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Synchronous droughts and floods in the Southern Chinese Loess Plateau since 1646 CE in phase with decadal solar activities

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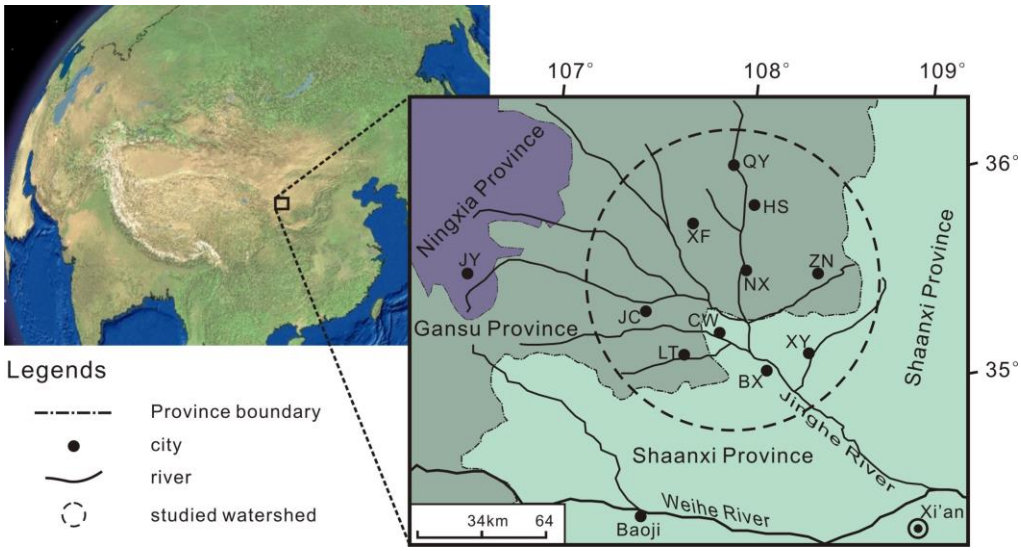

Fig. 1 The catchment of River Jing in the southern CLP and locations of ten selected counties (as indicated by solid dots within the dashed circle) in the mid-reaches of River Jing. Ten counties included in our study are: 1. Qiangyang county (marked as QY), 2. Heshui county (marked as HS), 3. Xifeng county (marked as XF), 4. Ningxian county (marked as NX), 5. Zhengning county (marked as ZN), 6. Jingchuan county (marked as JC), 7. Changwu county (marked as CW), 8. Xuanyi county (marked as XY), 9. Lingtai county (marked as LT), and 10. Binxian county (marked as BX). Jingyuan county (marked as JY) is the source water of River Jing.)

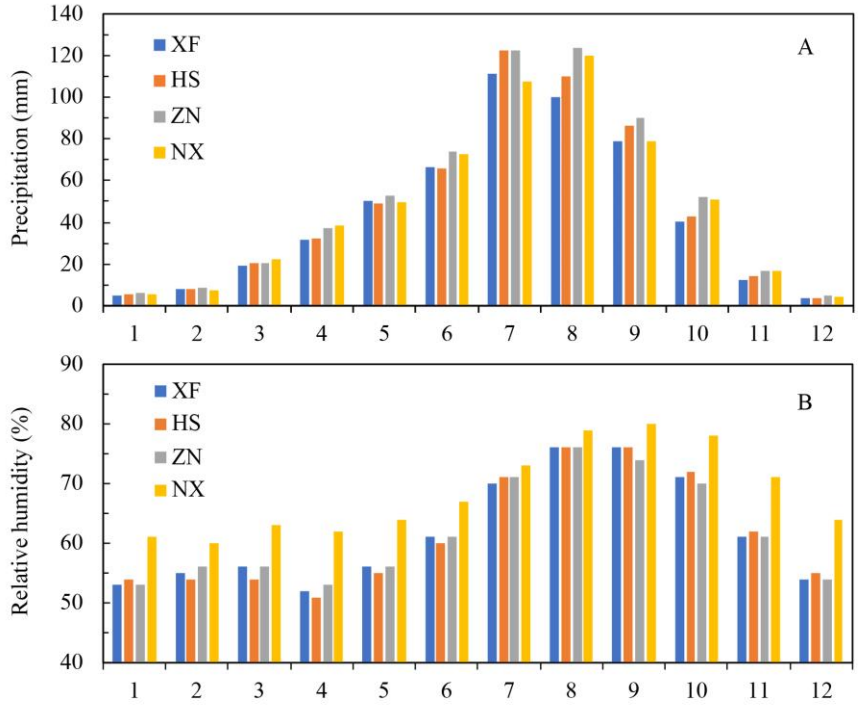

Fig. 2 Monthly climatology records from 1955 to 2005 at meteorological stations within the XF, HS, ZN and NX counties, see Fig. 1 for their locations. A) The climatology of monthly mean precipitation (unit mm/month) in XF, HS, ZN, and NX stations from January to December (marked from 1 to 12). B) The climatology of monthly mean relative humidity (nonunital) in XF, HS, ZN, and NX stations from January to December (marked from 1 to 12).

