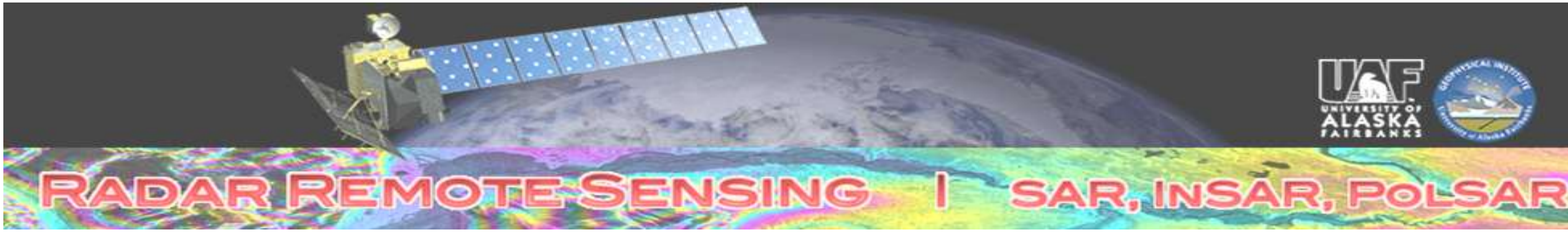


Characterization and Extent of Randomly-Changing Radio Frequency Interference in ALOS PALSAR Data

FJ Meyer[1) 2)], J Nicoll[2)], AP Doulgeris[3)]

[1)]*Earth & Planetary Remote Sensing, University of Alaska Fairbanks*
[2)]*Alaska Satellite Facility (ASF)*
[3)]*University of Tromsø, Romssa Universitehta. N-9037 Tromsø, Norway*

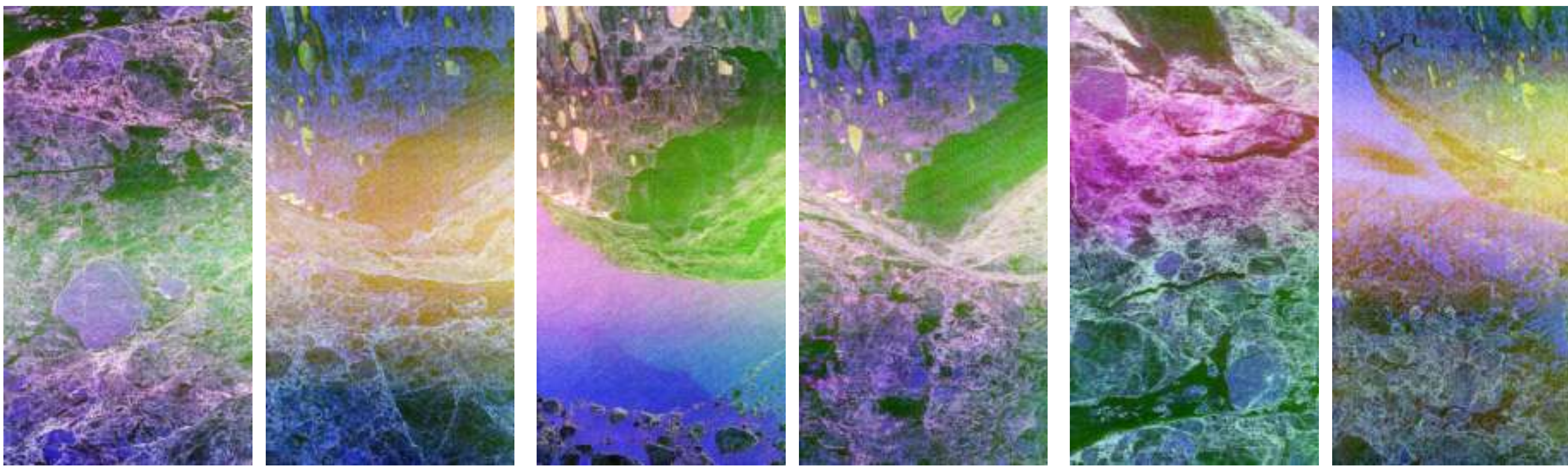
Collaborating Organizations:

Outline

- Motivation
- An Uncharacteristic RFI Source in the American Arctic
- Screening AADN's PALSAR Archive for RFI Issues
- Development of a Modified Notch Filter Approach for Signal Correction
- Performance of Notch Filter Algorithm
- Conclusions

Motivation

- In American Arctic, polarimetric data regularly affected by signal artifacts causing huge variations of polarimetric signature (see examples below)
- Initial survey showed: More than 80% of data over Barrow, AK affected
- **Source: High power RF interference**



An Uncharacteristic RFI Source in the American Arctic

- DEW line and North Warning System:
  - Array of long-range and short-range over-the-horizon surveillance and early warning defense system of US and Canada
  - Originally ~ 90 sites located along American Arctic Coast
  - Migrated to North Warning System in 1985 and reduced to ~50 Sites

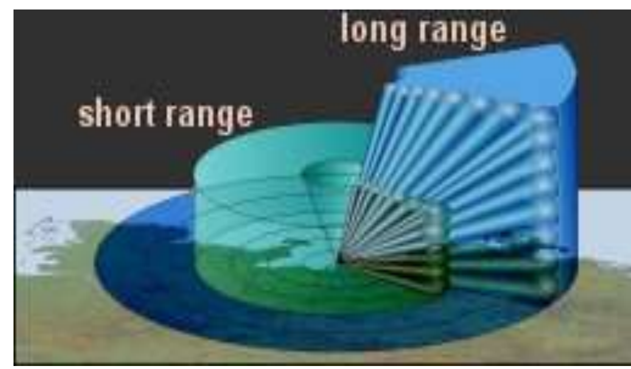
Short-range stations

Long-range stations

The Long Range Radar System FPS-117

- AN/FPS-117 Long Range Radar (Lockheed-Martin):
  - Pulsed phased array antenna system, with a PRF of up to 1500Hz
  - **L-band** frequency range of **1215-1400 MHz** (PALSAR f_c: 1270 MHz)
  - Low power, long range (up to 450km)
  - Randomly hopping among 18 channels in the 1215-1400 MHz band.

Specifications	
frequency:	1215 - 1400 MHz
pulse repetition frequency (PRF):	250 / 1100 Hz
pulsewidth (PW):	100 / 800 µs
peak power:	20 kW
displayed range:	bis 463 km
beamwidth:	β:3,4°, ε:2,7°

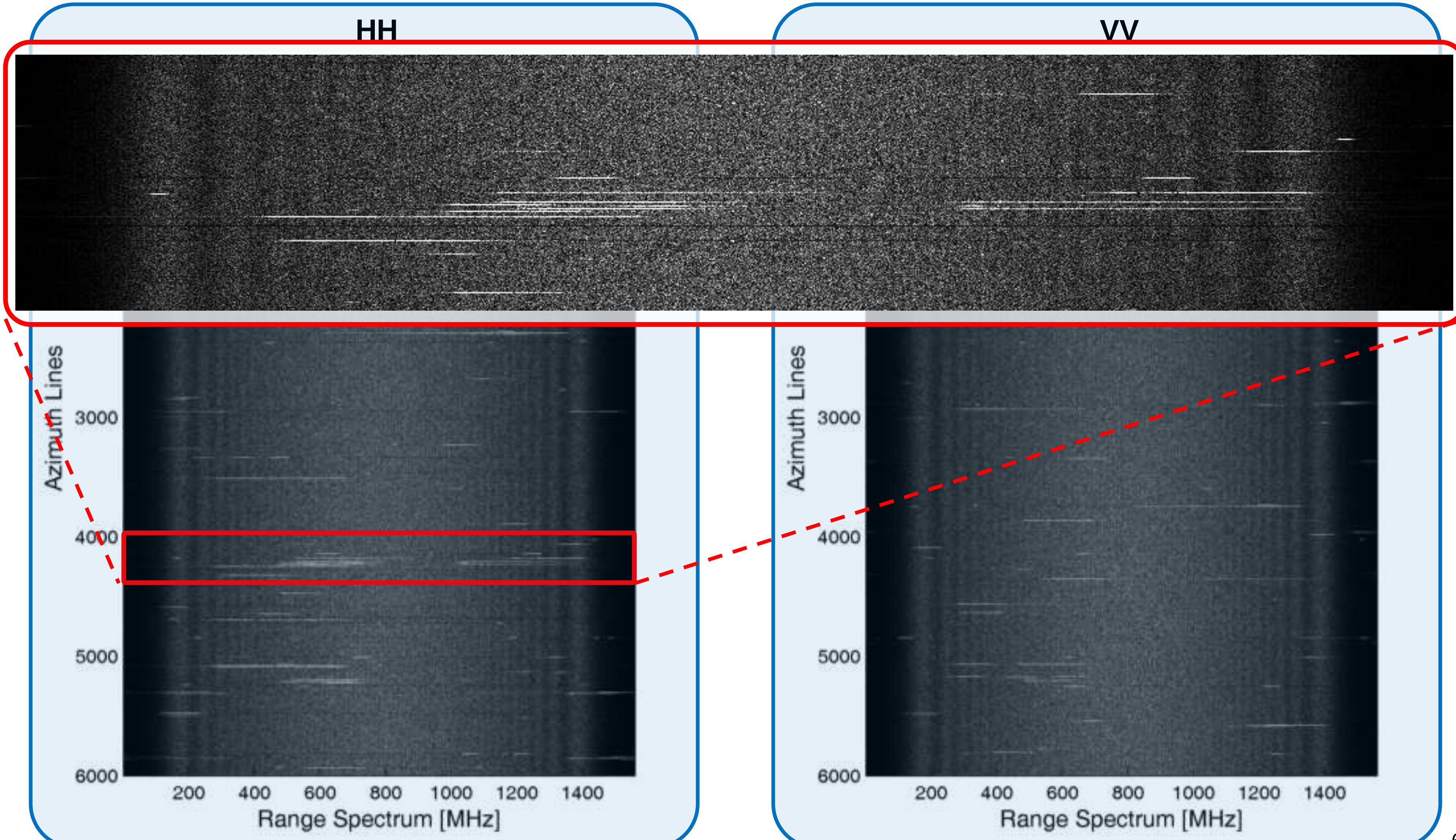


Source: Lockheed-Martin

Examples of Interference Signatures

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

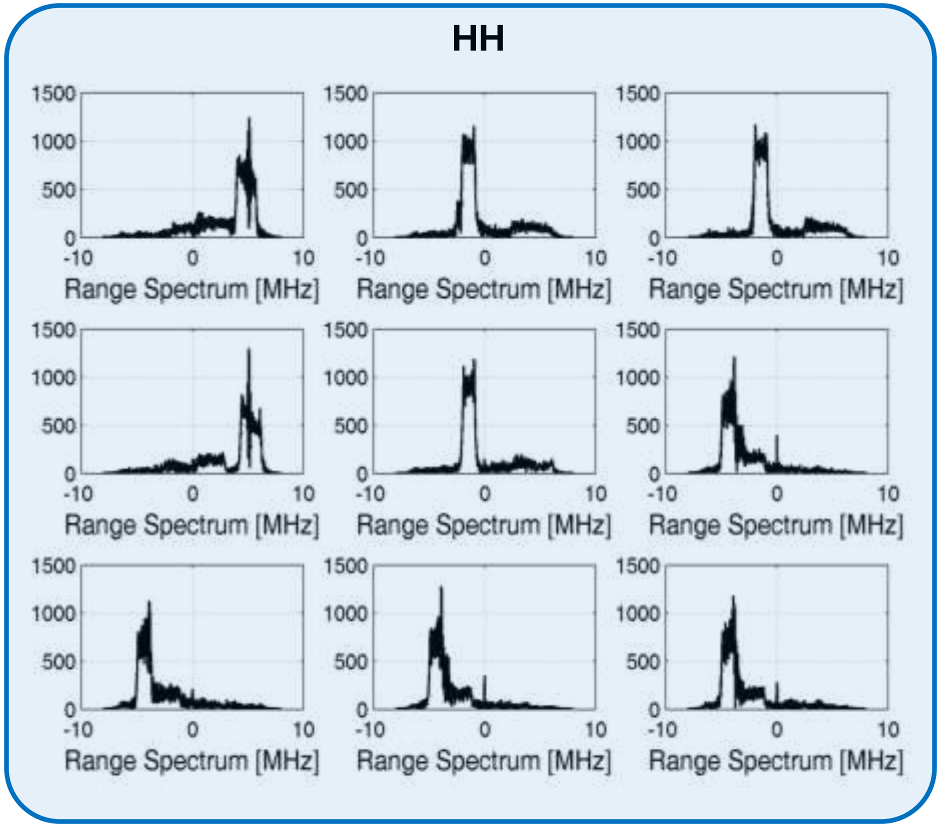
- Range-frequency azimuth-time representation:

