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Evaluating the potential of database technology for documenting environmental change in China's deserts

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ABSTRACT

Despite decades of research, fundamental questions remain about how China's deserts and desert margins function, how they interact with regional and global scale environmental systems, and how they have responded to recent natural and anthropogenic forced climate change. The predominant focus of desert research in China, and globally, has been site specific case studies within sub-disciplines. This highly focused view makes development of a comprehensive interdisciplinary understanding of these deserts difficult. The fields of database creation, data mining and modern statistics have advanced the analysis of complex real-world data, however these methods enjoy only a relatively modest penetration into the geosciences. We report herein on the application of these new technologies to desert environmental systems in China, and illustrate the potential value of well-constructed databases and tool-rich analysis environments at regional, local and site specific scales. Regional analysis suggests significant warm season decrease and cold season increase in cloudiness in China's deserts suggesting that contrasts between cold and warm season cloudiness may be increasing. At a local and site specific scale at central China's Tengger Desert/Helan Mountains climate transition we find a significant climate forced greening of the desert margin over the past decade which may be reversing desertification trends aiding China's remediation efforts. We note that this new approach provides a "living" archive that allows capture of changes currently occurring in China's deserts as well as allowing assessments of human efforts to modify desert and desert margin environments.

1. Introduction

1.1. Overview of China's desert environments

Aridity in China is typically associated with distance from oceanic moisture sources, the influence of global scale westerly airflow patterns, and flow blockage by the uplifted Tibetan Plateau (Li, 1991; Shi et al., 1998; Tooth, 2008). Eastern and western deserts have differential exposure to summer monsoon flow in response to strengthening and weakening of the Asian monsoon (Wu et al., 2007; Yang et al., 2011a, 2011b) leading to pronounced climatic contrasts between the two regions. At present the division between these two environments is roughly the Helan Mountains at 106°E longitude (Fig. 1). Desert areas to the east of this range are characterized primarily by stabilized low-lying anchored dunes (Sandy Lands — shadi) whereas those to the west tend to be characterized by linear and crescentic dune systems of larger size and greater mobility (Sandy and Gobi Deserts — shamo) (Wang et al., 2005; Yang and Scuderi, 2010; Yang et al., 2012) (Table 1). Evidence of past dune activity suggests that this was not always the case, with migrating dune fields also found in the eastern portion of the desert arc in the late-Pleistocene and early-Holocene (Yang et al., 2013).

Climatologically China's desert areas can be visualized in terms of annual precipitation (Fig. 2) with extremely arid (<100 mm) and arid areas (100 to 250 mm) found in the central and western portions of China, and semi-arid areas (250 to 500 mm) primarily in the east. However, during the early and middle Holocene, China's desert areas, and especially the semi-arid areas in eastern China, were influenced by a marked increase in monsoonal penetration and many of these areas, such as the Hunshandake Sandy Lands (Yang and Scuderi, 2010; Yang et al., 2011a, 2011b, 2013), transitioned between aeolian and lacustrine environments. To the west of the Helan Mountains, the large sand seas of the Badain Jaran and the Taklamakan Deserts as well as lake levels within these basins responded to this early to middle Holocene variability, and especially to the strength of the westerlies, and variability in the precipitation/evaporation ratio (Yang et al., 2011a, 2011b).

Recent human activity, including agricultural and extractive industry use has also contributed to change in these climatically sensitive regions (Yang et al., 2007). Current efforts to quantify and combat

