

Surface Hydrology

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About

Welcome to Surface Hydrology (71630) at the Hebrew University of Jerusalem. This is [Yair Mau](#), your host for today. I am a senior lecturer at the Institute of Environmental Sciences, at the Faculty of Agriculture, Food and Environment, in Rehovot, Israel.

This website contains (almost) all the material you'll need for the course. If you find any mistakes, or have any comments, please email me.

The material here is not comprehensive and **does not** constitute a stand alone course in Surface Hydrology. This is only the support material for the actual presential course I give.

Syllabus

Course description

This is an introductory course in Surface Hydrology, dealing with some of the major processes in the hydrologic cycle: precipitation, evaporation and transpiration, infiltration, runoff generation and streamflow. The different topics will be treated using mathematical models and practical programming exercises.

Course aims

The course aims at giving the students a quantitative understanding of the main processes in the hydrologic cycle. We will characterize the hydrologic cycle and its fluxes through mass balance equations. The random nature of the various processes will be studied with statistics, time series analysis, return periods, extreme value distributions, etc. We will take a “hands-on approach”, where students will actively engage with the material by analysing data and writing models using Python.

Learning outcomes

On successful completion of this module, students should be able to:

- Identify the various components of hydrologic budget and their interdependency.
- Describe the various processes in hydrology (precipitation, infiltration, evaporation, etc) in a mathematical language.
- Write computer code to analyze the statistics of hydrologic fluxes, and construct models of hydrological systems.

Books and other sources

- Dingman, S. L. (2015). Physical hydrology (3rd edition). Waveland press.
- Ward, A. D., & Trimble, S. W. (2003). Environmental hydrology. CRC Press.
- Brutsaert, W. (2005). Hydrology: An Introduction. Cambridge University Press.

Course evaluation

There will be some small projects during the semester, all worth 50% of the grade. A final and larger project (50% of the grade) will be due at the end of the semester. All projects will be done in Python (on Jupyter Notebooks).

Part I

Introduction

1 Water Cycle: Fluxes and Storage

<https://youtu.be/2ObMyytxLz8>

1.1 The natural water cycle (2019)

1.2 The new water cycle (2022)

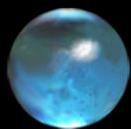
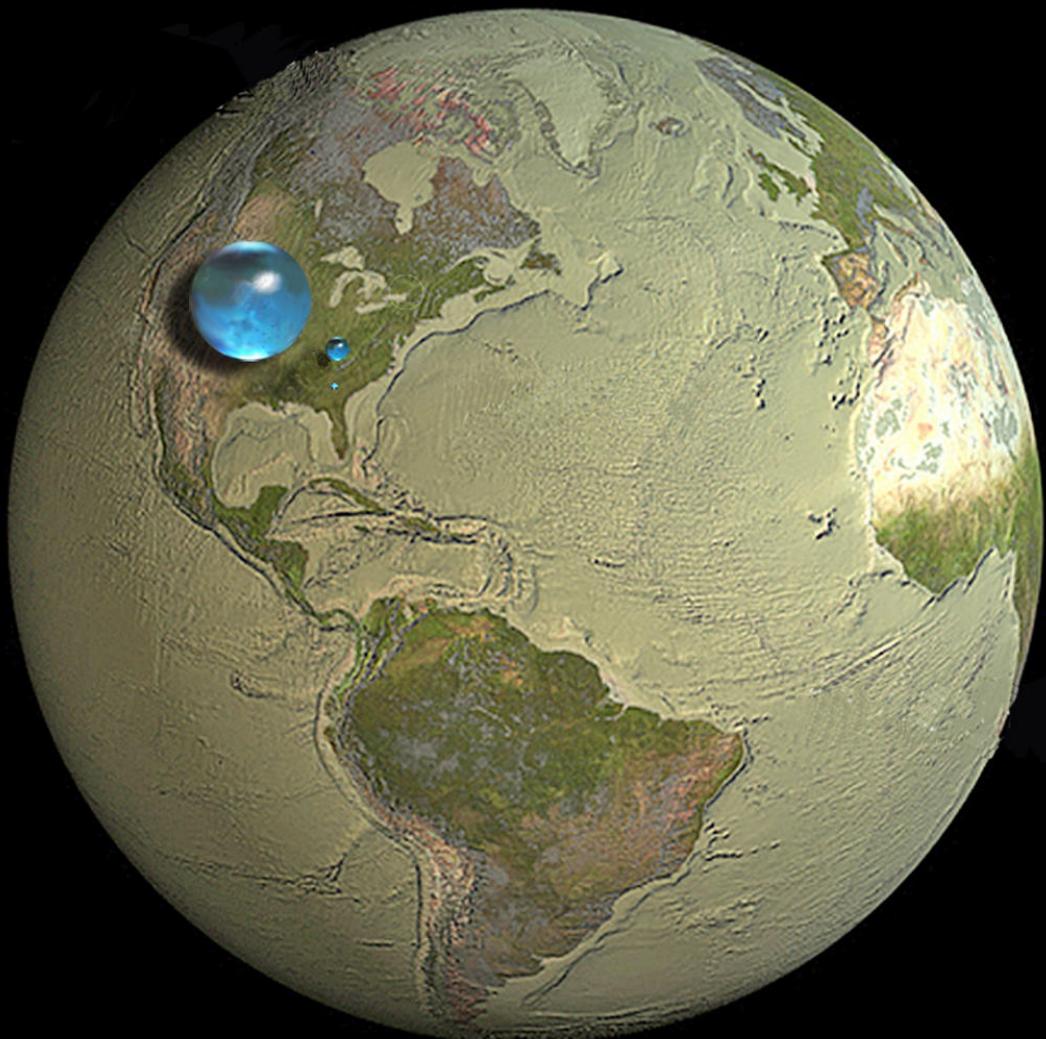
Interactive chart: Pools and fluxes in the water cycle

