Understanding uncertainties in future evapotranspiration projections to study the impact of climate change on hydrology over France

Thibault Lemaitre-Basset, Ludovic Oudin, Guillaume Thirel, Lila Collet

Understanding uncertainties in future evapotranspiration projections to study the impact of climate change on hydrology over France.

Session 6 : Understanding the human footprint on the hydrological cycle/processes in a changing world

Thibault Lemaitre-Basset; Ludovic Oudin; Guillaume Thirel; Lila Collet

Context

Potential evapotranspiration (PE) is an important input for hydrological model.

How will future climate impact potential evapotranspiration?

Understanding the uncertainty sources:
How future climate uncertainty, coming from RCPs, GCMs and RCMs, are transferred to PE projections?
How much the uncertainty in PE formulation contributes to overall climate impact uncertainty?

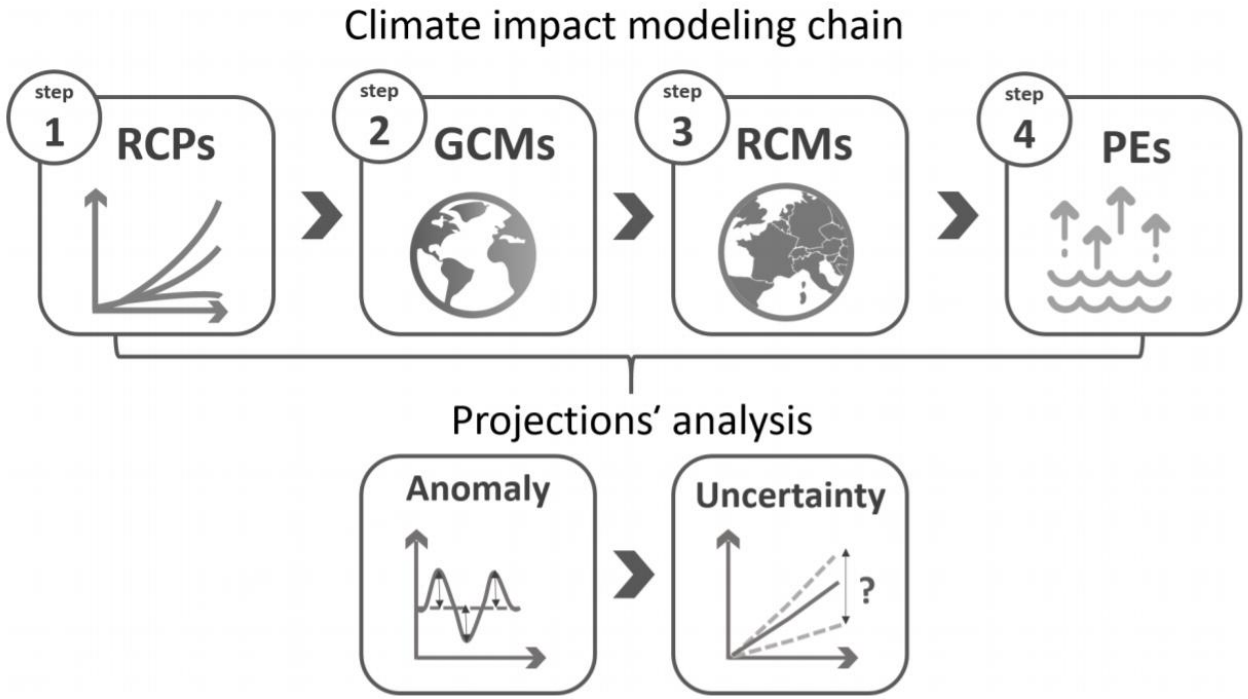
-> PART 1

Adapting PE formulations to account for surface–atmosphere interactions in a simplified way:
What are the differences between several existing schemes to account for elevated atmospheric CO_2 concentrations in PE estimations ?
What are the consequences on runoff projections ?

-> PART 2

PART 1: The contribution of potential evaporation formulation to uncertainty

Approach to quantify uncertainty



An ensemble of 30 GCM– RCM couples, from CMIP5 under 3 different RCPs (EURO-CORDEX)

7 PE formulations selected including physically and empirically based method.

Formulation	Variable
Penman	**SR, T, RH, u**
Penman-Monteith	**SR, T, RH, u**
Priestley-Taylor	**SR, T**
Morton	**SR, T, RH**
Oudin	**T**
Hamon	**T**
Hargreaves	**T**

