

Monitoring Land Deformation Using Permanent Scatterer InSAR Techniques (case study: Ho Chi Minh City)

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Key words: Permanent Scatterer InSAR

SUMMARY

The level of the ground water has been constantly lowering and the urbanization has been rapidly developing during the last decades due to the strong groundwater extraction has led to the subsidence of some areas in the Ho Chi Minh City. Land deformation at the rate of few centimetres per year can be measured at the heavy ground water pumping stations.

Most existing techniques for monitoring ground subsidence base on using methods of precise leveling, and more recently the GPS. These methods are generally expensive and inefficient for monitoring large areas. Besides, sparsely distributed data points are often insufficient to provide information on every localized ground subsidence.

Recent advances in the SAR interferometry, especially with the Permanent Scatterer InSAR (PSInSAR) is an appropriate remote sensing technique for measuring ground subsidence in urban areas at high accuracy and low costs.

Results demonstrate the effectiveness of employing the PSInSAR technique for land subsidence monitoring at Ho Chi Minh city and PSInSAR has enabled a long-term study of vertical land movements using SAR images.

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1. INTRODUCTION

Rapid increase of ground water use started in 1990 when HCM City were urbanized with five new districts, people and the industries used ground water as the main water resource. HCM City locates at the soft soil, the ground water use was in a large scale, ground water level decreasing (>20m from 1990 until now) caused deform of soil which makes the ground level goes down. The more ground water use the more land subsidence will happen and land deformation at the rate of few centimetres per year can be measured at the heavy ground water pumping stations. Land subsidence made original leveling height lapse and deteriorates flood prevention situation through knocking down the ground elevation. This involved certain difficulties for tide line analysis, flood prevention plan and management.

Therefore, it is important to be able to measure the subsidence values as a support to a better management of groundwater, in order to minimize future subsidence. Although many traditional methods such as precise levelling and GPS techniques can provide subsidence information, they are high cost, time-consuming and inefficient for monitoring large areas.

This study demonstrates the effectiveness of employing the PSInSAR technique for land subsidence monitoring at Ho Chi Minh city. Evaluating the preliminary result of land subsidence in city showed that due to the strong groundwater extraction has led to the subsidence of some areas and most of tide flood sites lie at these areas of the city.

2. AREA STUDY

Ho Chi Minh City has population 7 mil. people, 2095 km² area and great potential for developing industry, exports, tourism and services. The study area is composed of the urban inner core region, urban fringe region and a part of the suburban region of city. It is located at 10°50' northern latitude, 106°40' eastern longitude, and lies ~ 55 km inland at 2 m average height. In this area, flooding has become worse over the past ten years despite efforts to reduce flooding. One of the reasons is the fast-growing urbanization process and the widespread fill-up of rivers and canals all over the city; free of charge ground water and uncontrolled exploitation caused deform of soil which makes the ground level goes down,... SAR images used for this PSInSAR technique are ERS-1 and ERS-2 (14 scenes, from 1996 to 2002). We choose SRTM DEM data for our processing, In HCM City this DEM at 90-m posting (3 arc second) is available for download (<ftp://e0srp01u.ecs.nasa.gov>).