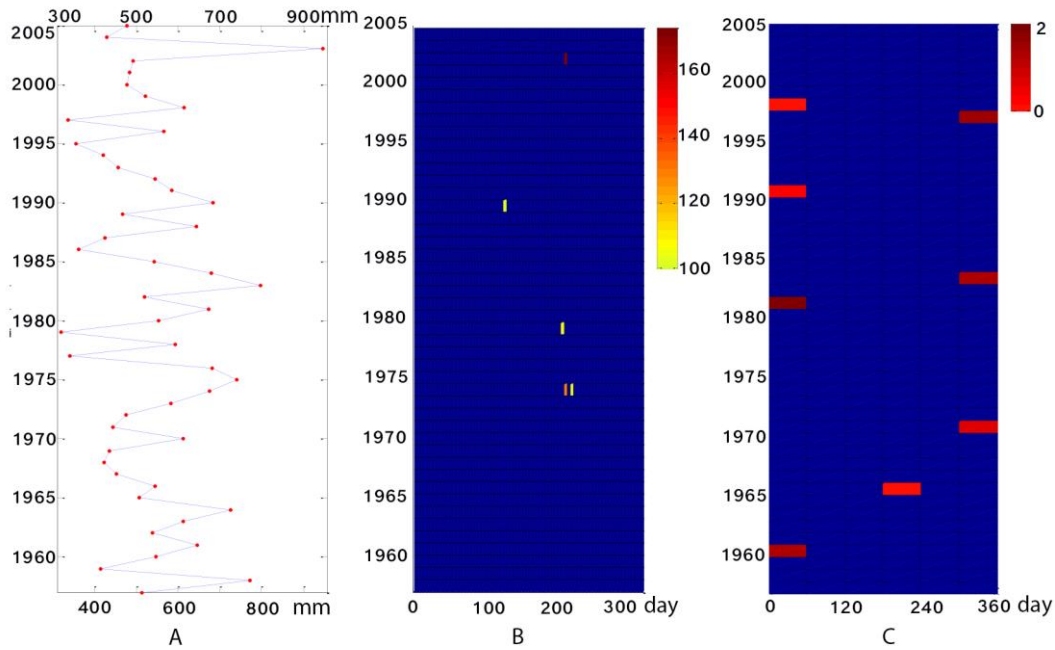

Fig. 3 Annual total rainfall at BX county (see Fig. 1 for BX location), and past droughts and floods (1955-2005) derived from daily rainfall observation at Binxian meteorological station. (A) The timeseries of annual total precipitation from 1955 to 2005. (B) The past floods based on 5-day accumulated rainfall above 100 mm, colour shades show the intensity of flood in mm. (C) The past droughts based on 60-day accumulated rainfall below 2 mm, colour shades show the severity of drought in mm. For both panel B and C, the X-axis is the day in a year marked from zero, and the Y-axis is the actual year of observation. We have to use the dark blue background colour therein to make it easier to identify the past flood and drought events than a white background.

