

REMOTE SENSING FOR NATURAL HAZARD STUDIES

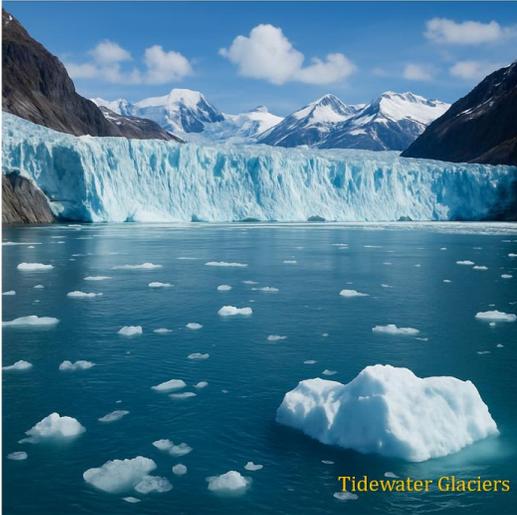
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Lec 19b: The Cryosphere Part B

Hello everyone, welcome to part 2 of Lecture 19. So, we were discussing the glaciers in this lecture. So, we will continue with that. So, in the previous part, I talked about the Randolph Glacier Inventory. So, this is just to continue with that one. So, if you are interested in working on the snow and glacier-related project, then you are supposed to use this Randolph Glacier Inventory for identifying the glacier boundary, and then you can proceed further. Now, we will see the tidewater glacier. So, these flow and terminate in the ocean; they often break off and are carved to form icebergs, and here this particular glacier in the Greenland ice sheet is said to move at 12,600 meter per year. So, you can see how a glacier can take the velocity. So, some of the glaciers are moving at a very fast rate, while some of them are very slow.

Tidewater Glaciers

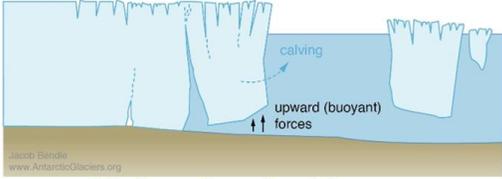
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Tidewater Glaciers



The image shows the glacier
crevassing a calving iceberg



The figure shows the calving event

Source: www.AntarcticGlaciers.org

Remote Sensing for Natural Hazard StudiesDr. R. Bharti

So, the key characteristics of these tidewater glaciers are calving, marine termination, cyclic advance and retreat, floating ice extension, and their dynamic behavior. So, this is one of the examples of tidewater glaciers, and here you can see there is one more image. So, here it shows the crevassing of a calving iceberg, and this is one image that beautifully

shows how these icebergs are basically floating. So, we will see the iceberg in detail; the term literally means ice mountains. Icebergs are huge chunks of floating ice that have broken off from an ice sheet or alpine glacier.

These can be as high as 5 meter in height. Smaller icebergs are known as growlers and bergy bits. Since these are hard to detect, they are extremely dangerous for ships. These are mostly seen in Antarctica and the North Atlantic Ocean. Here you can see that it is captured by the National Snow and Ice Data Center, showing an amazing glowing iceberg located off the coast of Iceland.

So, the ice sheet is a mass of glacier ice on the land surface that can extend to more than 50,000 square kilometer. Antarctica is witnessing the loss of ice mass at an average rate of 136 billion tons annually, while Greenland is losing about 267 billion tons each year. This is from NASA; the image shows the West Antarctic ice sheets being drained into the sea through the S-shaped glaciers. So, here you can see that the presence of crevasses at the glacier stop indicates the flow of ice over steep terrain, because, as I said, it will take the path through the slope, and due to gravity, it will start moving. If the temperature is changed, it will start flowing at a faster rate.

Ice caps are miniature ice sheets that cover less than 50 square kilometer; they comprise several merged glaciers. They have a dome-like shape due to their small size; the ice flow direction, as well as its surface shape, is more influenced by the underlying landscape. This is an image captured by MODIS. It shows the island ice caps, and here you can see that it was captured by MODIS.

