An inter-comparison project for km-scale Land Surface Model

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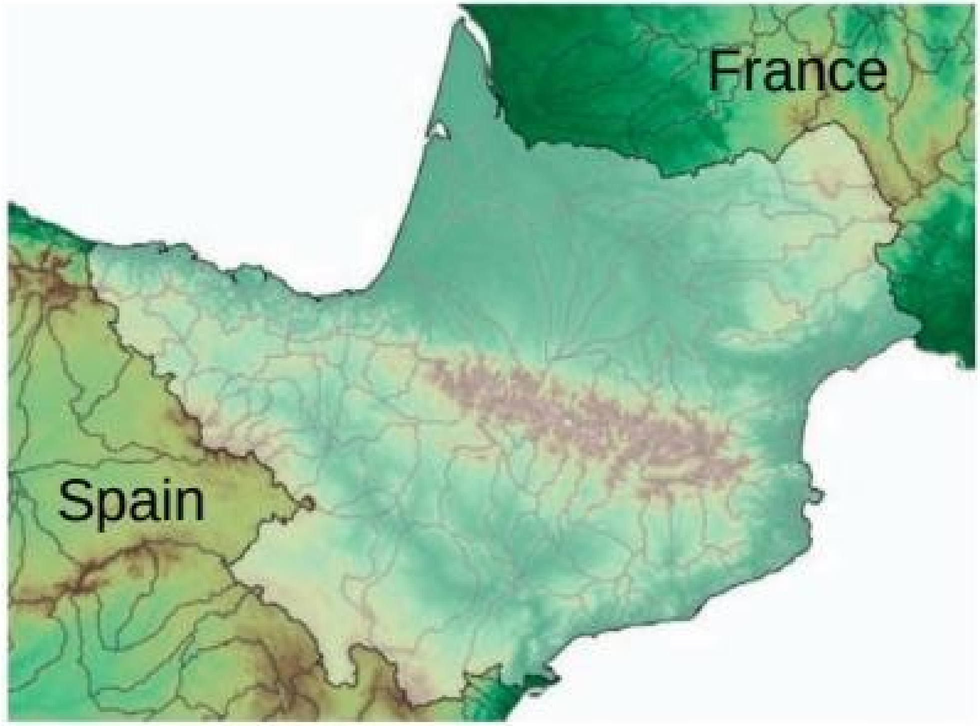
- Presentation of the km-scale atmospheric forcing
  - Construction method of the forcing
  - Validation with sub-diurnal meteorological observations
  - Issues with the radiative fluxes
  - Experimental protocol
- First analysis of the ORCHIDEE simulations
  - Catchment scale evaluation of the water cycle
  - Variability of the land surface temperature

Objectives for the forcing constructions

- To evaluate Land Surface Models (LSMs) at km-scale an atmospheric forcing data set at these resolutions is needed (8 atmospheric variables)
- The region is well observed, but only in the lower elevation areas : SAFRAN data sets for France and Spain
- Km-scale climate simulations (CP-RCM) can be used to extrapolate the observations in space and time.



The methodology used when bias correcting re-analysis is extended to produce a forcing data over the 1989-2013 period.

Strategy

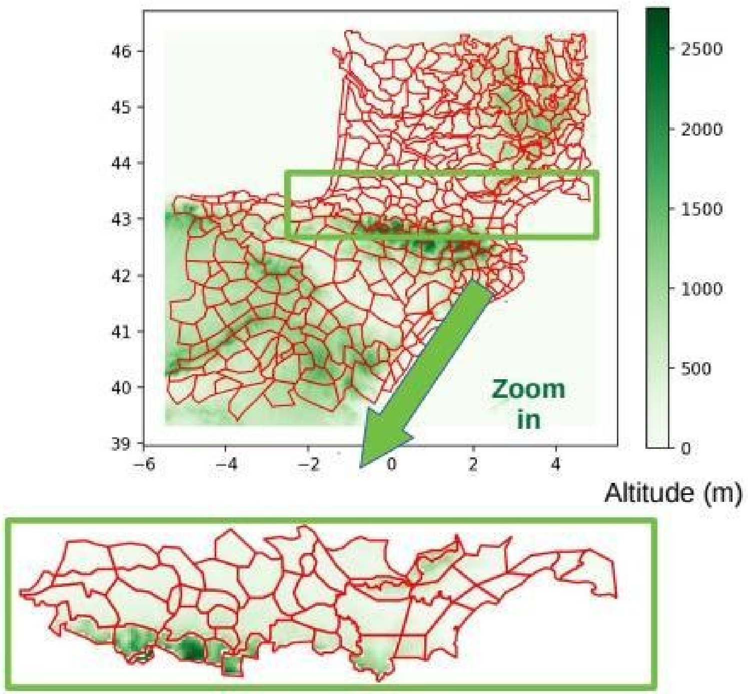
- **Datasets**:
- Observation-based dataset SAFRAN : polygon scale daily values for different altitude classes (1979-2013).
- Outputs from convection permitting regional climate models (CP-RCM : ETHZ, IPSL) at different spatial resolutions and hourly data (2000-2009).

- **Objective**:

Construct an atmospheric forcing for the longest period possible(1989-2013) :

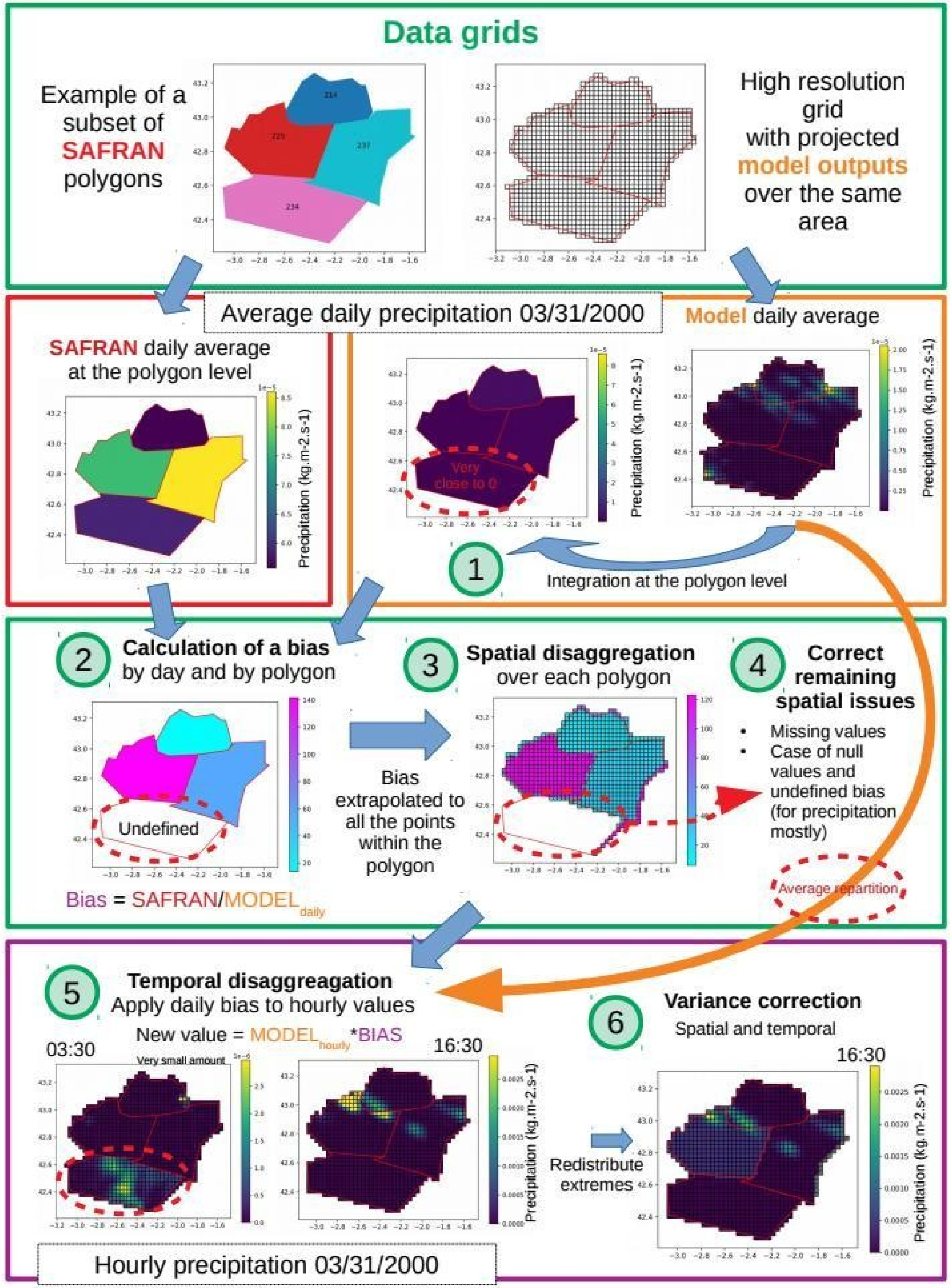
- favoring the SAFRAN observations at the daily scale, but
- favoring the altitudinal and sub-diurnal coherence of the CP-RCMs outputs.

