		Resumén	Metódo
1	Rouyeta Line ,Rune Lauknesa Tom , Hanne H. Christiansenc , Sarah M. Strandc,d , Yngvar Larsena. (2019). **Seasonal dynamics of a permafrost landscape, Adventdalen, Svalbard, investigated by InSAR.** Remote Sensing of Environment, 34, 17.	Nordenskiöld Land in Central Spitsbergen, Svalbard is characterized as a high latitude, high relief periglacial landscape with permafrost occurring both in mountains and lowlands. Freezing and thawing of the active layer causes seasonal frost heave and thaw subsidence, while permafrost-related mass-wasting processes induce downslope ground displacements on valley sides. Displacement rate varies spatially and temporally depending on environmental factors. In our study, we apply Satellite Synthetic Aperture Radar Interferometry (InSAR) to investigate the magnitude, spatial distribution and timing of seasonal ground displacements in and around Adventdalen using TerraSAR-X StripMap Mode (2009–2017) and Sentinel-1 Interferometric Wide Swath Mode (2015–2017) SAR images. First, we show that InSAR results from both sensors highlight consistent patterns and provide a comprehensive overview of the distribution of displacement rates. Secondly, two-dimensional (2D) TerraSAR-X InSAR results from combined ascending and descending geometries document the spatial variability of the vertical and east-west horizontal displacement rates for an average of nine thawing seasons. The remote sensing results are compared to a simplified geomorphological map enabling the identification of specific magnitudes and orientations of displacements for 14 selected geomorphological units. Finally, June to December 2017 6-day sampling interval Sentinel-1 time series was retrieved and compared to active layer ground temperatures from two boreholes. The timing of the subsidence and heave detected by InSAR matches the thawing and freeze-back periods measured by in-situ sensors. Our results highlight the value of InSAR to obtain landscape scale knowledge about the seasonal dynamics of complex periglacial environments.	Using maximal temporal baselines of 22 days (TSX) and 24 days (S1), the multi-year datasets include gaps during the winter periods. To take advantage of the large stacks of interferograms from disconnected subsets, we applied a multi-year averaging technique (stacking) based on interferograms from the thawing periods (2009–2017 for TSX and 2015–2017 for S1). **The applied stacking is a simple averaging of all selected interferograms weighted by the temporal intervals between the scenes. InSAR stacking reduces the atmospheric effects, assuming temporally uncorrelated tropospheric effects (Lyons and Sandwell, 2003; Peltzer et al., 2001; Sandwell and Price, 1998)**. Using S1 interferograms, we selected a temporally connected set of interferogram between June–December 2017 and we estimated displacement time series using the Small Baseline Subset (SBAS) method (Berardino et al., 2002). The phase inversion was performed using a L1-norm-based cost function, which is more robust than L2-norm with respect to unwrapping errors (Lauknes et al., 2011). **For the atmospheric filtering**, we used a spatial filter of 500 m spatial filter and a temporal filter of 12 days. All results were geocoded using a DEM at 20 m resolution (Norwegian Polar Institute, 2014a). InSAR stacking results for each dataset (TSX ascending, TSX descending, S1 ascending) correspond to one-dimensional (1D) displacement rates along the LOS (Table 1, column 7), based on several years. All maps based on stacking results highlight the average multi-year displacement rates during the 4-month thawing periods (June–-September), expressed in mm/summer. The results from ascending and descending geometries were combined

			to estimate 2-dimensional (2D) vectors in the plane spanned by the ascending and descending LOS directions (Eriksen et al., 2017). The results were decomposed into vertical (upwards-downwards) and horizontal (eastwards-westwards, E-W) components. 2D InSAR results were retrieved for TSX dataset only, due to unavailability of S1 IWS in descending geometry before 2018. It should be noted that the radar is still blind to movement orthogonal to the LOS plane, which leads to an underestimation of the displacement rates in case of a large horizontal component in the northsouth (N-S) direction. To avoid misinterpretation when comparing InSAR to geomorphology, we masked out pixels in areas where a significant horizontal component towards N or S is expected (Eckerstorfer et al., 2018).
2	Chengsheng Yang, Dongxiao Zhang , Chaoying Zhao , Bingquan Han , Ruiqi Sun , Jiantao Du and Liquan Chen. (2019). **Ground Deformation Revealed by Sentinel-1 MSBAS-InSAR Time-Series over Karamay Oilfield, China.** Remote Sensing, 11, 18.	Fluid extraction or injection into underground reservoirs may cause ground deformation,manifested as subsidence or uplift. Excessive deformation may threaten the infrastructure of the oilfield and its surroundings and may even induce earthquakes. Therefore, the monitoring of Surface deformation caused by oil production activities is important for the safe production of oilfields and safety assessments of surrounding infrastructure. Karamay oilfield is one of the major oil and gas fields in China. In this study, we take the Karamay oilfield in Xinjiang as a case study to detect surface deformation caused by subsurface fluid injection. Sentinel-1A images of 32 ascending (Path 114) and 34 descending (Path 165) tracks spanning March 2017 to August 2018, were used to derive vertical and horizontal deformation over Karamay oilfield using the MSBAS-InSAR method. The observed two-dimensional deformation exhibited significant vertical and east-west deformation in this region.The maximum uplift and horizontal velocity was	**A stacking method was proposed by Sandwell et al. in [35]. The mathematical model is shown in Equation (1). The assumption in this method is that the atmospheric signal is random in time, and ground deformation changes linearly. By averaging the unwrapped phase sets, the atmospheric delay phase is weakened and the linear deformation rate is extracted**. According to the law of error propagation, when stacking N unwrapped interferograms, the linear deformation signal is increased N times, and the atmospheric phase error is only increased √ N times. When the weighted average of the unwrapped phases of the N interferograms is calculated, the atmospheric influence weakens the original value of 1/√N, thereby increasing the signal-to-noise ratio [36,37]. Consequently, the random part of the atmospheric phase is greatly weakened [38]. As a result, the stacking method

		approximately 160 mm/year and 65 mm/year, respectively. We also modeled one of the typical deformation zones using a dislocation model in a homogenous elastic half-space	represents a better choice to obtain the average rate of the ground deformation. If the selected interferograms are connected end-to-end with the master-slave image, the phase noise of the slave image in the previous interferogram and the master image of the latter interferogram can be counteracted when using Equation (1) to stack. However, we must ensure the quality of the first and last interferograms.
3	**Fault edge detection for analyzing surface deformations with ground movement models**	extensive dewatering for the mining of lignite◮ consequence is extensive subsidence of ground ◮ monitoring of towns with high precision leveling ◮ position of measured height changes due to infrastructure ◮ target: parametrization and estimation of height changes ◮ two necessary consecutive steps ... 1. detect fault edges, if existent 2. preclude fault edges, if not existent	
4	Fattahi, H., and F. Amelung (2016), **InSAR observations of strain accumulation and fault creep along the Chaman Fault system, Pakistan and Afghanistan**, Geophys. Res. Lett., 43, 8399–8406, doi:10.1002/2016GL070121.	We use 2004–2011 Envisat synthetic aperture radar imagery and InSAR time series methods to estimate the contemporary rates of strain accumulation in the Chaman Fault system in Pakistan andAfghanistan.At29 Nwefindlong-termslipratesof16 ± 2.3 mm/yrfortheGhazabandFaultandof8 ± 3.1 mm/yrfor the Chaman Fault. This makes the Ghazaband Fault one of the most hazardous faults of the plate boundaryzone. We further identify a 340 km long segment displaying aseismic surface creep along the Chaman Fault,withmaximumsurfacecreeprateof 8.1 ± 2 mm/yr.TheobservationthattheChamanFaultaccommodatesonly30% of the relative platemotion between India and Eurasiaimplies that the remainder is accommodated southand east of the Katawaz block microplate.	We assume that the relative plate motion is accommodated by movements along one or more vertical strike-slip faults that are either locked or creeping from the surface to some depth. **We model a fault as acombination of a buried infinite screw dislocation in an elastic half-space representing interseismic strainaccumulation along a locked fault [Savage and Burford, 1973] and a dislocation extending from the surface to a given depth, representing the accommodation of strain by shallow creep [Segall, 2010, equation 2.30].The fault-parallel surface velocity due to slip along N parallel faults is given by**…
5	Wright, T., Parsons, B., Fielding, E., 2001. **Measurement of interseismic strain accumulation across the North**	In recent years, interseismic crustal velocities and strains have been determined for a number of tectonically active areas through repeated measurements using the Global Positioning System. The	**To analyse the variation of phase (or displacement) across the fault, we use a simple model in which right-lateral aseismic slip, s, occurs at depth on a vertical fault beneath**

