Record year for annual retreat rate of Whittier Glacier from South Alaska in 2014

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ABSTRACT: An unexpectedly retreat of 0.655 km² yr^{-1} was calculated for Whittier Glacier, South Alaska only for 2014 year. Under recent global warming the Arctic regions presents various fluctuations in the ice mass retreat. Here we bring forward the maximum retreat rate of Whittier Glacier in the last 42 years. Starting to 1973, the glaciers from Passage Canal melt continuously, but no more than 0.105 km² yr^{-1}. From September 2013 to September 2014 Whittier Glacier registered a huge area retreat of 0.655 km² yr^{-1} and beat the record measured up present.

KEY WORDS: Whittier Glacier, retreat rate, climate warming, GIS, satellite images

1. Introduction

The rise of global temperature has negative impact at regional scale of Artic region and also in many sites of Alaska areas. The southern part of Alaska is characterized by a very humid climate with mean annual precipitation over 5000 mm yr^{-1}. Under recent global warming, the mean annual temperature reaches about 5°C in the Passage Canal fjord, located in South Alaska. For these reasons the glaciers behaviour from South Alaska have a complicated tendency. The last four decades show a continuous retreat of glaciers from Passage Canal (Nistor and Petcu, 2015), without stop of retreat or accumulation in the ice mass. This regression contributes at sea level rise both of Pacific Ocean and global sea level, but also contributes to local ecosystems disturbances (Nistor and Petcu, 2014).

Temperatures and precipitations are main climatic data that influences the glaciers behaviour. During the last century many glaciers of entire world registered high lose areas related to climate warming. For current century was predicted rise in temperature and decrease in precipitations quantity (Stavig at al. 2005) in North America and many future scenarios show an increase of 1-3 °C in Global temperature trend (IPCC, 2001; The Canadian Centre for Climate Modelling and Analysis, 2015). Cox et al. (2000) explain that at natural climate warming is added the contribution of artificial carbon dioxide, fact for which the European glaciers from Alps are affected more.

The glaciers studies are essentially because reflect very well the global warming influences on Earth. Haeberli et al. (1999), Oerlemans (2005), Shahgedanova (2005) speak in theirs studies about climate warming and decline of glaciers in many sites of the Globe. The glaciers from South Alaska were inventoried in the twentieth century by United States Geological Survey (USGS), Mayo et al. (1977), Kennedy et al. (2006), Molnia (2001, 2006, 2008), and recent by Huss and Farinotti (2012).

Here we report the Whittier Glacier most striking retreat from the last forty years.

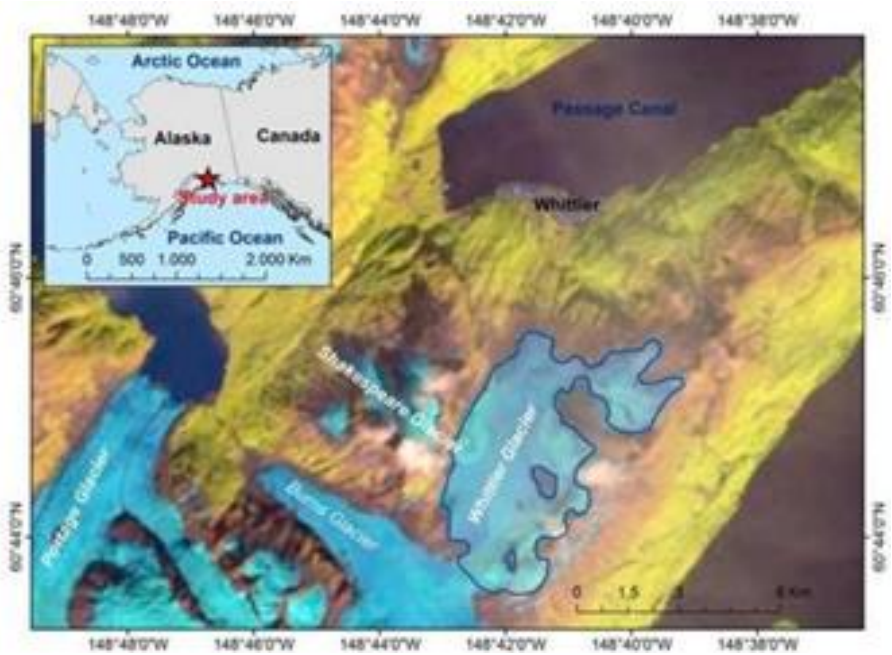

Figure 1 Location of the Whittier Glacier on the Alaska map using state boundary and Landsat image from September 2014. Landsat images courtesy of the U.S. Geological Survey.

