Australian Government

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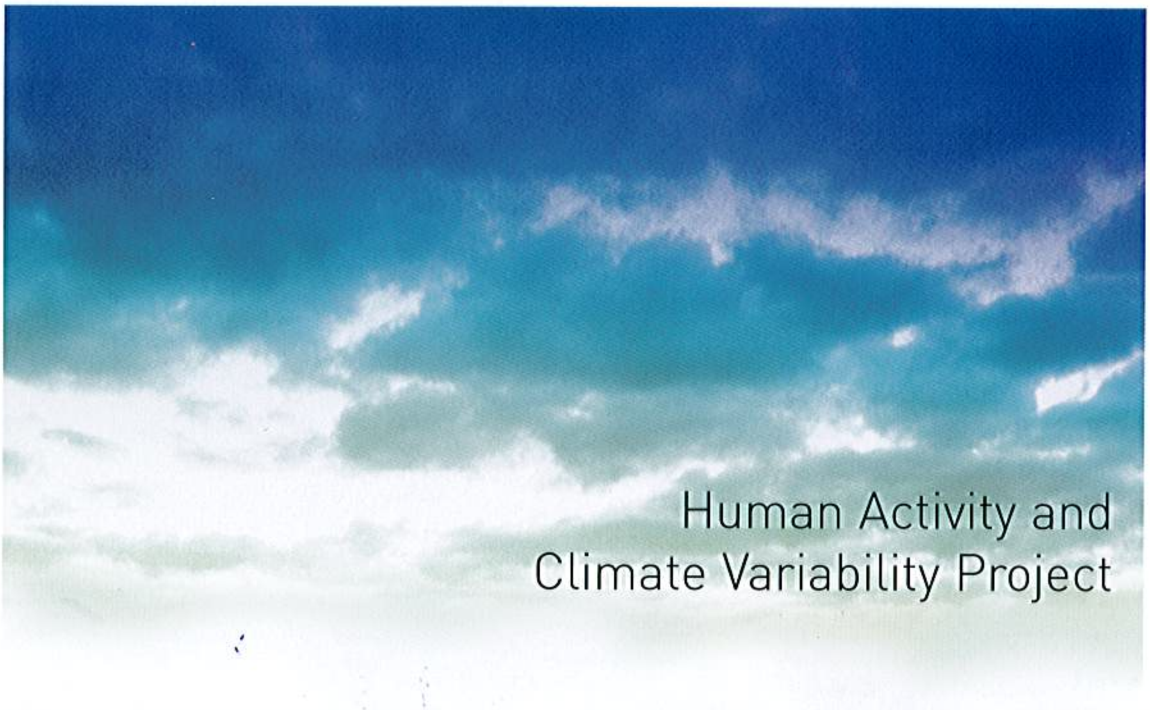
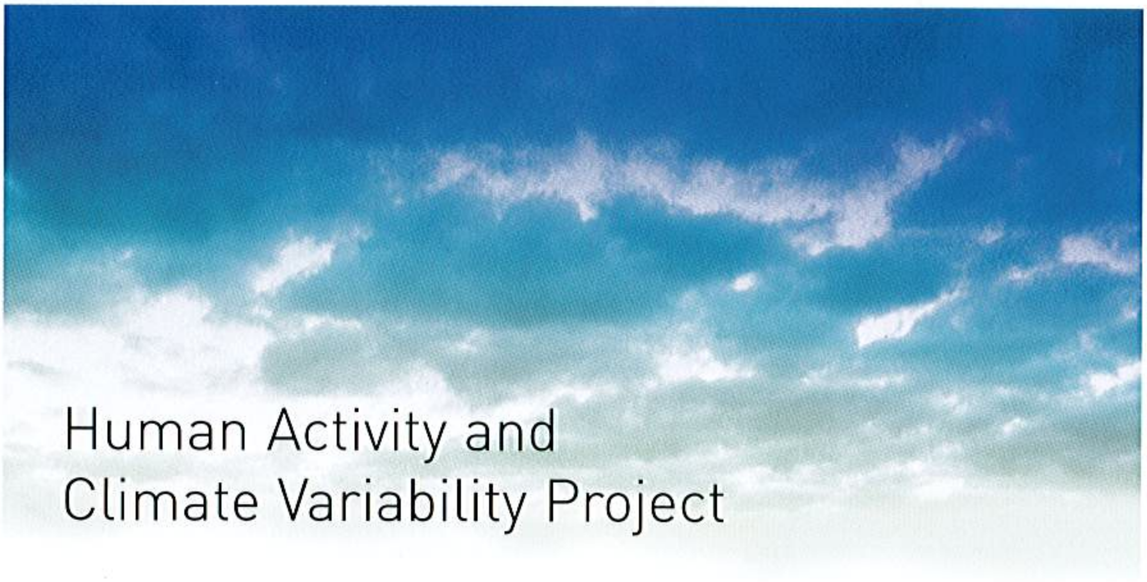


Human Activity and Climate Variability Project



Human Activity and Climate Variability Project

Human Activity and Climate Variability Project
An Overview & Introduction

ANSTO has developed unique expertise and built a strong capability in Australia (and indeed in the Asian-Pacific region) in nuclear techniques applied to study natural processes. Capabilities include isotope-dating techniques, trace element analysis of aerosol particles and the use of radon-isotopes as a tracer for large-scale air movement. This enables ANSTO to collaborate in, and indeed lead/co-ordinate large interdisciplinary teams to address questions arising from the effects of human activities on the climate system and to distinguish between human impact and climate variability. Such a team was utilised in the Human Activity and Climate Variability project, which commenced in July 1999.

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

Past - Natural archives of human activity and climate variability

Present - Characterisation of the global atmosphere using radon and fine particles

Future - Climate modelling: evaluation and improvement

Main objectives

- To determine what proportion 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 on climate through analysis and sourcing of fine particles and characterisation of air samples using radon concentrations in the East Asian region.
- To contribute to the improvement of land surface parameterisation schemes and investigate the potential to improve global climate models, thus improving our understanding of future climate.

Project outputs

- Departments such as, Land and Water Conservation, National Parks and Wildlife Services, Sydney Water Corporation and the Australian Antarctic Division can now use the results of the natural archive studies in their management and policy documents.
- ANSTO's contribution to the ACE-Asia project has generated data for the official data archive of this

international project. Papers have been published in and are being prepared for international journals on air mass characterisation in collaboration with other participants.

