



Veðurstofa Íslands Internal Report

Anne Choquet

The use of a Geographic Information System (Arc/Info, version 7) for avalanche purpose in Iceland

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Study of avalanche dynamics with the aim of mapping risk areas, training in the construction of models of natural phenomena.

(Acronym : TAMAM)

The use of a Geographic Information System
(Arc/Info, version 7) for avalanche purpose
in Iceland

ANNE CHOQUET

Preliminary report, made for the Human Capital and
Mobility meeting of the 25 June 1996

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The Icelandic conditions

The past year has been very disastrous in Iceland concerning avalanches. Especially the two accidents at Súðavík and Flateyri, killing 14 and 20 people respectively which is very high considering the small number of Icelandic people (267 809 inhabitants).

As a result of this, the Avalanche Division of the Icelandic Meteorological Office (IMO) has grown very rapidly. The IMO has now been given the responsibility of setting up the hazard zoning and the evacuation plans all over the country. We could compare that to the French situation ; the IMO has to deal with the research part as the Cemagref and the practical job (hazard mapping, public relations with local people..) as the "Restauration des Terrains en Montagne". The IMO also has to decide the extent and timing of the evacuations. This winter, the lack of snow gave a relief and allowed the setting up of the evacuation plans.

Of course, the help and advice from different countries is welcome. Icelanders are trying to work as much as possible with people abroad such as the Norwegian, the Canadian, the French, the Swiss, the Italians...

My work in the IMO should be considered, as such a cooperation.

Introduction

A Geographic Information System, Arc/Info (version 7.03) has been acquired for the Avalanche Division. The aim of my job is to set up the way to use it and to make it useful for the future. That means, at first, to set up the avalanche mapping, but also, work out the 3-dimensional possibilities to help in the avalanche modelisation, establish the link with the Database (Ingres)... Later on, the idea is to use Arc/Info as a help for the avalanche forecasting, which means that it should be linked with the meteorological data. The Avalanche Division would like to be able to compare the present meteorological conditions (taking also in account the previous days) and find the most similar day in the past to know if avalanches happened then. This would have to be complemented with a snow stratigraphy analysis. The program is supposed to take much more than one year, but I have to take into account those needs from the start.

Until now, most of the time was spent setting up the map prototype and choosing a way to store the geographical data. Hnifsdalur is our testing area for mapping. On this zone, we have tested the possibilities of the *regions*, new feature class in the version 7 of Arc/Info (as line, polygon, point). I have worked on other villages as well, to make sure that Hnifsdalur is really a representative area. In the Avalanche Division, there is one person responsible for each community. So by starting the work for other communities I have the opportunity to explain how to use Arc/Info to digitize the data, and to show how the maps will be made. One of the priorities in the avalanche division, concerning my work, is to make people used to this new tool, to ensure that it will still be in use when I will leave Iceland. It is quite obvious that people will avoid using such a new tool, as long as they have to spend more time and energy than without it. Thus, it is very important to overcome this initial stage of getting acquainted to the tool.

I also consider it a part of my job, to inform the Icelanders about the French knowledge. It can consist of finding some articles about a subject, or to establish contact with the French expert.

The files structure

The software Arc/Info has been set on a Digital Alpha UNIX Workstation. The first step has been to consult each file, describing the contents and trying to find a better way to name it and rank it. The fact is that many files have been imported from another company (HNIT) and that none in the IMO really knew about their content. It explains how much time consuming this part of the job was. Nevertheless, it was for me a way to know more about the available *coverages* (in the Arc/Info meaning : layer of information) we have to make the avalanche maps.

Until now, those imported covers from HNIT, which we may use as *backcoverages*, were really heterogeneous. This could give some troubles for the IMO as far as we would like to produce the same kind of map all over the country. For that reason, Gilles Borrel (from Cemagref, France) and Magnus Már Magnusson (leader of the Avalanche Division) began during the summer 1995 to set up the future *coverage* content, as it should be made by HNIT in the future. These imported *coverages* have been renamed (using similar name when the content is similar) and classified.

