IPILPS: Isotopes in Project for Intercomparison of Land-surface Parameterization Schemes

Experiment Proposal

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Abstract

IPILPS is a new type of PILPS experiment in which the process of international intercomparison will inform, illuminate and educate the land-surface scheme (LSS) parameterization community while new aspects of LSS are being developed. Specifically, IPILPS is a component of the current initiative to add isotopic (stable and radioactive) representation to atmospheric and land-surface models. The science questions to be addressed by IPILPS include:

- What is the ability of LSSs to reproduce isotopic components of the water and mass (carbon initially) budgets?
- Do isotopic fluxes between the atmosphere and the land-surface depend more strongly on the ambient atmospheric conditions, the land-surface conditions or the gross exchanges between them?
- Is it possible to generate 'adequately correct' isotopic pools and fluxes without adding (great) complexity to the LSSs?

IPILPS is open to LSSs which already have or soon intend to incorporate stable water isotopes and/or carbon isotopes. It will be as valuable for LSS owners to join IPILPS prior to incorporation of isotopic pools and fluxes as to participate once these are added.

1. Introduction: Isotopes and the Land Surface

Numerical models of weather and climate, which have revolutionized our understanding of global processes over the last four decades, urgently require deconvolution of the multiple use of meteorological and hydrological data as both inputs and validation. This proposal delivers this essential in the form of stable water isotopes (SWIs) applied to current and future predictions. Isotopes are one of the most useful and innovative tools for understanding complex processes in the water cycle, paleoclimate and biogeochemistry on many timescales. An increasing variety of isotope data is now available and active research continues to expand the range of species.

1.1 Stable Water Isotopes

Isotopes, particularly the stable isotopes occurring in water molecules and those of carbon, are employed widely in earth system science. The stable isotopes of hydrogen and oxygen carried by water have been used to interpret long-term temperature trends since Dansgaard (1964). More recently, water isotopes have been recognized in carbon isotopic differentiation and in monitoring biological and abiological sources and sinks of CO_2 and CH_4 (Peylin *et al.,* 1999). While early Atmospheric Global Climate Models (AGCMs) were able to be verified against isotopic measurements (e.g. Joussaume *et al.,* 1984), more recent models challenge the empirical relationships underlying some data applications (Kavanaugh & Cuffey, 2003; Dyer *et al*., 2003). Stable and radio-isotopes in water can be used to measure and improve prediction in groundwater recharge; determine the relative contributions to total evapotranspiration from plant transpiration (non-fractionating) and open water evaporation (fractionating) (Salati and Vose, 1984); establish the flux and age of groundwater entering riparian systems; and quantify the amount of salt moving through rivers and soils (Simpson and Herczeg, 1991).

The naturally occurring isotopologues of water, commonly, but incorrectly, termed 'isotopes', of interest as possible tracing and validation tools in hydrological simulations are $^1H_2{}^{18}O$ and $^1H^2H^{16}O$. Isotopic enrichments, $\delta^{18}O$ and δD, relative to the Vienna standard, exhibit systematic variations in the water cycle as a result of phase change and diffusion-derived isotopic fractionation (Gat, 1981). Temperature-dependent equilibrium fractionation, combined with temperature-independent kinetic effects during evaporation and turbulent scale interactions in the atmospheric boundary layer increase the heavy isotope species in surface waters producing enrichment along evaporation lines below the meteoric water line (MWL) (Craig, 1961). Coupled with measurement of isotopes in water sources, SWI characteristics in river discharge now provide insight into basin-integrated hydro-climates (Gibson and Edwards, 2002; Henderson-Sellers *et al.*, 2004). Large catchment simulations of water resources where isotopes could be applicable include water re-cycling as a function of precipitation type and variability (Salati *et al.*, 1979); evaporation sourcing (i.e. whether water vapour comes from transpiration or from evaporation from rivers, lakes, soil water or the vegetation canopy) (Henderson-Sellers *et al.*, 2002); ice and snow temperature deposition determination; and aquifer and soil processes including those dependent upon precipitation intensity and melt-water contributions (Gat, 1996).

Vegetation interaction with water modifies isotopic ratios in soil water, groundwater and rivers, affecting the oxygen isotopic composition of atmospheric CO_2 (Farquhar *et al.,* 1993). In the Amazon, interception of rainfall by the plant canopy is the source of re-evaporated isotopically enriched water (Gat and Matsui, 1991; McGuffie and Henderson-Sellers, 2004). This process causes a lower continental depletion in heavy isotopes: 1.5‰ cf. 2‰ per 1000 km on other continents (Ingraham and Craig, 1986). In contrast, desert plants, usually inactive during the winter, transpire summer rainwater from the soil so that moisture in deeper soil layers and groundwater acquires the isotopic characteristics of the winter precipitation (Gat, 2000). Such water-mediated gradients of $\delta^{18}O$ may reveal important information about the actions of the terrestrial biosphere on the carbon cycle (Peylin *et al.,* 1999). To interpret biological exchange of isotopes on a global scale, modellers must calculate photosynthetic and soil respiratory discrimination of ^{18}O and the oxygen isotopic composition of plant and soil water (Riley *et al.,* 2002). Recent research offers tantalising glimpses of the new understanding attainable by innovative application of SWI to such ecosystem and climate questions.

1.2 Land Surface and Hydro-climatic Modelling

As the land surface is the locus of human activities, realistic simulation of continental near-surface weather and hydro-climate is important. A land-surface parameterization scheme, or simply a land-surface scheme (LSS), is an algorithm for determining the exchanges of energy, mass and momentum between the atmosphere and continents. These exchanges are complex functions of physical, chemical and biological processes encompassing a range of temporal and spatial scales. Depending on the selected simplifications, LSSs in today's numerical models range in complexity from the classic "bucket" (Manabe, 1969) through soil-vegetation-atmosphere transfer schemes (SVATs) (Sellers *et al.,* 1986; Wilson *et al.*, 1987) including sub-grid scale variations (Avissar, 1992; Famiglietti and Wood, 1995) to third generation LSSs which incorporate photosynthesis, respiration and decay (Xiao *et al.,* 1998; Dai *et al.*, 2003).

