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한국지구물리 · 물리탐사학회
추계학술대회 및 정기총회

Evaluation of interferometric coherence over snow/ice-covered areas with space-based quadruple polarimetric X-band synthetic aperture radar

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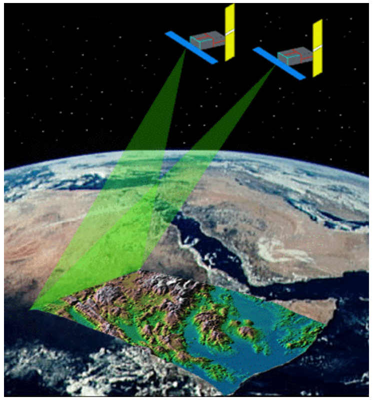
Why SAR?

- Independent on day-and-night or weather condition to get image, because it uses microwave electro-magnetic signals.

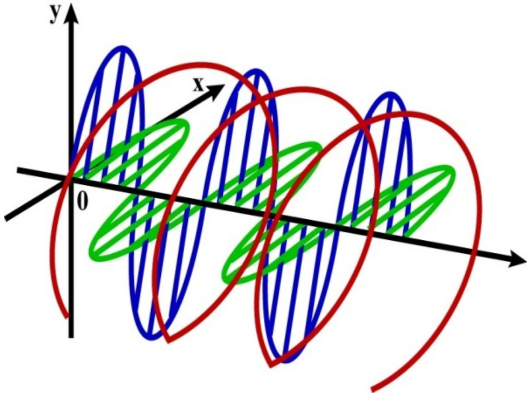
- Dielectric constant of Microwave signals is sensitive to water surface or moisture and surface roughness, thus SAR is very useful to discriminate ice in the ocean and classify the ice type.

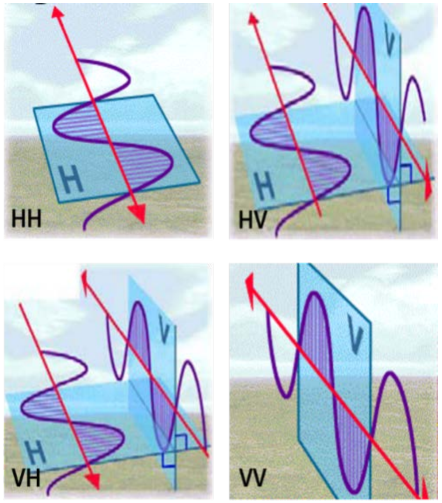
- Interferometric SAR application provides topographic mapping, estimation of displacement, monitoring of ice movement velocity, etc.

- Polarimetric SAR image is very useful to classify the ice surface type , because it provides various scattering behavior information on the surface.



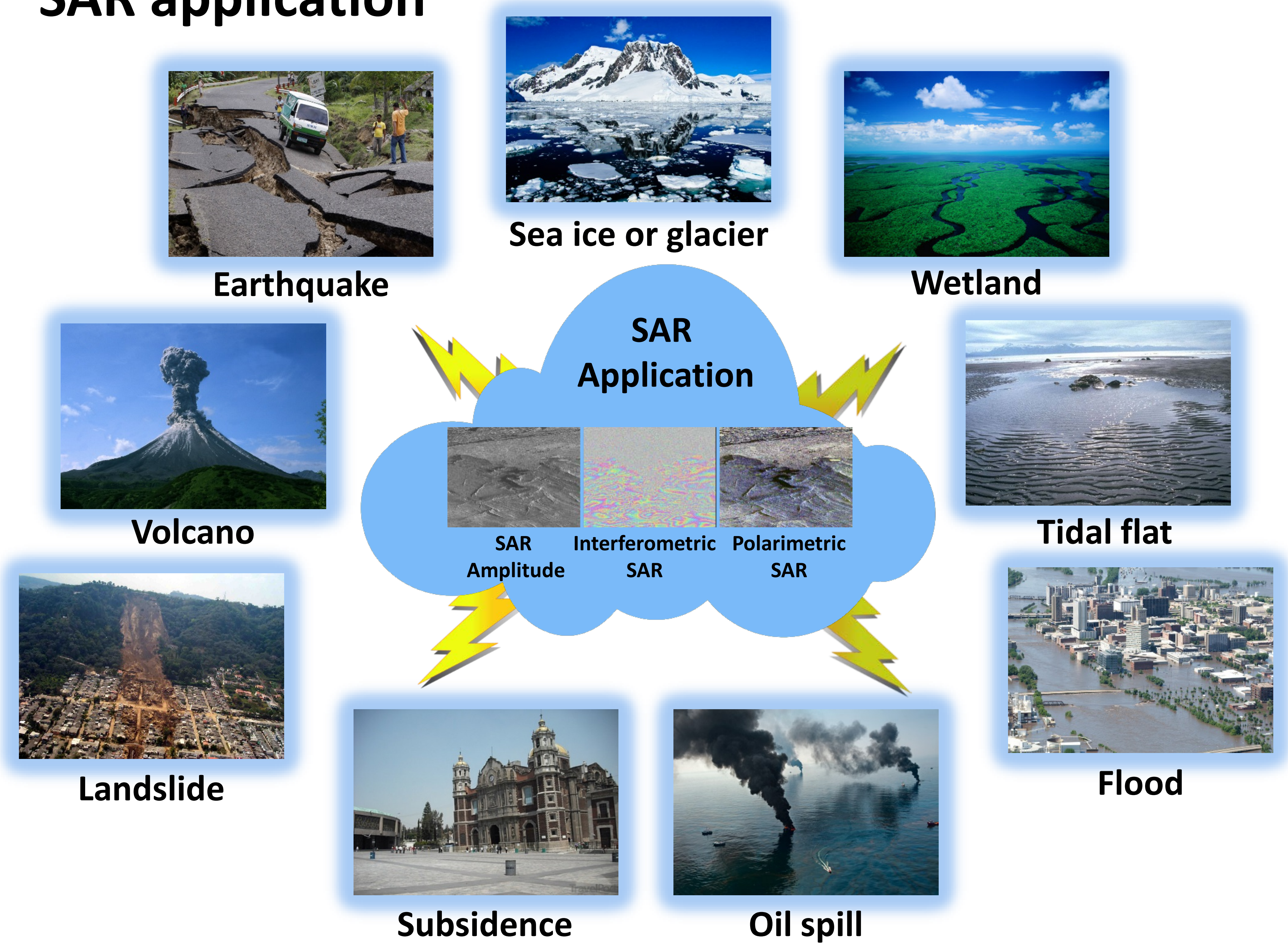
Two or more data acquisition of the same area from nearby location (< 1000 m)

