Adaptive Wireless Ad-hoc Sensor Networks for Long-term and Event-oriented Environmental Monitoring in Terrestrial Systems

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Outline

1. Introduction and Basic Concepts of Wireless Ad-hoc Sensor Networks
2. Application Examples:

   (i) Interaction of Biotic and Abiotic Processes

   (ii) Processes in Aquatic Systems
3. Conclusion

Introduction (1)

Monitoring and Exploration in Environmental Science

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Introduction (2)

Problem Analysis

State of the art: point measurement

- Low resolution (time and space)
- Single parameter monitoring

Heuristic sensor positioning

- Often not optimized for the application

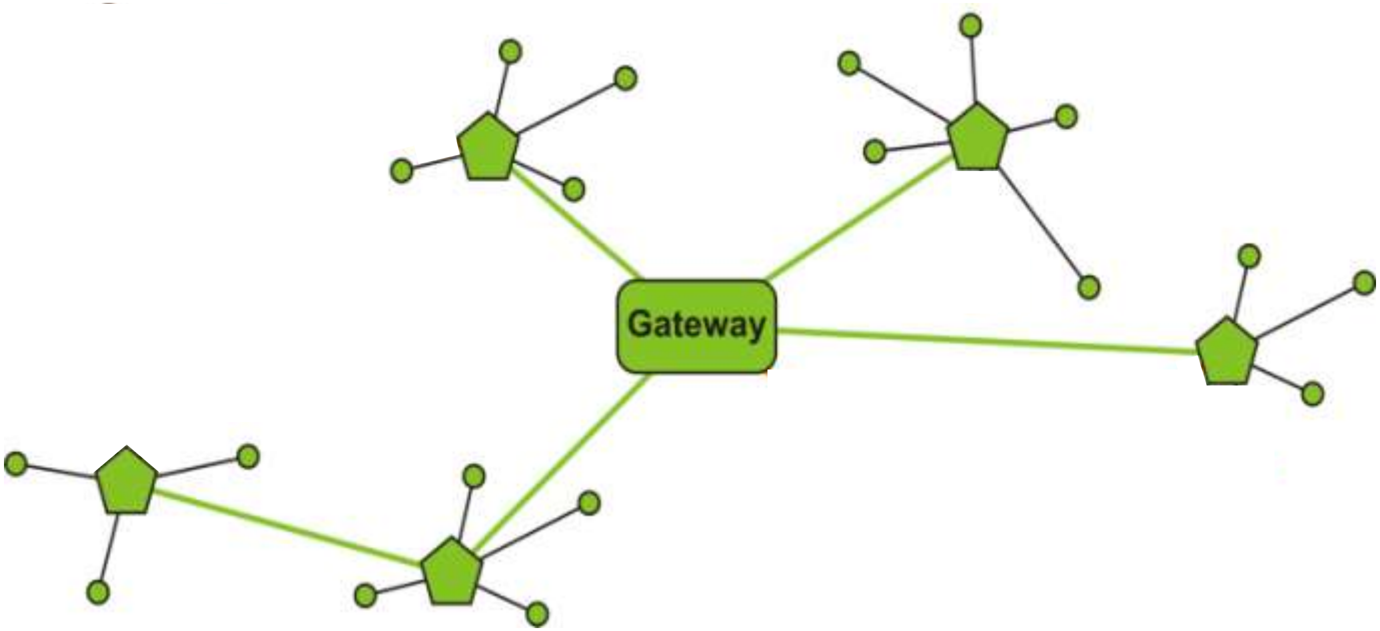
Scale overlapping processes

- Difficult to detect/monitor

Increasing of information quality:
adaptive measurement, adaptive data, …

Wireless ad-hoc Sensor Networks (1)

Basic Concepts



Sensor → Sensor Node → Gateway → Database

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M. Goetze, W. Kattanek, R. Peukert, E. Chervakova, H. Töpfer, P. Dietrich and J. Bumberger:
A Flexible Service and Communication Gateway for Monitoring Applications. Proceedings of the IEEE SoftCOM 2013, 6 pages.

Wireless ad-hoc Sensor Networks (2)

Potentials and Challenges

Adaptive process oriented approach

- Self-organizing network: suitable for installation, modification and operation
- Adress the heterogeneity of process parameter

Multiple data collection

- Time synchronization within the network
- Open platform to connect sensors and actuators
- Process-oriented data collection
- Signal conditioning/processing close to the sensor

Network Challenges

- Energy harvesting, wake-up functions, sensor costs, outdoor capability, range, Vandalism

Data Challenges

- Overcome scales (field continuation…)
- Data fusion / multi parameter inversion
- Compressed sensing, Distributed computing

Wireless ad-hoc Sensor Networks (3)

Technical Realization

- Mobile ad hoc network (MANET) characteristic
- Communication standard IEEE 802.15.4, 6LoWPAN, bidirectional protocol capability, TERENO database connectivity
- Transmission frequencies depends on application scenario
- Base station with a embedded Linux (using FGPA)
- Nodes with a TinyOS (using MCU)

