Using GPS as a reference frame for SAR images applied to a post eruptive period for Okmok Volcano, Aleutian Islands, Alaska

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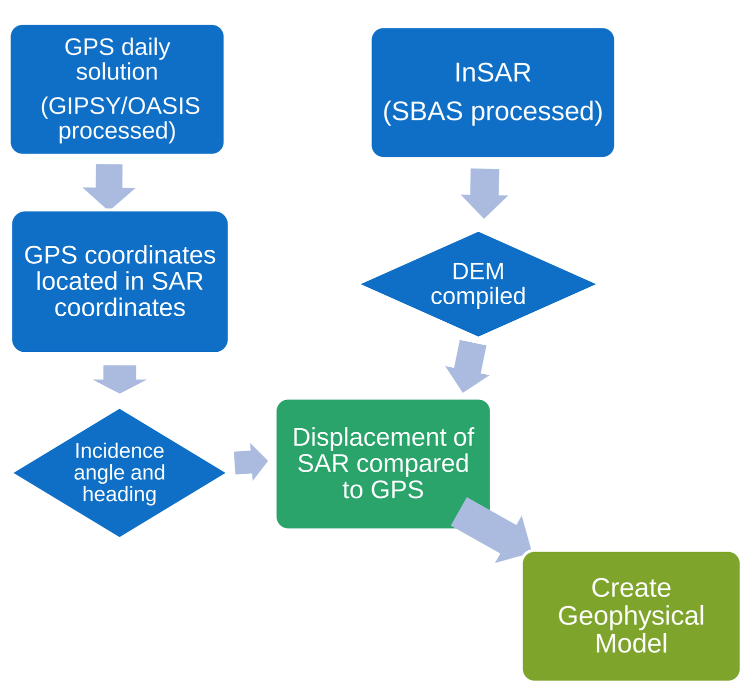
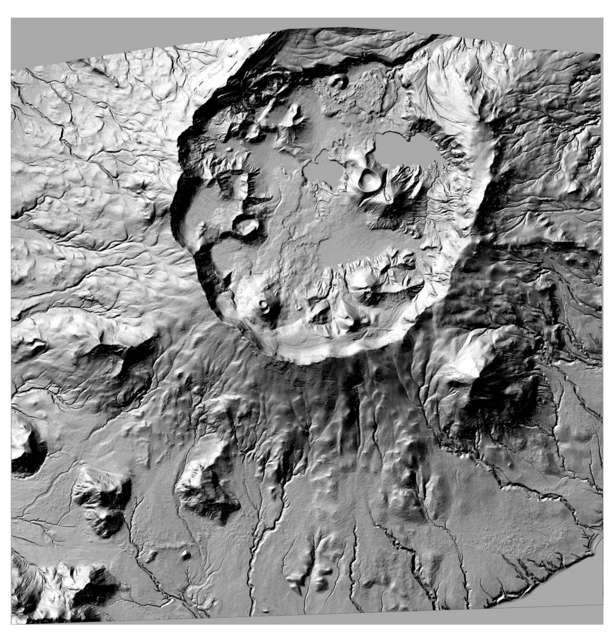
Abstract

While high spatial coverage makes InSAR a popular tool to study active volcanoes its use can possess challenges for certain environments. Volcanoes along Alaska's Aleutian chain are difficult targets for InSAR as their seasonal snow cover causes decorrelation close to the volcanic caldera, their exposed location in the North Pacific renders them prone to severe atmospheric phase artifacts, and their location on small islands prevents the selection of suitable reference points necessary for deformation analysis. Existing GPS networks define a known reference frame in which SAR is better understood.
Okmok volcano is one of the most active volcanoes in the Aleutian Island Chain and shows significant non-linear deformation behavior as it progresses through its eruption cycles. A stack of L-band imagery acquired by the SAR sensor PALSAR on board the JAXA Advanced Land Observing Satellite produced a post eruption deformation time series between August 2008 and October 2010. This data along with a merged DEM comprised of AirSAR SRTM and Worldview-1 stereo pair data, and GPS data from 3 continuous and 3 post eruption campaign sites was used for this study.
In this research, a comparison and combination of InSAR and GPS time-series data will be presented aimed at the following research goals: 1) What is the accuracy and precision of InSAR-derived deformation estimates in such challenging environments; 2) How accurate can the deformation of the InSAR reference point be estimated from a joint analysis of InSAR and GPS deformation signals; 3) How non-linear volcanic deformation can be constrained by the measurements of a local GPS network and support the identification of residual atmospheric signals in InSAR-derived deformation time series.
Further research into the combination of GPS and InSAR applied to the nonlinear aspect of volcanic deformation can enhance geodetic modeling of the volcano and associated eruption processes.

