IMPROVING THE SNOWMELT MODELLING IN MESOSCALE HYDROLOGIC MODEL (mHM) with SATELLITE BASED DYNAMICALLY CALCULATED DEGREE-DAY FACTOR

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AGENDA

- Motivation
- Objective
- Study Areas
- Methodology
- Results
- Discussion and Future Works

MOTIVATION

- Fresh water sources are under stress
  - Better management for mountain watersheds
    - More realistic modelling
      - Snow-related dynamics dominant in mountains
        - Need for more realistic snow modelling

Taurus Mountains, Turkey

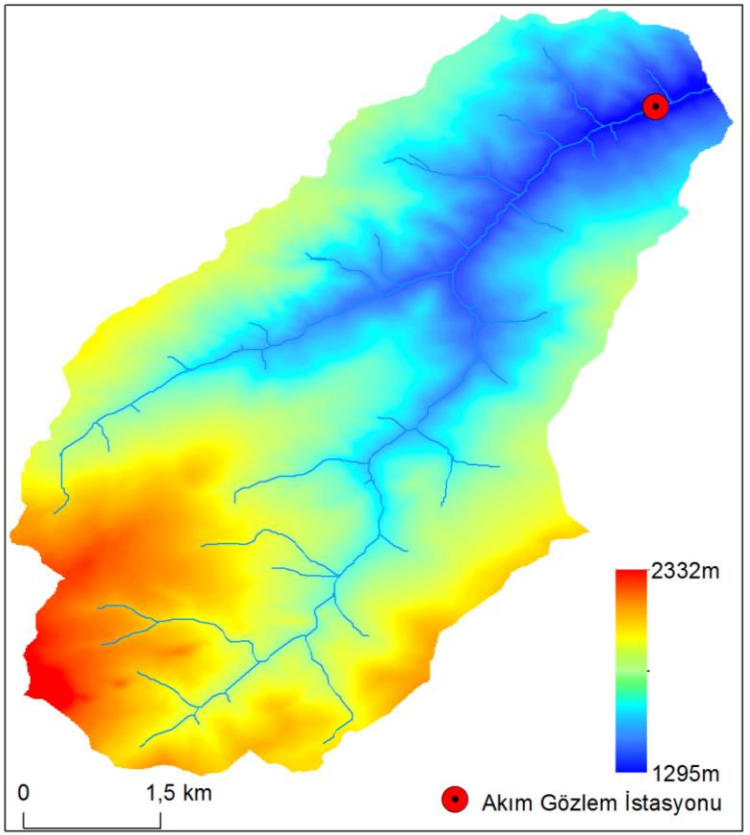
Encyclopædia Britannica

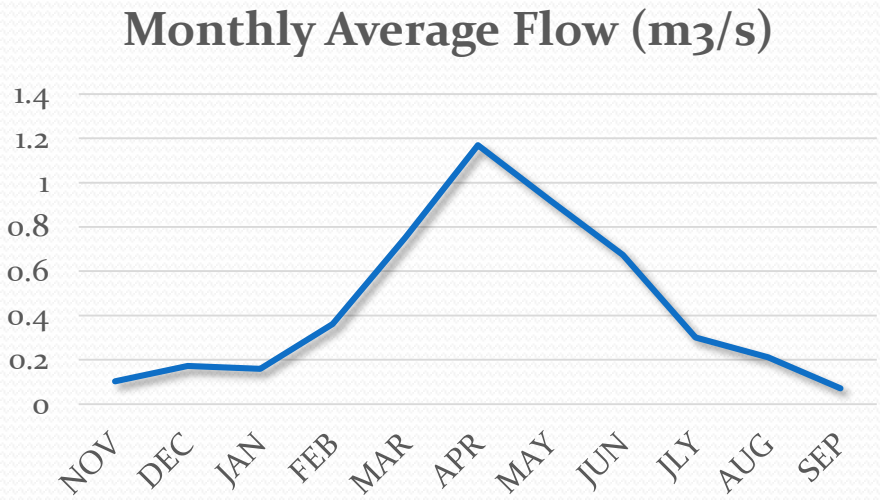
OBJECTIVE

- Achieve More Realistic Snow Modelling:
  - Degree-day factor
    - Based on satellite imagery
    - Spatio-temporally dynamic
  - Test results
    - mHM hydrologic model
    - Karanlıkdere basin
    - Bahcelik basin

STUDY AREA: Karanlikdere

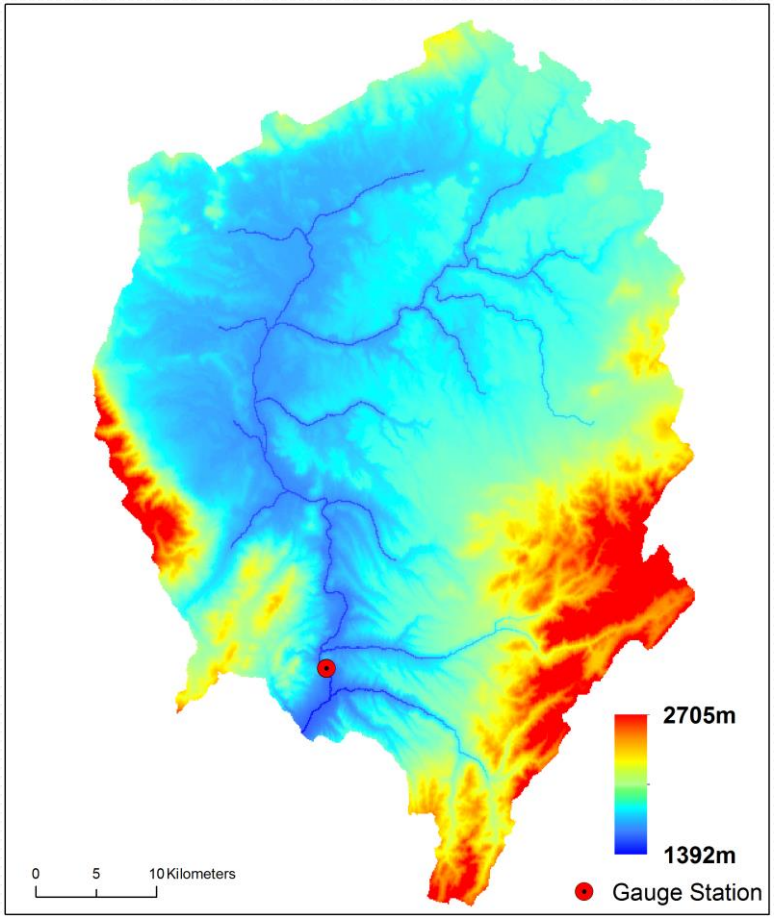
- Karanlıkdere Basin
  - Mountain basin
  - 1295 - 2332m elevation
  - ~30 km^2 area

