Final report
Guest research collaboration on Arctic clouds (GCloudI) to
Alexander Chernokulsky

Background.

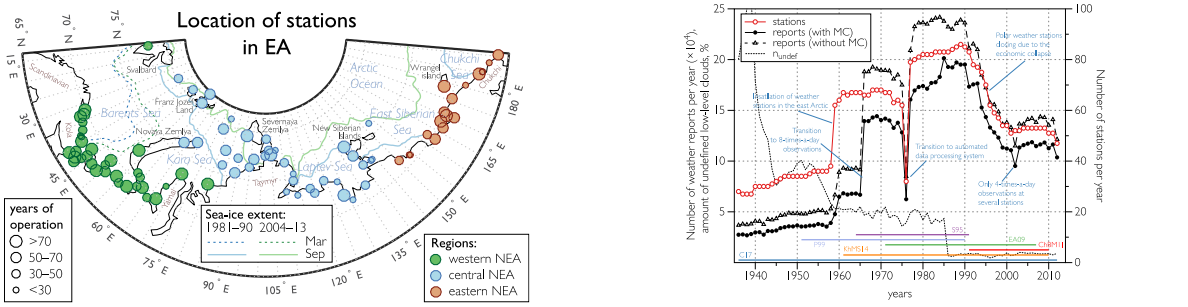

Figure 1. (left panel) Geographical locations of the meteorological stations analyzed in the project; and **(right panel)** historical variation of the number of cloud records used in the project.

The sea ice reduction in the Arctic Ocean modifies the cloud cover with a suggested large effect on the cloud types. Furthermore, some researchers suggested that there could be strong positive feedbacks between the polar warming and the cloudiness in the changing climate. There are however serious drawbacks in the published, mostly satellite- and model-based studies. Namely, the studies do not differentiate the cloud impact with respect to the cloud type. By the other words, the increasing cloudiness and the cloud moist convection mean the increasing fraction/optical thickness of clouds everywhere; whereas the observations reveal that the convective clouds undergo spatial self-organization into the persistent cloud roll/cell patterns. The cloud self-organization implies several important effects. The convective cloud transformation opens a significant fraction of clear sky. Commonly observed in Norwegian Sea, convective clouds are increasingly frequent in the Barents, Kara seas, and, perhaps, in the eastern arctic seas as well. Despite the important role of the polar clouds and the cloud-related feedbacks, their climatology is still incomplete and inconsistent. The models are rather inaccurate in simulations of the polar clouds. They require significant improvement of the polar cloud processes' parametrizations, to which the lack of robust climatology and the micro-scale process knowledge are the major impeding factors. Although there are significant challenges in composing the polar cloud climatology, there are large archives of the Russian historical data now available, but unprocessed and unpublished. The project intends to advance the statistical processing methodology, quality control methods and interpretation theories to close the data and knowledge gaps.

Objectives.

- Extend statistical processing and publication of the historical station data, involving the data from the eastern arctic area into the analysis.
- Investigate the cloud type's statistics and the cloud type's transformation in response to the sea ice, atmospheric circulation and temperature changes.

More specifically:

A. Process the historical observational cloud data from the Kara, Laptev, East-Siberian, Chukchi seas. **(completed)**

B. Prepare the combined climatology of the cloud cover and cloud types over the Eurasian Arctic east of the Norwegian Sea. **(completed)**

C. Improve interpretation of the observed cloud type changes in the polar region and combine the IAP cloud climatology and the NERSC modelling studies. **(completed)**

D. Explore the wider impact of the polar cloud types and the cloud cover changes. **(completed)**

Implementation (describe how the project was realized, steps in the process)

The detailed description of the project activity and results could be found on https://www.nersc.no/project/gcloudl

During the initial research visit of A. Chernokulsky, the data set was developed and analyzed. Lectures were given at University in Bergen, Bjerknes Centre for Climate Research, and Nansen Centre.

The web-page with the research results was created.
The first project publication by Chernokulsky et al. (2018) was submitted to *Russian Meteorology and Hydrology*.

During the final research visit of A. Chernokulsky, the data set was made available; the analysis was visualized and processes into a final publication.

The second project publication is submitted to the *International Journal of Climatology*.

Achievements (what was achieved in relation to the objectives? what was the added value to education, outreach or communication about climate science?)

