DEVELOPMENT OF A SNOW REANALYSIS PIPELINE USING DOWNSCALED ERA5 DATA

Laura Sourp, Simon Gascoin, Wassim Baba, César Deschamps-Berger, Esteban Alonso González

INTRODUCTION

- **Reanalyses products** are too coarse to be used as direct input to snow model
- MicroMet-SnowModel (Liston et al. 2006) can be useful to **downscale** reanalysis data and simulate SWE distribution (e.g. Andes: Mernild et al. 2017; Atlas: Baba et al. 2018)
- **Assimilation of remote sensing snow cover area** can correct biais (Andreadis & Lettenmeier 2006)

1 GENERAL PRESENTATION OF THE ESP

DEM, Period,
Reanalysis,
Perturbations

Input data

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Preprocessing for
SnowModel

Downloading ERA5,
data preparation

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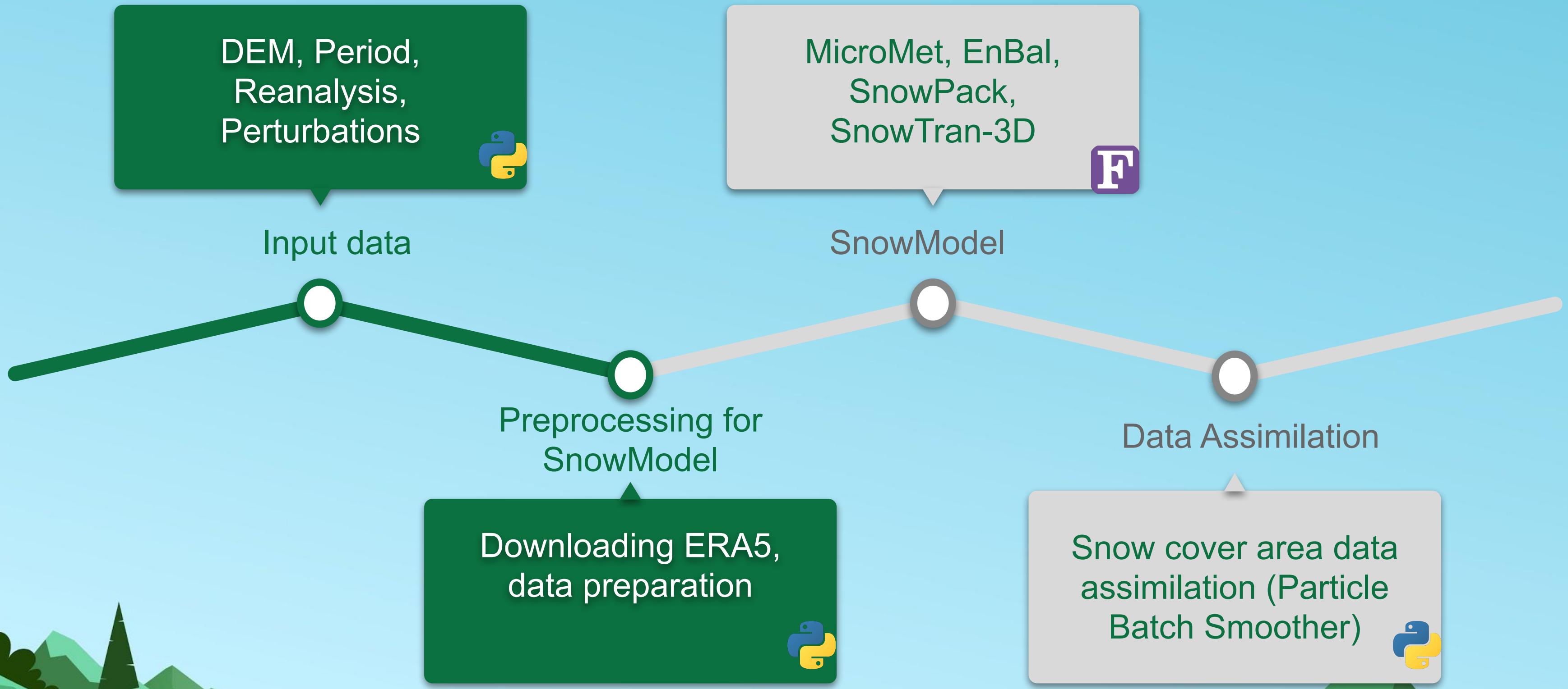
MicroMet, EnBal,
SnowPack,
SnowTran-3D

