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TEMPERATURE AND PRECIPITATION IN MONGOLIA BASED ON DENDROCLIMATIC INVESTIGATIONS

by

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SUMMARY

Recent tree-ring studies in Mongolia provide evidence of unusual warming that is in agreement with large-scale reconstructed and recorded temperatures for the Northern Hemisphere and the Arctic. The Mongolian proxy record for temperature extends back over 450 years and is an important addition to the global tree-ring database. Precipitation reconstructions based on tree rings reflect recent increases but show that the increases are within the long-term range of variations. There is evidence for quasi-solar periodicity in long-term reconstructed precipitation variation, also shown by previous studies. Mongolia has excellent sampling resources for future studies.

Key words: Tree rings, Mongolia, paleoclimate, climatic change.

INTRODUCTION

Mongolia, with a largely agrarian economy, is subject to regional and global changes in climate. The country has an extreme continental climate comprised of very cold winters and hot summers. Much of the country is semi-arid to arid and precipitation variations have a profound impact on the economy. The northwestern part of the country is within the region of the Mongolian or Asiatic high, one of the most extreme atmospheric pressure regions of the world. This high influences circulation for much of Central Asia. The climate of Mongolia is dominated by advected air masses, although in summer local radiation balances and convective storms also influence precipitation and temperature. Recorded climatic data are rather short with few meteorological or hydrological records extending back past the 1940s. Thus, there is need for better and more extended climatic information for the country itself and for the region's role in larger-scale climatic variations.

Tree-ring analysis can provide high-resolution, extended records of climate variations. Initial tree-ring studies in Mongolia started in the 1980s with some of the first reports published in the 1980s and early 1990s. Nachin (1998) gives a description of some of the earlier studies using tree-ring analysis in Mongolia. Many of these stud-

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Table 1. Listing of Mongolian–American Tree-Ring Project (MATRIP) tree-ring sampling sites and data processing: sites 1–5 sampled in 1994, sites 6–12 in 1997. rw = ring width, d = density, s = spectral analysis, est = estimated.

Sample sites	Location	Elevation		Tree species	No. of trees (cores)	Variables	Time span (years)
		(m)	(feet)				
1. Hovsgol Nuur (Lake Hovsgol)	Lat. 50° 46.02' N Long. 100° 11.96' E	2300	(7540)	*Larix sibirica*	20 (50)	rw / d / s	467
2. High pass (Tarvagatay Nuruu, Tarvagatay Mts)	Lat. 48° 17.51' N Long. 98° 55.87' E	2400–2440	(7900–8000)	*Pinus sibirica* few *Larix sibirica* (much rot)	25 (50)	rw / s rw / s	530 592
3. Lost pine (northwest of Batsumber)	Lat. 48° 31.25' N Long. 106° 34.49' E	1280	(4200)	*Pinus sylvestris*	15 (28)	re	189
4. Terelj (east of Ulanbaatar)	Lat. 47° 54.39' N Long. 107° 26.58' E	1550–1580	(5100–5200)	*Larix sibirica*	16 (41)	rw / s	393
5. Manzshir Hiid (Manzshir Monastery)	Lat. 47° 45.96' N Long. 105° 59.72' E	1740–1770	(5700–5800)	*Pinus sibirica* (few *P. obovata*, very young)	15 (32)	rw / s	211
6. Tsagaanzaluu Uul (White Young Mt)	Lat. 46° 46.31' N Long. 102° 36.46' E	1980	(6500)	*Larix sibirica*	20	est	300
7. Hdagtai Uul	Lat. 46° 39.39' N Long. 102° 31.13' E	2130	(6990)	*Larix sibirica*	20	est	300
8. Outlier trees	Lat. 47° 47.21' N Long. 107° 30.00' E	1415	(4640)	*Larix sibirica*	18	est	300
9. Marmot Kill Camp	Lat. 47° 47.02' N Long. 108° 52.42' E	1630	(5350)	*Larix sibirica*	20	est	400
10. Urgun Nars	Lat. 48° 34.62' N Long. 110° 32.75' E	1070	(3500)	*Pinus sylvestris*	25	est	300
11. Dadal	Lat. 49° 00.75' N Long. 111° 35.53' N	1020	(3340)	*Pinus sylvestris*		est	350
12. Inferno Ridge	Lat. 48° 49.85' N Long. 111° 40.13' E	900	(2950)	*Pinus sylvestris*	26	est	250

ies are in Russian and Mongolian and are not readily available. The number of studies was limited by lack of trained personnel, equipment, and financial support. Some of the earlier data and collections are noted in Lovelius et al. (1992) and Anonymous (1995).

In 1995 a Mongolian-American tree-ring project (MATRIP) was started and field collection of samples took place in 1995 and 1997. A paper describing the first results came out in 1996 (Jacoby et al. 1996) and a more intensive phase of the project began in 1997. Figure 1 and Table 1 show the MATRIP collections to date. They extend from two sites at elevational tree line down to lower forest border sites where the trees end and grasslands begin. There are several intermediate sites. The highest sampling location is a mesic site at the treeline in the Tarvagatay Mts. where the dominant limiting factor to growth is temperature (Jacoby et al. 1996). The other tree-line site is a drier location above Lake Hovsgul where both moisture and temperature influence tree growth. Three sites are at or very near the lower limit of tree growth where moisture is the dominant limiting factor.

