Playa Soil Moisture And Evaporation Dynamics During The MATERHORN Field Program

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1. MOTIVATION

- Soil moisture content is a key driver of eco-hydrological and meteorological processes
- It is an important variable that improves near surface temperature and moisture prediction, cloud formation and ABL structure
- It is critical for accurate numerical weather forecasting (i.e. WRF) simulations over playa (Massey et al. J Appl. Meteorol. Climatol. 2014)

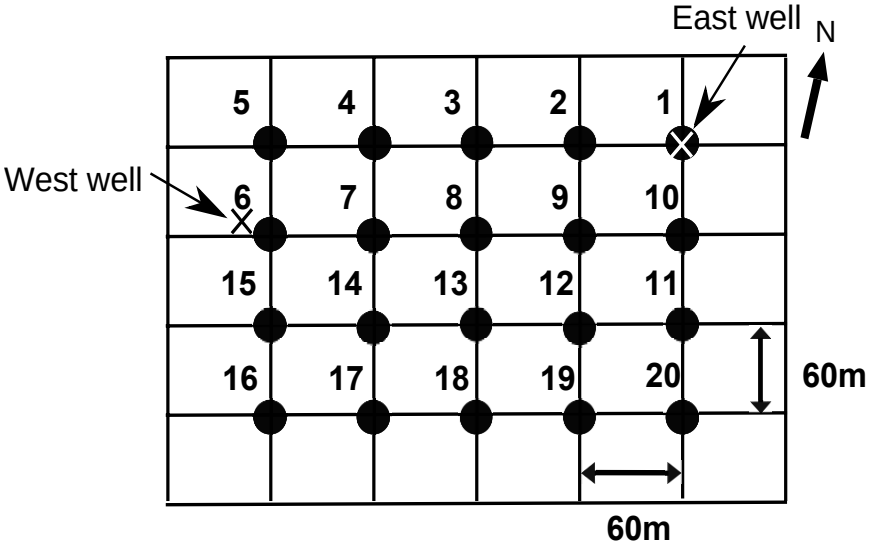
2. OBJECTIVES

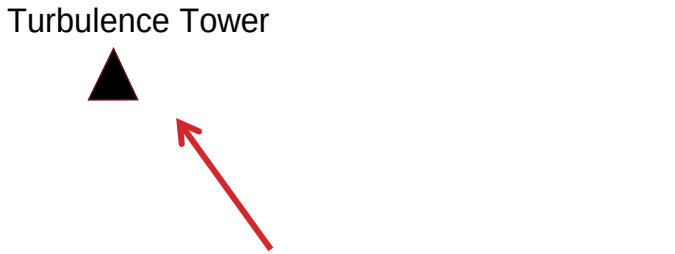
- To describe how soil moisture affects the surface energy balance in an arid area
- To identify the key controlling mechanisms on evaporation after a rain event
- To explore the existence of nocturnal evaporation and investigate its main driving factors
- To characterize the spatial heterogeneity in soil moisture and evaporation rates

3. METHODS

- **Site:**
  - Desert playa
- **Soil moisture content sampling:**
  - Transect
  - Method: Gravimetric method (Johnson 1962)

