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# Advanced corrections for InSAR using GPS and numerical weather models

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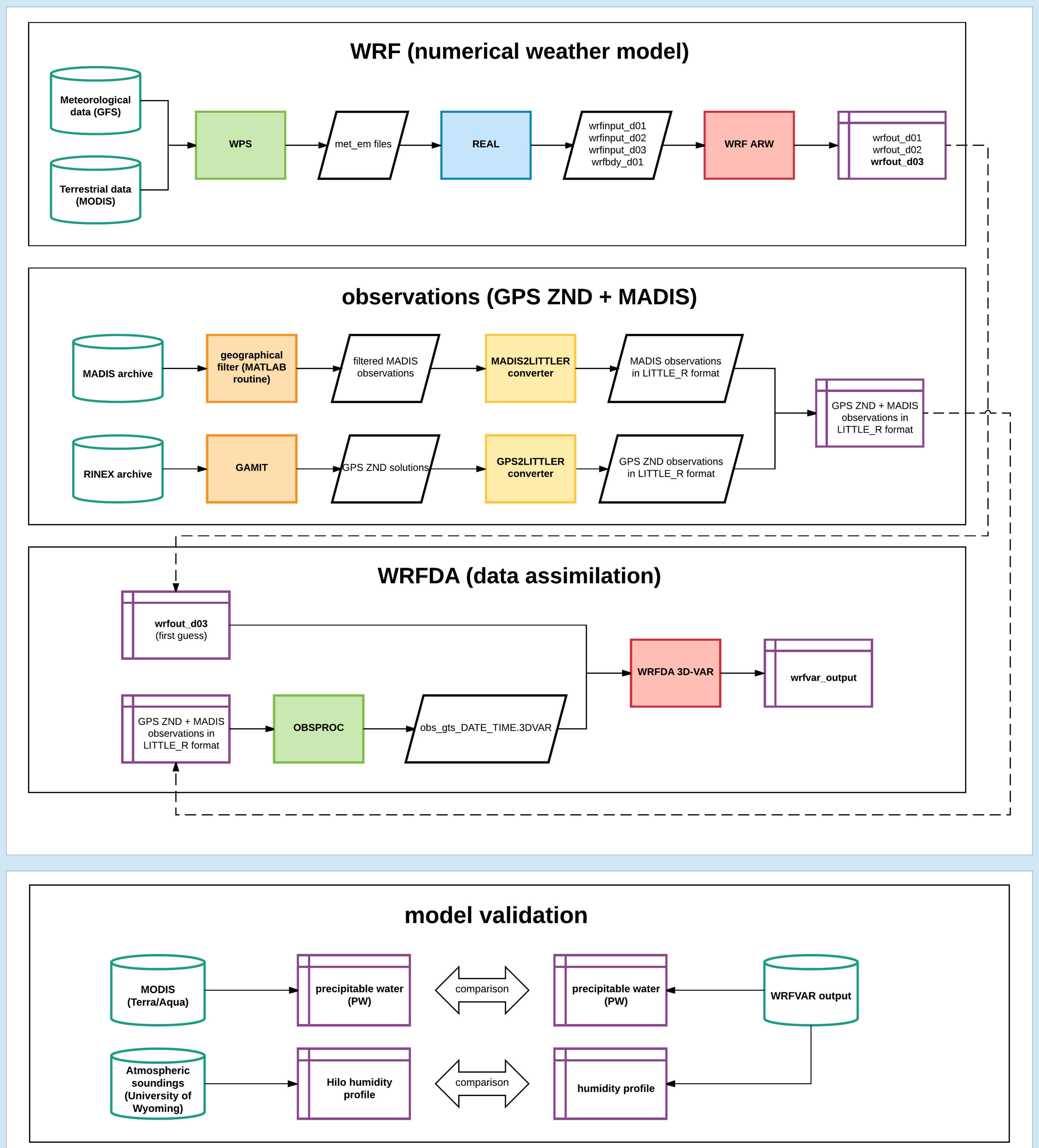
## INTRODUCTION