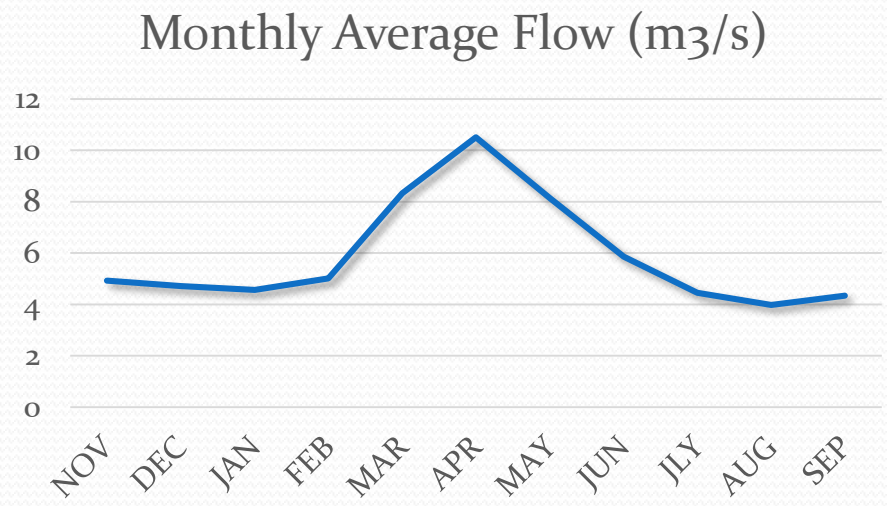




STUDY AREA: Bahcelik

- Bahcelik Basin
  - Mountain basin
  - 1392 - 2705m elevation
  - ~2500 km^2 area





METHODOLOGY

- Degree-day Factor Conventionally:
  - Simple computation
  - Reduced data need
  - Relatively good performance
  - **Generally accepted constant in basin**
    - Spatially and/or Temporally

- **Followed Methodology**[1] (He et al., 2014)**:**
  - Daily average temperature
  - Daily precipitation
  - MODIS Snow cover data

1 He, Z. H., et al. "Estimating degree-day factors from MODIS for snowmelt runoff modeling." *Hydrology and Earth System Sciences* 18.12 (2014): 4773-4789.

METHODOLOGY (Cont.)

$$V_s = SD \cdot SCA \quad (1)$$

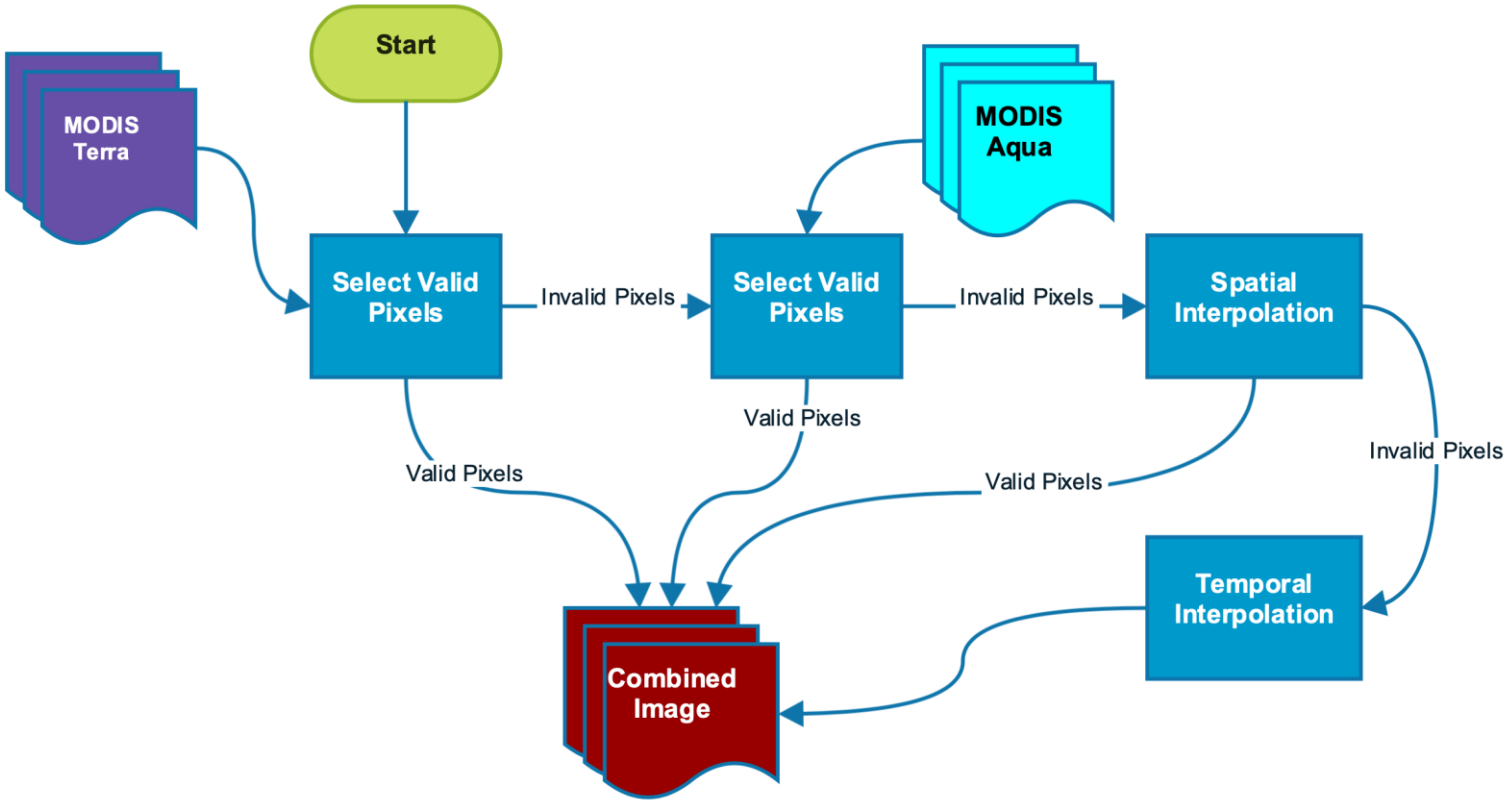
V_S : Volume per area of snow (mm^3 / mm^2)
SD : Snow depth (mm)
SCA: Snow-covered area (%)

$$p_s \cdot \frac{dV_s}{dt} = \begin{cases} P, & T < T_S \quad Accumulation \\ P_s - M, & T_S \leq T \leq T_R \quad Accumulation + Ablation \\ -DDF\ (T - T_m), & T > T_R \quad Ablation \end{cases} \quad (2)$$

p_s : Snow density (%)
V_S : Volume per area of snow (mm^3 / mm^2)
P : Daily precipitation (mm)
P_s : Daily snowfall(mm)
M : Daily snowmelt depth (mm)
T_s : Temperature threshold for snowfall (^oC)
T_R : Temperature threshold for rain (liquid) (^oC)
Tm : Temperature threshold for melting (^oC)

