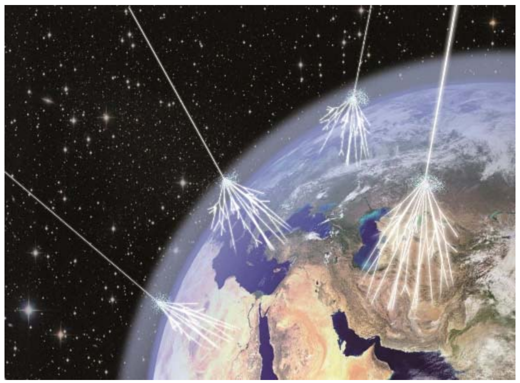
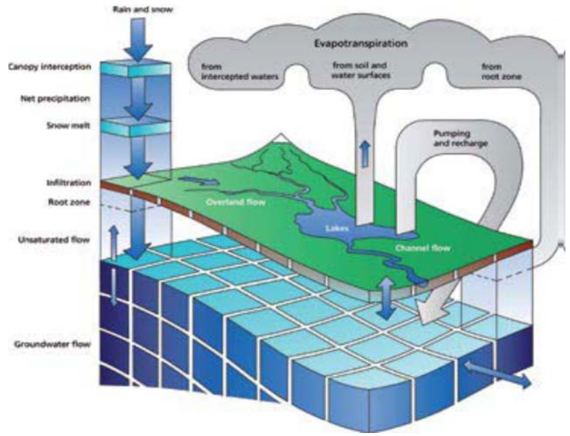
HOBE Center for Hydrology

Hydrological Observatory

HOBE – the Danish Hydrological Observatory 2007 - 2019

Karsten Høgh Jensen
University of Copenhagen





Funding

- 64.8 mill. DKK from VILLUM FONDEN
- ~30 mill. DKK additional funding from various sources

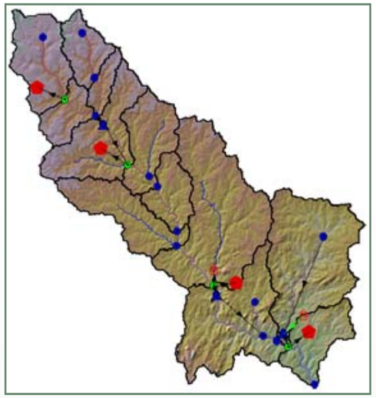
Partners:

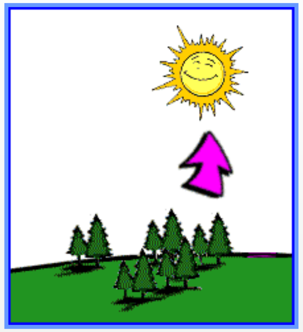
- University of Copenhagen
- Aarhus University
- Technical University of Denmark
- Geological Survey of Denmark and Greenland
- Danish Meteorological Institute

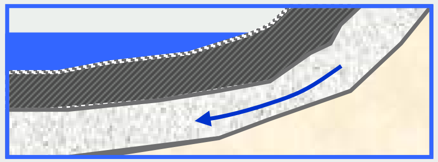
Outputs

- PhDs
  - Graduated: 24
  - Still enrolled:5
- Postdocs: 21
- International journal papers: 122
- Internal conference presentations:160
- Danish journal papers:10
- Technical reports: 4
- Popular science: 2
- Newspaper articles, press releases, TV: 8

Original point of departure:
Problems with closure of water budget







Precipitation =
Evapotranspiration +
Stream flow +
Groundwater pumping +
Submarine groundwater discharge

General motivations for hydrological observatories

- Lack of knowledge on the hydrological processes at catchment scale
- Lack of knowledge on the non-linear interaction and feed-back mechanisms between hydrological compartments at catchment scale
- Lack of knowledge on catchment response to land and climate change

- New developments in sensor technologies and measurement techniques for state variables and fluxes for different spatial and temporal scales (ground-based, air-borne, satellite-borne sensors)
- New developments in modeling distributed and integrated modeling

- Provision of access to high-quality data for the research community

- Development of state-of-the-art methods technologies to practical applications

Hydrological observatories

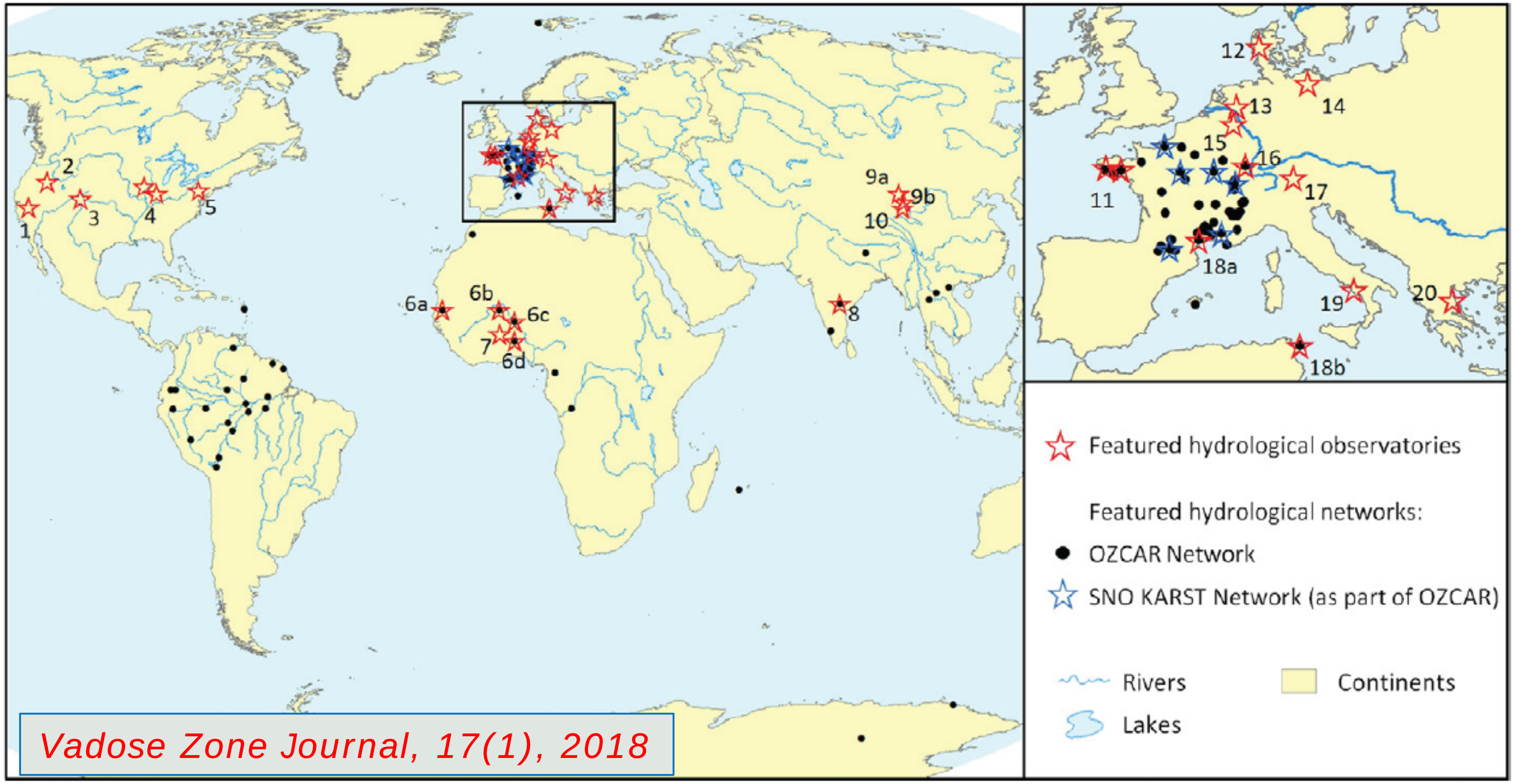
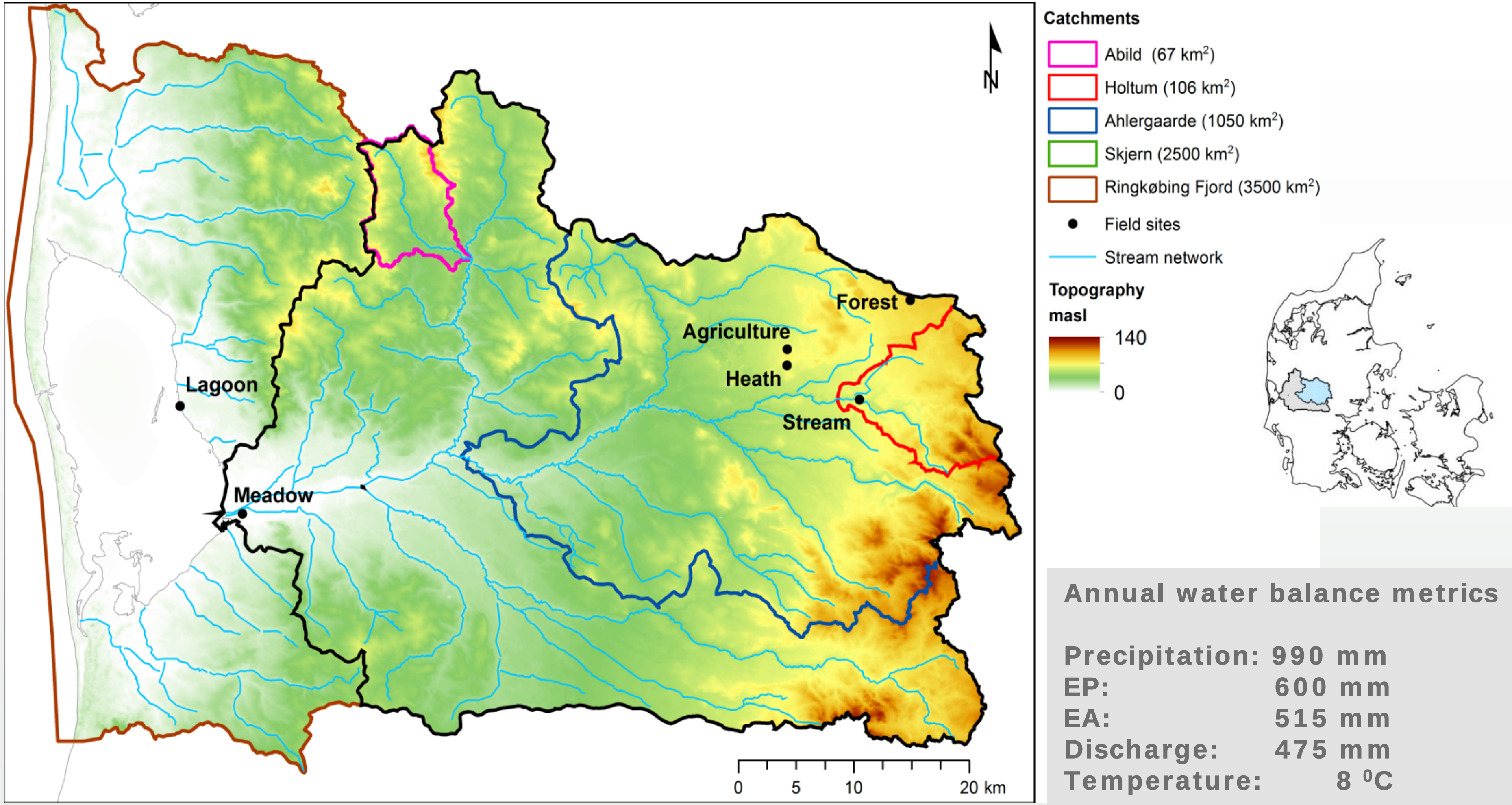


Fig. 1. World map showing the locations of the hydrological observatories featured in this special section: Southern Sierra CZO (1), Reynolds Creek Experimental Watershed and CZO (2), East River, Colorado, watershed (3), Intensively Managed Landscape CZO (4), Susquehanna Shale Hills CZO (5), AMMA-CATCH observatory network (6a,6b), WASCAL observatory (7), Hyderabad observatory (8), Heihe Observatory Network (9a), CHOICE observatory (9b), Qinghai Lake Basin CZO (10), AgrHyS Observatory (11), HOBE Hydrological Observatory (12), TERENO-Rur Hydrological Observatory (13), TERENO-NE Observatory (14), Hupsel Brook catchment (15), Strengbach catchment (16), TERENO Pre-Alpine Observatory (17), OMERE observatory (18a,18b), Alento Hydrological Observatory (19), and Pinios Hydrological Observatory (20). Research sites belonging to the OZCAR CZO network, including some featured hydrological observatories and the SNO KARST network, are also located on the world map.

Study area - Skjern catchment and associated subcatchments – nested approach



Annual water balance metrics

Precipitation: 990 mm
EP: 600 mm
EA: 515 mm
Discharge: 475 mm
Temperature: 8 ^{0}C

Long-term observations of Q, P, ET, GWL

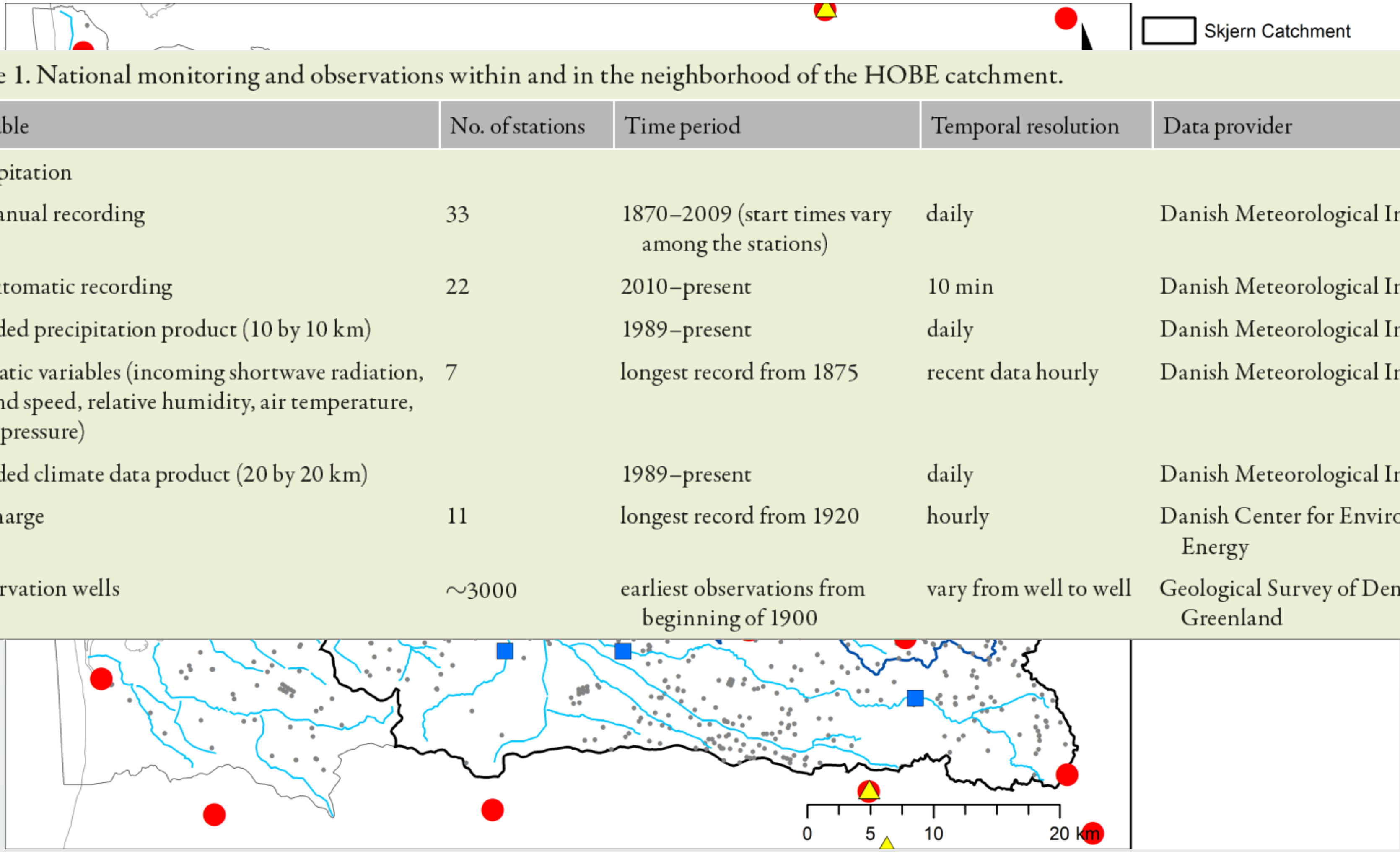


Table 1. National monitoring and observations within and in the neighborhood of the HOBE catchment.

