Continuous simulation of the inflow discharge for regulated reservoirs using distributed hydrological model with continuous soil moisture account

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AIM OF THE WORK

To develop a distributed, grid, physically based hydrological model for continuous simulation of the inflow to the Lake Maggiore in Northern Italy, on the Alps.

The hydrological model is a component of a more complex Decision Supporting System for the real time management of the regulation policy of lake stage.

Useful in particular during flood events.

In the real time configuration, hydrologic model will be forced by rainfall forecast with two days in advance.

FEST-WB: <u>F</u>lash – flood <u>E</u>vent – based <u>S</u>patially – distributed rainfall – runoff <u>T</u>ransformation – including <u>W</u>ater <u>B</u>alance
(Prof. M., Mancini)

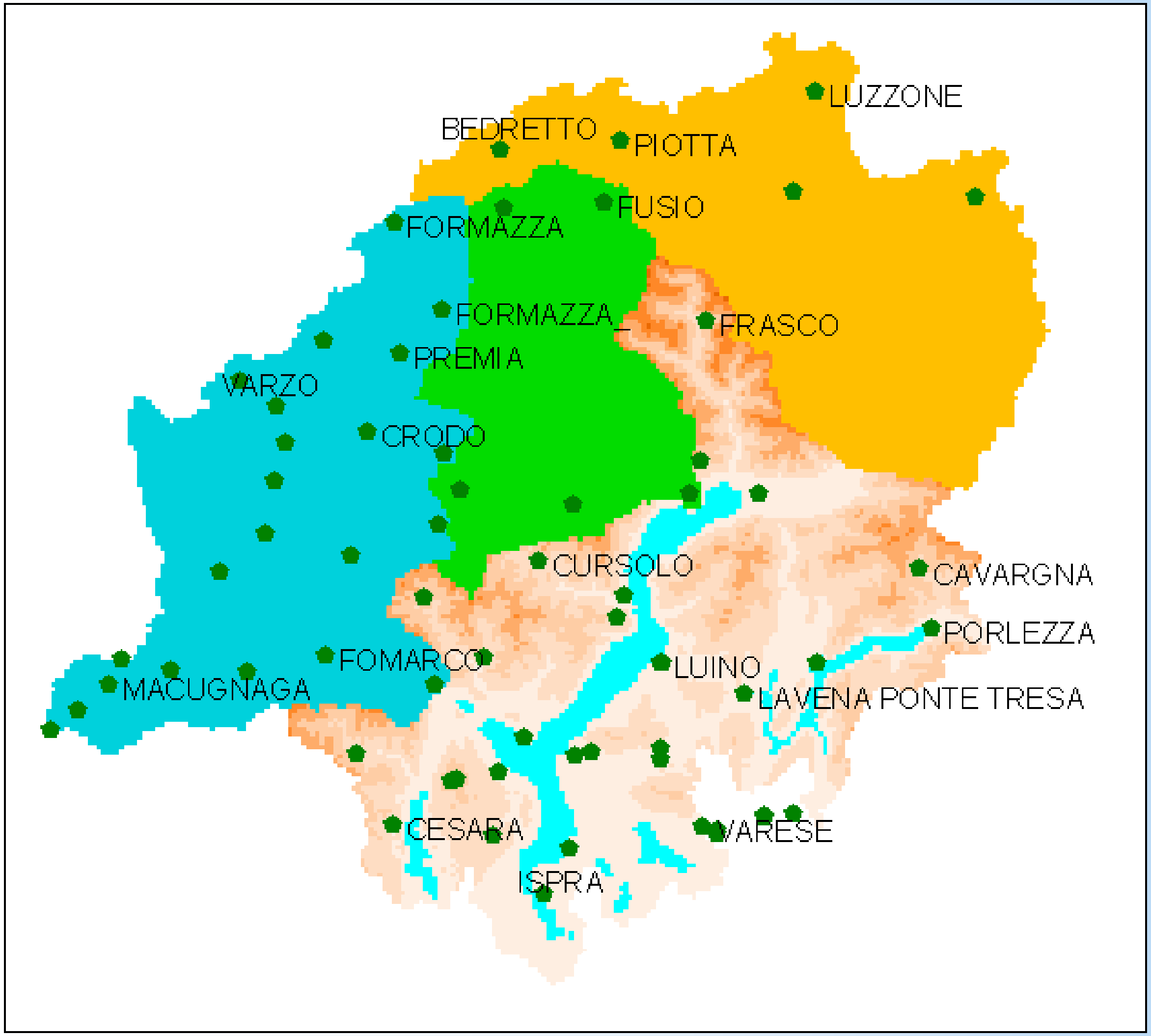
THE CASE STUDY

BASIN	Km^2
TICINO	1537
TOCE	1544
MAGGIA	902
Total	**3983**
TOTAL LAKE BASIN	**6598**

MAIN BASINS = 60.4 %

AVAILABLE TIME SERIES

From 1 January 2000 To 31 Dicember 2003
hourly or sub-hourly time step

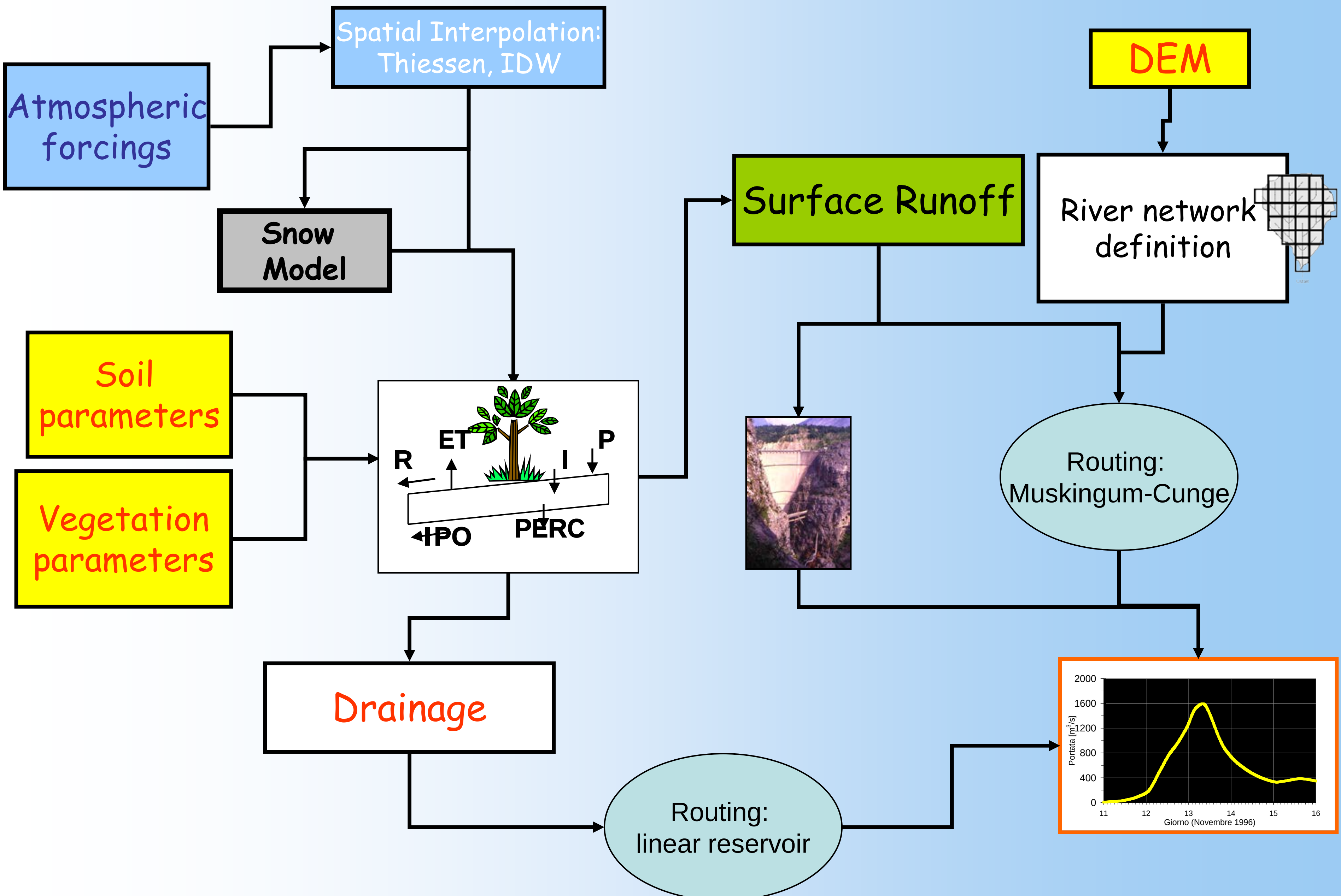


Position of meteorological stations:

- rain gages
- temperatures
- total solar radiation
- air relative humidity

Real time monitoring network managed by Regione Piemonte, Regione Lombardia and Switzerland.

DISTRIBUTED MODEL FLOW CHART



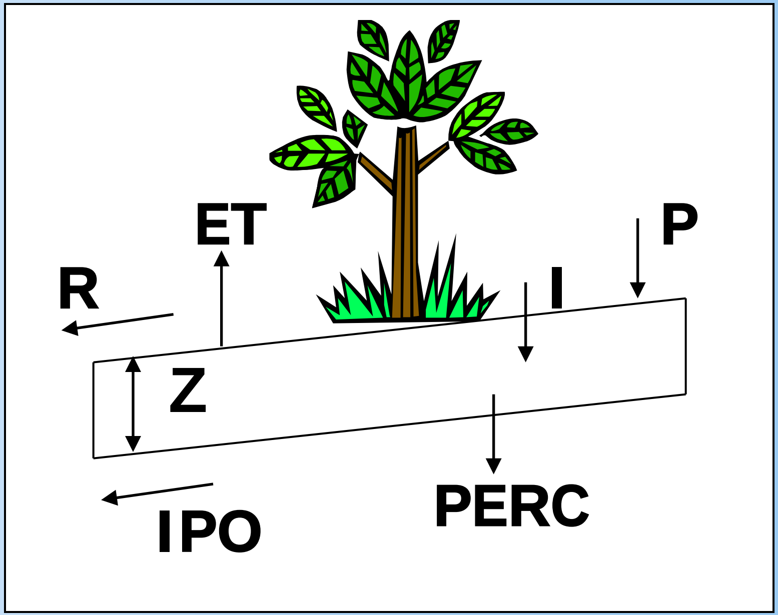
SOIL MOISTURE UPDATING

$$P_{tot} = R + ET_{eff} + PERC + (\theta_{t+1} - \theta_t) * Z$$

$$\theta_{t+1} = \theta_t + \frac{(I - PERC - ET)}{Z}$$

$$PERC = K_{sat} \cdot \left(\frac{\theta - \theta_{res}}{\theta_{sat} - \theta_{res}}\right)^{\left(\frac{2+3\cdot B}{B}\right)}$$

