HYDROMETEOROLOGY

HYDROMETEOROLOGY

Course - Second Class

By

Prof. Dr. OSAMA T. AL-TAAI | Hydrometeorology | 2022
Department of Atmospheric Science, College of Science, Mustansiriyah University, Baghdad-Iraq

February-2022

PREFACE TO THE COURSE

Hydrology is a long continuing hydro science and much work done in this field in the past, particularly in Iraq, was of empirical nature related to development of empirical formulae, tables and curves for yield and flood of river basins applicable to the particular region in which they were evolved by investigators like Basra, Maysan, Dhi Qar, etc. In this course, there is a departure from empiricism and the emphasis is on the collection of data and analysis of the hydrological factors involved and promote hydrological design on sound principles and understanding of the science, for conservation and utilization of water resources. Hydrological designs may be made by deterministic, probabilistic and stochastic approaches but what is more important is a 'matured judgment' to understand and avoid what is termed as 'unusual meteorological combination'. The course is written in a lucid style in the metric system of units and a large number of hydrological design problems are worked out at the end of each article to illustrate the principles of analysis and the design procedure. Problems for assignment are given at the end of each Chapter along with the objective type and intelligence questions. A list of references is included at the end for supplementary reading.

Prof. Dr. Osama T. AL-TAAI

February-**2022**

CONTENTS

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 decision makers.

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 a wide range of climatic variables. The water moves from one reservoir to another, such as 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.

The water cycle involves the exchange of energy, which leads to temperature changes. 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 influence climate.

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 including erosion and sedimentation. The water cycle is also essential for the maintenance of most life and ecosystems on the planet.

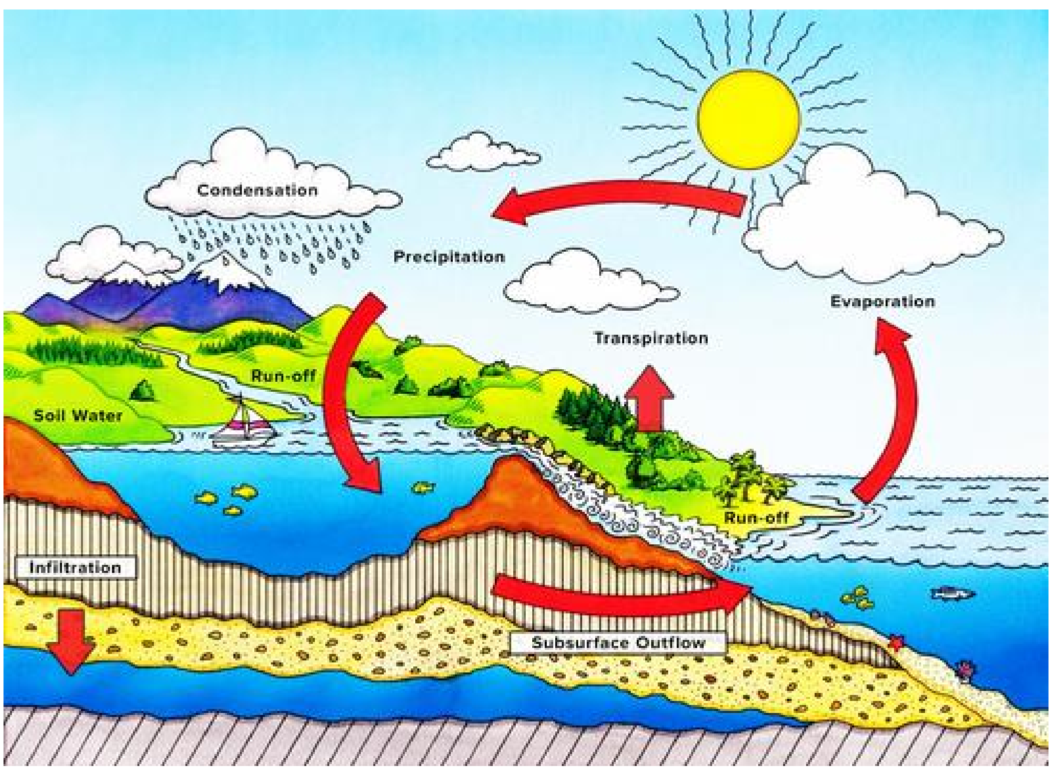

Figure 1. Water cycle

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 H_2O has less density compared to the major components of the atmosphere, nitrogen and oxygen, N_2 and O_2. 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.