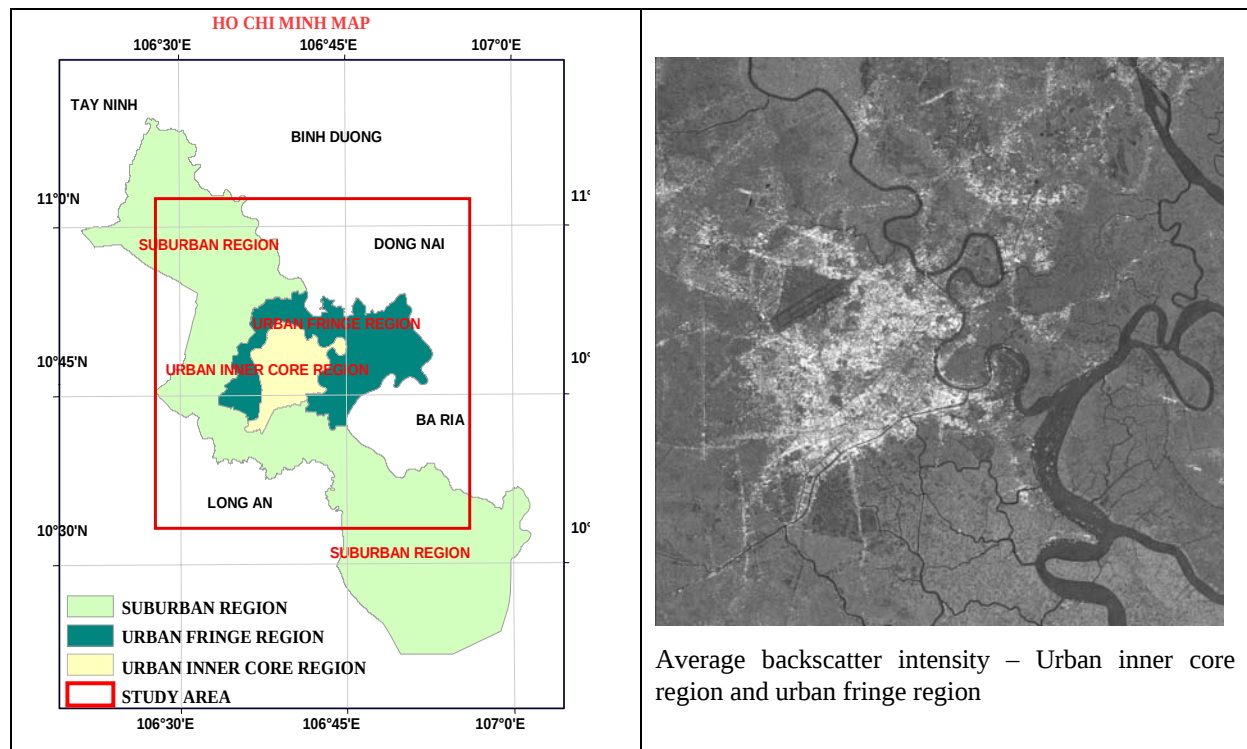


Figure 1: Study Area, Ho Chi Minh City - Vietnam

3. PERMANENT SCATTERER INSAR (PSInSAR)

Interferometric Synthetic Aperture Radar (InSAR) is a technique first suggested in the early 1970s (Graham, 1974). Permanent scatterer InSAR is an extension of the conventional InSAR, which offers a practical way to reduce the main errors in conventional methods: atmospheric delay, temporal and spatial decorrelation. This technique was developed in the late 1990s by A. Ferretti, F. Rocca, and C. Prati of the Politecnico di Milano (POLIMI). The main characteristics of this method are that it utilizes a single master in a stack of differential interferograms, and that only time-coherent pixels, i.e. “Permanent Scatterers” (PS) are considered (Ferretti, et al, 2000) or persistent scatterers (Hooper, et al. , 2007).

PS typically corresponds to objects on man-made structures such as buildings, bridges, dams, water-pipelines, antennae, as well as to stable natural reflectors. Indeed, the PS comprises a sort of “natural geodetic network” for accurately monitoring surface deformation phenomena, as well as the stability of individual structures (Ferretti, et al, 2000).

Hooper, et al., 2007 have developed a good PS processor – StaMPS and fortunately this processor is free for scientific research (www.hi.is/~ahooper/stamps). Therefore, in this study, StaMPS is used to detect the land subsidence in Ho Chi Minh City.

There are four parts to StaMPS, each discussed in detail can be found in (Hooper, et al. , 2007):

1. Interferogram Formation: There are aspects of interferogram formation for PS processing that differ from conventional interferogram formation. First of all, we choose as the “master”, the image that minimizes the sum decorrelation, i.e., maximizes the sum

correlation, of all the interferograms. Secondly, for coregistration, the function that maps the “master” image to each other image is estimated by weighted least-squares inversion. Once the mapping functions are estimated, we resample each image to the “master” coordinate system, using a 12 point raised cosine interpolation kernel. Then we form a raw interferogram by differencing the phase of each image to the phase of the “master”. Finally, we remove the geometric phase terms which are due to the “master” and ‘slave’ images being acquired from different points in space.

