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THE HYDROLOGICAL CYCLE AND HUMAN IMPACT.

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INTRODUCTION: -

The hydrological cycle is usually called a recurring consequence of different forms of movement of water and changes of its physical state in the nature on a given area of the Earth (a river or lake basin, a continent, or the entire Earth). The movement of water in the hydrological cycle extends through the four parts of the total Earth system— atmosphere, hydrosphere, lithosphere, and biosphere—and strongly depends on the local peculiarities of these systems. The terrestrial hydrological cycle is of a special interest as the mechanism of formation of water resources on a given area of the land. The global hydrological cycle is also often considered, taking into account its role in the global climate and other geophysical processes. It is obvious that the role of different processes in the hydrological cycle and their description have to depend on the chosen spatial- temporal scales. The main components of the terrestrial hydrological cycle and the global

The generation of precipitation is commonly considered as the beginning of the terrestrial hydrological cycle. The precipitation may be in the form of rainfall or snow. The falling snow forms the snow cover where the snow may change its properties and may partially transform into ice. The rain or melt water may be intercepted by vegetation cover or detained by land surface.

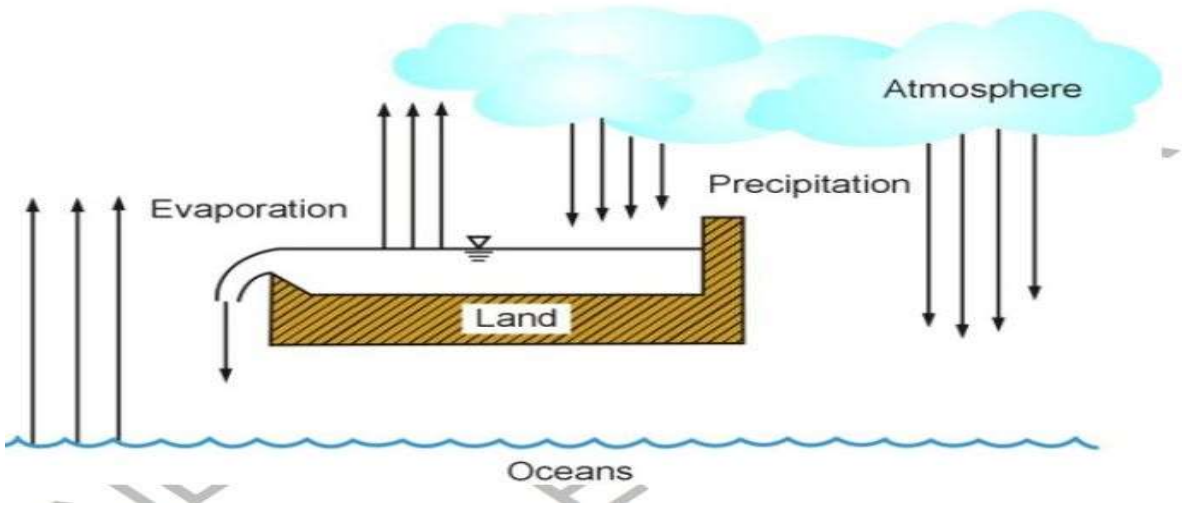

Figure 1 Global hydrological cycle are presented.

depressions, may infiltrate into the soil, or may run over land surface into streams. The infiltrated water may store in the soil as soil moisture or may percolate to deeper layers to be stored as groundwater.

During cold periods a portion of infiltrated water may freeze in the soil. A part of water intercepted by vegetation, accumulated in the land surface depressions, and stored in the soil, may return back to the atmosphere as a result of evaporation. Plants take up a significant portion of the soil moisture from the root zone and evaporate most of this water through their leaves.

Figure 2. Terrestrial hydrological cycle.

Beside water which travels to the streams over the land surface, the stream runoff also includes water which moves to the streams through the upper soil horizons, flows out from deep layers as springs, and seeps directly in the river channels. The water collected in the river channel systems flows to lakes, seas, and oceans.

