Effects of elevation bands and snow parameters on the hydrological modeling of the upper part of the Garonne watershed (France)

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INP ENSAT

UNIVERSITÉ TOULOUSE III PAUL SABATIER

ANR adapt'eau

attenagua

Mountainous areas

- Mountainous areas is an important component for many watersheds
  - Large range of elevations
  - Snow is the common form of keeping water in the mountainous region

- Important in hydrological modelling
  - Snowfall-melting processes

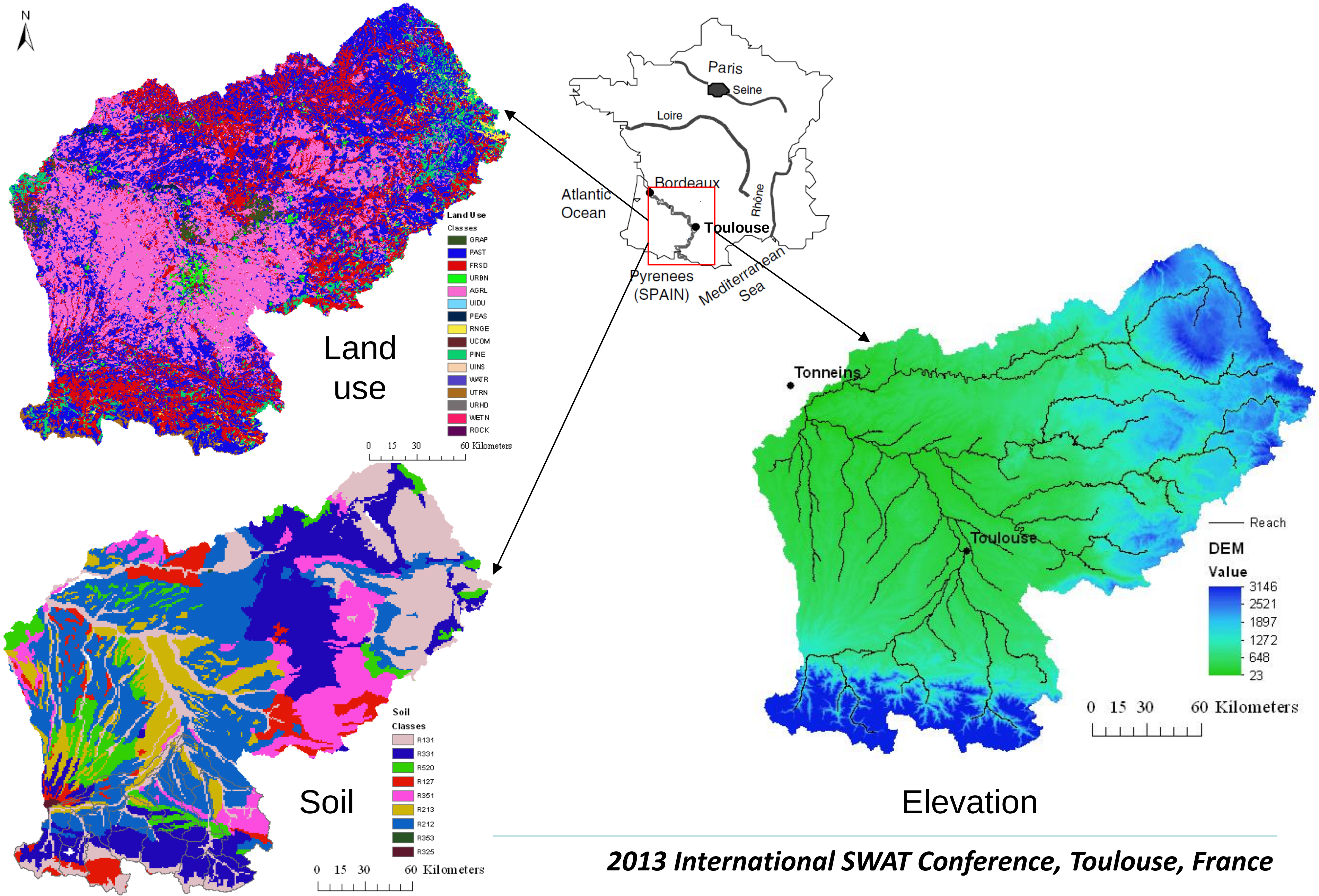
Objective

- Modeling hydrology of catchments included mountainous regions accurately

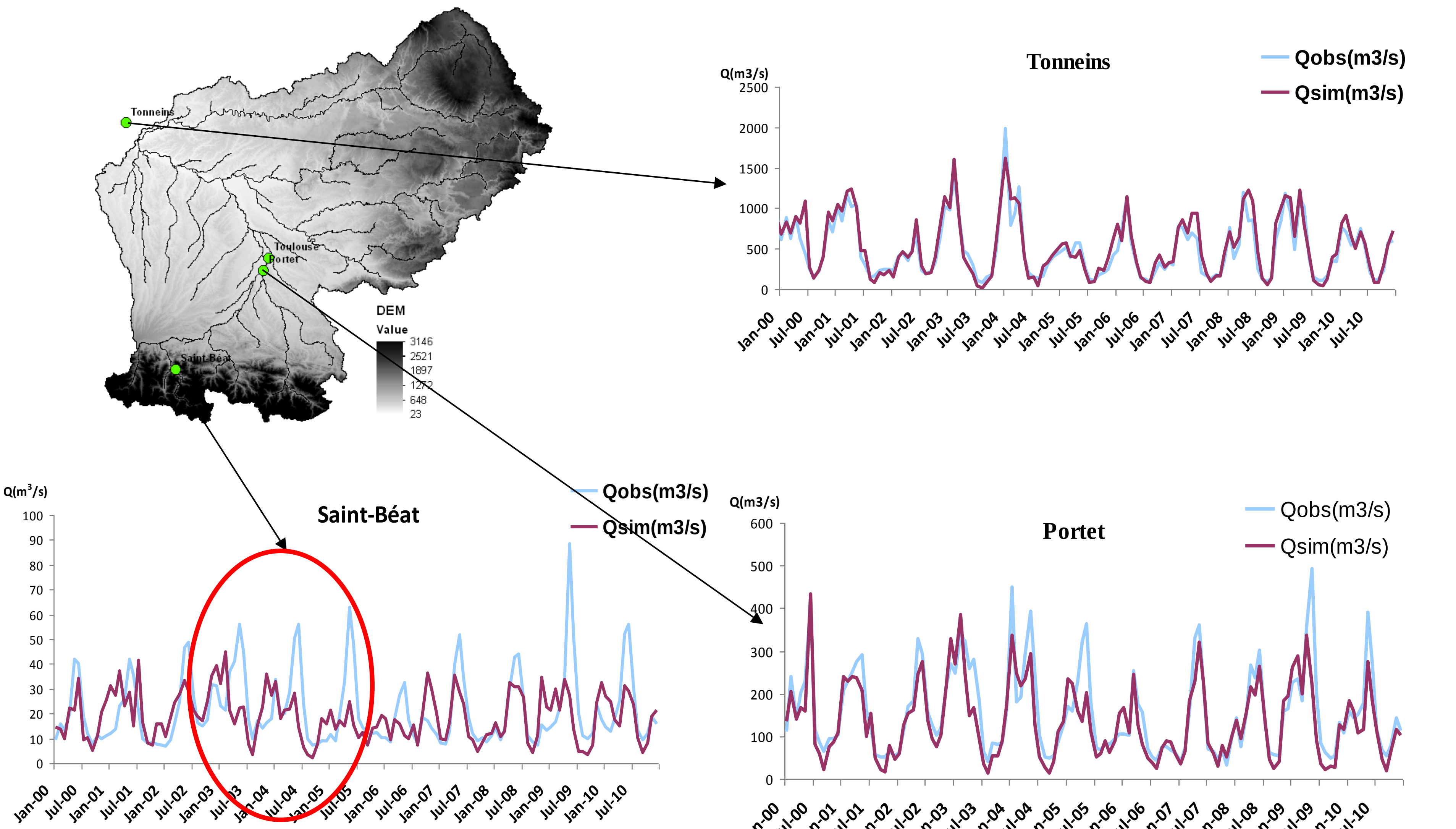
- SWAT model
  - has been successfully applied all over the world
  - there are already some successful studies on the mountainous areas with SWAT

