Copernicus Arctic Regional Reanalysis (CARRA): list of references

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This page includes a list of scientific work that fully or partly include diagnostics and verification and/or description of the Copernicus Arctic Regional Reanalysis (CARRA) data set. The list includes links, abstract of peer-reviewed work and some details to provide initial insight on what part of the CARRA data is evaluated. The list is not necessarily complete in terms of including all published work on and with the CARRA data set, but provides a starting point to seek information on the quality of different aspects of the data set in the literature.

Peer-reviewed studies

Schyberg et al. in preparation: The Copernicus Arctic regional reanalyis

Type of study: System description	**Parameters**: 2m air temperature and humidity, 10m wind speed, precipitation, Mean sea Level Pressure	**Comparison against:** synop observations, ERA5	**Region and time period:** 1991-2020, both CARRA domains (sub-regions: Svalbard, coast, inland etc…)	**Features**: Summary statistics, trends, case-studies

Summary/abstract (paper):

This paper is in preparation and will provide a full scientific description and evaluation of the Copernicus Arctic Regional Reanalysis. Abstract and link to published paper will be provided when published.

Batrak, Y., Cheng, B., and Kallio-Myers, V.: Sea ice cover in the Copernicus Arctic Regional Reanalysis, The Cryosphere Discuss. [preprint], https://doi.org/10.5194/tc-2023-74, in review, 2023.

Type of study: Evaluation /verification	**Parameters**: Sea ice properties	**Comparison against:** satellite products, buoys, ERA5	**Region and time period:** mainly 2000-2020, CARRA-East and CARRA-West	**Features**: Summary statistics, climatology

Summary/abstract (paper):

The Copernicus Arctic Regional Reanalysis (CARRA) is a novel regional high-resolution atmospheric reanalysis product that covers a considerable part of the European Arctic including substantial amounts of ice-covered areas. Sea ice in CARRA is modelled by means of a one-dimensional thermodynamic sea ice parameterisation scheme, which also explicitly resolves the evolution of the snow layer over sea ice. In the present study we assess the representation of sea ice cover in the CARRA product and validate it against a wide set of satellite products and observations from ice mass balance buoys. We show that sea ice cover in CARRA adequately represents general interannual trends towards thinner and warmer ice in the Arctic. Compared to ERA5, sea ice in CARRA shows a reduced warm bias in the ice surface temperature. The strongest improvement was observed for winter months over the Central Arctic, and the Greenland and Barents seas where a 4.91 °C median ice surface temperature error of ERA5 is reduced to 1.88 °C in CARRA on average. Over the Baffin Bay, intercomparisons suggest the presence of a cold winter-time ice surface temperature bias in CARRA. No improvement over ERA5 was found in the ice surface albedo with spring-time errors in CARRA being up to 8 % higher on average than those in ERA5 when computed against the CLARA-A2 satellite retrieval product. Summer-time ice surface albedos are comparable in CARRA and ERA5. Sea ice thickness and snow depth in CARRA adequately resolve the annual cycle of sea ice cover in the Arctic and bring added value compared to ERA5. However, limitations of CARRA indicate potential benefits of utilising more advanced approaches for representing sea ice cover in next generation reanalyses.

https://tc.copernicus.org/preprints/tc-2023-74/

Box, J. E., Nielsen, K. P., Yang, X., Niwano, M., Wehrlé, A., van As, D., Fettweis, X., Køltzow, Morten A. Ø., Palmason, B., Fausto, R. S., van den Broeke, M. R., Huai, B., Ahlstrøm, A. P., Langley, K., Dachauer, A., & Noël, B. (2023). Greenland ice sheet rainfall climatology, extremes and atmospheric river rapids. *Meteorological Applications*, 30(4), e2134. https://doi.org/10.1002/met.2134

