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Scaling Individual VLBI Solutions by Variance Component Estimation for Intra-technique Combination

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In intra-technique combination we combine the same type of observations which sometimes have different quality due to different analysis strategies and parametrization of the individual solutions. Thus, the various solutions have to be scaled against each other. The respective scale factors of individual solutions can be estimated within the general combination model. This can be performed by variance component estimation (vce). In this study, individual VLBI (Very Long Baseline Interferometry) solutions in the year 2002 have been chosen for intra-technique combination on normal equation level. Scaling factors of normal equations were calculated from both, variance component estimation and traces of individual normal equation matrices. For the first part of the study, those Analysis Centers (AC) were chosen, which use different software and different prior information, but the same anaysis strategies. The results show that combination with vce provides the best results. In a further investigation, the other AC solutions (e.g., MAO-Main Astronomical Observatory, IAA-Institute of Applied Astronomy) which use different analysis strategies were taken. We present a combination methodology in the Bayesian framework using weighted Normal-Wishart priors. All combination procedures have been done with a MATLAB based software developed at the Institute of Geodesy and Geophysics, Vienna.

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Introduction: This poster presents the linear model with unknown variance components for combining station coordinates of different VLBI AC (Analysis Center) solutions and prior information on parameters of station coordinates. The estimates of the variance components lead to the weighting of different AC solutions which is one of the most important part of combination to obtain the most reliable estimates of VLBI station coordinates.

Intra-technique combination by using different scaling factors: The idea within the intra-technique combination is that we combine same type of data with somehow different quality. In case of the combination of parameters from different VLBI AC solutions on the normal equation level, normal equation matrices for each individual solution may be differently scaled. Scale factors can be estimated within the combination model by variance component estimation (vce) and matrix trace solution method. Within the vce, an estimated variance component is introduced for each individual solution in the combined adjustment model by calculation based on group redundancy numbers and residuals of each individual solution. By matrix trace solution as a scaling factor, traces of individual normal equation matrices are used as characterizing criterion of a matrix at least to a limited extent.

Tanir et al. (2005) presented results of intra-technique combination on normal equation level for VLBI station coordinates by using these different scaling factors. It is concluded within this study that by using different types of scaling methods significantly different scale factors are derived which influence the combination results. When we look at the smoothness parameters of combined station coordinates with different scaling methods, vce scaling method gives more smooth results than matrix trace method.

Intra-technique combination by using Bayesian inference on vce: Solutions from different AC have to be combined by applying appropriate weighting for determination of concerning parameters. In addition, the regularization of parameters might be also an important issue for combination. In this study, we apply a method which propose to do these two important tasks by Bayesian inference on variance components.

There are different types of regularization algorithms. In our study, we use Tikhonov regularization. By Tikhonov regularization, the regularization parameter multiplied by the positive definite matrix -the inverse of the covariance matrix of parameters given by prior knowledge-is added to normal equation matrices (see Koch and J. Kusche (2002)). In this study, we apply Bayesian inference on variance components. We use the linear model with unknown variance components for different VLBI AC solutions and prior information on the station coodinate parameters.

Linear model: Gauss-Markov Model
Observation equations for determining station coordinates from different types of VLBI AC solutions;

$$A_i x = l_i + v_i \qquad D(l_i/\sigma_i^2) = \sigma_i^2 P_i^{-1}$$

determination of parameters with prior information

$i \in \{1,\dots,n\}$ n different kinds of observations l_i

By applying Tikhonov regularization, the expected value of the unknown parameters which is in observation equation;

$$x = \mu + v_\mu \qquad D(\mu/\sigma_\mu^2) = \sigma_\mu^2 P_\mu^{-1}$$

$ux1$ vector of μ prior information for unknown parameters

uxu matrix of P_μ weight for unknown parameters

σ_i^2 variance components of different VLBI AC solutions

σ_μ^2 variance component of the prior information for regularization parameter

Unknown variance components σ_i^2 and σ_μ^2 are calculated iteratively. In this study, we started with approximate values for these variance components, the variance components are iretatively calculated until they convergence. After the last iteration, we have relative weights $w_1, w_2, \dots, w_{n-1}$ with $i \in \{1,\dots,n\}$ and regularization parameter λ .

