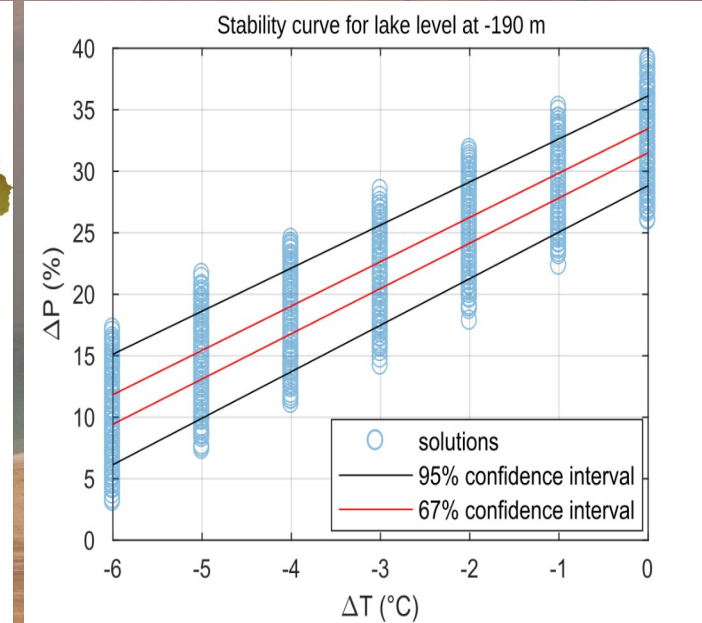
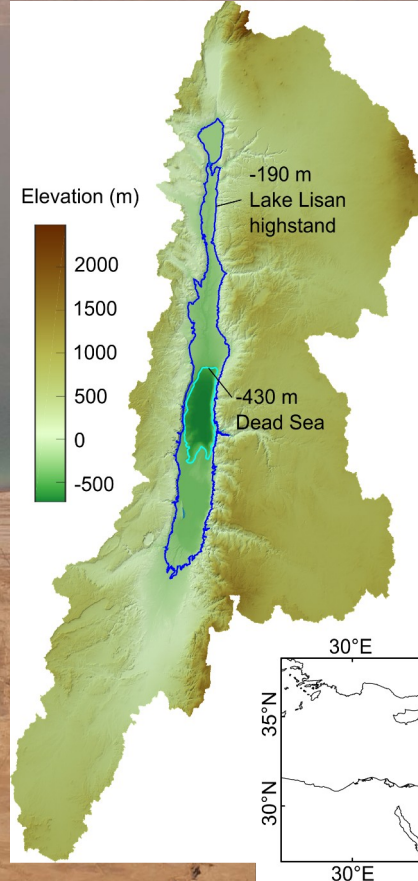
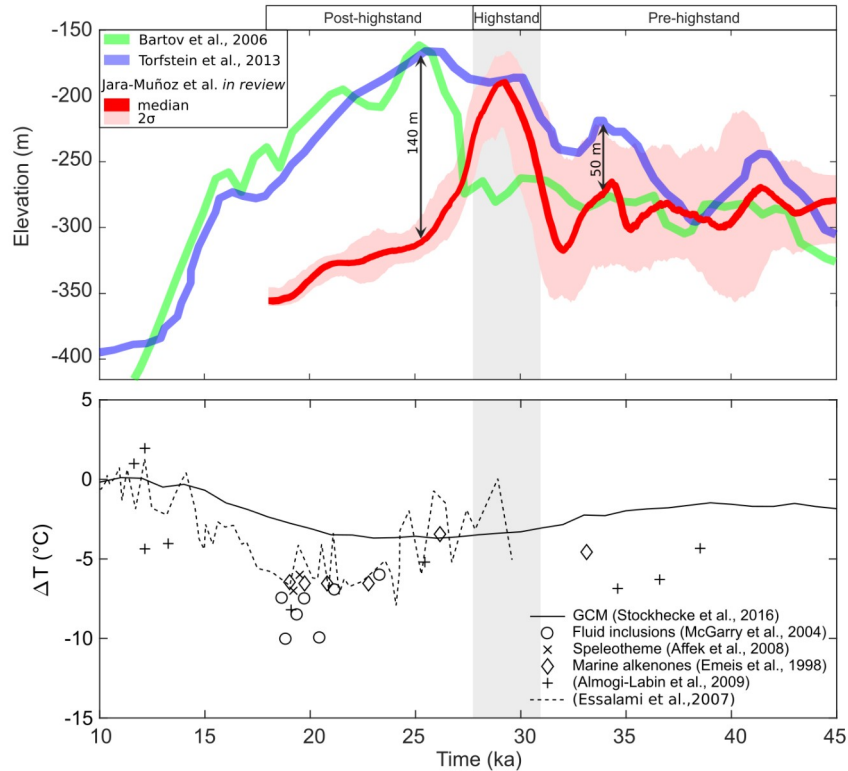