SR: Solar Radiation, T: Temperature, RH: Relative Humidity, u: wind speed

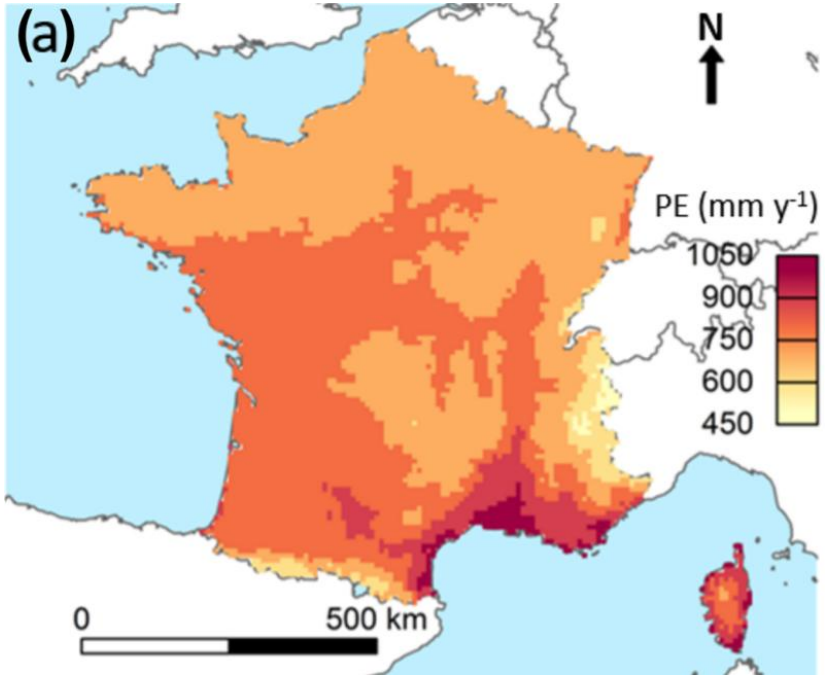
1) Complete the available ensemble of climate projections with a b*ayesian process*

2) *An analysis of the variance is performed to* quantify the contribution of models

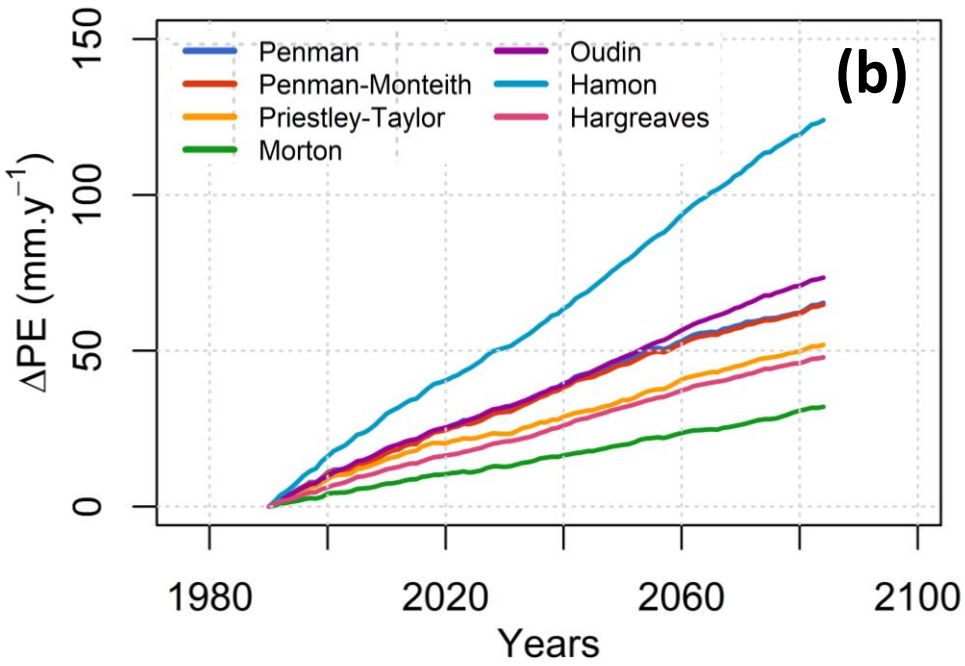
`QUALYPSO` method is available on R CRAN (G. Evin et al., 2019)

QE-ANOVA approach for climate change analyses established by Hingray et Saïd (2014)

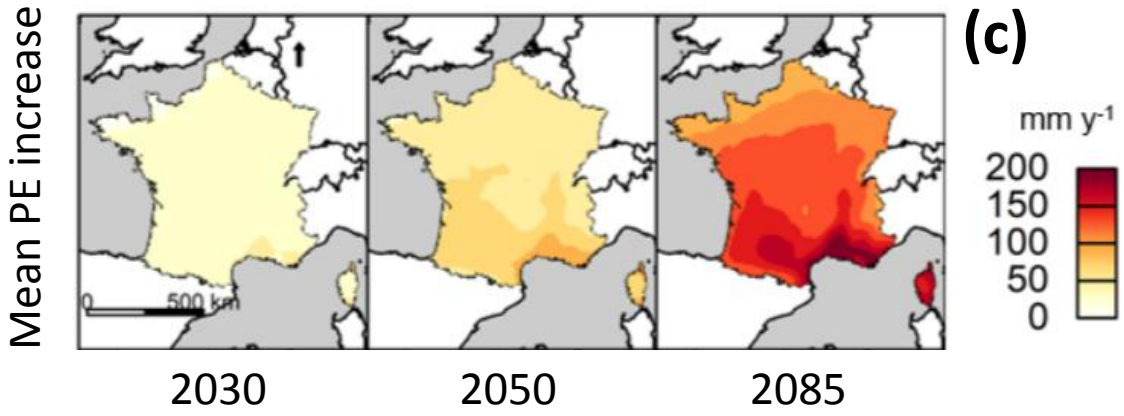
Results: potential evapotranspiration projections