	Anatolian Fault by satellite radar interferometry. Geophys. Res. Lett. 28 (10), 2117–2120. X	terrain in such areas is often remote and difficult, and the density of GPS measurements relatively sparse. In principle, satellite radar interferometry can be used to make millimetric-precision measurements of surface displacement over large surface areas. In practice,the small crustal deformation signal is dominated over short time intervals by errors due to atmospheric, topographic and orbital effects. Here we show that these effects can be overcome by stacking multiple interferograms, after screening for atmospheric anomalies, effectively creating a new interferogram that covers a longer time interval. In this way, we have isolated a 70 km wide region of crustal deformation across the eastern end of the North Anatolian Fault,Turkey. The distribution of deformation is consistent with slip of 17–32 mm/yr below 5–33 km on the extension of the surface fault at depth. If the GPS determined slip rate of 24±1 mm/yr is accepted, the locking depth is constrained to 18±6 km.	**a locked upper crust of thickness d. For buried faults, the displacements, y, at distance x from the fault are equivalent to those caused by an infinitely-long screw dislocation in an elastic half-space ($y = s\pi \tan^{-1} xd$) [Savage and Burford,1973]. The model assumes pure right-lateral slip on a vertical fault.** Failure to meet these conditions would produce an asymmetrical deformation pattern, which is not evident.Additional data from ascending satellite passes would enable this to be tested, but few data are available for ascending passes in this location.The slip rate on the fault and the elastic lid thickness were determined by minimising the misfit between the model displacements, converted to phase changes, and the observed phase profile (Fig. 3a), assuming that slip at depth is coin cident with the surface trace of the North Anatolian Fault.The best-fit model has 22 mm/yr of slip beneath a 14 km elastic lid. The fit to this simple model is good up to distances of 100 km away from the fault. Towards the southern end of our profile the model diverges from the observations where the profile crosses the Ovacik Fault. It is tempting to ascribe this to left-lateral slip of ∼5 mm/yr on that fault. However, the sign of the phase change across the Ovacik fault reverses in the eastern half of our interferogram, and we cannot be confident that this small signal is resolvable above the atmospheric noise A-posteriori errors on the slip rate and fault locking depth are determined using a Monte-Carlo simulation technique (Fig. 3b). There is a clear trade-off between the fault locking depth and slip rate that arises because of the tight constraint on phase gradient near the fault: larger slip rates require deeper locking depths.

6	Qu, F., Lu, Z., Kim, J., & Zheng, W. (2019). **Identify and Monitor Growth Faulting Using InSAR over Northern Greater Houston, Texas, USA.** Remote Sensing, 11, 1498.	Growth faults are widely distributed in the Greater Houston (GH) region of Texas, USA, and the existence of faulting could interrupt groundwater flow and aggravate local deformation.Faulting-induced property damages have become more pronounced over the last few years, necessitating further investigation of these faults. Interferometric synthetic aperture radar (InSAR) has been proved to be an effective way for mapping deformations along and/or across fault traces.However, extracting short-wavelength small-amplitude creep signal (about 10–20 mm/yr) from long time span interferograms is extremely difficult, especially in agricultural or vegetated areas. This study aims to position, map and monitor the rate, extent, and temporal evolution of faulting over GH at the highest spatial density using Multi-temporal InSAR (MTI) technique. The MTI method, which maximizes usable signal and correlation, has the ability to identify and monitor faulting and provide accurate and detailed depiction of active faults. Two neighboring L-band Advanced Land Observing (ALOS) tracks (2007–2011) are utilized in this research. Numerous areas of sharp phase discontinuities have been discerned from MTI-derived velocity map. InSAR measurements allow us to position both previously known faults traces as well as nucleation of new fractures not previously revealed by other ground/space techniques. Faulting damages and surface scarps were evident at most InSAR-mapped fault locations through our site investigations. The newly discovered fault activation appears to be related to excessive groundwater exploitation from the Jasper aquifer in Montgomery County. The continuous mining of groundwater from the Jasper aquifer formed new water-level decline cones over Montgomery County, corroborating the intensity of new fractures. Finally, we elaborate the localized fault activities and evaluate the characteristics of faulting (locking depth and slip rate) through modeling MTI-derived deformation maps. The SW–NE-	Growth faulting has influenced a wide variety of geological conditions in GH, and is known to have impacted and damaged buildings, highways, wells, and pipelines [2,4]. Locating and characterizing active faults is crucial for protecting people and infrastructure from severe damage. **The objective of this work is to carry out an integrated study of the active faults over northern GH region, including establishing position and monitoring the distribution, velocity, and temporal development of faulting utilizing MTI technique.** Furthermore, we use the analysis to identify the key driving mechanisms. To do so, we utilized L-band ALOS datasets, which can reach to the ground partially penetrating through vegetation to obtain ground surface information and reveal the faulting creep over northern GH region.First, we estimated the long-term deformation rate from 2007 to 2011 by MTI to characterize the spatial distribution of active faults. Second, we mapped fault fractures by phase jumps/discontinuities identified from our InSAR average deformation map. Our InSAR mapped fault traces were validated through LiDAR, geophysical survey and field investigated observations. Third, we derived the fault slip models from two independent InSAR displacement measurements to study the characteristics of faulting. Finally, we expound how the faulting over GH is in connection with regional faults,sedimentary history of the Gulf of Mexico, salt movement and fluid extraction.