Type of study: Evaluation and precipitation analysis	**Parameters**: Rainfall	**Comparison against:** in-situ, ERA5	**Region and time period:** CARRA-West	**Features**: Summary statistics, climatology, trends, case studies

Summary/abstract (paper):

Greenland rainfall has come into focus as a climate change indicator and from a variety of emerging cryospheric impacts. This study first evaluates rainfall in five state-of-the-art numerical prediction systems (NPSs) (CARRA, ERA5, NHM-SMAP, RACMO, MAR) using in situ rainfall data from two regions spanning from land onto the ice sheet. The new EU Copernicus Climate Change Service (C3S) Arctic Regional ReAnalysis (CARRA), with a relatively fine (2.5km) horizontal grid spacing and extensive within-model-domain observational initialization, has the lowest average bias and highest explained variance relative to the field data. ERA5 inland wet bias versus CARRA is consistent with the field data and other research and is presumably due to more ERA5 topographic smoothing. A CARRA climatology 1991–2021 has rainfall increasing by more than one-third for the ice sheet and its peripheral ice masses. CARRA and in situ data illuminate extreme (above 300mm per day) local rainfall episodes. A detailed examination CARRA data reveals the interplay of mass conservation that splits flow around southern Greenland and condensational buoyancy generation that maintains along-flow updraft 'rapids' 2km above sea level, which produce rain bands within an atmospheric river interacting with Greenland. CARRA resolves gravity wave oscillations that initiate as a result of buoyancy offshore, which then amplify from terrain-forced uplift. In a detailed case study, CARRA resolves orographic intensification of rainfall by up to a factor of four, which is consistent with the field data.

https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/met.2134

Frank, L., Jonassen, M. O., Skogseth, R., & Vihma, T. (2023). Atmospheric climatologies over Isfjorden, Svalbard. Journal of Geophysical Research: Atmospheres, 128, e2022JD038011. https://doi.org/10.1029/2022JD038011

Type of study: climatology	Parameters: near-surface temperature, humidity and wind as well as total cloud cover and precipitation	Comparison against:	Region and time period: Isfjorden, Svalbard, June 2011–May 2021	Features: climate statistics and synoptic flow type

Summary/abstract (paper):

The Isfjorden region at the west coast of Spitsbergen is the most easily accessible area in the Svalbard Archipelago, making it a perfect outdoor laboratory for Arctic research. Due to its location in the high Arctic together with its complex terrain, the climatic conditions vary substantially both in time and space. Based on a new high-resolution reanalysis, we present climatologies of five major atmospheric variables over the Isfjorden region during 2011–2021 with special focus on local effects. For example, we find that topographic channeling effects often lead to differences in near-surface wind speeds of several m s1 over small horizontal distances. During winter, the fjord acts as a heat and moisture island, ultimately impacting the adjacent low-elevation land areas. These land–sea gradients reverse during summer. High mountain areas surrounding the fjord experience substantially different climatic conditions, with for example, seasonal precipitation doubling from sea level to approximately 700 m. The spatial variability over the Isfjorden region is in general found to be smaller than its temporal counterpart but larger than the diurnal cycle. Besides these findings, this study furthermore demonstrates the importance of high-resolution regional atmospheric reanalyses compared to global products for the characterization of the local micro-climate over Arctic fjords and the interaction with surrounding land areas.

https://doi.org/10.1029/2022JD038011

Grinsted, A., Rathmann, N. M., Mottram, R., Solgaard, A. M., Mathiesen, J., and Hvidberg, C. S.: Failure strength of glacier ice inferred from Greenland crevasses, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1957, 2023

Type of study: Glacier	Parameters: surface air temperature	Comparison against:	Region and time period: Greenland, 1991-2020	Features: Input to glacier calculations