1.3 Global water distribution

Table 1.1: Source: Water Science School (2018). (**Percents are rounded, so will not add to 100**)

Water source	Volume (km ³)	% of freshwater	% of total water
Oceans, Seas, & Bays	1,338,000,000	—	96.54
Ice caps, Glaciers, & Permanent Snow	24,064,000	68.7	1.74
Groundwater	23,400,000	—	1.69
Fresh	10,530,000	30.1	0.76
Saline	12,870,000	—	0.93
Soil Moisture	16,500	0.05	0.001
Ground Ice & Permafrost	300,000	0.86	0.022
Lakes	176,400	—	0.013
Fresh	91,000	0.26	0.007
Saline	85,400	—	0.006
Atmosphere	12,900	0.04	0.001
Swamp Water	11,470	0.03	0.0008
Rivers	2,120	0.006	0.0002
Biological Water	1,120	0.003	0.0001

The World's Water

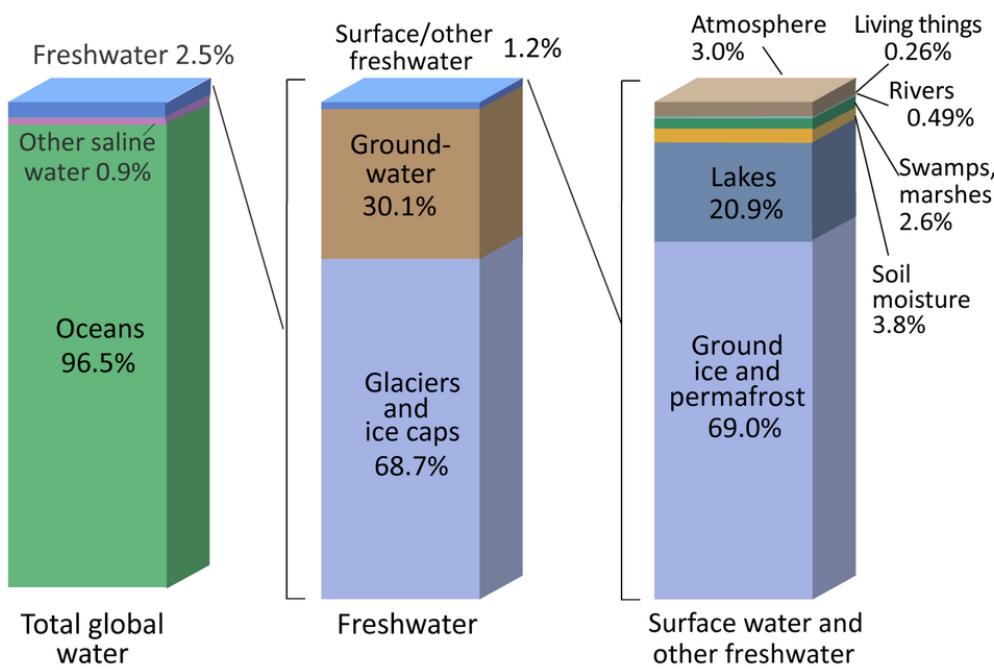


- All water on, in, and above the Earth
- Liquid fresh water
- Fresh-water lakes and rivers

Howard Perlman, USGS,
Jack Cook, Woods Hole Oceanographic Institution,
Adam Nieman
Data source: Igor Shiklomanov
<http://ga.water.usgs.gov/edu/earthhowmuch.html>

Figure 1.1: Source: Water Science School (2019c)

Where is Earth's Water?



Credit: U.S. Geological Survey, Water Science School. <https://www.usgs.gov/special-topic/water-science-school>
Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

Figure 1.2: Source: Water Science School (2018)

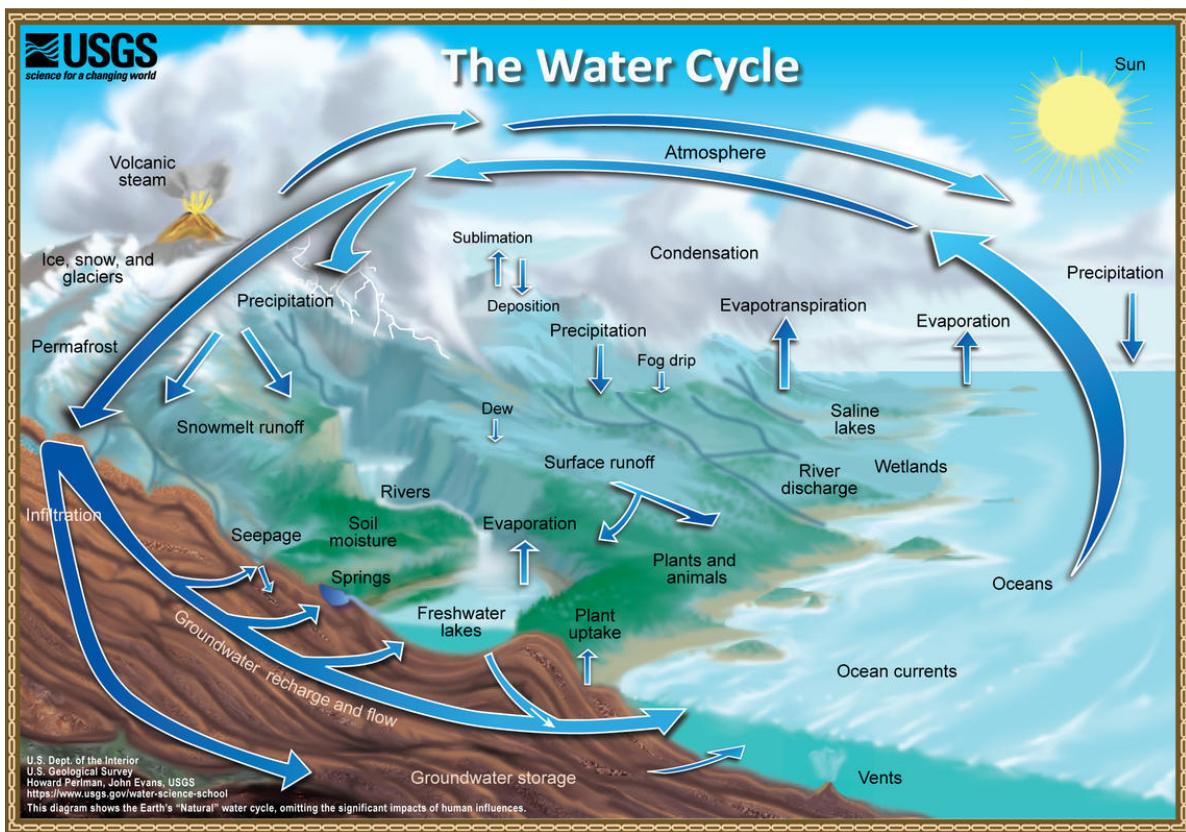
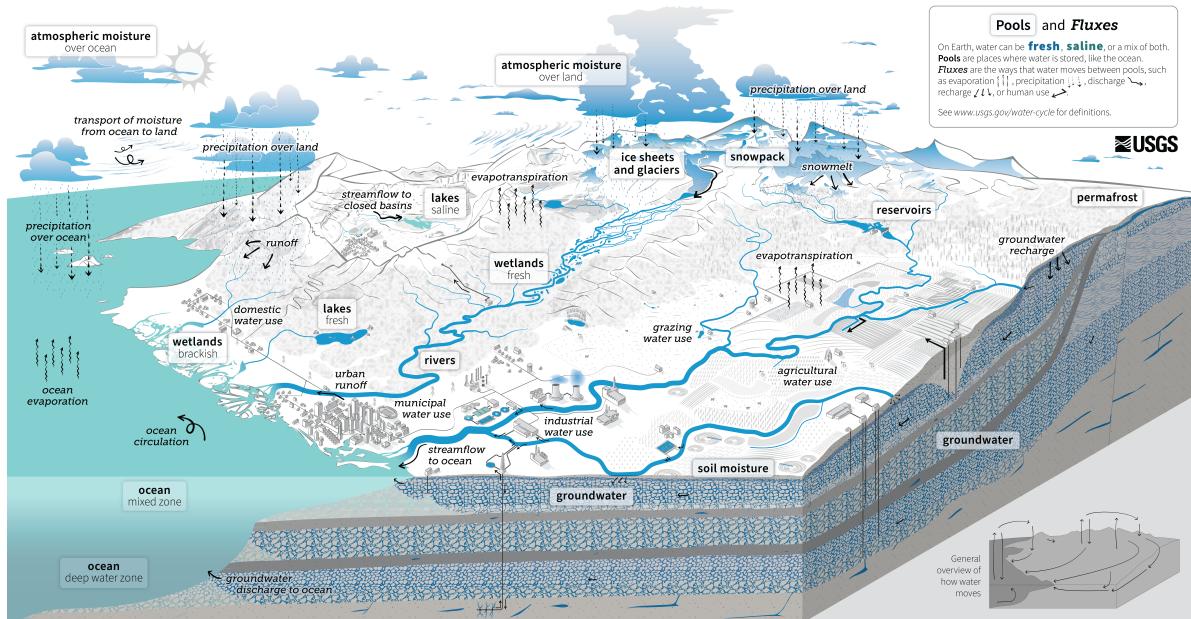


