1.4 EVALUATING THE IMPACTS OF CLIMATE CHANGE ON RAINFALL EXTREMES FOR HAWAII AND COASTAL ALASKA

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1. INTRODUCTION

Recently, climate change studies have focused on a variety of impacts that are likely to result from increased warming. Many of these impacts are of direct importance to coastal communities, where low-lying Pacific Islands are most susceptible to sea-level rise, and Alaska has coastal erosion concerns. In fact, some have said that island communities are perhaps at the most risk for climate change impacts, and that such impacts may already be occurring (Firing et al. 2004; Merrifield et al. 2004).

One important impact that is routinely overlooked is the aspect of heavy rain events, specifically their recurrence frequency and spatial distribution in a warming climate. While the current literature states that episodes of heavy rains are likely to increase (CCSP 2008), discussion of these scenarios in distant locations, such as the central or northern Pacific, is missing. This may be due in part to the remote nature of the island chain and the large grid spacing domain used in current global climate models. However, it is prognosticated that the Pacific Islands may experience an increase in heavy downpours and rainfall during the summer months, rather than during their typical winter months rainy season. This off-season increase could result in flooding, which would act to reduce drinking water quality and threaten crops (Burns 2002).

To help shed some light on the subject of heavy rains in the Pacific, statistical models were run through the historical data for Hawaii and southern coastal Alaska. The analysis stems from the use of the so-called Frich indices (Frich 2002), which are used to assess trends in climate variables owing to climate change. The indices contain thresholds for maximum and minimum temperature, growing degree days, various precipitation parameters, and others. For this study, the following precipitation climate change indices were selected:

- Annual number of days > 50 mm (R50)
- Annual number of days > 10 mm (R10)
- Simple Daily Intensity Index (SDII)
- Average Annual Precipitation

The SDII is computed by dividing the number of days with rainfall greater than 1 mm into the total annual rainfall (mm).

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2. DATA and METHODS

The data used in the analysis came from the Global Historical Climate Network (GHCN) –daily data [1]. Stations were selected for Hawaii and coastal Alaska from the provided inventory list. For Hawaii, this included over 500 stations. In the case of southern coastal Alaska, stations were selected by their regional latitude and longitude (discussed further in section 4). In order to run the Frich Indices computation code[2], the period of record and available data had to meet certain requirements. Without modification, the code requires stations to have only three (3) days per month missing, and a maximum of 15 days per year missing. The initial runs at these criteria drastically reduced the number of available stations to be used in assessing precipitation trends. Thereafter, a sensitivity analysis was performed (not shown) to determine what criteria would allow the maximum of number of stations while resulting in an analysis that was robust enough to draw conclusions from resulting statistics. The new criteria were then set at a maximum of nine (9) missing days per month and 45 missing days per year. Linear trends were used to gather a first approximation of how heavy rainfall events varied through time.

3. HAWAII

The Hawaiian Islands are located near 20N latitude and 160W longitude. The geography of the Hawaiian Island chain is partially mountainous and flat near the coastal plain. Peak mountain elevations across the chain range from 1230 m to 4205 m. The spatial distribution of the stations in Hawaii is such that a majority are concentrated at lower elevations, with fewer stations at the higher elevations. In this regard, observed precipitation patterns at the low elevation stations are obviously not representative of higher level elevation stations (and visa-versa). Thus it was necessary to separate the stations into more representative groups so that more meaningful trends could be deduced. To that end, three groups were generated, one for stations below 500 m, another for stations between 500 and 1000 m, and finally for those stations above 1000 m. This binning resulted in 424 stations in the lowest bin, 69 stations in the middle range, and 62 stations in the highest elevation bin.

[1] Available online at http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/
[2] Available online at http://cccma.seos.uvic.ca/ETCCDI/software.shtml

3.1 *Elevation below 500 meters*

Trends in heavy rainfall events for the lowest elevation stations in Hawaii appear to be on the decrease (Fig 1). The Simple Daily Intensity Index (SDII) is shown to be decreasing and the downward linear regression trend line is statistically significant at the 95% confidence level. In addition, both the downward trends in annual number of days with rainfall greater than 10 mm and 50 mm are both statistically significant above the 99% level. As for total annual precipitation (not shown), there is a statistically significant (P > 99%) downward trend since the early 1900s, from an average of about 2000 mm per year to roughly 1450 mm per year in 2007.