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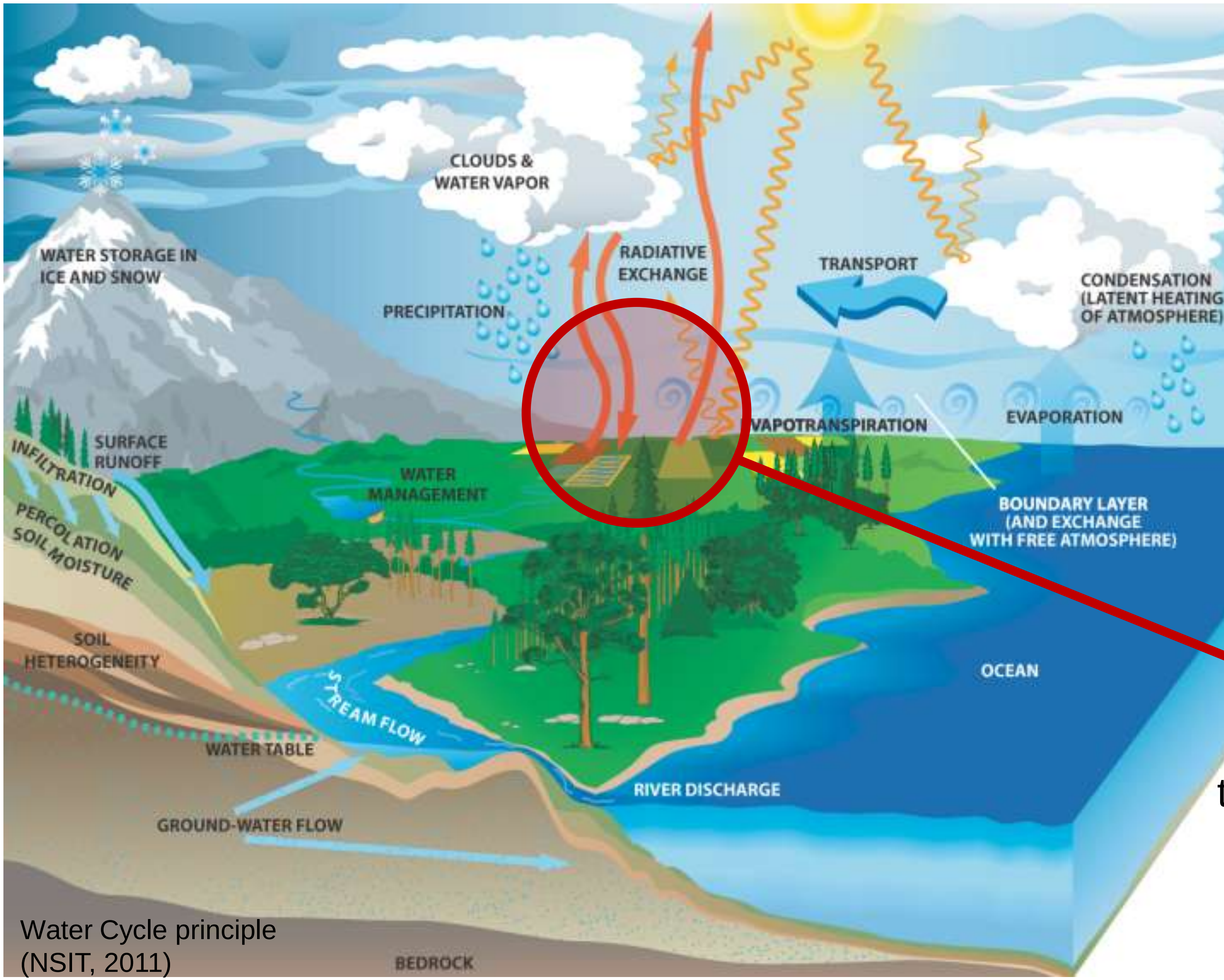
Interaction of Biotic and Abiotic Processes

Motivation



Water Cycle principle
(NSIT, 2011)

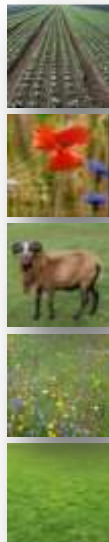
radiation,
temperature,
gases, …

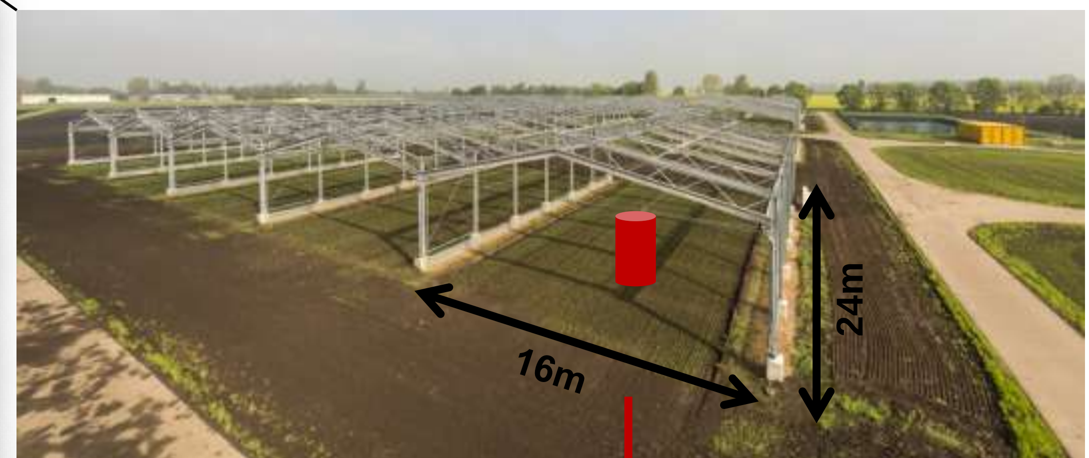
Large-scale Microclimate Wireless Sensor Network (1)

Global Change Experimental Facility – GCEF, Germany

Land use types

- Conventional agriculture
- Organic agriculture
- Extensive grasslands (grazed)
- Extensive grasslands (mowed)
- Intensive grassland (mowed)





