WILLIAMS RS, Jr and FERRIGNO JG eds (2012) *Satellite image atlas of glaciers of the world. State of the Earth's cryosphere at the beginning of the 21st century: glaciers, global snow cover, floating ice, and permafrost and periglacial environments.* (USGS Professional Paper 1386-A) United States Geological Survey, Denver, CO, 546pp. ISBN 987-0-607-98287-9, softback (also available at http://pubs.usgs.gov/pp/p1386a/)

This is the second to last volume in a huge 11-volume publication that was started by Richie Williams and Jane Ferrigno in 1979. The aim was to produce an atlas of satellite images of the glaciers around the world, primarily for the period 1972–82, based on images from Landsat 1–3. Landsat 1 (originally named ERTS-1) was launched in July 1972, and Landsat 3 ceased collecting data in March 1983. This 10 year dataset would thus provide a benchmark for comparing future glacier changes.

From the start this was a very ambitious project, with high rewards for those studying global glacier changes. It must be very pleasing for Williams and Ferrigno to note now both that the project is close to completion and that its value has increased beyond what they could predict when it was started 34 years ago. It was not then known how long the Landsat programme would last, and indeed it ran through difficult periods of constrained funding and support. We can now see that this programme has become the longest-running enterprise acquiring satellite imagery of Earth. The instruments on the Landsat satellites have sent back millions of medium-level resolution images at different spectral bands, mostly in the visual range. This is still continuing; the most recent satellite, Landsat 8, was launched on 11 February 2013.

In addition to the volume reviewed here, US Geological Survey (USGS) Professional Paper 1386 contains ten other volumes covering the glaciers of different regions of the Earth, sequenced 1386-B to -K, of which -D on Iceland is not yet published. Volume 1386-A contains both general discussions, and synthesis of data presented in the other ten volumes, and is therefore very different from the others. This soft-cover book in US letter-size format has 496 pages of main text, and is heavy in more than one sense.

The book has five main chapters. The first (68pp.) discusses the various components of the Earth system and their relationship, including the global hydrologic cycle. The other four chapters discuss the state of the cryosphere at the beginning of the 21st century for, respectively, glaciers (243pp.), snow (31pp.), floating ice including sea ice (35pp.) and lake and river ice (43pp.), and permafrost and periglacial environments (71pp.). As can be seen from the page counts, the emphasis of 1386-A is still primarily on the state of the glaciers. Williams and Ferrigno are the editors for all five chapters, while about 20 different authors have written the various subsections.

The important new information presented is in the section on the glaciers on planet Earth. Here the results from the other ten volumes are summarized and it is concluded that the total area of the Earth covered by glaciers is 15 926 087 km^2. For the Antarctic ice sheet the editors provide no new numbers, but use the area given by Drewry and others (1982), 13 586 400 km^2. As this value was given to the nearest 100 km^2 it is somewhat misleading to suggest that the total area of glaciers on Earth is now known to the nearest km^2.

But this is a minor quibble. What is important are the results compiled in the ten other volumes, summarized in the glacier chapter, and which provide data for practically all other glaciated areas on Earth. This large undertaking has involved 133 scientists with local knowledge, and the figures and maps provide excellent baselines against which future changes can be measured. I expect that USGS Professional Paper 1386-A–K will remain a central reference source for those studying glacier changes wherever they work.

The usefulness of 1386-A, apart from the section summarizing the other ten volumes, is not so obvious. The aim seems, unrealistically, to be to try to cover 'everything' related to the cryosphere. The chapter on glaciers, for example, also treats approaches to classifying glaciers (geophysical/morphological), global glaciations through geologic time, ice cores and climate, changes in glaciers and sea level, mass-balance measurements, glacier discharge impact on ocean salinity, glaciological hazards and much more. The sections are well illustrated, but some texts are descriptive rather than analytical, and some subsections only partially cover the subject. The section on ice cores, for example, primarily deals with tropical high mountain glaciers and only sparingly addresses ice cores from the Greenland and Antarctic ice sheets. The section on glaciers and sea level makes little use of the Gravity Recovery and Climate Experiment (GRACE) tandem satellite observations and does not discuss the effects on regional sea level resulting from the geoid changes when a large ice mass like Greenland's is significantly reduced. Some statements are misleading, such as this one in an abstract (p. 69): 'Virtually all of the Earth's glaciers, from the smallest mountain glacier to the large ice sheets in Greenland and Antarctica, are retreating and losing mass (except for surge-type glaciers and some tidewater glaciers).' This is misleading in the sense that it overstates our knowledge, especially with regard to Antarctica. It also wrongly suggests that surge-type glaciers are not losing mass. Such glaciers (which represent a trivial amount of the total glacier volume and therefore probably should not be singled out) may be retreating or advancing independent of climate change, but I do not believe there is evidence that their mass change differs systematically from other glaciers in the same region. Other statements lack precision, such as this one on albedo (p. 78): 'snow-covered or relatively clean glacier ice has a high albedo'. At ~0.5 the albedo of ice cannot be said to be high.

The book therefore cannot stand alone as textbook material for a glaciology course, but perhaps that was never an aspiration. The subsection I found most informative was that on permafrost, maybe because that was the subject with which I was least familiar.

Some of these deficiencies are perhaps caused by what seems to have been a very long interval between preparation and publication, as most of the material seems to have been written around 2005 and there are relatively few references from the past 5 years. I guess that the wish to make this book cover a vast array of subjects may have been a challenge to production speed, but this reduces its value. I will illustrate this with two examples.

The section on sea ice presents data primarily from 1979–2003 and seems to have been mostly written in 2004. I found only three references more recent than 2004, and no post-2003 data. If my surmise of time of writing is correct, then it is a pity this article was not published in 2005, when it would have been very apt and useful. Given the large

https://doi.org/10.3189/2013JoG13J136 Published online by Cambridge University Press

reduction in Arctic sea-ice extent in recent years, and much-increased sea-ice observations and research, it is now outdated. For example, it states that the evidence for trends in Arctic sea-ice thickness is inconclusive. The authors would not have written that today.

Correspondingly the section on snow cover seems to have been mostly finished around 2006, and with one exception all illustrations and data presented refer to the period up to 2005, also the year of the most recent references (with one exception).

This delay in publication is particularly unfortunate considering that the cryospheric changes in recent years have in most cases been the largest during the satellite era, and in view of the very large advances in knowledge made during the International Polar Year (IPY; 2008/09). Perhaps I have missed it, but I could not find any reference to IPY results.

Another illustration of the delay in publishing is the posthumous inclusion (authors died in 2009 and 2012) of a section on glacier mass changes and their effect on the Earth system. This section contains both material covered elsewhere (sea level, glaciological hazards, etc.) and a strange passage on glacier hydrology and ocean salinity subheaded 'Glacier impact on the world ocean' which did not include effects from Greenland or Antarctica or iceberg calving.

I suggest that the way to get maximum benefit from this book is to use it as a smorgasbord of articles to suit different tastes, all with some nutritional value, but some more palatable than others. The various sections in 1386-A are all well referenced up to the first few years of this century, and in many cases give an excellent introduction to the subject, not least its history. My advice to the potential reader is thus to pick from these articles when you want to get an overview of a theme and its state of knowledge around 2005.

REFERENCE

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https://doi.org/10.3189/2013JoG13J136 Published online by Cambridge University Press