to assimilate SD <sub>IMS</sub>	IMS=1 & SD <sub>model</sub> < 10 <sup>-9</sup> cm	IMS=1 & SD <sub>model</sub> < 1cm
Vertical correlation length	800m	500m
Upper limit for snow depth	1.4m	3.0m

IMS is not assimilated on the red shading

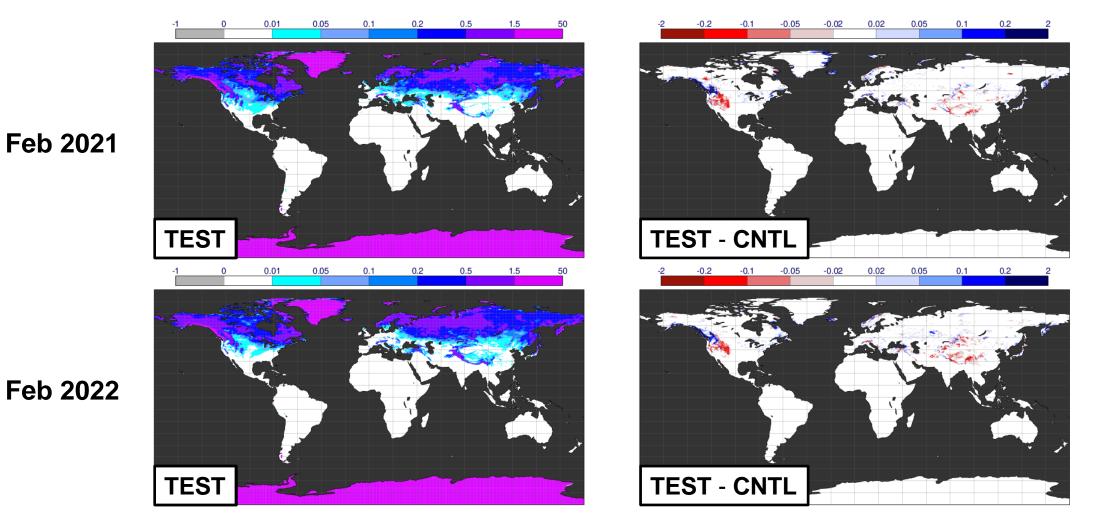
Revised thinning for IMS



In this presentation, I will show results based on the CY48R1.1 for 2 winter seasons



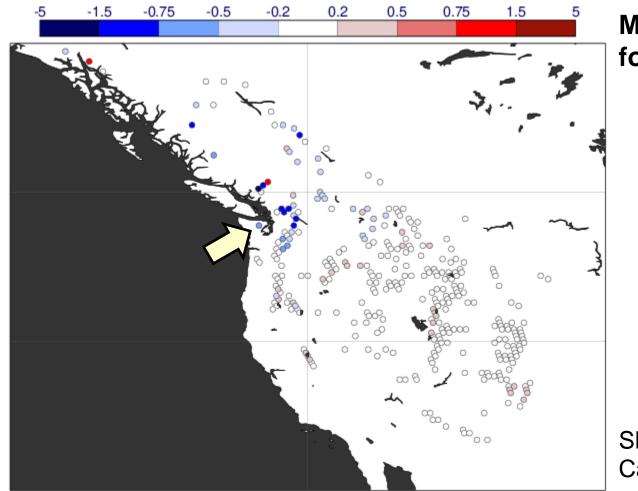
#### Impact of revised snow DA on snow depth



• Snow depth is reduced on mountainous areas by assimilating IMS (except the Northern Rockies)

• Almost similar impact for winter 2020/21 and 2021/22

#### Validation of snow depth against the SNOTEL and CanSWE



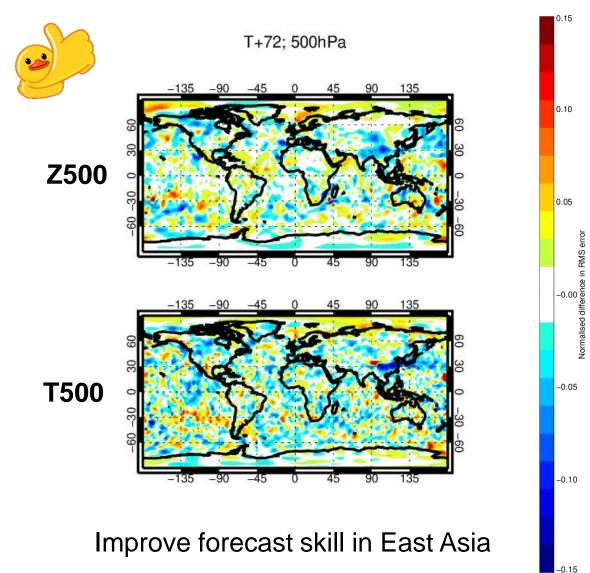
Mean absolute errors for Feb 2021 and 2022

SNOTEL: Serreze et al. (1999) CanSWE: Vionnet et al. (2021)

- Snow depth is increased on the Northern Rockies by the upper limit change
- Mean absolute errors are much reduced against in situ observations on the area

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#### Scorecard for winter 2020/21

