Ensemble Stream Flow Forecasts through the Data Assimilation of H-SAF Snow Products

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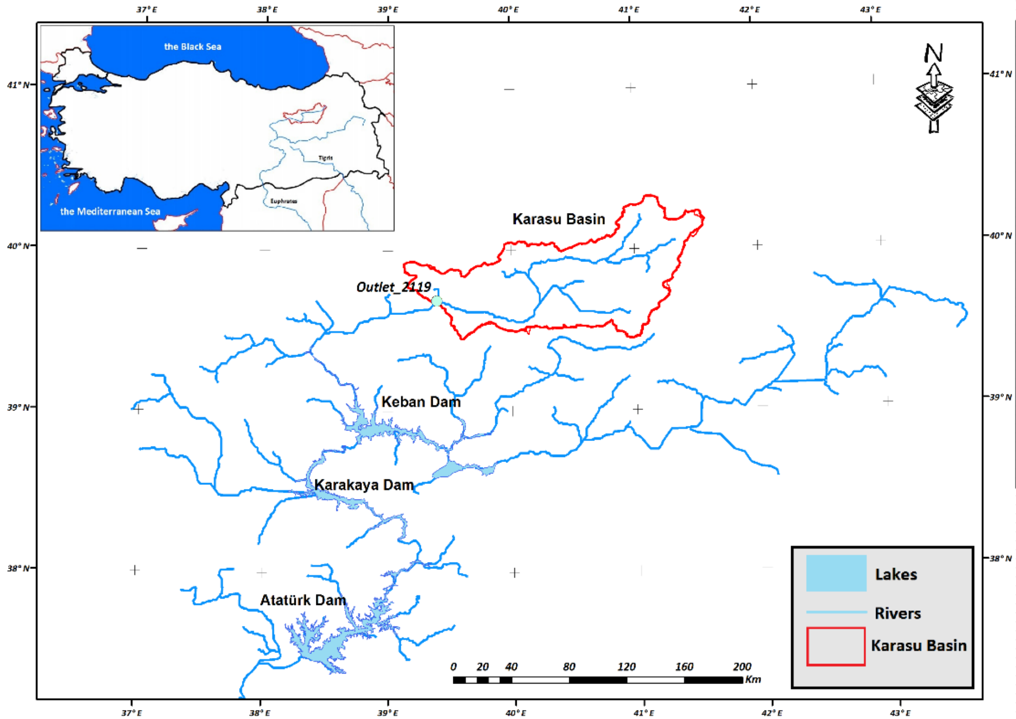
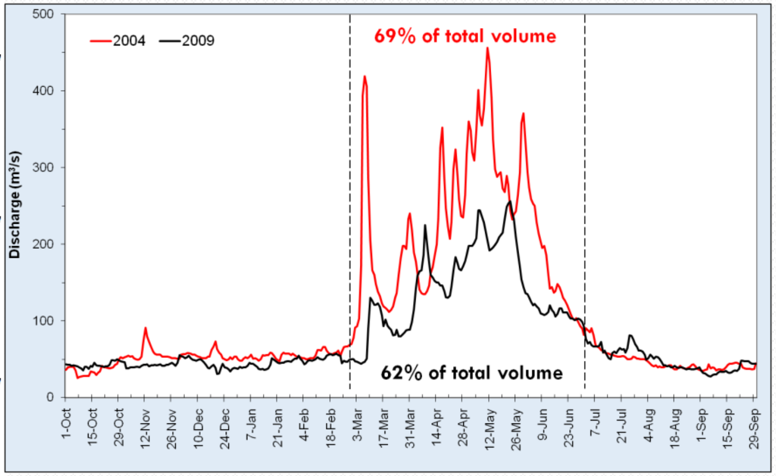
Motivation

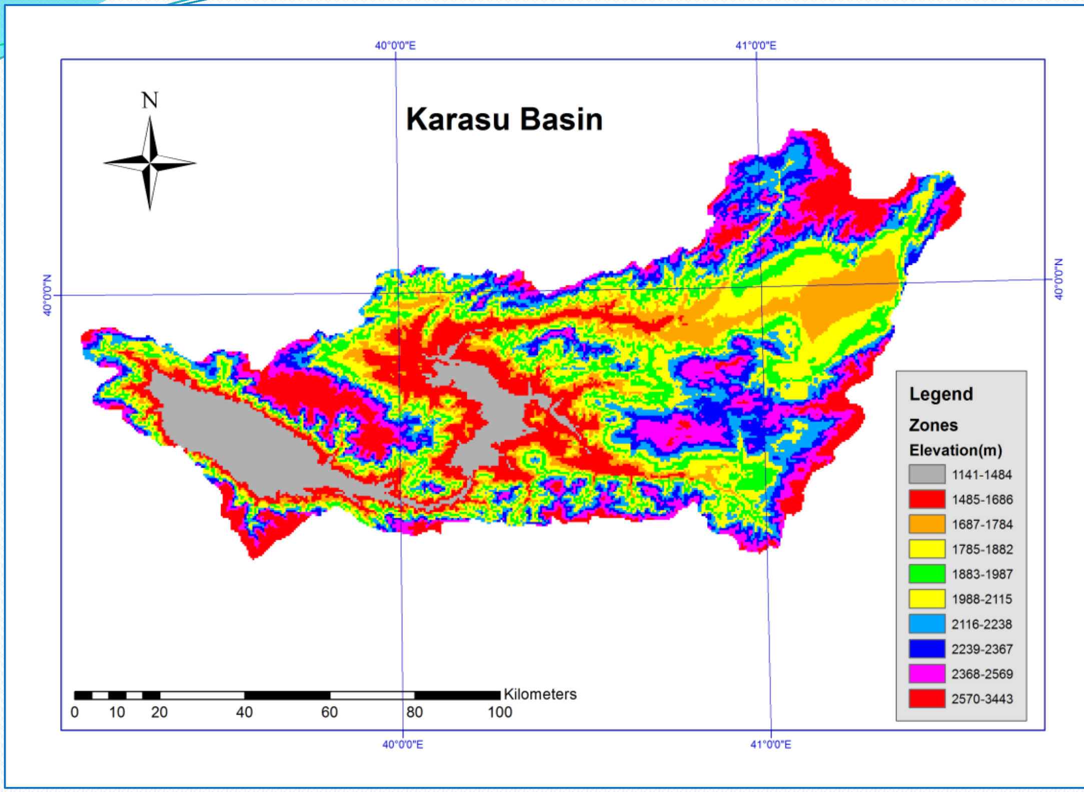
- Contribution to the exploitation of H-SAF products in operational hydrology.
- Application of the implemented framework for hydro-validating HSAF snow product data regarding the improvement of the lead-time accuracy of forecasts

Importance of snow for the Upper Euphrates Basin





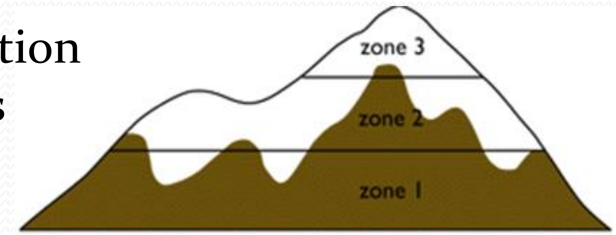
60–70% of the total runoff volume originates during snowmelt period….



➢The Upper Euphrates Basin (Karasu)

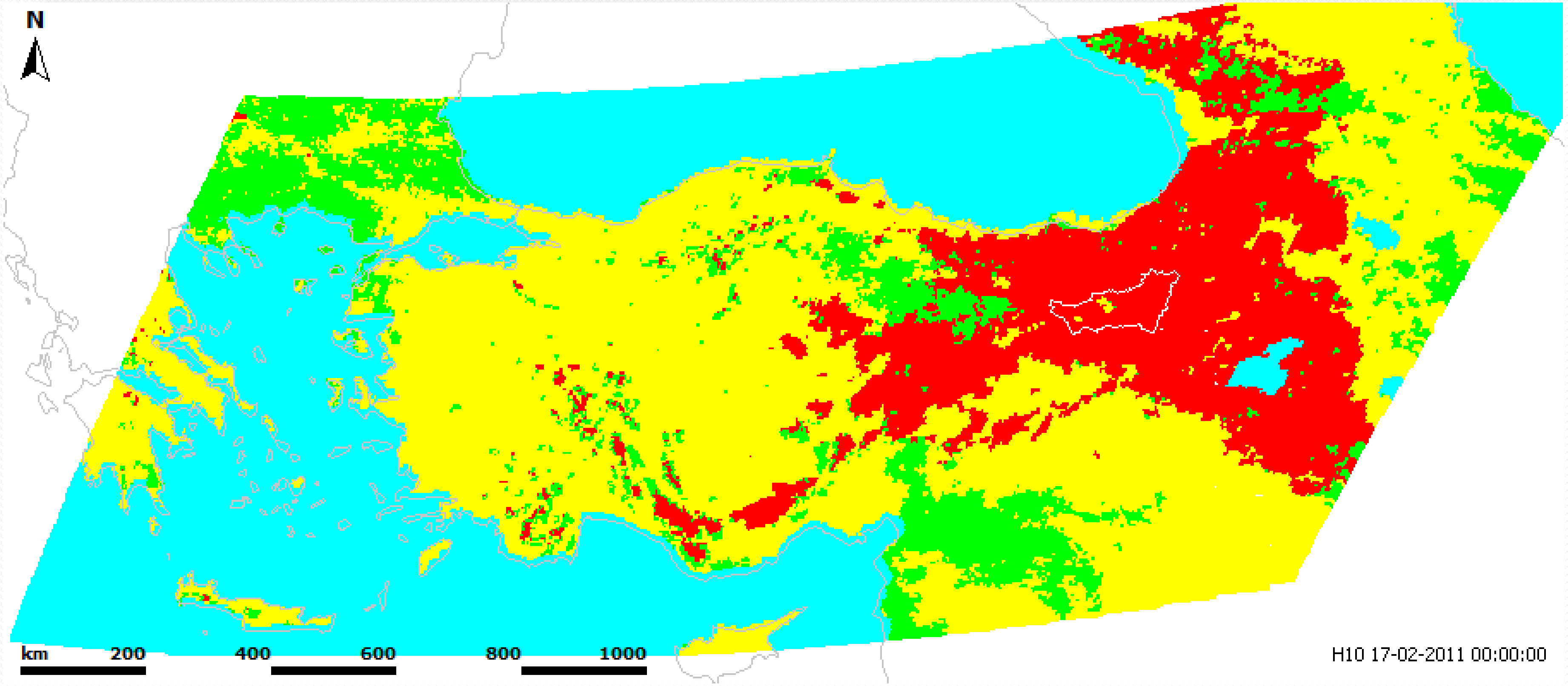
➢The main land-cover types are pasture, cultivated land and bareland.

Elevation zones



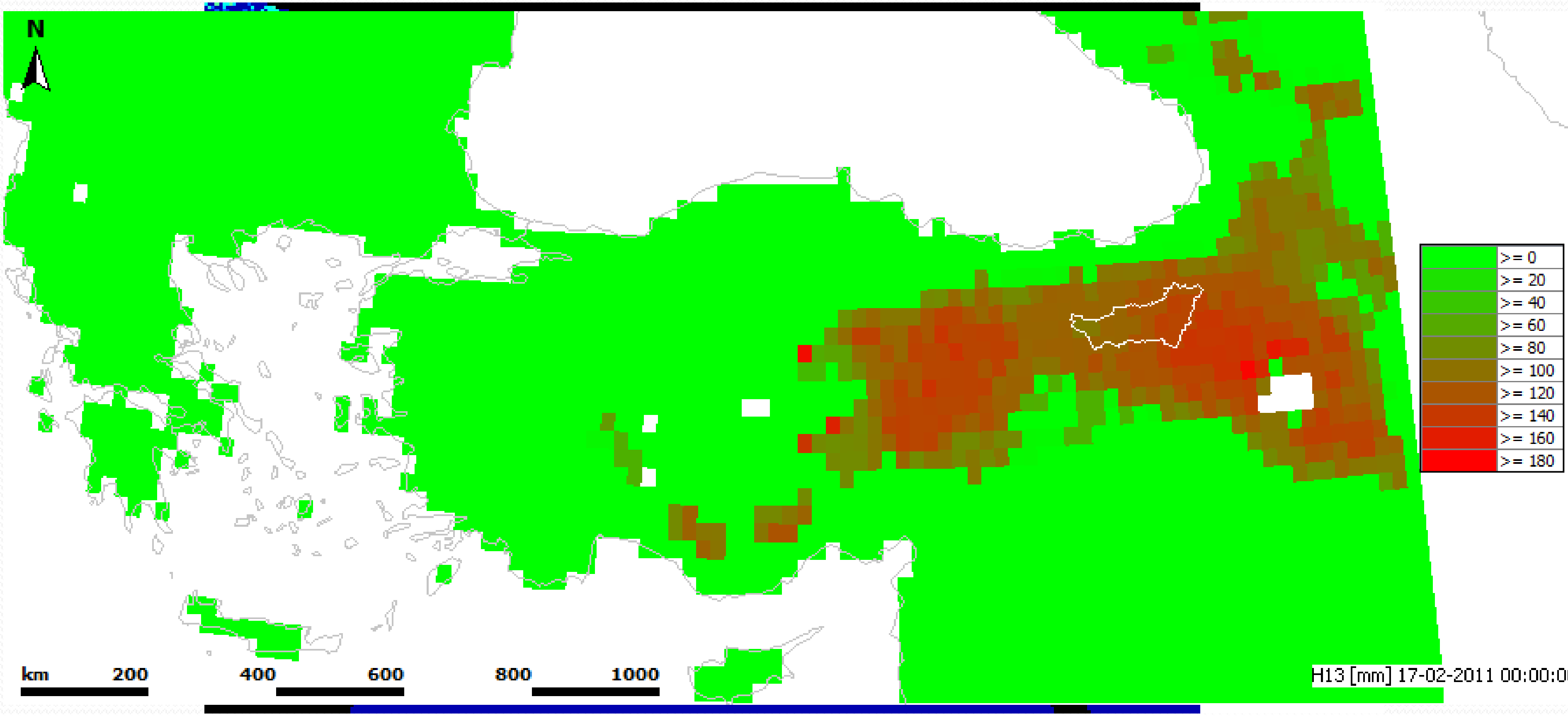
	Elevation range (m)	Area (km²)	Hypsometric Mean Elevation (m)	Slope (%)
Karasu	1125-3487	10275	1983	19.24