Desert Playa, Dugway, MAY 24, 2013

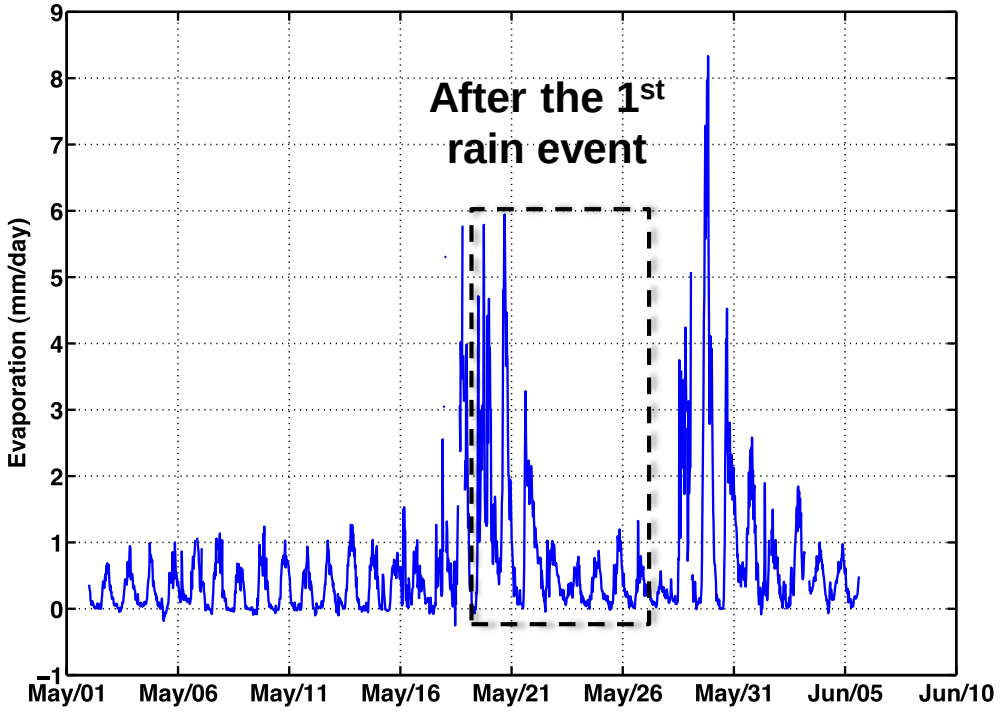




Evaporative flux is computed from turbulence tower by eddy-covariance method;

4. RESULTS AND DISCUSSION
--- BRIEF CLIMATOLOGY

- **Rain events:**
  - 1st rain event: May 17th and 18th , total rain fall: 15.8 mm
  - 2nd rain event: May 28th , total rain fall: 10.2 mm
- **Evaporation rate:**
  - Peak 1: 5.94 mm day^{-1} (154.7 W m^{-2})
  - Peak 2: 8.33 mm day^{-1} (216.9 W m^{-2})
- **Cumulative evaporation:**
  - The entire month: 19.28 mm
  - 73.3% of the total rainfall



4. RESULTS AND DISCUSSION
--- Atmosphere-soil moisture dynamics

Teuling et al. (GRL 2006) model:

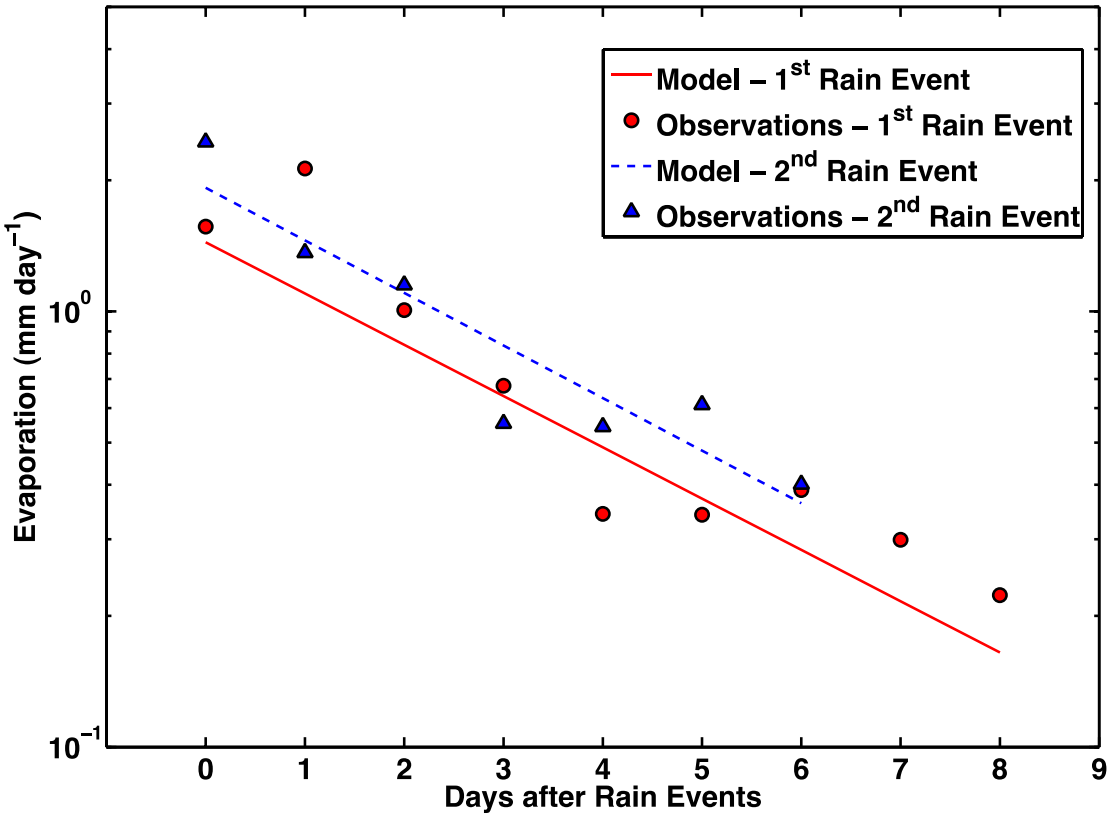
- Start from simplified terrestrial water balance
- Assumptions:

