Integrating SAR interferometry into surface soil moisture retrieval: a Sentinel-1 case study

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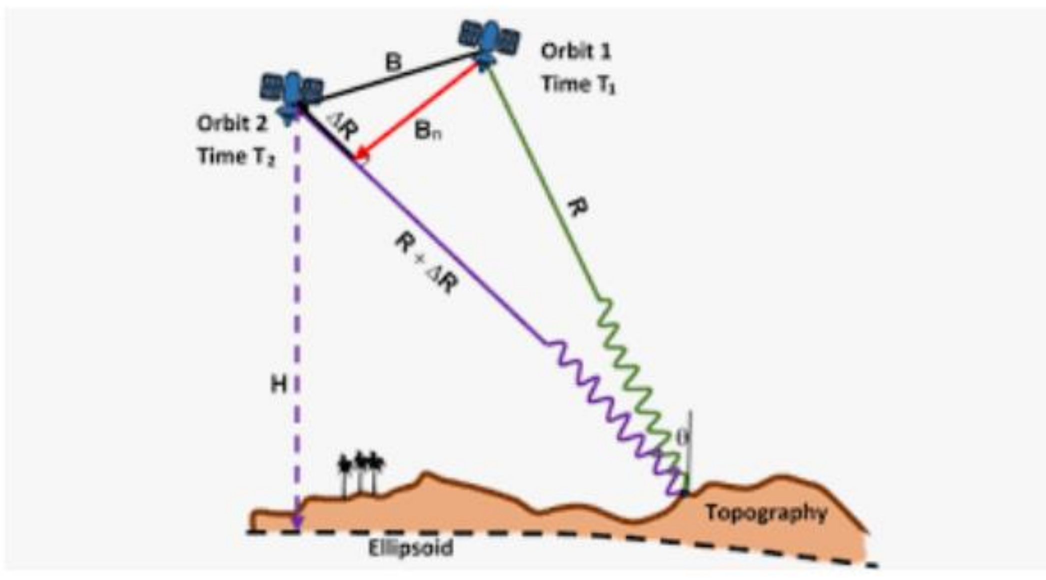
SAR interferometry: powerful technique enabling DEM generation and centimetric measurements of surface ground deformation…

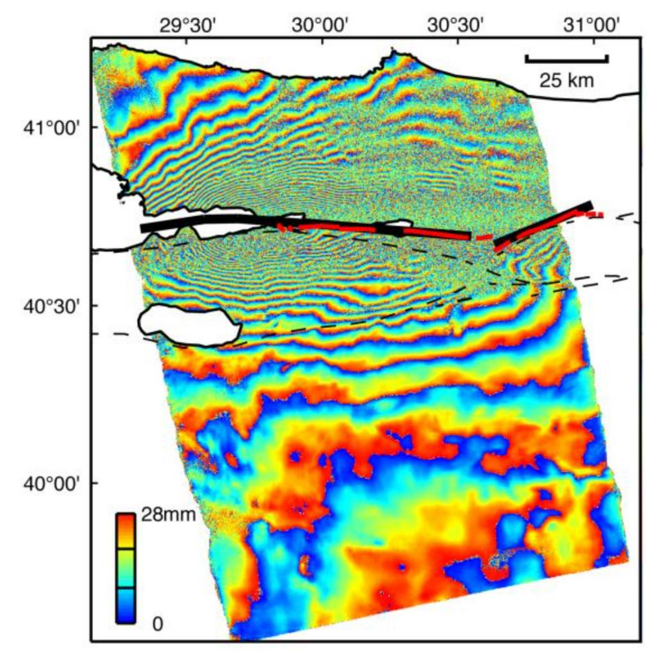


…based on the measurement of the phase difference (i.e., the interferometric phase) between SAR images from slightly different positions at the same time or at different times