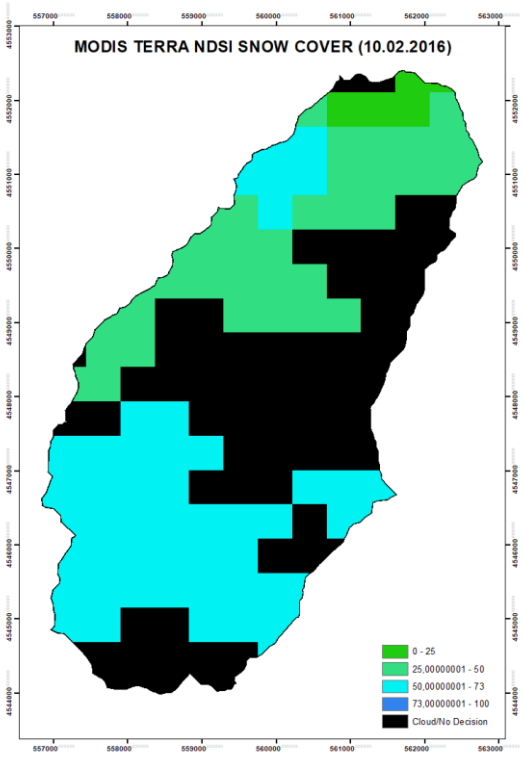
METHODOLOGY (Cont.)

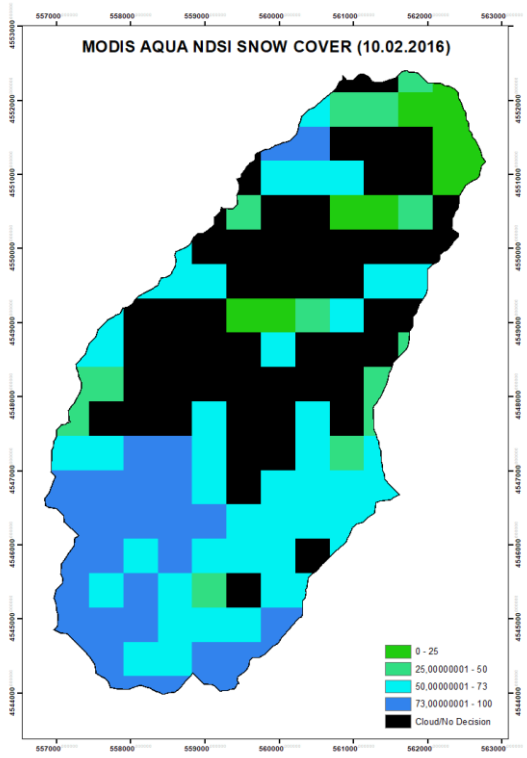
- Preparing MODIS Data
  - Pixel based approach

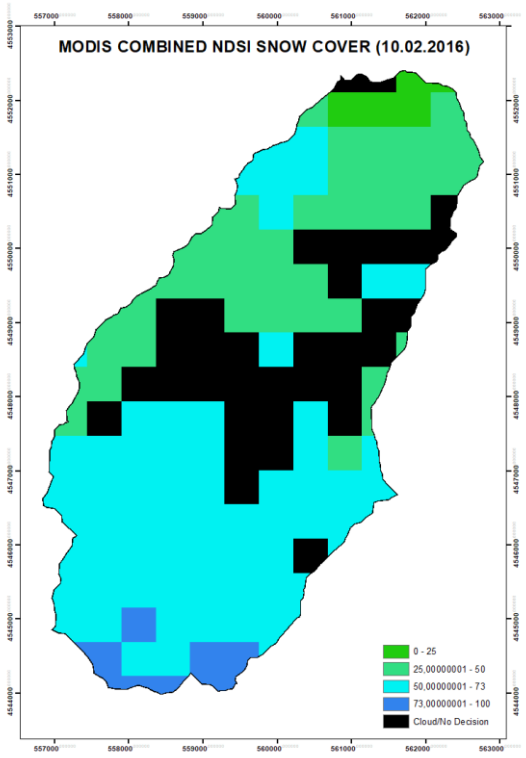


METHODOLOGY (Cont.)