3.2 *Elevation between 500 and 1000 meters*

Trends in heavy rainfall for the middle range of elevations, between 500 and 1000 m, also show a gradual decline in the occurrence of heavy rainfall events (Fig 2). The SDII, R10 and R50 trends are all declining since 1905, and are all statistically significant above the 99% confidence level. The trend for total annual precipitation (not shown) is also decreasing, and is statistically significant at the 99% confidence level. Here, much like the lower elevations, average annual values have dropped from their peak values in the 1920s and 1940s (> 2000 mm), to just under 1500 mm since 2000.

3.3 *Elevation over 1000 meters*

The final analysis for Hawaii was conducted for stations with elevations greater than 1000 m. These stations tend to lie above the trade-wind inversion, which acts to cap upward vertical motion and thus limits cloud development (Giambelluca and Luke 2007). The downward trend in heavy rainfall events for these stations is tremendous (Fig 3), and is reflected in the statistical significance, which is at the 99% level for all three, SDII, R10, and R50. When examining the trend for total annual precipitation (not shown), there is a slight downward trend, but it is not statistically significant.

4. ALASKA

Due to the size of Alaska, and the nature by which locations in southern coastal Alaska receive their rainfall, the coastline was split into three sections: southeast, central, and southwest. In this case, the definition of “coastal” is inland 40 km from the coastline, and the analysis begins in 1920 rather than 1905, due to the sparseness of station density in the early part of the record. Each of these three regions was explored with the same analysis technique as Hawaii (i.e., the same Frich indices were used), all with uniquely interesting results.

4.1 *Southeast*

The southeast coastline of Alaska is characterized by the geographic region bounded by 140W and 120W longitude, and between 50N and 60N latitude. This includes such locations as Juneau, Sitka, and Annette. There has been a slight downward trend in the average annual precipitation (not shown), but it is not statistically significant. There is, however, a statistically significant trend (above the 97% confidence level) for both the SDII and R10 Frich indices. Interestingly, for the heavier rain events above 50 mm, the trend is essentially neutral and is not statistically significant (Fig 4).

4.2 *Central*

The central coastline of Alaska is bounded by the region 150W to 140W longitude, and between 50N and 62N latitude. This includes locations as Anchorage, Cordova, and Valdez. In this region, a strong negative trend has been apparent since 1920 (Fig 5) in the SDII, R10, and R50 climate change parameters. All of these are statistically significant above the 98% confidence level. In terms of average annual precipitation (not shown), there is a statistically significant negative trend since 1920 in this region of coastal Alaska. During the 1920s, average annual values were near 1500 mm, but by the year 2007, this had fallen to just over 1000 mm.

4.3 *Southwest*

The southwest portions of Alaska are primarily composed of the Aleutian Islands, but were generalized to include the region bounded by 170W and 150W longitude, and 50N to 60N latitude. This region includes cities such as Cold Bay and Kodiak. Unlike the other regions in Alaska, there is an upward trend in the SDII (i.e., precipitation intensity), and in the number of days with greater than 10 mm of rain (Fig 6), though only the SDII is statistically significant (P > 99%). While the graph also shows a decreasing trend in the R50 parameter, its trend is also not statistically significant at the 95% level. For the average annual precipitation (not shown), there is a strong upward trend in this region since the 1920s, and it is statistically significant above the 99% confidence level. Average annual precipitation totals were just over 2000 mm in the early part of the record, but have since averaged near 3500 mm since roughly the 1970s.

5. CONCLUSIONS

Climate change impacts on coastal communities are often discussed with attention to sea-level rise and freshwater availability (complicated by saltwater intrusion). However, heavy rain events are also important, as increases could result in more flooding episodes and risks to drinking water, while decreases could result in agricultural impacts and weaker supply issues. Preliminary research results show that the incidences of heavy rain events across the Hawaiian Islands have actually decreased since 1905. A similar decreasing trend is also evident across portions of southern coastal Alaska since about 1920. The decreases in Hawaii may be attributable a possible poleward shift in the observed Pacific storm track (Yin 2005), suggesting that many routine frontal passages and other synoptic-scale features may be bypassing the region to the north. In addition, according to Cao (2007), the trade wind inversion height may also be trending lower, suggesting a gradual shift toward a drier climate in Hawaii. Interestingly, Chu and Chen (2005), using a computed Hawaii Rainfall Index, found a decreasing trend in standardized November-March rainfall totals. These findings are generally inconsistent with previous thoughts that a warming climate would result in more precipitation over the Hawaiian Islands (Christensen et al. 2007).

