

Comparison of NWP based nowcasting (AROME) with classical system

I. Technical implementation

RC - LACE stay report

by Mirela Pietrisi

Supervisors: Christoph Wittmann, Florian Meier and Yong Wang

1 Introduction

The main goal of this stay was to assess the AROME Nowcasting system skills to accurately predict the precipitation field, which is considered one of the most difficult parameter to forecast due to its complexity. In order to do this evaluation, the MET (Model Evaluation Tools) package developed at NCAR, maintained and enhanced by the Developmental Testbed Center (<http://www.dtcenter.org/>) was installed on vguest computer at ZAMG. The MET package includes traditional verification approaches, spatial forecast and ensemble verification methods. It is modular and flexible which means that each tool can be run individually without running the entire set of tools.

The verification procedure entails the comparison of AROME Nowcasting forecasts with INCA analysis. Furthermore, the two nowcasting systems AROME and INCA forecast will be compared to determine the skill of high-resolution precipitation forecast.

2 Compilation of the external libraries

The required libraries for compiling the MET package are:

- netcdf library (if the versions V4.4.x are used, then the libraries should be compiled with `-disable-netcdf-4` option)
- GSL library (GSL-1.11)
- NCEP's BUFRLIB (MET is not compatible with the last version, V11.0.0, therefore the used version is V10.2.3)
- Cairo and FreeType libraries (for building MODE-Graphics tool)
- copygb utility for regriding GRIB data
- wgrib and wgrib2

The MET package was developed and tested on Debian Linux using GNU and PGI compilers (<http://www.dtcenter.org/met/users/>), but it can be build also on CentOS or openSUSE Linux OS. After the registration on the DTC web page, the two packs `met-5.1_bugfix` and `met-5.1_patches` were downloaded (<http://www.dtcenter.org/met/users/downloads/index.php>).

The version MET5.1 had some issues during the compilation that were solved in the newest one METV5.2 (released in August 2016). The encountered problems were related to the flex and yacc libraries. The `'config.tab.yy'` needed by the `'config.tab.cc'` doesn't exist. Also in the `config.log` appears the error `/met-5.1/lex.yy.c:1186: undefined reference to 'yywrap' /tmp/ccIs9WHZ.o: In function 'yylex'`. The solution was found in a previous `met_help` ticket.

After applying the `met5.1_patches` (http://www.dtcenter.org/met/users/support/known_issues), setting the environment variables in bash profiles and updating the two Makefiles from `vx_color.Makefile.in` and `vx_config.Makefile.in`, the compilation finished successfully.

In addition to the external libraries compiled before, the NCEP's GRIB2 C-Library compiled with JASPER, PNG and Z libraries was needed to enable `grib2` files. After unpacking the `g2clib-1.6.0-patch.tar.gz` package it fails to produce the configure file. To solve this, the makefile has to be edited like this:

```
DEFS=-DUSE_JPEG2000 -DUSE_PNG -D.64BIT_
```

```
INC=-I$HOME/jasper-1.900.1/include -I$HOME/libpng-1.2.56/include -I$HOME/zlib-1.2.8/include
```

```
CFLAGS= $(INC) $(DEFS) -fPIC
```

MET expects the library to be renamed like this: `libgrib2c.a`. This library is needed prior to the `libjasper.a`, `libpng.a` and `libz.a` libraries.

To configure the package the option `'CXXFLAGS = -D_64BIT_'` needs to be added in the Makefile. If this option is missing, the tools will be compiled, but the execution of `grid_stat` tool (with the `grib2` files) will fail returning the message: “out of memory” or “segmentation fault”.

3 Short description of MET package

The MET package consists in a set of verification tools which can be run from the command line:

- **Point-Stat** - matches gridded forecast to point observations and supports several interpolation options
- **Grid-Stat** - matches gridded forecast to gridded analysis field
- **Series-Analysis** - perform a grid-to-grid comparison over a series of fields, most commonly a time-series
- **Ensemble-Stat** - compare an ensemble of gridded forecasts to point and/or gridded observations
- **MODE** - perform an object-based verification approach to a gridded forecast and gridded analysis field
- **Wavelet-Stat** - spatial decomposition method to investigate how forecast errors varies with the length scale (apply an intensity-scale decomposition verification approach to a gridded forecast and gridded analysis field)

4 Files transformation

The MET package can handle gridded input data in one of three formats: GRIB1, GRIB2 or netCDF classic format. To be read it by the MET tools, the INCA analysis and INCA forecast files had to be converted into the format required by the software.

