Lunch Presentation

PHD Topic

Flood risk management on small catchments due to extreme storm events under future climate and land use changes.

12th of January 2017

Part_I

General Introduction

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1.1 General and specific objectives of the research work

General Objectives

- To develop evidence based effective approaches in reducing flood risks
- To reduce the societal risks associated with climate and land use changes

Specific Objectives

- To analyze, understand, and draw conclusions on how small catchments responded to extreme storm events.
- To analyze, understand, and draw conclusions on how do small catchments respond to future extreme storm events under land use and climate change scenarios.
- To produce flood risk assessment methods and evaluate the method under future land use and climate changes on small catchments
- To contribute to a local guideline for flood risk management strategy on small catchments under future climate and land use changes

1.2 Local Flood Risk

Local flood risk in small cathcment = Probability of flooding of infrastructures × Hazard × Receptor × Vulnerability

Probability of flooding = From the frequency analysis. The flood selected may range from one with a 50% probability of exceedance (2-year flood-used as a case study in the following slides) to one with a 0.5% (200-year flood)

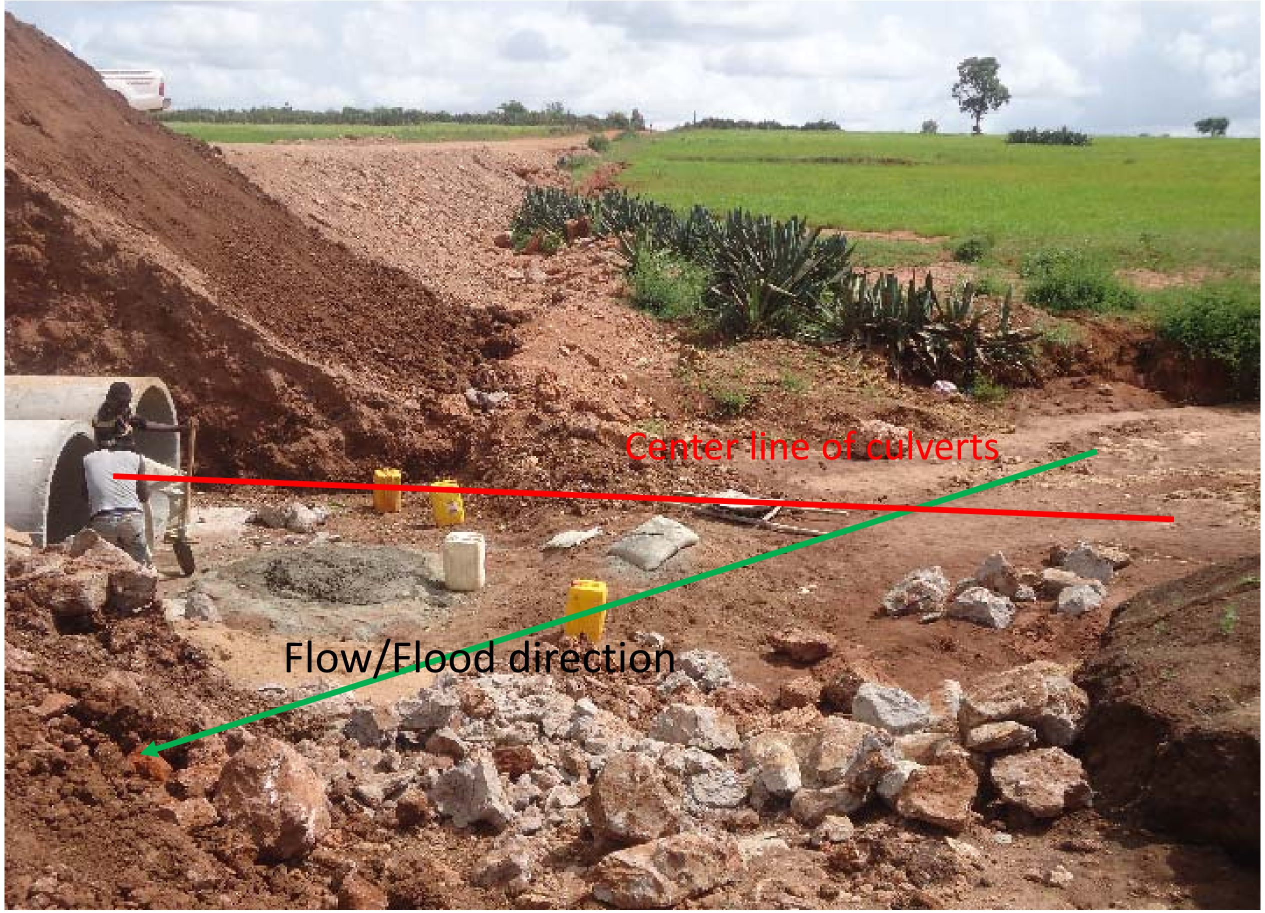
Hazard = Flood discharge, depth, velocity, volume etc. For design of culverts, peak discharge is common

Receptor = Infrastructures or assets affected by the flood (Culverts, houses, bridges, roads, crops etc.)

Vulnerability = degree of resilience to flooding (land use, design and construction, physical geology and topography of the catchment affect the vulnerability magnitude) – very important

The spring 2016 master thesis result shows the design flood (Hazard) is not exceeded at damage point

1.2.1 Risk of culverts and my experiance from Ethiopia- access road to GD_III Hydropower project



Two main problems

1. Design flood problem

- Under sized culverts- Design problem (the peak design discharge used is small)

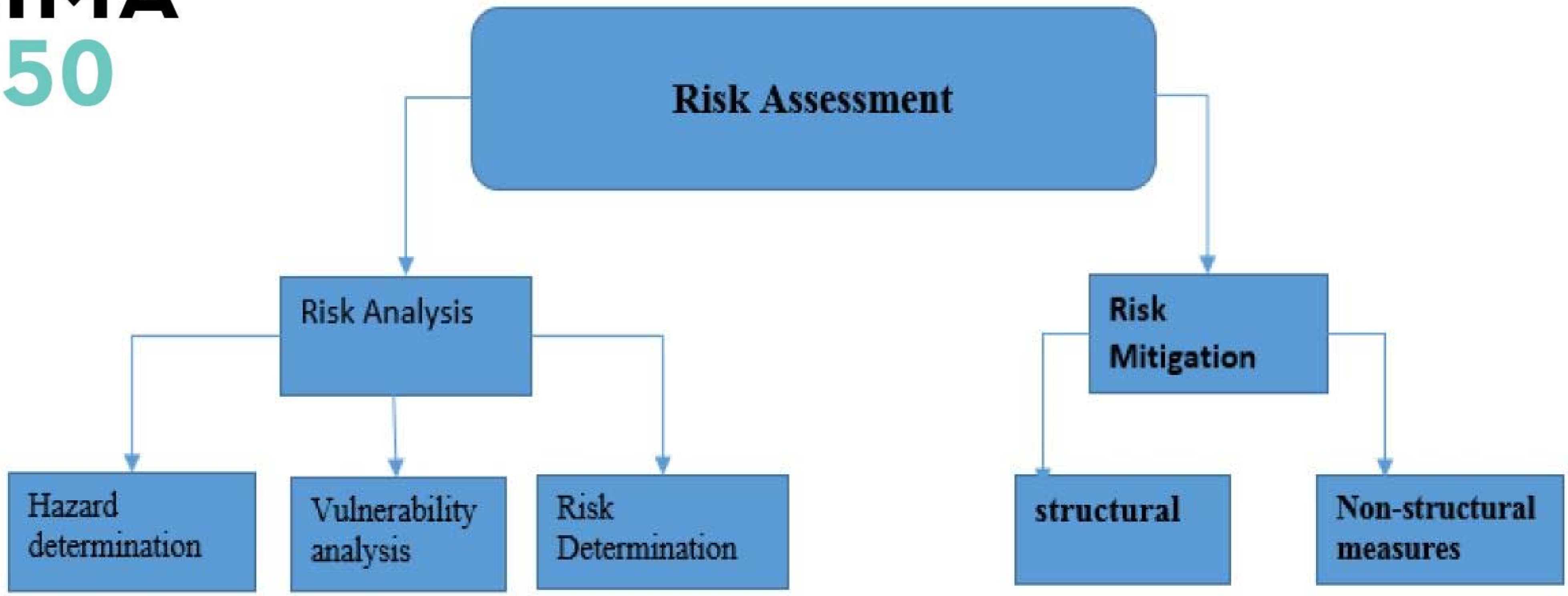
2. Problem in the design and method of construction