The observations and retreat area calculations were done using remote sensing based on satellite images and Geographical Information Systems (GIS) environment.

2. Whittier Glacier and surroundings

Whittier Glacier is an outlet glacier (Fig. 1) which has main flow direction from south- southwest to north-northeast and presents a particular shape, with different thickness from west to east. The terminus morphology of the glacier is appropriate to epi-karstic landforms and no compact and high thickness in ablation zone was found: little ice caves, crevices, and loopholes (Fig. 2). Because of this aspect the retreat is very differently from northwest to northeast and in lateral zones too.

In ablation zone the epikarst ice-forms are formed like underground ice galleries and at terminus an underground drainage system was verified in field research. During the summer periods, in several places of the Whittier Glacier there are portions with surface flow streams and water flow through the ice mass and crevices area. This phenomenon was checked during the field research in 2009 and 2010 (Fig. 3).

3. Materials and methods

3.1. Materials

The preliminary research of Whittier Glacier includes literature review, field research, and delineation of outlines of Whittier Glacier based on satellite images from 1973 to 2014. The oldest data about Whittier Glacier was mentioned by Krimmel and Meier (1989). They confirmed that in 1910 the terminus of Whittier was at one km from shore. The field research helped us to locate more appropriate the glacier on the topographical map and in the same time, the boundary at the contact with others glaciers has been established.

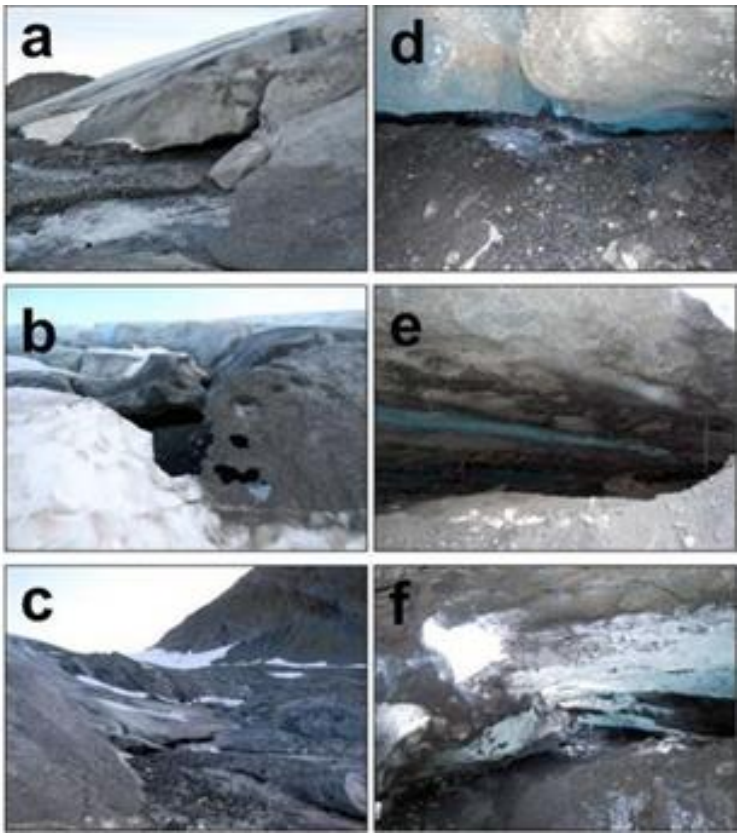

Figure 2 Morphological aspects of terminus at Whittier Glacier. Photo courtesy: Nistor a. Terminus of Whittier Glacier, b. Surface epikarstic landforms due to ice melting and water impact on ice mass, c. Drainage streams and “whale back” landforms in front of the terminus, d. The glacier ice mass in contact with the sliding bed, e. Galleries under ice mass, f. A little gallery like a “cave” in ice mass where the melting is visible.

