P13.1 An Automatic Tracking and Recognition Algorithm for Thunderstorm Cloud-Cluster (TRACER)

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1. INTRODUCTION

The detection, tracking and early-warning technique based on highly spatiotemporal weather radar measurements is one of the most important nowcasting techniques. Several methodologies were developed in published literature, however, the cross-correlation technique and centroid tracking technique are the two primary schemes. The former is based on first to divide the radar echo region into many blocks or cells, then to obtain the mean movement vector of the echo area by analyzing the maximum cross-correlations between a cell in the latest data field and the corresponding cell in the previous data field (i.e., Rinehart and Garvey 1978; Crane 1979). Its disadvantages are not able to accurately identify the borderlines of the tracked cloud clusters and to present the physical characteristics of the individual cells. The centroid tracking scheme is to first detect a single storm cell, then to locate its centroid position, volume and equivalent cloud area, and finally to analyze the evolution of this cell for tracking and prediction of its movement (i.e., Bjerkaas and Forsyth 1979; Austin and Bellon 1982; Rosenfeld 1987; Johnsoon *et al.* 1998). This scheme is focused on individual cell, while not pay too much attention to the cell merging or splitting during its life cycle and the overall characteristics of the cloud clusters. Some other schemes applied some kinds of combinations of these two basic techniques (i.e., Dixon and Wiener 1993).

The borderline correlation scheme developed in this study for automatic identification, tracking and short-term forecast of thunderstorm cloud clusters involves three major components: (1) detection of thunderstorm cloud cluster borderlines based on spatial distribution of radar measurements; (2) establishment of the ancestries of thunderstorm cloud clusters using pattern recognition and topology techniques; and (3) short-tern forecast and analysis of the cloud clusters using a linear extrapolation scheme. This system is named as the automatic Tracking and Recognition Algorithm for Thunderstorm Cloud-Cluster (TRACER). Preliminary results with the real-time weather radar observations on 23 April 2007 over Shenzhen of China indicate that TRACER could accurately identify, analyze, and predict various cloud clusters.

2. METHODOLOGY AND DATASET

The first important step of TRACER is to deal with the missing data because weather radar measurements often involve missing pixels that create big problems for detection of the cloud borderlines and tracking of the clouds. An “expending-shrinking” scheme is developed to process the missing data so that the overall cloud edge can be well defined in TRACER (Li *et al.* 2005). Then, a cloud cluster topological relationship (Zhou and Long 2004) has to be established in order to create the cloud cluster life cycles.

Six indices (i.e., Quad tree, Overlap, Size, External Rectangle Area, Overall Pattern

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Similarity, and Partial Similarity) are used to track cloud evolutions so that the cloud ancestries can be established. The quad tree index (Hearn and Baker 1997) is based on gradually dividing a 2Nx2N area into a gridded region with each grid for a single cloud cell. The basic idea is to divide a cloud area into four equal-sized sub-regions. Each sub-region could be further divided into another four sub-regions until the preset criteria are met or each sub-area is only for a single cloud cell. Preliminary results demonstrate this quad tree technique is quite efficient to identify similarities among many clouds. It is also the key index in tracking a cloud life cycle. Other indices are used to modify or improve the initial cloud detection with the quad-tree method. For example, the overall pattern similarity index is applied to deal with two clouds that have an overall similar shape but different detailed structures. Figure 1 presents three different cases in which has an overall similar pattern but difference in detail. This index can improve the accuracy of detecting cloud pattern similarities.

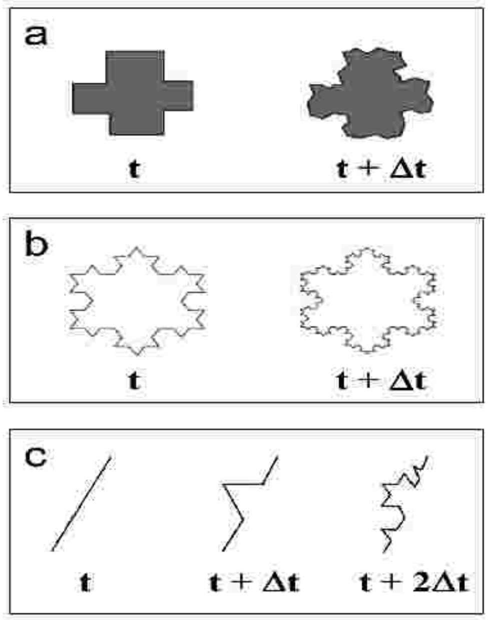

Fig 1: Schematic explanation of three cases in which each has an overall pattern similarity but different detailed structures at time t and t+Δt.

