



# 46<sup>TH</sup> IAH CONGRESS MALAGA 2019

GROUNDWATER MANAGEMENT AND GOVERNANCE  
COPING WITH WATER SCARCITY

46<sup>th</sup> CONGRESS OF INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS



**CEHYUMA**  
CENTER OF HYDROGEOLOGY  
OF UNIVERSITY OF MALAGA



UNIVERSITY  
OF MALAGA

## Congress Programme



# SCIENTIFIC PARTNERS

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# SCIENTIFIC PROGRAMME

## Topic 1 - Groundwater assessment and management

Groundwater management should be based on adequate resource assessment and aquifer functioning. Nevertheless, groundwater is in the origin of many conflicts. In many cases, these conflicts arise not due to groundwater availability but to poor management and governance.

## Topic 2 - Groundwater and climate change

Countries from temperate zones of the Earth, such as Western Mediterranean countries of both Southern Europe and North Africa, are expected to experience impacts on the sustainability, quantity, quality, and management of water resources. Future scenarios forecast the decline in streamflow reducing reservoir storage for population supply. In this context, groundwater becomes an increasingly strategic resource to meet water demand from urban areas and agriculture.

## Topic 3 - Groundwater sustainability and governance

Major changes are ongoing in population growth, human migration, and land use, increasing the stress on the available quantity and quality of water resources. Water demand is increasing particularly in regions where it is already scarce, both for human and agricultural uses. It is important to analyze the sustainability of groundwater use around the world, and especially of some of the largest aquifers in the world. At the current pace, aquifers on which millions of people depend could be depleted in the near future. Can we move from groundwater mining into groundwater usage of renewable resources?

Within this topic will be organized a session on [Groundwater and water security in developing countries \(Topic 3.1\)](#).

## Topic 4 - Groundwater footprint and virtual water

Water resources management is an important issue in arid and semi-arid regions. In many cases water conflicts arise not because of the scarcity in water resources but because of improper management. Concepts such as virtual water and water footprint can help in improving current management practices and provide new insights, a new awareness about the importance of the resource. The groundwater footprint has served to bring awareness about the current usage of groundwater and to point out the aquifers whose management is unsustainable. The low number of abstracts submitted to this Topic has been included in related topics.

## Topic 5 - Tools, methods and models to study groundwater

This topic deals on the broad spectrum of methodologies and models conventionally applied in Hydrogeology (hydrogeological mapping, hydrodynamic, hydrochemistry, isotopes, tracers, etc.), but particularly to the most innovative ones and to new trends in modelling.

Within this topic several sessions will be organized:

- [Topic 5.1](#) - Dynamic Analogues (TOTAL)
- [Topic 5.2](#) - High island hydrogeology

- **Topic 5.3** - Advanced modelling tools for subsurface hydrology: from the vadose zone to deep environments.
- **Topic 5.4** - Innovative approaches for understanding groundwater flow systems

## **Topic 6 - Groundwater, wetlands and natural heritage**

Most wetlands, particularly the permanent ones, are groundwater dependent. They are fragile ecosystems that can be located in the recharge or in the discharge areas of aquifers (some can be located in an intermediate position). To recognize the relationship between wetlands and groundwater is crucial for their adequate management and the preservation of the natural heritage to which they belong.

## **Topic 7 - Karst Hydrogeology**

This section deals with the recent advances and novel application of research methods in hydrogeological studies in karst systems. Special emphasis will be focused on issues related to quantity and quality of karst waters, hydrodynamic, hydrochemistry and isotopes. A deeper understanding of tracing techniques by means of fluorescent and natural tracers are key aspects for a more precise conceptualization of carbonate karst aquifers. Additionally, new trends on groundwater recharge and water management as well as modeling methods for simulating flow distribution, solute transport and reactive (coupled) processes will also be highlighted in this topic.

## **Topic 8 - Groundwater quality and pollution processes**

Groundwater usage, once available, very often depends on its quality. Groundwater quality is greatly modified by the geologic substratum, but also it is threatened by human-induced pressures and the appearance of emerging chemicals. Therefore, appropriate groundwater protection and remediation strategies (in case of polluted waters) must be applied for preserving present and future human health and its well-being.

## **Topic 9 - Groundwater and socio-economic development in Latin-America**

Under this heading it is proposed to organize an Ibero-American mini-symposium, specifically targeted to Iberian and Latin-American participants, concerning on topics like mining activities, groundwater monitoring and assessment, socio-economic impact of groundwater.

## **Topic 10 - Urban groundwater**

Groundwater forms a pivotal resource for future cities worldwide, for water, energy, flood mitigation, integrated surface-ground water management, and low carbon, equitable and sustainable cities. All abstracts on presentation of new scientific understanding of key processes of urban groundwater resources, contamination impacts and opportunities, are welcomed, as well as interdisciplinary presentations on urban planning, groundwater management and use.

