Fuzzy Verification Test and Comparison of Three Types of Severe Convective Weather Nowcasting

X. Zhang , J.H.Dai*, B.P.Li, M.Mao

Shanghai Meteorological Service, Shanghai

Introduction

- It is difficult to forecast severe convective weather because of its characteristics of small scale and rapid development. Fuzzy verification methods developed these years can get different kinds of verification information at different spatial scales by using a spatial window or neighborhood surrounding the forecast and/or observed points. Five kinds of fuzzy verification methods (Upscaling, Minimum coverage, Fuzzy logic, Multi-event contingency table and Fraction skill score) were introduced into the verification operations of severe convective weather nowcasting of China Meteorological Administration (CMA).
- Based on the one-hour reflectivity extrapolation products of the CMA Severe Weather Analysis and Nowcasting(SWAN) system and NowCAsting and Warning System(NoCAWS) of Shanghai Meteorological Service, we verified three types of severe convective weather (thunderstorm cell, squall-line and systemic heavy rainfall) with fuzzy verification methods. Furthermore, nowcastings for three idealized severe convective weather models were built to test the performance of the above-mentioned methods.

Methodology

➢Fuzzy verification

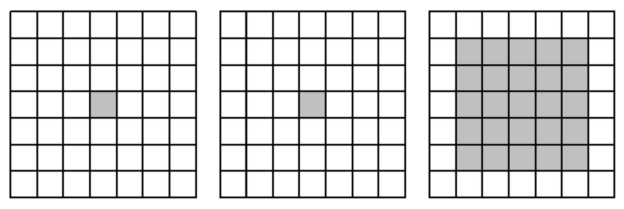
Fuzzy verification assumes that it is acceptable for the forecast to be slightly displaced and still be useful. The degree of allowable displacement is defined by a local neighborhood. The difference between traditional and fuzzy matching of forecasts is illustrated in the Figure below.

➢Forecast System

- CMA SWAN (Severe Weather Automatic Nowcasting system)
- SMS Nowcasting & Warning System (NoCAWS)

➢ Forecast Products

- One-hour reflectivity extrapolation products



The treatment of spatial scale with the same event by traditional and fuzzy verification methods. (a. observation, b. traditional verification, c. spatial scale fuzzy verification)

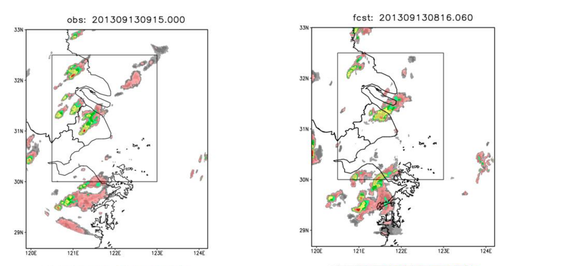
Fuzzy method	Description	Contributors
Upscaling	Useful forecast resembles the observations when averaged to coarser scales.	Zepeda Arce, Weygandt S. S. , Yates E et al.
Minimum coverage	Useful forecast predicts the event over a minimum fraction of the region of interest.	Damrath U.
Fuzzy logic	Useful forecast is more correct than incorrect.	Elizabeth E., Damrath U.
Multi-event contingency table	Useful forecast predicts at least one event close to an observed event.	Atger. F.
Fractions skill score	Useful forecast has similar frequency of forecast events and observed events.	Roberts and Lean

Results and Discussion

◆ Verification of three types of severe convective weather in Shanghai

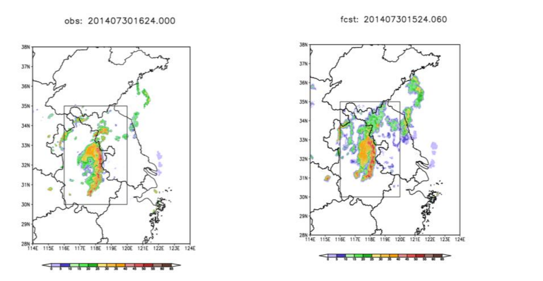
Based on the one-hour reflectivity extrapolation products of the SWAN and NoCAWS system , three types of severe convective weather were verified with fuzzy verification methods.

