

# Examples of training activities in EU projects MUSTANG, Panacea and TRUST

### Auli Niemi

### Uppsala University, Department of Earth Sciences

### **BASRECCS/ENOS** meeting Tallinn, Estonia 26.9.2018



- A few words about the projects
- Examples of the training activities
- Book Niemi et al. (eds.) 'Geological Storage of CO2 in Deep Saline Aquifers'







### UPPSALA Projects

**MUSTANG** – large-scale integrating project for **quantifying** saline aquifers for CO2 Geological Storage (2009-2014)

- UU Coordinator

Panacea – project focusing on long term effects of CO2 Geological Storage (2012-2014)

- UU WP leader (led by EWRE, Israel)

**TRUST** – project continuing and **expanding the field experiment** of MUSTANG (2012-2017)

- UU WP leader (led by EWRE, Israel)

CO2QUEST – project focusing on effect of impurities of CO2 stream (2013- 2016)

- UU WP leader (led by UCL, England)



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In the context of these projects also devepoled the Heletz, Israel CO<sub>2</sub> injection site

- Scientifically motivated
  CO<sub>2</sub> injection experiment site of scCO2 injection to
  a reservoir layer at 1600 m
  depth, with comprehensive monitoring and sampling
- Developed in the frame of EU FP7 projects MUSTANG, TRUST and CO2QUEST

Target reservoir layers of total ~11 m thickness





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### Heletz - Residual Trapping Experiment - 2016







### Tracer injection and sampling -Residual Trapping Experiment II (Aug – Oct 2017)



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### Key training activities (of Mustang, Panacea, Trust)

- Training courses
- Education of PhD students, MSc students, Post Docs
- Other dissemination activities such 'Brainstorming days', organizing sessions at EGU etc., incorporation of learnings to regular curriculum courses at partner universities
- Book Niemi et al. (eds.) 'Geological Storage of CO2 in Deep Saline Aquifers



#### UPPSALA UNIVERSITET Training Courses

- CSIC, Barcelona, Spain, June 2010
- Edinburgh University,
  Edinburgh, Scotland, June 2011



- iTOUGH short course, Uppsala, Sweden, November 2012 (by LBNL, USA, personnel)
- Göttingen University, Göttingen, Germany October 2013
- CNRS, Montpellier, France, October, 2015
- CSIC, Barcelona, Spain, September, 2017



### Edinburgh, Scotland, June 2011

TRAINING COURSE PROGRAM OUTLINE		
Tuesday 21st J	une	
14:00	Registration	
14:30	Introduction to course	
15:00- 17:00	Visit to University Edinburgh CCS laboratory	
18:00 -20:00	Evening meal Royal Mile, Networking with MUSTANG partners	
Wednesday 22	nd June	
OVERVIEW KEY	YNOTE LECTURES	
8:30 - 9:15	CCS Global Status and Challenges. John Gale (IEA-GHG),	
9:15 - 10:00	Recent advances and key questions in modelling CO2 geological storage. Karsten Pruess (LBNL, USA)	
10:00 - 10:30	Coffee Break	
10:30 - 11:45	Review of global status of CCS projects, and experiences from US Regional partnership program. Larry Myer (LBNL retired, USA)	
11:45 -12:30	Christian Bernstone Industry experiences of CCS in Europe and European CCS Demonstration Plant in Janschwalde.(Vattenfall AB)	
12:30 - 1:15	Lunch	
1:30 - 18:00	Field visit to St Andrews Caprock and Reservoir Analogue Site	
Thursday 23rd	June	
TOPICAL LECT	URES	
9:00 - 9:45	Industrial CO2 storage (STAOIL, Torp)	

9:45 - 10:15	Coffee break
10:15 - 10:25	Introduction to lectures (Uppsala University, Niemi)
10:25 - 10:55	Risk Management of CCS projects. (OXAND, Le Guen)
10:55 - 11:25	HTT tests for characterisation and monitoring. (Göttingen University, Sauter)
11:25 - 11:55	Application of seismic methods for CO2 monitoring, an example from the Ketzin site, Germany. (Uppsala University, Juhlin)
11:55 - 12:15	Instrumentation of CO2 and injection experiments.(EWRE, Bensabat)
12:15 - 13:15	Lunch
13:15 - 13:45	Mathematical models of two phase flow, energy and multicomponent reactive transport in deep formations. (Tecchnion, Bear)
13:45 - 14:15	Simulation of CO2 geological storage with multiphase multicomponent models. (Uppsala University, Niemi)
14:15 - 14:45	Scale effects of processes in geological CO2 storage. (CSIC, Dentz)
14:45 - 14:55	Coffee
14:55 - 15:25	Novel numerical techniques for modelling crack formation. (Nottingham University, Power)
15:25 - 16:15	Laboratory experiments for geological CO2 storage. (CNRS, Luquot)
16:15 - 16:30	Wrap up





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### Montpellier, France, October 2015