- A significant scientific contribution has been made to the understanding and characterisation of regional air masses in Asia/Australia by publishing scientific analysis of measurements, maintaining data quality and guiding scientific projects at selected observation stations.
- Evaluation of the use of naturally occurring isotopes in regional moisture studies has been demonstrated and published
- Analysis of output from a large number of GCMs with particular reference to the behaviour of their land-surface schemes has contributed to improvements in model predictions.

Significant project outcomes

- An improved understanding of natural and anthropogenic factors influencing change in our environment. Results are being used to improve management policies and develop long term management strategies.
- 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 isotopes and other trace species in the atmosphere on a regional and a global basis.
- Improved understanding of the impact of different land-surface schemes on simulations by atmospheric models and validation of these predictions.

Synergies between the individual task objectives as well as the tools and techniques developed have been major strengths of this project. Historical anthropogenic pollutant trends as inferred from natural archives assist with the estimation of future loadings and stresses to catchments as well as identify likely sources of pollutants from existing and proposed developments. Improving techniques for the identification of climate signatures in natural archives, as well as spatial and temporal distribution of climatic related aerosols (charcoal, pollens, dust etc.) can help test contemporary hypotheses regarding natural and anthropogenic climate forcings and their spatial/temporal influence. The air mass characterisation and elemental fingerprint analysis of fine particle aerosol samples presently being conducted will enable accurate determination of aerosol source regions and relative apportionment between various natural and anthropogenic source types. The immediate applications of such data to regions affected by pollution advection and researchers interested in emission mitigation strategies are evident. Furthermore, the aerosol composition information will help to reduce the uncertainty in the radiative and optical properties of aerosols, and the long-term, high resolution radon concentration time series will provide a unique tool with which to evaluate transport and mixing schemes of regional and global climate models. Improved model parameterisations will ultimately lead to the generation of more reliable future climate scenarios. Since a substantial amount of transport and mixing of anthropogenic pollutants occurs within the lower atmosphere (or boundary layer), where the majority of energy exchange processes also take place, an appropriate choice of land surface scheme for numerical simulations is essential. An important outcome of these "past" and "present" techniques is they have enabled us to generate potentially new data sources for the evaluation of global climate models running historical scenarios, which in turn, would lead to improved future climate predictions.

HACV Past →
Natural archives of human activity and climate variability

Figure 1: Location of research sites with respect to mean annual Australian climatic patterns. Base image adapted from Commonwealth Bureau of Meteorology 2003 rainfall records.

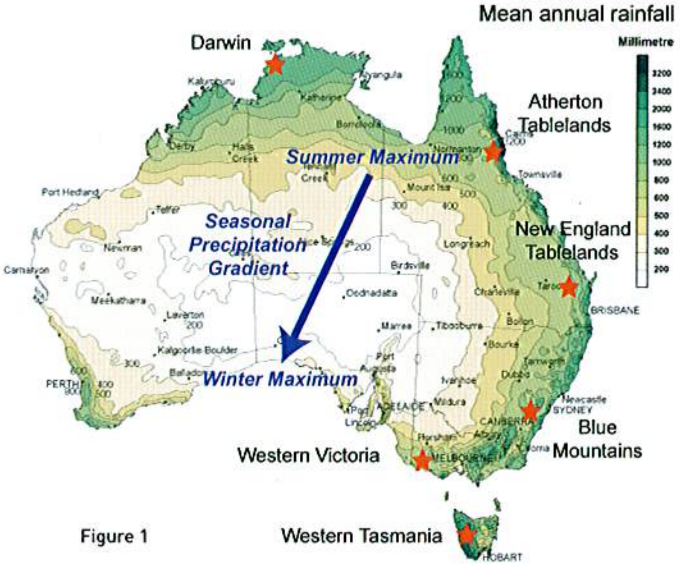


Figure 1

In many areas, environmental changes caused by human impact are not well understood or documented, particularly in post-colonial Australia. In order to improve our understanding, and minimise the impact our interaction with the environment has, this issue needs to be addressed. Climate variability is another driving force behind environmental changes and therefore the extent to which landscapes are affected by human activity, climate variability or a combination of these effects, requires investigation. One way this can be achieved is to reconstruct environmental histories of particular areas through the investigation of natural archives (Battarbee, 1986; Brugam, 1978).

This research aimed first to determine whether historical records of human activity and climate variability were contained within natural archives in Australia, secondly, whether a clear distinction could be made between signals of human impact and climate variability, and thirdly, how widespread and reliable these natural archives were.

Research sites were chosen based on their climatic region and level of human disturbance as shown in Figure 1. Natural archives were collected from lakes, swamps and marshes (Figure 2) which are known to accumulate

Figure 2

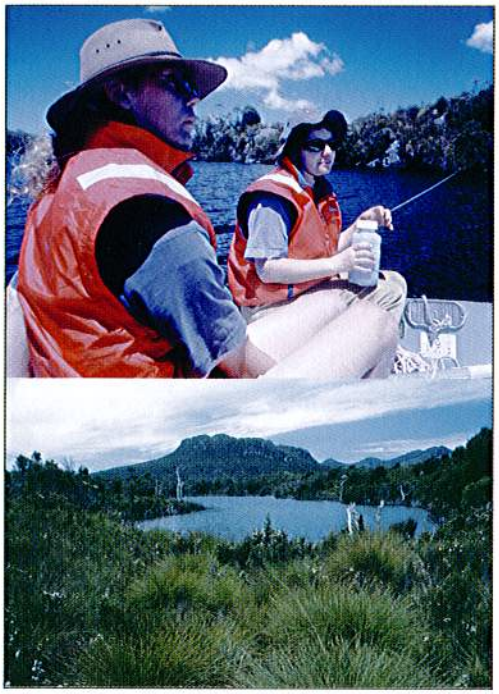


Figure 3

Figure 2: Typical lakes in Western Tasmania from which natural archives are collected.

