Limiting factors of SAR interferometry

Rüdiger Gens

Causes of decorrelation

$$\gamma = \gamma_{baseline}\ \gamma_{SNR}\ \gamma_{Doppler}\ \gamma_{volume}\ \gamma_{temporal}\ \gamma_{atmosphere}$$

$$\gamma = (1 - \delta)$$

$$\gamma = coherence$$

$$\delta = decorrelation$$

- baseline decorrelation
- thermal noise
- non-overlapping Doppler spectral energy

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$$\gamma = (1 - \delta)$$

$$\gamma = coherence$$

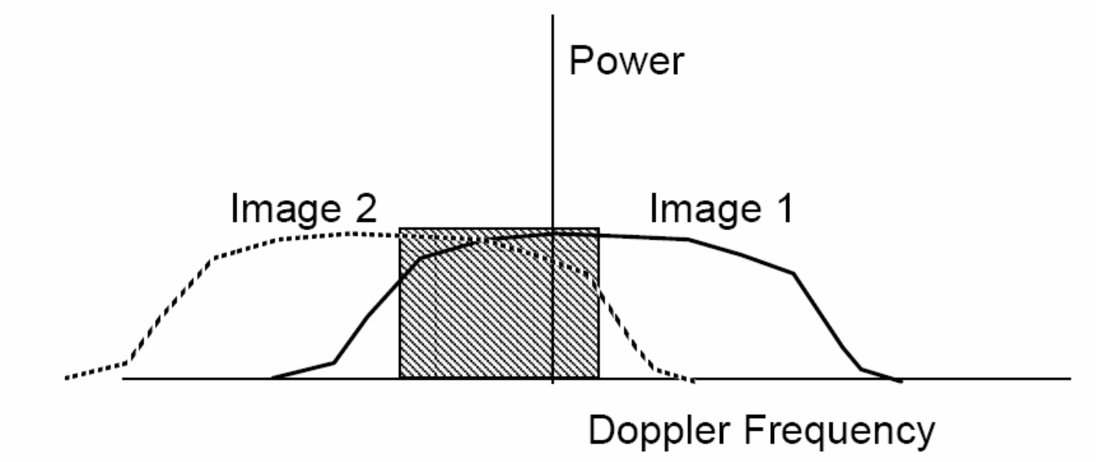
$$\delta = decorrelation$$

- volume scattering
- temporal changes
- atmospheric phenomenon

Geometrical decorrelation

- occurs as the separation between the two orbital trajectories (baseline) increases
- correlation coefficient is inversely proportional to the perpendicular baseline component

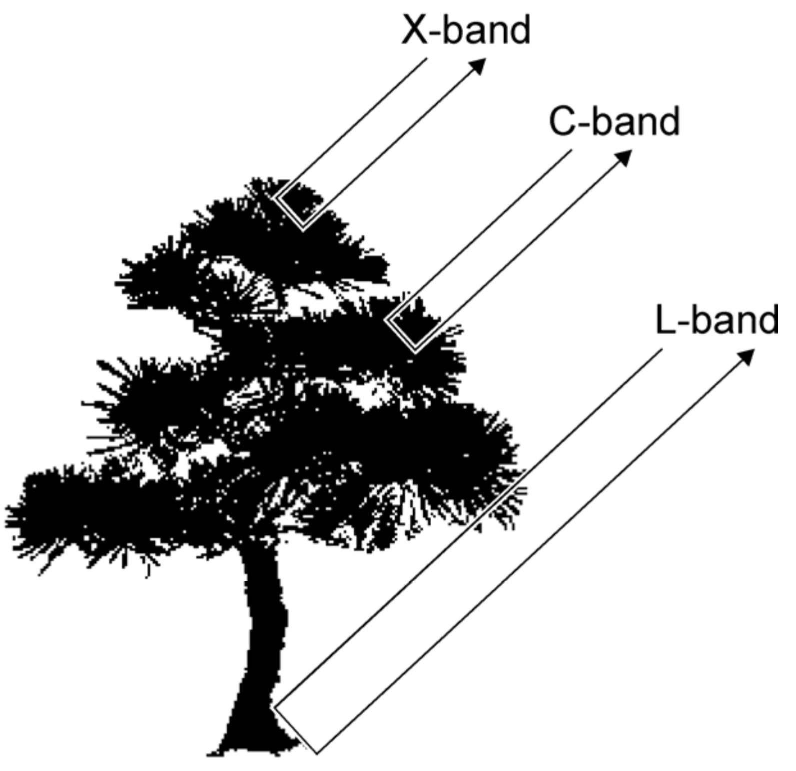
Non-overlapping Doppler Spectral Energy



Source: Carande

- Doppler spectral width determined by azimuth beam width of SAR
- Doppler center frequency determined by attitude, antenna and earth rotation
- for max coherence, filter out non-overlapping energy

Volume scattering



- scattering from different (random) heights within each resolution cell, such as in volume scattering, produces decorrelation

Temporal decorrelation

- change of scattering within a resolution cell or their electrical properties
  - function of time between the first and the second data acquisition
  - caused by vegetation, wind effects, soil moisture, snow fall, farming activities etc.