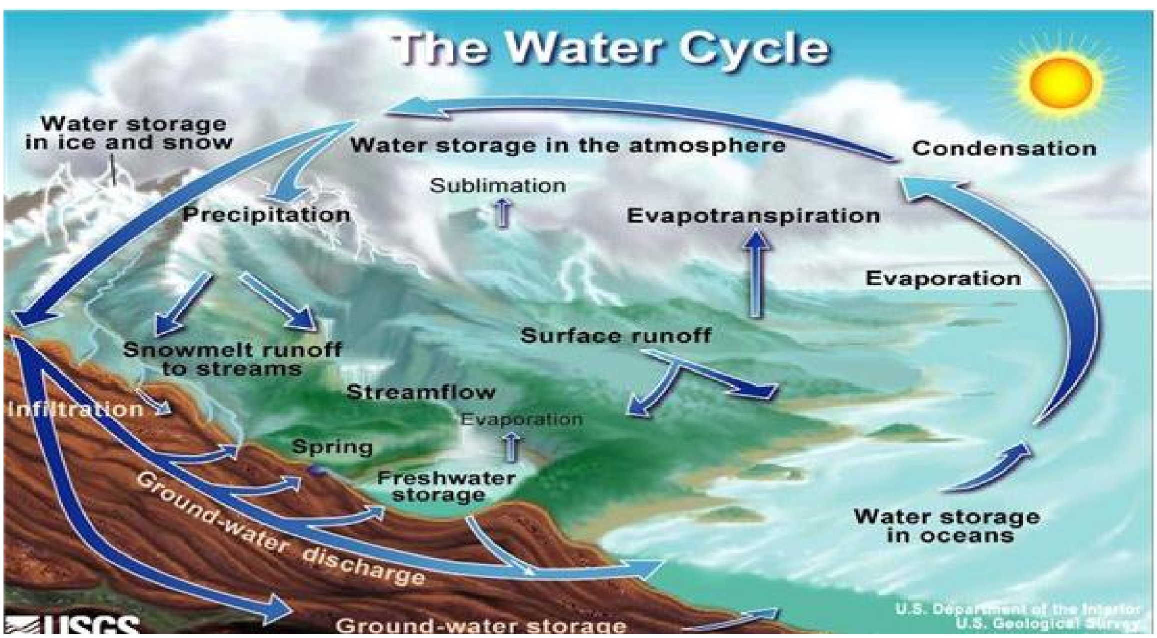

Figure 2. Elements of water cycle

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, so that the water condenses and "precipitates". Thus, fog and mist are not precipitation but 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 water vapor to the air. Precipitation forms as smaller droplets coalesce via collision 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. If enough moisture and upward motion is present, 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

Precipitation is a major component of the water cycle, and is responsible for depositing most of the fresh water on the planet. Approximately 505,000 km3 (121,000 mi3) of water falls as precipitation each year, 398,000 km3 (95,000 cu mi) of it over the oceans.

