Geomatics Canada
Scientific Presentation 2

NEW INSIGHTS INTO FAST GROUND SUBSIDENCE IN SOUTHERN SASKATCHEWAN FROM MODELLING OF RADARSAT-2 DINSAR MEASUREMENTS

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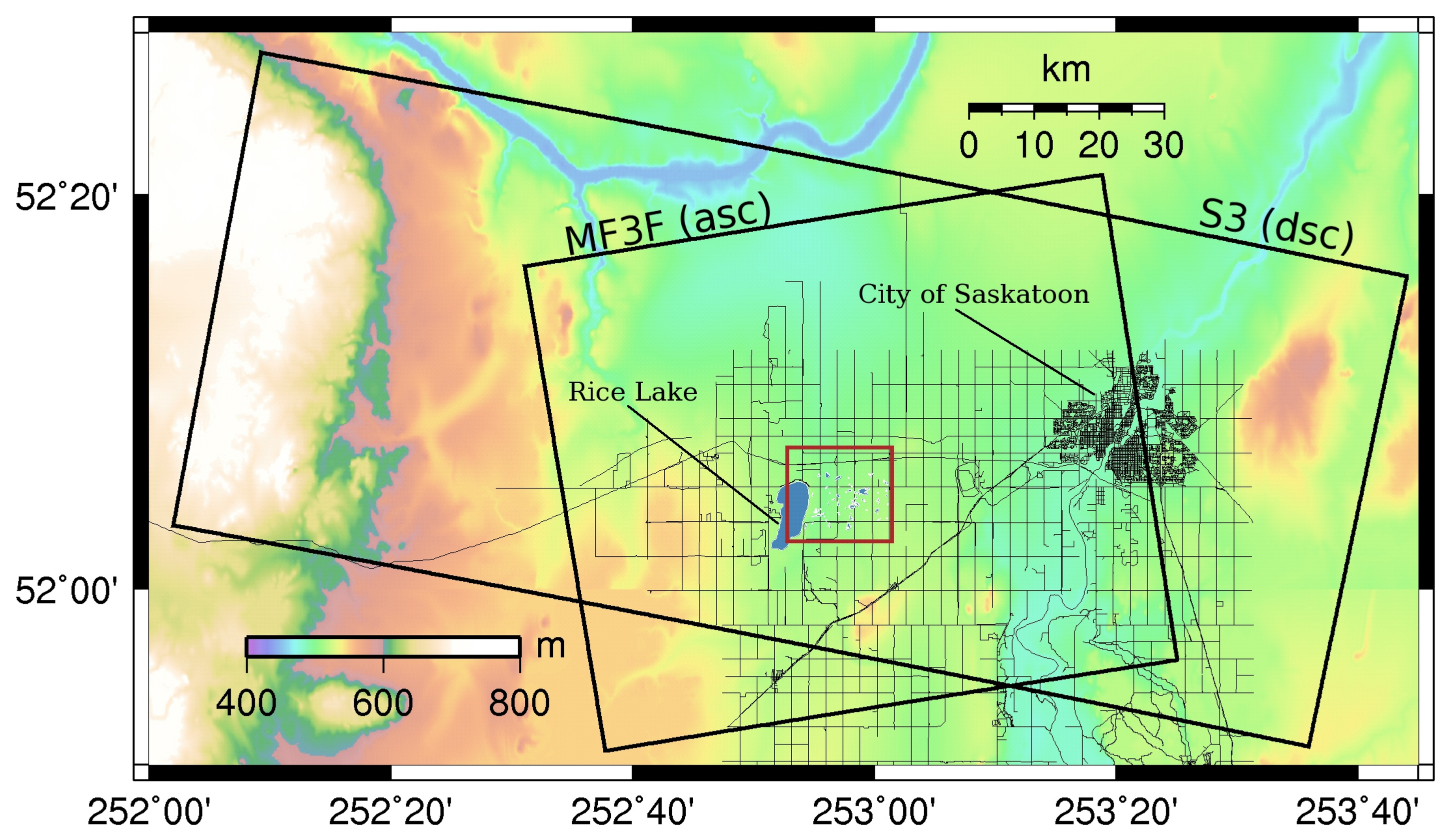
ABSTRACT