Summary/abstract (paper): Ice fractures when subject to stress that exceeds the material failure strength. Previous studies have found that a von Mises failure criterion, which places a bound on the second invariant of the deviatoric stress tensor, is consistent with empirical data. Other studies have suggested that a scaling effect exists, such that larger sample specimens have a substantially lower failure strength, implying that estimating material strength from laboratory-scale experiments may be insufficient for glacier-scale modelling. In this paper, we analyze the stress conditions in crevasse onset regions to better understand the failure criterion and strength relevant for large-scale modelling. The local deviatoric stress is inferred using surface velocities and reanalysis temperatures, and crevasse onset regions are extracted from a remotely sensed crevasse density map. We project the stress state onto the failure plane spanned by Haigh–Westergaard coordinates, showing how failure depends on mode of stress. We find that existing crevasse data is consistent with a Schmidt–Ishlinsky failure criterion that places a bound on the absolute value of the maximal principal deviatoric stress, estimated to be (158 ± 44) kPa. Although the traditional von Mises failure criterion also provides an adequate fit to the data with a von Mises strength of (265 ± 73) kPa, it depends only on stress magnitude and is indifferent to the specific stress state, unlike Schmidt–Ishlinsky failure which has a larger shear failure strength compared to tensile strength. Implications for large-scale ice-flow and fracture modelling are discussed.

https://doi.org/10.5194/egusphere-2023-1957

Hansche, I., Shahi, S., Abermann, J., & Schöner, W. (2023). The vertical atmospheric structure of the partially glacierised Mittivakkat valley, southeast Greenland. Journal of Glaciology, 1-12. doi:10.1017/jog.2022.120

Type of study:	Parameters:	Comparison against:	Region and time period:	Features;
Investigation of atmospheric temperature inversions	air temperature	UAV-observations compared with CARRA, ERA5, ERA-interim and radiosondes	Mittivakkat valley (southeast Greenland), field campaign summer 2019	Inversion characteristics, comparisons by correlation and RMSE

Summary/abstract(paper):

Air temperature inversions, a situation in which atmospheric temperature increases with height, are key components of the Arctic planetary boundary layer. The present study investigates the spatial and temporal variations of temperature inversions over different surface types (rock, gravel, snow, ice) along the Mittivakkat valley (southeast Greenland). For this purpose, 113 vertical profiles with high spatio-temporal resolution of air temperature and relative humidity were collected with unoccupied aerial vehicles (UAVs) during a 13-day field campaign in summer 2019. Air temperature inversions were present in 83% of the profiles, of which 24% were surface-based inversions and 76% were elevated inversions. The proglacial area covered with bare rock and gravel induces surface heating and convection during the day and, through interaction with local circulation patterns, leads to the frequent formation of elevated inversions. In contrast, the glacier surface itself acts as a persistent cooling surface and leads to the formation of surface-based inversions. A low-level fog layer that forms under the inversion layer may be causing non-linear vertical ablation gradients on Mittivakkat Gletsjer. Furthermore, we demonstrate that atmospheric measurements using UAVs can better capture small-scale processes than other products like radiosonde or modeled reanalysis data.

https://www.cambridge.org/core/journals/journal-of-glaciology/article/vertical-atmospheric-structure-of-the-partially-glacierised-mittivakkat-valley-southeast-greenland/F47255DD27CFAE332D23FD61FBEEB448

Helgason, H. B. and Nijssen, B.: LamaH-Ice: LArge-SaMple Data for Hydrology and Environmental Sciences for Iceland, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2023-349, in review, 2023

Type of study: Hydrology	Parameters: Precipitation	Comparison against: in-situ observations	Region and time period: Iceland, 1991-2023	Features: Precipitation amount

Summary/abstract (paper):