Figure 3: Collection of natural archives using custom made ANSTO sampling equipment. Natural archives can provide high-resolution evidence of historical changes.

indicators of local and even regional landscape changes, often brought about by human activity and/or climate variability such as flood events, bush fires, land clearing, mine drainage and aerial pollution. Indicators used in this research include trace metals, organic matter, pollen, diatoms, dinoflagellates, charcoal, sediment grain size and stable nitrogen ratios.

Lead-210 (^{210}Pb), the naturally occurring radioactive isotope (radioisotope) of lead, is used to determine sediment accumulation rates and the age distribution of natural archives (Goldberg, 1963; Krishnaswamy *et al.*, 1971). This allows events as determined by the above mentioned indicators, to be pin-pointed in time. Our custom made sampling equipment (Neale and Walker, 1996) enables annual and even sub-annual signals of human activity and climate variability to be determined, thereby providing high-resolution evidence of historical environmental changes (Figure 3).

Looking for climate clues at a pristine site

Western Tasmania was chosen as a region with a possible strong climate signal (high winter rainfall), where little to no human impact was expected for most of the sites studied (Figure 1). However, evidence from the first sampling campaign revealed that considerable amounts of trace metals had been aerially transported with concentrations peaking in the 1960s and 70s (Harle *et al.*, 2002). Figure 4 shows a typical trace metal profile from one of the Tasmanian lakes.

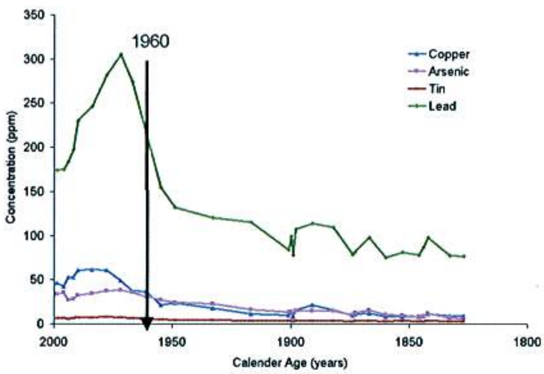
These unexpected results raised two questions; how extensive was the spatial and temporal dispersal of trace elements, and what was the source of the trace elements? It was hypothesised that the apparent aerial pollution was a result of mining activities in Central Western Tasmania although evidence for the most significant impacts as shown by the trace metal profile coincides with the escalation of open cut mining in Tasmania rather than earlier phases of smelter produced pollution (Harle *et al.*, 2002).

Further research efforts were then focussed on the temporal dispersal of trace metals from mining areas including Queenstown. The spatial and temporal distribution of lead (Pb) across western Tasmania is shown in Figure 5. The concentrations are highest close to the mining areas but all sites showed a marked increase above background levels around 1960.

Figure 4: Trace metal profile from a sediment core collected from Lake Dora in Western Tasmania. The trend in this profile is typical of other sites investigated in Western Tasmania.

Figure 5: Map of the Tasmanian mainland showing mining areas and temporal lead (Pb) concentrations (1900s, 1960s and present day concentrations).

Figure 4



Past and Present Lead Concentrations in Western Tasmania

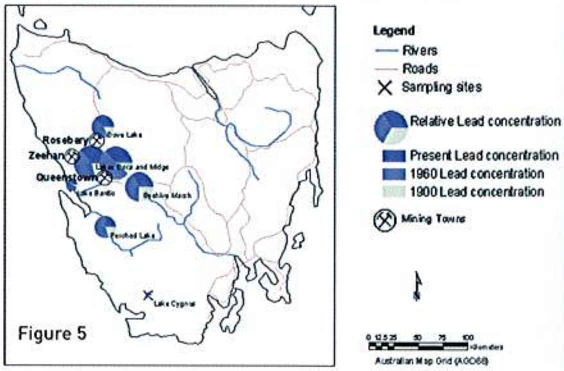


Figure 5

It has been demonstrated by a historical environmental reconstruction, using trace metal analysis and ANSTO's nuclear dating facilities, that supposedly pristine areas have been contaminated by past mining activities, which were an unexpected distant source.

Known sources of contamination due to human impact or climate events?

Lake Burragorang, contained by Warragamba Dam, is the principal drinking water storage for the Sydney region (Figure 6). This catchment receives uniform seasonal rainfall (Figure 1) and the area has been modified over the last 120 years by activities such as mining, dam construction, agriculture and urbanisation. These activities, particularly over the last 50 years, have the potential to cause increased erosion as well as organic and inorganic pollution transport, which could lead to a decline in water quality.

Sediment cores were collected and investigated from selected sub-catchments of Lake Burragorang known to have various levels of human disturbance including the Nattai River, Coxs River, Tonalli River, Werri Berri Creek and Lacys Creek.

Natural archives revealed different indicators in different catchments. A fire history in the Nattai River, inferred from charcoal peaks in sediment cores, correlated with recorded major fire events. The $\partial^{15}N$ signature results from sediments collected in Werri Berri Creek indicate the nitrogen source in the upper catchment is predominantly human and animal produced while results from the lower catchment were more characteristic of an undisturbed environment.

The town of Yerranderie, an abandoned silver-lead-zinc-mining town lies within the Tonalli River catchment (Figure 7). Numerous sulphide-tailing dumps provide an abundant source of heavy metals and their dispersal was found to be primarily dependent on rainfall (Harrison *et al.*, 2003). The sediment core collected in the Tonalli River / Lake Burragorang junction revealed a human activity and climate variability signal as shown in Figure 8. Heavy metal concentrations were found to increase with the introduction of mining and dam construction while they fluctuated in response to heavy rainfall. While found to not impact on the water quality, the levels of some metals exceeded the sediment quality guidelines (ANZECC and ARMCANZ, 2000).

