SAR monitoring of coastline change in Shanghai, China

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Abstract In this paper, we extract the waterline from synthetic aperture radar (SAR) images to illustrate coastline change in Shanghai, China. Nine ERS-2 and ENVISAT SAR images acquired between 1998 and 2006 were selected and a new land-water classification scheme was implemented to obtain coastline. The results show that the seaward coastline change between 1998 and 2000 is faster in the eastern part and slower in the western part in the study area. Later, between 2000 and 2005, coastline changes faster in both eastern and western sides. Coastline remained virtually unchanged between 2005 and 2006.

1. Introduction
Nanhui New City (NNC) is a recently developed district located approximately 60 km to southeast of Shanghai, China. Construction began in 2002 and is scheduled to complete in 2020. The site is located at the tip of the peninsula between Yangtze River and Hangzhou Bay (Figure 1). The total planned area is 311.6 km^2, of which 42.8% is reclaimed from the sea. NNC is one of the largest land reclamation projects in the world.

The coastline in this area has been changing significantly. In this study, we use images acquired from synthetic aperture radar (SAR) to monitor coastline changes of NNC.

2. Datasets

2.1. SAR data
Nine SAR images from ERS-2 and ENVISAT satellites were selected for coastline extraction. They are all in C-band with approximately 30 m spatial resolution and a pixel spacing of 12.5 m. The swath width is about 100 km. Table 1 lists SAR data and ancillary information used in this study.

2.2. In situ tidal-level data
In this study, the in situ tidal-level data measured at Luchaogang Hydrologic Station (Figure 1) located to the south of NNC is provided by the Shanghai Pudong New Area Hydrology and Water Resource Administration. The tidal-level data is referenced to the Wusong datum plane. The tidal gauge time series data covers the entire study period.

3. Image processing

3.1. SAR image speckle reduction

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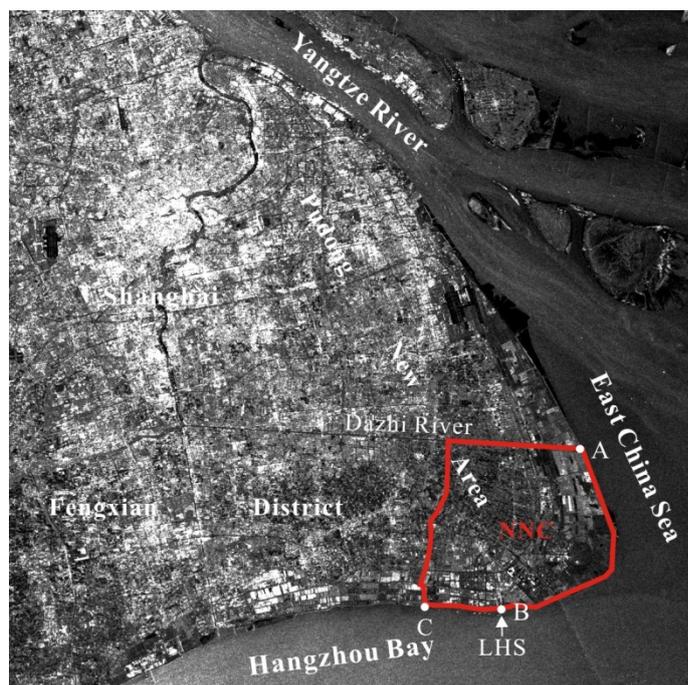
Figure 1. ENVISAT ASAR image of Pudong New Area, Shanghai. The image was acquired at 13:44:50 GMT on September 13, 2010. Orbit: 44639; Mode: ascending pass; Polarization: VV; Swath: IS2. NNC: Nanhui New City; LHS: Luchaogang Hydrologic Station; A: Dazhi River Mouth, B: Luchao Port, C: boundary between Fengxian District and Pudong New Area.

Table 1. Summary of the SAR acquisition information and associated tidal level predicted by linear interpolation of in situ water level data measured at Wusong datum plane. HT: high tide, LT: low tide.