- MODIS data process: Karanlikdere Basin

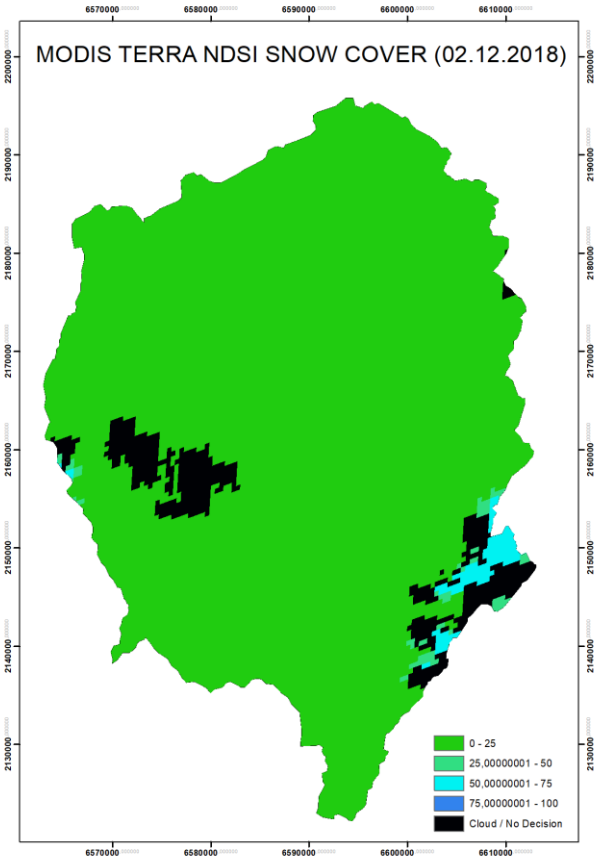


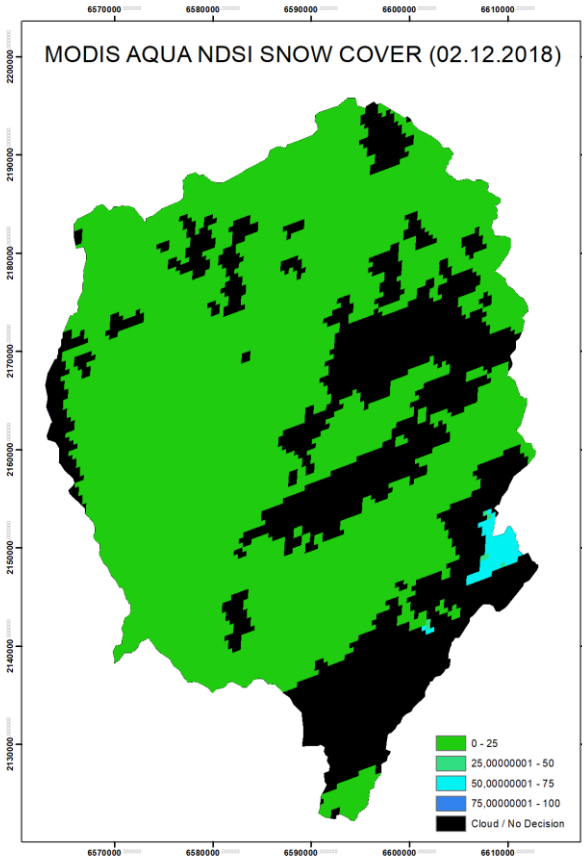


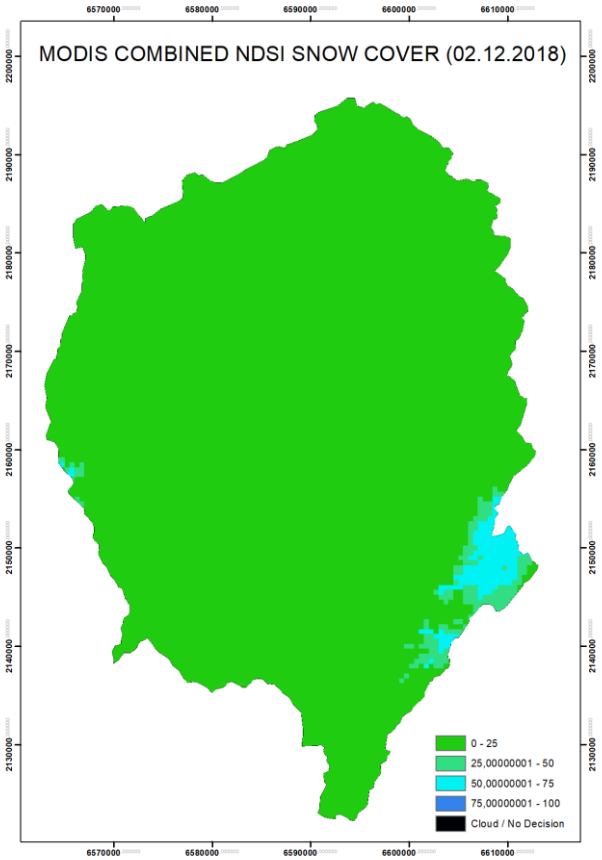


METHODOLOGY (Cont.)

- MODIS data process: Bahcelik Basin







METHODOLOGY (Cont.)

- Daily Degree-day Factor Calculation:
  - At days of ablation
    - T_R = 2,5 °C
    - $T_S = T_M$ = 0 °C
    - SCA = From MODIS data (daily)
    - p_s =

Month	Snow Density (%)
December	0,25
January	0,25
February	0,27
March	0,30

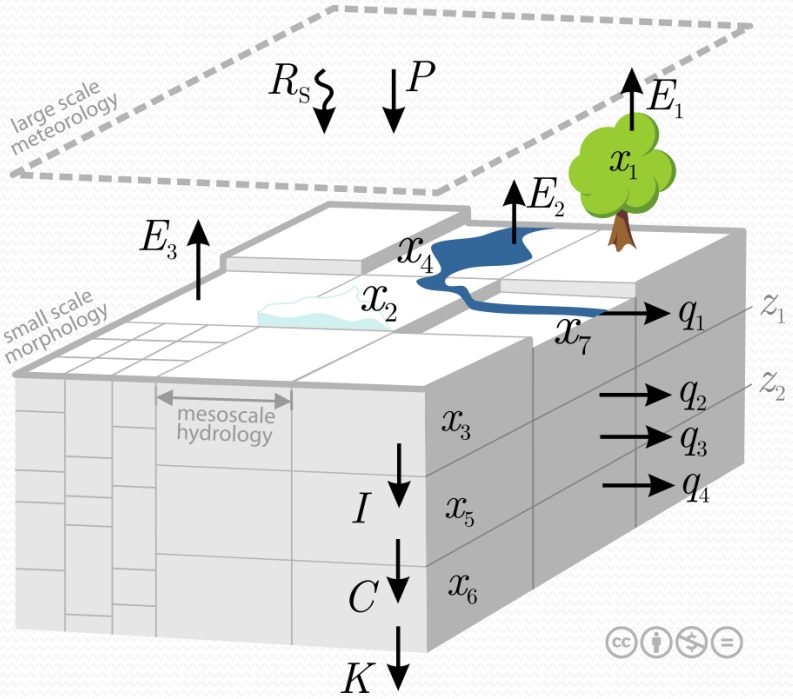
$$p_s \cdot \frac{dV_s}{dt} = -DDF\ (T - T_m), \qquad T > T_R$$

$$p_s \cdot V_s(t) - V_s(t-1) = -DDF\ (T(t) - 0)$$

$$\text{Daily} \qquad DDF(t) = -\frac{p_s \cdot V_s(t) - V_s(t-1)}{(T(t))}$$

METHODOLOGY (Cont.)

- Mesoscale Hydrologic Model (mHM)
  - 10^2 – 10^4 km^2 basins
  - Distributed model
  - Tested on 400+ basin
  - Utilize sub-grid variability
  - Multi-parameter Regionalization
    - Use data at finest scale available
    - Link to global parameters
    - Max. 53 calibration parameters
  - Open source



METHODOLOGY (Cont.)

- Data Sources:

Data Type	Data Source
Meteorological Data	State Meteorological Service (MGM) Joint Research Center (JRC)
Hydrometric Data	State Hydraulic Works (DSI)
Elevation Data	General Directorate of Mapping (HGM)
Land Use Data	Ministry of Agriculture and Forestry
Geological Data	DG Mineral Research and Exploration (MTA)
Leaf-Area_Index Data	MODIS Land Cover Type Product
Soil Data	Harmonized World Soil Database
Satellite Data	MODIS 500m resolution Snow Products

METHODOLOGY (Cont.)

- mHM Calibration
  - Modelling grid: 1 x 1 km
  - Sub-grid: 100 x 100 m
  - Meteo-grid: 25 x 25 km
  - Dynamically Dimensioned Search (DDS) algorithm
  - 7500 iteration
  - Objective Function:

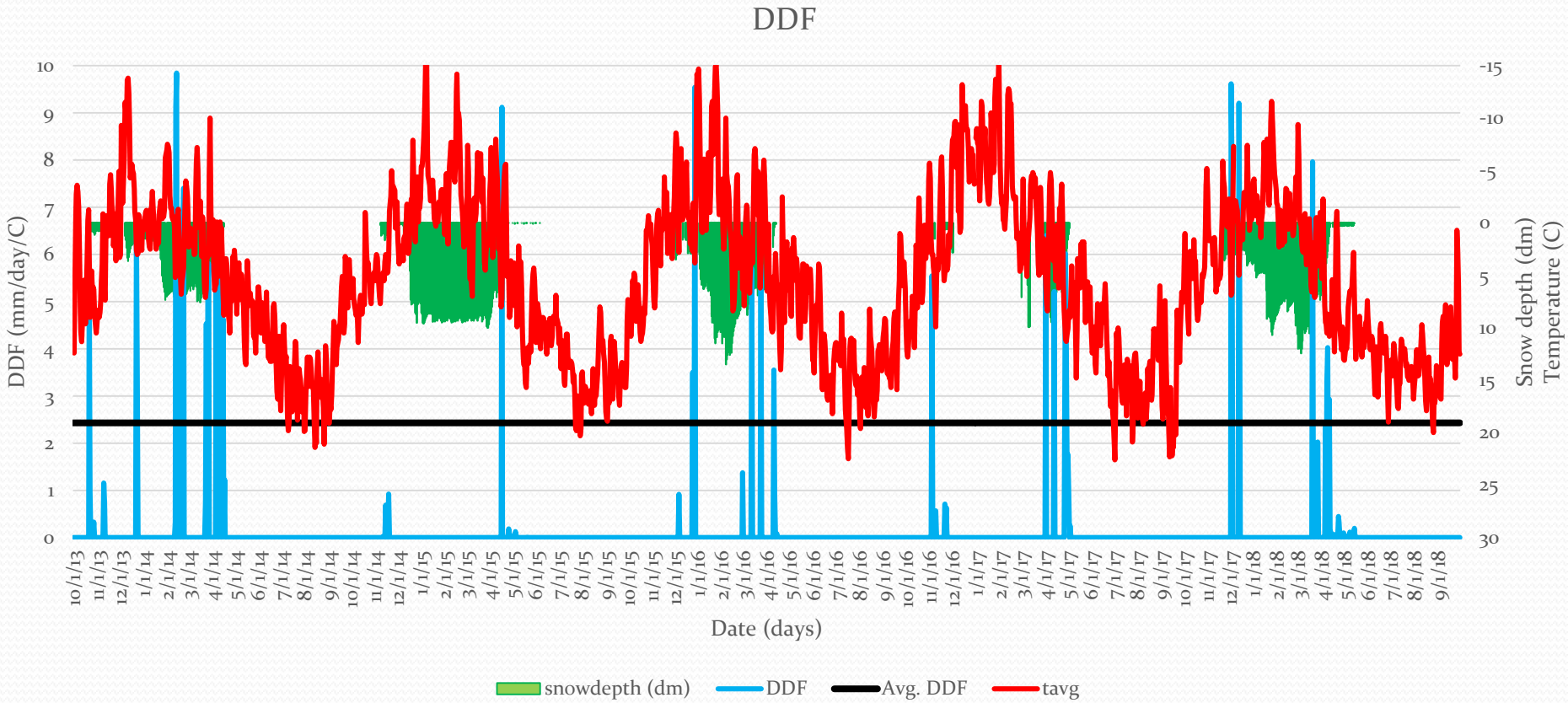
$$\min Z = 1 - \frac{1}{2}[NSE - \ln(NSE)]$$

Z : Objective Function
NSE : Nash-Sutcliffe efficiency

- Simulation period:
  - Karanlikdere Basin: 1.12.2014 - 30.09.2017 – Warm up: 180 days
  - Bahcelik Basin: 1.10.2003 – 30.04.2017 – Warm-up : 365 days

RESULTS

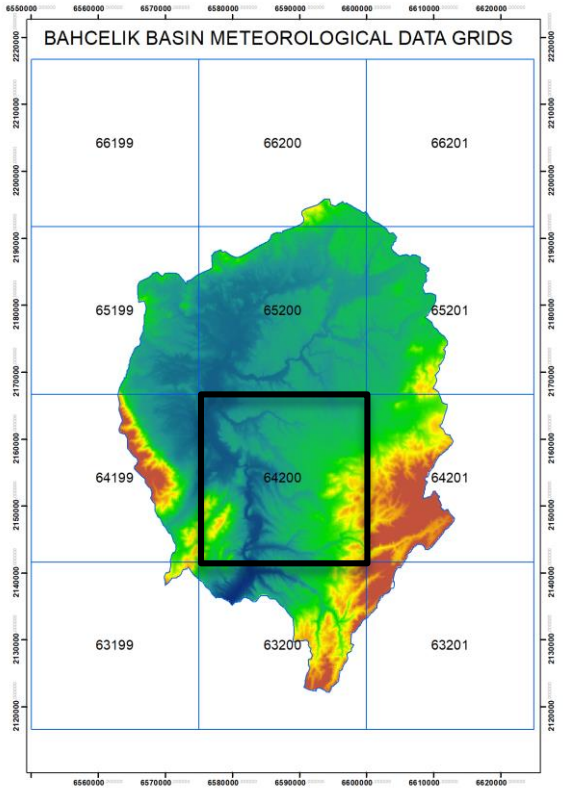
- Daily Degree-day factors for Karanlikdere Basin

