Evapotranspiration (ET) enhanced by advection in the Atacama Desert, ET-DATA field experiment

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MOTIVATION

- In arid regions ET exceeds precipitation, compromising the water availability.
- Models underestimate ET because physical processes occurring at scales smaller than the grid size.
- We hypothesize ET depends on the interaction between large scale circulation and local conditions (Fig 1).
- Our goal is to describe and quantify the physical processes that control ET in arid regions characterized by heterogeneous surfaces.

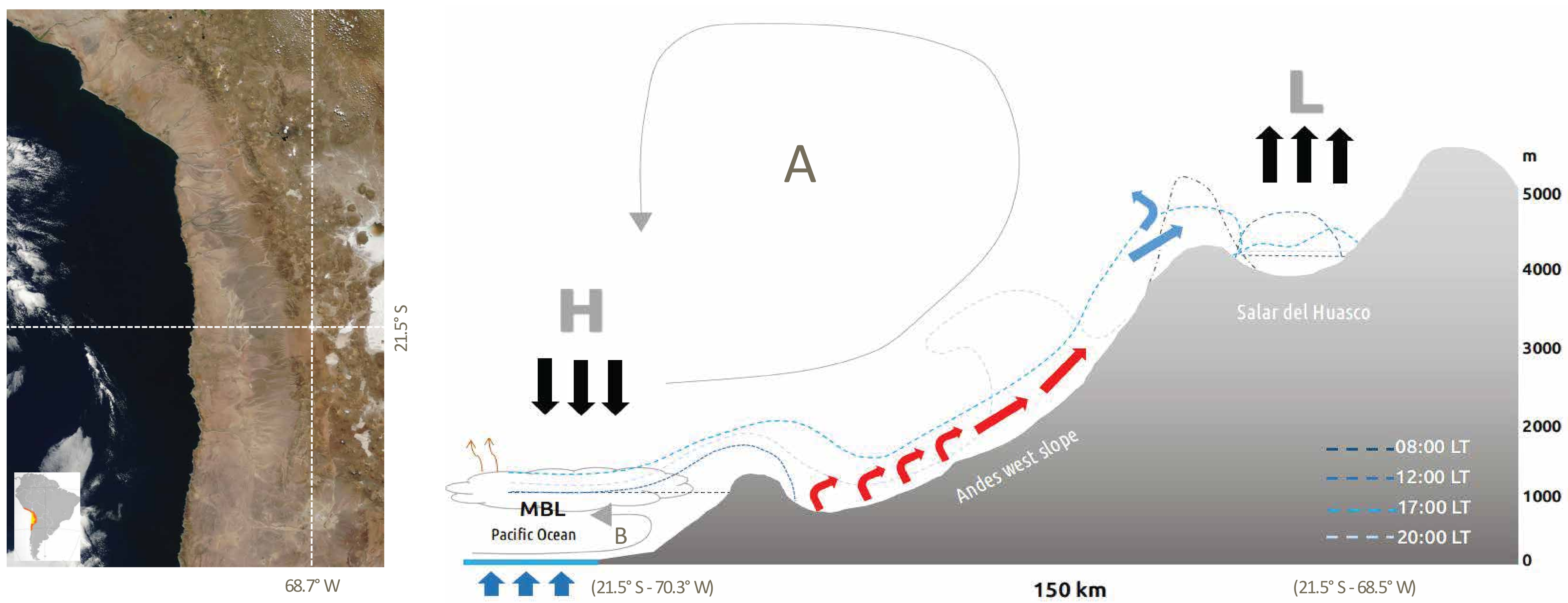
Fig 1. Regional circulation between the Pacific Ocean and Andes west slope. Local circulation at Salar del Huasco

APPROACH

- Weather Research and Forecasting Model (**WRF**) for analyzing the regional circulation.
- Fieldwork experiment performed for 10-days in Nov-2018 at Salar del Huasco, (21.5 °S - 68.5 °W). **ET** by **D**ry **A**ir **T**ransport over the **A**tacama Desert (ET-DATA), that combined horizontal and vertical high-resolution measurements for analyzing local conditions.

