Radar Interferometric Features related to Oyster Sea Farming Site: Preliminary Results

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Abstract

Unregistered oyster farms were detected and investigated using SAR data sets. We succeeded in generating 21 radar interferometric pairs over the structures, and found that residual interferometric phase has a linear relationship with the variation of tide height. Details of backscattering mechanism and optimal imaging parameters are not known yet, and will be investigated using JPL AIRSAR data acquired as a part of PACRIM-II experiment. If the backscattering properties are understood, sea level change can possibly be estimated by SAR.

Introduction

Along the south coast of the Korean Peninsula, a number of sea farming (or mari-culturing) sites are being operated. The types of sea farming vary region by region, but seaweed and laver farms are the most popular ones. The artificial structures, usually rectangular shaped, of seaweed and laver farm are deployed above water surface, and can easily detected in optic remote sensing imagery especially in winter. Conversely, most other sea farming structures are set up under water, and rarely detectable by remote sensing.

The structure we are interested in here is oyster sea farm that is composed of horizontal wood bar, about 1.5 m long and 10 cm in diameter, staying about 1-2 m above seawater surface. A horizontal wood bar is supported by two vertical wooden bars. Oyster farms normally consist of fifty to one hundred bars in array. These structures are not visible by any current civilian satellite optic system including IKONOS. SAR, however, well images the artificial structures under favorable conditions. Especially L-band SAR system is effective and provides radar interferometric pair as long as baseline is short enough. The interferometric phases vary somewhat systematically, and we will discuss if it is feasible to estimate the variation of tide height by radar interferometry. Since the research is so far in early stage, many questions are yet to be answered. JPL AIRSAR acquired SAR data over the test site with XTI1 mode on September 30, 2000. The data is being processed by JPL, and is expected to provide clues to understanding backscattering properties and the relationship between interferometric phase and tide conditions.

Site and Data

The test site is shown in Figure 1. The oyster farms are imaged as bright scatterers. Coastal environments of the region are comprehensively described by [1]. The oyster farms in this region are not registered, and consequently no official information is available. It is useful even simply detecting the unregistered farming structures by remote sensing. Figure 2 shows the artificial structures made of horizontal and vertical wooden bars. The horizontal bars keep staying at least 1-2 m above water surface all year long, while oyster grows from July to September.

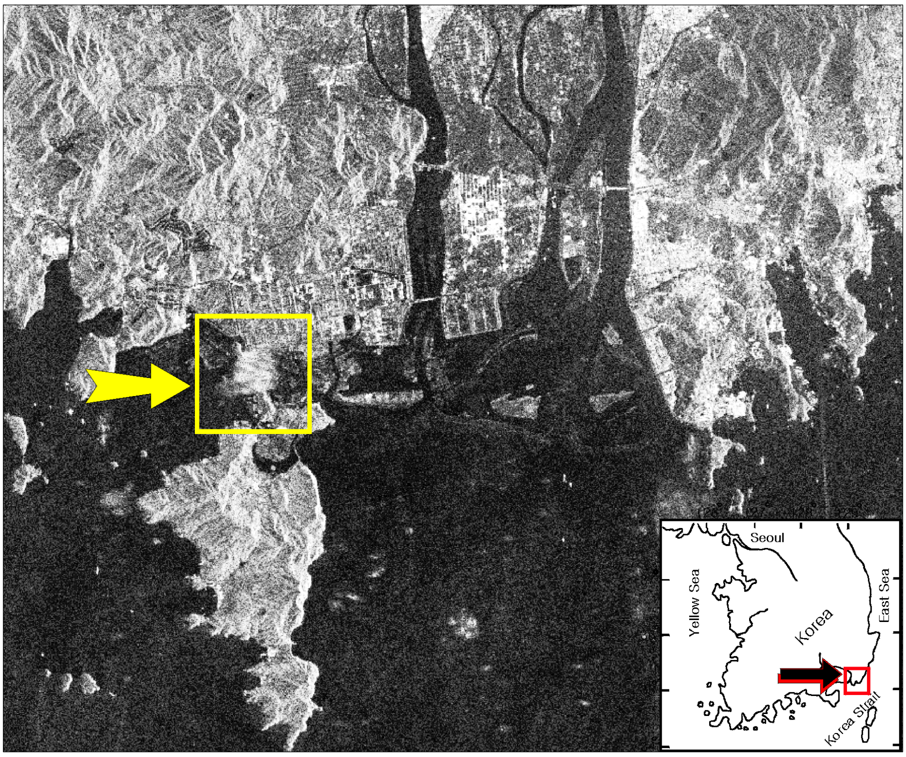


Figure 1. Location map of the test site and JERS-1 SAR amplitude image. The oyster farms are marked by square.