Late Pleistocene paleo-hydrological reconstruction based on a new lake-level curve of the Dead Sea **Jürgen Mey¹, Julius Jara-Muñoz², Manfred R. Strecker²**

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Lake level = -190 m
 $\Delta T = -3^\circ\text{C}$
 $\rightarrow \Delta P = 17 - 25 \%$

The lake level curve I



Fig. 1| Dead Sea lake paleoshorelines carved into colluvial deposits (A-C) and into bedrock (D) (Jara-Muñoz et al., *in review*).

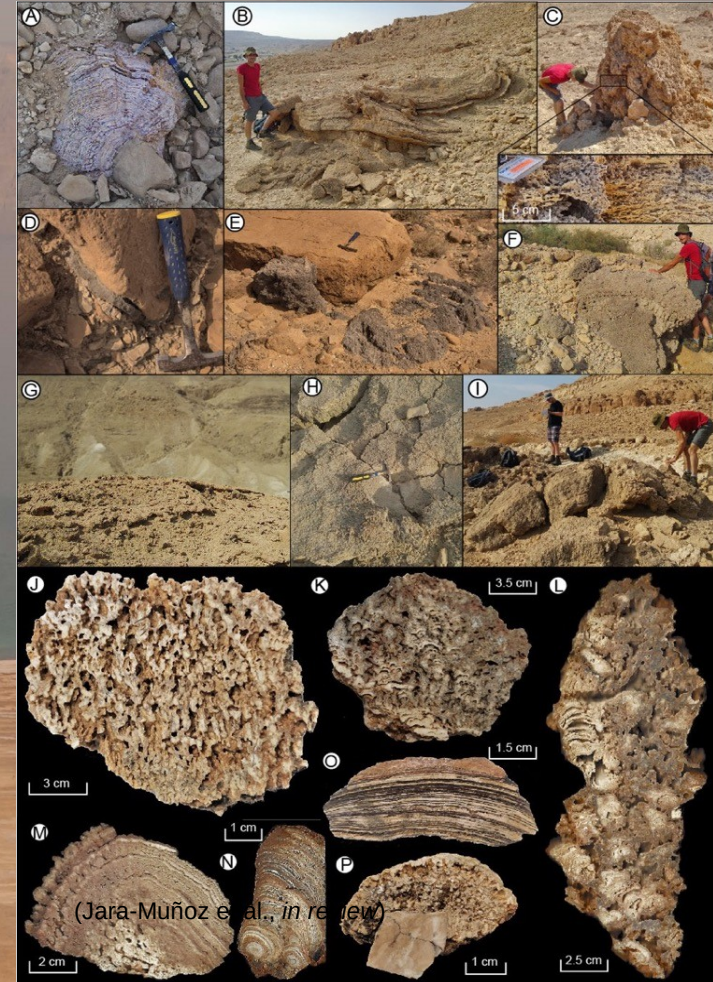


Fig. 2| Morphology and macrofabrics of stromatolites that have been dated with ^{14}C and U-TH.

