

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

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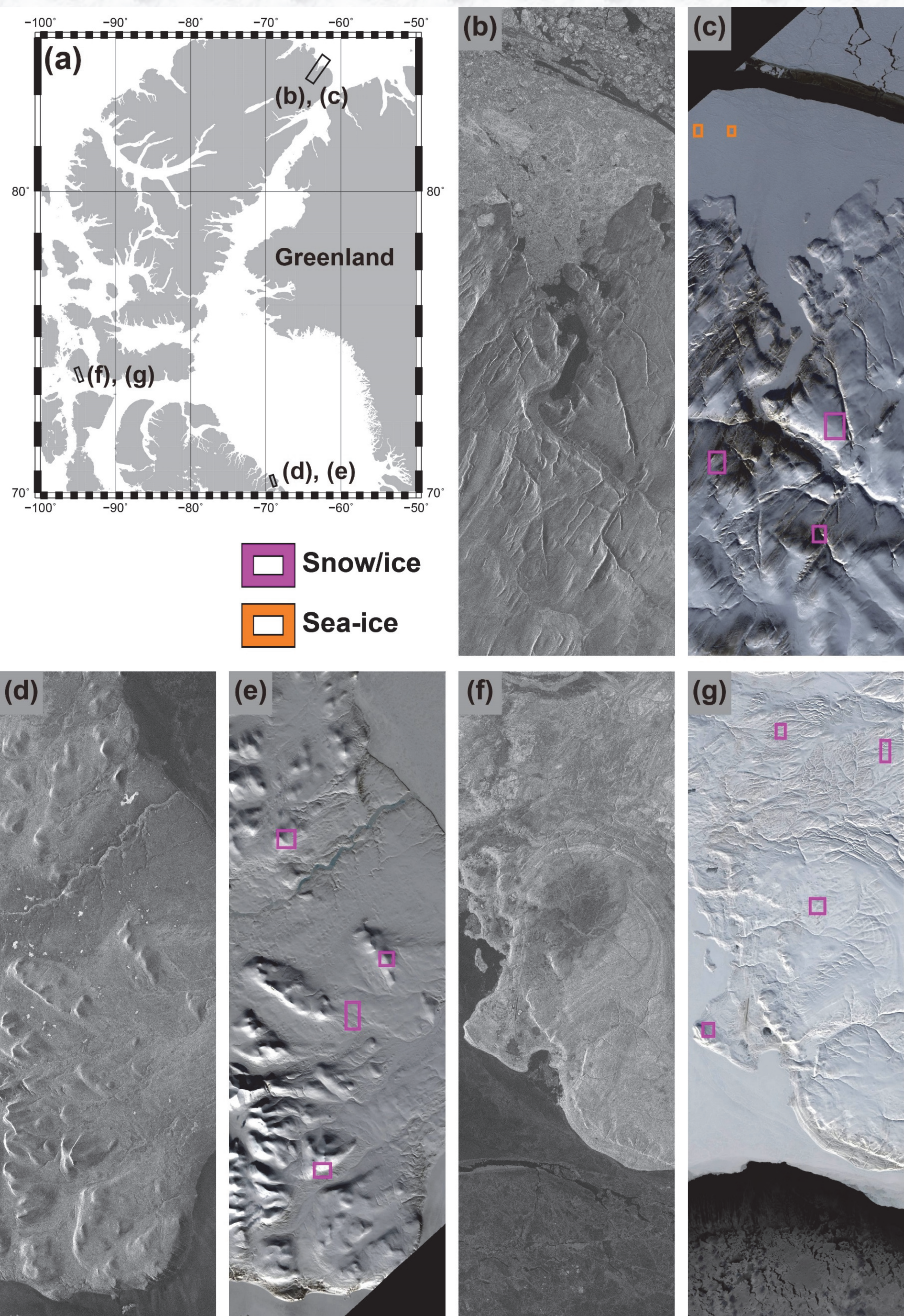


Abstract

Coherent space-based InSAR observations over snow/ice-covered areas have been very useful resources for detecting glacier movements [1-3]. Coherence is considered a critical parameter for evaluating the quality of an InSAR observation. This study evaluates interferometric coherence using quadruple polarimetric TerraSAR-X (TSX) X-band observations, which were acquired during Dual Receive Antenna campaign period in 2010. We used a total of 57 TSX quad polarization images acquired at latitude higher than 60 degrees north. The coherence analysis of the entire study areas yield high coherence levels in all polarization modes from 0.38 to 0.57, with highest values in VV, then HH, and lowest in HV. It is very surprising that the short wavelength X-band SAR observations can maintain such a high coherence level over snow/ice-covered surfaces. Because it was assumed that the shorter X-band wavelength radar signal can be significantly decorrelated by quickly changing surfaces like snow/ice-covered or vegetated regions. It is interesting that the highest coherence value was found in the VV-pol, because in most scattering environments, HH-pol coherence is the highest [4, 5]. We conducted a comparative coherence analysis by analyzing additional 25 TSX images acquired over six different scattering environments (classes) and compared their coherence characteristics. The scattering six classes are: forest, agriculture, wetland, sea-ice, snow/ice, and urban area. Our results show highest VV-pol coherence in snow/ice, sea-ice, and some agriculture and forest environments, whereas highest HH-pol coherence values are found in urban, wetland and some agriculture and forest environments. In forest and agricultural environments, both HH-pol and VV-pol show similar degree of coherence. In summary, our results indicate that VV-pol is preferable for X-band InSAR applications over the snow/ice-covered areas.

