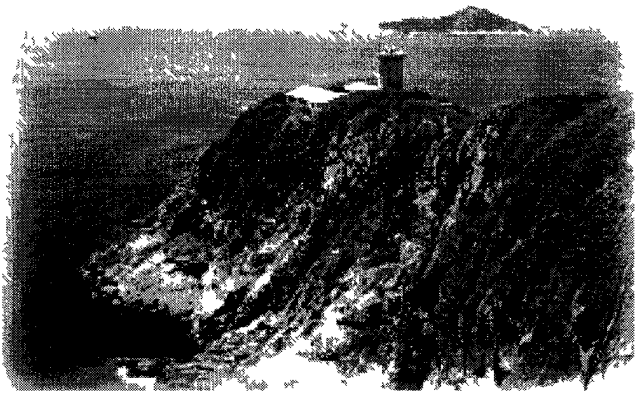
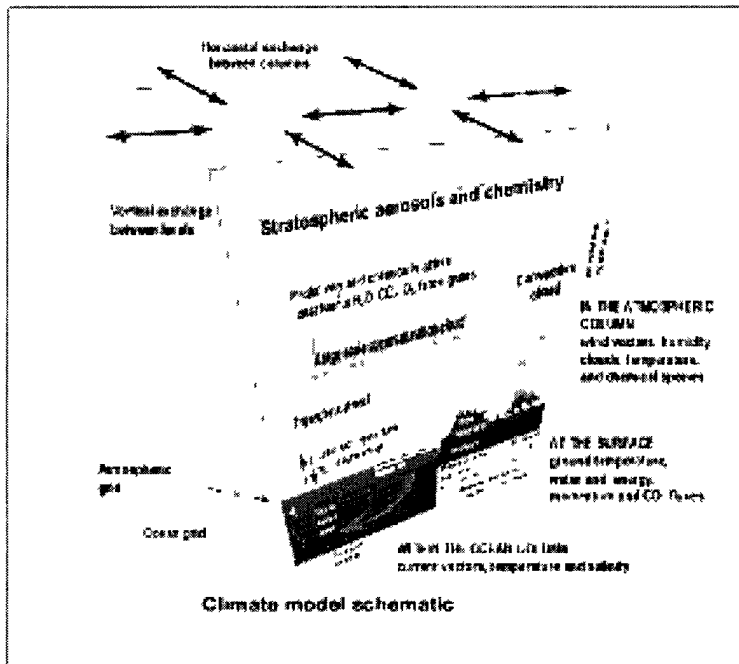




AU0221937

ANSTO/E-749
ISBN 0-642-59996-3
ISSN 1030-7745

Human Activity and Climate Variability Project Annual Report 2001



by K.J. Harle, H. Heijnis, A. Henderson-Sellers,
S. Sharmeen and W. Zahorowski



Project OP- 0050: Human Activity and Climate Variability

Project Leader: Dr Henk Heijnis (Henk.Heijnis@ansto.gov.au)

Website: <http://home.ansto.gov.au/ansto/environment1/>

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Project overview

P1.1 Project scope

This project aims to utilise nuclear techniques to investigate evidence of human activity and climate variability in the Asia Australasian region. It was originally designed to run over three years, commencing July 1999, with three parallel research tasks:

Task 1: Past - Natural archives of human activity and climate variability

Task 2: Present - Characterisation of the global atmosphere by use of radon and fine particles

Task 3: Future - Climate modelling: evaluation and improvement

P1.2 Main project objectives

- To determine what proportions of changes in natural archives are due to human activity and climate variability.
- To contribute to the understanding of the impact of human induced and natural aerosols in the East Asian region on climate through analysis and sourcing of fine particles and characterisation of air samples using radon concentrations.
- To contribute to the improvement of land surface parameterisation schemes and investigate the potential to use isotopes to improve global climate models and thus improve our understanding of future climate.

P1.3 Significant project outputs

- The Department of Land and Water conservation, National Parks and Wildlife Services, Sydney Water Corporation and the Australian Antarctic Division would use the results of the natural archive studies in their management and policy documents.
- The ACE-Asia project will generate data for the official data archive for this international project. Papers will be prepared for an international journal on air characterisation in collaboration with other participants.
- A significant scientific contribution will be made to the understanding and characterisation of regional air masses in Asia/Australia by publishing scientific analysis of measurements, maintaining data quality and guiding the scientific projects at selected observation stations.
- Evaluation of a proposed new technique for determining changes in the surface water budget.
- Analysis of a large number of AGCMs with particular reference to the behaviour of their land-surface schemes.

P1.4 Significant project outcomes

- An improved understanding of natural and anthropogenic factors influencing change in our environment. Results could be used in improving management policies and developing long term management strategies.

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- A better understanding of the role of aerosols in climate forcing in the Asian region, leading to improved ability to predict climate change.
- An improved understanding of long term changes in the concentrations of trace species in the atmosphere on a regional and a global basis and their use in model evaluation.
- Improved understanding of the impact of different land-surface schemes on simulations by atmospheric models.

P1.5 Summary of progress December 2000 - November 2001

	Task 1	Task 2	Task 3
Milestones set	15	14	6
Milestones achieved	13	5	4
Milestones ongoing	6	9	4
Publications and reports	27 papers/abstracts 48 reports	6 papers/abstracts 23 reports	20 papers/abstracts/posters 16 reports
Research co-operation	11 universities 1 Government organisation 1 International organisation	2 universities 2 Government organisations ACE-Asia international partners	2 universities 2 Government organisations 27 PILPS international modelling groups 35 AMIP international modelling groups
External usage of facilities	10	NA	NA
Fieldwork trips (ANSTO)	6		NA
Supervision of students	3 PhD 1 Masters 2 Hons	1 PhD 1 Hons	1 Hons

NA = Not applicable

P1.6 Future of the project

In order to complete our project and increase ANSTO's international profile – as decided at the mid-year CBA meeting on 1999, we have to achieve the following:

- 1) Align ourselves with the recently developed mission of the IGBP/PAGES research program "Human Interactions on Terrestrial Ecosystems" and co-ordinate the Australasian research effort. The project leader has been elected to represent the Australasian region and the project team is now actively seeking support from other researchers. An AINSE sponsored workshop was successfully organised to engage the Australian research community (September 2001). A SE-Asian/ Australasian conference will be organised in consultation with the International Project Leader (February 2003)
- Further research should focus on: how widespread and reliable are evidence of major climatic events, such as storms and El Nino/La Nina cycles, in natural archives? This would require more natural archives to be examined from northern Australia and also records to be obtained from southern Australia. The spatial extent of mining related pollutants, in the form of aerosol particles, is of importance to managing the waste in the future. A combination of aerosol and archival studies will address this issue.
- 2) A two-year extension to ANSTO's involvement in the ACE-Asia program is the minimum requirement for us to achieve most of our extended scientific objectives. Such an extension will allow us to collect sufficient

P1. Project Overview

data to more accurately quantify seasonal fine particle concentration variations over the region, as well as to fingerprint and quantify source contributions across the study area based on a statistically significant number of pollution events. This would also provide sufficient time to apply Chemical Mass Balance and Positive Matrix Factorisation techniques to integrate aerosol and radon data. Overall, the proposed extension would put us in a better position to meet the expectations of our international collaborators whose programs rely on our data and require our expertise.

3) The ANSTO involvement in international initiatives of AMIP II and GLASS show clearly that June 2002 is not a good closing date for the research in this project. The ANSTO contributions to both research programs are essential to other partners and therefore a premature end would cause major disruptions to this international effort.

In terms of AMIP II we anticipate the release of another 10 AGCMs' data around June 2002 and also additional evaluation data between January and June 2003. One further year would allow ANSTO researchers to progress much further into the complete data analysis. Two further years (i.e. until June 2004) would allow us to complete all the analysis as we proposed to AMIP and to participate in the AMIP II planned for July 2004.

For PILPS and GLASS there are equally sound reasons for either a one, or preferably a two, year extension to Task 3. As can be seen in the timeline diagram, ANSTO researchers are committed to co-ordinating PILPS component of GLASS into early 2004. Thus we all likely to be involved into the first half of 2004. Ideally, therefore, a two-year extension to this task of this project is desirable in order to allow us to fulfil our international scientific commitments.

In Summary: In order to achieve these goals we seek another two years of further support for our project. This is a direct result of the project team's successful push to be members of International fora and ANSTO's unique contribution to these international projects.

P1.7 Project team 2001

ANSTO

- Mr Nathan Allen
- Mr Chris Bowles
- Dr Scott Chambers
- Mr Robert Chisari
- Dr Eric Clayton
- Dr David Cohen
-
- Mr David Garton
- Dr Kate Harle
- Dr Henk Heijnis
- Professor Ann Henderson-Sellers
- Mr David Hill
- Mr Quan Hua
- Dr Parviz Irannejad
- Dr Geraldine Jacobsen
- Mr Andrew Jenkinson
- Mr Gordon McOrist
- Dr Saniya Sharmeen
- Dr David Stone
- Mr James Sutherland
- Dr Wlodek Zahorowski
- Dr Ugo Zoppi
- Ms Atun Zawadzki

External collaborators

- Dr Richard Arimoto (New Mexico State Uni, USA)
- Dr Tim Bates (NOAA/PMEL, USA)
- Dr Brendan Brooke (QUT)
- Dr Hoshin Gupta (Uni of Arizona, USA)
- Dr Simon Haberle (Monash)
- Dr Takatoshi Hattori (Central Research Institute of Electric Power Industry, Japan)
- Dr Lesley Head (UOW)
- Professor Phan Duy Hien (Vietnam Atomic Energy Advisory Board, Vietnam)
- Professor Min Hu (Peking Uni, China)
- Professor Peter Kershaw (Monash)
- Professor Y.J Kim (Kwangju Institute of Science and Technology, Korea)
- Professor Takao Lida (Nagoya Uni, Japan)
- Dr John McGregor (CSIRO)
- Dr Kendal McGuffie (UTS)
- Assoc. Prof. Andrew McMinn (IASOS, UTas)
- Assoc. Prof. David Perry (NTU)
- Dr Tom Phillips (LLNL)
- Prof. Andrew Pitman (Macquarie)
- Dr Steve Ryan (NOAA/CMDL, USA)
- Dr Cath Samson (UTas)
- Dr Jie Tang (Chinese Academy of Meteorological Sciences, China)
- Mr John Tibby (Monash)
- Dr Katsuhiko Yoshioka (Shimane Inst. Environment. Studies, Japan)
- Dr Huqiang Zhang (BoM)
- Dr Yulong Xia (Macquarie University)
- Scientists and technical support from CGPAPS, BoM, the Antarctic Division and PCMDI of the Lawrence Livermore National Laboratory.

Students

- Mr Mark Arnold (UNSW-Hons)
- Mr Gary Buchanan (UTS-Hons)
- Ms Megan Coles (NTU-PhD)
- Mr John Paul Colliton (UTS-Hons)
- Ms Fiona Dick (Newcastle-PhD)
- Ms Nicola Franklin (Sydney-PhD)
- Ms Ros James (UNE - PhD)
- Mr Peter Murry (Newcastle-PhD)
- Ms Kate Panyatou (UOW-PhD)
- Ms Bec Scouller (Macquarie - Masters)
-
-

Task 1: Past - Natural archives of human activity and climate variability

T1.1 Task 1 research focus, objectives and scope

T1.1.1 Research focus

Task 1 of the HACV project is focused on investigating natural archives of Australian baseline environmental conditions. Knowledge of the state of the Australian environment, including natural climate variability, prior to colonial settlement is vital if we are to define and understand the impact of over two hundred years of post-industrial human activity on our landscape. Unfortunately, there is a distinct lack of measured historical data, particularly in Australia where monitoring records do not extend beyond 200 years into the past. Further, those records that do exist are generally associated with extensive alteration of the landscape and consequently frequently fail to capture the natural conditions. However, there is an alternative source of information about natural and anthropogenically influenced environments in the form of high resolution sediment records. Study of such natural archives is growing in Australia, aided greatly by the recent development of high resolution sampling equipment. Also of great importance is lead-210 dating, without which establishing a chronology for these records would be difficult.

ANSTO, in conjunction with our university partners, is leading a major research effort to provide natural archives of human activity and climate variability over the last 500 years in Australia. Task 1 is the focus of this effort, utilising a variety of techniques, including lead-210 and radiocarbon dating and analyses of proxy indicators (such as microfossils) as well as direct evidence (such as trace elements) of human activity and climate variability.

T1.1.2 Objectives

Task 1 has three main objectives:

- To identify the best indicators of past human activity and climate variability in sediment records (natural archives);
- To determine what proportion changes in the landscape/terrestrial ecosystems are due to human activity or climate variability or an interaction of both;
- To contribute to the IGBP sponsored project investigating Human Impact on Terrestrial Ecosystems (HITE).

T1.1.3 Scope

Task 1 has and will continue to fulfil these objectives through the:

- location of high-resolution natural archives spanning the last 200 years;
- improvement of isotope-dating techniques in order to establish a reliable chronology;
- identification of geochemical and biological indicators of human activity;
- identification of geochemical and biological indicators for natural climate cycles;
- comparison of records derived from natural archives with available historical records;
- linkage of results with aerosol, radon and climate modelling analyses;
- HITE SCOPE

T1.2 Task 1 progress

T1.2.1 Summary of progress

The progress of analyses of sediment cores from sites selected in this study are outlined in Table T1.1. More detailed reports of the progress made since the last annual review (November 2000) are given in the following sections.

Table T1.1: Summary of progress made on sediment cores from the project sites.

Site area	Site	¹⁴ C	²¹⁰ Pb	Sediment	Trace elements	Pollen	diatoms	Charcoal
Northern Territory	Annaburro	NA	■	■	■	■	NA	NA
	Billabong							
Atherton Tableland (QLD)	Lake Euramoo*	■	■	■	■	■	■	■
Lake Burragorang (NSW)	Tonalli River*	NA	■	■	■	NA	NA	NA
	Lacy's Creek*	NA	■	■	■	NA	NA	NA
	Nattai River	NA	■	■	■	NA	NA	■
Victoria	Hogan's Billabong	NA	■	■	NA	NA	■	■
	Lake Cullulleraine	NA	■	■	NA	NA	■	■
	Tower Hill	■	■	■	NA	■	■	■
Tasmania (western)	Lake Dora*	■	■	■	■	■	■	■
	Midge Lake*	■	■	■	■	■	■	■
	Perched Lake*	■	■	■	■	■	■	■
	Lake Cygnus	■	■	■	■	■	■	■

NA = not applied ■ completed ■ in progress

*progress reported in 2000 review report

T1.2.2 Northern Territory

Annaburro Billabong

Collaborative researchers: Mr Gary Buchanan (Honours student UTS), Dr Graziella Caprarelli, Assoc. Prof. Greg Skilbeck (UTS), Assoc. Prof. David Parry (NTU)

Site description and selection rationale

Annaburro Billabong is a billabong located between Darwin and Kakadu (Figures 1.1 and 1.2) near the junction of the Mary and McKinlay Rivers at 12°55'S, 131°40'E in the Northern Territory. It has formed in a localised depression that is possibly an ancient segment of the Mary River, which flows north from near Pine Creek to the Arafura Sea. The billabong is maintained by groundwater as well as monsoonal floods

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from the Mary River, with a possible influence also from the McKinlay River. Sediment supplies are derived from monsoonal flood deposits as well as *insitu* biogenic production. The surrounding vegetation consists predominantly of open woodland, *Melaleuca* swampland and grassy plains. Much of it has been heavily influenced by cattle and buffalo grazing. The site was chosen because of its potential to record a variety of human activity in the region as well as a possible signal of southern oscillation (ENSO) driven past climatic variation.

Annaburroo Billabong is located on Annaburroo Station, which has had a varied history. It was originally used for buffalo hunting throughout the 1900s until the mid-1980s. Since then it has been used for cattle grazing and in recent times has been developed as a tourist destination, with accommodation being built within 50 m edge of the billabong. In the broader region, mining in the upper catchment of the Mary River dates back to 1865, with widespread activity by 1881. Early mining activities largely consisted of numerous small, shallow workings with most of the now known major mineral deposits, excluding iron ore and uranium, being exploited (Needham and Roarty, 1980). This mining was carried out in the absence of strict environmental regulations and is likely to have had a considerable impact on the local region. Larger scale production developed in the 1940s with the commencement of uranium exploitation. By the mid-twentieth century most of the smaller mines had been abandoned.

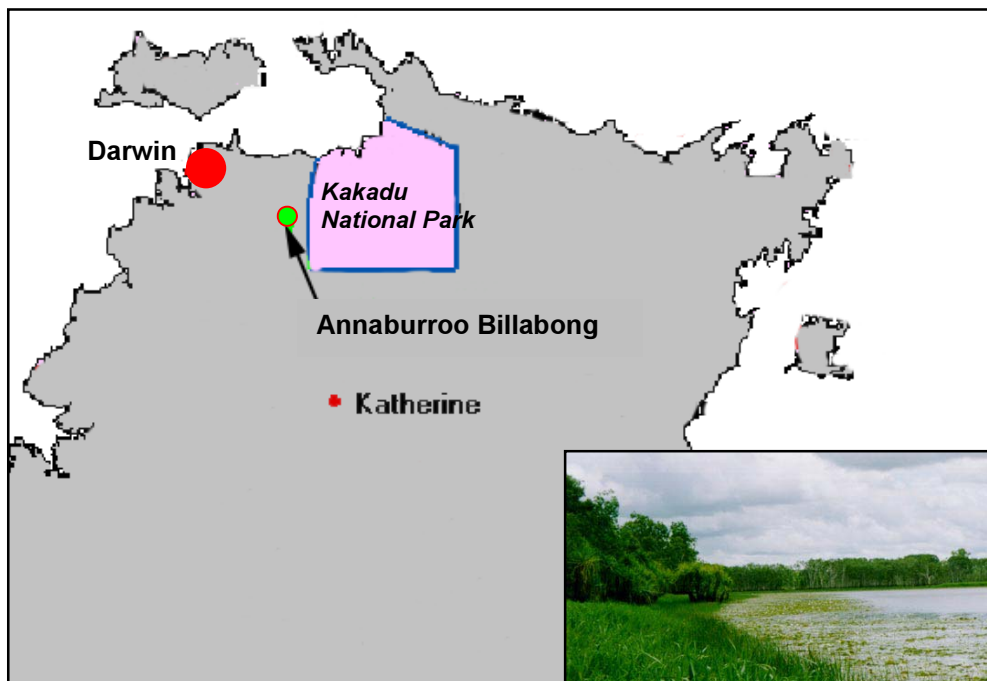


Figure 1.1: Regional map showing location of Annaburroo Billabong



Figure 1.2: Photo of Annaburroo Billabong looking north

Progress

Work on this site is being carried out by an Honours student from the University of Technology Sydney - Mr Gary Buchanan.

Eight cores were extracted from Annaburroo Billabong on two field trips carried out jointly with researchers from the Northern Territory University and the University of Technology Sydney (one in November 2000 and seven in May 2001). Initial data from the November core (AL2 C1) suggests that sedimentation in the

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Billabong occurred in pulses (Figure 1.3), with three distinct pulses occurring in the past ~100years. On the basis of these preliminary results it is believed sediments in the Billabong may be largely the result of multi-decadal flood events.

Lead-210, grain size, loss on ignition, trace element and pollen analyses were carried out on samples from seven of the eight cores. Results of these analyses are currently being interpreted as part of the Honours work of Gary Buchanan. Full results will be available later this year.

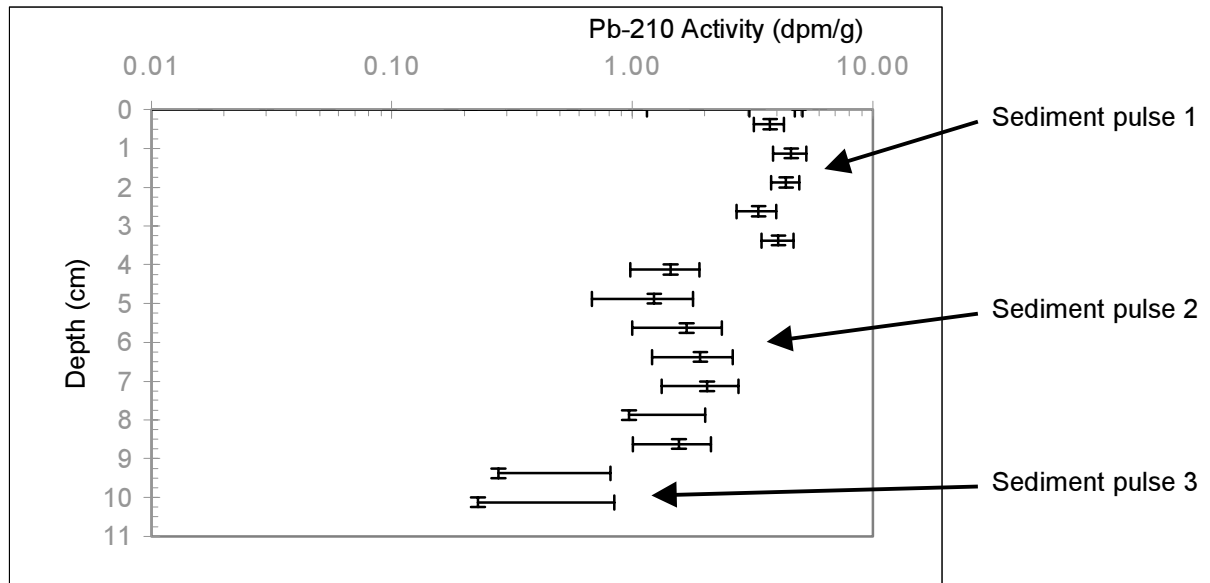


Figure 1.3: Plot of excess ²¹⁰Pb activity vs depth for Annaburroo Billabong core AL2 C1

T1.2.3 Atherton Tableland, QLD

Lake Euramoo

Collaborative researchers: Dr Simon Haberle and Dr John Tibby (Monash)

Progress

A rationale for site selection, a site description and results of the trace element, sediment, charcoal, ¹⁴C and ²¹⁰Pb analyses of two sediment cores from Lake Euramoo (Atherton Tableland) were presented in the 2000 HACV annual report (pp7-10).

Since November 2000 pollen, diatom and trace element analyses (NAA) have been completed on an 8.4 m core from Lake Euramoo, which spans the Holocene period. The diatom and pollen results are currently being interpreted by collaborators at Monash University. The trace element results are currently being interpreted. Selected trace element results (Al, As, Ce and La) are presented in Figure 1.4. There is some suggestion that values increase from ca 1885., which may be related to catchment disturbance associated with logging and burning in the area. Al and Ce values exhibit a decrease after ca 1940, which may be related to a change in land use from forestry to agriculture. Some decreases are also evident in the concentrations of As and La at this time, although not as clearly. Further work will be carried out comparing the trace element results with other results.

All of the results are currently being put together for publication.

T1. Task 1 - Natural archives

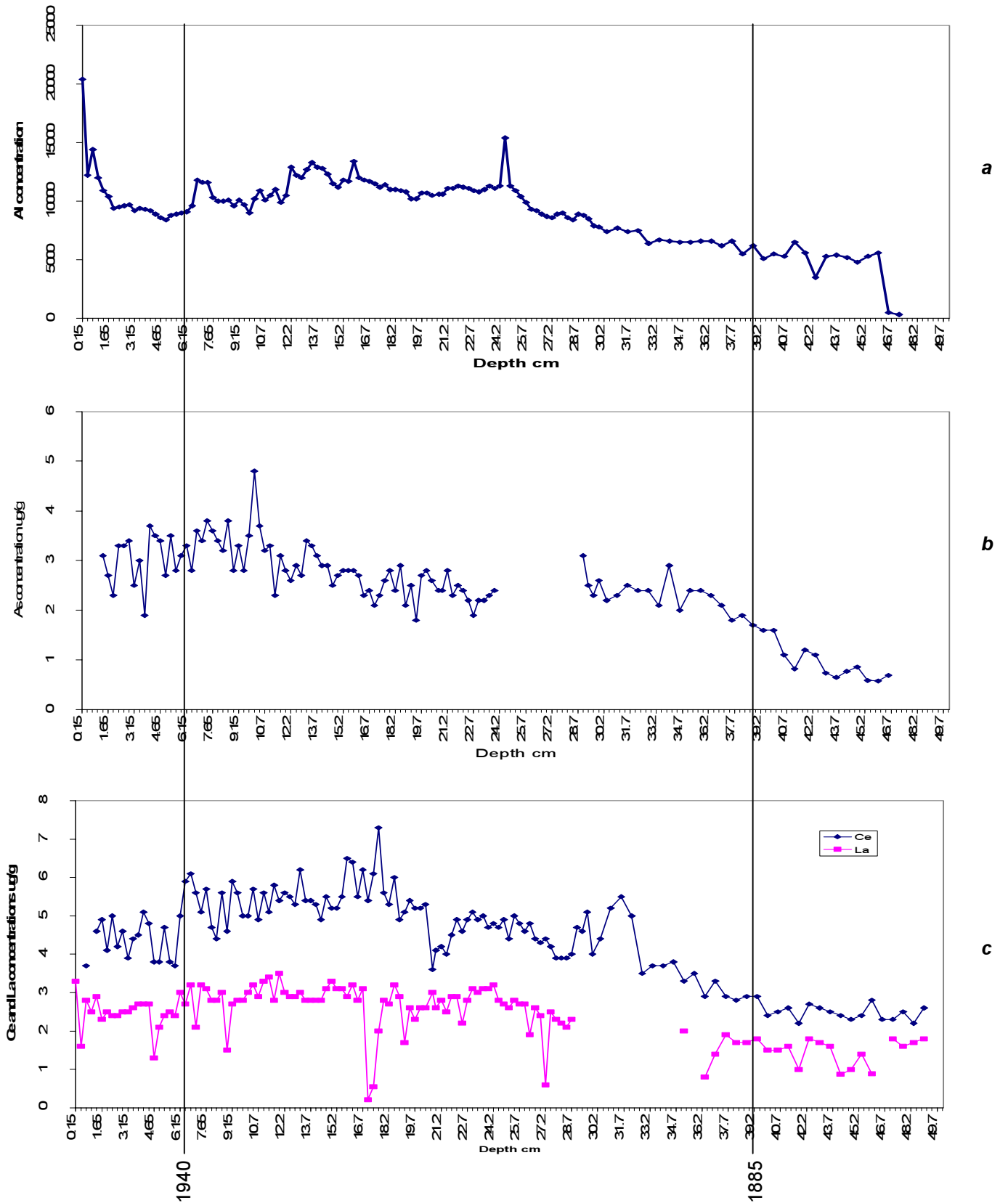


Figure 1.4: Selected trace element results (NAA) from Lake Euramoo core 1. a. aluminium; b. arsenic; c. rare earths - cerium and lanthanum. The latter may provide good indications of erosion.

