Decomposition of surface consistent statics

Steve Kim (smkim@ucalgary.ca) and John C. Bancroft

ABSTRACT

Traveltime differences between traces and a model trace may be decomposed into source and receiver statics. The decomposition of these statics is a difficult problem because the inversion process is rank deficient. The rank can be increased by adding a stabilizing equation to make the process invertible. Three stabilizing equations are tested and evaluated to demonstrate their effectiveness in stabilizing the process.

DISCUSSION

Consider *N* shots whose reflection energy is acquired by *M* receivers. There will be a static s_i for each shot *i*, and a static r_j for each receiver *j*. These are not known at this time. There will be *N*M* traces, each with a total static of $t_{ij} = s_i + r_j$. We estimate the value of t_{ij} from techniques such as cross-correlation between each input trace and a model trace. We now want to estimate the *M+N* values of s_i and r_j from the *N*M* measurements of t_{ij}. We have many more equations of t_{ij} than the unknowns s_i and r_j, and one might assume that a simple least squares formulation would solve the problem. That is not the case. Even though we have many more equations than unknowns, many of the equations are linearly dependent and could be reduced to one less than the number of unknown statics making the solution of s_i and r_j impossible.

STATIC MODEL

We simplify the problem by assuming we have three sources (shots) shooting into the same five receivers giving fifteen traces. Fifteen correlation times will be designated t_k, where *k* varies from 1 to 15. The equations of the traveltimes and source and receiver statics can be either written as $\boldsymbol{Gm} = \boldsymbol{t}$ or in matrix form:

8 statics

15 tt's

$$\begin{bmatrix} 1 & & & 1 & & & & \\ 1 & & & & 1 & & & \\ 1 & & & & & 1 & & \\ 1 & & & & & & 1 & \\ 1 & & & & & & & 1 \\ & 1 & & 1 & & & & \\ & 1 & & & 1 & & & \\ & 1 & & & & 1 & & \\ & 1 & & & & & 1 & \\ & 1 & & & & & & 1 \\ & & 1 & 1 & & & & \\ & & 1 & & 1 & & & \\ & & 1 & & & 1 & & \\ & & 1 & & & & 1 & \\ & & 1 & & & & & 1 \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \\ s_3 \\ r_1 \\ r_2 \\ r_3 \\ r_4 \\ r_5 \end{bmatrix} = \begin{bmatrix} t_1 \\ t_2 \\ t_3 \\ t_4 \\ t_5 \\ t_6 \\ t_7 \\ t_8 \\ t_9 \\ t_{10} \\ t_{11} \\ t_{12} \\ t_{13} \\ t_{14} \\ t_{15} \end{bmatrix}$$

The rows of ***G*** represent the traveltimes and the columns represent the source and receiver statics.

