Review of the Arctic observational studies

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Outline

- About our team
- Field observations
- Recent results
- Future collaboration

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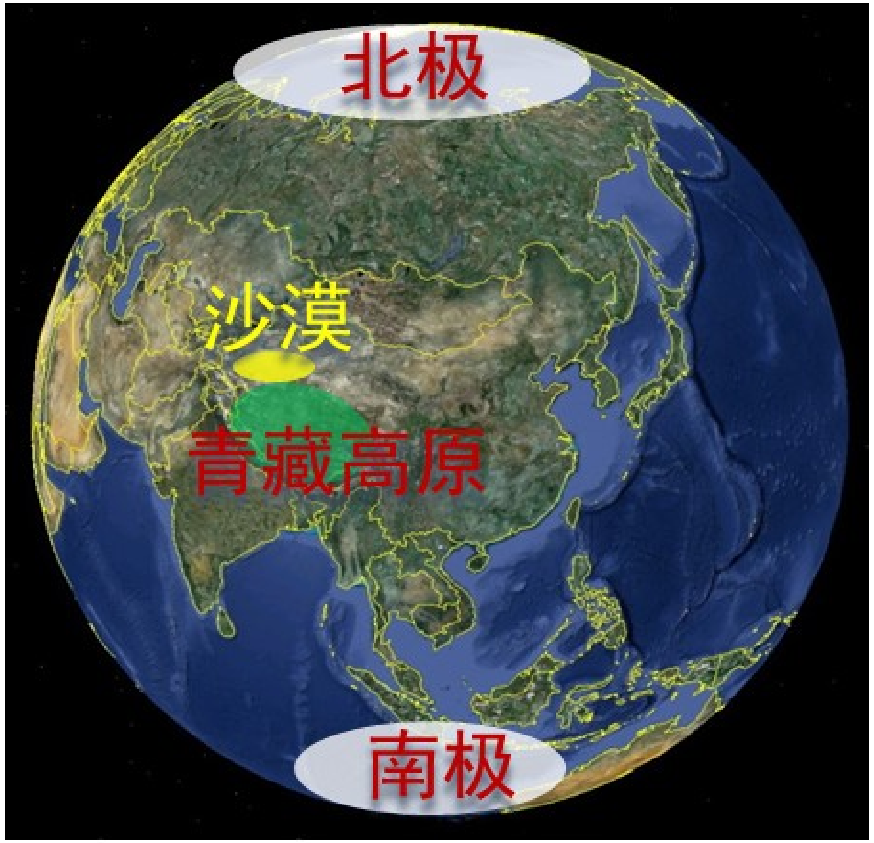
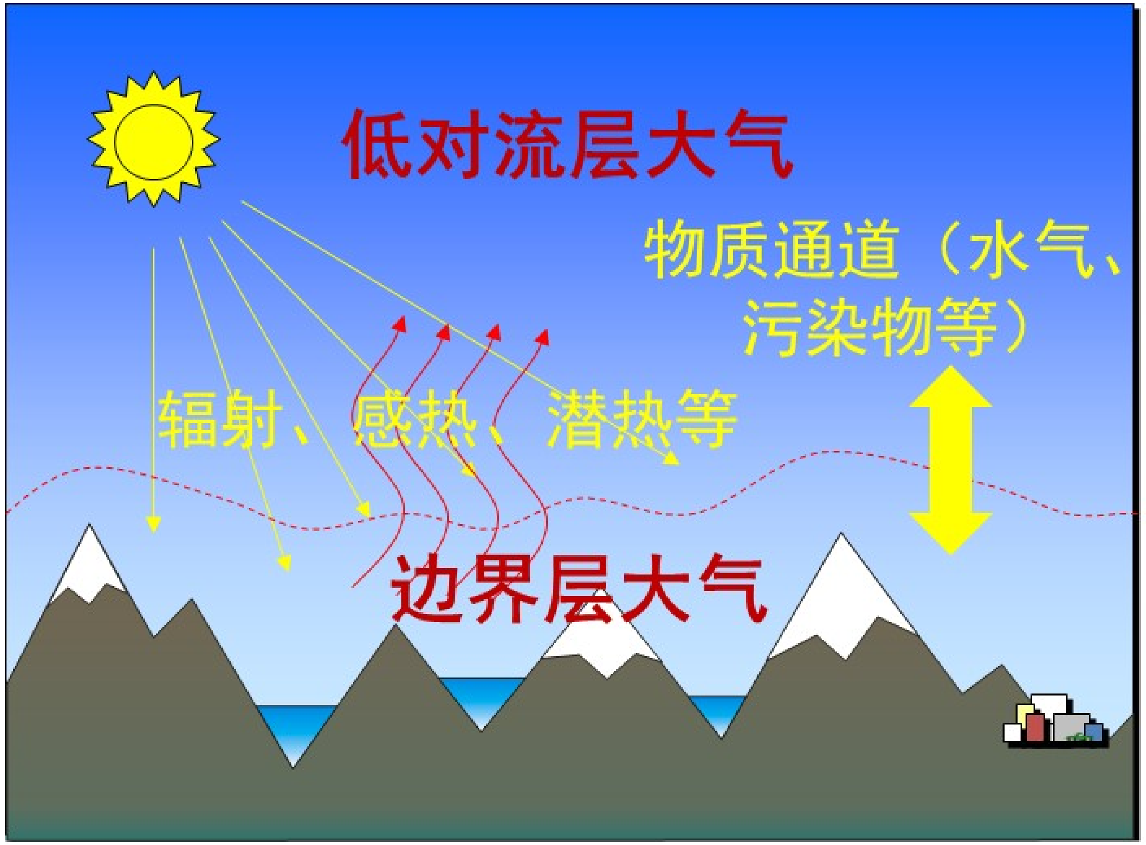
About our team



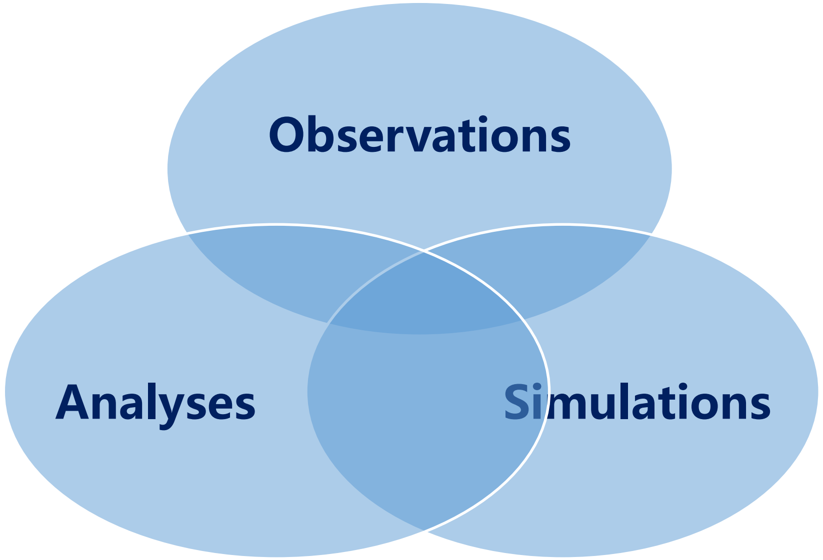


Lower atmosphere from ground upwards to 10 km

The lower atmospheric processes over complex and inhomogeneous terrain in the extremely hard working regions (TP, Antarctica, Arctic, desert) .

About our team

Observations, theoretical analyses, and numerical simulations, focused on the special and complicated lower atmospheric processes.



Instruments：

About our team

Campaigns：

1997-1998：West Pacific Scientific Expedition；

1998：Yalung Zangbo Water Passage Expedition；

1999：The First China Arctic Scientific Expedition；

2000-2004：Mt. Everst Atmospheric Environment Monitoring；

2005-2006：The Land-Air Exchange Processes Observations over the middle Himalayas；

2011-2013：The Land-air Exchange Processes Observations over the east Himalayas；

2016-2023：Arctic Atmospheric Processes Observations；

2020-2021：Boundary Layer Experiment in Taklimakan Desert；

About our team

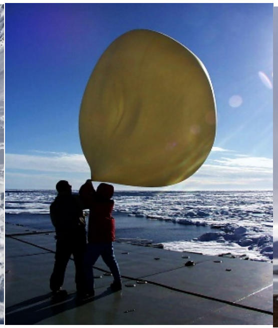
The most recent works :

- **Plateau mountain meteorology : mountain circulation, land-air exchange process, multi-scale interaction, et al.;**
- **Polar atmospheric processes: lower atmospheric structure, energy exchange, et al.;**
- **Sichuan-Tibet Railway construction: extremely weather disaster and their impacts on the railway, et al.;**
- **Aviation meteorological services: dangerous weather prediction, et al..**

Tower Obs.

Cross-river by yak

Glacier Obs.



GPS sonding

UAV Obs.

Desert Obs

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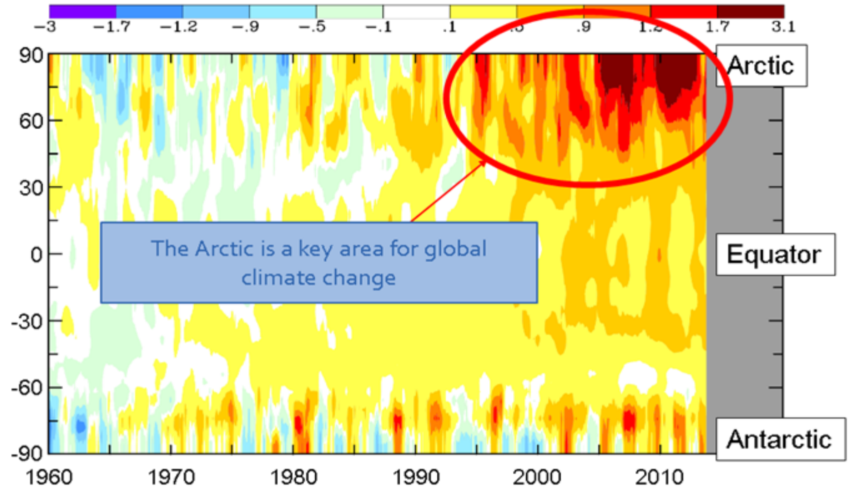
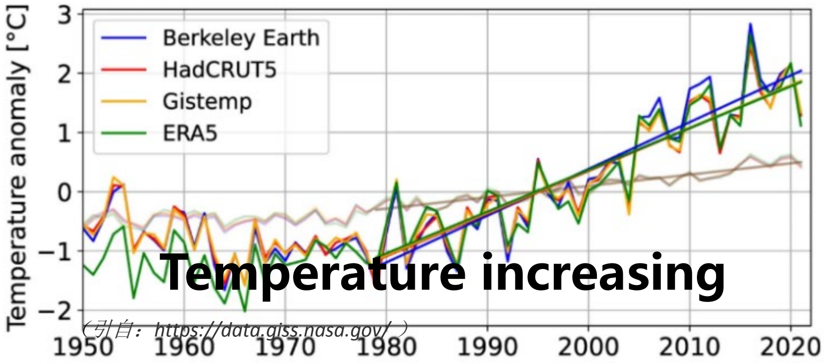
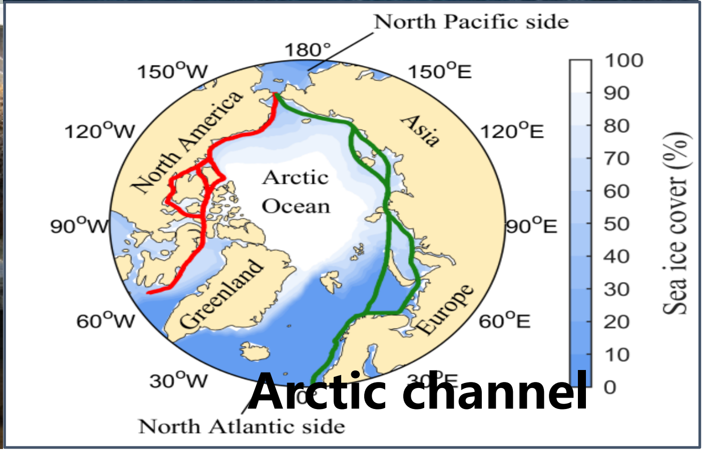
Field observations





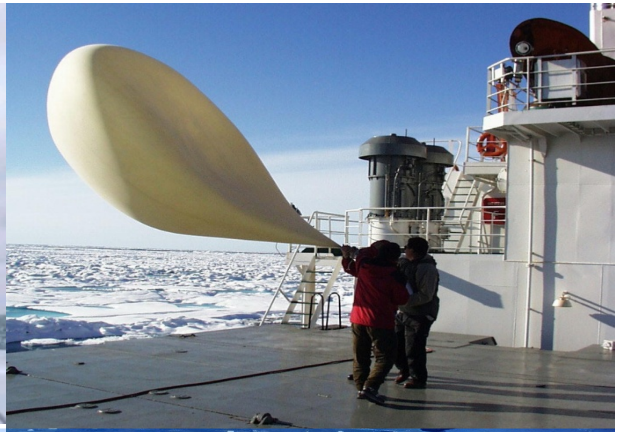
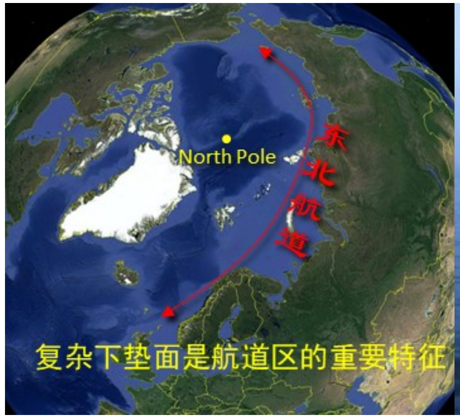


The Arctic amplification affected the local weather and environmental processes, such as sea ice shrinking, glacier retreating, permafrost melting, and so on.

Field observations

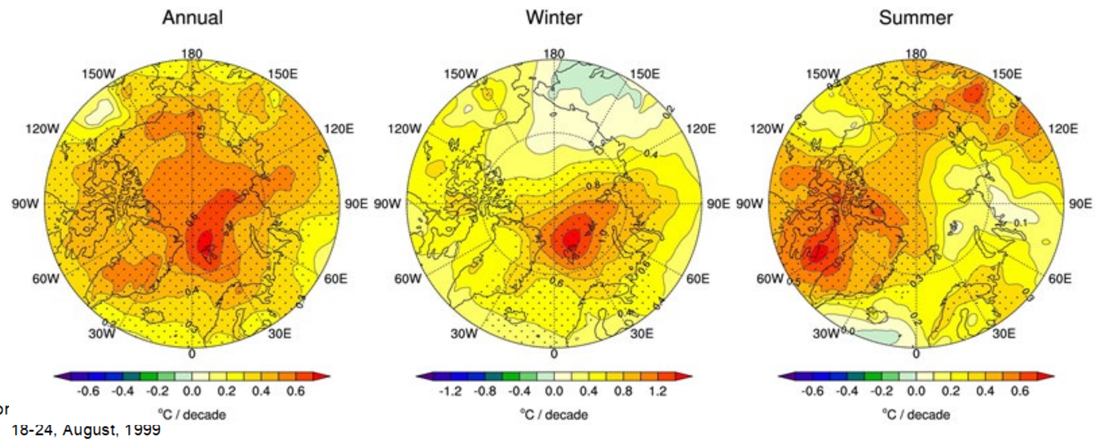
Extreme atmospheric conditions:

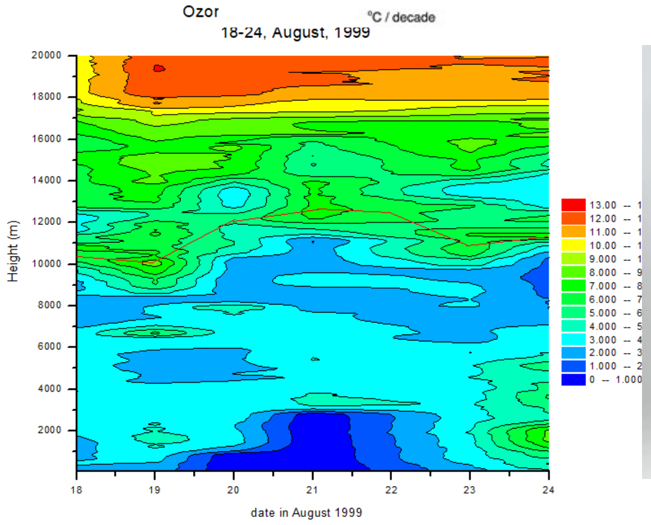
- Low temperature and icing;
- Sea fog/low visibility;
- Strong wind/wind shear;
- Atmospheric duct;
- Sea ice;
- ……

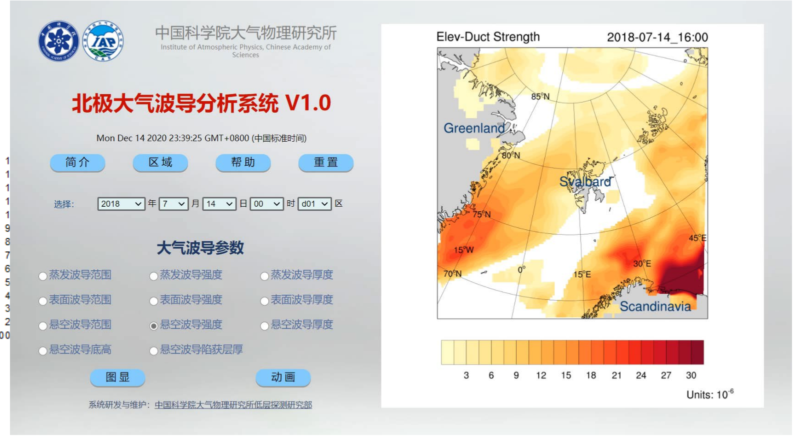





Research on the Arctic

- **Arctic Climate and Quick Change**
- **Multiscale Atmospheric Processes**
- **Prediction Technology**
- **Atmospheric Observation, the Base**



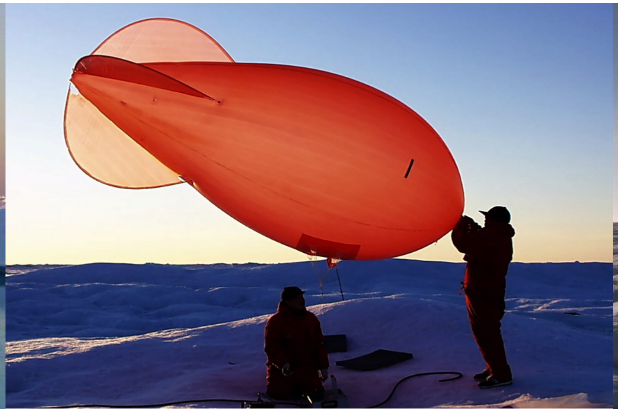




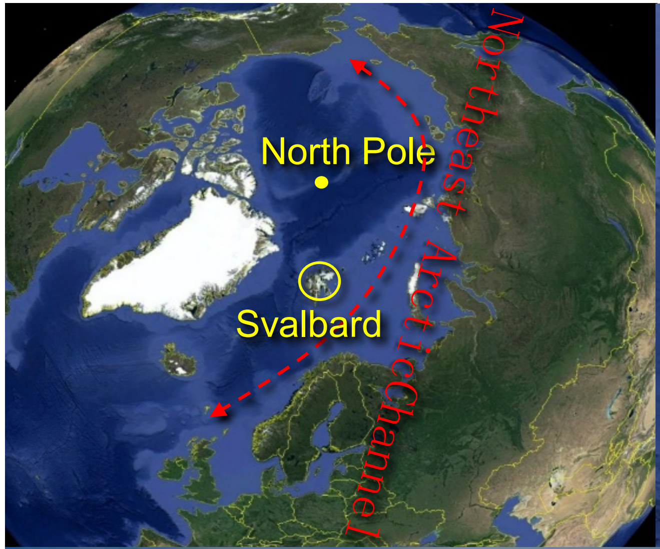
Field observations

- 1990s, Arctic studies with Norway and Sweden
- 1999, the First Chinese Arctic Ocean Expedition
- 2000-2003, the Arctic Expedition to Svalbard
- 2003, IAP-Nansen Center
- 2016-Now, Atmospheric Observation Experiment at Svalbard






Field observations



Field observations

Ny-Ålesund is a hub for international Arctic scientific research and environmental monitoring. More than 20 countries have established stations, including the atmosphere, ocean, glacier, ecology and so on.