(Famiglietti e Wood 96)



EVAPOTRANSPIRATION → PRIESTLEY TAYLOR (PET)

$$ETP = \alpha \frac{\Delta}{\Delta + \gamma} E_r$$

Er (Rn)

$$ETeff = ETP \cdot \frac{\theta_{t-1} - WP}{FC - WP}$$

INFILTRATION MODEL

SCS-CN method (1956) modified for continuos soil moisture accounting

$$I = P_{TOT} - R$$

$$Ia = 0{,}2\ S$$

$$R = \frac{(P_{TOT} - Ia)^2}{P - Ia + S}$$

I = infiltration

P_{TOT} = precipitation

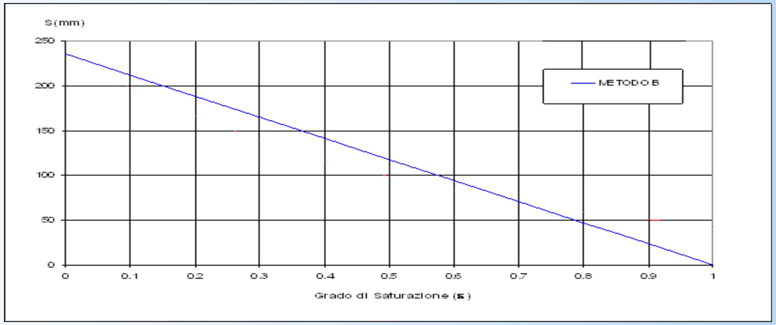
R = runoff

Ia = initial abstraction

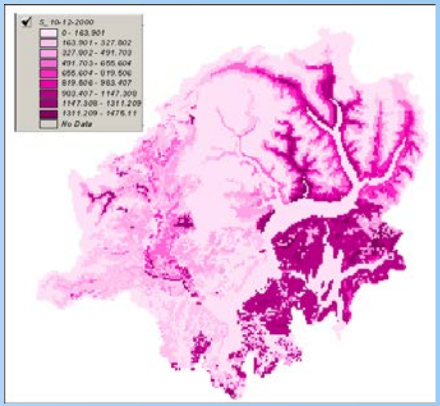
S (potential maximum retention) linear function of the soil degree of saturation (ε)