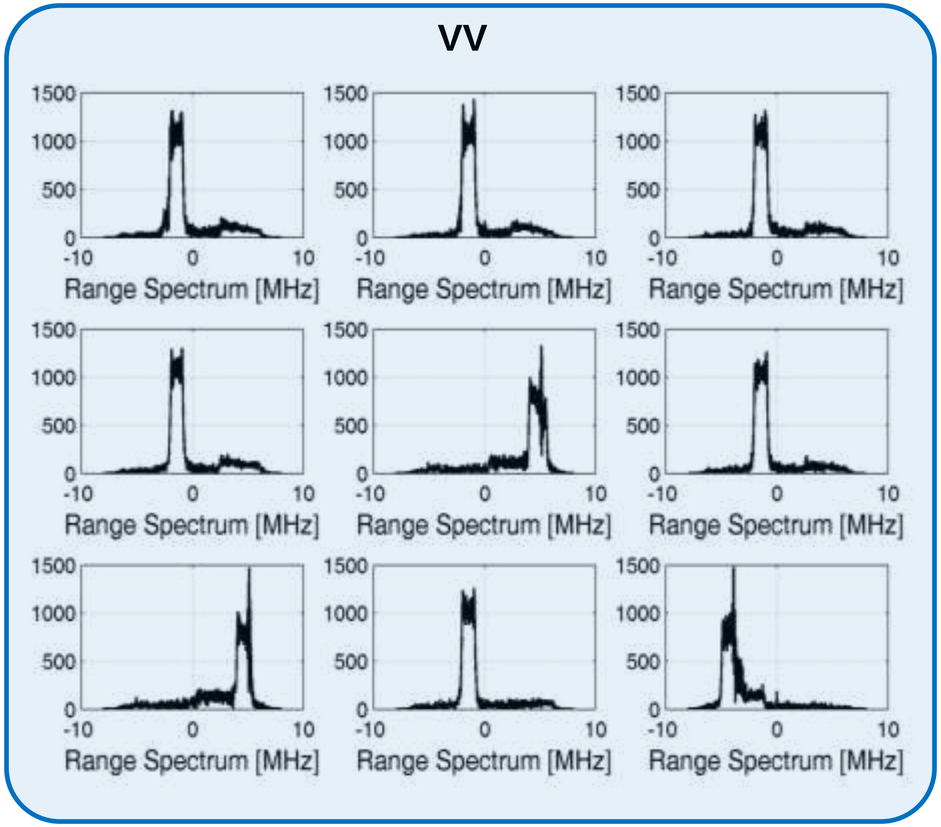


Examples of Interference Signatures

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

- Bandwidth and Power:
  - ~ 1 – 2.5 MHz bandwidth; f_c changing on pulse-by-pulse basis



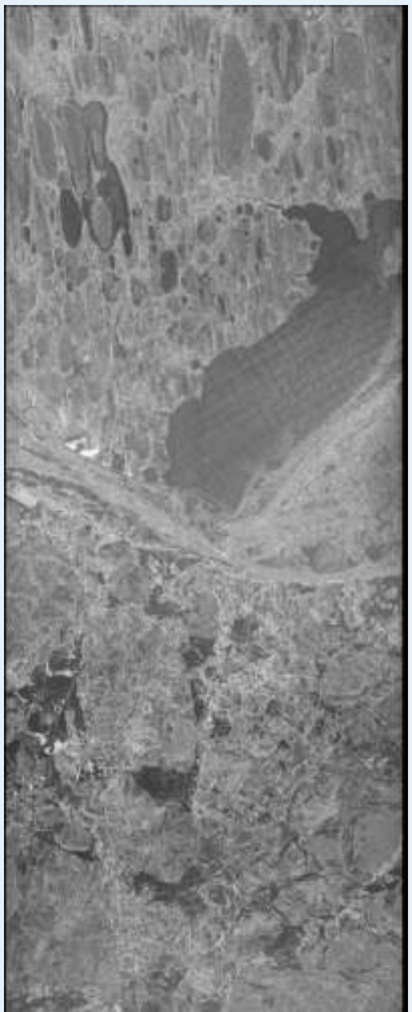


Effects on SAR Imaging and Polarimetry

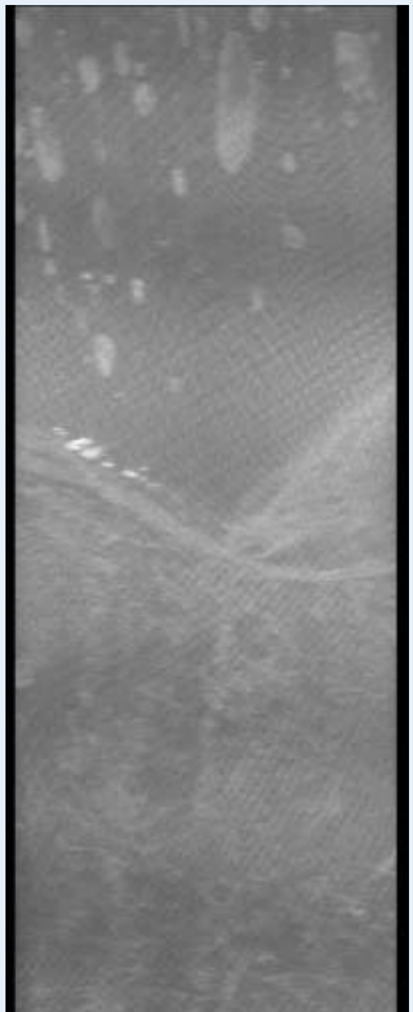
PALSAR PLR21.5: Orbit: 17260; Frame: 1440

- Focused SAR image without notch-filtering

HH

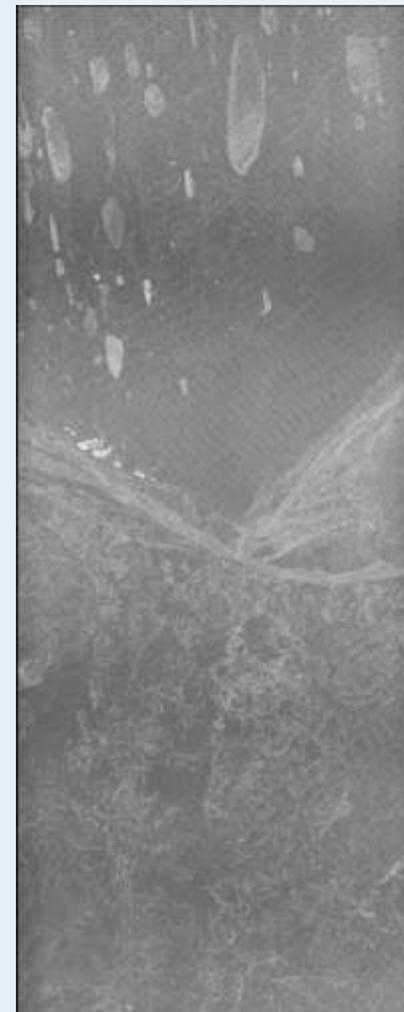


HV



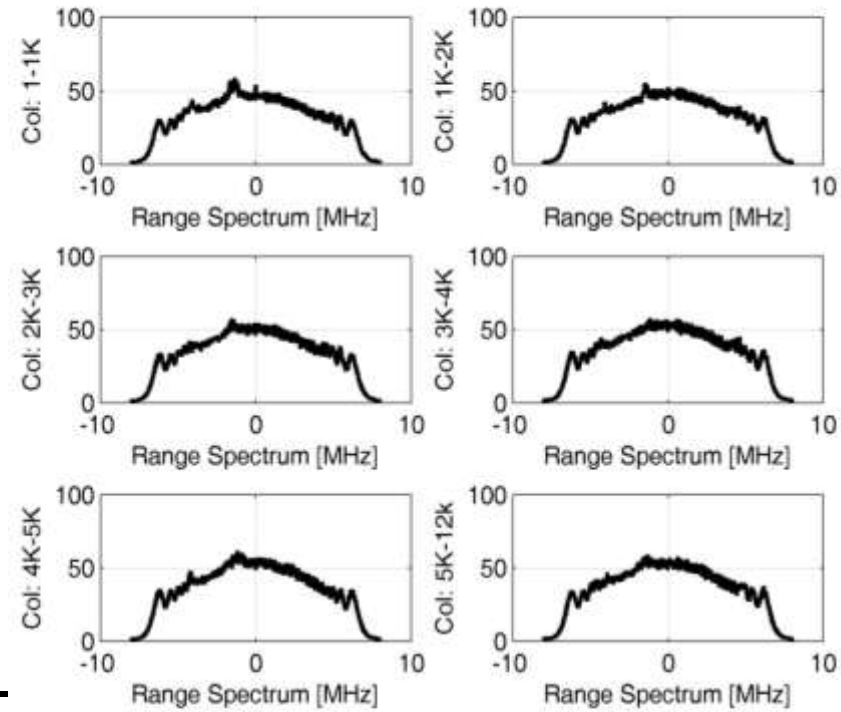
VV

VH



PALSAR Operational Notch Filter

- Notch filtering during range compression:
  - Range FFT of block of 256 azimuth lines
  - Average spectrum along azimuth
  - Analyze gain for anomalies & apply notch filter if anomaly is detected
  - Then perform range and azimuth compression



- Problem:
  - Due to the wide bandwidth and changing center frequency, anomalies difficult to detect by PALSAR notch filter

→***Especially in the cross-pol channels***, PALSAR processor not able to provide sufficiently corrected data