The glacier geomorphology is very important. So, if you see, the glacier morphology is influenced by climate and topography; based on the combined factors, they can be of two types. The first one is the constrained glacier, and the other is the unconstrained glacier. So, in constrained glacier morphology, flow patterns are dependent on underlying topography, and as a result, we have Piedmont glaciers, then we have cirques glaciers, Icefields, niche glaciers, valley glaciers, and Transaction glaciers. In an unconstrained glacier, we have morphology and flow patterns that are independent of the underlying topography. So, here we have ice sheets, ice caps, and ice streams; these are not controlled by the topography.

So, let us see the details of the Piedmont glacier. So, these glaciers occur when the valley glacier spreads like a lobe, and here you can see the Alaskan glacier that is one of the examples. Malaspina Glacier, which is the largest Piedmont glacier, is shown in the MODIS satellite image here. Then we have the cirque glacier. So, these bowl-like depressions are a result of glacier erosion and are found at the sides of the mountain. So, you can see this kind of depression will create the cirque glacier. This is one example; then we have an ice field. So, these are extensive ice areas that are an interconnected series

of glaciers and ice caps. The image shows the ice field of North Patagonian located in the southern part of South America. It shows numerous radiating valley glaciers here.

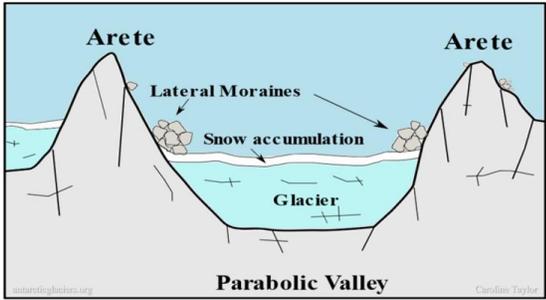
Then we have the Niche glacier. These forms are where the accumulation of ice takes place on the mountainside Niche, like a depression or rock bench, and are smaller in size compared to the surf right. The image shows a typical example of a niche glacier. So, here we have valley glaciers that originate from the mountain glaciers; they flow down beyond the snow line. So, if we suppose that this is one mountain and this is our snow line, above that there will be accumulation or there will be solid precipitation.

So, this is the accumulation area, but these valley glaciers flow down to the snow line. This is another example of a valley glacier. So, this is from Sentinel-2 data; it shows the large valley glacier found in Alaska. So, here you can see how these are coming along. Then we have transaction glaciers; these are radiating interconnecting glaciers that form when the bedrock valleys are deeply dissected, resulting in the overflow of ice to the cols located between adjacent valleys.

Arete



Aretes are thin, jagged ridges that are formed by the glaciers' erosion between two bowl-shaped hollows.



The figure shows a schematic diagram of a parabolic valley. This depicts a flat valley bottom and steep U-shaped sides that culminate at sharp aretes

Source: www.antarcticglaciers.org

So, here you can see that the image shows a typical glacier transaction; here, we have arêtes, which are thin, jagged ridges formed by glacial erosion between two bowl-shaped hollows. So, here you can see this is one, this is the second one, and here we are calling it arete. And this is where we have this snow accumulation, and we will also have the lateral moraines here on both sides. Then we have fjord glaciers. So, the glacier erosion feature that forms between the steep slopes is represented as a long, narrow, and deep-sea inlet.

These are asymmetric bedrock hills which has a gently sloping stoss side and a quarried or plucked lee side



Image depicts the Roche moutonnée being exposed as the Goldbergkees Glacier in Austria thins and retreats.

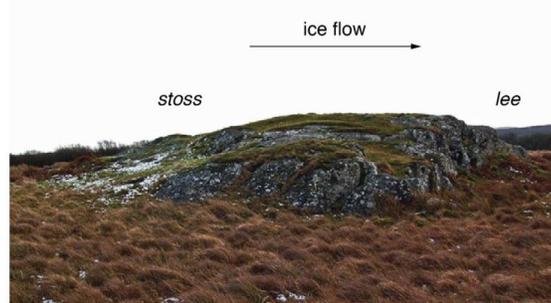


Image depicts the Roche moutonnée showing a gentler stoss side and a quarried lee face.

