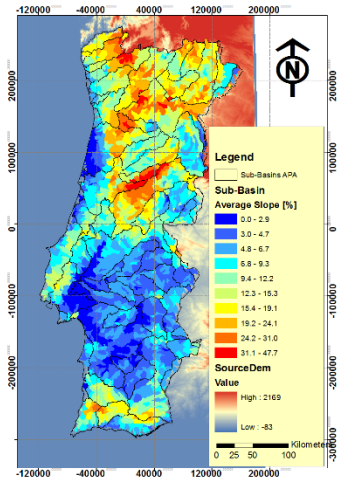
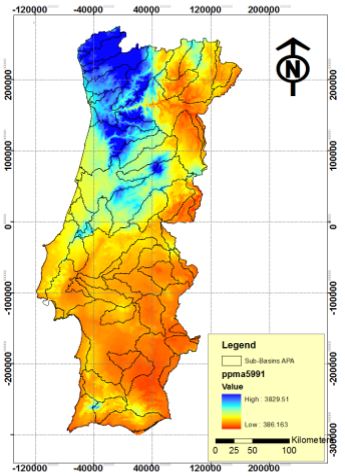
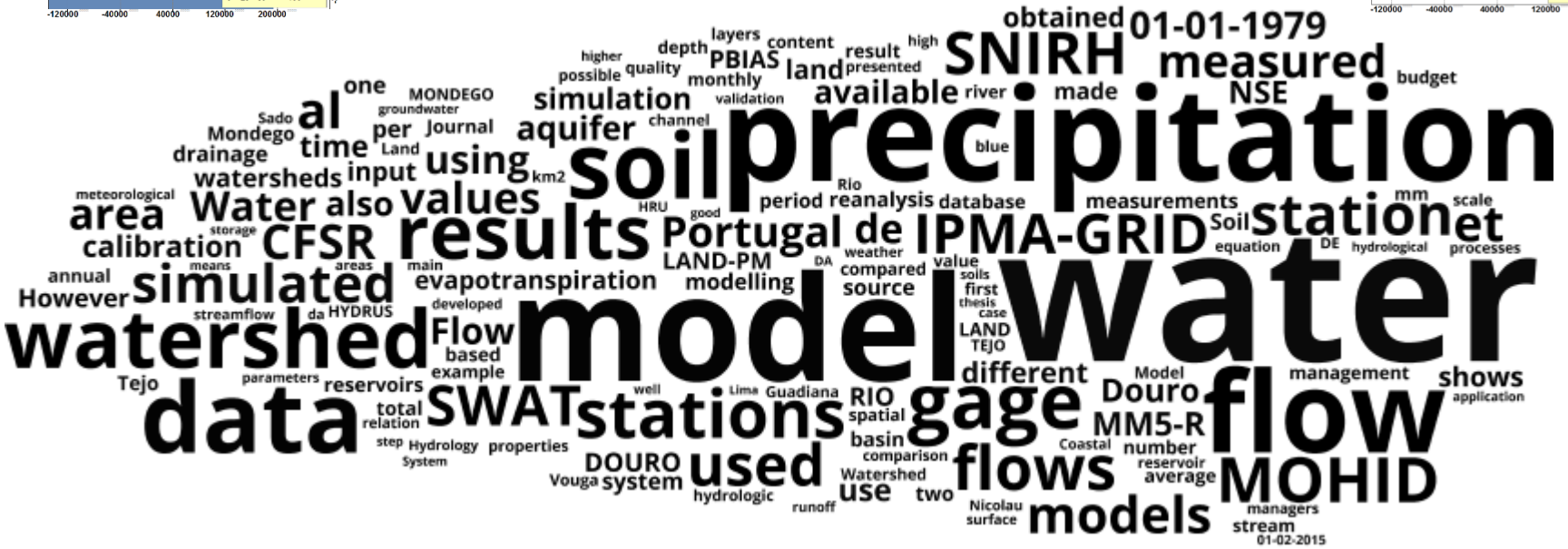
Hydrologic modelling for Portugal



Pedro Chambel Leitão

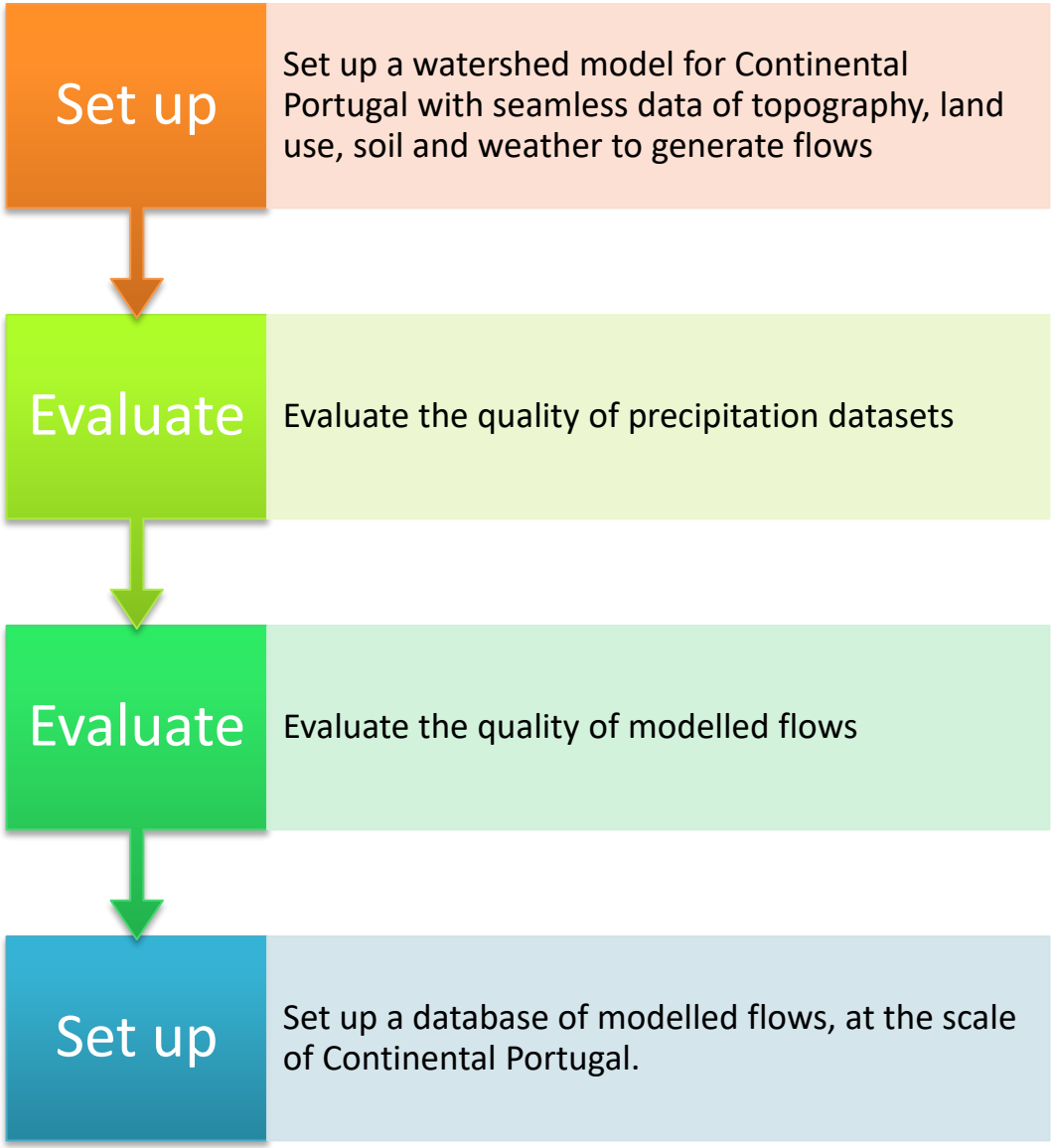




General objective

1. Is it possible to apply a unified modelling strategy to estimate flows throughout the entire continental portion of the country?

