# Spring snow albedo feedback in daily data over Russia: Comparing in-situ measurements with reanalysis products

**Martin Wegmann**[1], Olga Zolina[1], Hans-Werner Jacobi[1]
*1 Institut des Géosciences de l'Environnement, University of Grenoble, France*

## Background

- **Global warming** is enhanced at high northern latitudes where the Arctic surface air temperature has risen at twice the rate of the global average in recent decades.
- This recent Arctic warming signal likely results from several factors such as the **albedo feedback** due to a diminishing cryosphere, enhanced poleward atmospheric and oceanic heat transport, and changes in humidity.
- **Surface albedo feedback** is stating that the additional amount of shortwave radiation at the top of the atmosphere decreases with decreasing surface albedo whereas surface air temperature increases with decreasing surface albedo. It is considered a **positive feedback** in that an initial warming perturbation than kicks off a strengthening warming.
- Looking at the **Northern Hemisphere with its large landmasses**, snow albedo feedback is especially strong (in spring) since most of these landmasses experience snow cover during boreal wintertime.
- Unfortunately, so far there remains a **lack of reliable observational data** over large parts of the cryosphere. Satellite products cover large parts of the NH, however lack high temporal resolution and have problems with large solar zenith angles as well as over complex terrain (eg. Wang et al. 2014).
- **CMIP3 and CMIP5** model families represent the feedback process accurately, but there are still inherent **biases and outdated parameterizations** (Fletcher et al. 2015).

? *How well do recent reanalysis products reproduce snow and radiation features on a daily resolution ?*

? *How high is the spring snow albedo feedback in stations over Russia?*

? *How strong is it compared to gridded data? What are important differences?*

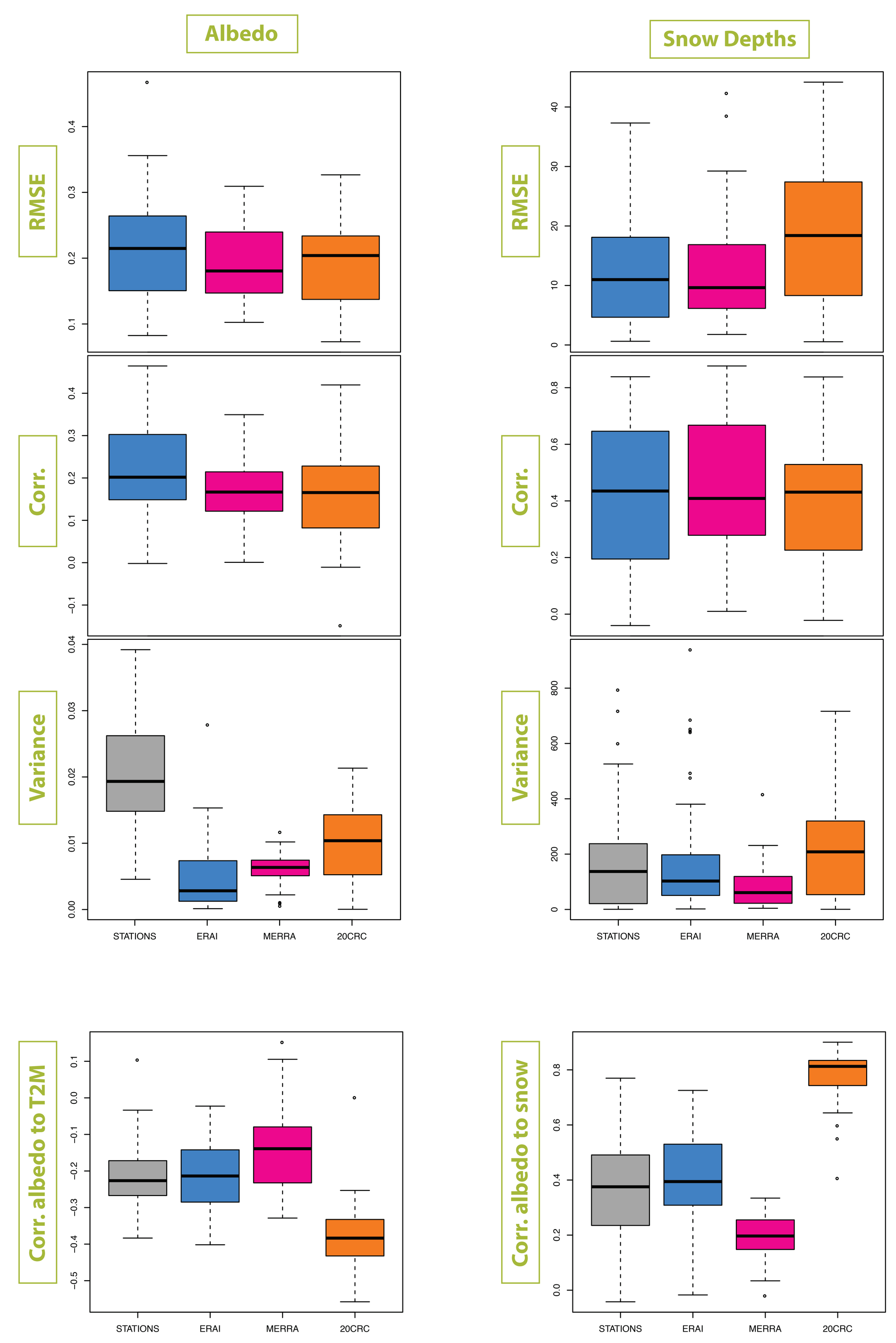
? *How is the temporal and spatial evolution of SAF (snow albedo feedback)?*

