Attachment no 3

Self – presentation in English including the information on published scientific papers and on the didactic achievements, scientific cooperation and the popularization of science.

1. Name and Surname

Mateusz Moskalik

2. Scientific titles and degrees – including names, places, dates and titles of the dissertations

- 2012 **PhD in Earth sciences** Institute of Geophysics PAS, Warsaw
  Morphological variability of the bottom and the acoustic identification of the bottom deposits of the early periglacial marine environment in the area of Brepollen (Hornsund, Spitsbergen).
- 2005 **MSc in Physics** Faculty of Physics of University of Warsaw, Warsaw
  Propagation of the natural earthquakes seismic waves in the area of marginal zone of the Barents Sea shelf in connection to the earth crust models in the area.

3. Scientific employment

- od 08.2012 **adjunct**, Polar and Marine Research Department, Institute of Geophysics PAS, Warsaw
- 11.2010 - 07.2012 **technical employee – specialist-geophysicist**, Polar and Marine Research Department, Institute of Geophysics PAS, Warsaw
- 11.2005 - 10.2010 **PhD student**, Polar and Marine Research Department, Institute of Geophysics PAS, Warsaw
- 07.2005 - 09.2005 **field assistant**, Deep Structures Lab, Institute of Geophysics PAS, Warsaw
- 06.2003 - 10.2004 **scientific observer - seismologist**, Polish Polar Station Hornsund, Polar and Marine Research Department, Institute of Geophysics PAS, Warsaw
- 06.2000 - 06.2000 **field assistant**, Deep Structures Lab, Institute of Geophysics PAS, Warsaw

4. Scientific achievements according to the art. 16 paragraph 2 of the act from 14th of March 2003 of the degrees and the title in science and art (Logbook No 65, pos. 595 with changes).

a) Title of scientific achievement

Abiotic environment of subpolar fjords as a result of the recent climate change – scientific results and the impact.

b) Author/authors, title/titles of publications, year of issue, title of the paper with the description of the individual contribution of the applicant

(1) **Moskalik M.**, Pastusiak T., Tęgowski J. 2012. Multibeam bathymetry and slopes stability of Isvika Bay, Murchisonfjorden, Nordaustlandet. *Marine Geodesy*, 35, 4, 389-398
Applicant's contribution: measurements in field; general concept of the paper, preparation and analysis of the data; comprehensive data preparation and analysis; interpretation and discussion on the results; preparation of the manuscript including figures;

(2) Staszek M., **Moskalik M.** 2015. Contemporary sedimentation in the forefield of Hornbreen, Hornsund. *Open Geosciences*, 7, 1, 490-512
Applicant's contribution: management of the project financing the survey and data preparation; measurements in field; the concept of the paper, preparation and analysis of the data; substantive care and advisory on the data analysis done by the main author, MSc student under applicant's mentorship; contribution in the interpretation and discussion; co-authorship in writing of the manuscript and creating figures;

(3) Zagórski P., Rodzik J., **Moskalik M.**, Strzelecki M.C., Lim M., Błaszczyk M., Promińska A., Kruszewski G., Styszyńska A., Malczewski A. 2015. High Arctic coastal erosion: multidecadal (1960-2011) shoreline changes in Isbjørnhamna (Hornsund, Svalbard). *Polish Polar Research*, 36, 4, 369-390
Applicant's contribution: management of the project under which the archived data was processed; co-authorship of the concept of the paper, data processing and analysis; complete processing of the

bathymetric data used in the paper; contribution in the interpretation and discussion; co-authorship in writing of the manuscript and creating figures;

(4) Głowacki O., **Moskalik M.**, Deane G.B. 2016. The impact of glacier meltwater on the underwater noise field in a glacial bay. *Journal of Geophysical Research: Oceans*, 121, 12, 8455-8470

Applicant's contribution: participation in the fieldwork; participation in creating the concept of the paper, data processing and analysis; complete processing of the CTD data used to calculate the sound velocity; scientific mentorship on the main author (applicant's PhD student) performing the modeling and acoustic data analysis; contribution in the interpretation and discussion; co-authorship in writing of the manuscript and creating figures;

(5) Ćwiąkała J., **Moskalik M.**, Forwick M., Wojtysiak K., Giżejewski J., Szczuciński W. 2018. Submarine geomorphology at the front of the retreating Hansbreen tidewater glacier, Hornsund fjord, southwest Spitsbergen. *Journal of Maps*, 14, 2, 123-134

Applicant's contribution: management of the project under which the bathymetric data was purchased and processed; contribution to the concept of the paper, data processing and analysis; substantive care and advisory in developing the bathymetric map, backscatter map and geomorphological map done by the main author (applicant's PhD student); contribution in the interpretation and discussion; co-authorship in writing of the manuscript and creating figures;

(6) **Moskalik M.**, Ćwiąkała J., Szczuciński W., Dominiczak A., Głowacki O., Wojtysiak K., Zagórski P. 2018. Spatiotemporal changes in the concentration and composition of suspended particulate matter in front of Hansbreen, a tidewater glacier in Svalbard. *Oceanologia*, 60, 4, 446-463

Applicant's contribution: participation and direction of the fieldwork; general concept of the paper, preparation and analysis of the data; comprehensive data preparation and analysis; coordination and participation in the interpretation and discussion on the results; coordination and participation in the manuscript preparation; preparation of all figures;

(7) **Moskalik M.**, Zagórski P., Łęczyński L., Ćwiąkała J., Demczuk P. 2018. Morphological characterization of Recherchefjorden (Bellsund, Svalbard) using marine geomorphometry. *Polish Polar Research*, 39, 1, 99-125

Applicant's contribution: management of the project under which the bathymetric data was purchased and processed; contribution to the concept of the paper; concept of the processing and analysis of the bathymetric data; independent processing and analysis of the bathymetric data; participation in preparation of geomorphological background; coordination and participation in the interpretation and discussion on the results; coordination and participation in the preparation of the manuscript and figures;

(8) Wojtysiak K., Herman A., **Moskalik M.** 2018. Wind wave climate of west Spitsbergen: seasonal variability and extreme events. *Oceanologia*, 60, 3, 331-343

Applicant's contribution: management of the project under which the fieldwork and its preparation was executed, including the processing of modelled data; participation and coordination of the fieldwork; participation in the concept of the paper, data processing and analysis; mentorship and advisory with the data processing performed by the main author (applicant's PhD student); participation in the interpretation and discussion on the results; contribution to the preparation of the manuscript and figures;

(9) Herman A., Wojtysiak K., **Moskalik M.** 2019. Wind wave variability in Hornsund fjord, west Spitsbergen. *Estuarine, Coastal and Shelf Science*, 217, 96-109

Applicant's contribution: management of the project under which the fieldwork and processing was made; participation and coordination of the fieldwork; participation in the concept of the paper, processing and analysis of the data; scientific mentorship and advisory in data processing performed by the second author (applicant's PhD student); participation in the interpretation and discussion on the results; participation in the preparation of the manuscript and figures;

(10) Zagórski P., Mędrek K., **Moskalik M.**, Rodzik J., Herman A., Pawłowski Ł., Jaskólski M. 2019. Short-term development of Arctic beach system: Case study of wave control on beach morphology and sedimentology (Calypsostranda, Bellsund, Svalbard). *Polish Polar Research*, 40, 2, 26p.

Applicant's contribution: manager in the project financing the fieldwork and its processing; contribution to the concept of the paper, processing and data analysis; preparation of the grain size – related data; participation in the interpretation and discussion on the results; participation in the preparation of the manuscript and figures;

c) Discussion on the goal of the paper/papers and results including the possible utilization

(1) Introduction, current state of knowledge, motivation in achieving the scientific goal

Recent change of the climate of the Arctic is firstly linked to the growth of air temperature, which is faster than in other latitudes (Pithan and Mauritsen 2014). Those changes are also transformation of the rain cycle. Increase in precipitation is observed in the area of southern Spitsbergen during late summer and early autumn (Osuch and Wawrzyniak 2016a), with the increase of liquid precipitation also during the winter (Łupikasza et al. 2019; Oltmanns et al. 2019). Moreover, it is predicted for this growth to continue for air temperature and the precipitation in next decades (Osuch and Wawrzyniak 2016b). Other indicator of the climate change is the retreat of the glaciers (Błaszczyk et al. 2013; Pälli et al. 2003). Along with the precipitation it contributes to the amount of freshwater in polar seas (Bamber et al. 2012). In the same time the water temperature in fjords is increasing (Pavlov et al. 2013; Zhuravskiy et al. 2012) and the length of the sea ice occurrence period is decreasing (Muckenhuber et al. 2016; Zhuravskiy et al. 2012) even in the winter (Onarheim et al. 2014). Increase in storm intensity is also observed (Bertin et al. 2013; Kushnir et al. 1997) which in turn contributes to the accelerated coastal erosion (Barnhart et al. 2014).

All mentioned phenomena have influence on the abiotic environment and its processes. It is necessary to investigate those changes to understand their influence on the biotic environment in local and global scale. For example, change in the delivery of mineral and organic matter and nutrients to the oceans directly impacts the primary production, and indirectly changes the amount of CO_2 in the atmosphere. Glaciers are, via calving, melt-out and subglacial run-off, the main source of the freshwater in fjords (Błaszczyk et al. 2019). Suspended sediment matter is mainly delivered to the fjords by the glacial run-off. According to studies, run-off freshwater contribution can be 100 times less in volume than the glacial melt, which may provide as much as half of all the freshwater contribution to fjords (Bartholomaus et al. 2013; Motyka et al. 2003, 2013). The glaciers are storing mineral and organic matter, which is released during the melt of the cliffs (Anesio and Laybourn-Parry 2012; Anesio et al. 2017; Hood et al. 2009, 2015). Considering disproportion of the run-off and melt-out freshwater, the matter stored in the glaciers may influence the balance of the suspended sediment delivery to the fjords. The other source of the matter delivered to the ocean are fluvioglacial flows from the land-terminating glaciers (Łepkowska and Stachnik 2018). Tidal flat build-up frequently occurs in proximity of the outlets of those flows, which limits the transport of sediment to the open sea (Zajączkowski and Włodarska-Kowalczuk 2007). This kind of regime, different from the glacial (Zajączkowski 2008), can become the prevalent one in the future. Besides, the intensification of storms can contribute to increase in erosion of coasts and tidal flats, and eventually to the release of previously accumulated inorganic and organic matter. Suspended sediment matter adsorbs significant part of the nutrients (Hawkings et al. 2014, 2017; Hodson et al. 2017) causing the increase of the primary production in polar seas and oceans (Arrigo et al. 2017; Bhatia et al. 2013; Alderkamp et al. 2012). Indirectly it is decreasing the levels of CO_2 in oceans and, consequently in the atmosphere (De Baar et al. 2008; Gerringa et al. 2012). Along with the progressing glacial retreat the amount of suspended matter increases, and so are the nutrients in polar seas. It is then expected for the primary production to rise and for CO_2 levels to drop. This would mean we are dealing with the negative feedback that would regulate the amount of this greenhouse gas in the atmosphere. Moreover, currently occurring climatic change would cause the increase of its importance. Recent studies prove the opposite. The balance of nutrients favorable for the plankton growth is observed in the forefields of tidewater glaciers. It is caused by the nutrients of deep-water origin that are delivered to the surface by the upwelling occurring on the forefield of the glacier. This is not the case for the glaciers terminating in shallow water or on land, where the nutrient balance is unfavorable for the primary production. (Hopwood et al. 2016, 2018; Meire et al. 2016, 2017). This indicates that the progressing retreat of the glaciers can lead to the decrease of the influence of the primary production on the CO_2 reduction. On the other hand, due to the intensification of storms the impact of the nutrients stored in the coastal sediments may increase (Wehrmann et al. 2014). Those can become the key factor in the nutrient balance in polar regions.

Scientific tasks set by the applicant in this achievement are the necessary abiotic background for investigations such as:

- recognition of the bottom bathymetry resulting from glacial retreat, being a factor that is influencing the hydrography of fjords and the sedimentary processes;
- recognizing the processes of sedimentation on the forefields of glaciers, which control the sediment delivery to the sea and its deposition on the sea bottom;
- wind wave and coastal erosion analysis – the factors of increasing importance in polar regions, that influence the environment and also human economy;
- recognition of the fjords' hydrography constituted by the warming of fjord waters, freshwater input from land or by sea currents and tides, which is a governing factor for the sedimentary processes;

For purely logistical reasons the fieldwork of the applicant was performed inside two fjords of Spitsbergen: Hornsund and Recherchefjorden. In the first one, the Polish Polar Station managed by the Institute of Geophysics PAS is located. Parallel fieldworks executed in Recherchefjorden were based on the Curie-Sklodowska University Polar Station in Calypsobyen. This collaboration was built on the scientific network raised on the frame of the project named *"The influence of the glaciation of the coastal water on waves and the coastal morphodynamics in polar regions on the example of the southwestern Spitsbergen – Analysis of the processes, modeling and prediction"* managed by the applicant and financed by the National Science Centre in years 2014-2018.