Moreover, the terminus zone and flow water intrusion into ice mass were checked in field survey. The geomorphology of the Whittier town and Whittier Glacier area was recently presented by Nistor (2013). For present study were used Landsat satellite images dating to 1973 and 2014, in spectral visible available on United States Geological Survey's Earth Resources Observation web-site (United States Geological Survey, 2015). The spatial resolution of the Landsat images was 30 X 30 m. The satellite images were analysed through Geographical Information System (GIS) and the numerical statistics were compared in aim to obtain the Whittier Glacier physical characteristics.

3.2. Methods

The observations were done based on optical analysis of Landsat satellite images and (GIS). We chose to use the satellite images because the temporal resolution was available in the fall months, thus the snow presence is minimal and cannot influences the analysis. Other advantage of satellite images is that the images are georeferenced and are easy to integrate in GIS (Holobâcă 2013). The free costs represent also an important reason for which we preferred satellite images rather than aerial photos.

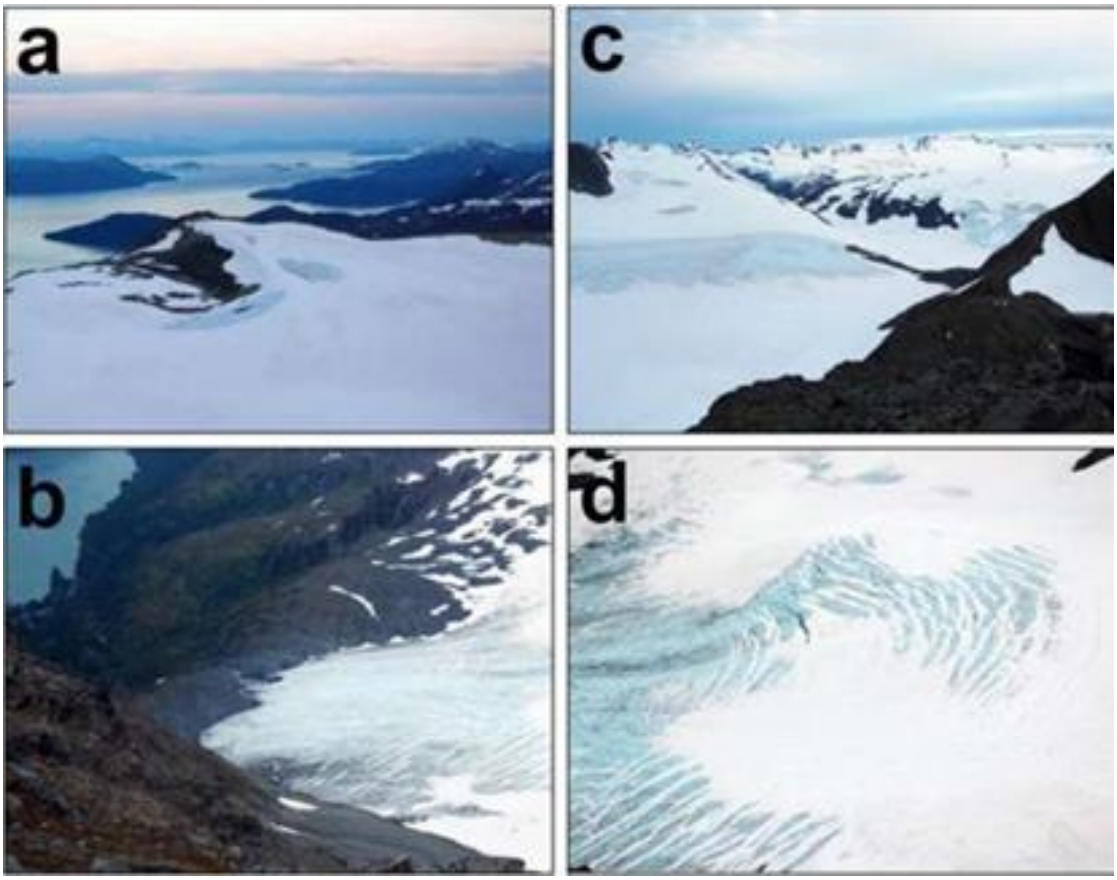

Figure 3 Advanced melting sectors of Whittier Glacier due to water intrusion in the ice mass. a. In the north-western part of the glacier. b. At the terminus of the glacier. c. In the Eastern part of glacier. d. In the Northern part, near the ablation zone

The satellite images from September 2013 and September 2014 were considered into manual digitization of Whittier Glacier outlines. Based on GIS measurements, the calculation of Whittier Glacier area was carried out. The remote sensing and GIS applications were widely used for the glacier studies by Gao and Liu (2001), Dong et al. (2013), Nistor (2014).

