NOWCASTING FROM URBAN TO CONTINENTAL SCALE USING A KERNEL-BASED LAGRANGIAN APPROACH: AN ILLUSTRATION OF SCALING CHARACTERISTICS

Evan Ruzanski[1] and V. Chandrasekar[2]
[1]Vaisala, Inc., Louisville, Colorado
[2]Colorado State University, Fort Collins, Colorado

ABSTRACT

The Collaborative Adaptive Sensing of the Atmosphere (CASA) radar nowcasting system was developed to provide highly localized urban-scale quantitative precipitation forecasts using networked X-band radar data. This paper illustrates the scalability of the CASA nowcasting system to continental-scale and discusses model parameterization relative to the space-time characteristics of precipitation.

1. INTRODUCTION

The CASA nowcasting system was shown to provide valuable nowcasts during the 2009 Integrative Project 1 experiment, where nowcasting from 0–30 min was beneficial for emergency decision-making support and 0–5-min nowcasts were used to effectively adjust the radar network scanning strategy to better observe the atmosphere (Ruzanski et al. 2011). Data from four networked X-band radars were merged and projected onto a grid covering an approximate area of 140 km × 140 km with 0.5 km spacing (~8×10^4 data points). Nowcasts were generated within the 1-min data update period.

This study investigates the scalability of the nowcasting model to larger scale, specifically continental-scale using CASA radar data collected during a precipitation event beginning on 0054 UTC 31 Mar 2009 and Unidata NEXRAD Level III (N0R) composite radar data collected during an event that began on 0002 UTC 14 Apr 2011. The N0R data cover an approximate area of 4800 km × 3300 km with 4-km grid spacing (degraded from 1-km for computational purposes) and approximate temporal resolution of 5 min. Behavior and parameterization of the model are related to the characteristics of precipitation scales.

2. NOWCASTING MODEL

Motion estimation is performed by the Dynamic and Adaptive Radar Tracking of Storms (DARTS) technique, which represents the general continuity equation describing the flux of an observed precipitation field represented by a sequence of radar reflectivity fields as a discrete linear model formulated in the Fourier domain and solved using linear least squares estimation (Ruzanski et al. 2011). The parameters of interest in this study are the number of Fourier coefficients, N_x and N_y, in each of the two spatial dimensions. These determine the cut-off frequency, ω_c, of the spatial Fourier lowpass filter (LPF) implemented by determining the dimensions of the design matrix **H** in the linear model **y** = **Hx**, which is pseudo-inverted to retrieve the motion vector estimates in **x**.

Advection is performed using a sinc kernel-based approach, shown by

$$F(t+\delta_t) = F(t) - \left\{ \frac{U}{\Delta x}\left[\mathbf{AF}(t)\right] + \frac{V}{\Delta y}\left[\mathbf{F}(t)\mathbf{Z}\right] \right\} \delta_t, \quad (1)$$

where $F(t)$ is the field at time t, U and V are the motion vector field components, Δx and Δy are the grid spacings in each respective dimension, **A** and **Z** are matrices of sinc-kernel derivatives, **F** represents the field truncated to the appropriate dimension, and δ_t is the advection time step. The parameter δ_t determines the granularity of the advection (integration) process and must be appropriately chosen to ensure convergence. The maximum value of δ_t to ensure convergence is considered in this study.

3. EXPERIMENTAL SET-UP AND RESULTS

Two experiments were performed to assess the characteristics of the nowcasting model relative to the size of the data and precipitation scales being tracked. The first experiment considered a radar data field of fixed size (0.5 km for CASA and 4 km for N0R) while the normalized cut-off frequency of the LPF represented by the dimensions of **H** was varied from 0.25 to 1.0 in steps of 0.25. The results are shown in Fig. 1.

