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Book reviews

Energy and Water Cycles in the Climate System edited by E. Raschke and D. Jacob (Springer-Verlag, 1993) ISBN 3 540 54590 5. Hardcover. viii + 467 pp. $281.00.

This book is a collection of 15 lectures given at a NATO Advanced Study Institute in September-October 1991 designed to introduce students to a number of the interdisciplinary aspects of GEWEX (the Global Energy and Water Cycle Experiment). The level at which the lectures are pitched varies throughout, depending on the individual lecturer involved, although the choice of lecturers seems to be a good one.

The first chapter is a review by Peixoto of the energy, moisture and entropy budgets for the climate system derived from observations and is essentially a compilation of his work published in collaboration with Oort and others over the last two decades. This is followed by Ernst Klinker's fairly comprehensive comparison of the global hydrological cycle and its simulation in the ECMWF model. Klinker stresses that caution should be taken when using long time-series of analyses from NWP centres to study climate issues because the inevitable evolution in model resolution and parametrisation schemes injects strong signals into the model climate record which can be easily misinterpreted.

Raschke's brief nontechnical review of the radiation-cloud-climate interaction starts with a simple treatment of the physics of radiative transfer and the role of cloud microphysics, followed by a cursory review of a number of empirical studies of radiative cloud effects on climate and model intercomparison studies. The following chapter by Del Genio is an excellent review of the feedbacks due to atmospheric water vapour and how they are treated in global models. He discusses various areas needing improvement in both convective and stratiform cloud parametrisations and the validation strategies required, and points out that much of the recent data from cloud data experiments such as FIRE have shown how complex cloud behaviour can be but have yet to be instilled into insights useful to climate modellers.

In the next two chapters Bill Rossow gives a review of satellite data sets relevant to GEWEX, with strong emphasis on results he and his co-workers have derived from ISCCP. He makes the point that cloud amount is an arbitrary quantity depending on a choice of threshold; assuming an optical depth threshold of 0.2 gives a global cloud amount of about 60 per cent but a threshold of 0.1 leads to essentially globally overcast conditions! Rossow concludes that ISCCP and ERBE are useful for studying some key climate questions but the work is really only just beginning.

Ruprecht reviews the observation and analysis of rainfall with an emphasis on the problems associated with shipborne rain-gauges and concludes that we really don't know the amount of global rainfall or its interannual variability with any great accuracy.

In chapter 8 Talagrand presents a good basic course in data assimilation with particular emphasis on variational techniques. Overall I consider this to be an excellent introduction to assimilation and the directions in which it appears to be heading.

Willebrand starts off the lower boundary layer part of the book with a chapter on the heat and freshwater flux forcing the oceans, in which he points out that the flow of global evaporation is only one-third the strength of the Gulf Stream near Florida. He goes on to review the relationships between surface fluxes and large-scale transports, emphasising the large uncertainties in the available data. In her chapter Delecluse considers the modelling of ocean circulation starting with a brief review of the physics involved, and points out that because the ocean basins communicate via very narrow passages horizontal resolution can be crucial. She goes on to describe the schemes incorporated in three global models emphasising the large uncertainties in the surface boundary conditions and closes her lecture with the reasons for the current proliferation of tropical ocean models.

In a somewhat pessimistic review of air-sea fluxes Hasse makes the statement 'Personally, I believe that profile measurements at ships are not only useless but rather detrimental: severely biased measurements are worse than no measurement.' He goes on to say that world map isolines of precipitation are educated guesses rather than measurements. Wind data are problematical because most wind measurements are Beaufort scale estimates but the link between Beaufort scale and wind can be biased by up to 20 per cent. Added to these problems is the fact that a five per cent error in the insolation (a modest amount given the variability of cloud and its predominant role) or evaporation could lead to an error of 50 per cent or more in the surface heat balance.

