



Single pass bistatic interferometry for sea ice build-up around offshore structures

Oliver Lang, Jan Anderssohn, Parivash Lumsdon – Astrium GEO-Information Services

Kim Partington - Polar Imaging Ltd.

TanDEM Science Proposal: OCEA1139

All the space you need



Outline

- Scope of the study – operational relevance
- Caspian Sea ice topography
- Pt. Barrow ice topography
- Conclusions and recommendations

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Background and Scope

- Pilot Project with commercial background (Astrium, Polar Imaging, NCOC)
- **Goal:** Identify hazards for oil exploitation installations and ship traffic
- **Method:** Evaluation of TanDEM-X elevation models over sea ice



Source ENI: http://www.eni.com/en_IT/innovation-technology/eni-projects/kashagan/kashagan-project.shtml



Requirements for an operational Service

Example: Sea-ice deformation, thickness ca. 50cm

Monitoring of:

- Ridged ice as navigation constraint
- Sea ice pressure build-up on structures
- Potential grounded ice for:
 - basal scouring of buried pipelines
 - Vessel navigation hazards
 - refloated stamukha in spring

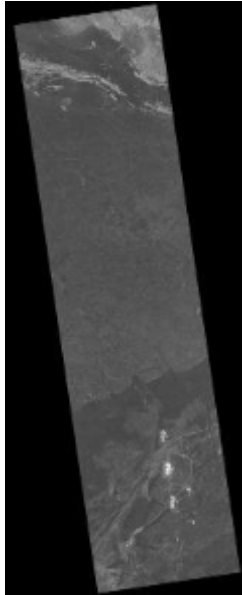


Typical mid-winter conditions:

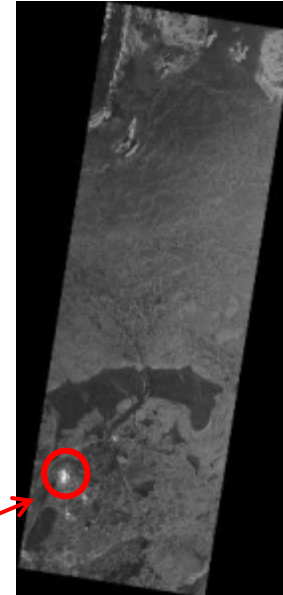
Snow thickness	20 cm
Snow condition	All frozen
Surface air temperature	-17.4° C
Level Ice thickness	60 cm



Dual-polarimetric bistatic datasets



4 ascending pairs:	
Effective baseline	166 m
2π ambiguity	63 m
Incidence angle	54°
Polarisations	HH VV



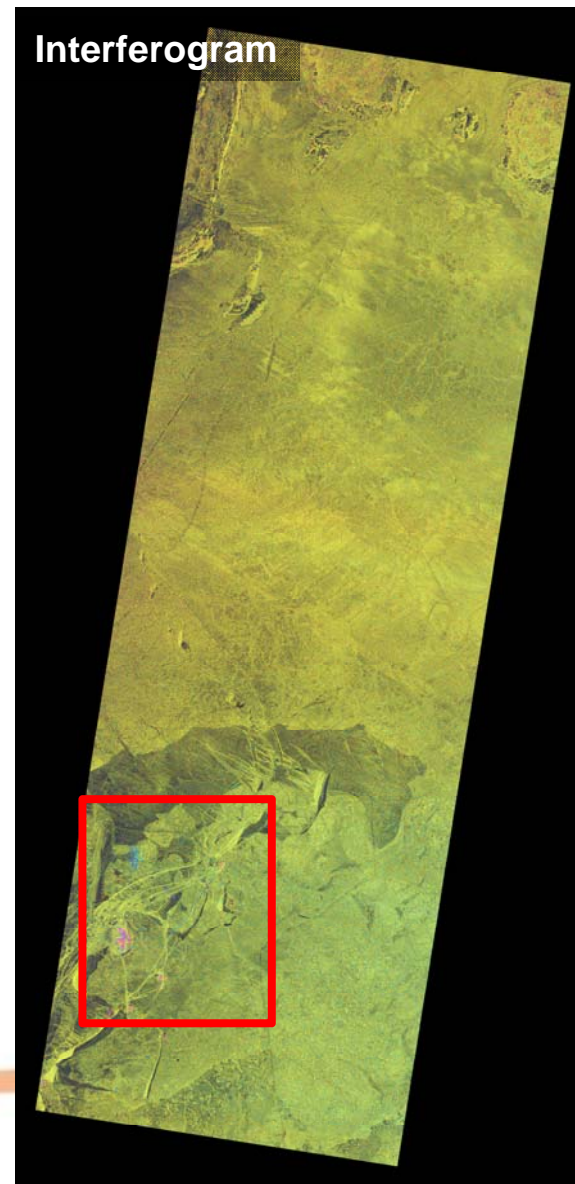
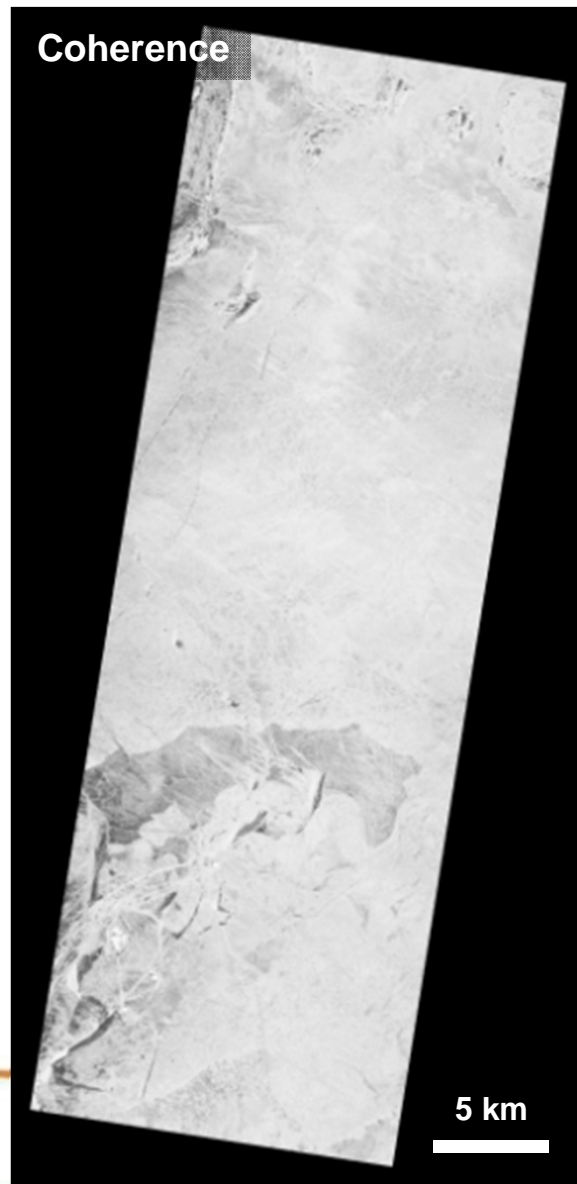
Island D

