# REMOTE SENSING FOR NATURAL HAZARD STUDIES

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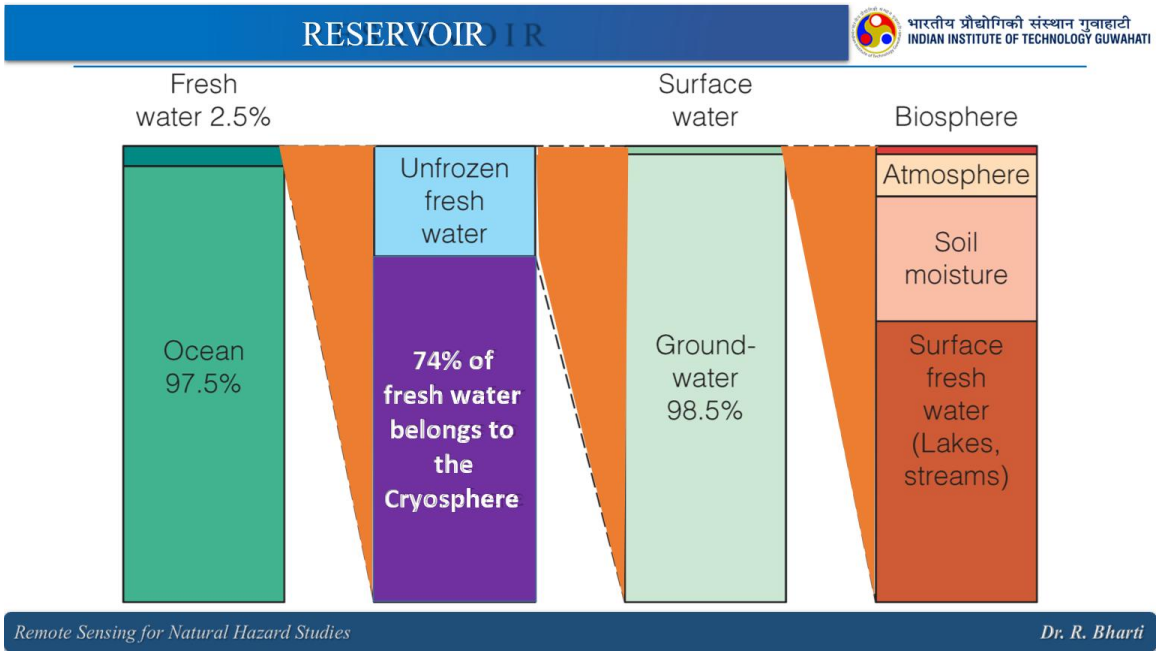
## Lec 19a: The Cryosphere Part A

Hello, everyone. Welcome to Lecture 19. This is the first lecture of Module 6, and today we will start with the cryosphere. So, in the initial phase, we will try to understand what we mean by cryosphere, why it is important, and slowly we will get into the hazards related to the cryosphere. So let us start. So, to understand the cryosphere, we need to know about the hydrosphere.

So, the hydrosphere is the Earth's blanket of water and ice. So, it has both components: water and ice. And if you see the origin of this hydrosphere, it is from a Greek word. So here it is: Hydor and Spira. So hydro means water, and spira means the globe, ball, or sphere. So together, they make this hydrosphere.




When we talk about the water available on Earth, we see that only 2.5 percent of the Earth's water is fresh water, while 97.5 percent of the water belongs to the ocean, which is not potable. Now, out of this 2.5 percent, 74 percent belongs to the cryosphere; it is basically frozen fresh water. And the rest 26 percent is the unfrozen fresh water. If you see further

division, 26 percent of fresh water here is made up of 98.5 percent groundwater, and the rest is surface water and from this surface water, we have the atmosphere, soil moisture, and surface fresh water in the form of lakes and streams. So, this is our biosphere, So, here the important thing is that 74 percent belongs to the cryosphere. So, you see the huge amount of water that is stored in the cryosphere is very, very important to survive on this particular planet. The cryosphere, when we say it, is basically Earth's cover of snow and ice. Here again, it comes from a Greek word, cryos and spira.

So, this is one photograph I have used to show the water present in the three forms. So, you can see some examples here; water is present in all three forms. So, let us understand one by one what the cryosphere is. What do we mean by the cryosphere? So, the cryosphere refers to all frozen water on Earth, including ice, snow, and permafrost. It plays a crucial role in Earth's climate system.

