Along−Track Interferometry

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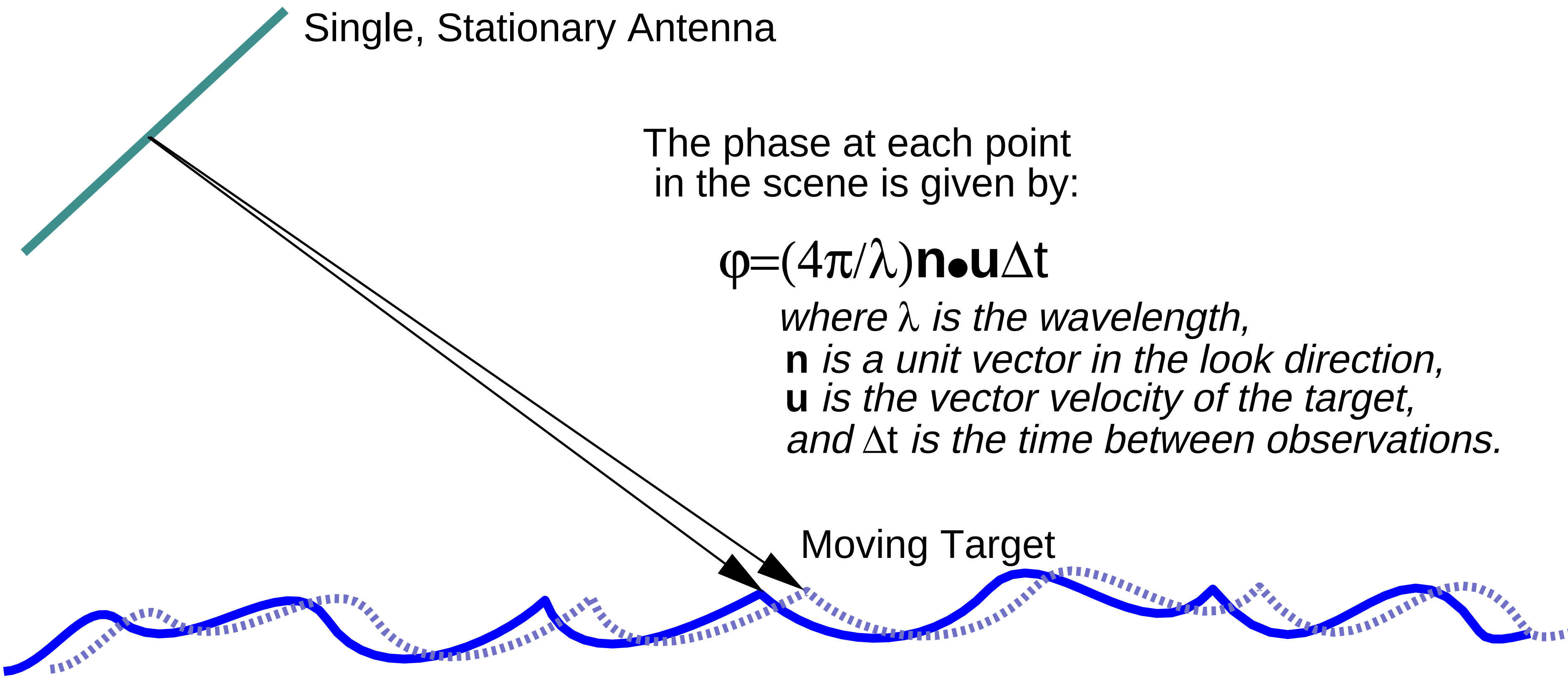

The phase at each point in the scene is given by:

$$\varphi=(4\pi/\lambda)\mathbf{n}\bullet\mathbf{u}\Delta t$$

where λ *is the wavelength,*
n *is a unit vector in the look direction,*
u *is the vector velocity of the target,*
and Δt *is the time between observations.*

No interferometric baseline!
Antenna is formed by synthetic aperture.
Use two antennas on moving platform to achieve time interval.
All motion measured via ATI are components of the velocity along the look vector.
Identical to Repeat−Pass Interferometry, except...

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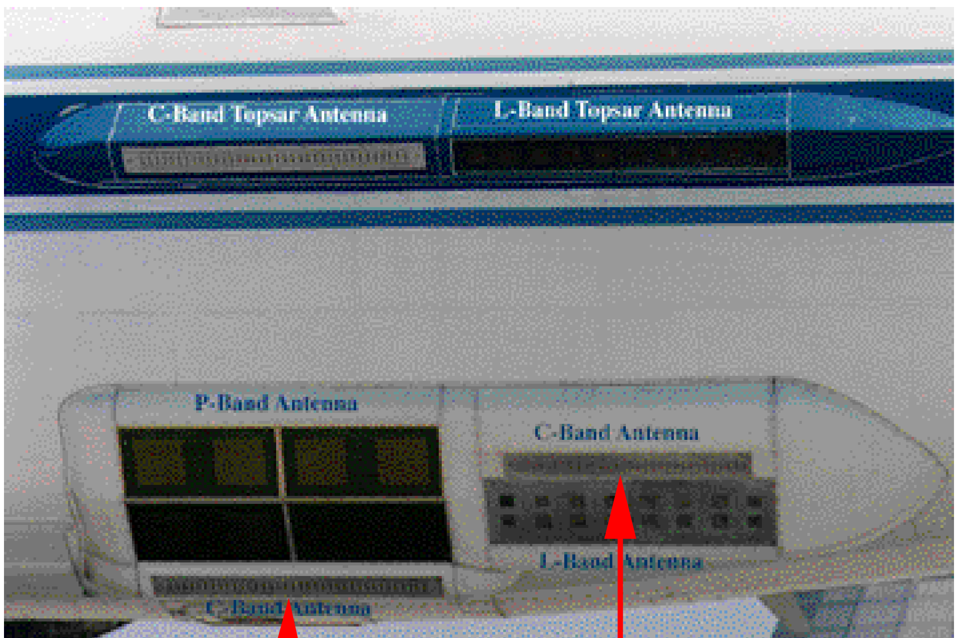
Soren Madsen	*Diane Evans*
Richard Carande	*Charles Werner*
Paul Rosen	*Ellen O'Leary*

Why ATI?

- Provides a direct measurement of velocity (vs. altimetry).
- Highlights ocean boundaries (wave velocity vs. height).
- Direct measurement of ocean coherence time.
- Better wave spectra than conventional SAR.
- Detection of moving targets: vehicles, ships, wakes.
- Mapping of surfactants, upwelling, pollution, surf–zones.

AIRSAR ATI Capability

20 meters along track



2 meters along track

L−Band

Velocity Wrap

Full Baseline:	1.2 m/s
Half Baseline:	2.4 m/s
Single Pulse:	92 m/s

C−Band

Velocity Wrap

Full Baseline:	3.0 m/s
Half Baseline:	5.9 m/s
Single Pulse:	22 m/s

Minimum detectable velocities will depend on surface brightness, system noise and number of looks. Typically phase resolution is 2−20 degrees, corresponding to a few cm/s.

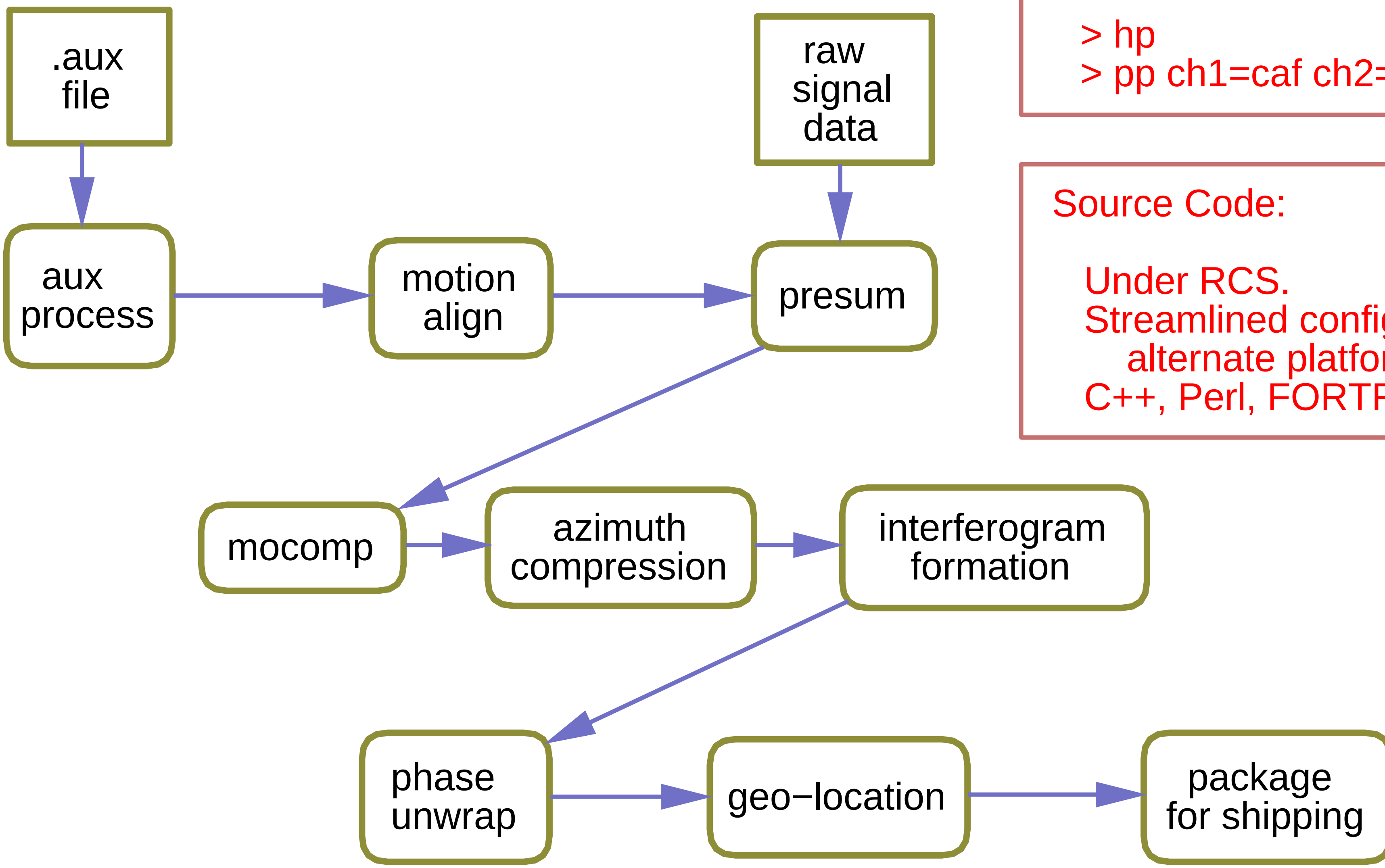
ATI Processor

Commands:

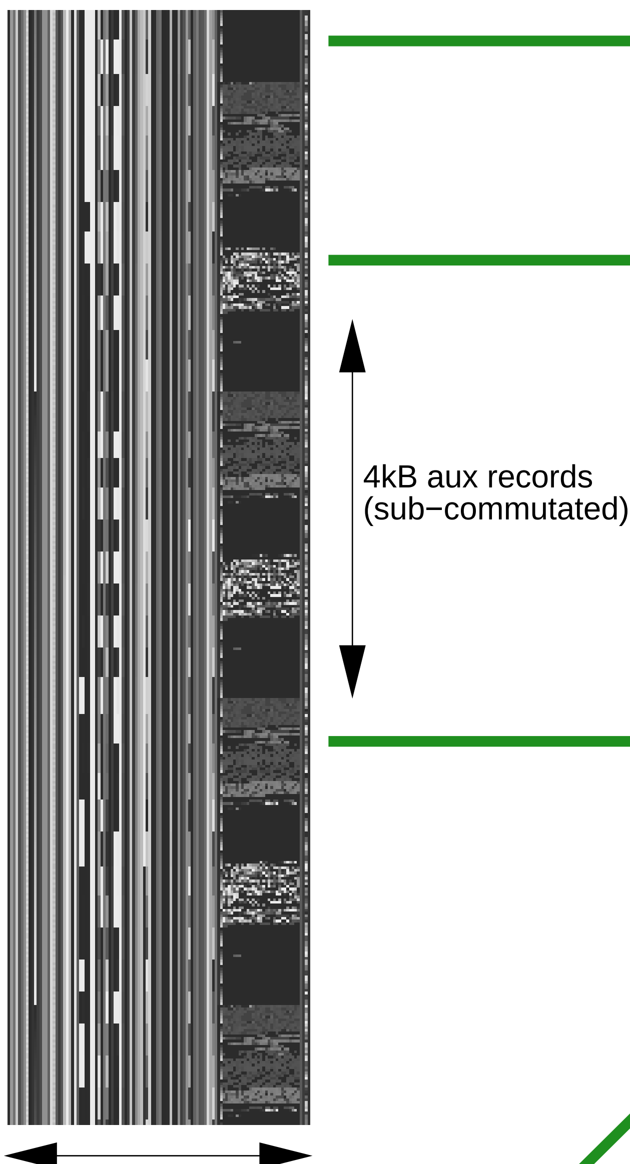
> hp
> pp ch1=caf ch2=caa

Source Code:

Under RCS.
Streamlined config for alternate platforms.
C++, Perl, FORTRAN

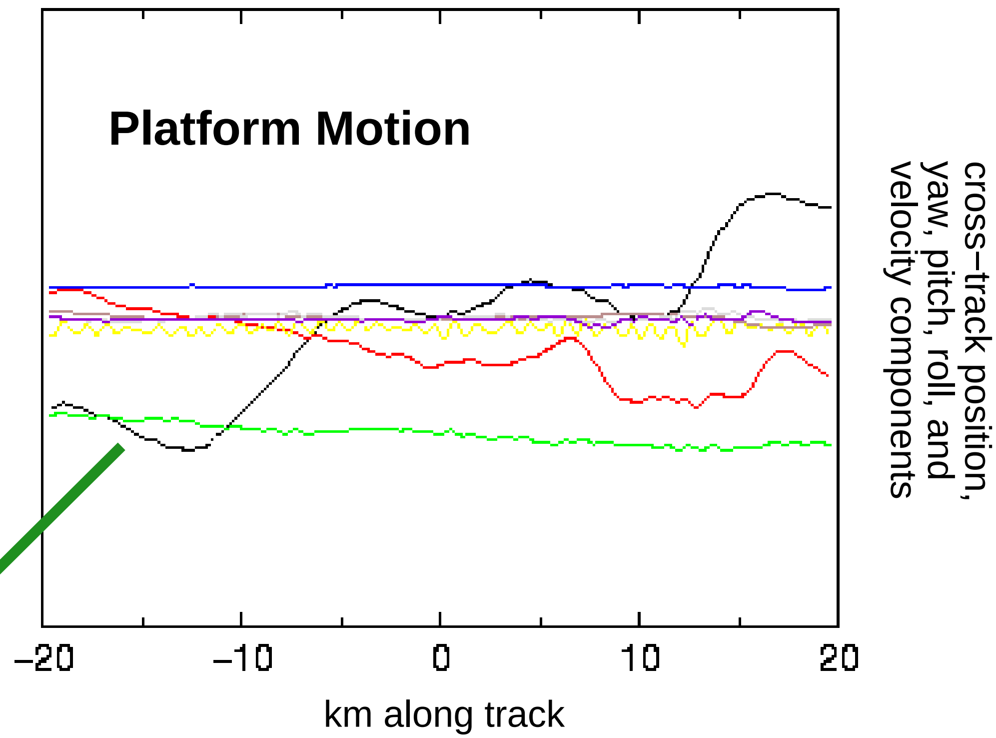


.aux File Processing



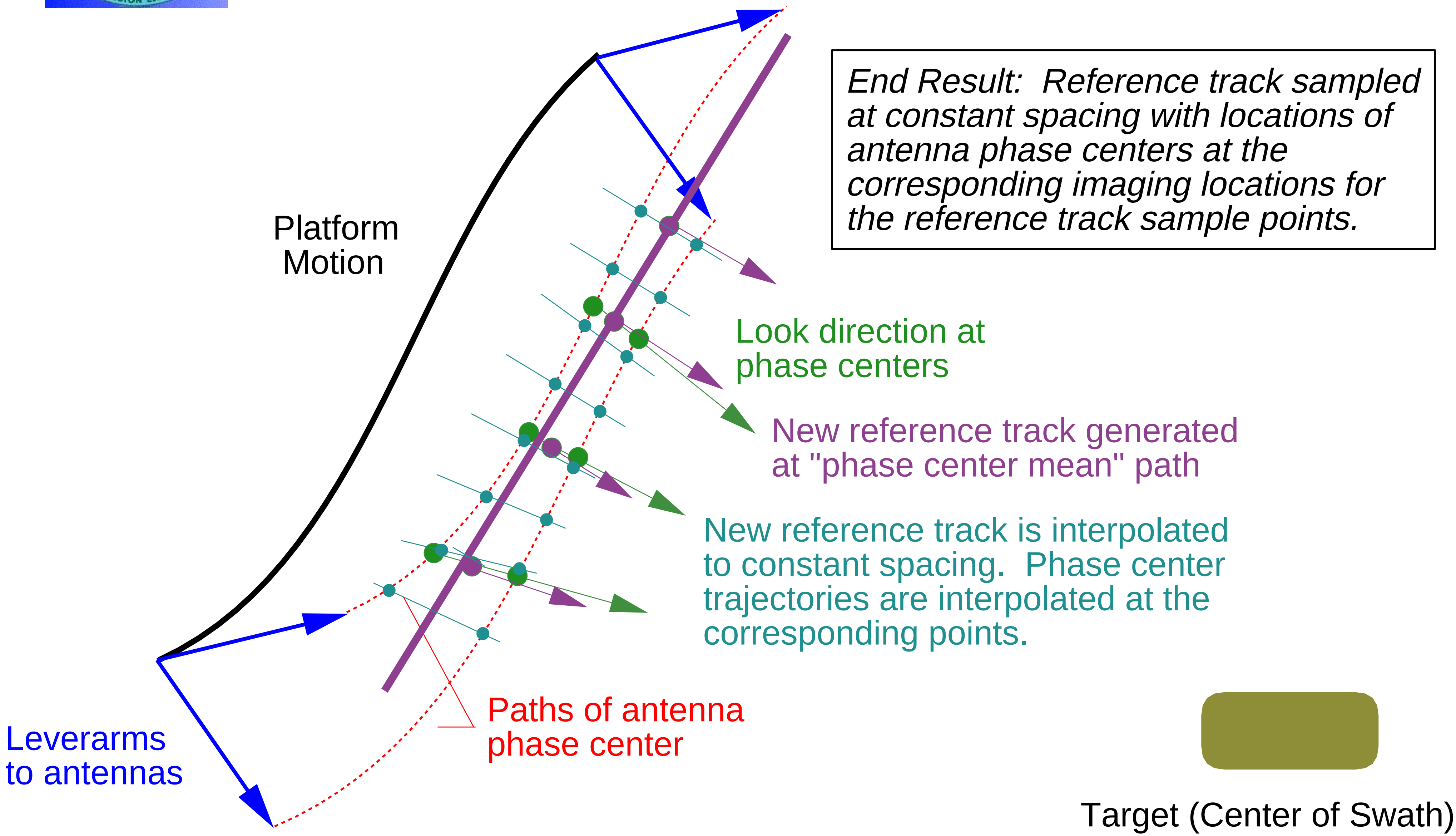
Aux Parameter File (RDF):
decoded radar configuration,
calibration information (based on date in header file), and
motion−processing information.

Frame File: time−tag for every pulse.



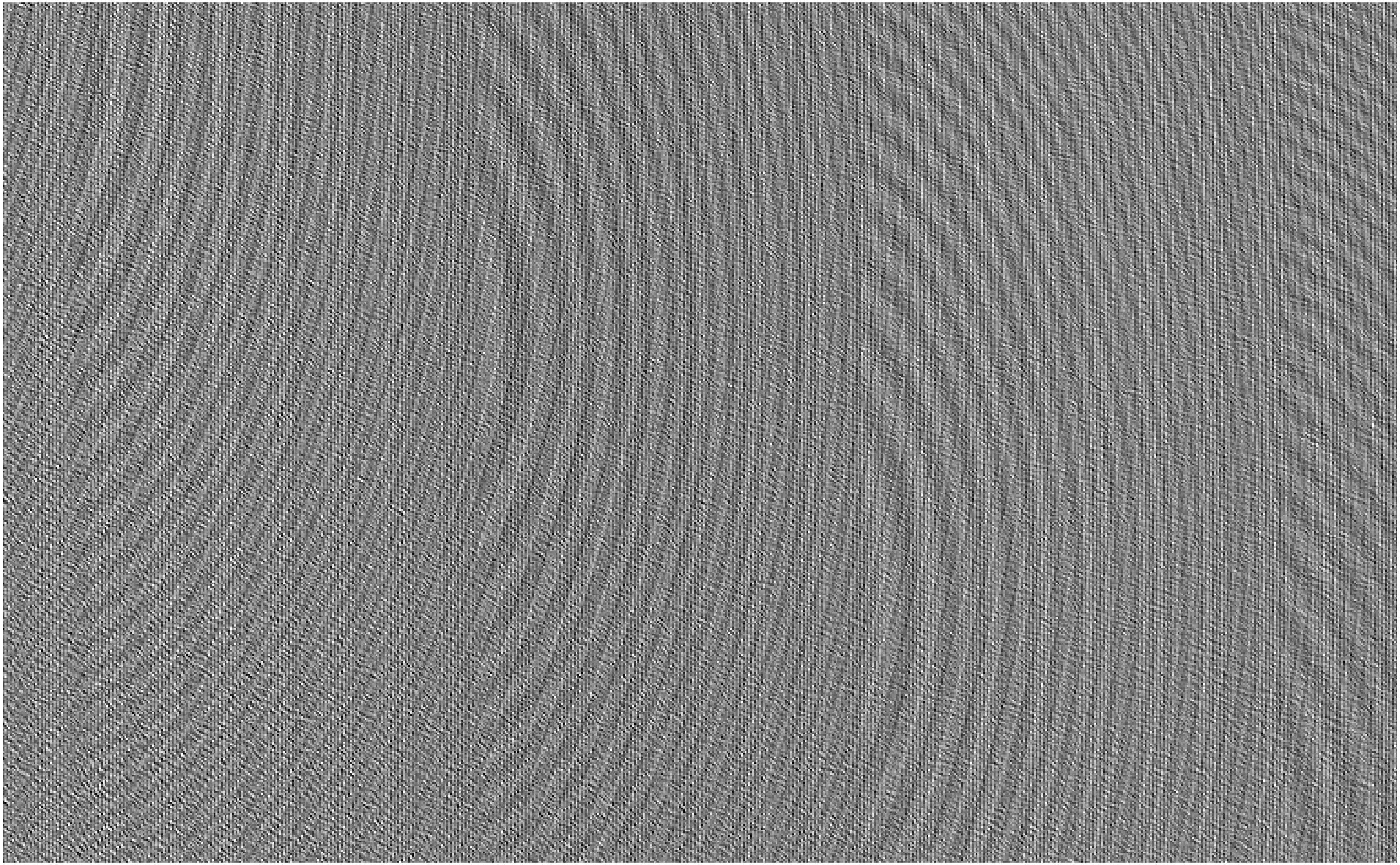
Reference Track: Peg point and heading.

Motion Alignment

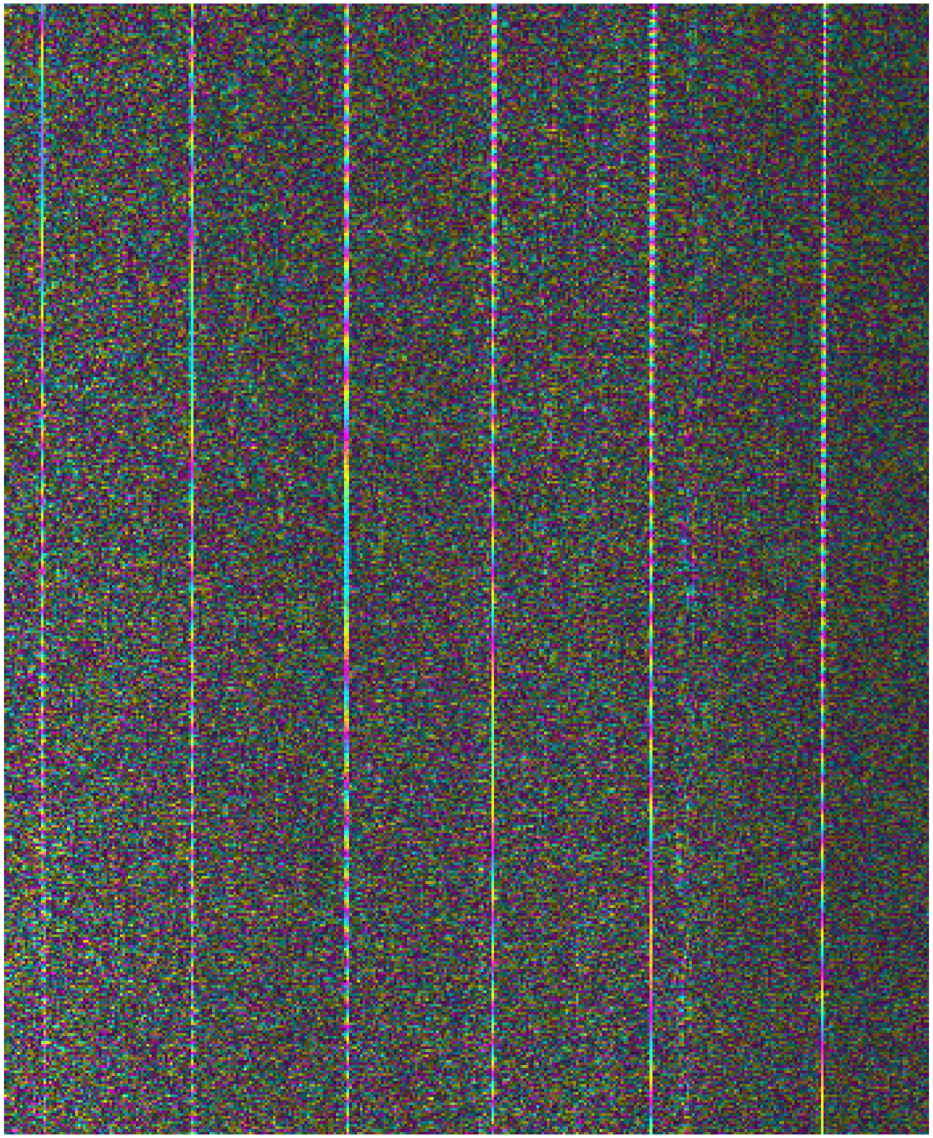


AIRSAR Signal Data

"Point Target Simulator Simulator"



Presumming/Interpolation



1) Signal returns are range compressed.

2) Doppler (as a function of look angle) is book−kept via motion data.

3) Interpolation buffer is filled−−−one filter−length's worth of pulses at a time. Filter length varies as ratio of resampled pulse spacing to the original pulse spacing along−track.

4) Pulses in buffer are base−banded to remove Doppler.

5) Pulses are interpolated.

6) Doppler shift is re−introduced to interpolated pulses. Phase continuity from pulse−to−pulse is carefully maintained.