The first evaluation tests with the two nowcasting systems were done using the `Grid_Stat` tool.

The INCA analysis files transformation

The INCA analysis files conversion from text-based data files into netCDF format was done using the NCAR Command Language (NCL), V6.1.2 software (<https://www.ncl.ucar.edu/>). The built-in function `asciiread` was used to read the hourly ASCII files (the 15 min precipitation files were hourly cumulated) into CF-compliant netCDF. Further, the observations were interpolated into AROME grid using the built-in function `obj_anal_ic` (this function is available in versions starting with V5.2.0).

The interpolation method chosen was Cressman with the `rscan` factor varying from 0.028 to 0.018 (`rscan = (/0.028, 0.020, 0.018/)`)

The INCA forecast files transformation

The files are written in GRIB2 format with a Lambert native projection. Currently MET is not supporting this projection and the files should be transformed in a regular latitude-longitude projection. Thereby, firstly we tried to use `grib_api` external tools from ECMWF. Since the INCA forecast files are not written in a standard `grib2` format, there were encountered some problems related to unrecognized some keys (`StartStep` and `EndStep`) and when we did the remapping from Lambert native projection to a regular latitude-longitude grid.

Consequently, the CDO (Climate Data Operators) tool was utilized first to postprocess the `grib2` files and then to write them in a regular latitude-longitude grid.

The following commands were employed for conversion of the files:

- `$CDO/cdo splitsel,192,1 fic.grb2 fic2`
- `$CDO/cdo splitsel,4,0 fic2000000.grb2 out`
- `$CDO/cdo -timsum out0000$range$.grb2 out0000$range$.acc.grb2`
- `$CDO/cdo -f grb2 remapbil,my_targetgrid.txt out0000$range$.acc.grb2 tmp.grb2`

The file `my_targetgrid.txt` was configured as it follows:

```
gridtype = lonlat
gridsize = 70400
xname = lon
xlongname = longitude
xunits = degrees_east
yname = lat
ylongname = latitude
yunits = degrees_north
xsize = 320
ysize = 220
xfirst = 8.50000
xinc = 0.028000
yfirst = 45.500000
yinc = 0.018000
```

The masking verification region

To apply Met tools, it is necessary to define spatial verification regions. An example, used further for our scope, was to specify for verification a specific region defined by a polyline consisting of latitude-longitude points. Thereby, for our purpose, the **Gen-Vx-Mask** tool is applied to define the bitmapped masking region using as input a gridded model (AROME model) and one ASCII file. The output of the **Gen-Vx-Mask** tool is a NetCDF file containing a bitmap for the masking region (figure 1).

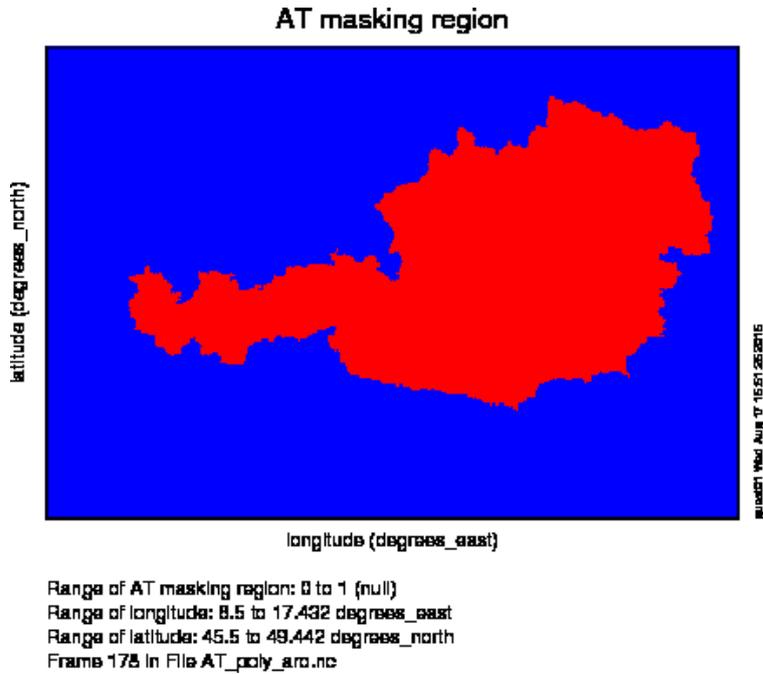


Figure 1: The output of the Gen-Vx-Mask tool showing the domain

5 Grid-Stat tool - the computation of statistics

The **Grid-Stat** tool provides both traditional and spatial verification. To avoid the double penalty problem, new spatial methods are used, as Fractions Skill Score - FSS (Roberts and Lean, 2007).