(1.1) Bathymetry and the morphology of the bottom

Morphology of the glaciers' forefield is mainly a result of glaciers' dynamics. On the areas exposed by retreating glacier both on the land and under the water, periglacial processes leading to the adaptation to new conditions occur. Description of geomorphological forms gives an opportunity to directly define the glacier's behavior and the environmental conditions that were present after the retreat. The survey of the land areas uncovered can be achieved by methods such as: satellite, aerial and land photogrammetry, laser scan surveys, geodetic surveys, geophysical profiling via georadar and electroresistive methods and sampling followed by the analysis in the laboratory. Those methods enable the detailed recognition of the structure and the origin of the geomorphological forms, from the microscale, or single accumulation or erosion features, through the groups of those forms, ending on the macroscale – areas occupied by the glaciers or glacial systems and ice sheets. In case of the glacial retreat exposing new marine areas the previously listed techniques are not applicable, which renders the survey more challenging. During last few decades rapid development of the marine scientific equipment took place. Devices such as subbottom profiler, multibeam echosounder, interferometric echosounder or side scan sonar were introduced to the common use. By using those devices one is able to produce the model of the bottom including the information about the geomorphological features, type and sub-bottom structure of the sediment. Availability of listed techniques resulted in the rapid increase of the number of publications describing polar regions and glacial forefields. It is not the applicant's task to list them all. That is why it is important to mention about two collective papers. The first one edited by Davies et al. (1997) contains papers of 88 authors from 10 countries and was mostly based on surveys done by subbottom profiler and side scan sonar. The second one edited by Dowdeswell et al. (2016), was done by aggregation of surveys performer by circa 180 authors from 20 countries. As the authors note, it is a summary on the current state of knowledge about the glacial-marine environment which was possible to achieve by the broad application of multibeam echosounders. It would be reasonable to assume that, considering significant involvement of Polish scientific centers in polar studies (including glaciology and oceanography) such research should be conducted with contributions from polish scientists. Alas, in last years, **the research with use of the above equipment and the archived data was only conducted by the applicant and a small team of scientists.**

(1.2) Sedimentation

The main sedimentary processes on the glacial forefields are: (i) direct deposition of the sediment carried by the glacial waters, of quantity dependent of the suspended sediment concentration and intensity of the flow; (ii) direct deposition of the load melted out from the glacier's cliff or from its surface which is dependent of the amount of clastic sediment in and on the glacier, and also from the thermal and mechanical abrasion; (iii) sediment melted out from the icebergs dependent on the amount of icebergs (calving events), sediment concentration in the iceberg, its drift and turning; (iv) deposition from suspension. Total sedimentation is modified by: (i) redistribution of the sediment caused by its instability on the slopes; (ii) remobilization of the sediment caused by drifting icebergs; (iii) washing out by the currents, tides and waves (Bennet and Glasser 2009). These processes occur with variable intensity dependent on the distance from the ice cliff, quality and quantity of the sediment and the hydrological conditions. Basing on the variability of the bottom deposits in front of the ice cliff, three zones can be distinguished:

- marginal zone, in contact with the cliff, dominated by direct deposition of the sediment from the glacial waters, ice cliff and glacier's surface;
- internal proximal zone with prevailing deposition from suspension and additional deposition from icebergs;
- external proximal zone with prevailing deposition from the icebergs and additional deposition from suspension;
- distal zone, where the importance of fine – fraction wash – out is increasing, therefore the bottom sediment is becoming richer in coarse fractions.

The presented model, is including neither water circulation (see 1.4) nor the influence of the bottom morphology. Numerous moraine ridges, particularly the ones related to the glacial extent in the end of Little Ice Age, or those originated from glacial charge, due to their sizes, can influence the water circulation and the sedimentation on the glacier's forefield forming a specific sediment traps for the settling matter.

Previous studies on the suspended sediment concentration in fjords of Spitsbergen were carried out in central parts of fjords (Sagan and Darecki 2018; Svendsen et al. 2002), river mouth areas (Dowdeswell and Cromack 1991; Zajączkowski and Włodarska-Kowalczuk 2007) and in bays with tidewater glaciers (Elverhøi et al. 1983; Görlich et al. 1987; Schildt et al. 2017; Szczuciński and Zajączkowski 2012; Trusel et al. 2010; Urbański et al. 2017; Zajączkowski 2002, 2008). Those studies took place mostly in the summer. So far, few studies did consider the whole – year observation of the variation of the suspended sediment concentration and its controlling factors. For example Szczuciński and Zajączkowski (2012), conducted the study on the sedimentation processes in the forefield of Nordenskiöldbreen in Adolfbukta both in the summer and in the autumn. They observed, that during the autumn, the sedimentation rate decreases faster than the sediment concentration in the water column. As a potential cause of prolonged presence of the suspended sediment in water they suspected decreased effectiveness of the flocculation processes in autumn, but they also pointed out other potential causes such as: changes in the location of the glacial outflows, fluctuations in their intensity and sediment load, influence of local wind conditions, tide, wave and resuspension related effects.

Precise recognition of the bottom's morphology, seasonality of sedimentary processes and its controlling factors requires continuous monitoring of the suspended matter concentration and sedimentation rate, carried out along with the oceanographic, glaciological and meteorological observations in area with already recognized bathymetry. **Such monitoring, in area of Hansbukta, on the Hansbreen forefield, has been initialized by the applicant in year 2015.** It has become a supplement of the existing environmental monitoring conducted by the Polish Polar Station in Hornsund.

(1.3) Wind waves and the coastal erosion

In the report on the state of the arctic coasts (Forbes 2011) it is concluded, that the polar coastal zones are one of the most violently changing environments, and are particularly vulnerable to the climate change. It is explained by the fact, that the environment is adapting to the new conditions: deglaciation of new areas by retreating glaciers, thawing of permafrost, warming of the sea water, reduced sea ice time and increased number of storms. Despite the above, the mechanics of polar coasts are recognized to the degree that does not enable the full understanding of the controlling mechanisms, let alone the prediction or modeling of their future evolution. This can be explained by the low number of scientific papers on the subject and also their lacking quality. In the 80s Trenhaile (1983) concluded, that there is too little basic information about the coastal processes on high latitudes, despite that those coasts are circa 30% of all the coastlines (Byrne and Dionne 2002). In aforementioned report it is estimated that only 1% of arctic coasts are investigated well enough to be able to quantitatively describe the processes that occur (Forbes 2011). This research was closely related to ACD group (Arctic Coastal Dynamic). It was focused on the processes of thermoabrasion of permafrost in ice -rich Alaskan, Canadian and Siberian coasts, which are characterized by one of the fastest rates of retreat, reaching 10 meters per year (Aré 1988; Lantuit and Pollard 2008; Lantuit et al. 2011; Nikiforov et al. 2005; Overduin et al. 2007; Rachold et al. 2005). In comparison the areas of Svalbard, Franz Joseph Land or the Canadian archipelago are poorly recognized. Frankly, one of the key conclusions of the most important summaries concerning polar research development (eg.: Byrne and Dionne 2002; Forbes and Syvitski 1994; Forbes and Taylor 1994; Forbes 2011; John and Sugden 1975; Trenhaile 1997; Urdea 2007) is the need of long-term monitoring of the coast evolution in those areas. **This work has been started in Hornsund in 2015 by the initiative of the applicant,**

under his scientific project *"The influence of the glaciation of the coastal water on waves and the coastal morphodynamics in polar regions on the example of the southwestern Spitsbergen – Analysis of the processes, modeling and prediction"*. It focuses particularly the two bays – Isbjornhamna and Hansbukta, and they consist of the following tasks:

- logging of the tides and waves via underwater wave buoys anchored at the bottom of the fjord in the inshore, serviced annually by scuba divers;
- autonomous photo-documentation of the sea ice for both bays;
- autonomous photo-documentation of the coastline evolution.

Mentioned monitoring is continued after closing of the project in framework of the Polar and Marine Research Department of the Institute of Geophysics PAS and of the Polish Polar Station in Hornsund.

(1.4) Hydrography of the fjords

West Spitsbergen fjords are under the influence of two different, but often mixing water masses: warm Atlantic water carried by the West Spitsbergen Current, and colder, less salinized arctic water from the Barents Sea delivered by the South Spitsbergen Current (Saloranta and Svendsen 2001; Swerpel 1985; Walczowski 2013). Altough Hornsund is the most southern fjord of the western Spitsbergen, and is probably the best indicator of the delivery of the cold Arctic water before it is mixed with warm Atlantic water, there is very few papers concerning the hydrogrphy of this fjord. In contrast to the more northern fjords such as: Van Mijenfjorden (Skarðhamar and Svendsen 2010), Isfjorden (Nilsen et al. 2008, 2016; Pavlov et al. 2013), Kongsfjorden (Cottier et al. 2005, 2007; Svendsen et al. 2002) and also Storefjorden located to the east of Spitsbergen (Fer and Ådlandsvik 2008; Haarpaintner et al. 2001; Skogseth et al. 2004, 2005, 2008), where the works are executed by big international groups, Hornsund area has gained few investigations, done mainly by polish groups (Swerpel 1985; Urbański et al. 1980). The situation changed in recent years, due to the works of the team from the Institute of Oceanology PAS, by compiling the measurements done cyclically since 2001 with use of r/v Oceania (Promińska et al. 2017, 2018) as well as the numeric modelling (Jakacki et al. 2017). Those works indicate that the Hornsund waters are colder and less salinized than the fjords located more to the north. The cause of this phenomenon can be found in the direct influence of Arctic water mentioned above, and also larger amount of glaciers in the fjord. Increase in water temperature and salinity is also observed in the fjord, which points to the increasing influence of atlantic water. In mentioned research the irregularity in the transition from winter to summer conditions in the fjord is also pointed out. Because of the lack of the whole-year monitoring of the water temperature and salinity in the fjord there was no possibility for better recognition of this process. Precise recognition of hydrographic processes for the individual bays is not possible, although they seem to vary in terms of the oceanographic conditions (sea currents) and also in terms of bathymetry and the individual glaciers.

Forefields of tidewater glaciers have very specific hydrology. Warm, salinized sea water flows in the direction of the glacier by the bottom to be mixed with cold freshwater from the melting glacier. Upwelling occurs in the area of mixing, meaning the freshwater, which is less dense than the sea water flows up to the surface. In consequence, brackish surface layer of water moving away from the glacier is created. Brackish waters are clearly separated from the deeper layers by so-called pycnocline – the density boundary resulting from the difference in the temperature and salinity (Cauche et al. 2014; Motyka et al. 2003, 2013). Aforementioned process is driven by the glacial outflows and it is expected to accelerate in the ablation period. Its short-term intensification may be a result of increased precipitation or increased melting of the glacier.

The precise recognition of Hornsund's hydrography and characteristics of its annual cycle in its individual fragments requires all-year oceanographic monitoring. The beginnings of such works were done in frames of individual scientific projects executed by the Institute of Oceanology PAS, but were restricted to summer, and sometimes spring season only. **Regular monitoring of hydrological conditions in Hornsund consisting of the temperature and salinity measurements, has been designed and initiated by the applicant in the year 2015**. It is conducted in the framework of the Polar and Marine Research Department of the Institute of Geophysics PAS and the Polish Polar Station Hornsund. It consists of the regular profiling in network of points (initially throughout the year, since 2019 the period from May to October), and continuous, all-year measurements by CTD buoys anchored on the bottom of the fjord in the inshore (serviced by SCUBA divers).

(2) Elaboration of the individual papers

(2.1) Bathymetry and bottom morphology (papers no: 1, 5, 7)

2.1.1. Geomorphometry – the tool in recognizing the geomorphology of the fjords *(paper no 7)*

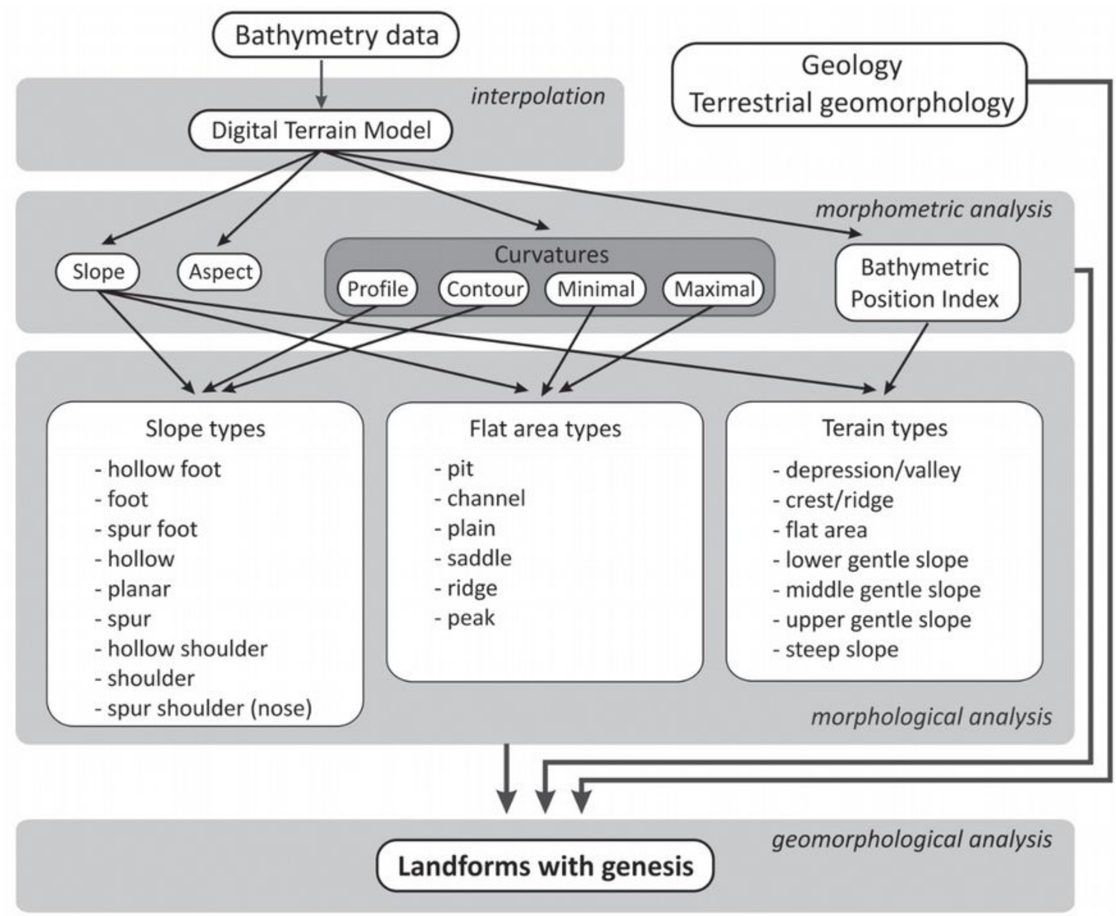

Figure 2.1.1. Diagram of the geomorphometric analysis of the bathymetric data (from Moskalik et al. 2018 doi:10.24425/118740)

The role of the geomorphological analysis is to extract the terrain forms and to describe their forming processes. Basing on the digital terrain model, with use of geomorphometric techniques one can describe the morphology by determining the mathematical morphometric and morphological parameters. The results of the above procedure combined with the geological and geomorphological background can be used to create the geomorphological recognition of the studied area. (Fig. 2.1.1). The mentioned analysis has been applied to the Recherchefjorden (see 2.1.2). Two types of the bathymetric data were available for the area: (i) point bathymetric data collected by the Norwegian Hydrographic Service in years 1985-1994, and (ii) bathymetric profiles executed in years 2011-2012. Basing on these data, a digital terrain model (DTM) was made. Kriging technique, described by the applicant in his doctoral thesis, was used for interpolation. The following morphometric parameters were determined, basing on the DTM:

- The first derivative of the DTM expressed by the slope angle and direction;
- The second derivative of the DTM expressed via curves plotted on: maximum slope angles, equal depth lines, minimum and maximum;
- Bathymetric position index (BPI), determining the difference between the given depth value and the mean depth value of the nearest neighbors.