Access to mountainous regions for monitoring streamflow, snow and glaciers is often difficult, and many rivers are thus not gauged and hydrological measurements are limited. Consequently, cold-region watersheds, particularly heavily glacierized ones, are poorly represented in large-sample hydrology (LSH) datasets. We present a new LSH dataset for Iceland, termed LamaH-Ice (LArge-SaMple DAta for Hydrology and Environmental Sciences for Iceland). Glaciers and ice caps cover about 10 % of Iceland and while streamflow has been measured for several decades, these measurements have not been published in a consistent manner before. The dataset provides daily and hourly hydrometeorological timeseries and catchment characteristics for 107 river basins in Iceland, covering an area of almost 46,000 km^2 (45 % of Iceland's area), with catchment sizes ranging from 4 to about 7,500 km^2. LamaH-Ice conforms to the structure of existing LSH datasets and includes most variables offered in these datasets, as well as additional information relevant to cold-region hydrology, e.g., timeseries of snow cover, glacier mass balance and albedo. LamaH-Ice also includes dynamic catchment characteristics to account for changes in land cover, vegetation, and glacier extent. A large majority of the watersheds in LamaH-Ice are not subject to human activities, such as diversions and flow regulations. Streamflow measurements under natural flow conditions are highly valuable to hydrologists seeking to model and comprehend the natural hydrological cycle or estimate climate change trends. The LamaH-Ice dataset (Helgason and Nijssen, 2023) is intended for the research community to improve the understanding of hydrology in cold-region environments.

https://doi.org/10.5194/essd-2023-349

Khachatrian, E.; Asemann, P.; Zhou, L.; Birkelund, Y.; Esau, I.; Ricaud, B. Exploring the Potential of Sentinel-1 Ocean Wind Field Product for Near-Surface Offshore Wind Assessment in the Norwegian Arctic. *Atmosphere* 2024, *15*, 146. https://doi.org/10.3390/atmos15020146

Type of study: Intercomparison	Parameters: wind speed	Comparison against: Sentinel wind, in-situ, ERA5, NORA3	Region and time period: Goliat station off the Northern Norway coast, 2022	Features: wind

Summary/abstract (paper):

The exploitation of offshore wind resources is a crucial step towards a clean energy future. It requires an advanced approach for high-resolution wind resource evaluations. We explored the suitability of the Sentinel-1 Level-2 OCN ocean wind field (OWI) product for offshore wind resource assessments. The SAR data were compared to in situ observations and three reanalysis products: the global reanalysis ERA5 and two regional reanalyses CARRA and NORA3. This case study matches 238 scenes from 2022 for the Goliat station, an oil platform located 85 km northwest of Hammerfest in the Barents Sea, where a new offshore wind park has been proposed. The analysis showed that despite their unique limitations in spatial and temporal resolutions, all data sources have similar statistical properties (RMSE, correlation coefficient, and standard deviation). The Weibull parameters characterizing the wind speed distributions showed strong similarities between the Sentinel-1 and all reanalysis data. The Weibull parameters of the in situ measurements showed an underestimation of wind speed compared to all other sources. Comparing the full reanalysis datasets with the subsets matching the SAR scenes, only slight changes in Weibull parameters were found, indicating that, despite its low temporal resolution, the Sentinel-1 Level 2 OWI product can compete with the more commonly used reanalysis products in the estimation of offshore wind resources. Its high spatial resolution, which is unmatched by other methods, renders it especially valuable in offshore areas close to complex coastlines and in resolving weather events at a smaller scale.

https://doi.org/10.3390/atmos15020146

Kirbus, B., Schirmacher, I., Klingebiel, M., Schäfer, M., Ehrlich, A., Slättberg, N., Lucke, J., Moser, M., Müller, H., and Wendisch, M.: Thermodynamic and cloud evolution in a cold air outbreak during HALO-(AC)3: Quasi-Lagrangian observations compared to the ERA5 and CARRA reanalyses, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-2989, 2023.