With Radarsat-2 Differential Interferometric Synthetic Aperture Radar (DInSAR) we observed a fast (approximately -10 cm/year) ground subsidence in southern Saskatchewan, affecting some limited areas located between Rice Lake and the city of Saskatoon. The deformation maps were calculated using 2008-2013 RADARSAT-2 SAR data from two different beams: Multi-Looked Fine and Standard. We performed standard InSAR analysis and reconstructed two dimensional, east-west and vertical time series of ground deformation with the Multidimensional Small Baseline subset (MSBAS) method (Samsonov and d'Oreye, 2012). Analysis of the MF3F and S3 time series revealed that the subsidence rate is nearly constant during the entire observation period, which suggests that it is not related to groundwater withdrawal that should have been affected by seasonal variations. We further selected highly coherent ascending and descending interferograms spanning November 2011 – April 2011 for simple elastic modelling. The inversion solves for several parameters, including source depth, precise location and volume change rate. Two regions of subsidence with nearly circular shapes were analyzed. The elastic modelling of the observed deformation is consistent with volume changes of spherical and/or sill-like sources at source depths ranging from 600 to 1500 m. We also investigated the impact of this subsidence on the redistribution of surface water levels and its impact on farming.

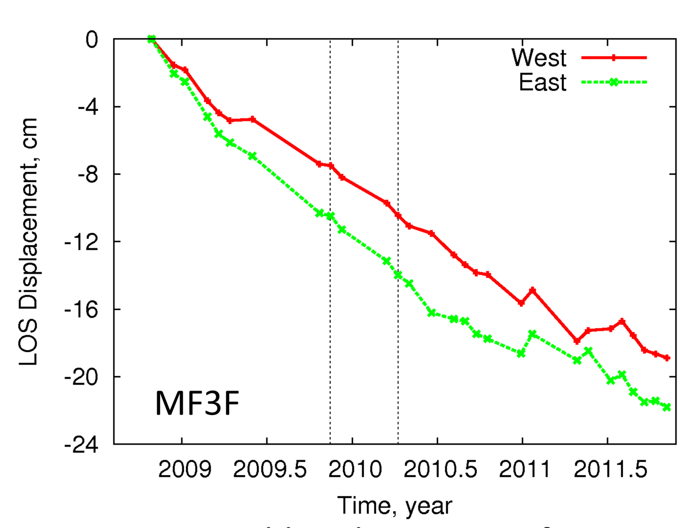
STUDY AREA IN SOUTHERN SASKATCHEWAN

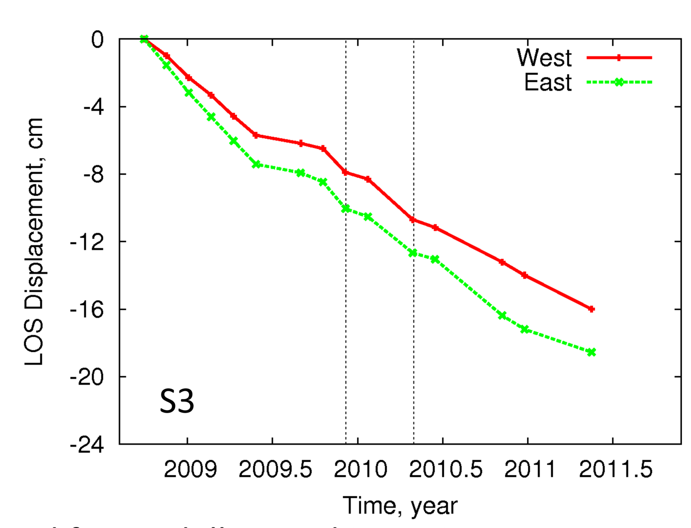


One ascending MF3F and one descending S3 RADARSAT-2 beams were used in this study, where α - incidence angle, θ – satellite azimuth, N – number of SLC images from each beam, and M – number of calculated interferograms.