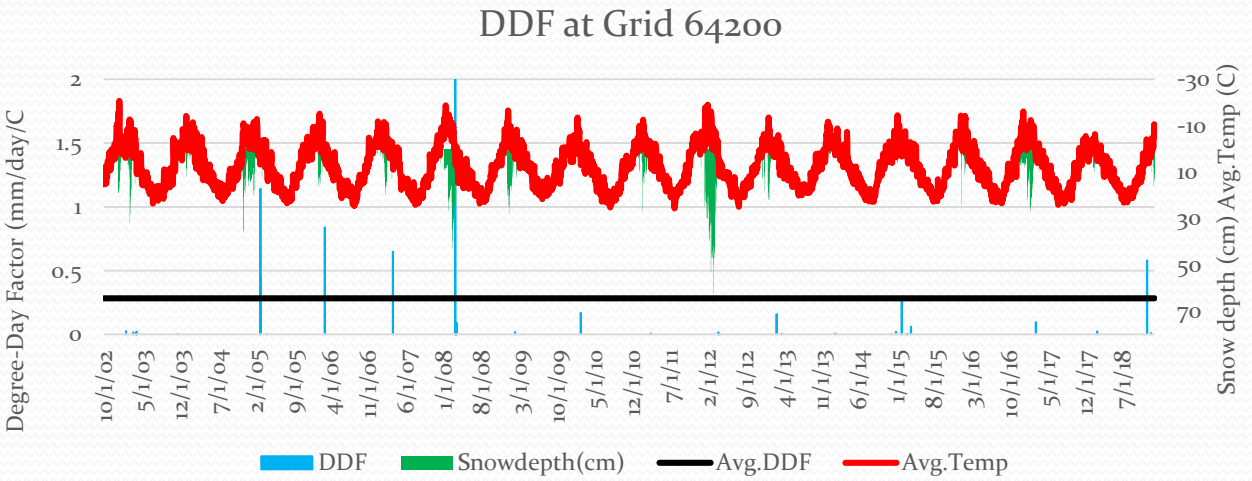


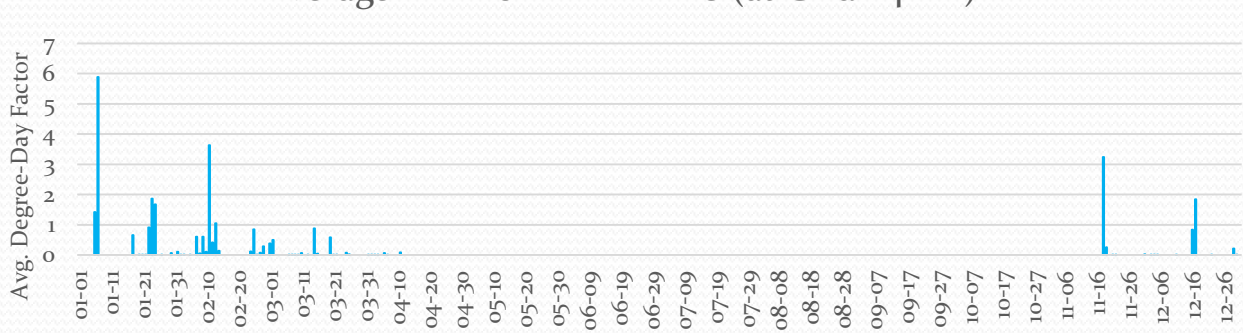
Avg. calculated DDF = 2.431 | mHM calibrated DDF (forest): 2.395

RESULTS (Cont.)

- Daily Degree-day factors for Bahcelik Basin



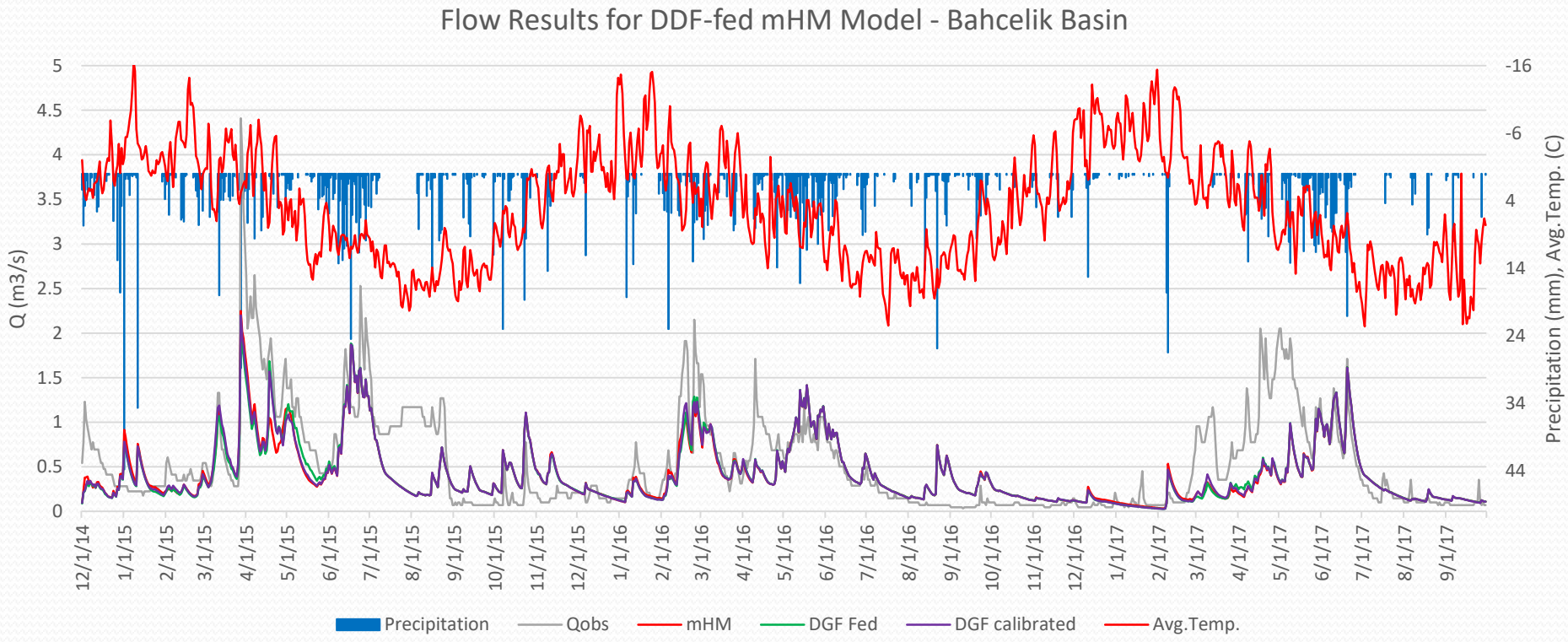




Avg. calculated DDF = 0.2826 | mHM calibrated DDF (pervious): 0.1237

RESULTS (Cont.)

