



**Nivo glaciological changes in Alpine catchments:
impacts on hydrological regimes and aquatic ecosystems:
Focus on potential evapotranspiration (PET)**

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Anthony Lemoine, Isabelle Gouttevin, Thomas Condom, Sophie Cauvy-Fraunié, Juliette Becquet, et al.. Nivo glaciological changes in Alpine catchments: impacts on hydrological regimes and aquatic ecosystems: Focus on potential evapotranspiration (PET). XIth Scientific Assembly of the International Association of Hydrological Sciences (IAHS 2022), May 2022, Montpellier, France. 23 p. hal-03685602

HAL Id: hal-03685602

<https://hal.inrae.fr/hal-03685602>

Submitted on 2 Jun 2022

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➤ Nivo-glaciological changes in Alpine catchments: impacts on hydrological regimes and aquatic ecosystems

Focus on potential evapotranspiration (PET)

Anthony Lemoine, Isabelle Gouttevin, Thomas Condom, Sophie Cauvy-Fraunié, Juliette Becquet, Jordi Bolibar and Antoine Rabatel

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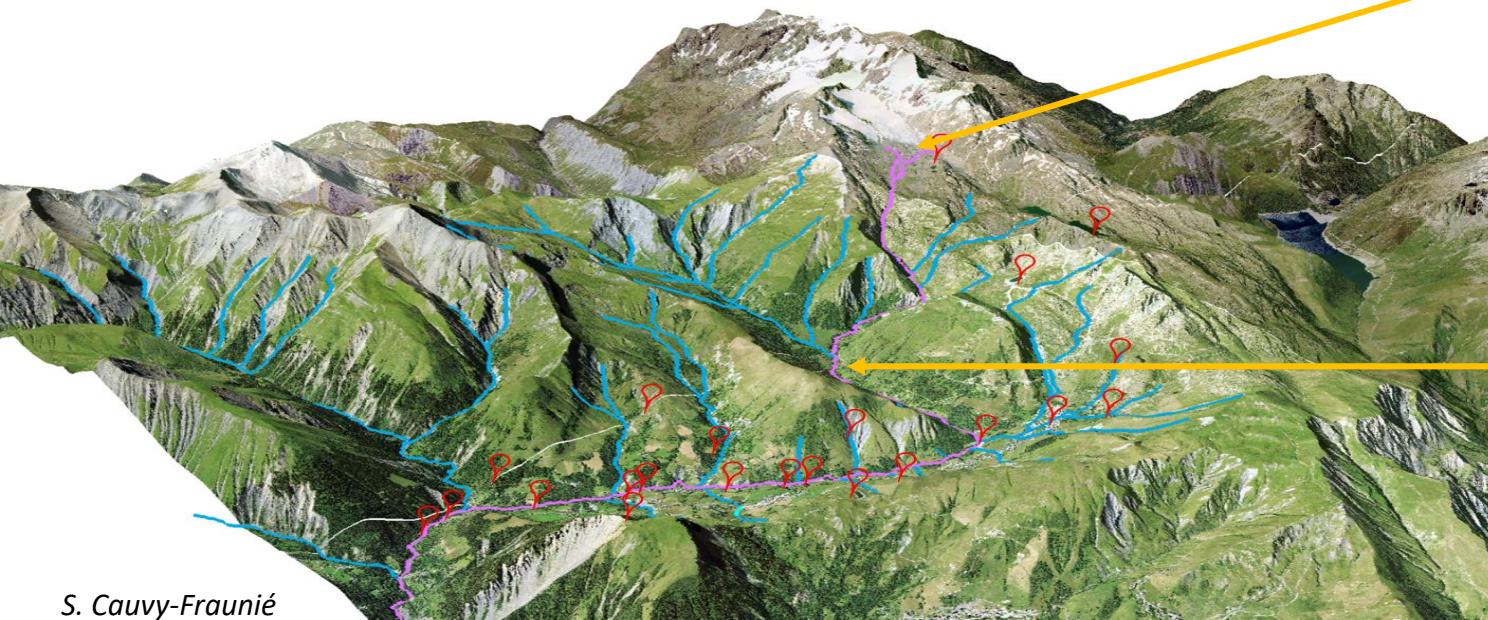
➤ Introduction

➤ Water resource issues in the mountains

Case study : Arvan river (58 km²), Grandes-Rousses massif (Savoie)

Decrease of the water stock in solid form

→ induces irreversible changes on the hydrological regimes of alpine rivers and affects their ecological functioning.