5 descending pairs:	
Effective baseline	24 m
2π ambiguity	255 m
Incidence angle	38°
Polarisations	HH VV

- Strong az-ambiguities
 - Low coherence over ice (avg. 0.4)
- ➔ Not used for analysis

- Weak az-ambiguities
 - suitable coherence over ice (avg. 0.7)
- ➔ Used for DEM processing

Sea Ice Topography from TanDEM-X

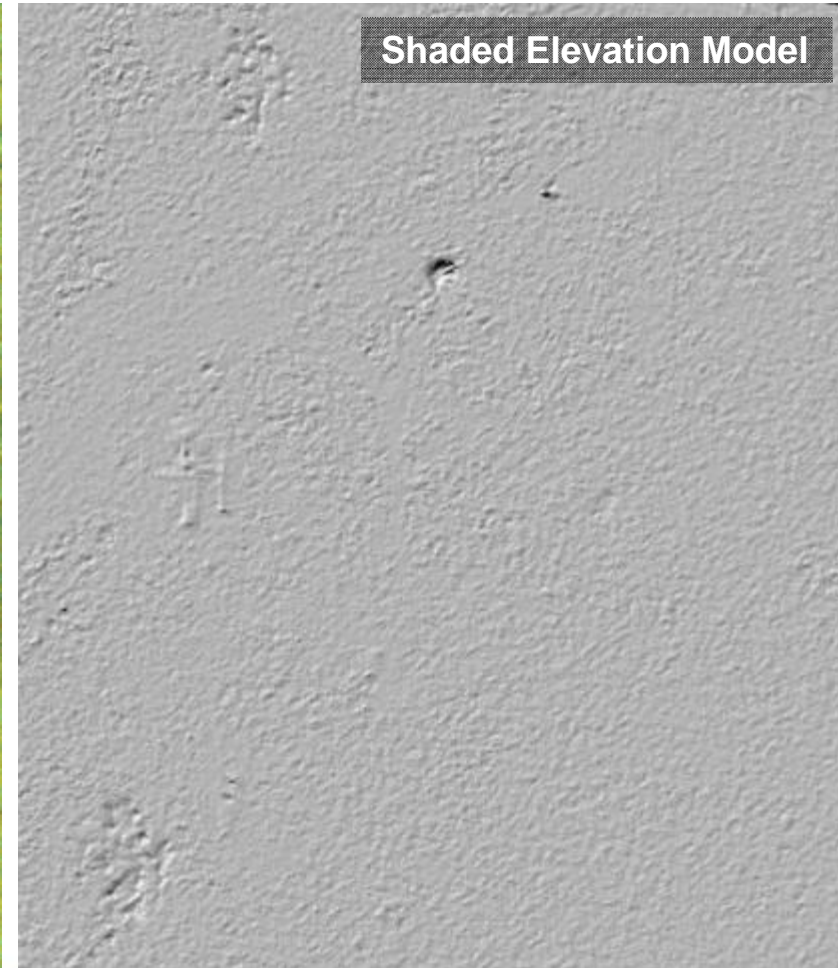
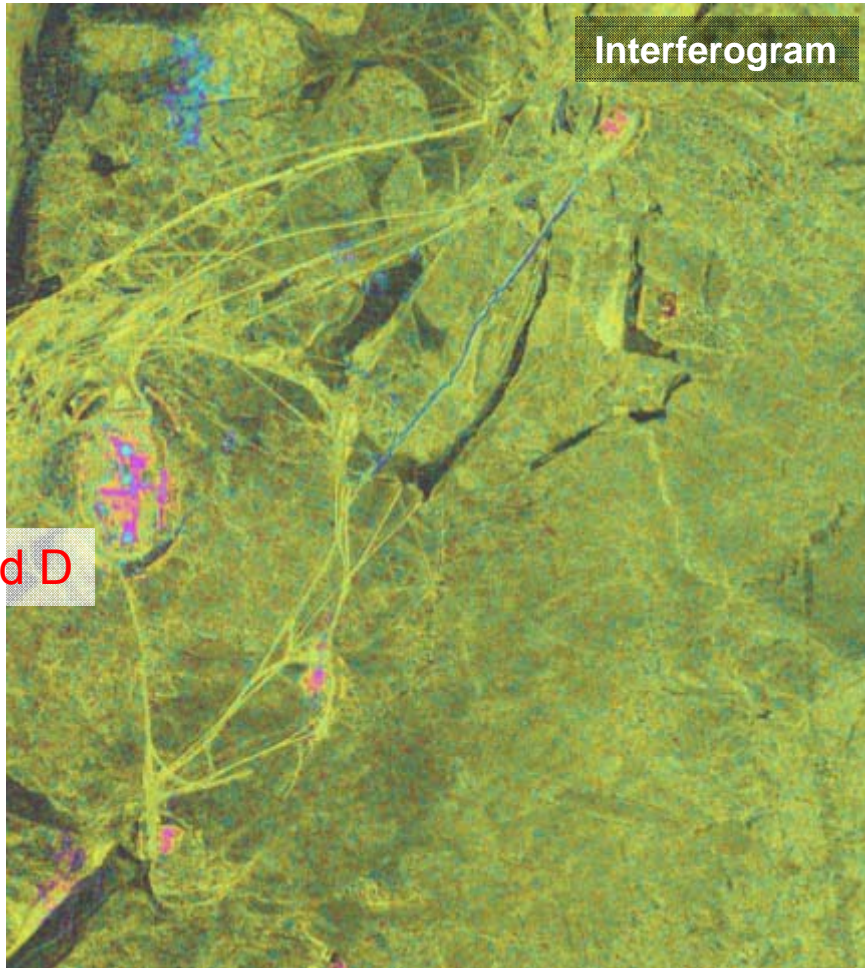


TanDEM pair:
16 Jan 2012



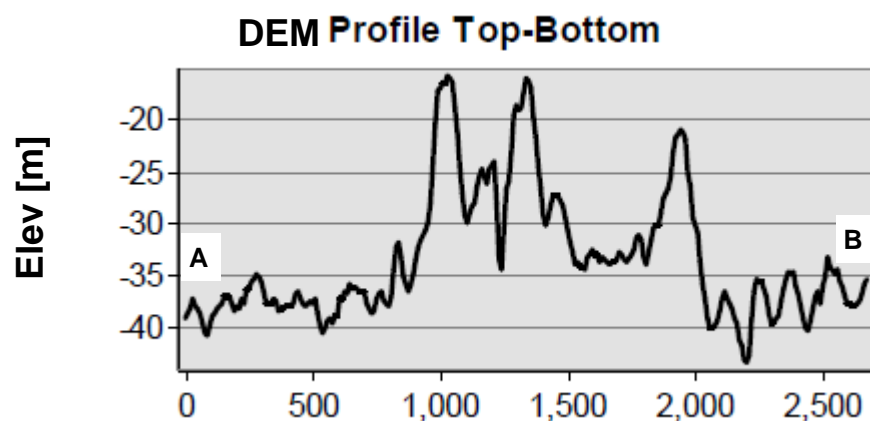
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Sea Ice Topography from TanDEM-X



