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CLIMATE CHANGE IMPACT ON GLACIERS RETREAT IN PASSAGE CANAL FJORD, ALASKA

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Abstract: The recent climate changes of the Globe and continuous warming of the Artic regions conduct at melting of larges areas covered by ice. The rise in sea water level risk connected to disturbances of enormous biogenesis and ecosystems has come to signal the effects of ice melting and glaciers retreat. Here we present a method to assess the climate change impact on glaciers from Passage Canal Fjord. Climate data, satellite images, and the thickness of three glaciers represent the main data used into climate change impact analysis. The mean temperature data and the melting volume values of Billings, Learnard, and Whittier Glaciers from 1972-2014 were introduced into an artificial algorithm based on a matrix method to assess the climate change impact on these glaciers. The main results indicate that glaciers retreat represents about 30.05% of the entire ice cover areas of the Passage Canal. An absolute melting volume value of 0.44 km^3 from 1972 to 2014 was calculated for the study area which corresponds to $2.95x10^{-5}$ mm in sea level rise. Based on the matrix method the medium impact of climate change was found for the Billings and Learnard Glaciers and the high impact was found for the Whittier Glacier.

Keywords: climate change, glacier melting, satellite images, Passage Canal, sea level rise.

1. INTRODUCTION

The environments systems are continuously in changing and the human safety in term of habitat and real conditions of life depend by both the daily activities and the natural Global changes implications. During the last decade were claimed in many papers the climate warming and climate changes (Haeberli et al., 1999; Kargel et al., 2005; Oerlemans, 2005; Păcurar, 2015). The Global climate changes were announced by IPCC (2007) and a rising in temperature up to 3°C were predicted for current century (Stavig et al., 2005; The Canadian Centre for Climate Modelling and Analysis, 2015). Due to climate regime changes of the Earth, the ecosystems resilience is facing with high risk (Kløve et al., 2014), the water resources and agricultural areas are negatively affected (Bachu & Adams, 2003; Prăvălie et al., 2014), and coastal habitats are indirectly exposed to danger because of rise in sea level and decreased of shorelines, inundation and erosion (Khalsa et al., 2004; Church et al., 2008).

The glaciers are most sensitive indicator to climate change and recently, the climate warming influences negatively the glaciers balance due to continuously decline of glaciers in many locations of the Globe (Shahgedanova et al., 2005; Painter et al., 2013), fact for which the Arctic and Antarctica regions are widely included into several researches. The high mountains ranges from entire world covered by glaciers are also inventoried by scientists in aim to understand which the impact of climate changes on extensions of ice mass is and the possible floods that may occur due to ice melting are checked. Recent studies contest that climate change affects drastically and direct the glaciers, ecosystems, and natural systems because of increasing in CO_2 and emissions of greenhouse (Cox et al., 2000). Indirectly, the melting of ice is negative influenced by recent climate warming. Nistor & Petcu (2014) show the role of glaciers melting in the ecosystem changes in theirs study about Prince William Sound landscape, South Alaska. Together with Global warming, the industrial black carbon contributes at the acceleration of Alpine glaciers retreat (Painter et al., 2013). In the Himalaya Range the main glaciers regressions reason are the climate warming, sudden rainfalls, debris cover, and black carbon (Kulkarni & Bahuguna, 2002; Kulkarni et al., 2007; Scherler et al., 2011).

Alaska represents an important realm of glaciers, due to high glaciation and due to high number of glaciers, ice fields, and marine ice packs. In South Alaska was observed significant glaciers changes (Nistor & Petcu, 2015; Nistor & Porumb-Ghiurco, 2015). Farinotti et al., (2009), Huss & Farinotti (2012) inventoried the glaciers from many locations of the Globe. They carried out also the thickness of glaciers from Passage Canal Fjord. Recently, Nistor & Petcu (2015) bring forward the melting areas of glaciers from Passage Canal based on Geographical Information System and satellite images. They observed that between 1985 and 2013 the lost ice areas of glaciers from passage Canal was approximatively 4.89 km^2. The melting of glaciers plays an important role not only for terrestrial ecosystems and freshwater, but also has direct implication for the global sea level rise. In the last decades many studies brought in front the problem of sea level rise (Warrick & Oerlemans, 1990; Pfeffer et al., 2008; Little et al., 2013). Nicholls & Cazenave (2010) mentioned that the mains factors in sea level rise are ocean warming and coming water from ice melt and terrestrial reservoirs. The observations about increasing of global sea level were done in the 20th century (Nicholls & Cazenave, 2010). Meier et al. (2007) claim a value of 3.1 ± 0.7 mm/year for worldwide sea level. A drastic result of approximatively 1 m sea level rise was claimed by Titus (1989) for the U.S. coastal wetlands.