- Test the effects
  - Snowfall-melting processes
  - Elevation

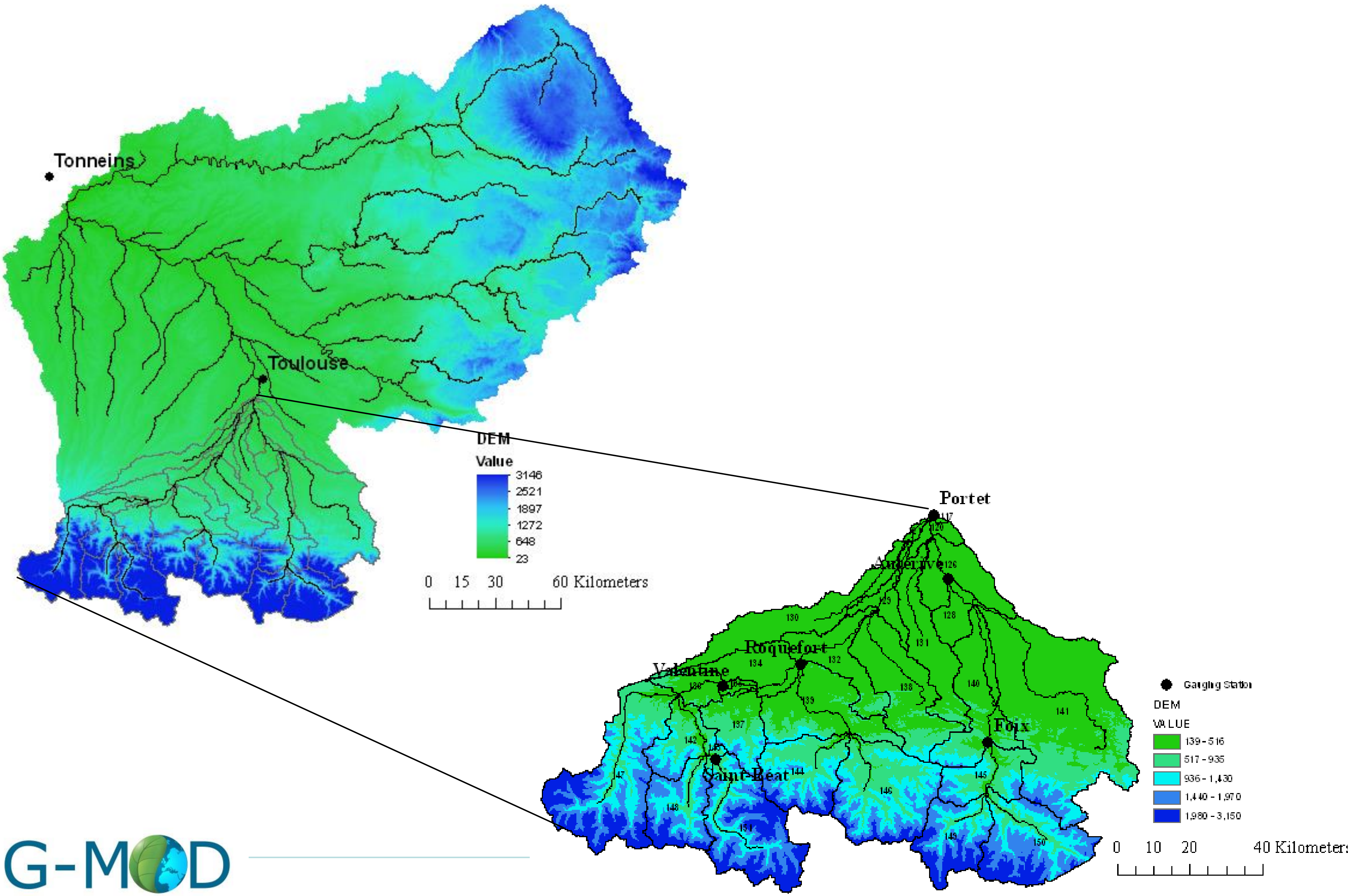
Study area


N
Land use
Land Use
Classes
GRAP
PAST
FRSD
URBN
AGRL
UIDU
PEAS
RNGE
UCOM
PINE
UINS
WATR
UTRN
URHD
WETN
ROCK
0 15 30 60 Kilometers
Paris
Seine
Loire
Bordeaux
Rhône
Atlantic Ocean
Toulouse
Pyrenees (SPAIN)
Mediterranean Sea
Soil
Soil
Classes
R131
R331
R520
R127
R351
R213
R212
R353
R325
0 15 30 60 Kilometers
Tonneins
Toulouse
Reach
DEM
Value
3146
2521
1897
1272
648
23
0 15 30 60 Kilometers
Elevation

Simulated results without snow and elevation bands



Study area



Tonneins
Toulouse
DEM
Value
3146
2521
1897
1272
648
23
0 15 30 60 Kilometers
Portet
Roquefort
Valentine
Saint-Beat
Foix
DEM
VALUE
139 - 516
517 - 935
936 - 1,430
1,440 - 1,970
1,980 - 3,150
0 10 20 40 Kilometers

Elevation and snow in SWAT

- Elevation bands
  - Variation of precipitation and temperature with elevation

$$R_{band} = R_{day} + (EL_{band} - EL_{gage}) \cdot \frac{plaps}{days_{pcp,yr} \cdot 1000}$$

Recorded rainfall

Rainfall in the elevation band

Elevation space between the band and recording gage

Variation of rainfall (each Km)

$$T_{mx,band} = T_{mx} + (EL_{band} - EL_{gage}) \cdot \frac{tlaps}{1000}$$

Variation of temperature (each Km)

- Snowfall-melting processes

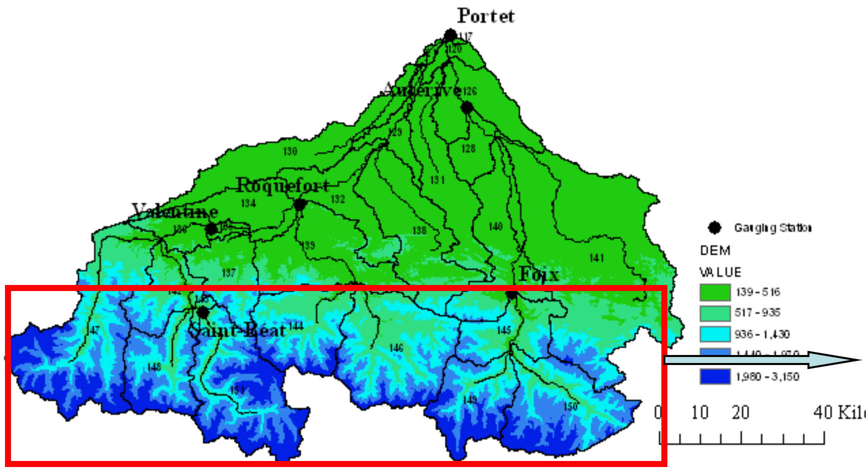
$$SNO = SNO + R_{day} - E_{sub} - SNO_{mlt}$$