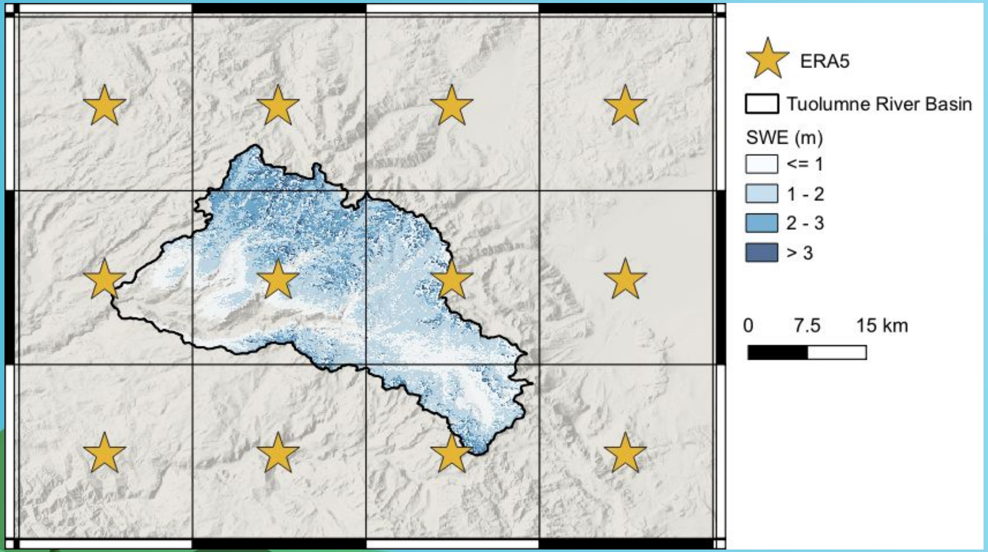
SnowModel

1 GENERAL PRESENTATION OF THE ESP



2 EVALUATION

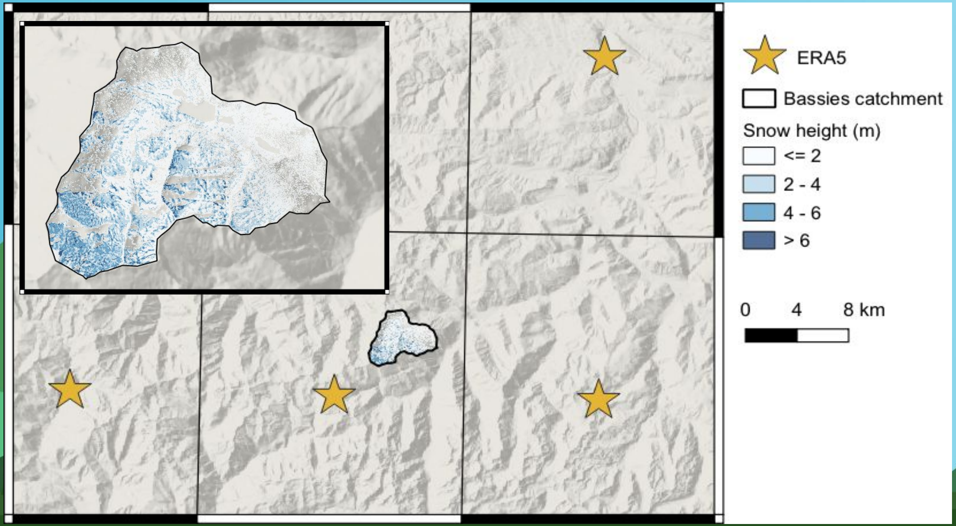
A Tuolumne (USA) ASO HS (2012-2019)