$$\varepsilon_t = \frac{\theta_t - \theta_{res}}{\theta_{sat} - \theta_{res}}$$

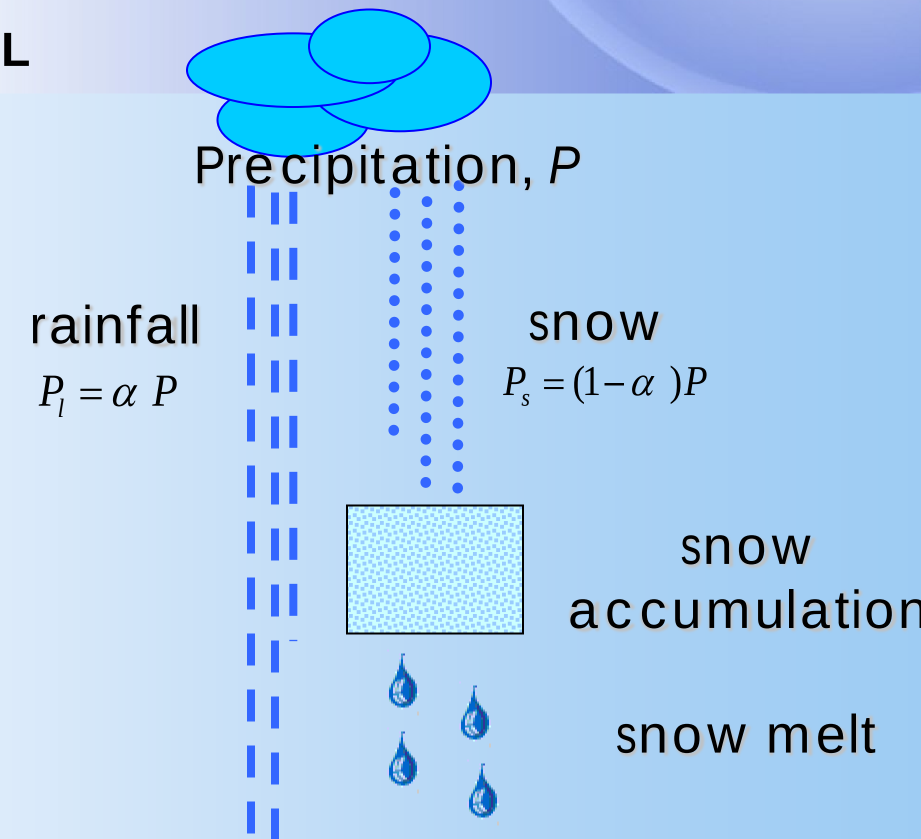
$$S_t = S_1 \cdot (1 - \varepsilon_t)$$



S map at the beginning of the storm

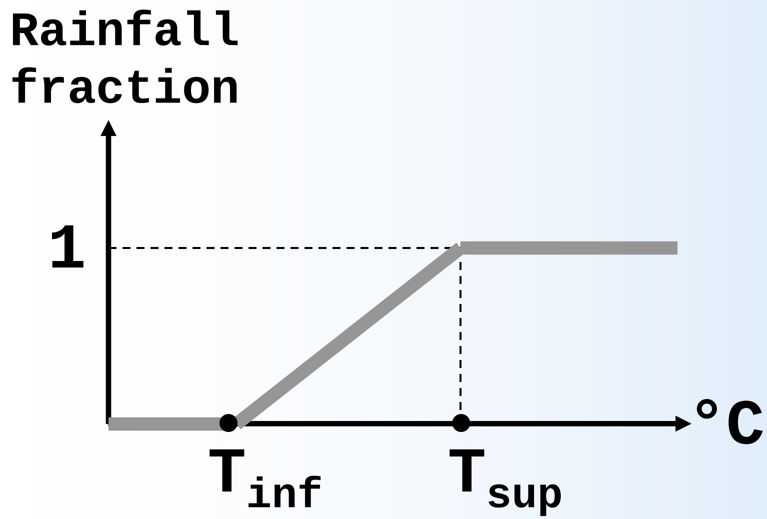


SNOW DYNAMICS MODEL



SNOW ACCUMULATION

$$
\begin{cases}
\alpha = 0 & \Leftrightarrow T_a \le T_{inf} \\
\alpha = \dfrac{T_{air}(t) - T_{inf}}{T_{sup} - T_{inf}} & \Leftrightarrow T_{inf} < T_a < T_{sup} \\
\alpha = 1 & \Leftrightarrow T_a > T_{sup}
\end{cases}
$$



SNOW MELT

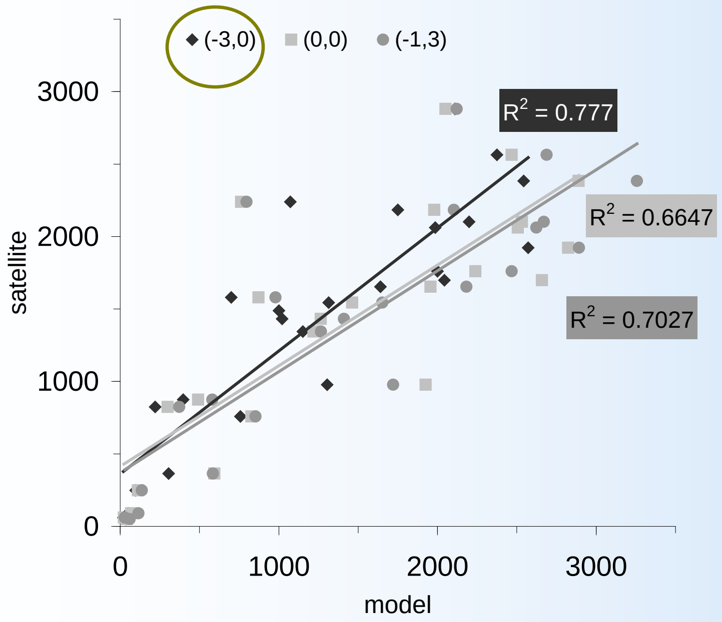
$$SnowMelt = C_m (T_a - T_b)$$

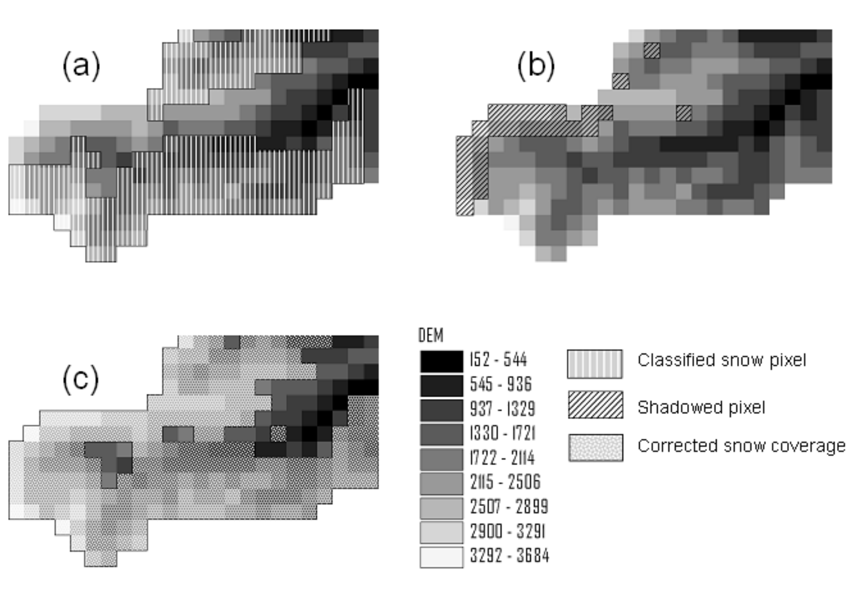
T_a = air temperature
T_b = threshold temperature
C_m = melt coefficient [m/(s °C)]

