ASSIMILATION OF EUMETSAT SNOW COVERED AREA DATA INTO CONCEPTUAL HYDROLOGIC MODEL

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OUTLINE

- Introduction
- EUMETSAT HSAF Snow Cover and SWE Products
- Validations of Snow Products
- Hydrological modeling
- Study Area
- Results
- Discussion of the results

Introduction

- Snow is one of the main water resources, therefore monitoring and estimating the snow water equivalent play important role in predicting discharges during melting seasons.
- Snow covered area, snow water equivalent are either inputs for hydrological models or internal variables that can be assimilated during modeling.
- Turkey is a mountainous country, and many basins in the country are largely fed from snow whereby nearly two-thirds occur in winter and may remain in the form of snow for half of the year.

Introduction

- Snow cover and SWE products have been developed in the framework of EUMETSAT, H-SAF Project.
- Snow cover product (H10) is generated by using data from Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument making observations from a geostationary satellite Meteosat Second Generation (MSG).
- Snow Water Equivalent product (H13) is generated from SSMI/S radiometer.
- The validation of these products are a continuous process since 2009.

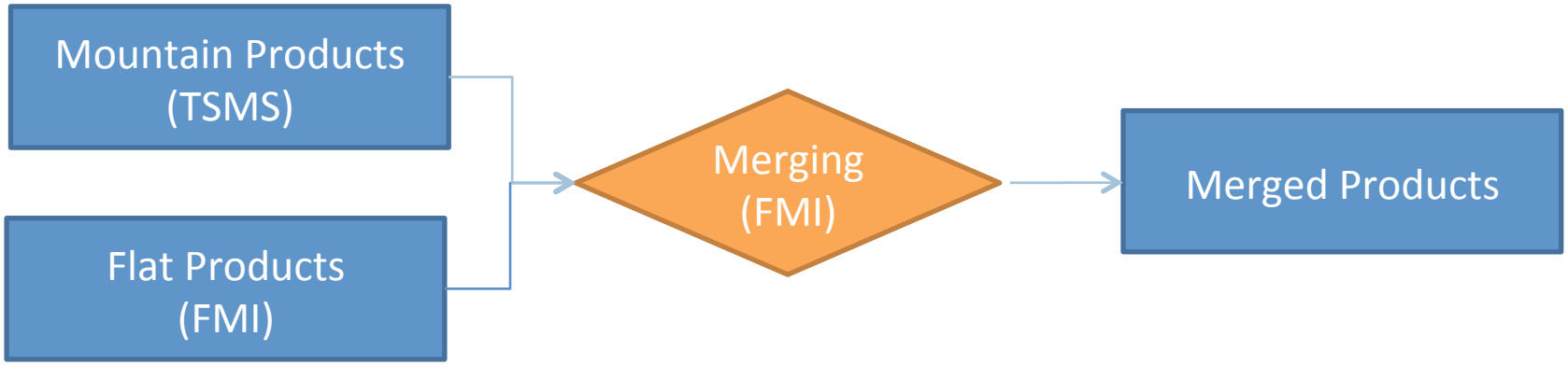
Aim of the study

- To evaluate the potential of EUMETSAT snow covered area product for improving hydrological simulations in a gauged catchment.

- To compare H13 SWE values with the model simulated SWE values.

HSAF SNOW PRODUCTS

- Snow Recognition Product (H10)
- Snow Status Product (H11)
- Fractional Snow Cover Product (H12)
- Snow Water Equivalent Product (H13)

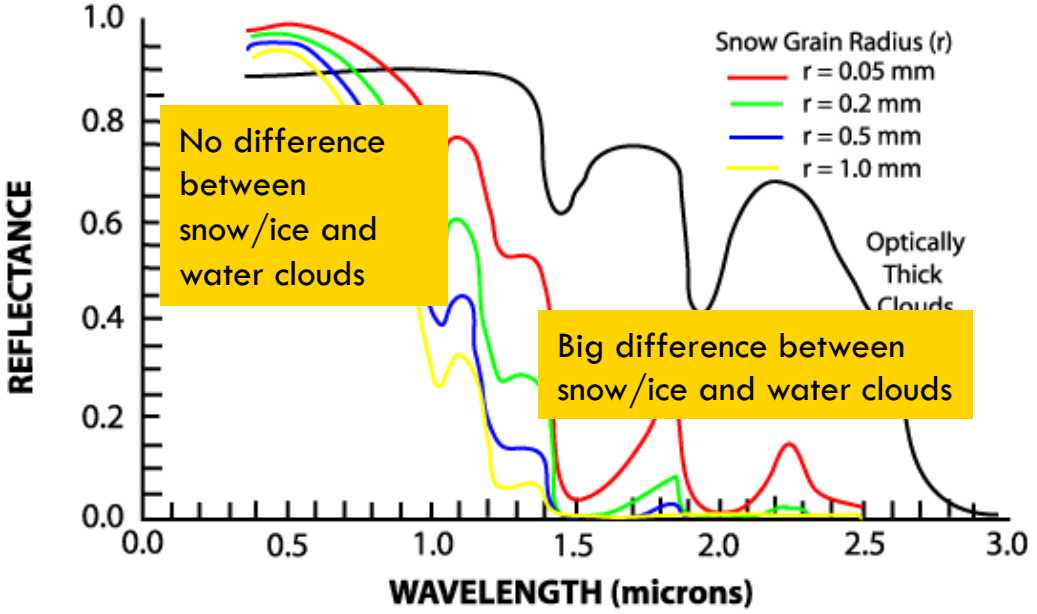


The chain of the products are presented in the poster

'HSAF Snow Product Chain at TSMS'

Snow Recognition Methodology

- Snow identification technique is based on satellite observations in the visible, near-infrared, shortwave-infrared and infrared bands.
- The basic principle behind the snow recognition algorithm is on the different spectral characteristics of snow, cloud and land.



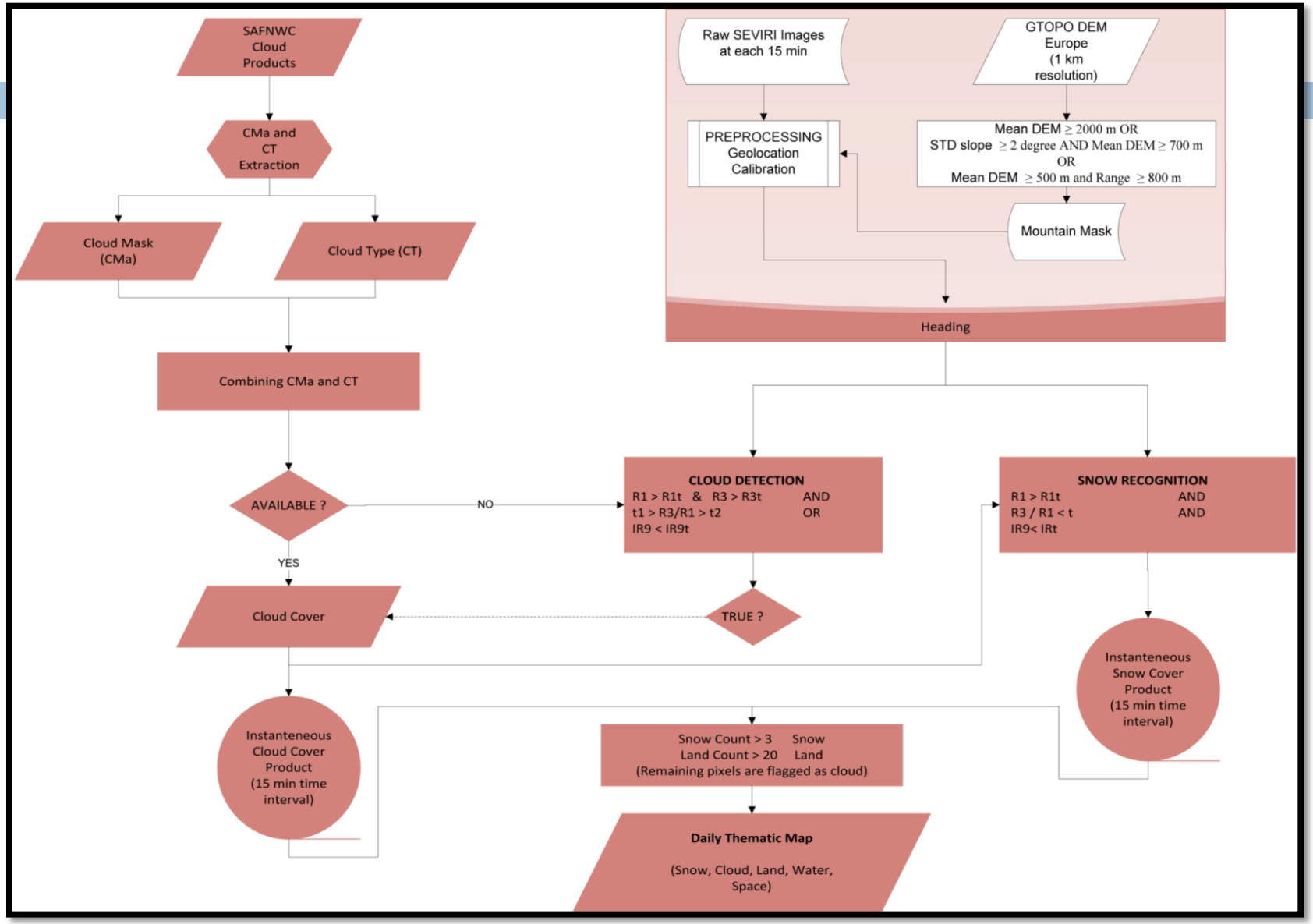
Different Reflectivity of Ice/snow versus Watercloud in 0.6 μm and 1.6 μm [*EUMETSAT*, 2004d].