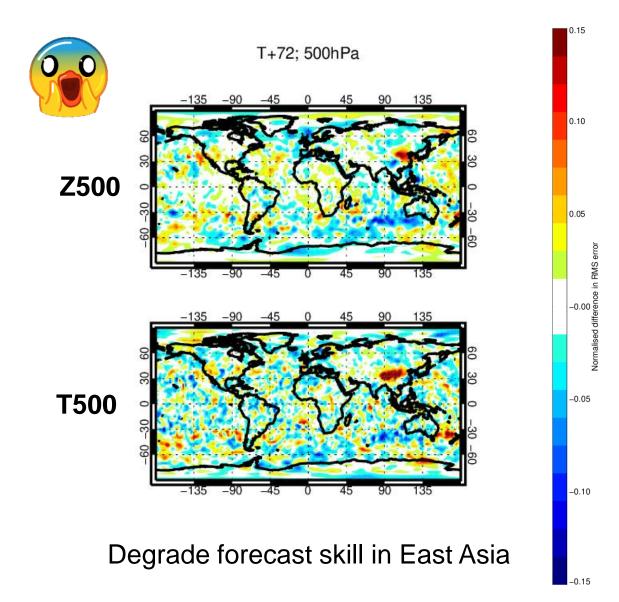


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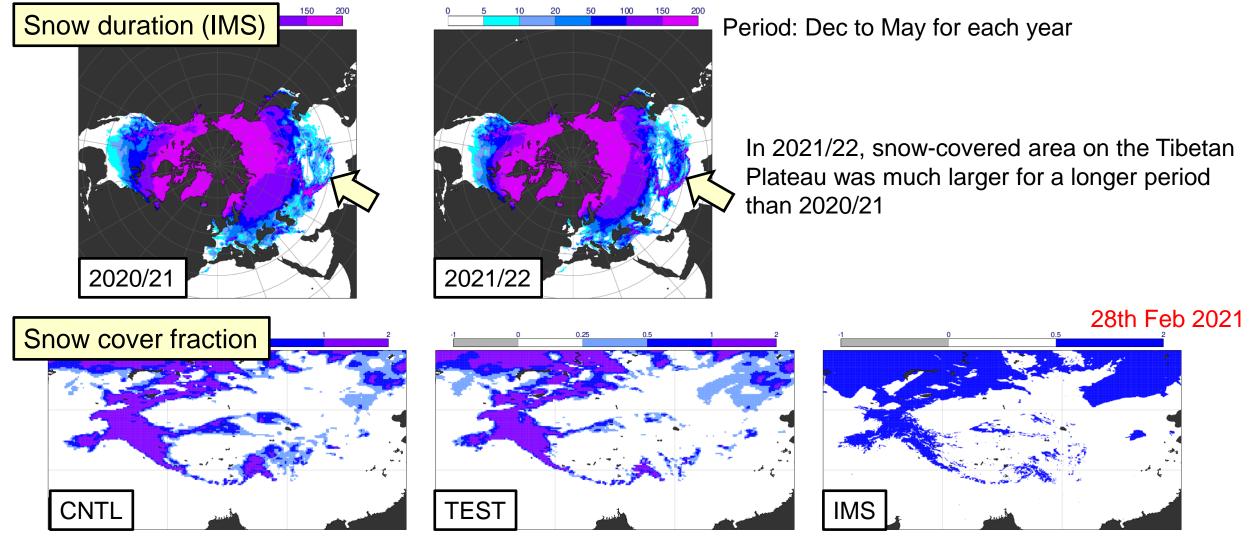
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#### **Scorecard for winter 2021/22**



