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

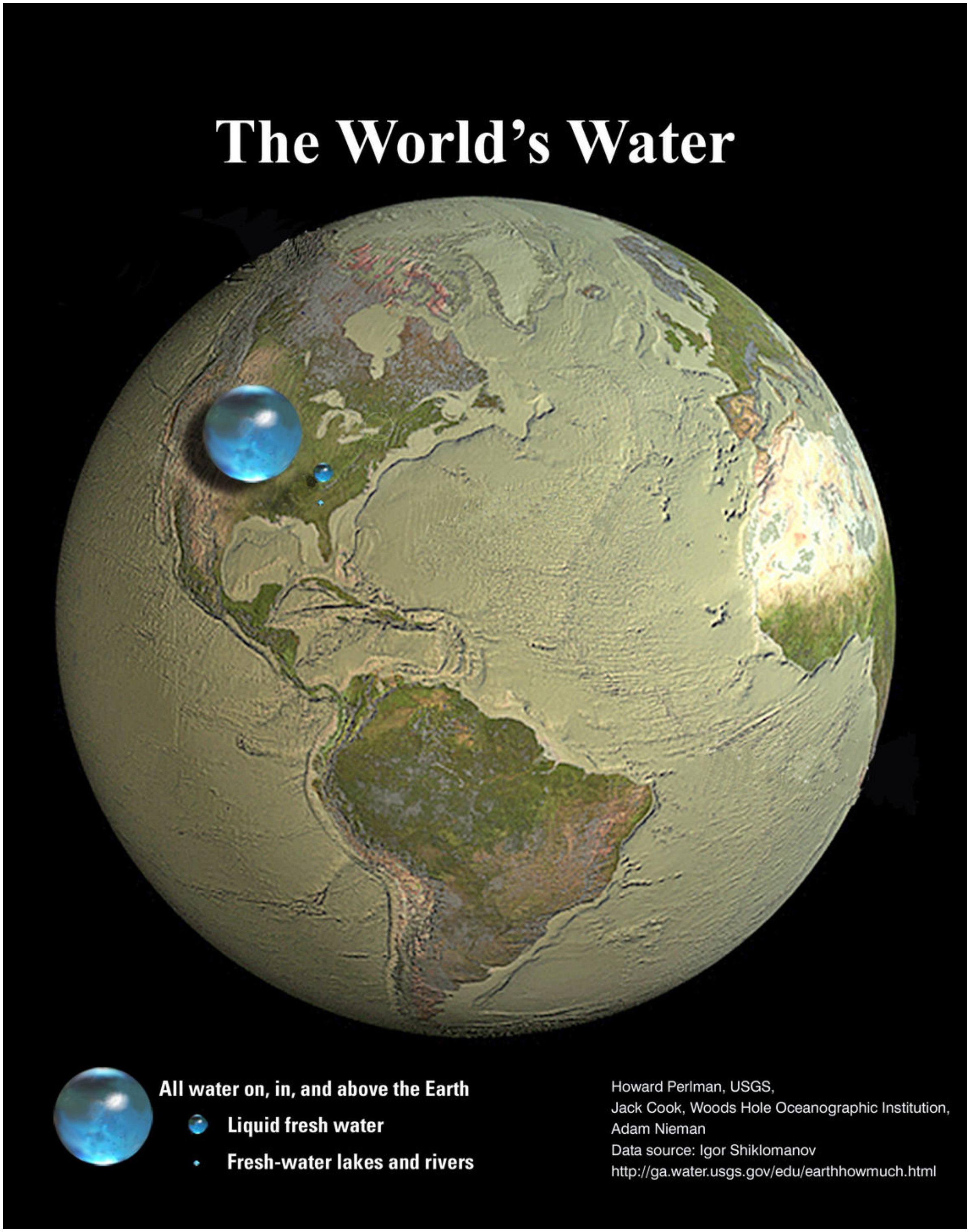


Figure 1.1: Source: Water Science School (2019c)