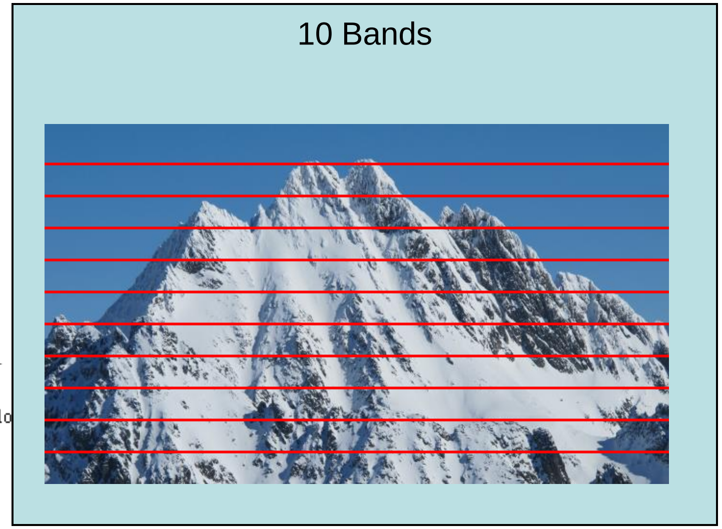
Sublimation

Existed snow

Rainfall as snow

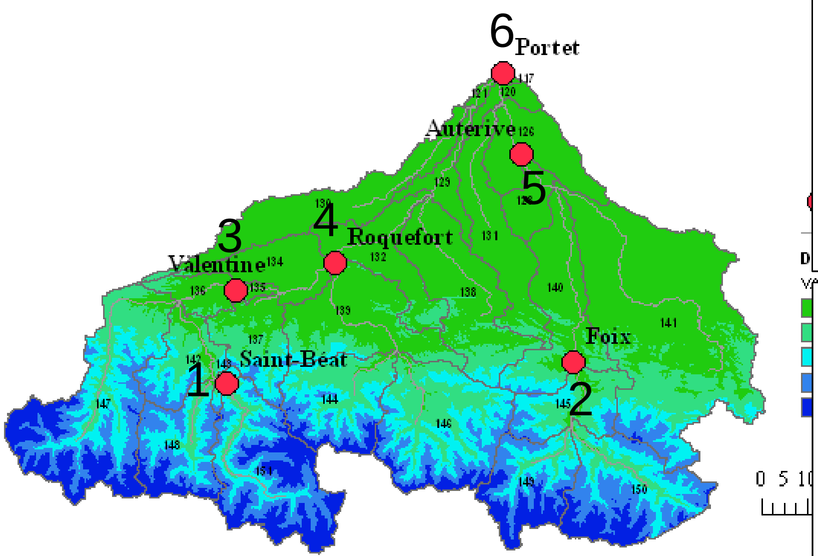
Subbasins with elevation bands

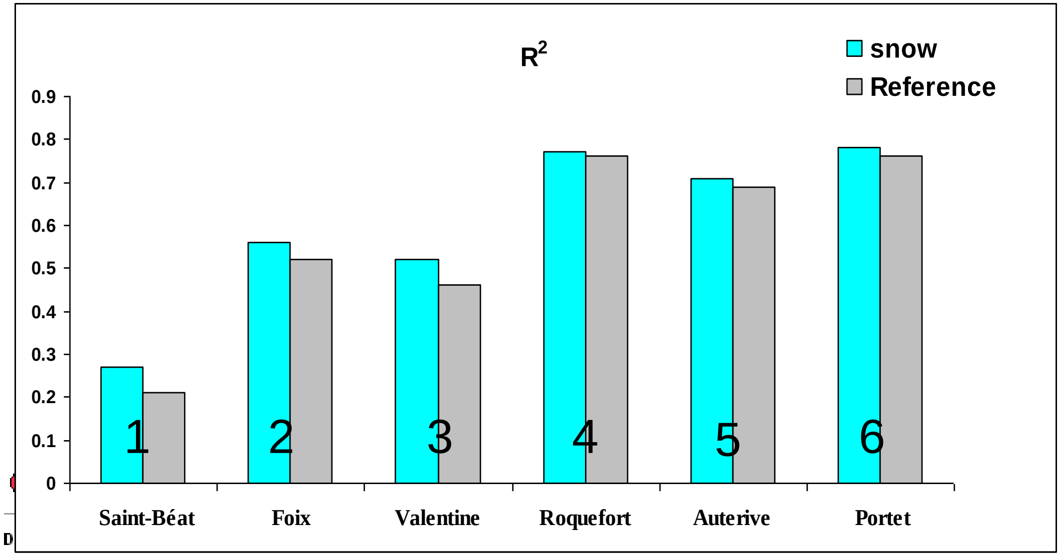


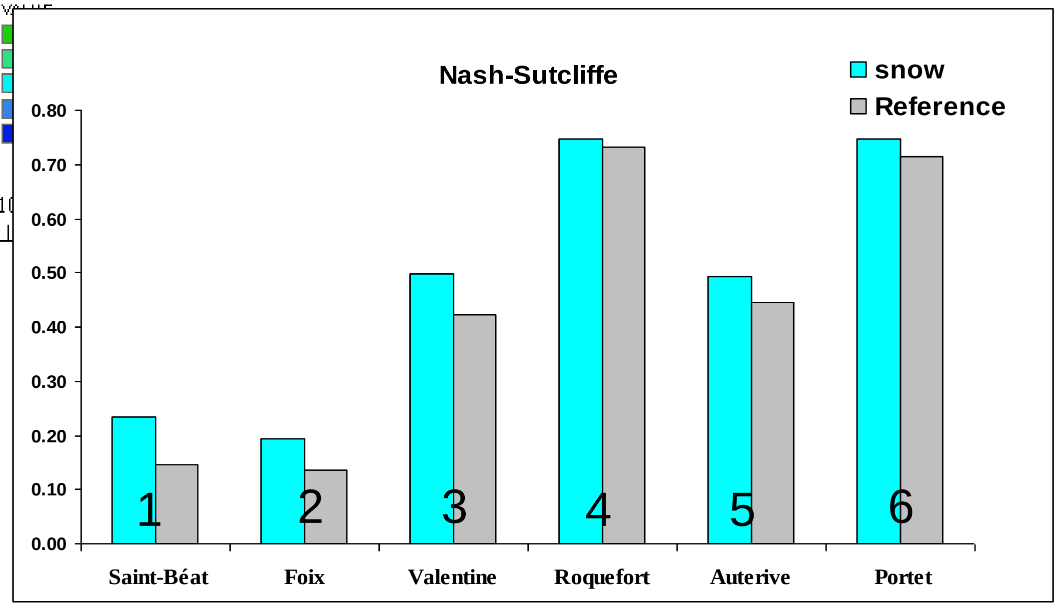


Parameters	Component	Description	Default value	Applied value
TLAPS	Subbasin	Temperature lapse rate (°C/km)	0	-6.3
PLAS	Subbasin	Precipitation lapse rate (mm/km)	0	415
SNO_SUB	Subbasin	Initial snow water content (mm)	0	84