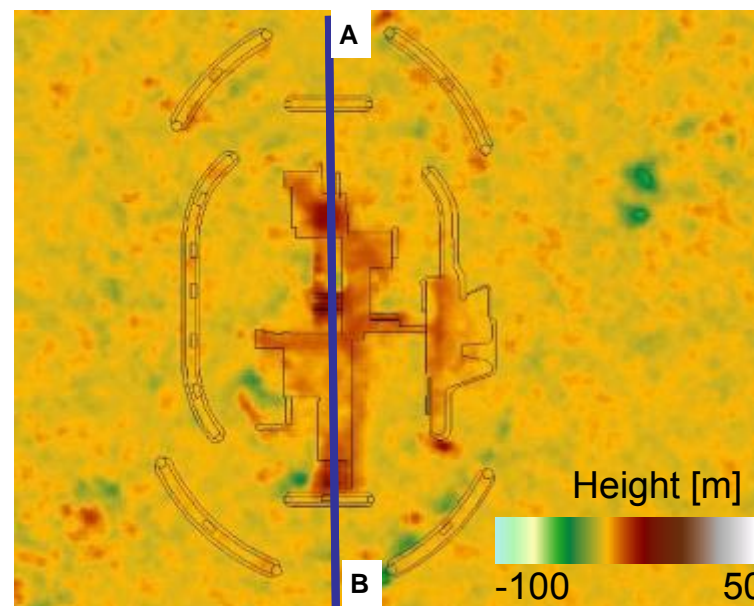
TanDEM pair:
16 Jan 2012

Accuracy: empirical estimation



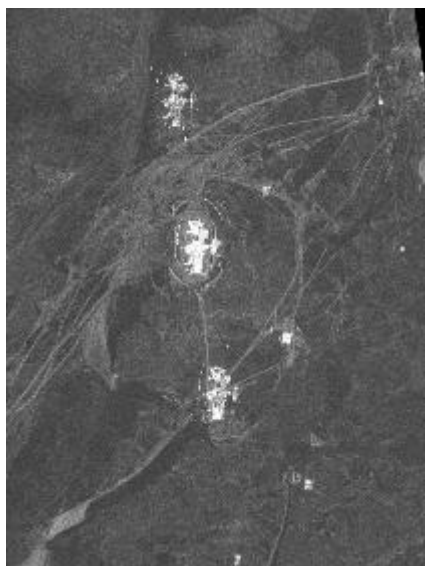
- Artificial structure well visible in DEM
- DEM profile corresponds well to structure and real heights
- STD on level ice: 1.2 m

Bistatic DEM at Island D



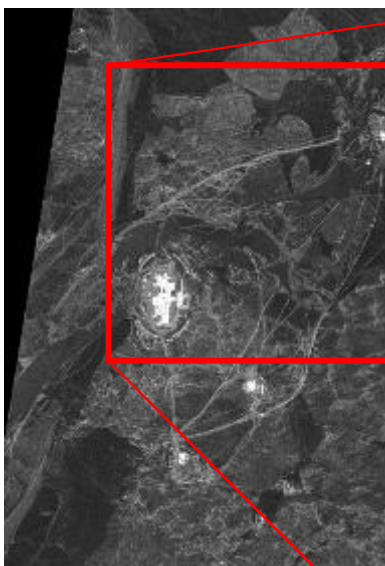
Artifacts: Azimuth Ambiguities

ascending



amplitude

descending



amplitude

TanDEM pair: desc, 16 Jan 2012



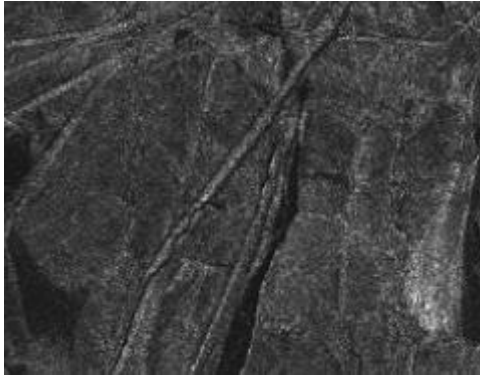
interferogram

- Significant Azimuth Ambiguities in Amplitude and Phase

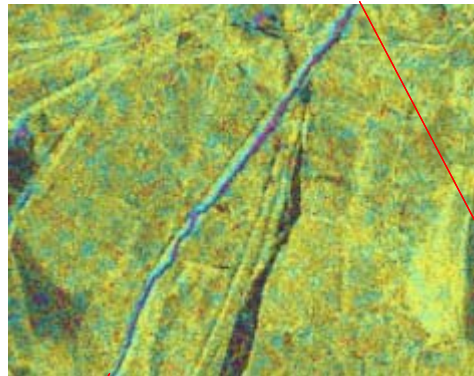
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Artifacts: over-estimation of topography features

