Sources of Phase Decorrelation in SAR Scene Coherence Images from Arctic Environments

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INTRODUCTION

"*Coherence*" is a measure of the phase correlation between radar data pairs. It is often used to evaluate a set of interferometric radar data since phase must be well correlated for all range and azimuth coordinates. An image of coherence, often called a *scene coherence image* can be synthesized from interferometric pairs. If the phase correlation is high between passes, then the area is bright; if the phase correlation is low, the area is displayed dark.

Several factors can lead to phase decorrelation, from inherent sources in the radar system and processor to the imaging geometry and transient atmospheric effects. Terrain sources indicate changes within the scene between the two passes. In this work, we identify some terrain effects occurring in Arctic environments and show applications of scene coherence images for providing geomorphological information and revealing temporal changes related to climatic conditions.

Data from ERS-1/-2 and RADARSAT-1 in the Canadian Arctic reveal patterns in scene coherence images closely associated with geomorphological features, such as drainage networks and the orientation of bedrock layering. Large slope gradients exert important control on coherence loss due to viewing geometry. Subtle topographic variations can be enhanced in scene coherence images by environmental changes. The accumulation and migration of snow drifts and compaction or recrystallisation of the snow pack explain some of these features. Mass-wasting of loose surficial material and processes in the active layer causing expansion or cracking are other sources of phase decorrelation visible in coherence images.

Canadian Arctic Archipelago

[**figure 1**]
Three study sites in the High Arctic are used to illustrate some examples of temporal changes in the terrain which are likely sources of phase decorrelation in scene coherence images.

Bathurst Island
- snow drifting and accumulation of snow in topographic depressions
- active layer processes

Ellef Ringnes Island
- topographic effects and viewing geometry

Axel Heiberg
- mass wasting and glacier flow

- active layer processes

Bathurst Island

The temporal changes associated with changes in thickness of the snow pack (drifts and deflation) and possibly recrystallisation of snow in deeper accumulations along the drainage newtwork.

[**figure 2**]
Scene Coherence Images over 1-, 12-, and 24-day intervals reveal increasing loss of coherence with time.

[**figure 3**]
During the 12-day ERS-1 repeat-pass interval, ambient temperature remained below freezing and snow precipitation was recorded to total about 2 cm.

[**figure 4**]
Broad traingular patterns caused by a loss of phase coherence between ERS-1 passes is likely explained by gusting winds, prevailing from the north, that redistribute the snow cover.
Dendritic network of seasonal active streams is clearly visible and like caused by local changes (recrystallisation and accumulation) in the snow pack accumulation.

[**figure 5**]
Snow drifting and deflation easily evolve with shifting wind patterns across vast barren plateaus

[**figure 6**]
Formation of large-scale ice-wedges in the active layer caused by thermal contraction cracking of the ground may result in a loss of phase coherence.

[**figure 7**]
Gentle topographic depressions between small ridges of resistant strata illustrating thicker snow cover.

[**figure 8**]
Deep accumulations of snow with recrystallised layers occupying incised topography of the drainage system.

Axel Heiberg Island

The effects of terrain movements on scene coherence images can be illustrated by glacier flow and mass movements along unstable mountain slopes.

[**figure 9**]
Significant displacement over 24 hours of Iceberg Glacier is evident in this coherence image.
A large 1 × 4 km area on the east-facing slope (radar back slope) exhibits a loss of phase coherence. This is likely due to a large block slide, or shifting of the numerous blocks in the talus, as seen below:

[**figure 10**]
Large perched blocks occupy the talus slope of this mountain range, 8 km south of Strand Fjord.

[**figure 11**]
Close-up view of the block sizes associated with this area of low scene coherence.

Ellef Ringes Island

The InSAR viewing geometry of the imaging platform is well illustrated by the abrupt topographic features associated with the erosion of exposed evaporite domes. Maximum slopes for which phase coherence is reached is related to the InSAR baseline and local radar incidence angle.

[**figure 12**]
Few significant terrain changes occur over the 1-day interval image produced from ERS-1 / ERS-2 tandem mode data. Steep topography accompanies the sub-circular perimeter of Isachsen Dome, however loss of phase coherence occurs primarily at the fore slope and back slope areas (with respect to radar look-direction).
Deeply incised topography internal to the dome well illustrates the geometrical limitations on obtaining high phase coherence.

CONCLUSIONS

- Scene coherence images from ERS-1/-2 and RADARSAT-1 InSAR data taken over over 1 to several day intervals reveal terrain patterns associated with drainage networks and the orientation of bedrock layering.

- In barren periglacial environments, like the High Arctic, radar coherence images often reveal greater geomorphologic detail than can be seen in SAR backscatter images or optical data. These images have application for interpreting and understanding landforms of subtle expression and should be considered as an important tool for monitoring terrain changes, especially during the dark winter months when other methods of observation are difficult to implement.

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