WE AIM TO UNDERSTAND:

1. The influence of regional circulation on the ET diurnal cycle.
2. ET dynamic over heterogeneous surfaces.
3. The physical interactions between the processes that drive the ET evolution .



1 . REGIONAL CIRCULATION

Our results confirm the main regional circulation described by Rutllant et al 2003 and Muñoz et al 2018, but also contribute to new findings of its influence on a local scale (Fig 1).

- Reinforcing of cell A (Fig 1) by anabatic wind (Fig 2b).
- Moisture transport (sea breeze) from above MBL (B) to Andes west slope, reaching the highlands (Fig 2d).
- Heterogeneous moisture transport due to the topographic channeling.

Regional circulation influence results in two wind regimes:

1. Local: dominated by local circulation during the morning. Slow windspeed and random direction.
2. Regional: dominated by larger-scale circulation during the afternoon. High wind speed and W-SW direction.

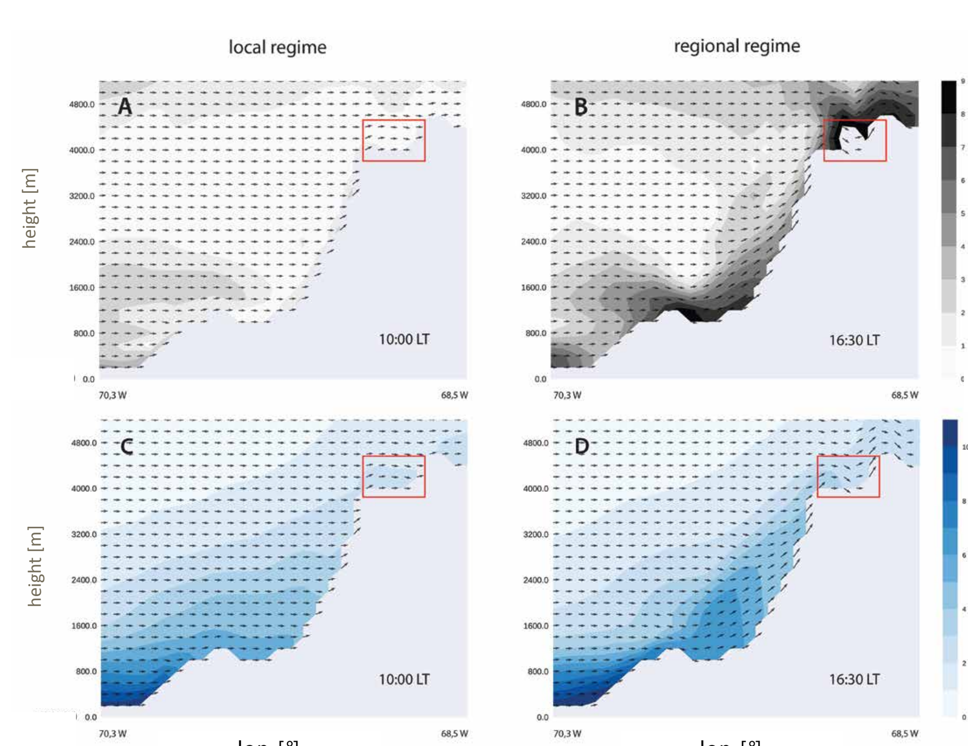


Fig 2. WRF vertical cross section from 21.5°S - 70.3°W to 21.5°S - 68.5°W for November 2018. (a, b) Wind speed and direction in the morning and afternoon. (c, d) Specific humidity transport in the morning and afternoon.