The forcing data is produced on a simple regular lat/lon grid of 3 km resolution.



Methodology

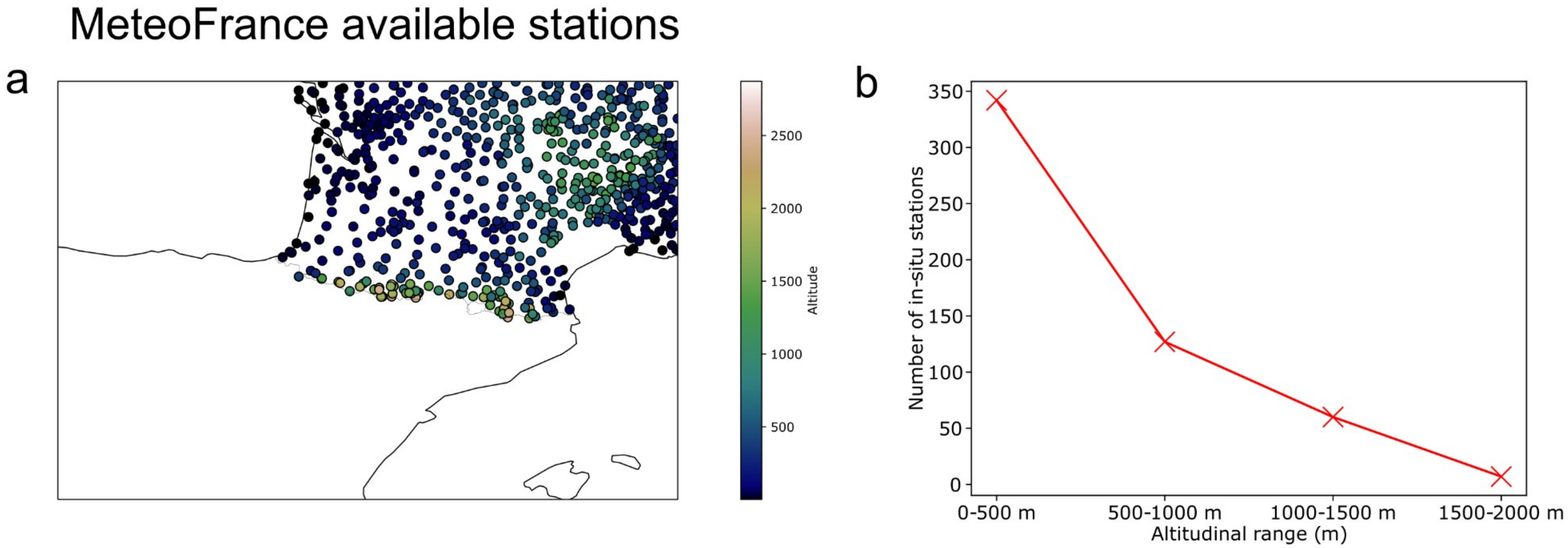
1. Aggregation of daily average of the output of the CP-RCM for comparison with SAFRAN.
2. Calculation of a bias between SAFRAN and the CP-RCM :
   - averaged over the polygon (avg), or
   - by altitude class (alt).
3. Spatial disaggregation of the daily bias on the common high resolution grid.
4. Correction of remaining issues : missing values and undefined biases.
5. Application of the bias to correct the hourly values of the CP-RCM.
6. Correction of the temporal and spatial variance to smooth out extreme values due to the disaggregation.



Forcing vs Observations: Validation

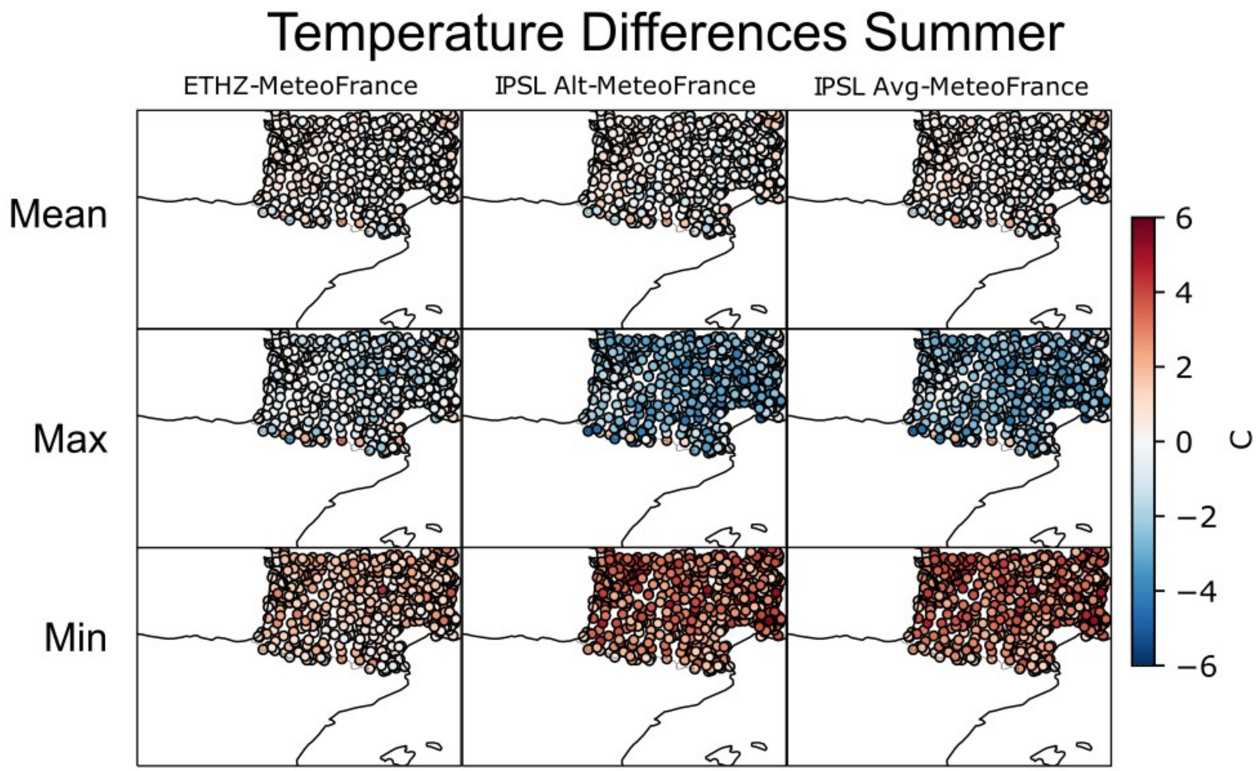
Validation using Météo France stations

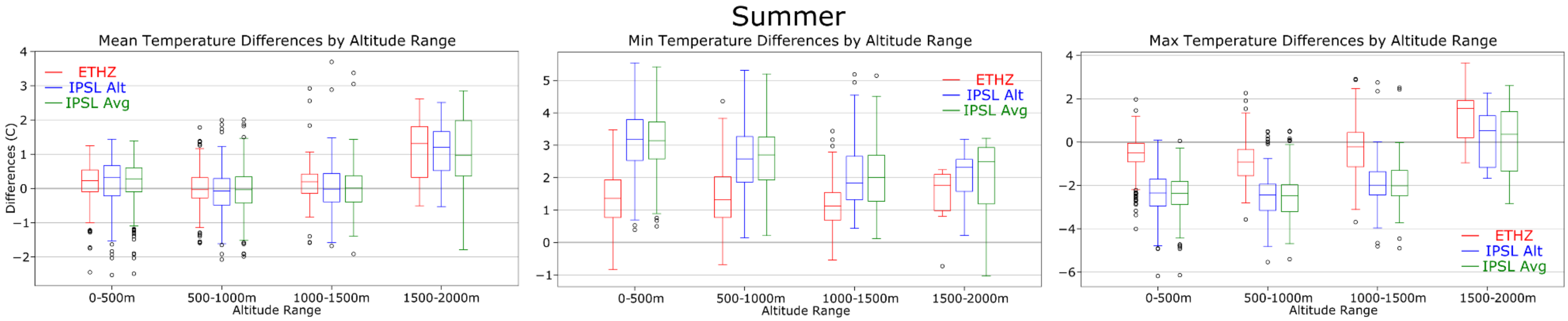
- 651 in-situ stations with temperature, relative humidity and rainfall information (2000-2009).
- This information is partially contained in the forcing through the bias correction (SAFRAN is based on Météo France data!).
  - Focus will be on sub-diurnal characteristic which are inherited from the km-scale climate models.
- Most weather stations are located in low-altitude zones.