- The center line the culverts do not concide with the flood direction

example of Culverts with high risk

Few of them constructed along the access road had been washed away soon after their completion

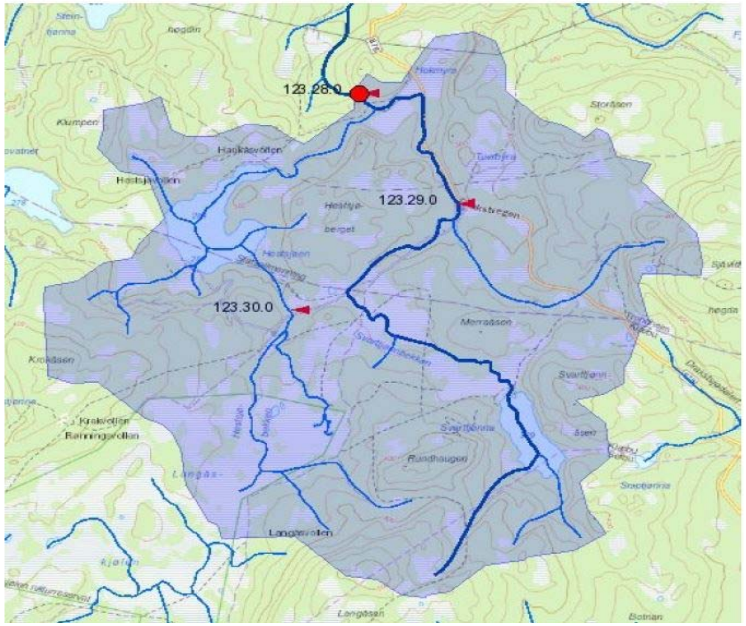
1.2.2 Risk Assessment



1.2. **Challenges of local flood risk management at small catchments**

Small gauged catchment

The red arrows are discharge gauge stations with in Sagelva catchment



- It is possible to get data and possible to setup hydrological models
- They are small in numbers and sparsely located
- They are the basic units to transfer hydrological model parameters to ungauged catchments
- Getting high time resolution and continuous data is a challenge

Catchment of interest (Study catchment)

The red dots are damage points along the rail road while the purple is culvert at Garli-Soknedal area

- They are not gauged and not possible to get data
- It is not possible to setup hydrological models for flood risk managment with out transferring parameters from gauged catchment
- located upstream of receptor (infrastructure)
- Study of local flood risk management is very much important
- Methods of flood estimations should be transferred from gauged catchments to them to determine hazards (Floods, volumes etc.)
- Vulnerability parameters have to be determined also

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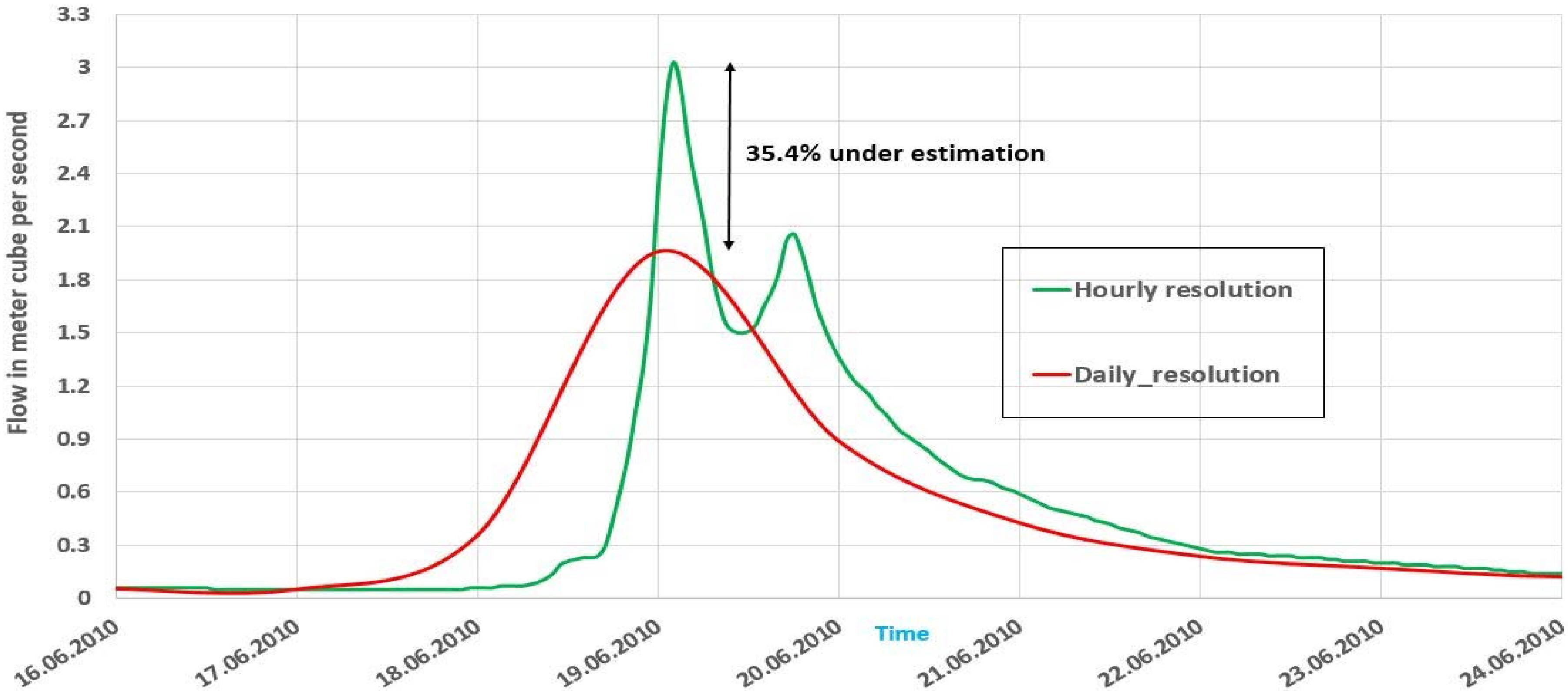
1.3. How we are working to address the challenges at the point of interest?