In Alaska, however, two regions, the central and southeast, were found to exhibit strong decreasing trends in heavy precipitation events. Yet, in the southwest region of the state, heavy precipitation events were shown to be increasing. There is currently a dearth of peer-reviewed literature on precipitation trends in Alaska under the influences of climate change. However, generalized studies, such as that from the Arctic Climate Impact Assessment (ACIA, 2005), suggest that precipitation along Alaska's southern coastline should be increasing (especially in the boreal autumn and winter seasons), owing to increased global evaporation. Clearly, it is still too early to say for certain the direction of the future change in heavy rain events across this region, but if the presented results are any indicators, such events may in fact be lessening. Future work will focus on narrowing the uncertainties in these results and will explore more conceptually and quantitatively (e.g., through the use of more complex statistical methods) the magnitude and direction of the historically observed trends in both Alaska and Hawaii.

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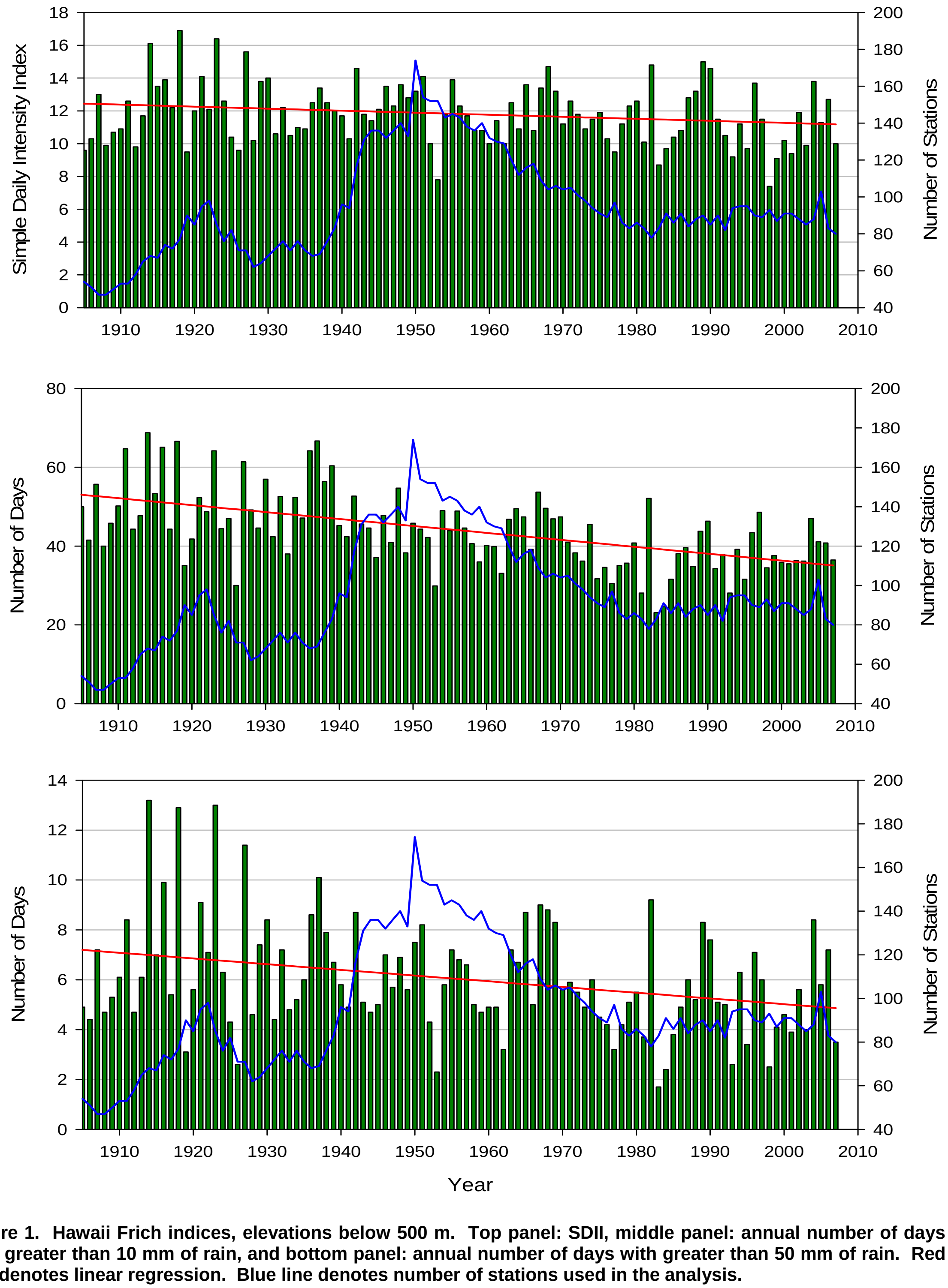

