Journal of Geophysical Research: Atmospheres

Supporting Information for

Increased Fire Activity in Alaska since the 1980s: Evidence from an Ice Core-derived Black Carbon Record

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Contents of this file

Table S1 and Figures S1 to S5, and Text S1.

Introduction

The supporting information includes a table and five additional figures as described in the main text. Text S1 and its corresponding figures provide a case study of atmospheric circulation patterns for 1957 and 1969, the two largest fire seasons of the 20th century.

Table S1. Annual area burned in Alaska in acres (original data) and in hectares (AICC, 2020).

Year	Acres	Hectares
1939	5,000,000	2,023,428
1940	4,500,000	1,821,085
1941	3,654,774	1,479,035
1942	452,510	183,124
1943	666,773	269,833
1944	110,604	44,760
1945	117,313	47,475
1946	1,438,963	582,328
1947	1,431,665	579,374
1948	35,190	14,241
1949	18,148	7,344
1950	2,063,984	835,265
1951	221,669	89,706
1952	74,690	30,226
1953	472,549	191,234
1954	1,391,691	563,197
1955	23,582	9,543
1956	476,593	192,870
1957	5,049,661	2,043,525
1958	317,215	128,372
1959	596,574	241,425
1960	87,180	35,280
1961	5,100	2,064
1962	38,975	15,773
1963	16,290	6,592
1964	3,430	1,388
1965	7,093	2,870
1966	672,765	272,258
1967	109,005	44,113
1968	1,013,301	410,068
1969	4,231,820	1,712,557
1970	113,486	45,926
1971	1,069,108	432,653
1972	966,247	391,026
1973	59,816	24,207
1974	662,960	268,290
1975	127,845	51,737
1976	69,119	27,971
1977	2,295,808	929,081
1978	7,757	3,139
1979	389,925	157,797
1980	129,892	52,565
1981	536,217	216,999
1982	70,798	28,651
1983	98,164	39,726
1984	115,871	46,891
1985	406,429	164,476
1986	481,808	194,981
1987	222,066	89,867
1988	2,153,298	871,409
1989	68,453	27,702
1990	3,189,079	1,290,574
1991	1,637,950	662,855
1992	150,006	60,705
1993	712,868	288,487
1994	265,709	107,529
1995	43,932	17,779
1996	599,100	242,447
1997	2,026,806	820,219
1998	173,405	70,175
1999	1,005,409	406,875
2000	756,282	306,056
2001	216,032	87,425
2002	2,183,265	883,536
2003	602,718	243,911
2004	6,590,140	2,666,935
2005	4,649,597	1,881,625
2006	266,268	107,755
2007	649,411	262,807
2008	103,649	41,945
2009	2,934,608	1,187,594
2010	1,125,419	455,441
2011	293,018	118,580
2012	286,888	116,099
2013	1,316,289	532,683
2014	233,849	94,635
2015	5,111,453	2,068,531
2016	500,949	202,727
2017	652,904	264,221
2018	411,177	166,397
2019	2,585,625	1,046,365