amplitude

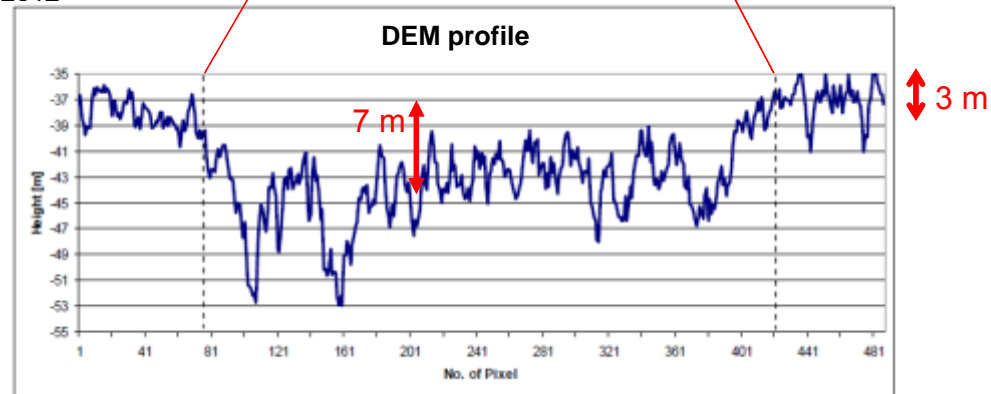


interferogram



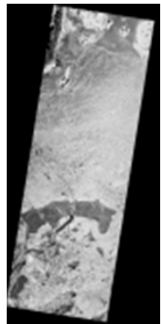
- Noise floor (emp. STD): 1.2 m
- Ice crack depth (emp.): 7 m
- Ice thickness (meas.): 0.6 m

TanDEM pair: desc, 16 Jan 2012



- Significant over-estimation of DEM variations at cracks
- Origin: path delay by multiple reflection ?

Comparison: Bistatic Coherence – Ice Chart



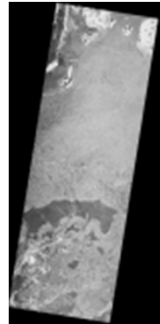
5 Jan 2012



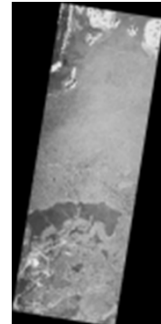
16 Jan 2012



27 Jan 2012



7 Feb 2012



18 Feb 2012

- Limited correlation between ice chart and bistatic Coherence
 - Temporal and spatial Coherence variations interesting for ice classification
- ➔ further investigation needed



