

# **SWING**

## **“Stable Water Isotope Intercomparison Group”**

### **Summary Report from the 1<sup>st</sup> SWING Workshop IAEA Headquarters, Vienna, Austria, 25-27 February 2004**

#### ***Summary***

This SWING workshop was a first meeting of a consortium of international well-known scientists with expertise on both stable water isotope modelling and measurements. The objectives of the meeting were the following:

- Enable an overview about on-going isotope modelling activities and measurement campaigns
- Initiate a proposed stable water isotope modelling intercomparison project
- Identify the most important need of new observational isotope data
- Strengthen the linkage between the stable water isotope modelling community and the International Atomic Energy Agency (IAEA) as one of the key contributors of observational present-day water isotope data.

The meeting was kindly sponsored by the Hydrology Section of the IAEA and held at the IAEA Headquarters, Vienna, on Feb. 25-27, 2004.

#### ***Rationale for a Stable Water Intercomparison Project***

Since more than four decades the isotopic composition of water stored in various archives (e.g. ice cores, ground water) has been used to study changes in the hydrological cycle on timescales from glacial-interglacial to short term variations. Such changes of the hydrological cycle play a crucial role forcing both past and future variability of the Earth's climate system. However, the interpretation of isotopic variations in terms of climate change is often handicapped by an observational lack of other relevant climate parameters (e.g. temperature, relative humidity, precipitation) both in space and time.

Modelling the isotopic composition of water within the hydrological cycle of general circulation models (GCM) may help to overcome this deficit on available climate data. Isotope GCMs simulate the  $^{18}\text{O}/^{16}\text{O}$  (and/or  $^2\text{H}/^1\text{H}$ ) relation as an independent quantity within a closed “model world” where all other relevant climate parameters are known, too. This enables an improved analysis of (simulated) isotope variability in terms of climate change. Modelling of stable water isotopes also offers the potential to improve our understanding of current-day tropospheric and stratospheric water vapour and cloud processes.

To ensure isotope GCM reliability, any isotope GCM simulation must pass a rigorous comparison of simulated versus observed isotope data (model-data-intercomparison). In addition, artefacts in isotope simulations based on a specific GCM model set-up or parameterisation have to be identified. The latter can be achieved by comparing simulation results of several different isotope GCMs run under identical boundary conditions (model-model intercomparison).

### ***Aims and Objectives of the First Workshop***

During the last decade several state-of-the-art GCM models (GISS, ECHAM, LMD, GENESIS and others) have been enhanced by the capability to simulate the atmospheric and/or ocean cycle of H<sub>2</sub><sup>18</sup>O and <sup>1</sup>H<sup>2</sup>H<sup>16</sup>O (=HDO). The purpose of this first SWING workshop was bringing together experts from the various research groups to discuss the following topics:

- Enable an overview about isotope GCM modelling activities 20 years after the first GCM modelling exercises of J. Jouzel, S. Joussaume. R. Koster and others
- Identify the most important need of new observational isotope data in space, time and the various aggregate forms of water (focus on modern climate variability and potential future climate changes)
- Initiate a water isotope modelling intercomparison project by discussing possible future common isotope GCM experiments of the various research groups
- Strengthen the linkage between the modelling community and the International Atomic Energy Agency (IAEA) as one of the key contributors of observational present-day water isotope data (GNIP network)

### ***Overview of the Given Presentations***

The first half of the workshop was dedicated to an overview about isotope research using GCMs and ongoing related scientific modelling and measurements activities. 14 scientific experts and consultants from 7 different countries reported on the following:

#### **Part #1 Isotope GCM Modelling Efforts:**

*Gavin Schmidt* (GISS, USA) started the presentations by giving a key overview of recent model activities using the new GISS Model E ocean-atmosphere coupled GCM. At present, this is the only coupled GCM that includes a water isotope module. Gavin focussed on recent simulation results related to upper troposphere-stratosphere water exchange (comparison of model results to CRYSTAL-FACE data), the possible effect of new diffusion coefficients suggested by Cappa et al. (2003) on Deuterium excess simulations, and on the temperature-isotope relation for modern and LGM climate simulations.

