In-situ snow depth data holdings for the evaluation of snow models and reanalyses

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Towards a global archive of historical in situ snow data
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Outlines

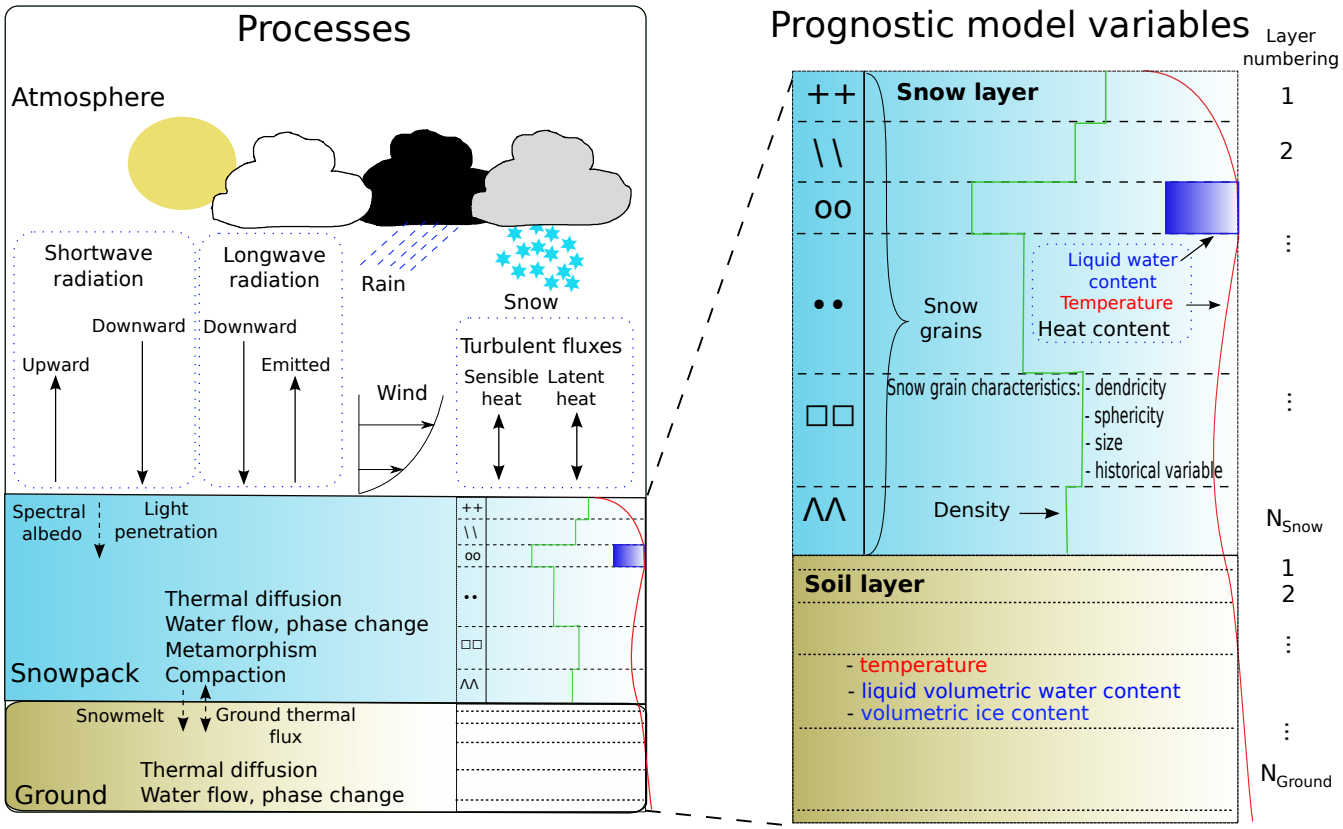
- Daily snow depth : a key variable in the evaluation of snowpack models and reanalysis
- Historical in situ snow depth data collected from different sources to evaluate ERA-20C
- The major issues regarding climatological studies : zero snow depth and landscape representativeness

1. Snow depth to evaluate models : a few examples
2. In situ “global daily” snow depth data set for ERA-20C evaluation
3. Major Issues for in-situ snow depth usefulness

A large diversity in numerical snow models

- Detailed snowpack models for avalanches and snow research : Anderson, Crocus, SNOWTHERM, SNOWPACK, SMAP
- Simple uni-layer snow models for weather forecast and climate models : a lot !
- Intermediate complexity snow models embedded in weather prediction and climate models : ISBA-ES, JULES, SNICAR, HSNOWTESSEL ...
- Detailed snow models in regional climate models simulating ice-sheets surface mass balance : RACMO, MAR
- Intermediate complexity snow models embedded in hydrological models : VIC, ...

