

SUMMERTIME INTRASEASONAL AND INTERANNUAL LIGHTNING VARIATIONS IN THE WESTERN UNITED STATES

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Cloud-to-surface lightning strikes in the Western States have been monitored continuously by automated detectors since 1985 (Orville, 1994; Wacker and Orville, 1999). Analyses of the resulting records can be used to complement precipitation observations in studies of the North American monsoon. Although fire seasons vary from place to place, warm-season lightning also has much practical significance as a potential trigger of wildfires because one-half to two-thirds of all western wildland fires are caused by lightning (Pyne et al., 1996; Knapp, 1997). In this paper, the summer lightning season is defined as May through September. Patterns and regularities in daily counts of lightning strikes from 1985 to 1996 are being analyzed to assess predictability of clusters of lightning strikes and thereby, perhaps, to improve the predictability of wildfire risks.

Days on which numerous lightning strikes (often many thousands) were observed in a given location generally are associated with atmospheric-circulation patterns over the Pacific-North American sectors that correspond to locally warm surface temperatures and moderate (but not large) moisture transports into the lightning areas. For example, in Fig. 1, the 700-mbar height anomalies associated with numerous lightning strikes in western Montana include a broad high-pressure anomaly over Montana, Saskatchewan, and much of interior western North America (suggesting subsidence and warm surface temperatures) and strong pressure gradients along a line from south to northwest (suggesting anomalous moisture transport from the south and southeast

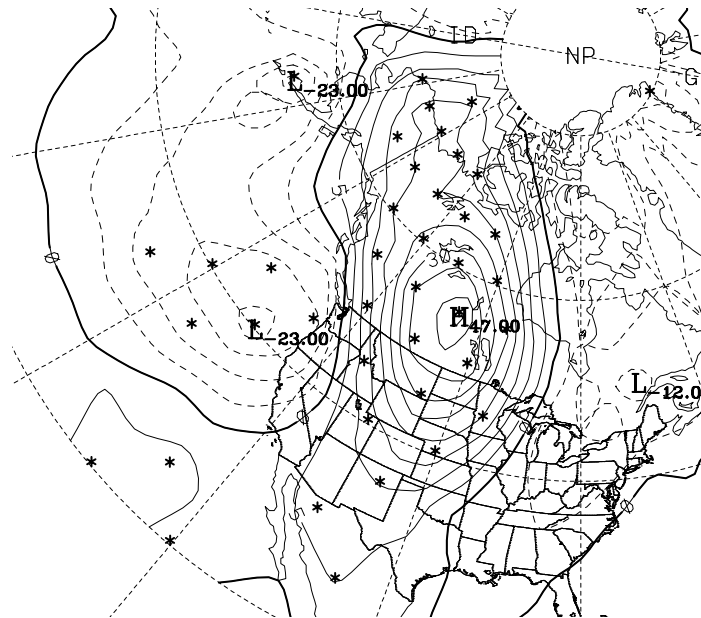


Figure 1. Composite mean of daily 700-mbar height anomalies on the 52 summer days during 1985-96 with largest numbers of lightning strikes in western Montana. Contour interval is 5 m; dashed where anomalies are negative; asterisks indicate significant (95%-confidence) departures from climatology.

