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STATISTICAL ESTIMATION AND RE-ANALYSIS OF PRECIPITATIONS OVER FRENCH MOUNTAIN RANGES

USING WEATHER PATTERNS, WATER BALANCES AND SNOW MEASUREMENTS ASSIMILATION

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EDF

Introduction

Why a french hydropower company is interested in ***precipitation estimation*** ?

2 forecast contexts :

water resources management (several days to several months ahead)

flood events (several hours to several days ahead)

Introduction

Is precipitation estimation easy in mountain ranges ?

Certainly not, essentially because of :

High spatial and temporal variability of precipitation

Scarcity of observations (poor network and no remote sensing)

Example

What is the annual mean of precipitation on the small catchment of Gloriettes ?

Question

How can we estimate rainfall **fields** in **mountains** with **point** observations often placed in **valley** ?

spatial interpolation + **elevation extrapolation**

PhD research (Gottardi et al., 2009)

Outline

① EDF statistical method for precipitation estimation in mountains

② First validations

③ Assimilation of snow observations

④ Second (more) validations

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EDF STATISTICAL METHOD FOR PRECIPITATION ESTIMATION IN MOUNTAINS

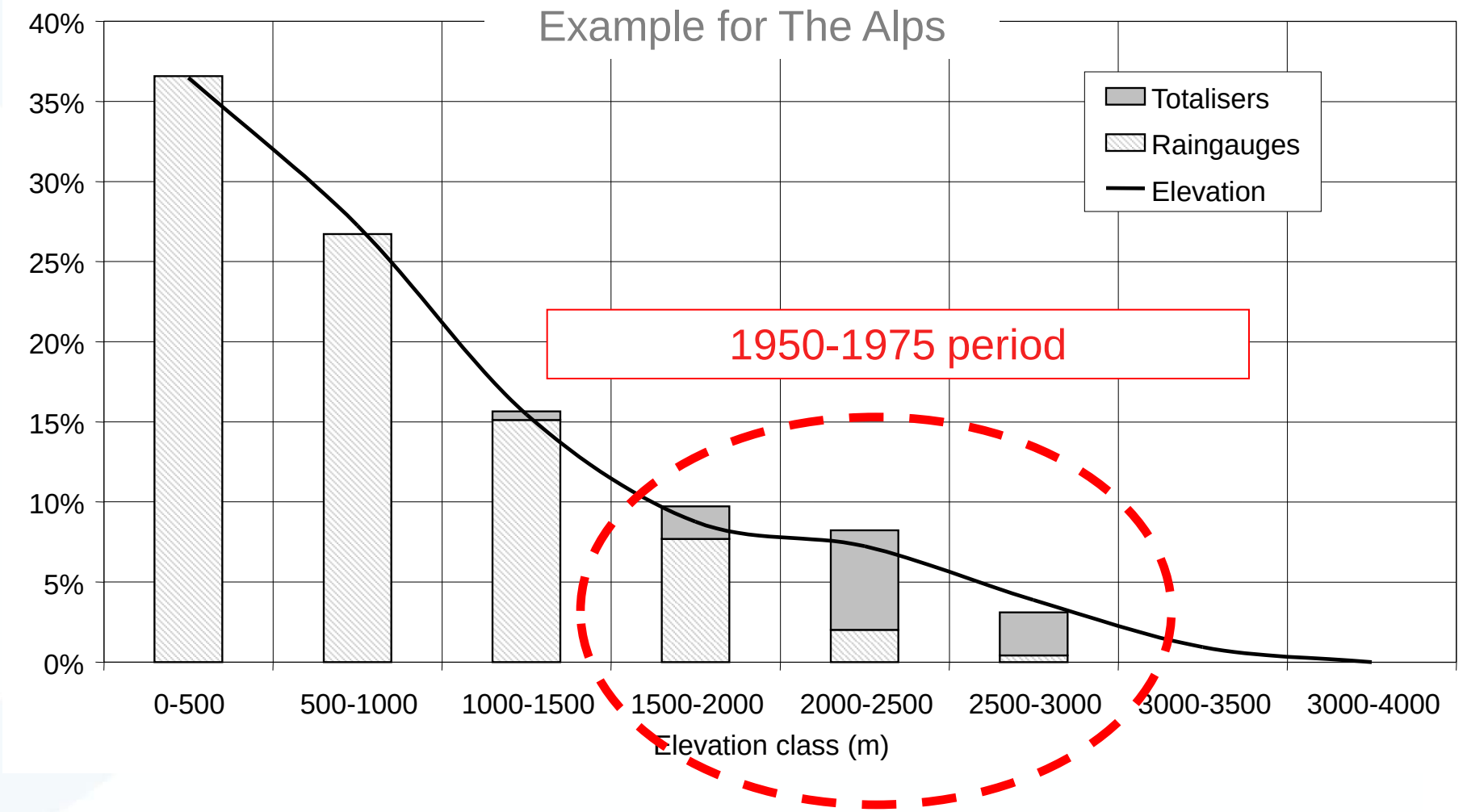
Raingauges network

~1900 raingauges
~220 totalisers

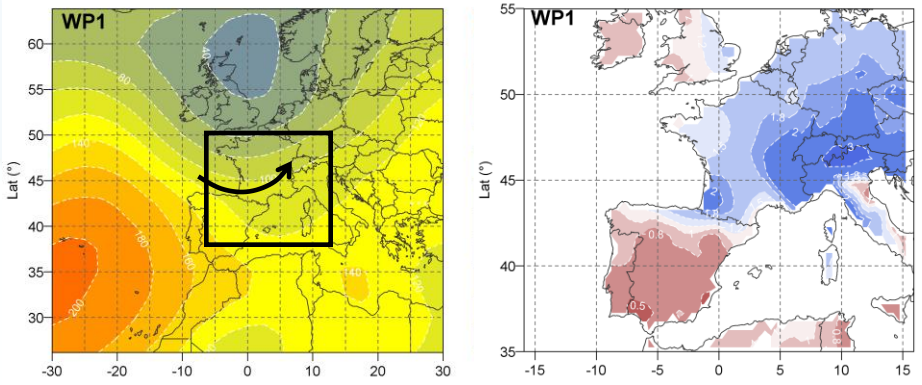
PG2000 raingauge

Mougin totaliser

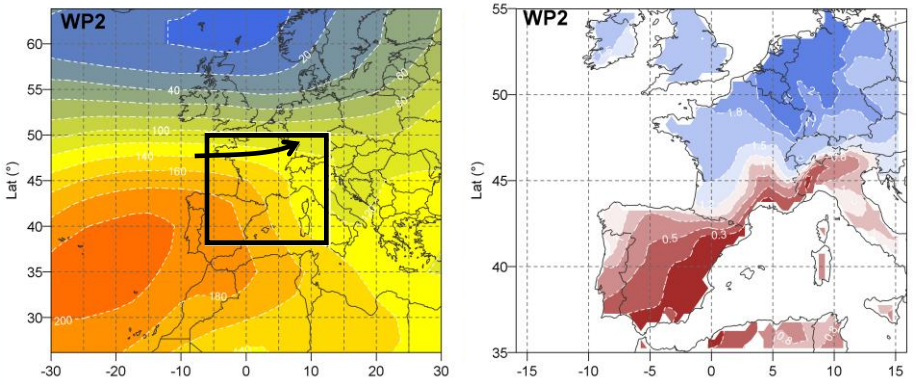
Which period ?



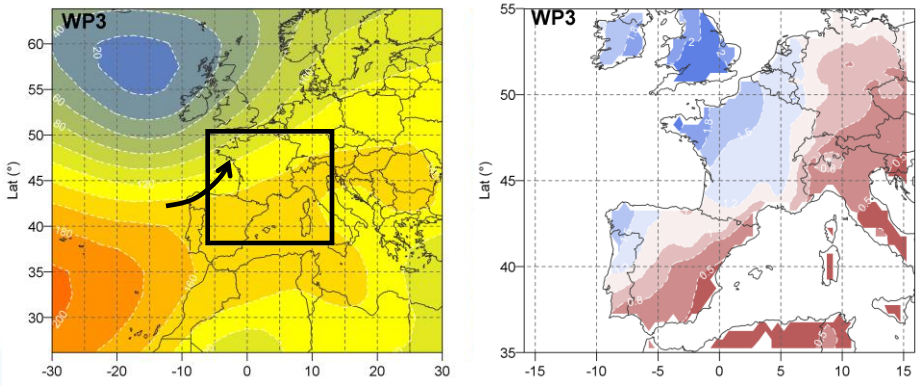
Weather patterns : Pressure and rainfalls (1)



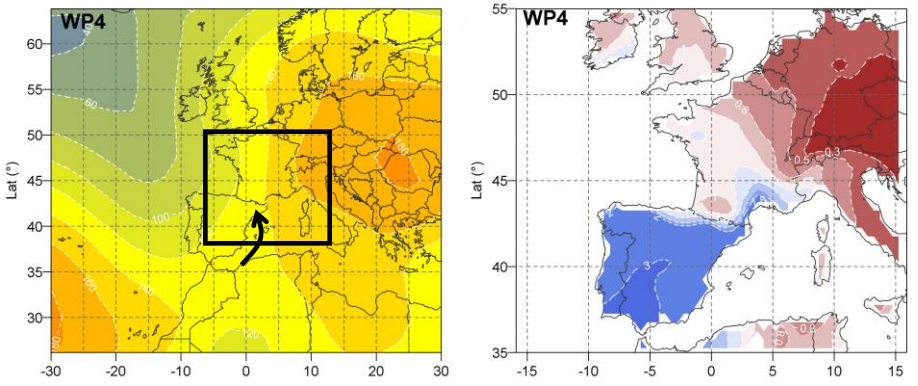
WP 1 : Atlantic Wave (7%)



WP 2 : Steady Oceanic (24%)

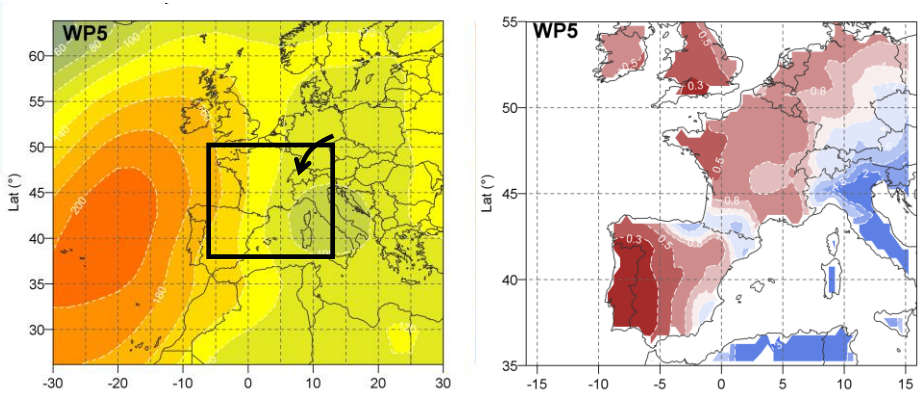


WP 3 : Southwest Circulation (8%)

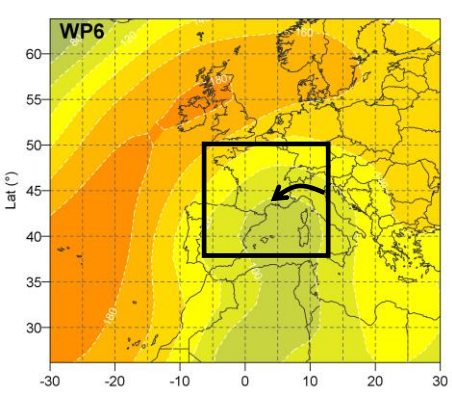


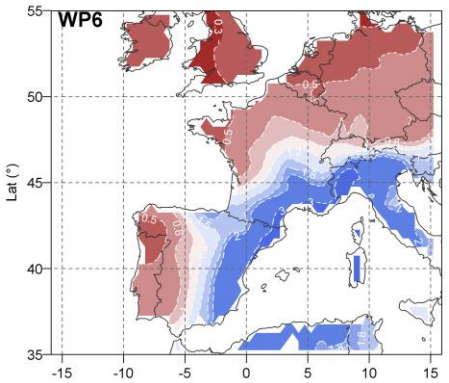
WP 4 : South Circulation (18%)

Weather patterns : Pressure and rainfalls (2)

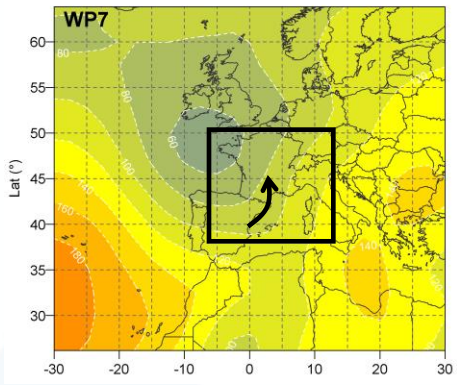


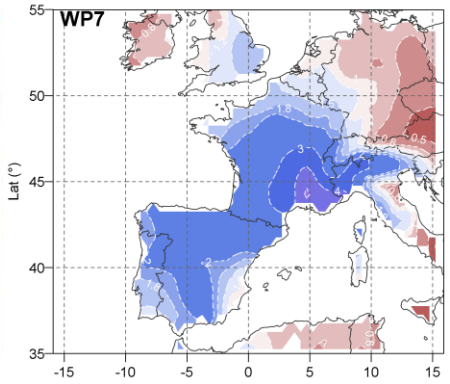
WP 5 : Northeast Circulation (7%)