Specific objectives



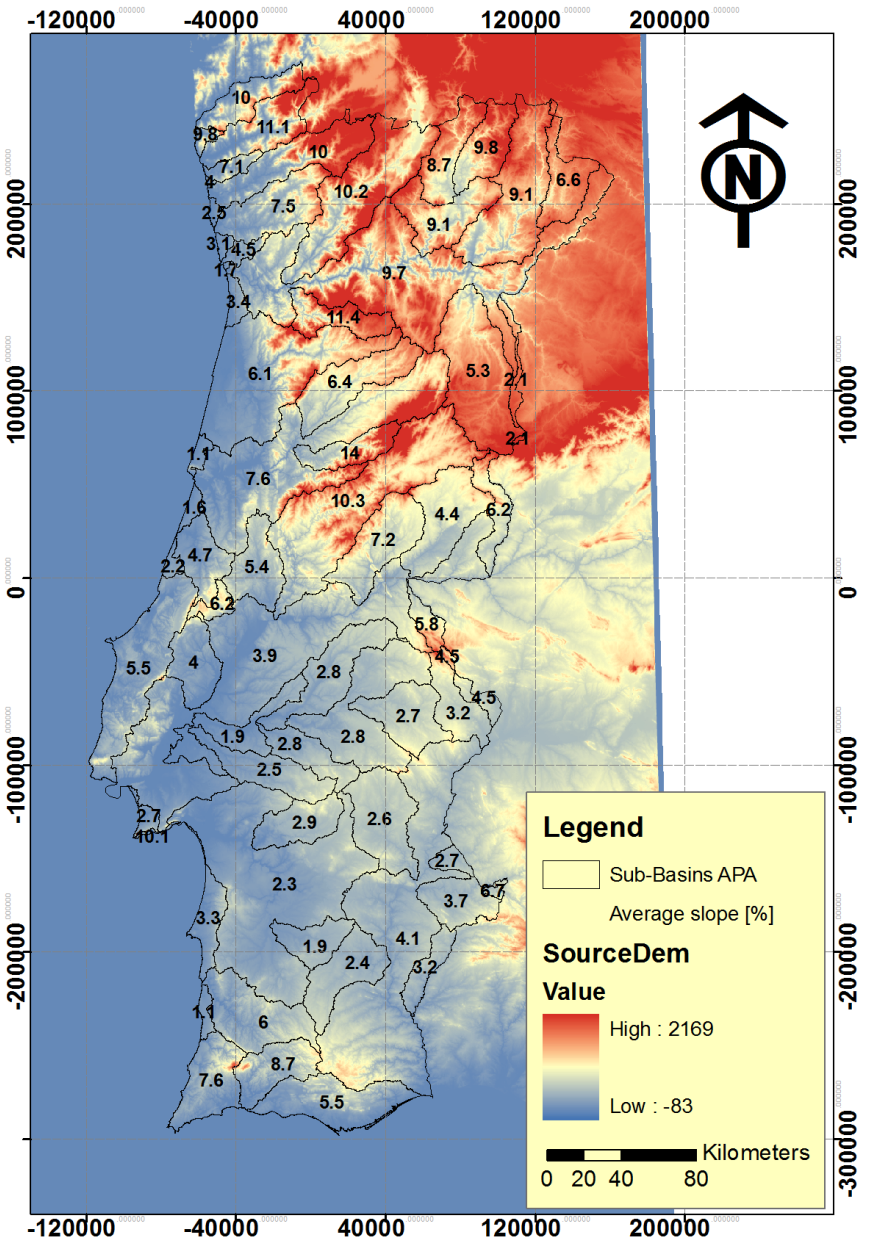
Methodology

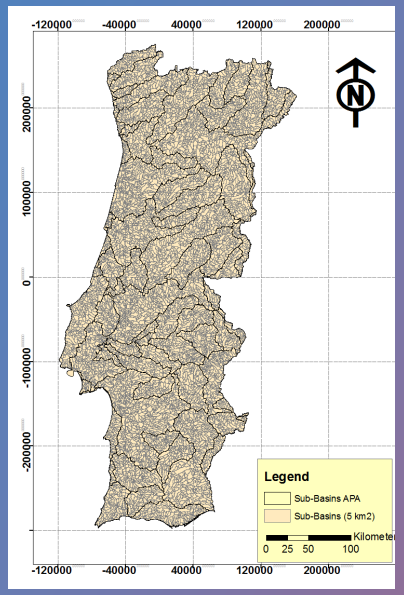
- The volume variation of a watershed ($^{\partial S}/_{\partial t}$ where *S* is stored volume and *t* is time) depends on the fluxes of the watershed. The possible fluxes are Precipitation (P), Evapotranspiration (ET), Flow in outlet of watershed (Q_{CH}) and Flow through aquifer in or out of watershed boundaries (Q_{GW}).

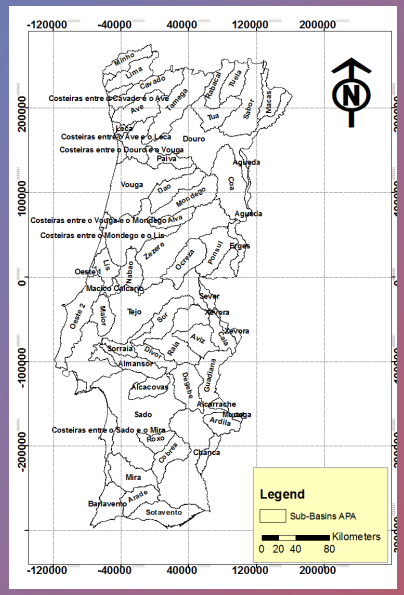
$$\frac{\partial S}{\partial t} = P - ET - Q_{ch} - Q_{gw}$$

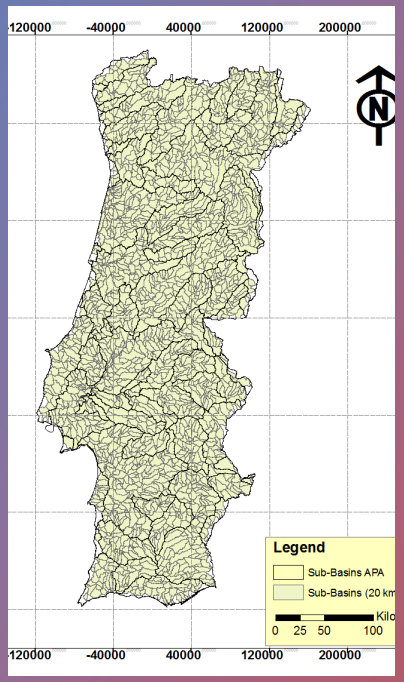
Geometry definition

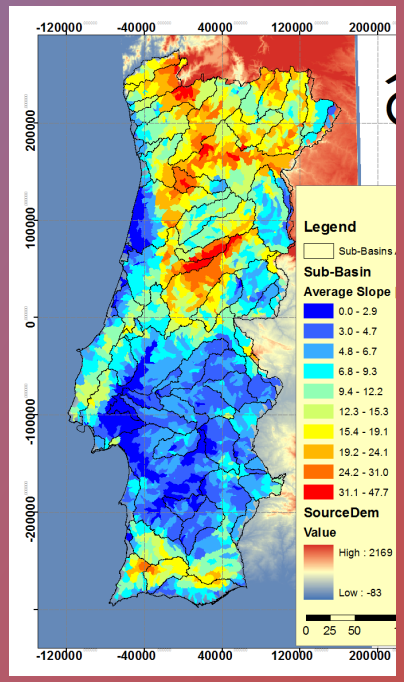
- The digital elevation model (DEM) is in a raster format with a grid resolution of 70 m which was clipped from the Shuttle Radar Topography Mission (SRTM) DEM data. This generated a file with 4358 * 9356 cells.
- Figure shows the average slope for each of the represented sub-basins. The highest slopes are located in the sub basins in the north-east of Portugal, and the lowest in the south and west of Portugal.