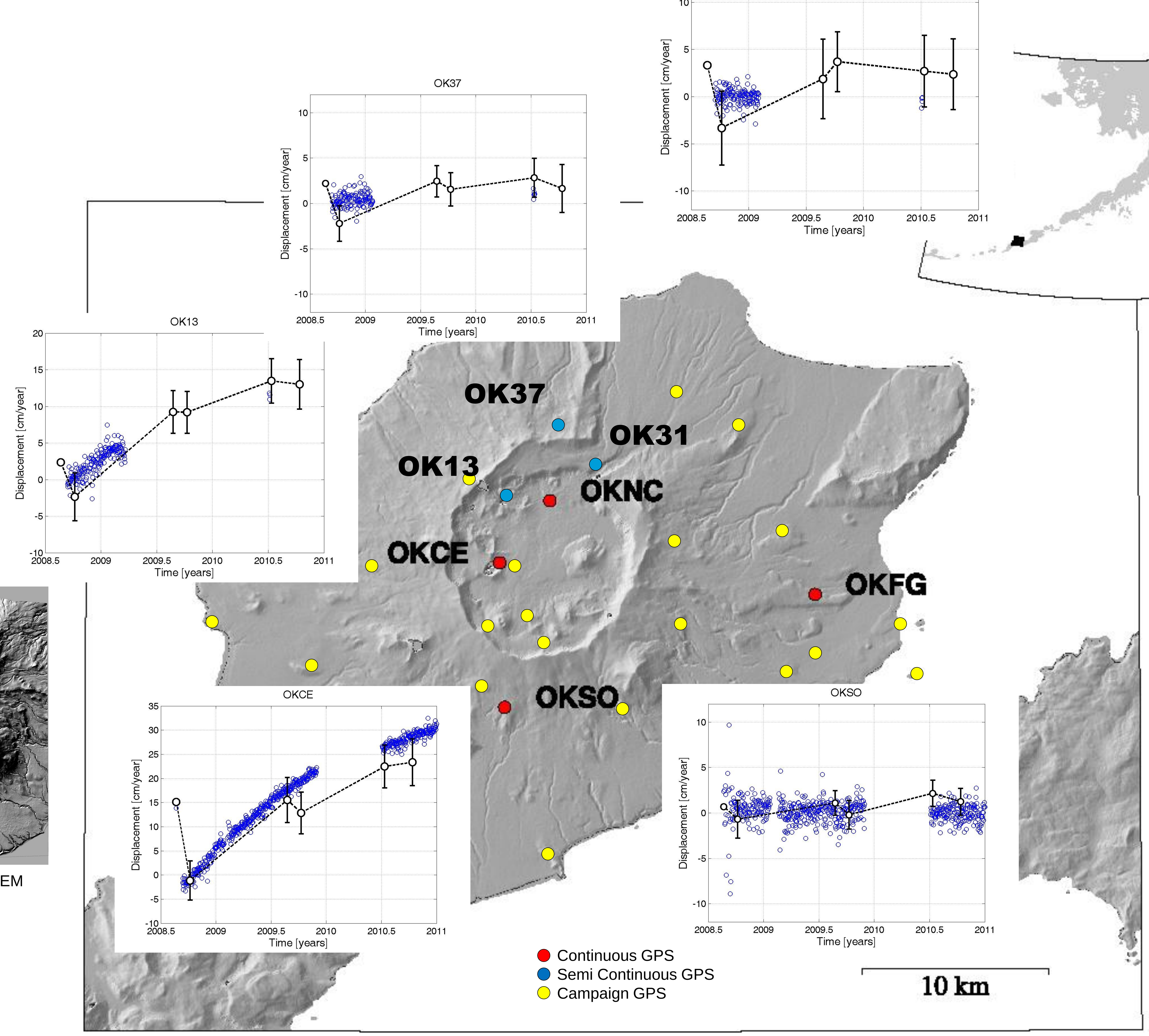
DEM and InSAR methodology

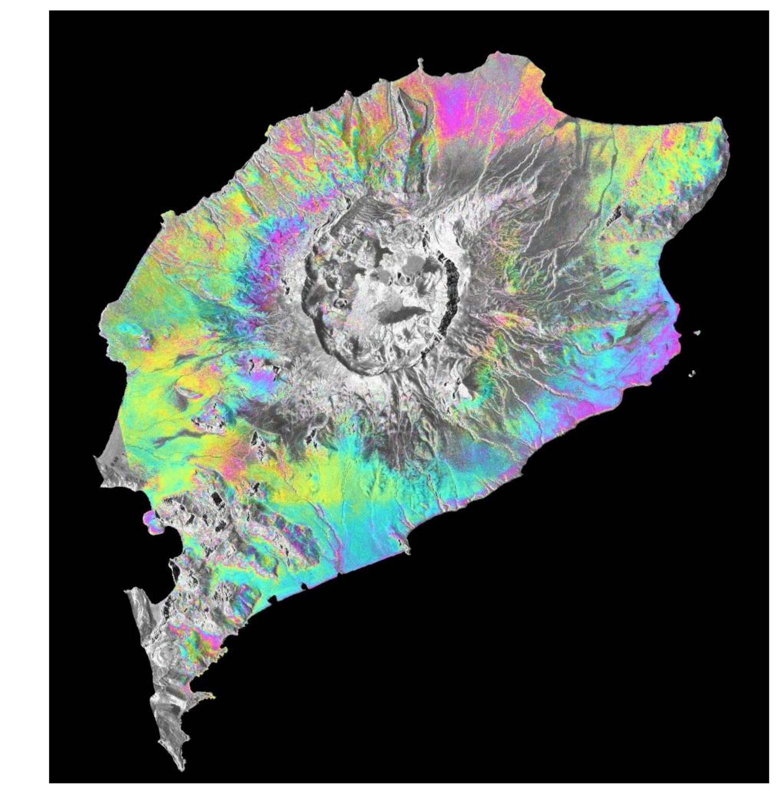



2010 Worldview-1 stereo pair DEM

To compare the two sets of data (InSAR to GPS) new DEM information was necessary. Recently acquired DEM data from Alaska Volcano Observatory in January 2010, from a Worldview-1 stereopair flight (image seen above) enhanced the accuracy of the SAR. The DEM data was used with a stack of L-band imagery acquired by the SAR sensor PALSAR on board the 46 day repeat orbit JAXA Advanced Land Observing Satellite. This stack of 6 summer and fall images (upper right) from 2008 – 2010 that span the post-eruptive period until the demise of the ALOS satellite in 2010. The data was processed using the Short BAseline Subset (SBAS) method. This method extracts the deformation time series and converts this into Line of Sight (LOS). I take it one step further and look at specific pixels containing the GPS station and obtain a time series of the deformation at that point. I calculated the GPS location in the SAR coordinates and located it the 10X10m pixel. I then took the average deformation of an area 30x30 pixels to obtain the motion.
The reference point for this stack of images was set outside the proposed area of deformation. For the comparison a point located near OKFG was used. This single point reference makes it easier to remove local tectonic signals i.e. plate motion by removing the signal seen at OKFG from all other GPS stations.
