FIRST RESULTS FROM iPILPS

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Isotopes, particularly the stable water isotopes (SWIs), are one of the most useful and innovative tools for understanding complex processes in the water cycle, paleoclimate and biogeochemistry on many timescales. The stable isotopes of hydrogen and oxygen carried by water have been used to interpret long-term temperature trends and to monitor biological and abiological sources and sinks of CO_2 and CH_4. Atmospheric Global Climate Models were used to verify and interpret isotopic measurements over 20 years ago and recently climate models around the world have "rediscovered" the potential of SWIs (e.g., Stable Water Isotopes Intercomparison Group).

The naturally occurring water 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 Mean Ocean Water (VSMOW) exhibit systematic variations in the water cycle as a result of phase change and diffusion-derived isotopic fractionation. Coupled with measurement of isotopes in water sources, SWI characteristics are just beginning to provide insight into basin-integrated hydroclimates (Henderson-Sellers et al., 2004).

Isotopes in PILPS (iPILPS), under the GEWEX Land-Atmosphere Systems Study (GLASS), is a new Project for the Intercomparison of Land-surface Parameterization Schemes (PILPS; Henderson-Sellers et al., 1993) experiment synergistically linking land surface scheme (LSS) modeling and SWI analysis. iPILPS will establish, in collaboration with the International Atomic Energy Agency (IAEA) Moisture Isotopes in the Biosphere and Atmosphere, a globally spanning set of isotope-based sites in well-monitored catchments for LSS evaluation and improvement. The goals of iPILPS are to (i) offer a framework for intercomparison of isotope-enabled land-surface schemes (ILSSs) and (ii) encourage improvement of these schemes by evaluation against high quality (isotope) observations.

Phase 1 of this new GEWEX project tests the hypothesis that: Observation and analysis of the diurnal fluxes of ${}^1H_2{}^{18}O$ and ${}^1H{}^2H{}^{16}O$ among the soil, plants and atmosphere can accurately determine the partitioning of precipitation into transpiration, evaporation and total runoff (surface plus soil drainage). iPILPS will contribute to (i) improving the accuracy with which land-surface schemes partition net available surface energy into latent and sensible heat fluxes, and thus, (ii) to decreasing uncertainty in hydroclimate modelling and water resource vulnerability predictions.

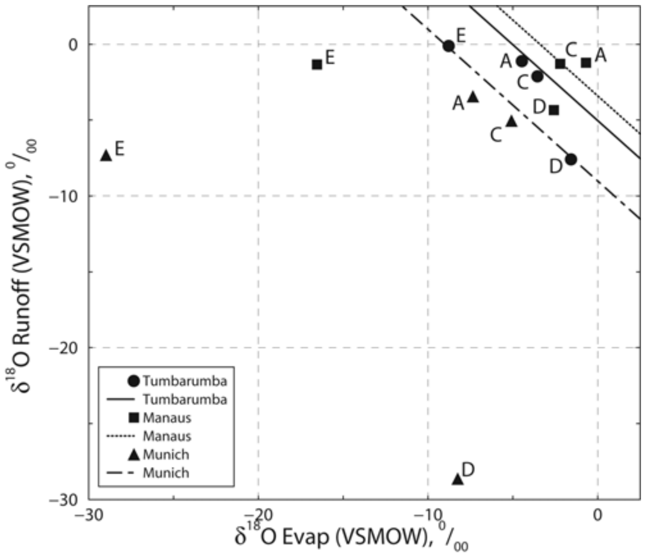
The iPILPS experiment was conducted for three sites covering a range of climatologies: (i) mid-latitude (deciduous) grass/woods, nominally at Munich, 48°N 11°E; (ii) tropical (evergreen) rainforest, nominally at Manaus, 3°S 60°W; and (iii) mid-latitude eucalypt (evergreen) forest, nominally at Tumbarumba, 35°S 148°E. These three locations were selected to link iPILPS to three GEWEX Continental-Scale Experiments (CSEs): the Baltic Sea Experiment (BALTEX), the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) and the Murray-Darling Basin (MDB) Project.