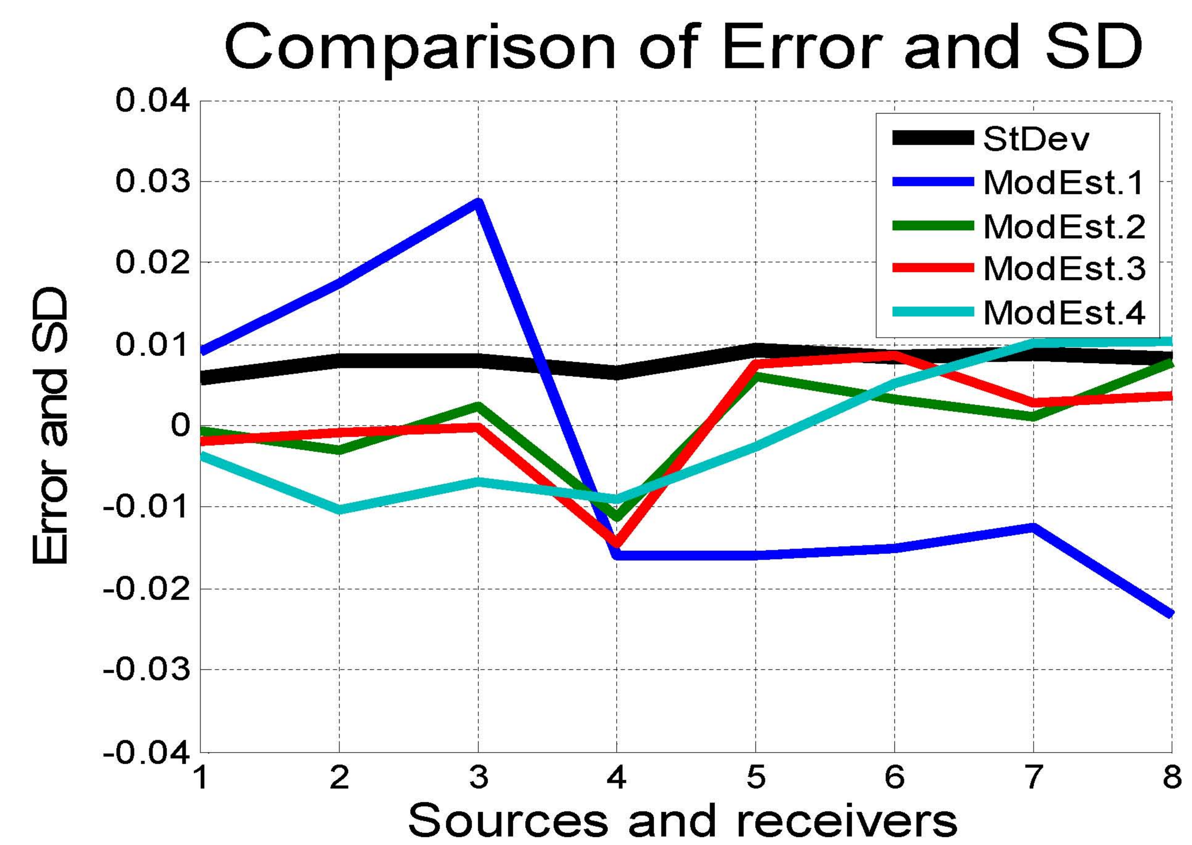

FIG. 1. The errors from four trial solutions and corresponding standard deviation of 100 trials are shown here using equation $s_1 - r_1 = 0$. This equation was chosen because we can assume these two statics at a coincident source and receiver location are equal when using a surface source such as a Vibroseis.