Image Formation

1) Process in patches corresponding
   to azimuth reference function length
   plus overlap buffer. For each patch:

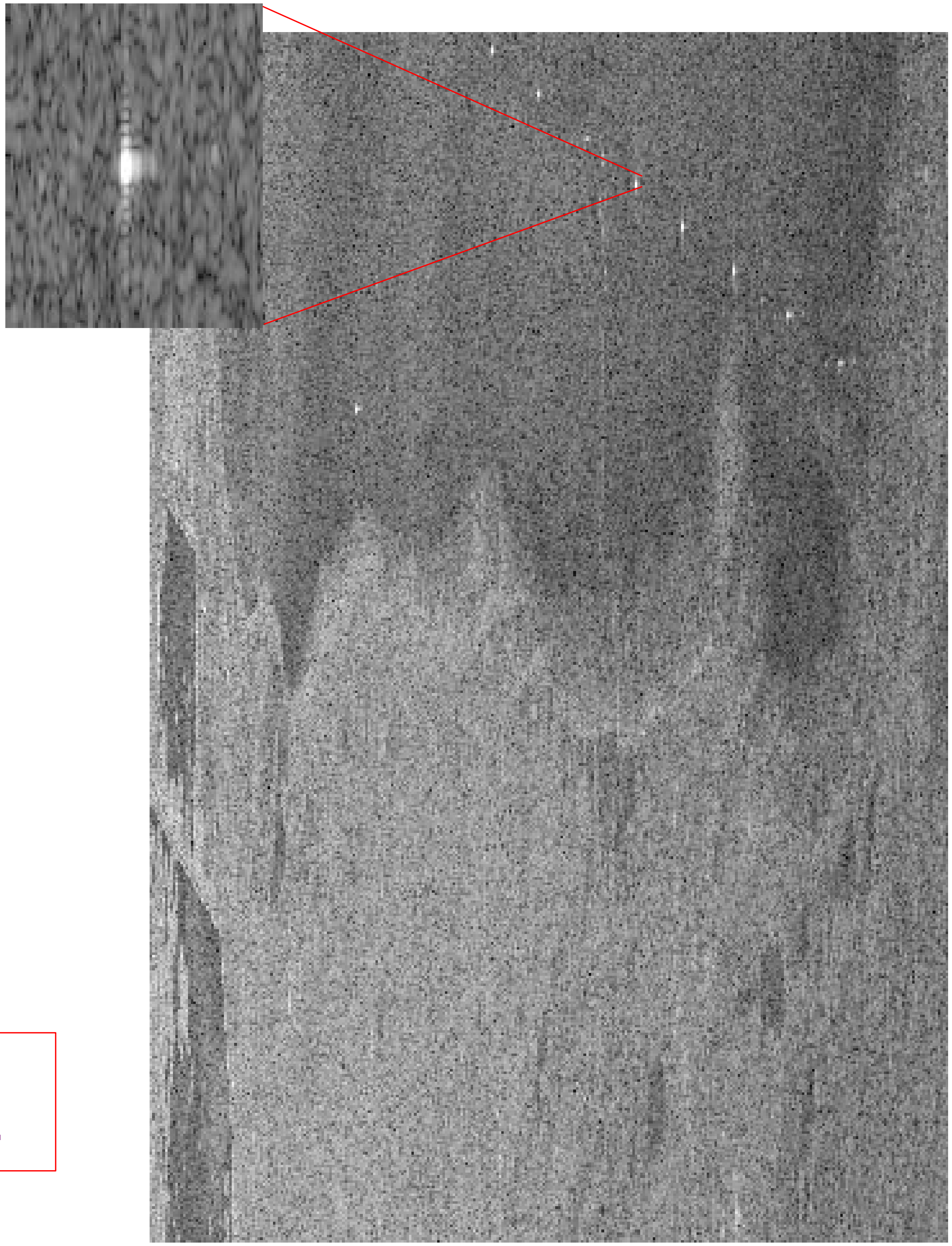
2) Propagate phase of each sample from
   the phase center of the antenna to the
   reference track. (Motion−compensation)

3) FFT in azimuth.

4) Interpolate samples to compensate for
   range walk as a function of doppler shift.
   (Range migration.)

5) Conjugate multiply with azimuth reference
   function.

6) Inverse FFT in azimuth.



Room for improvement:
  Use DEM for mocomp elevation reference.

Interferometric Calibration

Rosamond Calibration Site:

Color represents ATI phase with expanded scale:

one color cycle = 90 degrees of phase.

Calibration Procedure:

1) Compare Doppler estimates from signal data to INU−based predictions to fit for yaw and pitch biases.

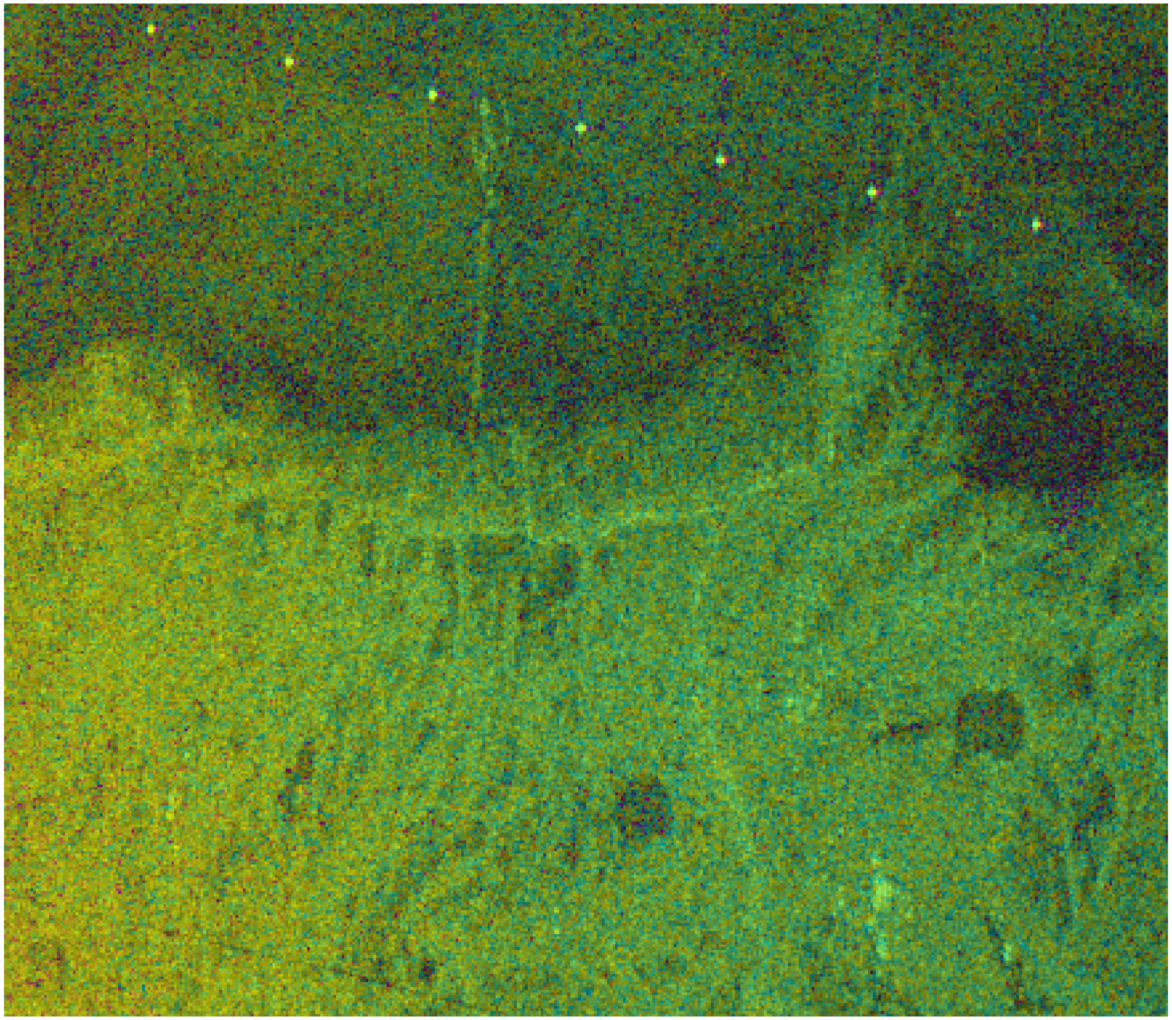
2) Use standard scene (with corner reflectors) to get common range delay.

3) Cross−correlate (in small blocks) images from both interferometric channels to get differential delay and along−track antenna leverarm components.

4) Use phase of flat, stationary calibration scene to determine cross−track and vertical antenna lever arm components.

5) Use stationary surface at known elevation reference to determine phase offset.

"Once per flight season"



Geo−coding

Determine the (s,c) coordinate for each (pulse,slant range) coordinate:

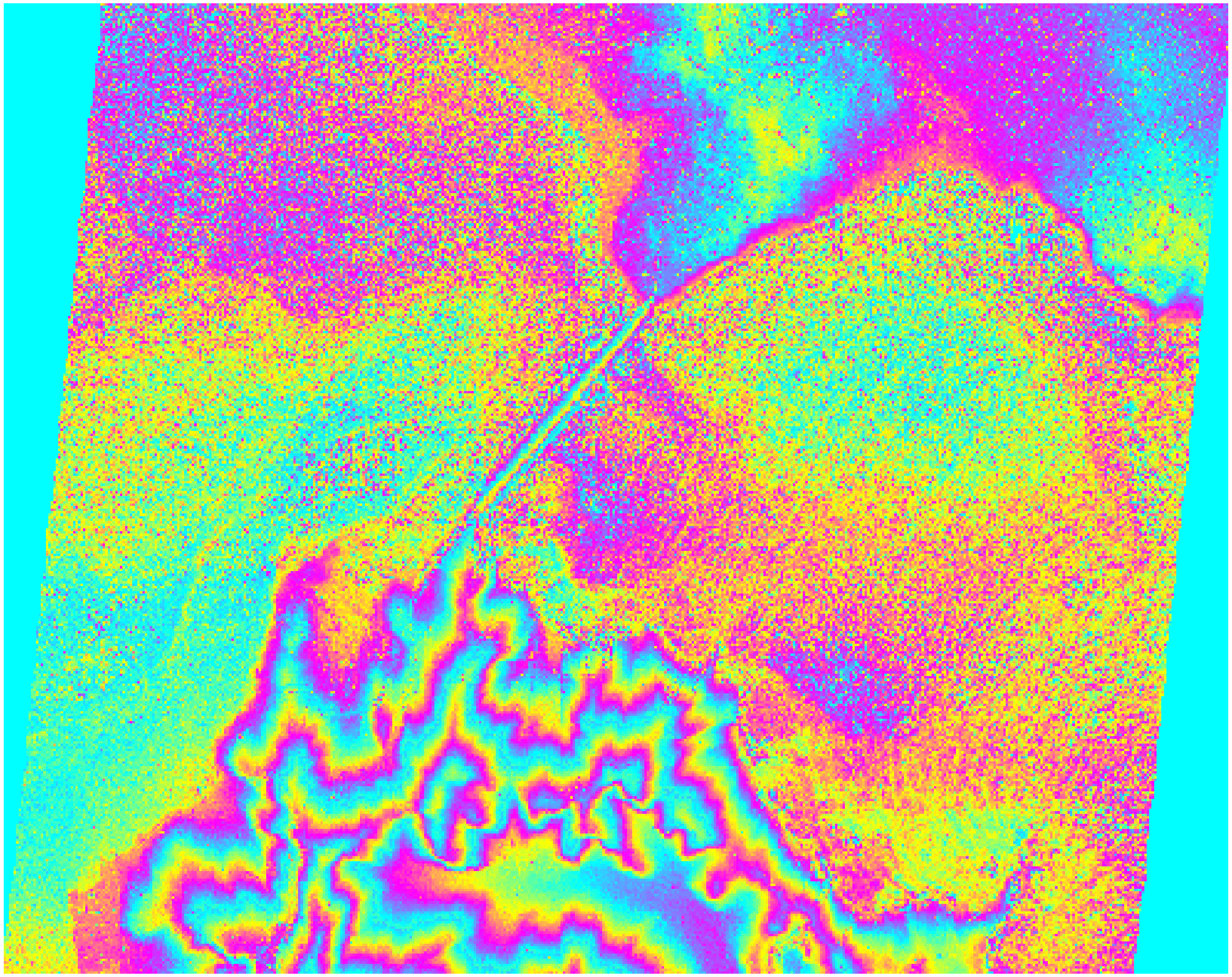
(h=constant elevation reference)

a) Determine the dimensions and grid−spacing of the ground−projected image.

b) Step through each grid−point:

   i) Determine point on the reference track where the grid−point was imaged.
   ii) Compute the range from the reference track coord to the grid coord.
   iii) Use (pulse, range) coord to interpolate into slant−range image to get value for the current grid point.

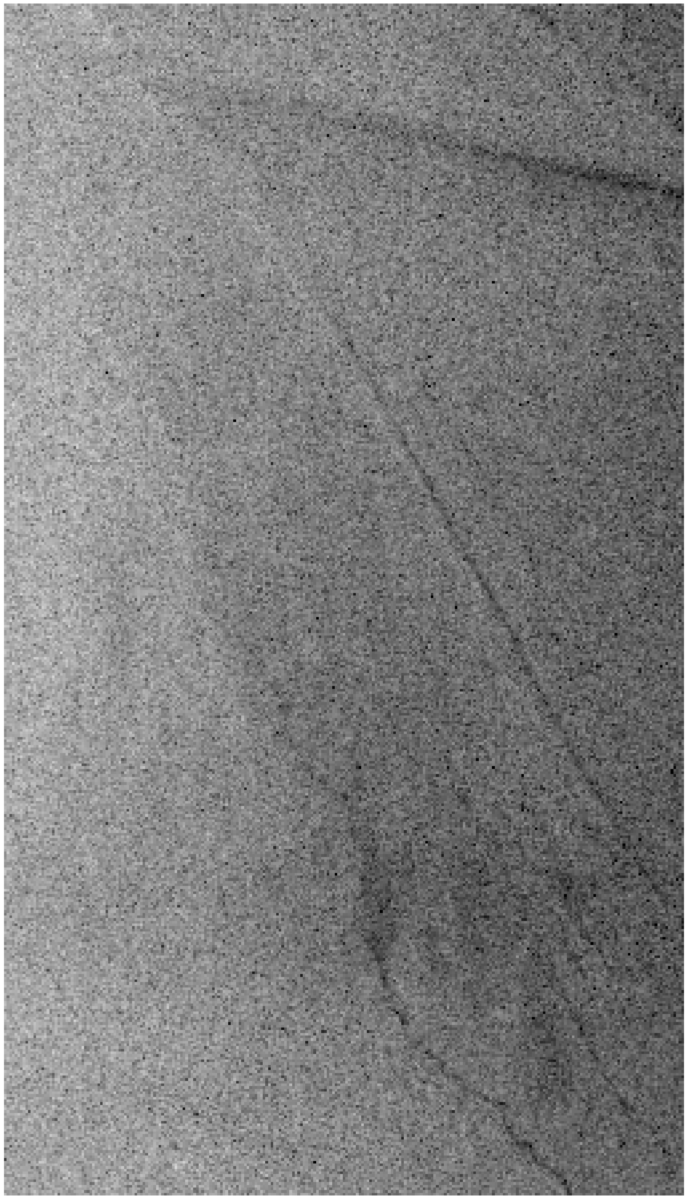
c) Convert (phase offset and scale factor) from phase to m/s.