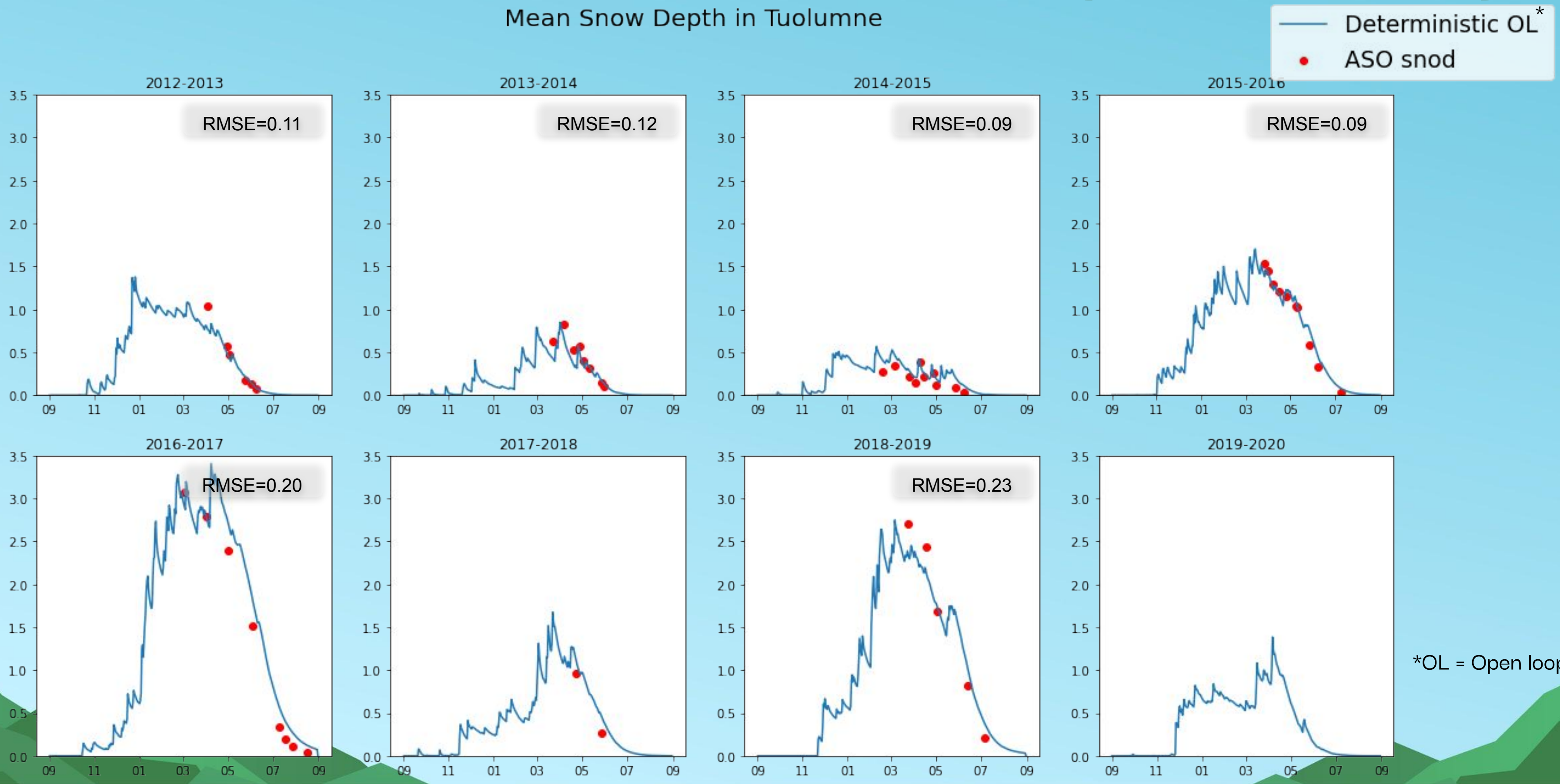
2 EVALUATION

A Tuolumne (USA) ASO HS (2012-2019)

B Bassiès (France) Pléiades HS (2015-2020)

