Reviews

HERZFELD, U.C. 2004. *Atlas of Antarctica: topographic maps from geostatistical analysis of satellite radar altimeter data.* Berlin, Springer Verlag. 364pp. ISBN 3-540-43457-7, hardback, with appended CD-ROM. £115.50, $159, €150.

In this fascinating, useful, but error-marred book, Herzfeld utilizes satellite radar-altimeter data from NASA's Seasat and Geosat and the European Space Agency's ERS-1 and ERS-2 (European Remote-sensing Satellite 1 and 2) missions to prepare a collection of topographic maps covering all of Antarctica to 81.5° S. As she writes, 'the Atlas maps are the highest-resolution elevation maps available today, derived from satellite radar altimeter data by application of a geostatistical method, which was specifically designed by the author for the problem of ice-sheet mapping'. The geostatistical approach is an important advance in Antarctic glaciological mapping and the author has done the community a great service in publishing this atlas, which is the product of many years of work by Herzfeld and her students. The maps and supporting elevation data are contained on a CD-ROM that many users will find highly useful. A fine cover gives the volume an attractive appearance.

The main atlas comprises 100 maps of surface elevation from Geosat/GM (Geodetic Mission) and ERS-1 data. This will be a hugely valuable resource to anyone interested in Antarctic glaciology or geography. The maps are at a scale of 1 : 5 000 000, nicely chosen to match that of a standard wall map of Antarctica. They are conveniently arranged in overlapping sectors with latitudinal and longitudinal boundaries chosen to yield maps 500–700 km across. The overlaps are well designed to provide ease in tracing features from one map to the next. All maps are presented as Universal Transverse Mercator (UTM) projections, with 'northing' and 'easting' scales in hundreds of kilometers. North of the southern limit of the GeosatT orbit (72.1° S) each sector contains two maps, one from Geosat/GM, the other from ERS-1. The remaining sectors include the rest of the ERS-1 orbital coverage, to 81.5° S.

Accompanying each map, or pair of maps, is descriptive text that emphasizes the geographical features of the area. Much of it was taken from Swithinbank's (1998) marvelous image atlas of Antarctic glaciers and from the authoritative US gazetteer, *Geographic names of the Antarctic* (Alberts, 1995), both of which Herzfeld frequently references. The *Atlas* reveals many previously unmapped details in ice-sheet topography, particularly about small glacial systems.

Many readers will be particularly interested in the regions of variable topography near coasts and mountain ranges, although the broad, nearly featureless plateaus in the interior of the ice sheet hold details of interest to ice-sheet glaciologists. The principal difficulty with radar altimetry, however, as Herzfeld makes clear, is that it becomes decreasingly accurate as the relief increases. The Geosat and ERS-1 altimeters had different instrumental characteristics and their ground tracks were very different in both density of coverage and direction of travel. Consequently, it is instructive to compare the maps of the same sectors from the two satellites (presented side by side for that purpose) to gain a sense of the accuracy and reliability of the maps.

One example serves to show both the strengths and the weaknesses of the radar altimetry: the map of the Walgreen and Eights Coasts. Here is a magnificent portrayal of the Pine Island Glacier drainage system, including an apparently realistic portrait of the small ice shelf in Pine Island Bay. In contrast, Thurston Island is reduced to three or four islets, King Peninsula is distorted in shape and displaced eastward, and Abbot Ice Shelf, between the two, has virtually disappeared.

Unfortunately, using this atlas can be very frustrating. To wit:

1. There are no figure numbers in the main atlas section. Each section of the text corresponding to one map carries a cumbersome identifier like 'm165e157–173n67–721 Pennell Coast'. That means the central meridian is 165° E, the longitudinal range is 157–173° E and the latitudinal range is –67 to –72.1° N. When reference is made to a map in the text, only the identifier is used; no page number is given. There are no page headings either, so it is slow work to find a referenced map.

2. The maps are presented with UTM coordinates in hundreds of meters; geographic coordinates are indicated only in the nominal, inexact figures given in the map identifier. Nevertheless, references in the text to particular features, many of which are not labeled on the maps, are commonly specified by latitude and longitude, with no UTM coordinates.

3. There is no subject index, although there is an index of those place names that appear on maps. References in that index are to map identifiers, not pages.

There are errors, as well as inconveniences. A sampling: It is meaningless (dimensionally unbalanced) to say that the removal of snow (in tons) across the coast at Port Martin 'corresponds to removal of half of the estimated accumulation'. It is not true that 'the ice in Prince Gustav Channel is the northernmost ice shelf in Antarctica' – that ice has been gone for a decade. The statement 'the Geomagnetic South and North Poles . . . wander with time (and so the compass declination changes slowly at every place on Earth)' confuses the geomagnetic and magnetic poles. Although the 'McMurdo Ice Shelf . . . has one of the largest ablation areas in Antarctica', it is incorrect that it is 'indicative of a warming climate' and that 'the . . . tongue of Koettlitz Glacier is also wasting away'. Robert Scott and his party did not use Byrd Glacier to ascend to the inland ice. The passage, 'Beyond Peacock Bay, south and north of Cape Waite, and further east beyond Abbot Ice Shelf is Thurston Island . . . In the small ice shelf between Thurston Island and Eights Coast is Sherman Island' is wrong on three counts. It is Peacock Sound, not Peacock Bay; it is north and east of Cape Waite, between Thurston Island and Eights Coast, and the western portion of Abbot Ice Shelf overlies it.