- Analyzing the existing flood estimation methods with hourly time resolution
- Proposing appropriate method for Hazard estimations depending on the principle «right answer for the right reason».
- To incorporate impact of land use changes in the method proposed
- Analyzing the future climate change scenarios on the catchments
- Coordinating with other work packages especially WP3 to incorporate vulnerability parameters
- Contributing to local flood risk management in small ungauged catchments under future land use and climate changes.

1.4. Why high time resolution? To be close to the daily instantaneous flood which is mainly responsible for damage

June 2010 flood due to extreme precipitation event with horly and daily time resolution (45mm precipitation per day) at Hokfossen



It is better to underestimate by 25% using hourly time resolution than estimating exactly (100% accuracy) using daily time resolution

1.5 The three main research questions planned in the research plan

- How did small catchments respond to extreme storm events?
- How do small catchments respond to future extreme storm events under climate and land use change scenarios?
- What are the effective methods in flood risk reduction on small catchments due to extreme storm events under future land use and climate changes?

Part_II

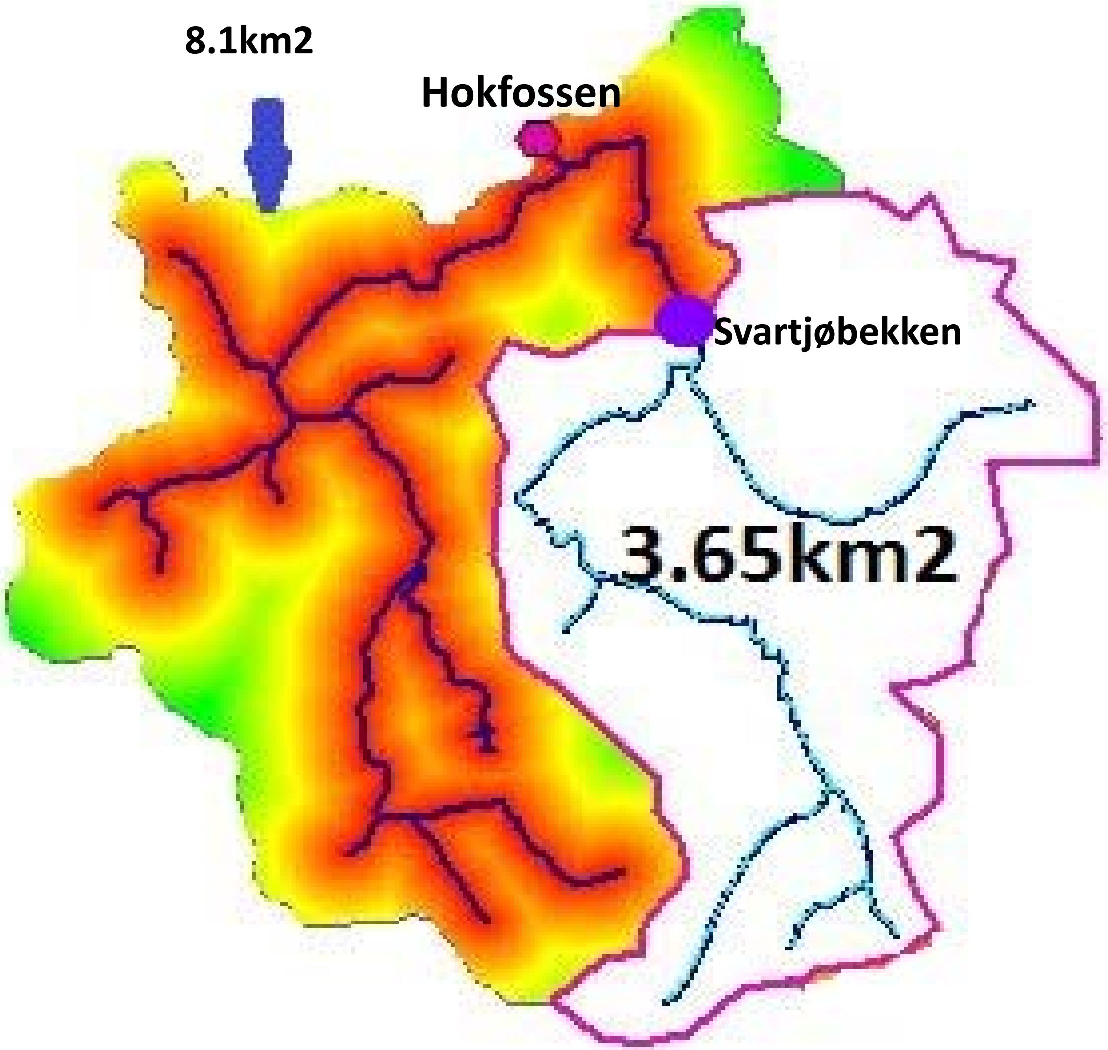
Hazard(Flood discharge/volume) Estimation

a) How did small catchments respond to extreme storm events?

Analysis and comparison of flood estimation methods on small unregulated catchments (<50km2) during extreme events

Case study for June 19^{th} 2010 flood (2-year flood) due to extreme Precipitation event

1. Gauged catchments used for hydrological analysis



<u>8.1km^2(Hokfossen)</u>
Skog= 75.7%
Sjø = 3.9%
Myr = 20.2 %

<u>3.65km^2(Svartjø.)</u>
Myr = 16.4%
Sjø = 2.7%
Skog = 80.9%

2. Flood estimatimation methods in small catchments (Hazard determination)

- **Rational method = Qp=CIAk_f** : for very small catchments
- **PQRUT**: is a simple, lumped, event-based precipitation-runoff model
- **Regional flood frequency analysis:** Regional smoothning of flood data. A separate method has been developed within the NIFS project (< 50km2)
- **Distance Distribution Dynamics (DDD)**: is an alternative rainfall-runoff model with less parameters that has recently been developed by Skaugen & Onof (2013).

"Getting the right answers for the right reasons could be crucial for getting the right answers at all, if conditions shift beyond our range of prior experience (due to extreme precipitation events, climate change, or shifts in land use, for example)" James W. Kirchner

2.1 The rational method

- Even if it is recommended for very small catchments, it is also being used for small catchments for its simplicity and time saving
- For sagelva catchment (8.1km^2), time of concentration =2.6hrs$\approx 3hrs$

Which precipitation events contributed to peak flood?

a)From **19**th @02:00 to 18th @03:00hr (24hrs duration)? **45mm**

b) From **19**th @02:00 to 18th @14:00hr (13hrs duration)? 33.23mm

c) From **18**th @17:00 to 19th @00:00hr (8hrs duration)? 30.62mm

d) The maximum precipitation events in three consequative hours

(From **18**th @19:00 to 21:00 hrs) (3hrs duration)? 15.73mm

Or any other duration and precipitation value?