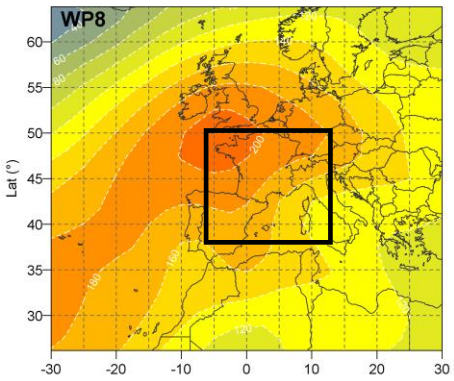


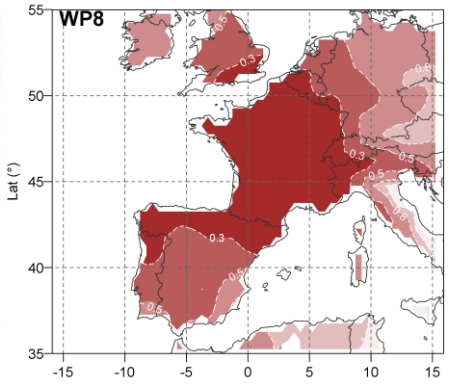
WP 6 : East Return (6%)





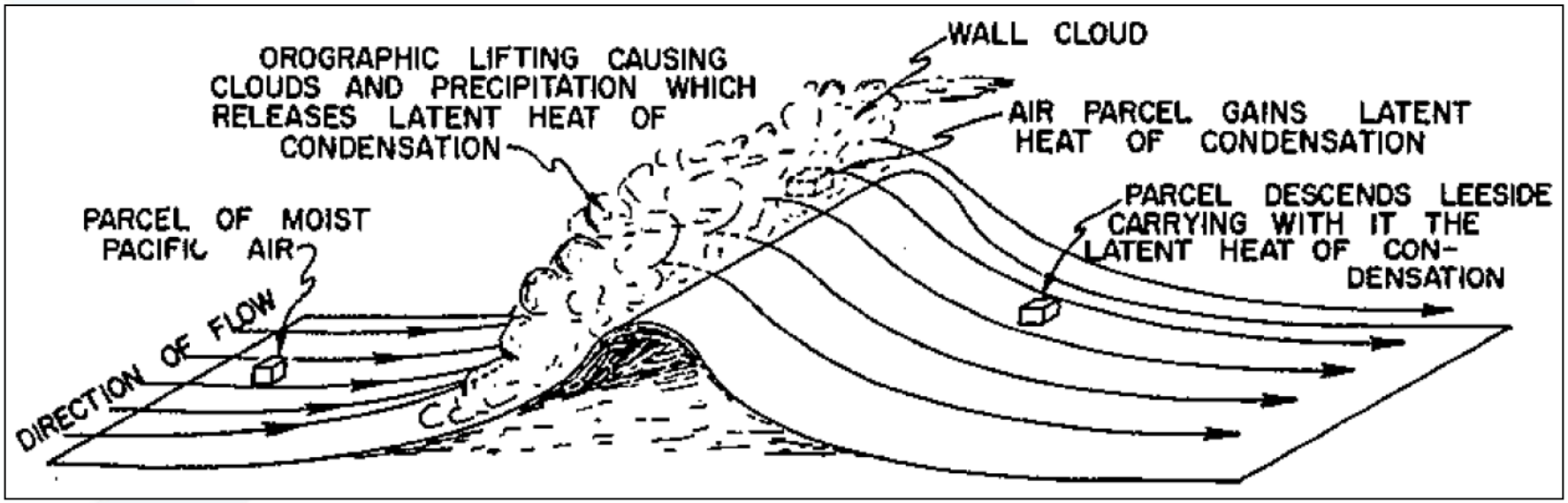
WP 7 : Central Depression (3%)





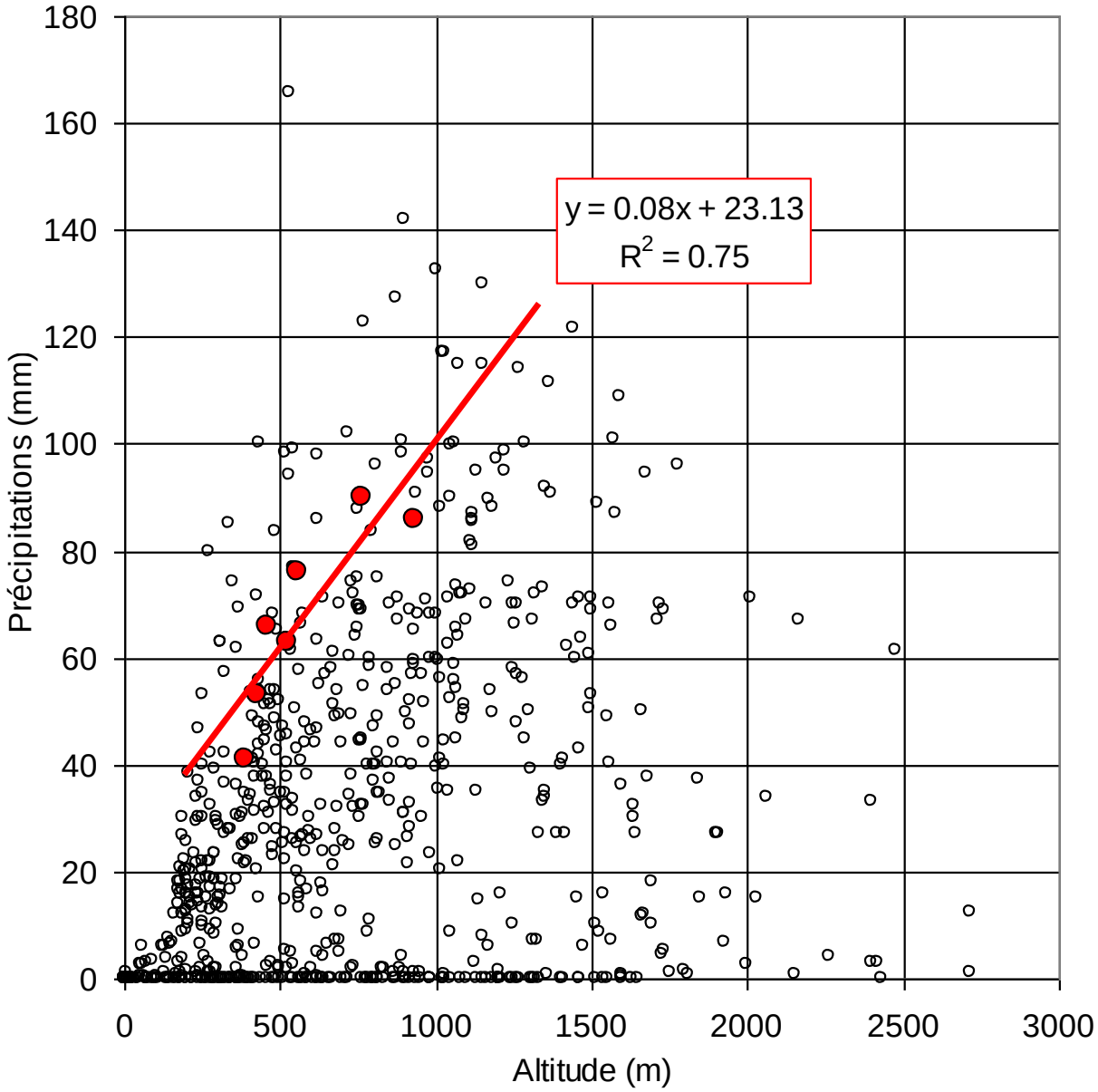
WP 8 : Anticyclonic (27%)

Modelisation of the local orographic effect



Mountain weather & Climate, Roger G. Barry (2001)

Local linear regression

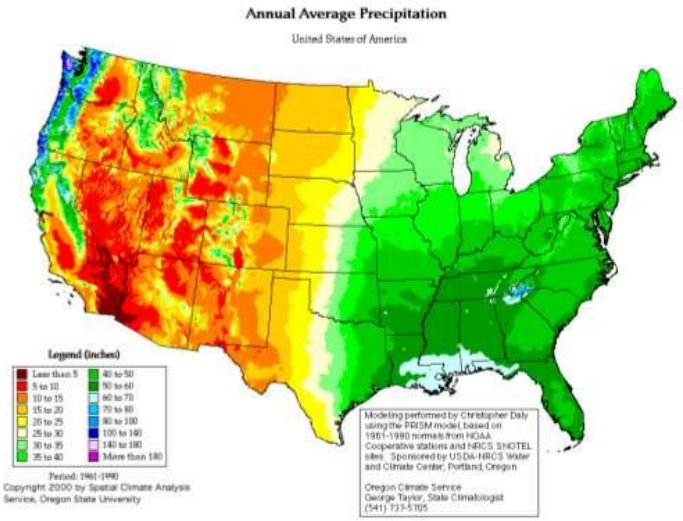


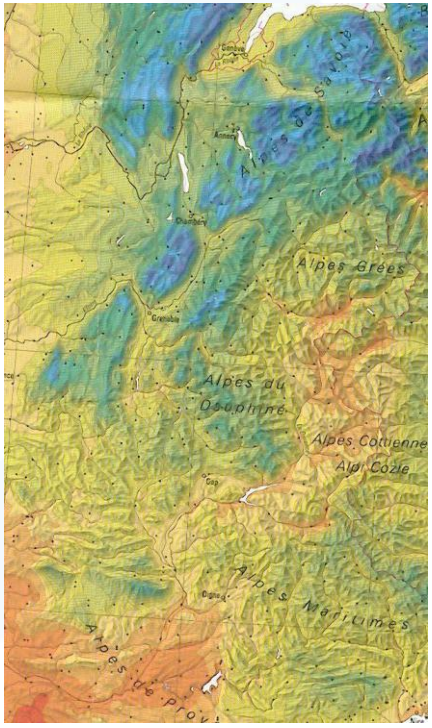
Precipitations of Nov.26,1983 on The Alps

Other works

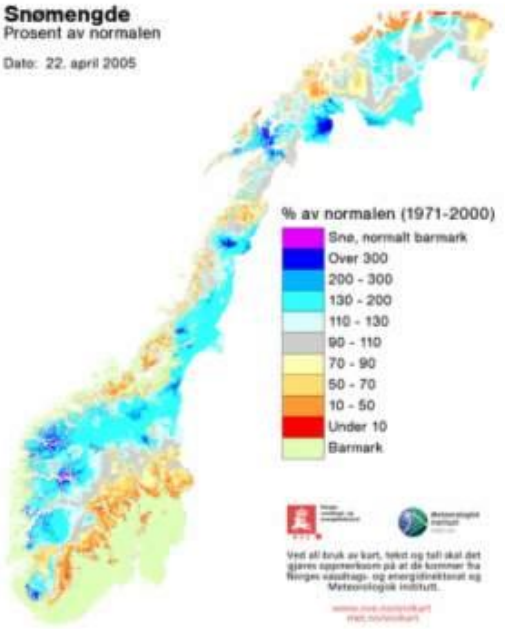
USA

Precipitation-elevation **R**egressions on **I**ndependent **S**lopes **M**odel (Daly et al., 1994)



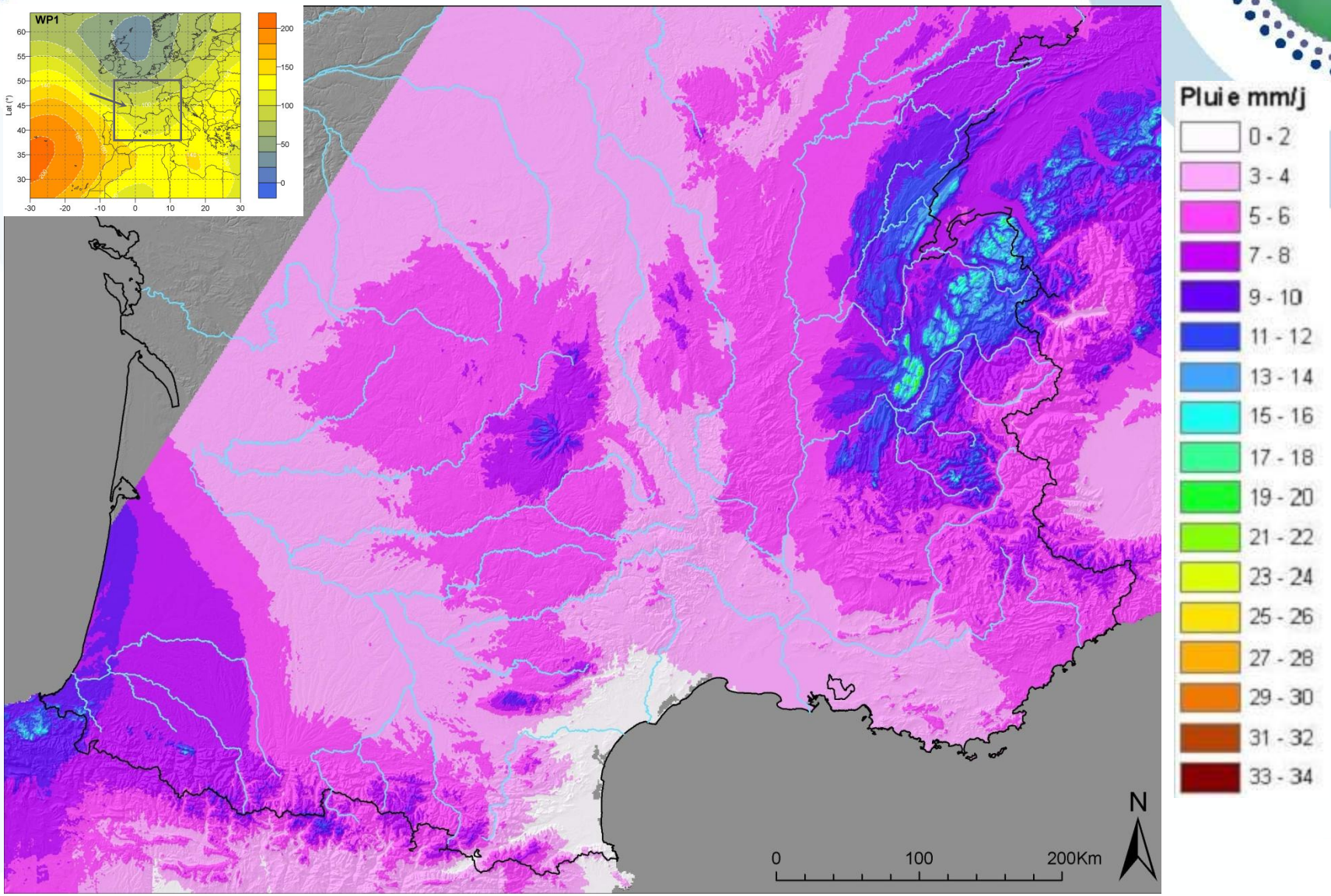


Switzerland (Frei and Schär, 1997)