Figure 1. Hawaii Frich indices, elevations below 500 m. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.

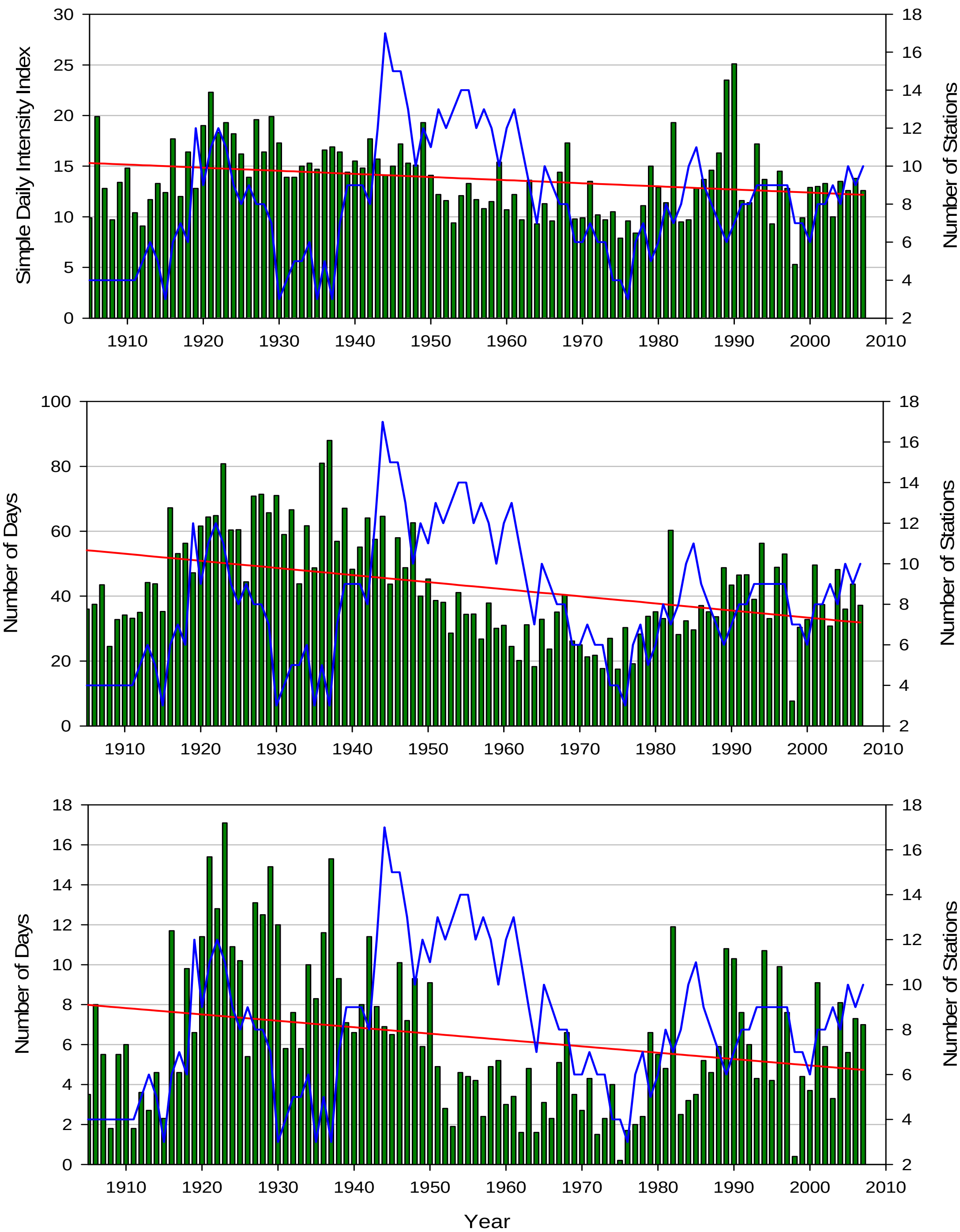

Figure 2. Hawaii Frich indices, elevations between 500 and 1000 m. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.