Figure 2. Photo showing wooden frames for oyster farming.

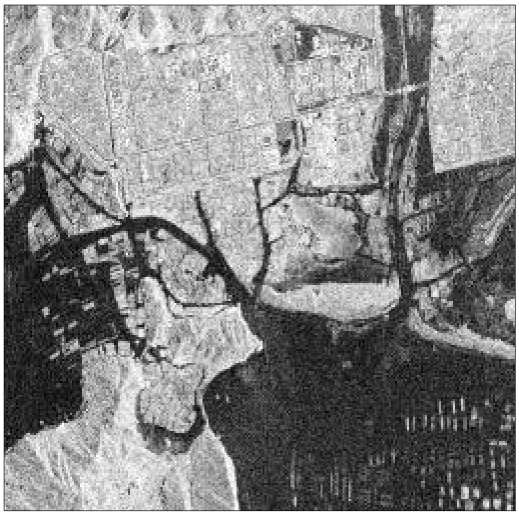
In the test site, we acquired 26 SAR data sets as summarized in Table 1. Only one ERS-1/2 tandem pair was acquired during ERS-1/2 tandem mission period. Although 5 RADARSAT C-band SAR data sets had been acquired over the test area, beam modes were all different. In ERS-1/2 tandem images (tidal conditions were close each other), the structures are detectable in one data set but not in the other. We failed to generate an interferogram using ERS-1/2 tandem pair over the oyster farm. In RADARSAT images, the structures were imaged only by fine beam descending mode. Two RADARSAT data sets in Figure 3 were acquired under almost the same tidal conditions (only 6 cm difference in tide height), but descending mode was much more effective to render the structures. We were not able to generate RADARSAT SAR interferogram because the pair of the same beam mode was not available.

On the contrary, the oyster farms were commonly well imaged by JERS-1 L-band HH-polarization SAR system. We acquired 18 JERS-1 SAR data sets over the test site, and succeeded in generating 21 pairs of JERS-1 SAR interferograms as summarized in Table 2. JPL AIRSAR data was acquired with XTI1 mode on September 30, 2000. The quick look image of AIRSAR L-band HH-polarization (Figure 4) shows details of the structures. The AIRSAR data is being processed by JPL.

Table 1. Summary of SAR data sets.

Data No.	Sensor	Date (Local time)	Tide height (cm)
1	JERS-1 SAR	1992/12/12 (11:03)	88.0
2	"	1994/01/17 (11:01)	167.0
3	"	1995/05/16 (11:06)	156.0
4	"	1995/08/12 (11:08)	146.5
5	"	1995/11/08 (11:09)	129.0
6	"	1996/05/02 (11:10)	69.0
7	"	1996/06/15 (11:10)	80.0
8	"	1996/10/25 (11:10)	68.0
9	"	1997/01/21 (11:09)	80.4
10	"	1997/06/02 (11:08)	49.4
11	"	1997/10/12 (11:11)	49.0
12	"	1997/11/25 (11:13)	75.0
13	"	1998/01/08 (11:14)	64.0
14	"	1998/02/21 (11:15)	91.0
15	"	1998/05/20 (11:16)	62.8
16	"	1998/07/03 (11:17)	89.1
17	"	1998/08/16 (11:18)	94.0
18	"	1998/09/29 (11:18)	92.6
19	ERS-1	1995/12/27 (22:41)	48.0
20	ERS-2	1995/12/28 (22:41)	43.0
21	RADARSAT(F4)	1996/08/05 (18:29)	62.0
22	" (S5)	1996/08/12 (18:25)	164.0
23	" (S3)	1997/04/07 (06:29)	134.0
24	" (F2)	1998/01/22 (18:25)	77.0
25	" (F3)	1999/11/13 (06:21)	71.0
26	AIRSAR (XTI1)	2000/9/30 (17:12)	being processed

(a)



(b)

Figure 3. RADARSAT SAR images acquired by (a) fine beam 2 ascending mode and (b) fine beam 3 descending mode.

Table 2. Summary of JERS-1 SAR intereferometric pairs.