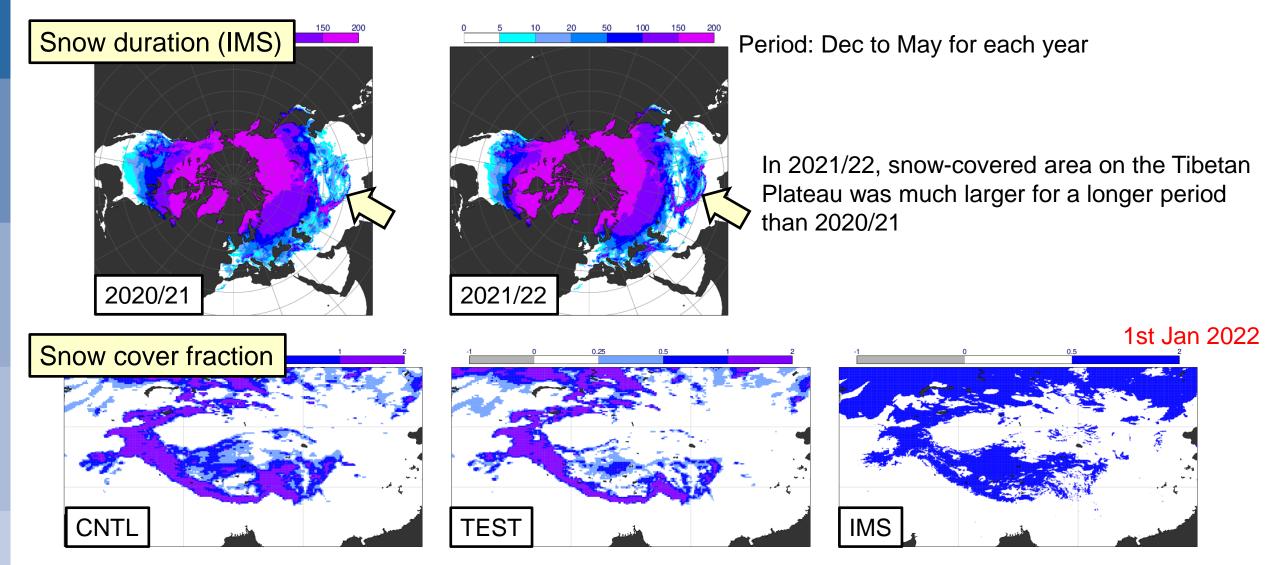
8 © ECMWF

# What's the difference between 2020/21 and 2021/22?



Snow cover fraction is improved by assimilating IMS in 2020/21, but...

# What's the difference between 2020/21 and 2021/22?



Insufficient snow cover fraction for shallow snow — Need to improve SCF parameterization in the IFS

## **Revised snow cover parameterization for the CY49R1**

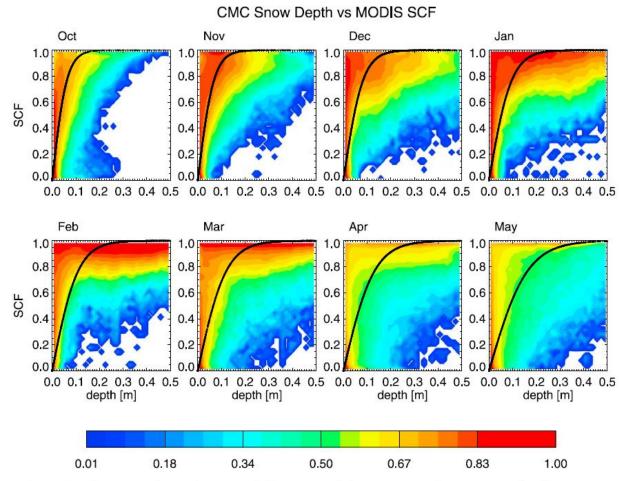
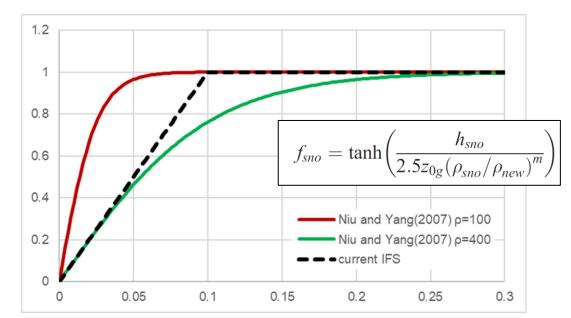


Figure 2. Same as Figure 1 except daily averaged data were used to generate the histograms.

Swenson and Lawrence (2012)

- SCF doesn't depend on snow depth only
  - Accumulation or melting, vegetation, etc...
  - Described in Niu and Yang(2007), Swenson and Lawrence (2012), Nitta et al. (2014)
- The Niu and Yang (2007) SCF has been tested



- SD<sub>IMS</sub> is also changed from 5cm to 3cm

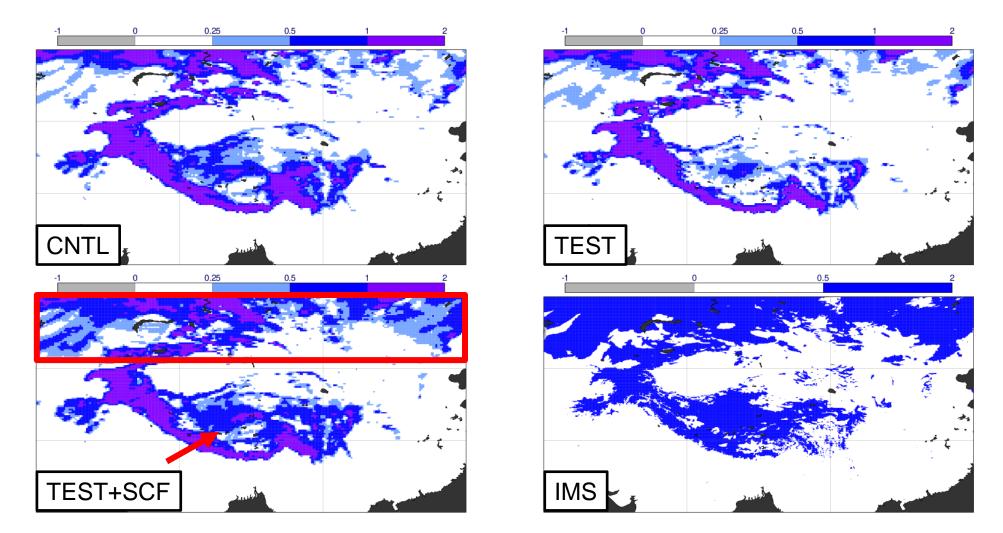
#### Validation of snow cover duration against IMS

