Python interface for object-oriented verification methods: SAL

Proyect 13: Postprocess advanced methods and presentacion of products of ensemble predictions for the short range

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(Madrid)
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OUTLINE

- New verification methods. Motivation.
- SAL (Structure-Amplitude-Location).
- Software design: python interface + fortran90
- Verified periods.
- Summary.
TRADITIONAL Vs. OBJECT-ORIENTED VERIFICATION METHODS

Traditional methods:
- **Measures-oriented**: matching forecast grid to an observation grid or set of points.
  - Counts of fc-obs pairs (y/n) → contingency table → verification scores (RMSE, POD, FAR, CSI, ...).
- No diagnostic information.
- No consistent with visual evaluation of forecast.
- Insensitive to differences in location, shape, and timing errors → **double penalty problem**

**Which forecast would you rather use?**

**HIGH RESOLUTION MODEL**
**LOW RESOLUTION MODEL**
**OBSERVATIONS**

hit rate=0 but A is better!!!

hit rate > 0 E right shape ???
DOUBLE PENALTY PROBLEM

HARMONIE (2.5km)  ECMWF T1279 (16km)  OBSERVATIONS

MSE = 8.9  S = 0.07  A = 0.07  L = 0.03
MSE = 6.8  S = 0.5  A = -0.3  L = 0.08
MSE, S, A, L = 0  perfect forecast

RMSE

Oct 2011  Jan 2013
NEW VERIFICATION METHODS:  
SAL (Structure-Amplitude-Longitude) 

• Object-oriented verification methods are especially suitable for:  
  high-resolution forecasts  
  highly localized and episodic phenomena → rainfall  

• Based on the identification of coherent and contiguous entities with characteristic attributes

SAL does not compare attribute values of individual objects searching for matches in obs and fc fields (e.g. MODE), but…

• Derives attribute values of individual objects.  
• Averages these values for obs and fc fields separately.  
• Calculates the difference between averaged values of the obs and fc fields.

S - shape and size  
A - total amount of pcp  
L - pcp distribution
SAL: PROCEDURE

1 ) Upscale observations to model grid
2 ) Search of objects in forecast and observation fields separately:
   - **Thresholding**: subjective task (visual inspection)
     \[ R^* = f R^{\text{max}} \]
     \[ R = P95 \quad f = 1/15 \]
   - **Clustering**: selection of grid points belonging to an object (8 neighbors).

3 ) Object properties:
   - \( R_n \rightarrow \) total pcp of the object
   - \( x_n \rightarrow \) MC
   - \( V_n \rightarrow \) scaled volume or total pcp of the object normalized by its max value

4 ) Field properties:
   - \( D \rightarrow \) domain-average pcp value in the field
   - \( V \rightarrow \) weighted mean of objects scaled volume in the field
   - \( x \rightarrow \) field MC
   - \( r \rightarrow \) weighted mean of the distance between objects MCs and the field MC.
   - \( d \rightarrow \) max distance between two points in the field

5 ) SAL parameters: normalized differences of field properties.
   - **Structure** \( \rightarrow \) size and shape of pcp objects
   - **Amplitude** \( \rightarrow \) accuracy of the total amount of pcp
   - **Location** \( \rightarrow \) accuracy of the pcp distribution and relative positions of objects in the field.
SSDM database

SSDM
models
leadTimes 006, 030

030 - 006

model grbFile
24hAccumPcp

SAL

SAL plot

Objects maps

PyDESIGN

filesAdmin

AEMET
pluvioTermo
Network

CRONTAB
monthly retrieval
lag: 4 months

validation

observations
obsHour 07:00

Csv → Geo conversion

upscaled
obs. grbFile

Grid template
(model file)

python
fortran90

filesAdmin

ssdm

models
leadTimes 006, 030

030 - 006

model grbFile
24hAccumPcp

SAL

upscaled
obs. grbFile

SAL plot

Objects maps

Grid template
(model file)

python
fortran90
Welcome to vpAEMET’s documentation!