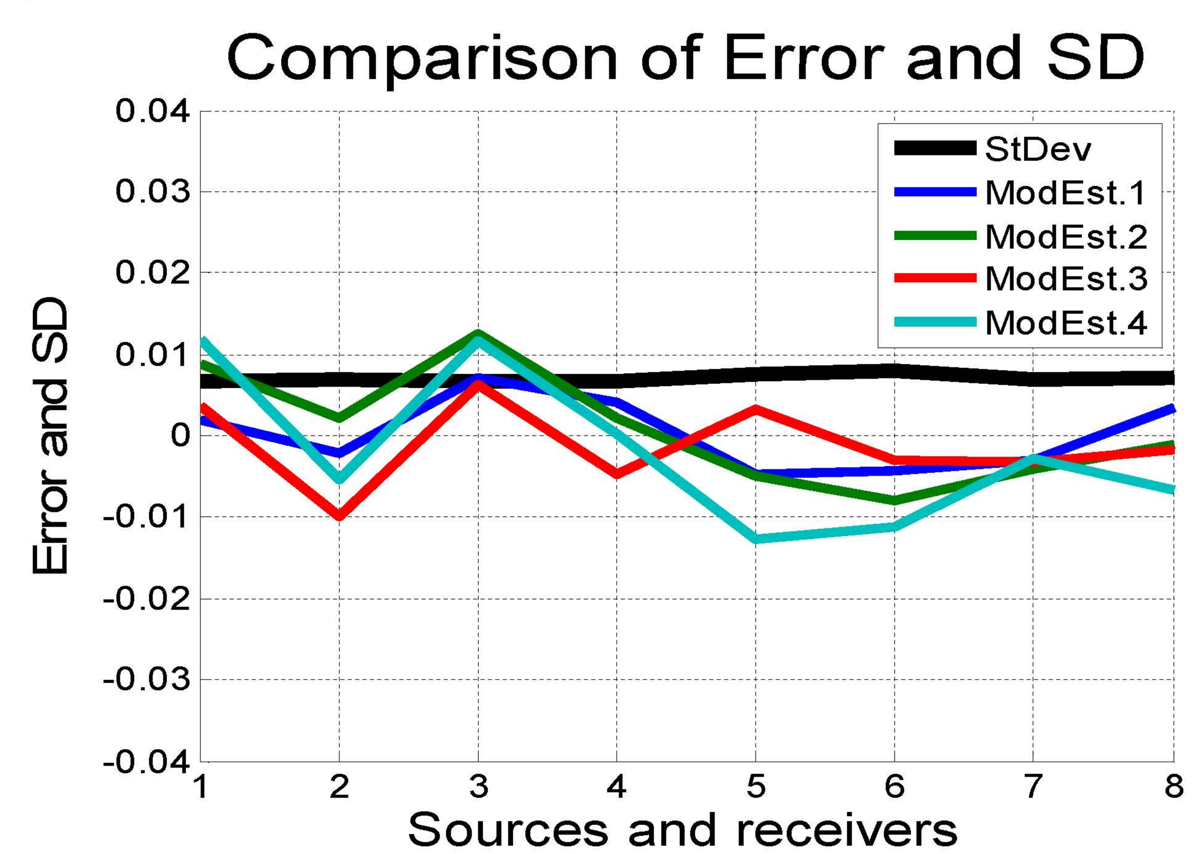

FIG. 2. The errors from four trial solutions and corresponding standard deviation of 100 trials are shown here using equation $s_1 + s_2 + s_3 - r_1 - r_3 - r_5 = 0$. This equation was chosen because we assume that each source location corresponds with receiver locations r_1, r_3 , r_5.