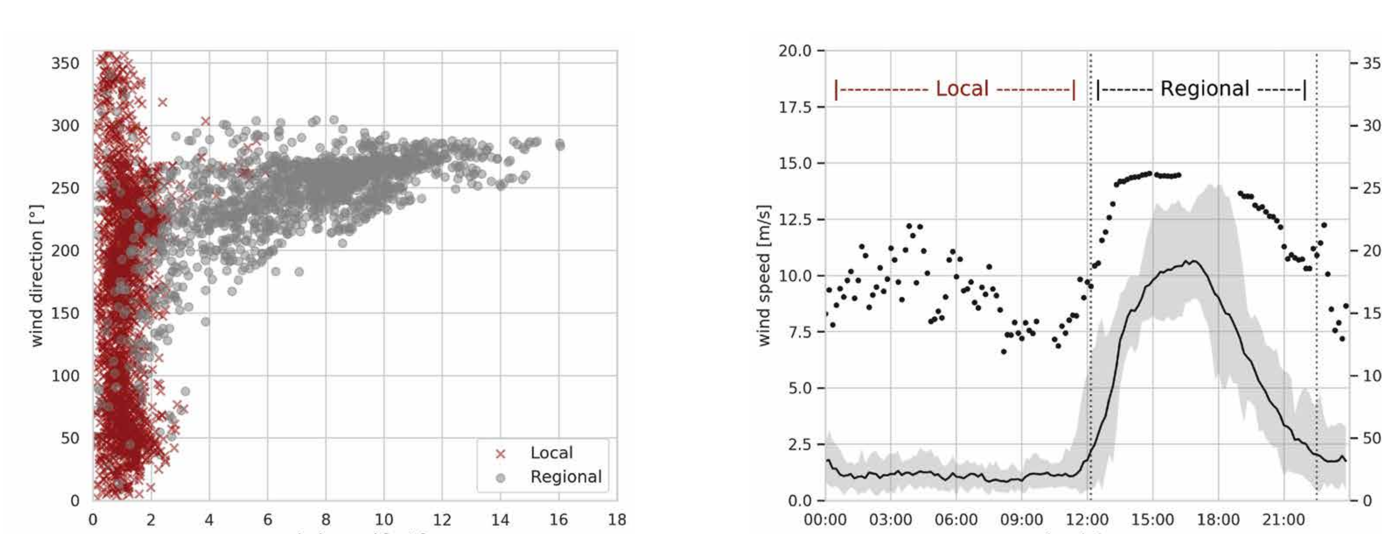


Fig 3: Wind regimes classified from observations. (a) The relation between wind direction and wind speed. (b) Diurnal cycle of wind speed (solid lines and shade) and wind direction (dots), same regimes are shown.

2 . LOCAL CONDITIONS

Turbulent fluxes behave differently over heterogeneous desert surfaces, being challenging to represent them realistically.

- Available energy (Rn) to evaporate seems to be enough in all cases but does not follow the same diurnal cycle than its partition.
- Evaporation rates (~LE) are very high over the water, very low at wet-salt and almost null at the desert surface.
- In all cases, ET (~LE) occurs during the regional regime, from 12:00 LT.

During the regional regime, the atmospheric boundary layer (ABL) structure shows an extreme change in its growth. ABL height decreases due to the entrance of cold and moist air.