The lake level curve II

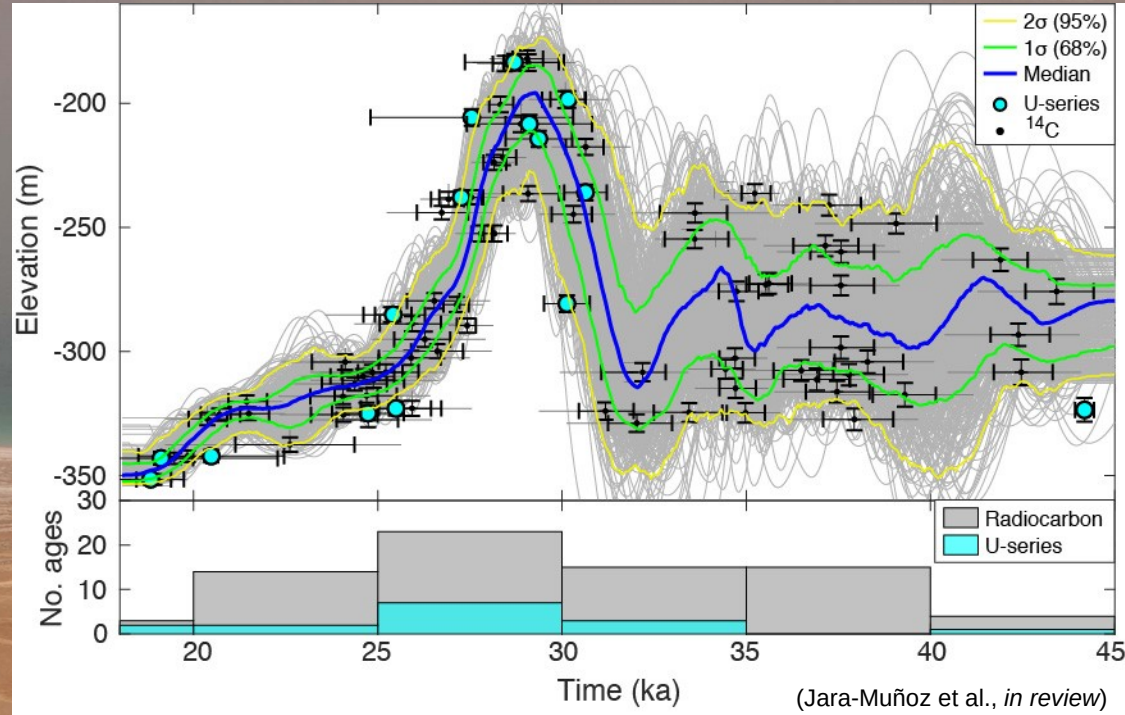


Fig. 3| Lake-level reconstruction based on fossil stromatolites. Grey lines are iterated smoothing splines generated from randomly optimized samples.

The model

Discharge: $D = P \cdot (1 - \lambda) - E$

Energy balance: $F = QR + QS + QL + QG = 0$

Radiative flux: $QR = SW_{net} + LW_{net} = SW_{in} (1 - \alpha) [1 - (a + bc)c] + \varepsilon_s LW_{in} + LW_{out}$

Incoming longwave flux: $LW_{in} = \varepsilon_a \sigma T_a^4 (1 + a' c^{b'})$

Atmospheric emissivity: $\varepsilon_a = 1.24 \left(\frac{h_r e_a}{100 T_a} \right)^{\frac{1}{7}}$