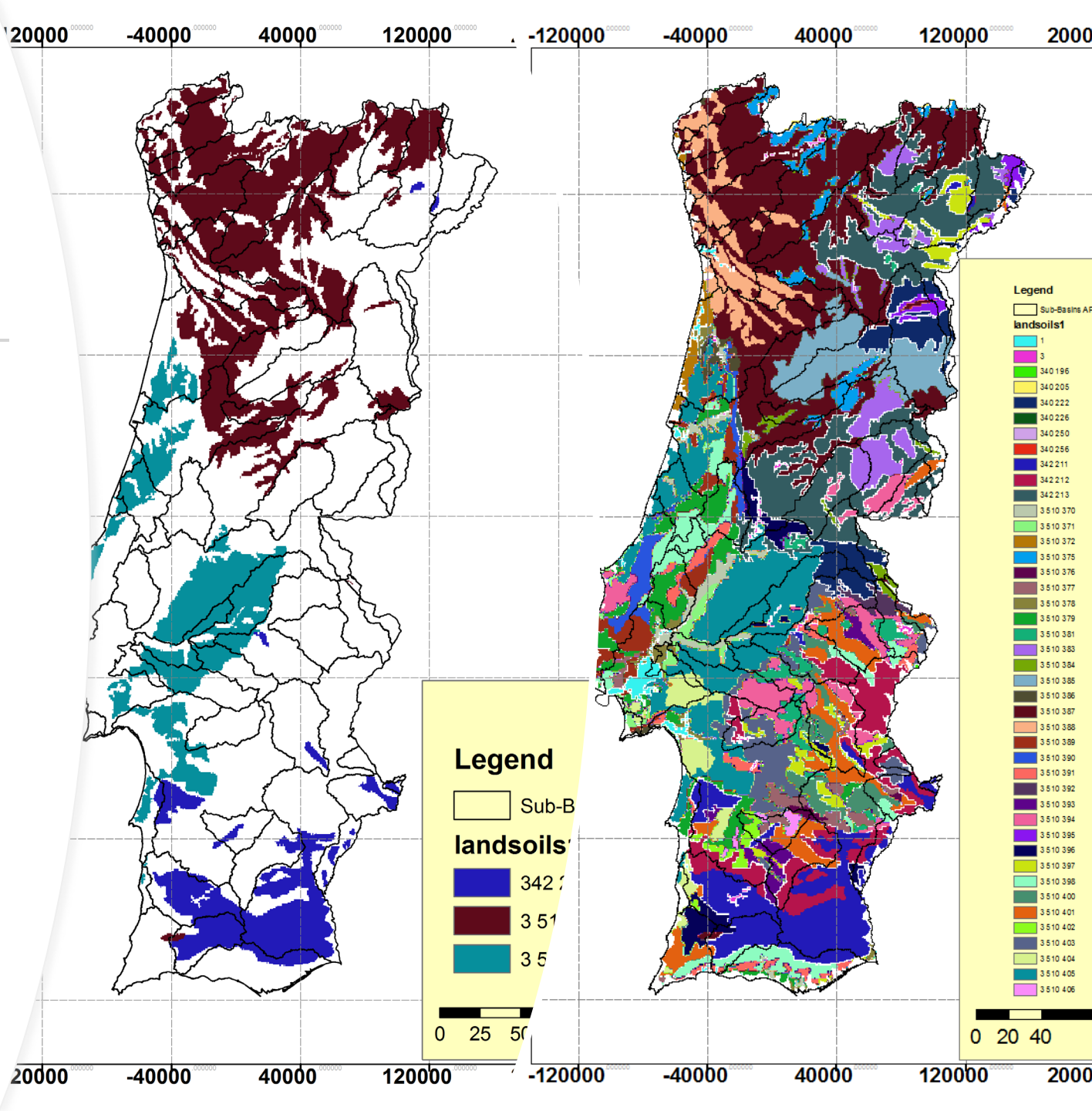


Geometry definition

- First a mask of Portugal was imposed on the DEM
- Then applying a flow accumulation threshold, Continental Portugal was subdivide in sub-basins, based on the DEM.
- Two threshold were tested:
  - 5 km2
  - 20 km2
- Average slope per subbasin

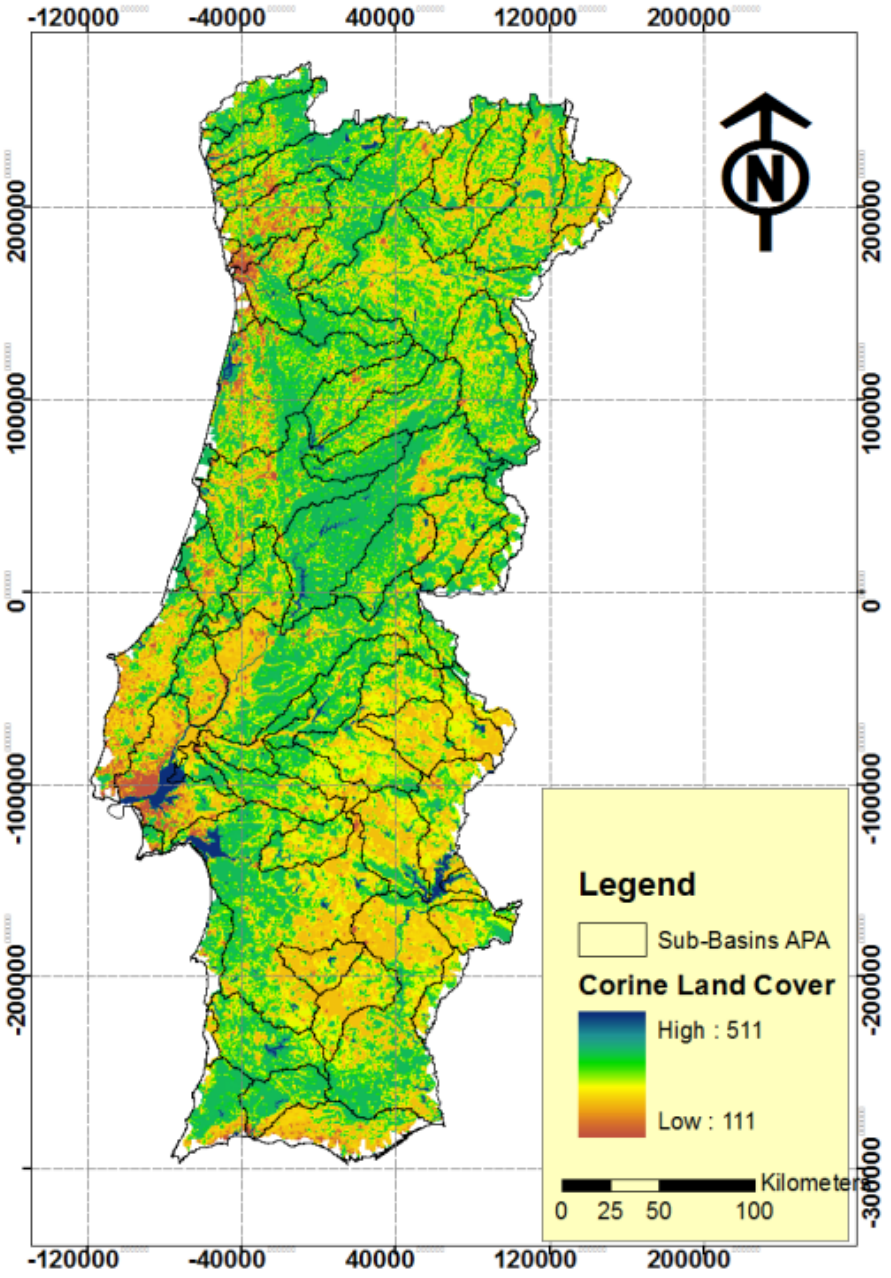
Input - Soil

- Soil Geographical Database of Eurasia (SGDBE) is available at the Soil Typological Unit (STU) level, characterised by attributes specifying the nature and properties of soils.
- For mapping purposes, the STUs are grouped into Soil Mapping Units (SMU) since it is not possible to delineate each STU



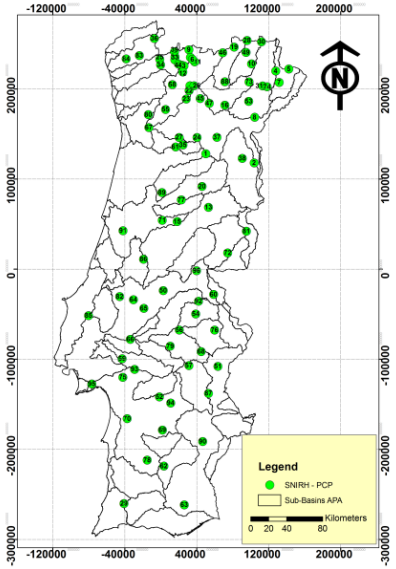
Inputs-Land Use

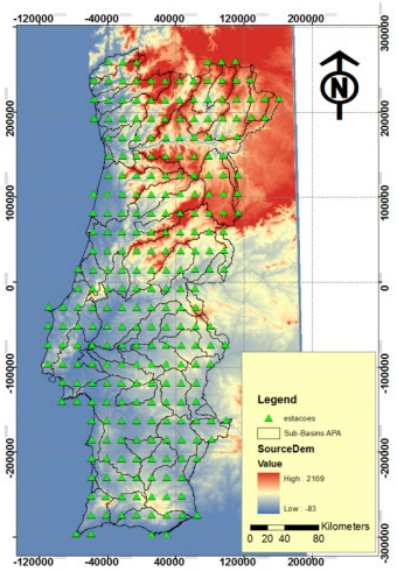
- Corine Land Cover 2006 represents the main land use-land cover of Europe with a legend of 50 classes.
- In terms of agricultural practices it distinguishes between cold season annuals from warm season annuals but it does not differentiate the kind of crop.
- The CORINE land cover classification codes were converted to the SWAT land cover/plant codes

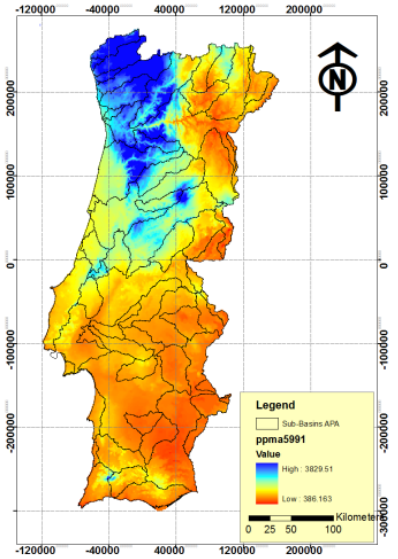


Three Precipitation Datasets based on measurements

1. SNIRH was obtained from 96 weather stations.
2. IPMA-GRID is a gridded precipitation dataset that resulted from an interpolation of 806 weather stations between 1950-2003
3. Map of average annual precipitation in Portugal obtained from APA “Atlas da água”, which we named after the Thesis reference (Nicolau, 2002).