When we consider the global hydrological cycle, the principal process is water exchange between the atmosphere, the land, and the oceans. In this case, the main components are the precipitation on the land and the oceans, the evaporation from the land and the oceans, and the runoff from the land to the oceans. The movement of water in the hydrological cycle is linked with erosion and transport of sediments and chemicals. The erosional and depositional effects of streams, waves, and ice have produced a diversity of Earth's landscapes that make the Earth's surface unlike that of any other planets.

2. The Terrestrial Hydrological Cycle

The key component of the terrestrial hydrological cycle is generation of river runoff and movement of water in the river networks. The main land area units where this process occurs is the river watersheds. The sizes of these areas vary from tens of to 6900 square km (the Amazon River catchment area). Within these areas, distinct spatial differences, in topography, geology, vegetation, soil properties, land use, and meteorological conditions may be well-expressed even on small scales. The land surface heterogeneity may be essentially strengthened by human activities, that can cause a significant modification of the characteristics of the natural landscapes. Therefore, to describe the terrestrial hydrological cycle it is important not only to single out the main processes, but also to take into account the relevant topographic, geological, vegetation, and soil parameters that control runoff generation conditions and give an opportunity to represent the land surface heterogeneity.

2.1. Precipitation

Precipitation is the principle source of the Earth's water supply and may occur in liquid (rain) and solid (snow) forms. The production of the precipitation results from condensation of small water vapor droplets around available nuclei, or from ice crystal process in the clouds. Water droplets are increased in size by means of collision and coalescence until they attain approximately 2 mm in diameter; under action of gravity they then begin to descend to the Earth's surface forming the rainfall. Ice crystals may also collide and stick to one another, forming snowflakes. These snowflakes can reach the ground in the form of snow or rain, depending on the temperature of the lower atmosphere. For the condensation of water vapor or the creation of ice crystals, it is necessary for the moist air to cool to a sufficient extent and generate lift. Precipitation can be classified into four main types according to the air lifting mechanism: (1) frontal precipitation, where the lifting is due to relative movement of two large air masses; (2) precipitation caused by horizontal convergence; (3) convective precipitation; and (4) orographic precipitation. Each type rarely occurs alone in nature, but some may dominate under certain conditions.

Frontal or cyclonic precipitation occurs at convergence of air masses of various character and at different temperatures. A warm front is formed when warm air rises over the cold air at a relatively gentle slope of 1:100 to 1:400. The precipitation zone extends 300–500 km ahead of the warm front. A cold front is formed when cold air moves under a warm air mass forcing the latter upward. A steeper sloping interface (1:25 to 1:100) is observed. The precipitation zone is limited in this case to about 80 km ahead of the front. The horizontal convergence of air into a low-pressure point results in vertical displacement of air, which may lead to condensation and precipitation. Such meteorological processes commonly occur on or near the tropics as northern and southern components of the trade winds and easterlies. The cold air that commonly prevails over warm oceans in the lower latitudes during the latter part of summer, causes tropical storms during which enormous wet air masses pulled in the lower layers rise in the upper atmosphere. The resulting rains fall mostly near the trajectory of the tropical storm center.

2.2. Snow Cover and Ice

Permanent snow cover is formed on about 20 percent of the Northern hemisphere and about 15 percent of the Southern hemisphere. A significant part of the land is covered by snow several times during the cold period. Changing the heat balance of the land, the snow cover has a considerable effect on the climate. The presence of snow cover on a drainage basin also greatly influences runoff generation. In many parts of the world, river runoff consists mainly of water yielded by the melting of snow. The snowmelt spring runoff of most large plain rivers of Russia and Canada exceeds half of annual runoff; at the same time, the portion of snowmelt runoff from mountain areas in the arid regions can be significantly larger.

