Co-seismic Deformation of the February 21, 2011 Christchurch (New Zealand) Mw 6.1 Earthquake from JAXA/ALOS PALSAR Interferometry

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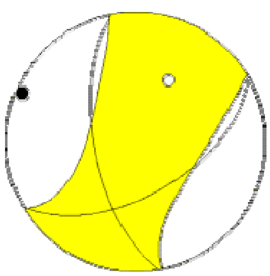
1. Introduction

On 2011 February 21 23:51:42 UTC, a Mw6.1 (or M6.3) earthquake struck south island of New Zealand. The epicenter of the quake is located at 43.583°S, 172.701°E by USGS CMT solution, which is near the city of Christchurch, New Zealand. The quake leads to 147 persons lost their lives and ~300 people missing until now (2011-02-28). The best double couple solution of the quake from USGS CMT solution is:



Best Double Couple: Mo=1.9*10**18 (Nm)
NP1: Strike= 60 Dip=56 Slip= 148 (the identified fault plane)
NP2: 170 64 39

Fig 1. The best double couple solution of the Christchurch (New Zealand) Mw 6.1 Earthquake
(http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usb0001igm/neic_b0001igm_cmt.php)

The depth of the hypocenter is estimated as ~5-10 km. The earthquake has mainly a right-lateral strike-slip component with also a thrust component. The very shallow hypocenter and oblique focal mechanism may be two of the reasons for heavy damages to the populated Christchurch city in this area.

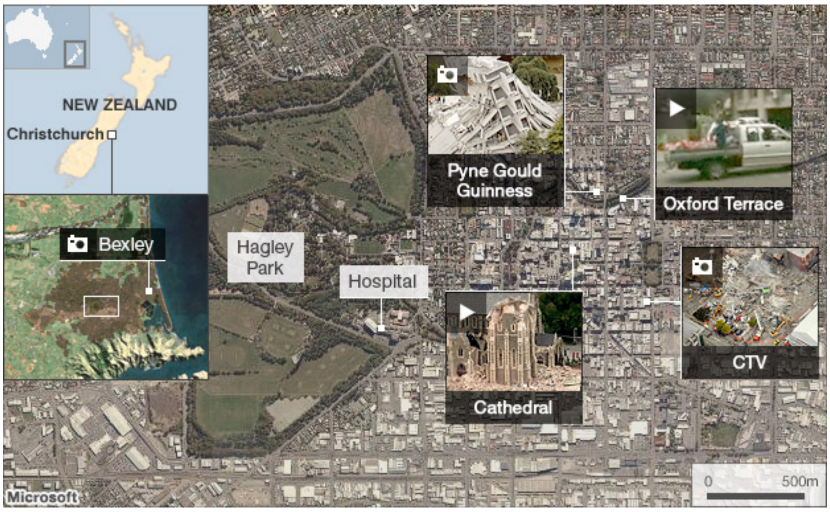


Fig 2. Location and Damages of the Christchurch city after the earthquake

(http://www.bbc.co.uk/news/world-asia-pacific-12533291#cathedral)