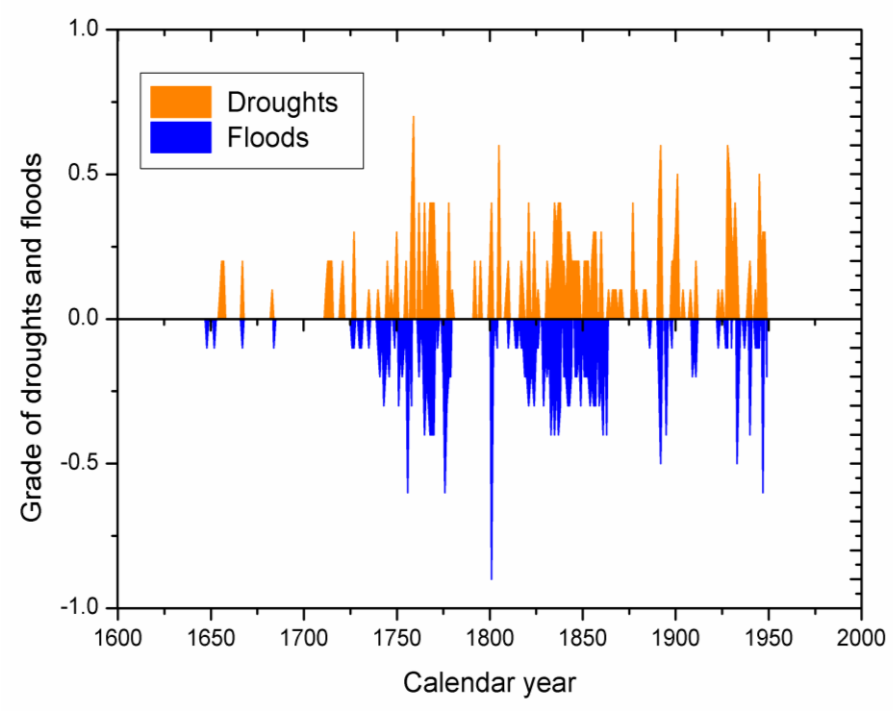

Fig. 4 The derived timeseries of floods and droughts at the catchment scale in the mid-reaches of River Jing (1646-1949). See Section 3 for more details about how we have reconstructed the timeseries from historic archives.

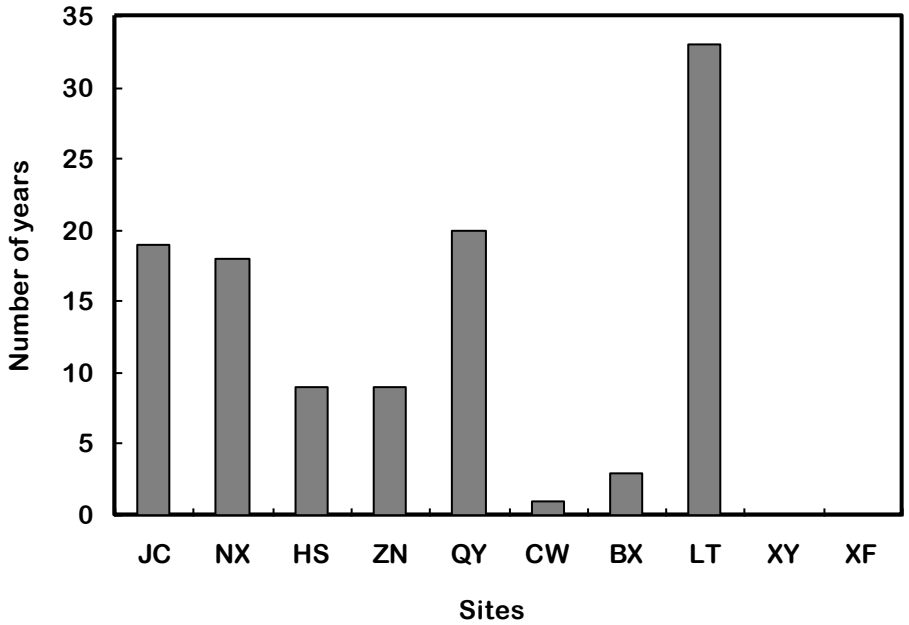

Fig. 5 The frequency plot shows the number of years with records of both droughts and floods in the same year during the Qing Dynasty era (1646-1949) as based on the historic archives. JC, NX, HS, ZN, QY, CW, BX, LT, XY, and XF are short names for ten counties in Fig. 1. LT county had the largest number among the ten, while XY and XF counties did not have both droughts and floods occurred in the same year during the period.