- **Interferometric Synthetic Aperture Radar (InSAR)** observations have the potential to be effectively used for hazard monitoring and mitigation of areas affected by active volcanoes, earthquakes and landslides (Fig. 1A, 1B).
- The temporally-varying non-isotropic distribution of **atmospheric water vapor** limits the accuracy of InSAR observations. Water vapor is responsible for changes in refractivity which are unrelated to the true ground motion signal (Fig. 1C).
- **Numerical Weather Models (NWM)** are a promising tool for generating atmospheric correction fields for InSAR. NWMs can be used to create a custom analysis for the area of interest by assimilating all available meteorological observations into a high-resolution atmospheric model valid for the time of the InSAR scene.

## CUSTOM ATMOSPHERIC ANALYSIS STRATEGY



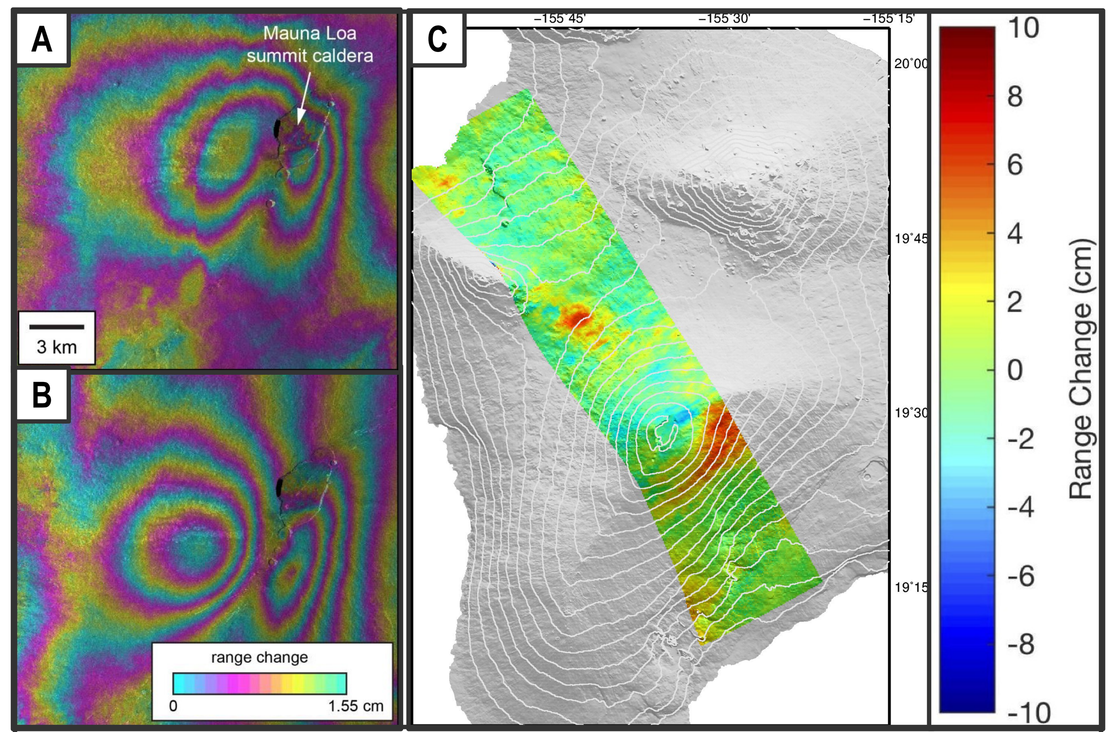




**Figure 1. A, B:** Interferograms from COSMO–SkyMed data showing surface deformation on the Mauna Loa volcano spanning October 25, 2014 – June 22, 2015 (A) and June 22, 2015 – May 23, 2016 (B) (Source: USGS); **C:** UAVSAR interferogram for 21:21:24 – 21:58:13 October 6, 2016 UTC (11:21 – 11:58 am HST). The red/blue areas show some strong small-scale atmospheric features caused by water vapor variations in the 37 minutes between acquisitions.