*David Noone* (University of Colorado, USA) presented simulation results of the Melbourne University GCM (MUGCM) focussing on the isotopic signal in precipitation over Antarctica. Identification of source regions (“tagging”) of water vapour and the potential use of water isotopes as a tool to study large-scale circulation changes (zonal mean versus eddy transport of water vapour) were one centre of this research work. David Noone also reported on ongoing research activities of incorporating a water isotope module into the next release of the NCAR Community Climate System Model (CCSM3).

*Jo Brown* (University of Reading, UK), a former colleague of David Noone, has also been working with the MUGCM model. Her research area covers interannual to decadal variability of water isotopes in precipitation in the El Niño / Southern Oscillation (ENSO) region and attempts to directly simulate the <sup>18</sup>O isotopic ratio of coral records. Within this context, a method of interactively calculated ocean surface water values of δ<sup>18</sup>O using the MUGCM precipitation and evaporation fluxes was presented.

*Ann Henderson-Sellers* (ANSTO, Australia) gave a short excursion on applications of stable water isotopes in current climate and forecast models to constrain basin scale gross water budgets.

*Kei Yoshimura* (University of Tokyo, Japan) is currently working on the development of a Raleigh-type Isotope Circulation Model (ICM). The ICM is not an isotope GCM, but a somewhat simpler Raleigh-type model operating on a global spatial scale and driven by isotope GCM output or reanalyses data (e.g. provided by ECMWF or NCAR). So far, it has mainly been used to analyse the major forcing factors of short-term (< 10 days) variability of isotopes in precipitation.

*Martin Werner* (MPI Biogeochemistry, Germany) presented past and present isotope results of the Hamburg GCM ECHAM, release cycles 3 and 4. Past research activities have focussed on glacial-interglacial climate changes and the use of stable water isotope records of polar ice cores as a temperature proxy. More recent analyses focus on decadal and interannual variability seen in the isotope records of tropical ice cores and the potential use of the deuterium excess as an independent proxy of source temperature changes.

*Paul Valdes* (University of Bristol, UK) gave an overview about future isotope modelling projects (BRIDGE, ASCRIBE, ISOMAP-UK) related to the Hadley Centre Climate Model (HadCM3 and several other model derivatives). The HadCM3 model has been used for numerous paleo-climate simulations, participating in several other model intercomparison studies like AMIP or PMIP. For future paleo-climate projects, the addition of water isotope to the hydrological cycle of HadCM3 has high priority. *Julia Tindall* (also University of Bristol, UK), who will be in charge of this task, participated at this workshop, too.

#### Part #2 SWING Related Projects:

*Ann Henderson-Sellers* (ANSTO, Australia) informed the participants about ongoing activities of the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) and future plans of IPILPS (Isotopes in PILPS). She strongly encouraged a cooperation of the IPILPS and the SWING projects to exploit synergies. A sharing of quality data (GNIP and GNIR networks) and of detailed model information (both isotope-enabled land surface schemes (LSS) and GCM output data) would ease the use of the SWING GCM output data as forcing for the projected LSS intercomparison within IPILPS. Such offline land-surface intercomparison could then enable an improved comparison of isotope GCM simulation results with observations available at sites (or river basins) studied in IPILPS.

*John Roads* (Scripps Institution of Oceanography, USA) gave an overview of the GEWEX Hydrometeorology Panel (GHP). This programme coordinates different continental scale projects (e.g. BALTEX) and different working groups (e.g. Water and Energy Budget Studies and Water Resource Applications). John Roads suggested that it was important to inform the broader GEWEX/GHP scientific community about the ongoing SWING research activities, as there might be some overlapping research interests. We therefore plan to present the SWING project at the upcoming 10th GEWEX-GHP Meeting (Montevideo, Sept. 6-10. 2004.)

#### Part #3: New Techniques Related to Isotope Measuring and Modelling:

*Kristof Sturm* (LGGE, France) presented isotope modelling research activities of both the French LCSE and LGGE institutes. His own work focuses on implementing stable water isotopes in the regional GCM REMO 5.0. First REMO simulations of the European Alps were forced with

ECMWF reanalyses data and ECHAM4 isotope GCM output as prescribed boundary conditions. Simulation results are in good agreement with observational data, and showed a clear improvement especially in alpine and alpine-related terrains as compared to the direct ECHAM4 isotope GCM output. Next steps of the regional modelling approach will be simulations over the South American Andean region and the evaluation of several alternative downscaling techniques (multi-variable regression, kriging, dynamical downscaling).