Figure 1.3: Source: Water Science School (2019g)



The Water Cycle

The water cycle describes where water is on Earth and how it moves. Water is stored in the atmosphere, on the land surface, and below the ground. It can be a liquid, a solid, or a gas. Liquid water can be fresh (saline), or salty, or briny. Water moves through many places. It's stored. Water moves at large scales and at very small scales. Water moves naturally and because of human actions. Human water use affects where water is stored, how it moves, and how clean it is.

Pools store water. 96% of all water is stored in **oceans** and is **saline**. Some water is stored in **lakes**, **rivers**, **wetlands**, **ice sheets and glaciers**, and in **snowpack** at high elevations or near the Earth's poles. Water vapor is a gas and is stored as **atmospheric moisture** over the oceans and land. In the air, fresh water is stored as **permafrost** and liquid water is stored as **soil moisture**. Deeper below ground, liquid water is stored as **groundwater** in aquifers, within cracks and pores in the rock.

Fluxes move water between pools. As it moves, water can move from the atmosphere, land, soil, and gas. **Circulation** moves water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the surface through **streamflow**, **runoff**, **urban runoff**, **municipal water use**, **industrial water use**, and **discharge in ocean**. In the air, fresh water is stored as **permafrost** and liquid water is stored as **groundwater recharge**. Underground, groundwater flows within aquifers. It can return to the surface through natural **groundwater discharge** into rivers, the ocean, and from **springs**.

