NATIONAL GEODETIC SURVEY

Improving Regional Geoid by optimal Combination of GRACE Gravity Model and Surface Gravity Data

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Overview

- Combination methods used in local geoid determination
- Numerical results and comparisons
- Conclusions

Combination Methods

Remove-restore (R-R)

$$N_{R-R} = N^{GGM} + \frac{R}{4\pi\gamma}[\iint_{\sigma}(\Delta g^{s} - \Delta g^{GGM})S(\psi)d\sigma$$

$$= \frac{R}{4\pi\gamma}\iint_{\sigma-A}\Delta g^{GGM}S(\psi)d\sigma + \frac{R}{4\pi\gamma}\iint_{A}\Delta g^{s}S(\psi)d\sigma$$

- Surface gravity data used in the local integral
- GGM gravity used in the integration outside the local region
- Accurate long wavelengths of GGM are not used in local integration

Combination Methods

- **Modified Stokes Kernel (Kleusberg and Vanicek method, K-V)**

$$N_{K-V} = N^{GGM} + \frac{R}{4\pi\gamma}\iint_A S^H(\psi)(\Delta g^s - \Delta g^{GGM})d\sigma$$

$$S^H(\psi) = S(\psi) - \sum_{n=2}^{M} S_n(\psi) = \sum_{n=M+1}^{\infty} S_n(\psi)$$

- **100% long wavelengths of GGM, if integration is global**
- **Long wavelengths of the terrain effect ignored**
- **Truncation error (non global integration) is significant**

Combination Methods

Spectral combination using 2D FFT

- FFT of surface gravity data and GGM on the same grid
- Spectral cut and paste, weighted mean of low frequencies
- No truncation error
- Long wavelengths of terrain effect can be treated
- Proper taping is favorable
- No equal distance along latitude direction

Numerical results and comparisons

Data Used

- GGM02S to degree and order 110, EGM96 from degree 111 to 360
- Surface gravity data used the GEOID03 computation that includes surface anomaly, altimetry gravity, shipborne gravity (2.6 million points data)
- Terrain correction computed from 30”/3” DEMs
- 6169 GPS/leveling data at benchmarks over CONUS

Modified Stokes Kernel (K-V)

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GPS/Leveling Comparisons (STD, cm)

	R-R	K-V N=20	K-V N=30	K-V N=360
National	19.7	29.3	28.6	29.1
Individual States	8.4	8.7	8.0	11.8

Discussions

- In comparison with standard R-R, modified Stokes kernel method produces worse results. This may due to

1. Truncation error
2. Excluding long wavelengths of the terrain effect.

- Remedies

1. Use modified Stokes kernel in least squares fashion (minimizing the truncation error)

2. Proper treatment of long wavelengths of the terrain effect

Spectral Combination using 2D FFT

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GPS/Leveling Comparisons (std, cm)

	R-R	Cut/Paste N=8	Cut/Paste N=14	Weighted average N=114
National	19.7	29.3	28.6	22.2
Individual States	8.4	8.1	7.8	7.8

Discussions

- Spectral combination has not produced better results at national level, but improves comparisons at state level.
- Smaller discrepancy of the weighted mean in the spectral domain indicates the long wavelengths in surface gravity data are not totally useless.
- Weighted average in the spectral domain is preferred over simple spectral cut/paste method.
- More investigations in proper weighting GGM and surface gravity data should be conducted

Conclusions

- Longer wavelengths have larger contribution to geoid, so the combination has to be carefully done.
- Truncation error is significant for modified Stokes kernel. If the maxim degree is 110, the error could reach 30% or more of the signal.
- Long wavelength of the terrain effect can not be ignored.
- Spectral combination improves the results state by state, but not nationally
- The effect of topography is different on GGM and surface gravity data. Proper treatment of this effect is crucial to a successful combination