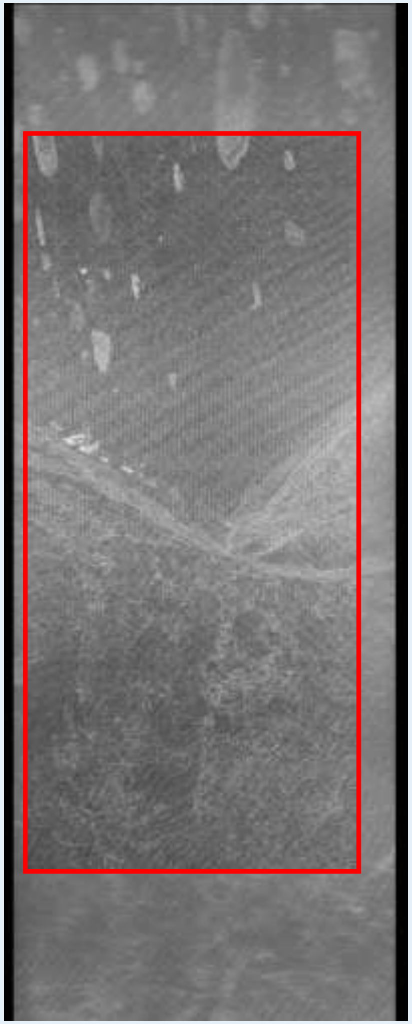
Effects on SAR Imaging and Polarimetry

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

- Focused SAR image with PALSAR operational notch-filtering

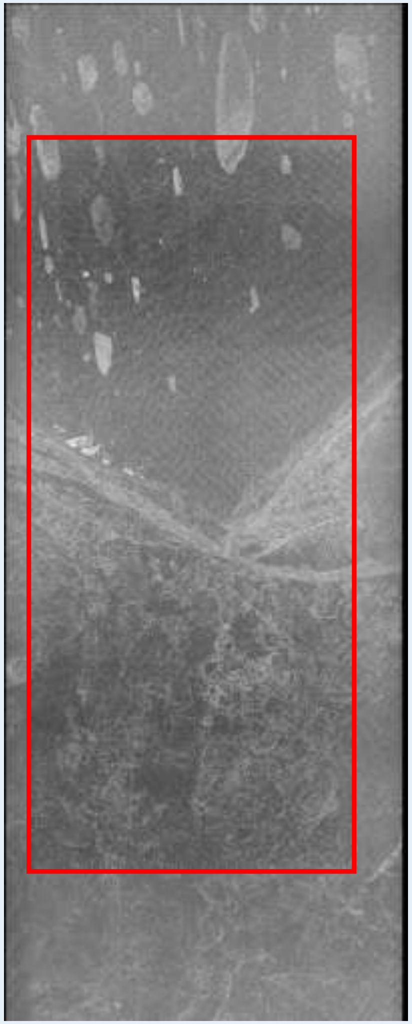
HH

HV



VV

VH



A Simple RFI Screening Method

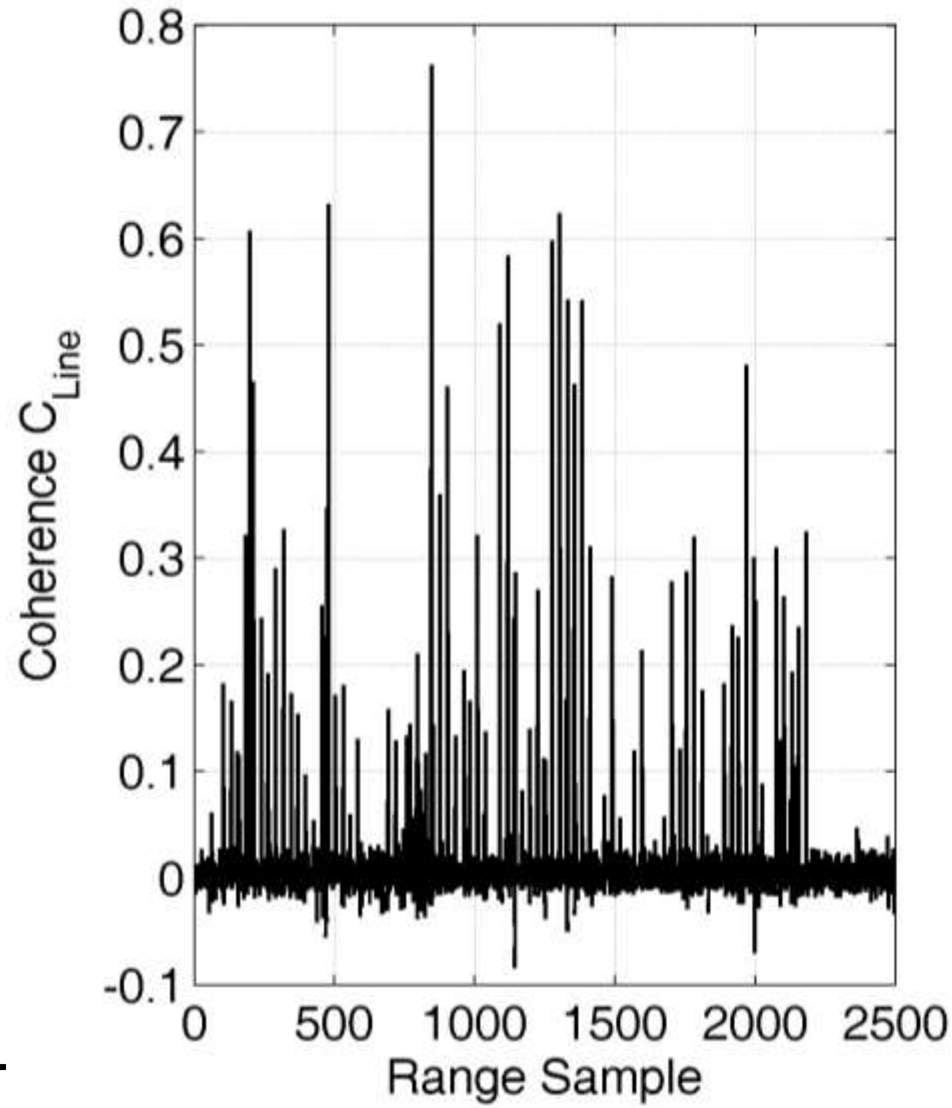
- Per column of range compressed raw data, calculate coherence between odd and even samples:

$$C_{Line} = \frac{\left|\left\langle f_{even} f_{odd}^{*} \right\rangle\right|}{\sqrt{\left\langle f_{even} f_{even}^{*} \right\rangle \left\langle f_{odd} f_{odd}^{*} \right\rangle}}$$

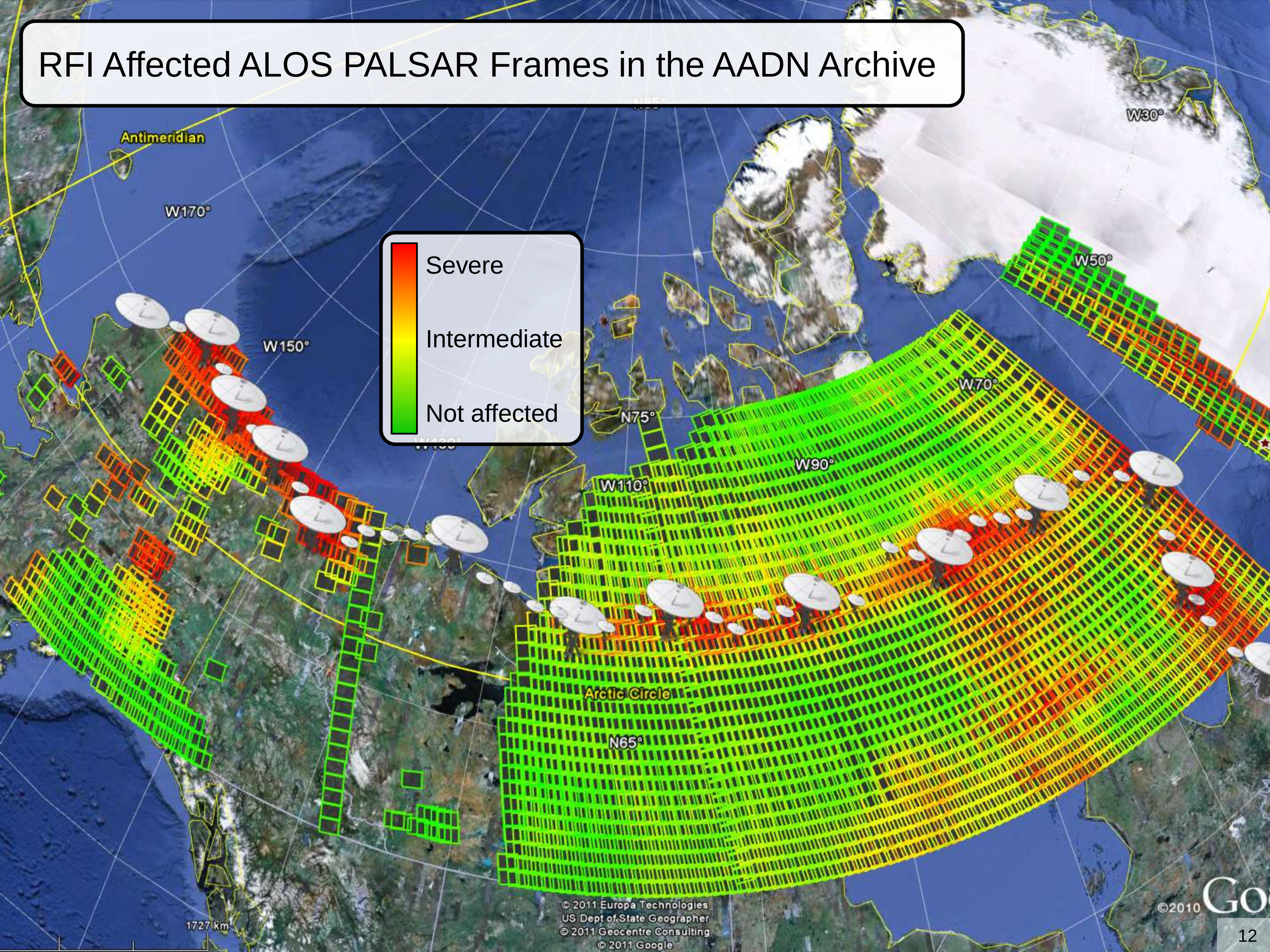
- This coherence is composed of SAR signal and RFI components

$$C_{Line} = C_{RFI} + C_{SAR}$$

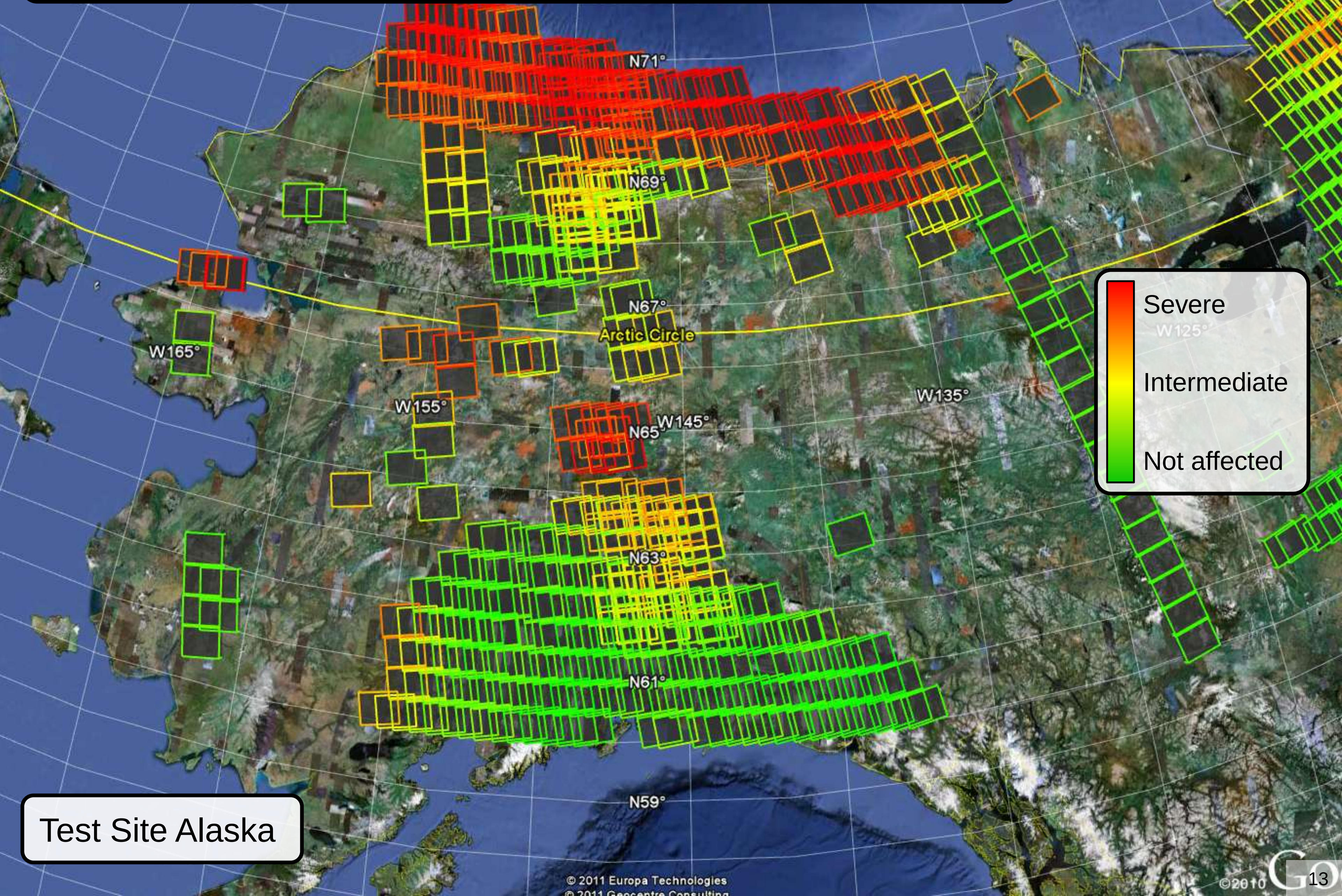
- C_{SAR} is small and can either be ignored or identified in an averaging process
- The plot to the right shows results where high coherence peaks correspond to RFI affected lines