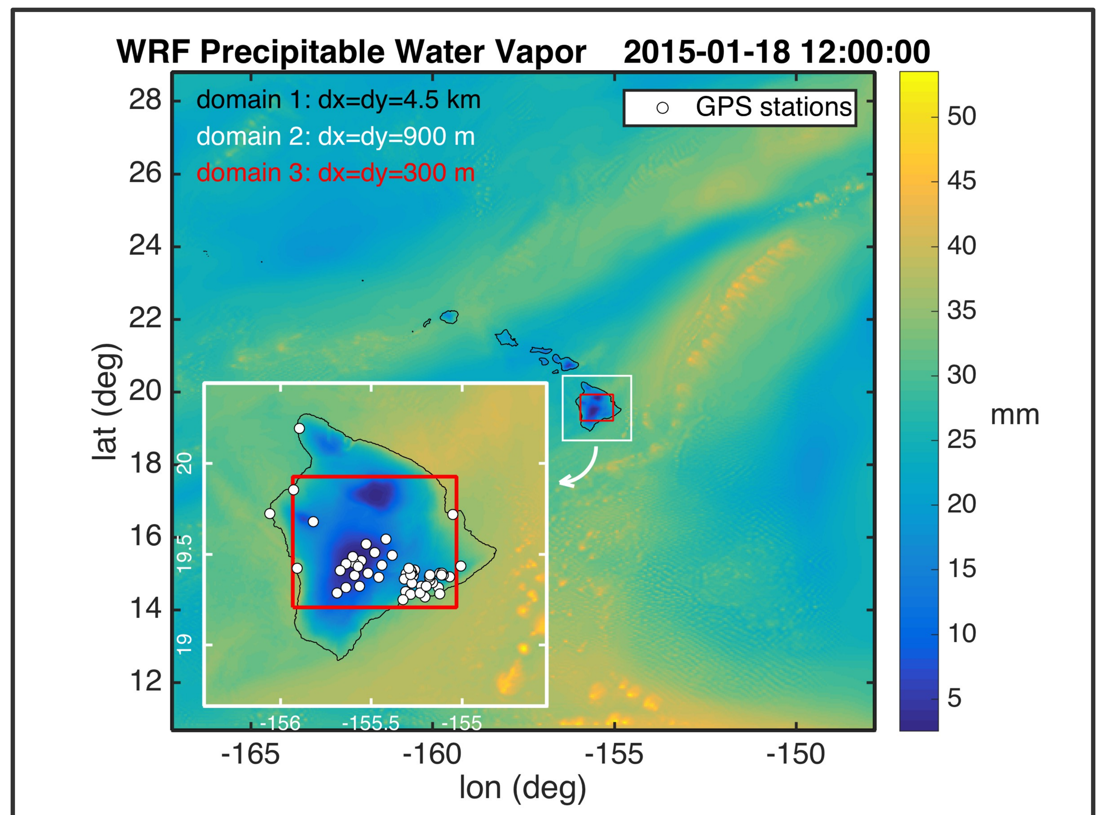



**Figure 2.** WRF model output for January 18, 2015 12 UTC showing the simulated precipitable water vapor (PW) and the 3-domains configuration with their respective horizontal resolutions. The white dots on the Big Island of Hawaii correspond to the locations of the GPS stations used in the custom analysis for the 300 m resolution domain (domain 3, red).