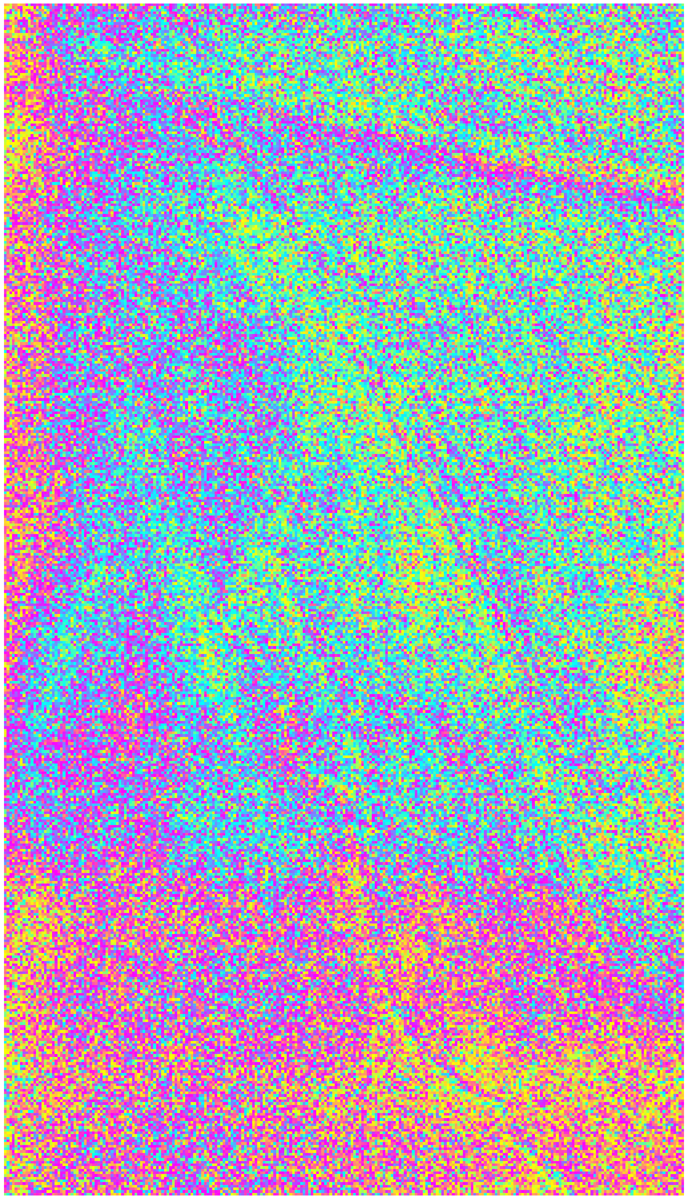
Open Ocean

Key West 312−2, EOCAP '98, L−Band

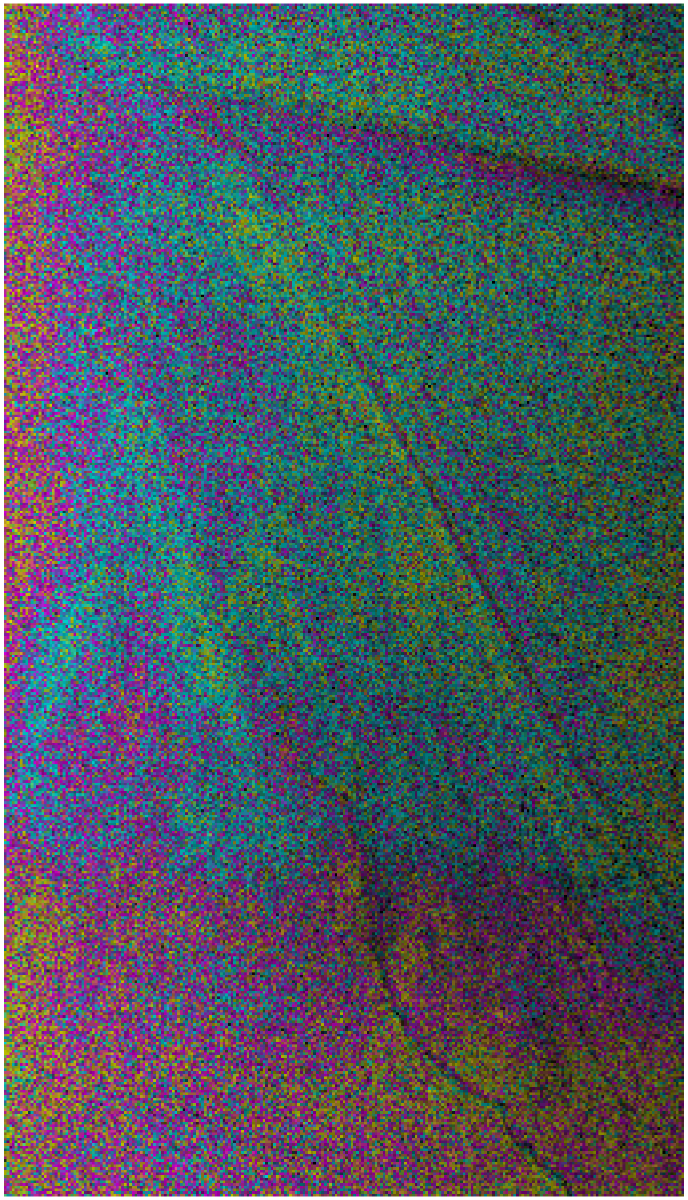
magnitude



phase

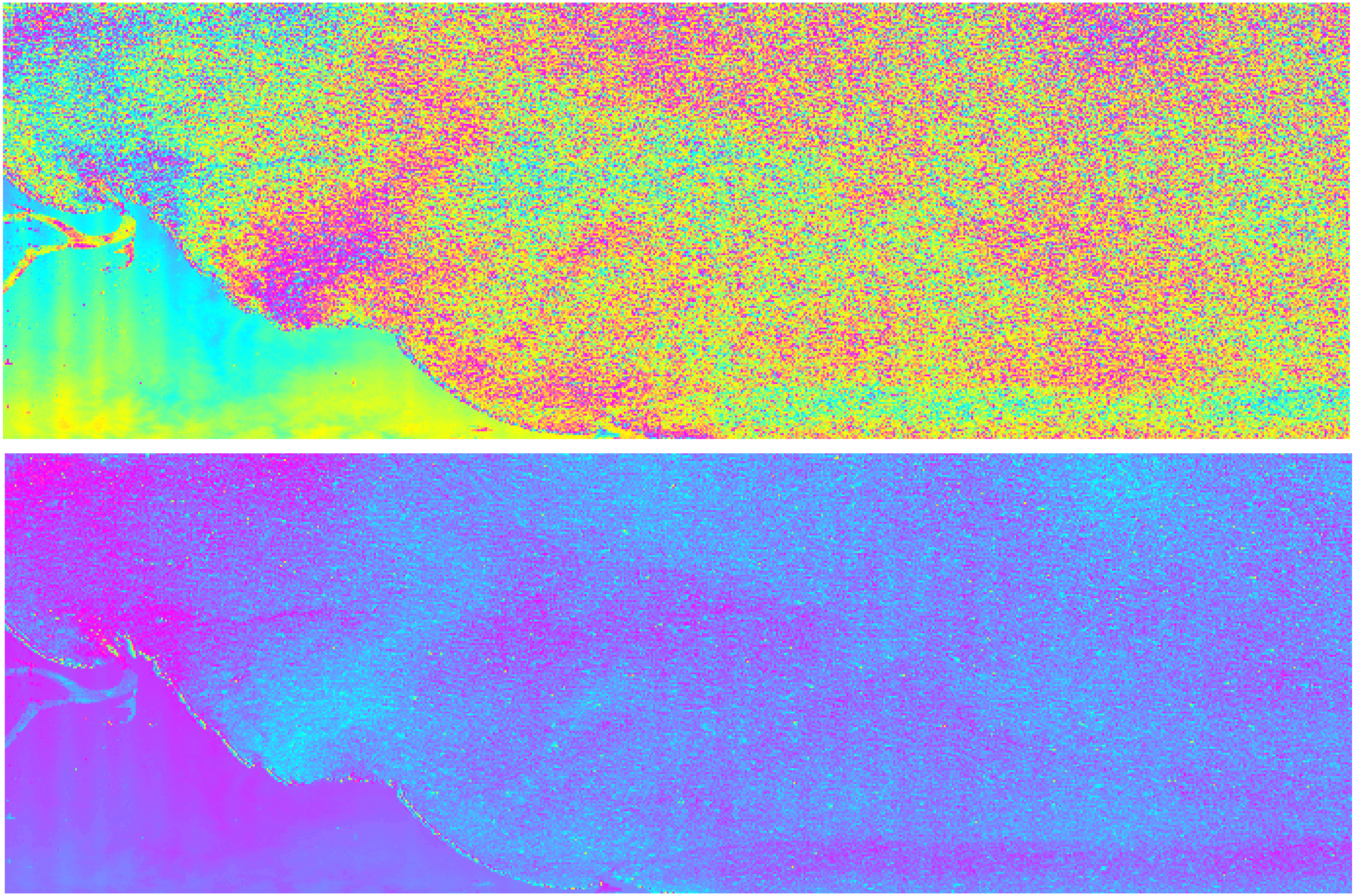


mix

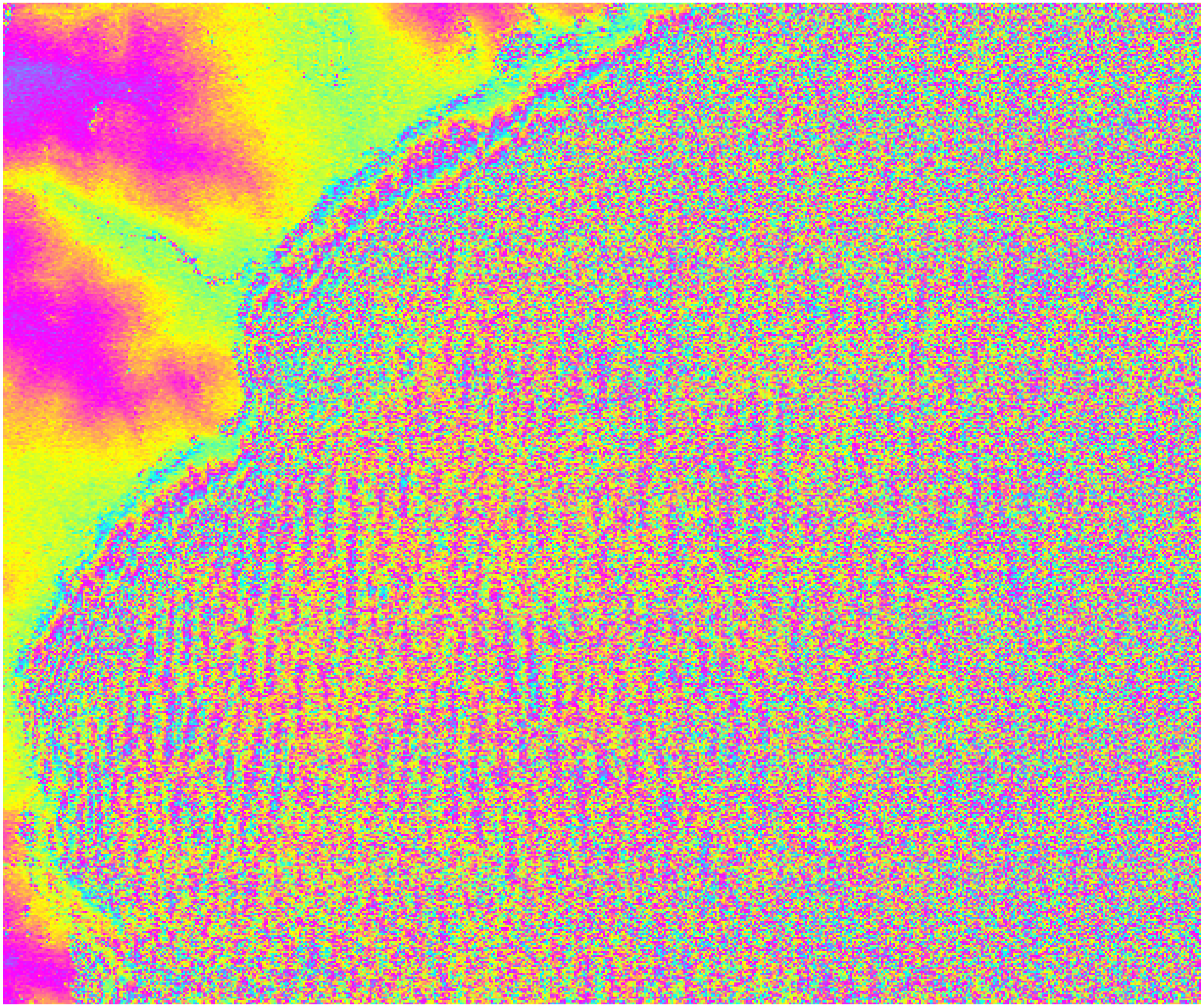


East Australia Coast

PacRim '96: (Near Brisbane) L−Band AF/AA, 12x132 looks, 60 & 240 cm/s wrap



East Australia Coast



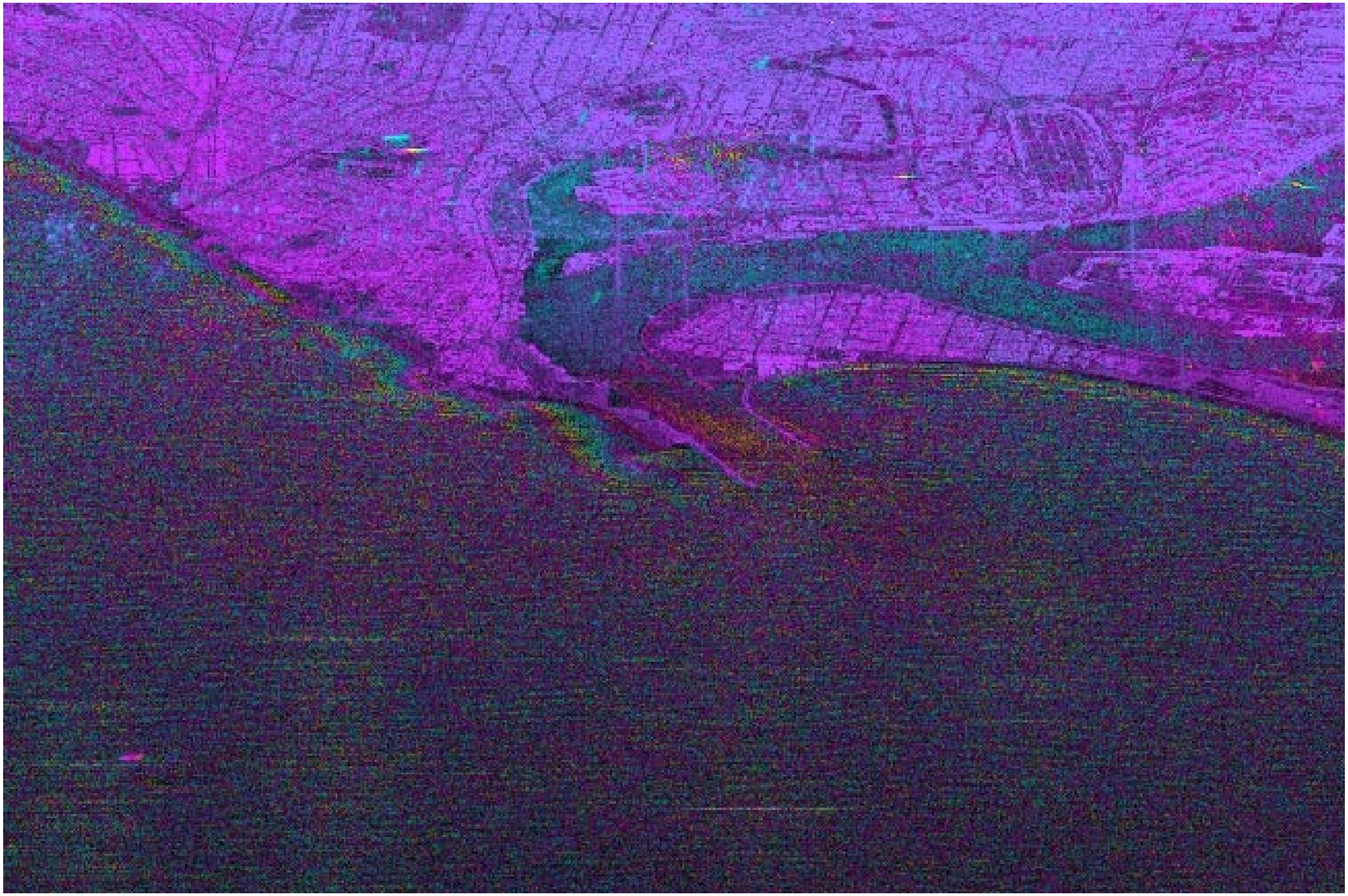
PacRim '96
Near Brisbane

C−Band, AF−AA
1 look in range,
13 looks in az.