RFI Affected ALOS PALSAR Frames in the AADN Archive

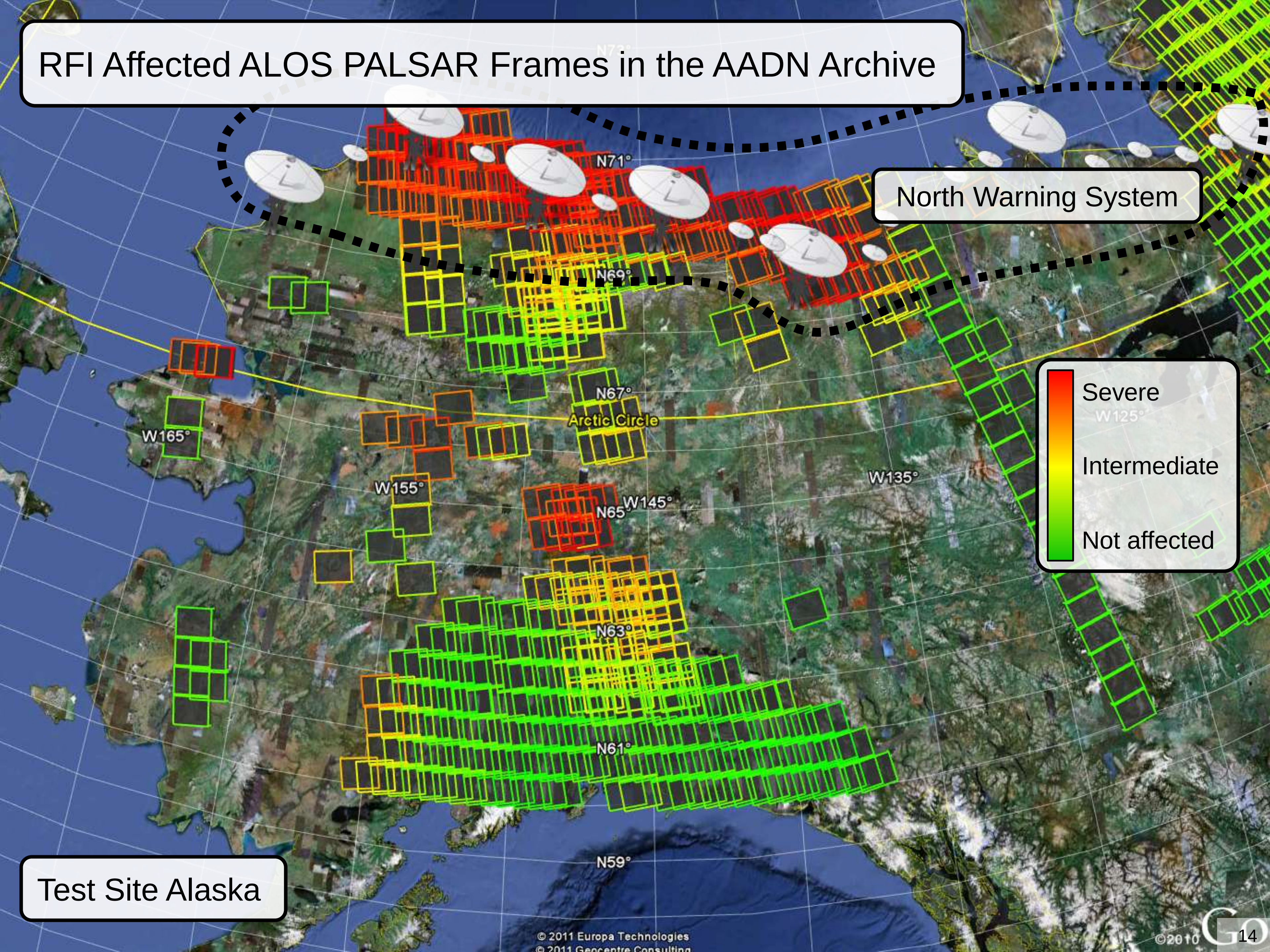


RFI Affected ALOS PALSAR Frames in the AADN Archive



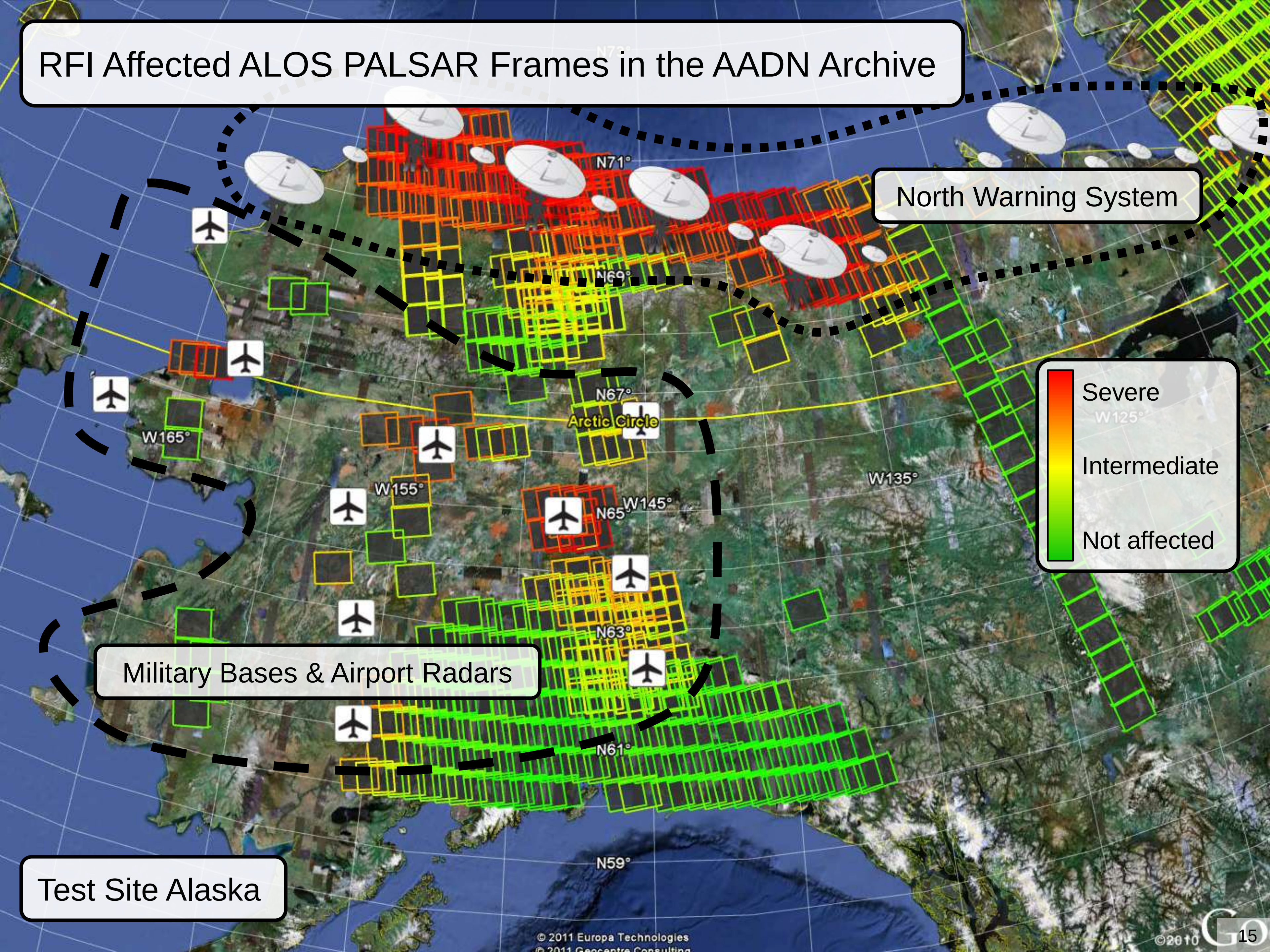
Test Site Alaska

RFI Affected ALOS PALSAR Frames in the AADN Archive



Test Site Alaska

RFI Affected ALOS PALSAR Frames in the AADN Archive

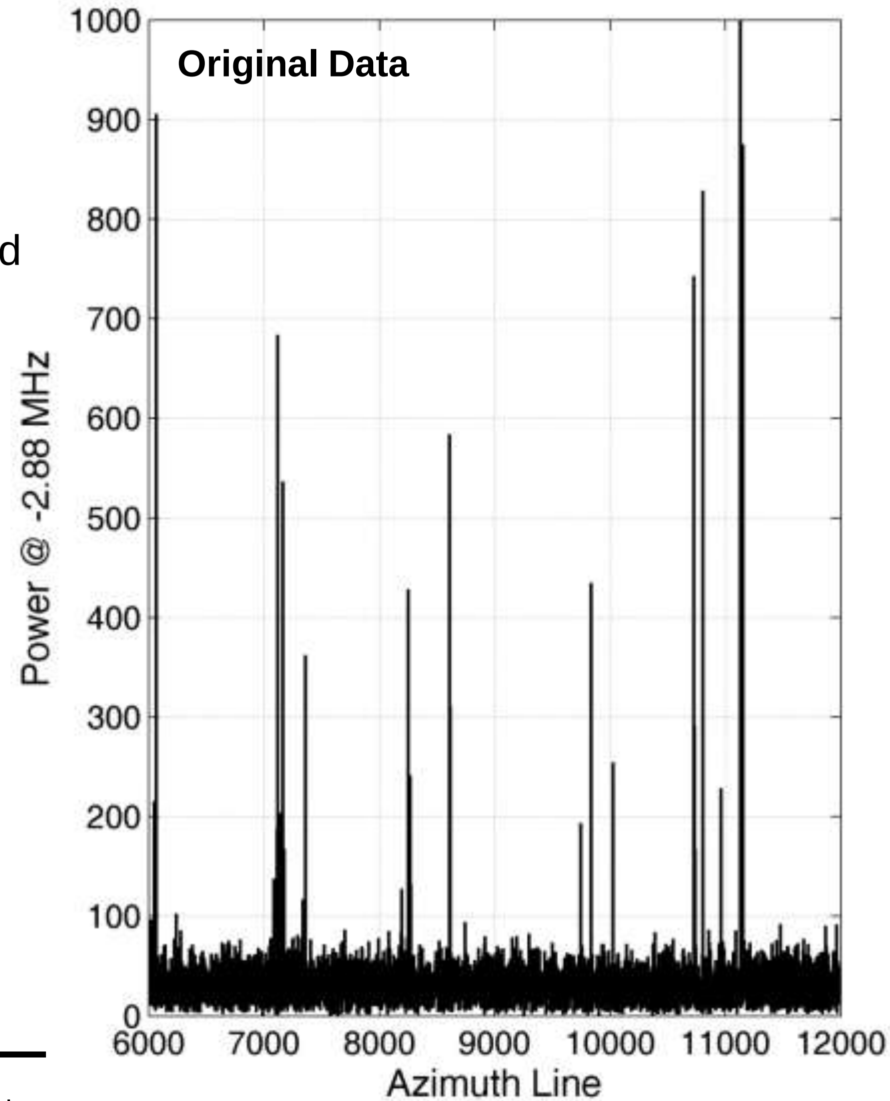


Test Site Alaska

Notch Filtering based on Azimuth Analysis

- Signatures are high power, narrow in azimuth time, wide bandwidth
  →detection based on azimuth analysis proposed

- Workflow:
  – Range compression
  – Range FFT
  – Cut through azimuth-time range-frequency diagram along azimuth
  – Detection of interference by local outlier analysis along azimuth
  – Notch filtering by removal of detected outliers
  – Azimuth compression