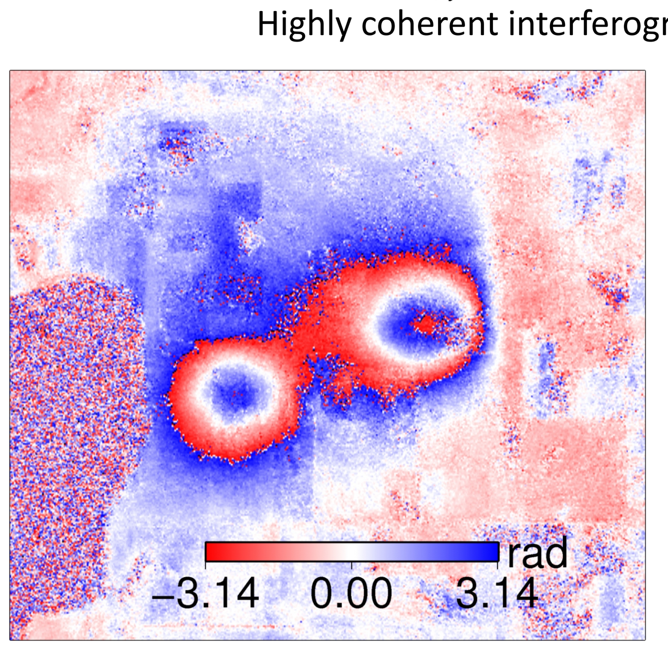
InSAR set	Time span	$\alpha°$	$\theta°$	N	M
MF3F, (asc)	20081027-20111223	-9	45	23	29
S3, (dsc)	20080929-20110821	-169	36	15	23

Time series of ground deformation for centers of subsidence calculated from RADARSAT-2 data with the SBAS method (Samsonov et al., 2011). Dashed lines outline span of highly coherent interferograms used for modelling.