		oriented faults pertain to normal faulting with an average slip rate of 7–13 mm/yr at a shallow locking depth of less than 4 km. Identifying and characterizing active faults through MTI and deformation modeling can provide insights into faulting, its causal mechanism and potential damages to infrastructure over the GH.	
7	Yun, Hye-Won & Kim, Jung-Rack & Yoon, Hasu & Choi, Yunsoo & Yu, Junghum. (2019). **remote sensing Seismic Surface Deformation Risks in Industrial Hubs: A Case Study from Ulsan, Korea, Using DInSAR Time Series Analysis.** Remote Sensing. 11. 10.3390/rs11101199.	The unprecedentedly strong 2016 Gyeongju and 2017 Pohang earthquakes on the Korean Peninsula aroused public concern regarding seismic hazards previously considered improbable. In this study, we investigated the effects of recent seismic activity close to the epicenters of both earthquakes in the heavy industrial complex of Ulsan. This was performed using Sentinel-1 InSAR time series data combined with on-site GPS observations and background GIS data. The interpretations revealed on going to pographic deformation of a fault line and surrounding geological units of up to 15 mm/year.Postseismic migrations through the fault line, coupled with the two earthquakes, were not significant enough to pose an immediate threat to the industrial facilities or the residential area. However,according to InSAR time series analyses and geophysical modelling, strain from the independent migration trend of a fault line and eventual/temporal topographic changes caused by potential seismic friction could threaten precisely aligned industrial facilities, especially chemical pipelines.Therefore, we conducted probabilistic seismic hazard and stress change analyses over surrounding areas of industrial facilities employing modelled fault parameters based on InSAR observations.These demonstrate the potential of precise geodetic survey techniques for constant monitoring and risk assessment of heavy industrial complexes against seismic hazards by on going fault activities.	In these circumstances, we performed a geophysical inversion, employing the Geodetic Bayesian Inversion Software (GBIS) [65] to define more clearly the deformation source and its contributions. .This software is capable of deformation source parameter inversion using Markov-chain Monte Carlo methods [66] and the Metropolis–Hastings algorithm [67] even with InSAR observations in a complicated scenario [68]. We assigned the initial parameters of the fault line sets (Table 5) based on the known geometry of the Ulsan fault, and considered two plausible scenarios: (1) the Ulsan fault and its interaction with the surrounding soft ground units is responsible for the deformation pattern in the target area (i.e., the single fault model); and (2) full deformation is induced by the interaction between multiple faults, and thus the fault system could produce a localized deformation in the Ulsan central city area (i.e., the multifault model).The multifault line model, consisting of the Ulsan fault and the fault lines directly crossing Ulsan city area, is less feasible
8	Zhu, Sen & Xu, Caijun & Wen, Yangmao & Liu, Yang. (2016). **Interseismic**	The Altyn Tagh Fault (ATF) is one of the major left-lateral strike-slip faults in the northeastern area of the Tibetan Plateau. In this study,	To aid in the interpretation of the first-order characteristics of the LOS velocity map, a simple elastic model with single

	Deformation of the Altyn Tagh Fault Determined by Interferometric Synthetic Aperture Radar (InSAR) Measurements. Remote Sensing. 8. 233. 10.3390/rs8030233.	the interseismic deformation across the ATF at 85˝E was measured using 216 interferograms from 33 ENVISAT advanced synthetic aperture radar images on a descending track acquired from 2003 to 2010, and 66 interferograms from 15 advanced synthetic aperture radar images on an ascending track acquired from 2005 to 2010. To retrieve the pattern of interseismic strain accumulation, a global atmospheric model (ERA-Interim) provided by the European Center for Medium Range Weather Forecast and a global network orbital correction approach were applied to remove atmospheric effects and the long-wavelength orbital errors in the interferograms. Then, the interferometric synthetic aperture radar (InSAR) time series with atmospheric estimation model was used to obtain a deformation rate map for the ATF. Based on the InSAR velocity map, the regional strain rates field was calculated for the first time using the multi-scale wavelet method. The strain accumulation is strongly focused on the ATF with the maximum strain rate of 12.4 ˆ 10´8/year. We also show that high-resolution 2-D strain rates field can be calculated from InSAR alone, even without GPS data. Using a simple half-space elastic screw dislocation model, the slip-rate and locking depth were estimated with both ascending and descending surface velocity measurements. The joint inversion results are consistent with a left-lateral slip rate of 8.0 ˘ 0.7 mm/year on the ATF and a locking depth of 14.5 ˘ 3 km, which is in agreement with previous results from GPS surveys and ERS InSAR results. Our results support the dynamic models of Asian deformation requiring low fault slip rate.	fault geometry was used to invert the slip-rate and locking depth of the ATF.Although one more complex model may be more appropriate for this fault, the lack of data near the fault makes it hard to constrain the deformation using a complex model. Consequently, we assumed a strike-slip fault with 90˝ dip angle. We assumed that LOS deformation is a combination of fault parallel deformation and vertical deformation, ignoring normal fault deformation, which is justified by GPS measurements [11].We modeled the fault as a buried infinite screw dislocation in a homogeneous, isotropic elastic half-space, where aseismic slip occurs at a rate (s) below a locking depth (d) during the interseismic period.Under this assumption, we converted displacement of two profiles in LOS direction into horizontal displacements parallel to the fault and vertical displacements. We accounted for both horizontal and vertical displacement with two data tracks in our inversion rather than accounting for only horizontal displacement [16] with only one track, in our inversion process the contribution from vertical components is subtracted from the InSAR observations. The relationship between LOS displacements and horizontal and vertical displacement is given by:
9	Poenaru, Violeta & Popescu, Anca & Patrascu, Carmen & Cuculici, Roxana. (2015). **Assessment Of Rosia Jiu Mining Area Through TerraSAR-X New**	The paper evaluates new Staring Spotlight mode capabilities to monitor the mining activities impacts on the environment to ensure an effective management and to prevent possible natural and technological hazards.The societal and environmental impacts are huge such as: the topographic alteration, changes in the soil	Thus, numerical models required for understanding of the mining site conditions such as proper representation of the geology and rock mass properties can be applied to assess land deformations. In this paper, an approach based on the Interferogram stacking technique **[10]** was proposed to

	Imaging Modes. 10.5270/Fringe2015.pp291.	structure and vegetation coverage, influence on the underground water resources and on the rain water draining regime and air pollution. Rosia Jiu opencast test site is affected by subsidence phenomena caused by the closing of the hollows remained from the underground exploitation of lignite and by altering of the hidro-geological conditions, due to the applying of a forced and high intensity dewatering of the aquifer system within the area. A methodology based on deformation maps is designed for monitoring of the elastic deformation, early warning stage and detection of the risk occurrence. Intense mining activities from the summer - autumn seasons implied as interferometric pairs to have very low coherence making almostimpossible to find PS candidates.	extract average displacement maps. This class of algorithms mitigates the influence of the atmospheric phase screen on the phase and subsequent influence on the final deformation estimate, leading to average displacement rates with an increased sensitivity to measurements given the noise removal [11]. The basis of this approach lays in weighting of the interferometric stack and combining the result to get an average displacement map. The average deformation rates for the Rosia Jiu area are computed assuming linear displacement rates in the scene, caused by the continuous excavation in the area. The starting point for this algorithm is a stack of subpixel level coregistered and radiometrically calibrated ST TerraSAR-X images. Given the small number of available image samples (10), we generate interferogram using all possible interferometric pairs.
10	Khakim, Mokhamad Yusup Nur & Tsuji, Takeshi & Matsuoka, Toshi. (2013). **Detection of Localized Surface Uplift by Differential SAR Interferometry at the Hangingstone Oil Sand Field**, Alberta, Canada. Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of. 6. 2344-2354. 10.1109/JSTARS.2013.2254471.	—We estimated the surface uplift (heave) rate due to steam-assisted gravity drainage (SAGD) at the Hangingstone oil sand field in Alberta, Canada, by stacking differential synthetic aperture radar (SAR) interferograms. To improve accuracy, a Landsat-7 Enhanced Thematic Mapper Plus intensity image was coregistered with the SAR intensity image. We examined three interferogram filtering methods and identified one that provided the desired effect of light filtering in areas of low noise and heavier filtering in high-noise areas. Based on our analysis of interferogram coherences, site-specific decorrelation highly depends on local seasonal changes. Stacking was performed to estimate the surface uplift rate while removing atmospheric and seasonal effects. The amounts of the uplift rate and slope change estimated by means of InSAR analysis reached a maximum of 3.6 cm/yr and 0.003%, respectively, for the period of 2007–2008. Comparison of the magnitude and patterns of the estimated	For large baseline changes along track due to squinted orbits, the differential interferogram still retains some residual phase components not yet compensated for after baseline corrections using GCPs and a baseline model. These residual phase components appear as linear or quadratic trends in the interferograms. To correct for such residual trends, we applied a detrending process by using the “grdtrend” component of the Generic Mapping Tools software package (GMT) [22]. This program locally fits phase variations to identify a trend and then removes it. This