The need to analyze these diverse schemes systematically motivated the World Climate Research Programme (WCRP) in 1992 to launch the Project for the Intercomparison of Land-surface Parameterization Schemes (PILPS) (Henderson-Sellers and Brown, 1992; Henderson-Sellers *et al.*, 1993). PILPS' goal is to enhance understanding of the parameterization of fluxes of water, energy and carbon between the atmosphere and the continental surface in climate and weather forecast models (http://www.pilps.mq.edu.au). PILPS diagnoses the behaviours of participating LSSs in controlled experiments implemented in two modes: "off-line" (no feedback to the atmosphere) (Pitman *et al.,* 1993; Luo *et al.*, 2003) and coupled to an atmospheric host (Henderson-Sellers *et al.*, 2003a,b; Irannejad *et al.*, 2003). This proposal is innovative in creating a new PILPS experiment synergistically linking LSS modelling and SWI analysis.

PILPS is a collaborative participant in AMIP (the Atmospheric Model Intercomparison Project, http://www-pcmdi.llnl.gov/amip/; Gates *et al.*, 1996) focussed on simulation of the global climate over the period 1979-1996. AMIP has conducted two phases of experiments so far. Although designed to evaluate LSSs, there were difficulties in AMIP I including failure to initialise soil moisture consistently; a restricted set of "standard output" variables; limited variety of LSSs; poor quality control of archived results; and relatively poor LSS documentation. Originally intended as validation, the AMIP I diagnostics generated three main findings: no "best" LSS exists; every LSS is an outlier in some aspect (Love & Henderson-Sellers, 1994); and serious errors of execution such as non-conservation of continental moisture or energy and pronounced trends in moisture stores traced back to coding and coupling errors and incorrect initialisation (Love *et al.*, 1995). Following AMIP I, the Bureau of Meteorology Research Centre, Australia (BMRC) and the Laboratoire de Meteorologie Dynamique, France (LMD) each undertook a pair of 'revisits' revealing that coupling land-surface schemes with different complexities causes widespread statistically significant differences in continental climates (cf. Yang *et al.,* 1995).

In AMIP II (Gates *et al.*, 1999), we have discovered a clear chronological sequence of: first generation 'no canopy'; second generation (e.g. SiB & BATS); and 'recent' LSSs showing that, while three decades of research have improved continental surface modelling capability, full confidence in our ability to project hydro-climates remains elusive, in part due to uncertainties in surface observations (Henderson-Sellers *et al.*, 2003a). Coupled AMIP-LSS experiments confirm that different schemes interact differently with different atmospheric forcing and exhibit a variety of climate sensitivity. These results show that LSSs are important to GCM predictions such that new, or changed, land-surface components will increase diversity among climate simulations (Irannejad *et al.*, 2003). At the basin scale, the inter-model scatter in energy and moisture partitions among coupled simulations is substantially greater than in comparable off-line experiments, suggesting that the long-held belief that two-way feedbacks between land and atmosphere dampen land-surface climate differences is incorrect (Irannejad *et al.*, 1995; Qu and Henderson-Sellers, 1998). This new PILPS experiment has the potential to reduce the uncertainty in these predictions by, for example, establishing what part of total evaporative exchange is through plants (isotopically non-fractionating for water isotopes).

Shao and Henderson-Sellers (1996) found qualitatively good annual cycles of soil moisture with important seasonal effects: growing season underestimation of runoff and overestimation of evapotranspiration due to the neglect of subgrid scale variations. Further experiments revealed lack of conservation and large ranges in latent heat flux (e.g. 100 W m^{-2} in forests and 50 W m^{-2} for grasslands) annually with larger monthly and diurnal ranges (Pitman *et al.,* 1999). The range amongst the predictions as compared with observed turbulent fluxes and the problem of non-zero total energy budgets persist (Chen *et al.*, 1997), as does arbitrary specification of soil depths and hence soil moisture stores (Slater *et al.*, 2001). PILPS most recent off-line experiment, focussing on carbon, has discovered two classes of LSS carbon behaviour: rapid equilibrium of net primary productivity (NPP) with important CO_2 sinks early in the simulation and more gradual increase of NPP beginning with a null CO_2 net sink. The evolution of total biomass over a 100 year experiment varies from 1-16 kg per square metre of carbon with soil carbon from 1-10 kg (cf. ~7 kg observed at Loobos). Overall, experiments focussing on energy, carbon and water fluxes over multiple seasonal cycles across climatically diverse, continental-scale basins (Wood *et al.,* 1998; Bowling *et al.,* 2003) clearly demonstrate value in using catchment data to calibrate LSSs. This new PILPS effort exploiting SWIs will establish, in collaboration with MILE-net, a globally-spanning set of isotope-based 'sites' in well monitored catchments for LSS evaluation and improvement (cf. Zhang *et al.*, 2001).

2. IPILPS Beginnings

2.1 Background

An initial proposal for an international off-line LSS intercomparison was presented to the GEWEX Land Atmosphere System Study (GLASS) Scientific Steering Committee (SSC) in July 2003. GLASS approved the proposal, in principle, and requested that the inclusion of carbon isotopes be considered also. A provisional time-line was set.