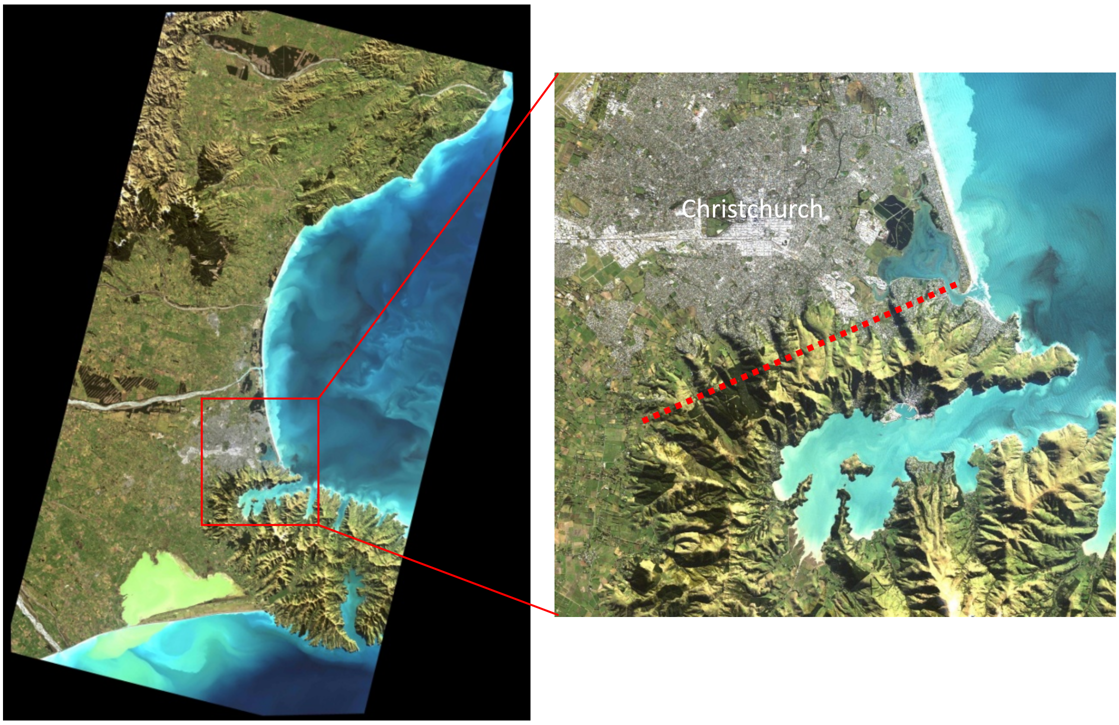


Fig 3. JAXA/ALOS AV2 image before the earthquake on 28/7/2009. The red rectangle shows the location of the Christchurch city and the inferred fault location of the Feb. 21, 2011 earthquake from seismic wave inversion (USGS)
(Note the fault dips to the South from the USGS solution).

From the seismic wave solution, we know that the fault is south dipping. In addition, according to the recent aftershock relocation reported by GNS of New Zealand, we know that the Christchurch may be located at the opposite side of the hanging wall of the fault plane (Fig 3). This can be verified in the InSAR interferometric results. Because the hanging wall side always has stronger shaking than its counterpart, this is vital to the evaluation of the hazard assessment.

We also know that the Feb. 21, 2011 event could be an aftershock of the Sept. 3, 2010 Mw7.1 Darfield earthquake happened to the west of the Christchurch. The understanding of that earthquake is also very important for this one.

2. The Sept. 3, 2010 Mw7.1 Darfield Earthquake of New Zealand

Though the Darfield earthquake size is much larger than the magnitude of this one, there is no casualty reported in that earthquake. According to the USGS report, it is a nearly pure right-lateral strike-slip fault. Both quakes are very close to each other on their spatial locations (Fig 4).

