

Short Communication

Response to comments on ‘Influences of the Bermuda High and atmospheric moistening on changes in summer rainfall in the Atlanta, Georgia region, the United States’

Jeremy E. Diem*

Department of Geosciences, Georgia State University, Atlanta, GA, USA

ABSTRACT: Researchers have come to differing conclusions about multi-decadal changes in the position of the western ridge of the Bermuda High during the summer. This communication examines trends for 72 periods within the entire period of record (1948–2012), while also comparing variances in the Western Bermuda High Index (WBHI) and the latitudinal position of the western ridge. The western ridge has not moved significantly eastward or westward over either 1948–2012 or the past 60 years. The western ridge underwent a major westward shift from 1976 to 1977, but it did not stay in that western position during subsequent decades. Over the past 30–40 years, the western ridge has moved significantly eastwards and southwards. Finally, the WBHI, rather than the latitude of the western ridge, has had a definitive increase in variance over time and is the likely cause of increased summer rainfall variability in the southeastern United States.

KEY WORDS precipitation; rainfall; synoptic; southeastern United States; summer; circulation; Bermuda High; variability

Received 25 September 2012; Revised 10 December 2012; Accepted 22 December 2012

1. Introduction

Li *et al.* (2013) have concerns with the research presented in Diem (2012), which examines the impact of the Bermuda High (aka North Atlantic Subtropical High, NASH) and atmospheric moistening on summer rainfall variability in the Atlanta, Georgia region. Li *et al.* (2013) refer often to the research in Li *et al.* (2011), which also examined changes in the western ridge of the North Atlantic Subtropical High. The location of the western ridge is the point where the 1560-m line at 850 hPa intersects the ridge line of the Bermuda High (Li *et al.*, 2011). Key differences in research on the western ridge presented in Li *et al.* (2011) and Diem (2012) are provided in Table 1. A difference not provided in Table 1 is as follows: Li *et al.* (2011) state that the increased latitudinal movement of the NASH caused increased rainfall variability in the Southeast, while Diem (2012) attributes the increased variability to changes in the Western Bermuda High Index (WBHI), which is a newly devised index based on the Bermuda High Index (Stahle and Cleveland, 1992). The WBHI is based on 850-hPa heights and is the standardized pressure gradient across the southeastern United States (Diem, 2012). For 34 overlapping 30-year periods beginning from 1948 and ending by 2009, the WBHI had an increase in variance

whereas the latitude of the western ridge of the NASH did not (Diem, 2012). Li *et al.* (2013) also stated that Diem (2012) only examined trends from 1978 to 2007; that study examined trends for 32 periods with an ending year of 2009. Therefore, trends from 1978 to 2007 were never examined. What is needed for clarity on the topic of changes in the NASH is a comprehensive examination of changes in the western ridge of the NASH using different starting and ending years.

The remainder of this communication shows how the western ridge and the WBHI have changed over 1948–2012 and during 72 periods within that period. WR1 and WR2 are the longitude and latitude, respectively, of the western ridge. Gridded 850-hPa geopotential-height data were extracted from the NCEP/NCAR Reanalysis dataset (Kalnay *et al.*, 1996) of the Earth System Research Laboratory of the National Oceanic and Atmospheric Administration to extend the values of WR1, WR2 and the WBHI from 2009, which was the ending year in Diem (2012) to 2012. As is done in Diem (2012), Spearman’s ρ statistic is used to test for significant temporal trends; the tests are one-tailed with a chosen significance level of 0.01.

2. Results

Inter-annual variations in WR1 reveal a major shift in the location of the western ridge in the 1970s (Figure 1). WR1 underwent a dramatic shift from 1976 to 1977; the mean position of the ridge 5 years prior to the shift was

* Correspondence to: J. E. Diem, Department of Geosciences, Georgia State University, 33 Gilmer Street SE, P.O. Box 4105, Atlanta, GA 30302–4105, USA. E-mail: gegjed@langate.gsu.edu

Table 1. Key differences in research on the western ridge of the Bermuda High presented in Li *et al.* (2011) and Diem (2012). The dataset used in both papers is NCEP/NCAR Reanalysis. WR1 is the longitude of the western ridge. WR2 is the latitude of the western ridge.