Ice chart provided by NCOC

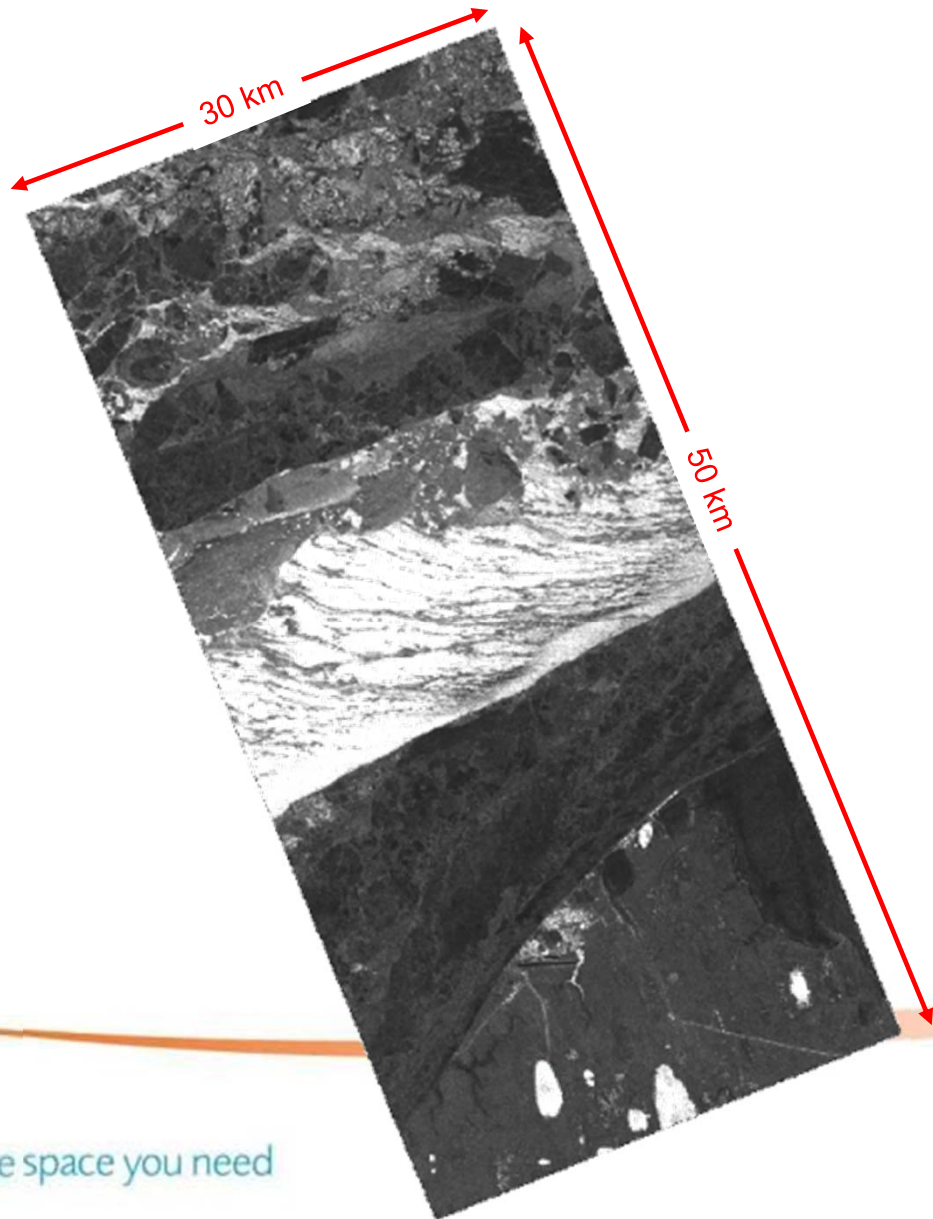
Preliminary Conclusions

- Monitoring of sea-ice ice topography features from TanDEM pairs: possible but challenging
- ➔ Extension of study on 2nd test site: Pt. Barrow, Alaska: TanDEM Supersite
- ➔ Use steep incidence angle and large baseline

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All the space you need

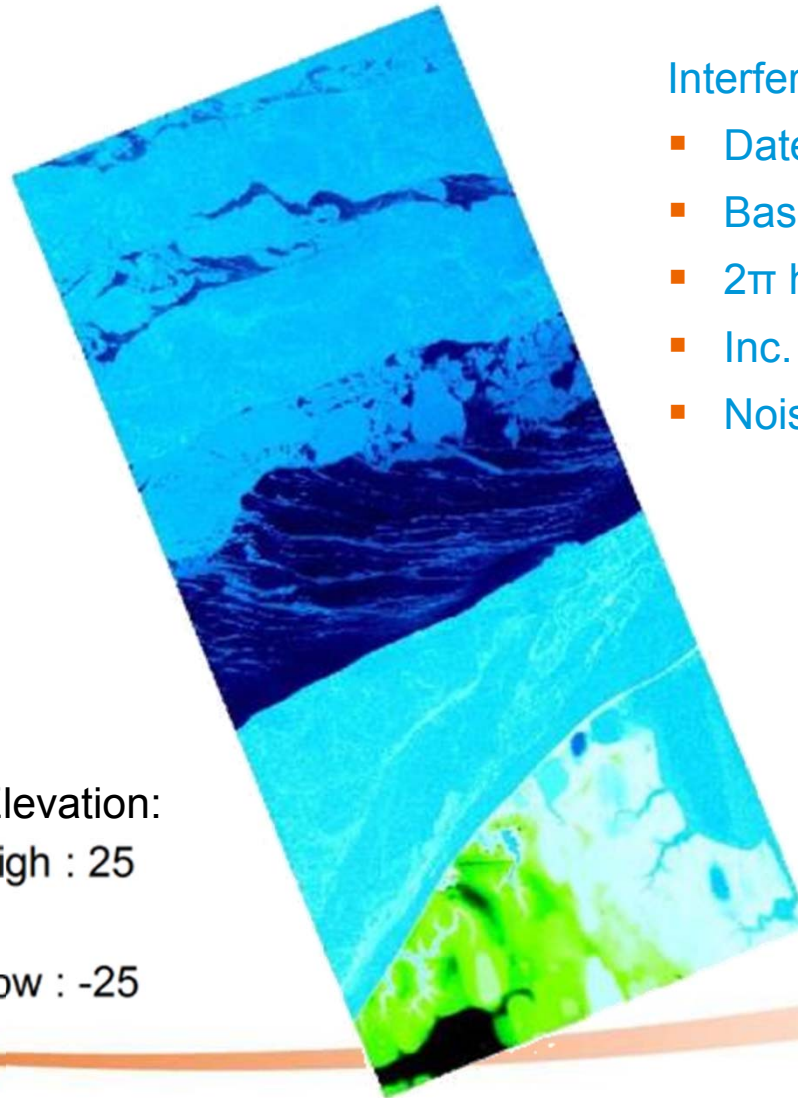
TanDEM Supersite Pt. Barrow (Alaska)



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All the space you need

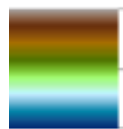
Sea-Ice Topography: Pt. Barrow



Interferometric DEM

- Date: 2012/04/10
- Baseline: 311 m
- 2π height ambig.: 10 m
- Inc. angle: 20°
- Noise floor (emp. STD): 0.19 m

Relative Elevation:



High : 25

Low : -25

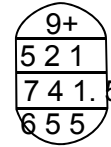
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Corresponding Ice Chart

Sea ice chart subset (Canadian Ice Service)
2012/04/09



Total concentration:
>90%



Predominant ice types:
Old ice / thick 1st year ice
/ medium 1st year ice
Forms of Ice:
Fast ice