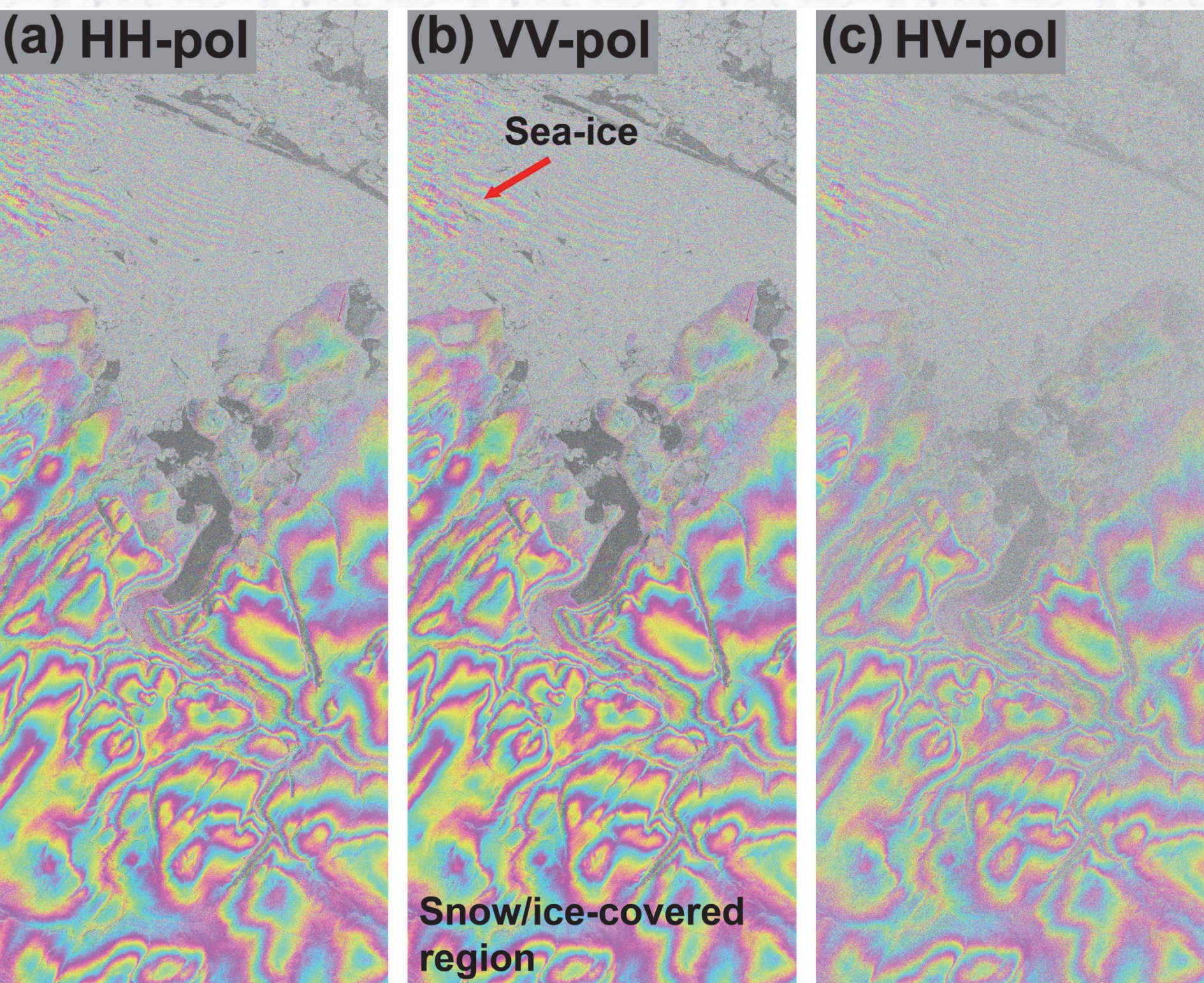
1. Study area for snow/ice-covered and sea-ice region

- (a) Location map showing three swaths of the TSX quad-pol data over the study areas.
- The rest of the figure presents SAR amplitude (HH-pol) and Landsat-8 Operational Land Imager (OLI) optic images of our study areas in Canada, which include the Ellesmere Island (b-c), Baffin Island (d-e), and Cornwallis Island (d-e).
- Selected areas used for quantitative coherence analysis of snow/ice-covered surface are shown in magenta and of sea-ice regions are shown in orange.