HSAF SNOW PRODUCTS

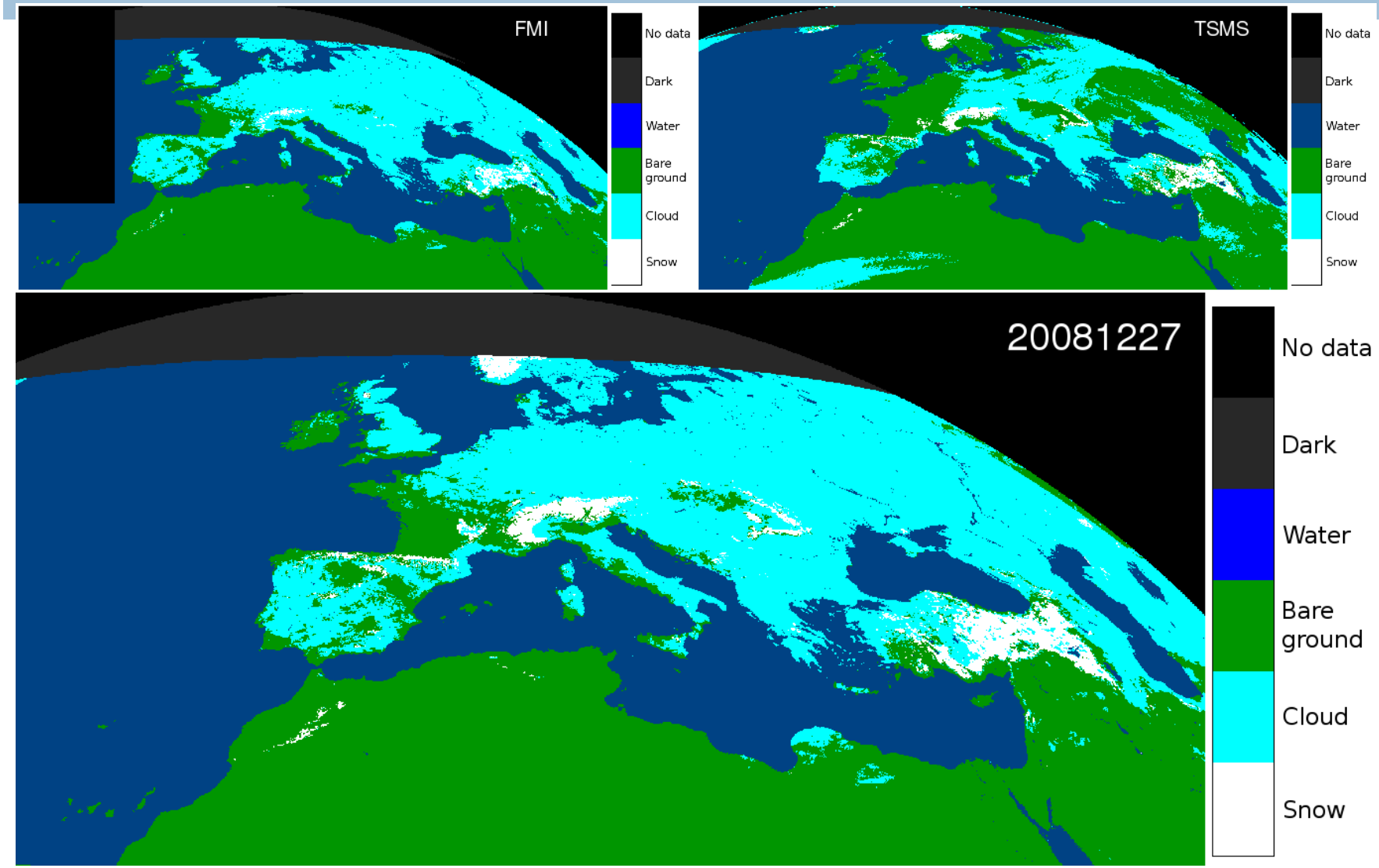
- Due to a low reflectance of the snow cover in the infrared and a high reflectance in the visible, the snow index (SI) enhances the difference of the spectral response of the snow cover from the response of other surfaces and is thus beneficial for snow detection.
- The algorithm for single image SR uses simple threshold values coupled with conditions combining different channels.

Channel no.	Central Wavelength (μm)	Description
1	0.635	Visible (VIS0.6)
3	1.64	Near Infrared (NIR1.6)
4	3.90	Shortwave Infrared (IR3.9)
9	10.80	Infrared (IR10.8)

H10 Snow Recognition Algorithm



H10 Merged Snow Products



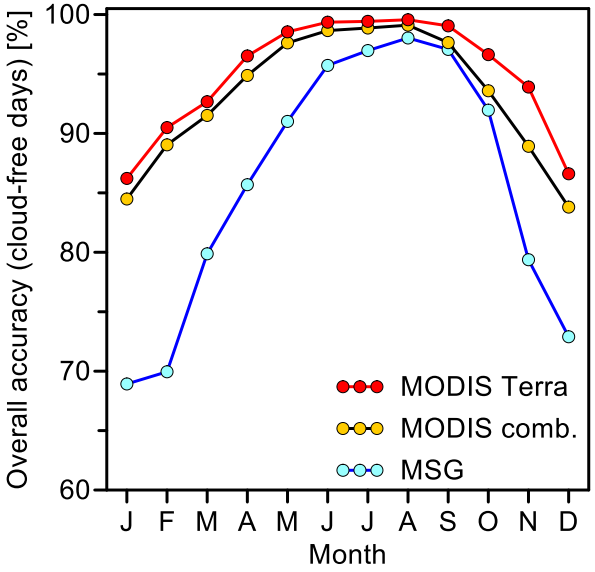
H10 Validation Results

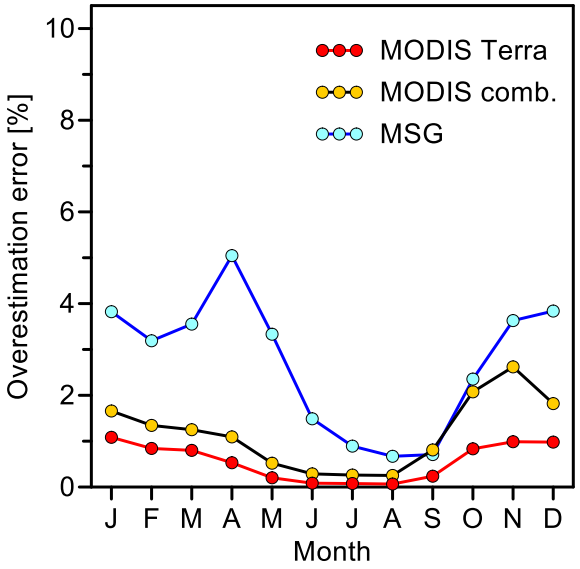
- Water year 2010 (01.10.2009 – 30.09.2010)
  POD= 0.73 FAR= 0.28
- Water year 2011 (01.10.2010 – 30.09.2011)
  POD= 0.85 FAR= 0.15
- Water year 2012 (01.10.2010 – 30.09.2012)
  POD= 0.85 FAR= 0.15
- Water year 2013 (01.10.2012 – 30.09.2013)
  POD= 0.89 FAR= 0.14

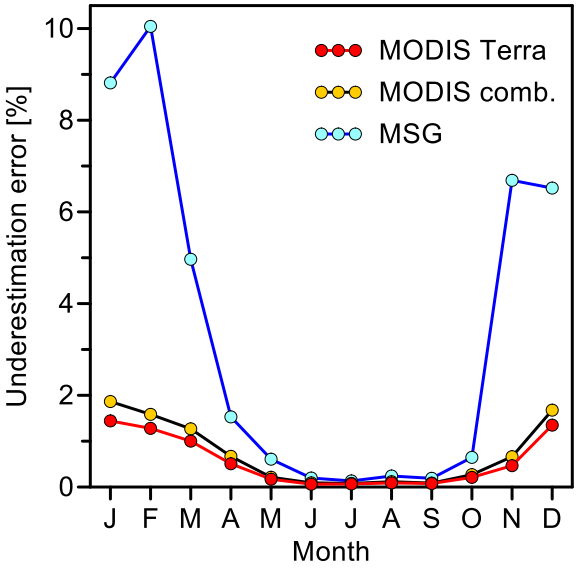
		Ground Observation	
Snow Cover Product		Snow Presence	None
	Snow Presence	a	b
	None	c	d

POD	FAR	HR	SMR
$\frac{a}{(a+c)}$	$\frac{b}{(a+b)}$	$\frac{(a+d)}{(a+b+c+d)}$	$\frac{c}{(a+b+c+d)}$

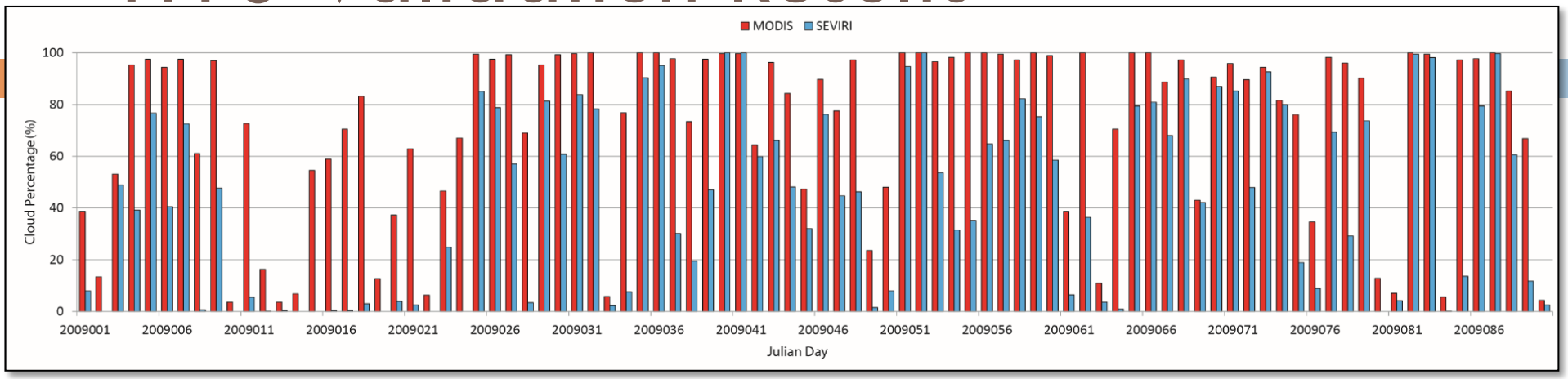
H10 Validation Results



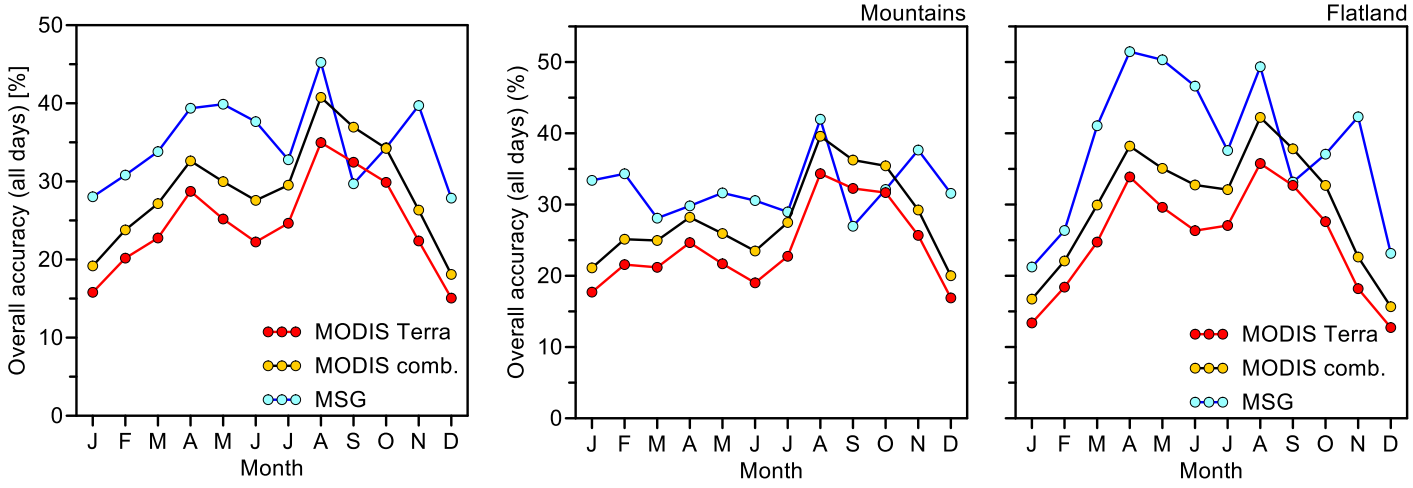




H10 Validation Results



The possibility of 37% cloud cover reduction from MSG-SEVIRI compared to using only one daily observation from MODIS