Timeline (proposed) for Stage 1 (SWI):

1. August 2003: In principle approval given by GLASS Panel of science motivation & interest - gained
2. September 2004: Full Approval by GLASS Panel at 2004 SSC meeting
3. October/November 2004: Data availability and quality control confirmation
4. November/December 2004: Experimental framework agreement
5. January/February 2005: Call for participation to all current & past PILPS and AMIP II DSP 12 members
6. April/May 2005; First workshop and analysis

7. December 2005: Publication including a special session at AGU Fall Meeting in San Francisco

IPILPS will assess the simulation of isotopic fluxes in basin-scale hydrology, focusing on the 'big leaf' representation of land surfaces in numerical models as the current mechanism for incorporating water isotopes. Simulations of fluxes and reservoirs of the isotopes $H_2{}^{18}O$ and $^{1}H^{2}H^{16}O$ will, we believe, be demonstrated in IPILPS to have diagnostic utility in evaluating surface energy and water budgets and stable isotopic interpretation of basin water budgets will, hopefully, be shown to add information about the gross water fluxes and future prediction skill. Applications of stable isotopic behaviour in global climate and earth system models include river isotopic characterization of basin changes, plant-respired oxygen isotope 'tagging' and resolving uncertainty in more basic criteria such as conservation and capture of the current mean climate.

A survey of current LSS owners indicates that IPILPS should be a two-stage intercomparison. Currently, enough schemes incorporate SWI to make a 2004-5 intercomparison possible and valuable. IPILPS comprises the land-surface modelling component of the proposed SWING (Stable Water Isotopes INtercomparison Group) (http://www.bgc-jena.mpg.de/bgc-synthesis/projects/SWING/index.shtml) inter-comparison effort It is likely to constitute one of its first steps. The second stage of IPILPS which is proposed for 2006 will include carbon isotopes. However, s two LSSs willing and able to participate in Stage 1 (SWI) already compute carbon pools and carbon isotopes, the first stage will help establish the basis for Stage 2 (CI).

2.2 Goals

IPILPS is a new type of PILPS experiment. It has the advantage of beginning before many LSSs have incorporated water and carbon isotopes. This means that (for the first time) we can inform the LSS community as it incorporates SWIs and carbon isotopes rather than having to try to determine strengths and failures of coding *post facto*. This is very exciting and adds urgency to the timelines for IPILPS.

The initial goal of IPILPS is to compare and contrast the calculation of gross and isotopic fluxes between the land surface and the atmosphere. It was recognized that this step is a prerequisite to the second goal of evaluating the calculated isotopic fluxes by comparison with high quality observations. It is anticipated that many of the early 1990s' lessons learned with gross fluxes will be revisited for isotope fluxes including: conservation, initialization, spin-up impact and group means' outperforming of individual LSSs (e.g. Love *et al*., 1995 and http://gcte-focus1.org/basin.html).

The scientific hypotheses to be tackled in IPILPS include:

- The ability of LSSs to reproduce isotopic components of the water and mass (carbon initially) budgets is directly related to their ability to reproduce gross water and mass budgets;

- Isotopic fluxes between the atmosphere and the land-surface depend more strongly on the land-surface parameterization than on the computed atmospheric conditions; and

- It is possible to generate ‘adequately correct’ isotopic pools and fluxes without adding complexity to the LSSs beyond a ‘bucket’ hydrology and a (one line) stomatal resistance term.

We believe that isotopes offer a novel and unique tool with which to test and improve LSSs. For example, as transpiration does not fractionate while evaporation does, the SWIs differentiate plant-effected vapourisation from non-plant processes.

2.3 Data

The GNIP database comprises ^{18}O, D and tritium values of monthly composite precipitation samples collected from 1961 at a network of 550 meteorological stations irregularly distributed over the globe (Rozanski *et al.*, 1993). The GNIR database is much more recent (Gibson *et al.*, 2002) but also includes at least monthly ^{18}O and D values in river water for selected large river basins including the Mackenzie, Amazon and Murray-Darling. BASIN (Biological Aspects of Stable Isotope Network), which operates in Focus 1 of Global Change and Terrestrial Ecosystems (GCTE) of the IGBP and is funded by NSF is generating quality-controlled isotopic data from selected sites in America available as test and/or collaboration sets for IPILPS

All these data are discontinuous in time and space and some lack metadata. An important background goal will be to (re)construct quality metadata for sites within the three selected river basins. Archival material relating to existing data in the GNIP record will be provided by the IAEA (pers comm., P. Aggarwal, April 2004). New information relating to specific sites will be acquired as part of the approved “^{18}O in Terrestrial Environment” (previously MILE-net ‘Moisture Isotopes in Land Ecosystems’) (G. Farquhar, pers. comm., May 2004).

Quality control of available isotopic data is sometimes difficult to establish. Minimum reported analytical uncertainty in ^{18}O and D measurements is 0.2‰ and 2‰ respectively although some laboratories achieve lower values (Panarello *et al.*, 1998). Uncertainty in d-excess is strongly dependent on the uncertainty in deuterium (2‰) and is currently estimated at $u(d) = v[(ud^2H)^2 + 8\ (ud^{18}O)^2]$ ~ 2.08‰. The current uncertainty leaves obvious room for improvement. Although recommendations regarding this will be important, the main goal for this project is to establish criteria for data quality which can be used to evaluate LSSs.

The original goal was to accomplish data collection and metadata restoration, for at least one test site in a selected basin, by November/December 2004. However, following the MILE-net meeting at the IAEA HQ in late May it has been recognized that diurnally resolved data will not be available this year. In fact in some places it will have to await new observation campaigns e.g. in Australia. IPILPS is now an important driver for acquiring these diurnally resolved SWI and conventional flux observations.

3. IPILPS Experimental Development

All the data will be provided and collected using the NetCDF format and the ALMA conventions (www.lmd.jussieu.fr/ALMA). File naming will follow previous PILPS experiments: [modelname]_[simulation]_[location]_ipilps.nc where 'modelname' is the LSS name and 'location' is one of the three sites to be simulated in IPILPS. Input and output management will be handled via the PILPS web page hosted by Macquaire University (http://www.pilps.mq.edu.au). All participants will be able to view results as they are submitted but only the LSS owner will be able to identify their specific results. Basic quality control will be operated by ANSTO staff and LSS owners will be advised of difficulties as they arise.