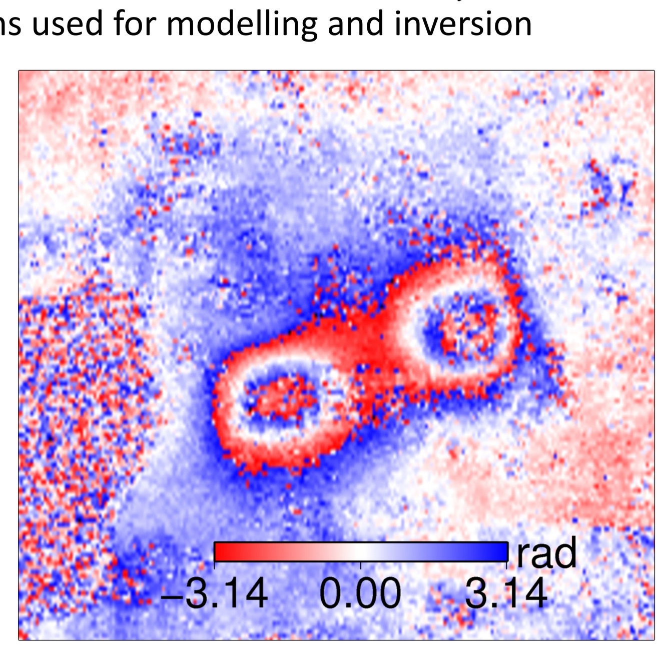




Highly coherent interferograms used for modelling and inversion

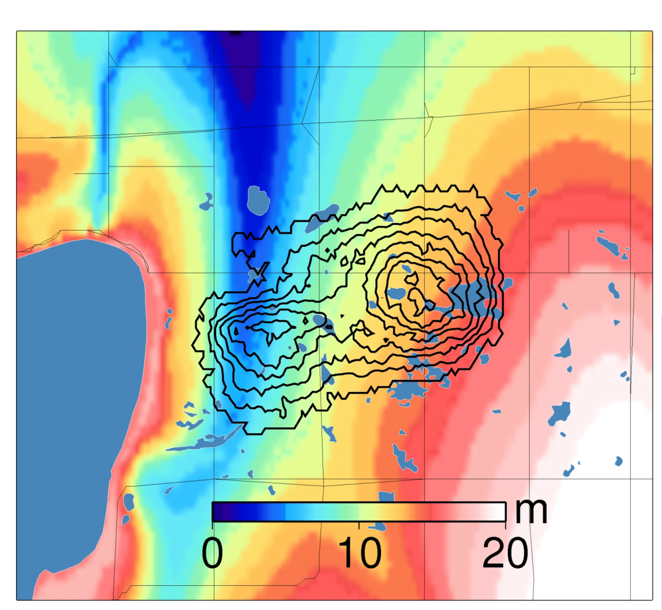


MF3F (asc): 20091115-20100408



S3 (dsc): 20091205-20100428

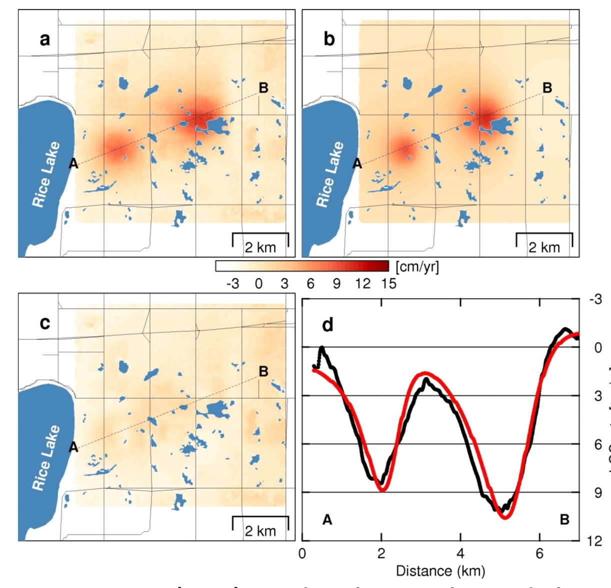
2 cm contours of 2009-2011 subsidence over SAR intensity map, area is covered by agricultural fields