Mean annual PE (mm y^{-1}) computed with climate projections from 1976 to 2005 over France



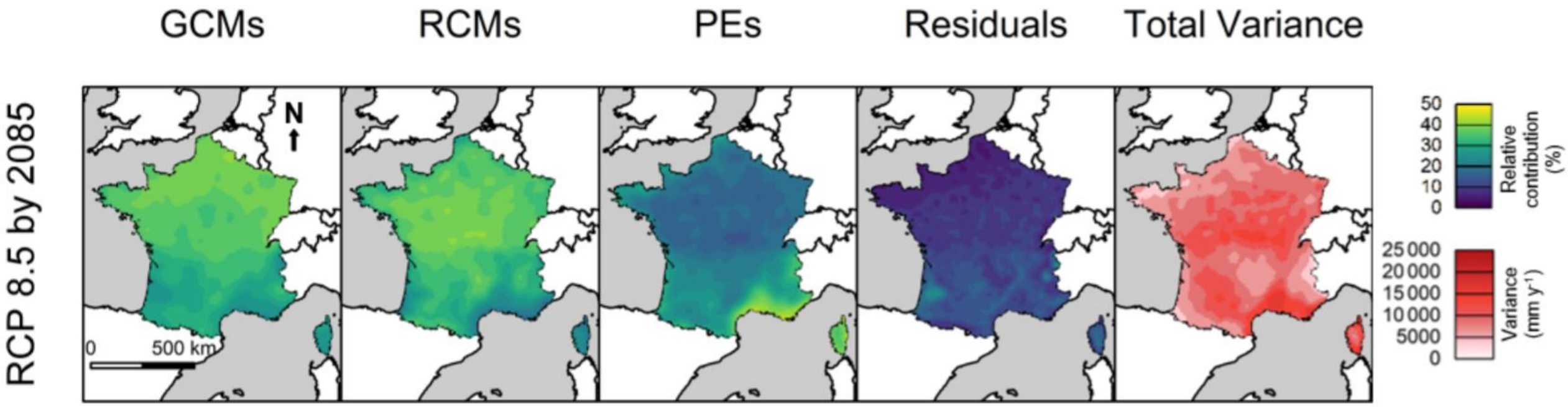
Anomalies are computed with a 30-years reference period, and a 30-years rolling mean is applied.



Thibault Lemaitre-Basset et al. 2022

https://doi.org/10.5194/hess-26-2147-2022

Results: Uncertainty analysis



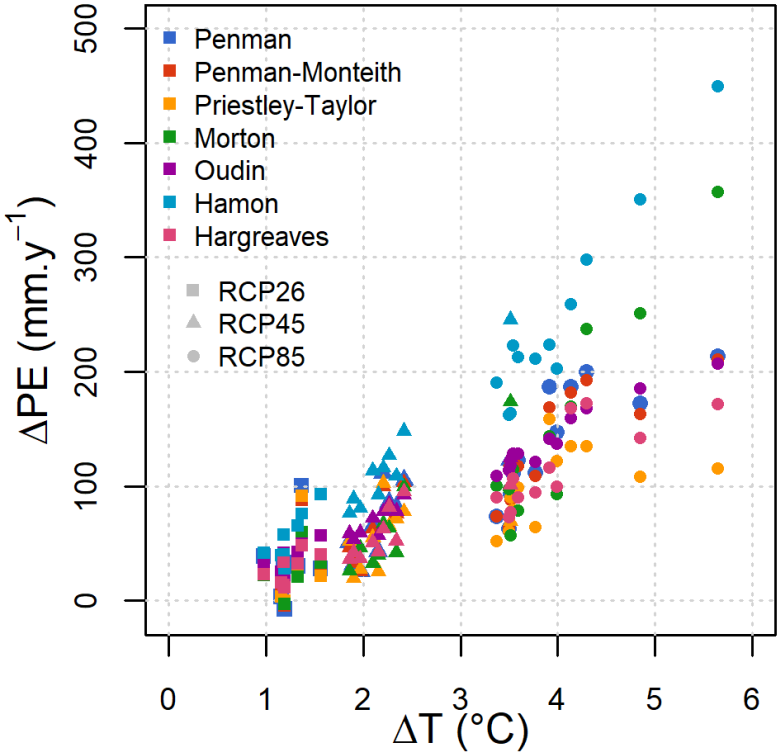
Ranking of modelling step contribution to total uncertainty.