Variable	No. of stations	Time period	Temporal resolution	Data provider
Precipitation				
Manual recording	33	1870–2009 (start times vary among the stations)	daily	Danish Meteorological Institute
Automatic recording	22	2010–present	10 min	Danish Meteorological Institute
Gridded precipitation product (10 by 10 km)		1989–present	daily	Danish Meteorological Institute
Climatic variables (incoming shortwave radiation, wind speed, relative humidity, air temperature, air pressure)	7	longest record from 1875	recent data hourly	Danish Meteorological Institute
Gridded climate data product (20 by 20 km)		1989–present	daily	Danish Meteorological Institute
Discharge	11	longest record from 1920	hourly	Danish Center for Environment and Energy
Observation wells	~3000	earliest observations from beginning of 1900	vary from well to well	Geological Survey of Denmark and Greenland

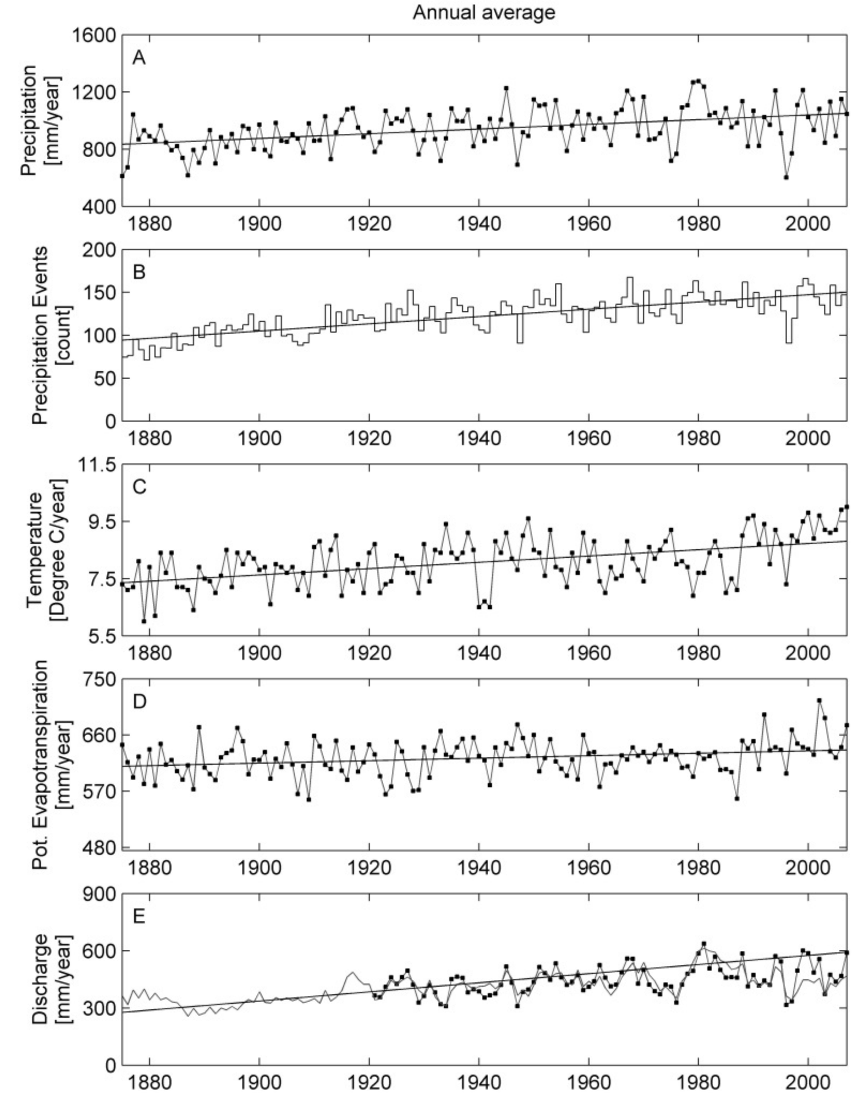
Evidence of climate change in Ahlergaarde catchment

Increase per decade

- Temperature: 0.1 °C
- Precipitation: 16 mm
- Etp: 2 mm
- River discharge: 13 mm

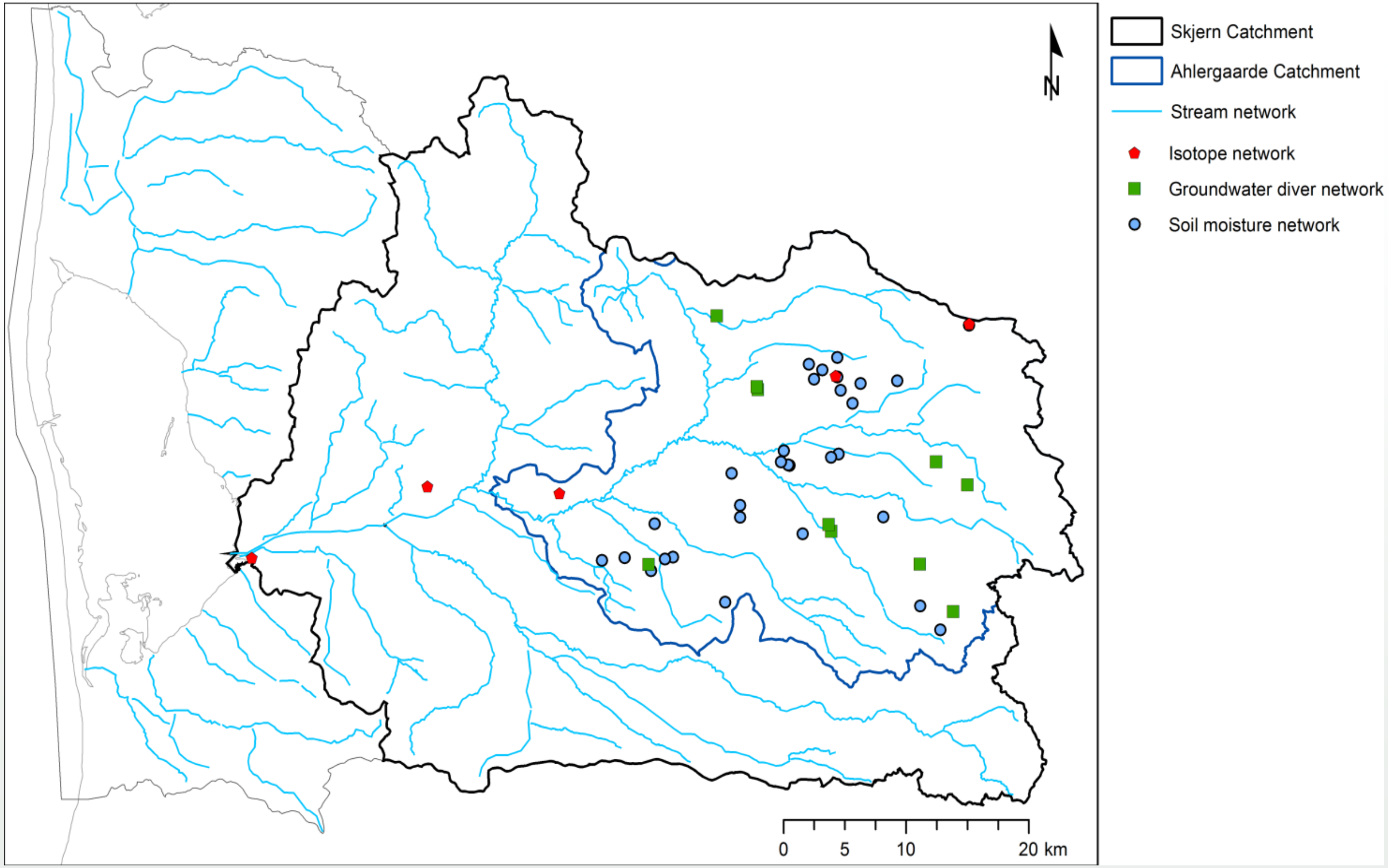
Increase over 133 years

- Temperature: 1.4 °C (18%)
- Precipitation: 218 mm (26%)
- Etp: 25 mm (4%)
- River discharge: 166 mm (52%)

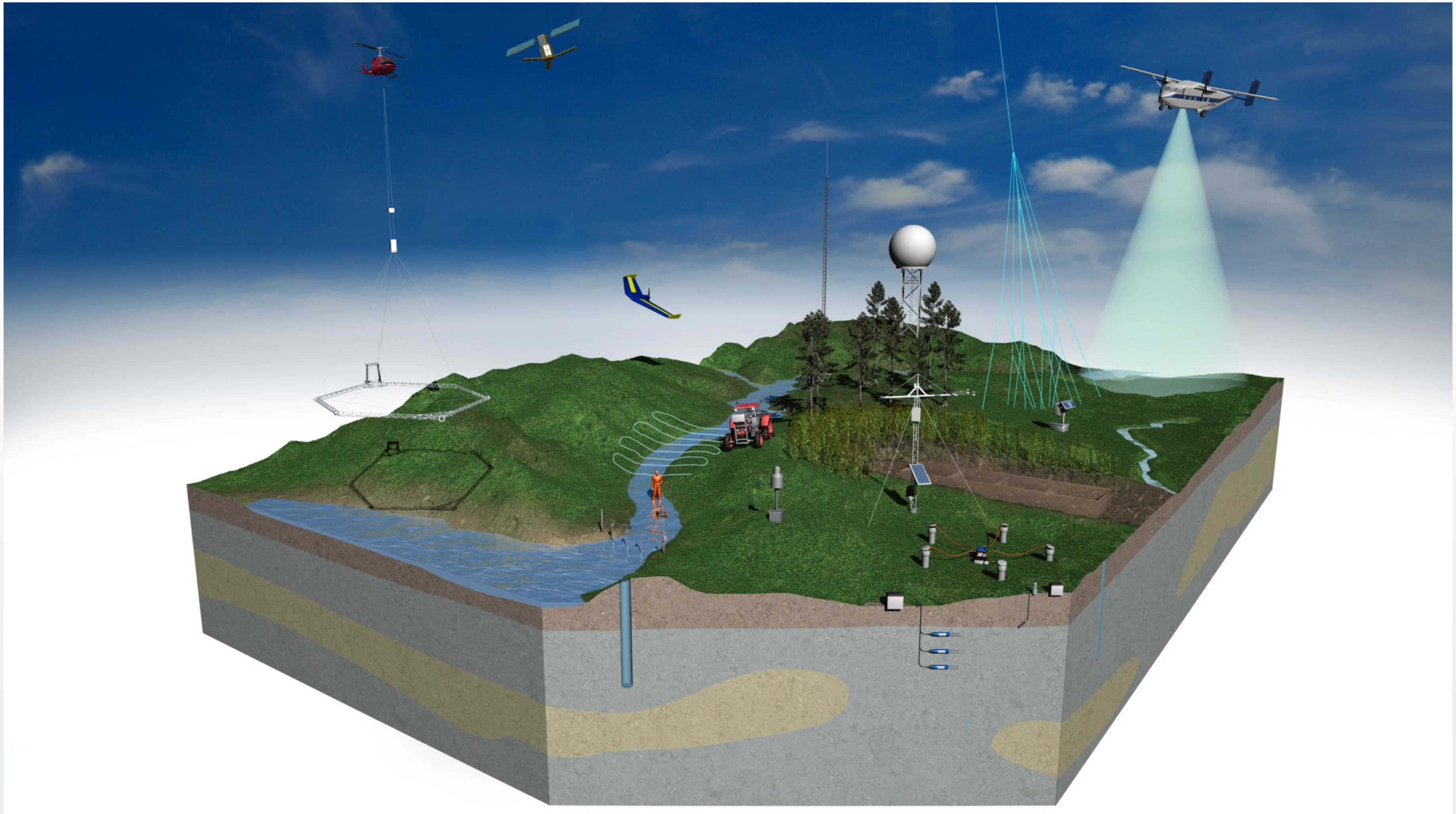


Karlsson et al., 2014

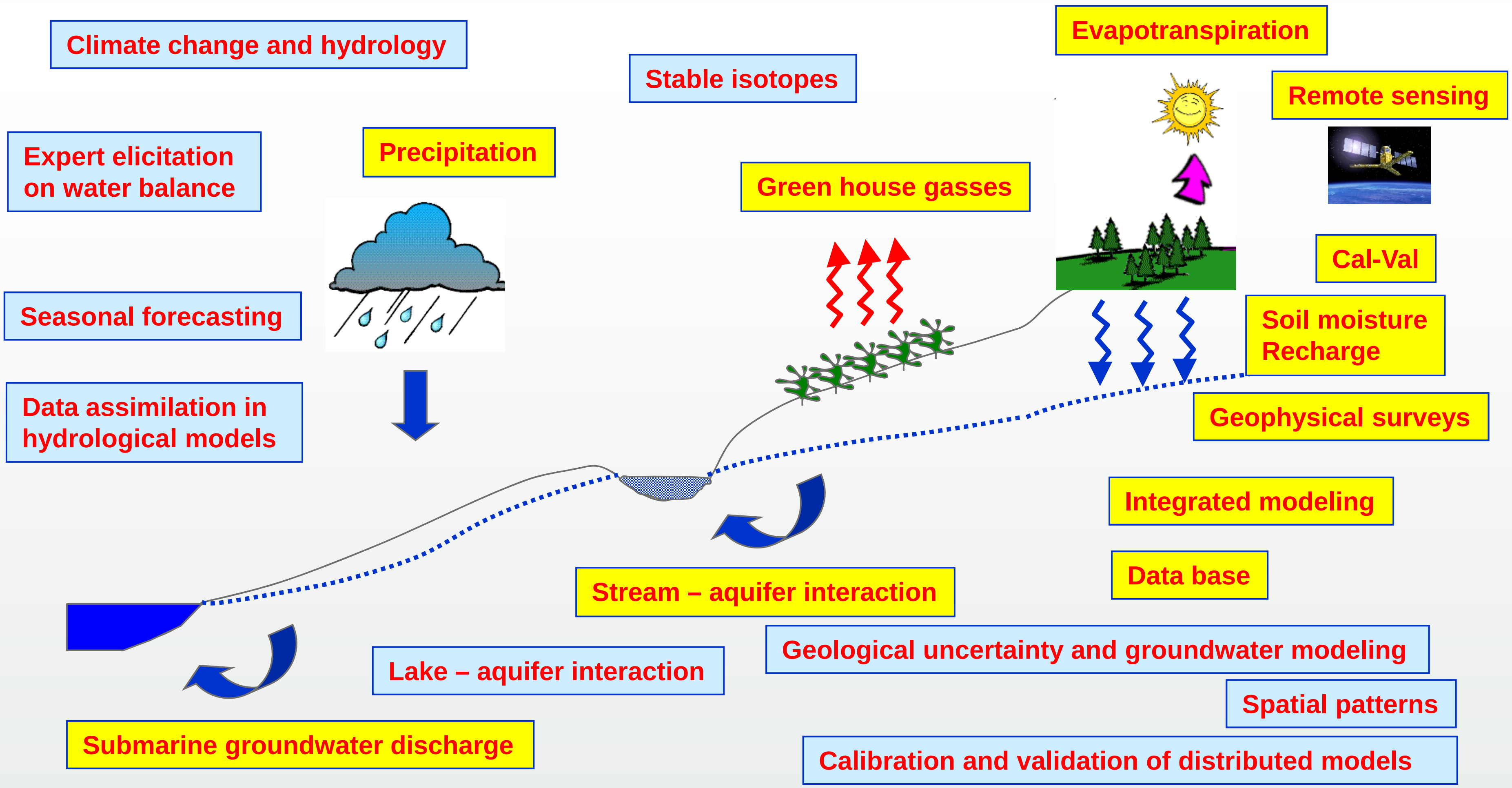
Dedicated observations



New instrumentation techniques

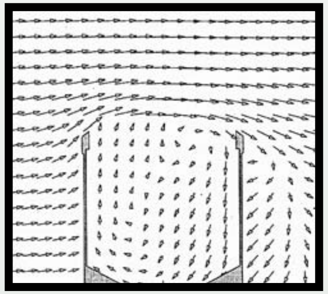


Project components



Research issues: Precipitation

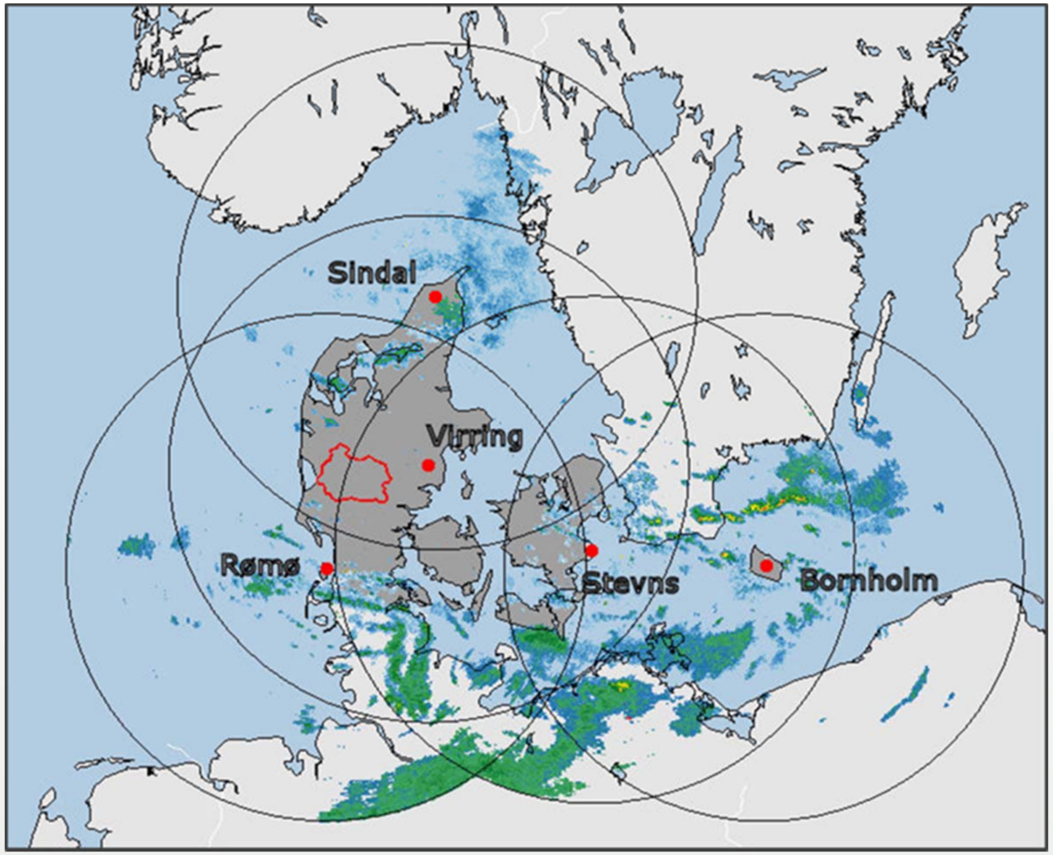
- Measurement and bias-correction of precipitation at local scale (rain gauges)
- Estimation of precipitation at catchment scale (weather radar)
- Analysis of precipitation processes across the catchment
- Quantification of uncertainty propagation in the hydrological system