We alter the water cycle. We redirect rivers. We build dams that store water. We drain wetlands and pollute them. We divert water from rivers, lakes, reservoirs, and groundwater aquifers. We use water to supply our **homes and communities**. We use it for **agricultural irrigation** and **grazing livestock**. We use it in **industrial** activities like hydroelectric power generation, mining, and desalination. The amount of water that is available depends on how much water is in each pool (water quantity). It also depends on when and how fast water moves (water timing), how much water we use (water use), and how clean the water is (water quality).

We affect **water quality**. In agricultural and urban areas, the waste products from humans and animals return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these sources, contaminated water can cause harmful algal blooms, dead zones, and human health concerns. Climate change is affecting the water cycle. It is affecting water quality, quantity, timing, and use. It is causing ocean acidification, sea level rise, and more extreme weather. By understanding these impacts, we can work toward using water sustainably.

Figure 1.4: Source: Water Science School (2022)

1.4 Energy drives the hydrologic cycle

From Margulis (2019)

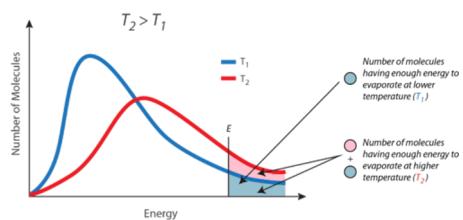
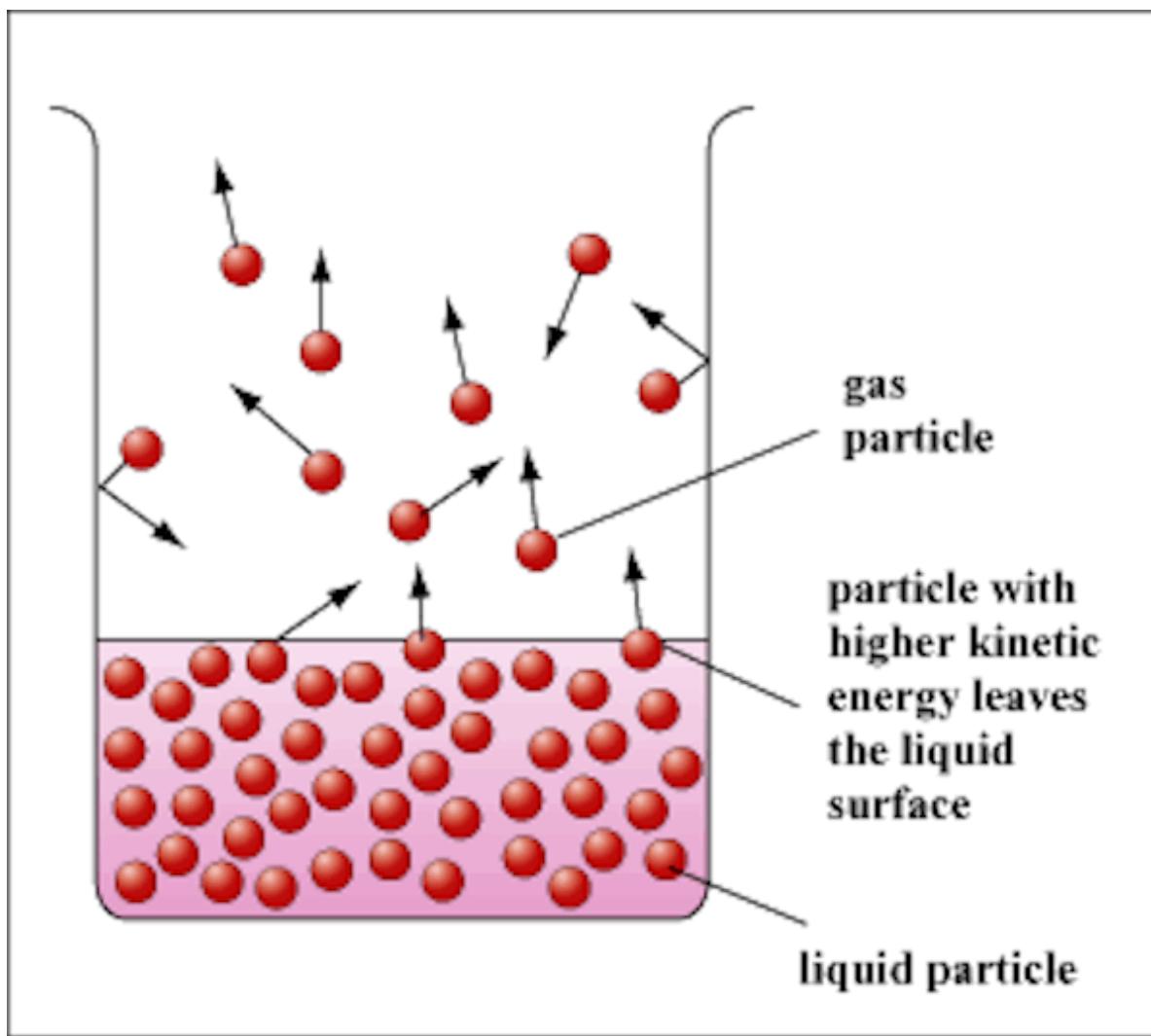
A key aspect of the hydrologic cycle is the fact that it is driven by energy inputs (primarily from the sun). At the global scale, the system is essentially closed with respect to water; negligible water is entering or leaving the system. In other words, there is no external forcing in terms of a water flux. Systems with no external forcing will generally eventually come to an equilibrium state. So what makes the hydrologic cycle so dynamic? The solar radiative energy input, which is external to the system, drives the hydrologic cycle. Averaged over the globe, 342 W m^{-2} of solar radiative energy is being continuously input to the system at the top of the atmosphere. This energy input must be dissipated, and this is done, to a large extent, via the hydrologic cycle. Due to this fact, the study of hydrology is not isolated to the study of water storage and movement, but also must often include study of energy storage and movements.

