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GEOINFORMATICS
지적정보학과

Joint KSGPC–UNSW Seminar on Geomatics

Datum Transformation to the Global Geocentric Datum for Seas and Islands around Korea

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Background

❖ Korean Survey Law Revision to change the national datum to the World Geodetic Datum from January 1, 2003

- ✓ Keep pace with international trends
- ✓ Establish the spatial data infrastructure which is compatible worldwide

❖ The National Geographic Information Institute (NGII): Transformation for land data is determined through the project of Geodesy 2002

- ✓ 107 first order common points
- ✓ Parameters of Molodensky-Badekas (Yoon, 2003)
- ✓ Distortion modeling using least squares collocation
- ✓ Final transformation accuracy better than 20 cm nationwide

❖ The National Oceanographic Research Institute (NORI): Responsible for ocean data

- ✓ Initiated In a project on the determination of the datum transformation parameters for ocean data in Oct. 2003

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Purpose/Contents

❖ Procedures and results of the Korean ocean datum transformation are presented.

✓ Description of the data

✓ Parameter estimation of the seven parameter transformation

✓ Station distribution optimization

✓ Distortion modeling

✓ Results and analyses

DATA ACQUISITION

❖ **Acquired from 1997 to 2002 through the campaign of the determination of a Korean territorial baseline issued by NORI**

❖ **Total of 492 points with GPS static methods**

✓ **30 second intervals for 24 hours**

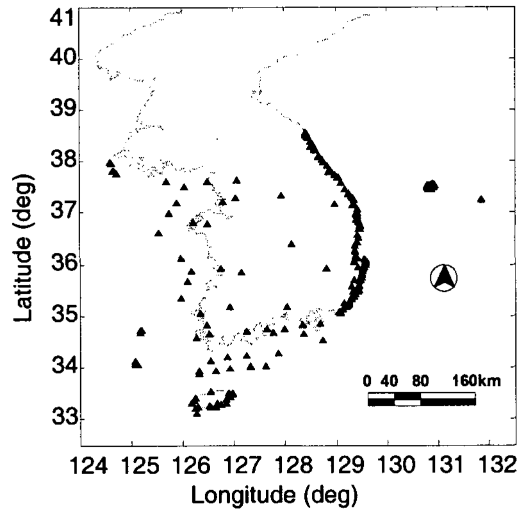
✓ **12 and 18 control points located on land and shore area, respectively**

✓ **Processed with GPSurvey from Trimble in baseline determination mode by fixing the control points.**

✓ **Network adjustment using TrimNet Plus**

✓ **315 points after outlier test are selected for parameter determination**

Station Distribution



Data is significantly dense in the area of the East Sea and southern Islands

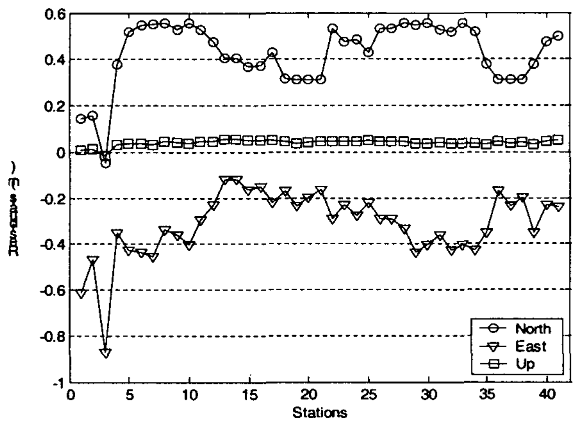
⇨ Causes some biases in the estimated transformation parameters, which leads to the necessity of the optimized station distribution

TRANSFORMATION PARAMETER ESTIMATION

❖ Parameter estimation for three popular similarity transformation models: Bursa-Wolf, Molodensky-Badekas, and Veis

Model		Tx (m)	Ty(m)	Tz (m)	Rx (arcsec)	Ry (arcsec)	Rz (arcsec)	Scale (ppm)
BW	Par.	-121.24	471.20	654.80	-1.62	2.03	1.92	8.17
	S.D.	0.986	0.746	0.871	0.025	0.030	0.029	0.010
MB	Par.	-146.84	504.34	685.66	-1.62	2.03	1.92	8.17
	S.D.	0.022	0.022	0.022	0.025	0.030	0.029	0.010
Veis	Par.	-146.84	504.34	685.66	-0.01	-0.01	-3.23	8.17
	S.D.	0.022	0.022	0.022	0.032	0.029	0.021	0.010

Example of biases after transformation



Residuals after the similarity transformation

Stations are densely distributed to the east and north relative to the location of Jeju Island,

⇨ Estimated parameters generate significant biases in those directions for the Jeju area.