2m Air Temperature

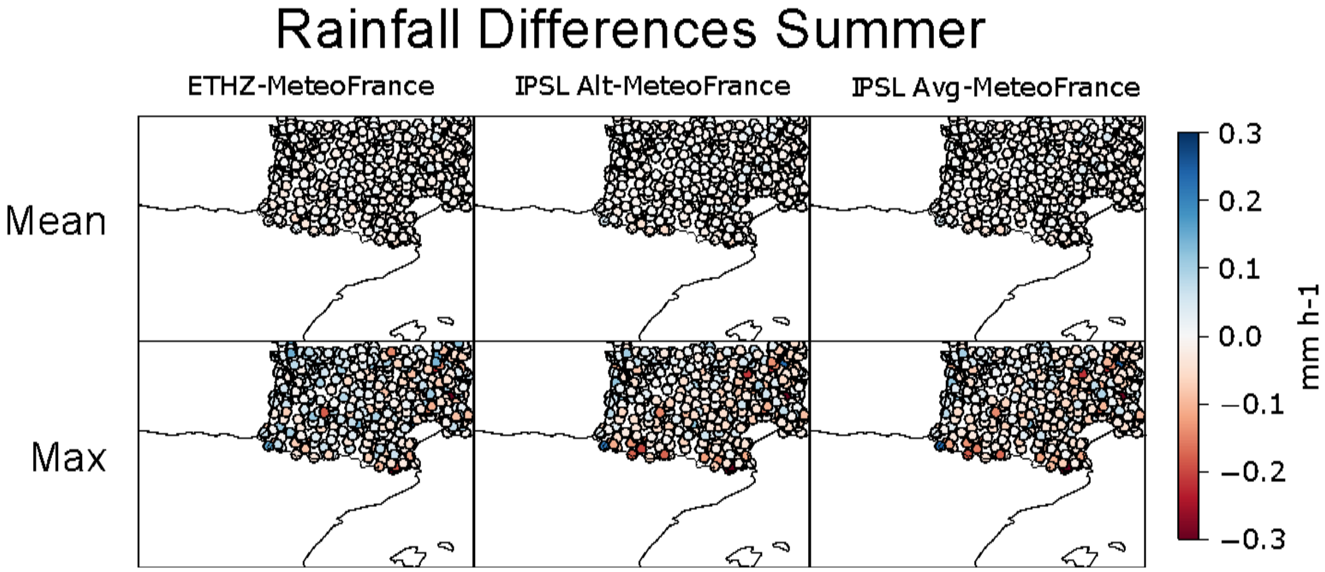
- Hourly observations allows to analyze the diurnal cycle (amplitude and timing).
- Mean summertime temperature (JJA) is similar between observations and forcing (due to bias correction!).
- Underestimated amplitude of the diurnal cycle (lower maximum and higher minimum temperatures).
- Equally well represented maximum/minimum temperature over altitude ranges.

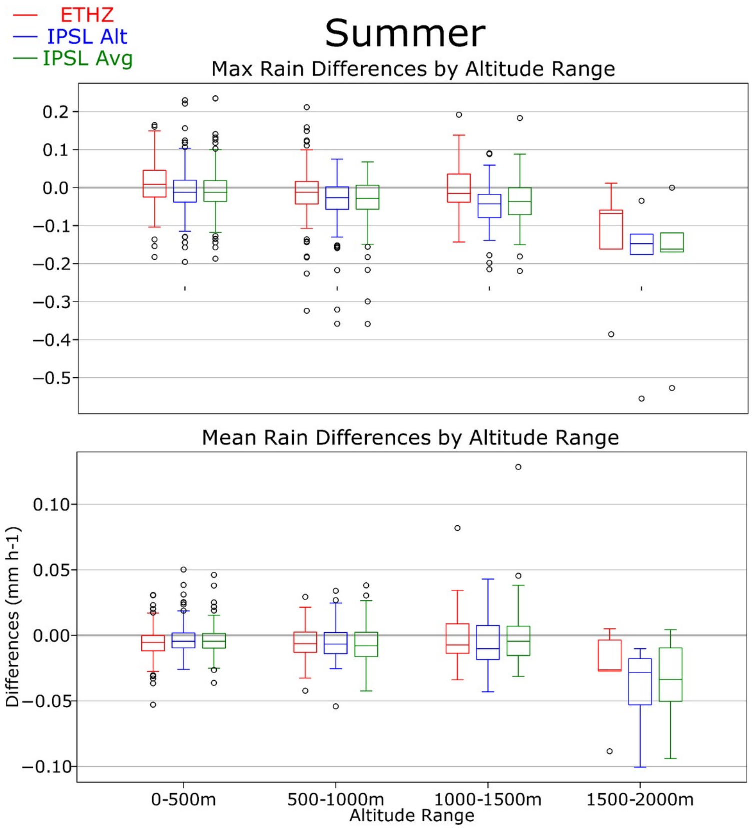


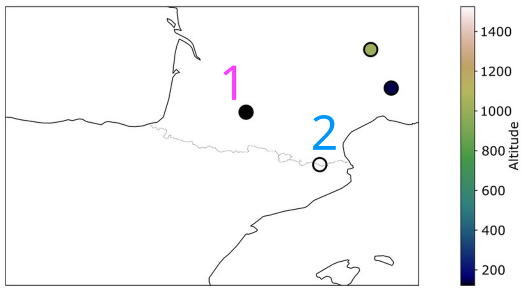


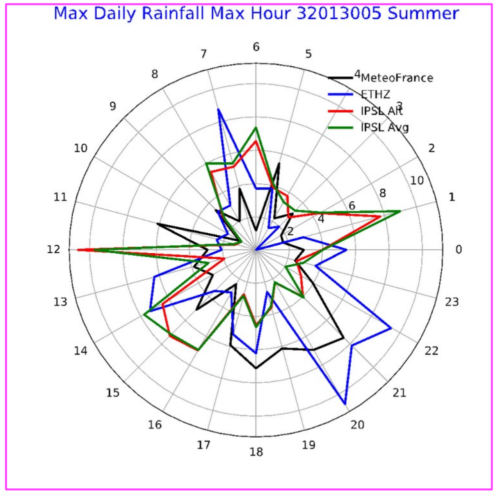
Rainfall

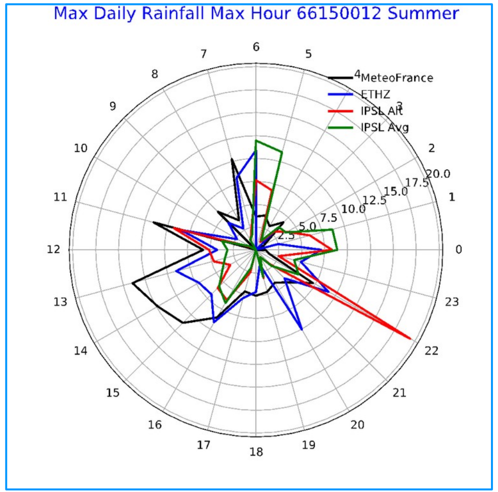
- Small differences in the mean rainfall (more significant over higher elevations!).
- Underestimated rainfall in the forcing.
- The diurnal cycle of summer precipitation is not too bad.



