Mapping isotope variability in water resources research

Recent activities of the International Atomic Energy Agency

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IAEA - Isotope Hydrology Section, Vienna
OUTLINE

• Current work on water isotope data compilation at the IAEA

• Current status of GNIP and other isotope networks and databases.

• Isotope mapping in connection with the understanding of the water cycle and water resources management
Rationale for IAEA’s Work in Water

• United Nations Agency
• Mandate has 3 areas of work
• 1- Non-proliferation
• 2- Nuclear safety
• 3- Peaceful uses of nuclear/isotope technology
  • Agriculture, Human Health, Industrial Applications and……………….Water!
Themes where isotopes are applied

- **Groundwater assessment & management** (origin, recharge, flow, gw dynamics, interconnections, vulnerability, etc)
- **Catchment hydrology** (surface water)
- Groundwater-surface water interactions
- Increasingly **inter-sectorial themes** (catchment/aquifer management, river basin mgmt, coastal zone mgmt etc.)
- Others (**geothermal**, artificial recharge, wetlands, **urban hydrology**, etc)
Elements of the IAEA’s Water Resources Programme

• Advancing the field of Isotope Hydrology and adapting technology through research (CRPs, technical meetings, etc.)

• Providing isotopic tools and support services

• Capacity-building for problem solving (Technical Cooperation Programme)
Support through Technical Cooperation Projects

• About 85 active projects (funding ~$ 8 to 10 M/cycle)
Isotope monitoring programmes

- **Global Network of Isotopes in Precipitation (GNIP)**
  - Monthly, event, vapour, Antarctica

- **Global Network of Isotopes in Rivers (GNIR)**

- **Moisture Isotopes in the Biosphere and Atmosphere (MIBA)**
You are in: Home » Nuclear Sciences and Applications » Water Resources Programme » GNIP

GNIP Programme
Global Network of Isotopes in Precipitation

Resources

Global Network of Isotopes in Precipitation

Welcome to the Global Network of Isotopes in Precipitation (GNIP) and its associated database. The IAEA’s Water Resources Programme and the World Meteorological Organization (WMO) have been surveying the content of hydrogen and oxygen isotopes in precipitation since 1961. The data are used for a variety of purposes in the fields of hydrology, oceanography and hydrometeorology and in investigations related to the Earth’s water cycle and climate changes.

Description and Mode of Operation

General
GNIP: Current status

- GNIP data distributed into 4 categories:
  - GNIP- monthly ~100,000 records ~910 st
  - GNIP- event ~15,000 records ~150 st
  - GNIP- vapour ~1,000 records ~10 st
  - GNIP- Antarctica* ~1230 sites

MONITORING ISOTOPES IN PRECIPITATION: GNIP
Development of GNIP

1) 1960s Radioactive fallout: Thermonuclear atmospheric tests (1952-1963) → global monitoring

2) 1961 - 1975 Full network → isotope hydrology

3) 1976 onwards - reduced GNIP + development of National Networks (200 operational stations)
Main applications of GNIP data

- basic isotope data for the use of environmental isotopes in hydrological investigations: Isotope hydrology

- investigations of past and present climate changes and the response of the hydrological cycle to climatic fluctuations

- calibration and validation of atmospheric circulation models (AGCM) with varying degrees of complexity

- isotopes as tracers of water or biological material for ecology, food, forensic studies, etc.
Contents of the GNIP database

Monthly values:

• Total amount of precipitation (mm)
• Type of precipitation (rain, snow, both)
• Mean air temperature (°C)
• Mean water vapour pressure (hPa)
• Stable Isotope contents (O-18, H-2) (‰)
• Tritium content and uncertainty (TU)
Operation of GNIP

- International Atomic Energy Agency
  - Isotope Hydrology Section
  - Isotope Hydrology Laboratory
- World Meteorological Organization
  - Link to the stations
  - Meteorological information
- Cooperating institutes and laboratories (voluntary basis)
- Scientific Steering Committee
The network is composed of:

- **IAEA/WMO stations** located in climatically relevant locations

- **National networks** composed of stations operated by national authorities

- **Affiliated stations** which are stations resulting from studies, often of short-term in nature
National networks

Argentina, Australia, Austria, Canada, China, Chile, Croatia, France, Germany, India, Netherlands, Portugal, South Africa, Spain, Switzerland, Turkey, USA

One GNIP station maintained in:

Algeria, Egypt, Indonesia, Israel, Jordan, Morocco, New-Zealand, Poland, Slovenia, U.K.
GNIP stations
Status of the network in 2008

About 185 active stations in 53 countries

The Isotope Hydrology Laboratory of IAEA is currently performing isotope analyses of about 30% of the collected precipitation samples.