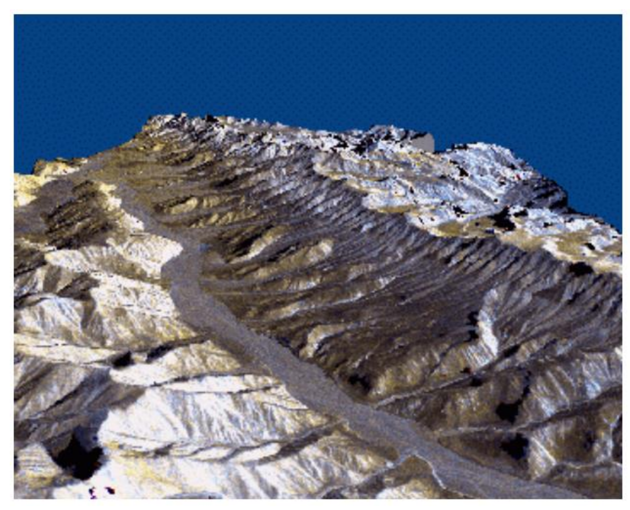
Contributors to SAR interferometric phase

$$\phi = \phi_{DEM} + \phi_{flat} + \phi_{disp} + \phi_{atm} + \phi_{noise}$$

$$-\frac{4\pi}{\lambda}\frac{B_n s}{R\tan\theta} \qquad -\frac{\Delta q}{\sin\theta}\cdot\frac{B_n}{R_0}\cdot\frac{4\pi}{\lambda} \qquad +\frac{4\pi}{\lambda}d$$

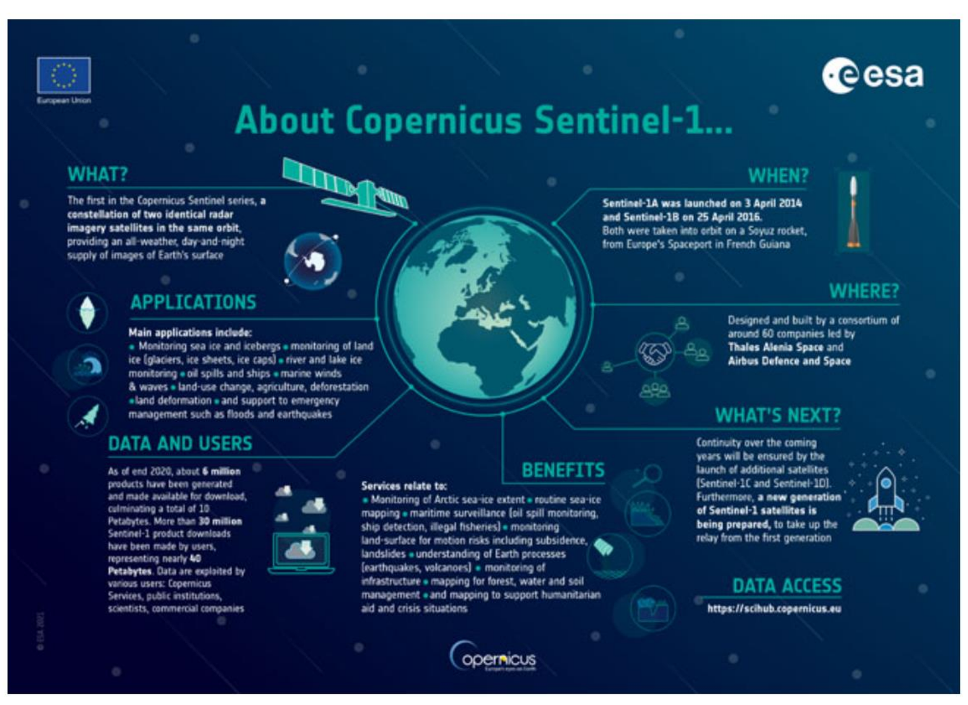


Interferogram produced using ERS-2 data from 13 August and 17 September 1999, spanning 17 August Izmit (Turkey) earthquake. (NASA/JPL-Caltech) [Wikipedia]