T1. Task 1 - Natural archives

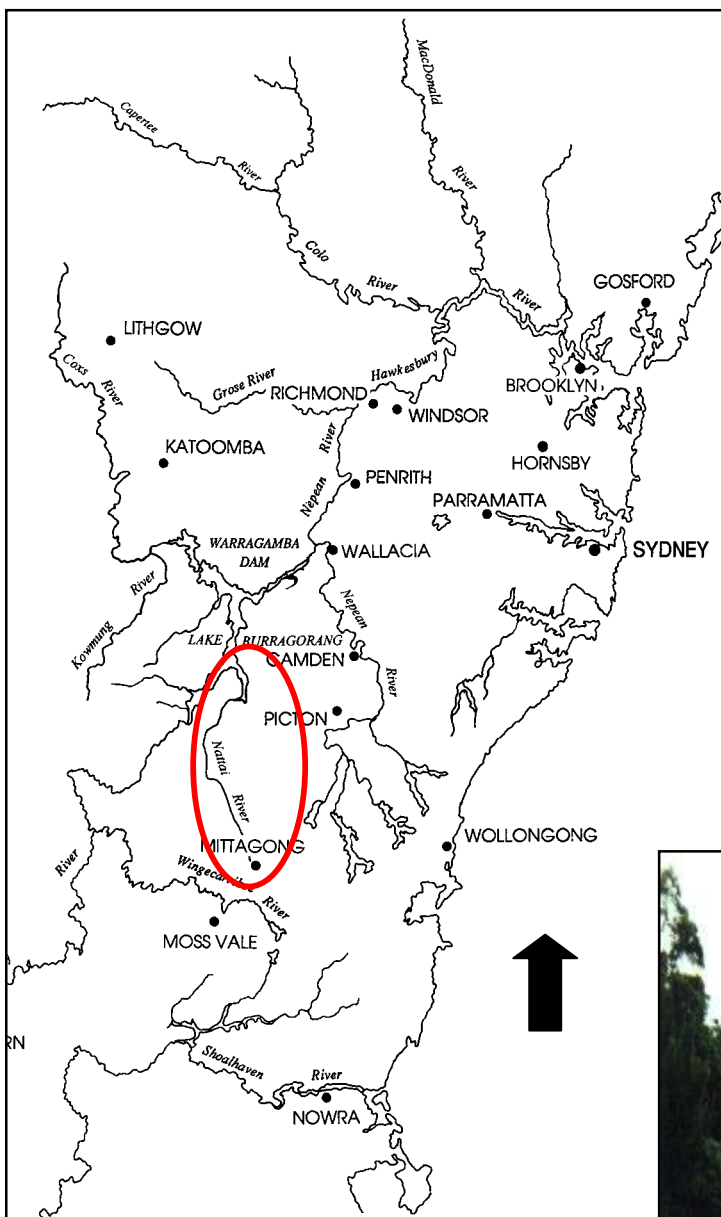
T1.2.4 Blue Mountains, NSW

Nattai River

Collaborative researchers: Mr John Paul Colliton (Honours student UTS), Dr Graziella Caprarelli, Dr Greg Skilbeck (UTS), Sydney Catchment Authority

Site description and selection rationale

The Nattai River is one of the source streams for Lake Burragorang, Sydney's largest water reservoir. It lies in the southeast sector of the Burragorang catchment (Figures 1.5, 1.6), extending over 60 km northward from Mittagong to the eastern shore of the lake. The Nattai catchment falls within the Nattai Reserves System, which has recently been awarded World Heritage status. The catchment is dominated by dry sclerophyll communities, with pockets of warm temperate rainforest along the eastern escarpment.

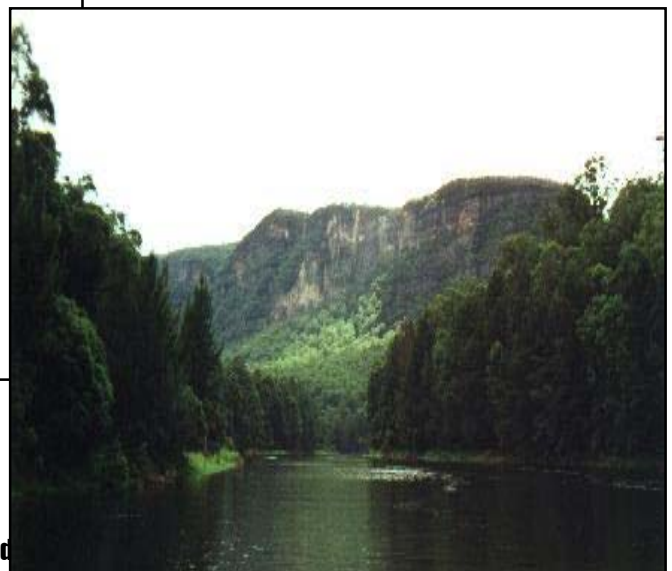


The Nattai River was chosen to compliment the studies carried out in the Burragorang catchment during the first stage o of the HACV project - Tonalli River, Lacy's Creek and Cox's River. The Nattai catchment includes a mixture of largely pristine environments and human impacted areas, with abandoned coal mines and livestock grazing widespread in the upper catchment as well as urban settlements. The latter includes the Mittagong Sewage Treatment Plants, which is of major concern in regards to

Figure 1.5: Map showing the location of the Nattai River.

potential water pollution in the Burragorang catchment.

Figure 1.6: Mouth of the Nattai River



T1. Task 1 - Natural archives

Progress

Work on this site is being carried out by an Honours student from the University of Technology Sydney - Mr John Paul Colliton.

Six sediment cores were extracted from the lower reaches of the Nattai River. Lead-210, grain size, loss on ignition, trace element and macroscopic charcoal analyses were carried out on samples from four of these cores. In addition, trace element analyses were carried out on seventeen surface samples collected within the catchment. Results of these analyses are currently being interpreted as part of the Honours work of John Paul Colliton. Full results will be available later this year.

Preliminary results show that there is a good correlation between the dated occurrence (1950s-1960s) of peaks in macroscopic charcoal content in three of the cores and the historic record of fires in the Burragorang Valley. A major fire event affecting more than half of the protective vegetative cover within the Warragamba catchment took place in 1958 (McElroy and Relph, 1961). Further recorded fires impacting on the Nattai River occurred during the mid- to late-1960s (Sydney Water Corporation, 1997). The increase in macroscopic charcoal has a direct correlation with the organic content and an inverse relation with the percentage < 63 μm grain size fraction (Figure 1.7). This has been interpreted as evidence of an increase in surficial erosion caused by the reduction in fire cover associated with the fire events.

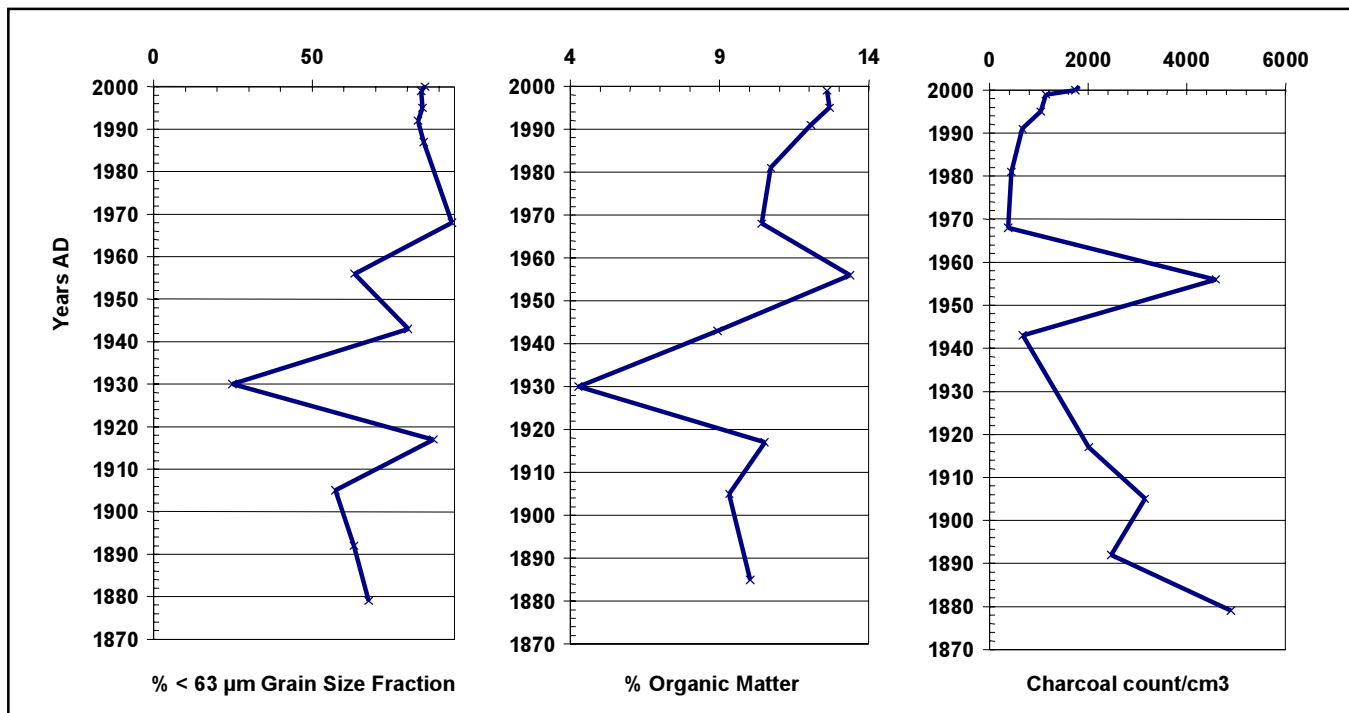


Figure 1.7: grain size, organic matter and macroscopic charcoal results from NC core #5

T1.2.5 Victoria

Three sites in Victoria (Figure 1.8) are being studied in conjunction with researchers at Monash University for the HACV project. These are Lake Cullulleraine, Hogan's Billabong and Tower Hill. The first two are along the Murray River whilst the latter is in south west Victoria. Progress of Lake Cullulleraine and Hogan's Billabong are reported below.

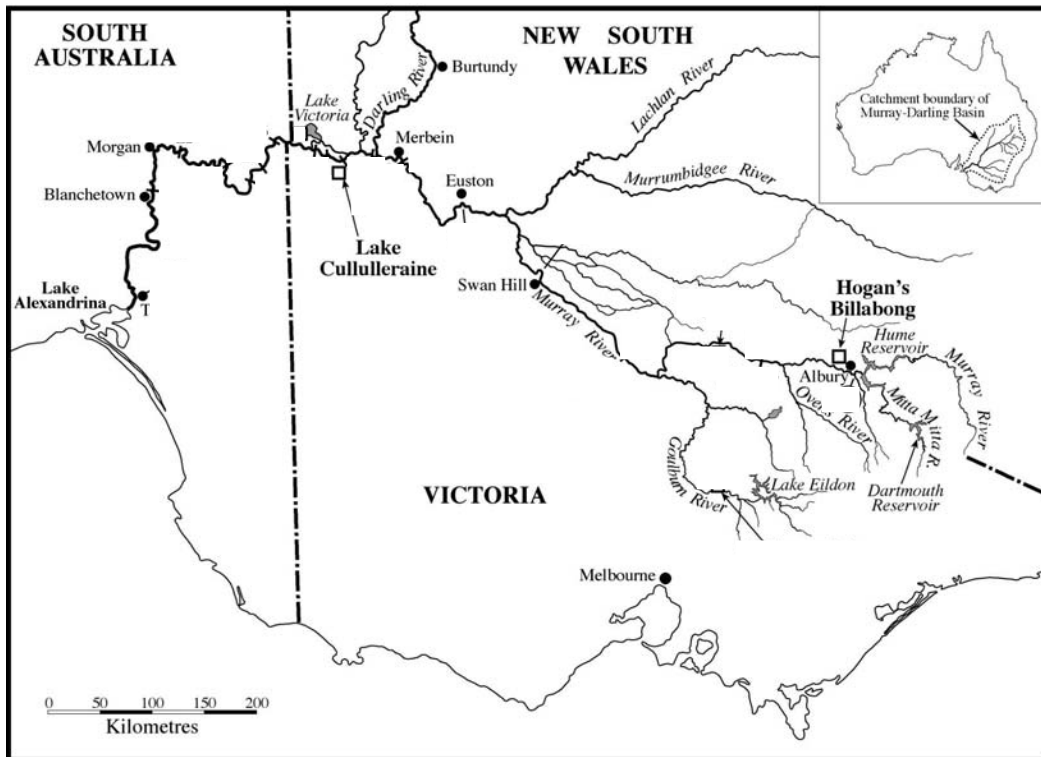


Figure 1.8: Map of southeast Australia showing location of Lake Cullulleraine and Hogan's Billabong

Hogan's Billabong

Collaborative researchers: Dr Michael Reid (Monash), Prof. Peter Kershaw (Monash), Dr Carl Sayer (University College London)

Site description and selection rationale

Hogan's Billabong is a relatively large billabong on the upper Murray River, close to Albury (36:01:27S, 146:42:46E). Work was initiated at this site following observations by Dr Ralph Ogden that *Cladoceran* evidence indicated that the submerged aquatic macrophyte community had been "lost" from the system.

Progress

Lead-210 determinations have been completed for this site (Figure 1.9) but due to the variable nature of fluvial inputs to the site, it has been difficult to determine an absolute chronology, though changes in the ^{210}Pb and ^{226}Ra may help elucidate important changes in sediment sources.

Diatom, pollen and macrofossil analysis have been completed for the Hogan's record (Figure 1.10). Pollen analysis (analyst: Peter Kershaw, Monash), combined with basic sediment analysis techniques reveal dramatic initial impacts by European settlers, with increased soil erosion and differential declines in tree taxa such as *Callitris*.

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The high resolution diatom record (analyst: Michael Reid, Monash) supports earlier inferences from Cladoceran analysis of a "switch" from a submerged macrophyte dominated to plankton dominated system, which occurs early in the post-contact period. The diatom record also reveals evidence of increased pH in the system. Later increases in *Aulacoseira granulata* are indicative of changes in the Murray River's trophic structure, resulting from river regulation.

Macrofossil study (Carl Sayer, University College London) provides further evidence of the reduction in aquatic plants in the system with decreases in the remains of macrophyte associates such as *Tricoptera* larval cases and *Plumatella* stratoblasts. Subsequent changes, such as the reduced abundance of *Daphnia ephippia* and fluctuations in *Azolla* leaves and Chironomid head capsules require further investigation.

In addition to providing supporting evidence for Ogden's hypothesis of declines in submerged aquatic macrophytes in Murray River billabongs associated with European settlement, the study has provided strong evidence that the proximal mechanism driving this decline was a dramatic increase in suspended silts and clays resulting from erosion and not blooms in phytoplankton, periphyton or *Azolla*.

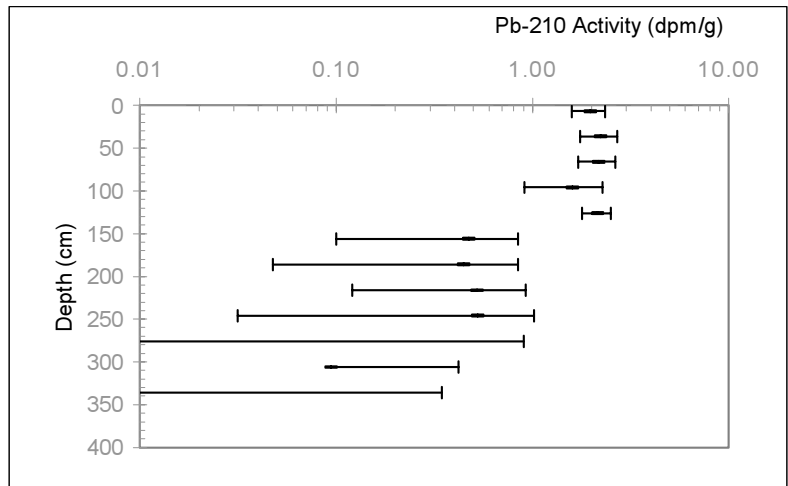


Figure 1.9: Plot of excess ²¹⁰Pb activity vs depth for Hogan's Billabong

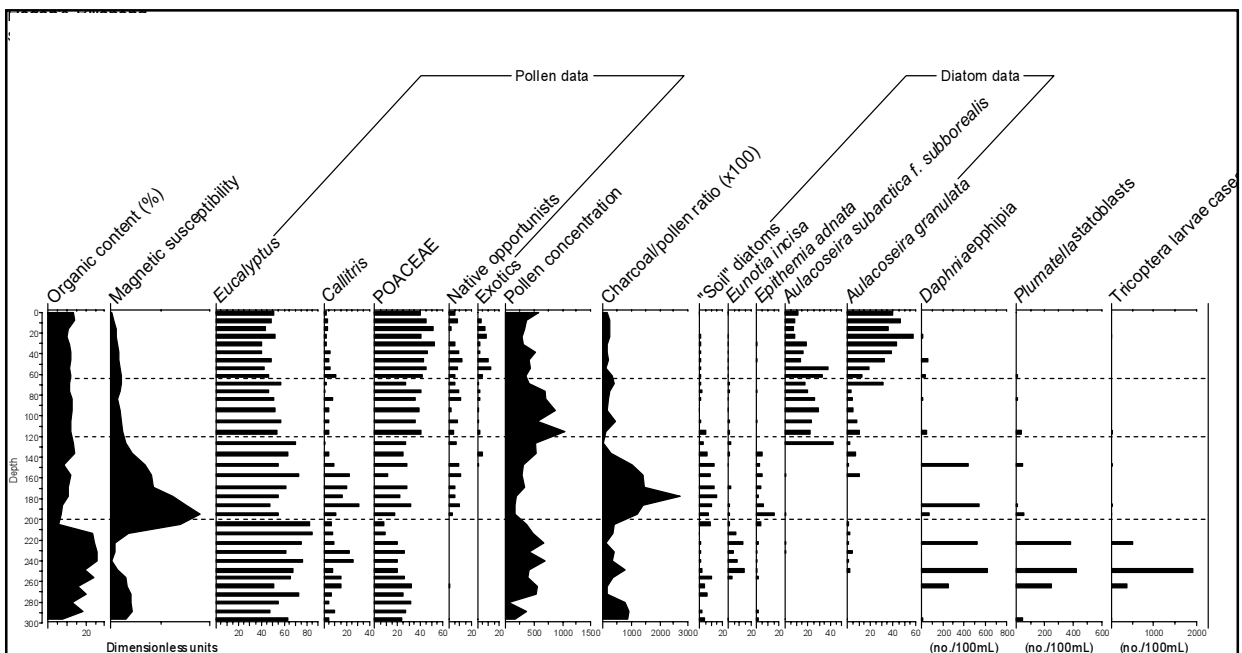


Figure 1.10: Summary microfossil diagram from Hogan's Billabong. Depths adjusted for compaction based on correlated one metre livingstone core sections

T1. Task 1 - Natural archives

Lake Cullulleraine

Collaborative researchers: Ms Jennie Fluin (Monash University)

Site description and selection rationale

Lake Cullulleraine is an “off river” storage basin, located to the west of Mildura (34:15:24S, 141:43:48E) which stores water extracted from the Murray River. The site was selected, because of its regular connection to the Murray River, to provide a recent high resolution history of water quality changes in the river for the past c. 70 years.

Progress

The contiguous high resolution diatom record (Figure 1.11), which forms part of Fluin’s thesis has now been completed and the ^{210}Pb profile (Figure 1.12) has provided a robust chronology (Figure 1.13) with which to interpret changes in the system.

Major conclusions from the diatom study are:

- The stabilisation of the lake basin after the late 1930s also resulted in the development of littoral vegetation, as reflected by an increase in littoral flora.
- During the post Second World War period (1948 onwards) there has been a substantial shift in the diatom community in response to increasing in nutrient concentrations within the lake. Consequently, aquatic vegetation growth has also increased.
- Starting in the 1960s, and peaking in the late 1970s, there has been an increase in salinity within the lake, as indicated by increases in taxa such as *Actinocyclus normanii* f. *subsalsus*.
- The diatom sequence in the last 10 years shows an improvement in trophic status.

The Lake Cullulleraine record also provides a likely date for the shift towards the current state of *Aulacoseira granulata*’s dominance of the phytoplankton in Murray River. This change (dated to c. 1965) is also observed at Hogan’s Billabong, but due to the problems of obtaining a simple record of exponential decay in unsupported ^{210}Pb could not be precisely dated.

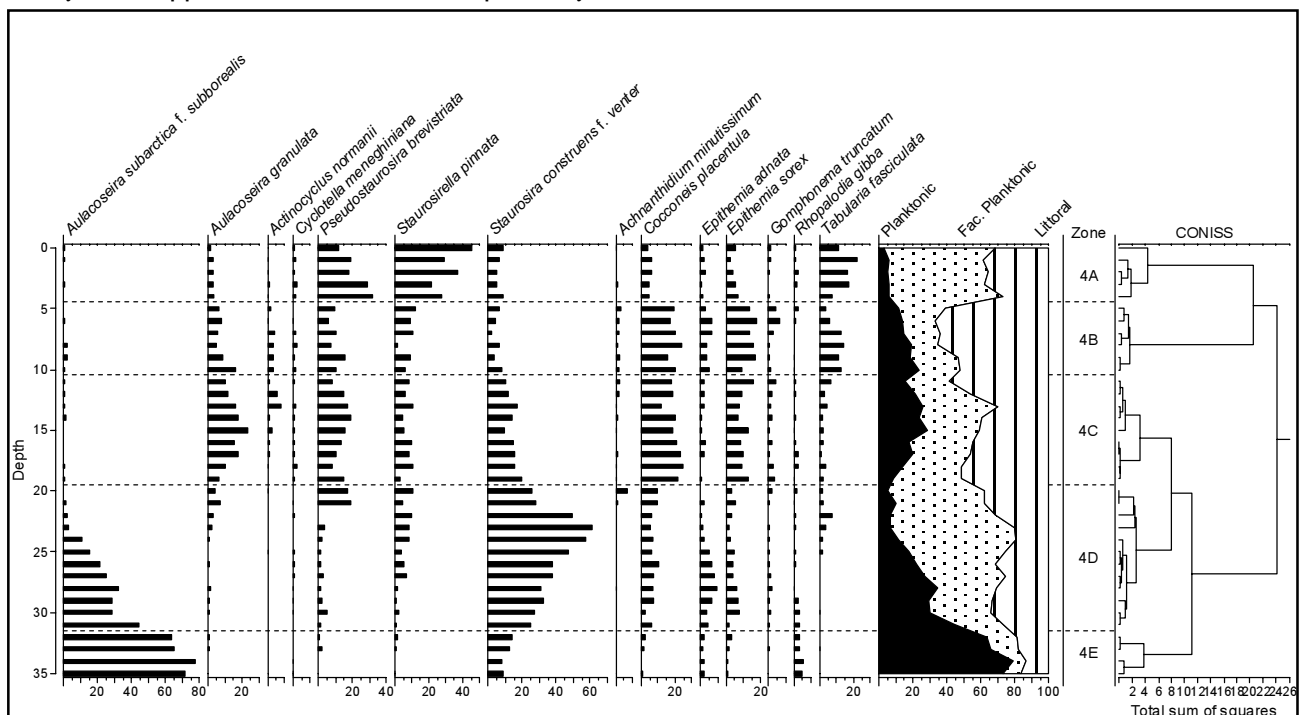


Figure 1.11: Diatom record from Lake Cullulleraine

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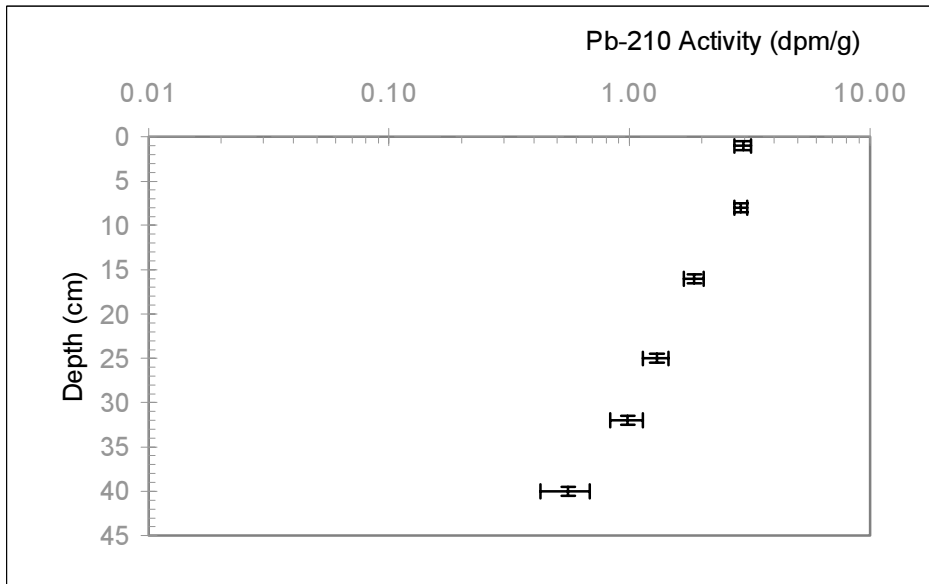


Figure 1.12: Plot of excess ^{210}Pb activity vs depth for Lake Cullulleraine

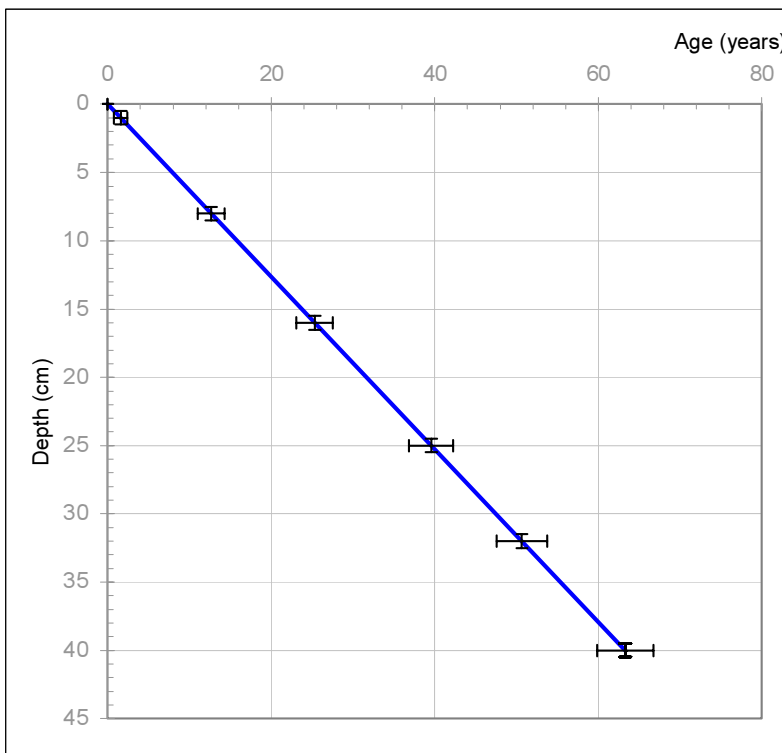


Figure 1.13: Age versus depth plot for Lake Cullulleraine core

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T1.2.6 Western Tasmania

Continuing the work commenced in stage 1 of the project, the progress since November 2000 on sediment cores from three of the four sites selected in southwest Tasmania (Figures 1.14, 1.15) are reported below. Site descriptions and selection rationale are reported in the HACV 2000 Annual Report (pp 11-18) as are the results from the fourth site, Lake Dora. Research on the latter was largely carried out by Ms Kate Britton as part of her Honours degree. Kate was awarded a first class Honours and received the University of Wollongong best Bachelor of Environmental Science Honours Graduate in 2000 award. Kate also won the Australian Water Association Inaugural student prize for her work on Lake Dora.

In addition, modern trace element data has recently been acquired from the Cape Grim records, which will be compared to concentrations in the Tasmanian natural archives. It is hoped that the combined data will improve the understanding of spatial distribution of pollutants in western Tasmania.