Snowfall over an area is more uniform than rainfall, however; snow accumulation is largely a function of elevation, slope, exposure, and vegetative cover. Snow spatial redistribution is strongly affected by the interaction of wind and topography as well as by interaction of wind and vegetation. Gullies and surface depressions are filled up by snow first of all and can accumulate a considerable portion of the total river basin snow resources (in some parts of Russia, the snow in rills and gullies consists of about 30 percent of total river basin snow resources). In forests, much of the intercepted snow is blown off and accumulates on thesoil surface. The snow retention coefficients (the ratios of snow catch in the surface in question to the accumulation in an otherwise virgin soil) vary from 0.4 for open ice surface and 0.9 for arable land, to 1.2 for hilly district and 3.2 for edges of forests. During blowing and transport of snow significant evaporation(sublimation) may occur (the evaporation losses may reach 40–50 percent of annual snowfall). The snow water equivalent (the depth of water which would result from the melting of the snow) in forest areas is usually 10–40 percent more than in the open areas (in some cases, a general increase of precipitation in the forest is possible). Snow accumulation generally increases with elevation because of the combined effect of the

prevailing lower temperatures and the increased frequency of precipitation events caused by orographic effects.
The small-scale variations of snow cover, caused by spatial change of terrain, vegetation, and local meteorological conditions, are superimposed on large-scale variations associated with physiographic and climatic zonality. This leads to very large spatial variability of snow cover characteristics, and they are often considered as random values. The coefficients of spatial variation of the snow water equivalent range from 0.15–0.20 in the forest zone to 0.30–0.60 in the steppe zone. To describe spatial variability of the snow water equivalent one commonly applies the lognormal or gamma statistical distributions.
After snowfall, the snowpack undergoes essential transformation (metamorphosis) caused by compaction, action of the thermal gradients, and change in the crystal structure resulting from interactions of ice, liquid water, and water vapor. Because of migration of water vapor and the freezing together of the small particles of ice, the average ice particle size increases and to the end of winter a snowpack commonly consists of uniform coarse crystals (the process of the formation of coarse snow crystals is called riping). The metamorphosis of snow produced a significant change of density and other physical properties of snow. Snow at the time of fall may have a density as low as 0.01 to as high as 0.15 gcm^{-3}; snowfall in the form of dry snow may vary in density between 0.07 and 0.15 gcm^{-3}; average wind-toughened snow has a density about 0.28–0.30 gcm^{-3}. Ripe snow has a uniform density of 0.4–0.5 gcm^{-3}. The greatest density that can be attained by shifting the snow grains around is about 0.55 gcm^{-3}. Further densification, which can occur under action of deformation, refreezing, and recrystallization, produces a compact, dense material called firn. At a density of between 0.82 and 0.84 gcm^{-3}, the air spaces disappear and the material becomes impermeable to air and water. This material can be defined as ice. The old ice has a density about 0.90 gcm^{-3};

Processes

Many different processes lead to movements and phase changes in water

Precipitation
Condensed water vapor that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, graupel, and sleet. Approximately 505,000 km^3 (121,000 cu mi) of water falls as precipitation each year, 398,000 km^3 (95,000 cu mi) of it over the oceans. The rain on land contains 107,000 km^3 (26,000 cu mi) of water per year and a snowing only 1,000 km^3 (240 cu mi).[3] 78% of global precipitation occurs over the ocean.

Canopy interception
The precipitation that is intercepted by plant foliage eventually evaporates back to the atmosphere rather than falling to the ground.
Snowmelt
The runoff produced by melting snow.
Runoff
The variety of ways by which water moves across the land. This includes both surface runoff and channel runoff. As it flows, the water may seep into the ground, evaporate into the air, become stored in lakes or reservoirs, or be extracted for agricultural or other human uses.

