# Reconstructing rainfall in sandy drylands of southern Africa:

## Exploring the potential of the CMB hydrostratigraphy approach in Kalahari sand dunes


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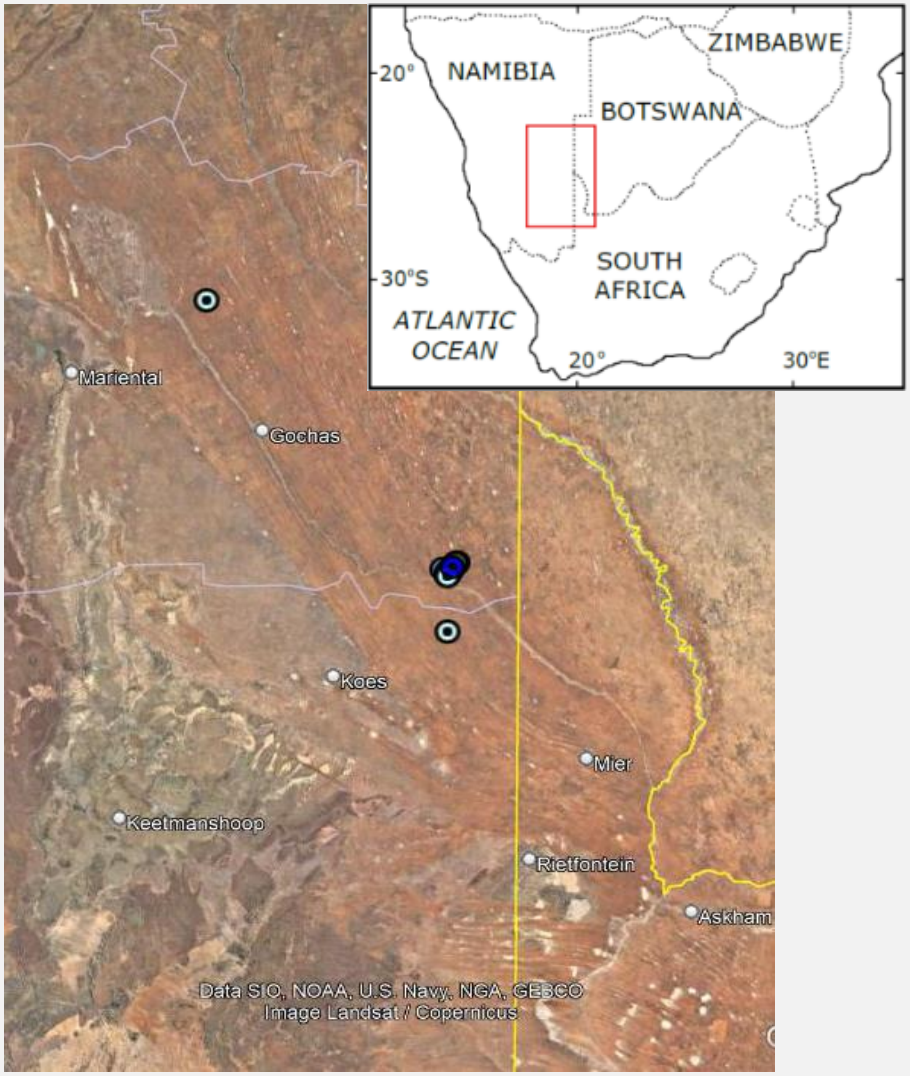


