Displacement field in the Japanese islands revealed by combining mode rotation procedure with principal component analysis

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A variety of geophysical datasets involve the information on the characteristic spatiotemporal structures of many types of geophysical events. Among them, there are some events which mutually overlap in space and time. The 2000 volcanic event around the Miyakejima and Kozushima islands and the 2000 slow-slip event on the plate boundary between the Philippine Sea plate and the Eurasian (Amurian) plate in the Tokai district are typical of such overlapping events. Principal component analysis (PCA) is one of the most useful statistical tools in capturing the spatiotemporal structures of such geophysical events in geophysical datasets.

PCA alone, however, frequently results in any linear combination of the modes which reflect the mixtures of some underlying geophysical processes. This is definitely one of the highest hurdles in modeling the spatiotemporal characteristics of a displacement field.

In order to addressing this problem, Kawamura and Yamaoka (2005) developed the statistical combined approach based on PCA and mode rotation procedure. We here applied the combined approach to the displacement field over the Japanese islands to capture its characteristic deformation patterns and to obtain some new knowledge on their related geophysical processes. The methodology adopted here is fully explained in Kawamura and Yamaoka (2005). In applying the combined approach, we divided the Japanese islands into three parts: west Japan, east Japan, and north Japan. The time period adopted for PCA is from February 1996 to December 2002. Secular and periodic components for each station were excluded beforehand.

As expected, we obtained the results in which many modes were contaminated by other modes for all of the three parts. On the contrary, application of the combined approach resulted in the spatial and temporal modes in which the crustal deformation associated with the events extracted with PCA was relatively emphasized. The interpretations of results for the three parts after applying the combined approach are summarized as follows.

For west Japan, the 1st and 2nd mode separated only the signals of the 2000 Tottori-Ken-Seibu earthquake and the 2001 Geiyo earthquake from other events, respectively. The 3rd mode included the 1996 Hyuga-nada earthquakes and the 1996 Tanegashima Island earthquake. The 4th mode included the 1996-to-1997 Bungo-Channel slow-slip event and the 1997 Kagoshima-Ken-Hokuseibu earthquakes. It should be noted that the Bungo-Channel slow-slip event was clearly recognized.

For east Japan, the 1st to 3rd modes corresponded to successive different stages of the 2000 Miyake-Kozu volcanic event. The 4th mode separated the 1996, 1997 and 1998 East-off Izu-Peninsula earthquake swarm. The 5th mode clearly corresponded to the 2000 Tokai slow-slip event. The 1st mode allowed us to conclude that the 2000 Tokai slow-slip event is preceded by the 2000 Miyakejima-Kozushima volcanic event.

For north Japan, the 1st mode included a widespread anticlockwise displacement pattern centering on around the Usu volcano and reverse sense of the postseismic effect by the 1994 Far Off Sanriku earthquake. The 2nd mode separated the 2000 Usu volcanic event from other events. The 3rd mode included the deformation patterns associated with the 1998 Iwate volcanic activity and the 1998 Iwate-Ken-Nairiku-Hokubu earthquake. The extraction of the postseismic effect by the Far Off Sanriku earthquake would reflect its continuation past March 1996. The widespread anticlockwise deformation pattern in the 1st mode may be related to plate motion.

These results indicate that the combined approach using PCA and mode rotation procedure is useful even for the dataset covering broader region and spanning longer time period. On the other hand, the limitation of the combined approach was clarified, which resulted in the failure in extracting some damaging earthquakes, for example, because of the limited number of stations which detected such earthquakes.