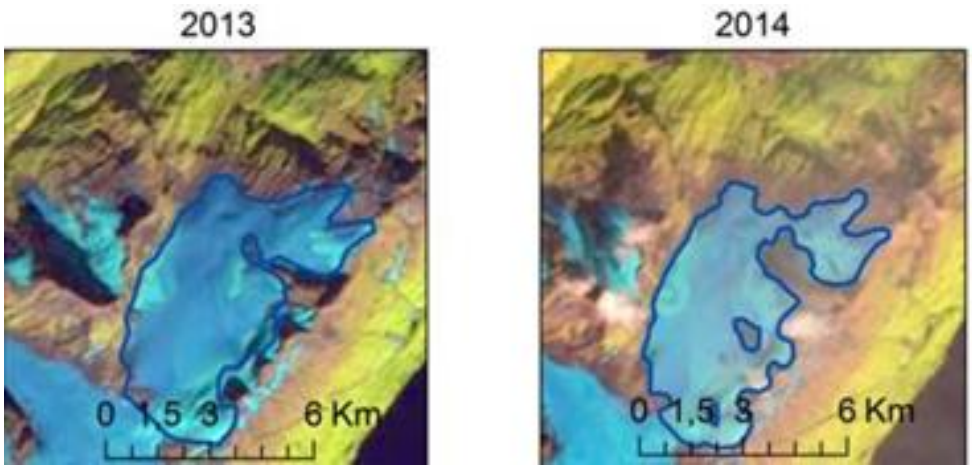

Figure 4 Whittier Glacier outlines in 2013 and 2014. Landsat images courtesy of the U.S. Geological Survey.

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4. Results

Figure 4 indicates the difference between extensions of Whittier Glacier in September 2013 and September 2014. An annual retreat value of 0.655 km² yr^{-1} was calculated for 2014. This value represents the record of annual retreat rate register at Whittier Glacier. Taken into account the oldest satellite images, we observed that from 1973, when the Whittier Glacier had an area of 9.652 km², to 1985 the Whittier Glacier loosed in area with 1.092 km². The annual retreat rate during this period was 0.0682 km² yr^{-1}. From 1985 to 1994, the annual retreat rate was 0.061 km² $yr^{-1}$and the glacier diminished from 8.56 km² to 8.008 km². The annual retreat rate increased slowly during 1995 – 1999, showing a value of 0.091 km² yr^{-1}. In the 1999 year, the Whittier Glacier had 7.55 km² in area and in 2006 Whittier Glacier had 7.279 km². During 1999 to 2006 the annual retreat rate of the glacier was 0.038 km² yr^{-1}. From 2006 to 2013 the total retreat in areas was 0.555 km² and the annual retreat rate was 0.079 km² yr^{-1}. Between 2011 and 2013 was verified an annual retreat value of 0.105 km² yr^{-1}.

Table 1 Physical characteristics of Whittier Glacier in 2013 and 2014.

Year	2013	2014
Length (km)	4.33	4.33
Square area (km²)	6.724	6.069
Volume (km³)	0.443	0.400

Source: GIS statistics

Since in many cases the highest temperatures and lowest values of precipitation quantity plays an important role in the reduction of glacier ice mass, the positive temperature highest than 10 °C in

Whittier area during 2014 summer conducts at melting of significant area of Whittier Glacier. The small thickness of Whittier Glacier in the terminus area together with water flow demonstrates a significant contribution at Whittier Glacier reduction during the last five years and even more during 2013 to 2014. Table 1 illustrates the values of Whittier Glacier physical characteristics in 2013 and 2014.

5. Conclusion

The first and most important conclusion carried out from our study is that Whittier Glacier will have a drastically reduction in 21 century, especially in 2014. These findings would seem that a high discharge of Whittier Creek and others streams that feed from Whittier Glacier ice mass threatens the Whittier town by flooding and erosion. Moreover, the marine biome and salmon prohibition of Passage Canal could be seriously affected by heating the water in this fjord. Considering Whittier Glacier characteristics and local meteorological data conditions, we want to focus in the future to calculation of loosed ice mass volume and possible sea raised in Whittier area.

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