A Fast-Mapping Method for Bolometer Array Observations at the IRAM 30-m Telescope

David Teyssier, Albrecht Sievers
IRAM, Granada, SPAIN.

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1 Introduction

We present a fast-mapping method that can be used to map large fields with array receivers mounted in the nasmyth focus of the 30-m Telescope. This method was successfully tried using the 37-channel MPIfR Bolometer array during winter 1999 (173-98, Pérault et al.). Usually, maps are done in Azimuth, Elevation in such a way that a fully sampled map is obtained with each "pixel" of the array. All these maps are finally averaged to give a vastly oversampled final map. For this, we use vertical offsets (in elevation) of 4" or 5" between consecutive subscans (i.e. scanlines in azimuth). If we drop the requirement that the individual coverages fully sample the region to be mapped, one may use larger vertical offsets and still obtain a fully sample final map. As we show below, a vertical offset of 23" is a good compromise when using the 37-channel bolometer. For a given time one can thus observe a 6 times larger field than before. Instead of e.g. 6.5'×5', a 15'×13.5' field can be mapped within 1.5 hours.

2 The method

The problem is to find the optimal vertical spacing between subscans. One way of reasoning could be that, by jumping a row of pixels up between each scanline plus a small distance (equal to the final sampling desired, here 4"), consecutive rows of bolometer pixels just nicely "fill in the gaps" (Fig. 2.a and 2.c) and don't scan the same elevation (Fig. 2.b and 2.e).

For the winter 1999 sessions, the mean distance between the beams of the 37-channel bolometer was **20"**. Thus we tried the method using a vertical offset of **24"**. The final distribution of the points seen by the whole array then depends on the elevation of the source due to the array rotation in the sky with elevation. That is the reason why, for a given source elevation, some vertical offsets should be "forbidden" to avoid gaps in the final map (see section 3). Figure 1 shows the array orientation w.r.t. the horizontal frame at various elevations for the 19 and 37-ch. arrays.

Combining this method with fast scanning velocities (typically 6 to 8"/s), we did large maps of 7'×6' and 11'×5' in about 20 minutes. Such short times had never been used before at the 30-m telescope for maps of this size and the results we observed tend to prove that this method could be considered more seriously. Another advantage of such short maps is the small field distorsion, provided that the elevation is not too high, when we convert from horizontal to equatorial frame.