Type of study: Arctic air mass transformations	**Parameters**: temperature, humidity, clouds	**Comparison against:** in-situ observations and ERA5	**Region and time period:** Fram strait, 1. April 2022	**Features**: Cold air outbreak

Summary/abstract (paper):

Intense air mass transformations take place when cold, dry Arctic air masses move southward from the closed sea ice onto the much warmer ice-free Arctic ocean during marine cold air outbreaks (MCAOs). In spite of intensive research on MCAOs during recent years, the temporal rates of diabatic heating and moisture uptake relevant also for cloud formation/dissipation have not been measured along MCAO flows. Instead, reanalyses have typically been used for climatological investigations of MCAOs or to supply higher-resolution models with lateral boundary conditions and time-dependent forcings. Meanwhile, the uncertainties connected to those datasets remain unclear.

Here, we present height-resolved observations of diabatic heating rates, moisture uptake, and cloud evolution measured in a quasi-Lagrangian manner. The investigated specific MCAO was observed on 01 April 2022 during the HALO-(AC)3 airborne campaign that was conducted in spring 2022. Shortly after passing the ice edge, maximum diabatic heating rates larger than 6 K h1 and moisture uptake of more than 0.3 g kg1 h1 were measured close above the ocean surface. As the air mass continued its drift southwards, clouds started to form and vertical mixing within the steadily deepening boundary layer was intensified. The quasi-Lagrange observations are compared with reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF) latest global reanalysis ERA5 and the Copernicus Arctic Regional Reanalysis (CARRA). It was found that the mean absolute errors (MAEs) of ERA5 versus CARRA data are 60 % higher for air temperature over sea ice (1.4 K versus 0.9 K), and 70 % higher for specific humidity over ice-free ocean (0.12 g kg1 versus 0.07 g kg1). We relate these differences not only to issues with representations of the marginal ice zone and corresponding surface fluxes in ERA5, but also to the cloud scheme producing excess liquid-bearing clouds and precipitation, causing a too-dry marine boundary layer. Overall, the combination of CARRA's high spatial resolution, an improved handling of cold surfaces, and the demonstrated higher fidelity towards the observations, make it a well-suited candidate for further investigations of Arctic air mass transformations.

https://doi.org/10.5194/egusphere-2023-2989

Køltzow M., Schyberg H., Støylen E., & Yang X. (2022). Value of the Copernicus Arctic Regional Reanalysis (CARRA) in representing near-surface temperature and wind speed in the north-east European Arctic. Polar Research, 41. https://doi.org/10.33265/polar.v41.8002

Type of study: Evaluation/verification	**Parameters**: 2m air temperature, 10m wind speed	**Comparison against:** synop observations, ERA5	**Region and time period:** 1998-2018, CARRA-East (sub-regions: Svalbard, coast, inland etc…)	**Features**: Summary statistics, spatial and temporal variability, extremes/ high-impact

Summary/abstract (paper):

The representation of 2-m air temperature and 10-m wind speed in the high-resolution (with a 2.5-km grid spacing) Copernicus Arctic Regional Reanalysis (CARRA) and the coarser resolution (ca. 31-km grid spacing) global European Center for Medium-range Weather Forecasts fifth-generation reanalysis (ERA5) for Svalbard, northern Norway, Sweden and Finland is evaluated against observations. The largest differences between the two reanalyses are found in regions with complex terrain and coastlines, and over the sea ice for temperature in winter. In most aspects, CARRA outperforms ERA5 in its agreement with the observations, but the value added by CARRA varies with region and season. Furthermore, the added value by CARRA is seen for both parameters but is more pronounced for temperature than wind speed. CARRA is in better agreement with observations in terms of general evaluation metrics like bias and standard deviation of the errors, is more similar to the observed spatial and temporal variability and better captures local extremes. A better representation of high-impact weather like polar lows, vessel icing and warm spells during winter is also demonstrated. Finally, it is shown that a substantial part of the difference between reanalyses and observations is due to representativeness issues, that is, sub-grid variability, which cannot be represented in gridded data. This representativeness error is larger in ERA5 than in CARRA, but the fraction of the total error is estimated to be similar in the two analyses for temperature but larger in ERA5 for wind speed.