23 other laboratories are analysing GNIP samples.

Isotope and meteorological data are compiled and uploaded into ISOHIS/GNIP database once a year.
Operational Problems

- Partial or incomplete isotope records
- Sudden closure of stations
- Sampling/storage protocols not followed
- Uneven spatial coverage of stations
- Need for data in remote areas
- Replacement by automatic weather stations
- Continuity of GNIP “national coordinators”
- Collaboration on voluntary basis
Unequal geographical distribution

GNIP stations (monthly)
Initiatives to correct negative trend

- Involvement of other groups/organizations
  - Collection → Met. Services (WMO)
  - Analysis → IH labs

- Creation/continuity of National Networks

- Long/term operation - GAW stations

- Focus on remote or climate-sensitive areas

- Links with other projects/programmes
  (e.g. AMMA, )
Global Terrestrial Network
Hydrology (GTN-H)
"Network of Networks"

- **Soil moisture**
  - In-situ Soil Moisture Network (planned)
    - SMOS, HYDROS

- **Ground water**
  - IGRAC

- **Lake levels**
  - GTN-L?
    - SHI St. Petersburg?

- **Water vapour**
  - WMO WWW

- **River discharge**
  - GRDC / GTN-R

- **Snow cover**
  - NSIDC
  - WGMS / GTN-G

- **Evapotranspiration**
  - FLUXNET

- **Water quality / BGC fluxes**
  - GEMS/Water

- **Water use**
  - FAO/AQUASTAT

- **Isotopes**
  - IAEA / GNIP

- **Precipitation**
  - GPCC
  - GPCP
  - NCDC / GSN

**Global network/coverage**

- **Defined and contact established**
- **Partly existing/identified and/or contact to be improved**
- **No identified**

**GCOS Essential Climate Variable**
$\delta^2H$ vs $\delta^{18}O$ relationship - GMWL

$\delta^2H = 8.09 \delta^{18}O + 11$
$r^2 = 0.99$

$\delta^2H = 7.75 \delta^{18}O - 5$
$r^2 = 0.99$
Global air temperature vs $\delta^{18}$O relationship

GNIP-Monthly

GNIP-Antarctica
Also provided by GNIP

• Chronicle of tritium injected by the thermonuclear tests in 1960s and progressive decline to pre-nuclear levels

• Input function of tritium for models in hydrogeology (and oceanography) to estimate groundwater residence times in the aquifers
Primary objective of GNIP - Tritium released by atmospheric nuclear tests
Other global isotope monitoring activities

- **Isotope Network of Isotopes in Rivers (GNIR)** → J. Gibson, B. Fekete

- **Moisture Isotopes in the Biosphere and Atmosphere (MIBA)** → Brent Helliker
GNIR: Time-series of oxygen-18 in European rivers (12 month running means)
River Isotope Data Applications

- Integrated river (USGS) and precipitation (GNIP) isotope data into continental scale hydrological models → Balazs Fekete will talk about this

- Also incorporated in Leavesley’s USGS model for validating runoff routing estimates
GNIR sites (about 20,000 records being compiled and revised)
Moisture Isotopes in the Biosphere and Atmosphere (MIBA)

A global network to sample water isotopes in:

- Plant leaves
- Plant stems
- Soil water
- Atmospheric vapor

→ Links water/soil/atmosphere
Resources

Moisture Isotopes in the Biosphere and Atmosphere

Background and Justification

The International Atomic Energy Agency (IAEA), in cooperation with the WMO, has long been operating the Global Network of Isotopes in Precipitation (GNIP), which has provided global data to understand and simulate the water cycle under present and past climates. Recently, the IAEA initiated efforts to improve the availability of isotope data on other water cycle components in an effort to supplement GNIP data and integrate isotope applications in hydrological cycle, carbon cycle, and climate research. The group for Moisture Isotopes in the Biosphere and Atmosphere (IAEA-MIBA) was constituted and includes a group of scientists with diverse research interests ranging from local ecosystems to global scales. read more
MIBA sites (work in progress: 1000 records in IAEA’s web page)
Isotopes in surface and ground waters (IGLASS)