… 50 Plots

→ 250 nodes including routers

Measurement every 15min on 50 Plots:
→ 770 sensors

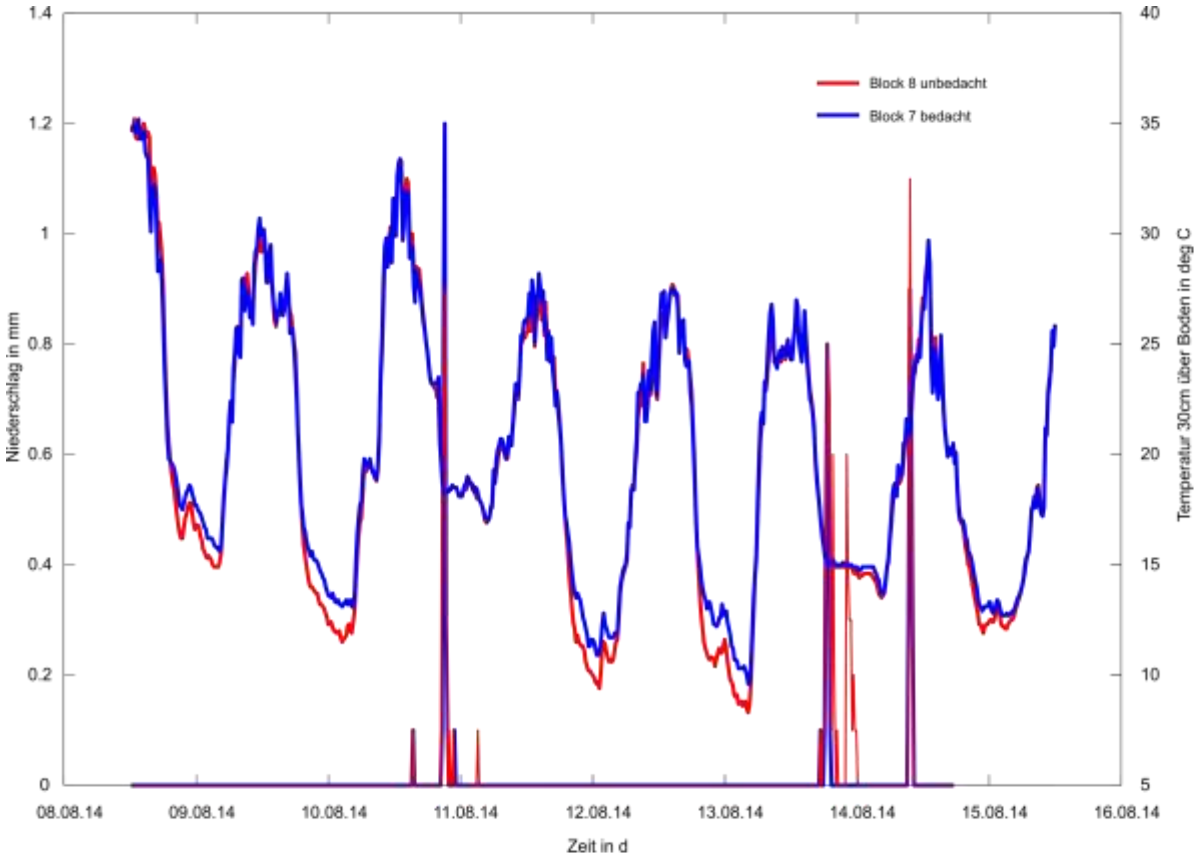
Measurement data:
~ 75e3 measurement values / d = 6Mb/d
~ 27e6 measurement values / a = 2,2Gb/a

- Air humidity (3 heights)
- Air temperature (3 heights)
- Soil moisture (3 depths)
- Soil temperature (3 depths)
- Photosynthetically active radiation(PAR)
- Solar radiation
- Precipitation

Large-scale Microclimate Wireless Sensor Network (2)
Global Change Experimental Facility – GCEF, Germany

Microclimate tripod
(1x per plot: 3 heights
and 3 depths)

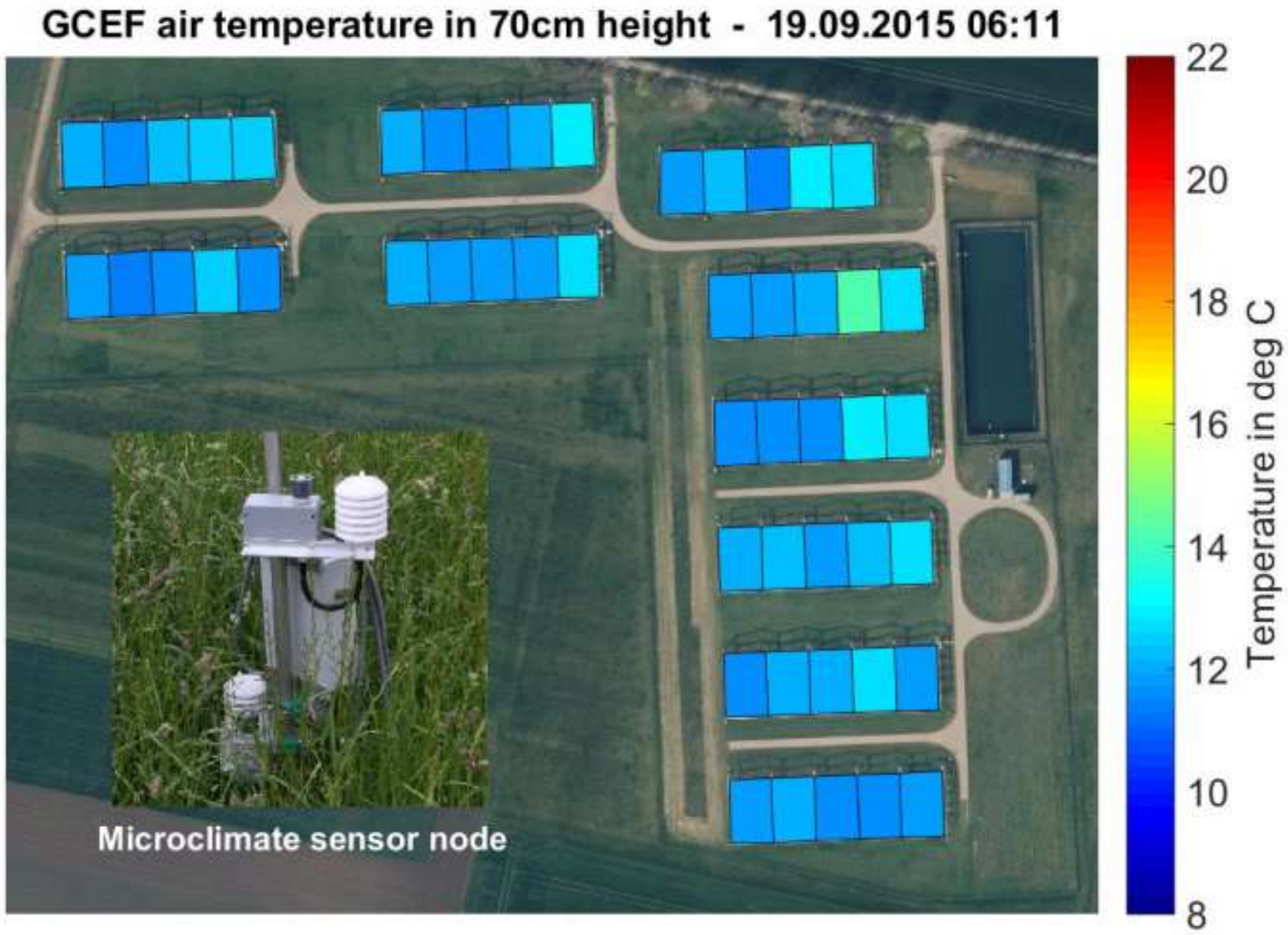
Measuring stations
(1x per Block: rain und
radiation measurement)



Figures: Base instrumentation in the GCEF wireless sensor network and exemplary measurement results

Large-scale Microclimate Wireless Sensor Network (3)

Global Change Experimental Facility – GCEF, Germany



Mobile Wireless ad-hoc Sensor Networks (1)