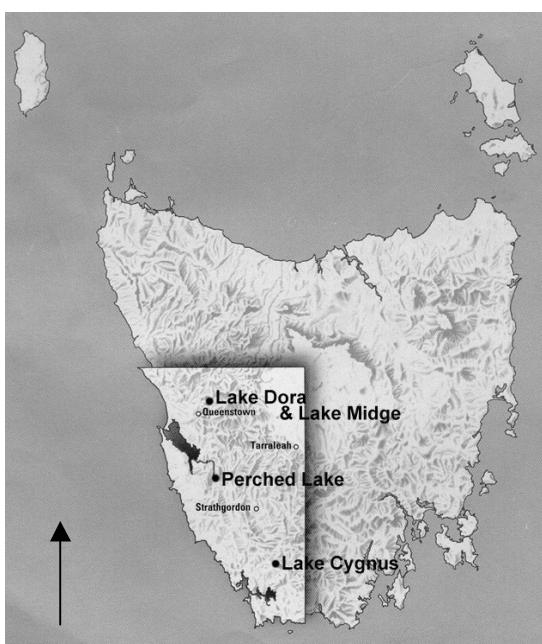


Figure 1.14: Map of Tasmania showing location of sites



Figure 1.15: Photos of two of the SW Tasmanian sites. a. Midge Lake; b. Lake Cygnus

Perched Lake

Collaborative researchers: Mr Ente Rood (University of Amsterdam)

Progress

Since November 2000, ^{210}Pb , pollen, loss on ignition and trace element analyses have been completed on a 10 cm core from the centre of Perched Lake. Samples below 5 cm in the ^{210}Pb profile (Figure 1.16) exhibit a near vertical trend, suggesting that they are at background level and therefore beyond the ability of the technique to provide ages. There is a suggestion of steepening in the top three samples of the ^{210}Pb profile, implying an increase in sedimentation rate. However, this is most likely an artefact of these samples being collected from the sediment water interface, with compaction not yet apparent. The remainder of the profile exhibits an even trend, indicating relatively constant sedimentation in the lake with little disturbance of the local catchment over the past 120 years. The overall age of the core is estimated as being 200 years, based on extrapolation from the last sample with above background ^{210}Pb activity (5.25 cm). Pollen analysis provides evidence of disturbances to rainforest communities in the region (Figure

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1.17). These are interpreted as being due to local area disturbance associated with convict logging in the early 18th century and the Franklin Dam project in the early 1980s as well as wider regional disturbance caused by ore prospecting and settlement in western Tasmania from the mid-18th century. The regional disturbance is also evident in the Lake Dora record (Figure 1.18). Interestingly and rather unexpectedly, given the remoteness of the site, the trace metal profile exhibits significant increases in lead, copper and other metals commencing in the early 1890s (Figure 1.17). This correlates with the establishment of the first smelters in the Queenstown region, some 55 kilometres to the north and indicates that pollution from these smelters was much more widespread than initially anticipated. A further increase in levels is evident from the 1930s, coinciding with the establishment and growth of open cut mining. As with the Lake Dora record, it is believed that this rise in values reflects increased availability of metals through the expansion of mine spoils, with aerial transport of particles from these heaps across the landscape. In addition, it is believed that major fires in the region, mostly initiated by mineral prospectors, may have contributed to the demise of rainforest and alpine vegetation.

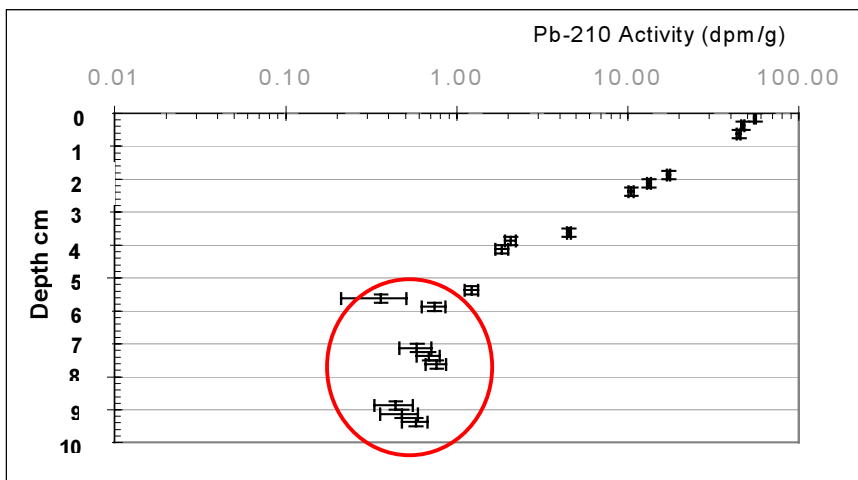


Figure 1.16: ²¹⁰Pb profile from Perched Lake core 2. The points circled in red are interpreted as being background level.

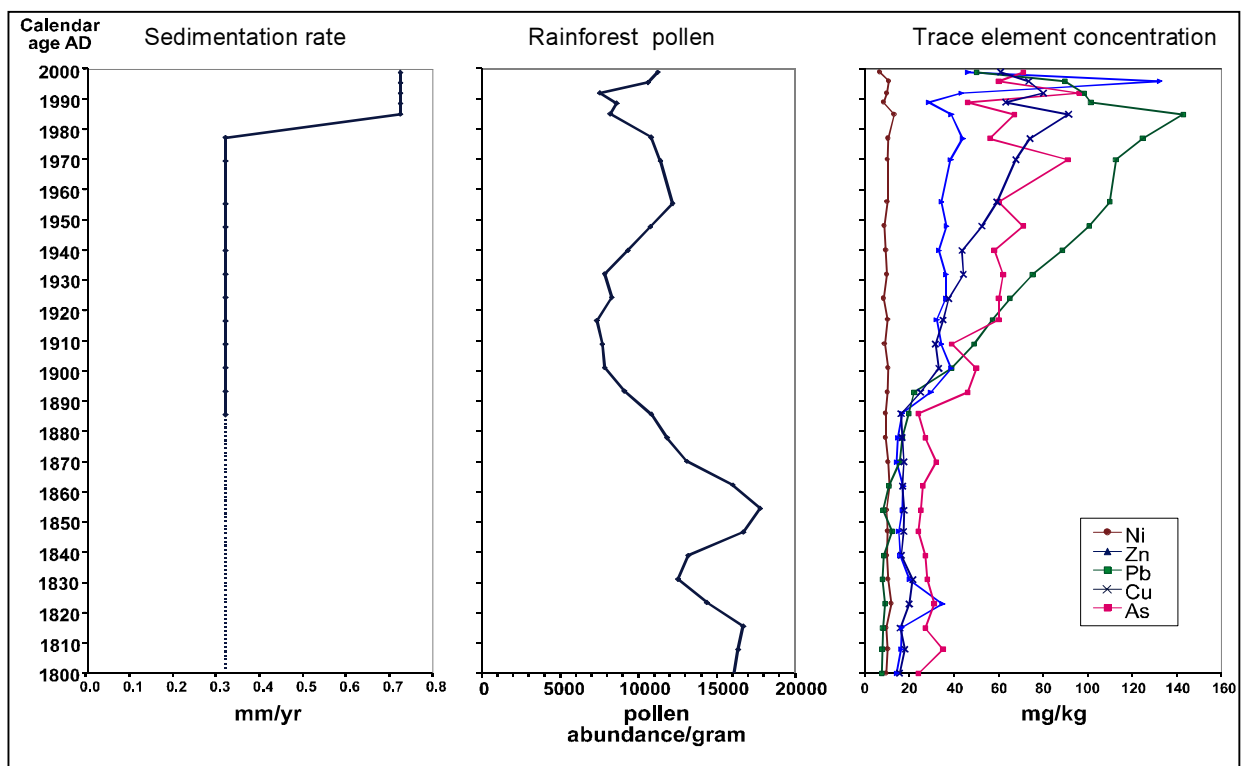


Figure 1.17: Summary of results from Perched Lake core 2. The sedimentation rate is derived from the ²¹⁰Pb profile, with constant sedimentation being postulated below 5 cm.

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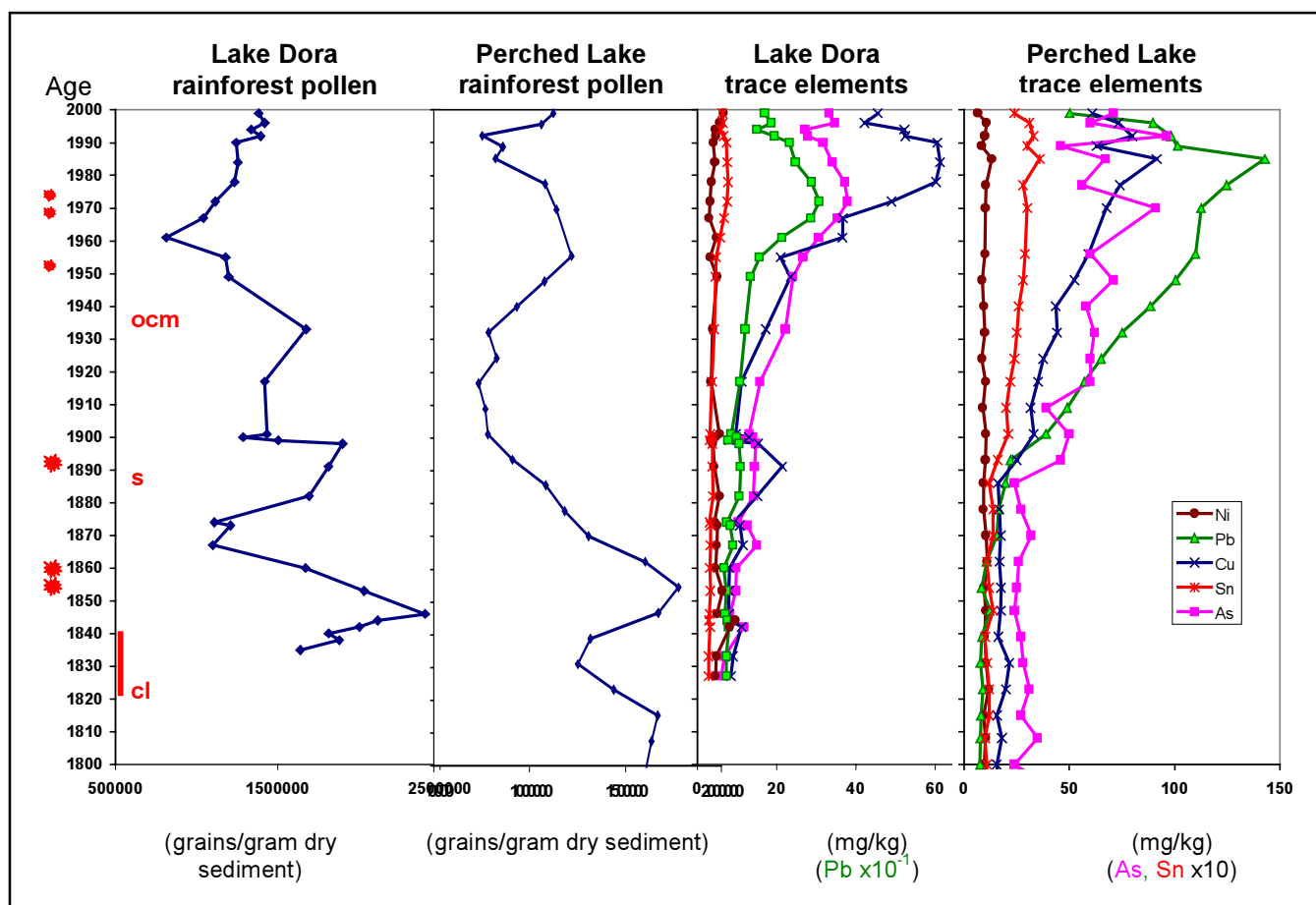


Figure 1.18: Comparison of Lake Dora and Perched Lake records. cl = convict logging; sm = smelters; ocm = open cut mining expands; * = major regional fires (mostly from mineral exploration); * = small regional fires.

Lake Cygnus

Progress

There has been some progress on two sediment cores (LC1 and LC2) extracted from Lake Cygnus, although much work remains to be done. Radiocarbon dates have been acquired for both cores. For the 50 cm LC1 core, ages of 4760 ± 40 BP, 8540 ± 60 BP and 10230 ± 60 BP were acquired for 25 cm, 41.5 cm and 50 cm respectively. For the 10 cm LC2 core, ages of 2900 ± 40 BP and 4540 ± 40 BP were acquired for 5.75 cm and 10 cm. Preliminary ^{210}Pb analysis of samples from core LC1 indicate overall constant sedimentation for the top 6 cm (Figure 1.19), with an estimated age of 110 yrs for 5.5 cm (Figure 1.20). Lead-210 analysis of samples from core LC2 are in progress. Results are expected by mid-November.

Samples from two of the cores have been prepared for diatom and pollen analyses. Counting of these samples has not yet commenced. Samples from core LC2 for trace element analysis are currently being processed. Results are expected by the end of the year. It will be interesting to see if there is a similar pattern in the trace metal concentrations as that evident in the Perched Lake and Lake Dora cores. This would have significant implications for the extent of pollution from the mid-west mining centres.

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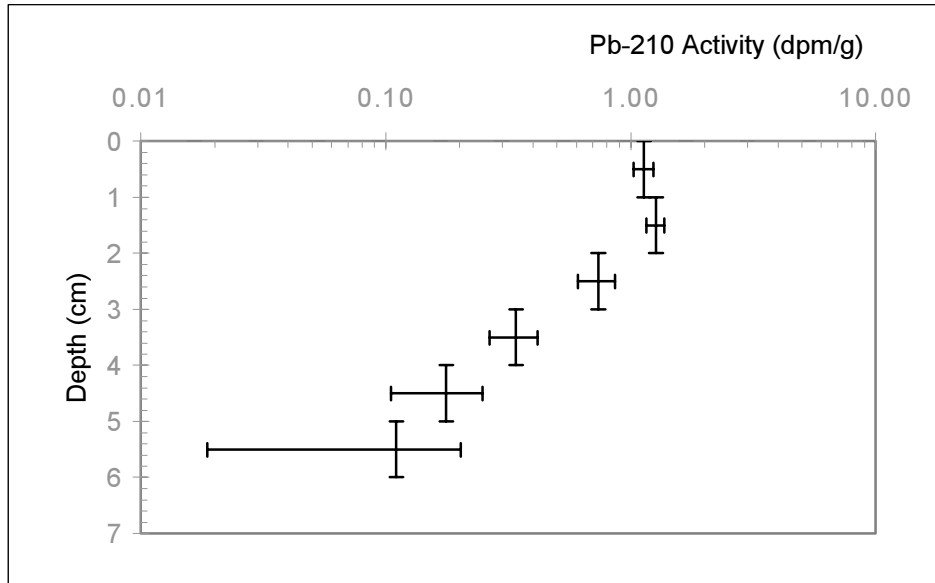


Figure 1.19: ^{210}Pb profile from Lake Cygnus core 2.

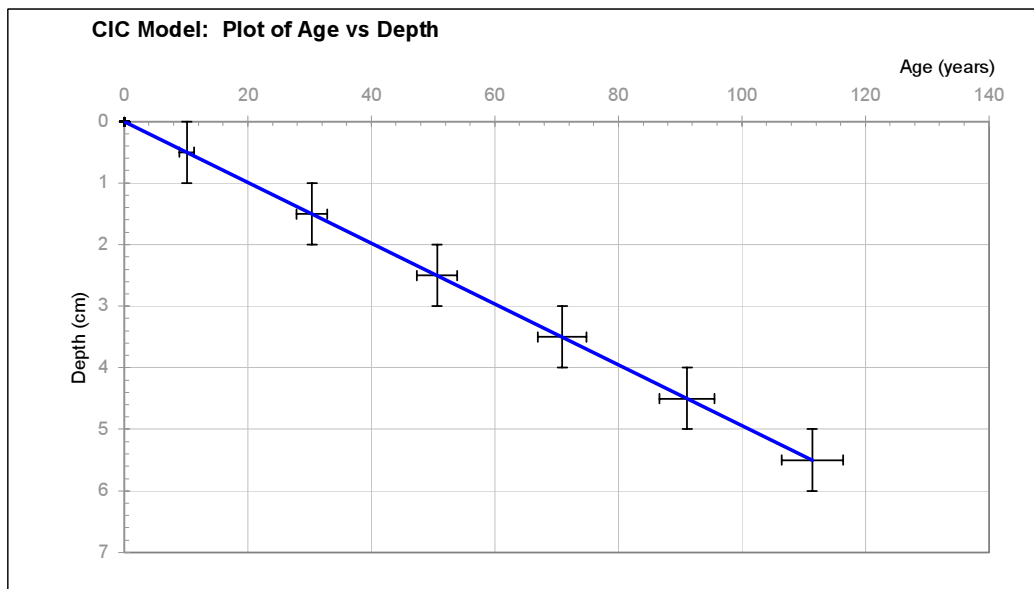


Figure 1.20: Age versus depth plot for core LC1 based on ^{210}Pb data.

Midge Lake

Progress

There has been no further progress on the 51 cm core extracted from this site since the last HACV annual report (2000). Given its proximity to Lake Dora, this site has been given the lowest priority of the four Tasmanian sites, emphasis rather being on determining spatial trends.

T1.3 Task 1 reports and papers (December 2000-November 2001)

Journal articles

- Harle, K.J., Britton, K., Heijnis, H., Zawadzki, A. and Jenkinson, A.V. Mud, mines and rainforest: a short history of human impact in western Tasmania using pollen, trace metals and lead-210. *Australian Journal of Botany*. In press.

Journal articles on related topics

- Hall, A.M., Gordon, J.E., Whittington, G., Duller, G.A.T. and Heijnis, H. 2001. Stage 5 interglacial and interstadial environments on the Shetland Islands, Scotland. *Journal of Quaternary Science*. In press.
- Shulmeister, J., Shane, P., Lian, O.B., Okuda, M., Carter, J.A., Harper, M., Dickinson, W. Augustinus, P. and Heijnis, H. 2001. A long late-Quaternary record from Lake Poukawa, Hawke's Bay, New Zealand. *Palaeogeography, Palaeoclimatology, Palaeoecology*. In press.
- Wagstaff, B.E., Kershaw, A.P., O'Sullivan, P.B., Harle, K.J. and Edwards, J. 2001. An Early to Middle Pleistocene palynological record from the volcanic crater of Pejark Marsh, Western Plains of Victoria, southeastern Australia. *Quaternary International*, **83-85**, 211-232.

Unrefereed articles

- A.P. Kershaw and K.J. Harle. 2001. Studies on the Quaternary history of the Western Plains of Victoria, Australia: Climate, vegetation and lake levels. In B. Joyce, P. Kershaw and K. Harle (Eds). *Quaternary History of the Western Plains: flows and volcanoes - craters and pollen*. AQUA pre-conference field trip guide, AQUA Biennial Conference 2001.
- Harle, K.J. and Kershaw, A.P. Quantitative reconstruction of climates from the Lake Wangoom record using the modern analogue approach. In B. Joyce, P. Kershaw and K. Harle (Eds). *Quaternary History of the Western Plains: flows and volcanoes - craters and pollen*. AQUA pre-conference field trip guide, AQUA Biennial Conference 2001.

Internal reports

- K.J. Harle and H. Heijnis. Report on Northern Territory field work, Nov-Dec. 2000
- J.P. Colliton. Report on field work undertaken on Nattai River, March 2001.
- G. Buchanan. Report on Northern Territory field work, May 2001.
- K.J. Harle. Recommendations for the HACV database.
- K.J. Harle. Recommended procedure for logging samples into the HACV database, June 2001.
- J.P. Colliton. Report on field work undertaken on Nattai River, June (parts A and B) 2001.
- J.P. Colliton. Report on field work undertaken on Nattai River, July 2001.
- K.J. Harle. Task 1: Summary science progress report for July 2000 to June 2001.

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Conference abstracts

- Britton, K., Harle, K.J., Heijnis, H., Zawadzki, A. and Jenkinson, A. 2001. Mud, mines and rainforest: a short story of human impact in central west Tasmania as derived from Lake Dora. Abstracts, 2001 AQUA Biennial Conference, Port Fairy, 5 Feb.-9 Feb.
- Buchanan, G. 2001. Annaburroo Billabong. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Haberle, S.G., Atkinson, A., Heijnis, H., Zoppi, U., Lawson, E., Kershaw, A.P. 2001. Fire, El Niño, and Rain Forest Dynamics in Northeast Queensland. Abstracts, 2001 AQUA Biennial Conference, Port Fairy, 5 Feb.-9 Feb.
- Harle, K.J., Britton, K., Rood, E., Heijnis, H., Zawadzki, A., Jenkinson, A.V., Allen, A. and Wheeler, B. 2001. Timber, tin and convicts: evidence for 180 years of colonial impact in western Tasmania derived from two high resolution palaeoenvironmental records. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Harrison, J., Heijnis, H., Caprarelli, G. 2001. Historical pollution in the sediments of the Tonalli River (NSW) Australia. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Harrison, J., Heijnis, H., Caprarelli, G., Chisari, R. and Wong, H. 2001. A study of Human Activity and Climate Variability within the Tonalli River Catchment, Greater Blue Mountains World Heritage Area (NSW). Abstracts, 2001 AQUA Biennial Conference, Port Fairy, 5 Feb.-9 Feb.
- Heijnis, H. 2001. The principle of ^{210}Pb dating of sediments. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Heijnis, H., Harle, K.J., Haberle, S., Tibby, J., Harrison, J. and Britton, K. 2001. Case studies on Human Activity and Climate Variability from Australia. Human Impact on Terrestrial Environments (HITE) meeting. Bern 15-17 June, 2001.
- Heijnis, H., Harle, K.J., Haberle, S., Tibby, J., Harrison, J. and Britton, K. 2001. Case studies on Human Activity and Climate Variability from Australia. Challenges of a Changing Earth: Global Change Open Science Conference, Amsterdam. 10-13 July, 2001.
- James, R., Haworth, R. and Jenkinson, A. 2001. Changes in estuarine sedimentation rates in the last 200 years: case studies from New South Wales from disturbed and relatively undisturbed environments. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Leahy, P.J. and Heijnis, H. 2001. The late Quaternary palaeoecology of the Yarra River: an archive for catchment management. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- McDonald, J., Drysdale, R., Heijnis, H. and Ihlenfeld, C. 2001. Stable isotope and trace element geochemistry of speleothems from Cliefden Caves, central NSW: Implications for palaeoclimate reconstruction. Abstracts, 2001 AQUA Biennial Conference, Port Fairy, 5 Feb.-9 Feb.
- McKenzie, M., Kershaw, P., Orr, M., Lawson, E., Heijnis, H. and Roberts, R. 2001. A high resolution record of vegetation and climate through 'the last glacial cycle' from Caledonia Fen, the southeastern highlands of Victoria, Australia. Abstracts, 2001 AQUA Biennial Conference, Port Fairy, 5 Feb.-9 Feb.
- McMinn, A., Heijnis, H., and Hallegraeff, G. 2001. Ballast water transport of toxic dinoflagellates; sediment core evidence using Pb-210 profiles in marine sediments. Archives of Human Impact of the Last 200 years, AINSE/ANSTO. 27 July 2001.
- Kershaw, A.P., Reid, M.A., Tibby, J., Fluin, J., Leahy, P., Heijnis, H., Ogden, R.W. & Sayer, C.D. (2001). Patterns of ecological change in major river catchments of south-eastern Australia. *Abstracts*,

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IGBP Open Science Conference, Amsterdam, 10-13th July, 2001. Also presented at the Australian Society for Limnology (ASL) Congress, September 28 - October 1, 2001, Moama, N.S.W.

Theses

- G. Buchanan. 2001. Environmental Geochemistry: Chronology of Sediment and Land-Use/Vegetation History in the Kakadu Area, NT. Unpublished Honours Thesis, Environmental Science, University of Technology, Sydney.
- J.P. Colliton. 2001. The Impact of European Settlement and Coal Mining on the Nattai River Catchment, NSW. Unpublished Honours Thesis, Environmental Science, University of Technology, Sydney.

T1.4 Task 1 summary and future directions

- Work has been completed on seven of the twelve sites selected for this project. Progress is well advanced for the remaining five sites.
- The ²¹⁰Pb dating has been shown to be very successful, with the high resolution sampling regime adopted improving the understanding of changes in sedimentation rates as well as establishment of more precise chronologies.
- The combination of ²¹⁰Pb, trace elements, inorganic content (LOI method), grain size, pollen, diatom and charcoal evidence from the sediment archives have been shown to be extremely useful tools for reconstructing past human activity and the impact this has had on the Australian landscape. In many cases, previously unrecorded impacts have been identified (eg. the wide dispersal of high levels of trace metals in western Tasmania from the mining centres in the central west).
- There has been good correlation between the evidence in the natural archives and historical records of human activity. In many cases, such as western Tasmania, the natural archives provided evidence of human impacts not recorded in the historical records.
- Although there is some evidence of climatic variability from the natural archives, the signals are not as easily discerned as those for direct human activity and impact on the landscape. This question will be further explored in the remaining months of the project.
- The work carried to date in the HACV project has provided an advanced contribution to the newly initiated Focus 5 of IGBP-PAGES -Human Impact and Terrestrial Ecosystems (HITE). With an anticipated five year span, the project has the potential to be one of the main contributors to this international program.

T1.5 Task 1 and international project timelines

An IGBP PAGES sponsored international initiative has recently commenced to gather and compare records of human impacts on terrestrial ecosystems (HITE) from around the world. The HITE project was commenced in mid-2001 with an international meeting in Bern. The research from Task 1 of the HACV project was a major component of the science presented at this meeting, being well in advance of many other research organisations. Dr Henk Heijnis was appointed as the Southern Hemisphere representative for the HITE project. HITE presents an important opportunity for ANSTO to demonstrate in an international

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arena its leading edge skills and experience in researching the impact of human activity on terrestrial ecosystems. However, to contribute in a meaningful way would require an extension of the project to allow key questions posed by HITE to be answered in the time frame set for HITE (Figure 1.21). These questions are listed below:

1. What have been the major human impacts that have influenced the ecosystems that we see in the present day?
2. To what extent and in which ways are the changes brought about by the combination of human and natural influences threatening the future functioning of terrestrial ecosystems?
3. How may information about past conditions help inform about suitable land use or management strategies in the present and future ecosystem?
4. Is it possible to use records of past ecosystems to develop generalisations regarding the natural non-linear ecosystem dynamics, such as thresholds, response time-lags and recovery timescales?
5. What insights do palaeo-data give on frequencies and magnitudes of ecological change, especially those perceived as extreme events?
6. How can palaeo-records interact with ecosystem modelling?

Task 1 has already provided answers, or partial answers to some of these questions. From the research conducted several questions have arisen which if addressed, would also contribute to the HITE questions. These include:

- What is the spatial extent of pollution from the western Tasmanian mining region? Does this have implications for water quality and biodiversity? This would require extending the spatial spread of natural archives examined and in turn the analysis of several more high resolution sediment cores.
- What are the most important potential sources of pollution in the Lake Burragorang catchment? This would require further work in the Burragorang sub-catchments.
- How widespread and reliable are evidence of major climatic events, such as storms and El Nino/La Nina cycles, in natural archives? This would require more natural archives to be examined from northern Australia and also records to be obtained from southern Australia.

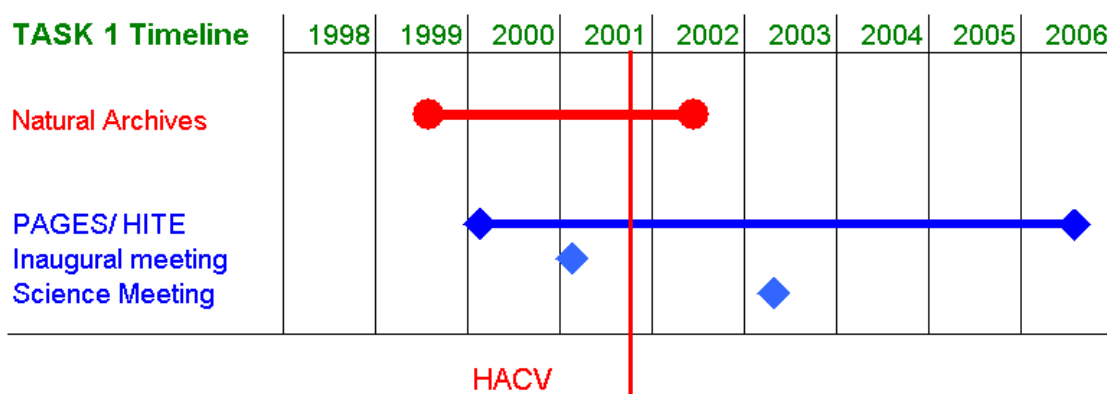


Figure 1.21: Timeline of Task 1 against the PAGES Human Impact on Terrestrial

T1.6 References

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- McElroy C.T. and Relp R.E. 1961. Explanatory notes to accompany geological maps of the inner catchment, Warragamba storage. *Department of Mines Technical Reports* 6, 65-80.
- Needham R.S. & Roarty M.J. 1980. An Overview of Metallic Mineralisation in the Pine Creek Geosyncline. In J. Ferguson & A.B. Goleby *Uranium in the Pine Creek Geosyncline*. International Atomic Energy Agency. Vienna.
- Sydney Water Corporation. 1997. *Bush Fire (Fuel) Management Plan, Sydney Water Special Areas*. Sydney Water Corporation Limited

T2. Task 2 - Characterisation of the global atmosphere

Task 2: Characterisation of the global atmosphere using radon and fine particles

T2.1 Objectives for the reported period

- To complete the deployment of radon detectors and aerosol samplers at selected enhanced /super sites in the ACE-Asia study domain;
- To upgrade a radon detector for use on board NOAA R/V Ron Brown during the first ACE-Asia Intensive Operation Period (IOP);
- To process and interpret available experimental data collected at the sites.

