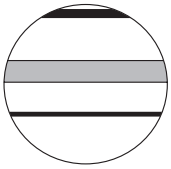

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Lewis and Clarks' Tempest: The '*perfect storm*' of November 1805, Oregon, USA

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Abstract

Three weeks after arriving near the Pacific Northwest (PNW) coast in November 1805, Lewis and Clarks' Corps of Discovery experienced a two-day windstorm that may have rivaled the strongest historically documented storms of the nineteenth and twentieth centuries. Based on the Corps' detailed historical accounts describing the event as the *perfect storm,* we characterized the severity of the 1805 windstorm using tree-ring growth anomalies from windsnapped Sitka spruce collected at three sites along the northern Oregon Coast. We compared the 1805 gale to eight other documented events with comparable storm tracks and exceptional magnitude including the 1880 and 1951 events that each caused more than a billion board feet (*c.* 2.4 million m^3) of windthrow. Statistical comparison of tree-growth responses revealed that the 1805 windstorm was the only event to differ significantly (χ^2; test, $p < 0.05$, d.f. = 1) from all other storms. Our findings demonstrate the potential application of tree-ring data and historical documents to understand previously obscure climatic events similar to the extreme droughts that led to the demise of the Roanoke Colony during the sixteenth century and adversity experienced by the Jamestown Colony during the seventeenth century. Specifically, we identify the Lewis and Clark tempest of 1805 as being among the most severe PNW windstorms during the past two centuries, and may have contributed to the Corps' dismal view of coastal Pacific Northwest weather.

Keywords

dendroclimatology, dendroecology, Lewis and Clark, Pacific Northwest, Sitka spruce, windstorms

Introduction

Windstorms generated by intense mid-latitude cyclones and typhoon remnants occur frequently along the Pacific Northwest (PNW) coast where they can create peak wind gusts exceeding 285 km/h (Lynott and Cramer, 1966; Read, 2009; Taylor and Hatton, 1999). The force of these windstorms often results in severe ecological and economic impacts including extensive forest blowdown, property damage, and power outages (Lynott and Cramer, 1966; Read, 2009; Ruth and Yoder, 1953). We discuss such an event that occurred in November 1805 when Lewis and Clarks' Corps of Discovery experienced a two-day windstorm that rivaled the strongest historically documented storms (Read, 2009) of the nineteenth and twentieth centuries. Based on the Corps' historical accounts (Moulton, 2005), we characterize the severity of the 1805 windstorm using tree-ring growth anomalies from old-growth, windsnapped trees collected along the northern Oregon Coast (Figure 1). Our results allow us to demonstrate the utility of first-person observations for identifying obscure, high-impact wind events (e.g. Mock and Dodds, 2009) and place more recent windstorms within a broader historical context.

Several studies representing different forest types have documented the impact of windstorms on tree growth and their integral role as a disturbance agent (e.g. Everham and Brokaw, 1996). Severe windstorms principally influence tree growth through two mechanisms. The first mechanism is accelerated radial growth (ecological release) in response to reduced light competition following canopy removal (windsnap) or windthrow (blowdown) of a neighboring tree (e.g. Veblen et al., 1989, 2001). The second mechanism is growth reduction (suppressed radial growth) resulting from the reduced photosynthetic capacity of a tree following canopy trauma or removal (e.g. Lafon and Speer, 2002). Stand-scale studies further reveal that windstorm-generated damage can cause both growth suppressions and/or releases in response to the same windstorm event (Marks et al., 1999; Taylor and Halpern, 1991). Other research documents the occurrence of narrow tree rings within a two-year window of hurricane landfall in the southeastern USA (Henderson, 2006). Here, we use similar tree-growth anomalies (releases and suppressions) to determine the intensity of the Lewis and Clark 1805 wind storm relative to more recent, documented windstorms.

