remote sensing

MDPI

Supplementary Materials for

Land subsidence in Tianjin, China: before and after the South-to-North Water Diversion

Xiao Yu [1]*, Guoquan Wang [1], Xie Hu [2], Yuhao Liu [1] and Bao Yan [3]

[1] Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX 77204, USA
[2] College of Urban and Environmental Sciences, Peking University, Beijing 100871, China
[3] Key Laboratory of Urban Security and Disaster Engineering of Ministry of Education, Beijing University of Technology, Beijing 100124, China
* Correspondence: xyu3@central.uh.edu

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Introduction

This supporting material includes four sections: one text, one table, and two figures. Text S1 explains the details of Principal Component Analysis and processing steps. Table S1 shows the parameters of the Sentinel-1 dataset applied in the study. Figure S1 shows the interferogram baseline network. Figure S2 shows the look vector map in east-west, north-south, and vertical direction for both tracks.

Text S1. Principal Component Analysis

PCA is commonly achieved through Singular value decomposition (SVD) in the realization (Gerbrands, 1981).

$$X = U\Sigma W^T \qquad \text{(S1)}$$

where U is the $m \times m$ left singular vector matrix of X, W is the $n \times n$ right singular vector matrix of X (i.e., the eigenvectors of $X^T X$), containing the eigenvectors (also called coefficients) of the matrix. The rows of score represent the dates, and the columns correspond to the principal components with the first one ranking as the top first component. The $m \times n$ PCs score matrix P can be derived as

$$P = XW \qquad \text{(S2)}$$

Here, the score matrix P is the representations of X in the principal component space, where the rows of score represent the pixels, and the columns correspond to the principal components with the first one ranking as the top first component.

In this study, we use the internal function *pca* in Matlab to conduct the PCA analysis, which can be described as:

$$[coeff, score, explained] = pca(X) \qquad \text{(S3)}$$

The input X is a m-by-n matrix comprising the InSAR-derived displacement time series at all pixels. The original spatial resolution of the InSAR-derived displacement map is 40 m by 40 m. The high-resolution results in heavy computational burden for the PCA process. Therefore, we resample the spatial resolution to 60 m by 60 m. The subsidence in the original 40-by-40 m^2 pixel is used for the 60-by-60 m^2 pixel. In total, the study area comprises 12,221,280 resampled pixels, a product of 2592 rows in latitude by 4,140 columns in longitude. The InSAR-derived time series comprises cumulative displacement on 322 different dates. The displacements at the first date (10/22/2014) is set as zero, and the displacements at each pixel on other dates are referred to the first date. So, the dimension of the input matrix X is 12,221,280 by 322. Each component (m, n) in the matrix represents the displacement at the pixel (m) on the date (n).

The output of the PC analysis mainly includes three parts: $coeff$, $score$, and $explained$. The $coeff$ is the eigenvectors (W) with the dimension of 322 × 322, delineating the temporal features of subsidence. The rows correspond to 322 dates and the columns correspond to 322 principal components (PCs). The $score$ is the score matrix P with the dimension of 12,221,280 × 322, depicting spatial features of subsidence. The rows correspond to 12,221,280 pixels and the columns correspond to 322 principal components (PCs). The PC scores can be converted to deformation units by multiplying the eigenvector at a given date. The $explained$ is a 322 by 1 matrix, delineating the percentage of the total variance explained by these 322 PCs.

Table S1. Parameters used for Sentinel-1 data processing.

Flight direction	Ascending	Descending
Relative orbit	69	149
Time span	10/22/2014 – 12/20/2021	05/31/2015 – 12/07/2021
Beam mode	IW (Interferometric wide swath)	
Number of scenes	188	134
Wavelength	5.546 cm	