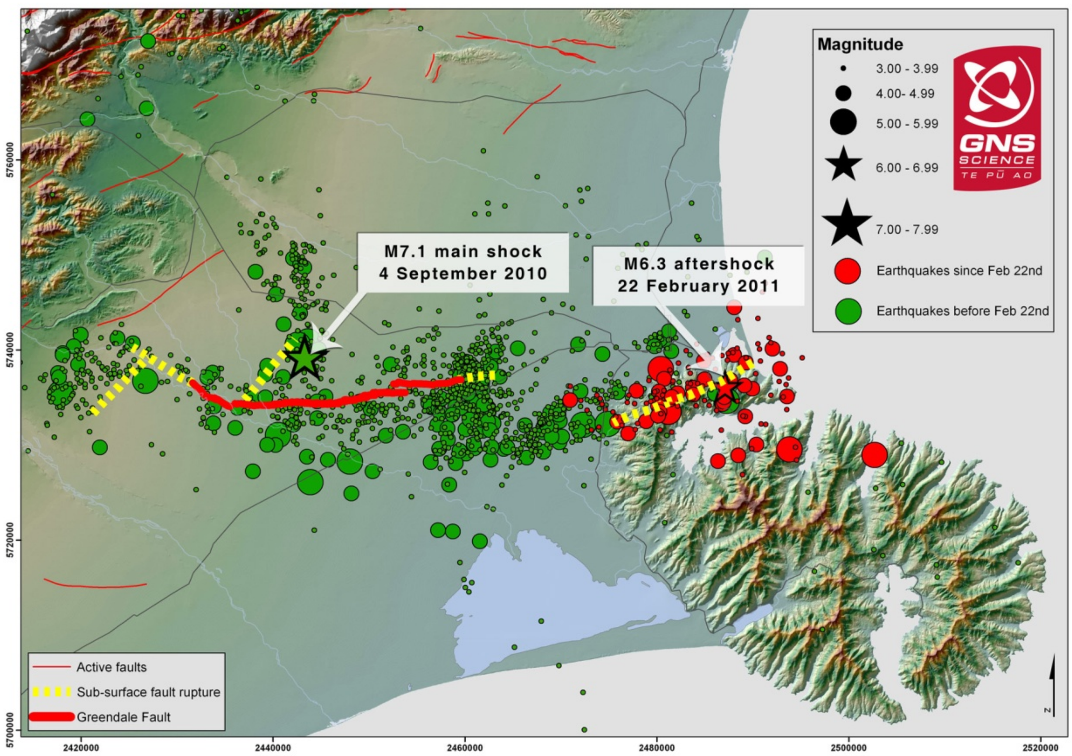


Fig 4. Surface rupture of the Darfield earthquake and inferred fault location of the Christchurch earthquake on Feb. 21, 2011 from GNS, New Zealand.

(http://www.geonet.org.nz/var/storage/images/media/images/news/2011/lyttelton/57171-1-eng-GB/Lyttelton.jpg)

The Darfield earthquake deformation is well captured by the JAXA ALOS satellite and two interferograms are produced by the data in ascending pass. Here we show one of the best quality interferogram of the earthquake published by J. Beavan et. al.

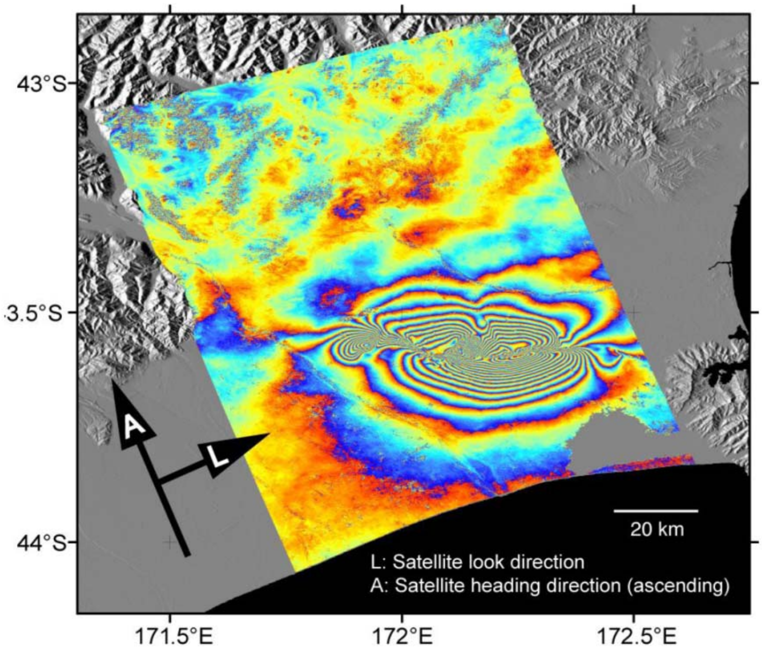


Fig 5. Interferogram of the Darfield earthquake by J. Beavan et. al (GNS, New Zealand), BULLETIN OF THE NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING, Vol. 43, No. 4, December 2010

3. InSAR processing of the Christchurch earthquake on Feb. 21, 2011

After the Christchurch earthquake, JAXA provide a nearest available acquisition for the earthquake, we think it is very valuable for our understanding of this shallow event and its seismic hazard aspects.