SNOCOVMX	Basin/snow	Minimum snow water content of SNO_{100}(mm)	1	200
SNO50COV	Basin/snow	Fraction of snow volume of 50% snow cover	0.5	0.18
SFTMP	Basin/snow	Snowfall temperature (°C)	1	1.5
SMTMP	Basin/snow	Snow melt base temperature (°C)	0.5	2.5
SMFMX	Basin/snow	Maximum snowmelt rate (mm/C-day)	4.5	8.88
SMFMN	Basin/snow	Minimum snowmelt rate (mm/C-day)	4.5	0.64
TIMP	Basin/snow	Snowpack temperature lag factor	1	0.44

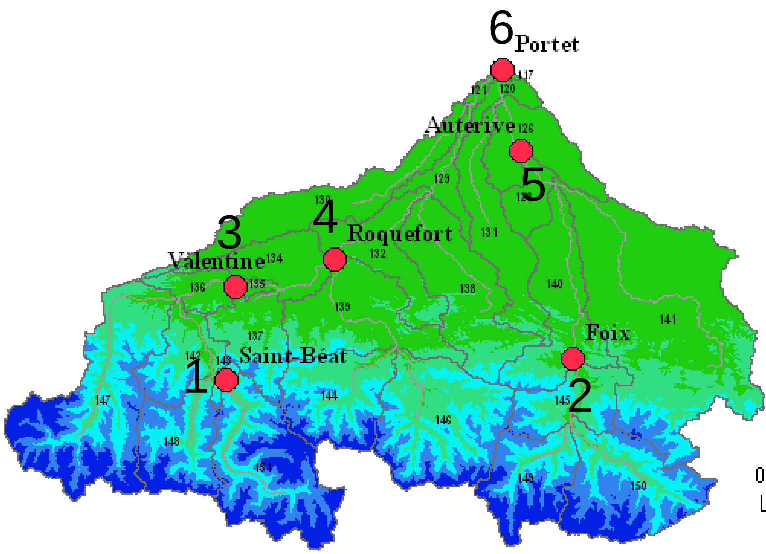
Simulated results - altered snow parameters