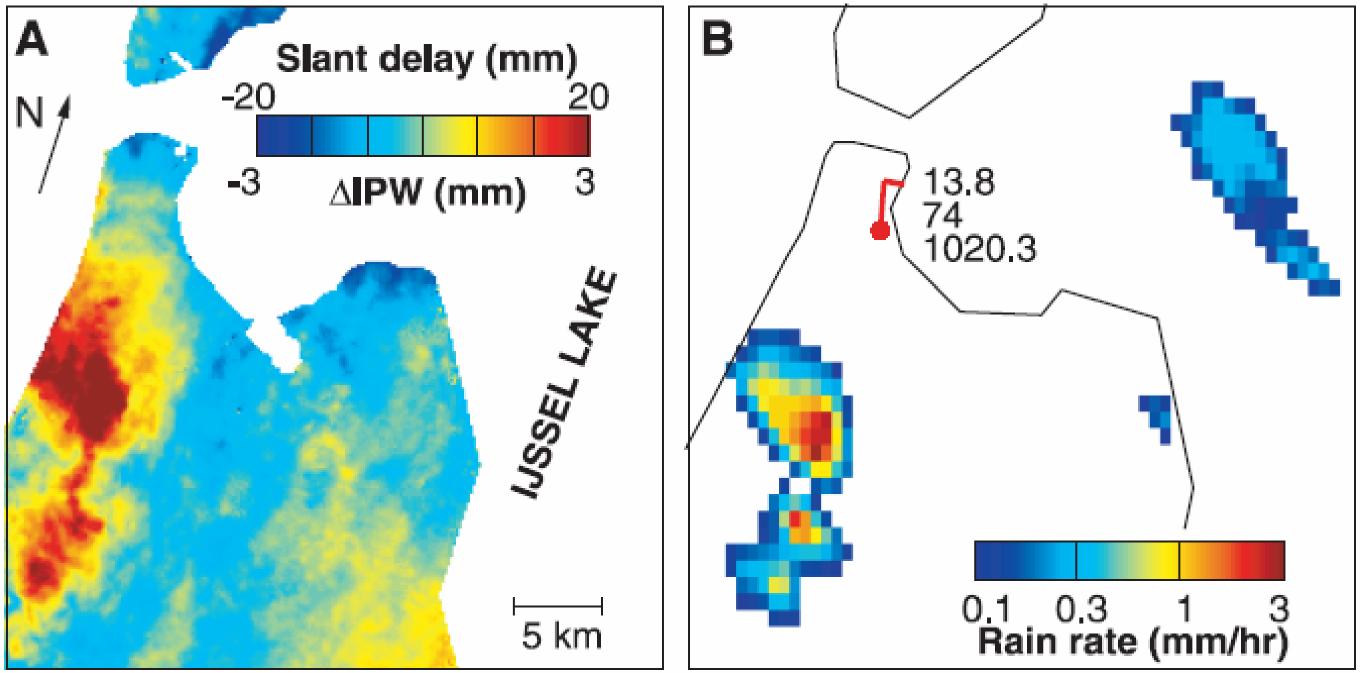
Atmospheric perturbation

- ionospheric path delay
  - variations in the total electron content along the path (depends on the time of day and influences the whole scene homogeneously)
  - traveling ionospheric disturbances (cause localized artifacts)
- *tropospheric path delay*
  - dominant dry part
  - small but highly variable wet part which is caused by the strong temporal and spatial variability of the water vapor concentration

Tropospheric water vapor

- probably most limiting factor for differential SAR interferometry
- very localized, heterogeneous effect
  - can cause misinterpretation of deformation fields derived by InSAR in the order of centimeters