Ypersele gives an excellent introduction to sea-ice geophysics for researchers with an interest in polar phenomena, reviewing both thermodynamic and dynamic models of sea-ice. In a common theme for these lectures, Ypersele laments the state of sea-ice databases and goes on to make a plea for continuity of climate data as opposed to the progress that can be made from the introduction of new, different instruments. He concludes by considering the need to parametrise the modification of sea-ice albedo by the variation of penguin numbers, but neglects to point out the dependence of these on the fish population and hence krill concentration which depends in turn on the amount of UV radiation reaching the ocean.

The last section of the book concentrates on the land-atmosphere interface, starting with a review of the specific scientific and technical objectives of GEWEX followed by an informative review of SVATS (soil-vegetation-atmosphere-transfer-schemes) by Shuttleworth. This begins with the physics needed to describe SVATS, is illustrated with present-day examples, and emphasises the problems associated with subgrid-scale variation.

Larsen's article on observing and modelling the PBL is a disappointment. In his attempt to describe some simple pictures for turbulence and introduce the basic statistical tools, the sparcity of definitions, large number of typographical errors, incorrect equation numbers and confusing use of language in places make it difficult for novices to the field.

The final chapter is a multi-author review of the terrestrial hydrological cycle covering the role of water on land and the mutual interaction of surface and sub-surface processes with the atmosphere. It introduces model equations for the interaction of soil moisture with liquid water and plant roots and considers the need for meteorologists and hydrologists to combine in future observational studies of terrestrial hydrology. This is followed by two brief appendixes, the first a review of the type of database required to manage the one terrabyte of incoming information per day expected to come from EOS by the year 2000. Pointing out that satellite data used to be considered a write-only archive, Dozier suggests that a more useful database will have fast network access for researchers all over the world, allow analysis of various forms of data ranging from raster data to point profiles, and permit transparent remote visualisation, and that prototypes are under developement. The second appendix consists of an even briefer review of contributions from the students involved in the course and probably could have been omitted.

On the whole this book represents a worthwhile attempt to tie together the various disciplines involved in GEWEX in an introductory form. Some of the articles are marred by typographical errors and varying degrees of tortured English, although this should hamper understanding in only a few isolated cases. Most articles contain bibliographies which provide the next step for students who wish to move on from the introductory material presented. The cost of the book is excessive (even for students), which means that only libraries should consider buying it.

Lawrie Rikus

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El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation

edited by H.F. Diaz and V. Markgraf (Cambridge University Press, 1992) ISBN 0 521 430429. 476 pp. $135.00.

What do cores from Pacific corals, North American tree rings, ice core records from Peru, global fishery catch records, and the thirteen hundred year record of Nile flood height have in common? These and other proxy climate records have the potential to tell us much about variations in the El Niño-Southern oscillation (ENSO) phenomenon for the period prior to that of instrumental records.

ENSO is the single most important source of global interannual climatic fluctuations, and one phase of the phenomenon, El Niño, is notorious for the droughts it can bring to eastern Australia, India and Indonesia among its many other effects. Not much is known about the long-term stability of ENSO. Has it behaved throughout the recent geological past much as it has over the last 100 years? Or have there been periods when its activity has increased or decreased, or periods when its mean state shifted towards one phase?

Answers to such questions are not just important in reconstructing past climates, but are relevant to projecting the future behaviour of ENSO. If there is evidence that ENSO changes its behaviour with changes in the base climate (such as between the Little Ice Age and the present), this may help us to predict how ENSO will behave in the warmer climate expected in the future due to the enhancement of the greenhouse effect. Furthermore, current global climate models, the main tool we have for projecting future climate change, tell us little about the future of ENSO because they do not, as yet, adequately simulate current ENSO behaviour. This increases interest in palaeoclimatic studies of the long-term behaviour of ENSO.

Diaz and Markgraf's book is an excellent compilation of research relevant to these questions. It contains papers by most of the main researchers working in the field of reconstructing past ENSO behaviour from non-instrumental records (some more well known being D. Enfield, W. Quinn and L. Thompson), as well as authors who have made major contributions to ENSO research in general (e.g. G. Meehl and N. Nicholls). Together the papers (22 in number) provide a good summary of previous relevant work but also introduce some substantial new results and analysis, and, in general, rigorous and appropriate statistical methods are employed. Also, for readers with little background in ENSO, the earlier chapters (particularly those by Diaz and Kiladis and by Enfield) describe the details of ENSO behaviour and its impacts from the instrumental record.

