Introduction/ Methods
Seasonality
precipitation
moisture sources
North-Atlantic Oscillation
precipitation
moisture sources
Temporal trend
Conclusions

- Display for virtual EGU conference 2020 -
Lagrangian detection of moisture sources for an arid region in Northeast Greenland: relations to the North-Atlantic Oscillation and temporal trends from 1979 to 2017

Lilian Schuster[1], Fabien Maussion[1], Lukas Langhamer[2], Gina E. Moseley[3]

[1]Department of Atmospheric and Cryospheric Sciences, University of Innsbruck, Austria
[2]Department of Geography, Humboldt University of Berlin, Germany
[3]Institute of Geology, University of Innsbruck, Austria

8th of May, 2020

E-mail: lilian.schuster@student.uibk.ac.at

Introduction

- Northeast Greenland is predicted to be one of the most sensitive terrestrial areas of the Arctic to anthropogenic climate change, resulting in an increase in temperature that is much greater than the global average. Associated with this temperature rise, precipitation is also expected to increase as a result of increased evaporation from an ice-free Arctic Ocean[a].
- In recent years, numerous palaeoclimate projects have begun working in the region with the aim of improving our understanding of how this highly-sensitive region responds to a warmer world. However, a lack of meteorological stations measuring precipitation within the area makes it difficult to place the palaeoclimate records in the context of modern climate. The study region hosts many speleothem-containing caves that are being studied in the framework of the Greenland Caves Project (`greenlandcavesproject.org`).

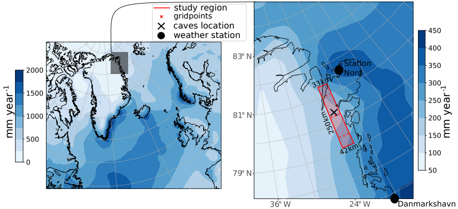

Figure 1: **Average of yearly ERA-Interim precipitation (1979–2017). The study region is depicted with the nine gridpoints located between 22.5° W and 21° W and between 79.5° N and 81° N. Average precipitation in the study region is 207 [192, 224][b] mm year^{-1}.**

Figure 2: **Photograph from the dry study region near to the location of the caves,** ©Robbie Shone/Greenland Caves Project (August 2015)

This study aims to improve our understanding of precipitation and moisture source dynamics over a small arid region located at 80° N in Northeast Greenland using reanalysis data from the European Centre for Medium-Range Weather Forecasts (ERA-Interim) from 1979 to 2017.

[a] **Bintanja, R.** *et al.*: Future increases in Arctic precipitation linked to local evaporation and sea-ice retreat, `https://doi.org/10.1038/nature13259`, 2014

[b] [,] denotes the 95 % confidence interval computed by a bootstrapping method

Method to estimate moisture sources contributing to precipitation

moisture source uptake locations diagnosed by identifying specific humidity changes along lagrangian backward trajectories

(trajectories computed as in Langhamer (2018)[a] based on Sodemann et al. (2008)[b] and using LAGRANTO[c])

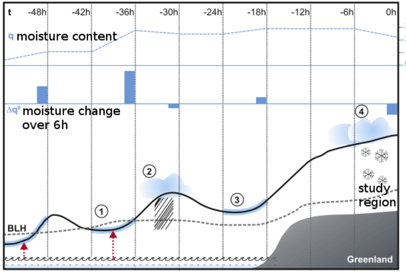

Figure 3: Sketch of method to identify moisture uptake along backward trajectory, adapted from Sodemann (2008)[b] Fig. 1

① (below 1.5xBLH [Boundary Layer Height]) $\Delta q \uparrow$: assumed evaporation & moisture uptake over this location

② $\Delta q \downarrow$: precipitation $\Rightarrow$ newly weighted moisture sources

③ (above 1.5xBLH) $\Delta q \uparrow$: location of evaporation unknown can **not** be assigned to evaporation at surface

included moisture source locations are those where moisture uptake occurred below the scaled BLH!

[a] **Langhamer, L.** *et al.*: Lagrangian Detection of Moisture Sources for the Southern Patagonia Icefield (1979-2017), https://doi.org/10.3389/feart.2018.00219, 2018

[b] **Sodemann, H.** *et al.*: Interannual variability of Greenland winter precipitation sources: Lagrangian moisture diagnostic and North Atlantic Oscillation influence, https://doi.org/10.1029/2007JD008503, 2008

[c] **Sprenger, M.** and **Wernli, H.**: The LAGRANTO Lagrangian analysis tool – version 2.0, https://doi.org/10.5194/gmd-8-2569-2015, 2015

Annual cycle of precipitation in study region

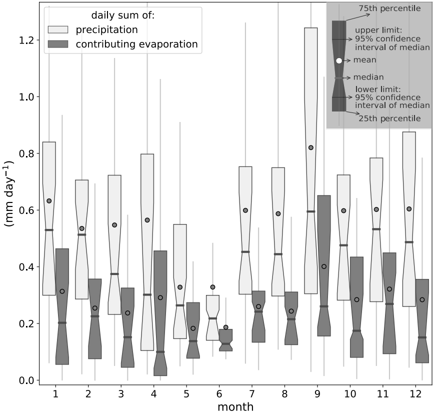

Figure 4: Boxplots show annual cycle of precipitation and summed up attributed contributing moisture sources in the study region for all months (February 1979–May 2017 using ERA-Interim).