- Flow simulations for Karanlikdere Basin

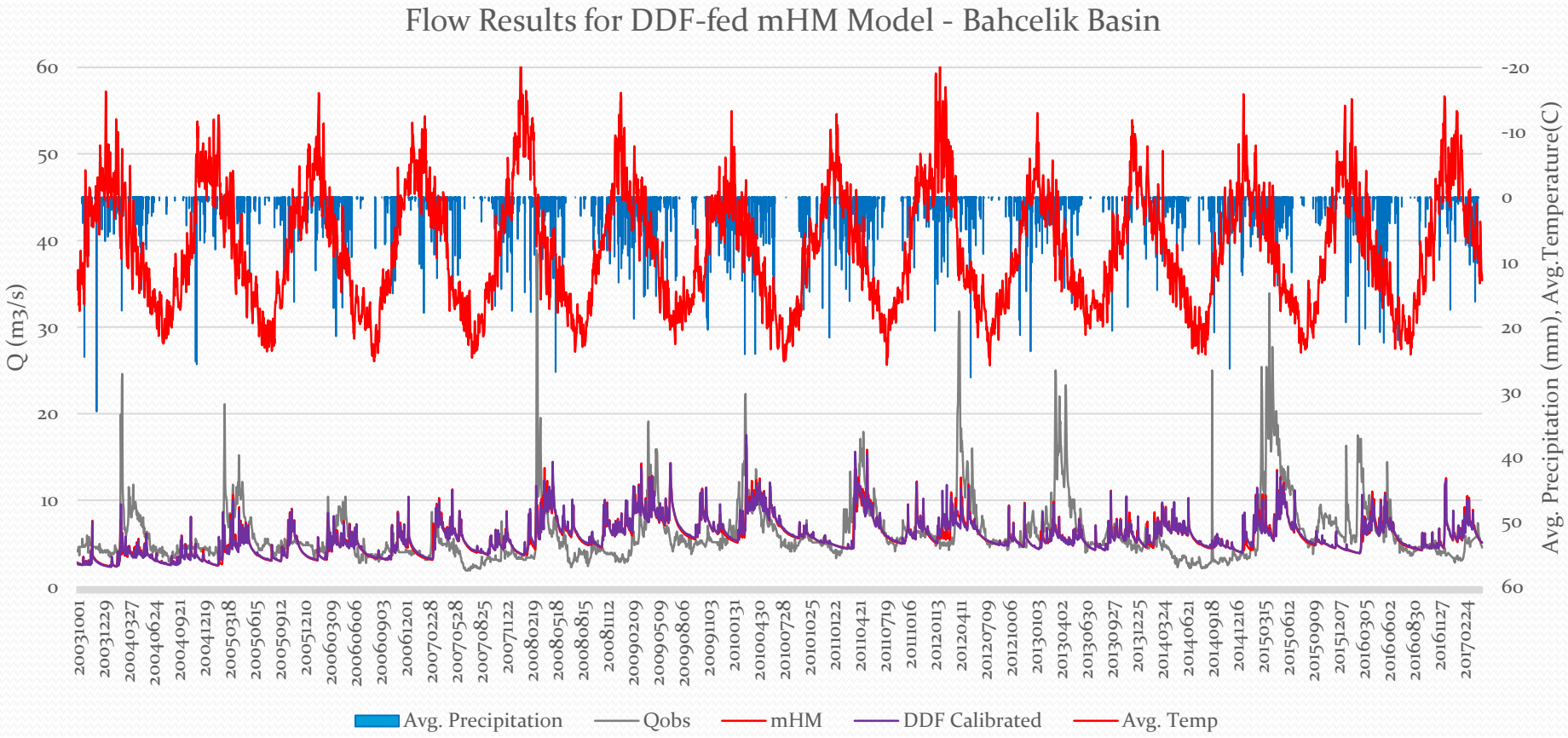


mHM NSE: 0.45078 KGE: 0.281

DDF Calibrated mHM NSE: 0,45785 KGE: 0.292

RESULTS (Cont.)

- Flow simulations for Bahcelik Basin

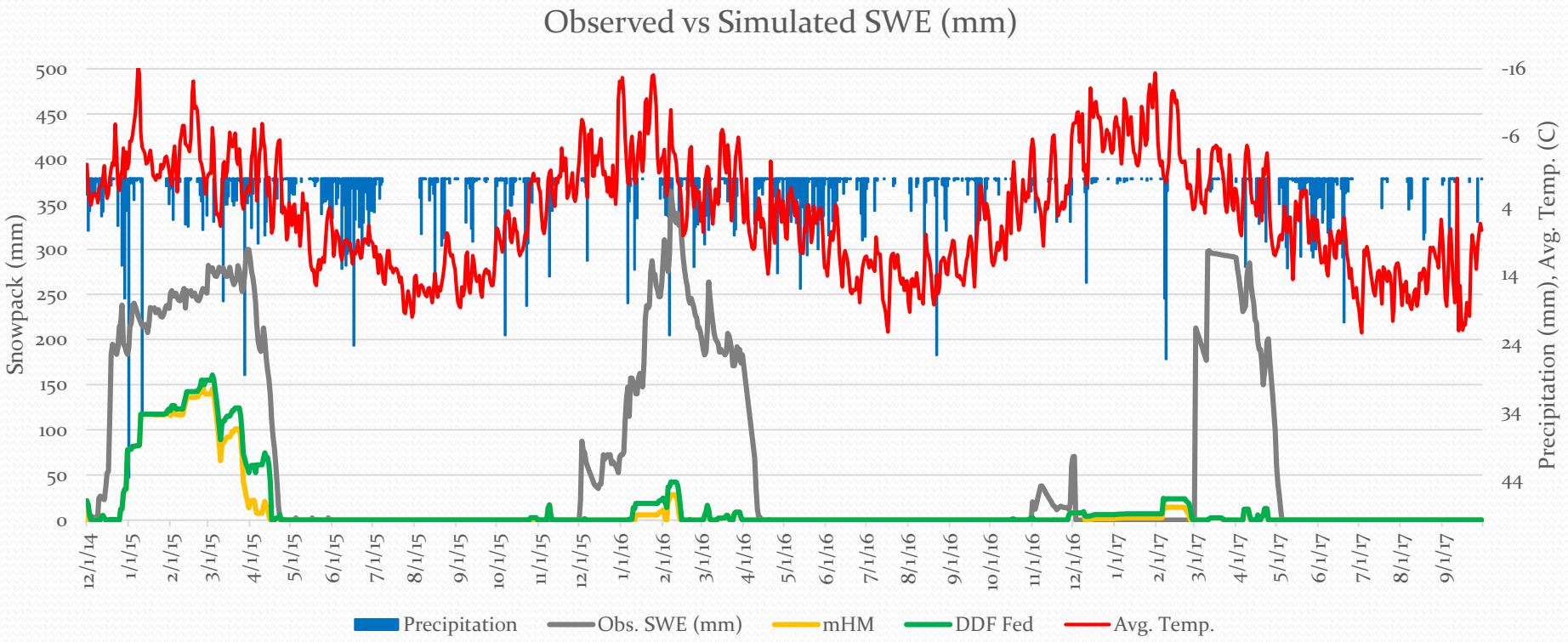


mHM NSE: 0.11149 KGE: 0.25381

DDF Calibrated mHM NSE: 0.07003 KGE: 0.21543

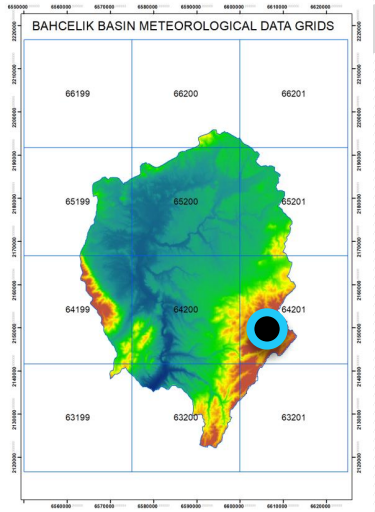
RESULTS (Cont.)