S. Cauvy-Fraunié



St Sorlin glacier



Arvettaz and Arvan rivers

 Glacier and snow contributions
 Snow contribution

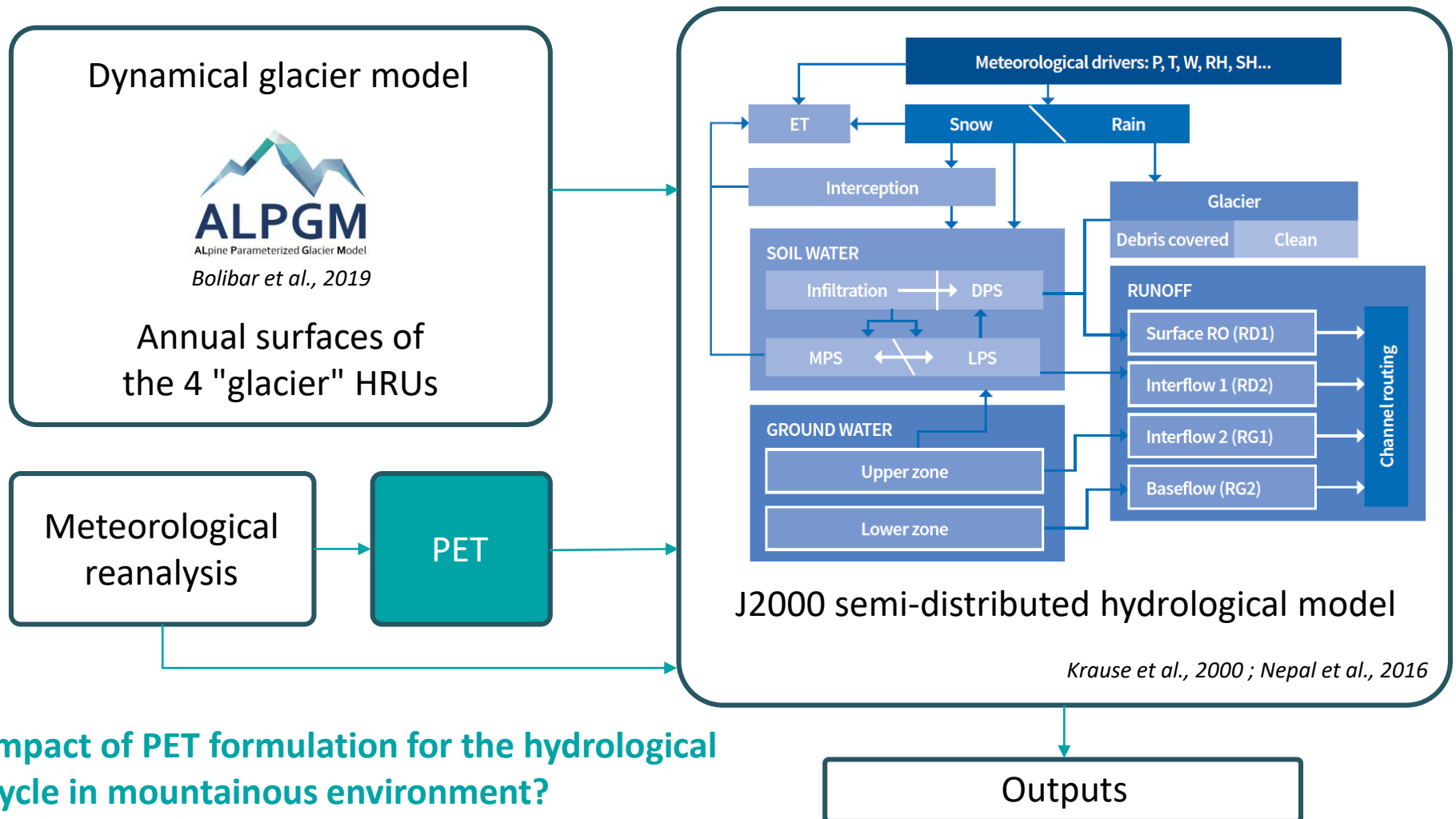
 Hydroecological sampling point

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Hydrological changes in Alpine catchments: focus on potential evapotranspiration

31th May 2022 / IAHS 2022 / A. Lemoine, I. Gouttevin, T. Condom, S. Cauvy, J. Becquet, J. Bolibar & A. Rabatel

➤ Hydro-glaciological modeling chain



Impact of PET formulation for the hydrological cycle in mountainous environment?

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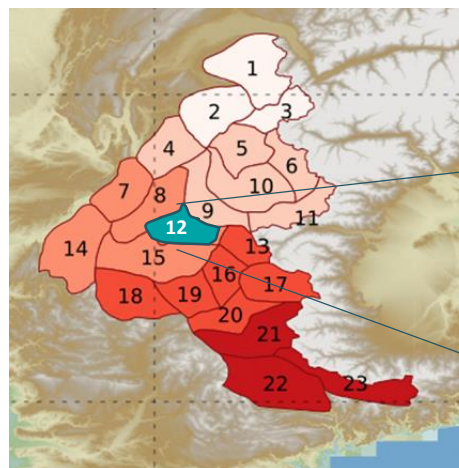
➤ Data and methods

➤ S2M meteorological reanalysis

Durand et al., 2009 ; Vernay et al., 2022

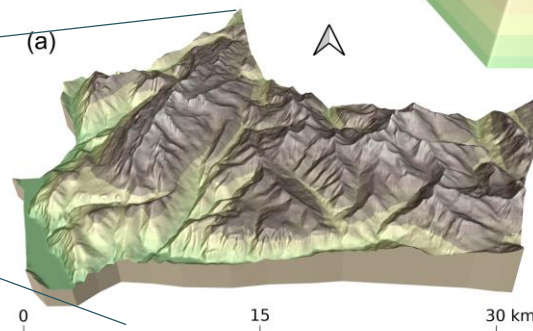
SAFRAN–SURFEX/ISBA–Crocus–MEPRA

- Meteorological reanalysis since 1948 for Corsica, the Pyrenees and the Alps.
- Each mountain range is divided into massifs.
- Massifs are represented by altitudes bands of 300 m.

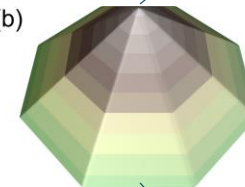


Vernay et al., 2022

Grandes-Rousses massif



(b)

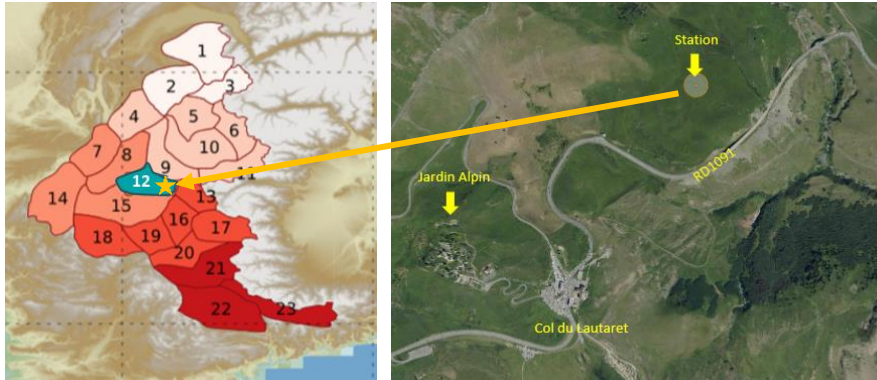


Alt. (m)

3600
3300
3000
2700
2400
2100
1800
1500
1200
900
600

➤ Evapotranspiration in situ data at Lautaret pass

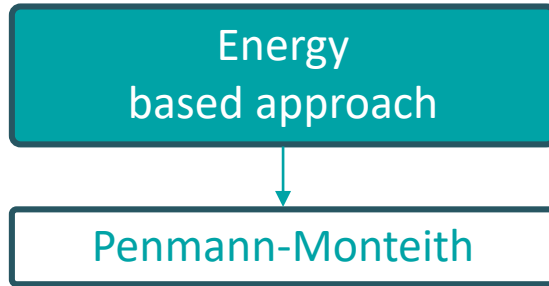
FluxAlp station (East of Grandes-Rousses massif)



- Under the Lautaret pass (towards Briançon).
- Meteorological station.
- Turbulent fluxes by eddy covariance and **actual evapotranspiration (AET)**.
- Half-hourly time step since 2012.
- Altitude: 2050 m.
- Alpine meadow.