Snow Recognitation Product, H10



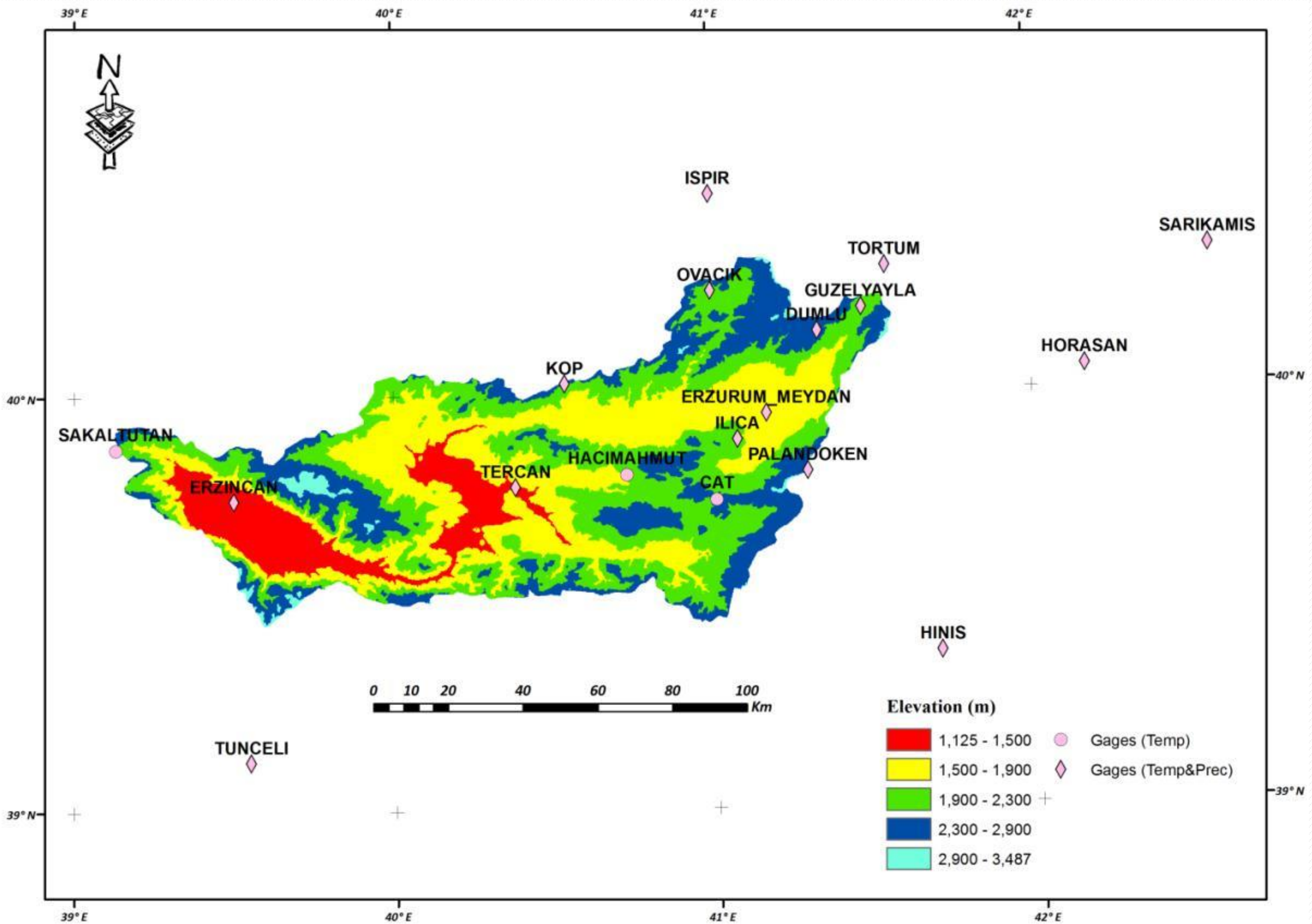
- **Coverage**: 25-75°N lat, 25°W-45°E long
- **Cycle**: Daily
- **Resolution**: 1 to 5 km
- **Accuracy**: POD 95 %, FAR 10 %

Snow Water Equivalent, H13

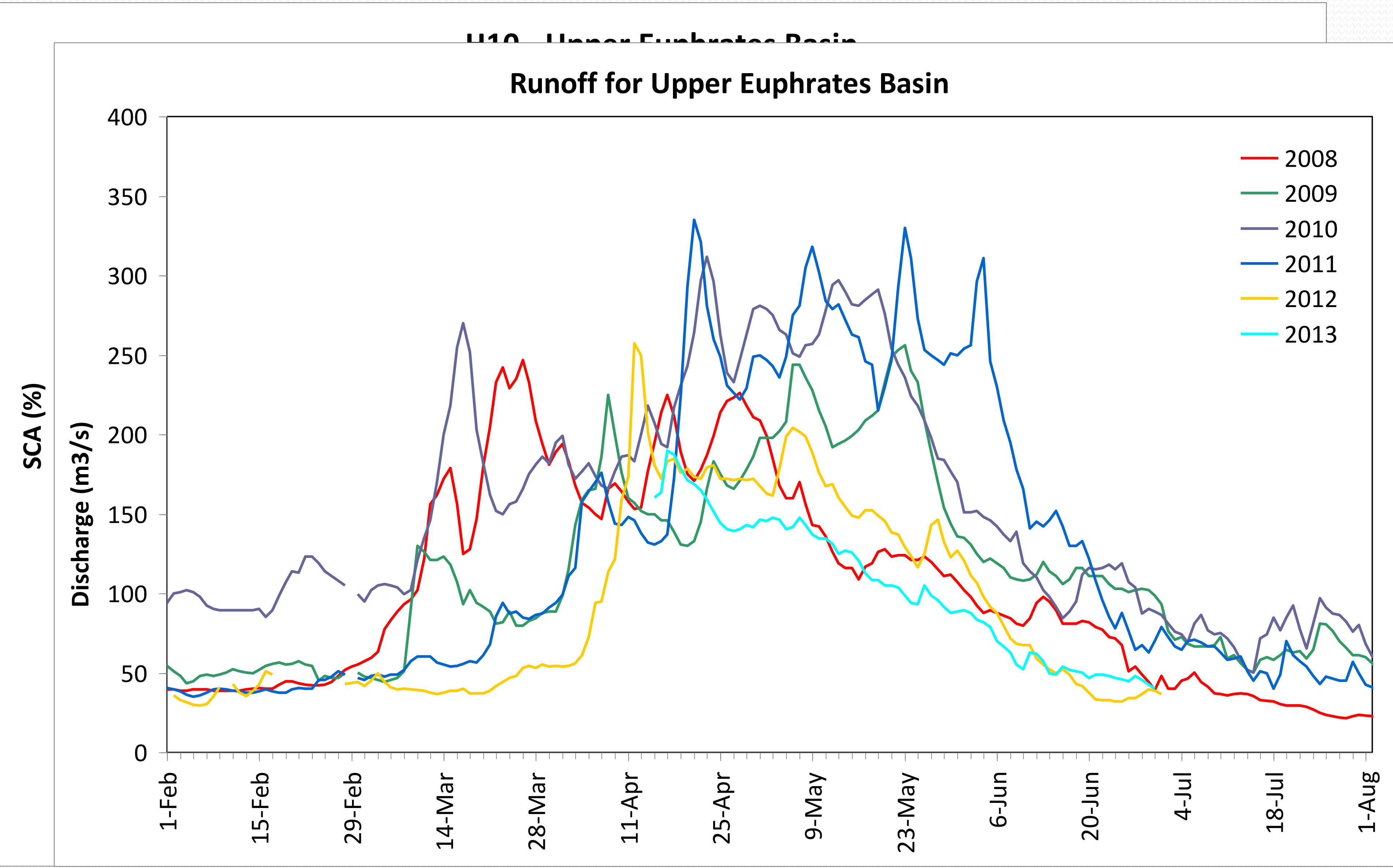


- **Coverage**: 25-75°N lat, 25°W-45°E long
- **Cycle**: Daily/weekly
- **Resolution**: 10-30 km (0.25 degrees)

Monitoring

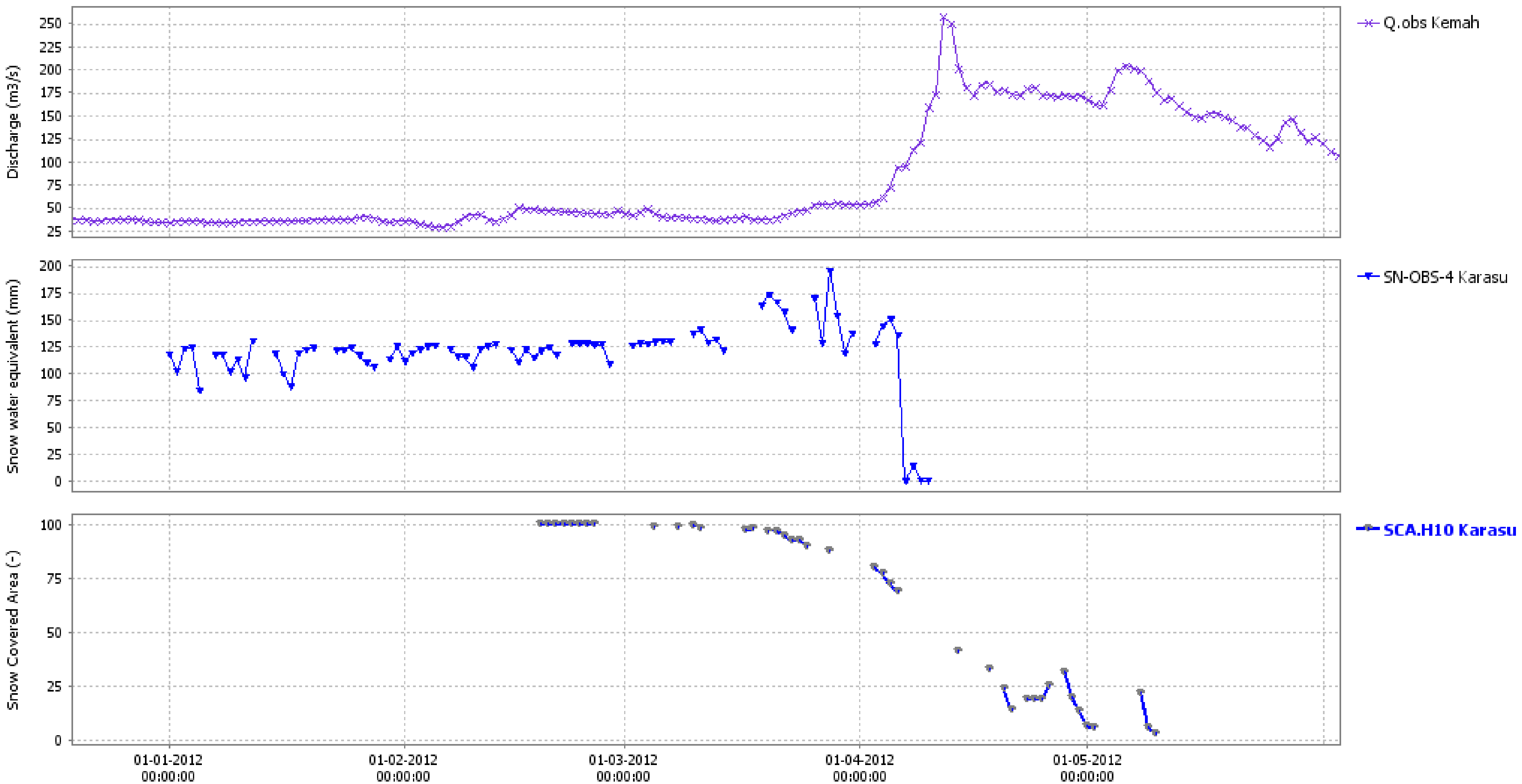

39° E
40° E
41° E
42° E
40° N
39° N
N
ISPIR
SARIKAMIS
TORTUM
OVACIK
GUZELYAYLA
DUMLU
HORASAN
KOP
ERZURUM_MEYDAN
ILICA
SAKALTUTAN
PALANDOKEN
HACIMAHMUT
TERCAN
CAT
ERZINCAN
HINIS
TUNCELI
0 10 20 40 60 80 100 Km
Elevation (m)
1,125 - 1,500
1,500 - 1,900
1,900 - 2,300
2,300 - 2,900
2,900 - 3,487
Gages (Temp)
Gages (Temp&Prec)

Monitoring



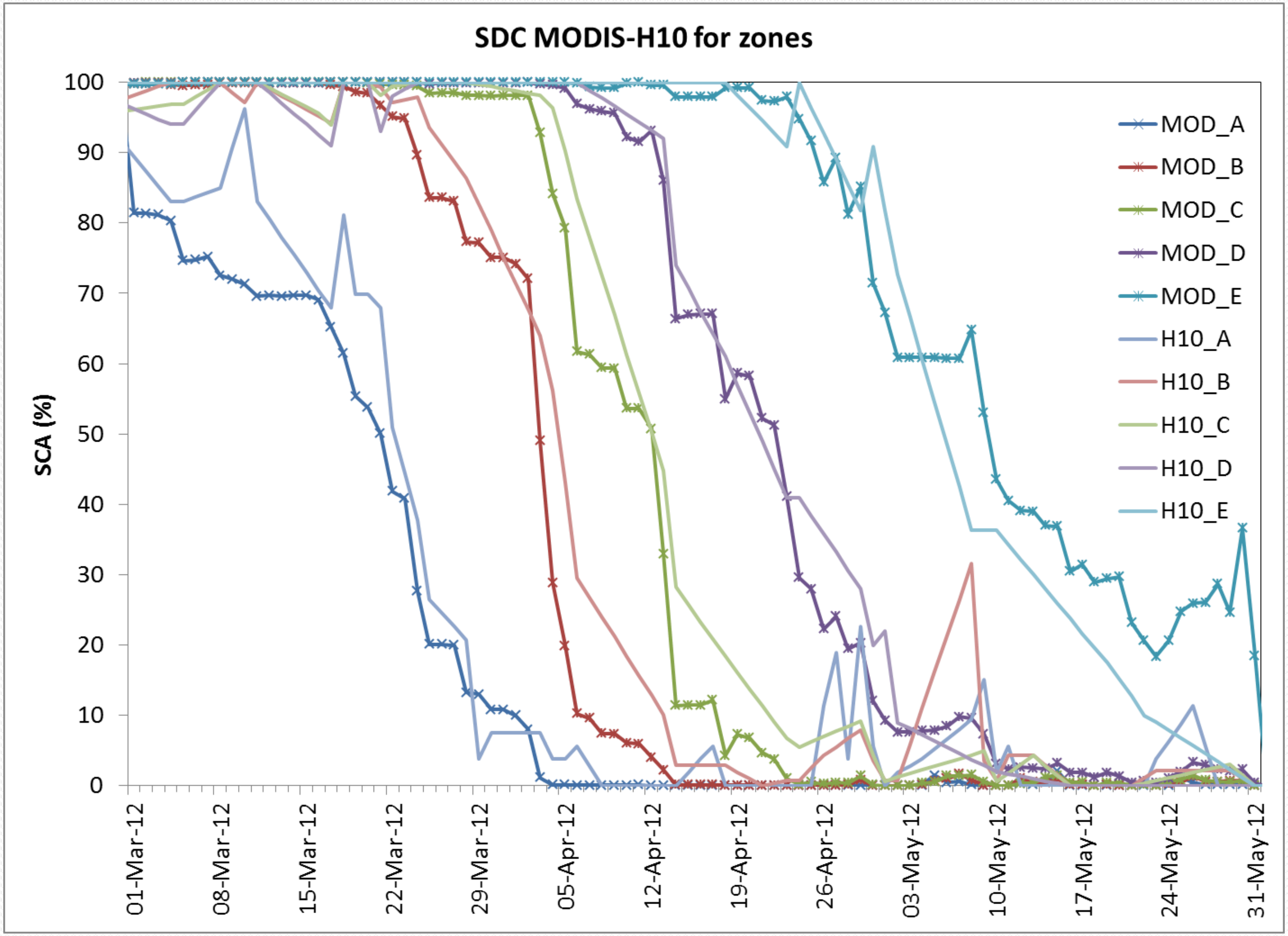
Runoff for Upper Euphrates Basin
SCA (%)
Discharge (m3/s)
0
50
100
150
200
250
300
350
400
1-Feb
15-Feb
29-Feb
14-Mar
28-Mar
11-Apr
25-Apr
9-May
23-May
6-Jun
20-Jun
4-Jul
18-Jul
1-Aug
2008
2009
2010
2011
2012
2013