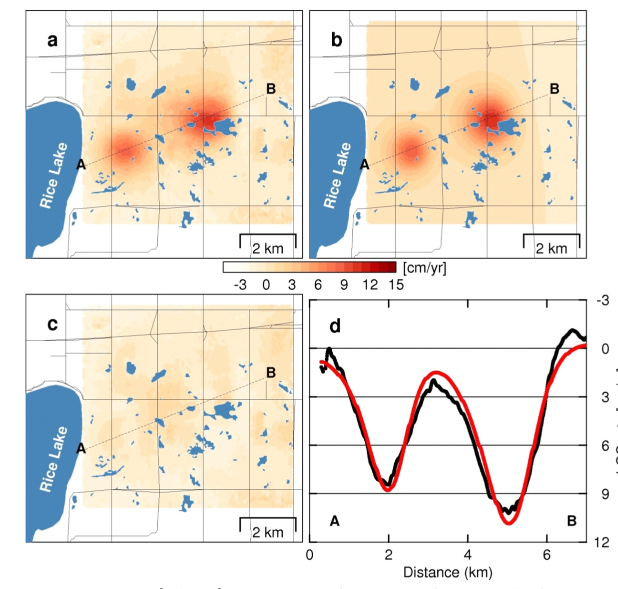
Topographic map shows very flat land with variety of water bodies

MODELLING AND INVERSION RESULTS USING SPHERICAL (MOGI, 1958) AND CIRCULAR HORIZONTAL FRACTURE or SILL (SUN, 1969) MODELS

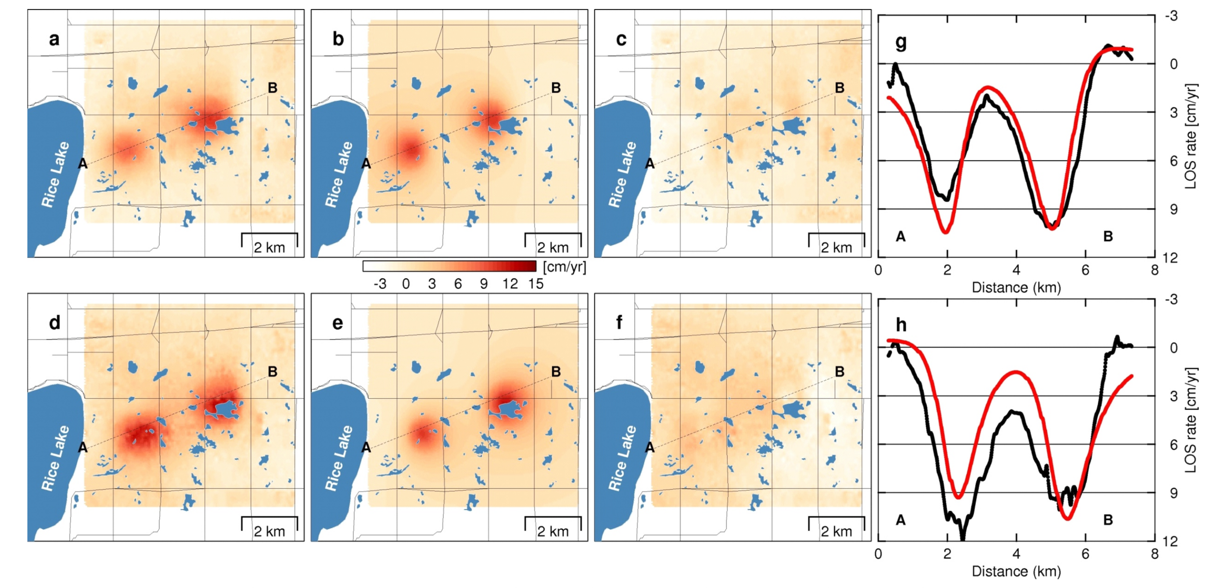
InSAR data (a), model (b), residual (c) and AB profile (d)