1. No rainfall;
2. No runoff;
3. E(t) =c S(t);

$$l = 1/c$$

$$E(t) = E_0 \exp(-\frac{t - t_0}{l})$$

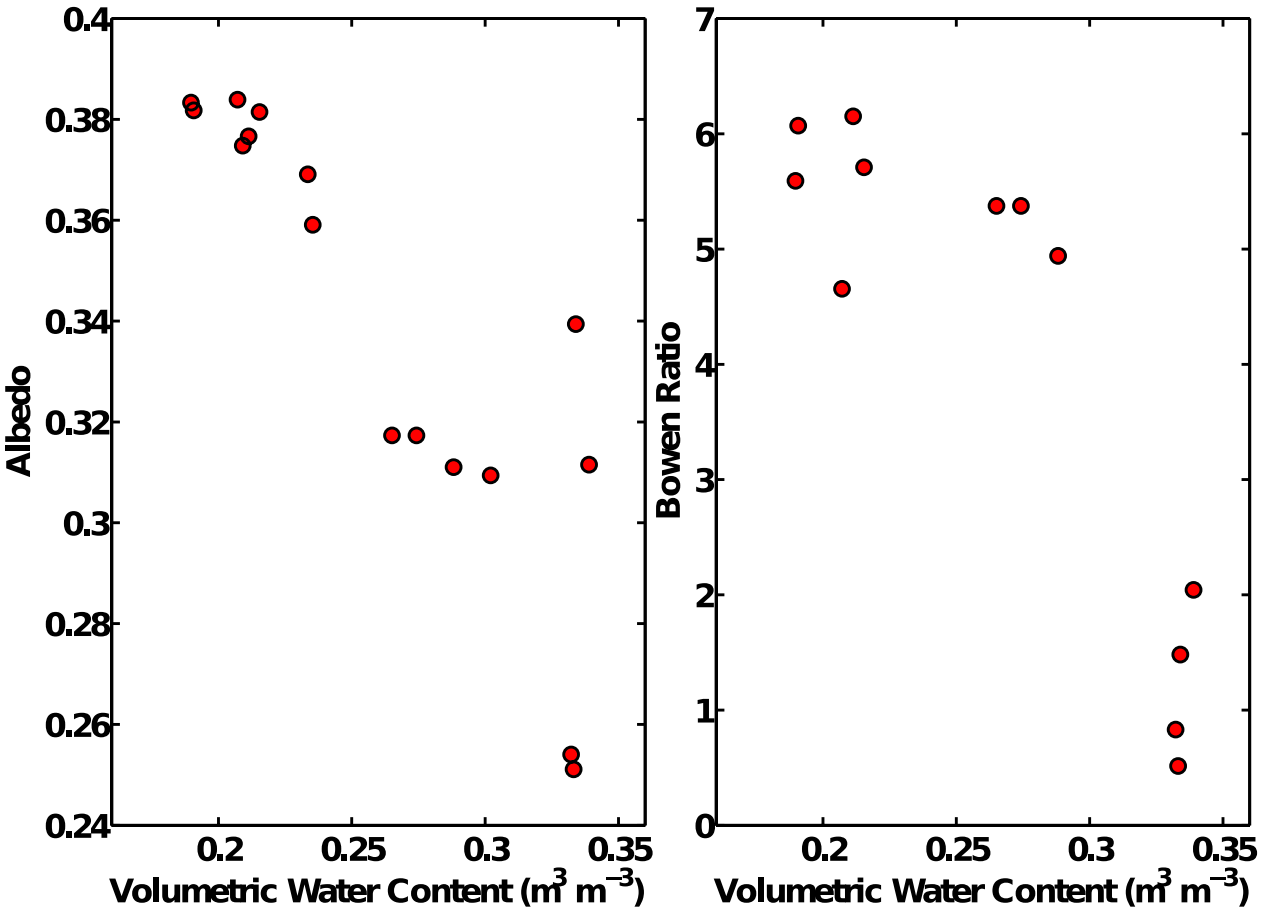
$$l = 3.64 days$$



4. RESULTS AND DISCUSSION

--- Atmosphere-soil moisture dynamics

Albedo and Bowen ratio decrease as VWC increases.