Improved Calibration and Validation of Remote Sensing Data

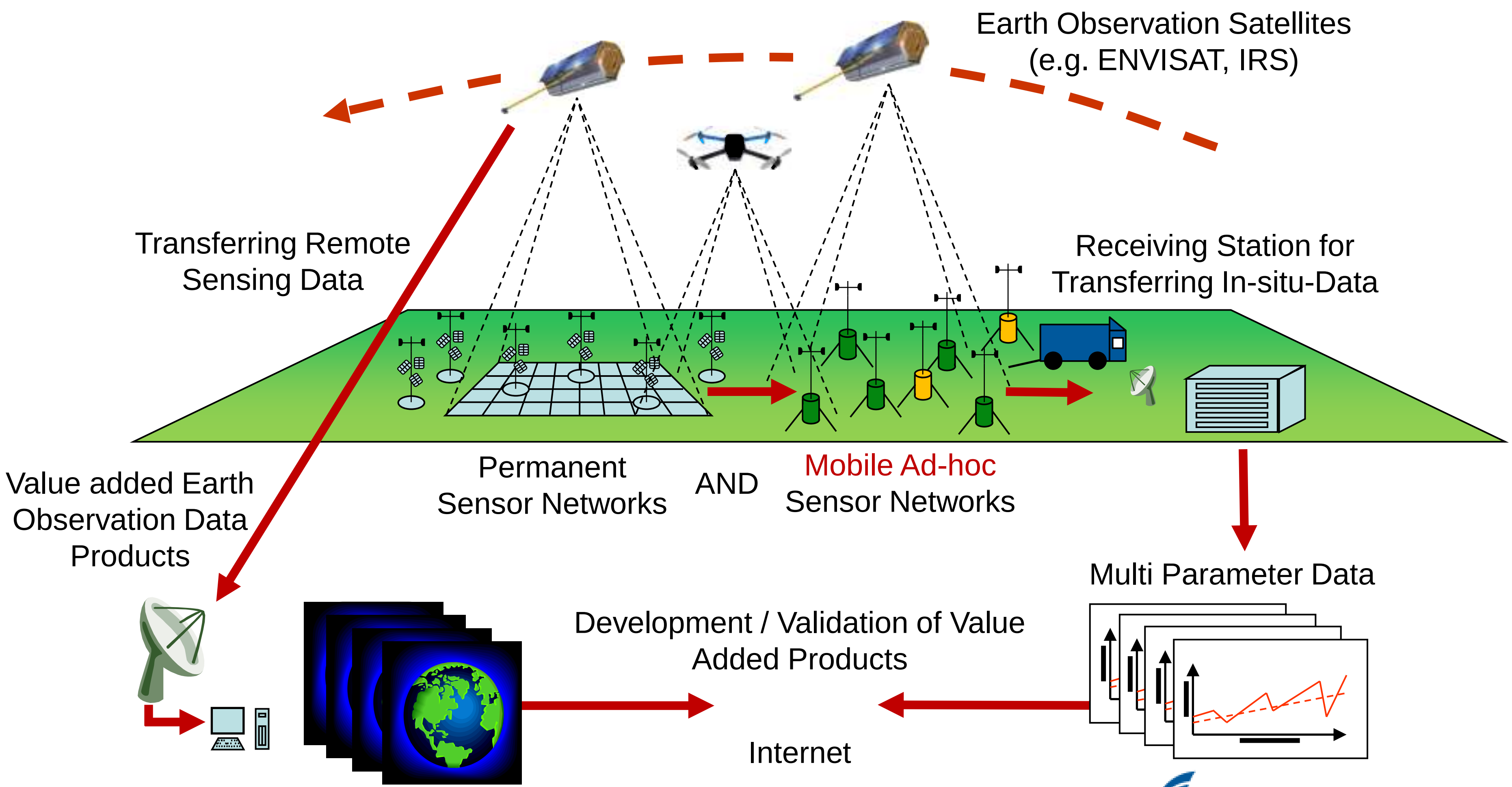


Figure: Automated sensor network (after Borg, 2013)

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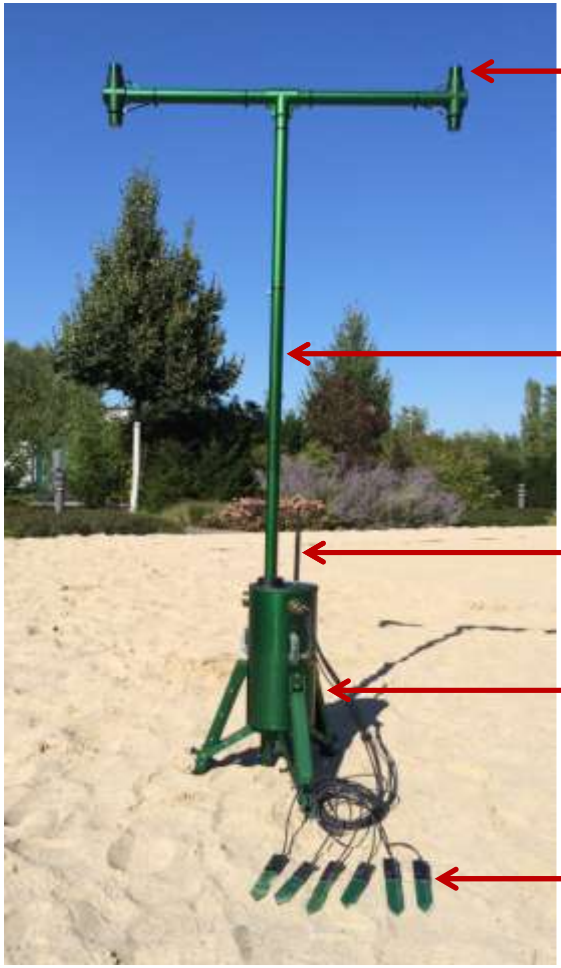
Mobile Wireless ad-hoc Sensor Networks (2)

Example of Technical Realization



Optical sensors: photosynthetically active radiation (PAR) and 4 wavelength specific sensors (net balance)

Stand up to 2.5m optional

Network antenna and GPS/GLONASS/Galileo sensor for position determination

Basis node of the mobile ad-hoc sensor network: energy, electronic segment and tripod