The slope angle and direction enable the analysis of sediments' redeposition, direction of transport and its redeposition's location (see 2.1.4). Basing on the plotted curves, one can determine the morphological features of the slopes by distinguishing: (i) shoulder slopes, (ii) planar slopes (iii) and foot slopes, as well as the morphologic features located on the slopes: (iv) spurs and (v) hollows. Additionally four combinations of the above features are distinguished, describing the slope type and the feature (spur/hollow shoulder, spur/hollow foot). Basing on the minimum and maximum curvatures, the following morphological features not related to the slopes can be detected: (i) peaks, (ii) pits, (iii) plains, (iv) saddles, (v) ridges and (vi) channels. BPI supplemented with slope angle value enables detection of the terrain forms like: (i) crests, ridges, (ii) depressions, valleys, (iii) flat areas, (iv) steep slopes and (v) gentle slope, including the location of foot and shoulder. Mathematical parameters of the morphometry along with the resulting morphological forms enabled the designation of the morphologically distinct areas (see 2.1.2).

__2.1.2. Geomorphology of the Recherchefjorden__ (paper no 7)

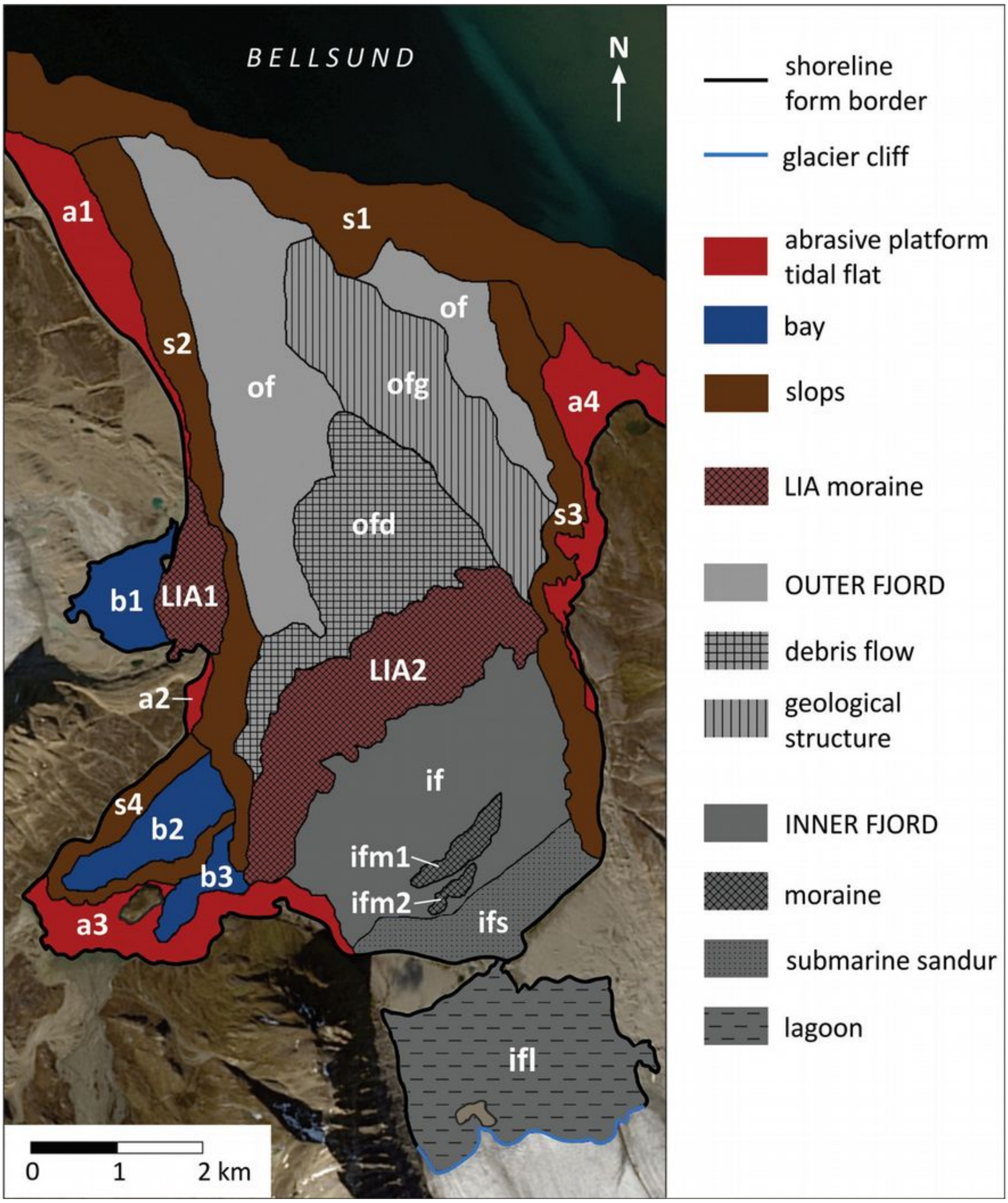

Figure 2.1.2. Map of the Recherchefjorden area with the geomorphological interpretation (from Moskalik et al. 2018 doi:10.24425/118740)

On the basis of the geomorphometric analysis (see 2.1.1) the map of Recherchefjorden was created (Fig. 2.1.2). By complementation of the mentioned analysis with the land geological and geomorphological data, geomorphological forms and their genesis has been recognized in listed areas.

Well-developed steep slopes on the eastern and western side of the fjord show the dominating influence of the glacier in their development process. However, in analysis of the depth distribution values, it is impossible to determine the dominating value that would exceed the mean depth, as well as in the case of Brepollen area with glaciers key influence during the formation of the fjord's bottom. It shows that the geomorphology of Recherchefjorden is highly diverse. It is also clearly visible on morphometric maps and on the morphological forms. Ultimately, the following zones were distinguished in the area:

- Main moraine ridges related to the extent of Renardbreen (LIA1) and Recherchebreen (LIA2) during the Little Ice Age (LIA);
- Abrasive platforms in the coastal zone and the tidal flat near the mouth of Chamberlindalen (a1-a4);
- Two bays: Josephbukta with very diverse bottom resulting from the retreat of Renardbreen (b1), and Vestervågen with two distinctive basins (b2, b3) with relatively flat bottom;
- Distinctive slopes building i.a.: the closing of Recherchefjorden from the north (s1), western and eastern fjord's bank (s2, s3), slopes in the second of the mentioned bays (s4);
- Outer fjord (of) not covered by the glacier during LIA located north of the LIA2 divided to two areas: first related to the geological structures (ofg), and the second one consisting of the mass movement from LIA2 moraine (ofd);
- Internal fjord (if), with bottom more diverse than the outer fjord, which is caused by the direct influence of the outflows of Recherchebreen during its' retreat after LIA. On the basis of the performer analyses it was possible to distinguish the following sub-zones in this zone: (i) glacial charge – generated moraines (ifm1, ifm2); (ii) separated lagoon (ifl) divided tectonically to the eastern and western part; (iii) submarine sandur (ifs) accumulated fluvioglacially when the Recherchebreen was located on land building the lagoons closure.

__2.1.3. Geomorphology of the forefield of Hansbreen, the tidewater glacier__ (paper no 5)

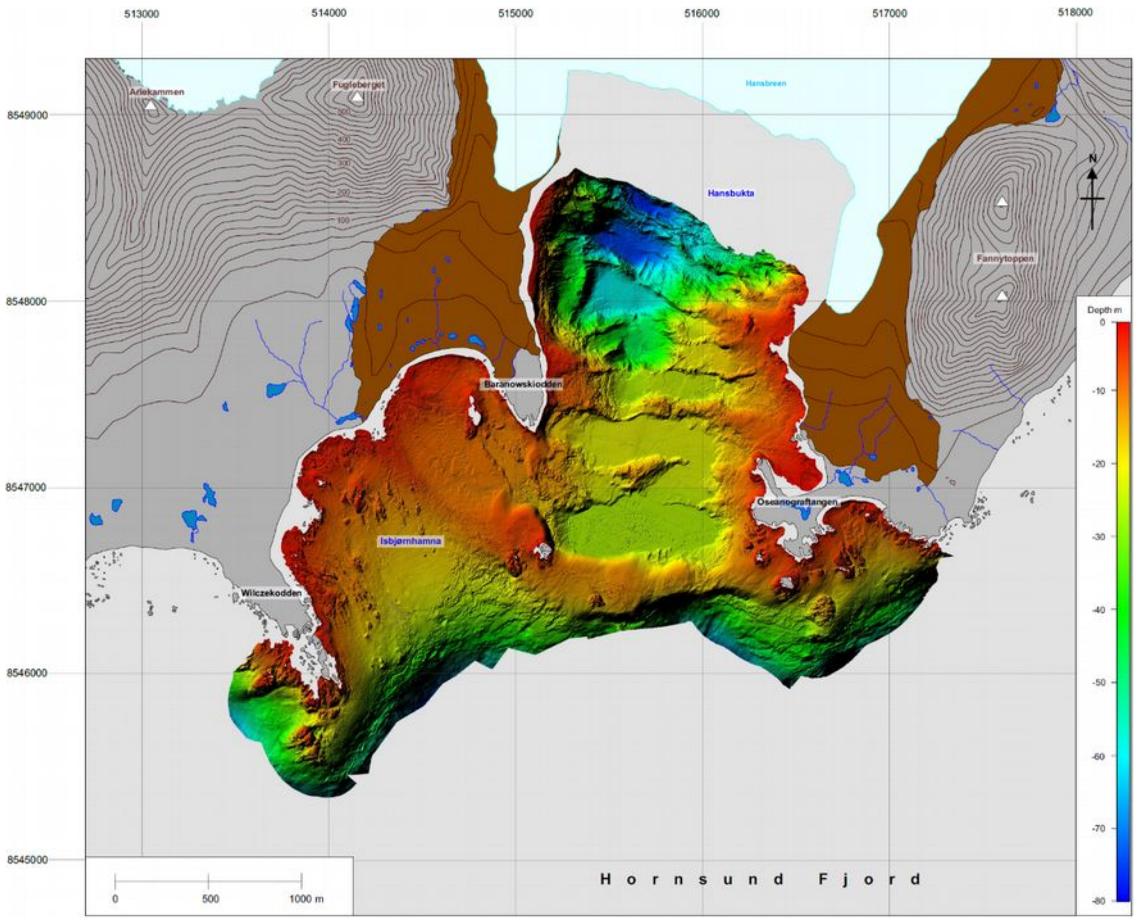

Figure 2.1.3.A. Bathymetric map of the bays: Hansbukta and Isbjørnhamna. Map's legend – see fig. 2.1.3.B (from Ćwiąkała et al. doi:10.1080/17445647.2018.1441757)

Despite, that Hansbreen is one of the most investigated glaciers in Svalbard, so far it is unknown, if the glacier had any charge episodes. Previous studies resulted in contradictive conclusions. In this study the bathymetric data were used (fig. 2.1.3.A)and the geomorphological map of the bays' bottom was created (fig. 2.1.4.B) in search for an answer to this question. The following terrain forms were distinguished:

- Terminal moraine determining the extent of Hansbreen during LIA;
- recessional moraine ridges formed during the winter advances of the glacier;
- megaripples located on the ridge of the terminal moraine and in the central part of Isbjørnhamna, formed by the swell entering the bay from the Atlantic(see 2.3);
- flat-floored depressions with increased deposition of suspended sediment (see 2.2);
- pits and ploughmarks formed by the iceberg anchoring or drag;
- pockmarks in one of the high-accumulation areas, formed by the seepage of fluids or gasses;
- slopes affected by mass wasting;
- rock outcrops.

On the bottom of bays within the Hansbreen forefield no charge – related features were observed, which shows beyond the doubt that the glacier has not charged in the period after LIA.

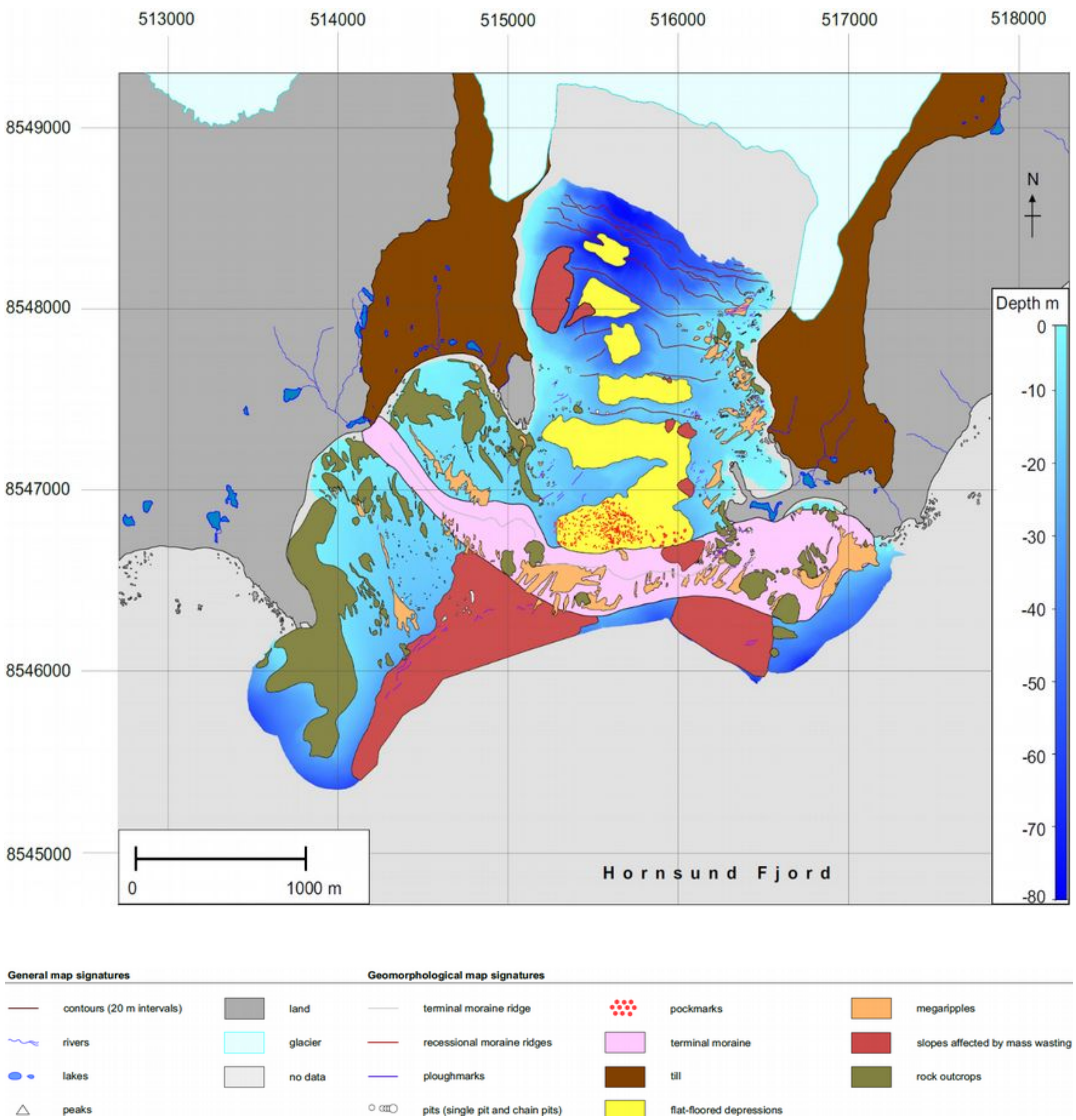

Figure 2.1.3.B. Geomorphological map of the bays: Hansbukta and Isbjørnhamna including the legend. (from Ćwiąkała et al. doi:10.1080/17445647.2018.1441757)