4. RESULTS AND DISCUSSION
--- Atmosphere-soil moisture dynamics

- **Peak value of NR:**

Increase from 400 W m^{-2} to 500 W m^{-2}

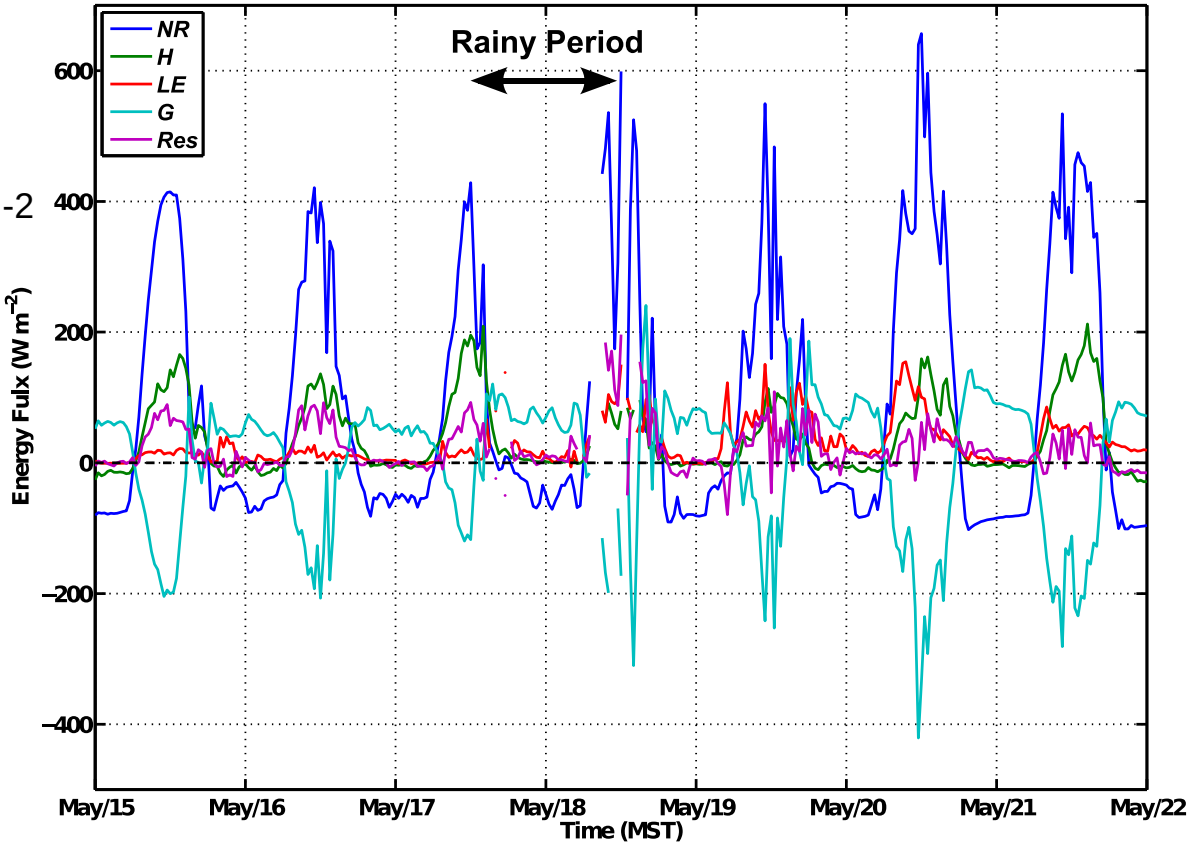
- **Peak value of H:**

Decrease from 200 W m^{-2} to 100 W m^{-2}

- **Peak value of LE:**