The earliest data is along the Path 335 to the east (Fig 6), where part of the data coverage is in the sea. Even though it's impossible to get any information in the sea, we have the good opportunity to capture the deformation near the coast. We think most of the deformation should be included in this area. The current data available is acquired on 25/02/2011 11:50:39.865 (after the earthquake) and 10/01/2011 11:51:39.711 (before the earthquake) in ascending pass with a perpendicular baseline of ~-391.97. The pre-seismic data has precision orbit information; however, the post-seismic data has only predicted orbit data for now. Because most of the data coverage on Path 335 is in the sea and it will have influences on the InSAR analysis, we ask for 3 frames of SAR data in this path, so that it simplifies the InSAR co-registration of the two images. We expect the Path 336 data could be acquired in the future for more reliable analysis because this data will have more complete coverage of the current earthquake.

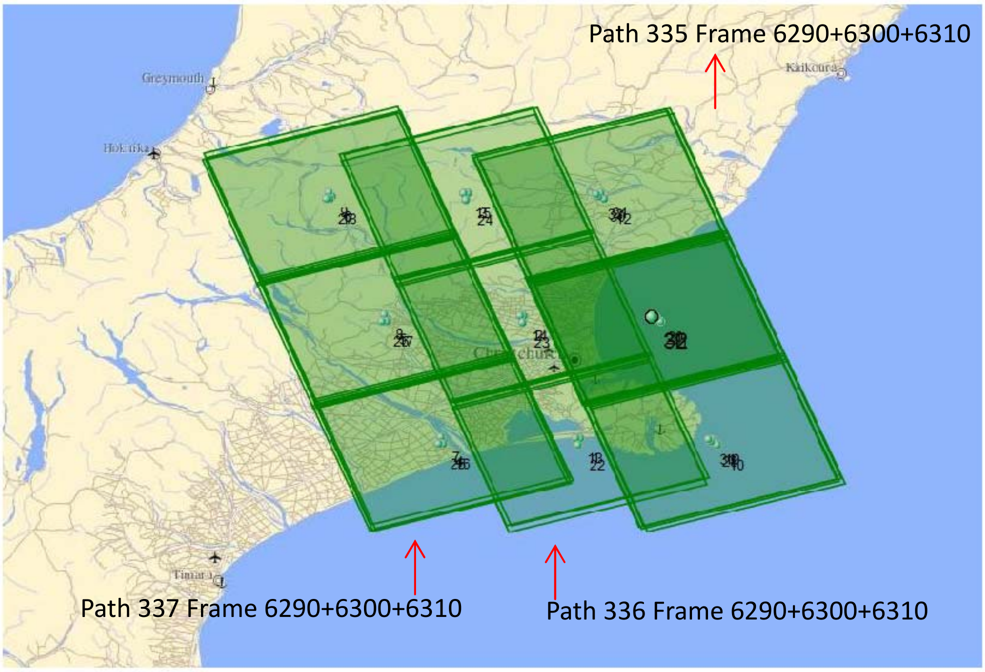
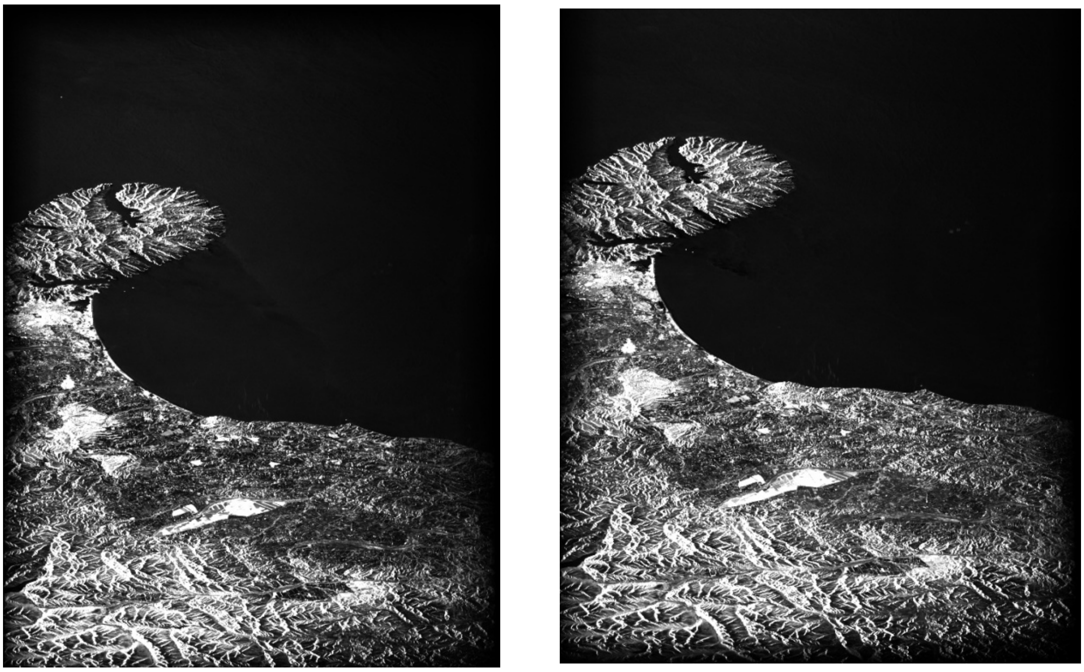


