On the value of High Resolution Weather Models for Atmospheric mitigation in SAR Interferometry

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Abstract. Signal propagation delay induced by the Earth's troposphere is one of the major error sources in surface deformation monitoring using SAR Interferometry (**InSAR**). The difficulty of modeling the delay mainly comes from the high temporal and spatial variation of water vapor. Although previous studies have proposed a number of approaches for wet delay mitigation using for instance the Global Positioning System (GPS) [5] or space-borne spectrometers such as the Medium Resolution Imaging Spectrometer (MERIS) [3] these methods are only feasible under optimal conditions in terms of the spatial density of the GPS network or the absence of cloud coverage, respectively. Currently, world-wide fine-resolution water vapor maps can be obtained from Numerical Weather Models (NWM) [1]. Therefore, it is of importance to investigate the feasibility and limitations of NWM for delay mitigation in InSAR.

In this study, the state-of-the-art Weather Research and Forecasting (WRF) [6] NWM is used to estimate differential delays with a spatial resolution of ~1 km at the time of the Envisat SAR acquisitions over flat areas (e.g. The Netherlands) as well as regions with significant topography (e.g. Mexico-City). The estimated differential delays are subtracted from the interferograms formed by the SAR images to mitigate the atmospheric disturbance. We processed 4 Envisat interferograms (track 255, frame 3216) over Mexico-City, and 9 interferograms over the Netherlands (track 380 and 423). All interferograms have short temporal baselines (≤ 70 days) to suppress temporal decorrelation and to minimize possible surface deformation. The topographic phase in the interferograms is removed by using the 3 arc-second resolution Digital Elevation Model from the Shuttle Radar Topography Mission. A spatial averaging window of 50 by 250 pixels in range and azimuth respectively, is applied to the topography-corrected interferograms to reduce decorrelation or processing-induced noise. After averaging, the spatial resolution of the interferograms is 1 km in both ground range and azimuth direction. As a result, each interferogram mainly represents the atmospheric delay difference between the two SAR acquisitions.

The results show that the NWM is able to reduce the delay signal in three interferograms over Mexico-City. The power suppression of the atmospheric phase screen (APS) in the interferograms is given in Table 1. The maximum power suppression is -2.3 dB for the interferogram MC4 (14838-15339) in which the topographic-dependent differential delay variation is clearly visible, see Figure 1. In the case of The Netherlands though, the NWM has almost no effect on atmospheric mitigation. In 4 out of 9 cases the APS variability becomes even larger. The best as well as the worst results from the corrected interferograms using the NWM is presented as structure functions with respect to wavelength and is shown in Figure 1. Moreover, the structure functions of the NWM over flat areas show that the model underestimates the spatial variation of the differential wet delays at all wavelengths.

	Netherlands									Mexico-City			
Interferogram #	NL1	NL2	NL3	NL4	NL5	NL6	NL7	NL8	NL9	MC1	MC2	MC3	MC4
APS reduction (dB)	-0.4	-0.2	+1.2	-0.8	-0.7	+0.3	-0.7	-0.3	+ 0.1	-0.3	+0.4	-1.3	-2.3
STD orig/ corrected (mm)	6.4/ 6.0	4.8/ 4.9	3.9/ 4.6	4.0/ 3.4	2.4/ 2.2	3.5/ 3.7	3.1/ 2.8	3.6/ 3.3	4.8/ 5.4	5.4/5.3	6.4/6.7	6.1/5.4	9.0/5.2

Table 1: Power and standard deviation reduction using the WRF NWM for the APS (differential delays) for interferograms over The Netherlands and Mexico-City.

In order to explain the difference in the performance of the NWM we separated the total differential delay in the mountainous areas around Mexico-City into (i) a vertical stratification term assuming that the delay varies only with altitude and has no horizontal fluctuations, and (ii) a turbulent mixing term which only accounts for the horizontal variations of the delay [2]. These results show that the NWM can effectively model the vertical stratification part in the interferograms but in most cases it significantly underestimates the spatial variability of the turbulent mixing term. This conclusion is corroborated by the comparison between a number of NWM realizations and MERIS reduced resolution (~1 km) water vapour measurements, in case of cloud-free images.

Although our evaluation is based on the WRF model only, this model is expected to perform better than older generation NWMs, such as MM5, NH3D [1,4]. Therefore, based on the case studies performed here we come to the conclusion that the value of current NWMs for atmospheric mitigation is currently limited to mountainous regions, and that the application of NWM results in areas without significant topography may deteriorate the interferometric results instead of improving them. Unless Numerical Weather Models improve their reliability in terms of the small-scale (turbulence) modeling, their results are insufficiently reliable for operational InSAR correction.