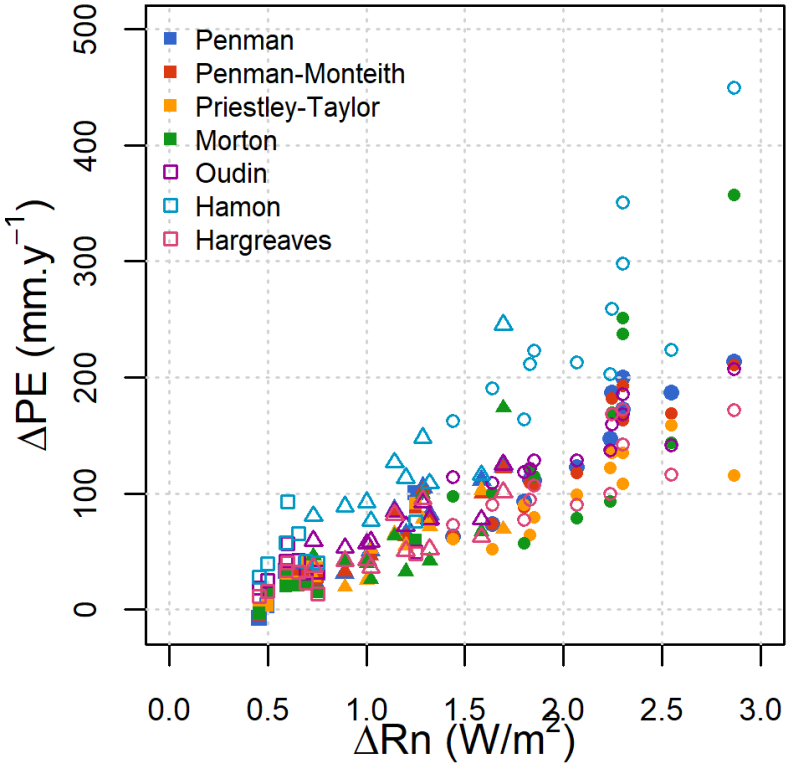
PE formulation is a minor source of uncertainty in PE future anomaly on most of the country.
However, it is the major sources of uncertainty over the mediterranean region.

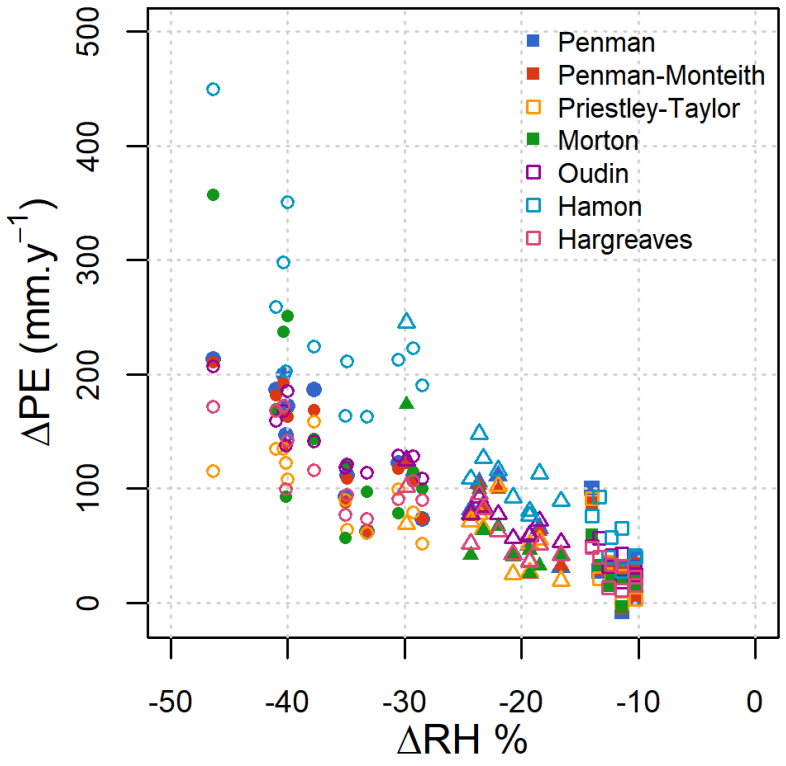
Thibault Lemaitre-Basset et al. 2022
https://doi.org/10.5194/hess-26-2147-2022

Results: Role of climate variables

- Correlation between PE anomalies and temperature (T), net radiation (Rn), and relative humidity (RH).
- Even formulations that do not use Rn and RH, the associated PE estimation is still consistent.