PNW windstorms are classified into six types based on their storm tracks (Read, 2009). Of these, Class 2 events (C2) are noteworthy because their northeastward-tracking patterns result in their landfall in northern Oregon or southern Washington and generate high winds in the populous Willamette Valley and forested Coast Range (Figure 2; Read, 2009). Consequently, C2 events are among the most severe storm types to affect the PNW and include two of the five storms during the past 130 years (9 January 1880 and 4 December 1951) estimated to have caused

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Figure 1. Windsnap and blowdown of Sitka spruce at Cape Lookout State Park, Oregon following a windstorm in 2007

more than a billion board feet of forest blowdown (Read, 2009). The 1805 event matches C2 storm-track criteria based on the Corps' description of a SW to NW wind shift concurrent with wind speed intensification and post-frontal hail (Moulton, 2005; Figure 2).

Beginning 27 November, the Corps of Discovery encountered '*violent*' (per Clark) southwesterly winds that forced them to seek refuge at Tongue Point (then Point William), 10 km east of present-day Astoria, Oregon (Moulton, 2005). Severe weather conditions continued until the following noon when winds changed to northwesterly flow and intensified to 15–20 min periods of sustained gales (Moulton, 2005). Clark later recorded that post-noon winds on 28 November '*blew with Such violence that I expected every moment to See trees taken up by the roots, maney were blown down*'[1] while Private Whitehouse called it *a* '*perfect storm*' (Moulton, 2005). In Clark's 30 November 1805 journal entry, he describes the size of the Sitka spruce trees (i.e. 'Pine Spruce'), around Tongue Point: '*The hills on this Coast rise high and are thickly covered with lofty pine maney of which are 10 & 12 feet through and more than 200 feet high*.' The following day Sergeant Gass wrote that hunting was '*impossible*' because the area was '*full of thickets and fallen timber*' (Moulton, 2005). It is unclear if Gass was referring the fallen timber as storm-related or pre-existing, but no similar comments precede this statement despite that the Corps had been hunting in the area since 7 November.

Data and methodology

We analyzed tree-ring data collected at three sites along the northern Oregon coast during the summers of AD 2008 and AD 2009 (Figure 2): (1) Cape Lookout State Park (16 trees, 22 cores, beginning date AD 1701); (2) Cape Meares State Park (17 trees 26 cores, beginning date AD 1661); and (3) Cape Falcon (Oswald West State Park) (18 trees, 29 cores, beginning date AD 1582). Our combined sample size included 51 trees and 77 cores in AD 2008, with a sample depth of 43 trees and 61 cores dating to AD 1805. At each site we collected two cores from large, windsnapped old-growth (> 350 yr) Sitka spruce (*Picea sitchensis*) trees identified by the absence of an upper bole. We minimized potential confounding factors that would affect tree growth and alter our interpretation of windstorm events by avoiding trees with visual evidence of either fire or lightning scars. Additional causes of tree damage – ice storms, heavy snowfall events, or convective storm outbursts – are uncommon along the PNW coast and are less likely to have influenced our results (annual snowfall for Astoria averages 11.9 cm (5.1 inches) with storms exceeding 15.24 cm/day (6 inches/day) occurring on average once every 12 years; http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or0324). We determined the tree-growth relationship with climate using stepwise linear regression models that compared the mean radial growth indices from the three Cape sites (dependent variable) with monthly climatic data including 1-yr lags for October, November, and December precipitation and temperature from Oregon Climate Division 1 or Astoria HCN (independent variables) based on the period 1895–2008.

We processed our core samples following standard procedures (Speer, 2010; Stokes and Smiley, 1968) and crossdated our cores using the list method to ensure dating accuracy (Yamaguchi, 1991). Crossdating of the measured series was verified statistically using the program COFECHA (Grissino-Mayer, 2001). All ring widths were then measured to 0.001 mm precision. We compiled three site chronologies derived from individually standardized cores applying a 30-yr cubic spline using the program ARSTAN (Cook and Holmes, 1986) to preserve high-frequency growth variance while removing age-related growth trends. We then identified years with an index value < 50% below the average site value as a growth suppression attributed to windstorm-induced canopy removal. Index values > 50% above the site average were identified as growth releases caused by windstorm-induced canopy openings including windfall of neighboring trees. In either case, the ± 50% threshold was only applied to the first and second years of growth following major C2 events.