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

ICE MELTING

4-1 Ice and snow melting

A Snowmelt system prevents the build-up of snow and ice on walkways, patios and roadways, or more economically, only a portion of the area such as a pair of 2-foot (0.61 m)-wide tire tracks on a driveway or a 3-foot (0.91 m) center portion of a sidewalk, etc. They function even during a storm thus improve safety and eliminate winter maintenance labor including shoveling or plowing snow and spreading de-icing salt or traction grit (sand). A snowmelt system may extend the life of the concrete, asphalt or under pavers by eliminating the use salts or other de-icing chemicals, and physical damage from winter service vehicles. Systems are available in two broad types based on heat source: electric resistance heat and heat from a combustion or geothermal source delivered hedonically (in a fluid). Arguably, electric snowmelt systems requires less maintenance than hydro snowmelt systems because there are minimal moving parts and no corroding agents. However electric snowmelt systems tend to be much more expensive to operate. Most new snowmelt systems operate in conjunction with an automatic activation device that will turn on the system on when it senses precipitation and freezing temperatures and turn off the system when temperatures are above freezing. These types of devices ensure the system is only active during useful periods and reduces wasteful energy consumption. A high limit thermostat further increases efficiency when installed in conjunction with the automatic snow melt controller to temporarily disable the system once the slab has reached a sufficient snow melting temperature. Some building codes require the high limit thermostat to prevent energy waste. Though their total environmental impact depends on their energy source. Current systems are more cost effective in the long run than continual salt dumping and removal, and reduce waste by extending the life of the concrete.

4-2 Snow conversion

When the temperature is around 30 degrees, one inch of liquid precipitation would fall as 10 inches of snow assuming the storm is all snow. But, the amount of moisture in each snowflake differs depending on the temperature changing the snow to rain ratio.

For example, our big December snowstorm occurred with temperatures closer to 25 degrees. During that storm the snow ratio was closer to 15 inches of snow to one inch of rain. We had 1.75 inches of "liquid equivalent," yet ended up with 23.2 inches of snow, not 17.5 inches of accumulation. In fact, I took this into account when forecasting 15 to 25 inches from the Philadelphia area southward for the storm. We even showed a graphic on-air explaining those estimates. We've had storms with snow closer to 20 degrees moving the snow ratio closer to 20 to one. And, when it's warmer (35 to 40 degrees), the ratio moves to 5:1.

4-3 Melting processes

It happens every year, with the beginning of the warmer spring the snow in the mountains starts to melt. To understand the physics during the snow melt you just have to look at your lawn after a rain. The water source is different but the result is the same. Forced by gravity the water is pulled to the ground. At first, the dry ground is able to absorb the water, holding it in its upper layers. After a while the ground gets saturated and unable to bind the water. At this point you would recognize the building of puddles in your lawn. For the mountain region this means that the water starts to flow towards the deepest point. This happens at about 10 to 15 cm below the surface, just below the roots of the low vegetation. I don't get further into the physics of that but you may easily see this by pulling up a square of grass including its roots and surrounding ground. The flow of water is slow but steady facing a high resistance. Only if the supply of water is larger than the subsurface flow can carry, the water will flow on the surface. The water eventually will end up in a creek or stream and gets carried it away. The following stages apply for the spring runoff:

Progress	Season	Applies to	
Initial Runoff	Early Spring	Low level snow pack	Daytime temperatures are high enough to start the snow melt process. The ground absorbs the water, allows a slow subsurface flow. Cooler night temperatures interrupt the melting process and the supply of water, but subsurface flow continues throughout the night.
	Early Spring	Low level snow pack	As the temperatures get higher the melting process intensifies. During daytime the saturation point of the ground is reached, increasing the water pressure and speed of the subsurface flow. Exceptional hot days or rain may result in temporary surface flow.
Main Runoff	Late Spring / Early Summer	Low level and medium level snow pack	Warmer weather causes a constant supply of water during day and night. Subsurface flow reaches its maximum, surface flow starts. The amount of water produced by the melting process reaches its maximum and runoff continues into late night. Rain showers add water to the surface flow, which reaches the stream system very fast and can cause critical peaks.
	Summer	Medium and high level snow pack	Low level snow is gone, medium level snow continues to melt. The runoff slows down since temperatures in higher elevations are lower and the total snow surface is much smaller. Subsurface flow is slower because of the increased resistance due to larger flow distances. Also hot weather heats up the ground in lower elevations and vaporizes part of snow water.
Final Runoff	Late Summer / Early Fall	High level snow pack	Usual very limited visual indications of the runoff other than slowly decreasing snow pack. Snow melts only during daytime on hot days. Subsurface flow only, much of the water gets absorbed in lower elevations. Stream network is back to normal levels.