➤ Potential evapotranspiration formula

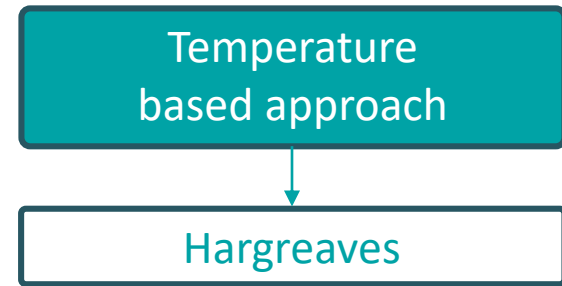
Two approaches



$$PET = \frac{\Delta (R_n - G) + \frac{(\rho C_p \delta_e)}{r_a}}{\lambda \left[\Delta + \gamma \left(1 + \frac{r_s}{r_a} \right) \right]}$$

Diagram showing variable dependencies for the Penmann-Monteith formula:

- $f(\alpha, t_a, r_g, R_a)$ points to R_n
- $f(al\text{ti}, t_a)$ points to Δ
- $f(al\text{ti}, q_a)$ points to δ_e
- $f(t_a)$ points to Δ
- $f(al\text{ti})$ points to r_a
- $f(u_a)$ points to r_a
- $f(r_s)$ points to r_s



$$PET = 0.0022 R_A \delta_t^{0.5} (T + 17.8)$$

Diagram showing variable dependencies for the Hargreaves formula:

- $f(lat)$ points to R_A
- $f(t_{a\text{min}}, t_{a\text{max}})$ points to δ_t
- $f(t_a)$ points to T

meteorological variables : air temperature (t_a), min. air temperature ($t_{a\text{min}}$), max. air temperature ($t_{a\text{max}}$), specific humidity (q_a), wind speed (u_a), longwave radiation (r_g), shortwave radiation (R_a), albedo (α), altitude ($al\text{ti}$), latitude (lat)

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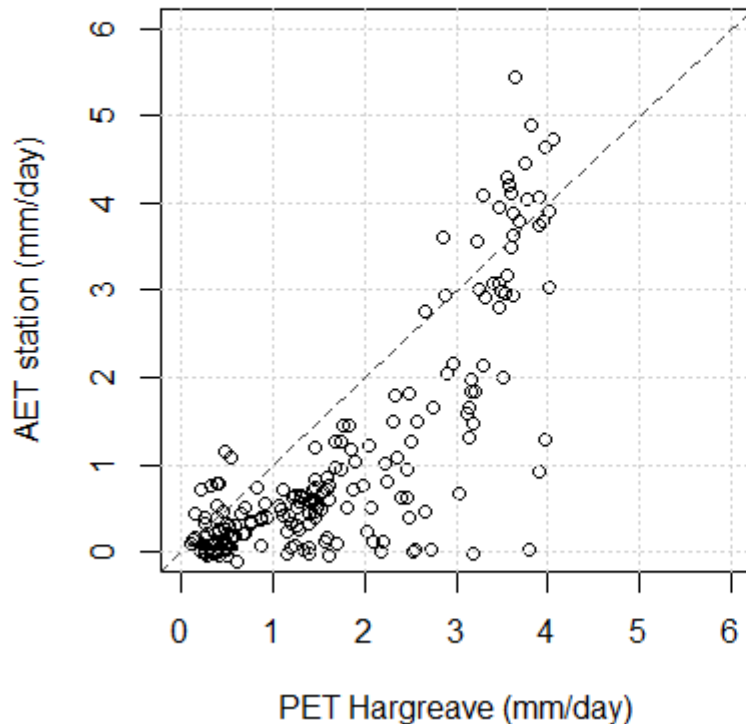
➤ Results



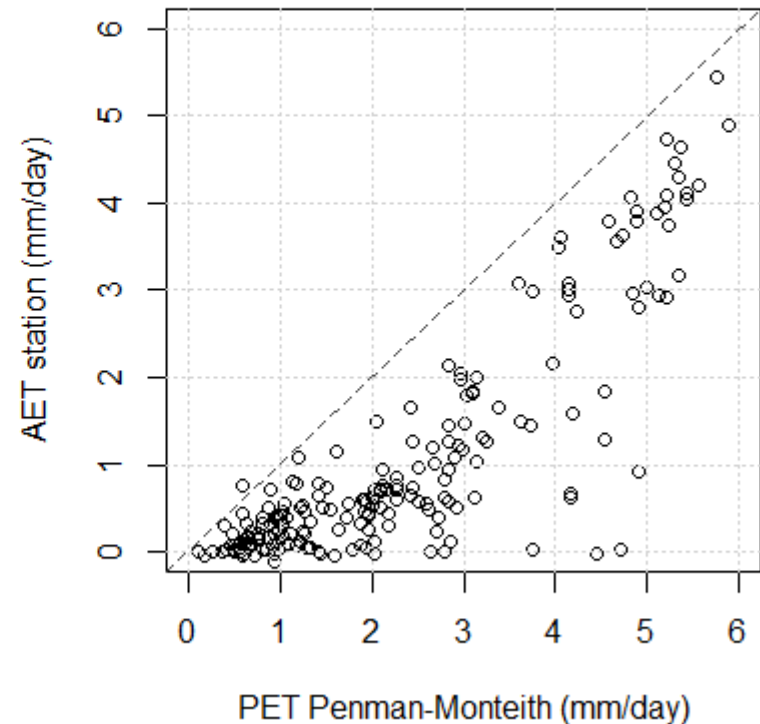
➤ Correlation between AET and PET at Lautaret pass