The lower forest border between trees and grasslands in Mongolia is important as this is the most likely area to find trees that are primarily stressed by lack of moisture. The observable lower forest border is often misleading as human activities may be limiting the extent of trees rather than ecological factors. Judging by the scarcity of fallen branches, absence of seedlings, and relatively high elevations of some lower forest borders, several of the sites are locations where the trees end due to long-term grazing

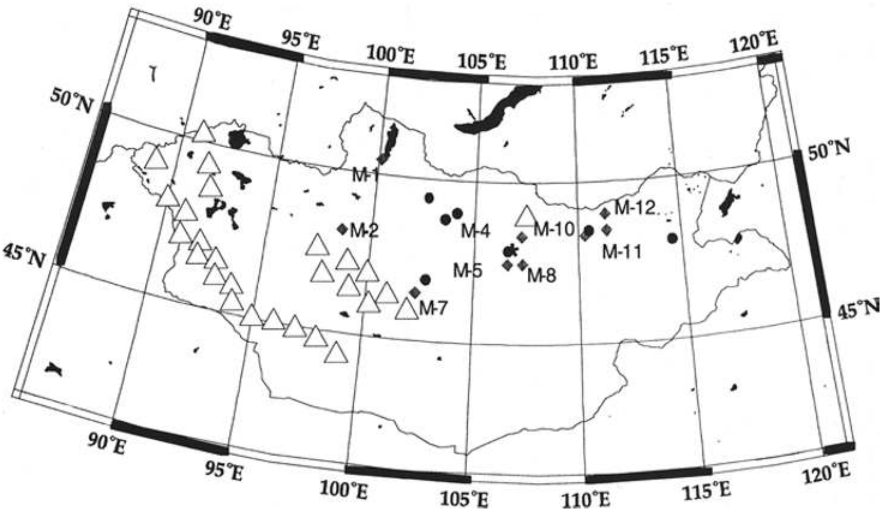

Fig. 1. Location of tree-ring sites. △ = mountain ranges; ◆ = tree-ring sampling sites; ● = meteorological sites; ★ = Ulaan Baatar, capital of Mongolia and a meteorological station; M-# = MATRIP tree-ring sampling site identification number.

and/or tree harvesting for various purposes. At these locations the trees have a mixed climate response and are less useful for reconstruction of precipitation or drought variations. They may be of value for studies of synoptic variations in climate.