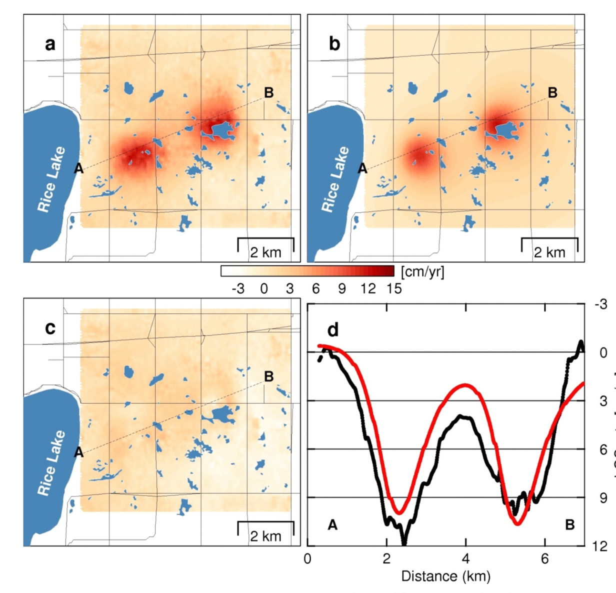
MF3F (asc) and spherical model



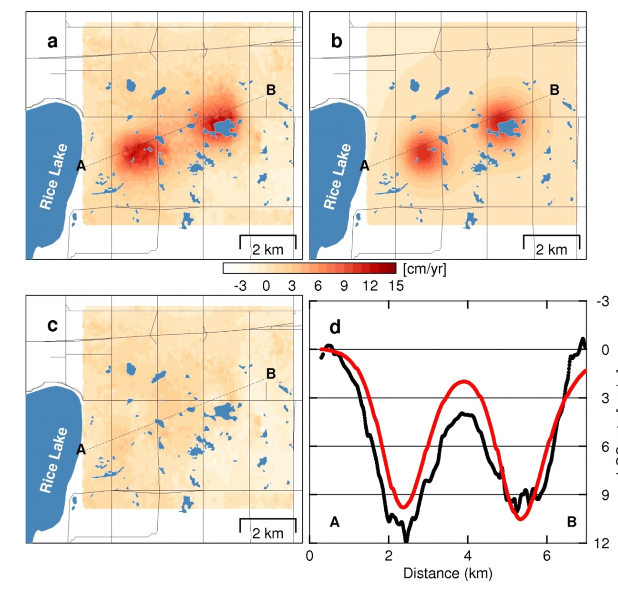
S3 (dsc) and spherical model



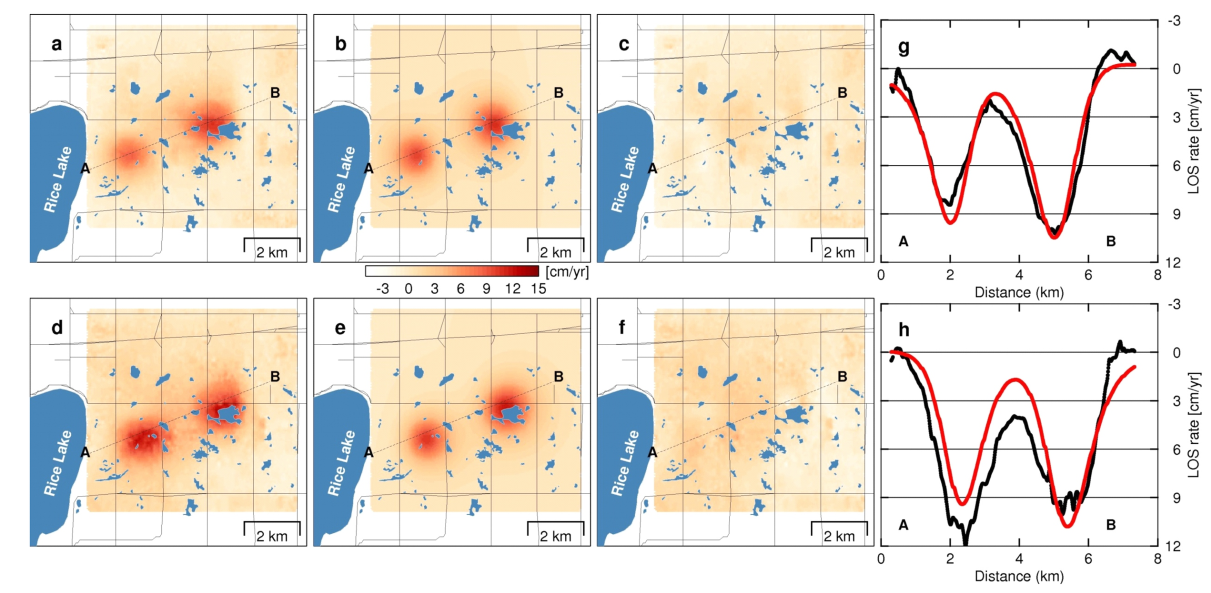
MF3F (asc, top) and S3 (dsc, bottom) and spherical model