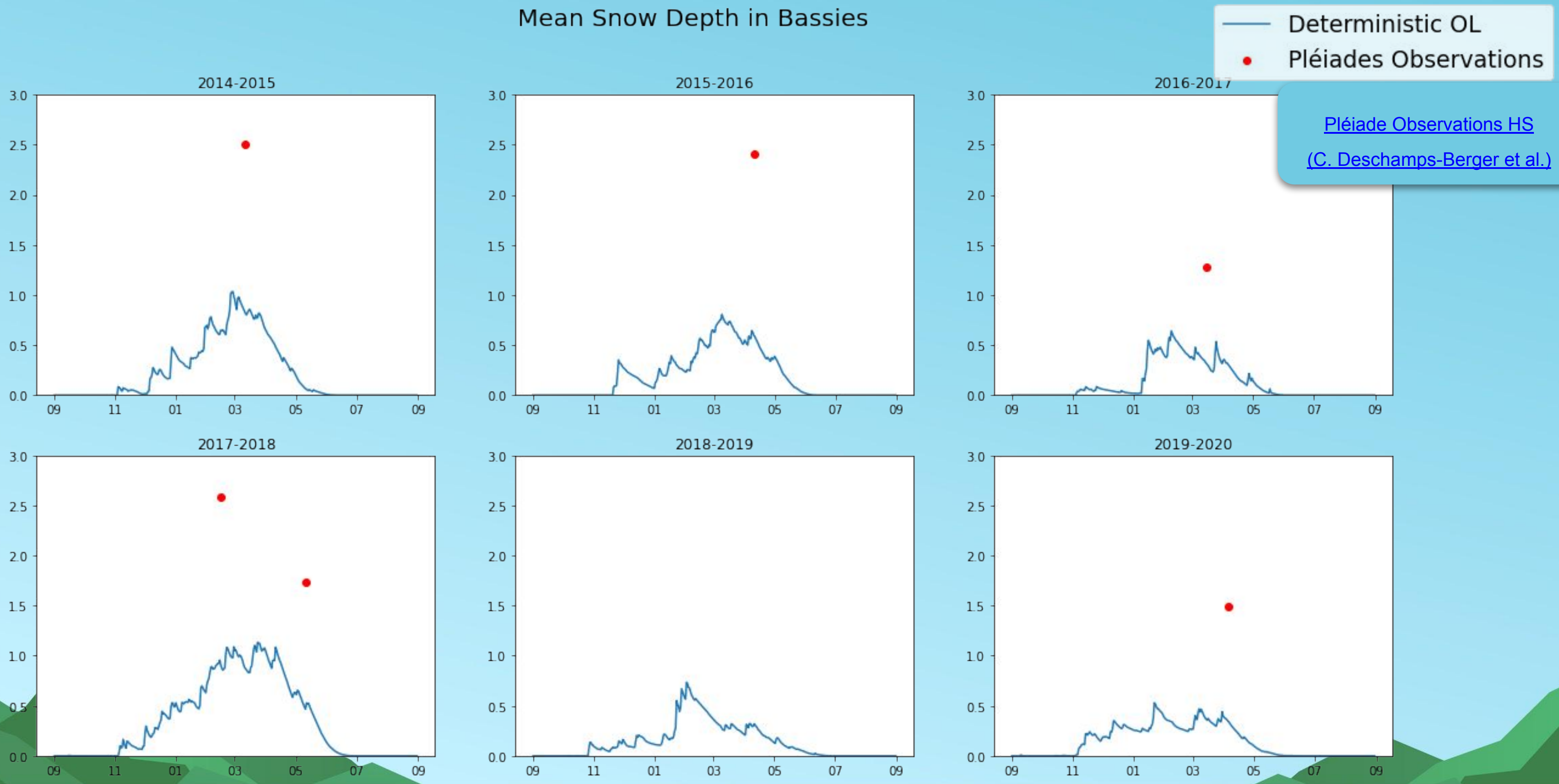


2A EVALUATION IN TUOLUMNE (1200 KM^2)



*OL = Open loop

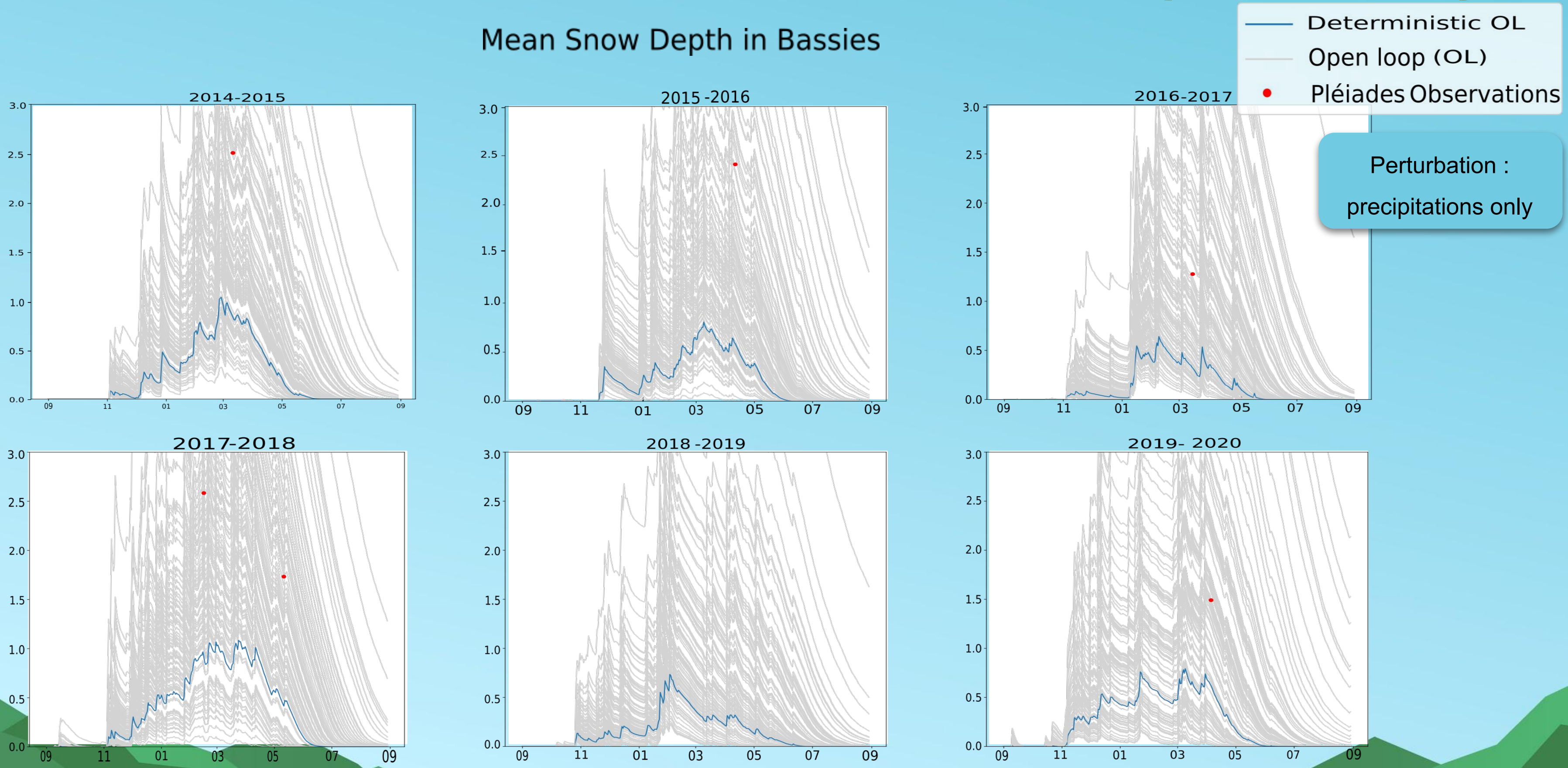
2B Evaluation in Bassies (14 km^2)



[Pléiade Observations HS](#)