4-4 Calculations of total melting

Out main interest here is to apply the first law of thermodynamics to chemical reactions carried out under certain conditions. These conditions are constant volume and constant pressure. This is because when we carry out the experiment in the laboratory, we usually work with definite volume (constant volume) of reaction. In addition, the pressure inside the laboratory is pretty much the same as the atmospheric pressure, which is constant (constant pressure). Thus we have two different kinds of quantities, ΔE and ΔH, to measure the energy changes one at constant volume (ΔE) and another at constant pressure (ΔH). Both are thermodynamic state functions; ΔE is known as the change in internal energy and ΔH is labeled as the change in enthalpy (from Greek, enthalpies, to warm). Remember, the word enthalpy is simply a fancy word for heat at constant pressure.

FLOWS

A flood is an overflow of water that submerges land which is usually dry. The European Union (EU) floods directive defines a flood as a covering by water of land not normally covered by water. In the sense of "flowing water", the word may also be applied to the inflow of the tide. Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an area flood. While the size of a lake or other body of water will vary with seasonal changes in precipitation and snow melt, these changes in size are unlikely to be considered significant unless they flood property or drown domestic animals. Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway. Floods often cause damage to homes and businesses if they are in the natural flood plains of rivers. While riverine flood damage can be eliminated by moving away from rivers and other bodies of water, people have traditionally lived and worked by rivers because the land is usually flat and fertile and because rivers provide easy travel and access to commerce and industry. Some floods develop slowly, while others such as flash floods, can develop in just a few minutes and without visible signs of rain. Additionally, floods can be local, impacting a neighborhood or community, or very large, affecting entire river basins.

5-1 River flow

Floods occur in all types of river and stream channels, from the smallest ephemeral streams in humid zones to normally-dry channels in arid climates to the world's largest rivers. When overland flow occurs on tilled fields, it can result in a muddy flood where sediments are picked up by run off and carried as suspended matter or bed load. Localized flooding may be caused or exacerbated by drainage obstructions such as landslides, ice, debris, or beaver dams. Slow-rising floods most commonly occur in large rivers with large catchment areas. The increase in flow may be the result of sustained rainfall, rapid snow melt, monsoons, or tropical cyclones. However, large rivers may have rapid flooding events in areas with dry climate, since they may have large basins but small river channels and rainfall can be very intense in smaller areas of those basins. Rapid flooding events, including flash floods, more often occur on smaller rivers, rivers with steep valleys, rivers that flow for much of their length over impermeable terrain, or normally-dry channels. The cause may be localized convective precipitation (intense thunderstorms) or sudden release from an upstream impoundment created behind a dam, landslide, or glacier. In one instance, a flash flood killed eight people enjoying the water on a Sunday afternoon at a popular waterfall in a narrow canyon. Without any observed rainfall, the flow rate increased from about 50 to 1,500 cubic feet per second (1.4 to 42 m^3/s) in just one minute.

Two larger floods occurred at the same site within a week, but no one was at the waterfall on those days. The deadly flood resulted from a thunderstorm over part of the drainage basin, where steep, bare rock slopes are common and the thin soil was already saturated. Flash floods are the most common flood type in normally-dry channels in arid zones, known as arroyos in the southwest United States and many other names elsewhere. In that setting, the first flood water to arrive is depleted as it wets the sandy stream bed. The leading edge of the flood thus advances more slowly than later and higher flows. As a result, the rising limb of the hydrograph becomes ever quicker as the flood moves downstream, until the flow rate is so great that the depletion by wetting soil becomes insignificant.