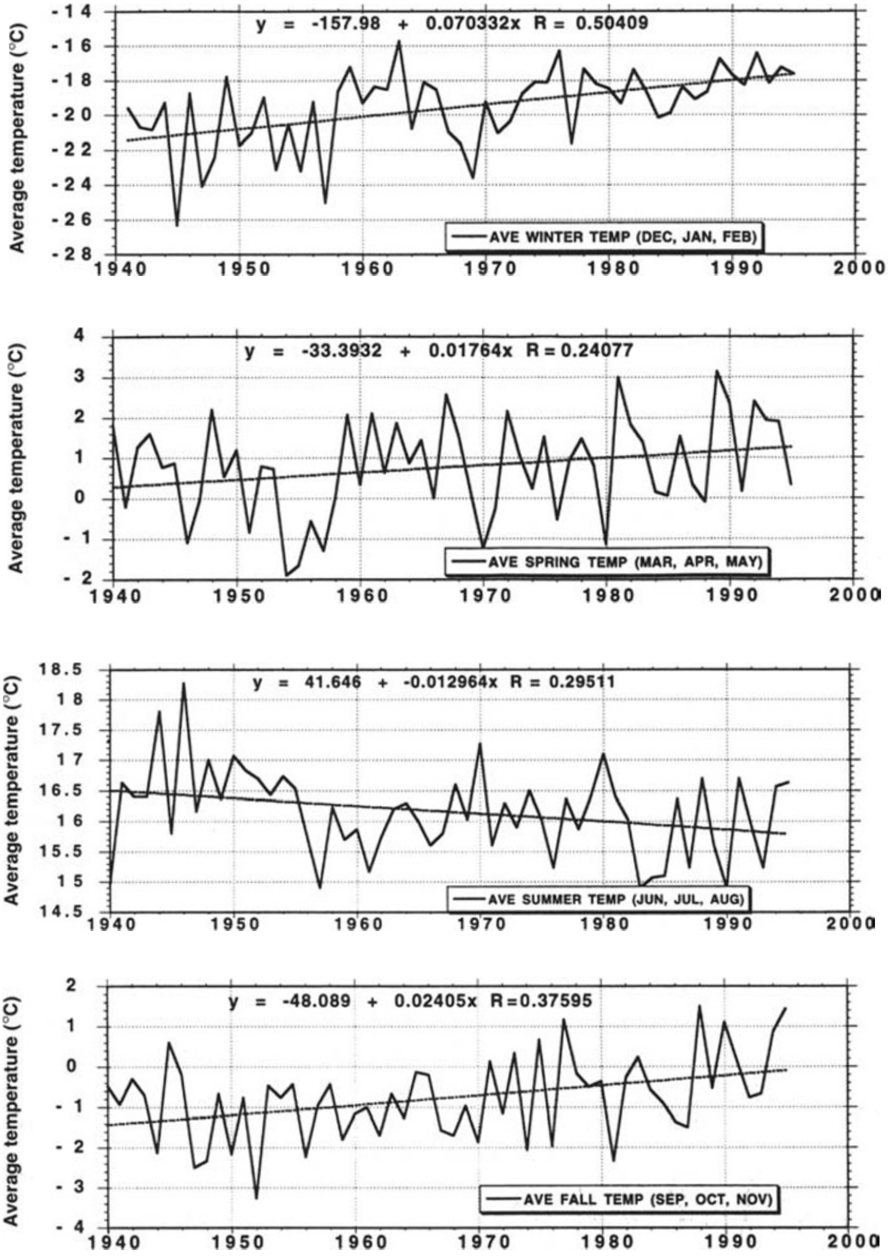

Fig. 2. Central Mongolia temperature trends for winter, spring, summer, and fall.

The three main species we have sampled and found useful are Siberian pine (*Pinus sibirica* Du Tour), Scots pine (*P. sylvestris* L.), and larch (*Larix sibirica* Ledebour). We tried to find sites with the least evidence of human disturbance. There was evidence of fire in three of the sites where we sampled Scots pine but there seemed to be little effect in most of the cores and resulting ring-width series. With its thick bark, the mature Scots pines are relatively resistant to fire damage. The larch do have some problems. There is a serious heartrot problem and at some sites with old-aged trees it is difficult to find trees that yield solid cores extending to the central rings. Also, we have observed anatomical symptoms in larch that may indicate tree damage due to insects. The xylem cell patterns are similar to those described by Weber (1997) for damage by larch budmoth to trees in Switzerland. This potential problem is being investigated further to see the effect on trees and the ring-width series.

We have found living trees over 500 years in age and a radiocarbon analysis indicates an age of about 700 AD for the inner rings of a dead snag. There are abundant dead snags at a few sites. Thus there is potential for millennial length chronologies.

TEMPERATURE

Analyses of recorded temperatures by Dagvadorj and Mijiddorj (1996) showed increases for fall, winter, and spring temperatures but decrease in summer temperature for the 1940 to 1995 period (Fig. 2).

They also note the following changes in the recorded temperatures: winter heating degree days are less, the growing season is longer by about 10 to 20 days due to the warmer spring and fall, the extreme heat in summer is less, and annual temperatures have increased by about 1.8 °C in Western Mongolia, 1.0 °C in Central Mongolia, and 0.3 °C in Eastern Mongolia.

A comparison between annual temperatures for Mongolia and the Northern Hemisphere shows that the trends in Mongolia reflect the same general trends although the trend in Mongolian temperatures for the 1950s through 1970s is slightly above the Northern Hemisphere temperature trend (Fig. 3, top). The agreement is due to the dominant effect of advected air masses into and through the country causing large-scale influences on climate. The best temperature tree-ring series from Tarvagatay Mts. (cf. Fig. 1) shows agreement in trend with the recorded Northern Hemisphere temperature (Fig. 3, bottom) and the grid box temperature for Central Mongolia (which is essentially the Irkutsk, Russia record). Figure 4 shows the agreement between the Tarvagatay tree-ring width index series and an Arctic zone temperature reconstruction based primarily on latitudinal tree-ring records (D'Arrigo & Jacoby 1992; Jacoby et al. 1996).

The conclusion is that there is definitely unusual warming for this site in Mongolia. This warming and previous low-frequency variations reflect temperature changes similar to the larger-scale, hemispheric temperature trends (Jacoby et al. 1996).