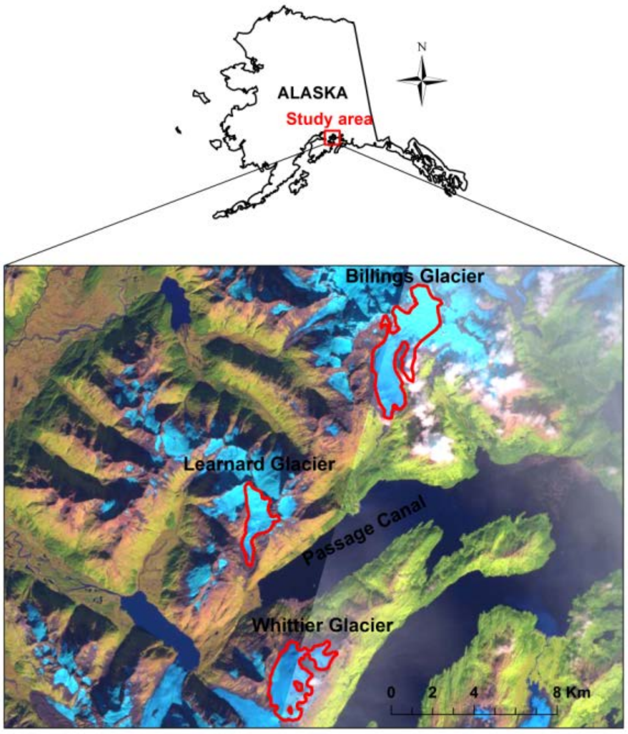

Figure 1. Location of the main glaciers from Passage Canal on the Alaska map using state boundary and Landsat image from September 2014. Landsat images courtesy of the U.S. Geological Survey.

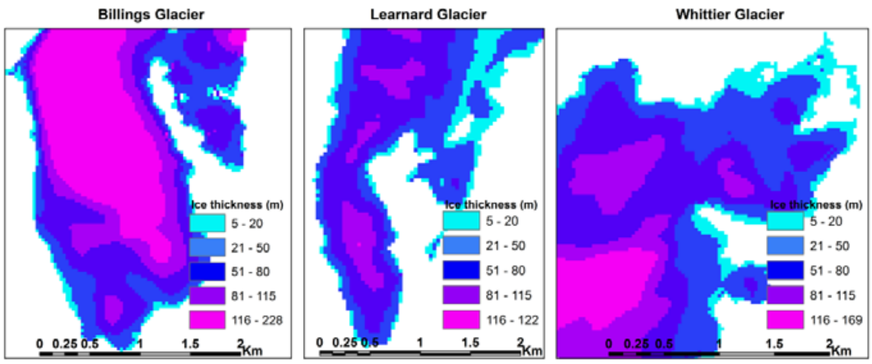

Figure 2. Thickness of Billings Glacier, Learnard Glacier, and Whittier Glacier. Sources: Farinotti et al. (2009), Huss and Farinotti (2012).

			Melting Volume km³				
			0 - 0.1	0.11 - 0.2	0.21 - 0.3	0.31 - 0.4	> 0.4
		Impact	Very low	Low	Medium	High	Very high
Mean air Temperature °C	0 - 2	Very low	Very low	Very low	Low	Medium	Medium
	2 - 3	Low	Very low	Low	Medium	Medium	Medium
	3 - 4	Medium	Low	Medium	Medium	High	High
	4 - 5	High	Medium	Medium	High	High	very high
	> 5	Very high	Medium	High	High	very high	very high

Climate change impact				
very low	low	medium	high	very high

Figure 3. Inference matrix 5 x 5 used in the assessmnt of climate change impact on glaciers.