Phase wrap
corresponds to
1.5 m/s here.

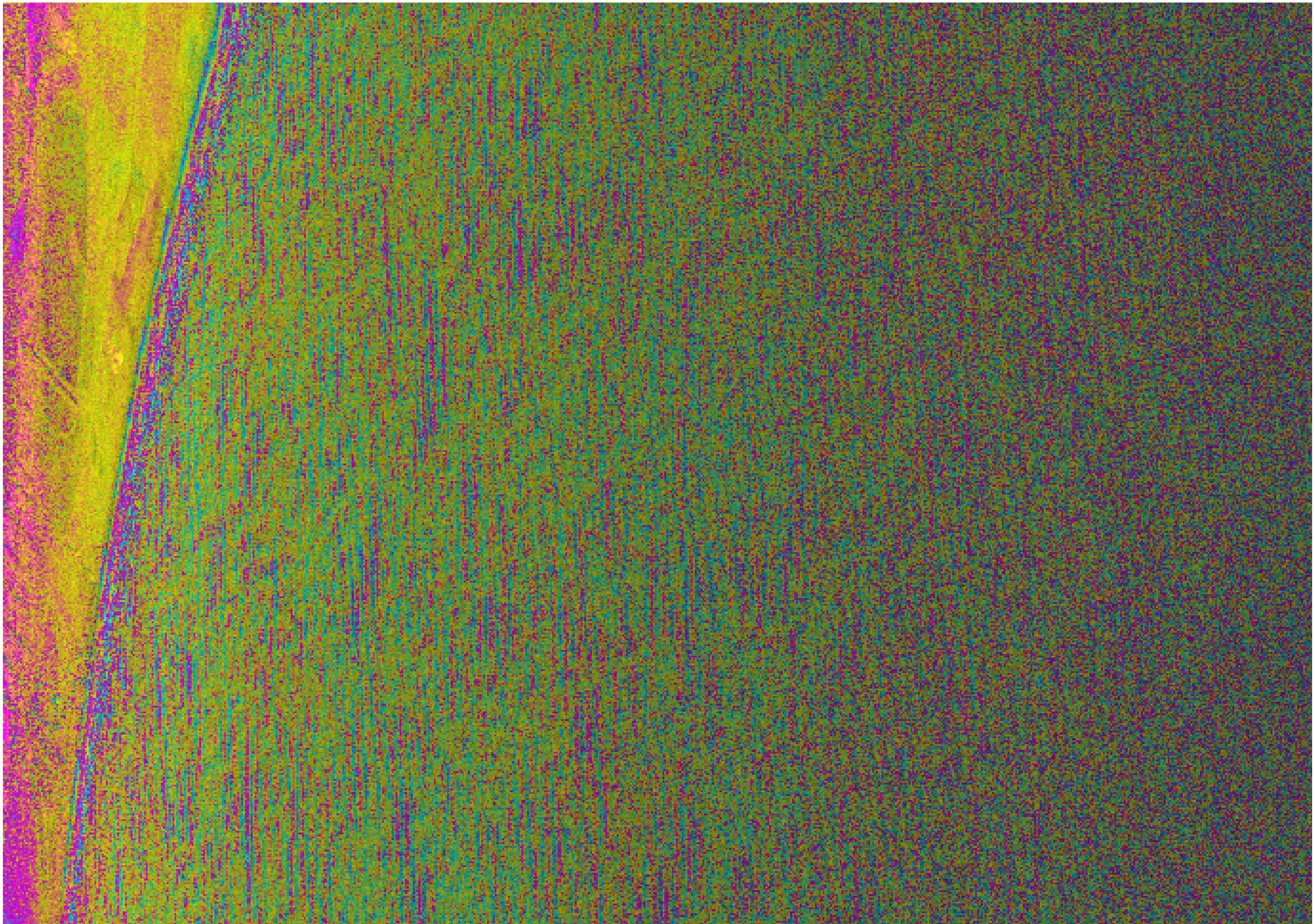
Brisbane Harbour

L−Band, East Australia Current 180−1, acquired during PacRim



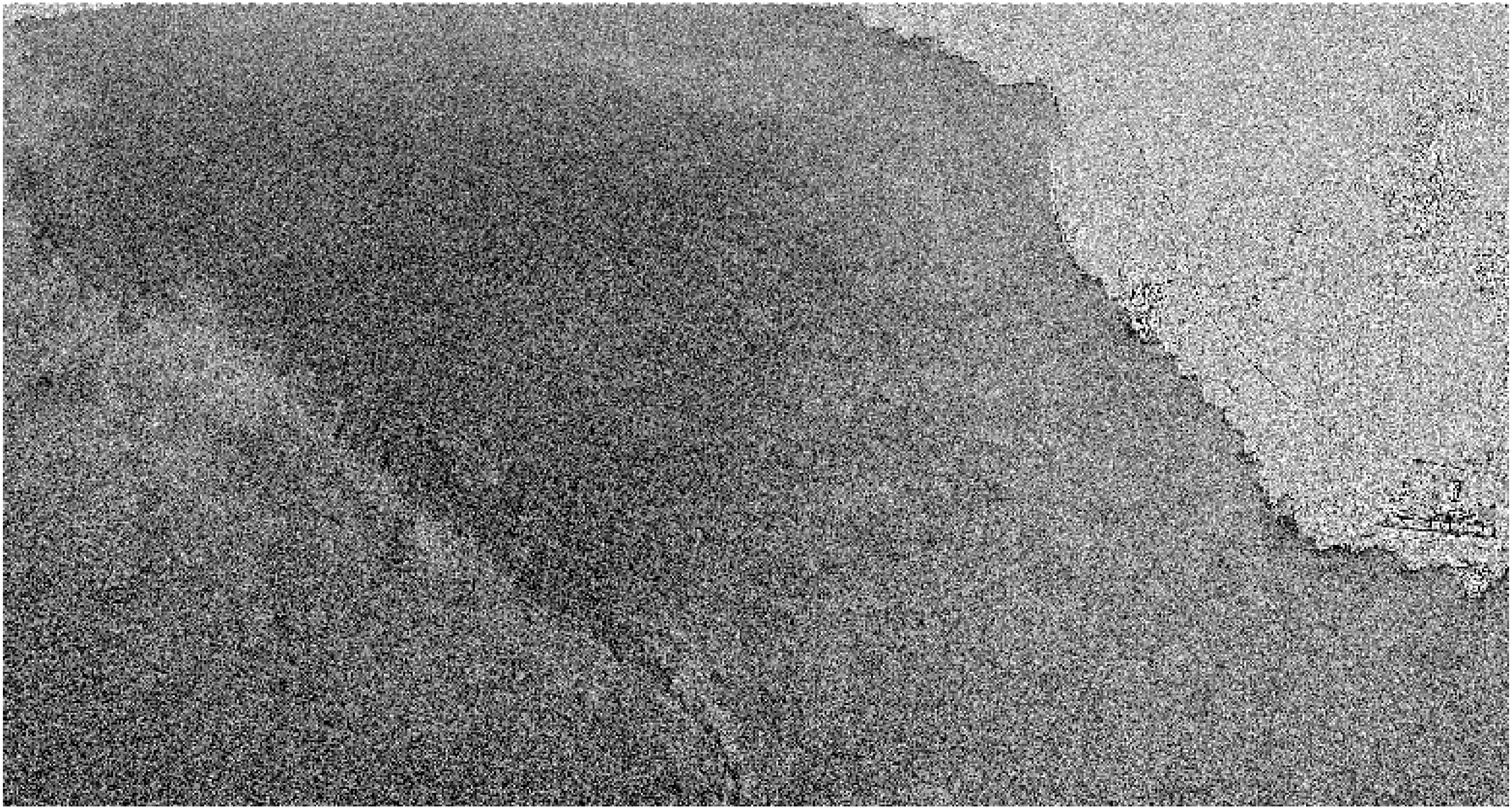
Brisbane Harbour

C−Band, East Australia Current 180−1, acquired during PacRim



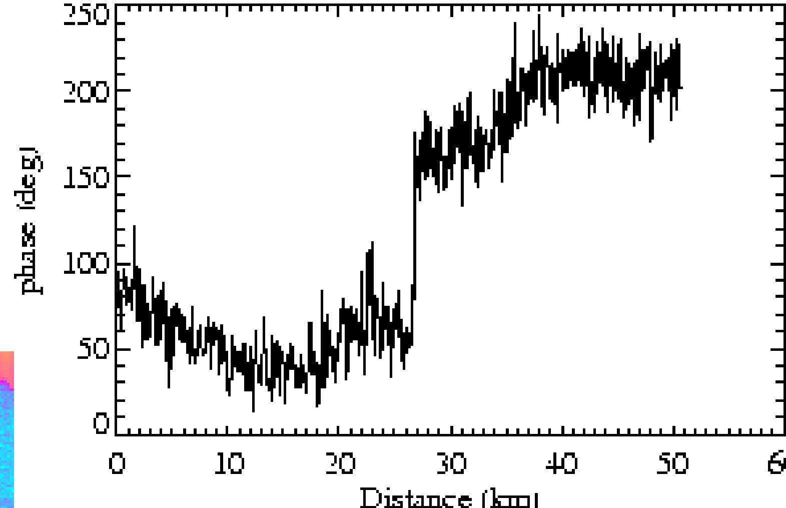
Kohala Coast

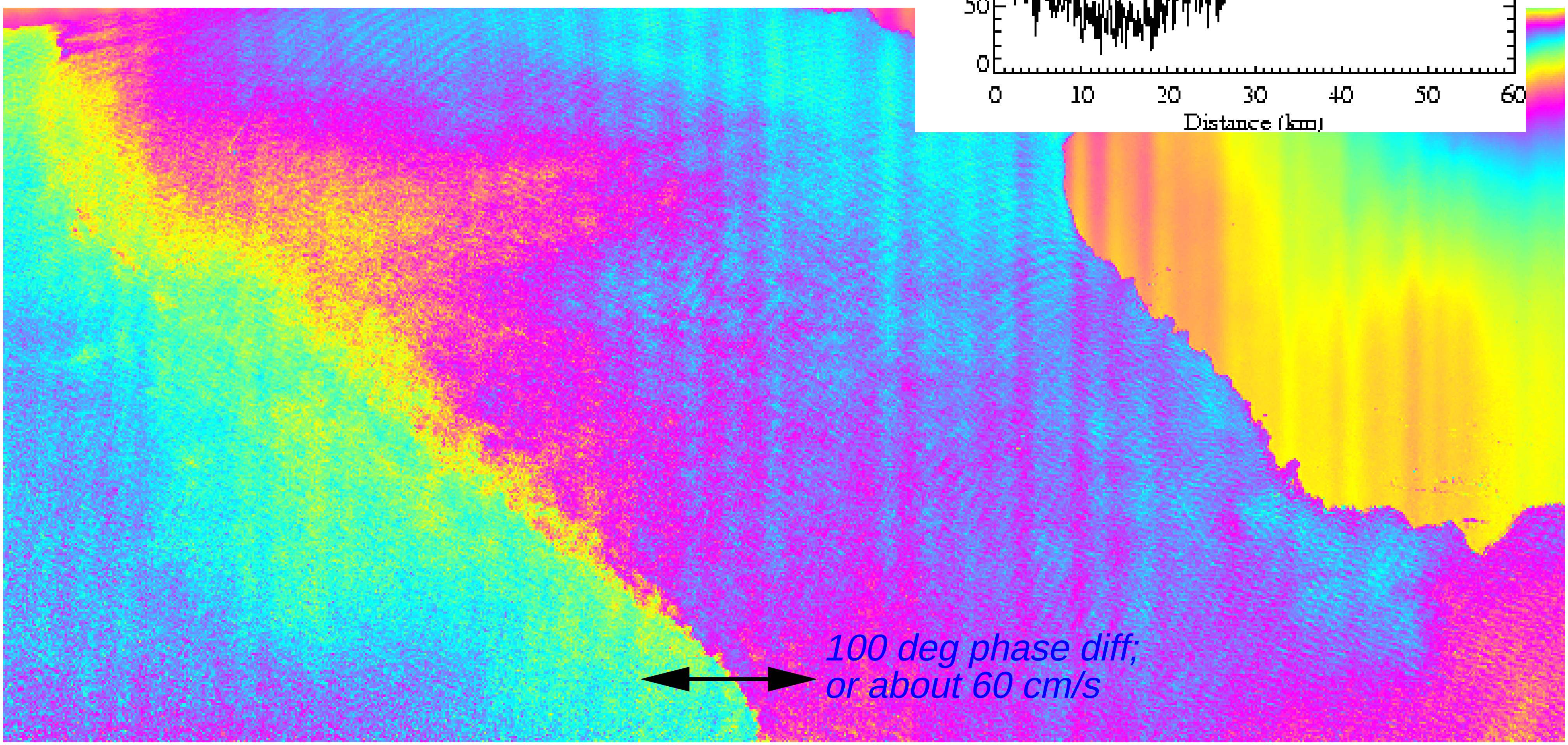
PacRim '96: Kohala Coast Correlation Map (4x64 looks) shows wind−shielding