Packages

- filesAdmin — Package with classes for file administration
- ssdm — Package with classes for SSDM database management
- verification — Package with classes to apply verification

Scripts

- Requirements for running scripts
- SAL — A brief description
- test_iSAL — Top-level script to run SAL verification

Indices and tables

- Index
- Module Index
- Search Page
A single verification

**False Alarms**

**Corner**

**IQR**

**Median**

**False Alarms**

**Missing Events**

**LOCATIONS**

**SAL PLOT**

**Model forecasts ...**

**S**: Structure
-2 ... 0 ... +2
objects
too small or
too peaked
Perfect
objects
too large or
too flat

**A**: Amplitude
-2 ... 0 ... +2
averaged
QPF under-
estimated
Perfect
averaged
QPF over-
estimated

**L**: Location
0 ... +2
wrong location of
Total Center of Mass
(TCM) and / or of
objects relative
to TCM

Wernli et al., 2008
SAL - A Novel Quality Measure for the Verification of Quantitative Precipitation Forecasts.
SAL RESULTS

PCP MAPS FOR EACH VERIFICATION

OBJECT MAPS

FORECAST

OBSERVATION

SAL RESULTS FILE

<table>
<thead>
<tr>
<th>date</th>
<th>coMOx</th>
<th>coMOy</th>
<th>coOBx</th>
<th>coOBy</th>
<th>ME(bias)</th>
<th>MSE</th>
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</thead>
<tbody>
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<td>20111001</td>
<td>346.65</td>
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<td>0.001</td>
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<td>186.42</td>
<td>102.23</td>
<td>298.55</td>
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<td>87.69</td>
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<td>0.007</td>
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<td>328.49</td>
<td>225.82</td>
<td>331.65</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</table>
HARMONIE (2.5km)

MODEL

OBSERVATION

S = 0.09
A = -0.09
L = 0.05

S = 1.3
A = 1.0
L = 0.3

S = -1.3
A = -1.5
L = 0.5

S = 1.3
A = -0.8
L = 0.5
## VERIFIED PERIODS

<table>
<thead>
<tr>
<th></th>
<th>ECMWF T799 (0.25°)</th>
<th>ONR (0.16°)</th>
<th>HNR (0.05°)</th>
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<tbody>
<tr>
<td>2007-2010</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
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<table>
<thead>
<tr>
<th></th>
<th>ECMWF T1279 (0.125°)</th>
<th>HNR (0.05°)</th>
<th>HARMONIE (2.5km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct 2011-Jan 2013</td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
</tbody>
</table>

XXXII Jornadas Científicas de la AME
GRID INTERPOLATION
Oct2011-Jan2013  HARMONIE (2.5km)

S changes slightly → objects in model field are smoothed due to interpolation

S = -0.09  S = 0.008
A = 0.03    A = 0.03
L = 0.13    L = 0.12
MODEL COMPARISON
Oct2011-Jan2013

ECMWF T1279 (0.125º)  HNR (0.05º)  HARMONIE (2.5km)

- S → improvement at higher resolutions
- A → not correlated with resolution.
- L → without significant variability with resolution

<table>
<thead>
<tr>
<th></th>
<th>ECMWF T1279</th>
<th>HNR</th>
<th>HARMONIE</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.8</td>
<td>0.5</td>
<td>0.006</td>
</tr>
<tr>
<td>A</td>
<td>0.14</td>
<td>0.5</td>
<td>0.04</td>
</tr>
<tr>
<td>L</td>
<td>0.10</td>
<td>0.17</td>
<td>0.12</td>
</tr>
</tbody>
</table>

1 False Alarm  1 Missing Event
MODEL COMPARISON
Oct2011-Jan2013: subdomain CVBM

CE T1279 (0.125°)

HNR (0.05°)

HARMONIE (2.5km)

SAL parameters present higher values but same tendencies as in the whole domain.
Seasonal variability 2011/12
HARMONIE (2.5 km)

<table>
<thead>
<tr>
<th></th>
<th>MAM</th>
<th>JJA</th>
<th>SON</th>
<th>DJF</th>
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</thead>
<tbody>
<tr>
<td><strong>HARMONIE (2.5 km)</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAL</td>
<td>-0.03</td>
<td>-0.06</td>
<td>0.002</td>
<td>0.06</td>
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<tr>
<td></td>
<td>0.11</td>
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<td>0.09</td>
<td>-0.07</td>
</tr>
<tr>
<td></td>
<td>0.11</td>
<td>0.14</td>
<td>0.12</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>HNR (0.05º)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAL</td>
<td>0.4</td>
<td>1.1</td>
<td>0.7</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>0.9</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>0.14</td>
<td>0.20</td>
<td>0.15</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>ECMWF T1279 (0.125º)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAL</td>
<td>0.8</td>
<td>1.0</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>0.24</td>
<td>0.5</td>
<td>0.009</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>0.10</td>
<td>0.10</td>
<td>0.11</td>
<td>0.14</td>
</tr>
</tbody>
</table>

03/06/2013
AEMET, Agencia Estatal de Meteorología
• **SAL software framework finished:**
  - Upscaling observations to grid models.
  - Retrieving forecast fields from SSDM AEMET database.
  - Providing SAL plots + objects maps for single verifications.
  - Supports Lambert conformal projection (gribApi 10.0) and rotated grids.
  - Allowing to generate SAL results for selected subdomains.
  - Code documented with Sphinx.