No.	Interferometric Pair		Altitude of ambiguity(m)	Tide height difference (cm)
	Master	Slave		
1	95/08/12	95/11/08	-241.99	17.5
2	96/05/02	96/10/25	256.72	1.0
3	96/05/02	97/01/21	-156.27	-11.4
4	96/06/15	96/10/25	273.44	12.0
5	96/06/15	97/01/21	-152.82	-0.4
6	96/10/25	97/01/21	-104.57	-12.4
7	96/10/25	97/06/02	-238.7	18.6
8	97/01/21	98/05/20	-106.35	17.6
9	97/06/02	98/05/20	-119.00	-13.4
10	97/11/25	98/01/08	-85.29	11.0
11	97/11/25	98/02/21	-281.48	-16.0
12	97/11/25	98/07/03	275.74	-14.1
13	97/11/25	98/09/29	149.70	-17.6
14	98/01/08	98/02/21	114.88	-27.0
15	98/01/08	98/07/03	72.51	-25.1
16	98/02/21	98/07/03	194.61	1.9
17	98/02/21	98/08/16	-115.37	-3.0
18	98/02/21	98/09/29	105.86	-1.6
19	98/07/03	98/08/16	-74.48	-4.9
20	98/07/03	98/09/29	216.06	-3.5
21	98/08/16	98/09/29	51.00	1.4

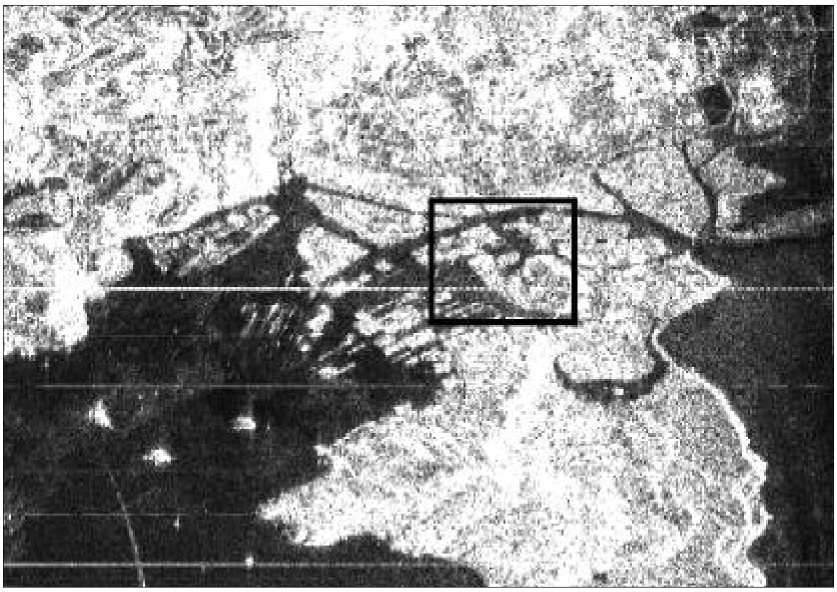


Figure 4. AIRSAR L-band HH-polarization quick look image.

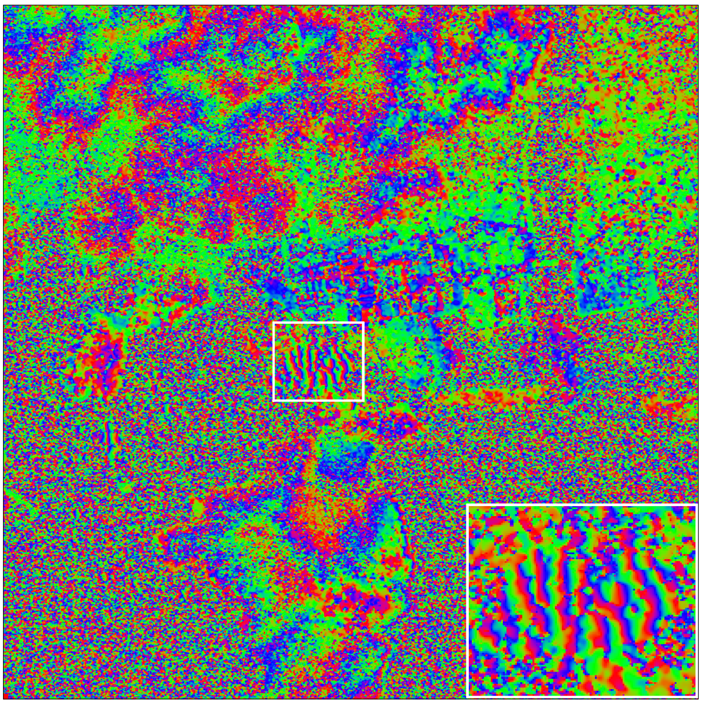
Processing and Summary

As examples shown in Figure 5, interferograms with relatively high coherence around the oyster farms were achieved from JERS-1 SAR data pairs having favorable baseline conditions. The coherence of the interferogram was nearly independent of tidal conditions, time interval of the pair, and season (recall that the surface of the frame is covered with oyster from July to September).