T2.2 Outputs for the reported period

- Functional radon detectors and aerosol samplers at the selected ground sites and sea platform;
- Elemental analysis of fine particles sampled at five basic and enhanced/super ground stations with emphasis on carbonaceous, mineral dust and industrial emissions;
- Real time, high sensitivity, hourly radon concentrations in air at selected enhanced ground stations and sea platforms in the ACE-Asia study domain;
- Preliminary analysis of radon time series data from Kosan and Hok Tsui sites.

T2.3 Background

The International Global Atmospheric Chemistry Project, IGAC, has recognised that the major limitation in our ability to predict climate change is our lack of understanding of direct and indirect forcing by aerosols (1,2). Aerosol effects on the thermal and optical properties of the atmosphere are a large source of uncertainty in predicting future climate. Consequently, IGAC has been co-ordinating the Aerosol Characterisation Experiment (ACE), a multinational effort including ANSTO researchers, to address this issue. In particular, the ACE-Asia project will target the sources and evolution of aerosols in eastern Asia and the northwestern Pacific. This region encompasses both sources and outflow areas of major anthropogenic and natural aerosols from East Asia. Task 2 of the HACV project contributes to ACE-Asia by running radon detectors and collecting aerosol samples at selected ACE-Asia enhanced and super sites. This effort is crucial for regional spatial and temporal aerosol source region characterisation, the evaluation of inventories of climatically sensitive gases, and for the validation of chemical transport models.

These efforts build upon the radon and fine particle database currently being gathered in the Australasian region in order to improve the global perspective of anthropogenically induced climate change. In order to perform the measurements and interpretation of radon and aerosols for the ACE-ASIA campaign, ANSTO draws upon a wealth of experience gained through similar research at the Cape Grim Baseline Air Pollution Station.

T2. Task 2 - Characterisation of the global atmosphere

T2.4 Key questions

- What is the elemental composition of East Asian aerosols ?
- How does the composition of East Asian aerosols vary spatially and temporally (seasonal/interannual)?
- How accurately can East Asian inventories of climatically sensitive trace gases, and their spatial/temporal variability, be determined using radon observations in conjunction with trace gas measurements?
- How well can the regional chemical transport models reproduce local time-series of radon concentrations?
- To what extent can the source of continental aerosols and loading be identified using a combination of trace elements and radon?
- To what extent will predictions of radiative properties of evolving aerosols be improved by experimental input data for aerosol size distribution and elemental composition?

T2.5 Progress Summary

T 2.5.1 Measurement site overview

Within the present reporting period, site selection and their subsequent instrumentation has been completed. The measurement sites were required to meet several selection criteria regarding their location, degree of interaction with other teams within the ACE-Asia project, and possible links to other regional/global projects of interest.

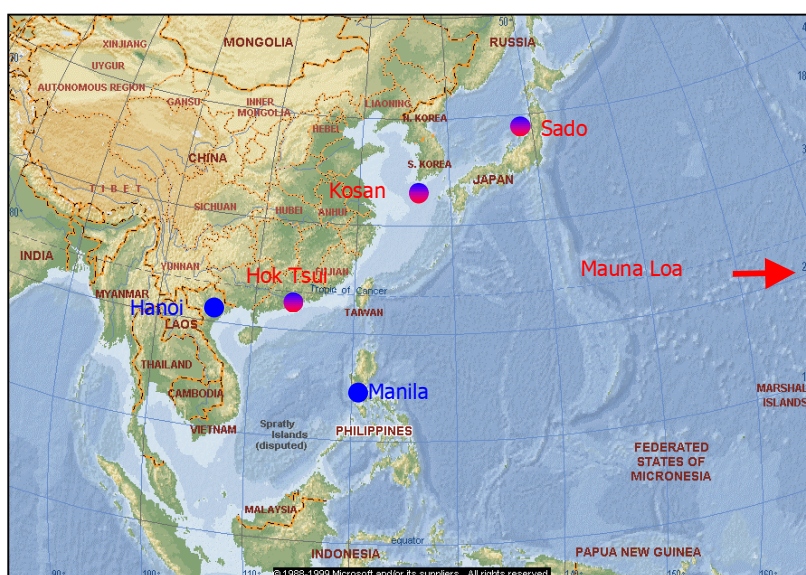


Figure T2.1. Geographical location of ANSTO radon detectors and aerosol samplers participating in the ACE-Asia program. Sites marked in blue have aerosol samplers only, sites in red have radon detectors only and sites in red and blue are dual sites.

T2. Task 2 - Characterisation of the global atmosphere

- **The location** of each site conforms to overall ACE-Asia objectives. In particular (a) all sites but one are coastal/island sites, and are thus ideal to observe the continental outflow to the Pacific (Kosan, Sado), or regional pollution sources (Hong Kong, Manila), and (b) the sites are latitudinally spread across the ACE-Asia study domain, and are thus well suited to investigate the outflow of mixed natural (mineral dust) and anthropogenic aerosols (Kosan, Sado), or predominantly anthropogenic outflow (Hong Kong, Manila).
- **A high degree of interaction** with other teams has been secured by operating at super or enhanced ACE-Asia sites. For instance, the Kosan site was the focus of the first field intensive activities. Furthermore, the Hok Tsui site has numerous links with high profile research programs such as the NASA Global Tropospheric Experiment (NASA/GTE), East Asia/North Pacific Regional Experiment (APARE), World Meteorological Organization-Global Atmospheric Watch, Transport and Chemical Evolution of the Pacific (TRACE-P) and The Yangtze Delta of China as an Evolving Metro-Agro-Plex (CHINA-MAP project). Aerosol measurements will also be conducted at the Kosan site by US researchers, which will provide a good opportunity for an intercomparison of sampling and analytical techniques.

T2.5.2 Team of collaborators

The core of the collaborative research team formed in 1999/2000 has remained the same, although there have been some additions as a result of staff relocations in the Meteorological Research Institute (Korea) and CMDL/NOAA. The team has proved to be very effective in establishing the instrumentation, maintaining the sites and providing support for complementary information including meteorological data. The updated team of collaborators and their affiliation is shown in Table 2.1.

Table T2.1: Task 2 in ACE-Asia: sites, measurements, collaborators and their affiliation

Station name/ Location	Location, country	Collaborator(s)	Affiliation
Hanoi	Vietnam	Pham Duy Hien	Vietnam Atomic Energy Scientific Board, Ministry of Science, Technology and Environment, Hanoi
Hok Tsui/Hong Kong Is.	Hong Kong Is., Hong Kong	Tao Wang and Steven Poon	Hong Kong Polytechnic University, Hong Kong
Kosan/Cheju Is.	Cheju Is., Korea	Chang-Hee Kang, Jiyong Kim and Hye-Joung Shin	Cheju National University, Cheju; Meteorological Research Institute, Seoul
Sado Is./Sea of Japan	Sea of Japan, Japan	Mitsuo Uematsu and Kiyoshi Matsumoto	University of Tokyo
Manila	The Philippines	Flora Santos	Philippines Nuclear Research Institute
Mauna Loa Observatory	Hawaii, USA	John E Barnes and Paul Fukumura-Sawada	CMDL/NOAA
NOAA research vessel R/V Ron Brown	Based in Seattle, Washington, USA	Jim Johnson and Tim Bates	PMEL/NOAA

T2. Task 2 - Characterisation of the global atmosphere

T2.5.3 Instrumentation of the ground sites and a ship platform

Instrumentation of all sites has been completed. A timeline (Figure T2.2) shows all major dates/periods for the reported year. Most of the operations were completed on time. The only exception was instrumentation of the Sado Is. site. Commissioning of this site was planned for January 2001, and all instrumentation was despatched to the site on schedule in December 2000. However, the January installation initially planned was cancelled due to unusually severe weather. This setback, as well as subsequent difficulties associated with a non-standard power supply on the island, and damage done to part of the instrumentation while in transit to the site, delayed progress. The Sado Is. radon detector was eventually commissioned four months later than initially planned. The remaining technical difficulties led to a fully operational set of aerosol samplers in August 2001.

Testing of the upgraded radon NOAA/PMEL-ANSTO detector was completed in December 2000, well ahead of the first IOP in March/April/May.

Photos of the installation at various sites are give in Figure T2.3.

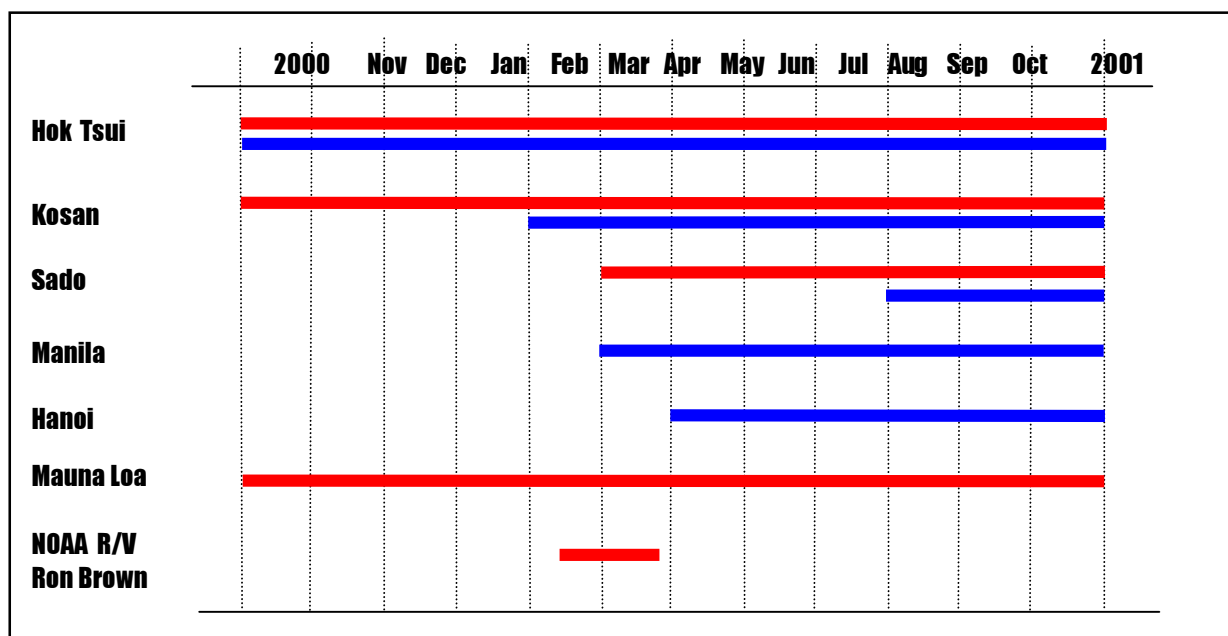


Figure T2.2. A timeline for the operational phase of the instrumentation at the network sites and a ship platform (NOAA R/V Ron Brown). Red- radon detectors, blue- aerosol samplers.

T2. Task 2 - Characterisation of the global atmosphere

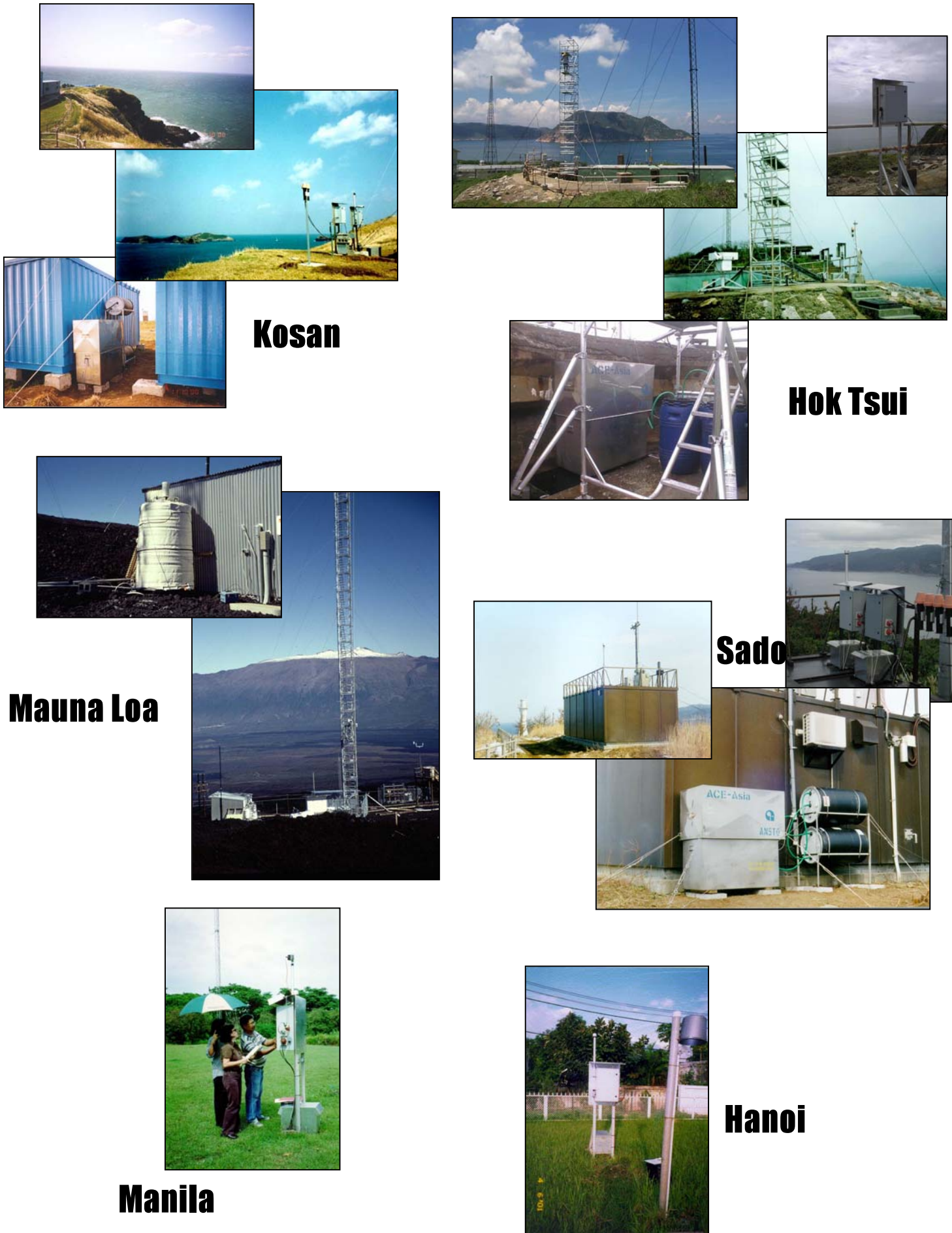


Figure T2.3: Images of the ACE-Asia sites

T2. Task 2 - Characterisation of the global atmosphere

T2.5.4 Progress of measurements and analysis of data

With all instrumentation now in place, the main focus has changed from construction and deployment to collection and quality control of the incoming data, instrument maintenance, preliminary processing and interpretation of available radon data using the supplied meteorological information.

The processing of aerosol filters and radon data from all sites is performed continuously. The processed data is available within three months of collection.

T2.5.5 The first Intensive Operation Period (IOP)

All aerosol samplers and radon detectors, with the exception of Sado, were collecting data during the first Intensive Operation Period (IOP).

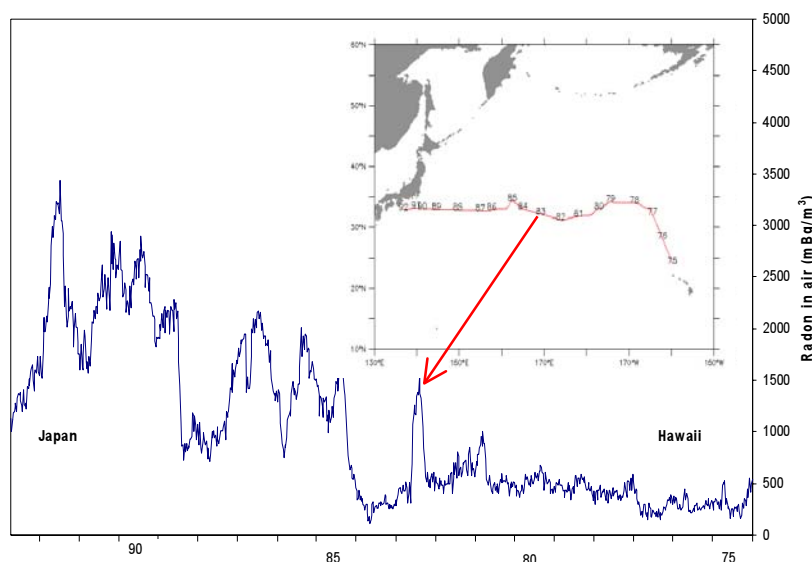


Figure T2.4: Hourly radon concentration in air recorded by a 750 L radon detector on board the NOAA R/V Ron Brown on her approach to the Asian continent. The inset shows the corresponding transect, where the numbers indicate Julian day of year 2001.

A ship-borne radon detector run jointly by ANSTO and PMEL/NOAA completed a 38 day cruise during the first IOP period. The ship departed Honolulu on 14 March 2001, reached the west coast of Japan 17 days later, and then conducted two transects in the Sea of Japan. Fig. T2.4 shows radon concentration measured during the first phase of the cruise. The background concentration rises steadily as the ship approaches the East Asian land mass. The background concentrations represent that of “unperturbed” marine air close to Hawaii and Japan, respectively. Influence of continental air is evident and superimposed on the rising background with first significant occurrence on day 83 (red arrow).

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T2.5.6 External funding

A collaboration has been established with the Hong Kong Research and Grants Council (RGC), Hong Kong Polytechnic University, University of California at Irvine and ANSTO which has led to a successful grant of about HK\$1.0M for three years from July 2001 for long term and intensive sampling within the ACE Asia Project. ANSTO has been allocated HK\$40,000 of this for intensive sampling in 2002.

A grant application in support of radon research activities at two ground sites (Kosan and Hok Tsui) for a year starting in April 2002 has been prepared and submitted to the Asia-Pacific Network for Global Change Research (APN).

T2.5.7 Aerosol measurements - first examples

We are currently sampling fine PM_{2.5} and coarse 2.5 to 10 µm diameter particles at 5 ACE Asia sites. The Hong Kong and Manila sites commenced in Jan 2001, the Korean site on Cheju Island and the Vietnam site in Hanoi in April 2001 and the Japanese site on Sado Island in August 2001.

Accelerator based nuclear techniques of analysis are being applied to quantify over 25 different elemental and chemical species from hydrogen to lead, including the key components of elemental carbon, sulphate and soil important for the ACE Asia experiment.

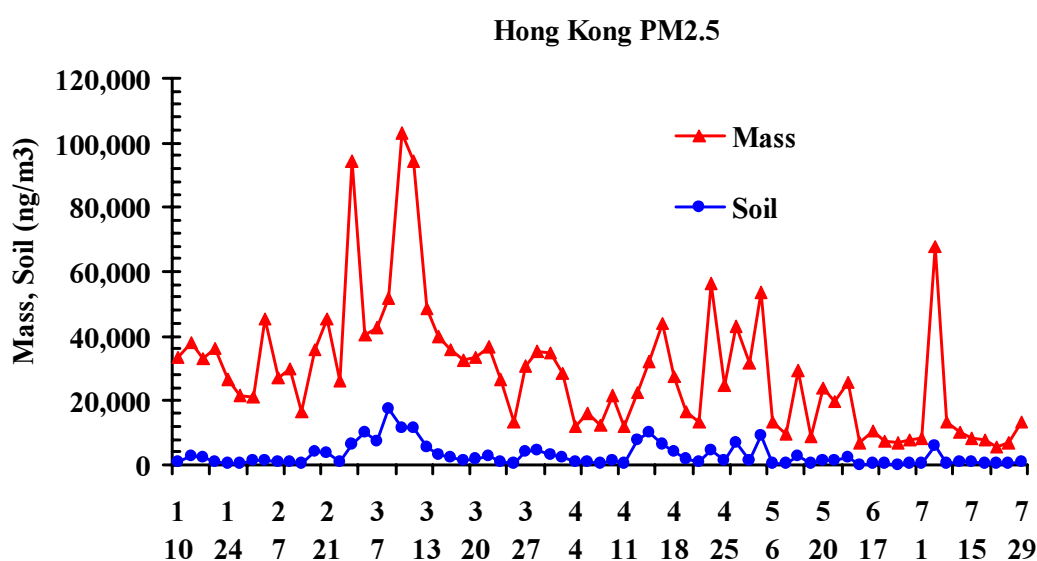


Figure T2.5 (a)

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Cheju PM2.5

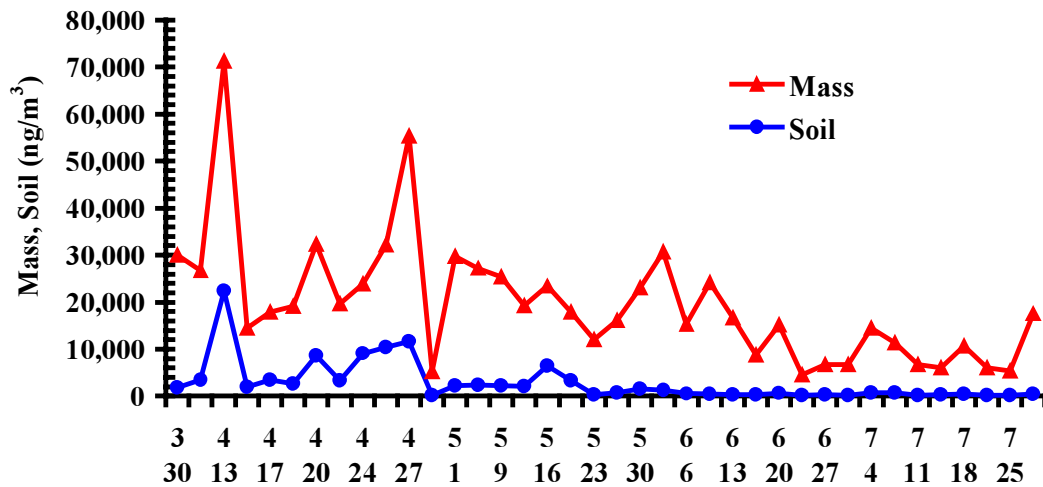


Figure T2.5 (b)

Figures T2.5 a and b show the fine particle mass loadings for the Hong Kong and Cheju Island sites up to the end of July 2001. Note the start times for the two plots are different. Samples were collected for 24 hours from midnight to midnight every Wednesday and Sunday except for the intensive operational period between March and May when samples were collected on four days every week.

Note the US EPA annual average standard for fine PM_{2.5} particles is currently only 15,000 ng/m³ and 65,000 ng/m³ for a 24 hour period. Both these sites exceed these limits. The interesting point about these two graphs is the large very soil component in the fine fraction on certain days at both sites (e.g. 13 April). This indicates significant long range regional transport of large amounts of soil. This is confirmed by the NASA TOMS satellite images for 9 April 2001 showing the start of a major dust storm in central China and its evolution by 13 April all the way round to North America and Canada.

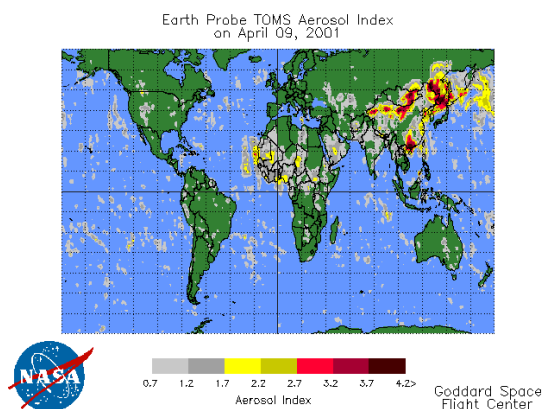


Figure T2.6 (a). TOMS satellite image 9 April

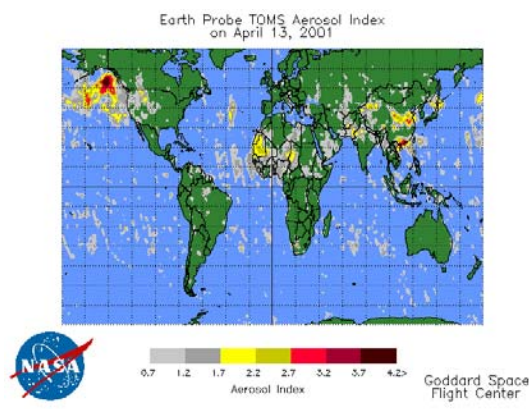


Figure T2.6 (b). 5b TOMS satellite image 13 April

Five day backtrajectories at the Hong Kong and Cheju Island sites confirm this major pollution transport event that we measured at Hong Kong and Cheju Island on 13 April originated from China. Figs. T2.7 a and b show such trajectories for the Hong Kong site on 12 and 14 April. The three different trajectories correspond to different starting heights of 100m, 500m and 100m above the sampling site.

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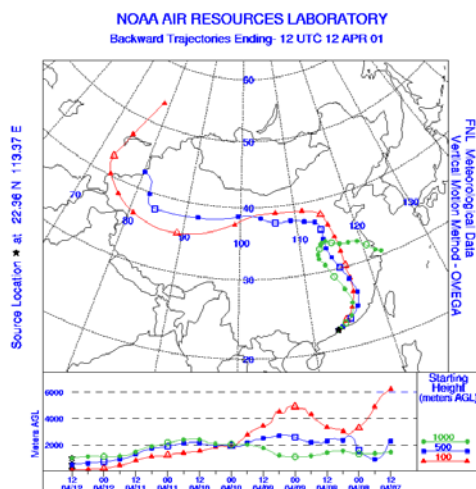


Fig. T2.7 (a) Five day backtrajectories from Hong Kong from 12 April 2001

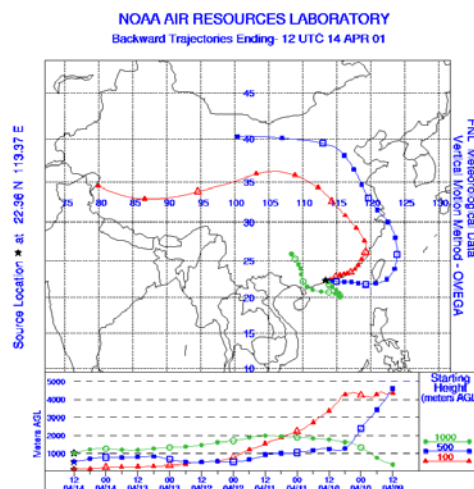


Figure T2.7 (b). 6b Five day backtrajectories from Hong Kong from 14 April 2001

We expect dust from the northwestern parts of China and industrial pollution from central and eastern parts of China to affect the Hong Kong site.

The multi-elemental analysis techniques at ANSTO will allow us to quantify and characterise fine particle aerosols components collected at the ACE Asia sites provided enough data can be collected. Below is a summary of the major components found in the fine fraction for the four ACE Asia sites to date. It is just the average over time with no consideration for season or wind direction. It includes the key Asian aerosol components of elemental carbon (ElC), soil and sulphates.