3.1 Off-line Intercomparison

The goals of IPILPS are to (i) offer a framework for intercomparison of isotope-enabled land surface schemes (LSS) and (ii) encourage improvement of these schemes by evaluation against high quality (isotope) observations. The PILPS community has proposed three locations for Isotope PILPS:

i) wet sclerophyll forest, Tumbarumba, Australia: 35°S, 148°E

ii) tropical, rain forest, Manaus, (or Santarém) Brazil: 3°S, 60°W

iii) mid-latitude deciduous woodland, say Vienna, Austria (Saclay, France), 48°N, 16°E

At present we believe that the only way of supplying data with which to force participating LSSs is from an isotope-enabled atmospheric model. Of the SWING participants Kristof Sturm is willing (and able) to supply five years' surface and near-surface forcing from REMO (REgionales MOdel, developed by the Max Planck Institute for Meteorology, Hamburg) for three locations at the required temporal resolution, probably every 15 minutes. The spatial resolution of REMO (http://lgge.obs.ujf-grenoble.fr/~sturm/REMOiso/PhD_index.htm) is ½ degree (~ 54km) with a model timestep of 5 minutes (Sturm *et al.*, 2004a). REMO is nested into ECHAM and the first 5 years' output will be derived from nesting into the 'climatological' version of ECHAM which had a constant annual cycle in SSTs.

3.2 Forcing Data

The forcing data includes magnitudes of each isotope (i.e. $^{1}H_2{}^{18}O$ and $^{1}H^{2}H^{16}O$) in precipitation and in water vapour at the atmospheric lowest level plus all the standard (ALMA) meteorological forcing including 'regular' water ($^{1}H_2{}^{16}O$). Kristof Sturm has integrated an isotope module into REMO. Currently, REMOiso is the only functional RCM with SWI module worldwide, hence it is a crucial component of IPILPS. REMO uses the same physical schemes as the ECHAM-4, which provides its lateral boundary conditions. It runs on an Arakawa C grid with 0.5° resolution (~54 km), offering a factor of two improvement as compared with the highest resolution for ECHAM (T106 ~ 125 km). REMO can further be nested in itself, reaching a 1/6° resolution (~18 km). The SWI module computes the $H_2{}^{18}O$ and $HD^{16}O$ cycles identically to the standard $H_2{}^{16}O$

hydrological cycle. Fractionation processes are represented at all steps of the hydrological cycle: kinetic fractionation during open-sea evaporation, thermodynamical equilibration between vapour, liquid and ice phases according to convective and large-scale cloud microphysics, re-evaporation and kinetic equilibration of falling rain droplets and vertical diffusion through the planetary boundary layer (PBL). REMOiso has been applied and validated in several climatic environments including the three regimes selected for IPILPS.

Offline simulations need appropriate boundary conditions, i.e. input from a host model representing the atmospheric processes as close as possible to the actual meteorological conditions. Furthermore, both climatic and isotopic variables should be coherent. Even though the surface features are better represented in REMOiso than a GCM, running in a climatological mode does not permit reproduction of a specific synoptic meteorological situation. Reanalyses, on the other hand, assimilate all available meteorological observations and so are believed to provide the best estimation of the actual state of the atmosphere (cf. Henderson-Sellers *et al.*, 2003b). At present, no isotopic reanalysis information is available so to resolve this problem, Georg Hoffmann, Max Kelley and Kristof Sturm are developing a nudged version of ECHAMiso: leaving the (isotopic) water cycle untouched, the model dynamics is forced to match the reanalyses while conserving the water budget. Hence the simulated precipitation events correspond better to observed precipitation. This nudging technique applied to a SWI GCM is a unique feature, from which REMOiso will greatly benefit in the form of accurate lateral boundary conditions. Similar nudging will be applied to REMO in near future.

At present, one REMOiso study domain covers the European continent, encompassing temperate, Mediterranean and subpolar climates. As a current interest focuses on almost all of the South American continent, including the Amazon, the arid grassland regions such as Brazil's Nordeste and the Andes glaciers there is a second domain centred on Manaus (Sturm *et al.*, 2004b). To date, model evaluations have been successful both for total simulated precipitation amounts and their isotopic signature. The model parameterisation has been proved to be elaborate enough to represent secondary effects such as the deuterium excess well. Based on these experiments, we are confident that REMOiso will perform well in all climatic environments selected for IPILPS.

3.3 Off-line Evaluation: Existing and New Observations

We are very keen to obtain high quality observations of isotopic data in vapour, precipitation, soil and plant water and river run off. The IAEA archives some of these data within GNIP and GNIR as monthly averages. Individual laboratories have similar data archived at higher temporal resolution. In the context of GEWEX prime focus on the diurnal cycle, it seems likely that monthly averaged data will be of only modest value.

Under the IAEA CRP on "$\delta^{18}O$ in the Terrestrial Environment" Australian delegates (led by Professor Graham Farquhar of the ANU) have agreed to make detailed observations at a site west of Canberra. Tumbarumba (35° 39' 20.6" S 148° 09' 07.5" E), which will be the Australian site, is located between Canberra and Wagga Wagga. The vegetation is classified as wet sclerophyll forest with the dominant species being *Eucalyptus delegatensis* and average tree height of 40 m. The site is 1200 m above mean sea level with mean annual precipitation of 1000 mm and temperature ranging between -10 to 30 ^{o}C.

Details of the observations to be conducted have not yet been established but the campaign will be designed specifically to derive data for IPILPS. A preliminary field effort using the Fourier Transform Infra-Red spectrometry (FTIR: University of Wollongong) will start in Jan/Feb 2005.