- Compilation of isotope and hydrochemical data obtained as part of about 350 IAEA-supported TC projects in developing countries

- Geo-referenced isotope database (about 50,000 records)
  - Shallow and deep groundwaters
  - Spring waters
  - Geothermal manifestations
  - Lakes, swamps, wetlands, etc
  - Rivers
Isotope data availability
Asia & Pacific 2008
ISOHIS
Isootope Hydrology Information System

WISER
Water Isotope System for Data Analysis, Visualization, & Electronic Retrieval

www.iaea.org/water
• Monitoring networks (GNIP, GNIR, MIBA) → about 140,000 records

• Hydrological, isotope and hydrochemical data from ~350 Isotope Hydrology projects → 40,000 records → 50,000 records

• IAEA Technical Cooperation Projects (~300 projects 1970-2005)

• Non-IAEA projects contributing with additional isotope data (~50 projects)
ISOHIS contents

- Project code and background info
- Sample names and description
- Geographical coordinates and sample type
- Information on hydrological settings
- Isotope and chemical data (100+ param.)
- Laboratory codes, source of info, etc.
WISER

GIS Mapping for Analysis, Visualization and Retrieval of Hydrochemical and Isotope Data for local to global scales.

Attention: If you want to use all functions, please deactivate the pop-up blocker of your internet browser.

The WISER has been developed by IAEA in collaboration with the University of Vienna, IfGR
### GNIP MONTHLY STATIONS

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ATLAS OF ISOTOPE HYDROLOGY AFRICA
Presents summary information of about 10,500 water samples - 26 countries and 79 IAEA projects
GIS products

- Global and regional isotope maps showing areal distribution – input function to water systems and sources of water

- Isotope cross-sections and 3D-blocks. Depth oriented sampling, allows visualizing vertical structure of water bodies: age and/or water quality distribution.
Isotope maps/visualization tools

- $^{18}$O in prec. distribution maps and animations (Birks et al.)
- Gridded global/regional isotope maps $1^\circ \times 1^\circ$
- Regional maps isotopes in precipitation (arithmetic/weighted means)
- Isotope cross-sections and 3D blocks in aquifers
- Combined isotope maps ($^{18}$O - $^{14}$C in groundwaters, $^{18}$O in present-day prec. and in gw, etc.)
isotope data, basic meteorological variables as recorded by the stations such as type and amount of precipitation, surface air temperature and vapour pressure.

World maps showing spatial distribution of $\delta^{18}$O/trit in precip.
Animations: seasonal variation of isotope concentrations in precipitation
Regional isotope maps
Gridded isotope maps

3D-diagrams to visualize groundwater origin, dynamics and flow patterns

Fig. 1: Hydrogeological setting of Chapai Nawabganj area.
Santiago de Chile: Isotopes as a tool to define sources of recharge, groundwater origin, flow patterns and pollutant transport

Interpolation methods (under testing)

- Multivariate interpolation
- Inverse distance weighting
- Kriging
- Optimal interpolation (Ganding’s approach)
- Weighted anisotropic interpolation
Isotope contents in “deep” groundwaters – Northern Africa → mapping fossil gw
Isotope contents in “deep” groundwaters – Northern Africa
$\delta^{18}O \, (\%o)$

Deep groundwater

Present-day precipitation

$\delta^{18}O \, (\%o)$

$> 0$

$-11$
Recent recharge to deep aquifers (1968-1978)
Concluding remarks

• The IAEA has extended isotope monitoring beyond GNIP and provides access to other global isotope databases.

• Current efforts focus now on the compilation of historical isotope data (mainly ground- and surface waters) and the development of geostatistical methods and GIS tools.

• Contributions of data/samples/analysis to GNIP (after publication) and to the other isotope databases are welcome (such as Antarctica), at ihs@iaea.org.
Thank you !!!