Monitoring



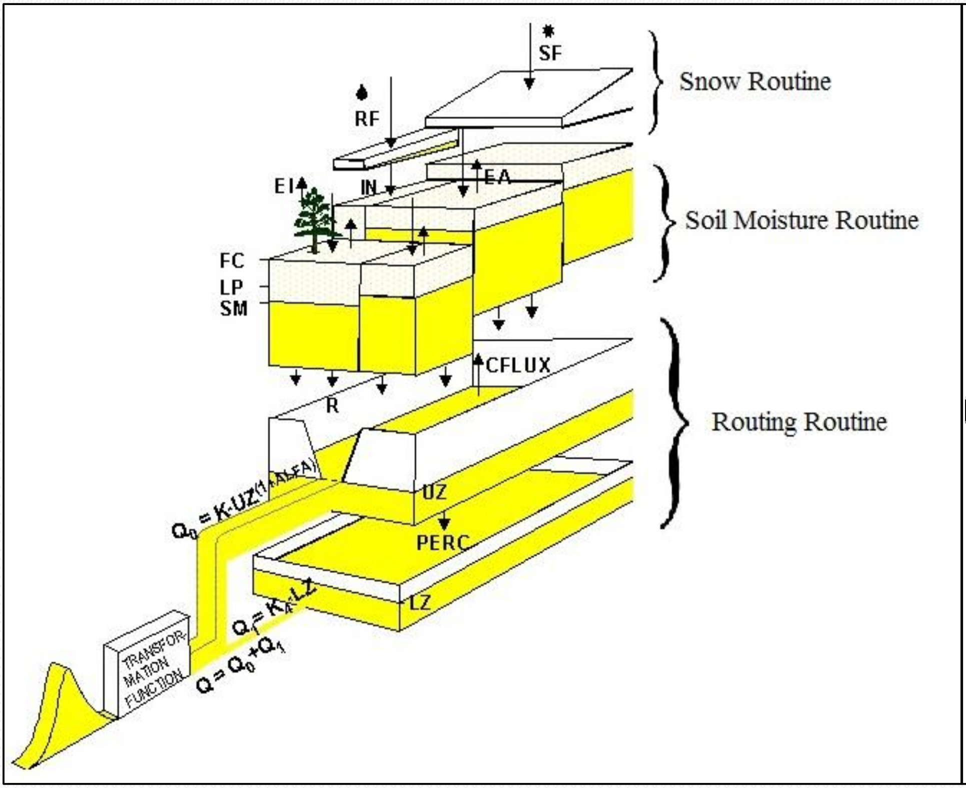
Discharge (m3/s)
250
225
200
175
150
125
100
75
50
25
Q.obs Kemah
Snow water equivalent (mm)
200
175
150
125
100
75
50
25
0
SN-OBS-4 Karasu
Snow Covered Area (-)
100
75
50
25
0
SCA.H10 Karasu
01-01-2012 00:00:00
01-02-2012 00:00:00
01-03-2012 00:00:00
01-04-2012 00:00:00
01-05-2012 00:00:00

Comparisons



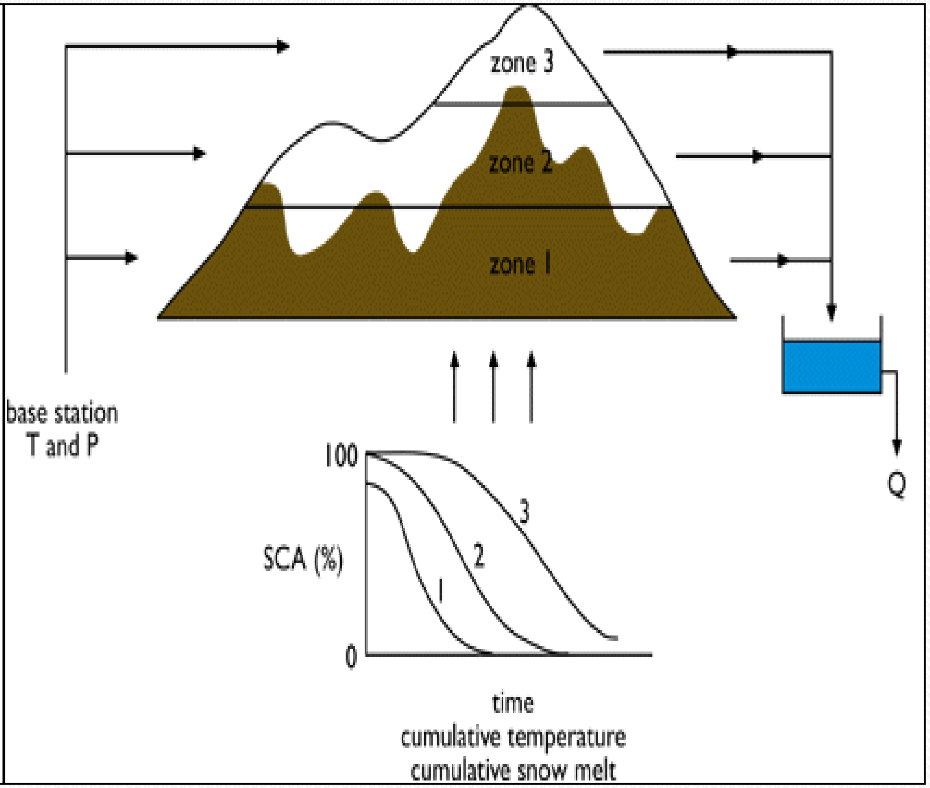
Hydrological Models (HBV and SRM)

HBV
(Hydrologiska Byråns Vattenbalans)



(Lindström et al., 1997)

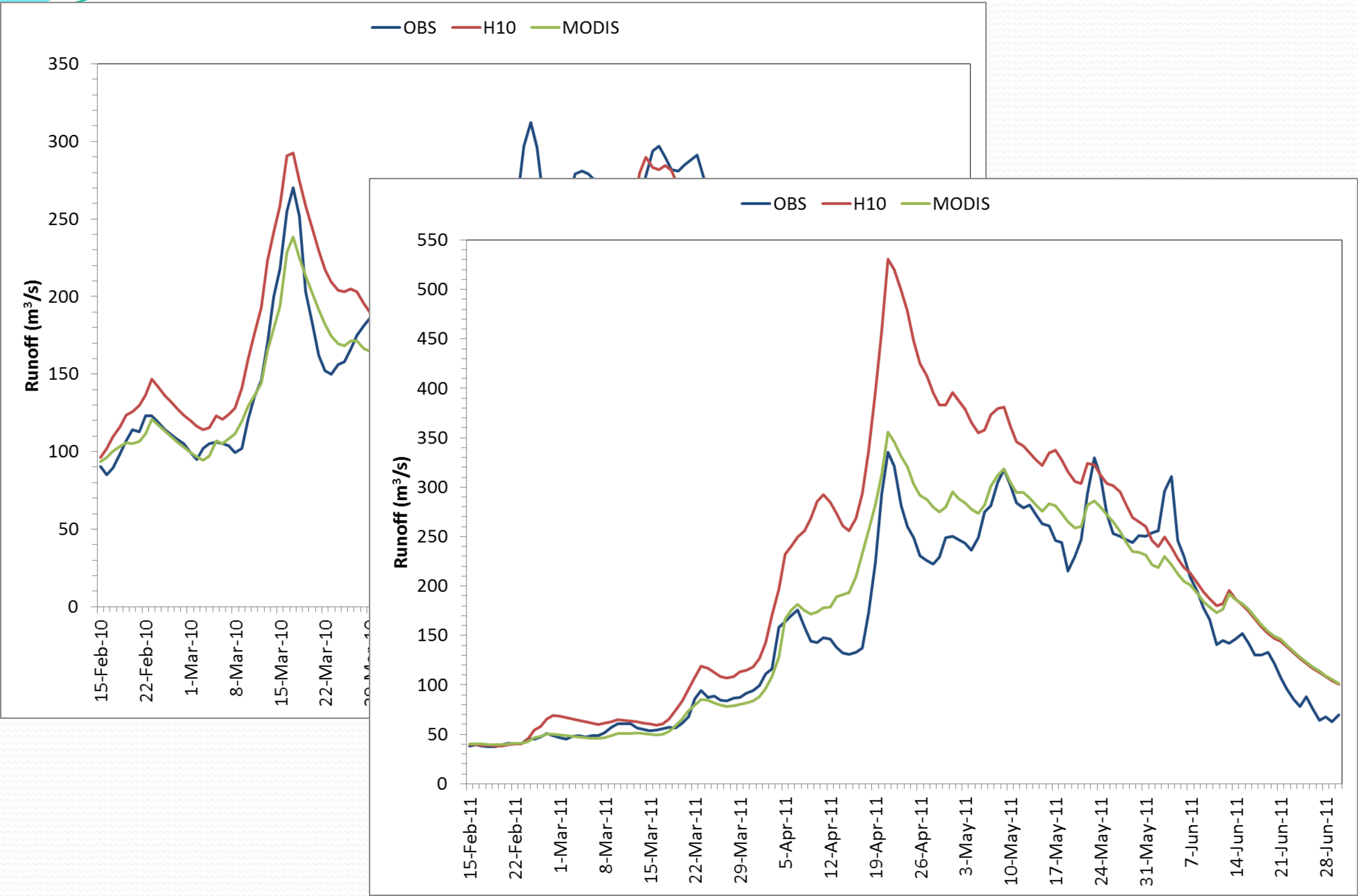
SRM
(Snowmelt-Runoff Model)



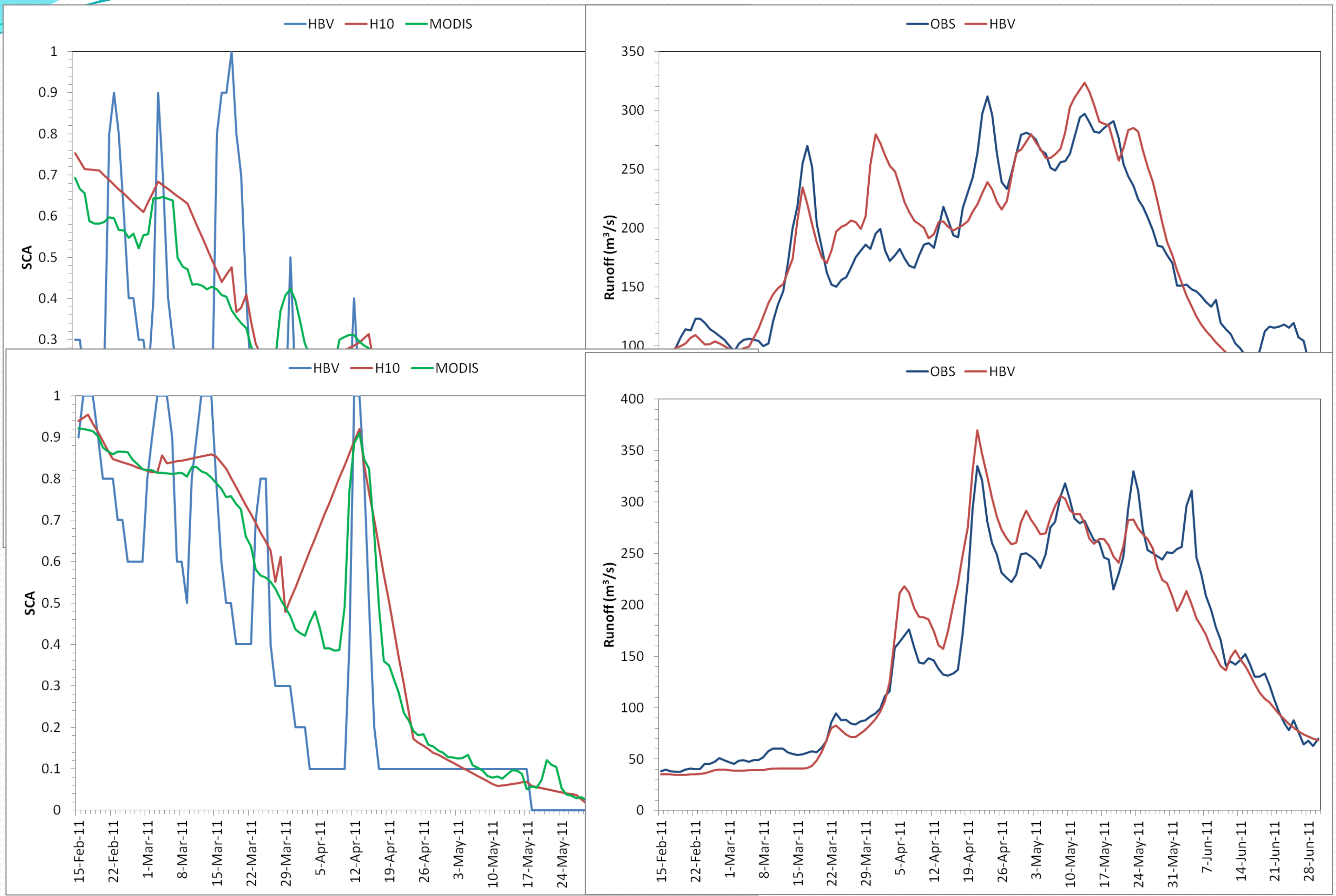
(Martinec et. al 2008)

$$Q_{n+1} = [c_{Sn} * a_n (T_n + \Delta T_n) S_n + c_{Rn} P_n] * (A \cdot 10000 / 86400) * (1-k_{n+1}) + Q_n k_{n+1}$$

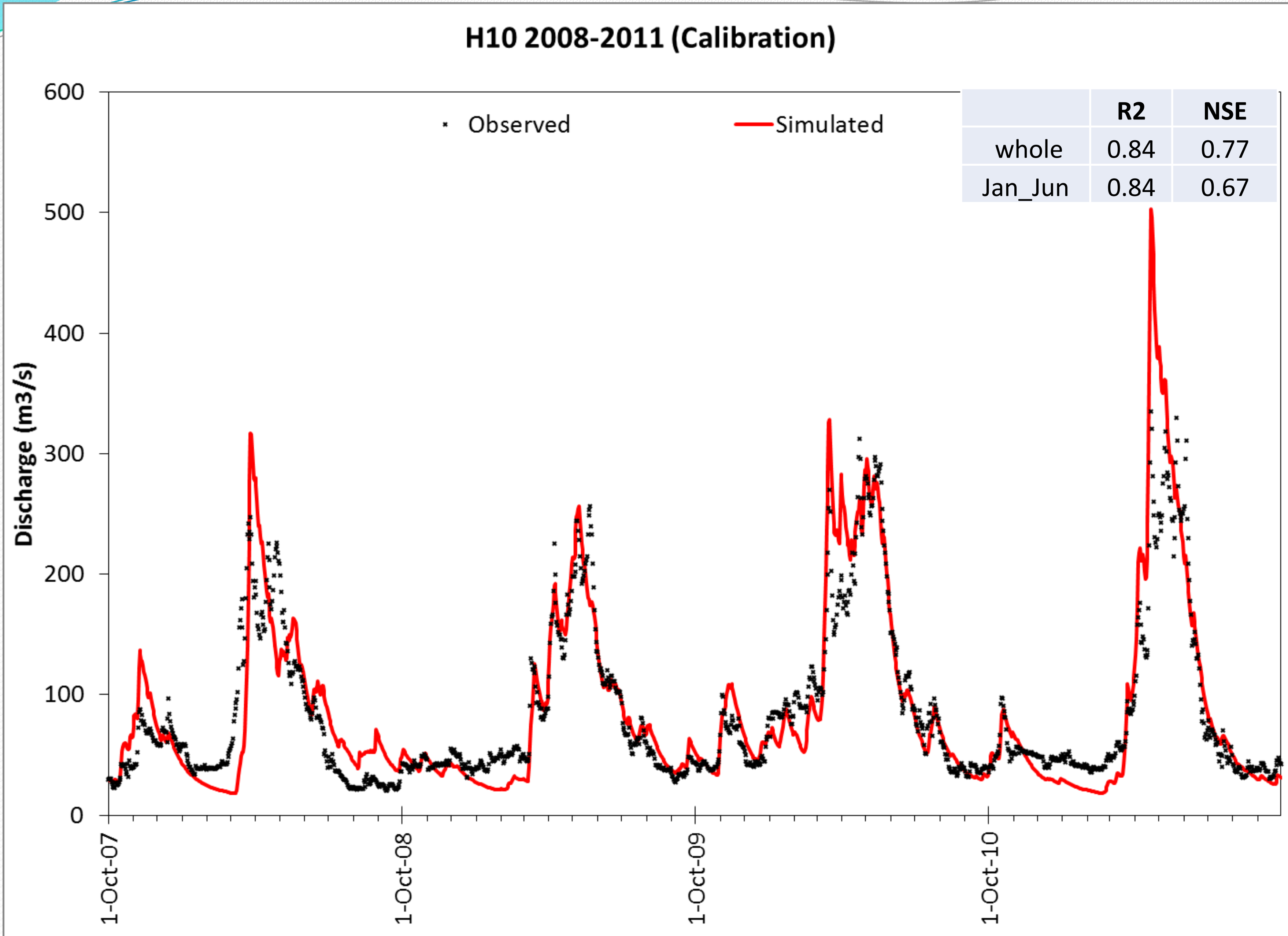
Hydro-Validation Studies



Hydro-Validation Studies



SRM Model - H10 (Calibration)



