WMO REGIONAL ASSOCIATION II – ASIA (RA-II Asia)
WORKING GROUP on HYDROLOGICAL SERVICES (WGHS)
Fifth Session of the WGHS
THIMPHU, BHUTAN
(26 to 28 November 2018)

"CRYOSPHERE MODELLING"

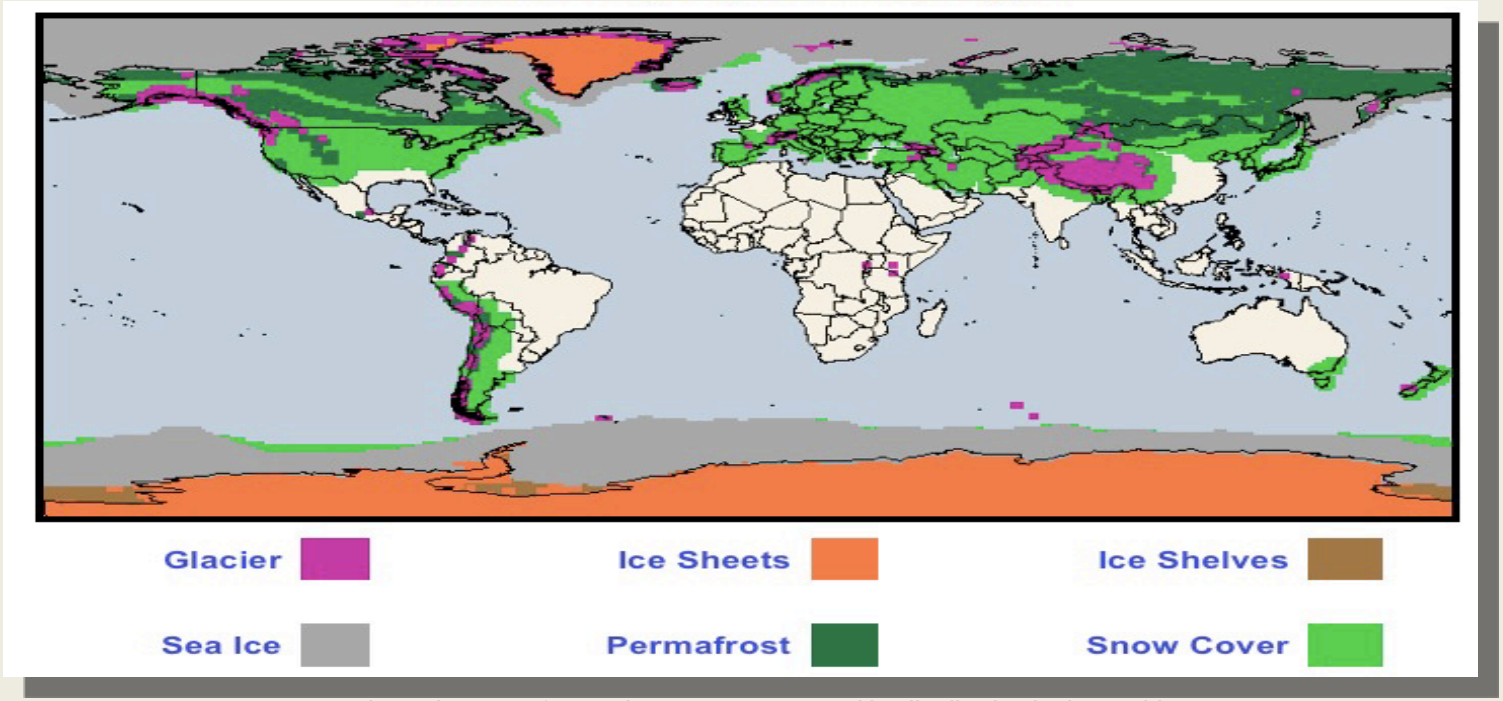
BORSHCH Sergey
(Hydrometeorological Center of Russia)

According to Working Plan on the 16-th of November:

- the reference materials, documents and investigations about the main types and features of cryospheric phenomena in the plain and mountain river catchments of Asia were collected;

- Methods and models used to calculate and predict snow cover characteristics and processes associated with the formation and destruction of snow cover in plain and mountain river basins were collected and studied;

- the article "Snow routes network optimization in the Upper Volga basin" has been prepared and published (in Hydrometeorological Research and Forecasting, #3 (369), 2018, pp. 62-73. *Borshch S.V., Leonteva E.A., Simonov Yu.A., Khristoforov A.V., Chupin I.V.).- in Russian.*