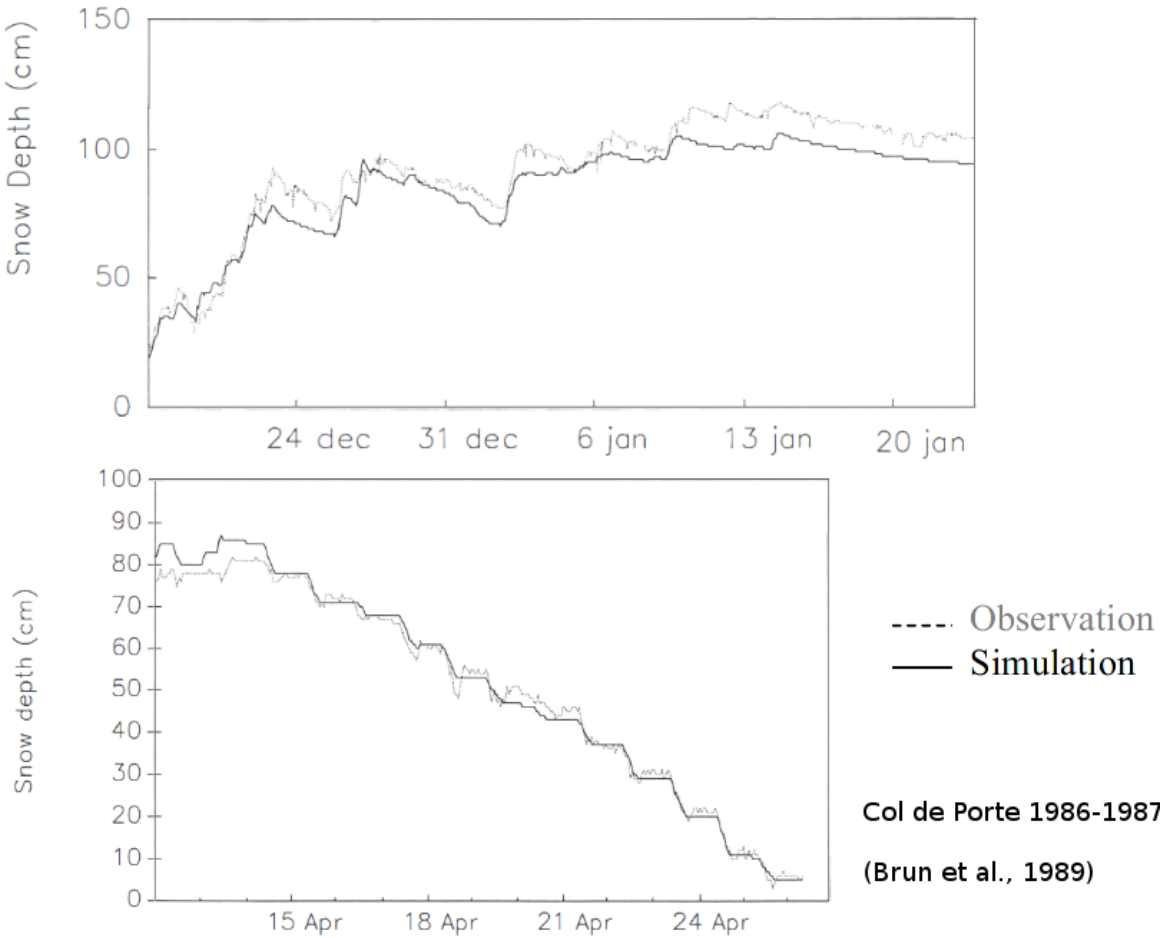
Crocus / ISBA-DF : a coupled snowpack / soil model



(Brun et al., 1989, 1992 ; Vionnet et al., 2012)

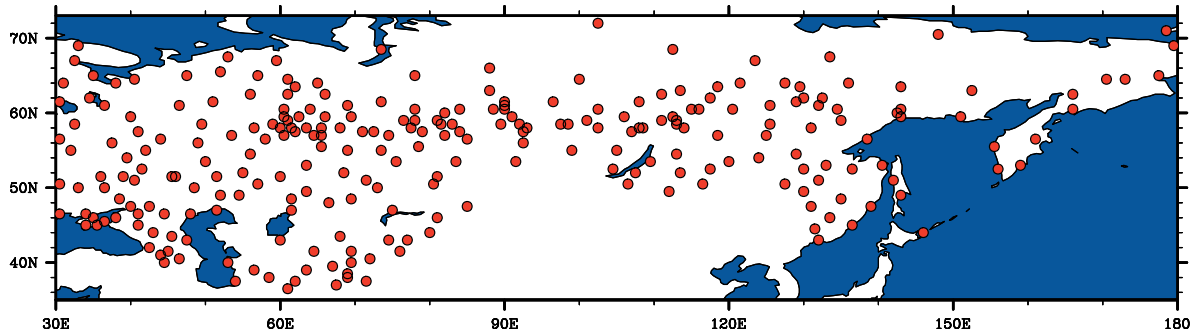
Optional blowing snow processes : compaction and sublimation

Snow depth is a variable evolving under the control of concurring key physical processes : a great challenge for snow models !



A case example of historical data sets for model evaluation

- Historical Soviet Daily Snow Depth (HSDSD) :
  - *daily snow depth at synoptic stations (open fields) / year-round*
  - *263 stations : > 1,100,000 quality-controlled obs. (1979-1993)*
  - *some records start in 1891*
  - *easy access from NSIDC portal*



- + co-located observations of SWE 3-6 times/month
- + co-located monthly observations of soil temperature

Simulation configurations

ERA-interim reanalysis ECMWF

- $\sim$ 80 km resolution
- 4D-Var assimilation system
- precipitation from model forecasts
- radiation from model forecasts

(Dee et al., 2011)

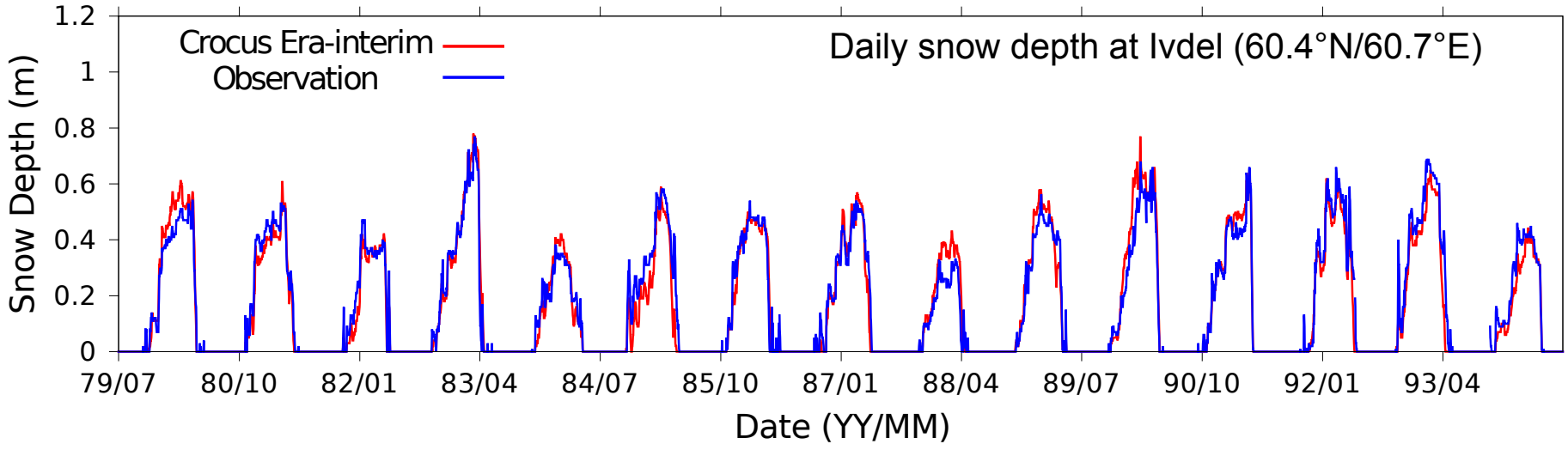
Crocus snow model ISBA-DF soil model

- simulations at each station site (altitudinal correction)
- 2D simulations over Eurasia
- outputs : snow depth, SWE, density, soil and snow internal profiles

+ additional configurations/options :

- forcings from Global Forcing Princeton University data set (PGF) (NCEP-NCAR reanalysis and monthly precipitation scaling from CRU/GPCP)
- ...

