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Coralline alga reveals first marine record of subarctic North Pacific climate change

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[1] While recent changes in subarctic North Pacific climate had dramatic effects on ecosystems and fishery yields, past climate dynamics and teleconnection patterns are poorly understood due to the absence of century-long high-resolution marine records. We present the first 117-year long annually resolved marine climate history from the western Bering Sea/Aleutian Island region using information contained in the calcitic skeleton of the long-lived crustose coralline red alga *Clathromorphum nereostratum*, a previously unused climate archive. The skeletal δ^{18}O-time series indicates significant warming and/or freshening of surface waters after the middle of the 20th century. Furthermore, the time series is spatiotemporally correlated with Pacific Decadal Oscillation (PDO) and tropical El Niño-Southern Oscillation (ENSO) indices. Even though the western Bering Sea/Aleutian Island region is believed to be outside the area of significant marine response to ENSO, we propose that an ENSO signal is transmitted via the Alaskan Stream from the Eastern North Pacific, a region of known ENSO teleconnections.
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[2] The subarctic North Pacific - Bering Sea climate has been undergoing major changes which purportedly threaten the world's largest fisheries and endanger unique ecosystems between Siberia and Alaska [*Grebmeier et al.*, 2006; *Overland and Stabeno*, 2004]. Instrumental temperature records indicate two regime shifts during the mid 1970's and late 1990's [*Volkov and van Aken*, 2005] were followed by major ecosystem reorganizations [*deYoung et al.*, 2004; *Francis et al.*, 1998]. However, in the absence of reliable century-long oceanographic records, long-term climate dynamics and teleconnection patterns in this region are poorly understood [*MacDonald and Case*, 2005]. Thus, it remains unclear whether recent changes are unique or recurrent events. In order reconstruct past climate evolution we collected a 5-cm thick live crust of the shallow water coralline red alga *Clathromorphum nereostratum* in August 2004 at Attu Island (52°47N; 173°10E) in the western Bering Sea/Aleutian Island region (Figure 1). This region is influenced by the east-west flowing Alaskan Stream, i.e. the swift and narrow western boundary current of the cyclonic eastern subarctic gyre located just south of the Alaska Peninsula and Aleutian Islands [*Reed and Stabeno*, 1994]. The Alaskan Stream originates in the Gulf of Alaska and enters through Aleutian Island passes into the Bering Sea where it is the dominant source of relatively warm, fresh and nutrient-rich water [*Reed and Stabeno*, 1994]. While *C. nereostratum* has only been described from the central and western North Pacific and Bering Sea region [*Lebednik*, 1976], coralline red algae grow in shallow marine settings of all climate zones. Coralline red algal skeletons form by accretion of high-Mg calcite mainly during the summer months. In the dark winter months and at temperatures below 5°C, skeletal growth of *C. nereostratum* slows or ceases entirely so that the summer-winter transition forms a distinct growth line. This assumption is based (1) on aquaculture studies that indicated a slowdown or halt in growth at low light intensities and/or low temperatures in a coralline red algae of the same genus (*C. circumscriptum*) [*Adey*, 1970]. (2) Highest correlations of isotope data were found when correlated to averaged June–November monthly sea surface temperatures (SSTs). During these months SSTs exceed 5°C in the region studied. The regular pattern of summer growth increments and winter growth lines enables a precise calendar dating of each portion of the hard tissue. Vertical growth is not influenced by an ontogenetic, asymptotic growth trend common to other marine biota frequently used as mid- and high-latitude climate archives such as bivalve mollusks [*Schöne et al.*, 2003]. Vertical accretion rates averaged 350 μm per year in the studied samples (ranging between 190 and 650 μm per year). A specimen collected alive at Attu Island was U/Th-dated at 850 ± 28 years cal BP, making *C. nereostratum* one of the longest-lived marine organisms. The age model for the 117-year old alga presented here is based on counting of annual growth increments, and confirmed by multi-collector inductively coupled plasma mass spectrometer derived U/Th ages [*Fietzke et al.*, 2005], which precisely match the number of annual increments (Table 1). Carbonate for δ^{18}O measurements was taken at subannual resolution by micromilling. Each milling step perpendicular to the direction of growth measured 60 μm (Figure 1). Depending on annual

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