The objectives of the present study are to calculate the lost areas and melting volume during 1972-2014 of Billings Glacier, Learnard Glacier, and Whittier Glacier which are in Passage Canal and to assess the climate change impact on these glaciers. The sea level rise due to melting ice mass of the studied glaciers was estimated too. The main reason for which were chosen these glaciers is related to few investigations and limited previous works regarding the climate change effects on glaciers from Passage Canal. Secondly, because of the location of the Chugach Mountains in north and Kenai Mountains in south of Passage Canal, the Billings Glacier, Learnard Glacier, and Whittier Glacier are supposed to have different retreat comportment influenced by the local climate. Finally, the typology and the size of these three glaciers are representative for the whole Prince William Sound area, where the Passage Canal Fjord is included, fact for which theirs study provides outcomes for the most important region from South Alaska.

2. BACKGROUND OF GLACIERS FROM PASSAGE CANAL

Passage Canal is the Western fjord from Prince William Sound, South Alaska. The Passage Canal is bordered in North by Chugach Mountains and in South by Kenai Mountains (Nistor, 2013). In West extremity, there is Portage Pass that separates the Chugach Mountains by Kenai Mountains. This mountain area of Passage Canal is covered by main three types of glaciers: outlet glaciers, tidewater glaciers, and hanging glaciers. Frequently on high plateau or inside glacial cirques are found ice blocks or remaining snow from the previous winter. The more important existing glaciers from Passage Canal are: the Billings Glacier in North of fjord, the Learnard Glacier in West of the fjord and the Whittier Glacier in South of fjord (Fig. 1).

Billings Glacier represents a tidewater glacier and is in the Western Chugach Mountains and it has flow direction from North to South. Learnard Glacier is a small tidewater glacier and extends in the Western extremity of the Passage Canal, flowing from North to South. Whittier Glacier is an outlet glacier and it has South South-West to North North-East flow direction. Research into past Billings, Learnard, and Whittier Glaciers changes was conducted through remote sensing using satellite images and Geographical Information System (GIS) by Nistor & Petcu (2015). The GIS applications were widely applied in spatial analysis by Dezsi et al., (2015) and Nistor et al., (2015). Based on delivered data of glaciers thickness (Farinotti et al., 2009; Huss & Farinotti, 2012), the mean thickness of Billings Glacier terminus has around 60 m, the mean thickness of Leranard Glacier terminus has around 45m, and the mean thickness of Whittier Glacier has around 55m (Fig. 2).

3. MATERIALS AND METHODS

3.1. Climate data

Monthly and annual mean air temperature data of Whittier station (see Western Regional Climate Center, 2015) were analysed for a long term period, from 1960 to 2010 in aim to observe the relationship between retreat rate values of glaciers and temperature trend in the study area. Mean of annual and monthly air temperature, annual and monthly precipitation, monthly snowfall, and annul snow depth were considered into characterization and climate analysis of the Passage Canal Fjord. The most important climate data are temperature and precipitation, fact for which in many studies have been used to climate indices calculation (Deniz et al., 2011).

3.2. Landsat satellite images

The spatial extension of Billings Glacier, Learnard Glacier, and Whittier Glacier have been analysed through Landsat images and the melting area of these glaciers were calculated using Geographical Information System. Landsat satellite images (United States Geological Survey 2015) served to manual vectorization of glaciers outlines from Passage Canal. The remote sensing from satellite images was computed using ArcGIS 10.1 environment. The imagery analysis was based on visible spectral images and was applied to delineating point by point the glaciers contour. The older Landsat data used in present study dating from 1972 and the recent images are dating from 2014. In aim to avoid the cloud cover and for easy distinguish the glacier ice with seasonal snow we analysed the satellite images from late summer and early fall periods. Compared the vector data of both past and recent periods, we could extract the lost ice mass.

3.3. Calculation of melting ice volume and sea level rise

The lost volume of glaciers was carried out from the total retreat areas and glaciers thickness data grid investigated by Farinotti et al., (2009), Huss & Farinotti (2012). In addition, our study provides the possible sea level rise. From the melting volume calculations was carried out the contribution of Passage Canal glaciers at sea level rise scaling the total areas of Planetary Ocean and connected seas.