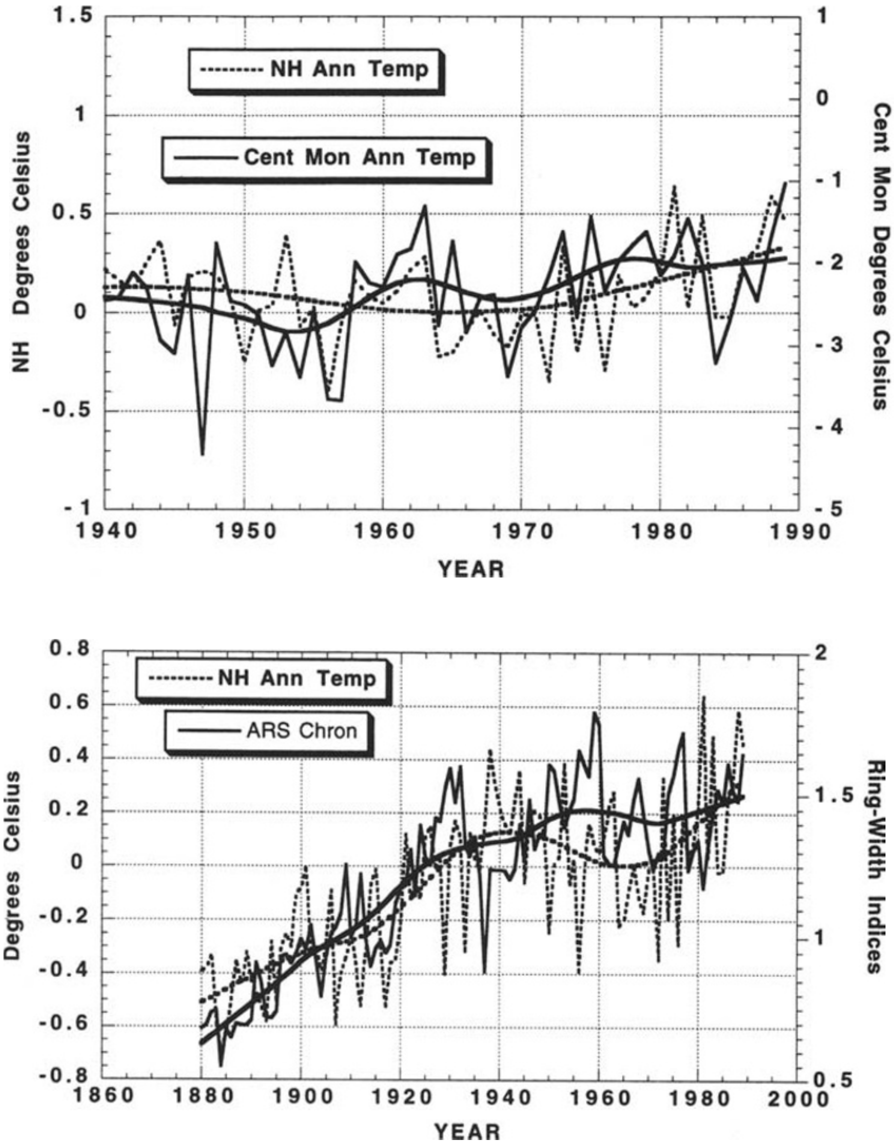

Fig. 3. Northern Hemisphere annual temperature and Central Mongolia annual temperature (top) and Northern Hemisphere annual temperature and Tavargatay ring-width indices (bottom).

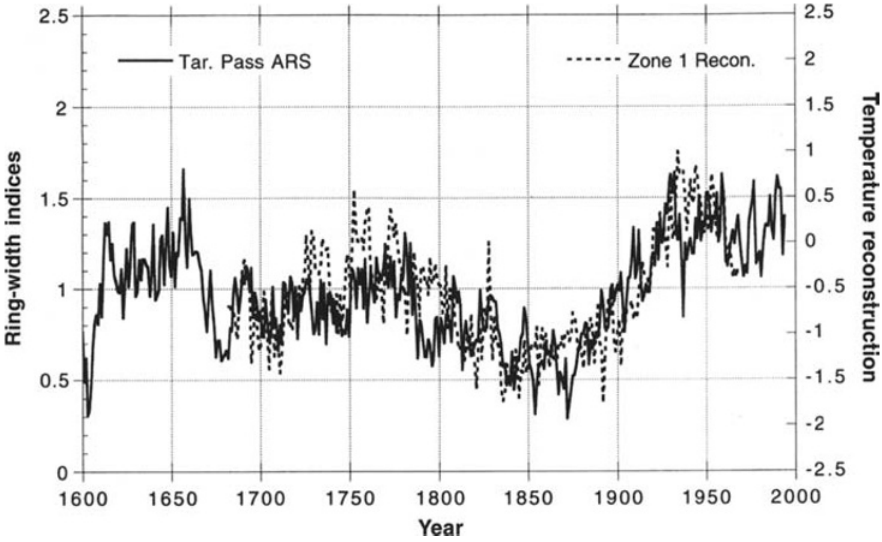

Fig. 4. Tarvagatay Pass ring-width indices and Arctic zone temperature departures.

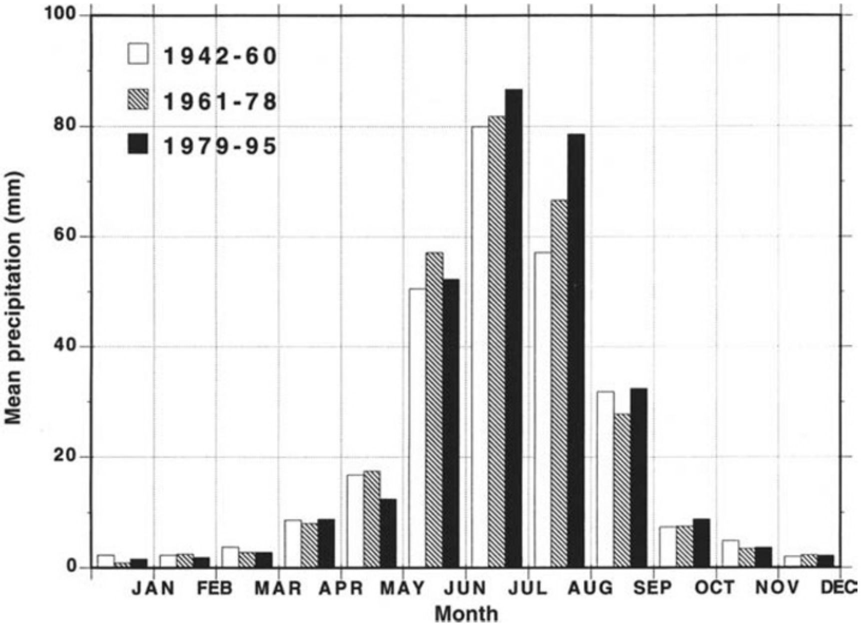

Fig. 5. East Central Mongolia precipitation distribution.