# VENUE

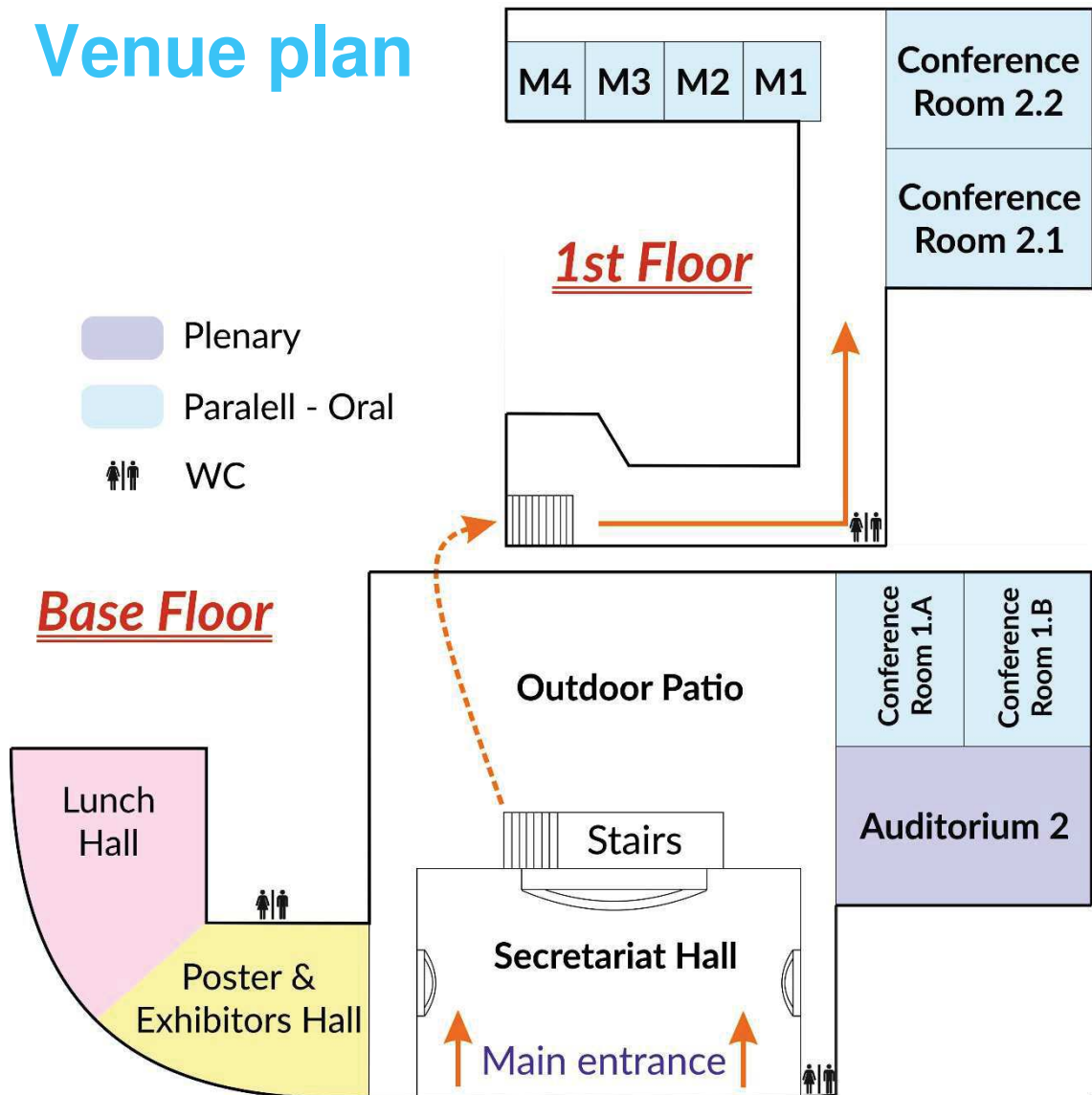
## Congress Venue

### Trade Fairs and Congress Center of Malaga (FYCMA)

Av. de José Ortega y Gasset, 201  
29006 Málaga



## Venue plan



# PROGRAMME AT-A-GLANCE

Time	Sunday 22 <sup>nd</sup>	Monday 23 <sup>rd</sup>	Tuesday 24 <sup>th</sup>	Wed. 25 <sup>th</sup>	Thursday 26 <sup>th</sup>	Friday 27 <sup>th</sup>
09:00	Pre-congress short courses & IAH Council Meeting (Ada Byron Research Building)	Open ceremony	Plenary Lecture	Mid Congress field trips	Plenary Lecture	Plenary Lecture (9:00-9:30)
10:00		Opening Lecture				
10:00	Coffee break	Coffee break	Parallel-Oral		Coffee break (10:40-10:40)	
10:30						
10:30	Parallel-Oral	Parallel-Oral	Parallel-Oral		Coffee break (10:40-11:15)	
11:15						
12:45	Lunch	Lunch	Lunch		Parallel-Oral	
14:20						
14:20	Plenary Lecture	Plenary Lecture	Plenary Lecture	Plenary Lecture		
14:50						
15:00	Parallel-Oral	Parallel-Oral	Parallel-Oral	Parallel-Oral		
16:00						
16:00	Poster and Coffee Break	Poster and Coffee Break	Poster and Coffee Break	Poster and Coffee Break		
17:00						
17:00	Registration	Parallel-Oral	General Assembly	Parallel-Oral (17:00-18:00)		
18:30	Icebreaker Cocktail (19:00 - 21:00)	Comissions and Networks	Comissions and Networks			
18:30						
19:30	Social Events	Walking Tour (21:00)	ECHN Event (20:30-22:30)	Comissions and Networks (18:00-19:30h)		
19:30						
Social Events				Gala Dinner (20:45)		
					Closing ceremony	

## SUNDAY 22<sup>ND</sup>

### RESEARCH BUILDING ADA BYRON

<b>9:00 - 18:00</b>	<p><b>Pre-congress courses</b> <i>Room B.1.1 and Room A.O.1</i></p> <p><b>IAH Council meeting</b> <i>Room B.0.6</i></p>
<b>14:00 - 18:00</b>	<p><b>IAH Commission on Transboundary Aquifers</b> <i>Room B.2.10</i></p>
<b>18:00</b>	<p><b>Departure to Congress Venue</b></p>

### TRADE FAIRS AND CONGRESS CENTER

<b>17:00</b>	<p><b>Early Registration</b></p> <p><i>It is highly recommended that you register on Sunday before the ice-breaker to avoid long lines on Monday.</i></p>
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### EVENING SOCIAL

<b>19:00 - 21:00</b>	<p><b>ICE-BREAKER COCKTAIL</b></p> <p><i>Meeting point: Venue of the Congress: Trade Center of Malaga</i></p>
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## MONDAY 23<sup>RD</sup>