		surface uplift demonstrated that the uplift estimated from InSAR analysis agrees well with that obtained by conventional geodetic (GPS) surveys from a network of 54 monuments. Surface slope changes due to SAGD that we detected by using InSAR over one year in this oil sand field were small, so destruction of surface facilities by uplift is unlikely in the short term.	can be done using a three-parameter fit (a constant and coefficients of and) for linear trend surfaces or a six-parameter fit (a constant and coefficients of , , , , and) for quadratic trend surfaces. The accuracy of vertical displacements obtained from individual differential interferograms is limited mainly by the atmospheric path delay term. To reduce the effect of atmospheric disturbance, we used a stacking technique combining multiple observations into a single deformation map. The stacking was performed by taking a weighted average of interferograms with the time interval of interferogram as a weight [23]. The main assumption of the stacking technique is that the correlations of displacement phases between independent pairs of interferograms are strong and are therefore enhanced by stacking, whereas the error terms such as atmospheric effects, signal noise, and other decorrelations are random and are therefore suppressed by stacking [24].
11			
12	Sharov, Aleksey & Gutjahr, Karlheinz & B, F. & A, M.. (2012). **METHODICAL ALTERNATIVES TO THE GLACIER MOTION MEASUREMENT FROM DIFFERENTIAL SAR INTERFEROMETRY**.	Algorithmic variations to the glacier motion estimation from differential SAR interferometry are discussed in the present paper. Two efficient albeit relatively simple algorithms for modelling glacier dynamics using spaceborne INSAR data have been devised and tested as alternatives to the conventional DINSAR approach. Neither of the algorithms involves the procedure of interferometric phase	Sometimes, a combination of three or more interferograms taken either from parallel or from opposite, i.e. ascending and descending orbits is used, but the necessity of performing two dimensional phase unwrapping of each original interferogram in the case of phase noise with unavoidable error propagation is probably the most serious

		unwrapping, thus excluding the areal error propagation and improving the modelling accuracy. In general, they remain feasible even under significant phase noise. An original gradient approach (GINSAR) to differential processing of repeat-pass SAR interferograms based on the calculation of interferometric phase gradients, the generation of glacier slope maps and the analysis of differences between multitemporal slope maps provides global and fast solutions to unsupervised glacier change detection and ice motion estimation. A transferential approach is based on the interferometric measurement of the fast-ice translation forced by the glacier flow and provides good reference values on the glacier frontal velocity and velocity gradients for the GINSAR technique. A comparative analysis of the results obtained by different techniques was performed and algorithmic singularities were discussed. The revealed differences of up to 40% between the GINSAR velocities and those surveyed in the field are explained.	restriction to the multiple baseline approach in particular and to the whole DINSAR method in general. An essential enhancement to the multiple baseline technique based on stacking / averaging phase gradients was offered in (Sandwell & Price 1998) with the aim to decrease errors due to atmospheric-ionospheric disturbances and to improve the general quality of INSAR data for both topographic recovery and change detection. The phase gradient approach ensures serious processional advantages, e.g. it delays the procedure of phase unwrapping until the final step of the DINSAR processing, but remains, however, largely untested and is rarely mentioned in literature. The sea ice thickness grows through time and sea-ice deformation features become noticeable in late-winter interferograms, but, nevertheless, the transferential technique remains feasible up to the time of melting and disintegration of the coastal ice. The main drawback to the transferential technique is that it is not suited for the velocity measurement / representation over the whole glacier area. For the reliable separation between the topographic and the motion phase and the accurate determination of the velocity field over the whole glacier area we devised (independently of the publication by D.Sandwell & E.Price) an original gradient approach, which is presented below
13	Liu, Guoxiang & Buckley, Sean & Ding, Xiaoli & Chen, Qiang & Luo, Xiaojun. (2009). **Estimating Spatiotemporal Ground Deformation With Improved Permanent-Scatterer Radar**	Synthetic aperture radar interferometry has been applied widely in recent years to ground deformation monitoring although difficulties are often encountered when applying the technology, among which the spatial and temporal decorrelation and atmospheric artifacts are the most prominent. The persistentscatterer interferometric	The method used for PS detection basically follows that proposed by Ferretti et al. [16]. We, however, first carry out radiometric calibration for all the amplitude images similarly to Lyons and Sandwell [14]. A radiometric calibration factor is calculated for each image as the ratio between the

	Interferometry. Geoscience and Remote Sensing, IEEE Transactions on. 47. 2762 - 2772. 10.1109/TGRS.2009.2016213.	synthetic aperture radar (PS-InSAR) technique has overcome some of the difficulties by focusing only on the temporally coherent radar targets in a time series of synthetic aperture radar (SAR) images. This paper presents an improved PS-InSAR technique by introducing PS-neighborhood networking and empirical mode decomposition (EMD) approaches in the PS-InSAR solution. Linear deformation rates and topographic errors are estimated based on a least squares method, while the nonlinear deformation and atmospheric signals are computed by singular value decomposition and the EMD method. An area in Phoenix, AZ, is used as a test site to determine its historical subsidence with 39 C-band SAR images acquired by European Remote Sensing 1 and 2 satellites from 1992 to 2000.	amplitude of the image (mean of all pixels) to the mean amplitude of all the images. Each SAR amplitude image is then divided by this ratio to make the brightness between the images consistent and comparable. The calibrated images are then averaged to generate a multi-image reflectivity map. The mean amplitude and the standard deviation (SD) of each pixel, and the overall mean amplitude and SD of all the pixels can be calculated based on the calibrated amplitude images. A pixel is considered as a PS candidate only if it satisfies the following two empirical criteria simultaneously. LS adjustment computation can be performed to eliminate the geometric inconsistencies (i.e., misclosures of loops) and obtain the most probable estimates of the linear deformation rates and elevation errors at all the PS points. The two types of values: linear deformation rates and elevation errors can be estimated separately.
14	Onuma, Takumi & Ohkawa, Shiro. (2009**). Detection of surface deformation related with CO2 injection by DInSAR** at In Salah, Algeria. Energy Procedia. 92. 2177-2184. 10.1016/j.egypro.2009.01.283.	InSAR, standing for Interferometric Synthetic Aperture Radar, has been proved as a promising remote sensing technique for mapping of topography and monitoring of ground displacement at an order of centimeters or millimeters. Several spaceborne SAR systems including ALOS PALSAR, JERS-1 SAR, ERS1/2 AMI, ENVISAT ASAR and Radarsat SAR, have been widely used for mapping of surface deformation. These are referred to as the active type sensors which transmit radar pulses towards the earth and receive echoes back off the Earth's surface. Because of the nature of radio wave, spaceborne SAR systems have the observation capability at all weather, day and night conditions, which is suitable for monitoring of Earth's surface. Although many InSAR application	Detailed explanation and discussion on the basic of InSAR technique is out of the scope of this paper, and is introduced in [1]; the extension of InSAR technique, Differential InSAR (DInSAR), and the stacking of the differential phase are the keys for the work of this paper. Selection of interferograms with long interval and with short baseline leads to better result. Because the longer the interval, the larger the cumulative amount of displacement, which makes the ratio of phase noise to the differential phase small. Stacking is performed by weighted sum of individual differential phases with the time interval of the interferogram as a weight [7]. The stacking of multiple interferograms is the simplest but robust approach comparing with other advanced ones such as Point Target analysis [8] and Small Baseline Subset