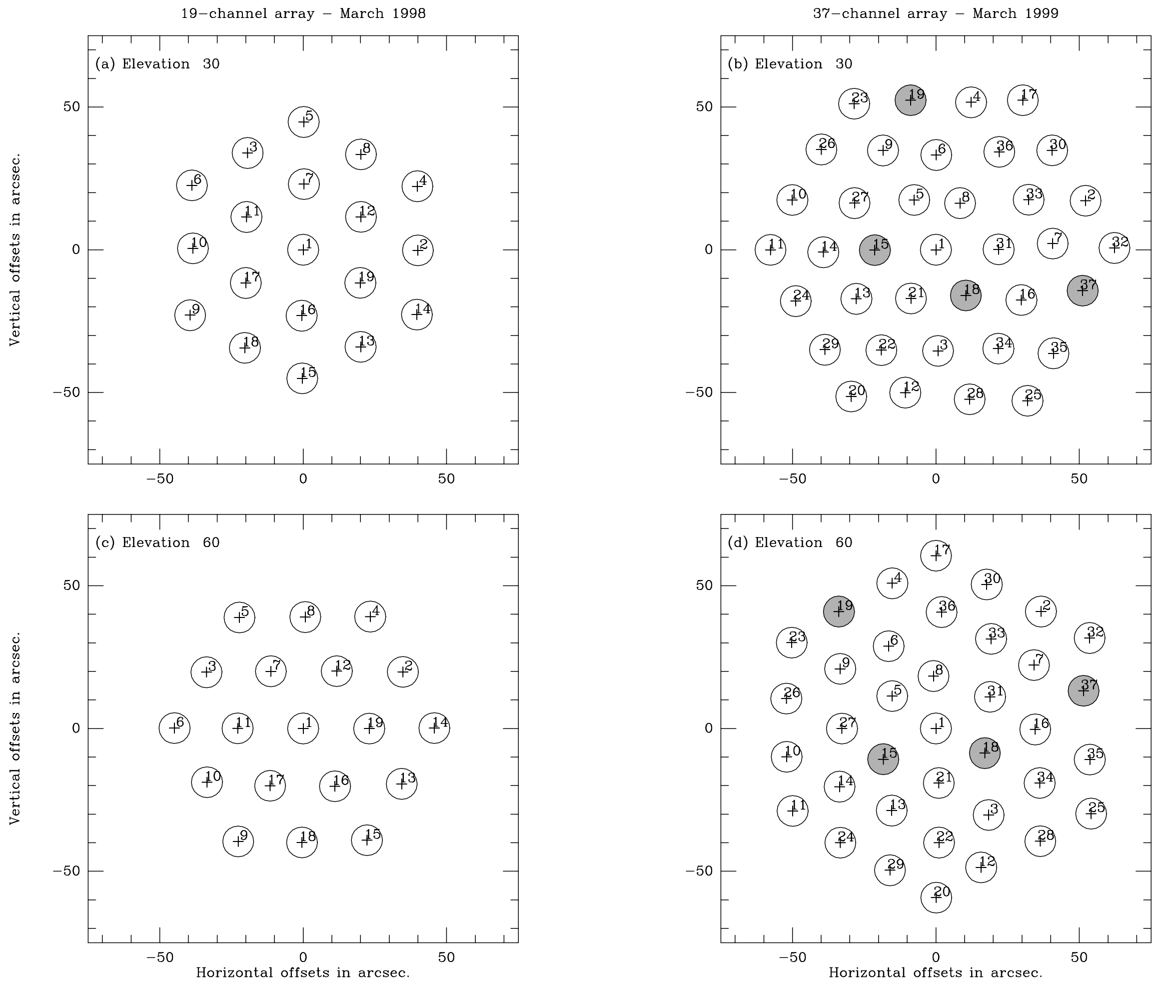

Figure 1: 19 and 37-ch.arrays displayed at elevations 30 and 60°. Filled channels are the ones that needed to be flagged during the winter 98/99 period (dead or noisy channels).

3 Simulations

We did simulations of the pixels distribution on the sky for a map knowing its dimensions, the original sampling and the elevation of the source (i.e. the rotation angle of the bolometer array). Some examples are displayed in Figure 2 for the 19 and 37 channel arrays where a central region of 24"×24" is shown.

We first would like to emphasize that the maximum vertical offset available for a given final sampling (say 4") is limited by the number of rows of the array. This result is illustrated by Figures 2.c and 2.f that show cases where the number of rows of the array (5 and 7 resp.) is not large enough to avoid gaps in the final map.
Other results of Figure 2 confirm the intuitive choices for vertical sampling. Once the distance between rows is known, one can easily derive the vertical offsets to be avoided (Fig. 2b and 2.e) and the ones to be used (Fig. 2a and 2d).