Using tree-ring evidence, we determined the severity of the 1805 windstorm event by comparing the frequency of post-storm growth suppressions and growth releases to eight documented C2 events. Seven of these windstorms occurred during 1950–2008, the period of the best meteorological documentation. The eighth C2 event, the 1880 windstorm (Read, 2009) caused storm damage in the Willamette Valley, northwestern Oregon, and southern Washington comparable to that of the 1962 Columbus Day Storm (Lynott and Cramer, 1966; Read 2009). For each event, we recorded the average annual percentage of growth releases or growth suppressions from the three sites for the first growing season year following the event plus the following year. Thus, suppressions and releases recorded in years 1806 and 1807 were summed by site then averaged for the three sites and used as a proxy to measure the strength of the 1805 windstorm (Figure 3), a process repeated for the eight other C2 events. We then used Pearson's chi-squared values to test for goodness-of-fit by comparing the number of affected cores for each C2 event to all other events combined to determine if any event differed from the

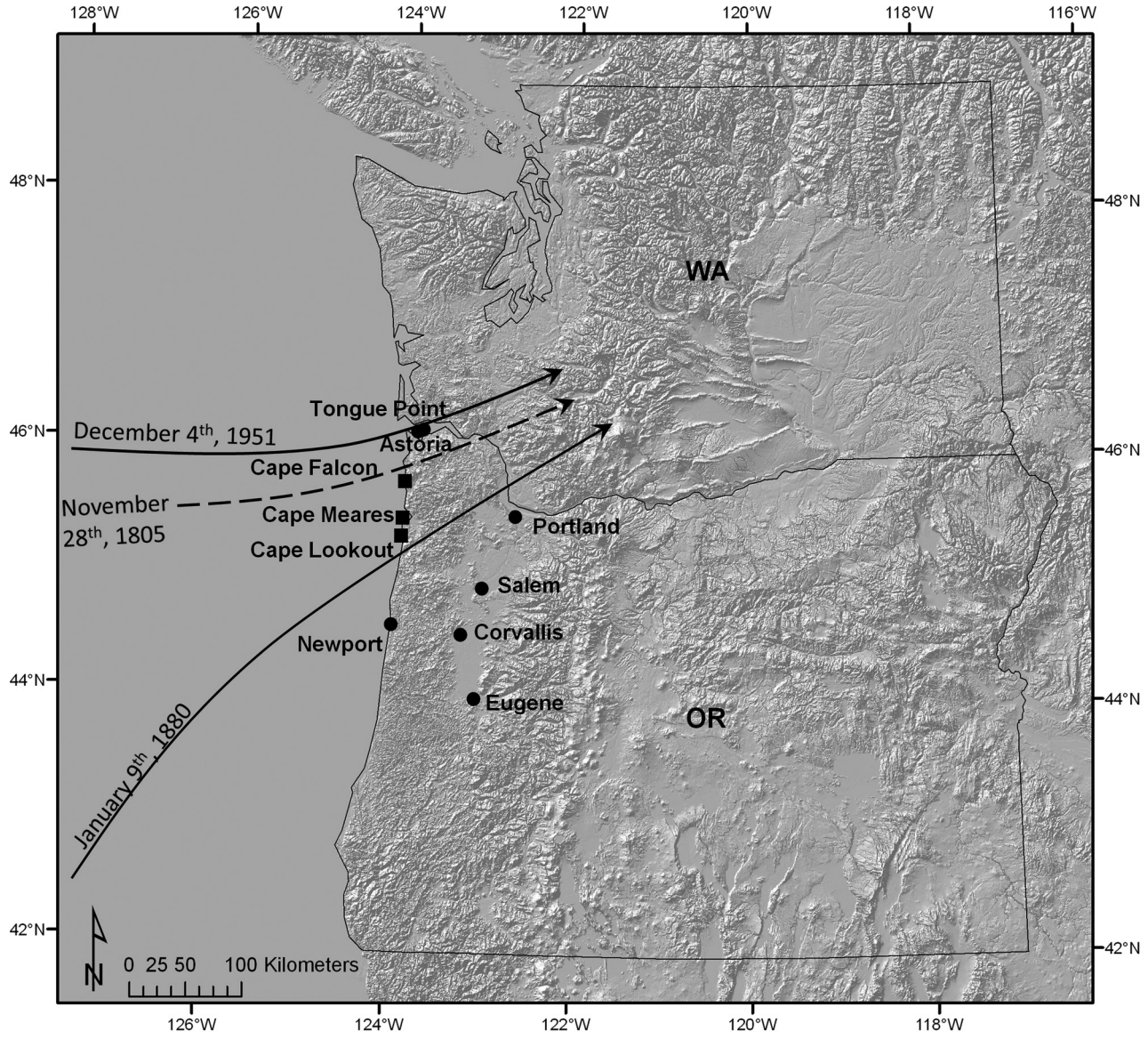

Figure 2. Location of tree-ring data collection sites (squares), Astoria, Newport, inland cities and the Corps' encampment site of Tongue Point (circles). The estimated path of the 1805 storm is based on the number of cores affected at each site and notes from Lewis and Clarks' journals; estimated paths of the 1880 and 1951 C2 events are from (Read, 2009)

others (Figure 3). This analysis was based on 1210 standardized ring-width values (122–146 ring-width values per event) representing the first and second growing seasons after each of the nine C2 windstorms.

Results and discussion