Configuration file

The settings of the Grid-Stat tool are controlled by the configuration file which is passed on the command line. Some options of this configure file are listed bellow:

```
field = [
  {
    name = "APCP";
    level = "A1";
    cat_thresh = [ >=0.1, >=0.25, >=0.5, >=1.0, >=2.0, >=4.0, >=8.0, >=16.0, >=32.0 ];
  }
];
```

where *cat_thresh* are the thresholds used for FSS computation.

Due to the fact that computation of FSS by applying bootstrap method is costly, the interpolation method applied is the *nearest grid point*. A square neighborhood of a particular size is defined as 1x1, 3x3, 5x5, 7x7, 9x9, 11x11 pixels centred around each pixel (Mittermaier, Roberts and Thompson, 2013). The fractions of occurrence of 1h rainfall accumulations with different neighborhoods sizes (*width*) are computed for the forecasts and observations and then these fractions are compared. The related settings in the configure file are as follows:

```
// Neighborhood methods ! For FUZZY verification
nbrhd = {
```

```

vld_thresh = 0.5;
width = [ 1,3,5,7,9,11 ];
cov_thresh = [ >=0.5 ]; proportion of observations in specified neighborhood which must exceed observation threshold
};

```

This method allows us to see how forecast skill varies with neighborhood size and can determine the smallest neighborhoods size that can be used to give sufficiently accurate forecast.

6 First trials

The FSS skill score was computed using a two weeks data sample (from July 2016). These preliminary tests were performed subsequent to finalize every technical steps required by regarding the Grid-Stat tool. The plots were realized by the means of the NCL graphical package.

The plots presented below prove that the Grid-Stat tool was successfully implemented and executed.