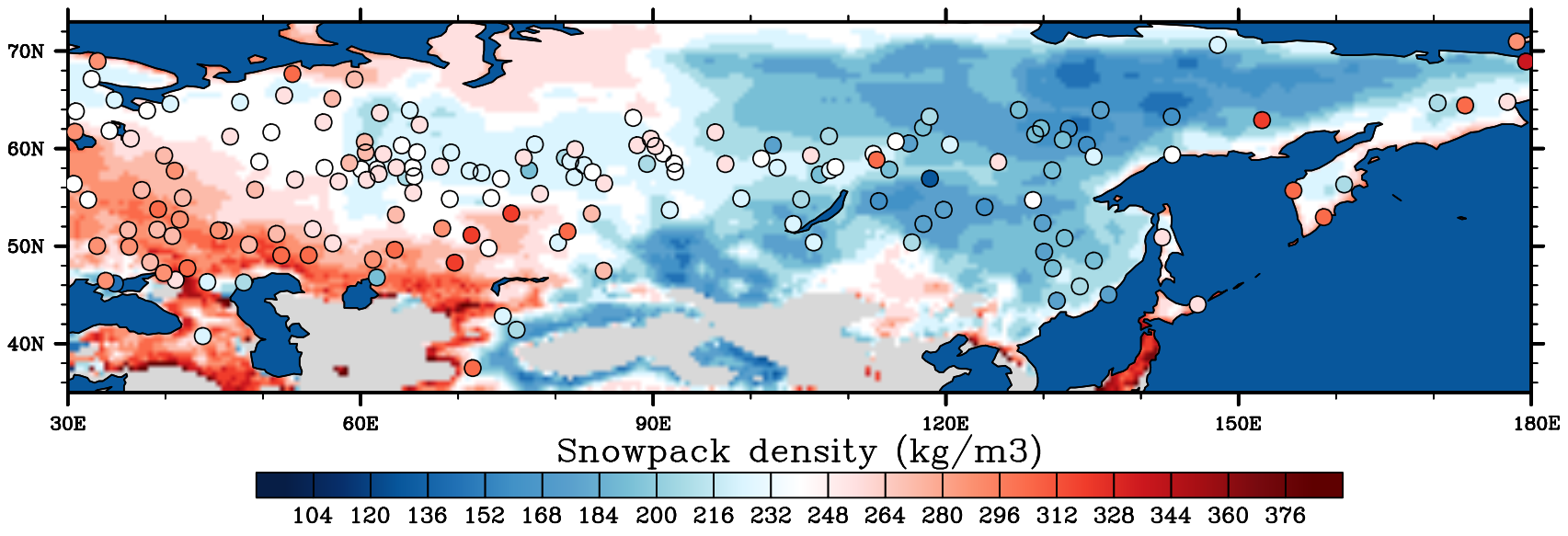
Illustration of Era-interim / Crocus performance



Similar performance to local simulations
driven with observed meteorological observations !

(Brun et al., 2013)

Evaluation of simulated snowpack density



Comparison between observed (circles) and simulated density (2D field) on 10 March (average 1979-1992)

(Brun et al., 2013)

Evaluation of simulated snowpack density

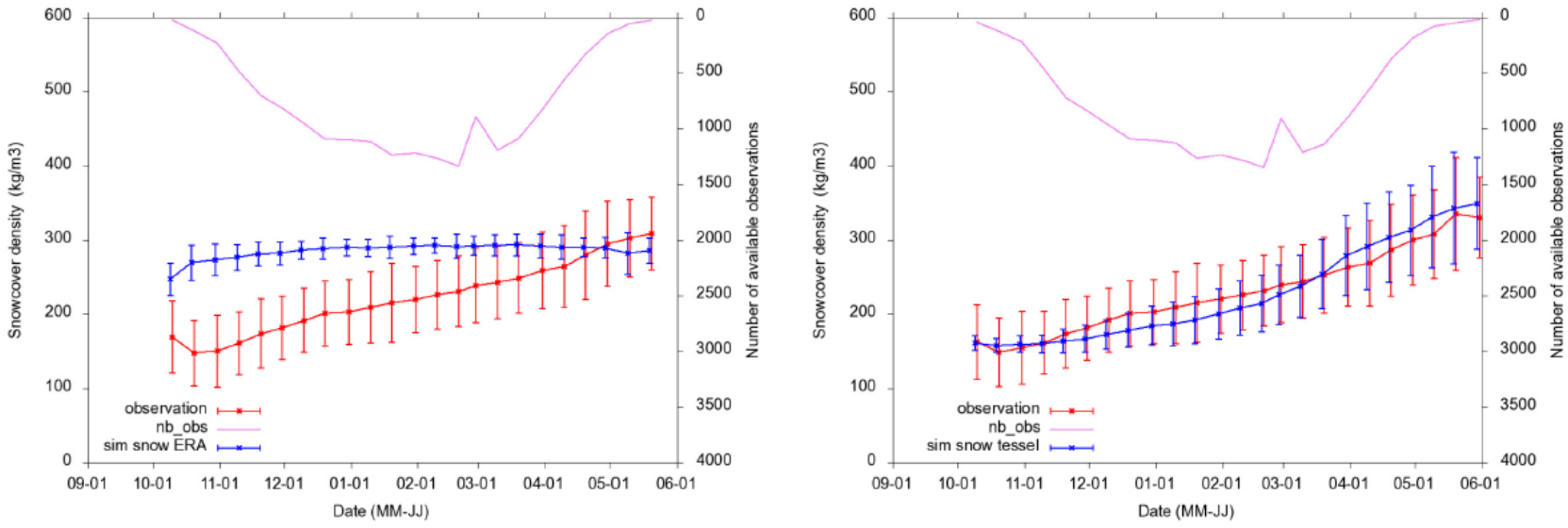


Figure 5: Snow density seasonal evolution as observed (red) and estimated (blue) by the ERA-Interim reanalysis (left) and by the offline HTESSEL simulations (right) driven by ERA-Interim.

