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Editorial: North Pacific Environment and Paleoclimate From the Late Pleistocene to Present

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Editorial on the Research Topic

North Pacific Environment and Paleoclimate From the Late Pleistocene to Present

The vast area of the North Pacific, spanning ∼55° longitude, represents a challenge for documenting and understanding the geologic history of ocean, atmosphere, and terrestrial environmental change. This special issue highlights site-specific analyses to address various questions and provides clues that arise in response to continued North Pacific warming today in a rapidly changing climate (**Figure 1**). The emergence of new methods and novel application of existing methods serve to enhance our fundamental understanding of natural modes of climate variability driven by ocean and atmospheric circulation patterns, including the role of external (e.g., insolation) vs. internal forcing [e.g., El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO)]. Included in this volume are geographically diverse studies that present new and traditional methods for the interpretation of climate records drawn from pollen, macrofossils, tree rings, diatoms, grain size, and glacial studies. Many provide new geographic comparisons, such as Kamchatka and Hawaii, or emerge from novel geologic archives and environments, such as the marine shelf, a thermokarst lake, and a fossil forest.

Questions of natural variability targeted in the compendium include:

- What are geographic patterns of temperature and moisture variability since deglaciation?
- How does carbon accumulation compare among wetlands throughout the North Pacific, and how does moisture affect the differences in accumulation rates?
- What role does seasonality play in the temperature and moisture balance of a region?
- What are the primary controls on glacial advance in non-tidal glaciers of the North Pacific coast?
- Do productivity patterns in the ocean and land show synchronous response to climate variability?
- What are the relationships between patterns of thermokarst modification and changes in climate, forest growth, and fire regimes?
- How can lake basin morphology affect shifts in mixing depths, which impact diatom paleorecords?

We solicited studies from across the entire North Pacific. The studies range from the Hawaiian Islands in sub-tropical North Pacific (Beilman et al.,), California, and Montana in mid-latitude eastern Pacific (Carlin et al.; Kirby et al.; Stone et al.), Kamchatka in the high-latitude western Pacific (Nichols et al.), and Alaska, in high latitude central North Pacific, with numerous new Holocene records from Kodiak Island (Peteet et al.), southcentral Alaska (Jones et al.), southeastern Alaska coast (Ager; Gaglioti et al.), southern Interior Alaska (Bigelow et al.) to as far north as the Yukon