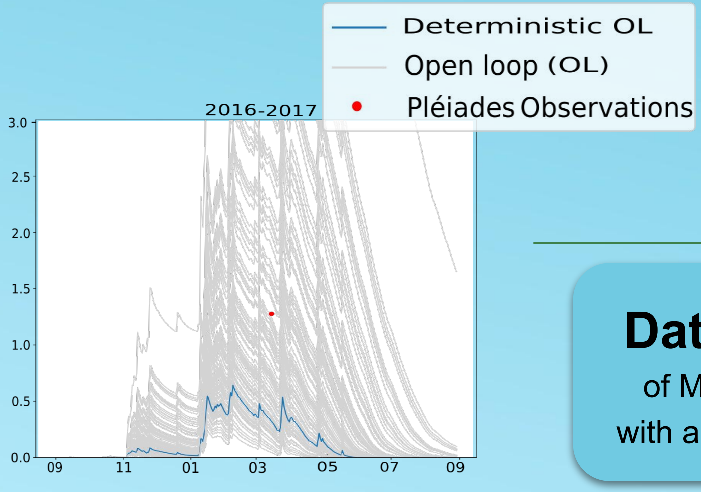
[(C. Deschamps-Berger et al.)](#)

2B ENSEMBLE RUN IN BASSIES (14 KM^2)



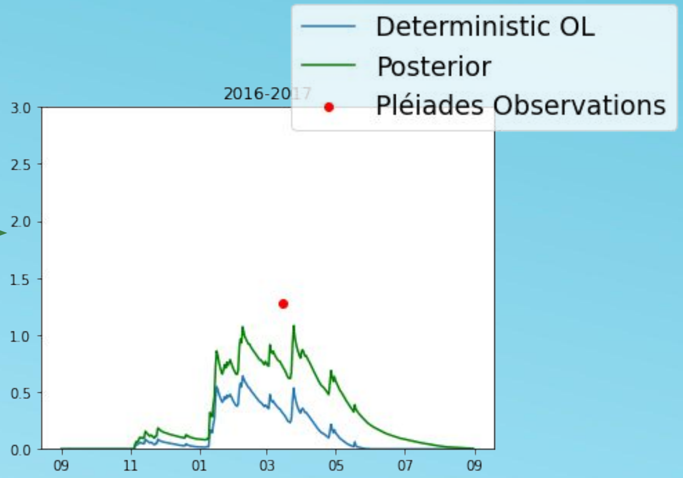
Perturbation :
precipitations only

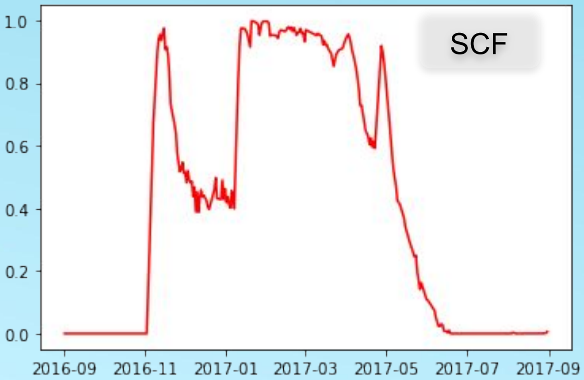
2B DATA ASSIMILATION IN BASSIES (14 KM^2)