https://polarresearch.net/index.php/polar/article/view/8002/14479

Isaksen, K., Nordli, Ø., Ivanov, B. et al. Exceptional warming over the Barents area. Sci Rep 12, 9371 (2022). https://doi.org/10.1038/s41598-022-13568-5

Type of study:	**Parameters:**	**Comparison against:**	**Region and time period:**	**Features;**
Investigation of temperature trends	2m air temperature	ERA5, dependent and in-dependent in-situ/synop	1991-2020, Svalbard and Barents Sea area	Trends, summary statistics (bias, standard deviation of error, RMSE), sea-ice dependency

Summary/abstract(paper):

In recent decades, surface air temperature (SAT) data from Global reanalyses points to maximum warming over the northern Barents area. However, a scarcity of observations hampers the confidence of reanalyses in this Arctic hotspot region. Here, we study the warming over the past 20–40 years based on new available SAT observations and a quality controlled comprehensive SAT dataset from the northern archipelagos in the Barents Sea. We identify a statistically significant record-high annual warming of up to 2.7 °C per decade, with a maximum in autumn of up to 4.0 °C per decade. Our results are compared with the most recent global and Arctic regional reanalysis data sets, as well as remote sensing data records of sea ice concentration (SIC), sea surface temperature (SST) and high-resolution ice charts. The warming pattern is primarily consistent with reductions in sea ice cover and confirms the general spatial and temporal patterns represented by reanalyses. However, our findings suggest even a stronger rate of warming and SIC-SAT relation than was known in this region until now.

https://www.nature.com/articles/s41598-022-13568-5

Moore, G. W. K., & Imrit, A. A. (2022). Impact of resolution on the representation of the mean and extreme winds along Nares Strait. Journal of Geophysical Research: Atmospheres, 127, e2022JD037443. https://doi.org/10.1029/2022JD037443

Type of study:	**Parameters:**	**Comparison against:**	**Region and time period:**	**Features;**
Investigation of wind speed in complex terrain	10 m wind speed	ERA5, ECMWF Operational analysis and in-situ/synop	2016-2019, Nares strait	General statistics and extremes

Summary/abstract (paper):

Nares Strait is the long and narrow strait bounded by steep topography that connects the Arctic Ocean's Lincoln Sea to the North Atlantic's Baffin Bay. The winds that blow along the strait play an important role in modulating ice and water exports from the Arctic Ocean as well as in helping to establish the Arctic's largest and most productive polynya that forms at its southern terminus. However, its remote location has limited our knowledge of the winds along the strait. Here we use weather station data from the region as well as two reanalyses and an operational analysis with nominal horizontal resolutions that vary from 30 to 2.5 km to characterize the wind field in the vicinity of the strait. The strait has a width that varies from 40 to 100 km and as such the wind field is typically ageostrophic and controlled by the pressure gradient in the along-strait direction. We show that model resolution plays a role in the representation of both the mean and extreme winds along the strait through the ability to represent this ageostrophic flow. Higher windspeeds occur in the vicinity of Smith Sound and are associated with a left-hand corner jet. Kane Basin, the widest section of the strait, is characterized by a gradient in windspeed with higher speeds in the center of the basin and lower winds in the eastern basin that is the result of sheltering by the steep topography of the upstream Washington Land peninsula.

https://doi.org/10.1029/2022JD037443

Lundesgaard, Ø., Sundfjord, A., Lind, S., Nilsen, F., and Renner, A. H. H.: Import of Atlantic Water and sea ice controls the ocean environment in the northern Barents Sea, Ocean Sci., 18, 1389–1418, https://doi.org/10.5194/os-18-1389-2022, 2022

Type of study:	Parameters:	Comparison against:	Region and time period:	Features;
Ocean properties	10m wind speed & MSLP	in-situ/synop, ocean currents	2018-2020, Northern Barents Sea	Relationship between atmosphere forcing and ocean currents