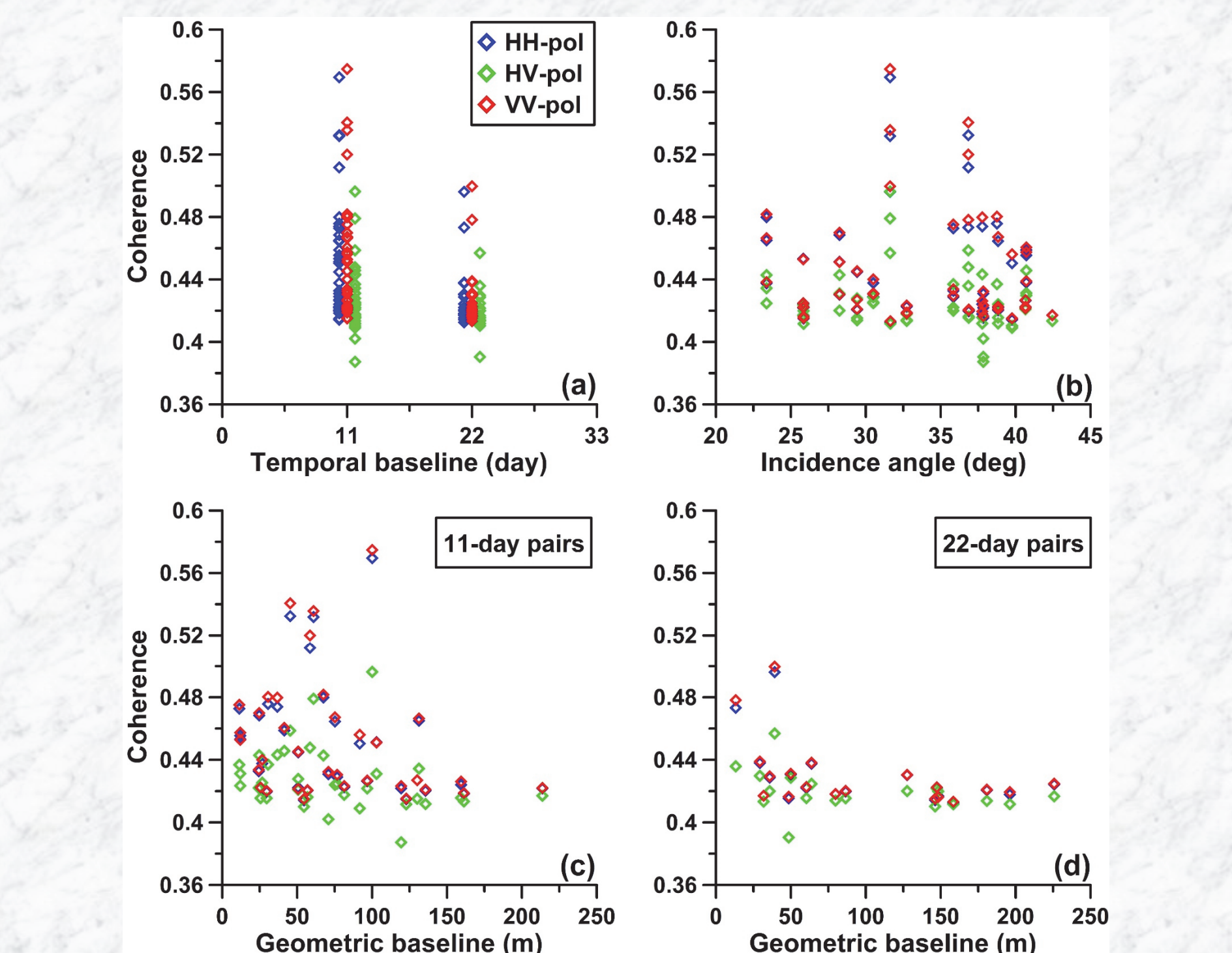
2. First dataset

- 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.
- The interferograms dates are: 2010-04-11 and 2010-04-22 (11 day temporal baseline) and its perpendicular baseline is -45.33 m.