PRECIPITATION

Changes in precipitation have occurred for Central Mongolia. The recorded data from 1940 to present show an increase in total annual precipitation. We divided the precipitation record into three approximately equal time periods for comparison. The greatest monthly increase is in August, the second wettest month of the year, when the precipitation has increased by about 33% (Fig. 5). For May, a much drier month, precipitation has decreased by about 25%. Ring-width chronologies from two moisture-sensitive, lower forest border sites were used to make reconstructions of precipitation. For each reconstruction several meteorological stations were merged to produce a better regional precipitation record for the area around the site. In the recorded data the drought of 1944 was the most severe and there is a general trend upwards since then. This year is also the most extensive drought in the 200-year record reconstructed from historical information by Mijiddorj and Namhay (1993).

The tree-ring data from Urgun Nars (Table 1) in East Central Mongolia had the highest variance explained by monthly precipitation data. The sampled species is Scots pine. Using the data from January of the prior year through October of the current or growth year, precipitation could explain 58% of the tree-ring variation using the 1942–1995 period. The standard chronology from the program ARSTAN was used in the modeling. A positive response to mid-summer to fall precipitation of the prior year and to spring and summer of the current year was shown (Fig. 6). Two models were made based on this result: 1) summer precipitation of June, July, and August and 2) annual precipitation for a year extending from prior August to current July. Each model included ring-width indices for the current year and the following year because the correlations (Fig. 6) indicated the effect of prior year precipitation on the

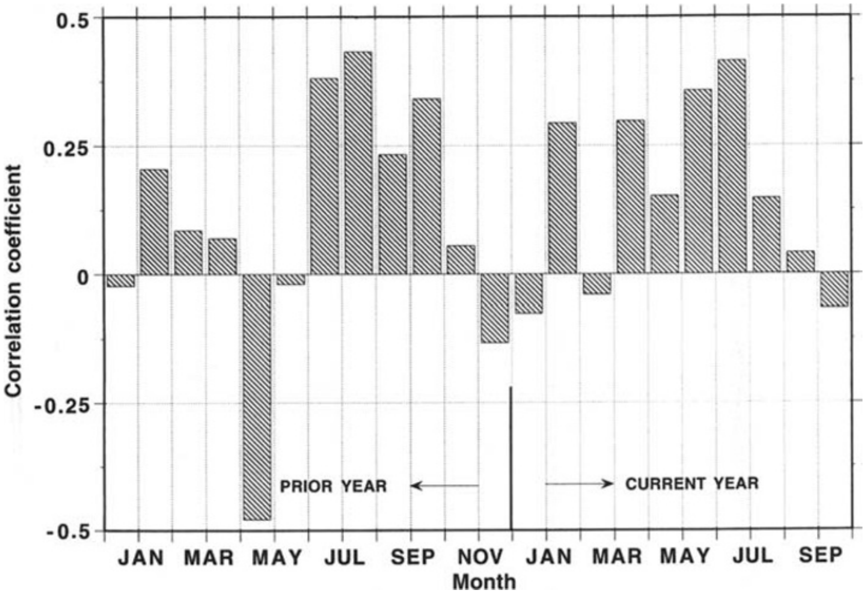

Fig. 6. Urgun Nars monthly correlation with East Central Mongolia precipitation.

next year's growth. The models explained 42% of the variation in summer precipitation and 54% of the variation in annual precipitation. Due to the shortness of the meteorological record, calibration-verification analyses were not performed. The reconstructions are shown in Figure 7.