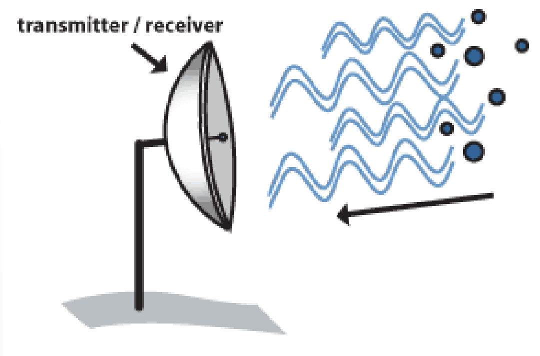


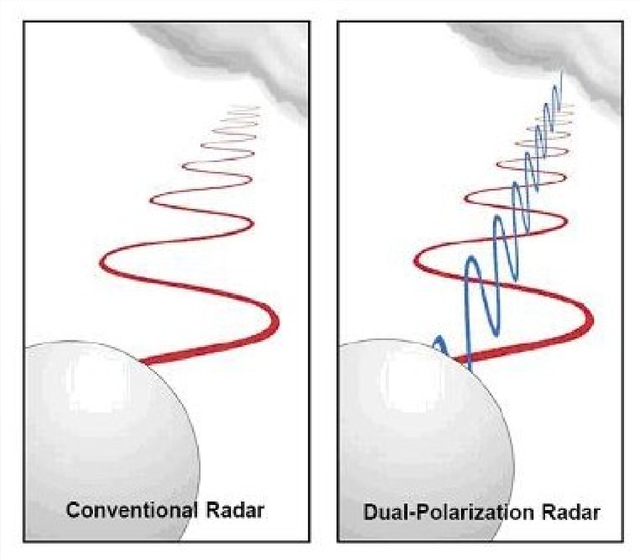
Month	Standard 1960 - 1990	Local 1989 - 1999	Dynamic 2000 - 2003
1	1.38	1.27	1.19
2	1.39	1.29	1.27
3	1.33	1.27	1.21
4	1.23	1.23	1.16
5	1.13	1.14	1.11
6	1.11	1.11	1.09
7	1.1	1.11	1.09
8	1.1	1.08	1.09
9	1.11	1.09	1.09
10	1.13	1.1	1.11
11	1.22	1.2	1.13
12	1.35	1.22	1.21
Average	1.22	1.18	1.15

Stisen et al., VZJ, 2011

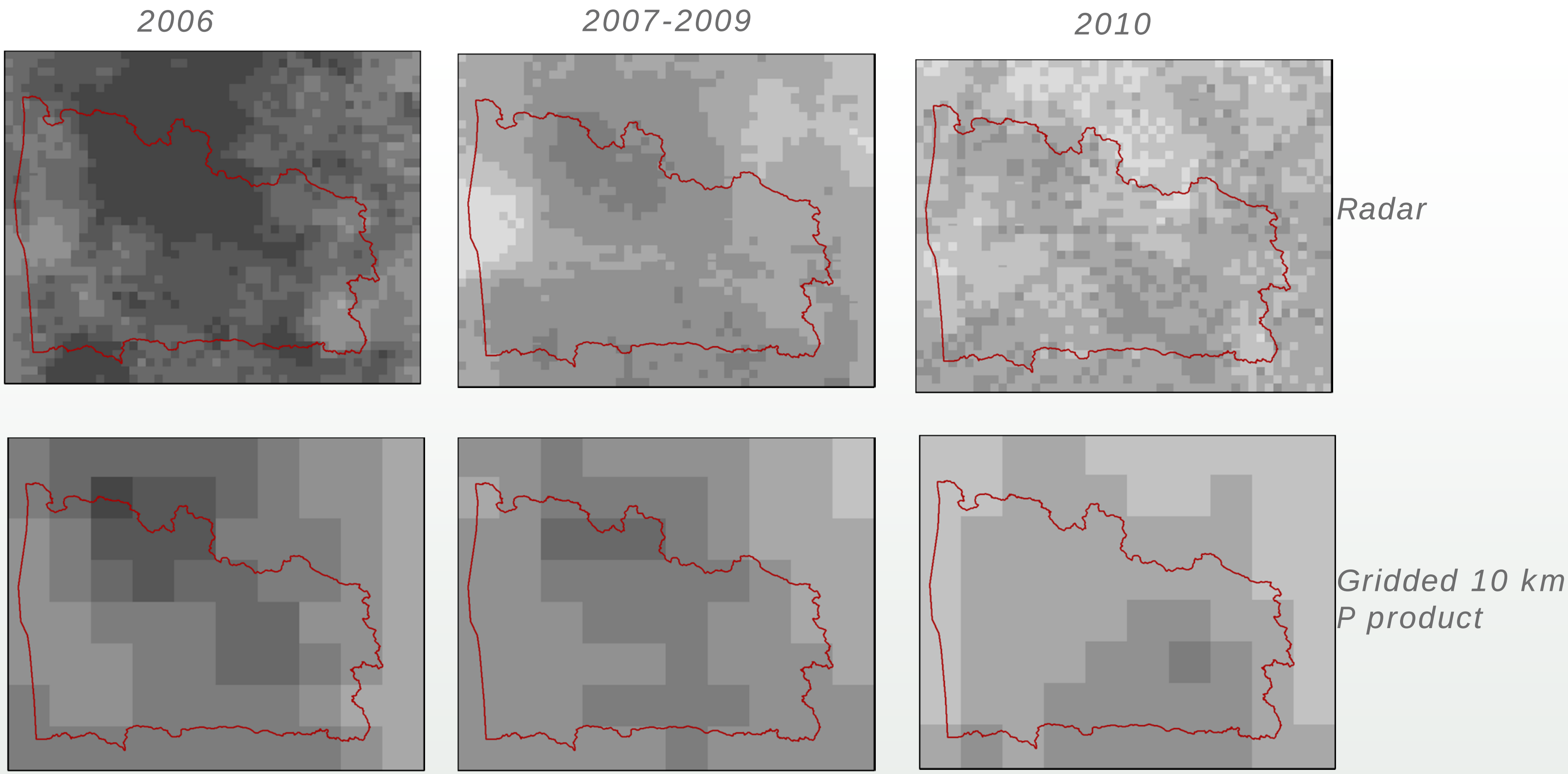
Precipitation estimate at catchment scale: Weather radars





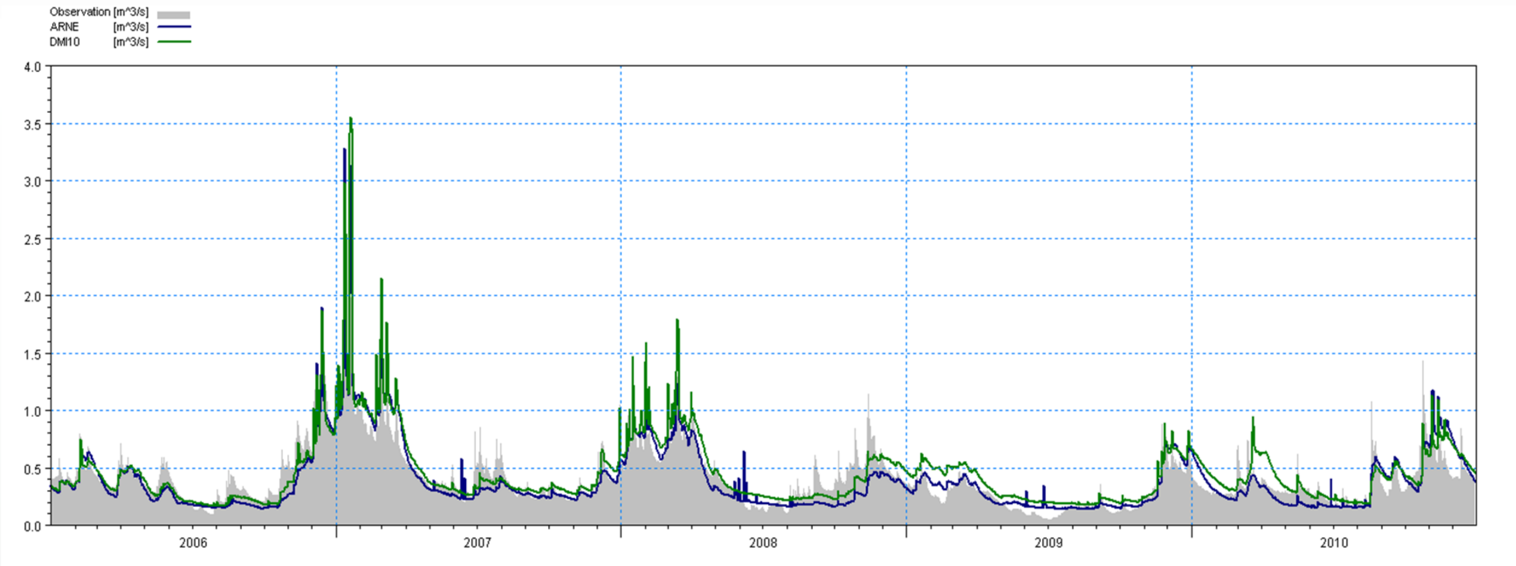


Radar (single-pol) and rain gauge based precipitation

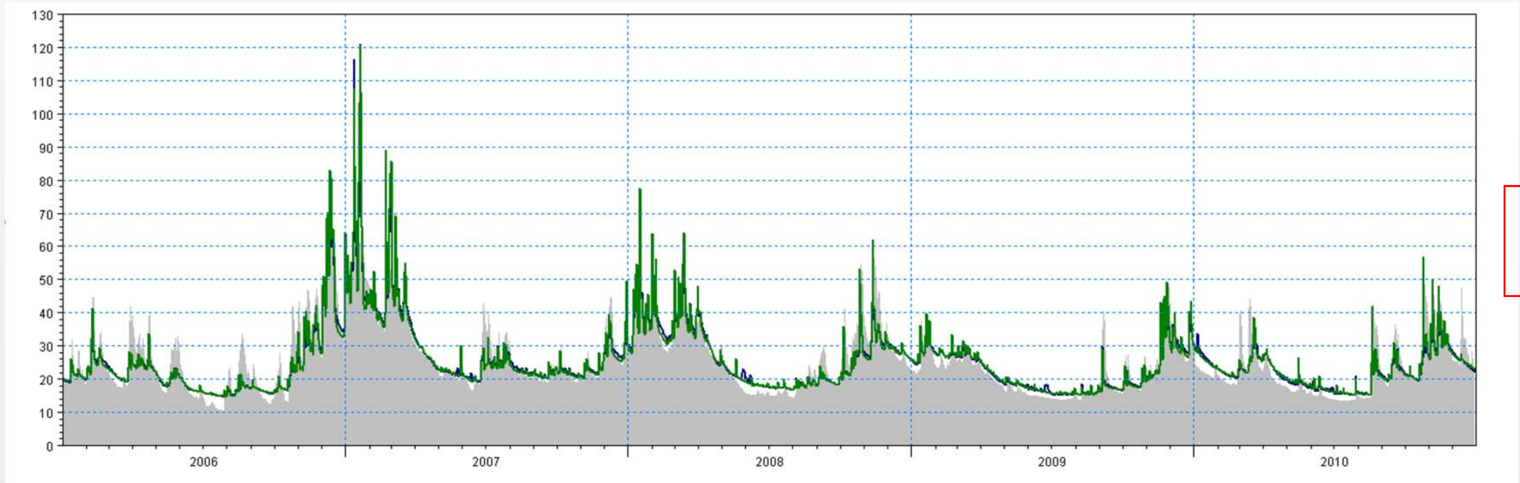


He et al., WRR, 2013

Simulated discharge of upstream and downstream stations



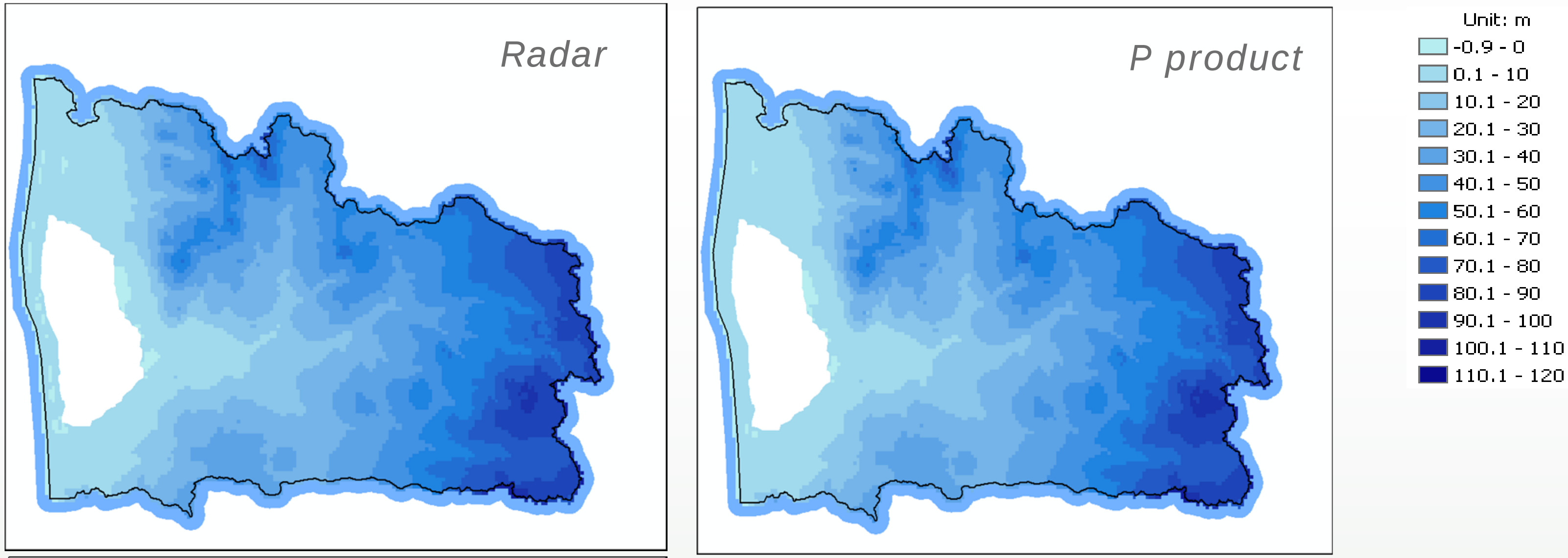
Upstream 47 km²

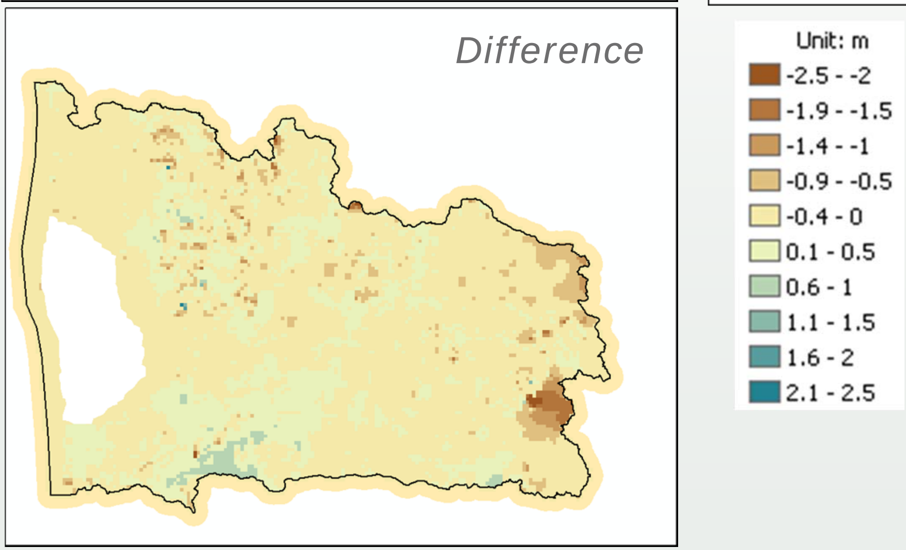


Downstream 1550 km²

He et al., WRR, 2013

Average groundwater head (2006-2010)



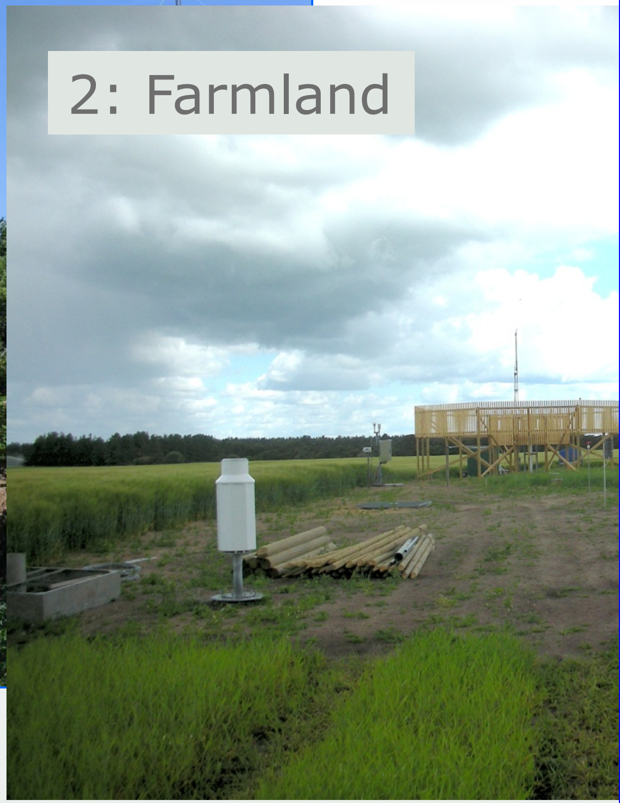


He et al., WRR, 2013

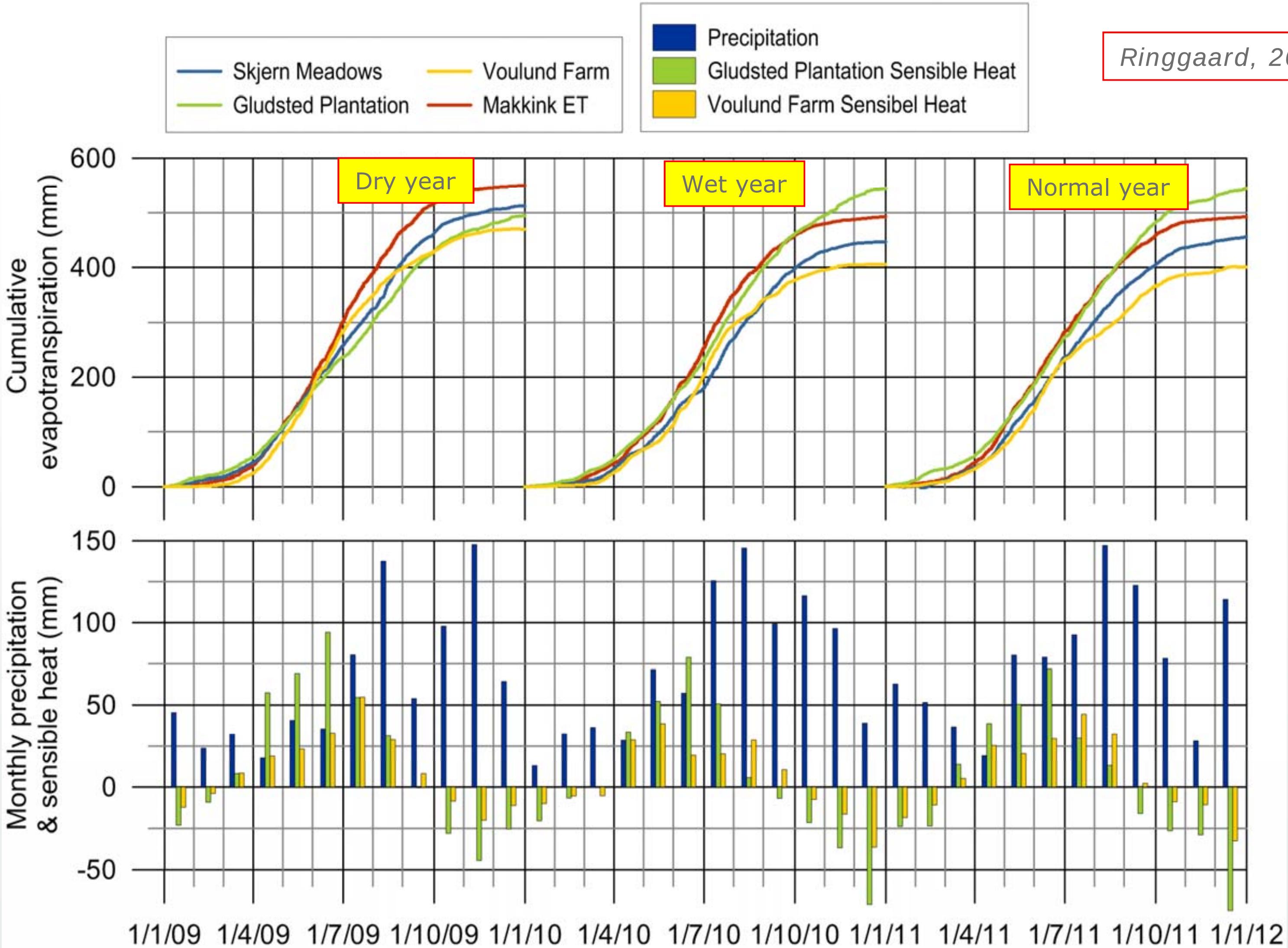
Research issues: Evapotranspiration

- Measurement of ET for different vegetation types at local scale
  - ➜ Measurements used for constraining modeling
- Estimation of ET at intermediate scale
- Estimation of ET at catchment scale