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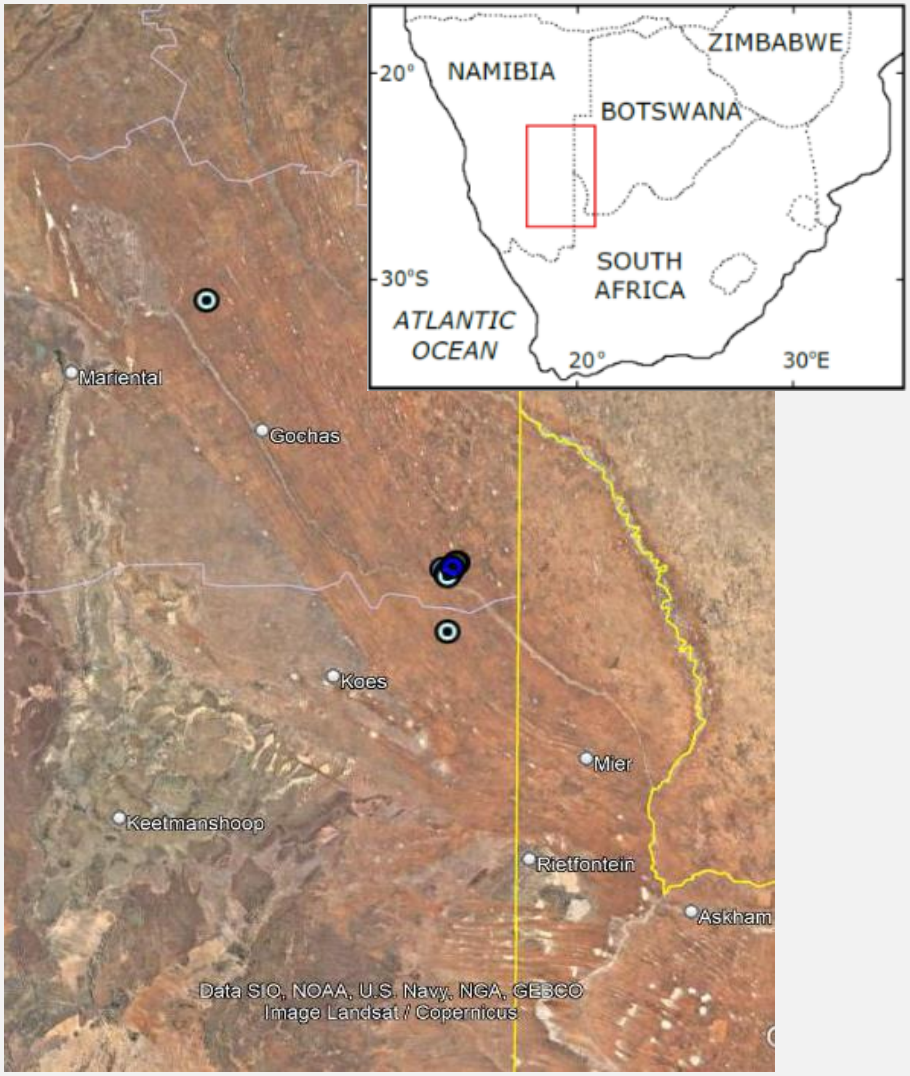


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## Introduction

- Reconstructing past moisture availability: palaeohydrological response to climate forcing.
- The vadose (or unsaturated) zone offers a novel archive '**hydrostratigraphy**' where rainfall proxies are scarce [1,2]
- Approach particularly successful in the Badain Jaran Desert, China, SW USA and north Africa.
- So... is it suitable and reproducible in the southern Kalahari?


[1] Edmunds, W. M., Tyler, S. W. 2002. *Hydrogeol.* 10, 216-228.
[2] Stone, A., Edmunds, W. M. 2016, *Earth-Sci. Rev.* 157, 121-144.