1.5 Components of the water cycle

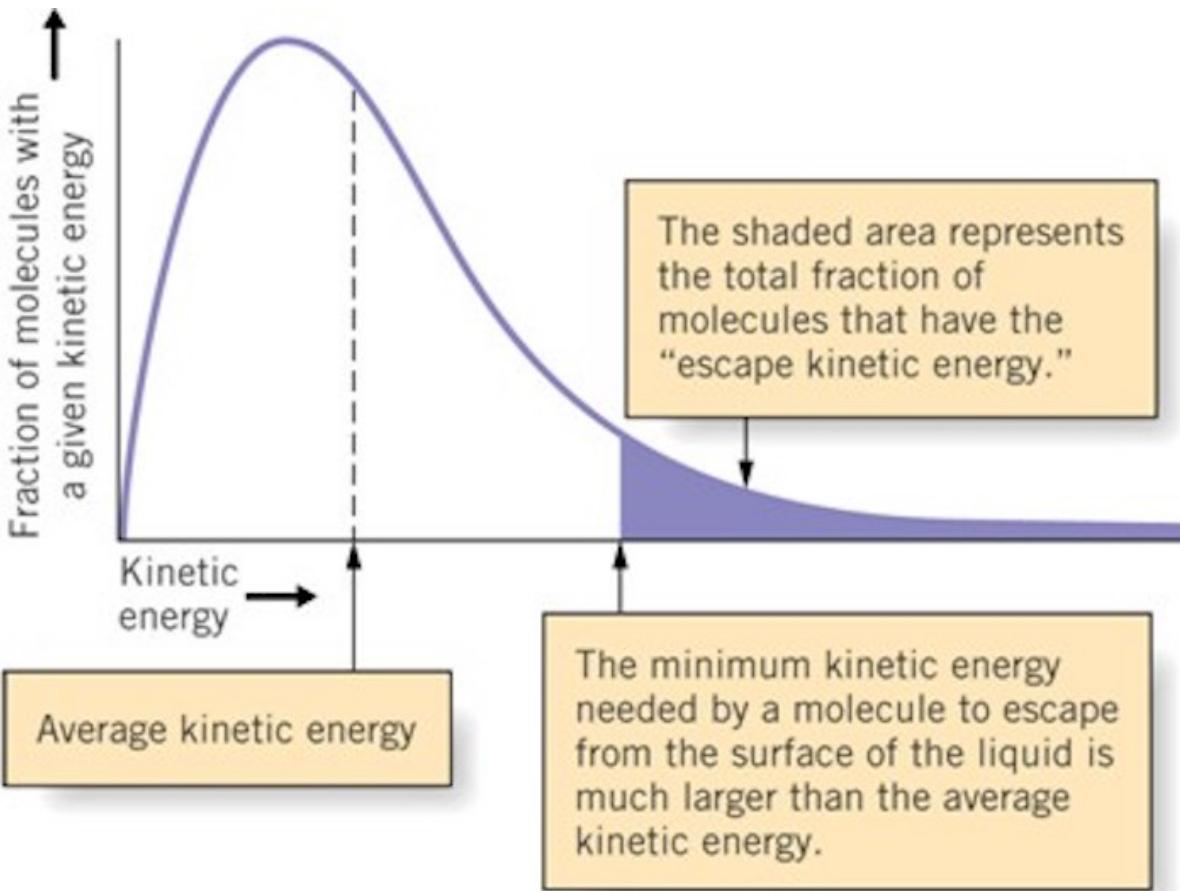
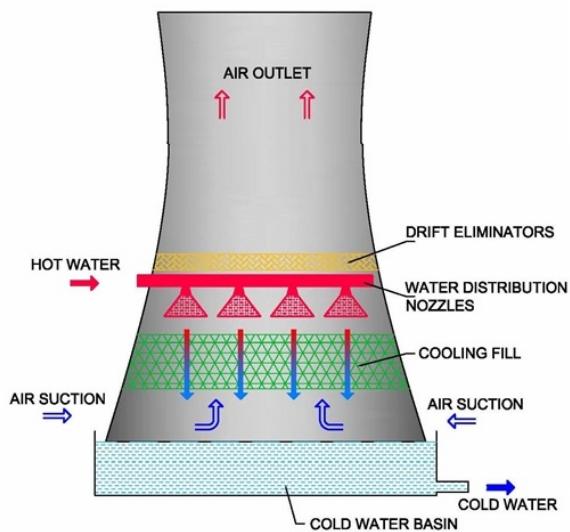
1.5.1 Water storage in oceans