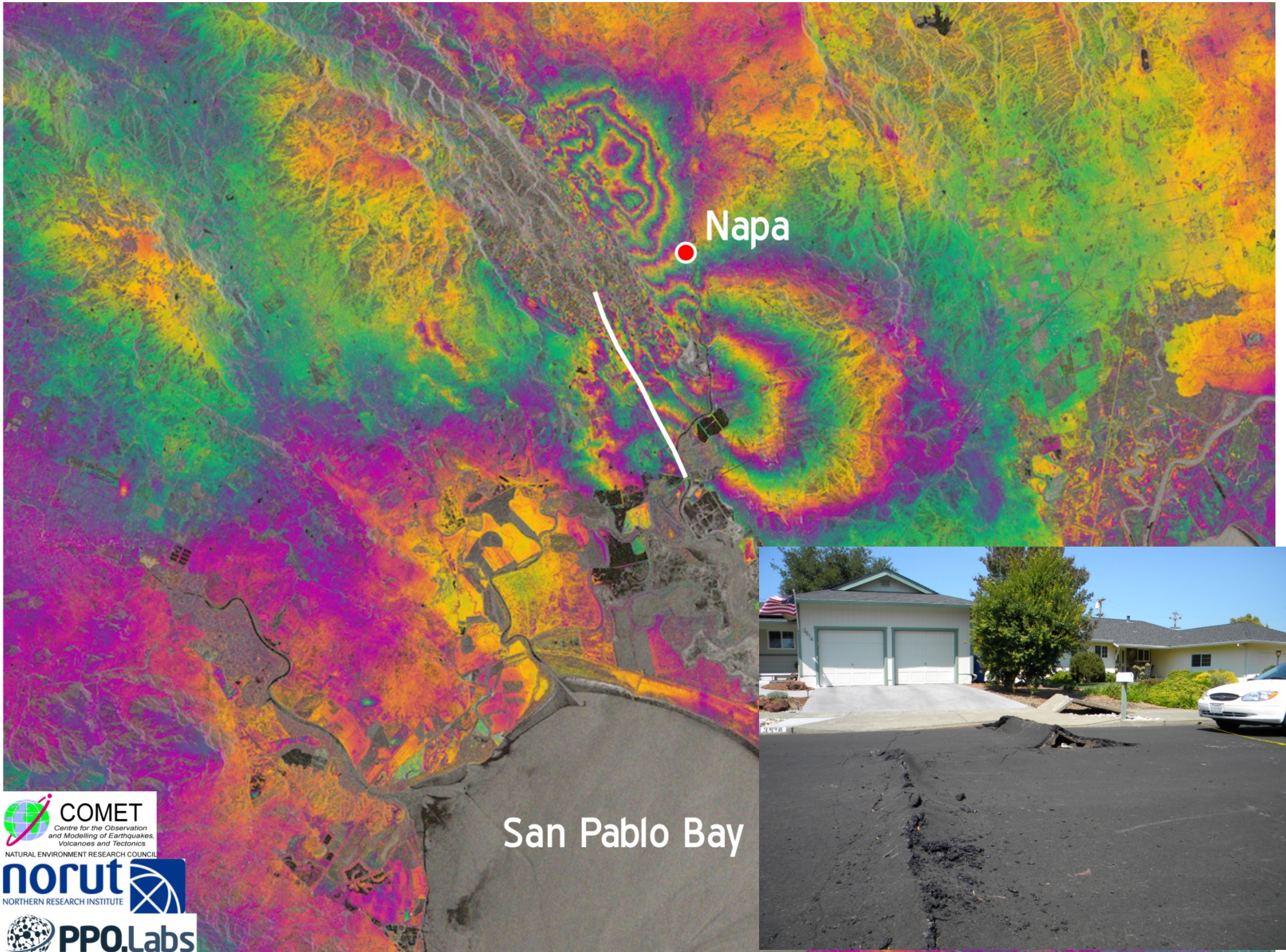




- Electric field is composed of two orthogonal sinusoidal waves with different amplitude and phases.

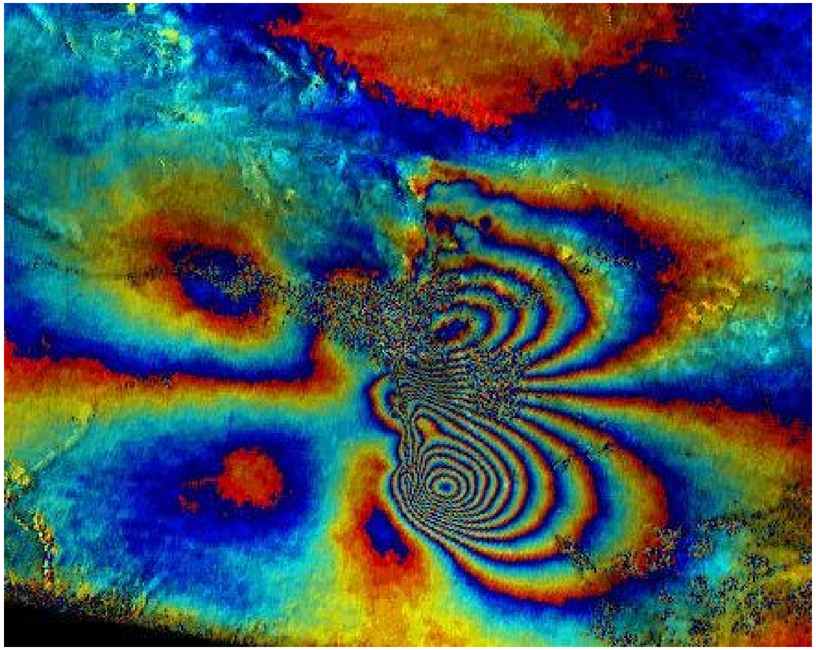
SAR application





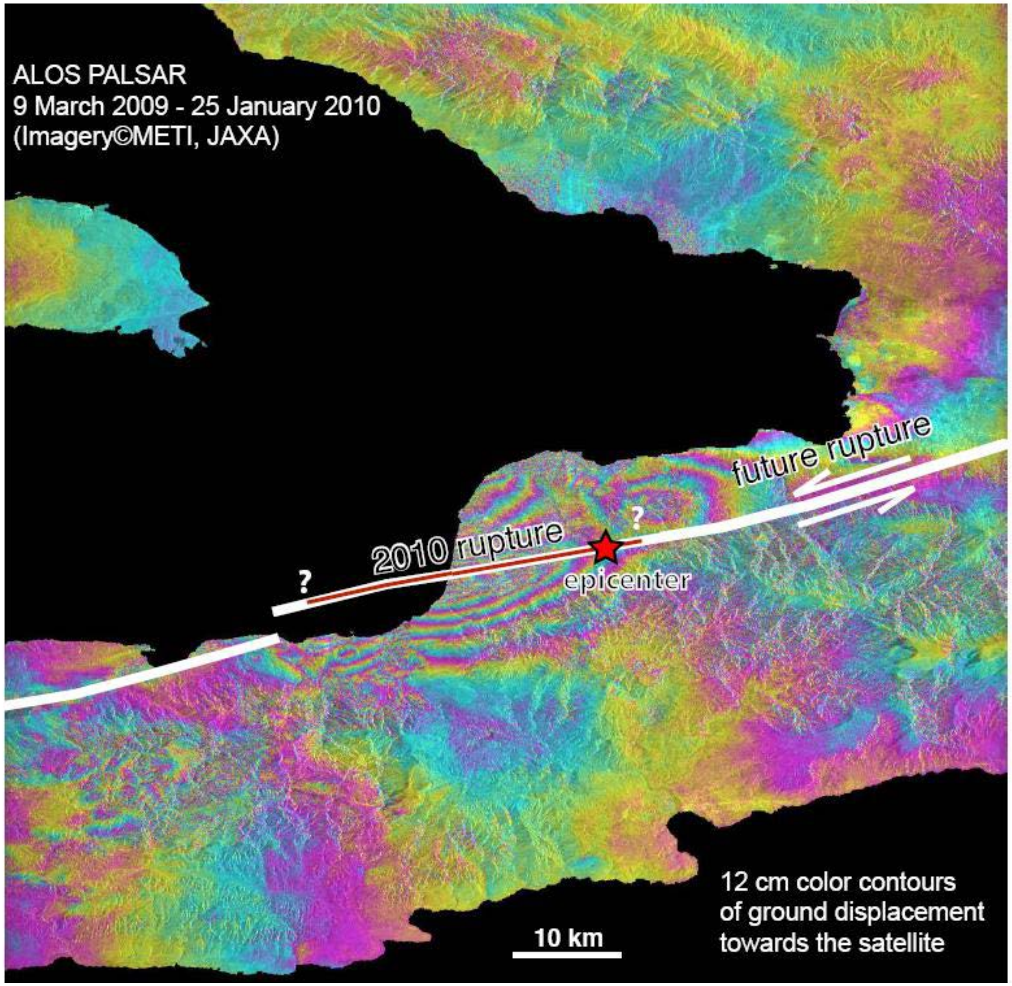
http://ewf.nerc.ac.uk/2014/09/02/new-satellite-maps-out-napa-valley-earthquake/

