EVALUATION OF INTERFEROMETRIC COHERENCE OVER POLAR REGIONS WITH SPACE-BASED QUADRUPLE POLARIMETRIC SYNTHETIC APERTURE RADAR

Sang-Hoon Hong [(1)(2)], **Shimon Wdowinski** [(2)], **Don Atwood** [(3)], and **Jeong-Won Park** [(1)]

(1) Division of Polar Ocean Environment, Korea Polar Research Institute, Incheon, Korea
(2) Division of Marine Geology and Geophysics, University of Miami, FL, U.S.A.
(3) Michigan Tech Research Institute, Michigan Technological University, MI, U.S.A.

Abstract

There is concern that the global warming is being accelerated by the increase of the greenhouse gases. The polar region plays an important role for heat balance in the Earth system. Glacier has been identified as sensitive indicators of global climate change. The loss of snow and ice in glaciers and ice sheets affects sunlight reflection which is quite correlated with the albedo effect. It is evident that the continuous retreat of glaciers and loss of sea ice, as reported in the recent polar research [1]. Hence, the changing climate accelerates change of temperature and precipitation, which affect the total mass loss of glaciers. Thus monitoring on glacier can be very useful to understand the effects of global warming.

Recently space-based synthetic aperture radar (SAR) system with various polarizations have been launched and operated successfully. Interferometric SAR (InSAR) application has been widely used to monitor surfaces' displacement as well as to extract topographic information for various geodetic applications. Especially space-based SAR observation over polar regions has been very useful resource to detect surfaces' change such as movement of glacier, etc [2-3]. In the InSAR application, coherence is considered as a very critical parameter to evaluate the quality of an InSAR observation. However the InSAR application has been somewhat limited because of severe temporal decorrelation effect over snow or ice-covered regions. In this study, we evaluate interferometric coherence using quadruple polarimetric (quad-pol) TerraSAR-X (TSX) X-band observations over the polar regions. The quad-pol TSX datasets were acquired during Dual Receive Antenna (DRA) campaign period from April to May 2010. Total 57 images over 20 swaths above 60 degrees north latitude are retrieved. The temporal baselines of all interferometric pairs range from 11 to 22 days which are suitable to maintain high coherence level in the short wavelength X-band observations, and small geometric baselines of 12 ~ 226 m are discovered. The data were processed using the commercial GAMMA software, which calculates interferograms and coherence. Multi-looking was applied to reduce undesirable phase noise. The interferograms processing contains phase filtering to enhance the signal to noise ratio of the phase.

Our results represented high coherence in all polarization modes from 0.38 to 0.57, with highest values in VV, then HH, and lowest in HV or VH. It is very surprising that the short wavelength X-band SAR observations can maintain such a high coherence level, even though the temporal baseline is quite short. Also all the quad-pol interferograms showed very similar fringe patterns regardless of the polarization type. It is interesting that the highest value of coherence was found in the VV-pol. In general land application, the coherence of HH-pol is better than that of VV-pol. It implies that the scattering behavior in the medium of snow or ice is different from that of the vegetation covered land area. For further coherence analysis, we collected Total 25 TSX quad polarization images over various land cover type which is not covered snow or ice to compare the coherence characteristics. The six classes representing forest, agriculture, wetland, seaice, snow/glacier, and urban area are selected to evaluate the coherence. The VV-pol coherence is higher than that of HH-pol in the seaice and snow/glacier covered surface as preliminary coherence analysis. In the case of urban and wetland areas, the HH-pol shows higher level of coherence than the VV-pol. At the both of the forest and agricultural area, the difference of coherence of between the HH-pol and the VV-pol is not much. It is very interesting that the coherence level over snow/glacier covered surface is high as the urban area, though severe temporal decorrelation has been expected. Thus we suggest that the VV-pol could be chosen for the InSAR applications over the polar regions, if we can select the polarization at the SAR acquisition.

1. Preliminary coherence analysis

- Total 57 images over 20 swaths above 60 degrees northern high latitude.
- Temporal baselines: 11 – 22 days
- Geometric baselines: 12 – 226 m
- The ROI_PAC and GAMMA software were used to calculate repeat pass interferograms. The coherence analyses were conducted with estimation window of 5 by 5 pixels for all interferograms.
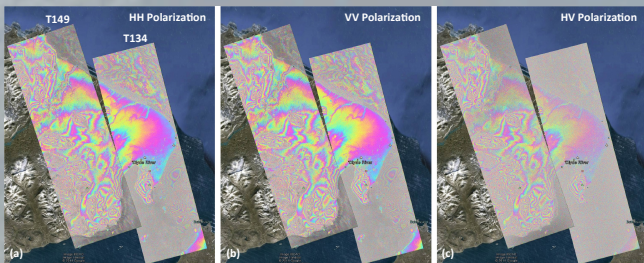- High coherence in all polarization modes: 0.38 – 0.57