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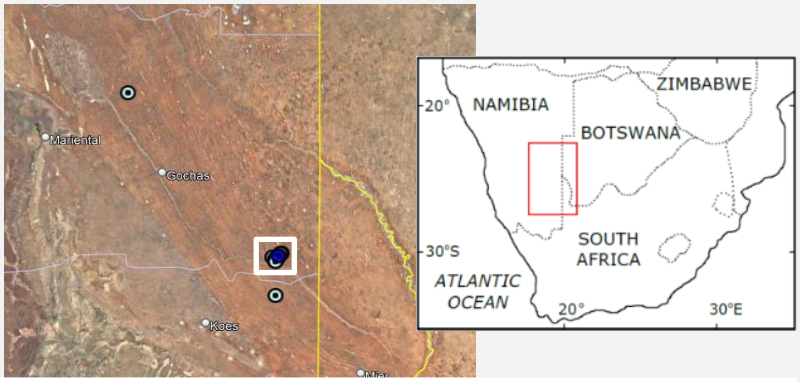


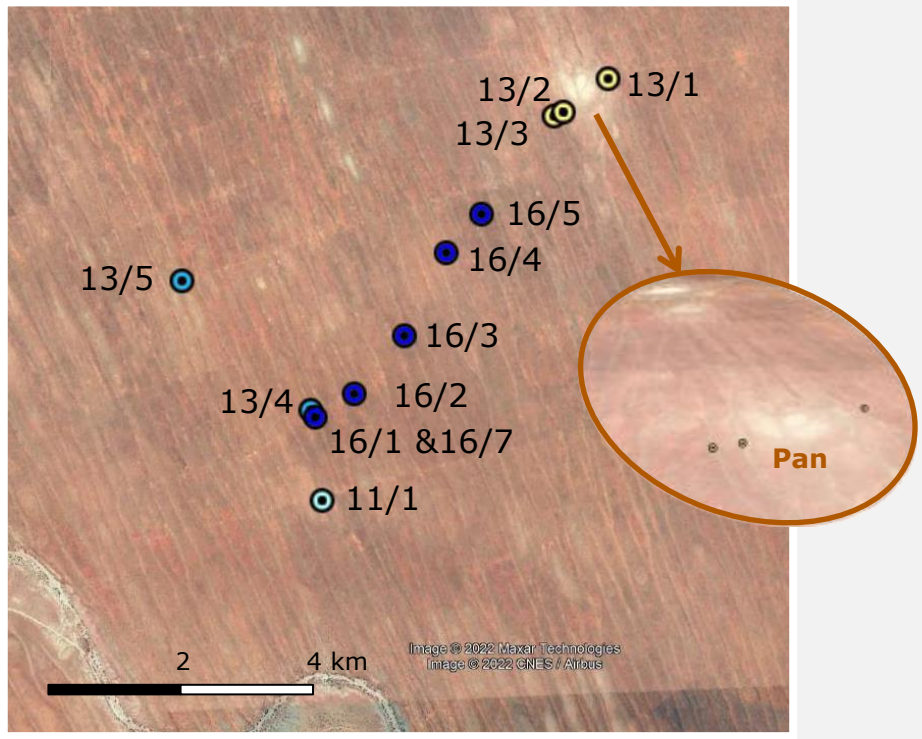


## Study site & approach

- Linear dunes above the 3-layer Stampriet aquifer.
- Suitable target: moderately-sorted sands, semi-arid setting, vegetation-free crests.
- Repeat sampling in uniform area (2011, 2013, 2016).
- Dunes near a pan also targeted, with hypotheses they = unsuitable

**Methods**

- Augured sand profiles
- Gravimetric moisture content, pore moisture elutriation, $Cl^-$ analysis ion chromatography, sedimentology analysis via laser granulometry.
- Moisture transport modelling using STEMMUS