A local storm at September 13th ,2013.



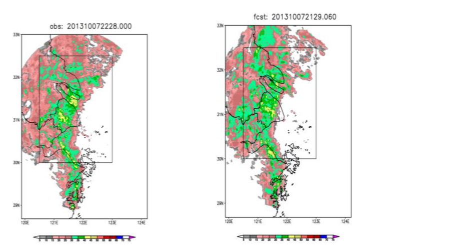
The radar reflectivity (unit: dBz) observation (left) and 1h extrapolation forecast (right) provided by NoCAWS during a local storm at September 13th ,2013.

A squall line at July 30th, 2014

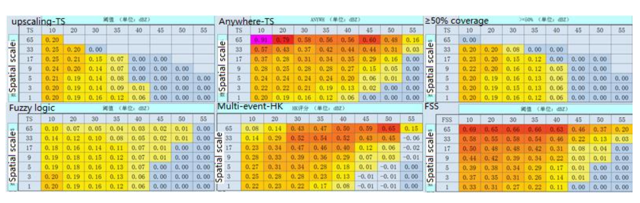


The radar reflectivity (unit: dBz) observation (left) and 1h extrapolation forecast (right) provided by SWAN during a squall line at July 30th, 2014.

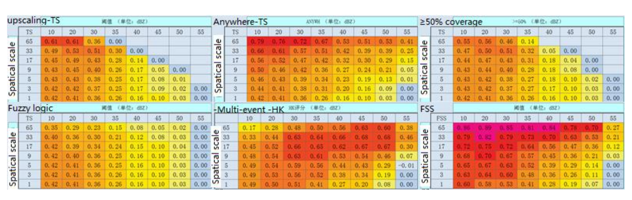
Typhoon Fitow at July 30th, 2014.



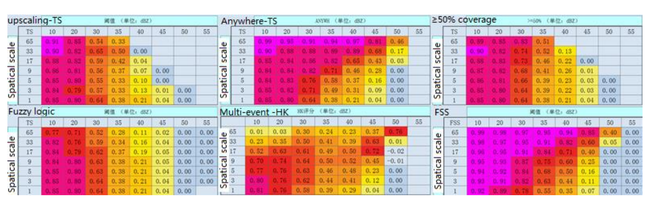
The radar reflectivity observation (left) and 1h extrapolation forecast (right) provided by NoCAWS during heavy rain of Typhoon Fitow at July 30th, 2014.



Fuzzy verification on 60 min NoCAWS radar reflectivity extrapolation forecast at 8:16 am, September 13th, 2013.



Fuzzy verification on 60 min SWAN radar reflectivity extrapolation forecast at 16:24 pm, July 30th, 2014.



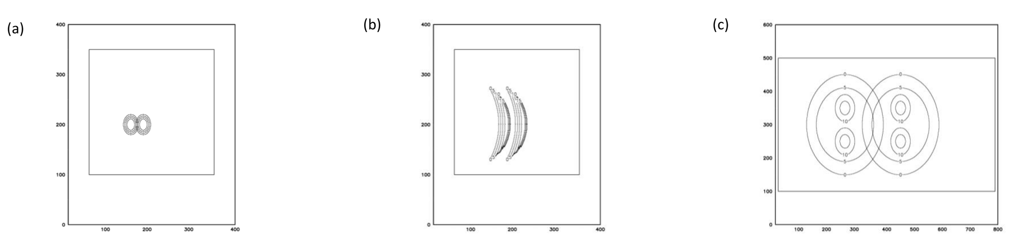
Fuzzy verification on 60 min NoCAWS radar reflectivity extrapolation forecast at 21:29 pm, October 7th, 2013.