#### -300 -100 -75 -50 -25 25 75 100 300 -300 -100 -75 -50 25 50 50 75 100 300 -300 -100 -75 -50 -25 25 50 -25 75 100 300 CNTL - IMS TEST+SCF - IMS TEST - IMS

- CNTL has negative biases of snow cover duration (number of days when SCF>50%)
  - Worse on the Tibetan Plateau in **TEST**, although looks better for snow depth
- The negative biases are improved by the revised SCF parameterization (TEST+SCF)

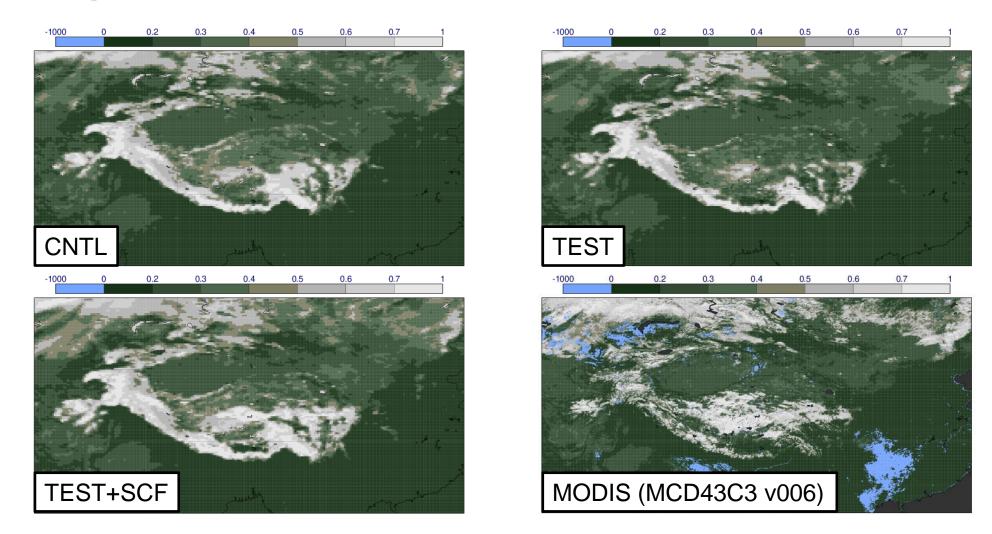
#### Period: Dec 2021 to May 2022

#### An example of snow cover fraction on 1st Jan 2022



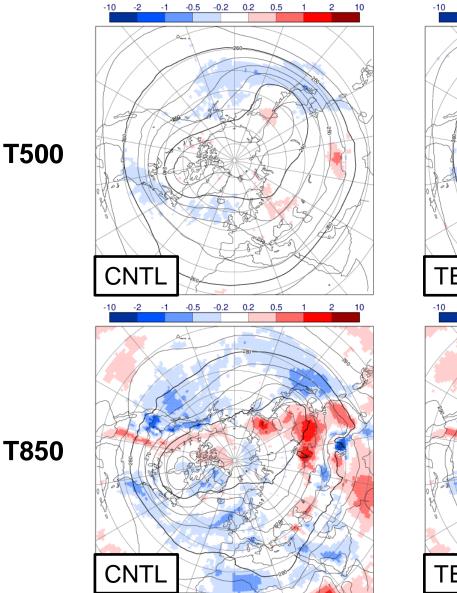
• SCF is increased for shallow snow by the revised SCF parameterization

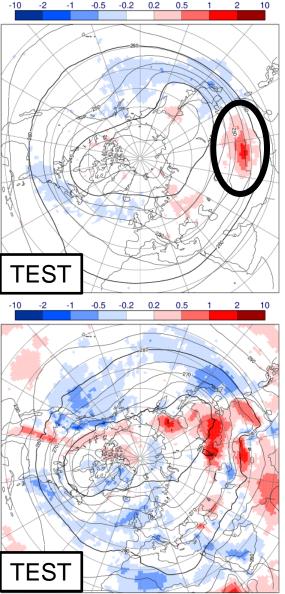
#### An example of albedo on 1st Jan 2022



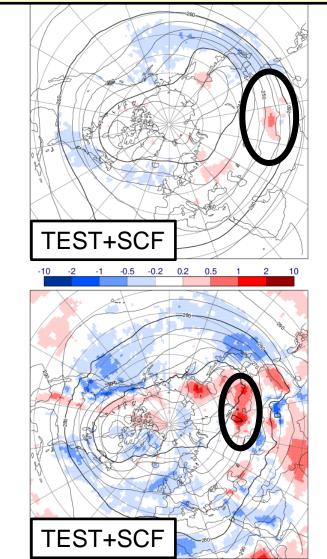
• Albedo is also increased especially on the Tibetan Plateau

# Mean biases of T850 and T500 at T+48





Warm biases of temperature are reduced in the TEST+SCF experiment



Winter 2021/22

EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

#### **Scorecards of TEST against CNTL**

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#### **Scorecards of TEST+SCF against CNTL**

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#### Snow cover has large impact on NWP, especially around East Asia

