Research on the vertical crustal deformation at the northeastern margin of the Tibetan Plateau by combining GRACE and GPS data

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Introduction

The tectonic movement of the northeastern margin of the Tibetan Plateau has been very strong since the new tectonic period, which is very important in terms of geotectonic position. In this paper, two types of geodetic measurements, GRACE and GPS, are combined to study the vertical crustal deformation on this area, for obtaining more information of the crustal tectonic deformation field there.

GRACE and GPS Data

The GRACE Level-2 monthly data used here were obtained from the GSM Release-05 products provided by the Center for Space Research (CSR), University of Texas, for the period between March 2002 and November 2014 up to degree 60.

The GPS measurements used in this paper are provided by the Crustal Movement Observation Network of China (CMONOC) and were collected by 40 continuous GPS stations along the margin of the Tibetan Plateau.

The GPS data can be divided into two groups: Period I includes 4 long occupational sites – DLHA, DXIN, XNIN and YANC – with approximately 15 years of observations, and period II includes stations with nearly 4 years of observations.

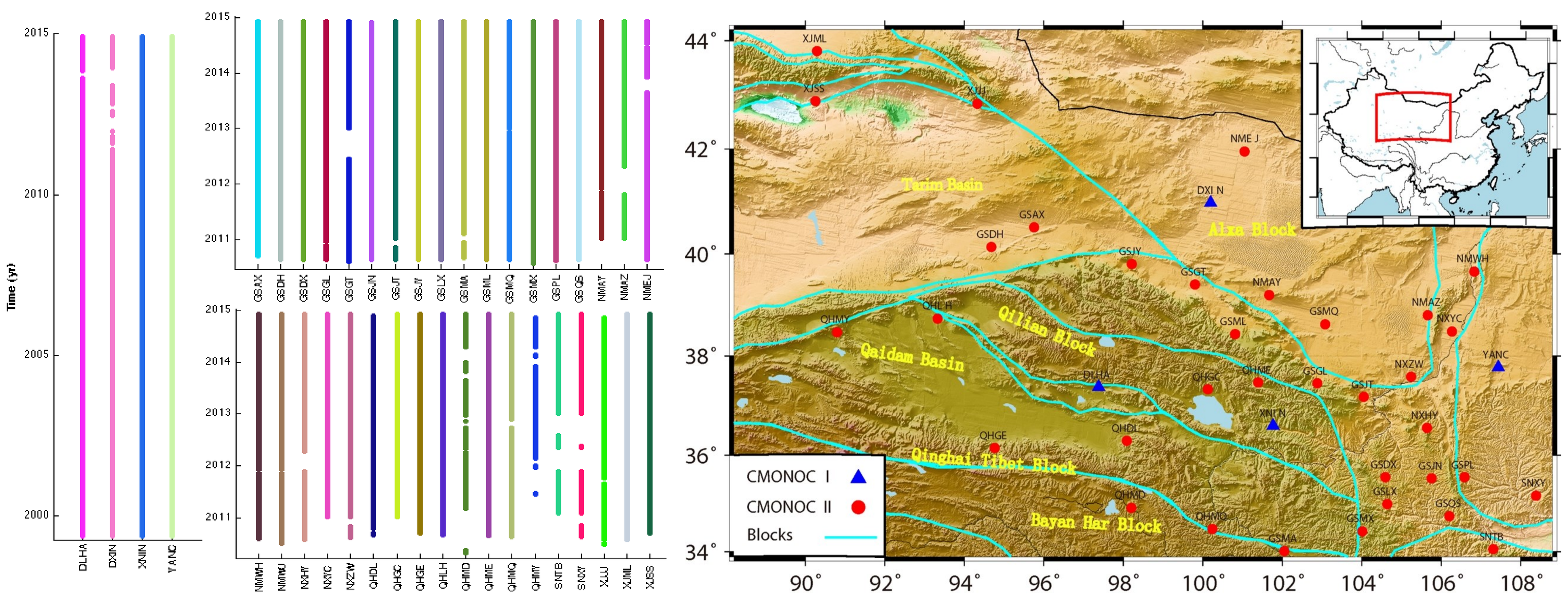


Figure. 1 Data availability and the locations of the GPS stations at the northeastern margin of the Tibetan Plateau

Results

Both GRACE and GPS vertical time series show significant seasonal variations.

To further analyze the correlation between these two time series, we simultaneously fit the mean, trend, annual and semiannual signals using the following equation:

$$y = a + b\,t + A_a \cos\left(\omega\left(t - \Phi_a\right)\right) + A_{sa} \cos\left(2\omega\left(t - \Phi_{sa}\right)\right)$$

The two geodetic data sets are highly consistent in terms of the amplitudes and phases of the annual signals.