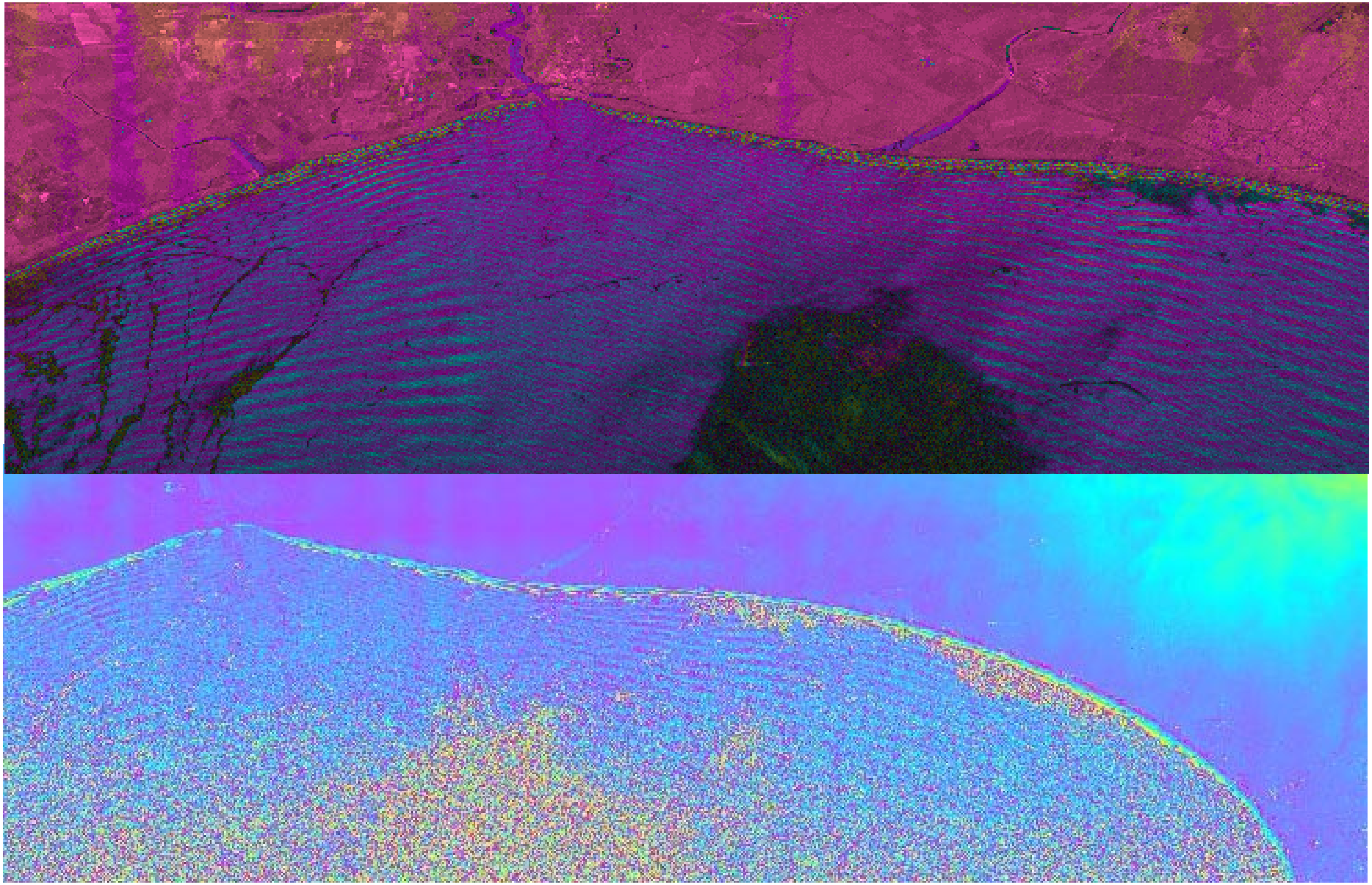
Kohala Coast (cont'd)

PacRim '96: Kohala Coast
AA/AF Interferometric Phase
(8x120 looks) approx. 60m pixels



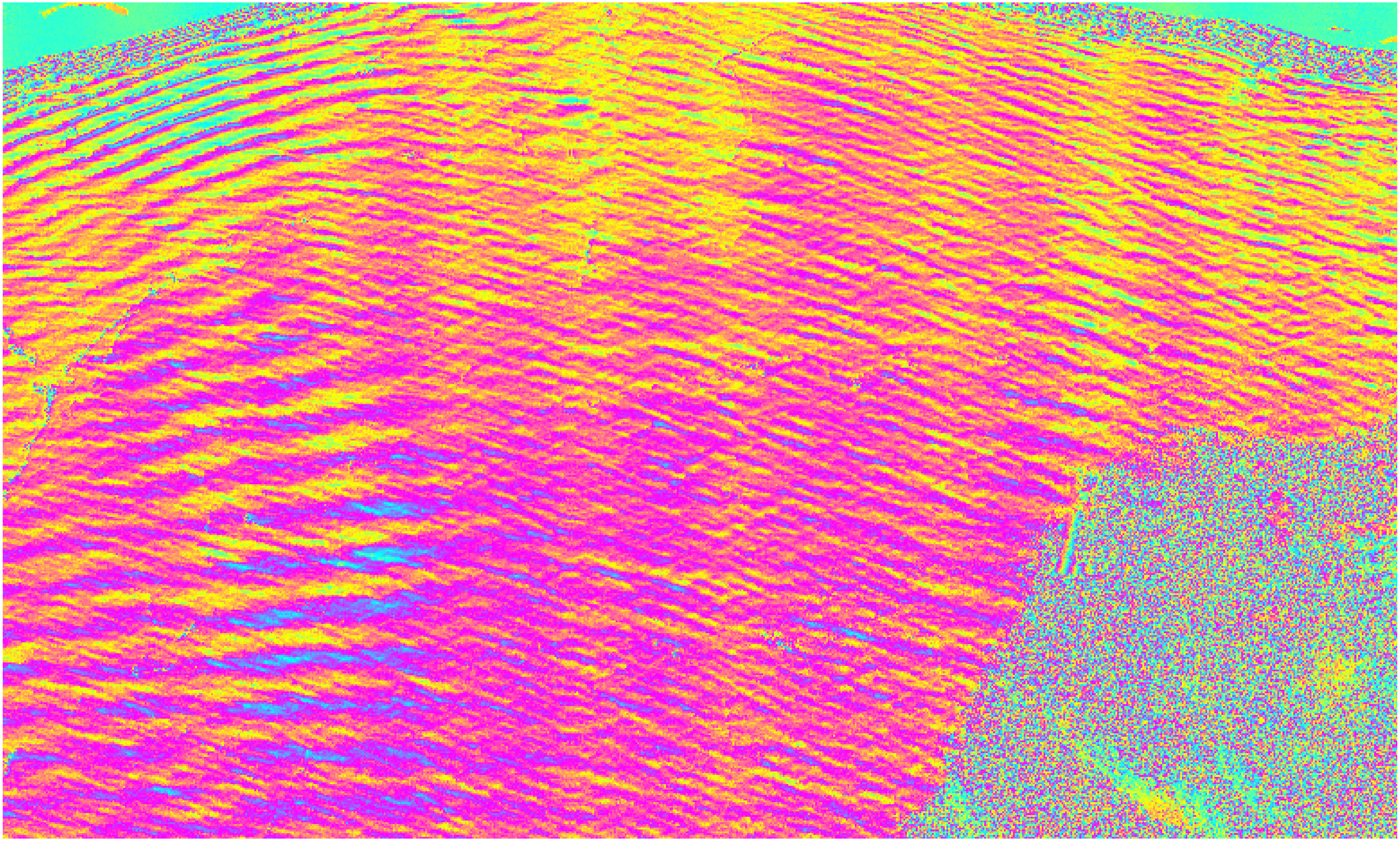


Monterey Bay (L and C)