		examples related with earthquakes, volcanic activity, landslide, glaciers motion, and ground subsidence have been reported in the past decade [1][2], to date there is no examples concerning with the monitoring of CO2 injection. The primary objective of this paper is to investigate the applicability of satellite-borne InSAR technique to the monitoring of surface deformation at CO2 injection site, by applying the technique on the actual project being operated at In Salah, Algeria (Figure 1).	Algorithm [9]. Although the precise orbit state vectors for an interferometry pair can be used for the calculation of the baseline, the one calculated from the orbit information may contain certain error that is one of sources of phase error in the differential interferogram. This can be reduced by the refined baseline calculated from the height data of ground control points (GCP) extracted from DEM and corresponding differential phase. DEM data used in the work is the Shuttle Radar Topography Mission version 2 of 3-arcsecond (SRTM3), of which cell size is about 90m x 90m. The area of the In Salah Gas Project is characterized by the distribution of low relief hills with elevation ranging from 420m to 580m. Considering this topographic feature of the area as well as the accuracy of the SRTM3 and the interferogram pixel dimension of 80m x 90m, the contribution of 'Itopo in Eq. (1) to the differential phase is negligible.
15	Liu, Guoxiang & Buckley, Sean & Ding, Xiaoli & Chen, Qiang & Luo, Xiaojun. (2008). **Mapping ground deformation by Radar interferometry based on permanent-scatterer network: algorithm and testing results.**	The full operational capability of synthetic aperture radar (SAR) interferometry in deformation monitoring has not been achieved yet due to the negative influences of spatio-temporal decorrelation and atmospheric delay. With the use of time series of SAR images, deformation extraction can be however improved by only tracking some objects with steady radar reflectivity, generally referred to as permanent scatterer (PS). This paper presents an attempt to explore a PS-networking approach to isolate deformations from other effects such as atmospheric signals and topographic errors. The deforming process in time and space is modelled and estimated with a very strong network which is formed by connecting adjacent PSs. The linear deformations and topographic errors are estimated by optimizing objective functions and by adjusting the network via weighted least squares (LS) solution. The time series of nonlinear	A strategy proposed early is to stack the multiple interferograms (Sandwell & Price, 1998). Ground deformation analysis can be therefore improved by enhancing fringe clarity and suppressing atmospheric effects. Afterwards, a very generic approach, called permanent scatters (PS) technique, was proposed to extract both linear and nonlinear deformations from a set of interferograms by isolating atmospheric effects and topographic errors (Ferretti et al., 2000, 2001). Since PSs are usually some hard objects such as buildings and rocks, they can

		deformations and atmospheric signals are computed by singular value decomposition (SVD) and empirical mode decomposition (EMD). To validate the algorithm, 39 ERS C-band SAR images acquired over Phoenix in Arizona (USA) from 1992 to 2002 are used to detect land subsidence caused by the excessive groundwater withdrawal.	remain temporal coherent radar reflectivity, and thus facilitating deformation extraction on the basis of PSs' phase measurements with high signal-to-noise ratio (SNR). Subsequently, another effective approach, called small-baseline subset (SBAS) method, was developed to further decrease the negative influences due to decorrelation noise and bias (Berardino et al. 2002). PS technique suffers from spatial decorrelation as some longspatial baselines may result in by sharing a unique master image in forming interferometric combinations, while SBAS technique suffers from errors caused by full-resolution phase unwrapping. However, the two techniques can complement each other (Mora et al. 2003). Combining the merits of PS and SBAS technique, this paper presents an improved algorithm to isolate and extract deformations, topographic errors and atmospheric signals with a very strong network formed by freely connecting neighbouring PSs. To maximize coherence of all the SAR dataset, the spatial and temporal baseline thresholding are applied when forming

			interferometric combinations. The phase modelling is based on the network. The linear deformation velocities and topographic errors are first estimated by optimizing an objective function of each arc (a connection of two PSs) and adjusting the network by LS solution. Time series of phase measurements at each PS is then reconstructed by singular value decomposition (SVD) and decoupled into nonlinear deformations and atmospheric signals by a relatively new signal analysis method - empirical mode decomposition (EMD), proposed by Huang et al. (1998).
16	Sharov, Aleksey & Gutjahr, Karlheinz & Pellikka, Petri. (2004). **Phase gradient approach to the evaluation and mapping of glacier rheology from multi-pass SAR interferograms**. 10.1142/9789812702630_0017.	Evaluation and mapping of glacier rheology1 is one of the most interesting and puzzling applications of differential radar interferometry (DINSAR). The DINSAR method based on differencing between two co-registered repeat-pass SAR interferograms of the same glacier provides a unique opportunity to detect and to measure even small glacier motions and ice deformations in the subcentimetre range. Short-term ice velocities and their long-term variations can be surveyed with high spatial resolution over large glacial areas even if the glacier surface is snow-covered. Under favourable conditions, the accuracy of measuring the magnitude of ice-surface velocity from spaceborne differential interferograms is comparable with that from field surveys [1]. These unprecedented technical capabilities and notable availability of spaceborne. interferometric data are greatly valued by experts studying glacier dynamics.Numerous examples have already been shown of	The idea of using SAR interferometric phase gradients for terrain modelling and studying related phenomena is not very new. 10 years ago, it was already demonstrated that phase gradient maps could be derived directly from complex SAR interferograms and applied to measuring both the magnitude and aspect of terrestrial slope without phase unwrapping [14, 15]. To our knowledge, the idea of applying the phase gradient approach to change detection was first presented in a paper by D.Sandwell and E.Price, who performed stacking and averaging of phase gradients with the aim of detecting and decreasing errors due to atmospheric-ionospheric disturbances in order to improve the general quality of INSAR data [16]. The subsequent work by our research group showed the applicability of this approach to the

		successful DINSAR applications to monitoring ice-sheet motion [2], mapping three-dimensional flow of large glaciers [3], measuring outlet glacier velocities [4], studying flow instability [5] and identifying surge effects on ice fields [6]. The performance of this generally promising technique is not always flawless, however, and there remains some uncertainty as to how it will operate in a given glacier environment and season different from those studied in preceding applications. In fact, previous applications of glacier interferometry were mostly local in character, each focussed on one or several neighbouring glaciers of the same morphological class, and only very few comparative studies have analysed the performance of the DINSAR method for different glacier types, extents and periods.	unsupervised detection of glacier changes and the spatial reconstruction of glacial flow from multi-pass INSAR data [17].The underlying concept of the GINSAR approach is to proceed from operations on original SAR interferograms to the analysis of their derivatives,making use of the fact that, for the great majority of points in the interferentialpicture, partial gradients of the unwrapped interferometric phase $\Psi(x, y)$ are equal to partial gradients of the wrapped phase.
		Detección de bordes	
a	Bachofer, Felix & Quénéhervé, Geraldine & Zwiener, Thimm & Maerker, Michael & Hochschild, Volker. (2016). **Comparative analysis of Edge Detection techniques for SAR images.** European Journal of Remote Sensing. 49. 205-224. 10.5721/EuJRS20164912.	Paleo-shorelines and ancient lake terraces east of Lake Manyara in Tanzania were identified from the backscatter intensity of TerraSAR-X StripMap images. Because of their linear alignment, edge detector algorithms were applied to delineate these morphological structures from those Synthetic Aperture Radar scenes. Due to the physical properties of microwave signals, this application has proven to be a challenging task for edge detectors. This study compares the performance of different combinations of speckle reduction techniques and edge operator in detecting linear paleo-shorelines. The Roberts, Sobel, Laplacian of Gaussian and the Canny edge detector algorithms were applied to extract and revise those linear structures. The comparison shows that the Canny edge detector is especially suitable for images with strong speckle noise. Canny achieves relatively high accuracies compared to the other operators. The stronger the filtering and speckle noise reduction, the better the performance of the other edge detection operators,	The study has demonstrated that by using edge detectors, morphological features in SAR images can be detected with high accuracies. We compared different. speckle reduction techniques in combination with different edge detectors, striving to detect paleo-shorelines in a TSX1 SAR image. The case study determined that the performance of the proposed pre-processing techniques and edge detectors lead to different accuracies. The Canny edge detector is especially suitable for images exhibiting a high speckle noise. The combination of DWT and the Canny operator yields the highest accuracies and provides stable results with different pre-processing steps. First-derivative edge operators have proven to perform well when applied to speckle reduced images. Median filtering proved to be an advantageous pre-processing step.