5-2 Sources of river flow

A river is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river. In some cases a river flows into the ground and becomes dry at the end of its course without reaching another body of water. Small rivers can be referred to using names such as stream, creek, brook, rivulet, and rill. There are no official definitions for the generic term river as applied to geographic features, although in some countries or communities a stream is defined by its size. Many names for small rivers are specific to geographic location; examples are "run" in some parts of the United States, "burn" in Scotland and northeast England, and "beck" in northern England. Sometimes a river is defined as being larger than a creek, but not always: the language is vague. Rivers are part of the hydrological cycle. Water generally collects in a river from precipitation through a drainage basin from surface runoff and other sources such as groundwater recharge, springs, and the release of stored water in natural ice and snowpack (e.g. from glaciers). Potamology is the scientific study of rivers while limnology is the study of inland waters in general. Extraterrestrial rivers of liquid hydrocarbons have recently been found on Titan. Channels may indicate past rivers on other planets, specifically outflow channels on Mars and rivers are theorized to exist on planets and moons in habitable zones of stars.

5-3 Flood operations

Operation Flood, launched in 1970, was a project of India's National Dairy Development Board (NDDB), which was the world's biggest dairy development program. It transformed India from a milk-deficient nation into the world's largest milk producer, surpassing the USA in 1998,[2] with about 17 percent of global output in 2010–11. In 30 years it doubled milk available per person, and made dairy farming India’s largest self-sustainable rural employment generator. It was launched to help farmers direct their own development, placing control of the resources they create in their own hands. All this was achieved not merely by mass production, but by production by the masses. The Anand pattern experiment at Amul, a single, cooperative dairy, was the engine behind the success of the program. Verghese Kurien, the chairman and founder of Amul, was named the chairman of NDDB by the then Prime Minister of India Lal Bahadur Shastri.

Kurien gave the necessary thrust using his professional management skills to the program, and is recognized as its architect. Operation Flood is the program behind "the white revolution." It created a national milk grid linking producers throughout India with consumers in over 700 towns and cities, reducing seasonal and regional price variations while ensuring that the producer gets a major share of the price consumers pay, by cutting out middlemen. The bedrock of Operation Flood has been village milk producers' co-operatives, which procure milk and provide inputs and services, making modern management and technology available to members. Operation Flood's objectives included:

1. Increase milk production ("a flood of milk")
2. Augment rural incomes
3. Fair prices for consumers

5-4 Components of river flow

1. Direct Precipitation on stream flow
2. Surface runoff
3. Subsurface runoff
4. Grand water flow

EVAPORATION

Evaporation is a type of vaporization of a liquid that occurs from the surface of a liquid into a gaseous phase that is not saturated with the evaporating substance. The other type of vaporization is boiling, which is characterized by bubbles of saturated vapor forming in the liquid phase. Steam produced in a boiler is another example of evaporation occurring in a saturated vapor phase. Evaporation that occurs directly from the solid phase below the melting point, as commonly observed with ice at or below freezing or moth crystals (naphthalene or par dichlorobenzene), is called sublimation. On average, a fraction of the molecules in a glass of water have enough heat energy to escape from the liquid. The reverse also happens water molecules from the air enter the water in the glass, but as long as the relative humidity of the air in contact is less than 100% (i.e., saturation), the net transfer of water molecules will be to the air. The water in the glass will be cooled by the evaporation until an equilibrium is reached where the air supplies the amount of heat removed by the evaporating water. In an enclosed environment the water would evaporate until the air is saturated. With sufficient temperature, the liquid would turn into vapor quickly (see boiling point). When the molecules collide, they transfer energy to each other in varying degrees, based on how they collide. Sometimes the transfer is so one-sided for a molecule near the surface that it ends up with enough energy to "escape" and enter the surrounding air.

Evaporation is an essential part of the water cycle. The sun (solar energy) drives evaporation of water from oceans, lakes, moisture in the soil, and other sources of water. In hydrology, evaporation and transpiration (which involves evaporation within plant stomata) are collectively termed evapotranspiration. Evaporation of water occurs when the surface of the liquid is exposed, allowing molecules to escape and form water vapor; this vapor can then rise up and form clouds.