Based on the percentage of sampled trees affected by C2 storms (Figure 3), we submit that the 1805 windstorm was likely the most severe C2 windstorm yet documented in the PNW during the past 200 years. Statistical comparison of tree-growth responses revealed the 1805 windstorm was the only storm to differ significantly (χ^2; test, $p < 0.05$, d.f. = 1, Figure 3) from all other storms. Based on the fewer number of trees affected at Cape Falcon relative to Cape Meares or Cape Lookout, we place the landfall of the 1805 event just north of Cape Falcon (Figure 2). This is consistent with three lines of circumstantial evidence. First, storm-center landfall for most (88%) known C2 events have occurred between Newport on the central Oregon coast and Astoria (Read, 2009).

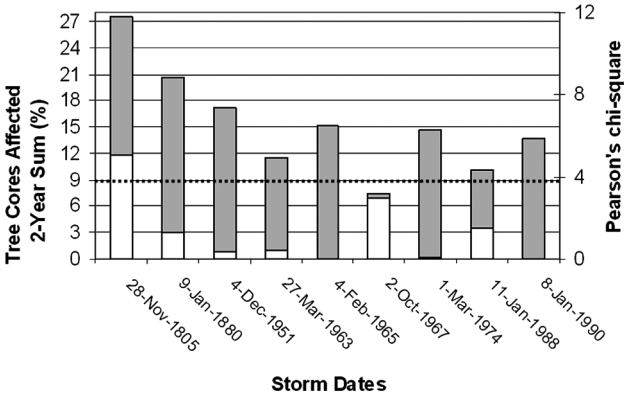

Figure 3. Percentage of cores collected from live trees responding to C2 windstorms (gray) based on the mean ring widths during the first two growing seasons following each storm. Pearson's chi-squared values (white) were used to test for goodness-of-fit by comparing the number of affected trees for each C2 event to all other events combined. The 1805 storm was the only C2 event to have significantly differed ($\alpha = 0.05$, dashed line) from all other storms

Table 1. Standardized radial growth/climate relationships based on data from Astoria HCN (top) and Oregon CD1 (bottom). R^2 values are 0.14 and 0.19, respectively

Variable	β	*p*-value	Partial R^2
(Constant)	1.769	0.000	
March precipitation	0.010	0.023	0.057
April temperature	−0.017	0.010	0.038
September precipitation	−0.016	0.024	0.042
Variable	**β**	***p*-value**	**Partial R^2**
(Constant)	3.177	0.000	
April temperature	−0.020	0.004	0.086
September precipitation	−0.020	0.011	0.066
June temperature	−0.020	0.036	0.033

The 8 January 1990 C2 event was the exception to this trend making landfall approximately 40 km north of Astoria. Second, the wind shift from SW to NW noted in the Corps journal entries suggests the center of the storm was south of Astoria as it moved eastward. Third, the comparatively low number of anomalies recorded at Cape Falcon appears consistent with: (A) the sheltering effect from the initial southwesterly winds by Neahkahnie Mountain (elevation 512 m) located 1 km east; and (B) its lower sensitivity to northwesterly winds as the storm center followed its northeast trajectory.

