4.1. Snowmelt submodel of TETIS

The snowmelt submodel of the TETIS model is a distributed hydrological conceptual model, which is able to simulate continuously the main components of the hydrological cycle. The model has been applied to different basins during the last years, with good results in different climatic scenarios, with a wide range of basin areas (Viecel, 2001; Franques et al., 2002; Viecel et al., 2002a, 2002b and 2002c). Franques et al. (2004) has carried out a model validation in TETIS for runoff production at each cell consists of five vertical levels, each representing the different snow cover classes in an upper soil layers. These levels are called: snow, sub-snow, sub-surface, sub-groundwater, aquifer and in the areas of snow an additional level is activated to represent the snow melt. This conceptualization prevents all processes taking their physical meaning (Flores et al., 2007). At each cell the main snow parameters must be estimated previously using topographical, environmental, land use, pedological and climatic data. The TETIS model uses geographic information, inputs y parameters (Table 3), following the algorithm described in Figure 1. The snowmelt parameters and area are described in Table 1.

4.2. Inputs of model

The TETIS model uses the inverse distance method to interpolate spatially large inputs such as rainfall, interception and the snow covered area of the snow water equivalent initial value.

4.3. Raster information

The evaluation of the modeled results was performed using the observed snow water equivalent (SWE) at daily scale, daily discharges at the basin outlet and some snow-covered areas provided by NOAA (Figure 2 and Table 1). The temporal and spatial validation using five periods must be considered in both basins excellent for discharges (NSEs higher than 0.95) and good for snow distribution (daily spatial coverage errors ranging from -10 to 27%).

5. Model Calibration

The TETIS model includes an automatic calibration, based on the SCE-UA algorithm (Duan et al., 1992). To this end, the best parameters range is defined following a split-structure, as presented by Franques and Berntsen (1995) and Franques et al. (2002). In this way, the calibration involves in TETIS II two correction factors (CF1 and CF2), which globally determine the different parameters used in each cell. Each study period is characterized by a degree of stability in the energy fluxes and assess what degree of complexity is recommended for the model. The sensibility analysis results are presented in Table 4. The automatic calibration allows to validate the model using observed and simulated streamflow only at the three designated basin outlets (Clementine and Gardnerville) and SNM NEL in Table 3.

5.1. Automatic Calibration I

The automatic calibration was carried out three steps (Figure 3). In calibration I, the automatic calibration methodology was the same as in calibration II, but with a different period of time. Spatial calibration is performed using the same period of time used during the calibration but in an other subbasin, usually located upstream. And the validation is carried out by comparing observed and simulated streamflow only at the three designated basin outlets (Clementine and Gardnerville) and SNM NEL in Table 3.

5.2. Calibration II (degree-day submodel)

The calibration parameters were done using all the SNM NEL stations in the American River and Carson. In the calibration of the snowmelt submodel in both basins, medium and high snow cover were used the parameters for the American River basin T=28, M=2.7 y M=5.3 and for the Carson River T=35, M=2.8 y M=5.8. The results obtained are shown in Figure 2 (M=2.88 for American River and M=2.93 for Carson River basin).

5.3. Automatic Calibration III

The model was carried out three hydrologic episodes (Table 3), of binary: measured runoff at the basin outlet and the Nash-Sutcliff coefficient, which is implemented in the distributed and conceptually based TETIS model, assuming an empirical relationship between air temperatures and melt rates, applied and revised (e.g. Clyde, 1931; Coble, 1934; Corps of Engineers, 1956; Hoinkes and Stolzenburg, 1979; Bartsch et al., 1983). The degree-day method was implemented with a simple and parametric programming using one chemical weighting for snowfall and another for snow.

6. Model Validation

Distributed models were validated temporarily, spatially and temporally, according to the available data (Table 5). The first case is validation using the same gauge station used during the calibration but with a different period of time. Spatial calibration is performed using the same period of time used during the calibration but in an other subbasin, usually located upstream. And the validation is carried out by comparing observed and simulated streamflow only at the three designated basin outlets (Clementine and Gardnerville) and SNM NEL in Table 3.

7. Conclusions

As expected, the model does not map the observed snow water equivalent (SWE) at daily scale, daily discharges at the basin outlet and some snow-covered areas provided by NOAA (Figure 2 and Table 1). The results in Table 2 show the validation of the three hydrologic episodes (Table 3) of binary: measured runoff at the basin outlet and the Nash-Sutcliff coefficient, which is implemented in the distributed and conceptually based TETIS model, assuming an empirical relationship between air temperatures and melt rates, applied and revised (e.g. Clyde, 1931; Coble, 1934; Corps of Engineers, 1956; Hoinkes and Stolzenburg, 1979; Bartsch et al., 1983). The degree-day method was implemented with a simple and parametric programming using one chemical weighting for snowfall and another for snow.

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