*Vyacheslav Zakharov* (Ural State University, Russia) has been the Principal Investigator of the IMG/ADEOS satellite project. Within this project,  $\delta D$  values of total water column amounts have been retrieved under clear sky conditions for the period December 1996 – July 1997. This data can be used for data-model comparisons of the stratosphere-troposphere water vapour exchange. Upcoming new instrumental data (e.g. NASA/TES spectrometer) will most likely enhance such analyses in the nearby future.

*Kimpei Ichiyonagi* (JAMSTEC, Japan) reported on the FORSGC network of Isotopes in Precipitation. Its focus lies on Asian monsoon circulation changes imprinted in the isotopic composition of precipitation. The FORSGC network has observational sites in Nepal/Tibet, Thailand, Indonesia and several surrounding Asian islands and was started in early 1999. Measurements of the isotope signal in precipitation are partly resolved on a daily to hourly time scale to improve the understanding of isotope processes in clouds and related convective precipitation events.

*Maxwell Kelley* (MIT/GISS, USA) presented some isotopically relevant moisture origin analyses from the GISS GCM, which determine source patterns to higher spatial resolution than previously and generalize existing technique by tagging evaporated moisture with spherical harmonic coefficients instead of geographic location. Source latitudes and continental fractions of Greenland and Antarctic snowfall roughly agree with those from lower-resolution GCMs and/or source analyses. For tropical ice-core locations, the relatively high resolution of the source patterns provides insight into the potential impact of precipitation recycling.

*Laurence Gourcy* (IAEA, Austria) concluded the session with a brief overview of IAEA activities related to the Global Network of Isotopes in Precipitation (GNIP).

### ***A Roadmap of Future SWING Activities***

The second half of the workshop was filled with discussions about the next research activities of the SWING project and the development of a more long-term project perspective. The following items were discussed and decided on:

- Three state-of-the-art isotope GCMs (GISS Model E, MUGCM, ECHAM4) are ready for common isotope simulations and present the initial core of the SWING model suite. Three more GCMs (CCSM3, HadCM3, CCSR) are most likely ready within the next 6-12 months and will join as soon as possible. Two 'older' isotope GCMs (LMD, GISS II) are still used by other research groups, which might also be interested in joining the SWING project and thus will be informed about it by M. Werner.
- In *Phase 0* (Feb-May 2004) of the SWING project, the intercomparison will consist of setting up an initial website and database. Already available model output of present-day control simulations of the different isotope GCMs will be collected. In addition, a pool of the available

'forward proxy models' (e.g. for coral records, foram records, lake carbonate, tree-ring cellulose) will be made distributable to all project members.

- Phase I (Feb-Dec2004) will focus on model-data-intercomparison for the *present-day climate*. Two new simulations with all available isotope GCMs will be performed using identical boundary conditions:
  - A 'climatological' control run with prescribed SST from the HadISST 1 data set, mean of period 1980-2000, all other boundary conditions (e.g. CO<sub>2</sub>) set to 1980's value
  - A 100-years simulation with prescribed SST from the HadISST 1 data set, period 1880-2000, and "recommended" other common boundary conditions (still to be defined in detail)
- For the model-data-comparison of the Phase I results, the following *available observational data* will be compiled and used:
  - Monthly mean values of all GNIP stations with at least 3 continuous years of both <sup>18</sup>O and D measurements. Laurence Gourcy (IAEA) will provide an update of the latest GNIP data including the 2001's measurements, and she will also calculate climatological mean isotope series, similar as Jean Birks (U of Waterloo, CA) has done it with older GNIP data.
  - For the 100-yrs simulation, only: monthly mean values of all GNIP records with at least 20 years of continuous measurements.
  - Isotope values of ocean surface waters (to be prescribed as a boundary condition for the present-day simulations) will be derived from the O-18 database maintained by Gavin Schmidt.
  - At present, two different satellite water isotope data sets exist: (i) The ATMOS data of lower stratospheric (tropical) Deuterium minimum (around -653‰) can be compared with January vertical profile minima of the different GCM simulations. (ii) The ADEOS satellite data provides δD values of the total water vapour column amount. To correctly compare these observational values with the GCM output, the weighting functions for both D and water vapour from the satellite retrieval algorithm should be applied in an identical manner to the GCM output data, if possible.
  - At present, two different satellite water isotope data sets exist: (i) The ATMOS data of lower stratospheric (tropical) Deuterium minimum (around -653‰) can be compared with January vertical profile minima of the different GCM simulations. (ii) The ADEOS satellite data provides δD values of the total water vapour column amount retrieved on clear sky observation spots. To correctly compare these observational values with the GCM output, the introduction of satellite-imitating diagnostics is needed including cloud distributions measured by image sensors (OSTC, AVNIR, POLDER) of the ADEOS satellite.
  - Tropospheric isotope profiles: The CRYSTAL-FACE data does not seem feasible for any model-data-comparison, yet. Older vertical profiles published by Ehhalt, Rozanski and Sonntag might be usable but this item needs further investigation.

