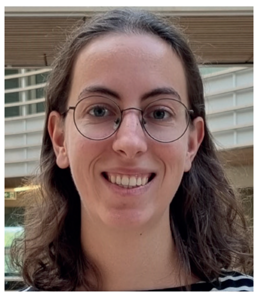
Identifying meteorological pathways for more rain in dry areas through Enhanced Atmospheric Moistening



Sarah Warnau

sarah.warnau@wetsus.nl

Motivation

Freshwater scarcity is a pressing global issue, driven by several processes, including land use change, global warming and regional climate change, and the increase in demand due to population growth. Water conservation strategies play an important role in alleviating the stress on the freshwater resources. However, there is a point where these measures alone may be insufficient. In certain regions, there is a fundamental scarcity of freshwater. In these situations, an input of freshwater is needed. With the Natural Water Production theme at Wetsus, we are looking into ***Enhanced Atmospheric Moistening (EAM) by efficiently evaporating sea water with the goal of enhancing rain regionally as a new way of increasing freshwater availability.***

Technological challenge

The state of the atmosphere is driven by large scale systems (synoptic) and diurnal and seasonal changes in incoming solar radiation, affecting the regional energy and water balances, and thus the evaporation rate of the technology. This affects the growth and the composition of the Atmospheric Boundary Layer (ABL), the lowest layer in the atmosphere that is directly affected by the surface of the earth. For clouds to form and develop two levels need to be reached:

- First, moist air parcels from the surface need to be lifted to reach their lifting condensation level, where droplets can form.
- Second, the level of free convection needs to be reached for clouds to deepen and become rain clouds (Fig. 1).

There are two important mechanisms to lift a moist parcel (Fig. 2):

- Convection and growth of the ABL, and
- Lifting of the ABL, e.g. by passing over a mountain range.

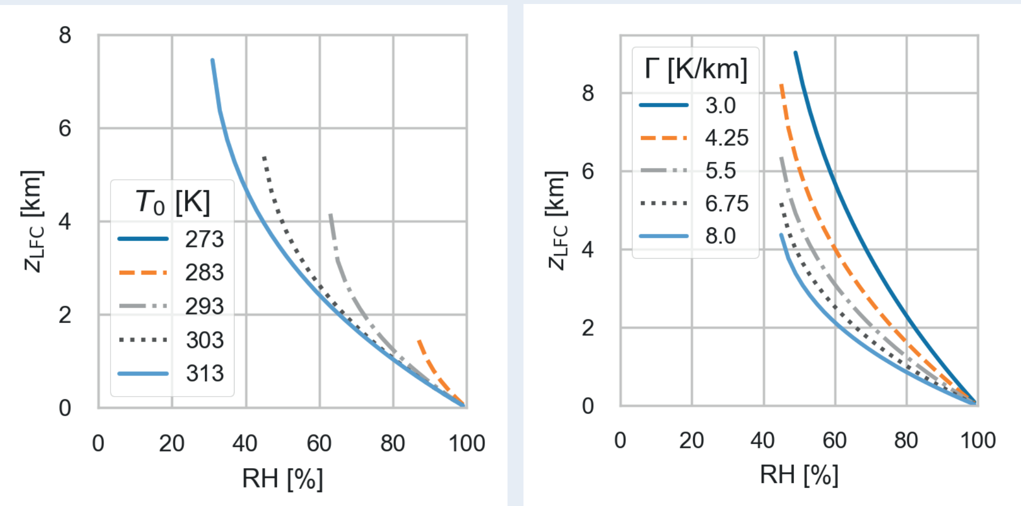


Fig 1. The height of the Level of Free Convection (zLFC [km]) as a function of relative humidity (RH [%]) at the surface, for different linear profiles of tempearture for the Free Atmosphere (FA) without a boundary layer: $T_{FA}(z) = T_0 - \Gamma z$. On the left: LFC for different surface temperatures (T0 [K], Γ=6 K/km). On the right: LFC for different lapse rates (Γ [K/km], T_0=303 K). Not all conditions result in an LFC, e.g. the temperature must be high enough. Furthermore, a more stable atmosphere (lower Γ) will cause the LFC to be higher and thus more difficult for moist air from the surface to reach. With EAM we aim to increase the RH to lower the LFC.