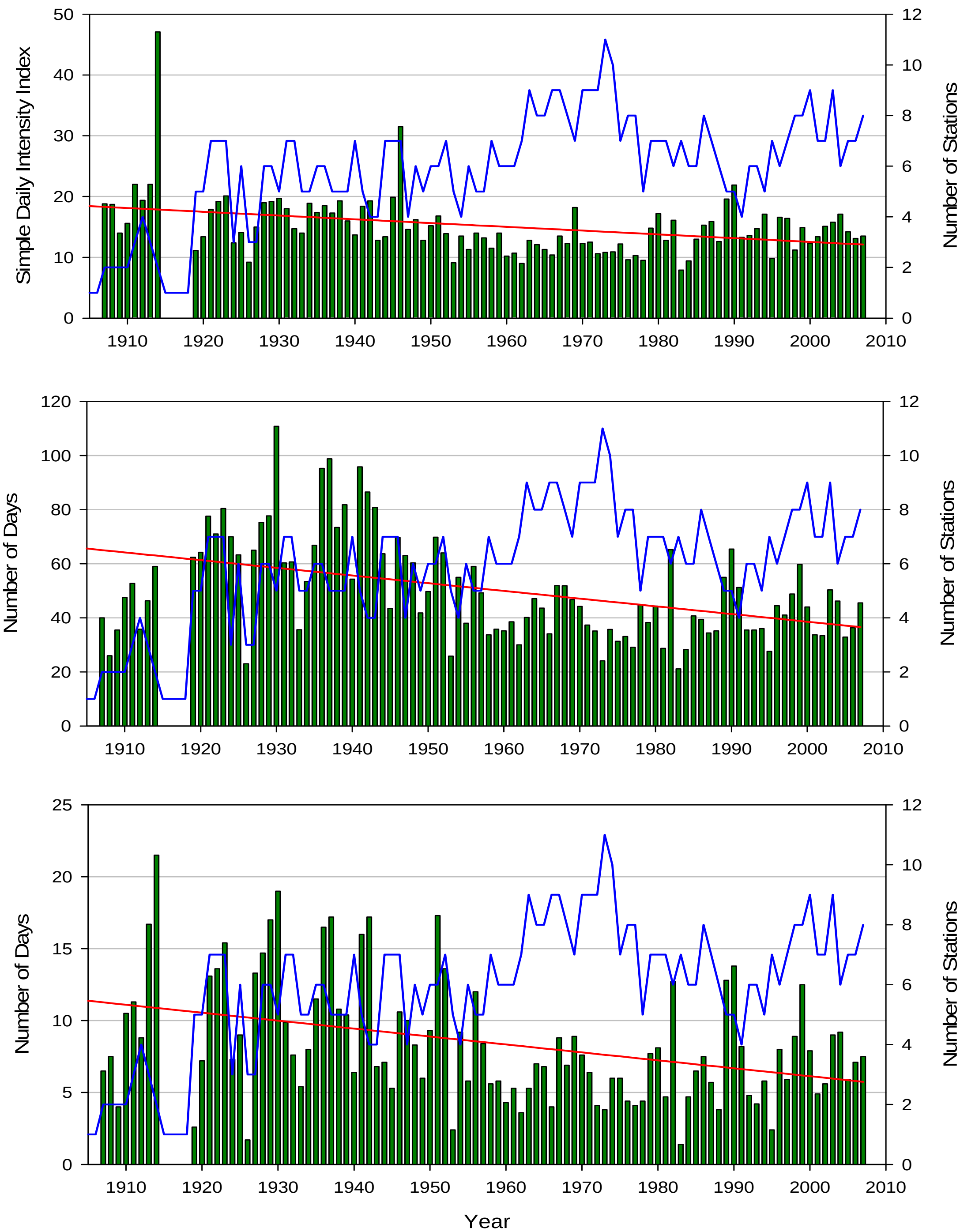

Figure 3. Hawaii Frich indices, elevations above 1000 m. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.