Summary/abstract (paper):
The northern Barents Sea is a cold, seasonally ice-covered Arctic shelf sea region that has experienced major warming and sea ice loss in recent decades. Here, a 2-year observational record from two ocean moorings provides new knowledge about the seasonal hydrographic variability in the region and about the ocean exchange across its northern margin. The combined records of temperature, salinity, and currents show the advection of warmer and saltier waters of Atlantic origin into the Barents Sea from the north. The source of these warmer water masses is the Atlantic Water boundary current that flows along the continental slope north of Svalbard. Time-varying southward inflow through cross-shelf troughs was the main driver of the seasonal cycle in ocean temperature at the moorings. Inflows were intensified in autumn and early winter, in some cases occurring below the sea ice cover and halocline water. On shorter timescales, subtidal current variability was correlated with the large-scale meridional atmospheric pressure gradient, suggesting wind-driven modulation of the inflow. The mooring records also show that import of sea ice into the Barents Sea has a lasting impact on the upper ocean, where salinity and stratification are strongly affected by the amount of sea ice that has melted in the area. A fresh layer separated the ocean surface from the warm mid-depth waters following large sea ice imports in 2019, whereas diluted Atlantic Water was found close to the surface during episodes in autumn 2018 following a long ice-free period. Thus, the advective imports of ocean water and sea ice from surrounding areas are both key drivers of ocean variability in the region.

https://doi.org/10.5194/os-18-1389-2022

Steffensen Schmidt, L., Schuler, T. V., Thomas, E. E., and Westermann, S.: Meltwater runoff and glacier mass balance in the high Arctic: 1991–2022 simulations for Svalbard, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-1409, 2023.

Type of study:	Parameters:	Comparison against:	Region and time period:	Features;
glacier mass balance, runoff and snow conditions	2m air temperature, 2m relative humidity, 10m wind speed, incoming short- and longwave radiation	Dependent and independent in-situ observations-	1991-2021, Svalbard	Evaluation of CARRA used as forcing data for relevant parameters. Bias and RMSE are calculated.

preprint open for discussion

Summary/abstract (paper):

The Arctic is undergoing increased warming compared to the global mean, which has major implications for fresh-water runoff into the oceans from seasonal snow and glaciers. Here, we present high-resolution (2.5 km) simulations of glacier mass balance, runoff and snow conditions in Svalbard from 1991–2022, one of the fastest warming regions in the Arctic. The simulations are created using the CryoGrid community model forced by both CARRA reanalysis (1991–2021) and AROME-ARCTIC forecasts (2016–2022). Updates to the water percolation and runoff scheme are implemented in the CryoGrid model for the simulations. In-situ observations available for Svalbard are used to carefully evaluate the quality of the simulations and model forcing. The overlap period of 2016–2021, when both CARRA and AROME-ARCTIC data are available, is used to evaluate the consistency between the two forcing datasets.

We find a slightly negative climatic mass balance (cmb) over the simulation period of 0.08 m w.e. yr1, but with no statistically significant trend. The average runoff was found to be 41 Gt yr1, with an significant increasing trend of 6.3 Gt decade1. In addition, we find the simulated climatic mass balance and runoff using CARRA and AROME-ARCTIC forcing are similar, and differ by only 0.1 m w.e. in climatic mass balance and by 0.2 m w. e. in glacier runoff when averaged over all of Svalbard. There is, however, a clear difference over Nordenskiöldland, where AROME-ARCTIC simulates significantly higher mass balance and significantly lower runoff. This indicates that AROME-ARCTIC may provide high-quality predictions of the total mass balance of Svalbard, but regional uncertainties should be taken into consideration.