Infiltration
The flow of water from the ground surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater.[5] A recent global study using water stable isotopes, however, shows that not all soil moisture is equally available for groundwater recharge or for plant transpiration.
Subsurface flow
The flow of water underground, in the vadose zone and aquifers. Subsurface water may return to the surface (e.g. as a spring or by being pumped) or eventually seep into the oceans. Water returns to the land surface at lower elevation than where it infiltrated, under the force of gravity or gravity induced pressures. Groundwater tends to move slowly and is replenished slowly, so it can remain in aquifers for thousands of years.
Evaporation
The transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere.[7] The source of energy for evaporation is primarily solar radiation. Evaporation often implicitly includes transpiration from plants, though together they are specifically referred to as evapotranspiration. Total annual evapotranspiration amounts to approximately 505,000 km^3 (121,000 cu mi) of water, 434,000 km^3 (104,000 cu mi) of which evaporates from the oceans.[2] 86% of global evaporation occurs over the ocean.[4]
Sublimation
The state change directly from solid water (snow or ice) to water vapor by passing the liquid state.
Deposition
This refers to changing of water vapor directly to ice.
Advection
The movement of water through the atmosphere.[9] Without advection, water that evaporated over the oceans could not precipitate over land.
Condensation
The transformation of water vapor to liquid water droplets in the air, creating clouds and fog.
Transpiration
The release of water vapor from plants and soil into the air.
Percolation
Water flows vertically through the soil and rocks under the influence of gravity.

The water cycle involves many of these processes.

Residence times

The residence time of a reservoir within the hydrologic cycle is the average time a water molecule will spend in that reservoir (see adjacent table). It is a measure of the average age of the water in that reservoir.

Groundwater can spend over 10,000 years beneath Earth's surface before leaving. Particularly old groundwater is called fossil water. Water stored in the soil remains there very briefly, because it is spread thinly across the Earth, and is readily lost by evaporation, transpiration, stream flow, or groundwater recharge. After evaporating, the residence time in the atmosphere is about 9 days before condensing and falling to the Earth as precipitation.

The major ice sheets – Antarctica and Greenland – store ice for very long periods. Ice from Antarctica has been reliably dated to 800,000 years before present, though the average residence time is shorter.[12]

In hydrology, residence times can be estimated in two ways. The more common method relies on the principle of conservation of mass and assumes the amount of water in a given reservoir is roughly constant. With this method, residence times are estimated by dividing the volume of the reservoir by the rate by which water either enters or exits the reservoir. Conceptually, this is equivalent to timing how long it would take the reservoir to become filled from empty if no water were to leave (or how long it would take the reservoir to empty from full if no water were to enter).

An alternative method to estimate residence times, which is gaining in popularity for dating groundwater, is the use of isotopic techniques. This is done in the subfield of isotope hydrology.

Changes over time

Time-mean precipitation and evaporation as a function of latitude as simulated by an aqua-planet version of an atmospheric GCM (GFDL's AM2.1) with a homogeneous “slab-ocean” lower boundary (saturated surface with small heat capacity), forced by annual mean insolation.

The water cycle describes the processes that drive the movement of water throughout the hydrosphere. However, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,500,000 mi^3 (1,386,000,000 km^3) of the world's water supply, about 321,000,000 mi^3 (1,338,000,000 km^3) is stored in oceans, or about 97%. It is also estimated that the oceans supply about 90% of the evaporated water that goes into the water cycle.

During colder climatic periods, more ice caps and glaciers form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age, glaciers covered almost one-third of Earth's land mass with the result being that the oceans were about 122 m (400 ft) lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 5.5 m (18 ft) higher than they are now. About three million years ago the oceans could have been up to 50 m (165 ft) higher.

global climate models, present robust evidence of an intensified global water cycle at a rate of 8 ± 5% per degree of surface warming. This rate is double the response projected by current-generation climate models and suggests that a substantial (16 to 24%) intensification of the global water cycle will occur in a future 2° to 3° warmer world.

The Human Influence on the Terrestrial Hydrological Cycle: -

Human activities that change the land cover of river basins and are aimed at regulating the water fluxes in nature can considerably change the hydrological cycle of the separate river basins, and even of large regions. A striking example of such change is the present-day situation in the Aral Sea basin, where intensive irrigation has resulted in almost full cessation of the water inflow from the Syr-Darya River and the Amu-Darya River, as well as the drastic drop in the Aral Sea level. Other well-documented examples include the increased drought risks in the Mediterranean and the Sahel, following removal of vegetation by forest clearing and overexploitation respectively. There are also some indications that the considerable changes in scale and frequency of flooding in the Ganges basin may be explained by deforestation in the local mountainous region.