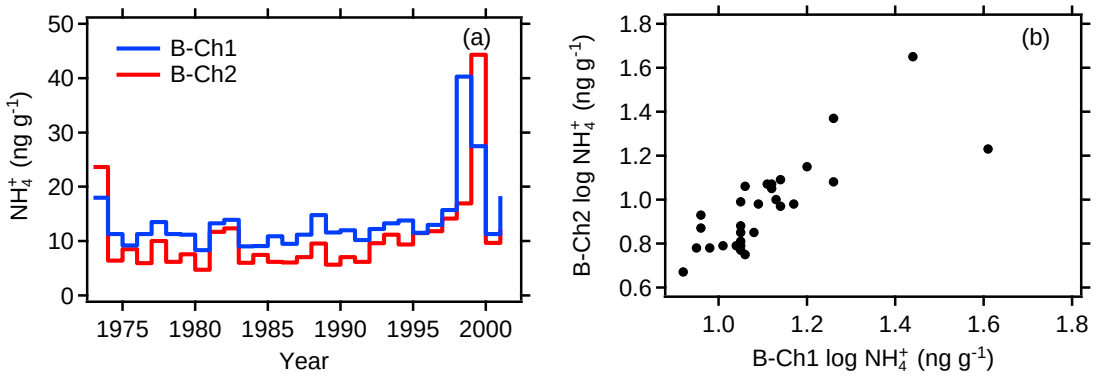

Figure S1. Ammonium annual concentrations from B-Ch1 and B-Ch2 shown as (a) time series between 1973 and 2001, and (b) scatter plot of their respective log concentrations.

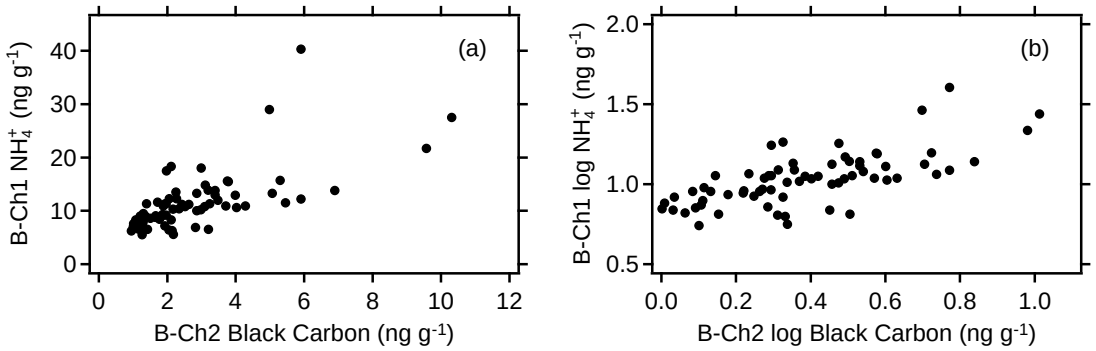

Figure S2. Comparison of (a) annual concentrations, and their respective (b) log concentrations of black carbon from B-Ch2 and NH_4^+ from B-Ch1.