2.1.4. Bottom slopes stability *(paper no 1)*

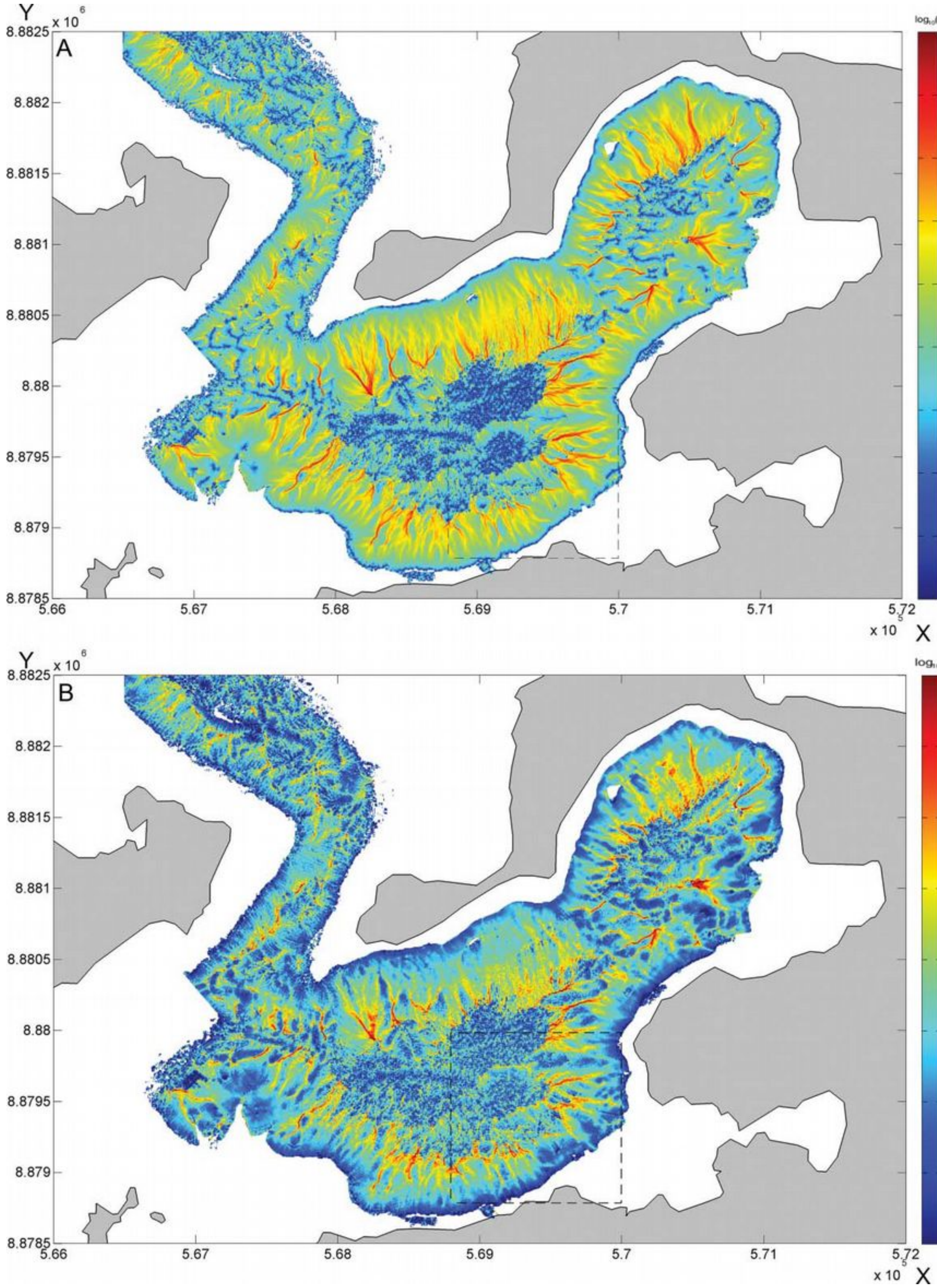

Figure 2.1.4. (A) The surface of the area alimented by the deposits from redeposition; (B) normalized map of the probability of sediment redeposition (from Moskalik et al. doi:10.1080/01490419.2011.638040)

One of the key problems in sedimentary processes (see 2.2.) is the sediments' redeposition. Information on the redeposition is useful i.a. in palaeoceanographic studies, where the choice of the sampling location with low probability of redeposition is the key. The applicant proposed the bathymetric data analysis, using modified method of the drainage area and stability index analysis. In drainage area analysis it is assumed that the flow always occurs from the highest to the lowest area. Sediment redeposition is an impulse process. It can be triggered in whichever point, so it is assumed that the transport can be started from every direction, to the lower area. When determining the value of the surface of the source area the weight proportional to the slope gradient value in given direction was applied. (fig. 2.1.4.A). The next step of the analysis requires the use of the stability index values. It specifies the ratio of the triggering stress to the real stress in the sediment. Stability index is dependent of the parameters like sediment's cohesion, internal friction angle, slope angle, sediment's density, thickness of the sediment layer and hydration. With some assumptions one can state that this index is inversely proportional to the tangent of the slope angle. For gentle slope (close to horizontal) its value approaches infinity and for the steep slope (almost vertical) it approaches 0. The probability of redeposition of sediment in given place rises with the area's capability to accumulate (its surface area) and drops with low chance of mass movement occurrence (known from the stability index). Mathematically, it has been calculated by dividing this two values (fig. 2.1.4.B). This method enables to quickly analyze slope stability when the DTM is available, obtained, for example, from the multibeam survey (i.e.: see 2.1.3 and previous analysis), or from the data interpolation obtained by point measurements and bathymetric profiling (i.e.: see 2.1.1, 2.1.2*)*.

(2.2) Sedimentation (papers no: 2, 5, 6)

***2.2.1. Seasonal variability of the sediment concentration in the water column on the forefield of Hansbreen** (paper no 6)*

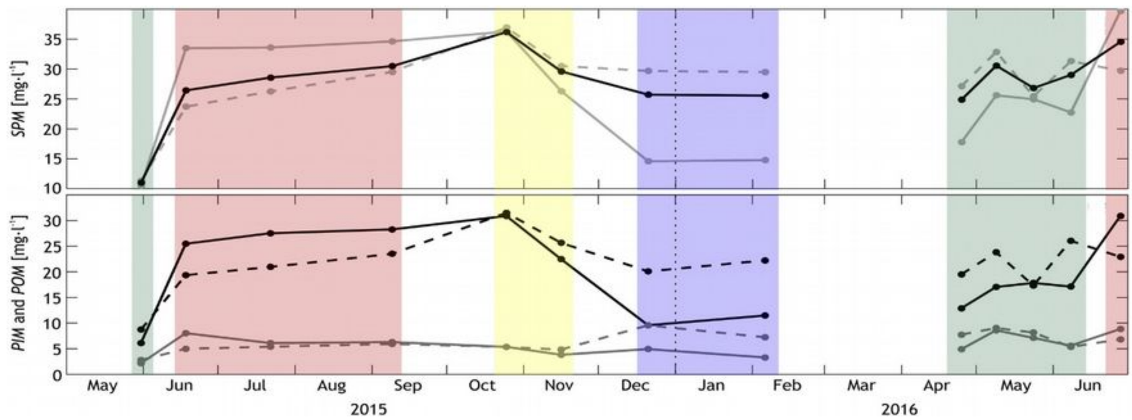

Figure 2.2.1.A. Annual variability of the mean concentration of suspended particle matter (SPM) divided to organic (POM) and inorganic (PIM) parts. Upper plot: black solid line – mean SPM value, grey solid line – mean SPM value on depth down to 10 m, grey dashed line – mean SPM value for depths from 20 to 50 m. Lower plot: black solid line – mean PIM value for depth down to 10 m, black dashed line – mean PIM value for depths from 20 to 50 m, grey lines analogously for POM. Colors mark seasons: spring (green), summer (red), autumn (yellow), winter (blue) (from Moskalik et al. 2018 doi:10.1016/j.oceano.2018.03.001)

Monitoring conducted with use of Polish Polar Station has enabled acquisition of unique dataset of the seasonal variability of SPM concentration in water column (fig. 2.2.1.A, 2.2.1.B) along with the meteorological and oceanographical background. The analysis shows that the main source of SPM are the glacial outflows. The remaining sources, like the sediment present in the sea ice or transport from land are significant only in specific periods during the year. Factors like stratification and circulation of water (see 2.4.1.), wind waves (see 2.3.1. and 2.3.2.), sea ice presence, glacial ablation, bathymetry (see 2.1.3.) influence the seasonal and spatial variability of SPM concentration, both the organic (POM) and inorganic (PIM) parts. The cycle of annual variability has been divided into seasons:

- **Summer** (fig. 2.2.1.A red, fig.2.2.1.B second row)
  Characterized by well-developed surface layer of brackish water that flows from the glacier front to the outside of the bay. This phenomenon has significant influence on the distribution of SPM. The highest SPM concentration occurs above the pycnocline which is a barrier for the falling sediment particles. Regarding the flocculation processes, grain aggregates are formed, which are able to pierce this barrier. With the increase of the freshwater content, pycnocline effect weakens, which results in the increase of the SPM concentration in deeper parts of the bay.
- **Autumn** (fig.2.2.1.A yellow, fig. 2.2.1.B third row)
  Weakening of the pycnocline effect combined with intensified wave activity are contributing to water mixing in the bay. This results in almost homogenous distribution of SPM concentration (both POM

and PIM). In this period the highest mean concentration of SPM is observed, which is a result of somewhat restricted water mass exchange with fjord caused by the ridge closing the bay. In time, decrease in SPM is observed, particularly in the surface layer. On the turn of autumn and winter, increase in POM in the surface layer is observed, which is probably caused by the inflow of zooplankton – rich waters from the shelf.

- **Winter** (fig. 2.2.1.A blue, fig. 2.2.1.B fourth row)

  In the surface layer, further decrease in SPM concentration is observed, down to the lowest values noted during the whole measurement cycle. In deep water the SPM concentration is still high, probably due to the resuspension processes and episodic glacial outflows during the winter.

- **Spring** (fig. 2.2.1.A green, ryc.2.2.1.B first row)

  During the study, two consecutive spring seasons were observed, both different in regard of the sea ice presence. SPM concentration was the lowest during the sea ice – rich season, after its decay. In the next season with poor sea ice presence, the SPM concentration level was similar to those observed during the winter. The difference results from the restricted influence of resuspension caused by damping of wind waves by the sea ice. POM concentration increase was also observed in this period, due to growth of phytoplankton.

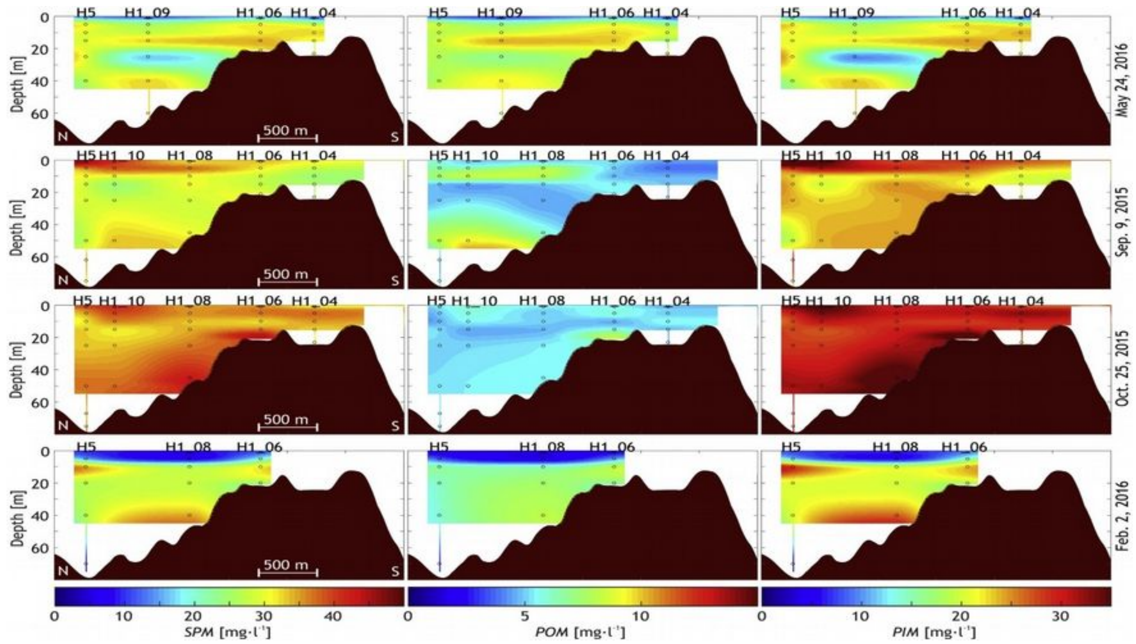

Figure 2.2.1.B. Example of the spatial distribution of suspended sediment concentration in the water (SPM – left column) with the division into organic (POM – middle column) and inorganic (PIM – right column) parts for seasons (rows from the top): spring, summer, autumn and winter (from Moskalik et al. 2018 doi:10.1016/j.oceano.2018.03.001).