The annual sea level absolute changes value has come out from calculation of melting volume and oceans areas. The melting ice volume was divided by oceans and seas areas (3.519×10^8 km^2) and thus, the possible sea level rise of Passage Canal glaciers was estimated (Eq. (1)).

$$SLR = (Vmi / Aso) \times 10^6 \quad (1)$$

where:
SLR Sea level rise (mm)
Vmi Volume of melting ice (km^3)
Aso Area of seas and oceans (km^2)

3.4. Assessment of climate change impact on glaciers through matrix method

We propose a new method to assess the climate change impact on glaciers. The method is based on an artificial intelligence algorithm which combines the classified temperature data with lost volume of the glaciers in the last four decades. This method was performed through a 5 x 5 matrix values and returns the predefined classes of impact: (i) very low, (ii) low, (iii) medium, (iv) high, and (v) very high. We adopted a supervised classification of mean air temperature data and classification of lost volume values in predefined classes.

The inference matrix method is showed in figure 3 and was constructed strictly for the Passage Canal Fjord study case. Considering the range of mean air temperature in the study area and the range of the ice lost volume related to the analysed glaciers, we have chosen classes of the assessment impact in the way to evaluate the climate change effects on existing glaciers in respective area. Also, these classes were set in a manner in which the obtained results can be compared with each other and to observe better where the climate change impact is. Thus, the mean air temperature from 0°C to 5°C was divided in five classes as: between 0°C to 2°C the climate impact should be very low; between 2°C to 3°C the climate impact should be low; between 3°C to 4°C the climate impact should be medium; between 4°C to 5°C the climate impact should be high; for the values which exceed over 5°C the climate impact should be very high. One other hand, the melting volume was divided into five classes as follow: between 0 km^3 to 0.1 km^3 the impact should be very low; between 0.11 km^3 to 0.2 km^3 the impact should be low; between 0.21 km^3 to 0.3 km^3 the impact should be medium; between 0.31 km^3 to 0.4 km^3 the impact should be high; for the values which exceed over 0.4 km^3 the impact should be very high.

The matrix method could be easily modified and integrated for others places from the world, combing the climate data and field glaciers measurements from that place. For instance, if the method is applied for others glaciers with different location, the minimum and maximum value of mean air temperature is required and divided it in approximate equal classes. On the other hand, the minimum and maximum value of lost ice volume should be preferable divided in the appropriate classes, follow the equal procedure. In this way, the matrix method could be modified and used for assess the climate change impacts on others glaciers, without taint in performance. In the glaciers study this method may be considered innovative, even if the inference matrix method was imported from others environmental areas like Engineering, Hydrology or Geology expertise (Nistor et al., 2016).

4. RESULTS

Overall, the findings presented below indicates that the climate change influences on glaciers from Passage Canal have strongly impact from area retreat and lose volume during the last four decades. The climate data analysis shows an average value of 4.96 °C in the mean annual air temperature from 1985-2010. During this period, the mean annual temperature ranged from 3.64 °C to 6.24°C (Fig. 4a).

The years with elevated mean air temperature are 1993, 1997, and 2005, fact for which in these set times the retreat rate of glaciers are higher than in others years. Analysing the mean monthly data during 1960-2010 it was observed that mean air temperature reaches values around 12-13°C, especially in the summer period (June, July, and August) (Fig. 5a). The coldest months are January, February, November, and December when the monthly air temperature fall below 0°C.

The annual precipitation trend from 1985-2010 shows values which exceeds 7000 mm in one year. Thus, the annual precipitation ranged from 2819 mm to 7182 mm and register an average value of 5265 mm. Interestingly, the mean annual precipitation have slightly negative trend, with particular high values, often over 5000 mm up to 1995. From 2003 to 2010 the annual precipitation values fall below 5000 mm, with an exception in 2008 when the precipitation registered 5148 mm (Fig. 4b). This detail may contribute at glaciers retreat due to the negative balance in ice mass accumulation decrease. Going in the mean monthly data during 1960-2010 it was observed that mean precipitation exceeds 500 mm during winter and fall months (Fig. 5b). The months with lower precipitation values are June and July, when the monthly precipitation falls below 300 mm. The mean monthly data of snowfall were also analysed during 1960-2010 in aim to understand the period of snow accumulation. Figure 5c illustrates that in winter and early spring period (January, February, December, and March) the snowfall values exceed 1000 mm. The summer months represent integral the period without snowfall during the 1960-2010.