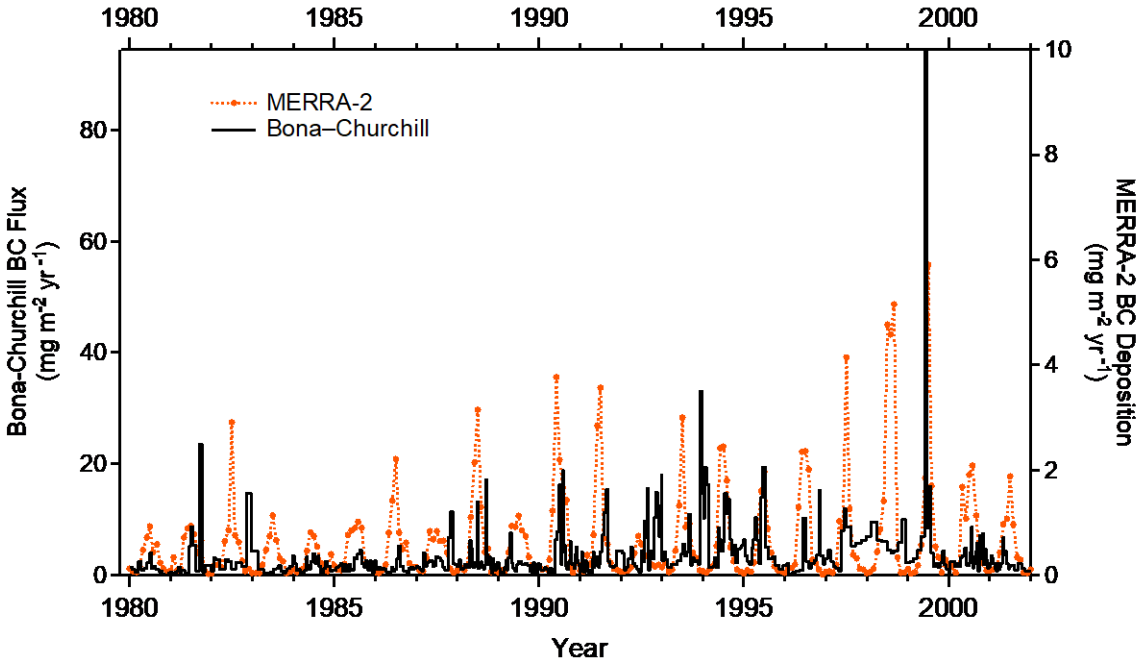

Figure S3. Comparison of the Bona-Churchill BC flux (black line) with BC deposition at Bona-Churchill from MERRA-2 (brown dotted line) at the top of the record between 1980 and 2001.

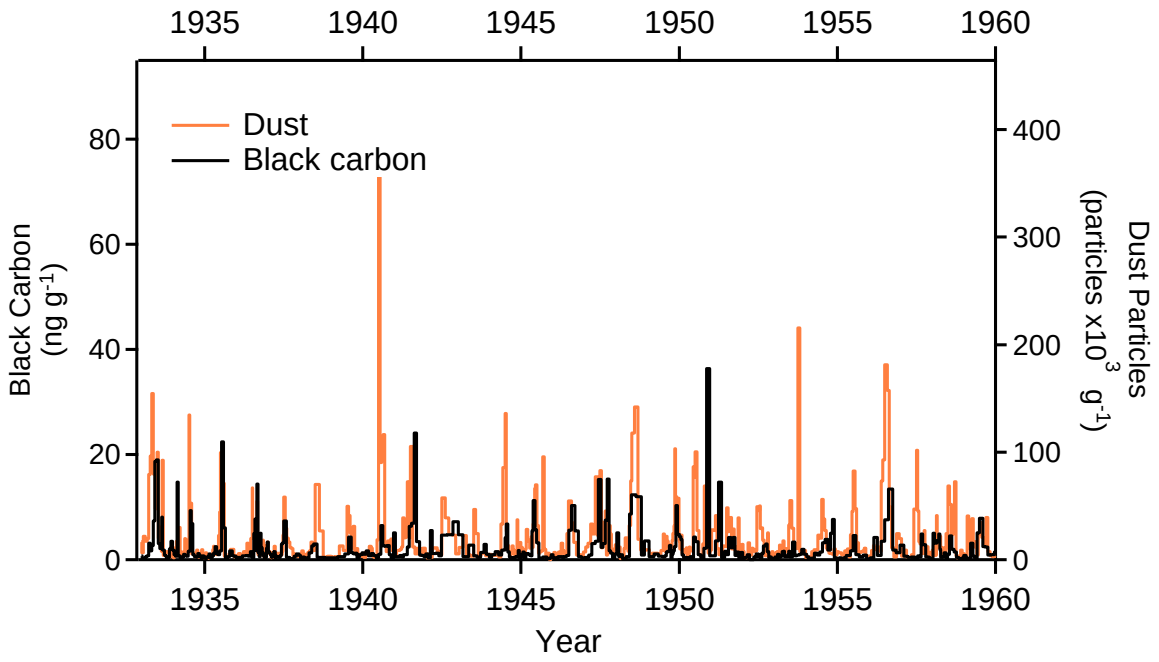

Figure S4. Comparison of black carbon concentrations from B-Ch2 (black line) with dust particles concentrations from B-Ch1 (brown line) from the bottom of the record between 1933 and 1960.