Fig 6. ALOS PALSAR ground coverage of the earthquake area

We use ROI_pac software developed at JPL/Caltech for the analysis on the PALSAR 1.0 data. The data is provided by JAXA under the Sentinel Asia Framework.



Before the earthquake (10/01/2011) After the earthquake (25/02/2011)

Fig 7. ALOS PALSAR amplitude before and after the earthquake in radar coordinates

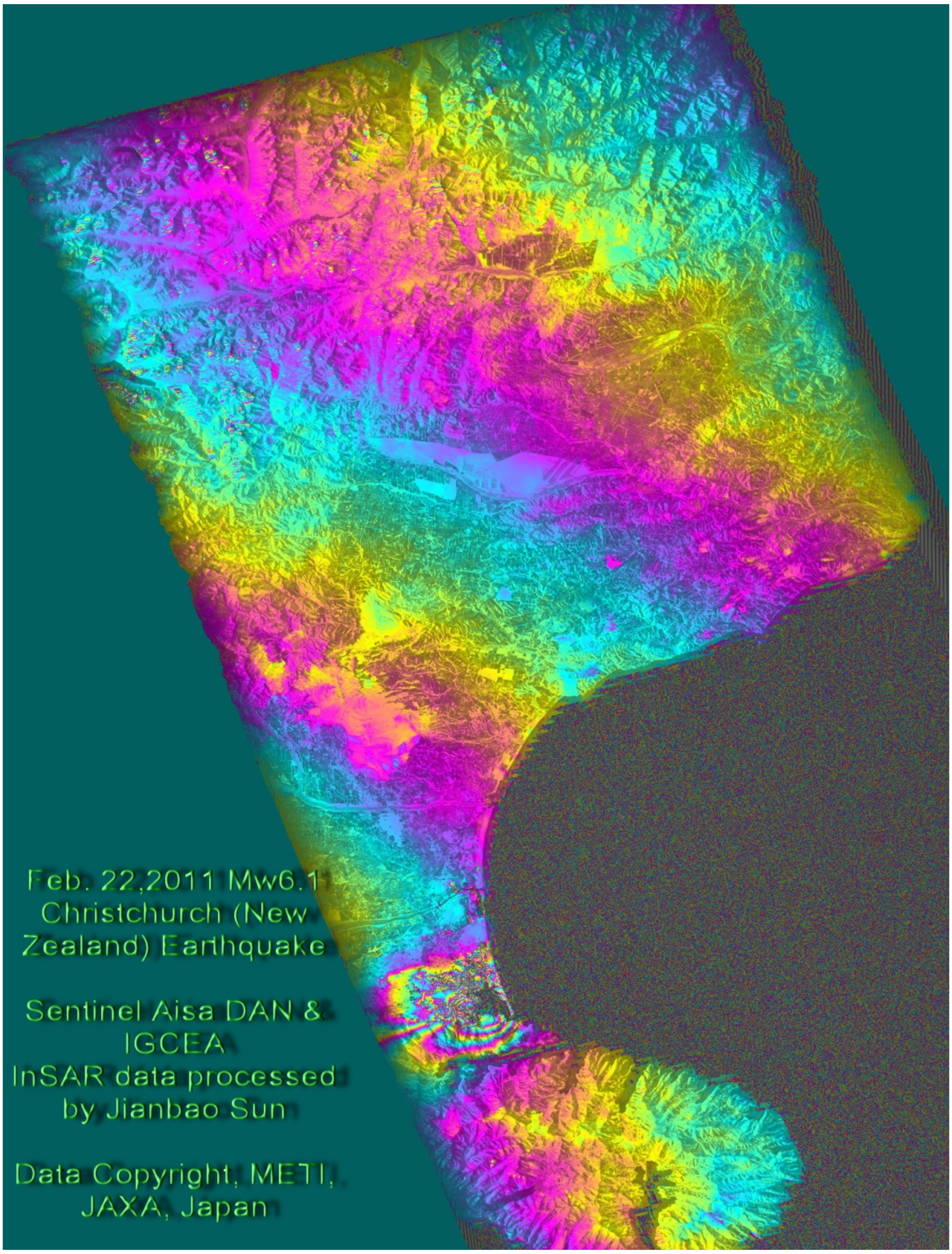


Fig 8. ALOS PALSAR interferogram formed using the data of Fig 7. The interferogram is in wrapped phase with one cycle equivalent to ~11.8 cm LOS displacement on the ground. Note that because the predicted orbit used in the post-quake data, there are some orbit ramps left in the data. The seismic area is clear on the map (see the density fringes) and the Christchurch city suffered from strong shaking according to its location on this map.

In order to better understand the earthquake origins, we removed some typical errors in the data and provide the unwrapped phase in Fig 9. There is only real deformation left and some noise area is masked. It’s clearer that the Christchurch have very large deformation (Fig 9).