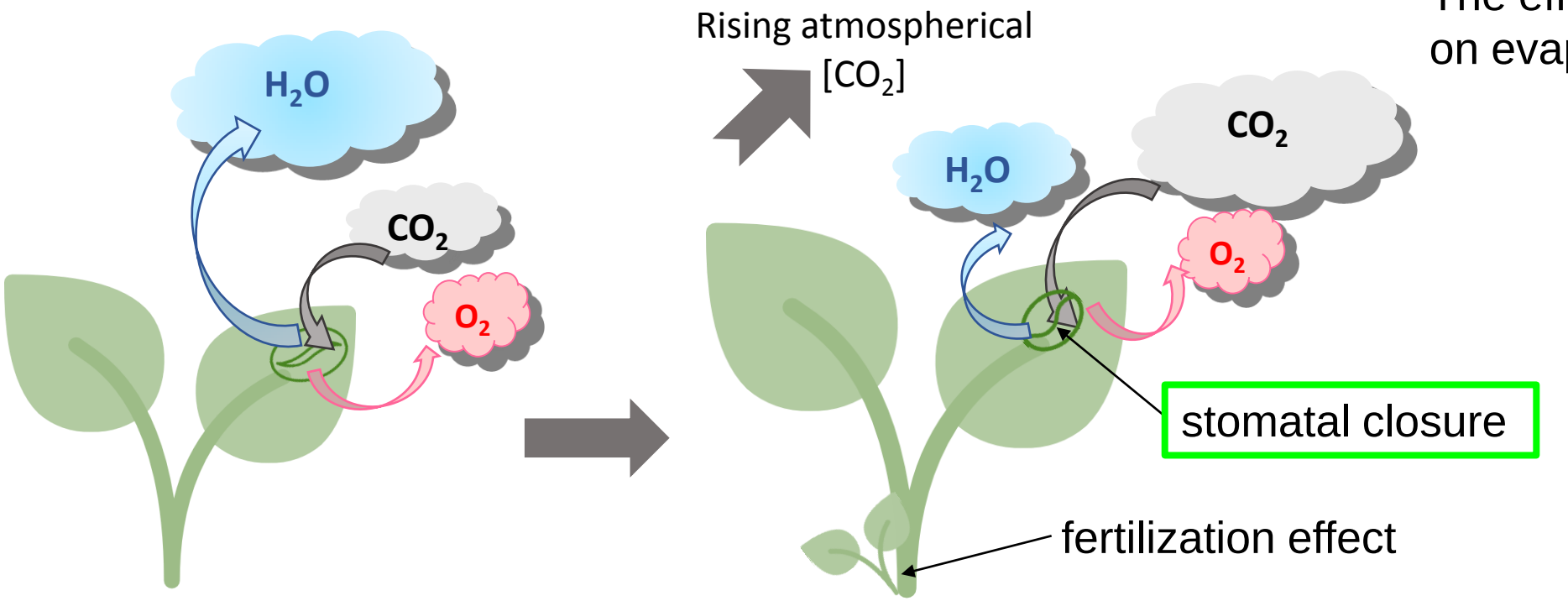


Thibault Lemaitre-Basset et al. 2022
https://doi.org/10.5194/hess-26-2147-2022

PART 2: The effect of CO_2 on stomatal resistance in Penman–Monteith PE formulation

Investigate the role of other variables

The effect of carbon dioxide on evapotranspiration



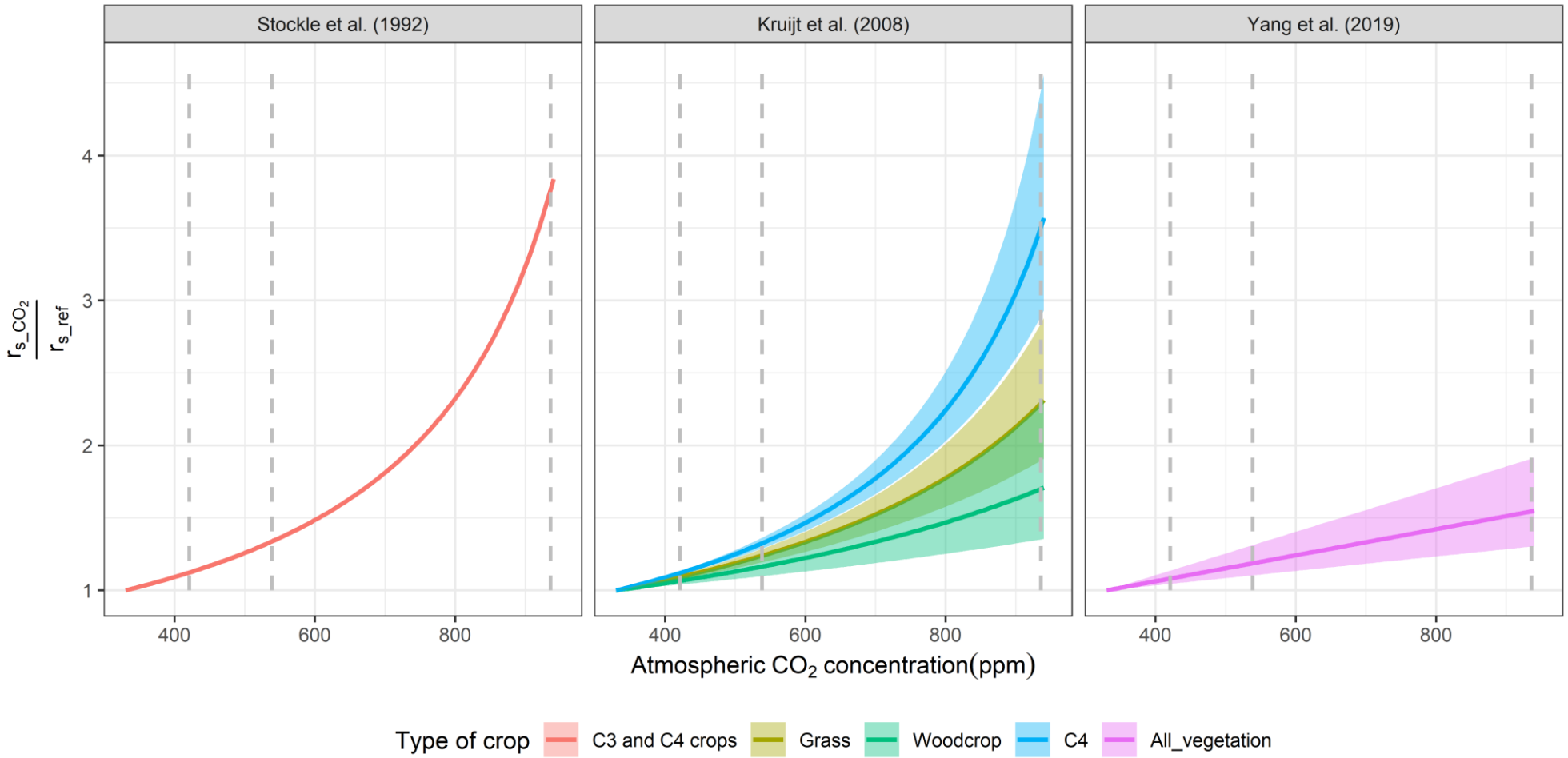
Penman–Monteith (FA056) formulation :