The data produced from both the CARRA and AROME-ARCTIC forced CryoGrid simulations are made publicly available, and these high resolution simulation may be re-used in a wide range of applications including studies on glacial runoff, ocean currents, and ecosystems

https://egusphere.copernicus.org/preprints/2023/egusphere-2022-1409/

Vickers Hannah, Saloranta Tuomo, Køltzow Morten, van Pelt Ward J. J., Malnes Eirik, 2024, An analysis of winter rain-on-snow climatology in Svalbard, Frontiers in Earth Science, Vol 12, 10.3389/feart. 2024.1342731

Type of study: Rain on snow	Parameters: Precipitation and temperature	Comparison against: in-situ + other ROS data sets	Region and time period: Svalbard 2004-2020	Features; Rain-on-snow

Summary/abstract (paper):

Rain-on-snow (ROS) events are becoming an increasingly common feature of the wintertime climate Svalbard in the High Arctic due to a warming climate. Changes in the frequency, intensity, and spatial distribution of wintertime ROS events in Svalbard are important to understand and quantify due their wide-ranging impacts on the physical environment as well as on human activity. Due to the sparse nature of ground observations across Svalbard, tools for mapping and long-term monitoring of ROS events over large spatial areas are reliant on remote sensing, snow models and atmospheric reanalyses. However, different methods of identifying and measuring ROS events can often present different interpretations of ROS climatology. This study compares a recently published Synthetic Aperture Radar (SAR) based ROS dataset for Svalbard to ROS derived from two snow models and a reanalysis dataset for 2004–2020. Although the number of ROS events differs across the datasets, all datasets exhibit both similarities and differences in the geographical distribution of ROS across the largest island, Spitsbergen. Southern and western coastal areas experience ROS most frequently during the wintertime, with the early winter (November–December) experiencing overall most events compared to the spring (March–April). Moreover, we find that different temperature thresholds are required to obtain the best spatial agreement of ROS events in the model and reanalysis datasets with ground observations. The reanalysis dataset evaluated against ground observations was superior to the other datasets in terms of accuracy due to the assimilation of ground observations into the dataset. The SAR dataset consistently scored lowest in terms of its overall accuracy due to many more false detections, an issue which is most likely explained by the persistence of moisture in the snowpack following the end of a ROS event. Our study not only highlights some spatial differences in ROS frequency and trends but also how comparisons between different datasets can confirm knowledge about the climatic variations across Svalbard where *in-situ* obs ervations are sparse.

https://www.frontiersin.org/articles/10.3389/feart.2024.1342731/full

A selection of relevant presentations

Box, J., 2022: C3S General Assembly, September 2022: What can the Copernicus Arctic Regional Reanalysis (CARRA) add to the existing reanalysis information in Greenland? (Presentation) Recorded presentations available at: https://climate.copernicus.eu/5th-c3s-general-assembly

Box, J., 2022: Copernicus Polar Workshop, September 2022, Extreme Greenland ice sheet climate events in high-detail via the Copernicus Arctic Regional Reanalysis (CARRA).

Køltzow, M. et al., 2022, C3S General Assembly, September 2022: The strengths and weaknesses of the new Arctic (CARRA) and European (CERRA) regional reanalyses (Presentation) Recorded presentations available at: https://climate.copernicus.eu/5th-c3s-general-assembly

Multiple authors, 2020: User workshop on Copernicus regional reanalysis for Europe and the European Arctic, September 2020. Multiple (recorded) presentations.

A selection of relevant conference abstracts and not peer-reviewed literature

Dahlgren, P. and T. Valkonen, 2021: Use of wind retrievals in regional reanalysis, 15th International Winds Workshop, online, abstract available in abstract brochure here: http://cimss.ssec.wisc.edu/iwwg/iww15/index.html

Kallio-Myers, V., Batrak, Y., and Cheng, B.: Comparison of Arctic sea-ice albedo between CARRA and ERA5 reanalyses and satellite based CLARA-A2, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-1510, https://doi.org/10.5194/egusphere-egu23-1510, 2023.

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