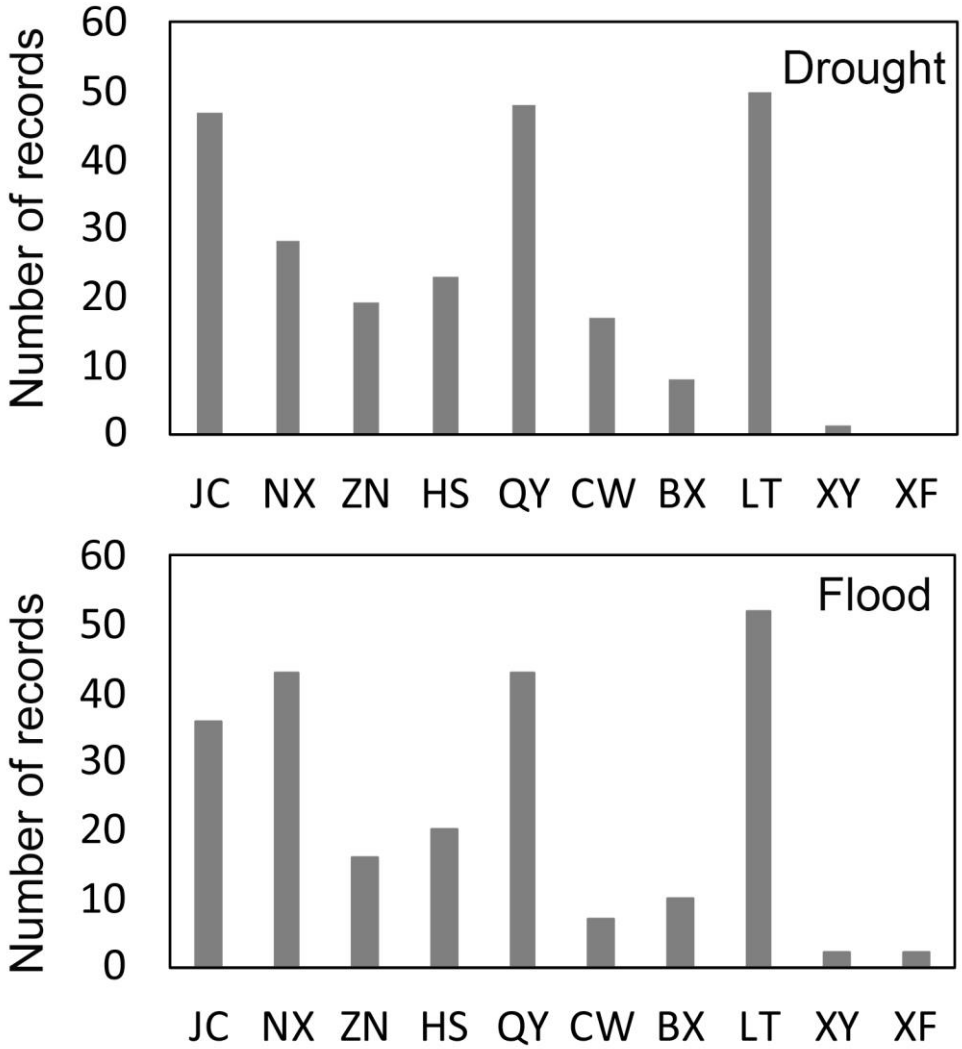

Fig. 6 Regardless the year of occurrences, the frequency plot shows the total number of records for droughts (top panel) and floods (bottom panel) during the Qing Dynasty era (1646-1949) as based on the historic archives in the catchment of River Jing. JC, NX, HS, ZN, QY, CW, BX, LT, XY, and XF are short names for ten counties in Fig. 1. LT county had the largest number of records among the ten, while XY and XF counties had the minimum records of droughts and floods during the period.