Much of the proxy ENSO data sets discussed in the book are resolved annually and provide scope for identifying individual El Niño events and other ENSO activity going back 500 years or more. Data are drawn from sources in South America, the Pacific, Australia, Asia and Africa. However, North American tree-rings are the proxy data used most in the book. This accurately reflects a marked geographical bias in research on the topic, but may give a misleading impression regarding where in ENSO's domain of influence its effects are strongest. Work to date on ancient ENSO will need to be balanced in the future by a greater focus on potential ENSO proxies from the equatorial Pacific and the eastern hemisphere where some of the strongest ENSO signals occur.

As good as this book is, it barely begins to answer the questions about ENSO posed above. Most of the pre-instrumental records considered do not contain a very strong ENSO signal, and cannot individually make a good proxy for ENSO activity. Nevertheless, contributors draw conclusions about changes in ENSO behaviour based on data from single regions only. Perhaps not surprisingly, these conclusions can appear to conflict. For example, Quinn (chapter 6) notes more frequent weak Nile floods, suggestive of more El Niño activity, in the latter part of the Little Ice Age (18th and 19th centuries), whereas the chapters by Lough (who looked at tree rings) and by Michaelsen and Thompson (who looked at American tree-rings and ice cores) conclude that ENSO activity has changed little over the last 400 years or so. Swetnam and Betancourt (chapter 14) see a weakened ENSO signal in the late 1700s in the fire scars preserved in tree ring cores from western North America, whereas Cleaveland et al. (chapter 15) found evidence of increased ENSO activity at that time in the record of tree-ring widths from eastern North America. Attempting to reconcile and interpret such differences (perhaps in terms of a changing ENSO teleconnection pattern) is made more difficult through the authors using a range of very different analysis techniques. Some authors attempt to reconstruct the record of past El Niño events (one phase of the phenomenon) whereas others the full Southern Oscillation Index (SOI). The conclusions of some authors are based only on changes in their proxy record of the spectral frequencies characteristic of ENSO.

Despite such disagreement in regional series, there is still every reason to believe that the variability in common amongst ENSO indicators taken from around the globe will provide a reasonable guide to past ENSO activity. This means that a good synthesis of the results of the field is essential if the proxy evidence of past ENSO behaviour is to be used to address questions regarding the stability of ENSO. Ideally, multiregional analyses need to be undertaken which use proxy data from throughout ENSO's domain of influence. This need is recognised by the editors and many of the authors in this book, but it is only addressed to a limited extent in the chapters by Quinn (chapter 6), Diaz and Pulwarty (chapter 8) and in the editors' concluding chapter. The study by McGlone et al. (chapter 21) is also multiregional but uses more coarsely resolved pollen records and draws conclusions on ENSO activity by more indirect means (whether or not the regional vegetation indicated in the pollen record is adapted to climate variability characteristic of ENSO). Their data enable them to consider the entire Holocene, and their evidence suggests that ENSO was less active prior to around 5000 years ago.

Overall, any shortcomings of this book mainly reflect the shortcomings of the field of research it summarises. In most respects it is a fine book, and one which has been much needed. Until now relevant work has appeared scattered across a broad range of journals, reflecting the diversity of disciplines that have collected evidence of past ENSO behaviour. This book will be an essential reference for those working in the field for some years to come and will stimulate the multidisciplinary and multiregional analysis that is needed if we are to unravel as much as we can about ENSO's history.

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Collected Papers of Lewis Fry Richardson. Volume 1, Meteorology and Numerical Analysis; Volume 2, Quantitative Psychology and Studies of Conflict edited by O.M. Ashford, H. Charnock, P.G. Drazin, J.C.R. Hunt, P. Smoker and I. Sutherland (Cambridge University Press, 1993) ISBN 0 521 38297 and 0 521 38298 X. 1016 pp. and 762 pp. $325.00 each.