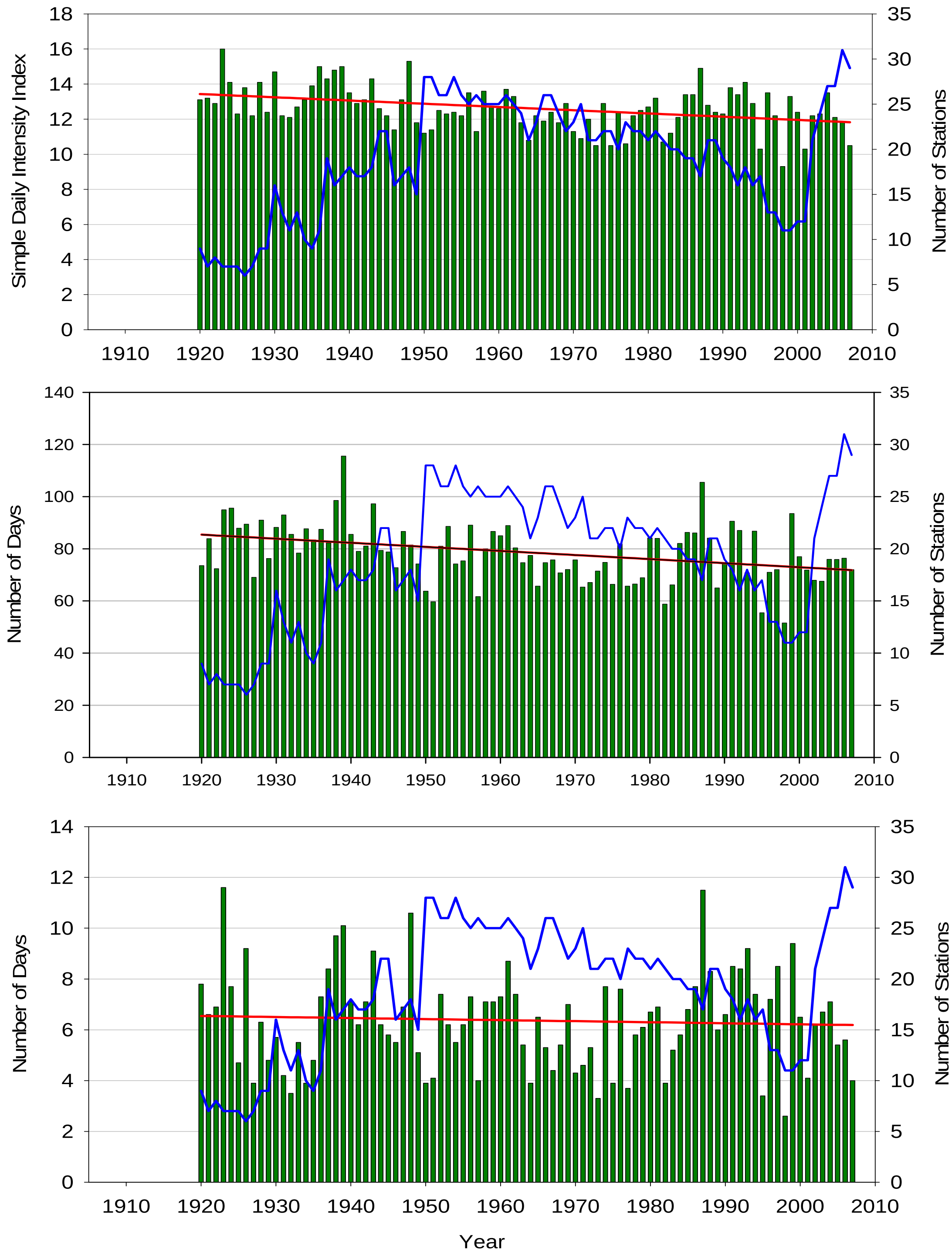

Figure 4. Southeast Alaska Frich indices. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.