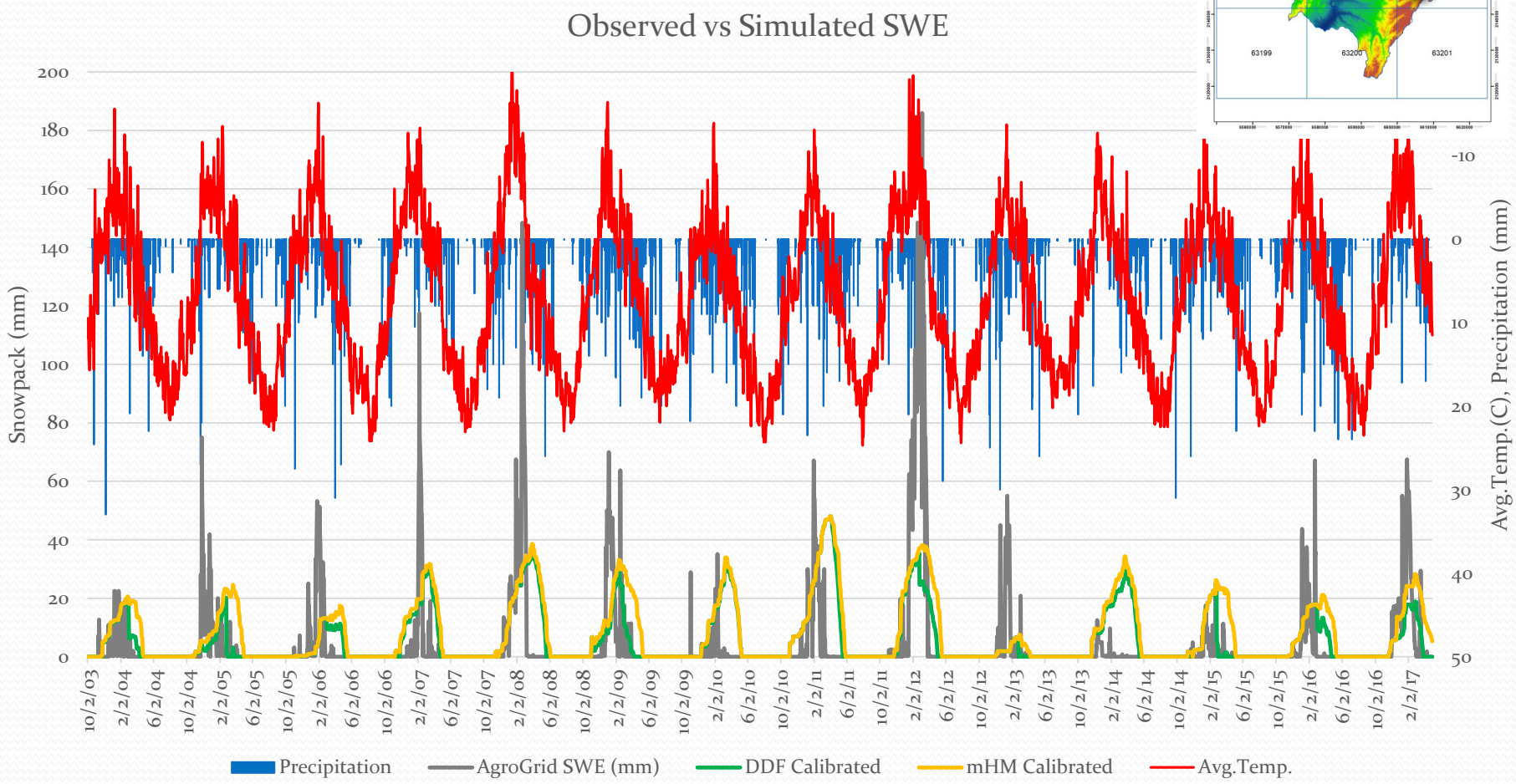
- Snowpack Simulations: Karanlikdere Basin



RESULTS (Cont.)

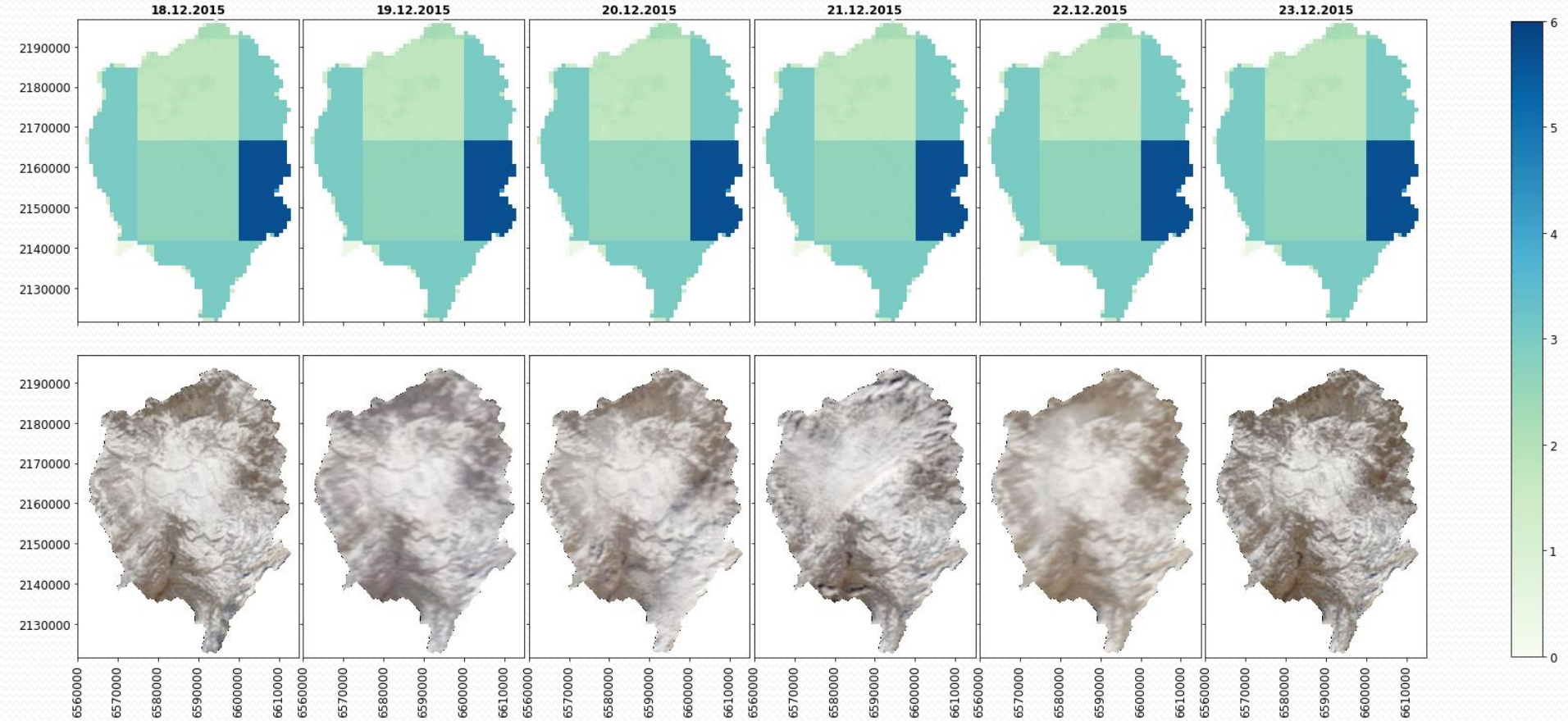
- Snowpack Simulations: Bahcelik Basin





RESULTS (Cont.)

- Bahcelik Basin Simulated SWE vs MODIS Imagery



DISCUSSION and FUTURE WORKS

- Results
  - Slight differences in terms of flow simulation
  - Improvement on SWE simulations
  - Consistency between average calculated DDF and mHM calibrated DDF

- Error Sources
  - Data quality (meteorological and flow data)
  - Relatively short period of availability
  - Size of basin for Karanlikdere

- Future Works
  - Add spatial snow distribution as calibration parameter to mHM
  - Improve meteorological data with ground-based observations
  - Investigate other remote sensing snow data

Thank You.