		compared to the Canny edge detector. The application of a wavelet transformation reduces the presence of artifacts resulting from speckle noise and emphasizes the detection of the target features.	
B	Chen, Shou-Cih & Chiu, Chung-Cheng. (2019**). Texture Construction Edge Detection Algorithm**. Applied Sciences. 9. 897. 10.3390/app9050897.	The edge detection algorithm is the cornerstone of image processing; a good edge detection result can further extract the required information through rich texture information and achieve object detection, segmentation, and identification. To obtain a rich texture edge detection technology, this paper proposes using edge texture change for edge construction and constructs the edge contour through constructing an edge texture extension between the blocks to reduce the missing edge problem caused by the threshold setting. Finally, through verification of the experimental results, the proposed method can effectively overcome the problem caused by unsuitable threshold setting and detect rich object edge information compared to the adaptive edge detection method.	Edge detection technology is the main method used to detect the contour of objects. Recently,many experts and scholars have been working on various image edge detection technologies. However, finding rich object edges from target images is still a challenging and popular topic. The traditional edge detection technology developed in the early days mainly aimed to find the discontinuity in the gray-level intensity of a pixel. After obtaining the gradient information by a first- or second-order differential operation, the intensity difference between the center and adjacent pixels was observed and analyzed to obtain the edge. For example, Robert's operator [1] uses a 2 × 2 mask to calculate the difference between adjacent pixels in the diagonal direction to obtain the gradient information and determines the edge retention through a threshold setting. Because the mask used is 2 × 2 in size and has no clear center, resulting in an inaccurate range of values, the Prewitt operator [2] was developed, which uses a 3 × 3 mask for gradient operations, combining horizontal and vertical gradients. In this operator, the component obtains the gradient information of the entire image, and finally, retains the edges through a threshold setting.
C	Zhang, Chuanwei & Yu, Zhengyang. (2019). **Translation of Image Edge Detection Based on Python.** IOP Conference Series: Earth and	Matlab software is often used in image processing, with the development of science and technology, a lot of data to be efficient and real-time processing is valued. Python as a new interpretation scripting language, the program is simple,easy tounderstand, and	Canny operator edge detection is a multi-level differential edge detection algorithm, which is a good tradeoff between image filtering and edge detection.

	Environmental Science. 252. 052121. 10.1088/1755-1315/252/5/052121.	maintain real-time processing. Using python in image processing, can well keep the requirements of the designer, because of the open and free program, reduce the difficulty of programming, and enhance the interest of programmers. In this paper, through the comparison between canny operators, Sobel operator, lapla operator in image processing, the simulation results verify that the canny operator has good detection effect. The simulation results show the advantages of python, is suitable for the use in image processing.	The Canny operator edge detection operator satisfies the following three criteria: (1) Signal to noise ratio criterion (2) Location accuracy criteria (3) Single edge response criterion Canny is the best operator for detecting step edges. The design process is as follows: (1) First, the Gauss filter is used to smooth the image (2) Differential operators are used to calculate the magnitude and direction of the gradient (3) Non maximum suppression of the gradient amplitude (4) Double threshold algorithm is used to detect and connect edges
D	Changhong, Yang & Xiong, Zou & Jiali, Xu. (2019). **A Novel Edge Detection Algorithm Based on Distance.** Journal of Physics: Conference Series. 1237. 022039. 10.1088/1742-6596/1237/2/022039.	Under the framework of Canny algorithm, a distance-based edge detection algorithm is proposed to improve the gradient magnitude of Canny. In our algorithm, the gradient magnitude can be acquired by taking the distance from the center of the mask as the weight factor. The operator not only can calculate the image gradient better, but also has good separability in the horizontal and vertical directions, and its gradient amplitude has a certain degree of rotation invariance. Finally, this operator is compared with various gradient operators for the Lena image simulation and the actual waterfront edge detection experiment. It shows that the operator has a better edge detection effect from the experimental results.	It not only proposes three criteria to evaluate the performance of edge detection: 1) SNR criterion; 2) positioning accuracy criterion; 3) unilateral response criterion; and it establishes an algorithm framework for edge detection (as shown in Figure 1). First, the Gaussian filter is used to smooth theimage, and the finite difference of the first-order partial derivative is used to calculate the amplitude and direction of the gradient, and then the gradient direction and the double threshold are used to find the local maximum point in the image, thus the strong edge (the gradient amplitude is greater than the high threshold) and the weak edge (the gradient threshold is smaller than the high threshold and larger than the low threshold) are obtained. Finally, edge tracking (when the strong edge and the weak edgeare connected, the weak edge is determined as the edge) completes the detection of the image edge.

E	Maksimovic, Vladimir & Lekic, Predrag & Petrovic, Mile & Jaksic, Branimir & Spalevic, Petar. (2019). **Experimental analysis of wavelet decomposition on edge detection.** Proceedings of the Estonian Academy of Sciences. 68. 284. 10.3176/proc.2019.3.06.	The influence of different wavelet transformations and decomposition on edge detection was examined, using convenient operators to images of various complexities. Berkeley Segmentation Database images with the corresponding ground truth were used. The categorization of those images was accomplished according to the degree of complexity in three groups (small, medium, and large number of details), by using discrete cosine transformation and discrete wavelet transformation. Three levels of decomposition for eight wavelet transformations and five operators for edge detection were applied on these images.As an objective measure of the quality for edge detection, the parameters "performance ratio" and "F-measure" were used.The obtained results showed that edge detection operators behaved differently in images with a different number of details.Decomposition significantly degrades the image, but useful information can be extracted at the third level of decomposition, because the image with a different number of details behaves differently at each level. For an image with a certain number of details, decomposition Level 3 in some cases gives better results than Level 2. The obtained results can be applied to image compression with different complexity. By selecting a certain combination of operators and decomposition levels, a higher compression ratio with preserving a larger amount of useful image information can be achieved. Depending on the image resolution whereby the number of details varies, an operator optimization can be performed according to the decomposition level in order to obtain the best possible edge detection	Edge detection is one of the basic problems, but also one of the most useful and most commonly used operations in digital image processing. The edges are areas of the image with great differences in pixels intensity and represent the boundaries of the objects, so they can be used to identify objects, detect the position of the object in the image, and detect object orientation. The representation of an image using object edges present in the scene drastically reduces the amount of data that has to be processed, whereby the information on the object shape is still retained. The major issue with edge detection is that it is needed to determine exactly where the edges really are (i.e. exist), since the problem with "false" edges is often present. The edge itself is a part of the image where it has variations in the intensity of grey (28 or 216 levels of grey intensity). Depending on the change in grey intensity in neighbourhood pixels, edge models are classified as step and ramp models.
F	Zhou, Xiaoliang & Xu, Lamei & Wang, Jing. (2019). **Road crack edge detection based on wavelet transform.** IOP Conference Series: Earth and	In this paper, the edge detection of road surface crack images is studied. The traditional edge detection algorithms such as Gaussian-Laplacian and Canny operator are used to extract the edge of the crack. The experimental results show that the edge extraction is not complete and sensitive to noise. Therefore, the modern wavelet	The traditional method of pavement crack detection is introduced. The limitation of traditional edge detection method in pavement crack detection is demonstrated, especially in terms of anti-noise ability. The order edge operator is not ideal in terms of continuity, and the second-