…Analysis using options_a,c, d (b option does not lie with in IDF curve)

- precipitation duration 24hrs , Precipitation of option_a = 44.91mm
- Intensity = $^{49.91mm}/_{24hrs}$= 2.1mm/hr ; Cav = 0.36; A= 8.1km^2
- Qp = Cav * I* A = $1.5m^3/_s$; Qobserved =$3.02m^3/_s$
- From IDF curve of TYHOLT, 49.91mm precipitation for 24hrs durarion corresponds to a 5 year return period.

Option_d

- Precipitation duration = Tc =3hrs, Precipitation of option_d = 15.73mm
- Intensity = $^{15.73mm}/_{3hrs}$= 5.24mm/hr ; Cav = 0.36; A= 8.1km^2
- Qp = Cav * I* A = $4.2m^3/_s$; Qobserved =$3.02m^3/_s$
- From IDF curve of TYHOLT, 15.73mm precipitation for 3hrs duration corresponds to a 2 year return period.

Option_c

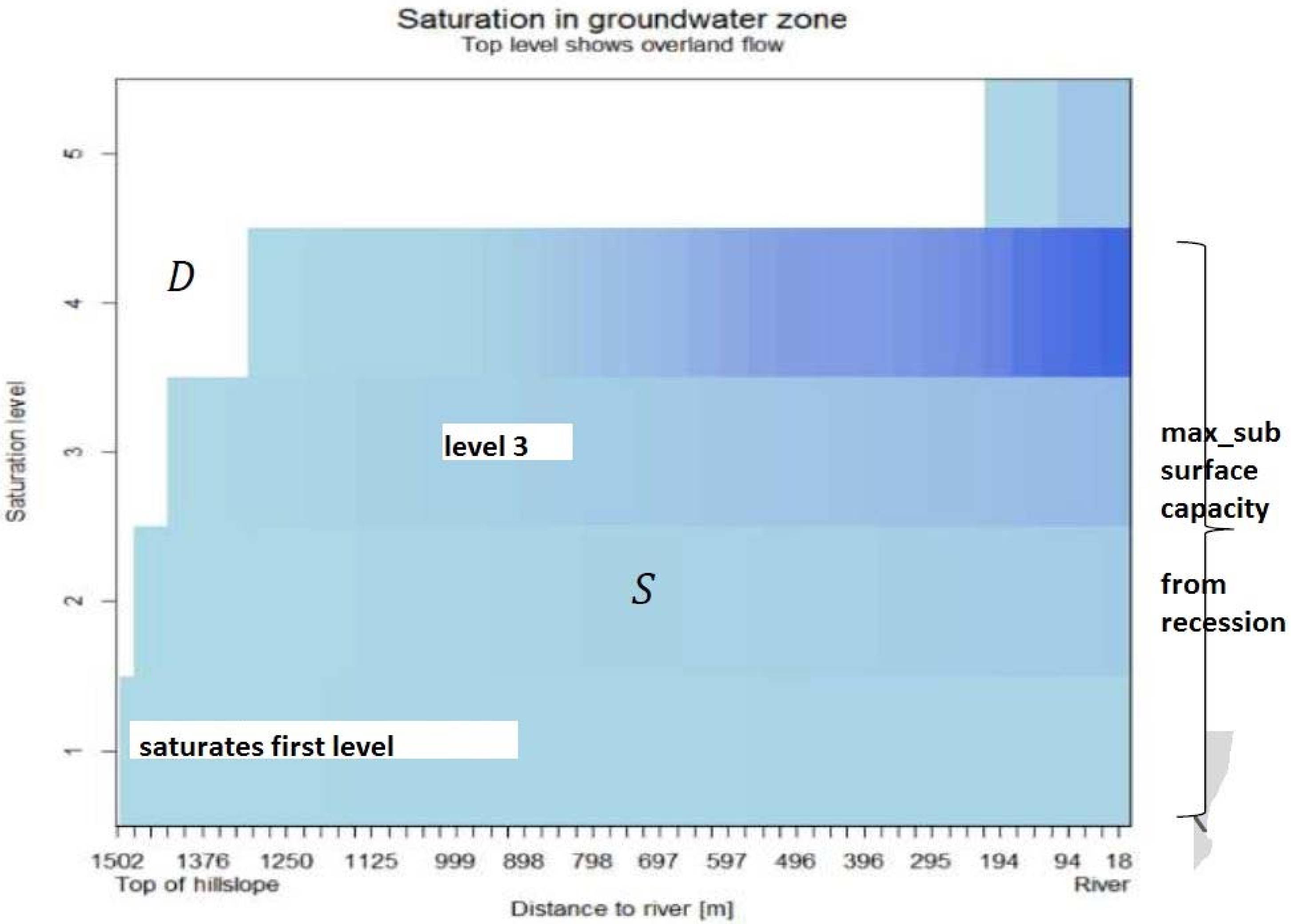
- Precipitation duration = 8hrs, Precipitation of option_c = 30.62mm
- Intensity = $^{33.62mm}/_{8hrs}$= 3.82mm/hr ; Cav = 0.36; A= 8.1km^2
- Qp = Cav * I* A = $3.06m^3/_s$; Qobserved =$3.02m^3/_s$
- From IDF curve of TYHOLT, 30.62mm precipitation for 8hrs durarion corresponds to a 2 year return period.

Is it giving the right answer due to right reason?? No, 8.1km^2 is large catchment for rational method