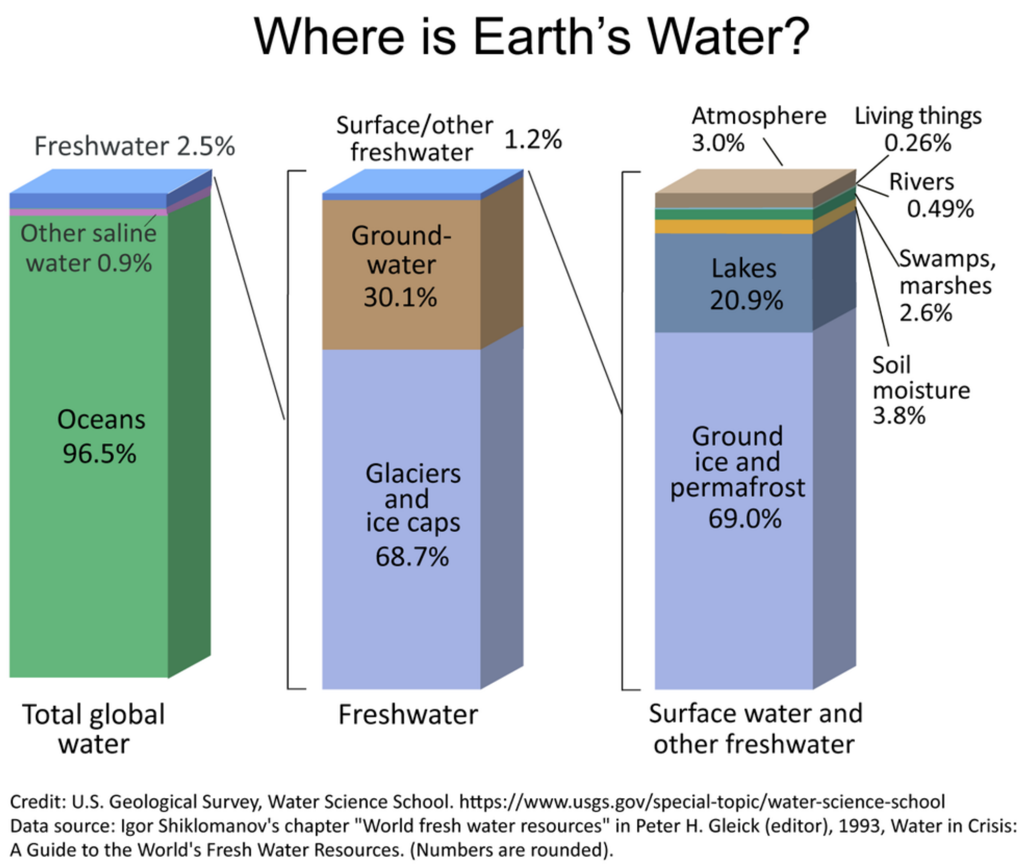


Figure 1.2: Source: Water Science School (2018)