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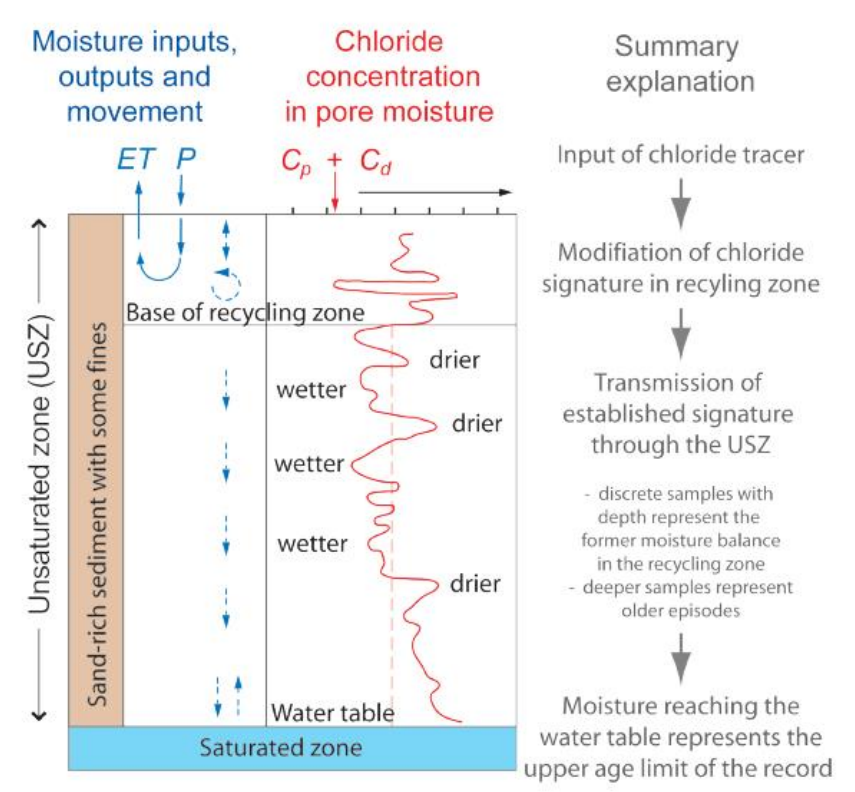
## The hydrostratigraphy method




*Schematic of the approach, adapted from*[2].

Key assumptions:

(i) vertical moisture infiltration (below recycling zone)

(ii) long-term average stable $Cl^-$ input (*Cp*)

(iii) no extra (non-meteoric) $Cl^-$ sources

(iv) no Cl- uptake by vegetation

Chloride mass balance approach to calculate moisture residence times ($t$) at any depth ($z$)

$$t = \int_0^z \frac{\theta \; C_s \; dz}{P\,(C_p) + C_d} \qquad \text{[Eq. 1]}$$

[2] Stone, A., Edmunds, W. M. 2016, *Earth-Sci. Rev.* 157, 121-144. [3] Cook, P. G., Edmunds, W. M., Gaye, C. B. 1992, *Water Re. Res.* 28, 2721-2731.