**Contact me:**
**martin.wegmann @univ-grenoble-alpes.fr**

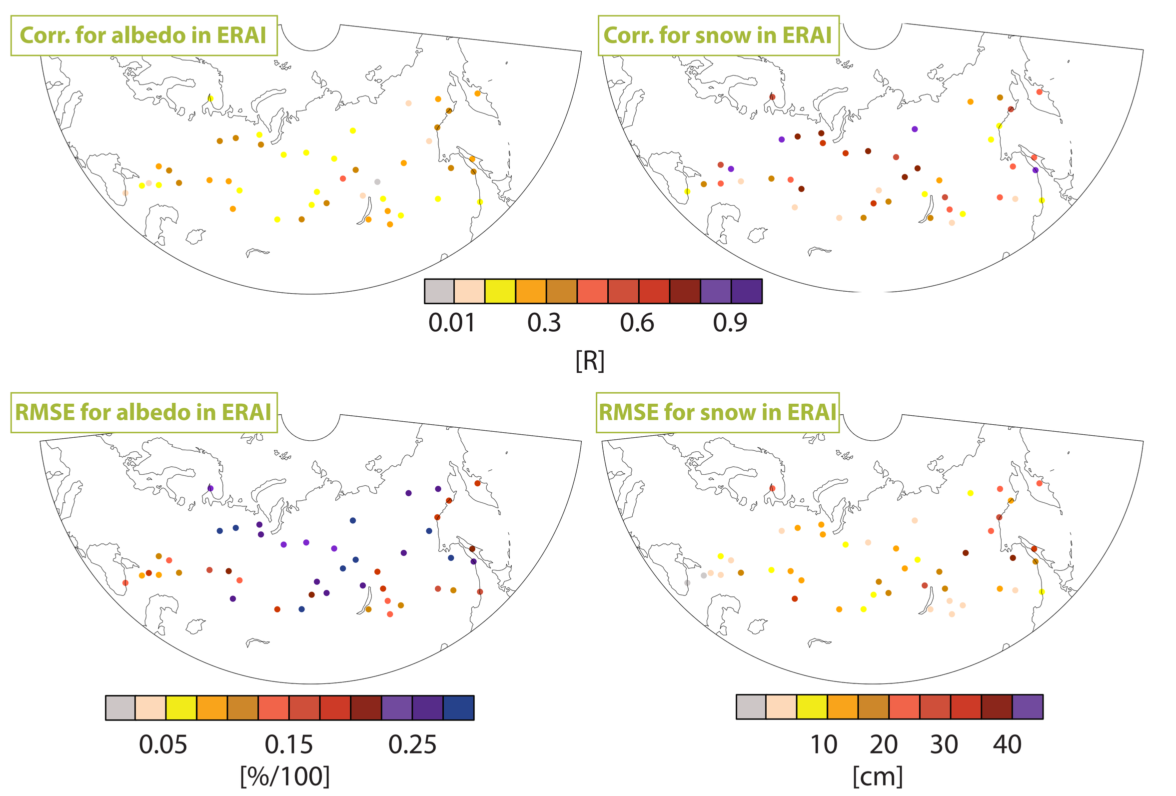
*The authors acknowledge funding by the Belmont Forum, especially within the project ARCTIC-ERA.*