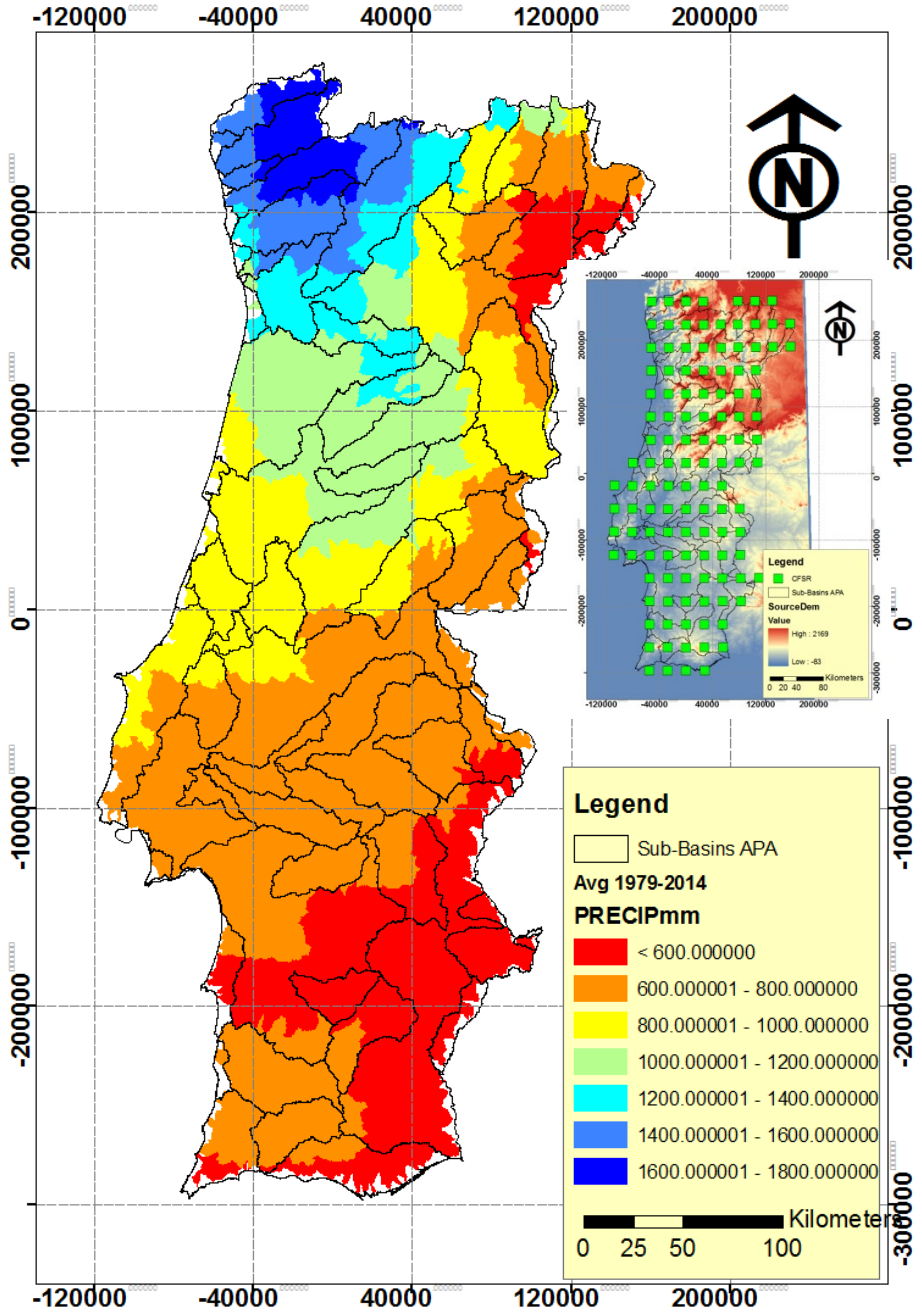




Reanalysis

Reanalysis data provide a seamless and coherent record of the global atmospheric circulation. Unlike weather analyses from operational forecasting systems, a reanalysis is produced with a single version of a data assimilation system.

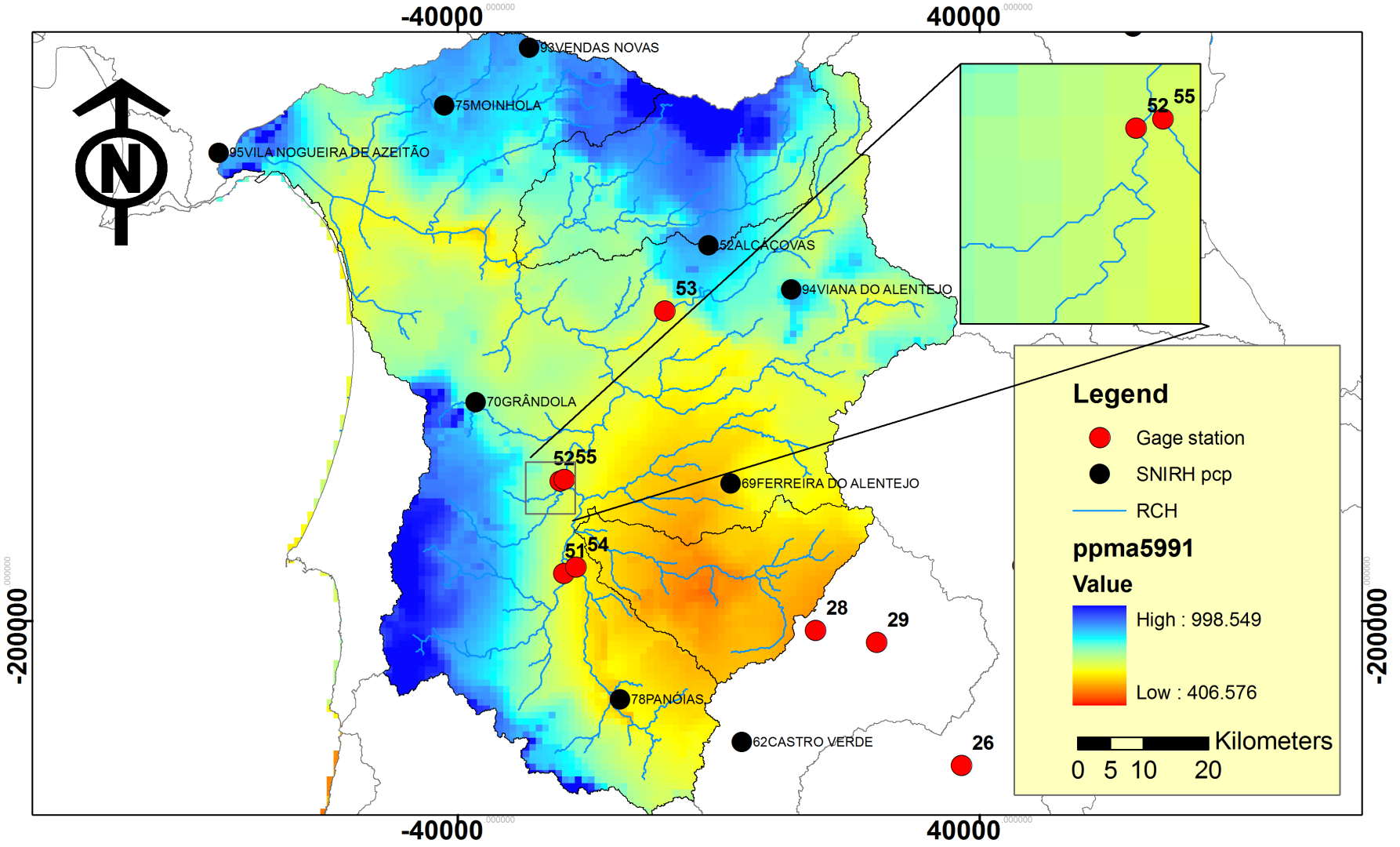
In the present work, the NCEP Climate Forecast System Reanalysis (CFSR) was used as an example of a global reanalysis. MM5-R was used as example of a local reanalysis.