SNOW MODEL CALIBRATION

NOAA-AVHRR remote images
(1.1 km X 1.1 km) 10 February 2001

Number of snow covered pixels:





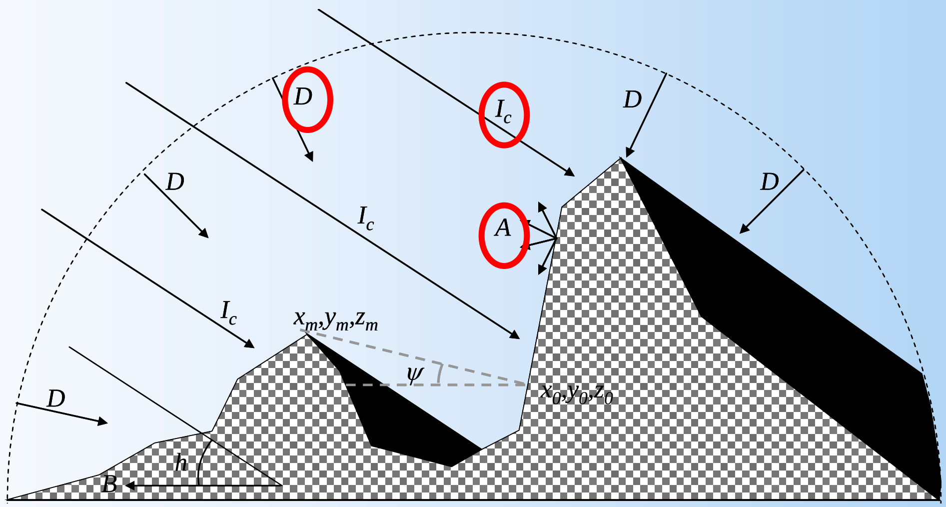
(a) pixels classified as snow covered
(b) higher crests induced shadowed pixels
(c) resulting snow coverage after elevation based correction

EFFECT OF TOPOGRAPHY ON SHORTWAVE RADIATION

Incident short wave radiation for clear sky condition:

$$S_{in} = I_c + D + A$$

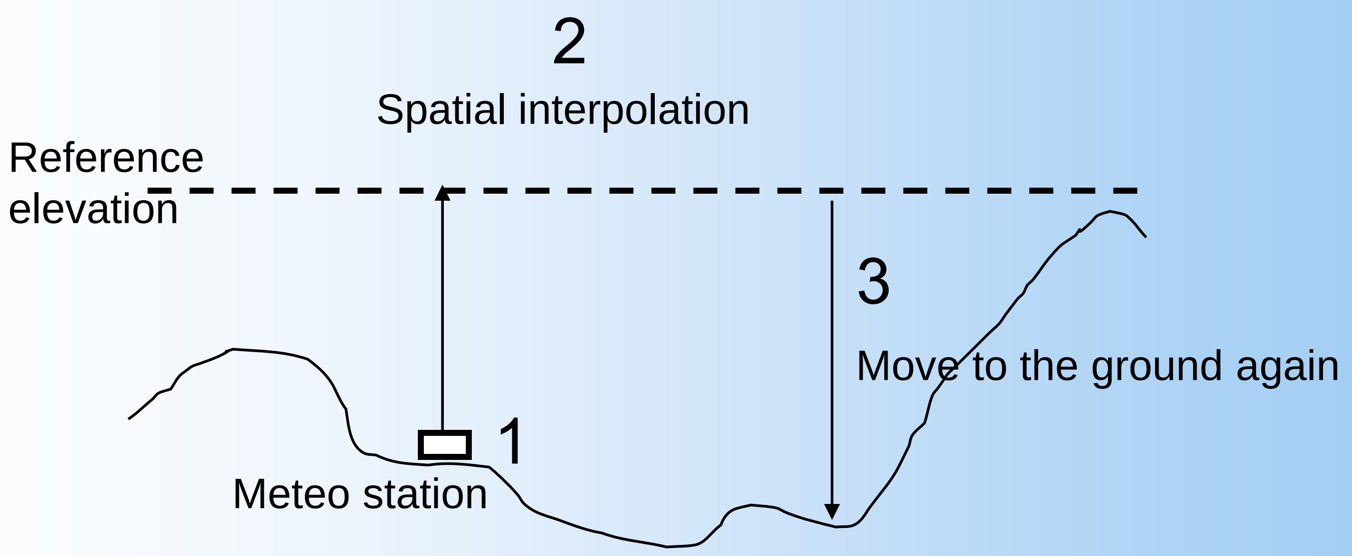
- I_c: direct
- D: scattered
- A: reflected



Topographic constraints:

- slope
- aspect
- shadowing

EFFECT OF TOPOGRAPHY ON AIR TEMPERATURE



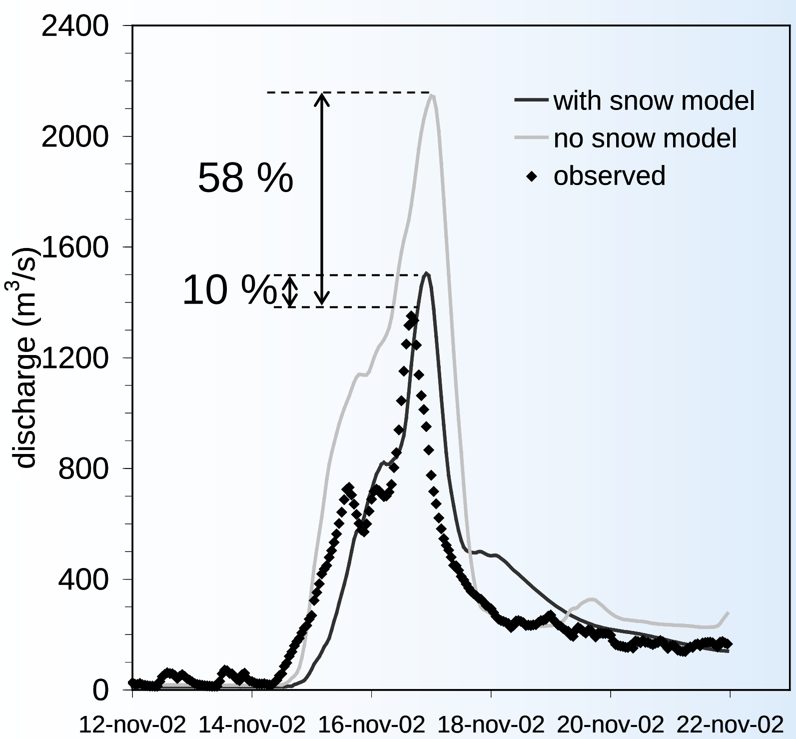
(1) Move measurements on a reference plane keeping into account a fixed thermal gradient (-0.0065 °Cm^{-1})

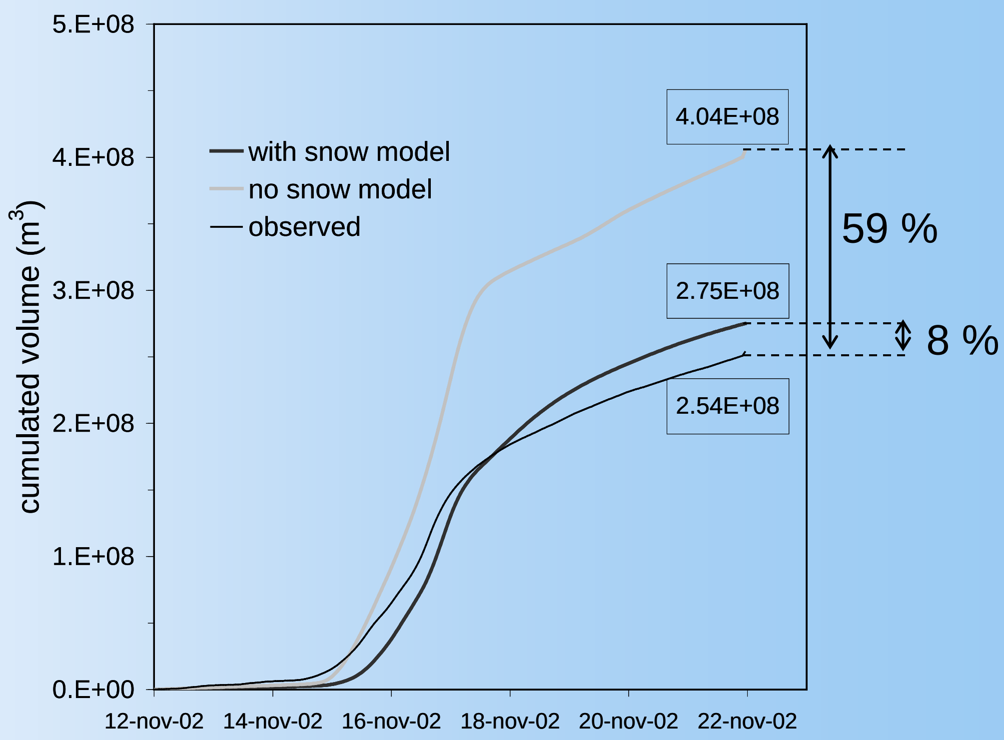
(2) Spatial interpolation on the reference plane

(3) Data are taken to the ground keeping into account a fixed thermal gradient (-0.0065 °Cm-1).