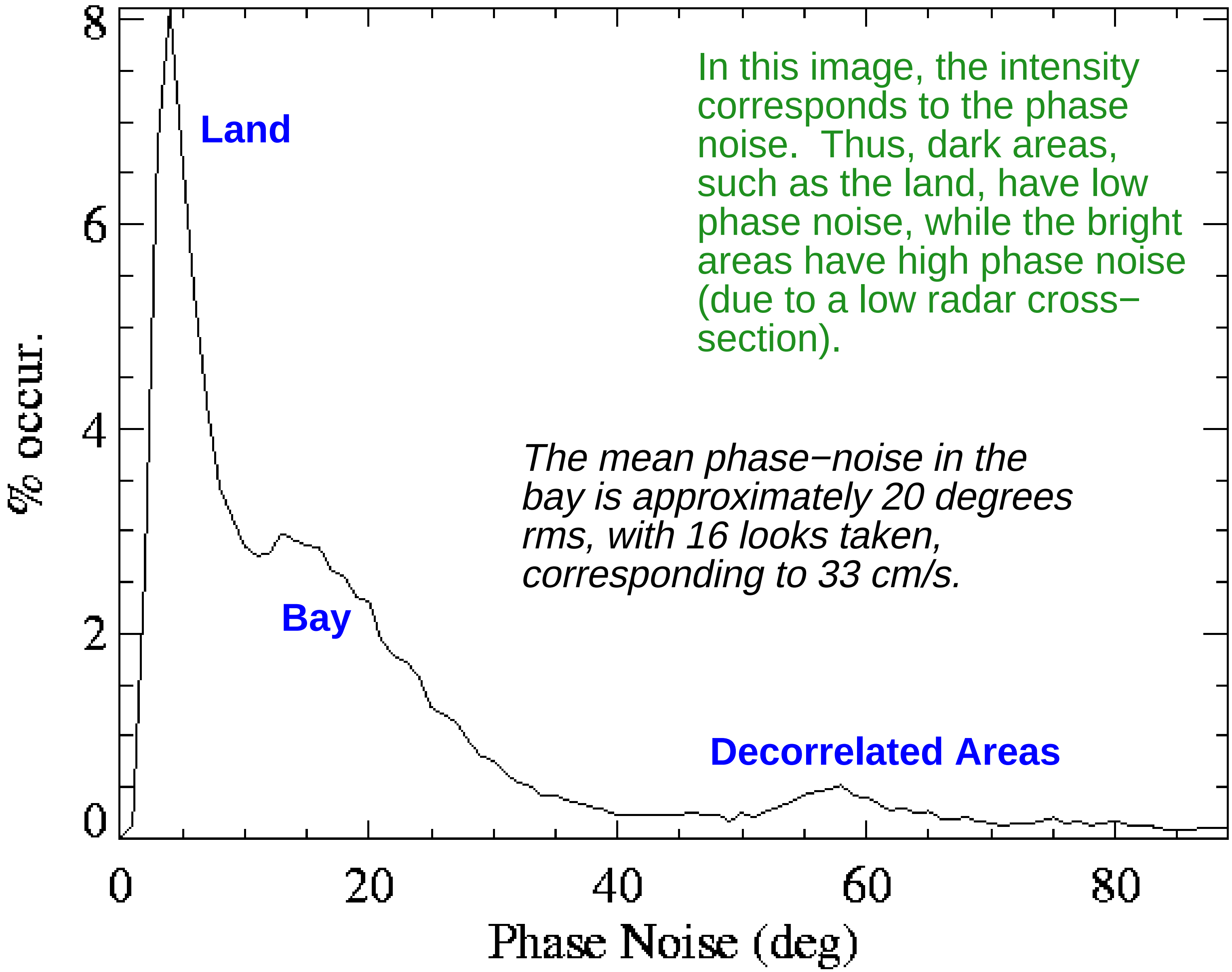
Monterey Bay: Detail

EOCAP ’98: L−Band AF/AA, 4x24 looks, 180 degrees color wrap



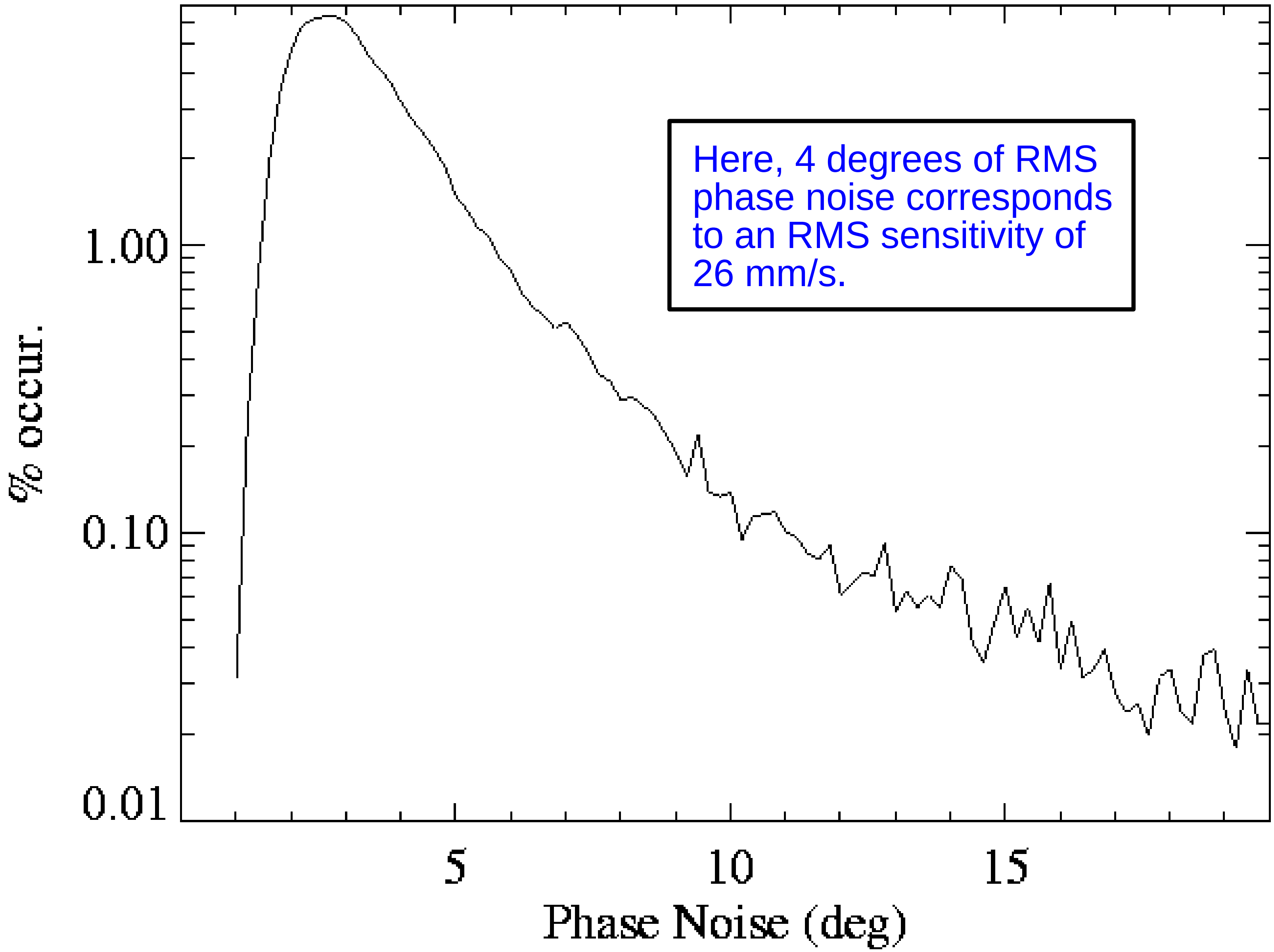
Phase Noise: C−Band

San Francisco 1998; Lower SNR Configuration



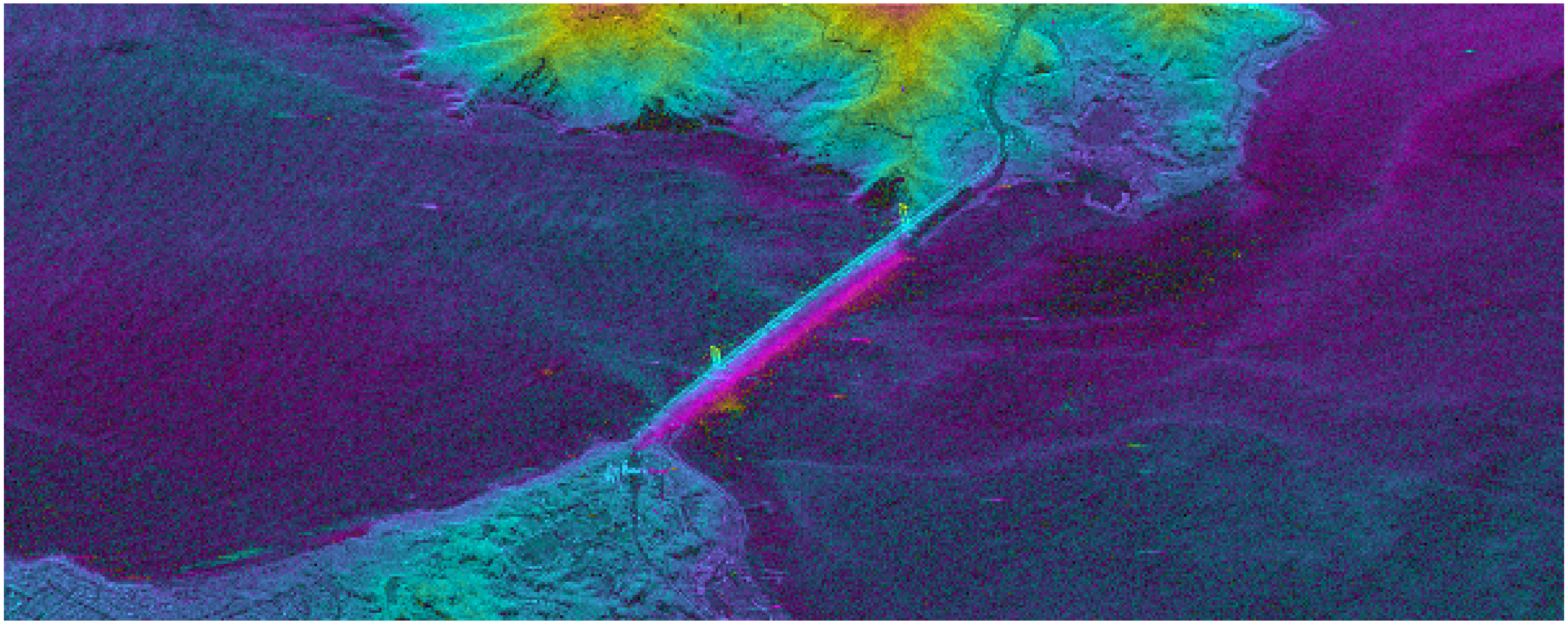
Phase Noise: L–Band

EOCAP '98: Montery Bay, L–Band, 4x32 Looks



ATI Ping−Pong

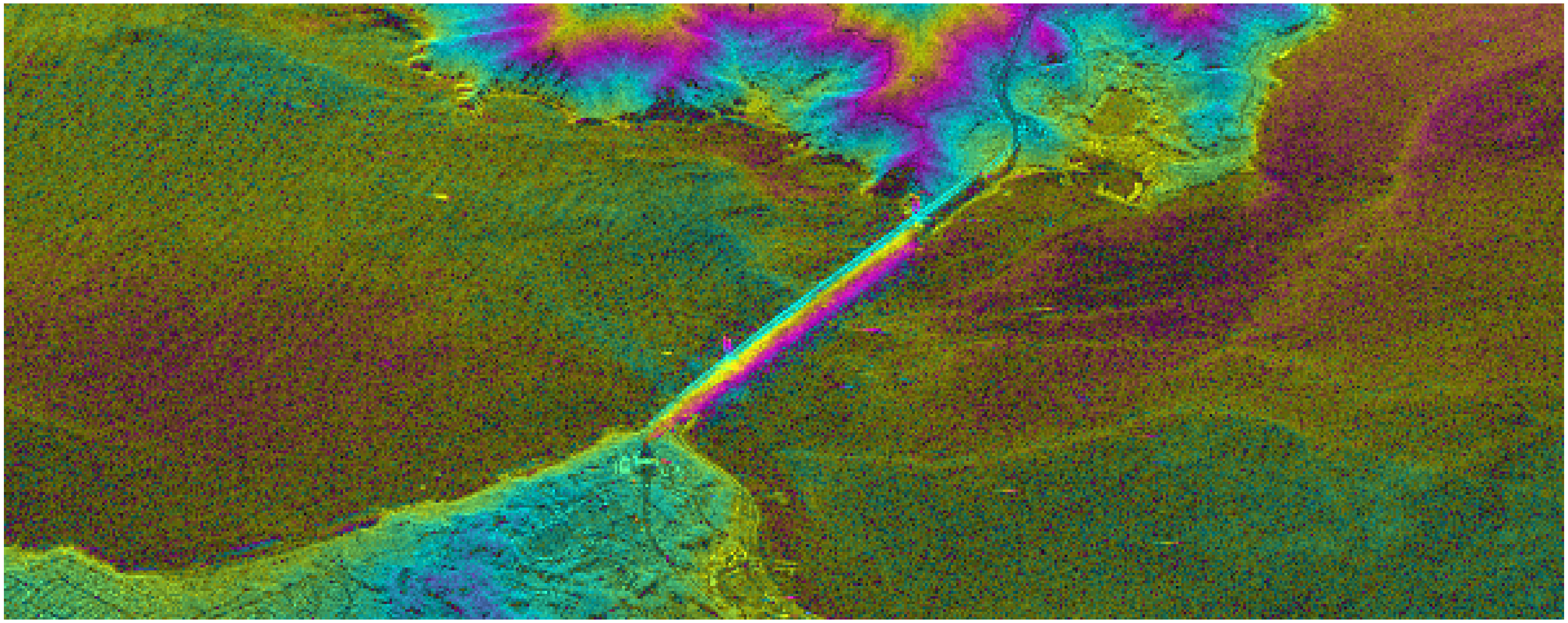
AF/AA



C−Band
EOCAP ’98

Velocity wrap for upper interfogram is twice that of the lower.

These data were collected in the experimental reduced−SNR configuration.