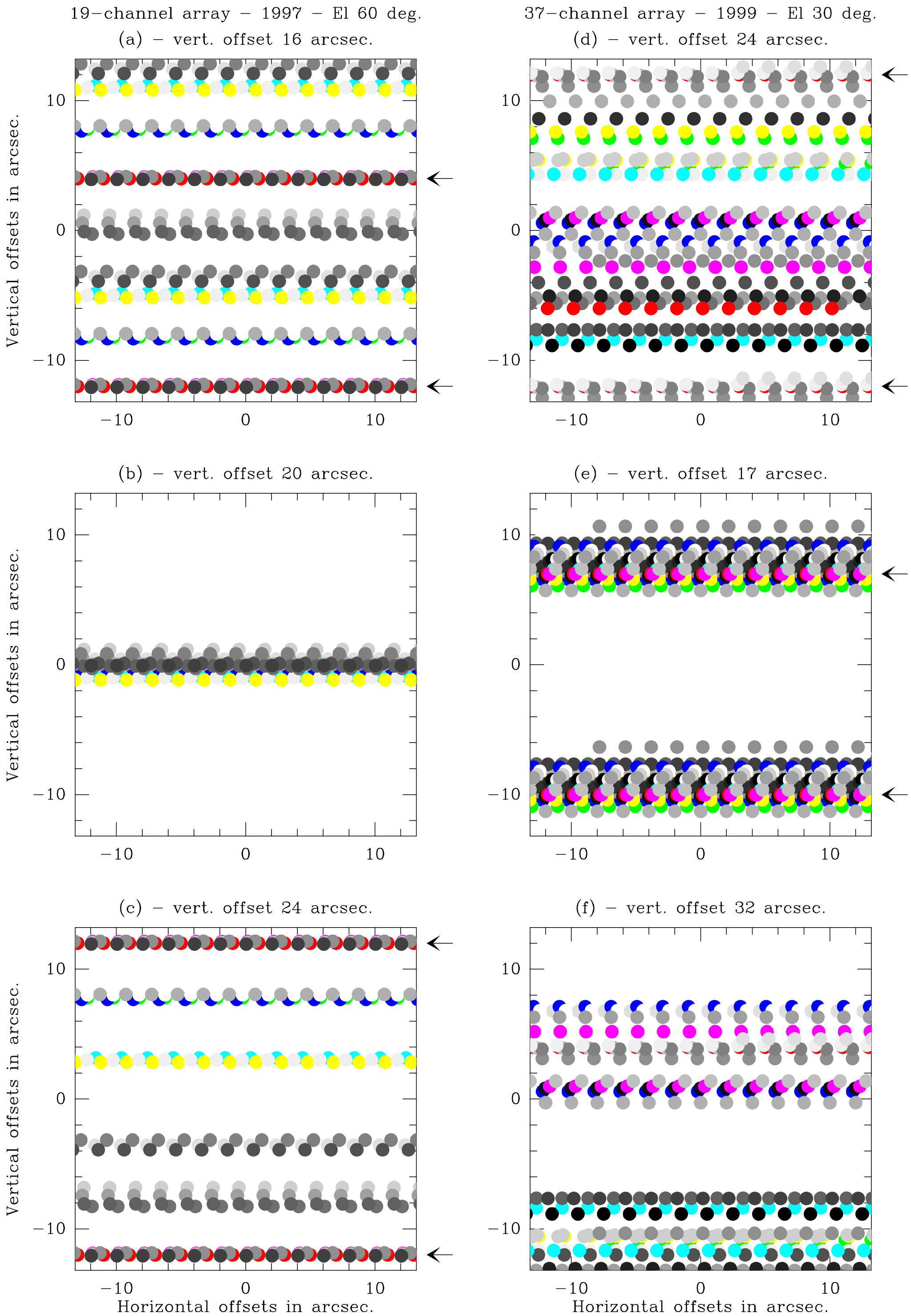

Figure 2: Pixels distribution in a 24"×24" region for the 19 and 37-ch. arrays (each color represents a beam). Horizontal sampling is 2". Elevation is chosen so that the beams form horizontal rows as shown in Fig. 1.b and 1.c. Arrows indicate where one row repeats (consecutive subscans). (a) and (d): good vertical sampling, no gaps larger than 4". (b) and (e): the vertical offsets correspond to the distance between rows: scanlines overlap and large parts of the map is never filled. (e) and (f): the vertical offset is too large w.r.t. to the number of rows, see text.

Another simulation approach deals with the weights distribution on a map for a given final regridding (see e.g. Fig. 3.b, 3.d and 3.f). This provides a estimation of the number of beams contributing to a pixel in the final map and thus to detect gaps (low weights). We computed weights maps for a series of source elevations and vertical offsets and confirmed the intuitive conclusions drawn from the previous simpler simulations.

As a general conclusion of the simulations we did, we observe that for any elevation, vertical samplings of **22" to 24" always give acceptable results for the 37-ch. array**.

4 Examples

In this section, we present some recently reduced maps of sources mapped with the method described above. The zenith opacity was rarely more than 0.25. Figures 3.a, 3.c and 3.e show map of sources at elevations 30^o, 48^o and 46^o respectively. Scanning velocity was 6"/s. Figures 3.b, 3.d and 3.f display the corresponding weight maps, with contours 10%, then 80, 90 and 100%. Typically, the 10% level shows the total mapped area, whereas higher weights characterize an ideal flat top level where a maximum number of pixels would contribute to the map.

Noise r.m.s. comparison

The expected noise r.m.s. reached in a map with a vertical offset of 24" should be sligthly more than twice ($\sqrt{5}$) the one reached with the conventional 4" step. To compare the method at this point, we made maps of the same target with the "normal" and the "fast" procedure. They are separated by only 2 hours, on either sides of transit, and the opacity was between 0.15 and 0.2 during this time. Figure 4 displays the maps and the corresponding weight maps.

We limit the tested area to the center, expected to be covered by a maximum number of channels. The r.m.s. reached with the "normal" map is about **12 mJy**, with some baseline limitations, whereas the "fast" map yields **22 mJy** of noise. This would tend to show that the noise behaves as expected, but further tests should be done in that direction.

5 Conclusions

The short analysis of the fast-mapping method presented here tends to show that this procedure could become a efficient way to considerably reduce the observing time for large field coverage. Recent observations confirm its feasibility and do not show evidences of a degradation of the signal quality. Simulations show that vertical offsets of **23"** for the 37-ch. and **16"** for the 19-ch.bolometers can be safely used at any elevation.