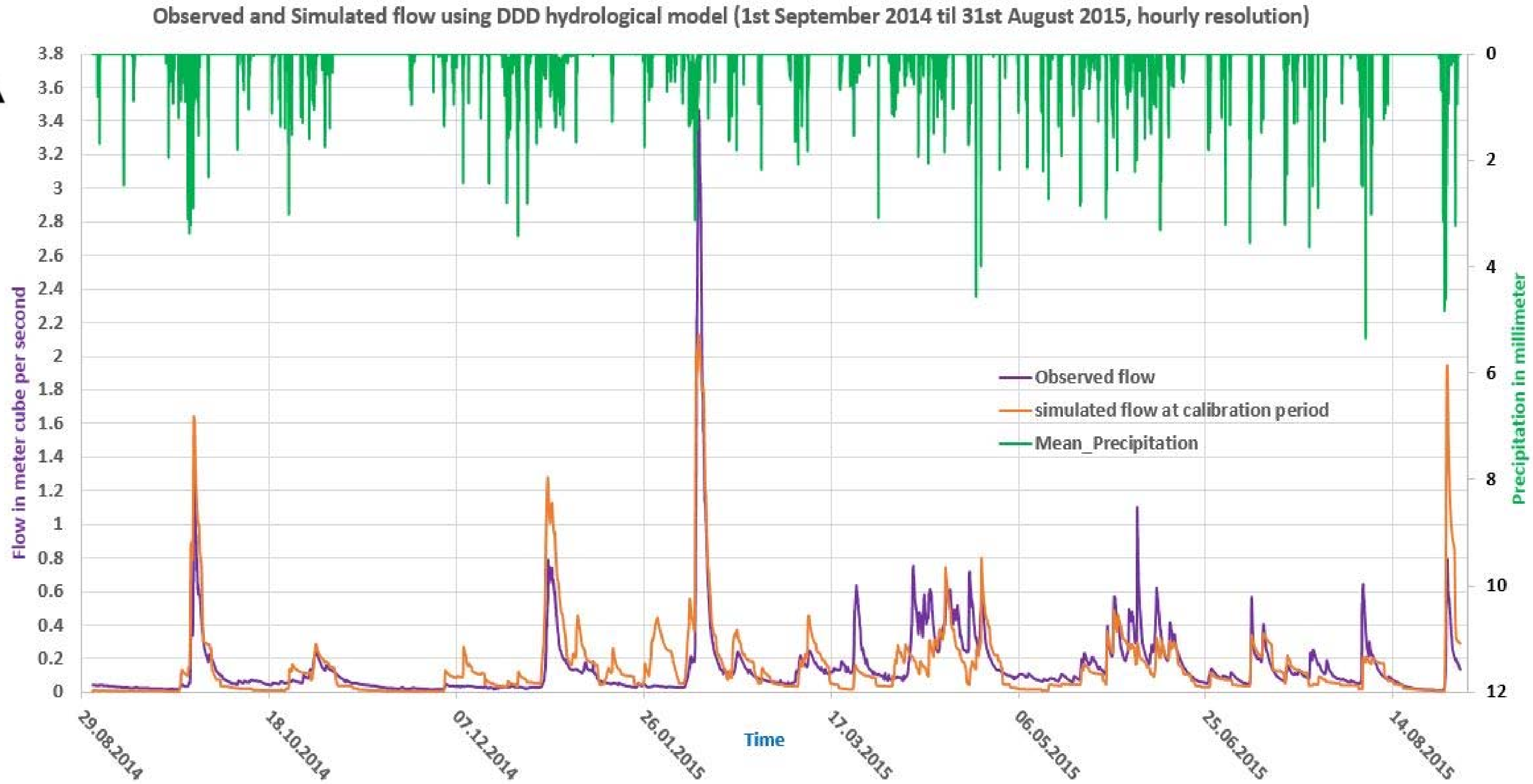
2.2 Distance Distribution Dynamics (DDD) hydrological model

- A continuous, parameter parsimonious rainfall-Runoff hydrological model
- Runoff dynamics are modelled by unit hydrographs arranged in parallel, turned on and off according to level of saturation
- The parameters of the unit hydrographs are determined from observed data, no calibration(in principle)
- Still we need to calibrate few parameters for hourly temporal resolution. Example **degree hour factor for actual evapotranspiration**