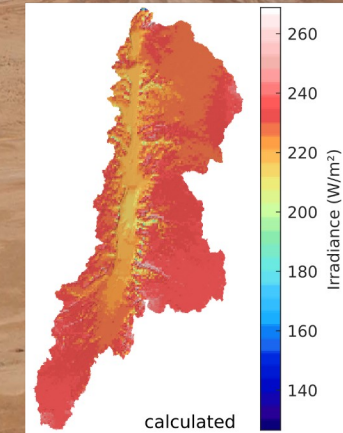
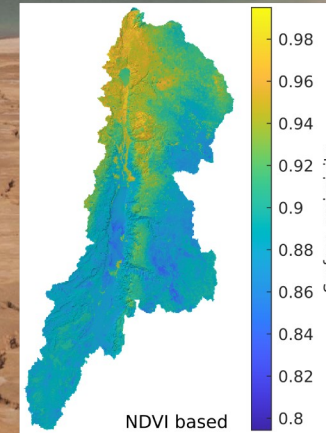
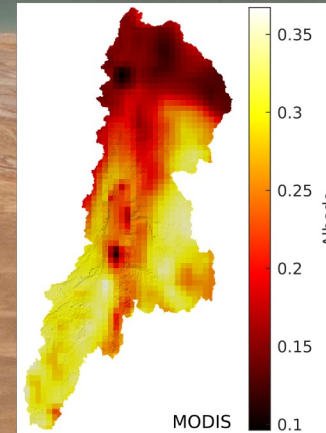
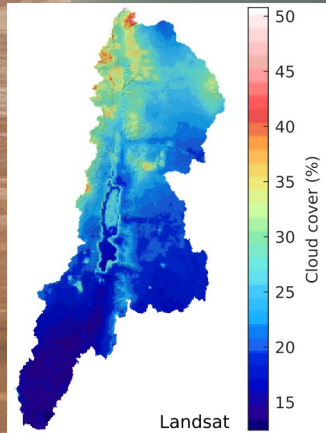
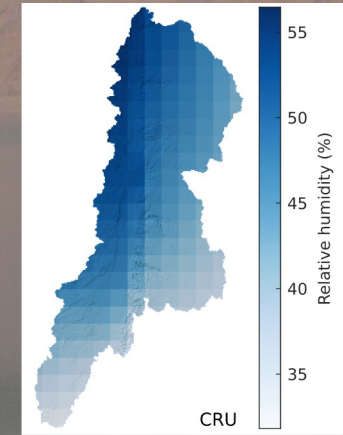
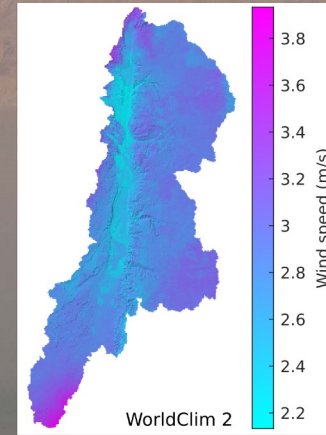
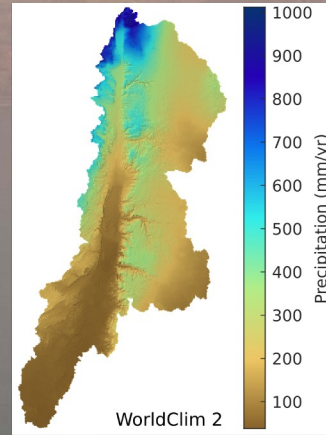
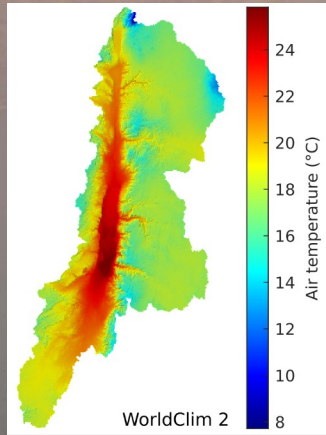
Outgoing longwave flux: $LW_{out} = \varepsilon_s \sigma T_s^4$

Surface emissivity: $\varepsilon_s = 1.0094 + 0.047 \ln(NDVI)$

Evaporation: $E = \frac{0.622 \cdot \rho_0}{p_0} \cdot C_d f u \cdot (h_r \cdot e_a - e_s)$

