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

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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

Land use

Soil

Elevation

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Simulated results without snow and elevation bands

Tonneins

Portet

Saint-Béat

G-MOD

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Elevation and snow in SWAT

• Elevation bands
  – Variation of precipitation and temperature with elevation

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

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

• Snowfall-melting processes

\[ SNO = SNO + R_{day} - E_{sub} - SNO_{mlt} \]
### Subbasins with elevation bands

#### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Component</th>
<th>Description</th>
<th>Default value</th>
<th>Applied value</th>
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</thead>
<tbody>
<tr>
<td>TLAPS</td>
<td>Subbasin</td>
<td>Temperature lapse rate (°C/km)</td>
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</table>
Simulated results - altered snow parameters

Nash-Sutcliffe

R^2

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Simulated results - added elevation bands

\[ R^2 \]

FNormalized Nash-Sutcliffe

\[ 0.10 \]

\[ 0.20 \]

\[ 0.30 \]

\[ 0.40 \]

\[ 0.50 \]

\[ 0.60 \]

\[ 0.70 \]

\[ 0.80 \]

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Simulated results
-applied snow parameters and elevation bands

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Discharge variation of Saint-Béat and Valentine

**Graphs:**
- **Saint-Béat**
  - Q_{obs}(m^3/s)
  - Q_{ele+snow}(m^3/s)
  - Q_{reference}(m^3/s)
- **Valentine**
  - Q_{obs}(m^3/s)
  - Q_{ele+snow}(m^3/s)
  - Q_{reference}(m^3/s)
• 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

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

where \( SNO_{mlt} \) is the amount of snow melt on a given day (mm H2O), \( b_{mlt} \) is the melt factor for the day (mm H2O/day-°C), \( sno_{cov} \) is the fraction of the HRU area covered by snow, \( T_{snow} \) is the snow pack temperature on a given day (°C), \( T_{mlt} \) is the base temperature above which snow melt is allowed (°C).

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

where \( b_{mlt} \) is the melt factor for the day (mm H2O/day-°C), \( b_{mlt6} \) is the melt factor for June 21 (mm H2O/day-°C), \( b_{mlt12} \) is the melt factor for December 21 (mm H2O/day-°C), \( d_n \) is the day number of the year.

\[ sno_{cov} = \frac{SNO}{SNO_{100}} \cdot \frac{SNO}{SNO_{100}} \cdot \exp\left( \frac{cov_1 - cov_2 \cdot SNO}{SNO_{100}} \right)^{-1} \]

where \( sno_{cov} \) 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), \( SNO_{100} \) is the threshold depth of snow at 100% coverage (mm H2O), \( cov_1 \) and \( cov_2 \) are coefficients that define the shape of the curve, the values used for \( cov_1 \) and \( cov_2 \) are determined by the equation using two known points: 95% coverage at 95% of \( SNO_{100} \) and 50% coverage at a user specified fraction of \( SNO_{100} \)

\[ T_{snow(d_n)} = T_{snow(d_n-1)} \cdot (1 - l_{sno}) + \bar{T}_{av} \cdot l_{sno} \]

where \( T_{snow(dn)} \) is the snow pack temperature on a given day(°C), \( l_{sno} \) is the snow temperature lag factor, and \( T_{av} \) 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\(_2\)O), \( R_{day} \) is the amount of precipitation on a given day (added only if average temperature is lower than the boundary temperature (mm H\(_2\)O), \( E_{sub} \) is the amount of sublimation on a given day (mm H\(_2\)O), \( SNO_{mlt} \) is the amount of snow melt on a given day (mm H\(_2\)O).

\[ R_{band} = R_{day} + (EL_{band} - EL_{gage}) \cdot \frac{plaps}{days_{pcp,yr} \cdot 1000} \text{ when } R_{day} > 0.01 \]

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

\[ T_{mn,band} = T_{mn} + (EL_{band} - EL_{gage}) \cdot \frac{tlaps}{1000} \]

\[ \overline{T}_{av,band} = \overline{T}_{av} + (EL_{band} - EL_{gage}) \cdot \frac{tlaps}{1000} \]

where \( R_{band} \) is the precipitation falling in the elevation band (mm H\(_2\)O), \( R_{day} \) is the precipitation recorded at the gage or generated from gage data (mm H\(_2\)O); \( EL_{band} \) is the mean elevation in the elevation band (m), \( EL_{gage} \) is the elevation at the recording gage (m), \( plaps \) is the precipitation lapse rate (mm H\(_2\)O/km), \( days_{pcp,yr} \) is the average number of days of precipitation in the sub-basin in a year, where \( T_{mx,band} \) is the maximum daily temperature in the elevation band (°C), \( T_{mn,band} \) is the minimum daily temperature in the elevation band (°C), \( T_{av,band} \) is the mean daily temperature in the elevation band (°C), \( T_{mx} \) is the maximum daily temperature recorded at the gage or generated from gage data (°C), \( T_{mn} \) is the minimum daily temperature recorded at the gage or generated from gage data (°C), \( T_{av} \) 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.
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