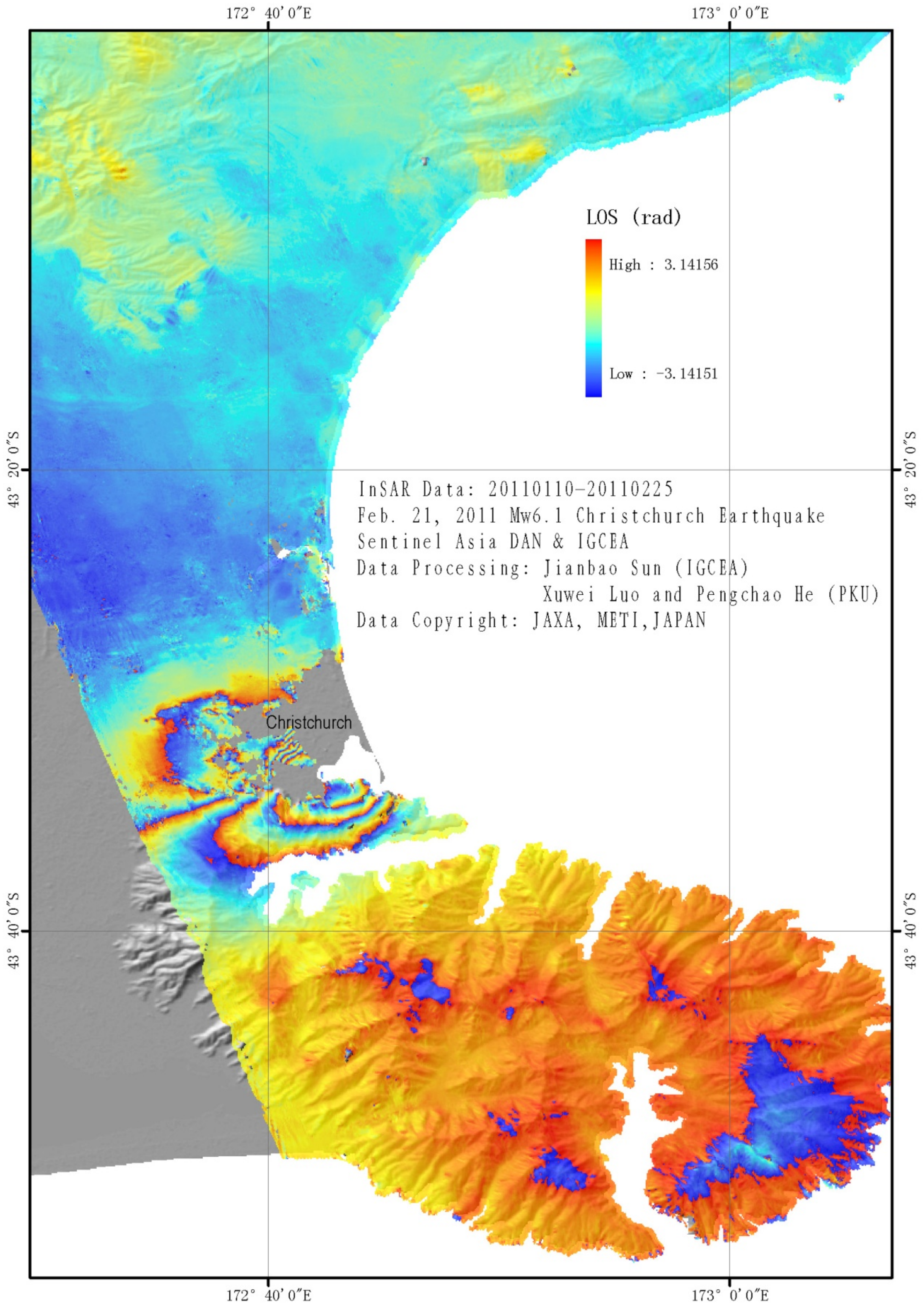


Fig 9. ALOS PALSAR interferogram with rewrapped phase after unwrapping and error corrections. One color cycle equals to ~11.8 cm LOS displacement.

4. Conclusions

We produced the InSAR interferograms of the Feb. 21, 2011 Mw6.1 Christchurch (New Zealand) earthquake under the Sentinel Asia framework.

The result is successful even though there is some information lost near the Christchurch city. We think that the earthquake a bit complex from the ALOS interferogram even if the magnitude is not so large. The complex activities of the quake may be the reason of the heavy damages from the small quake. The most important question is that if there is any blind fault under the Christchurch city. There is no clear aftershock or surface rupture data which can provide evidences for this. From the InSAR results only, we can’t exclude that the Christchurch city is in the hanging wall side. So the fault line may be not a simple straight line underground.

It would be extremely valuable if the neighbor track data in Path 336 can be acquired for the further analysis.