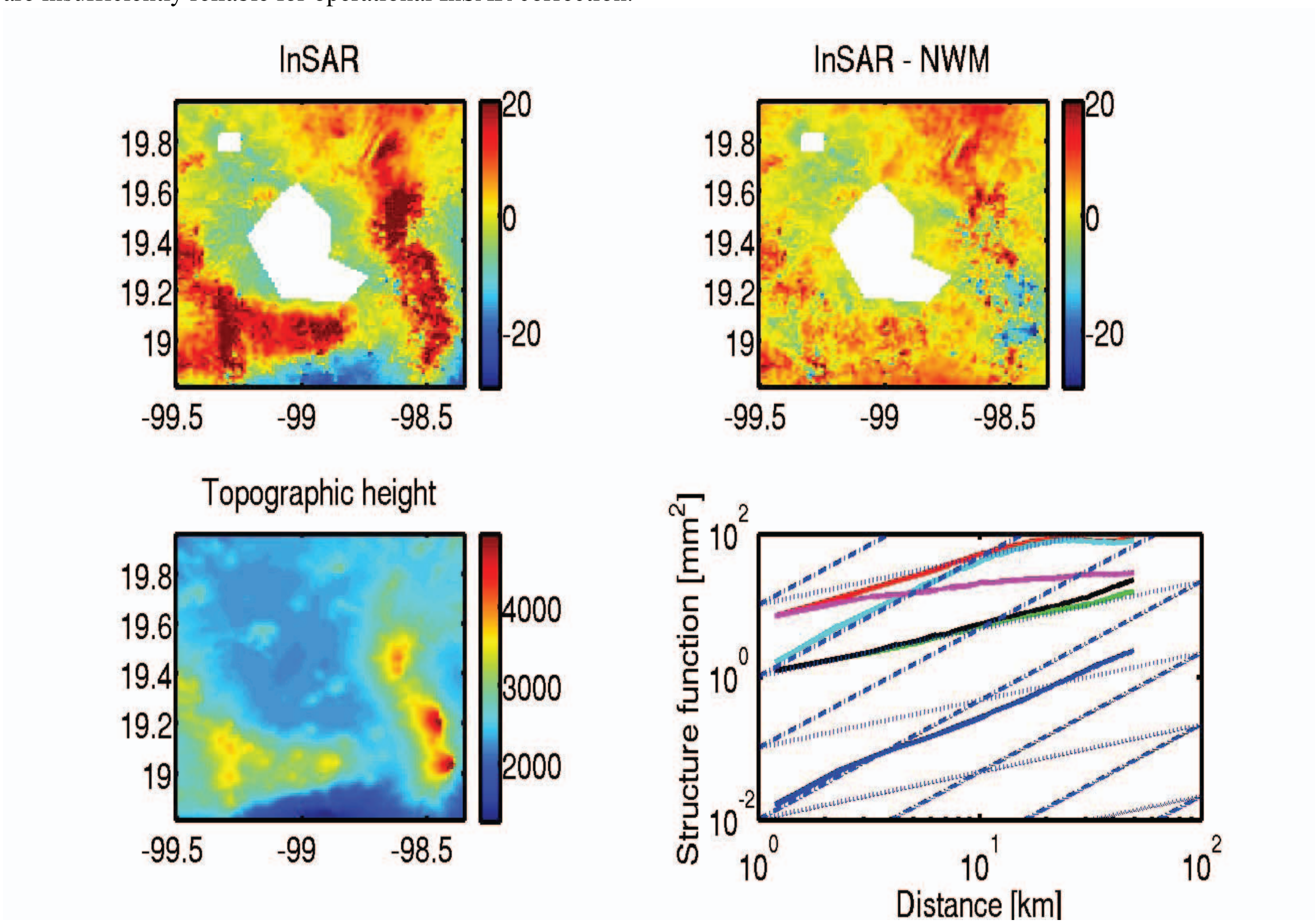

Figure1. Top-left: original interferogram MC4 (best reduction), colour-bar unit: millimeter; Top-right: corrected interferogram; Bottom-left: topography of Mexico-City, colour-bar unit: meter; Bottom-right: structure functions of the original InSAR APS shown in red (MC4) and green (NL3), NWM shown in cyan and blue which refer to the red and green ones respectively, and corrected interferogram shown in magenta and black which refer to the red and green ones respectively; The best mitigation case is MC4 and the worst case is NL3. The subsiding part of Mexico-City is masked out. The dotted lines follow a 2/3 and a 5/3 slope for reference.

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