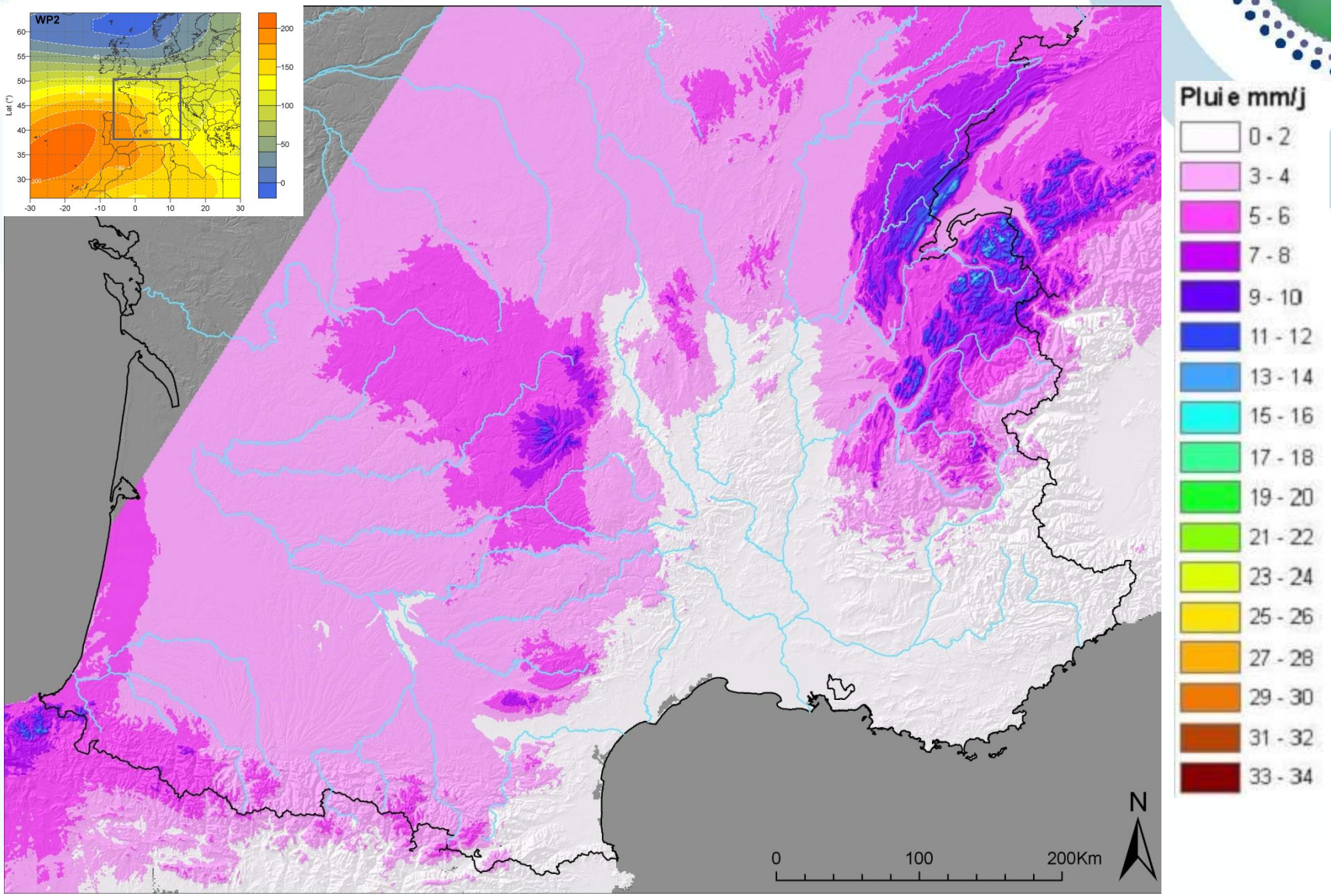


Norway (Tveito et al.,2004)

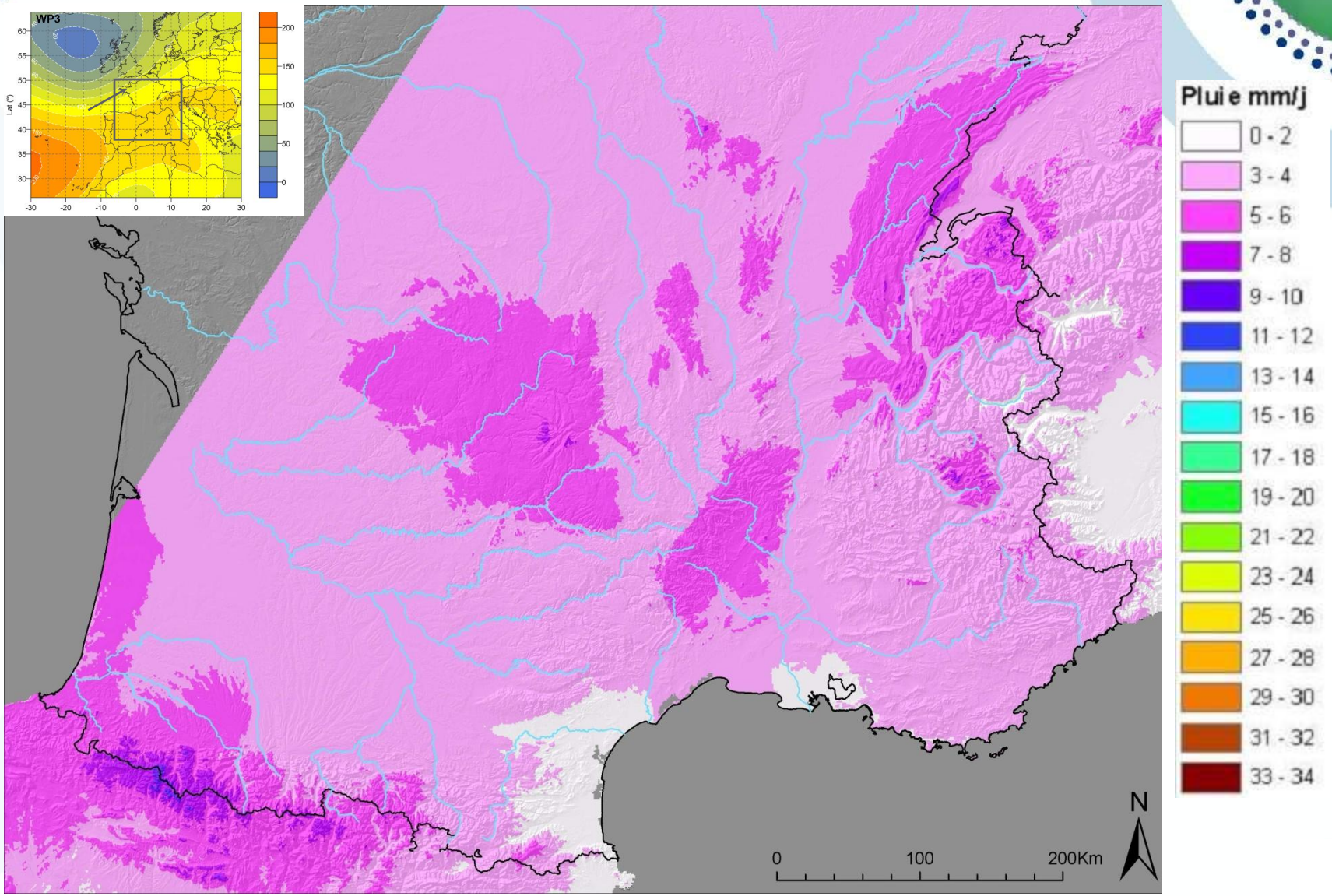
WP1 average rainfield (Atlantic Wave)



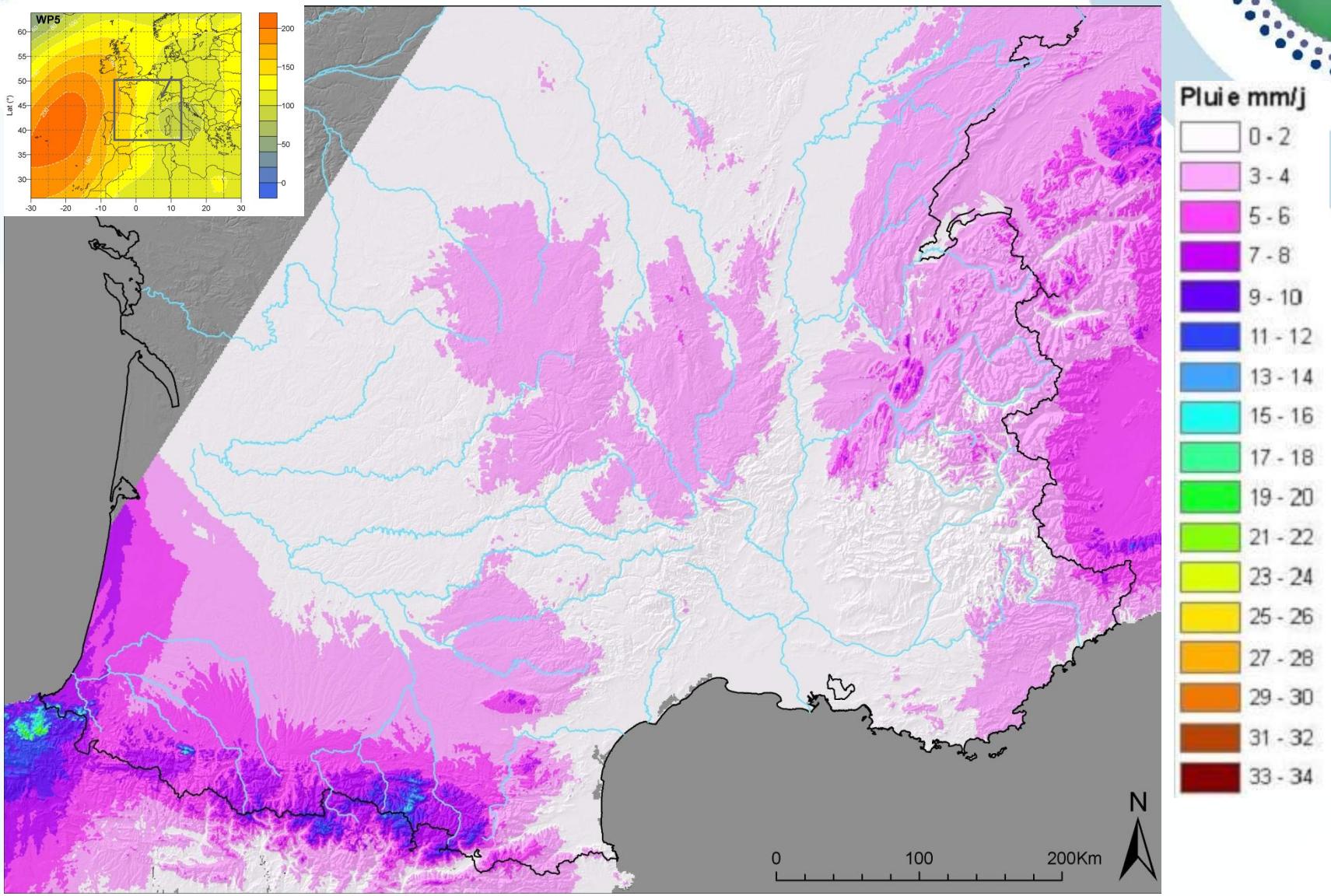
WP2 average rainfield (Steady Oceanic)



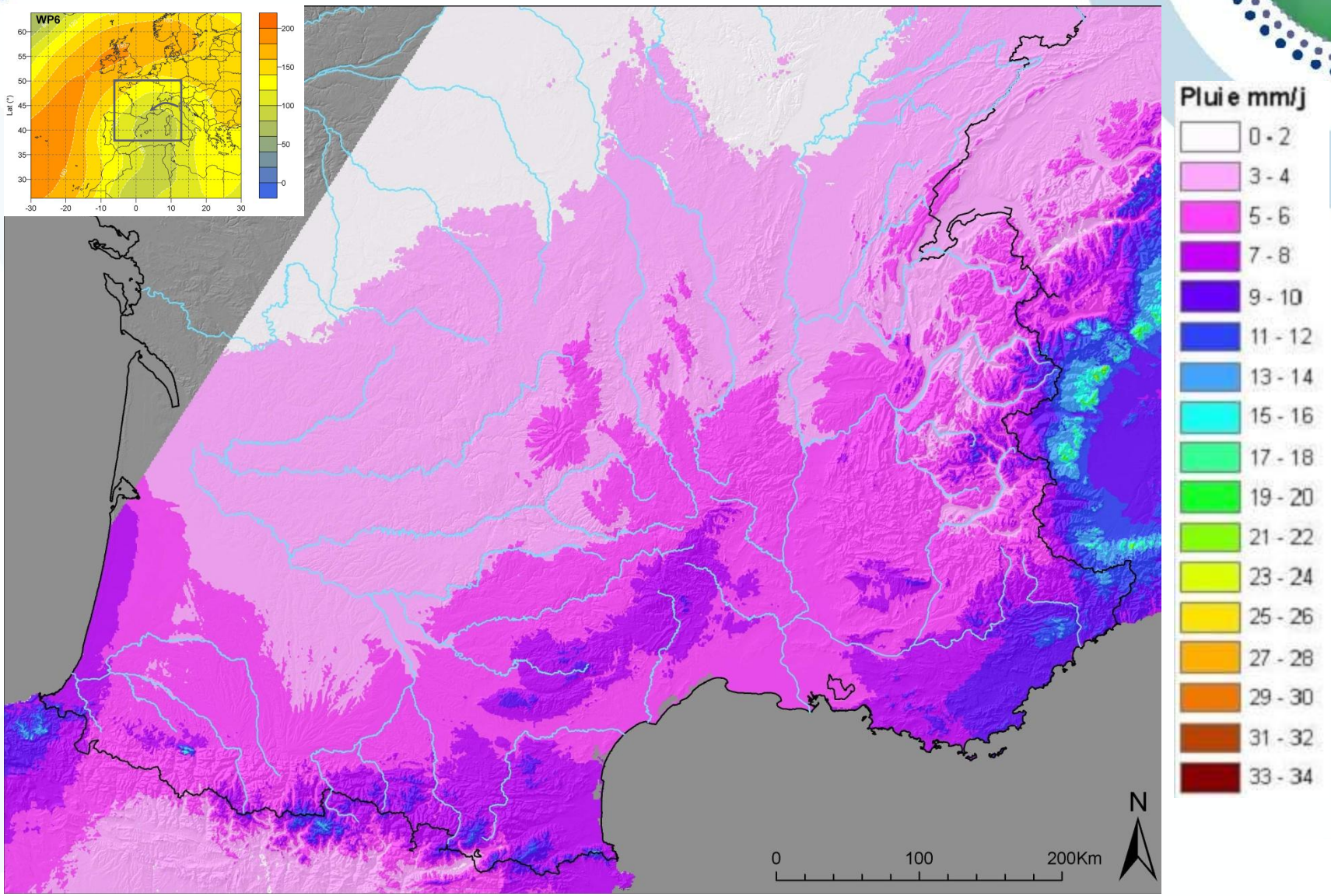
WP3 average rainfield (Southwest Circulation)