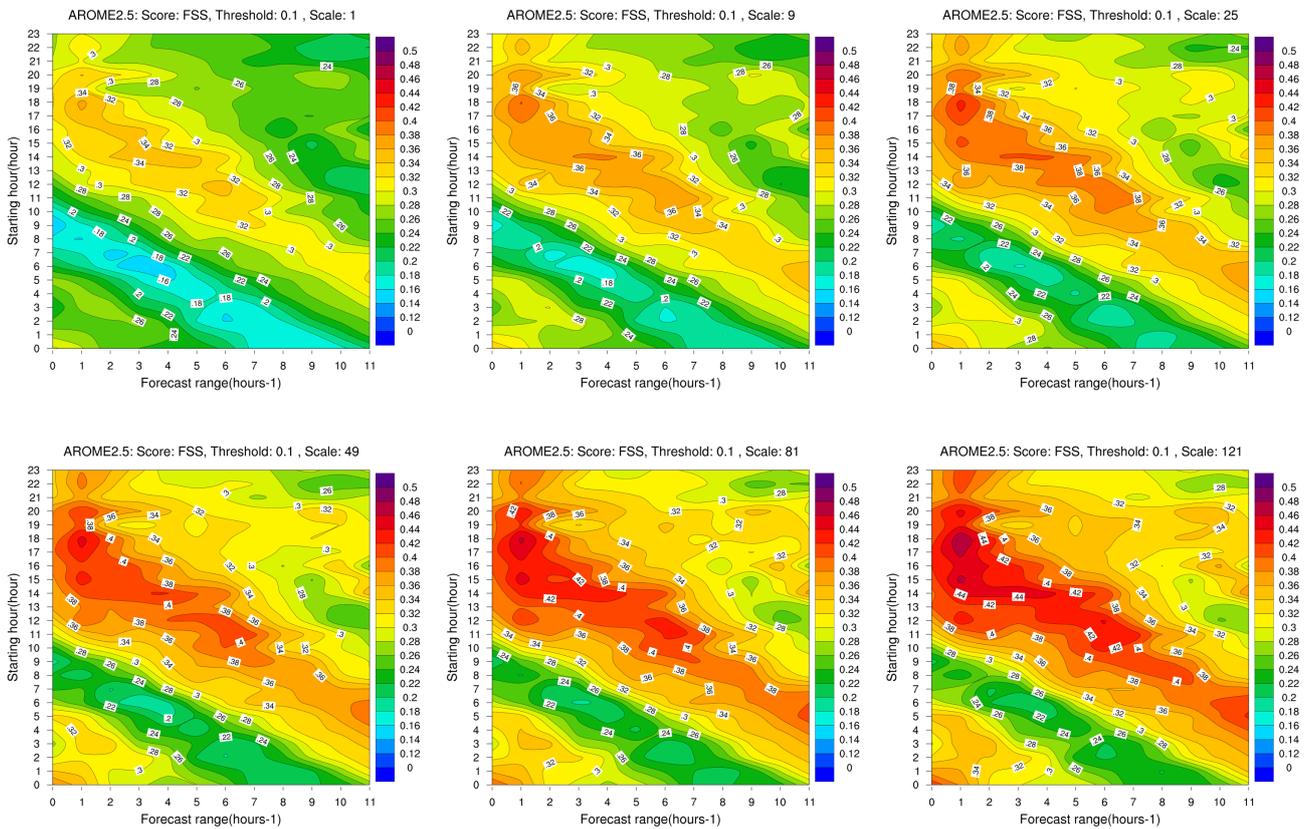


Figure 2: FSS for AROME Nowcasting, threshold ≥ 0.1 mm/h

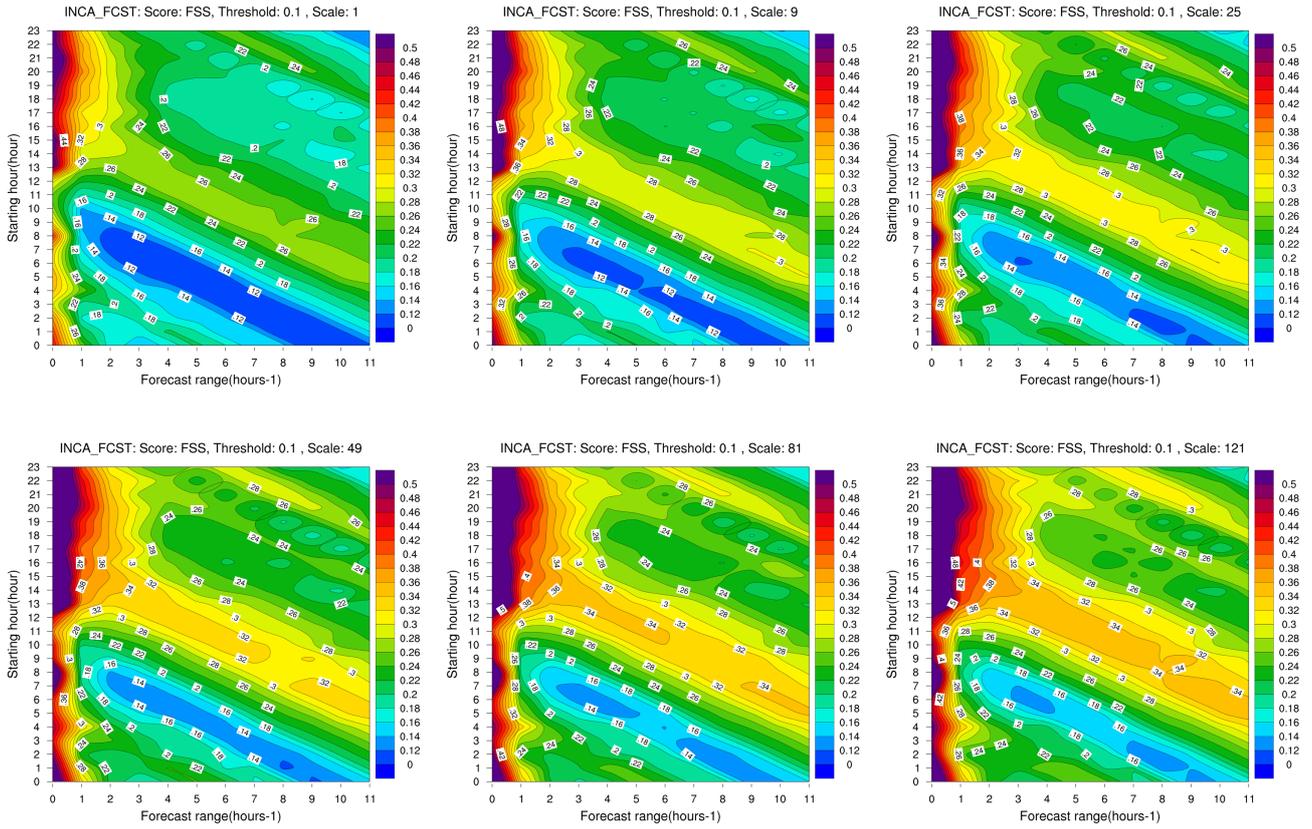


Figure 3: FSS for INCA forecast, threshold ≥ 0.1 mm/h

Difference Fraction Skill Score(FSS)-(INCA_FCST-AROME2.5) - 1h total precipitation. Threshold ≥ 0.1 mm/h