- **Upscaling :** It is a method with observations and forecasts both averaged to lager scales. The verification results tend to be better with a higher threshold and a larger neighborhood due to the special smoothing.
- **Minimum Coverage:** For large scale precipitations the user need to choose a larger fraction standard and proper neighborhoods. However, better scores for squall-line and systemic heavy rainfall (typhoon Fitow) are got in the test, while a low score for the verification for thunderstorm cell with the minimum coverage method.
- **Fuzzy Logic:** The TS score decreases with larger threshold and neighborhood for the forecast of thunderstorm cell case. For the forecast of squall-line case the TS scores do not show obvious differences with small neighborhood sizes, but the TS scores begin to decrease when the neighborhood size is bigger than 33km. The verification test of typhoon Fitow as a respective of systemic heavy rainfall shows a similar result as that of the squall-line.
- **Multi-event:** The HK score decreases when neighborhood scale increases for low rainfall thresholds. However, the HK score has a positive correlation with neighborhood scale for high rainfall thresholds.
- **FSS:** The FSS scores has a positive correlation with neighborhood scales and a negative correlation with rainfall threshold. The scores have no obvious different rules in the verifications of three types of severe convective weather.

◆ Verification of three idealized severe convective weather models

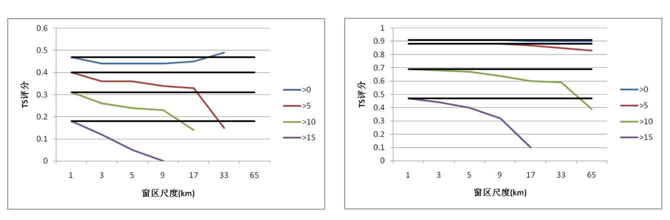
Nowcastings for three idealized severe convective weather models were built to test the performance of the above-mentioned methods.

Three idealized severe convective weather models

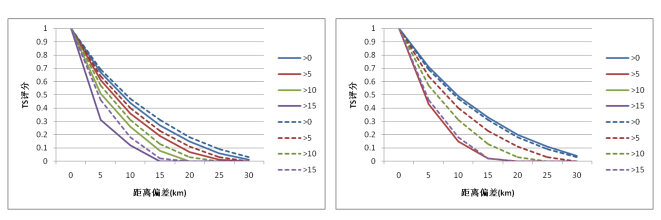


The ideal model diagrams indicate thunderstorm cell (a), squall line (b) and large scale heavy rain (c). Contour line is 0,5,10,15, and spatial resolution is 1 km. The rectangle area indicates the verification scope.

◆ **Upscaling:** isolated or severe convections can be decayed or missed with larger neighborhoods. Therefore, the upscaling method is applicable to large scale light precipitations.

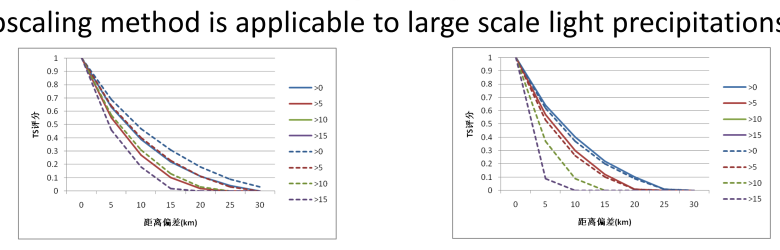


TS scores at different neighborhoods of thunderstorm cell (left) and large scale heavy rain (right) forecast with 10km distance bias. The black solid lines indicate traditional TS score, while the colored lines indicate upscaling method.



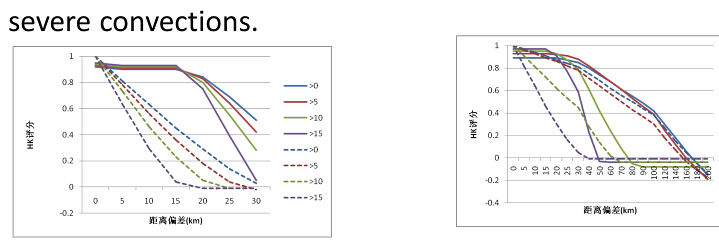
TS score of thunderstorm cell model at different distance bias for neighborhood of 5km (left) and 33km (right). The solid lines indicate fuzzy verification, while dash lines for traditional.