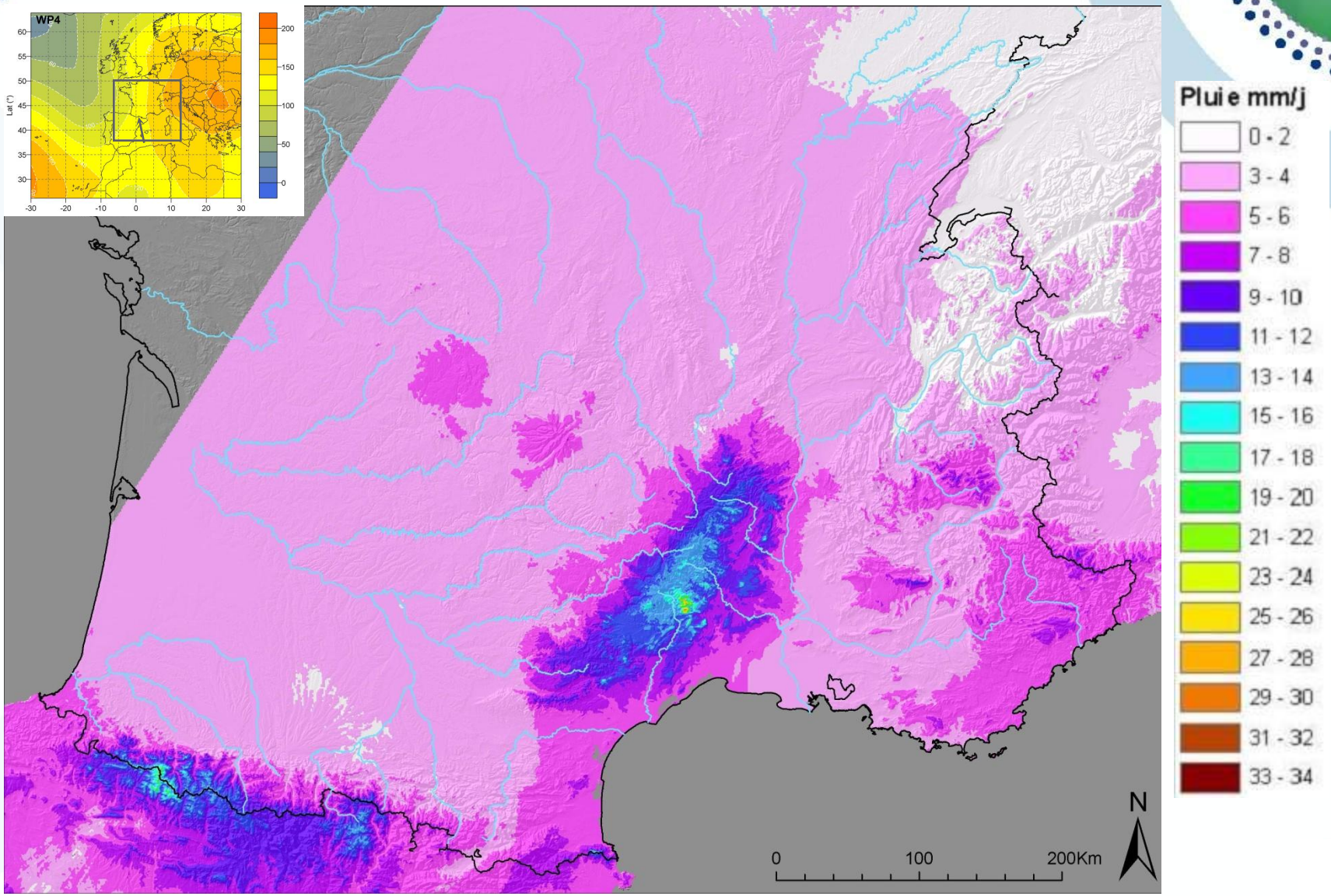
WP5 average rainfield (Northeast Circulation)



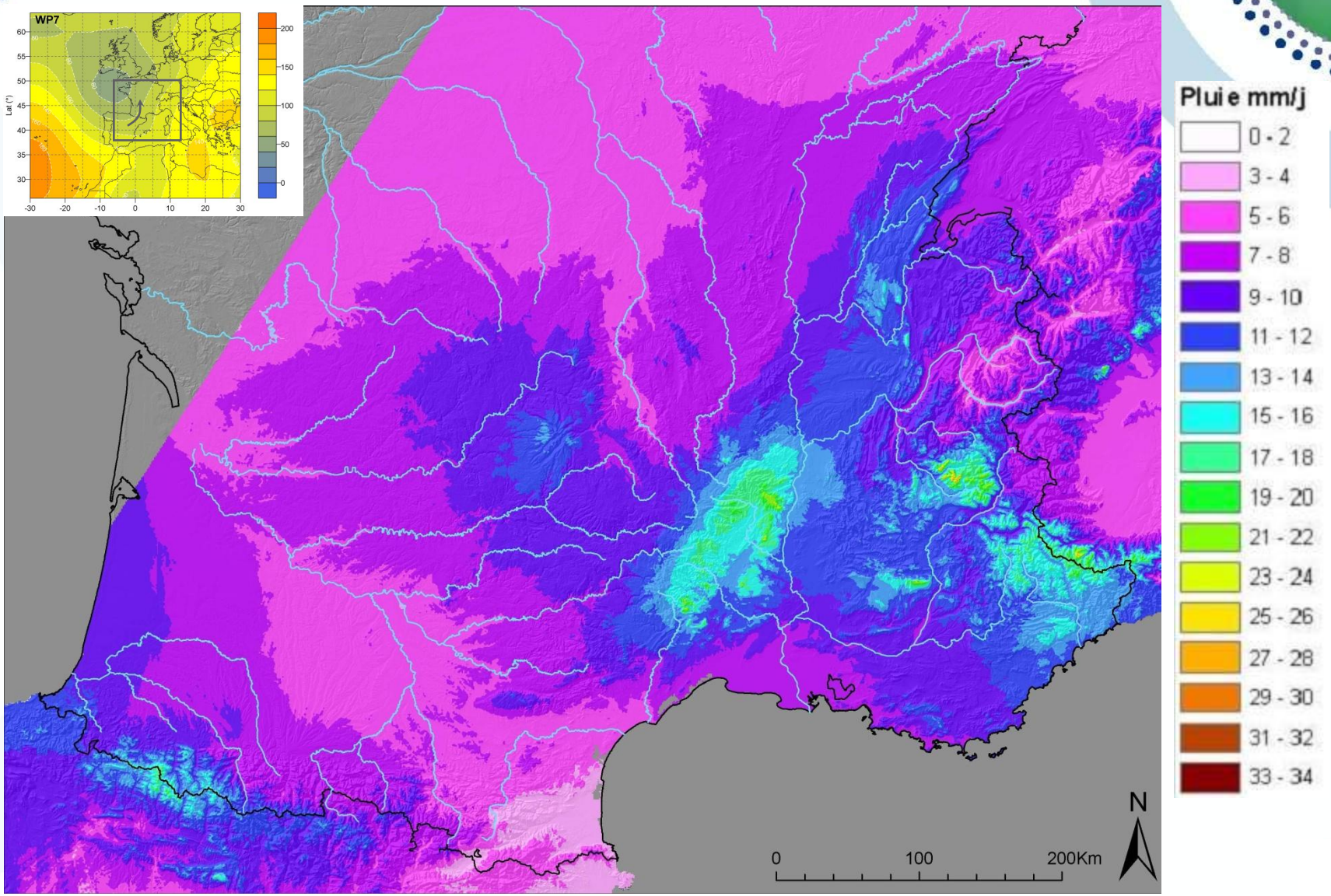
WP6 average rainfield (East Return)



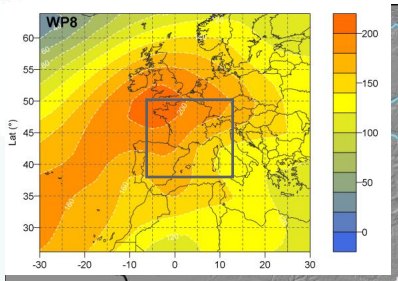
WP4 average rainfield (South Circulation)



WP7 average rainfield (Central Depression)



WP8 average rainfield (Anticyclonic)

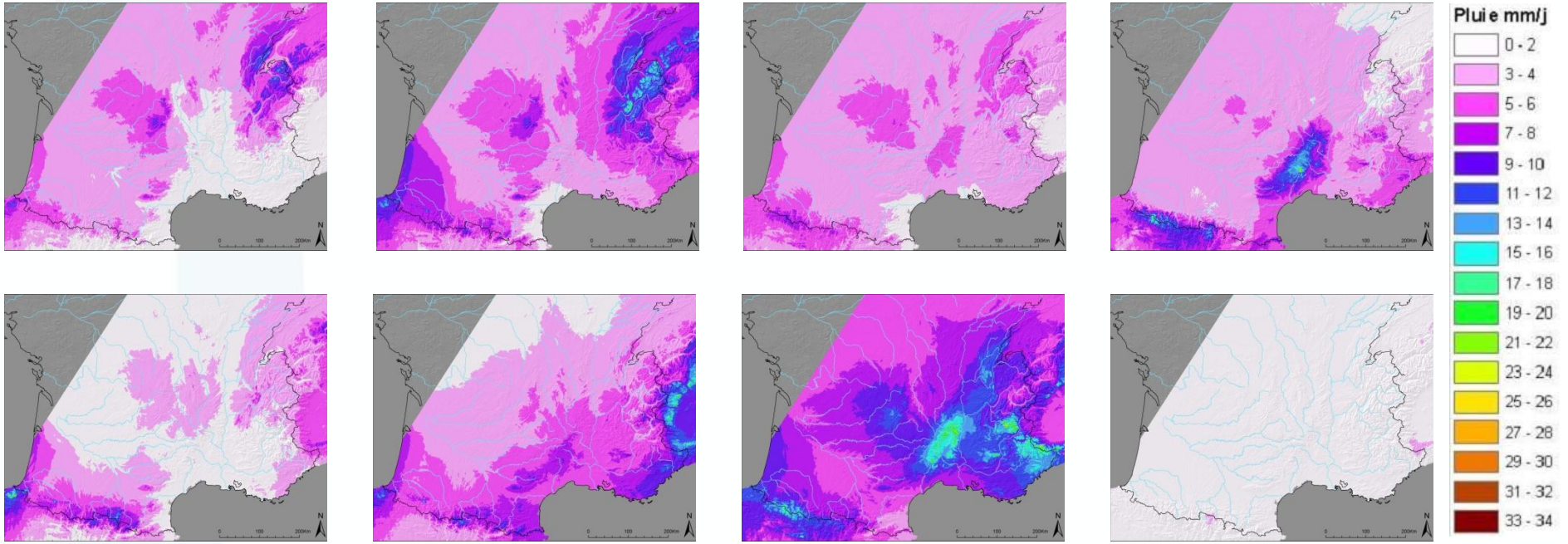


Pluie mm/j
0 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 14
15 - 16
17 - 18
19 - 20
21 - 22
23 - 24
25 - 26
27 - 28
29 - 30
31 - 32
33 - 34