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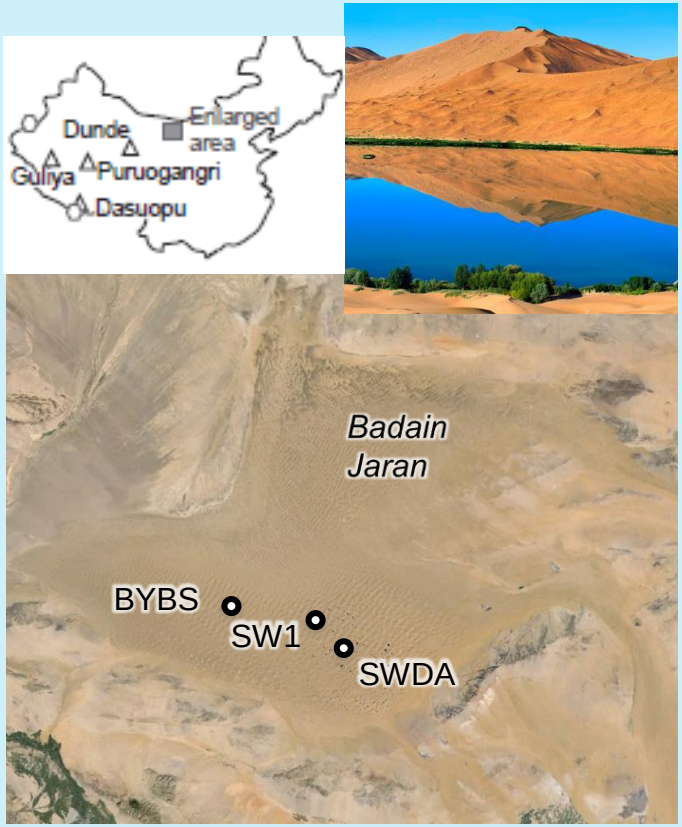
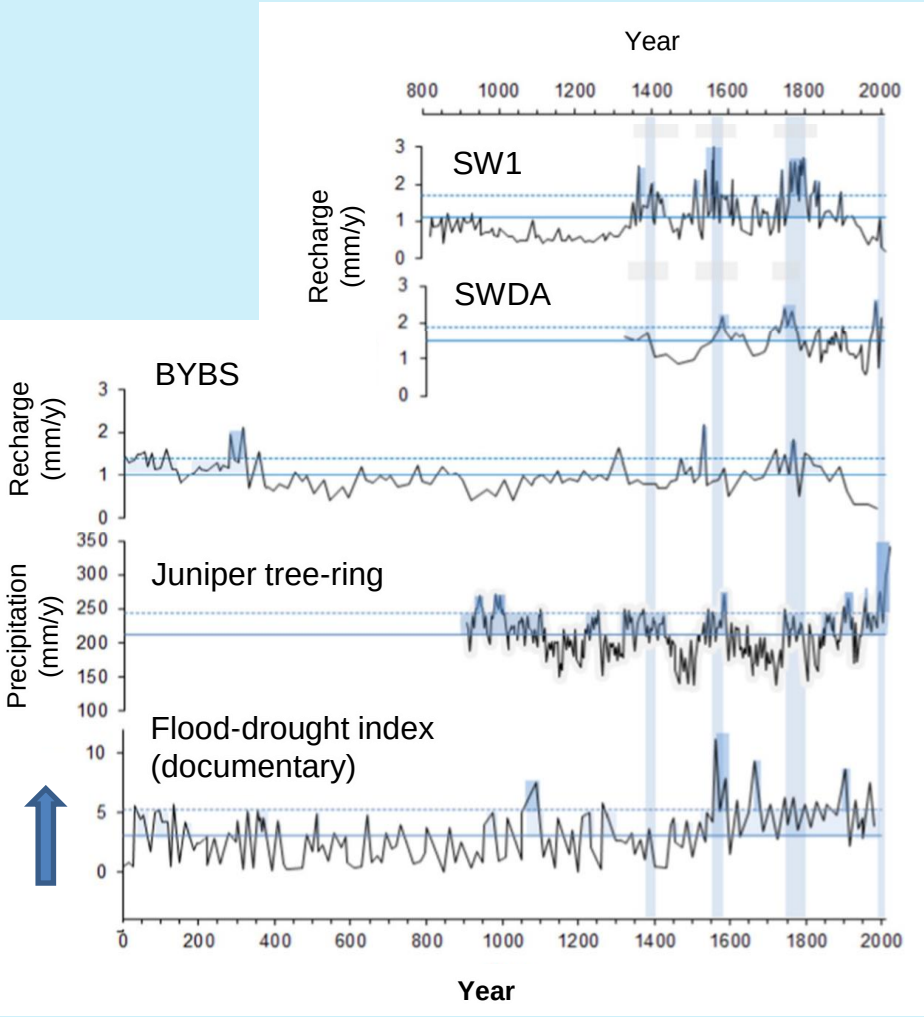
## Example applications