PM2.5	Manila Philippines	Hok Tsui Hong Kong	Cheju Island Korea	Hanoi Vietnam
Av. Mass ($\mu\text{g}/\text{m}^3$)	45.2	29.1	19.7	29.5
Elemental C (%)	26.1	6.84	5.26	9.98
Soil (%)	3.04	8.56	14.33	9.43
Amm. Sulfate (%)	16.4	39.0	40.3	27.0
Organics (%)	44.6	21.1	9.6	25.3
Seaspray (%)	2.40	11.1	6.57	2.73
Non Soil K (%)	0.43	1.30	0.82	1.40
Pb (%)	0.10	0.24	0.12	1.00
Sum (%)	93.2	88.2	76.9	76.8
Cl loss (%)	74.5	87.9	90.8	87.6

The total 'mass closure' for our analysis is good, with the sum of the estimated components being between 76% and 93% of the total measured gravimetric mass. This is fairly accurate considering that the aerosols contain significant water vapour and some nitrates not estimated by techniques at ANSTO. The chlorine loss is estimated by assuming all the sodium and chlorine are associated with seaspray and then calculating the expected chlorine concentrations from the measured sodium concentrations. The fact that chlorine may have other sources besides seaspray shows that there are significant chlorine losses from all

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of these ACE Asia sites measured to date. This is probably related to the high fine particle sulfate aerosol component and acid aerosols at each of these sites. This could also be confirmed by measurements done by other collaborators at each ACE Asia site.

Key elements present as oxides in soil are Al, Si, Ca, Ti, Mn and Fe. Plots of the Al vs Si, Ca vs Si, Ti vs Si and Fe vs Si show that all these key soil indicator elements are well correlated. Figures T2.8 a to d show such plots for all four ACE Asia sites for fine particle data collected up to the end of July 2001. The good correlation across all sites for the same six major soil components demonstrates the similar composition of soil reaching each of the sites and again emphasises the common source of this fine particle soil.

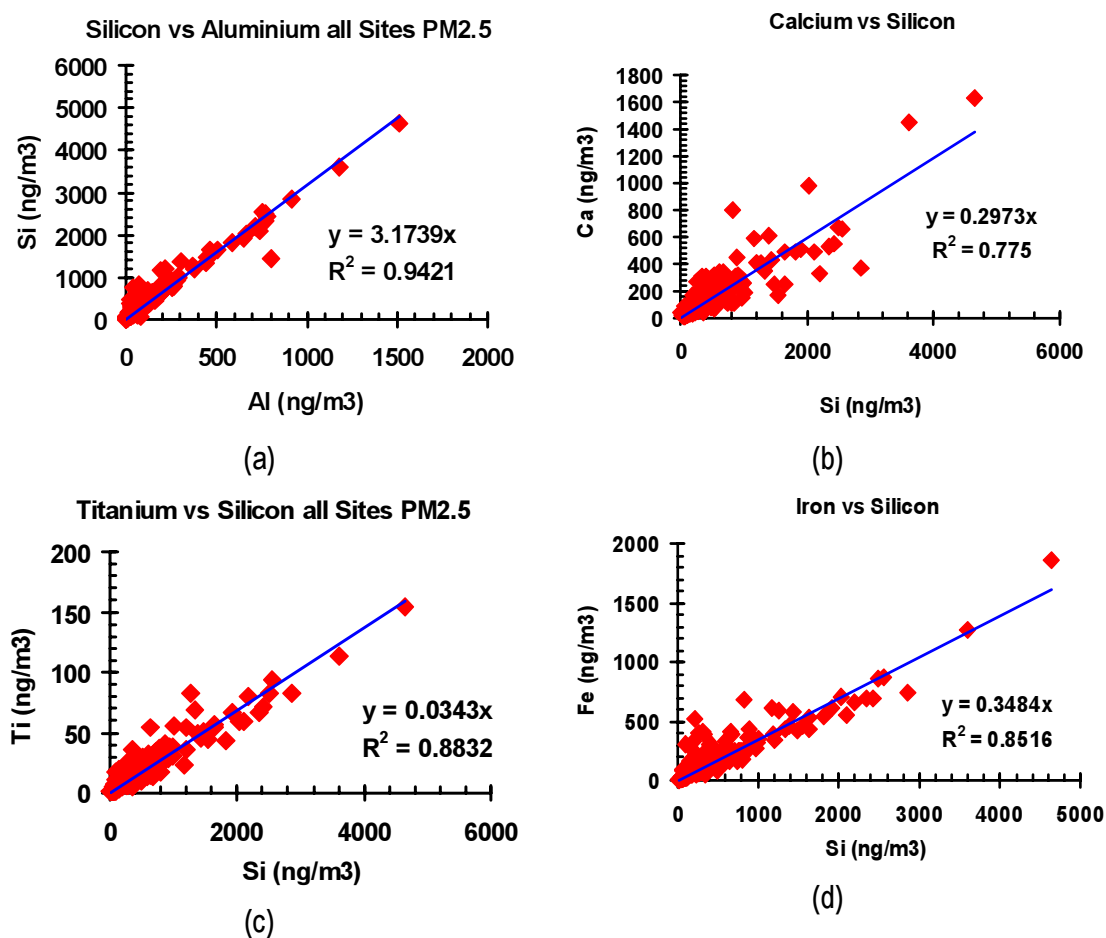


Figure T2.8: A scatter diagram of silicon vs aluminium, calcium, titanium and iron elements specific to natural dust, from four ACE-Asia stations (Hong Kong, Cheju, Hanoi and Manila).

The high degree of correlation shown in Figure T2.8 allows us to generate a common ACE Asia soil fingerprint using these and other elements and their oxide compositions.

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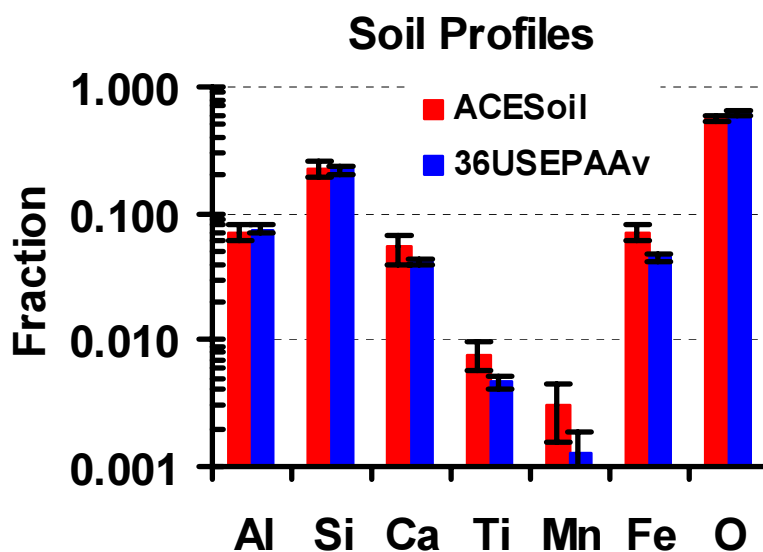


Figure T2.9: ACE Asia Soil fingerprint

Figure T2.9 shows such a fingerprint for soil and compares it with the average of 36 different US EPA soil fingerprints obtained across America. If sufficient data can be obtained under a number of different seasonal and wind conditions other source fingerprints can be obtained for sources such as seaspray, automobiles, industry, coal combustion and biomass burning for example. Characterisation of fine particle source components in this matter will lead to quantitative source contribution estimates through standard chemical mass balance (CMB) techniques and newer positive matrix factorisation (PMF) methods. In particular PMF can include radon and wind speed and direction data with the aerosol measurement data to provide a more comprehensive characterisation and quantification method.

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T2.5.8 Radon measurements – contrasting two ACE-Asia sites

Preliminary monthly and seasonal analyses have now been performed on the available data (almost a year) collected from the Hok Tsui and Kosan sites. In both cases, seasonal analyses have been centred on the first ACE-Asia Intensive Operation Period (March-May 2001). Consequently, throughout the following discussion seasons have been defined as follows: Winter (December-February)¹, Spring (March-

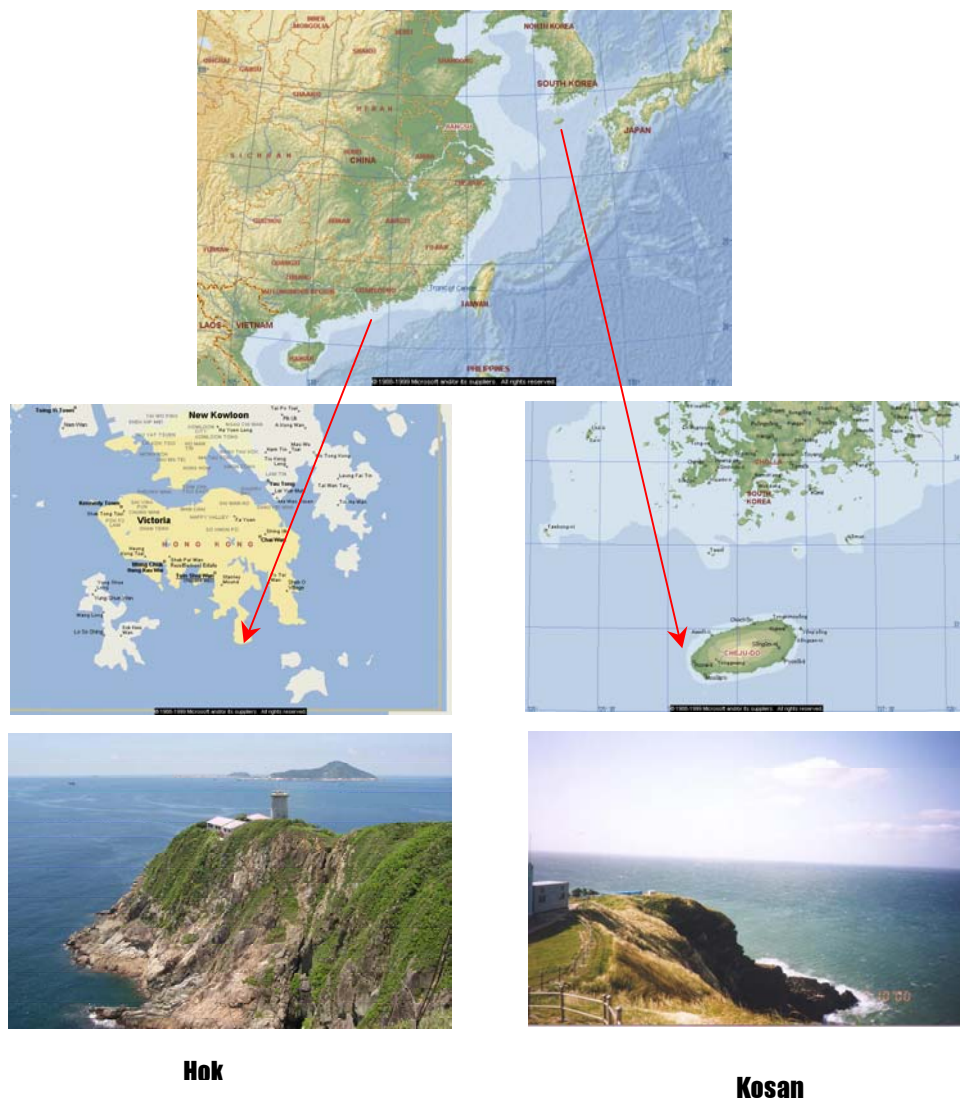


Figure T2.10: Comparison of locations for the Hok Tsui (Hong Kong) and Kosan (Korea) radon monitoring sites within the ACE-Asia study domain (20-May) and Summer (June-August).

Synopsis of radon measurements at Kosan

Radon measurements at the Kosan ACE-Asia super site began in November 2000. Accounting for instrument calibration periods and a small number of malfunctions, a high (92%) data recovery rate was achieved for the radon measurements at this site. A significant seasonality is evident in the observed radon concentrations. Average values at Kosan in Winter are approximately 25% higher than in Summer. These changes are brought about by a combination of three effects: (i) increased dilution of a roughly

¹ An instrument malfunction prevented the data collected in December 2000 at the Hok Tsui site from being used.

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constant source in the atmospheric boundary layer (ABL), (ii) longer air mass transit times to Cheju Island over water due to reduced wind speed, and (iii) seasonal changes in predominant wind direction. The most surprising result from our preliminary data analysis to date is a fairly isotropic distribution of radon concentration with wind direction for two of the three seasons so far observed. This finding contrasts with similar observations at baseline monitoring sites considering the relatively well defined continental and oceanic sectors around the Kosan site. One interpretation of this finding is that the regional meteorology is particularly complex in Winter and Spring. Under such conditions, wind direction alone would not be a suitable criterion for distinguishing the origin of air masses. Relatively low radon concentrations were observed from the oceanic sector (140-220°) in Summer, which indicates a more consistent fetch over the East China Sea and western Pacific Ocean throughout this season.

Synopsis of radon measurements at Hok Tsui

The Hok Tsui site is near the southern boundary of the ACE-Asia study domain (~20°- 40°N) and has been operational since August 2000. However, initial problems with the aspiration of the detector prevented the use of data prior to January 2001. Over the past eight months there has been an 83% data recovery at this site. Data recovery was poorest during Winter, which, combined with the rejection of data in December, has led to a relatively small number of samples for this season (Figure T2.12a). Consequently, the Hok Tsui Winter findings may not be representative of a typical Winter for the region. Large seasonal changes in average radon concentration were observed, with Winter values almost four times greater than Summer values. Based on the site meteorological data there was a pronounced seasonal change in wind direction from north to northeast in Winter to roughly east-west in Summer, as would be expected with the northward migration of the Intertropical Convergence Zone. In general, air mass fetch from this site is continental to the north and west, and oceanic to the east and south. Histograms of hourly radon concentration indicate a regular occurrence of near baseline conditions for wind fetch over the oceanic sector in Summer. A wider spread of concentrations is evident in the Winter months when land fetch is more common and wind speeds higher. The pronounced seasonality in mean radon concentrations and wind patterns indicates that air masses arriving at the Hok Tsui site have experienced a long term trajectory that is relatively consistent with their direction of travel upon reaching the site. In Spring, some high radon concentrations were noted in the oceanic sector (45° to 230°), which are thought to correspond to nearby land masses such as the Philippines.

A preliminary comparison of hourly radon observations from Hok Tsui and Kosan

Data Overview

Figures T2.11 a-c are time-series representations (by season) of the data collected at Kosan that will be discussed below. Several long term trends are evident. In Winter there are prolonged stretches of data with wind directions close to north (0°), and minimum values of radon concentration rarely drop below 2000 mBq/m³. Conversely, in Summer there are prolonged stretches of data with wind directions close to south (180°) and minimum radon concentrations drop well below 1000 mBq/m³.

Figures T2.12 a-c are the corresponding time-series plots for Hok Tsui. The paucity of Winter data at this site is evident in these plots. Similar long term trends in wind direction and radon concentration are evident at this site compared to Kosan. The magnitude of radon concentrations at Hok Tsui however is much larger than at Kosan. This can be attributed in part to the difference between coastal (Hok Tsui) and island based (Kosan) monitoring sites. The Hok Tsui site has an extended immediate land fetch over almost 180° of arc. Land fetch over Cheju Island is short compared to the mainland, and to the north and west the mainland is 100 to 500km distant, respectively, allowing dilution and removal by radioactive decay within the air mass en-route to the site.

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Kosan Site, Korea

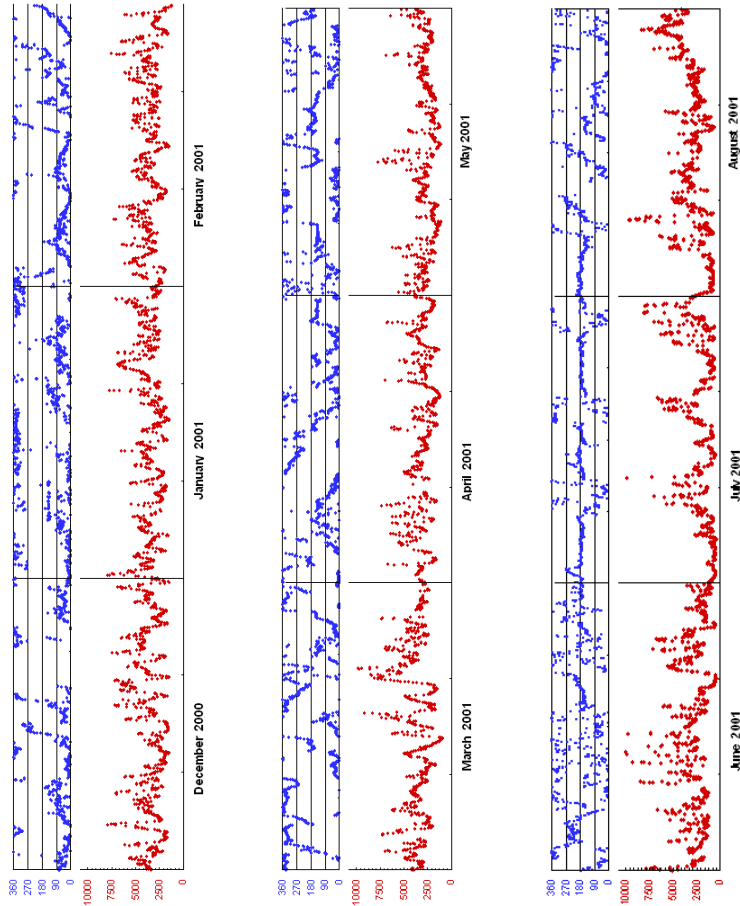


Figure T2.11: (a-c) Kosan Seasonal time-series of hourly wind direction and radon (mBq/m^3)

Hok Tsui Site, Hong Kong

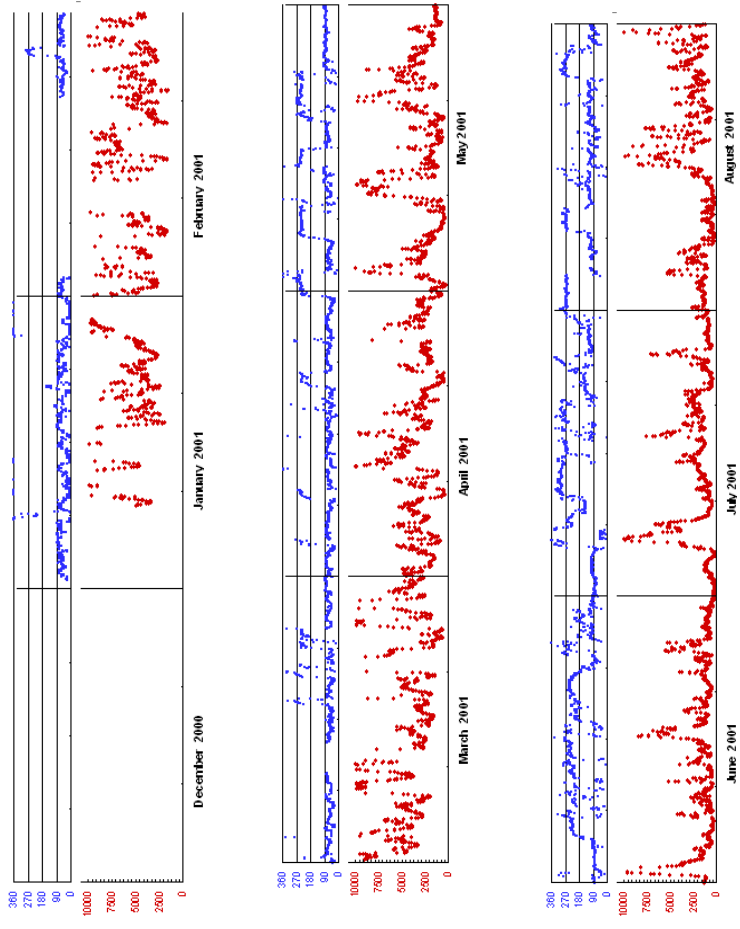


Figure T2.12: (a-c) Hok Tsui Seasonal time-series of hourly wind direction and radon (mBq/m^3)

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Seasonal Analyses

Both sites exhibit seasonality in mean radon concentration (Figure T2.13 a,b). However, where there is almost a factor of four decrease from Winter to Summer at the Hok Tsui site, there is only a ~25% reduction at the Kosan site over the same period. This contrast between the sites is large considering that both sites have relatively well defined sectors of continental and oceanic fetch for air masses arriving at the site, but is attributable to the previously mentioned differences between coastal and island monitoring sites.

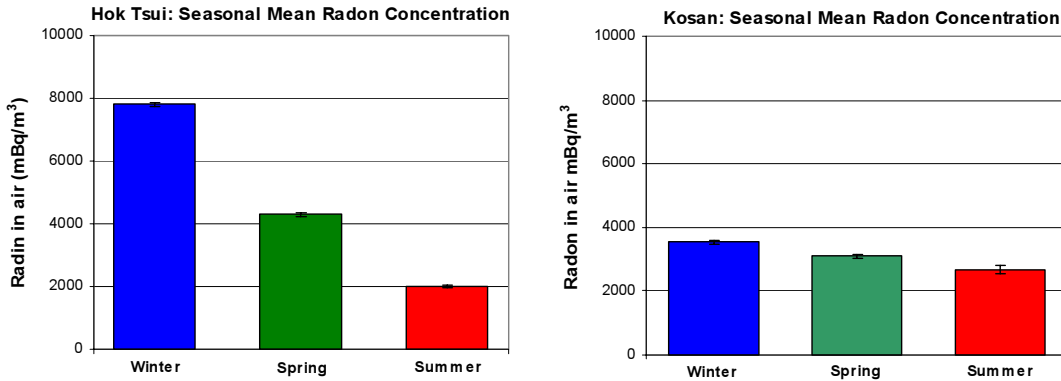


Figure 2.13: Seasonally averaged radon concentration (mBq/m^3) at (a) Hok Tsui and (b) Kosan. Error bars denote standard error.

Diurnal Composite Plots

Composite diurnal plots by season for each site indicate some structure (Figure T2.14 a,b). At Hok Tsui the magnitude of the seasonal variability in radon concentration is far greater than that of the diurnal variability. This is a consequence of the sharp land-ocean demarcation near the mainland site and seasonal changes in wind patterns. The opposite is true for measurements at Kosan, the island site.

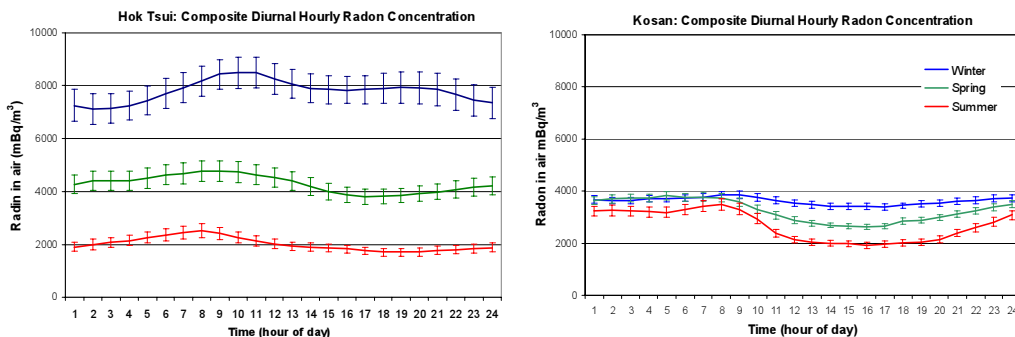


Figure 2.14: Composite diurnal plots of hourly radon concentration by season for (a) Hok Tsui and (b) Kosan. Error bars denote standard error.

Some of the difference in magnitude of the diurnal signal between the two sites may be attributed to differences in the heights of the radon intake masts. At Hok Tsui the intake mast is tall (approximately 15m) whereas at Kosan the sample intake is at a height of 4-5m. Since radon is of terrestrial origin, the near surface radon concentration gradient will be high, particularly at night during stable conditions. Consequently, the lower intake height at the Kosan site would accentuate radon dilution effects within the ABL. The depth of the ABL (a function of surface heating, refer Figure T2.15) determines the volume of air into which radon from the surface is mixed. In Summer, when temperatures are higher the mixing volume increases causing a daytime reduction in radon concentration. The near surface

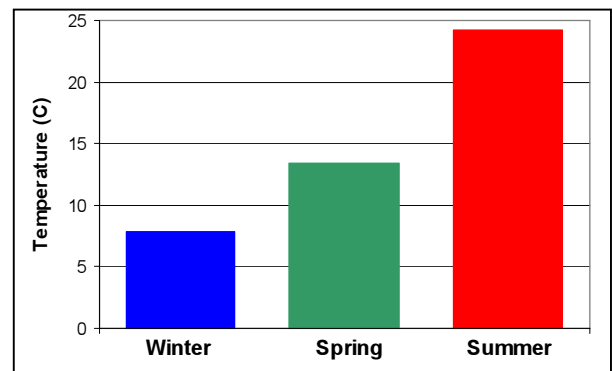


Figure T2.15: Kosan average near surface temperature.

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radon gradient will depend on the degree of mixing near the surface. During the day when mixing within the ABL is strongest, differences imposed by the dissimilar intake mast heights will be minimised. At these times, in Summer, the average radon concentrations observed at each site are similar (Figure 2.14 a,b).

Wind Speed and Direction

Both sites exhibit seasonality in wind speed direction. At Hok Tsui the prevailing wind direction changes from between north to northeast in Winter to virtually east-west in Summer (Figure T2.16 a-c) as would be expected with the northward migration of the Intertropical Convergence Zone. For this site the predominant land fetch sector is 230° to 45° with the remaining sector open to the South China Sea and the western Pacific. For the same period at Kosan there is a gradual shift from northerly to southeasterly (Figure T2.17a-c). At Kosan the most consistent oceanic fetch (i.e. no significant land mass for $\geq 1000\text{km}$) is between south-southwest and southeast. Both sites show a tendency for wind speed to decrease from Winter to Summer (Figure T2.18 a,b), however the change at Hok Tsui ($\sim 2\text{m/s}$) is considerably smaller than at Kosan ($>4\text{m/s}$).

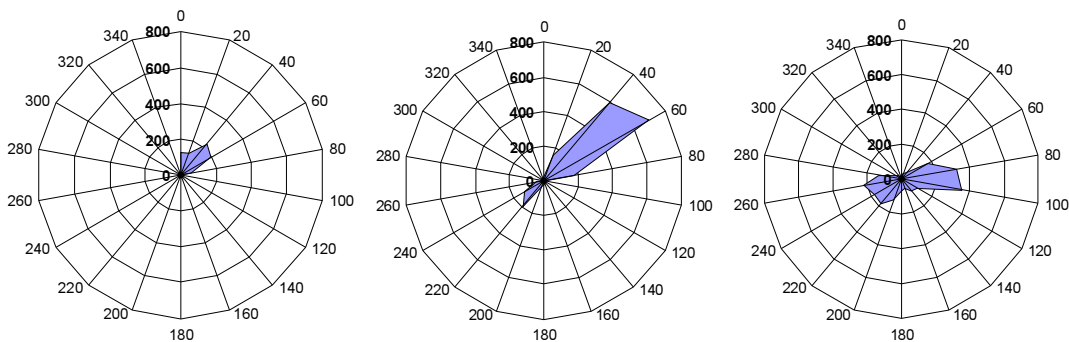


Figure T2.16: Number of hourly samples per 20° wind sector at Hok Tsui in (a) Winter, (b) Spring and (c) Summer. Note the limited data recovery at Hok Tsui in Winter, see text for details.