AET (station measurement), PET (formula with station data) in 2017

AET station - PET Hargreaves



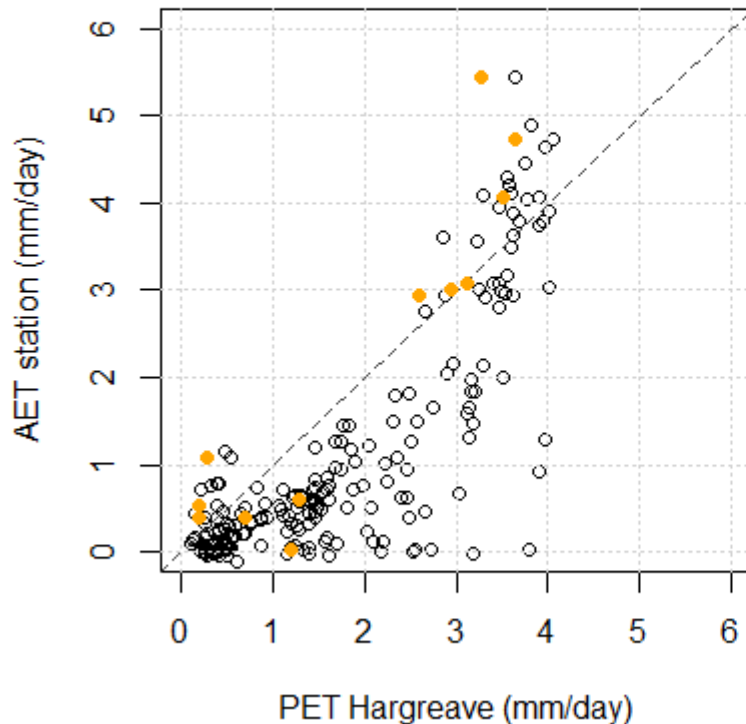
AET station - PET Penman-Monteith



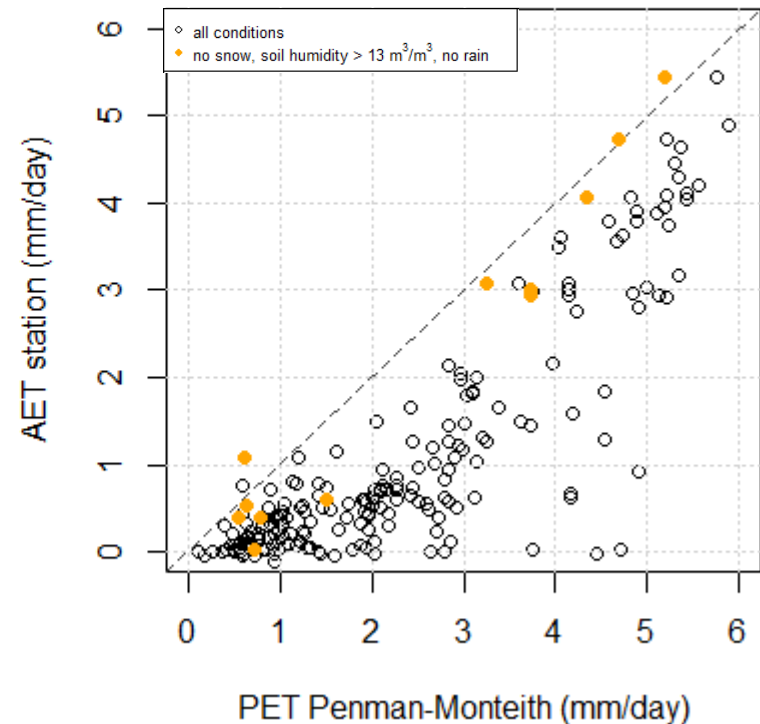
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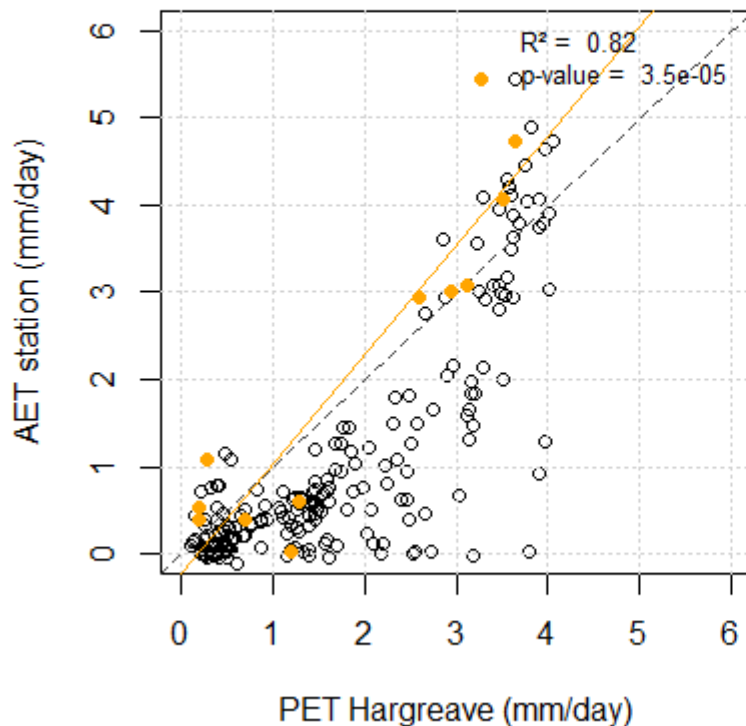


- PET equivalent to AET with : **no snow on the ground, water saturated soil and no rain.** ♦

