A pattern recognition algorithm for early characterization of seismic clusters in Italy

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TOPIC: FORECASTING OF SUBSEQUENT STRONG EARTHQUAKE BASED ON SEISMIC PRECURSORS

1. DATABASE

Location of the earthquakes in Italy and surroundings from 1980 to 2014 from 2 catalogues:

1980-2004:
A 102,536 earthquakes catalogue proposed by Lolli and Gasperini (2006). It is a compilation obtained by integrating with uniform criteria different catalogues:
http://legacy.ingv.it/roma/ret/rms/bollettino/

2005-2015:

DATA SELECTION

• Clusters were selected by a windowing algorithm for cluster identification. In this work the “mainshock” is the first event with MS>4.5 in a cluster and “aftershocks” are the following events.
• The radius of the cluster (R) and its duration (T) depend on the mainshock magnitude (Mm). 106 cluster were detected.

\[ R = 1.421 \times 10^{-0.04 M_m} \] Uhrhammer (1989)
\[ T = 60 + 60 \times (M_m - 4) \] Lolli and Gasperini (2003)

• If after the “mainshock” another event with magnitude ≥ Mm-1 occurs, the cluster is labeled as being of type “A”; otherwise it is considered of type “B” (Vorobieva 1999).

1st selection:
N. of aftershock ≥ 3
85 clusters: • 30 A • 55 B

2nd selection: (8 only):
N. of aftershock ≥ 10
55 clusters: • 30 A • 25 B

3. METHOD

• In order to compare precursors performances we selected 10 different time periods (in days: [0, 0.25] [0.25, 0.5] [0.5, 0.75] [0.75, 1] [1, 2] [2, 3] [3, 4] [4, 5] [5, 6] [6, 7]) and for each time period we calculated the values of all the tested precursors.
• Due to limitations with completeness magnitude and to the fact that we can “forecast” a cluster as type A only if the strongest aftershock is after the selected end time period for precursors evaluation, the number of available patterns is low, ranging from 35 for the time interval (0,0.25) to 28 for the time interval (0,7).

4. RESULTS

• The performances change with time: for shortest time of observation they are poorer.
• This is related to both the lower statistics and to a higher percentage of A clusters.
• However, for longest times there may be confusion among classes.
• For example for precursor S the best performances are obtained for time less or equal to 2 days.

   • The pruning allowed to develop two leaves decision trees (a simple threshold).
   • The threshold changes with time.

   [Graph showing decision tree and pruning]

   - Precursors N, S, SLCum, Qcum, Q and N2 (N with N≥Mm-3) supply small classification errors.
   - The error on classification (Err) is the ratio of the number of wrongly classified on the number of available data
   - Constant feature corresponds to the hypothesis that all the clusters are B therefore Err corresponds to the percentage of A clusters.

   - North-Eastern Alps and Southern Italy are characterized by type B clusters.
   - Central Apennines and Sicily are prevalently of type A.
   - Po Valley has an intermediate behavior.
   - There is a general hint that the strongest magnitude mainshocks (Mm≥5.8) may correspond to A class clusters. The one with Mm25.8 belonging to the class B is the Irpinia one, in which strong aftershocks may be hidden in the mainshock due to the waveform superposition and the analogue recording in the 1980’s. Friuli earthquake cluster in 1976 (Mm=6.4) was of type A. A larger dataset must be used to verify this result.

   - The depth distribution of mainshocks is related to the differences in magnitude between mainshock and subsequent strong earthquake, but the quality of the catalogue depth estimation in the early years is too low to detect it.

   - The previous tree after pruning

   - An example of decision tree for 3D classification: criteria are decision nodes: rectangles are leaves.