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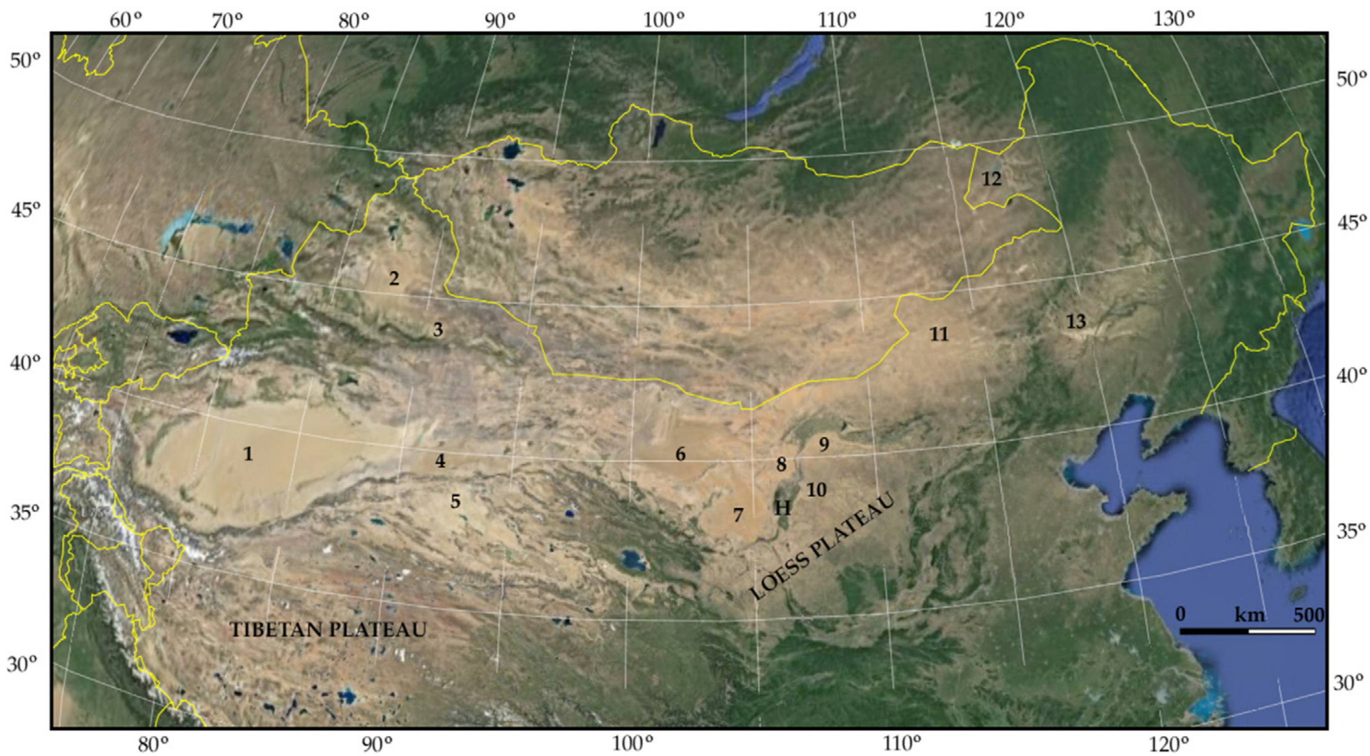

Fig. 1. Chinese desert distribution. Numbering as in Table 1. H designates the position of the Helan Mountains. Scale varies across image. Scale bar for 40°N.

desertification, including China's Grain to Green Program (GTGP), have focused on vegetative restoration and reclamation of sandy areas (Feng et al., 2013), the use of mitigating practices to control degradation of marginal desert areas (Li et al., 2004) and approaches designed to reduce dust production (Zhang et al., 2003).

As such, Chinese deserts and desert margins are regions that are highly sensitive to climate change with migrating climatic boundaries that respond to varying wind flow patterns, differential monsoon penetration, and even human activity. Currently only small portions of China's deserts have been extensively monitored with baseline information often incomplete or, in the case of large portions of these deserts, completely unavailable. Assessment of the impacts of current change and understanding of how these systems responded to past climatic variability is extremely difficult with these data constraints. A more complete understanding of these systems requires the use of new approaches to characterize and monitor China's deserts.

1.2. Organization and purpose of the paper

The purpose of this project was to assess the possibility of constructing a comprehensive database of Chinese deserts for environmental monitoring and analysis, and specifically to determine the content of such a database, to estimate its size, and to envision a plan for its construction in a format that would link to a larger global-scale version. Recent advances in database technology as well as examples of global-scale databases are reviewed to provide context for this work.

The entirety of China's desert area is captured in our top-level database structure and analysis of data and metadata in the database is used for countrywide regional-scale analysis. A smaller prototype multi-scale/temporal subset of this dataset from the Badain Jaran and Tengger Deserts is then introduced, and analysis of data within it is used to illustrate possible local and site-specific scale environmental assessment. Examples range from analysis of a single variable from all of China's deserts (cloudiness — solar radiation receipt) to studies in specific

Table 1
Chinese deserts west to east.

Map ID.	Desert	Type	Area km^2	Location
1	Taklamakan	Shamo	337,000	Tarim Basin, Xinjiang
2	Gurbantunggut	Shamo	49,000	Jungger Basin, Xinjiang
3	Turpan	Shamo	2500	Turpan Basin, Xinjiang
4	Kumtag	Shamo	23,000	Eastern Xinjiang, Western Gansu
5	Chaidamu Basin	Shamo	35,000	Chaidamu Basin, Qinghai
6	Badain Jaran	Shamo	45,000	West Alashan Plateau, Inner Mongolia
7	Tengger	Shamo	43,000	Southeast Alashan Plateau, Inner Mongolia
8	Wulanbuhe	Shamo	10,000	Northeast Alashan Plateau, Inner Mongolia
9	Kubuqi	Shamo	17,000	North Ordos Plateau, Inner Mongolia
10	Maowusu	Shadi	32,000	central-southern Ordos Plateau, Inner Mongolia
11	Hunshandake	Shadi	21,000	Eastern Inner Mongolia Plateau
12	Hulunbeier	Shadi	7000	Hulunbeier High Plain, NE Inner Mongolia
13	Horqin	Shadi	42,000	East Inner Mongolia Plateau/NE Plains