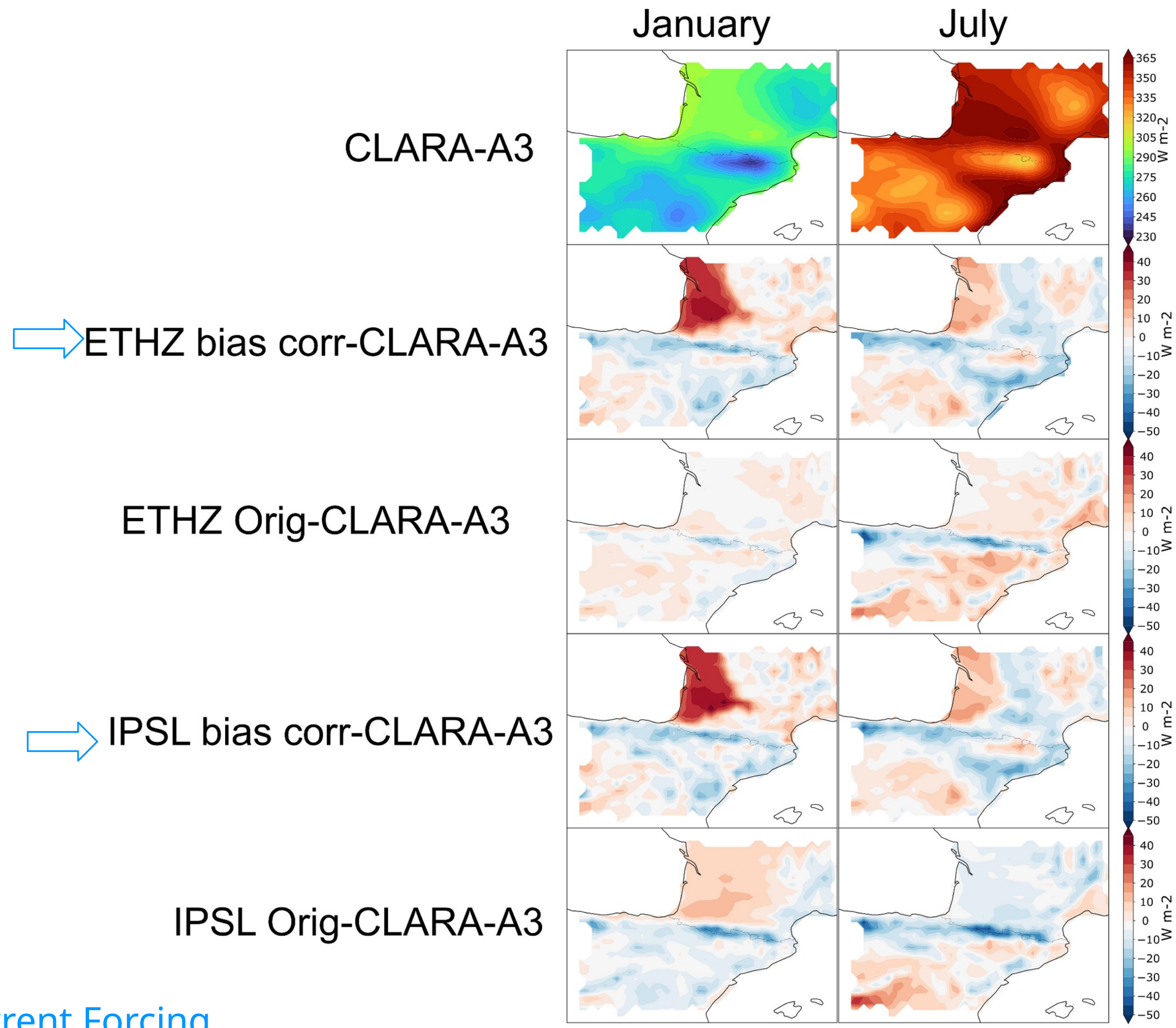








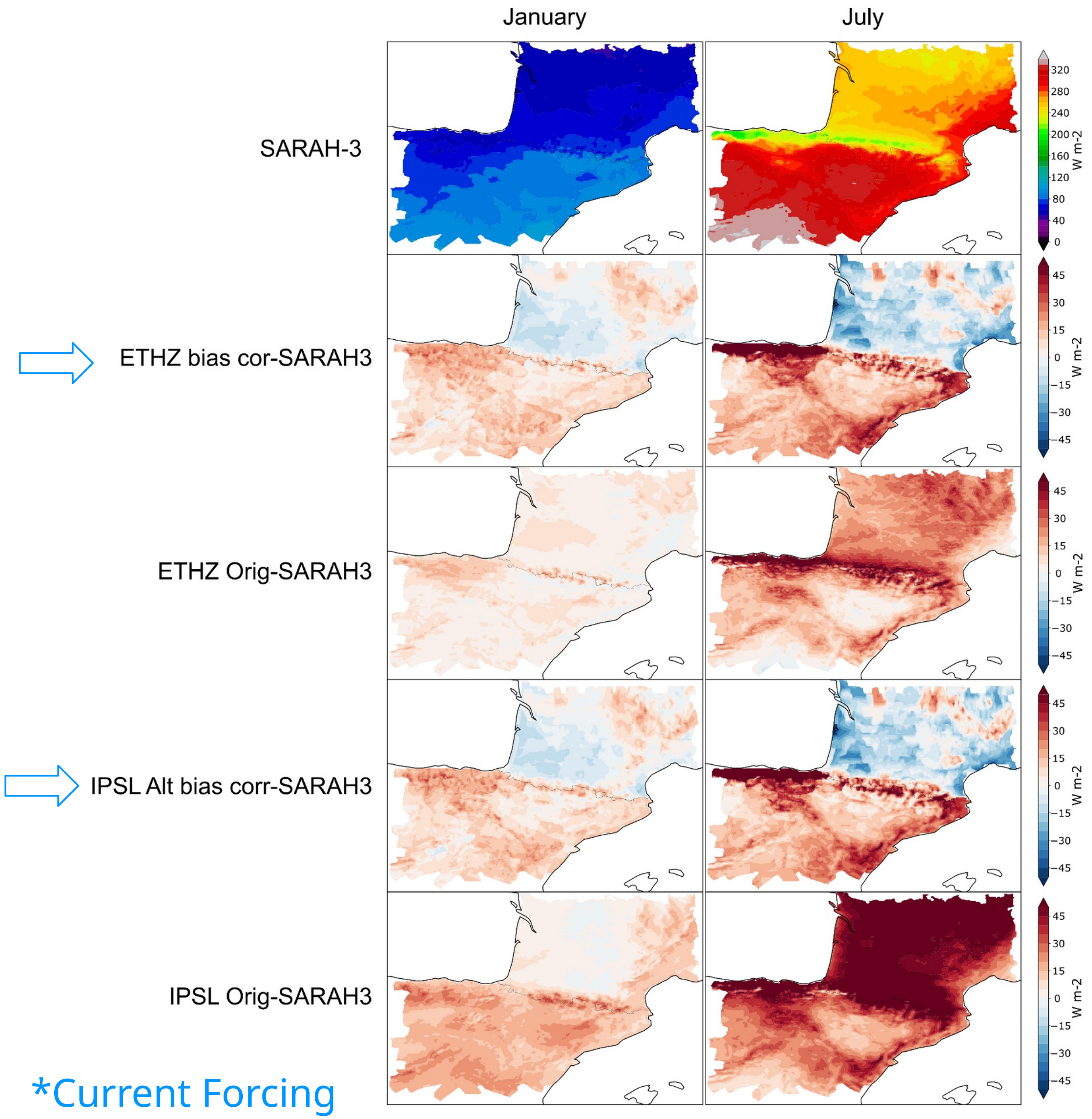
Radiation : Issues inherited from ERA-I



*Current Forcing

- Observed LWdown data is the CLARA product from CM-SAF (EUMETSAT).
- Overestimation of incoming longwave radiation over The Landes (SW of France) and over Spain.
- Underestimation North of the Pyrenees

Solar Radiation : Inherited bias from ERA-I



*Current Forcing

- SARAH is the daily CM-SAF product for SWdown.
- Underestimation of incoming SWdown north of the Pyrenees and overestimation to the South.
- Strong topographically induced errors.
- The original bias in the km-scale models was a systematic overestimation.
- The CP-RCM systematically overestimate the flux, IPSL in particular!

Solution:
Bias correction using EUMETSAT data (satellite derived estimates) instead of ERA-Interim

Experimental Protocol

Proposed Experimental Protocol

A first version of the forcing can be downloaded now (see Wiki of gitlab).
An updated version, with improved radiative fluxes, will follow shortly !

- **Simulations to be done**:
- 3 simulations using the available forcing :
  - ETHZ CP-RCM with altitude averaged bias
  - IPSL CP-RCM and altitude averaged bias
  - IPSL CP-RCM and bias correction per altitude
- One coarse resolution run for reference (WFDE5 forcing at 0.5°).
- Free **LSMs configuration** (e.g. interactive vegetation, anthropogenic water use, …).
- **Proposed spin-up:** One full 1989-2013 simulation. Use the final start as the initial condition for all three simulations.
- **Simulation period:** 1989-2013. Analysis will start with September 1989.
- **Requested outputs**:
- Variable names/units based on ALMA.
- Precipitation (Rainf, Snowf), Evaporation and its components (Evap, PotEvap, …), Water fluxes out of soil reservoirs (Qs, Qsb), surface temperature (RadT), …
- Details at: https://gitlab.in2p3.fr/ipsl/lmd/intro/liaise-forcing/-/wikis/home