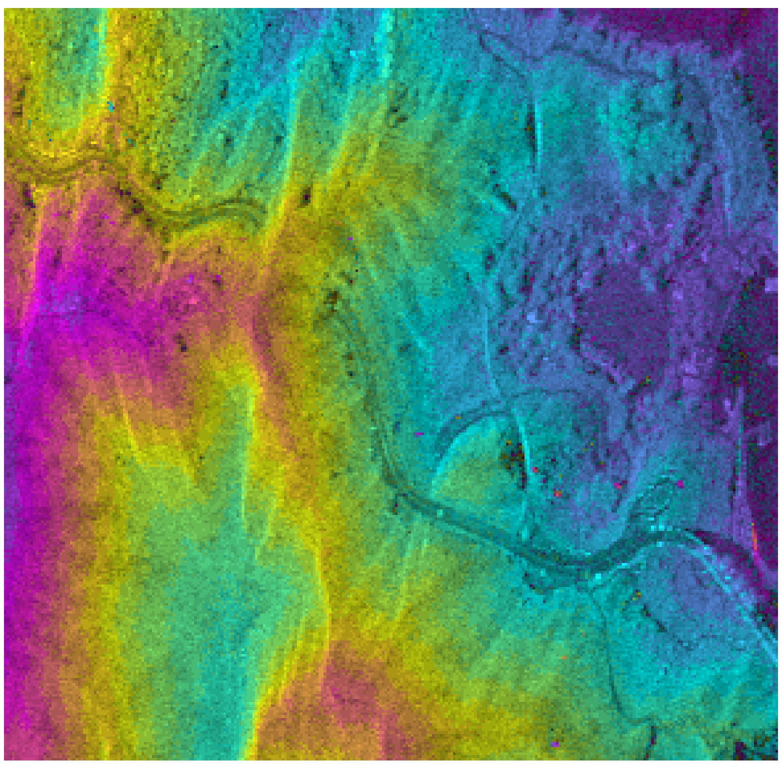
FF/AA

ATI Application: GMTI

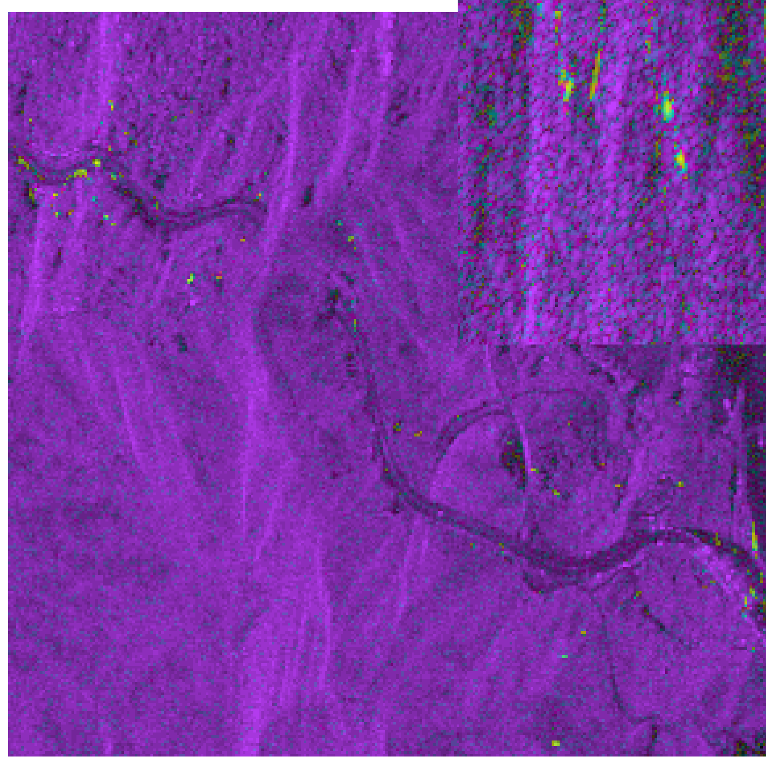
C–Band, Golden Gate
EOCAP '98

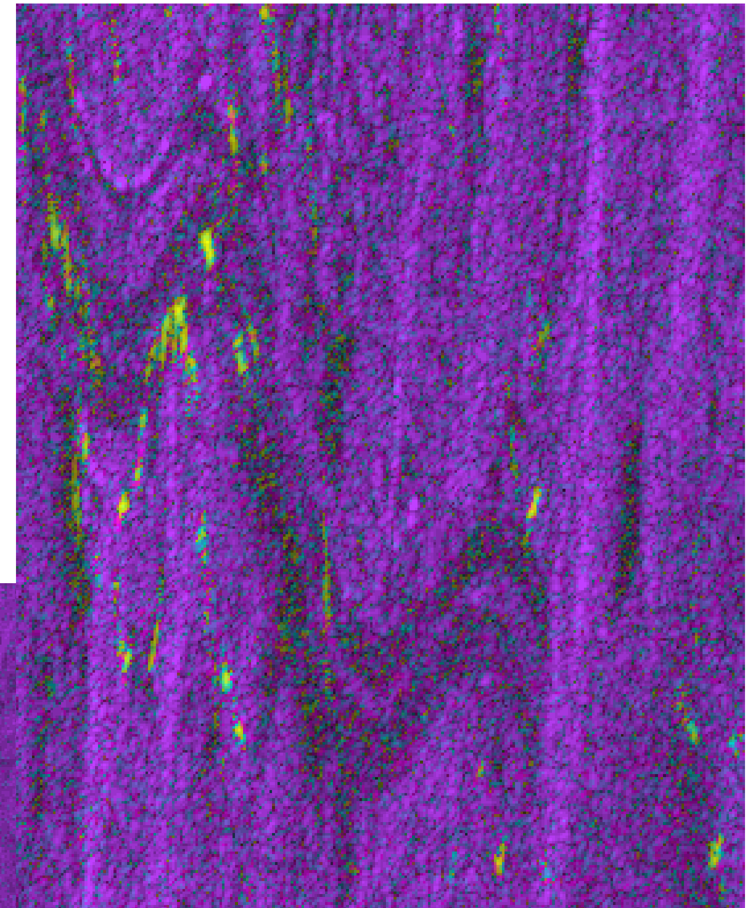
16 Looks

AF/AA



AF/FA

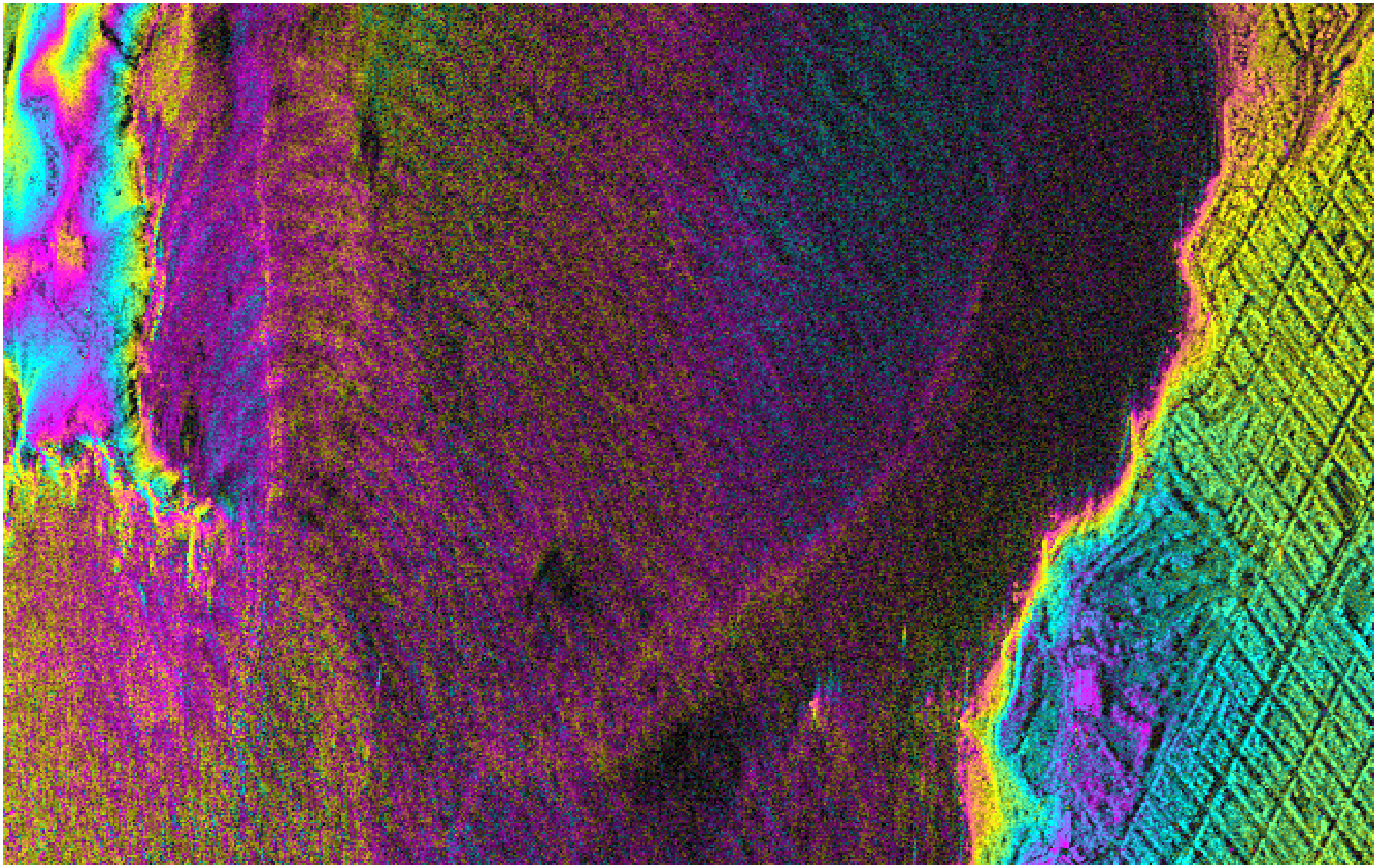




1 Look

Diffraction off of Pt. Bonita

EOCAP '98: C−Band FF/AA, 2x8 looks, 180 degrees color wrap



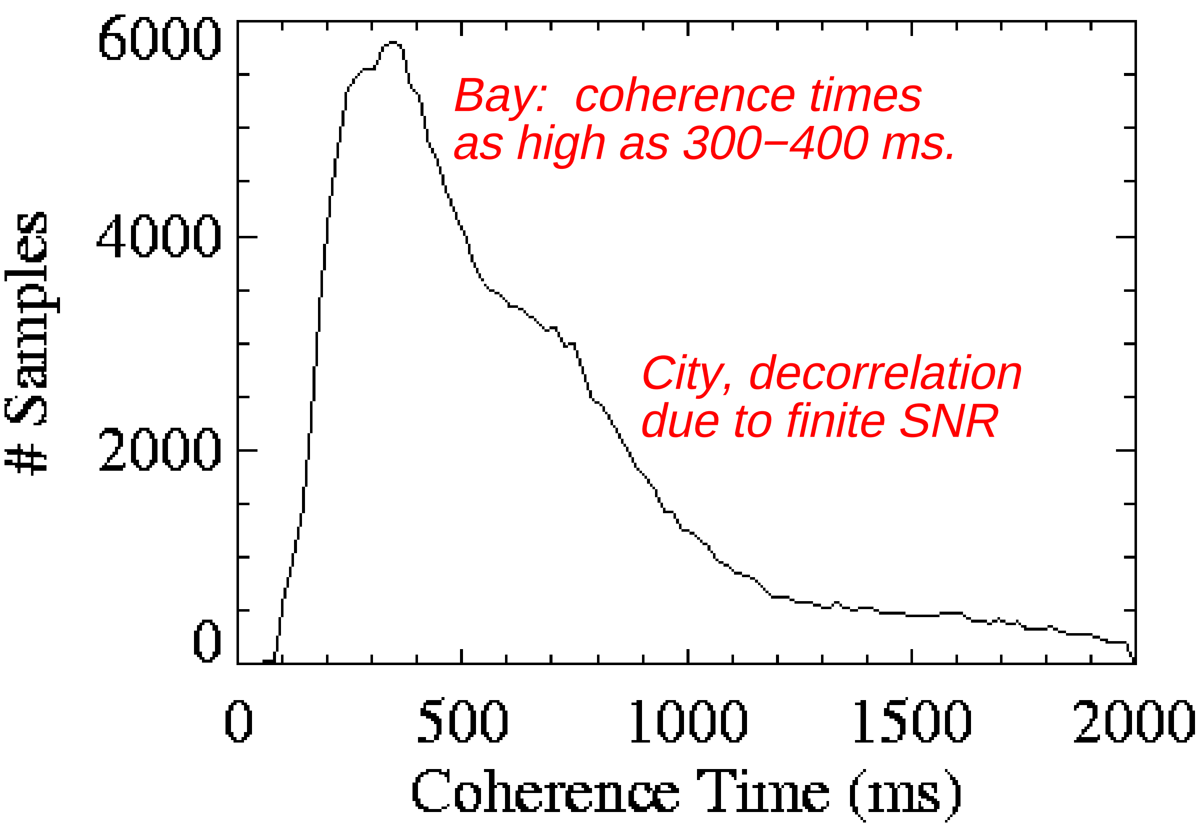
Coherence Time

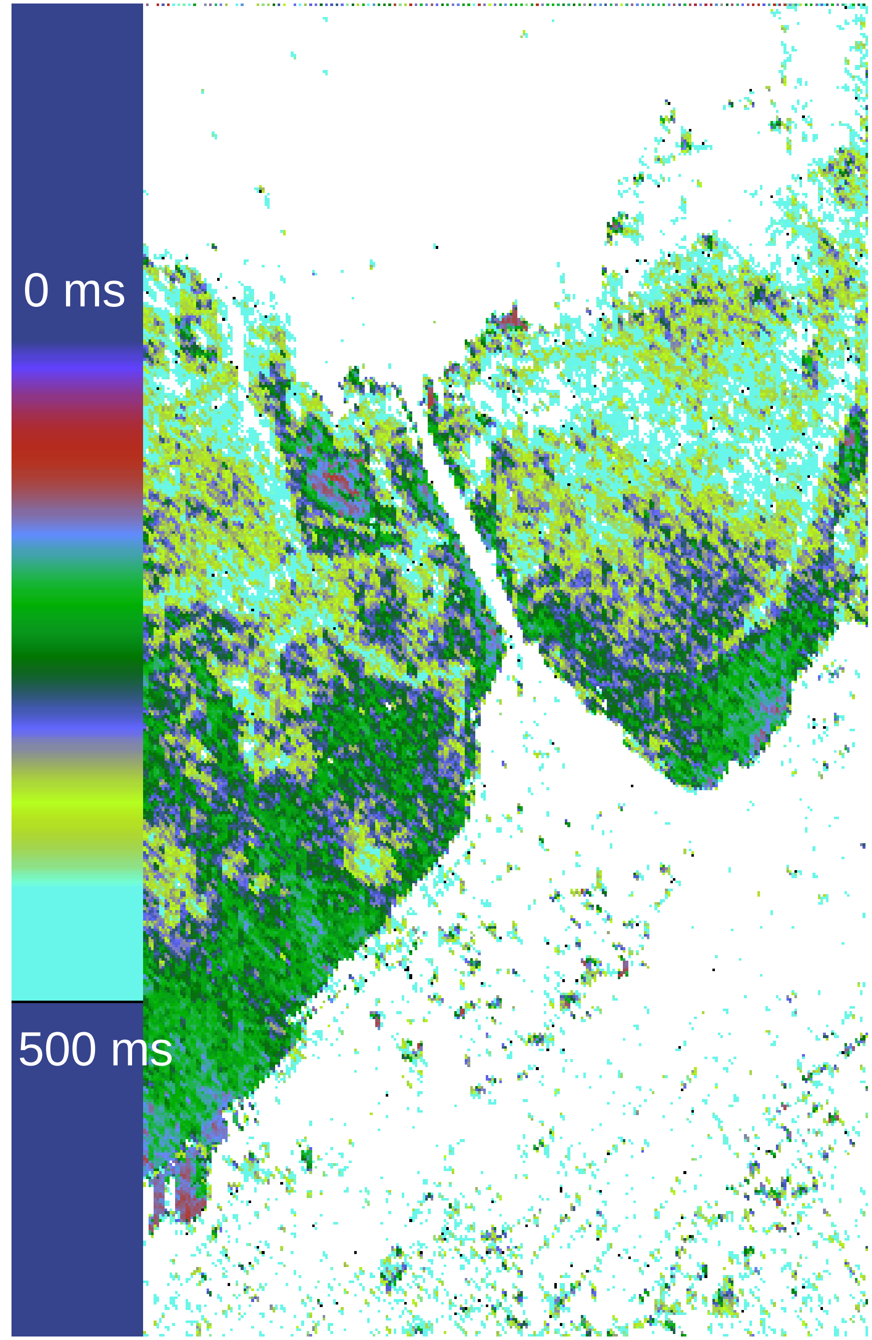
$$\gamma=\gamma_n \exp(-t^2/\tau^2)$$

Gaussian Model

- γ total correlation
- γ_n zero−time correlation (SNR−related)
- t observation time interval
- τ coherence time

Here we have used two times, t=4.8ms and t=9.5ms with the C−band radar to get estimates of the coherence time in San Francisco Bay.

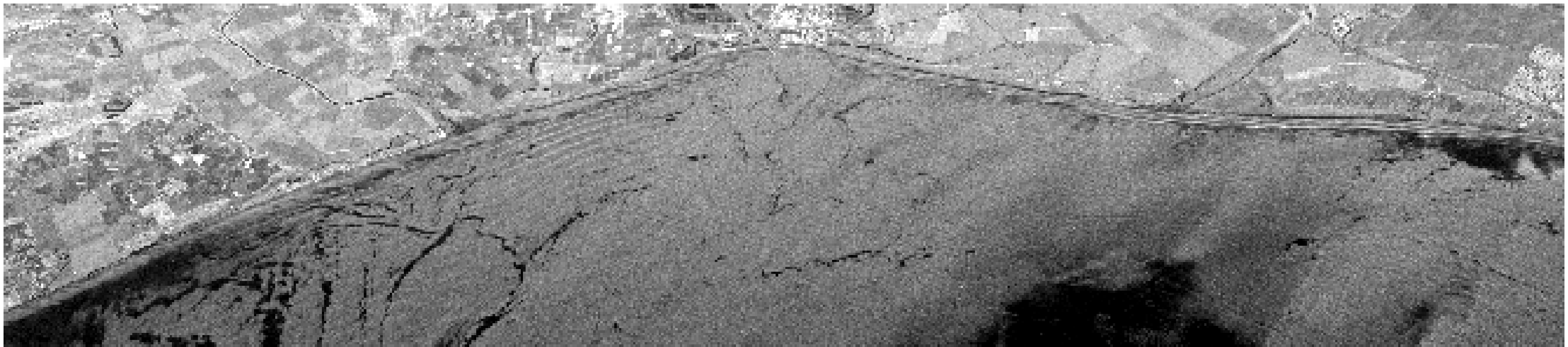




Surf Zone Mapping

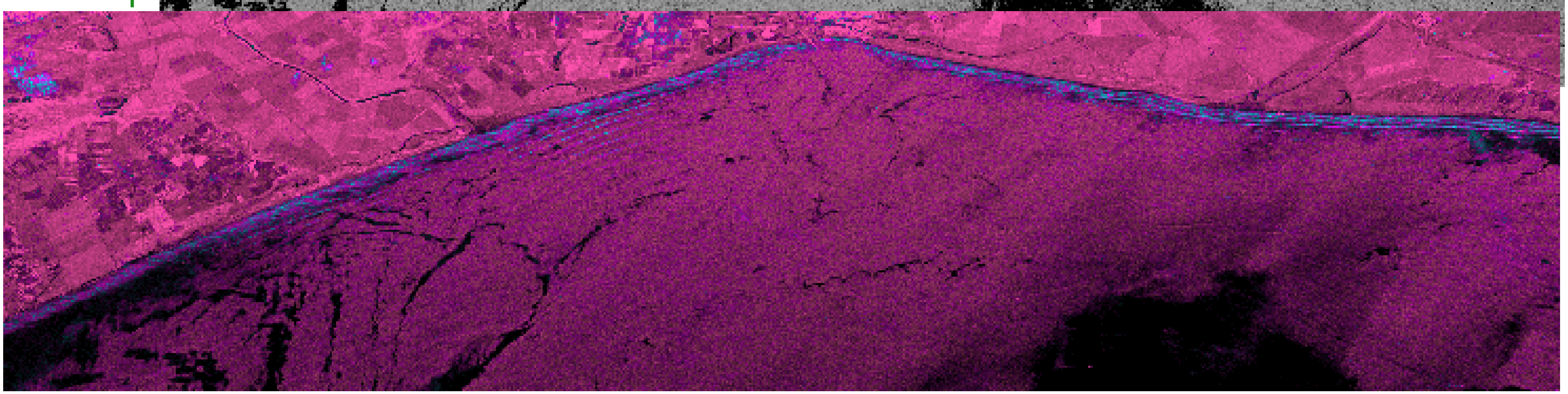
Surfactants/Upwelling areas are dark; surf−zones are bright but decorrelated

Magnitude Image



Correlation Image

Surf Zone Map



ATI Status at AIRSAR

- **Processor is functional, ported to several platforms.**
- **Calibration in progress: baseline and delays look good.**
- **Example ATI dataset available before Christmas 1999.**
- **Future: Fully polarimetric C−band ATI (data acquired)**
- **Simultaneous XTI/ATI (data acquired)**
- **Vector ATI (algorithm development)**