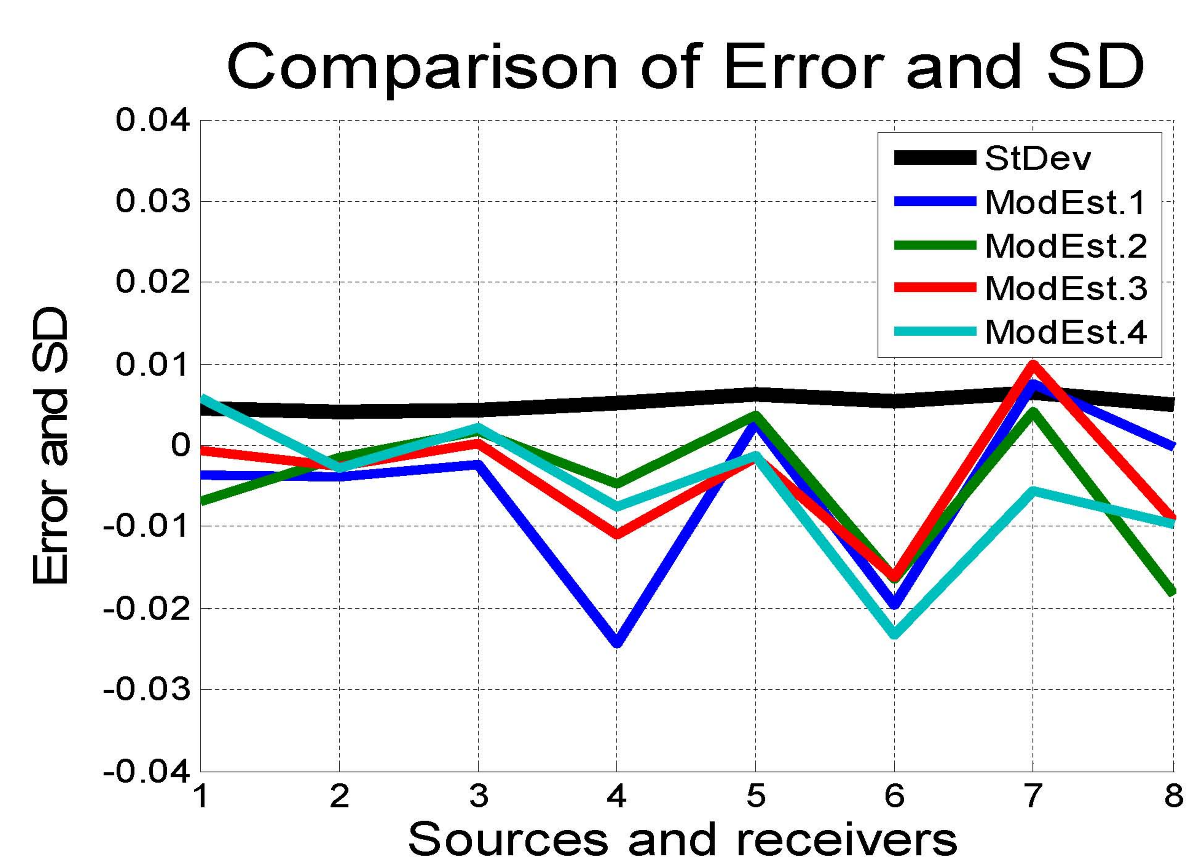

FIG. 3. The errors from four trial solutions and corresponding standard deviation of 100 trials are shown here using equation $(s_1 + s_2 + s_3)/3 - (r_1 + r_2 + r_3 + r_4 + r_5)/5 = 0$. This equation was chosen by assuming that the average of the source statics are equal to the average of the receiver statics.

The noise added for figures 1-3 was 10%. Standard deviation of the true static was 0.010 sec and the standard deviation of the noise was 0.001 sec, for a signal-to-noise (SNR) ratio of 10.