4. IPILPS Experiment Draft (Stage 1 – SWI)

The current plan is to undertake IPILPS LSS' evaluation in three stages:
(i) spin-up simulations confirm conservation of all three water isotopes and energy;
(ii) comparison over 3 years with monthly mean values from IAEA; and
(iii) detailed comparison with diurnally resolved observations provided by individual laboratories and /or through MILE-net (now officially approved as a Co-operative Research Project (CRP) by the IAEA entitled "δ^{18}O in the Terrestrial Environment").

4.1 Equilibration Experiment

Year 1's forcing applied over many years

a) Meteorological forcing provided as $^1H_2{}^{16}O$, $^1H_2{}^{18}O$, $C^{18}O^{16}O$ and $^1H^2H^{16}O$ at 15 or 30 minute intervals for 1 year (for spin-up) plus vegetation and soil parameters provided as generic descriptors only (intentionally):

i) Tumbarumba– evergreen eucalypt (LAI≤2); poor saline soil, fine texture
ii) Manaus – evergreen tropical forest (LAI≥3); deep mineral soil, coarse texture
iii) Vienna (Saclay) – deciduous woodland (LAI≤2); aerated soil, coarse texture.

b) All LSSs to be run for as many years as they need to create an equilibrium situation in both conventional fluxes (energy, water and carbon if available) and also for available isotopic fluxes – at least $^1H_2{}^{18}O$ and $^1H^2H^{16}O$

Goal: set up and tuning.

Year 2 forcing applied repeatedly

c) Start from results from (b) but initialize all stable isotope reservoirs to V-SMOW and all gross water reservoirs to half of capacity.

d) Spin-up to be conducted for as long as required using Year 2 forcing to achieve equilibrium in all reservoirs. Equilibrium is defined as year-to-year change of ≤0.05 mm d^{-1} [This may be too large. Needs discussion] in gross water reservoirs. Equilibrium in isotopes to be established as part of this experiment. LSSs to determine (i) number of years to achieve equilibrium and (ii) definition of equilibrium for $^1H_2{}^{18}O$ and $^1H^2H^{16}O$.

Goal: determination of spinup times.

4.2 Basin and Site Scale Evaluation

Years 3 to 5 forcing applied sequentially

e) Monthly means of precipitation forcing will be constrained by GNIP precipitation values to the extent possible (illuminated by REMOiso reanalyses project) to create high quality forcing
f) Monthly averaged run-off and deep soil water isotopic results will be compared with GNIR and GNIP/ISOHIS archive values- first step at evaluation (monthly)
g) Sample periods of sub-diurnally resolved data will be made available for detailed diurnal isotopic flux evaluation as follows:
i) near canopy vapour
ii) at least three layers of soil water
iii) leaf (and preferably stem) water
iv) transpired flux from canopy
v) total evapotranspired flux from surface
vi) runoff
and, hopefully in Stage 2 (CI):
vii) $C^{18}O^{16}O$ ecosystem flux
viii) surface $C^{18}O^{16}O$ flux.
The minimum goal is three periods of high quality isotopic data for at least 5 days at each of the three IPILPS sites. Scale issues will pose a serious problem. In the first instance, evaluation will be against point measurements but we hope to develop data for watersheds at our three sites.
Goals: monthly mean basin-scale evaluation and site-specific diurnal evaluation.

4.3 Factorial Assessment
Adding isotopes to existing codes for land-atmosphere exchanges of energy, water and mass will increase their complexity. Two fundamental questions to be addressed by IPILPS are: (i) how much more complex must LSSs be made in order to represent isotopic fluxes correctly and (ii) can correct simulation of isotopic fluxes direct the reduction of complexity? For example, Noone has claimed "state of the art" simulation of global-scale atmospheric $C^{16}O^{18}O$ using NCAR's CLM to compute net water and energy exchanges with the addition of a simple "bucket" scheme to compute the isotopic composition of transpired and evaporated water (D. Noone, pers. comm., Aug. 2004).

Factorial experiments are a powerful means of assessing the importance of particular parameters and combinations of parameters to the outcomes of processes (Henderson-Sellers, 1993). IPILPS will use a factorial methodology to evaluate and rank the LSS parameters that have the most impact on SWI exchanges with the atmosphere and pools at the terrestrial surface. The factorial experiments will follow Henderson-Sellers (1993) focussing on the monthly and diurnal isotopic fluxes already assessed (e-g). The aim will be to determine the degree of LSS complexity required for 'adequate' isotopic simulation.
Goal: determination of most important LSS factors for isotopic prediction.

5. Participation, Extension, Publications and Visitors' Input
5.1 Participation
It is unknown how many LSS have SWI and/or carbon isotope capability. The number is likely to be few (less than 10 probably at present- August 2004) but as GCMs and

regional models gain carbon and water isotopes their land-surface schemes will have to have these added also. A call for participation will be sent out to all current and past PILPS and AMIP II DSP 12 and SWING members as soon as the experimental design is approved.

The following LS modelling groups have already indicated that they are interested in participating in IPILPS and are able to begin doing so early in 2005:

- ECHAM/REMO 'bucket plus rs' (Hoffman & Sturm)
- MECBETH (Cuntz)
- ISOLSM (Riley & Irannejad)
- CLMiso (Noone)
- GISS LSSiso (Schmidt)
- ORCHIDEE LSSiso (de Noblet and IPSL)
- SiB3 (Suits)

This number is very satisfactory for the early stages of IPILPS.

5.2 IPILPS Stage 2 (CI)

As described above, it is planned to extend the initial SWI intercomparison to include carbon isotopes (CI). Stage 2 (CI) of IPILPS will build upon both the findings from Loobos in PILPS C (Viovy, 2003) and on IPILPS Stage 1 (SWI). At this stage, no timeline is possible for Stage 2 (CI) because its evolution is dependent upon the development of more LSSs incorporating carbon isotopes (Cuntz, 2004, pers. comm.)