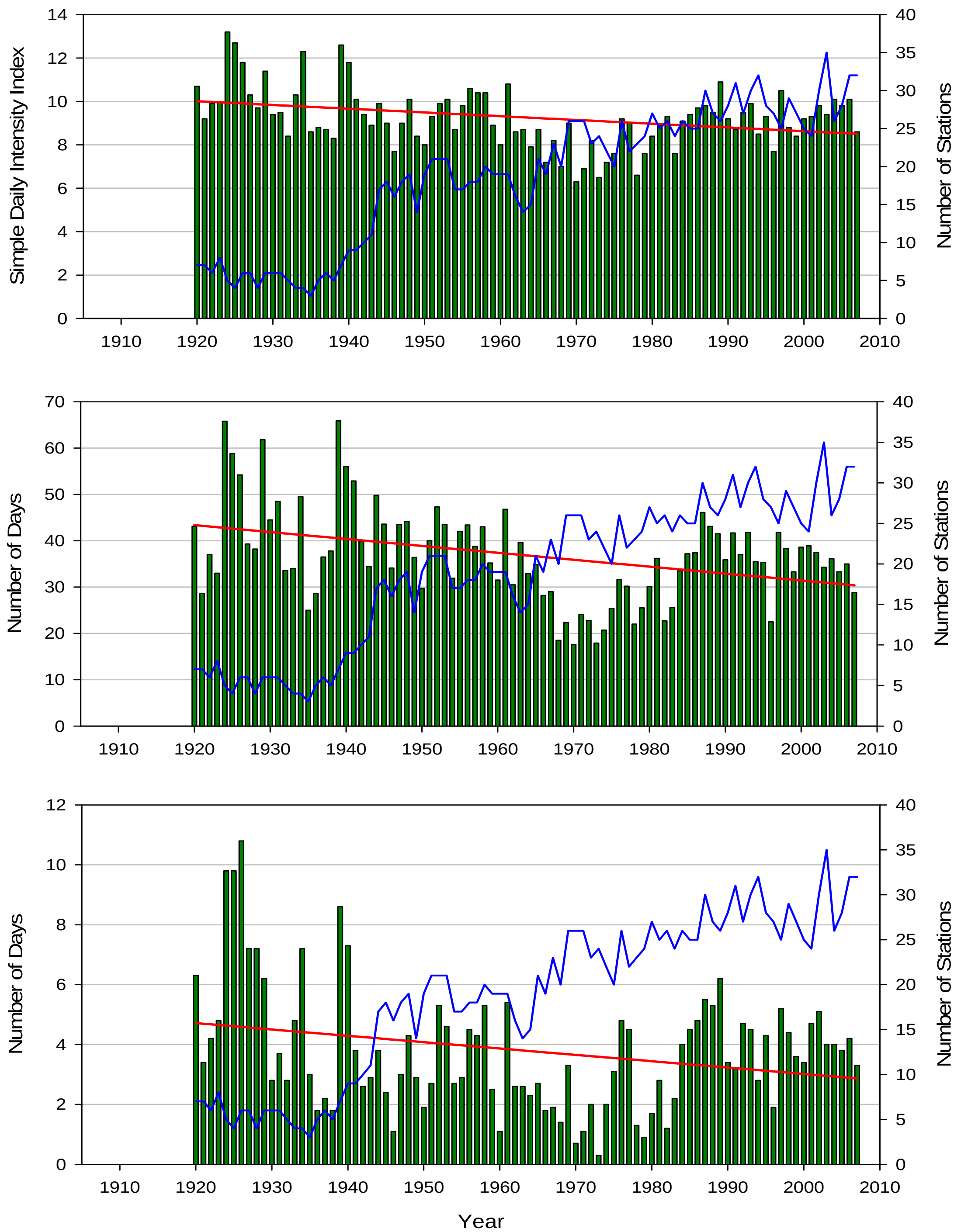

Figure 5. Central Alaska Frich Indices. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.