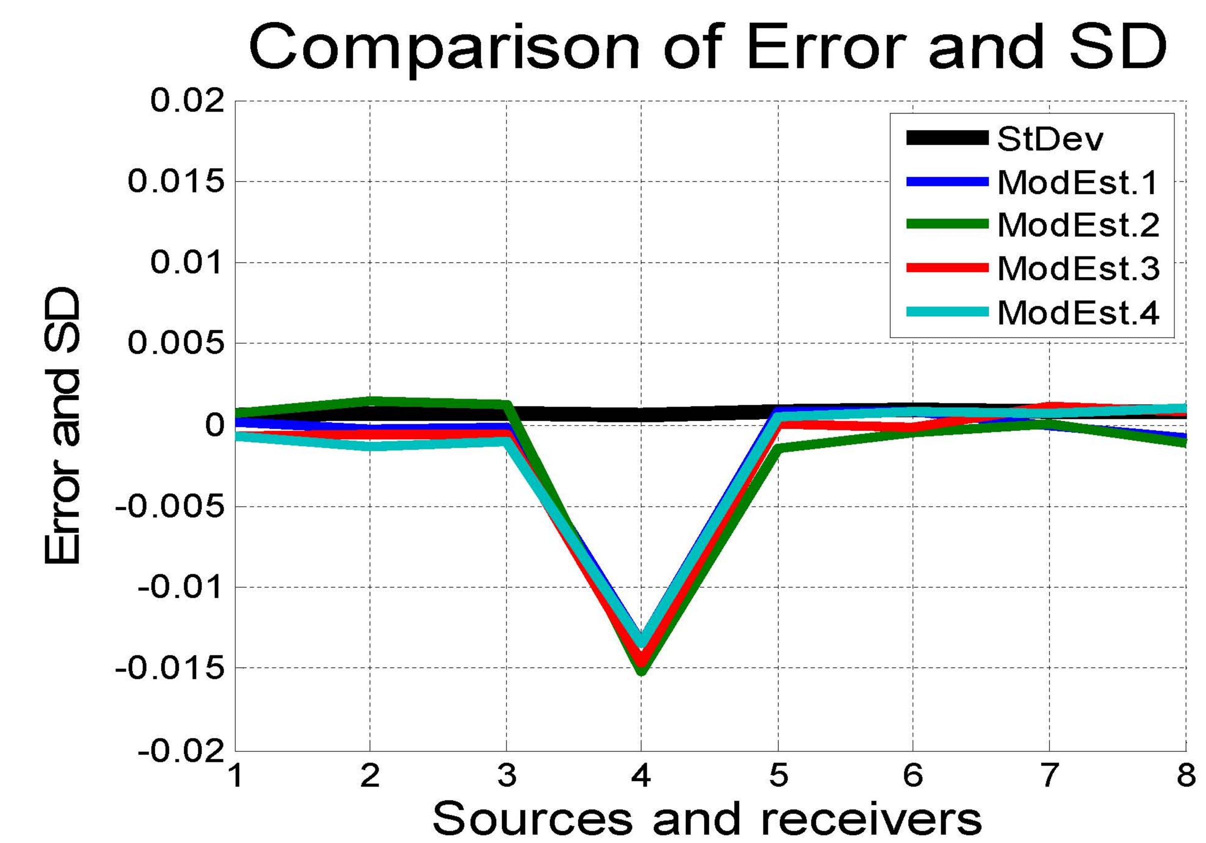

FIG. 4. This is similar to figure 1 but with 1% noise instead of 10% noise.

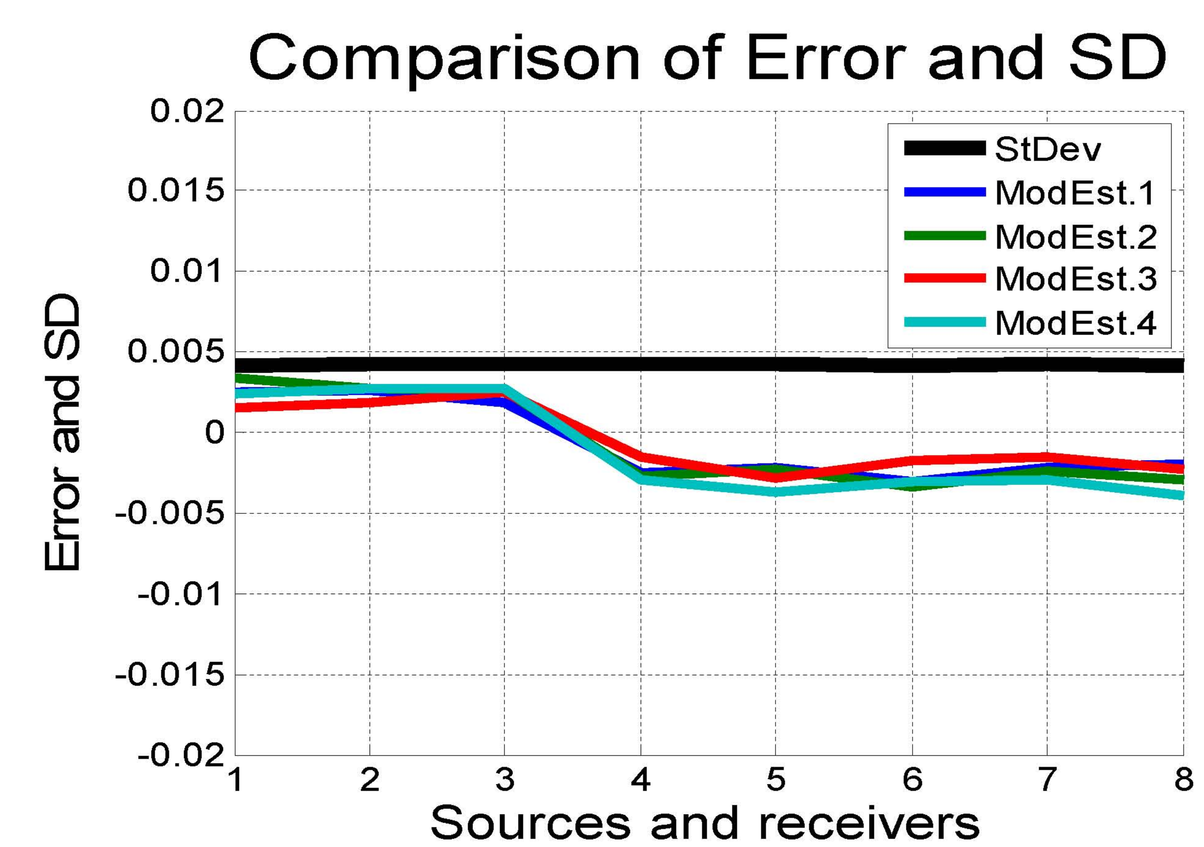

FIG. 5. This is similar to figure 2 but with 1% noise instead of 10% noise.

