Spatial Verification of high resolution precipitation forecasts over southern South America

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International Verification Methods Workshop Online 2020-IVMW-O

Motivation:

There is an increasing demand for high-quality precipitation forecasts of different scales and for different users. Thus, precipitation of high resolution convection- allowing WRF forecasts are verified.

Objective:

To evaluate the performance of precipitation forecasts from the Weather and Research Forecasting Model (WRF) over southern South America using the Method for Object Based Diagnostic Evaluation (MODE).

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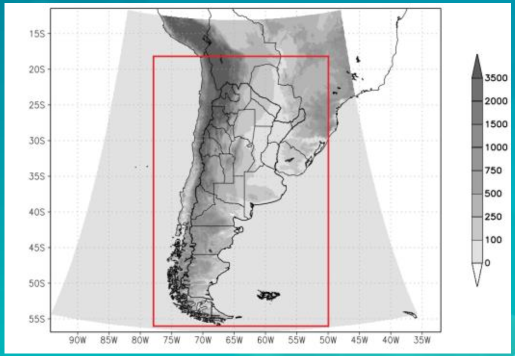
3 and 24-hour accumulated precipitation results from the WRF cycle for 6 UTC were analysed, for the two-year period from 2017 to 2018. In addition, the results of the spatial verification were complemented with the results of the point to point verification.

WRF domain



Verification domain

Data

WRF

- WRF-ARW version 3.8, operationally running at the National Meteorological Service of Argentina since 2017. 48-h forecasts, four cycles a day.
- Spatial resolution: 4 km.
- Temporal resolution: 1 hour.
- Convection-allowing forecasts (not parameterized).
- Initial and boundary conditions: GFS/NCEP hourly forecasts.
- 24 h accumulated precipitation: 6 to 30 hour lead time.

IMERG-F

- GPM derived product IMERG Final Run version.
- The estimates are calibrated with surface observation.
- Spatial resolution: 0.1 º.
- Temporal resolution: 30 minutes.
- Some studies in South America have used these precipitation estimates and the results were reliable (Hobouchian 2017). Furthermore, studies in other regions have shown that the additional calibration improves the estimation (Foelsche y otros,2017; Tan y otros, 2017; Wang y otros 2017).

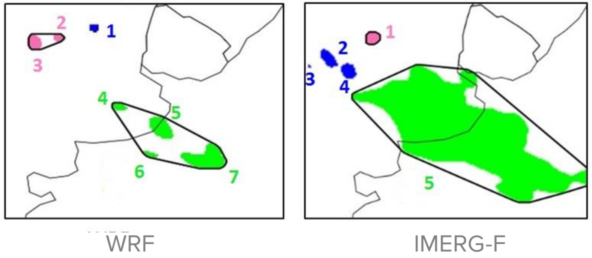
MODE (Brown et al., 2004; David et al., 2006)

http://www.dtcenter.org/met/users/

- Defines objects (regions of interest) in the forecast and observation fields.
    - Convolution Radius (R)
    - Threshold (T)
- Compares attributes of the objects in both fields and apply a fuzzy logic algorithmic → Total Interest (I)

The user must define a threshold for the Total Interest:

- matched objects: objects in different fields.
- merged objects: objects in the same fields.
- cluster objects.



- **Unmatched objects** (false alarms/misses) are in blue.
- **Matched objects** have the same color.
- **Clusters** have the same color and bounded by a black line.

Selection of R and T

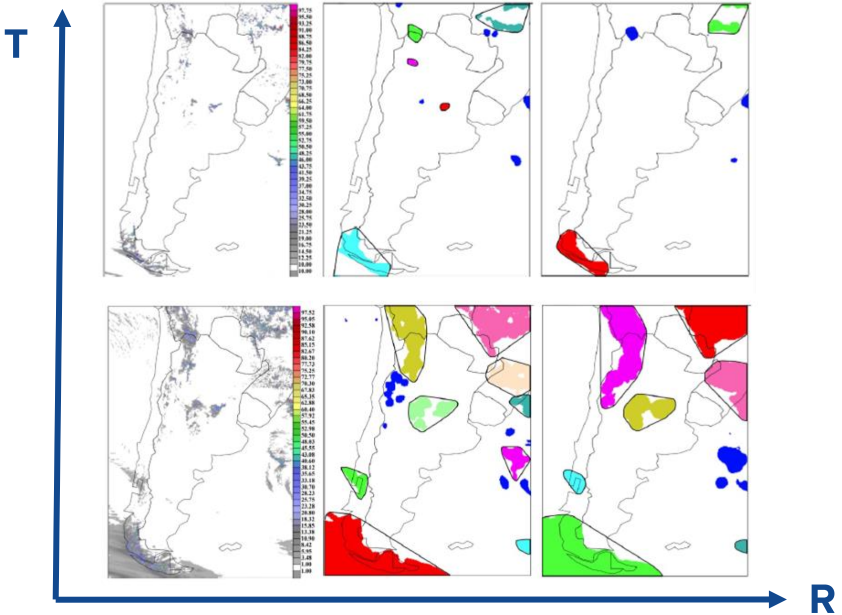
The study was focus on the mesoscale and synoptic systems verification:

I ≥ 0.7

(Davis et al., 2009; Clark et al., 2012; Bender & Ynoue, 2014; Yan & Gallus, 2016)

Challenges:

- To use the same value of R and T for all the verification domain and for all the period.
- Lack of previous studies about how to use MODE in the region of interest.



24-h accumulated precipitation of 19/02/2018 12 UTC: precipitation events in different regions of domain

For February 2018, several tests were ran to select threshold and convolution radius adequate values for 24 h and 3 h accumulated precipitation.

24-h accumulated precipitation:

- A threshold of 1 mm in 24 h allows us to identify if the event happened or not.
- A threshold of 10 mm in 24 h is associated to longer-period systems or intense precipitation.
- The size of the objects decreases as the threshold increases.

- Objects retain much of the spatial detail of the original field when the values of convolution radius are smaller.
- As the radius increases the smoothing becomes stronger. Some objects can't be identified (north and center of Argentina for T= 10mm)

Due to the significant value of intense precipitation forecasts, R and T adequate to evaluate forecasts of those events were selected:

- R=50 km & T ≥ 10 mm in 24 h-accumulated precipitation.
- R=50 km & T ≥ 3 mm in 3 h-accumulated precipitation.

Results - 24 h accumulated precipitation

- **Point to point verification**

24-h accumulated precipitation ≥ 10 mm

	Mean
BIAS Score	1.08
POD	0.45
ETS	0.27
FAR	0.54

- Bias Score ≅ 1 → good rain relative frequency forecast

- POD
- FAR
- ETS

} false alarms and misses

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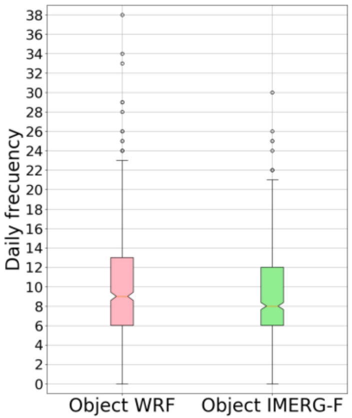
high resolution precipitation forecasts are susceptible to the double penalty

- **Mode verification**

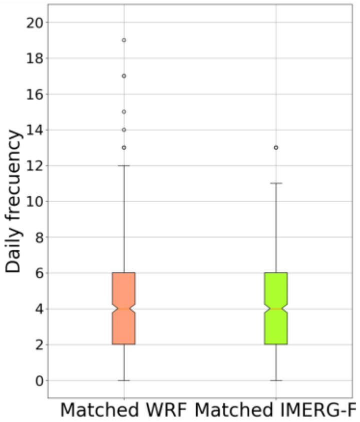


Total numbers of objects = matched + unmatched objects

R = 50 km; T ≥ 10 mm

The picture shows the daily objects frequency in WRF (Object WRF) and IMERG-F fields (Object IMERG-F), which include hits, false alarms (forecast field) and misses (observed field).

WRF overforecasts the number of precipitation objects.



Matched objects

R = 50 km; T ≥ 10 mm; I≥ 0.7

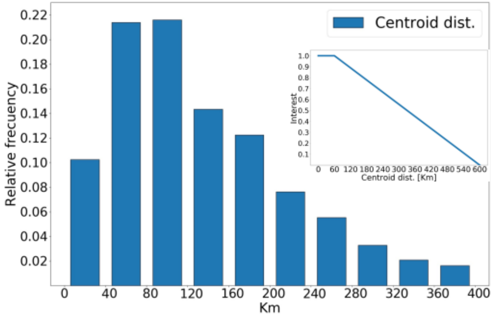
In comparison with the total number of objects, the number of matched objects daily decreases because some objects are false alarms events, misses events or some attributes objects have small interest and their total interest is lower than 0.7.