5.3 Whole Community Involvement

We shall work with all of the international community to publish results during and at the conclusion of this first phase of IPILPS. We are hoping that our Visiting Fellows will participate in IPILPS and contribute in one or more of the following ways:

1. by bringing observational data which can be used and jointly analyzed with ANSTO experimenters;
2. by offering an isotope-enabled LSS or forcing model which can be directly used in IPILPS; or
3. by participating in the development of the IPILPS experiment including: (i) its formulation; (ii) running LSSs; and (iii) analysis with ANSTO researchers.

We have high hopes of establish a strong Senior Visitor Program at ANSTO to support IPILPS. Dr Joel Gat of the Weizmann Institute of Science, Rehovot, Israel is our first Fellow who will join IPILPS from January to April 2005. Dr Luis Martinelli has also expressed interest in joining IPILPS specifically to assist in observations of SWIs at one or more of the designated experimental sites.

References

Avissar R., 1992, Conceptual Aspects of a Statistical--Dynamical Approach to Represent Landscape Subgrid-scale Heterogeneities in Atmospheric Models. *J. Geophys. Res.*, **97**, 2,729-2,742

Bowling, L.C., Lettenmaier, D.P., Nijssen, B., Graham, L.P., Clark, D.B., El Maayar, M., Essery, R., Goers, S., Gusev, Y.M.,Habets, F., *et al.*, 2003, Simulation of high-latitude hydrological processes in the Torne-

Kaliz basin: PILPS Phase 2(e): 1: Experiment description and summary intercomparisons, *Global Planetary Change*, **38(1-2)**, 1-30

Chen T.H., Henderson-Sellers, A., Milly, P.C.D., Pitman, A.J., Beljaars, A.C.M., Polcher, J., Abramopoulos, F., Boone, A., Chang, S., Chen, F., Dai, Y., Desborough, C.E., Dickinson, R.E., Dumenil, L., Ek, M., Garratt, J.R., Gedney, N., Gusev, Y.M., Kim, J., Koster, R., Kowalczyk, E.A., Laval, K., Lean, J., Lettenmaier, D., Liang, X., Mahfouf, J.-F., Megelkamp, H.-T., Mitchell, K., Nasonova, O.N., Noilhan, J., Robock, A., Rozensweig, C., Schaake, J., Schlosser, A., Schulz, J.P., Shao, Y., Shmakin, A.B., Verseghy, D.L., Wetzel, P., Wood, E.F., Xue, Y., Yang, Z.-L. and Zeng, Q., 1997, Cabauw Experimental results from the project for Intercomparison of Land-surface Parameterization Schemes, *J. Climate*, **10**, 1194-1215

Craig, H., 1961, Isotopic variations in meteoric water. *Science*, **133**, 1702-1703

Dai, Y., X. Zeng, R.E. Dickinson, I. Baker, G.B., Bonan, M.G. Bosilovich, A.S. Denning, P.A. Dirmeyer, P.R. Houser, G. Niu, K.W. Oleson, C.A. Schlosser, and Z.-L. Yang, 2003, The common land model, *Bull. Amer. Meteor. Soc.*, **84**, 1013-1023.

Dansgaard, W., 1964, Stable isotopes in precipitation. *Tellus*, **16**, 436-468

Dyer, L., Henderson-Sellers, A., McGuffie, K. and Irannejad, P., 2003, Linking water flux parameterisation schemes to isotopic measurements in basin-scale to climate models, *EOS Trans, AGU* **84 (46),** AGU Fall Meeting Suppl.,B51E-1008, December 8-12 2003

Famiglietti J.S. and Wood E.F., 1995, Effects of spatial variability and scale on areally averaged evapotranspiration. *Wat. Resour. Res.,* **31**, 699-712

Farquhar, G.D., Lloyd, J., Taylor, J.A., Syverston, L.B., Hubick K.T, Wong S. and Ehleringer, J.R., 1993, Vegetation effects on the isotopic composition of the atmospheric CO_2, *Nature*, **363,** 439-443

Gat, J.R., 1981, Paleoclimate conditions in the Levant as revealed by the isotopic composition of paleowaters, *Israel Meteorol. Res. Pap.*, **3,** 13-28

Gat, J.R., 1996, Oxygen and hydrogen isotopes in the hydrological cycle, *Ann.Rev. Earth Planet. Sci*., **24**, 225-262

Gat, J.R., 2000, Atmospheric water balance – the isotopic perspective, *Hydrol. Proc.*, **14**, 1357-1369

Gat, J.R. and Matsui, E., 1991, Atmospheric water balance in the Amazon Basin: an isotopic evapotranspiration model, *J. Geophys. Res.,* **96(D7)**, 13,179-13,188

Gates W.L., Henderson-Sellers A., Boer G.J., Folland C.K., Kitoh A., McAvaney B.J., Semazzi F., Smith N., Weaver A.J. and Zeng Q.-C., 1996, Climate models - evaluation, In: Houghton J.T., Meira Filho L.G., Callander B.A., Harris N., Kattenberg A. and Maskell K. (eds.), Climate Change 1995. The Science of Climate Change, Cambridge University Press, Cambridge, 229-284

Gates, W.L., Boyle, J.S., Covey, C., Dease, C.G., Doutriaux, C.M., Drach, R.S., Fiorino, M., Gleckler, P.J., Marlais, S., Phillips, T.J., Potter, G.L., Santer, B.D., Sperber, K.R., Taylor, K.E. and Williams, D.N., 1999, An overview of the results of the Atmospheric Models Intercomparison Project (AMIP I), *Bull. Amer. Meteor. Soc*., **80**, 29-55

Gibson J. J. and. Edwards T.W.D., 2002, Regional water balance trends and evaporation-transpiration partitioning from a stable isotope survey of lakes in northern Canada, *Global Biogeochemical Cycles*, **16,** 10.1029/2001GB001839

Gibson, J.J., Aggarwal, P., Hogan, J., Kendall, C., Martinelli, L. A., Stichler, W., Rank, D., Goni I., Choudury M., Gat, J., Bhattacharya, S., Sugimoto, A., Fekete B., Pietroniro A., Maurer T., Panarello H., Stone D., Seyler P., Maurice-Bourgoin L. and Herzceg A., 2002, Isotope studies in large river basins: a new global rearch focus, *EOS,* **83,** No 52, 613-617

Henderson-Sellers, A. and Brown, V.B., 1992, PILPS: Project for Intercomparison of Land-surface Parameterization Schemes, Workshop Report and and First Science Plan, IGPO Publication Series No. 5, Science and Technology Corporation, Hampton, VA, 51pp.