(Balsamo et al., 2012)

Main results from the comparison of ERA-interim/Crocus with in-situ data

Present performance of reanalyses and snow models $\Rightarrow$ very performing simulations of local snowpacks

- Small bias in snow depth, onset and melt-out dates, density, SWE and soil temperature (open field and flat)
- A few stations are poorly simulated (unresolved local meteorological conditions : wind, precipitation)
- Much better performance with ERA-Interim than with PGF
- Blowing snow sublimation is a critical process
- Similar performance to satellite snow products which assimilate snow observations $\Longrightarrow$ complementarity still to be exploited !
- Similar performance for snow variables with HTESSEL in ERA-interim/Land

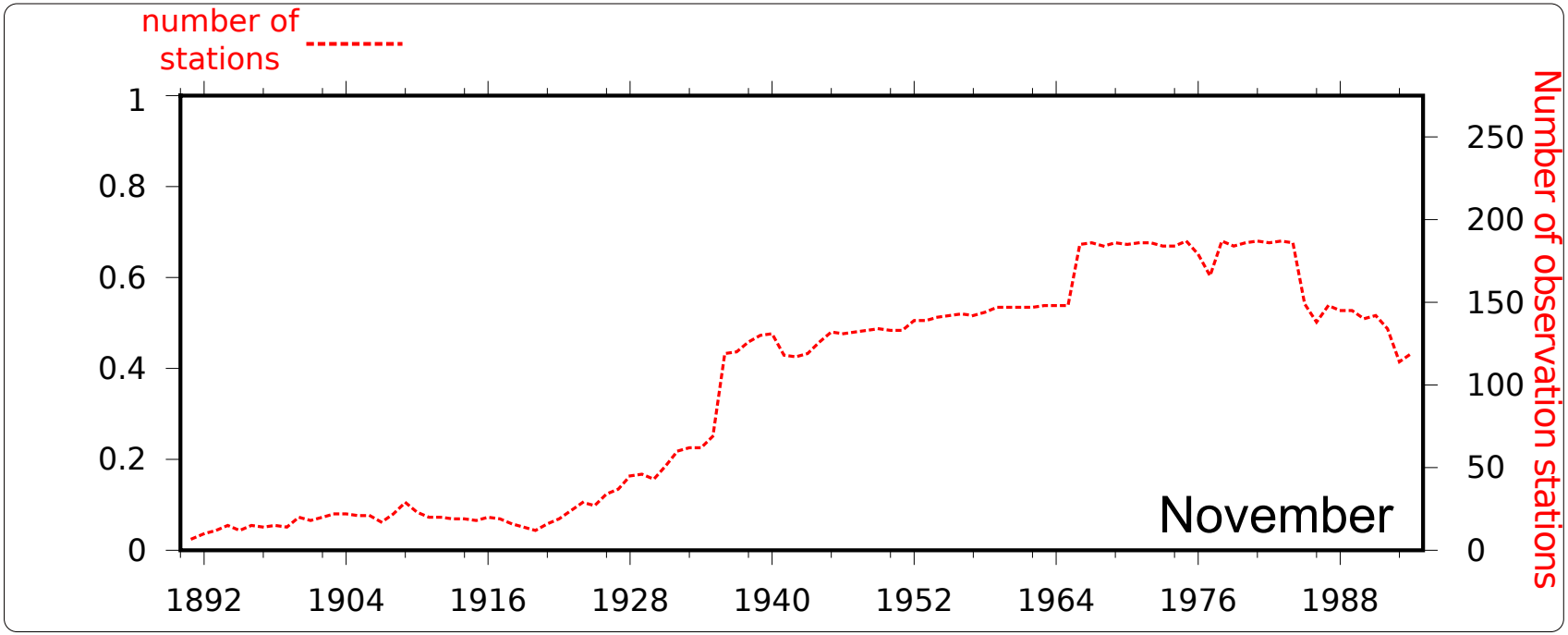
Performance of 20CR snow cover over Northern Eurasia (South 60N)

Evaluation of 20CR snow cover Autumn (October and November)

- Extraction of 20CR daily snow cover gridded field
- Transformation into a binary field (snow / no snow) (threshold 50%) : $\Longrightarrow$ SC-20CR
- Same process with Northern Hemisphere weekly snow cover extent : $\Longrightarrow$ SC-NOAA
- Transformation of in-situ snow depth observations into "snow / no snow" (threshold 5 cm)
- Creation of a snow detection performance index :
  - rate of daily in-situ observations in agreement with SC-20CR
  - rate of daily in-situ observations in agreement with SC-NOAA

(Peings et al., 2013)

Performance of 20CR snow cover over Northern Eurasia (South 60N)



(Peings et al., 2013)