◆ **Minimum coverage:** isolated or severe convections can be decayed or missed with larger neighborhoods. Therefore, the upscaling method is applicable to large scale light precipitations.



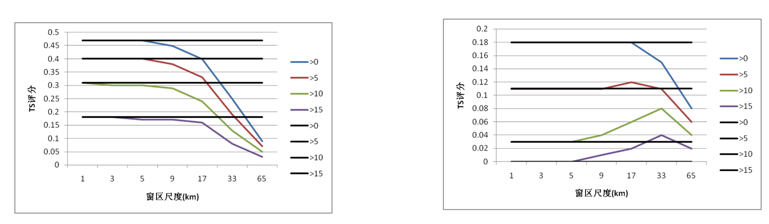
TS score of thunderstorm cell (left) and squall line (right) model at different distance bias for neighborhood of 33km with 50% coverage. The solid lines indicate fuzzy verification, while dash lines for traditional.

◆ **Multi-event:** It is meaningful for the verification of isolated or severe convections.

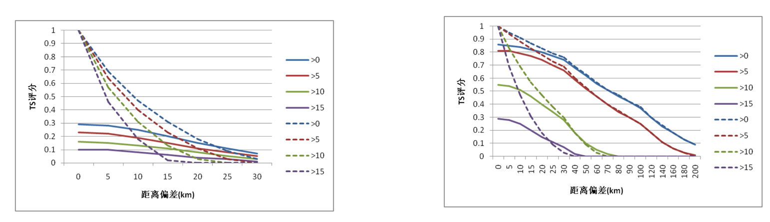


HK score of thunderstorm cell (left) and large scale heavy rain (right) model at different distance bias for neighborhood of 33km. The solid lines indicate fuzzy verification, while dash lines for traditional.

◆ **Fuzzy Logic:** isolated or severe convections can be decayed or missed with larger neighborhoods. Therefore, the upscaling method is applicable to large scale light precipitations.



TS scores of thunderstorm cell forecast at different neighborhoods with 10km (left) and 20km (right) distance bias. The black solid lines indicate traditional TS score, while the colored lines indicate fuzzy logic method.



TS score of thunderstorm cell (left) and large scale heavy rain (right) model at different distance bias for neighborhood of 33km. The solid lines indicate fuzzy verification, while dash lines for traditional.

Conclusions

➢Compared to traditional metrics with the strategy of "point to point", fuzzy verifications can give additional information in different scales and evaluation strategies, and evaluate forecasts more comprehensively and objectively.
➢Upscaling method is applicable to large scale light precipitations since isolated or severe convections could be decayed or missed with larger neighborhoods.
➢The fuzzy logic method has a wide application range from small scale to large scale precipitation. It is quite sensitive to the spatial distribution of rainfall and will get high scores at some scale neighborhoods for certain type of precipitations.
➢For minimum coverage method, better scores for squall-line and systemic heavy rainfall (typhoon Fitow) are got in the test, while a low score for the verification for thunderstorm cell with the minimum coverage method.
➢The Multi-event contingency table method is meaningful for the verification of isolated or severe convections.
➢The FSS scores has a positive correlation with neighborhood scales and a negative correlation with rainfall threshold. The scores have no obvious different rules in the verifications of three types of severe convective weather.
➢For the severe convective events with characteristics of high thresholds and small scales, the fuzzy verification methods including minimum coverage with low fraction, fuzzy logic and multi-event contingency table show more potential value than the traditional ones.

FURTHER INFORMATION
Dr. J.H. Dai,
Shanghai Meteorological Service, Shanghai
Tel: (86) 54896235, E-mail: djhnn@sina.com

Acknowledgements

- This work is based on the research of Dr Elizabeth E. Ebert, Zepeda Arce, Damrath U., Atger. F., Casati B., Weygandt S. S. Roberts. N. M., H. W. Lean, and Yates E., without whom we can't go this further.
- This research was supported by the China Public science and technology research funds projects of Meteorology. (Grant No. GYHY201006002)