Soil sensors: moisture and temperature measurement

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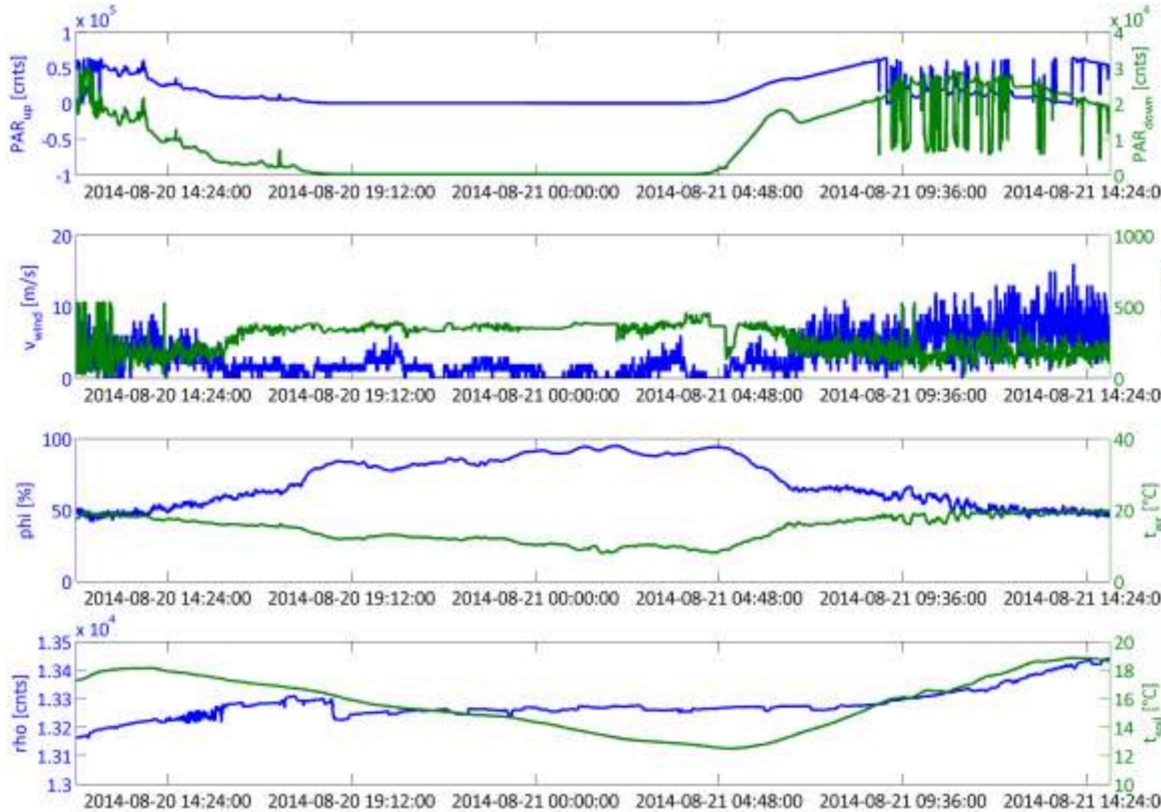
Mobile Wireless ad-hoc Sensor Network (2)

Results from the SABLE – Campaign 2014, Pforzheim



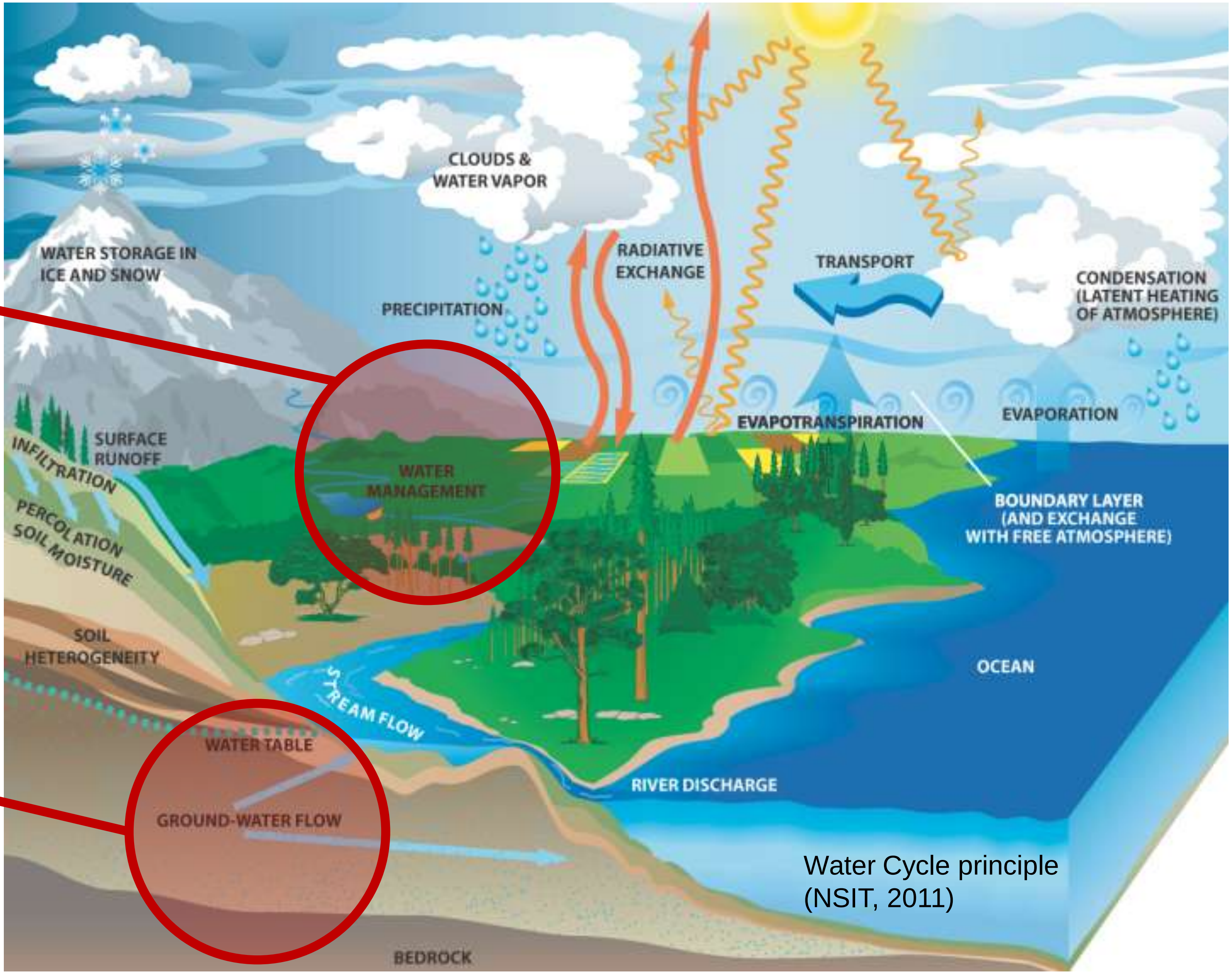
Figures: Network node in the Surface Atmospheric-Boundary-Layer Exchange (SABLE) Campaign (Universität Hohenheim, Ecole Polytechnique Paris, KIT) and first exemplary measurement results