Norway

Germany

Korea and France

India

England

China

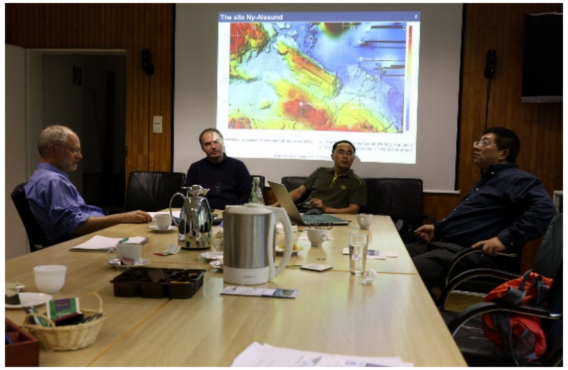
Italy

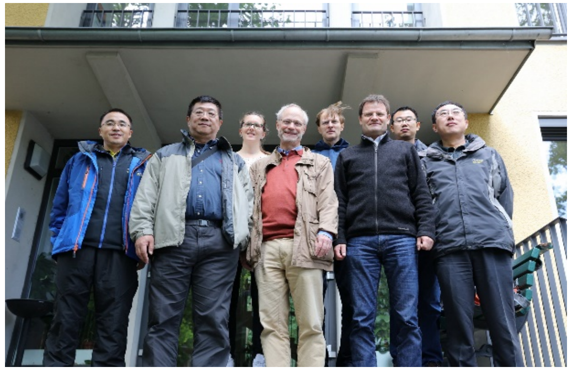
Field observations

International Cooperation :

Alfred Wegener Institute (AWI), Russian Northern University, Norwegian Polar Institute (NPI)


MOSAIC plan


Field observations discussions


AWI


Russian Northern University


Discussion with UNIS


IAP, RUS

Field observations

Domestic Cooperation :

State Oceanic Administration (SOA), Polar Research Institute of China (PRIC)

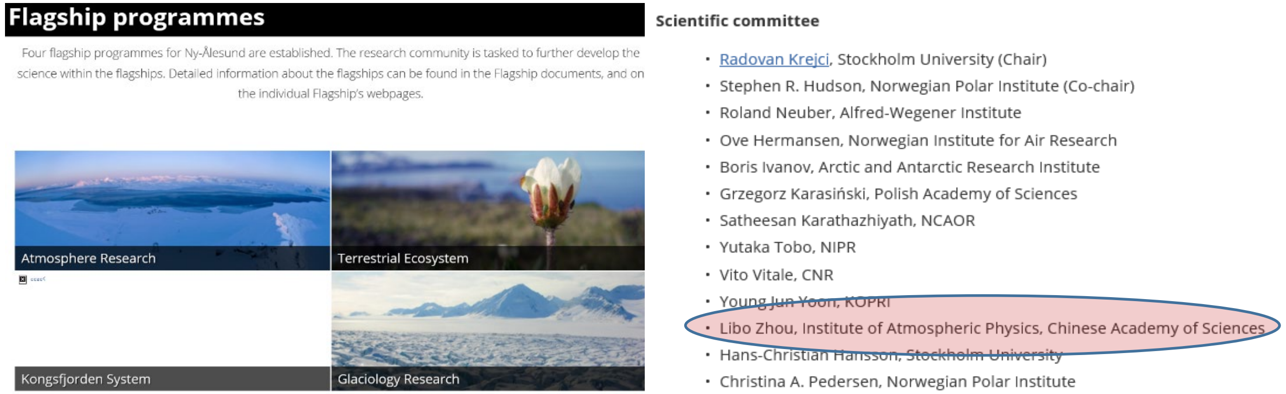
TMT observation in 1999

Xuelong Vessel

Yellow River Station

Atmospheric Flagship Programmes

47th NySMAC meeting



Flagship programmes

Four flagship programmes for Ny-Ålesund are established. The research community is tasked to further develop the science within the flagships. Detailed information about the flagships can be found in the Flagship documents, and on the individual Flagship's webpages.

Scientific committee

- Radovan Krejci, Stockholm University (Chair)
- Stephen R. Hudson, Norwegian Polar Institute (Co-chair)
- Roland Neuber, Alfred-Wegener Institute
- Ove Hermansen, Norwegian Institute for Air Research
- Boris Ivanov, Arctic and Antarctic Research Institute
- Grzegorz Karasiński, Polish Academy of Sciences
- Satheesan Karathazhiyath, NCAOR
- Yutaka Tobo, NIPR
- Vito Vitale, CNR
- Young Jun Yoon, KOPRI
- Libo Zhou, Institute of Atmospheric Physics, Chinese Academy of Sciences
- Hans-Christian Hansson, Stockholm University
- Christina A. Pedersen, Norwegian Polar Institute

Ny-Ålesund Newsletter – 40th Edition – February 2018

A New CAS Project ALEEABL - Field Observation on Land-air Exchange Processes at Ny-Ålesund

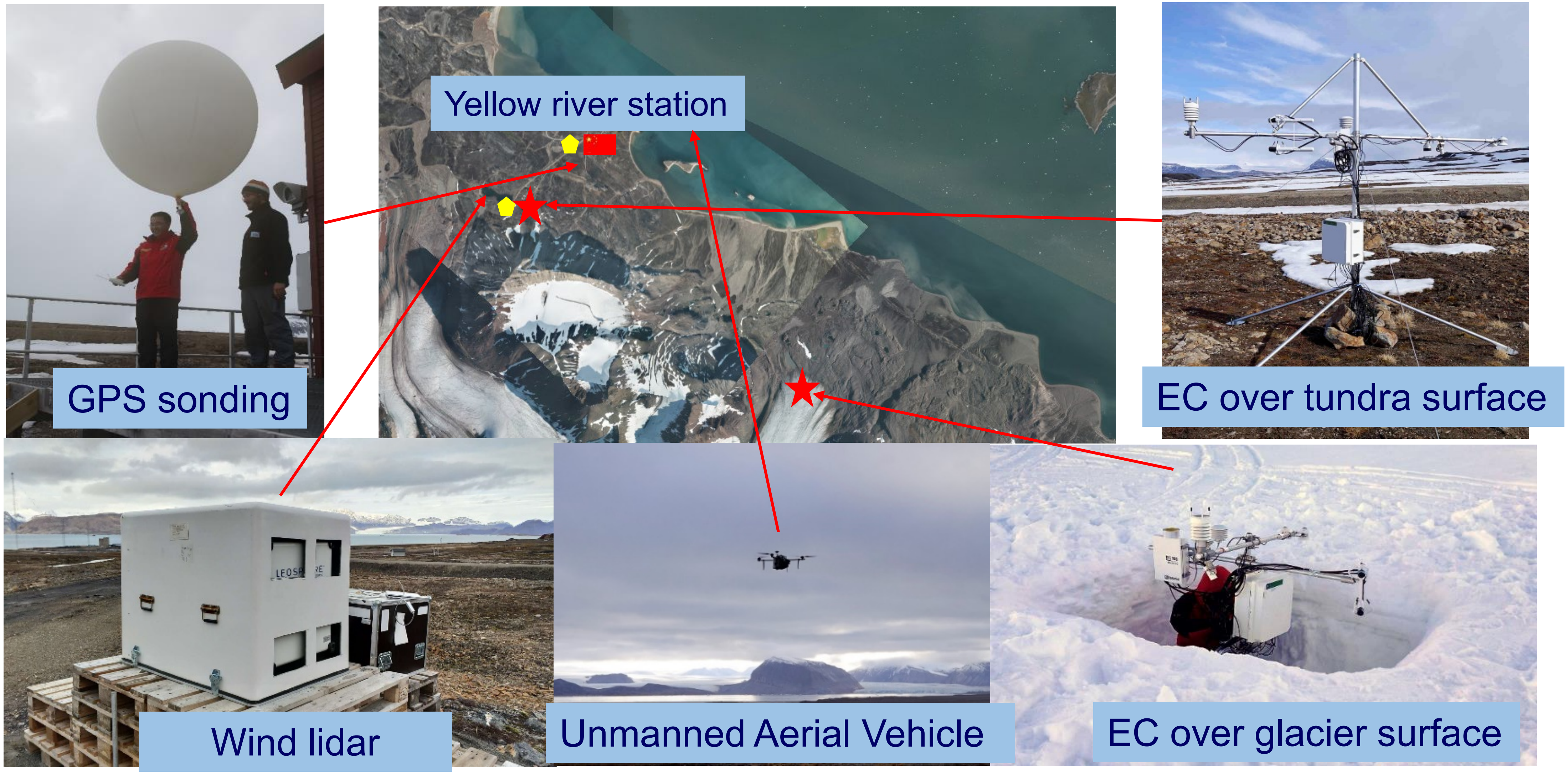
By Libo Zhou, Institute of Atmospheric Physics, Chinese Academy of Sciences

The Arctic as the cold source of the global atmosphere is experiencing an extremely fast change, which would have fundamental impacts on the

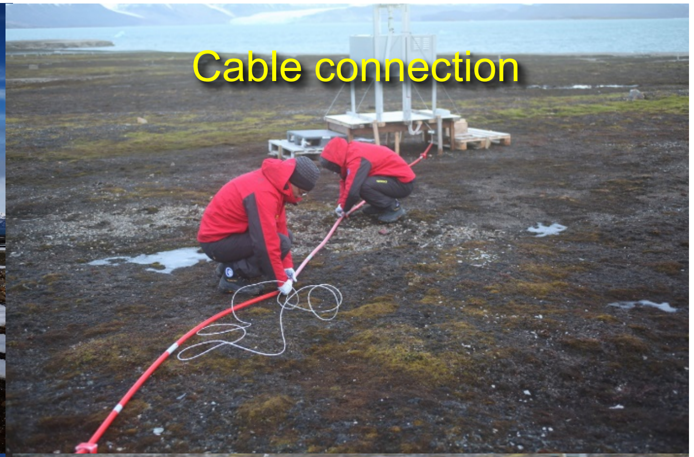
Last May, we made a field investigation to Ny-Ålesund, with three typical surface covers and ideal observation sites selected. Last October, a

Newsletter Report

Field observations



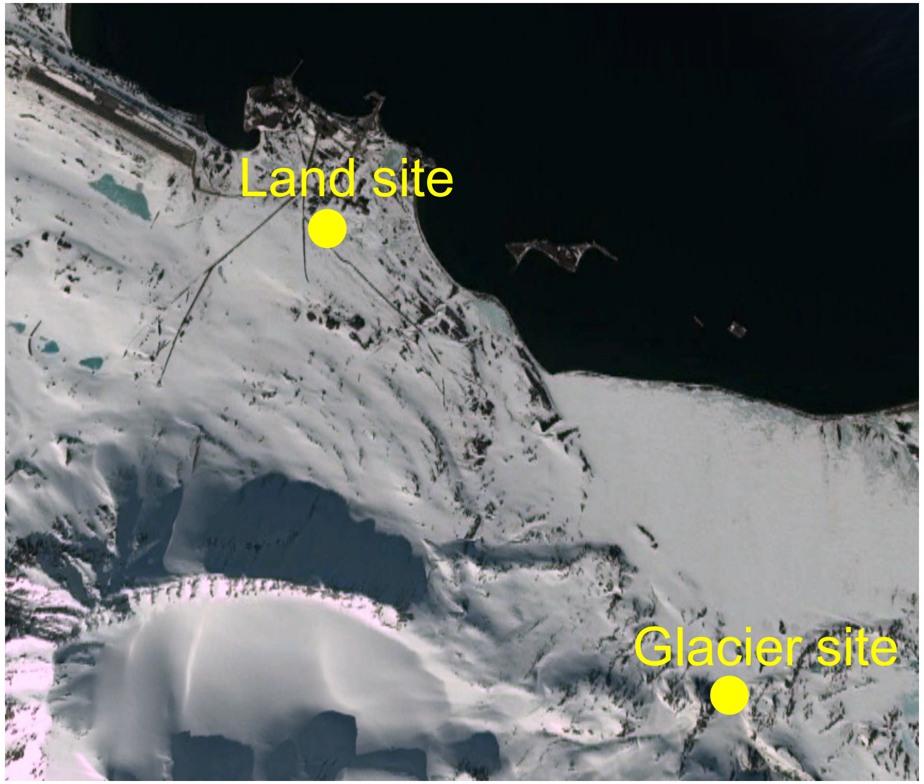
Field observations



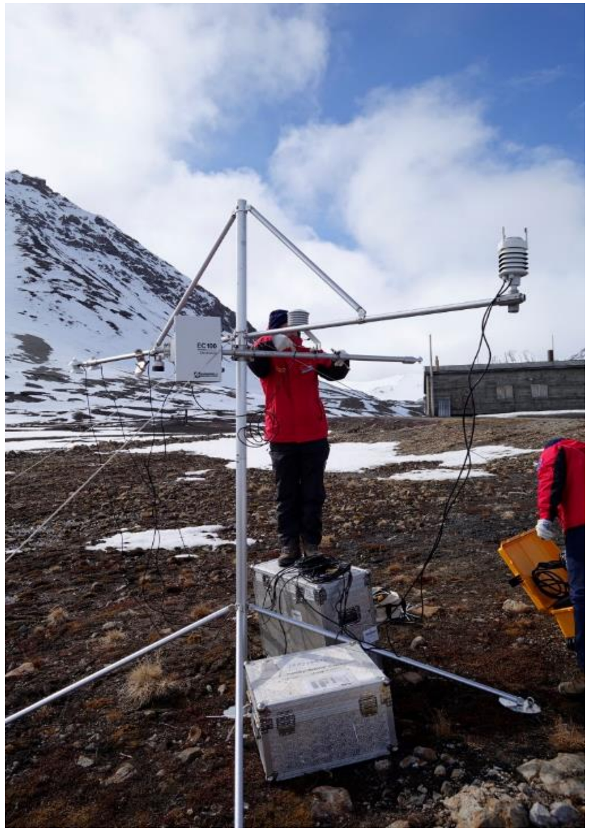
Surface observation

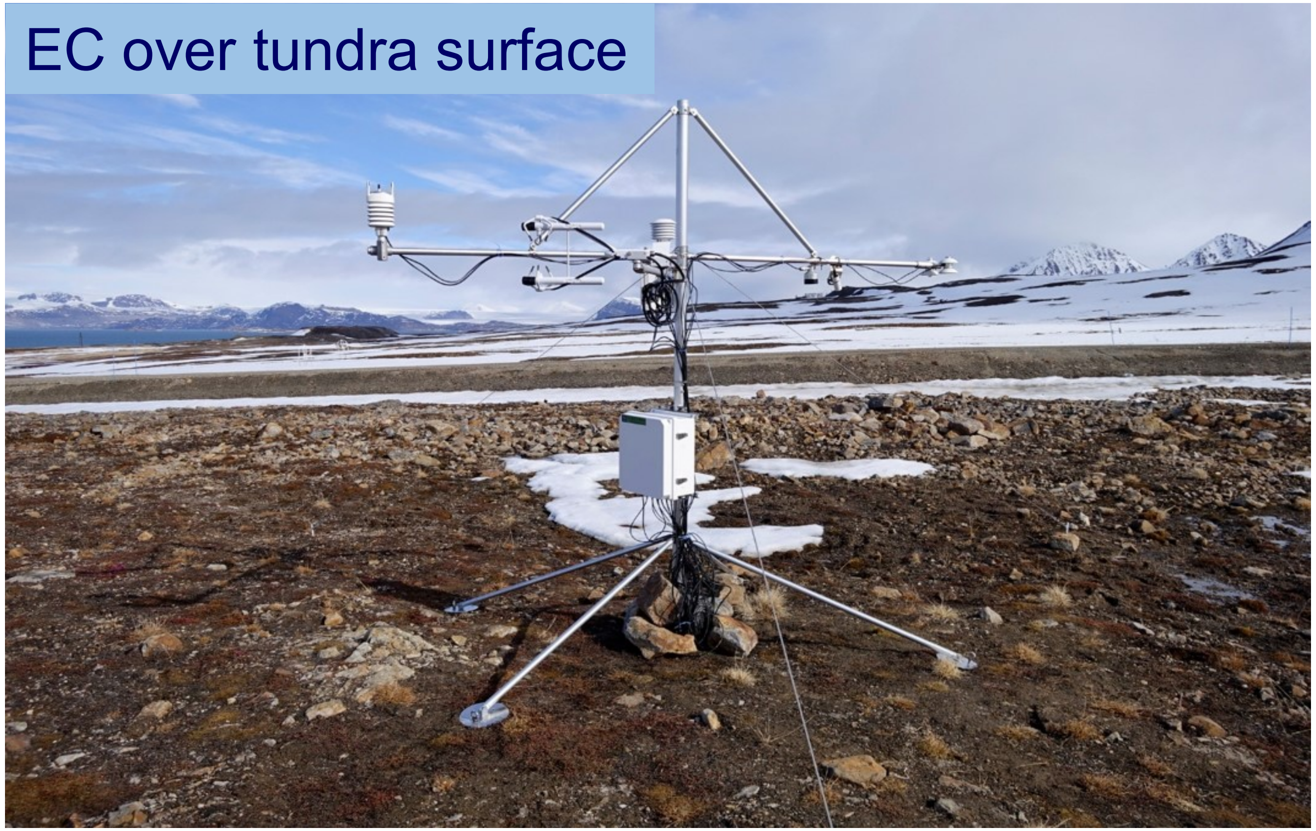
to understand the surface air and surface-air exchange

1. Radiation: short/long wave
2. Surface air: wind, temperature, humidity, pressure
3. Surface-air exchange: sensible heat, latent heat, momentum fluxes