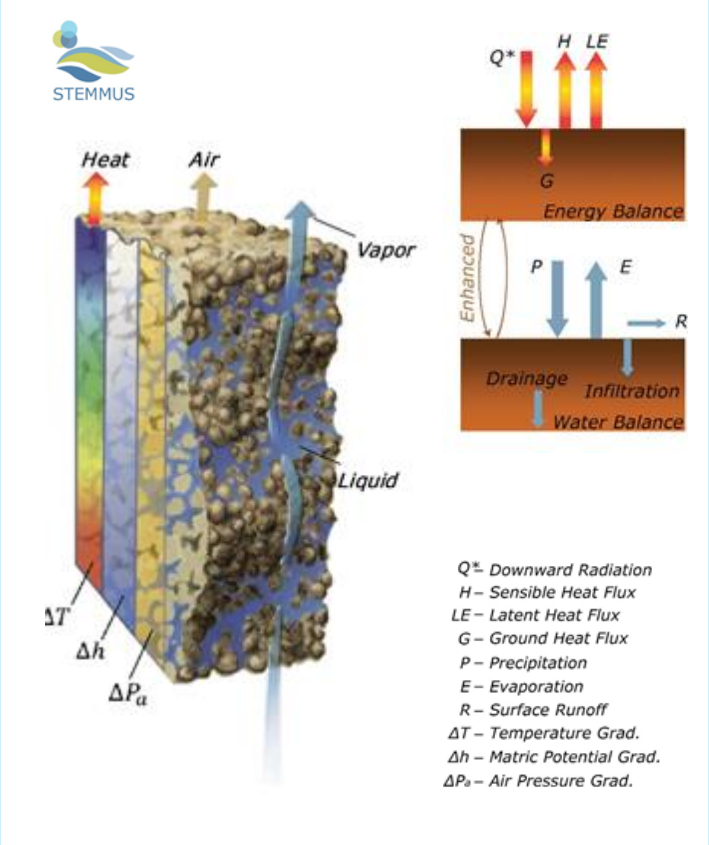




[4] Gates, J. et al. 2008. *Holocene* 18, 1045-1054. [5] Ma, J. et al. 2009 *Palaeogeogr. Palaeoclimatol. Palaeoecol*. 276, 38-46.

# Reconstructing rainfall in sandy drylands

## STEMMUS model [4,5]

- To help interpret our field hydrostratigraphies
- Simulates coupled liquid water and water vapour, along with dry air and heat transfer in unsaturated sediments.
- Developed specifically for desert areas.
- A two-phase heat and mass flow model, that considers liquid flux & vapor flux and also models matric potential.l




[4] ttps://blog.utwente.nl/stemmus/ [5] Github: https://github.com/yijianzeng/STEMMUS

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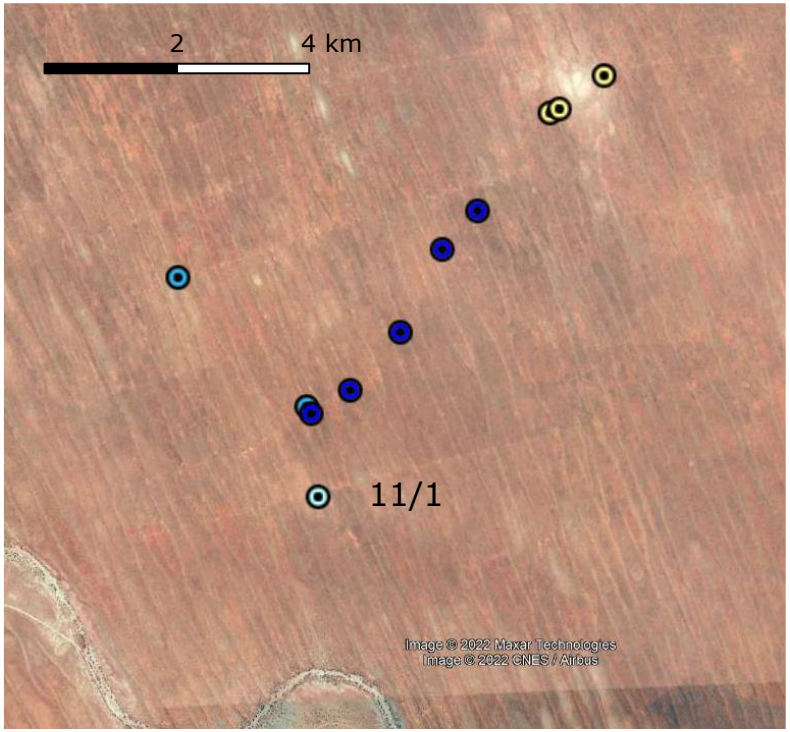