For InSAR processing, the SBAS method was chosen because it works well for applications in volcanic areas as it is considered to be "model free" and a linearity with deformation in time is not required. SBAS approximates linearity from one image to the next giving the sequence a longer temporal baseline and a shorter spatial baseline resulting interferograms have better coherence.

Okmok Geodetic Network





GPS methodology and data

There are two types of GPS setups that are used in this study: Semi-continuous at OK13, OK31, OK37 (below left) and continuous GPS PBO style at OKFG and OKSO (center) and a pillar mount at OKCE (right). The GPS processing was done using GIPSY/OASIS version goa-5.0 software designed by NASA at the Jet Propulsion Laboratories (JPL). The semi-continuous sites were part of a post eruption campaign and were installed in mid September and retrieved in April. The 3 sites provided over 6 months of data each dependant upon battery life.
For the analysis it was assumed that all motion seen at OKFG was significantly tectonic and more importantly non-volcanic. This allowed for the easy removal of the OKFG signal from all the other sites of interest.
In order to compare the GPS to the InSAR, the motion must be in the same trajectory thus a calculation of GPS into a LOS motion was calculated using the equation below. This is taken from Hassen
LOS = U*(cos(inc)-sin(inc)*(N*cos(heading-1.5*pi)+E*sin(heading-1.5*pi))