Preliminary Results with ORCHIDEE

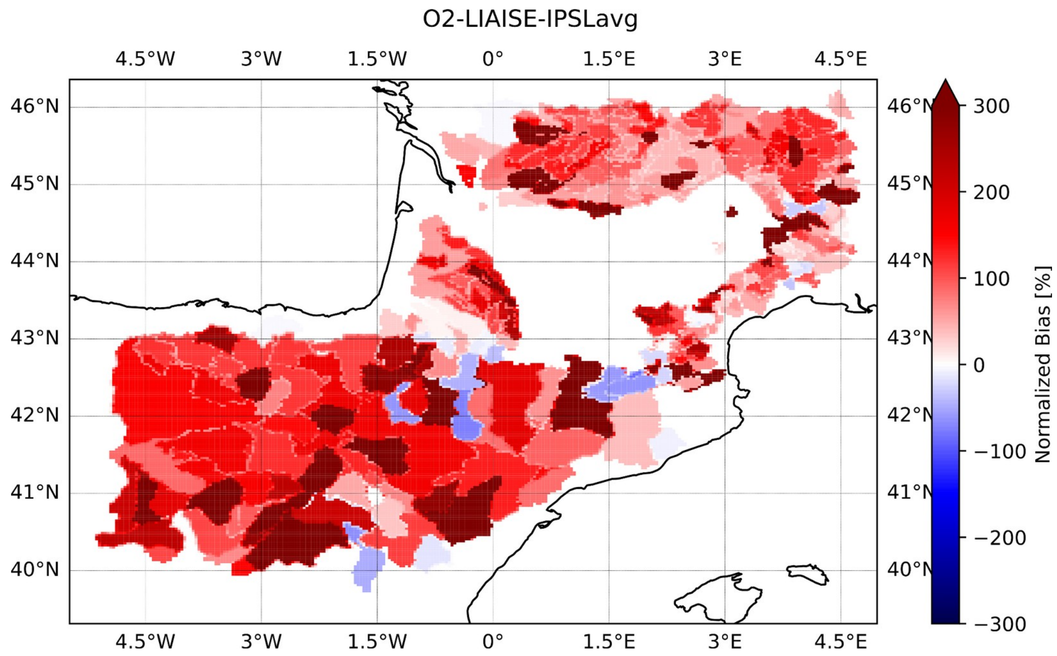
Catchment level water balance

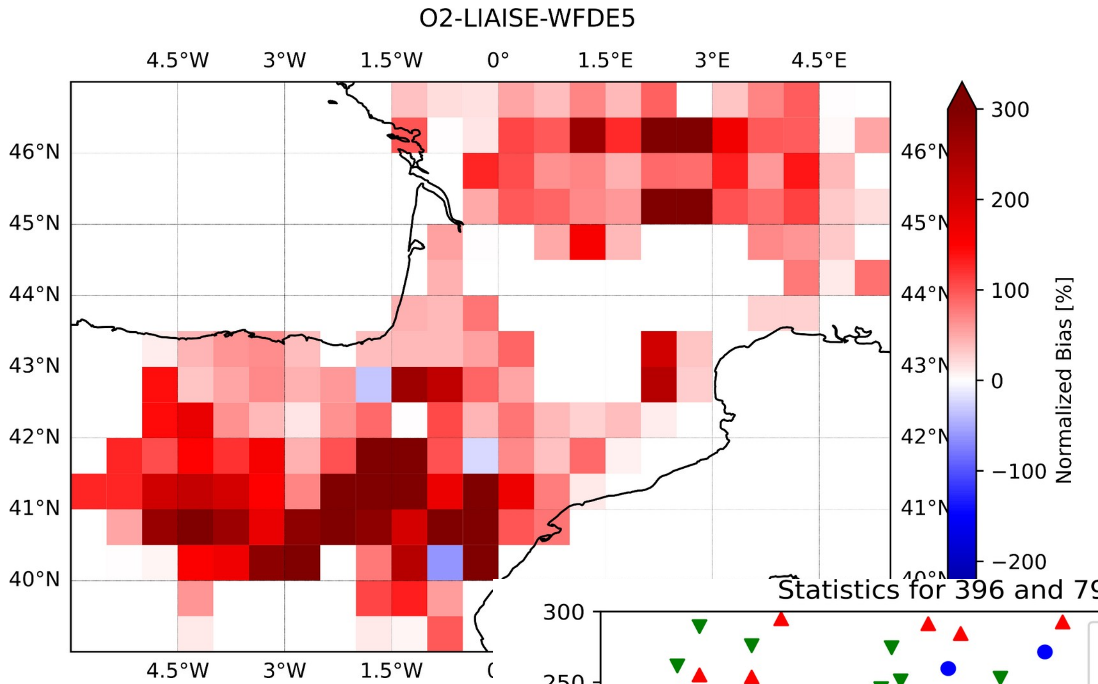
- The region has a wealth of discharge observations. About 400 stations have overlapping data with the LIAISE forcing period.
- Not all can be used at low resolution as some catchments are too small.
- With averages over the hydrological year (1st Sep. to 31st of Aug.) the water balance over catchment S can be approximated by :

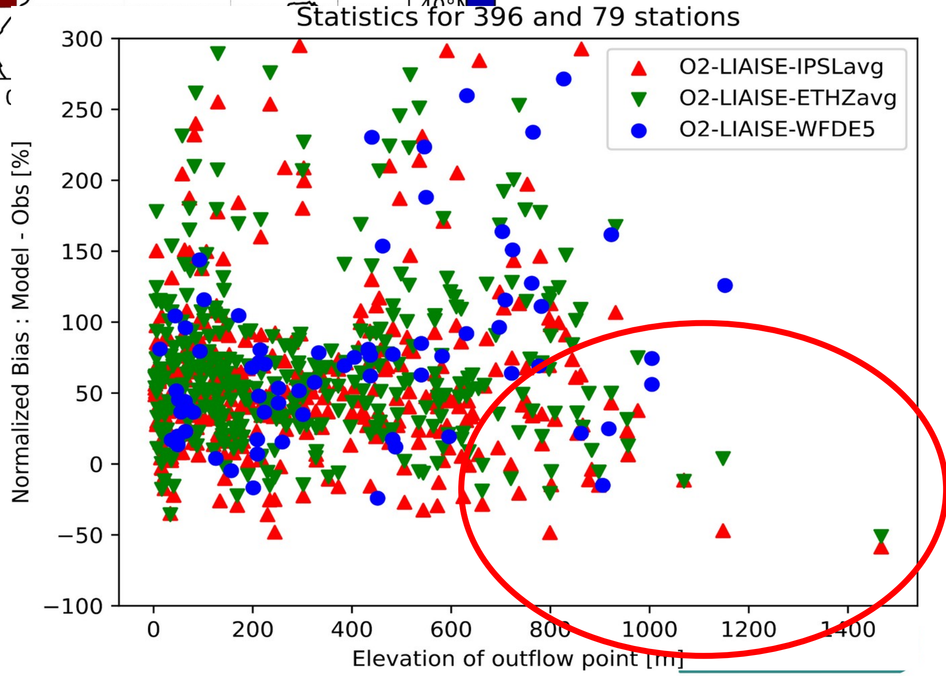
$$\int_S \bar{P} - \bar{E}\, ds = \bar{Q}_{obs} = \left(\bar{Q}_s + \bar{Q}_{sb}\right)$$

- This allows to evaluate the models and the forcing.
- It provides some indications how the extra resolution is used by the models in their representation of the water cycle.
- ORCHIDEE was run with the poor radiative fluxes !