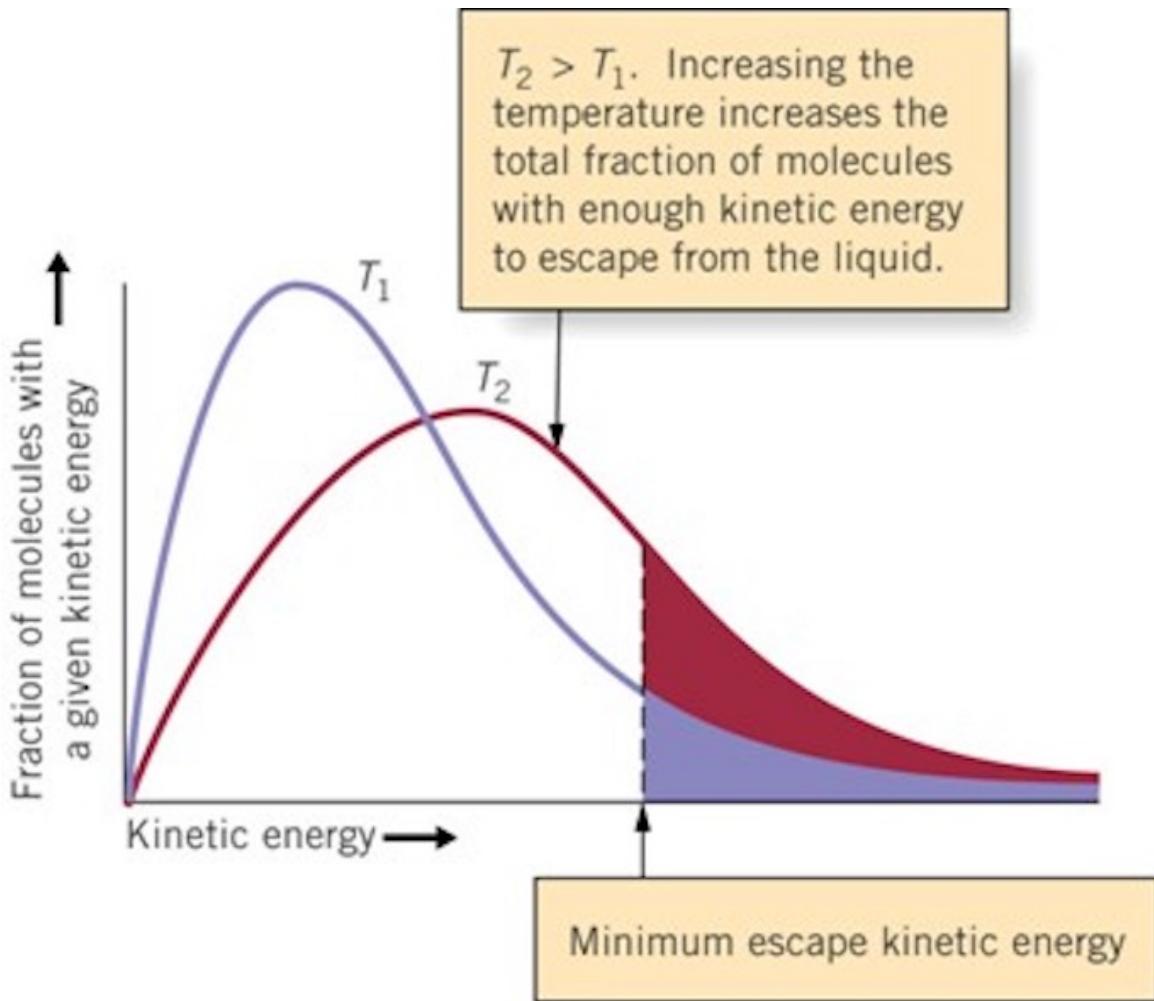
1.5.2 Evaporation / Sublimation

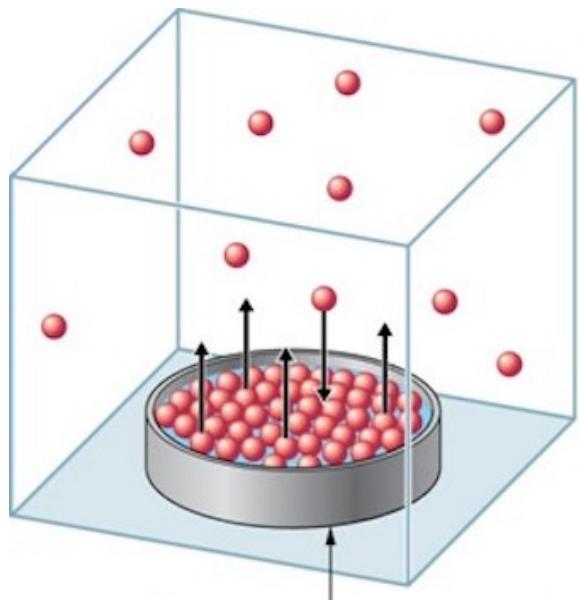
Evaporation → cooling



WET COOLING TOWER
NATURAL DRAFT

