Abstract. Trends have been analysed for 12 years of chemical data from six mountain lakes in the UK Acid Waters Monitoring Network (AWMN). With minimal local anthropogenic impacts, these sites offer the best available opportunity for clear identification of surface water chemical response to external factors, whether natural or anthropogenic. Results indicate that natural climatic variations have had a major impact on lake chemistry, through fluctuations in (i) intensity of storms, which cause dilution of weathering-derived base cations, and/or displacement of hydrogen and aluminium ions on soil exchange sites by deposited marine base cations; and (ii) winter temperature, which is thought to be inversely related to spring nitrate (NO₃⁻) maxima. Both climatic factors can be linked to the North Atlantic Oscillation. For the first decade of AWMN monitoring these natural ‘confounding factors’ to a significant extent obscured any recovery from acidification due to declining anthropogenic sulphur deposition. However, the additional data presented here provide strengthening evidence for chemical recovery at a number of sites, at which decreases in sulphate (SO₄²⁻), acidity and labile aluminium can now be identified. It is believed that changes at these sensitive mountain lake sites may herald more widespread recovery in UK surface waters as pollutant emissions decline further. However, large increases in dissolved organic carbon, and hence in organic acidity, may have partially offset reductions in mineral acidity. The cause of these increases remains uncertain, but may be linked to climatic change.

Keywords: acidification, climate, recovery, trend analysis

1. Introduction

In order to demonstrate the value of reductions in emissions of acidifying compounds at the national and European scale, it is necessary to establish that these reductions have led to measurable environmental benefits. One important expected benefit is the recovery of acidified, biologically impoverished, freshwater systems, but in the UK at least this recovery has been difficult to validate. Several factors have contributed to these difficulties, foremost among which was the lack of an extensive monitoring program during the 1970s and 1980s. Deposition data for this period indicate large reductions in sulphur deposition (RGAR, 1997), but surface water monitoring data are extremely limited for the 1970s, and restricted to localised studies for most of the 1980s. Of the records available, those in Galloway, southwest Scotland (Harriman et al., 1995), the Lake District, northwest England.
(Tipping et al., 1998), and the South Pennines, northern England (Evans and Jen-kins, 2000) suggest some recovery in pH, whilst others in mid-Wales (Robson and Neal, 1996; Reynolds et al., 1997) show little or no change.

In 1988, regular standardised monitoring of 22 lakes and streams began in the UK with the creation of the Acid Waters Monitoring Network (AWMN) (Patrick et al., 1995). However, the detection of chemical recovery in this dataset has been problematic because (i) reductions in sulphur deposition occurred more slowly in the 1990s than in the 1980s; (ii) decreases were smallest in the remote, wet-deposition dominated regions where most AWMN sites are located, and (iii) no clear decreases were observed in nitrogen deposition (Fowler and Smith, 2000). An analysis of AWMN data for 1988–1998 (Monteith and Evans, 2000) revealed declining non-marine sulphate (xSO₄) trends at only three sites, and rising pH at only six. Much of the chemical variation observed appeared to be linked to climatic fluctuations, rather than to changes in acid deposition. Analysing AWMN data for 1990–1997, Stoddard et al. (1999) were also unable to find evidence for recovery in the UK, despite observing decreasing xSO₄ and rising alkalinity in Scandinavia and North/Central Europe over the same period. Evidence for chemical recovery has also been obtained by more detailed studies of other European impacted regions, including Norway (Skjelkvåle et al., 1998), Sweden (Wilander and Lundin, 1999), the Czech Republic (Veselý et al., 1998) and Slovakia (Kopáček et al., 1998).

In addition to limitations in the availability and length of long-term datasets, the detection of recovery trends may be hindered by characteristics of the sites themselves. Factors likely to obscure the link between deposition and surface water chemistry include land-use impacts, and any local pollutant sources. In the UK, coniferous forestry plantations have been shown to have a major effect on runoff chemistry (e.g. Stoner and Gee, 1985), and at least one forested site in the AWMN appears still to be acidifying (Monteith and Evans, 2000). Additional difficulties are encountered at streams due to short-term episodicity; at the River Etherow AWMN site, for example, pH can vary from > 7.0 at baseflow to < 4.0 at high flows, making it extremely difficult to detect underlying trends.

This study, utilising two more years of data than were available for analysis by Monteith and Evans (2000), attempts to determine whether recovery from acidification is now occurring in the UK by examining data for six small unforested mountain lake sites within the AWMN. These sites, which are subject to minimal local impacts, and which have a relatively stable short-term chemistry, are hypothesised to be among the most sensitive in the network to changes in external factors. They are therefore expected to show the earliest indications of chemical recovery in response to reductions in acid deposition.