The snow depth values during 1985-2010 ranged from 10.87 cm to 85.54 cm and an average value of 42.09 cm was calculated for this period. The higher values of snow depth exceed 80 cm in 1988 and 1999, while the lower values which fall below 20 cm were identified in 1994, 1996, 2003, and 2005 (Fig. 4c).

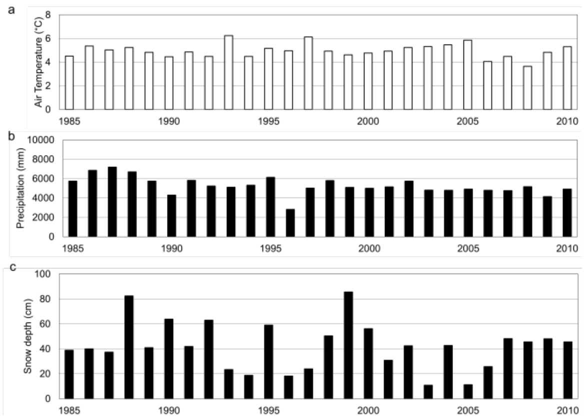

Figure 4. a. Annual air temperature trend related to 1985-2010 period. b. Annual precipitation trend related to 1985-2010 period. c. Annual snow depth trend related to 1985-2010 period.

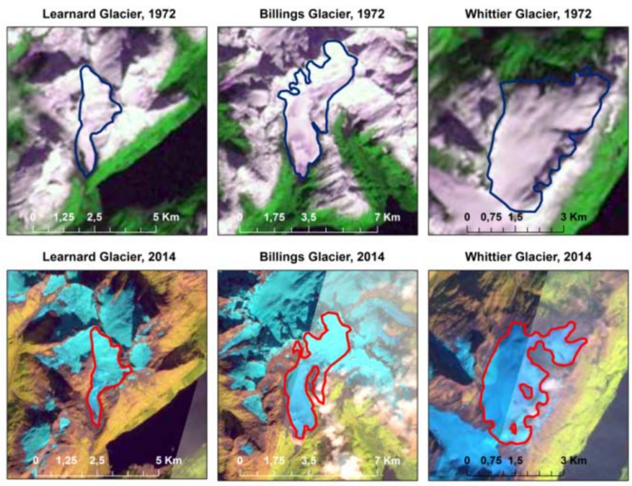

Figure 6. Landsat mosaic images and outlines of Billings Glacier, Learnard Glacier, and Whittier Glacier in 1972 and 2014 years. Landsat images courtesy of the U.S. Geological Survey.