Sensor	Orbit	Date(D/M/Y)	Time(UT)	Tide level (m)
ERS-2 SAR	15116	12/03/1998	02:29	3.88 *(HT 4.00 LT -0.14) rising*
ERS-2 SAR	15388	31/03/1998	02:32	1.61 *(HT 3.89 LT -0.28) rising*
ERS-2 SAR	24406	21/12/1999	02:32	3.66 *(HT 3.72 LT -0.22) descending*
ERS-2 SAR	25408	29/02/2000	02:32	1.88*(HT 3.02 LT 1. 09) descending*
ENVISAT ASAR	17084	06/06/2005	13:45	3.73 *(HT 4.18 LT -0.04) rising*
ENVISAT ASAR	17091	07/06/2005	02:02	2.95*(HT 3.22 LT 0.18) descending*
ENVISAT ASAR	17592	12/07/2005	02:02	0.40*(HT 3.16 LT 0.29) rising*
ENVISAT ASAR	24327	25/10/2006	13:42	1.73*(HT 3.30 LT 0.89) rising*
ENVISAT ASAR	25107	19/12/2006	02:02	3.67*(HT 3.78 LT -0.33) rising*

Speckle noise is a granular noise that degrades the quality of SAR images. In this study, commonly used Lee filter [1] was applied to reduce the speckle noise to enhance the radiometric information in each SAR image.

3.2. SAR geometric correction
The collected SAR images are all Level 1B product with location accuracy of 150 m. We used ground control points (GCPs) to make geolocation correction to all SAR images. The averaged residual geolocation accuracy is less than 50 m.

3.3. Coastline extraction from SAR imagery

Many semi-automatic or automatic algorithms [2,3,4,5,6] algorithms have been developed to extract a single-pixel boundary between land and water from SAR images. In this study, we developed a new image segmentation procedure for coastline extraction from SAR images. We divide an image into many blocks, divide each block into regions using Normalized Cut [7], find the thresholds for each region based on a global threshold value, and then combine all blocks.

4. Results and Discussions

4.1. The extracted coastlines of Nanhui New City
Nine waterlines are extracted from the SAR images between 1998 and 2006. Among these, four are at high tide, four at middle tide and one at low tide. To obtain coastlines, 1) the waterlines were divided into four groups. The first group corresponds to March 12, 1998 and March 31, 1998; the second group to December 21, 1999 and February 29, 2000; the third group to June 6, 2005, June 7, 2005 and July 12, 2005; the fourth group to October 25, 2006 and December 19, 2006. 2) The multi-year average mean high tide level was calculated. The average high-tide water level measured between 1992 and 2010 is 3.56 m. For each group, the waterlines were extracted and the coastline was obtained by interpolation. The obtained coastlines were shown in Figure 2.

4.2. Coastline changes of Nanhui New City, Shanghai
The seaward coastline change of NNC from 1998 to 2006 is shown in Figure 2. For the convenience of the description, the coastline of NNC was divided into two areas. The first area (S1) is from northern Dazhi River (marked with 'A' in Figure 1) to southern Luchao Port (marked with 'B' in Figure 1). The second area (S2) is from Luchao Port to western the boundary between Fengxian District and the Pudong New Area (marked with ' C' in Figure 1).

Figure 2 shows that from December 1998 to January 2000, S1 moved seaward at different speeds. The middle section moved a longer distance (averaged 1,170 m) than the two sides (averaged 390 m). During this period, S2 remained virtually unchanged.

From January 2000 to June 2005, both S1 and S2 varied rapidly. For S1, the western part moved a shorter distance (averaged 250 m) than the middle and the eastern part (averaged 2,710 m). Most of S2 moved seaward as well and the change distance is between 170 m and 1,250 m. From June 2005 to November 2006, both S1 and the eastern section of S2 remained unchanged. The western section of S2 moved 380 m seaward.

In summary, the coastline overall moved seaward from 1998 to 2006. The change is faster in S1 region during 1998-2000 periods and virtually no change in the S2 region. Later during 2000-2005, coastline had undergone faster development in the entire region. Coastline remained virtually unchanged after 2005.

5. Conclusions
In this study, we successfully extracted the coastlines of Shanghai from a series of ERS-2 and ENVISAT SAR images acquired between 1998 and 2006 using a new image segmentation scheme. These coastline changes are discussed. The coastline in the study area moved seaward from 1998 to 2006. The change is faster on the east side with an average speed of more than 430 m/year, and no change on the west side between 1998 and 2000. Between 2000 and 2005, coastline change became faster on both east and west sides, with an average speed of 320 m/year and 130 m/year respectively. After 2005, coastline remained virtually unchanged.

