ENSO influences the Location, Extent, Intensity of Atmospheric Ridges over Western North America

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Overview

We build a climatology of the location, spatial extent and core intensity of ridges across western North America and the Northeast Pacific for every season. We also identify extreme ridges based on their size and intensity. To evaluate the potential for seasonal predictability, we examine the influence of opposite phases of El Niño–Southern Oscillation (ENSO) on the seasonal characteristics of all ridges as well as the extreme ridges.

Data and Methods

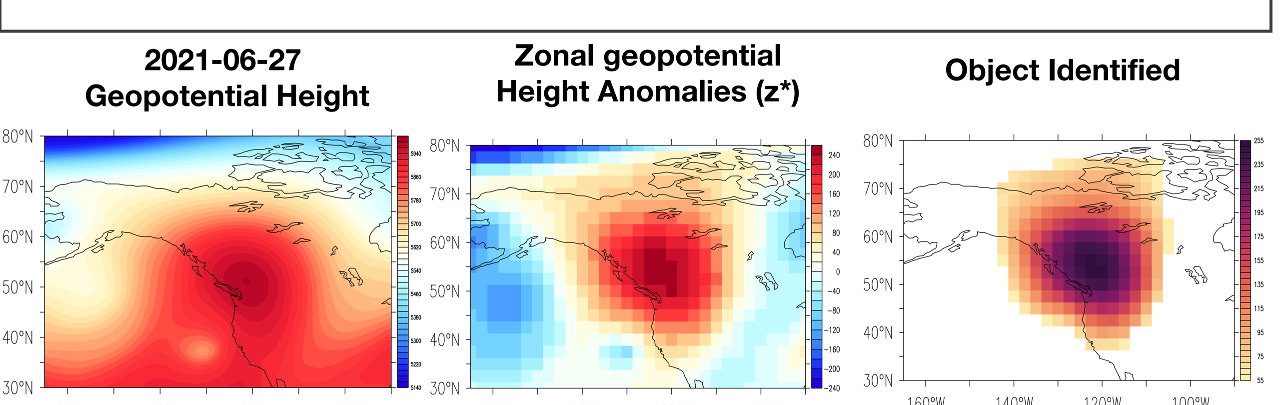
Data Source: ERA5 500-hPa geopotential heights during 1950-2022

Ridge Identification: We first calculate the 75th percentile of the zonal geopotential height anomalies (Z^*) for each month over the climatological period (1991-2020) over our domain (30°-80° N). A 3-month centered window is used to obtain this threshold. Then we find the maximum Z^* exceeding this 75th percentile threshold. If the eight surrounding grid cells of this maximum are larger than the threshold and within 85% of the maximum, these nine grids will form the **core**. Next, we iteratively search surrounding, connected grid cells to identify the ridge object. We apply a minimum size threshold of 50,000 km^2 for ridge objects included in the analysis.

Characteristics: For each ridge object, we calculate its centroid, spatial extent, and intensity. If the ridge's centroid is within 30°-80° N and 165° - 100° W, it will be selected for our study. Spatial Extent is defined as latitude weighted area. Core Intensity is defined as the core's latitude weighted intensity.

Extreme Ridges: Top 10% of ridges based on spatial extent or core intensity

Significant Test: two-tailed permutation test with 10,000 iterations



1. Circulation Examples

Below are the largest and most intense ridges in each season that occurred in the recent 5-year period (2018-2022). Most of these ridges have been associated with notable surface impacts across the region including the 2021 PNW heatwave, the 2021 December winter storm. The 2022 December ridge later developed into a blocking that caused the 2022 mid-October heatwave.