The studies in Lake Burragorang have demonstrated that

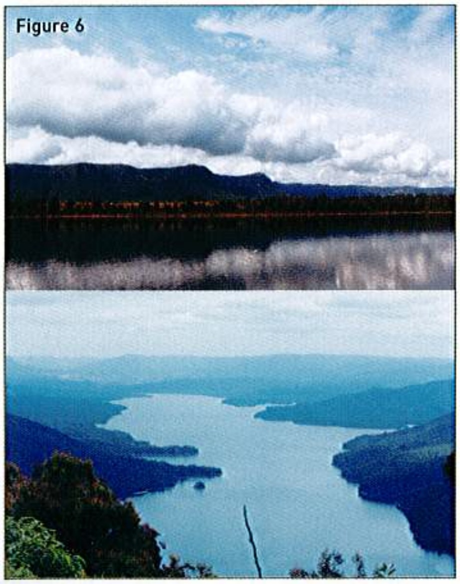


Figure 8

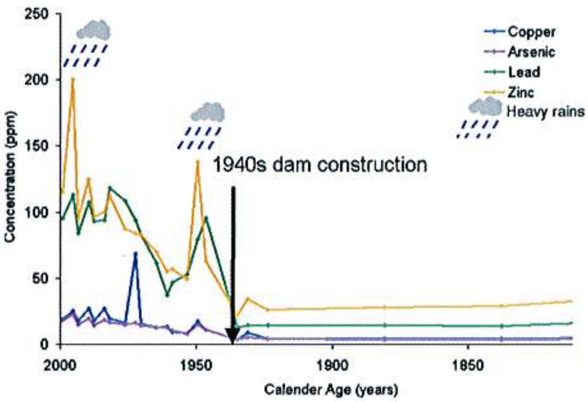


Figure 6: Lake Burragorang, contained by Warragamba Dam, is the principal drinking water storage dam for the Sydney region.

Figure 7: The Silver Peaks mine tailing heap at Yerranderie in the Tonalli River catchment.

Figure 8: Metal concentration profile from a sediment core collected at the Tonalli River / Lake Burragorang junction. Metal concentrations increase in response to mining and dam construction and fluctuate in response to heavy rainfall.

in general, natural archives over the last 200 years do not reveal a detailed climate record. However, in the Tonalli River case study the modification of the landscape in the form of mine tailing dumps actually enhanced the climate signal.

This project contributes comprehensive scientific data from the Southern Hemisphere to the Human Impact and Terrestrial Ecosystems project (HITE), a sub-project of the International Geosphere-Biosphere Programme (IGBP). Our understanding of the behaviour of ^{210}Pb particularly in the Southern Hemisphere, where it is less frequently studied, coupled with the use of natural archives of human activity and climate variability, assist in the determination of historical trends. These can be used to estimate future loadings and stresses to catchments and identify likely sources of pollutants from existing and proposed developments thus negating the need for on-going monitoring.

HACV Present →

Characterisation of the global atmosphere using radon and fine particles

Figure 9

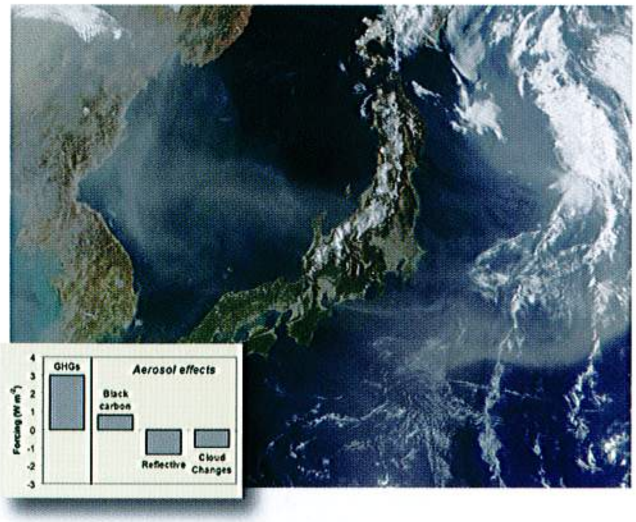


Figure 9: Satellite photograph of a mixture of natural and anthropogenic aerosols from the Asian continent being advected across Japan on 2 April 2002. Image courtesy of the NASA MODIS Rapid Response System image gallery. Inset: Comparison of climate forcing estimates of greenhouse gases and aerosols, adapted from Hansen (2004).

In recent decades, greenhouse gas research has proven beyond reasonable doubt that natural and anthropogenic trace gases (e.g. CO_2, CH_4 and CFCs) directly impact global climate. Recent estimates indicate that the global average total climate forcing due to greenhouse gases is approximately +3 Wm^{-2} (Figure 9 inset).

Aerosols can also directly impact climate, a fact evidenced by the Mount Pinatubo eruption in 1991. The materials injected into the stratosphere by this single eruption covered much of the Earth's surface and reduced 1992 average temperatures for some regions by approximately 0.5°C compared to the 30-year average. However, depending on aerosol type, bright (e.g. sulphates) or dark (e.g. black carbon), their individual climate forcing may be positive or negative. Since the source distributions and strengths, as well as interaction between anthropogenic and natural aerosols are not well known, the net climate forcing due to different types of aerosols is difficult to determine.

With a growing global population, and changing land-use practices, anthropogenic pollutants are increasingly enhancing the natural aerosol and trace gas loadings of the global atmosphere. Thus it is a concern that one of the greatest uncertainties in contemporary climate

Figure 10: Network of ANSTO radon and aerosol sampling sites for the ACE-Asia campaign, insets show examples of detector installations.

Figure 11: Daily mean radon concentrations for 3 years at 3 sites, an example of the extensive ACE-Asia radon data set.

Figure 10

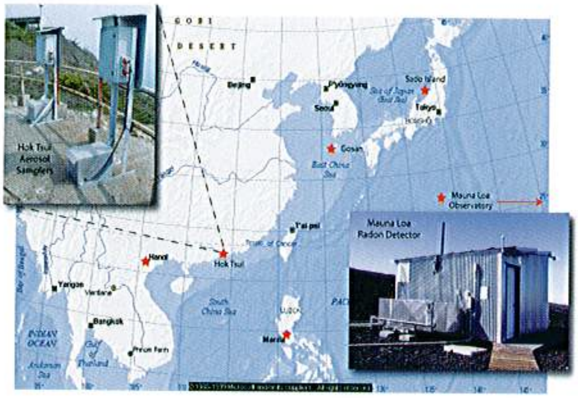
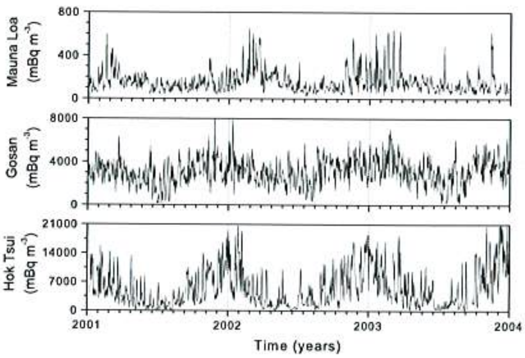


Figure 11



models can be attributed to the radiative and optical properties of aerosols (Climate Change, 2001; Guelle *et al.*, 1998). This shortcoming seriously compromises the ability of the scientific community to forecast net climatic forcing as a result of anthropogenic activity.