Reanalysis vs measurements

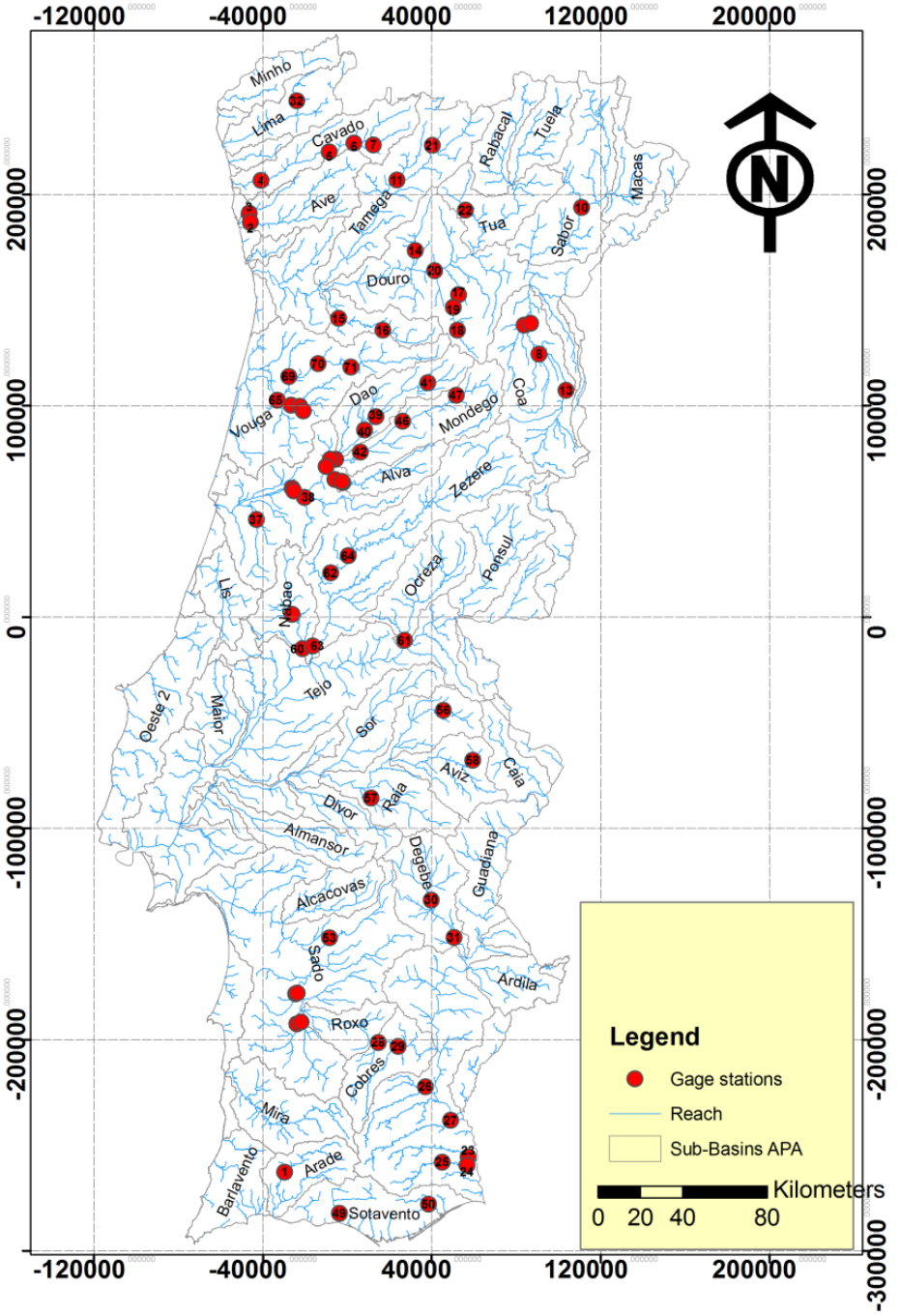
Y \ *X*	SNIRH	IPMA-GRID	MM5-R	CFSR
	R^2 / *m*			
SNIRH	1.00 / 1.00	0.73 / 1.04	0.23 / 0.78	0.48 / 0.87
IPMA-GRID		1.00 / 1.00	0.49 / 0.90	0.85 / 0.91
MM5-R	-	-	1.00 / 1.00	0.71 / 0.93
CFSR	-	-	-	1.00 / 1.00

Sado


-40000
40000
-200000
93VENDAS NOVAS
75MOINHOLA
95VILA NOGUEIRA DE AZEITÃO
52ALCÁCOVAS
94VIANA DO ALENTEJO
53
70GRÂNDOLA
5255
69FERREIRA DO ALENTEJO
5154
28
29
78PANÓIAS
62CASTRO VERDE
26
Legend
Gage station
SNIRH pcp
RCH
ppma5991
Value
High : 998.549
Low : 406.576
Kilometers
0 5 10 20

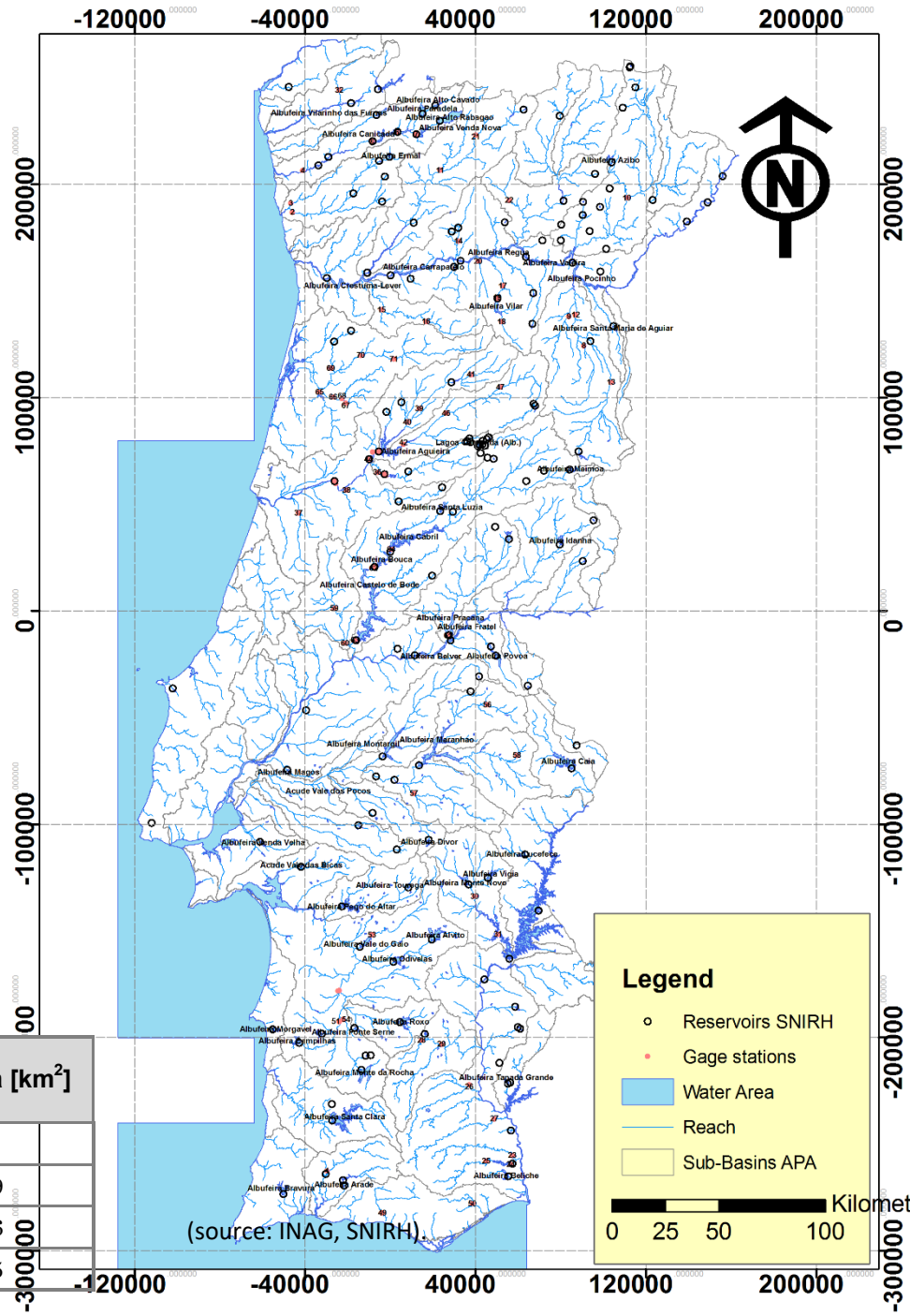
Gage stations

- Two types of flows were retrieved:
  - flow in river
  - flow affluent to reservoir.
- Stations with a minimum of 15 years of data
- Stations with drainage area between 100 and 5000 km2.