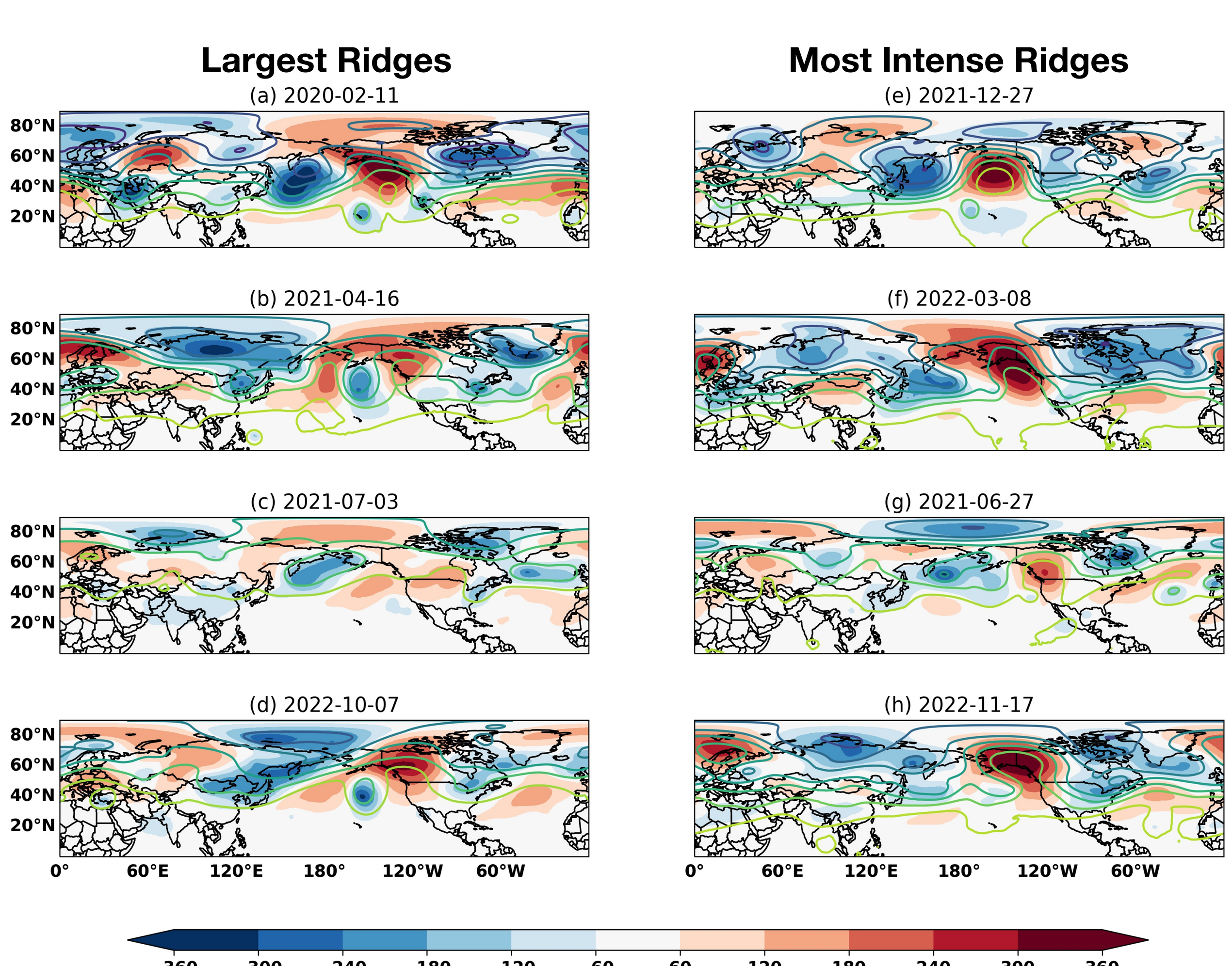


Figure 1: The Northern Hemisphere geopotential height (contour) and Z^* (shading) configuration of the largest (a-d) and most intense (e-h) ridges during 2018-2022.

2. Spatial Climatology of the Ridges

Ridges show distinct differences in frequency, extent, and intensity between seasons. The highest frequency of ridges occur along the coast and the northeast Pacific during boreal fall, spring, and winter (Fig. 2a-d). In contrast, during summer, the highest ridge frequency is more inland. For all seasons, the largest ridge extents occur at at higher latitudes (Fig. 2e-h). Their intensity varies substantially between seasons, with the highest intensity occurring over the northeast Pacific and Alaska in most seasons (Fig. 2i-l). Boreal winter ridges are larger and more intense while the extent and intensity of summer ridges are the smallest.

