Enhancing the local water cycle via evaporation for a sustainable water supply

Gholamabbas Sadeghi

gsad@wetsus.nl

Motivation

Solar radiation is absorbed by the Earth's surface. Part of it is lost as sensible heat (warming the atmosphere), and another part as latent heat (evaporation) [1]. Fig. 1(a) shows a schematic of the natural water cycle, in which the water evaporates by sunlight, moves upwards, forming condensation clouds, and finally precipitates to complete the cycle. Higher atmospheric temperatures lead to drought. Even though evaporation increases due to the increased water-carrying capacity of air, condensation/precipitation no longer occurs because the point of saturation is not reached anymore. This is often the problem in semi-arid areas of high(er) temperature. The water cycle can be enhanced by promoting evaporation and inhibiting the warming of the atmosphere. Here we explore technology to maximize the sun's radiant energy transformation, using a so-called solar simulator into water evaporation while reducing sensible heat production. In order to improve the evaporation performance and lower the sensible heat transferred to the environment, a solar absorber can be customized [2] as indicated in Fig. 1 (b).

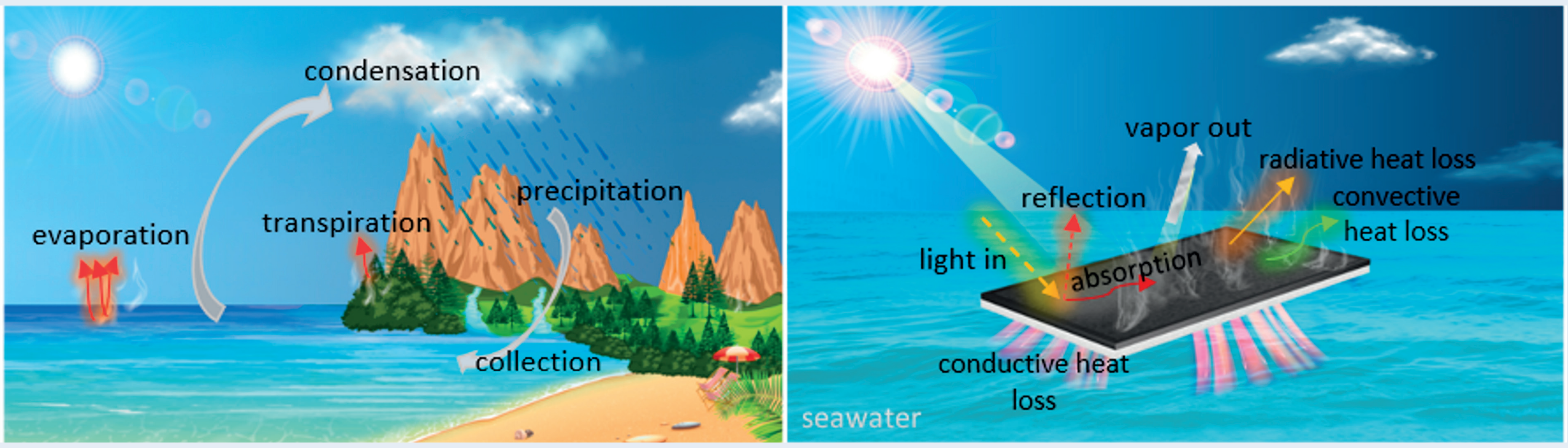

Fig. 1. (a) Schematic of the natural water cycle including evaporation from seawater, transpiration from plants, forming clouds as condensation, and precipitation to enrich watersheds, b) energy balance of a direct solar steam generator (DSSG) throughout the input light to the vapor generation processes indicating the involved energy interactions.

Technological challenge

In terms of solar evaporation efficiency, the latent heat production in Fig. 1(a) is far from optimal. One reason is that part of the incident light on the sea surface is used to warm up the bulk water underneath by means of conduction. This energy is later released as radiative heat loss (infrared bypass radiation) warming the atmosphere. To remedy this energy loss, localized heating will be exploited. The primary challenge is to ensure minimal radiative heat loss (infrared bypass radiation) from the solar evaporator despite a highly efficient light absorption property. The experimental setup is further composed of a concealed light simulator, a light absorber immersed in water, thermocouples to monitor the temperature along the entire system, and a balance to record the evaporation rate. Challenges ahead include mimicking solar radiation regarding light quality and light intensity, effective water transport from bulk to the surface of the light absorber, and mitigation of salt deposition. Research lines of the ongoing project include different desalination-evaporation geometries as well as investigation of the effect of different environmental conditions like wind speed.

Research goal

This project aims to regreen deserts in semi-arid areas by providing sufficient water for agriculture. It is foreseen that in the final stage, the vegetation itself restores the local water cycle. In general, the major goals of this research can be summarized as:

- The design and building of an efficient solar simulator to mimic sunlight.
- Optimizing a direct solar steam generation (DSSG) material that absorbs low-wavelength light but has a low emissivity of high-wavelength radiation.
- Designing an integrated desalination device.
- The evaluation of the (large-scale) device in terms of impact applying atmospheric boundary layer (ABL) modeling.

References:

[1] NASA (2022). "earthobservatory.nasa.gov/features/Energy Balance/page5

[2] Liu, X., et al. (2020). "Towards highly efficient solar-driven interfacial evaporation for desalination." Journal of Materials Chemistry A 8(35): 17907-17937

G. Sadeghi Eng.D, prof.dr.ir. B. Hamelers
dr.ir. S. Porada PhD, dr.ir. H. Miedema PhD

wetsus european centre of excellence for sustainable water technology

UPPWATER Dutch water tech

SBO-instituut Dutch Institute for Strategically Important Research

WAGENINGEN UNIVERSITY & RESEARCH