<b>8:15 - 9:00</b>	<p><b>Registration</b></p>
<b>9:00 - 10:00</b>	<p><b>Opening Ceremony</b> <i>Auditorium 2</i></p>
<b>10:00 - 10:30</b>	<p><b>Opening Lecture</b> <i>Auditorium 2</i></p> <p><b>Managed Recharge to Restore Aquifers: Past, Present and Future #878</b> <b>Speaker: Jesus Carrera, Institute of Environmental Assessment and Water Research (IDAEA-CSIC)</b></p>
<b>10:30 - 11:15</b>	<p><i>Coffee break</i></p>

<b>11:15 - 12:45</b>	<b>Parallel – Oral</b> <i>Monday Morning. Session 1 to 7. Topics 1, 2, 3, 3.1 and 5.</i>	
<b>12:45 - 14:20</b>	<i>Lunch</i>	
<b>14:20 - 14:50</b>	<b>Plenary Lecture</b> <i>Auditorium 2</i> <b>Groundwater Project and eBooks: An Evolving Platform for Groundwater Education and Practice #781</b> <b>Speaker: John A. Cherry, G<sup>360</sup> Institute for Groundwater Research</b>	
<b>15:00 - 16:00</b>	<b>Parallel – Oral</b> <i>Monday Afternoon. Session 1 to 7. Topics 1, 2, 3 and 5.</i>	
<b>16:00 - 17:00</b>	<b>Posters with refreshments</b> <b>Meeting of IAH-Italian Chapter</b> <i>Multiuse room 1</i>	<b>Wikipedia edit-a-thon*</b> <i>Multiuse room 4</i> <b>Chair: Kirsty A. Upton</b>  <b>*16:00 - 19:00</b>
<b>17:00 - 18:30</b>	<b>Parallel – Oral</b> <i>Monday Afternoon. Session 8 to 15. Topics 1, 2, 3.1, 5.3, 8 and 10.</i>	
<b>18:30 - 19:30</b>	<b>IAH Early Career Hydrogeologists Network (ECHN) meeting</b> <i>Conference room 1.A</i>	

### EVENING SOCIAL

<b>21:00</b>	<b>WALKING TOUR IN MALAGA CITY</b> <i>Meeting point: C/ Molina Larios 22. Malaga</i>	<i>Dinner not included</i>
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## TUESDAY 24<sup>TH</sup>

<b>9:00 - 10:30</b>	<b>Plenary Lectures</b> <i>Auditorium 2</i> <b>Chair: Bruce Missier</b>
	<b>9:00 - 9:30</b> <b>Transboundary Aquifers: Groundwater Management and Governance in a Water Scarce World #873.</b> <b>Speaker: Gabriel Eckstein, Texas A&amp;M University</b>
	<b>9:30 - 10:00</b> <b>Groundwater, water-security and sustainable livelihoods #601</b> <b>Speaker: Alan MacDonald, British Geological Survey</b>
	<b>10:00 - 10:30</b> <b>Climate Change Effects on Groundwater: Expectations and Observations #618</b> <b>Speaker: Matthew Rodell, NASA Goddard Space Flight Center</b>

<b>10:30 - 11:15</b>	Coffee break
<b>11:15 - 12:45</b>	<b>Parallel – Oral</b> <i>Tuesday Morning. Session 1 to 8. Topics 1, 2, 3, 5.3, 8 and 10.</i>
<b>12:45 - 14:20</b>	Lunch
<b>14:20 - 14:50</b>	<b>Plenary Lecture</b> <i>Auditorium 2</i> <b>New city planning policy processes – creating a prescient awareness of groundwater for future places and people #876</b> <b>Speaker: Helen Fallas, British Geological Survey</b>
<b>15:00 - 16:00</b>	<b>Parallel – Oral</b> <i>Tuesday Afternoon. Session 1 to 8. Topics 1, 2, 3, 5, 5.3, 8 and 10.</i>
<b>16:00 - 17:00</b>	<b>Poster with refreshments</b>
<b>17:00 - 18:30</b>	<b>General Assembly</b> <i>Auditorium 2</i>
<b>18:30 - 19:30</b>	<b>Meetings of commissions and networks</b>  <b>National Chapters meeting</b> <i>Auditorium 2</i>  <b>IAH Urban Groundwater Network</b> <i>Conference room 1.B</i>  <b>IAH Commission on Regional Groundwater Flow</b> <i>Conference room 2.1</i>  <b>IAH "Forward look initiative." The future of Hydrogeology</b> <i>Conference room 2.2</i>  <b>IAH Burdon Groundwater Network for International Development</b> <i>Multiuse room 1</i>  <b>Water-Food-Energy nexus and Groundwater (UNESCO IGCP-684)</b> <i>Multiuse room 2</i>  <b>IAH Network Coastal for Aquifer Dynamics and Coastal Zone Management (CAD-CZM)</b> <i>Multiuse room 3</i>

## EVENING SOCIAL

<b>20:30 - 22:30</b>	<b>ECHN EVENT</b> Meeting point: Jardín Botánico of UMA. Bulevar Louis Pasteur 29. Malaga.
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## WEDNESDAY 25<sup>TH</sup>

### Field trip 1



#### Wetlands

**Departure** 8:30 / **Return** 19:00 approx.

**Meeting point:** The City Hall of Malaga

**Guides:** José Manuel Gil, Luis Linares, Miguel Rodríguez and Claus Kohfahl

*Field trip supported by*



ACADEMIA MALAGUEÑA  
DE CIENCIAS

### Field trip 2



#### Axarquia region

**Departure** 8:00 / **Return** 19:00 approx.

**Meeting point:** The City Hall of Malaga

**Guides:** Antonio González, Manuel López Chicano, Jorge Prieto and María Luisa Calvache

*Field trip supported by*



SOFTCRITS  
Software for Critical Systems

### Field trip 3



#### Eastern coast

**Departure** 8:30 / **Return** 20:30 approx.

**Meeting point:** The City Hall of Malaga

**Guides:** Cristina Liñán, José Benavente, Francisco Carrasco and Lucía Ojeda

*Field trip supported by*



FUNDACIÓN  
Cueva de Nerja

### Field trip 4



#### Costa del Sol

**Departure** 8:30 / **Return** 19:00 approx.

**Meeting point:** The City Hall of Malaga

**Guides:** Damián Sánchez and Manuel Argamasilla

*Field trip supported by*



HIDRALiA



SUEZ

**Field trip 5**



**Karst hydrogeology**

Departure 9:00 / Return 19:00 approx.