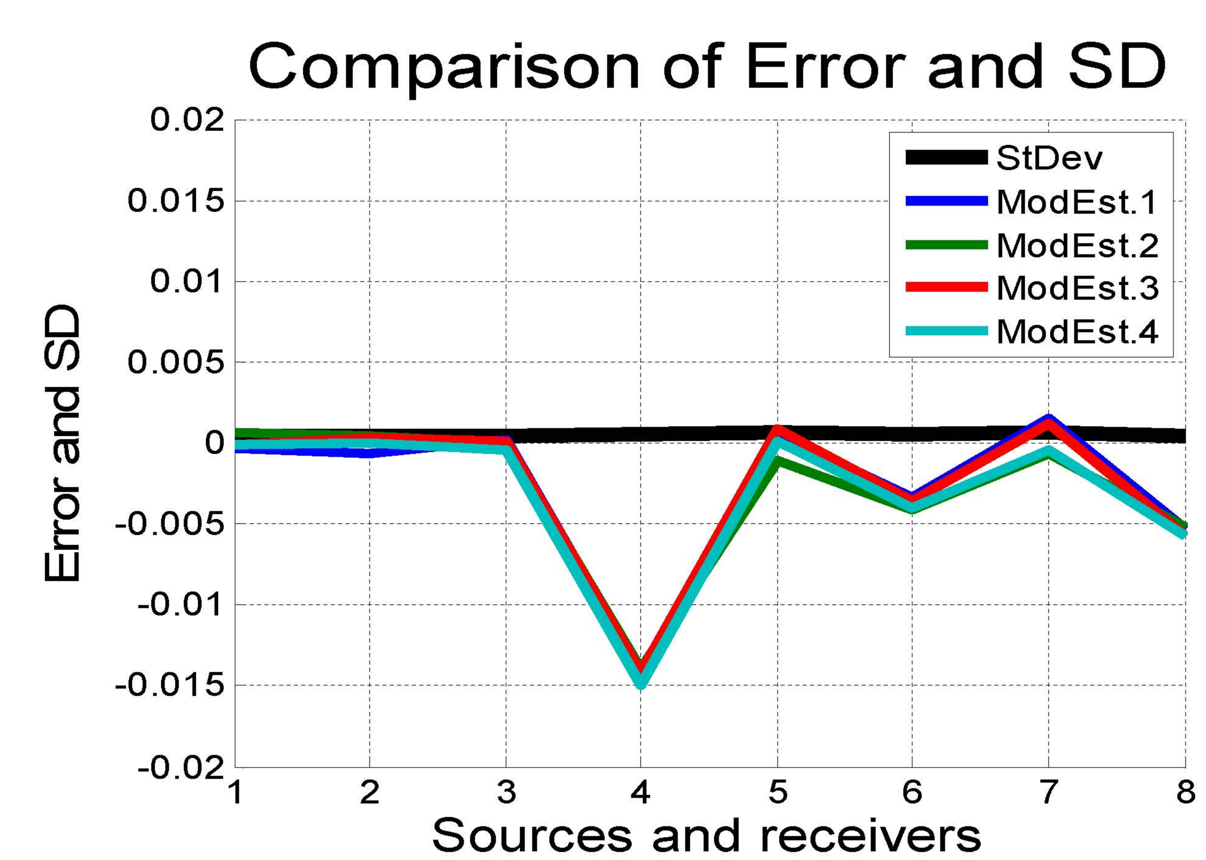

FIG 6. This is similar to figure 3 but with 1% noise instead of 10% noise.

The noise added for figures 4-6 was 1%. Standard deviation of the true static was 0.010 sec and the standard deviation of the noise was 0.0001 sec, for a signal-to-noise (SNR) ratio of 100.