Moving Horizon Estimation (MHE)

- Hydrological Model (e.g. HBV)

$$x^k = f(x^{k-1}, d^k, u^k)$$

$$y^k = g(x^k, d^k, v^k)$$

- Moving Horizon Estimation (MHE)

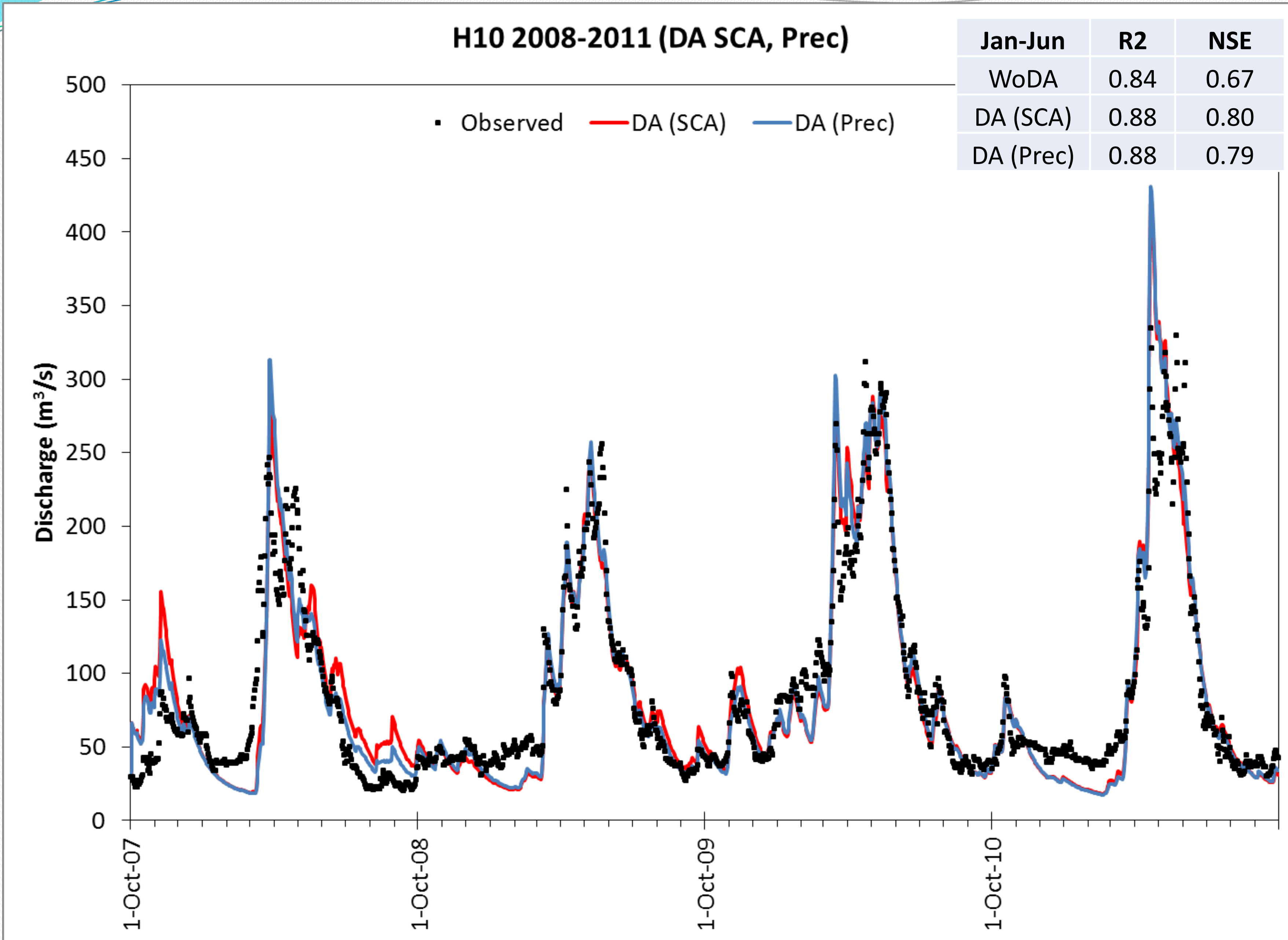
$$\min_{u,v} \sum_{k=-N+1}^{0} w_x \left\| \hat{x}^k - x^k(u) \right\| + w_y \left\| \hat{y}^k - y^k(u,v) \right\| + w_u \left\| u^k \right\| + w_v \left\| v^k \right\|$$

$$\text{subject to} \quad u_L \le u^k \le u_U$$

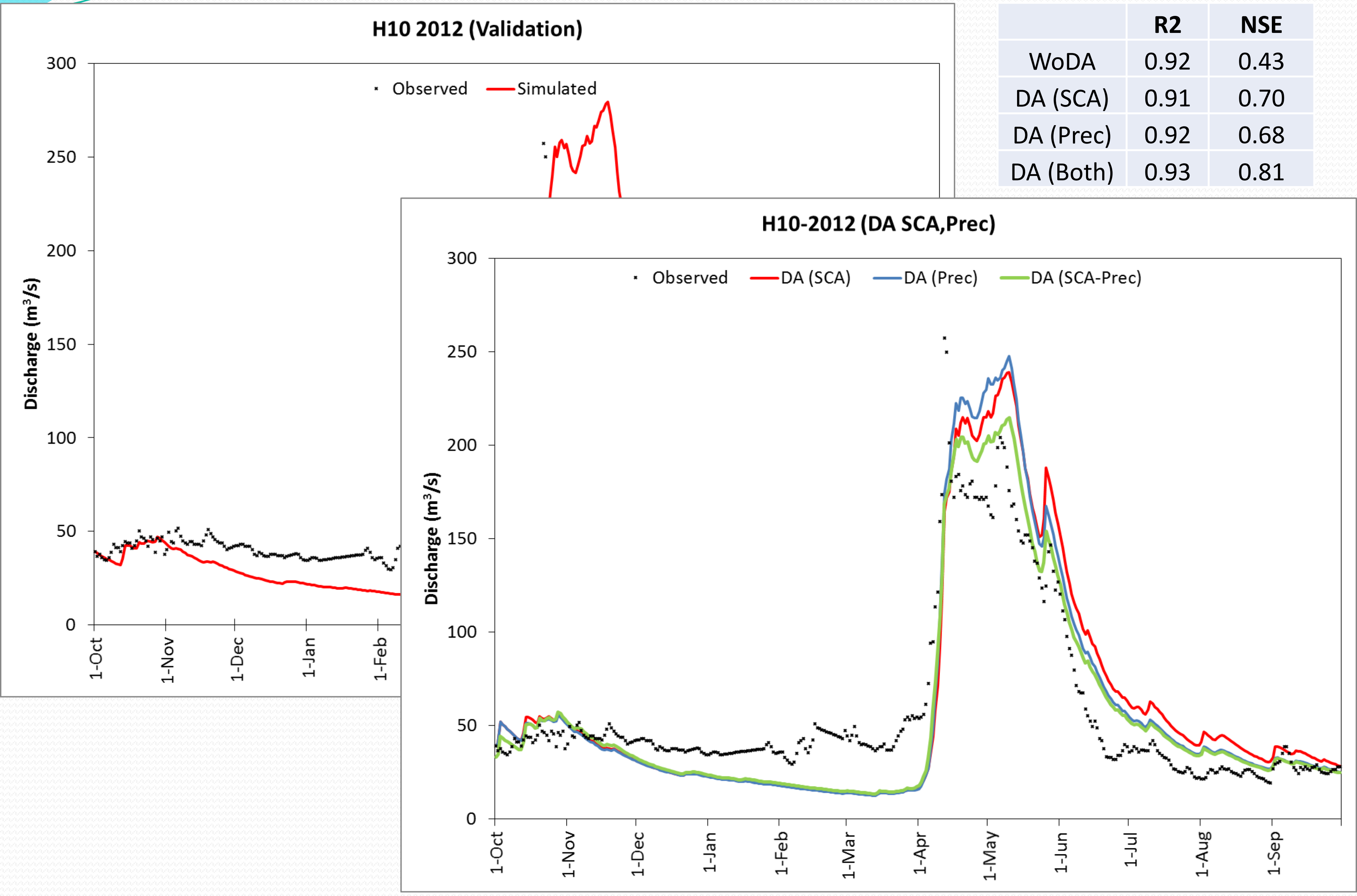
$$v_L \le v^k \le v_U$$

SRM Model - H10 (Calibration-DA)

Jan-Jun	R2	NSE
WoDA	0.84	0.67
DA (SCA)	0.88	0.80
DA (Prec)	0.88	0.79



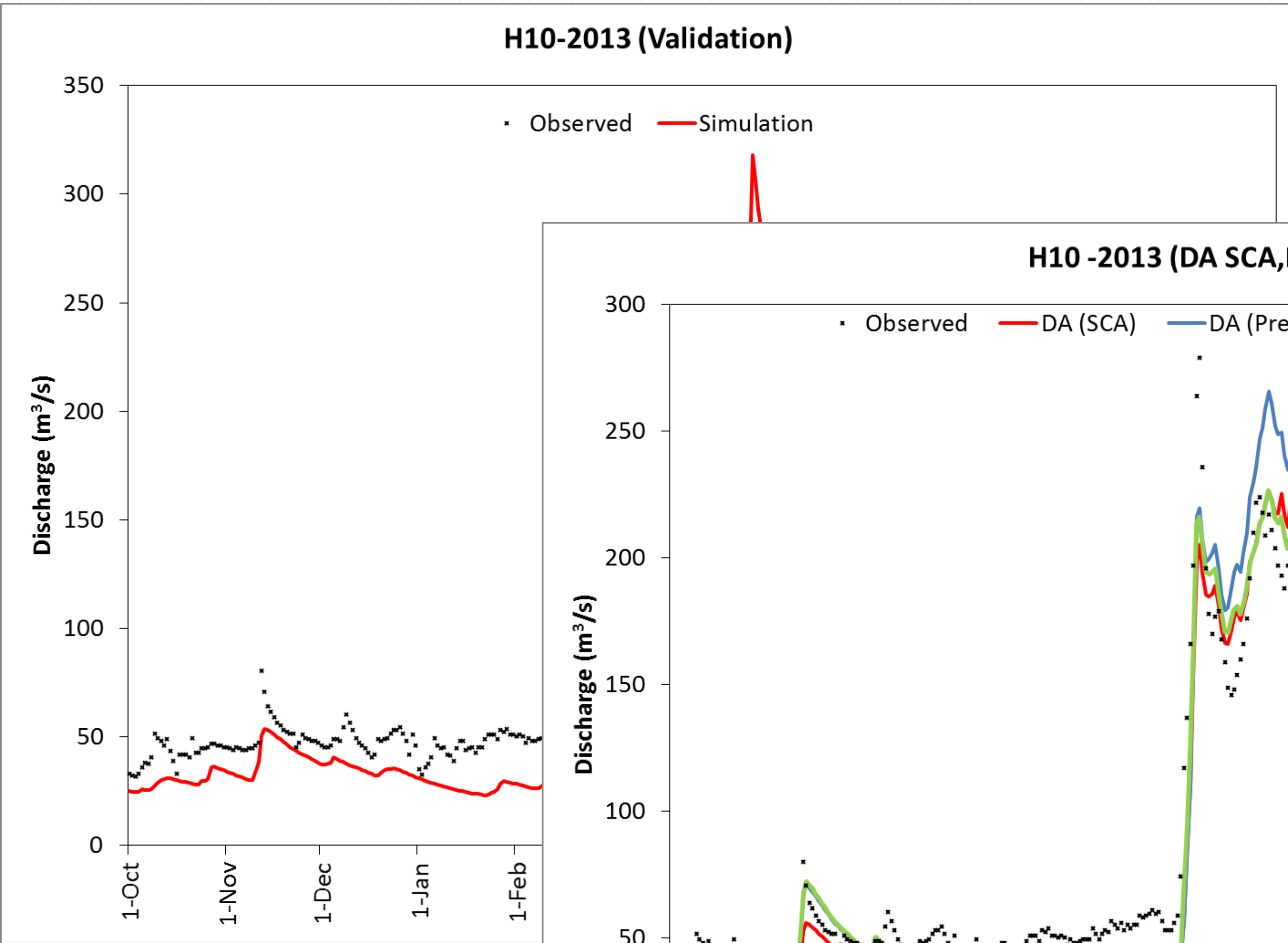
SRM Model - H10 (Validation)