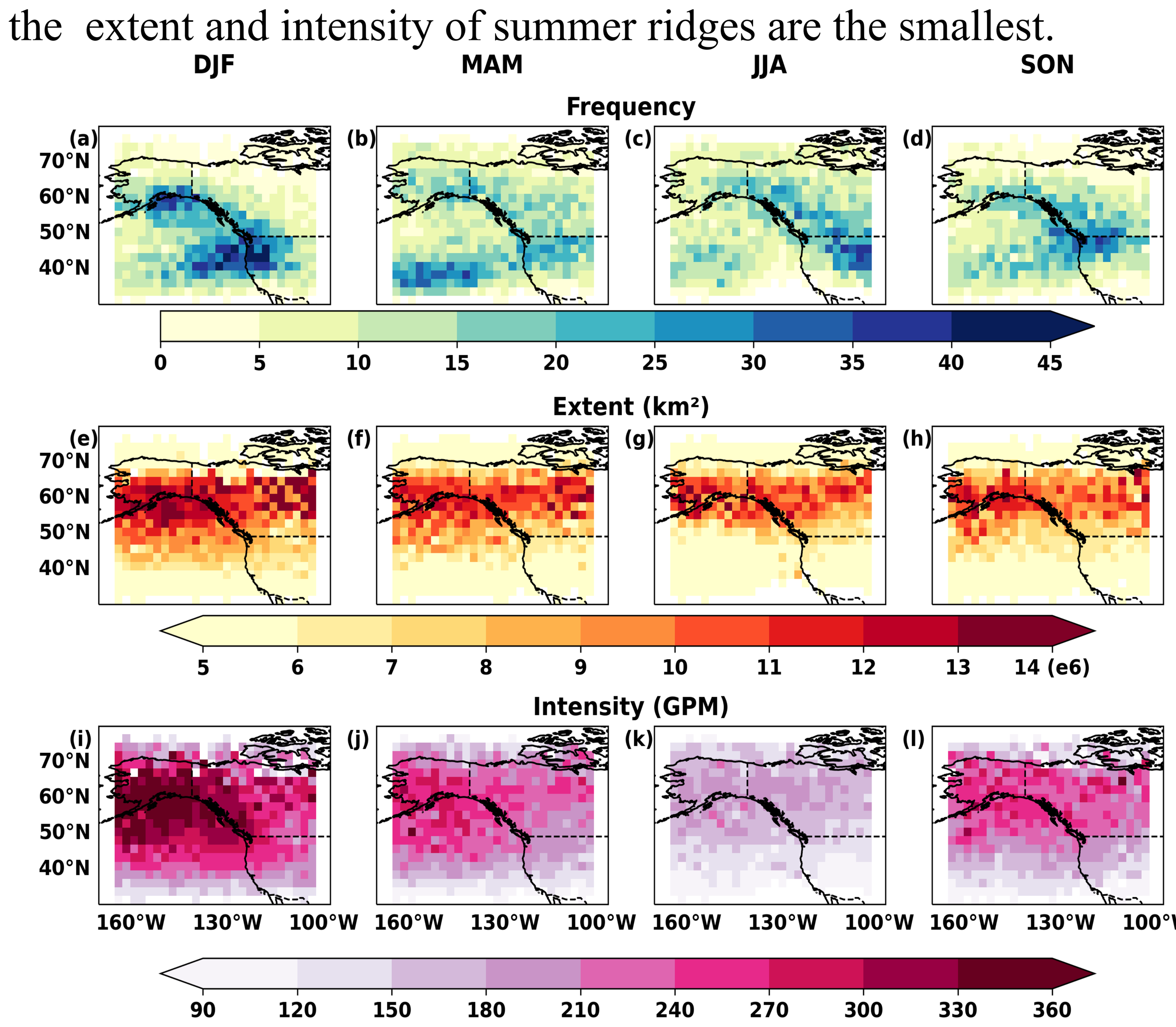


Figure 2: Spatial distribution of ridge frequency (a-d), extent (e-h) and intensity (i-l) during 1950-2022. Ridges are grouped based on the location of their centroid

3. Long-term Trend of the Ridges

We do not find any significant long-term trends for most characteristics of the ridges in any season. The exception is the intensity of summertime ridges, which is decreasing at a 90% confidence level.

There is substantial multidecadal variability in the frequency of ridges. The timeseries show a tendency towards more frequent ridges in the winter and spring and less frequent ridges in summer and fall over the past two decades.

Figure 3: Temporal distribution of ridges' frequency (a-d), extent (e-h),and intensity (k-l). For the ridges we identified, we group them by each year. The thin lines are the events for each year and the thick lines are 10-year rolling mean. The shading is between the minimum and maximum value for each year.