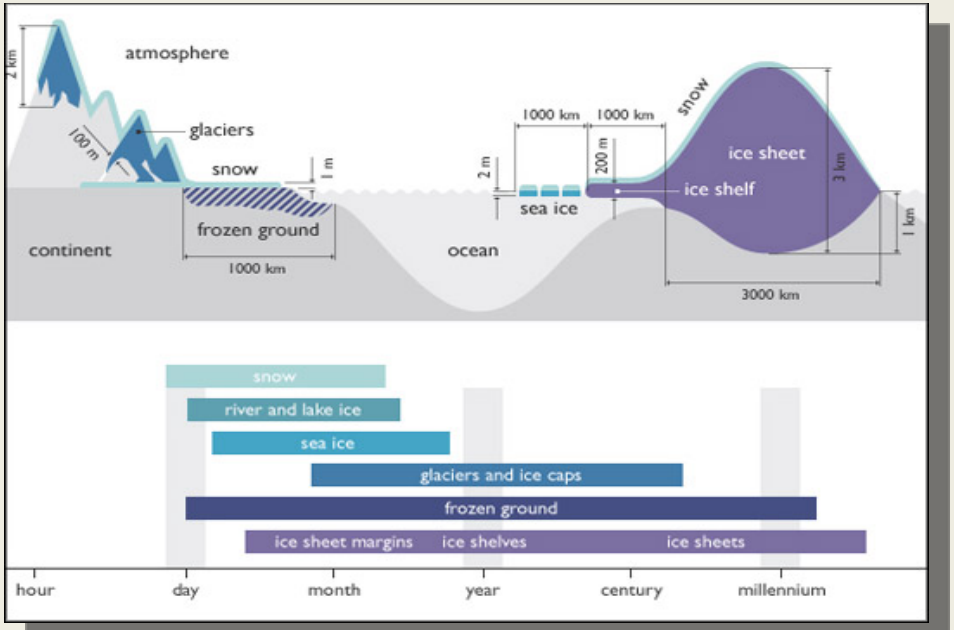
The main types of cryosphere components and its distribution in the world

According to IPCC definition (*IPCC WDII AR5 2014*) the **cryosphere** is the part of the Earth system and includes such components:
-solid precipitation,
- snow,
-sea ice,
-lake and river ice, icebergs,
- glaciers and ice caps,
- ice sheets and ice shelves, -
- permafrost and seasonally frozen ground. The cryosphere is global, existing not just in the Arctic, Antarctic and mountain regions, but at all latitudes and in approximately one hundred countries.

Thus, the **cryosphere** is ice cover, frozen water, found in the form of: sea ice, ice on the river, lake, snow cover, glaciers, ice caps, ice sheets and frozen soil (including permafrost).

In each of these forms, water is in a solid state in a certain period. Snow cover, ice on rivers and lakes has a seasonal character. In turn, the stability of sea ice (with the exception of ice in the central part of the Arctic Ocean) lasts several years.

Meanwhile, the ice sheet or underground ice remains frozen for 10,000–100,000 years or more



Components of the cryosphere according to IPCC © IPCC Ice in the Arctic © NASA

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The animation shows the global advance and retreat of daily snow cover along with daily sea ice surface temperature over Asia from September 2002 through May 2003. The snow cover was measured by the MODIS instrument on the Terra satellite, while the sea ice surface temperature was measured by the MODIS instrument on the Aqua satellite.

All cryosphere components are distributed in Asia, including:

1.Solid precipitation originates in clouds where air temperatures are below freezing and the temperature at the ground is less then 5˚C.

2.Snow is a form of precipitation consisting of small ice crystals, and *snow cover* is a layer of snow on the soil surface, that forms in a result of snowfalls.

3.Ice is a water in a solid state. *Ice cover* is solid ice formed during the cold season on the surface of oceans, seas, rivers, lakes, artificial reservoirs, and also brought from neighboring areas. In high-latitude areas there is year-round.

4.Glaciers and ice caps is a moving natural accumulation of ice and firn on the earth's surface, resulting from the accumulation and transformation of solid precipitation with a positive multiyear balance.

5.Permafrost is frozen for a long time, from several to tens and hundreds thousands of years, rocks. In Russia, about 60% of the country's territory is located in the permafrost zone. *Seasonally soil frozen* is the depth at which the 0-degree isotherm is located as a result of the cooling of the soil during the cold season.