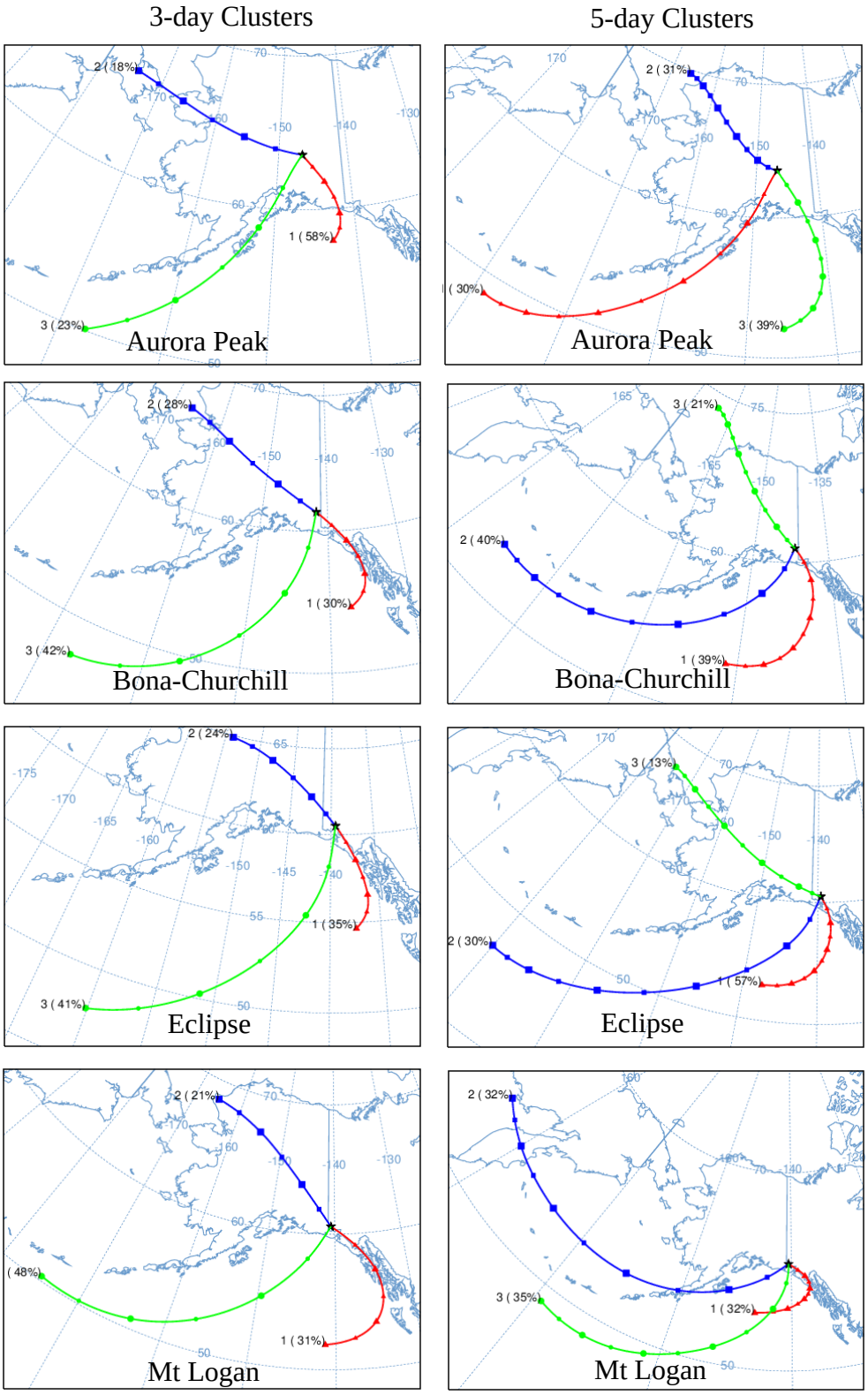

Figure S5. Clusters of 3- and 5-day back trajectories for Aurora Peak, Bona-Churchill, Eclipse Icefield, and Mt. Logan ice core drilling sites between 1948 and 2001 for May–August.

Text S1. Atmospheric Circulation Patterns for the 1957 and 1969 large fire years

The fire history data for Alaska are shown in this study at the statewide level. The potential of individual fires to be preserved in the Bona-Churchill black carbon (BC) and ammonium (NH_4^+) records depends on the intensity of the fires, their proximity to the ice core drill site, and the overlying atmospheric conditions.