Reservoirs

- Location of gage stations in relation to reservoirs
- Reservoirs with high storage capacity:



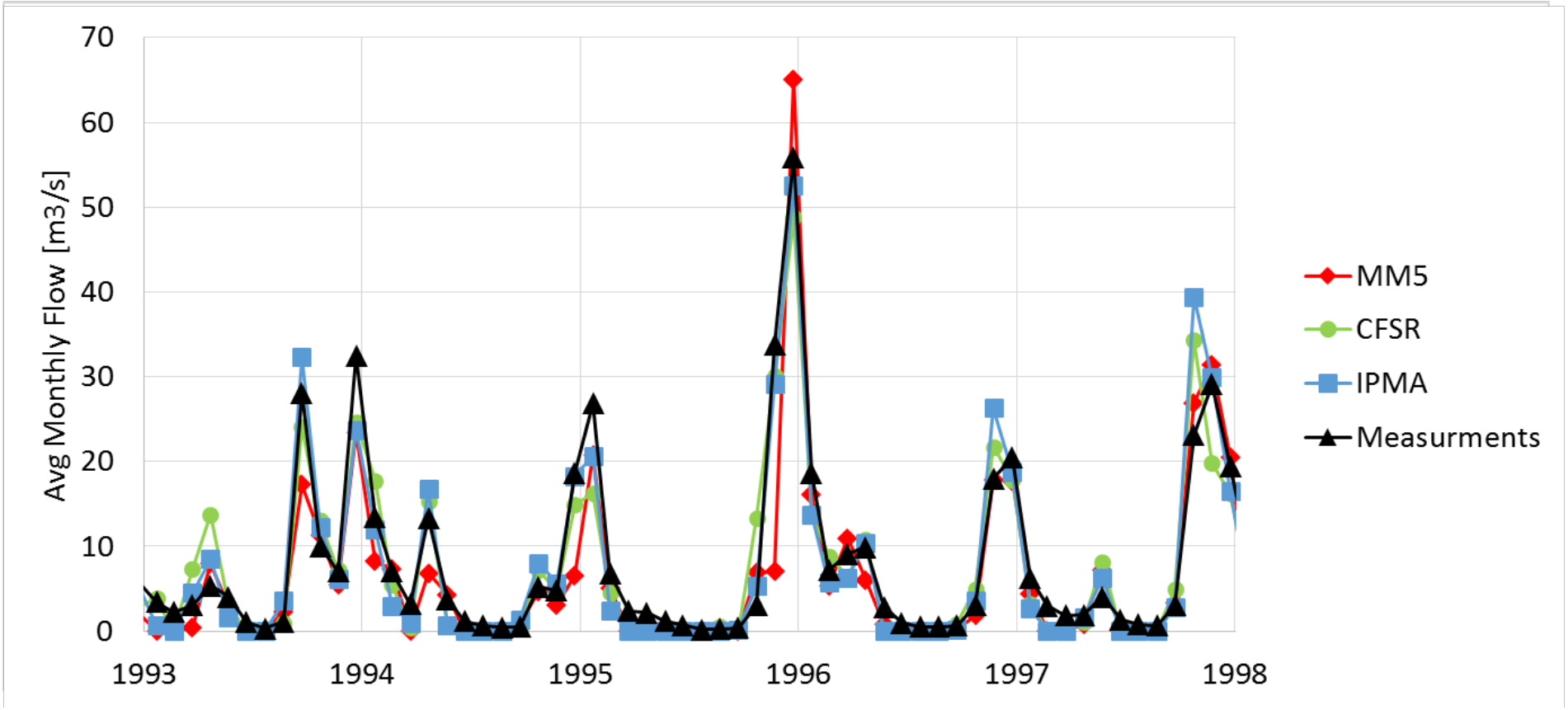
Reservoir	Watershed	Year	Active storage [hm^3]	Total area [km^2]
Alto Rabagão	CÁVADO	1964	557	103
Aguieira	MONDEGO	1981	216	3069
Cabril	TEJO	1954	615	2416
Castelo de Bode	TEJO	1951	902	3965

Model calibration

- SWAT groundwater hydrologic parameters

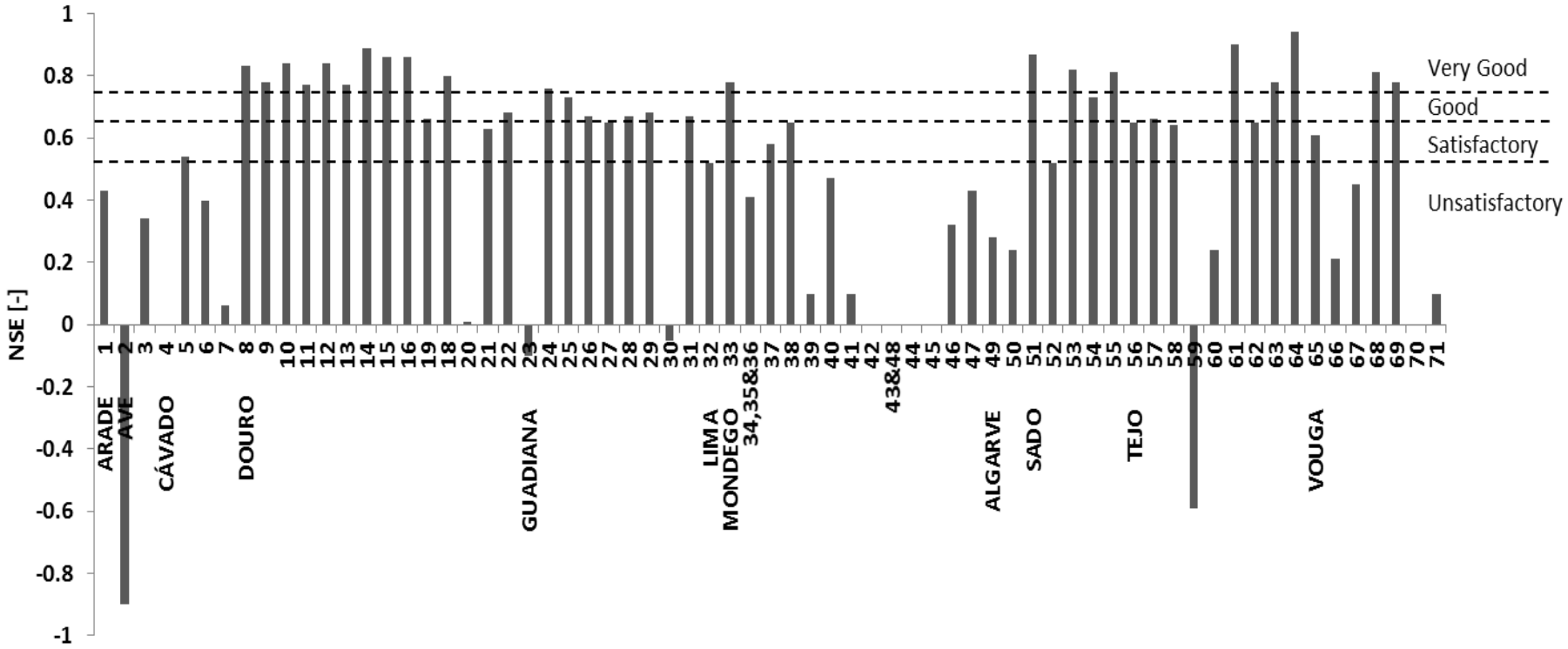
Name	Description	Default value	Calibrated value
GW_DELAY	Groundwater delay [days]	31	6
ALPHA_BF	Baseflow alpha factor [days]	0.048	0.8
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur [mm]	1	200
GW_REVAP	Groundwater "revap" coefficient	0.02	0.2

