The Earth's ice

Where can it be found?

Glaciers may exist only on two conditions : the first, which is quite obvious, is that the annual temperatures must be below zero for a certain period of the year, so that ice can be preserved, the second, which is less intuitive, but equally indispensable, is that a sufficient amount of snow required to form a certain mass of ice must fall. In fact, just as excessive heat does not allow the preservation of a glacier, likewise, scarce precipitations prevent the formation of a glacier even where temperatures are below zero : for this reason, in the Polar desert areas glaciers do not form. Glaciers therefore are excellent indicators of two of the most important climatic parameters : temperature and precipitation.

Depending on their geographic location, the temperatures within and at the base of the glacier, where the glacier comes into contact with the bedrock, vary. This is why there is a distinction between cold or Polar glaciers, with temperatures that are constantly and entirely below zero, and temperate glaciers that may have higher temperatures on their surface and/or at the base, accompanied by melting phenomena: the presence or not, of water in the liquid state influences the behaviour of the glaciers, and the response to climatic variations is very different in the two cases. The former are to be found in the high latitudes, the latter in the lower latitudes, but at high levels, where the air becomes cool because of the altitude, and the heat of the low latitude is compensated by this effect : temperate glaciers are the glaciers we find in the Alps, but also particular glaciers as those which can be found in tropical or equatorial areas, such as the glaciers of Mount Kilimanjaro or Mount Kenya in Africa, or the glaciers in the Peruvian and Bolivian Andes .

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Clear distinction must be made between the ice covering lands above sea level and sea ice floating in the Polar seas. In order to be considered a glacier, the ice must move under the thrust of its own weight : therefore sea ice or icebergs, even though they move at times, cannot be considered glaciers, as their movement is passive, generated by sea currents, wave motion or winds.
Even though they are formed by the same material, the Earth’s glaciers are very different one from the other, in extension, ice-thickness, geographical position and climate regime, topographical situation and shape. All these factors determine, besides quite a different appearance, also a very different behaviour and a different response to climatic variations. Researchers who study glaciers use many different classifications, some are rather complex, also depending on the type of study that one intends carrying out. A first, important distinction can be made between frozen ice , that includes sea ice and permafrost, and glacier ice, that includes the ice-sheets, ice shelves and mountain glaciers.

How much ice is there on the Earth?

Most of the Earth’s ice that we see is to be found in large masses of “nearly” pure ice (due consideration must be given to the aspects described above) : ice-sheets and glaciers of various types,ice shelves and sea ice packs. It is quite easy to calculate the surface of the areas covered with ice: it has been calculated that this amounts to approximately 15 million km^2, equal to one tenth of the surface of the Earth’s emersed land. It is more difficult, on the contrary, to calculate the volume of ice because the thickness of the entire covered area must be known : using special techniques it is possible to measure the ice thickness in various points of a glacier and therefore to estimate the volume. For example the average thickness of the Antarctic sheet is 2,100 m, with peaks of 4,800 m in Land of Wilkes, in the Eastern sector: with a surface of little less than 13,600,000 km^2, the total volume of the Antarctic ice is 30 million km^2. Someone had fun calculating that this is equivalent to 9×10^{16} ice cubes! (source: Smiraglia)

Sea ice: cold polar seas

Sea ice has a completely different origin from glacier ice. Sea ice in fact forms due to direct freezing of sea water, when the temperature of the air remains below -1.8°C for a few days. Its formation, which is seasonal, is spectacular: at first ice