…Sub surface in DDD

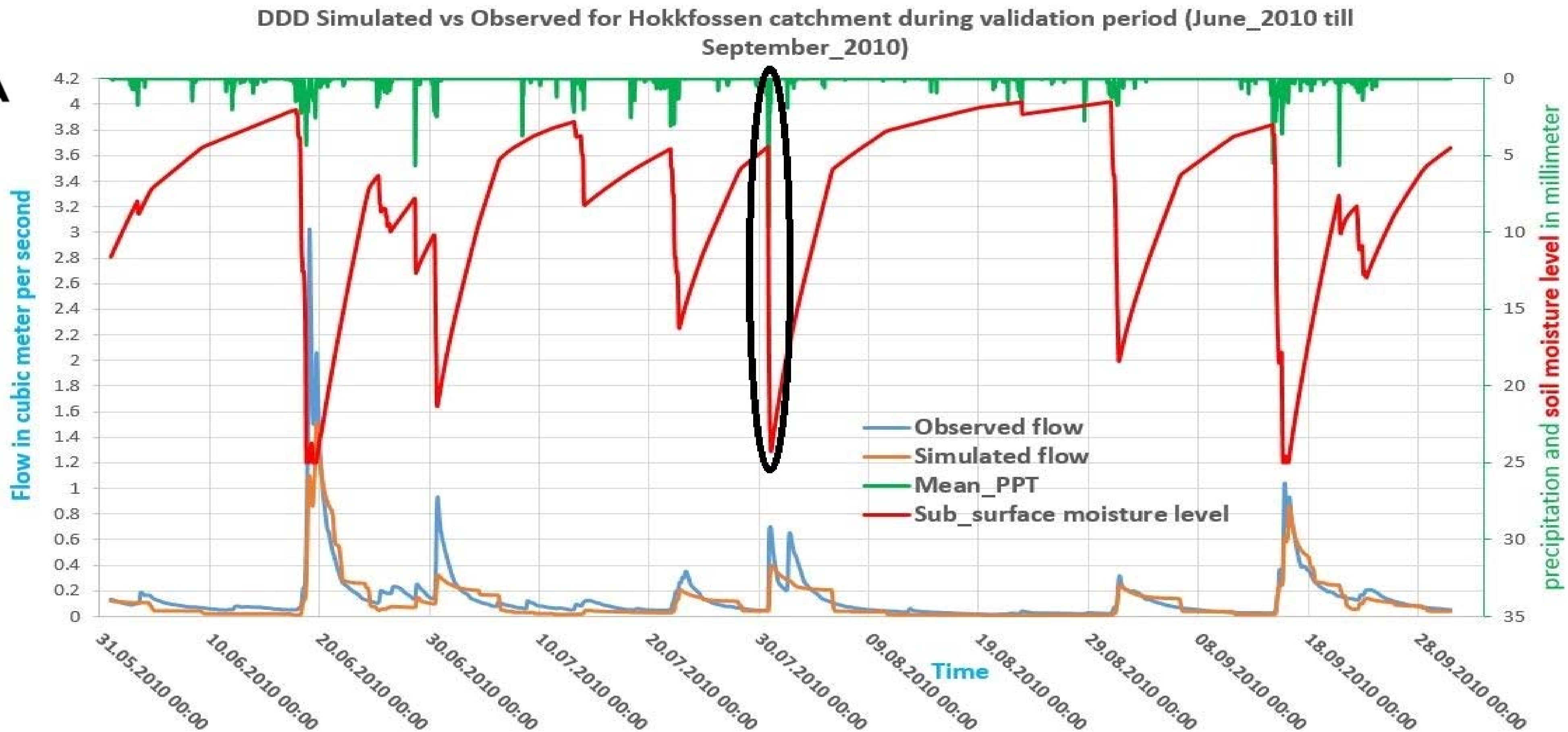


22.1 DDD Simulated vs observed for Hokkfossen catchment (8.1km2) during calibration period



Efficiency Criteria NSE = 0.611 BIAS =1.008 KGE = 0.807

2.2.2 Performance of DDD at Validation period (from 1st May till 30th September, 2010)



Efficiency Criteria

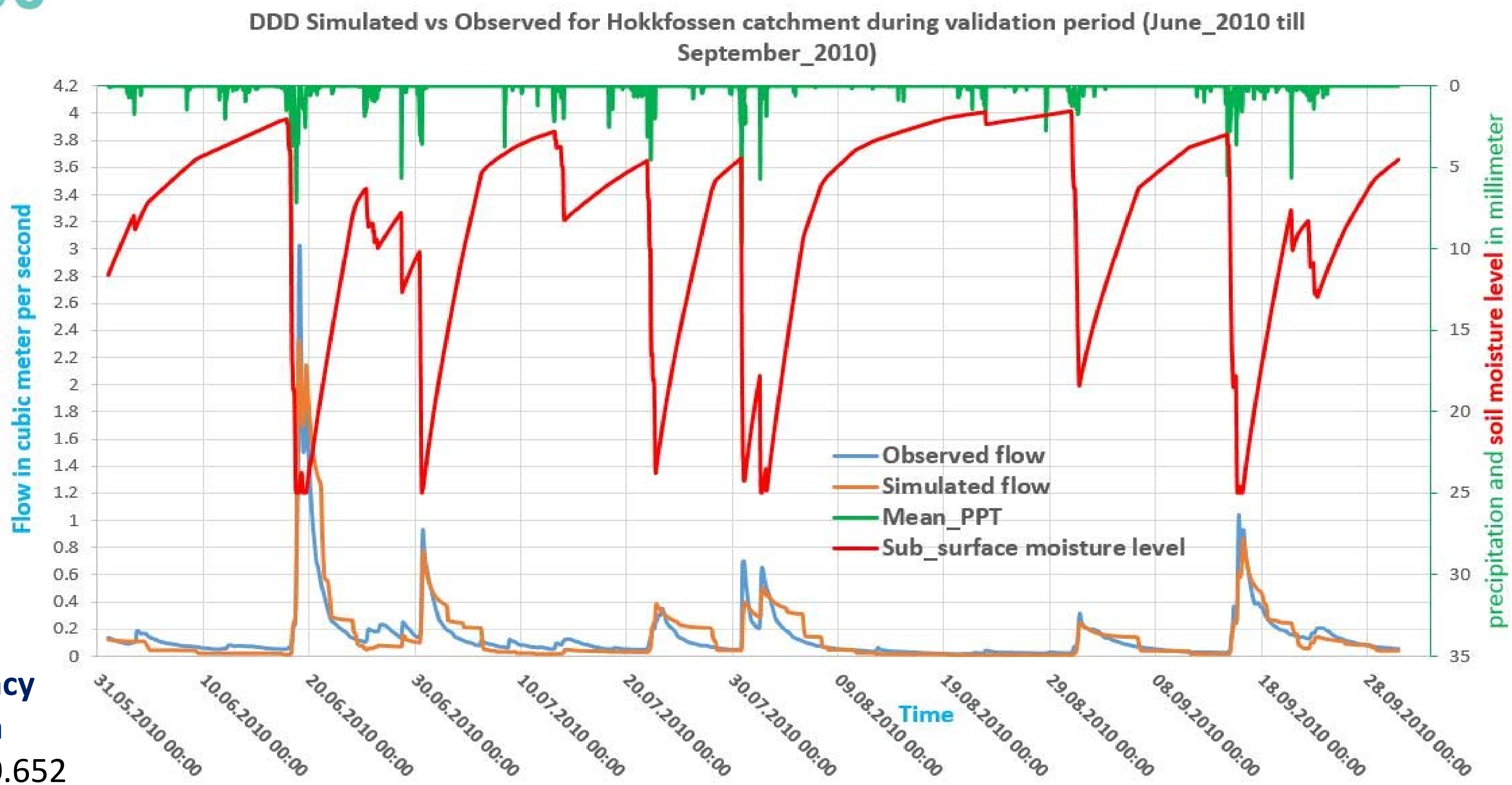
NSE = 0.582

BIAS =0.665

KGE = 0.589

The red curve shows the fluctuation in the sub surface moisture of the cachment at each time step. 25mm is the maximum value (sub surface storage capacity) determined from recession analysis. It tells the antecedent moisture content in the catchment which is not handled by PQRUT, rational method or frequency analysis.