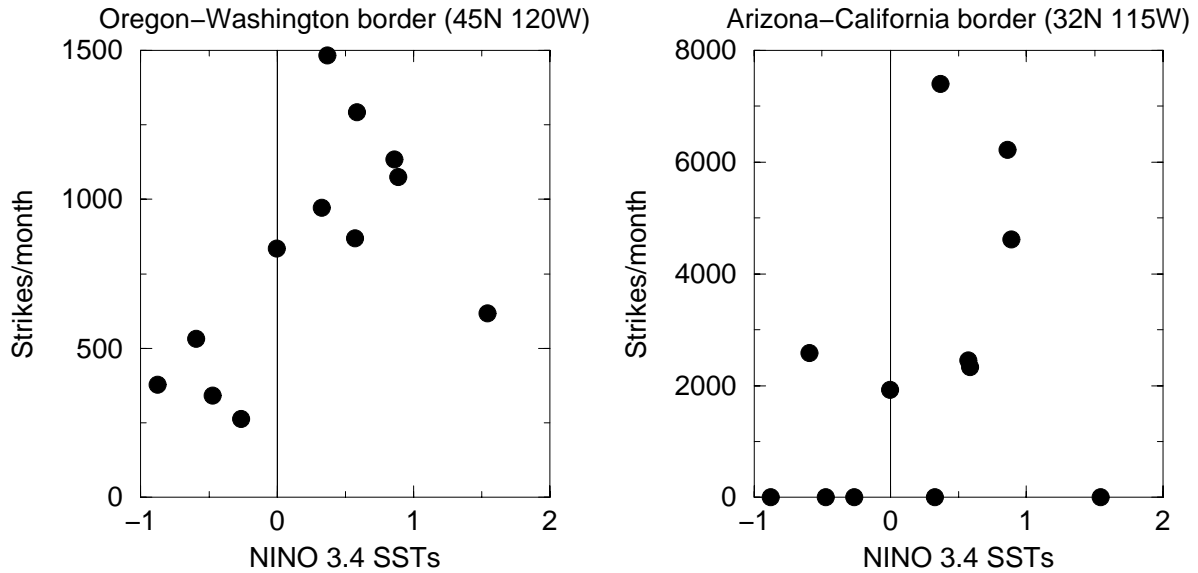


Figure 2. May-September 1985-96 monthly-mean lightning counts in two 1x1 latitude-longitude cells, as functions of concurrent Niño 3.4 sea-surface temperatures (SSTs). Niño 3.4 SSTs are the average of SST anomalies in the region from 5S-5N, 170W - 120W, and are a common index of El Niño status (warmer Niño 3.4 SSTs mark El Niños, cooler SSTs mark La Niñas).

into the region). The scales of the associated atmospheric-circulation anomalies are large and thus may be modulated by even larger scale and potentially predictable climatic conditions. For example, on interannual time scales, several of the El Niño summers during the period of record have been accompanied by increased lightning-strike counts (relative to other summers) in many areas of the West including the Northwest, Dakotas, and interior Southwest. Two examples of seasonal-total lightning-strike variations with El Niño status are shown in Fig. 2.

The lightning-strike series are better suited (with only 11 years of coverage) for analysis of intraseasonal (10- to 100-day) variations of the sort that might be associated with fits and starts of the North American monsoon. Notable intraseasonal lightning episodes are present in the time series and appear as north-propagating episodes of lightning occurrence, reminiscent of northward monsoon surges. For example, intraseasonally varying bursts of lightning occurrence extending northward from Arizona, through the central Great Basin, and into Idaho during an extended period in summer 1991 are shown in Fig. 3. Similar episodes characterize corresponding