Among the various advantages the method offers, we can remind:

- small field distorsion in equatorial frame for short, say 20 minutes, coverages (nearly rectangular maps)
- larger fields can be observed within a given time (due to field rotation and other reasons, it is not practical to do coverages that take more than say 2 hours to complete)
- fast exploration of large unknown fields to detect sources on sides (important at the time of restoring) and maybe concentrate on isolated targets
- several maps of the same field at different hour angles reduce baseline effects, like stripes, when averaging.

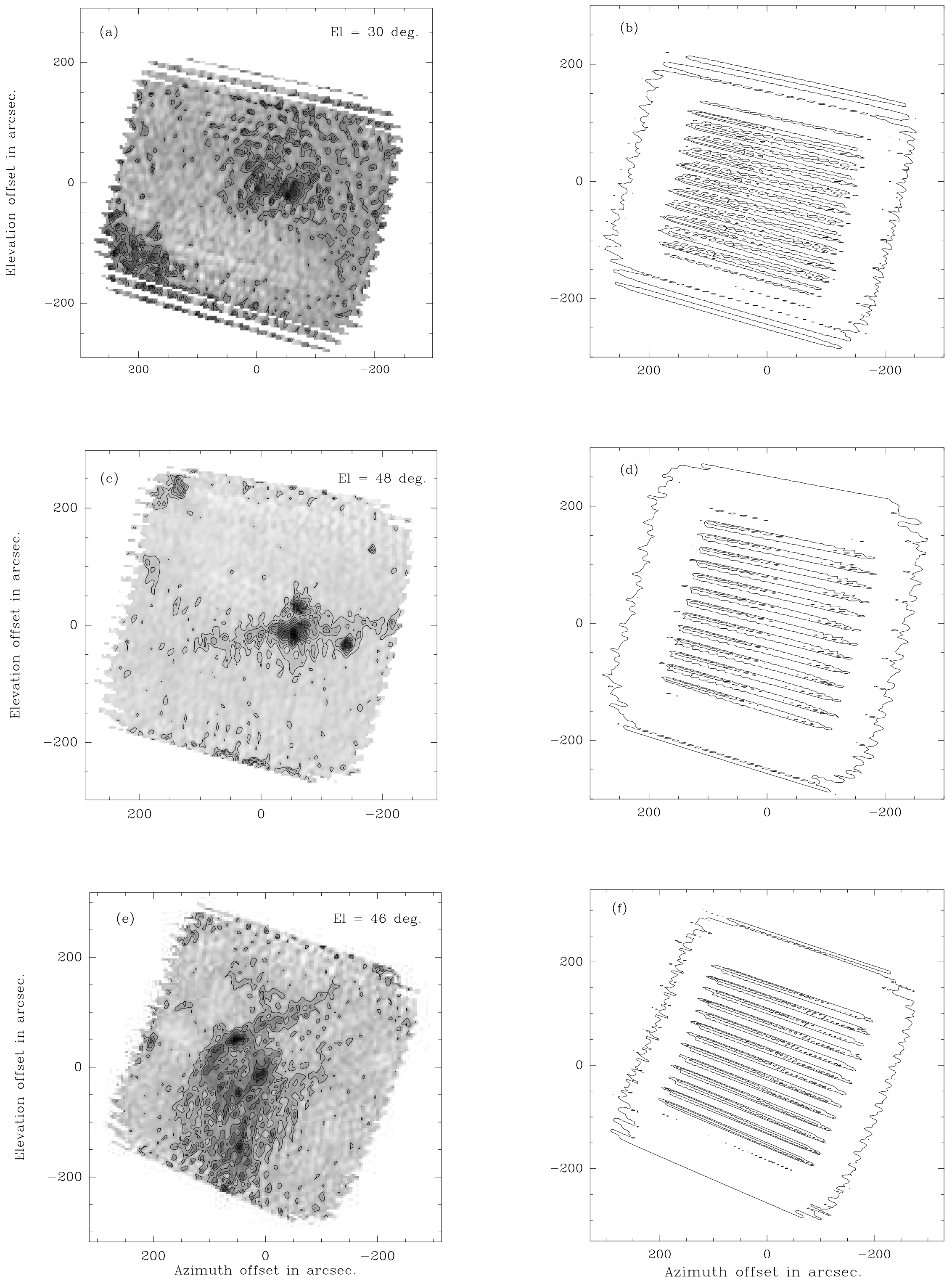

Figure 3: Examples of fast-mapping results. Maps size is 420"×375", scanning velocity 6 "/s, vertical offset 24". (a), (c) and (e): maps are skynoise filtered, contour levels are 90, 180,..., 540 cts (resp. 115, 230,..., 1700 cts, and 100, 200,..., 600 cts). (b), (d) and (f): weight maps, levels are 10, 80, 90 and 100%.