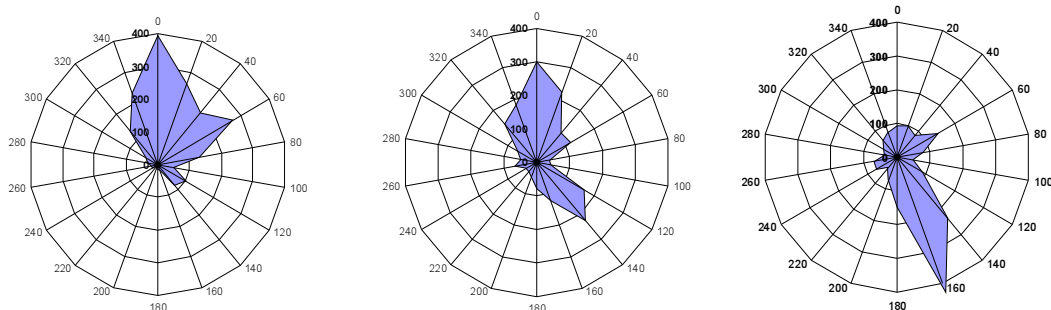


Figure T2.17: Number of hourly samples per 20° wind sector at Kosan in (a) Winter, (b) Spring and (c) Summer.

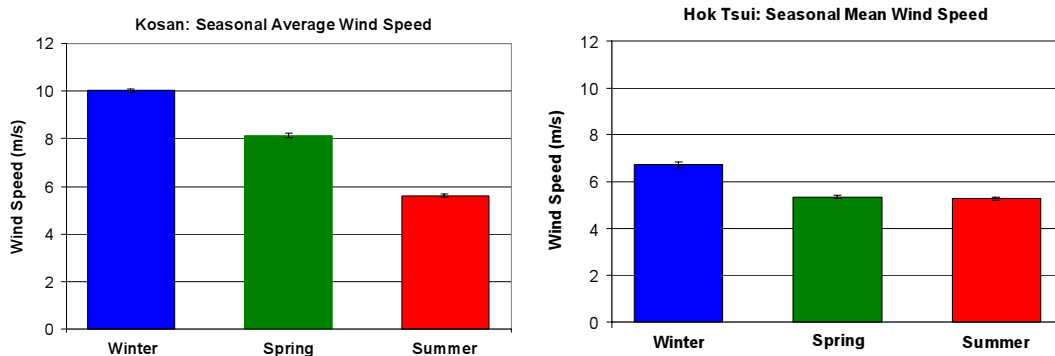


Figure T2.18: Seasonally averaged wind speed for (a) Kosan and (b) Hok Tsui. Error bars denote standard error.

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For each site there is a shift from predominantly continental air mass fetch in Winter to predominantly oceanic air mass fetch in the Summer based on the local average wind direction. This is reflected in the seasonal average radon concentration plots (Figures T2.13 a,b). However, as previously noted, the magnitude of seasonal change in average radon concentration was very different between the sites. In order to elucidate this seasonal observation we performed an analysis of the angular distribution of radon by season at each site (Figures T2.19 a-c and T2.20 a-c).

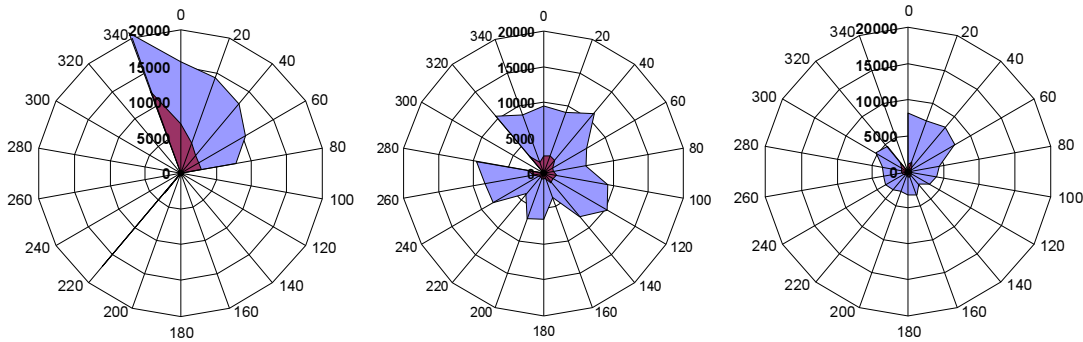


Figure T2.19: Average 25 and 75 percentile radon concentration per 20° wind sector at Hok Tsui in (a) Winter, (b) Spring and (c) Summer. Sectors containing less than 8 samples per season have been omitted.

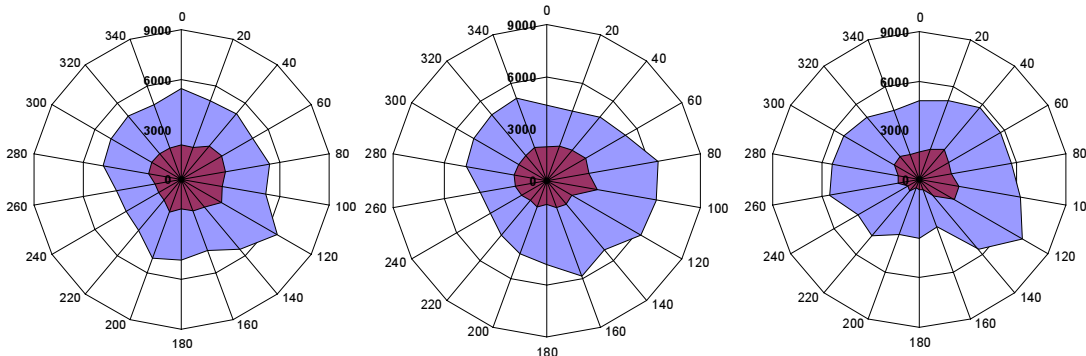


Figure T2.20: Average 25 and 75 percentile radon concentration per 20° wind sector at Kosan in (a) Winter, (b) Spring and (c) Summer. Sectors containing less than 8 samples per season have been omitted.

At Hok Tsui, radon concentrations were consistently high from the region of continental air mass fetch, the clearest example being in Winter when winds were mostly from the north. In Spring, some high radon concentrations were recorded in the oceanic sector (45° to 230°) which correspond to nearby (~700km) land masses such as the Philippines. Air masses travelling at the average speed recorded at Hok Tsui could travel this distance in ~1.5 days, which is short compared to the 3.8 day half life of radon.

A close inspection of the hourly radon data over one week indicates the sensitivity of radon concentration to air mass contact with land when slight changes in wind direction cross the Chinese coastline (Figure T2.21).

At Kosan, a surprising result was the fairly isotropic distribution of radon concentration with wind direction for two of the three seasons so far observed. This finding contrasts with similar observations at baseline monitoring sites considering the well defined continental and oceanic sectors around the Kosan site. One interpretation of this observation is that the regional meteorology is

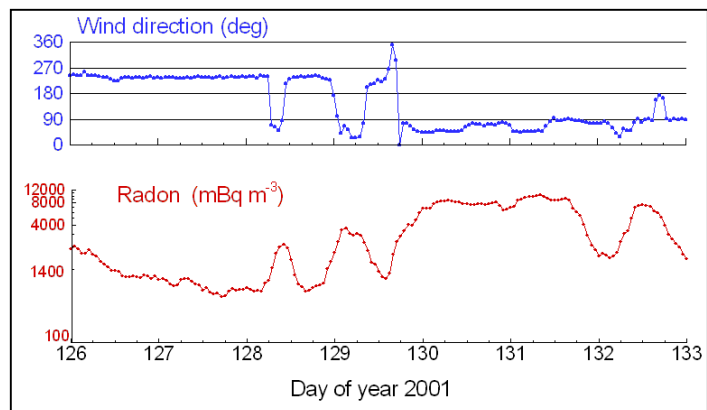


Figure T2.21: Hourly radon observations recorded at Hok Tsui in 2001

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particularly complex in Winter and Spring at Kosan. That is, the observed wind direction of air masses arriving at the site may not be representative of their long term fetch. Under such conditions, wind direction alone would not be a suitable criterion for distinguishing the origin of air masses. Observed radon concentrations at Kosan in Summer however are typically lower from the oceanic sector which indicates that air masses arriving from that direction in that season had a more consistent fetch along their observed direction of travel (over the East China Sea and western Pacific Ocean). One persistent feature of the radon observations at Kosan was the Cheju Island radon signature (to the east southeast). This signal is stronger in Summer than Winter because the lower wind speed results in a longer contact time of the air mass with land as it passes over the island.

Figures T2.22 and T2.23 contrast the location and angular distribution of radon concentrations observed at a baseline station for the Global Atmospheric Watch Program and two ACE-Asia radon monitoring sites. The maps of Figure T2.23 help to visualise the regional continental and oceanic fetches for approaching air masses. The ratio between maximum continental and minimum oceanic radon concentrations at a site is an indication of the time since last land contact (a surrogate for air mass "cleanliness") of an air mass that has arrived from the oceanic sector. The lower the ratio, the "cleaner" the oceanic air. At Cape Grim this ratio is 0.065, indicating very clean air from the oceanic sector. At Hok Tsui and Kosan the ratios are 0.19 and 0.62, respectively, indicating that air masses arriving from a direction of suspected oceanic fetch have in fact recently been in contact with land. From these examples it is clear that at Cape Grim, wind direction alone can be used as a relatively reliable indicator of air mass origin. In contrast, the relatively isotropic angular distribution of radon about the Kosan site, the primary surface station for the first ACE-Asia IOP, indicates that wind direction is not a good criterion to indicate air mass origin. This will have serious implications for the interpretation of data collected at the Kosan site during the first ACE-Asia IOP, and highlights the necessity of a tracer species such as radon to indicate recent land contact.

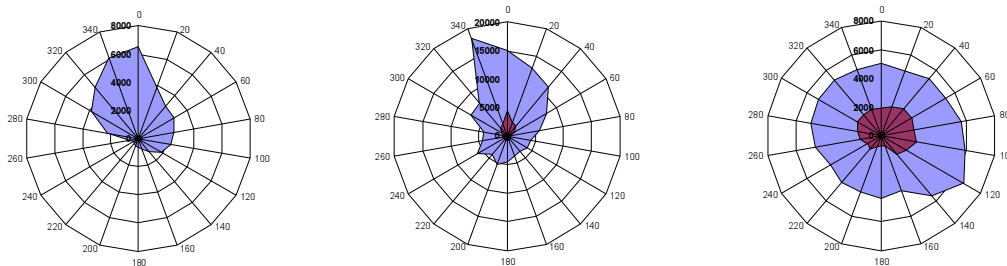


Figure T2.22: The angular distribution of radon in air (mBq/m^3) at (a) the Cape Grim Baseline Air Pollution Station, Tasmania, (b) the Hok Tsui ACE-Asia site, and (c) the Kosan ACE-Asia site. The purple and maroon shadings indicate 75 and 25 percentile concentrations for each 20° wind sector (note the difference in scale between plots).



Figure T2.23: Site locations of (a) Cape Grim site, (b) the Hok Tsui ACE-Asia site, and (c) the Kosan ACE-Asia site.

Given that locally observed wind directions are most frequently from the respective oceanic sectors of each site in Summer, one way to look at the consistency of fetch is to examine the seasonal histogram of hourly

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radon observations (Figure T2.24 a). The sample distribution at Hok Tsui is heavily skewed to low radon concentrations, indicating frequent occurrences of conditions resembling baseline conditions. For this to occur, air masses arriving at the site must have had a long trajectory over water. The distribution at Kosan however is more broad, indicating that a larger percentage of air masses arriving at the site with a local wind direction toward oceanic fetch (Figure T2.23c), have in fact, recently been in contact with land.

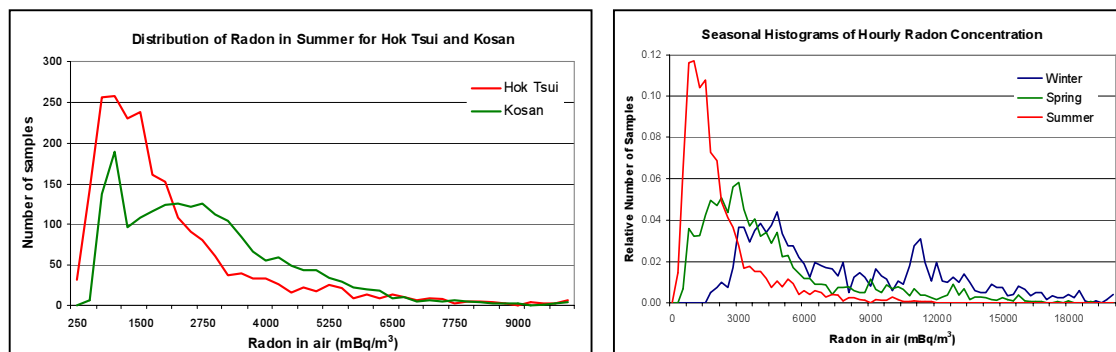


Figure T2.24: Histograms of hourly radon concentration (a) measured at Hok Tsui and Kosan in Summer, (b) measured at Hok Tsui in Winter, Spring and Summer.

There is a large change in the distribution of hourly radon concentration observations at Hok Tsui with season (Figure T2.24 b). Based on our observations, low radon conditions are hardly ever observed at the Hok Tsui site in the Winter months, which is also evident in Figure T2.12a. However, the large spread of the radon concentration histogram (Figure 2.24b) indicates that air masses arriving at the site from the continent have had vastly different contact times with land. This will have a strong bearing on the amounts of aerosols they are able to collect and redistribute.

Conclusions

- This review period comes less than one year after the official commencement of the ACE-Asia campaign in January 2001;
- The past year has seen the completion of commissioning of all new ANSTO radon detector and aerosol monitoring sites;
- Preliminary analysis of the radon concentration data presently available (three seasons) from two of the sites, Kosan (Korea) and Hok Tsui (Hong Kong), have been presented.
- The Kosan site was selected for analysis since it was the primary surface site for the first ACE-Asia Intensive Operation Period.
- Results from Kosan (a "marine perturbed" site) were contrasted with those from Hok Tsui (a coastal site), also the closest operational radon monitoring site to Kosan at the commencement of the IOP.
- The extended temporal coverage of data (nine months) was possible because the Kosan and Hok Tsui sites were fully operational well ahead of the first ACE-Asia IOP, March-May 2001, when most of the other investigators commenced operations.
- Preliminary analyses of monthly and seasonal data indicate that both sites have unique characteristics and that land contact can not be reliably parameterised by wind speed and direction alone, particularly in the case of Kosan.
- Our observations have demonstrated the sensitivity of radon measurements to land mass contact, even at high temporal resolution, which indicates that is a key tracer for air mass characterisation;

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- The full potential of these observations will be realised when (i) matching data for climatically active gases and aerosols are provided for these sites by our research collaborators, and (ii) preferably more than one complete year of data have been collected. Both of which require ANSTO's continued involvement in the ACE-Asia campaign beyond the present Project completion date of June 2002.

T2.6 Task 2 Reports and Papers

- Heijnis, H., S. Chambers, A. Henderson-Sellers, W. Zahorowski, S. Whittlestone, P. Irannejad, K. Harle, S. Haberle and A. Atkinson. 2000. Human Activity and Climate Variability: Applications of Nuclear Science. 2000 Fall Meeting of the American Geophysical Union, Moscone Center, San Francisco, CA, 14-19 December
- Heijnis, H., S. Chambers, A. Henderson-Sellers, W. Zahorowski, S. Whittlestone, P. Irannejad, K. Harle, A. Jenkinson, S. Haberle, A. Atkinson. 2001. Poster entitled Human Activity and Climate Variability: Applications of Nuclear Science. *Conference on the Study of Environmental Changes Using Isotope Techniques*, Vienna, Austria, 23-27 April, 2001.
- Chang-Hee Kang, Sung-Nam Oh, Jiyoung Kim, Wlodek Zahorowski, Scott Chambers and Ann Henderson-Sellers. 2001. Radon program at the Kosan site, Korea. *ACE-Asia Workshop*, Sogwipo City, Cheju, Korea, 19-20 March 2001
- Hye-Jung Shin, Jiyoung Kim, Chang-Hee Kang, Wlodek Zahorowski, Sung-Nam Oh and Byoung-Cheol Choi. 2001. Atmospheric Natural Radioactivity(Radon-222) Measurements at Remote Site in Korea: Preliminary Results Proceedings on the 2001 Spring Conference of Korean Meteorological Society, page 392-395.
- Scott Chambers, Tao Wang, Wlodek Zahorowski, Steven Poon and Ann Henderson-Sellers. 2001. Air mass characterisation using radon-222 at the ACE-Asia Kosan site ACE-Asia Workshop, California Institute of Technology, Pasadena, California, USA, 29 Oct-01 Nov 2001
- Wlodek Zahorowski, Jiyoung Kim, Scott Chambers, Chang-Hee Kang, Hye-Joung Shin and Ann Henderson-Sellers. 2001. Radon-222 measurements at the ACE-Asia Hok Tsui site: first eight months of observations ACE-Asia Workshop, California Institute of Technology, Pasadena, California, USA, 29 Oct-01 Nov 2001

T2.7 Summary and Future Directions

T2.7.1 Summary of the reported year (November 2000-October 2001)

- Instrumentation of the selected ACE-Asia sites has been completed. Commissioning of all but the Sado site was achieved on schedule;
- All sites but Sado participated in the first IOP in April-May 2001;
- A radon detector run jointly by ANSTO and PMEL/NOAA has been upgraded and collected data while on board NOAA R/V Ron Brown during the first IOP;
- All site management issues were dealt with promptly, resulting in a steady flow of radon data and aerosol filters;

T2. Task 2 - Characterisation of global atmosphere

- The analysis of all recorded/collected material is on schedule;
- A grant application to the APN has been submitted in support of regional inventory analyses based on radon time series;
- Preliminary radon results from Kosan and Hok Tsui sites were presented and discussed at an ACE-Asia workshop at the California Institute of Technology, Pasadena in Oct/Nov 2001.

T2.7.2 Anticipated highlights for November 2001-June 2002

- First quantification of regional and seasonal fine aerosol characteristics – based on year long sampling at Hok Tsui and Kosan sites;
- First assessment of East Asian radon concentrations and seasonal variability of radon based on year long observations at Hok Tsui and Kosan sites (with Meteorological Research Institute, Korea, Cheju National University and the Hong Kong Polytechnic University);
- Participation in an intercomparison of analytical techniques for the determination of elemental composition of natural dust;
- First assessment of regional inventories of NO_x and CH₄ - based on radon time series measured at Hok Tsui (with the Hong Kong Polytechnic University)
- Preparation of one year radon datasets from all four ACE-Asia radon monitoring sites for comparison with an atmospheric transport model (with Max Planck Institut für Meteorologie, Hamburg).

Throughout the year:

- Ongoing analysis of filters and radon data from all sites
- Management of the measurement programs at all sites

T2.8 Task 2 International Collaborators Timelines and extension of the project

The ACE Asia Project is planned to operate on two timeframes, long and short term. The long term sampling is scheduled for up to 5 years of continuous monitoring at a network of surface sites from January 2001. The short term sampling is based on several 6-12 week intensive operation periods in different seasons, which

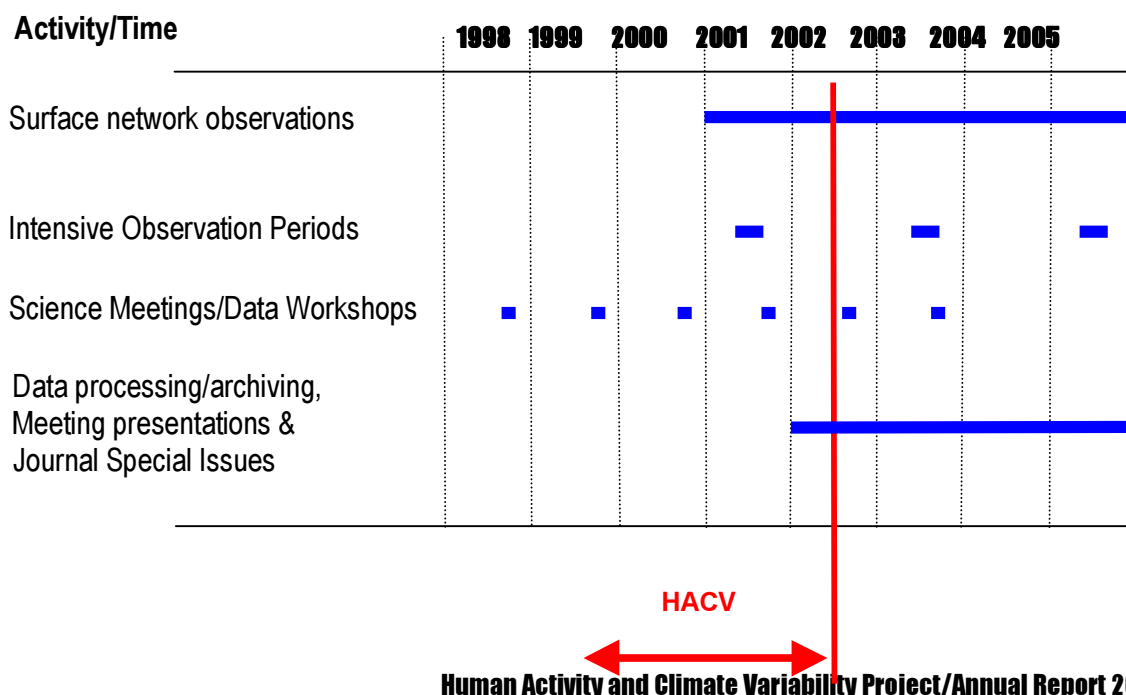


Figure T2.25: Timeline of the ACE-Asia activities

T2. Task 2 - Characterisation of global atmosphere

would include additional sea and airborne measurement platforms (Figure T2.25). The long term measurements will target seasonal and inter-annual variations across the study region, whereas the intensive short term sampling will target individual severe pollution events in an attempt to characterise their sources, origins and evolution.

The crucial role that radon measurements will play in the interpretation of results across the study region has been demonstrated. Based on the ACE-Asia timeline, a closing date of June 2002 for contributions of Task 2 research to the ACE-Asia campaign would compromise the broader research goals and collaborative efforts. Our commitment to the project is for continuous measurements at a network of sites concluding at the end of 2005. ANSTO provides unique experimental input to the combined ACE-Asia database at the sites we are involved in.

In the light of the above information, it is evident that a two-year extension to ANSTO's involvement in the ACE-Asia program is the minimum requirement for us to achieve most of our scientific objectives. Such an extension would at least allow us to collect sufficient data to more accurately quantify seasonal fine particle concentration variations over the region, as well as to fingerprint and quantify source contributions across the study area based on a statistically significant number of pollution events. This would also provide sufficient time to apply Chemical Mass Balance and Positive Matrix Factorisation techniques to integrate aerosol and radon data. Overall, the proposed extension would put us in a better position to meet the expectations of our international collaborators whose programs rely on our data and require our expertise.

A tentative list of objectives for the proposed extension period would include:

- Quantification of the inter-annual variability in the composition of East Asian aerosols;
- Fingerprinting and sourcing of pollution events;
- Multi-year, high resolution datasets for testing of atmospheric transport models;
- Quantification of the inter-annual variability in radon concentration at all sites;
- Development and application, in the ACE-Asia context, of an aerosol sourcing method using a combination of aerosol, radon and meteorological data;
- Regional East Asian inventories of climatically sensitive trace gases and elucidation of their spatial and temporal variability.

T2.9 References

1. Climate Change 2001 (IPCC Third Assessment), Cambridge University Press, 2001
2. ACE-Asia web site and various linked documents <http://www.joss.ucar.edu/ace-asia/planning.html>

T3. Task 3 - Future climate modelling

T3. Task 3: Future - Climate modelling: evaluation and improvement

T3.1 Task 3 Objectives

1. To investigate the use of naturally occurring isotopes in regional moisture studies
2. To improve land surface parameterisation and investigate its potential to improve global climate models and thus improve our future climate change predictions

T3.2 Task 3 Current Research Hypothesis

1. Stable isotopes of water provide a novel data source for evaluation of GCM simulations of regional hydrology
2. Land-surface scheme (LSS) complexity improves the simulation of continental near-surface climates

T3.3 Task 3 Background

At the project review in November 2000 it was recommended that resources be primarily focused on AMIP II data analysis i.e. Objective 2. This direction has been taken, however Objective 1 has also made some progress.

In year 1 Objective 1 focused on radon. At last year's project review it was recognised that further progress depends on:

- (i) confirmation of regional relationships between radon emanations and soil moisture
- (ii) successful simulation of these regionally

It was recommended that no further investment be made in radon without these. Despite every conceivable effort of ANSTO's behalf the Cape Grim Working Group failed (until August 2001) to support ANSTO and to deliver any results or progress on these two science blocks. Consequently, radon research was discontinued for the year. Recently the Management Group of the Cape Grim Baseline Air Pollution Station has accepted an ANSTO proposal for a new radon program at Cape Grim and nominated Wlodek Zahorowski Lead Scientist of the program.

This year (year 2) research under Objective 1 has focussed on oxygen and hydrogen isotopes derived from the IAEA Global Network of Isotopes in Precipitation (GNIP).

T3.4 Task 3 Progress Summary

Within Objective 1

- (i) Negotiations with the Cape Grim Committee on radon research were pursued to a successful conclusion in August 2001
- (ii) IAEA GNIP database has been investigated to ascertain the availability of basin-scale isotopic data: identified the Amazon basin
- (iii) GNIP data for the Amazon were analysed and compared with available GCM simulations of the basin hydrology (papers presented and published)

Within Objective 2

T3. Task 3 - Future climate modelling

- (i) Research with imposed LSS complexities using CHASM (jointly with Macquarie University) completed — papers published and presented
- (ii) Surface energy and surface water budgets for 16 AMIP II AGCMs and three reanalyses products analysed and visualisations of 17 years of energy and water “residuals” generated
- (iii) Availability and quality of “truth” (i.e. observations and reanalysis results) were assessed for the continental surface energy and water budgets for the AMIP II period (papers presented and published)
- (iv) A lag correlation analysis of AMIP II simulations initiated jointly with BMRC

T3.4.1 Details on Objective 1:

Research hypothesis: Stable isotopes of water provide a novel data source for evaluation of global climate models' (GCMs) simulations of regional hydrology

Summary

Global Climate Models (GCMs) are the predominant tools with which we predict the future climate. In order that people can have confidence in such predictions, GCMs require validation. As almost every available item of meteorological data has been exploited in the construction and tuning of GCMs to date, independent validation is very difficult. This year Task 3 has explored the use of isotopes as a novel and fully independent means of evaluating GCMs. The focus is the Amazon Basin which has a long history of isotope collection and analysis and also of climate modelling: both having been reported for over thirty years. Careful consideration of the results of GCM simulations of Amazonian deforestation and climate change suggests that the recent stable isotope record is more consistent with the predicted effects of greenhouse warming, possibly combined with forest removal, than with GCM predictions of the effects of deforestation alone.

Isotopes and GCMs in the Amazon

Global climate modelling and isotopic analysis in the Amazon both have histories of over thirty years (e.g. Salati *et al.*, 1979; McGuffie and Henderson-Sellers, 2001) and these histories are not unconnected. For example, an important review of Amazonian isotopic and other data was published by Salati and Vose (1984). This paper was influential because its publication coincided with the first reports of a simulation using a Global Climate Model (GCM) to assess the possible impact of deforestation of the Amazon. Indeed, Salati and Vose (1984) quote preliminary (1983) results from the work of Henderson-Sellers and Gornitz (1984). Although the Salati and Vose (1984) paper was primarily a collection of their, and others', previous work with isotopic analysis, it underlined to the newly emerging global climate modelling community that the Amazon recycles about half its water within its basin.