N

0 100 200Km

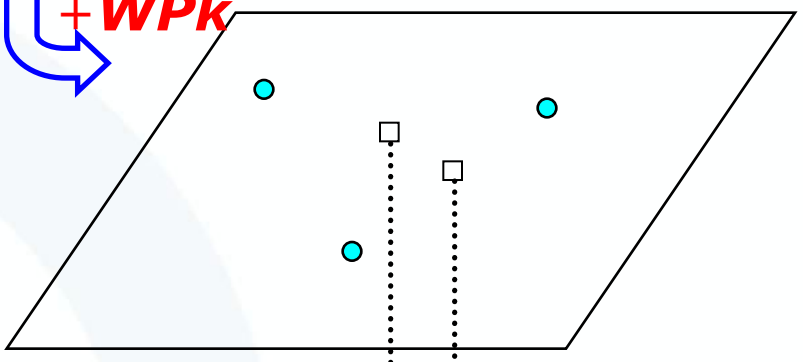
8 Precipitation guess fields



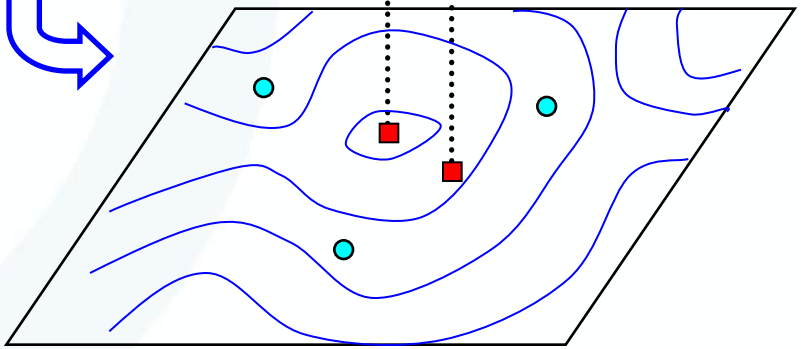
Daily estimation using WP guess fields

Obs. of the Day

+ ***WPk***



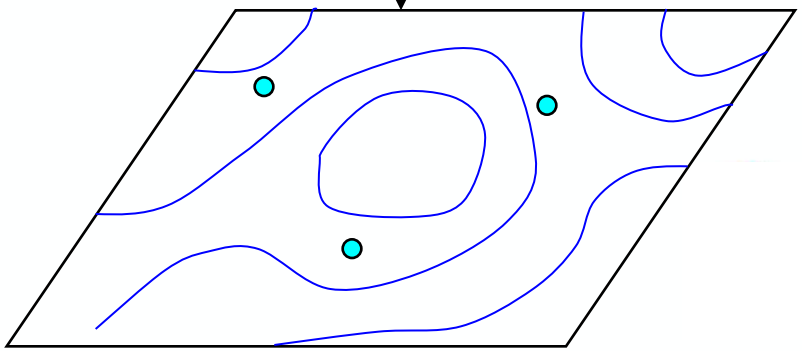
Guess Field ***WPk***



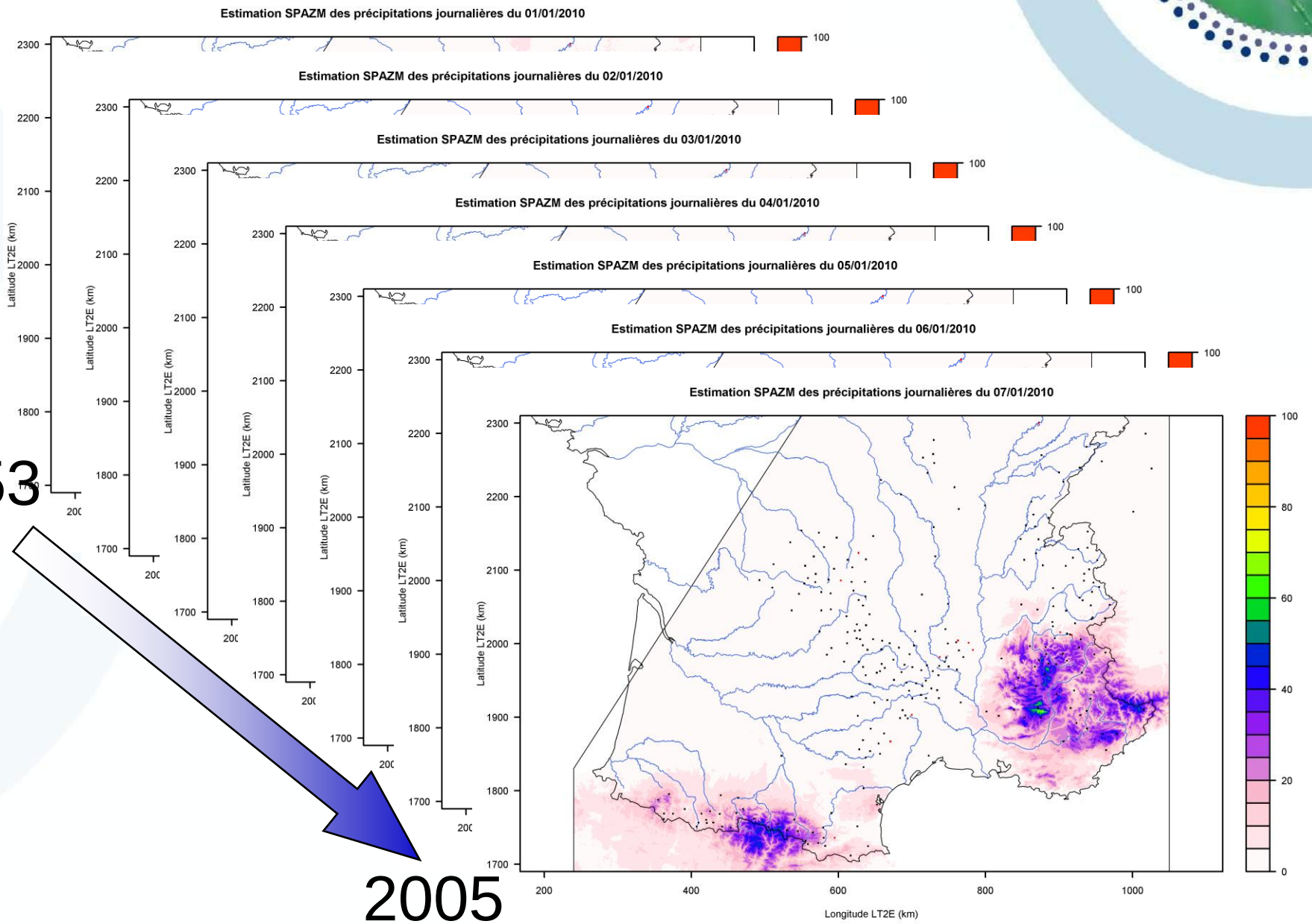
Guess field of the weather pattern

But

Constrained by observations of the day



First estimation of daily precipitation



1953

2005

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FIRST VALIDATIONS

Validations

2 validation processes

Snow network
SWE measurements

Local validation

Annual Water Balance
Runoff measurements

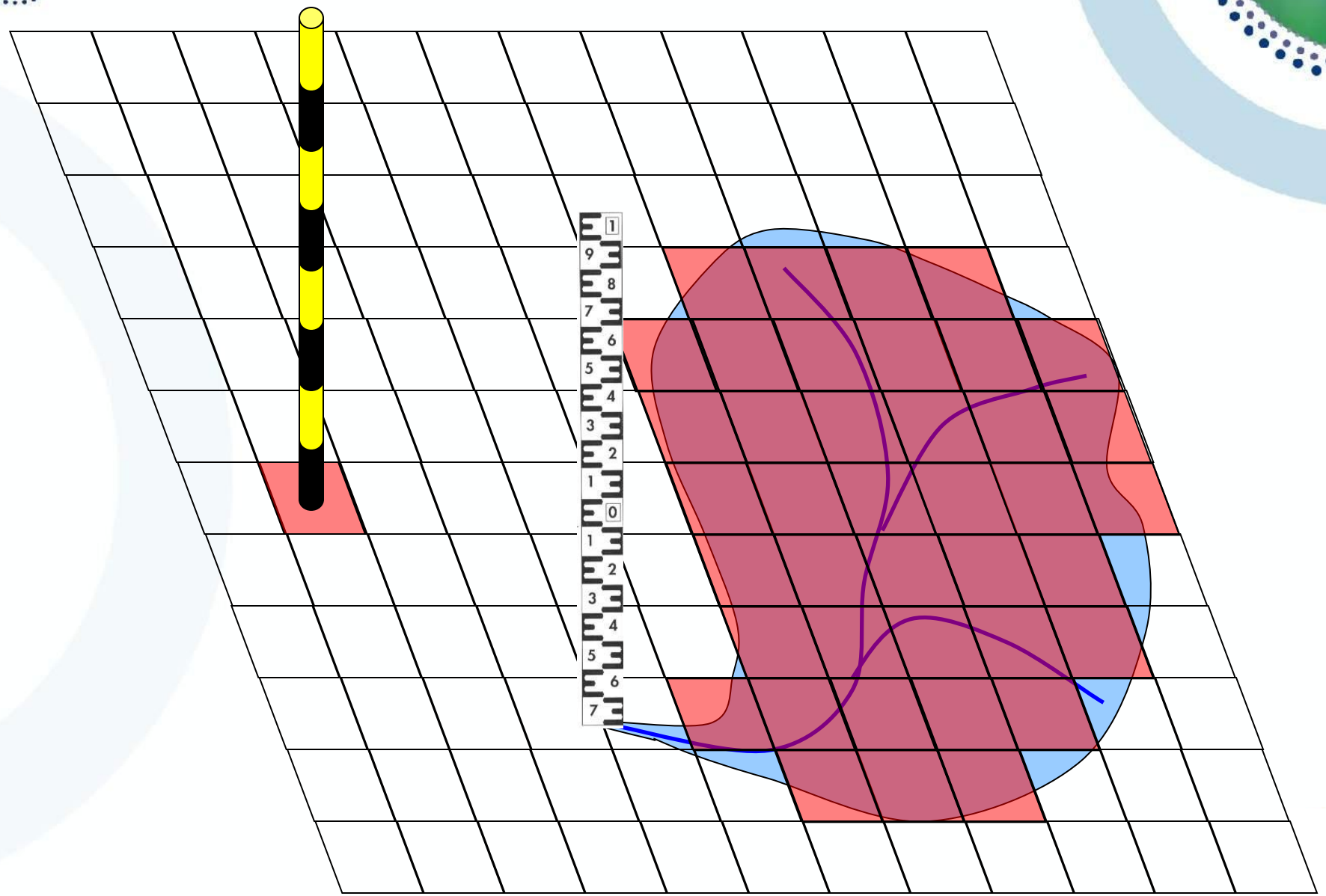
Global validation on catchments

BUT

SWE = Snow – rain/melting
⇨ Snow model
⇨ Temperature model

Runoff = Precip – RET ± Δstock
⇨ Evaporation model
⇨ Temperature model

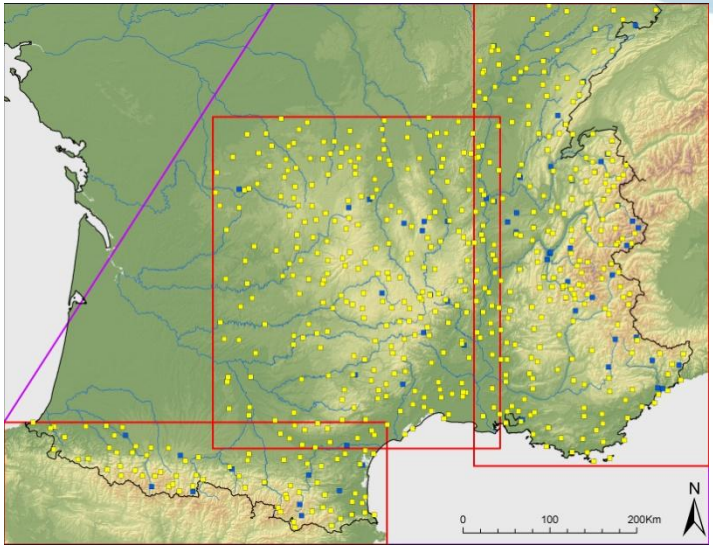
Validations

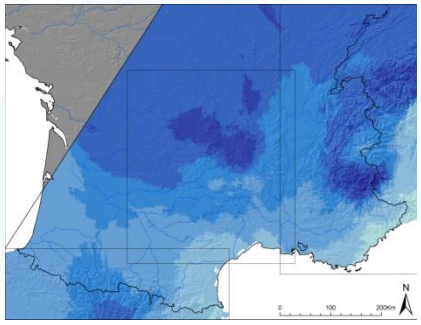


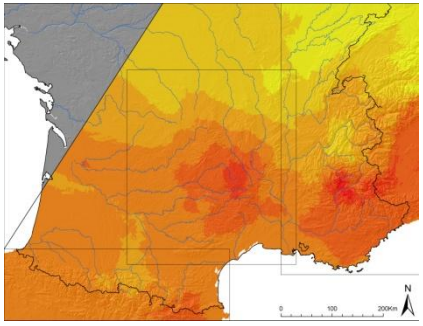
Temperature Model

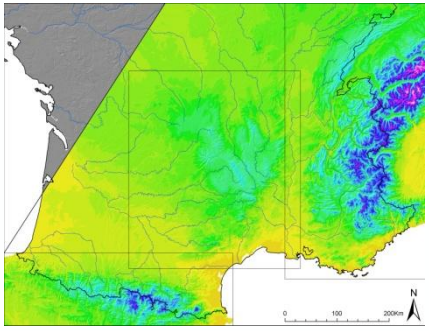
- ⇨ Rain/Snow discrimination
- ⇨ Snowmelt estimation
- ⇨ PET estimation

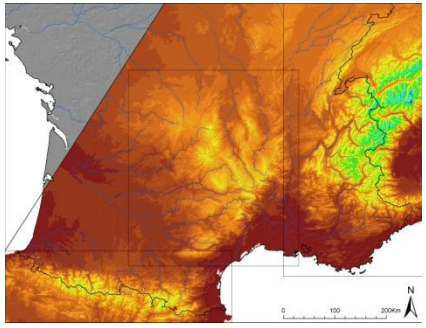
Cartography of
the daily Tmin and Tmax
for the 1953-2005 period