Lewis Fry Richardson (1881-1953) was a highly creative and original thinker. In meteorology he is widely known for performing the first numerical weather prediction (NWP) experiment and for characterising the thermal stability of turbulent flow by the nondimensional number now known as the 'Richardson number'. But he was a pioneer in many fields of study, including numerical analysis, hydrology, numerical weather prediction, oceanic echo-ranging techniques, turbulence, diffusion, fractal geometry, acoustics, statistical mechanics, psychology, eugenics and peace research. Forty years after his death Cambridge University Press has decided to honour Richardson by publishing his collected papers. This event is most welcome indeed, because Richardson's work was far ahead of its time and contains many valuable insights, and is still often quoted.

Volume 1 is devoted to his meteorological and numerical analysis papers. The editors have included several short background papers which give an overview of different areas of Richardson's work. These include: a foreword by K.A. Browning, a general introduction to Richardson's life and work by J.C.R. Hunt, a description of his meteorological contributions by H. Charnock, and a discussion of his numerical analysis by L. Fox and his work on fractal geometry by P.G. Drazin.

From the very beginning Richardson was concerned with developing practical methods for solving partial differential equations applied to real problems which were not amenable to analytical means. He devised both graphical and finite difference techniques to do this and applied them to the difficult problems of computing the stresses in masonry dams and optimising the drainage flow of water in saturated peat moss. It was developing the mathematical tool of applying finite difference techniques in these problems (including the Richardson relaxation technique) that led him to the vision of numerically predicting the weather.

His meteorological work encompassed a number of difficult and important areas for meteorological modelling, e.g. turbulent mixing and the structure of the boundary layer, thermodynamics, the water content and optical properties of clouds, and surface albedo. He realised that meteorological understanding and modelling efforts were hampered by a lack of reliable data. To address this problem, he developed a number of novel measurement techniques, including 'lizard balloons' for measuring the ratio of pressure to temperature, 'cracker balloons' for measuring temperature, and an air-gun technique in which metal spheres were shot vertically upwards for measuring upper-level winds and temperatures.

His major meteorological contributions include his criterion of just-no-turbulence, defining for the transition from laminar to turbulent flow in a stratified fluid (1920); the concept of the energy cascade of turbulent eddies (1922); the 4/3 power law for the eddy diffusivity for a cloud of particles (1926); and his book, *Numerical Prediction by Numerical Process* (NPNP), which was one of the first textbooks on dynamical and thermodynamical meteorology. His penetrating insight into the nature of locally isotropic turbulence (1922, 1926) strongly influenced Kolmogorov and Obukhov in their development of the 2/3 power law for the velocity structure function and the $-5/3$ power law for the energy spectrum 15 years later. (Richardson's measurements were the only empirical verification of inertial subrange theory at that time.) His numerical weather experiment (1922) influenced Charney and his collaborators who performed the first successful NWP forecasts 28 years later, using a simpler model. Forty-five years after the publication of NPNP, technology had advanced to the point where the leading national weather services were using forecast models virtually identical to Richardson's model.

Richardson also examined diffusion in the sea by measuring the separation distance of pairs of drifting parsnips in an experiment with Henry Stommel (1948). The sinking of the *Titanic* stimulated him to develop the theory of echo-ranging (1912). This led to two patents, precursors to sodar and sonar; one was for warning ships about unseen large floating objects (e.g. icebergs) in a fog and the other was for warning ships about submerged objects or shallow ocean depth.

In numerical analysis Richardson devised a method of extrapolation (1927), now known as 'Richardson extrapolation', which is valid for solving both initial-value and boundary-value problems. Although other methods have overtaken it for initial-value applications (called 'marching problems' by Richardson), it is still commonly used for boundary-value problems (called 'jury problems' by Richardson).

Fractal geometry arises in Richardson's research in the self-similarity of the turbulent energy cascade: 'big whirls have little whirls that feed on their velocity, and little whirls have lesser whirls and so on to viscosity – in the molecular sense' (1922). It also arises when he explores the question, 'Does the wind possess a velocity? This question, at first sight foolish, improves on acquaintance' (1926). Fractals appear again in Volume 2 in his peace studies when considering the borders between nations he discusses the self-similarity and fractal dimensions of coastlines.