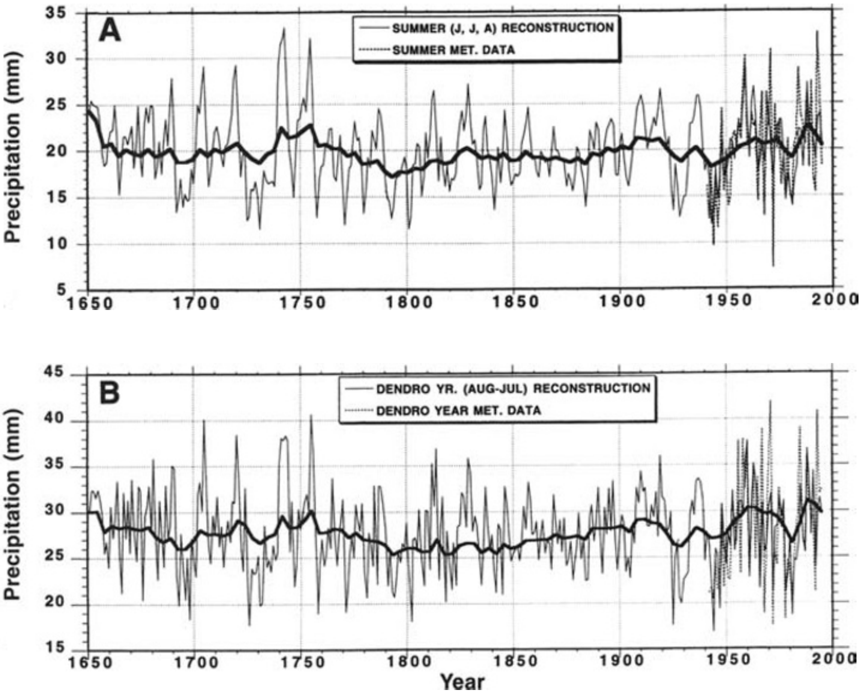

Fig. 7. Urgun Nars precipitation reconstructions for East Central Mongolia. The thick line indicates a smoothed reconstruction.

The other moisture-stress tree-ring data are Siberian pine samples from Manzshir Hiid (Table 1) in Central Mongolia. The variation in tree growth explained by monthly precipitation was 41%. The standard chronology was used and the correlations with monthly precipitation are shown in Figure 8. The reconstruction is for February through

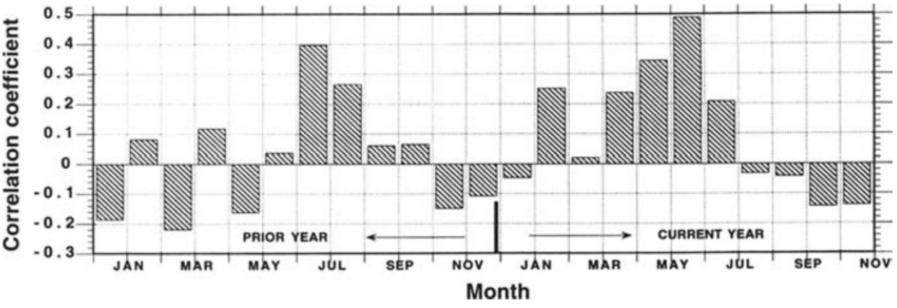

Fig. 8. Manshir Monastery monthly correlation with Central Mongolia.

July and also uses current year and following year ring-width indices for estimating the seasonalized precipitation. The model explains 36% of the precipitation variation (Fig. 9).

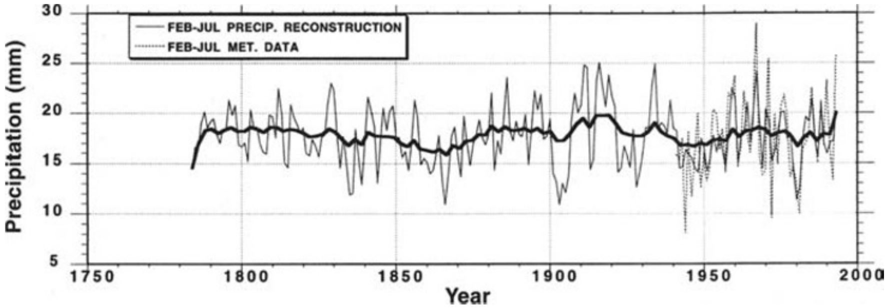

Fig. 9. Manshir Monastery precipitation reconstruction for Central Mongolia. The thick line indicates a smoothed reconstruction.

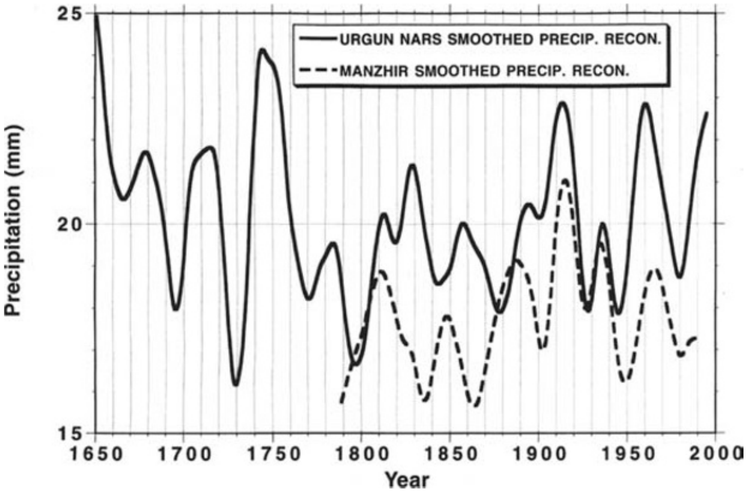

Fig. 10. Urgun Nars versus Manshir Monastery smoothed precipitation reconstructions.