Figure 1. Quadruple polarimetric interferograms over two tracks of T134 (11 April 2010 and 22 April 2010, Perpendicular baseline: -75.2 m, temporal baseline: 11 days) and T149 (12 April 2010 and 23 April 2010, Perpendicular baseline: -67.5 m, temporal baseline: 11 days) over Baffin, Canada. The highest coherence levels in VV, then HH, and lowest in HV or VH.
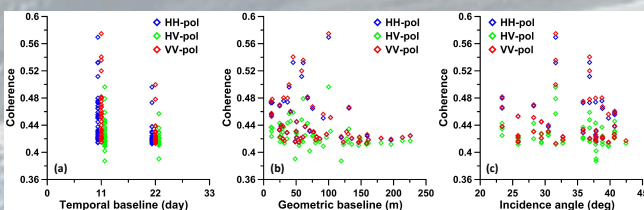

Figure 2. Coherence analysis of the TSX quad polarization data over northern polar regions (the region north of 60° north latitude). Co-polarization interferograms (HH and VV) show significantly higher coherence than the cross-polarization interferogram (HV). Especially, the VV co-polarization shows the highest level of coherence in the polar region. (a) Temporal decorrelation effect is significant, even though we have only limited dataset with at most small temporal baselines of 22 days (b) Short geometric baseline (< 125 m) promises to maintain high coherence in general, and (c) Incidence angle does not affect to maintain the coherence with the TSX dataset.

2. Summary of the preliminary coherence analysis

- The short wavelength (X-band) data show high coherence although common scattering theories suggest that the shorter wavelength SAR data has been suffered from temporal decorrelation even polar regions.
- However the coherence of the VV polarization is very slightly higher than that of the HH polarization. Thus archived imagery of HH polarization would also useful for InSAR application.
- Surprisingly the HV polarization signal can maintain coherence over the polar regions.
- It is very interesting that the VV polarization shows the best and the HH polarization represents the next in coherence level. Usually the HH polarization shows the best coherence level in the most of land application.
- Thus further coherence analysis will be performed to prove the coherence characteristics over snow or ice comparing with other TSX dataset collected over various land cover types.

3. Datasets

- Total 25 TSX quad polarization images over 9 swaths for various land cover types as below.
- Interferometric pairs with only 11-day temporal baseline are selected to reduce temporal decorrelation effect
- Perpendicular baselines: -127 – 256 m
- The ROI_PAC and GAMMA software were used to calculate repeat pass interferograms. The coherence analyses were conducted with estimation window of 5 by 5 pixels for all interferograms.

Table 1. List of TerraSAR-X X-band Synthetic Aperture Radar (SAR) interferometric pairs

Area	Date	Track	Incidence angle (°)	Perpendicular Baseline (m)
Isfahan (Iran)	2010-04-14/2010-04-25	N8 / stripFar_010	37.78	-62.38
Isfahan (Iran)	2010-04-25/2010-05-26	N8 / stripFar_010	37.78	86.39
Everglades (U.S.A.)	2010-04-16/2010-04-27	N44 / stripNear_008	32.68	-33.48
Everglades, (U.S.A.)	2010-04-21/2010-05-02	N112 / stripFar_006	29.36	-126.50
Ellesmere Is. (Canada)	2010-04-11/2010-04-22	N128 / stripNear_010	36.84	-45.33
Ellesmere Is. (Canada)	2010-04-22/2010-05-03	N128 / stripNear_010	36.84	58.56
San Francisco (U.S.A.)	2010-04-11/2010-04-22	N129 / stripFar_011	39.71	21.96
San Francisco (U.S.A.)	2010-04-22/2010-05-03	N129 / stripFar_011	39.71	-121.06
Baffin (Canada)	2010-04-12/2010-04-23	N149 / stripNear_004	23.38	-67.50
Baffin (Canada)	2010-04-23/2010-05-04	N149 / stripNear_004	23.38	131.31
Graham Is. (Canada)	2010-04-12/2010-04-23	N150 / stripFar_007	31.62	-60.92
Graham Is. (Canada)	2010-04-23/2010-05-04	N150 / stripFar_007	31.62	100.08
Taishan (China)	2010-04-13/2010-04-24	N157 / stripFar_007	31.58	-79.56
Taishan (China)	2010-04-24/2010-05-05	N157 / stripFar_007	31.58	256.01
Vancouver (Canada)	2010-04-25/2010-05-06	N167 / stripNear_008	32.60	126.70