Although we attribute the high number of growth anomalies to specific events, we cannot exclude the possibility that they represent severe winter conditions and the cumulative effects of multiple storms. For example, Clark writes on 16 December 1805 '*The winds violent Trees falling in every derection, whorl winds, with gusts of rain Hail & Thunder, this kind of weather lasted all day, Certainly one of the worst days that ever was!*' Nonetheless, we are confident that the high incidence of growth anomalies captures windstorm severity and that our results do not represent an artifact of cumulative events. This confidence in our methodology is based on four observations. First, our growth anomalies correspond to years of well-documented *severe* C2 wind events (Figure 3). Second, our results appropriately rank the two most severe documented windstorms during the historical period (1880 and 1951). Third, the November windstorm was the only event noted by all the members of the Corps who kept journals; the 16 December event did not elicit a response from Private Whitehouse regarding windy or stormy conditions. Finally, the November storm was unique from all other notable wind events of the winter of 1805–1806 in that the Corps identified a wind shift from southwesterly to northwesterly, an indication that the storm had tracked inland and consistent with the known major C2 events identified by Read (2009).

Results from our growth-climate models revealed that unusually narrow or wide rings in these wind-damaged trees are much more likely to record high-wind events than (un)favorable temperature or precipitation. Annual radial growth was significantly influenced by April temperature, September precipitation and either June temperature or March precipitation when using either divisional ($R^2 = 0.19$, $p < 0.01$) or Astoria HCN data ($R^2 = 0.14$, $p < 0.01$), respectively; however, model parameters suggest response to temperature and precipitation variability is quite small (Table 1). Nonetheless, climatic conditions could affect our results indirectly as the influence of windstorms on forest trees is modulated by soil conditions, storm duration, wind intensity, and prior storm history. Each of the first three conditions was optimal for the 1805 event as recorded in the journals: (1) rainfall the previous nine days indicated saturated soil conditions; (2) stormy conditions occurred for approximately two days; and (3) fierce winds on the 27th were followed by stronger winds on the 28th. The absence of pre-1805 growth anomalies dispelled the possibility that the Lewis and Clark windstorm was related to a preceding event.

Conclusions

Our findings demonstrate the potential application of tree-ring data and historical documents to understand previously obscure climatic events similar to the extreme drought that led to the demise of the Roanoke Colony and decline of the Jamestown Colony (Stahle et al., 1998), or the generally favorable climatic conditions that benefitted Lewis and Clarks' expedition through the American West (Knapp, 2004). Specifically, we identify the Lewis and Clark tempest of 1805 as being one of the most severe PNW windstorms during the past two centuries, and place it in context to other known C2 events that have occurred since 1880.

Our results also make two historical contributions. First, they authenticate Clark's sense of frustration with the weather conditions near Fort Clatsop on 1 December 1805: '*The emence Seas and waves which breake on the rocks & Coasts to the S W. & N W roars like an emence fall at a distance, and this roaring has continued ever Since our arrival in the neighbourhood of the Sea Coast which has been 24 days Since we arrived in Sight of the Great Western; (for I cannot Say Pacific) Ocian as I have not Seen one pacific day Since my arrival in its vicinity, and its waters are forming and petially* [perpetually] *breake with emence waves on the Sands and rockey Coasts, tempestous and horiable*.' Second, the quantification of windstorm severity derived from tree-ring data and journal entries allow a new perspective on the history of westward expansion.

Prior to the onset of the of the Lewis and Clark expedition in AD 1804, President Jefferson and his protégé, Lewis, subscribed to the idea of the 'ultimate perfection of America' (Allen, 1975: 112) that envisioned a mirror image of the eastern USA in the Northwest that would provide 'perfect conditions for human progress' (Allen, 1975: 112). While this romanticized belief was steadfastly held by the Corps in its quest to reach the Pacific, it was severely undermined by Lewis' contempt for the weather conditions around Fort Clatsop. Ultimately miserable conditions wrought by frequent high winds, constant rain including 49 consecutive days (Knapp, 2004), and cold prompted the Corps of Discovery to advance their departure date from 1 April 1806, but even then Lewis noted on 20 March 1806 that '*It continued to rain and blow so violently today that nothing could be done towards forwarding our departure*.'

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Note

1. Quotes from the Lewis and Clark journal entries are verbatim with grammatical errors retained.

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