P : precipitation
 D : discharge
 E : evaporation
 λ : runoff coefficient
 ρ_0 : air density at sea level
 p_0 : air pressure at sea level
 C_d : surface drag coefficient
 f : moisture availability factor
 u : wind speed
 h_r : relative humidity
 e_a : sat. vapor pressure (air)
 e_s : sat. vapor pressure (surface)
 M : mass balance
 P_s : solid precipitation
 Q_M : latent energy flux of melting
 Q_L : turbulent latent energy flux
 L_M : latent heat of fusion
 L_L : latent heat of sublimation
 Q_R : net radiation flux
 Q_S : sensible heat flux
 Q_G : ground heat flux

The model inputs (mean annual values)

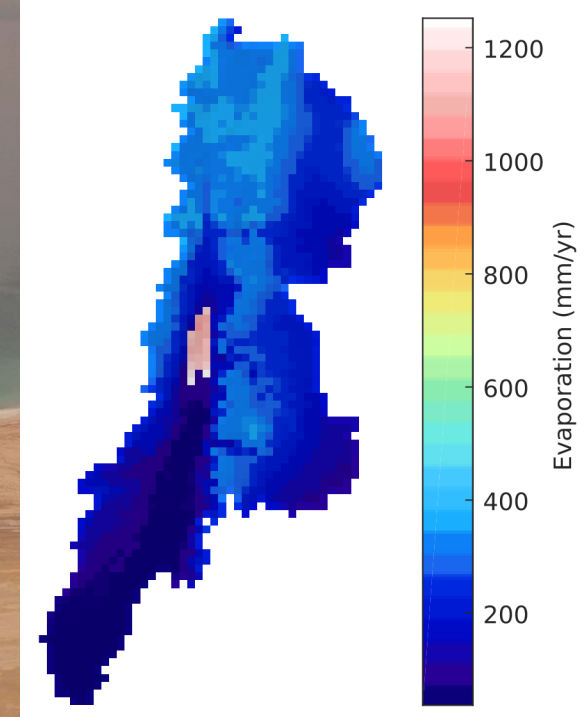


The model calibration

Without anthropogenic bias the lake level between 1970 – 2000 would be at ~ -394 m (Morin et al., 2018).

Calibration with observed lake level and evaporation rates

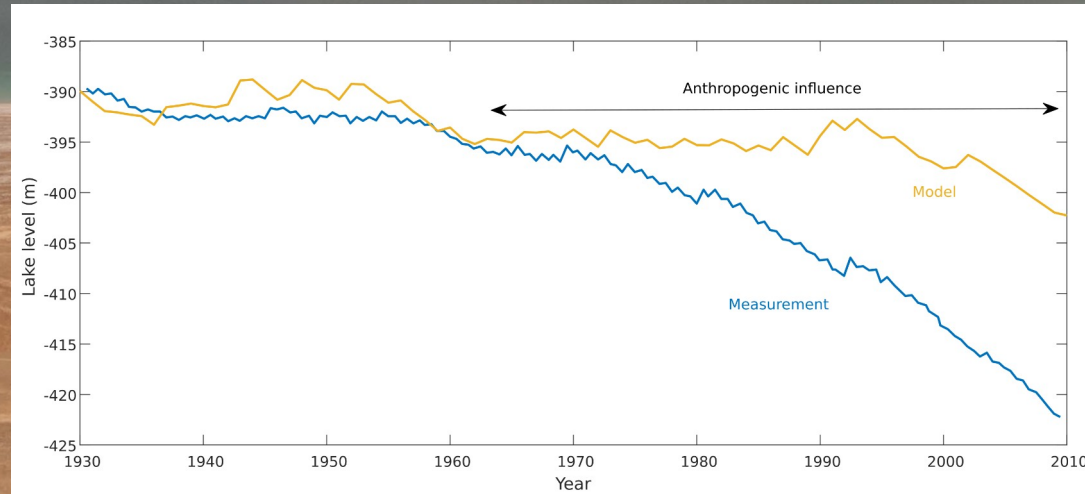
- 1) Search for moisture availability factor (f) over land for equilibrium lake level of -394 m.
- 2) Adjust surface drag coefficient (C_d) so that evaporation from present-day lake area is $1000 - 1200$ mm/yr (Stanhill, 1994; Lensky et al., 2005, Metzger et al., 2018).