EFFECT OF SNOW DYNAMICS ON FLOOD SIMULATION

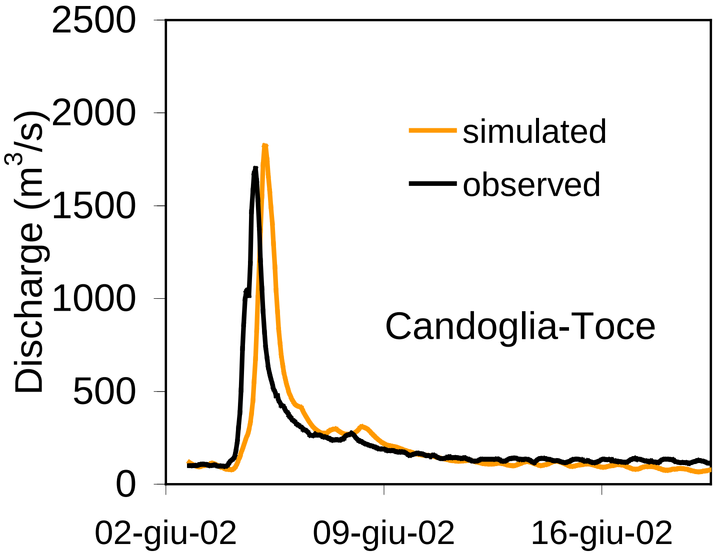
River Ticino at Bellinzona

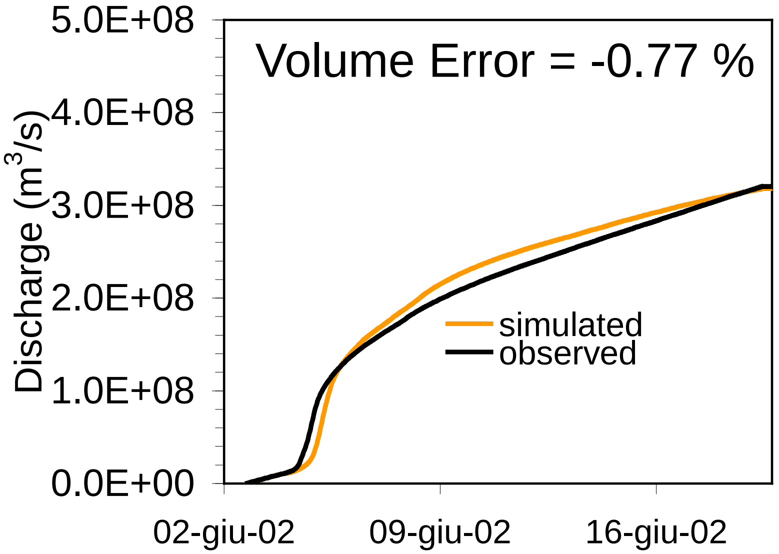




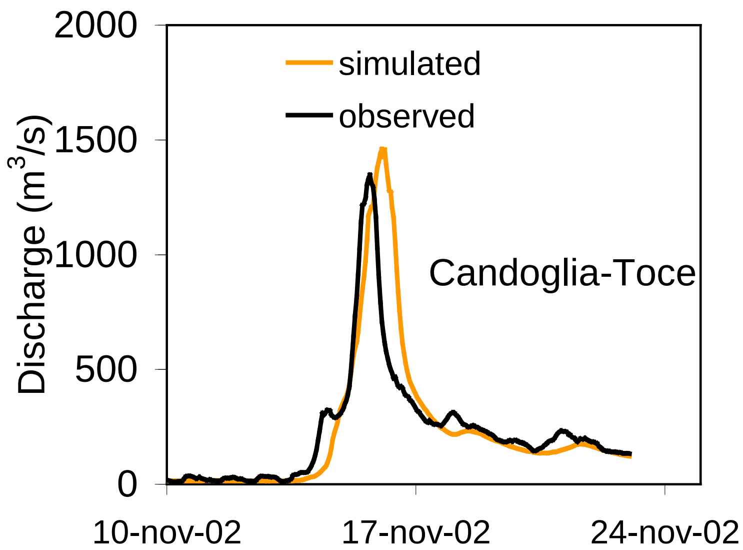
FLOOD EVENTS: section of Candoglia, River Toce

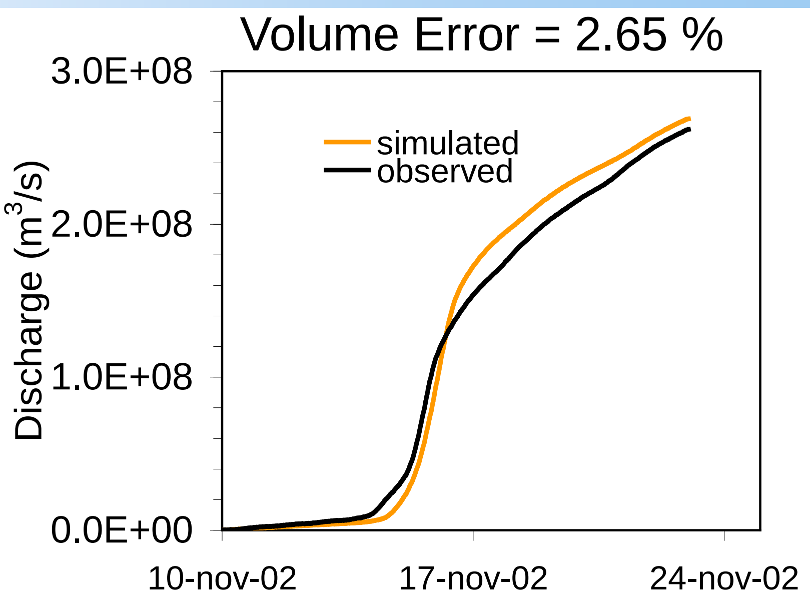
RMSE 253.1 m³/s   Peak error = 7.1 %   Nash = 0.15