## Results for Spring

### Evaluation of daily data

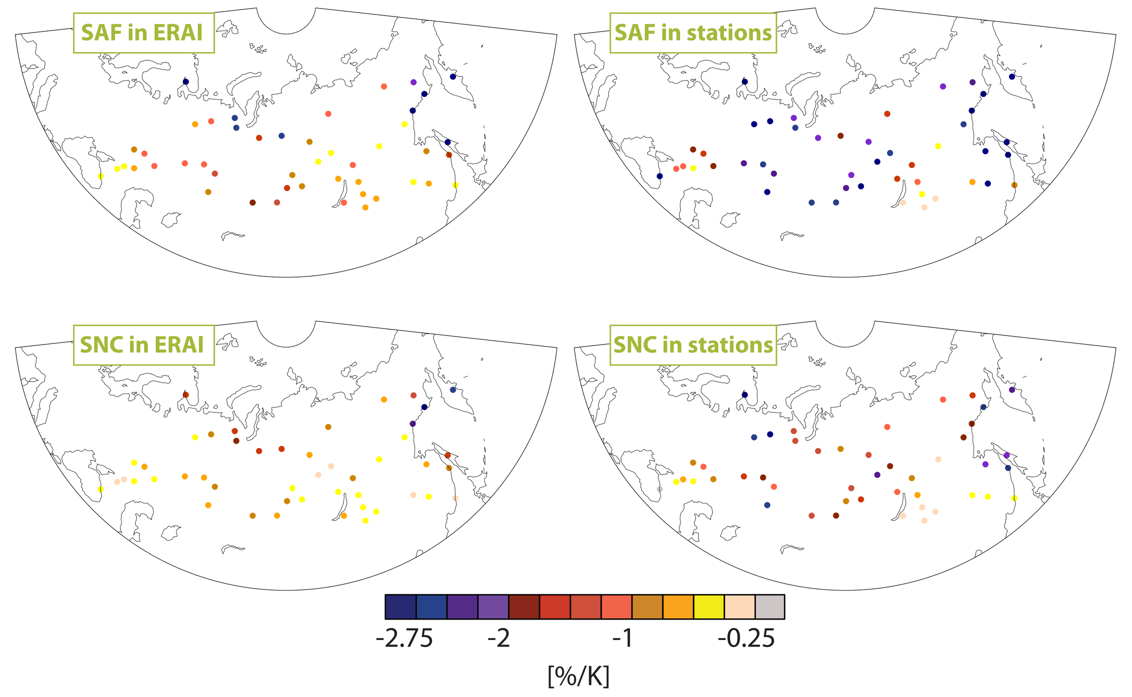


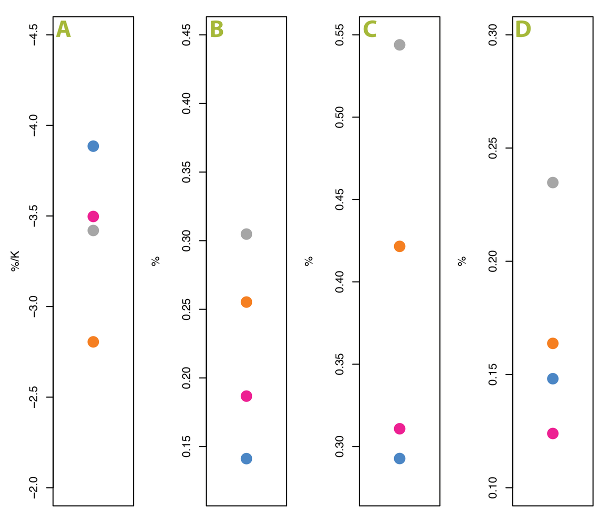

- For an assessment of snow depth and shortwave reflection performance we analyzed some **basic evaluation metrics** in the reanalyses compared to the stations. **Snow depths are considerably better reproduced than albedo**. Especially **day to day variability is understimated**.
- **20CRv2c does a fairly good job** compared to ERA-Interim and MERRA, which is surprising, considering the resolution and the assimilation scheme. However the **radiation-snow relationship is too simple/linear**. 20CRv2c is the only reanalysis which overestimates snow depths in most stations.




*Correlation and RMSE metrics for the comparison between ERA-Interim and the respective stations (e.g. correlation between station albedo and ERA-Interim albedo). High latitudes and central Siberia show high albedo RMSE values and high correlations for snow. These are regions of generally high snow cover. The opposite is true for snow RMSE and albedo correlation.*

### Spring snow albedo feedback


*A) snow melt sensitivity, B) albedo contrast, C) mean snow albedo, D) mean snow free albedo*

- The **relationship between SNC and TEM in stations is very similar** to reanalyses and the literature.
- The reason for the high SAF in stations is mostly a **high albedo contrast and a high snow albedo delta** within the season. Temperature and snow changes have minor impacts.
- The comparison of the average (over all 47 locations) snow albedo feedback terms reveals that **SAF is considerably stronger in stations** than in all reanalyses. Moreover it is higher than the estimates of satellite and model datasets.
- **SAF temporal evolution** over the 14 years shows a higher yearly variability in stations than in reanalyses. This is mainly influence by changes in snow free albedo.
- Spatially, **high SAF values are found in high latitudes**, towards Kamtchatka and central Siberia. Regions with generally high snow cover. Especially SNC in ERA-Interim shows a disctinct north-south gradient.