Air mass characterisation using tracers such as naturally occurring Radon-222 (radon) is an integral part of determining trends in background concentrations of trace species (Perry *et al.*, 1999; Pochanart *et al.*, 1999; Zahorowski and Whittlestone, 1999), which in turn helps in the assessment of national and international emission mitigation strategies. Of the various tracers that have been used to investigate the frequency, intensity and spatial extent of pollution incursions to the global atmosphere, radon is unique, in that it is an unambiguous indicator of recent terrestrial influence on an air mass, irrespective of whether the region is dominated by natural or anthropogenic sources of other pollutants.

Radon is a radioactive gaseous decay product of uranium (^{238}U), which is ubiquitous in most rock and soil types. It has a relatively short half-life (3.8 days), and since terrestrial radon fluxes are 2-3 orders of magnitude greater than oceanic fluxes, there is a large contrast between radon concentrations in fresh continental and aged oceanic air masses. Radon is inert, and poorly soluble, so its predominant atmospheric sink is radioactive decay. Since the half-life of radon is comparable to the lifetimes of short-lived atmospheric pollutants (e.g. NO_x, SO_2), the residence times of water and aerosols, and the time scale of many important aspects of atmospheric dynamics, it is a particularly useful tracer at local, regional or global scales.

At present, the East Asian region is of particular interest. Whilst it has been recognised as a large source of natural aerosols for centuries (Liu *et al.*, 1985; Zhang, 1984), anthropogenic emissions from East Asia have been increasing in recent decades, so much so that it has been identified as soon becoming the largest source region of anthropogenic pollution in the world (e.g. Perry *et al.*, 1999). The Aerosol Characterization Experiment (ACE-Asia) in the Asian-Pacific region is the latest in a series of initiatives of the International Global Atmospheric Chemistry (IGAC) Project aimed at reducing the uncertainties in radiative forcing by aerosols in climate models (Heubert *et al.*, 2003).

The transport of atmospheric pollution from Asia is largely controlled by continental outflow events. These outflow events can occur either at high altitudes (when

Figure 12

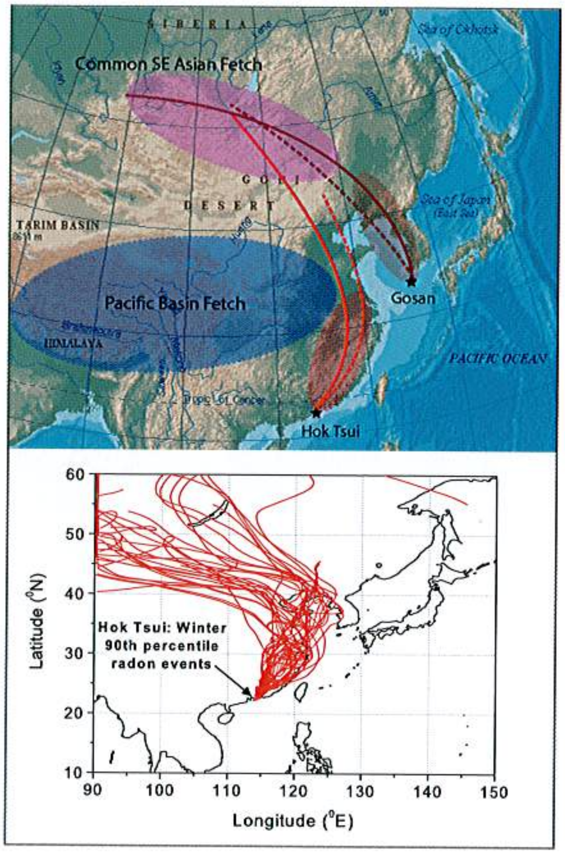
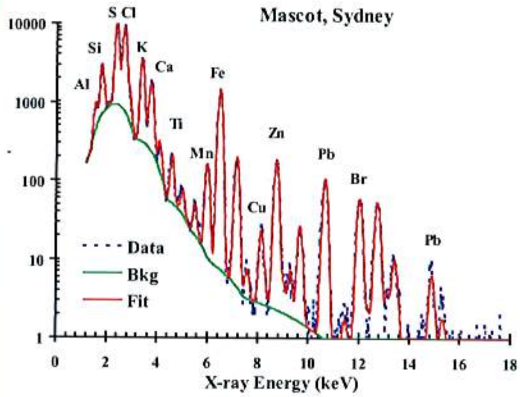


Figure 12: Composite seasona
trajectories (winter solid lines
spring dashed lines) and fetc
regions for air masses bringin
pollution to southeast Asia
coastal regions and the Pacifi
basin that have experienced th
greatest terrestrial influence
Inset shows the subset of Ho
Tsui back trajectories from whic
the winter composite was formed

Figure 13: An example PIX
spectrum of an aeroso
sample revealing the trac
elements present

Figure 13



pollutants are lifted into the sub-tropical jet stream), or low altitudes (within the boundary layer, linked to monsoonal circulation patterns) (Balkanski *et al.*, 1992; Kritz, 1990). The low level outflow events primarily affect the Southeast Asian coastal regions and reach partway into the Pacific Ocean. By contrast, the high level outflow events are much more pervasive, and are known to transport pollution across the entire Pacific Basin to the continental United States in less than a week (Perry *et al.*, 1999).

As part of the Human Activity and Climate variability Project, ANSTO scientists have been contributing to the international ACE-Asia campaign by conducting measurements of radon and fine particles at 6 sites in the Asian-Pacific region (Hanoi (Vietnam), Manila (Philippines), Hok Tsui (China), Gosan (South Korea), Sado Island (Japan) and Mauna Loa Observatory (Hawaii)) (Figure 10). ANSTO is presently a world leader in low level atmospheric radon monitoring, and has also made significant developments in the analysis and interpretation of atmospheric fine particle samples.