RMSE 166.2 m³/s   Peak error = 8.3 %   Nash = 0.59



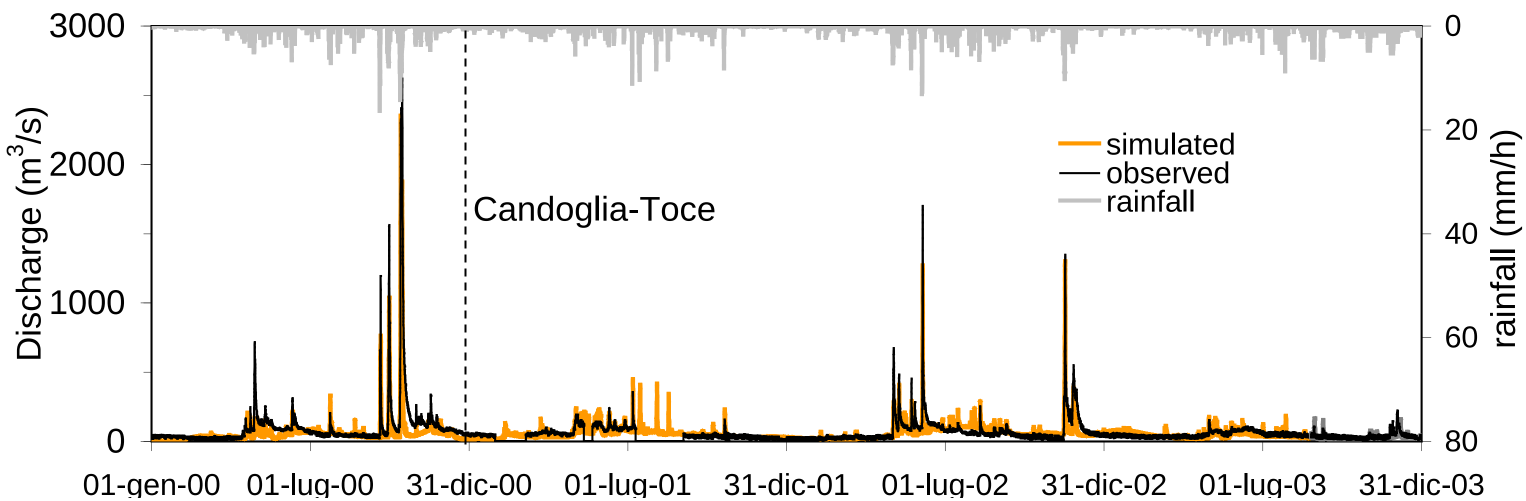


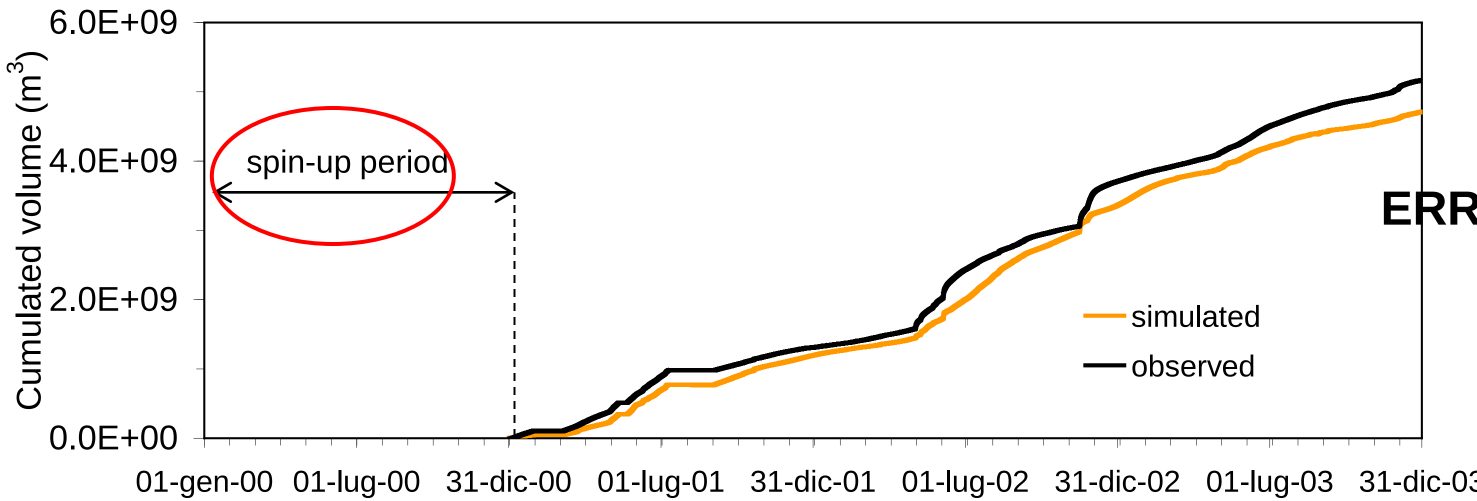
CONTINUOUS SIMULATION: Toce at Candoglia

Simulation period: 1° January 2000 – 31 December 2003
temporal step: 1 hour

RMSE 49.43 m³/s
NASH 0.71

$$\eta = 1 - \frac{\sum_{j=1}^{n_t} \left(Q_{m,j} - Q_{o,j}\right)^2}{\sum_{j=1}^{n_t} \left(Q_{o,j} - \overline{Q_o}\right)^2}$$





ERROR -8.5 %

CONCLUDING REMARKS

• The importance of simulating snow dynamics in mountain areas

•Possibility of using remote sensing images for the calibration of snow model parameters. Necessity of snow map correction.

•Distributed model simulate quite well flood volume. Suitable for a real time application for lake regulation.

Thank You for your attention !

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