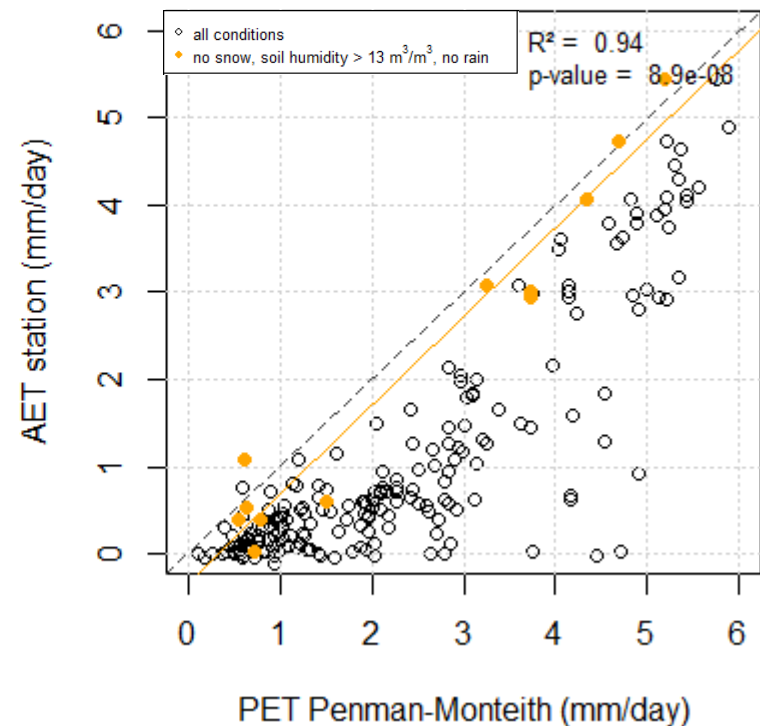
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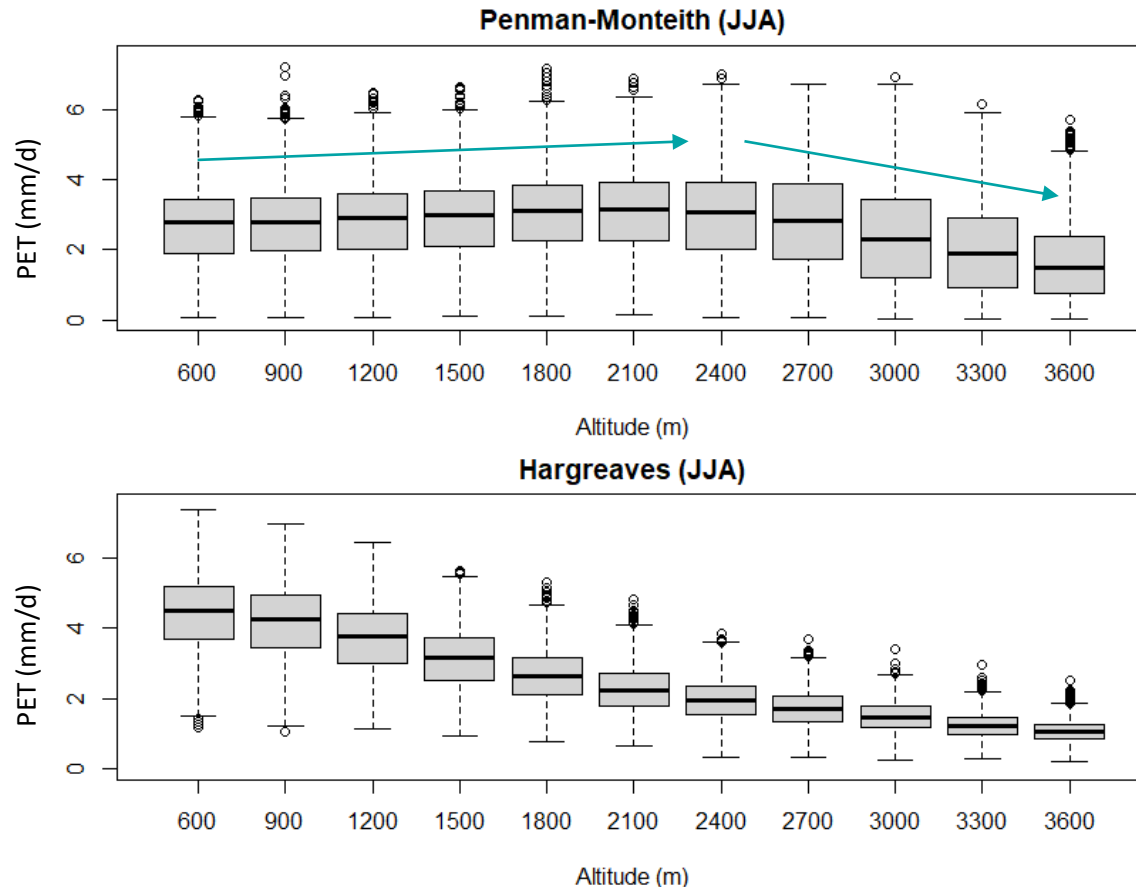
AET station - PET Penman-Monteith



➔ PET calculated with P-M gives a stronger correlation than with Hargreaves formula.

➤ PET of Penman-Monteith and Hargreaves

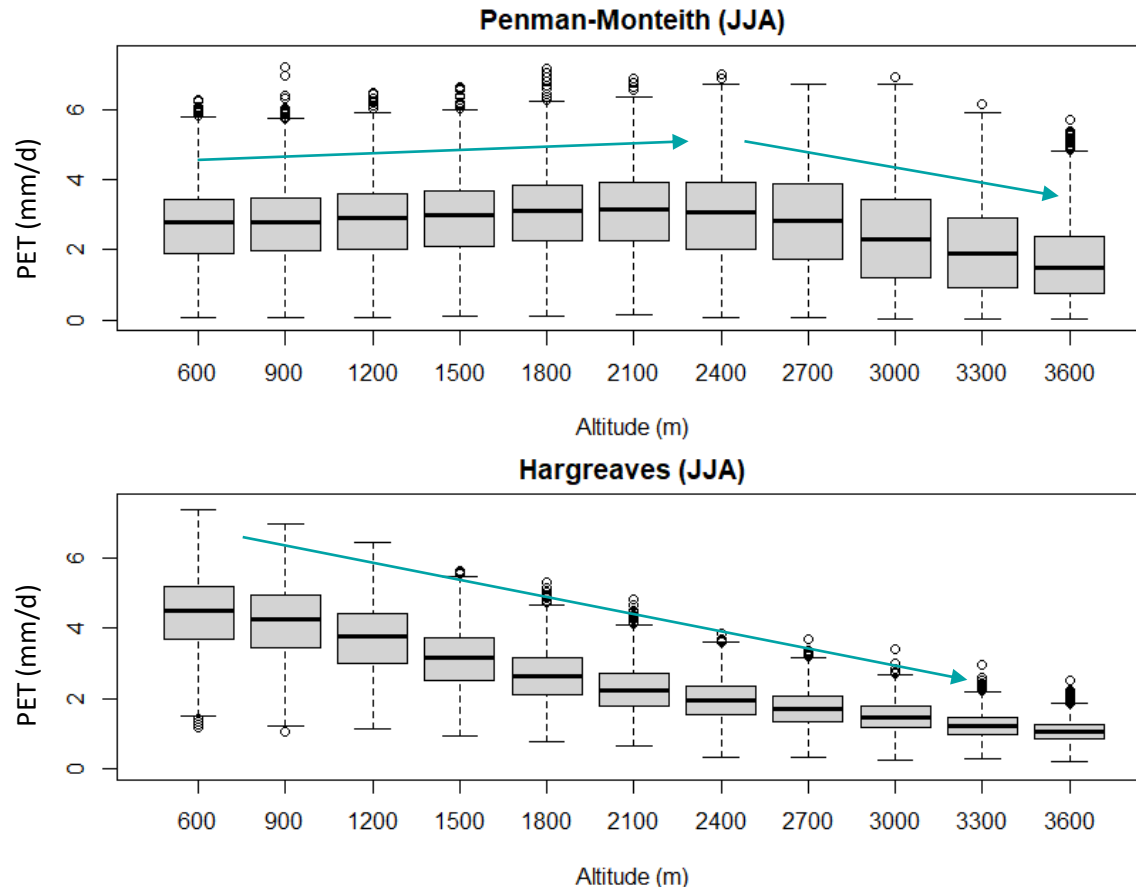
Evolution by altitude bands over 1958-2018 (summer)



- P-M: mean PET increase from 600 m.a.s.l to 2100 m.a.s.l and then decrease.
- Hargreaves : decrease of PET with altitude.
- At 600 m.a.s.l, 3 mm/d (P-M) and 4.5 mm/d (Hargreaves) for PET average.
- At 2100 m.a.s.l, 3.5 mm/d (P-M) and 2.5 mm/d (Hargreaves) for PET average.
- For PET Hargreave, dispersion decreases with altitude.