Henderson-Sellers, A., 1993, A factorial assessment of the sensitivity of the BATS land-surface parameterization scheme, *J. Clim.*, **6,** 227-247

Henderson-Sellers A., Yang Z.L. and Dickinson R.E., 1993, The Project for Intercomparison of Land-surface Schemes (PILPS). *Bull. Amer.Meteor.Soc.,* **74,** 1,335-1,349

Henderson-Sellers, A., McGuffie, K., Zhang, H., 2002, Stable isotopes as validation tools for global climate model predictions of the impact of Amazonian deforestation, *J. Climate,* **15(18),** 2664-2677.

Henderson-Sellers, A., Irannejad, P., McGuffie K. and Pitman, A.J., 2003a, Predicting land-surface climates – better skill or moving targets? *Geophys. Res. Lett.,* **30(14),** 1777-1780

Henderson-Sellers, A. Irannejad, P. McGuffie K., Sharmeen, S., Phillips, T.J., McGuffie, K. and Zhang, H., 2003b, Evaluating GEWEX CSES' simulated land-surface water budget components, *GEWEX News* August 2003, 3-6

Henderson-Sellers, A., McGuffie, K., Noone, D. and Irannejad, P., 2004, Using stable water isotopes to evaluate basin-scale simulations of surface water budgets, in press, *J. Hydrometeorol.*

Ingraham, N.L., and R.C. Craig, 1986, Hydrogen isotope study of large-scale meteoric water transport in northern California and Nevada, *J. Hydrol.,* **85,** 183-197

Irannejad P., Henderson-Sellers A., Shao Y. and Love P.K., 1995, Comparison of AMIP and PILPS off-line landsurface simulations. Proceedings of the First International AMIP Scientific Conference, Monterey, California, USA, 15-19 May 1995, WCRP-92, WMO/TD-No. 732, 465-470

Irannejad, P., Henderson-Sellers, A. and Sharmeen, S., 2003, Importance of land-surface parameterisation for latent heat simulation in global atmospheric mo dels, *Geophys. Res. Lett.,* **30(17),** 1904-1907

Joussaume, S. Sadourny, R. and Jouzel, J., 1984, A general circulation model of water isotopes cycles in the atmosphere, *Nature,* **311**, 24-29

Kavanaugh J.L. and Cuffey, K.M., 2003, Space and time variation of δ^{18}O and δD in Antarctic precipitation revisited, *Glob. Biogeochem. Cycl.,* **17**, doi:10.1029/2002GB001910

Love, P.K., and Henderson-Sellers A., 1994, Land-surface climatologies of AMIP-PILPS models and identification of regions for future investigation (PILPS Phase 3a). GEWEX Report, IGBPO Publication Series No. 13, 48 pp.

Love P.K., Henderson-Sellers, A. and Irannejad, P., 1995, AMIP diagnostic subproject 12 (PILPS Phase 3): Land surface processes, Proceedings of the First International AMIP Scientific Conference, Monterey, California, USA, 15-19 May 1995, WCRP-92, WMO/TD-No. 732

Luo, L., Robock, A., Vinnikov, K.Y., Schlosser, C.A., Slater, A.G., Boone, A., Braden, H., Cox, P., de Rosnay, P., Dickinson, R.E., Dai, Y.-J., Duan, Q., Entin, J., Etchevers, P., Henderson-Sellers, A., Gedney, N., Gusev, Y.M., Habets, F., Kim, J., Kowalczyk, E., Mitchell, K., Nasonova, O.N., Noilhan, J., Pitman, A.J., Schaake, J., Shmakin, A.B., Smirnova, T.G., Verseghy, D., Wetzel, P., Xue, Y., Yang, Z.-L. and Zeng, Q.C., 2003, Effects of frozen soil on soil temperature, spring infiltration, and runoff: results from the PILPS 2(d) experiment at Valdai, Russia, *J. Hydrometeorology***, 4,** 334-351

McGuffie, K. and Henderson-Sellers, A., 2004, Assessing simulation of the Amazon basin with stable water isotopes, in press, *J. Geophys. Res. (Atmospheres)*

Manabe S., 1969, Climate and ocean circulation: 1. The atmospheric circulation and the hydrology of the earth's surface, *Mon. Wea. Rev*., **97**, 739-774

Panarello, H.O., Araguás-Araguás, L., Gerardo-Abayo, J. and Gilbert, E., 1998, The role of the Global Network for Isotopes in Precipitation (GNIP) in hydrological and hydroclimatic studies. In Isotope Techniques in the Study of Environmental Change. Proc. Symp., IAEA, Vienna, 14-18 April 1997, pp 79-91

Peylin P., Ciais P., Denning A.S, Tans P.P., Berry J.A. and White J.W.C., 1999, A 3-dimensional study of delta O18 in atmospheric CO_2: contribution of different land ecosystems, Tellus Series B-Chemical and Physical Meteorology, **51 (3),** 642-667

Pitman AJ., Henderson-Sellers A., Abramopoulos F., Avissar R., Bonan G., Boone A., Cogley J.G., Dickinson R. E., Ek M., Entekhabi D., Famiglietti J., Garratt J.R., Frech M., Hahmann A., Koster R., Kowalczyk E., Laval K., Lean L., Lee T.J., Lettenmaier D., Liang X, Mahfouf J.F., Mahrt L., Milly C., Mitchell K., de Noblet N., Noilhan J., Pan H., Pielke R., Robock A., Rosenzweig C., Running S.W., Schlosser A., Scott R., Suarez M., Thompson S., Verseghy D., Wetzel P., Wood E., Xue Y., Yang Z.L., Zhang L., 1993, Results from the off-line Control Simulation Phase of the Project for Intercomparison of Land Surface Parameterisation Schemes (PILPS). GEWEX Tech Note, *IGPO Publ Series*, 7:47.