2. Phase Stability Estimation: We make an initial selection of candidate pixels based on analysis of amplitude, and then use phase analysis to estimate the phase stability of these pixels in an iterative process.

3. PS Selection: We estimate for each pixel the probability if it is a PS pixel based on a combination of amplitude and estimated phase stability. We then use the estimated probabilities to select PS pixels, rejecting those that appear to be persistent only in certain interferograms and those that appear to be dominated by scatterers in adjacent PS pixels.

4. Displacement Estimation: Once selected, we isolate the signal due to deformation in the PS pixels. This involves “unwrapping” the phase values and subtracting estimates of various nuisance terms.

4. PERMANENT SCATTERER INSAR (PSInSAR)

4.1 Experimental PSInSAR results

First of all, SAR ERS-2 (acquired in 21 May 1996) is choose as ‘Master’ image, the image that minimizes the sum decorrelation, i.e., maximizes the sum correlation, of all the interferograms. Table 1 shows baseline information with respect to this master.

Table 1: Baseline and doppler centroid frequency information

ID	Sensor	Date	Orbit	F_{DC} (Hz)	B_⊥ (m)
1	ERS-1	05-Feb-1996	23839	-205	481
2	ERS-1	15-Apr-1996	24841	-317	540
3	ERS-1	20-May-1996	25342	-274	73
4	ERS-2	06-Feb-1996	4166	-11	655
5	ERS-2	12-Mar-1996	4667	-33	543
6	ERS-2	16-Apr-1996	5168	-24	88
7	ERS-2	21-May-1996	5669	0	0
8	ERS-2	03-Sep-1996	7172	25	-365
9	ERS-2	28-Oct-1997	13184	44	-692
10	ERS-2	17-Nov-1998	18695	-12	-66
11	ERS-2	11-Jan-2000	24707	16	-325
12	ERS-2	15-Feb-2000	25208	298	464
13	ERS-2	17-Oct-2000	28715	-38	343
14	ERS-2	26-Nov-2002	39737	-924	-85

The 13 single-look interferograms were established from 14 scenes, all with respect to one ‘super master’ image, using DORIS (Hanssen, 2001). Then, we subtract the reference phase and SRTM DEM simulated phase as figure 2.