Meeting point: The City Hall of Malaga

Guides: Matías Mudarra, José Francisco Martín and Ana Isabel Marín

Field trip supported by



**Field trip 6**



**Guadalhorce river basin**

Departure 8:00 / Return 19:00 approx.

Meeting point: The City Hall of Malaga

Guides: Iñaki Vadillo and Begoña Urresti

Field trip supported by



**Field trip 7**



**Sierra de Mijas - Bajo  
Guadalhorce**

Departure 9:00 / Return 18:00 approx.

Meeting point: The City Hall of Malaga

Guides: José Manuel Nieto and Javier Martín Arias

**Field trip 8**



**Serranía de Ronda**

Departure 8:00 / Return 19:00 approx.

Meeting point: The City Hall of Malaga

Guides: Bartolomé Andreo, Juan Antonio Barberá and Beatriz de la Torre

Field trip supported by



## THURSDAY 26<sup>TH</sup>

<b>9:00 - 10:30</b>	<p><b>Plenary Lectures</b> <i>Auditorium 2</i></p> <p style="text-align: right;"><b>Chair: Antonio Chambel</b></p> <p><b>9:00 - 9:30</b> Improving groundwater storage and quality in a seawater intruded multi-aquifer system by managed aquifer recharge #641 <b>Speaker: Elango Lakshmanan, Anna University</b></p> <p><b>9:30 - 10:00</b> Dealing with geological heterogeneity and uncertainty in groundwater modelling: challenges and lessons learnt #589 <b>Speaker: Marijke Huysmans, Vrije Universiteit Brussel</b></p> <p><b>10:00 - 10:30</b> Karst functioning: What do we learn from the various modeling methods? #554 <b>Speaker: Hervé Jourde, Université de Montpellier 2</b></p>
<b>10:30 - 11:15</b>	<i>Coffee break</i>
<b>11:15 - 12:45</b>	<b>Parallel – Oral</b> <i>Thursday Morning. Session 1 to 8. Topics 5, 5.1, 6 and 7.</i>
<b>12:45 - 14:20</b>	<i>Lunch</i>
<b>14:20 - 14:50</b>	<p><b>Plenary Lecture</b> <i>Auditorium 2</i></p> <p><b>Groundwater and socioeconomic development in Latin America #875</b> <b>Speaker: Ricardo Hirata, University of Sao Paulo</b></p>
<b>15:00 - 16:00</b>	<b>Parallel – Oral</b> <i>Thursday Afternoon. Session 1 to 8. Topics 5, 5.1, 7 and 8.</i>
<b>16:00 - 17:00</b>	<b>Poster with refreshments</b>
<b>17:00 - 18:00</b>	<b>Parallel – Oral</b> <i>Thursday Afternoon. Session 9 to 16. Topics 5, 5.2, 5.4, 7 and 8.</i>
<b>18:00 - 19:30</b>	<p><b>Meetings of commissions and networks</b></p> <p><b>General Assembly of IAH - Spanish Chapter</b> <i>Conference room 1.A</i></p> <p><b>IAH Commission on Karst Hydrogeology</b> <i>Conference room 1.B</i></p> <p><b>IAH Commission on Groundwater and Climate Change</b> <i>Conference room 2.1</i></p> <p><b>IAH Commission on Managing Aquifer Recharge (MAR)</b> <i>Conference room 2.2</i></p> <p><b>IAH Early Career Hydrogeologists Network - SIDI session</b> <i>Multiuse room 1</i></p>

**EVENING SOCIAL**

<b>20:45</b>	<p><b>CONGRESS DINNER</b>  <i>Meeting point: Museo Automovilístico. Av. De Sor Teresa Prat 15, Malaga.</i></p>
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**FRIDAY 27<sup>TH</sup>**

<b>9:00 - 9:30</b>	<p><b>Plenary Lecture</b>  <i>Auditorium 2</i></p> <p><b>The importance of biological processes in quantifying the connection between wetlands and groundwater #89</b>  <b>Speaker: Donald Rosenberry, U.S. Geological Survey</b></p>
<b>9:40 - 10:40</b>	<p><b>Parallel – Oral</b>  <i>Friday Morning. Session 1 to 7. Topics 5, 5.4, 8 and 9.</i></p>
<b>10:40 - 11:15</b>	<p><i>Coffee break</i></p>
<b>11:15 - 12:45</b>	<p><b>Parallel – Oral</b>  <i>Friday Morning. Session 8 to 15. Topic 5, 5.4, 6, 8 and 9.</i></p>
<b>12:45 - 14:30</b>	<p><i>Lunch</i></p>
<b>14:30 - 15:00</b>	<p><b>Plenary Lecture</b>  <i>Auditorium 2</i></p> <p><b>The Good, the Bad and the Bottled: considerations of the effects of our habits on the water and environment protection #868</b>  <b>Speaker: Stefano Viaroli, Roma Tre University</b></p>
<b>15:00 - 16:00</b>	<p><b>Closing Ceremony</b>  <i>Auditorium 2</i></p>

## Monday Morning 3: Topic 2

Multiuse room 2 (11:15-12:45)