	Environmental Science. 237. 032132. 10.1088/1755-1315/237/3/032132.	analysis method is adopted to extract the complete and accurate crack edges.	order operator is more sensitive to noise. Then a modern edge detection method is proposed. The wavelet detection method can obtain ideal results for edge detection of pavement images. Wavelet analysis adds edge detection to very effective de-noising function, and under the multi-scale multi-resolution decomposition, it improves the precision of edge detection, and more complete and accurate edge crack are obtained.
H	Ghiasi-Shirazi, Kamaledin & Safabakhsh, Reza. (2009). **Omnidirectional edge detection.** Computer Vision and Image Understanding. 113. 556-564. 10.1016/j.cviu.2009.01.001.	In this paper we propose a new method for extending 1-D step edge detection filters to two dimensions via complex-valued filtering. Complex-valued filtering allows us to obtain edge magnitude and direction simultaneously. Our method can be viewed either as an extension of n-directional complex filtering of Paplinski to infinite directions or as a variant of Canny's gradient-based approach. In the second view, the real part of our filter computes the gradient in the x direction and the imaginary part computes the gradient in the y direction. Paplinski claimed that n-directional filtering is an improvement over the gradient-based method, which computes gradient only in two directions. We show that our omnidirectional and Canny's gradient-based extensions of the 1-D DoG coincide. In contrast to Paplinski's claim, this coincidence shows that both approaches suffer from being confined to the subspace of two 2-D filters, even though ndirectional filtering hides these filters in a single complex-valued filter. Aside from these theoretical results, the omnidirectional method has practical advantages over both n-directional and gradient-based approaches. Our experiments on synthetic and real world images show the superiority of omnidirectional and gradient-based methods over n-directional approach. In comparison with the gradient-based method, the advantage of omnidirectional method lies mostly in freeing the user	DESIGNING optimal linear filters for edge detection in images has been a popular subject of research for the past three decades and a large number of methods have been proposed for this purpose. Edge detection methods can be broadly divided into three categories: 1. Methods that only detect edge magnitude and provide no directional information. These methods are usually based on the Laplacian of Gaussian (LoG) operator [1][2] and solve the problem directly in two dimensions. More sophisticated methods based on LoG also exist which are nonlinear [3]. These methods, which are not directional, are not further considered in this paper. 2. Approaches that detect both magnitude and direction of edges by extending a 1-D optimal edge detection filter to two dimensions [4][5][6][7]. 3. Methods that detect both magnitude and direction of edges and solve the problem directly in two dimensions, but do not fall within the category of linear filtering, e.g. [8]. In this paper, we study approaches for extending 1-D edge detection filters to two dimensions and propose a new method as well. The standard method for this extension was proposed by Canny[5].

		from specifying the smoothing window and its parameter. Since the omnidirectional and Canny's gradient-based extensions of the 1-D DoG coincide, we have based our experiments on extending the 1-D Demigny filter. This filter has been proposed by Demigny as the optimal edge detection filter in sampled images.	
I	Bezdek, James & Chandrasekhar, Ramachandran & Attikouzel, Y.. (1998). **A geometric approach to edge detection.** Fuzzy Systems, IEEE Transactions on. 6. 52 - 75. 10.1109/91.660808.	This paper describes edge detection as a composition of four steps: conditioning, feature extraction, blending, and scaling. We examine the role of geometry in determining good features for edge detection and in setting parameters for functions to blend the features. We find that: 1) statistical features such as the range and standard deviation of window intensities can be as effective as more traditional features such as estimates of digital gradients; 2) blending functions that are roughly concave near the origin of feature space can provide visually better edge images than traditional choices such as the city-block and Euclidean norms; 3) geometric considerations can be used to specify the parameters of generalized logistic functions and Takagi–Sugeno input–output systems that yield a rich variety of edge images; and 4) understanding the geometry of the feature extraction and blending functions is the key to using models based on computational learning algorithms such as neural networks and fuzzy systems for edge detection. Edge images derived from a digitized mammogram are given to illustrate various facets of our approach.	We have made and will briefly discuss six points, viz.: 1) viewing edge detection via the architecture shown in Fig. 2 clarifies the role of each part of the edge detection process; 2) good features for edge detection need not be digital gradients but may be statistical, etc.; 3) a small basis set of windows may clarify feature performance and are essential for training computational learning models for edge detection; 4) a proper match between the desired features of the edge detector and the graph of the blending function leads to (visually) optimal edge images;
J	Wang, Ke & Xiao, Pengfeng & Feng, Xuezhi & Wu, Guiping. (2011). **Image feature detection from phase congruency based on two-dimensional Hilbert transform.** Pattern Recognition Letters. 32. 2015-2024. 10.1016/j.patrec.2011.08.013.	The theory of phase congruency is that features such as step edges, roofs, and deltas always reach the maximum phase of image harmonic components. We propose a modified algorithm of phase congruency to detect image features based on two-dimensional (2-D) discrete Hilbert transform. Windowing technique is introduced to locate image features in the algorithm. Local energy is obtained by	In this section, some test images and the outputs from phase congruency based on 2-D Hilbert transform are presented. Fig. 7 shows three detection results of rice image using the proposed method with three different size of window. As shown in Fig. 7b,

		convoluting original image with two operators of removing direct current (DC) component over current window and 2-D Hilbert transform, respectively. Then, local energy is divided with the sum of Fourier amplitude of current window to retrieve the value of phase congruency. Meanwhile, we add the DC component of current window on original image to the denominator of phase congruency model to reduce the noise. Finally, the proposed algorithm is compared with some existing algorithm in systematical way. The experimental results of images in Berkeley Segmentation Dataset (BSDS) and remotely sensed images show that this algorithm is readily to detect image features.	because the small size of window is chosen in the calculation, there is visible noise in the detection result. Fig. 7c illustrates an ideal output of detection. In Fig. 7d, the detection result from a larger size of window, we can see that the detection becomes more illegible. Thus, we should choose an appropriate size of window to calculate PC in order to reduce the noise, even though has added the DC component to the sum of Fourier amplitude.
k	Suzanne Lyons and David Sandwell. (2003). ***Fault creep along the southern San Andreas from interferometric synthetic aperture radar, permanent scatterers, and stacking.*** JOURNAL OF GEOPHYSICAL RESEARCH, 108, 1-24.	Interferometric synthetic aperture radar (InSAR) provides a practical means of mapping creep along major strike-slip faults. The small amplitude of the creep signal (<10 mm/yr), combined with its short wavelength, makes it difficult to extract from long time span interferograms, especially in agricultural or heavily vegetated areas. We utilize two approaches to extract the fault creep signal from 37 ERS SAR images along the southern San Andreas Fault. First, amplitude stacking is utilized to identify permanent scatterers, which are then used to weight the interferogram prior to spatial filtering. This weighting improves correlation and also provides a mask for poorly correlated areas. Second, the unwrapped phase is stacked to reduce tropospheric and other short-wavelength noise. This combined processing enables us to recover the near-field (200 m) slip signal across the fault due to shallow creep. Displacement maps from 60 interferograms reveal a diffuse secular strain buildup, punctuated by localized interseismic creep of 4–6 mm/yr line of sight (LOS, 12–18 mm/yr horizontal). With the exception of Durmid Hill, this entire segment of the southern San Andreas experienced right-lateral triggered slip of up to 10 cm during the 3.5-year period spanning the 1992 Landers earthquake. The deformation change following the 1999 Hector Mine earthquake was much smaller (<1 cm) and broader than for the Landers event. Profiles across the fault during the interseismic phase show peak-to-trough amplitude ranging from 15 to 25 mm/yr (horizontal component) and the minimum misfit models show a range of creeping/locking depth values that fit the data.	
l	Parker J., Glasscoe M., Donnellan A., Stough T., Pierce M., Wang J. (2018)	Faced with the challenge of thousands of frames of radar interferometric images, automated feature extraction promises to spur data understanding and highlight	