Four years of forcing data was provided for the three locations from the isotope-enabled atmospheric model, REgionales MOdel: Max Planck Institute for Meteorology (REMO), nested into the "climatological" version of ECHAM General Circulation Model (GCM). One of the isotopic LSSs did not use the provided forcing, but ran coupled with the isotope-enabled Goddard Institute for Space Studies (GISS) GCM. The experimental design directed each ILSS to use the first year's forcing repeatedly for as many years as that ILSS required to achieve equilibrium (this experimental component was designated EQY1), and then used the next 3 years' forcing to create 3 years' simulations (BC24). **Here we present preliminary results of the EQY1 experiment by five ILSSs whose simulations are already available.** The five ILSSs whose simulations are included here are (see Henderson-Sellers *et al.* (2005) for corresponding references): REMOiso ILSS, GISS ILSS, MATSIROiso, ICHASM and ISOLSM. In keeping with PILPS usual practice of model anonymity, we have randomly designated letters *A* to *E* to the ILSSs. They correspond to a Soil Vegetation Atmosphere Transfer (SVAT) (A), a Bucket (B), a complex SVAT (C), a SVAT/Bucket (D) and SVAT (E).

Each ILSS initialized water reservoirs at half capacity, all water isotope reservoirs at the VSMOW and all temperatures at the supplied annual mean surface air temperature. Equilibrium was defined as being the first occasion on which the January mean values of surface radiative temperature, latent and sensible heat fluxes, and rootzone soil moisture did not change by more than 0.01 K, 0.1 W m^{-2} and 0.1 mm, respectively, in 2 consecutive years; no criteria were specified for isotopic equilibrium. **The results show large differences among the participating ILSSs in simulating components of the surface energy and water budgets.** The intermodel ranges of the mean annual sensible heat flux are 24, 43 and 49 Wm^{-2} and for evaporation they are 28, 46 and 45 kg m^{-2} month^{-1} for Tumbarumba, Manaus and Munich, respectively.

Scaling the annual mean sensible and latent heat fluxes of individual ILSSs by the average of all models' net radiation, confirms strong association between the partitioning of surface available energy and model complexity; the more complex the model the lower the simulated mean annual Bowen ratio, in line with the earlier PILPS findings (e.g. Henderson-Sellers *et al.*, 2003). The pattern is less clear for partitioning of precipitation between evaporation and runoff.

The partitioning of mean isotope delta values of precipitation ($\overline{\delta P}$) to isotopic delta values of evaporation ($\overline{\delta E}$) and runoff ($\overline{\delta R}$) for the EQY1 is shown in the figure below for the three sites. The results should lie on lines with an intercept of $\overline{\delta P}$ and a slope of -1. ILSS B is excluded from the figure due to an as-yet unexplained error in its hydrology files. The main feature of this analysis is that no ILSS fits the expected lines, although *A* and *C* are generally closer than *D* and *E*. *D* has a runoff value that is too isotopically depleted for all sites. This is probably because ILSS *D* is not in isotopic equilibrium, although it has reached equilibrium with respect to the total (or bulk) energy and moisture.



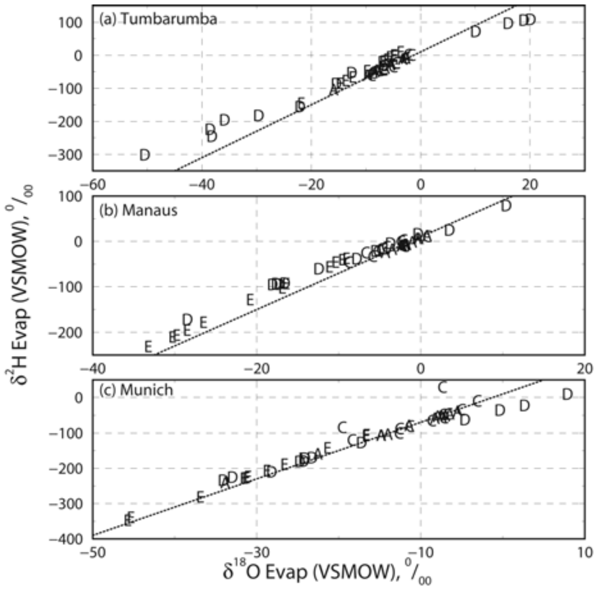
Evaporation v. runoff δ^{18}O (‰) simulated components of the annual mean water isotope budget for Tumbarumba, Manaus and Munich. The diagonal lines are the mean ^{18}O in precipitation as prescribed from REMOiso.