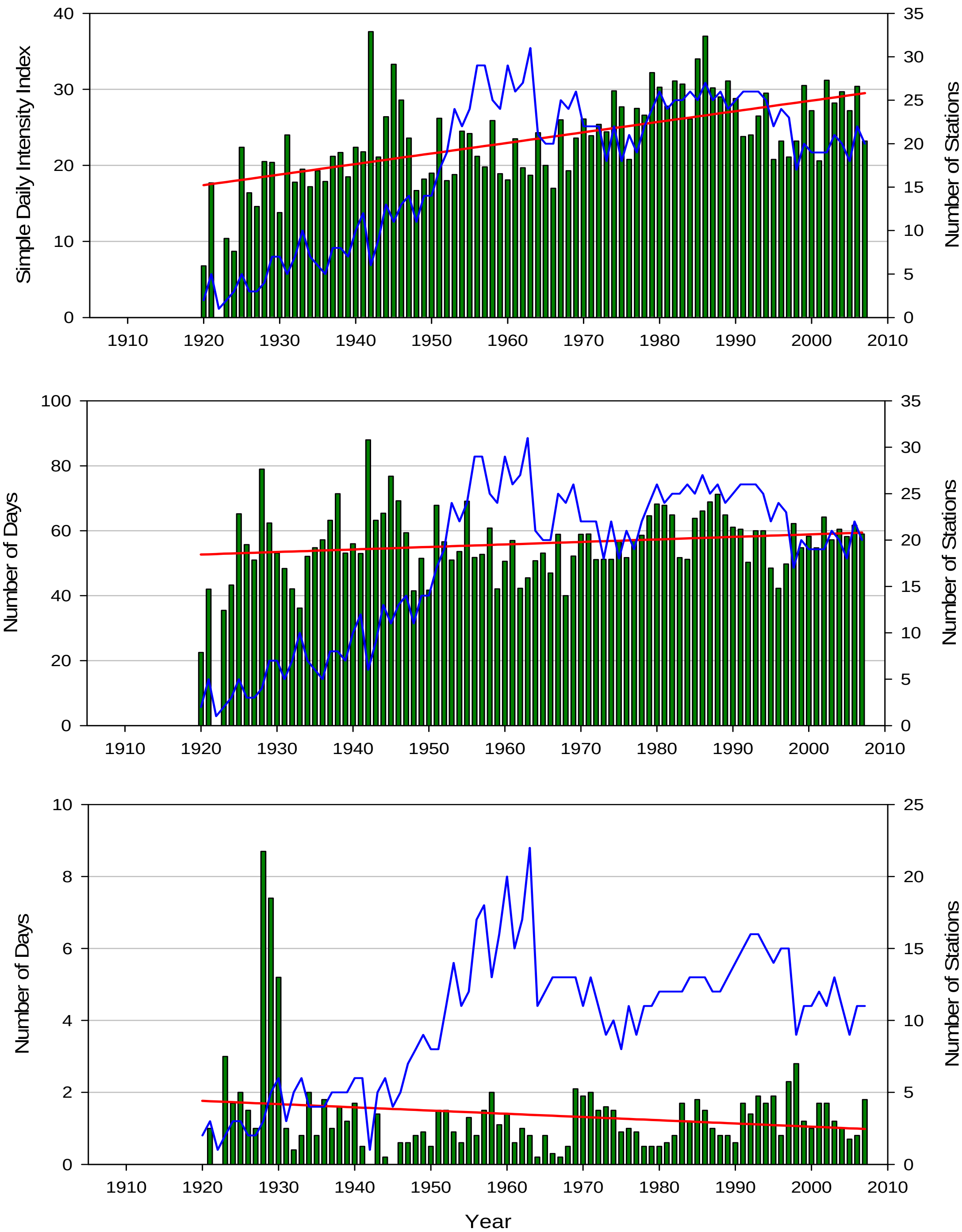

Figure 6. Southwestern Alaska Frich Indices. Top panel: SDII, middle panel: annual number of days with greater than 10 mm of rain, and bottom panel: annual number of days with greater than 50 mm of rain. Red line denotes linear regression. Blue line denotes number of stations used in the analysis.