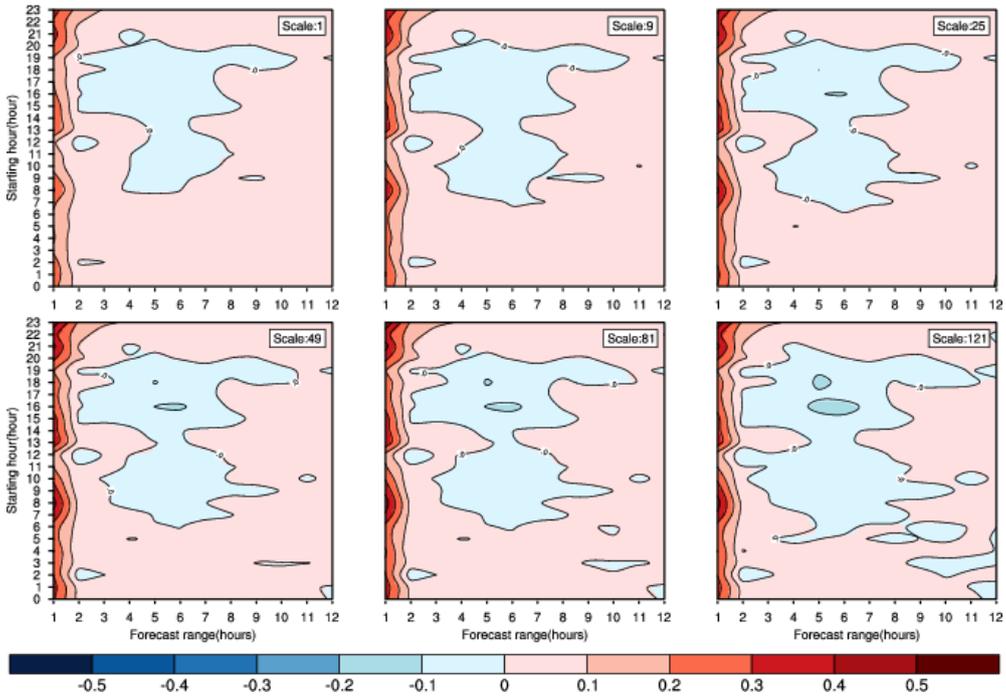


Figure 4: FSS difference between INCA forecast and AROME Nowcasting, threshold ≥ 0.1 mm/h

7 Conclusions

- the FSS approach can be used to evaluate the spatial and temporal variation in skill of both nowcasting systems (how the forecast skill varies with the neighborhood size)
- this verification approach can provide the scales where the data assimilation techniques adds most of the information (the benefits of data assimilation)

8 Outlook

- computation of FSS for the entire month (July 2016)
- computation of traditional scores
- testing MODE tool

Acknowledgments

I would like to thank to Yong Wang, Christoph Wittmann and Florian Meier for their constant help, advice and the entire support during my stay. Special thanks to my colleague from Romanian Meteorological Service, Otilia Diaconu, for fruitful discussion and help regarding the MET tools.

Model Evaluation Tools (MET) was developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center (DTC) through the grants from the National Science Foundation (NSF), The National Oceanic and Atmospheric Administration (NOAA), the United States Air Force (USAF), and the United States Department of Energy (DOE). NCAR is sponsored by the United States National Science Foundation.

References

- [1] Roberts NM, Lean HW. 2007. Scale-selective verification of rainfall accumulations from high-resolution forecasts of convective events. *Monthly Weather Review* 136: 78–97;
- [2] Marion Mittermaier, Nigel Roberts and Simon A. Thompson, 2013. A long-term assessment of precipitation forecast skill using the Fractions Skill Score. *Meteorol. Appl.* 20: 176-186, DOI: 10.1002/met.296