$$\lambda \cdot PE = \frac{\Delta R_n + (\rho_a \cdot \frac{C_P}{r_a})(e_s - e_a)}{\Delta + \gamma(1 + \frac{r_s}{r_a})}$$

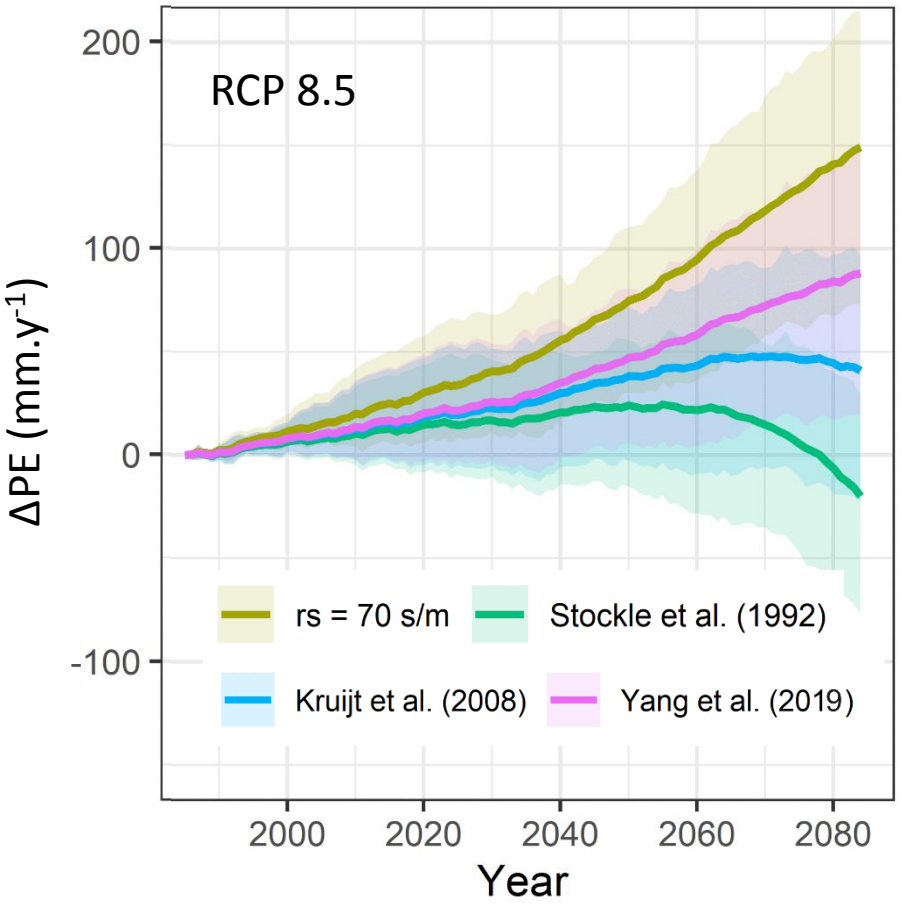
r_s = 70 s.m^{-1}

Investigate the role of CO2 on evapotranspiration

We compare 3 options from the literature to compute the effect of CO2 on stomatal resistance