- Not only near surface temperature, but also in the mid-to-upper troposphere

#### Importance of collaboration between modeling and assimilation team

– Crucial for addressing error compensation

#### • We can sometimes obtain a clue from experiments for different years

- In the case of snow changes, also important to have a look at spring

\* You can see the details based on CY49R1 at the IWG page. <u>https://confluence.ecmwf.int/pages/viewpage.action?pageId=327671988</u>

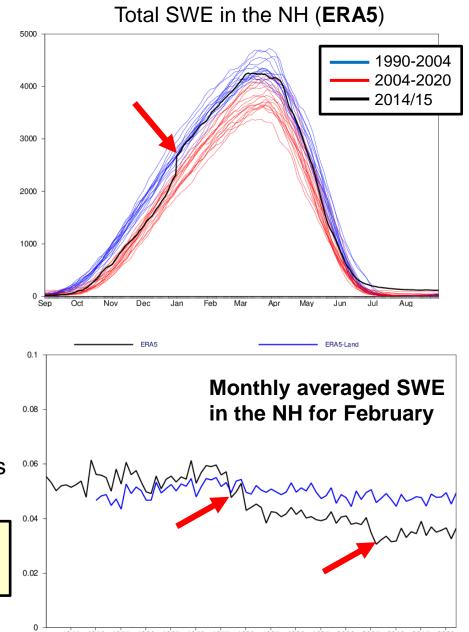
#### Outline

- Impact of revised snow data assimilation and snow cover parameterization
  - Implemented in the CY49R1
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# **Issues of snow analysis in ERA5**

- Inconsistency between before and after 2004
  - IMS has been assimilated since 2004
  - The difference of ERA5 and ERA5-Land looks particularly large between 2004 and 2010 (inconsistency of IMS?)
- Discontinuity between 2014 and 2015
  - Due to a stream change
- Inconsistency around 1970's
  - Upper limit for snow depth didn't work without observations

To be more consistent for longer years in ERA6, possibility of using the ESA CCI Snow have been explored



1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

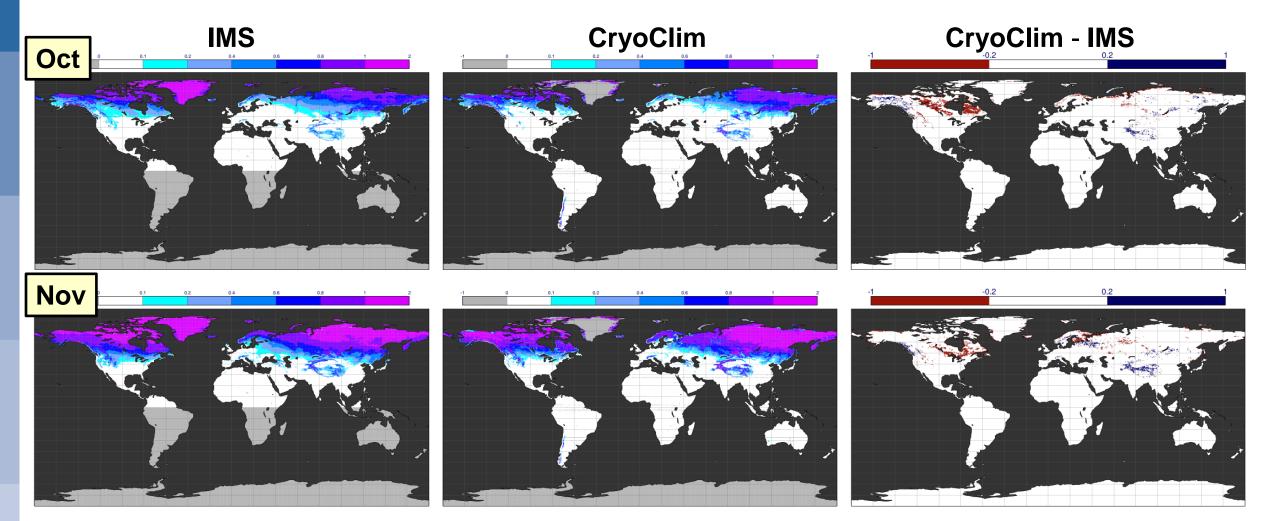
## **Comparison among satellite-derived snow cover products**

	ESA CCI Snow AVHRR	ESA CCI Snow CryoClim	IMS
Sensors	AVHRR	AVHRR,SMMR,SSM/I,SSMIS	Many satellites and sensors
Period	1982 - 2019 Longer noise: 1984-1985, 1987 Longer gap: 1994-1995	1982 - 2019	2004 - now
Mask	Cloud, polar night, Greenland, Antarctica	Greenland (except coast), Antarctica	Southern Hemisphere
Example	a b b b b b b b b b b b b b b b b b b b		

- The ESA CCI Snow has a longer period than IMS
- CryoClim has no cloud mask and looks more consistent with IMS

