PERFORMANCE ANALYSIS OF ATMOSPHERIC CORRECTION IN INSAR DATA BASED ON THE WEATHER RESEARCH AND FORECASTING MODEL (WRF)

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1. ABSTRACT

Due to the influence of the turbulent atmosphere, current high-quality Interferometric Synthetic Aperture Radar (InSAR) techniques, capable of mapping surface deformation rates with mm/year accuracy, require a large number of datasets (30-100 images) to successfully separate the different contributions to the interferometric phase, causing long response times of InSAR analysis systems. The temporal randomness of atmospheric delay also complicates Persistent Scatters (PS) processing, by requiring an additional spatial phase unwrapping step along the arcs of a PS network. Atmospheric correction has been attempted in the past using temporal averaging of interferograms (e.g. [1], [2]), by including GPS measurements ([3], [4]), or by applying observations of optical sensors like the Moderate Resolution Imaging Spectroradiometer (MODIS) (e.g., [5]) or the Medium Resolution Imaging Spectrometer (MERIS) (e.g. [6] – [8]). Tropospheric phase delay correction based on mesoscale numerical weather prediction (NWP) models was attempted in, e.g., ([9] – [11]). In [9] a combination of MERIS imagery and the mesoscale meteorological model MM5 is used, where the highly turbulent water vapor delay is extracted from MERIS and merged with other components derived from the lower resolution MM5 model. This research shows that mesoscale NWP models are adequate for predicting the long wavelength pattern of atmospheric delay, but fail to reproduce small-scale oscillations.

Within this paper, we will present an integration of InSAR observations with predictions from the *high-resolution* Weather Research and Forecasting Model (WRF), widely used at the University of Alaska Fairbanks [e.g. 12], and will analyze its performance for correcting atmospheric effects. The non-hydrostatic WRF model is capable of generating atmospheric phase delay maps with resolutions down to 500m. It is therefore expected to outperform other atmospheric models and is assumed to enable the prediction of the full phase delay signal without requiring additional data. The WRF model has the ability to be implemented with a nested grid system, allowing phase maps to be created with a very high spatial resolution across the full interferometric map.

2. APPROACH

As the research team has direct access to the WRF infrastructure, a thorough analysis of the WRF performance can be performed that includes assessing influences of the model setup on the resolved atmospheric phase delay signal. Specifically the following research will be presented:

- The procedure for extracting profiles of the atmospheric components water vapor, atmospheric temperature, and pressure along a given line-of-sight will be presented, and the conversion of those parameters to phase delay maps will be described.
- While it was shown in previous studies that the performance of WRF for predicting stratified atmospheric delay is satisfactory, its ability to sufficiently predict the turbulent part of the atmospheric signal has yet to be determined [13]. An example of atmospheric correction with WRF for mountainous terrain is show in Figure 1 for a SAR data set acquired over the island of Hawai'I (taken from [13]). It shows that stratified delay is modeled well while turbulent delay is underrepresented. To analyze the capabilities of WRF for modeling atmospheric turbulence, a performance analysis is presented that compares measured InSAR phase screens over flat and stable test sites in the Netherlands and around Lake Moore, Western Australia to WRF model results. By optimizing the similarity between WRF predictions and InSAR signals, an optimal parameterization of the WRF model for predicting turbulent atmospheric signals is determined. The searched parameter space includes lateral and vertical resolution including nesting, latency time between model initialization and SAR acquisition, method of model initialization, and assimilation of external data. Specifically the following results will be presented:
    - The sensitivity of the quality of predicted turbulent atmospheric delay to variations of model parameters will be presented, indicating that direct access to the model setup is

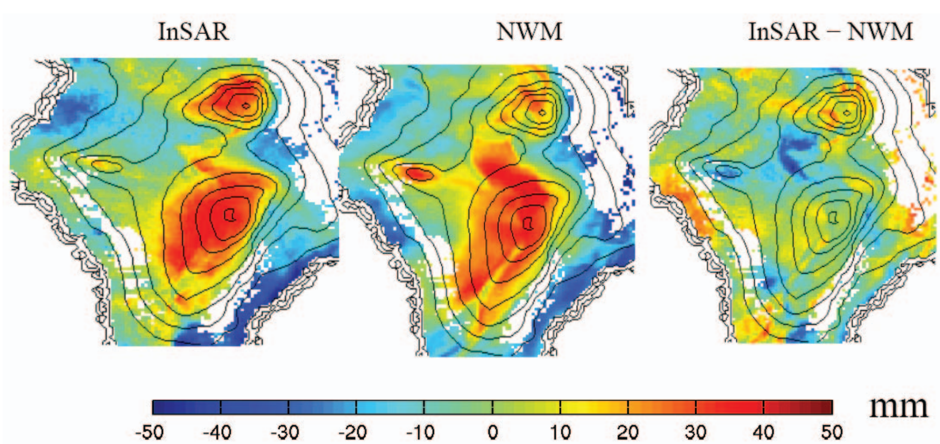

Figure 1: Example of atmospheric correction of InSAR data for a dataset acquired over the island of Hawai'i. From left to right: InSAR phase, phase delay predicted by WRF, difference between prediction and measured delay.

essential for significant reduction of turbulent atmospheric signals.

- The performance of the optimized model setup is derived by comparison with measured phase delay maps. Structure functions of residual atmospheric delay as well as the *residual atmospheric variance after atmospheric correction* σ_{ψ}^{2} [8] will be presented as key performance parameters. High quality correction with $\sigma_{\psi}^{2} < \pi/2$ may enable new concepts of PS processing, where surface deformation could be derived without requiring spatial phase unwrapping in PS networks.

- While direct access to a high-resolution weather prediction model like WRF is optimal for predicting atmospheric phase delays, this opportunity is only available to very few scientists. Therefore, the performance of a customized WRF setup is compared to different operational NWPs as well as global reanalysis data that are freely available. Investigated models include the operational Global Forecast System (GFS), the National Center for Environmental Prediction (NCEP) model, the European Center for Medium-Range Weather Forecasts (ECMWF) re-analysis dataset, the operational North American Mesoscale (NAM) model, and the North American Regional Reanalysis Archive (NARR) dataset. For this analysis, the island Hawai'i is added as additional test site as its significant topography allows to additionally analyze the performance of different models for predicting stratified delays.
  - Reanalysis data is compared to customized WRF runs for all three test areas to quantify the performance differences of turbulent as well as stratified delays.
  - Additional operational NWP models of varying resolution are tested to determine the performance of publicly available models for atmospheric correction and quantify their relative performance compared to WRF.

3. CONCLUSIONS

The main finding of the paper is that high-resolution NWP models are useful for mitigating atmospheric delay if direct access to the model parameters is available.

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