4. Extreme Ridge Characteristics during Different Phases of ENSO

During La Niña spring and fall, extreme large ridges locate at higher latitudes with many of them centered over central Canada (Fig. 4) and they are significantly larger than during El Niño seasons (Fig. 5). During Fall, the extreme large ridges are significantly more intense during La Niña and during summer, they are significantly more intense during El Niño. For extreme intense ridges, La Niña generally favors more of them over the northeast Pacific especially during winter, spring and fall. Extreme intense ridges during La Niña are significantly larger for all seasons and significantly more intense during winter. Summer extreme intense ridges center over western Canada during La Niña while over Alaska during El Niño.

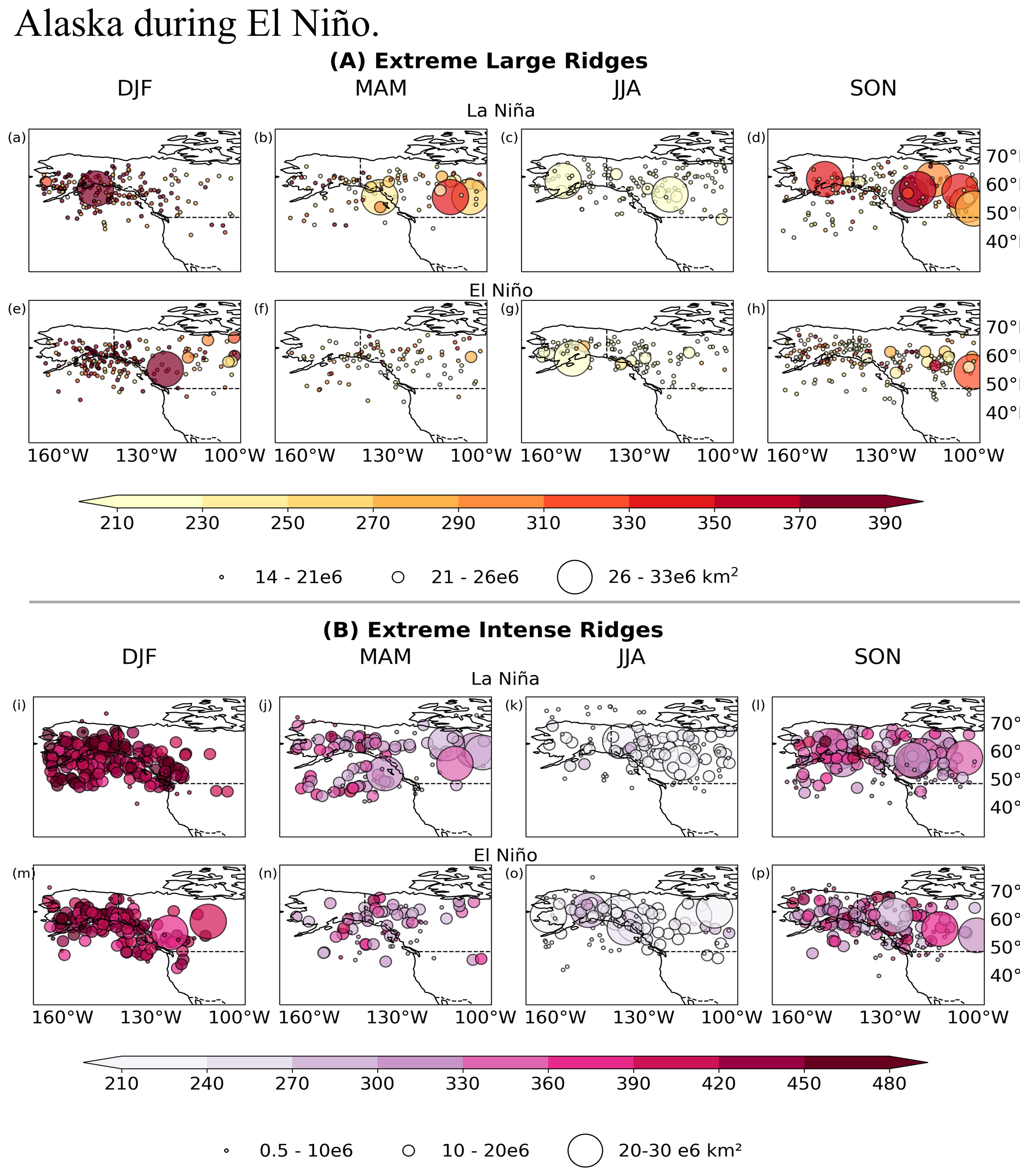


Figure 4: Extreme ridges' location, extent (circle) and intensity (shading) of extreme large ridge (a-h) and extreme intense ridges (i-p).