Figure 1, shows the new architecture. Under GIS, our superdirectory for Arc/Info, we have one *workspace* (it is a directory, in the Arc/Info language), for each community. If there are several villages in this community, we find other *workspaces* underneath. In those *workspaces*, are the *coverages* concerning the area.

The *coverages hus* (houses), *strnlin* (limit of the shore), *elpoints* (elevation points), *hlin* (elevation lines), *vatnafar* (hydrology), *samg* (roads), *mannv* (human constructions)... are the imported ones and contain different levels of information. They will be use as background for our maps.

The other *coverages snjfl-80, snjfl80-85, snjfl85-90, snjfl90-95, snjfl-95, hldsnojfl-95...* are the ones we are making in the Avalanche Division.

Storage within the coverages linked with the Database

Another part of the job was to define how we want to store the geographical information concerning avalanches. The avalanches will be digitized for each area. Until now, neither the Database, nor the geographical data in Arc/Info are ready. Nevertheless, for the Database as for Arc/Info, we are setting up everything taking into account the future link.

I chose to split the avalanches in 5-years *coverages*. For instance, the *coverage snjfl85-90* will contain all the avalanches occurred between 1985 and 1990 (a year here is always supposed to begin on the 1 August and to end the 31 July). This choice was made to have clear *coverages*, were it will be easy to distinguish the different avalanches. Usually, when we go farther into the past, there are fewer records. Thus we stop splitting those data into 5-years *coverages*. For instance, for Hnífsdalur, the *coverage snjfl-80* contains all the avalanches occurred before the 31 July 1980.

In those coverages, we are using one *region* (Arc/Info meaning) for each avalanche event. The *region* possibilities have been studied with the help of a trainee, Sandrine Sanchez, from the "Maitrise Science et Technique de la Montagne" in Chambéry, University of Savoie, France. She stayed at the IMO for one month, last January. The *region* possibilities appear to be really useful for the avalanche purpose. It allows to have avalanches recognized as an entity (made with several polygons) which can easily be selected and highlighted in Arcedit. We can use one of the *items* to select it, as the avalanche number, the date, the type... and there will even be more possibilities once Arc/Info will be link to the Database. Those avalanches identified as *regions* can also be moved really easily to other *coverages* or *subclasses* (using the commands *PUT* or *COPYFEATURES*).

Each *region* (so, each avalanche) can belong to 3 different *subclasses* that are called "certain", "certainin" (for certain-inaccurate) and "uncertain". The accuracy of the data will determine in which *subclass* the avalanche is. Further information will be given in the next paragraph dealing with the legend. *Subclasses*, as *regions*, have been introduced in the version 7 of Arc/Info. A *coverage* containing *regions* may have several layers of information, and those are the *subclasses*.

Figure 2 explains the organisation within each cover. The coverage contains 3 subclasses, in which the avalanche events are drawn as regions.

Choice of the legend

At the beginning, as I had been working only with Hnifsdalur, there were 2 different kinds of data. The avalanche was either wellknown ("certain"), or not ("uncertain").

When I began to digitize the data for Neskaupstaður, with Svanbjörg H. Haraldsdóttir, responsible of this area, it appeared clearly that the category "certain" and "uncertain" had to be defined more precisely, for two reasons. At first, we had to be sure that everyone in the office would put a given avalanche into the same category (certain or uncertain). Then, the legend of the map had to be made clearer for a better understanding. A review was necessary to ascertain all the kinds of data we would get and use for the mapping. In Iceland nowadays, the data is recorded by local snow observers. They measure and map each avalanche event and send a report to the IMO. In addition, there are older data that we want to use. Considering all the available data, it was decided that 3 categories would be necessary and they will be indicated in the legend as such :

"- Outlines of avalanches are certain.

Outlines of avalanches are measured or mapped with good accuracy by a contemporary.

- Outlines of avalanches are inaccurate.