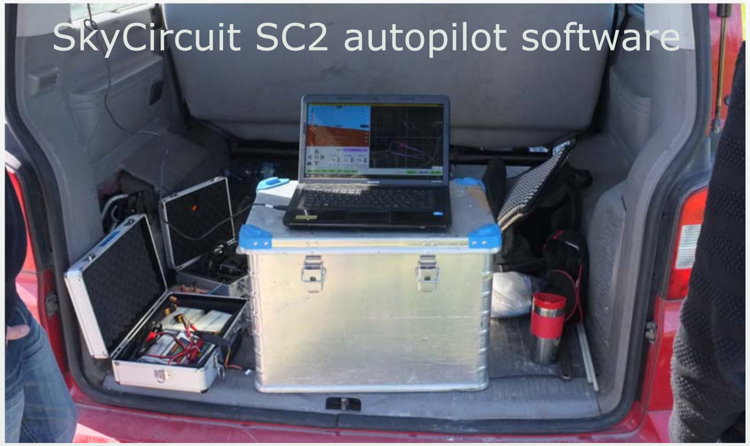
ET at local scale: Three flux towers



ET for three land surfaces



Evapotranspiration: Intermediate scale measurements using UAV

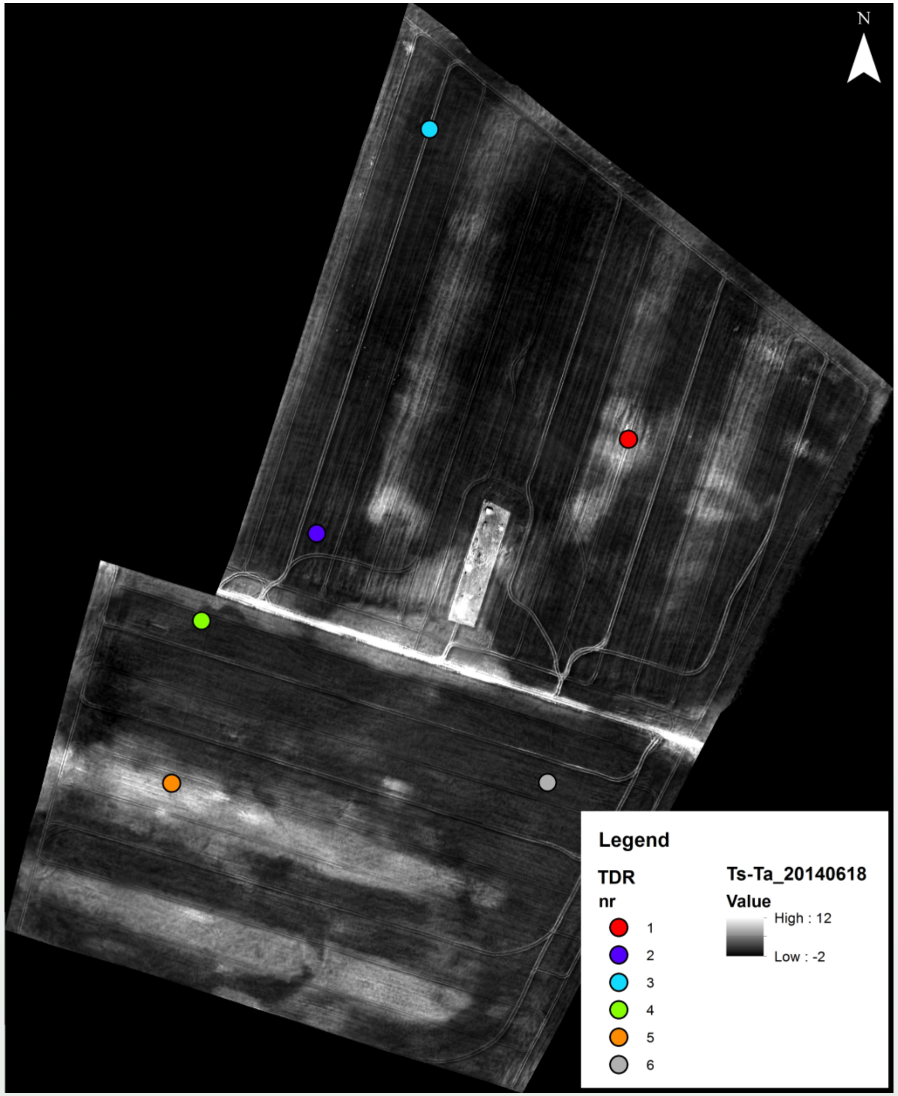


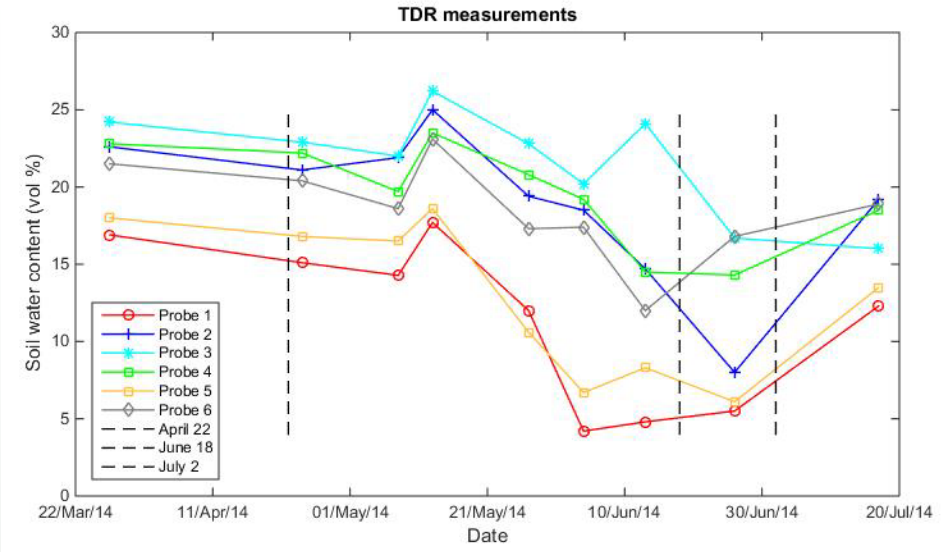
Fixed-wing **UAV** (Q300, QuestUAV, UK)
2.2 m wingspan; payload of 2 kg ~30 min in air;
60 km/h; flying height of 90 m

Optris PI 450 LightWeight **thermal infrared camera**
Detects infrared energy in the 7.5-13 µm; 380 g;
16 bit radiometric resolution; array of 382 x 288 pixels

Panasonic Lumix **RGB camera**
Consumer grade camera; detects energy in the red, green and blue bands; jpeg format

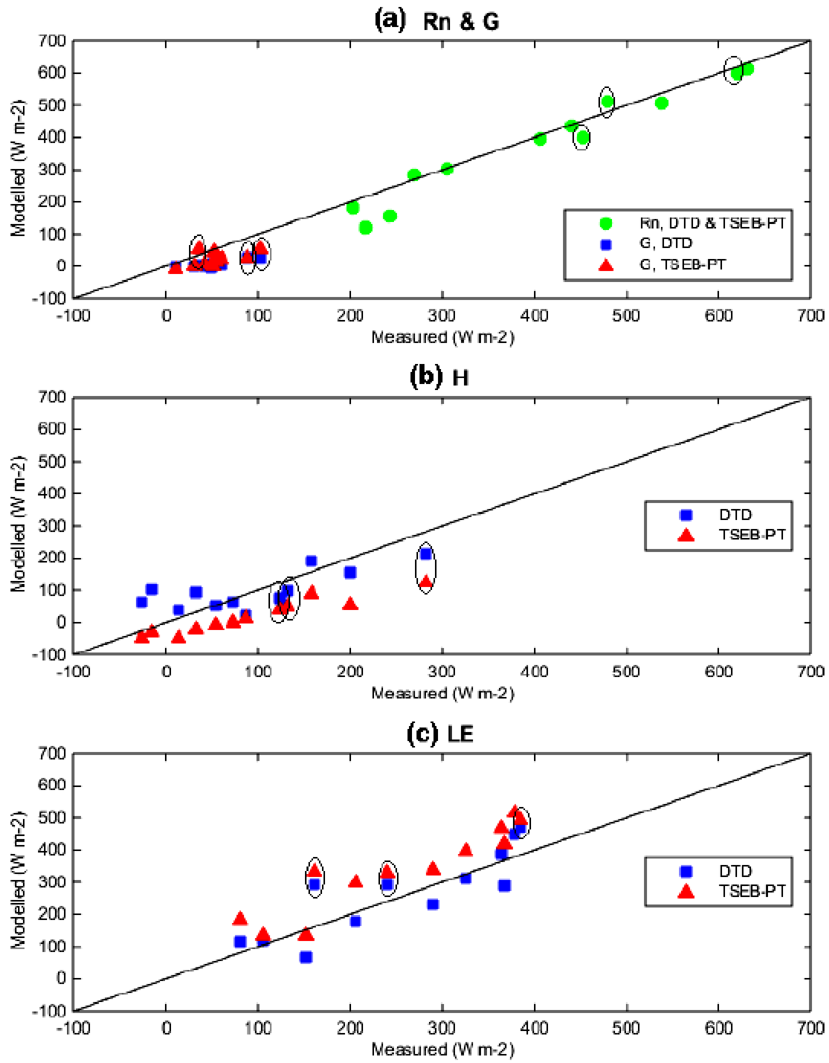
Mapping of surface temperature





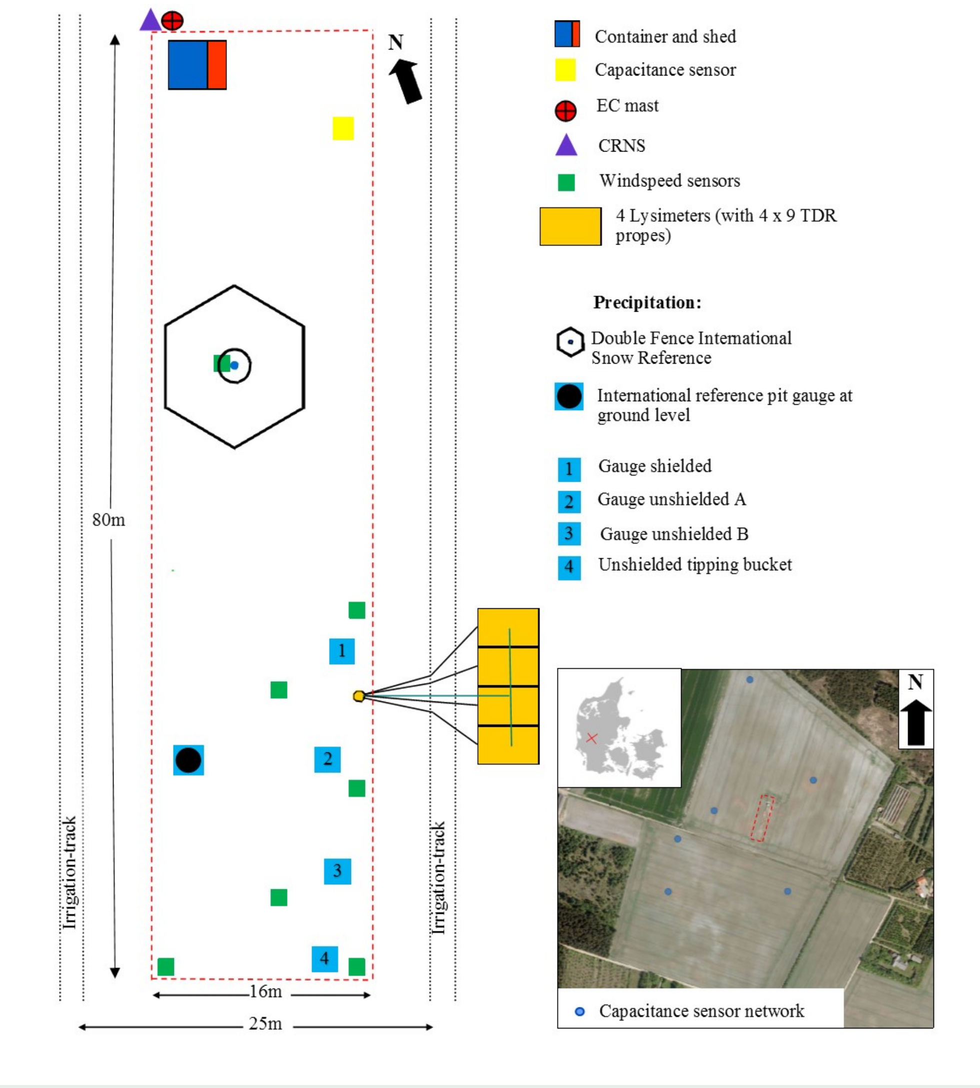
Hoffmann et al., HESS, 2016

Estimates of energy fluxes using two-source energy balance and dual temperature difference models