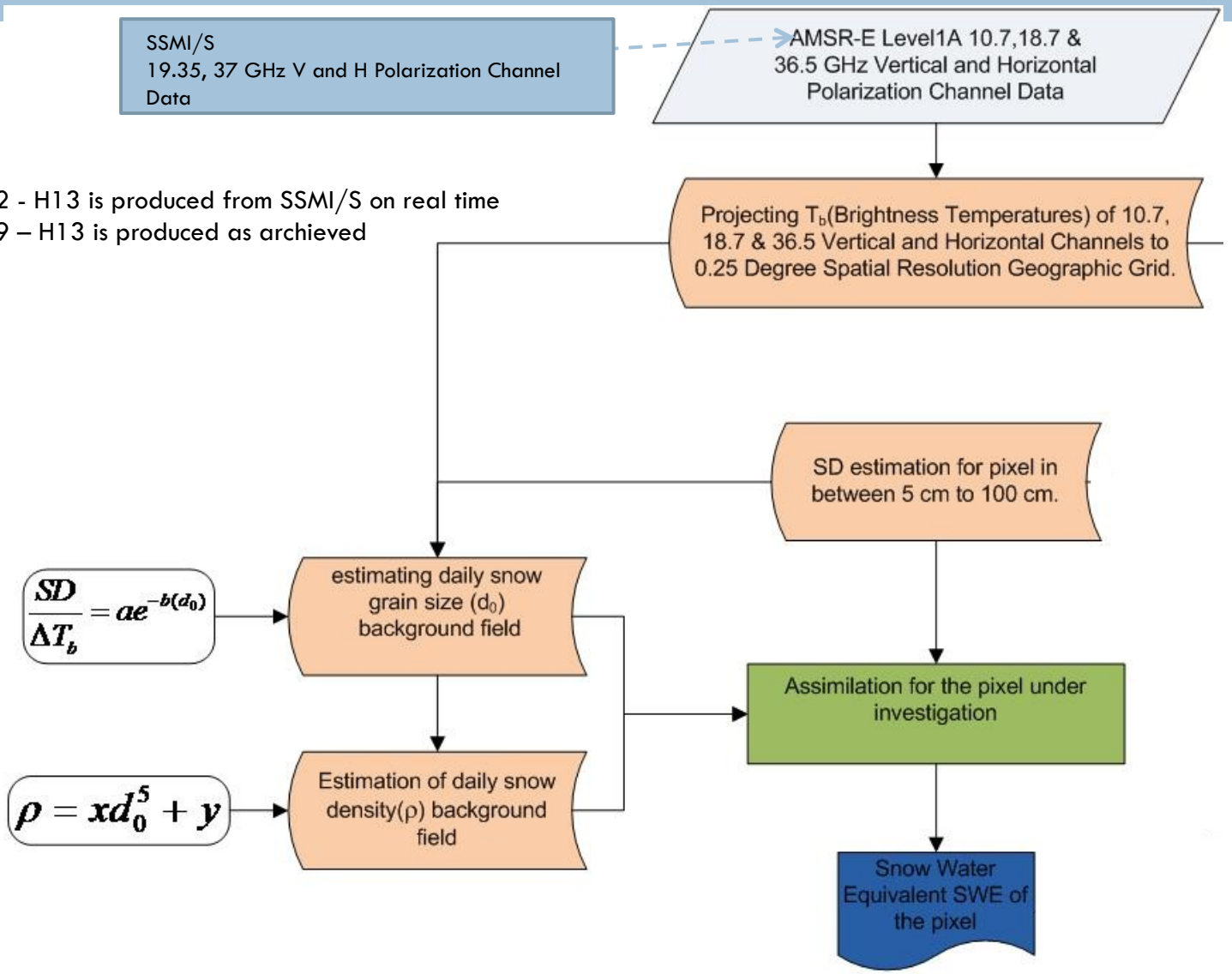
Surer and Akyurek, 2012
Evaluating the utility of the EUMETSAT HSAF snow recognition product over mountainous areas of eastern Turkey
Hydrological Science Journal, 57 (8), 1-11, 2012.

Surer , Parajka and Akyurek, 2014
Validation of the operational MSG-SEVIRI snow cover product over Austria
Hydrology Earth System Science Journal, (in print), 2014.

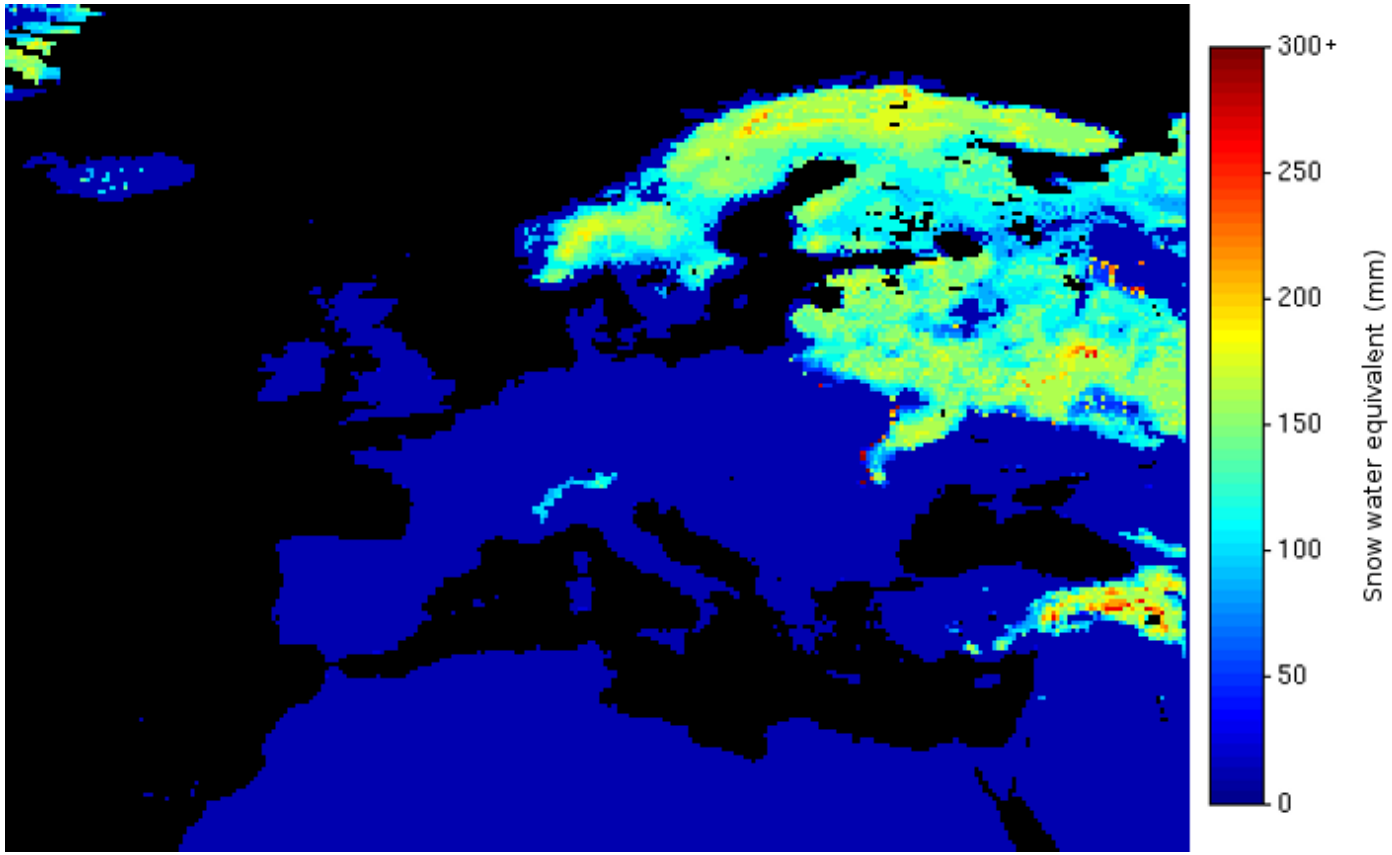
H13 Snow Water Equivalance

SWE (H13) RETRIEVAL DATA ASSIMILATION SCHEMA

10.04.2012 - H13 is produced from SSMI/S on real time
01.04.2009 – H13 is produced as archieved