In spite of the acknowledged and increasing contribution of the Asian region to the global atmospheric loading, few long-term measurements of pertinent atmospheric parameters for the region existed prior to the ACE-Asia campaign. The 3-year data set of radon and fine particle measurements so far obtained by ANSTO as part of this program is unique in temporal extent and spatial coverage (Figure 11). Whilst the full potential of such a comprehensive data set will not be utilised for some time, the initial findings have already proven valuable.

Using a combination of radon measurements and atmospheric back trajectory analyses, the seasonal as well as inter-annual variability in fetch regions across Asia of air masses that distribute pollution locally (Southeast Asia) and remotely (the Pacific Ocean and continental United States) have been characterised for the first time (e.g. Figure 12). Air masses crossing the Pacific Ocean sampled at Mauna Loa that had the strongest terrestrial influences had fetch regions quite distinct from air masses arriving in coastal regions of southeast Asia with the strongest terrestrial signature. Furthermore, the longer term fetch regions of air masses arriving at widely separated locations on the southeast Asian coastline shared similar origins.

Aerosol samples were analysed using a combination of four Ion Beam Analysis (IBA) techniques (Particle Induced X-ray and Gamma ray Emission, Particle Elastic Scattering

Figure 14: An example fingerprint of the "average soil" aerosol across all ACE-Asia sites derived via PMF techniques.

Figure 15: A daily comparison of the total measured gravimetric PM2.5 mass to the sum of the individual source contributions from species whose elemental fingerprints were estimated using PMF techniques.

Figure 14

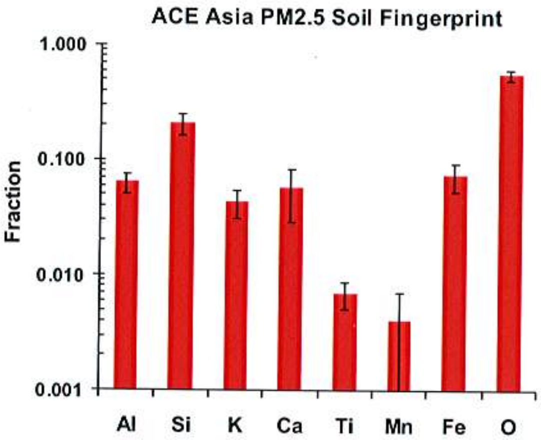
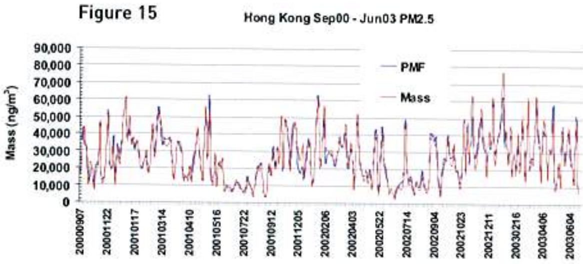


Figure 15



Analysis and Rutherford Backscattering) (Cohen *et al.*, 2003). Collectively, these techniques can identify 29 of the most commonly occurring elements with detection limits of 1-10 ng m^{-3} of air sampled (Figure 13). Positive Matrix Factorisation (PMF) was then employed to determine elemental fingerprints (e.g. Figure 14) and relative contributions of the more common aerosol constituents (e.g. sea spray, soil, organics, smoke, vehicle emissions, diesel etc.). The close comparison of the sum of individual source contributions from the PMF analysis to the total gravimetric PM2.5 mass on a daily basis (Figure 15), is one way of validating the technique and its results. This analysis has enabled the key climate forcing species of airborne mineral dust from deserts in northern China and Mongolia, as well as the anthropogenic aerosols from industrial processes in eastern China to be readily identified.

In addition to the research already carried out with these data sets, it is envisaged that future analysis and collaborative investigations will lead to the development of a better understanding of the key atmospheric processes that control transport, mixing and distribution of aerosols and trace gases, by performing detailed comparisons of modelled time series with this unique set of observations.

HACV Future → Climate Modelling: evaluation and improvement

Figure 16: Schematic of a land-surface parameterisation scheme.

Figure 17: Global Network for Isotopes in Precipitation (GNIP) station locations. For more information visit http://www.iaea.org.

Figure 16

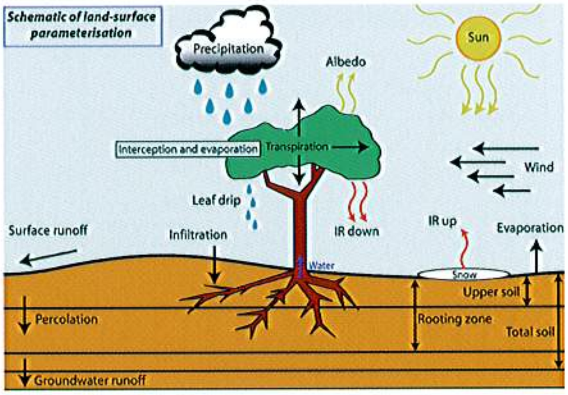
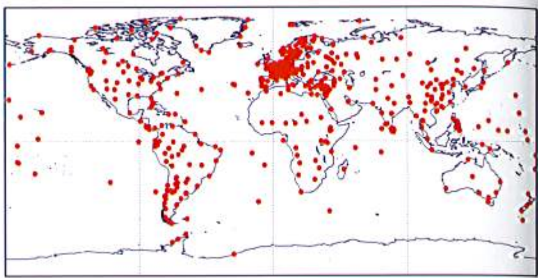


Figure 17



Energy exchange processes that drive the global climate system occur primarily at the Earth's surface. One third of this, the land, is also the focus of most human activities. Quantifying the impact of land-use change on climate processes is thus an essential step toward improved simulation of future climate change. Similarly, identifying the importance of climatic variability and change on the continental surface is crucial for future human welfare. In order for people to have confidence in such predictions, global climate models (GCMs) require validation. Isotopes are unique as they provide an independent validation tool that can also be used to gain insight into partitioning mechanisms (such as moisture fluxes between evaporation and transpiration) that are otherwise hard to quantify, as they are not directly observable at scales appropriate to atmospheric model grid cells.

