HYDROMETEOROLOGY

Lecture Title: HYDROMETEOROLOGY

Chapter One: Introduction

- **Definition of hydrometeorology.**
- **Importance and applications of hydrometeorology.**

Chapter Two: Water Cycle

- **Nature of water cycle.**
- **Elements of water cycle.**

Chapter Three: PRECIPITATION

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Chapter One: INTRODUCTION

Hydrology is a branch of Earth Science. The importance of hydrology in the assessment, development, utilization and management of the water resources, of any region is being increasingly realized at all levels. It was in view of this that the United Nations proclaimed the period of 1965-1974 as the International Hydrological Decade during which, intensive efforts in hydrologic education research, development of analytical techniques and collection of hydrological information on a global basis, were promoted in Universities, Research Institutions, and Government Organizations.

1-1 *Definition of hydrometeorology*

Hydrometeorology is a branch of meteorology and hydrology that studies the transfer of water and energy between the land surface and the lower atmosphere. UNESCO has several programmers and activities in place that deal with the study of natural hazards of hydro meteorological origin and the mitigation of their effects. Among these hazards are the results of natural processes or phenomena of atmospheric, Hydrological or oceanographic nature such as floods, tropical cyclones, drought and desertification. Many countries have established an operational hydro meteorological capability to assist with forecasting, warning and informing the public of these developing hazards.

A detailed hydro-meteorological study for the study area has been carried out using data obtained from the National Meteorological Agency (NMA). Data has been collected from seven stations in and around the sub-basin.

1-2 *Importance and applications of hydrometeorology*

This book describes recent developments in hydro meteorological forecasting, with a focus on water-related applications of meteorological observation and forecasting techniques. The topic includes a wide range of disciplines, such as rain gauge, weather radar, satellite, and river and other monitoring techniques, rainfall-runoff, flow routing and hydraulic models, and now casting and Numerical Weather Prediction. Applications include flood forecasting, drought forecasting, climate change impact assessments, reservoir management, and water resources and water quality studies. The book examines how recent developments in meteorological forecasting techniques have significantly improved the lead times and spatial resolution of forecasts across a range of timescales. These improvements are increasingly reflected in the performance of the operational hydrological models used for forecasting the impacts of floods, droughts and other environmental hazards. This has led to improvements in operational decision-making, which can range from decisions within the next few hours on whether to evacuate people from properties at risk from flooding, to longer-term decisions such as on when to plant and harvest crops, and to operate reservoirs and river off-takes for water supply and hydropower schemes. The book provides useful background for civil engineering, water resources, and meteorology and hydrology courses for post-graduate students, but is primarily intended as a review of recent developments for a professional audience.

Key themes: floods, droughts, meteorological forecasts, hydrological forecasts, demand forecasts, reservoirs, water resources, water quality, decision support, data assimilation, probabilistic forecasts. Kevin Sene is a civil engineer and researcher with wide experience in flood forecasting, water resources and hydro meteorological studies. He has published some 45 scientific and conference papers on topics in hydrology, hydrometeorology and hydraulics, and a book Flood Warning, Forecasting and Emergency Response.

Fresh water is one of our nation's most precious and valuable natural resources. The management of this resource requires accurate and timely information on precipitation and surface processes for water managers to make appropriate decisions regarding infrastructure and resources. Knowledge of both the amount and uncertainty of precipitation and stream flow information is also required by forecasters to produce robust hydrologic simulations of stream discharge, to issue flood warnings to the public, and improve overall awareness related to incoming storms. Recent studies have shown that climate change will increase the occurrence of extreme precipitation events over time, further highlighting the need for reliable information.

PSD's Hydrometeorology Modeling and Applications Team is focused on advancing hydrometeorology methods, models and applications to address weather and climate extremes. This information is used to provide guidance on observing network design, modeling assimilation and analysis, and predictions that can be applied in National Weather Service operations as well as informing local, regional, and national communities, planners, and decisionmakers.

Chapter two: WATER CYCLE

The **water cycle**, also known as the **hydrological cycle**, describes the continuous movement of water on, above and below the surface of the Earth. The mass of water on Earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on awiderangeofclimaticvariables.Thewatermoves fromonereservoirtoanother,suchas from river to ocean, or from the ocean to the atmosphere, by the physical processes of evaporation, condensation, precipitation, infiltration, surface runoff, and subsurface flow.In doing so, the water goes through different phases: liquid, solid (ice) and vapor.

Thewatercycleinvolvestheexchangeofenergy,whichleadstotemperaturechanges.For instance, when water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influenceclimate.