Fascinating as the main atlas is (problems notwithstanding), glaciologists may find still more interesting the chapter on monitoring changes in the Lambert Glacier/Amery Ice Shelf system. This is not new work – a shorter, early version was published in *Annals of Glaciology* and a full discussion in *Mathematical Geology* – but it is definitely apropos here and it lends much insight into both the radar altimetry and

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the behavior of this important glacial system. Another section, on detailed studies of 15 selected glaciers, is also absorbing and particularly useful to glaciologists.

The final section of the book presents maps of the Lambert Glacier/Amery Ice Shelf region in which the radar altimetry (ERS-1 and -2) is superimposed on a synthetic aperture radar (SAR) backscatter map from Radarsat. The correspondence between the surface elevation contours and the features seen in the radar image map demonstrates beautifully the value of combining data from two very different types of source.

The weakest part of the book is at the beginning. In a brief opening chapter the basic geographic divisions of the continent are summarized, but with many geographical errors. Next there is a simplistic and frequently inaccurate section on 'Climate change, sea-level rise, and changes in the cryosphere'; the simplism and inaccuracy are both epitomized by the first paragraph: 'The Antarctic Ice Sheet plays a major role in the Global System. Under warming climatic conditions, as have been observed in the past to present decades, the Antarctic ice is reacting sensitively.' The section contains a pair of serious misstatements: 'Antarctica is an arid continent, and most of the accumulation is by redeposition of drifting snow,' and '. . . mass loss by calving increases sea level'.

The next chapter covers satellite remote sensing. Here Herzfeld is on firm technical ground, although the writing is poorly organized and unbalanced. There is first a discussion of Landsat and Terra imagers. Included in the latter are ASTER (no mention of GLIMS, the strong glaciological component of ASTER science), MODIS and MISR. MISR characteristics are given in lengthy detail, whereas MODIS is allotted one sentence: 'MODIS data have been utilized in the study of snow surfaces on land.' There follows a good discussion of the merits and demerits of SAR; radar altimetry is introduced before returning to a second look at radiometry and the use of MISR to study the roughness of snow and ice surfaces. Finally, there is a full-page discussion of Envisat's instruments, most of which have nothing to do with observing the ice sheets.

A section on satellite radar altimetry is generally helpful. There is a good summary of the characteristics of Seasat, Geosat, ERS-1 and ERS-2, a clear explanation of the difference between Exact Repeat Missions (ERMs) and Geodetic Missions (GMs), and a particularly useful subsection on radar measurement principles. But again there are many errors. Although she mentions the Geodetic and Earth Orbiting Satellite 3 (GEOS-3), Herzfeld states in three different places that the first scientifically useful data came from Seasat, thus overlooking the initial radar-altimeter measurements of surface height in Greenland and Antarctica. Seasat and Geosat were designed to measure oceanic dynamic topography, not just the marine geoid. And nadir is not properly defined as 'a line from the satellite normal to the Earth's surface' when, as shown in the accompanying figure, the surface is sloping.

An informative section on radar altimetry over ice sheets and glaciers introduces the differences between mapping the oceans and mapping the ice sheets, including the effects of slope, roughness on various scales and 'snagging' on discontinuities in height or slope, followed by a mention of the application of waveform analysis to study surface roughness and signal penetration into the firn and to detect crevasses.

In a chapter on 'Data analysis methods applied in the Antarctic atlas', the author delves into subjects upon which much of her own research has been concentrated, so the writing is authoritative. The first section of the chapter contains a brief but useful presentation of atmospheric corrections, retracking, one method (among several that exist) of applying a slope correction, and the removal of bad data. The second section is very detailed and informative on exactly how the transverse Mercator projection used in the *Atlas* relates to geographical coordinates. The diagrams that lay out quantitatively the relationships in each mapped latitude band are helpful, indeed essential, when one tries to interpret the *Atlas* maps in term of latitudes and longitudes. (Herzfeld's repeated use of 'orthogonal' coordinate system where 'rectangular' coordinate system is meant causes some confusion until the reader catches on.)

The excellent third section explains, also in detail, the use of 'geostatistical estimation' to interpolate between track-line data, which obviously are highly non-random in distribution, for mapping purposes. Various experimental and model variograms, the particular family of estimators employed in 'kriging', and the application of the procedures to the Antarctic radar-altimeter data also are discussed. The development of these procedures (the basis of all the *Atlas* maps) has been one of Herzfeld's own valuable research contributions; their application has markedly improved the quality of elevation maps from radar altimetry.

A final comment on errors. Springer lists this book at US$159 (€150). For that price one has the right to expect high-quality production, yet I estimated some 50 production errors. There is a wide range of error types, ranging from 'fo' for 'of', through overlapping text in adjacent columns, an equation number separated from its equation by a line of text and misspellings (including 'lead' for 'led' in many places), to futuristic references: 'McIntyre, 19999', twice, and even 'McIntyre, 199999'!

Herzfeld states in her Preface, 'the Atlas is for educators, glaciologists, researchers, students, tourists, anyone interested in Antarctica'. I believe the *Atlas* will indeed become a valuable resource for Antarctic glaciologists and for anyone working with radar altimetry, but I suspect tourists and other lay people will find it rather tough slogging. Any who do use it should heed the author's repeated warnings about the geographic inaccuracies in the coastal regions, which they are most likely to encounter.

This is a book that all Antarctic glaciologists will want to own. It is truly unfortunate that it is flawed in so many, and so largely avoidable, ways. With careful technical and copy editing, it could easily have been so much better.

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