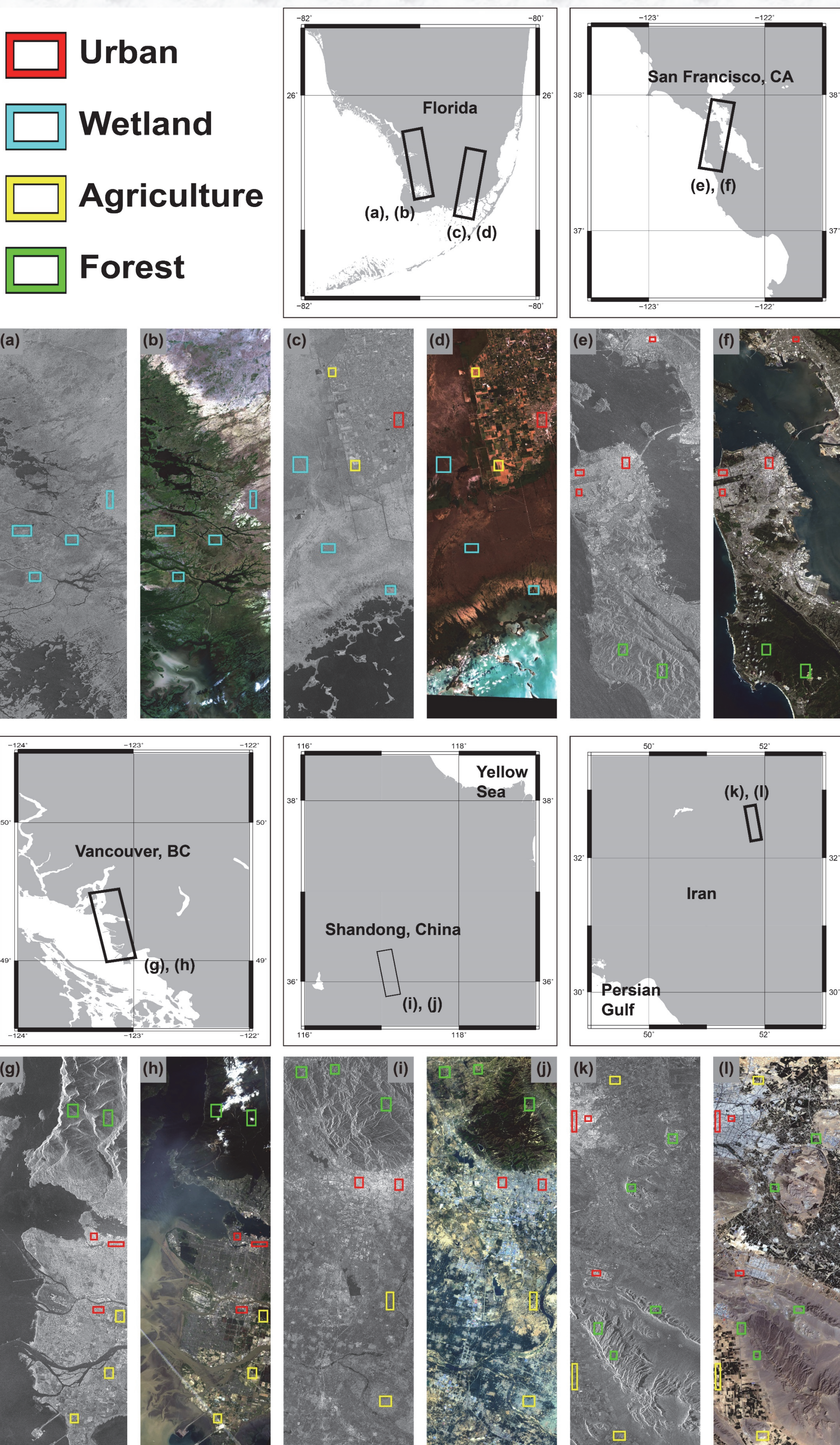
3. Preliminary coherence analysis

- (a) Coherence versus temporal baseline. Temporal decorrelation effect is significant, even though we have only limited a dataset with temporal baselines of only 11 and 22 days.
- (b) Coherence versus incidence angle
- (c) Coherence versus geometric baseline with 11-day temporal baseline pairs
- (d) Coherence versus geometric baseline with 22-day temporal baseline pairs
- Short geometric baseline (< 100 m) is showing an overall relatively high coherence.
- The co-pol interferograms (HH and VV) show significantly higher coherence than the cross-pol interferogram (HV).
- VV co-polarization shows the highest level of coherence in the polar region.



4. Study area for comparative analysis

- SAR amplitude (HH-pol) and the Landsat-8 Operational Land Imager (OLI) optic images of other non-snow/ice cover areas used for comparative coherence analysis (a-l).
- Location maps are displayed at the top of each images. (a-d) Everglades (U.S.A.), (e-f) San Francisco (U.S.A.), (g-h) Vancouver (Canada), (i-j) Taishan (China), and (k-l) Isfahan (Iran). Four classes of urban (red), wetland (cyan), agriculture (yellow) and forest (green) were chosen for the quantitative coherence analysis.