6. Acknowledgments
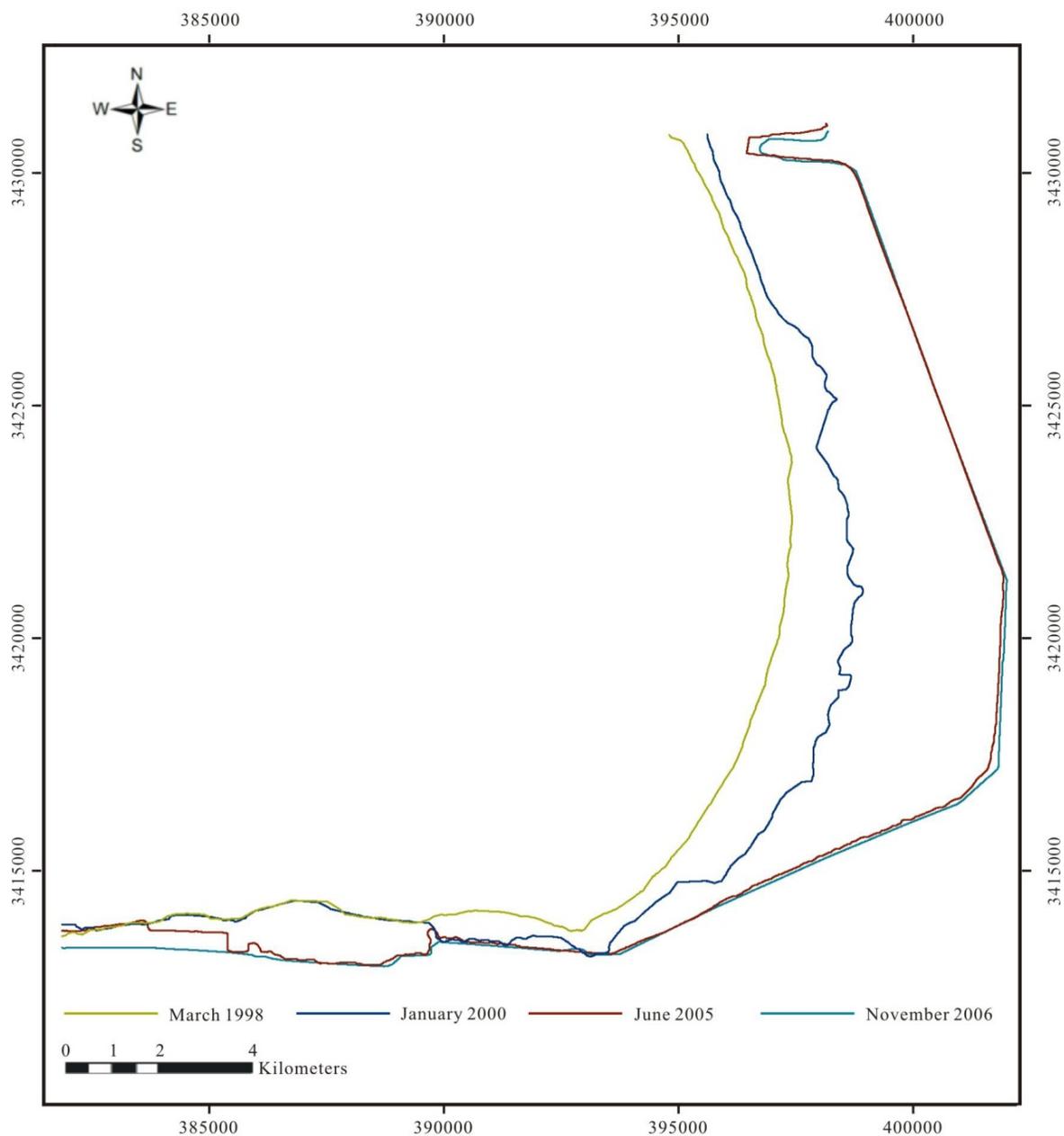
Figure 2. The obtained coastlines from SAR images. Projected coordinate system: WGS84 UTM zone 51N; unit: m.

7. References

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