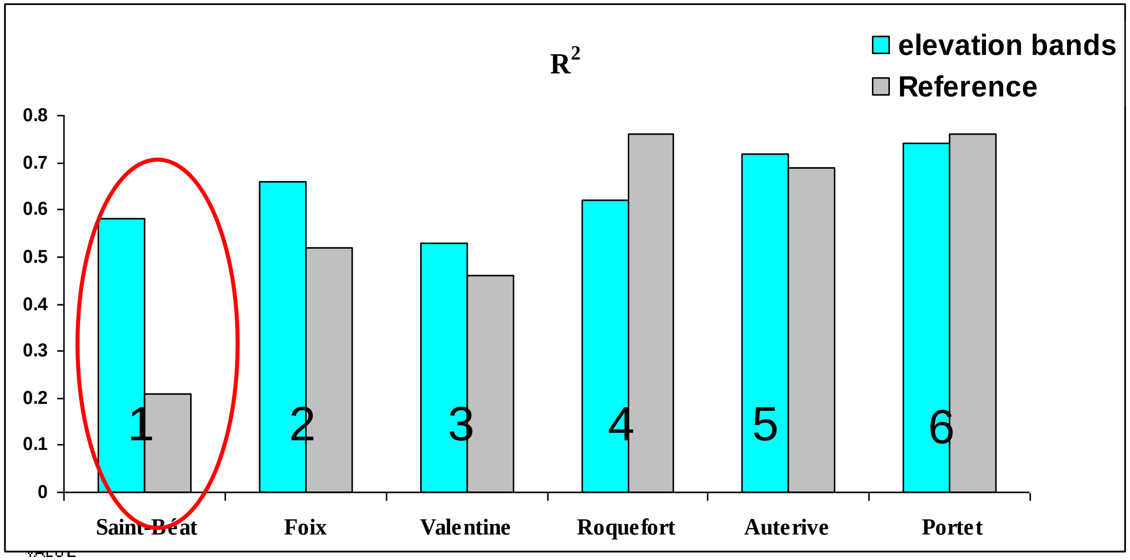


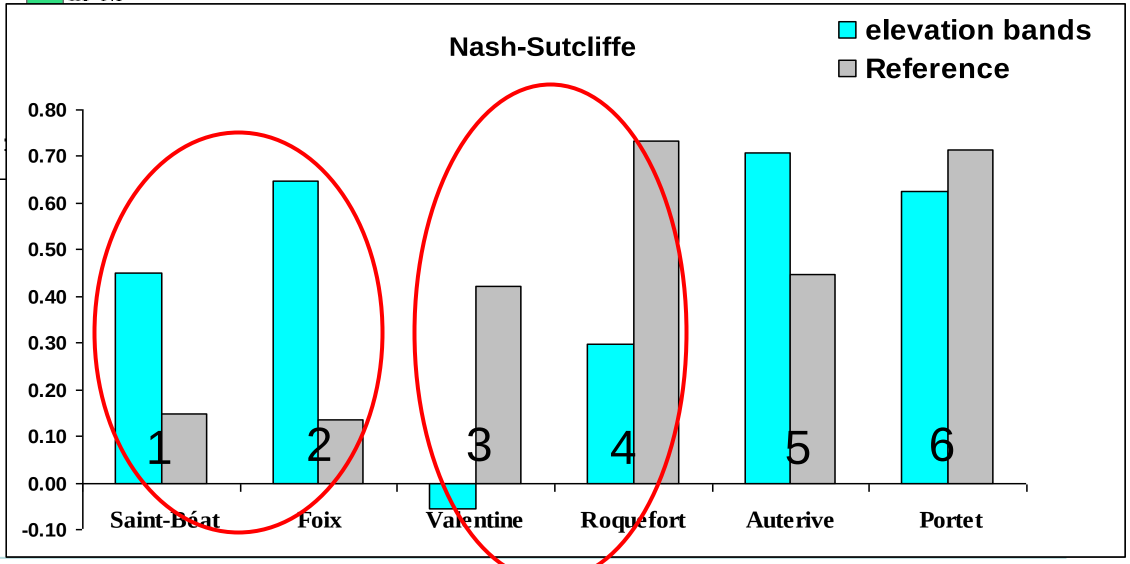




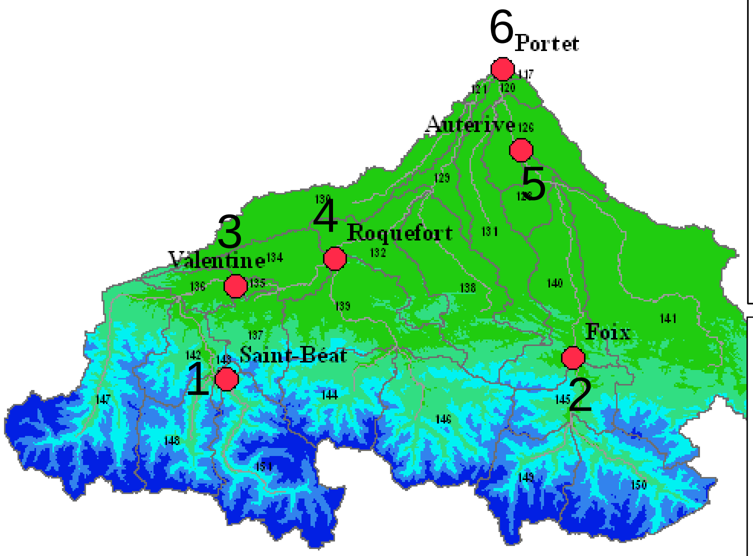
Simulated results - added elevation bands