2.2.2. Sedimentation model and bottom deposits of the forefield of Hornbreen (paper no 2)

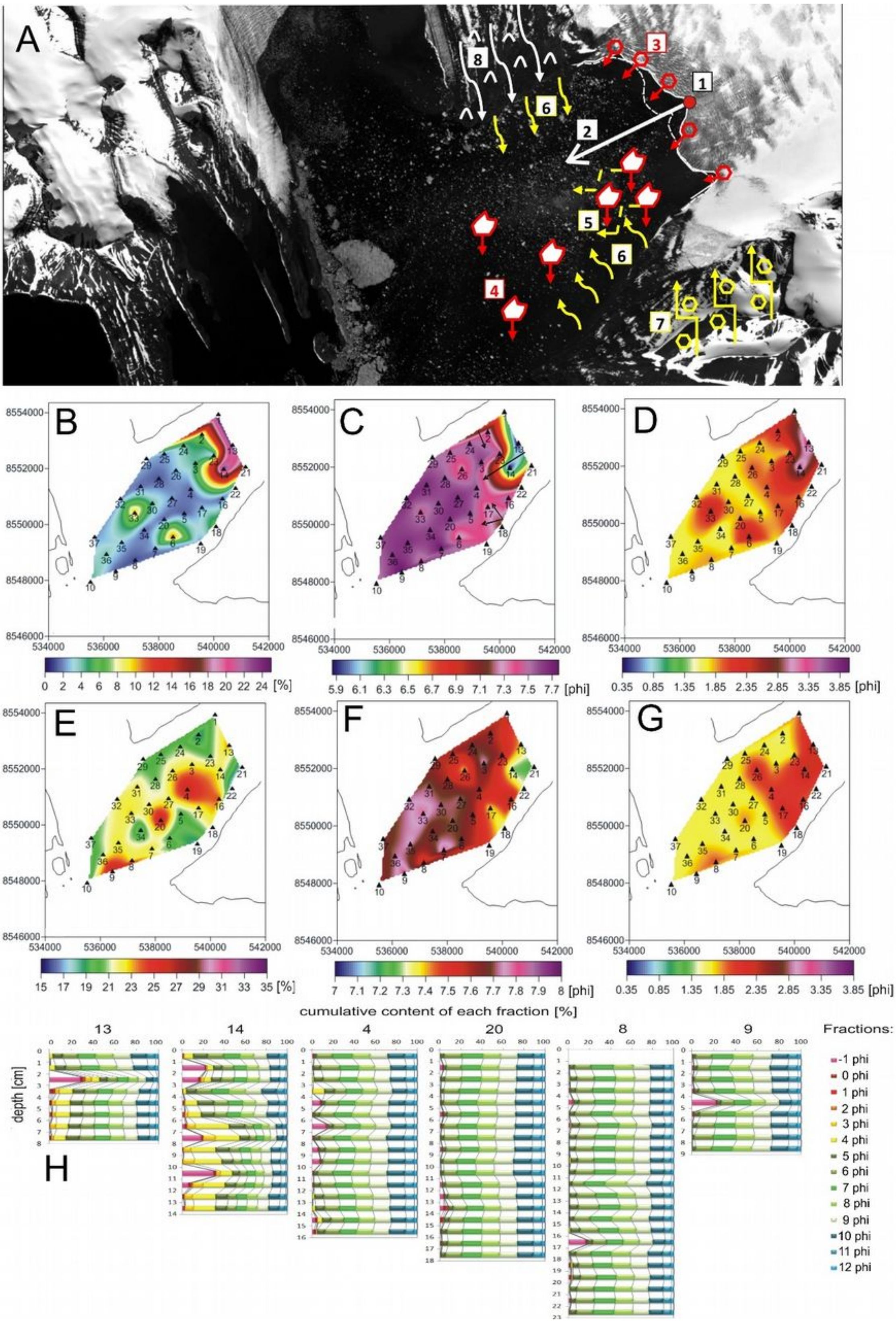

Figure 2.2.2. A) – the scheme of the sedimentary processes (1 – location of the main intraglacial water outflow, 2 deposition from suspension, 3 – direct deposition from glacial cliff, 4 – deposition from the icebergs, 5 – redeposition of the sediment by the icebergs, 6 – redeposition from the slopes, 7 – transport of sediment from mountain slopes to the glacier, 8 – transport via seasonal flows); B) the percentage of pebble and sand fraction in the surface deposits; D) the separation of surface deposits; E) content of clay fraction in dust and clay part from the surface deposits; F) mean grain size of clay and dust from surface deposits; G) separation of dust and clay in surface deposits; H) grain size distribution of the sediments from short cores on the profile perpendicular to the ice cliff (from Staszek and Moskalik 2015 doi:10.1515/geo-2015-0042)

Based on the detailed granulometric analysis of short cores from surface deposits (fig. 2.2.2.B-H) schematic model of sedimentary processes on the forefield of Hornbreen (fig. 2.2.2.A). This glacier's forefield is characterized by the following sedimentary processes:

- **Ice cliff-fjord contact processes** – not observed directly in analyzed deposits, but the temperature inside the fiord suggest their presence (ice cliff melt - out).
- **Direct deposition from the melt-out stream** – indicated by the presence of sand and gravel in samples collected in proximity of the glacial outflow.
- **Deposition from suspension** – observed as the decrease in mean grain size with increasing distance from the ice cliff.
- **Icebergs influence** – visible as the addition of the coarse fractions both near the ice cliff (rapid deposition from the icebergs near the calving area caused by turn-overs and fragmentation of the icebergs) and in considerable distance (ice rafted debris deposition).
- **Remobilization and redeposition of the sediment** – remobilization occurs mainly by the icebergs activity. It is indirectly evident by the size of observed icebergs. Redeposition of the sediment is visible through the enrichment in clay fraction in fjord axis, which is a consequence of the surface downflow along the slopes. On the basis of this study it is not possible to describe its mechanics. Regarding the fjord's geometry, the assumption has to be made that the wind waves influence is insignificant (see 2.3.2) and the dominating factor can be the waves generated by calving.

The above scheme of the sediment distribution on the forefield of the glacier is an example of classic model of sedimentation. It may be modified in regard of the influence of wind waves and bottom's morphology (see 2.2.3).

2.2.3. Bottom deposits and the sedimentation rate on the forefield of Hansbreen *(paper no 5)*

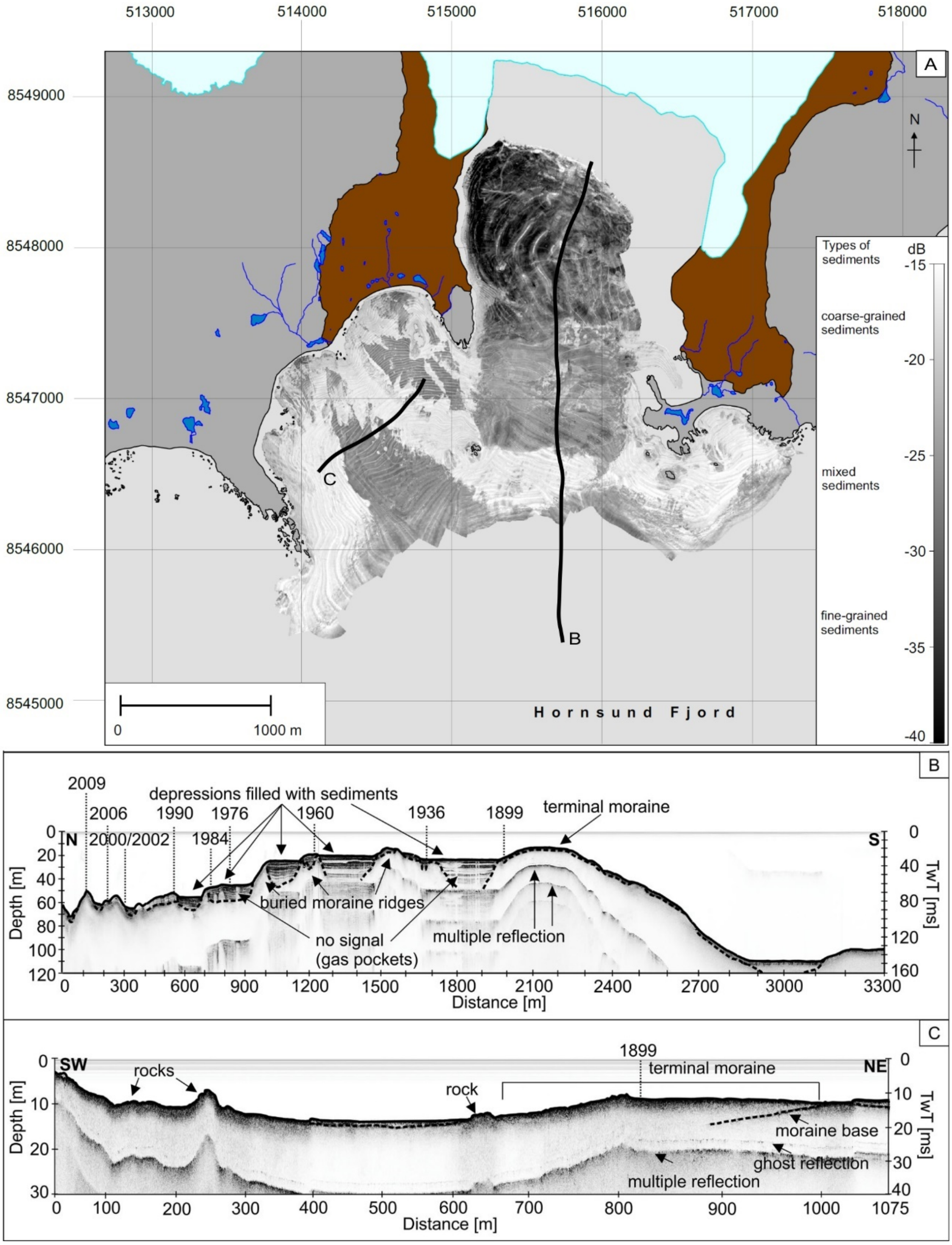

Figure 2.2.3. (A) The backscattering map from the multibeam echosounder with marked location of the seismoacoustic profiles. (B, C)seismoacoustic profiles with the interpretation and marked position of the ice cliff in years (from Ćwiąkała et al. doi:10.1080/17445647.2018.1441757)

The area of bays on the forefield of Hansbreen, besides the geomorphological analysis, has been analyzed regarding surface and internal sediment characteristics. This analysis was based on the processing of the backscattering signal (BS) from the available surveys made with the multibeam echosounder (fig. 2.2.3.A) and on the analysis of the executed seismoacoustic profiles (fig. 2.2.3.B,C). In the study, collected sediment samples were not analyzed. Using the data from BS, the surface deposits have been classified to coarse-grained (prevalence of sand and gravel) or rocky, fine-grained (prevalence of mud and clay) and mixed. The BS analysis suggests that the fine-grained sediments are located closer to the ice cliff than the coarse-grained. It is the opposite setting in comparison to the Hornbreen's forefield (see 2.2.2.). Distinctive sediment fractions in this area re tied to geomorphological forms (see 2.1.3.) e.g.: terminal moraine is mainly covered by the coarse-grained sediments, while flat areas, with fine grained ones. Note that erosion features related to the iceberg activity are observed in areas containing coarse-grained deposits. The influence of swell propagating from the outside of the fjord is also visible (see 2.3.2) as it generated megaripple fields. In those areas one can see the segregation of sediment by washing out fine grained fractions. It is visible on the BS map in form of sharp transition of the BS value and was also observed during the underwater works. From the analysis of the seismoacoustic profiles one can conclude that the thickness of the sediment layer on the flat areas is equal 10-25 m. This rate of deposition reaching 25 to 40 $cm \cdot year^{-1}$, was possible because of the specifics of water circulation and suspended sediment distribution in the bay closed by the sill (see 2.4 and 2.2.1).