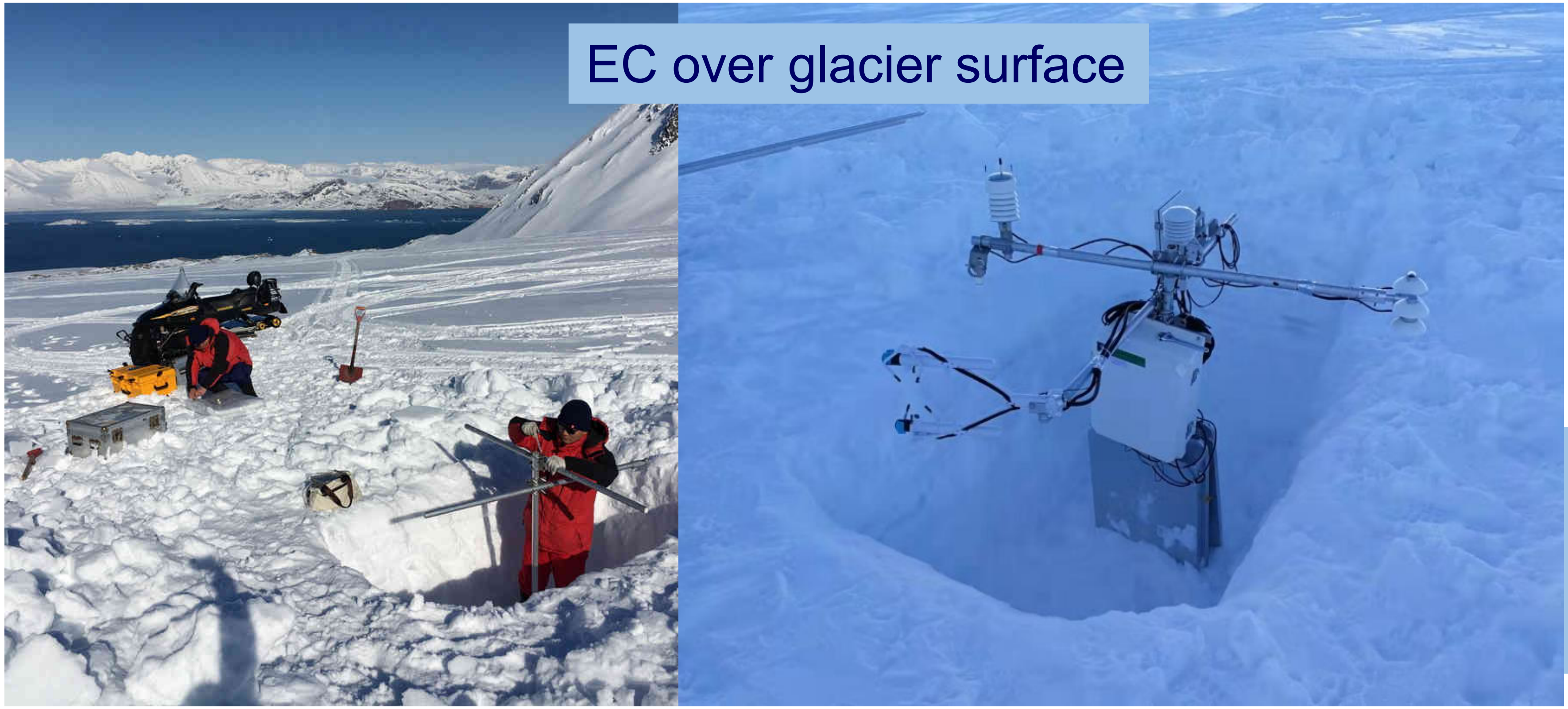
Field observations

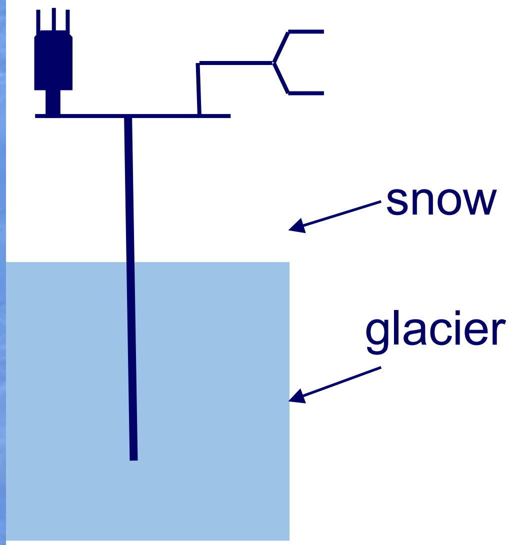




Location：78^{o}55’0.5”N， 11^{o}53’24.3”E
Period：June, 2018-now
Instrument：IGRASON EC, AWS, 4-componets radiation, snow depth sensor

Field observations





Location： $78^{o}52'39.8''$N, $12^{o}7'36.4''$E
Period： May-August, 2019
Instrument： IGRASON EC, AWS, 4-componets radiation, snow depth sensor

Field observations

Profile observation

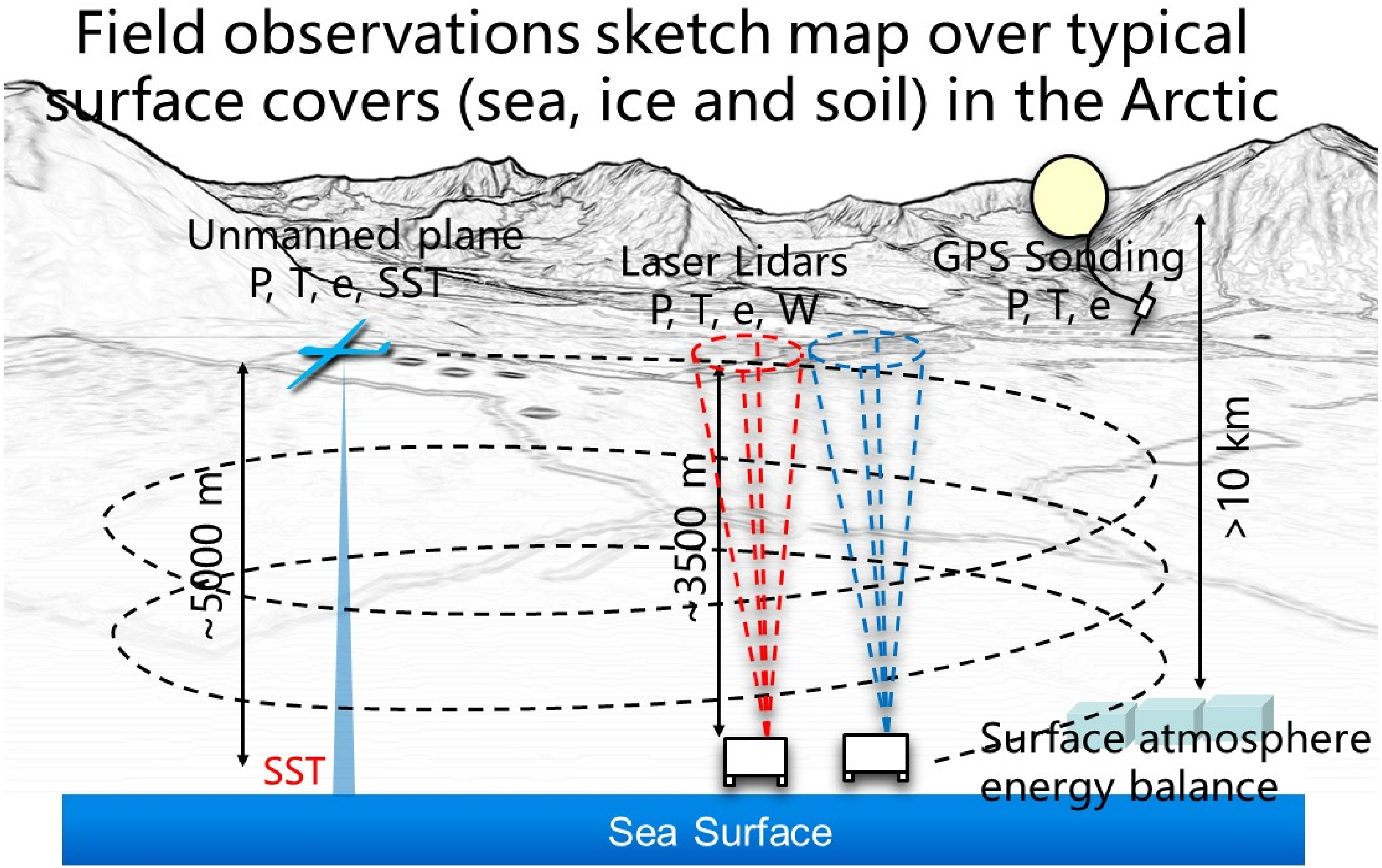
to understand the atmospheric structure with high resolution

1. Lidar: wind and temperature
2. GPS sonde(Ger): wind, temperature, humidity, pressure
3. Microwave radiometer(Ger): temperature and humidity
4. Multicopter: temperature, humidity, pressure

Lidar

GPS sonde

Field observations



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Recent results

1. Near-surface energy budget over glacier and tundra surfaces

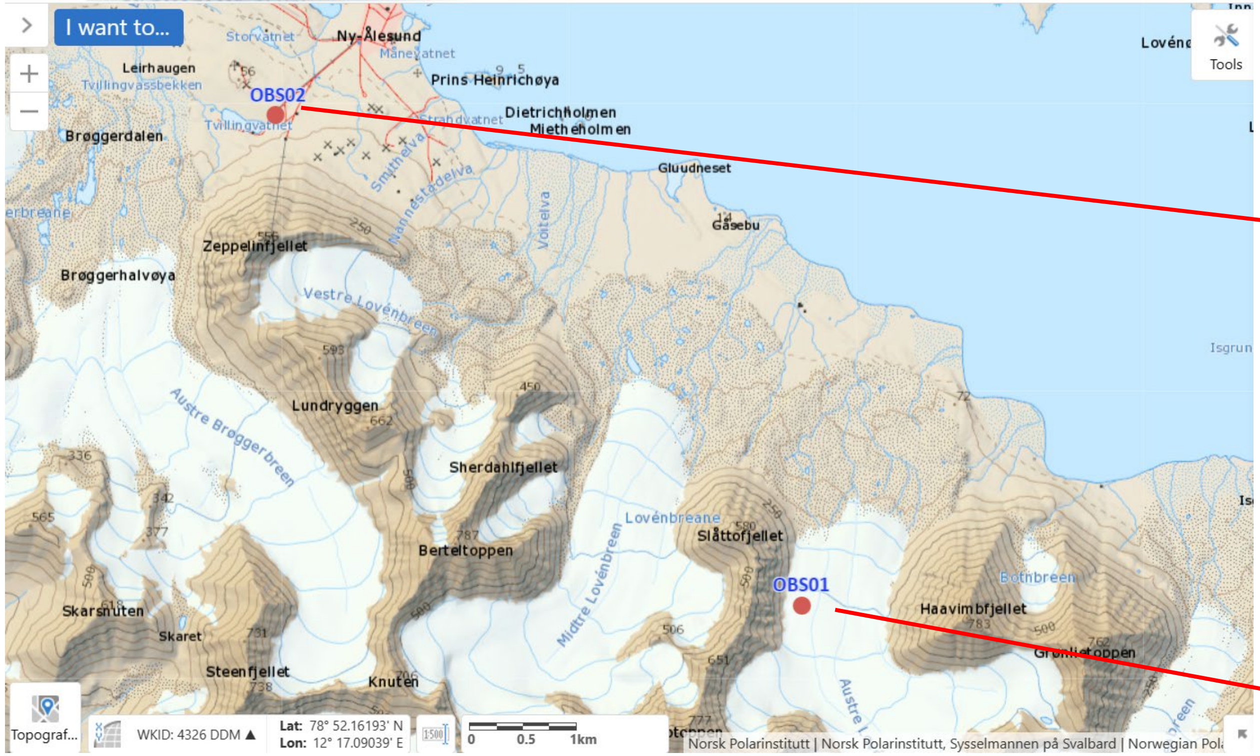
2. Surface atmospheric duct over Svalbard, Arctic

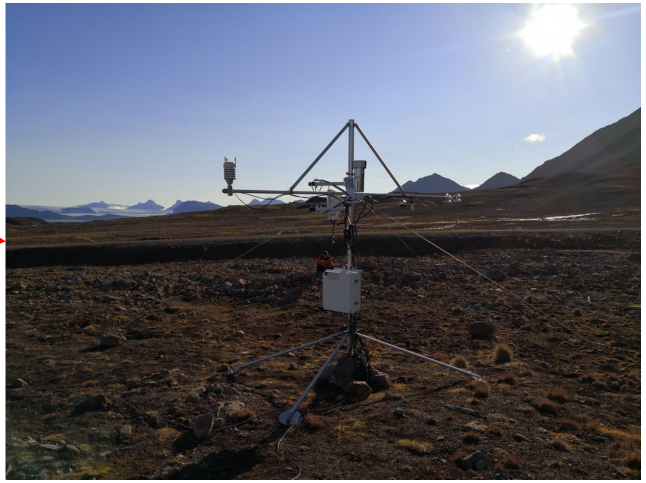
3. Surface heat transfer changes over Arctic land and sea connected to Arctic warming

4. Extreme wind over the Arctic passage and its possible influential factors

5. Modelling study of Snow darkening effect by Black Carbon deposition over the Arctic during melting period

1. Near-surface energy budget over glacier and tundra surface

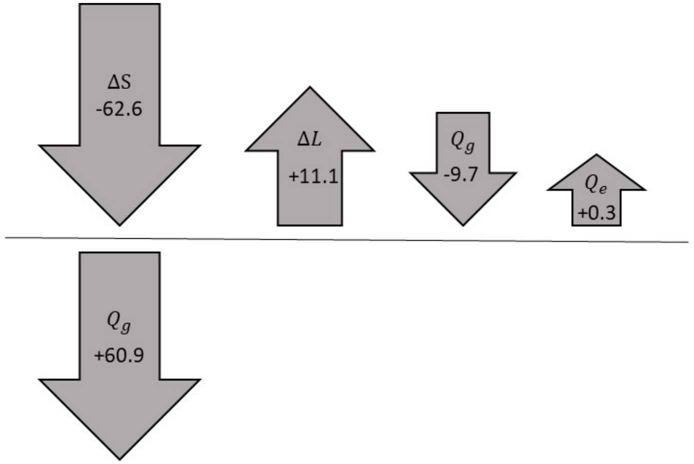


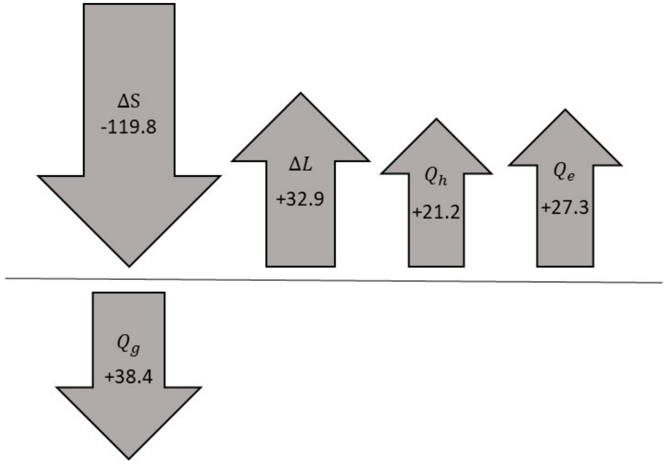


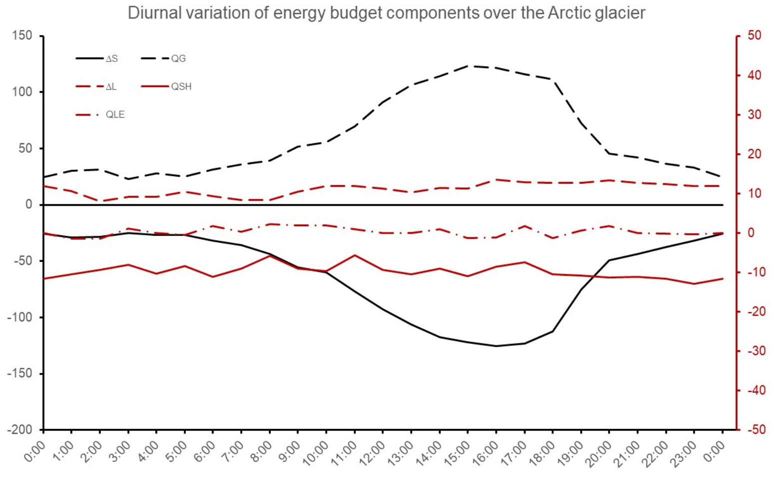
OBS01: 78º52’39.8”N, 12º7’36.4”E, 276 m a.s.l.

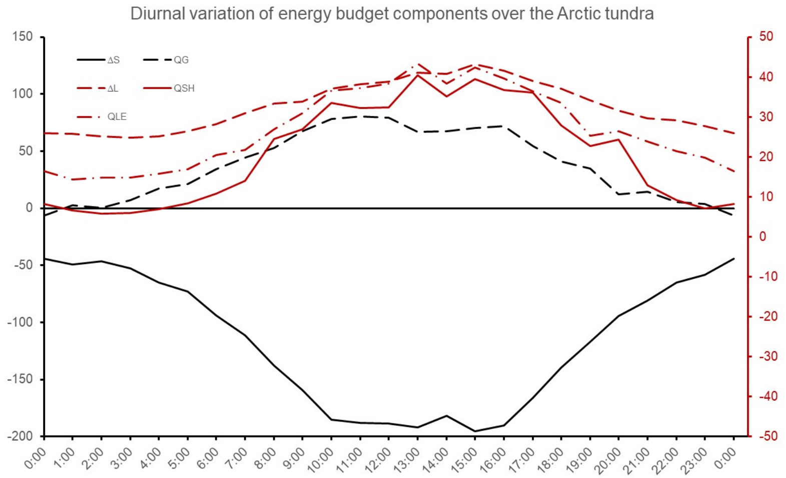
OBS02: 78º55’0.5”N, 11º53’24.3”E, 50 m a.s.l.

1. Near-surface energy budget over glacier and tundra surface



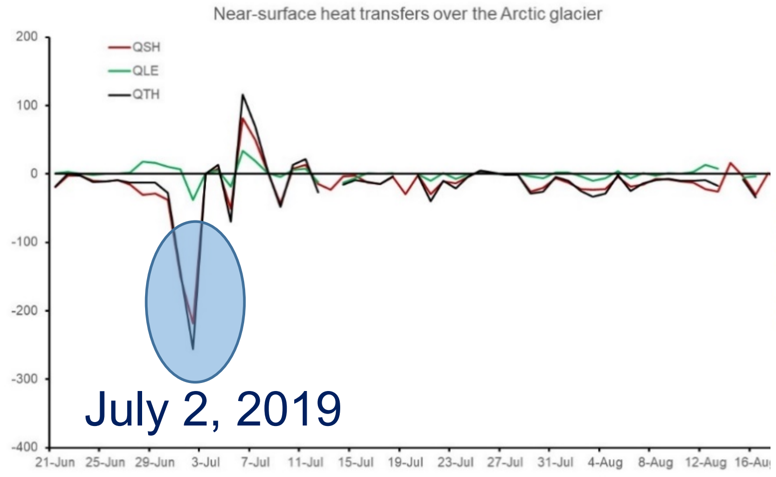


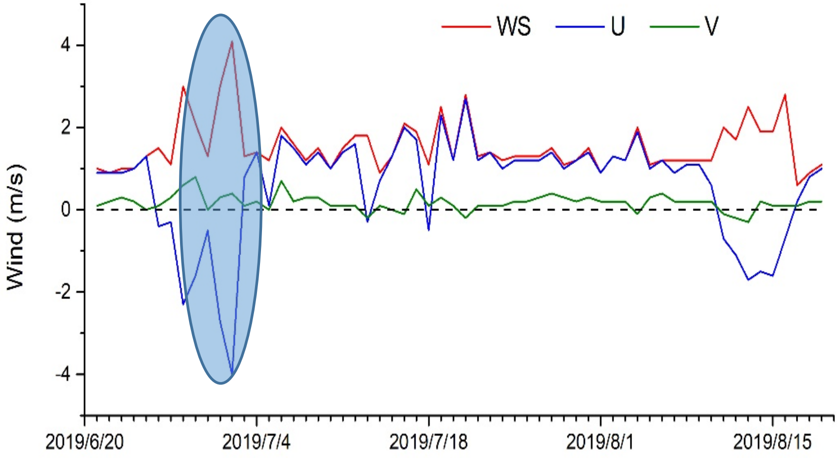


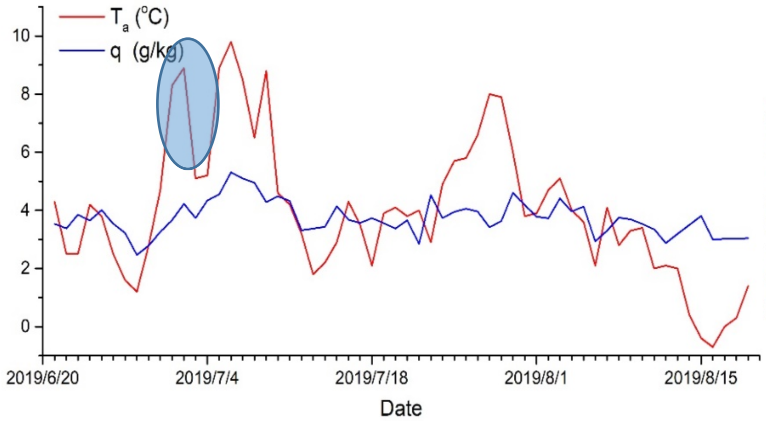


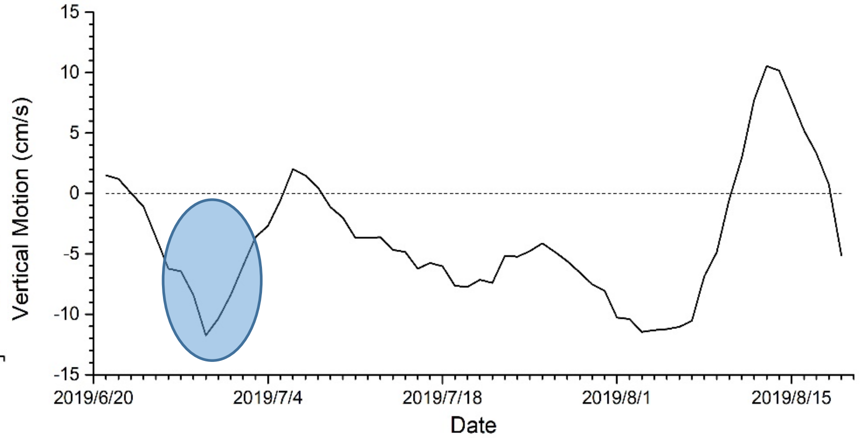
- Most of the incoming solar radiation was injected into the glacier;
- Net shortwave radiation and downward sensible heat flux are quite smaller over glacier than over tundra surface, due to the high albedo and icy surface;
- The other energy budget components are smaller over glacier surface, in comparison with those over the Arctic tundra surface.