The δ^{18}O:δ^{2}H ratio in evapotranspiration compared to the Global Meteoric Water Line (GMWL) indicates the relative contribution from evaporation and transpiration to the total evapotranspiration. The figure on the right illustrates the monthly δ^{18}O:δ^{2}H plots for evapotranspiration in the three sites. Linearity of scatter occurs if the monthly pattern of δ^{2}H is the same as δ^{18}O, while departures from the GMWL show deuterium excess excursions. The δ^{18}O:δ^{2}H ratio is different between different ILSSs. The expectation is that δ evaporation from soil will fall to the left of the GMWL, since the evaporation should be isotopically depleted, relative to the soil water and canopy-intercepted water. However, if the total evapotranspiration is made up of a relatively high proportion of transpiration, then the δ evaporation flux should fall closer to the GMWL, since at monthly timescales the expectation is that δ transpiration ≈δ root zone water.

Typically, moisture exchanges are complex and ILSS simulations respond to, for example, root zone isotope gradients driven by soil evaporation and plant transpiration. These effects are the basis for testing the iPILPS hypothesis. Our preliminary analysis shows the *d* evaporation values of ILSSs *D* and *E* appear to be more affected by soil and canopy evaporation than by transpiration. ILSSs *A* and *C* show a wide range of behaviours from place to place (see the figure on page 13). For example, for *C*, in Manaus, *d* evaporation is depleted relative to the GMWL while *A* is not. In comparison, *A* and *C* are both depleted in Tumbarumba, but not to the extent of E and *D*. These behaviors, likely functions of the size and residence times of the soil reservoirs which are the source of evaporation and transpiration, and the mixing and selection processes which affect these reservoirs, underpin the current iPILPS investigations.

In view of the importance of isotope modeling in understanding the variability of both contemporary and paleoclimate and the interpretation of isotope observations, understanding the isotope feedback between the land surface and the atmosphere is critical for perceptive interpretation over a wide range of timescales. **From the iPILPS experiments, thus far, three conclusions can be drawn:**

i) Isotopic equilibrium is independent of the total water and energy budget, that is, an ILSS that is in equilibrium with respect to bulk energy and water is not necessarily in isotopic equilibrium;



δ^{18}O v. δ^{2}H components of the 12 monthly water isotopes in evapotranspiration, shown for the final year of the equilibration simulation, EQY1, all in ‰ relative to VSMOW for (a) Tumbarumba, (b) Manaus, and (c) Munich. The GMWL line is the dashed diagonal.

ii) SWIs exhibit complex responses to the hydrological parameterizations of different land-surface schemes (given the same surface properties and forcing data for a particular location); and

iii) SWIs offer new tools for land-atmosphere parameterization evaluation. The isotope transfer characteristics allow investigation of parameterized relationships between moisture partitioning and land-surface scheme complexity.

iPILPS is open to all land-surface schemes owners and users. To participate contact ipilps@ansto.gov.au. All the current experiments and results are available at http://ipilps.ansto.gov.au. We anticipate that new simulations will be proposed around November which will probe the sensitivity of ILSSs to time constants of surface water reservoirs.

References

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

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

Henderson-Sellers, A., K. McGuffie, D. Noone, and P. Irannejad, 2004. Using stable water isotopes to evaluate basin-scale simulations of surface water budgets, *J. Hydrometeorol.*, 5, 805-822.

Henderson-Sellers, A., M. Fischer, I. Aleinov, P. Irrannejad, K. McGuffie, W.J. Riley, G. Schmidt,, K. Sturm, and K. Yoshimura, 2005. Stable water isotope simulation by current land-surface schemes: Results of iPILPS Phase 1, *Global and Planetary Change*, (submitted).