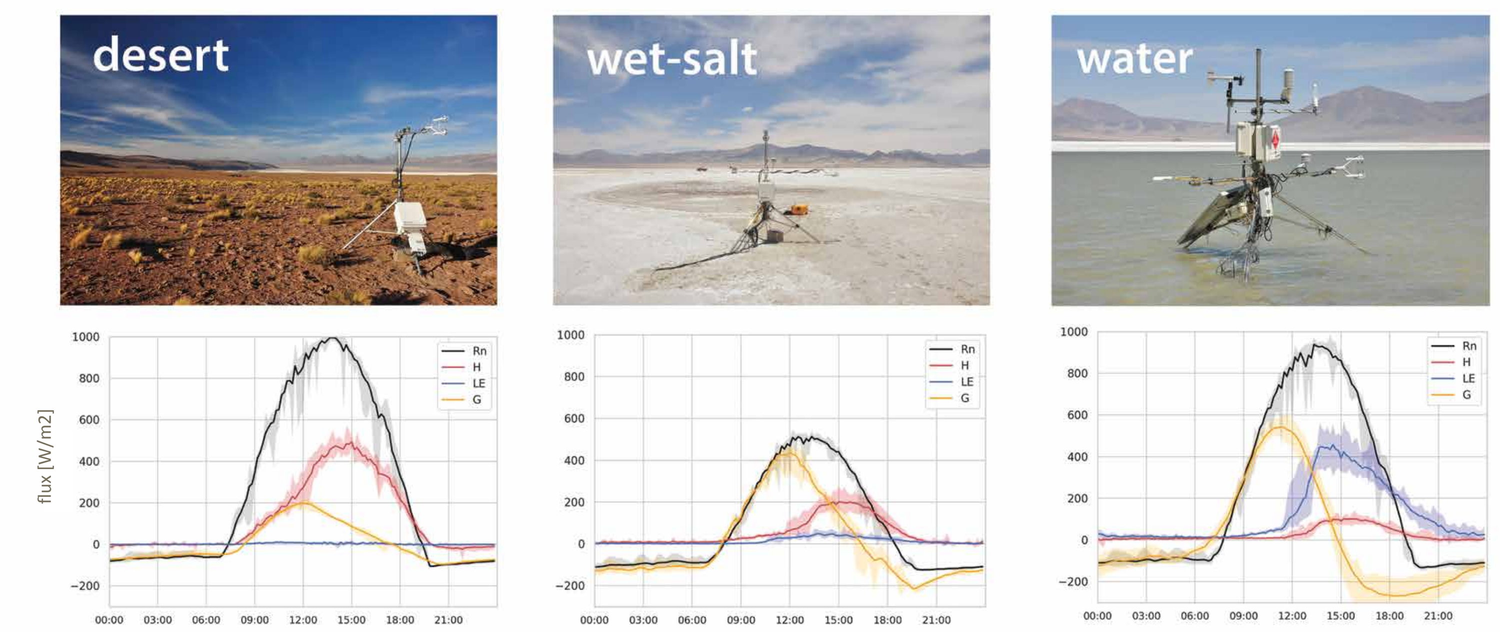
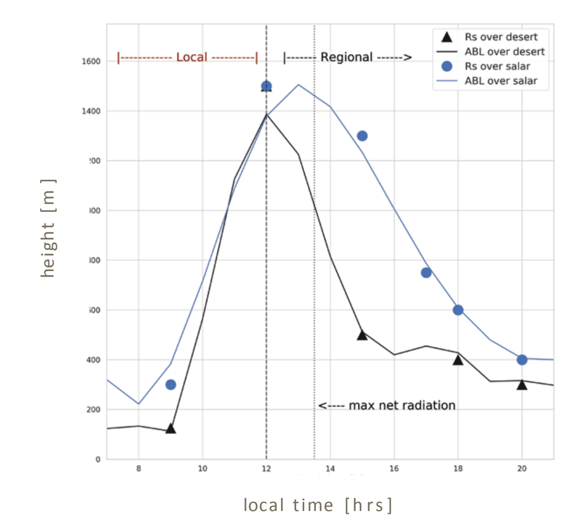


Fig 4: First row: Surface where the Eddy Covariances were installed. Second row: Mean diurnal cycle of surface turbulent fluxes over different surfaces; net radiation (Rn), sensible heat flux (H), latent heat flux (LE) and ground heat flux (G)



- Vertical observations show a different development of internal boundary layers, which grow separately. These internal boundary layers reach a similar mixing at 12:00 LT, coinciding with the regime change. The maximum growth is decoupled from the radiation peak.

Fig 5: ABL height diurnal cycle. Triangles and dots show radiosonde (RS) measurements over the desert and the Salar. The solid line shows the diurnal evolution of the ABL growth from a interpolation of measurements.

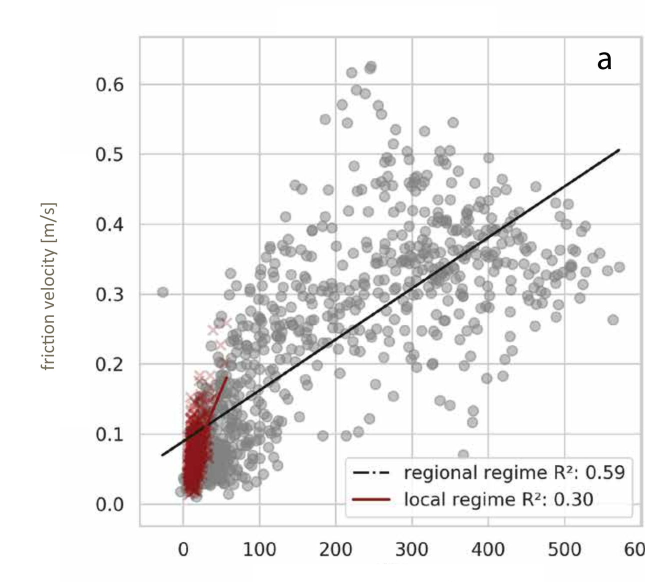
3 . INTERACTIONS

The interaction between regional circulation and surfaces fluxes, change the mixing conditions on the ABL, enhancing the ET. This interaction might be given by the friction velocity (turbulence), surface layer gradients and the net radiation.