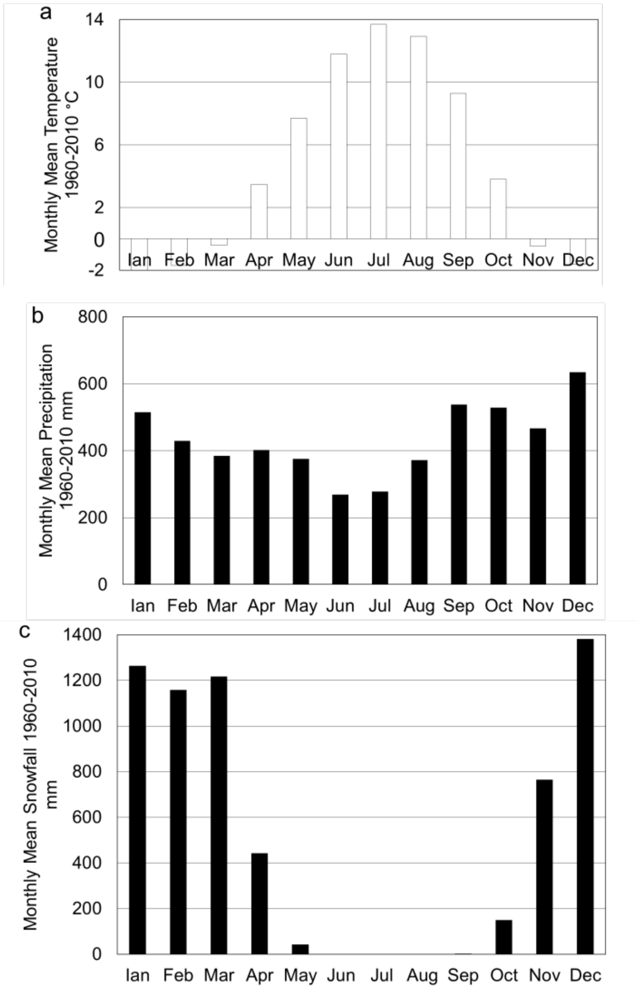

Figure 5. a. Monthly mean temperature related to 1960-2010 period. b. Monthly mean precipitation related to 1960-2010 period. c. Monthly snowfall related to 1960-2010 period.

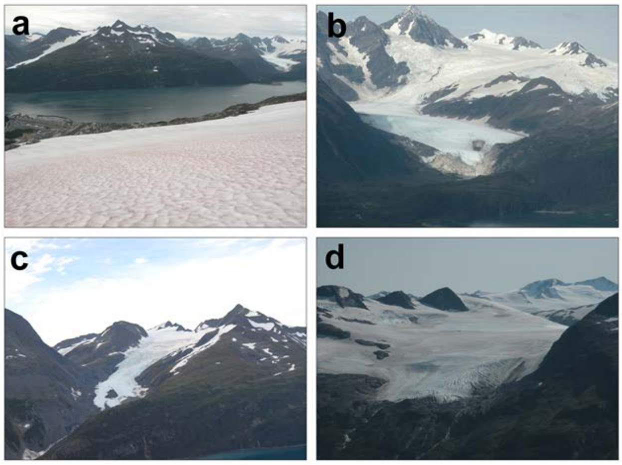

Figure 7. a. North-looking ground photograph of Passage Canal Fjord. b. Northeast-looking oblique aerial photograph of Billings Glacier. c. North-looking ground photograph of Learnard Glacier. d. South-looking aerial photograph of Whittier Glacier. Photo courtesy: Nistor MM.

Landsat images, starting with 1972 and completed in 2014 were used to assess the position of outlines of Billings Glacier, Learnard Glacier, and Whittier Glacier (Fig. 6). Figure 7 illustrates the extending of the studied glaciers and its position in the field. Based on measured areas in both set times, it was observed that Billings glacier decreased in the last 42 years by 3.1 km^2, with an average retreat rate of 0.11 km^2 yr^{-1}. The evaluated lost volume of ice from Billings Glacier is 0.19 km^3. Learnard Glacier retreated by 1.04 km^2 from 1972 to 2014, with an average retreat rate of 0.04 km^2 yr^{-1}. The total retreat of Learnard Glacier corresponds to 0.05 km^3. From 1972 to 2014 the Whittier Glacier decreased by 3.73 km^2 with an average retreat rate of 0.15 km^2 yr^{-1}. The lost volume of Whittier Glacier during the 42 years was 0.21 km^3. Table 1 shows the annual retreat rate of glacier from Passage Canal Fjord.

The most important effects of ice and glaciers retreat are showing on rise in sea water level risk connected to disturbances of enormous biogenesis and ecosystems. Considering the past and recent physical characteristics of Billings Glacier, Learnard Glacier, and Whittier Glacier and considering also the thickness of glaciers we were able to calculate the total lost ice mass volume during 1972 to 2014. Based on these characteristics of glaciers a value of total retreat area of 7.87 km^2 for all three glaciers was found. This corresponds to a volume of 0.44 km^3 of ice mass that represent around 0.001 mm in sea level increase from 1972 to 2014. The calculated annual sea level increase indicates a value of 2.96 x 10^{-5} mm yr^{-1}. Over 1972 to 2014, the total retreat area of Billings Glacier, Learnard Glacier, and Whittier Glaciers show about value of 30.05% of melting ice mass from entire three glaciers lost volume.