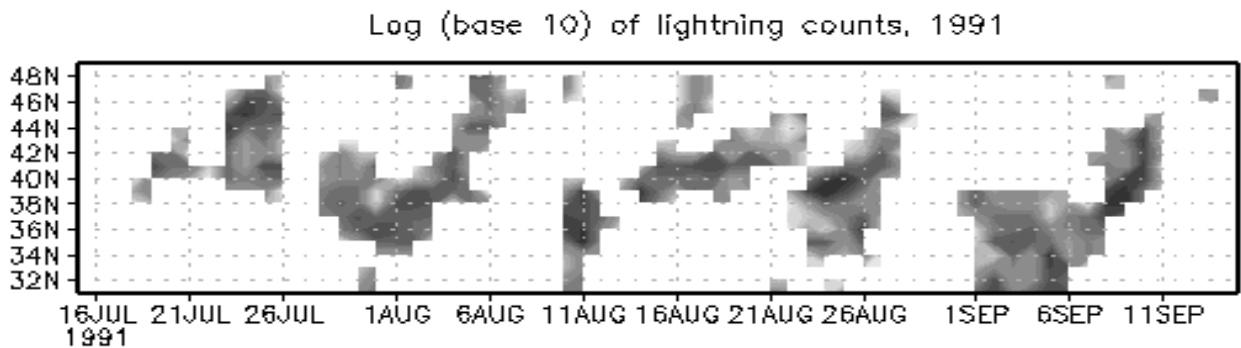


Figure 3. Time vs. latitude plot of logarithm of daily lightning-strike counts in 1x1 latitude-longitude cells along 115 W; darker areas correspond to orders of magnitudes more lightning counts and white areas indicate no lightning strikes.

DAILY LIGHTNING STRIKE FREQUENCIES, 1988-96
FRACTION OF 10-70 day MTM Spectral Power Density

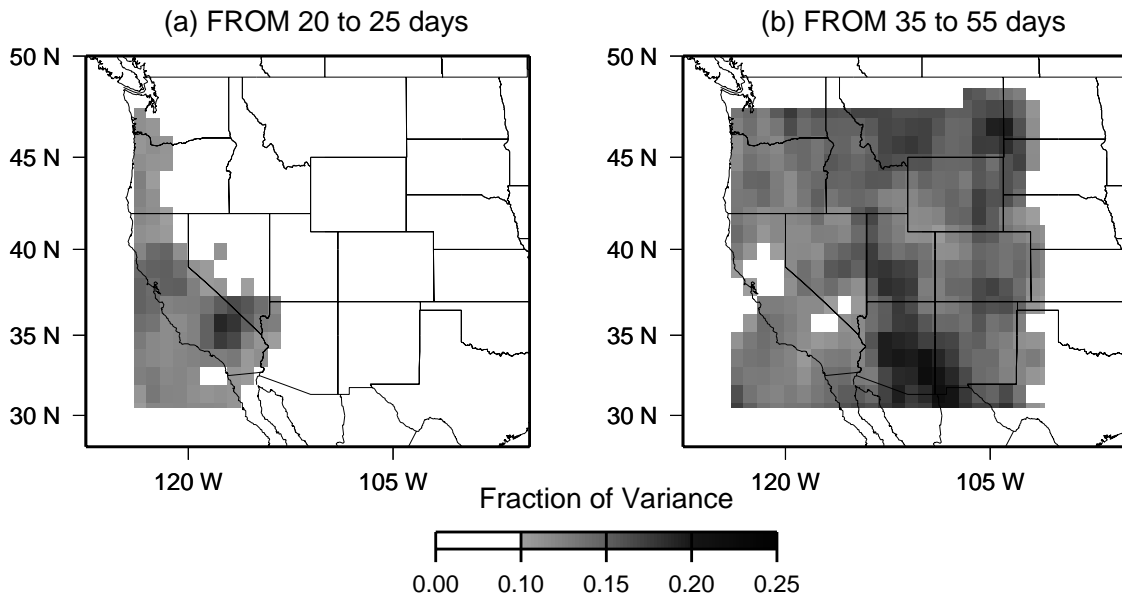


Figure 4. Fractions of overall intraseasonal variance of daily lightning-strike counts in 1x1 latitude-longitude grid cells found in frequency bands (a) from 20 to 25 days and (b) from 35 to 55 days. In white noise, the fraction of variance in each band would be 12%. Power spectral densities were estimated by the multitaper method (Mann and Lees, 1996), and comparisons with red noise indicate that centers of power in each panel are significant at 99% levels of confidence.