6-1 Mass transfer

Heat and Mass Transfer is a peer-reviewed scientific journal published by Springer. It serves the circulation of new developments in the field of basic research of heat and mass transfer phenomena, as well as related material properties and their measurements. Thereby applications to engineering problems are promoted. The journal publishes original research reports. As of 1995 the title "Wärme- und Stoffübertragung was changed to Heat and Mass Transfer.

6-2 Energy balance equation

Recently on the Internet, a common meme is that the application of thermodynamics to the human body is incorrect. This usually comes out of people talking about something that they clearly do not understand in any way shape or form which is the energy balance equation. This is usually used as a lead in to the idea that the “Calorie theory of weight gain and weight loss” is incorrect or what have you. This leads to even more abjectly stupid ideas that I’m not getting into here.

Today, I'm going to do my best to clear things up about what the energy balance equation does and doesn't mean and why people, who don't really have a clue what they're talking about, don't understand it. Hopefully by the time you've gotten to the end of this, you'll understand it.

What is the Energy Balance Equation?

In its simplest form, the energy balance equation is meant to represent what does (or at least should) happen to the body by looking at the difference between energy intake (from food) and energy output. In its exceedingly simplest form, the energy balance equation is this:

Energy in = Energy out + Change in Body Stores

This is essentially just a restatement of basic thermodynamics, since energy can't be created or destroyed, it all has to be accounted for in some form or fashion. In this case, differences between intake and output show up as changes in the energy stores of the body. Now, in the case of the human body, changes in energy stores will show up as changes in the amount of different tissues in the body. Excess energy is converted or stored via conversion into body tissue (e.g. body fat, muscle tissue, etc.). Since excess energy is stored in the body as tissues that contain mass, I will (marginally incorrectly) refer to changes in body mass throughout this article. I'm doing this as people tend to fixate on changes in mass/weight rather than on energy per se (we can measure changes in weight on the scale, or changes in fat or muscle mass; you can't readily measure changes in energy stores of the body). As you'll see below, this confusion about the energy value of different tissues is a big part of the confusion and claims regarding the equation itself. By the same token, if energy intake is less than output, the body will pull on stored energy within the body and there will be some loss of tissue (e.g. fat, muscle, etc.). Again, I'll refer to changes in mass in this article, just realize that, for technical accuracy, the real changes is in the energy store of the body. Now, the above is a very simplified version of the energy balance equation and this is part of where folks get into problems. But we have three basic bits of the equation: Energy In, Energy Out and Change in Body Stores. I want to look at each including some of the places that people make some really flawed arguments and draw some really flawed conclusions based on their misunderstanding of what's going on.

6-3 Application of energy balance equation

1. heat required for a process
2. rate of heat removal from a process
3. heat transfer/design of heat exchangers
4. process design to determine energy requirements of a process
5. pump power requirements (mechanical energy balance)
6. pattern of energy usage in operation
7. process control
8. process design and development

6-4 Evaporation from ice and snow

Notice that when the snow builds up in my patio, it starts to evaporate after a few days, even though the temperature is still below freezing. On average, what percentage of our snowfall each year evaporates back into the cold, dry air?

The transition of water from the ice phase (or snow) to the gas phase (or water vapor) is called sublimation. Sublimation is a common way for snow to disappear in Wisconsin winters. On warmer days, when temperatures are above freezing, we can see the melting process as snow leaves water behind on surfaces, which then evaporates or gets absorbed by the ground. We do not see the sublimation process because the snow goes directly into water vapor without first melting into liquid water. However, we do notice that the snow amount is decreasing, so snow sometimes seems to disappear on cold winter days. The rate of sublimation is a function of the weather conditions. It takes a lot of energy to turn ice into a gas called water vapor: about 7 times the amount of energy needed to boil that water. The energy needed to sublimate the snow off your patio comes primarily from the sun. So, sunny weather is the best weather for sublimating snow. Windy days are also good, as the wind helps to remove the water molecules once they leave the snow and enter into the atmosphere. A low humidity also helps to increase the rate of snow loss. So, the amount of snow that sublimates back into the air depends on the typical winter weather for a given location.

