

## An annually resolved reconstruction of summer North Atlantic Oscillation (SNAO) variability for the last 550 years

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Summer climate in the North Atlantic-European sector possesses a principal pattern of year-to-year variability similar to the North Atlantic Oscillation in winter. The 'Summer North Atlantic Oscillation' (SNAO), which is defined as the first EOF of July-August extratropical North Atlantic pressure at mean sea level, is characterised by a more northerly location and smaller spatial scale than its winter counterpart. Despite being of lesser amplitude than the winter NAO, the SNAO exerts a strong influence on European climate, e.g. rainfall, temperature and cloudiness, especially in North Europe. It plays a key role in generating summer climate extremes, including flooding, drought and heat stress in North Western Europe. There is a weak relationship between the SNAO and the El Niño/Southern Oscillation (ENSO). Modelling and observational results indicate that SNAO variations are partly related to the Atlantic Multidecadal Oscillation on interdecadal time scales. Using tree-ring records the SNAO was extended back to 1441. In the past 550 years, the SNAO has been variable on many time scales with a multi-century fluctuation between the late sixteenth and late twentieth centuries. In addition there is a slight overall positive trend, where the high SNAO values of the late twentieth century seem unprecedented in the record. Associations found in observations between the SNAO and climate features of the eastern North Atlantic Region, such as European drought and Sahel rainfall seemingly holds back in time. Extending the SNAO beyond the instrumental period will allow us to further investigate the role of the atmospheric circulation in modulating North Atlantic summer climate, as well as its association with ocean circulation.

## Vadose zone geochemistry and mineralogy of sulfide-rich tailings at the Greens Creek Mine, Alaska, USA

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Geochemical and mineralogical investigation of tailings at the Greens Creek Mine was performed to evaluate mechanisms controlling pore-water quality in the vadose zone. This underground Ag-Zn-Au-Pb mine extracts sphalerite [(Zn,Fe)S], tetrahedrite [(Fe,Zn,Cu,Ag)<sub>12</sub>Sb<sub>4</sub>S<sub>13</sub>], galena [PbS], electrum [AuAg] and pyrrargyrite [Ag<sub>3</sub>SbS<sub>3</sub>] from a volcanogenic massive sulfide-sedimentary exhalative (VMS-SEDEX) hybrid deposit. The gangue mineral assemblage is dominated by pyrite [FeS<sub>2</sub>], dolomite [CaMg(CO<sub>3</sub>)<sub>2</sub>], and quartz [SiO<sub>2</sub>]. Calcite [CaCO<sub>3</sub>] and barite [BaSO<sub>4</sub>] are also common, while arsenopyrite [FeAsS] and chalcopyrite [CuFeS<sub>2</sub>] are occasionally observed.

Tailings core samples were collected from five bore-holes ranging from 7 to 26 m in total depth. The majority of the 51 samples (77%) were collected from the vadose zone, which can extend to > 18 m in depth. Mineralogical investigation indicates that the occurrence of sulfide minerals follows the general order: FeS<sub>2</sub> >> (Zn,Fe)S > PbS, (Fe,Zn,Cu,Ag)<sub>12</sub>Sb<sub>4</sub>S<sub>13</sub> > FeAsS and CuFeS<sub>2</sub>, with FeS<sub>2</sub> accounting for < 20 to > 35 wt. % of tailings solids, and CaMg(CO<sub>3</sub>)<sub>2</sub> and CaCO<sub>3</sub> present at ≤ 30 and 3 wt. %, respectively. The solid-phase geochemistry generally reflects the mineral assemblage. However, the presence of additional trace elements, such as Cd, Cr, Co, Hg, Mo, Ni, Se, Tl, and V, is attributed to elemental substitution into sulfide phases.

Pore-water samples were collected from suction-lysimeters located at various depths and locations within the tailings facility. Pore-water pH generally ranges from 7 to 8.5 and the presence of metals and trace elements reflects the mineralogy. The presence of S<sub>2</sub>O<sub>3</sub> at aqueous concentrations up to 2000 mg L<sup>-1</sup> was observed, and increases in dissolved Ag generally correspond to the presence of S<sub>2</sub>O<sub>3</sub>. Evidence of SO<sub>4</sub> reduction, including decreases in dissolved SO<sub>4</sub>, S<sub>2</sub>O<sub>3</sub>, Fe and Zn, was also observed. A study is being conducted to evaluate the potential to enhance SO<sub>4</sub> reduction for passive *in situ* pore-water remediation within the vadose zone.