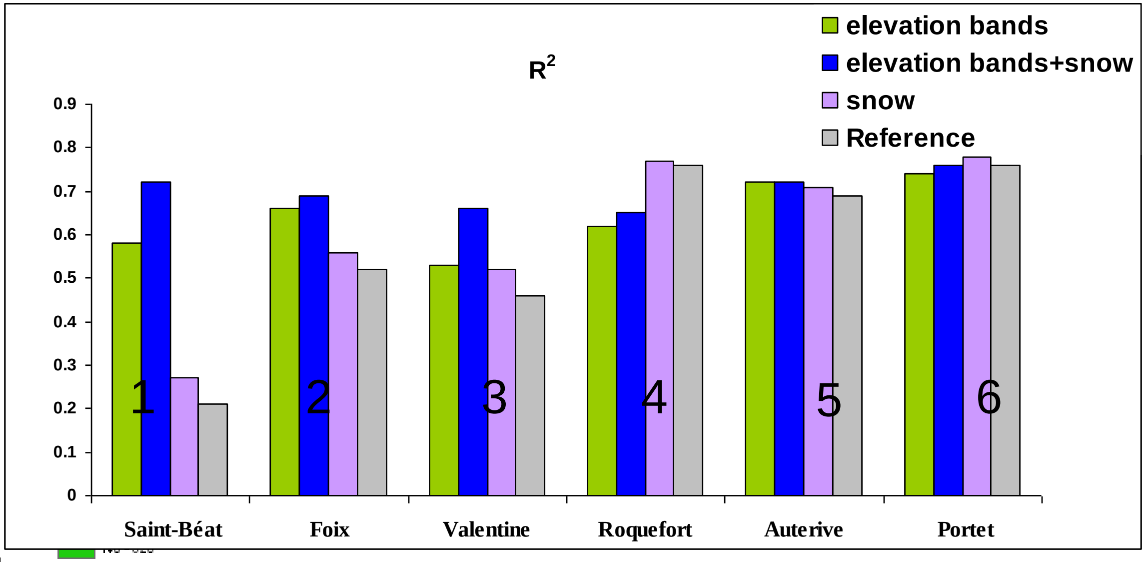


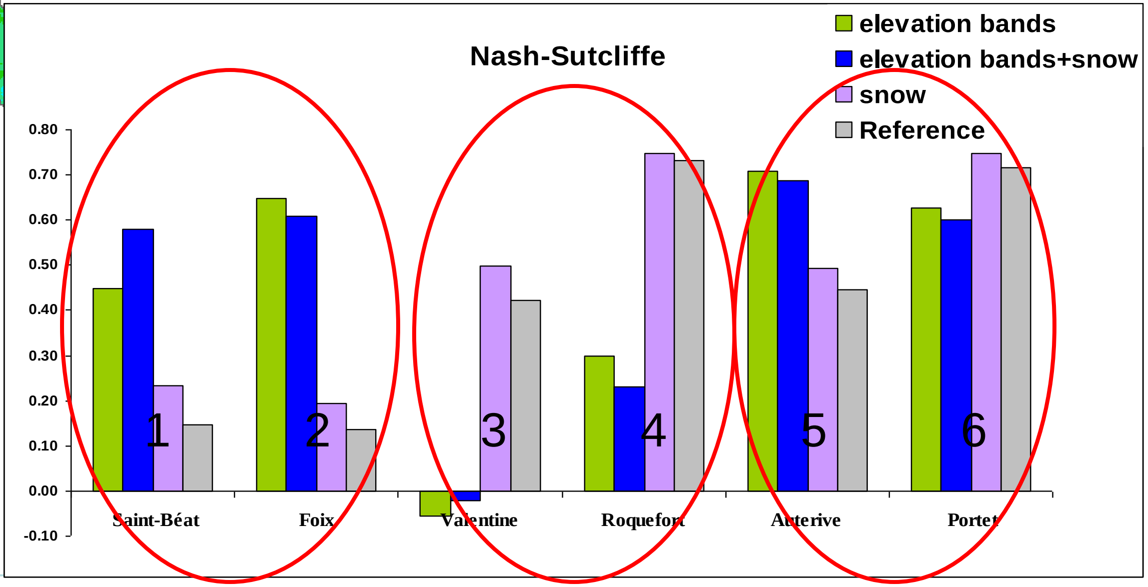




Simulated results
-applied snow parameters and elevation bands



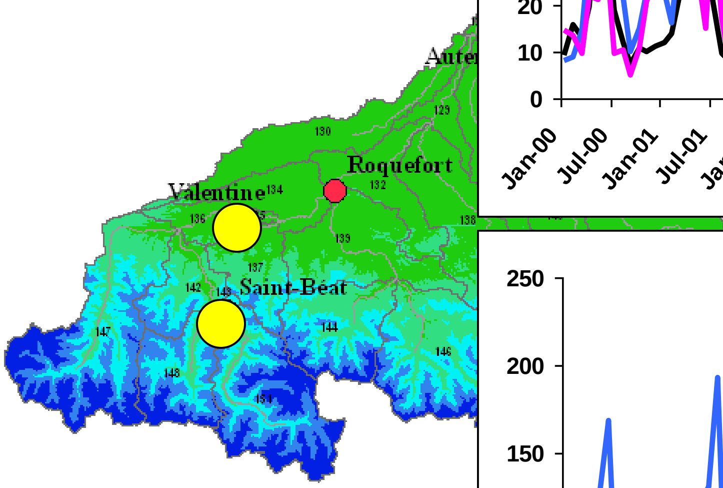


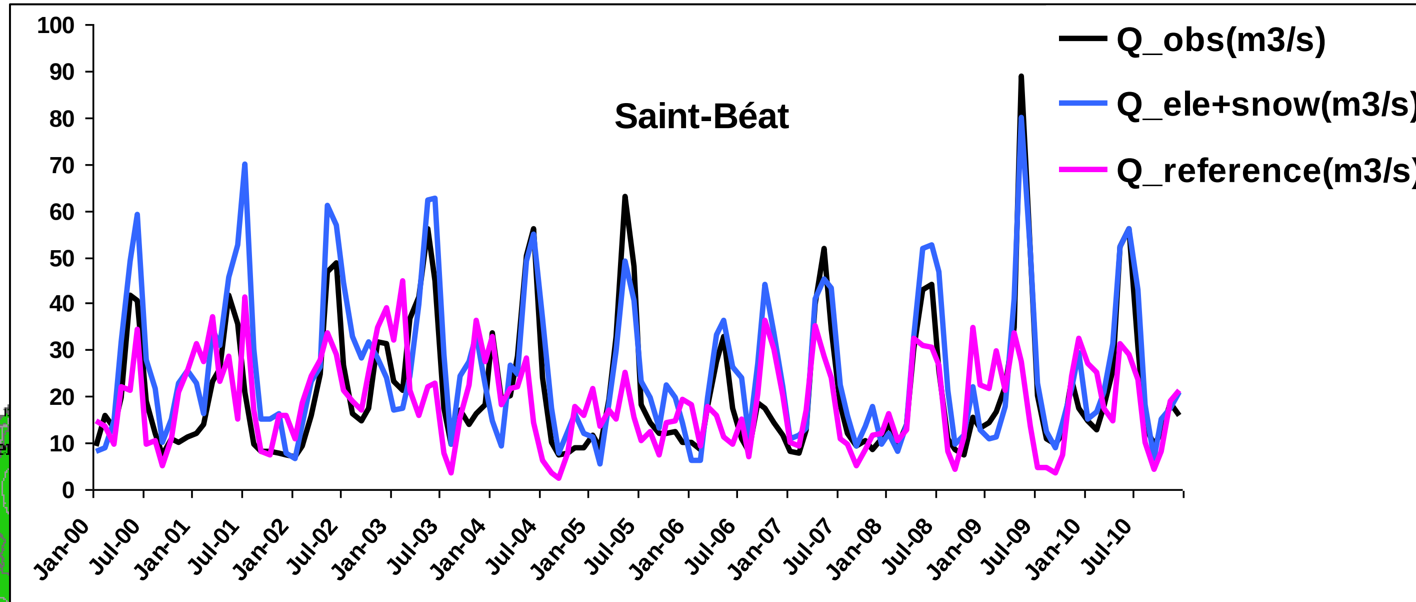


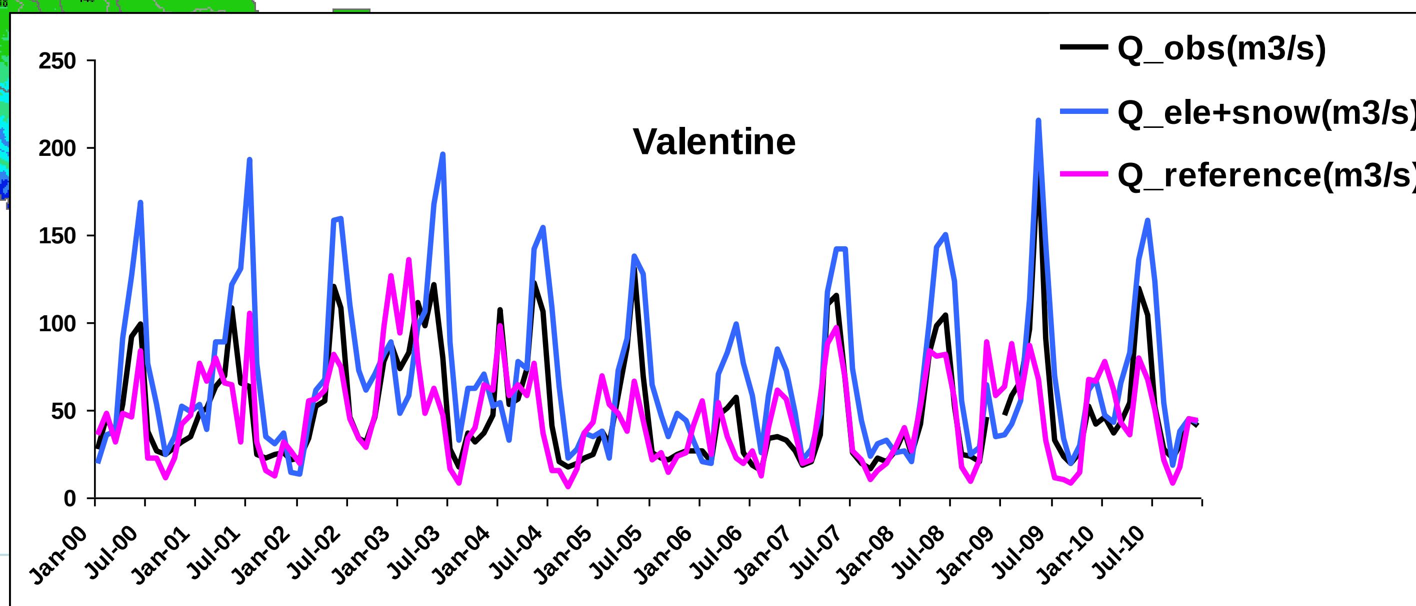
G-MOD

2013 International SWAT Conference, Toulouse, France

Discharge variation of Saint-Béat and Valentine



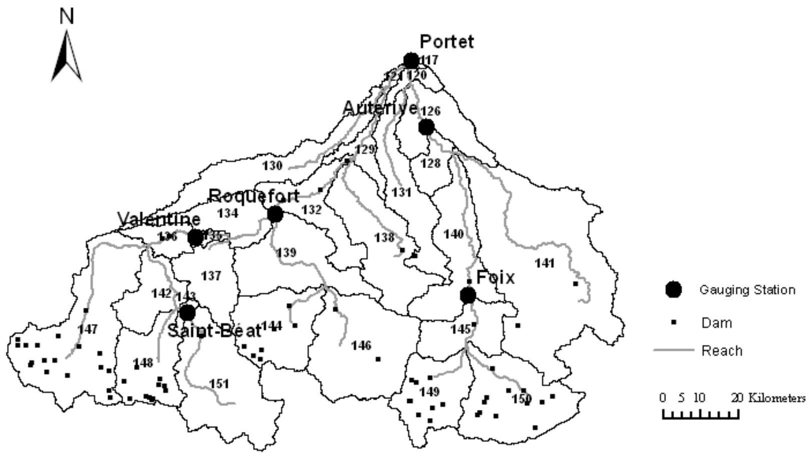




G-MOD

Discussion

- Dams on Garonne



- The evaporation is very low but infiltration of the surface water increased.
- The recharge of groundwater is increased in winter due to snowmelt and decreased in soil frost depth

Conclusion

- For most of the stations, adding elevation bands and snow parameters improve the simulated results
- Added elevation bands got better results than just modify snow parameters
- Small impact on station far from the mountains
- Few worse results
  - Possible impact of anthropization (dams)
  - Natural processes (special characteristic of mountainous hydrology)

Thank you!