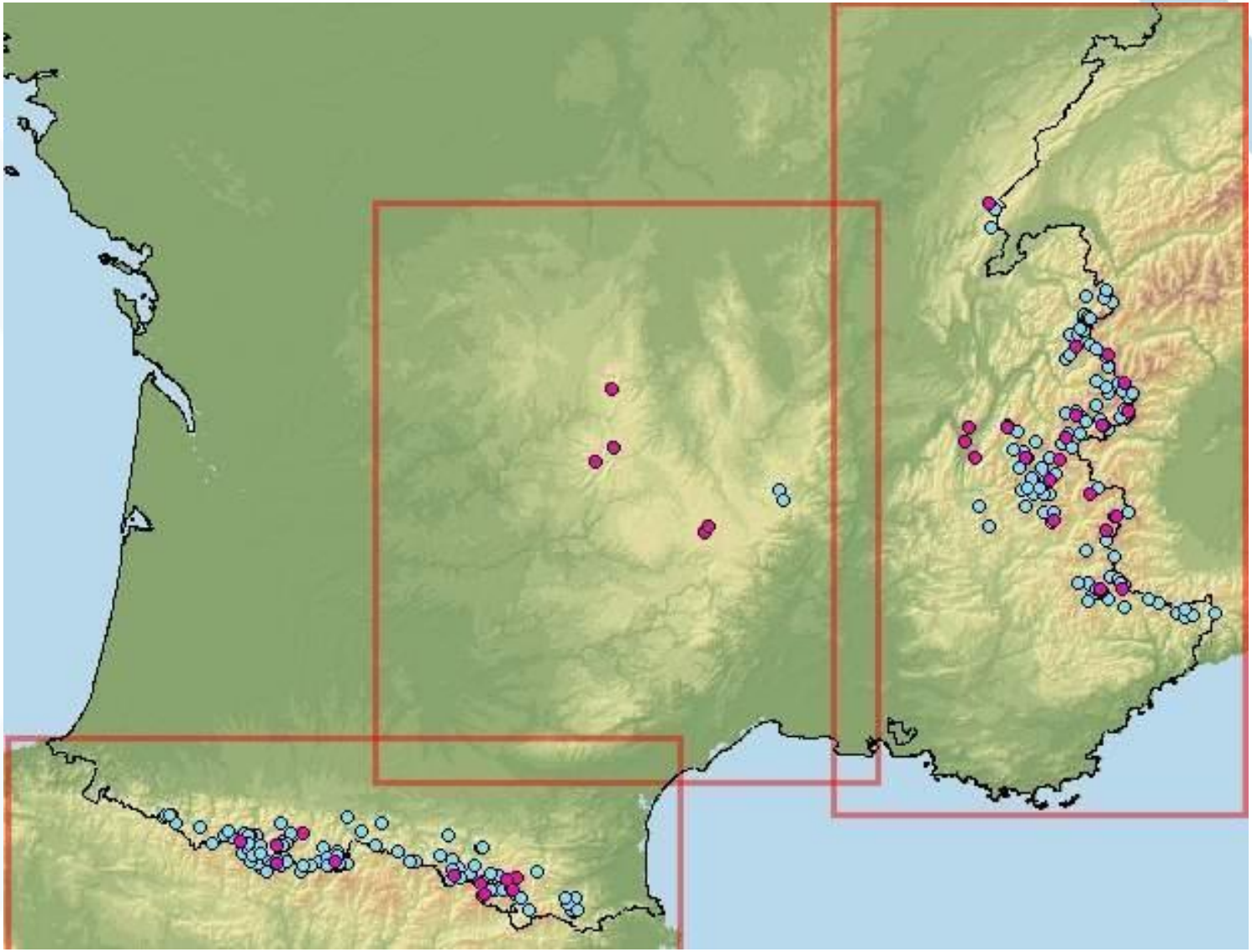








EDF Snow network



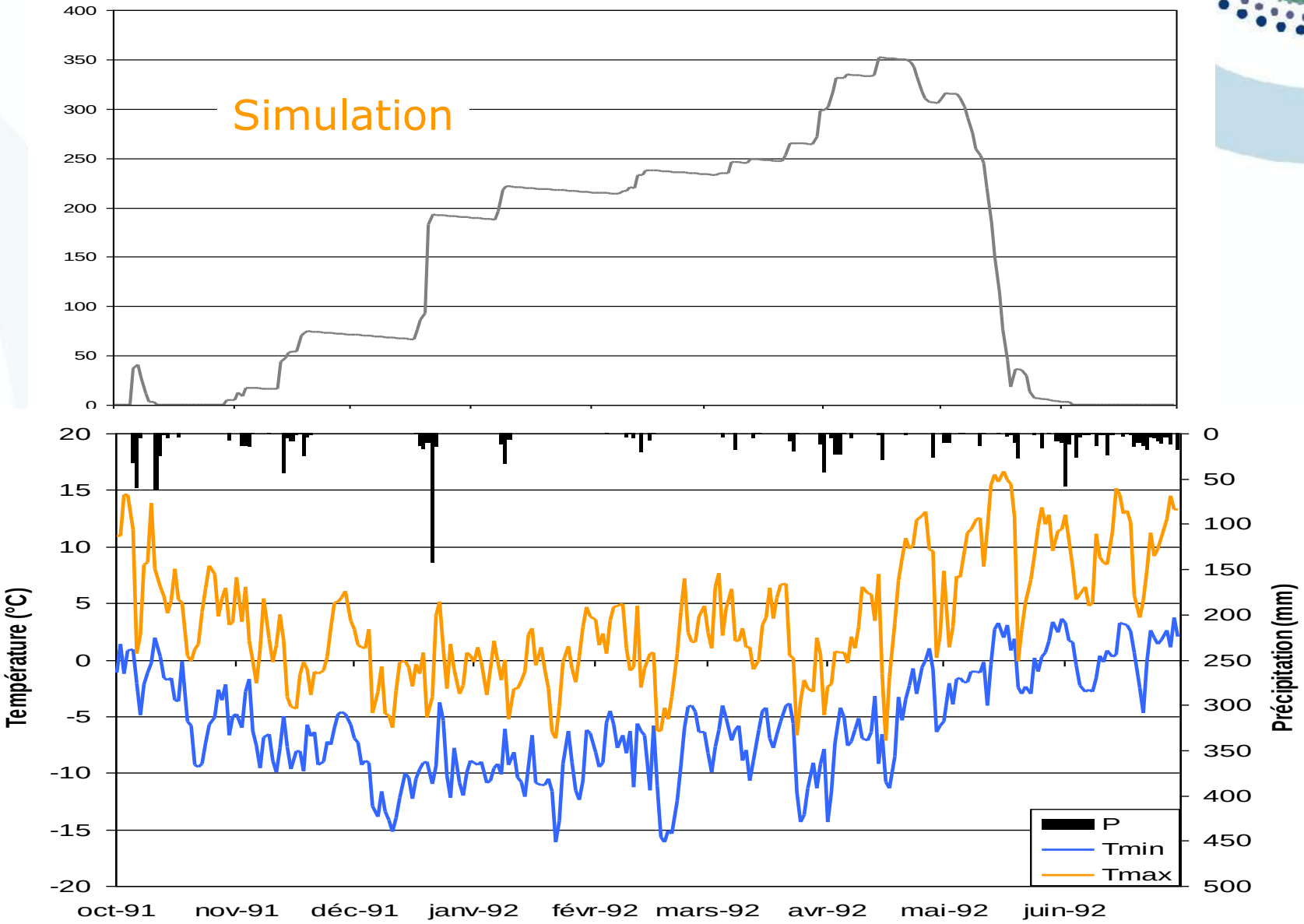
EDF snow network

~ 650 stations :

~ 325 core samplings	Monthly	**1948-2008**
48 gamma-rays attenuation SWE gauges	Daily	**1983-2003**
36 cosmic ray attenuation SWE gauges	Daily	**1999-2008**

