National Aeronautics and Space Administration

FY23 Lew Allen Award

Towards Improved Spatial Temporal Tropospheric Path Delay Corrections for InSAR

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Objectives: Determine whether tropospheric corrections derived from the NOAA High-Resolution Rapid Refresh (HRRR) model improves the estimate of tropospheric path delays for radar compared to those estimated from the global ECMWF High-Resolution (HRES) model. HRRR is a regional Numerical Weather Prediction (NWP) model that assimilates local observations from GNSS weather stations and ground-based NEXRAD radar. HRRR is anticipated to improve the spatial-temporal accuracy of precipitate water vapor and the ability to capture turbulent atmosphere. However, the HRRR model has not been used for Interferometric Synthetic Aperture Radar (InSAR) applications, nor has a statistical assessment been completed.

Background: InSAR is identified in the 2017 Decadal Survey as a primary measurement technique for the Surface Deformation and Change targeted observable. However, the delay of radar signals propagating through the troposphere is influenced by relative humidity, pressure and temperature (e.g., [1]), limiting the retrieval accuracy of ground displacement using InSAR. Various corrections methods for such tropospheric delays have been applied with varying degrees of success, including those estimated from sparse GNSS networks, spectrometer observations limited to cloud free, daytime retrievals, and weather models outputs which are not usually optimized on regional scales [2].

Approach and Results: We compare tropospheric delays derived from HRES and HRRR NWP models and determine the performance for InSAR by calculating the residual standard deviation between NWP and GNSS-derived Zenith Tropospheric Delay (ZTD) estimates. We analyze ZTD performance at a 12 day interval (e.g. NISAR revisit) over a 3.5 year period at local times representative of a 6 AM / PM (equatorial crossing) SAR orbit. We map the synoptic hour at which the weather model is available (every 6 hours for HRES, and hourly for HRRR) to the nearest local time. ZTD were computed and statistically analyzed through the open-source RAiDER package [3].

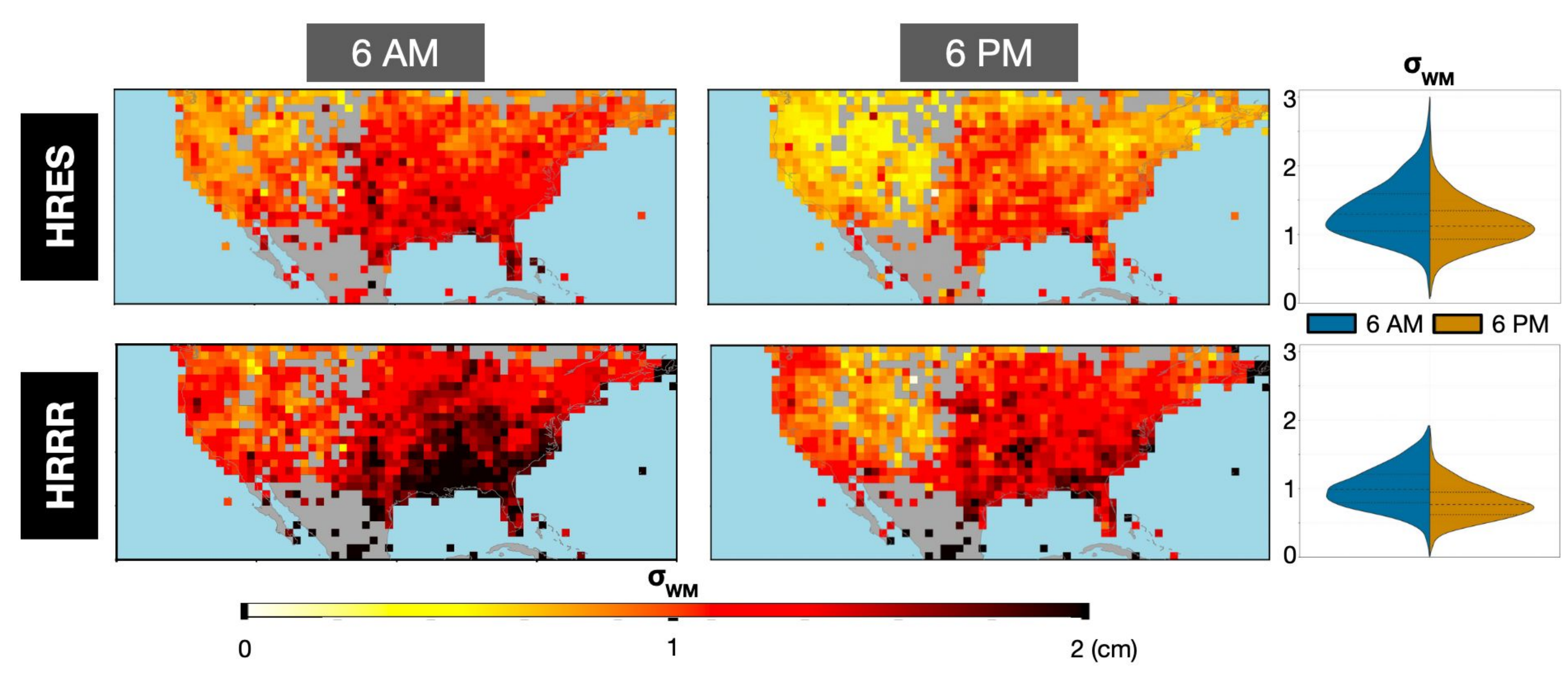

Figure 1. ZTD NWP standard deviation for HRES and HRRR at approximately 6 AM/PM local time. We find that HRES outperforms the HRRR NWP. Improved accuracy is observed consistently for both model at evening versus morning.