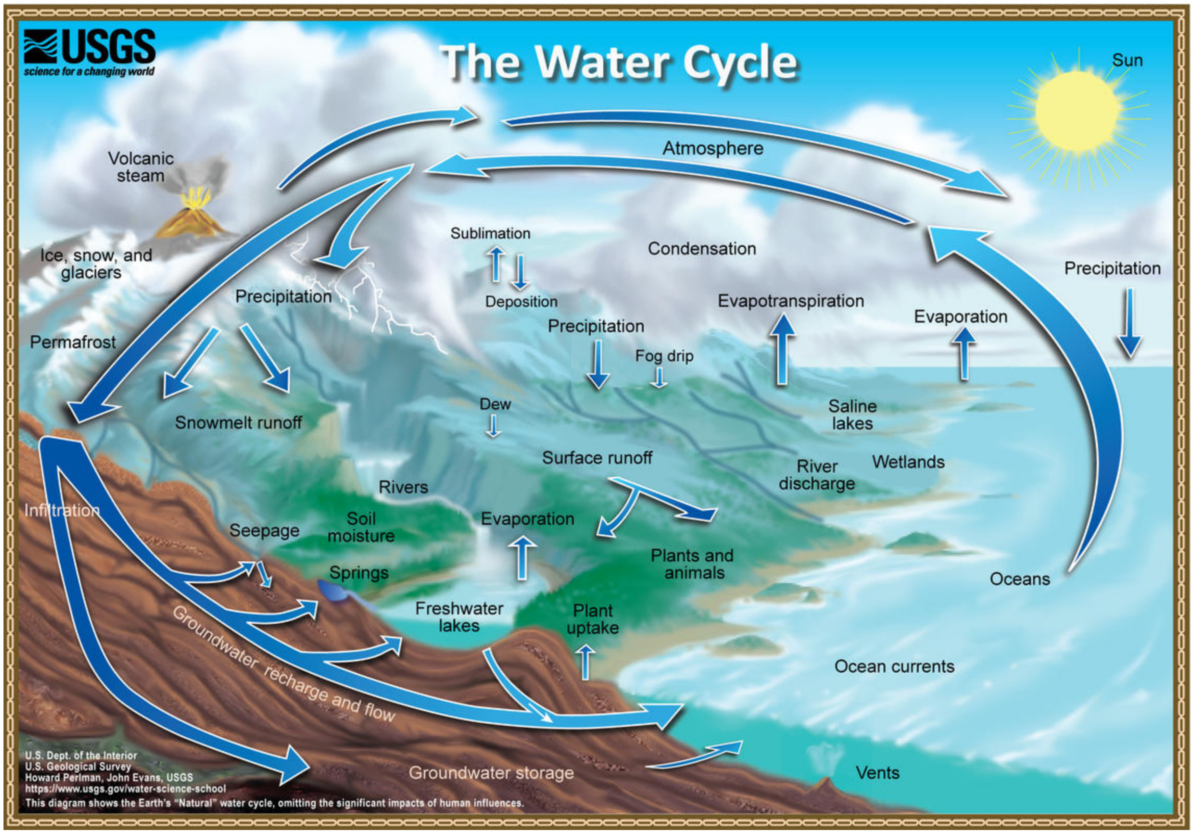


Figure 1.3: Source: Water Science School (2019g)