(2.3) Waves and the coastal erosion (papers no: 3, 8, 9, 10)

2.3.1. Wind wave climate of the west Spitsbergen *(paper no 8)*

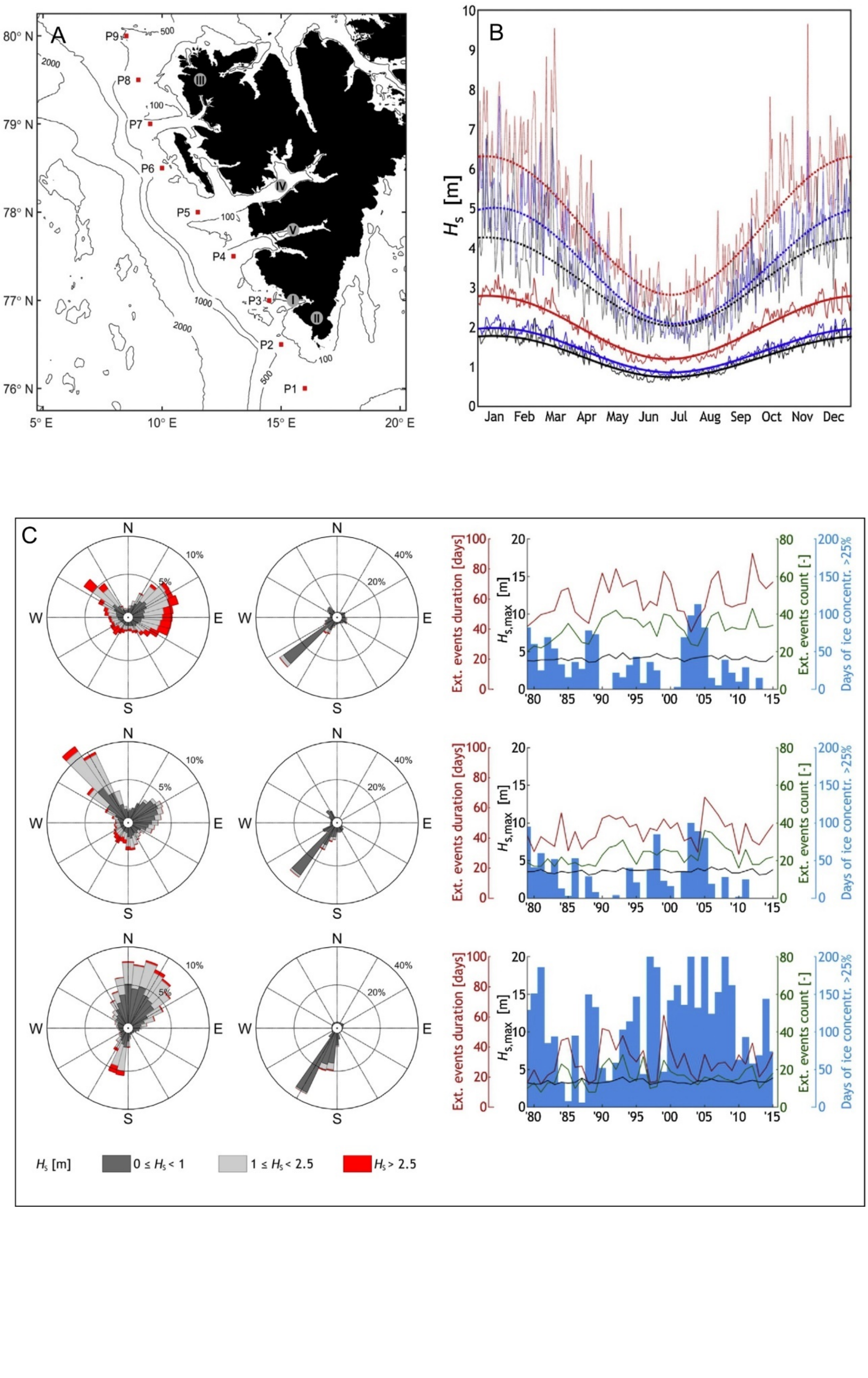

Figure 2.3.1. (A) Location of the analyzed data from the wave models (P1-P9). (B) seasonal variability of the significant wave height (H_s) in points P1 (red), P5 (blue), P9 (black) based on 37-year series of the ERAi model; solid line – daily average, dashed line – 99th quantile with the smoothed lines. (C) wind wave characteristics in points P1, P5 and P9 (in lines, from the top). In columns, from the left: wind sea rose, swell rose, variability of the extreme events in time (from Wojtysiak et al. doi.10.1016/j.oceano.2018.01.002).

In this study, the results from two wind wave models with data available for the western Spitsbergen were analyzed: Wave Watch III (WW3) and ERA-interim (ERAi). Both models, prior to the analysis were verified with the direct observations. The goal was to characterize seasonal and spatial characteristics of wind waves and their multidecadal variability (fig. 2.3.1.). The highest waves occur during the winter and the lowest during the summer. Spatial variability is well-pronounced, meaning the high waves (mean and extreme values) occur on the south of Spitsbergen throughout the year. Independent analysis of the directions of swell and wind sea has shown that the dominating direction of swell is from the south-west. This is not without meaning for the propagation of waves inside the fjords (see 2.3.2.) and for the coastal erosion (see 2.3.3.). In case of wind sea the dominating propagation directions are not so obvious. One of the most important findings for this study is in the analysis of the extreme event count in time. As previously mentioned, higher values of significant wave height were observed on the south of Spitsbergen. It is directly related to the extreme event count and duration. On the south of Spitsbergen the total duration of storms is roughly 2 times greater than on the north. Increase in count and duration of storms is observed only on the south, and it is equal 2 events per decade. This increase consists mainly of winter storms. The influence of sea ice is also important to note. In years abundant in sea ice both count and duration of storms was lower than in years, when the sea ice was absent.

2.3.2. Wave climate in Hornsund fjord (paper no 9)

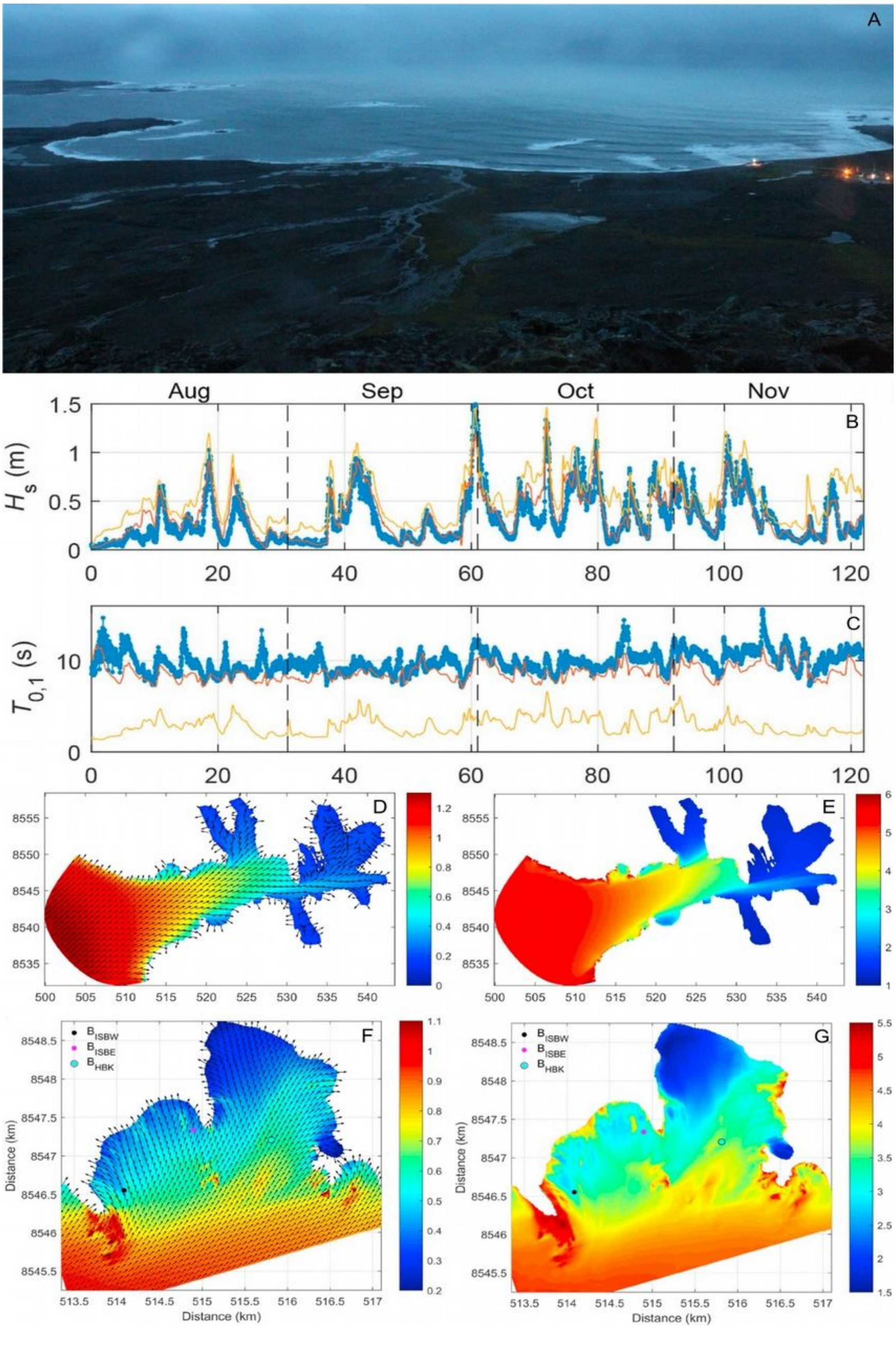

Figure 2.3.2. (A) Wind waves in Isbjørnhamna with long waves refracting off the penninsula. (B) Comparison of the measurements of significant wave height (blue points) with the results from the model in the part of the frequency spectrum corresponding to the measured values (red line)and for the whole spectrum (yellow line). (C) Comparison of the mean wave period analogously to the wave height. (D) Spatial distribution of mean significant wave height (color scale in meters) and the directions of propagation (arrows) in Hornsund fjord. (E)Spatial distribution of the mean wave period (color scale in seconds) in Hornsund. (F) and (G) analogously to the (D) and (E) but for Isbjørnhamna and Hansbukta. In (F) and (G) the location of 3 of 4 underwater wave logging stations in Hornsund used in this study (from Herman et al. doi.10.1016/j.ecss.2018.11.001).

In this study, spectral wind wave model was used to analyze the wave climate in Hornsund fjord. The model was validated via wave measurements done by wave buoys anchored on the bottom of the fjord in its northern and eastern side. In the range of frequencies registered by the buoys (restriction of the wave logging based on the bottom pressure measurements) the correlation of the significant wave height (e.g: fig 2.3.2 B) was in range of r^2=0,89÷0,95 and analogously in case of the mean wave period (e.g. fig. 2.3.2.A) in range of r^2=0,63÷0,87 depending on the location of grid point and nesting of the model. Produced model has enabled to assign the following features of wind waves in Hornsund:

- **Wave propagation from the ocean to the fjord**. Simulations performer for the propagation direction outside the fjord from north to south shows that the smallest loss of energy occurs for waves propagating from SW-SSW.
- **Mean value of the wave height in Hornsund** (fig. 2.3.2.D,E). Considering the prevailing propagation direction for swell from the open sea (see 2.3.1.), and their smallest attenuation, the highest waves during the year occur at northern coasts of the fjord and the smallest – in separated bays.
- **Wind waves in Isbjørnhamna and Hansbukta** (fig. 2.3.2.F,G). Those bays are located in the northern part of the fjord, near the fjord's entrance, meaning the high waves are expected there. In this area the diverse bathymetry has the biggest influence on the waves (see 2.1.3.) The role of peninsulas and islands is also important as the waves refract on both (fig. 2.3.2.A). Those processes contribute to the coastal erosion in the area (see 2.3.3.).

*2.3.3. **Erosion of the coast in Isbjørnhamna area*** *(paper no 3)*

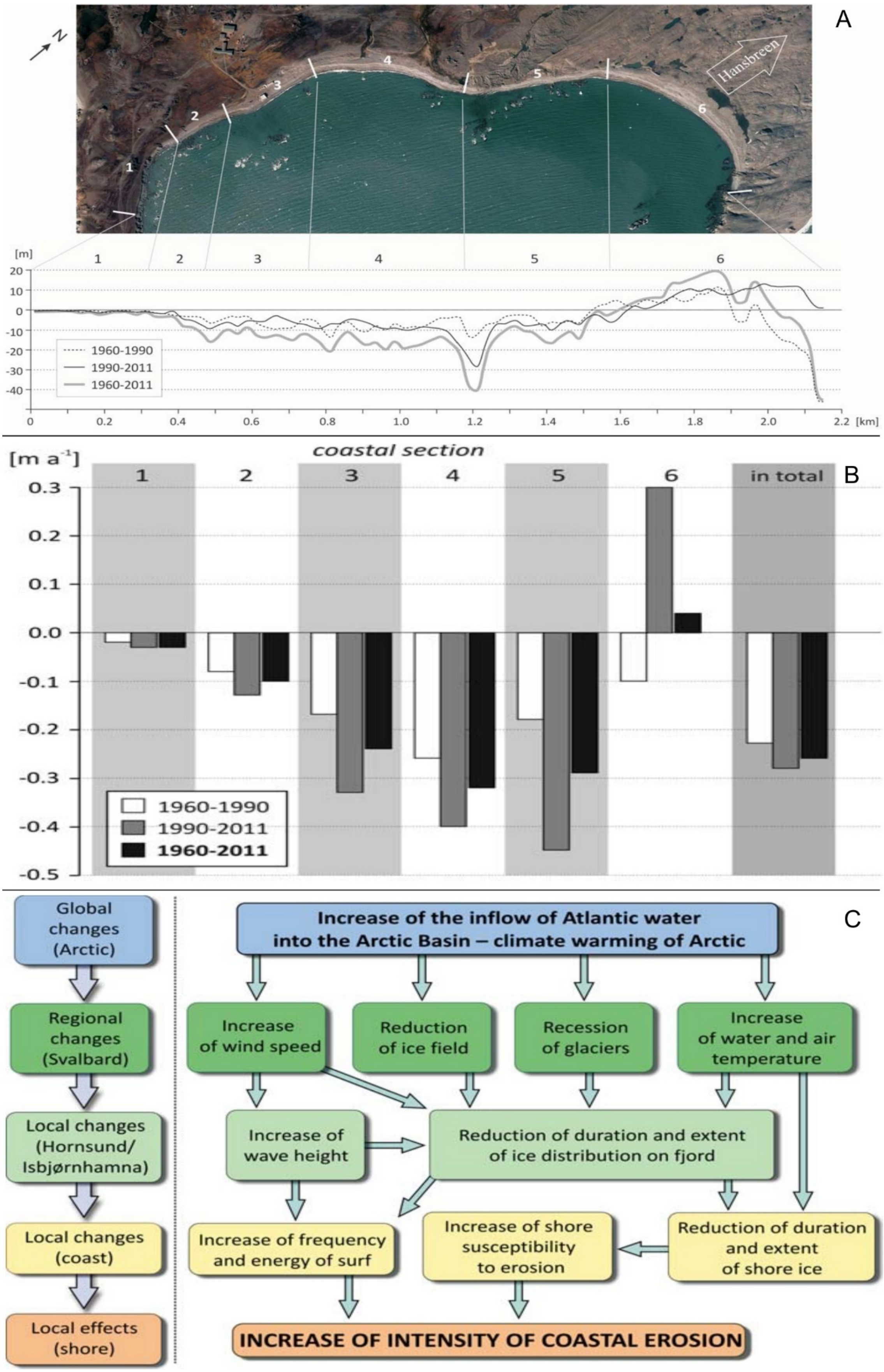

Figure 2.3.3. (A) Change of the coastline in the Isbjørnhamna area in years 1960-1990, 1990-2011, 1960-2011. (B) Mean-annual rate of retreat in years 1960-1990, 1990-2011, 1960-2011 for presented sections of Isbjørnhamna. (C) Diagram of the processes influencing the coastal erosion (from Zagórski et al. doi.10.1515/popore-2015-0019)

The dynamics of the Isbjørnhamna's coast was analyzed using the archived aerial photographs made in years 1960 and 1990, and also DGPS data from the year 2011 (fig.2.3.3.A). In the process, an analysis of the coast was performer considering building material characteristics, bottom's morphology (see more at 2.1.3), and the evolution of the coast and its governing factors. One of the main results here is pointing out the increasing trend of the erosion rate of the coast. Its value in years 1990-2011 was, in most of cases, more than two times greater than in years 1960-1990. Further measurements carried out in 2018 (unpublished) are confirming this trend, as in years 2011-2018 (7 years) the total value of coastal erosion was comparable to the one calculated in this study for years 1990-2011 (21 years). The main factors of the erosion rate changes are as follows:

- **wind waves** – in majority dominated by the swell propagating from the open sea to the fjord and the studied bay (see 2.3.1, 2.3.2);
- **ice on the fjord** – damping the waves, mostly the sea ice drifting from the open sea and from the icebergs;
- **shore ice occurrence** – in general protecting the coastal sediments, occurring from late autumn through the winter, until the early spring with maximum in April.