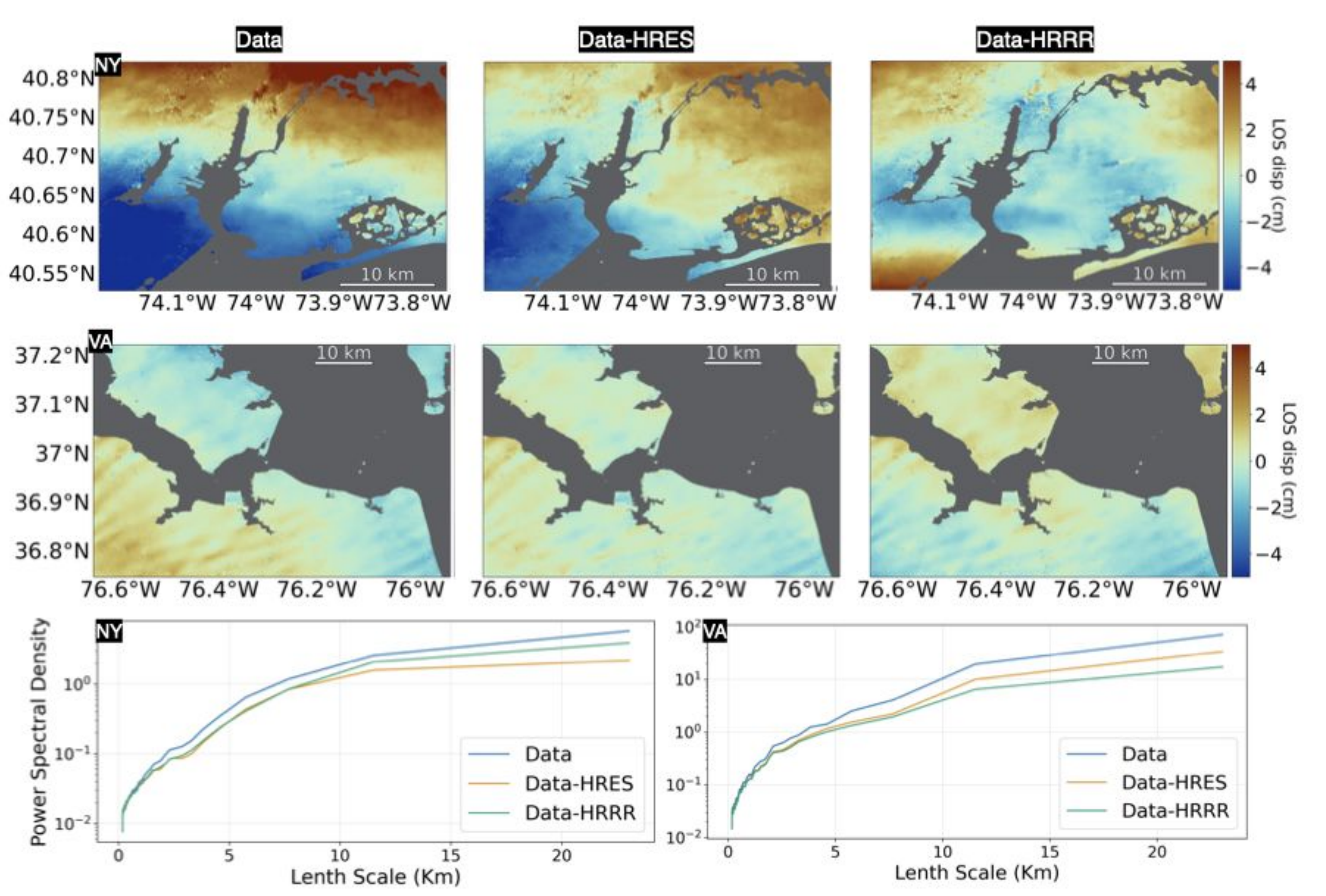

Figure 2. Evaluating performance of HRES and HRRR in reducing tropospheric noise for an interferogram over New York (top row) and Virginia (middle row). Power spectra results (bottom row) show NWP models reduce long-wavelength (>50km) tropospheric noise, but aren't able to correct at short spatial scales (<10km). We find that HRRR model performs better than HRES at the intermediate scale (e.g., NY).