MF3F (asc) and sill model

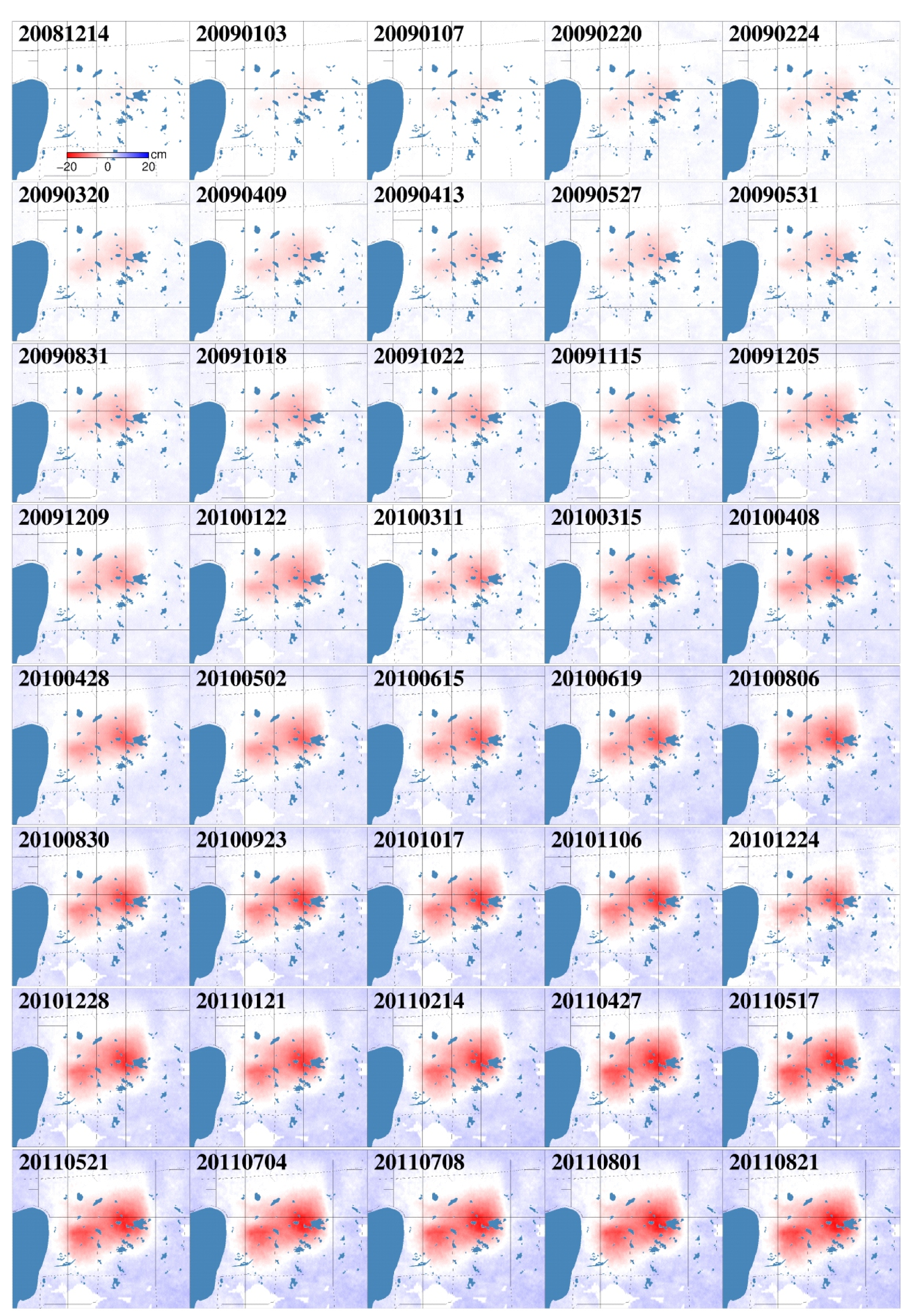


S3 (dsc) and sill model

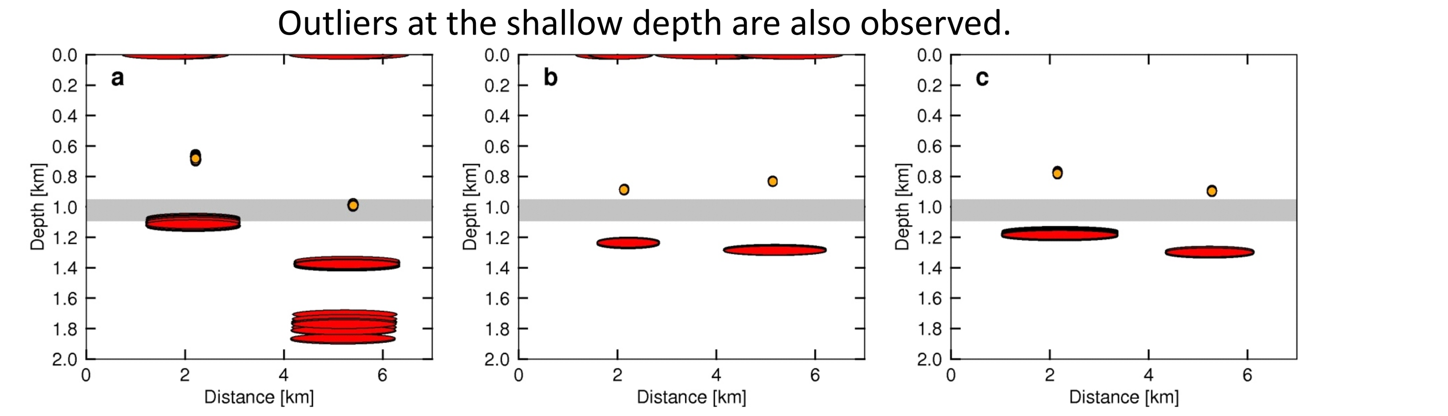


MF3F (asc, top) and S3 (dsc, bottom) and sill model

Cumulative time series of vertical component of ground deformation calculated with MSBAS method (Samsonov and d'Oreye, 2012)



Profiles across line A-B showing best fitting source parameters of 100 inverted sources for each data set. Outliers at the shallow depth are also observed.