**Results:**

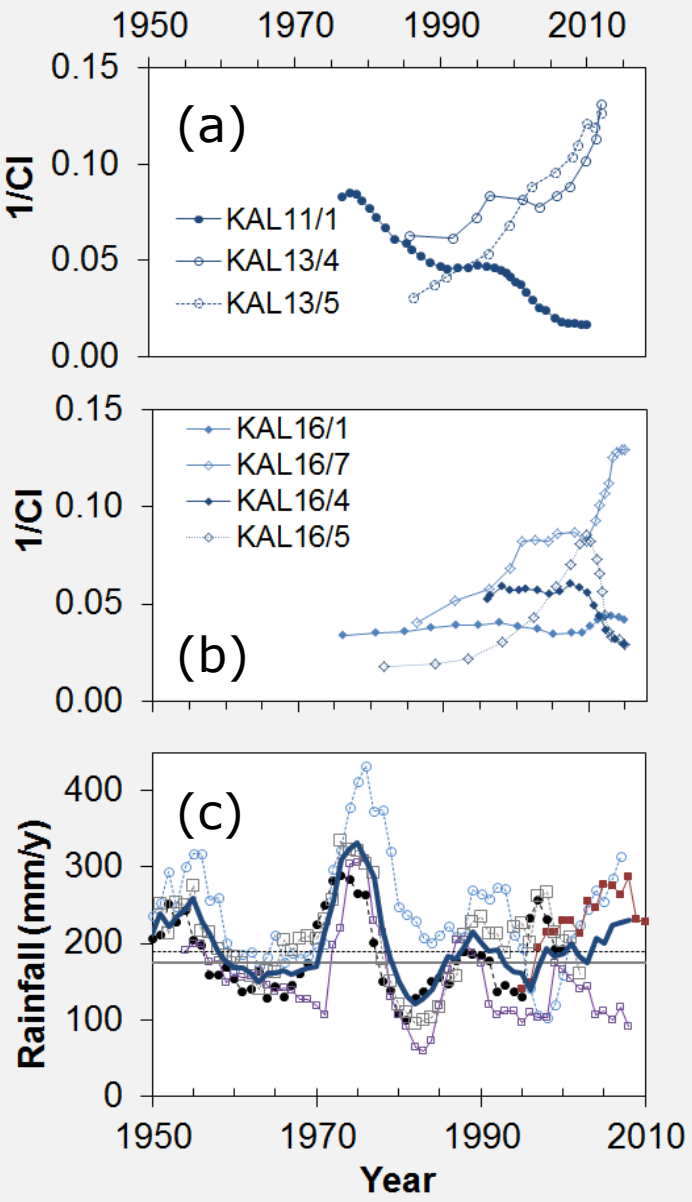
*In the live talk*

## Is it possible to produce hydrostratigraphies?

- Applying Eq. 1 & assuming a 3 m thick mixing-zone produces inconsistent results between dunes & no good correspondence with instrumental rainfall records,
- Likely problems for this method:
  - (1) addition of non-meteoric $Cl^-$
  - (2) moisture pathway behaviour


## Conclusions

- Data suggests this region is **not suitable** for hydrostratigraphies.
- There is a $Cl^-$ input source additional to meteoric input (associated with pans).
- Also likely that the vegetated nature of the landscape contributes to a thick mixing zone within these dunes.
- It is as important to report negative results as positive results.

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