6.In coastal Artic zone there are the ice sheets and ice shelves, that are a thick suspended platform of ice that forms where a glacier or ice sheet **flows** down to a coastline and onto the ocean surface.

Map of maximum soil freezing depth in Russia

The boundary of snow cover in the Amur River basin according to the data of the satellite AGUA / TERRA on November 22, 2018

Snow cover

Snow and snow cover are widespread in Asia in areas where negative air temperatures are observed. These areas include the vast territories of the Asian continent and cover both plain and mountain river basins.
Snow cover is very important for the river runoff formation both plain and mountain rivers.
So in Russia, in the countries of Central Asia, more than 70% of the river runoff is formed as a result of seasonal snow cover melting.

Distribution of seasonal snow cover on land (red line) and on sea ice (blue line) in January 1980 To [Kukla, 1981]. Image: "Ecology and life»

The main processes associated with snow cover is the formation and destruction of snow cover. These processes are very complex.

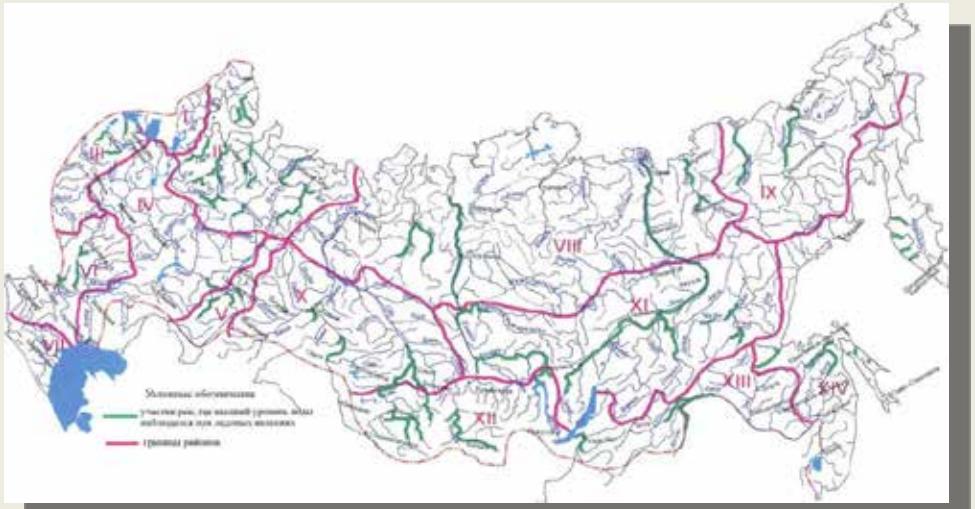
The formation of snow cover begins with snow falling on the surface of the Earth. Further, there are complex processes of re-formation of snow cover as a result of exposure to solar radiation, wind, liquid precipitation, etc. Snow cover becomes more dense, and its reflectivity decreases. These happens before the fall of a new portion of snow or before the beginning of the melting of the snow cover.

As a result of arrival of new portion of snow, the snow cover becomes less dense, and its reflectivity increases sharply.

Melting of the snow cover begins with the transition of the thermal balance on between the snow surface and the atmosphere to positive values.

Ice cover and glaciers

Ice cover in Asia is always associated with river systems in Asian countries, where there is a season with a more or less prolonged period of negative air temperatures. In this thematic area we consider only ice on the earth surface, in the rivers, lakes and reservoirs , excluding sea ice.