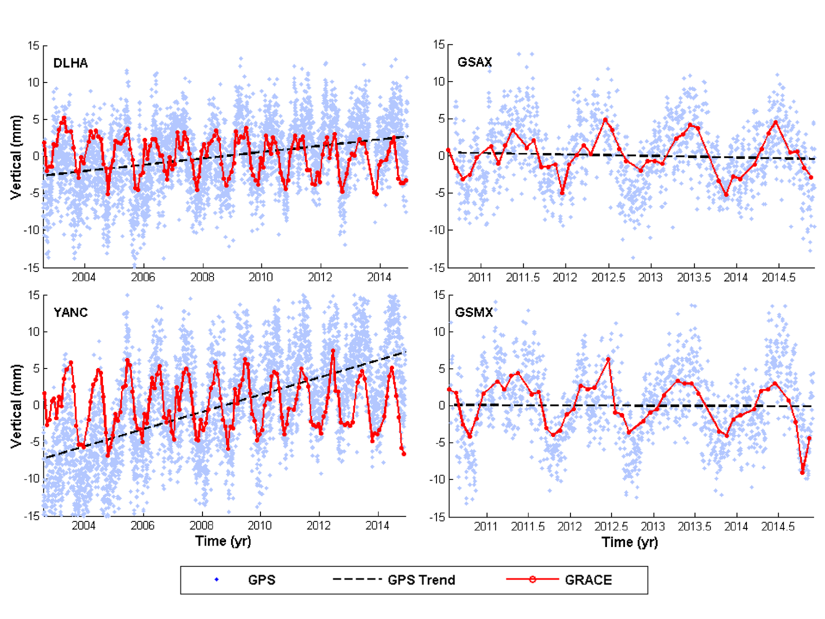


Figure. 2 The vertical time series of GRACE and GPS

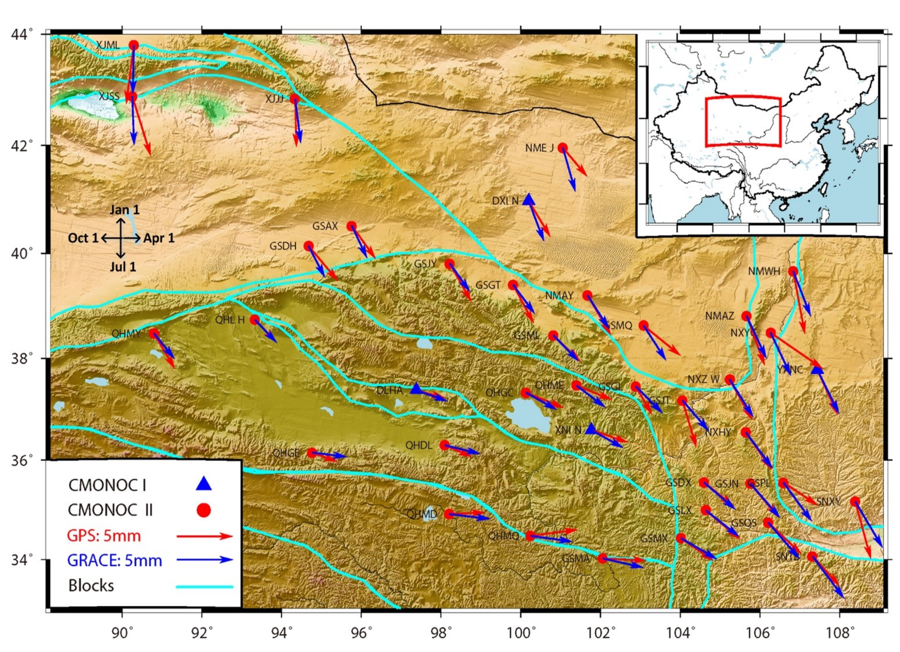
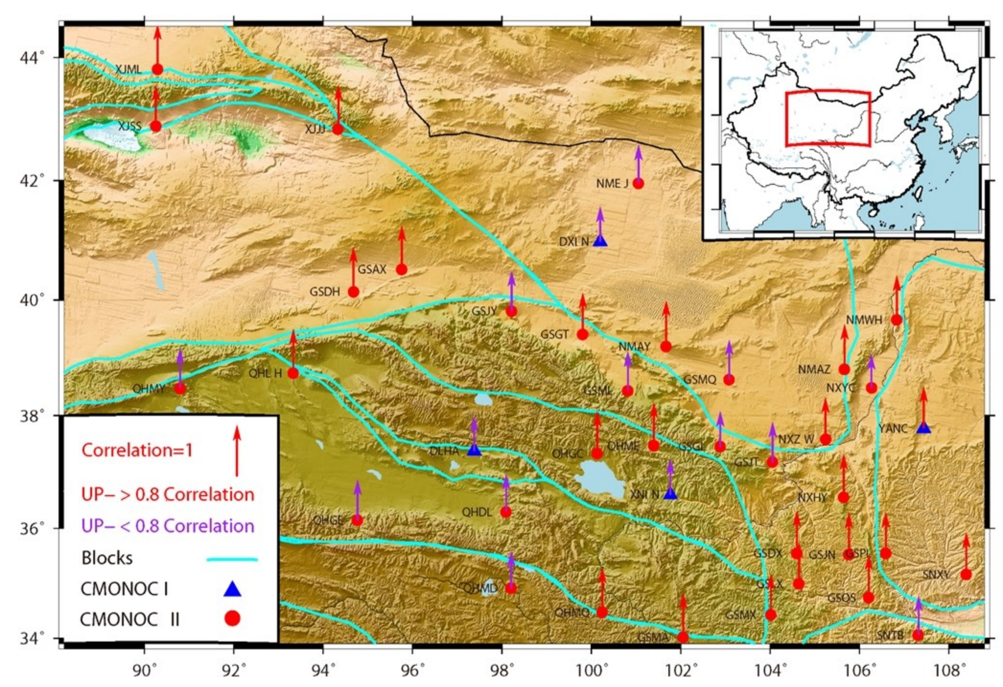