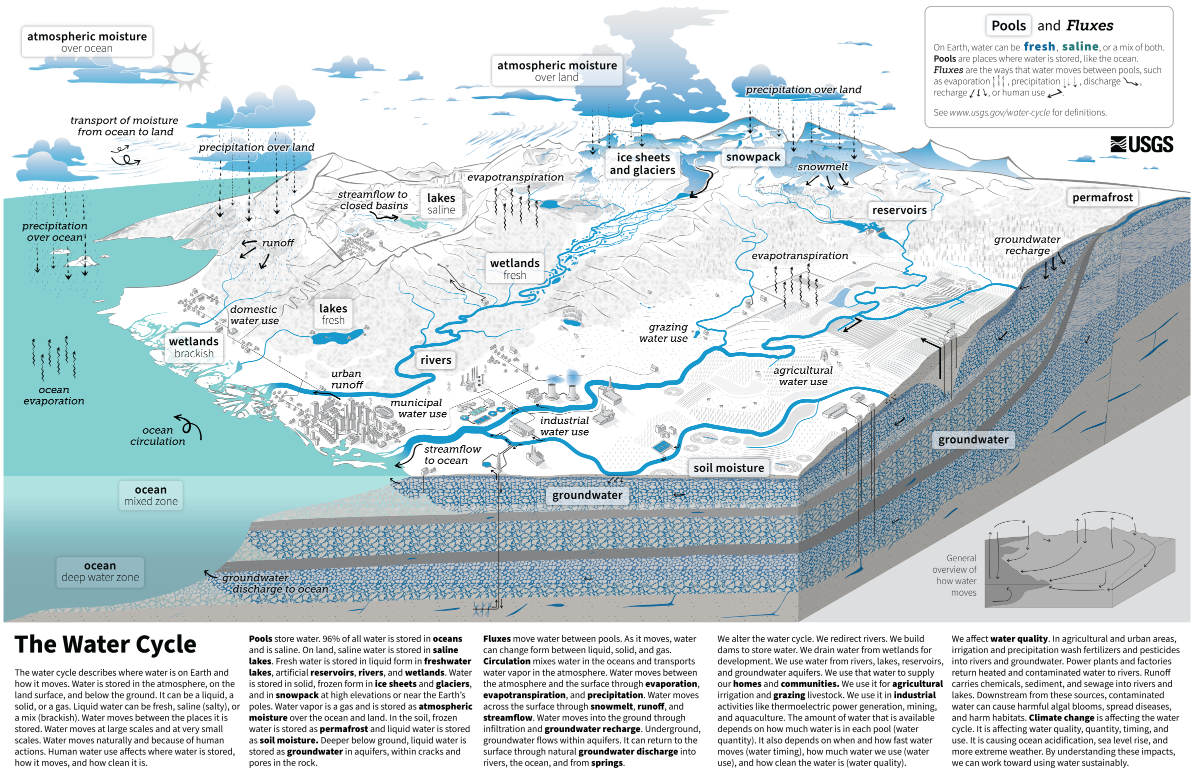


Figure 1.4: Source: Water Science School (2022)

1.4 Energy drives the hydrologic cycle

From Margulis (2019)

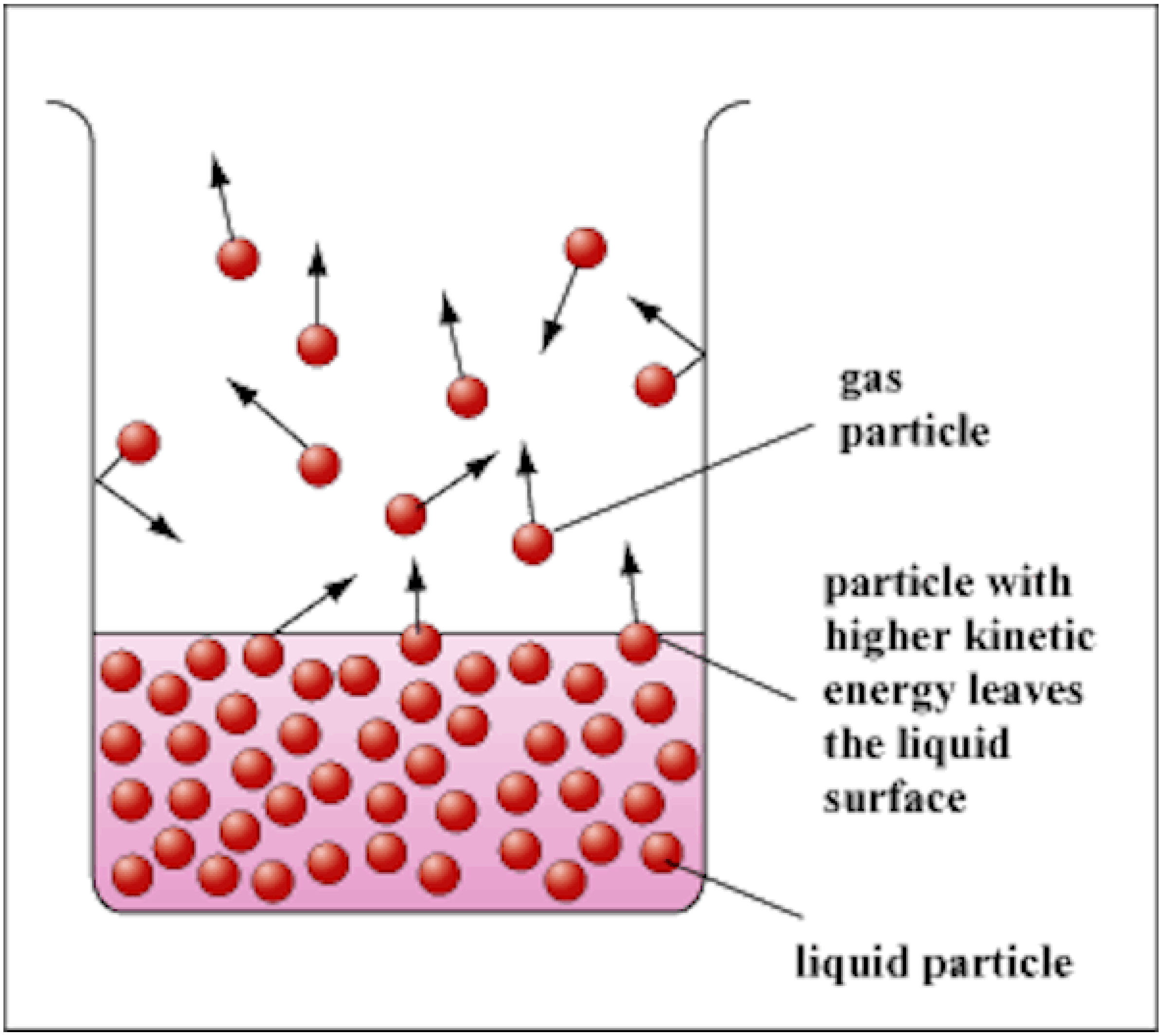
> A key aspect of the hydrologic cycle is the fact that it is driven by energy inputs (primarily from the sun). At the global scale, the system is essentially closed with respect to water; negligible water is entering or leaving the system. In other words, there is no external forcing in terms of a water 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.