Equations of snow melt

$$SNO_{mlt} = b_{mlt} \cdot sno_{\mathrm{cov}} \cdot \left[\frac{T_{snow} + T_{mx}}{2} - T_{mlt} \right]$$

where *SNOmlt* is the amount of snow melt on a given day (mm H2O), bmlt is the melt factor for the day (mm H2O/day-°C), *snocov* is the fraction of the HRU area covered by snow, *Tsnow* is the snow pack temperature on a given day (°C), Tmx is the maximum air temperature on a given day (°C), *Tmlt* is the base temperature above which snow melt is allowed (°C).

$$b_{mlt} = \frac{(b_{mlt6} + b_{mlt12})}{2} + \frac{(b_{mlt6} - b_{mlt12})}{2} \cdot \sin\left(\frac{2\pi}{365} \cdot (d_n - 81) \right)$$

where *bmlt* is the melt factor for the day (mm H2O/day-°C), *bmlt6* is the melt factor for June 21 (mm H2O/day-°C), *bmlt12* is the melt factor for December 21 (mm H2O/day-°C), dn is the day number of the year.

$$sno_{\mathrm{cov}} = \frac{SNO}{SNO_{100}} \cdot \left[\frac{SNO}{SNO_{100}} + \exp\left(\mathrm{cov}_1 - \mathrm{cov}_2 \cdot \frac{SNO}{SNO_{100}} \right) \right]^{-1}$$

where *snocov* is the fraction of the HRU area covered by snow, *SNO* is the water content of the snow pack on a given day (mm H2O), *SNO100* is the threshold depth of snow at 100% coverage (mm H2O), *cov1* and *cov2* are coefficients that define the shape of the curve, the values used for *cov1* and *cov2* are determined by the equation using two known points: 95% coverage at 95% of *SNO100* and 50% coverage at a user specified fraction of *SNO100*

$$T_{snow(d_n)} = T_{snow(d_n - 1)} \cdot (1 - l_{sno}) + \overline{T}_{av} \cdot l_{sno}$$

where *Tsnow(dn)* is the snow pack temperature on a given day(°C), *lsno* is the snow temperature lag factor, and *Tav* is the mean air temperature on the current day (°C).

Snow fall-melting and elevation bands in SWAT

$$SNO = SNO + R_{day} - E_{sub} - SNO_{mlt}$$

where *SNO* is the water content of the snow pack on a given day (mm H_2O), R_{day} is the amount of precipitation on a given day (added only if average temperature is lower than the boundary temperature (mm H_2O), E_{sub} is the amount of sublimation on a given day (mm H_2O), SNO_{mlt} is the amount of snow melt on a given day (mm H_2O).

$$R_{band} = R_{day} + \left(EL_{band} - EL_{gage}\right) \cdot \frac{plaps}{days_{pcp,yr} \cdot 1000} \; when R_{day} > 0.01$$

$$T_{mx,band} = T_{mx} + \left(EL_{band} - EL_{gage}\right) \cdot \frac{tlaps}{1000}$$

$$T_{mn,band} = T_{mn} + \left(EL_{band} - EL_{gage}\right) \cdot \frac{tlaps}{1000}$$

$$\bar{T}_{av,band} = \bar{T}av + \left(EL_{band} - EL_{gage}\right) \cdot \frac{tlaps}{1000}$$

where *Rband* is the precipitation falling in the elevation band (mm H2O), *Rday* is the precipitation recorded at the gage or generated from gage data (mm H2O); *ELband* is the mean elevation in the elevation band (m), *ELgage* is the elevation at the recording gage (m), *plaps* is the precipitation lapse rate (mm H2O/km), *dayspcp,yr* is the average number of days of precipitation in the sub-basin in a year, where *Tmx,band* is the maximum daily temperature in the elevation band (°C), *Tmn,band* is the minimum daily temperature in the elevation band (°C), *Tav,band* is the mean daily temperature in the elevation band (°C), *Tmx* is the maximum daily temperature recorded at the gage or generated from gage data (°C), *Tmn* is the minimum daily temperature recorded at the gage or generated from gage data (°C), *Tav* is the mean daily temperature recorded at the gage or generated from gage data (°C), *tlaps* is the temperature lapse rate (°C/km), and 1000 is a factor needed to convert meters to kilometers

	Parameters	definition	Min Value	Max Value	Applied Value
.bsn	ESCO	Soil evaporation compensation factor	0	1	0.5
	EPCO	Plnat watre uptake compensation factor	0	1	1
	SURLAG	Surface runoff lag time	0	10	1
.GW	GW_DELAY	Ground water delay	0	500	28
	GW_REVAP	Ground water revap	0.02	0.2	0.05
	RCHRG_DP	Deep aquifer percolation factor	0	1	0.15
	ALPHA_BF	Base flow alpha factor	0	1	0.08
.mgt	CN2	SCS curve number	35	98	AGRL 80 FRST 70 URBN 65
.bsn	PRF	Peak rate adjustment factor for sediment routing	0	2	0.58
	SPCON	Linear parameters for calculating the channel sediment routing	0.0001	0.01	0.01
	SPEXP	Exponent parameter for calculating the channel sediment routing	1	1.5	1.5