⇨ Station distribution was optimized to mitigate the effect by network optimization algorithm

STATION OPTIMIZATION I

Ref: Bae,T.S., ION 2005 National Technical Meeting

- Network optimization pursues high precision, reliability, and low cost

$$\alpha_p(precision) + \alpha_r(reliability) + \alpha_c(cost)^{-1} = \max$$

- Not easy to find the relative weights which satisfy all three components because of the high correlation among them.

⇨Optimization is usually considered to maximize the precision while maintaining the reliability and cost at certain levels.

⇨ Conditions of the optimized network are the homogeneity and isotropy of the errors at each station

STATION OPTIMIZATION II

- Criterion Matrix: Ideal cofactor/dispersion matrix satisfying homogeneity and isotropy possesses "Taylor-Karman structure" (Grafarend, 1970)

$$s := |\underline{r}_i - \underline{r}_j| = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

$$\sigma^2 (C_X)_{ij} := \begin{bmatrix} \Sigma_m(s) & 0 & 0 \\ 0 & \Sigma_m(s) & 0 \\ 0 & 0 & \Sigma_m(s) \end{bmatrix} + [\Sigma_l(s) - \Sigma_m(s)] \cdot \frac{1}{s^2} \begin{bmatrix} (x_i - x_j)^2 & (x_i - x_j)(y_i - y_j) & (x_i - x_j)(z_i - z_j) \\ (x_i - x_j)(y_i - y_j) & (y_i - y_j)^2 & (y_i - y_j)(z_i - z_j) \\ (x_i - x_j)(z_i - z_j) & (y_i - y_j)(z_i - z_j) & (z_i - z_j)^2 \end{bmatrix}.$$

$\Sigma_l(s), \Sigma_m(s)$ **: the longitudinal- and cross-correlation function**

σ^2 **: the expected/desired variance of the estimated coord.**

if the points P_i and P_j coincide: $\Sigma_m(0) = \Sigma_l(0) = \sigma^2$

STATION OPTIMIZATION III

- Optimize the cofactor matrix based on:

$$trQ_{\hat{\xi}} = tr(A^T PA)^-_{rs} = \min.$$

- Second Order Design (SOD) – optimize by varying P

$$\|Q_{\hat{\xi}} - C\| = \min.$$

$$\Rightarrow \|A^T PA - C^{-1}\| = \min_{P:=diag\,\underline{p}}.$$

$$\Leftrightarrow \|(A^T \odot A^T)\underline{p} - vecC^{-1}\|^2_{C\otimes C} = \min_{\underline{p}=vecdiagP}.$$

$$\Rightarrow (ACA^T * ACA^T)\hat{\underline{p}} = vecdiag(ACA^T)$$

- Compute weights to all network stations

$$(ACA^T * ACA^T)\hat{\underline{p}} = vecdiag(ACA^T)$$

Hadamard product

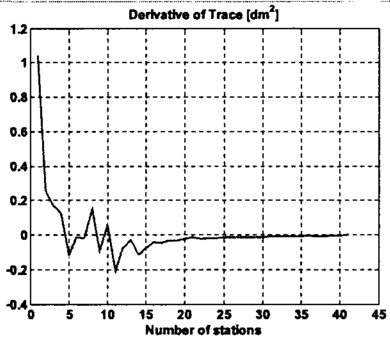
$$\underset{k\times l}{G} * \underset{k\times l}{H} = [g_{ij} \cdot h_{ij}]_{k\times l}$$

STATION OPTIMIZATION IV

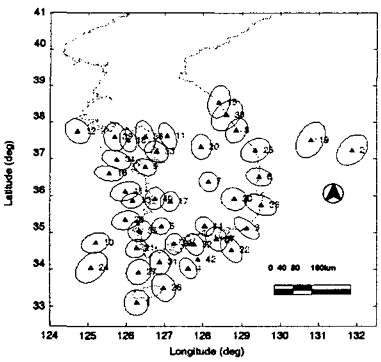
1. Choose one station from the candidate group as 1st station
2. Find 2nd station which has the max. distance from 1st one
3. Build a criterion matrix for first two stations
4. Compute the weight to each network station for all candidate stations
5. Find the station that has uniform weights to all network stations (min. RMS deviation of weight)
6. Repeat 4-5 until the desired number of stations is reached

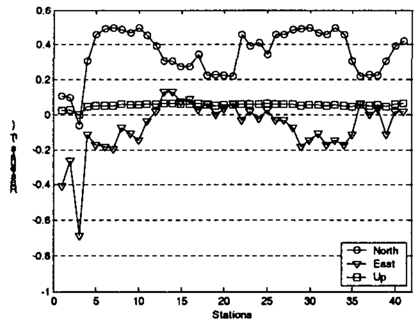
❖ Measure of Optimality: Compute the cofactor matrix (the pseudo-inverse of N) using SVD (Singular Value Decomposition)