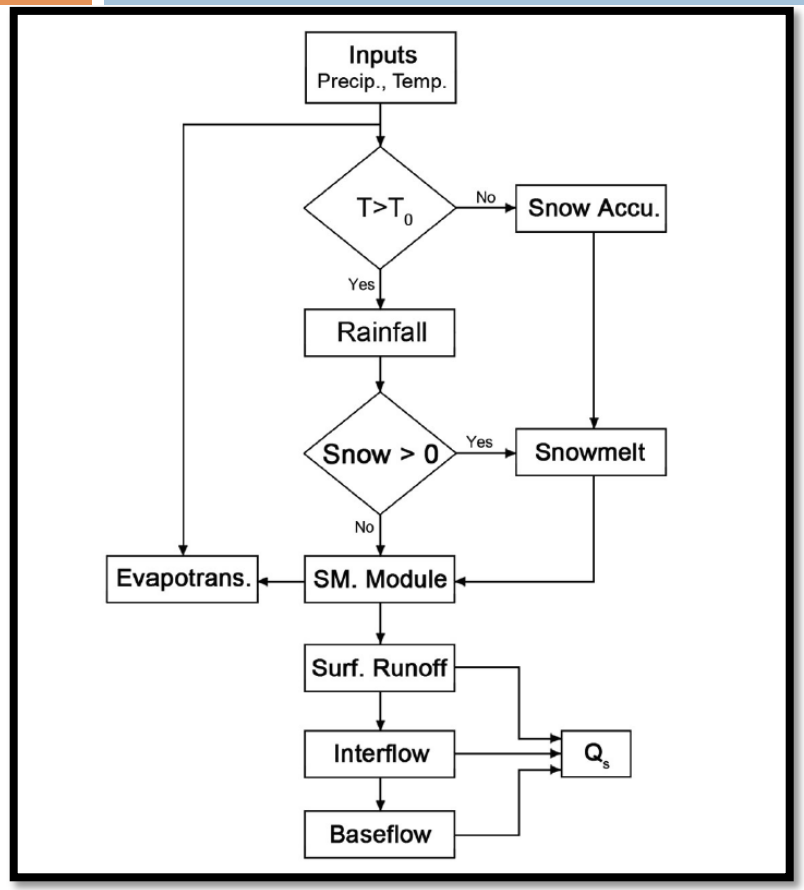
H13 SWE Product

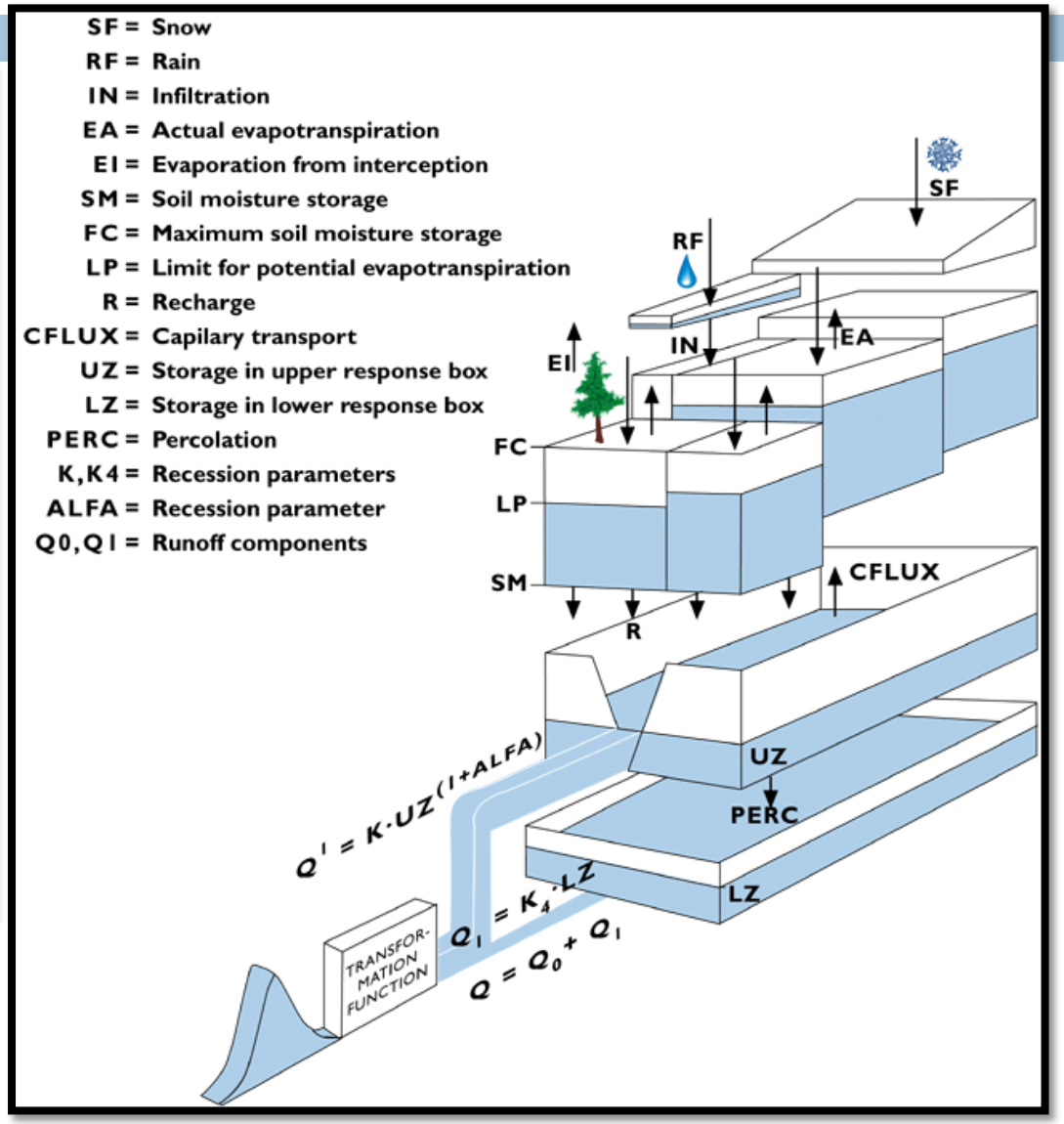


7.03.2013

2010 RMSE= 46.14 mm
2011 RMSE= 45.24 mm
2012 RMSE= 45.54 mm
2013 RMSE= 39.62 mm

Hydrological Modeling:HBV





- The HBV model is a conceptual hydrological model designed for use in mountainous environments.
- It is semi-distributed.

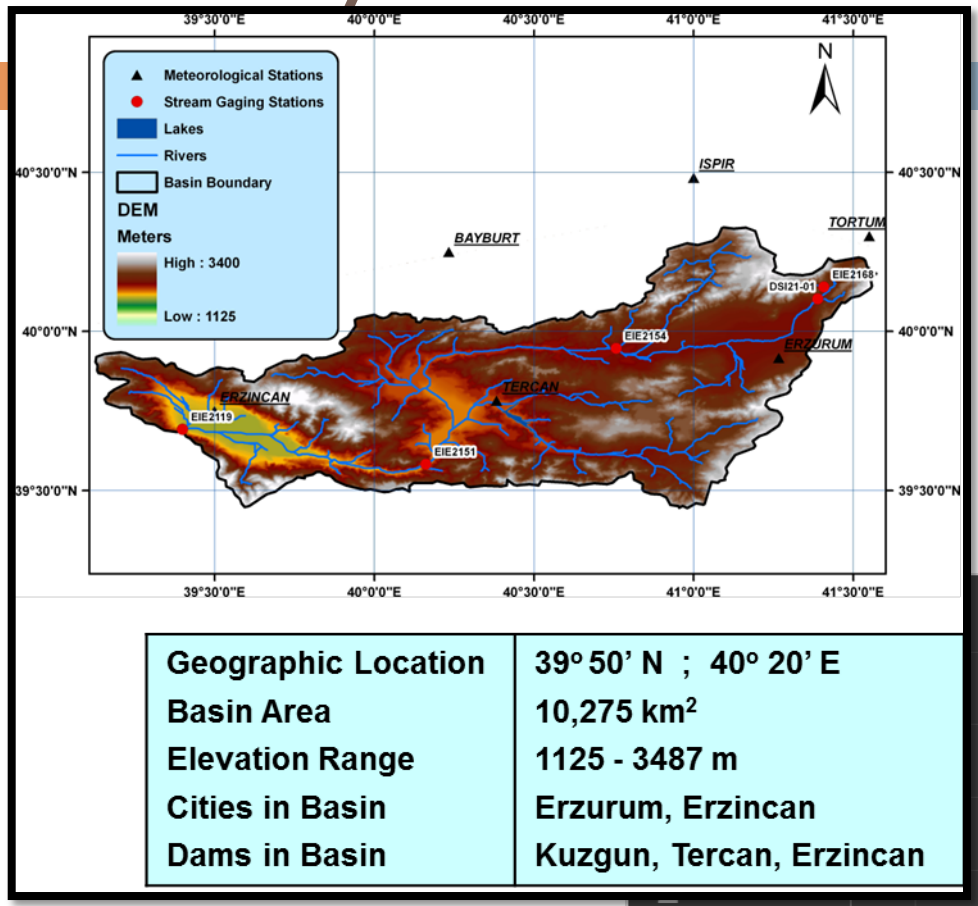
Hydrological Modeling:HBV

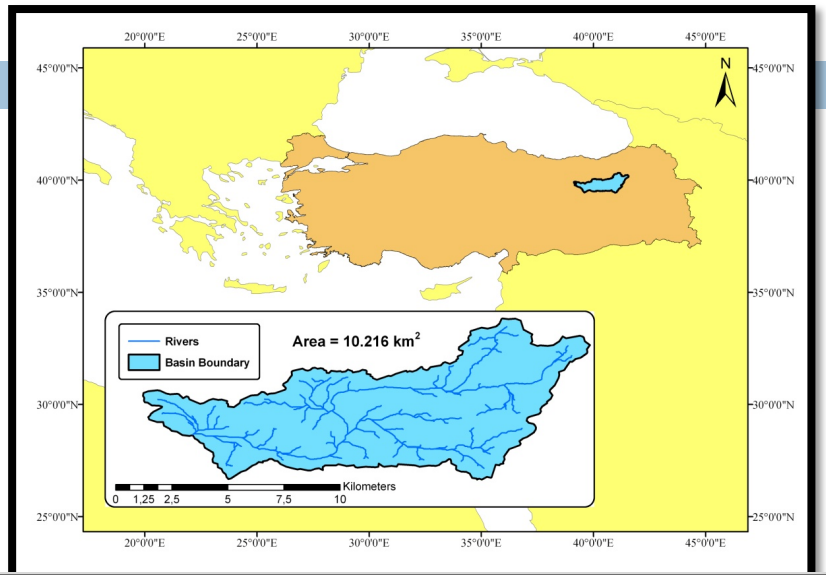
- The treatment of the snowpack in HBV is based on a simple accounting algorithm whereby snow water equivalent increases when precipitation falls as snow, but decreases when snow melt takes place.

- The existence and amount of snowfall is predicted using meteorological input data extrapolated to the mean elevation of each sub-area of the basin.

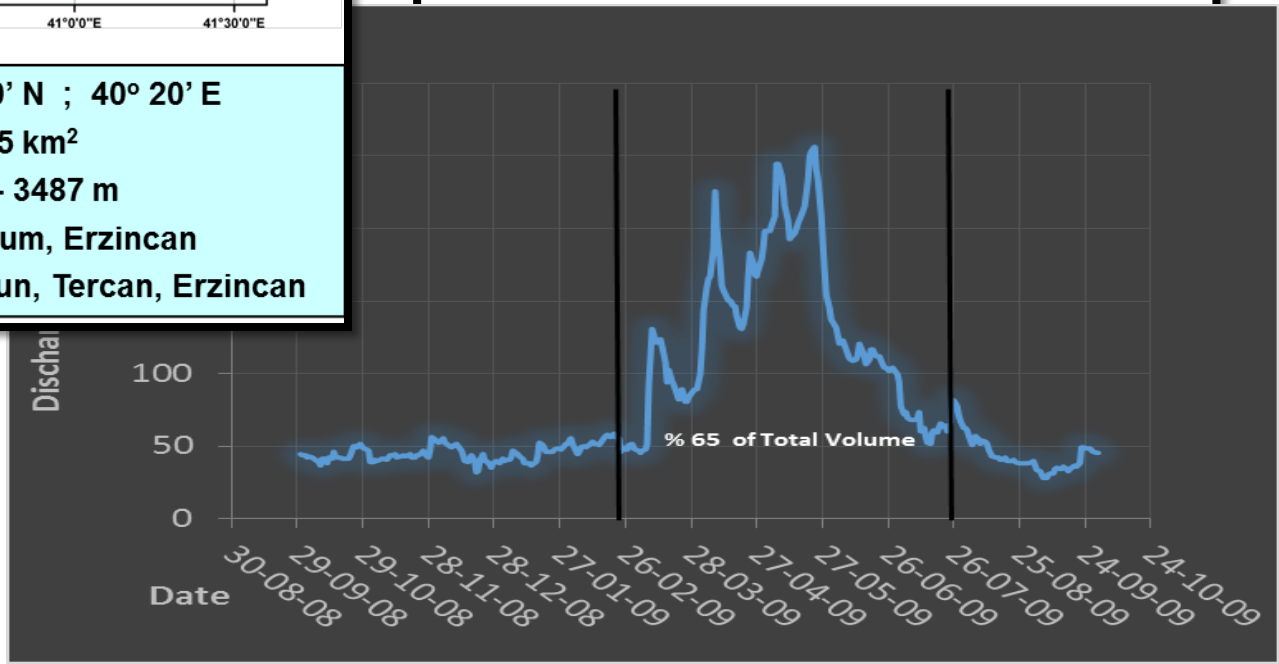
- Parameters for this are the temperature lapse rate, rain/snow threshold temperature, and multipliers applied to measured precipitation to allow for underestimation of snowfall and any increase in precipitation with elevation.