The two largest fire years of the 20th century in Alaska occurred in 1957 and 1969. Although 1957 was the 3rd largest fire on record, there is no discernible signal in the Bona-Churchill record. In fact, the Bona-Churchill record shows low fire activity during 1957. On the other hand, there is a distinct peak in BC and NH_4^+ coinciding with the 1969 fire season (Fig. 4). It is well known that in 1969 two large fires occurred in the Kenai Peninsula in what it is now the Kenai National Wildlife Refuge, which is near and upwind of Bona-Churchill. The proximity of the Kenai fires to the Bona-Churchill site likely contributed to the detection of the 1969 event in the BC and NH_4^+ records; however, it is unclear why no signal was recorded at Bona-Churchill during the large 1957 fire season. To test the role of the atmospheric transport conditions we analyzed the circulation patterns for these two years.

Given the high elevation of the Bona-Churchill site, upper-level (500 hPa) winds were evaluated during the peak fire season (June, July, and August) using NCEP/NCAR reanalysis (Kalnay et al., 1996). The comparison of the zonal and meridional wind patterns for these two years are shown in Figures S6 and S7.

Zonal wind patterns indicate predominant westerlies over Alaska with the exception of a narrow band of very weak westerlies or near easterlies over southern Alaska (Fig. S6). This band of easterlies may be a result of cyclones and their subsequent cyclolysis in the Gulf of Alaska. Compared to the climatology (1981-2010, Fig. S6c), the anomalies of upper-level zonal winds reveal stronger easterlies in 1957 over southern Alaska (Fig. S6d) and stronger westerlies in 1969 (Fig. S6e). Stronger westerlies in 1969 would provide conditions more conducive to the transport of fire-related aerosols from the interior of Alaska to the Bona-Churchill site in the southeast.

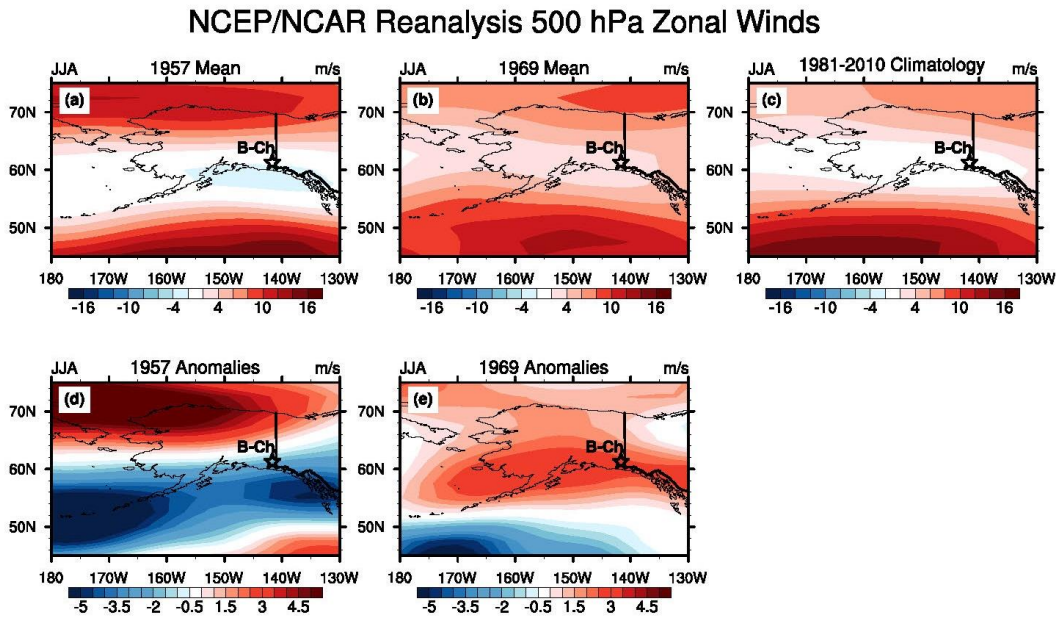

Figure S6. NCEP/NCAR reanalysis 500 hPa mean zonal winds (m/s) for June, July, and August (JJA) for (a) 1957, (b) 1969, and (c) the 1981-2010 climatological period. Anomalies from the climatological mean are shown for (d) 1957 and (e) 1969.