METHODS OF OBSERVATIONS AND NETWORKING

All national climate activities, including research and applications, are primarily based on observations of the state of the atmosphere or weather. The global observing system provides observations of the state of the atmosphere and ocean surface. It is operated by national meteorological and hydrological services, national or international satellite agencies, and several organizations and consortiums dealing with specific observing systems or geographic regions. The WMO global observing system is a coordinated system of different observing subsystems that provides in a cost-effective way high-quality, standardized meteorological and related environmental and geophysical observations, from all parts of the globe and outer space. examples of the observing subsystems relevant to climate are the global climate observing system (GCOS) surface network (GSN), the GCOS upper-air network (guan), regional basic climatological networks, global atmosphere watch (GAW), marine observing systems, and the satellite-based global positioning system. The observations from these networks and stations are required for the timely preparation of weather and climate analyses, forecasts, warnings, climate services, and research for all WMO programmers and relevant environmental programmers of other international organizations. This chapter on observations follows the sequence of specifying the elements needed to describe the climate and the stations at which these elements are measured, instrumentation, siting of stations, network design and network operations. The guidance is based on the WMO guide to meteorological instruments and methods of observation (WMO no. 8, fifth, sixth and seventh editions), the guide to the global observing system (WMO-no. 488) and the guidelines on climate observation networks and systems (WMO/td-no. 1185). Each edition of the guide to meteorological instruments and methods of observation has a slightly different emphasis. For example, the sixth edition contains valuable information on sensor calibration, especially of the basic instrumentation used at climate stations, but tables 2 and 3 of the fifth edition provide more information about the accuracy of measurements that are needed for general climatological purposes. Cross references are provided in the sections below to other WMO publications containing more detailed guidance.

Guidance is also based on ten climate monitoring principles set forth in the Report of the GCOS/GOOS/ GTOS Joint Data and Information Management Panel (Third Session, Tokyo, 15–18 July 1997, WMO/TD No. 847):

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms, and other factors pertinent to interpreting data (metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate monitoring products and assessments should be integrated into national, regional, and global observing priorities.

6. Operation of historically uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor areas, poorly observed parameters, areas sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements should be specified to network designers, operators, and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully planned manner should be promoted.
10. Data management systems that facilitate access, use, and interpretation of data and products should be included as essential elements of climate monitoring systems.

These principles were established primarily for surface based observations, but they also apply to data for all data platforms.

STATISTICAL ANALYSIS

Some well-known statistical tests and procedures are:

- Analysis of variance (ANOVA)
- Chi-squared test
- Correlation
- Factor analysis
- Mann–Whitney *U*
- Mean square weighted deviation (MSWD)
- Pearson product-moment correlation coefficient
- Regression analysis
- Spearman's rank correlation coefficient
- Student's *t*-test
- Time series analysis
- Conjoint Analysis

REFERENCES

1. "Hydro-meteorological hazards United Nations Educational, Scientific and Cultural Organization". Unesco.org. Retrieved 2016-08-05.
2. "Flood Forecasting Centre". Ffc-environment-agency.metoffice.gov.uk. 2011-09-22. Retrieved 2014-05-28.
3. "Information national". Vigicrues. Retrieved 2014-05-28.
4. "Hydro-Meteorology". Imd.gov.in. Retrieved 2014-05-28.
5. "Flood Forecasting Service". Sepa.org.uk. Retrieved 2014-05-28.
6. "Republic Hydrometeorological service of Serbia Kneza Višeslava 66 Beograd". Hidmet.gov.rs. 2014-05-18. Retrieved 2014-05-28.