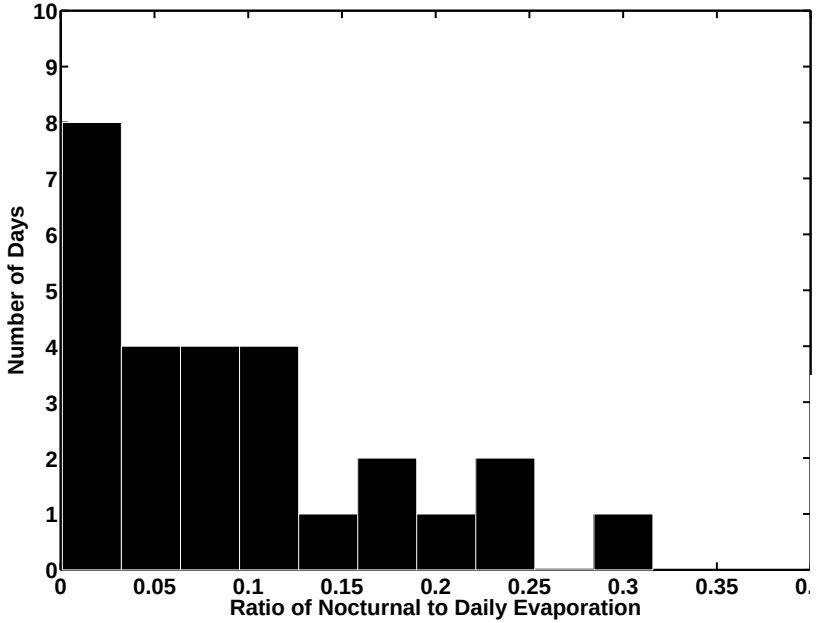
Exponentially decay

$$NR = H + LE - G + Res$$



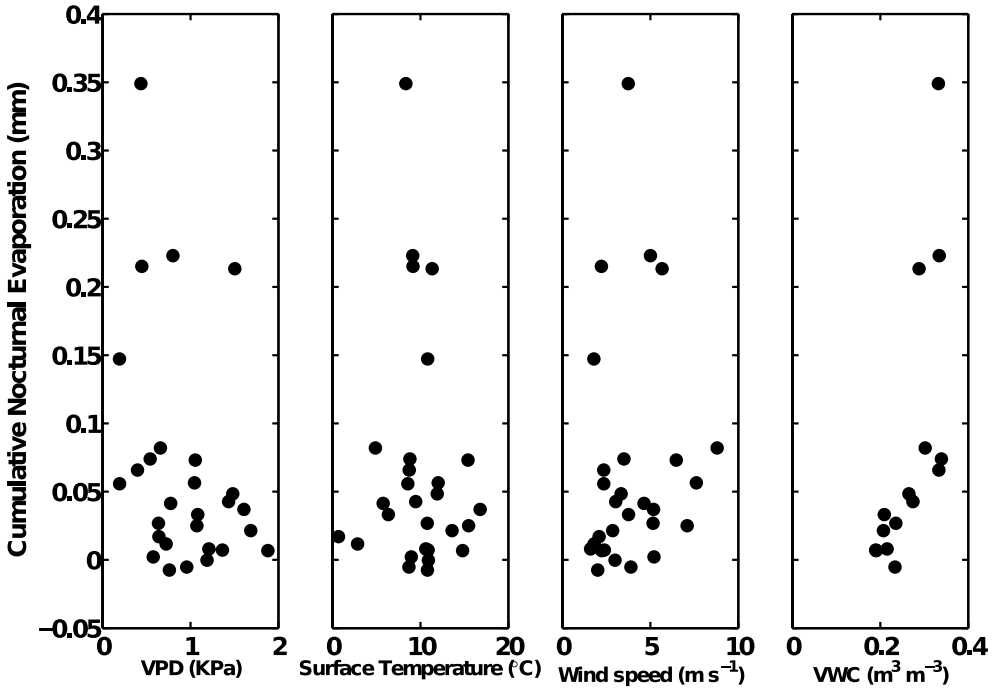
4. RESULTS AND DISCUSSION

--- Nocturnal evaporation



Nocturnal evaporation can account for up to 30% of the cumulative daily evaporation