$Q_{\xi} = N^{+}$ where $N = A^T PA$



STATION OPTIMIZATION V



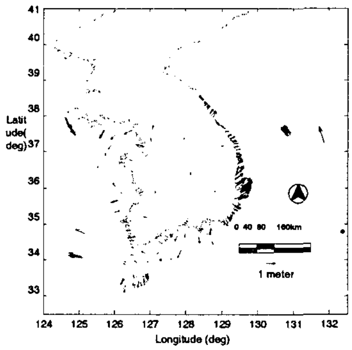


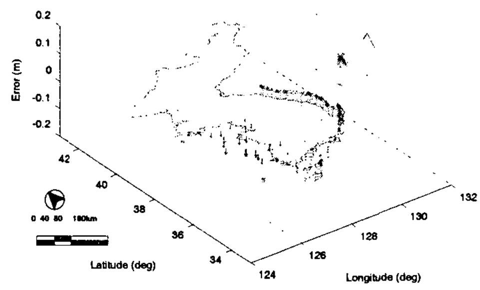
Estimated parameters of the Molodensky-Badekas model using optimized stations of data.

Parameters	Tx (m)	Ty (m)	Tz (m)	Rx (arcsec)	Ry (arcsec)	Rz (arcsec)	Scale (ppm)
Estimates	-145.36	504.49	686.80	-1.57	1.97	1.87	8.62
Std. Dev.	0.055	0.055	0.055	0.094	0.081	0.097	0.332

DISTORTION CORRECTION I

- Distortions in old coordinates for some reason such as different surveying and adjustment methods, the similarity transformation would still leave significant residuals





DISTORTION CORRECTION II

Calculation of empirical autocorrelation based on the data

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Fit the empirical models to an analytical model

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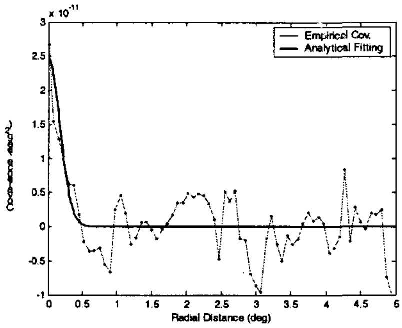
Estimate the distortion by LSC

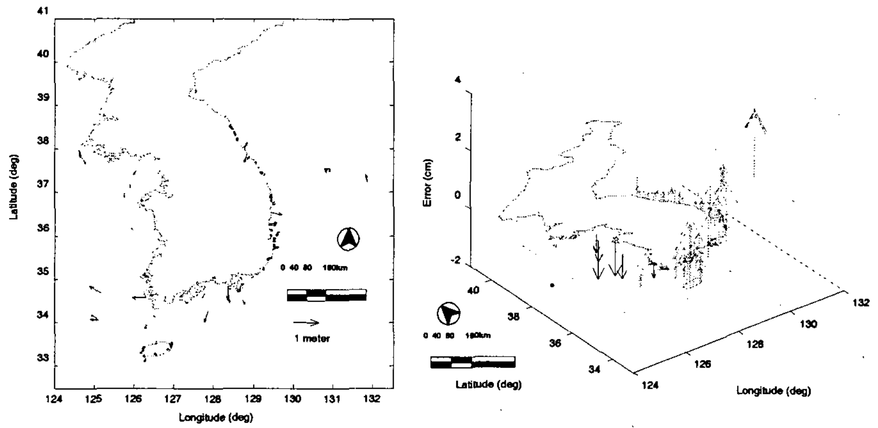
General Procedure of LSC

$$C(\|h\|) = C_0 e^{-A^2 h^2}$$



DISTORTION CORRECTION III

- Distortions are predicted by LSC and saved in 1′×1′ grids for latitudes of 33° to 39° and longitudes of 124° to 132°.
- Distortion at an arbitrary point can be estimated using bilinear interpolation
- Biases less than 1.5 cm and standard deviations less than 15 cm were checked using 165 points data which was not used in estimation procedures.



Conclusions

- The transformation parameters of Molodensky-Badekas model was estimated for the datum transformation of Korean ocean spatial data.
- For better accuracy in the transformation, the station distribution was optimized using network optimization theory. It was found that the station optimization considerably contributes to eliminate the biases in the transformation achieving biases less than 10cm with standard deviation less than 55 cm after similarity transformation.
- Further improvement on the transformation was achieved by modeling and predicting the distortions with least squares collocation. The accuracy of the transformation was checked with 165 checkpoints and an overall accuracy better than 15 cm was achieved.
- It is considered that this study could be a good example of conducting a datum transformation showing intensive data screening, station optimization, and distortion correction, so that it can be referenced by any national coordinate transformation task.

Thank you for your attention !

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