plots (not shown here) for about half of the summers for which data are available. On these intraseasonal time scales, a potentially important mode of lightning variation has a 35- to 55-day time scale similar to the tropical Madden-Julian oscillations (MJO; Madden and Julian, 1971). These lightning variations are centered in the deep southwest (i.e., near the heel of New Mexico; Fig. 4b) but extend over much of the interior west. This intraseasonal lightning mode is synchronized—on average—with the phases of MJO variations of tropical outgoing longwave radiation (OLR) around Indonesia. The low point in the lightning cycle corresponds to anomalous convective activity east of Indonesia, and the high point (and, especially, a few days prior to the high point) is associated with suppressed convective activities in the same region (Fig. 5). A more localized lightning mode exhibits 20- to 25-day variations over California (Fig. 4a) and may correspond to a summertime continuation of 20- to 25-day tropical forcings of wintertime precipitation there (Mo, 1998) and an expression of the more widespread 22-day precipitation mode of summertime precipitation in the Southwest (reported by Mo in this volume). This 20- to 25-day lightning mode is not so synchronous with oscillatory OLR variations in the tropics.

Thus, historical lightning-strike series can provide additional perspectives from which to monitor and characterize intraseasonal (and, perhaps, longer term) variations of the summer climate of the Western States. This additional perspective may help to better understand and predict the evolution and consequences of the North American monsoon in the Southwest, and provide intraseasonal predictive capability for natural wildfire starts.

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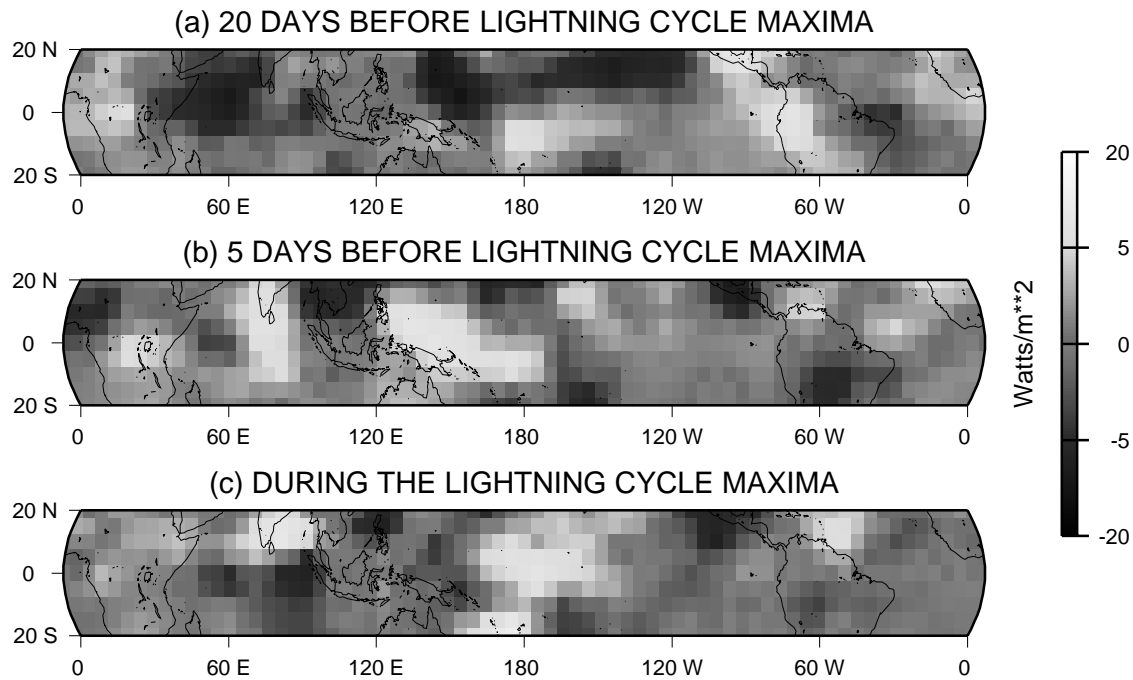


Figure 5. Composite averages of outgoing longwave radiation (OLR) anomalies during various phases (panels a-c) of multitaper reconstructions of cycles in the 35- to 55-day frequency band at 32N 108W, based on the 33 largest episodes in the reconstructions. Dark shades (negative OLRs) correspond to anomalously rainy conditions in the tropics; light shades correspond to dry conditions. Notice reversal of OLR patterns over Indonesia and Mexico during the cycles.

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