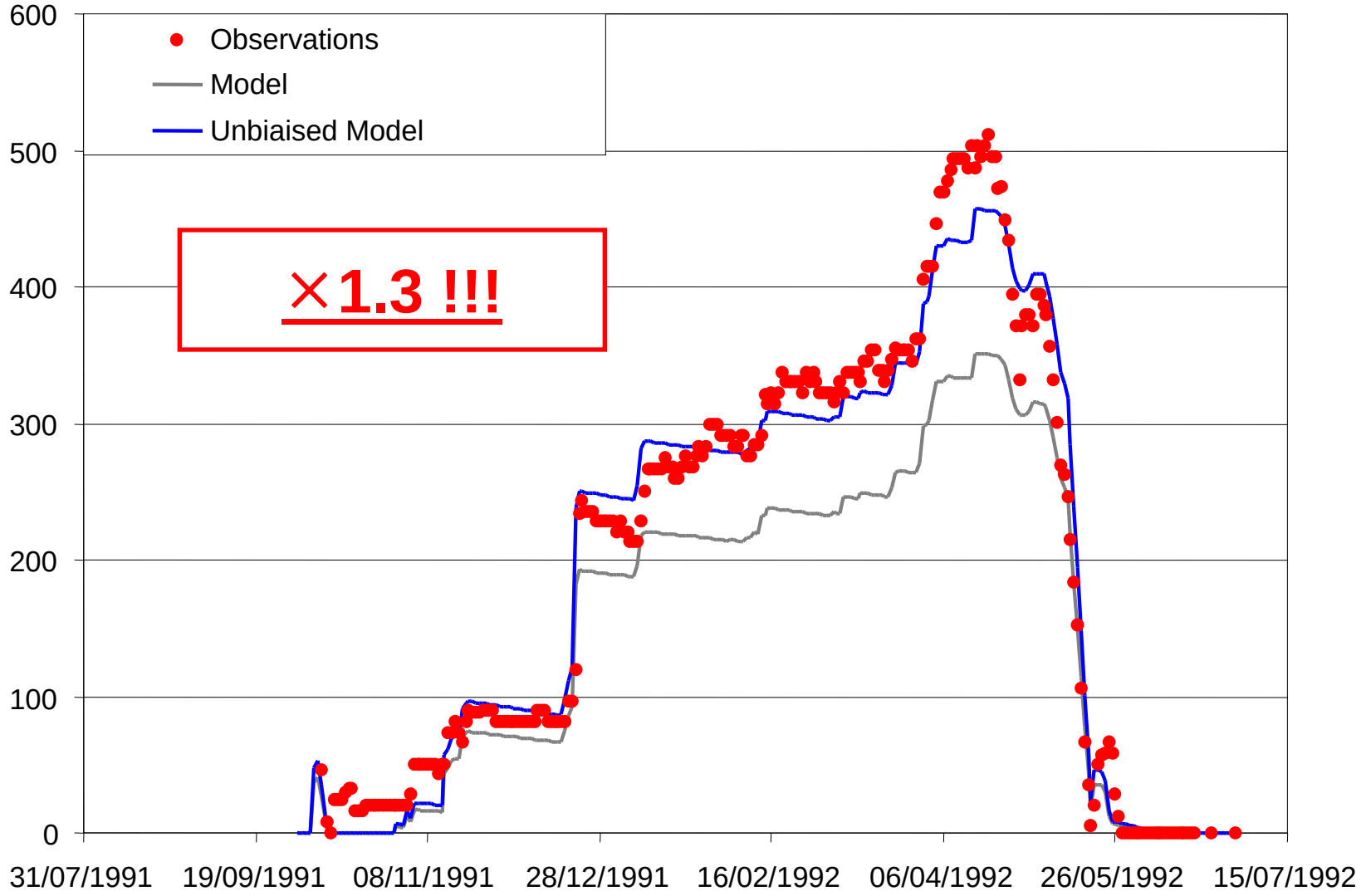
Snow Model : a degree-day model

SWE gauge of Chardonnet, winter 1992

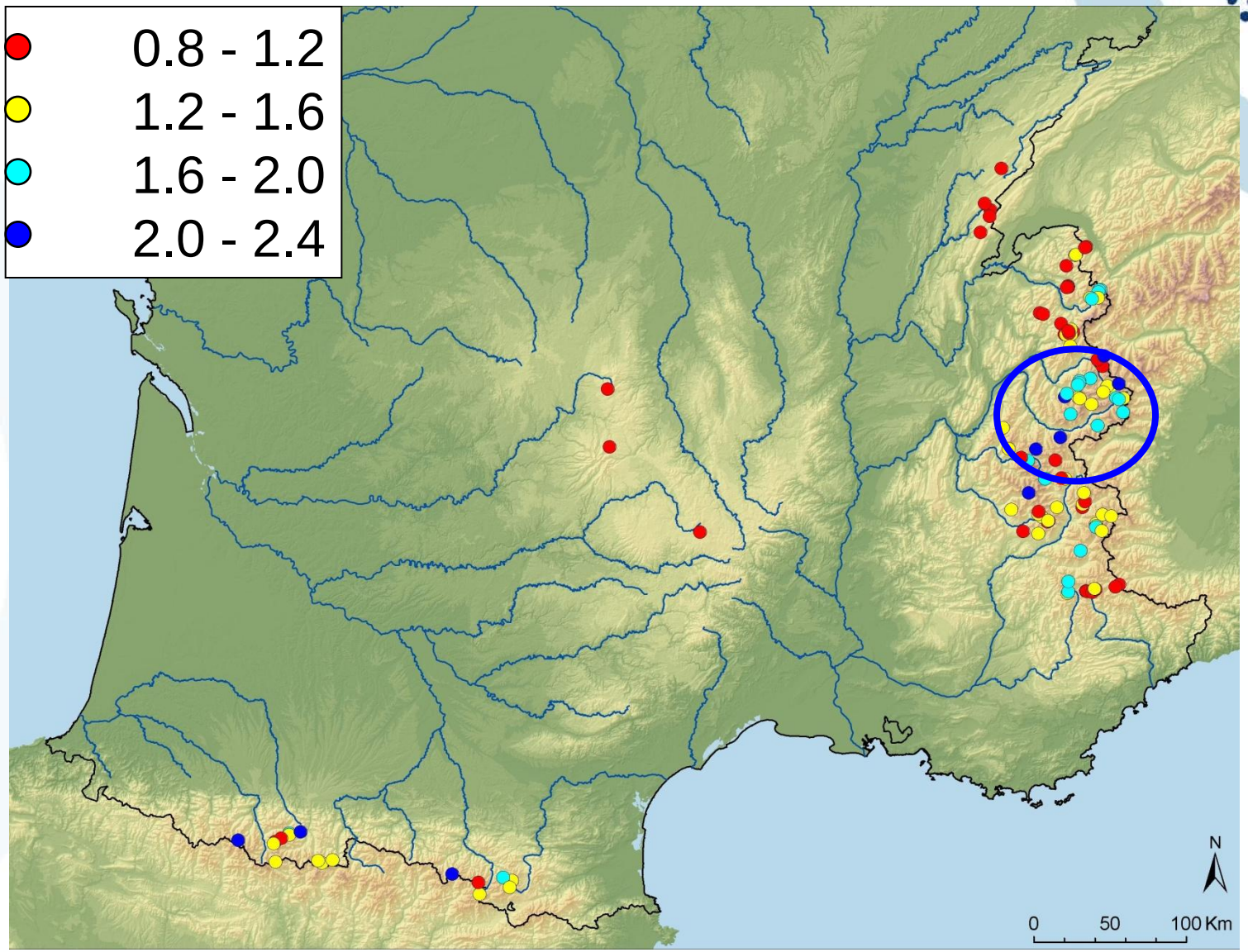


Snow Model

SWE gauge of Chardonnet, winter 1992

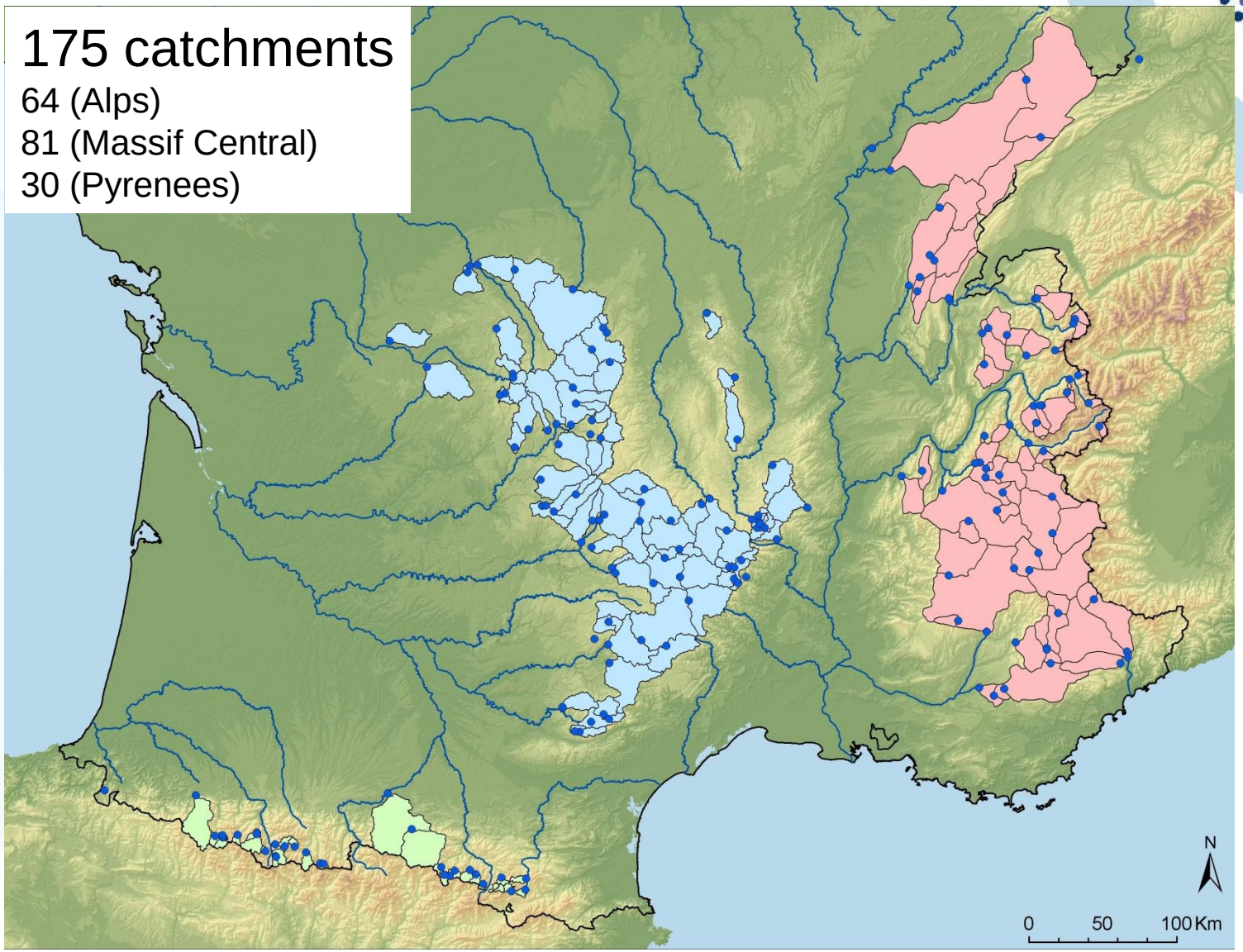


Snow validation



Precipitation increase to unbias snow simulation

Gauged catchments for water balance



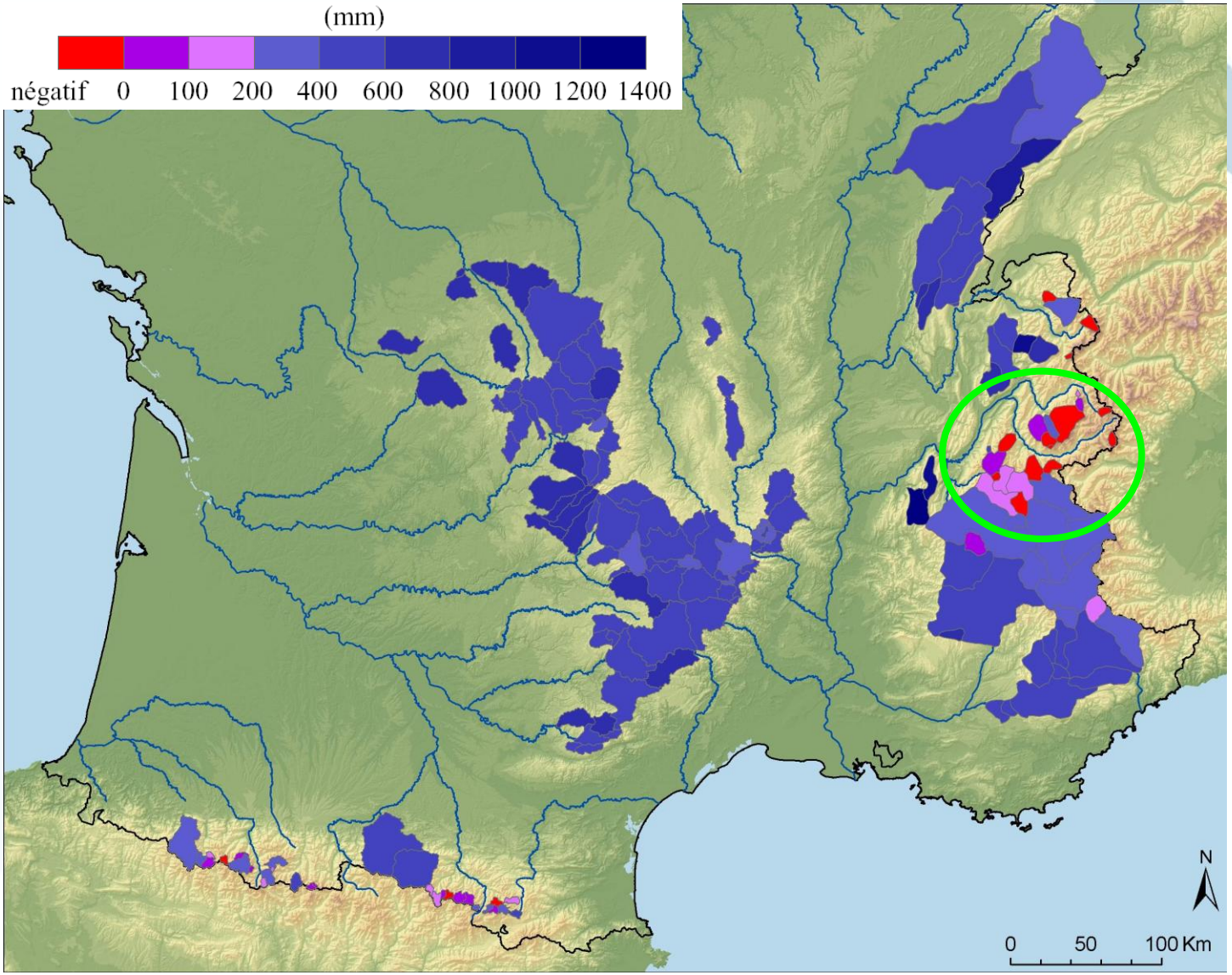
Annual Water balances Validation

➢ *Comparison :*

Annual deficit **D**
(Annual Precipitation – Annual Runoff)
⇔
Real Evapotranspiration **RET**
(Turc, 1953 ; Menzel and Lang, 1998 ; Mouelhi, 2003)

Hypothesis : **D ≈ RET**

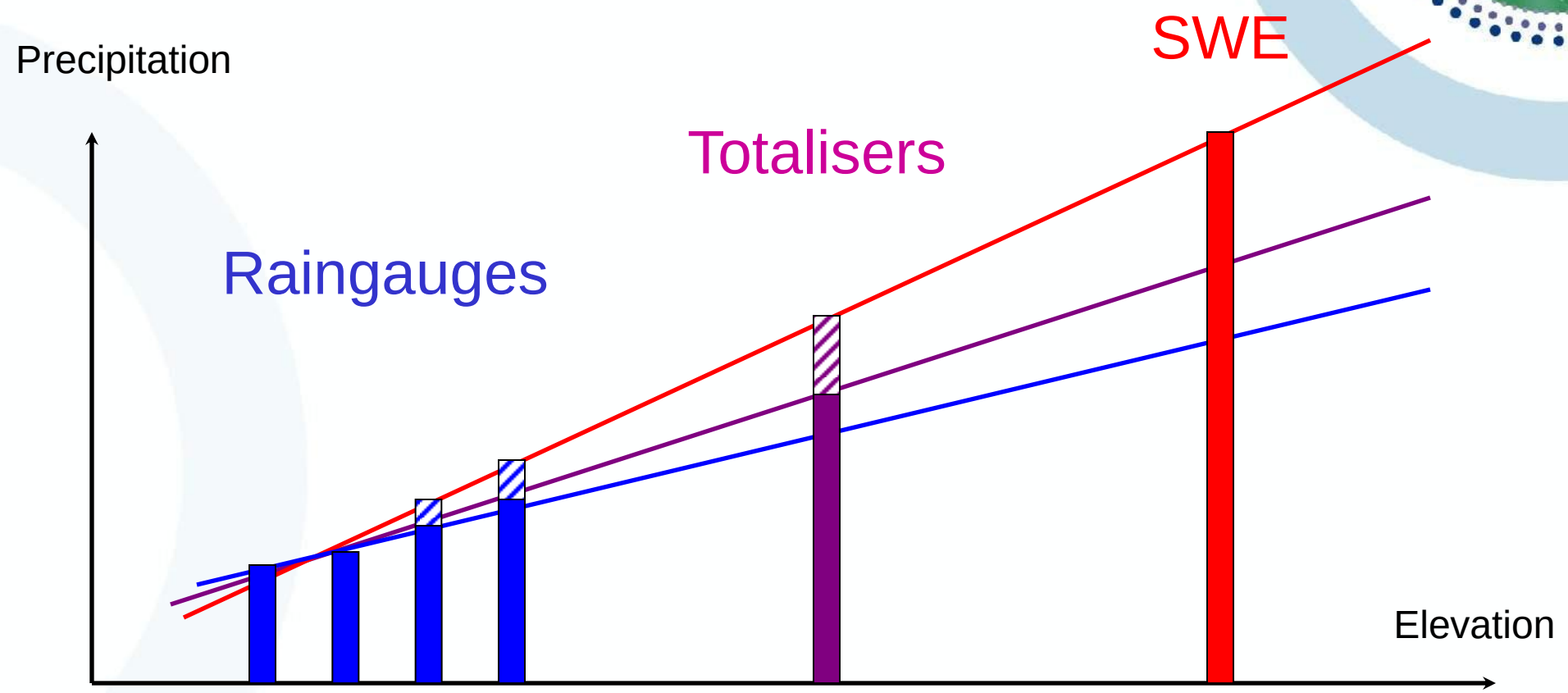
Water balances

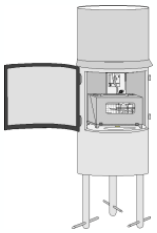


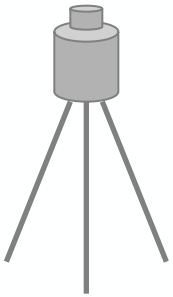
Annual Mean deficit for the 1985-2005 period

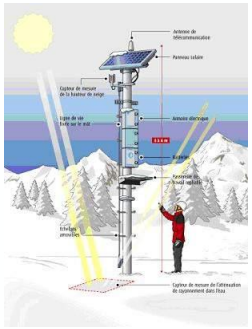
ASSIMILATION OF SWE MEASUREMENTS

Introduction of snow measurements in weather pattern guess fields

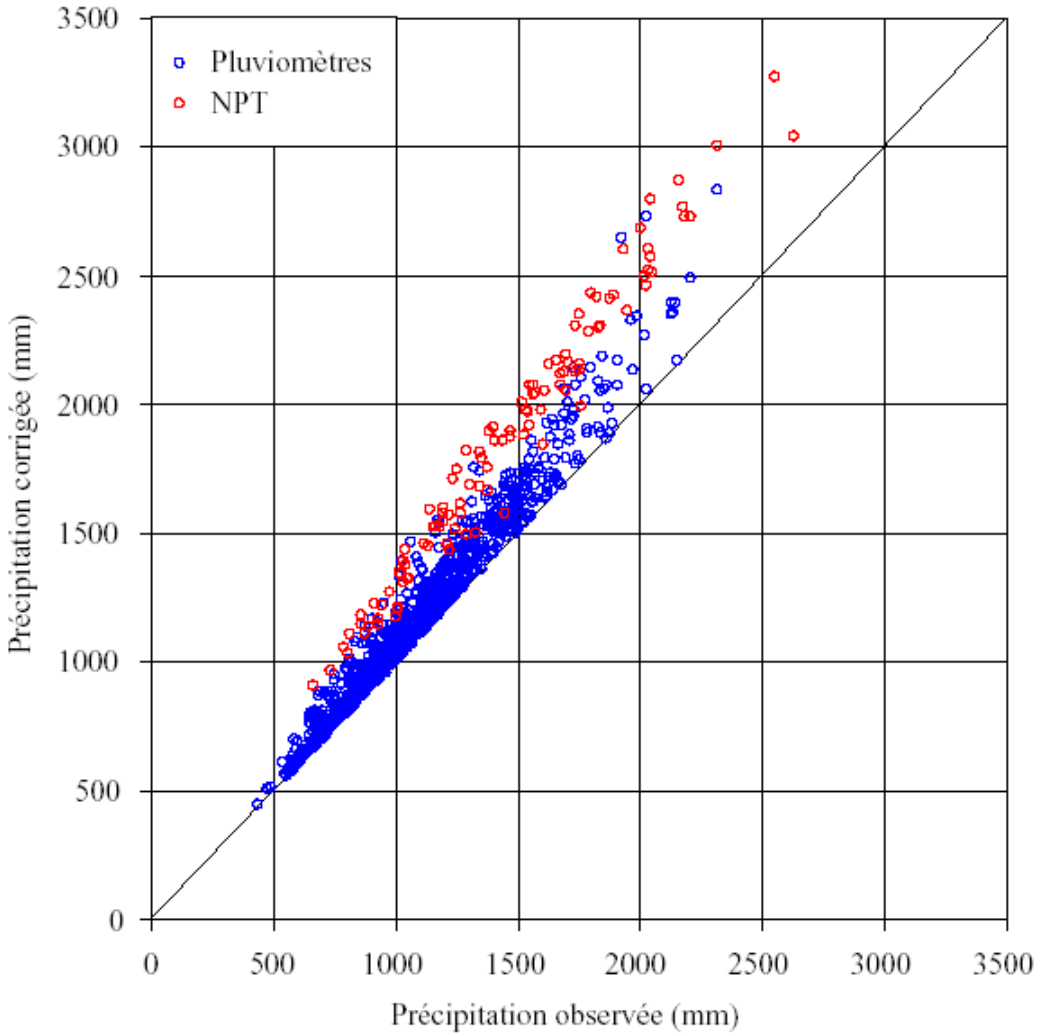








Correction of rain gauges measurements as a function of the solid fraction (snow)



$$P_j^* = C(FS_j) \cdot P_j$$

$$C(FS_j) = 1 + 0{,}6 \cdot FS_j$$

Replay all the process…

⇨ New weather pattern guess fields with :