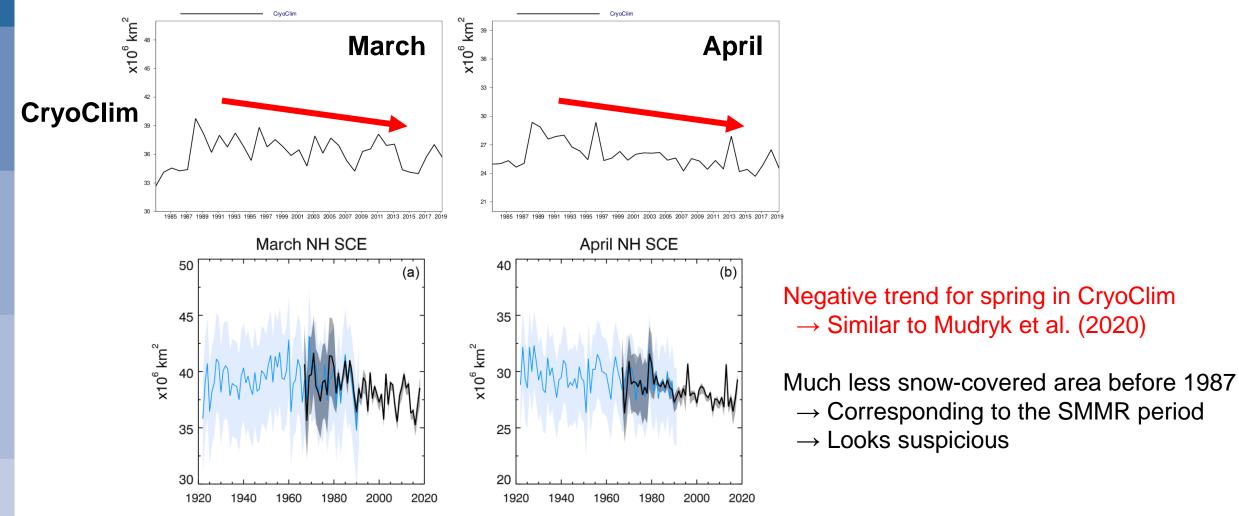
# Monthly climatology of IMS and CryoClim

Period: 2006 to 2020



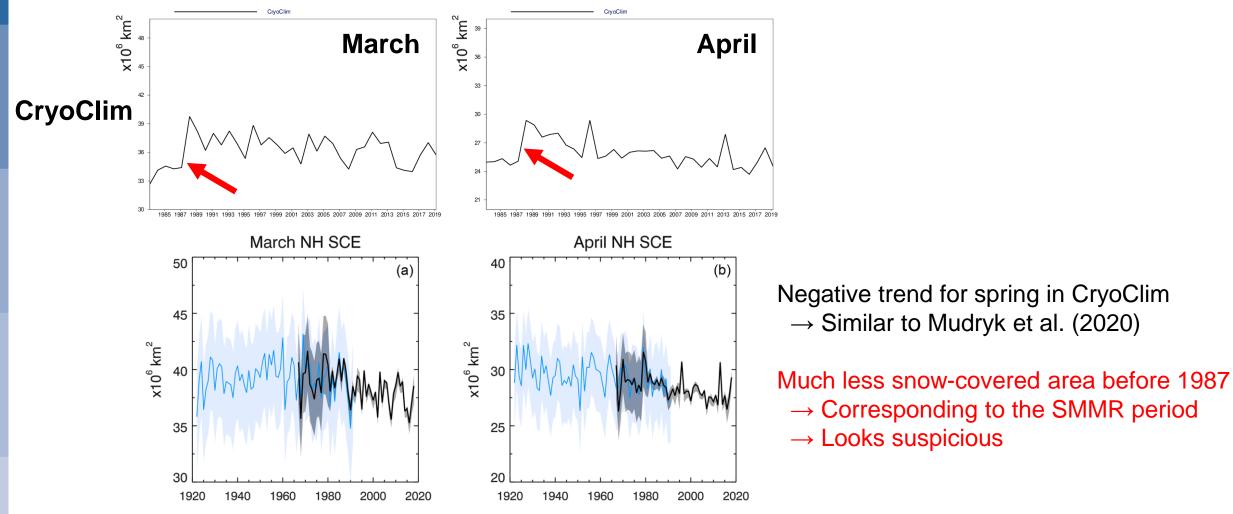
• IMS and CryoClim are consistent in many regions, but not consistent in some regions

## Interannual variability of the CryoClim snow cover extent



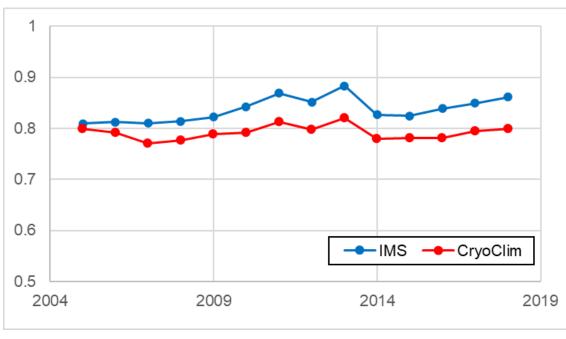
Mudryk et al. (2020): snow cover extent based on multi-dataset