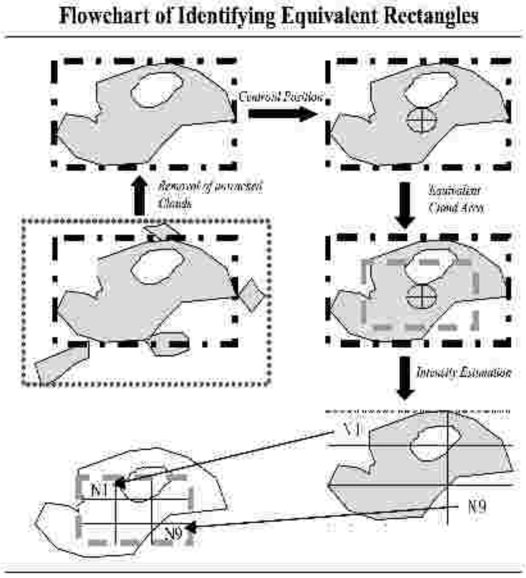

Fig 2: Flowchart of identifying equivalent rectangles.

The process of establishing the cloud life cycles will take a large computational power. In order to overcome this computational speed issue, a simplified approach for TRACER is developed by searching the equivalent rectangles. This process is illustrated in Fig 2., i.e., dividing the equivalent rectangle and the external rectangle into same grid patterns; and obtaining the cloud intensity at each grid. The principal idea behind comparison of the equivalent rectangles is that the spatial process of comparing rectangles is much faster than comparison of other irregular cloud patterns. Thus, it is first to determine whether the equivalent rectangles are similar before checking any other indices. If it passes this check, further indices are analyzed. Otherwise, the detection processes stop here. By doing so, the cloud pattern identification speed is improved dramatically. Another advantage of using the equivalent rectangle method is that these rectangles also carry directional intensity information.

Therefore, the cloud detection and tracking procedures could establish the cloud ancestries that are applied for cloud linear extrapolation nowcasting predictions.

3. RELIMINARY RESULTS

Working with a GIS system, TRACER has a strong user interface capacity, which can display properties of a cloud in terms of time, central intensity, moving speed by clicking a selected cloud on a computer screen. Using GIS information as the background condition, the future position of a cloud cluster in 15 minute, 30 minutes and 60 minutes can be easily displayed.

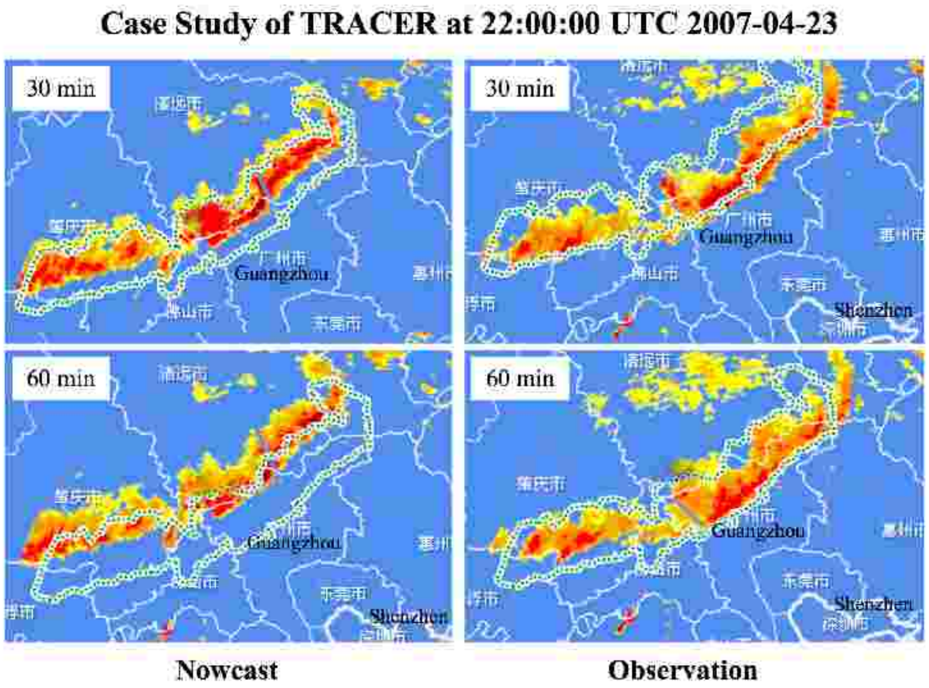

Fig 3: Case study of TRCAER's performance on a squall-line clouds at 22 UTC on 23 April 2007 observed by Doppler radar at Shenzhen, China. The left panels show its current cloud position, 30 minutes and 60 minutes forecasted positions (the dotted line indicates the predicted radar echo intensity great than 35 DBZ). The right panels overlap the corresponding nowcating cloud positions and the actually observed clouds.