Study area: Karasu Basin

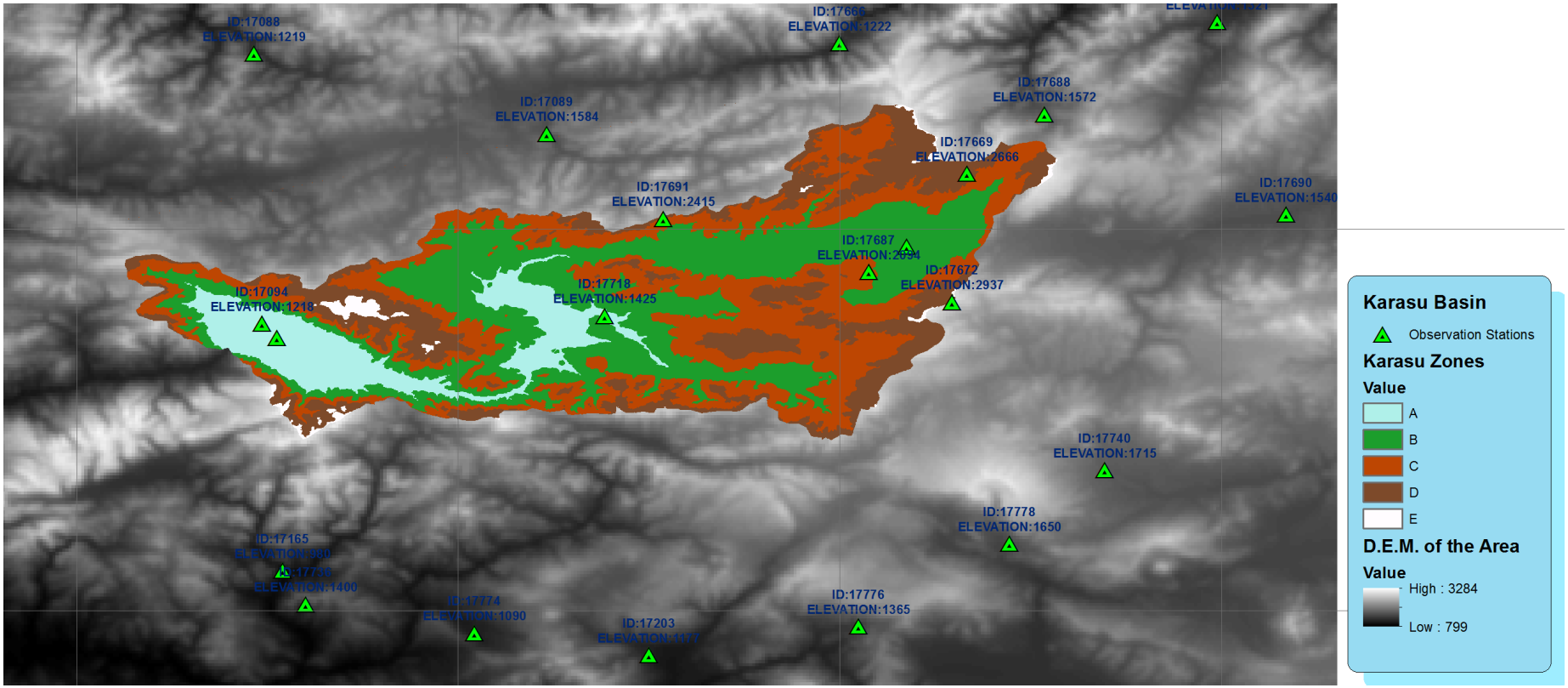




Geographic Location	39° 50' N ; 40° 20' E
Basin Area	10,275 km²
Elevation Range	1125 - 3487 m
Cities in Basin	Erzurum, Erzincan
Dams in Basin	Kuzgun, Tercan, Erzincan

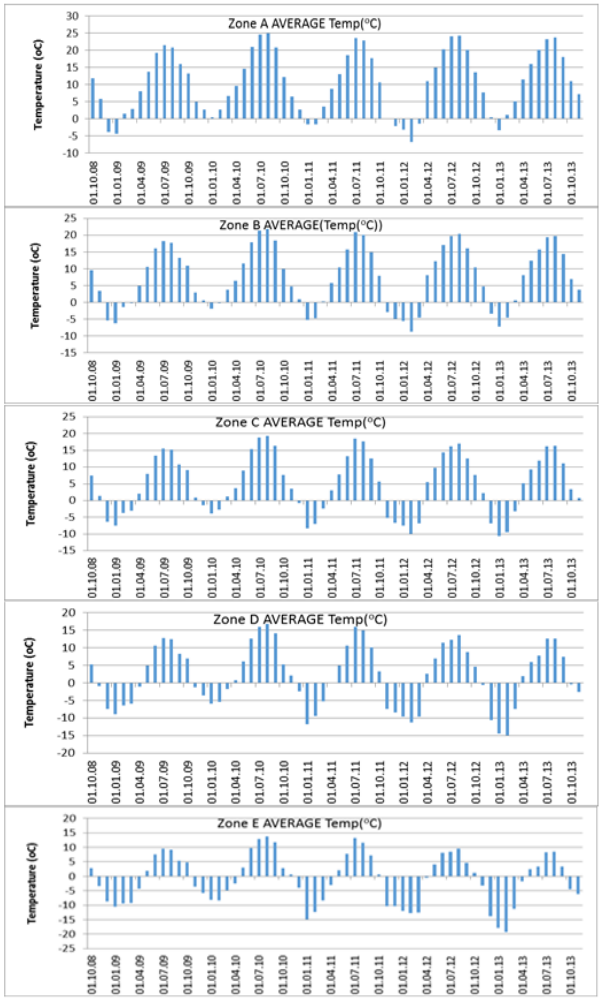


Study area: Karasu Basin

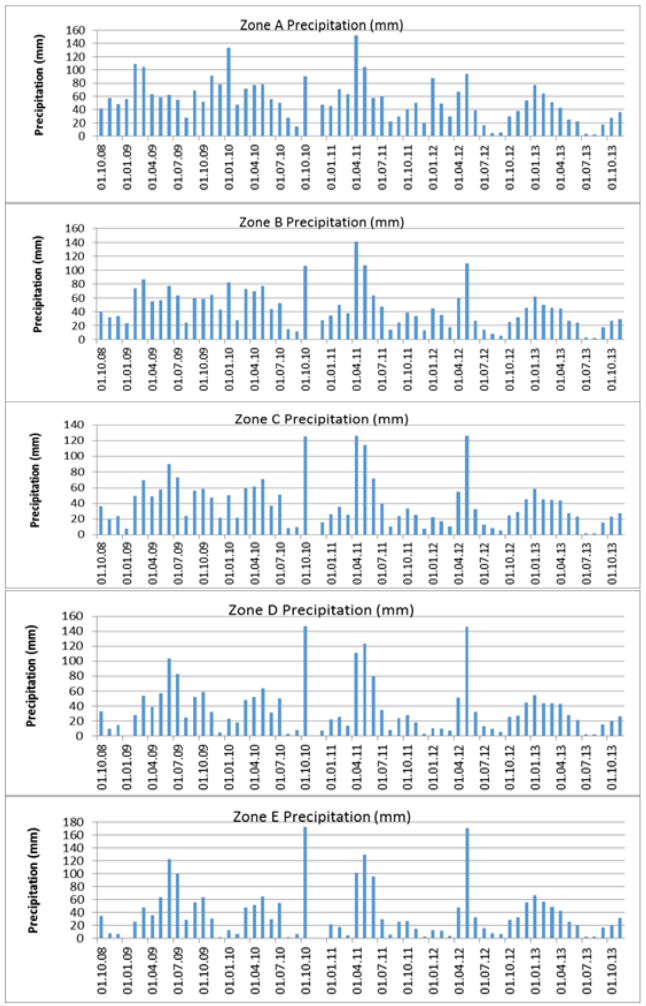


Input Parameters

Zone	Elevation (m)	Area (km2)	Area (%)
A	1100-1500	1158	11.43
B	1500-1900	3467	34.23
C	1900-2300	3427	33.83
D	2300-2900	2012	19.86
E	2900-3400	65	0.64



Mean monthly Temperature



Monthly Precipitation

Modelling

Model parameter		Model component	Lower	Upper
Snow correction factor(-)	CSF	Snow	0	1.5
Degree Day factor(mm/°Cday)	DDF	Snow	0	5.0
Rain air temp. Thresold (°C)	T_{rain}	Snow	2	2
Snow air temperature threshold (°C)	T_{snow}	Snow	-2	-2
Melting air temperature threshold (°C)	T_{melt}	Snow	-2.0	2.0
Soil moisture state/maximum soil moisture storage (-)	LP/FC	Soil	0	1.0
Maximum soil moisture storage (mm)	FC	Soil	0	600
Runoff generation to the soil moisture state (-)	BETA	Soil	0	20
Very Fast storage coefficient (days)	K0	Runoff	0	2.0
Fast storage coefficient (days)	K1	Runoff	2.0	30
Low storage coefficient (days)	K2	Runoff	30	250
Threshold of storage state exceedence (mm)	LSUZ	Runoff	1.0	100
Percolation rate (mm/day)	CPERC	Runoff	0	1.0
	BMAX	Runoff	10	10
Routing parameter	CROUTE	Runoff	26.5	26.5

Nash-Sutcliffe Model efficiency for high, and low flows

$$ME=1-\sum i=1\uparrow n\square(Qobs,i-Qsim,i)2\ /\sum$$

$$M\downarrow\uparrow log\ E=1-\sum i=1\uparrow n\square(\log(Qobs,i)-\log(Qsim,i))2\ /\sum i=1\uparrow n\square(\log(Qobs,i)-log\ Qobs\ ))2$$