The evaporative phase of the cycle purifies water which then replenishes the land with freshwater.The flow of liquid water and ice transports minerals across the globe. It is also involved in reshaping the geological features of the Earth, through processes includingerosionandsedimentation.Thewater cycleisalsoessentialforthemaintenance of most life and ecosystems on the planet.

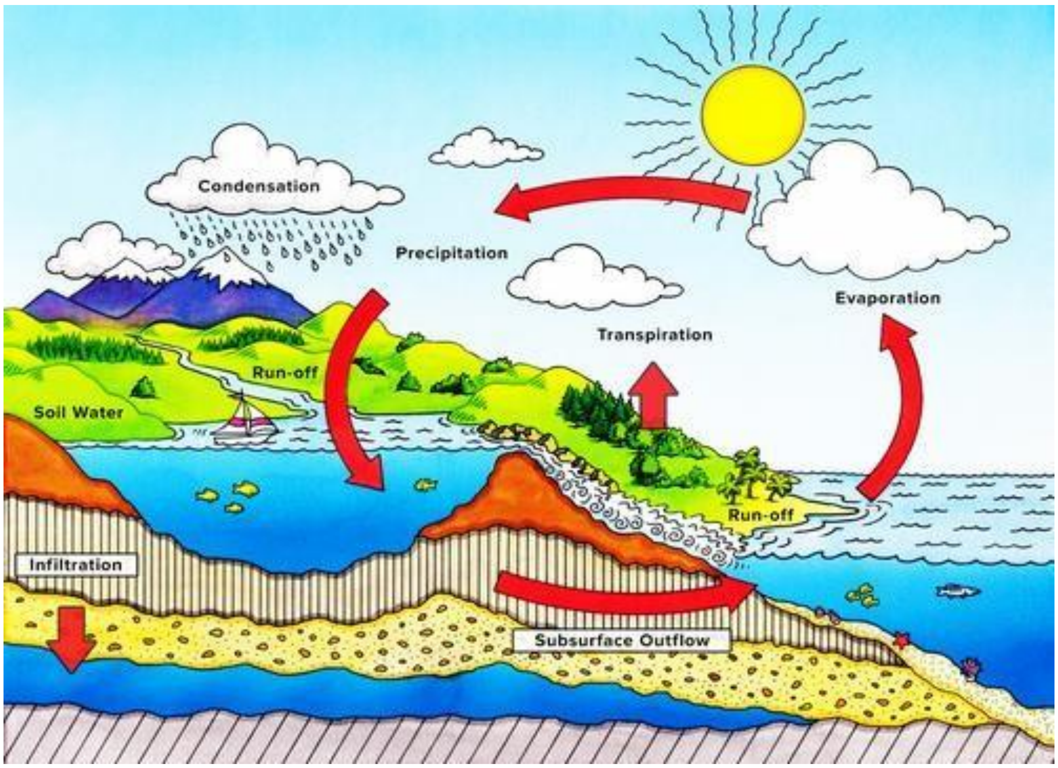

Figure 1. Water cycle

1-1 *Nature of water cycle*

The sun, which drives the water cycle, heats water in oceans and seas. Water evaporates as water vapor into the air. Ice and snow can sublimate directly into water vapor. Evapotranspiration is water transpired from plants and evaporated from the soil. The water vapor molecule H2O has less density compared to the major components of the atmosphere, nitrogen and oxygen, N2 and O2. Due to the significant difference in molecular mass, water vapor in gas form gains height in open air as a result of buoyancy. However, as altitude increases, air pressure decreases and the temperature drops. The lowered temperature causes water vapor to condense into a tiny liquid water droplet which is heavier than the air, such that it falls unless supported by an updraft. A huge concentration of these droplets over a large space up in the atmosphere become visible as cloud. Fog is formed if the water vapor condenses near ground level, as a result of moist air and cool air collision or an abrupt reduction in air pressure. Air currents move water vapor around the globe, cloud particles collide, grow, and fall out of the upper atmospheric layers as precipitation. Some precipitation falls as snow or hail, sleet, and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Most water falls back into the oceans or onto land as rain, where the water flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with stream flow moving water towards the oceans. Runoff and water emerging from the ground (groundwater) may be stored as freshwater in lakes. Not all runoff flows into rivers, much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers, which can store freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as groundwater discharge. Some groundwater finds openings in the land surface and comes out as freshwater springs. In river valleys and floodplains, there is often continuous water exchange between surface water and ground water in the hyporheic zone. Over time, the water returns to the ocean, to continue the water cycle.

