DINSAR: Differential SAR Interferometry

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SAR interferometric phase: ground motion contribution

If a scatterer on the ground slightly changes its relative position in the time interval between two SAR acquisitions (e.g. subsidence, landslide, earthquake ...), an additive phase term, independent of the baseline, appears.

\[ \Delta \varphi_{\text{displacement}} = \frac{4\pi}{\lambda} d \]

Here, \( d \) is the relative scatterer displacement projected on the slant-range direction.
SAR interferometric phase: ground motion contribution

The sensitivity of the interferometric phase to the ground motion is much larger than that to the elevation difference.

In the ERS case assuming a perpendicular baseline of 150m the following expression of the interferometric phase (after interferogram flattening) holds:

\[ \Delta \varphi = \Delta \varphi_{\text{elevation}} + \Delta \varphi_{\text{displacement}} = \]

\[ = -\frac{q}{10} + 225d \]
SAR interferometric phase: ground motion contribution
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Image courtesy of S. Madsen,
SAR interferometric phase: ground motion contribution
Differential Interferometry

The landslide of St. Etienne de Tinee
Estimated motion

Space-varying time-constant velocities have been hypothesized.

Color coded subsidence velocity in millimeters per year is shown.
Differential Interferometry

Interferogram  
Synthetic Interferogram  
Differential Interferogram
Differential phases along the Valle del Bove

Master: April 96
SAR interferometric phase: atmospheric contribution

If the propagation medium changes the time interval between two SAR acquisitions (e.g. humidity, temperature, pressure ...), an additive phase term, independent of the baseline, appears.
Summary of the SAR interferometric phase contributions

\[ \Delta \phi = \Delta \phi_{\text{flat}} + \Delta \phi_{\text{elevation}} + \Delta \phi_{\text{displacement}} + \Delta \phi_{\text{atmosphere}} + \Delta \phi_{\text{noise}} \]

\[ \frac{4\pi}{\lambda} \frac{B_n s}{R \tan \theta} \]

\[ \frac{\Delta q}{\sin \theta} \frac{B_n}{R_0} \frac{4\pi}{\lambda} \]

\[ + \frac{4\pi}{\lambda} d \]
THE SAR INTERFEROGRAM GENERATION
Interferogram generation

- Registering parameters estimate
- Local frequency estimate
- Co-Registering & resampling
- Spectral Shift & common band filtering
- Coherence estimate
- Complex multi-looking & subsampling
- Flattening & mosaicking
- Interferogram

SLC

Master

Orbits

Slave

Range 2x oversampling

Sept. 3, 2007      Lecture D1Lb5-1      Interferometry: coherence      Rocca 14
Image-coregistering
Complex multilook

A “cleaned” interferogram is achieved by averaging in areas of uniform phase. SNR improves $\propto$ the number of looks. Usually the averaging window is adaptive.
For evaluating noise performances, the interferometric phase difference (that is usually topographic-dependent) is assumed to be zero.
The complex interferogram (pixel-to-pixel):

\[
i(\hat{P}) = s_1(\hat{P}) \times s_2^*(\hat{P}) \propto (v + n_1)(v + n_2) = |v|^2 + v^*n_1 + vn_2^* + n_1n_2^*
\]

contains signal and noise contributes.

For SNR >> 1 the interferogram SNR is \( \propto \) the image SNR. For SNR << 1 the interferogram SNR worsens, \( \propto (\text{SNR})^2 \).

We are interested in phase noise, as phase is the signal. Phase statistics is known for *homogenous target* (speckle-only). Phase std can be expressed in terms of image SNR.

This curve holds for 1 look. For pure noise \( s_f = p/3 \). SNR \( \rightarrow f \) is hardly invertible for SNR < 0, that would be useful to estimate multi-look-averaged performances.

*Noise in interferometry*
Estimates of the coherence

Coherence can be estimated, in each pixel, by averaging over area of stationary phase.

\[
\hat{\gamma} = \frac{\sum \sum v_1 v_2^* e^{-j\phi(r_n, x_m)}}{\sqrt{\sum \sum |v_1|^2 \sum \sum |v_2|^2}}
\]

Topographic phase, \(\phi\), is assumed locally flat (a 2D complex sinusoid). Hence it can be retrieved by means of instantaneous frequency estimators.

Coherence is biased \(\rightarrow 1\) when # freedom degrees is one, or when one scatterer prevails.
Coherence maps

Amplitude  Phase  Coherence
Coherence estimate (ML)

mean

variance
Coherence histograms

Coherence histogram are used to evaluate image quality, like in comparing the output of two different interferometric processors.
Uses of coherence

Coherence maps are much useful for two purposes:

(1) they provide a local measure of “quality” (e.g. DEM accuracy)

(2) the provide useful and quantitative information on scene “features”.

These information are complementary with the intensity image ($\sigma_0$)
Etna precise coherence maps

- April 96
- May 96
- August 95
- September 95
- November 95
- December 95
Mt. Vesuvius

Detected

Coherence
Mt. Vesuvius segmentation
A vegetation model is used. A 1 x 1 degree NOAA AVHRR NDVI (Normalized Differential Vegetation Index) mosaic for the month of March (1994) was used to feed this model. The model was empirically derived by polynomial fitting to a scatterplot of average coherence values versus average corresponding NDVI values for 4005 frames of ERS tandem data collected over North America.

Predicted coherence
(0.4…0.8) for the
month of March.

Predicted coherence
(0.4…0.8) for the
month of September.

Image courtesy of Atlantis
Atmospheric artifacts

Atmospheric inhomogeneities, due to variations in Pressure, Temperature, Humidity affects light speed velocity. The delay variation in the repeat interval results in a “phase screen”, hence a noise.

“Atmospheric” noise is fractal (f^α) power spectrum (α~2/3), hence it is correlated in space (~ hundred of meters). Coherence maps cannot measure this noise.

Atmospheric artifacts can be up to two fringes. This is converted in elevation error, depending on the baseline. The error cannot be estimated or recovered.
Atmospheric artifacts can be detected in a multi-baseline environment, since atmosphere is incorrelated in time.

**Error Map: May – December**

![Image: Error Map showing atmospheric artifacts](image)

**Etna**

**Paris (+ reflectivity)**

*Atmospheric artifacts*