A *pulse-to-pulse* interferometry mode to map velocity fields over quickly decorrelating surfaces with the Gamma Portable Radar Interferometer (GPRI).

Silvan Leinss, Charles Werner, Urs Wegmüller

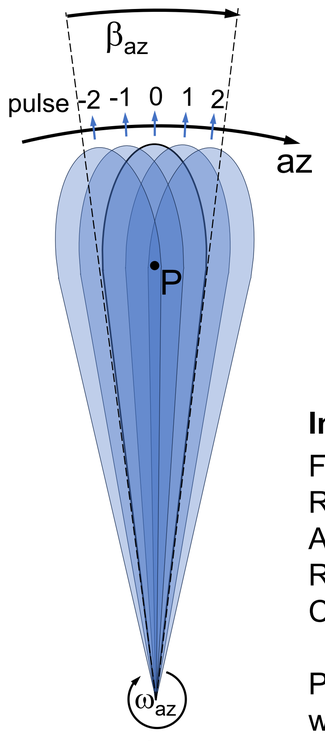
Pulse-to-pulse interferometry

Motivation:

- The echos of coherent pulses are recorded line-by-line in a real-aperture SLC image (no aperture synthesis for real aperture radar).
- The Pulse repetition frequency (PRF) is much larger than antenna rotation rate: the area covered by the beam pattern is measured for $t_\beta = \beta_{az}/\omega_{az}$ = 27 ms … 4s or $N = t_\beta \cdot PRF$ = 1 … 400 000 pulses. → Consecutive pulses are coherent. →Pulse-to-pulse interferometry possible.

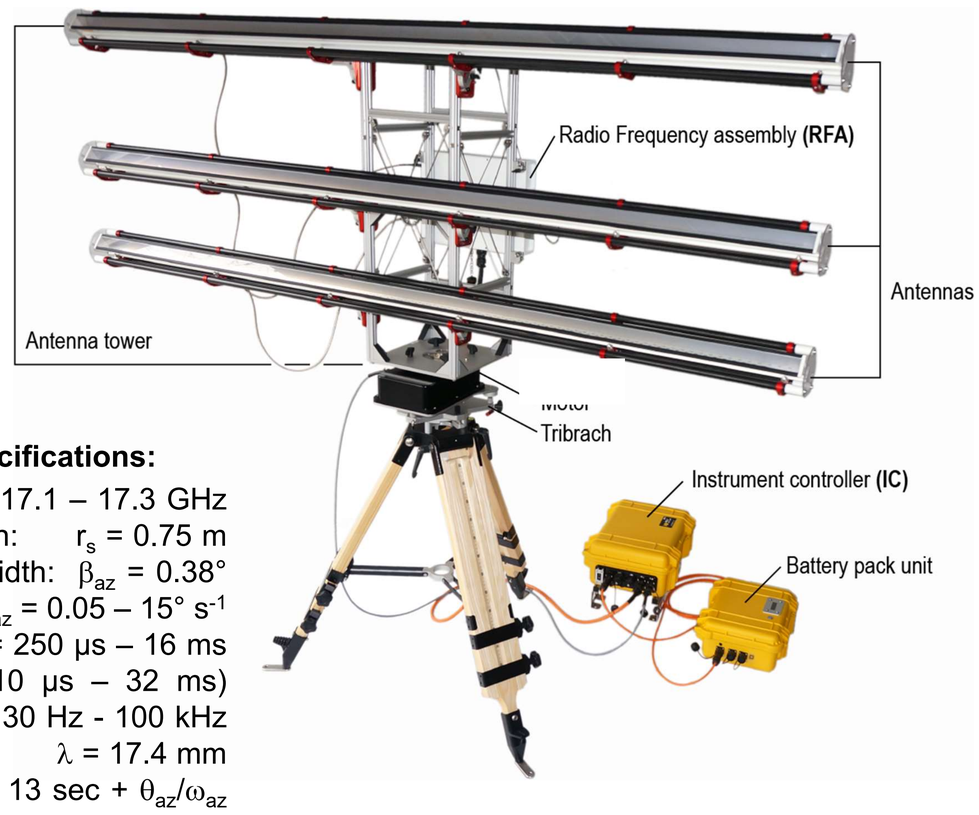
➔ Deformation of surfaces can be measured that decorrelate within a few milliseconds. Maximum deformation velocity $v_{max} = \frac{\lambda}{4\tau} \sim$

➔ SNR improvement by coherent averaging of consecutive pulses.