Radar image for Earthquake



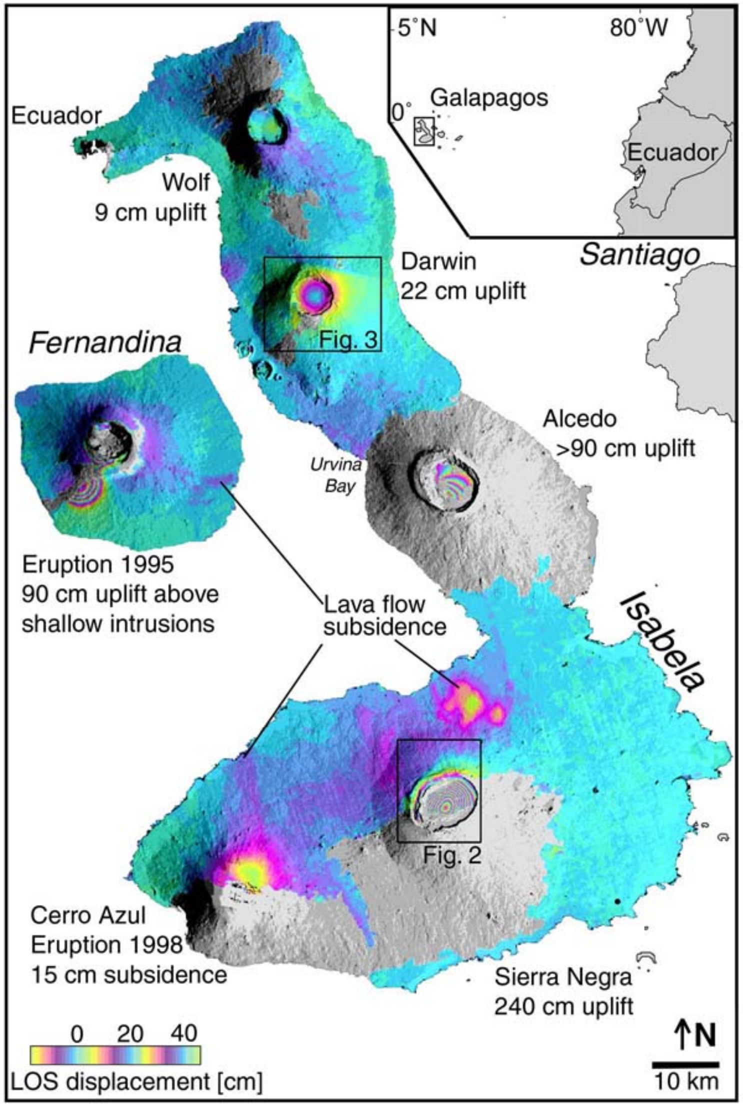
Bam Earthquake at Iran
(From ESA)

GROUP ON
EARTH OBSERVATIONS

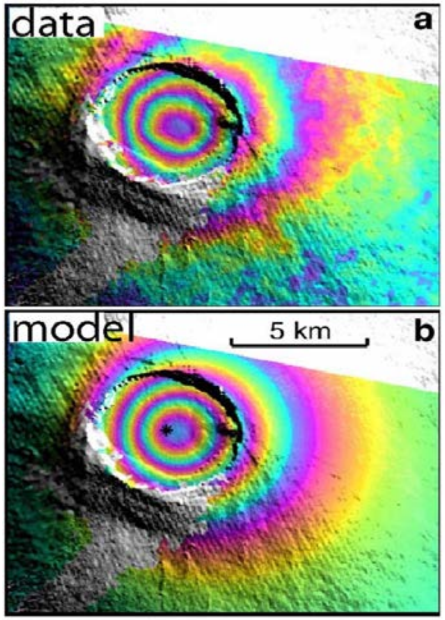


Haiti Earthquake (From U. of Miami)

Volcano

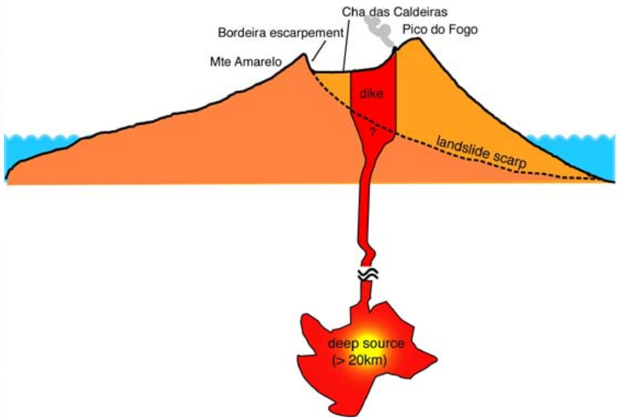


Darwin volcano



Central magma reservoir beneath caldera at 3 km depth

Fogo, Cape Verde - structural model



Surface deformation of Galapagos volcano (From U. of Miami)

InSAR application

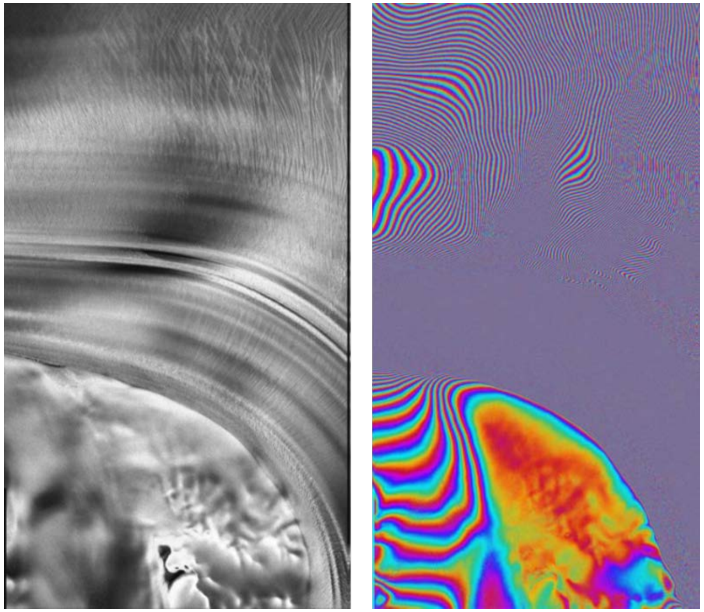
- Interferometric SAR application

: Estimation of topographic height and velocity of movement of glacier or sea ice

