AN ATTEMPT TO DETECT SECULAR DEFORMATION ASSOCIATED WITH THE SUBDUCTION OF THE PHILIPPINE SEA PLATE WITH ALOS/PALSAR

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ABSTRACT

We try to detect interseismic deformation due to subduction of plates with InSAR. We collected all the ALOS/PALSAR images acquired along two strips in southwestern Japan. Stacking, after eliminating noisy and low-coherent interferograms, shows the rate of line-of-sight displacements consistent with GPS data. However, the magnitude is about twice as large. Orbital inaccuracies and ionospheric disturbance may be the main error factors, because the expected deformation pattern of long-wavelengths resembles to artifacts due to these effects. Furthermore unwrapping caused difficulty in some interferograms since steep topography of Shikoku ranges decrease coherence with long base lines. On another strip, we tested a long-wavelength noise reduction technique using GPS displacements. This method enables significant reduction of apparent ionospheric noise. The average displacement rate shows small-wavelength fluctuations mostly in areas having altitude contrasts. While they seem to be mainly caused by tropospheric phase delays, some deformation signals around active faults (that are often collocated with altitude contrasts) may be hidden.

Key words: InSAR; ALOS/PALSAR; interseismic deformation, subduction, Philippine Sea plate.

1. INTRODUCTION

There are several reports on the detection of secular deformation during interseismic periods, including several mm/yr slip of strike-slip faults, with time series analyses of space-borne SAR data (e.g. Lanari et al., 2007). We try to detect interseismic deformation due to the subduction of plates with a similar approach. We selected southwestern Japan as the study area (Fig.1).

The southwestern Japan arc has a strike perpendicular to the track of the Japanese Advance Land Observation Satellite (hereafter ALOS) and gradient of deformation also is parallel to the ascending orbit of ALOS. Displacements observed by continuous GPS network (Geographical Survey Institute’s Earth Observation Network: hereafter GEONET) have a large NNW-ward component (~5cm/yr) in the southern part of Shikoku w.r.t the northern coast of Honshu (Fig.2). Fig.2 shows synthetic interferogram computed from GPS velocities for both descending and ascending orbits. We observe it is obvious that about half cycle of phase changes (~5cm range changes) is expected in five years. The range change may be concentrated near the tip of Kii peninsula and Shikoku for the descending orbit. Thus the southwestern Japan is one of the most suitable sites to study the applicability of SAR to the detection of secular deformation.

2. STACKING ANALYSES OF IMAGES IN SHIKOKU

We collected all the images of Phased Array-type L-band SAR (PALSAR) since May, 2006: 21 images from the path 417 (Cape Muroto,southern tip of Shikoku island, to Okayama, western part of Honshu). Fig.3 shows temporal and spatial baselines of all the images. During first 2 years, perpendicular baseline increased up to 5,000m. Therefore it was hard to find pairs with short perpendicular and long temporal baselines. However adjustment of orbit in July, 2008 enabled us to find suitable pairs. So far we have 21 pairs suitable for this analysis.
Figure 2. Simulated range changes in southwestern Japan using the five-year displacement field. GEONET GPS displacements in a full year of 2007 are converted to LOS direction and five-times exaggerated (top) interferogram from ascending orbit, (bottom) that from descending orbit. Blue and red arrows are horizontal and vertical displacements, respectively. Horizontal displacements are in ITRF2000. Rectangles in the upper figure denote the area of ALOS/PALSAR images used in this study: Western area is the path 417, while eastern one is path 414.

As a first step, we examined interferograms to identify error factors for these target areas. Fig. 4 shows examples of interferograms. Some of them have more than one cycle of phase changes, which is much larger than the expected crustal deformation. These problematic interferograms have a common master/slave images acquired on particular dates. We suppose these images are affected by the Traveling Ionospheric Disturbance (TID: Saito et al., 2002).