Important papers were published in the early 1990s on the subject of isotopic analysis of Amazonian precipitation and its implications for regional hydrology and climate. Gat and Matsui (1991) employed a simple box model of the central Amazon Basin to demonstrate that some of the water recycling is from fractionating sources. Using data from the International Atomic Energy Authority/World Meteorological Organization (IAEA/WMO) global station network up to 1981, they interpreted a +3‰ deviation from the World Meteoric Line as indicative of 20-40% of the recycled moisture within the basin being derived from fractionating sources such as lakes, the river or standing water. The paper by Victoria *et al.* (1991) also used IAEA/WMO data; they analysed isotopic results from Belem and Manaus over the fourteen year period from 1972 to 1986. Using the box/sector model of Dall'Olio (1976) these researchers were able to

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employ isotopic data to show that wet season recycling is by means of transpiration while dry season recycling in the Amazon is primarily by re-evaporation of precipitation intercepted on the canopy. Since the mid 1990s, there have been relatively fewer papers on Amazonian isotopes, although Gat (2000) reviews some work and reports that an updated model of the Amazon's water balance, which uses isotopic input, improves earlier predictions.

The first GCM simulation of the impact of Amazonian deforestation was published by Henderson-Sellers and Gornitz (1984). Since then, there have been a large number of similar GCM simulations. Some of the differences in the outcomes of GCM predictions are due to the imposed differences in surface albedo, surface roughness, density and mix of original and replacing vegetation, soil type and state and so on. McGuffie *et al.* (1998) review the problems associated with correctly specifying climate model parameters in both control (present day) and deforested simulations and find that almost all models predict increased surface temperatures following deforestation. There is also general agreement that both precipitation and evaporation decrease but less consensus on the sign of the change in atmospheric moisture convergence (e.g. Table 3.1, top line). A detailed literature survey has not revealed any GCM simulations of the impact of Amazonian deforestation tested against the available isotopic data. This is partly the result of the relevant research communities' ignorance of one another. It may also be because very few GCMs have, as yet, included isotopic composition as a computed variable. Notable exceptions include work by Jouzel *et al.* (1991, 2000) but neither of these studies include consideration of deforestation impacts.

Table 3.1. Stable isotopic and global climate model characterisation of climate change in the Amazon

Amazonian Deforestation Simulations (e.g. McGuffie <i>et al.</i> , 1998)	<ul style="list-style-type: none"> - decrease in precipitation - decrease in evaporation - less water recycling - ?decrease in atmospheric moisture convergence
Recent Isotopic Record (derived here)	<ul style="list-style-type: none"> - more water recycling in the wet season - greater relative importance of transpiration and canopy evaporation in the wet season - decrease in runoff ratio (equivalent to a decrease in atmospheric moisture convergence)
Greenhouse Impacts in Amazon (e.g. Houghton <i>et al.</i> , 2001)	<ul style="list-style-type: none"> - increase in precipitation - increase in evaporation - intensification of hydrological recycling - ?sign of atmospheric moisture convergence change unknown

The data used in this study were obtained from the Global Network for Isotopes in Precipitation database (IAEA/WMO 1999), jointly maintained by the World Meteorological Organization (WMO) and the International Atomic Energy Agency (IAEA) since 1961. From each Amazon station, monthly average values of temperature, humidity, precipitation, precipitation type, deuterium, oxygen-18 and tritium are available (Table 3.2). As part of the Human Activities and Climate Variability (Task 3) ongoing research into the possible synergies between isotopic and global climate modelling studies of Amazonian deforestation, we have examined these IAEA/WMO station records in the Amazon Basin for temporal trends. We find noticeable changes in the wet season, which extends from about December to May. The continental gradient of $\delta^{18}\text{O}$, already the weakest in the world, has been further weakened over the last three decades in the wet months from December to May.

Table 3.2 IAEA/WMO Amazon Basin isotope collection station location details and availability. The last column is the percentage of the total months of observation for which both deuterium (D) and oxygen 18 (^{18}O) observations are available.

Station	IAEA ID#	Location	Alt (mASL)	Operational	No. Months & % of total	% time for D and ^{18}O
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Belem	8219100	1.43°S, 48.48°W	24	1965-1987	264	87.5%
Cayenne	8140500	4.83°N, 52.37°W	8	1962-1975	156	38.5%
Manaus	8233100	3.12°S, 60.02°W	72	1965-1990	300	52.0%
Porto Velho	8282500	8.77°S, 63.92°W	105	1965-1983	216	33.3%
Sao Gabriel	8210600	13.0°S, 67.08°W	87	1961-1990	348	26.7%
Izobamba	8404400	0.37°S, 78.55°W	3058	1968-1997	324	93.1%

In the 1960s, when the collection of isotopic data began in the Amazon Basin, monthly average values of the deuterium excess at Manaus were significantly greater than at Belem for both the wet and dry seasons. Furthermore, there was no significant difference between the mean monthly deuterium excess values from the wet to the dry season at either the coastal or interior sites. By the 1980s, the Belem mean monthly deuterium excess for both the wet and dry seasons have increased slightly compared to the values in the 1960s, but the difference is not statistically significant. In contrast, large changes are observed in the seasonal deuterium excess inside the basin at Manaus. Although the annual mean deuterium excess at Manaus in the 1980s ($11.83 \pm 0.44\text{‰}$) is not significantly different to that in the 1960s ($12.62 \pm 0.48\text{‰}$), results now show a significant difference between the wet and dry season values. In particular, the deuterium excess has decreased in the wet season and increased in the dry season. The difference in deuterium excess between Belem and Manaus is also much reduced in the wet season and Manaus' wet season value is significantly decreased in the 1980s.

Plausible explanations of the wet season deuterium excess decrease involve either more non-fractionating (e.g. transpiration) or less fractionating (e.g. lake) recycling, or both. Thus the observed temporal shift in isotope data (1960s to 1980s) requires a change in the recycling behaviour in the Amazon. These isotopic results are consistent with the GCM deforestation predictions, which show less overall transpiration only if there has been a relative decrease in the evaporation of water from lakes and other fractionating sources over this period. Table 3.1 summarizes the divergence among present day characterizations of Amazonian climate change as derived from (i) deforestation studies with GCMs; (ii) isotopic data; and (iii) greenhouse simulations with GCMs.

Isotopic Evaluation of GCMs' Simulation of the Amazon region

There are at least two methods available for isotopic evaluation of GCMs' simulation of the Amazon climate. One is to utilize the results such as those of Gat and Matsui (1991) regarding the relative amounts of water recycled in the Amazon from fractionating and non-fractionating sources. They deduced by comparing deuterium and oxygen isotopic observations with results from their box model of the central Amazon Basin that of the input precipitation 10%-20% is re-evaporated from fractionating sources (e.g. lakes and rivers), 30%-40% from non-fractionating sources (e.g. transpiring plants and complete re-evaporation of canopy-intercepted water), with about half of the total hydrological budget going to runoff. These values ought to be able to be used to evaluate GCMs. Here, this method is tested using a series of GCM experiments conducted with the USA's National Center for Atmospheric Research's Community Climate Model (CCM1-Oz) (McGuffie *et al.* 1998).

The GCM results analyzed are found to be different from those of Victoria *et al.* (1991) who claimed on the basis of isotope analysis that transpiration is the major source of recycled water in the wet season. We find that at least one GCM simulates transpiration as being very much more significant in the Amazon forest's dry season budget of recycled water. Unfortunately, although the land surface scheme (BATS – the Biosphere Atmosphere Transfer Scheme) used in the CCM1-Oz simulations does permit inclusion of lakes, this option was not used in these GCM experiments. It was therefore not possible to examine the Gat and Matsui (1991) conclusion regarding the fraction of recycled moisture from lakes directly.

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Although these results are somewhat inconclusive, it appears that there are grounds for suspecting that a more thorough examination of the components of the Amazonian water cycle using isotopic data could both reveal inadequacies in some current climate model simulations and, hopefully, indicate how simulations by GCMs could be improved to more completely and correctly capture important moisture exchanges. This is an interesting issue because it has been shown that tropical deforestation has the potential to excite large-scale Rossby waves in the atmosphere. These waves can propagate from the source of their initiating disturbance into the middle and high latitudes of both hemispheres and, hence, prompt impacts far distant from deforestation in the Amazon (Zhang *et al.* 1996).

This isotope-GCM "missing link" is a second method of GCM evaluation using isotopes which warrants further detailed study. One possibility is that the temporal isotopic records are illustrative of the impact of Amazonian deforestation. At present, the available GCM studies are unable to demonstrate or deny the validity of this conclusion. Another possibility that deserves some consideration is that the disturbances in the isotopic record over time have not been caused solely by forest removal. Although the regional extent of deforestation in the Amazon is great, there are other effects which may also be contributing to the observed temporal shifts in the isotopic signatures. These could include both the direct and indirect effects of greenhouse gas increases.

There have been very few GCM studies so far which have attempted to assess the impact of deforestation and greenhouse gas increases in the Amazon. The paper by Henderson-Sellers *et al.* (1995) was not focussed on deforestation but did consider plant physiological responses to increased atmospheric CO₂ levels which includes stomatal closure. Costa and Foley's (2000) study is a much more sophisticated evaluation of the independent and combined effects of stomatal closure in response to an enriched CO₂ atmosphere, deforestation and greenhouse warming. Zhang *et al.* (2001) consider the latter two effects but not the plant physiological responses. The challenge for future use of isotopic signatures for GCM evaluation is to know which of these representations most closely fit "present-day" isotopic measurements.

An outstanding disagreement among GCM representations of the impact of Amazonian deforestation is the sign of the change in moisture convergence (e.g. Table 3.1). The challenges associated with predicting this are illustrated in Zhang *et al.* (1996) which shows the changes in the vertically-integrated water flux across the north, south, east and west boundaries of the Amazon Basin as derived from one set of GCM simulations of deforestation. This year in Task 3 the possibility of determining at least the sign of this important change has been examined by reverting to the isotopically-derived central basin box model of Gat and Matsui (1991). Since the total runoff equals the atmospheric moisture convergence, changes in either indicate a change in the other. We have employed values of parameters derived by Gat and Matsui (1991) and investigated the effects of modelling runoff larger and smaller than their values. Our results suggest that it is necessary to decrease the runoff fraction by 10% in order to match the changed isotopic signature at Manaus between the periods 1965-75 and 1980-90. This result is consistent with the majority of GCM simulations.

Importance of future use of isotopes in evaluating global climate models

To date this part of the HACV Task 3 research has demonstrated that results derived from isotopic data from the IAEA/WMO network can be compared with outputs from GCMs. We find that water recycling in the central Amazon has changed over the last thirty years, significantly so in the wet season. While some GCM results may be consistent with this conclusion, the selected GCM results analyzed here fail to simulate the relative components of transpiration and re-evaporated canopy interception for the complementary dry season correctly. The failure by the CCM1-Oz simulations to represent the relative seasonal importance of transpiration (non-fractionating) as compared to the fractionating evaporation seems likely to be traceable to the land-surface parameterization scheme: BATS. This land-surface

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scheme does have an option to incorporate open water bodies but this was not employed. Furthermore, a literature review indicates no other GCM simulation of the Amazon involving open lakes and river surfaces as a source of recycling water in the basin. The isotopic data show this to be an important omission and indicate the need to include water surfaces in land-surface parameterization, at least for the Amazon, in the future.

Our results suggest that further detailed analysis and extension to the very large number of GCMs already claiming to predict the impacts of Amazonian deforestation. At a minimum, it is recommended that additional GCM predictions of the climatic and hydrological impacts of Amazonian deforestation be evaluated against all the available isotopic data. Additionally, it might be valuable for current assessments of the performance of land-surface schemes in atmospheric models to include an evaluation of small land-locked water bodies as sources of atmospheric moisture (e.g. Irannejad *et al.*, 2000). A new intercomparison of climate model simulations of Amazonian hydrology might also be possible, perhaps under the auspices of the Atmospheric Model Intercomparison Project II (e.g. Phillips *et al.*, 2000). There is potential to explore isotopic modification by Amazonian deforestation by utilizing state of the art land surface schemes combined with one of the current 'isotope' GCMs (e.g. Hoffman *et al.*, 2000). Such an examination would fit into the suite of land-surface intercomparisons organized by the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) (e.g. Henderson-Sellers *et al.*, 1995; Schlosser *et al.*, 2000). Data from the isotopic archive for Amazonia could be offered through the GLASS (Global Land Atmosphere System Study) of GEWEX to form the basis of a new stand-alone and coupled (to an isotope-tracking GCM) pair of intercomparison and validation experimental simulations. There is also the obvious and beneficial synergy derivable from the use of isotopes for this task suggest that new observational programmes, such as the Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA), embrace isotopic studies (e.g. Vörösmarty *et al.*, 2001).

Future opportunities for Task 3 validation and model improvement include: (a) regional to basin-scale moisture convergence estimates; (b) evaluation of model partitioning among transpiration, free evaporation and canopy evaporation; and (c) detection and attribution of the impacts of forest change and greenhouse gas increases.

T3.4.2 Details on Objective 2

Research hypothesis: Land-surface scheme (LSS) complexity improves the simulation of continental near surface climates.

This hypothesis has been examined primarily using AMIP II data but also drawing on the CHASM model in joint research with Macquarie University.

Research with imposed LSS complexities using CHASM (jointly with Macquarie University) completed — papers published and presented

Six modes of land surface schemes which is able to vary the complexity of the surface energy balance are used with prescribed atmospheric forcing from locations representative of coniferous forest, tropical forest, temperate and tropical grassland and a semi-arid region. The simulations utilised a multi-criteria calibration methodology which, combined with the different surface energy balance configurations allows an examination of the relationship between land surface model complexity and model performance, independent of differences in the effective values of model parameters.

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Results indicate that the most complex model performed best over the calibrated period providing the data set is reasonably long and complete, providing support for the inclusion of explicit representations of key elements of the surface energy balance. Experiments that explored the ability of the model to simulate the second half of each data set following calibration to the first half of each data set showed that all models have considerable skill in the simulation of the latent heat fluxes although only a small benefit was gained from using the most complex mode. In the case of the sensible heat flux, the order of model performance was closely associated with complexity providing strong support for more complex representations of the surface energy balance.

This study also explored the sensitivity of the results to the time scale of model calibration and found little sensitivity to whether time step, daily or monthly calibration was used. Overall the results support the use of multi-criteria calibration with LSSs since the removal of uncertainty associated with effective parameter values permits an evaluation of the value of additional complexity in parameterisations of the surface energy balance. This study suggest that much of the scatter found in the PILPS Phase 2(e) and possibly in other intercomparison experiments can be explained by biases caused by the prescription of model parameters. This suggest that in future intercomparisons, modellers are either free to choose parameters, or that some form of calibration is performed to permit models maximise performance and remove biases associated with effective parameter values. It is acknowledged that the results of this study are limited by the quality of the observational data. Efforts to collect high quality data sets are to be strongly encouraged, but from the perspective of land surface modelling, a relatively small number of data sets where all the meteorological forcing is collected and the turbulent energy flux measurements are made in parallel with soil moisture and temperature, are more valuable than a large number of short, lower quality data sets.

Surface energy and surface water budgets for 10 AMIP II AGCMs and three reanalyses products analysed and visualisations of 17 years of energy and water “residuals” generated

Conservation of energy and water, a fundamental requirement for all land surface modelling, is hard to demonstrate. Conservation of energy at the surface is achieved by balancing a change in the energy state of the surface with the net radiation and sensible, latent and snow melt heat flux. While the conservation of water is achieved by balancing a change in the soil moisture with the precipitation and runoff and evaporation. It is expected that over the longer time scale total energy residuals (i.e. the ground heat flux) and the soil moisture change should be zero.

In this study surface energy and surface water budgets for 10 AMIP II AGCMs and two reanalysis products were analysed and visualisations of 17 years of energy and water “residuals” were generated. The energy residuals, i.e. the ground heat flux, were calculated as,

$$GH = \text{Net radiation} - \text{latent heat} - \text{sensible heat} - \text{snow melt heat}$$

Water residuals, i.e. the changes in soil moisture, were calculated as

$$\Delta \text{Soil Moisture} = \text{Precipitation} - \text{runoff} - \text{evaporation}$$

Three sets of animations were generated. The two animations were for the calculated ground heat flux, over the land surface (e.g. Figure 3.1). They were accumulated for each month and displayed as a line graph along with the world map. Among these two animations, one is for the continental surface overall for all 10 AMIP II models and the other one is for the eight climate zones for model A. This shows that the model functions well except for the extreme climate zones,

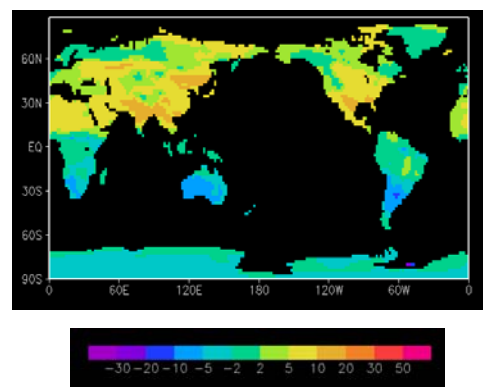


Figure 3.1. Global distribution of the calculated ground heat flux for model A in

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polar and extremely humid, which have a mean heat flux value some five times larger than for the other zones.

The last animation dealt with calculated changes to soil moisture, over the land surface. This was also accumulated for each month and displayed as a line graph, alongside a world map showing this calculated change in soil moisture. Note that this calculation had not been normalised to precipitation.

Both the ground heat and soil moisture balance calculations (e.g. Figures 3.2 and 3.3) showed that the models had some difficulties with some variables. For example snow melt and run off presented difficulties for some models.

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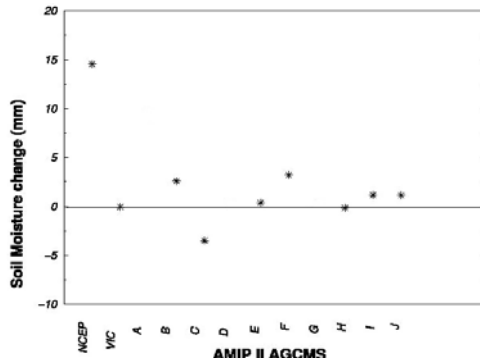


Figure 3.2. The mean monthly change in soil moisture (in mm) for all models and two

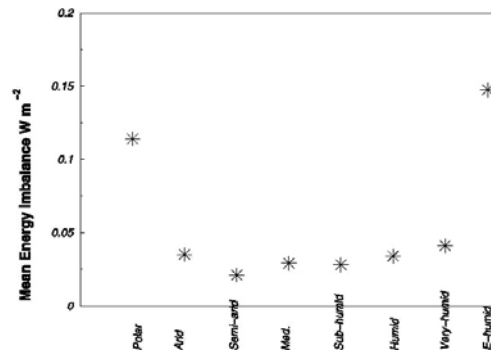


Figure 3.3. The ground heat flux (in W/m^2) in different de Martonne climate zones for model A.

Evaluation of the continental component of the global water cycle in AMIP II simulations (with UTS)

Introduction

- Problem: lack of reliable observational data sets for the evaluation of the land-surface simulations by global climate models (GCMs).
- Hypothesis: reanalysis products provide a suitable option for model validation (Phillips *et al.*, 2000).
- Material: simulated global land-surface for the period 1979-1995 by 10 AMIP II AGCMs, global off-line simulation by the VIC land-surface scheme and three reanalysis data sets (ECMWF, NCEP/DOE and NCEP/NCAR).
- Method: analyses are performed globally, over selected GEWEX-CEOP regions and in different climate zones as defined by the de Martonne aridity index (Figure 3.4) using the climatological precipitation and near surface air temperature (Legates and Willmott: available on line http://tao.atmos.washington.edu/data_sets/legates).

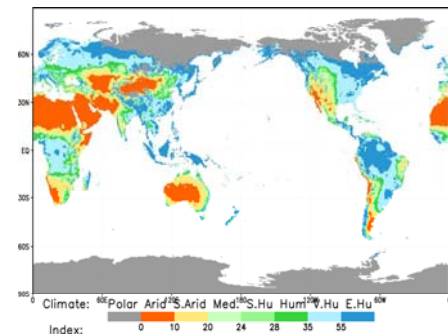


Figure 3.4. Global distribution of the de Martonne aridity index ($I=P/(T+10)$) as defined by Willmott and Legates precipitation (P) and air temperature (T)

Surface energy balances

Over the de Martonne climates (Figure 3.5):

- In most climates the surface available energy (SAE) of most AMIP II AGCMs is within the range of the reanalyses (area between the diagonal lines);
- In all climates at least one of the surface fluxes from AGCMs within the ranges of reanalyses;
- Globally, compared to reanalyses most AMIP II AGCMs overestimate sensible heat flux (SH) and underestimate latent heat flux (LH);
- Models' LH and SH better in arid climates;
- Models' SAE better in more humid climates;

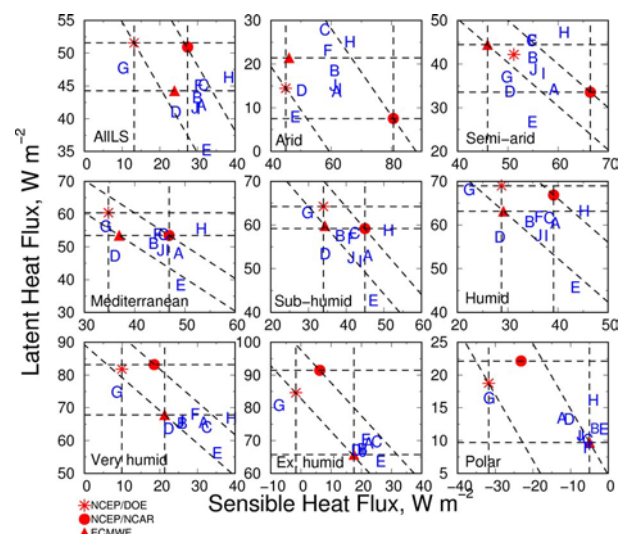


Figure 3.5. Partitioning of surface available energy between mean latent and sensible heat fluxes. The areas between the dashed lines show the ranges of the reanalyses.

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- Reanalyses agree better with each other in the intermediate climates (Mediterranean to Humid).

Over the GEWEX/CEOPs (Figure 3.6):

- Simulated SAE, SH and LH compared to reanalyses different in different climates;
- AGCMs agree better with ECMWF than with two NCEP reanalyses;
- Reanalyses agree well for SAE, but not for SH and LH.

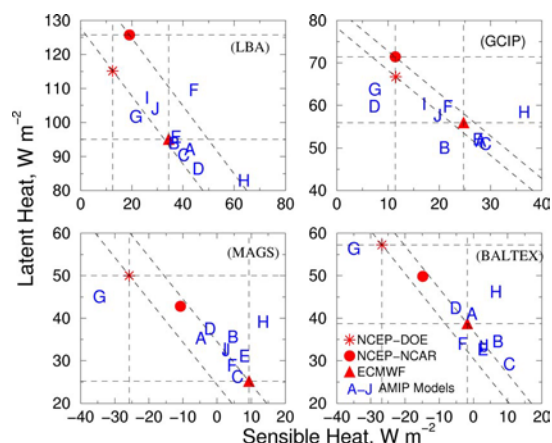
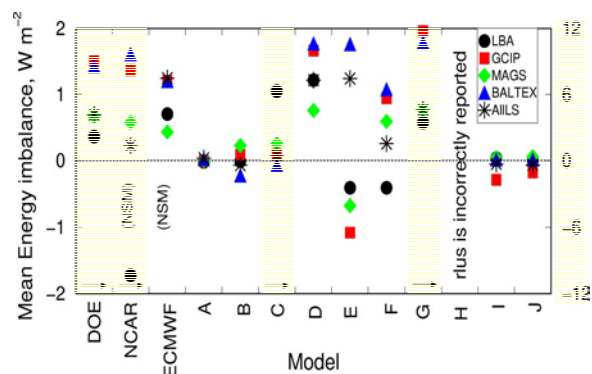


Figure 3.6. Partitioning of surface available energy between mean LH and mean SH for selected GEWEX COEP regions.

Energy residuals (Figure 3.7):

- Globally, most models and the reanalyses seem not to conserve energy over the AMIP II period (land-surfaces cooling down or warming up);
- The magnitude of energy residual varies regionally (may be climate-specific?) confirmed by animation.

Figure 3.7. Calculated mean energy residual of reanalyses and AMIP II models globally and in selected GEWEX/COEP regions for the period 1979-1995. The energy imbalance of the shaded columns is shown on the right-hand side. NSM is where snow melt heat is not included.



Surface water balance (Figure 3.8):

- AGCMs perform less well in simulating surface evaporation (smaller coefficients of correlation and larger deviation of normalised standard deviation) in arid climates;
- Inter-model differences larger in arid climates;
- As climate becomes wetter, coefficients of correlation increase nonlinearly and inter-model differences decrease;
- Inter-climate variability of AGCMs evaporation more consistent with ECMWF;
- Spatio-temporal correlations greater when compared to NCEP/NCAR (may be temporal trends).

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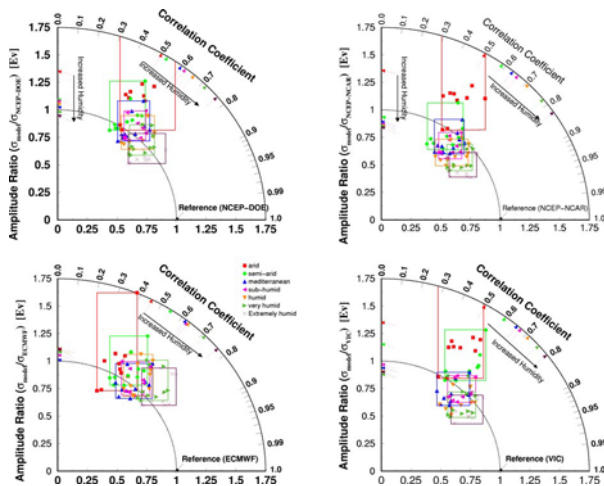


Figure 3.8. Taylor diagram demonstrating the spatio-temporal statistic of AMIP II AGCMs against different reanalyses. The arrow heads are averages of 10 models. Radial distance is spatio-temporal amplitude ratio; dotted quarter circle is perfect match of standard deviations; angular dimension is cosine of spatio-temporal pattern correlation; straight-line distance from 'reference' to points is normalised RMS error.

Over All Land Surfaces (Figure 3.9):

- Some AGCMs and reanalyses do not conserve water for the AMIP II period (wrong units? soil moisture trend?);
- Most models agree better than reanalyses with mean estimate (based on different observational data sets) for runoff ratio and evaporation ratio.

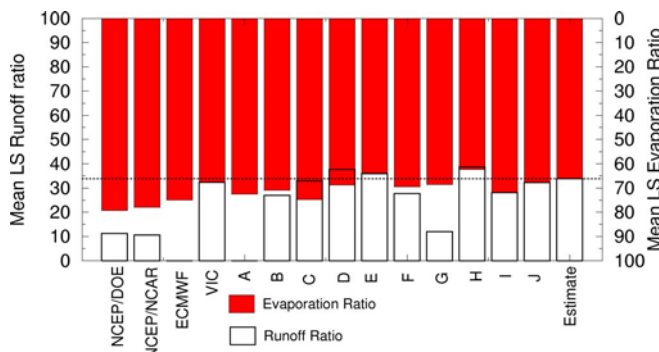


Figure 3.9. Mean land-surface evaporation ratio and runoff ratio by 10 AMIP II AGCMs and by different reanalyses. 'Estimate' is the average of five different estimations based on observed stream flow and the GPCP precipitation.

Evaporation ratio for some AGCMs (Figure 3.10):

- Evaporation ratio greater than unity for some AGCMs, especially over the arid climate;
- Some, but not all of this misbehaviour is due to poor initialisation of soil moisture and very long spin-up period for the soil moisture.