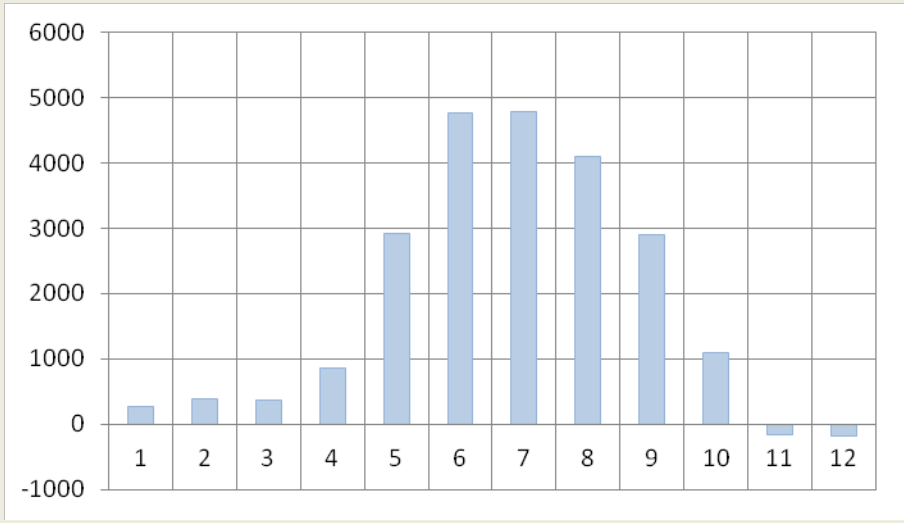


Sections of rivers where the maximum for the year water levels are associated with ice phenomena (green lines). The borders of the districts are shown by pink lines, and the Roman numerals are conditional numbers of the districts.

In the modern era on Earth, natural solid ice occupies 72.4 million km2 on the earth's surface and in the upper layers of the earth's crust, which is 14.2% of the planet's area and almost half of the land surface.

In Asia, the ice cover takes 136760 km^2.

The ice cover in Asia accumulated 16,260 km^3 of fresh water.



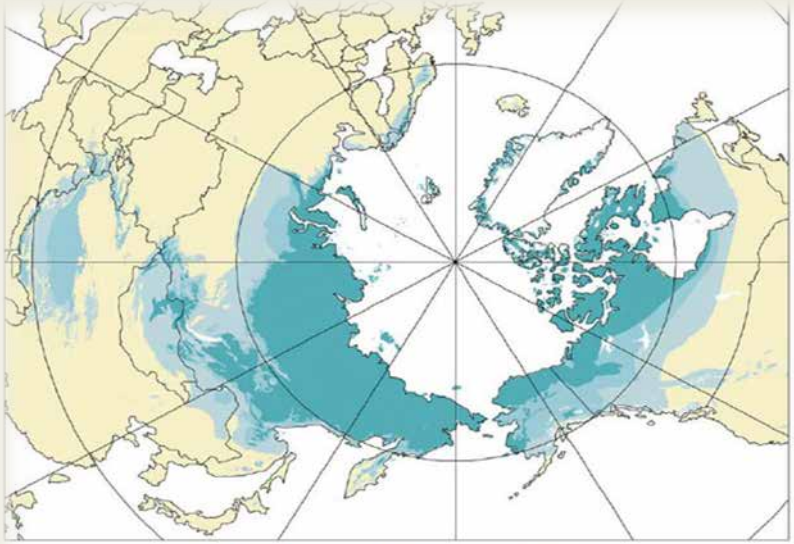
Average for a long period (from 1899 to 2017) useful inflow of water into lake Baikal (in m3 / s)

Ice jam in the Lena River

Permafrost

Asia's permafrost is concentrated in a number of areas: Russia, China, Mongolia, parts of Central Asia and the surrounding mountain ranges. The vast majority of Asia's permafrost does not concern developed or developing areas.

In the zone of permafrost groundwater is in the form of ice, its depth sometimes exceeds 1000m. The continent, where the permafrost is completely absent - this is Australia, in Africa it is possible only in the highlands. Much of the current permafrost has been inherited from the last ice age, and now it is slowly melting. The ice content in frozen rocks varies from a few percent to 90%.



Map of the distribution of permafrost. The boundary of permafrost is not the same, in Asia it is located much further south.

Permafrost is very sensitive to climate change. If global warming continues, according to the calculations of Russian specialists, for example, in Russia about 25 percent of the infrastructure exposed to permafrost may be destabilized by mid-century.

In Yakutsk, the largest city in the world, built on permafrost, an increase in average annual air temperature of 1.5 ° C can deform almost all the foundations of buildings.

While the northern ports can benefit from rising temperatures, because warming will reduce the ice load on ships.
Despite advances in engineering, permafrost continues to pose problems for railways, roads, bridges, ramps, etc. .

Permafrost in Yakutia

Methods and models used to calculate and predict snow cover characteristics

The most important characteristics of snow cover are:

1. Snow water equivalent (St),
2. The amount of melt water formed from melting snow cover (Ss),
3. The area of the river basin covered with snow (Fs),
4. Loss of melt water to evaporate from the surface of the snow (Es),
5. The amount of water frozen in snow cover due to frost (Sf),
6. Loss of melt water on infiltration into the soil (Sinf).
7. The retention of melt water on the surface of the river basin in low forms of relief (Sr).