Outlines of avalanches are mapped by a contemporary or according to reliable sources, but the outlines may be inaccurate.

- Outlines of avalanches are uncertain.

Outlines of avalanches are mapped according to uncertain sources."

It is more cumbersome to deal with 3 than with 2 classes, but on the other hand, this choice seems to fit better to the Icelandic data and permits us to distinguish data which should not be mixed, because their level of accuracy is clearly different.

Once this legend had been chosen, it was necessary to add one subclass in each coverage and to put the corresponding avalanches in it. It has been a way to test how handy it was to work with *regions*. One more time, this work was made with our training area, Hnifsdalur.

The avalanche division will try to implement the French method of photointerpretation and if this is successful, a fourth subclass will be necessary.

The map

Before making a map-prototype, we had to define the exact information we wanted this map to display.

The Icelandic avalanche map, as the Carte de Localisation Probable des Avalanches (CLPA) in France should display a clear information to be easily understood. So, as for the CLPA, it was chosen to show the maximum extension of the avalanche events without distinguishing each avalanche path. This map should be considered as historical, and not a hazard map. It can only answer the question "Does the IMO know of avalanches occurring in this place?". To avoid misunderstanding these sentences will be displayed on the map :

"The map shows the maximum extent of recorded avalanches. Neither frequency nor velocity is depicted on the map."

"The map only shows the extent of known avalanches. If an avalanche is not shown on the map it does not mean that the place has never been overridden by an avalanche."

Until now, it has not really been decided to whom the map is supposed to be shown. It is sure that this document should be available for the local snow observers. The rescue teams, which play a big part in Iceland, may have access to this document as well. It should be clear that the showing, selling or giving of this map can not be made without an explanation. In France, the main problem was that people used this map as a hazard map. To avoid the spread of this dangerous misunderstanding, it was decided that the CLPA will not be a public document in France... neither should this map be in Iceland, in my opinion.

Organisation of the data on the map

The *coverage snjfl-95* is made by adding all the 5-years coverages (+ *snjfl-80*) ; it contains all the avalanches we know. This *coverage* is very crowded but is necessary to have, before erasing all the limits and get the maximum extension.

As mentioned before, there are 3 kinds of data ; certain, certain-inaccurate and uncertain. The map should make this distinction as well, but, we want the accurate information to be shown with more priority than the inaccurate one. For a better explanation, [figure 3](#) shows how we would do for 2 layers of information : certain and uncertain. With one more layer (certain-inaccurate), the process is still the same.

The *coverage hldsnojfl-95* is the cover that we are using to make the map. As [figure 3](#) explains, the maximum extent of the certain (c) data is laid on the maximum extension of the certain-inaccurate data (not shown), which is laid on the uncertain avalanches (u). When there is only one kind of data (as shown in (a) and (b)), we drop all the limits within the different avalanche path. When there are several kinds of data (as shown in (c) and (d)), the limits of the most accurate data are kept.

The Arc/Info process

Once the composition of the map was decided, the Arc/Info process was defined as describe below.

First, to gather all the 5-years coverages, the UNION command was used. This Arc command adds two different coverages together. We had to make intermediate coverages (*snjfl-85*, *snjfl-90*) to be able to add *snjfl-80*, *snjfl80-85*, *snjfl85-90*, *snjfl90-95*. The final map gathering all those *coverages* is called *snjfl-95*. [Figure 4](#) sums up the exact process. I will not give here further information about the UNION command, but I will just specify that we use the "nojoin" specification to have fewer *items* copied in the *Polygon Attribute Table (PAT)* of the new cover. This would have taken memory and as we are using *regions*, we use the *PATsubclass* as a complete *Attribute Table* with all the *items* we need.

The next step is to make the *coverage hldsnojfl-95* using *snjfl-95*.

Hldsnojfl-95 should contain only the maximum extension of the avalanche paths and the data should be organized as was defined in the previous paragraph.