….After the gridded precipitation corrected using the Helligdagshaugen raingauge



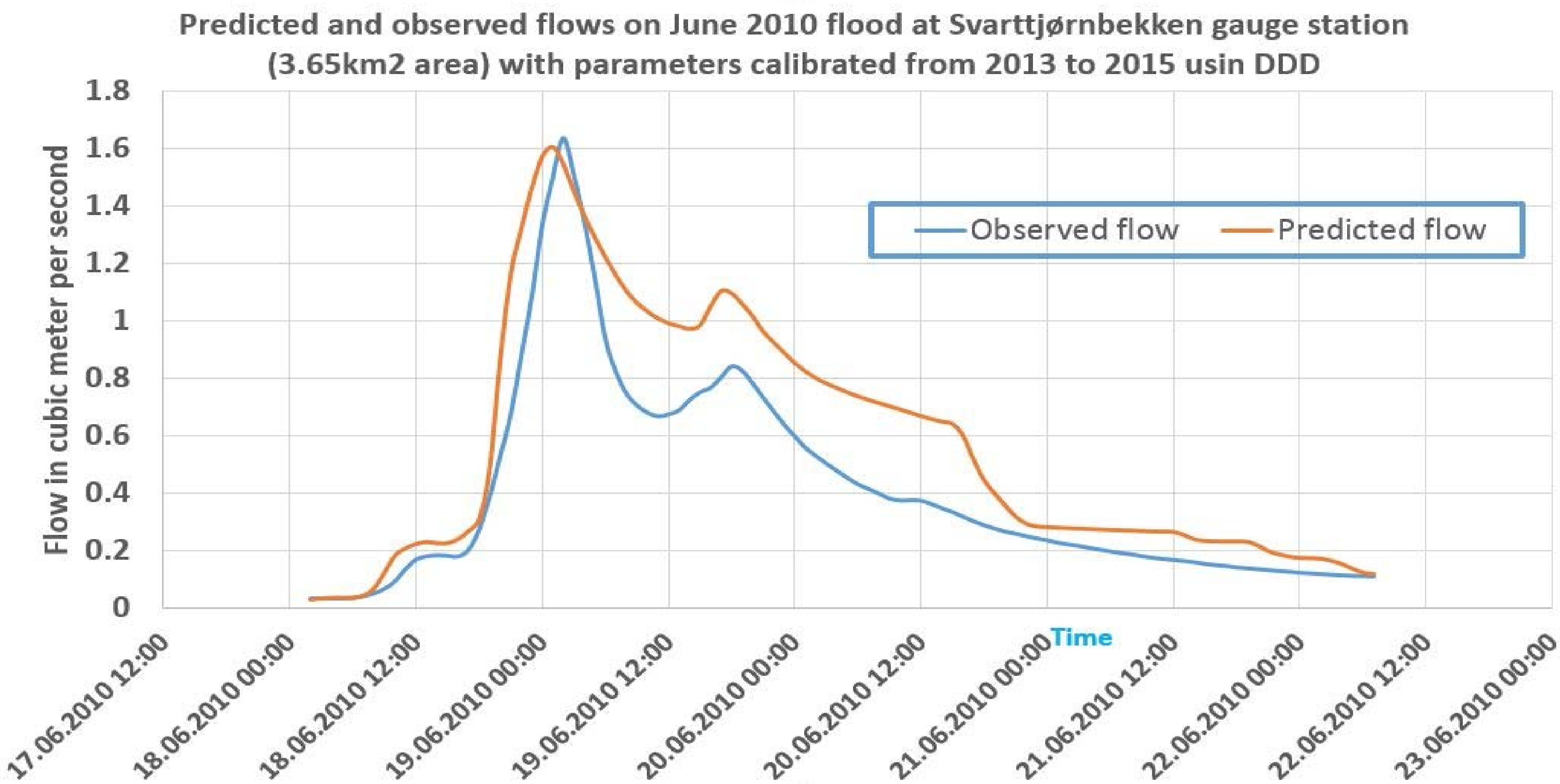
Efficiency Criteria

NSE = 0.652

BIAS =0.843

KGE = 0.614

2.2.3 DDD performance at validation period at Svarttjørnbekken gauge station for June 2010 flood event



2.2.3 Discussions on DDD results

- The capacity of the subsurface storage (25mm) estimated from recession is well reflected during the validation period
- As the subsurface moisture level shows, the two highest floods on June 19^{th}, and on September 15^{th} happened when the sub surface is at its full saturation and they preceded by wet periods.
- The impact of antecedent moisture content on floods due to extreme event is well reflected in July 30^{th} and 31^{st} 2010
- The July low flood result shows extreme precipitation does not necessarily produce extreme floods.

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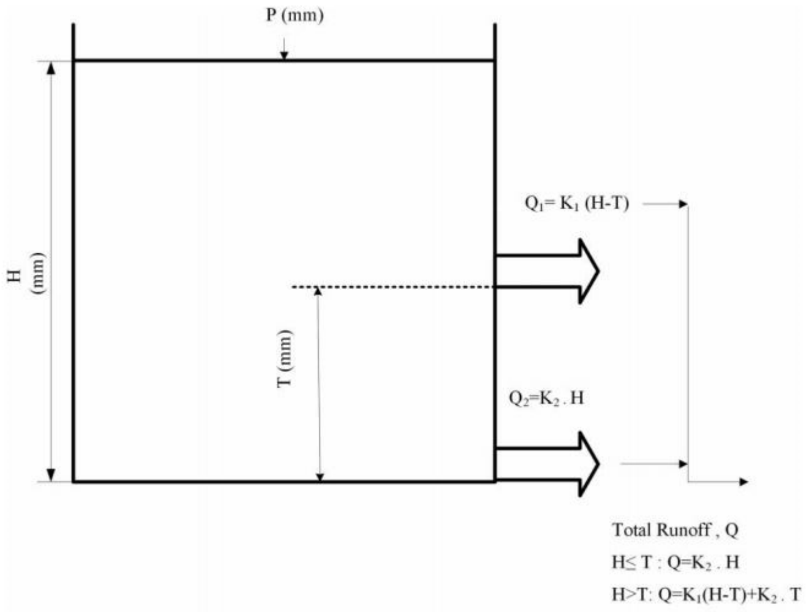
…Discussions

Why low peak flood when the sub surface is at saturation? July event

- The precipitation events are preceded by little rainfall periods
- Even if the subsurface is saturated,there was not much saturation excess flows as the duration of extreme precipitation is small
- The simulated flood peak has been under estimated using the gridded precipitation ? When corrected using the rain gauge data, the underestimation is small
- There is a general small (<25%) under estimation of peak flows. Precipitation input error is the main factor.

2.3 PQRUT analysis

- Is an event based hydrological model that follows simple reservoir concept
- Primarily applied to ungauged or regulated catchments

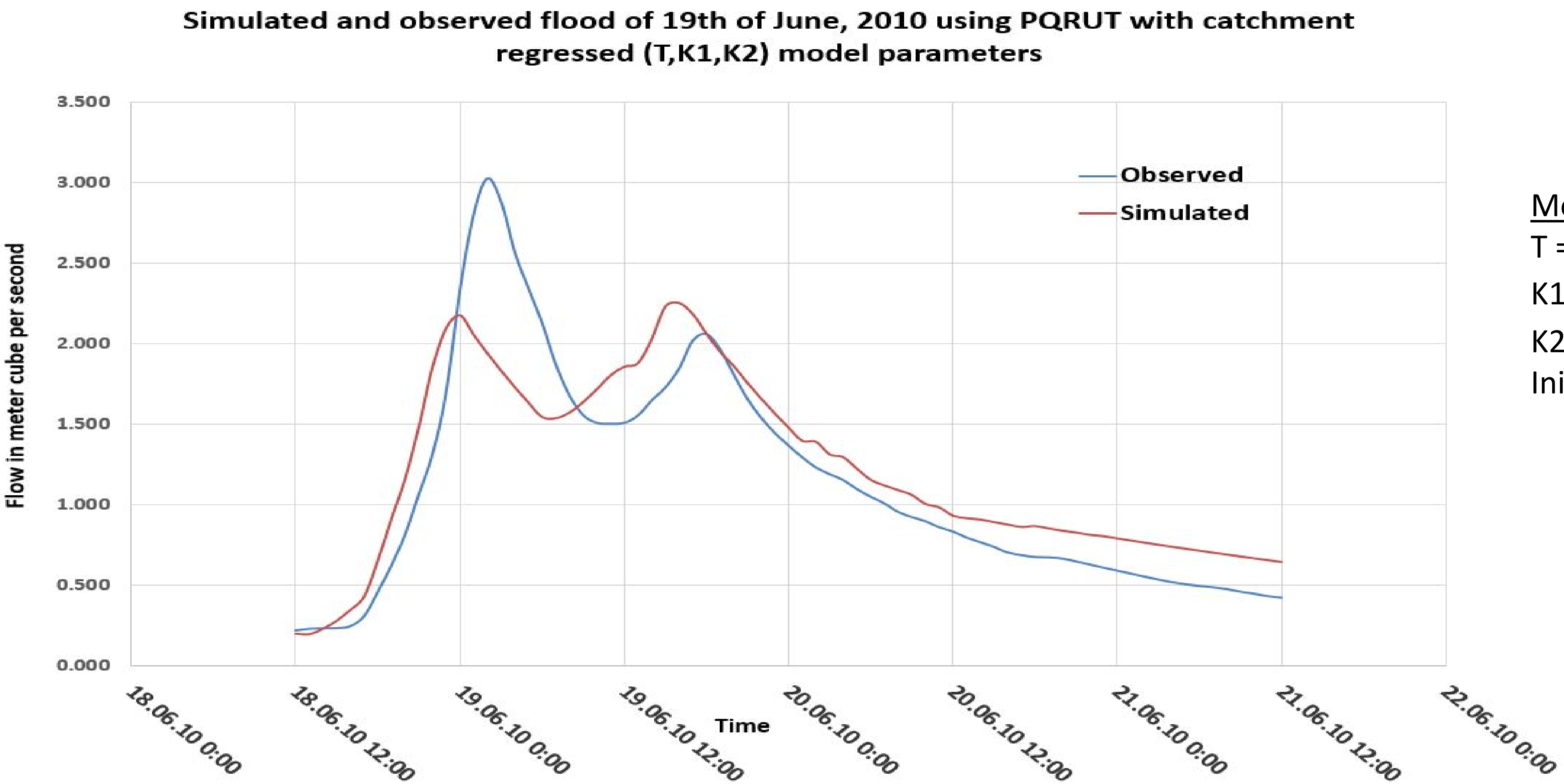


$$K_1 = 0.0135 + 0.00268\,Hl - 0.01665\,lnA_{SE} \quad (1)$$

$$K_2 = 0.009 + 0.21\,K_1 - 0.00021\,Hl \quad (2)$$

$$T = -9.0 + 4.4\,K_1^{-0.6} + 0.28\,QN \quad (3)$$

Estimated 2010 flood using Catchemt regressed parameters and initial condition of DDD