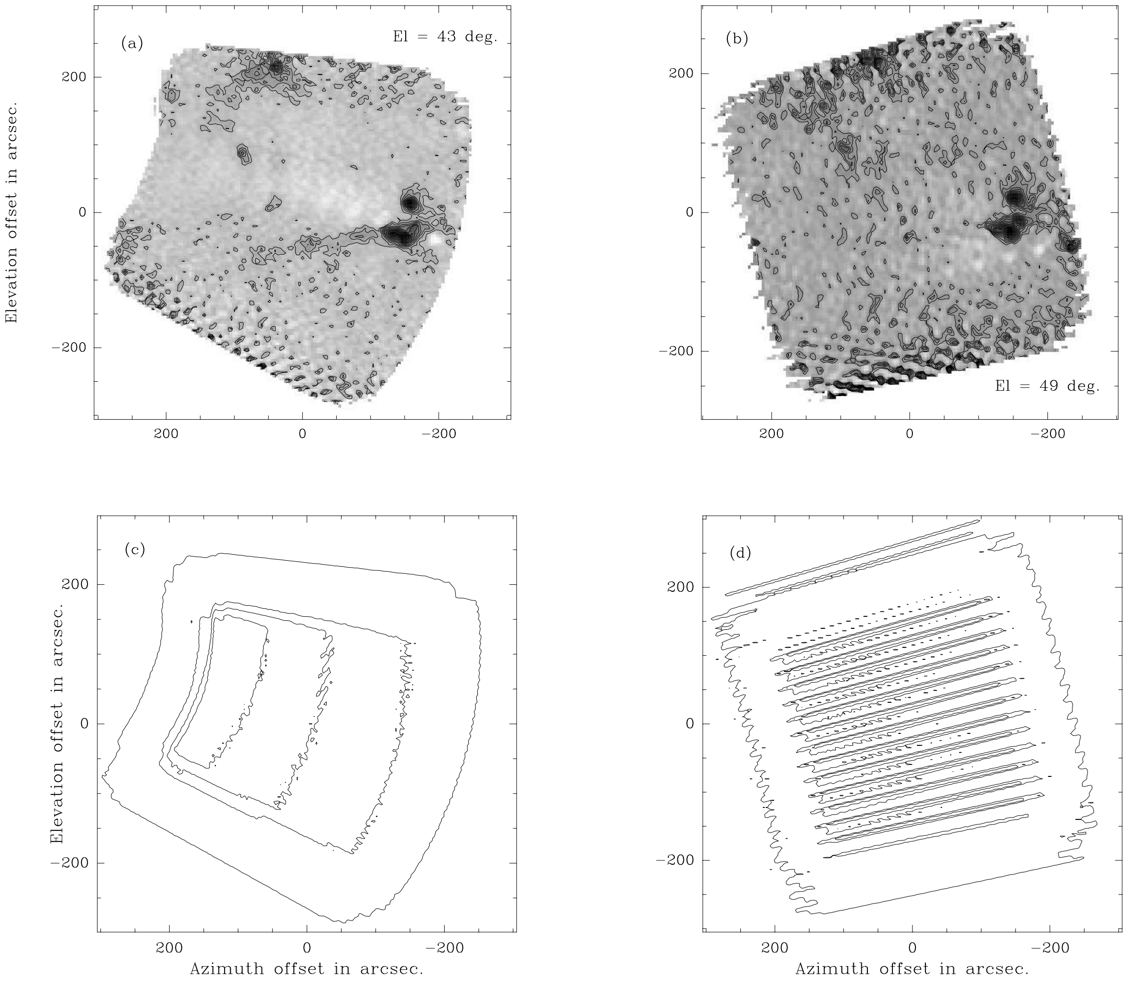

Figure 4: Comparison of "normal" and "fast" mapping. Maps size is 420"×375", scanning velocity 8 "/s, vertical offset 4" (90 minutes of time) and 24" (21 minutes of time). (a) and (b): maps are skynoise filtered, contour levels are 100, 200,..., 1200 cts for both cases. (c) and (d): weight maps, levels are 10, (70 for (c)), 80, 90 and 100%. On the left map, high levels suffer from field distorsion and get more and more restricted to the left side of the map where scan lines are closer together.

Of course, further tests need to be done to improve our understanding of this method (e.g. behaviour of the noise when averaging coverages, comparison of very large fields with "normal" and "fast" methods,...). Its application to large maps should thus not yet be automatic.