East Asian monsoon variability and groundwater recharge in northern China

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Background

The deserts of the Alashan Plateau are near the current northernmost extent of the East Asian Summer Monsoon, and are therefore sensitive to changes in its intensity. However, monsoonal histories of these marginal areas are poorly understood relative to humid and high altitude locations in China owing to the shortage of suitable archives. Filling this gap is important for examining spatial complexity of monsoon impacts and has added significance for understanding desert palaeohydrology in water scarce environments.

Fig. 1 Badain Jaran Desert landscape sand dunes and groundwater-fed lakes

Results

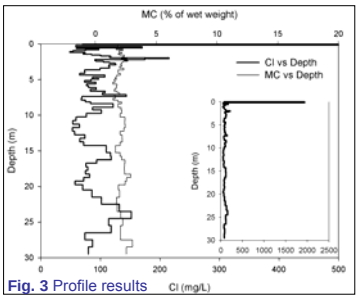

Fig. 3 Profile results

Trends in the time series of 1/Cl serve as an indicator of moisture changes over time for the case that Cl concentration is inversely proportional to recharge (i.e. assuming constant Cl inputs). Based on these trends a **700-year qualitative recharge history** is proposed for the Badain Jaran Desert which portrays approximately century-scale moisture cycles.

Fig. 5a Steady state vs transient Cl input scenarios

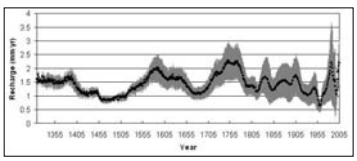

Fig. 5b Monte-Carlo simulation of 2σ errors

Chloride concentrations are shown to vary significantly with depth, with a weighted mean of 91 mg/L below the root zone. The peak concentration in the near-surface is 1938 mg/L. **Moisture contents** are relatively constant (1-3% of total sample weight). Using steady-state chloride mass-balance, this translates to a **mean recharge rate** of 1.4 mm/yr.

A **chronology** for the profile is established by comparing cumulative Cl from the surface to depth z_i with the rate of Cl influx:

$$t = \frac{1}{P \cdot C_p} \int_0^{z_i} \theta(z) C_r(z) dz$$

where t represents time and θ is volumetric moisture content (2).

The **robustness** of the record is tested by comparing with a proxy-based time-varying Cl input function with transient Cl mass balance (6) (Fig 5a); monte-carlo error estimates from uncertain inputs (Fig 5b); additional profile records (7) (Fig 5c); and local rainfall monitoring records from the last 50 years. It is found that century and multi-decadal scale signatures are persistent despite uncertainties in the Cl deposition input function.

Fig. 5d Recharge record vs recorded rainfall history

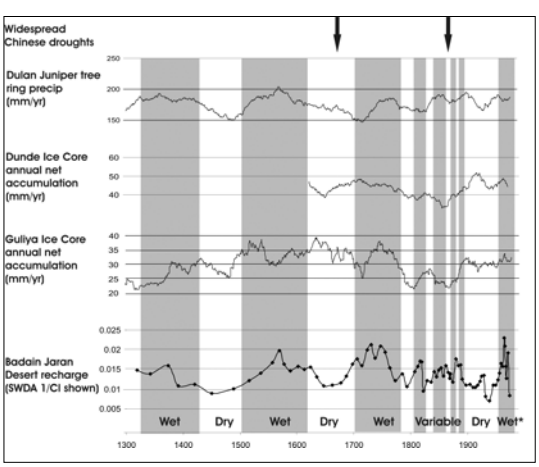

Fig. 4 Moisture proxy comparison

Good agreement is found in **comparison with other moisture proxies** from the region, particularly with the Juniper tree-ring palaeo-rainfall record from Dulan, northeastern Qinghai Province (3). Relationships with Tibetan Plateau ice core records (4) are not as clear although some parallels are apparent. Qualitative wetness/dryness indices based on historical documents from Eastern China (5) are also in general agreement, which suggests that recharge fluctuations are largely driven by fluctuations in monsoon intensity.

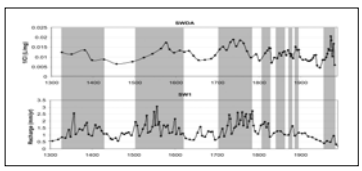

Fig. 5d Comparison of profile recharge records

Unsaturated zone moisture samples were collected by hand auger from high sand dunes in the Badain Jaran Desert to a depth of 30m. Sampling density was initially 12.5 cm and was coarsened with depth. Moisture was extracted by elutriation and major ion concentrations and physical parameters were analyzed. Temporal variability and chronology are established with mass balance of chloride assuming piston-like unsaturated flow (1).

Implications

This 700-year semi-quantitative history of diffuse groundwater recharge in Inner Mongolia is proposed on the basis of solute data from multiple unsaturated zone groundwater profiles using mass balance of chloride to establish recharge rates and profile chronologies. Four relatively humid (1330-1430, 1500-1620, 1700-1780 and 1950-1990) and three relatively arid phases (1430-1500, 1620-1700 and 1900-1950) are discernable across the profiles. The recharge history broadly reflects multi-decadal to century timescale precipitation changes in the northern Tibetan Plateau, suggesting that climatic variability in northwestern China tends to persist across the region's steep SW/NE moisture gradient and that variations in East Asian Monsoon intensity demonstrably affect desert recharge rates.

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For further information

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Acknowledgments

We wish to acknowledge the generous support of the Royal Society; British Geomorphology Research Group (BGRG); Royal Geographical Society; and Environmental Change Institute of Oxford University.