Response to the reviewers' comments (1) on HESS-2009-180

Dear Prof. Goovaerts,

Below are our responses to your comments and suggestion. Actually, as the issues that you pointed out are mostly mathematical, we invite our collaborator, Dr. Oleg Makhnin, from Department of Mathematics at New Mexico Tech, to address your comments together.

Sincerely,

Huade Guan
On behalf of the co-authors.

General comments

This paper presents the application of common statistical (correlation analysis and regression) and geostatistical (residual kriging) techniques to the study of relationship between chloride deposition and potential covariates (coastal distance, elevation, slope angle and orientation), followed by the mapping of chloride deposition and concentration. Both types of techniques rely on different assumptions, a fact that has been overlooked by the authors. In particular, the tests of hypothesis regarding the significance of correlation coefficients are based on the assumption of spatial independence of observations, which is invalidated by the spatial structure of the semivariogram of Figure 6a. Traditional linear regression also assumes the stationarity of the regression coefficients throughout the study area, which is not always appropriate. Other techniques, such as geographically-weighted regression and kriging with an external drift, provide ways to incorporate the spatial coordinates of observations directly into the correlation analysis and to account for spatially varying impact of covariates. The most critical issue in the paper is the uncertainty map displayed in Figure 7d. Instead of adding up standard deviations (a quantity that is not additive), the authors should have added up variances, then compute the square root of that sum. This mistake led to an overestimation of the uncertainty intervals, which explains the conservative nature of uncertainty measures noticed by the authors.

Discussion

Thanks for pointing out the strict statistical assumption for the correlation analysis. We agree that due to the spatial dependence within each variable, the *p*-values from the correlation analysis are not strictly correct. Nevertheless, the p-values should be still useful to compare which variables are more important than others to be associated with chloride depositions.

We agree that one linear regression cannot apply over space without limitation. Some understanding to the climate setting is useful to determine to what spatial extent the regression is appropriate. For example, in PRISM, the regression is applied to each topographic facet. For ASOADeK, we generally do separate regression for each subregion if the study area is too large. For example we separate Taiwan into four subregions when ASOADeK is applied (Guan et al., Journal of International Climatology, 2009). The regression performance itself also tells whether the regression is appropriate. For this study area, it is relative small, and has a climate condition relatively simple. The ASOADeK regression captures over 80% of spatial variability for monthly precipitation (Guan at al., Journal of Hydrology, 2009). Based on this previous work, and our understanding on climate factors that might impact chloride deposition, we think it is appropriate to apply the regression over this study area. However, we do find that site #16 and site #17 do not fit the overall controlling processes that are represented in the regression. These two sites are excluded from the regression.

We agree that other techniques may provide better solution mathematically. However, they do not necessarily provide inference that is physically meaningful (Isaaks and Srivastava 1989 book p532). We actually tried GLS-regression for Taiwan precipitation case, resulted in some prevailing moisture direction inconsistent with the observations. Thus, for this study we decided to use simple traditional OLS-regression. For similar reason, we didn't try kriging with external drift. Instead, we follow (Isaaks and Srivastava 1989 book p532), to do the residual kriging. Besides contributing to mapping, the additional benefit from the regression is that we recover the beta coefficients to use for interpretation, e.g. we can discuss the effect of windward and leeward slope.

You are right about the uncertainty calculation. We didn't think carefully about this issue, and stated that the uncertainty map is only served as an indicator of the uncertainty. Anyway, this problem is now fixed, following your advice.

Actions
We now clearly state the problem of spatial dependence on correlation analysis. The p-values are now used as illustration, rather a strict statistical test for the hypothesis. Calculate the new mapping uncertainty, and provide an equation showing how it is calculated.

Specific comments

The cross-validation study should be better explained. Traditionally, one observation is discarded at a time and re-estimated using the remaining observations and the semivariogram model fitted to the entire dataset. It is unclear whether the authors have computed a new semivariogram and conducted a new regression each time one observation was discarded.

Discussion
Yes, we have done the cross validation as you described.

Actions
We clarify this in the text.

Technical corrections

1. Page 5860, line 23. Write "significantly associated".
2. Page 5861, line 24. The authors should clarify what they mean by "direction kriging".

Discussion
"direction kriging" should be "direct kriging". In the paper, direct kriging means that we do ordinary kriging with the observed chloride deposition, to distinguish residual kriging.

Actions
They are fixed.