Anti-correlation of summer/winter monsoons?

Arising from: G. Yancheva *et al.* *Nature* **445,** 74–77 (2007)

On the basis of the anti-correlation of their palaeoclimatic proxy for the strength of the East Asian winter monsoon from Lake Huguang Maar, China, with stalagmite records of the strength of the summer monsoon, Yancheva *et al.*[1] claim that the strengths of the summer and winter monsoons are anti-correlated on a decadal timescale. They argue that the summer rainfall deficit during AD 700–900 that they infer from their evidence of a stronger winter monsoon, in conjunction with a Tanros battle, led to the collapse of the Tang dynasty (AD 618–907). Using historical climate records, we show here that most cold winters during AD 700–900 were associated with relatively wet summers, indicating that the strengths of the winter and summer monsoons were not negatively correlated during this period.

Yancheva *et al.*[1] deduce an inverse correlation of winter and summer monsoons by comparing centennial- to millennial-scale proxy records of winter monsoon strength from Lake Huguang Maar with records of summer monsoon strength from Chinese caves. Their inference that summer rainfall was low during AD 700–900 contradicts historical climate records for the same period. Chinese historical records can provide records of climatic events on annual to daily timescales[2]. A wetness index for the past 2,000 yr based on 36,750 historical climate records shows that China experienced two wet climate phases that bracketed a dry spell during AD 700–900, rather than a "general shift towards drier climate"[1]; wet conditions are recorded in AD 711–770 and 811–1050, with a dry phase in AD 771–810 (ref. 3; Fig. 1), so the last thirty years of the Tang dynasty were relatively wet, not dry.

The historical records show that the climate entered a cold phase from the middle of the eighth century, when the number of cold events between AD 756 and 907 were more than double the number in AD 618–755 (refs 4, 5; Fig. 1), implying that the winter monsoon was strong during the late Tang dynasty. Furthermore, out of 22 cases of severe cold (with anomalously frozen and heavy snow) during AD 700–900, only two occurred in years with a summer rainfall deficit[2], suggesting that 90% of the harsh winter events were associated with plentiful summer rainfall. This implies that cold winters and wet summers were characteristic of the climatic conditions of the late Tang period, suggesting that the strengths of the winter and summer monsoons were not anti-correlated during this interval.

Yancheva *et al.*[1] interpret their record of titanium (Ti) counts, which has near-annual resolution, as a measure of winter monsoon strength[1]. However, the intervals of increased winter monsoon strength indicated by this record are not always coincident with the intervals indicated by the historical records of severe winter frequency (Fig. 2). During AD 800–900, the highest Ti counts occur around the AD 860s, which is within a period when severe winters were infrequent; according to the historical records, only one

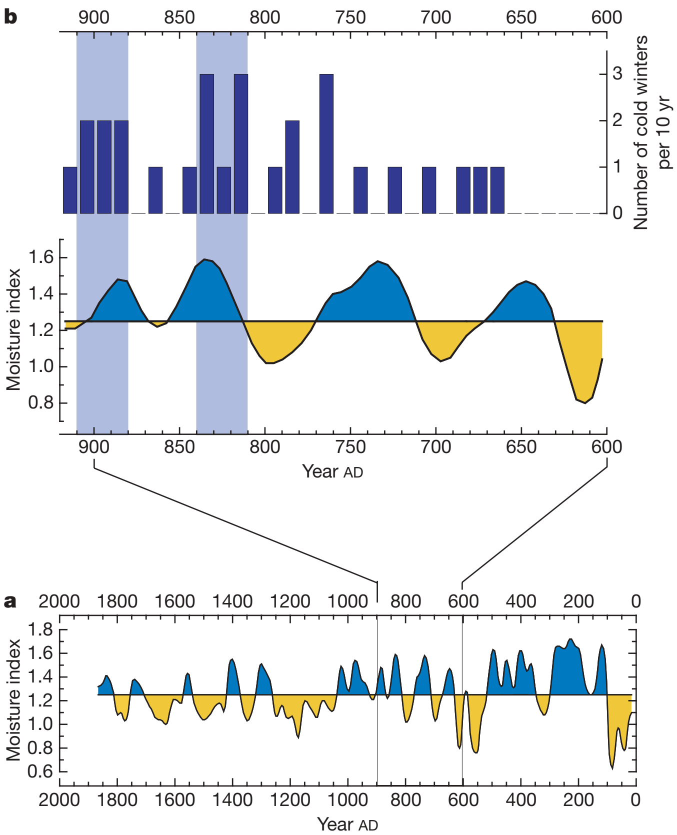

Figure 1 | Climate fluctuations during the past 2,000 yr based on Chinese historical documentary records. a, The moisture index series at a 5-yr resolution for East China during AD 1–1900; wet and dry intervals are indicated by the blue and yellow shading, respectively (redrawn from ref. 3). **b,** Comparison of the number of severe cold winters per decade (dark blue bars) and the moisture index series for the Tang dynasty (AD 618–907). During the late Tang dynasty (AD 810-907), the increase in the frequency of severe cold winters is associated with plentiful summer rainfall (pale blue shading).