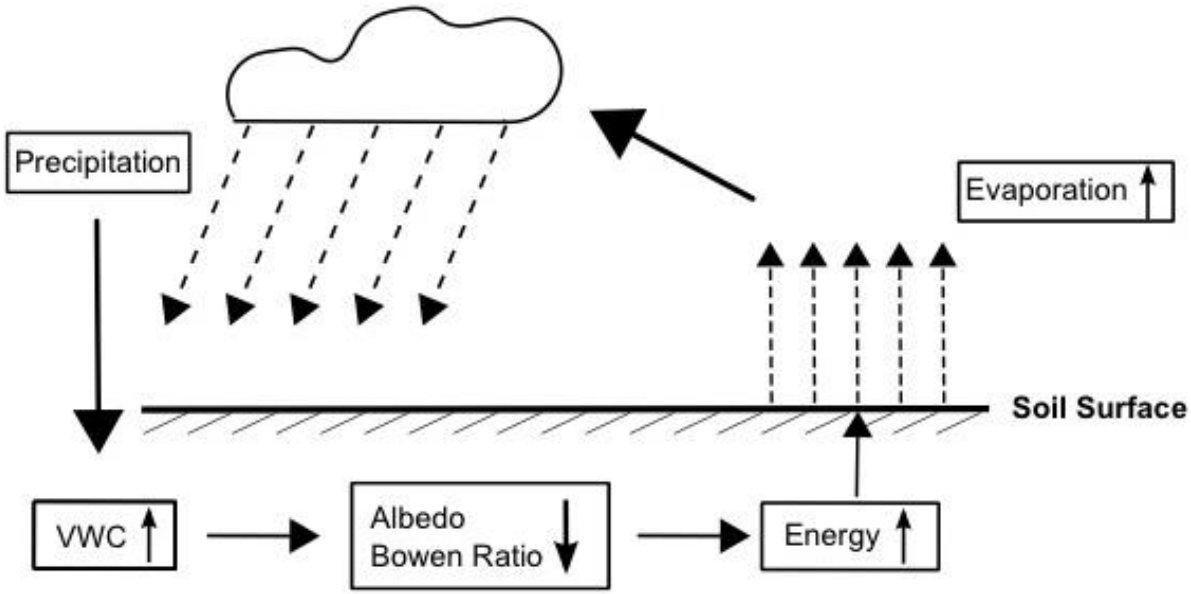
- No clear relation between nocturnal evaporation and atmospheric drying demand
- Nocturnal evaporation is positively correlated with VWC



4. RESULTS AND DISCUSSION

--- Atmosphere-soil moisture dynamics

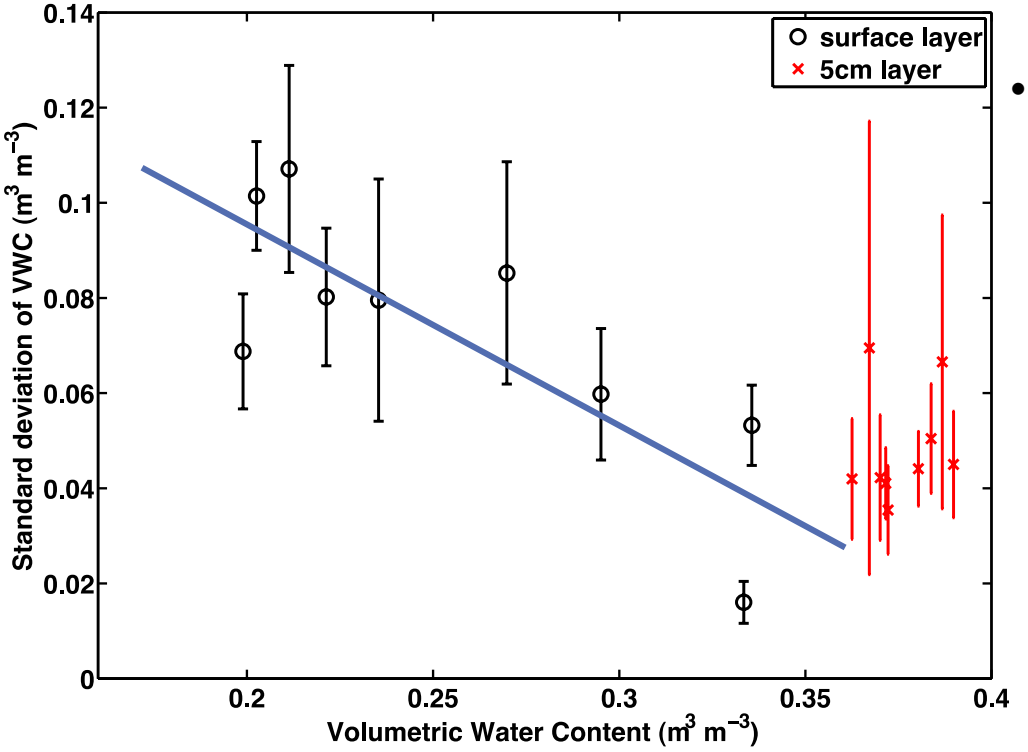
Positive feedback loop



4. RESULTS AND DISCUSSION
--- Spatial heterogeneity of soil moisture

- **0 – 2 cm layer**
  - **Mean**: 0.2559 $m^3\ m^{-3}$
  - **Std**: 0.0724 $m^3\ m^{-3}$
- **4 – 6 cm Layer**
  - **Mean**: 0.3760 $m^3\ m^{-3}$
  - **Std**: 0.0485 $m^3\ m^{-3}$

