

Comparative assessment of regionalisation methods of monitored atmospheric deposition loads

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Abstract

The objective of this investigation is to assess the suitability of well-known regionalisation methods of data from existing deposition monitoring networks for use in water resources management. For this purpose a comparison of the applicability and accuracy of various regionalisation methods was made. A crucial point is the data demand of the various methods. In this investigation the deterministic and geostatistical methods inverse distance weighting (IDW), ordinary kriging (OK) and external drift kriging (EDK) as well as the chemical transport models METRAS-MUSCAT, EMEP, EDACS and EUTREND have been characterised and evaluated. The methods IDW and OK have been applied to the investigation areas—the German Federal States of Lower Saxony and Saxony. An evaluation of these methods was carried out with a cross-validation procedure. The result was in most cases a higher accuracy for the OK method. The EDK method has been investigated in order to find suitable drift variables from the parameters precipitation amount, altitude and wind direction. With help of a correlation analysis a suitable drift variable could not be found. After the application of OK, verification was carried out by a comparison of the estimated data set with an independently determined data set. The result was a relatively smaller deviation of the estimated data set. The investigation considers data from routine monitoring networks as well as networks for special applications and has been carried out on the basis of monitoring networks of the two states. The investigated database was wet and bulk deposition of the substances NH_4^+ , SO_4^{2-} , NO_3^- , Na^+ , Pb^{2+} , and Cd^{2+} in Lower Saxony and SO_4^{2-} in Saxony. From this, a consistent database of bulk deposition data was built. From all applied methods OK proved to cope best with the data deficiencies that were found.

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1. Introduction

With regard to the protection and sustainable development of soils and waters, there is a growing need for the authorities to obtain integrated and area-specific

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environmental information. Typically, the measurement of atmospheric deposition and substance transport in soils and groundwater is carried out on the basis of sectoral monitoring networks, i.e. networks for deposition, seepage water and groundwater. Because each network was designed without regard to the others, the monitoring stations of the various networks are located independently. For this reason methods have to be developed, that can be used to link available information at various monitoring points in various monitoring networks. Common methods for the regionalisation of seepage and groundwater data are geostatistical and deterministic methods. The objective of this investigation was to find a comparable method to regionalise available monitoring data from existing routine deposition networks with a maximum accuracy and acceptable effort for water resources management. The project was initiated to exemplify a suitable regionalisation method for the networks in the German Federal States of Lower Saxony and Saxony. The concept was to assess well-known regionalisation methods as well as chemical transport models (CTMs) with regard to their accuracy and feasibility under given conditions. Special networks from various institutions should be considered. The investigated database was for a time period from 1995 to 1998. The investigation was carried out by means of bulk deposition data.

2. Monitoring networks, database and data treatment

In Germany, an official countrywide deposition monitoring network is operated by the Umweltbundesamt (UBA). It consists of 37 measuring stations (status quo in 2001) for the monitoring of regional pollutant transport. Furthermore, the German Federal States operate monitoring networks to fulfil different research objectives, e.g. air hygiene, documentation of input paths or registration of basic impacts of emissions far from the source. Additional operators of networks on local and regional scales exist (see Gauger et al., 1997, 2000, 2002).

The number of available monitoring stations amounts to 76 in Lower Saxony (area: 47.343 km²; i.e. one station per 623 km) and 24 in Saxony (area: 18.338 km²; i.e. one station per 764 km²). The locations of the stations are shown in Fig. 1.

The observed substances are, in general, NH₄⁺, NO₃⁻, SO₄²⁻, Cl⁻, Na⁺, K⁺, Mg²⁺, Ca²⁺, H⁺, Cd²⁺, Pb²⁺ and the amount of precipitation. For this investigation the following substances were selected: NH₄⁺, SO₄²⁻, NO₃⁻, Na⁺, Pb²⁺ and Cd²⁺ in Lower Saxony and SO₄²⁻ in Saxony. The selection was carried out on the basis of the needs formulated by the water resources stakeholder group of the project and the quantity and quality of the

available database. The total number of monitoring stations that could be used for the investigation period 1995 to 1998 were as follows. In Lower Saxony, 44 stations could be used for the substances ammonium, sulphate and sodium, 57 for nitrate and 18 for cadmium and lead. In Saxony, 19 stations could be used for sulphate.

The sampling techniques in Germany that are applied in the Federal States may be divided into wet-only and bulk-sampling. Therefore, wet-only measurements have to be converted to bulk. This was done according to Gauger et al. (2000). Thereby, the wet-only were increased by a parameter-dependent factor (f_p , see Table 1) based on the following equation:

$$X_{p\text{-Bulk}}^* = X_{p\text{-Wet}} \times 1/f_p, \quad (1)$$

where $X_{p\text{-Bulk}}^*$ is the calculated amount of the parameter p in the bulk sampler, $X_{p\text{-Wet}}$ is the measured amount of the parameter p in the wet sampler and f_p is the factor according to Table 1 for parameter p [-]. The parameter p is the acronym of the substance to be measured.

Sulphate data were corrected with the so-called “sea-salt correction” after Gauger et al. (1997). Because rainwater contains ions originating from seawater that is transported into the continent by sea spray the sea-salt correction is used to correct the measured ion content from a sample for the sea-salt contribution. This sea-salt influence would produce a trend in the data set which overlays the impacts of other sources. Eq. (2) is based on the assumptions that sodium is 100% sea-borne near the coast and the ratio of element concentrations in seawater and sea spray is equal. These assumptions are plausible for northern and western Europe (Gauger et al., 1997) as well as for the wet deposition in East Germany (UN ECE, 1996).

$$S_{\text{SSC}} = S_{\text{dep}} - Na_{\text{dep}} \left(\frac{S_{\text{SW}}}{Na_{\text{SW}}} \right), \quad (2)$$

where S_{SSC} is the corrected sulphur deposition in consideration of sea spray emissions (SSC = sea-salt corrected) in [mol_{eq} ha⁻¹ a⁻¹], S_{dep} is the deposition of sulphur in [mol_{eq} ha⁻¹ a⁻¹], Na_{dep} is the deposition of sodium in [mol_{eq} ha⁻¹ a⁻¹] and $S_{\text{SW}}/Na_{\text{SW}}$ is the concentration ratio of sulphur to sodium in sea water which is equal to 0.120 (UN ECE, 1996).

The data of the networks are available in different time steps (weeks, monthly averages or sums). At some monitoring stations the time series are incomplete. Especially in winter there are some months without any data, e.g. because of plugging of the samplers by snow. In order to guarantee a consistent database, the missing data were interpolated. For this, in some cases

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