5. Second dataset

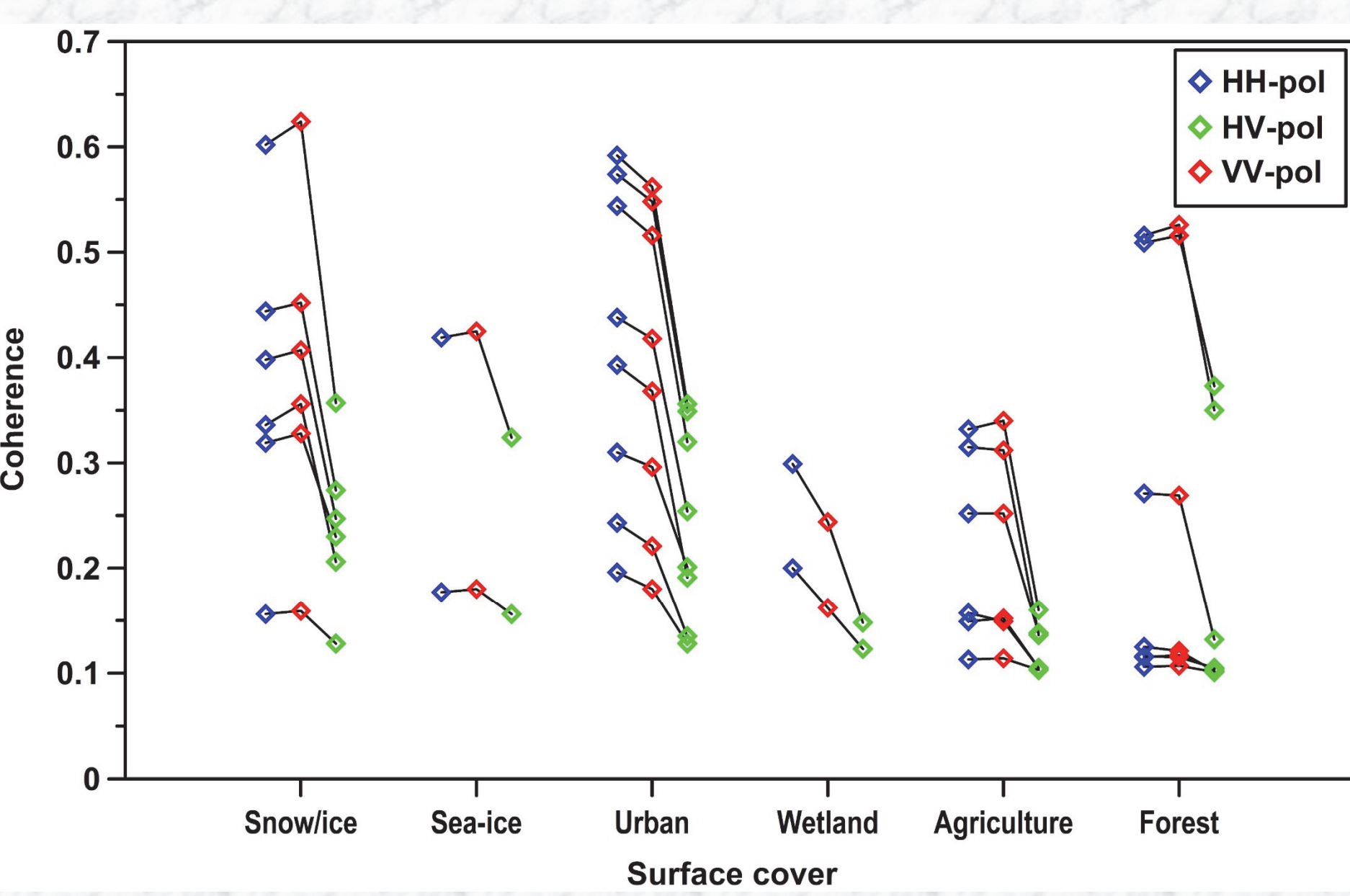
- Total 25 TSX quad polarization images over 9 swaths for various land cover types as below.
- Interferometric pairs with only 11-day temporal baseline are selected to reduce temporal decorrelation effect
- Perpendicular baselines: -127 – 256 m
- The ROI_PAC and GAMMA software were used to calculate 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 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