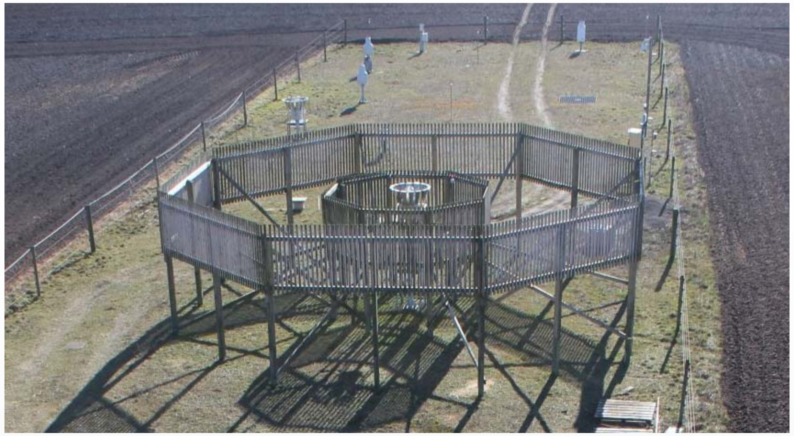


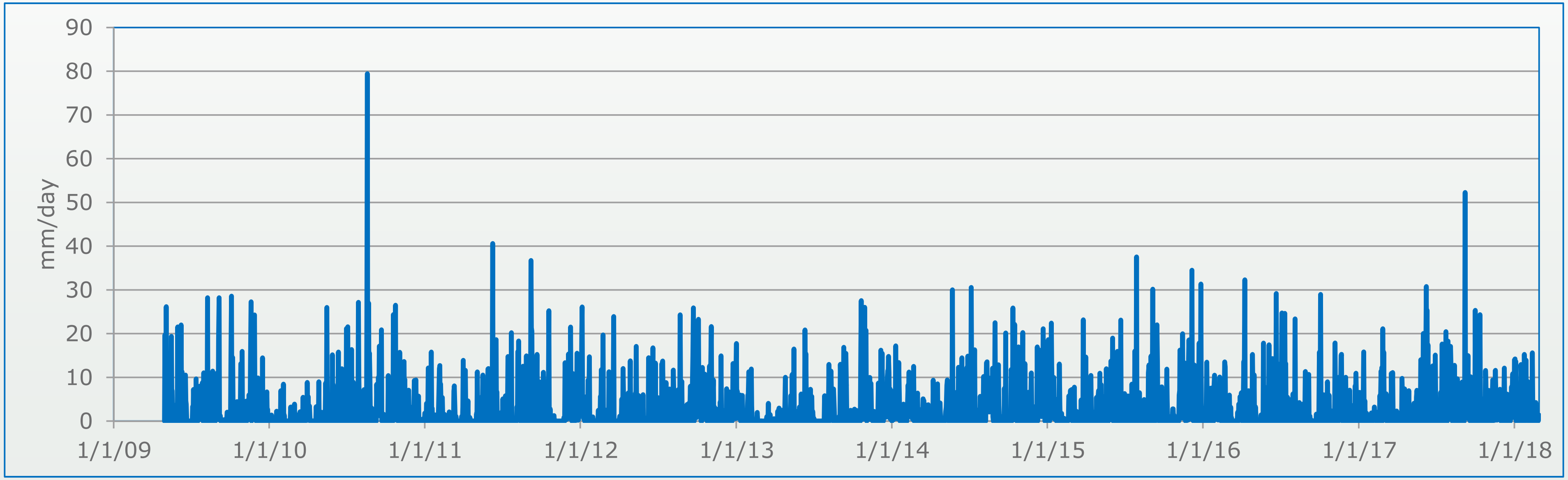
Hoffmann et al., 2016

Layout of agricultural field observatory

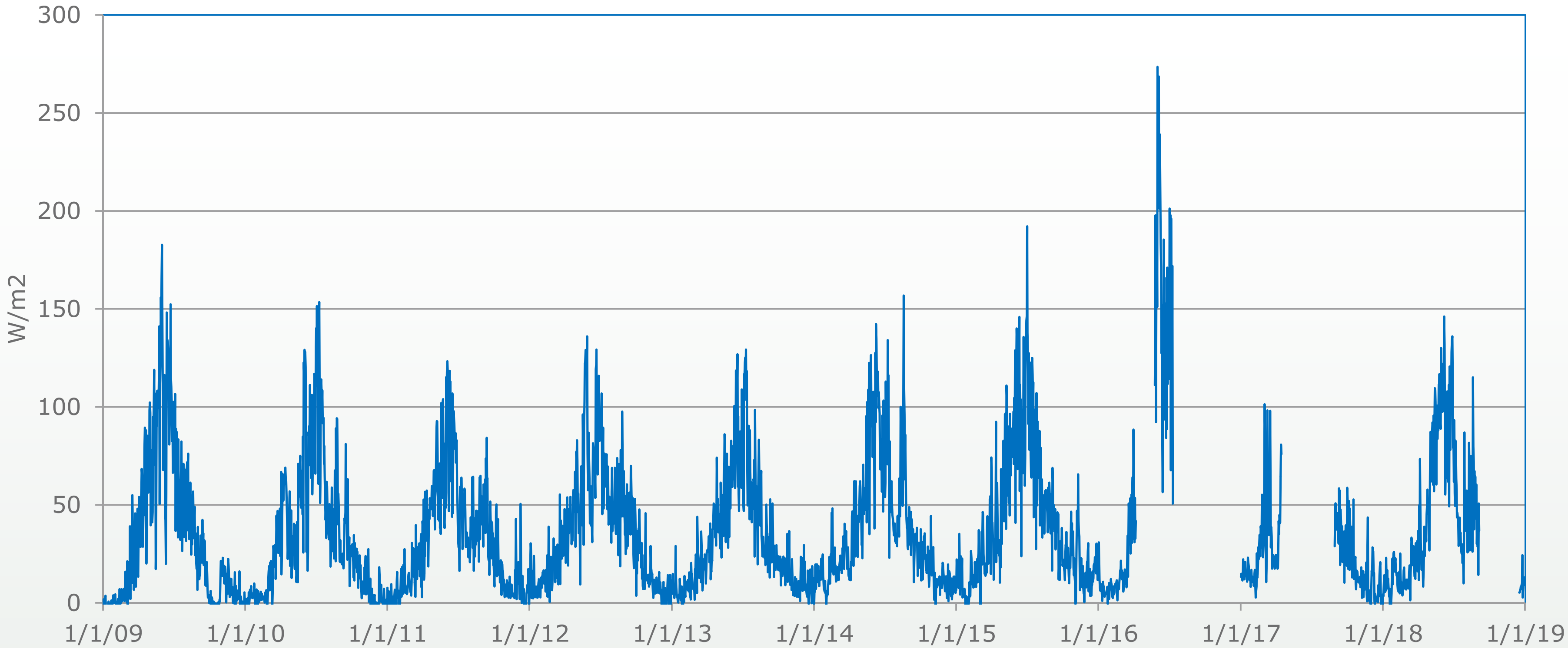


Rainfall – Best of Voulund

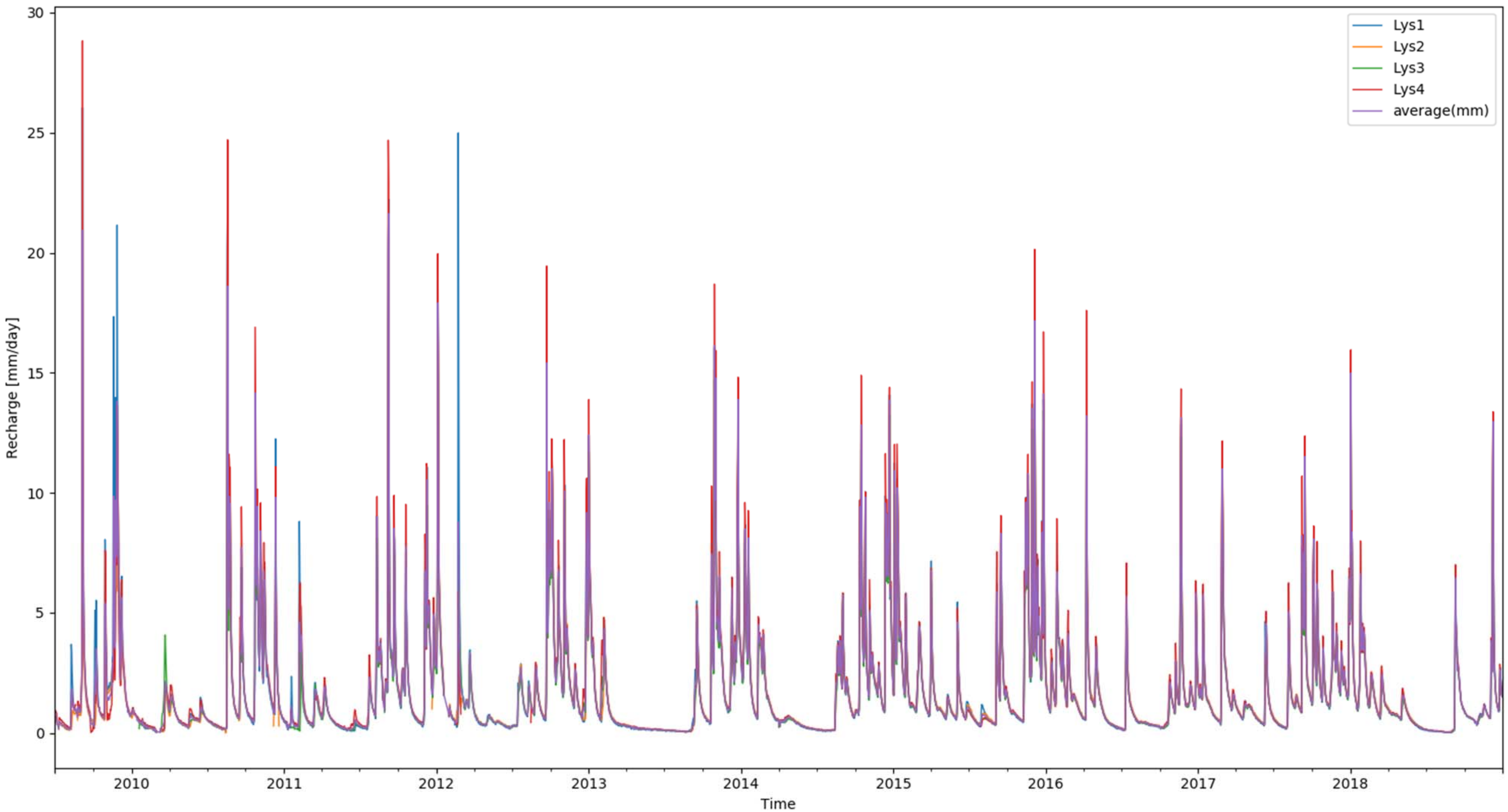




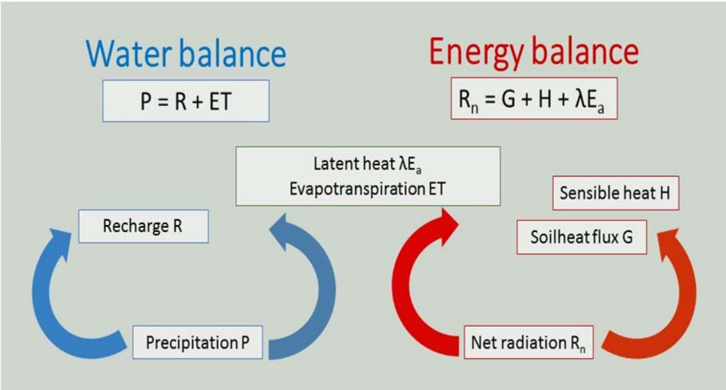
Flux measurements of ET (Latent heat)

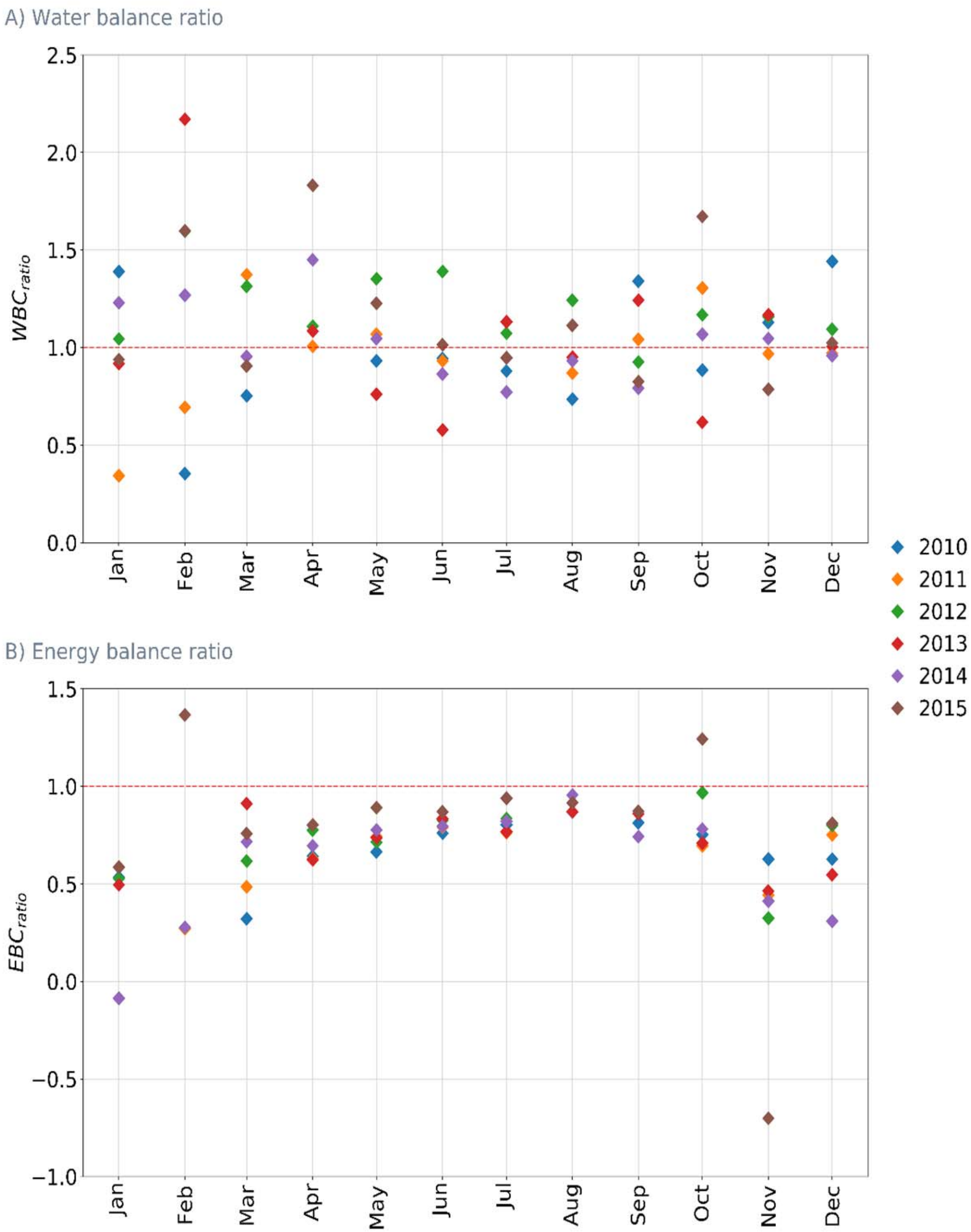


Recharge meaurements in lysimeters

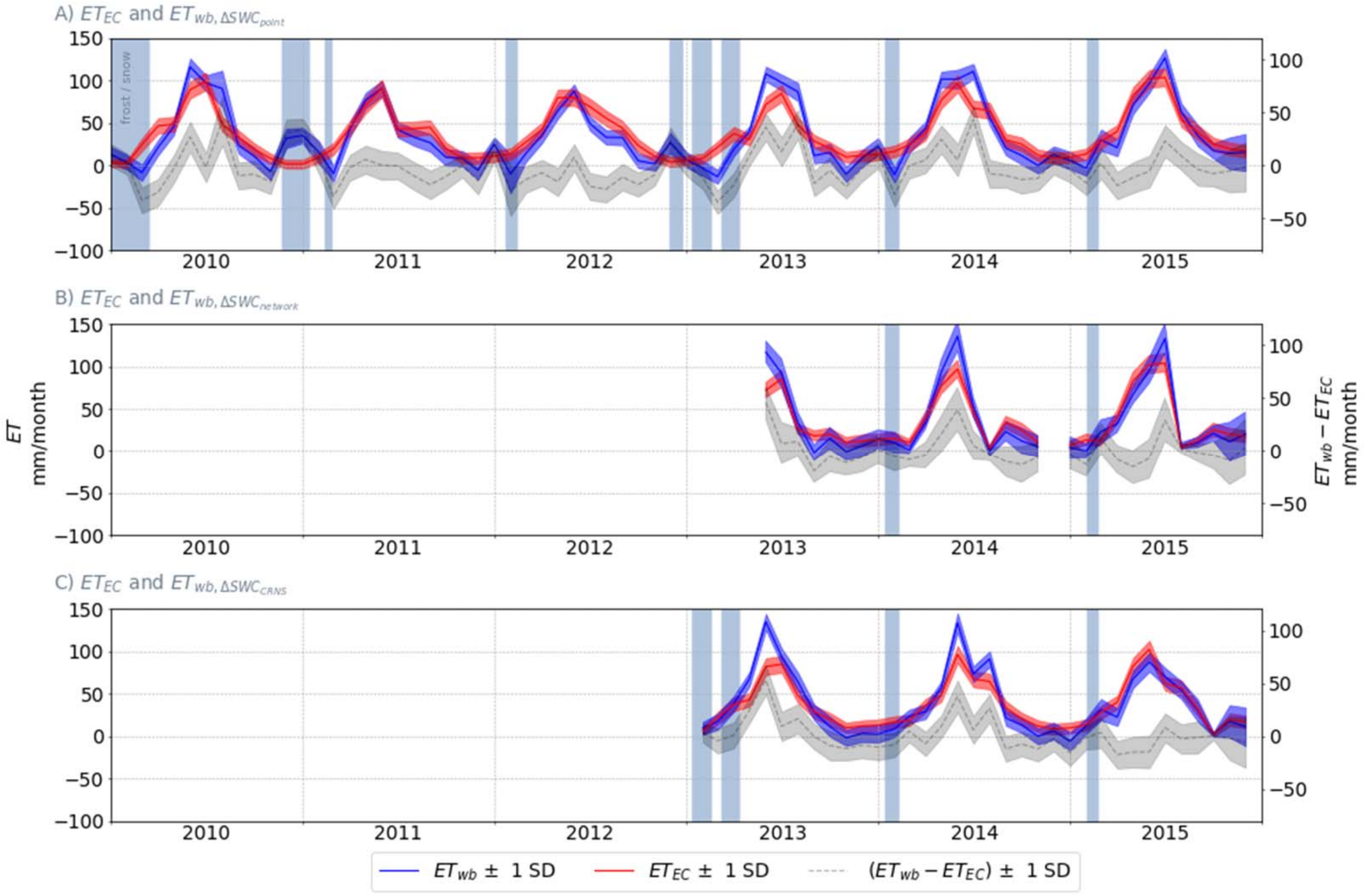


Water and energy balances for agricultural site





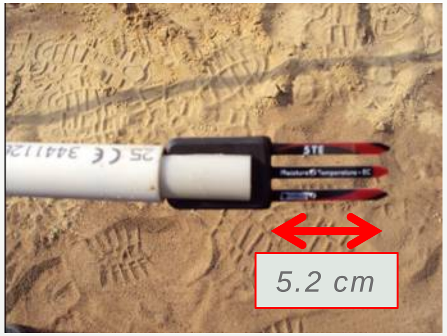
Comparison ET_{EC} and ET_{wb}

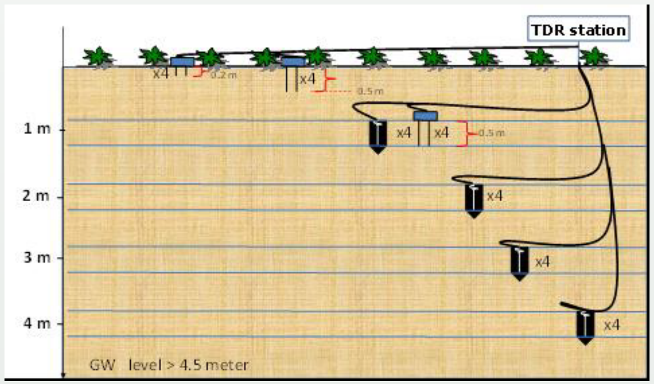


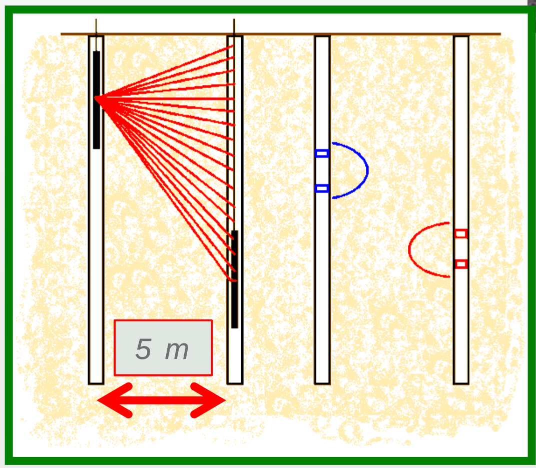
Research issues: Soil moisture

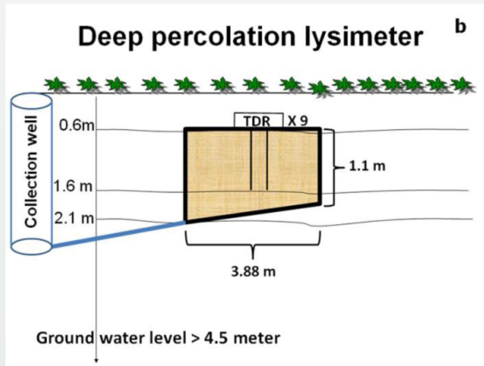
- Measurement and estimation of soil moisture at different spatial scales
- Interaction between vegetation and soil moisture
- Scaling of soil moisture measurements
- Use of soil moisture for estimating water balance at the local scale
- Use of soil moisture for constraining distributed models
- Use of soil moisture for data assimilation in distributed models