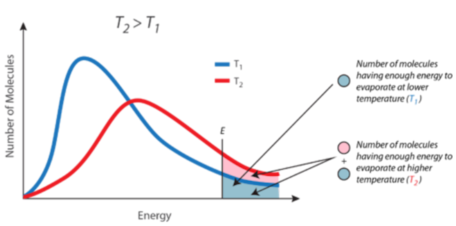
1.5 Components of the water cycle

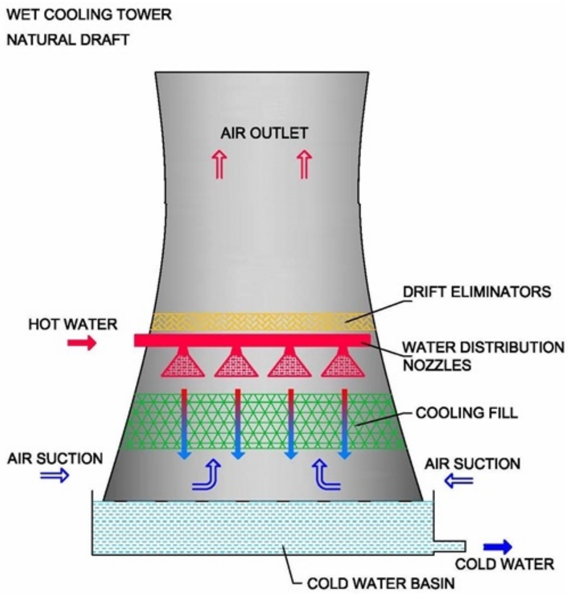
1.5.1 Water storage in oceans

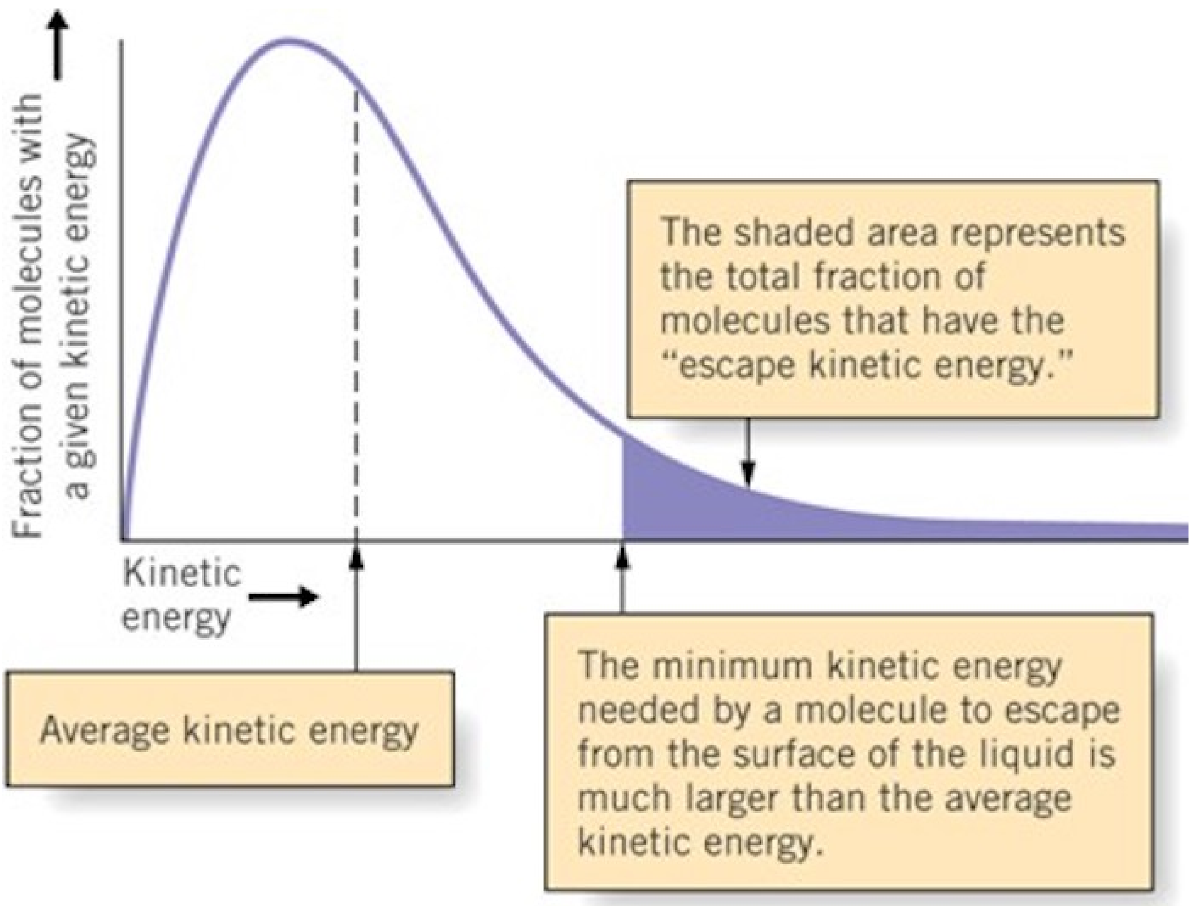