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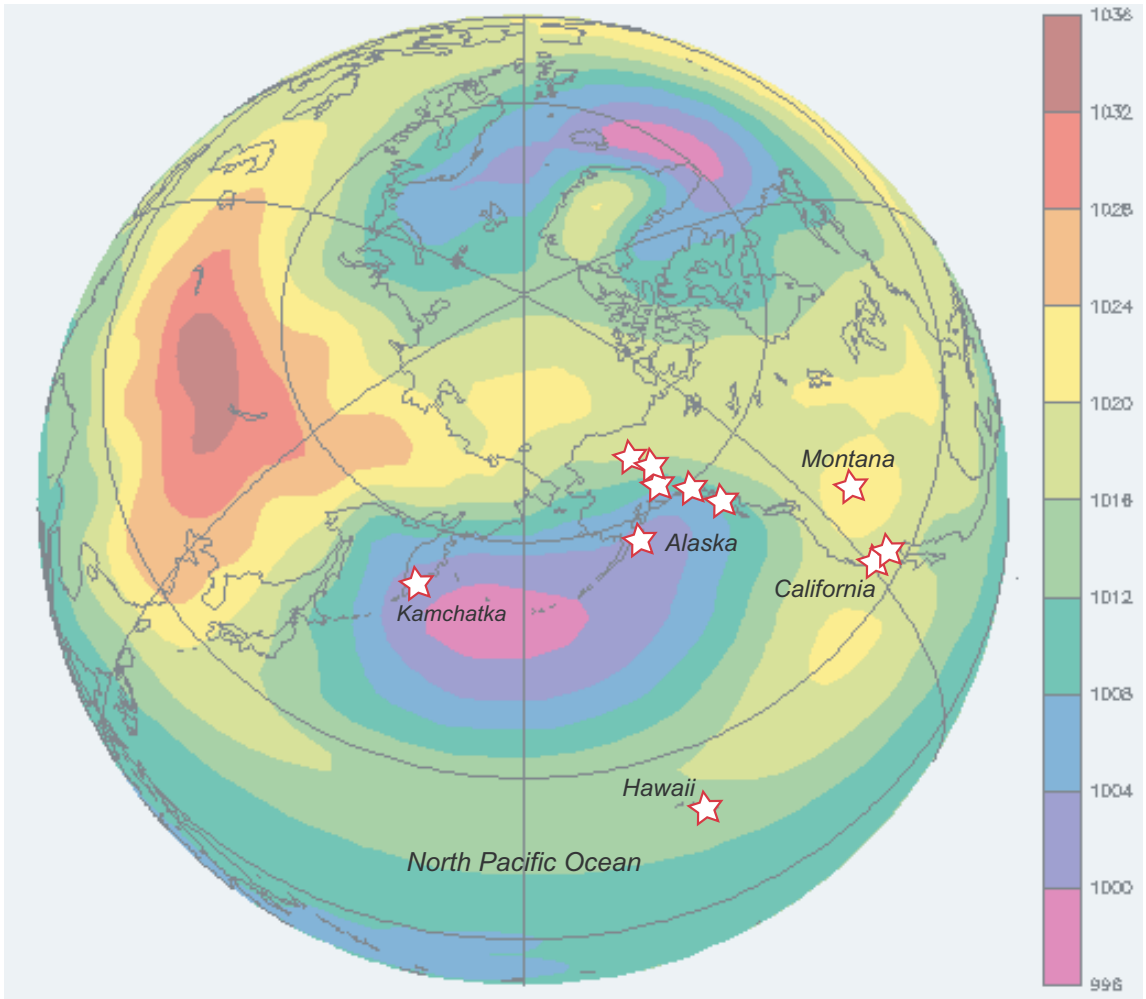

FIGURE 1 | Locations of the North Pacific paleoenvironmental studies included in this volume shown with composite sea level pressure to illustrate their relationship with dominant atmospheric flow patterns. Scale is in millibars (mb) (U.S. National Oceanic and Atmospheric Administration).

Flats in Interior Alaska (Anderson et al.). Evidence of North Pacific climate variability emerges from both the terrestrial and marine realm and connections between them under various modes of climate variability are also explored (Berkelhammer).

Several of the studies spanning the Holocene, employ similar geochemical proxies to elucidate patterns of synoptic responses to both internal and external hydroclimate variability. Early Holocene conditions from southcentral coastal Alaska (Peteet et al.) to Kamchatka, Russia (Nichols et al.) indicate patterns of warm and wet conditions in the early Holocene, before transitioning to drier conditions or more zonal atmospheric flow patterns in the mid-Holocene. The same geochemical proxy employed on a peatland from Hawaii shows climatic shifts occurring on similar timescales (Beilman et al.), suggesting North Pacific-wide changes associated with summer insolation. In the late Holocene, a proposed shift from insolation-dominance to internal influence by ENSO begins to influence the North Pacific, which is manifested as greater extratropical moisture reaching Hawaii and coupled with a trend toward warmer tropical sea-surface temperatures (Beilman et al.). Concurrent with these shifts is gradually increasing moisture in Kamchatka (Nichols et al.). These hydroclimatic shifts are consistent with patterns of vegetation change recorded by pollen and plant macrofossil records from southcentral and southeastern Alaska (Ager; Peteet et al.).