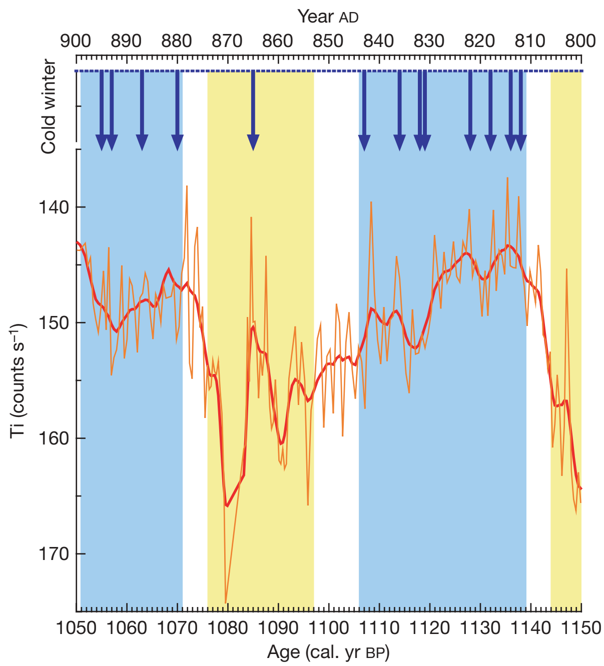

Figure 2 | Comparison between severe cold winters recorded in Chinese historical documents[2] and the Ti counts from Lake Huguang Maar. Severe cold winters recorded are shown by blue arrows. The Ti counts from Lake Huguang Maar are shown by the thin red curve (the thick red curve has been smoothed with a 9-point running average, after Yancheva *et al.*[1] from data archived at the World Data Center for Paleoclimatology, Boulder, Colorado, USA) during AD 800–900.The high Ti counts correspond to the lowest frequency of severe cold winters (AD 850–870; yellow shading), while the low Ti counts correspond to increased frequency of cold winters (AD 810–840, 880–900; blue shading). The winter monsoon strength inferred from Ti counts contradicts that based on the occurrence of cold winters in ancient Chinese records.

(AD 865) occurred between AD 850 and 880. In contrast, AD 810–840 witnessed seven very severe winters, including the sea ice event of AD 822 (ref. 2), which is often considered to be the coldest interval during the Tang dynasty. According to the interpretation of Yancheva *et al.*[1], the lower Ti counts recorded in Lake Huguang Maar[1] during this interval indicate that the winter monsoon was weak during this interval (Fig. 2), in conflict with the historical evidence. Their proxy-based assessment of intervals of increased winter monsoon strength during this period should therefore be called into question.

Furthermore, the intervals of increased winter monsoon strength in AD 810–840 and AD 880–900, indicated by an increase in the frequency of cold winters recorded in the historical records, were both associated with plentiful summer rainfall, whereas the interval of reduced winter monsoon strength between about AD 850 and 870 was associated with a summer rainfall deficit (Fig. 1). This casts further doubt on the proposal of Yancheva *et al.* that the strengths of the winter and summer monsoons were anti-correlated at a multidecadal scale during AD 600–900.

Yancheva *et al.* say that the Tang dynasty began to ebb in the eighth century, after a defeat by the Arab army in AD 751, but that border battle was not a major event; it is better known for spreading ancient Chinese paper-making techniques to the Arabic countries by prisoners[6]. Instead, most Chinese historians agree that the decline of Tang dynasty began with the An-Shi riot in AD 755, owing to the resulting disorders, which exhausted resources[6]. The view of Yancheva *et al.* on the historical significance of the border conflict in AD 751 is therefore in doubt.

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Received 17 February; accepted 24 August 2007.

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doi:10.1038/nature06338

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Replying to: De'er Zhang & Longhua Lu *Nature* **450,** doi:10.1038/nature06338 (2006)

Zhang and Lu[1] argue that Chinese historical climate records contradict certain of our interpretations[2] based on Lake Huguang Maar sediment records. Interpreting these records as an indicator for winter monsoon winds and Chinese cave records as an indicator for summer monsoon rainfall[3], we observed[2] an inverse relationship between winter and summer monsoons on a millennial timescale over the past 16,000 yr. In sediments deposited during the period of Classical Chinese dynastic history, we found evidence for a temporal coincidence between winter monsoon strengthening and the terminations of important dynasties[2]. Extrapolating the inverse monsoon relationship to these multidecadal timescales, we suggested that reduced summer rainfall contributed to dynastic terminations, including that of the Tang (AD 618–907). Zhang and Lu[1] challenge the validity of the summer/winter monsoon relationship on the grounds that historical records indicate that relatively cold winters tended to be associated with relatively wet summers over the period they considered. They argue that the Tang dynasty decline was associated with cold winters, in agreement with our findings[2], but they find no evidence for rainfall changes having contributed to the decline of the Tang.