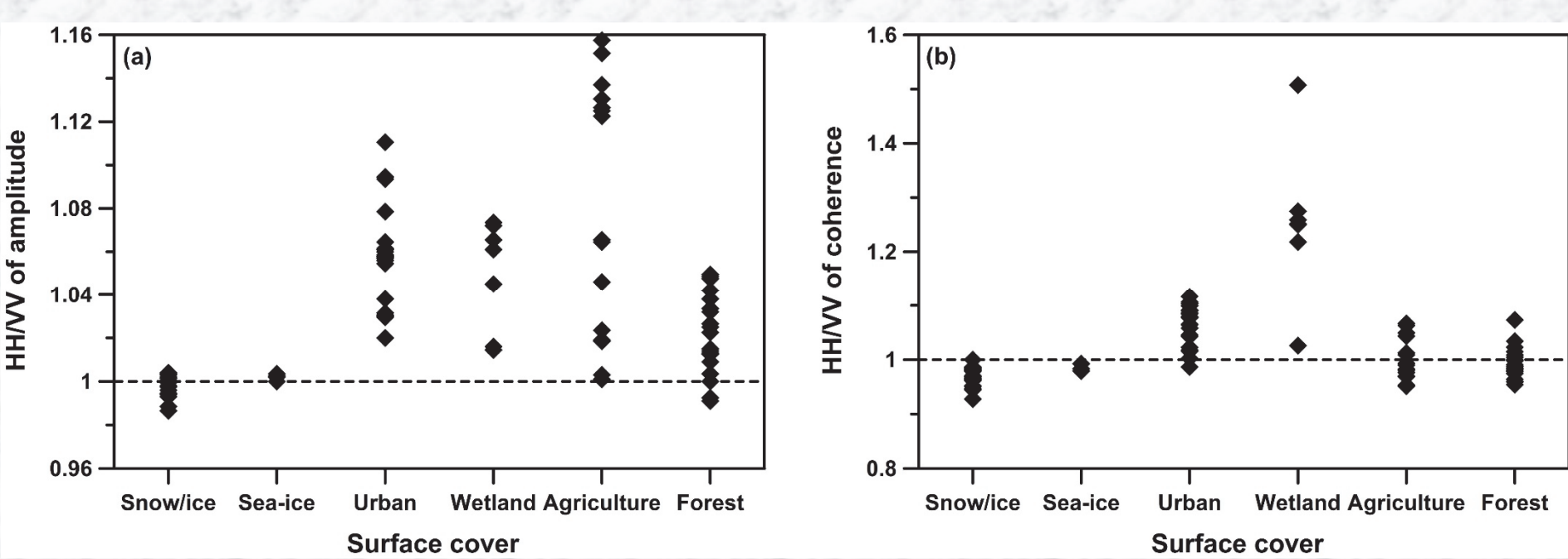
6. Coherence analysis

- Coherence analysis over selected six classes of snow/ice, sea-ice, urban, wetland, agriculture and forest regions.
- The VV-pol shows stronger coherence than the HH-pol in the snow/ice-covered regions, whereas the higher coherence in the HH-pol is observed at the urban and wetland areas compared with the VV-pol.
- The similar degree of coherences at between the HH-and the VV-pol is maintained at the agriculture and forest areas.



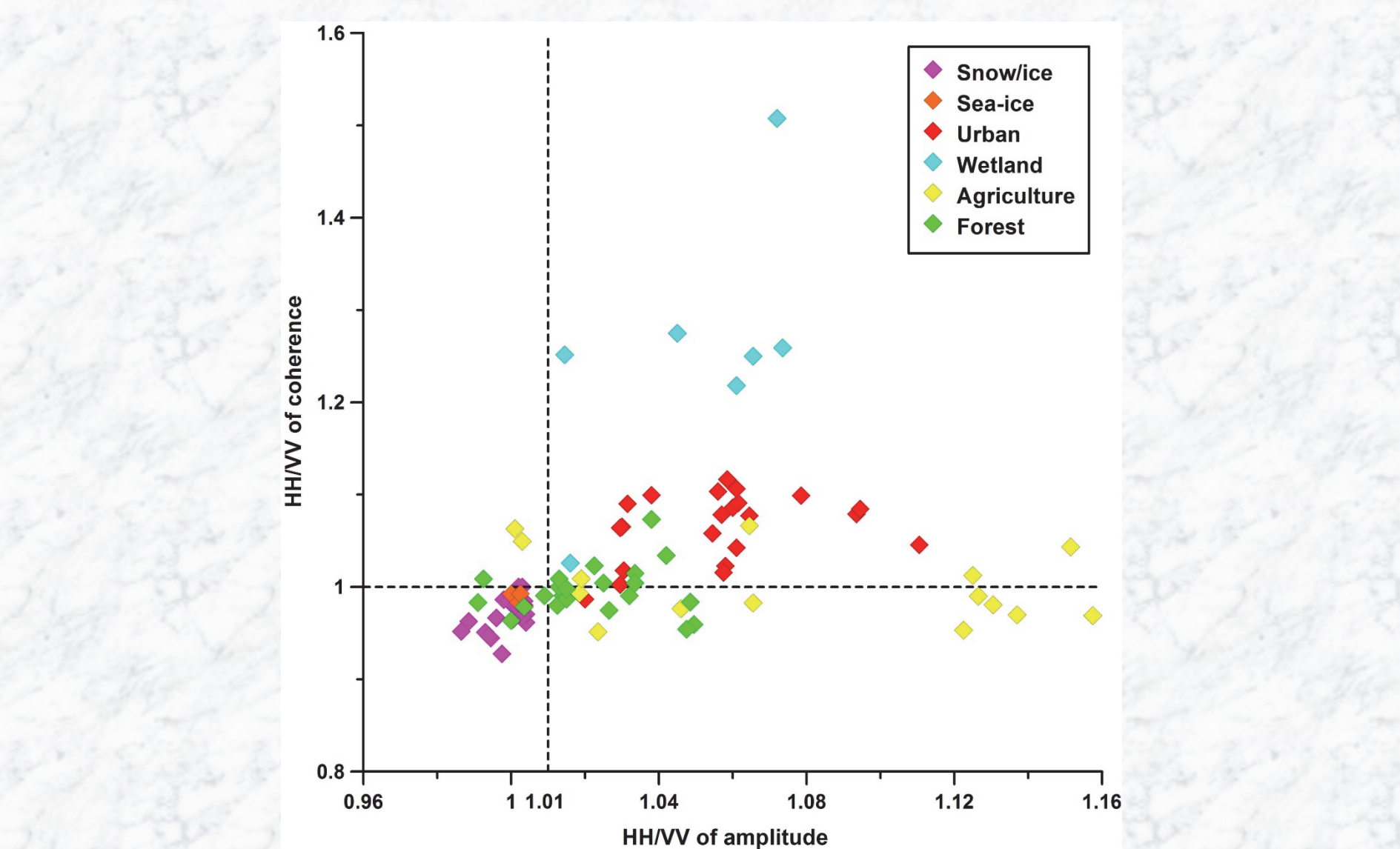
7. HH/VV of amplitude versus HH/VV of coherence

- Co-polarization ratio (HH/VV) of amplitude (a) and coherence (b) over the six studied classes of surface cover types.
- The amplitude ratios (a) show a similar or slightly higher VV-pol values snow/ice-covered and sea-ice regions and significantly higher HH-pol values in the non-snow/ice regions.
- The coherence ratios show higher VV-pol values over snow/ice-covered and sea-ice regions, similar coherence HH- and VV-pol level in agriculture and forest areas, and significantly higher HH-pol coherence in urban and wetland areas.