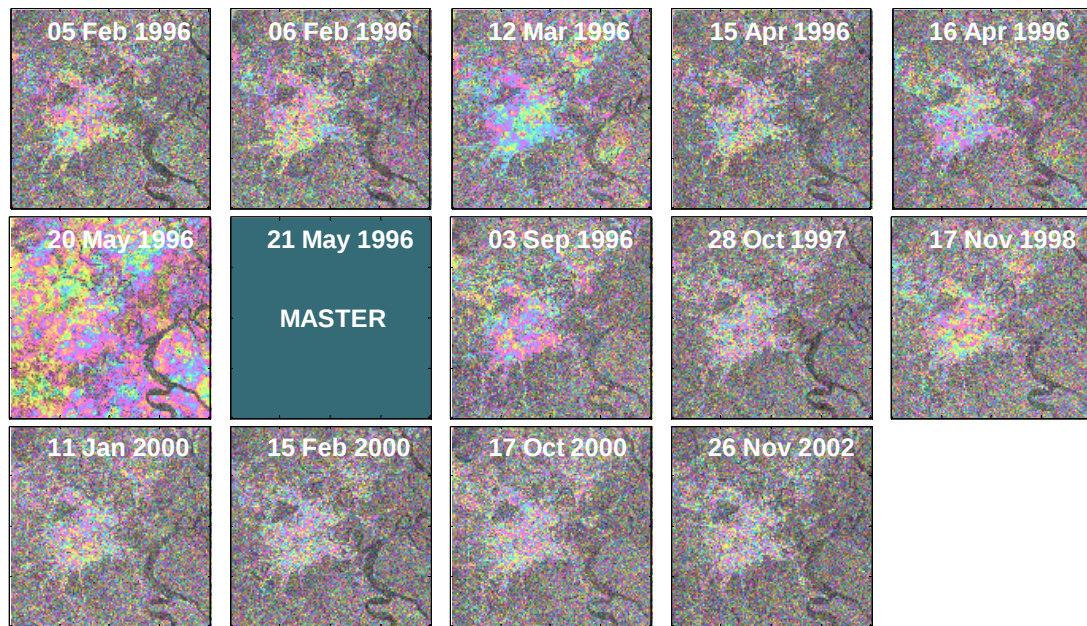


Figure 2: Differential Interferograms

Next step, StaMPS is applied to analyze phase history. 35326 stable-phase pixels, PS candidates, are identified in our study area. Ultimately, after unwrapping phase and filtering spatially correlated noise, it calculates a mean velocity light-of-sight LOS value for each PS pixels from 1996 to 2002. These velocity values of PS pixels are given relative to PS pixels in the Tan Son Nhat Airport – North of urban inner core reigon. The result is remapped from the SAR coordinate system to cartographic orientation as figure 3.