Using the artificial intelligence algorithm, implemented into matrix method, the climate impact on Billings Glacier, Learnard Glacier, and Whittier Glacier was assessed. Considering a mean air temperature value of 4.96 °C for the study area and glaciers lost volume in the last four decades, different climate impacts for the three glaciers were founded. Applying the matrix method for the Billings Glacier it was observed that based on the melting volume value of 0.19 km^3, the impact is medium. Learnard Glacier registered an ice mass lost volume of 0.05 km^3 for the 1972-2014 period and a medium climate impact was assessed.

Interestingly, the lost volume of Whittier Glacier between 1972-2014 was 0.21 km^3 even if the flow direction of this glacier is South South-West to North North-East. Based on the matrix method the climate impact on Whittier Glacier is high.

5. DISCUSSION

The main goal of the present paper was to assess the climate impact on glaciers from Passage Canal Fjord. The melting areas and melting volume of Billings Glacier, Learnard Glacier, and Whittier Glacier were calculated based on Landsat satellite images, respectively based on thickness of mentioned glaciers. The climate data of mean air temperature, precipitation, snowfall, and snow depth served to characterize the study area. The mean annual temperature for long time was used together with melting volume into a matrix method 5 x 5 to assess the climate impact on glaciers. In addition, the contribution of lost ice volume from glaciers located in Passage Canal on sea level rise was estimated.

The most important detail of the results is that all three glaciers from Passage Canal are in continuous retreat from 1972 to 2014. It would have been expected the continuous melting of glaciers considering the positive values of mean air temperature in the area, which ranged during 1985-2010 from 3.64 °C to 6.24 °C. More than this, the decrease of mean annual precipitation below 5000 mm from 2003 to 2010 indicates an approximate decrease of ice mass and snow in the study area. Also, the analysis of the snowfall trend concerned that during 1985-1994 period, 1994-1999 period, and 2006-2011 period, when the snowfall values were low, the retreat rate of all three glaciers were higher than the mean (e.g. 0.07 km^2 yr^{-1}, 0.13 km^2 yr^{-1}, 0.09 km^2 yr^{-1} for Billings Glacier; 0.02 km^2 yr^{-1}, 0.03 km^2 yr^{-1}, 0.03 km^2 yr^{-1} for Learnard Glacier; 0.06 $km^2 yr^{-1}$, 0.09 km^2 yr^{-1}, 0.07 km^2 yr^{-1} for Whittier Glacier.

As a consequence of glaciers retreat, the flow discharge of Billings Creek, Learnard Creek, and Whittier Creek increase in summer and early autumn periods because of ice melting and low evaporation rate, fact for which the geomorphology of streams changed drastically and also the biocenosis of the fresh water ecosystems is disturbed too. The same phenomenon occurs with many glaciers located in Kenai and Chugach Mountains which flow over the Pacific Ocean. The synergy of these ice masses contribute at sea level rise only about 2.96 x $10^{-5}mmyr^{-1}$. Even if this value contributes with small amounts at the Global sea level, the findings are helpful in calculations of mountains glaciers from South Alaska contribution to sea level rise. The limitation of the study is that in the calculations of sea level rise we ignored the assumptions of Earth curvature and spreading out of ocean water when the sea level rises. Our estimation consider a simply model calculation which overestimates the real sea level rise and emphasizes the potential sea level rise under ice glaciers volume melting.