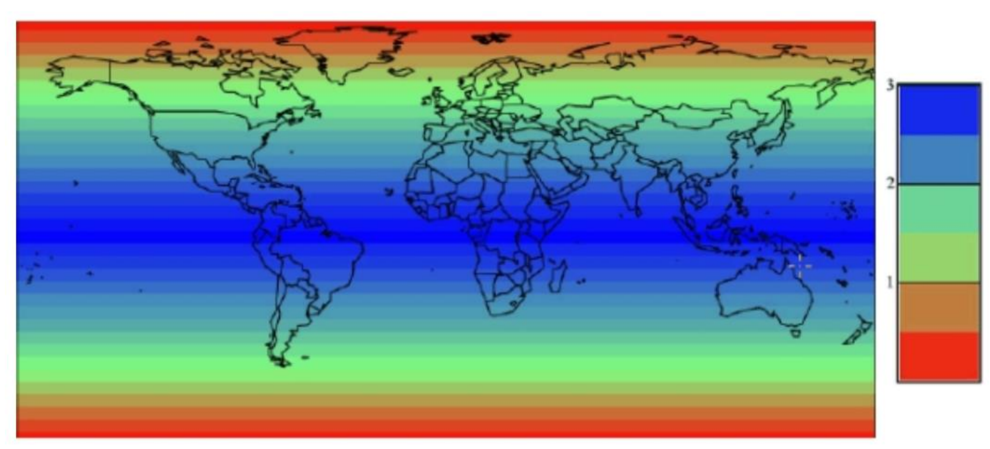


Perspective view of Karakax Valley (northern Tibet) derived from SIR-C interferometric DEM and SIR-C imagery [http://www.geo.cornell.edu/geology/eos/research/Interf_DEMs.html]

The Sentinel-1 radar observatory

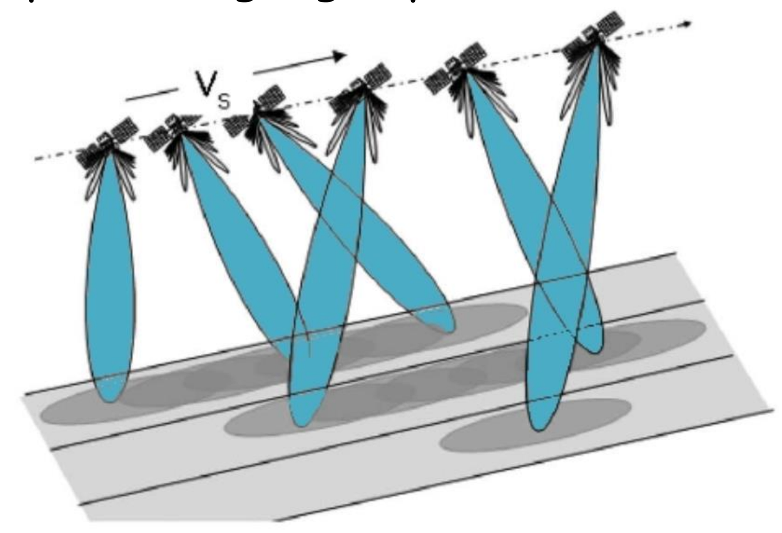


Revisit time for S-1A & S-1B in Days per Revisit



✓ Two satellites in a 12 day orbit
✓ Repeat frequency: 6 days (important for coherence)
✓ Revisit frequency: (asc/desc & overlap): 3 days at the equator, <1 day at high latitudes (Europe ~ 2 days)

Interferometric Wide swath, i.e., the pre-defined acquisition mode over land, allows wide spatial coverage preserving high spatial resolution