4. Interferogram and Pauli-decomposition over snow/glacier area

- Pauli-based decomposition was applied for selection of the region of interest. (Blue: HH+VV, Red: HH-VV, Green: HV)
- Surface and volume scattering are dominant over the snow/glacier covered area, but a little of double bounce scattering.
- High coherence level was discovered despite of temporal decorrelation. It implies that the X-band SAR signal can be also useful to study for the velocity of the glacier or displacement over snow/glacier covered area
- In the surface scattering dominant area, generally, higher coherence is maintained than volume scattering dominant area.
- It is interesting that the coherence is maintained over the seaice which has not moved much for time span of two acquisitions.
- Seaice and snow/glacier classes are selected for the coherence analysis.
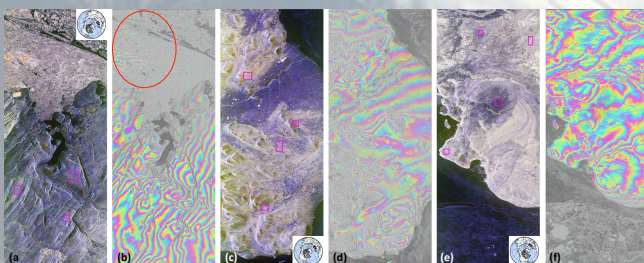

Figure 3. (a, c, e) Pauli decomposition display (Blue: HH+VV, Red: HH-VV, Green: HV), (b, d, f) Unfiltered flattened interferogram over snow/glacier covered surface. (a, b) Ellesmere Is. (Canada), (c,d) Baffin (Canada), and (e,f) Graham Is. (Canada)

5. Region selection

- In order to select region of interest to comparative analysis, six swaths dataset have been processed.
- Forest, agriculture, wetland and urban areas are selected to compare with the coherence from seaice and snow/glacier covered surface.
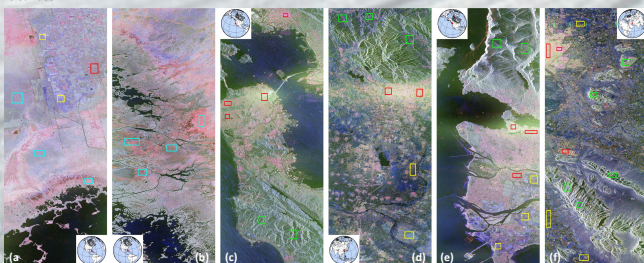

Figure 4. (a-f) Pauli decomposition display (Blue: HH+VV, Red: HH-VV, Green: HV), (a, b) Everglades (U.S.A.) (c) San Francisco (U.S.A.), (d) Taishan (China), (e) Vancouver (Canada) and (f) Isfahan (Iran)

6. Coherence analysis

- In the snow/glacier covered region, the coherence from the VV-pol shows higher level than that of the HH-pol.
- It is interesting that most of the coherence over the snow/glacier covered region is ranged from 0.16 to 0.62 which is high as the coherence (from 0.18 to 0.56) over the urban area.
- The HH-pol coherence is higher that the VV-pol in the wetland and urban areas.
- Similar level of coherence between the HH-pol and the VV-pol was maintained over the forest and agriculture areas.
- Thus we suggested that the VV-pol is preferred for interferometric application over the polar regions which are covered snow or glacier.
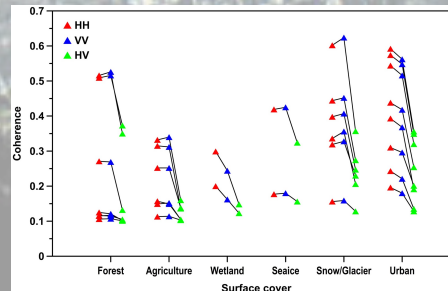

Figure 5. Coherence analysis over selected regions of forest, agriculture, wetland, seaice, snow/glacier and urban environment.

Acknowledgement

Reference

[1] Stammerjohn, Sharon, et al. "Regions of rapid sea ice change: An inter-hemispheric seasonal comparison." Geophysical Research Letters 39.6 (2012).
[2] Rignot, Eric, et al. "Recent Antarctic ice mass loss from radar interferometry and regional climate modelling." Nature Geoscience 1.2 (2008): 106-110.
[3] Joughin, Ian, et al. "Greenland flow variability from ice-sheet-wide velocity mapping." Journal of Glaciology 56.197 (2010): 415-430.