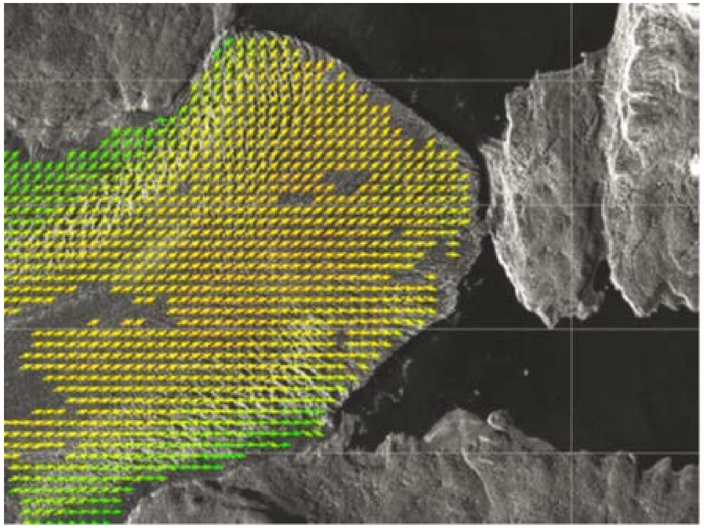
: Estimation of subsidence on bare rock in polar region

: Include change detection topography, boundary, thickness over polar region

: Include InSAR data processing and development algorithm for time-series displacement



Interferometric SAR application using TerraSAR-X@DLR



Velocity of glacier movement with Cosmo-SkyMed@ASI

Coherence

- **A measure of correlation in an interferogram**

- **The coherence ranges from 0.0 to 1.0**

- **A measure of the quality of an interferogram**

- **0.0 coherence : no useful information**

- **1.0 coherence : perfect information**

Decorrelation factor

- **Geometric decorrelation**
  : generate the difference in the incidence angle between two acquisitions

- **Doppler centroid decorrelation**
  : caused by the differences in the Doppler centroids between two acquisitions

- **Temporal decorrelation**
  : caused by surface changes in the terrain between temporal time span

- **Volume decorrelation**
  : generated by different penetration depth in a medium, and joined with the temporal decorrelation

- **Thermal or system noise decorrelation**
  : caused by the satellite system including antenna characteristics and gain factors

- **Processing decorrelation**
  : mainly caused by the co-registration including re-sampling the data

First dataset

- **TerraSAR-X (TSX) Dual Receive Antenna (DRA) campaign data**
  : From April to May 2010
  : Quadruple polarization and along track interferometric products
  : Still open calls in http://sss.terrasar-x.dlr.de

- **In general mode, TSX do not collect quadruple polarization products.**

- **Total 57 images over 20 swaths**

- **Temporal baseline: 11-22 days**
- **Geometric baseline: 12-226 m**
- **Incidence angle: 24-43 degress**

Second dataset

- **Total 25 images over 20 swaths**
- **Temporal baseline: 11 days**
- **Geometric baseline: -127-256 m**

Parameter	TerraSAR-X
Carrier frequency	X-band (9.6 GHz)
Wavelength	3.1 cm
Polarization	Quad-pol
Revisit cycle	11 days
Pulse repetition frequency	2915 - 3197 Hz
ADC sampling rate	164.8 MHz
Azimuth pixel spacing	2.35 ~ 2.43 m
Range pixel spacing	0.91 m

Second dataset

Site	Location	SAR image		Track	Incidence angle (°)	Perpendicular Baseline (m)
		Master	Slave			
A	Ellesmere Is. (Canada)	2010-04-11	2010-04-22	N128 / stripNear_010	36.84	-45.33
A	Ellesmere Is. (Canada)	2010-04-22	2010-05-03	N128 / stripNear_010	36.84	58.56
B	Baffin Is. (Canada)	2010-04-12	2010-04-23	N149 / stripNear_004	23.38	-67.50
B	Baffin Is. (Canada)	2010-04-23	2010-05-04	N149 / stripNear_004	23.38	131.31
C	Cornwallis Is. (Canada)	2010-04-12	2010-04-23	N150 / stripFar_007	31.62	-60.92
C	Cornwallis Is. (Canada)	2010-04-23	2010-05-04	N150 / stripFar_007	31.62	100.08
D	Everglades (U.S.A.)	2010-04-16	2010-04-27	N044 / stripNear_008	32.68	-33.48
E	Everglades (U.S.A.)	2010-04-21	2010-05-02	N112 / stripFar_006	29.36	-126.50
F	San Francisco (U.S.A.)	2010-04-11	2010-04-22	N129 / stripFar_011	39.71	21.96
F	San Francisco (U.S.A.)	2010-04-22	2010-05-03	N129 / stripFar_011	39.71	-121.06
G	Vancouver (Canada)	2010-04-25	2010-05-06	N167 / stripNear_008	32.60	126.70
H	Taishan (China)	2010-04-13	2010-04-24	N157 / stripFar_007	31.58	-79.56
H	Taishan (China)	2010-04-24	2010-05-05	N157 / stripFar_007	31.58	256.01
I	Isfahan (Iran)	2010-04-14	2010-04-25	N008 / stripFar_010	37.78	-62.38
I	Isfahan (Iran)	2010-04-25	2010-05-06	N008 / stripFar_010	37.78	86.39