needles and thin plates form. These, floating, give the sea surface a particular “oily” appearance, the so-called greasy ice. The crystals aggregate, originating slabs that get increasingly thick, and due to the continuous collisions provoked by wave motion, they take on a circular form with raised borders, which look like large white pancakes, from which the name pancake ice. As the low temperatures persist, the slabs join together thus forming a continuous sheet, the pack. The thickness varies between 1 to 5-7 metres, and increases continuously due to sea water that freezes at the base and supply of snow on the surface. Currents, winds, tempests keep the pack in constant movement, causing breakage of the big slabs, overlapping or piling up and collisions, creating a tormented landscape, made up of ridges jutting from the ice and large fractures, making exploration very difficult. It is a very dangerous area for navigation : even very large tonnage ships have been trapped between drifting slabs and have been literally crushed by ice. The history of polar exploration is studded with adventures and tragedies connected with the dangers of the pack. Unlike in the Antarctic, that is a continent, in the Arctic, the few lands above sea level are made of archipelagos of islands. Therefore there are no large glaciers or big ice-sheets, but only an enormous extension of sea ice floating on the Arctic sea. However a vast area of sea ice also surrounds the Antarctic, and reaches its maximum extension in September, reaching a width of 2,000 km. Unlike glaciers and the ice-sheets, whose size remains practically unaltered during the course of the year, sea ice undergoes spectacular variations in its expanse, which can be appreciated particularly when observed from a satellite on areas that cover 15-20 million km2 of the Polar seas. The variations are particularly evident around the Antarctic , where sea currents tend to push away the fragments of the pack, dispersing them, when these are not so big, in the Arctic sea, where currents tend, on the contrary, to concentrate the large drifting ice floes around the North Pole. Their moving away is also hindered by the presence of the surrounding land above sea level. Unlike glacier ice, which may date back various thousands of years, the age of sea ice is rarely more than a year. Large ice floes that are many years old can be found only in the Arctic Sea.

Permafrost: frozen ground

When the mean annual temperatures of the air remain below zero for long periods of time, the water in the ground is always in the solid state, and the land is permanently frozen. This state is named permafrost (i.e. permanent ice). The land, hardened and without any liquid water, is made up of mineral particles (particles of soil, grains and rock debris of various sizes) cemented together by ice. The depth of the ice depends on how cold the climate is, and can reach many dozens of metres (in some areas in Siberia and Alaska, with mean annual air temperature ranging between -7 and –16°C, permafrost was found at a depth of 300-600 m, with a maximum depth of 1,500 m in an area of Northern Siberia). In summer, a thin layer on the surface, the so-called active layer, is heated by the sun and the ice can melt. Since the permafrost below is impermeable, the melted water cannot be moved away and the thawed land becomes soft and drenched with water, often marshes and swamps form, and there may be serious problems with the stability of buildings that are built on this kind of terrain. In order to build in these areas, particular construction techniques are required, where the buildings rest on poles dug into the ground till they reach the permanent frozen layer: similar to “pile dwellings” on the soft, loose active layer. Permafrost may be found in small areas in the high mountains (also in the Alps), but mainly in very vast areas in the high latitudes: approximately one fifth of the emersed land is affected by this phenomenon (half of the territory of the former Soviet Union, half of the Canadian territory, three quarters of Alaska, almost the whole of Greenland and the Antarctic) (source: Smiraglia).

Ice-sheets: continental glaciers

Ice-sheets, also known with the Norwegian term, inlandsis, continental ice, are expanse of ice with a surface area of over 50,000 km2, where ice buries and masks the underlying relief that does not influence its trend. The surface is generally mildly convex, like a kind of very flat dome, from which higher peaks of the underlying relief may emerge; these are named nunatak, an Inuit term that means “isolated mountain”. The central, more raised sector, of an ice-sheet is known as the dome. Ice caps are similar to ice-sheets but their size is smaller. From the ice-sheets, ice flows branching off radially in various directions, forming the so called outlet glaciers. These are veritable rivers of ice, at times their size is immense: the world’s largest glacier is Lambert Glacier that flows from the Antarctic sheet. It is 400 km long and over 50

km wide. Most outlet glaciers reach the sea where they form snout of ice floating on the sea surface and extend even for many kilometres - through a process called calving most icebergs are formed here. The Lambert Glacier for example, flows into the Amery Ice shelf forming a floating tongue that extends up to 300 km with a front that is 200 km wide. Approximately 85.7% of the ice on world's surface is found in the large ice-sheets of Antarctica, about 10.9% are in the Greenland ice-sheet : these two areas together account for almost the entire amount of the world's ice (96.6%). Much smaller ice-sheets and ice caps are found in Alaska, on the islands of the Canadian archipelago (Baffin, Ellesmere, Heiberg, Victoria) and in Iceland, on the Jan Mayen, Svalbard and Franz Josef Land archipelagos and on the Scandinavian peninsula (where the most extensive glacier is Jostedalsbre , where bre means glacier, the largest in Europe, excluding Iceland). In the Southern hemisphere, vast extensions of ice, similar to ice-sheets can be found in the Patagonian Andes, forming the Hielo Continental (hielo means chill or ice in Spanish) with a surface area of 17,000 km2 and 50 outlet glaciers spreading from it : some of these terminate in large ice contact lakes, like Lake Vidma and Lake Argentino.