- We confirm the regional influence on ET since R^2 higher in regional than local regimes (Fig. 6a and 6b).
- Eq1: Moisture gradients (Δq) and friction velocity (U*) during the regional regime seem to control ET dynamic (Fig. 6a and 6b).
- Eq2: Radiation does not show a clear control over the ET, because of the lag of ET in the diurnal evolution (Fig. 6c).

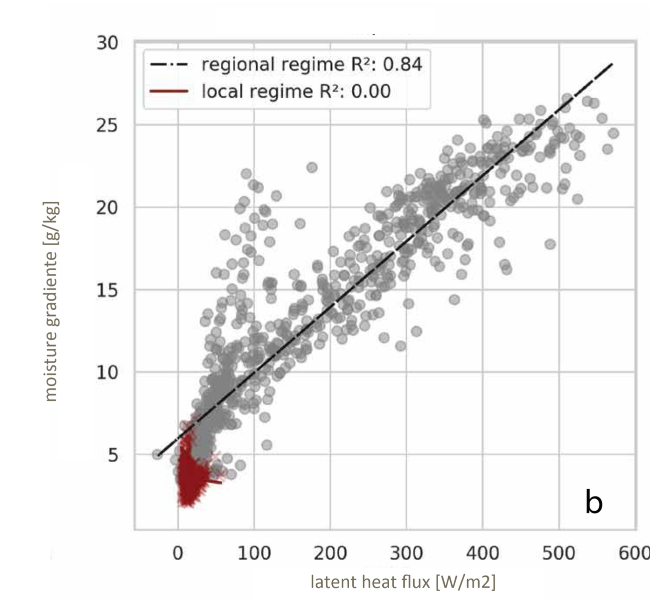
Conclusion

ET is not limited by energy or water (depending on surface), but it is limited by the wind. This, which depends on the regional circulation, favors the mixing between internal boundary layers then enhances the ET.



1. $$LE = \frac{\rho L_v}{\frac{1}{U^*}}(q_{sat}(T_s) - q_a)$$

2. $$R_n = G + H + LE$$



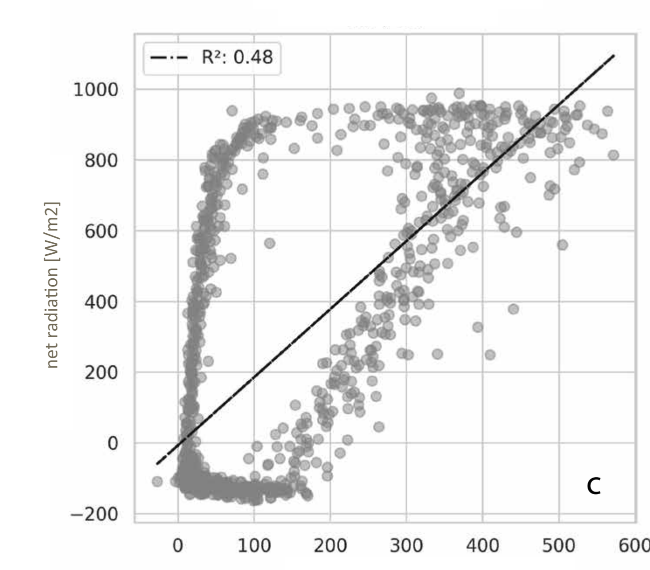


Fig 6: The relation between LE and the main physical processes involved, in both wind regimes over the water. (a) Friction velocity, (b) surface layer moisture gradient, and (c) net radiation.

TAKE HOME MESSAGE

An accurate understanding of the processes that drive ET on arid regions, and therefore their representation in numerical models would help us to accurate the water balance and consequently the water management.

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