➤ PET of Penman-Monteith and Hargreaves

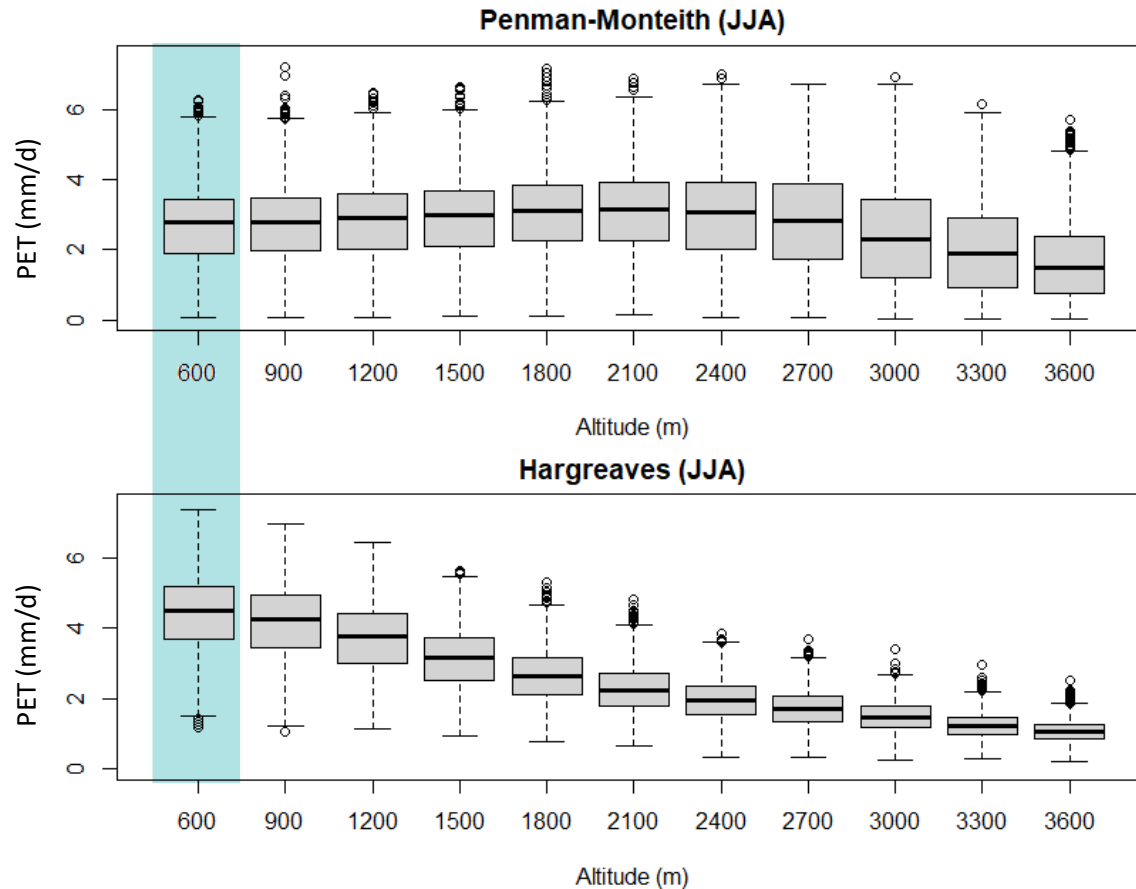
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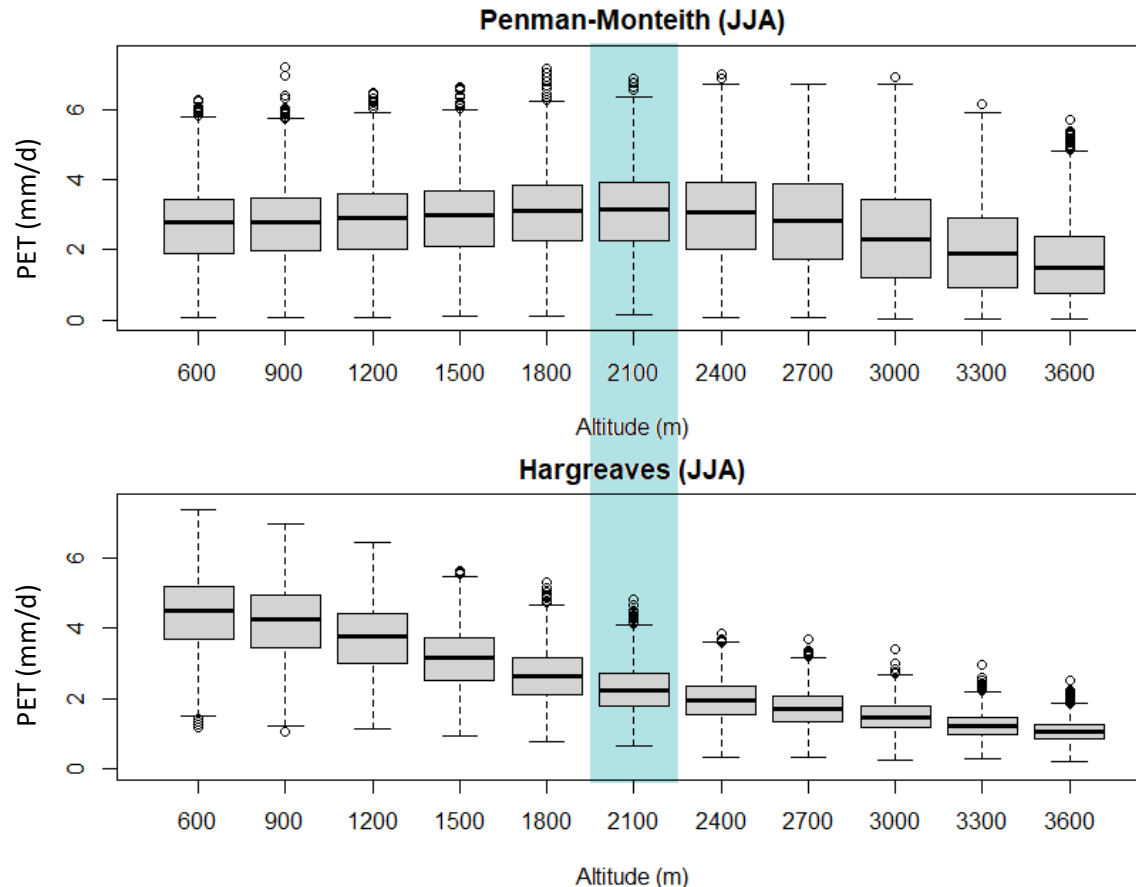
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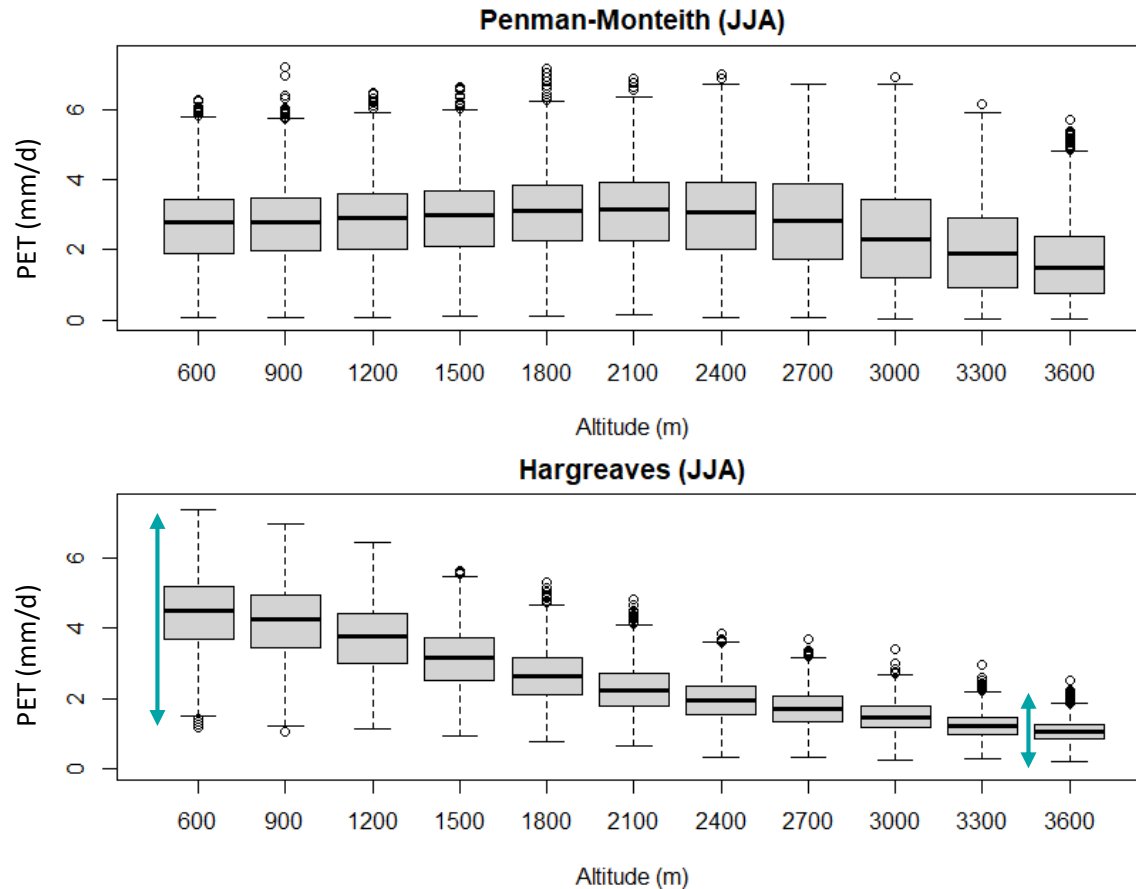
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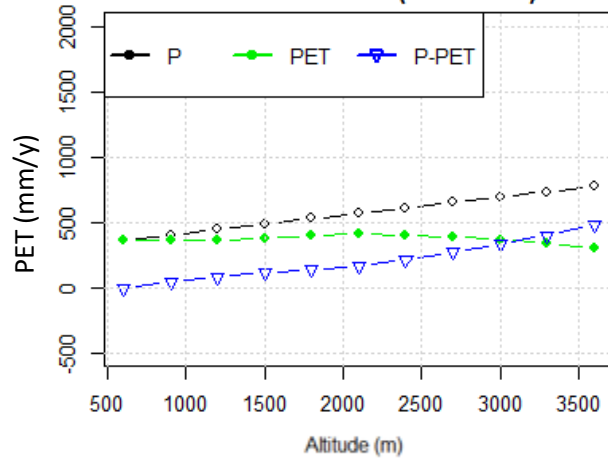