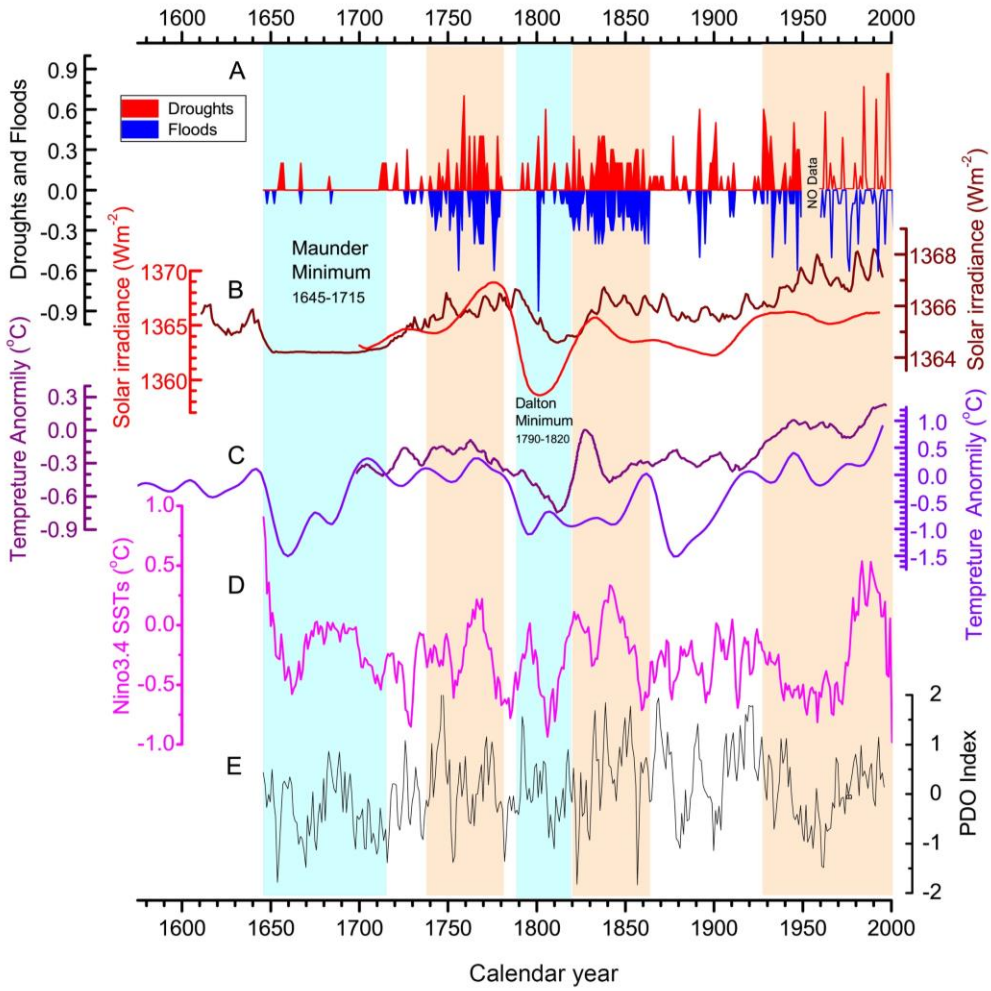

Fig. 7 A comparison of droughts and floods in the mid-reaches of River Jing (A) with: (B) the reconstructed solar irradiance (the red line in B is from Solanki and Fligge, 1999, and the wine line is from Lean et al., 1995); (C) the reconstructed temperature (the purple line is from Mann et al., 2008, the violet line is the reconstructed winter mean temperature in east China from Ge et al., 2003); (D) the reconstructed Nino 3.4 SST index（Li et al., 2013）, and (E) the reconstructed PDO index (Macdonald et al., 2005). The blue bands show that the colder climate during the Maunder Minimum corresponds to the very few droughts and floods. The light orange bands show episodes of warmer climate (e.g., higher solar activity and higher ENSO/PDO index) and higher frequency of both flood and drought disasters.

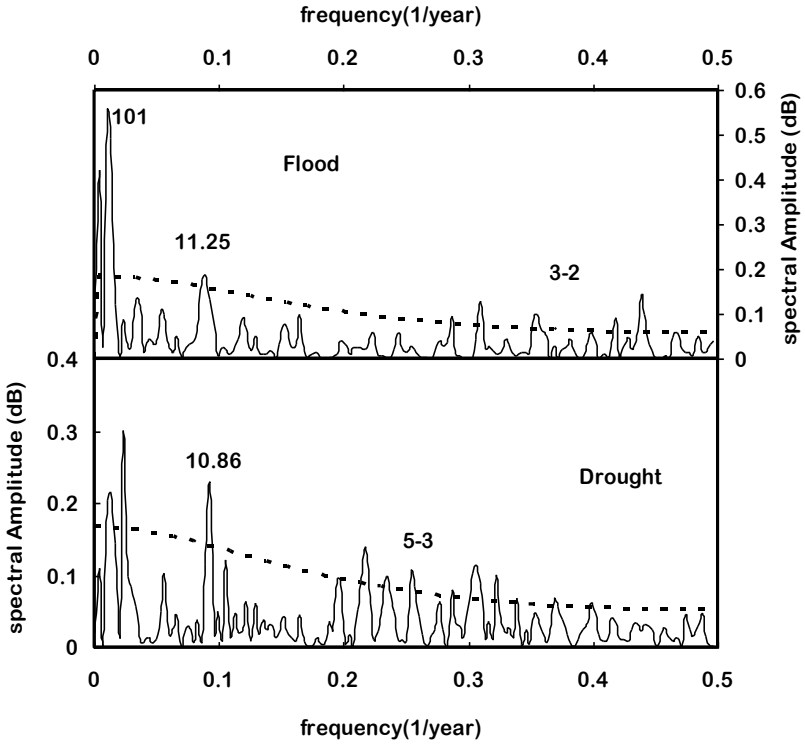

Fig. 8 Result of spectral analyses on the flood and drought timeseries as derived in Fig. 4 (1646-1949). Dashed lines are for 95% statistical significance levels in our spectrum analyses.