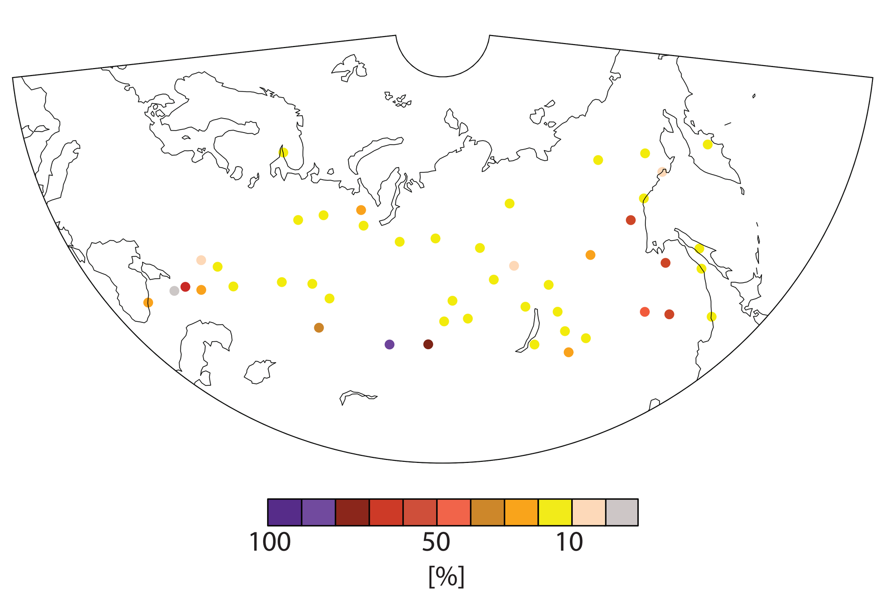
**Upcoming Experiment:**
**Set vegetation of gridboxes in station locations to grass, to come closest to WMO station guidelines. For this we will use ERA-Interim land, to improve land surface representation.**

## Conclusions

- **Reanalysis products reproduce snow depth fairly well**, especially in terms of variability. 20CRv2c captures snow variability surprisingly well, although only surface pressure is assimilated, however shows its flaws in RMSE of snow depths. The relation between radiation and snow depth is too simple in 20CRv2c, which results in unrealistically high correlation values.
- **Albedo values in reanalyses compared to the stations differ substantially**, especially variability is not well captured. This is due to the vegetation mask and grid averaging.
- **SAF, SNC and TEM values are substantially higher in stations** than in reanalyses. The main reason for this is a high albedo contrast and change of snow albedo within the season. High SAF values are mainly found at hight latitudes and central Siberia.

## Setup

### Data




*Location of the 47 stations which offer daily radiation, snow depth and 2m temperature observations. Color coded is the mean relative amount of missing daily observations for shortwave radiation in spring (MAMJ) during the period 2000-2013. Missing data in temperature and snow depth observations are negligible.*

- Daily **snow depth, 2m temperature and radiation observations** from 47 Russian meteorological stations. Solar Radiation and Radiation Balance Data is from The World Network (1964-2015) of WMO World Radiation Data Center (WRDC) at Voeikov Main Geophysical Observatory, Sankt-Petersburg.

The same variables are taken from:

- **ERA-INTERIM** (Dee et al. 2011) reanalysis on a 0.5° x 0.5° resolution
- **20CRv2c** (Cram et al. 2015) reanalysis on a 2° x 2° resolution
- **MERRA** reanalysis (Rienecker et al. 2011) on a 0.5° x 0.625° resolution

### Methods

- We use **47 stations for the period 2000-2013** to analyze spring snow albedo feedback. We define **spring as MAMJ** (month to month changes are calculated as A-M and so on) since this is the period of the strongest feedback. To compare station data with gridded products, we choose the **closest gridcell to the respective station location**.
- We calculate **snow albedo feedback (SAF)** as the sum of the **snow cover component (SNC)** and the **temperature sensitivity component (TEM)**, where

$$SNC = \left(\overline{\alpha_{snow}} - \alpha_{land}\right) \Delta S_c / \Delta T \qquad TEM = \overline{S_c}\, \Delta \alpha_{snow} / \Delta T$$

and where $\Delta$ represents the month to month change, overbars represent the spring mean, $S_c$ is snow cover fraction, $T$ is 2 m temperature and $\alpha$ is albedo, either for snow covered (snow) or snow free (land) settings.

- We used a logarhythmic function to convert snow depth to snow cover, where following Fletcher et al. 2015, **2.5 cm snow was defined as 100% snow cover**.
- We calculate **albedo from upward and downward solar radiation** or from net solar radiation and downward solar radiation. We do NOT take albedo directly from the model output.
- The monthly snow albedo was averaged over all days with > 25% snow cover
- The monthly snow free albedo was averaged over all days with = 0% snow cover