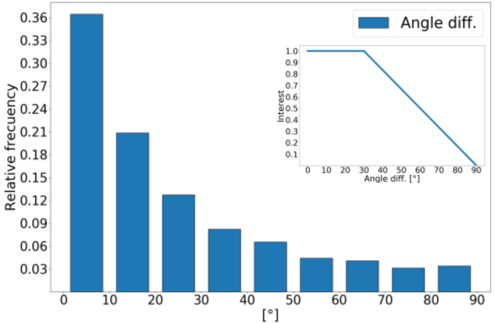
The frequency of forecast matched objects is similar to the frequency of observed objects.

Results - 24 h accumulated precipitation

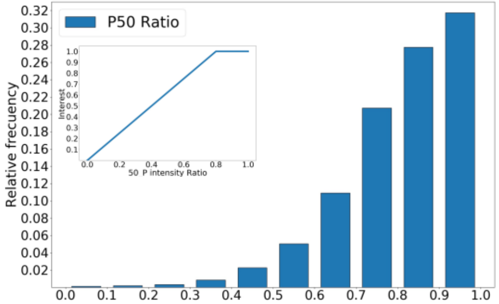
- **Mode verification**
  Cluster: R = 50 km; T ≥ 10 mm; I ≥ 0.7

Attributes for the matched clusters with the highest weights:

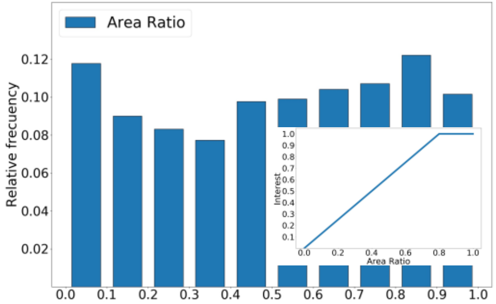




Small values of centroid distance and angle difference get small location errors.



High values of intensity ratio get small intensity errors.

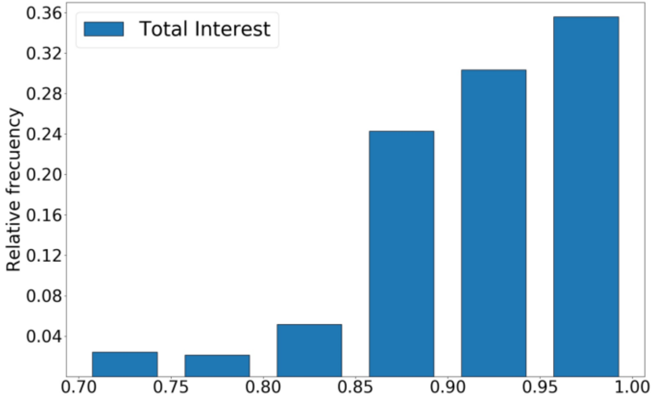


High values of area ratio get small coverage errors.

The histogram of Total Interest summarises the results of the previous attributes.

The most matched clusters have a total interest above 0.95:

- Short distance between the centroid of pair of clusters.
- Small differences between the orientation of pair of clusters.
- High intensity ratio between the pair of clusters.



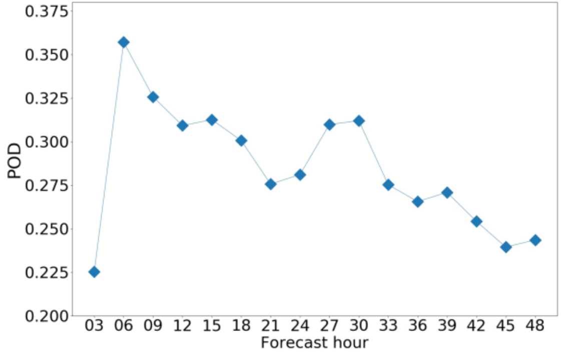
WRF has a high performance to forecast the location and intensity of clusters with R = 50 km and T ≥ 10 mm.

WRF precipitation forecasts show some coverage errors.