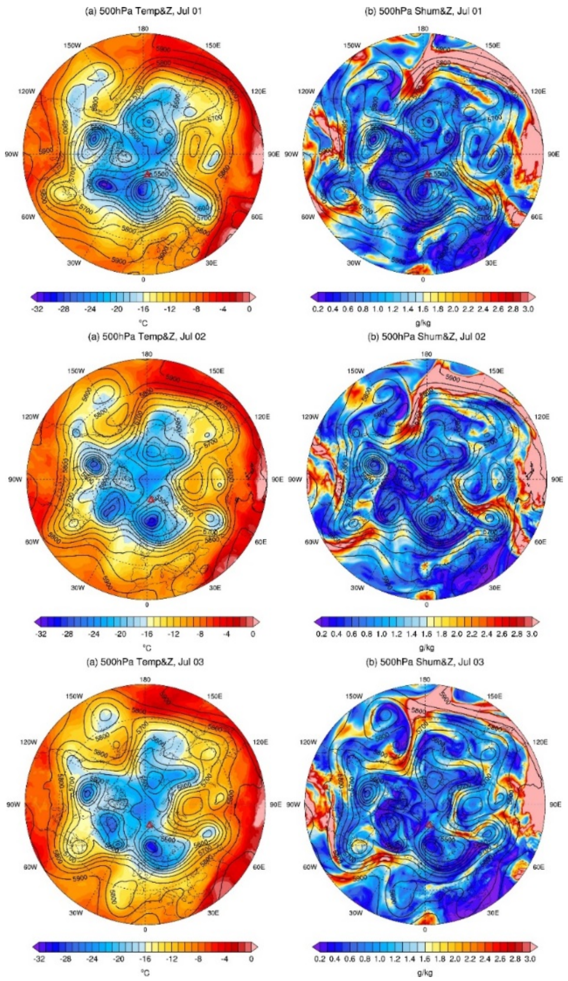
1. Near-surface energy budget over glacier and tundra surface



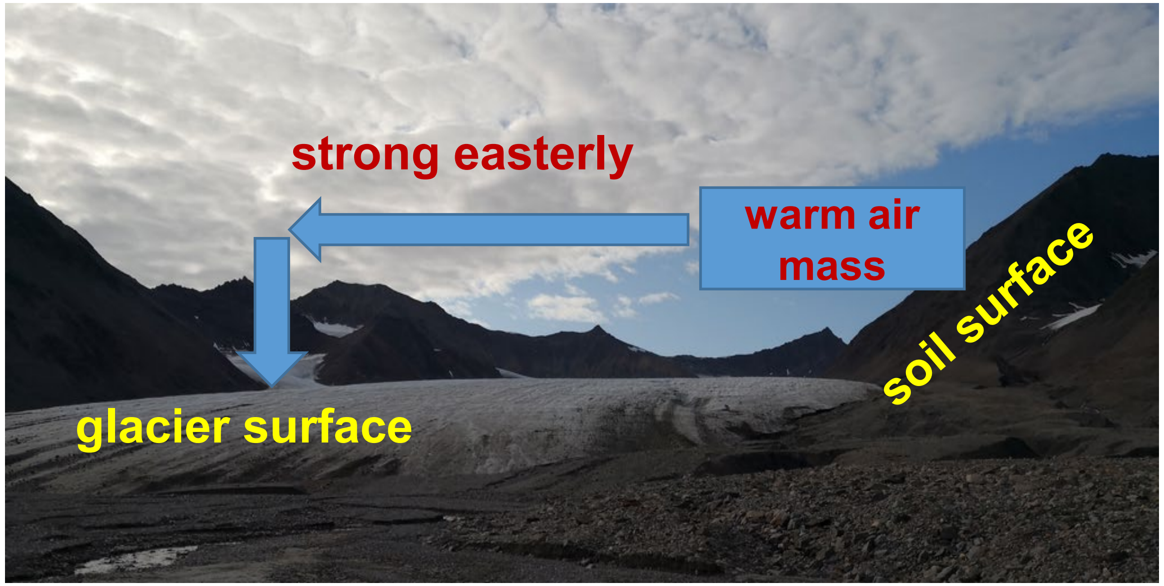








The heat transfer minimum (July 2, 2019) is mainly caused by the strong local thermal contrast



A strong easterly over Mt. Havvim Bfjellet (soil and rock surface) may bring the warmer air mass westward, result in a high air temperature and strong negative temperature gradient between the surface and air. A downward air motion prevailed, which may bring warmer air downward and lead to downward heat transfer (negative heat fluxes) over the glacier.

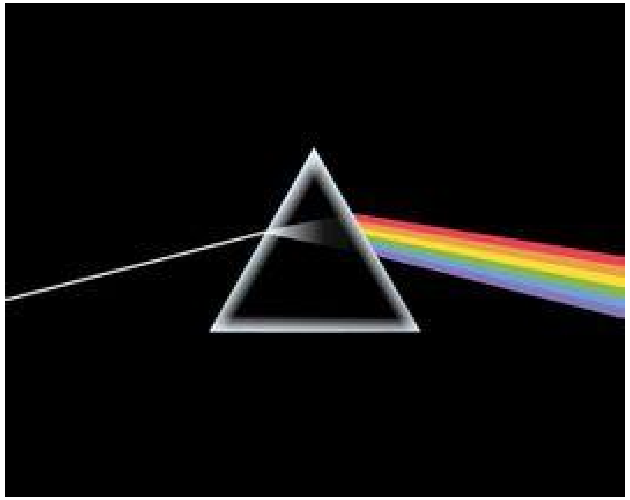
Conclusions:

1) Due to the high albedo and icy surface, the energy budget over the glacier is characterized by less net short-wave radiation and a lower sensible heat flux, greatly differing from that over the tundra.
2) Most of the incoming solar radiation was injected into the glacier, expressed by both the energy budget and the similar diurnal variations in the net shortwave radiation flux and the downward ground heat flux.
3) The near-surface heat transfers over the Arctic glacier exhibited strong daily variations during the experiment, with the maximum downward and upward heat fluxes occurring on July 2 and 6, 2019, respectively. The maximum downward flux is mainly caused by the strong local thermal contrast above the glacier surface. However, the maximum upward heat flux on July 6, 2019, may not be explained by the classical turbulent heat transfer theory, possibly because of a countergradient heat transfer.

Zhou et al., J. Meteoro. Res,, 2024

2. Surface atmospheric duct over Svalbard, Arctic

Atmospheric duct is a refractive layer in atmosphere, trapping and guiding radio wave propagation along the curvature of Earth.



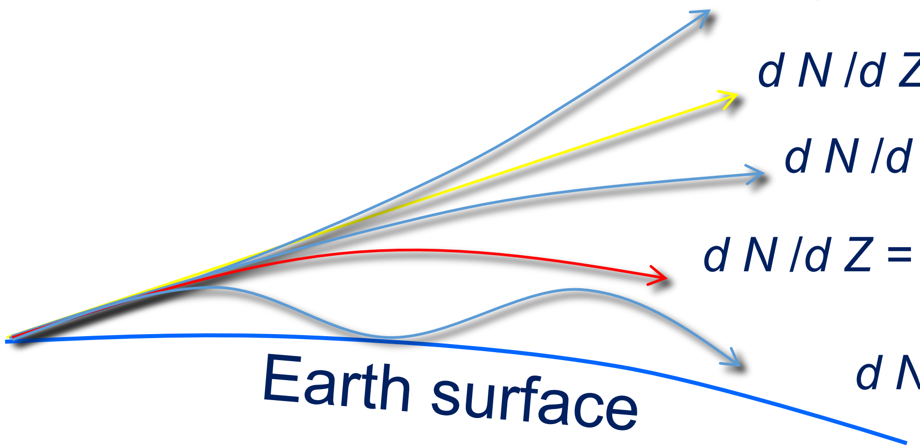
$dN/dZ > 0$, negative refraction

$dN/dZ = 0$, zero refraction

$dN/dZ < 0$, super-refraction

$dN/dZ = -0.157$, critical refraction

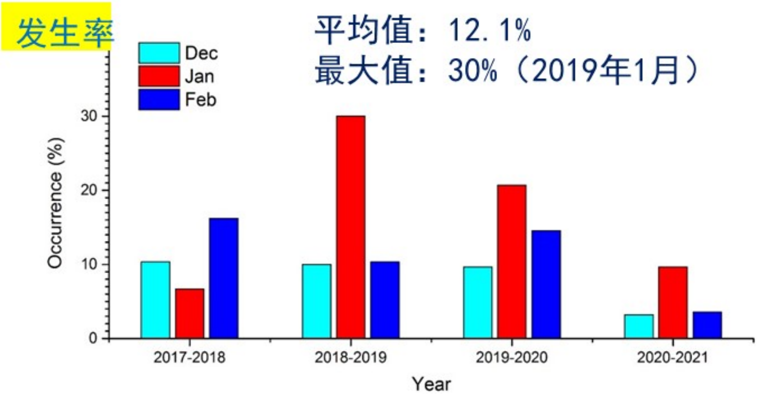
$dN/dZ < -0.157$, trapping refraction-atmospheric duct

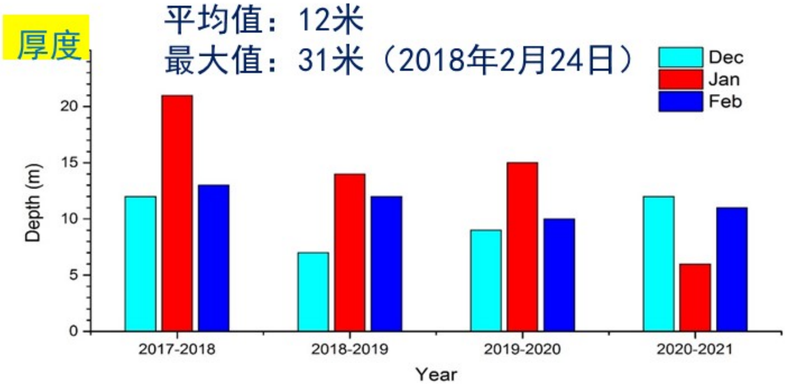


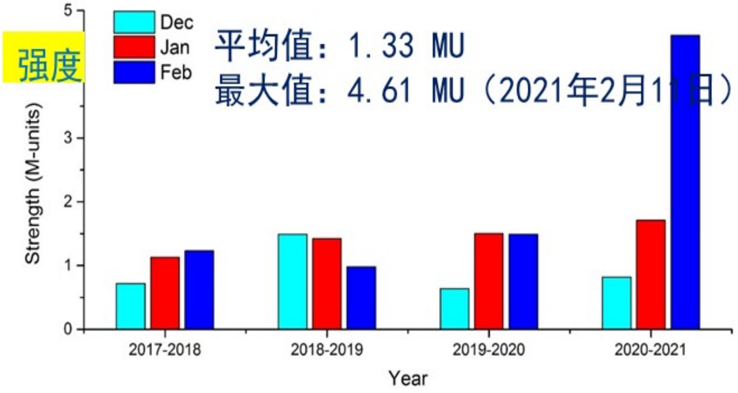
Atmospheric duct could disturb radar detection and radio communication in the Arctic, and risk the increasing human activities under Arctic warming. It is an urgent need to understand atmospheric duct in the Arctic, with distinct atmospheric system and environment.

Data: Radiosonde data, in winter months (Dec., Jan. and Feb.) from Dec. 2017 to Feb. 2020;

Profiles of atmospheric pressure, temperature, relative humidity and wind, with a vertical resolution about 10 m, usually once a day at 12:00 UTC, and specially 4-time a day at 00:00, 06:00, 12:00 and 18:00 UTC in periods of Feb. 2018 and Feb. 2020.

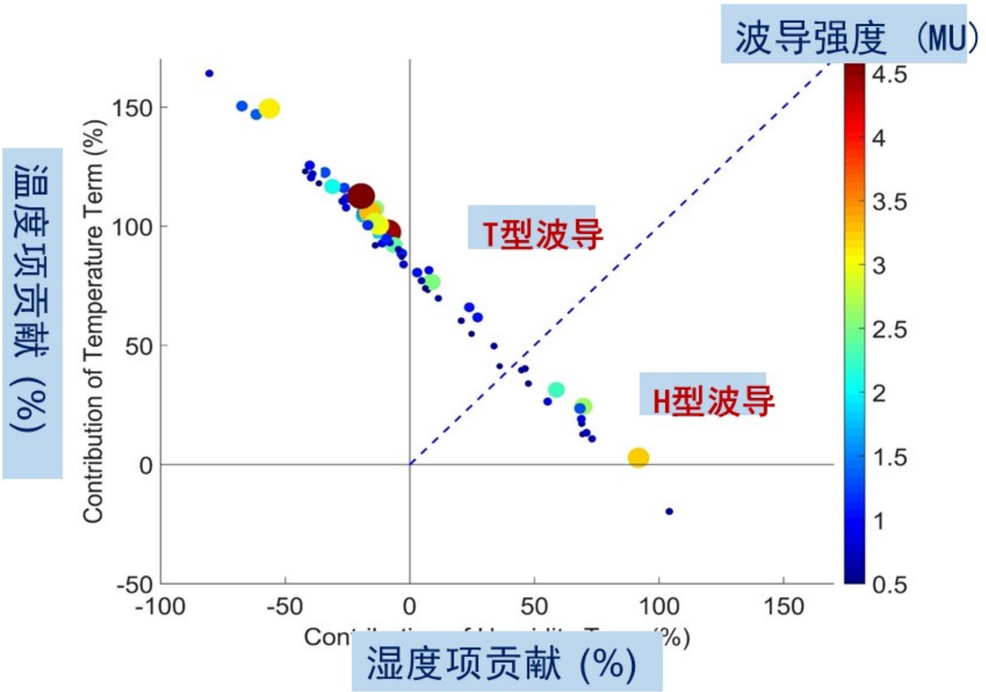






- The surface atmospheric duct has an averaged occurrence frequency of 12.1% over Svalbard, with averaged thickness and strength of 12 m and 1.33 M-units, respectively；
- Occurrence frequency of surface atmospheric duct is much higher than other Arctic region.

2. Surface atmospheric duct over Svalbard, Arctic

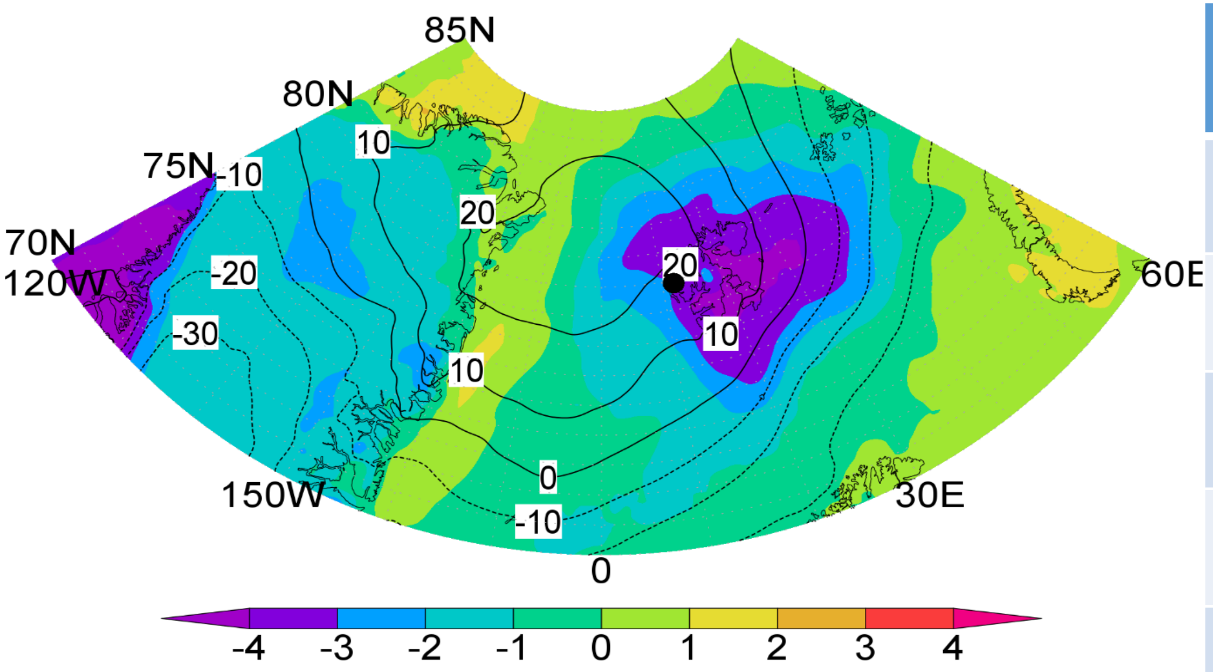


Percentage contributions of temperature and humidity terms to surface duct at Svalbard in winter months from Dec. 2017 to Feb. 2020

	T-type duct	H-type duct
Occurrence times	51	14
Occurrence frequency	78.5%	21.5%
Duct strength	1.37 MU	1.18 MU
Duct thickness	13 m	11 m

The surface duct in Svalbard winter could be categorized to two types, as T-type duct mainly supported by temperature inversion and H-type duct by humidity gradient. T-type duct dominated the surface duct in Svalbard winter, occupying 80% of all duct cases, indicating an importance of temperature inversion in constructing surface duct.