A number of other papers on instrumentation and measurement, including several with his students at Westminster Training College, are contained in this volume. It should be pointed out that Richardson left the UK Meteorological Office in 1920 for pacifist reasons when it was transferred to the Air Ministry. The bulk of the research reported in Volume 1 was done after 1920 in his 'spare' time and shows his passion for meteorology. But there came a time (about 1930) when Richardson felt that the only ones interested in his meteorological research were the 'poison gas experts'. He decided to give up meteorology at that time and destroyed all of his research that had not then been published.

Volume 2 also begins with several short background papers including a foreword by C.A.B. Smith, a repeat of the paper on Richardson's life and work by J.C.R. Hunt, an overview of his work in quantifying mental images and sensations by E.C. Poulton, a paper on Richardson's mathematical study of the causes of war by I. Sutherland, and an update on recent developments in this area by M. Nicholson.

Richardson from an early age planned to devote the latter part of his life to the study of living things. In 1926 he embarked on a Bachelor's Degree in Psychology, taking classes at night. But even before finishing his degree, he began his research into developing ways of quantifying the magnitudes of sensations, such as lightness, darkness, colour, loudness, mental images and pain. The idea of quantifying sensations was highly controversial at the time; no one before Richardson had demonstrated that it was possible and many thought that it was not. Richardson explored a number of ways of measuring sensations and tested them with the help of his wife, friends and relatives, and his students. He used models, equations and physical analogies to describe sensations. Although these concepts have since become commonplace in applied psychology, they were quite unfamiliar at that time.

Another of Richardson's major interests was peace research. While on the battlefield of World War I, serving with Friends' Ambulance Unit, Richardson developed a mathematical and psychological model of war and peace. He published his theory privately in 1919, because he could find no publisher. It was either ridiculed or ignored, but for Richardson it was very serious.

As the storm clouds of war began to gather in the mid-1930s Richardson returned again to study the causes of war. This time he developed an elaborate theory of arms races, eventually involving 10 nations. Evaluating the model parameters and testing the theory required a great deal of ingenuity. His theory showed remarkably good agreement with data for World War I. His analysis of the arms race preceding World War II indicated the war would eventuate and that Great Britain and Northern Ireland, France, Russia and Czechoslovakia would oppose Germany, Italy and Japan. The United States, China and Poland were not clearly shown to be on one side or the other.

He also compiled a comprehensive database on 'deadly quarrels', i.e. quarrels in which humans died ranging in scale from the murder of an individual up to the deaths of tens of millions of people in world war. He then methodically analysed his data and used it to test the statistical significance of various hypotheses and models. These models led him to study such fields as statistical mechanics, topology and fractal geometry. In order to have more time to work on peace research he retired early (1940).

Another area of his research into the psychology of international relations and the causes of war is Richardson's work on 'war moods'. He modelled these using epidemic disease theory. Richardson also wrote several papers outlining reforms in voting power for international organisations like the United Nations.

He tried for many years unsuccessfully to get his two book-length manuscripts published, *Arms and Insecurity* and *Statistics of Deadly Quarrels*, which summarised much of his peace research. Through the efforts of many people they were finally published in 1960 (seven years after his death). With the publication of these books, his work became more widely known in political and social science academic circles. Richardson's deterministic and statistical modelling efforts established two of the three main approaches currently used in the quantitative study of international relations (the third being game theory, pioneered by John von Neumann).

The *Collected Papers of Lewis Fry Richardson* brings together Richardson's papers, many of which are difficult to obtain. These two volumes allow the reader to gain an appreciation for the power of Richardson's intuition and insight, his attention to detail and his thoroughness, that made him one of the world's great meteorologists, and a scientist who had a profound influence on many fields. Some of his minor papers have been omitted in this collection, as have his three books, *Numerical Prediction by Numerical Process, Arms and Insecurity* and *Statistics of Deadly Quarrels.*

The *Collected Papers of Lewis Fry Richardson* is something that every meteorological library should possess.