• **Comparison of forecast quality using SAL method:**
  - **2007-2010**: HIRLAM (HNR 0.05º, ONR 0.16º) and ECMWF T799 (25 km).
  - **Oct2011-Jan2013**: HNR, ECMWF T1279 (16 km), and HARMONIE (2.5 km).

• **SAL solves double penalty problem** and provides quantitative, detailed, and explicit information about different aspects of forecast performance; allowing fair comparisons between models of different resolutions.
CONTRIBUTIONS


• *Influence of targeted observations on short-term forecasts of high-impact weather events in the Mediterranean.* J. Campins, B. Navascués, C. Santos, and A. Amo

THANK YOU
**SAL**: measured aspects of forecast quality (I)

- **AMPLITUDE** \( A \)
  
  Normalized difference of the domain-average pcp values between obs and fc fields.
  
  Measure of **quantitative accuracy** of the total amount of pcp in the region.

  \[ A = \frac{D(R_{mod}) - D(R_{obs})}{0.5[D(R_{mod}) + D(R_{obs})]} \]

- **LOCATION** \( L = L_1 + L_2 \)
  
  \( L_1 \rightarrow \) Normalized distance between the CM of the obs/fc pcp fields
  
  First order indication of the **accuracy of the pcp distribution**

  \( L_2 \rightarrow \) Takes into account the average distance between the CM of the total pcp field and individual pcp objects → **relative positions** of objects in the field.

  \[ L_2 = 2 \left[ \frac{|r(R_{mod}) - r(R_{obs})|}{d} \right] \]

  Not sensitive to rotation around CM

\( A([-2,2]) \)

- \( A = 0 \) total agreement
- \( A > 0 \) model overestimates
- \( A < 0 \) model underestimates

\( 03/06/2013 \)

AEMET, Agencia Estatal de Meteorología
**SAL: measured aspects of forecast quality (II)**

- **STRUCTURE $S$**

  Compare the volume of the normalized pcp objects. $V_n = \sum_{(i,j) \in \mathcal{R}_n} R_{ij}/R_n^{\text{max}} = R_n/R_n^{\text{max}}$.

  Information about **size and shape** of objects.

  Individual object volume $\rightarrow$ total pcp of the object normalized by its max value.

  A weighted mean of all objects pcp volume is calculated for obs and fc fields.

  $$V(R) = \frac{\sum_{n=1}^{M} R_n V_n}{\sum_{n=1}^{M} R_n}.$$  

  $$S = \frac{V(R_{\text{mod}}) - V(R_{\text{obs}})}{0.5[V(R_{\text{mod}}) + V(R_{\text{obs}})].}$$

  $S \rightarrow$ normalized difference between obs and fc weighted mean volumes.

  **$S[-2,2]$**

  $S >> 0 \rightarrow$ **model predicts widespread pcp** but observations show small convective events

  $S << 0 \rightarrow$ **model predicts small and/or picked pcp** objects compare to observations
Seasonal variability 2011/12
HARMONIE (2.5 km)

MAM

\[ S = -0.03 \]
\[ A = 0.11 \]
\[ L = 0.11 \]

JJA

\[ S = -0.06 \]
\[ A = 0.3 \]
\[ L = 0.14 \]

SON

\[ S = 0.002 \]
\[ A = 0.09 \]
\[ L = 0.12 \]

DJF

\[ S = 0.06 \]
\[ A = -0.07 \]
\[ L = 0.14 \]

03/06/2013

AEMET, Agencia Estatal de Meteorología
Seasonal variability 2011/12
ECMWF T1279 (0.125°)

MAM
S = 0.8
A = 0.24
L = 0.10

JJA
S = 1.0
A = 0.5
L = 0.10

SON
S = 0.8
A = 0.009
L = 0.11

DJF
S = 0.9
A = 0.20
L = 0.14
Seasonal variability 2011/12
HNR (0.05º)

MAM

S = 0.4
A = 0.6
L = 0.14

JJA

S = 1.1
A = 0.9
L = 0.20

SON

S = 0.7
A = 0.4
L = 0.15

DJF

S = 0.5
A = 0.6
L = 0.14