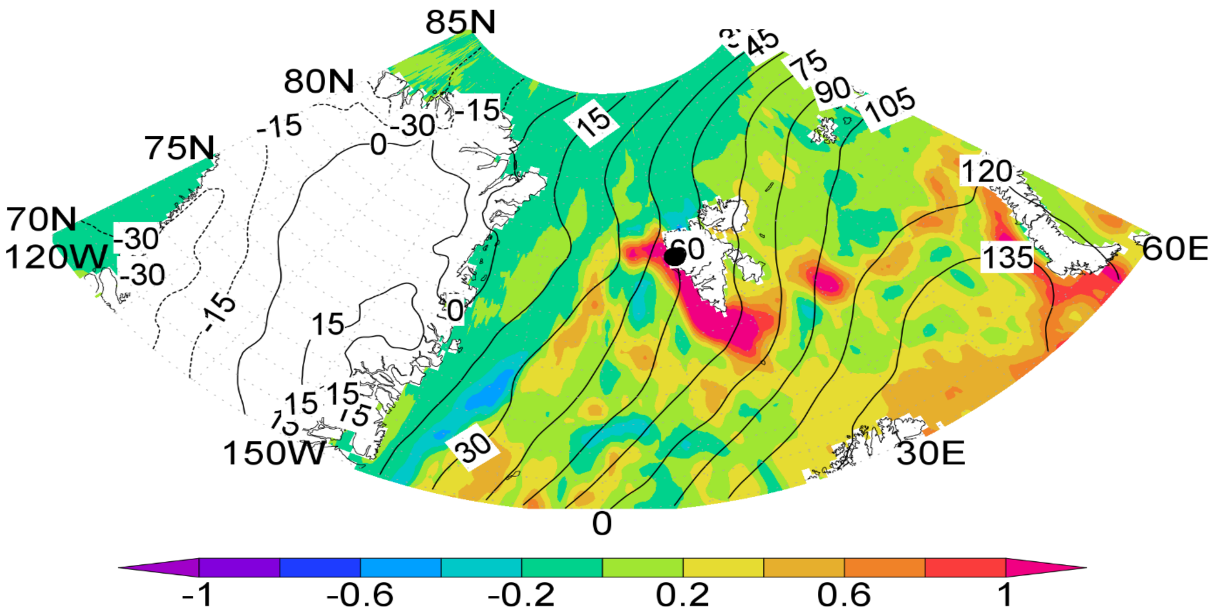
The temperature inversion caused by enhanced surface radiative cooling could be the main support to T-type surface duct under atmospheric condition with colder, drier and northeasterly weather



Temperature anomaly at 1000 hPa when T-type duct occurred

	T-type duct	Winter average
Clear day ratio	71.7%	21.8%
Total water vapor	2.5 kg/m^3	4.1 kg/m^3
DLR	190.2 W/m^2	227.5 W/m^2
NR	-45.6 W/m^2	-32.3 W/m^2
2 m temp.	-14.4°C	-8.6°C
2-50 m temp. inver. strength	2.3°C	0.5°C

The humidity gradient formed by increased evaporation on surrounding water could be the main support to H-type duct under atmospheric and oceanic condition with warmer, wetter and southeasterly weather, and higher SST.



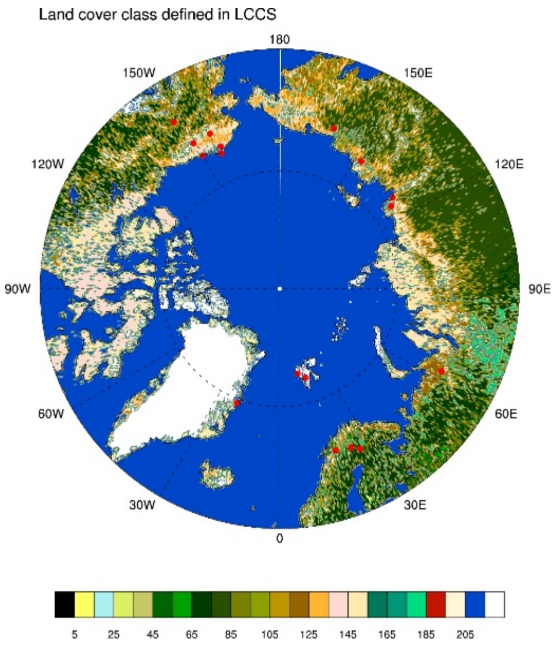
Temperature anomaly at 1000 hPa
when H-type duct occurred

	H-type duct	Winter average
Low clouds possibility	83.3%	63.4%
Total water vapor	5.6 kg/m^3	4.1 kg/m^3
DLW	261.3 W/m^2	227.5 W/m^2
NR	-26.8 W/m^2	-32.3 W/m^2
SST	0.7°C	-0.2°C
2 m q	2.18 g/kg	1.53 g/kg
2-50 m diff. of q	0.16 g/kg	0.02 g/kg

Zhu et al., AAAR, 2022

3. Surface heat transfer changes over Arctic land and sea connected to Arctic warming

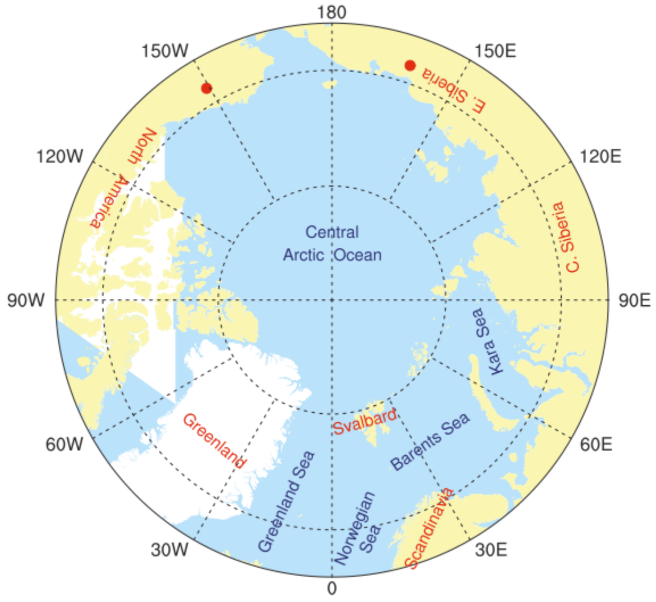
Surface cover	Summer		Winter		Reference
	SH	LH	SH	LH	
Floe	-2~2	1~7	-6~-3	~0	Persson et al. (2002)
Fjord	-30~-15	70~135	/	/	Fortuniak et al. (2014)
Tundra	22.5	22.5	-16	2.5	Westermann et al. (2009)
Tundra	22	44	-9	4	Langer et al. (2011a, b)
Greenland glacier	-3	5	-20	5	Miller et al. (2017)



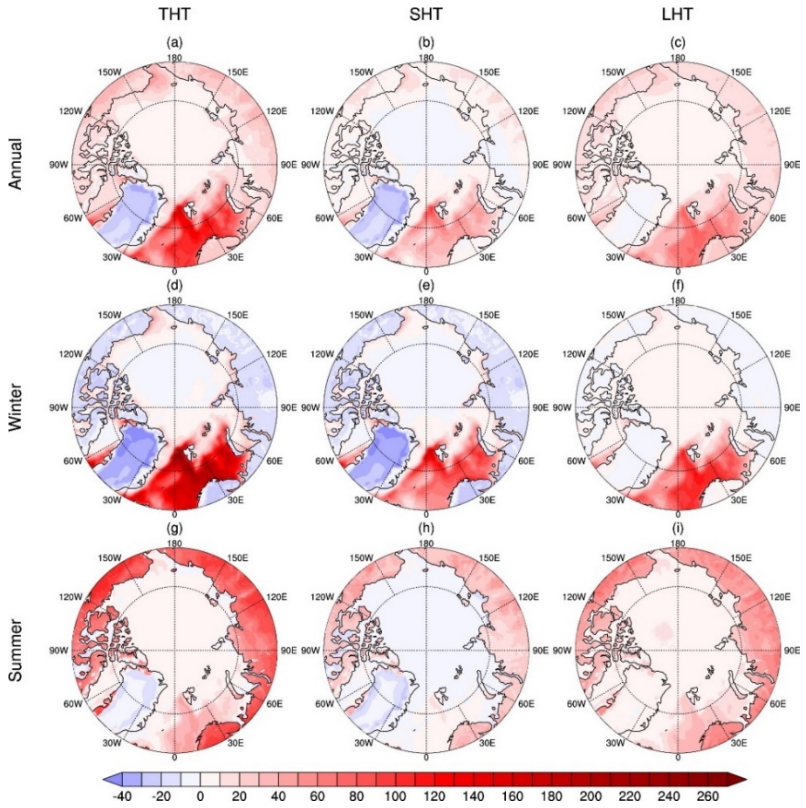
Stations from the Arctic flux-net

In-situ station observed different heat transfers over different surface covers, it is necessary to comprehensively analyze the heat transfer changes over the inhomogeneous Arctic region.

3. Surface heat transfer changes over Arctic land and sea connected to Arctic warming



Map of the Arctic north of 66N. The observation sites used for data validation are marked as dots. The main land and sea regions in discussion are also denoted.

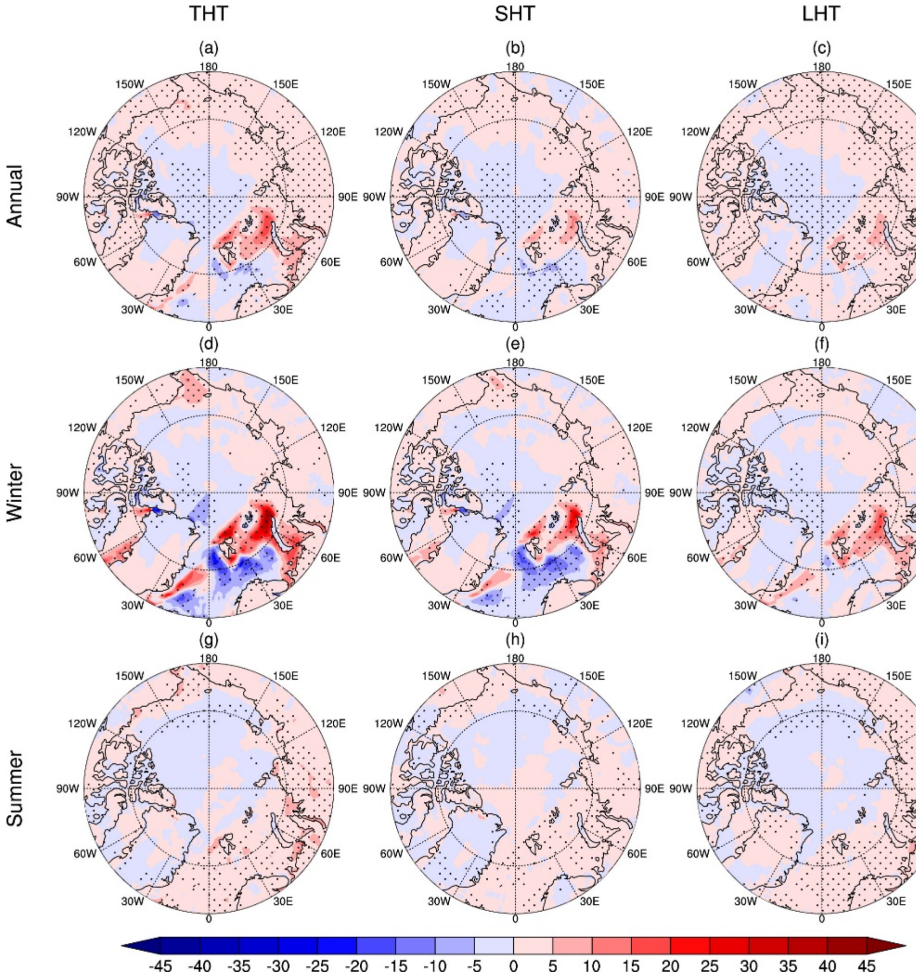


The average fluxes of total turbulent heat transfer (THT), sensible heat transfer (SHT) and latent heat transfer (LHT) over the Arctic, in W/m^2, for the annual, winter and summer means from 1979 to 2018.

The Arctic surface within 66N releases heat to the atmosphere, mainly by latent heat release, with an average of 20.0 W/m^2 and a total of 4.5 $\times 10^{14}$ W annually. The Arctic sea is the only contributor to the Arctic heat release in winter, and the land is the dominating contributor in summer.

Kong et al., Int. J. Clim., 2022

3. Surface heat transfer changes over Arctic land and sea connected to Arctic warming

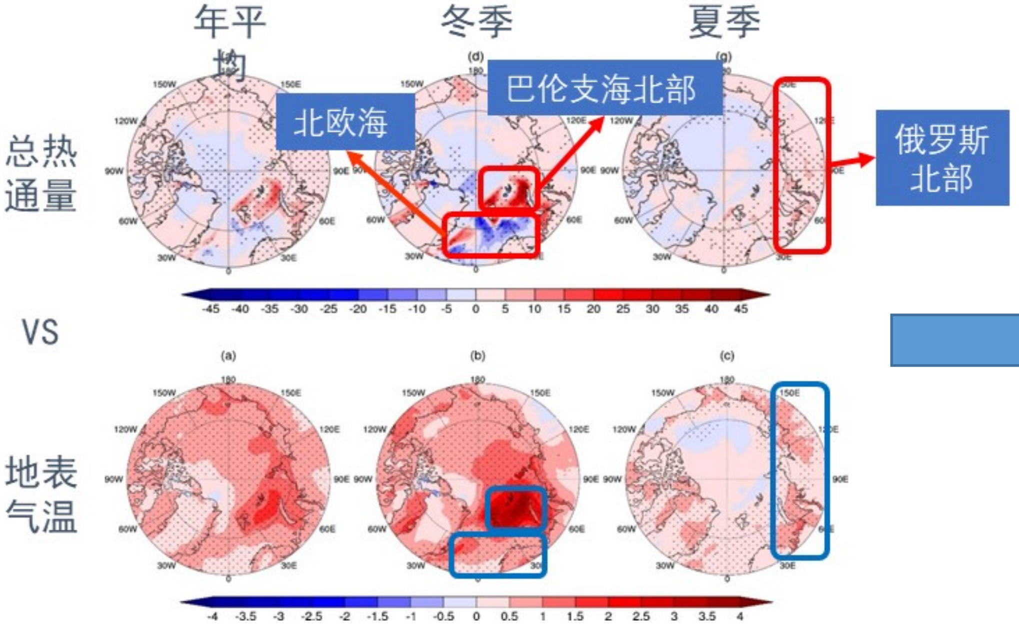


The annual, winter, and summer trends of total turbulent heat transfer (THT), sensible heat transfer (SHT) and latent heat transfer (LHT) over the Arctic from 1979 to 2018.

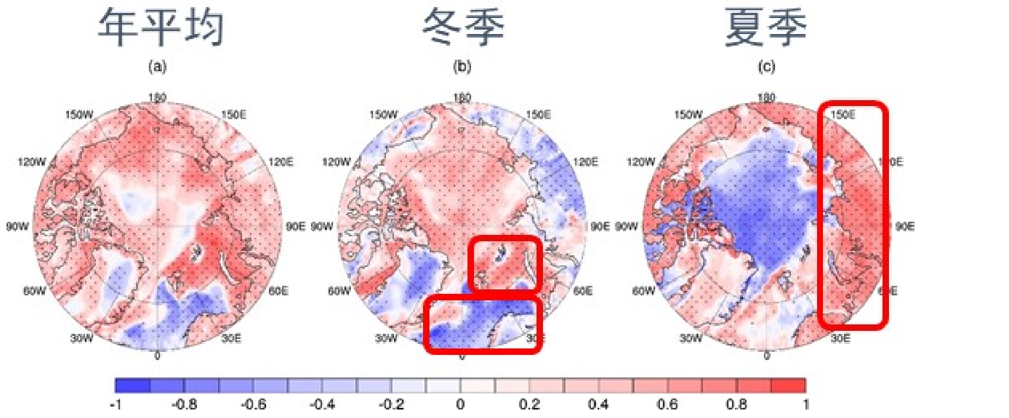
Heat release from surface to atmosphere over the Arctic markedly increased, mainly due to the increase in latent heat release, with a trend of 0.94 ±0.31 W/(m^2decade) annually from 1979 to 2018. The increase in heat transfer over the Arctic was slower in winter, with dominating contribution from the sea, and faster in summer, with contributions from both the land and sea.

Kong et al., Int. J. Clim., 2022

Surface heat transfer changes over Arctic is closely related to the surface temperature increase, but with different feedback processes.



Trends of surface air temperature over the Arctic from 1979 to 2018 for the annual (a), winter (b) and summer (c) means in ^{o}C/decade.



Correlation coefficients between interannual variations of surface heat transfer and surface air temperature over the Arctic,
for the annual (a), winter (b) and summer (c) means from 1979 to 2018.

Conclusions:

1) Heat transfer changed heterogeneously over the Arctic land and sea, with three major changes: (a) Northern Russia Increase over northern Russia in summer, mainly due to increases in latent heat release; (b) Northern Barents Increase over the northern Barents Sea around Svalbard Islands and Franz Josef Land in winter, due to both increases in sensible and latent releases; and (c) Nordic Sea Decrease over the Nordic Sea and northeastern Greenland Sea in winter, mainly due to decreases in sensible heat release.
2) Under Arctic warming, the Arctic sea dominated the surface temperature increase in winter, and both the Arctic land and sea contributed to the temperature increase in summer. The heat transfer change can be connected to Arctic warming by different feedback processes, especially over the three regions with major changes in heat transfer. The feedbacks between the major heat transfer changes and Arctic warming could impact further temperature increase over the Arctic land and sea, and consequently modify Arctic warming.

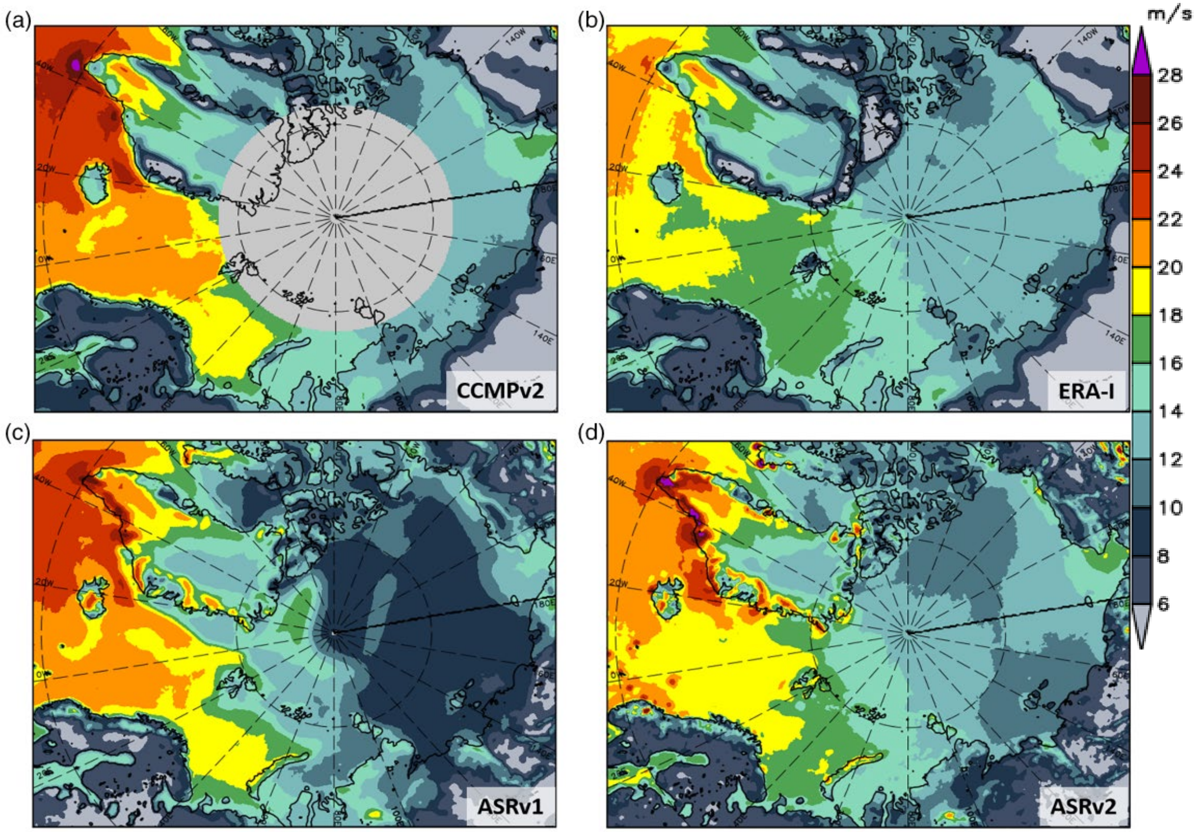
Kong et al., Int. J. Clim., 2022

Importance of the Arctic extreme wind:

- The Arctic is one of the windiest areas worldwide (Sampe and Xie, 2007).
- Extreme winds in the Arctic and around Greenland are important for the local weather and for the global climate.
- Extreme winds further constitute a hazard to marine activities (Hughes and Cassano, 2015), which are likely to increase in the future as sea ice is retreating (Stroeve et al., 2012) and large reservoirs of oil and gas will become accessible in the Norwegian and the Barents Sea (Gautier et al., 2009).
- Even coastal areas are endangered by storm surges (Brunner et al., 2004), which enhance coastal erosion (Harper, 1978).