- Spatial heterogeneity decreases with increasing VWC on surface layer



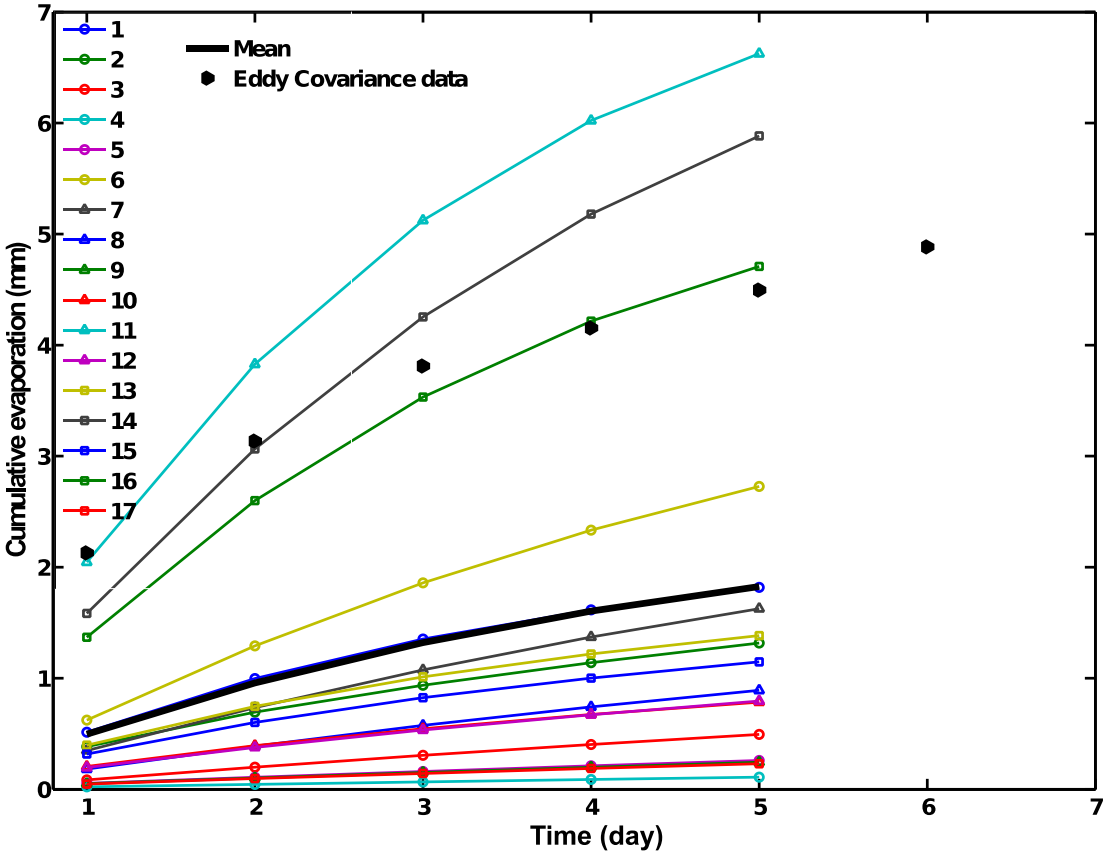
- 95% confidence interval is given by Jackknife resampling algorithm (Turkey, Ann. Math. Stat. 1958)

4. RESULTS AND DISCUSSION
--- Spatial heterogeneity of evaporation

Use the ***soil moisture depletion technique*** (Johnston et al. USDA For. Serv. Res. Pap. 1969) by solving ***Richards equation*** with a simple ***finite difference model*** (Clapp and Hornberger Water Resour Res, 1978 for more detail on the model)

BCs:

- Top: surface measurements of VWC and temperature;
- Bottom: assume a saturated soil with VWC = 0.46 $m^3\ m^{-3}$