InSAR

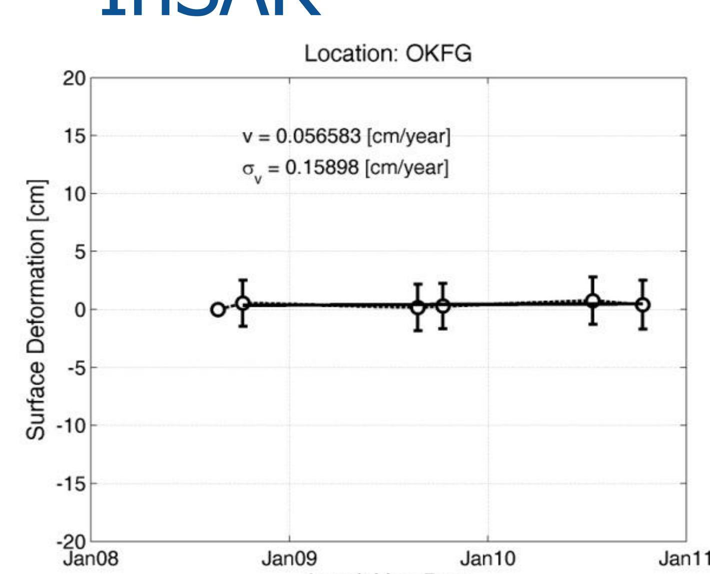


Figure #A Motion relative to site on Umnak Island

GPS

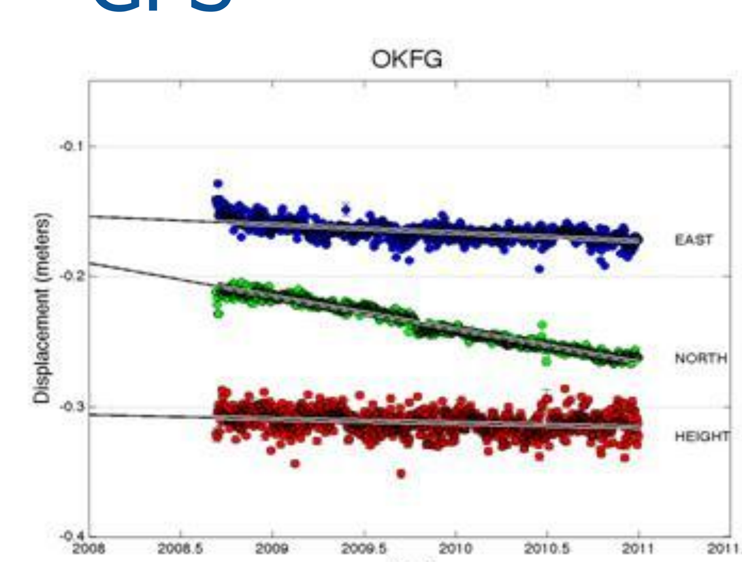


Figure #B Motion relative to NOAM plate

Comparison

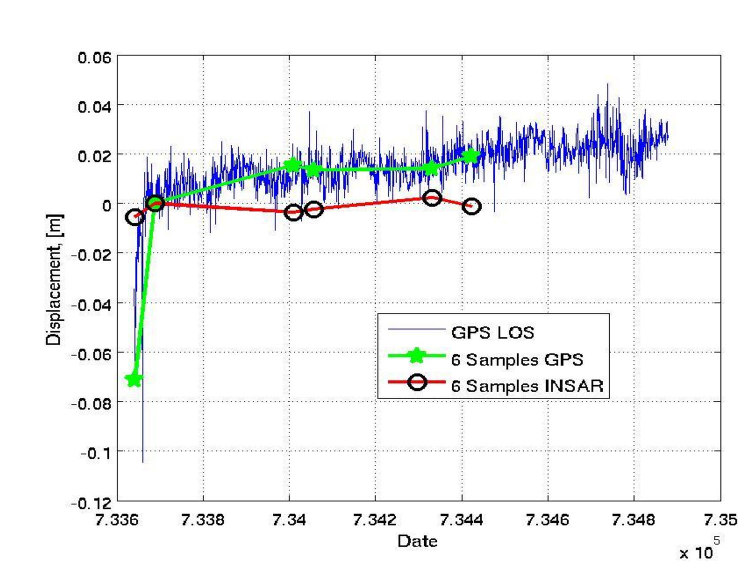


Figure #C Comparison of both sets of data

Conclusions and future work

In the center plots, the GPS daily solutions are represented by blue circles and the InSAR time series by open circles, both are set relative to the OKFG reference point. In conclusion these comparisons match within error bars of the SAR processing with the slight exception of OK31 and OK37. This is because the projected motion into the LOS direction and tends to show little of the actual deformation due to the heading path. OK31 also was difficult due to bad coherence in the InSAR, this led to point density issues and larger orbit errors. Thus it has the largest error bars.
Future work will include more analysis at the campaign sites (yellow dots). A combination of the data can assist with compiling a geophysical model of post eruptive deformation. Winter images while neglected before because of bad coherence, may also be used dependant upon the confidence level gained from the further processing.
Another data set available, includes corner reflectors installed in 2010. To do this the InSAR would be reprocessed using the StAMPS method that is commonly used for point target analysis.

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•Freymueller, J.T., and A.M. Kaufman(2010) , Changes in the magma system during the eruption of Okmok volcano, Alaska, based on GPS measurements, J. Geophys. Res., 115, B12415, doi:10.1029/2010JB007716
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