1.5.2 Evaporation / Sublimation

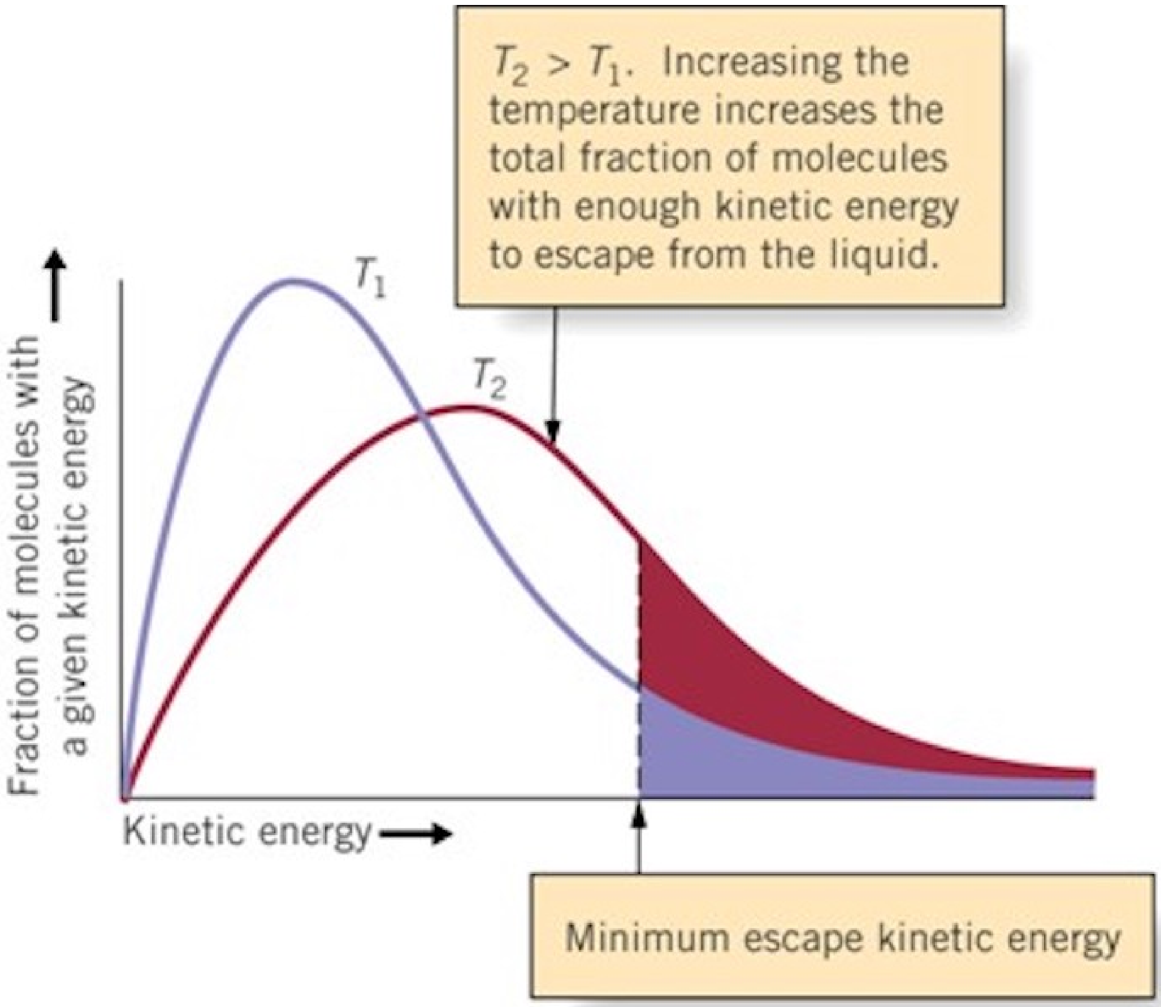
Evaporation $\longrightarrow$ cooling


gas particle
particle with higher kinetic energy leaves the liquid surface
liquid particle