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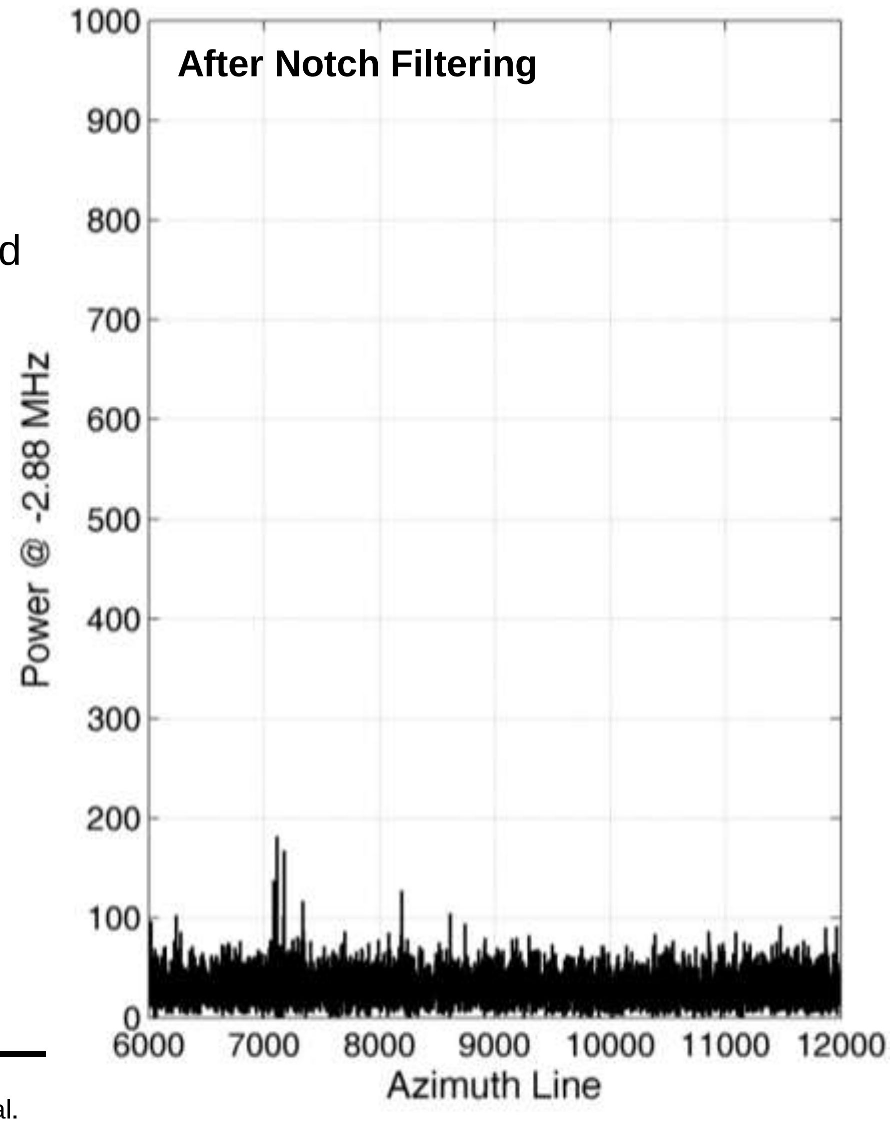


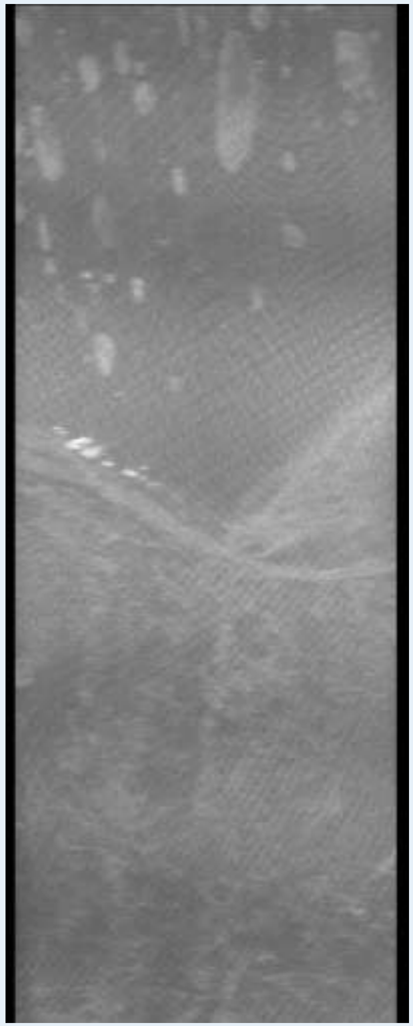
Effects on SAR Imaging and Polarimetry

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

- Focused SAR image without notch-filtering

HH

HV



VV

VH

Effects on SAR Imaging and Polarimetry

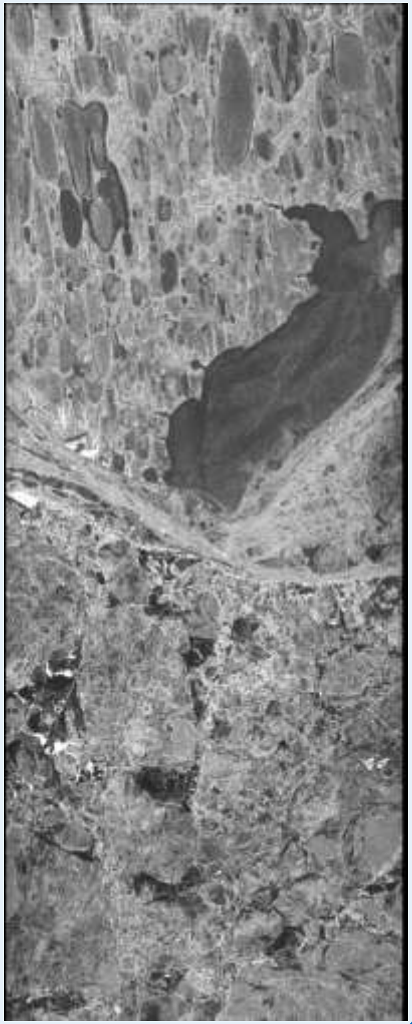
PALSAR PLR21.5: Orbit: 17260; Frame: 1440