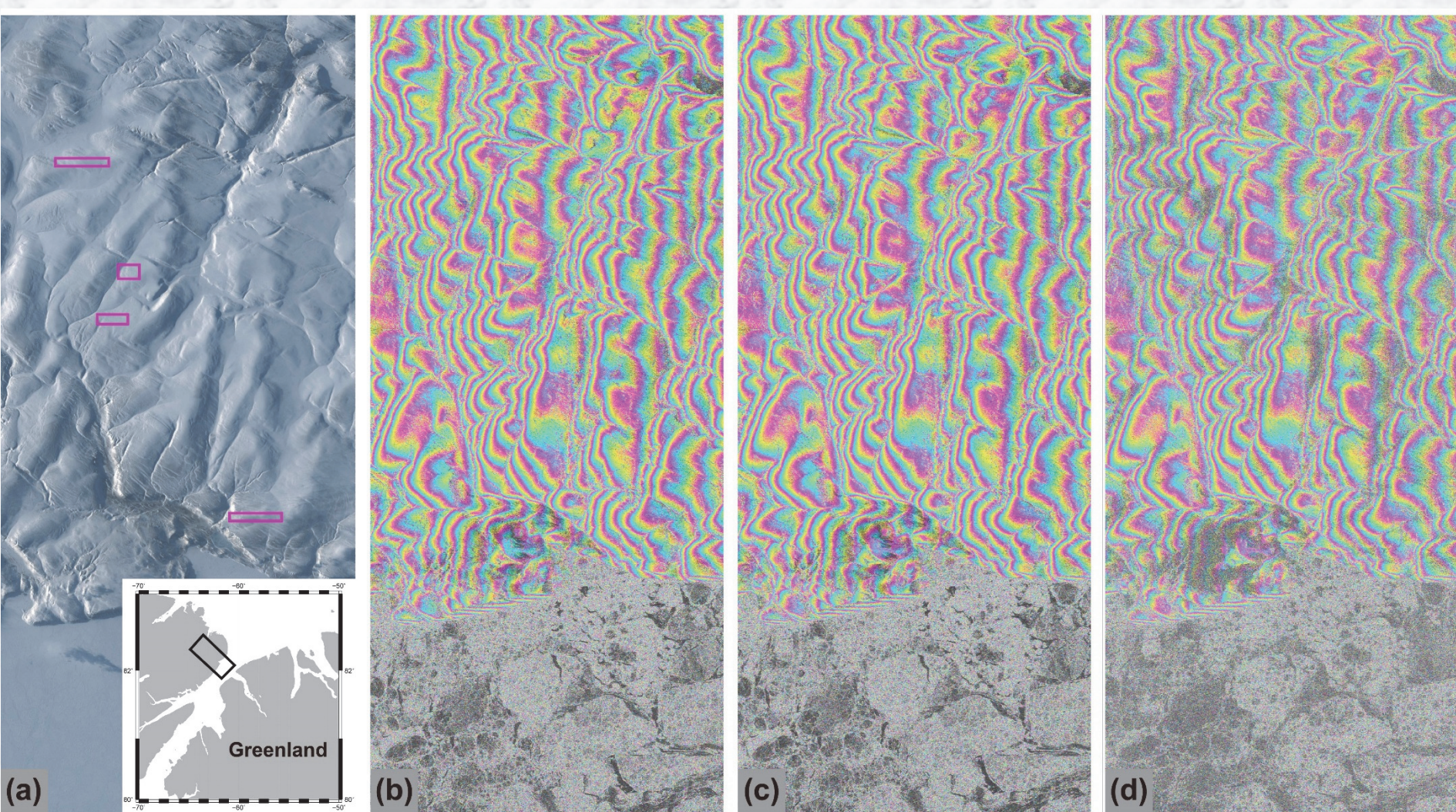
8. HH/VV of amplitude versus HH/VV of coherence

- Co-polarization ratio (HH/VV) of amplitude (a) and coherence (b) over the six studied classes of surface cover types.