- no distinct annual cycle:
  May and June drier and September wetter, September has greatest variability, while June displays least variability
- uneven distribution of daily precipitation throughout year:
  on avg. **5** top days of a year produce **24**% of annual precipitation in study region

summed up fraction of attributed moisture sources against precipitation amount over all 460 months: 48 %

- in summer, larger precipitation variability than for attributed sum of contributing moisture sources below scaled BLH (possibly due to enhanced convective activity)

Annual cycle of attributed moisture sources contributing to precipitation in study region (qualitative description)

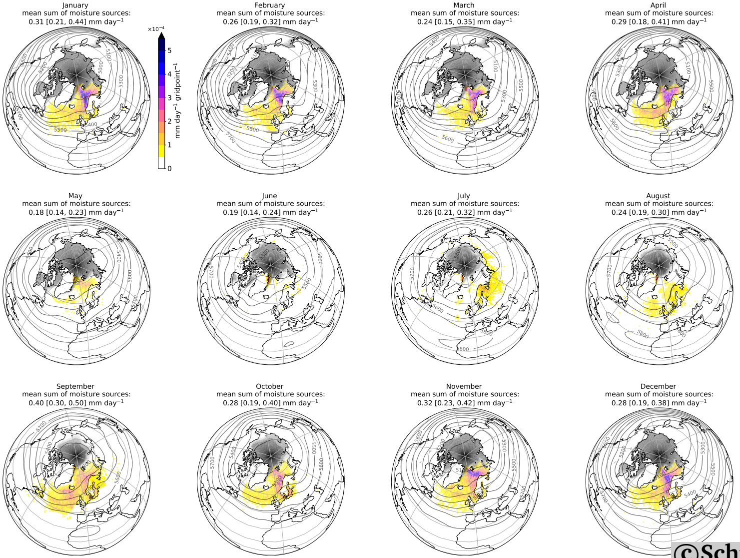

Figure 5: colored shading: attributed moisture sources contributing to precipitation in study region, grey shaded: mean ice extent, black contours: mean 500-hPa geopotential height

Annual cycle of attributed moisture sources contributing to precipitation in study region

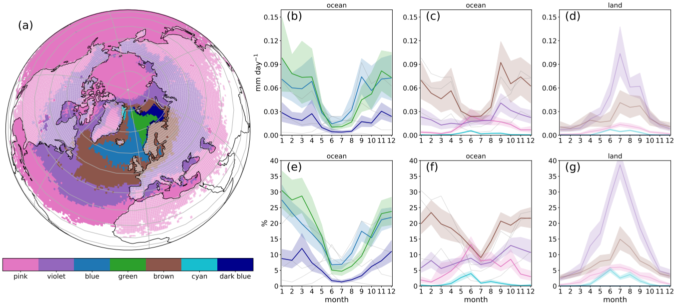

Figure 6: **(a) Region selection by K-Means clustering with additional manual separation**. The annual cycle of moisture sources contributing to precipitation in the study region is plotted for each cluster in **(b, c, d)** as absolute number and in **(e, f, g)** as relative number in % of the total diagnosed moisture source amount. The ocean (with sea ice) regions in **(b, c, e, f)** are separated from the land regions in **(d, g)**. Grey lines in **(b, c, e, f)** correspond to the missing ocean regions for better comparison. Shaded areas represent the 95% confidence interval of the mean. Summing up the different regions of relative contribution for ocean (e, g) and for land (g) gives the total land or ocean (with & without sea ice) contribution

- **winter:** mostly ocean sources, maximum over the Norwegian Sea
- **summer:** mostly land sources, from North Eurasian continent & locally

Relationship between North-Atlantic Oscillation (NAO) and precipitation in study region

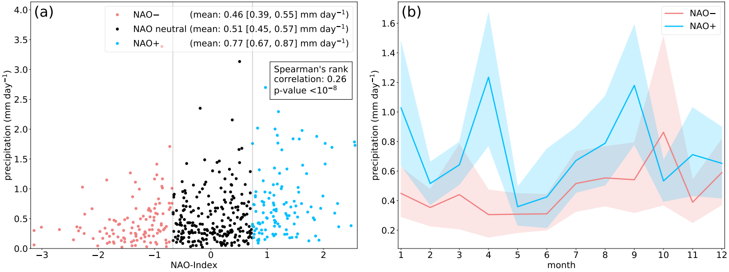

Figure 7: **(a)** Scatterplot of precipitation in study region against the North-Atlantic Oscillation (NAO) index with a total of 460 months (February 1979–May 2017 using ERA-Interim). Months were separated into months with NAO indices below or equal the 25 % percentile (NAO−), above or equal the 75 % percentile (NAO+), or in between (NAO neutral). **(b)** Mean annual cycle of precipitation in study region for months with NAO being below or equal the 25 % percentile (NAO−) and above or equal the 75 % percentile (NAO+). For each month of the year, specific 25 % and 75 % percentile thresholds were computed. The shaded areas represent the 95 % confidence interval of the mean.