- Focused SAR image with azimuth analysis-based notch-filtering

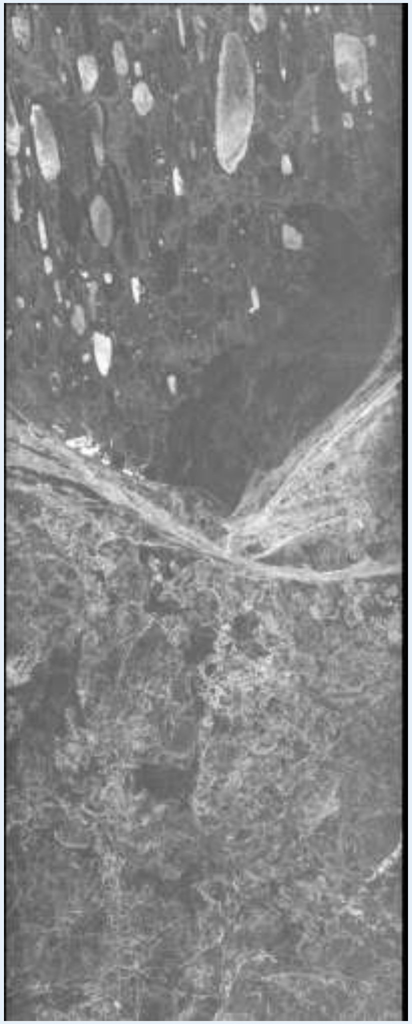
HH

HV

VV



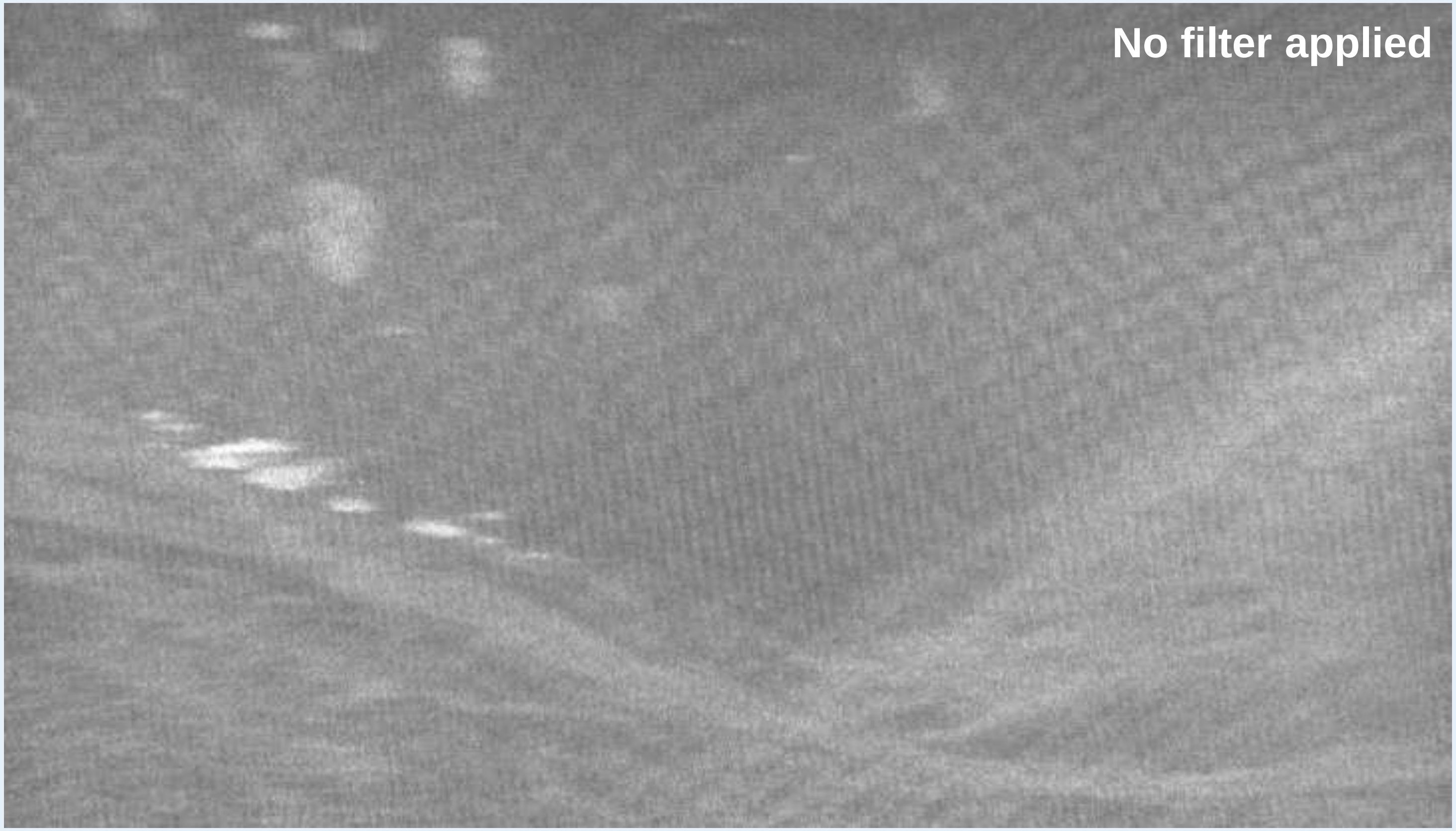
VH



Effects on SAR Imaging and Polarimetry

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

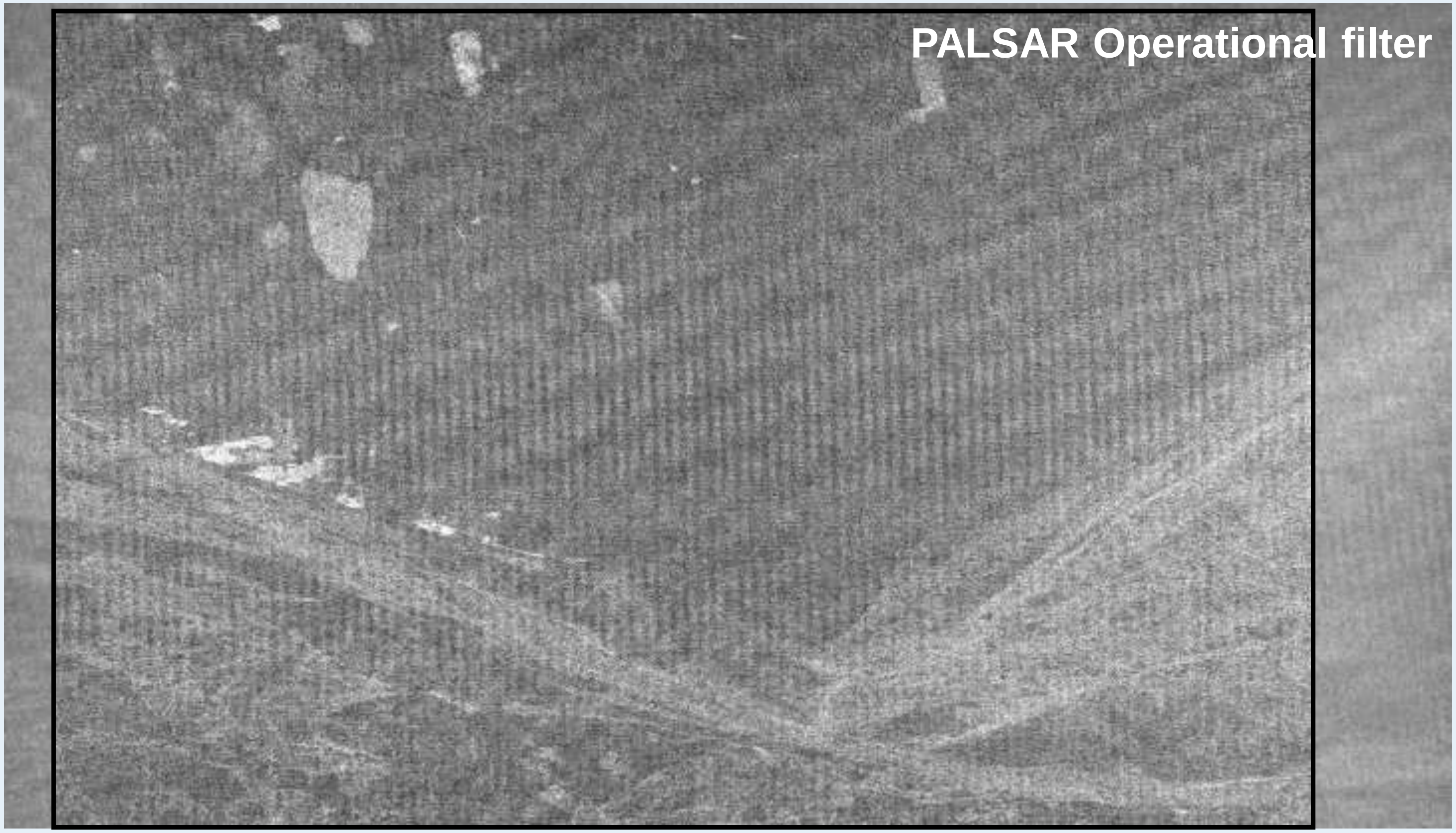
HV



Effects on SAR Imaging and Polarimetry

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

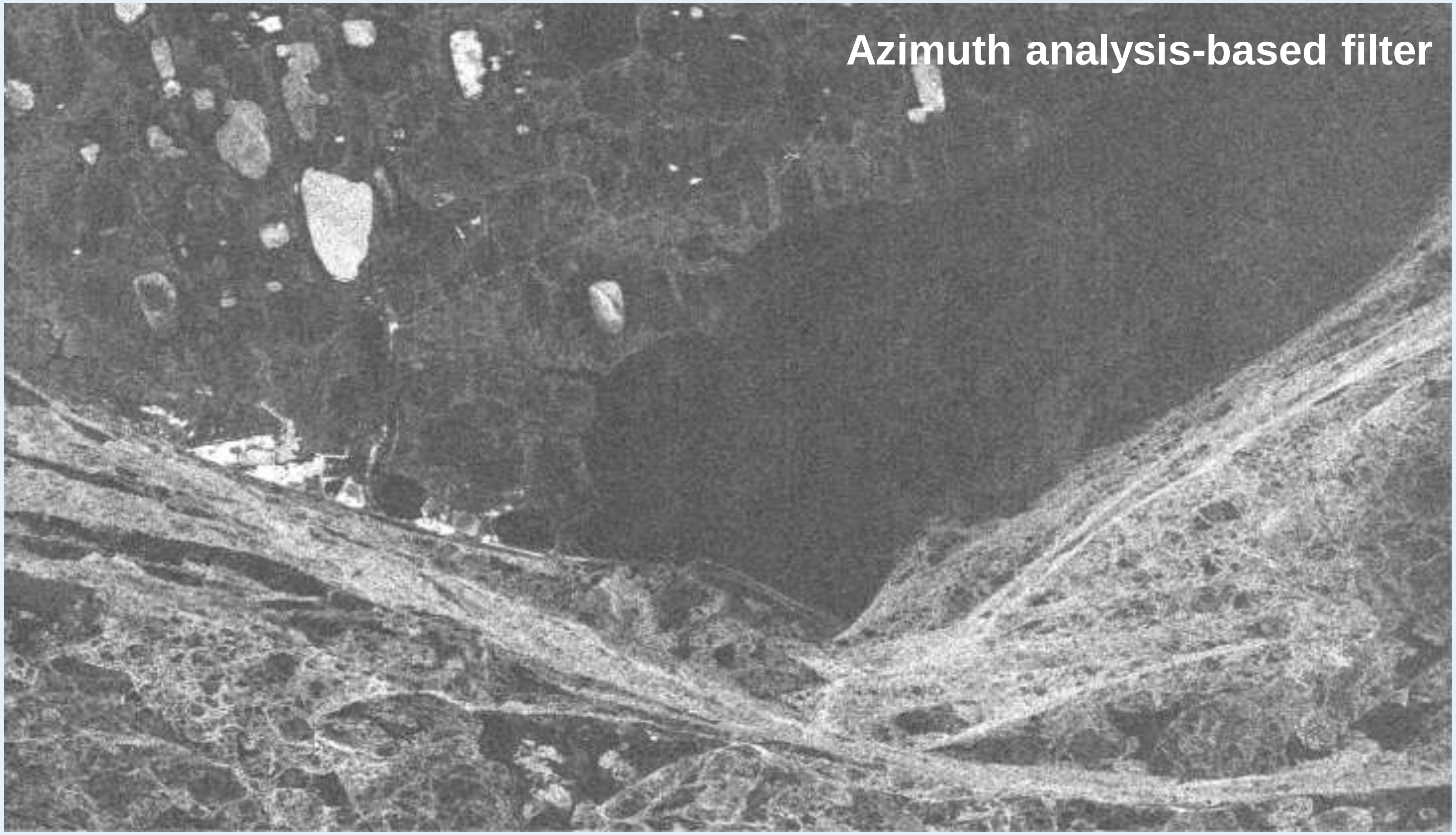
HV



Effects on SAR Imaging and Polarimetry

PALSAR PLR21.5: Orbit: 17260; Frame: 1440

HV



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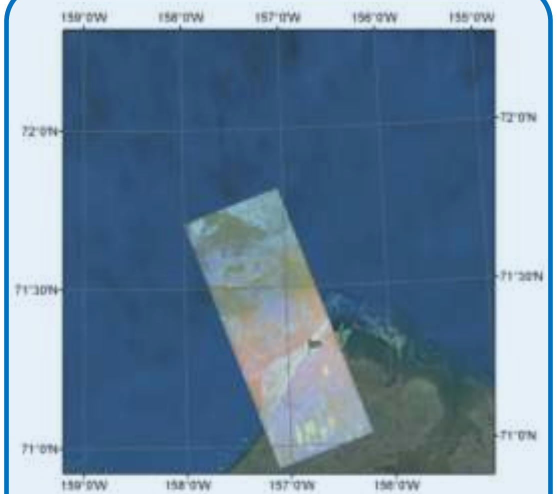
Correction Results – Polarimetric Signature

PALSAR PLR21.5: Orbit: 16837; Frame: 1440



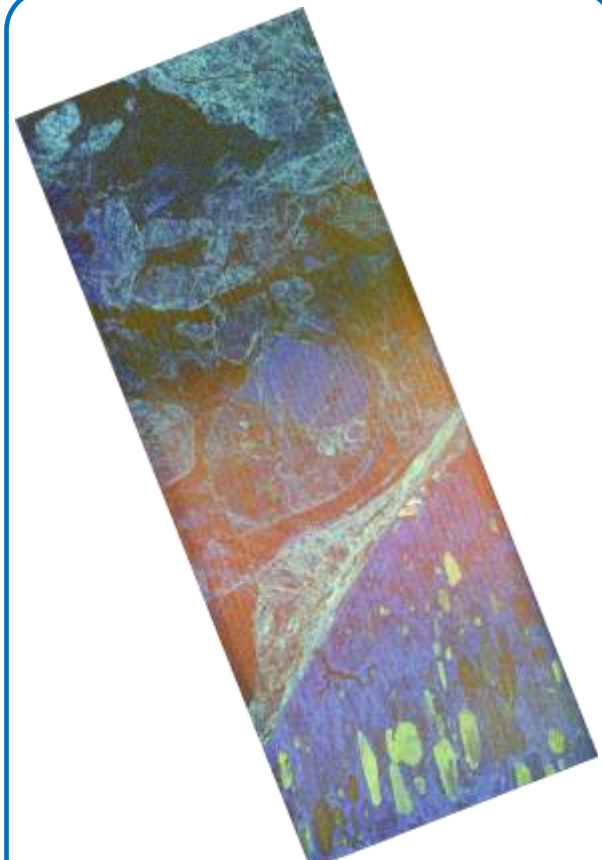
Geographic Location

Acquisition Date:

March 23, 2009

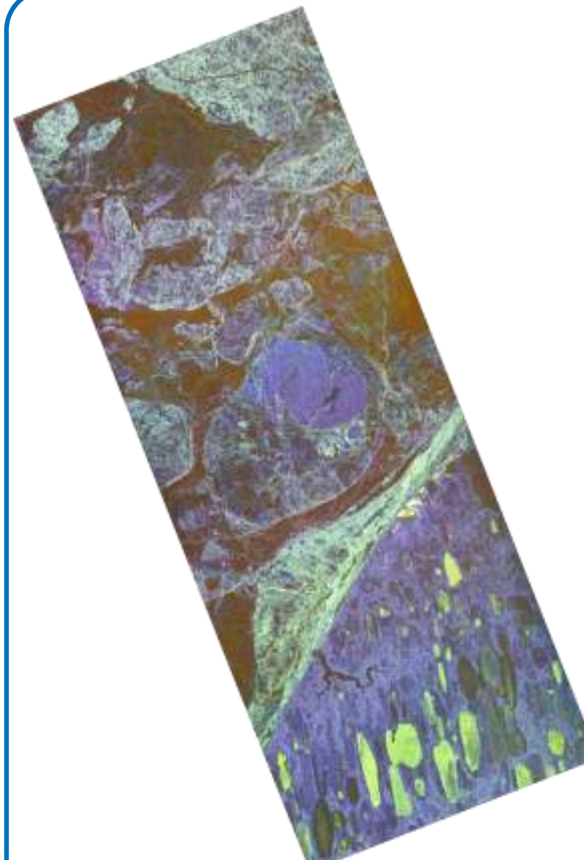
RFI Source:

Long Range Radar Station (LRRS) near Point Barrow, AK



Pauli Decomposition

Before Notch Filtering

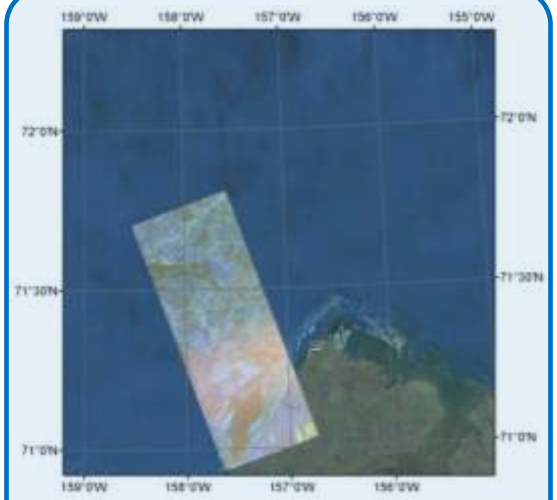


Pauli Decomposition

After Notch Filtering

Correction Results – Polarimetric Signature

PALSAR PLR21.5: Orbit: 17085; Frame: 1440



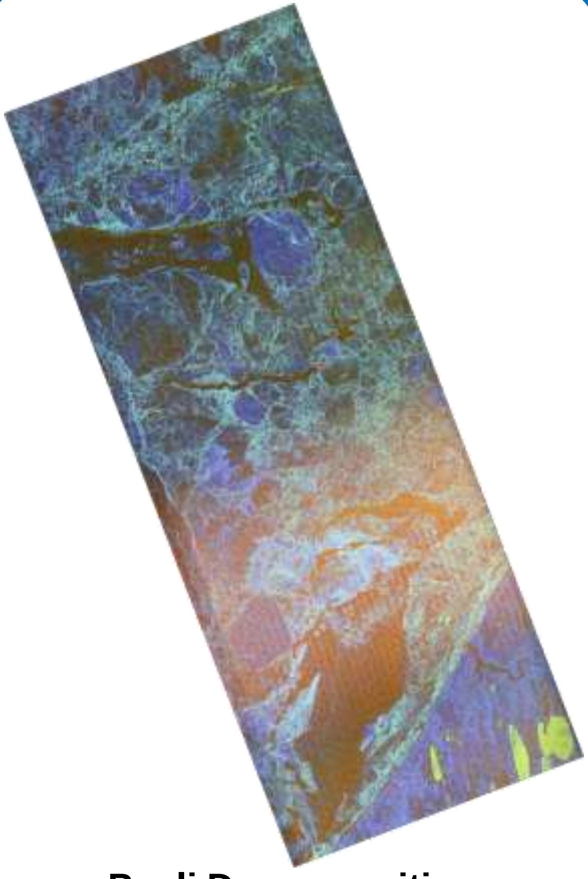
Geographic Location

Acquisition Date:

April 09, 2009

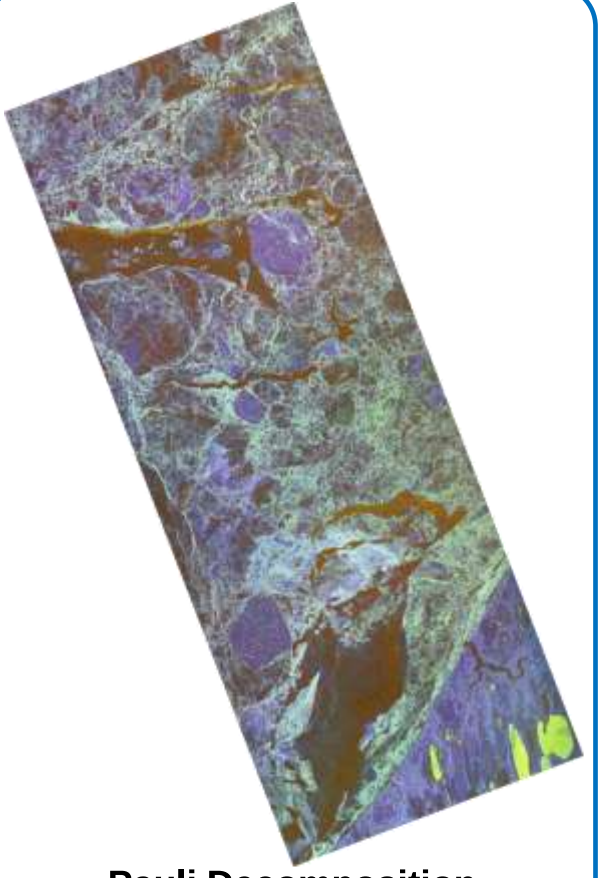
RFI Source:

Long Range Radar Station (LRRS) near Point Barrow, AK



Pauli Decomposition

Before Notch Filtering

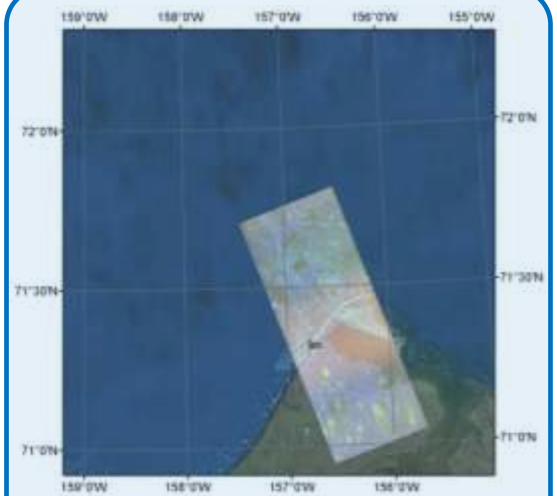


Pauli Decomposition

After Notch Filtering

Correction Results – Polarimetric Signature

PALSAR PLR21.5: Orbit: 17260; Frame: 1440



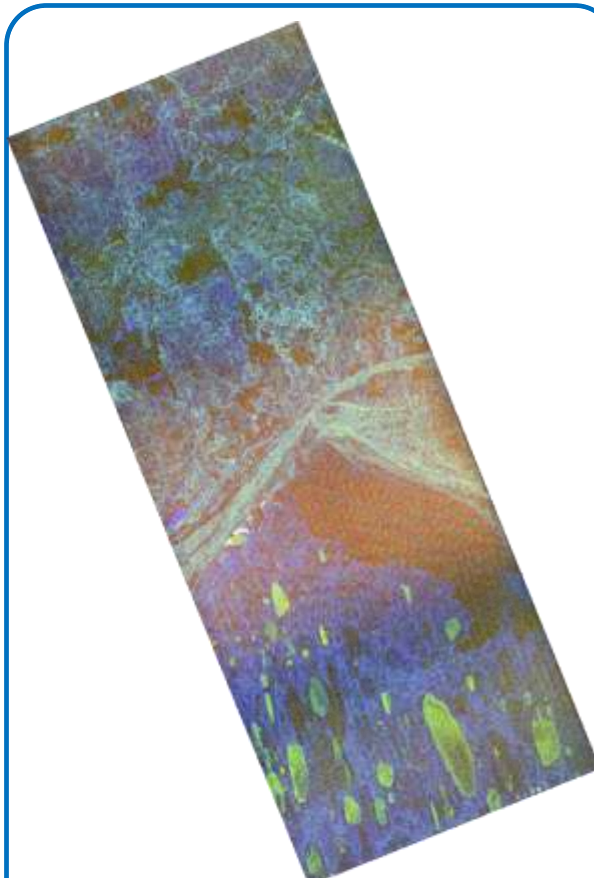
Geographic Location

Acquisition Date:

April 21, 2009

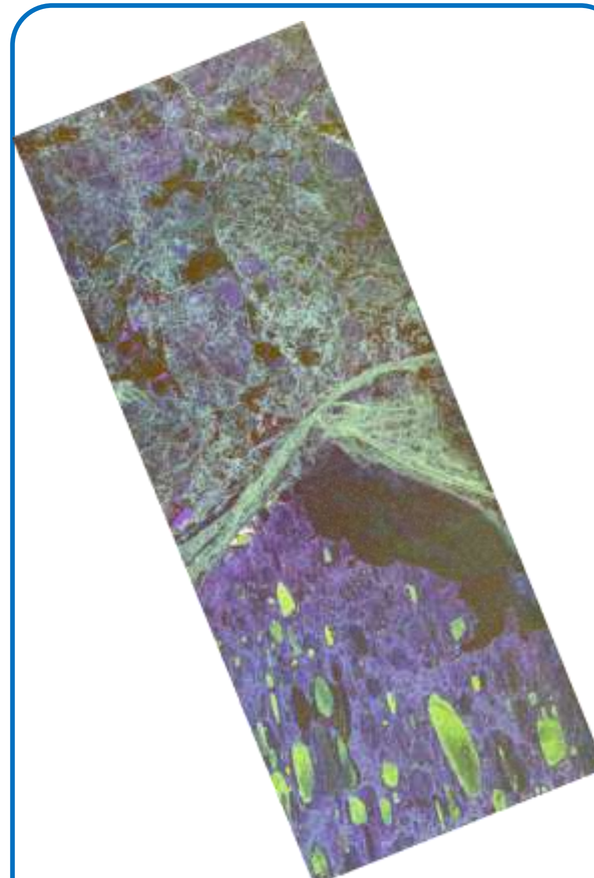
RFI Source:

Long Range Radar Station (LRRS) near Point Barrow, AK



Pauli Decomposition

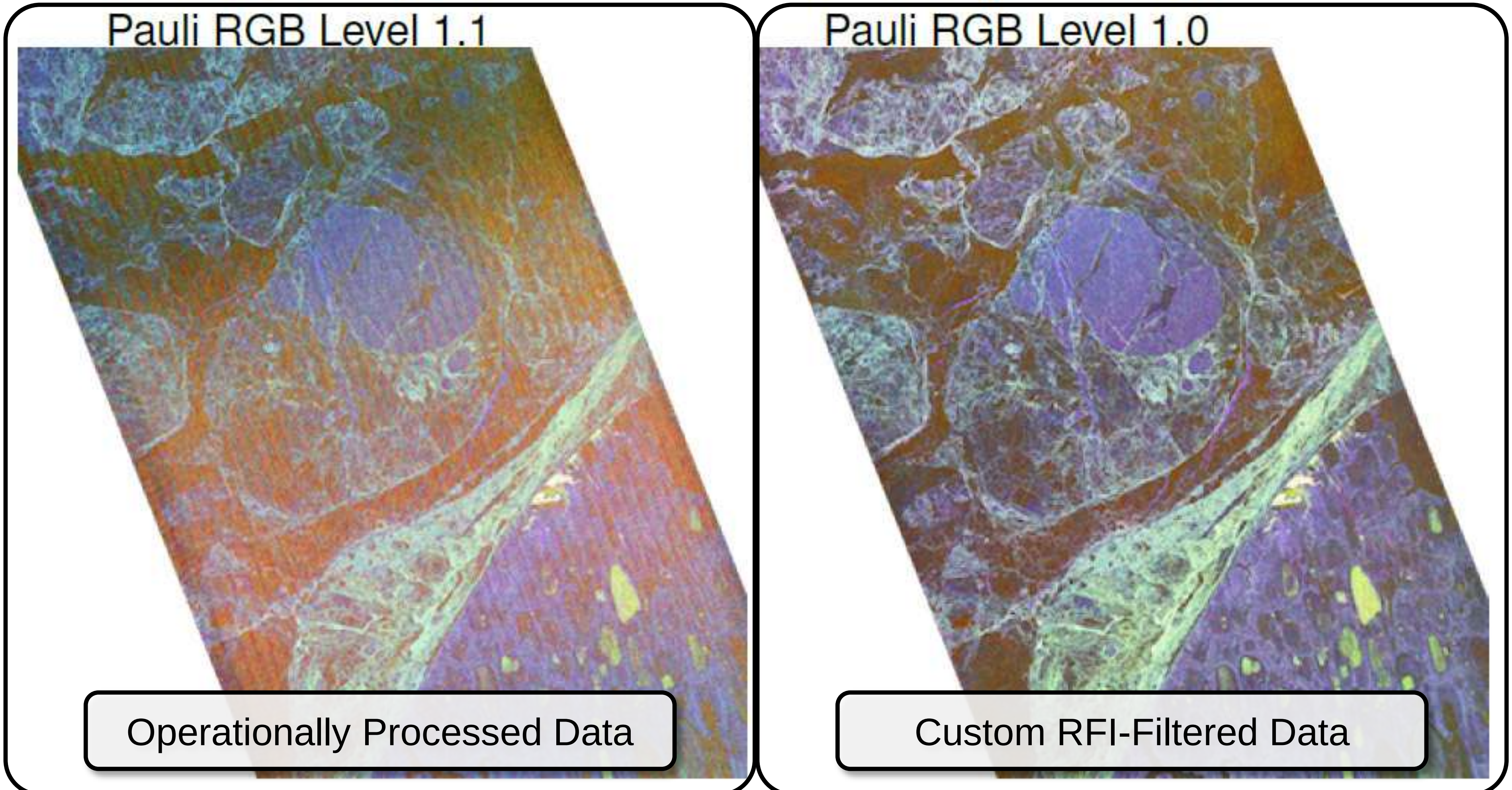
Before Notch Filtering



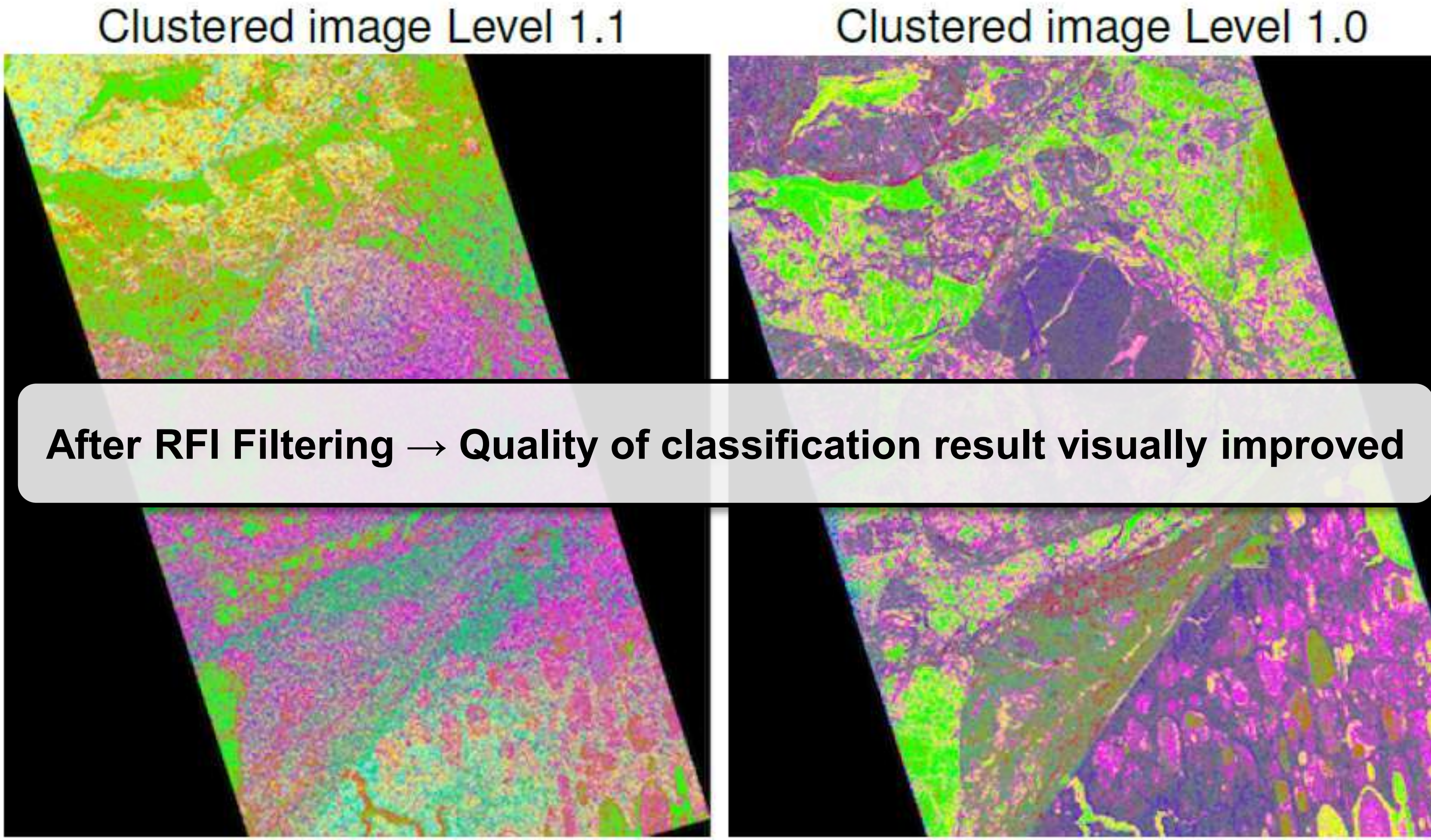
Pauli Decomposition

After Notch Filtering

Benefit of Developed RFI Filter for Polarimetric Classification of Sea Ice Features

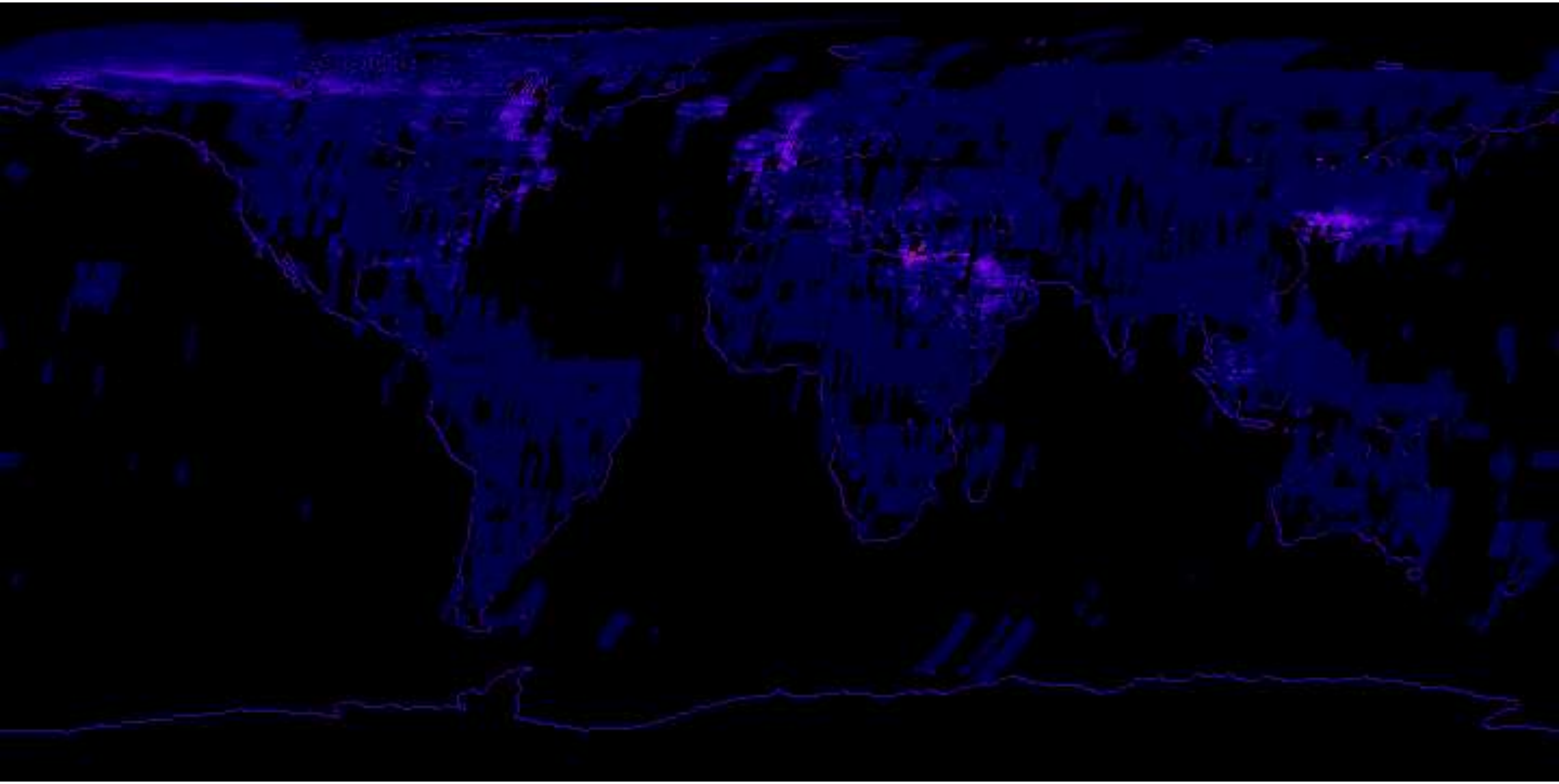


Benefit of Developed RFI Filter for Polarimetric Classification of Sea Ice Features



After RFI Filtering → Quality of classification result visually improved

RFI monitoring by JERS-1 SAR (1992-1998)



Normalized zero padded bandwidth (%)

RFI monitoring by PALSAR (2010~2011)

Normalized zero padded bandwidth (%)

Conclusions and Recommendations:

- L-band interference from over-the-horizon radars problematic in large parts of the American Arctic
- Pulsed ground based systems cause temporarily narrow, high-power, and wide bandwidth interferences with randomly changing f_c
- Standard PALSAR processing scheme insufficient for removing interferences
- A modified azimuth-based filtering algorithm shows good performance in removing RFI signals and restoring original data quality
- Real data examples show successful mitigation of interferences
- Polarimetric signatures after RFI filtering significantly improved
- Growing issues of RFI in Microwave Remote Sensing needs to be addressed

ANNOUNCEMENT:

2011 CEOS SAR Calibration and Validation Workshop

Fairbanks, Alaska

Workshop Dates: **November 7 – 9, 2011**

Abstract Deadline: **September 14, 2011**

More information at:

www.asf.alaska.edu/ceos_workshop/

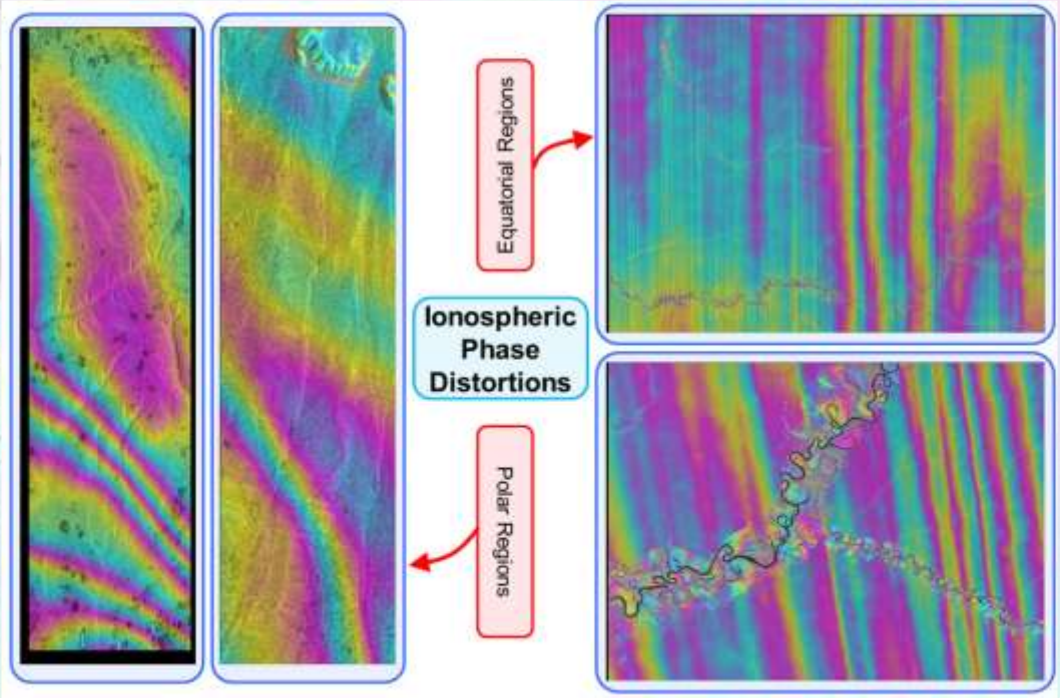
Open Three Year PhD Position

starting fall 2011 / spring 2012 for a radar remote sensing research project at the Geophysical Institute of the University of Alaska Fairbanks on

Theoretical Investigations into the Impact and Mitigation of Ionospheric Effects on Low-Frequency SAR and InSAR Data

Research Focus:

- Investigation of spatial and temporal properties of ionospheric effects in SAR data
- Development of statistical signal models
- Design of optimized methods for ionospheric correction

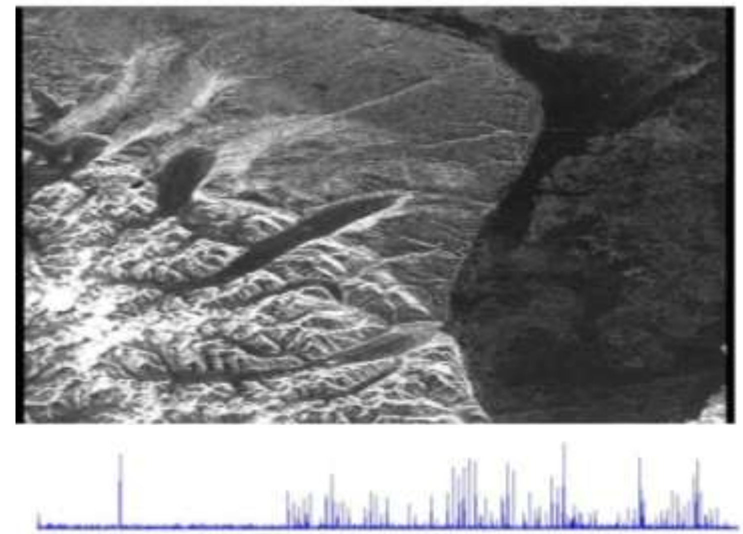


More information:

Dr. Franz Meyer (fmeyer@gi.alaska.edu) and at: www.insar.alaska.edu

Image and kml Creation

- An average coherence is calculated per image. For example to the right C=0.010 (1.0% RFI coherence)



- A kml bounding box is created and color coded according to interference severity (green=low RFI, yellow=moderate RFI, and red= high RFI).