	Radar Determination of Fault Slip and Location in Partially Decorrelated Images. In: Zhang Y., Goebel T., Peng Z., Williams C., Yoder M., Rundle J. (eds) Earthquakes and Multi-hazards Around the Pacific Rim, Vol. I. Pageoph Topical Volumes. Birkhäuser, Cham https://doi.org/10.1007/s00024-016-1403-z Radar Determination of Fault Slip and Location in Partially Decorrelated Images Keywords Radar interferometry fault slip computer vision Canny algorithm	geophysically active land regions for further study. We have developed techniques for automatically determining surface fault slip and location using deformation images from the NASA Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR), which is similar to satellite based SAR but has more mission flexibility and higher resolution (pixels are approximately 7 m). This radar interferometry provides a highly sensitive method, clearly indicating faults slipping at levels of 10 mm or less. But interferometric images are subject to decorrelation between revisit times, creating spots of bad data in the image. Our method begins with freely available data products from the UAVSAR mission, chiefly unwrapped interferograms,coherence images, and flight metadata. The computer vision techniques we use assume no data gaps or holes; so a preliminary step detects and removes spots of bad data and fills these holes by interpolation and blurring. Detected and partially validated surface fractures from earthquake main shocks, aftershocks, and aseismicinduced slip are shown for faults in California, including El MayorCucapah (M7.2, 2010), the Ocotillo aftershock (M5.7, 2010), and South Napa (M6.0, 2014). Aseismic slip is detected on the San Andreas Fault from the El Mayor-Cucapah earthquake, in regions of highly patterned partial decorrelation. Validation is performed by comparing slip estimates from two interferograms with published ground truth measurements.	
m	Wei Meng,Sandwell David ,Fialko Yuri and Bilham Roger . (2010). **Slip on faults in the Imperial Valley triggered by *the 4 April 2010 Mw 7.2 El Mayor-Cucapah earthquake revealed by InSAR.*** GEOPHYSICAL RESEARCH LETTERS, 38, 6.	Surface slip triggered by nearby earthquakes is common on faults in the Salton Trough region of Southern California [Rymer et al., 2002], a regional pull-apart basin formed at a releasing step over between major right-lateral faults associated with the Pacific and the North American plate boundary (Figure 1) [Elders et al., 1972]. The “trough” is filled with sediments mainly from the Colorado River and surrounded by Mesozoic basement rocks and Tertiary volcanic rocks [Dorsey, 2010]. Previous studies have documented triggered slip on faults in the Imperial Valley during more than 8 earthquakes in the last 50 years [Hudnut et al., 1989; Rymer et al., 2002]. Between earthquakes steady surface creep on these faults occurs at rates of a few mm/yr,	

		interrupted by episodic creep events [Rymer et al., 2002; Wei et al., 2009]. Sieh and Williams [1990] infer an association between shallow creep in unconsolidated sediments with inferred high pore pressures. Marone et al. [1991] and Du et al. [2003] provide a theoretical basis for both steady creep and episodic creep events along the respective faults.They show that in response to steady loading, a velocity- strengthening zone in the uppermost 3 km can host creep events, whose occurrence time may be advanced by shaking during the passage of seismic waves.[3] In this study we document triggered slip on faults in the Imperial Valley associated with the 4 April 2010 El Mayor-Cucapah Mw 7.2 earthquake using radar interferometry (InSAR) imagery, field surveys, and creepmeter data. Co-seismic offsets occurred on more than ten faults in this area. We estimate the depth of the triggered slip on the Superstition Hills Fault using dislocation modeling. We find that the results are consistent with previous inferences that slip extends only through the uppermost few kilometers roughly corresponding to the basement depth (3–5 km) [Wei et al., 2009]. The study illustrates that InSAR is an effective tool for measuring small fault offsets. Finally, we discuss the implications for the long-term slip budget. Comprehensive accounts of triggered slip are potentially important for slip budget analysis in the Imperial Valley region as well as seismic hazard assessment.	

n	Canny, J. (1986). A computational approach to edge detection. IEEE Transactions on Pattern Analysis and Machine Intelligence, 6, 679–698.	"-This paper describes a computational approach to edge detection. The success of the approach depends on the definition of a comprehensive set of goals for the computation of edge points. These goals must be precise enough to delimit the desired behavior of the detector while making minimal assumptions about the form of the solution. We define detection and localization criteria for a class of edges,and present mathematical forms for these criteria as functionals on the operator impulse response. A third criterion is then added to ensure that the detector has only one response to- a single edge. We use the criteria in numerical optimization to derive detectors for several common image features, including step edges. On specializing the analysis to step edges, we find that there is a natural uncertainty principle between detection and localization performance, which are the two main goals."	
ñ	Cai, Jiehua & Wang, Changcheng & Mao, Xiaokang & Wang, Qi-jie. (2017). **An Adaptive Offset Tracking Method with SAR Images for Landslide Displacement Monitoring.** Remote Sensing. 9. 830. 10.3390/rs9080830.	With the development of high-resolution Synthetic Aperture Radar (SAR) systems, researchers are increasingly paying attention to the application of SAR offset tracking methods in ground deformation estimation. The traditional normalized cross correlation (NCC) tracking method is based on regular matching windows. For areas with different moving characteristics, especially the landslide boundary areas, the NCC method will produce incorrect results. This is because in landslide boundary areas, the pixels of the regular matching window include two or more types of moving characteristics: some pixels with large displacement, and others with small or no displacement. These two kinds of pixels are uncorrelated, which result in inaccurate estimations. This paper proposes a new offset tracking method with SAR images based on the adaptive matching window to improve the accuracy of landslide displacement estimation. The proposed method generates an adaptive matching window that only contains pixels with similar moving characteristics. Three SAR images acquired by the Jet Propulsion Laboratory's Uninhabited	

		Aerial Vehicle Synthetic Aperture Radar (UAVSAR) system are selected to estimate the surface deformation of the Slumgullion landslide located in the southwestern Colorado, USA. The results show that the proposed method has higher accuracy than the traditional NCC method, especially in landslide boundary areas. Furthermore, it can obtain more detailed displacement information in landslide boundary areas.	
o	Kobayashi, T., Takada, Y., Furuya, M., and Murakami, M. (2009), **Locations and types of ruptures involved in the 2008 Sichuan earthquake inferred from SAR image matching**, Geophys. Res. Lett., 36, L07302, doi:10.1029/2008GL036907.	[1] We have detected detailed ground displacements in the proximity of the Longmen Shan fault zone (LMSFZ) by applying a SAR offset-tracking method in the analysis of the 2008 Sichuan earthquake. An elevation-dependent correction is indispensable for achieving sub-meter accuracy. A sharp displacement discontinuity with a relative motion of ~1–2 m appears over a length of 200 km along the LMSFZ, which demonstrates that the main rupture has proceeded on the Beichuan fault (BF) among several active faults composing the LMSFZ, and a new active fault is detected on the northeastward extension of the BF. The rupture on the BF is characterized by a right-lateral motion in the northeast, while in the southwest an oblique right-lateral thrust slip is suggested. In contrast to the northeast, where a major rupture proceeded on the BF only, in the southwest multiple thrust ruptures have occurred in the southeastern foot of the Pengguan massif.	
	• Fu, Kun & Zhang, Yue & Sun, Xuewen & Wenhui, Diao & Wu, Bin & Wang, Hongqi. (2016). **Automatic building**	Pendiente en visualizar	

	reconstruction from high resolution InSAR data using stochastic geometrical model. 1579-1582. 10.1109/IGARSS.2016.7729403. • Fu, Y.-S & Zhang, X.-L & Yang, T.-J & Hou, Y.-M. (2003). **Phase unwrapping with edge detection for interferometric SAR**. 18. • Kurbatova, E. (2018). **Edge detection of objects on the satellite images.** 115-122. 10.18287/1613-0073-2018-2210-115-122.		