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Annually resolved grain-size distributions in varved sediments using image analysis - application to Paleoclimatology

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Varved sediments are unique archives because they contain continuous and undisturbed records of past climatic conditions with an internal robust chronology. In many case, conceptual models for the varve formation can be established linking processes occurring in the watershed, such as river floods or snow melt, to specific lamina within the varve structure. However, the physical properties of such layers, including grain-size, are seldom measured despite their intrinsic value as indicators of hydrological processes.

This paper reviews the development and improvements of an image analysis methodology to extract grain-size data from finely laminated sediments. The technique uses thin-sections from sediment cores, scanning electron microscope images of carefully selected regions of interest from the thin-sections, and an image analysis routine to extract semi-automatically grain-size data.

An example from Cape Bounty in the Canadian High Arctic is presented: grain-size data within each varve was measured for the last 2845 years. Several particle size distribution indices for each individual facies were calculated and combined to identify each type of sedimentary facies encountered within the sequence. For instance, high standard deviation and 98th percentile index values are interpreted as high-energy events such as turbidites and debris flows.

Moreover, some grain-size indicators from the most recent varves correlate well with instrumental climate data. For instance, the 98th percentile grain size has a strong correlation (R^2=0.71) with summer rainfall. This kind of relationship allows for the calibration of the image-analysis generated grain-size data set in terms of hydroclimatic parameters. The rainfall reconstruction suggests that Cape Bounty recently experienced an unprecedented increase since $\sim$1920 AD.

These results contrast to other common varve measurements. For instance, varve thickness is not significantly correlated with the particle size distribution, and is poorly linked to the instrumental record. Indeed, sediment accumulation can result from the accumulation of different successive hydroclimatic and geomorphic mechanisms such as spring snowmelt, rain events and landslides, as well as by changes in lake circulation and stratification. Therefore, a detailed grain-size obtained using image analysis appears to be a better approach to reconstruct past hydroclimatic conditions in this clastic sedimentary setting and holds tremendous potential to improve paleoclimatic reconstructions.