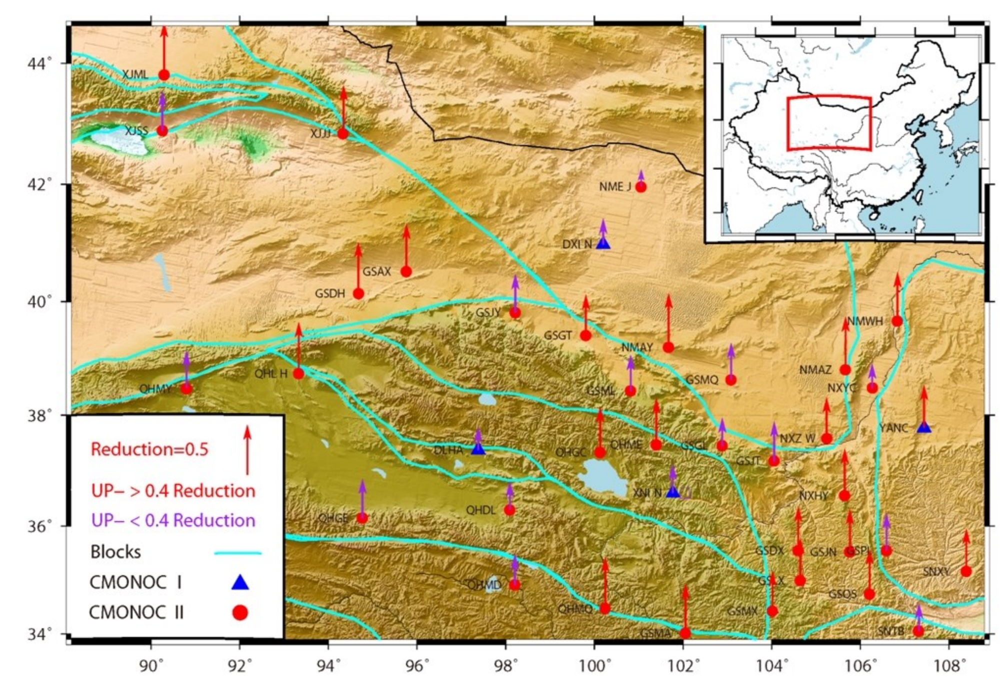
Figure. 3 Seasonal vertical deformation from GRACE and GPS

Results



Site	Correlation	Site	Correlation
DLHA	0.67	NMAZ	0.91
DXIN	0.73	NMEJ	0.75
XNIN	0.72	NMWH	0.90
YANC	0.81	NMWJ	0.78
GSAX	0.87	NXHY	0.89
GSDH	0.86	NXYC	0.71
GSDX	0.86	NXZW	0.88
GSGL	0.71	QHDL	0.81
GSGT	0.86	QHGC	0.86
GSJN	0.85	QHGE	0.80
GSJT	0.82	QHLH	0.89
GSJY	0.83	QHMD	0.79
GSLX	0.85	QHME	0.85
GSMA	0.87	QHMQ	0.91
GSML	0.79	QHMY	0.79
GSMQ	0.77	SNTB	0.78
GSMX	0.84	SNXY	0.83
GSPL	0.84	XJJJ	0.86
GSQS	0.87	XJML	0.87
NMAY	0.90	XJSS	0.81

Figure. 4 Correlation coefficients computed for the vertical time series from the 40 stations based on GRACE and GPS