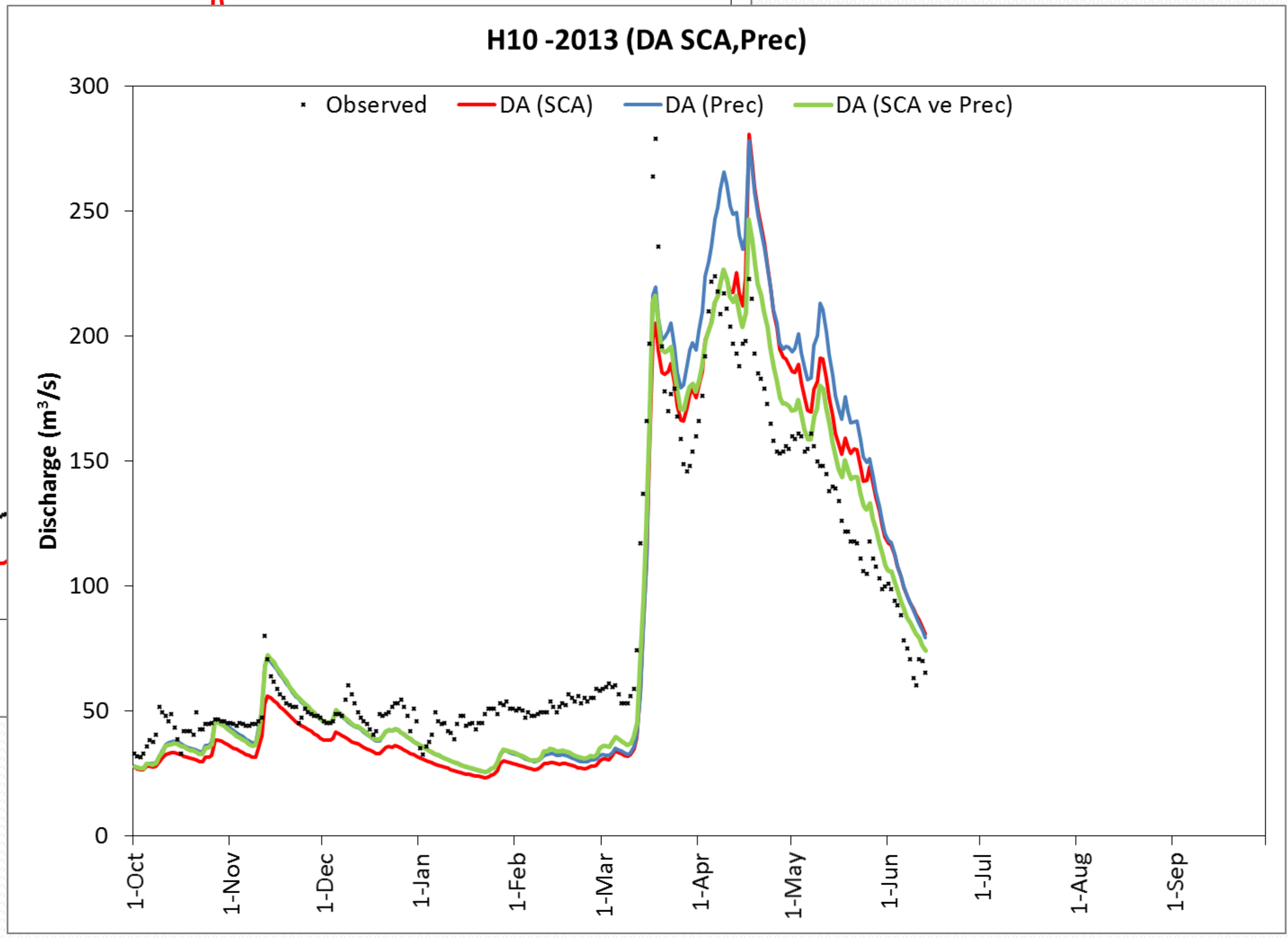


	R2	NSE
WoDA	0.92	0.43
DA (SCA)	0.91	0.70
DA (Prec)	0.92	0.68
DA (Both)	0.93	0.81

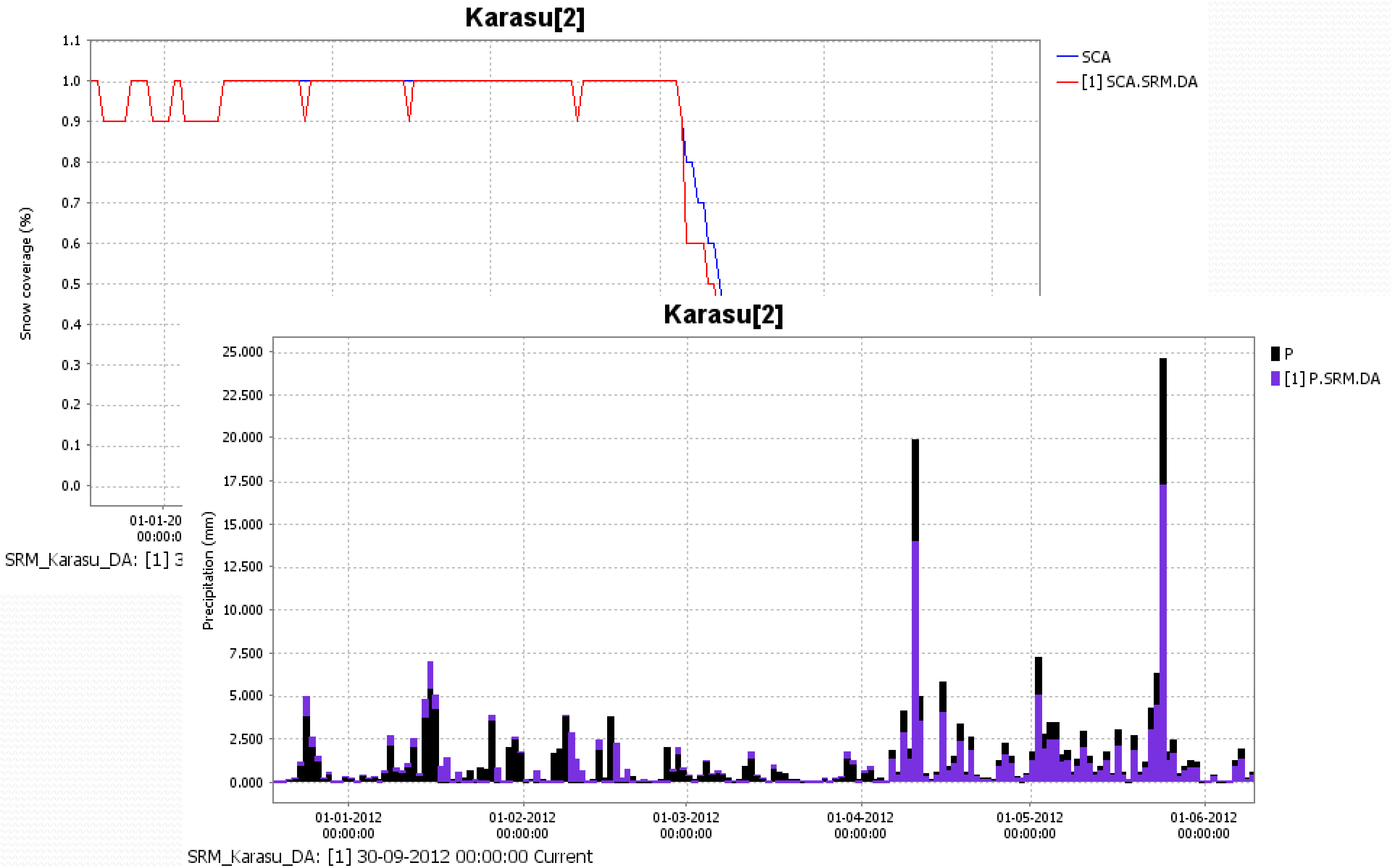
SRM Model - H10 (Validation)

	R2	NSE
WoDA	0.89	0.50
DA (SCA)	0.90	0.78
DA (Prec)	0.91	0.80
DA (Both)	0.94	0.78

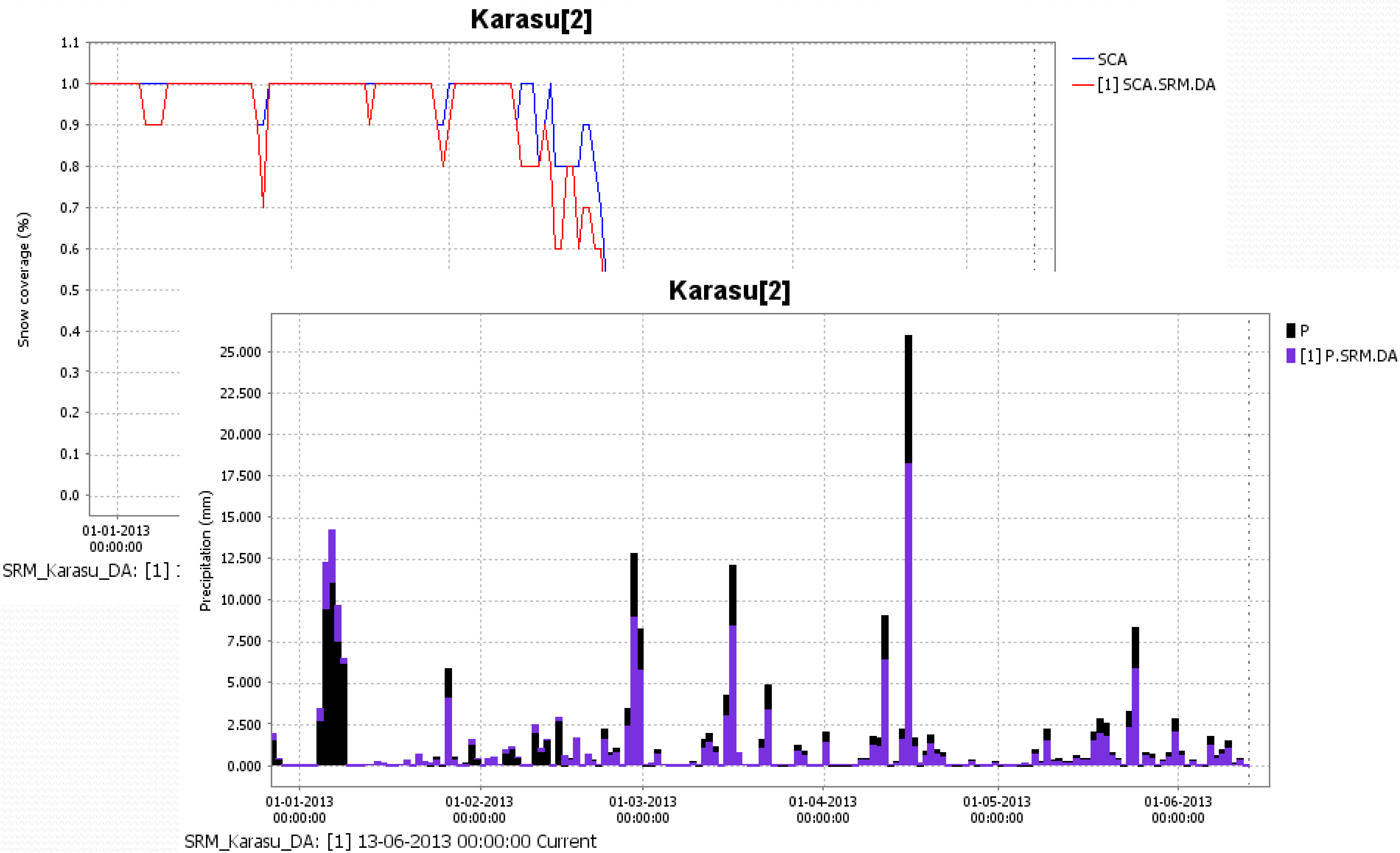




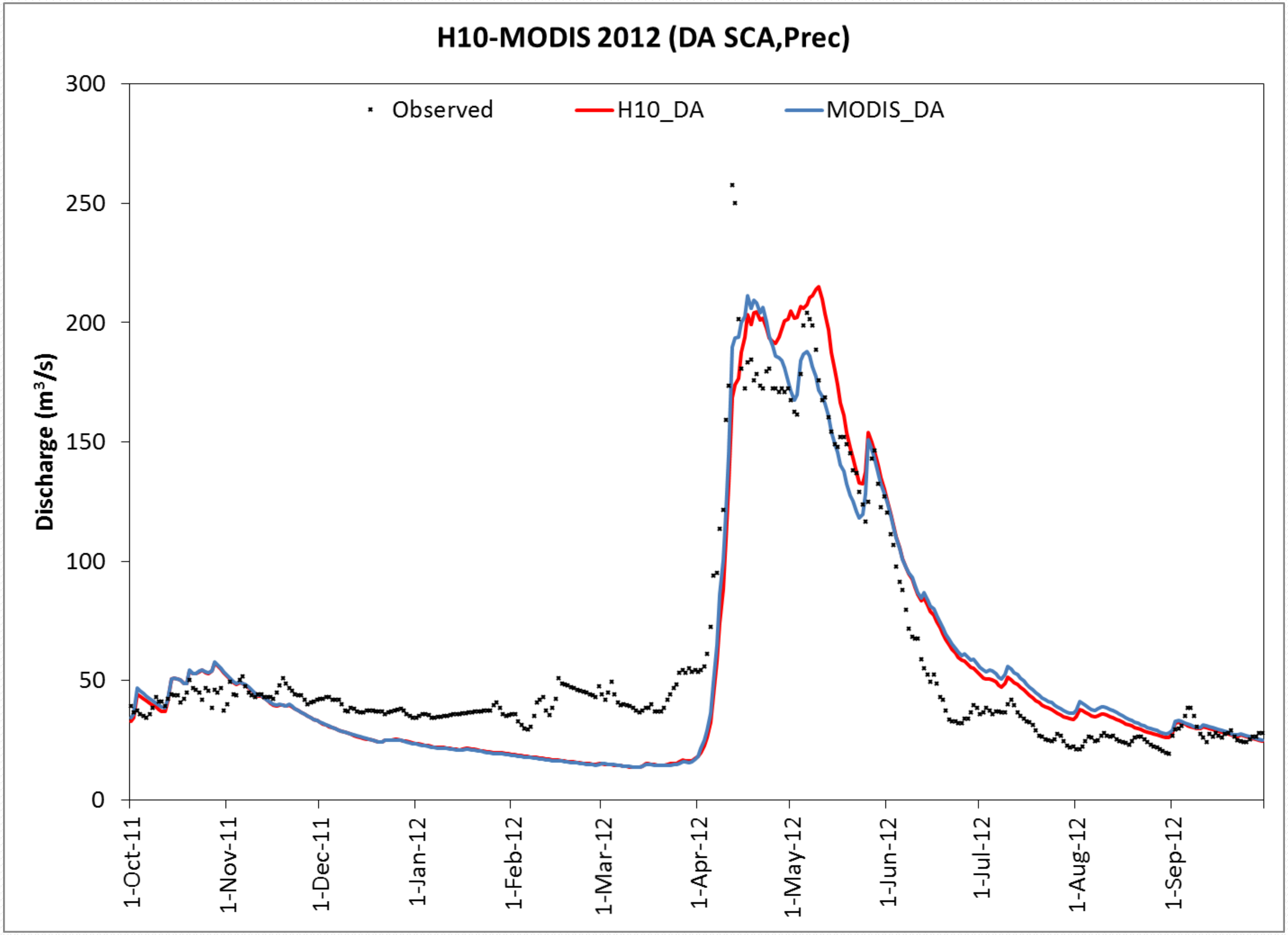
DA with SCA and Prec (2012)



DA with SCA and Prec (2013)



Comparison H10 and MODIS

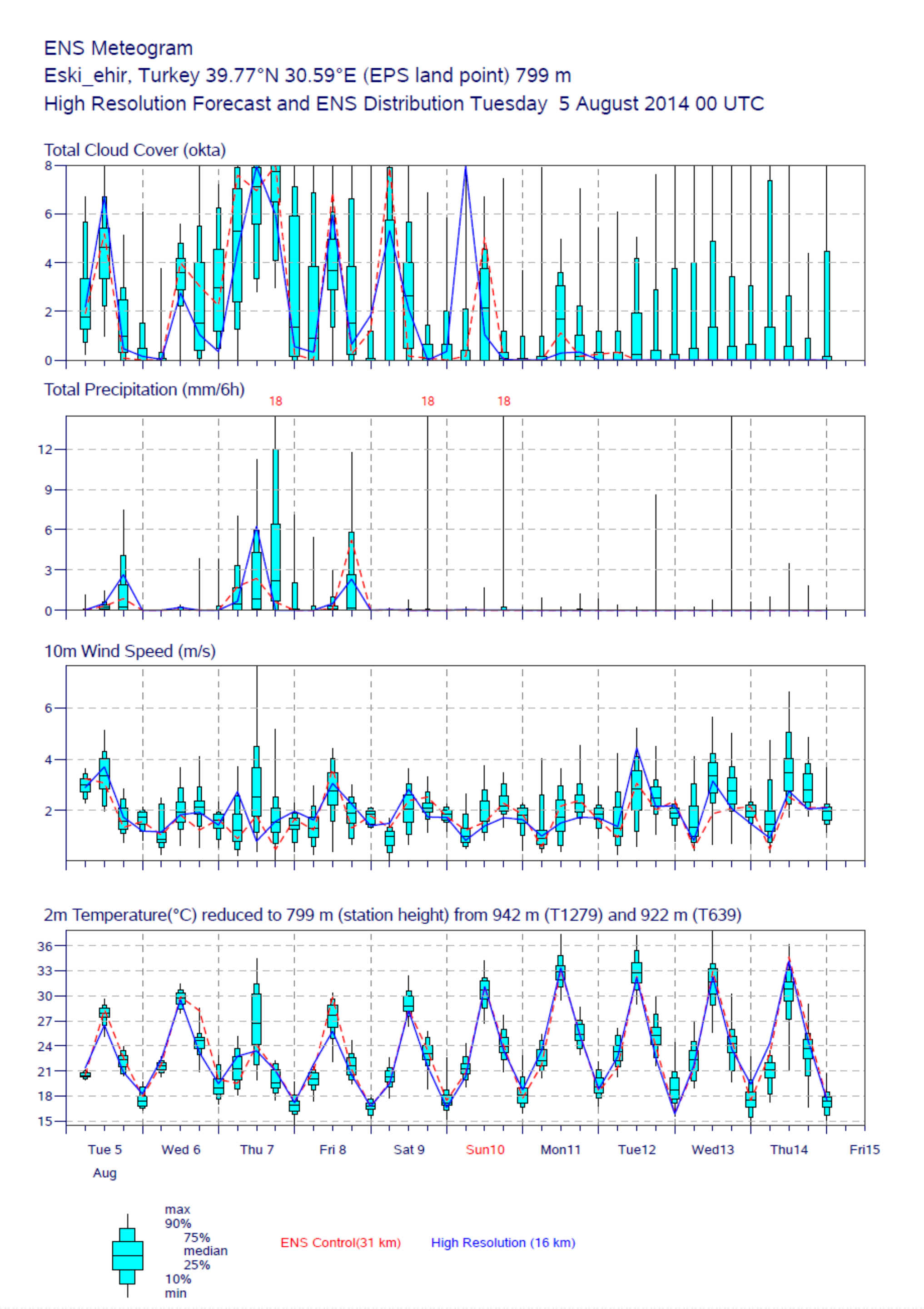


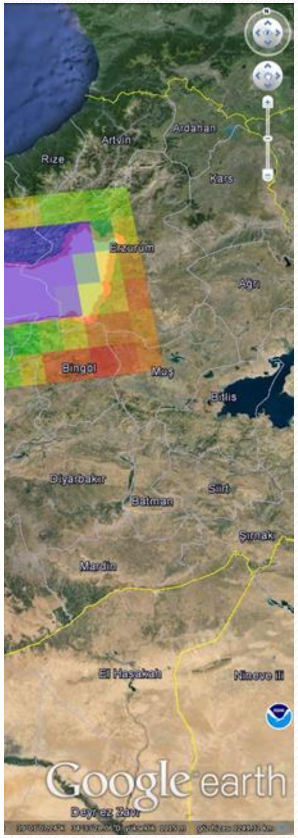
Statistical Comparisons

NSE (Jan-Jun)		H10	MODIS
Calibration	WoDA	0.67	0.60
Validation (2012)	WoDA	0.43	0.73
	DA(SCA)	0.70	0.79
	DA(Prec)	0.68	0.83
	DA(Both)	0.81	0.85
Validation (2013)	WoDA	0.50	0.81
	DA(SCA)	0.78	0.86
	DA(Prec)	0.70	0.89
	DA(Both)	0.88	0.92