Soil moisture and recharge at local scale: Agricultural field observatory

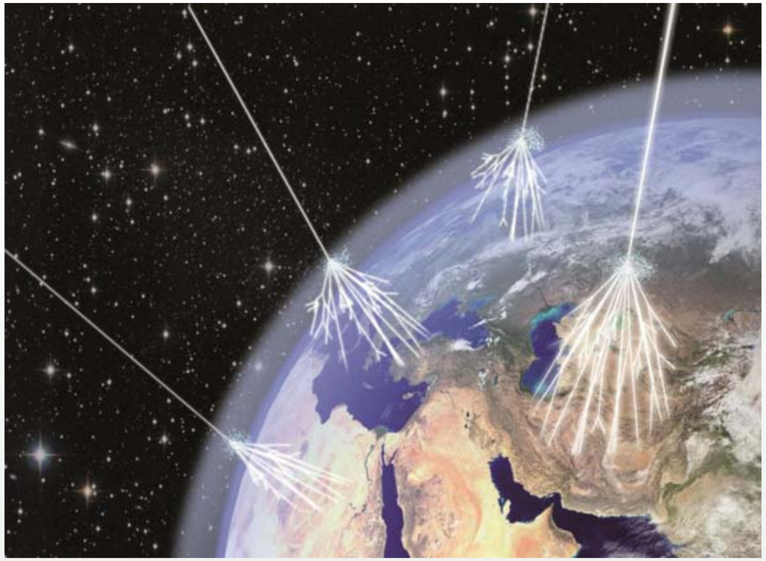


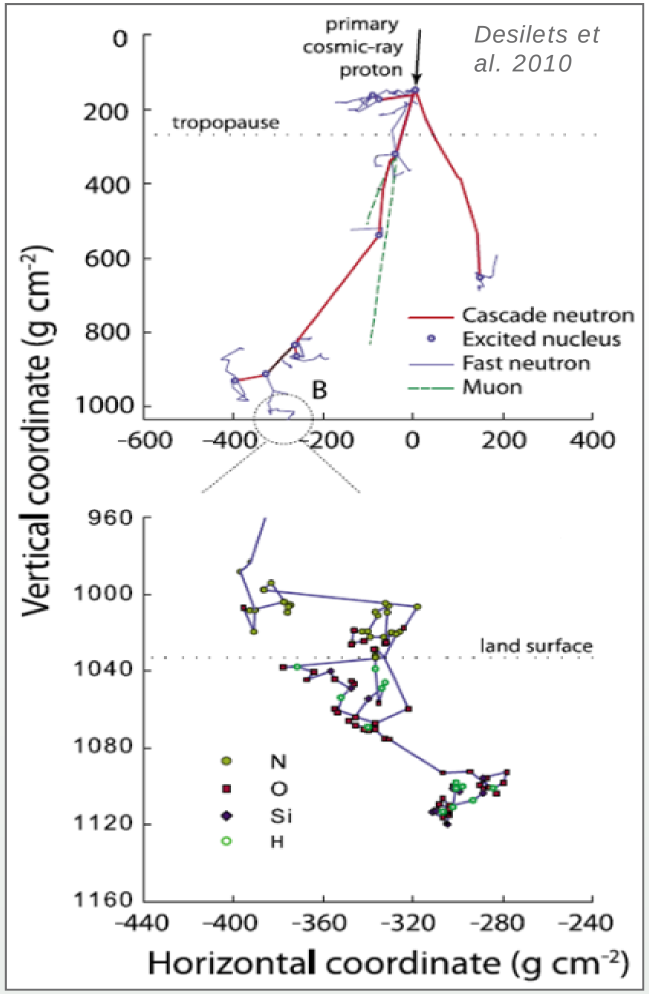




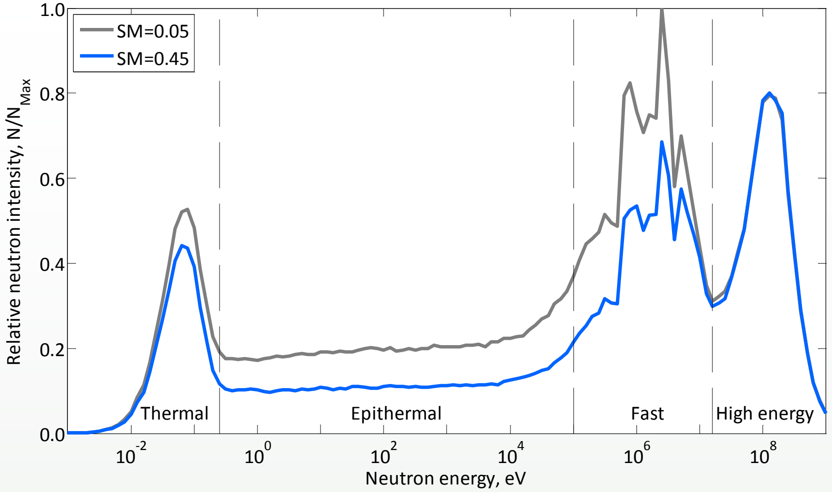


Soil moisture at intermediate scale: Cosmic ray

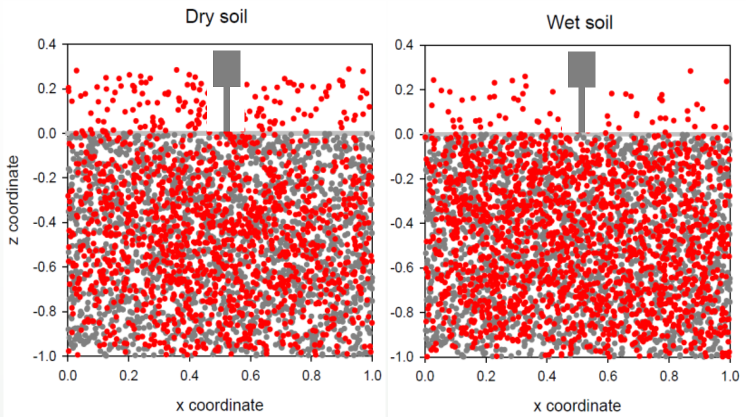


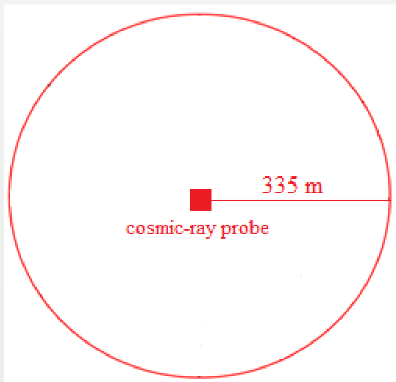


Soil moisture at intermediate scale: Cosmic ray



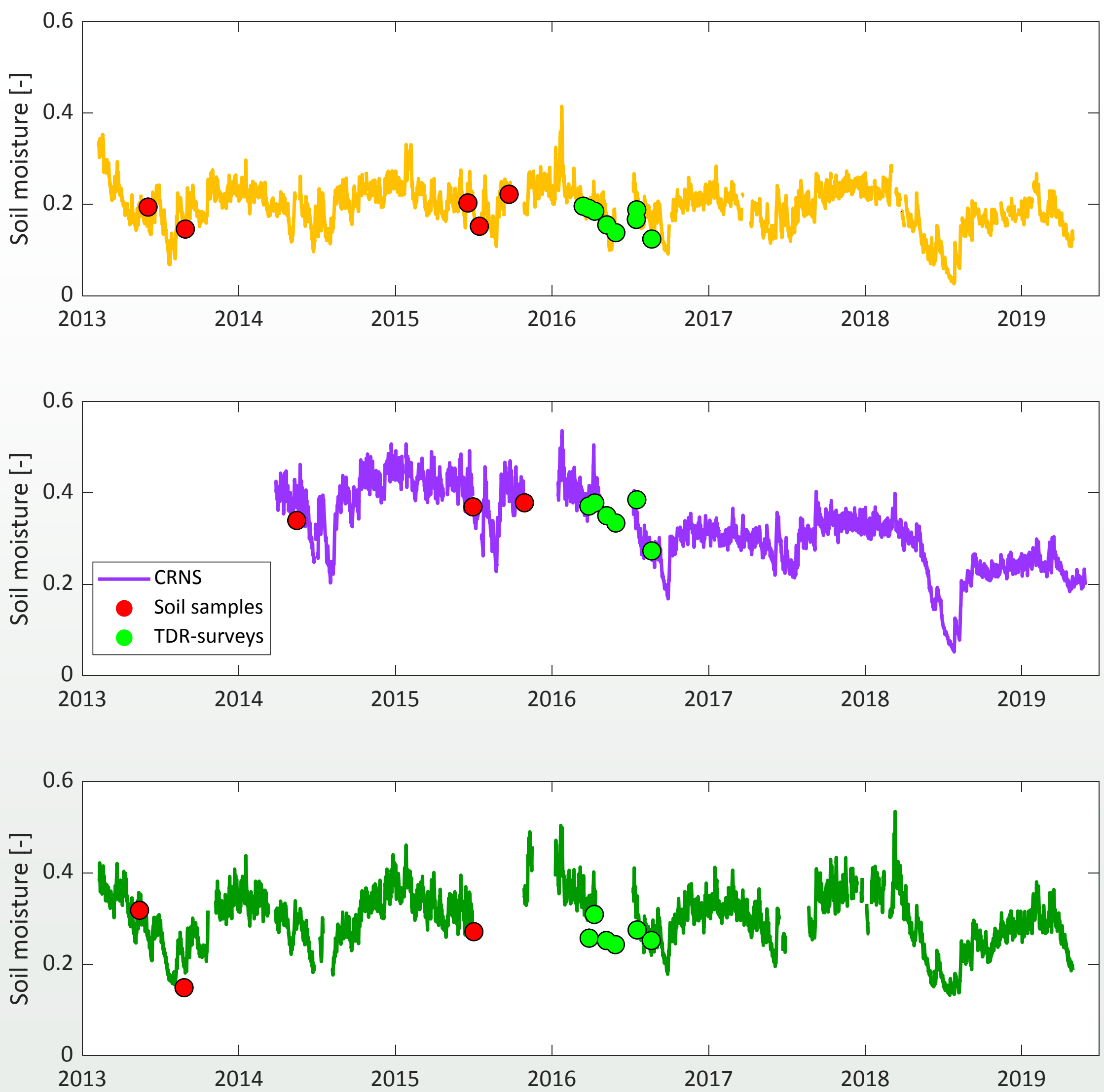
Neutron intensity and soil water content are inversely correlated