Increase in the coastal erosion rate on polar coasts, of which Isbjørnhamna is good example of, is the result of the cause-effect relations consequential of the climate change (fig.2.3.3.C). Global changes in Arctic imply regional changes in Svalbard. In the process of coastal erosion the key factors are: increase in wind speed, decrease of the sea ice, glacial retreat, increase in temperature of the sea and air. Regional changes influence the internal fjord regimes of the wind waves and the sea ice time and extent. These changes result in the increase of the storm events and reduce the protective role of the drifting and shore ice, which eventually causes the increase in erosion rate.

2.3.4. Short-term changes of the beach complex in Calypsostranda (Bellsund) *(paper no 10)*

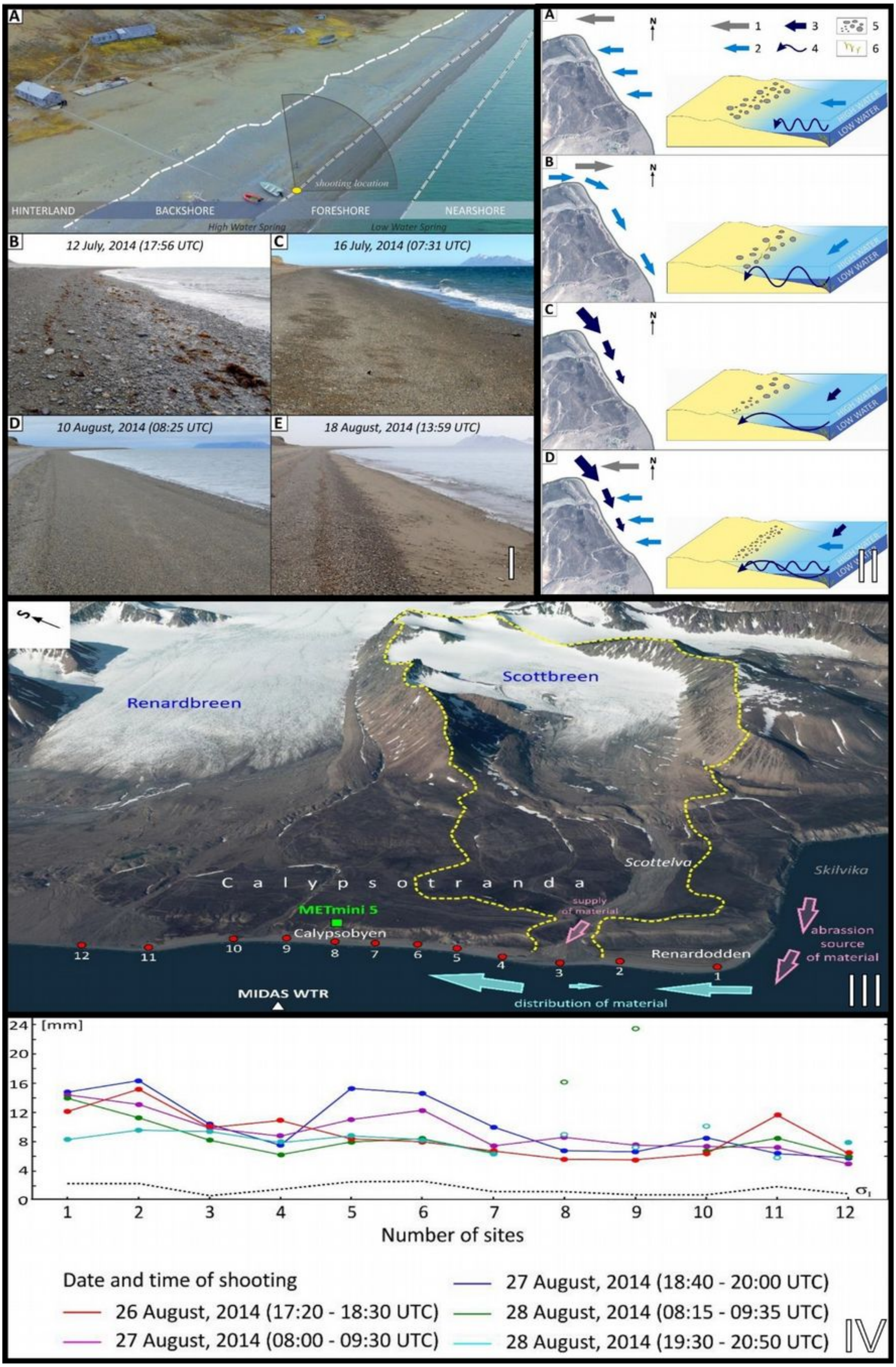

Figure 2.3.4. I) Elements of the coast (A)and the chosen photographs of the coast (B-E). II) The diagram of the wind wave influence on the beach sediments (A-D). Legend: 1 – wind direction, 2 – wind sea propagation direction, 3 – swell propagation direction, 4 – extent of the wave base and its influence on the bottom, 5 – grain size of the accumulated sediment, 6 – laminaria seaweed. III) The diagram of the material transport along the shore. IV) the variability of the mean grain size in consecutive ebbs. Location of the measurement points marked on (III), faulty grain size analysis marked by the empty circles (from Zagórski et al. doi.10.24425/ppr.2019.000000)

This summary is the one of the most precise studies on the transformation of the beach complex in Arctic based on the wind wave measurements, meteorological conditions and direct observation of the coastal sediment variability. Despite the fact of the significant wave height value rarely exceeded 0.5 m, the coastal sediment was of high variability both along parallel and perpendicular directions to the shoreline (fig. 2.3.4.(I, IV)). Due to the location of the study area on the south of the fjord, the influence of the swell is not direct, as the main propagation direction is south-west (see 2.3.1. and 2.3.2). In contrast to the Isbjørnhamna, where the main cause of the coastal dynamics is the swell (see 2.3.3), it is expected, that here, the main cause of the transformation is the wind sea. It is responsible for the erosion and redeposition of the sediment (fig. 2.3.4.(II)). It is particularly visible in case of the eastern wind. Wind sea generated from this direction has longer period than in case of western wind and is able to transport coarser grains and seaweed from the inshore. In contrast to the wind sea, significant swell height rarely exceeds 0.1 m and despite the longer period (circa 10 s) their destructive force is somewhat lower. However, considering their direction of propagation, from north to south, they are the key factor in sorting the sediment along the coastline (fig. 2.3.4.(III, IV)). Another important result of performer analyses is the occurrence of rapid changes in grain size of the sediment in time, frankly, during single tidal cycle (fig. 2.3.4.(IV)). The scale of those changes depends, obviously, on the wave type, its height and period but also on the direction of propagation (parallel or perpendicular to the coast).

(2.4) Fjords' hydrography (papers no: 4, 6)

Seasonal variability of the water temperature and salinity on the forefield of Hansbreen *(papers no 4, 6)*

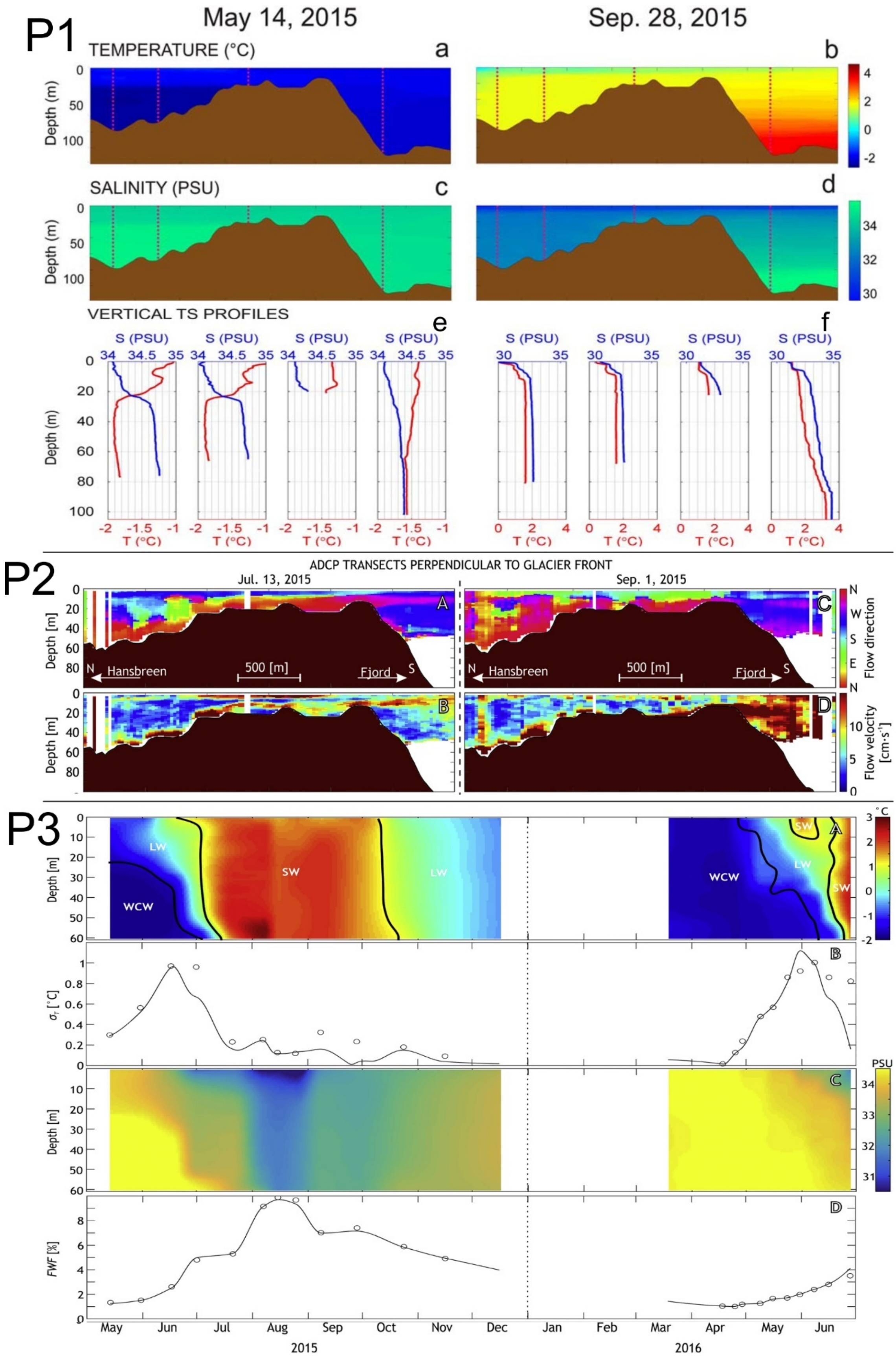

Figure 2.4.1. P1: Spatial distribution of the temperature (a, b) and salinity (c, d)on the basis of the spring and autumn measurements in the profile perpendicular to Hansbreen with example profiles from days of the survey (e, f) (from Głowacki et al. doi.10.1002/2016JC012355). P2: Water circulation in profile perpendicular to Hansbreen: flow direction (A, C), flow velocity (B, D) (from Moskalik et al. doi.10.1016/j.oceano.2018.03.001). P3: Seasonal variability of temperature (A), temperature's standard deviation (B), salinity (C), freshwater content (D)in the measurement profile on the forefield of Hansbreen in the center of Hansbukta (from Moskalik et al. doi.10.1016/j.oceano.2018.03.001).

The analysis of the seasonal variability of the temperature and salinity on the forefield of Hansbreen has been performed in scope of works concerning the analysis of sedimentary processes (paper no 6) and the influence of the glacier on the propagation of acoustic noise on its forefield (paper no 4). Both activities were executed in the same fieldwork period from May 2015 to June 2016. In spring period (beginning of May) the distribution of water temperature and salinity on the Hansbreen's forefield is rather homogenous (fig.2.4.1.P1.a,c,e). In the summer a thermohaline structure emerges (rapid change in temperature and salinity on the depth of few meters) which is a result of the warming of the surface water induced by the solar energy and the freshwater melt from the glacier creating surface brackish layer. Brackish surface layer flows out of the bay with velocity of 10-15 $cm \cdot s^{-1}$, while in the bottom layer flow in the direction of the glacier terminus is observed. Intensity of the outflows decreases in the autumn (fig. 2.4.1.P2). This type of circulation inside the bay and the presence of the sill blocking the water exchange with the fjord is visible in the distribution of the temperature and salinity in the bay and in the fjord (fig.2.4.1.P1.b,d,f). Variability of the water masses inside the bay on the forefield of the glacier is seasonal (fig.2.4.1.P3). In winter and early spring, the winter-cooled water (WCW) dominates, with temperature below -0.5°C and salinity above 34,4 PSU, formed when the bay gets cooled during the winter. In the spring, as the surface layer warms up, WCW transforms into the local water (LW) with temperature below 1°C. Along with further Warming combined with the delivery of freshwater from the glacier it transforms to surface water with temperature above 1°C and salinity below 34 PSU (SW). Practically, from the turn of June and July, whole bay is filled with SW water type. In autumn, along with decreased delivery of freshwater and decreased heat delivery it transforms back into the LW type, which is further transformed to WCW in the winter. The greatest variability of water masses in terms of temperature is observed in the WCW-LW-SW cycle (fig. 2.4.1.P3.B). The least salinized water occurs in August (fig. 2.4.1.P3.D). Small difference in temperature in autumn and decreased share of freshwater and the transformation of SW to LW in almost whole water column at one time is a sign that the water in the bay got mixed. Atlantic water type, its modification or transitional water seen in the fjord, is not observed in the bay. This observation confirms the role of the ridge closing the bay, as a barrier for the water mass exchange. Described hydrographical pattern observed in the bay implies seasonality of the distribution of suspended matter in water column (see 2.3.1) and in consequence also an intense deposition of sediments (see 2.3.3).