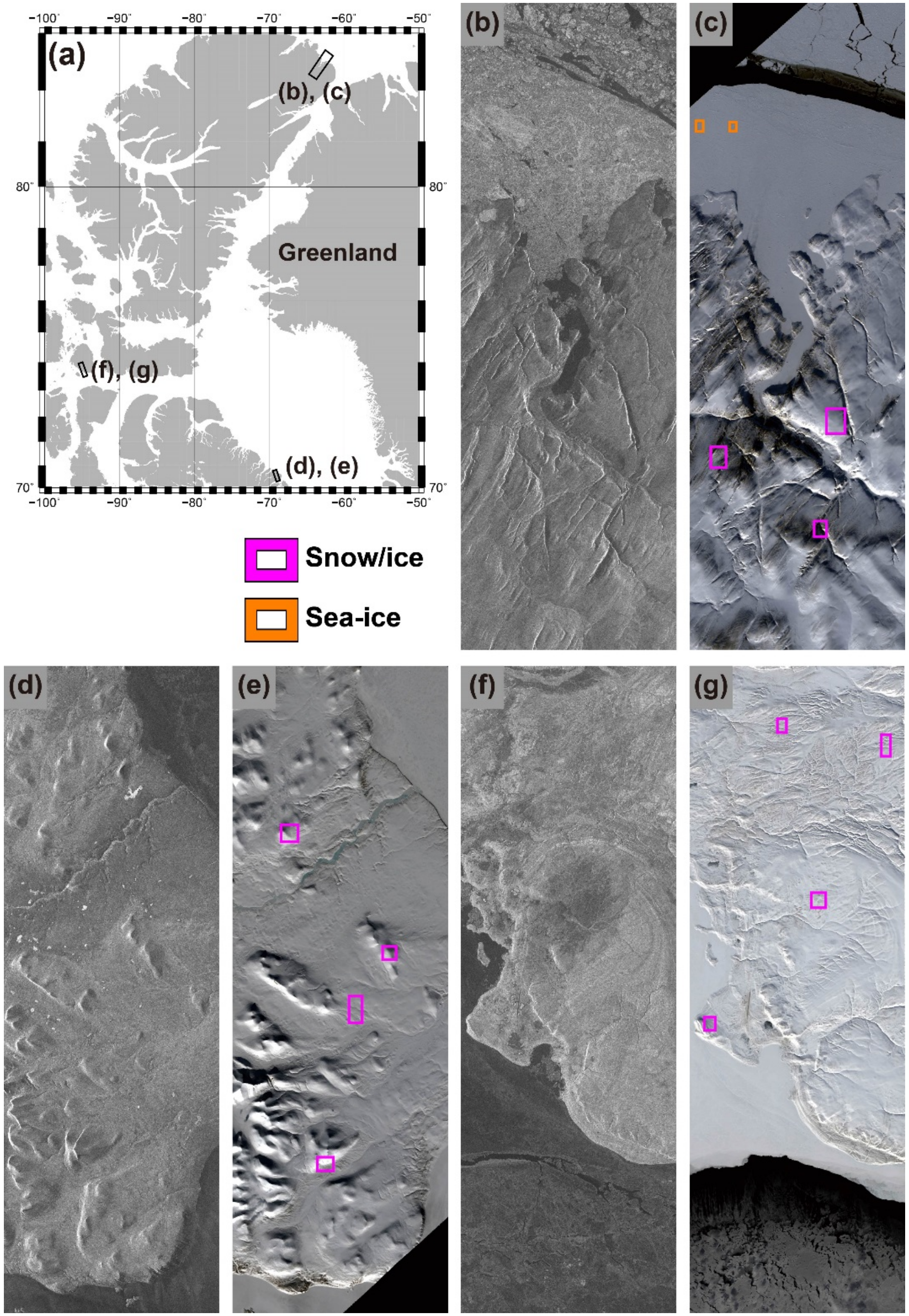
Interferometric processing

- **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**

- **Interpreter programming such as perl or python was used for computing efficiency**

Study areas

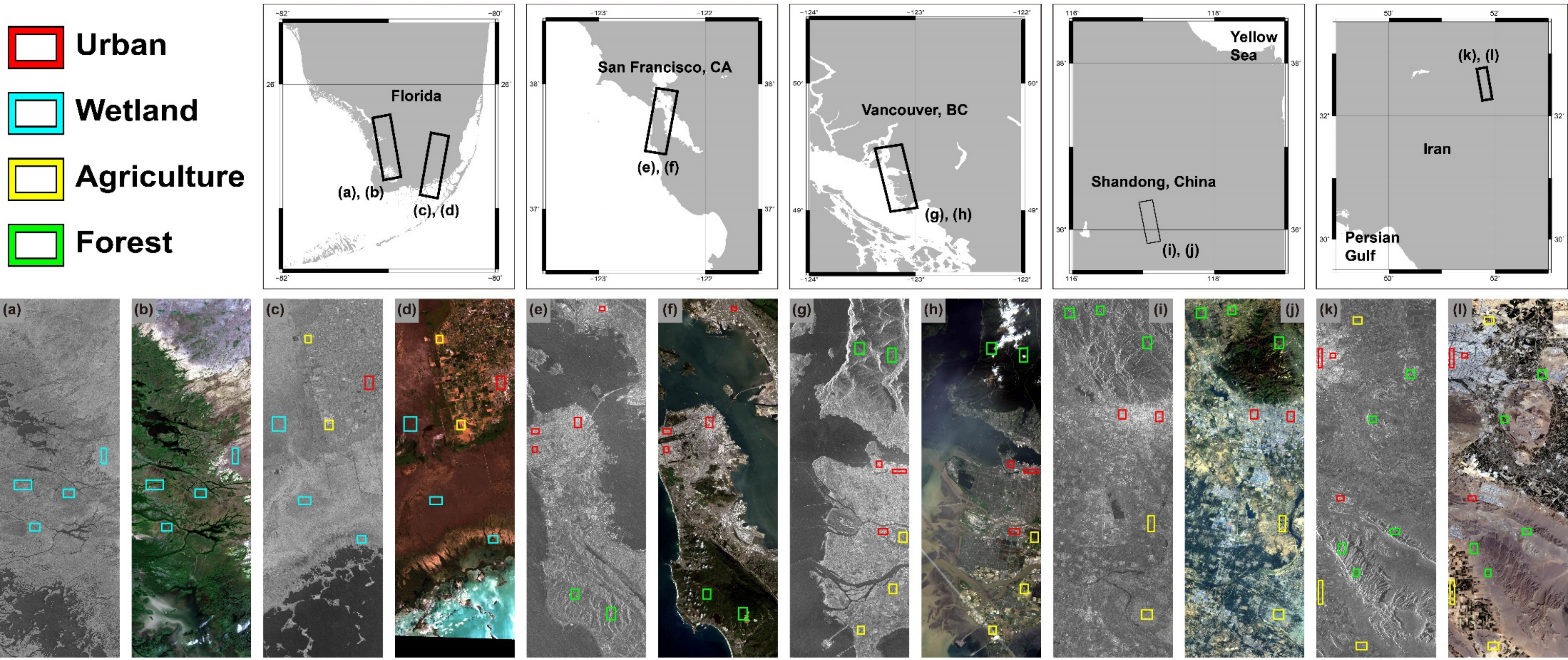


- (a) Location map showing three swaths of the TSX quad-pol data over the study areas.

- 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).