Sensor Network Applications in Aquatic Systems

Motivation

Lakes and Drinking Water Reservoirs

Groundwater Systems



Water Cycle principle (NSIT, 2011)

Management Aquifer Recharge (1)

Motivation: Solution to Water Scarcity and Drought

1. Lavrion – Greece
2. Algavre– Portugal
3. Arenales – Spain
4. Llobregat – Spain
5. Brenta – Italy
6. Serchio – Italy
7. Menashe – Israel
8. South Malta - Malta

MAR SOL MANAGED AQUIFER RECHARGE SOLUTIONS

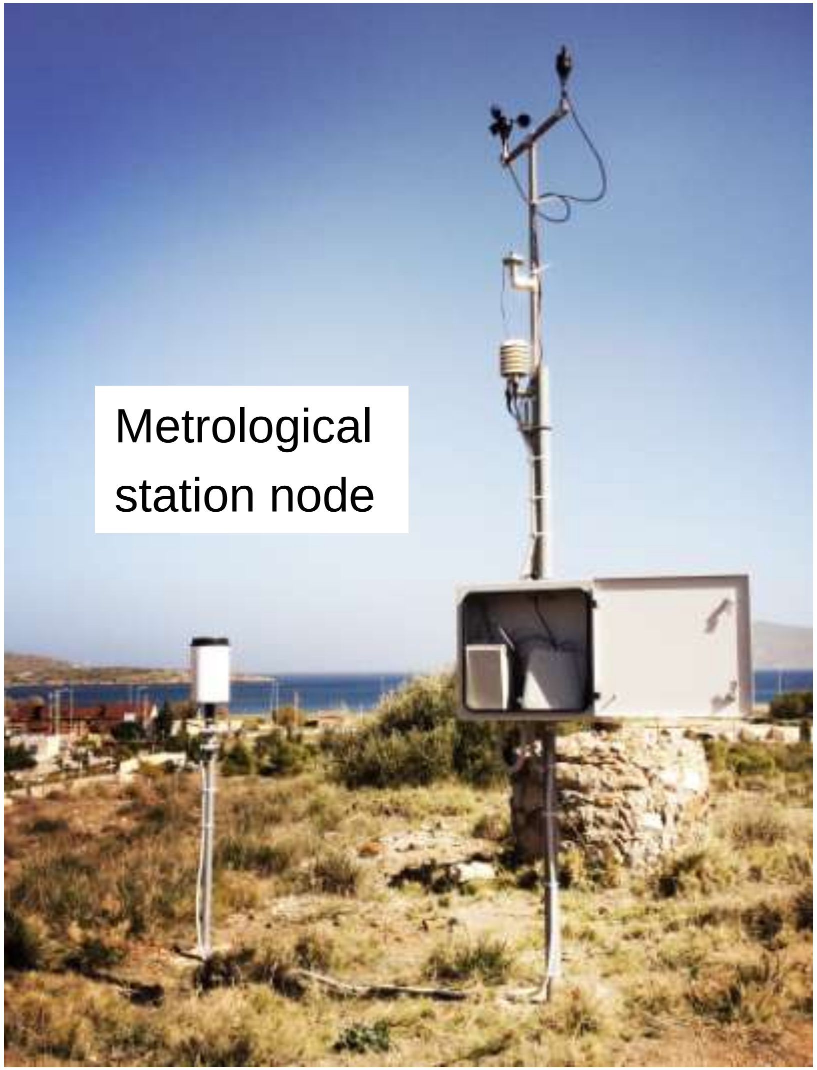
The MARSOL project receives funding from the European Union's Seventh Framework Programme for Research, Technological Development and Demonstration under grant agreement no 619120.

FP7-Env-2013-Water-Inno-Demo, Start: 12/2013, Duration: 3 Years

Management Aquifer Recharge (2)

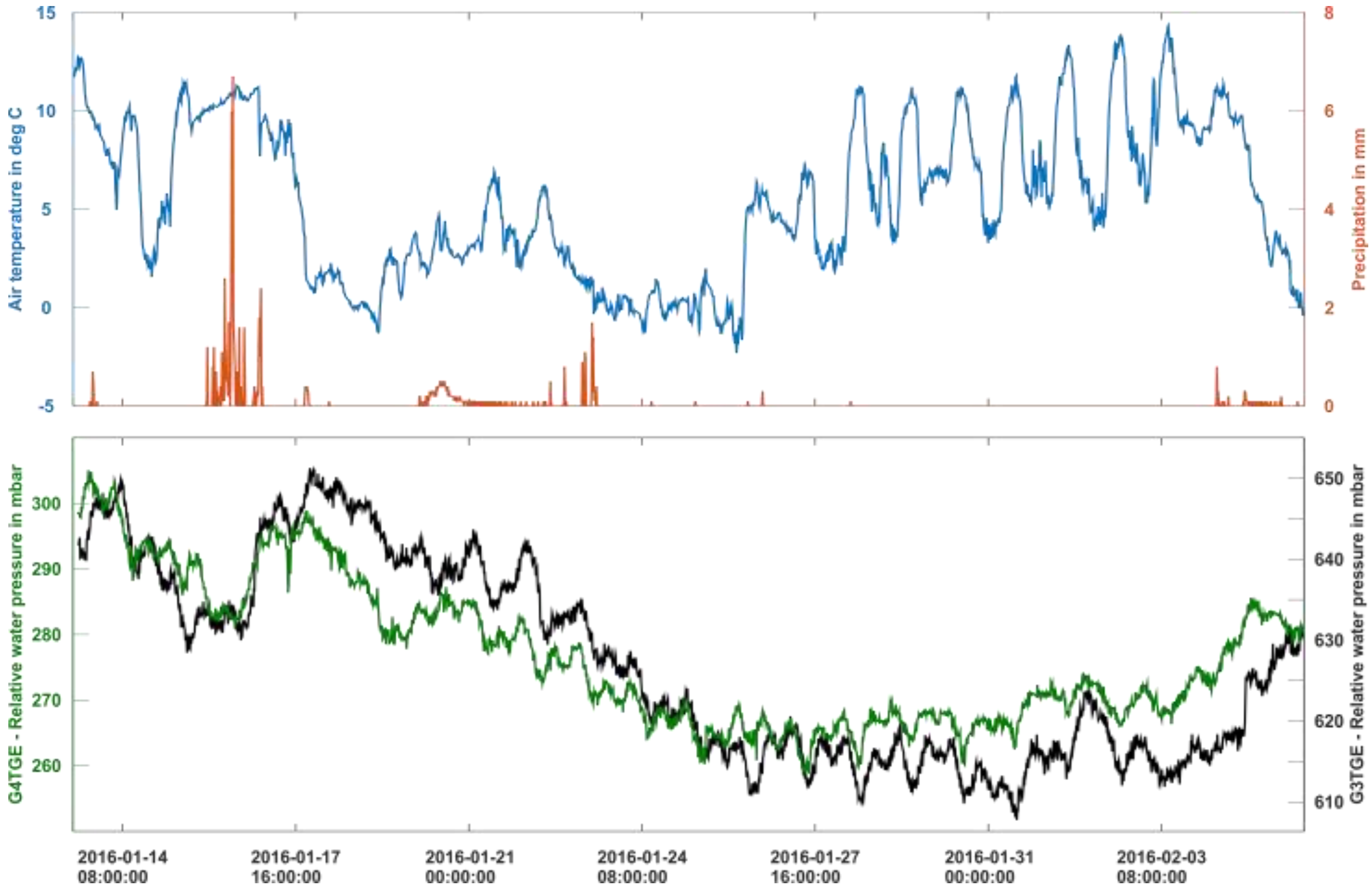
Network Implementation Demo Site Lavrion