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Imperial College

$\langle 0 \rangle$	SEVENTH FRAMEWORK PROGRAMME	TRUST.
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#### Advanced Course on CO<sub>2</sub> Sequestration in Deep **Geological Formations**

19-21 October 2015 Montpellier, France www.trustco2course.wordpress.com

#### 19 October 2015

8:30 - 9.00

#### PROGRAMME

- Registration 9:00 - 9:45 Introduction to geological storage of CO<sub>2</sub> and examples of field projects (Auli Niemi, University of Uppsala, Sweden)
- Experiences from natural analogues (Alfons van der Kerhof, University of Göttingen, Germany) 9:45 - 10:30
- 10:30 11:00 Coffee break
- 11:00 11:45Capacity estimates of CO<sub>2</sub> geological storage sites (Jesús Carrera, CSIC, Spain)
- 11:45 12:30 Approaches to large scale problems (Auli Niemi, Uppsala University, Sweden)
- 12:30 13:30 Lunch
- 13:30 15:00 Mathematical models for CO, spreading and related processes (part 1; two-phase flow; part 2, non-isothermal transport, deformable porous media) (Jacob Bear, Technion, Israel)
- 15:00 15:30 Coffee break
- Numerical Modeling of Geological Storage part 1; Methodologies, part 2; Results and examples. Hontomín example (Jesús Carrera, CSIC, Spain) 15:30 - 17:00
- 17:00 17:30Public perception and societal challenges associated with CCS (Meritxell Martell, Merience, Spain).

#### 20 October 2015

9:00 - 9:45	Laboratory experiments for CO2 geological characterization and leakage risks (Linda Luquot, CSIC)
9:45 - 10:30	Scale effects and upscaling (Marco Dentz, CSIC, Spain)
10:30 - 11:00	Coffee break
11:00 - 11:45	Fractured rock hydrology and implications for carbon storage / sequestration (Robert Zimmerman, Imperial College, UK)
11:45 - 12:30	Advanced methods for fracture propagation modeling (Adriana Paluszny, Imperial College, UK)
12:30 - 13:30	Lunch
13:30 - 14:15	Injection well-reservoir interaction (Myra Kitron-Belinkov, Technion, Israel)
14:15 - 15:00	Fluid mechanics and resulting geological response of sequestration (Herbert Huppert, University of Cambridge, UK)
15:00 - 15:30	Coffee break
15:30 - 16.15	Hydro-mechanical processes (Henry Power, Geo-Energy Research Centre, UK)

16: 15 - 17:00 Geophysical monitoring of CO2 geological storage sites, Ketzin case study (Fengjiao Zhang, Uppsala University, Sweden)

#### 21 October 2015

9:00 - 9:45	Characterization and monitoring of an injection experiment – Example from Heletz, Israel (Jacob Bensabat, EWRE, Israel)
9:45 - 10:30	Hydro-geophysical monitoring methods: lessons from shallow injection experiments at Maguelone (Philippe Pezard, CNRS, France)
10:30 – 11:00	Coffee break
11:00 - 11:45	Risk assessment in geological storage of CO <sub>2</sub> (Jacob Bensabat, EWRE, Israel)
11:45 - 12:15	Closure of the course

#### 14:00 - 18:00 FIELD TRIP!!

A bus will leave from the meeting to the Maguelone experimental site at 12:30 and will take us back at 18:00. The trip will be organised by CNRS.







### Montpellier, France, October 2015

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Imperial College

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- 10:30 11:00 Coffee break
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- 17:00 17:30 Public perception and societal challenges associated with CCS (Meritxell Martell, Merience, Spain).

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11:00 - 11:45	Risk assessment in geological storage of CO <sub>2</sub> (Jacob Bensabat, EWRE, Israel)
11:45 - 12:15	Closure of the course

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### Barcelona, Spain, September 2017

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#### AUDIENCE

This course is intended for graduate students and post-doctoral researchers, including M.Sc. and Ph.D. students in the fields of engineering (civil, chemical, mechanical and petroleum engineering), geology, and geophysics, as well as professionals who wish to gain a greater understanding of current research findings, modeling and planning elements of CCS projects.

#### 13 September 2017

8:30 - 9.00 9:00 - 10:00 10:00 - 11:30	Registration Introduction to geological storage of CO <sub>2</sub> and examples of field projects (Auli Niemi, University of Uppsala, Sweden) Mathematical models for CO <sub>2</sub> spreading and related processes: flow, two phases, non-isothermal, reactive transport, deformable porous medium (Jacob Bear, Technion, Israel)
11:30 - 12:00	Coffee break
12:00 - 13:00	Mathematical models for CO <sub>2</sub> spreading and related processes: flow, two phases, non-isothermal, reactive transport, deformable porous medium (Jacob Bear, Technion, Israel) – continuation
13:00 - 14:00	Lunch
14:00 - 15:00	Numerical Modeling of Geological Storage – part 1; Methodologies, part 2; Results and examples. (Jesús Carrera, CSIC, Spain)
15:00 – 15:30	Coffee break
15:30 – 16:30 16:30 – 17:30	Approaches to large scale projects (Auli Niemi, University of Uppsala, Sweden) Hydro-mechanical processes (Jesús Carrera, CSIC, Spain)