Figure 3 presents preliminary results of evaluating TRACER for a squall-line weather system on 23 April 2007 observed by the Doppler radar over Shenzhen, China. It shows the squall-line clouds approaching Guangzhou from northwest at 22 UTC. The dashed lines indicate the 30 and 60 minutes forecasted positions of this squall line (the upper and lower left panel). The observed squall line positions are displayed on the right panels. It is evident that the TRACER's nowcast are reasonable. Similar results are found for other cases (figures omitted).

4. CONCLUSIONS

An automatic system named TRACER based on cloud borderline correlation technique for thunderstorm cloud cluster detection, tracking and forecasting is described. Preliminary analysis of TRACER on real-time cloud systems presents reasonable results. This system is now in experimental mode of real-time weather forecast at Shenzhen weather station.

TRACER has three key components: (1) *cloud identification and process*: The limited small sized areas of missing data are first processed; and then the combination of six different indices of quad-tree, overlap, size, extra-rectangle, overall pattern similarity, and locally partial similarity is optimally considered to effectively identify each cloud life cycle and their ancestry relationship. (2) *optimization procedure*: the rectangles of equivalent cloudy area are applied to speed up cloud detection and tracking processes, i.e., small sized broken clouds adjacent to a target cloud are removed and the cloud intensity and propagation information are stored at each rectangle so that estimation of the cloud moving direction, speed, size, maximum intensity location, and present status (intensification or weakness and expansion or shrink) will be improved; (3) *linear extrapolation forecast*: once a cloud life cycle and ancestry are established, its nowcast on cloud direction, speed and intensity can be generated based on the cloud momentum. Additional corrections are necessary in order to improve the forecast accuracy. In general, the slower speed is preferred when a large uncertainty is present. Cloud area variation is adjusted by the cloud expansion coefficient. Cloud intensity change is tuned depending on the cloud size, i.e., the mean intensity is used for small sized cloud cluster, while the evolution of cloud changes at each rectangle for a large sized cloud cluster is utilized to adjust the cloud nowcast.

It is worth to point out that different TRACER criteria are selected with different cloud clusters depending on their life cycles, sizes, and intensities for better performance. More real-time nowcast results are now accumulated to build up sufficient samples for a detailed statistical analysis so that a comprehensive assessment can be conducted to demonstrate TRACER’s strength and weakness.

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5. REFERENCES

Austin, G. L. and A. Bellon, 1982: Very-short-range forecasting of precipitation by objective extrapolation of radar and satellite data. *Nowcasting*, [K. Browning, Ed.], Academic Press, 177-190.

Bjerkaas, C. L. and E. E. Forsyth, 1979: Real-time automotive tracking of severe thunderstorms using Doppler Weather Radar. Preprints, *11th conf. on Severe Local Storms*, 573-576

Crane, R. K., 1979: Automatic cell detection and tracking. *IEEE Trans. Geosci. Electron.*, **GE-17**, 250-262.

Dixon, M. and G. Wiener, 1993: TITAN: Thunderstorm identification, Tracking, anaysis, and nowcasting – A radar-based methodology. *J. Atmos. Oceanc Technol.*, **10**, 785-797.

Hearn, D. and M. P. Baker, 1997: Computer graphics, C version, 2nd Ed. Original edition published by Prentice Hall. Inc., a Simon & Schuster Company, 360 - 361.

Johnson, J. T., P.L. MacKeen, A. Witt, E. D. Mitchell, G.J. Stumpf, M.D. Eilys, and K.W. Thomas, 1998: The storm cell Identification and tracking algorithm: an enhanced WSR-88D algorithm. *Weather and Forecasting*, **13**, 263-276.

Li, Zhen-Wei., Liu Bing-Quan, and Zhu Jian-Min, 2005: Design and Realization of Contour Extraction of liver CT images Based on Genetic Algorithm. *Computing Technology and Automation*. **4**, 102-104.

Rinehart, R. E. and E.T. Garvey, 1978: Three-dimensional storm motion detection by conventional weather radar. *Nature*, **273**, 287-289.

Rosenfeld, D., 1987: Objective method for analysis and tracking of convective cells as seen by radar. *J. Atmos. Oceanic Technol.*, **4**, 422-434.

Zhou, Min and Long Zhao-Hua., 2004: Efficient algorithm of extracting digital image contour based on MAS wavelet transform. *J. Chongqing University of Posts and Telecommunications*, **4**, 44-48.