Ice shelves

When a glacier reaches the sea, it stretches into a floating snout. The confluence of various floating snouts gives origin to the formation of an ice shelf: a kind of flat shelf that floats on the sea and is anchored to the ground by the tongues that feed it. The most extensive ice shelf is the Ross Ice Shelf in Antarctica, with an average thickness of 300 m and a surface area of 530,000 km2 , equal to the area of France - it is bounded on the sea-front by ice walls up to 200 m high. The various tongues of ice that feed the ice shelves move at different speeds, and this, together with sea currents and wave motion, causes a great instability of the margins. In fact enormous fractures called chasms form, as for example the one seen on the Filchner Ice Barrier in Antarctica, that is 100 km long and 400 m to 5 km wide. These impressive fractures are the prelude to the detachment of enormous portions of the ice shelf that form gigantic tabular icebergs, which drift away . Scientific research base camps built on ice shelves were involved in the formation of these enormous icebergs that drifted away, as in the case of two American base camps and a Soviet one.

Icebergs

Icebergs (from ice and berg, mountain, mountains of ice) form in two conditions:

- when a glacier descends to the sea or to a lake, the terminal part of the snout starts floating when it comes into contact with water. Because of a phenomenon known as calving, large fractures form in the mass of ice, with the consequent detachment of portions of different sizes. The shape of this kind of iceberg is generally irregular, and the surface is jagged, tormented.
- The movements of currents and tides of the underlying water, together with the constant thrust of the glaciers that feed the ice shelves, cause fractures and fragmentation of the ice shelves. Every year, in Antarctica, for example, 1,450 to 2,000 km3 of ice are lost in this way (a volume that is equivalent to about half the annual amount of drinking water consumption worldwide).

These kinds of icebergs generally have the shape of flat tablelands whose surface is relatively smooth and regular. These are typical in the Antarctic zone, while icebergs of the first type form more easily in the Arctic seas, where lands are not surrounded by ice shelves of floating ice and the numerous glaciers from the land can therefore flow directly into the sea. Small sized icebergs may also form from blocks of ice collapsing from the fronts, which do not necessarily have to be floating on the sea or on a lake. Since the density of ice is less than the density of water, icebergs float on the surface of the sea; the submerged part is therefore 7-10 times (depending on the difference in density of water and ice) taller than the part above sea level. If we consider that some icebergs can be many dozens of metres high, above the surface of the sea, then we can well understand how the name "mountains of ice" is particularly indicated : for example, an iceberg that shows a 30 metre wall continues below sea level up to a depth of over 200 metres! The largest iceberg to be seen was an iceberg in the Antarctic, observed in 1956, whose size was 335 x 97 km, with a surface area of 31,000

km2, equal to the area of Belgium. After the fragmentation of iceberg B-15, which was as large as the Italian Abruzzi region, at present the largest iceberg is C-19A, as large as the Liguria region. Once they detach from the glacier or the ice-shelf, icebergs begin to drift pushed by winds, currents and tides. The erosion of wind and waves and the progressive melting process they undergo as they move towards warmer latitudes, decrease their size, besides the fragmentation caused by violent tempests or collisions with other icebergs or with the land. The destiny of icebergs, therefore, is to decrease in size till they disappear, however their life-span can be of many years.

Mountain glaciers

These, as their definition describes, are bodies of ice that are found in the mountains. These can be classified in many ways, bearing in mind their geographical position, shape, temperature. Size is not a criterion used to distinguish these glaciers, some of them are very small, as the Calderone glacier on the Gran Sasso d'Italia mountain in the Apennines, which is little more than a thin strip of old snow (at present it is considered practically "extinct"), or the gigantic ice "rivers", that are dozens or even hundreds of kilometres long, with ice thicknesses over 1000 m, as the large Alaskan glaciers, among which the most extended is the Bering Glacier, followed by the Malaspina Glacier whose outlet on the planes expands into a piedmont lobe that is the largest in the world.