### Groundwater and climate change

Chair: Xiaowei Jiang, Daniela Ducci

**11:15 - 11:30 Impacts of Climate Change on Groundwater – results from the BINGO project #46.** *Emilia Novo.*  
Speaker: Emilia Novo

**11:30 - 11:45 Fresh Groundwater Resources for the Future Generations of Yemen #58.** *Yusuf Al-Mooji.* Speaker: Yusuf Al-Mooji

**11:45 - 12:00 Drivers of changes in Austrian groundwater levels – climate vs. Water use #260.** *Steffen Birk, Johannes C. Haas.* Speaker: Steffen Birk

**12:00 - 12:15 Examination of the hydrologic cycle with long-term precipitation and groundwater level data #189.** *Csaba Ilyés, Endre Turai, Péter Szűcs.* Speaker: Csaba Ilyés

**12:15 - 12:30 Impact of climate change on groundwater recharge and base flow in the muda river basin, malaysia #91.** *Mohd Khairul Nizar Shamsuddin, Mohammad Firuz Ramli, Faradiella Mohd Kusin.* Speaker: Mohd Khairul Nizar Shamsuddin

**12:30 - 12:45 Assessing the groundwater potential of upper and middle aquifers in the Senegalese groundnut basin region – contribution of a numerical model #318.** *Rémi Vigouroux, Florence Lenhardt, Serigne Faye.* Speaker: Remi Vigouroux

## Monday Morning 4: Topic 3

Conference room 1.B (11:15-12:45)

### Groundwater sustainability and governance

Chair: Beata Jaworska-Szulc, Alfonso Rivera

**11:15 - 11:30 Pumping response and sustainable well yield of some hard-rock aquifers #264.** *Vincenzo Piscopo, Francesca Lotti.* Speaker: Vincenzo Piscopo

**11:30 - 11:45 The artificial recharge of an urban drinking water aquifer (udine – italy): a digital model to grow the water flow from wells, project the pollution protection works, optimize the cost-benefits #614.** *Gian Paolo Drolì, Gian Paolo Drolì.* Speaker: Gian Paolo Drolì

**11:45 - 12:00 How efficient energy production can be fostered in transboundary aquifers #475.** *Teodóra Szócs.* Speaker: Teodora Szocs

**12:00 - 12:15 Management of groundwater-energy-food nexus for sustainability #164.** *Makoto Taniguchi.* Speaker: Makoto Taniguchi

**12:15 - 12:30 The “hydropuls®” Process for Regeneration and Intensification of Wells #57.** *Toralf Fischer.* Speaker: Toralf Fischer

**12:30 - 12:45 Development of Integrated water resources management model in the transboundary Cijevna River Basin (Montenegro – Albania) #448.** *Momčilo Blagojević.* Speaker: Momčilo Blagojević



# Examination of the hydrologic cycle with long-term precipitation and groundwater level data

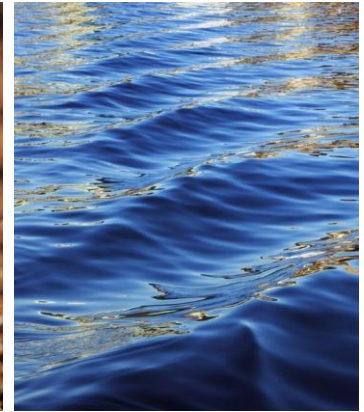
Csaba Ilyés – Dr. Endre Turai – Prof. Dr. Péter Szűcs

Institute of Environmental Management, Faculty of Earth Science and Engineering, University of Miskolc

MTA-ME Research Group of Geoengineering



**MISKOLCI**  
EGYETEM  
UNIVERSITY OF MISKOLC



Abstract ID: #189

22-27 September 2019 - **46th IAH Congress Malaga, Spain**  
Topic 2 - Groundwater and climate change

## Introduction

- The impact of the ever-changing climate on Earth is already evident in the emergence of weather extremes and increased water demand from the agriculture.
- These changes and the human responses to it can greatly change many elements of the hydrological cycle.
- Weather extremes all appear in the amount and intensity of the fallen precipitation, while increased water demand in many areas has led to a permanent water level decrease in mainly shallow groundwater aquifers.
- Examining the changes requires large amounts of measured data, both for rainfall and water levels.
- In our study, these two elements of the hydrological cycle were analyzed in the Carpathian Basin involving several sample areas.

## Introduction

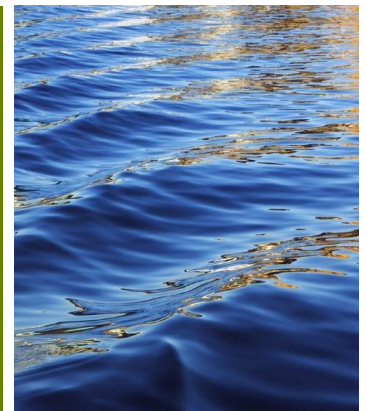
- On Earth approximately 400 000 km<sup>3</sup> volume of water is being transported annually in the water cycle.
- Which is affected by the changing climate and the meteorological extremities present in recent years.
- These changes in the behaviour of precipitation have an impact on the groundwater resources through the recharge, so we chose to investigate the precipitation, and shallow GW
- In Hungary most of the drinking-water is produced from GW resources (96%)