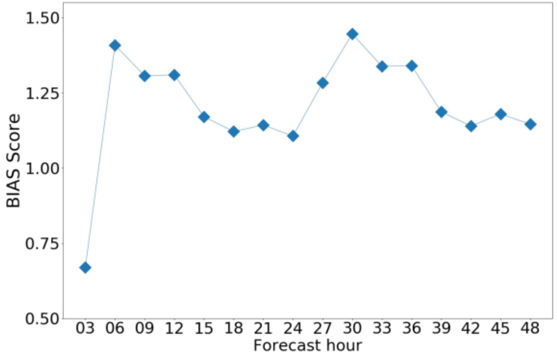
Results - 3 h accumulated precipitation

- **Point to point verification. 3-h accumulated precipitation ≥ 3 mm**
  Mean values from the two year period (2017-2018)

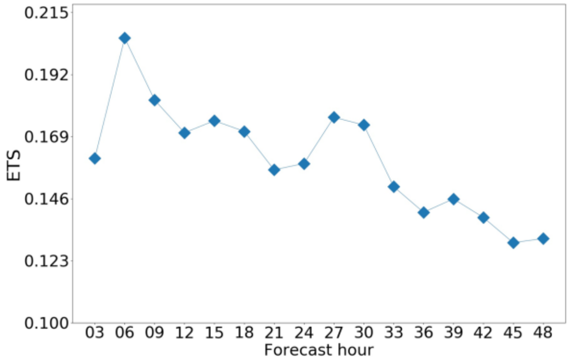
POD



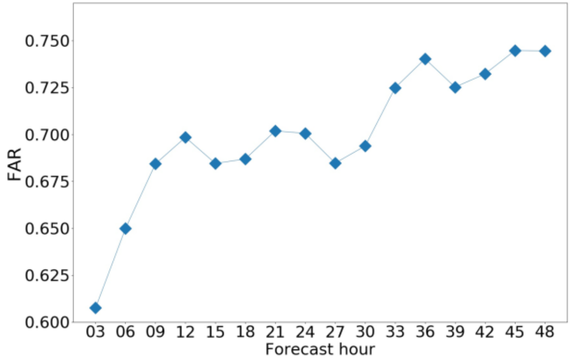
BIAS Score



ETS



FAR



- ETS and POD values decrease with lead time.
- WRF overforecast the precipitation events.
- False alarms ratio increase with lead time.

The verification scores show:

- Spin up in the first three forecast hours.
- The WRF skill to forecast the precipitation events decrease with lead time.

As the temporal resolution increases, the need to include spatial verification methods becomes more evident.

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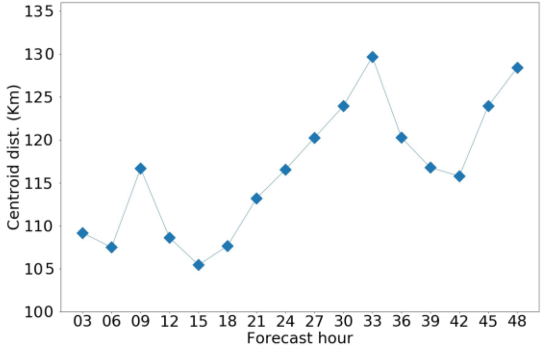
MODE

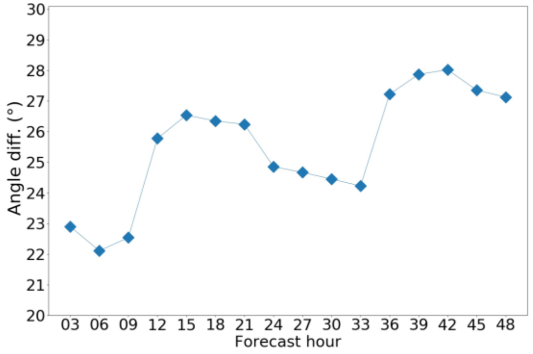
Results - 3 h accumulated precipitation

- **Mode verification Cluster: R = 50 km; T ≥ 3 mm; I ≥ 0.7**
  Mean attributes values for matched clusters, for two year period (2017-2018)