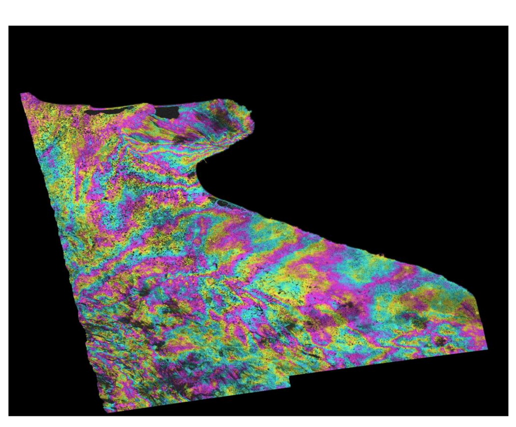


https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1

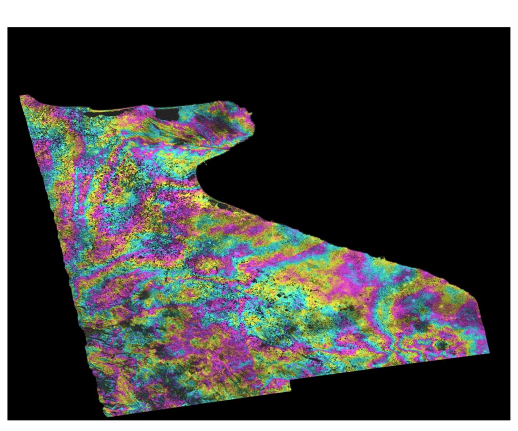
Proposed SSM retrieval approach integrating SAR interferometry

- Based on closure phase concept, i.e., interferograms combination to reduce atmospheric and deformation impact on interferometric phase

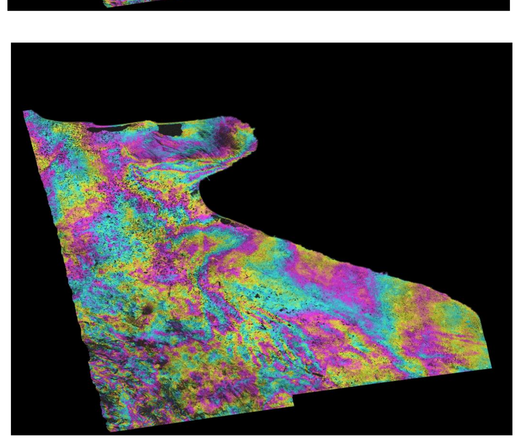
Sentinel-1
20200907-20200913
interferogram: $\Phi_{t,t+1}$



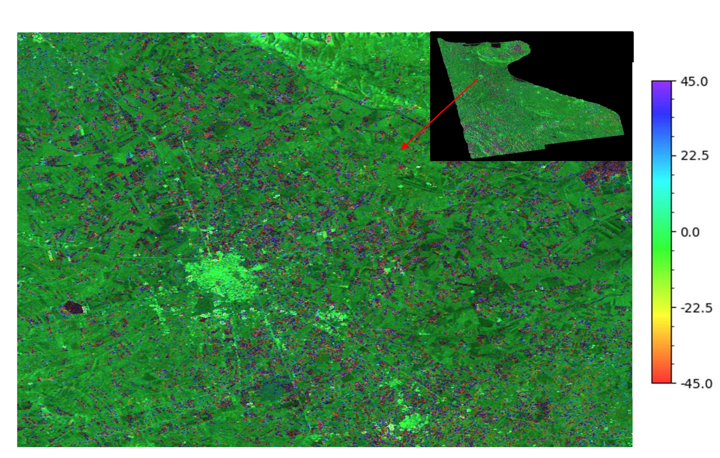
Sentinel-1
20200913-20200920
interferogram: $\Phi_{t+1,t+2}$



Sentinel-1
20200907-20200920
interferogram : $\Phi_{t,t+2}$



Sentinel-1
20200907-20200913-20200920
closure phase: $\Xi_t = \Phi_{t,t+1} + \Phi_{t+1,t+2} - \Phi_{t,t+2}$