Previous studies on the Arctic extreme wind:

Extreme winds are in particular generated in the vicinity of southeast Greenland, which is located at the end of the North Atlantic storm track, with the highest values (≥20 m/s) across all data sets occur in the North Atlantic, in the Greenland, Icelandic and Norwegian (GIN) Seas, and along Greenland's southeast coast. Very high values (>26 m/s) occur over the Irminger Sea at Cape Farewell, offshore the Ammassalik Island, and in the Denmark Strait .



The thresholds u95 for the POT method defined as the local 95% percentile of daily maximum wind speed in the winter (November – April) 2000/2001–2011/2012 for (a) CCMPv2, (b) ERA-I, (c) ASRv1, (d) ASRv2. From Gutjahr (Int. J. Climatol., 2018).

Differences are clearly seen on the Arctic extreme wind among different re-analysis data !!!

Previous studies on the possible impact factors for the Arctic extreme wind:

- **Strong mid-latitude cyclones or mesoscale processes, such as terrain-generated mesoscale winds around Greenland and polar lows (Condron et al., 2006, 2013; Morre and Renfrew, 2014; DuVivier and Cassano, 2015);**
- **Both local forcing and large-scale circulation, such as katabatic flow from glaciers (Vilma et al., 2011; Kitowska et al., 2021a; b);**
- **Atmospheric stability and sea surface roughness (Zapponini and Goessling, 2024);**
- **Large surface heat and moisture transfers→→Arctic sea ice formation and polar lows (Spall et al., 2003; Sproson et al., 2008; Zhang et al., 2008; Simmonds and Keay, 2009; Bracegirdle et al., 2009).**

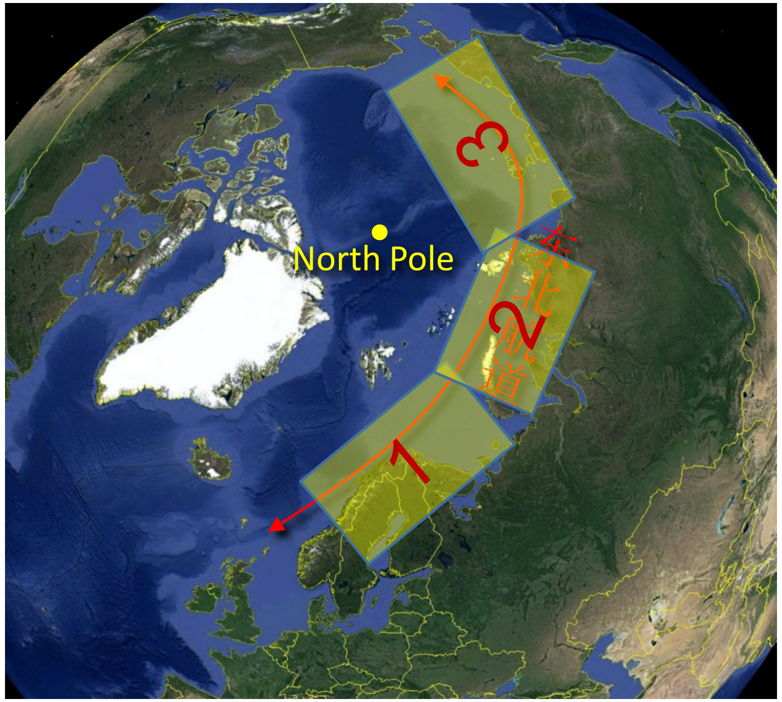
4. Extreme wind over the Arctic passage and its possible influential factors

Motivation:

Given the large differences from the reanalysis data, what is the "real" distribution of extreme wind over the Arctic passage, mainly based on the observational data? What is the main affected factors for the Arctic extreme wind?

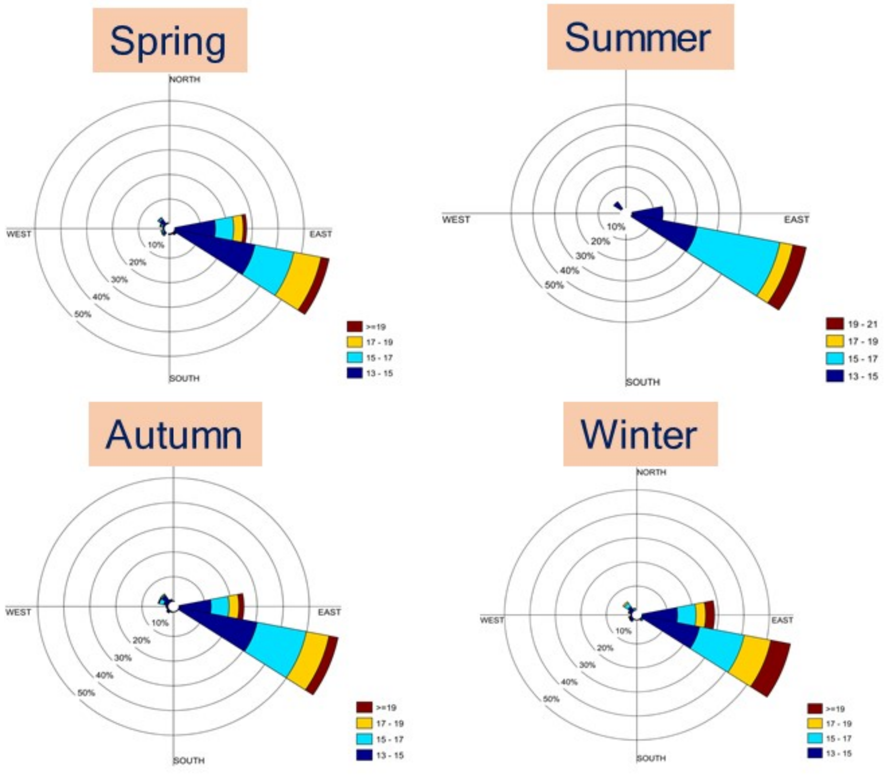
Firstly: How about extreme winds vary over a typical region of the Arctic northeast passage?

Secondly: How about extreme winds vary over whole Arctic northeast passage?



Extreme winds at Ny-Alesund, typical region of the Arctic northeast passage

Climatology and seasonal variation



Windrose diagram for each season

Occurrence, average and maximum speed of extreme wind event at Ny-Ålesund in the four seasons during 1991-2023

Season	Occurrence (%)	Ave. Speed (m/s)	Max. Speed (m/s)
Spring	1.9±1.5	15.0±0.9	28.3
Summer	0.2±0.4	14.4±1.0	26.7
Autumn	2.2±1.5	15.2±0.8	20.6
Winter	4.1±2.8	15.8±0.8	23.7
Annual	2.0±1.0	15.5±0.6	28.3

The Arctic extreme wind reaches the strongest, both its intensity and occurrence frequency, in winter at Ny-Ålesund, Svalbard, dominated by southeasterly and easterly winds.

Long-term trend in extreme winds

Long-term trend of occurrence, average and maximum speed of extreme wind event at Ny-Alesund in the four seasons during 1991-2023

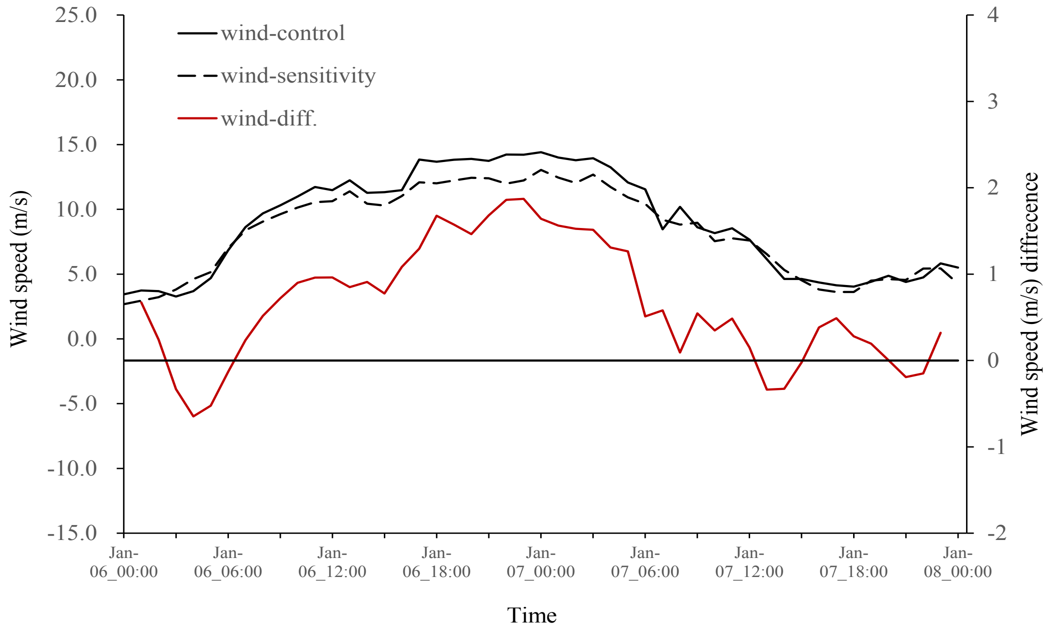
	Trend of occurrence (%/10a)
Annual	**-0.6±0.3***
Spring	**-0.7±0.5***
Summer	**-0.1±0.1***
Autumn	-0.5±0.6
Winter	**-1.6±0.9***

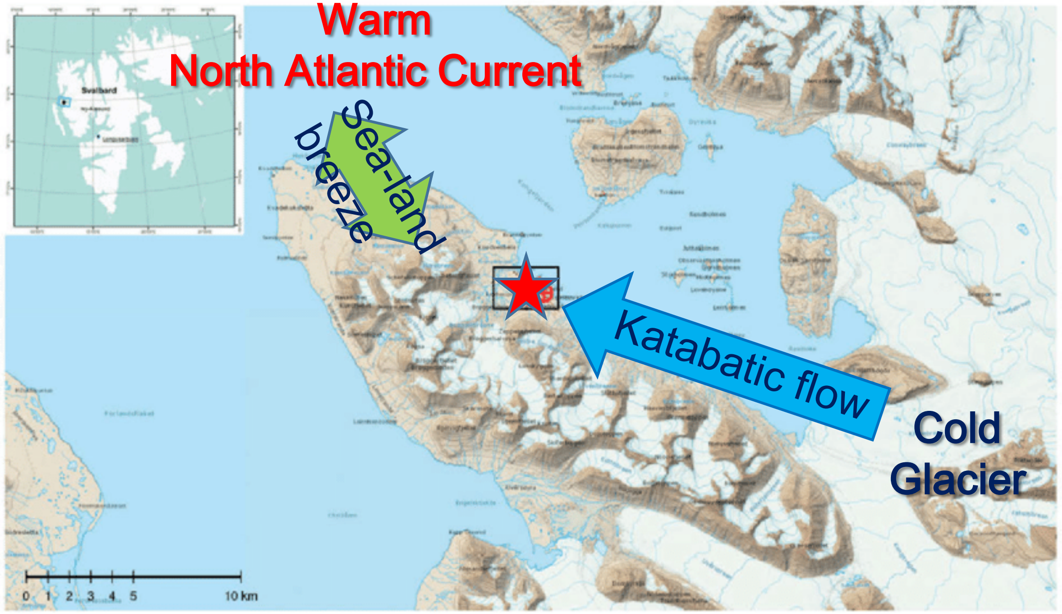
The Arctic extreme wind show decreasing trends in spring, summer and winter, and on annual basis.

	Trend of average speed ((m/s)/10a)
Annual	-0.1±0.2
Spring	-0.1±0.3
Summer	Not enough data
Autumn	-0.2±0.3
Winter	-0.0±0.3

	Trend of maximum speed ((m/s)/10a)
Annual	**-1.2±1.0***
Spring	**-1.3±1.1***
Summer	Not enough data
Autumn	-0.5±0.8
Winter	**-1.3±0.9***

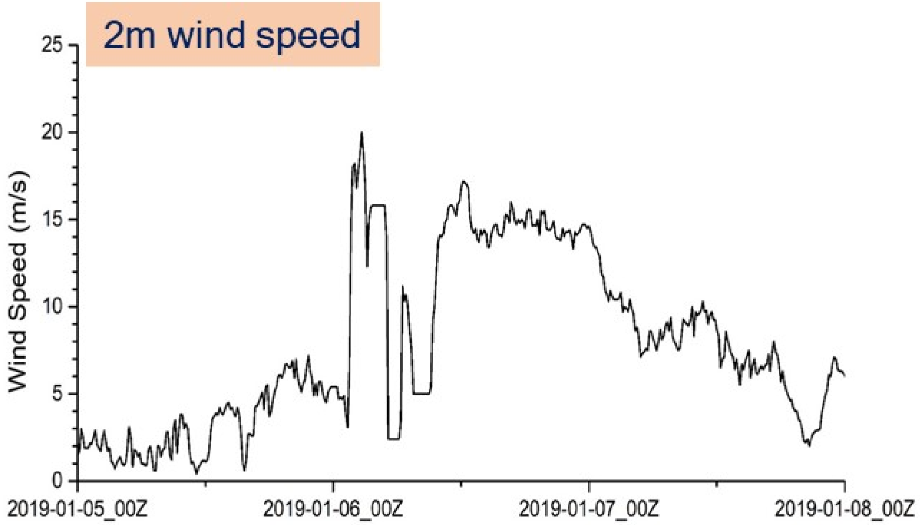
Influential factor: katabatic flow

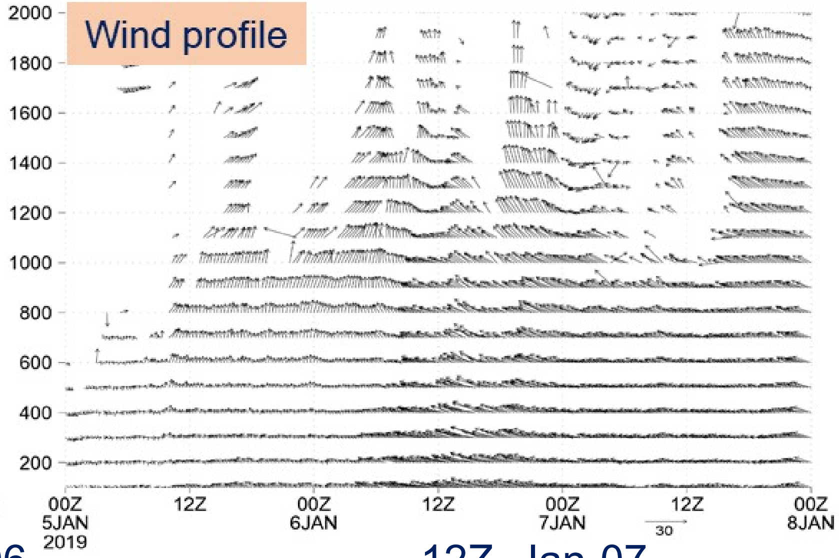


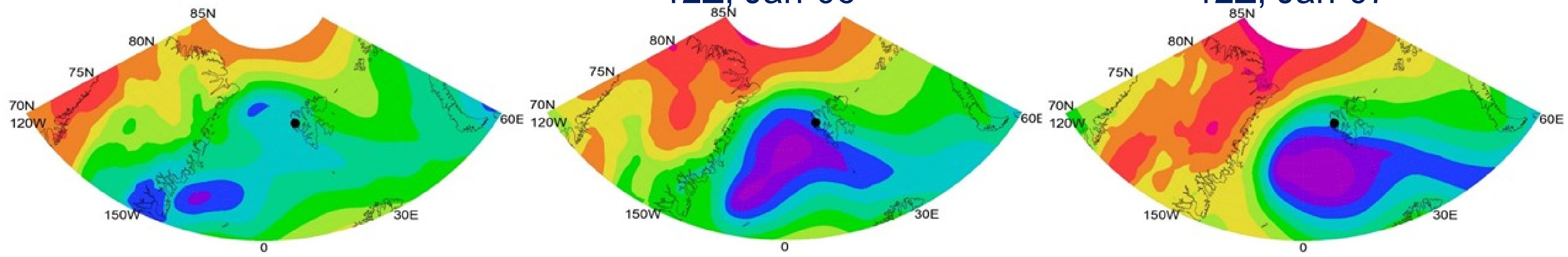


Sensitivity experiment: the extreme winds were more than 10% weakened when the snow–ice surface cover was replaced, the near-surface air temperature and specific humidity also decreased without the snow–ice surface cover. Therefore, we concluded that southeasterly winds from glaciers could strengthen low-level extreme winds over the Svalbard region.