Meridional wind patterns indicate weak southerly winds over Alaska during summer (Fig. S7a-c). In 1957, those southerly winds are stronger over western Alaska, while weak northerly winds over are observed over eastern Alaska (Fig. S7a). In 1969, weak southerly winds dominate over much of Alaska while northerly winds occur to the west (Fig. S7b). Near the Bona-Churchill drill site, the southerly component of the winds in 1969 (Figs. S7b, e) is like the 1981-2010 climatology (Fig. S7c), while in 1957, winds are predominantly from the north over the Bona-Churchill site (Fig. S7a, d). The zonal and meridional wind patterns indicate that southwesterly winds prevailed during the summer of 1969 while weak northeasterly winds occurred in the summer of 1957. These southwesterly winds would facilitate the transport of aerosols from several large fires that occurred in 1969 in southwestern Alaska and the Kenai Peninsula.

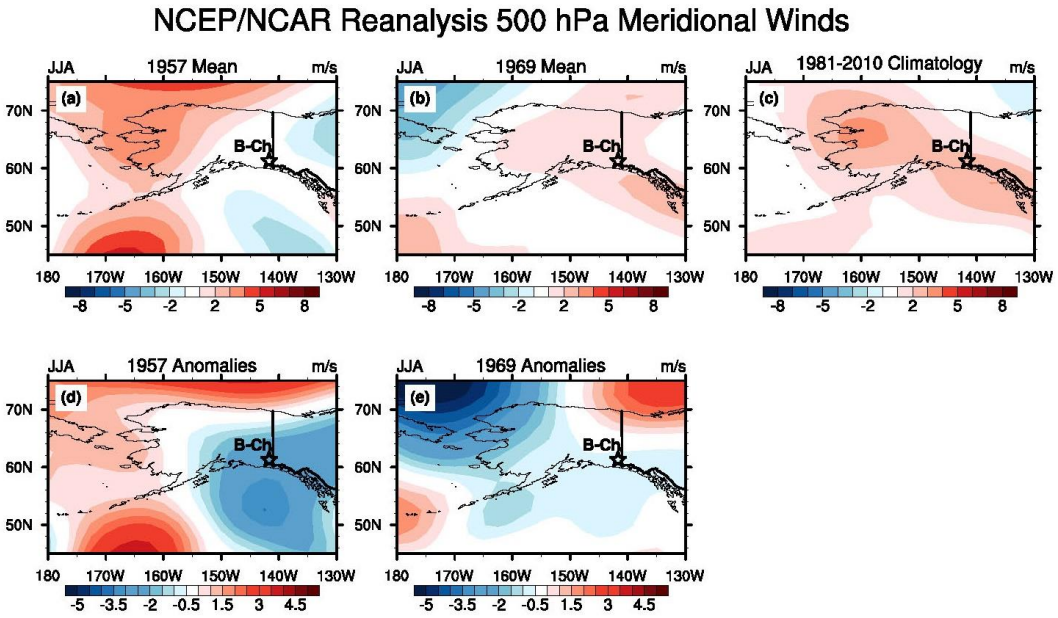

Figure S7: NCEP/NCAR reanalysis 500 hPa mean meridional winds (m/s) for June, July, and August (JJA) for (a) 1957, (b) 1969, and (c) the 1981-2010 climatological period. Anomalies from the climatological mean are shown for (d) 1957 and (e) 1969.

References

AICC (2020). Alaska Interagency Coordination Center: Alaska Fire History Chart with Data, Fort Wainwright, Alaska, USA.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., et al. (1996). The NCEP/NCAR 40-Year Reanalysis Project, *Bulletin of the American Meteorological Society*, *77*(3), 437-472, doi:10.1175/1520-0477(1996)077<0437:Tnyrp>2.0.Co;2.