Site	RMS Reduction	Site	RMS Reduction
DLHA	22.43%	NMAZ	59.52%
DXIN	30.73%	NMEJ	17.45%
XNIN	30.66%	NMWH	54.38%
YANC	41.04%	NMWJ	34.13%
GSAX	49.76%	NXHY	54.65%
GSDH	47.77%	NXYC	29.37%
GSDX	48.20%	NXZW	50.76%
GSGL	28.91%	QHDL	40.72%
GSGT	46.13%	QHGC	47.33%
GSJN	47.48%	QHGE	40.31%
GSJT	42.34%	QHLH	53.36%
GSJY	42.61%	QHMD	38.82%
GSLX	46.48%	QHME	47.21%
GSMA	49.45%	QHMQ	56.55%
GSML	38.65%	QHMY	39.05%
GSMQ	36.16%	SNTB	33.20%
GSMX	45.27%	SNXY	44.85%
GSPL	43.93%	XJJJ	48.61%
GSQS	51.23%	XJML	51.41%
NMAY	55.65%	XJSS	41.09%

Figure. 5 Reductions in the GPS signal WRMS (%) due to subtracting GRACE deformation from GPS height

GPS Campaign stations

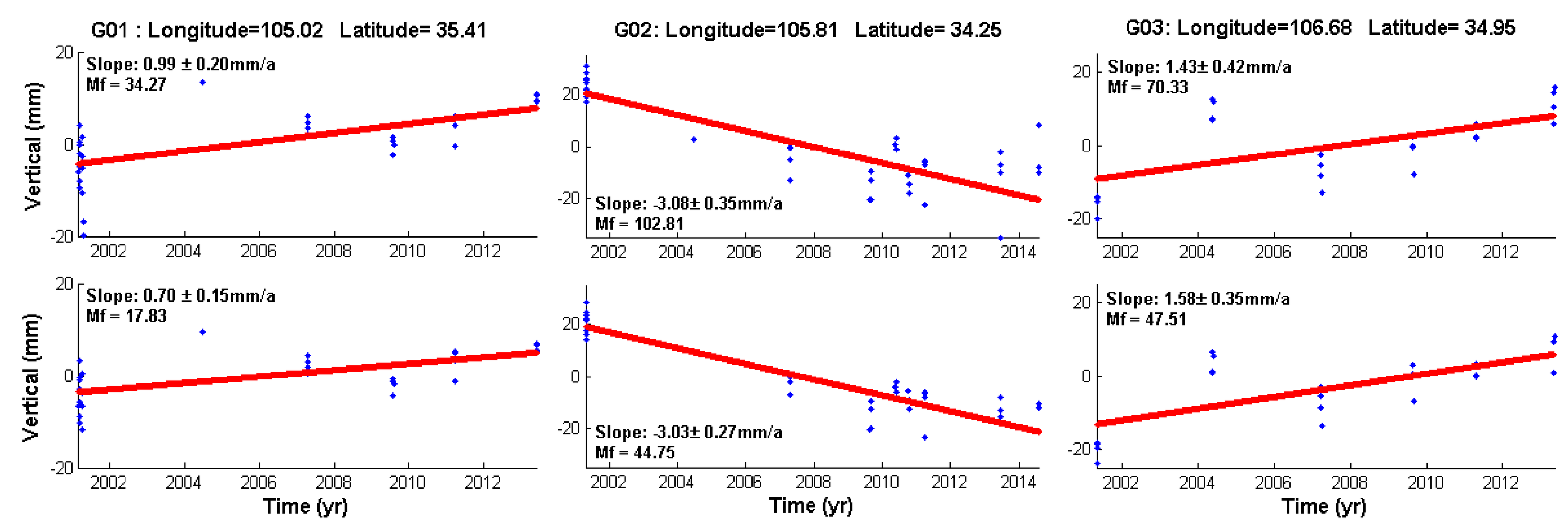


Figure. 6 Time series of campaign GPS stations in the vertical direction (top: original observed GPS time series; bottom: corrected time series with seasonal loading deformation removed based on GRACE data)

It is difficult to directly separate non-tectonic deformation from crustal movement in campaign GPS observations. We modified the campaign GPS time series by removing seasonal impacts using GRACE-derived seasonal variations.

Conclusions

This result suggests that increasing the length of the observation period eliminates the influences of some nonlinear factors in the GPS signals and is beneficial for extracting seasonal effects from GPS time series.

The correlations between GRACE-derived vertical deformation due to seasonal hydrological loading and GPS-observed seasonal position variations are very high for most of the 40 stations.

In addition, we found that approximately 73% of the GPS vertical time series featured a significant WRMS reduction of approximately 40%. This reduction reaches 60% by subtracting the corresponding seasonal components derived from GRACE measurements.

The estimated secular trends decreases by 46% in the vertical direction, indicating that the seasonal effect in campaign GPS stations can be modified well by GRACE data.