- Surface vapour measurements (Heidelberg, Saclay, Cape Grim, Vienna) might allow a model-data-comparison of short-term isotope variability. There may exist also high-frequency precipitation measurements at these stations.
- At this early stage, land surface data from the BASIN project and river runoff measurements by Kendall & Coplan and the GNIR project (Global Network of Isotopes in Rivers) will not be included in the intercomparison, but may be integrated in future SWING activities.
- A selection of available Antarctic and Greenland snow measurements has been compiled by Georg Hoffmann. He will be kindly asked to contribute this compilation to the SWING database.
- Detailed intercomparison of atmosphere land stable water isotope exchanges will be offered as an additional option based around one (or a few) locations where high quality observational data exist. These are likely to be selected from Heidelberg, Saclay, Cape Grim and Vienna but might alternatively be where the densest GNIP station continuous data exist.
- *Phase II* (approx. start Jan2005) will focus on model-data-intercomparison for *selected paleo time slices*. Several time slices of interest (LGM, YD, 8.2k) were already identified but the exact definition of boundary conditions for such paleo-simulations was postponed to a next SWING meeting.
- It was agreed on storing all different GCM model output in a common NetCDF format. The data should always be stored in original model grid, and an identical interpolation routine should be used to convert results to a common grid (2°x2°) to compare the results of the different GCMs. To reduce interpolation errors during grid conversion, one person will be in charge of converting the different GCM model output to the common grid, but the interpolation routine will be made available to all project members via the SWING website.
- The storage of comparable GCM simulation output from the SWING model suite in a common database will be of immediate, great use for several other water isotope related research groups/projects, like REMO, ICM and IPILPS.
- To facilitate the use of the isotope GCM results to a wider scientific community, short workshop reports of the SWING meeting will be submitted to EOS, IGBP and GEWEX newsletters. Furthermore, the SWING website will allow free data access to project members and the public. In addition, Ann Henderson-Sellers offered the possibility of a special issue of “Global and Planetary Change” dedicated to the SWING project. However, the workshop participants agreed that at this stage with no ‘real’ intercomparison results performed or analysed, it was too early to take such an offer. The same is true for a formal association of the SWING project to other well-known intercomparison studies (e.g. AMIP II, PMIP II).

### ***Recommendations for Future GNIP Activities Related to SWING***

The participants of this first SWING workshop all acknowledged the precious contribution of the Global Isotopes in Precipitation (GNIP) network maintained by the Hydrology Section of the International Atomic Energy Agency to the SWING project and the designed model-data-intercomparison study. To further facilitate these activities, two recommendations related to future GNIP activities are passed on to the IAEA:

- It is recommended that so-called 'climatological' values (i.e. mean annual value, mean values of all 12 individual months) of all GNIP stations with at least 3 years of continuous  $^{18}\text{O}$  and D measurements should be calculated (isotope values as precipitation-weighted means) and published on the IAEA/GNIP website. These values should be updated regularly (e.g. once a year) as new observational data becomes available for different GNIP stations. Such observational isotope climatology of the different GNIP stations will serve as a key *reference standard* to any future isotope model-data comparison (similar to the reference standards provided by the IAEA for isotope measuring laboratories).
- A key issue of recent Earth system research is the differentiation between natural climate variability and anthropogenic influenced climate change. Here, the GNIP stations with long continuous observational records of  $\delta^{18}\text{O}$  and  $\delta\text{D}$  in precipitation provide a very valuable tool, as such long-term direct observational measurements allow identifying influences of phenomena like El Niño or North Atlantic Oscillation (NAO) on the isotopic composition of precipitation. Therefore, the SWING project members propose that the IAEA should support the future continuation of such GNIP stations with long continuous observational records as well as possible.