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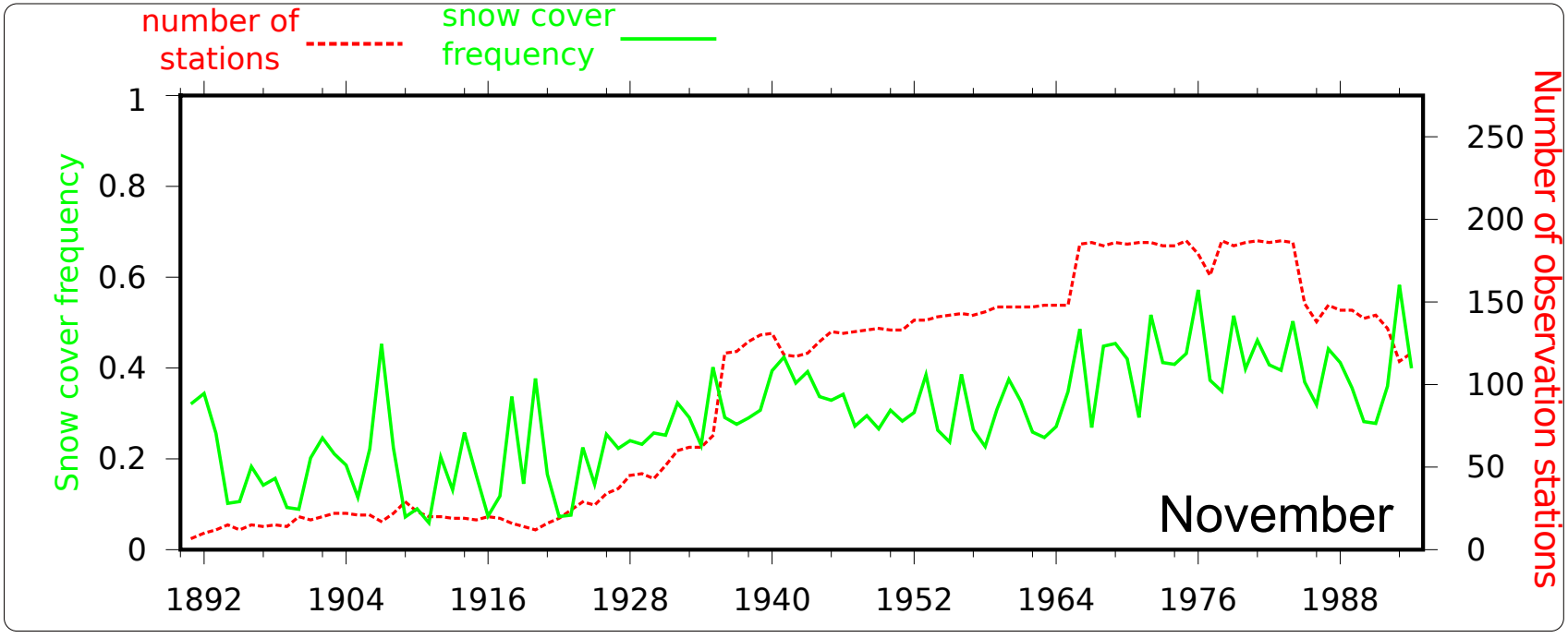

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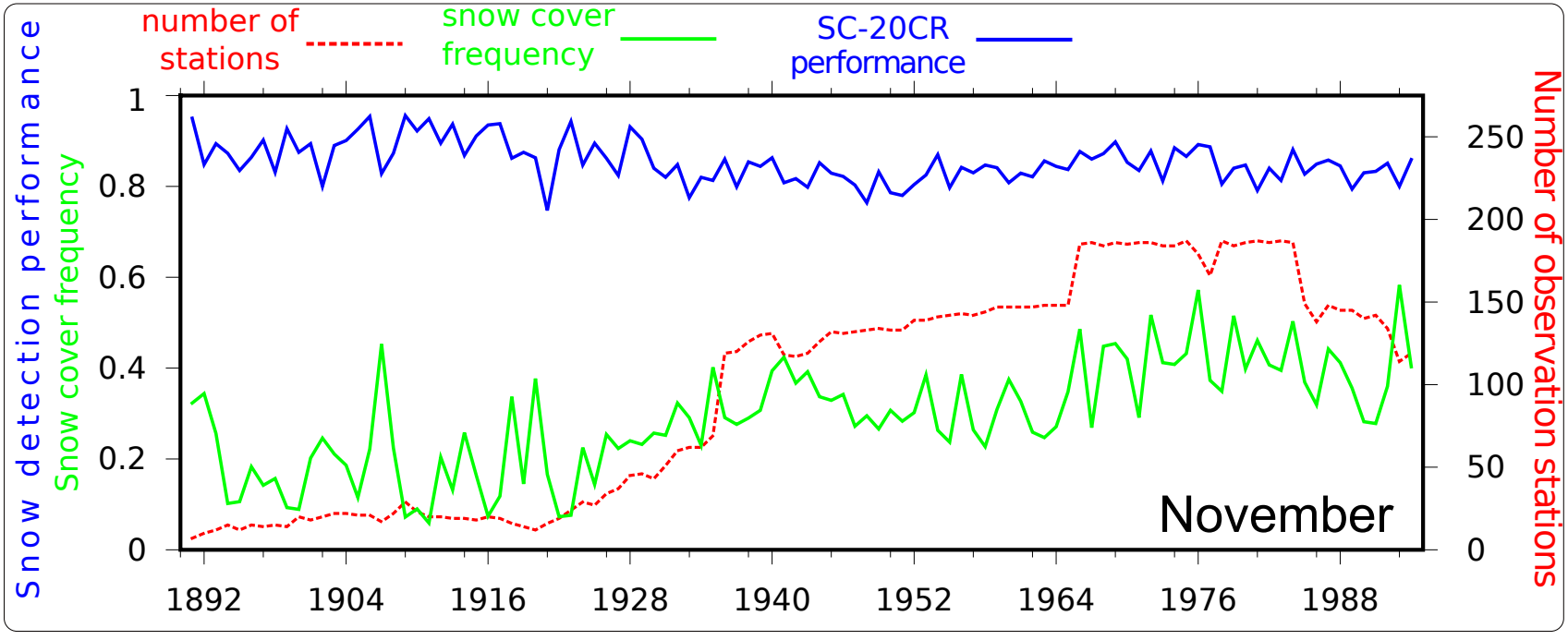