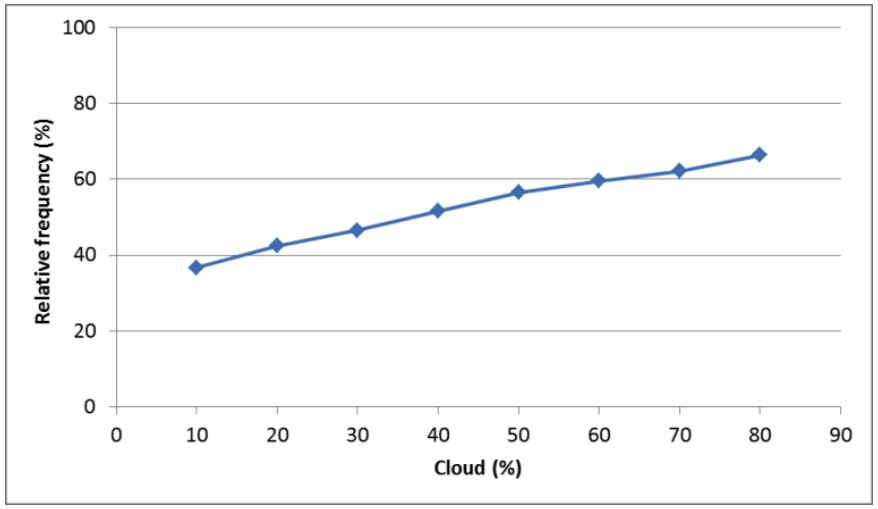
$$VE=\sum i=1\uparrow n\square Q\downarrow sim,i-\sum i=1\uparrow n\square Q\downarrow$$

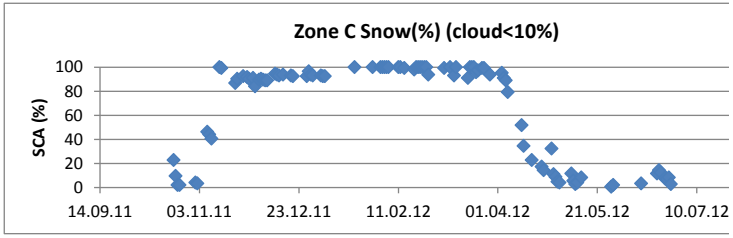
Under and Over estimation errors

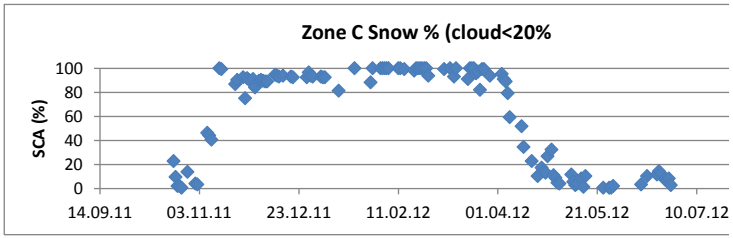
$$S\downarrow E\uparrow O=1/m.l\sum j=1\uparrow l\square m\downarrow o\cap(SWE>\zeta\downarrow S$$

$$S\downarrow E\uparrow U=1/m.l\sum j=1\uparrow l\square m\downarrow U\cap(SWE=0)\cap(SCA>\zeta\downarrow SCA\ )$$

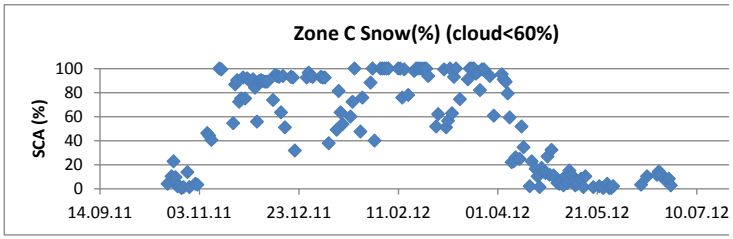
$$\zeta\downarrow SWE=0\quad\zeta\downarrow SCA=25\%$$





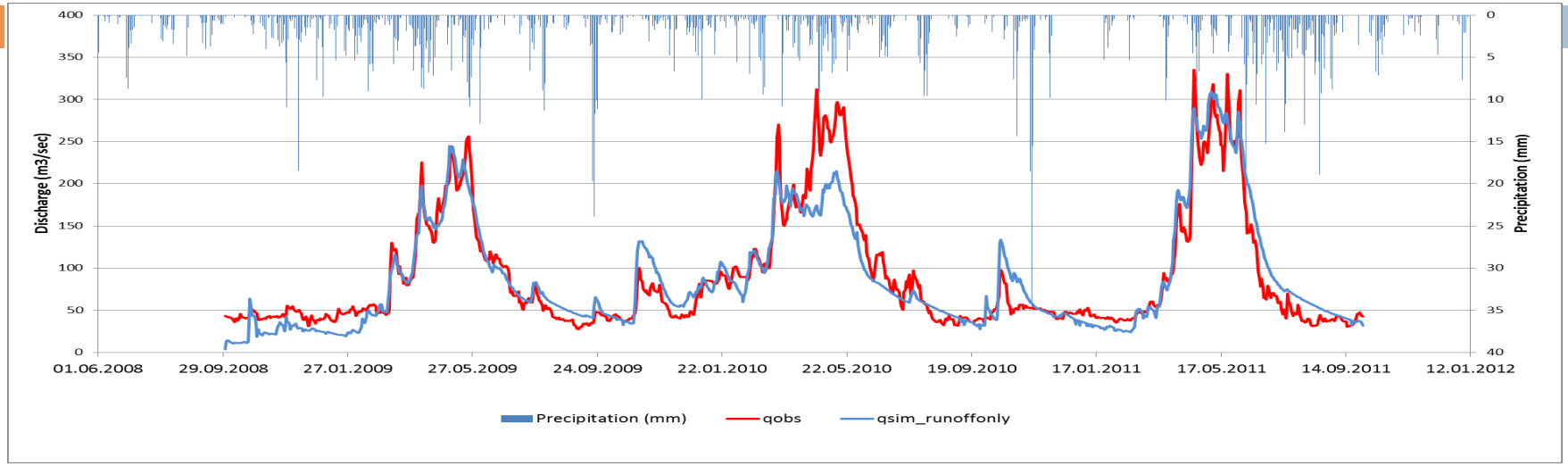


Number of days available for calculating snow covered area (SCA) from H10 snow product for different cloud thresholds

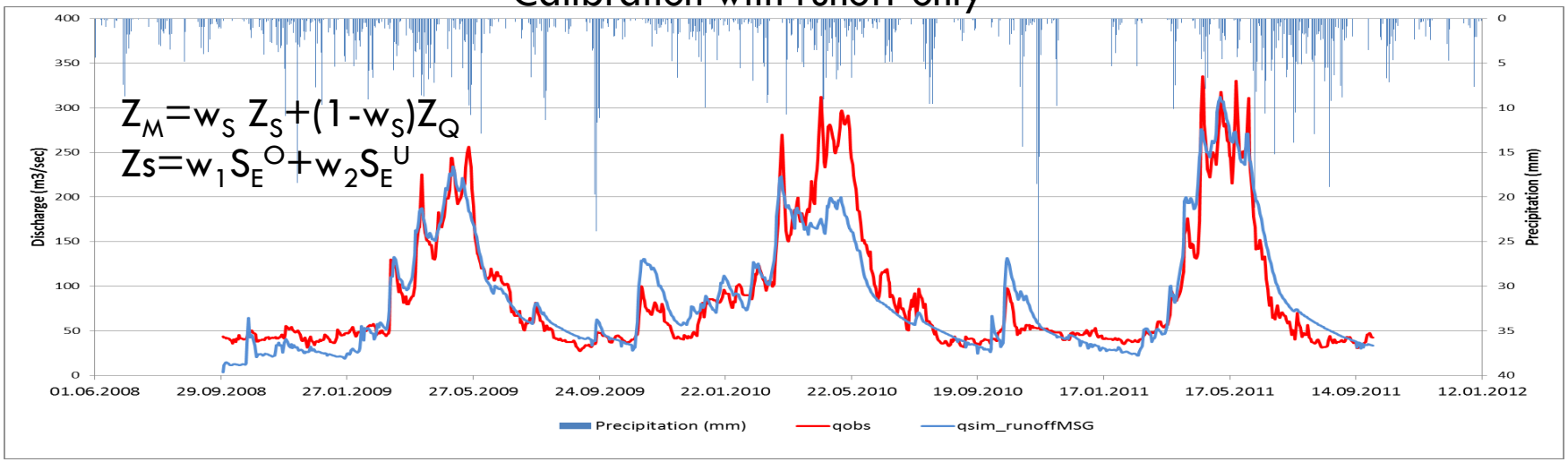


	Cloud<10%	Cloud<20%	Cloud < 40%	Cloud<60%	Cloud <80%
Volume error	0.0149	-0.0335	-0.0028	-0.0049	0,0022
M_E	0.7941	0.7914	0.7704	0.86	0,8021
$\log M_E$	0.7204	0.7002	0,7236	0.83	0,7909