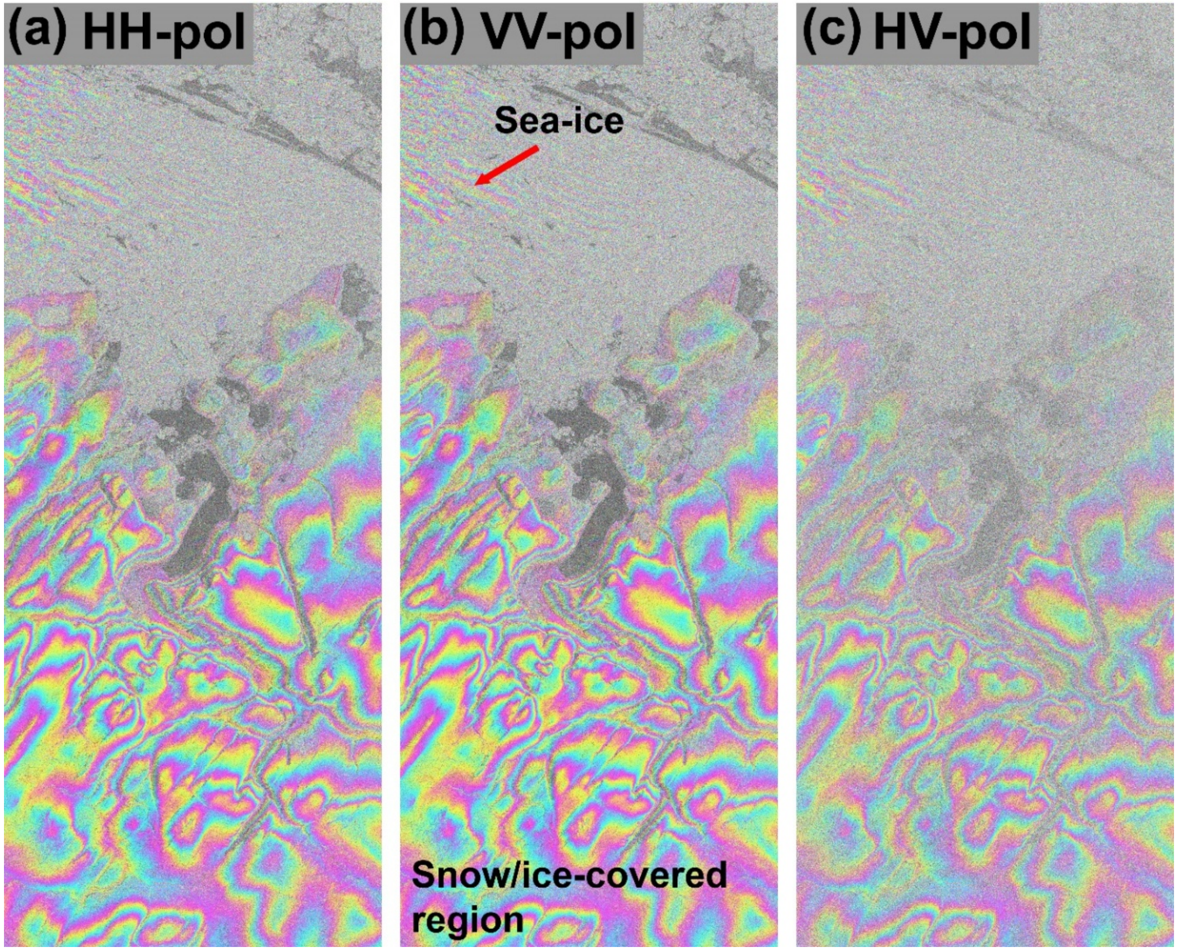
- Selected areas used for quantitative coherence analysis of snow/ice-covered surface are shown in magenta and of sea-ice regions are shown in orange.

Study areas



- SAR amplitude (HH-pol) and the Landsat-8 Operational Land Imager (OLI) optic images of other non-snow/ice cover areas used for 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.

Interferograms



- TSX quad-pol interferograms showing phase changes of snow/ice-covered regions in the Ellesmere Island, Canada, and sea-ice offshore.
- The interferograms dates are: 2010-04-11 and 2010-04-22 (11 day temporal baseline) and its perpendicular baseline is -45.33 m.
- The three interferograms show a very similar fringe pattern.
-The co-pol interferograms (a and b) maintain higher coherence than the cross-pol interferogram (c).

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. \

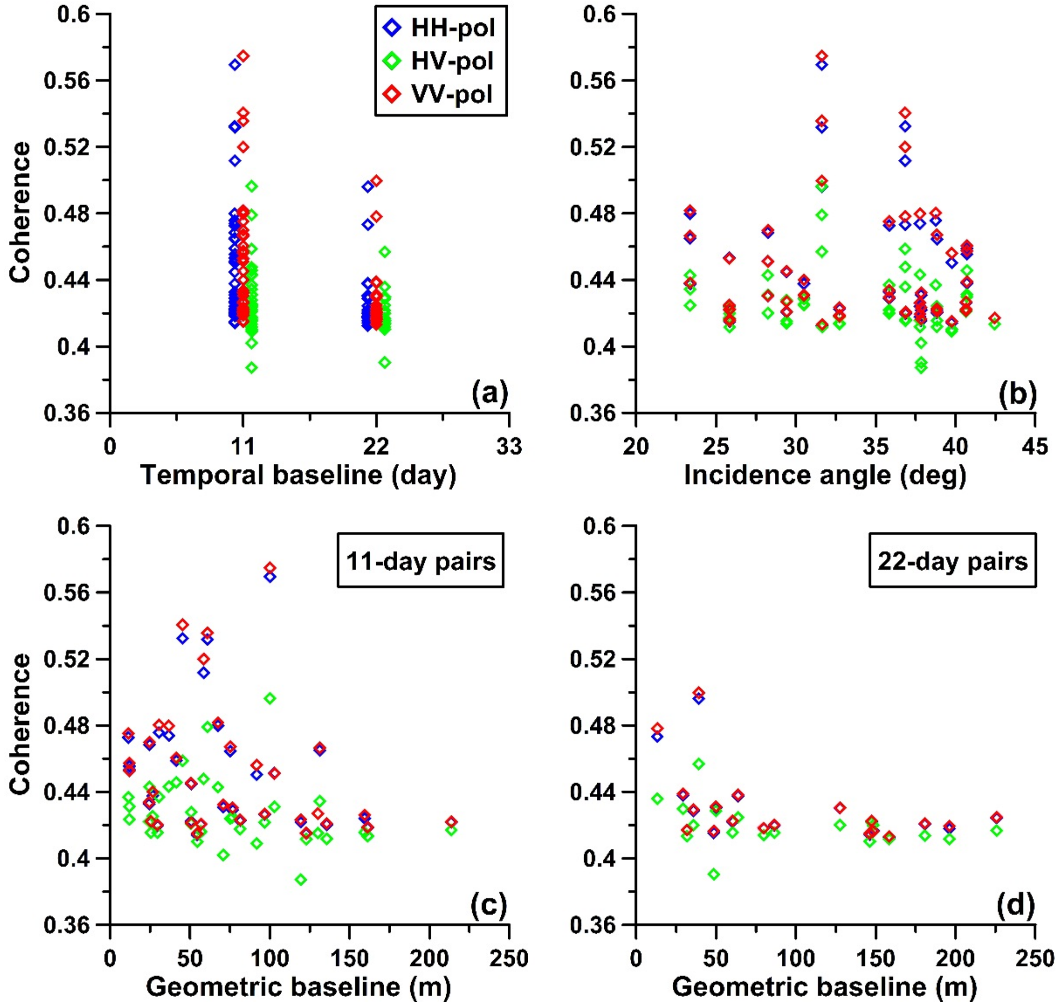
(b) Coherence versus incidence angle

Coherence versus geometric baseline with 11-day (c) and 22-day (d) temporal baseline pairs.