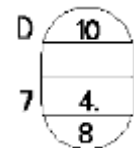
Total concentration:
50%



Predominant ice types:
Gray ice / New ice-frazil
Forms of Ice:
Small ice floe



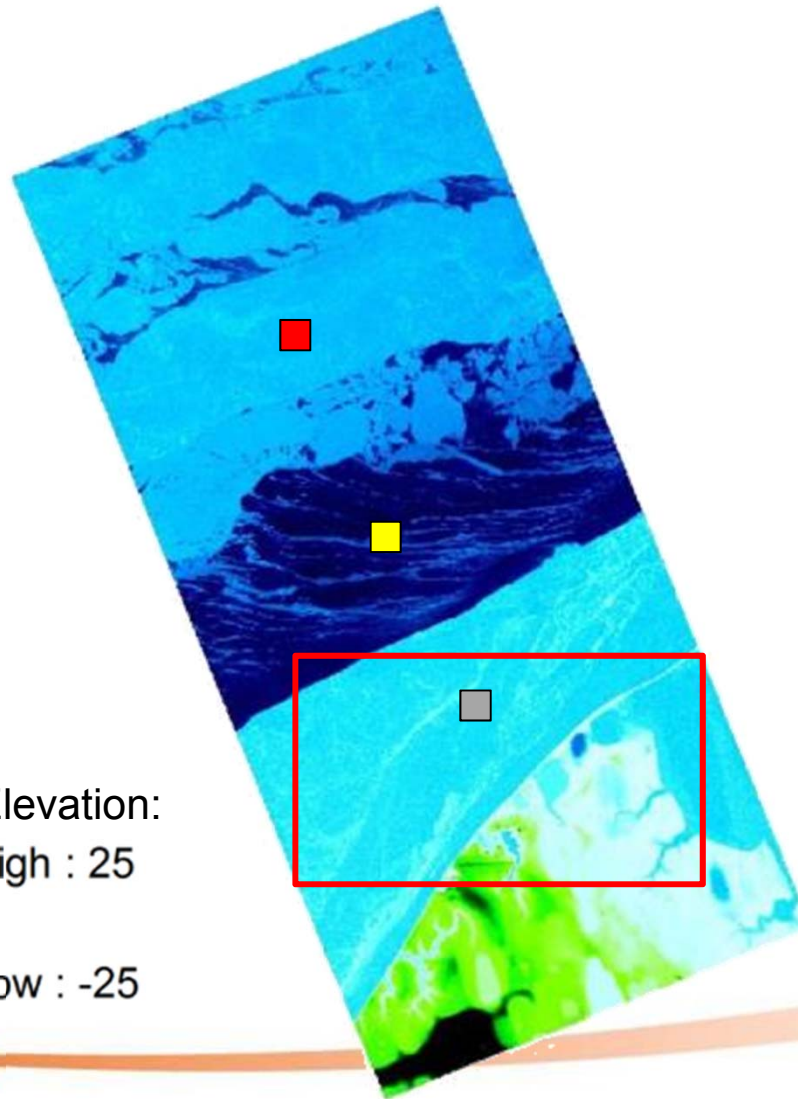
Total concentration:
100%



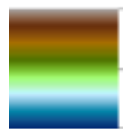
Predominant ice types:
Thick 1st year ice
Forms of Ice:
Fast ice



Sea-Ice Topography: Pt. Barrow



Relative Elevation:

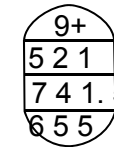


High : 25

Low : -25



Total concentration:
>90%

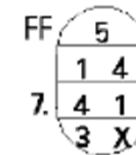


Predominant Ice types:
Old ice / thick 1st year ice
/ medium 1st year ice

Forms of Ice:
Fast Ice



Total concentration:
50%

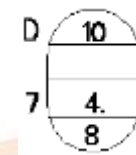


Predominant Ice types:
Gray Ice / New Ice-Frazil

Forms of Ice:
Small Ice Floe



Total concentration:
100%



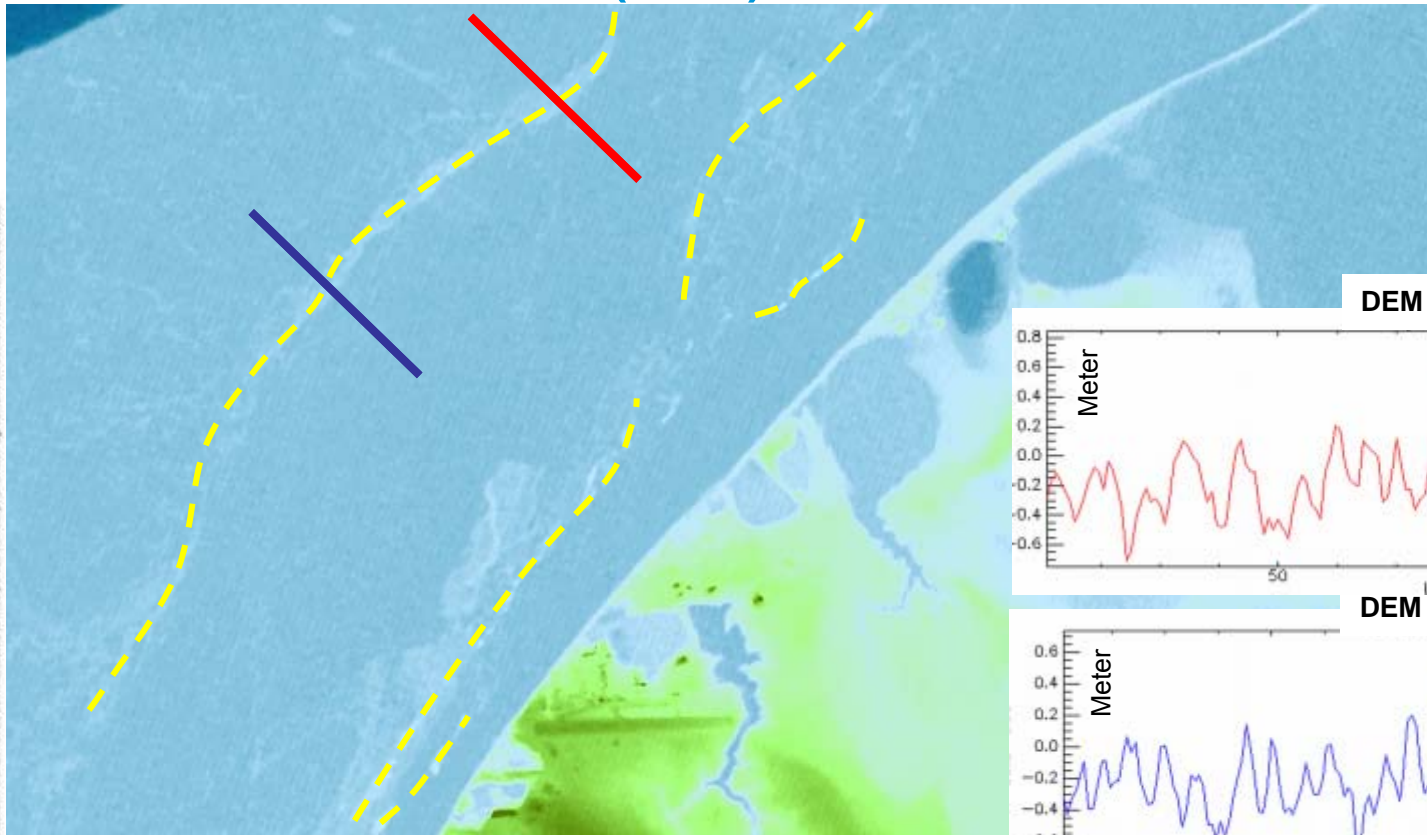
Predominant Ice types:
Thick 1st year ice

Forms of Ice:
Fast Ice

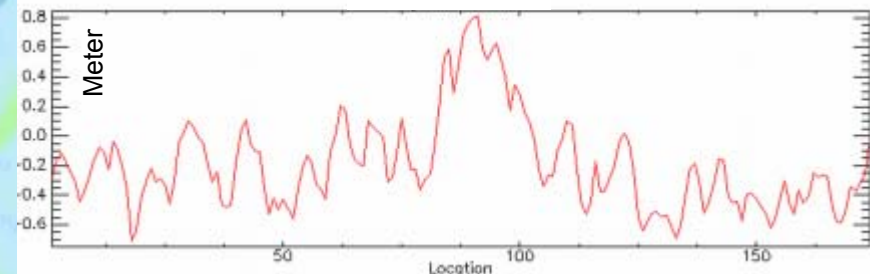
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Sea-Ice Topography: TanDEM SuperSite Barrow Sea (AK)

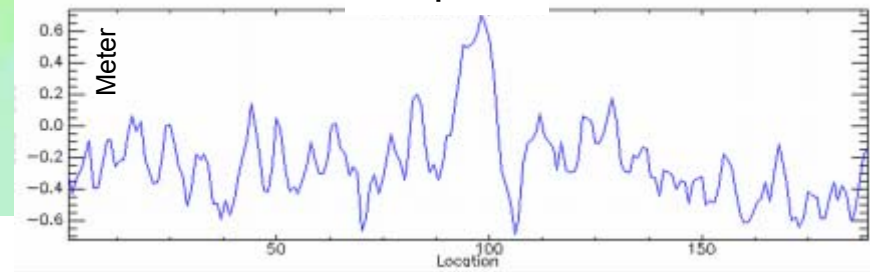
Relative Elevation:
High : 25
Low : -25



DEM profile



DEM profile



- Identification of potential ice ridges
- Elevation of ridges: 0.5 – 1.0 m

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Conclusion / Recommendations

- Use of incidence angles $< 30^\circ$
- Interferometric baselines > 300 m for detection of sub-meter vertical features

Further steps

- Cal/Val activities with Pt. Barrow results
- Usability of bistatic InSAR coherence for classification to be further investigated

Potential of bistatic ice mapping

- High operational potential after termination of Global DEM mission
- Reduction of accidents and environmental impacts
- Part of ice management plan
- 1-3 assessments per season to identify hazards

Acknowledgement:
the authors thank NCOC for supporting the study