So, here you can see that this is a typical representation of the cryosphere; here you have ice caps. Then you have snow and the glaciers are here; lake and river ice are present, and some of the floating ice is present on the ocean. Then we also have an ice sheet, and on top of that, you have snow cover, So, this is the typical representation of the cryosphere. Now, what are the different components of the cryosphere? So, the first one is the glacier and the ice caps. Then we have ice sheets, which are basically Greenland and Antarctica, as well as snow cover, sea ice, permafrost, icebergs, ice shelves, seasonally frozen ground, and solid precipitation.

So, when we talk about normal precipitation, it is in liquid form, but solid precipitation is basically where snowfall is happening, here you will understand the importance of the cryosphere. So, here you have ice sheets, here you have snow cover, glacier mass is present here, sea ice is present here, and together they are making this cryosphere. So, why it is important, we will try to understand. So, it is the freshwater storage, as we know it holds about 76 percent of the Earth's fresh water in the form of ice and snow. It also supports the ecosystem; it helps to sustain biodiversity by providing water to various ecosystems.

Then we have water resource regulation; it supplies fresh water to major rivers, supporting millions of people on this planet. Climate is an indicator because if there is a slight change in the climate variables, it will immediately impact the storage of snow and ice. So, change in ice and snow serves as a key indicator of climate change. Weather and climate influence the global temperature regulation because a huge area belongs to the cryosphere, which is basically ice and snow. And these are highly reflective in nature.

So, the solar radiation that is coming to the surface is getting reflected back because of this ice and snow, So, it is controlling or regulating the global temperature. Ocean currents and atmospheric patterns are governed by the presence of these cryospheric components. Livelihood support provides water for agriculture, hydropower, and drinking needs,

especially in downstream regions, because there is a fluvial system and here you have the glacier. So, this will melt and feed the water into this river, and it will reach downstream. Then the global impact, even remote cryospheric changes, affects sea levels and weather patterns worldwide.

So, we have seen different aspects of the cryosphere, how it is important in regulating the global temperature, and how it serves as fresh water storage. So, these are very important for our survival on this particular planet. So, the key cryospheric reasons for observing the Antarctic cryosphere. So, here you can see that the Antarctic cryosphere refers to the ice and snow covering the Antarctic continent, primarily consisting of the massive Antarctic ice sheets, which are the largest single mass of ice on Earth. Holding about 90 percent of the world's fresh water.

It also includes surrounding sea ice and ice cells; we will try to see what we mean by ice cells and sea ice, and this is along the coastline. Rising global temperatures are causing concern about potential ice sheet melting and sea-level rise. So, sea level rise is one of the important reasons why we are concerned about the cryospheric components, especially in the coastal region of Antarctica. So, you see this is from this particular link, and here the most important thing that they wanted to highlight is the Antarctic ice sheet, which holds enough ice to raise sea level by 58 meter, faces irreversible melting as temperatures increase, flooding coastlines up to .6 centimeter per year if current high emissions continue.

So, you can see how dangerous the situation will be if there is abnormal melting of the Antarctic glacier. So, it can raise the sea levels by 58 meter, and you can imagine what will happen to those areas in the coastal region, So, here you have the Antarctic and Arctic. So, these are the 2 areas. So, the Arctic cryosphere primarily consists of vast expanses of sea ice floating on the Arctic Ocean with a significant portion of land ice on Greenland's ice sheet. It is characterized by extremely cold temperatures, where most of the water exists in a frozen state.

It plays a crucial role in regulating Earth's climate due to its high reflectivity. We also call it the albedo of sunlight, So, this is what I said: if the sun is illuminating this area, what happens is that it gets reflected immediately, And because of this. We are having a lower temperature on the surface; otherwise, any other material other than this ice or snow will absorb the temperature, and then the global temperature will rise very soon. The Arctic cryosphere is rapidly shrinking, particularly in terms of summer sea ice cover. Here again, there is a highlight.

Arctic sea ice helps regulate global temperature; it both cools the Arctic and surrounding seas and reflects sun rays during summer. When it disappears, the dark ocean absorbs more heat, and the Arctic's entire ecosystem changes, So, the ecosystem of that particular area and the surrounding environment will be affected immediately, but as Earth. It will also be

affected. So, the key cryospheric reason that we have this Himalayan cryosphere is. So, here, if you see, the Himalayan cryosphere, often called the third pole, is a vast collection of ice and snow in the Himalayas, encompassing large glaciers and permafrost areas.