Pitman A.J., Henderson-Sellers A., Decborough, C.E., Yang, Z.-L., Abramopoulos, F., Boone, A., Dickinson, R.E., Gedney, N., Koster, R., Kowalczyk, E., Lettenmaier, D., Liang, X., Mahfouf, J.-F., Noilhan, J., Polcher, J., Qu, W., Robock, A., Rosenzweig, C., Schlosser, C.A., Shmakin, A.B., Smith, J., Suarez, M., Verseghy, D., Wetzel, P., Wood, E. and Xue, Y., 1999, Key results and implications from Phase 1(c) of the Project for the Intercomparison of Land-surface Parameterization Schemes, *Climate Dyn*., **15**, 673-684

Qu W.Q. and Henderson-Sellers A., 1998, Comparing the scatter in PILPS off-line experiments with those in AMIP I coupled experiments, *Global Planet. Change,* **19**, 209-224

Riley, W. J. Still, C. J. Torn, M. S and. Berry, J. A, 2002, A mechanistic model of $H_2^{18}O$ and $C^{18}OO$ fluxes between ecosystems and the atmosphere: Model description and sensitivity analyses, *Global Biogeochemical Cycles*, **16,** doi:10.1029/2002GB001878

Rozanski, K., L. Araguas-Araguas, and R. Gonfiantini, 1993, Isotopic patterns in modern global precipitation. *Climate Change in Continental Isotopic Records.* **Geophysical Monographs 78**, 1-36

Salati, E. and P.B. Vose, 1984, Amazon Basin: a system in equilibrium, *Science,* **225**, 129-137

Salati, E., A.D. Olio, E. Matsui, and J.R. Gat, 1979, Recycling of water in the Amazon Basin: An isotopic study, *Wat. Res. Res*., **15**(5), 1250-1258

Sellers P.J., Mintz Y., Sud Y.C., Dalcher A., 1986, A Simplified Biosphere Model (SiB) for Use within General Circulation Model, *J. Atmo. Sci.,* 43, 505-531

Shao, Y. and Henderson-Sellers, A., 1996, Modeling soil moisture: a Project for Intercomparison of Land Surface Parameterization Schemes Phase 2(b), *J. Geophys. Res. (Atmospheres),* **101 (D3),** 7227-7250

Simpson, H.J. and Herczeg, A.L., 1991, Salinity and evaporation in the River Murray basin, Australia, *J. Hydrol.,* **124,** 1-27

Slater G., Schlosser C.A., Desborough C.E., Pitman A.J., Henderson- Sellers A., Robock A. , Ya K., Vinnikov , Speranskaya N.A., Mitchell K., Boone A., Braden H., Chen F., Cox P., de Rosnay P., Dickinson R.E., Dai Y-J., Duan Q., Entin J., Etchevers P., Gedney N., Gusev Y. M., Habets F., Kim J., Koren V., Kowalczyk E., Nasonova O.N., Noilhan J., Shaake J., Shmakin A.B., Smirnova T., Verseghy D., Wetzel P., Xue Y., Yang Z-L., Zeng Q., 2001, The representation of snow in land-surface schemes: results from PILPS 2(d), *J. Hydrometeorology*, **2,** 7-25

Sturm, K., Langmann, B., Hoffman, G. and Stichler, W., 2004a, Stable water isotopes in precipitation: a regional circulation modelling approach, *Hydrological Processes* (in press)

Sturm, K., Vimeux, F. and Krinner, G., 2004b, Seasonality in the water isotope signal over South America, submitted to *J. Geophys. Res.*

Viovy, N., 2003, http://www.pilpsc1.cnrs-gif.fr/

Wilson, M.F., Henderson-Sellers, A., Dickinson, R.E. and Kennedy, P.J., 1987, Sensitivity of the biosphere-atmosphere transfer scheme (BATS) to the inclusion of variable soil characteristics, *J. Clim. Appl. Meteor.*, **26,** 341-362

Wood E.F., Lettenmaier D.P., Liang X., Lohmann D., Boone A., Chang S., Chen F., Dai Y., Dickinson R.E., Duan Q., Ek M., Gusev Y.M., Habets F., Irannejad P., Koster R., Mitchel K.E., Nasonova O.N., Noilhan J., Schaake J., Schlosser A., Shao Y., Shmakin A.B., Verseghy D., Warrach K., Wetzel Y., Xue Y., Yang Z.-L. and Zeng Q.-C., 1998, The Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) Phase 2(c) Red-Arkansas River basin experiment: 1. Experiment description and summary intercomparisons, *Global Planet. Change*, **19**, 115-135

Xiao X., Mellilo J.M., Kicklighter D.W., McGuire A.D., Prinn R.G., Wang C., Stone P.H. and Sokolov A., 1998, Transient climate change and net ecosystem production of the terrestrial biosphere, *Global Biogeochemical Cycles*, **12**, 345-360

Yang Z.L., Pitman A.J., McAvaney B., and Henderson-Sellers A., 1995, The impact of implementing the bare essentials of surface transfer land surface scheme into the BMRC GCM. *Climate Dyn.*, **11**, 279-297

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