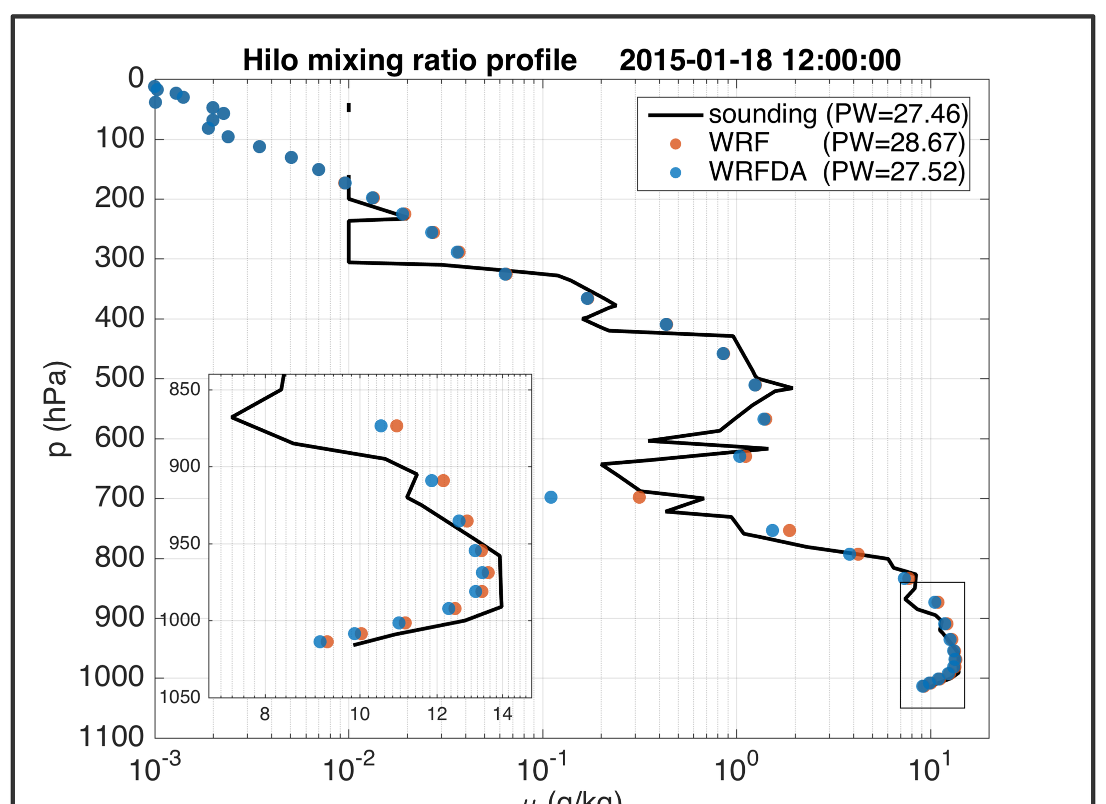



**Figure 3.** Water vapor mass mixing ratio profile at Hilo (Big Island). The black line is the radiosonde data, the red dots are the output from the WRF model and the blue dots from WRFDA (data assimilation). The inclusion of the GPS ZND data and the observations from the MADIS archive brings the total PW of WRFDA closer to the observed value.

## DATA AND MODELS

- Study site: Big Island of Hawaii
- InSAR satellite data: 745 COSMO-SkyMed scenes (2010-2016), 1 new scene every 2-3 days
- UAVSAR data: 50 scenes
- GPS Zenith Neutral Delay (ZND) data: network of 60+ GPS sites
- Meteorological observations: MADIS archive (METAR, Maritime, GOES, Mesonet, ACARS)
- NWM: Weather Research and Forecasting (WRF) model version 3.8:
  - model output at ~04 UTC and ~16 UTC matching COSMO-SkyMed scenes
  - model output matching UAVSAR acquisition times covering a 24-hour diurnal cycle
- Data assimilation: WRFDA version 3.8
- AWATOS2: zero/double-difference tomographic analysis package
- KARAT: ray-tracing software
- PyAPS: Python-based Atmospheric Phase Screen Estimation software