Calibration of the Model

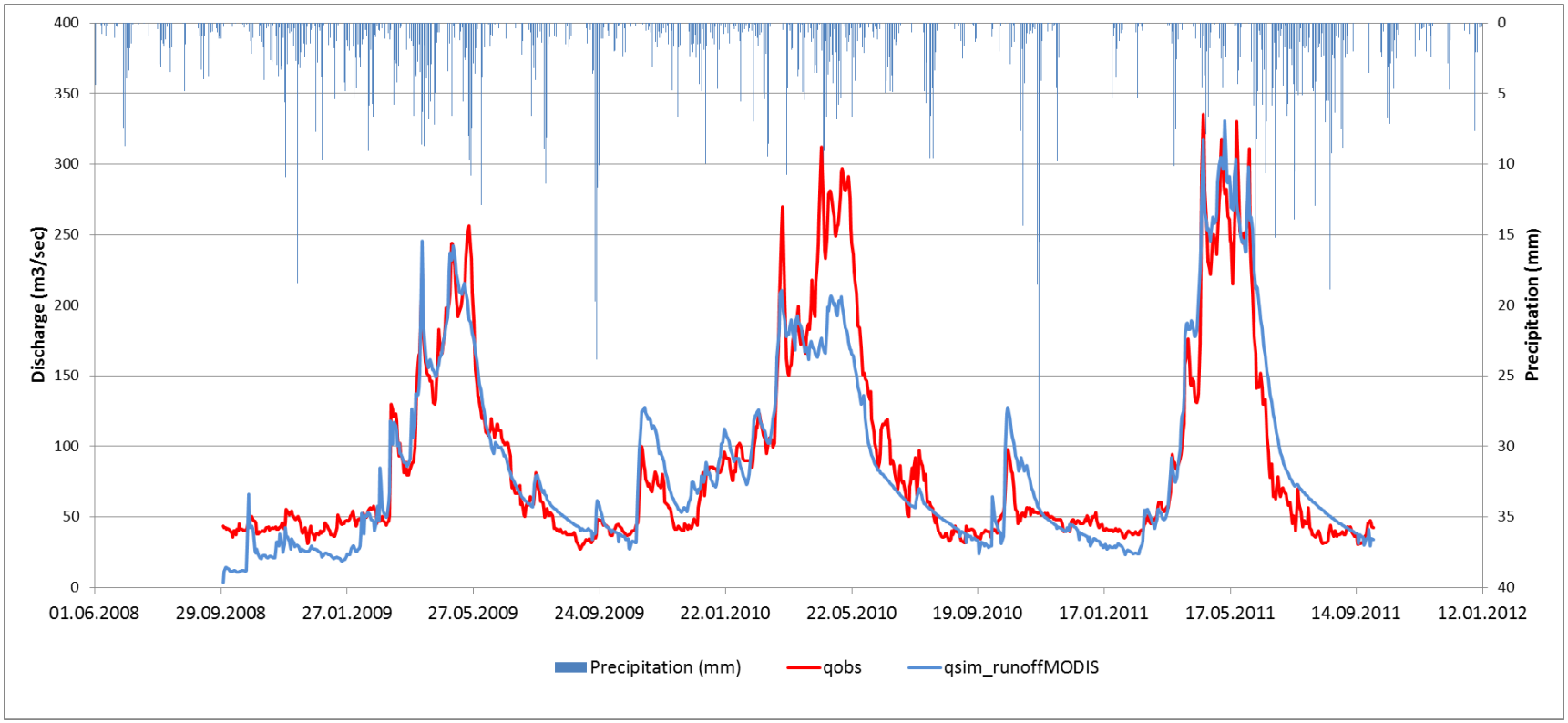


Calibration with runoff only



Calibration with runoff and MSG snow cover

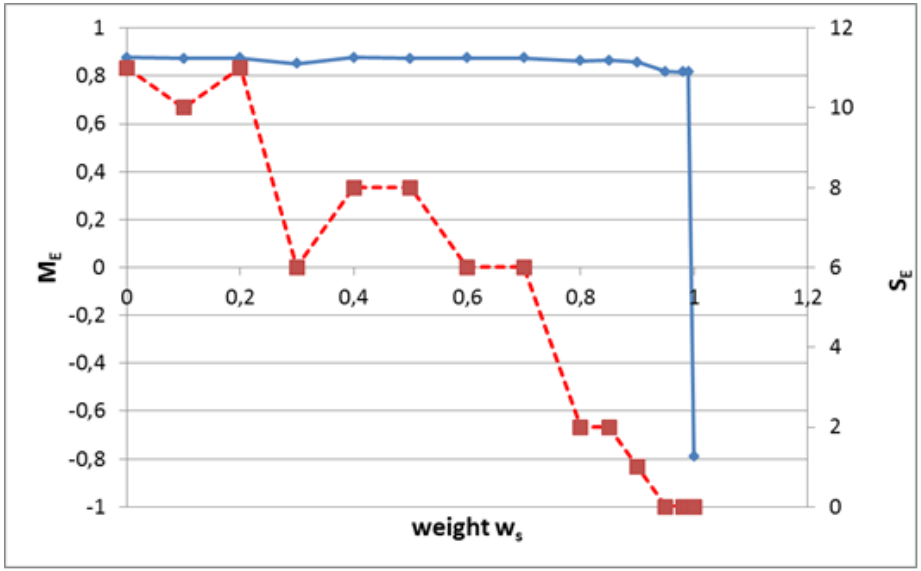
Calibration of the Model



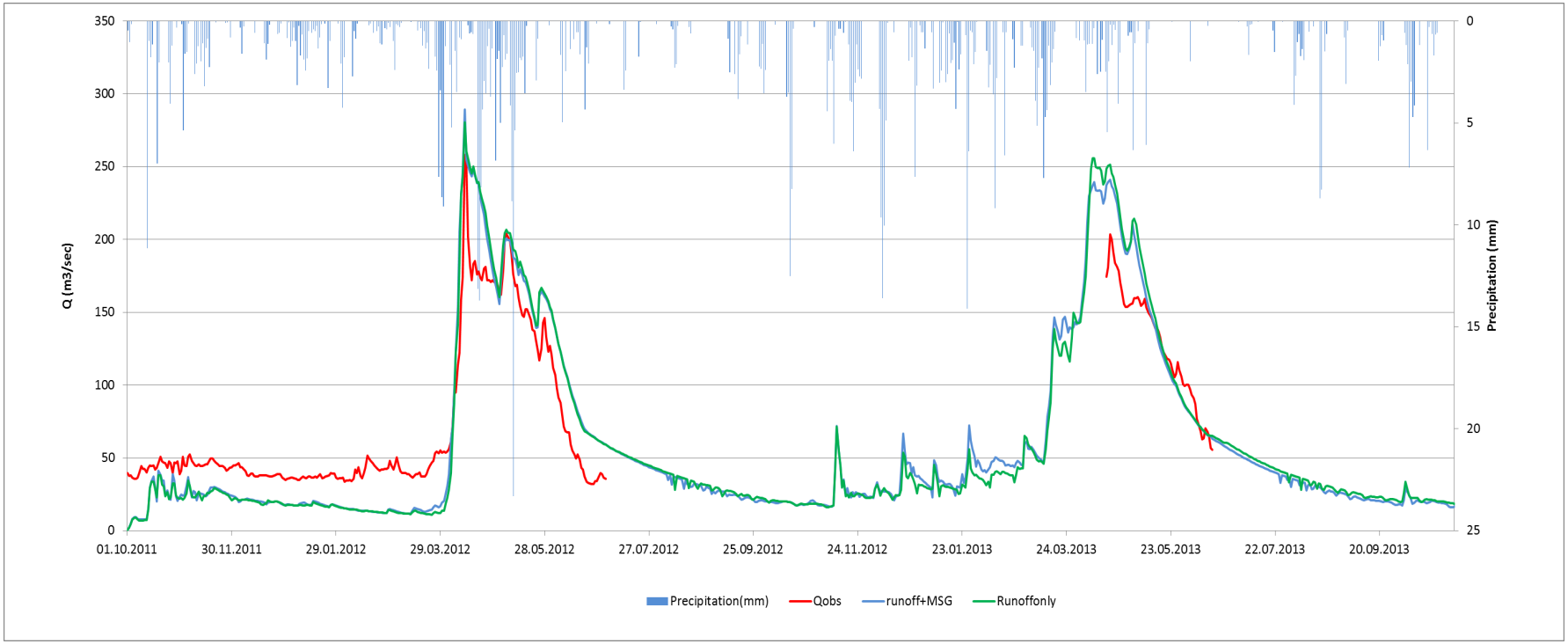
Calibrating with MODIS snow cover product

Verification of the Model

	CALIBRATION (2009-2011)			VERIFICATION (2012)	
Statistical Measures	**R u n o ff only**	**Runoff+ H10**	**Runoff+ MODIS**	**R u n o ff only**	**Runoff+H10**
volume error	-0,0052	-0,0049	-0,0072	-0,028	-0,032
snow overestimation (days)	11	2	0	1	0
snow underestimation	0	0	0	0	0
M_F	0,88	0,86	0,87	0,72	0,74
$logM_F$	0,83	0,83	0,84	-0,36	-0,19
Model Parameters					
CSF	1,3396	1,3315	1,3723		
DDF	4,0979	3,5105	2,1971		
Train	2	2	2		
Tsnow	-2	-2	-2		
Tmelt	1,9646	1,0582	0,5309		
LP/FC	0,0073	0,0116	0,0072		
FC	203,4657	215,1299	216,5497		
BETA	0,2754	0,2822	0,2957		
K0	0,88	1,3181	0,9828		
K1	29,4776	29,7388	29,7161		
K2	91,3269	83,9929	87,085		
LSUZ	91,2893	86,7095	74,1491		
CPERC	0,9357	0,8802	0,8427		
BMAX	10	10	10		
CROUTE	26,5	26,5	26,5		

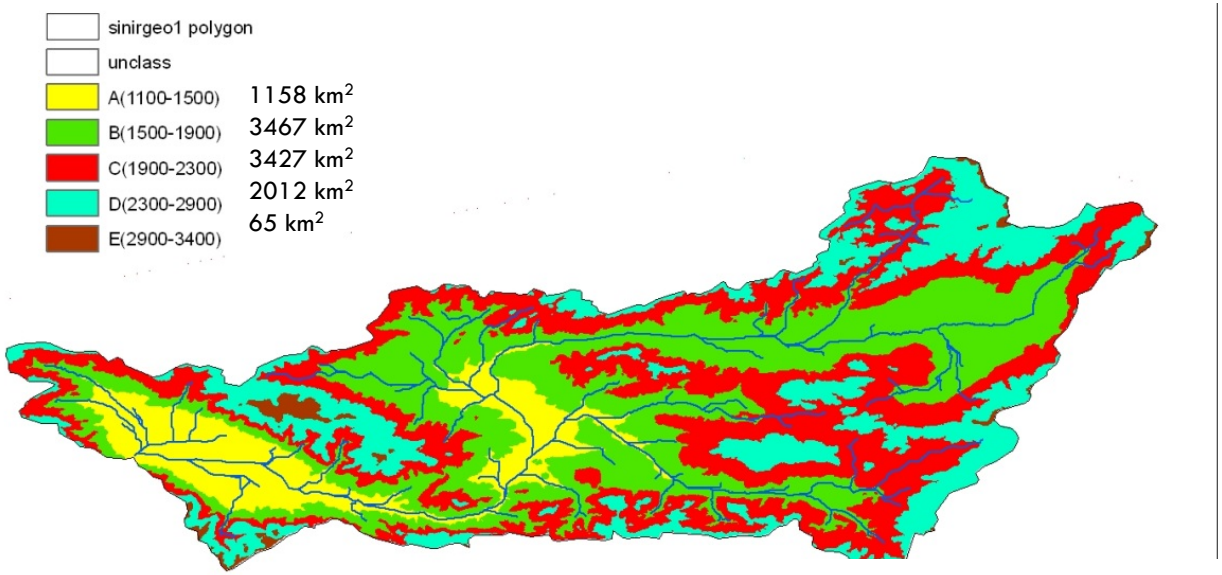


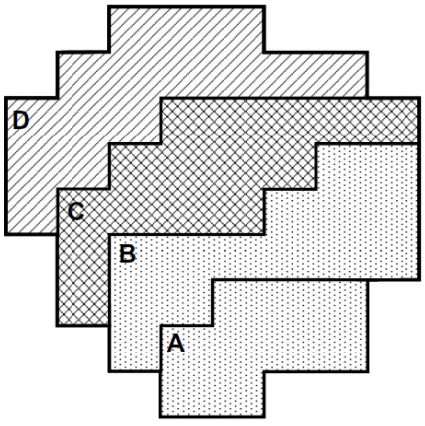
Results

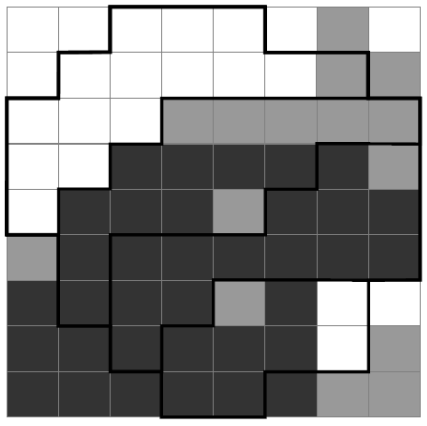


	runoffonly	runoff+msg
volume error	-0.028	-0.032
snow overestimation (days)	1	0
snow underestimation	0	0
ME	-0.72	0.74
logME	-0.36	-0.19