We compare our Lake Huguang Maar record during AD 550–1550 with two historical reconstructions (Fig. 1): a hydrologic reconstruction from the Jiang-Nan area in southeast China (25–31° N)[4], the most proximal record of which we are aware, and a lower-resolution, winter, half-year, temperature reconstruction for eastern China[5]. To clarify similarities between the Lake Huguang Maar sediment record[2] and the historical climate records[4,5], we have allowed for stratigraphic adjustments in the former by no more than 40 yr (Fig. 1). The higher-resolution historical reconstruction of wet/dry conditions in southeast China[4] corresponds well with weak/strong winter monsoon intervals, as indicated by our lake records and by the historical winter temperature record. Its correspondence with the wet/dry record of Zhang and Lu is uncertain; the apparent differences between the two wet/dry historical reconstructions may derive from geographic variability or error in the reconstructions. The previously observed longer-term anti-correlation between winter and summer monsoons seems to apply to a significant portion of the (multi)decadal-scale variability investigated here.

We acknowledge that much of the last 20 yr of the late Tang dynasty was characterized by wetter conditions[1]. Nevertheless, the end of the Tang dynasty at AD 907, which occurs at a sharp increase in Ti content at Lake Huguang Maar[2], is also marked by a sharp drying in the unsmoothed historical reconstruction of Zheng *et al.*[4] (Fig. 1, thin blue lines), as well as in the record presented by Zhang and Lu[1]. Thus, the historical data suggest that the Tang dynasty collapsed during a period of both cold winters and low and abruptly dropping rainfall (Fig. 1). This may be critical: the rate of climate change could be as important as mean climate from the point of view of social and political impact, as rapid change might disconnect social policies from environmental realities. We acknowledge the clarification of Zhang and Lu that the An-Shi rebellion was more important than the AD 751 Tanros battle in the weakening of the Tang empire.

Both temperature and rainfall seem to have had an important influence on Classical Chinese dynastic changes, including the decline of the Tang dynasty[1,4,5]. Although the reconstructions are somewhat ambiguous on the point, the inverse correlation between winter and summer monsoons observed on millennial timescales[2] does describe some of the decadal and multi-decadal climate variability in Chinese dynastic history.

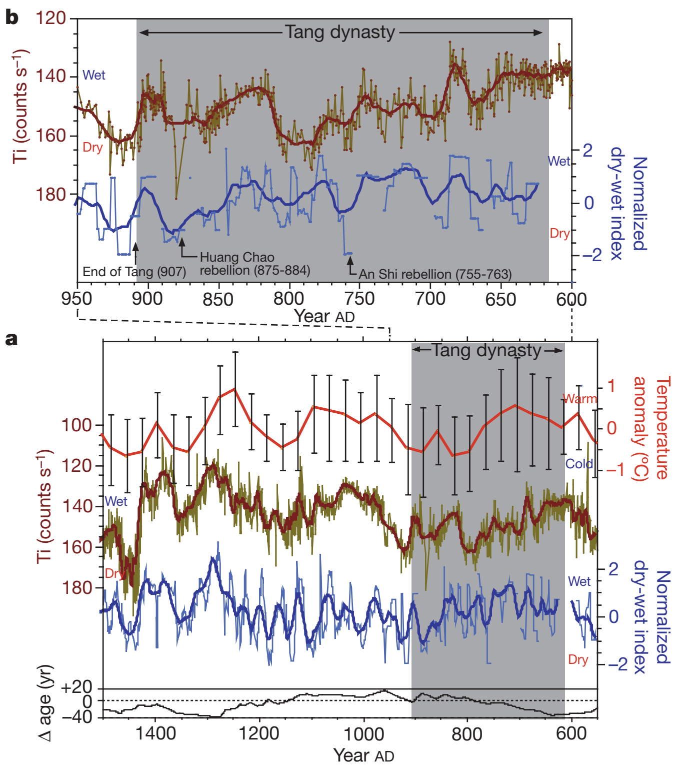

Figure 1 | Comparison of Chinese historical climate records[4,5] with the Lake Huguang Maar sediment record[2]. Comparisons are shown for the time intervals AD 550–1500 (**a**) and AD 600–950 (**b**). In **a**, the red line shows the reconstruction of winter half-year temperatures in eastern China[5] (error bars show uncertainties associated with historical data); **a** and **b** show the Lake Huguang Maar titanium record[2] (brown: original data and 15-point running mean), and the reconstruction of hydrologic conditions from the Jiang-Nan area in southeast China[4] (blue: original data and 15-point running mean). The latter are expressed as a normalized dry-wet index; data are connected by a thin blue line only where data points are available from consecutive years. High Ti values (plotted downward) are interpreted to reflect stronger winter monsoon winds[2]. We have allowed for stratigraphic adjustments in the Huguang Maar sediment record[2] that are consistent within error with the published age model. None of these were more than 40 yr, and most were much less, including during the interval of the Tang dynasty (black curve at bottom of **a** shows the adjusted timescale minus the ^{14}C-based timescale as described in Yancheva *et al.*[2], such that the vertical scale matches that of the *x*-axis).

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doi:10.1038/nature06339