Photos: Dr. László Lénárt



## Examination of long-term precipitation time series



## Methods & Materials

$$\cos(t) = \cos\left(\frac{2\pi}{T}t\right) = \cos\left(\frac{2\pi}{T}t\right) = \cos\left(2\pi\frac{1}{T}t\right) = \cos(2\pi ft)$$

$$f = \left(\frac{1}{T}\right)$$

Where,  $f$ : frequency,  
 $T=2\pi$ : period length

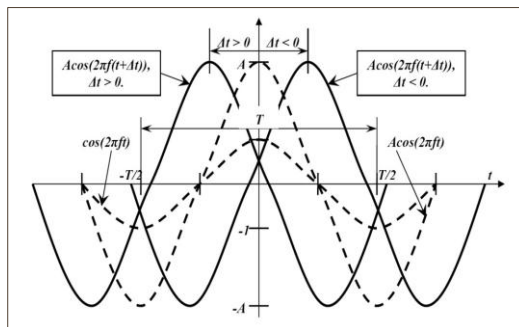
$$A * \cos(2\pi ft + \varphi)$$

Where,  $A$ : amplitude,  
 $\varphi$ : phase angle

$$Re[F(f)] = \int_{-\infty}^{+\infty} f(t) \cos(2\pi ft) dt$$

$$Im[F(f)] = \int_{-\infty}^{+\infty} f(t) \sin(2\pi ft) dt$$

The real and imaginary spectrum gives the weights of the sin-cos components.



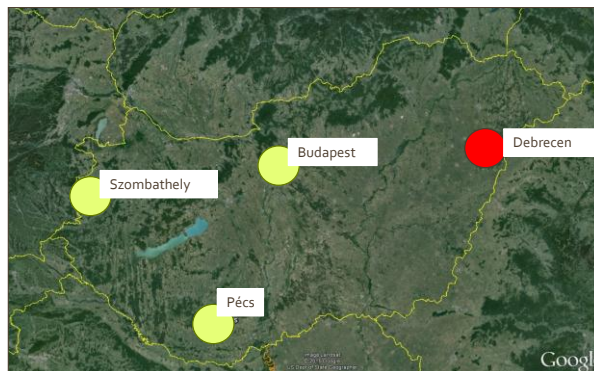
$$F(f) = A(f)e^{j\phi(f)}$$

Fourier-spectrums based on the  $\cos(2\pi ft)$  and  $\sin(2\pi ft)$  functions.

Search for periodic components in  $y(t)$  precipitation functions.

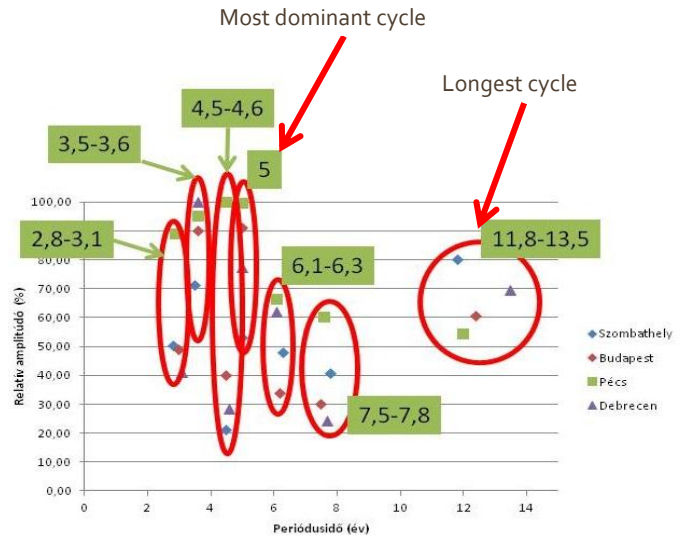
## Methods & Materials

- Cyclic properties of 110 year long data of annual and monthly rainfall
- Forecasting
- Wavelet-analysis



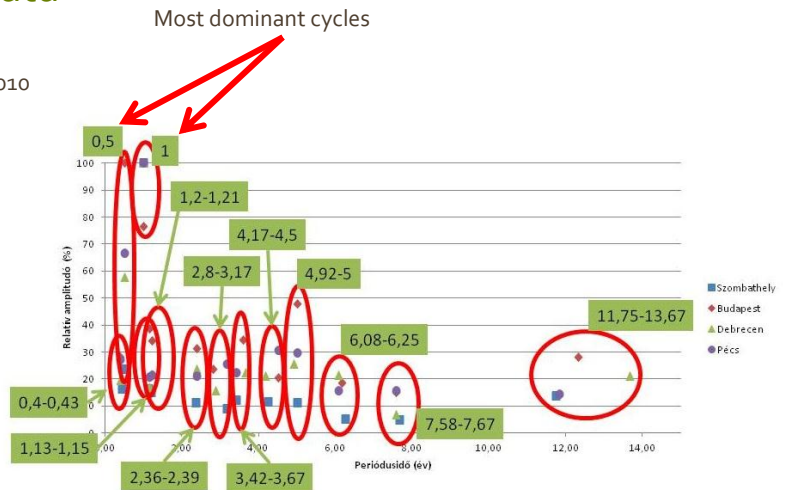
## Annual rainfall data

- Annual data:
  - Time span: 1901-2010
  - Time length: 110 years
  - Sampling rate: 1 year
- Budapest: 21 cycles
- Debrecen: 18 cycles
- Pécs: 17 cycles
- Szombathely: 20 cycles