Both reconstructions (Fig. 10) are in general agreement as one would expect. Neither reconstruction shows severe drought in the 1820s, especially 1827, which is shown in the historical reconstruction. The reconstructions are in agreement in the 1920s when both tree-ring reconstructions and the historical reconstruction all show severe drought (Mijiddorj & Namhay 1993). The tree-ring reconstructions are for Central and East Central Mongolia whereas the historical reconstruction is for all Mongolia and therefore some of the differences may be due to different geographical coverage. More tree-ring reconstructions are needed before full comparisons can be made.

SPECTRAL ANALYSES

Some earlier studies indicated quasi-solar periodicities in tree-ring data (e.g., Lovelius et al. 1992) and drought (Mijiddorj & Namhay 1993). Our analyses indicate that periodicities are very dependent on the tree response to climate. Temperature-sensitive trees as represented by the Tarvagaty site trees have very little periodicity. The trees from moisture-sensitive sites show much more spectral power indicating periodicities in the 22-year range and 3- to 4-year ranges. The 22-year periodicities in moisture-stressed trees and in drought occur in analyses of tree-ring data and drought in the coterminous United States of America (Cook et al. 1997) and were previously proposed by Douglass (1919). This periodicity attracts much discussion for two reasons. It indicates a response to solar activity and it confers some predictability of drought occurrence. The 3- to 4-year periodicities are in the range of ENSO variations. Spectral analyses of the precipitation data show significant 11-year and 30-year periodicities in spring and summer, respectively, and some 3- to 4-year periodicity in the fall, winter, and spring. All the spectral properties of the Mongolian tree-ring series warrant further investigation and interpretation beyond the scope of this paper.

CONCLUSION

The main conclusions of these initial studies are:

1) There is evidence of climatic change in Mongolia and temperature trends are in agreement with hemispheric trends towards warming in the 20th century.
2) Precipitation increased in recent decades but is within the range of long-term variations. The variations appear to have a periodicity related to solar variability.
3) Tree-ring analyses can be of great value in extending the climatic records for Mongolia.

ACKNOWLEDGEMENTS

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WOOD ANATOMY NEWS

Report from the XVI International Botanical Congress, St. Louis, 1–7 August 1999

International Botanical Congresses are grand affairs. Botanists of all persuasions, nationalities and interests converge on a place with limited biodiversity but abundant hotels, meeting rooms and restaurants for a jamboree of intellectual and nutritional over-consumption. This year St. Louis was the venue for around 4,700 delegates from 85 countries. With almost 3,000 posters and up to 20 concurrent sessions, choosing what to attend was often difficult, except for three unmissable sessions. The first, on evolution of conductive tissue, was organised by Sherwin Carlquist (who alas could not attend) and Dianne Edwards. It included papers on conductive tissues in the earliest vascular plants, trends of evolution in fossil woods, hormonal control of xylem morphogenesis, molecular and biochemical aspects of xylem cell wall development, and water movement in lianas. The last speaker, Frank Ewers, had to contend with a 25 minute delay to his 20 minute talk while the projector ate his slides! The two consecutive IAWA sessions were on xylem structure in tree biology, ecology and evolution (organised by Pieter Baas and Elisabeth Wheeler), and systematic wood anatomy and modern methodologies (Regis Miller and Teresa Terrazas). Abstracts for most of the papers in the IAWA sessions were published in IAWA Journal 20 (2), as were some of the poster abstracts. Subjects included archaeological and fossil wood, effects of stresses during maturation on cell wall structure, vessels in monocots, dendrochronology, climate and wood structure, wood anatomy in the context of the latest angiosperm phylogeny, legume, mahogany, Euphorbiaceae, cactus and cladistic wood anatomy. Some other sessions included talks on wood in whole or part, particularly those on palaeobotany, cell wall biosynthesis, shoot and root structure, sustainable tropical forestry and plant biomechanics. In such a tight programme, it was difficult to give enough attention to the posters. The exhibition hall where they were displayed was open only from 9.00 to 17.00 each day, and the lectures ended at 18.30. Looking through all the poster abstracts after the conference, I found 37 on wood or bark, ranging from dendrochronology to methods of embedding charcoal for light microscopy.

The IAWA reception, held on the evening preceding the IAWA symposia, was organised by Richard Keating. At the business meeting, Regis Miller welcomed us all and congratulated Ben ter Welle on his honorary membership in recognition of his long and

Regis Miller hands Ben ter Welle the Honorary Membership Certificate.

distinguished service as executive secretary (see IAWA Journal 20: 97–98). Regis nearly had us voting on the new council before any nominations or elections, but quickly saw the error of his ways. Pieter Baas, with Elisabeth Wheeler's permission, spoke for them both as editors of IAWA Journal. They have recruited a third editor, Barbara Gartner (see the next page of this issue). The editors would like to see the submission of more review articles and news items. When the meeting was opened for discussion, Richard Keating highlighted the possible fate of microscope slide collections made by eminent anatomists such as Adriance Foster and Katherine Esau. He suggested that IAWA should publicise the plight of these collections and help expedite their transfer to safe homes where they will be properly maintained. The news pages of the journal are an ideal place for such matters.