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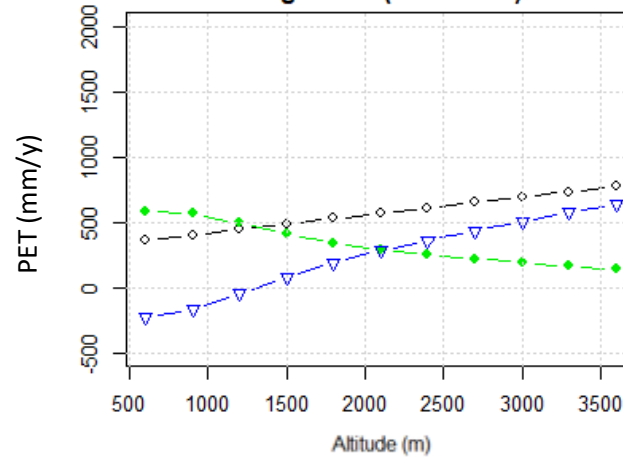
➤ Water balance: precipitations, PET, P-PET

Mean values over 30 years

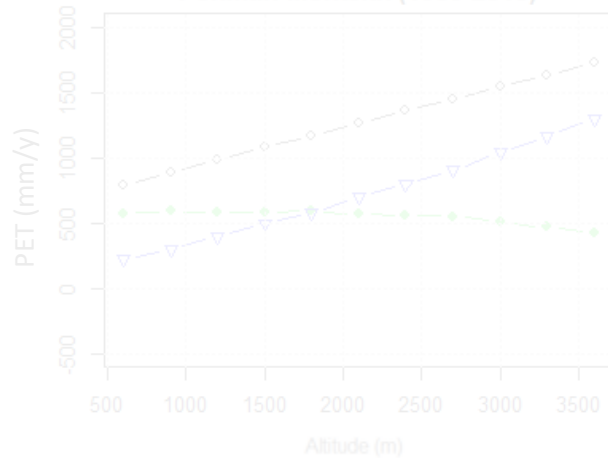
Penman-Monteith (1958-1988)