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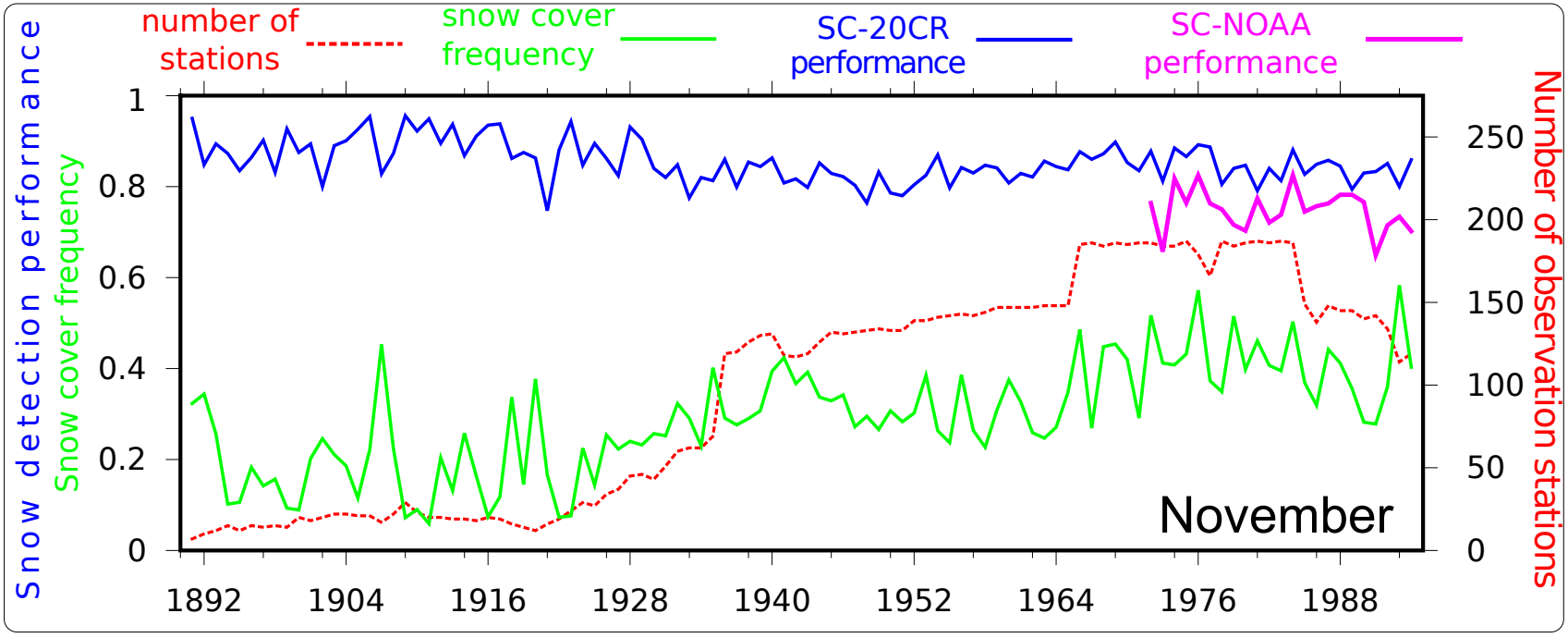


(Peings et al., 2013)

Design of a dataset for ERA-20C evaluation

Ideal in situ snow depth dataset

- global coverage : at least extension of in situ SD data beyond 1995 and FSU
- focus on long term series $\Longrightarrow$ at least 20 years
- year-round observations including zero snow depth
  - derivation of climatological snow cover indices
  - symmetry between positive and negative biases

Russia and FSU

Snow Depth Data from RIHMI-WDC (Olga Bulygina)

- file SCH9262.txt
- 600 stations with more than 20 years year-round data
- first records starting in 1874

Russia and FSU

Snow Depth, SWE and Density from RIHMI-WDC (Olga Bulygina)

- file SCHAF61.txt
- 376 stations "open field" with snow course data 3-6 times/month during the snow season
- 237 stations "forest"
- 97 stations perform both "open field" and "forest" observations
- first records starting in 1966

Canada

Data from Ross Brown and NCDC/GHNCD

- Data from Ross Brown
- 719 QC stations with more than 20 years and 300 obs/year on average
- no use of reconstructed snow depth except Summer (QC > 100)
- use of reconstructed zero snow depth for no-snow-season (QC = 100)
- first records start in 1881 - last records end in 2003
- extension beyond 2003 from NCDC/GHNCD (see USA) but first half 2004 is missing

USA

Data from NCDC/GHNCD

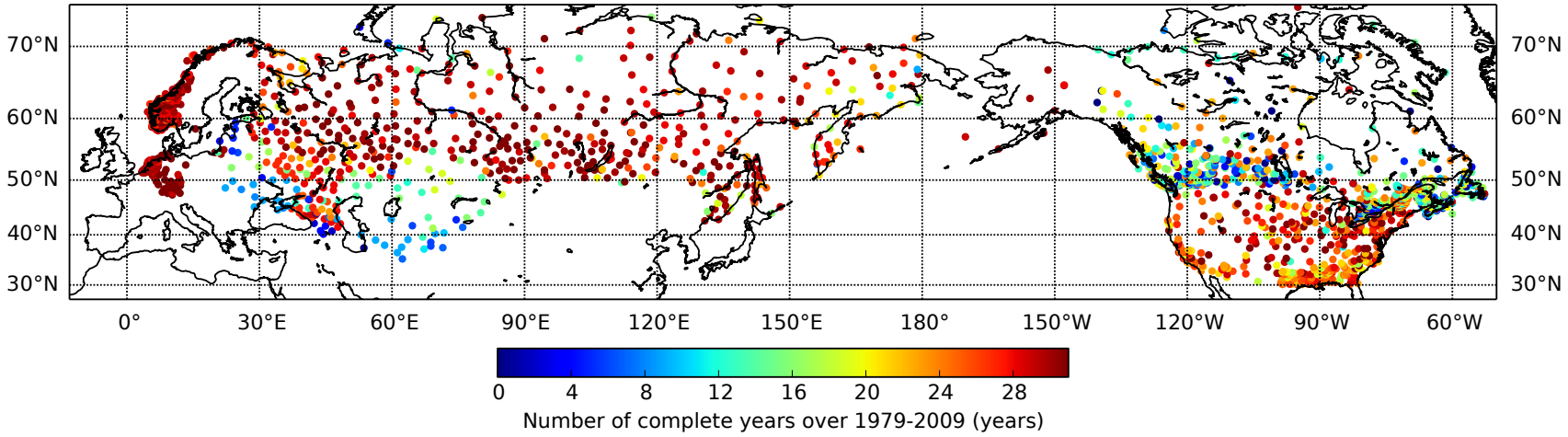
- file ghcnd_all.tar.gz from
  ftp ://ftp.ncdc.noaa.gov/pub/data/ghcn/daily/
- 355 stations with :
  - more than 40 years , 350 obs/year
  - latitude >= 30 N , ends after 2010
- first records starting in 1889