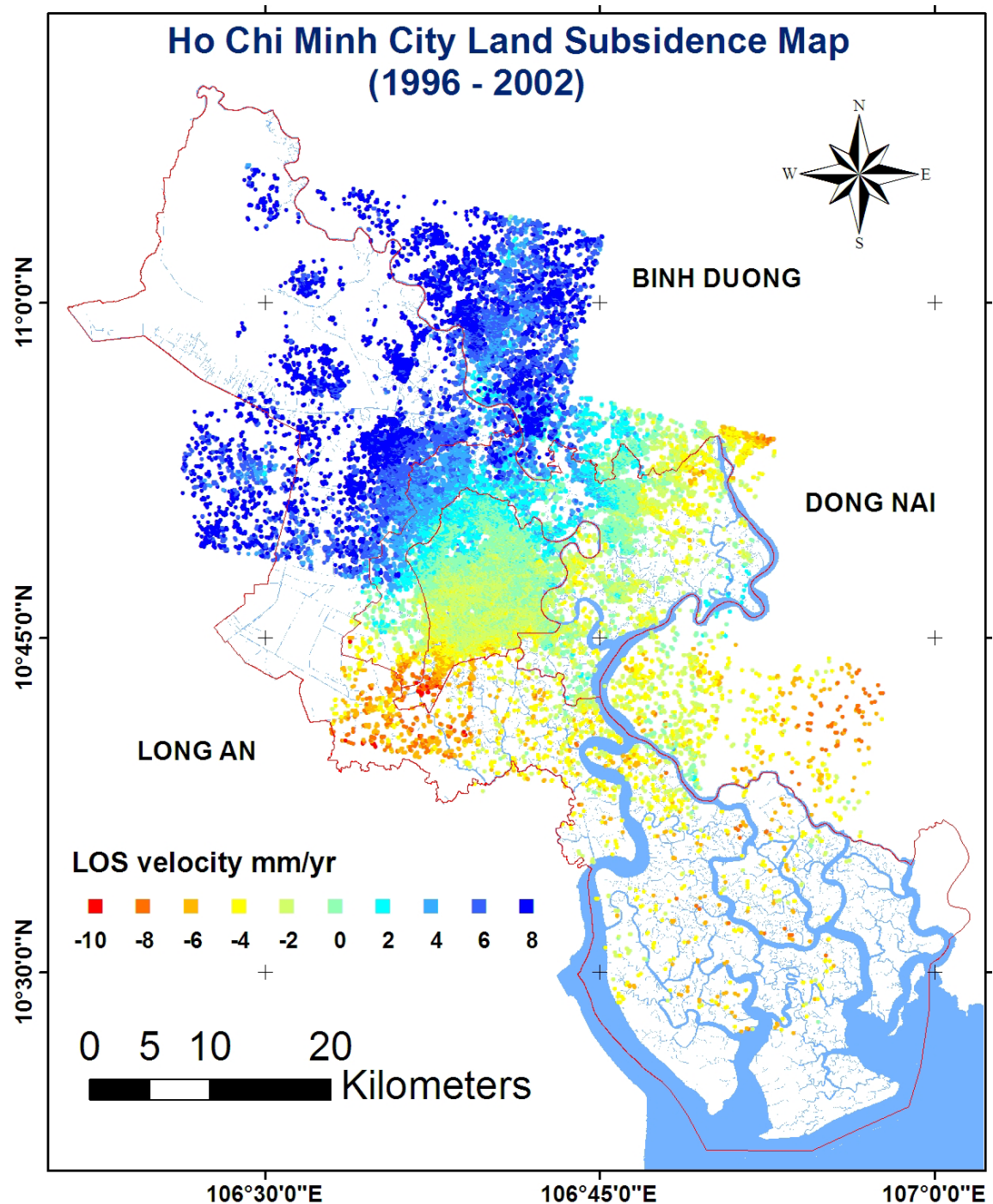


Figure 3: Mean velocity LOS 1996 -2002 (mm/yr)

The result shows a mean velocity light-of-sight value for each PS pixels from 1996 to 2002 in Ho Chi Minh City by means of PSInSAR technique. The deformation rates obtained fall in the interval -10mm/yr and +8 mm/yr.

4.2 Interpretation

Since there is no measurement available regarding to deformation in history, the validation of the results is impossible. Hence, in here we try to collect data for interpretation purposes. Nguyen Van Nga, 2005, had pointed out the most serious subsidence area of the city is the Southwest region. The city had 95 flooding-prone areas that may be caused by heavy rain, high tide, and land subsidence combined with a global sea level rise. Figure 4 shows the PSInSAR results in Southwest region and tide flood sites.

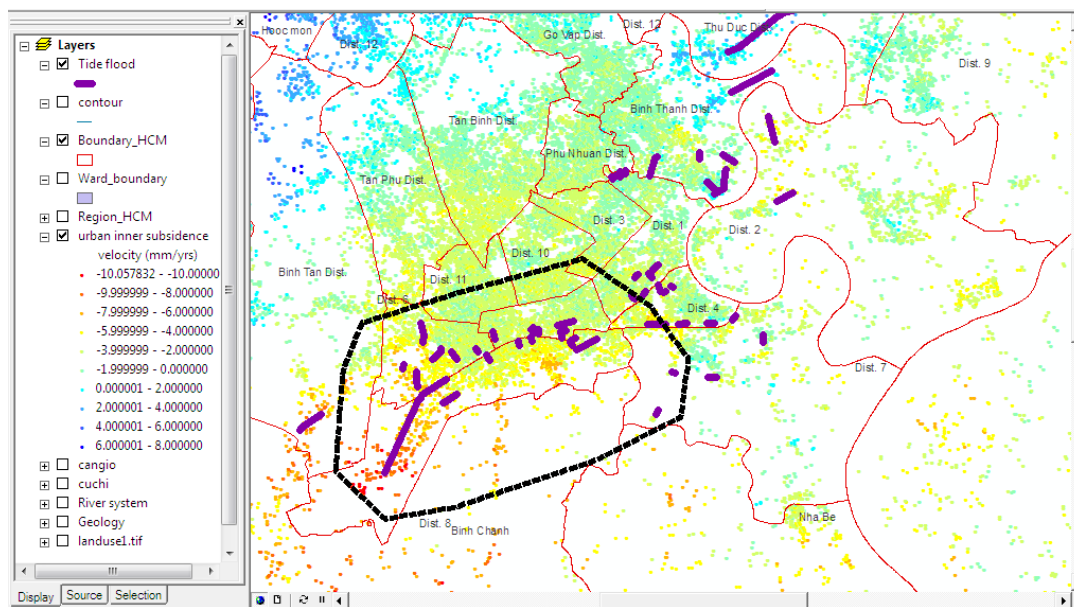


Figure 4: PSInSAR results and tide flood sites

Rapid increase of ground water use started in 1990 when HCM City were urbanized with some new districts, people and the industries used ground water as the main water resource. Besides, HCM City locates at the soft soil, the ground water use was in a large scale, ground water level decreasing (>20m from 1990 until now) caused deform of soil which makes the ground level goes down. The result obtained is in sympathy with some reported results.

