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Moisture Isotopes in the Biosphere and Atmosphere (MIBA) in Australia: A priori estimates and preliminary observations of stable water isotopes in soil, plant and vapour for the Tumbarumba Field Campaign

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Abstract

An integral part of isotopes in the Program for Intercomparison of Land-surface Parameterisation Schemes (iPILPS) [Henderson-Sellers, A., in press. Improving land-surface parameterization schemes using stable water isotopes; introducing the iPILPS initiative. Global and Planetary Change, in press] is that the models' outputs be evaluated against measured values of δ^2H and δ^{18}O in the various simulated environmental compartments. This paper outlines the steps taken in Australia to initiate measurement of these stable water isotopes (SWIs) in the field, at a cool-temperate forest site in S.E. Australia near Tumbarumba, specifically to facilitate the model evaluation process. The selected sampling methodologies are detailed within the context of a conceptual model developed to describe the land–atmosphere exchange systems. This model has also been used to make a priori estimations of the isotopic values to be expected in each measured sub-system. As the data resulting from the Tumbarumba field campaign emerge, they will be compared with these working hypotheses to evaluate and, where necessary, amend the conceptual model. Initial comparisons based on preliminary data are presented here. The new observations derived in March 2005 should allow the land surface schemes used in weather forecast and climate change models to better reflect the environments for which they are attempting to make predictions.

Keywords: stable water isotopes; measurement; IAEA; MIBA; Australia; land model evaluation

1. Introduction

1.1. Moisture Isotopes in the Biosphere and Atmosphere

The World Summit on Sustainable Development, in 2002, clearly recognized the need to improve the scientific understanding of the water cycle as one of the key goals to achieve enhanced global resource management. To progress that goal, the Moisture Isotopes in the Biosphere and Atmosphere (MIBA) network was established by the International Atomic Energy Agency (IAEA) in Vienna in May 2004. The primary aim of this network is to facilitate the acquisition of environmental and experimental data on stable isotopes in all phases of biospheric and atmospheric water.

MIBA has been initiated in response to the recognised lack of systematic observations of water isotopes at time

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scales more frequent than monthly and space-scales ranging from grid points to small basins. In these respects, the MIBA network complements and expands upon the Global Network of Isotopes in Precipitation (GNIP) program, which has operated in conjunction with the World Meteorological Organisation (WMO) since 1961 (Rozanski et al., 1993). MIBA also extends the Global Network of Isotopes in Rivers (GNIR) effort initiated in the late 1990s (Gibson et al., 2002).

The data acquired by MIBA are designed to address a number of important issues, including the following that were listed and expanded upon in the broadcast invitation to join the network (Knohl, 2004):

- regional-scale hydrological budgets;
- partitioning of annual carbon fluxes;
- development of new global change indicators;
- ecosystem functioning;
- interpretations of ^{13}C and ^{18}O analyses in organic matter;
- validation of general circulation models; and
- past global responses to climate change.

Indeed, stable water isotopes have recently been identified as having their most "beneficial use…to validate numerical simulations of the water cycle in order to enable the use of these models for long term predictions of climate patterns" (Miller et al., 2005).

1.2. Australian contribution to MIBA

The MIBA IAEA Collaborative Research Program (CRP) has the official title of 'Isotope methods for the study of water and carbon cycle dynamics in the atmosphere and biosphere'. Its stated aims are: To supplement GNIP data and integrate isotope applications in hydrological and climate research, the IAEA has initiated efforts to improve the availability of isotope data for water cycle components other than precipitation. At present 13 countries have joined this CRP, including Australia, which was a founding member. Some of the participants will be coordinating input from additional regions of the planet.

Within MIBA, the Australian contribution is listed in the CRP documentation as follows:

"The research will enhance global efforts to better understand biogeochemical cycles through isotope studies. This will be achieved through contributing isotope data and associated environmental measures, collected in Australian stations including sites in the Murray Darling Basin. The data will be designed to address specific deficiencies in understanding aspects of leaf and soil water enrichment in ^{18}O, the relationship between the oxygen isotope composition of water vapour and rainfall, and of factors affecting the water balance in the Murray Darling River(s) Basin.

More generally, the program will contribute to improved regional and global modelling of climate change and better management of water resources".

1.3. iPILPS and MIBA

Plant physiologists' interest in ^{18}O enrichment of CO_2 respired by vegetation (e.g., Farquhar et al., 1993) has combined with the suggestion that stable water isotopes (SWIs), or more specifically the three major isotopologues of water, $^1H_2^{16}O$ and its rarer equivalents $^1H_2^{18}O$ and $^1H^2H^{16}O$, can be used to quantify and partition evaporation and transpiration water fluxes (e.g., Yakir and Sternberg, 2000; Henderson-Sellers et al., 2004). Pressure from the global carbon modelling and the climate change communities have combined to encourage the incorporation of SWIs into land-surface parameterisation schemes (LSSs) (e.g., Henderson-Sellers, 2006, this volume; Fischer, 2006-this volume). The iPILPS (isotopes in the Project for Intercomparison of Land-Surface Parameterisation Schemes) initiative to compare isotopically-enabled land-surface schemes' representation of isotopic tracers is the result of these diverse but converging research community needs.

Evaluation of numerical models can be by direct intercomparison of their various individual outputs as well as by 'reality checks' against reasonable limits for the variables simulated. However, the best evaluation is generally believed to come from direct comparison with quality-controlled observational data. Hence, field-acquired data on $\delta^{18}O$ and δ^2H in soil, plant and the relevant liquid, solid and vapour (atmospheric) phase water is being sought. These data need to encompass the diurnal cycle and be sampled at space and time scales appropriate to those of LSSs in global carbon and climate models. The MIBA observational campaigns are important because very few existing data are publicly available, e.g., Harwood et al. (1998), Riley et al. (2003), Yepez et al. (2003) and Williams et al. (2004). A preliminary evaluation of existing data sources determined that new field-sampling programs measuring SWI in a range of environmental samples comprising soils, stem and leaves, vapour and precipitation were necessary for iPILPS evaluations.