Data analysis.
The project has completed the work with the data collection and analysis. Initial data for the presented analysis came from routine meteorological observations that conducted at 104 Russian meteorological stations located in the Arctic (see illustrations on https://www.nersc.no/project/gcloudl). *In situ* observations are preliminary processed and stored in the All-Russian Research Institute of Hydrometeorological Information, RIHMI (Bulygina et al., 2014; Chernokulsky et al., 2011). The RIHMI dataset contains information on total and low cloud cover and morphological cloud types for each report. This data set was quality controlled and processed. All satisfied reports were simply averaged (with equal weights) for each month for obtaining monthly means values. We calculated amount of different low-level cloud types; estimated amount of three following cloud groups: cumulus plus cumulonimbus, stratus plus nimbostratus, and stratocumulus. Although observations in the Russian Arctic started in 1893, the further analysis focuses on the period 1936–2013 because of an overall low quality of cloud observations in prior decades. After 1936, the systematic bias of analyzed cloud characteristics for seasonal means is below 3%. We calculated seasonal means by simple averaging of monthly means (if at least two monthly means were defined for a particular season) for one-month shifted calendar (that is January–February–March for winter and so on) and analyzed variations of cloud characteristics for each separate station. To simplify the presentation of results, we divided stations into coastal and island groups.

All data-related objectives were fully completed, and the final data set is now publicly available.

Added value to education, outreach and communication about climate science.
Alexander Chernokulsky run an extensive education and outreach activity. During his visit, he held seminars at NERSC and University in Bergen. He made the cloud data set available to the international research community. He run a training section for young scientists during the 22nd International school-conference for young scientists «Atmospheric composition. Atmospheric electricity. Climatic processes. SATEP-2018». He held the public lecture on a popular science forum “Scientists against myths” in Moscow (see https://www.youtube.com/watch?v=7VGtgSUB8DM in Russian).
The research results were presented to the scientific community at the European Geophysical Union Assembly and in a journal publication.

Publications

[***1st project publication***] Chernokulsky A.A., Kozlov F.G., Zolina O.N., Bulygina O.A. Semenov V. (2018). Climatology of Precipitation of Different Genesis in Northern Eurasia. *Russian Meteorology and Hydrology*, 43, 425-435. doi:10.3103/S1068373918070014.

[***2nd project publication***] Chernokulsky A.A., Esau I. (2019). Variability of the observed cloud cover and cloud types in the Eurasian Arctic in 1936–2012. *International Journal of Climatology*, submitted.

Other project communication activity

Chernokulsky A., Esau I., Bulygina O., Mokhov I. (2018) Long-term variability of cloudiness over the Russian and Norwegian Arctic, Abstracts of SCAR & IASC conference POLAR-2018, presented at Davos, on 19 June 2018, poster

Chernokulsky A., Esau I. (2018) Cloud cover and cloud types in the Russian and Norwegian Arctic 1936–2013, Proceedings of 22nd International school-conference for young scientists «Atmospheric composition. Atmospheric electricity. Climatic processes. SATEP-2018», p.92, presented at Maikop, on 27 September 2018, oral.

Chernokulsky A.V., Kozlov F.A. (2018) Precipitation type redistribution toward convective rainfall increase over Northern Eurasia in 1965-2017. Research Activities in Atmospheric and Oceanic Modelling. E. Astakhova (ed.), WCRP Report № 15/2018, P.02.07–02.08.

Shikhov A.N., Chernokulsky A.V., Sprygin A.A., Azhigov I.O. Identification of mesoscale convective cloud systems with tornadoes using satellite data, Sovremennye Problemy Distantsionnogo Zondirovaniya Zemli iz Kosmosa, V. 15, 2018, [in press].

Guest project GCloudl in NANSEN NEWS 2/2018

Chernokulsky A.V., Esau I., Bulygina O.N., Mokhov I.I. (2018). Long-term variability of cloudiness over the Russian and Norwegian Arctic, 07.03.2018, UiB GFI seminar [announce]

Budget (specify the final budget)

The project has accounted total for **84.219,16 NOK**

This amount has been used for:

- The publication cost is 13.477,99 NOK
- Consumables 2.140,08 NOK
- Alexander Chernokulsky research visit in 2017 – 23.965,33 NOK
- Alexander Chernokulsky research visit in 2018 – 44.635,33 NOK

The contract budget from the Norwegian Research Council is **84.000 NOK**, the own financing **219,16 NOK.**