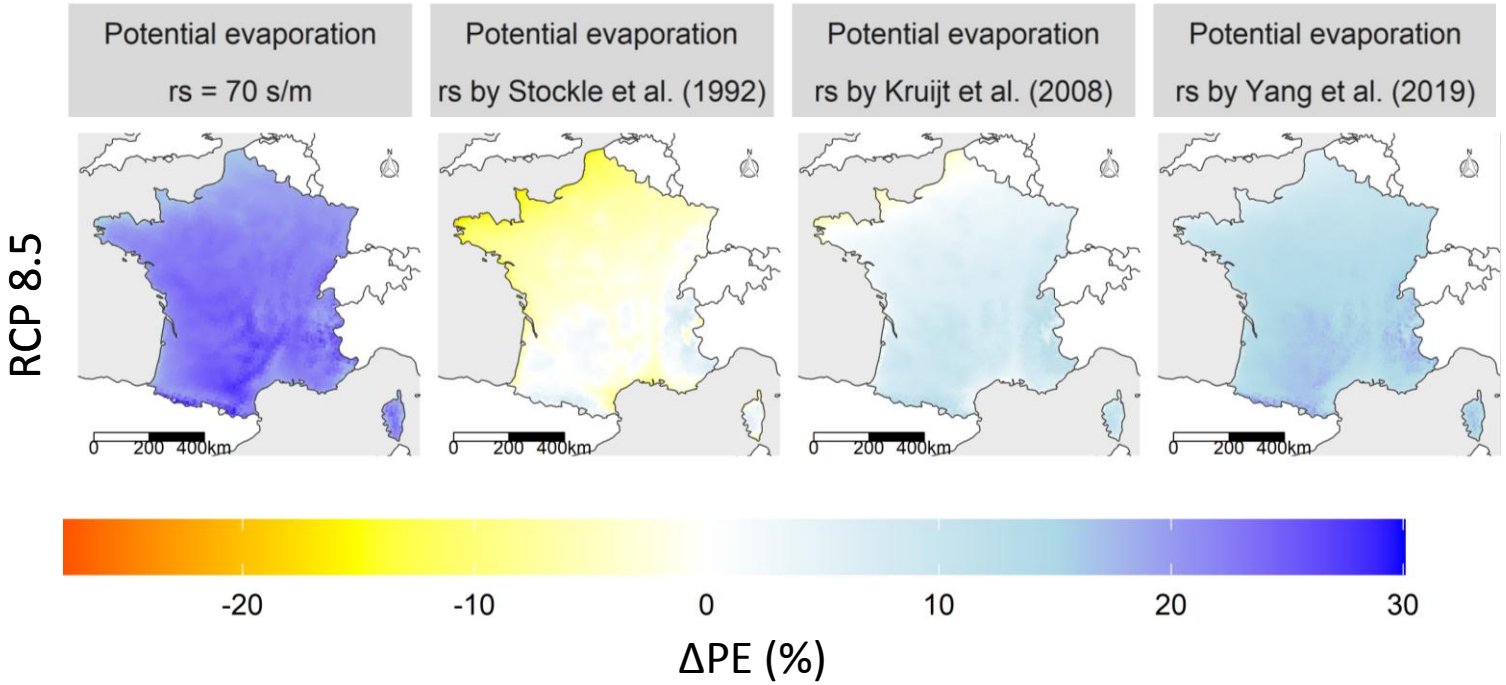


Results: potential evapotranspiration projections with r_s changes



RCP 8.5 scenario: 935 ppm in 2100

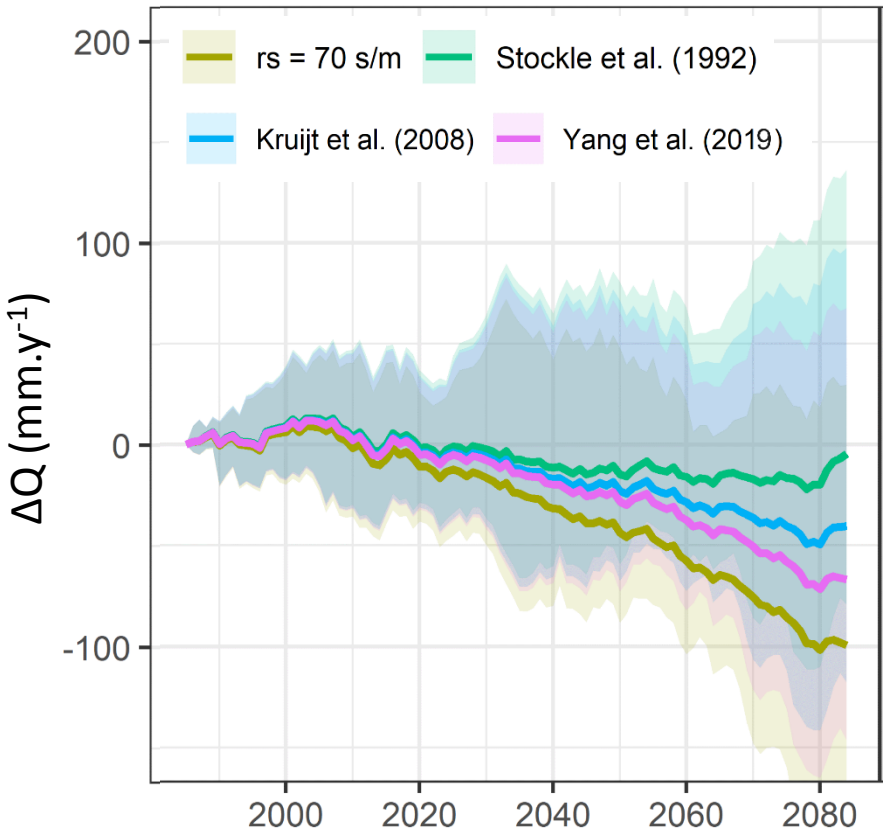
Spatial patterns of changes



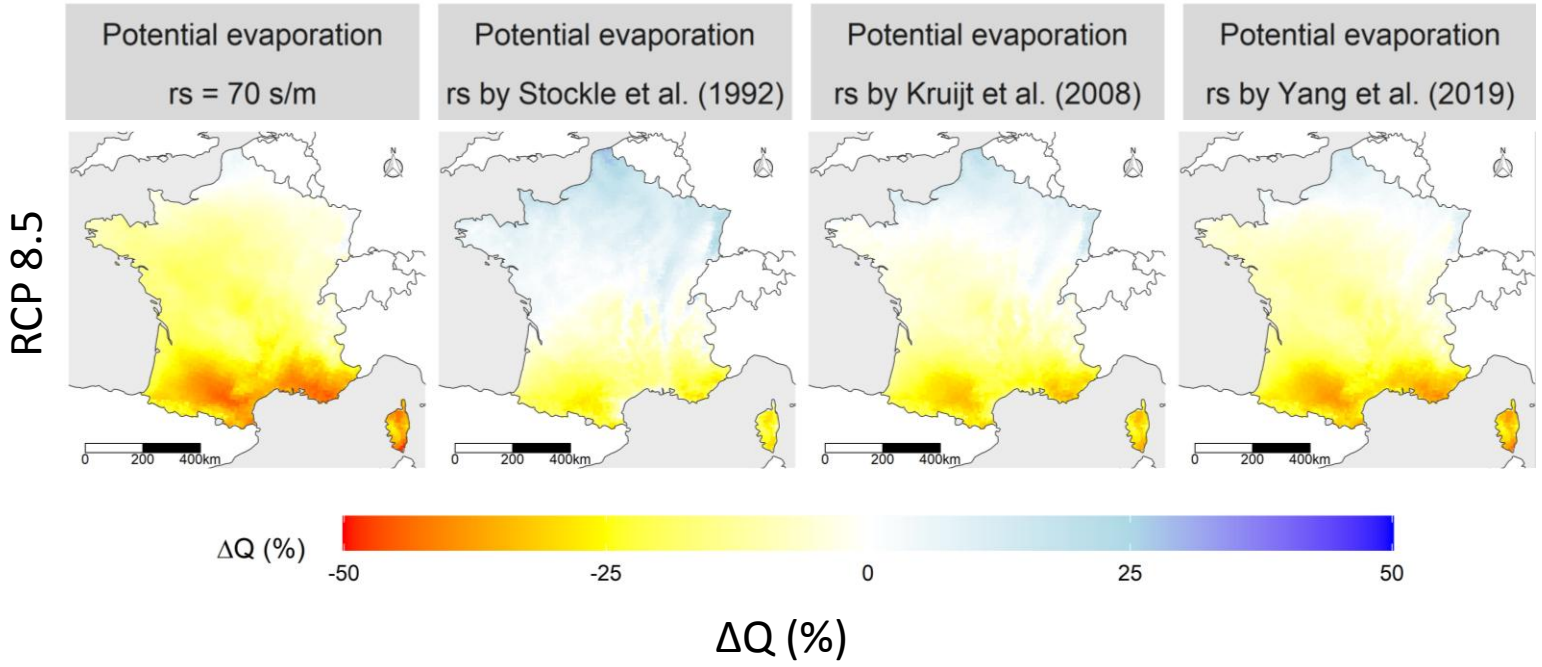
the evolutions in PE anomalies diverge and the trends depend greatly on the formulation of r_s.

Results: hydrological projections

We assess their impact on future runoff using the Budyko framework over France.



The implications of these different PE evolutions for simulated runoff are evident although dependent also on precipitation evolution



Our findings

- PE formulations uncertainty is minor compared to other uncertainty sources (RCPs, GCMs, and RCMs) for PE anomaly, but not in the Mediterranean part.
- Consistency between the climate variables used in the EP calculations is maintained in the future.
- CO_2 effect in Penman-Monteith formulation leads to reduced PE amounts
- CO_2 limits the annual runoff reduction, and even increases annual runoff in some regions. Whereas the classic Penman–Monteith formulation leads to decreasing runoff projections over most of France.

Perspectives

- Including the fertilization effect of CO_2 by adding the leaf area index (LAI) to our projections.