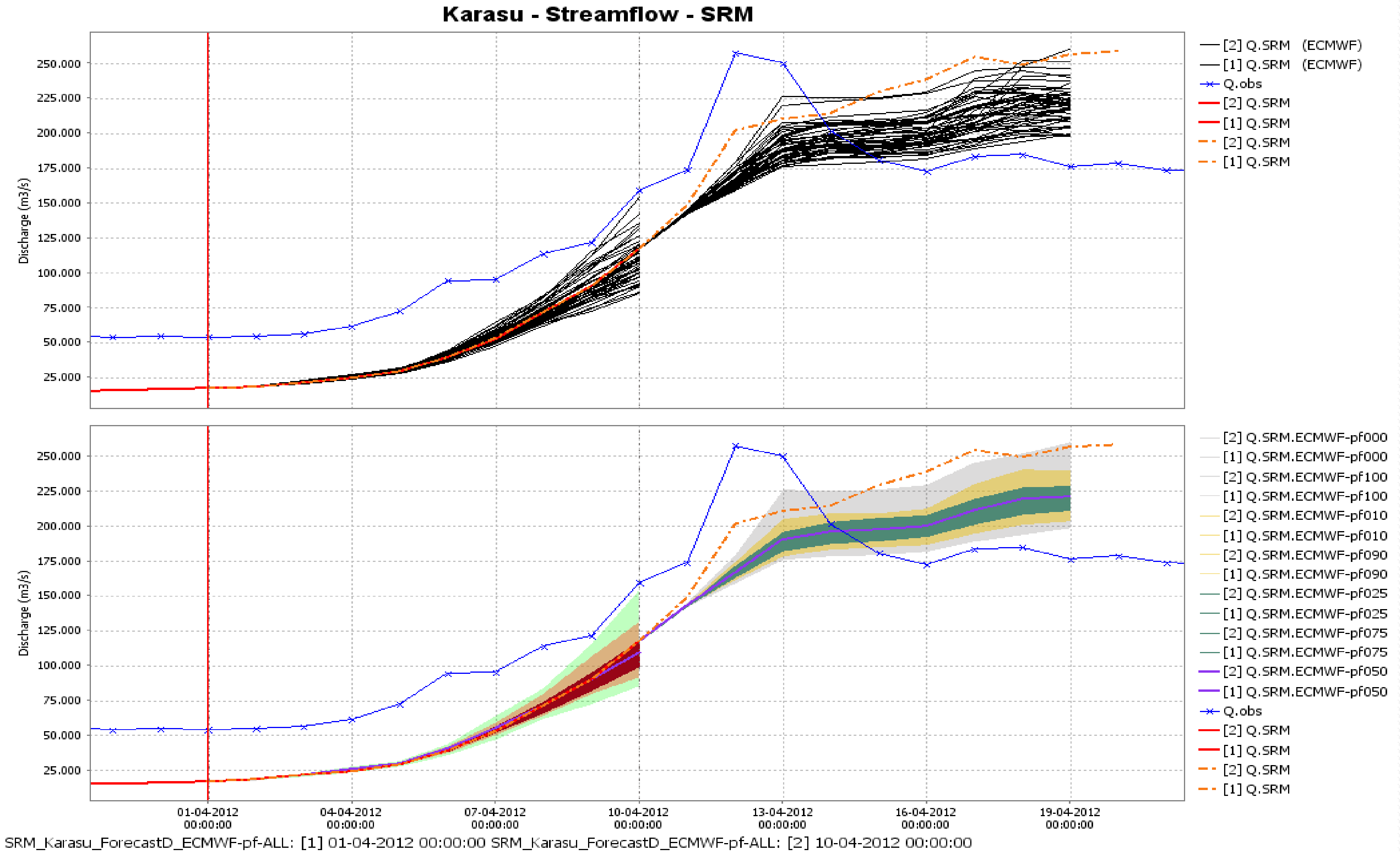
Ensem m (EPS)


Edirne
Tekirdağ
Çanakkale
Balıkesir
Manisa
İzmir

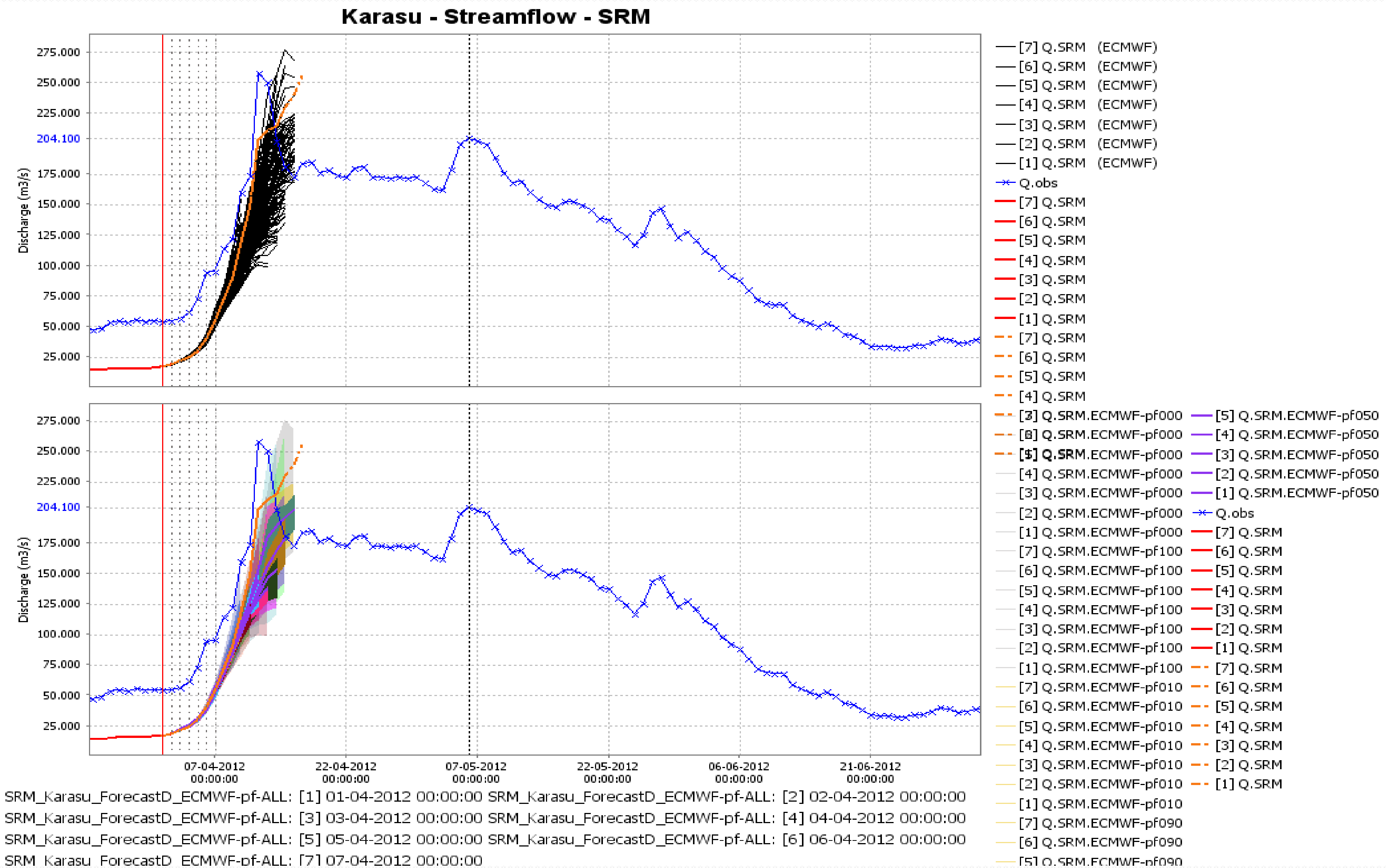

ENS Meteogram
Eski_ehir, Turkey 39.77°N 30.59°E (EPS land point) 799 m
High Resolution Forecast and ENS Distribution Tuesday 5 August 2014 00 UTC
Total Cloud Cover (okta)
Total Precipitation (mm/6h)
18
18
18
10m Wind Speed (m/s)
2m Temperature(°C) reduced to 799 m (station height) from 942 m (T1279) and 922 m (T639)
Tue 5
Aug
Wed 6
Thu 7
Fri 8
Sat 9
Sun10
Mon11
Tue12
Wed13
Thu14
Fri15
max
90%
75%
median
25%
10%
min
ENS Control(31 km)
High Resolution (16 km)


Rize
Artvin
Ardahan
Kars
Erzurum
Ağrı
Bingöl
Muş
Bitlis
Diyarbakır
Batman
Siirt
Şırnak
Mardin
El Hasakah
Nineve
Google earth

Karasu 2012 (H10)



Karasu 2012 (H10)



BC - EPS

T^*_{Corr} = $T_{Ensmeble}$+ (T_{Obs} - T_{Ens})

T^*_{Corr} : Bias corrected temperature ensemble

$T_{Ensemble}$: Raw temperature ensemble

T_{Obs} : Correction factor for observed temperature

T_{Ens} : Correction for ensemble temperature

P^*_{Corr} = $P_{Ensmeble}$ x $\frac{P_{Obs}}{P_{Ens}}$

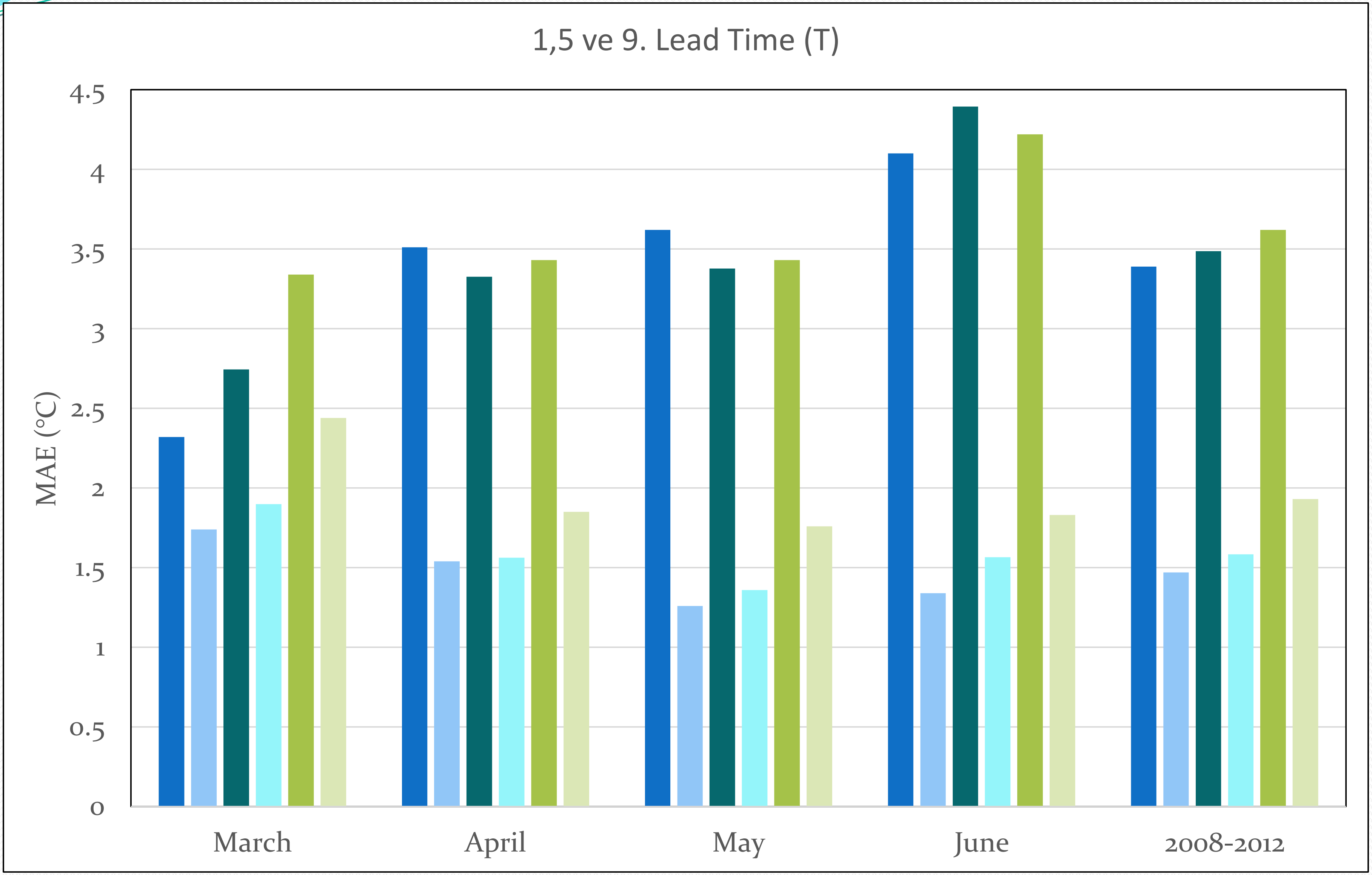
P^*_{Corr} : Bias corrected precipitation ensemble