Then we have Roche moutonnée; these are asymmetric bedrock hills which have a gently sloping stoss side and a quarried or plucked lee side. Here, the image shows the Roche moutonnée; you can see the stoss, the lee, and the ice flow. Then we have trim lines, so you can see these white marks and arrows. So, these erosional features mark the maximum vertical extent of the previous glaciation. So, here you can see that these are clearly visible.

So, the image depicts the valley side trimlines that mark the former thickness of the glacier, then we have Hummocky Moraine; this is another important aspect. So, the Hummocky Moraine forms when a landform melts out beneath a cover of debris that floats to the current position. The image shows the formation of hummocky moraine. Here you can see this is the first one, the surge; this is post-surge, and this is the landform melt-out; and here, after the melt-out, you have the hummocky moraines. Now, in glaciers, particularly at the snout of the glacier, you will always see something.

So, these are ridges of debris that are laid down by a glacier or pushed by it. So, you can see these are examples of moraines. So, the image shows a moraine formed at the lateral margin of the glacier. This is the schematic figure on the right that shows the types of moraine. So, here you can see this is lateral moraine, this is medial moraine, this is again lateral moraine, recessional moraine, and terminal moraine.

So, these are very clear from these examples when we talk about the terminal moraine. So, these are the moraine ridges marking a maximum limit of the advance of the glacier. They form at the glacier's terminus. So, here you can see the terminal moraine, and the image depicts the terminal moraine of the former ice sheet. Then we have a medial moraine.

So, these are the debris ridges that form at the surface of the glacier and run parallel to the ice flow direction. So, here you can see this is the medial moraine, and it is running parallel

to the ice movement. Then there is the recessional moraine; it is found behind the terminal moraine. So, here you can see that these are marked. This forms during the temporary halts or advances of glacier retreats.

Then we have proglacial lakes. The proglacial lakes originate at the glacier's margin as the accumulation of meltwater takes place against the hillside as well as the glacier debris reaches. These are found in the Quaternary deglaciation records. The figure shows the influence of ice advance and retreat on the evolution of the proglacial lake. Figures A and B indicate the longitudinal view while C and D show the plan view. So, these two are the planned views.

Now we have flowing glacier lakes, so you can see different types of flowing glacier lakes from different parts of the world. Now we have a supraglacial lake; the supraglacial lake originates when the accumulation of meltwater takes place in a topographic depression or on the glacier top. Ice shelves, as well as ice sheets. These are the lakes that are found on the surfaces of the glaciers. So, you can see here. The whole thing is a glacier here, and on top of that, you have a lake which is called a supraglacial lake. It is the most common type of ice-dammed lakes. These are some examples. So, how exactly are we looking at these glaciers and glacial lakes? So, remote sensing is one of the tools that can be effectively used in such studies. So, you can see the Siachen glacier, if you see, this is the location, and this is the satellite image.

This is also a satellite image, but this is the zoomed view. So, how does it appear in your satellite image? Then we have the Zemu Glacier; this is the Zemu Glacier, and you see this is the zoomed-in part of the Zemu Glacier. So how do they appear in your satellite image when you have them from different space agencies? So, we have two major sections: one is spaceborne remote sensing data, and the other one is airborne remote sensing. In spaceborne applications, you have optical and thermal sensors as well as radar. So, in airborne remote sensing, you have mainly radar and lidar, and these two different sections of remote sensing are widely used in snow glacier studies, particularly in cryospheric-related hazards.

So, these are some of the data sets that are available, and people have used them very effectively in cryospheric-related hazards or studies. So, we have already discussed in several lectures what the advantages are, particularly when we talk about the cryosphere, in relation to remote sensing in natural hazard studies. The field investigation is very tough; collecting in situ data in different high-altitude regions is very difficult. So, that is why these spaceborne datasets and airborne datasets are the prime inputs that we are using in our research. So, here you can see that in this particular work, different methods have been used to identify the snow cover or snow on the glacier present in a particular area.

Based on these inputs, you can analyze how they are changing over time. So, with this, I will end the lecture here. These are some of the references that have been used in this lecture, and we will continue this cryospheric module in the next lecture.