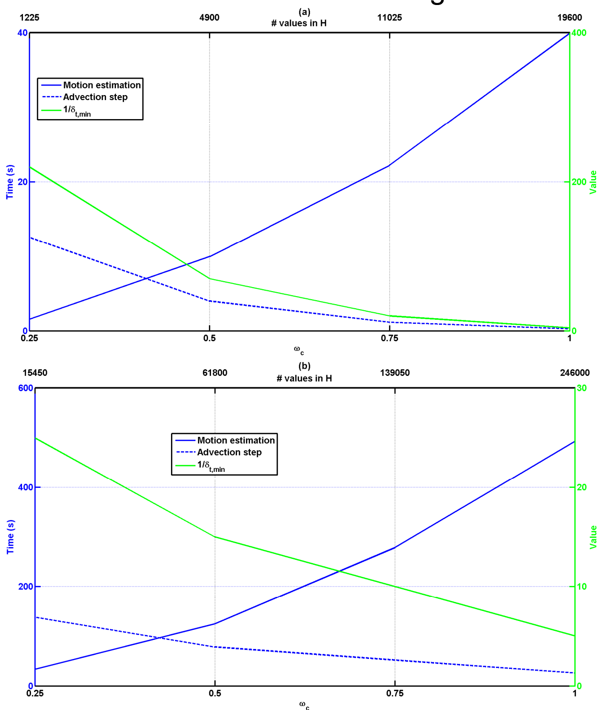

Fig. 1. Scalability and advection parameter characteristics considering a fixed data size and varying size of the model design matrix **H** for (a) CASA and (b) N0R data.

Fig. 1 shows that a smaller advection step size should be used to maintain convergence when estimating motion of larger precipitation scales, which generally propagate faster than smaller scales (Wolfson et al. 1999).

The second experiment considered data fields of different sizes and grid spacings (0.5, 1, 2, and 4 km for the CASA data and 4, 6, 8, and 12 km for the N0R data) and kept the cutoff frequency of the LPF fixed at 0.2. The results are shown in Fig. 2, which shows that a larger advection step size can be used with data that has been downsampled (and downsized) to lower resolutions. This likely illustrates the relative sensitivity of the advection method to higher resolutions of spatial extent and motion afforded by larger grid sizes with smaller grid spacings.

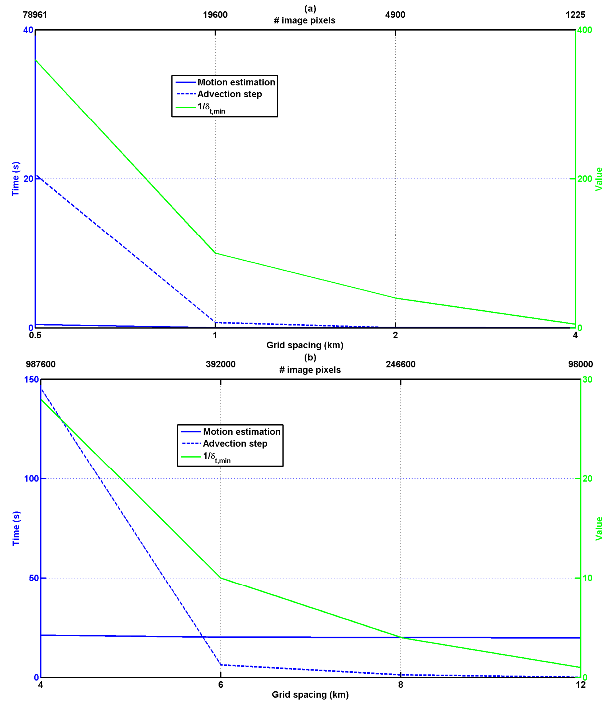

Fig. 2. Scalability and advection parameter characteristics considering a fixed size of the model design matrix **H** and varying data size for (a) CASA and (b) N0R data.

The results of both experiments show the nonlinear scaling behavior of the nowcasting model, suggesting that the model design matrix **H** should be truncated to facilitate reasonable computation times and the tracking of larger scales shown to be more representative of precipitation pattern envelope motion (Wolfson et al. 1999). These results also suggest an alternate advection scheme should be considered when using data projected onto large grids, with size dependent on the application requirements.

3. REFERENCES

Ruzanski, E., V. Chandrasekar, and Y. Wang, 2011: The CASA nowcasting system. *J. Atmos. Oceanic Technol.*, **28**, 640–655.

Wolfson, M., B. E. Forman, R. G. Hallowell, and M. P. Moore, 1999: The growth and decay storm tracker. Preprints, *Eighth Conf. on Aviation, Range, and Aerospace Meteorology*, Dallas, TX, Amer. Meteor. Soc., 58–62.

Acknowledgement. This work was funded by the NSF under grant number 0313747.