Biases in simulated discharge



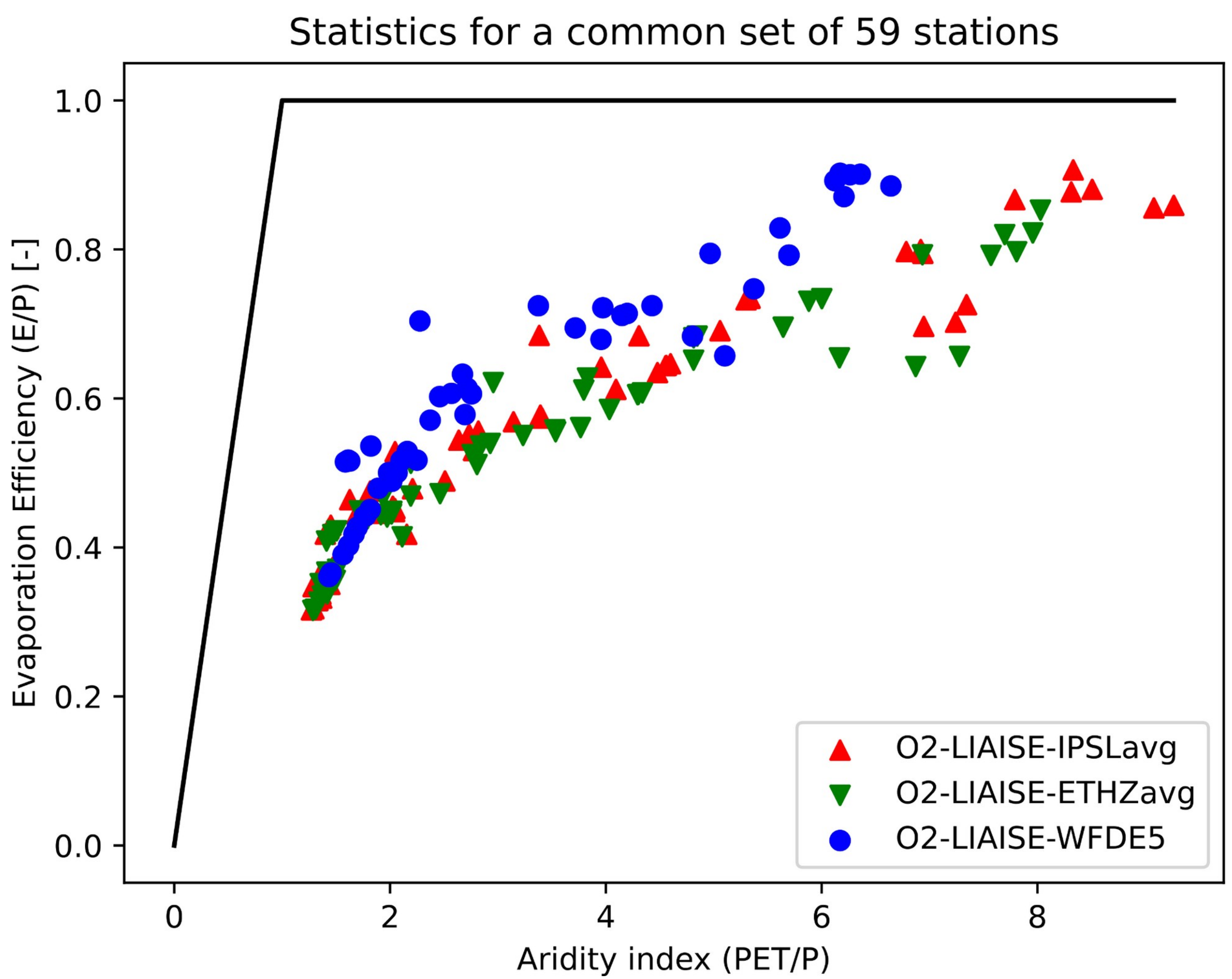




- At both resolutions ORCHIDEE has too little evaporation or is lacking human water usage.
- General biases are consistent between the LIAISE forcing and WFDE5.
- The higher resolution brings more details and will probably allow to attribute the evaporation errors to specific processes.
- Higher elevation catchments in particular will need to be analysed (assumed to be more natural !).

Characteristics of the largest catchments

- Only 59 catchments are well represented at both resolutions.
- For energy limited catchments (low PET/P) the higher resolution has little impact on evaporation.
- The more arid catchments have lower evaporation at 3km.
- The catchments also tend to become more arid (move to higher PET/P values).



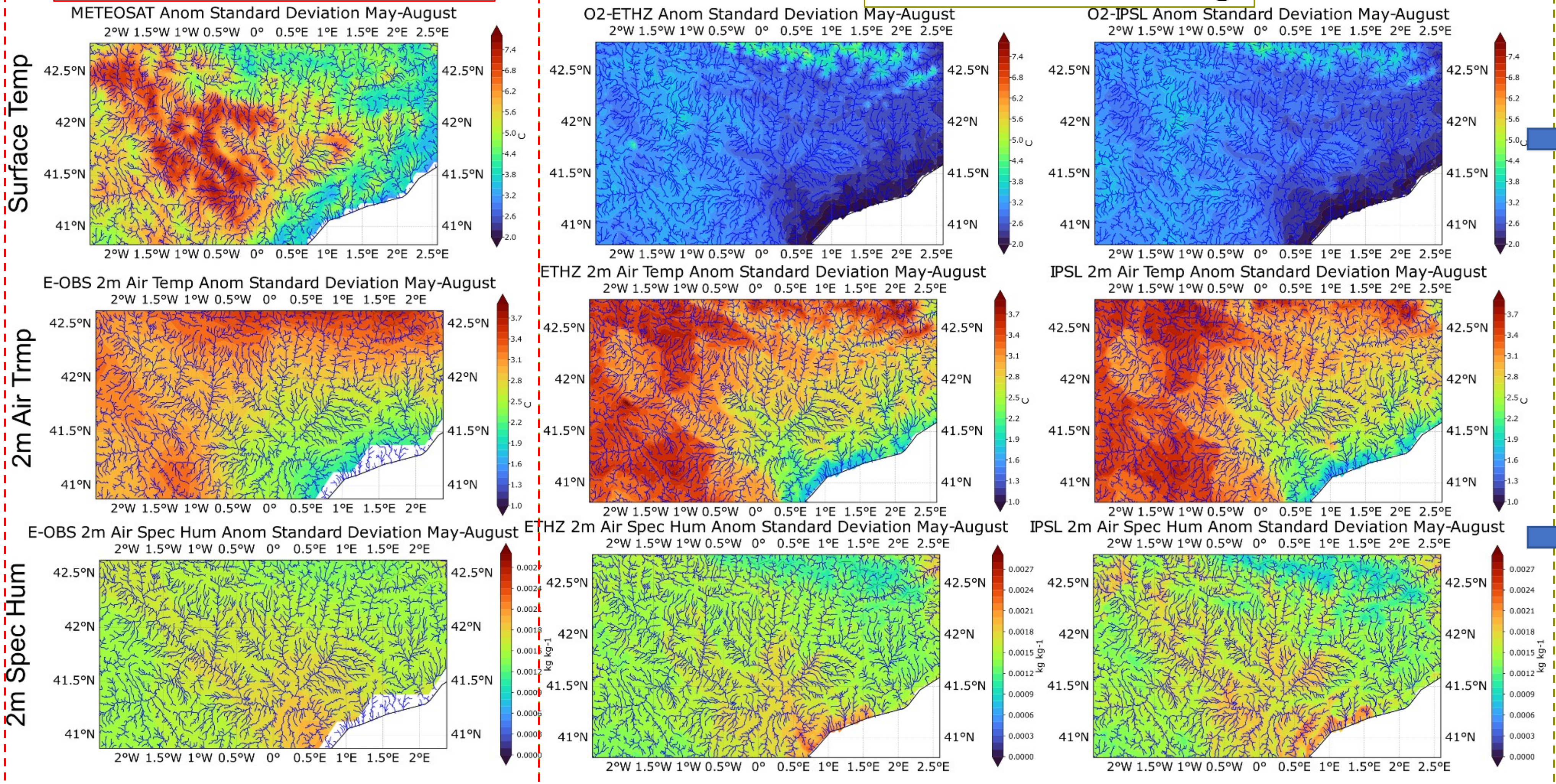
Budyko’s representation of hydrological regimes

Temporal variability in surface variables

Only summer considered here !

Independent estimates

ORCHIDEE & Forcing



Underestimated temporal variability of surface temperature in ORCHIDEE.

The temporal variability of 2m air temp and spec hum. is captured by the forcing

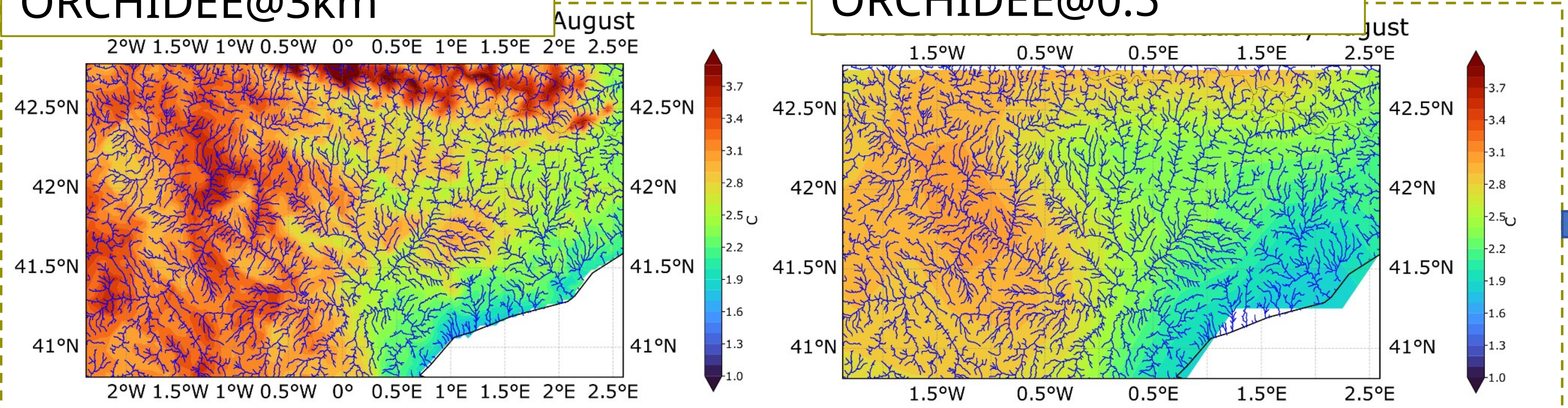
Remote sensed products and models perhaps define surface temperature differently !