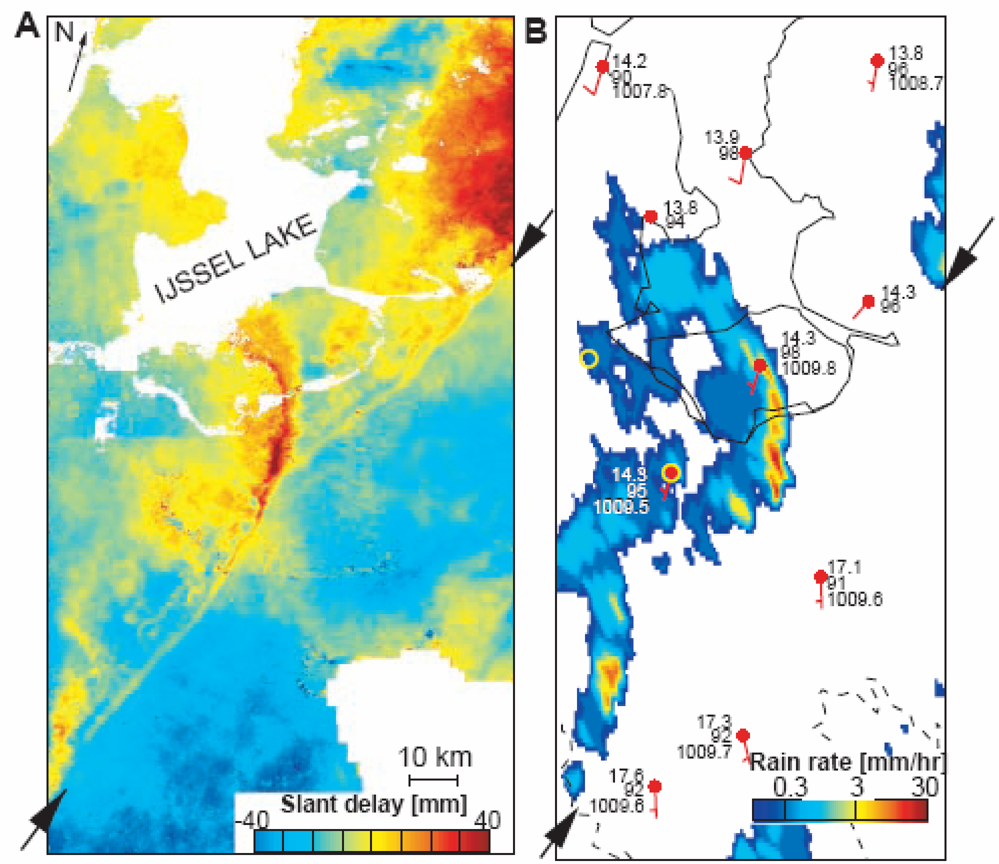
Example: the Netherlands
Effect of precipitation



- A: slant delay variation, mapped to zenith-integrated precipitable water differences
- B: weather radar rain rate; surface wind velocity was 4.1 m/s

Hanssen, R.F., Weckwerth, T.M., Zebker, H.A. and Klees, R., 1999. High-resolution water vapor mapping from interferometric radar measurements. *Science*, **283**(5406): 1297-1299

Example: the Netherlands
Effect of a cold front



- A: cold front is visible as the line between the arrows
- B: weather radar image
  - two weather radar stations are indicated by the yellow circles
  - superposed are surface observations

Hanssen, R.F., Weckwerth, T.M., Zebker, H.A. and Klees, R., 1999. High-resolution water vapor mapping from interferometric radar measurements. *Science*, **283**(5406): 1297-1299

Orbit errors

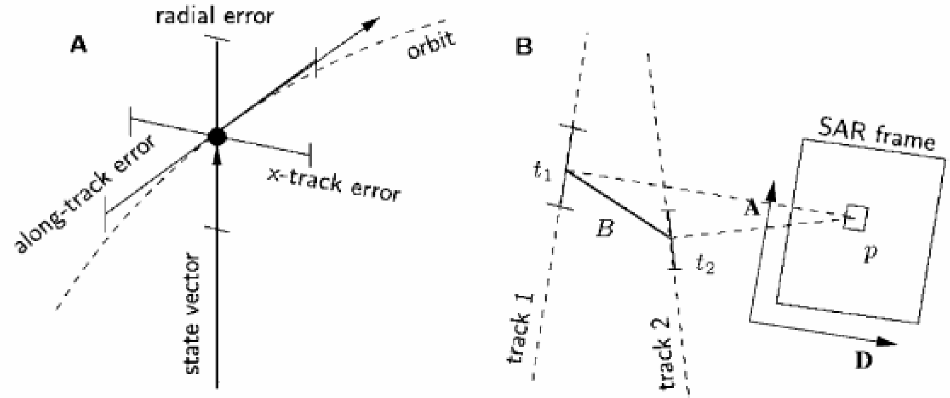


Fig. 3. A Three-dimensional sketch of the along-track, across-track and radial error bars. **B** Top view of two converging tracks. Resolution element *p* is observed at $(t = t_1)$ from the first track 1, and at $(t = t_2)$ from the repeat track 2. The along-track error is indicated by the error bars along the track, (from Hanssen 2001)

- orbital error vector is usually expressed in the coordinate system rotating with the satellite and consists of three components
  - along-track
  - across-track
  - radial

Orbit errors: Filtering approach

- orbital filtering approach can significantly improve precise orbit estimates of short arcs of ERS trajectories in an absolute sense
- approach restricted to those orbital passes in which SAR data were acquired
- limited to determining the across-track and radial components of the orbital trajectory
  - could use timing errors to estimate the along-track error

Kohlhase, A.O., Feigl, K.L. and Massonnet, D., 2003. Applying differential InSAR to orbital dynamics: a new approach for estimating ERS trajectories. *Journal Of Geodesy*, **77**(9): 493-502

Orbit errors: Filtering approach

- solving the weighted least-squares orbit determination problem

$$x^{lsq} = \left(A^T W A\right)^{-1} A^T W d$$

$$\delta r_i^{lsq} = r_i^{lsq} - r_i^{prior}, \quad \delta r_i^{lsq} \subseteq x^{lsq}$$

$$n_{12} = \left(r_2^{lsq} - r_1^{lsq}\right) - \left(r_2^{prior} - r_1^{prior}\right)$$
$$= B^{lsq} - B^{prior} \approx \Delta\left(\delta r_{12}\right)$$

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