Management Aquifer Recharge (3)
Network Implementation Demo Site Lavrion



Management Aquifer Recharge (4)

Network Implementation Demo Site Lavrion



Exemplary measurement results from the wireless sensor network in Lavrion

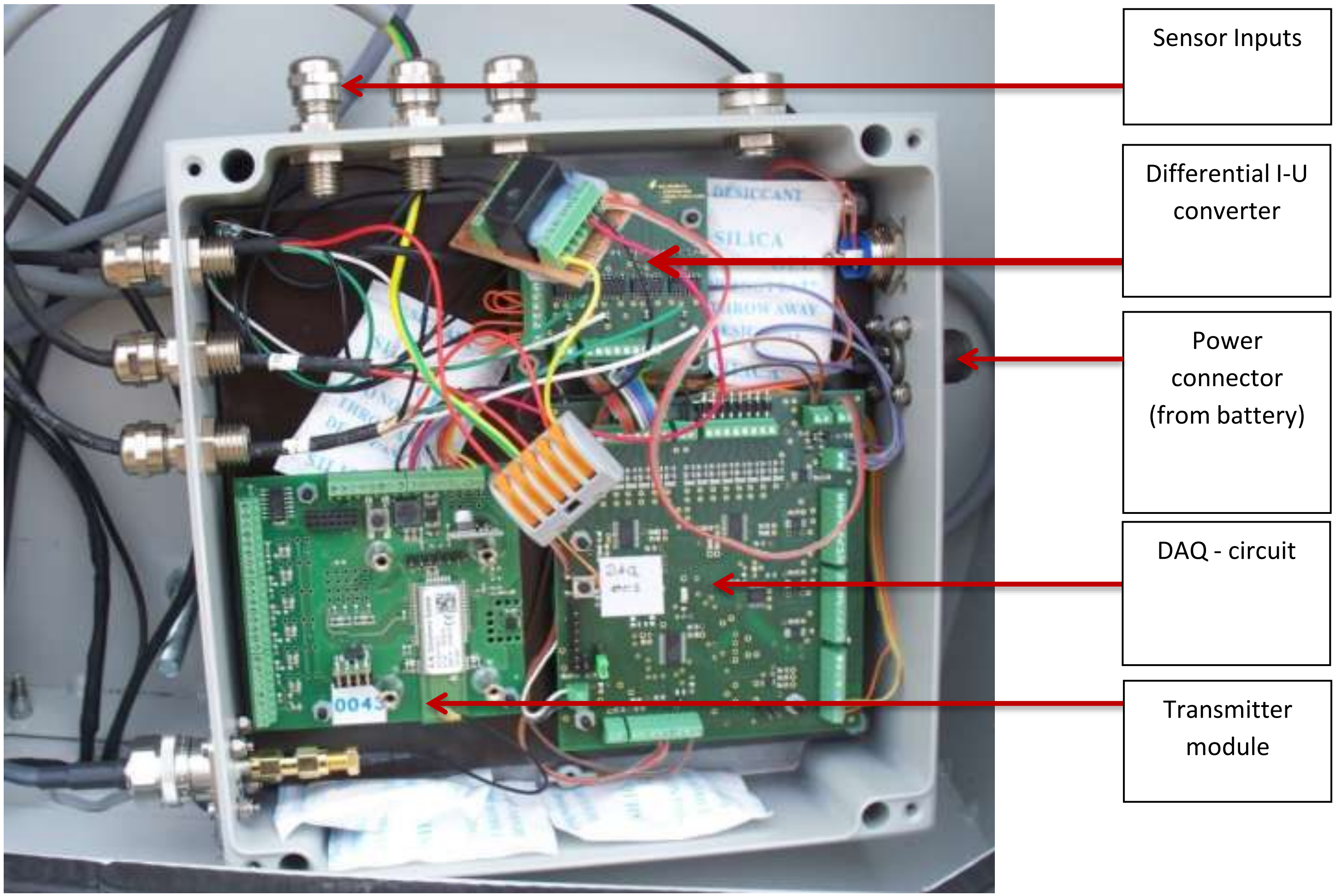
Conclusion

Wireless Sensor Networks have…

1. High potential in environmental science
2. Adress heterogenity of natural systems
3. Adaptiv approach and event-oriented measurement posibilities
4. Event triggered measurement (natural disasters, long-term regime shifts, water managment…)
5. Useful application to validate remote sensing data
6. Compressed sensing to optimise network distribution

Management Aquifer Recharge (5)