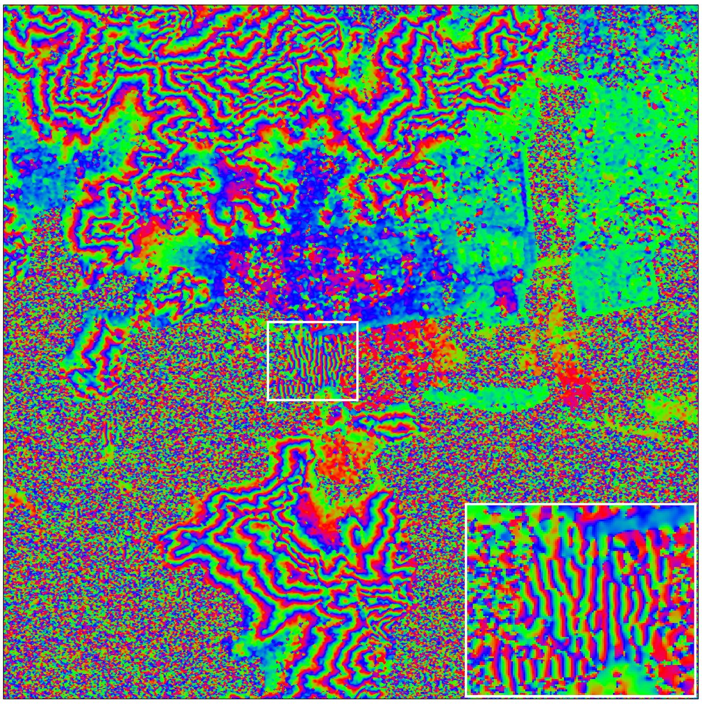
Since the orbit information of JERS-1 is inaccurate, the fine tuning of JERS-1 interferogram using orbit data is not reliable. Thus, we processed to minimize the difference between interferometric phase and DEM on land mass, which is similar to the method described by [2]. The resulting interferometric phase appeared to be governed by altitude of ambiguity that was defined by [3]. The best fitted line to the interferometric phases was found to be an inverse function as in Figure 6. The correlation coefficient of the estimated fitting function with the original phases was 0.96 and F value was 194.9. If the phase error was caused by inaccurate baseline information, the inverse function could be validated because the altitude of ambiguity is inversely proportional to the perpendicular baseline. We removed the modeled phase from the original interferometric phase, and had resulting residual phases as shown in Figure 7.

Figure 7 shows the residual phase versus the difference of tide height in the interferometric pair. The tide data was provided by National Oceanographic Research Institute and measured by tide gauges that recorded tide height every 10 minutes. Although the residual interferometric phases in Figure 7 are scattered from the fitted straight line, general trend is clearly linear. The estimated straight line by least square linear regression has statistical values of r = 0.75 and F = 27.0. Therefore, we can conclude that the residual interferometric phase has a linear relation with the tide height difference. We have also converted the residual phase into absolute height difference resulting that the estimated height difference from SAR inteferometric residual phase was larger than that of tide gauge data roughly by two times. The conversion from residual phase to absolute height on sea surface was neither an easy task nor reliable.

The results can be summarized as follows. L-band is effective to image the oyster farming structures on satellite-borne SAR observation. Interferogram having relatively high cohernce can be obtained from L-band SAR data set pairs over the structure even though sea surface conditions are continuously changed. Interfeometric phase estimated from JERS-1 SAR data has a close relationship with the altitude of ambiguity (or baseline). The residual interferometric phase is linear with the tide height change.



(a)



(b)

Figure 5. JERS-1 SAR interferograms showing the oyster farming structures.