[NAO− → NAO+] ⇒ larger and more variable precipitation in study region (most pronounced in January, April and September)

Relationship between North-Atlantic Oscillation (NAO) and attributed moisture sources of study region

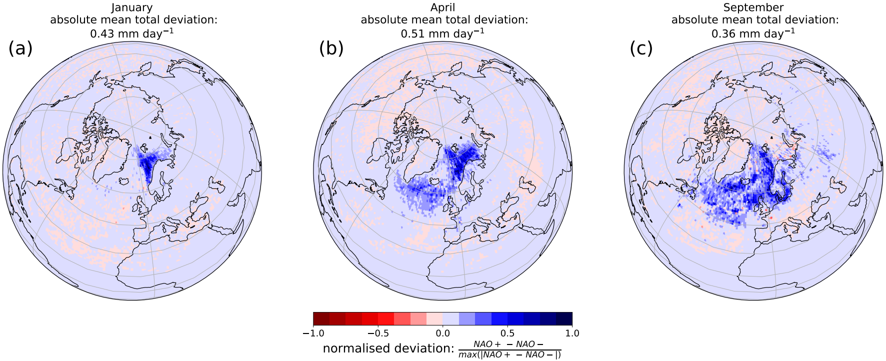

Figure 8: Normalised moisture source deviation between months being above or equal the 75 % percentile (NAO+) and months being below or equal the 25 % percentile (NAO−). Same thresholds as in Fig. 7b.

for NAO+ months in January, April and September:

more contributing moisture sources over North-Atlantic and specifically over Norwegian Sea diagnosed

Temporal trend in precipitation visible from ERA-Interim?

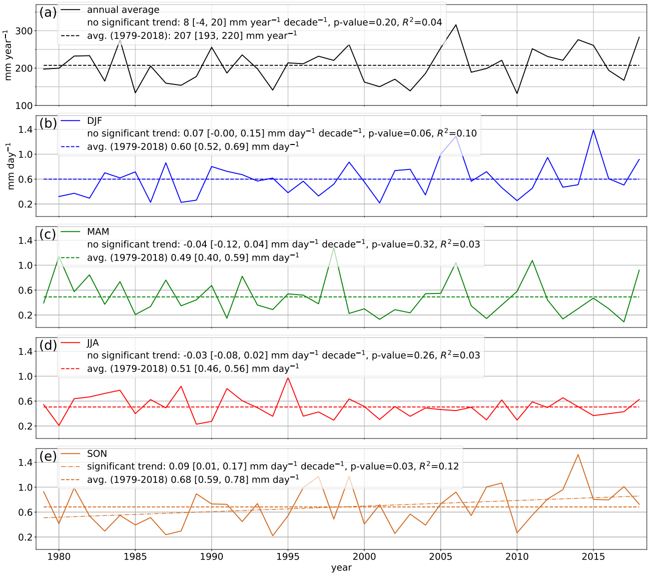

Figure 9: (a) Annual and (b-e) seasonal mean temporal evolution of precipitation amount in the study region from ERA-Interim.

40 years not long enough time period to recognise if a precipitation trend occurs!
Only in autumn (SON, Fig. 9e), there is a slight positive upward linear trend visible.

Conclusion

NE-Greenland precipitation and moisture sources

- 207 [192, 224][a] mm year^{-1} in study region → Arctic desert:
  precipitation relatively constant during year, but June is driest and September wettest
- regional moisture sources display strong seasonality:
  most dominant winter moisture sources are the ice-free North Atlantic ocean above 45° N, while in summer the patterns shift towards more local and North Eurasian continental sources
- during positive North-Atlantic Oscillation (NAO) phases: evaporation and moisture transport from the Norwegian Sea is stronger, resulting in larger and more variable precipitation amounts.
- annual mean temperature in study region has increased by 0.7 [0.4, 1.0]$^\circ$ C dec^{-1} according to ERA-Interim data (1979–2018),
  but no precipitation trend detected with exception of autumn where precipitation increases slightly over the period (8.2 [0.8, 15.5] mm season^{-1} dec^{-1}). This increase is consistent with future predicted Arctic precipitation change.

Financial Support This research has been supported by the Austrian Science Fund (grant no. Y 1162-N37) and with start-up funding from the University of Innsbruck Research Centre for Climate–Cryosphere and Atmosphere, both to Gina E. Moseley.

[a] [,] denotes the 95 % confidence interval computed by a bootstrapping method