What is role of the poor radiation ?

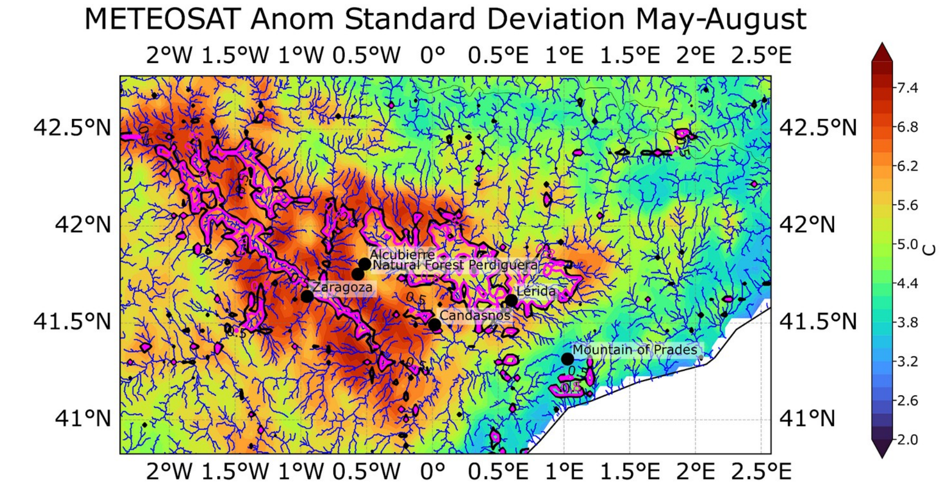
Temporal variability in surface temperature

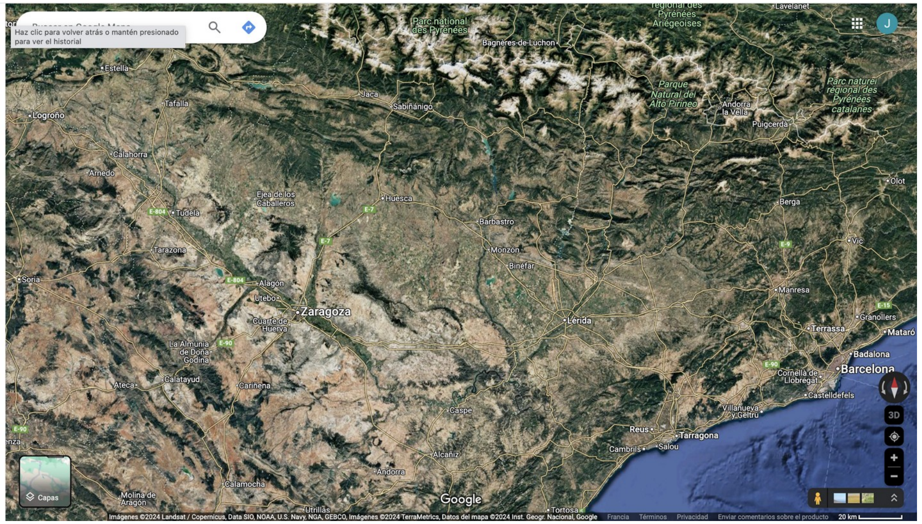
ORCHIDEE@3km

ORCHIDEE@0.5°



The coarser resolution forcing WFDE5 loses not only the spatial contrasts but also the temporal variability.



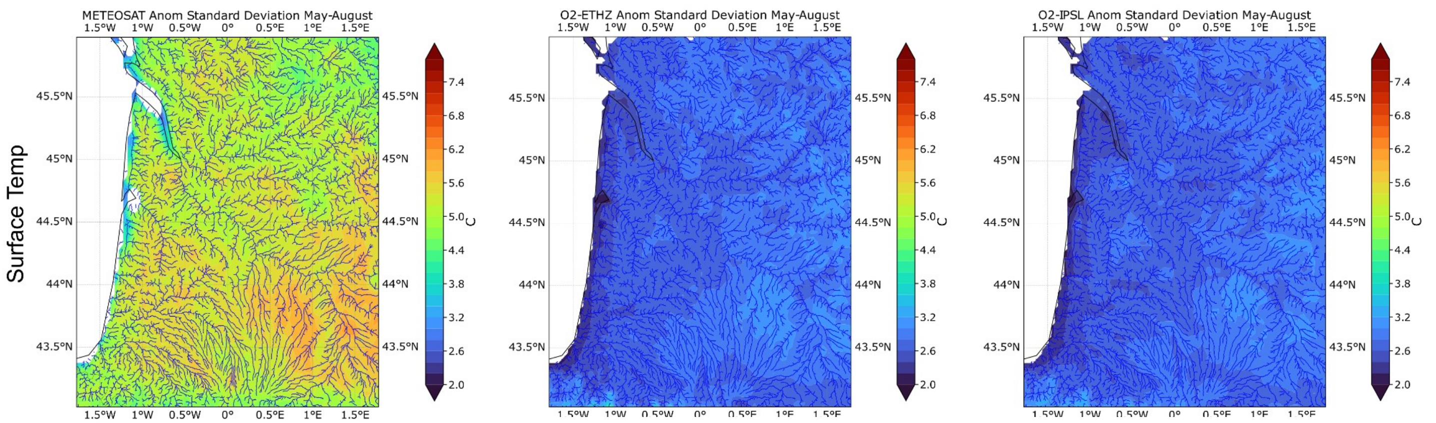


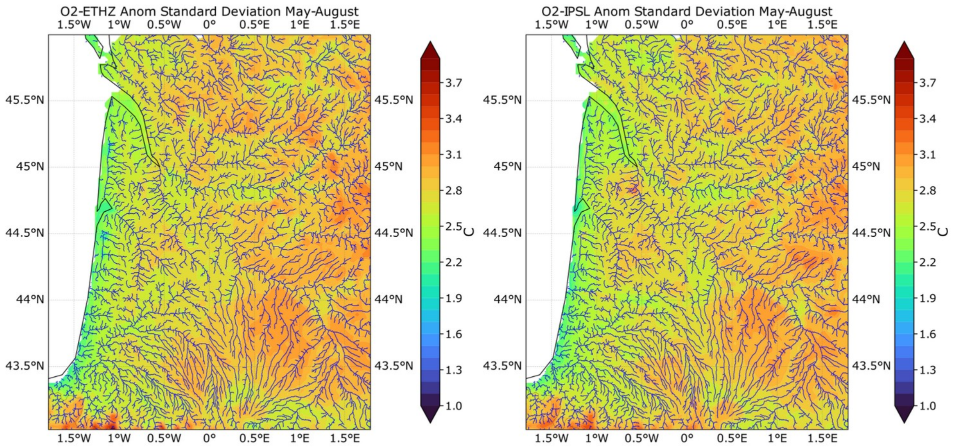
The satellite observations capture realistic processes :

- ➢ Less variability over irrigated or vegetated areas,
- ➢ More variability on the hill slopes and bare soil areas.

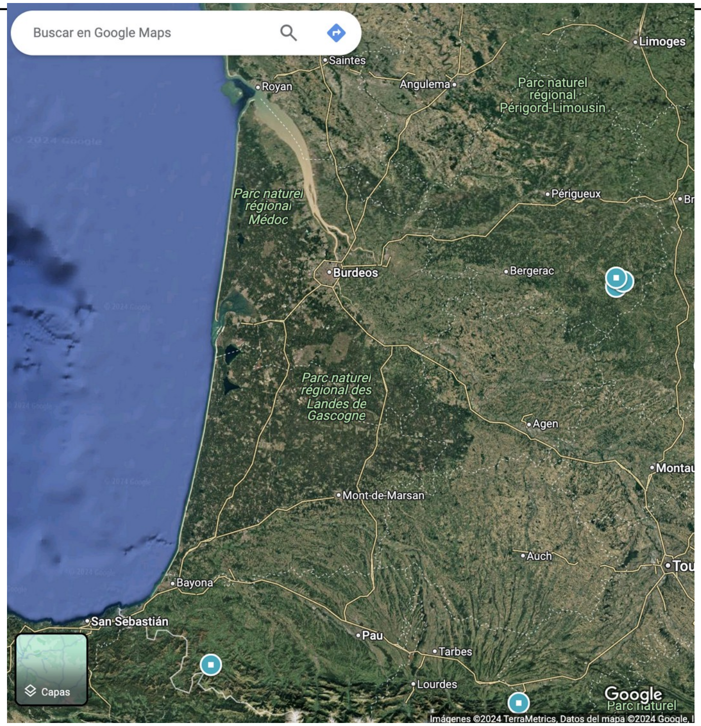
Variability in a wetter climate

Over a moister area like les Landes the temporal variability of surface temperature is lower.





In the wetter part of the domain, the spatial structures of variability are closer to those observed.