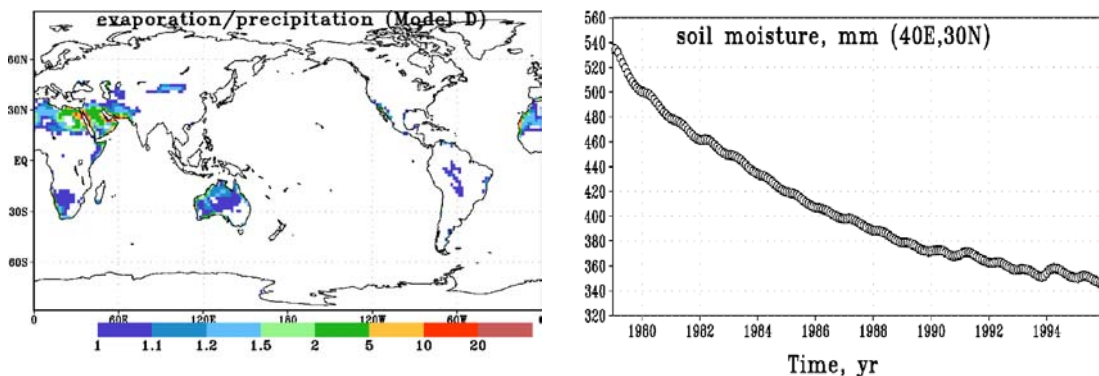


Figure 3.10. Evaporation ratio over the land grid points for a selected AGCM. Greater than unity values over arid and semi-arid regions is partly due to the poor initialisation and long spin-up period of the soil

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Evaporation (Figure 3.11):

- Spatio-temporal correlation coefficient of reanalyses' evaporation against VIC is greater in wetter climates;
- The inter-climate variations of reanalyses' evaporation greater than VIC in more arid climates;
- The range of correlation coefficients between the reanalyses and VIC is comparable with those of AGCMs and different reanalyses.

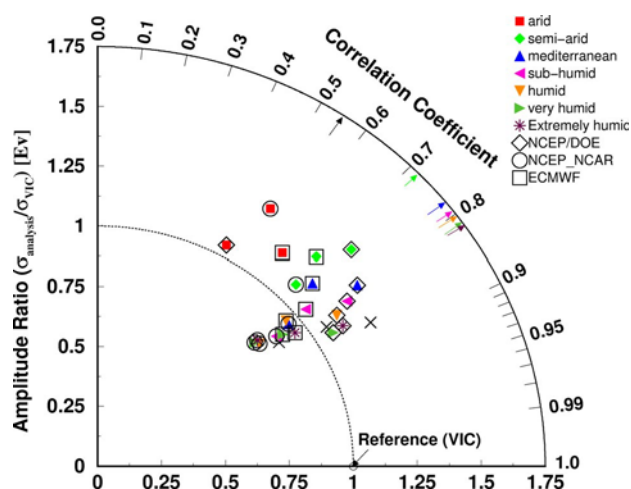


Figure 3.11. Taylor diagram demonstrating the spatio-temporal statistics of reanalyses' evapotranspiration against VIC. The arrow heads are averages of three reanalyses in different climates.

Conclusions

- The partitioning of surface energy between sensible and latent heat varies for AMIP II AGCMs and reanalyses across different climate zones; AGCMs are more consistent with different reanalyses in different climate zones;
- The ranges of latent heat and sensible heat among the reanalyses are at least of the same order of magnitude as those among the AMIP II AGCMs;
- The range of spatio-temporal coefficients of correlation between different reanalyses is comparable with those between AGCMs and different reanalyses; for both the values of correlation coefficients are larger in more humid climates than in more arid climates;
- Some AGCMs and reanalyses do not conserve surface energy and water over land surfaces; the magnitude of the imbalance varies in different regions and climate types;
- Compared to global estimates based on different observations, the mean evaporation ratio and mean runoff ratio over all land surfaces for the AMIP II period are better represented by AGCMs than by the available reanalyses.

A lag correlation analysis of AMIP II simulations (initiated jointly with BMRC)

The purpose of this part of the study under the AMIP II Subproject 12 is to try to answer the question whether and how land-surface processes and parameterization affect the predictability of climate anomalies on seasonal and longer time scale. Preliminary focus is on analyzing ten AMIP2 model data over Australian region with three questions in mind:

- (i) how different the models are in simulating key surface climate variables such as precipitation and surface temperature;
- (ii) how different the models are in simulating surface fluxes;
- (iii) connections between the model skill in simulating surface fluxes and key climate variables.

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From the results of ten AMIP II models released from PCMDI, we find:

- (i) the skill of models in reproducing the observed surface climate and climate anomalies varies across the ten models;
- (ii) the skill of models in reproducing the surface flux anomalies (derived from NCEP/NCAR reanalysis products) also varies across the ten models;
- (iii) the relationship between the model skill in simulating surface climate anomalies and its skill in simulating surface fluxes anomalies varies with models and with seasons (Figure 3.12);

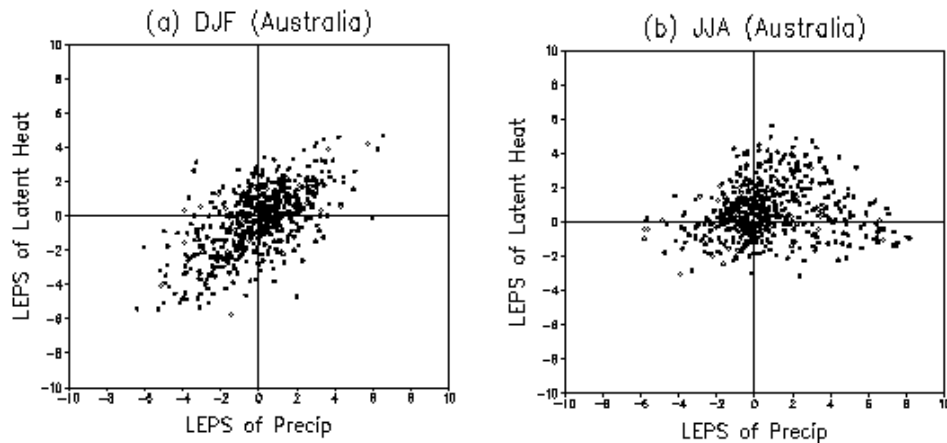


Figure 3.12. Linear Error in Probability Space (LEPS) score of an AMIP2 model simulation over the Australia continent. (a): relationship between LEPS of the model simulation of precipitation anomalies and surface latent heat anomalies in DJF against NCEP/NCAR reanalysis data; (b) as (a) but for JJA.

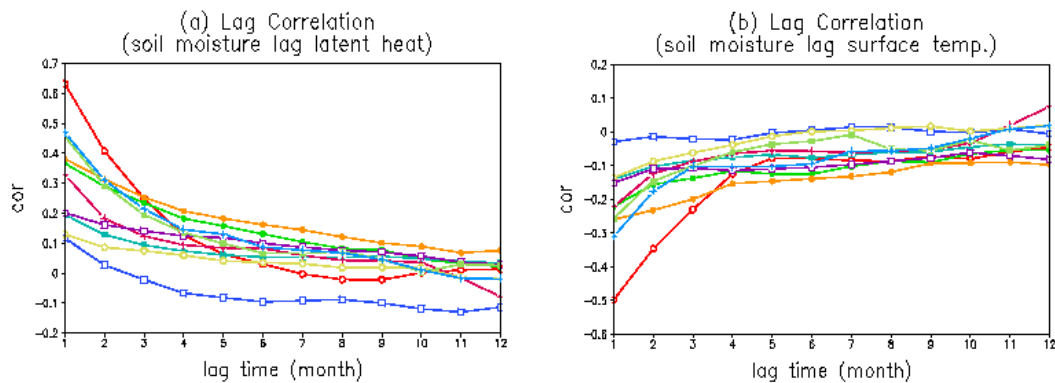


Figure 3.13. Lag correlations between model soil moisture anomalies and surface climate anomalies over the Australian continent from ten AMIP2 models (in different colours). (a): soil moisture with surface latent heat flux; (b): soil moisture with surface air temperature.

- (iv) lag-correlation analysis has revealed that the characters of climatic memory from land-surface processes (e.g. soil moisture) have different features in the ten models: some models show rapid interactions between the land-surface and the overlying atmosphere, while others show more slowly varying processes in which the anomalous surface conditions have longer time-scale impacts (Figure 3.13).

Current investigation is focusing on understanding whether and how such relationship are related to different complexity of the land-surface schemes. Understanding such different behaviours among the models will be of great value in studying the predictability of climate variations on seasonal and longer time scales.

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T3.5 Task 3 Reports and Papers

Objective 1

- Henderson-Sellers, A. 2001. Using isotopes to improve impact and hydrological predictions of land-surface schemes in global climate models. *Conference on the Study of Environmental Changes Using Isotope Techniques*, Vienna, Austria, 23-27 April, 2001.
- Henderson-Sellers, A., Chambers, S. and McGuffie, K. 2001. Isotopes as validation tools for prediction of the impact of Amazonian deforestation on climate and regional hydrology. *Conference on the Study of Environmental Changes Using Isotope Techniques*, Vienna, Austria 23-27 April, 2001
- (joint publication) Heijnis, H., Chambers, S., Henderson-Sellers, A., Zahorowski, W., Whittlestone, S., Irannejad, P., Harle, K., Jenkinson, A., Haberle, S. and Atkinson, A. 2001. Human Activity and Climate Variability: Applications of Nuclear Science. *Conference on the Study of Environmental Changes Using Isotope Techniques*, Vienna, Austria, 23-27 April, 2001.
- Henderson-Sellers, A., McGuffie, K. and Zhang, H. 2001. Evaluating predictions of the impact of Amazonian deforestation on climate and regional hydrology using stable isotopes. *4th International Scientific Conference on the Global Energy and Water Cycle*, Paris, France, 10-14 September 2001.
- Henderson-Sellers, A. 2001. Isotopes as validation tools for global climate models. *4th conference on Nuclear Science and Engineering in Australia*, Australian Nuclear Association (ANA). Sydney, Australia, 24-25 October 2001.
- Integrated climate system studies using isotopes, *ANSTO report*.

Objective 2

- Chambers, S., Durant, M., Chapin, F.S. and McGuire, D. 2000. Post-fire net carbon exchange of Alaskan boreal forests. *2000 AGU Fall Meeting*, San Fransisco, California, USA, 15-19 December 2000.
- Chapin, F.S., Chambers, S., Gottholdt, M.L., Rupp, S., Lydic, La-ona, Zavaleta, E. and Naylor, R. 2000. The influence of Human-Fire-Vegetation interactions on the regional climate of Alaska. *2000 AGU Fall Meeting*, San Fransisco, California, USA, 15-19 December 2000.
- Dunn, C.W., Randerson, J.T., Henkelman, J., Chambers, S. and Chapin, F.S. 2000. Ecosystem surface energy balance and carbon fluxes immediately following a severe boreal forest fire. *2000 AGU Fall Meeting*, San Fransisco, California, USA, 15-19 December 2000.
- Irannejad, P., Henderson-Sellers, A. and Chambers, S. 2000. Intermodel variability of the land-surface simulations by 10 AMIP II AGCMs: Comparison with three reanalysis products. *2000 AGU Fall Meeting*, San Fransisco, California, USA, 15-19 December 2000.
- Irannejad, P., Henderson-Sellers, A., Phillips, T.J. and McGuffie, K. 2001. Sensitivity of Climate Simulations to Land-surface Complexity: Starting AMIP II Diagnostic Subproject 12. *81st Annual Meeting of the American Meteorological Society*, Albuquerque, New Mexico, USA, 14-19 January 2001. A more detailed presentation of this work is also accessible at <http://www-pcmdi.llnl.gov/pilps3/ams2001/>.
- Irannejad, P., Henderson-Sellers, A., Phillips, T.J., McGuffie, K., Pitman, A.J. and Clayton, E.J. 2001, Evaluation of the continental component of the global water cycle: The dearth of validation data. *4th*

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International Scientific Conference on the Global Energy and Water Cycle, Paris, France, 10-14 September 2001.

- McGuffie, K. and Henderson-Sellers, A. 2001. Forty Years of Numerical Climate Modelling. *International Journal of Climatology*, 21(9), 1067-1109.
- McGuffie, K., Irannejad, P., Henderson-Sellers, A. and Phillips, T.J. 2001. Intermodel variations of AMIP II land surface simulations compared with alternative reference data: An assessment over different climatic zones. *8th Scientific Assembly of IAMAS*, Innsbruck, Austria, 10 – 18 July 2001.
- Phillips, T.J., Henderson-Sellers, A., Irannejad, P. and McGuffie, K. 2001. AMIP II Diagnostic Subproject 12: Land-surface processes and parameterizations (a joint AMIP/PILPS project). Accessible at <http://www-pcmdi.llnl.gov/pilps3/proposal/>.
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- Zhang, H., Henderson-Sellers, A. and McGuffie, K. 2001. The Compounding Effects of Tropical Deforestation and Greenhouse Warming on Climate. *Climatic Change*, 49, 309-338.
- Zhang, H., Henderson-Sellers, A., Pitman, A.J., McGregor, J.L., Desborough, C.E. and Katzfey, J. 2001. Limited-area model sensitivity to the complexity of representation of the land-surface energy balance. *Journal of Climate*, 14(19), 3965-3986.

Ann Henderson-Sellers participated in ABC "Science in the Bush" events in Dorrigo and Armidale on 8 and 9 March 2001 on the topic of "Whither Weather".

A major highlight this year was the recognition of the first PILPS paper (Chen *et al.*, 1997) as the most highly cited earth sciences paper in 1997 (Butler, 2001).

T3.6 Task 3 Summary and Future Directions

The two objectives of Task 3 are:

1. To investigate the use of naturally occurring isotopes in regional moisture studies
2. To improve land surface parameterisation and investigate its potential to improve global climate models and thus improve our future climate change predictions

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These have been turned into our two current research hypothesis:

1. Stable isotopes of water provide a novel data source for evaluation of GCM simulations of regional hydrology
2. Land-surface scheme (LSS) complexity improves the simulation of continental near-surface climates

This year (i.e. since the previous external project review in November 2000) we have made very significant scientific progress towards evaluating both these hypotheses. Specifically we have:

- (i) concluded the very protracted negotiation to allow radon research at the Cape Grim Baseline Air Pollution Station;
- (ii) completed a preliminary investigation of the use of GNIP data for large basin hydrological evolution of GCM simulations;
- (iii) evaluated the surface energy and water budgets of 16 AMIP II AGCMs and three Re-analyses data sets;
- (iv) completed an investigation of the importance of LSS complexity using the CHASM model and published the results;
- (v) established the most appropriate 'truth' to employ in forthcoming evaluations of AMIP II latent heat simulations;
- (vi) initiated a lag correlation analysis of AMIP II simulations; and
- (vii) initiated testing of latent heat as a means of characterising LSSs in AMIP II.

Despite the lack of radon-related research this year, substantial progress has been possible. The GNIP database is a valuable research source and our AMIP II analyses are now reaching the most productive scientific phase.

Next year (i.e. until June 2002) we anticipate being able to:

- (i) confirm and complete the GNIP Amazon isotopes study and publish;
- (ii) re-establish ourselves at Cape Grim;
- (iii) complete two lag-correlation studies of AMIP II data relating to land-surface hydrological simulation;
- (iv) characterise available AMIP II LSSs by their simulated latent heat fluxes; and
- (v) complete PILPS 2(e) and publish the first collection of papers.

However, although these are useful achievements, it can be seen from the attached AMIP II and GLASS timelines (Figures 3.14 and 3.15) that termination of this research in June 2002 will be premature for both these international projects.

T3.7 Task 3 International Collaborators Timelines

The timelines of AMIP II and GLASS (Figures 3.14 and 3.15) show clearly that June 2002 is not a good closing date for Task 3 research in this project.

In terms of AMIP II we anticipate the release of another 10 AGCMs' data around June 2002 and also additional evaluation data between January and June 2003. One further year would allow ANSTO researchers to progress much further into the complete data analysis. Two further years (i.e. until June 2004) would allow us to complete all the analysis as we proposed to AMIP and to participate in the AMIP II planned for July 2004.

For PILPS and GLASS there are equally sound reasons for either a one, or preferably a two, year extension to Task 3. As can be seen in the timeline diagram, ANSTO researchers are committed to co-

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ordinating PILPS component of GLASS into early 2004. Thus we all likely to be involved into the first half of 2004. Ideally, therefore, a two-year extension to this task of this project is desirable in order to allow us to fulfil our international scientific commitments.

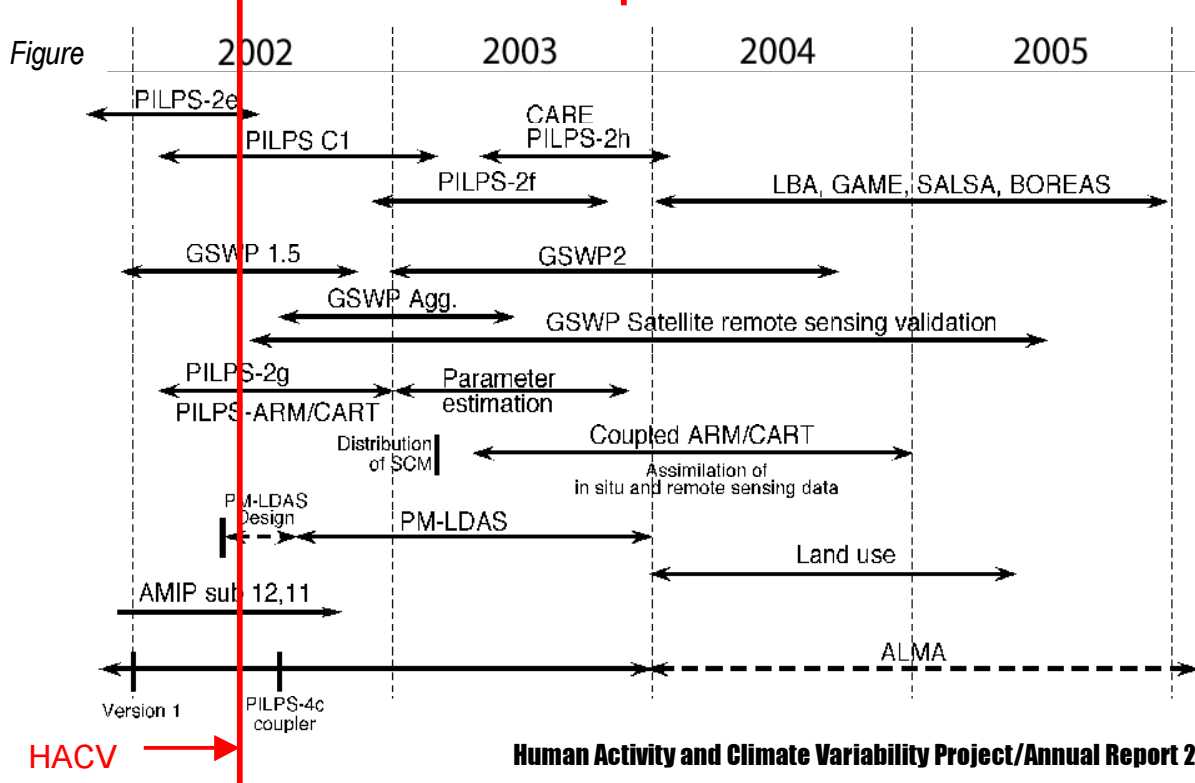
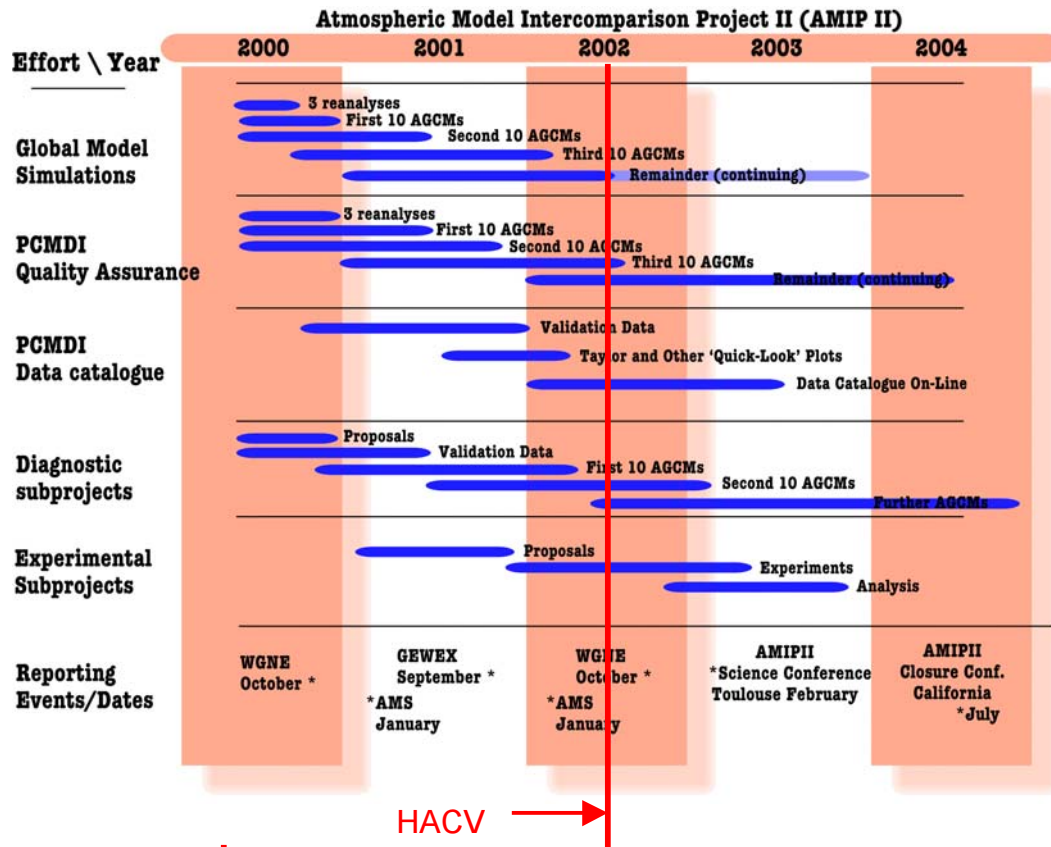


Figure 3.15 Timeline of Global Land Atmosphere System Study (GLASS)

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T3.8 References

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Human Activity and Climate Variability Project Glossary

ACE	Aerosol Characterization Experiment
ACE-Asia	Third ACE experiment focussing on East Asia
AGCM	Atmospheric Global Climate Model
ALMA	Assistance for Land-surface Modelling Activities
AMIP	Atmospheric Model Intercomparison Project
APS	Aerodynamic Particle Sizer
ASP	Aerosol Sampling Program
Asteraceae Liguliflorae	In Australia, less common pollen type of species from daisy family. eg. commonly derived from introduced species (eg. dandelions) but also from natives (eg. paper daisy)
Asteraceae Tubuliflorae	Common pollen type of daisy family - covers most species in this family occurring in Australia
BB	Biomass Burning
bc	black carbon
BMRC	Bureau of Meteorology Research Centre
BoM	Bureau of Meteorology (Australia)
BOREAS	Boreal Ecosystems-Atmosphere Study
Bq	becquerel
CCM	Community Climate Model
CCN	Cloud Condensation Nuclei
CEOP	Co-ordinated Enhanced Observing Period
CHASM:	CHAmeleon Surface Model
DARLAM	Division of Atmospheric Research Limited Area Model

DMS	Dimethylsulfide
DOE	Department of Energy
dpm/g	disintegrations per minute per gram
dystrophic	Applied to a lake that has become so shallow (through organic or inorganic sedimentation) and so depleted of oxygen (through the aerobic bacterial decomposition of the organic matter) that bog begins to form and peat to develop. A dystrophic lake may be regarded as the post- <i>eutrophic</i> stage in the transitional sequence of lake sedimentation, productivity and maturity.
ECMWF	European Centre for Medium-Range Weather Forecasts
EOS	Earth Observing System
epilimnion	The upper, warm, circulating water in a thermally stratified lake in summer. Usually it forms a layer that is thin compared with the <i>hypolimnion</i> .
eutrophic	Nutrient rich waters. Typically, eutrophic lakes are shallow, with a dense plankton population and well-developed littoral vegetation.
FF	Fossil Fuel
GAME	GEWEX Asian Monsoon Experiment
GCM	General Circulation Model: Global Climate Model
GEWEX	Global Energy and Water Cycle Experiment
GLASS	Global Land Atmosphere System study
GNIP	Global Network of Isotopes in Precipitation
GPCP	Global Precipitation Climatology Project
GSWP	Global Soil Wetness Project
GTE	Global Tropospheric Experiment
HITE	Focus 5 of IGBP/PAGES - Human Impact on Terrestrial Ecosystems
hypolimnion	The lower, cooler, non-circulating water in a thermally stratified lake in summer.
IAEA	International Atomic Energy Agency
IGAC	International Global Atmospheric Chemistry Project

IGBP	International Geosphere-Biosphere Programme
JGR	Journal of Geophysical Research
JOSS	Joint Office for Science Support
<i>Lagarostrobos franklinii</i>	Huon Pine. A rainforest conifer tree now endemic to Tasmania.
LBA	Large Scale Biosphere Atmosphere Experiments in Amazonia
LEPS	Linear Error in Probability Space
LH	Latent Heat
LOI	Loss On Ignition - a simple test where sediments are combusted at ca 500 ° C to determine the organic/inorganic content and ca 1000 ° C to determine carbonate content
LSS	Land-Surface Scheme
MAGE	Marine Aerosol and Gas Exchange Activity (IGAC)
MBL	Marine Boundary Layer
MCM	Multi-Criteria Method
MLO	Mauna Loa Observatory
Meromictic	Lakes whose waters are stratified permanently, usually because of some chemical difference between <i>epilimnion</i> and <i>hypolimnion</i> (eg. contrasting salinities and hence densities)
Mesotrophic	Waters intermediate between <i>oligotrophic</i> and <i>eutrophic</i> .
Monomictic	Lakes in which only one period of free circulation occurs. Free circulation is restricted by thermal stratification, with the formation of a distinct <i>epilimnion</i> .
NASA	National Aeronautical and Space Administration (USA)
NCAR	National Centre for Atmospheric Research
NCEP	National Centre for Environmental Predictions
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
<i>Nothofagus cunninghamii</i>	tree common in cool temperate rainforest (Victoria and Tasmania)

<i>Nothofagus gunnii</i>	small tree/shrub endemic to Tasmania - found in subalpine and alpine environments
NSF	National Science Foundation (USA)
nss	non sea salt
oc	organic carbon
Oligotrophic	Waters low in nutrients and with poor <i>primary productivity</i> . Typically, oligotrophic lakes are deep, with the <i>hypolimnion</i> much more extensive than the <i>epilimnion</i> . The low nutrient content means that plankton blooms are rare and littoral plants are scarce. The low organic content means that oxygen levels are high. Compared with <i>eutrophic</i> lakes, oligotrophic lakes are considered to be geologically young or little modified by weathering and erosion products.
PAGES	PAst Global ChangEs - a core project of IGBP aimed at providing a quantitative understanding of the Earth's past environment and defining the envelope of natural environmental variability within which the anthropogenic impact on the Earth's biosphere, geosphere and atmosphere can be assessed.
PCMDI	Program for Climate Model Diagnosis and Intercomparison
PEP II	Pole-equator-pole transect number 2. A subproject of PAGES synthesising environmental change along a transect through Asia and Australasia.
<i>Phyllocladus</i>	tree common in cool temperate rainforest of Tasmania
PILPS	Project for Intercomparison of Landsurface parameterisation Schemes
PIXE	Particle Induced X-Ray Emission
PM	Particulate Matter
PMIP	Palaeoclimate Model Inter-comparison Project
ppm	Parts per million
Rn	Radon
RH	Relative Humidity
RMS	Root Mean Square
SAE	Surface Available Energy
SeaWiFS	Sea Viewing Wide Field of View Sensor

SH	Sensible Heat
SALSA	Semi-Arid Land Surface-Atmosphere Program
TC	Tropical Cyclone
TOMS	Total Ozone Mapping Spectrometry
TRACE-P	Transport and Evolution over the Pacific
VIC	Variable Infiltration Capacity (Land-surface Scheme)
WCRP	World Climate Research Programme
WGNE	Working Group for Numerical Experimentation
WMO	World Meteorological Organisation