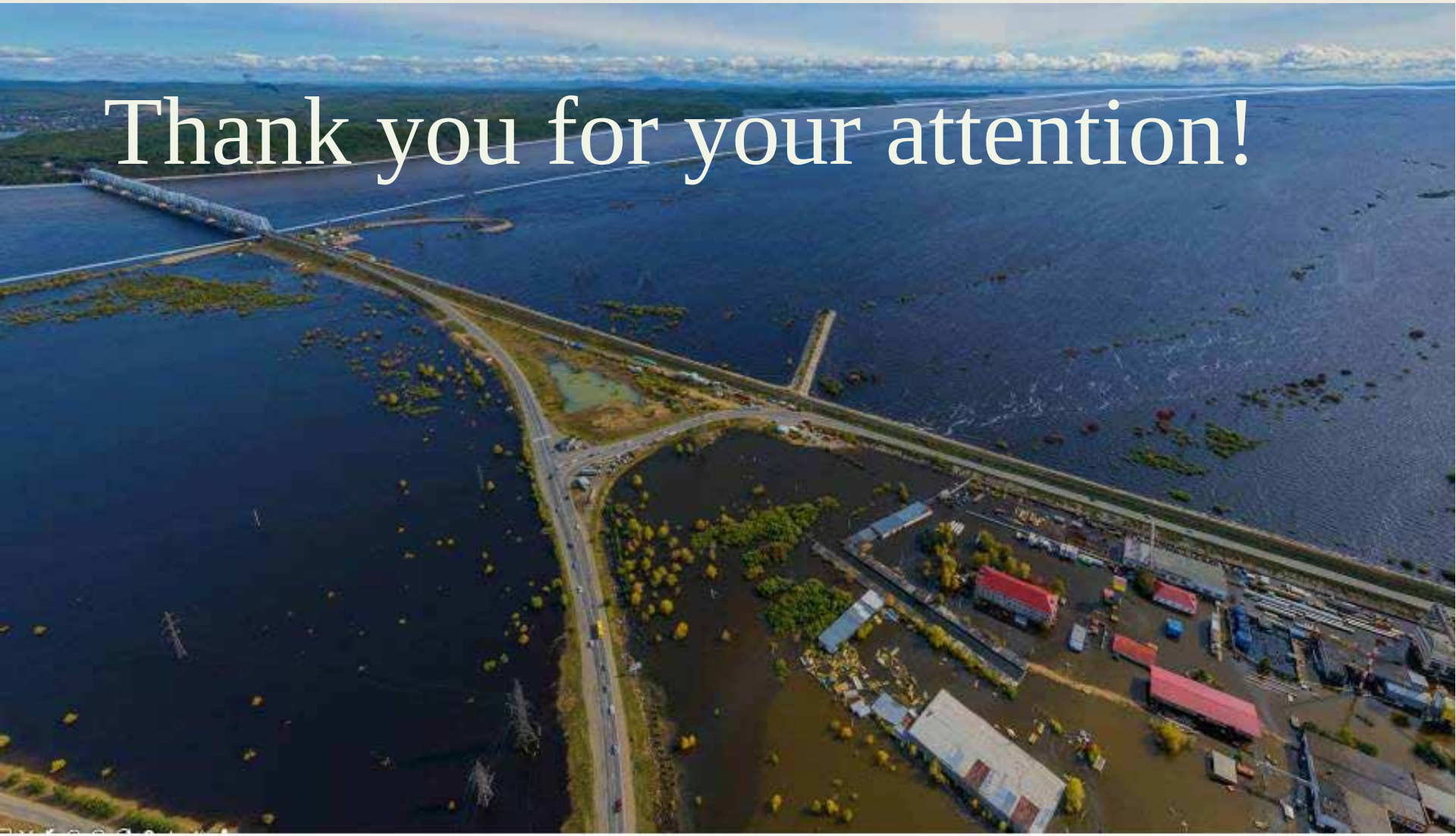
Snow melting in the plain river basin

The measurement of snow water equivalent on the snow routes network

The equation of water balance to calculate (forecast) river flow in the spring for a certain period of time (t) has such form:

$$Wt = (1-Fs)*Ss - Es - Sf - Sinf - Sr ;$$

Thus, the prediction of the volume of thawed outflow for a certain time interval (day, month, etc.) is reduced to the calculation (forecast) of the amount of water that reached the surface of the basin during the calculated time interval and the amount of water that was lost.


Thank you for your attention!