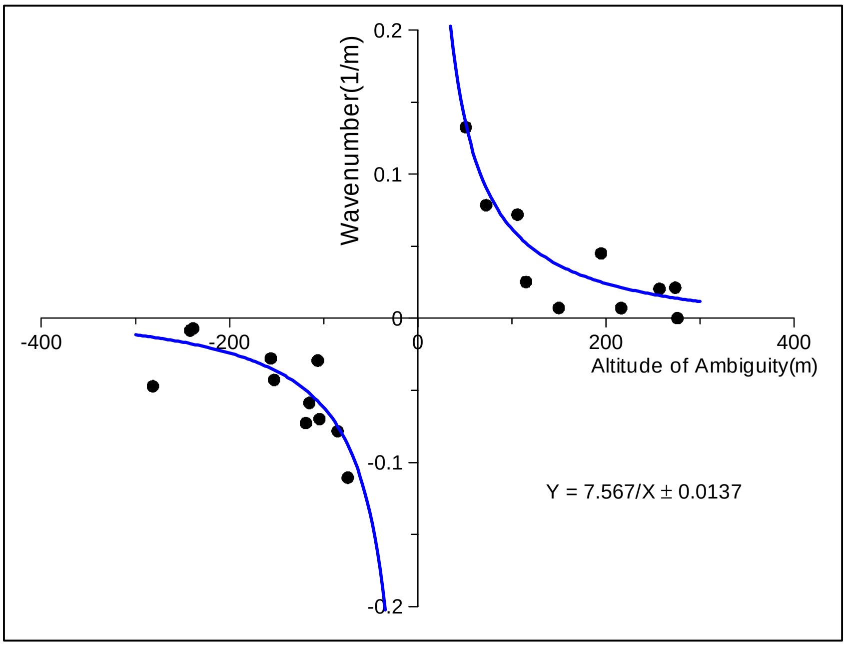


Figure 6. The altitude of ambiguity versus the interferometric phase of oyster farms.

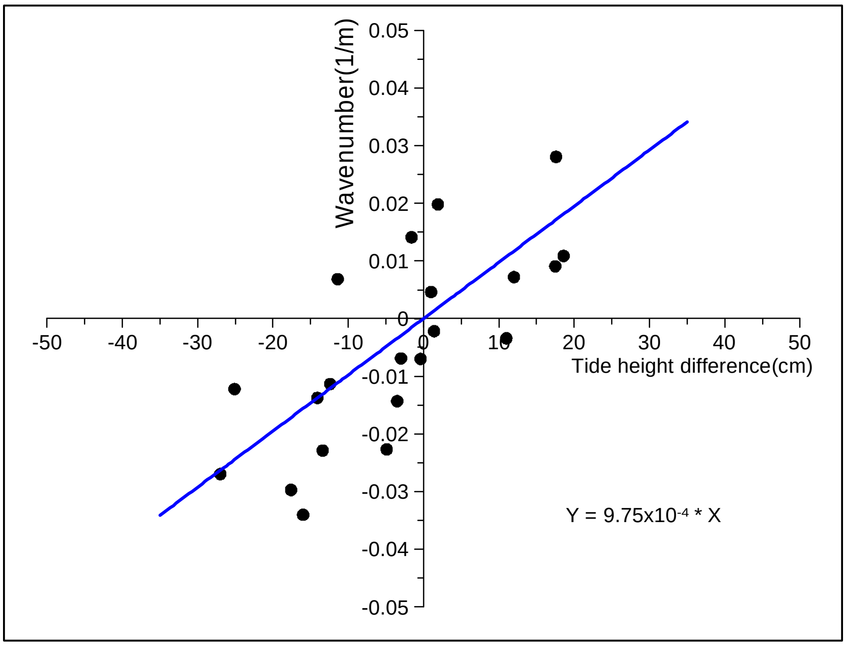


Figure 7. Linear relationship between tide height difference and residual interferometric phase after correction.

Future Works

If the measured SAR interferometric phase is directly proportional to the tidal conditions, one can possibly apply InSAR technique to the observation of sea level change. The results so far is, however, preliminary and many questions associated with these features are required to be investigated.

The major questions to be investigated are as follow:

1) Why L-band is more effective than C-band ? Are there other system parameters, for instances incidence angle, radar look direction, and polarization, governing the rendition ?
2) What is the properties of the backscattering ? Double bouncing by horizontal bars or corner reflection from vertical bars ?
3) Why is the interferometric phase closely related to the altitude of ambiguity ? Is it a JERS-1 orbit problem, or originated from backscattering geometry ?
4) Can you apply radar polarimetry to this problem ?
5) If the residual interferometric phase presents sea level change, how pricisely can we estimate it ?

Since JPL AIRSAR data is of a full polarization and provides airbone SAR interferometric pair, clues to understanding this interesting features can be achieved.

References

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[2] Seymour, M.S. and I.G. Cumming, 1996, An iterative algorithm for ERS baseline estimation, FRINGE'96, Sep. 30- Oct.2 1996, Zurich, Switzerland.

[3] Massonnet, D.D. and K.L. Feigl, 1998, Radar interferometry and its application to changes in the Earth's surface, Review of Geophysics, v.36, no.4, pp.441-500.