Example of measurements vs models



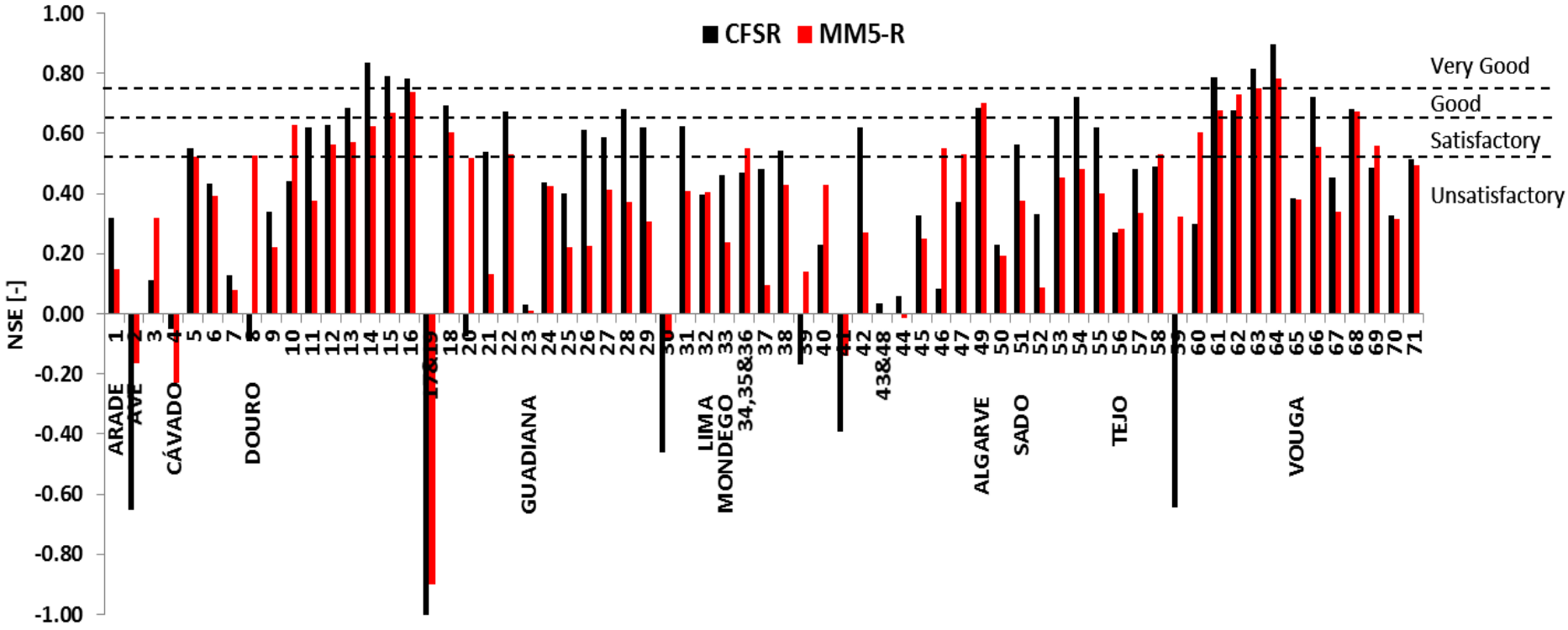
Calibration

- Flow obtained with IPMA-GRID precipitation (1979-2003)



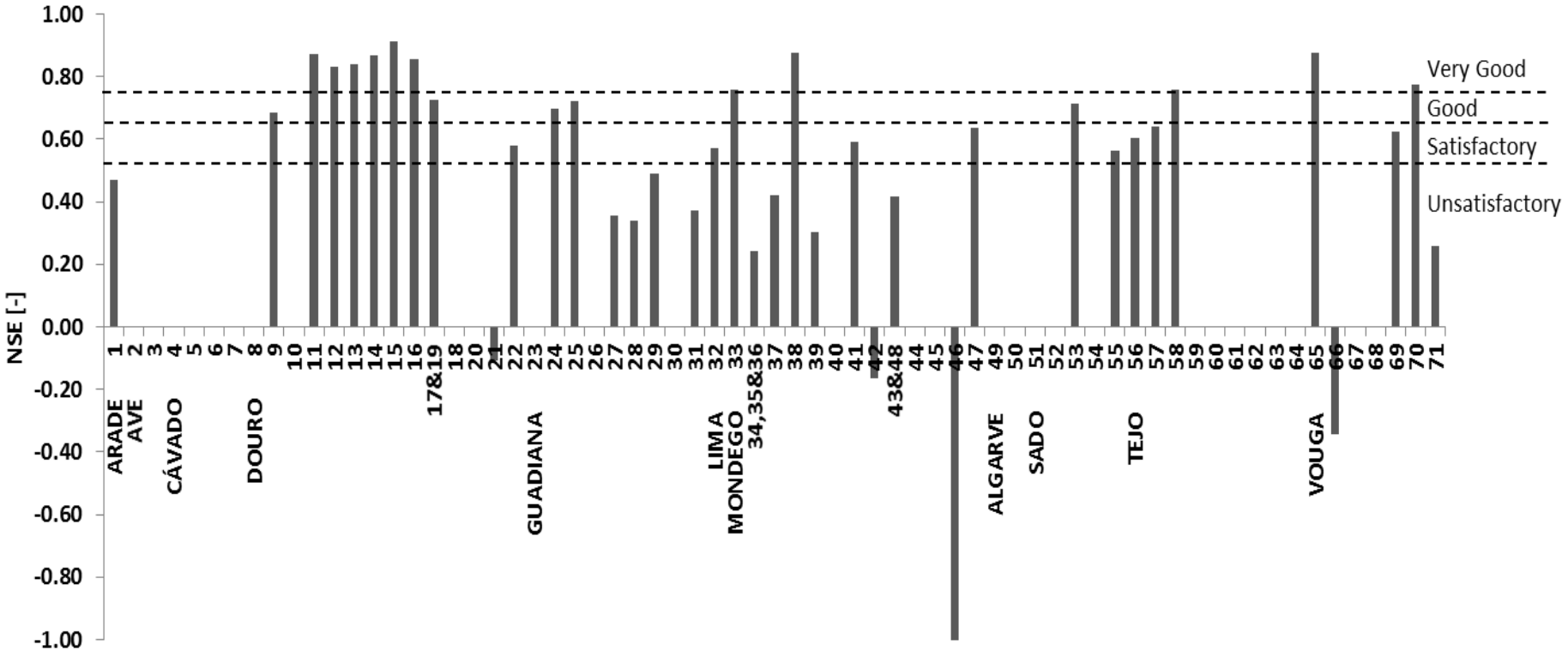
Reanalysis with calibrated model

- Flow obtained with CFSR and MM5-R precipitation (1979-2003)