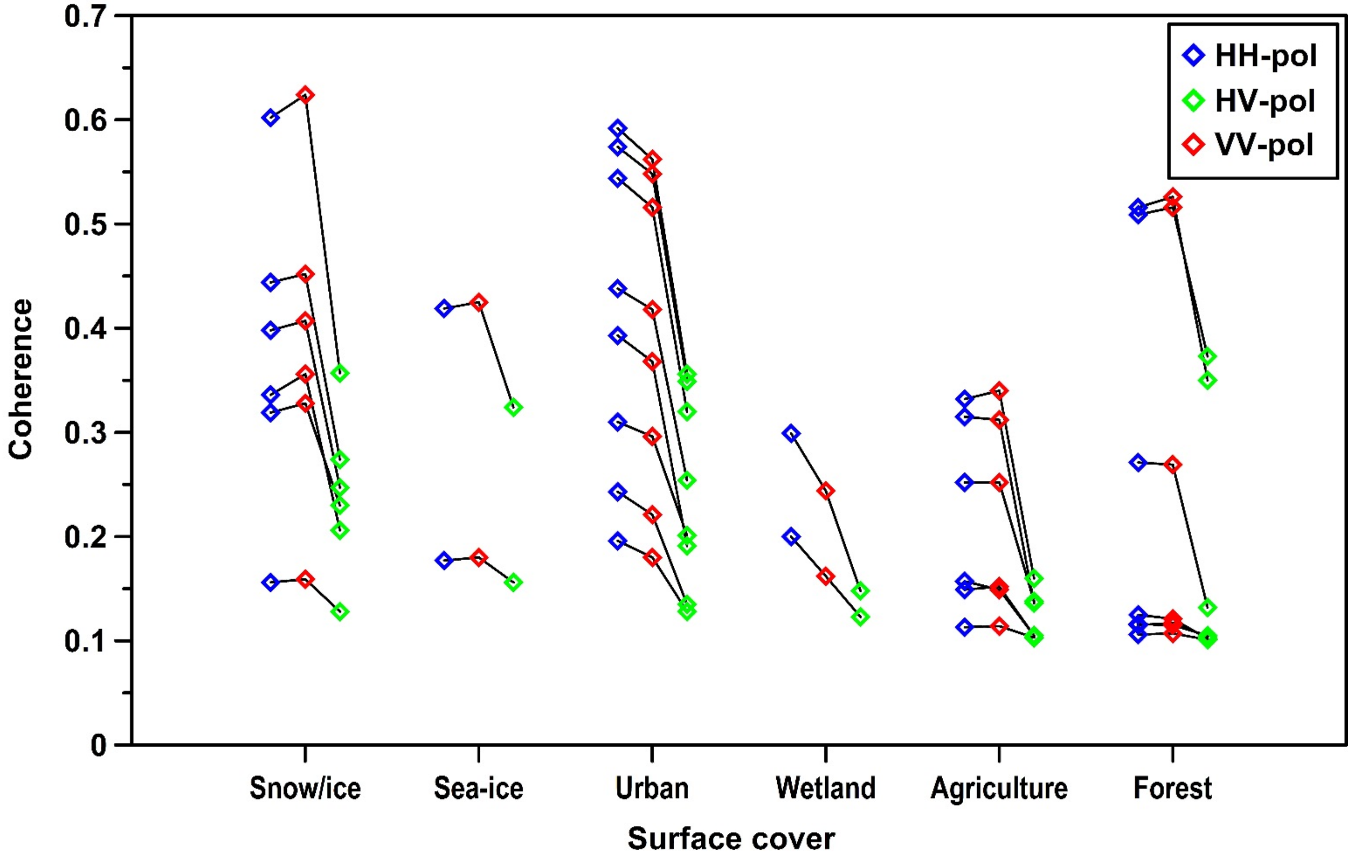
Short geometric baseline (< 100 m) is showing an overall relatively high coherence level.

The co-pol interferograms (HH and VV) show significantly higher coherence than the cross-pol interferogram (HV).

Furthermore, VV co-polarization shows the highest level of coherence in the polar region.