Having eaten all the food and drunk the bar dry, several of us still had the stamina to gate crash the palaeobotanists' party in another hotel. Elisabeth led the way, and we managed to merge in undetected. Our plan to blame Pieter for the intrusion if challenged, was unnecessary. A marvellous tradition amongst the palaeobotanists is the careful curation of a rogues gallery (or is it chamber of horrors?) in the form of photo albums of mostly still extant palaeobotanists. Perhaps we should do the same in IAWA? There are plenty of overlapping (or is it congruent?) characters.

The IAWA Softwood Committee (from left to right): Immo Heinz, Dietger Grosser, Regis Miller, Alex Wiedenhoeft, Lee Newsom, Peter Gasson, Pieter Baas, Jorgo Richter, Teresa Terrazas, Elisabeth Wheeler, Mitsuo Suzuki (Photo Tomoyuki Fujii).

On the penultimate day, the IAWA softwood committee met in the Holiday Inn. There are 16 members, and 12 were present. From 8.30 to 16.00 we discussed all the features and character states that should go in the list, and by the end had complete consensus. This was quite an achievement considering that it took a whole week locked in a room to do the hardwood list, including half a day to decide on the difference between distinct and indistinct growth rings! The task was much easier this time, because Jorgo Richter had done a sterling job coordinating all the committee members' views on a draft list, definitions and photos, that were prepared by Immo Heinz and Dietger Grosser, who were both present. Jorgo will prepare the final draft and circulate it to the committee. Publication will be in 2000, a fitting start for IAWA in the new millennium.

As at all IAWA and larger meetings, this was an ideal opportunity to meet old friends and colleagues, and to forge new collaborations. Even after a week, I was still bumping into people I hadn't seen before at the conference. St. Louis is the home of one of the world's greatest botanical gardens, and there was a regular free bus service to and from the conference centre for the duration of the conference. The coaches were particularly full on the last day, which coincided with the first rain in the area for weeks. The cafeteria and bookshop must have done a roaring trade! The next IBC will be in Vienna in 2005. There will be several IAWA meetings before this, and I have no doubt that we will again have a strong presence in Vienna.

Peter Gasson

ASSOCIATION AFFAIRS

Change of IAWA Administrative Office

At the end of this year Ms. Doortje Oosterwijk will retire as secretary and effective manager of the financial and membership administration in the IAWA Office in Utrecht. At the request of Executive Secretary Dr. Regis B. Miller, Ms. Emma van Nieuwkoop, currently also lay-out editor of the IAWA Journal in Leiden, has agreed to take over the extensive tasks from Doortje Oosterwijk. Thus your dues notices for IAWA will be sent by Doortje this fall for the last time. Please note her instructions very carefully, and help to effect a smooth transition by paying your dues promptly.

Barbara Gartner reinforces the editorial IAWA team

From this fall onwards Barbara Gartner will reinforce the ranks of the editorial duo Elisabeth Wheeler and Pieter Baas. Barbara is a native Californian but went to Swarthmore College (and studied with the plant demographer Jim Hickman), then went to University of Alaska Fairbanks (where she studied demography and ecophysiology of tundra plants with Terry Chapin, and developed a long-standing interest in growth forms and what they mean), then after several years of work in arctic restoration ecology and soil conservation in Guatemala (as a Peace Corps volunteer) she went to Stanford University (with Hal Mooney, Paul Green, and Mark Denny) where she studied structure / function relationships in *Toxicodendron diversilobum* (poison oak), a beautiful (but allergenic) plant that grows as a shrub and a liana depending on its

Barbara Gartner touching wood?

environment. She found that shrubs had wood that was more stiff and stems that were more tapered than lianas, but that it was primarily the contribution of their geometry, not the material (and the large second moment of area) that made shrubs stiffer than lianas. The xylem of the shrubs had half the specific conductivity (or permeability) of the lianas, but they also had only half the leaf area beyond a given transverse area of stem. Thus, there was compensation in leaf area per stem transverse area in these plants, so the leaf would not 'know' if it were sitting on a vine or a shrub.

Afterwards Barbara did a post-doc at Berkeley with Mimi Koehl looking at allocation to the anchorage function in plant roots (one usually assumes that enough root is made to hold a plant up when root is made for water and nutrient uptake – but do plants need to also allocate carbon for anchorage?). In 1992 she started as an Assistant Professor of Forest Products at Oregon State University, where she works at the interfaces of wood quality, wood anatomy, and plant physiology, still looking at questions of hydraulics and biomechanics, often with a view of understanding effects of environment on the properties of wood. She has worked on physiology and causes of juvenile vs. mature wood, tradeoffs between mechanics and hydraulics of reaction wood effect of elevated growth rate on mechanical and anatomical properties of wood, etc. In 1998 she became Associate Professor. She teaches classes in wood anatomy, wood properties, and structure/function relationships in wood. From August 1998 to 99 she worked in Montpellier, France, on tradeoffs between water transport- and mechanical functions in the wood of *Quercus ilex*.

Barbara brings new skills and scientific background to the editorial team and we are very grateful that she is prepared to put them in the service of the IAWA Journal.