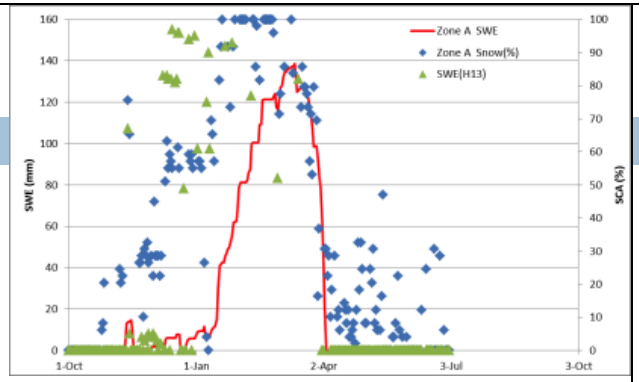
Results

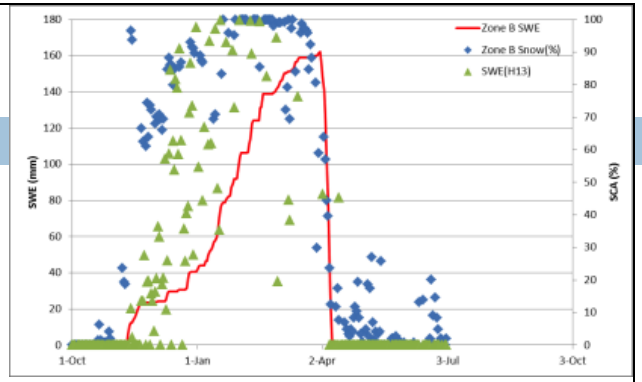

sinirgeo1 polygon
unclass
A(1100-1500)
B(1500-1900)
C(1900-2300)
D(2300-2900)
E(2900-3400)
1158 km2
3467 km2
3427 km2
2012 km2
65 km2

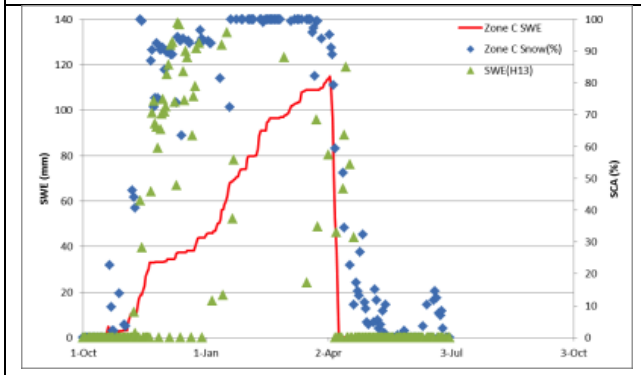

D
C
B
A
[mm]
0
50
100

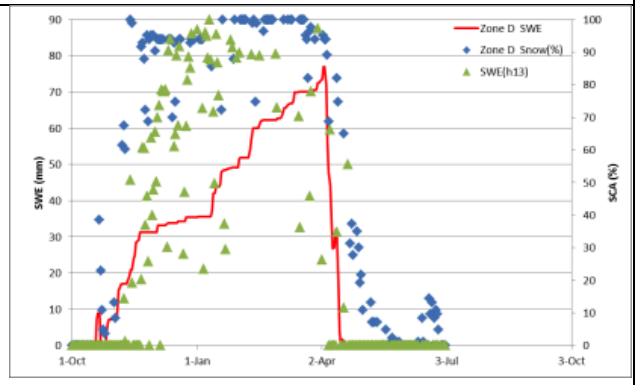

Snow
Land
Clouds

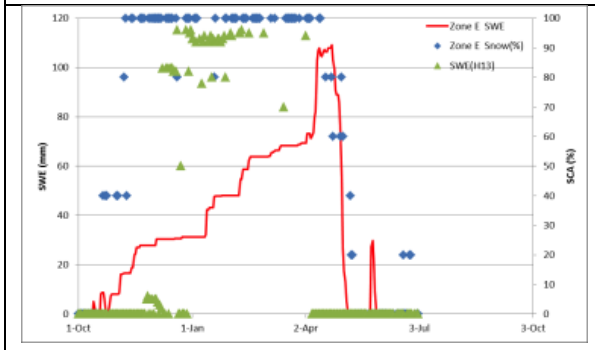
Results





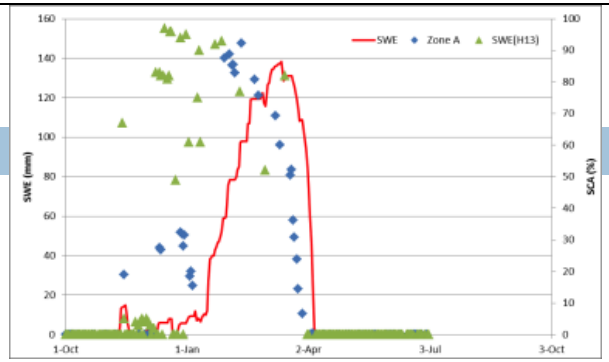


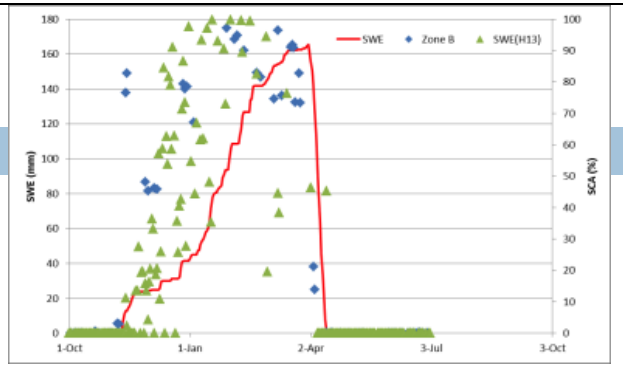


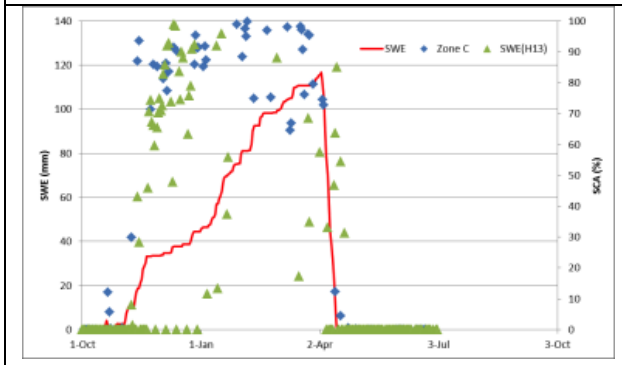


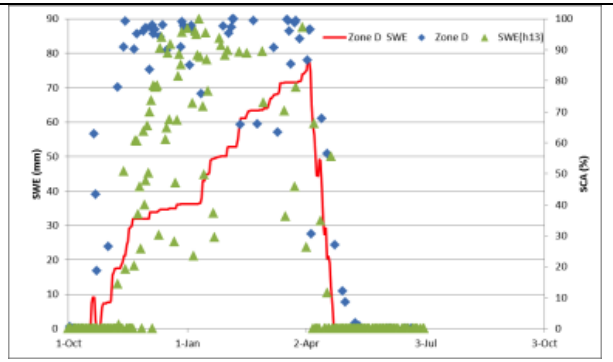
Model simulated SWE, SCA obtained from H10 and H13 SWE data for each zone.

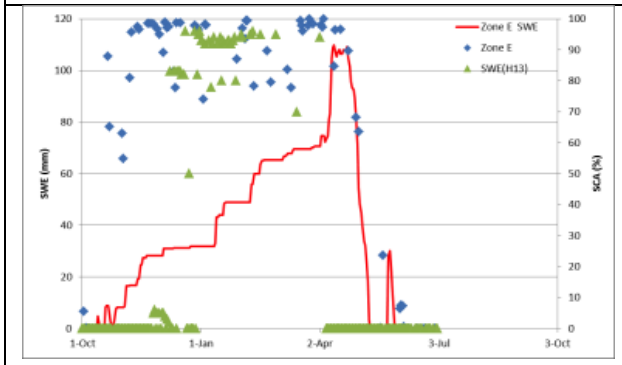
Results











Model simulated SWE, SCA obtained from MODIS snow product and H13 SWE data for each zone.

Results

Q max(m3/sec)				Model		H13	
Observed	Date	Model	Date	Date	SWE_{max} (mm)	SWE_{max} (mm)	Date
265	23.05.2009	216	17.05.2009	29.03.2009	113	128	25.03.2009
312	23.04.2010	198	12.05.2009	5.03.2010	47	115	19.03.2010
318	9.05.2011	315	8.05.2011	14.03.2011	93	152	15.03.2011
258	12.04.2012	261	12.04.2012	20.03.2012	118	181	20.03.2012
		241	18.04.2013	8.03.2013	128	179	8.03.2013

Table IV. Maximum SWE and Julian days of $SCA_{50\%}$, $R_{50\%}$, and SWE_{max}

	2004	2005	2006	2007	2008	2009	Mean	Standard deviation
Day of year of $SCA_{50\%}$	101	102	92	122	81	102	100	13
Day of year of $R_{50\%}$	121	122	122	130	105	130	122	9
SWE_{max} (mm)	197·5	185·34	171·78	191·0	174·14	185·03	184·13	9·8
Day of year SWE_{max}	73	73	71	71	53	76	70	8

73:14 March

Akyurek et al., 2011 «Investigation of the snow-cover dynamics in the Upper Euphrates Basin of Turkey using remotely sensed snow-cover products and hydrometeorological Data» HYDROLOGICAL PROCESSES
Hydrol. Process. 25, 3637–3648

Discussion of the results

- The early findings of MSG-SEVIRI snow product show good agreement with in situ data and with MODIS snow products.
- Its coarse spatial resolution may lead limitations in using this product for large scale studies.
- For flat areas underestimation error is high for MSG-SEVIRI snow product compared to other snow products. The most problematic areas were found out as forests, where forests block the snow surface from being visible and the shadows of the trees decrease the reflectance observed above the forest canopy.
- Overestimation error is high for mountainous areas. Because of large spatial resolution of MSG-SEVIRI snow product, misclassification problem of MSG-SEVIRI snow product is worse compared to MODIS snow products.

Discussion of the results

- The cloud clearance capability of MSG-SEVIRI snow product would make the product usable in hydrological modeling, especially for the areas where high cloud coverage may be seen during snow season.
- Calibration against SCA in addition to runoff improved the simulated runoff considerably.
- The snow model efficiency is improved. Important for representing the internal variables correctly especially for climate warming scenarios.
- H13 maximum SWE estimates are comparatively larger than model maximum SWE simulations. But their timing matches properly.
- Increased spatial and temporal resolution of satellite sensors and more accurate ground data the added value in hydrological simulation would increase.

ASSIMILATION OF EUMETSAT SNOW COVERED AREA DATA INTO CONCEPTUAL HYDROLOGIC MODEL

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