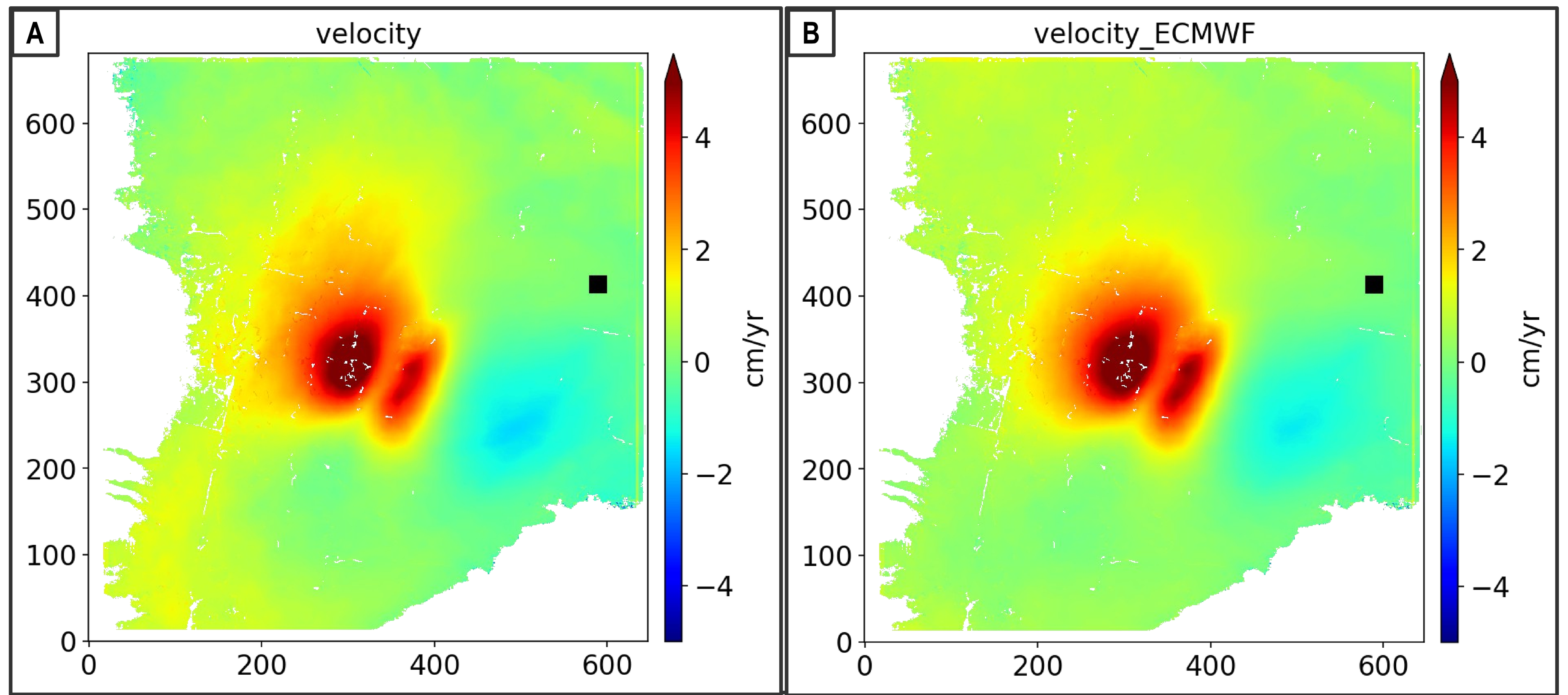



**Figure 4.** Preliminary result of a "velocity map" of the Mauna Loa inflation using InSAR data for 2015-2016 corrected with our custom analysis (A), compared with the default atmospheric correction using ECMWF ERA-Interim (B). Our corrected velocity field shows subtle differences that we are in the process of evaluating and validating.

## CONCLUSIONS AND OUTLOOK

- High-resolution output from a NWM in combination with local available observations offer an opportunity to produce a **reliable representation of the non-isotropic water vapor distribution** at the time of InSAR acquisitions.
- Such custom analysis can be used to derive **atmospheric correction products** (phase screens) for InSAR interferograms.
- Corrected InSAR interferograms will better **highlight the magmatic signal** (inflation/deflation) of active volcanic areas such as the Mauna Loa and Kilauea volcanoes on the Big Island of Hawaii (Fig. 4).
- In a future operational mode, low-latency atmospheric correction products can be used to effectively monitor hazardous volcanic areas for **eruption early warning, earthquake response and landslide monitoring**.

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