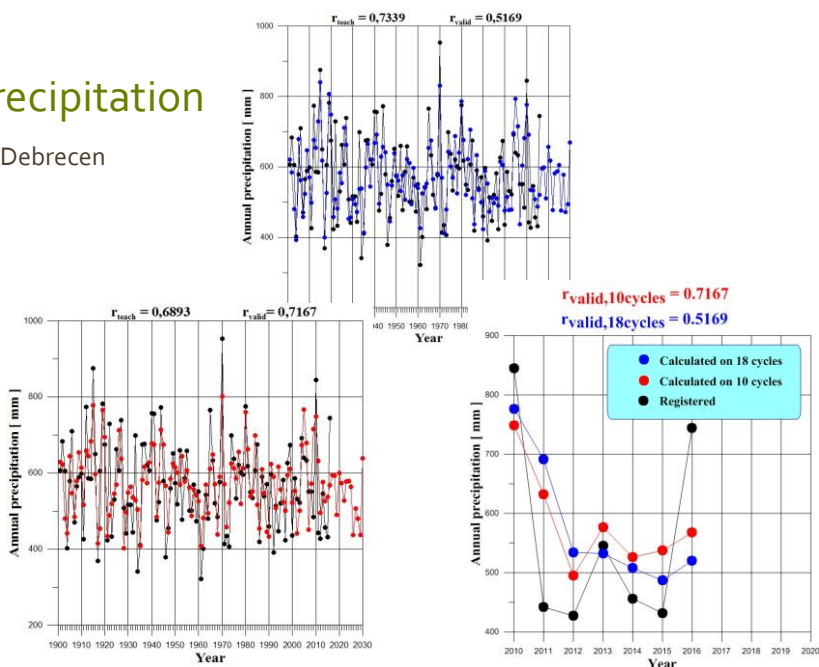
## Monthly rainfall data

- Monthly data:
  - Time span: Jan. 1901- Dec. 2010
  - Time length: 1320 months
  - Sampling rate: 1 month
- Budapest: 71 cycles
- Debrecen: 43 cycles
- Pécs: 65 cycles
- Szombathely: 19 cycles

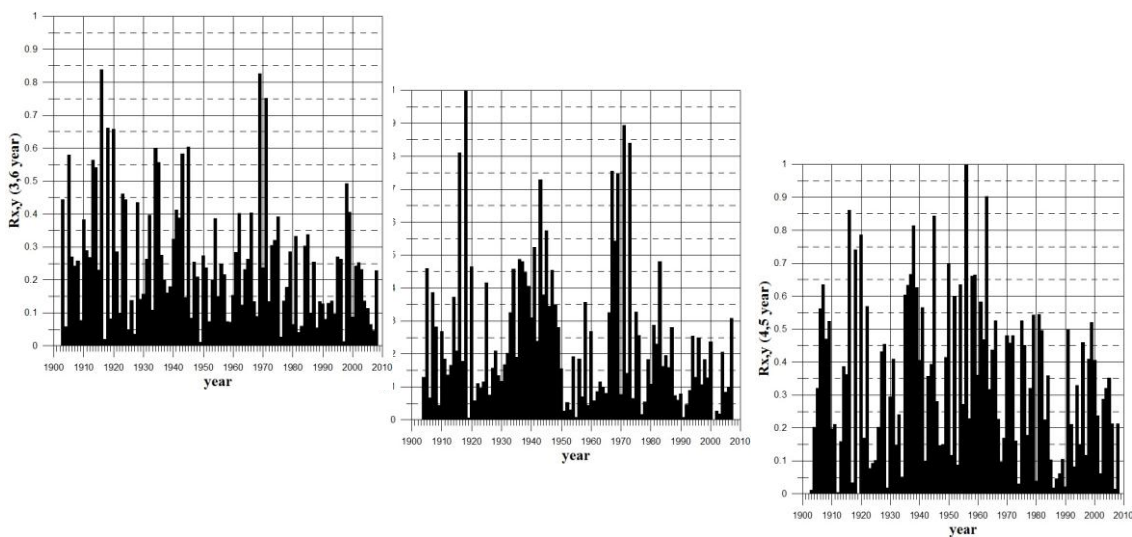


## Forecasting precipitation

- 10 major cycles from Debrecen
- $R=0,6893$ 
  - Medium correlation
- All 18 cycles
- $R=0,7339$ 
  - Strong correlation

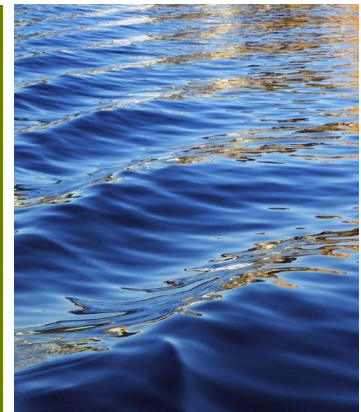


## Wavelet-analysis





# Examination of long-term shallow GW levels



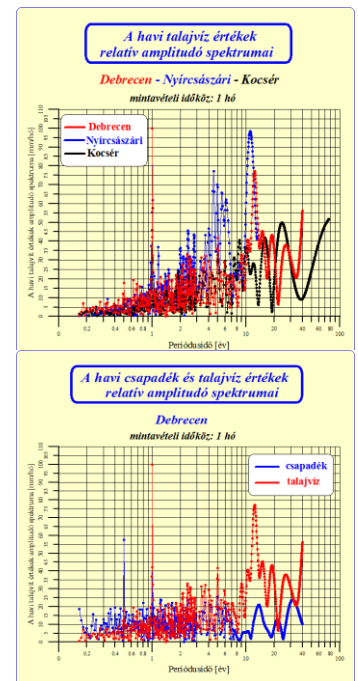
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## Monthly GW data

- 1 year, 3.7 years, 5 years and 11-12 years can be detected in the time series of the groundwater level in all three location.
- From the precipitation and the change of ground water level data a 1 year, 2.4 years, 3.67 and 5 year cycles can be detected (shown with red color).
- The 12.3 year cycle in the groundwater spectrum can be detected in the precipitation timeline of 13.7 years, while the 26.6 year groundwater cycle is also higher at 31.5 years.