The model validation

With time series of P and T the calibrated model should reproduce observed lake-level variations.

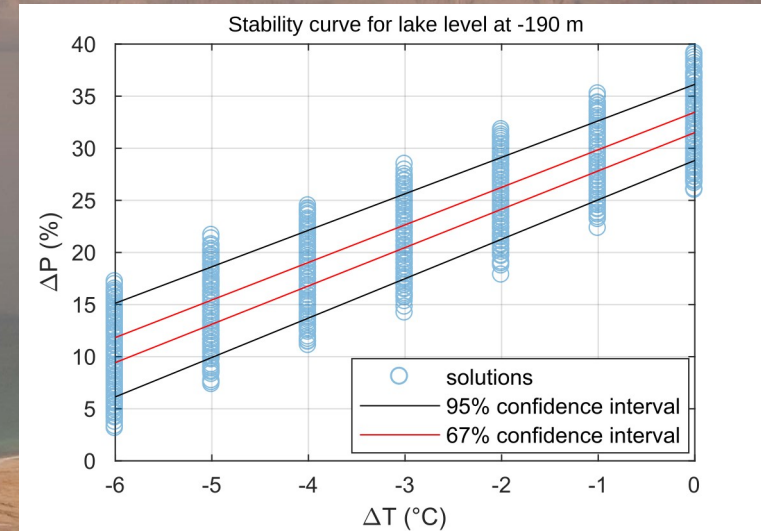
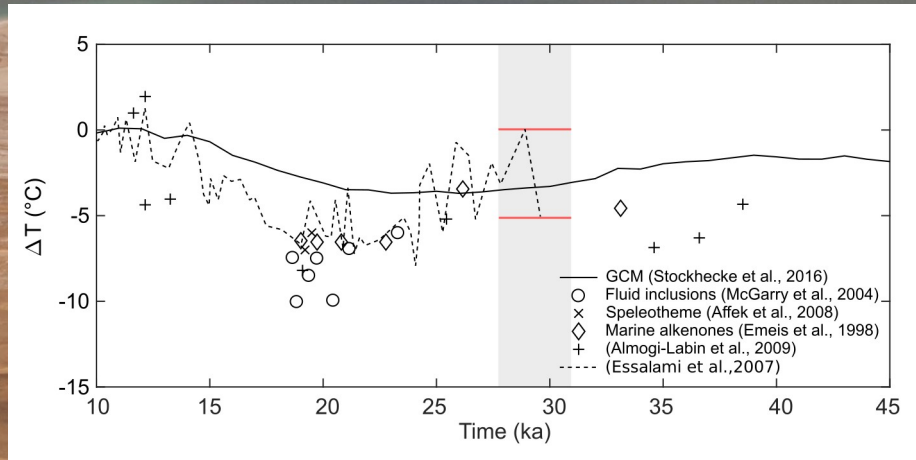
- CRU TS4.04 time series of P and T
- Lake-level observations from 1930 – 2010



The hydrological reconstruction

The calibrated/validated model is provided with past lake level and temperature anomaly estimates to solve for the required precipitation change.

- Monte-Carlo scheme where all other inputs (windspeed etc.) are randomly changed to $\pm 1\text{-}10\%$ the present-day values (Mey et al., 2020).



Lake level = -190 m

$\Delta T = -3^\circ\text{C}$

$\rightarrow \Delta P = 17 - 25 \%$

$\Leftrightarrow 40 - 60 \text{ mm/yr}$

The remaining difficulties

- Scarcity of climate proxy data for highstand interval 29 ± 1 ka
- Estimates of paleo-windspeed are lacking (dune migration?)
- Transfer coefficient for evaporation may have changed with changes in surface cover (vegetation).
- Seasonality changes not (yet) captured
- No plant transpiration included

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