Results of source modelling and inversion for spherical and sill models and for various data sets

Dataset	Source	Source type	Longitude	Latitude	Depth	Radius	ΔV	RMS
Ascending	E	Spherical	-107.01954	52.08520	0.988		-0.000559	0.94
	W	Spherical	-107.06308	52.07495	0.677		-0.000195	0.94
Ascending	E	Disk (sill)	-107.02142	52.08503	1.376	1.208	-0.000568	0.71
	W	Disk (sill)	-107.06390	52.07491	1.104	1.076	-0.000285	0.71
Descending	E	Spherical	-107.02317	52.08452	0.831		-0.000382	1.30
	W	Spherical	-107.06421	52.07480	0.886		-0.000424	1.30
Descending	E	Disk (sill)	-107.02243	52.08448	1.284	1.181	-0.000472	0.94
	W	Disk (sill)	-107.06281	52.07462	1.237	0.714	-0.000416	0.94
Joint	E	Spherical	-107.02119	52.08485	0.896		-0.000453	2.06
	W	Spherical	-107.06402	52.07501	0.775		-0.000305	2.06
Joint	E	Disk (sill)	-107.02181	52.08469	1.300	1.018	-0.000496	1.04
	W	Disk (sill)	-107.06314	52.07477	1.178	1.337	-0.000358	1.04

SUMMARY

- Performed InSAR processing of two RADARSAT-2 data sets over southern Saskatchewan between Saskatoon and Rice Lake and spanning 2009-2011;
- Identified two circular areas of subsidence with maximum rate of about 10 cm/year;
- Time series analysis based on SBAS and MSBAS methods revealed steady subsidence not affected by seasonal groundwater fluctuations;
  - Modelling with spherical and sill point sources and inversion identified two sources located at about 1 km depth;
  - By elimination of possible causes (groundwater, oil and gas, etc.) we determined that subsidence is most likely caused by mining;
  - Subsidence ongoing for long period of time in this flat agricultural region abundant of surface water and shallow groundwater will produce redistribution of water levels which in turn may increase susceptibility of this region to flooding.

ACKNOWLEDGMENT: We thank the Canadian Space Agency (CSA) for providing RADARSAT-2 data. Figures were plotted with GMT and Gnuplot software and statistical analysis was performed with R software. The work of PG was supported by Banting Postdoctoral Fellowship. The work of KFT was supported by an NSERC Discovery Grant.

REFERENCES:

K. Mogi. 1958. Relations between the eruptions of various volcanoes and the deformation of the ground surfaces above them. University of Tokyo, Earthquake Research Institute Bulletin, 36(2):99–134
S. Samsonov, P. Gonzalez, K. Tiampo, N. d' Oreye, (2013) Modelling of fast ground subsidence observed in southern Saskatchewan (Canada) during 2008-2011, submitted to NHESS
Samsonov S., Gonzalez P., Tiampo K., and d'Oreye N., 2013. Spatio-temporal analysis of ground deformation occurring near Rice Lake, Saskatchewan, and observed by Radarsat-2 DInSAR during 2008-2011, Canadian Journal of Remote Sensing, 39 (1), 27-33
Samsonov S. and d'Oreye N., 2012. Multidimensional time series analysis of ground deformation from multiple InSAR data sets applied to Virunga Volcanic Province, Geophysical Journal International, 191 (3), 1095-1108
Samsonov S., van der Koij M. and Tiampo, K., 2011. A simultaneous inversion for deformation rates and topographic errors of DInSAR data utilizing linear least square inversion technique, Computers & Geosciences, 37 (8), 1083-1091
R.J. Sun. 1969. Theoretical size of hydraulically induced horizontal fractures and corresponding surface uplift in an idealized medium. Journal of Geophysical Research, 74:5995–6011

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Natural Resources Canada Ressources naturelles Canada

2014

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doi:10.4095/295561

This publication is available for free download through GEOSCAN (http://geoscan.nrcan.gc.ca/).

Presented at the 34th Canadian Symposium on Remote Sensing Victoria, British Columbia
Date presented: August 2013

Recommended citation
Samsonov, S.V., González, P.J., Tiampo, K.F., d'Oreye, N., and Czarnogorska, M., 2014. New insights into fast ground subsidence in southern Saskatchewan from modeling of RADARSAT-2 DINSAR measurements; Geomatics Canada, Scientific Presentation 2, poster. doi:10.4095/295561

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