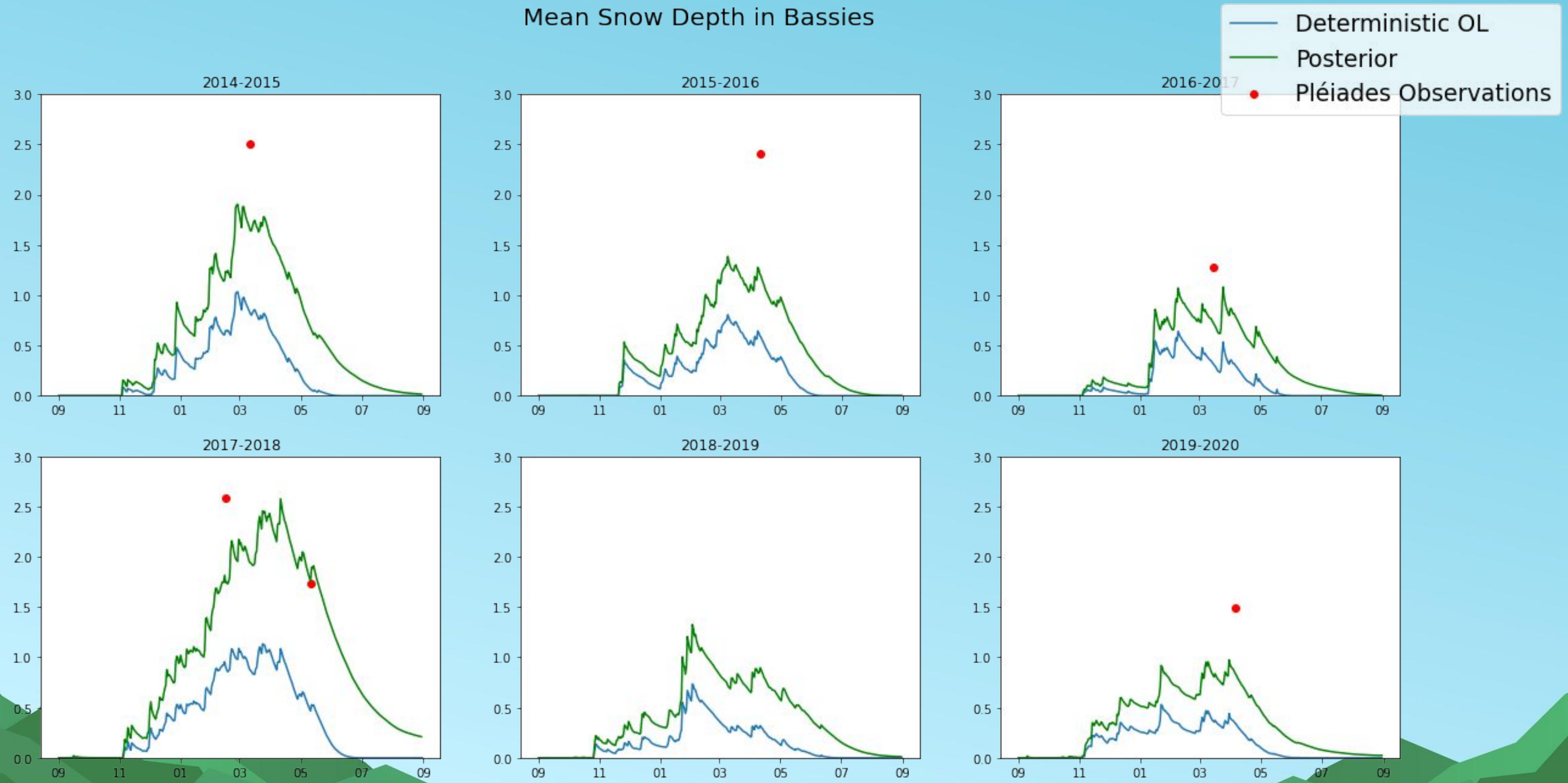
Data Assimilation

of MODIS snow cover area
with a Particle Batch Smoother





2B Data assimilation in Bassies (14 km^2)



3

CONCLUSION

- THE ADVENT OF REANALYSES IS A GAME CHANGER IN ENVIRONMENTAL SCIENCE
- THE ESP PROVIDES AN EASY WAY TO COMPUTE SNOW COVER WITH REANALYSES
- POSSIBILITY TO RUN ENSEMBLE SIMULATIONS BY PERTURBING PRECIP & T°C
- POSSIBILITY TO ASSIMILATE OTHER SNOW COVER AREA PRODUCTS (SENTINEL-2)
- DATA ASSIMILATION AVAILABLE, STILL UNDER EVALUATION

THANK YOU

Any questions?

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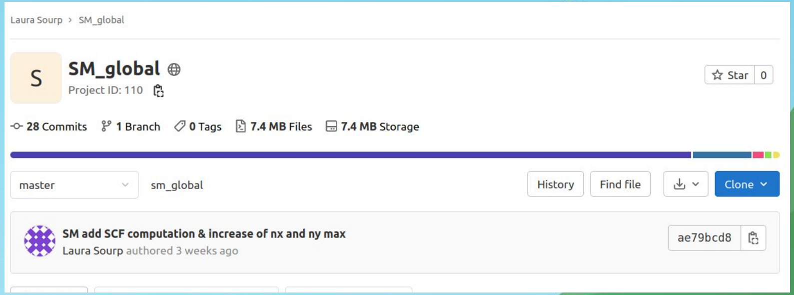
https://gitlab.cesbio.omp.eu/lauras/sm_global.git



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A. SNOWMODEL MODULES

MICROMET

Distribution of the meteorological variables across given landscape by spatially interpolating data and physical sub-models improvements

ENBAL

Computing energy fluxes between the snowpack and exterior environment

SNOWPACK

Computing snow depths and snow density with the meteorological forcings, the energy fluxes and mechanical processes

SNOWTRAN 3D

Redistribution of the snow according to the wind

A. SNOWMODEL MODULES

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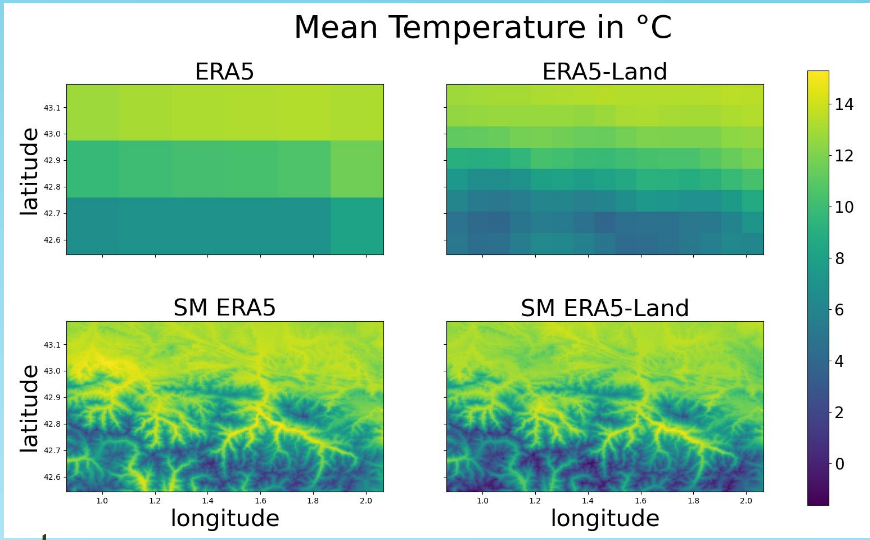
Temperature