$P_{Ensemble}$: Raw precipitation ensemble

P_{Obs} : Correction factor for observed precipitation

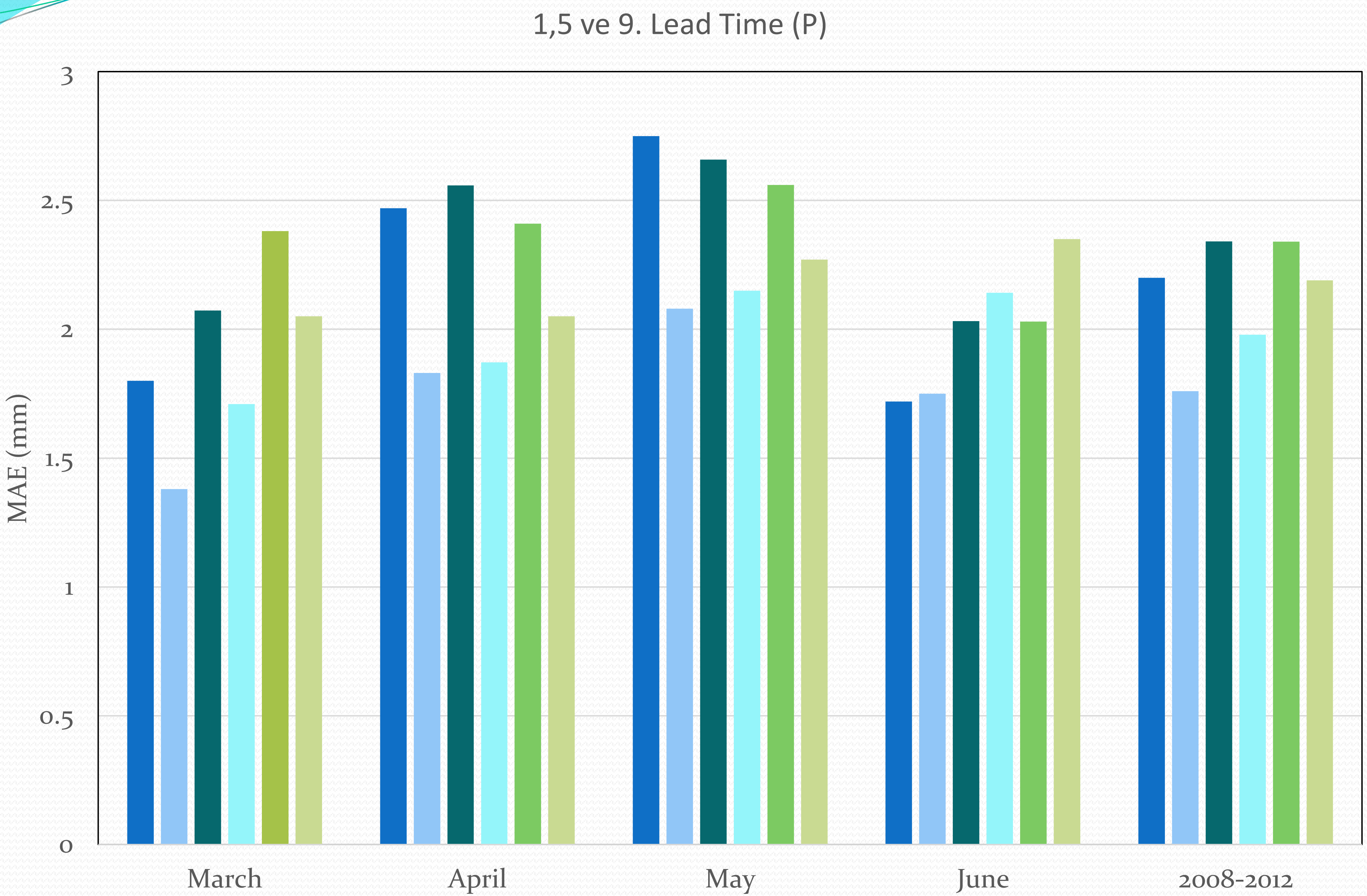
P_{Ens} : Correction for ensemble precipitation

EPS Temp MAE



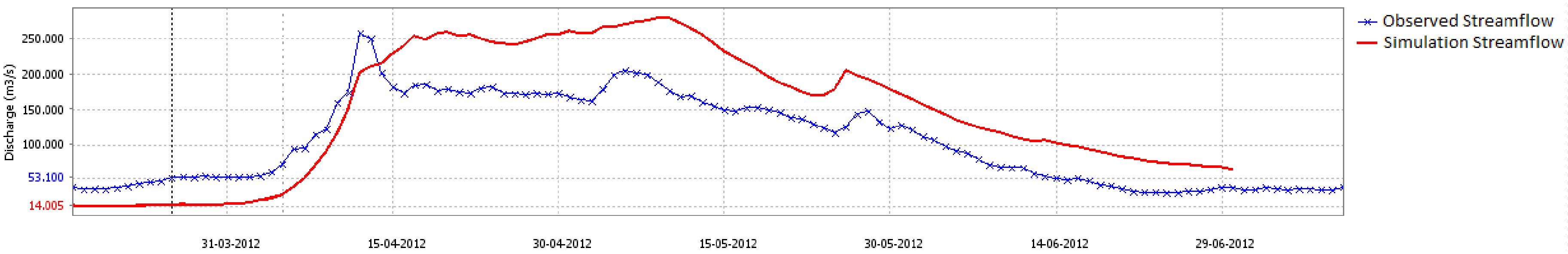
1,5 ve 9. Lead Time (T)
MAE (°C)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
March
April
May
June
2008-2012

EPS Prec MAE

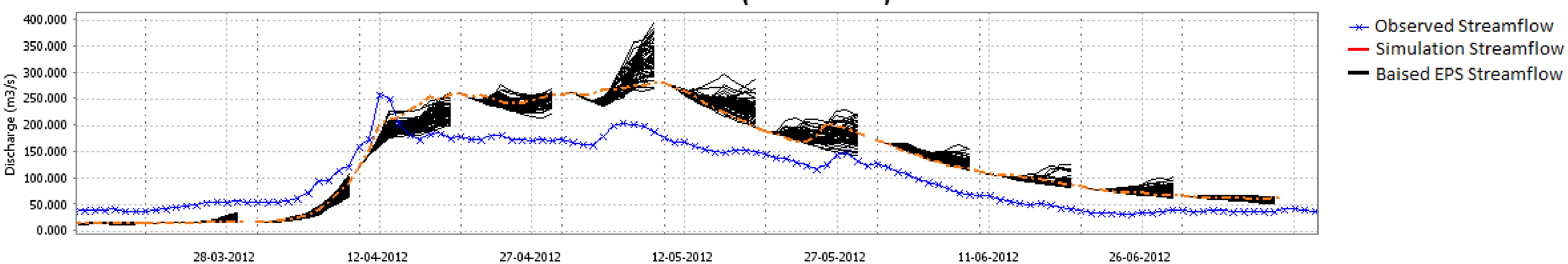

1,5 ve 9. Lead Time (P)
MAE (mm)
3
2.5
2
1.5
1
0.5
0
March
April
May
June
2008-2012

SRM – H10 – BC EPS - DA

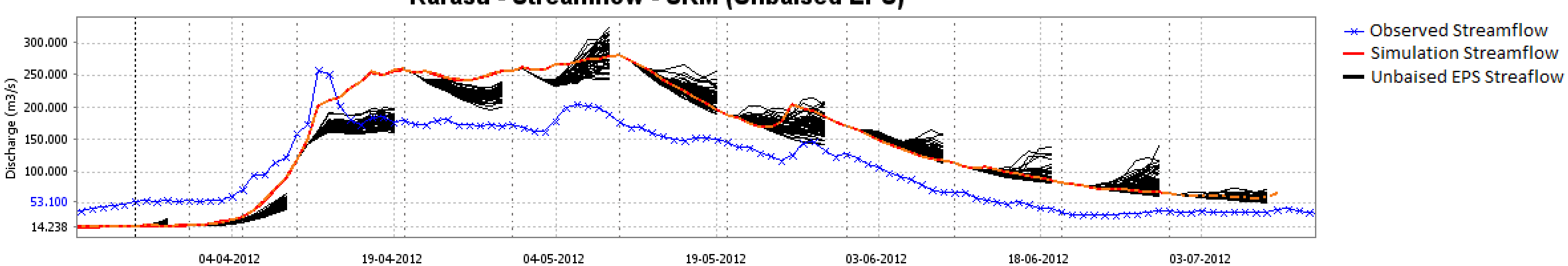
Karasu - Streamflow - SRM



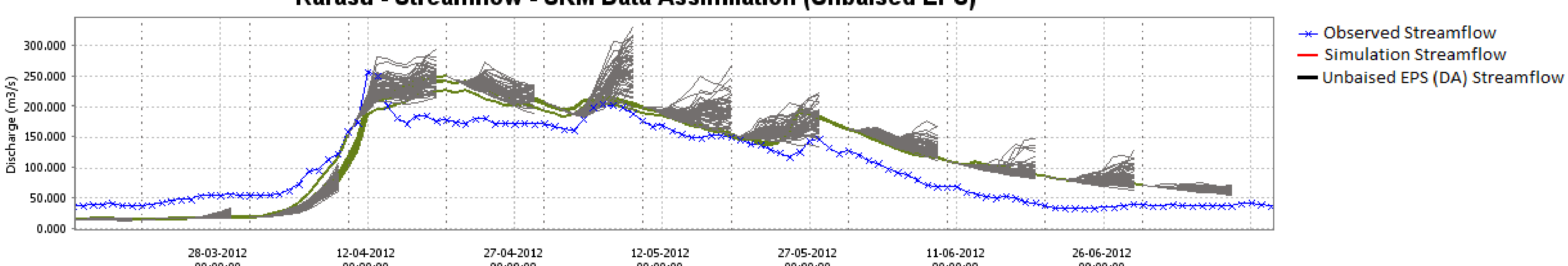
Karasu - Streamflow - SRM (Baised EPS)



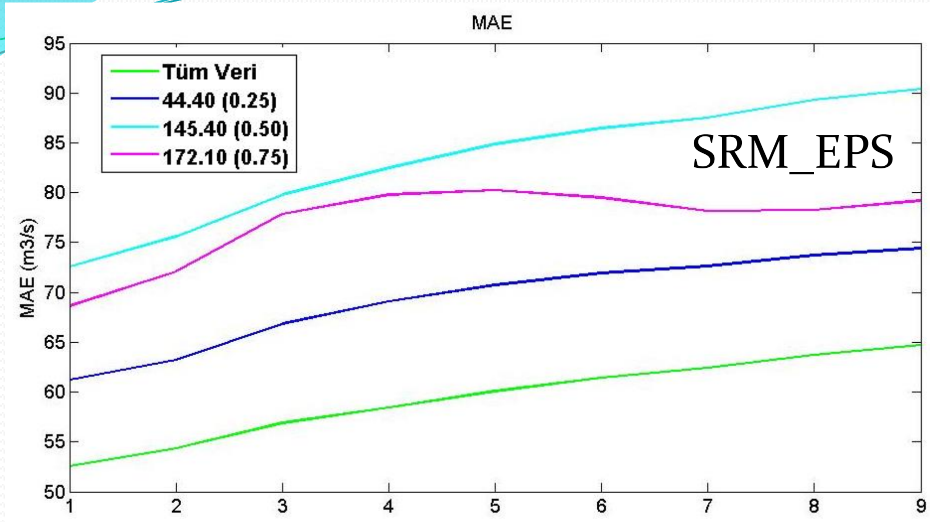
Karasu - Streamflow - SRM (Unbaised EPS)



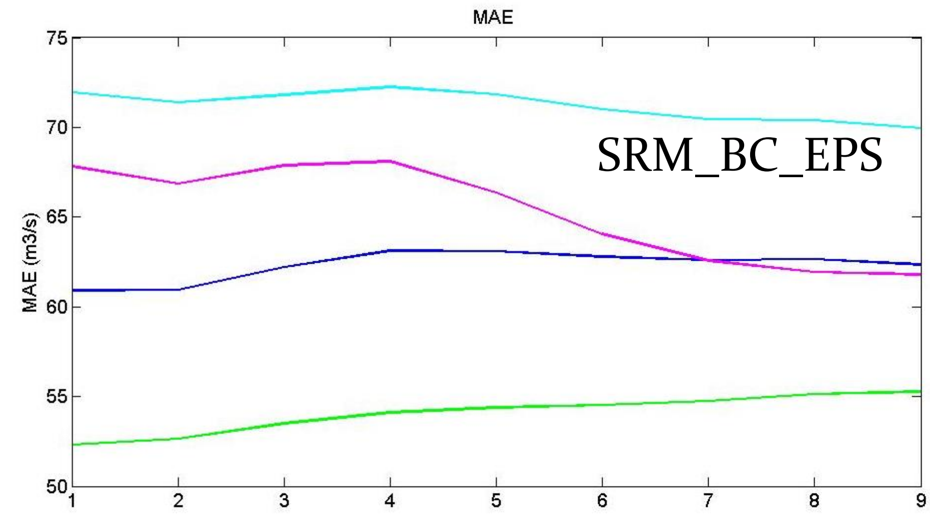
Karasu - Streamflow - SRM Data Assimilation (Unbaised EPS)



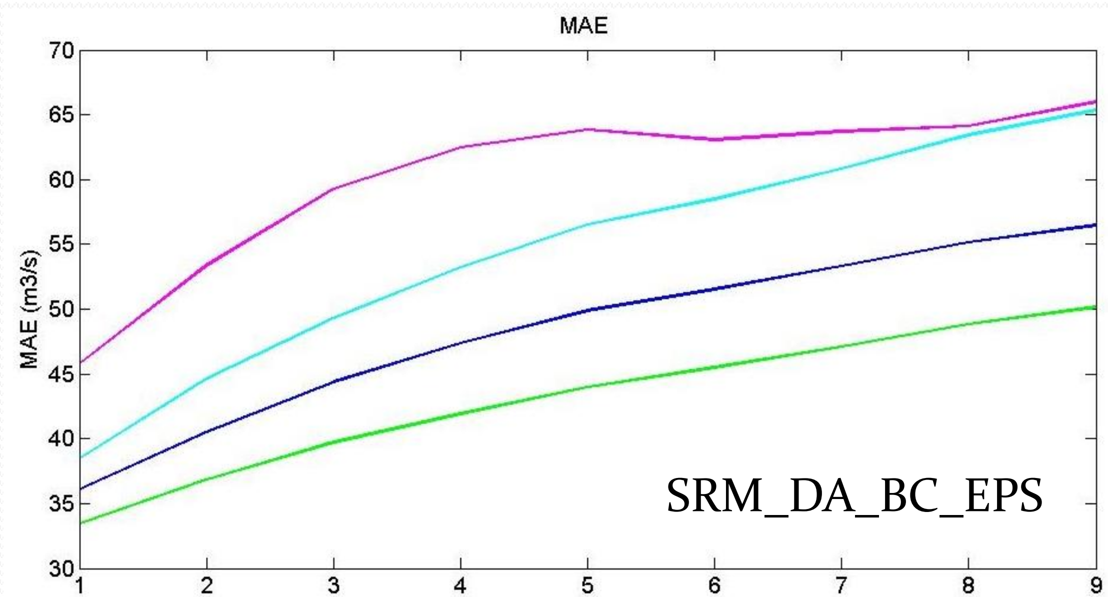
SRM 2012 EVS



MAE
MAE (m3/s)
Tüm Veri
44.40 (0.25)
145.40 (0.50)
172.10 (0.75)
SRM_EPS
95
90
85
80
75
70
65
60
55
50
1 2 3 4 5 6 7 8 9