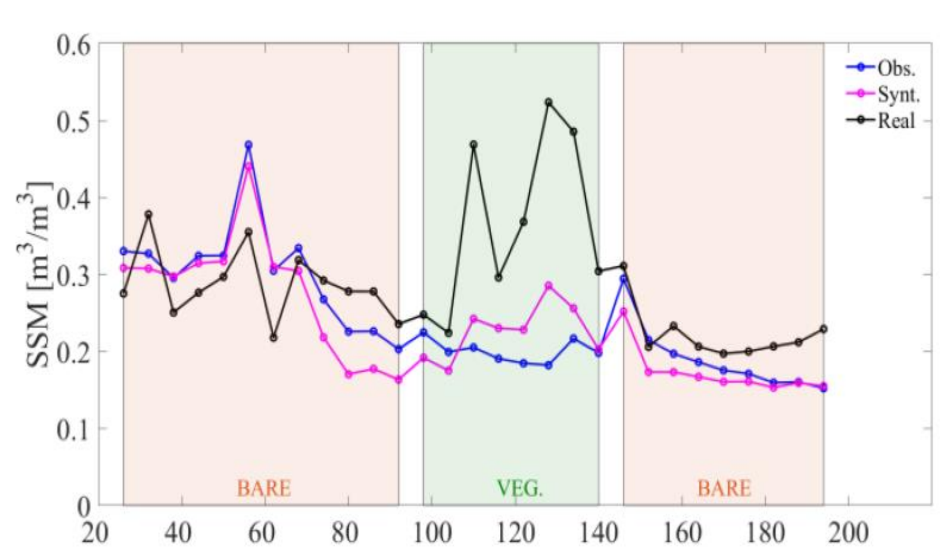
Integrated coherent-incoherent approach for surface soil moisture (SSM) retrieval

$$\begin{cases} \frac{\sigma^0_{t+1}}{\sigma^0_t} = \frac{|\alpha_{t+1}(\varepsilon_{t+1})|^2}{|\alpha_t(\varepsilon_t)|^2} \\ \frac{\sigma^0_{t+2}}{\sigma^0_t} = \frac{|\alpha_{t+2}(\varepsilon_{t+2})|^2}{|\alpha_t(\varepsilon_t)|^2} \\ \Xi_t = f(\varepsilon_t, \varepsilon_{t+1}, \varepsilon_{t+2}) \end{cases}$$

Incoherent approach: Balenzano et al., 2011, Palmisano et al., 2021

Coherent approach: De Zan et al., 2014

Simulated and experimental results



- Retrieved soil moisture from synthetic and **Sentinel-1** data (Palmisano et al., 2022)
- Comparison with **in situ** soil moisture over bare soils:
  - ✓ **Pearson correlation R=0.97 & RMSE=0.03 m³/m³**
  - ✓ **Pearson correlation R=0.80 & RMSE=0.05 m³/m³**

References

- Balenzano et al., "Dense temporal series of C- and L-band SAR data for soil moisture retrieval over agricultural crops," IEEE J. Sel. Topics Appl. Earth Observ. Remote Sens., vol. 4, no. 2, pp. 439–450, Jun. 2011.
- De Zan et al., "A SAR interferometric model for soil moisture," IEEE Trans. Geosci. Remote Sens., vol. 52, no. 1, pp. 418–425, Jan. 2014.
- Palmisano et al., "Sentinel-1 sensitivity to soil moisture at high incidence angle and the impact on retrieval over seasonal crops," IEEE Trans. Geosci. Remote Sens., vol. 59, no. 9, pp. 7308–7321, Sep. 2021.
- Palmisano et al., "Coherent and Incoherent Change Detection for Soil Moisture Retrieval From Sentinel-1 Data," in IEEE Geosci. Remote Sens. Letters, vol. 19, pp. 1-5, 2022.