Figure 6 shows the relationship connecting ground water pumping stations and land subsidence in the PSInSAR results in Southwest region. The point profile or deformation history of a point within region Dist. 1 from 1996 to 2003.



Fig. 5: Effect of tide and land subsidence

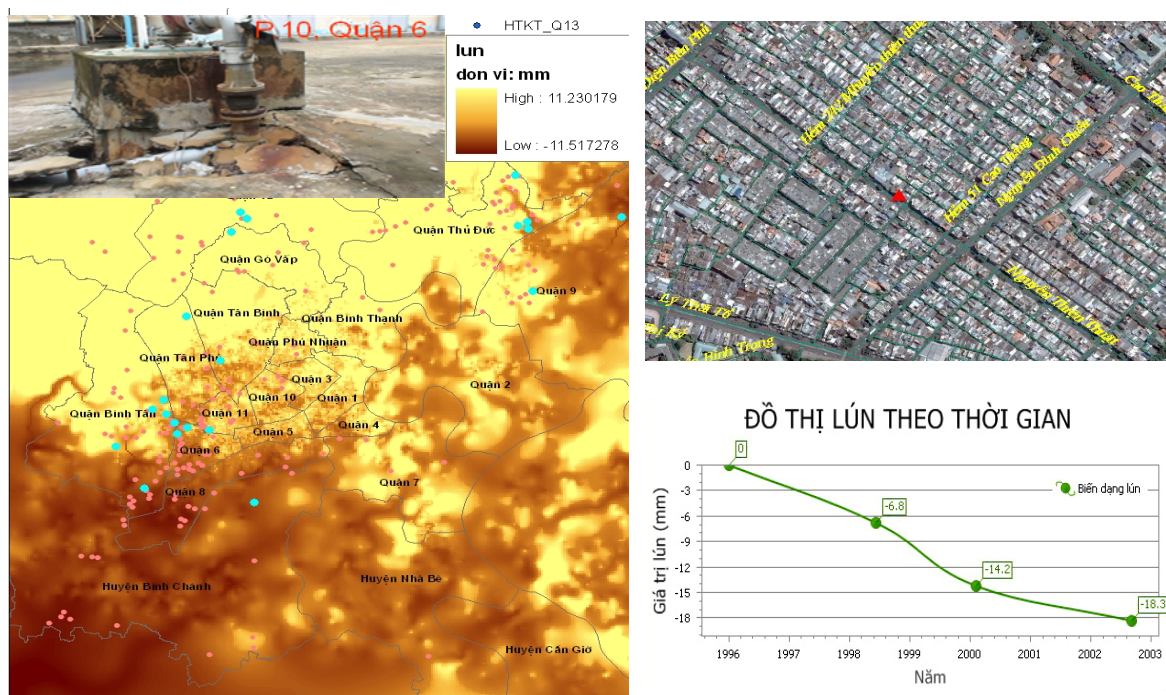


Figure 6: Ground water pumping stations and land subsidence

5. CONCLUSION

The applicability and effectiveness of using the PS InSar technique for monitoring ground deformation are investigated in Ho Chi Minh City. The result obtained is in sympathy with some reported results; urbanization and a rising population, cause more exploitation of underground-water and more large structures to be built. This is effecting HCM City surface causing significant ground deformation. Subsidence phenomenon in HCM City has not been previously measured or monitored. However, the primary results shows that deformation rates falling within the interval -10mm/yr and +8 mm/yr and the magnitude of land subsidence has reached to 30mm at some streets in downtown area from 1996 to 2003 because of groundwater overexploitation concentrated there.

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