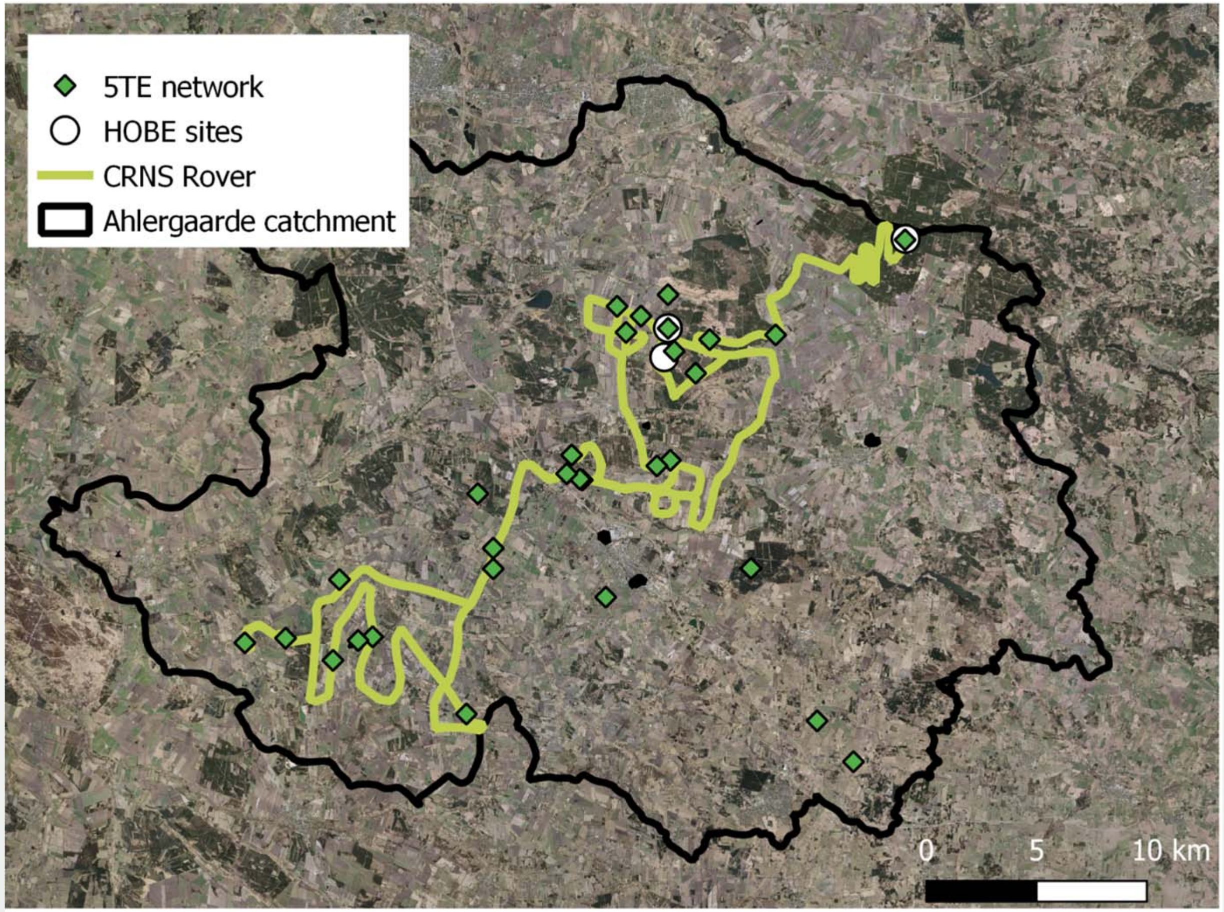


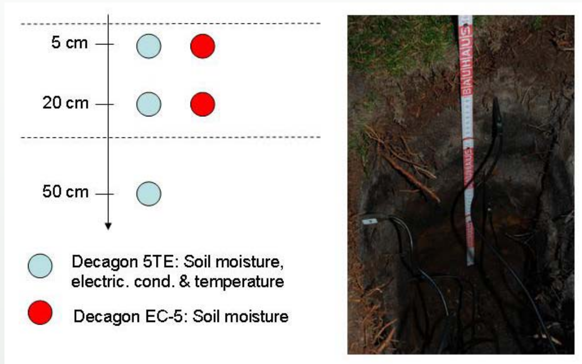
Foot print

Times series of soil moisture based on the cosmic ray method

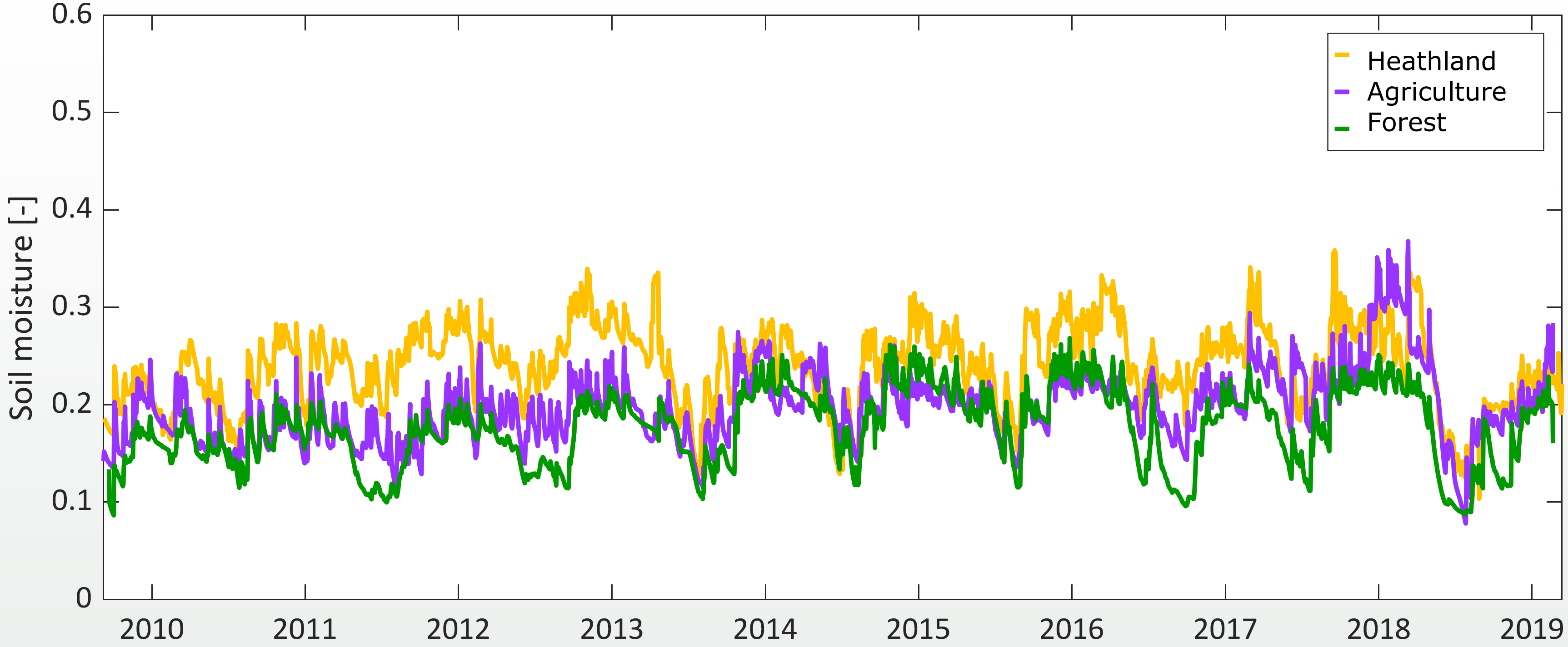


Soil moisture at regional scale: Distributed soil mositure network

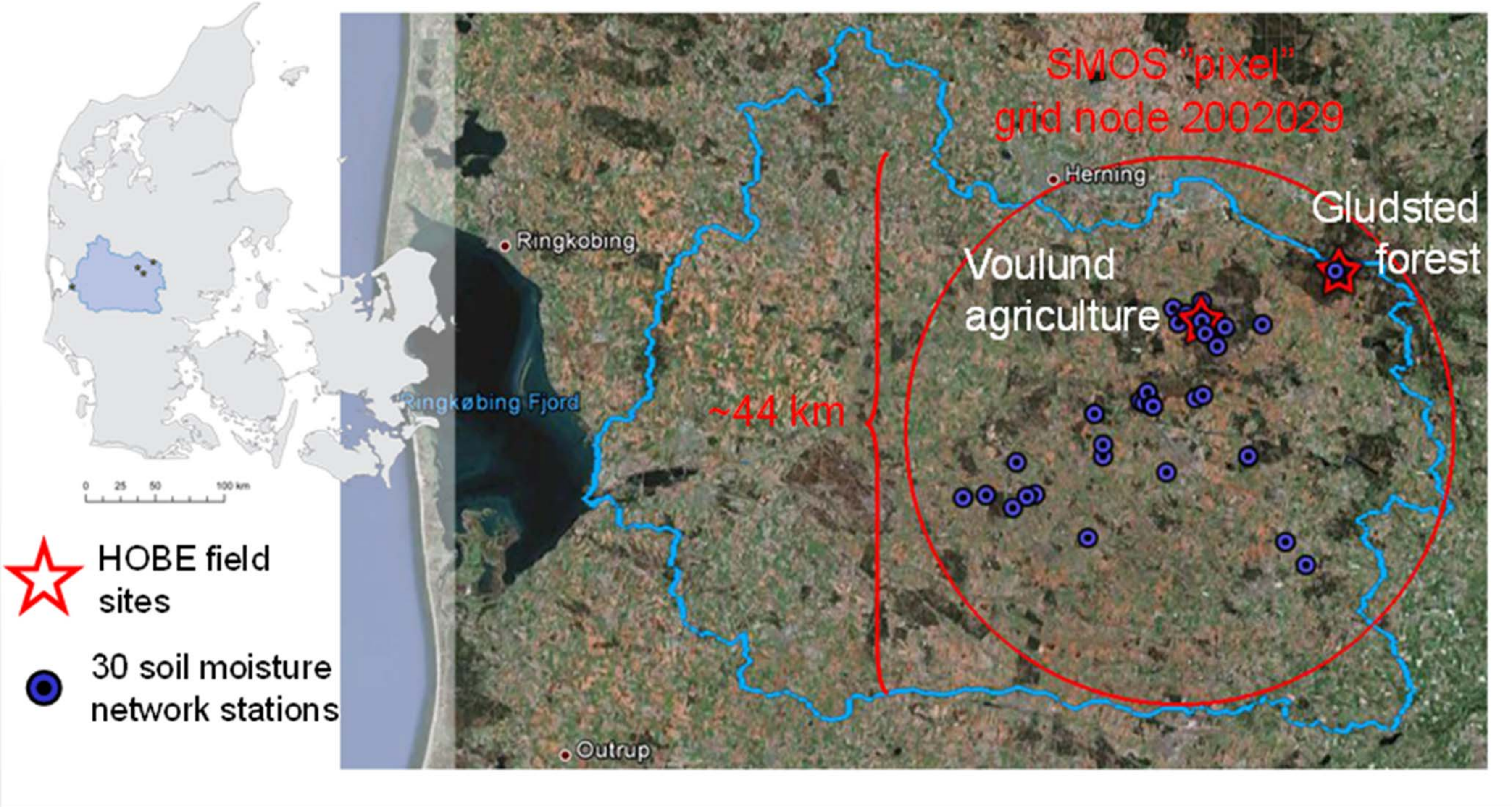




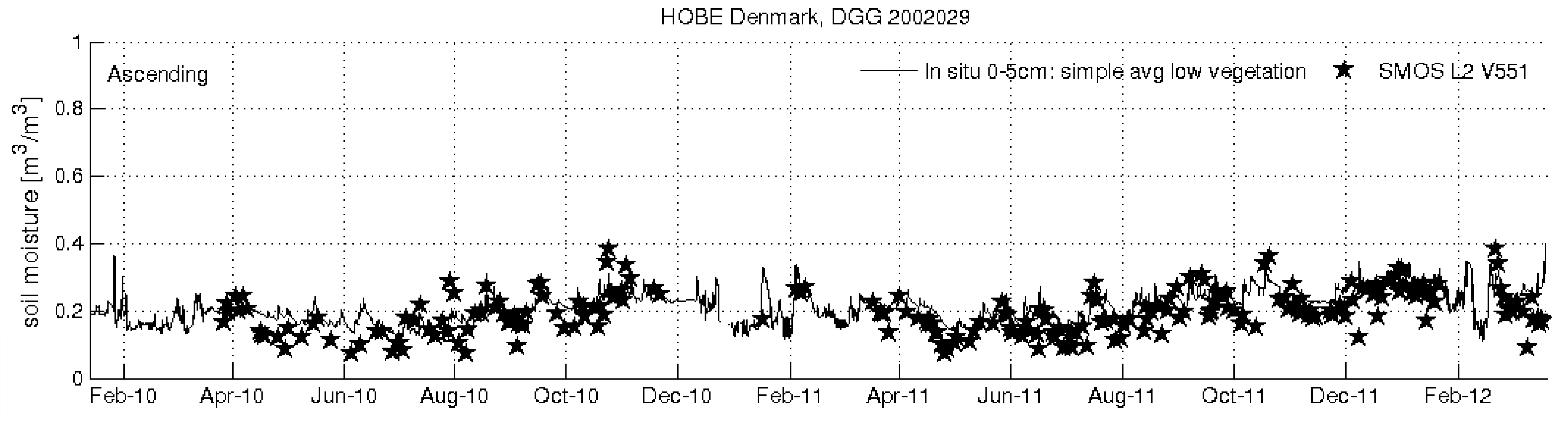
Time series of mean daily soil moisture based on soil moisture network

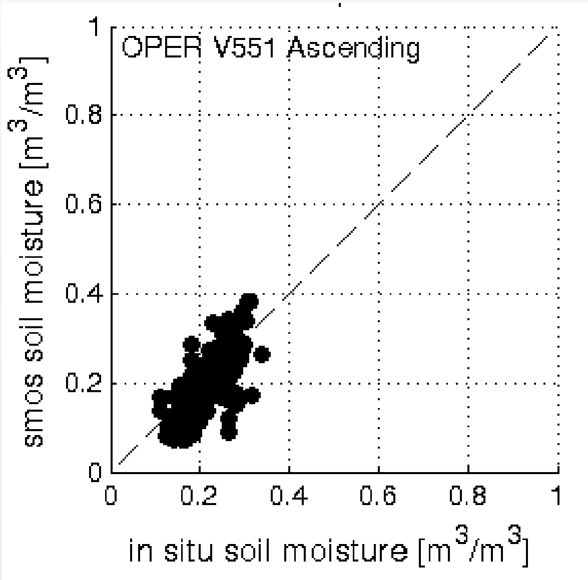


Soil moisture at larger scale: SMOS



CalVal: SMOS retrieved soil moisture and measurements





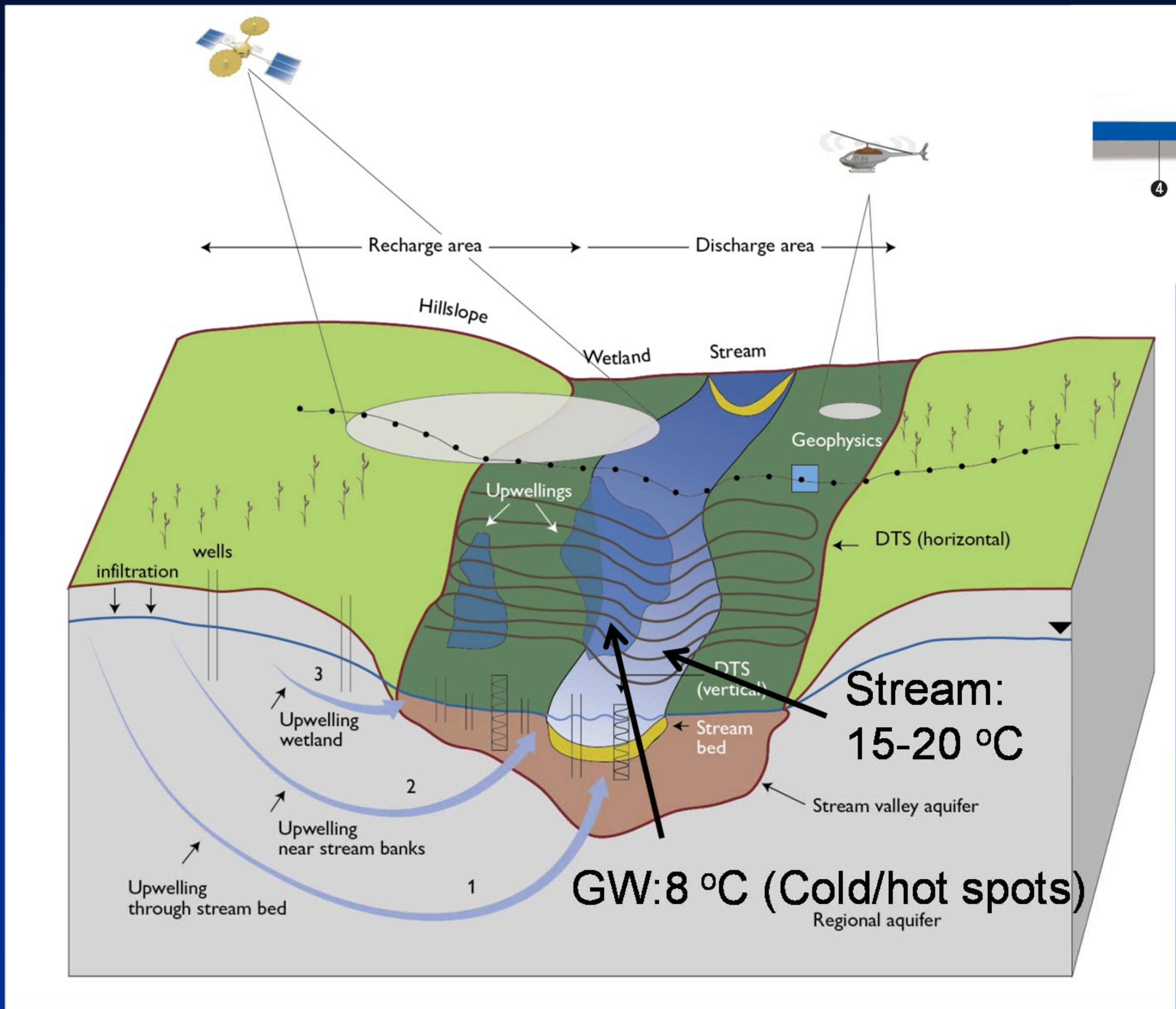
Number of Retrievals	***229***
R	***0.73***
RMSE (bias corrected)	***0.043***
BIAS	***-0.026***

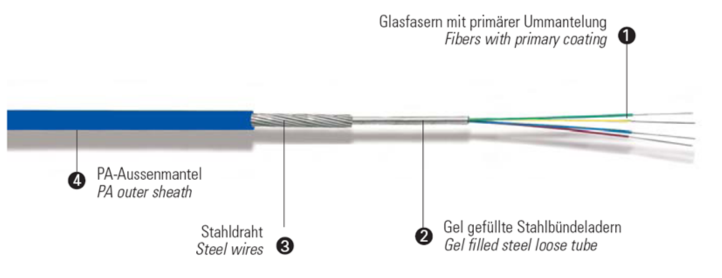
Bircher et al., 2012

Research issues: Groundwater – surface water interaction

- Analyze temporal and spatial patterns of interaction using hydrogeological, geophysical, and tracer techniques
- Particular focus on temperature as a tracer
- Scaling to catchment scale

Thermal Imaging (DTS)