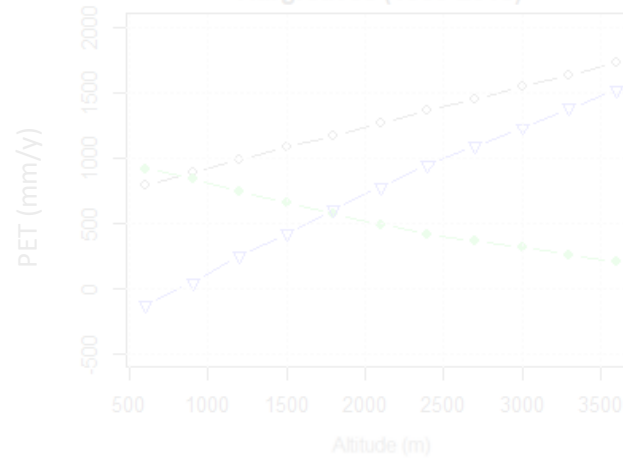
Hargreaves (1958-1988)



Penman-Monteith (1989-2018)



Hargreaves (1989-2018)

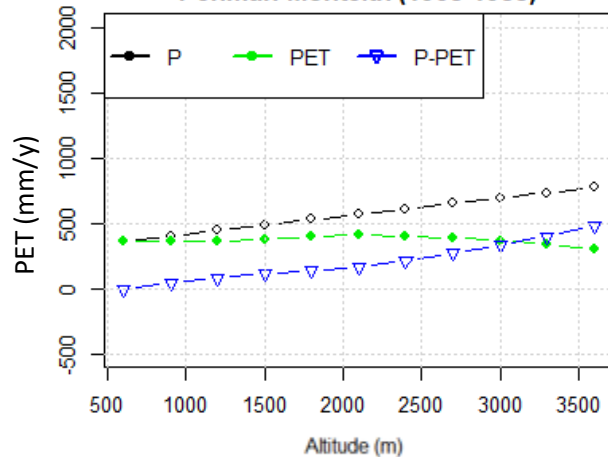


- With Hargreaves, PET stronger at low altitudes than P-M and it is the opposite for high altitudes.
- At low altitudes, there is a water deficit with the Hargreaves formulation.
- PET higher in 1989-2018 than 1958-1988 for all formulations.
- The decrease of PET with altitude on 1989-2018 is more marked than over the period 1958-1988 with Hargreave.

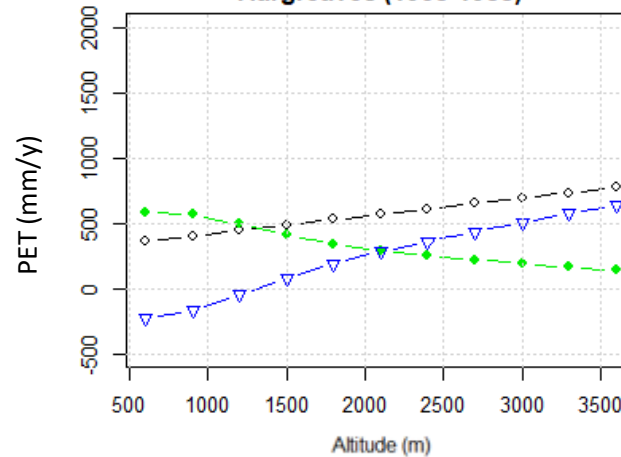
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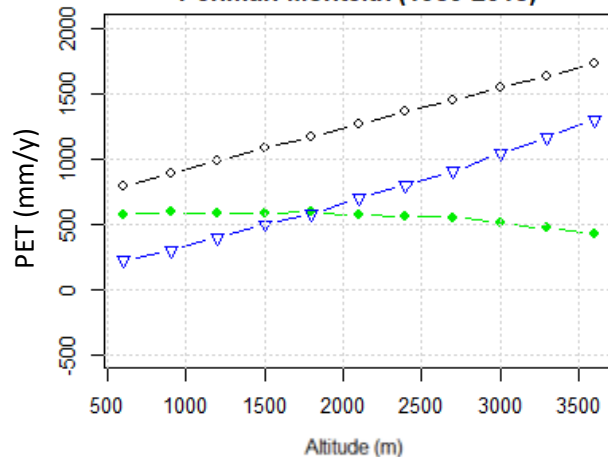
Penman-Monteith (1958-1988)



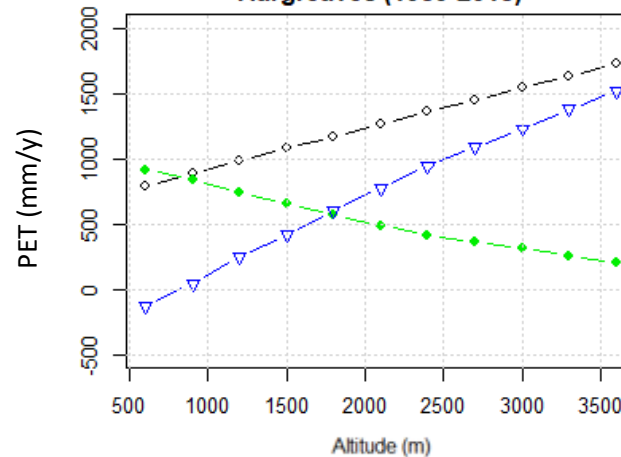
Hargreaves (1958-1988)



Penman-Monteith (1989-2018)



Hargreaves (1989-2018)



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➤ Take home message

→ It is the unique air temperature dependence in Hargreaves that governs this altitudinal evolution, whereas the P-M dependencies are more complex.

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➤ Conclusions

➤ Conclusions and perspectives

- Validation of the Penman-Monteith formula using data from the FluxAlp station (Lautaret pass);
- Potential evapotranspiration does not evolve linearly with altitude depending on the formulation used;
- PET increases at low altitudes in recent years, regardless of the calculation formula chosen;
- Extend the analysis of the evolution of PET on several massifs;
- Simulate the PET in future climate and analyze impact of PET formulation on the evolution of the water resource.

Thank you !



This work is funded by the project BERGER, which is part of Pack Ambition Recherche supported by the Auvergne-Rhône-Alpes region.



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