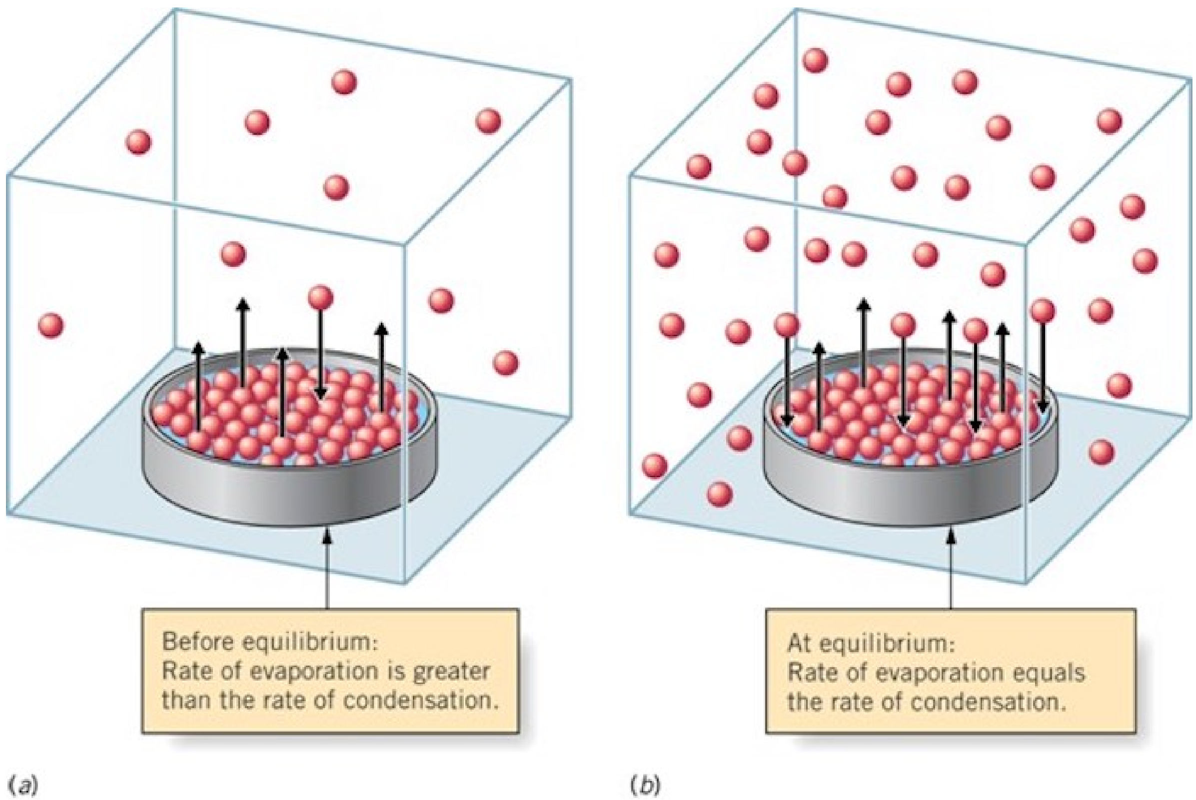

$T_2 > T_1$
Number of Molecules
Energy
T_1
T_2
E
Number of molecules having enough energy to evaporate at lower temperature (T_1)
Number of molecules having enough energy to evaporate at higher temperature (T_2)
+


WET COOLING TOWER
NATURAL DRAFT
AIR OUTLET
DRIFT ELIMINATORS
HOT WATER
WATER DISTRIBUTION
NOZZLES
COOLING FILL
AIR SUCTION
AIR SUCTION
COLD WATER
COLD WATER BASIN


Fraction of molecules with a given kinetic energy
Kinetic energy
The shaded area represents the total fraction of molecules that have the "escape kinetic energy."
Average kinetic energy
The minimum kinetic energy needed by a molecule to escape from the surface of the liquid is much larger than the average kinetic energy.



$T_2 > T_1$. Increasing the temperature increases the total fraction of molecules with enough kinetic energy to escape from the liquid.
T_1
T_2
Fraction of molecules with a given kinetic energy
Kinetic energy
Minimum escape kinetic energy


Before equilibrium:
Rate of evaporation is greater
than the rate of condensation.
(a)
At equilibrium:
Rate of evaporation equals
the rate of condensation.
(b)