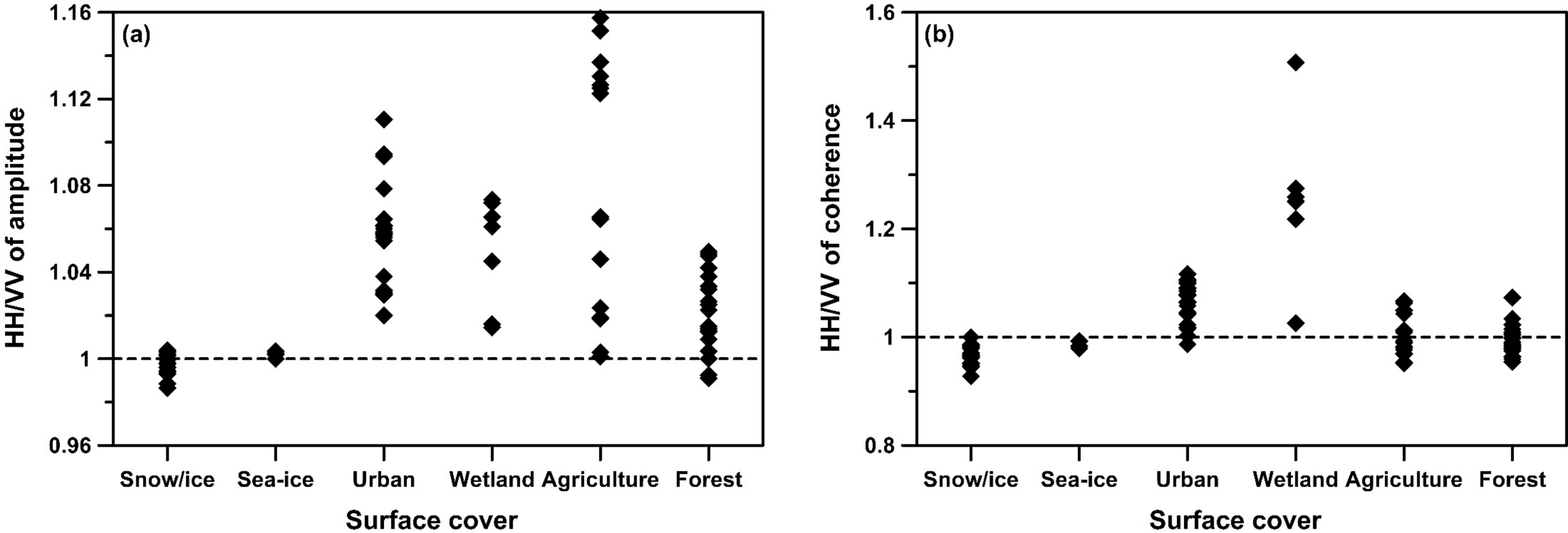


Coherence analysis



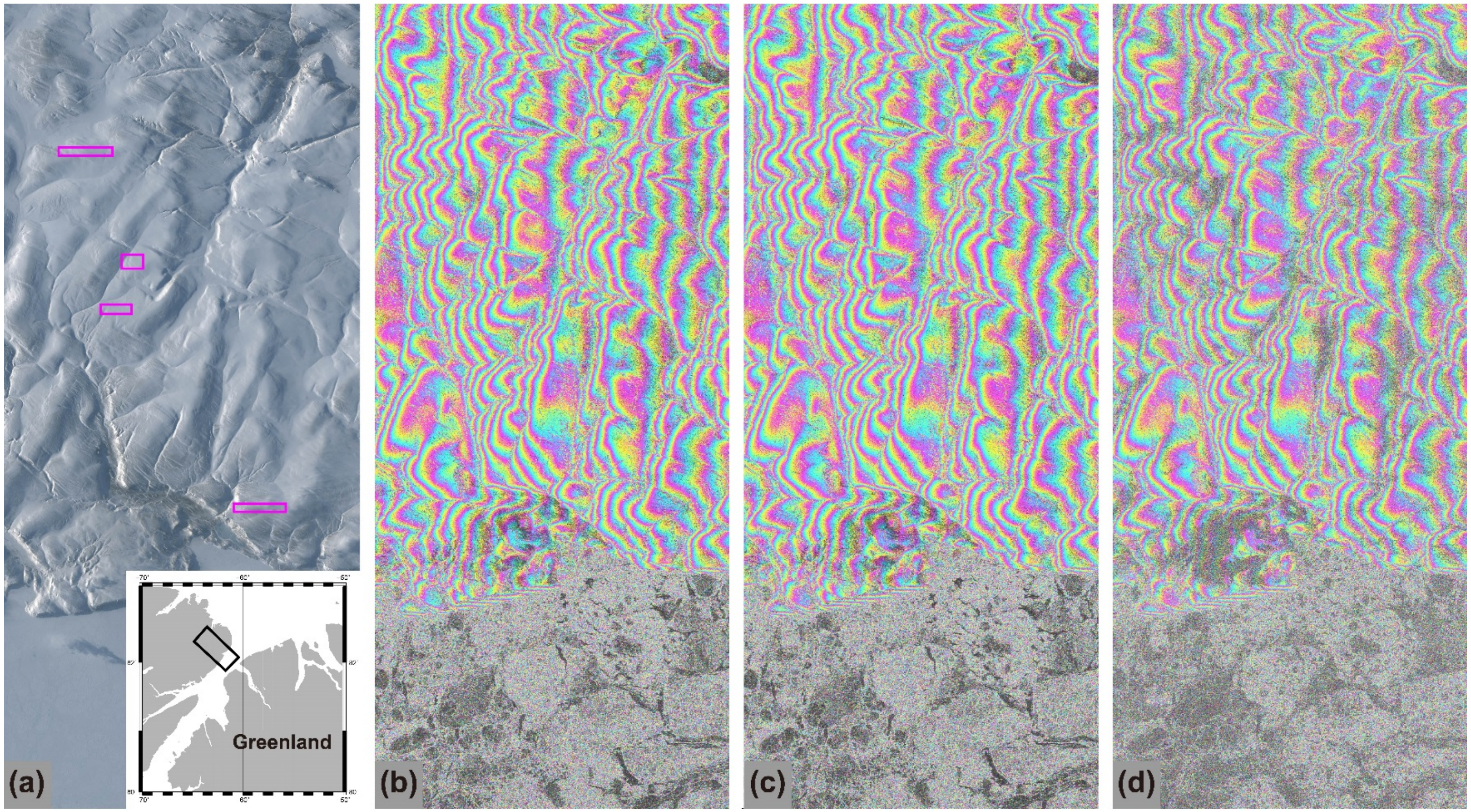
-Coherence analysis over selected six classes of snow/ice, sea-ice, urban, wetland, agriculture and forest regions.
-The VV-pol shows stronger coherence than the HH-pol in the snow/ice-covered regions, whereas the higher coherence in the HH-pol is observed at the urban and wetland areas compared with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

Coherence analysis



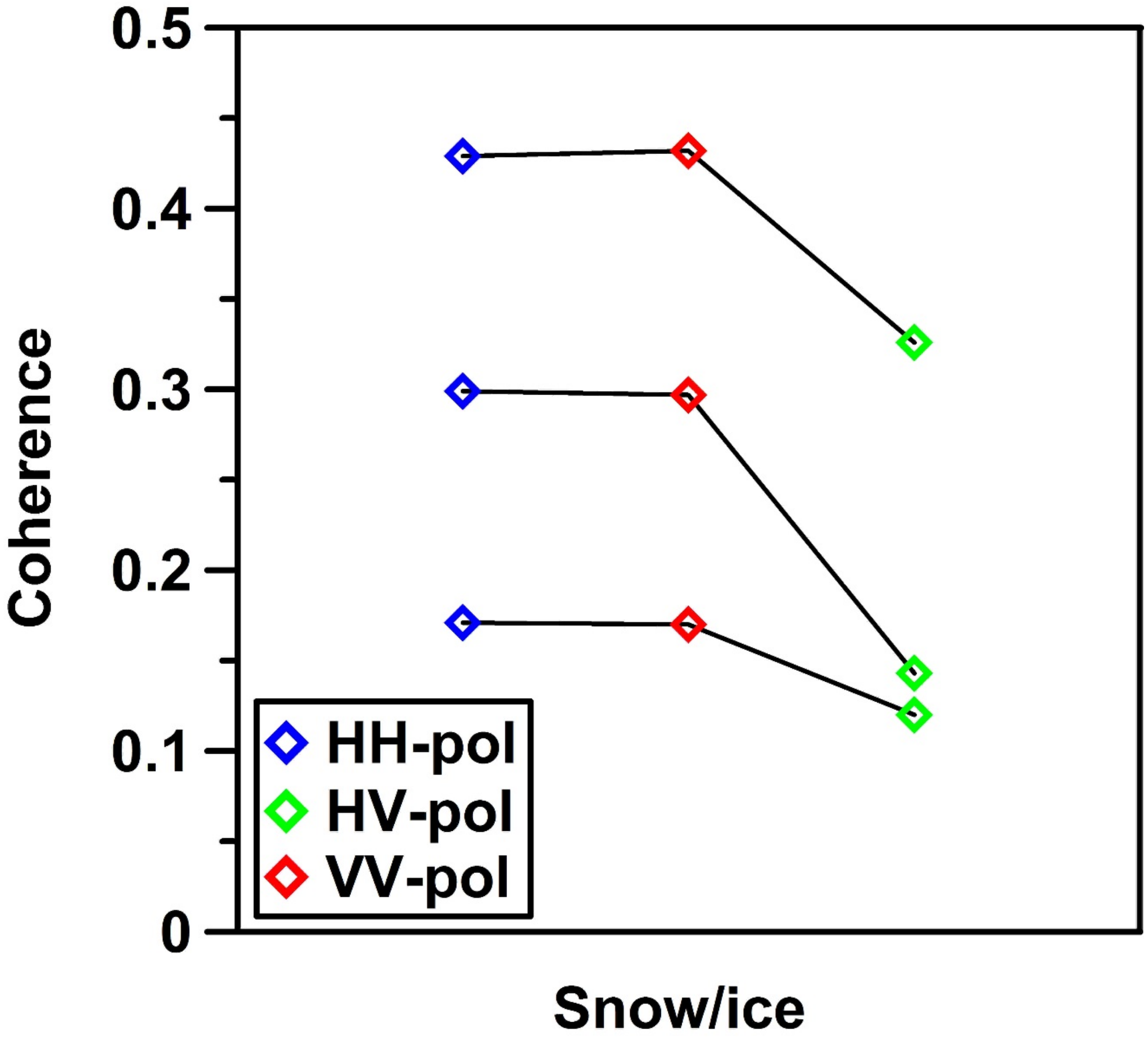
- Co-polarization ratio (HH/VV) of amplitude (a) and coherence (b) over the six studied classes of surface cover types.
- The amplitude ratios (a) show a similar or slightly higher VV-pol values snow/ice-covered and sea-ice regions and significantly higher HH-pol values in the non-snow/ice regions.
-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

ALOS interferograms



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).

Coherence analysis



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.

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.**

Acknowledgement

- **We thank to DLR to access TSX and JAXA and ASF to access ALOS PALSAR**

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Thanks for your attention