View from top

Gamma Portable Radar Interferometer



Instrument specifications:

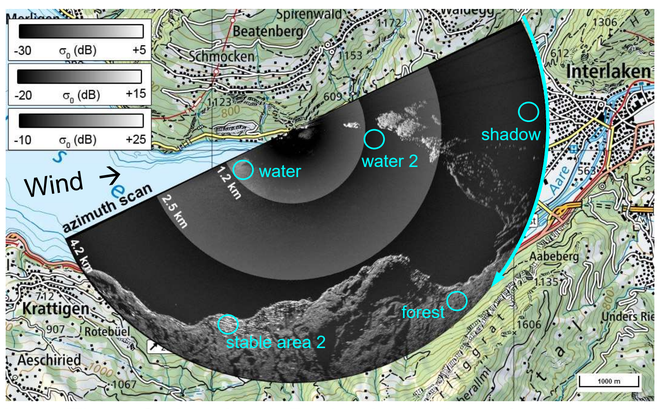
Frequency: f = 17.1 – 17.3 GHz
Range resolution: r_s = 0.75 m
Azimuth beamwidth: β_{az} = 0.38°
Rotation rate: ω_{az} = 0.05 – 15° s^{-1}
Chirp length: τ = 250 µs – 16 ms (10 µs – 32 ms)
PRF: 30 Hz - 100 kHz
wavelength: λ = 17.4 mm
time/acquisition: 13 sec + θ_{az}/ω_{az}

Mapping the line-of-sight velocity field of surface waves

Experiment

Instrument settings:

- azimuth sector: 180°
- rotation speed: ω_r = 2.5 deg/s
- chirp length: τ = 2 ms (PRF = 500 Hz, maximum range: 4.2 km)
- pulses / beamwidth: $N = b_{az}/\omega_r \cdot PRF$ = 80
- Range bandwidth: 200 MHz

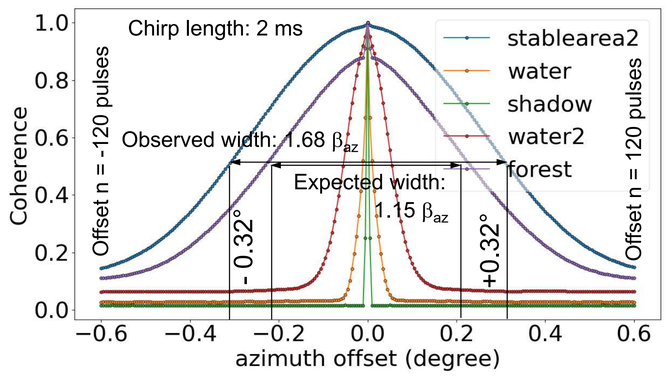


Lake Thun, Switzerland. Radar 65 m above lake, θ_{az} = 180°. 2022-06-24 10:20:45 UTC

Results

Pulse-to-pulse coherence:

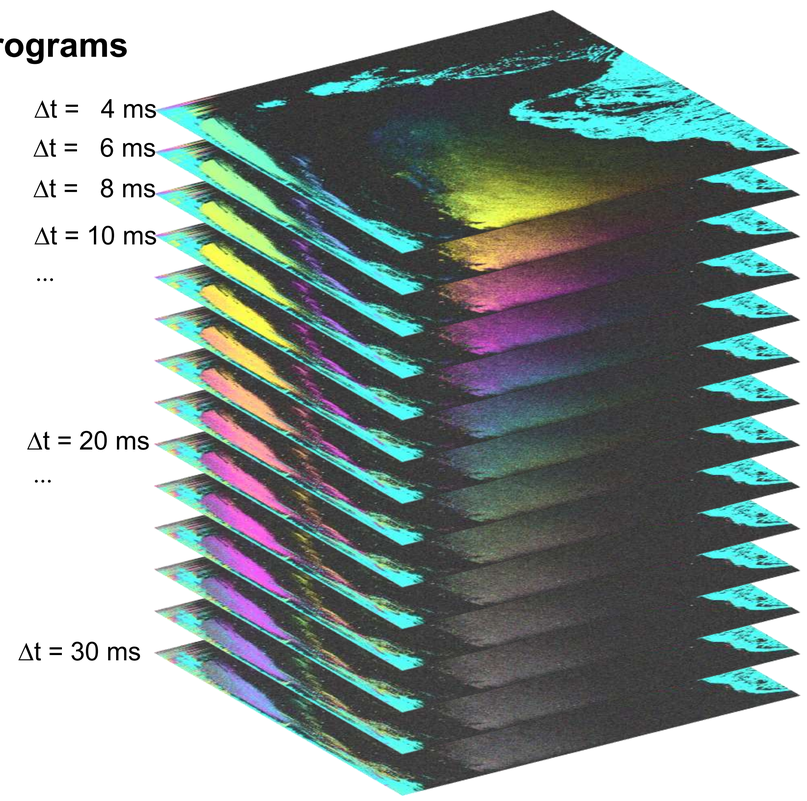
- For stable areas, the FWHM of the coherence should corresponds to 1.15 β_{az}
- Water decorrelates within 5 - 25 ms.
- Forest remains coherent at least for 80 pulses (160 ms).
- Shadow is completely decorrelated.