For that, we needed to build 3 coverages with the respective maximum extensions :

- Snjfl-u*, will contain the maximum extension of the uncertain avalanches
- Snjfl-i*, will contain the maximum extension of the certain-inaccurate ones
- Snjfl-c*, will contain the maximum extension of the certain avalanches.

This has been done with the REGIONQUERY command. In each of those new coverages (*snjfl-c*, *snjfl-i* and *snjfl-u*), we have now, only one *subclass* (called max) and one *region* (with discontinuous components because the avalanches were not necessarily overlapping).

Then, we put the coverage *snjfl-i* on *snjfl-u* and keep the limits of *snjfl-i*, as explained in (c) and (d) of [figure 3](#). For that, we use the UPDATE command and the resulting coverage is called *snjfl-ui*. The specification "keepborder" allows to keep the limits of the "strong" *coverage* (here, *snjfl-i*). We reuse the UPDATE command to lay *snjfl-c* on *snjfl-ui* and we obtain the last one : *hldsnojfl-95*.

The coordinate system

Until now, a local coordinate system was used. The imported coverages and the old avalanche data were in this local system. These coordinates are not referenced and it seemed better for the future to choose a regular coordinate system fitting to Iceland. Also, the implementation of Global Positioning System recording techniques makes it necessary to adopt a universally accepted coordinate system. After considering the advice from other institutes, we choose to work with the Gauss-Krüger coordinate system. The cylindrical projection used is the Transverse Mercator. The Gauss-Krüger coordinate system is the same as the Universal Transverse Mercator except that there are twice more zones, each spanning 3 degrees of longitude. Four belts cover Iceland, each one with a meridian in center line. The meridians are -24°, -21°, -18° and -15° (west from Greenwich).

In Iceland, the Hayford ellipsoid from 1924 is used with $a = 6\,378\,388$ m and $b = 6\,356\,911.94613$ m. In Arc/Info, those same parameters are settled for the ellipsoid International from 1909.

The transformation between local to Gauss-Krüger coordinates has been tested on Hnifsdalur. Five reference points had been measured with a Global Positioning System by another institute and were available to make the transformation. Other points have now to be measured all over the country to set up all the maps in Gauss-Krüger coordinates.

In Arc/Info we use the TRANSFORM command for each cover. Then, PROJECTDEFINE has to be used for one of the cover. There, we define the parameters concerning the projection we use.

The dialogue defining the projection is :

```
Arc>projectdefine cover <name of the cover>
Project>projection UTM                For Universal Transverse Mercator
Project>units meters
Project>spheroid int1909              For International from 1909
Project>parameters
Longitude > -24 0 0                  Parameters of the central meridian
Latitude > 0 0 0                     within the UTM projection
```

Then, for the other coverages, we can use the PROJECTCOPY command. To check whether the projection had been registered, we use the command DESCRIBE.

Transformations of the covers have been made for Hnifsdalur, but some problems still need to be solved because the transformation deforms the covers, affecting some parameters. Then, use the Arcplot command NEATLINE, to draw the new coordinate system on the map. We decided to have the latitude and longitude indicated as well.

After this last step, the Hnifsdalur map will be ready and will act as a model for the mapping.

What else ?

From the 8 to the 12 January, Harald Norem (from Norway) gave a course on snow engineering. Listening to this course, I had the opportunity to know more about the Nordic weather conditions and to learn about the Norwegian methods.

The same month, I attended a two-day meeting with David McClung (Canada), Bruno Salm (Switzerland) and Karstein Lied (Norway) held at the IMO. The task was mainly about the acceptable risk level and was also a way for me to know better about the actual Icelandic needs. A considerable number of houses in Iceland are in an unacceptably high risk situation as has been made all too clear by the catastrophic avalanches in 1995. I have been visiting Isafjordur and Flateyri, which was really impressive. The first defense structures will be built during the summer of 1996 and 1997. Most of the avalanche team is actually working on that project.

The 28 and 29 of March, there was an ORACLE and ESRI conference where I gave a talk. I was presenting the way we use Arc/Info for the avalanche mapping.