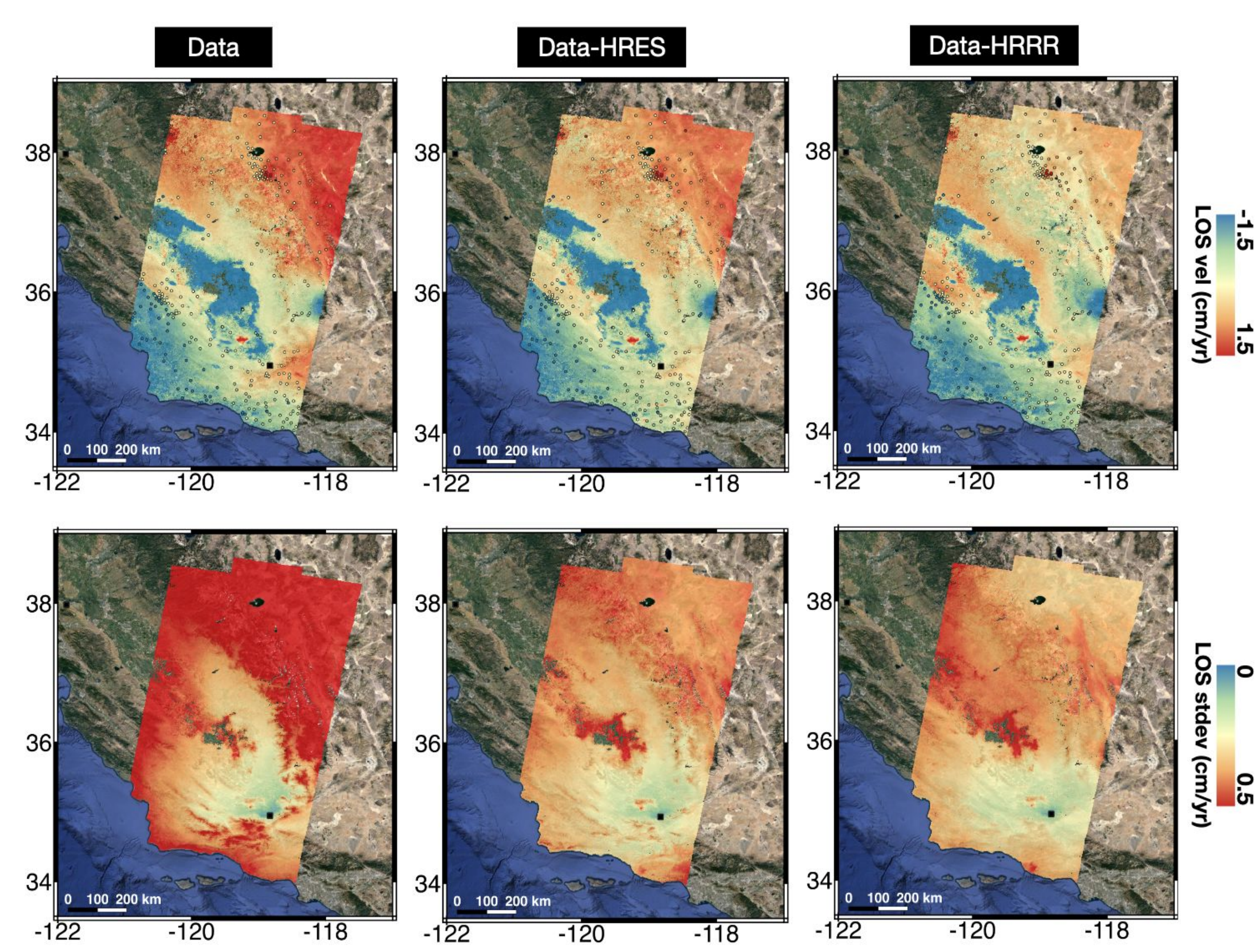

Figure 3. Combined impact of model mitigation and averaging over time for reduction of tropospheric noise to retrieve long-term surface displacement rates. After correction, we see a reduction of the long wavelength tropospheric noise for the displacement rates (top row) and with an improvement in the corresponding retrieval accuracy (bottom row) as a function of distance with respect to the reference point (black square).

References:

[1] Hanssen, R. F. (2001). Remote sensing and digital image processing. Radar interferometry: data interpretation and error analysis, Earth and environmental science, 2, 200-210.

[2] Bekaert, D., et al, (2015). A spatially variable power law tropospheric correction technique for InSAR data. Journal of Geophysical Research: Solid Earth, 120(2), 1345–1356.

[3] Maurer, J., et al, (2021). RAiDER: Raytracing Atmospheric Delay Estimation for RADAR. AGU Fall Meeting Abstracts, 2021

Significance/Benefits to JPL and NASA: Our NWP performance analysis is directly relevant for SAR missions operating in a dawn-dusk orbit (e.g., Sentinel-1, ALOS-2, NISAR etc.). Our results complement the global NWP (HRES, ERA5, GMAO, NCMR) performance analysis of the NISAR tropospheric Working Group, which are the most comprehensive and consistent analysis of NWP model performance available. Our findings further inform the OPERA and NISAR Solid Earth science teams on usage of the HRRR model over CONUS, coincident to multiple project validation sites.

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