No.	Debrecen (relative weight)	Nyírcsászári (relative weight)	Kocsér (relative weight)
1.	1 year (100%)	1 year (100%)	1 year (100%)
2.	12.3 year (77.3%)	11.1 year (98.3%)	24.2 year (49.9%)
3.	15 year (45.4%)	4.5 year (77.2%)	15.8 year (41.9%)
4.	18.9 year (43.2%)	4.9 year (70.1%)	8.5 year (40.6%)
5.	5 year (41.7%)	5.5 year (65.8%)	10.1 year (37.2%)
6.	10.5 year (40.7%)	6.2 year (62.1%)	5 year (32.6%)
7.	26.6 year (38.1%)	4 year (46.8%)	7.5 year (31.4%)
8.	9 year (32.9%)	2.4 year (45.5%)	6 year (29.5%)
9.	2.4 year (32.9%)	2.8 year (43.5%)	12 year (28.3%)
10.	3.7 year (32.2%)	3.7 year (43.2%)	1.9 year (23.7%)
11.	3.3 year (31.4%)	0.98 year (37.4%)	3.7 year (23.6%)



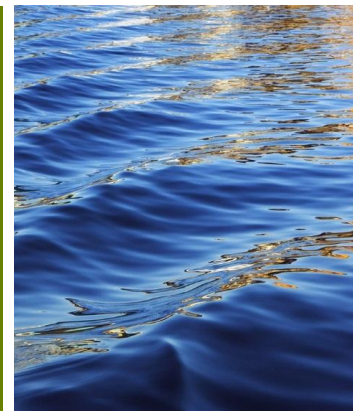
12

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# Classification of shallow GW wells

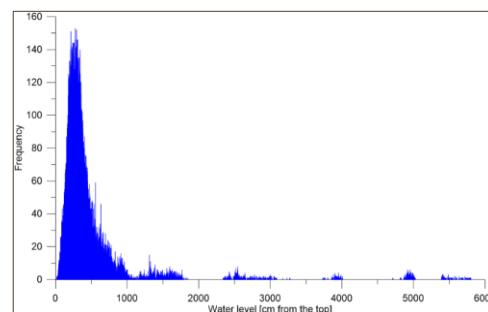
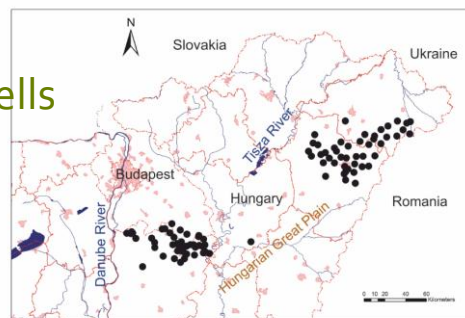


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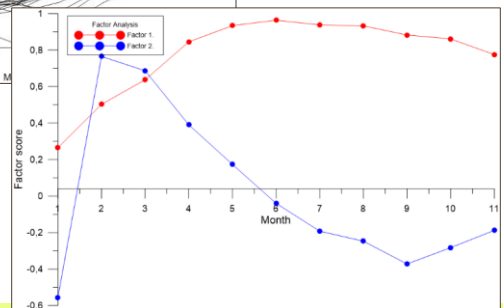
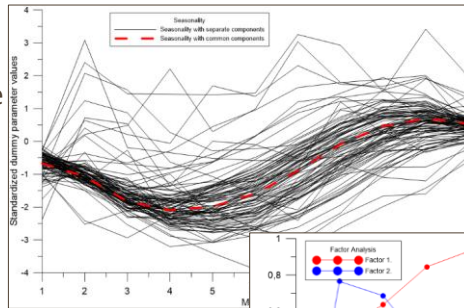
## Classification of shallow GW wells

- 95 GW wells from the Hungarian Great Plain
- Several time intervals
- The measurements are incomplete several times
- The time of establishment of the wells varies, so the start and end points of the time series are different
- The average depth of wells varies considerably
- The majority is 2-4 meters deep
- The measurements are concentrated mainly to this depth
- The empirical probability density function of the measurement data is unimodal and asymmetric with positive skewness.



## Classification of shallow GW wells

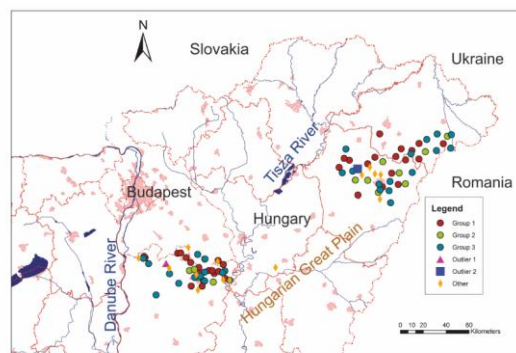
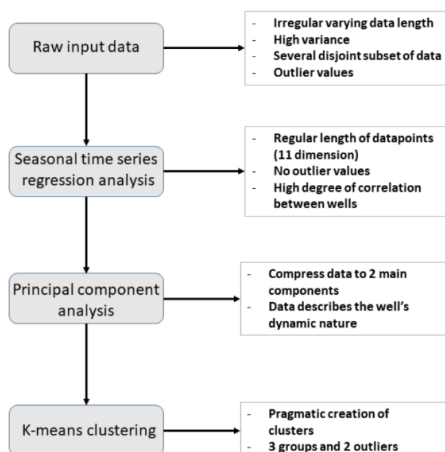
- Seasonal time regression analysis
- The models only characterize development of the groundwater, not the absolute depth of the wells
- The value of the 11 seasonal parameters was further compressed from an information point of view to 2 dimensions.



$$Y_{ij} = \beta_{1j} * X_j + \beta_2 * T_i + \sum_{k=1}^{11} \beta_{kj} * H_k \quad (1)$$

$$Y_{ij} = \beta_{0j} + \beta_{2j} * T_i + \sum_{k=1}^{11} \beta_{kj} * H_k \quad (2)$$

## Classification of shallow GW wells



## Conclusion

- Several cycles detected from precipitation and shallow GW datasets.
  - Most of them found country-wide, some are local.
  - The country-wide cycles shows climatic reasons (such as: El Nino)
  - Connection with the GW
- 
- Complex method for classify GW wells are defined and tested on a long-term time series of several wells.



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Thank You for Your Attention!