As I knew about the future plan of the IMO in the avalanche forecasting, I wrote an article presenting the expert models Crocus, Safran and Mepra, used in Meteo-France.

Then, I have read some articles about the models (topographical and dynamic) used by the Avalanche Division. It allowed me to know more about the parameters we would like to calculate automatically with Tin and Grid in Arc/Info in the future.

What's next

During the few months left, it seems to me that the priorities are :

- Finish the work on Hnifsdalur, concerning the coordinate system.
- Digitize all the data concerning Neskaupstadur with Svanbjörg H. Haraldsdóttir. This work will enable her to get accustomed to Arc/Info. It will permit me, by building the final map, to solve a new problem. For several avalanches there, we only know about the run-out zone. This can be easily understood by the fact that it is very dark in Iceland during the winter time. Also, the bad weather often affects the observations as well. When all the data will be in, I will be able to decide what is the best solution as to how to draw those avalanches on the final map.
- Work with the other people of the Avalanche Division on some projects using Arc/Info. As mentioned before, this is important to ensure that Arc/Info will be used to its full potential, and that everyone knows a bit about it. For that purpose, a small leaflet could be written to help the future work with Arc/Info.
- The uses of Tin and Grid in evaluating or calculating the various parameters for avalanche modelling have to be explored. Also their use as tools to aid in avalanche forecasting will have to be investigated.

Figure 1 : Architecture of the files

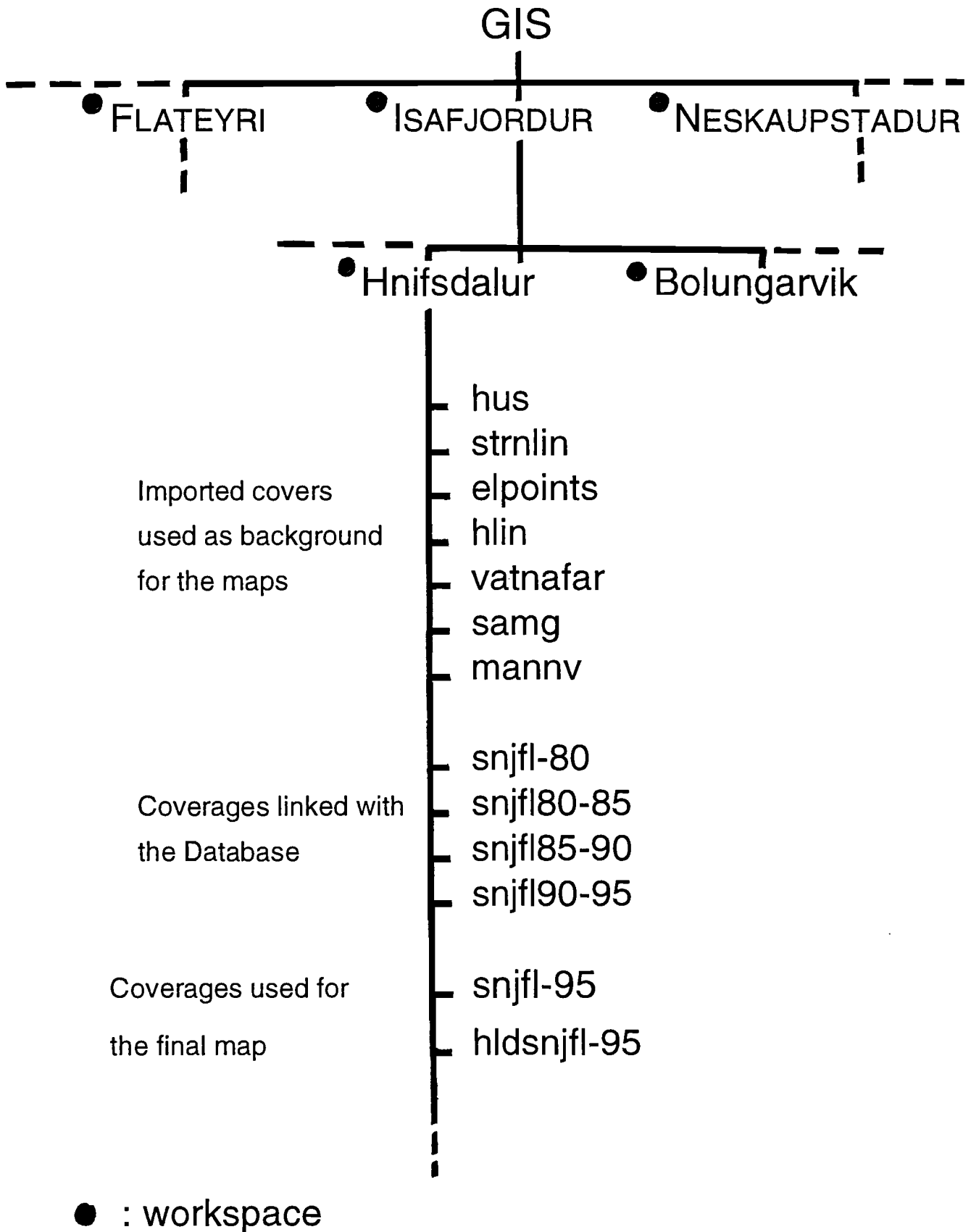
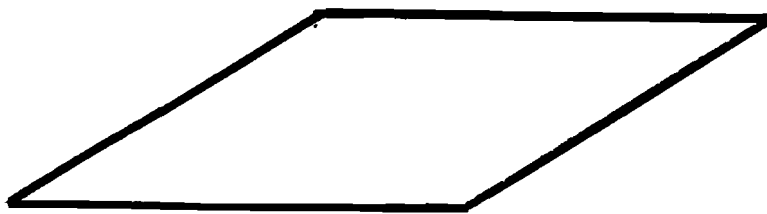
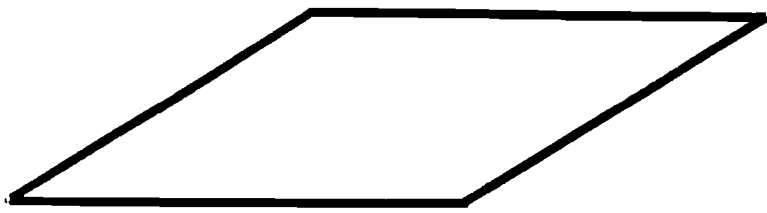