Table 1. Retreat rate of glaciers from Passage Canal (km² yr^{-1}).			
Period	Billings Glacier	Learnard Glacier	Whittier Glacier
1972-1985	0.03	0.00	0.00
1985-1994	0.07	0.02	0.06
1994-1999	0.13	0.03	0.09
1999-2006	0.07	0.02	0.04
2006-2011	0.09	0.03	0.07
2011-2013	0.05	0.07	0.11
2013-2014	0.35	0.10	0.65
Source: ArcGIS statistics			

An exhaustive study about sea level fluctuation in Alaskan fjords is extremely difficult to realize. The Passage Canal is connected at Planetary Ocean through Prince William Sound bay. Referring at total ice mass melting during 1972-2014, we estimated the sea level oscillation due to presented glaciers lost ice volume and seas and ocean areas. The first factor that influences the sea level rise in Passage Canal in present is the climate. This is due to climate warming that implies the glaciers melting faster. The second factor could be considered the glaciers orientation and it's flow direction. Due to elevated temperature in the summer period (over 13°C) and proximity of glaciers to Passage Canal which has a marine climate, the accumulation of snow is minor in case of Billings Glacier, Learnard Glacier, and Whittier Glacier. For this reason the climate conditions plays and decisive role on annual retreat rate and on melting volume of these glaciers. Due to this, the positive temperature and precipitation amount in summer period contribute to strong melt of glaciers which are located near the coastal zone.

The assessment of climate change impact on glaciers is hard such the glacial processes present a complex matter which includes also the latitude, terrain morphology, flow direction and local climate conditions. Even if the aims were completed, the methods used in this paper ignored the field measurements by Ground-penetrating radar during the long period. For this reason, the remote sensing and Geographical Information Systems technology were useful in the historical reconstruction of Billings Glacier, Learnard Glacier, and Whittier Glacier outlines and in the retreat ice area calculation. Regarding to the lost ice volume, the limitation of the product is come from the glaciers volume calculation for the pat period. In the present research the thicknesses of the glaciers have been kept constant due to lack of data for the 1970's years. The mentioned shortcoming of the lost ice volume and possible sea level rise could be neglected as regards the extension of oceans and seas of the Globe.

In the last 50 years nobody signaled the major changes in the sea level based on glaciers of the Passage Canal, fact for that our study contribute at specialized literature about glaciers, climate change, and South Alaska land.

6. CONCLUSIONS

We have defined a new method to assess the climate impact on glaciers integrating the mean air temperature and melting ice volume of glaciers into a matrix 5 x 5. The method applied in present paper considers the climate data and volume of melting ice mass of glaciers from Passage Canal Fjord.

The observations made by remote sensing on Billings Glacier, Learnard Glacier, and Whittier Glacier bring forward information about ice cover changes during 1972-2014. Based on the retreat area and glaciers thickness the melting volume of studied glaciers was calculated and also the sea level rise was estimated. Thus, the total retreat area of 7.87 km^2 for the studied glaciers was calculated. The total lost ice volume during 1972-2014 of Billings Glacier, Learnard Glacier, and Whittier Glacier was 0.44 km^3. This volume corresponds to 0.001 mm in sea level increase from 1972 to 2014 and the annual sea level increase shows a value of 2.96×10^{-5} mm yr^{-1}. Starting from 1972 to 2014, the total retreat area of Billings Glacier, Learnard Glacier, and Whittier Glacier was about of 30.05%, which indicates a considerable ice mass lost in the last five decades.

Due to the wide spread of Whittier Glacier terminus, but also due to its geographical position on a flat suspended plateau, without shady effects of surrounding mountains, it was observed that Whittier Glacier retreats by 3.73 km^2 during 1972-2014, in comparison with Billing Glacier and Learnard Glacier which retreat by 3.1 km^2 respective by 1.04 km^2. The melting volume of Whittier Glacier has also the highest value of 0.21 km^3, followed by Billings Glacier with a melting volume value of 0.19 km^3 and by Learnard Glacier with a melting volume value of 0.05 km^3. Taken together, the total melting volume of glaciers from Passage Canal during 1972-2014 contributes to Global sea rise oscillation by $2.96x10^{-5}$ mm yr^{-1}.

The melting area and volume lost ice due to climate conditions have implications on hydrology regime, coastal ecosystems, and sea level rise.

Based on the analysis of the satellite images along 1972-2014 period and including the glaciers spatial changes using the Geographical Information Systems, our survey was completed with the implementation of a matrix method which assess the climate change impact on the glaciers in Passage Canal Fjord. Adhering the above mentioned proceedings, we conclude that climate change impact on glaciers from Passage Canal Fjord is medium regarding the Billings and Learnard Glaciers and high regarding the Whittier Glacier.

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