Other countries

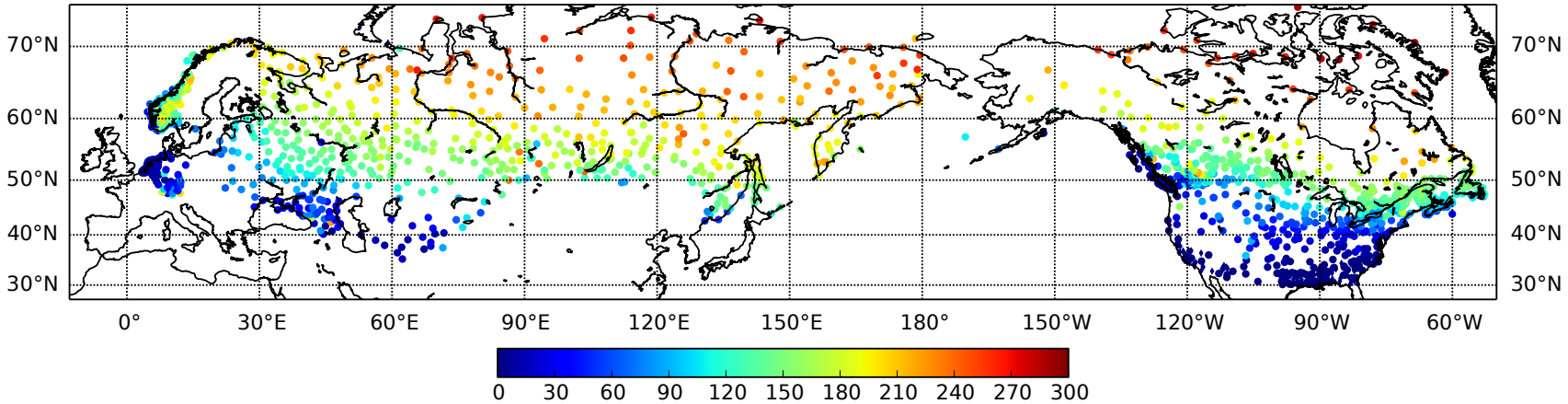
Data from NCDC/GHNCD

- file ghcnd_all.tar.gz from
  ftp ://ftp.ncdc.noaa.gov/pub/data/ghcn/daily/
- 448 stations with :
  - more than 40 years , 350 obs/year
  - ends after 2010
- first records starting in 1887
- Germany, Netherlands, Norway + 1 Sweden

Series length : complete years with 5 consecutive missing days permitted

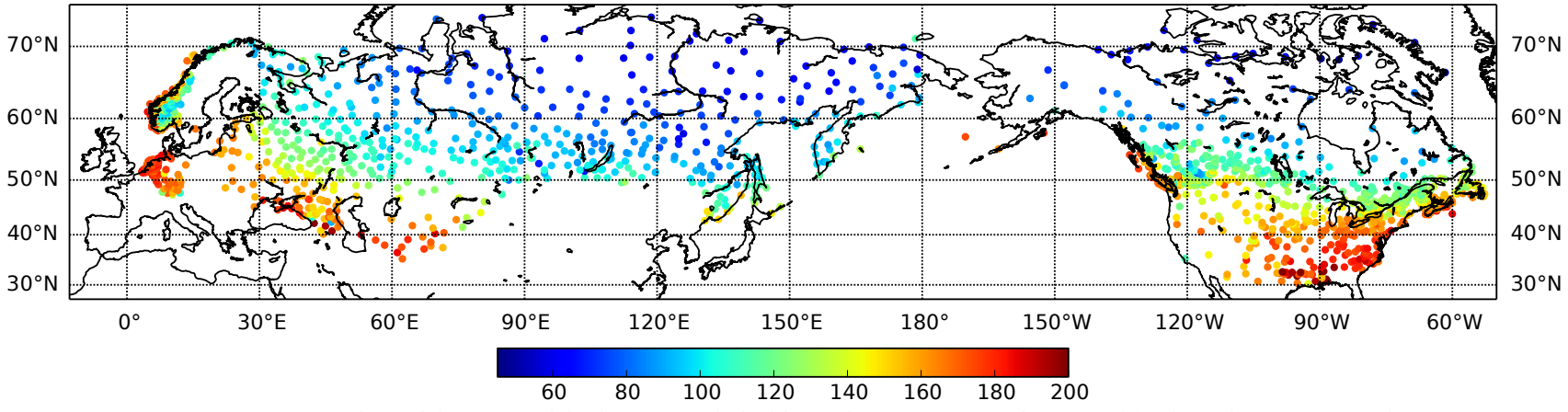


Mean number of days per year with snow on the ground



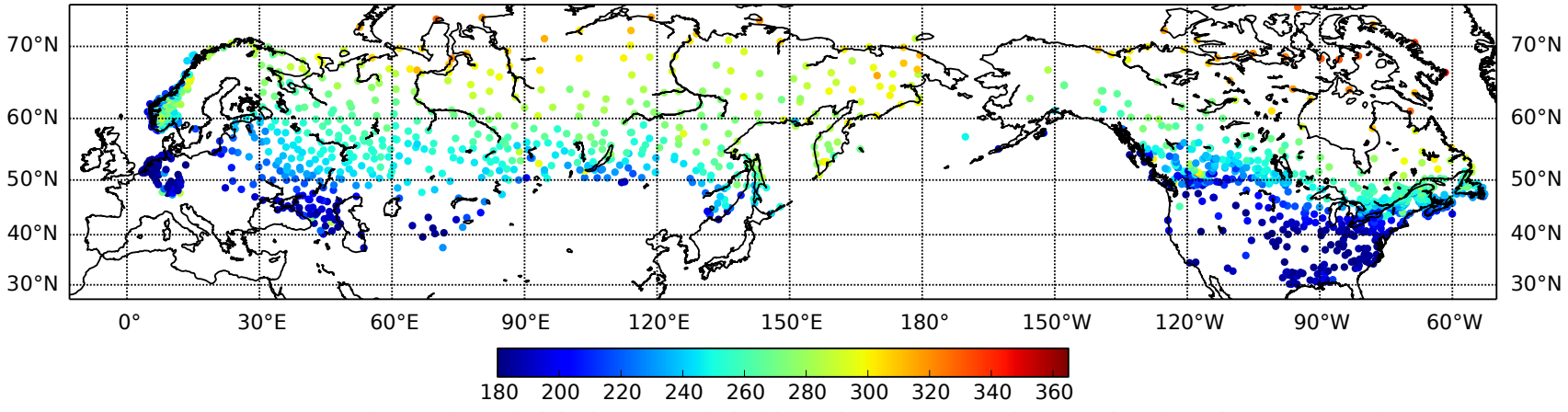
1979-2009 Mean number of days per year with snow on the ground (threshold 1 cm) (days)