At lower latitudes, severe drought more frequently occurred in southern California relative to modern conditions, during the early to middle Holocene (Kirby et al.), likely in response to higher summer insolation. During the mid-Holocene, Southern California summers and winters were more frequently wet, whereas a late Holocene trend in increasing aridity largely reflects dry summers as winter precipitation increased. Rising lake levels during the late Holocene in the northern Rockies coincides with broad shifts in North Pacific circulation patterns (Stone et al.) related to increased winter precipitation driven by sub-tropical teleconnections, such as ENSO and the PDO. The dominance

of ENSO and the PDO in controlling late Holocene terrestrial hydroclimate variability is apparent from numerous records in this volume. On shorter timescales (years to decades), Carlin et al. explore the relationships between climate, shelf sedimentation, and human impact off the coast of California.

Several studies in this volume address persistent questions about changing precipitation seasonality during the Holocene using a diverse set of proxies. For example, a study from southern California uses grain size to represent pluvials driven by winter changes in precipitation (Kirby et al.), while Gaglioti et al. suggests that winter precipitation increases that expanded coastal Alaskan glaciers were driven by a stronger Aleutian Low during the Little Ice Age.

Hydroclimate variability can impact ecosystem carbon dynamics carbon. Holocene carbon accumulation rates from wetlands are addressed in several studies in this volume, spanning the tropics (Beilman et al.) to the subarctic (Nichols et al.; Peteet et al.). On shorter timescales, the influence of ENSO and the PDO impacts marine and terrestrial productivity and carbon uptake is examined in records from the western coast of North America (Berkelhammer). Climate variability and fire also has major influence on permafrost carbon dynamics and thermokarst in relation to thermokarst lake shoreline expansion, addressed in Anderson et al.. Humans have inhabited the landscape for millennia, and human migration and habitation of North Pacific landscapes are factored into the interpretation of four paleoclimate records in the studies by Ager, Beilman et al., Carlin et al., and Bigelow et al..

A brief summary of each submission to this volume is provided below.

- Beilman et al. document Holocene effective moisture variations from a Hawaiian peatland and relationships with vegetation dynamics and carbon accumulation rates. They utilize leaf wax geochemical methods to generate a novel wetness index and hydrogen isotope proxies of precipitation source and jet stream position. The combined paleoclimatic data with carbon sequestration and vegetation from the north central Pacific provides a new and highly significant point of reference from comparisons with western North America.
- Carlin et al. examine grain size and chronology (^{210}Pb, ^{137}Cs, ^{14}C) in four cores from Monterey Bay, California, in order to investigate shelf sedimentation and ways in which it is affected by climate and humans. They conclude that during dry climatic intervals, sedimentation is dominated by coastal erosion rather than by riverine inputs. In contrast, during wet years more sand was transported from rivers than from coastal erosion to the shelf. They also conclude that dams created by humans contribute to more coastal erosion, and to transport of more littoral sediment offshore.
- Kirby et al. explore Holocene lake level variations in drought sensitive southern California using paleo lake water isotope ratios captured by sedimentary carbonate. In tandem with sediment grain size variations, a proxy for winter precipitation amounts, the extent of water isotope evaporative enrichment indicated by calcite oxygen isotopes is used to provide companion proxies for summer effective moisture. The combined data provide an enhanced record of drought that illustrates the relative effects of changes in seasonal moisture availability.
- Stone et al. utilize diatom-inferred lake mixing depth reconstructions in mountain regions of Montana to explore the extent of regional hydroclimatic variability during the Holocene by examining the influence of individual lake bathymetry. They show that the effects of complex basin morphometry on mixing depth varies with lake levels, thereby complicating interpretation of lake level trends from diatom data. Recognition of unique morphometric effects are found to resolve apparently contradictory late Holocene hydroclimatic trends and provide a new methodological approach that will benefit future work.
- Berkelhammer uses satellite-derived Solar-Induced Florescence and chlorophyll-alpha as proxies for land and sea productivity to determine whether marine-terrestrial synchrony is a widespread phenomenon during modes of climate variability, such as El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Results suggest that marine and terrestrial ecosystems are synchronous across thousands of miles of the North Pacific coastline and that the strength of the synchrony depends on the relative states of the PDO and ENSO.
- Peteet et al. focus on western Kodiak Island peatlands, where a 16,000-year carbon sequestration record is coupled to the vegetational and isotopic history. During cooler, drier climate such as the Younger Dryas, the records show a decline in carbon stored, while the wet and warm early Holocene produces maximum values. A very large deuterium/hydrogen isotopic shift in the mid-Holocene (6,500 years BP) suggests that moisture arrived from cooler waters or a more distal source. Neoglaciation about 3,700 years ago brings cooler conditions as *Artemisia, Betula*, and *Sphagnum* increase, and carbon sequestration increases, all linked to the intensification of the Aleutian Low.
- Jones et al. conduct an oxygen isotope analysis of modern peatland water-plant relationships to better understand the relationship of peatland water to precipitation, and how plant cellulose oxygen isotope differences differ in their offset to peatland water depending on species and location within a peatland. They determined that bryophytes (non-vascular) were not statistically different from one another, but that sedges (vascular) were offset from bryophytes. They use this information to re-evaluate results of a previously published peat oxygen isotope record, which has implications for the deglacial and Holocene evolution of the Aleutian Low in southcentral Alaska. This study also proves the utility of this novel proxy for paleo-hydroclimatic studies in the North Pacific.
- **Ager** provides a comprehensive overview of the southeastern Alaskan paleoecological history, including three new palynological records from the region. Hummingbird Lake, southwestern Baronov Island, begins about 15,000 years ago and mirrors the sequence of vegetational change found in previous regional cores. Two nearby marine records, though