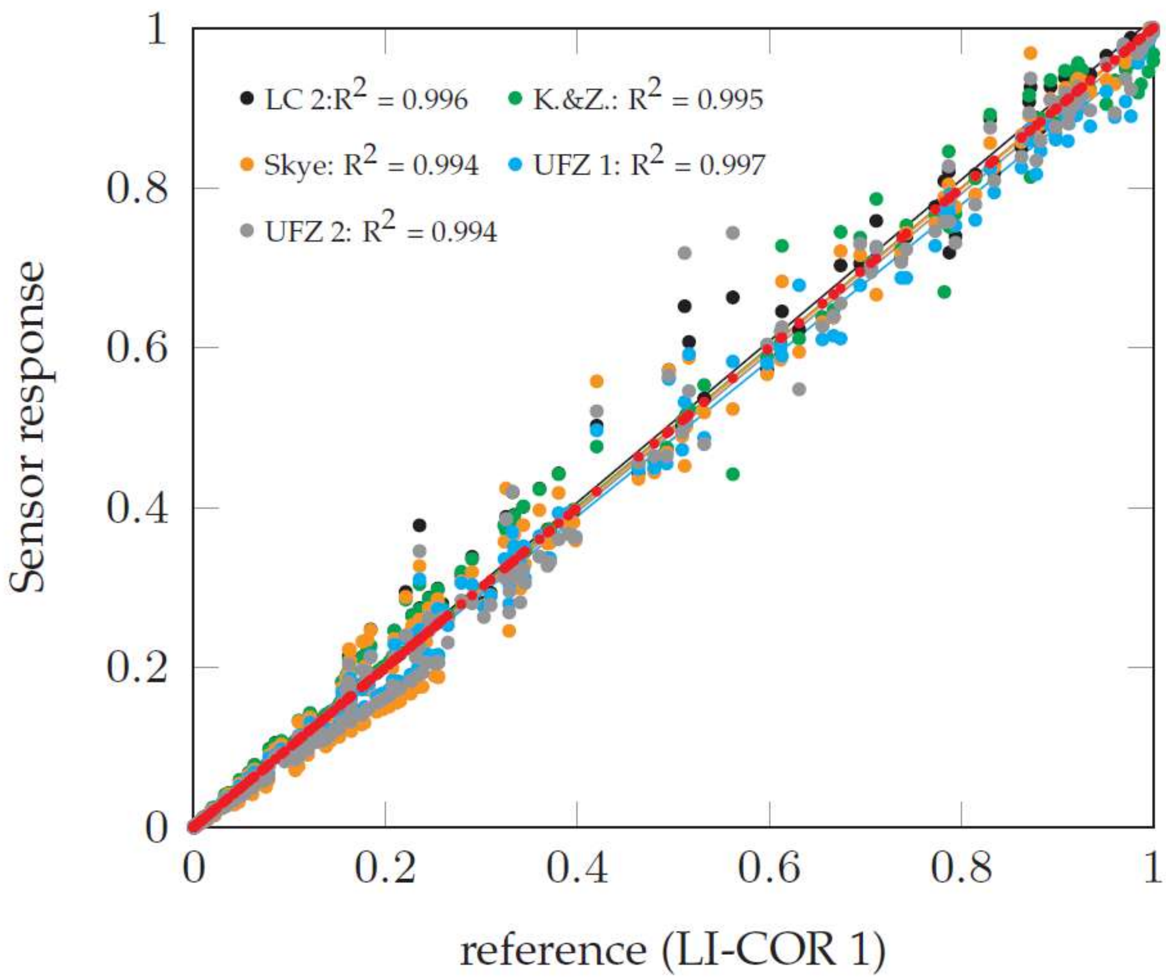
Demo Site Lavrion – Technical Realization



Sensor Development (2)

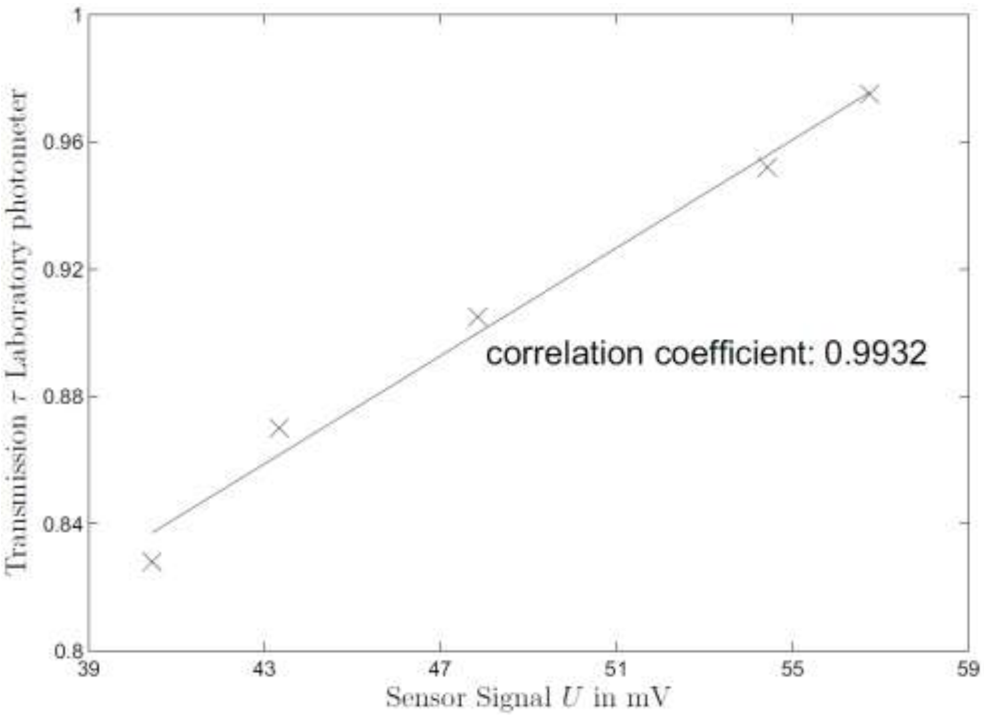
VIS/IR Radiation Sensors for Soil-Atmosphere Systems

PAR Sensor (400-700nm)



Catchment Dynamics and Reservoir Observatory (5)

Sensor Development of inexpensive SAK254 Sensors



Status

- Test probe
- Laboratory tests in comparison with conventional photometer
- First tests in the field

Outline 2015

- Implementation turbidity and temperature correction
- Anti-biofouling strategies
- 10 probes suitable for the field
- Field campaign in 2015

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