## Interannual variability of the CryoClim snow cover extent

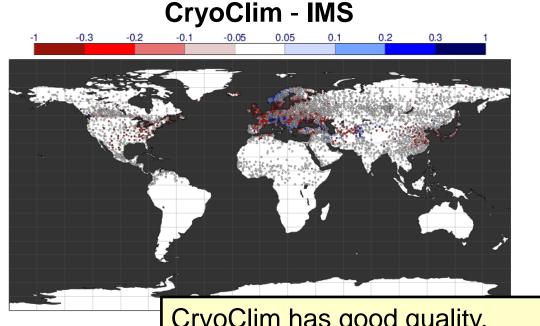


Mudryk et al. (2020): snow cover extent based on multi-dataset

# Validation of IMS and CryoClim against in situ observations



#### **Threat score**



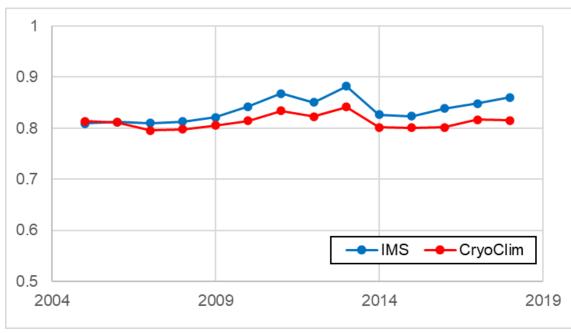
#### CryoClim has good quality, but IMS is better than CryoClim

	In situ observed ( <b>SD ≥ 1cm</b> )	In situ observed ( <b>SD &lt; 1cm</b> )
Snow-covered ( <b>SCF ≥ 50%</b> )	a Hit	b False alarm
Snow-free ( <b>SCF &lt; 50%</b> )	c Miss	d Correct no snow

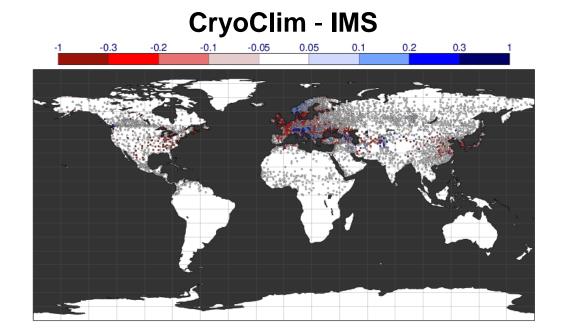
<u>Threat score = a / (a+b+c)</u>



## Validation of IMS and CryoClim after some modifications



#### **Threat score**



- Change a threshold for snow-covered/snow-free from 50% to 30% in CryoClim
- Mask snow-free areas if  ${\rm SCF}_{\rm clim}$  > 80% and  ${\rm SCF}_{\rm CryoClim}$  < 30%

> More consistent with IMS and better threat score, but the difference still seen after 2010

#### **Experiment settings**

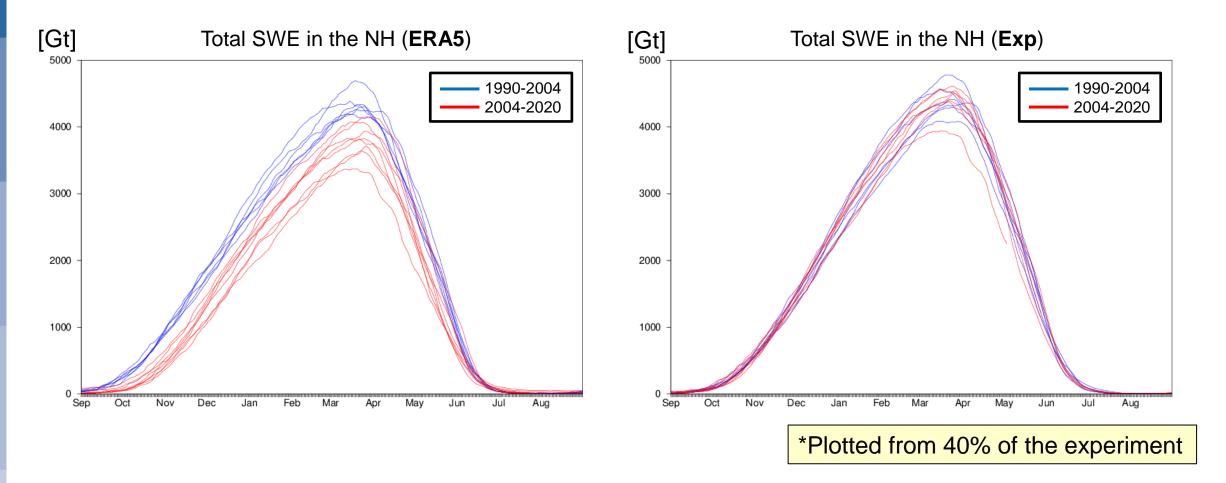
Thanks to Dinand!

- Branches: based on the CY48R1.1 for ERA6 development
  - Including the revised snow DA in CY49R1, upper limit of snow depth for the entire field
- Exp type: Stand-alone Surface Analysis only (without atmospheric 4D-Var) at TCo319
- Period: Sep 1968 to Aug 2020 (52 years / 13 streams)

Thanks to Marijana and Peter Lean!