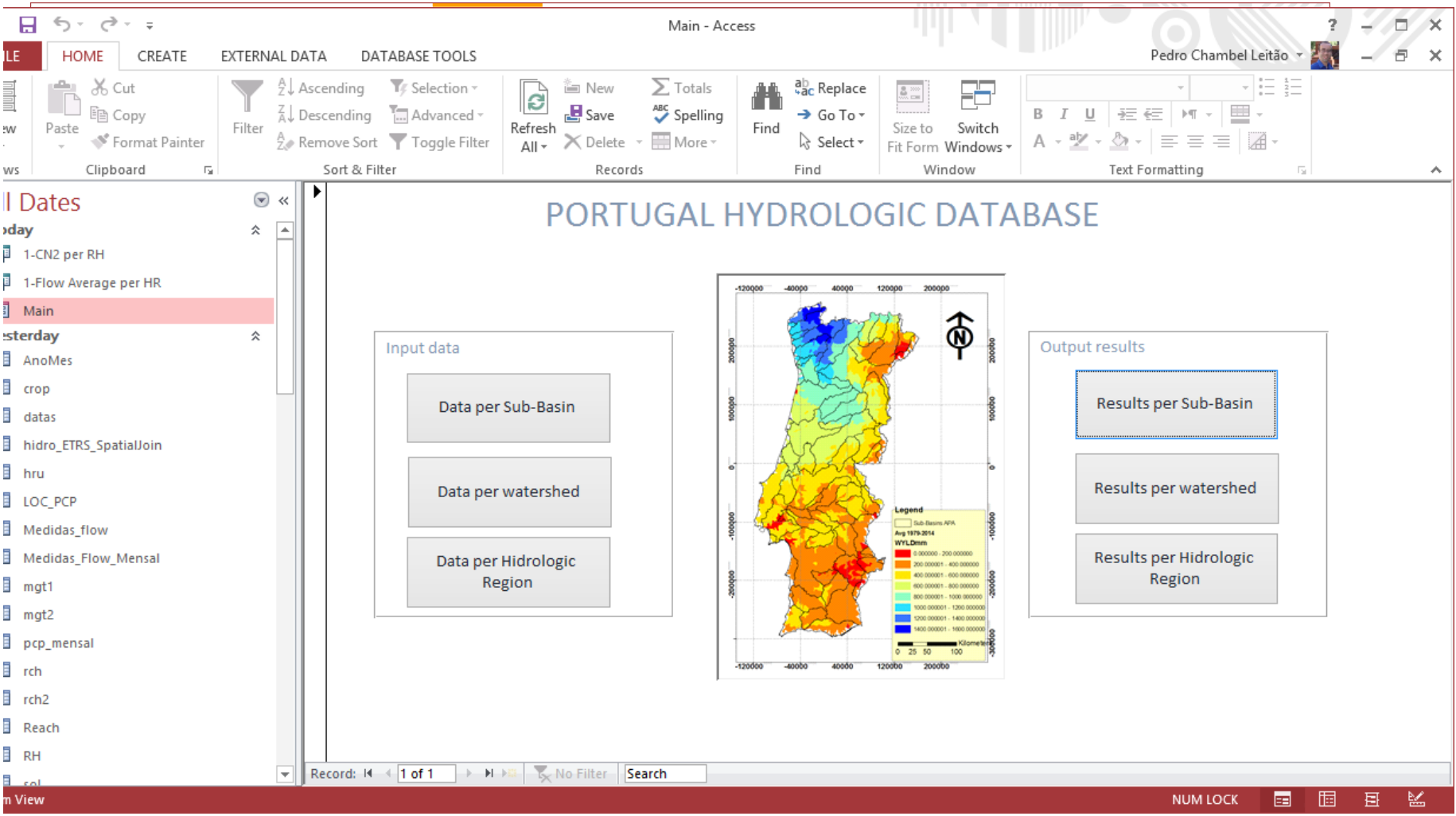


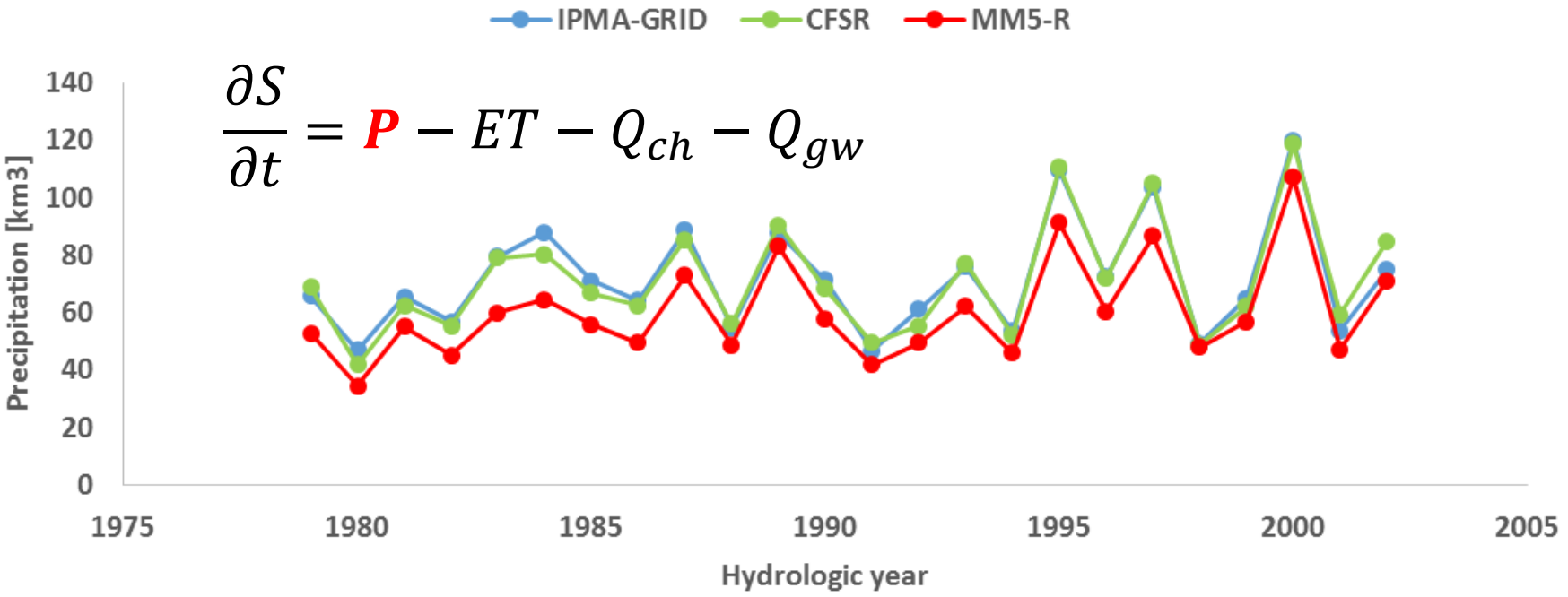
Validation

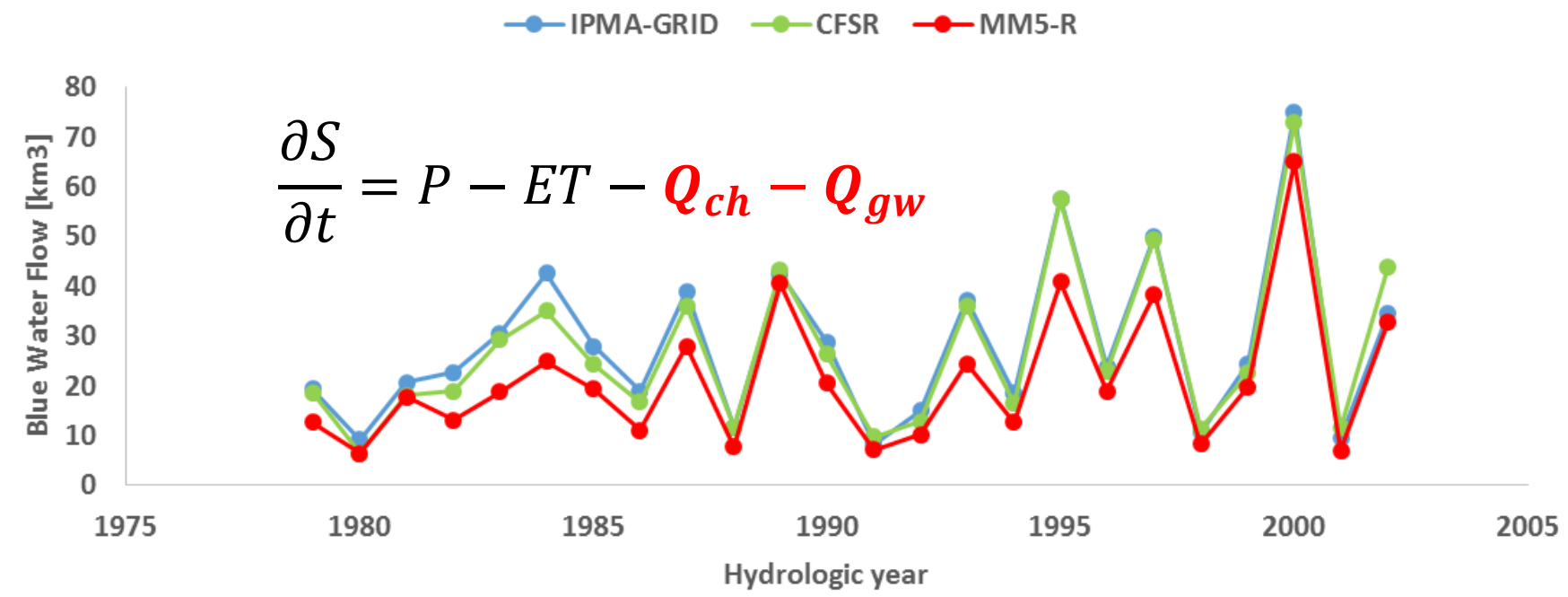
- Flow obtained with IPMA-GRID precipitation (1950-1978)



Database of modelled flows




IPMA-GRID
CFSR
MM5-R
$\frac{\partial S}{\partial t} = \boldsymbol{P} - ET - Q_{ch} - Q_{gw}$
Precipitation [km3]
140
120
100
80
60
40
20
0
1975
1980
1985
1990
1995
2000
2005
Hydrologic year


IPMA-GRID
CFSR
MM5-R
$\frac{\partial S}{\partial t} = P - ET - \boldsymbol{Q_{ch} - Q_{gw}}$
Blue Water Flow [km3]
80
70
60
50
40
30
20
10
0
1975
1980
1985
1990
1995
2000
2005
Hydrologic year

Water budget per HR (km3/24years)

Hydrographic Region	Code	P	ET	$Q_{Ch}+Q_{GW}$
Lima and Minho	PTRH1	80.45	24.21	56.30
Cavado and Leça	PTRH2	111.07	36.67	74.61
Douro	PTRH3	411.79	206.67	205.47
Mondego e Vouga	PTRH4	292.56	142.80	149.98
Tejo	PTRH5	494.37	356.25	138.35
Sado and Mira	PTRH6	140.73	118.44	22.45
Guadiana	PTRH7	144.85	123.61	21.47
Algarve	PTRH8	51.73	41.25	10.54

Conclusions

- The best available precipitation dataset was IPMA-GRID. This dataset was proven to be well correlated with SNIRH gage station.
- The biggest differences between IPMA-GRID and SNIRH were found in Ave, Cavado, Lima, Mondego and Arade and the smallest in Douro, Tejo, Sado and Vouga.
- Results show that the model can satisfactorily reproduce flows using IPMA-GRID precipitation, for example in Douro, while other watersheds, like Mondego, would need more detailed precipitation data to reproduce flows.

Conclusions

- The calibrated model was run with precipitation data from the MM5-R and the CSFR meteorological models with respectively 30 and 36 years of reanalysis as input. In general, model performance is reduced when using reanalysis. The decrease in performance is more significant in MM5-R than in CFSR.

Future work

- Include the creation of a geometry for the entire Iberian Peninsula with the subsequent development of an Iberian model.
- Precipitation should be improved for some watersheds like Mondego.
- Improved input on vegetation rooting depths associated with more information on water storage on soil and aquifer, can reduce the need for additional model calibration.

Future work

- The model should be further evaluated with the remaining stations, particularly in watersheds with poor calibration/validation
- The model should be calibrated for daily flows, and a similar database should be compiled.