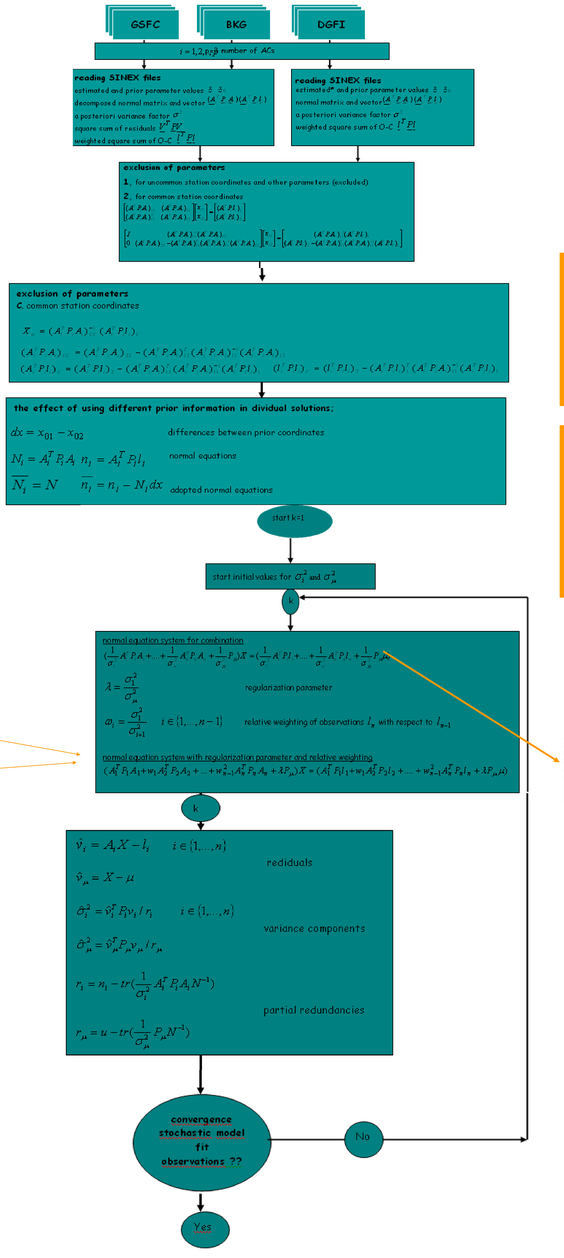

Figure 1. Combination by using vce estimation based on Bayesian Inference

contributing AC solutions
BKG: Federal Agency for Cartography and Geodesy (BKG), Leipzig
GSFC: NASA Goddard Space Flight Center, Greenbelt
DGFI: Deutsches Geodaetisches Forschungsinstitut, München

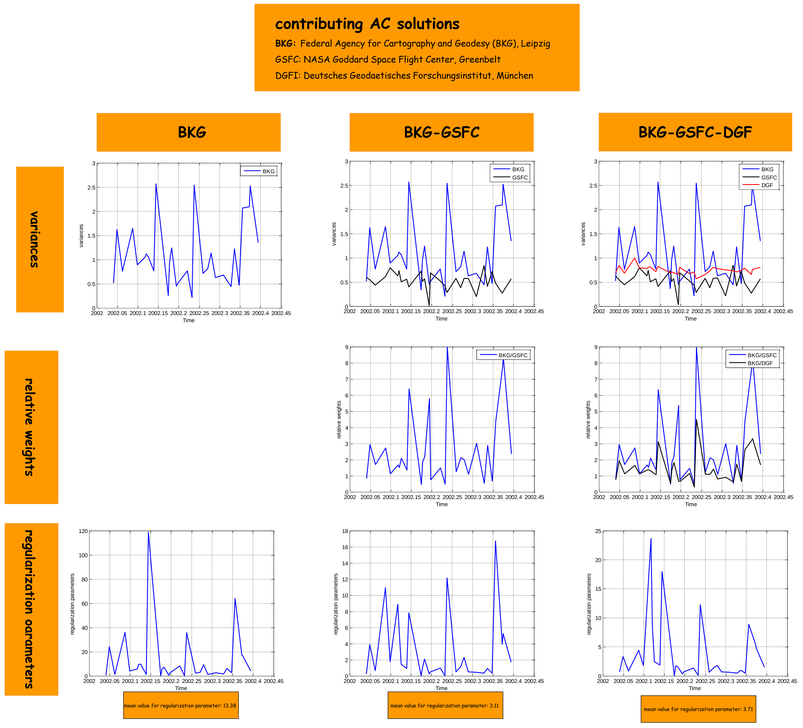

Figure 2. Changes in variances, weights and regularization parameter depends on used AC solutions

As a prior information for unknown parameters and their covariance matrix, results from matrix trace solution are used.

Results:

Adding more AC solutions to the combined station coordinates, the regularization parameter becomes smaller. This means that the stability of normal equation matrices for combined solutions depending on number of contributing AC solutions is improved.

Discussion

We can make some inference about combined solutions with different scaling factors by calculating of smoothness parameters.

$$smoothness = \sum_{i=2}^{n} |(X,Y,Z)_i - (X,Y,Z)_{i-1}|$$

Variance component estimation provides better results than matrix trace solution (see E.Tanir et al. 2005). But, how can we understand whether our vce method works well or not. The Bayesian inference on variance component estimation used in this study can provide also confidence intervals for unknown variance components and unknown regularization parameters which show how well these parameters are determined.

References:

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