	Li <i>et al.</i> (2011)	Diem (2012)
Time period	1948–2007	1948–2009
Sub-periods	a. 1948–1977 b. 1978–2007	a. Thirty-two periods with an ending year of 2009 b. Thirty-four 30-year periods
WR1 results	a. Westward shift of 6° from 1948–1977 to 1978–2007 b. Westward movement of 1.22° decade ⁻¹ for 1948–2007	a. Significant eastward movement from 1975–2009, 1976–2009, 1977–2009, 1978–2009, 1979–2009 and 1980–2009 b. No significant trend from 1948 to 2009
WR2 results	Variance increased by 47% from 1948–1977 to 1978–2007	a. Significant southward movement from 1973–2009, 1974–2009, 1975–2009, 1976–2009, 1977–2009, 1978–2009, and 1979–2009 b. No significant trend in variance

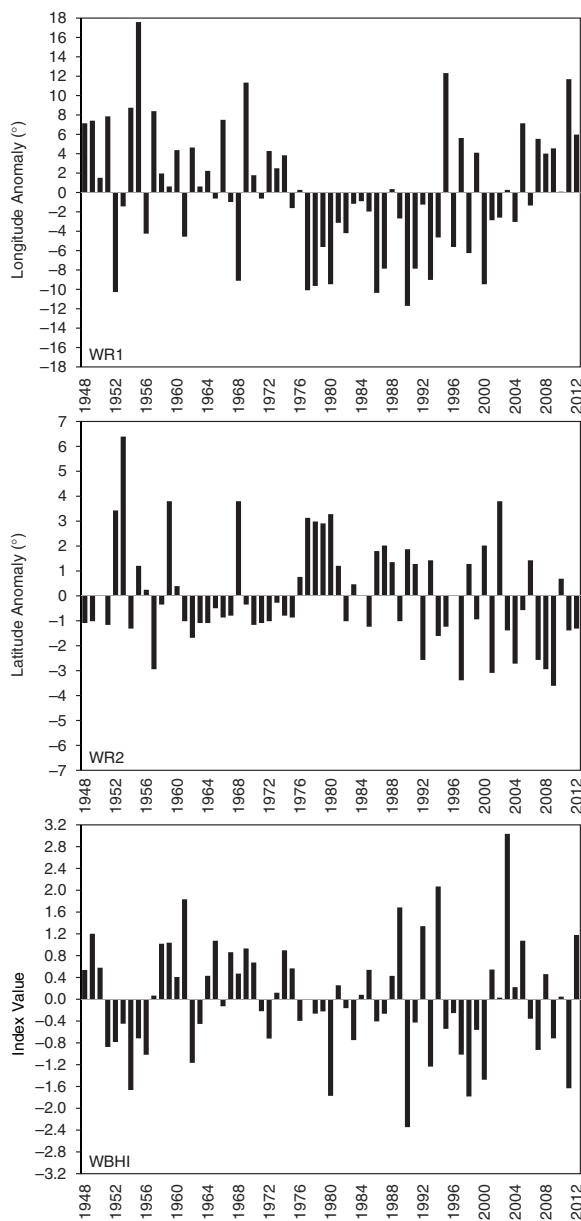


Figure 1. Inter-annual variations in the longitude (WR1) and latitude (WR2) of the western ridge of the Bermuda High as well as variations in the Western Bermuda High Index (WBHI).

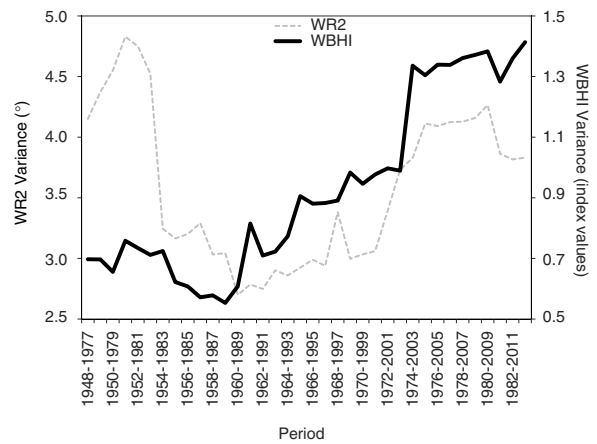


Figure 2. Inter-epochal variations in variance in the latitude of the western ridge of the Bermuda High (WR2) and the Western Bermuda High Index (WBHI).

83.8°W, while the mean position of the ridge 5 years after the shift was 93.2°W. Therefore, the ridge shifted approximately 1000 km westward. The ridge also shifted approximately 400 km northward. The ridge stayed west of 85°W until 1995 and then shifted to an eastern position in 2005. The mean position of the ridge since 2005 has been 80.9°W, which is a strongly eastward position.

The WBHI, rather than WR2, had a definitive increase in variance over time (Figures 1 and 2). The WBHI peaked in variance for the 1983–2012 period, and the variance has been relatively high since the 1974–2003 period. The variance for WR2 did not increase: the variance for the first 30-year period, 1948–1977, was 4.2°, while the variance for the last 30-year period, 1983–2012, was 3.8°. WR2 variance peaked for the 1951–1980 period, rather than during later periods. Li *et al.* (2011) only examined two periods, 1948–1977 and 1978–2007, and the variance for the second period was 4.1°, which, of course, is less than the variance during the first period.