Land surface parameterisations in contemporary atmospheric models (e.g. Figure 16) exhibit a wide range of complexity, from the classic bucket model (Manabe, 1969) to detailed soil-vegetation-atmosphere transfer schemes (SVATS) (e.g. Sellers *et al.*, 1986; Dai *et al.*, 2003). The perceived need to analyse these diverse schemes motivated the World Climate Research Program to launch the Project for the Intercomparison of Land-surface Parameterisation Schemes (PILPS) in 1992 (Henderson-Sellers *et al.*, 1996; Pitman *et al.*, 1999). Phase 3 of PILPS entails the diagnosis of land-surface schemes in the Atmospheric Model Intercomparison Project (AMIP) models, arranged under the auspices of Diagnostic Subproject 12 (DSP12). One of the major goals within this task of HACV is to evaluate the performance of present-day GCMs in simulating land-surface climates. For this purpose climate simulations from 20 AMIP II GCMs for the period 1979-1995 were evaluated using ground-based and satellite-derived land-surface observations.

As part of the project we have pursued the exploration of the use of stable water isotopes as a novel and fully independent means of evaluating GCMs, which are the predominant tools with which we predict the future climate. The data used in this aspect of our study are obtained from the Global Network for Isotopes in Precipitation (GNIP) database (Figure 17), jointly maintained by the World Meteorological Organisation (WMO) and the International Atomic Energy Agency (IAEA), since 1961.

Two basins have been chosen to carry out these analyses. Firstly, the Amazon basin, which represents an 'ideal' case study due to the simple topography of the inner basin,

Figure 18: Isotopic signature ($\partial^{18}O$) across a longitudinal transect of the Amazon from Belem on the coast through to the west. The open diamonds are the 1960s values while the solid squares are for the 1980s. Trend lines are shown that illustrate the east-west gradient over the two periods (Henderson-Sellers et al., 2002).

Figure 19: The 17-year mean total runoff ratio and evaporation ratio over MDB. It is assumed that conservation of water occurs when Pr=Ro+Ev (i.e. the sum of the two ratios is 100) (Irranejad, 2003).

Figure 18

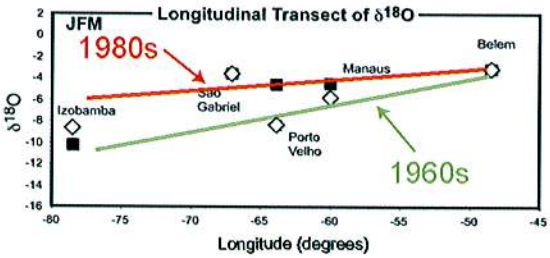
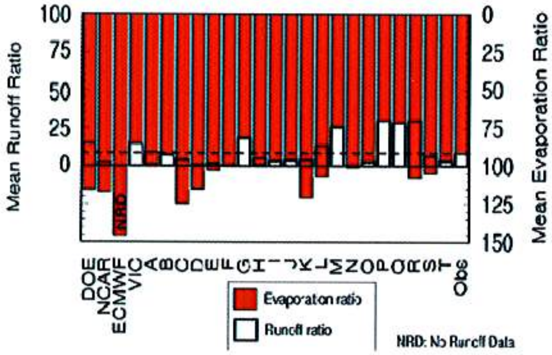


Figure 19



which combined with the trade wind flow, provides essentially a single water source (Henderson-Sellers *et al.*, 2002). Secondly we have looked at the Murray Darling Basin (MDB), which is a more complex case with large variations in its meteorology, climate and in the human exploitation of and dependence upon the state of land-surface.

Amazon Basin

The Amazon Basin has a long history of isotope collection and analysis and also of climate modelling: both having been reported for over thirty years (e.g. Henderson-Sellers and Gornitz, 1984; McGuffie and Henderson-Sellers. 2001). As part of our 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 statistically significant changes in the basin's water recycling behaviour over the past thirty years in the wet season which extends from about December to May (Henderson-Sellers *et al.*, 2002). The continental gradient of $\partial^{18}O$, already the weakest in the world, has been further weakened over the last three decades in the wet months (Figure 18). Using data from the 1960s and 1980s large changes are observed in the deuterium excess at Manaus between the wet and dry seasons. In particular, the deuterium excess has decreased in the wet season and increased in the dry season. Possible 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 isotopic data (1960s to 1980s) requires a change in the water recycling behaviour in the Amazon.

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.

Murray Darling Basin

Our proposal for the Murray Darling Basin to become a part of the Global Energy and Water Cycle Experiment Coordinated Enhanced Observing Period (GEWEX-CEOP) was approved in 2002. The MDB is an important area of study as our analysis shows that very few GCMs simulate the MDB adequately well and their differences

Figure 20: Plot of the increasing isotopic (D/H) ratio of the vapour and liquid phases as a finite amount of water is gradually evaporated at equilibrium and constant pressure, without mixing with outside air (Gat, 1981).

Figure 21: (a) Global Energy and Water Cycle Experiment Coordinated Enhanced Observing Period (GEWEX-CEOP) (http://www.gewex.org/cseslocation.html, 2002), and (b) de Martonne climate zones (Irranejad, 2003).

Figure 20

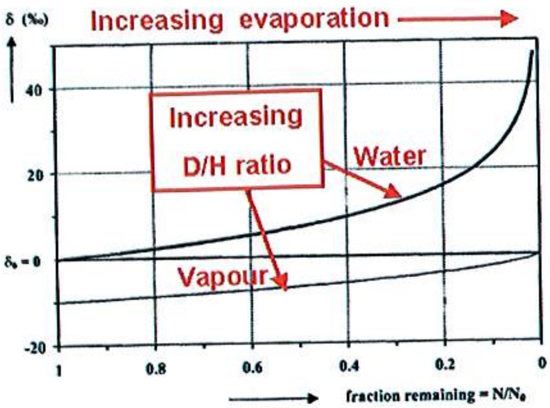
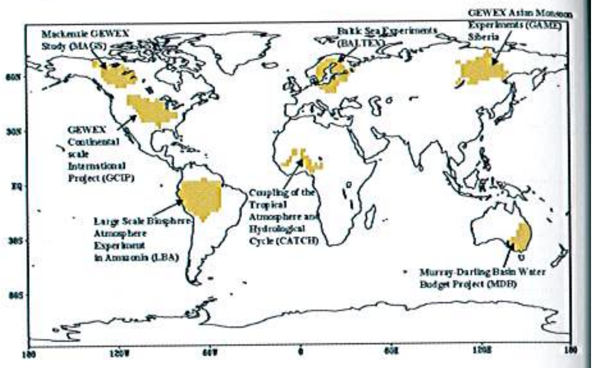