-SWE measurements,

-Corrected raingauges and totalisers measurements,

⇨ New daily estimations

⇨ New validations

SWE Model

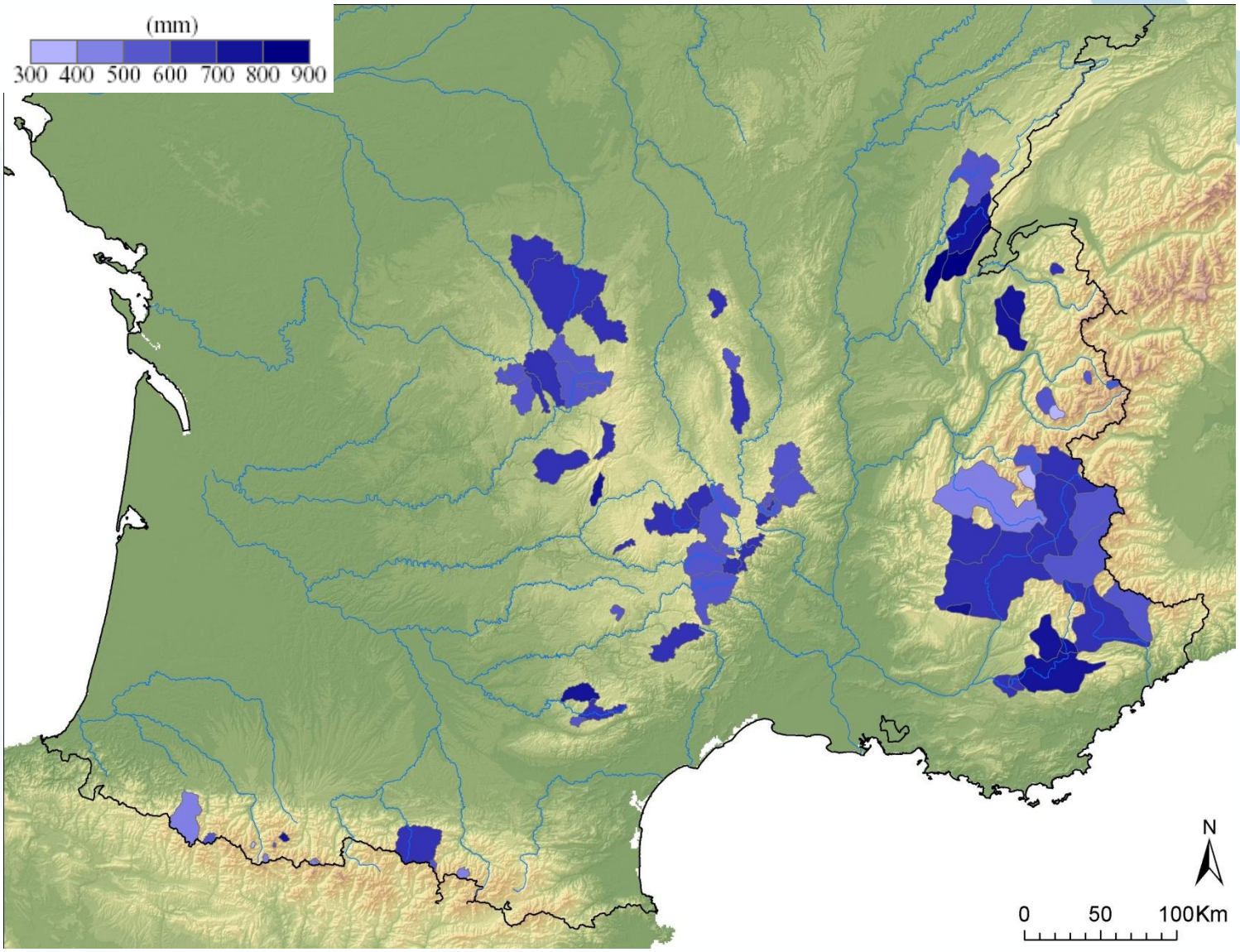
153 series are modeled
(core sampling, continuous SWE meas.)

To reproduce observations :

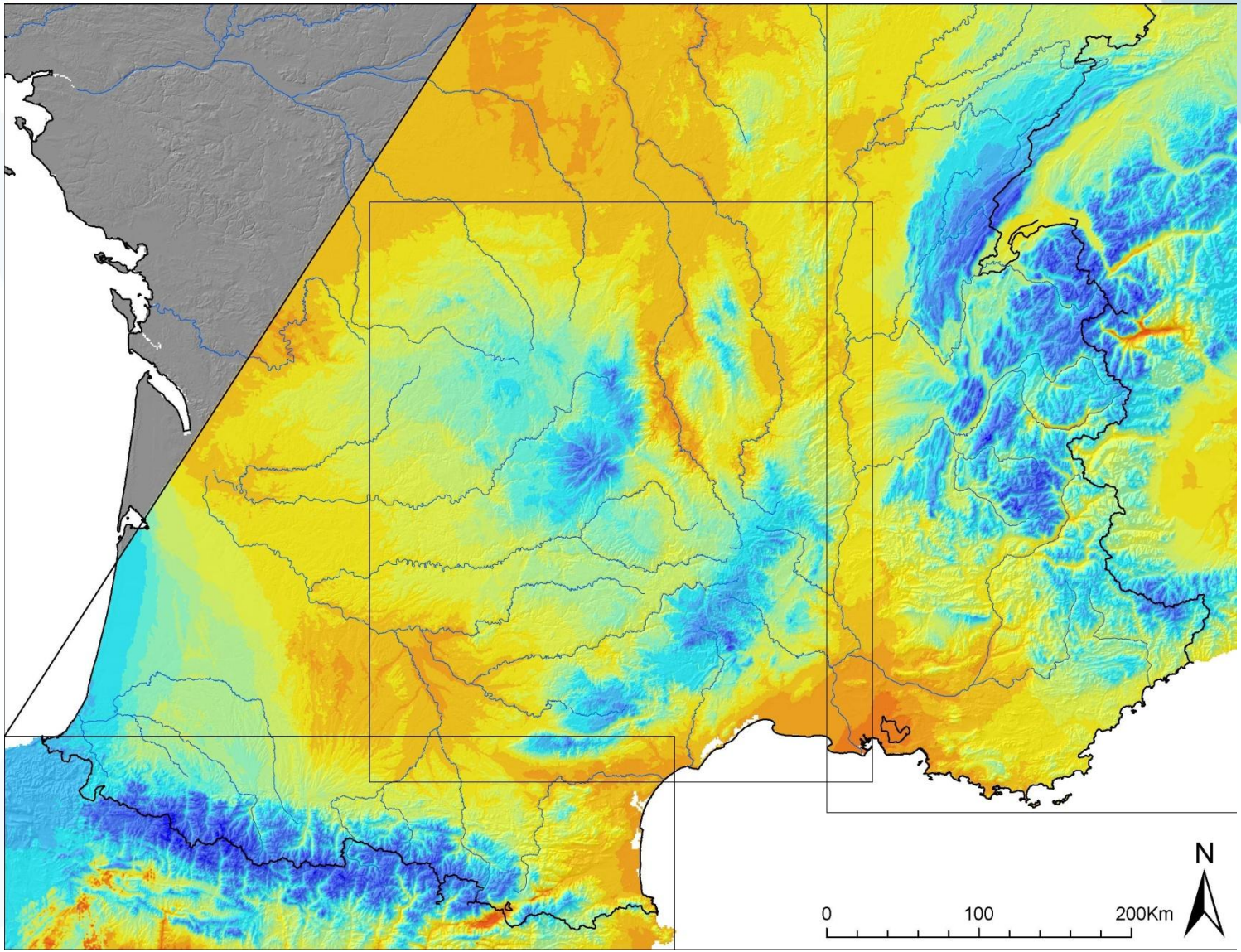
Before ☹
Mean multiplicative factor = 1.41
Std Dev. = 0.36

After ☺
Mean multiplicative factor = 0.96
Std Dev. = 0.18

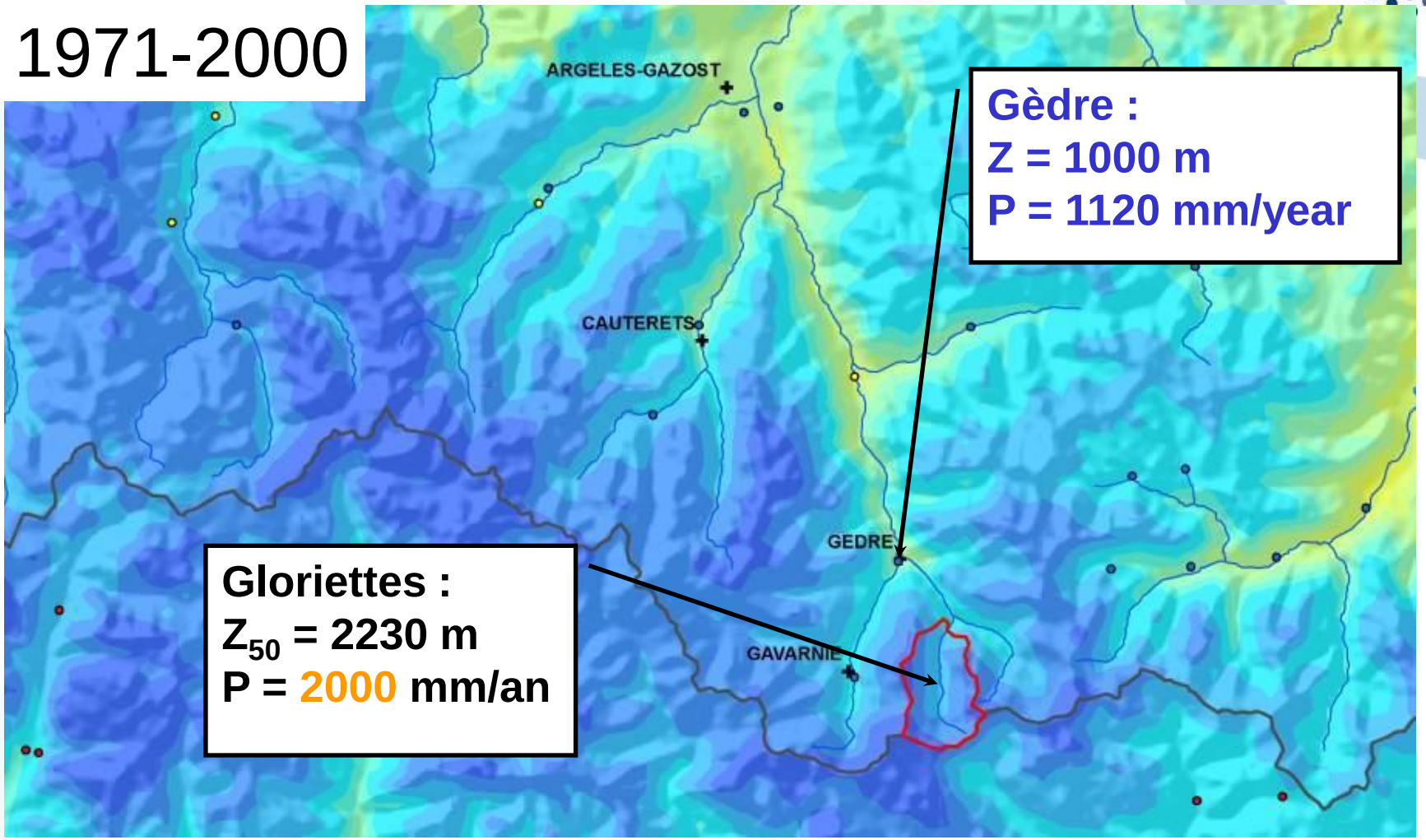
New annual water balances



Annual Mean of precipitation (1971-2001)



Zoom on the Gloriettes catchment



CONCLUSION AND OUTLOOK

Conclusion

⇨ Daily precipitation re-analysis

- 1km x 1km grid
- 1953-2005 period
- French mountain ranges

⇨ …Consistent with :

- Raingauges measurements,
- SWE measurements,
- Runoff measurements.

⇨ Synthesis of all the ground information available in mountains.

Outlook

- Real-time maps of precipitation (a prototype is running)
- SWE maps (Post-Doc work, distributed snow model)
- Better understanding of the snow hydrology
- Improvement of the operational seasonal forecast

Thank you for your attention