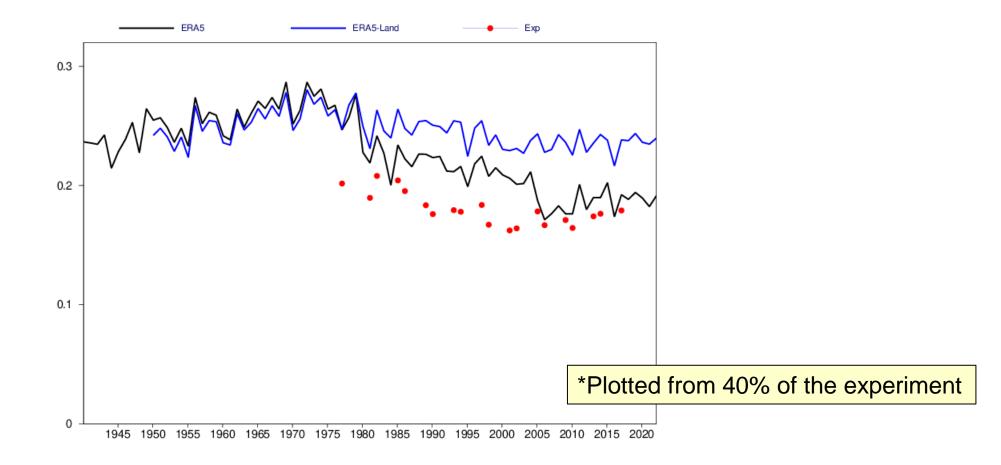
- The CryoClim data was converted from NetCDF to BUFR, then ODB
- Some modifications for CryoClim to be more consistent with IMS
  - Use the snow cover in the NH from 1987 (switch to IMS in 2010)
  - Assimilate binary information of snow-covered/snow-free: the threshold = 30%
  - Climatological QC: reject the snow cover if  $SCF_{clim} > 80\%$  and  $SCF_{CryoClim} < 30\%$

## Time series of SWE in the NH for 1990-2020



• Looks no gap between before and after 2004 in the experiment

## Time series of monthly averaged snow depth in February



- So far, more consistent for a longer period by using the CryoClim snow cover (Exp)
  - The multi-layer snow scheme in CY48R1 also contributes to reduction of positive biases

#### Summary

#### ERA5 has several issues on consistency of the snow analysis

- Several gaps in 1970's, 2004 and 2014/15

#### More consistent for longer years by the ESA CCI Snow CryoClim

- Contributions from not only DA but the multi-layer snow scheme
- Will be implemented in ERA6  $\rightarrow$  Possible to be much more improved than ERA5

#### Future prospects

- Possible to provide snow monitoring?
  - Climate Bulletins
  - WMO GCW snow tracker

the maps and guidance on how they are produced.	
MONTHLY CLIMATE UPDATE   MONTHLY SUMMARIES   EUROPEAN STATE OF THE CLIMATE   CLIMATE INDICATORS   FEATURED STORY	Plane About News Chjosphole Now Samade Satellites Activities Retrienze Data Pottal Duty
Highlights of the latest monthly summaries	Trackers
SNOVEMBER 2023 October 2023 highlights:  • October 2023 highlights:  • In October 2023 was the warmest October on record globally, with an average surface air temperature of 15.20°C. • In October 2023, precipitation was above average across most of Europe: Storm Babet hit morthern Europe, and storm Allne impacted Portugal and Spain, bringing heavy precipitation and flooding. • October marked the sixth consecutive month that Antarctic sea ice extent remained at record low_leagl for the time of year, and Arctic sea ice extent reached its <u>7th lowest value for October</u> .	GCV and its partners are developing various. Trackens" for the cryosphere Most are based on satellife data. That hardware increased and an exact state of cryosphere without to be mean state of the area developed. These and other frackens: some of which were not developed by/for GCV, are also available on the Cryosphere Move pages. FMLIGCW SWE Tracker is a product of the Finnsh Meteorological institute (FMI) based on Glossbare more varies of the developed as part of the Cic/V Seew Watch report. It institutes from approximately the final state of the final hardware and a state of the cic/V seew state of the circular state of the final hardware of the cic/V Seew Watch report. It is also approximately the state of the final hardware of the cic/V Seew Watch report. It is also approximately the May and early Cickber. Therefore, the pisting of the box developed and the final state the state of the circular state of the circular state of the circular state of the circular state the state of the circular state of the circle state of the circular state of the circle

### Other work on snow data assimilation in 2 years

#### Snow QC for fresh snow and SYNOP in China

- Implemented in the CY47R3 operational system in Feb 2023
- Snow fixes in the CY48R1 e-suite: excessive snow and missing observations
  - with Gabriele, Patricia, Tomas Kral and many others
- The offline land DA system for extended-range, SEAS6 and ERA6-Land
  - Implemented snow analysis and worked a bit on real-time system for SEAS6
  - David and Ewan are working hard on the real-time system now
- The SNOTEL assimilation: Patricia will continue the experiment
- Snow analysis in the SEKF towards a unified land DA system
  - Now possible to assimilate the 2D-OI analysed snow depth in the SEKF



Special thanks to everyone in ECMWF, especially to Coupled Assimilation Team! I had a great time with you!

Windermere in the Lake District