Acts as a crucial source of fresh water for several major river systems like the Indus, Ganga, and Brahmaputra, impacting the livelihoods of billions of people across the region. This cryosphere is rapidly shrinking, leading to concerns about water security and potential natural disasters, like glacial lake outburst floods. In the past few years, the incidence of GLOF has increased because of the increased melting. So, the climate is changing, and it is impacting the Himalayan cryosphere as well. So, here you can see that when we talk about the Himalayan glacier, we have Ladakh.

Then we have Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Sikkim, and Arunachal Pradesh. Together, they make up this Himalayan cryosphere, especially the Indian Himalayan cryosphere. So, we will try to understand what and how these glaciers are born, how the ice that is falling from the sky is getting accumulated, and how it is slowly being converted into a glacier. So, in the first step, what happens is that snow forms when water vapor in clouds freezes into ice crystals due to low temperatures, then it precipitates when snowflakes become heavy enough; they fall to the ground as snowfall if the entire domain has a low temperature.

Melting and runoff. As temperatures rise, snow melts into water, contributing to rivers, lakes, and groundwater recharge, playing a crucial role in freshwater availability. Then another form is the densification of glaciers. In high altitudes or polar regions, persistent snowfall compacts under its own weight. Turning into fern, the dense snow eventually forms glacier ice over time. So, again remember that I am calling it glacier ice, and slowly we will try to understand what exactly a glacier is and when we call it a glacier.

So, if you see here, this is one map that we have prepared from 1989 for the Himalayas, and here is how the snow cover is changing over time. So, every year it is inconsistent, and slowly it is changing. So, we will discuss this in the next few lectures. But for now, we will focus on glacier formation. So, the glaciers form when the snow has accumulated at a location year-round and has transformed into ice.

When the fresh snow falls, the previous layers are buried and compressed, which causes their recrystallization. So, there will be a recrystallization. So, here is the loose snow, then you have granular snow, then we have firn, then we have fine-grained ice, and then slowly we will have coarse-grained ice. And if you see how much time they are taking in nature, that is also given here. Eventually, ferns are formed, which are intermediate to snow and glaciers, and over time, when the air pockets are too low and the crystals are large enough, glacier ice forms.

So, here you can see the different spectral behaviors of snow. So, this is fresh snow, then we have fern, then we have recrystallized ice, glacier ice, and then dirty glacier ice. So, this is contaminated one. So, this is the difference between natural and refrigerated ice. So, here you see there is a difference between the glacier ice that is formed in nature and what we are freezing in the refrigerator.

So, if you see the different aspects like formation, we are freezing here, and in nature, it is metamorphism. Age: here it is a few hours to days and here 1,000 to millions of years. It is uniform and pure; right here, we can have trapped air and sediments. The density is less here in the refrigerated one, and here it is denser. Appearance is clear to slightly cloudy, and here it is bluish white.

This is a thermal property: it melts quickly, and here it melts at a relatively slower rate. So, when the snowpack grows thicker, we now understand that when there is snowfall, it slowly gets packed, and then metamorphism takes place, and then they grow, So, the amount of snowfall is greater than the amount of melting in that particular area, which will lead to an increase in snow depth. Subsequently, the deeper snow recrystallizes into denser ice under the increased weight of the overlying snow. Due to gravity, thicker and denser snow and ice start their movement because we are talking about these accumulations in high-altitude regions, and slowly because of this, they will start their movement downstream due to gravity. So, if this is the situation, then we say a glacier is born, A glacier is a persistent body of ice consisting largely of recrystallized snow which shows evidence of slow downslope or outward movement under the influence of gravity. So, this is very, very important: we cannot call everywhere glaciers; glaciers are only so when they have movement under the influence of gravity. Glaciers vary considerably in shape and size depending upon the topography they take or acquire their shape. We have a very good inventory. So, we call it the Randolph Glacier Inventory.

So, here all the glaciers across the globe are compiled in the Randolph Glacier Inventory. It was developed by the IPPC and is now available in the Glimpse Glacier Database, and it is available for public use. So, if any of you are interested in looking for a glacier body, mostly they have given names to some of the glaciers that have no name. So, this is available in the public domain. So, if you are interested in working on glacier or snow-related research, then you are supposed to refer to this because it is standard.

Thank you. I will end the first part of this lecture here, and we will continue this discussion in the next part. Thank you.