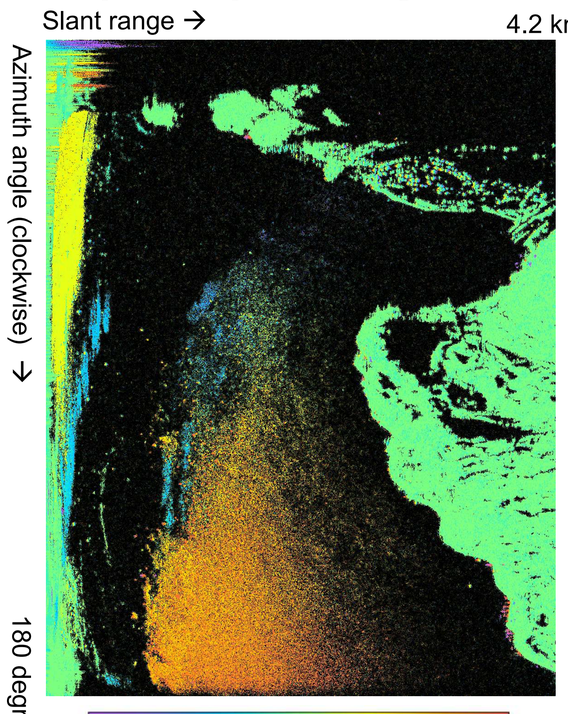
Pulse-to-pulse interferograms

Determine velocity by phase regression through time series of pulse-to-pulse interferograms.

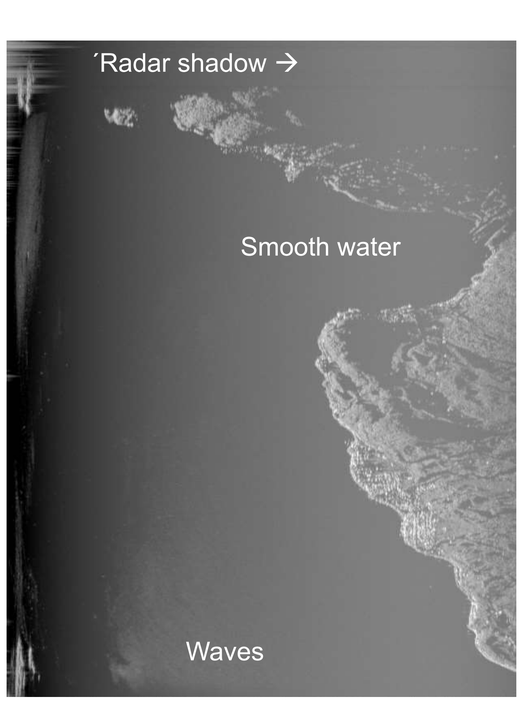
Standard InSAR time series analysis with Gamma program *def_mod*.



Velocity field by linear regression



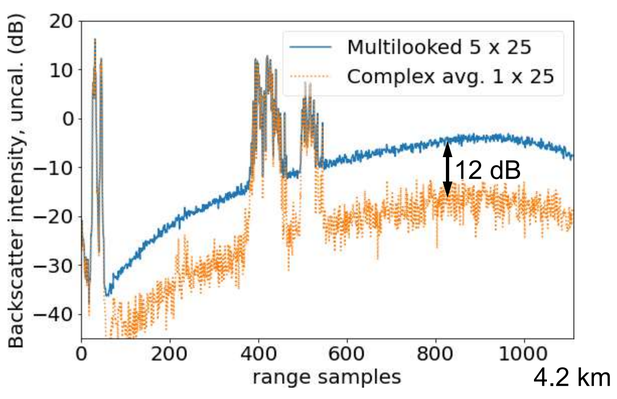
Brightness proportional to coherence.
(Uncertainty on the order of 1…10 mm /s)



(intensity multilooking: rg x az: 5 x 25 px)

SNR improvement due to coherent averaging

The coherence analysis showed that most surfaces (except of water) remain coherent over the total illumination time while the beam scans over the target area.
→ Coherent averaging of consecutive pulses improves the SNR.



(coherent averaging: 25 pulses (azimuth), intensity multilooking: rg x az: 5 x 1 px)

GAMMA REMOTE SENSING