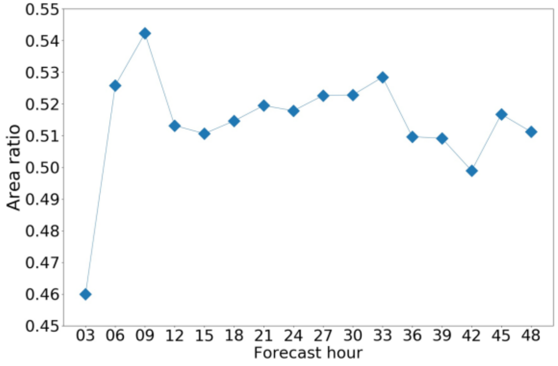
CENTROID DISTANCE



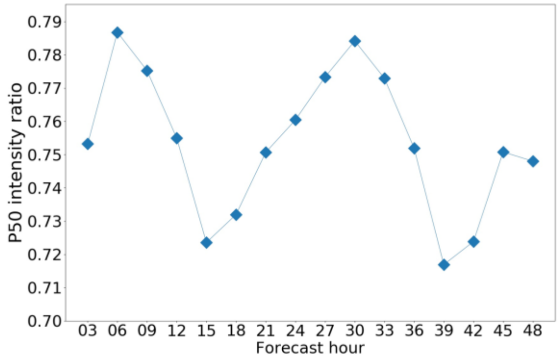
ANGLE DIFFERENCE



AREA RATIO



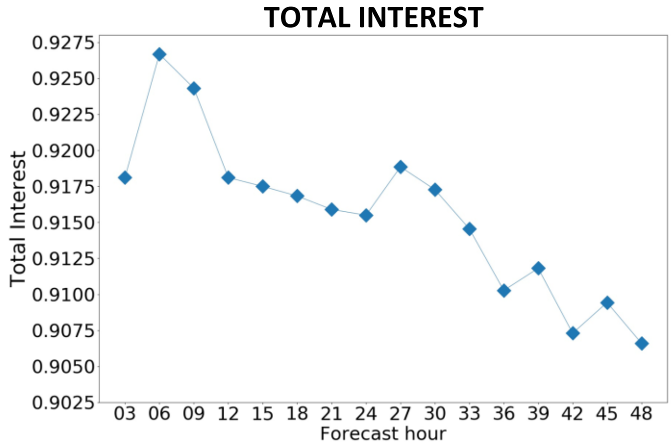
INTENSITY RATIO



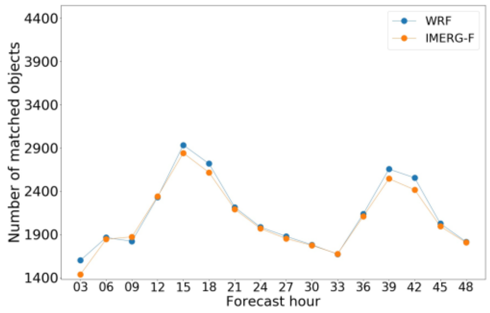
- The distance and the orientation difference between the matched clusters increase with lead time.
- Model spin up time is evident at the coverage precipitation forecast.
- The intensity ratio peaks during the morning.

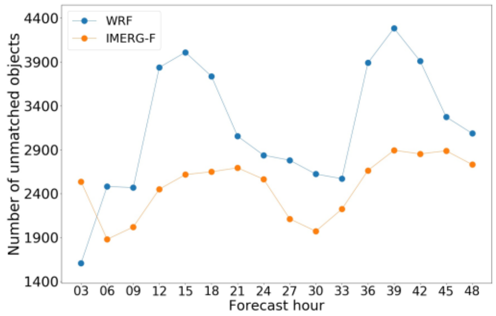
Results - 3 h accumulated precipitation

- **Mode verification Cluster: R = 50 km; T ≥ 3 mm; I ≥ 0.7**



Number of objects for the two year period





The histogram of the Total Interest is based on the matched objects, which take part of any pair of cluster. This result doesn't consider the unmatched objects.

Total interest values are higher than 0.9, influenced by:

- Centroid distance.
- Orientation difference.
- Intensity precipitation ratio.

MODE verification shows:

- Model spin up time is limited to the first three forecast hours.
- The WRF skill to forecast the precipitation remains high with lead time.

Conclusions

- MODE provides information about intensity, location and size errors of precipitation systems.
- Traditional verification provides a global idea of the precipitation forecast performance considering misses and false alarms rates.

MODE and traditional verification statistics are complementary verification methods.

- MODE results: WRF precipitation forecasts present some limitations to represent the coverage area. However, the forectats have small location and intensity errors.
- Point to point results: the results are influenced by the double penalty (misses and false alarms), which is more evident in studies with high temporal resolution.

Future works

- Although the values of R and T chosen were adequate for a global analysis, further analysis is needed to set these parameters according to a climatological fractional area, the season or using percentile intensity values.

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Ministerio de Defensa
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2020 | Año del General Manuel Belgrano