Due to human activities, the natural hydrological cycle of most river basins is becoming more and more transformed and regimented. The main stream flow regulation methods are construction of dams, levees, barrages, and dikes, which provide water accumulation, decreasing flood flow, and increasing low flow. The major effects of reservoir construction on the hydrological cycle (excepting runoff control) are an increase of evaporation and a rise of groundwater table. In dry regions, evaporation losses from the reservoir water surface may be so large that they seriously compromise any potential gains. At the same time, in the conditions of moderate climate, the reservoir losses on evaporation are relatively small. For instance, evaporation from the reservoirs in the Volga River basin (where there are about 300 reservoirs the storage capacity over 1 000 000 cubic meters) constitute less than 3–5 percent of the Volga River runoff. The rise in groundwater level along the reservoir periphery and in surrounding areas changes the runoff generation mechanism on these areas. Gradual change of the river flow regime can occur as a consequence of decreasing the river's ability to transport sediments, especially in upper parts and in reservoirs. Reduction of sediment input at the dam site reduces the river channel slope and the bed sheer stress, resulting in dropping flow velocities and the development of river meandering.

The impact of irrigation on the hydrological cycle is especially revealing in the arid regions, but it is also considerable in regions with moderate climate where irrigation is of supplementary character. Diversion of water for irrigation purposes from surface or groundwater resources modifies the natural hydrological processes. It is common for runoff and evaporation from irrigated areas to increase significantly. Irrigation in river basins where there is no additional method of supply often leads to runoff reduction in the outlet site. In many dry regions, a considerable rise in the groundwater table can occur because of water filtration from reservoirs, leakage from water distributing systems, and faulty irrigation technology. Such a rise may cause waterlogging of plants and development of soil salinization.

To remove excess water from waterlogged soils, drainage is applied in many regions of the world. The primary effect of drainage is the lowering of the groundwater table and the extension of the layer with unsaturated soil. As a result, evapotranspiration may considerably drop (in some cases, by more than 50 percent). The improvement of hydraulic conditions due to drainage increases flow velocities. In the first year's after construction of a drainage system, the annual runoff can increase by 20–30 percent. Especially large runoff rises can be observed during the low runoff months in winter and summer. Acceleration of flow also leads to a significant increase in flood peaks. After 10–15 years the impact of drainage on runoff decreases.

Because the quality of groundwater is mostly far better than that of surface water, and its temperature is relatively constant, large volumes of groundwater are extracted for domestic and industrial use in different regions of the world. If groundwater is extracted from confined aquifers below impermeable layers, the groundwater table is not, or is only slightly, affected. However, at some river basins the groundwater table often drops steeply, and this may reduce the surface runoff and the lower level of the small rivers. In many coastal areas, the extraction of groundwater leads to the seawater intrusion.

Together with direct change of the hydrological regime of the river basins by means of stream channel control, irrigation, drainage, and groundwater abstractions, changing the land use of river basins can exert significant influence on the hydrological cycle. Consequences of land use change may be revealed gradually, and be masked by climate variations, but an essential transformation of hydrological regime can occur. The most significant distortions of the hydrological cycle are observed in urbanized areas. The replacement of natural land cover by the urban impermeable surface causes great reductions in infiltration and evapotranspiration. The rainfall runoff from urbanized areas is mainly generated as overland flow and reaches the river drainage system very quickly. Accordingly, the rainfall flood volumes may increase by several times, and the peaks of the hydrographs may increase by 10–15 times. At the same time, snow transport may result in a decrease of snowmelt runoff. Due to reduction of infiltration and groundwater abstractions for urban water supply, falls in the groundwater table are also observed in urban neighborhoods.