1-2 *Elements of water cycle*

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, grapple, 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). 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.[6]

- **Subsurface flow**

The flow of water underground, in the vases 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.[8]

- **Deposition**

This refers to changing of water vapor directly to ice.

- **Advection**

The movement of water — in solid, liquid, or vapor states — through the atmosphere. Without advection, water that evaporated over the oceans could not precipitate over land.[9]

- **Condensation**

The transformation of water vapor to liquid water droplets in the air, creating clouds and fog.[10]

- **Transpiration**

The release of water vapor from plants and soil into the air. Water vapor is a gas that cannot be seen.

- **Percolation**

Water flows vertically through the soil and rocks under the influence of gravity

- **Plate tectonics**

Water enters the mantle via seduction of oceanic crust. Water returns to the surface via volcanism.

Water cycle thus involves many of the intermediate processes.

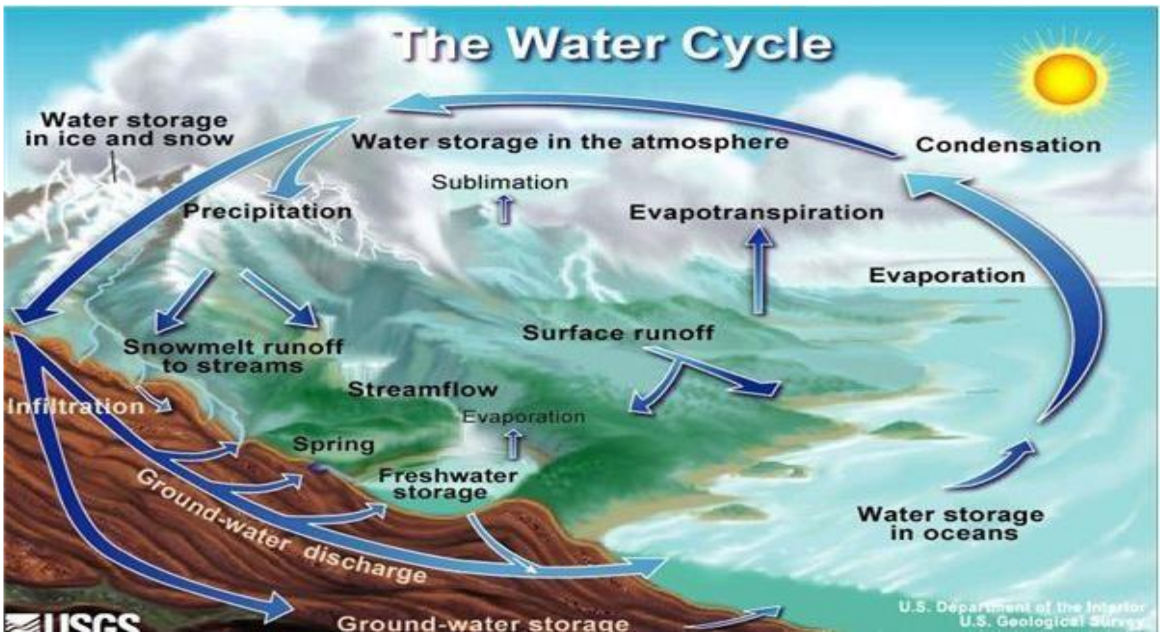

Figure 2. Elements of water cycle

Chapter Three: PRECIPITATION

In meteorology, precipitation is any product of the condensation of atmospheric water vapor that falls under gravity.

The main forms of precipitation include drizzle, rain, sleet, snow, grapple and hail. Precipitation occurs when a portion of the atmosphere becomes saturated with water vapor, sothatthewatercondensesand"precipitates". Thus,fogandmistarenotprecipitationbut suspensions, because the water vapor does not condense sufficiently to precipitate. Two processes, possibly acting together, can lead to air becoming saturated: cooling the air or adding watervaportotheair.Precipitationformsassmallerdropletscoalesceviacollision with other rain drops or ice crystals within a cloud. Short, intense periods of rain in scattered locations are called"showers."

Moisture overriding associated with weather fronts is an overall major method of precipitation production.Ifenoughmoistureandupwardmotionispresent,precipitation falls from convective clouds such as cumulonimbus and can organize into narrow rain bands. Where relatively warm water bodies are present, for example due to water evaporation from lakes, lake-effect snowfall becomes a concern downwind of the warm lakes within the cold cyclonic flow around the backside of extra tropical cyclones. Lake- effect snowfall can be locally heavy. Thunders now is possible within a cyclone's comma head and within lake effect precipitation bands. In mountainous areas, heavy precipitation is possible where upslope flow is maximized within windward sides of the terrain at elevation. On the leeward side of mountains, desert climates can exist due to the dry air caused by compressional heating. The movement of the monsoon trough, or inter tropical convergence zone, brings rainy seasons to savannah climes.

