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Linking solar forcing with climate and primary productivity changes in the Northeast Pacific: evidence from mid to late Holocene laminated sediments

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Marine-laminated sediments along the NE Pacific coast of British Columbia (Effingham inlet, Vancouver Island and the Seymour-Belize Inlet Complex (SBIC) on the mainland) provide an archive of mid to late Holocene climate variability at annual to millennial scales. Deposited under primarily anoxic conditions laminated annually deposited couplets are characterized by darker clay laminae that were accumulated under higher precipitation conditions in winter, and diatom-dominated laminae that were laid down when marine productivity was higher in the spring through autumn. The study comprised of two piston cores (TUL99B03 and TUL99B11; ∼5500 cal YBP-present) and a freeze core (TUL99B04; 1947-1993) from Effingham Inlet and two piston cores (VEC02A04 and VEC02A07; ∼4500-1000 cal YBP) and a freeze core (FC04; ∼1000 cal yBP -present) from the SBIC. Wavelet transform and other time series analysis methods were applied to sediment color (i.e. gray-scale values) line scans obtained from x-ray images of cores and compared with global records of cosmogenic nuclides (14C and 10Be), as well as the Ice Drift Index (hematite-stained grains) record to detect cycles, trends and non-stationarities in the sedimentary record. Similar analyses were carried out on diatom, dinoflagellate and fish scale records recovered from these same cores. The results indicate that the marine productivity and sedimentary record of the NE Pacific responded to abrupt changes and long-term variability in climate that can be linked to external forcing (e.g. variation in cosmic ray influx due to solar magnetic activity and variation in solar ultraviolet (UV) radiation through a typical solar cycle). A 2-7 year and 10-12 year cycle was recognizable suggesting that both the El Niño-Southern Oscillation (ENSO) and the sunspot cycle respectively had an influence on primary productivity and sedimentation processes. Correlations between the sunspot cycle, diatom abundance and ocean-atmosphere records available for the 20th century show a one-year lag between diatom abundance and the sunspot cycle. Higher spring (April/May) values of the North Pacific High pressure index during sunspot minima suggest that during this time, increased cloud cover and concomitant suppression of the Aleutian Low pressure system lead to strengthened coastal upwelling and diatom production earlier in the year. There is also evidence in the cores of a strong cooling in the NE Pacific at ∼ 3550 yr BP. This event is associated with widespread neoglaciation in the region that can be correlated to a weakening of high-frequency (50-150) year pulses at the Gleissberg solar cycle band. Episodes of low sun activity are characterized in the sedimentary record (e.g. 2350, 2750 and 3350 cal yBP) of the cores by intervals of clay-rich and thick laminae that were deposited under unusually wet conditions. These intervals of higher precipitation may have been related to a regional intensification of the Aleutian Low (AL) caused by an eastward migration of the Center of Action (COA) of the AL, which occurs during intervals of solar minima, similar to what occurred during the "Little Ice Age" (e.g. Sporer, Maunder and Dalton minima). Dryer conditions prevail in the region when the COA of the AL migrates westward and the COA of the North Pacific High migrates northward during intervals of solar maxima. These NPH and AL COA changes greatly impact the influence of open ocean upwelling in Effingham Inlet and estuarine circulation in the SBIC. These results suggest that solar cycles may exert a significant, though indirect influence on marine primary productivity in the northeast Pacific.