4. RESULTS AND DISCUSSION

--- Spatial heterogeneity

Spatial heterogeneity in soil moisture and water vapor fluxes exist at multiple scales

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07/23/2014
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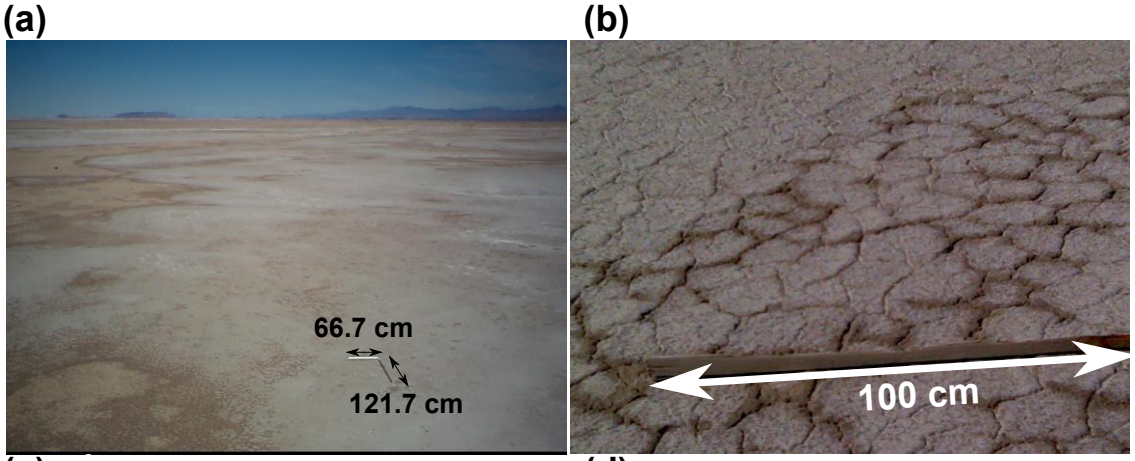

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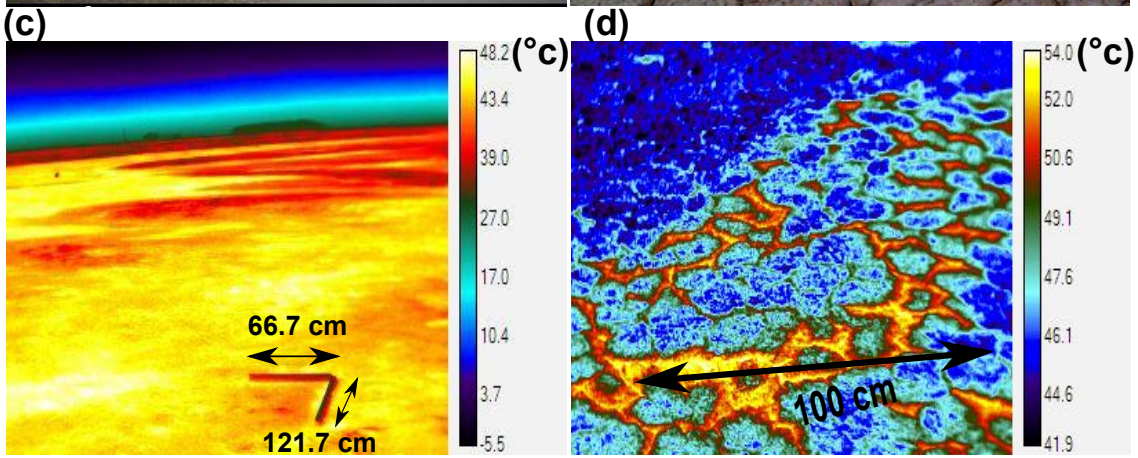

5. CONCLUSION

- **Temporal variation following rainfall:**
  - surface albedo decreases from 0.38 to 0.25
  - Bowen ratio decreases from 6 to 0.5
  - Net radiation increases by 25%, from about 400 W m^{-2} to 500 W m^{-2}
  - The ratio of nocturnal to daily cumulative evaporation reached up to 30%
  - A strong positive feedback loop

- **Spatial variation:**
  - More spatial heterogeneity in soil moisture in the surface soil layer under dry conditions
  - Significant spatial heterogeneity in cumulative evaporation rates following a rain event: from 0.1 mm to 6.6 mm


Thanks!
Questions?