Only WR1 had significant trends with a starting year of 1948 (Figure 3). There were 28 consecutive periods, beginning with 1948–1980 and ending with 1948–2007, with significant westward movements of WR1. Trends

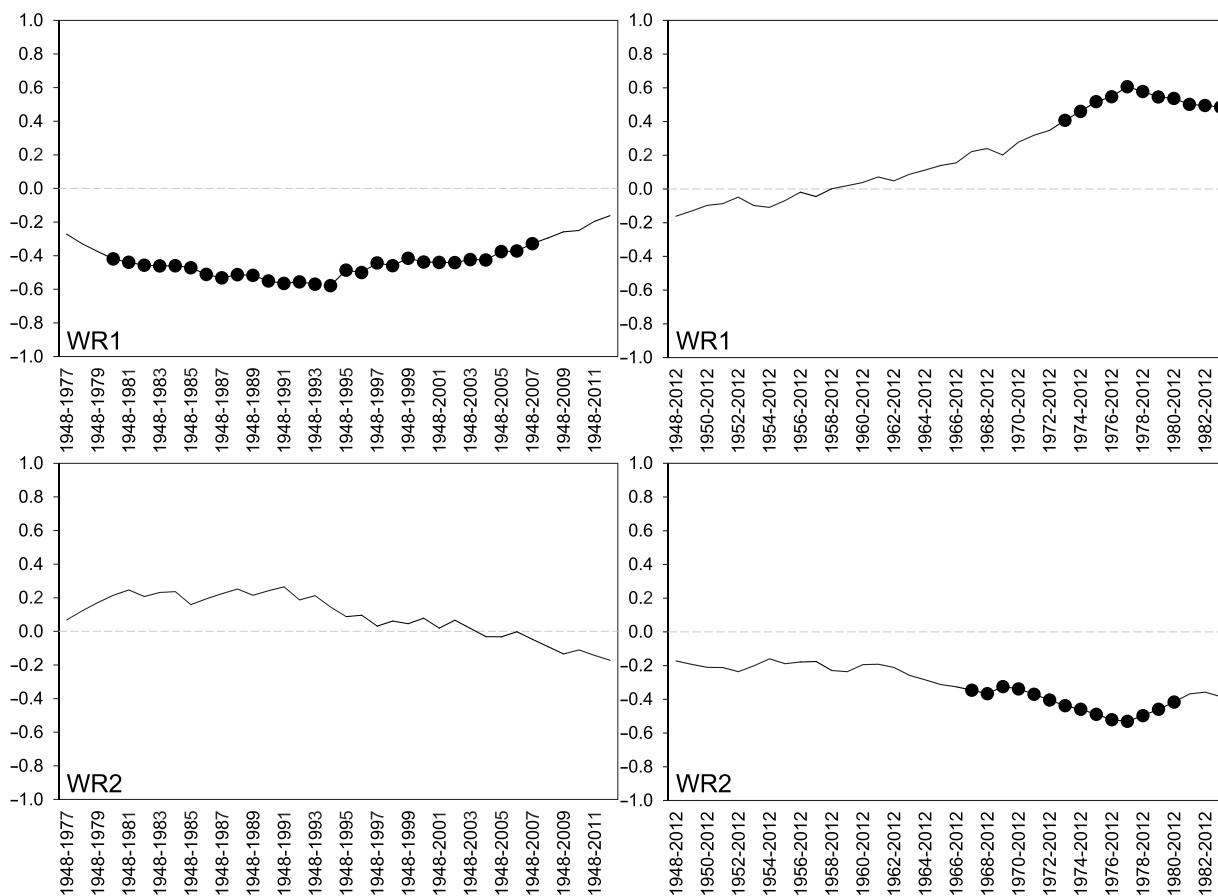


Figure 3. Trends in the longitude (WR1) and latitude (WR2) of the western ridge of the Bermuda High over periods ranging from 30 to 65 years. Values on the y-axis are correlation coefficients. Circles denote trends significant at the 0.01 level. The left panels have a starting year of 1948. The right panels have an ending year of 2012.

with ending years of 2008 and later were not significant. As noted previously in this communication, the western ridge moved to a more eastern position beginning in 2005.

Both WR1 and WR2 had significant trends with an ending year of 2012 (Figure 3). WR1 moved significantly westward during 11 consecutive periods, beginning with 1973–2012 and ending with 1983–2012. Therefore, contrary to what Li *et al.* (2013) state in their comment piece, WR1 has not shown a significant trend of westward movement over the past 60 years. Finally, WR2 moved significantly southward during 14 consecutive period, beginning with 1967–2012 and ending with 1980–2012.

3. Conclusions

This communication has focused on providing an up-to-date analysis of longitudinal and latitudinal movements of the western ridge of the Bermuda High. While the western ridge has shifted significantly westward, eastward and southward during certain multi-decadal intervals within the 1948–2012 period, those movements have been shown in Diem (2012) to not have significant

influences on summer rainfall variability in the southeastern United States. The WBHI, which has had substantial inter-annual variability over the past three to four decades, is a much more likely cause of the increased rainfall variability than are latitudinal movements of the western ridge of the Bermuda High.

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