Saito et al. (2002) presented similar wavy pattern of TEC distribution during night time. Some interferograms also contain orbital and tropospheric artifacts. Interferograms having the perpendicular baseline of more than 500 m were difficult to be unwrapped. We chose interferograms with less effects of ionosphere and unwrapped them. Finally we stacked the interferograms having high coherence. We used the Gamma software for the interferometry and stacking.

The rate of line-of-sight displacements computed from stacking (Fig. 5) shows range decrease around Cape Muroto relative to the northern Shikoku. This pattern is consistent with the LOS velocity field predicted by the GEONET (Fig. 6), but the magnitude is about twice as large.

3. SBAS ANALYSES OF IMAGES IN KII

14 images in Fig. 7 from the path 414 (Cape Shionomisaki, southernmost tip of Honshu, to Tango peninsula) were analyzed with the Small Baseline Subset technique (SBAS). Fig. 8 shows examples of interferogram. As is in the case of Shikoku, we find large disturbance probably due to ionosphere activity.

On this strip, we tested a long-wavelength noise reduction technique using GPS displacements, The algorithm is as follows (Fig. 9):
(a) Unwrap an interferogram,
(b) Extract values on pixels collocated with GPS stations,
(c) Compute LOS velocity from GPS displacement vectors,
(d) Subtract (c) from (b), leaving only the noise component
(e) Interpolate (d),
(f) subtract (e) from (a).
Some pairs including images acquired on some specific days such as Aug. 28, 2006, may have suffered from strong ionospheric disturbance. Short-wave-length disturbance that may have arisen from tropospheric effects are also recognized in some pairs. Interferograms with longer perpendicular baselines than 500m have low coherence in ranges.

This sequence of procedure outputs a corrected unwrapped interferogram that is free of noise having wavelengths longer than the spatial sampling of GPS stations. In the step (d), we assumed that GPS measurements are accurate.

Applying SBAS on the corrected interferograms still showed large perturbations with respect to time because of atmospheric noise, even with a temporal smoothing constraint. This is at least due to infrequent PALSAR acquisitions compared to, for example, ASAR onboard ENVISAT. Fig. 10 shows the average velocity obtained from the SBAS analysis. The long-wavelength pattern matches well with the interpolated GPS LOS velocity (Fig. 11) because we constrained it to be so. The short-wavelength patterns, on the other hand, are distinctive. Relatively large gradients are collocated with altitude contrasts (e.g., between a mountain and a basin).
Figure 7. Diagram that shows ALOS/PALSAR images and pairs for interferograms for path 414. Horizontal and vertical axes are date of acquisition and perpendicular baselines of images relative to that on Oct. 8, 2006, in m.

Figure 8. Examples of interferograms for the path 414. Disturbances which may have arisen from ionospheric or tropospheric disturbances are significant for some pairs.

While these short-wavelength patterns seem to be mainly caused by tropospheric phase delays, some deformation signals around active faults (that are often collocated with altitude contrasts) may be hidden.

4. SUMMARY

We have analyzed ALOS/PALSAR images in southwestern Japan to derive secular deformation due to the subduction of Philippine Sea plate. ALOS/PALSAR images contain severe ionospheric disturbances on some particular days, but other images were usable for our purpose. Relatively long perpendicular baseline prevents us from unwrapping of interferograms in steep topography. We could not necessarily obtain satisfied results due to the above reasons.

However, owing to the orbit adjustment in July, 2008, there are many pairs with long temporal and short perpendicular baselines. During next one year, the number of such pairs will increase and we hope it will help time series analyses.

Figure 9. Procedure of the reduction of long wavelength noise using GPS displacements: (a) Unwrapped interferogram. (b) Extracted LOS displacements at CGPS sites. (c) LOS velocity computed from observed GPS displacement vectors. (d) Difference between LOS velocities of InSAR and GPS. (e) Interpolation of differences. (f) Unwrapped interferogram with interpolated difference subtracted.

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Figure 10. Average range rates (m/yr) for path 414 obtained with SBAS analysis after correction of long-wavelength displacements using GPS data analysis.