<u>Model params</u>

T = 45mm

K1 = $^{0.058}/_{hr}$

K2 = $^{0.0017}/_{hr}$

Initial = 5mm

2.3.1 Discussions on PQRUT results

- It underestimates the first peak and overestimates the second peak higher than DDD
- The catchment regressed model parameter T=24mm is close to the subsurface capacity (25mm) estimated from the recession analysis
- The sub surface moisture condition could not be handled in PQRUT
- The initial condition is set to reflect the initial flow in the PQRUT tank
- How could we set the initial conditions when we do not have flow? DDD can have answer but not PQRUT

4. **Prelimenary Conclusions-more catchments and flood events are under analysis**

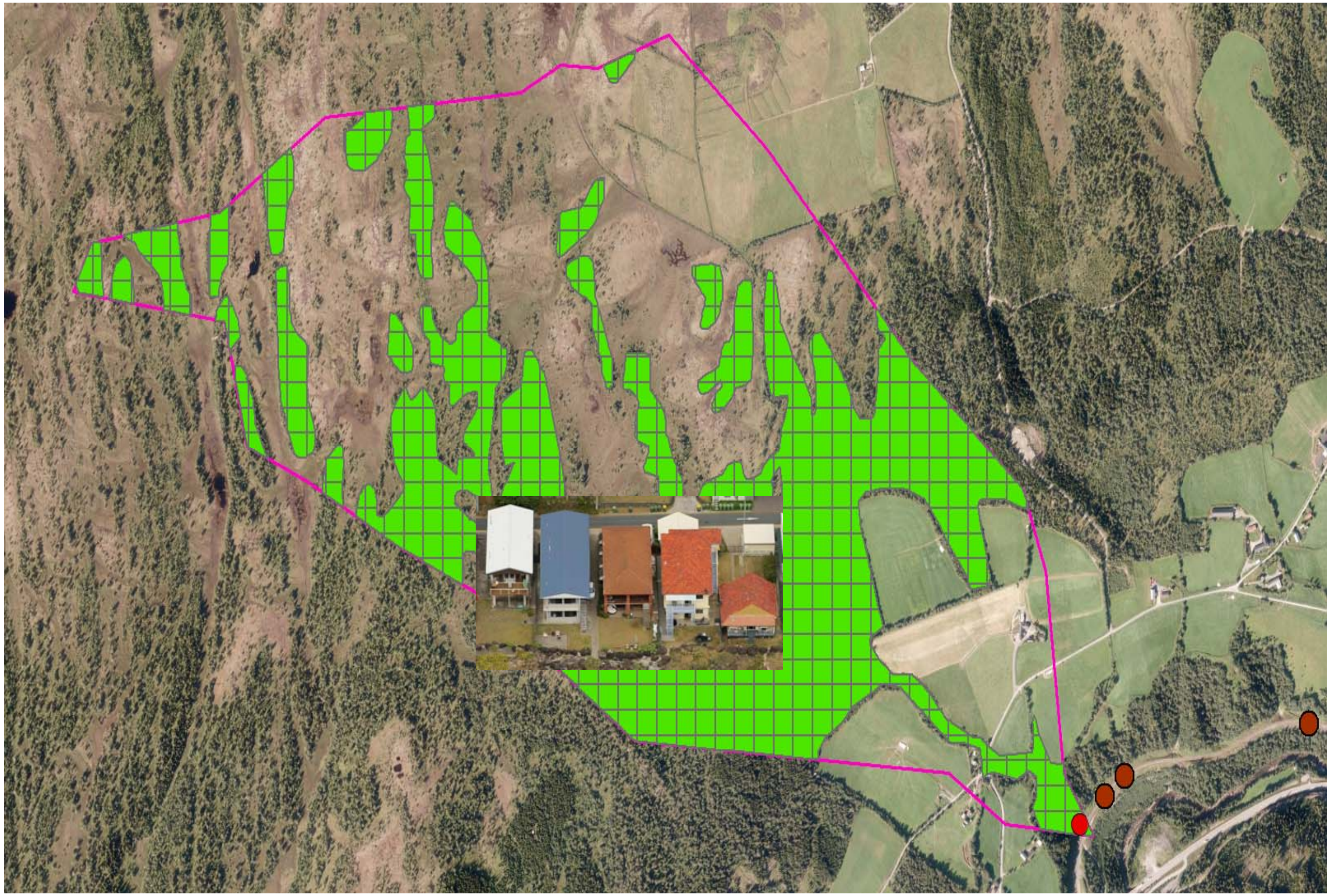
- It is possible to setup DDD hydrological model for high time resolution (hourly) time steps which is important for small catchments
- Since most of the model parameters are determined from GIS and hydro climatological data, there are less calibration parameters in DDD.
- Of all the existing methods, DDD hydrological model gave promising intermediate results for further study
- Using meteorological data especially precipitation input with high time resolution from improved technologies is crucial
- The interaction between the precipitation and the catchment before the peak flood is well modelled using DDD than PQRUT or rational methods

…Conclusions

- DDD able to model the subsurface soil moisture at hourly time step which is not handled by PQRUT, rational method or regional frequency analysis.
- How accurate we can measure/predict precipitation input has significant impact in the magnitude of simulated floods
- To use DDD for impacts of land use changes, land use tools shall be included
- DDD is much closer to the Kirchner principle than PQRUT or Rational method
- DDD has also a capability to simulate floods generated by snow melt and rain which is the concern under future variable climate change

“Getting the right answers for the right reasons could be crucial for getting the right answers at all, if conditions shift beyond our range of prior experience (due to extreme precipitation events, climate change, or shifts in land use, for example)” James W. Kirchner

5. How to use DDD at catchment of interest with hourly time resolution under future climate and landuse changes?



…How to use DDD

- DDD model parameters on hourly time resolution shall be transferred from gauged catchments to the interest catchments
- DDD is already in operational for flood forecasting on daily and 3hrs time steps and also used in FlomQ project
- Once DDD is operational in hourly time steps (we are also working in cooperation with developer Skaugen),

we will have a tool that can estimate the hazard (flood/volume) at the point of interest for flood risk management

- With the DDD model running in hourly resolution, the impacts of land use and climate changes shall be studied at the critical catchments

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Takk skal du ha !