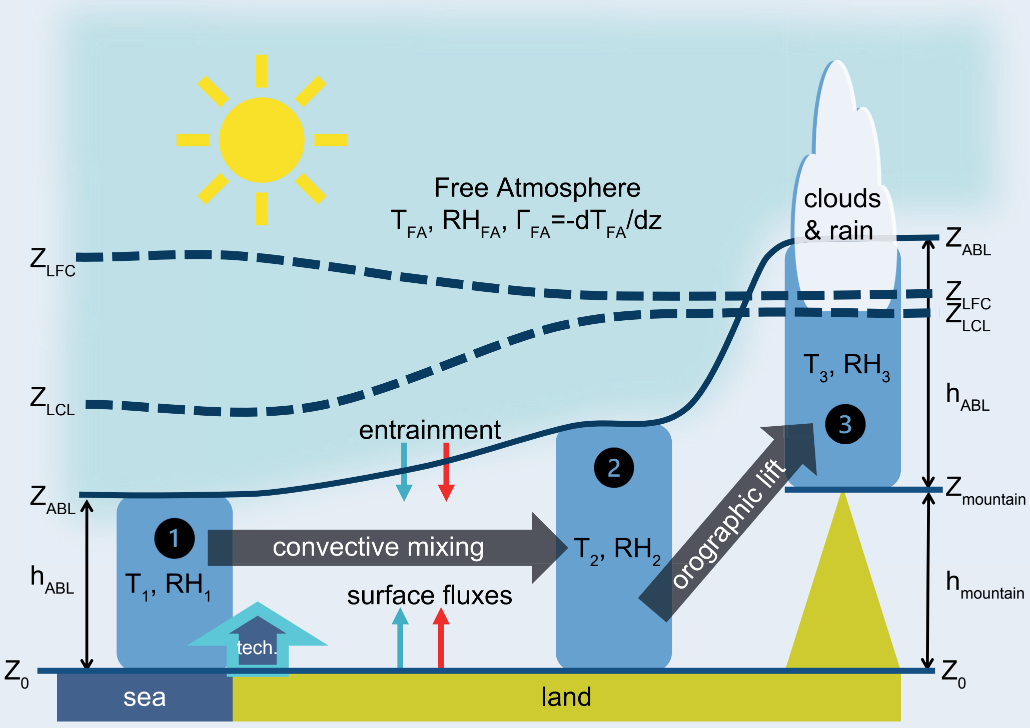


Fig 2. Schematic of the passing and development of an Atmospheric Boundary Layer (ABL) through a watershed bordered by the sea on the left and a mountain range on the right. The temperature (T) and relative humidity (RH) of the ABL change over time because of heat and moisture fluxes from the surface and entrainment of relatively warm and dry free atmospheric air (situation 1 to 2). T and RH change furter because of adiabatic expansion through lifting, in this case orographic lifting (situation 2 to 3). Because of the changes in the ABL properties, the Lifting Condensation Level (LCL) and the Level of Free Convection (LFC) can go up or down. Using an evaporation technology (blue arrow, tech.) to moisten the ABL at the right time under the right atmospheric conditions can enable the ABL to reach the LCL and LFC and deep convective rain clouds to form.

Using an evaporation technology can not only affect the moisture content of the ABL, but also the temperature and stability (Fig. 1). This interaction between the meteorological conditions and the evaporative flux of the technology make the design and implementation of EAM for more rain a challenge. On top of that, the atmospheric response to EAM in the form of rainfall (more rain, less rain, or no response) depends on the location, the daily conditions, and the type of technology that is used for evaporation.

Research goals

The goal of this project is to understand the atmospheric conditions and processes that determine how EAM with a technology for regional rainfall enhancement can be succesful. With this knowlegde we can

- improve the design of the technology for specific conditions,
- determine suitable locations where the probability of success is large, and
- design a control strategy for the technology. Since not all days are suitable for EAM to enhace rainfall, we need to be able to timely determine if the technology should be "switched on" and how much water vapor is needed for the best results.

UPPWATER Dutch water tech

SBO-instituut Dutch Institute for Strategically Important Research

prof.dr.ir. H.V.M. (Bert) Hamelers,
dr.ir. C.C. (Chiel) van Heerwaarden, dr. I.B. (Imme) Benedict

WAGENINGEN UNIVERSITY & RESEARCH