#### 14 September 2017

11:00 – 11:30 Coffee break	9:00 - 10:00 10:00 - 11:00	Characterization methods for geological reservoirs – Part 1 (Jesús Carrera, CSIC, Spain) Characterization methods for geological reservoirs – Part 2 (Auli Niemi, University of Uppsala, Sweden)
	11:00 - 11:30	Coffee break
11:30 – 12:30 Laboratory testing of properties relevant to CO <sub>2</sub> injection and spreading (Philippe Gouze, CNRS, France)	11:30 - 12:30	Laboratory testing of properties relevant to CO $_2$ injection and spreading (Philippe Gouze, CNRS, France)
12:30 – 13:30 Lunch	12:30 - 13:30	Lunch
13:30 – 15:30 Characterization, monitoring and field experiments of an injection site – the Heletz case, Israel (Jacob Bensabat, EWRE, Israel)	13:30 - 15:30	Characterization, monitoring and field experiments of an injection site – the Heletz case, Israel (Jacob Bensabat, EWRE, Israel)
15:30 – 16:00 Coffee break	15:30 - 16:00	Coffee break
16:00 – 17:00 Interactive exercise: public perception and societal challenges associated with CCS (Meritxell Martell, Merience, Spain).	16:00 - 17:00	Interactive exercise: public perception and societal challenges associated with CCS (Meritxell Martell, Merience, Spain).
17:00 – 17:30 Evaluation of the workshop and closure	17:00 - 17:30	Evaluation of the workshop and closure



### Educating PhDs – TRUST (2012-2018) project only

- Uppsala Univ, Sweden: 4+2 =6 completed, 2 underway
- CSIC, Spain: 1 completed, 4 underway
- Göttingen Univ, Germany: 2 completed, 2 underway
- ETH, Switzland: 1 completed
- Cambridge Univ, UK: 1 completed

### Total: 11 completed, 8 underway









### Post-Docs and MSc students - TRUST project (2012-2018) only

### **Post Docs:**

Uppsala University: 5 CSIC: 6 Imperial College: 1 Cambridge University: 1

### **MSc Theses:**

- Göttingen University: 9
- Imperial College: 3





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#### **Examples of other training activities** UNIVERSITET

- Brainstorming Day on 'The long term fate of geologically stored CO2' in 2013, Trondheim, Norway (jointly organized by MUSTANG, ULTIMATECO2, CO2CARE, CARBFIX and PANACEA projects) and in 2014, Paris, France.
- Organizing a session on CO2 ٠ (Field testing) at European Geosciences Union (EGU) meeting regularly since 2011
- Incorporating the learnings to • regular curriculum courses





#### UPPSALA UNIVERSITET A comprehensive text book



Niemi, A., Bear, J. and Bensabat, J. (Editors) (2017) GEOLOGICAL STORAGE OF CO2 IN DEEP SALINE FORMATIONS., Publisher Springer. 554 p. http://www.springer.com/gp/book/9789402409 949.



### Table of Contents (Niemi et al. (eds) 'Geological...)

Chapter 1 CO2 Storage in Deep Geological Formations: The Concept Gale, John Pages 1-14

Chapter 2 Overview of Processes Occurring During CO2 Geological Storage and Their Relevance to Key Questions of Performance Tsang, Chin-Fu and Niemi, Auli Pages 15-38

Chapter 3 Mathematical Modeling of CO2 Storage in a Geological Formation Bear, Jacob and Carrera, Jesus Pages 39-127

Chapter 4 Mathematical Modeling: Approaches for Model Solution Niemi, Auli, Yang, Zhibig, Carrera, Jesus, Power, Henry, McDermott, Chris, Rebscher, Dorothee, Wolf, Jan Lennard, May Franz, Figuereido, Bruno, Vilarrasa, Victor Pages 129-185



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#### Chapter 6 Laboratory Experiments

Gouze, Philippe, Edlmann, Katriona, McDermott, Chris and Luquot, Linda

Pages 249-307

### Chapter 7

### Site Characterization

Niemi, Auli, Edlmann, Katriona, Carrera, Jesus, Juhlin, Chris, Tatomir, Alexandru, Ghergut, Iulia, Sauter, Martin, Bensabat, Jacob, Fagerlund, Fritjof, Cornet, Francois, Vilarrasa, Victor, McDermott, Chris Pages 309-380



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#### Chapter 9

Natural Analogue Studies

McDermott, Christopher Ian, Miocic, Johannes, M. Edlmann, Katriona, Gilfillan Stuart Pages 473-520

Chapter 10 Risk Management for CO2 Geological Storage Projects

Le Guen, Yvi, Dias, Stephanie, Poupard, Olivier, Edlmann, Katriona, McDermott, Chris Pages 521-541



### A comprehensive text book



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## Thank you for your attention!

# This research was supported by EU FP7 projects MUSTANG, PANACEA and TRUST

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