younger, provide similar complementary pollen sequences. His paper elucidates regional links between these records and possible tree refugia, the Queen Charlotte Islands to the south, and early human colonization.

- Gaglioti et al. approach questions about late Holocene glacier activity in the St. Elias Mountains from a recently exposed "ghost," or fossil, forest located on the south-central coast. Utilizing dendrochronological cross-dating methods, comparisons with Little Ice Age chronologies from nearby glaciers, and paleoclimatic data, they explore the climate variables that may have controlled glacier fluctuations in the region. These comparisons are used to examine the prominent differences between the timing of Little Ice Age advances in Alaska and North Atlantic regions to propose the importance of winter precipitation for Gulf of Alaska glaciers during the nineteenth century.
- Bigelow et al. relate the vegetational and climate history from four lakes in the middle Susitna Valley, Alaska, to human occupancy in the region. Their multidisciplinary research includes pollen, diatoms, and geochemistry. Shrub tundra characterized the earliest vegetation about 12,000 years ago, followed by a possible Younger Dryas cooling and aridity, then subsequent warming in the early Holocene as forest advanced beyond present limits. Retreat of spruce after 4,500 years ago indicates late Holocene cooling.
- Anderson et al. explore Holocene thermokarst lake development and evolution in discontinuous permafrost landscape of northern Interior Alaska. The study highlights thermokarst evolution that is characteristic of loess uplands—a landscape that is widespread and yet frequently overlooked for paleoclimatic studies. The authors propose that initial thermokarst lake formation and expansion occurred during early Holocene warmth, corresponding with boreal forest and fire development. Following a period of stabilization, subsequent lake-level rise and fall were influenced by climate via groundwater-surface water dynamics and North Pacific atmospheric circulation variability.
- Nichols et al. use stable isotope geochemical and plant macrofossil record from a peatland in Kamchatka, Russia to examine hydroclimate variability and the controls on that variability in the northwestern Pacific. They find a generally wetter early and late Holocene with a drier, more episodic precipitation regime during the mid-Holocene. These patterns are similar to patterns recorded in the eastern North Pacific, as well as northern Japan. They conclude that the observed patterns can in part be explained by changes in tropical Pacific sea surface temperatures, highlighting the potential influence of the tropics across the broader North Pacific region.

AUTHOR CONTRIBUTIONS

MJ, LA, and DP contributed to writing. LA created the figure. MJ organized and edited.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.