Figure 2 : Levels of organisation within a coverage



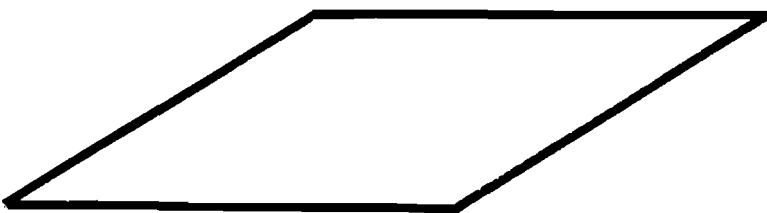
Subclass "certain"
3 regions

+



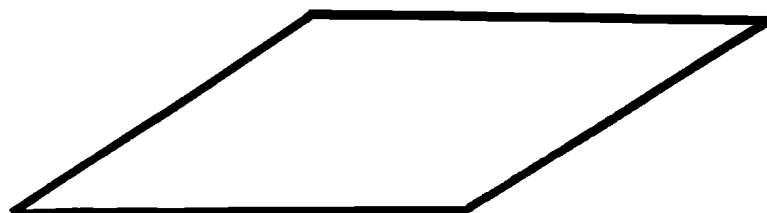
Subclass "certainin"
7 regions

+



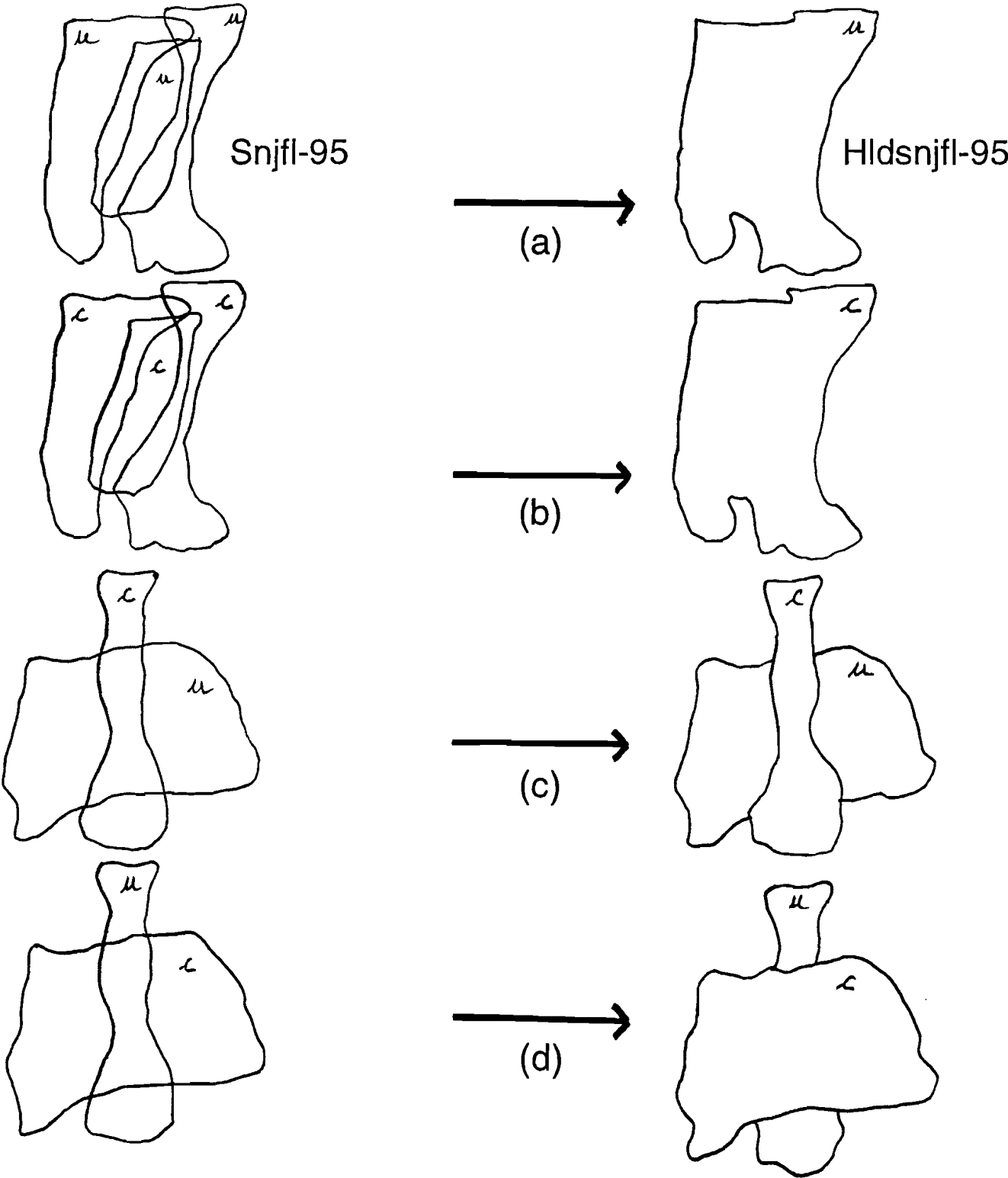
Subclass "uncertain"
5 regions

=