Influential factor: Icelandic Low

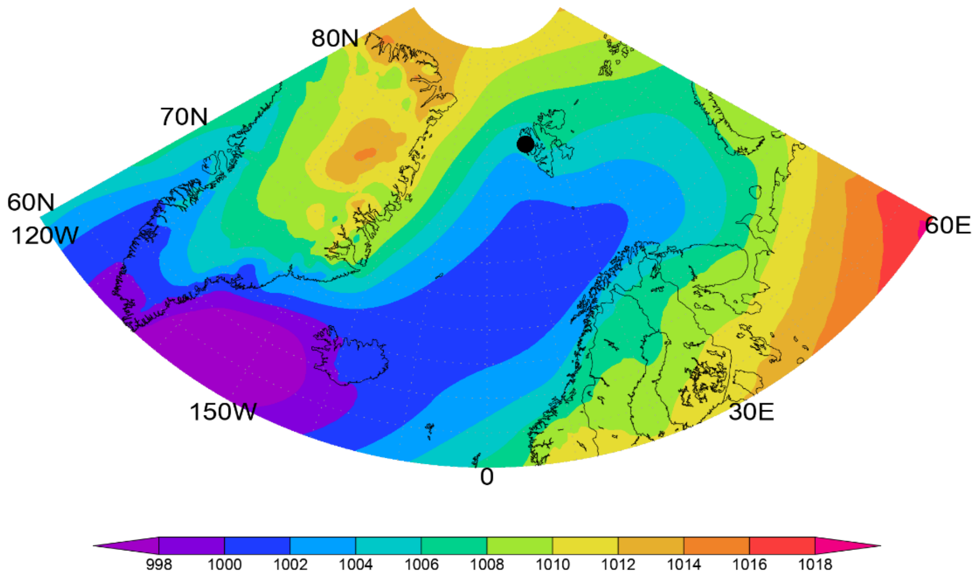


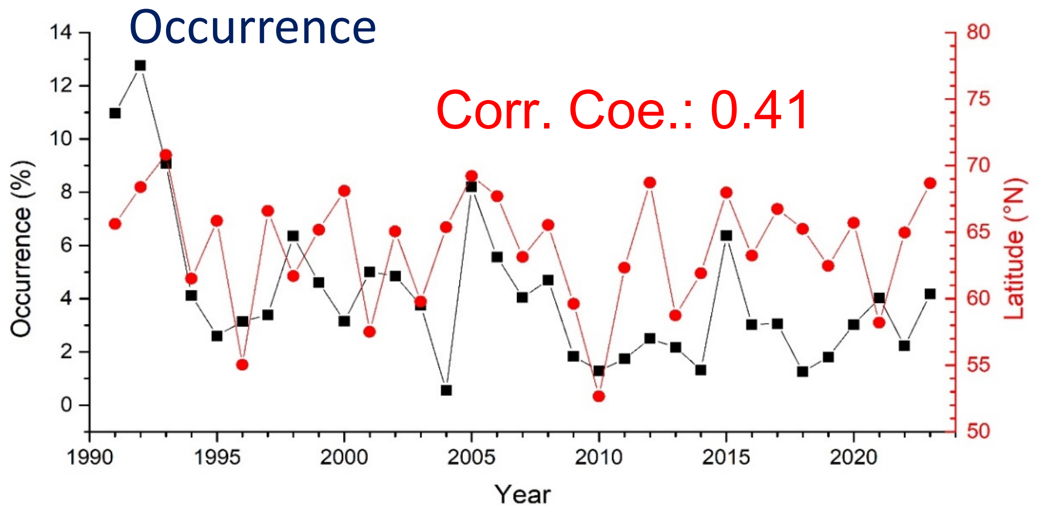


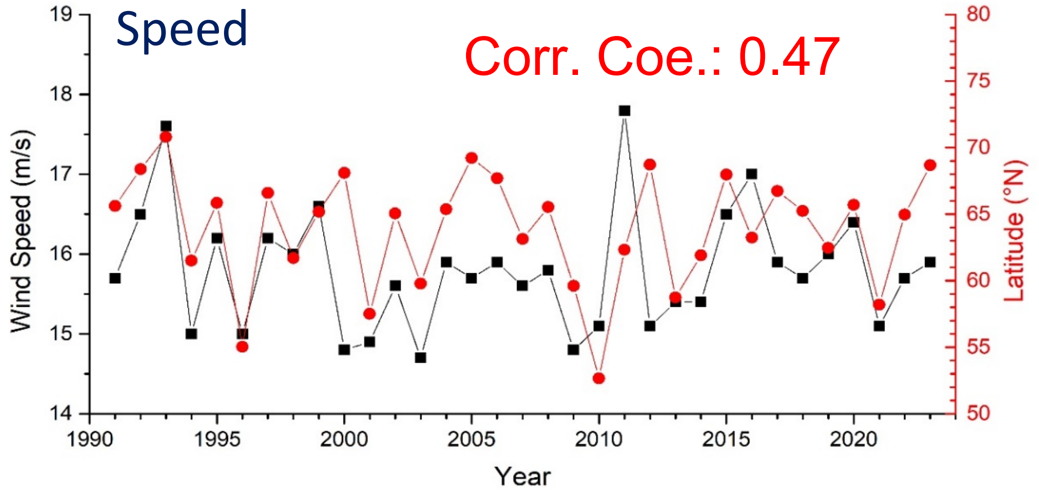


The variation of Icelandic Low could greatly affect the extreme wind over the Svalbard region, through the momentum transfer downward.

Influential factor: Icelandic Low



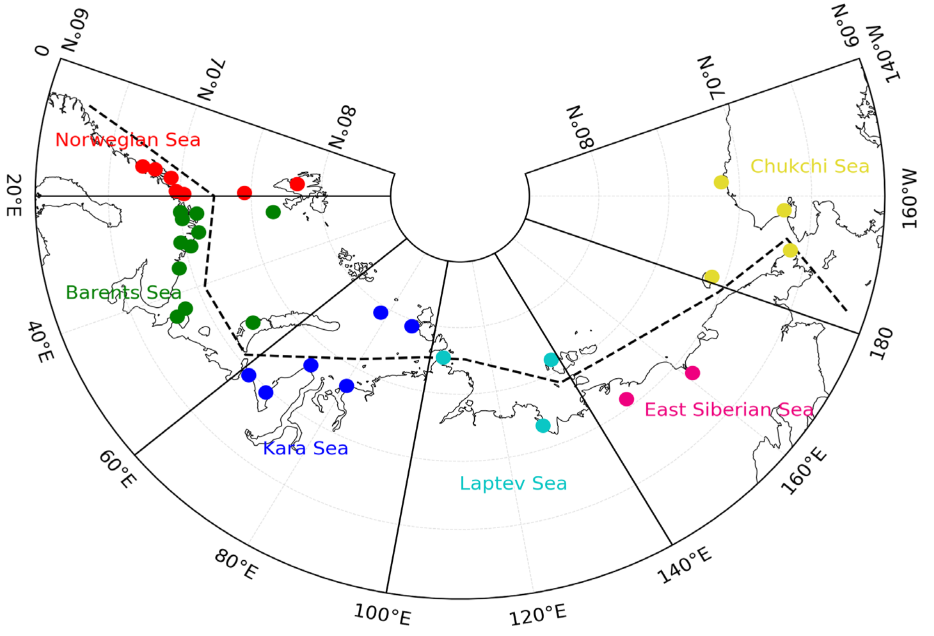




Based on Reanalysis data during 1991-2023:

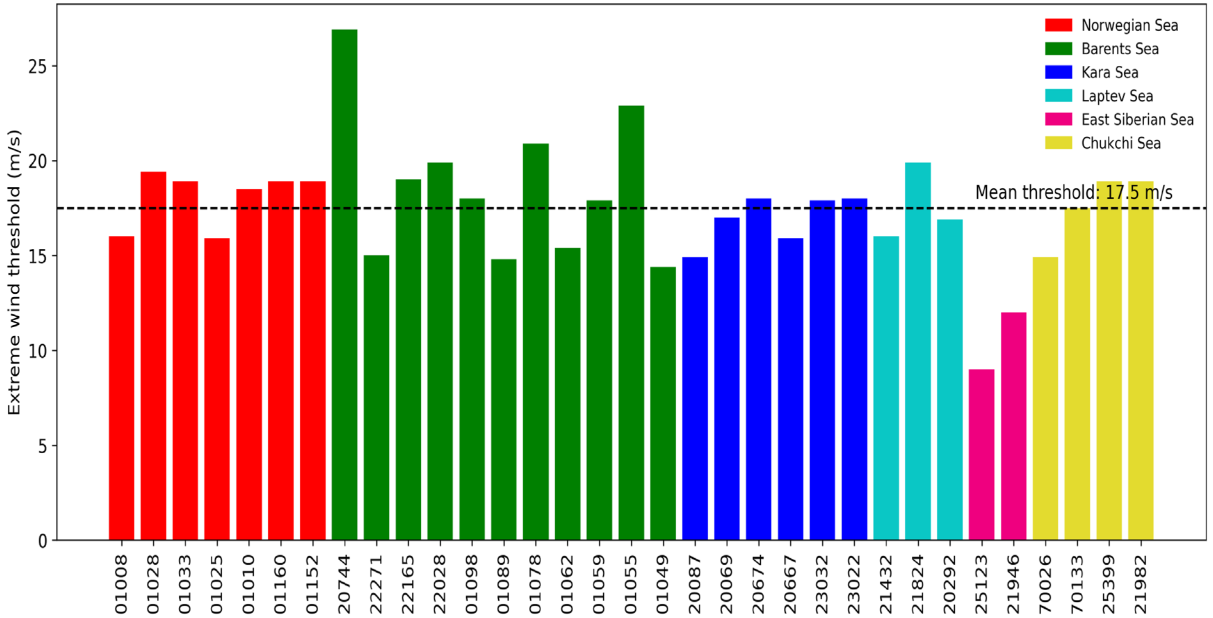
Occurrence and intensity of extreme wind in Ny-Alesund are significantly affected by the location of the Icelandic Low.

Extreme wind over the Arctic northeast passage



Data: 33 stations in total, from 1979 to 2024
6 sea regions: Norwegian Sea, Barents Sea, Kara Sea, Laptev Sea, East Siberian Sea and Chukchi Sea

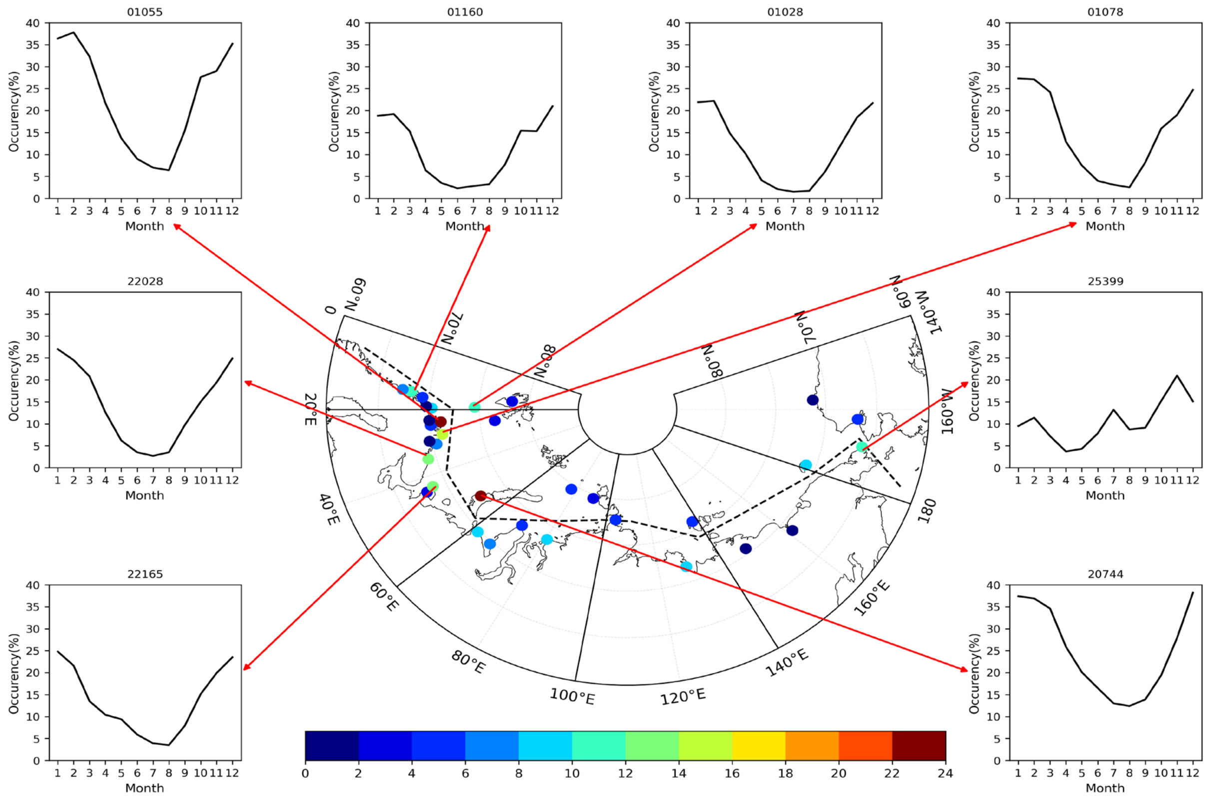
The extreme wind threshold at different stations along the Arctic northeast passage.



- Mean threshold over the Arctic northeast passage of 17.5 m/s;
- Strong extreme wind over the Barents Sea (26.9 m/s at 20744) and weak over the East Siberian Sea (9.0 m/s at 25123)

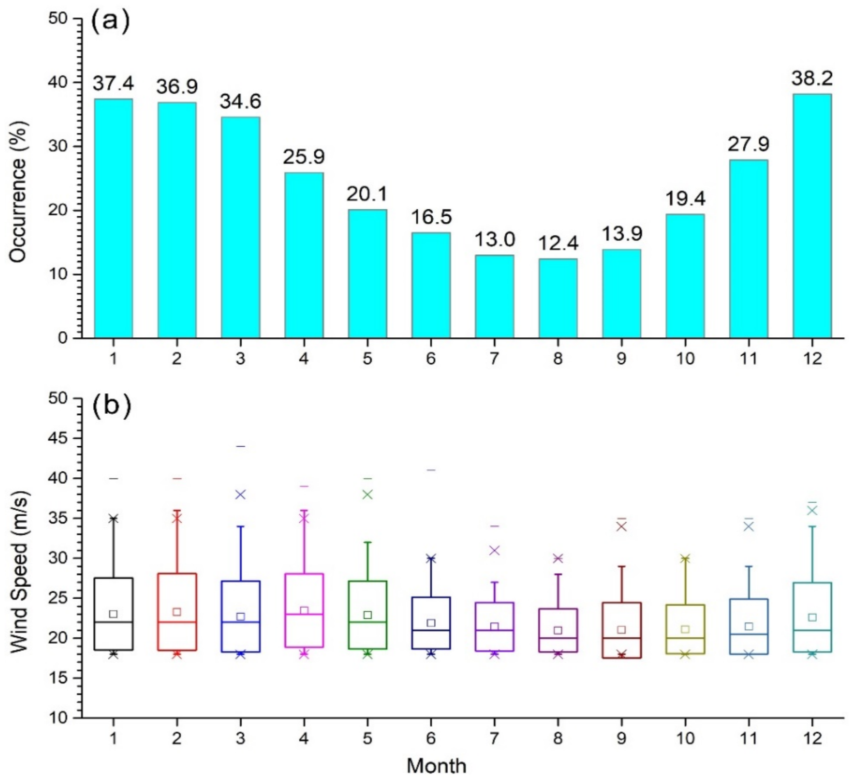
4. Extreme wind over the Arctic passage and its possible influential factors

Occurrence frequency of the extreme wind (percentage) over the Arctic northeast passage



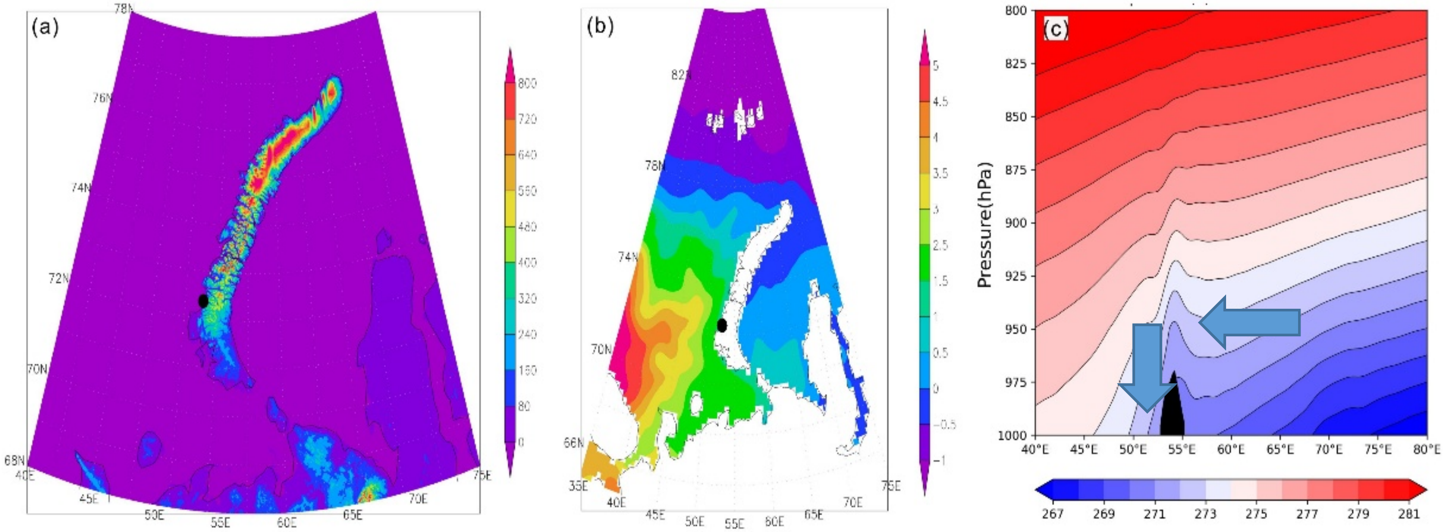
- Occurrence frequency at 8 stations higher than 10%;
- Most happened over the Barents Sea region, (5 of 8 stations), maximum of 24.7% at 20744 (Malye Karmakuly).

The extreme wind and its occurrence frequency at 20744



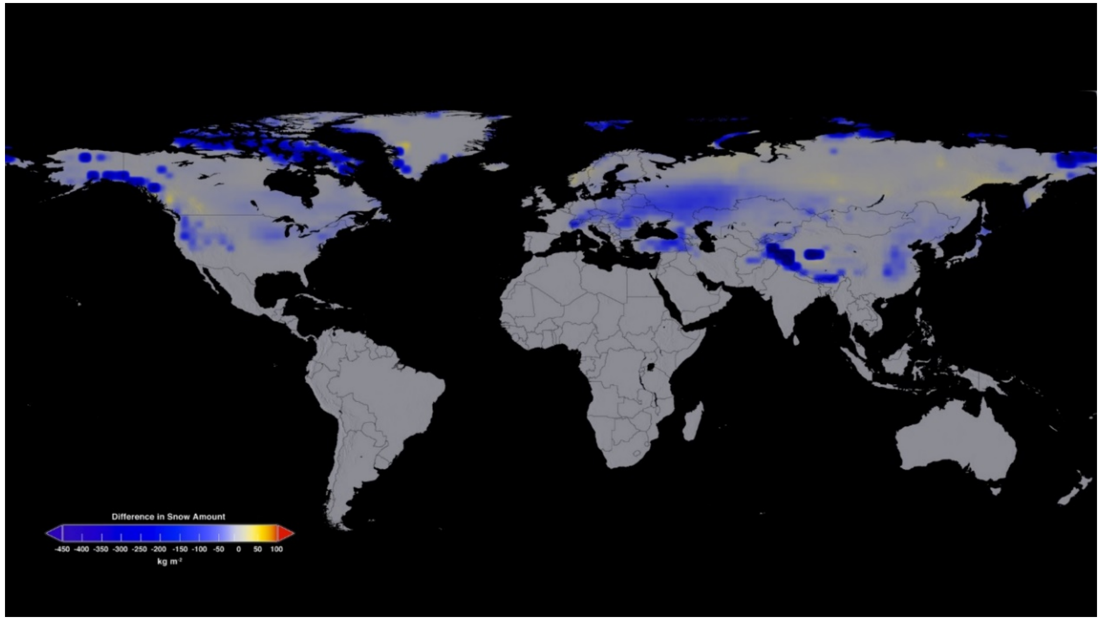
- The extreme wind and its occurrence frequency are high in winter and low in summer;
- The maximum wind speed of 44.0 m/s in March, minimum of 30.0 m/s in August.

Possible affected factors for the extreme wind at station no. 20744



The extreme wind over the west of Novaya Zemiya (station no. 20744) is closely related to the downward cold air mass crossing the mountains, as well as the strong cyclone system (called Bora wind or downslope storm).

Motivation: Snow darkening effect (SDE)

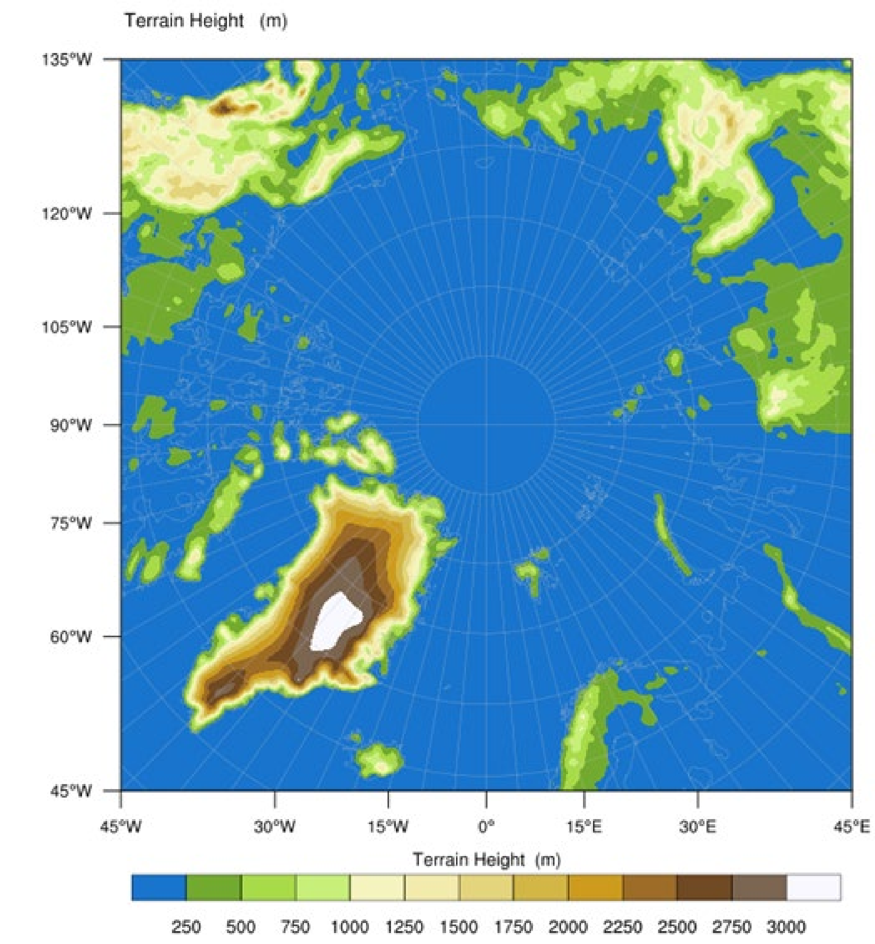


Darkened snow induced by deposition of light absorbing particles (b) Changes in spring snow amount due to the deposition of aerosols on snow averaged over 10 years.