(3) Summary

The most important results up to date are the following:

- Showing the usability of geomorphometry in the geomorphological analysis of the arctic fjords (paper no 7);
- determining of the glaciers extent in Recherchefjorden area during the Little Ice Age (paper no 7);
- showing the differences in the morphology of Josephbukta and Vestervågen as bays where respectively the glacier was present / not present in Holocene period (paper no 7);
- confirmation of partial charges of Recherchebreen (paper no 7);
- documentation of the submarine sandur in Recherchefjorden area (paper no 7);
- first description of the bathymetry of the lagoon on the forefield of Recherchebreen, along with showing its morphological diversity caused by the tectonic setting (paper no 7);
- execution of the first geomrphological survey of the submarine part of the forefield of Hansbreen (paper no 5);
- proving that Hansbreen has not had the charge episode since the end of Little Ice Age (paper no 5);
- introduction of the method for estimation of probability of occurrence of re- deposed sediment (paper no 1);
- first elaboration on the annual variability of the suspended sediment concentration in water along with the analysis of governing oceanographical and meteorological factors 9paper no 6);
- pointing out the role of the flocculation process in the distribution of suspended sediment concentration in the water column (paper no 6);
- observation of the shift in occurrence of the maximum suspended matter concentration in relation to the maximum of the glacial outflow intensity (paper no 6);
- pointing out the role of bathymetry in temporal and spatial variability of the suspended matter concentration in water (paper no 6);
- pointing out the problem in the interpretation of suspended matter concentration in water based on the satellite imagery, when the highest concentration of suspended particles occurs near the pycnocline – not at the surface, and observation of the high concentration of suspended particles in deep water in the period between the autumn and spring (paper no 6);
- showing that when the sea ice is not present during the winter-spring period, suspended sediment concentration in the spring is similar to the concentration in winter (paper no 6);
- observation of the decrease in suspended sediment concentration, in whole water column, in the spring, after the decay of the sea ice (it influences the depth of photic zone, the growth of phytoplankton and CO_2 reduction, which was mentioned in the introduction to the presented scientific achievement) (paper no 6);
- observation of the increased share of organic particles on the forefield of the glacier both in the spring (phytoplankton growth) and in the winter (zooplankton inflow) (paper no 6);
- characterizing of the sedimentary processes in the inner part of Hornsund fjord and pointing out the dominating role of the glacial outflows as the source of matter (paper no 2);
- creating a connection between the morphological forms on the forefield of Hansbreen and the grain size of its sediments (paper no 5);
- defining the annual sedimentation rate on the forefield of Hansbreen as 25 to 40 $cm \cdot year^{-1}$ in distinctive areas of accumulation (paper no 5);

- showing of the meaning of the wind waves in sediment segregation and the development of the megaripples (paper no 5);
- determining the seasonality of the wind waves characteristics in the western area of Spitsbergen (paper no 8);
- determining the dominating swell propagation direction in the western coast of Spitsbergen (from the south-west), which influences the increased erosion rates of the fjord coasts (paper no 8);
- showing that the increased extreme wind wave event count is most prominent on the south of Spitsbergen (paper no 8);
- pointing out the significant positive trend of the storm count on the south of Spitsbergen in the winter (paper no 8);
- pointing out the potential influence of the drifting sea ice on the wind waves, particularly for the extreme wave events (paper no 8);
- development and validation of the wind wave model for the Hornsund area (paper no 9);
- showing that due to the dominating direction of the wind waves propagation from the open sea to the fjord , the most vulnerable coasts are located on the northern side of Hornsund (paper no 9);
- analysis of the features of the wind waves in Isbjørnhamna, where the Polish Polar Station Hornsund (paper no 9);
- determining the features of the Isbjørnhamna's coast (paper no 3);
- analysis of the cause and effect factors influencing the increase of the erosion rates in Polar regions (paper no 3);
- pointing out the intensification of strong wind wave events and the decrease in the sea ice as the main causes of the increase in erosion rates of the coasts (paper no 3);
- observation of short-term changes of the coast under influence of the wind waves (paper no 10);
- observation of the sorting of sediment along the coast induced by swell (paper no 10);
- characterizing the annual variability of the temperature – salinity structure in Hansbukta on the forefield of Hansbreen (papers no 4 and 6);
- demonstrating the importance of sills on glacial forefields in the process of water mass exchange (papers no 4 and 6).

(4) Literature

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5. Summary of the highlights in other scientific achievements after receiving the PhD in the earth sciences degree (without considering the works related to the doctoral thesis)

(1) Using of passive acoustic methods in analysis of the ice processes in fjords

The development of marine passive acoustics as a tool in the monitoring of physical processes such as wind, waves, precipitation, have inspired the international scientific team directed by J. Tęgowski, prof. in the University of Gdańsk, for the implementation of the analogous methods in studying the polar fjords environment. The main research hypothesis was that the sounds generated by the ice processes like calving, underwater glacier front melt-out, glacial outflows or sea ice related processes generate sounds with distinctive characteristics. The recognizing of this characteristics will, in the future, enable the analysis of the ice phenomena by analyzing the registered sounds. The most important results achieved by the Polish – American team, which includes the applicant, are as follows:

- Showing the difference in characteristics of the acoustic signal generated by the ice cliff melt out and calving;
- determining of the amplitude-frequency characteristics of different kinds of calving, particularly pointing out the acoustics as a tool for distinguishing the surface and underwater phenomena;
- finding the dependence between the acoustic energy of the signal generated by the calving and the size of calved iceberg;
- introducing the method of locating the source of sounds generated by ice processes, by using the set of two or more hydrophones, enabling time-simultaneous monitoring of the number of glaciers and tracking the drift of icebergs;
- showing that, despite the same mechanics of releasing the pressurized gas from the glacial ice, it is possible to distinguish the difference between the sound of iceberg and ice cliff melt out, by using the statistical analysis of the acoustic signal;
- determining the density of the surface acoustic energy generated during the surface melt out of the iceberg;
- indicating the influence of the subglacial outflows on the forming of acoustic channels and their meaning for the propagation of the signals generated near the ice cliff (calving, melt out, glacial outflows);

Papers:

Deane G.B., Głowacki O., Tęgowski J., **Moskalik M.**, Blondel P. 2014. Directionality of the ambient noise field in an Arctic, glacial bay. *Journal of the Acoustical Society of America*, 136, EL350

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(2) Changes in the Arctic in Holocene period

Recent climate change imply the development of paleogeographic and paleoclimatic research in order to find out the role of human activity in this process. In case of the paleogeographic reconstructions there is a certain cyclicity of events to which the glaciers respond by advancing and retreating, that is less regular now than before. The goal of the study of Ćwiąkała and others (2014) was to juxtapose the chronology of glacial events in Svalbard, particularly in Holocene. This study was based on the review of available papers written by a number of scientific teams. Some changes of ideas were observed, as the new research techniques were introduced. Also, a conclusion emerged on the lack of investigations (presence of the stratigraphic gaps) for middle Holocene in Svalbard area. It requires further research with use of new, innovative approach.

Further works in which the applicant was involved, directed by Wegner (2015), were concerning the investigation of the variability in the delivery of terrigenous sediment by rivers and by coastal erosion followed by transport and burial in Arctic Ocean during the Holocene. Variability of those processes was a result of the sea level change, decay of the ice sheets, changing role of the transport of sediment by the sea ice and its redistribution by the ocean currents. In early and middle Holocene the sedimentation was higher than in later, cooler period. The sediment delivery via rivers has not been changing, meaning that the cause has to lie in the increased rates of coastal erosion in the warmer period. It is one of the key results in this study. It explains observed increase of coastal erosion rate during recent changes of the climate, analyzed as one of the achievements on which this application is based on.

More detailed studies in which the applicant participated were concerning changes ongoing in the North – Eastern Land (Ojala et al. 2014). Deglaciation in this area started 11 300 years ago, with the beginning of Holocene. Afterwards, this area was an open sea with increased primary production. More or less in the middle of the Holocene (5 800 years ago) an episode of rapid glacial advance has occurred. The decrease in global temperature resulted in the development of the ice sheet circa 2 500 years ago. The change happened during the last 500 years, since this area is seasonally ice-free. The applicant would like to note the effect that occurred after deglaciation in the beginning of Holocene, being the increase in primary production. It can be explained by the increased delivery of nutrients during the retreat of glaciers, which was mentioned in the introduction to the achievement being a base for this application.

Papers:

Ćwiąkała J., **Moskalik M.**, Rodzik J., Zagórski P. 2014. The glacial history of the Svalbard Archipelago from Late Vistulian to the present time. / Historia zlodowacenia archipelagu Svalbard od późnego vistulianu do współczesności. Annales UMCS, Sectio B: Geographia, Geologia, Mineralogia et Petrographia, 69(2), 27-52

Ojala A.E.K., Salonen V-P., **Moskalik M.**, Kubischta F., Oinonen M. 2014. Holocene sedimentary environment of a High-Arctic fjord in Nordaustlandet, Svalbard. Polish Polar Research, 35(1), 73-98

Wegner C., Bennet K.E., de Vernal A., Forwick M., Fritz M., Heikkila M., Lacka M., Lantuit H., Laska M., **Moskalik M.**, Pawłowska J., Promińska A., Rachold V., Vonk J.E., Werner K. 2015. Holocene state and fate of terrigenous material delivered to the Arctic Ocean. Polar Research, 34, 24964

(3) Other elaborations on the recent fjords behavior (not mentioned in the achievements)

In collaboration with the glaciologists team from the University of Silesia and oceanographers from the Institute of Oceanology PAS, the applicant has participated in the study on the intensity in the freshwater delivery to Hornsund, and in analysis of further development of this fjord in aspect of the retreat of glaciers. The result of the first paper (Błaszczyk et al. 2019) is recognizing the main source of freshwater in the fjord, being the subglacial outflows (39%) originating mainly from the melt of the snow and glaciers surface ablation. Further significant elements in this balance are: underwater cliff melt out (25%), liquid precipitation in the fjord's catchment area (28%) and snow melt out from the non-glaciated areas (7%). In this study the independent influence of every glacier in the fjord was also estimated. The second study performed by the team concerned the use of glaciological, geophysical, teledetective and oceanographic studies in the estimation of the future development of Hornsund (Grabiec et al. 2018). At the turn of the years 2050-2060 the result of progressing retreat of the Hornbreen-Hambergbreen glacier system (if the retreat rate will remain on today's level) a strait will form. This will change the system from the fjord-specific to the strait-specific with largely lesser influence of the glaciers in Hornsund. It will have large impact on hydrography as well as all abiotic and biotic processes in the fjord. This phenomenon motivates to conduct the research described in the introduction to the achievement on which this application is based on, as the nutrient delivery from land will also be affected, which can imply the increase of the phytoplankton growth or the opposite.

Papers:

Błaszczyk M., Ignatiuk D., Uszczyk A., Cielecka-Nowak K., Grabiec M., Jania J.A., **Moskalik M.**, Walczowski W. 2019. Freshwater input to the Arctic fjord Hornsund (Svalbard). Polar Research (accepted)

Grabiec M., Ignatiuk D., Jania J.A., **Moskalik M.**, Głowacki P., Błaszczyk M., Budzik T., Walczowski W. 2018. Coast formation in an Arctic area due to glacier surge and retreat: The Hornbreen–Hambergbreen case from Spistbergen. Earth Surface Processes and Landforms, 43, 387-400

6. Summary on the published papers, rewards, journeys, participation in projects, didactic achievements and popularization of science.

(up to day 2019.04.08)

(1) Bibliometrics

Web of Sciences:

No of papers: **22**; h-index: **7**; Total citations: **137**; Excluding self-citations: **97**;

Scopus:

No of papers: **22**; h-index: **7**; Total citations: **138**; Excluding self-citations: **93**;

Google Scholar:

No of papers: **37**; h-index: **8**; Total citations: **177**;

(2) Publications and doctoral theses

Sum of points granted by the Ministry of Science and Higher Education: **560**;
Aggregated 5-year Impact Factor: **44,561**;
Published after receiving the doctoral degree:

- Total publications: **26**;
- As editor: **1**;
- Registered in Web of Science: **22**;
- Total publications in titles with Impact Factor : **21**; ranked in quarters:
  Q1: **5**; Q2: **3**; Q3: **11**; Q4: **2**;

Published before receiving the doctoral degree:

- Total publications: **4**;
- Registered in Web of Science: **2**;

(3) Paper reviews: 5;

(4) Authorship/Co-authorship in conference presentations/posters

after receiving the doctoral degree:

- total: **58**;
- as the speaker: **8**;

before receiving the doctoral degree:

- total: **20**;
- as the speaker: **8**;

(5) Rewards and scholarships

- rewards: **3**; (including: **Prime Minister Reward for the Doctoral Thesis**)
- scholarships: **2**;

(6) Internships/short-term scientific trips to national/foreign institutions, field trips

- Short term visits in foreign institutions: **2**;
- Field trips: **13** (as the manager: **9**);

(7) Participation in scientific and infrastructural projects, roles taken

- Project manager: **2**;
- Principal investigator: **1**;
- investigator: **7**;
- field assistant: **3**;

(8) Educational activity and popularization of science

- PhD students – auxiliary promoter: **2**;
- PhD students – scientific mentor: **1**;
- MSc students – scientific mentor: **1**;
- interns – mentor: **3**;
- apprentices – mentor: **3**;
- students/doctoral classes given:
  lectures: **7**; laboratory: **1**; seminars: **2**;
- lectures/seminars as invited guest:
  foreign institutions: **2**; national institutions: **5**;
- popularization of science:
  popular-science documentaries: **1**; festivals of science: **2** (staff); photo exhibitions: **2** (arranger, author, multiple displays); multiple themed lessons in schools and kindergartens, popular science articles in themed papers;