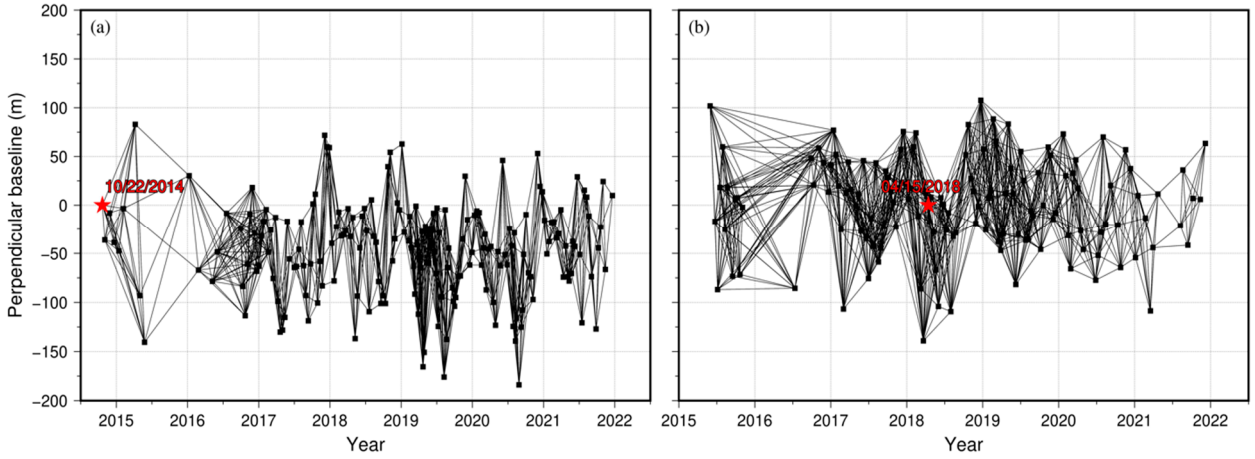

Figure S1. The baseline network of the Sentinel-1. (a) Ascending track: 188 scenes are used to generate 1,112 interferograms, and (b) descending track: 134 scenes are used to generate 1,181 interferograms. The horizontal axis represents the temporal acquisition dates, and the vertical axis is the spatial perpendicular baseline in meters. All images are geometrically aligned to a common reference image on 10/22/2014 for the ascending track and 04/15/2018 for the descending track. The reference image is chosen to cover of the whole study area and minimize perpendicular baselines between interferometric pairs without resulting in gaps between sub-swaths. Red star denotes the reference image, and black lines show the generated interferograms.

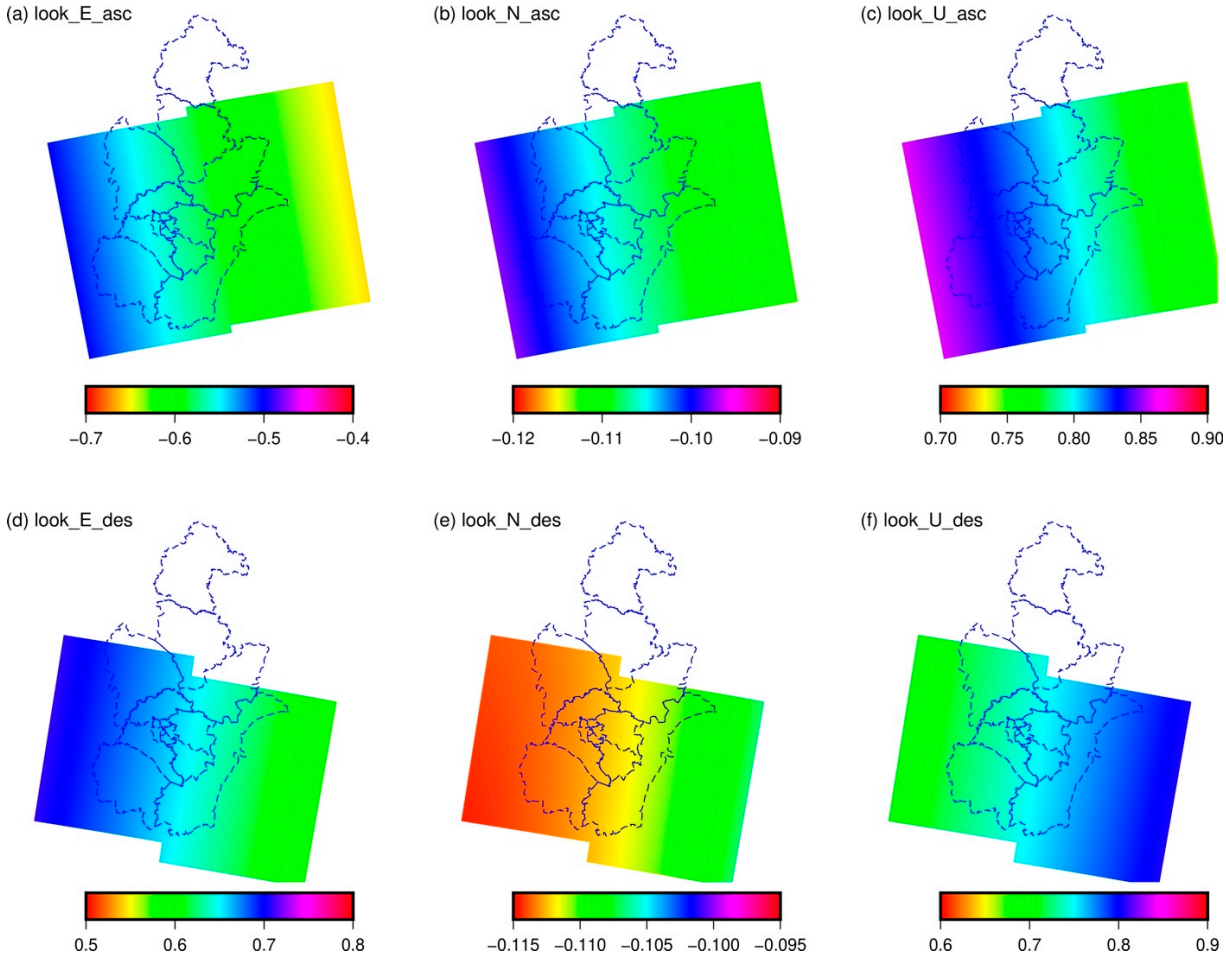

Figure S2. The east-west, north-south, and vertical direction look vectors of (a-c) the ascending track components and (d-f) the descending track components. The look vectors are computed using the look angles for Sentinel-1 satellites. The GMTSAR command *sat_look* is employed to generate these look vectors.