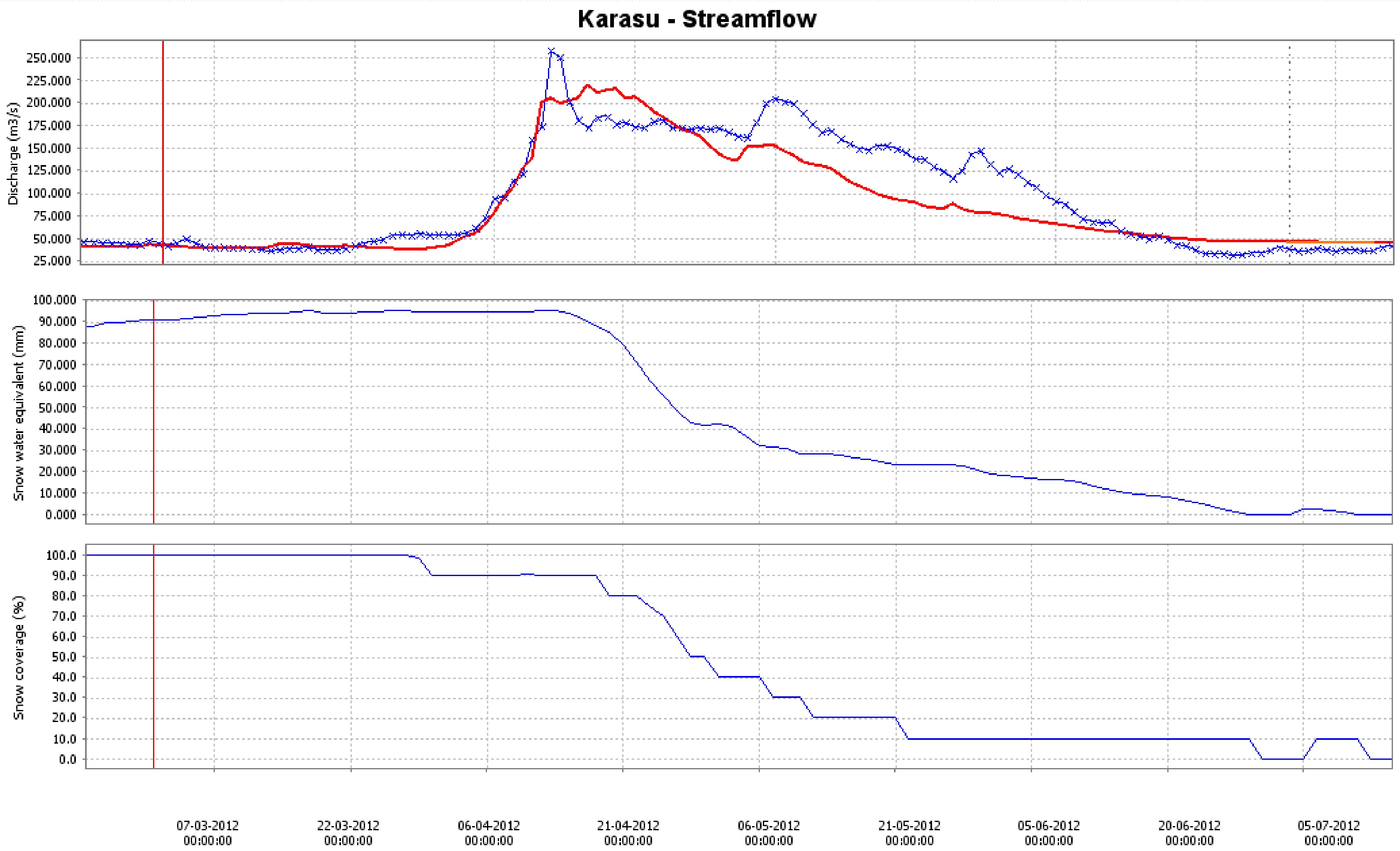


MAE
MAE (m3/s)
SRM_BC_EPS
75
70
65
60
55
50
1 2 3 4 5 6 7 8 9



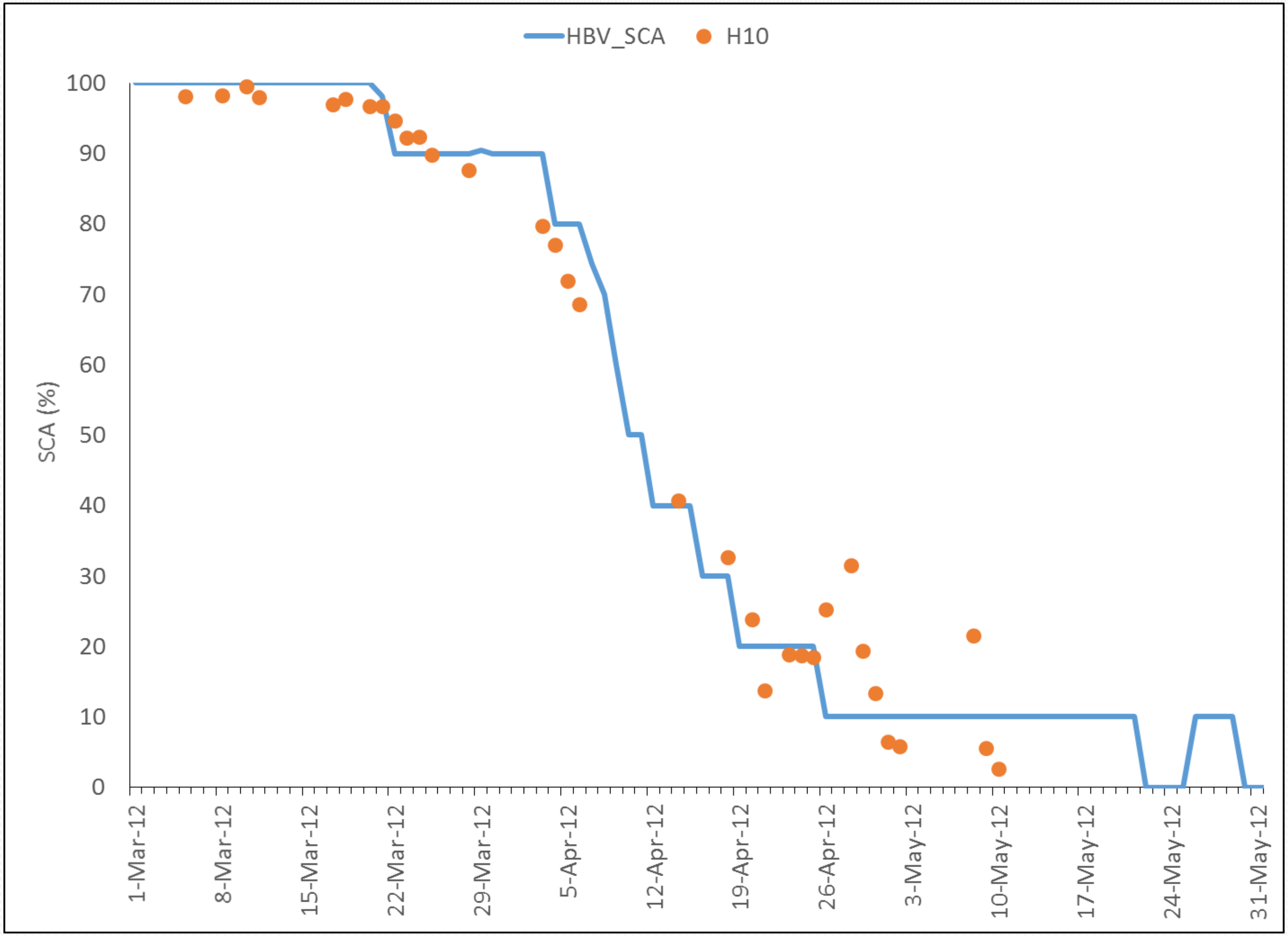
MAE
MAE (m3/s)
SRM_DA_BC_EPS
70
65
60
55
50
45
40
35
30
1 2 3 4 5 6 7 8 9

HBV Model

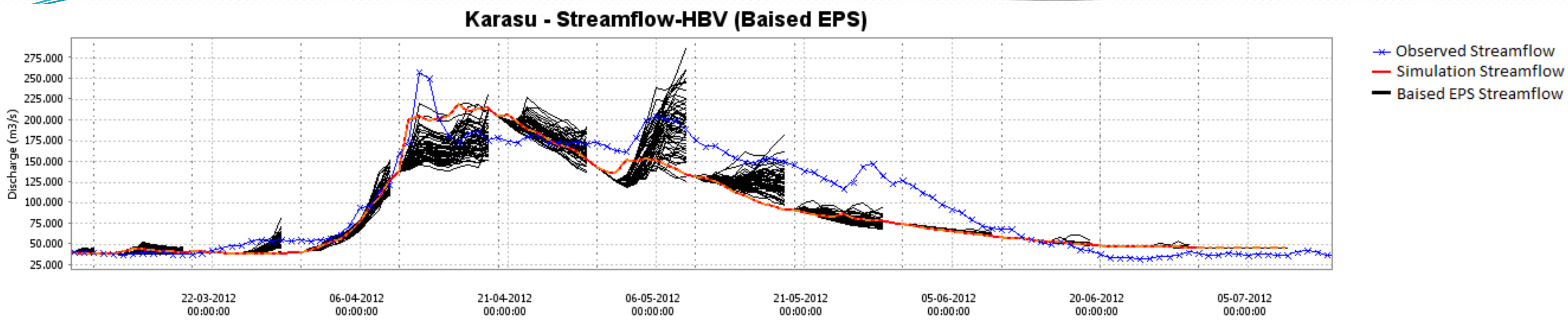


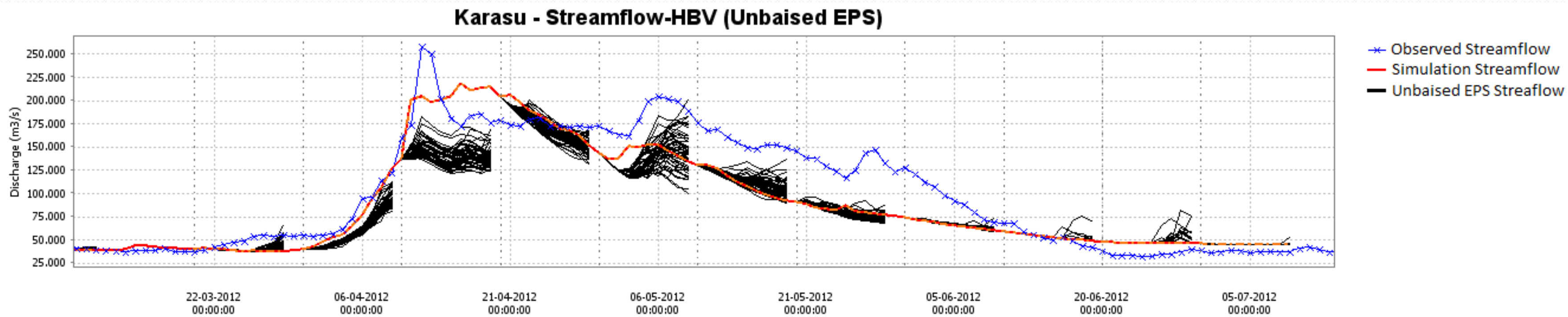
Karasu - Streamflow
Discharge (m3/s)
250.000
225.000
200.000
175.000
150.000
125.000
100.000
75.000
50.000
25.000
Snow water equivalent (mm)
100.000
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
Snow coverage (%)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
07-03-2012 00:00:00
22-03-2012 00:00:00
06-04-2012 00:00:00
21-04-2012 00:00:00
06-05-2012 00:00:00
21-05-2012 00:00:00
05-06-2012 00:00:00
20-06-2012 00:00:00
05-07-2012 00:00:00

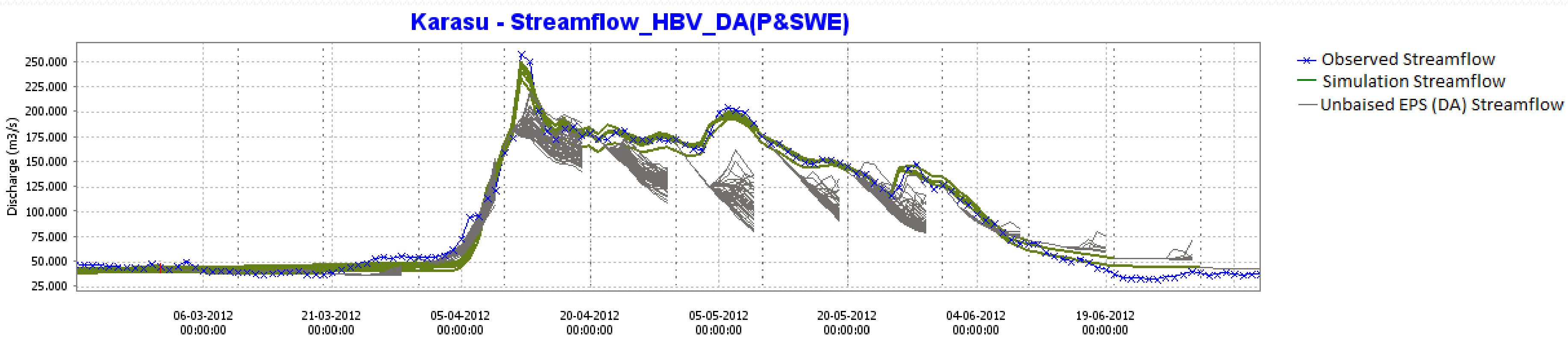
HBV Model Validation (H10)



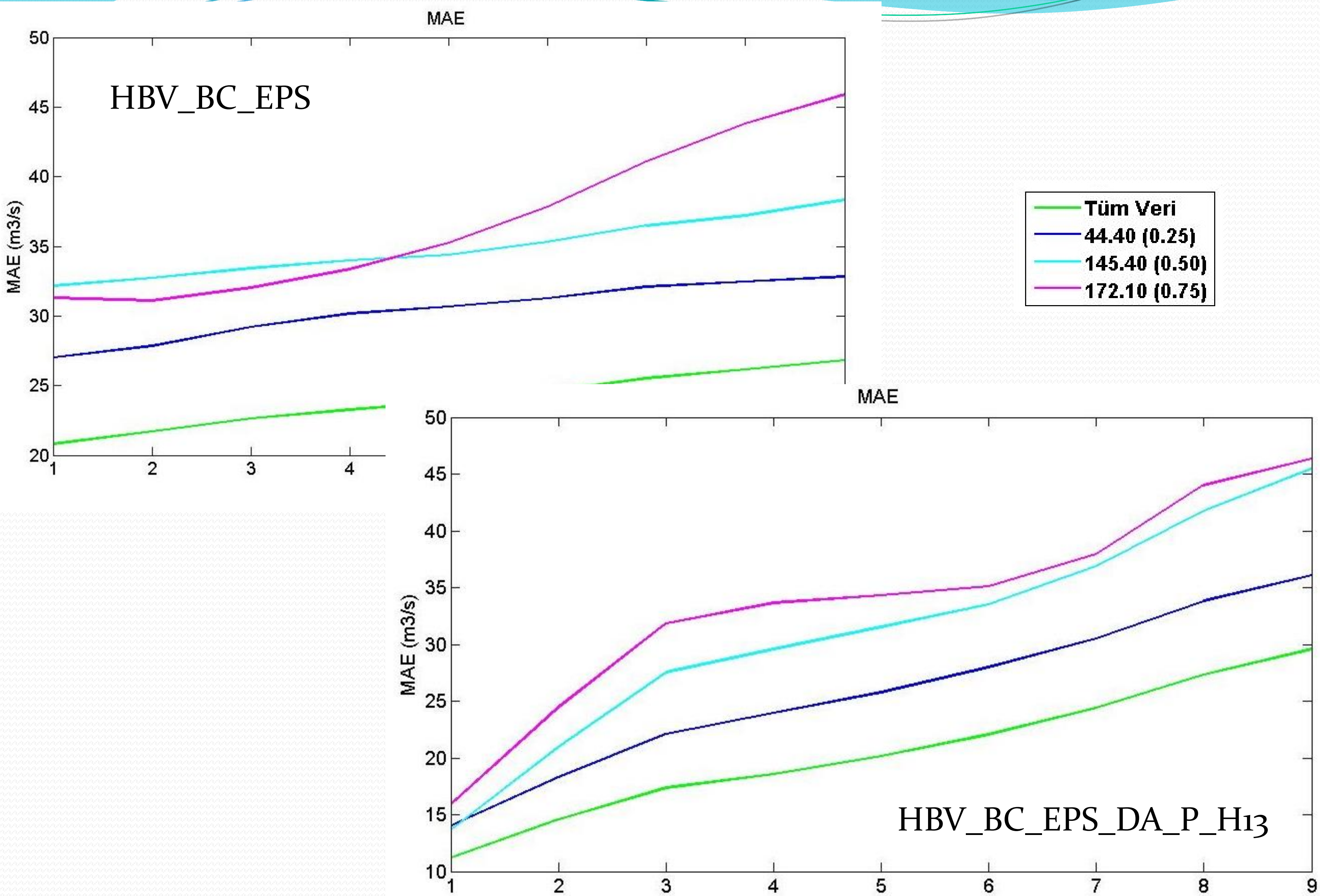
HBV – BC EPS – DA (H13)







HBV 2012 EVS


MAE
HBV_BC_EPS
MAE (m3/s)
50
45
40
35
30
25
20
1
2
3
4
Tüm Veri
44.40 (0.25)
145.40 (0.50)
172.10 (0.75)
MAE
HBV_BC_EPS_DA_P_H13
MAE (m3/s)
50
45
40
35
30
25
20
15
10
1
2
3
4
5
6
7
8
9

Conclusions

- A framework for DA integrated with hydrological models is setup and tested.
- Operational HSAF snow products are used in data assimilation procedure
- There is an enhancement in runoff prediction accuracy with NWP
- Research is ongoing…

Thank you…

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