Two regimes of temporal variability of surface temperature seem to exist :

- North West : energy driven
- South East : water availability driven

Which can be reproduced by the model ?

This preliminary analysis opens a lot of questions !

- Are the issues found with ORCHIDEE particular to this model ?
- Is the change of functioning of catchments with resolution linked to missing processes or poor input data at km-scale ?
- Do models have a too simplistic view of surface temperature ?
- Are they missing the processes (water management, hill slopes, …) which explain the higher temporal and spatial variability observed in the arid part of the domain ?

These are essential questions to answer before applying our LSM at km-scale resolutions !

The more models (LSMs and others !) participate in the LIAISE inter-comparison, the more confident we will be in our diagnostic.

Extra slides on forcing construction

Choice of integration and bias calculation at the polygon level

- SAFRAN variables are given by polygon and by altitude classes (every 300m).
- We can make different choices, favoring either the altitudinal distribution of SAFRAN or the one from the model outputs.

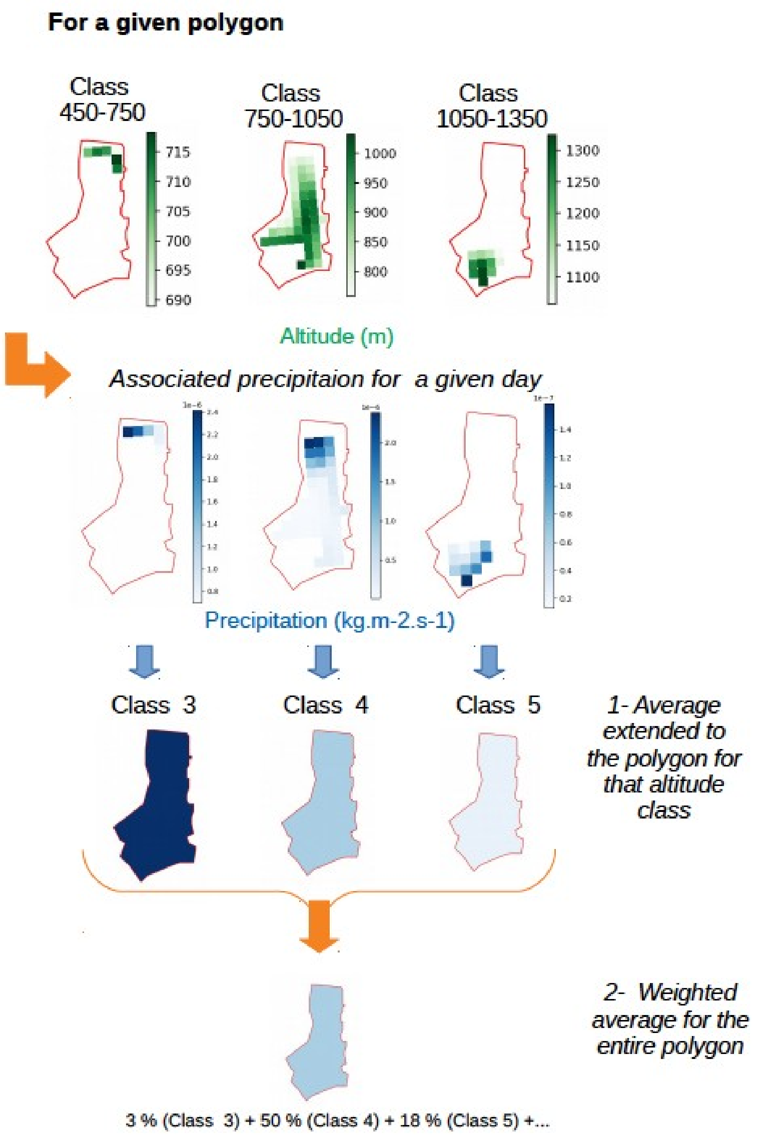
1. Bias by altitude class

- One bias calculated by polygon and by altitude class.
- Bias between SAFRAN and the model calculated for each class and polygons.
- This favors the altitudinal distribution in SAFRAN and accentuate a contrast between altitude classes.

Choice of integration and bias calculation at the polygo

2. Average bias over the polygon

- One bias per polygon, covering all altitude classes.
- This choice favors the altitudinal distribution of the model within each polygon.
- It increases the artificial discontinuities at the boarder of the polygons in the final product.



Variance correction

- Positive proportional bias applied to all points within a polygon increases the spatial contrasts over the polygon.
- The average and standard deviation at the polygon level is increased, leading to contrasted exagerated extreme values (precipitation and wind highly contrasted spatially, radiation variables highly contrasted temporally).
- Identifaction of maximum temporal/spatial (polygon level) variance acceptable for each month using the regional climate models.

Variance correction

- If this maximum variance is surpassed after the bias correction, a correction of variance is applied like:

1. First we shift the average of the polygon to center the values around the null value for that time step:

$$\forall p \text{ within the polygon, } ShiftValue_p = Value_p - Average_{polygon}$$

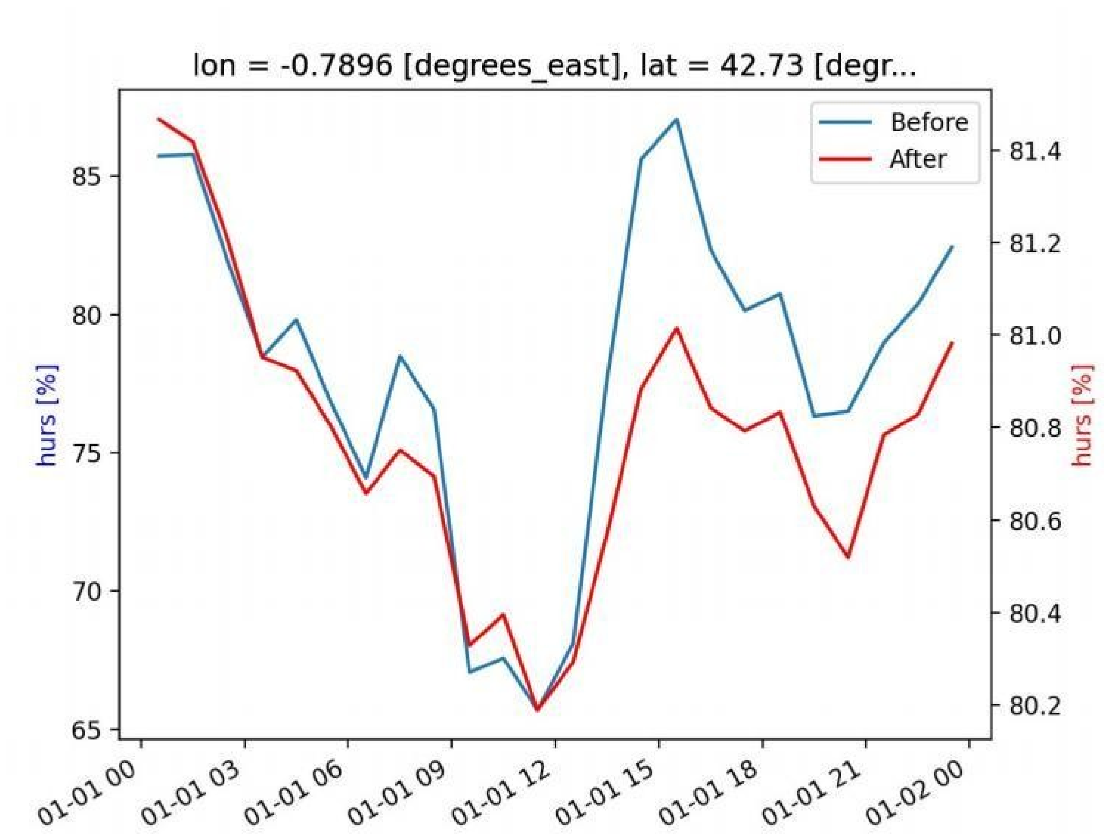
2. Then we correct the standard deviation around that shifted average:

$$\forall p \text{ within the polygon, } NewShiftValue_p = ShiftValue_p * \frac{\sigma_{max}}{\sigma_{shift}}$$

3. Last, we shift the average back:

$$\forall p \text{ within the polygon, } NewValue_p = NewShiftValue_p + Average_{polygon}$$

Variance correction



Analogue days

- It is useful to extend the methodology to the full period covered by SAFRAN (1979-2014).
- Need at leats 20 years of data to cover the climate variability.
- Using model values integrated at the polygon level for each altitude class, for each SAFRAN's day and each altitude class and variable a spatial correlation between SAFRAN's day and model's days.
- Instead of using the same date in model and SAFRAN for the bias correction, it is possible to use the model day with the best average spatial correlation, considering the spatial correlation for precipitation and temperature over the first four altitude classes ('analogue day').