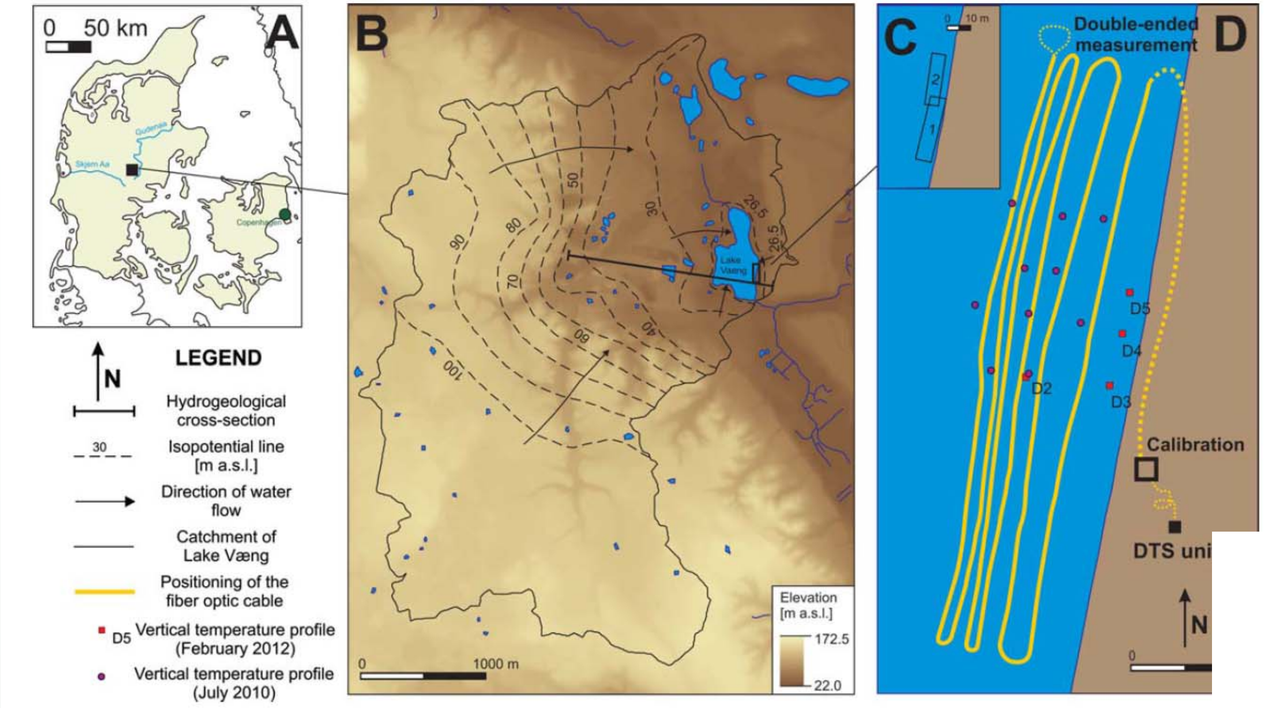


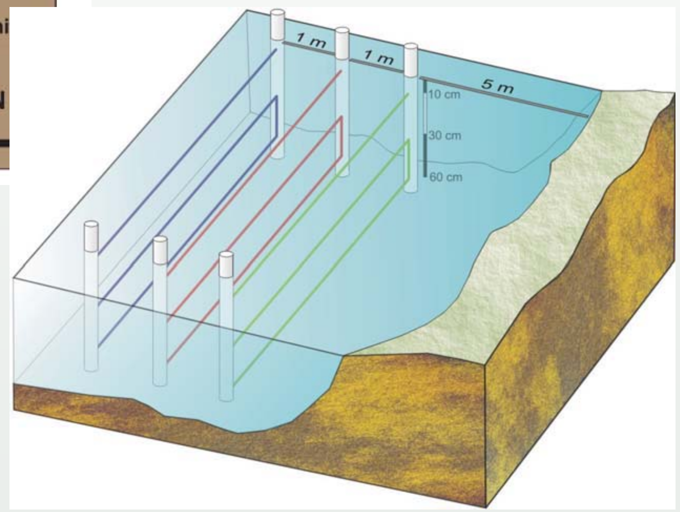
Laser impulse through Fiber-Optic cable

1 m and 1 min resolution

5 km length

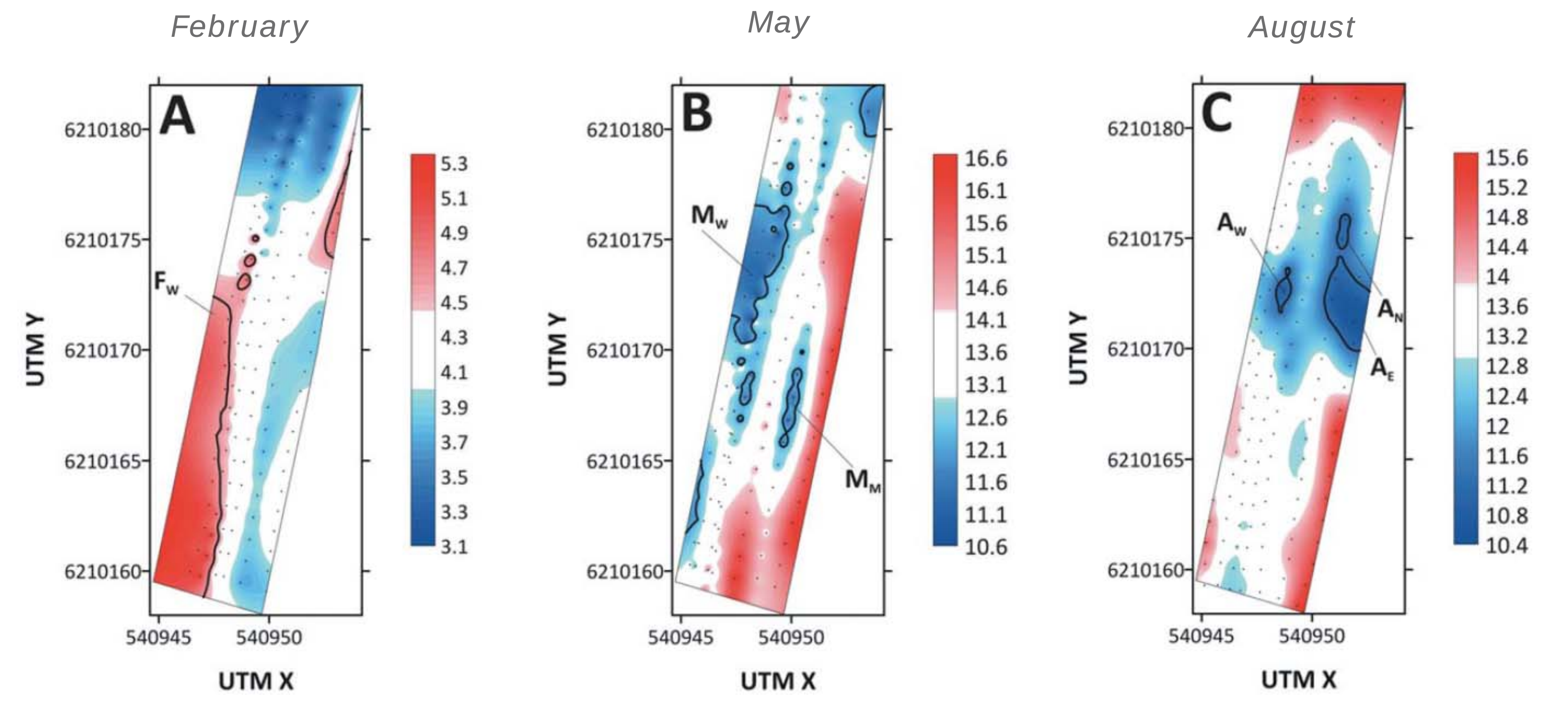
Measuring discharge into a lake by DTS





Sebok et al., WRR, 2014

Daily minimum temperatures



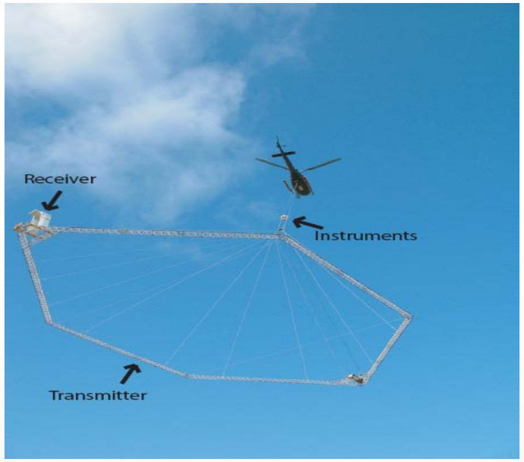
Sebok et al., WRR, 2014

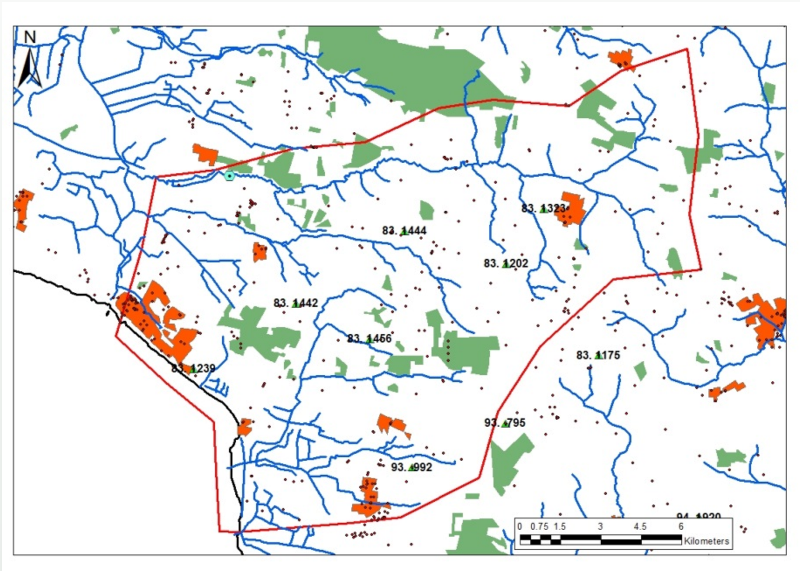
Research issues: Geological heterogeneity and groundwater flow and transport

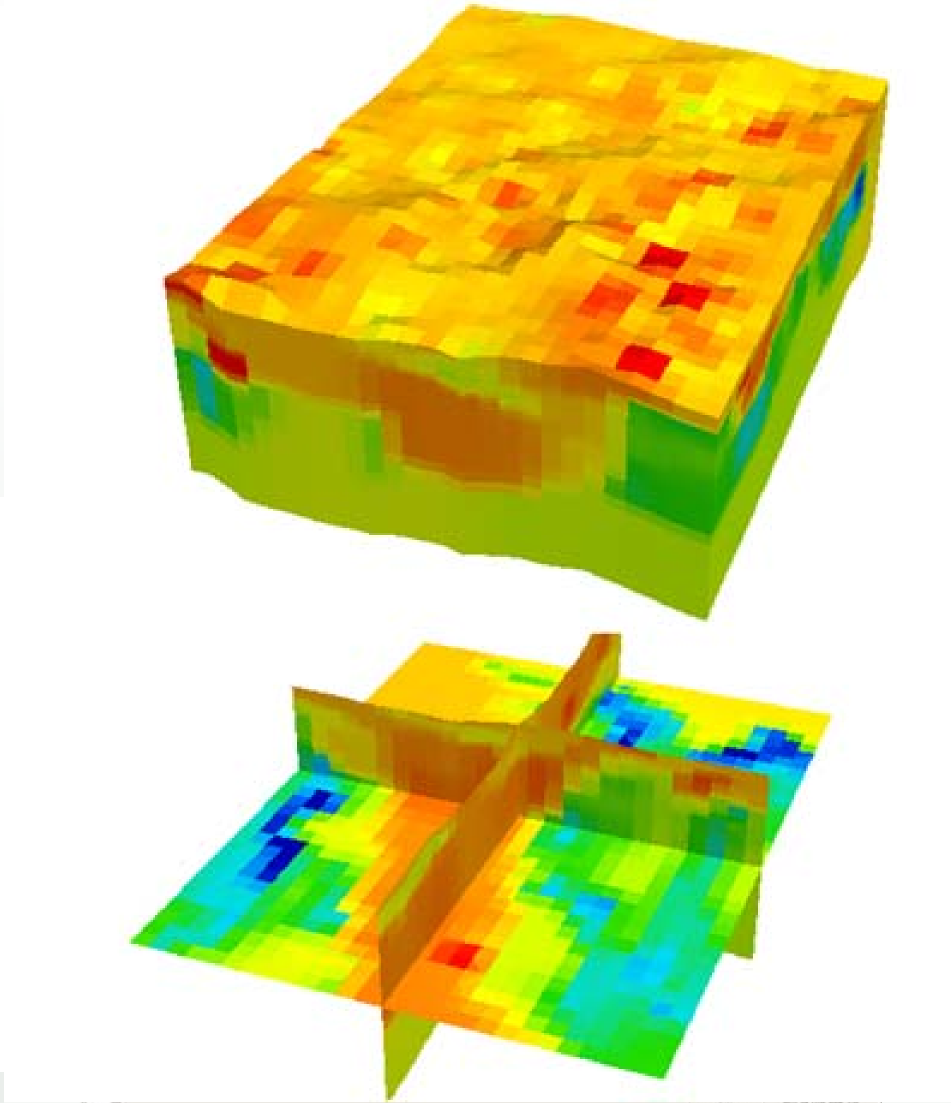
- Geostatistical methods MPS and TPROGS for simulations of geological realizations
- Airborne electro magnetic (AEM) data for soft-conditioning
- AEM data for developing Training Image (TI)

HOBE

AEM surveys and geological heterogeneity







Research issues: Integrated modeling

- Integration of monitoring data, measurements and experimental data representing various temporal and spatial scales
- Application of monitoring data, measurements and experimental data for multi-objective constraining of model
- Spatial calibration and evaluation of distributed hydrological model

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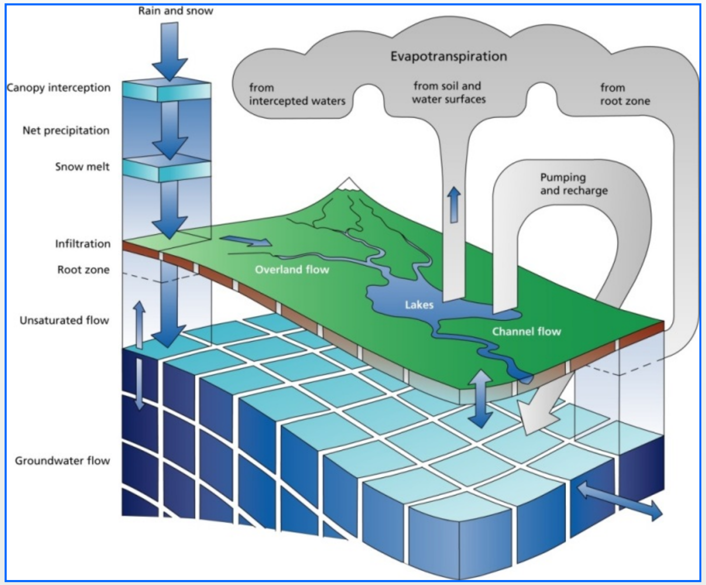
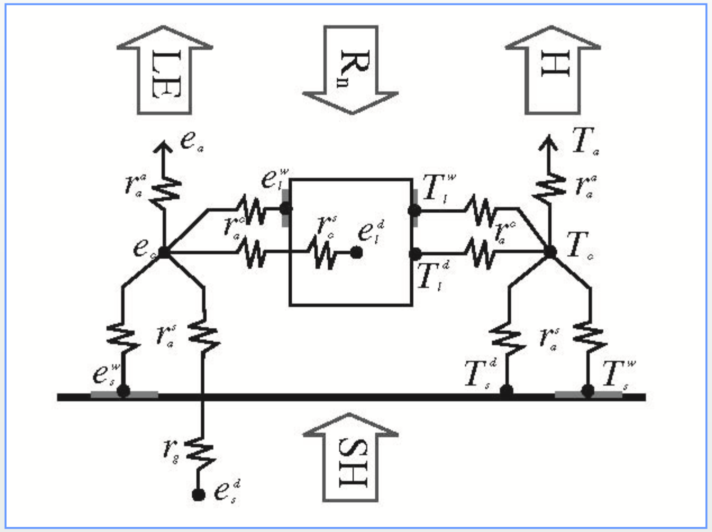
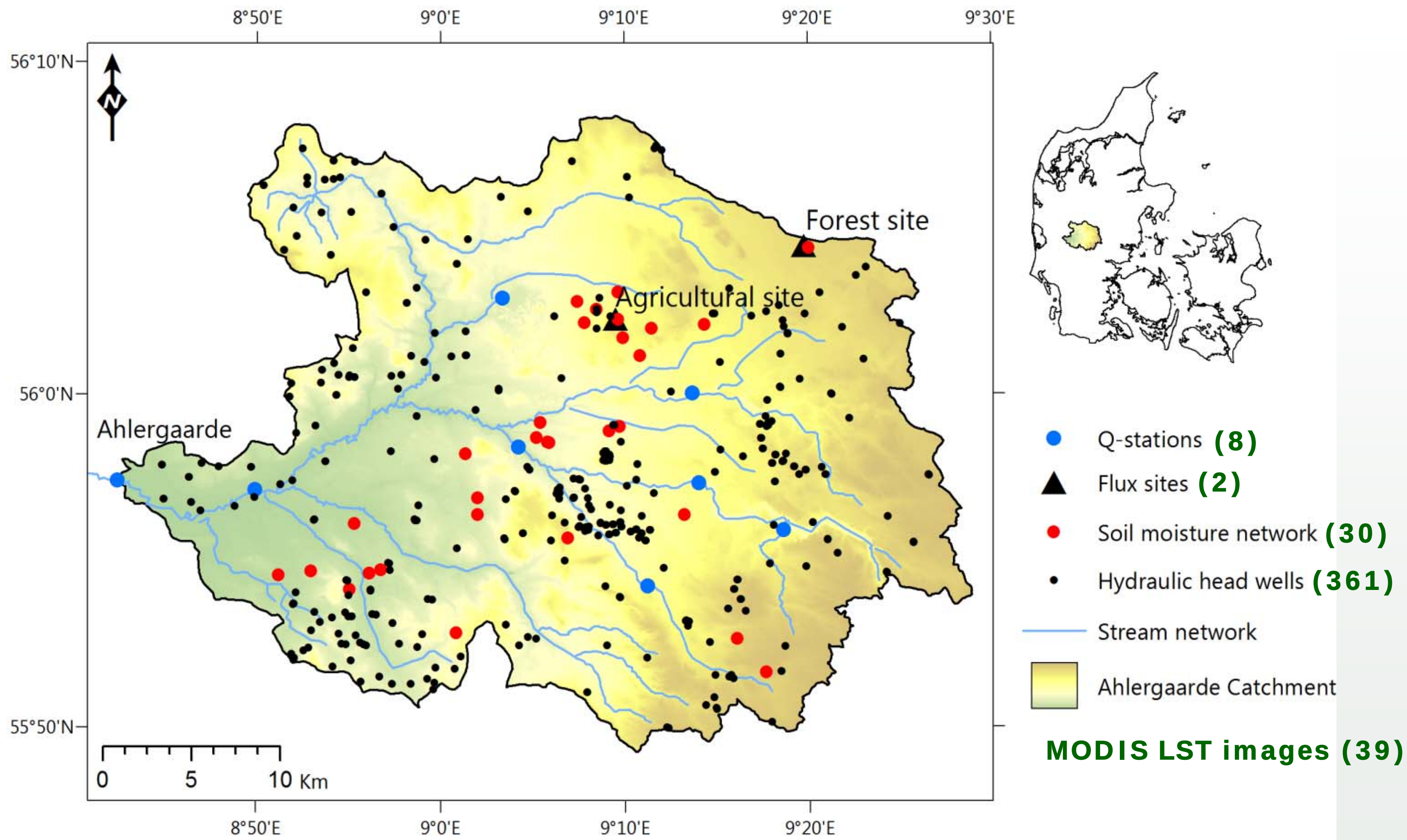


Land surface model (energy based)



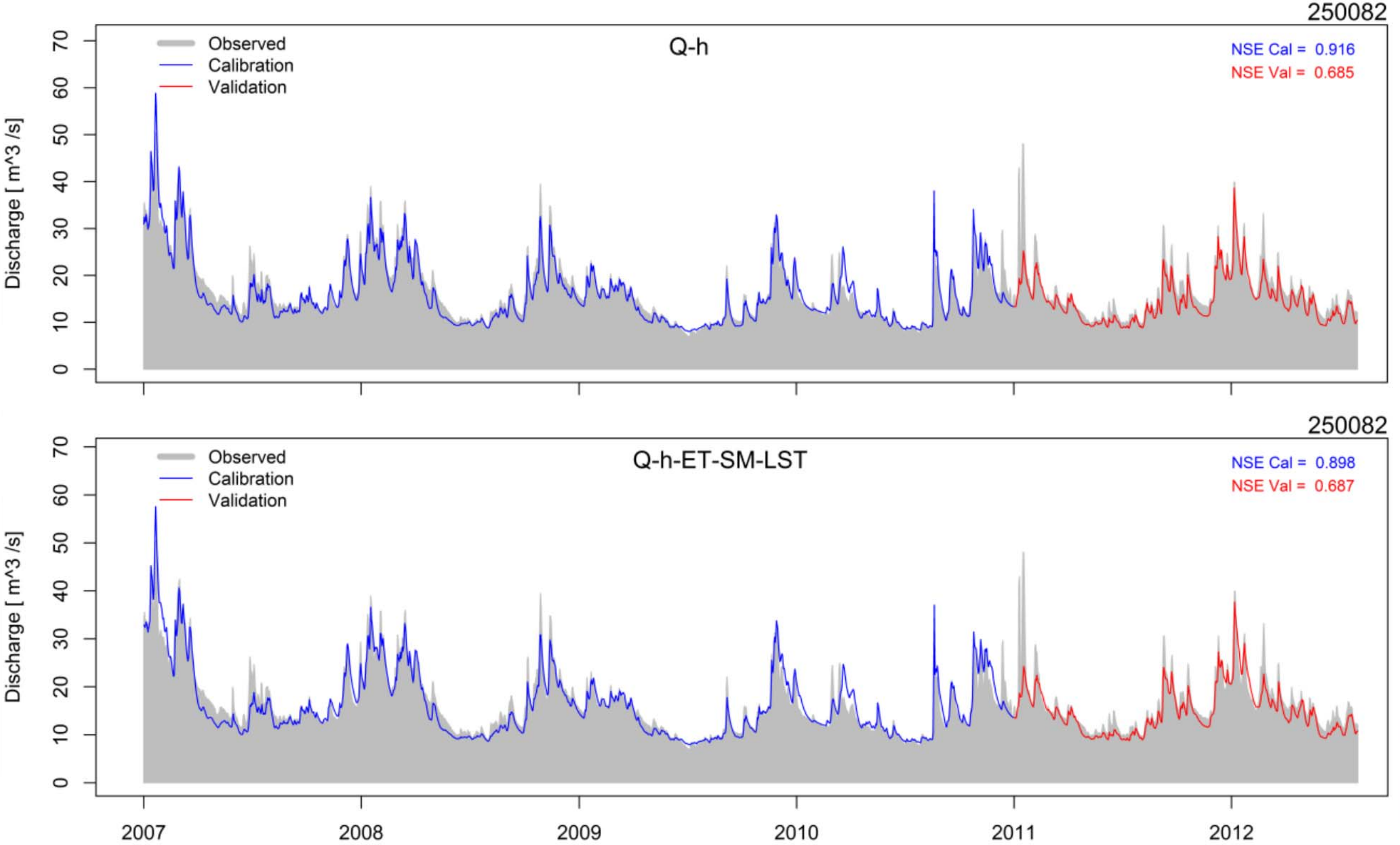
Model area



Stisen et al., 2019

Calibration and validation results

Stisen et al., HYP, 2019



Stisen et al., 2019

Major research findings

- Development and testing of innovative measurement technology
- Development of improved precipitation correction model for the whole DK
- Identification of energy fluxes over three dominant land-surface types
- Near-surface measurements from soil moisture network contributed to cal/val experiments and model calibration
- Innovative developments of the cosmic ray technique
- Innovative application of nature’s own tracers: temperature and isotopes
- Integration of ground-based and air-borne geophysical data in hydrological models
- Integration of remote sensing in hydrological models
- Better estimates of water balance at different spatial scales
- Much more certainty of hydrological fluxes and associated uncertainty than before HOBE
- Quantification of uncertainties

HOBE beyond September 2019

- ICOS will maintain the three flux stations until 2021
- Data will be retrievable from ICOS and ENOHA data bases
- Web maintained at a low level

Web site: http://www.hobecenter.dk/