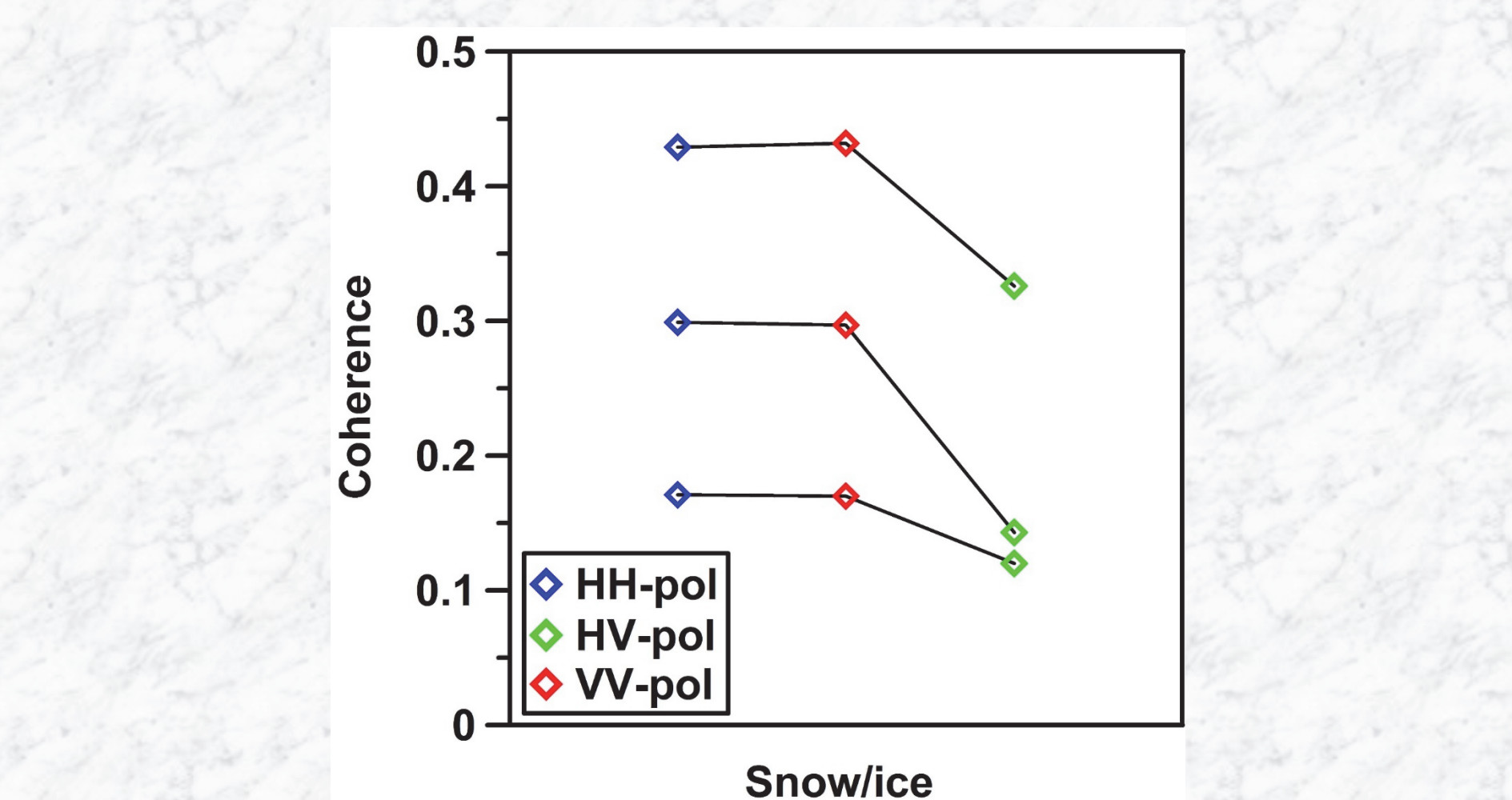
9. Evaluation of L-band quad-pol SAR observation

- The Landsat-8 OLI image (a) and the ALOS quad-pol interferograms (b-d) (2007-03-29 and 2007-05-14, perpendicular baseline: -236 m, temporal baseline: 46 days) of snow/ice-covered regions in the Ellesmere Island, Canada. The selected snow/ice-covered regions for the coherence analysis are shown in magenta color as shown (a). The three interferograms are HH (b), VV (c), and HV (d) show a very similar fringe pattern with similar level of coherence over the snow/ice-covered regions. It is interesting that the HV-pol interferogram (d) maintains very good coherence comparing with the co-pol interferograms (b and c).



10. HH/VV of amplitude versus HH/VV of coherence

Coherence analysis over snow/ice-covered region with the ALOS quad-pol L-band SAR observations. The HH-pol and VV-pol shows very similar level of coherence, and the HV-pol shows the lowest level of coherence.



11. Summary

- The VV-pol provides better coherence than the HH-pol over the snow/ice-covered regions.
- A comparative analysis between six land cover environments indicates that the high VV coherence is dominant only in the snow/ice and sea-ice environments.
- In other environments either HH-pol produces highest coherence (urban and wetlands) or both co-pol coherences are similar (agriculture and forests).
- Coherent interferometric phases were well maintained in the most of the snow/ice-covered regions as long as the temporal baseline was 11-day. Although some interferometric pairs with the 22-day temporal baseline also produce good coherence (> 0.4), the coherence level was significantly degraded compared to the 11-day interferograms.
- Our analysis also revealed that smaller geometric perpendicular baseline (< 100 m) can yield higher coherence over snow/ice-covered regions.
- Hence, the optimal conditions for interferometric application to observe snow/ice-covered regions with TSX observation involves VV-pol acquisitions with short temporal and short geometrical baselines.

12. Acknowledgement

- We thank to DLR to access TSX and JAXA and ASF to access ALOS PALSAR
- This study was supported by KOPRI project of PE16040.
- This work was also funded through NASA's award number NNX13AP95G.

13. Reference

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