Precipitation is a major component of the water cycle, and is responsible for depositing the fresh water on the planet. Approximately 505,000 cubic kilometers (121,000 cu mi) of water falls as precipitation each year; 398,000 cubic kilometers (95,000 cu mi) of it over the oceans and 107,000 cubic kilometers (26,000 cu mi) over land. Given the Earth's surface area, that means the globally averaged annual precipitation is 990 millimeters (39 in), but over land it is only 715 millimeters (28.1 in). Climate classification systems such as the Köppen climate classification system use average annual rainfall to help differentiate between differing climate regimes. Precipitation may occur on other celestial bodies, e.g. when it gets cold, Mars has precipitation which most likely takes the form of frost, rather than rain or snow

3-1 Types of precipitation

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Given the Earth's surface area, that means the globally averaged annual precipitation is 990 millimeters (39 in). Mechanisms of producing precipitation include convective, strati form, and orographic rainfall. Convective processes involve strong vertical motions that can cause the overturning of the atmosphere in that location within an hour and cause heavy precipitation, while strati form processes involve weaker upward motions and less intense precipitation. Precipitation can be divided into three categories, based on whether it falls as liquid water, liquid water that freezes on contact with the surface, or ice. Mixtures of different types of precipitation, including types in different categories, can fall simultaneously. Liquid forms of precipitation include rain and drizzle. Rain or drizzle that freezes on contact within a subfreezing air mass is called "freezing rain" or "freezing drizzle". Frozen forms of precipitation include snow, ice needles, ice pellets, hail, and grapple.

1. **Raindrops**
2. **Ice pellets**
3. **Hail**
4. **Snowflakes**
5. **Diamond dust**

3-2 Precipitation intensity

Precipitation is measured using a rain gauge. When classified according to the rate of precipitation, rain can be divided into categories. Light rain describes rainfall which falls at a rate of between a trace and 2.5 millimeters (0.098 in) per hour. Moderate rain describes rainfall with a precipitation rate of between 2.6 millimeters (0.10 in) and 7.6 millimeters (0.30 in) per hour. Heavy rain describes rainfall with a precipitation rate above 7.6 millimeters (0.30 in) per hour. Snowfall intensity is classified in terms of visibility. When the visibility is over 1 kilometer (0.62 mi), snow is determined to be light. Moderate snow describes snowfall with visibility restrictions between .5 kilometers (0.31 mi) and 1 kilometer (0.62 mi). Heavy snowfall describes conditions when visibility is restricted below .5 kilometers (0.31 mi).

3-3 Methods of measuring precipitation

Observation Instruments for measuring precipitation include rain gauges and snow gauges, and various types are manufactured according to the purpose at hand. Rain gauges are discussed in this chapter. Rain gauges are classified into recording and non-recording types. The latter include cylindrical and ordinary rain gauges, and measurement of precipitation with these types is performed manually by the observer. Some recording types such as siphon rain gauges have a built-in recorder, and the observer must physically visit the observation site to obtain data. Other types such as tipping bucket rain gauges have a recorder attached to them, and remote readings can be taken by setting a recorder at a site distant from the gauge itself to enable automatic observation.

As rain gauges measure the volume or weight of precipitation collected in a vessel with a fixed orifice diameter, the size of the orifice needs to be standardized. CIMO provides that its area should be 200 cm^2 or more, and types with an orifice area of 200 to 500 cm2 are widely used. In Japan, the rain gauge orifice diameter is set as 20 cm (314 cm^2). The receptacle has a rim at the top to keep the receiving area constant and a funnel to collect rainwater. The inside of the rim is vertical, and its outside has a sharp angle at the top to prevent external rainwater from splashing into the vessel.

1. Cylindrical Rain Gauges
2. Ordinary Rain Gauges
3. Siphon Rain Gauges
4. Tipping Bucket Rain Gauges
5. Tipping Bucket Rain Gauge Recorder
6. Exposure
7. Windshields

3-4 Precipitation calculations

There are different ways to calculate the amount of precipitation for a certain area:

1. Arithmetic Mean Method
2. Thiessen Average Method
3. Isohyetal Line Method
4. Triangulation method
5. Balance method