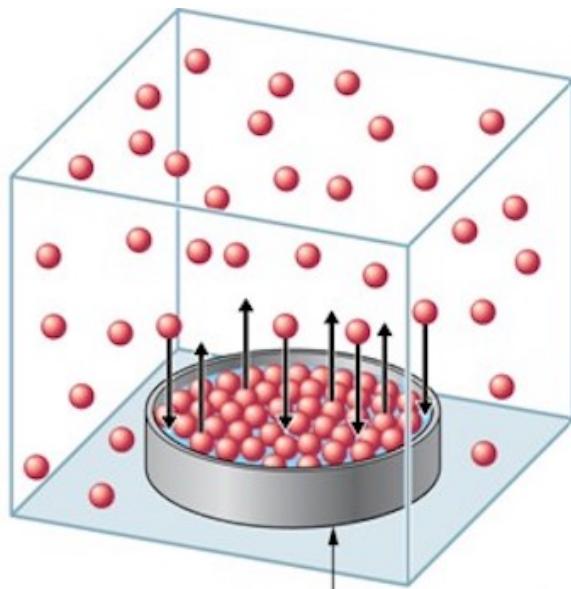






Before equilibrium:
Rate of evaporation is greater than the rate of condensation.

(a)



At equilibrium:
Rate of evaporation equals the rate of condensation.

(b)