The effects of agricultural and forestry practices on the hydrological cycle are less apparent, and depend, to a significant extent, on the physiographic and climatic conditions. It is evident that ploughing, especially contour ploughing, usually breaks up overland flow and increases infiltration. Some special types of ploughing may increase the depression and detention storage on gentle slopes from about 8–10mm (in the natural conditions) to 30–40mm. Tillage and the activity of plant root systems modify the structure of the upper soil layer and change not only the vertical permeability, but also the water retention capacity. Extension of vegetation cover and the leavesarea increases the interception of precipitation and evapotranspiration. Control of overland flow by dense permanent grasses on steeper slopes can reduce storm runoff from small watersheds by 20–25 percent. However, the relative influence of all these changes on annual and flood runoff is determined by the river basin and climate characteristics. In dry regions (for example, in the steppe zone), the 15–20 percent change of the annual runoff caused by agricultural practice has been fixed, and in different years these changes reached 30–40 percent. At the same time, in the wet regions, especially in the forest and northern forest steppe zone, the impact of agricultural practices on runoff may be neglected. The main clearly-expressed effects of deforestation on the hydrological cycle of a river basin are the increases in transpiration and interception of precipitation, which in turn result in a decrease of the volume of total runoff. Deforestation reduces infiltration and improves the conditions for overland flow. As a consequence, flood runoff and peak discharges may significantly increase. At the same time, the higher infiltration of forest soils increases the opportunity for recharge groundwater, and the flow of small rivers tends to be more sustained, especially in the case of the generation of snowmelt runoff, when forests further sustain flow by delaying the snowmelt. A rise in the groundwater table and an increase of ground runoff may also raise the low flow of medium- and large-sized rivers. Such effects often result in the conclusion that forests increase runoff. However, careful observations on representative and experimental basins do not commonly confirm such conclusions. For example, results of fifteen individual watershed-scale experiments, involving various rates of forest cutting, carried out during 50 years at the Coweeta Hydrologic Laboratory in Southern Appalachia, Long-term observations have also shown the strong dependence of runoff volume on the type of vegetal cover. Conversion of hardwood to pine reduced the annual runoff by 25 cm and produced significant reductions of monthly runoff. At the same time, forest cutting has led to a considerable increase in flood peaks. Similar results have been also received on the basis of analyzing data obtained in other physiographic conditions. Research carried out in the forest zone of the European part of Russia has shown that the influence of the forest on evapotranspiration and runoff significantly depends on the age of the forest. Cutting of old forest may not alter evaporation, and the increasing accumulation of snow may even lead to some growth of spring runoff. In many regions, deforestation has resulted in a significant increase in disastrous floods and has also caused severe soil erosion.

CONCLUSION: -

The hydrological cycle is usually called a recurring consequence of different forms of movement of water and changes of its physical state on a given area of the Earth. The role of different processes in the hydrological cycle and their description depends on the chosen spatial-temporal scales. The terrestrial hydrological cycle is of special interest as the mechanism of formation of water resources on a given area of the land. The main processes of this cycle include: precipitation; formation of snow cover; snow metamorphosis and formation of ice; melting of snow and ice; interception of precipitation by vegetation cover and storage in land surface depressions; infiltration of water into soil and vertical transfer of soil moisture; evapotranspiration; recharge of groundwater and ground flow; river runoff generation; and movement of water in river channel systems. The global hydrological cycle is produced by water exchange between the atmosphere, the land, and the oceans, and its main components are precipitation on the land and the oceans, evaporation from the land and the oceans, and runoff from the land to the oceans. Current scientific understanding of main processes qualitative peculiarities, and models of components of the terrestrial and global hydrological cycle are considered. The peculiarities of the modeling of the hydrological cycle of a river basin is demonstrated, taking into account the lack of measurable characteristics of environment. Estimations of influence of irrigation, land treatment, deforestation, and other human activities on the terrestrial hydrological cycle are presented. The role of the terrestrial hydrological cycle in the global climate system and global change is examined. The possible hydrological consequences of human-induced climate change are also discussed.