Dale Hess

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Atmospheric Convection by K.A. Emanuel (Oxford University Press, 1994) ISBN 0-19-506630-8. Hardcover. 580 pp. $110.00

'As Napier Shaw put it, "The understanding of a phenomenon is that account of it which rests in the mind." It is that account which we seek here. For complex nonlinear phenomena such as thunderstorms, such an understanding can only arise when the essence of the process is distilled from a combination of observations, detailed numerical simulations, simplified models that attempt to separate the wheat from the chaff, and application of physically based diagnostics to all the preceding.'

This quote from the introduction to a chapter on numerical modelling of clouds indicates Professor Emanuel's intentions for this book. It is intended as a graduate-level textbook aimed at instruction and learning; the author emphasises that it is not a reference book. The reader is expected to have a prior knowledge of geophysical fluid dynamics and atmospheric thermodynamics, and is referred elsewhere for information on cloud microphysics. Simple numerical models or scale analysis of relevant equations are used as the principal heuristic tools.

The book is divided into four parts. The first deals with dry convection, introducing the basic equations and appropriate approximations. These are applied to localised sources of thermals and plumes, before moving on to more distributed convection and the dry convective boundary layer.

In the second part, on '*Moist thermodynamics and stability*', the emphasis is on the retention of water in its vapour and liquid forms in the formulae developed. There is a brief treatment of the traditional skew T-log pressure diagram, but the author suggests that it is of limited usefulness for either computational or illustrative purposes in studying cloud processes. Several conservative variable diagrams are suggested for studying cloud processes such as mixing and evaporation.

The third part, '*Local properties of moist convection*', includes the two chapters (out of a total of 16 in the book) which deal mainly with a survey of observations. The cases and results discussed derive mainly from the continental United States. There are also chapters on numerical modelling of convective clouds, including the representation of microphysical processes, and on slantwise convection, a subject in which Emanuel played a pioneering role. The author modestly notes that there is only circumstantial rather than direct evidence for the latter phenomenon.

The fourth part is entitled '*Global moist convection*' but is rather a miscellany, including fog, stratocumulus layers and convective parametrisation schemes for numerical models. There is a chapter on interactions with the large-scale, but this does not extend to the global-scale in the sense of the role of convection in the Hadley or Walker cells.

Emanuel's book covers much of same material as Cotton and Anthes' *Storm and Cloud Dynamics* but with a different emphasis. The latter is a reference book with an extensive bibliography, and includes some topics not included in Emanuel's book such as radiation and cloud microphysics. It also contains a more comprehensive review of observations, but, in general, does not include the same detailed mathematical elaboration of simple models as in Emanuel's treatment.

A strength of Emanuel's book is its unified approach. It is best read sequentially as the author attempts to relate the more complex phenomena treated later to the fundamental fluid dynamics results treated earlier. The rigour of the thermodynamics with the emphasis on retaining the effects of liquid water is also useful in view of its rarity in basic texts. Like any good textbook there are challenging exercises at the ends of chapters. For some the author makes computer programs available for access over Internet, and encourages contact from readers – an attempt to extend the interactive approach of the lecture theatre.

On the other hand, the intellectual rigour occasionally turns a little obsessive. For example, his strong comments in the final chapter on the misguided nature of conditional instability of the second kind (CISK) and the Kuo convective parametrisation scheme detract from his didactic goals by not recognising the useful contributions these notions have made.

The presentation is that of a typical academic text book. While the editing has been thorough, some of the author's own diagrams look awkward and cluttered and some copied from other sources have inadequate captions given the use of symbols different to those used in the text.

It is a textbook, not a forecasting manual. A forecaster on the bench wanting a general reference book would probably prefer Cotton and Anthes' book. Those interested in a mathematical fluid dynamics approach for modelling convective phenomena or those wanting their thermodynamic outlook stretched from the conventional will find this a very useful book.

Terry Hart

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