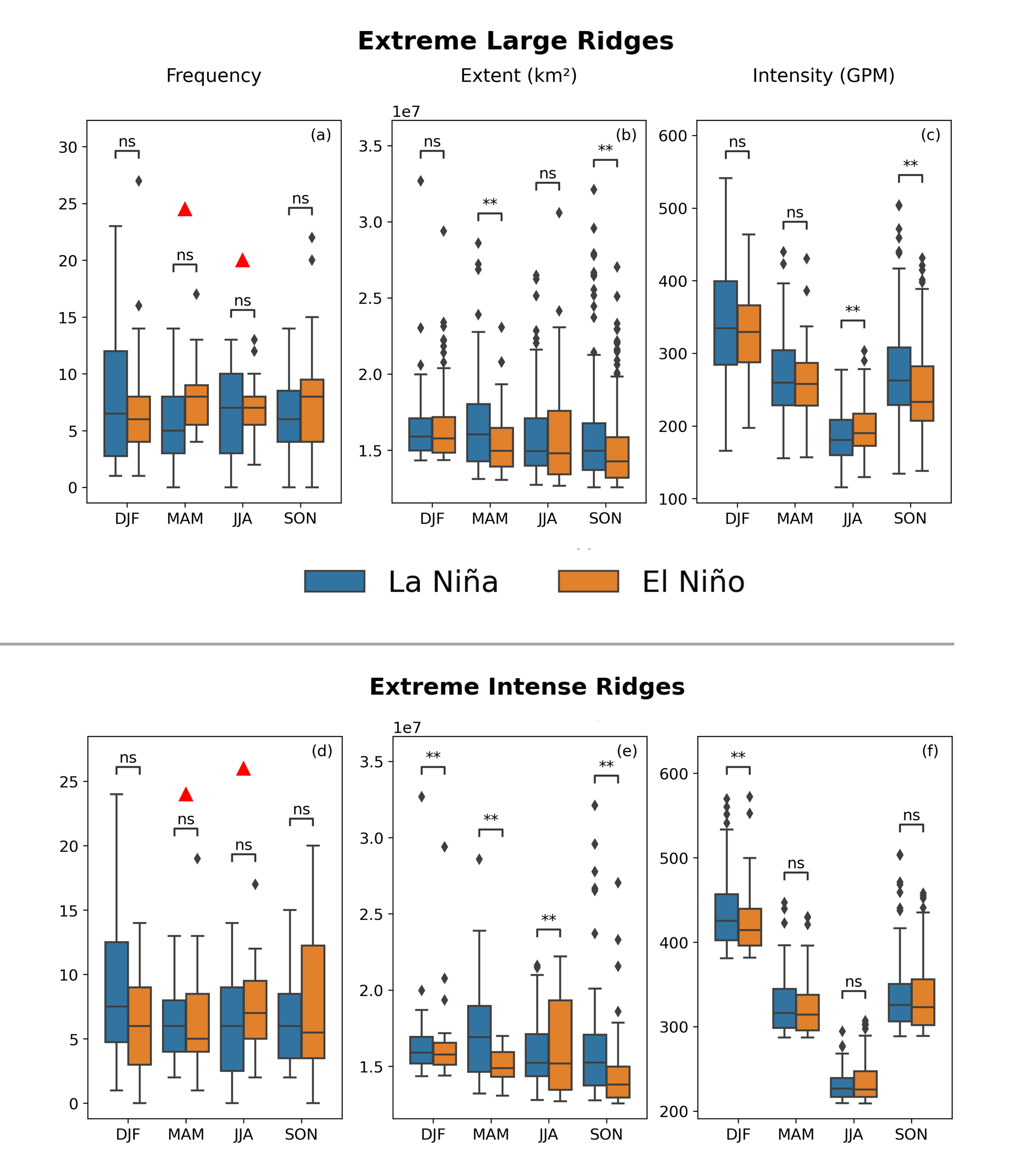


Figure 5: Distributions of the characteristics of extreme large (a-c) and intense (d-f) ridges during opposite ENSO phases. Star denotes significance of differences in distributions based on a permutation test. The red triangle denotes sample sizes <20.

Key Takeaways:

- Substantial variations in the location, frequency, and intensity of ridges between seasons. Wintertime ridges have the largest extent and intensity.
- No consistent long-term trend in ridge characteristics in any season
- ENSO affects the location, extent, and intensity of extreme ridges.