- How BC deposition affects surface energy exchange in the Arctic?
- Which surface and atmospheric variables are important to the intense of SDE?
- What are the crucial physical mechanisms affect the impacts of SDE by BC deposition?

Model setup

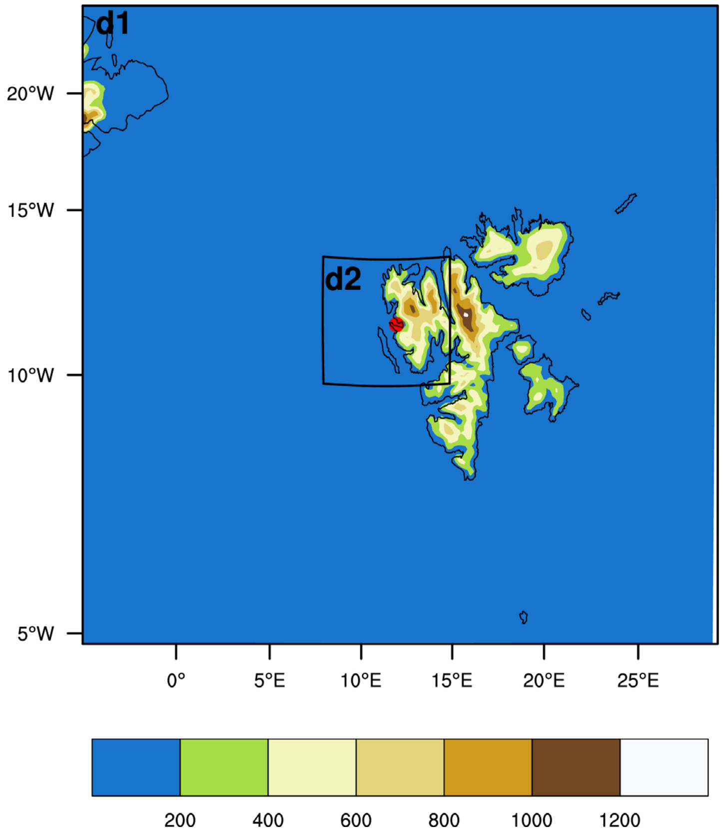
- **Model :** Polar-WRF V4.1.1
- **Study region:** Pan-Arctic
- **Resolution:** 27km×27km, 50 levels composed of vertical grid from surface to 10 hPa.
- **Initial meteorological field:** ERA5 (0.25°×0.25°,every 3h)
- **Snow depth:** NCEP-GDAS-FNL(0.1°×0.1°,every 3h)
- **Snow albedo scheme:** SNICAR



Model Domain

Cloud Microphysics Evaluation

- Region: Svalbard
- Periods: Winter (Feb 2019) and Summer (Aug 2018)
- Objective: Assess 8 microphysics schemes in simulating surface radiation and vertical atmospheric structure.



Polar-WRF domains and terrain height

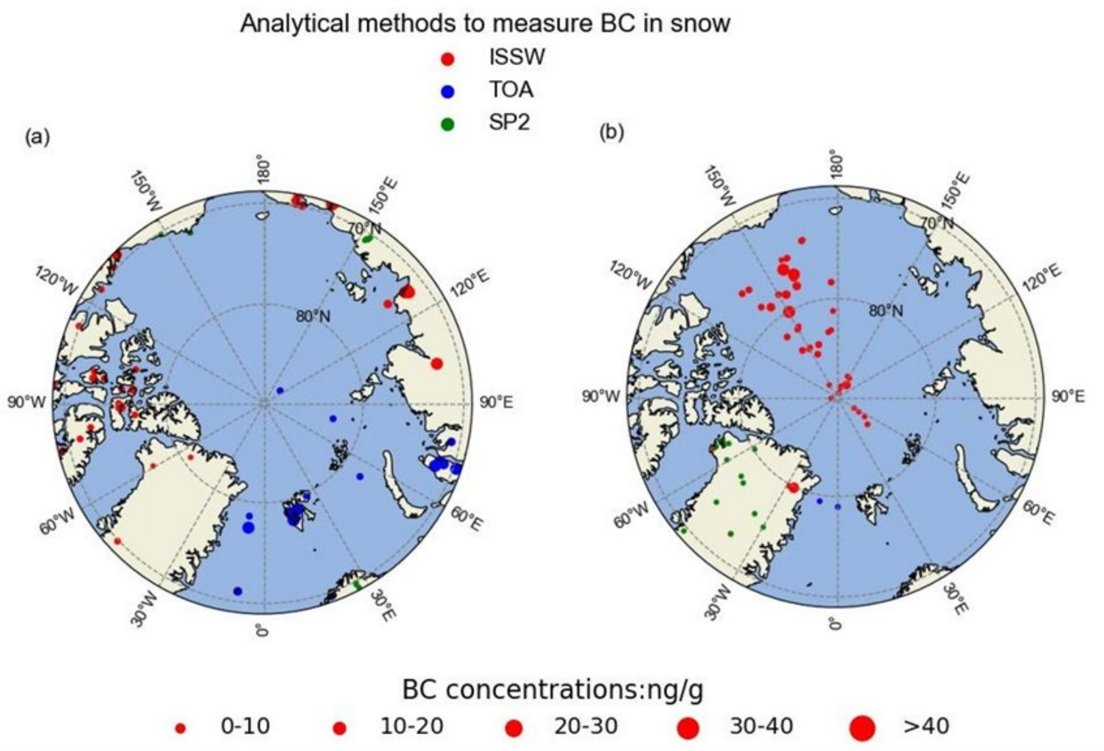
Key Conclusions

- Downward longwave radiation underestimated by all schemes.
- Low cloud cover overestimated in all schemes.
- Mixed-phase clouds:

  Winter: Ice water content overestimated, liquid water content underestimated

  Summer: Cloud top height and liquid water content underestimated
- Morrison scheme showed best overall near-surface meteorology (T2, Q2) in the winter, while Thompson scheme performed best in summer.

BC Deposition in Arctic Snow and Ice

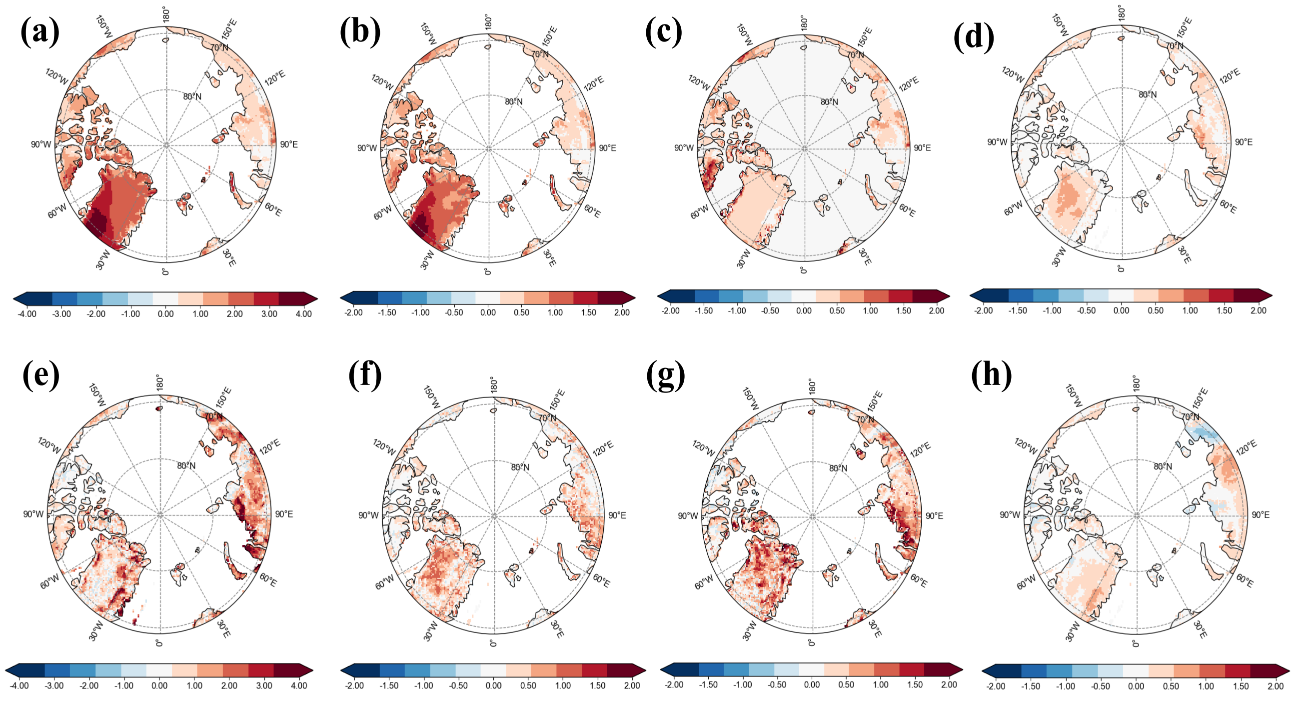


Locations and concentrations of BC snow observations collected from Arctic campaigns between 2005–2018 in spring (a) and summer (b). All of the data used in this figure have been reported in Doherty et al. (2010), Dou et al. (2012), Evangeliou et al. (2018), Forsström et al. (2013), Mori et al. (2019) and Zdanowicz et al. (2021). ISSW, Integrating Sandwich/Integrating Sphere Spectrophotometer; TOA, thermal-optical analysis; SP2, single-particle soot photometer.

The maximum value of BC deposition appears in the western Russian Arctic (26 ng·g^{-1}), and the minimum value appears in Greenland (3 ng·g^{-1}).

5. Modelling study of Snow darkening effect by Black Carbon deposition over the Arctic

Snow Darkening Effect (SDE) from BC depositon



- On average, BC deposition at 50 ng g^{-1} can cause 1.6 W m^{-2} and 1.4 W m^{-2} RF by SNICAR-OFF and SNICAR-ON respectively.
- Snow albedo reduction strongest in deep snow regions (Greenland, eastern Siberia).

Mean change induced by BC deposition in (a) RF (W m^{-2}) (b) sensible heat flux (HS) (W m^{-2}) (c) latent heat flux (LH) (W m^{-2}) (d) surface upwelling longwave radiation (LW) (W m^{-2}) from SNICAR-OFF, (f–j) The same as (e)–(h), respectively, except for SNICAR-ON. Positive (negative) values indicate gain (loss) by the atmosphere apart from RF.

Average changes in Heat Balance Components (W m $^{-2}$); Surface Skin Temperature, TSK (K); and snow melt (mm d-1) during simulation period between off-line -and on-line coupled simulations.

Component	Key Finding
Cloud microphysics	Morrison scheme showed best overall near-surface meteorology (in the winter, while Thompson scheme performed best in summer. Strong seasonal dependence; mixed-phase clouds remain poorly simulated.
BC Deposition in Arctic Snow and Ice	The maximum value of BC deposition appears in the western Russian Arctic (26 ng·g^{-1}), and the minimum value appears in Greenland (3 ng·g^{-1}). Model underestimation by factor of 2–3; regional variability not captured.
Snow Darkening Effect (SDE) from BC depositon	Snow depth is key control; offline simulations overestimate effects.The surface feedback is essential for accurate assessment to SDE by BC depostion.

Conclusion

- The high RF caused by BC deposition reached in 1-4 W m^{-2} mainly occurred in Greenland, Baffin Island and East Siberia, where areas with deep snow depth and large snow densities are prevalent.
- **The impacts of SDE by BC are strongly influenced by the snow depths**. For a given column-mean BC concentration in snow, the impacts of SDE are approximately 25-41% higher in deep snow-covered areas than in shallow snow-covered areas, leading to a 19-40% increase in snowmelt.
- **The processes of snow melting and land-atmosphere interactions have significant impacts on assessing the changes in surface energy balance by BC deposition**. The off-line simulation tends to overestimate the impacts of the SDE, by up **to more than 50% sometimes due to the lack of relevant processes.**

Zhang et al., Atmos. Chem. Phys., 2024

Some related papers

- Zilu Zhang, Shupo Ma*, Wei Cheng, Jinhuan Zhu, Peng Li, Fei Li, Libo Zhou*(2026), Evaluation of Polar-WRF microphysics schemes for simulations of lower atmospheric processes in the Svalbard region, Arctic, ***Atmospheric Research***, 330, 108597, ISSN 0169-8095, https://doi.org/10.1016/j.atmosres.2025.108597.
- Zhang, Z., Zhou, L.,Zhang, M, et al. Modeling and Analysis of Winter Arctic Clouds and Their Radiative Impacts Using Three Microphysics Schemes in Polar-WRF, ***Atmospheric Research***, 2026. (To be published).
- Zhang Z L, Zhou L B*, Zhang M G.* (2025), A numerical sensitivity study on the snow-darkening effect by black carbon deposition over the Arctic in spring, ***Atmos. Chem. Phys.***, 25, 1–25, https://doi.org/10.5194/acp-25-1-2025.
- Zhang Z L, Zhou L B*, Zhang M G. (2024), A progress review of black carbon deposition on Arctic snow and ice and its impact on climate change, ***Adv Polar Sci***, 35(2): 178-191, doi: 10.12429/j.advps.2023.0024.
- Zhou, L. B.*, J. H. Zhu, L. L. Kong, et al. (2024), The observed near-surface energy exchange processes over Arctic glacier in summer, ***J. Meteor. Res.***, 38(3), 600–607, doi: 10.1007/s13351-024-3158-2.
- Jinhuan Zhu, Han Zou, Linlin Kong, Libo Zhou, Peng Li, Wei Cheng and Shuangshuang Bian (2022), Surface atmospheric duct over Svalbard, Arctic, related to atmospheric and ocean conditions in winter, ***Arctic, Antarctic, and Alpine Research***, 54:1, 264-273, DOI:10.1080/15230430.2022.2072052.
- Kong L. L., H. Zou*, L. B. Zhou*, and J. H. Zhu (2022), Surface heat transfer changes over Arctic land and sea connected to Arctic warming, ***Int. J. Climatol.***, 1–16, https://doi:10.1002/joc.7808.
- Kong L. L., H. Zou*, L. B. Zhou*, and J. H. Zhu (2022), Atmospheric energy change in the Arctic troposphere under Arctic warming, ***Int. J. Clim.***, 1–12. https://doi.org/10.1002/joc.7638.

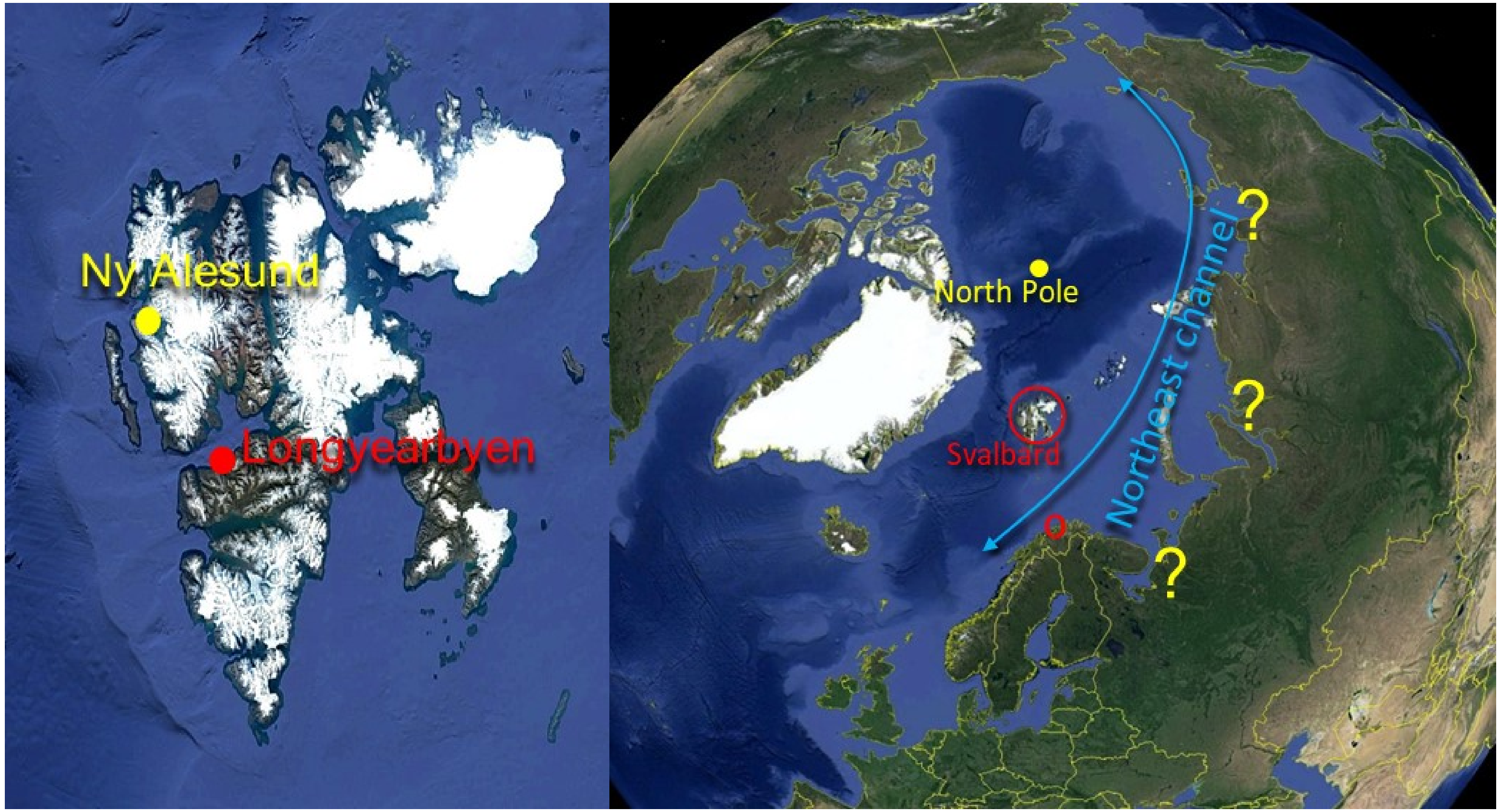
Outline

- About our team
- Field observations
- Preliminary results
- Future collaboration

Seeking further joint collaborations

IAP CAS–Germany Collaboration Observatory

- Surface Weather
- Eddy Covariance
- Radiation
- Vertical Wind, Temperature and Humidity Profile Lidars
- ……




Wish you a good mood very day, like her !!!
☺ ☺ ☺
Good Mood
STREET FOOD
Locally Sourced
Est. 2016
Made from scratch