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High resolution water stable isotope profiles of abrupt climate transitions in Greenland ice with new observations from NEEM

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In 1989 Willi Dansgaard and others, using the DYE3 ice core, showed that the abrupt termination of the Younger Dryas expressed in water stable isotope ratios and deuterium excess was completed in less than 50 years. A few years later, using the GISP2 ice core, Richard Alley and others proposed that snow accumulation at the site doubled in as little as 1-3 years across the same climate transition at the end of the Younger Dryas. Over the next two decades, in large part due to such observations from Greenland ice cores, a paradigm of linked, abrupt changes in the North Atlantic region has been developed around North Atlantic deep water formation, North Atlantic sea ice extent, and widespread atmospheric circulation changes occurring repeatedly during the last glacial period in response to changing freshwater fluxes to the region, or perhaps other causes. More recently, with the NGRIP ice core, using a suite of high resolution proxy data, and in particular deuterium excess, it was observed again that certain features in the climate system can switch modes from one year to the next, while other proxies can take from decades to centuries to completely switch modes. Thus, an event seen in the proxy records such as the abrupt end of the Younger Dryas (or other interstadial events) may comprise multiple climatic or oceanic responses with different relative timing and duration which potentially follow a predictable sequence of events, in some cases separated by only a few years.

Today, the search continues for these emerging patterns through isotopic and other highly resolvable proxy data series from ice cores. With the recent completion of the drilling at NEEM, many abrupt transitions have now been measured in detail over a geographic transect with drilling sites spanning from DYE3 in Southern Greenland, GISP2 in the central summit region, and up to NGRIP and NEEM in the far north. The anatomy of abrupt climate transitions can therefore be examined both spatially and temporally, where obtaining the highest possible temporal resolution is desirable to resolve patterns. A new method for measuring water stable isotope ratios has been developed during the NEEM project that allows us to measure a carefully controlled fraction of a continuously melted ice core section which is evaporated directly into Cavity Ring Down Laser Spectrometer in the Near-Infrared spectrum. In such a system the resolution can be maximized (and characterized) largely as a function of both the melt rate and minimizing subsequent mixing in the gas phase during analysis. These new detailed water isotope series from the NEEM ice core are examined with respect to the corresponding series from new and previously available series from the other ice cores. The emerging picture indicates that abrupt climate changes have both a temporal and geographic anatomy that can change from one event to the next in how they are recorded across Greenland. Together with modeling and chemical impurity data, these patterns we detect in the water stable isotope series will provide clues and constraints to the timing and origin of oceanic and atmospheric changes that make up an abrupt climate change.