$$T_0 = T_{stn} - \Gamma(z_0 - z_{stn})$$

Spatial interpolation (Barnes 1964)

$$T = T_0 - \Gamma(z - z_0)$$



$T_{stn/0}$: observed/sea level temperature

$z_{stn/0}$: observed/sea level elevation

Γ: lapse rate

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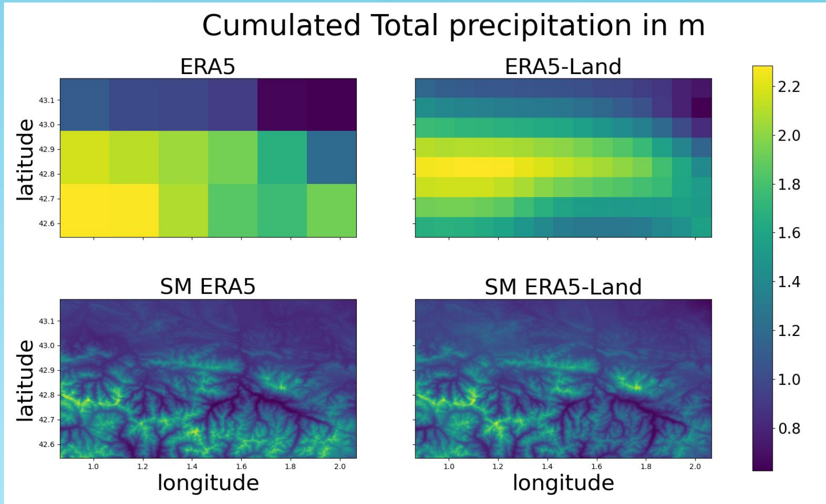
Precipitations

$$P = P_0 \left[\frac{1 + \chi(z - z_0)}{1 - \chi(z - z_0)} \right]$$

P_0 : sea level precipitations

$z_{./0}$: DEM/sea level elevation

χ: precipitations adjustment factor



A. SNOWMODEL MODULES

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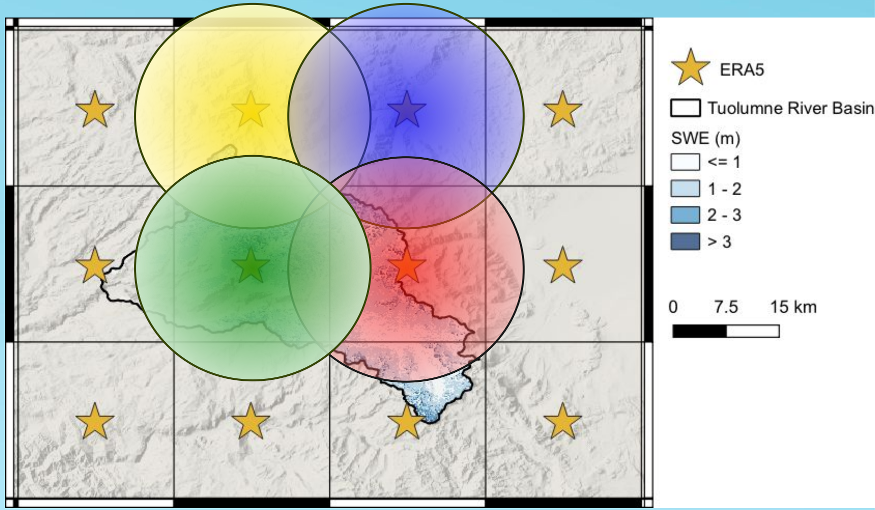
Distribution of the meteorological variables across given landscape by spatially interpolating data and physical sub-models improvements

Spatial interpolation (Barnes 1994):

A Gaussian distance-dependent weighting function

$$w = \exp\left(\frac{r^2}{f(dn)} \right)$$

2nd pass



A. SNOWMODEL MODULES - MICROMET

Relative Humidity to dewpoint temperature

$$e_s = a \exp\left(\frac{b.T^{°C}}{c + T^{°C}}\right)$$

30 km

$$e = \frac{RH}{100} \times e_s$$

30 km

$$T_{d,\,stn} = \frac{c.\ln(e/a)}{b - \ln(e/a)}$$

$$\Gamma_d = \lambda \cdot \frac{c}{b}$$

λ Depends on the month

$$T_{d,0} = T_{d,stn} - \Gamma_d (z_0 - z_{stn})$$

30 km

Spatial interpolation (Barnes 1964)