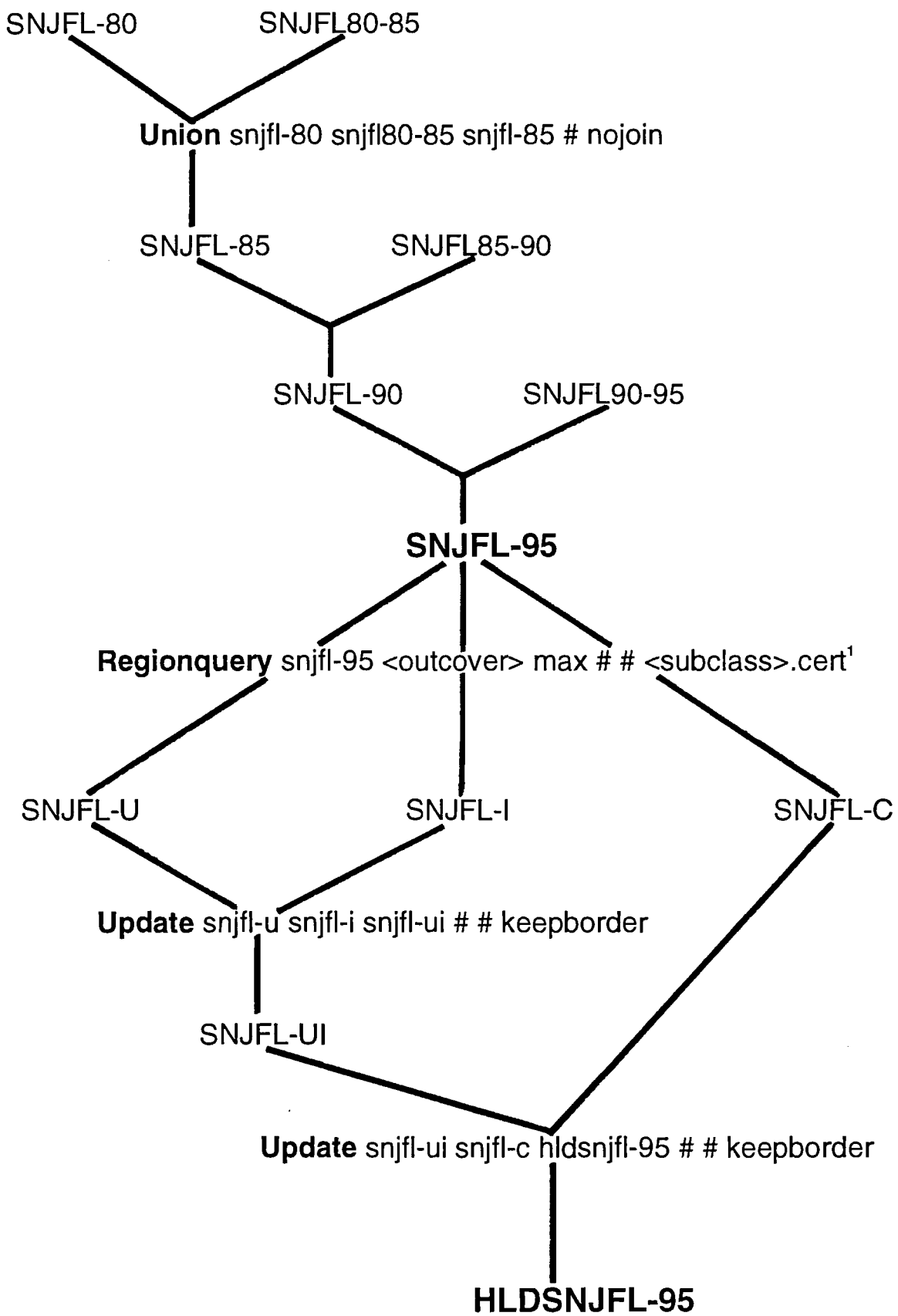
Coverage "snjfl80-85"
3 subclasses
15 regions

Figure 3 : Organisation of the data on the map



u : uncertain, c : certain

Figure 4 : The Arc/Info process to create hldsnjfl-95



¹ cert is the item that we want to keep from snjfl-95, in the outcover.