Figure 21a



are larger in this basin than any other of the GEWEX-CEOP basins (Figure 19). For better predictions of the land-surface variables (like evaporation, soil moisture) by the GCMs, we need observations, which are difficult to obtain at appropriate scales. However, we can use isotopic data to evaluate the evaporation rates from the MDB, and then attempts to improve land-surface scheme parameterisation can be evaluated using isotopic techniques. One example of this implementation of isotopic methods is in our water budget study where a logarithmic enhancement of the deuterium/hydrogen (D/H) ratio in the Darling River was discovered (Figure 20). This indicates almost complete evaporation and reveals the impacts of intense agricultural irrigation in semi-arid areas.

Land Surface Schemes

A land-surface scheme (LSS) is an algorithm for determining the exchanges of energy, mass and momentum between an atmospheric model and the simulated continental surface. As it is impossible to fully incorporate all processes into a numerical scheme, LSSs have been developed based on various simplifications. Our task group at ANSTO leads PILPS, through which a large number of international scientists collaborate, in order to evaluate a range of land surface parameterisations and determine the optimum scheme complexity required in climate models and weather prediction models. Our analysis of 20 AMIP GCMs was carried out over seven GEWEX-CEOP regions and eight de Martonne (de Martonne, 1948) climate zones (Figure 21). The purpose here was not to identify good or poor models but rather to try to understand the strengths and weaknesses in the community's land-surface prediction skill.

DSP12 has been successful in the sense that it has already delivered useful information to the climate modelling community. Specifically, a number of AMIP modelling groups have revised their land-surface outputs as a result of interaction with DSP12 and a smaller number of modelling groups are reconsidering their LSSs.

Analysis from DSP12 reveal for the first time three LSS "clusters": the (old) buckets; the (1980s/1990s) "SiBlings" and contemporary LSSs (Figure 22). The bucket models represent soil hydrology with no canopy processes and have been found to be too simplistic. Whereas the Simple Biosphere model ("SiBlings") use multi-layer soil schemes and canopy interception and its re-evaporation seem to be the best representation of the land-surface.

Figure 22: Partitioning of surface energy between sensible (SH) and latent (LH) heat fluxes for the sub-humid region by 20 AMIP II GCMs (shown as the letters A-T) and three reanalyses (NCEP-DOE, NCEP-NCAR and ECMWF) after scaling the fluxes based on the surface available energy. The evident clusters of the bucket schemes and the "SiBlings" are circled (Henderson-Sellers, 2003).

Figure 21b

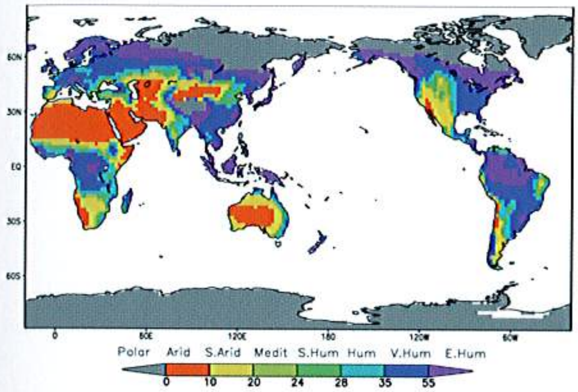
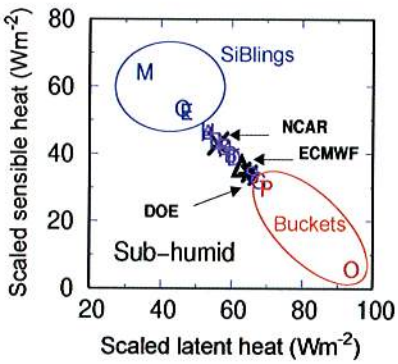


Figure 22



Interestingly the most recent (and central in Figure 22) schemes, some with fully parameterised carbon processes, simulate hydrology less well than their predecessors.

Comparing over 20 AMIP II GCMs and their LSSs, a number of conclusions have been drawn from our surface energy and surface water budget analysis. Firstly there are still limitations within some GCMs as they do not conserve surface energy and water over land surfaces. The magnitude of these imbalances varies in different regions and climate types. An interesting outcome from our comparison of the different types of LSSs within AMIP II is that a combined models' estimate is superior to any single model simulation in every situation reviewed.

Results from our surface energy budget analysis, show that the partitioning of surface energy between sensible and latent heat varies for AMIP II GCMs and reanalysis, across different climate zones (Henderson-Sellers, *et al.*, 2003). Results from our land-surface water budget study have shown that dry and warm basins (Mediterranean climate) are the least well simulated for almost all GCMs (Irranejad et. al., 2003). We conclude that land-surface scheme complexity does have an effect on the simulation of surface water budgets in the major basins and climate regimes of the world. This is clear because the surface water variables from the AMIP II GCMs depend on the LSS type to a greater extent than simulated precipitation and air temperature. Thus, the selection of a land-surface parameterisation scheme by climate modelling groups is important for prediction of variables such as evaporation and runoff, which are themselves critical for many human activities including agriculture and water resource management.

Meeting our objectives

- To determine what proportion 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 on climate through analysis and sourcing of fine particles and characterisation of air samples using radon concentrations in the East Asian region.

- To contribute to the improvement of land surface parameterisation schemes and investigate the potential to improve global climate models, thus improving our understanding of future climate.

Main conclusion: Human Activity dominates with climate variability often acting as a catalyst.

Main conclusion: We now have a large continuous data set demonstrating the nature and source of aerosol pollution in SE Asia. This data is being used to model long-term effects on global & local climate.

Main conclusion: We have demonstrated that Land Surface Parameterisation, linked with isotope studies can improve and verify global climate models and further improve future climate change predictions.

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