100 m

Sea level

$$T_d = T_{d,0} - \Gamma_d (z - z_0)$$

100 m

Actual elevation

$T_{d,stn/0}$: observed/sea level dewpoint temperature

$z_{stn/0}$: observed/sea level elevation

Γ_d: dewpoint lapse rate

A. SNOWMODEL MODULES - MICROMET

Wind speed and direction

$u = -W_{stn}\sin(\Theta_{stn})$
$v = -W_{stn}\cos(\Theta_{stn})$

30 km

Spatial interpolation (Barnes 1964)

100 m

$$W = (u^2 + v^2)^{(1/2)}$$

$$\Theta = \frac{3\pi}{2} - \tan^{-1}\left(\frac{v}{u}\right)$$

100 m

Terrain slope : β

Terrain slope azimuth : ξ

Curvature : Ω_c

Slope in wind direction: $\Omega_s = \beta\cos(\Theta-\xi)$

Wind weight factor : $W_W = 1+\gamma_s\,\Omega_s + \gamma_c\,\Omega_c$

Terrain wind speed : $W_t = W_W.W$

Diverting factor :

$\Theta_d = -0.5\Omega_s\,\sin[2(\xi-\Theta)]$

Terrain wind dir : $\Theta_t = \Theta + \Theta_d$

A. SNOWMODEL MODULES - MICROMET

Solar Radiation

$$Q_{si} = S^*(\Psi_{dir} \cos i + \Psi_{dif} \cos Z)$$

- Z : day, latitude, hour
- i : slope, slope azimuth, Z
- Ψ : Z, cloud fraction ($T^{°C}$ & T_d)

Longwave Radiation

$$Q_{li} = \varepsilon\sigma T^4$$

- ε : elevation, cloud fraction, $T^{°C}$
- σ : constante

Surface pressure

Pa

$$p = p_0 \exp\left(-\frac{z}{H_{atm}}\right)$$

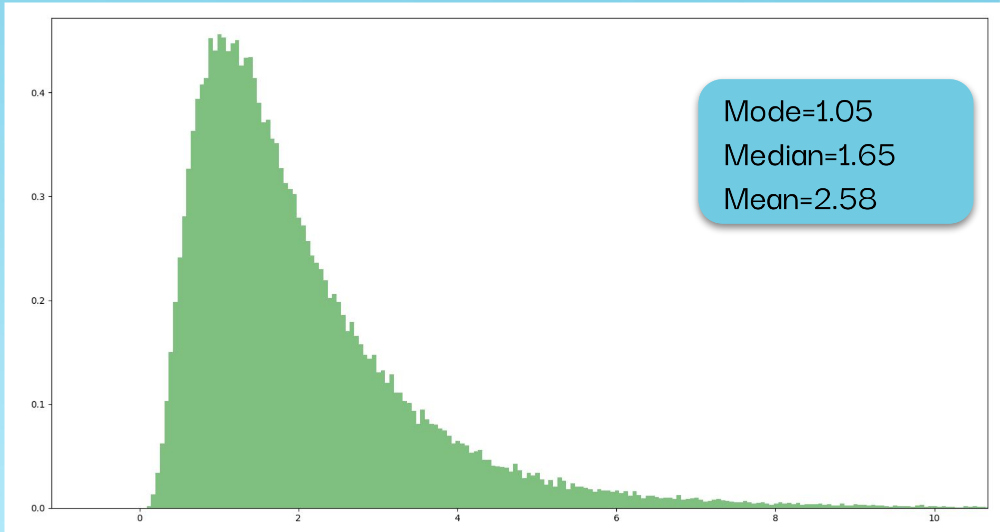
A. PREPROCESSINGS : PERTURBATIONS

All the precipitations are multiplied with the same b coefficient for one year and one particule:

$P_{new} = b*P_{ERA}$

$b \sim LN(\mu,\sigma)$

When launching the pipeline, the user chooses μ and $CV=e^{\sigma}-1$ (variation coefficient)



Density function for the log-normale perturbation with μ=0.5 and CV=0.75

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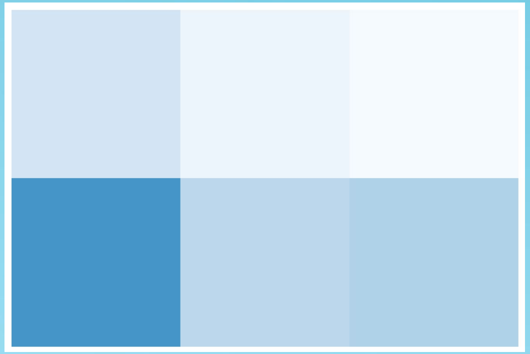

ERA5 precipitations at one random time

Perturbed ERA5 precipitations at the same time (b=2.58)

A. THE PBS FILTER IN THE ESP

DATA ASSIMILATION

Introducing a particle filter (PBS) with MODIS surface cover

1 ensemble : j=1,...,N

Y : matrix of the measurements of the **whole season**

Anterior: $Y^-_j = SWE^-_j$ with $w^-_j = 1/N$

Posterior : $Y^+_j = Y^-_j = SWE^-_j$

with $w^+_j = \frac{c_0}{N} p_V(Z-M^-_j)$

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