Mean date of the onset of continuous snow cover (longest snow covered period during the snow season)



1979-2009 Mean date of the onset of the longest period with continuous snow on the ground (# days since 1st August)

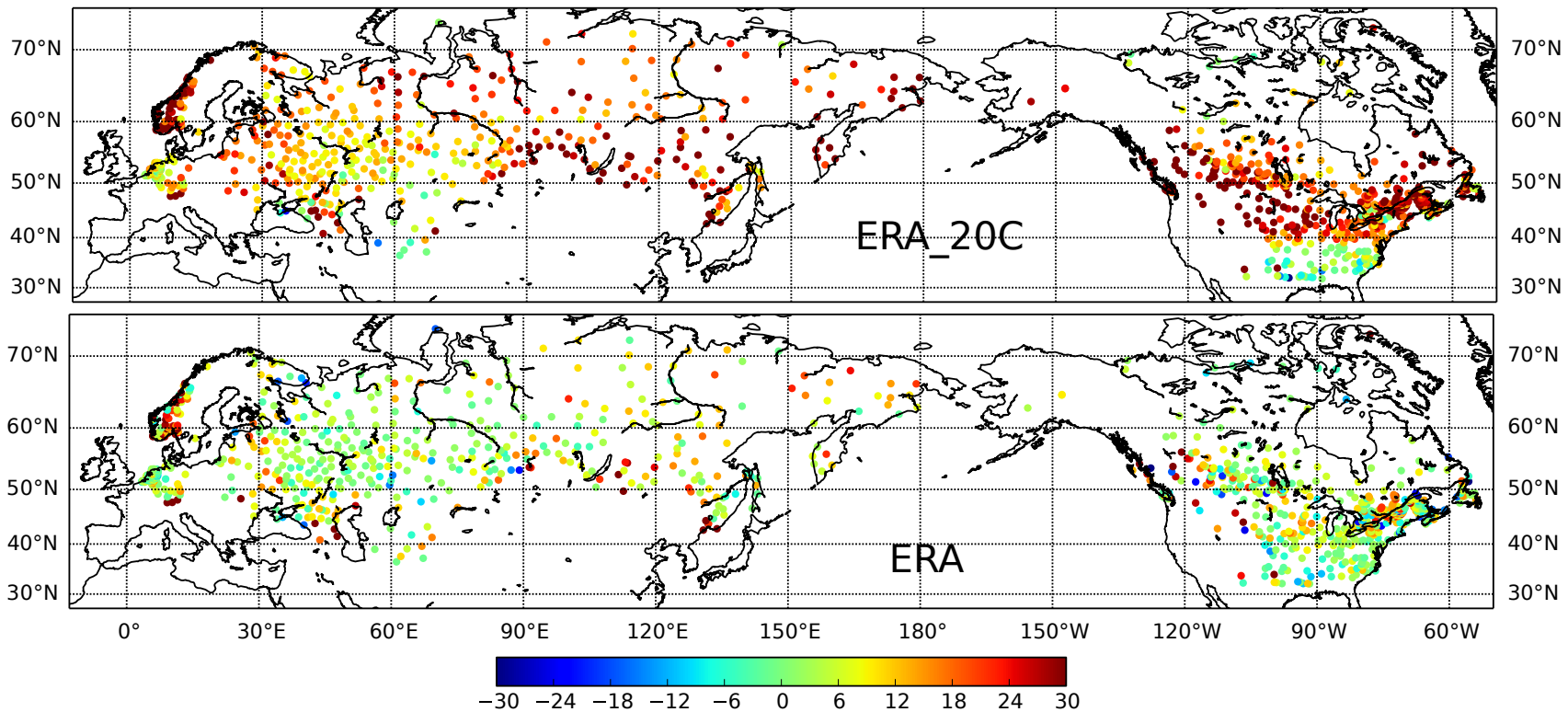
Mean date of the melting out of continuous snow cover (longest snow covered period during the snow season)



1900-2009 Mean date of the end of the longest period with continuous snow on the ground (# days since 1st August)

Use of in situ snow depth data to evaluate snow depth in ERA20C

Bias of the mean date of the melting out of continuous snow cover



1979-2009 bias Mean date of the end of the longest period with continuous snow on the ground (# days since 1st August)

Zero snow depth measurements

Issues and perspectives

- zero snow depth was not reported in historical SYNOP messages
- possible confusion with missing observations
  $\Longrightarrow$ impossibility to derive some climatological snow cover indices
  $\Longrightarrow$ asymmetry between positive and negative biases
- makes it difficult to process in-situ snow depth data from China and Mongolia
- reconstruction algorithms exist (Canada)
  $\Longrightarrow$ to be reviewed and applied to other data sets
- GCW initiative for improving the current observation of zero snow depth

Representativeness of in-situ observations with respect to vegetation

Issues and perspectives

- most of synoptic observations are representative of open fields (or clearings in forest regions)
- simulated snow depth is representative of the grid cell landscape
  $\Longrightarrow$ large differences may occur between forests and open fields
  $\Longrightarrow$ assimilation algorithms generally ignore this difference
- snow courses data performed both in forest and open fields may help to evaluate the representativeness of a given station