Evaluating radiative transfer schemes treatment of vegetation canopy architecture in land surface models

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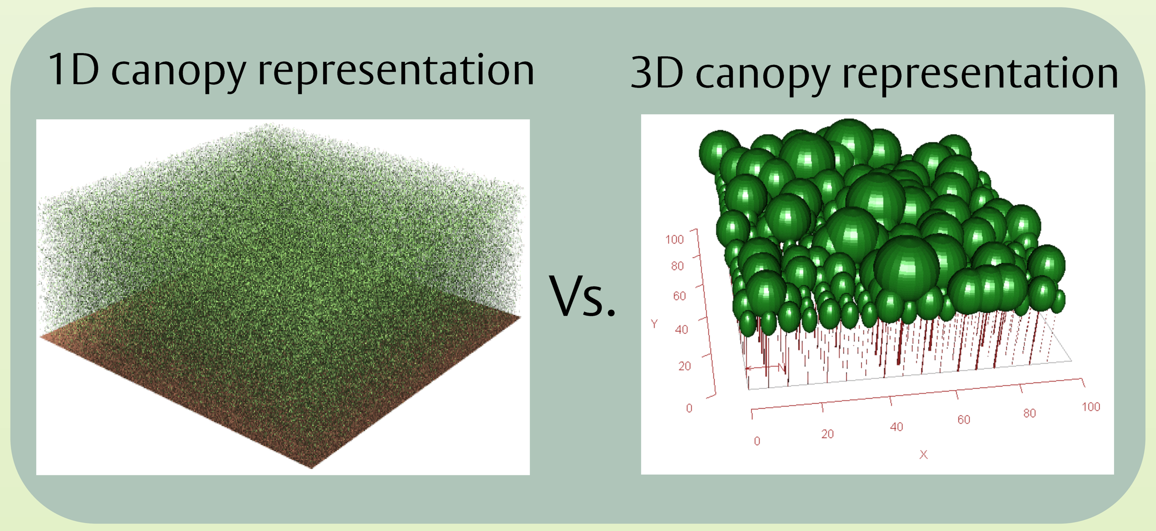
01 | Why does vegetation structure matter?

- Vegetation canopy structure affects radiation partitioning and land surface processes, as energy and water exchanges (*Loew et al., 2014*).



1D canopy representation	3D canopy representation
Simple physical basis	Complex physical basis
Computationally efficient	Computationally expensive
Suitable for large areas	Unsuitable for large areas
Good approximation for dense canopies	Good approximation for all types of canopies

02 | Methodology: the 'structure factor'

- Using a straightforward approach, which introduces a parameterisation in a 1D radiative transfer (RT) scheme ($\zeta(\theta)$) (*Pinty et al. 2006*), it is possible to recreate the vegetation radiative balance consistently with 3D representations. To find the additional parameters Eq. 1 describes the probability of beam penetration in a vegetation canopy:

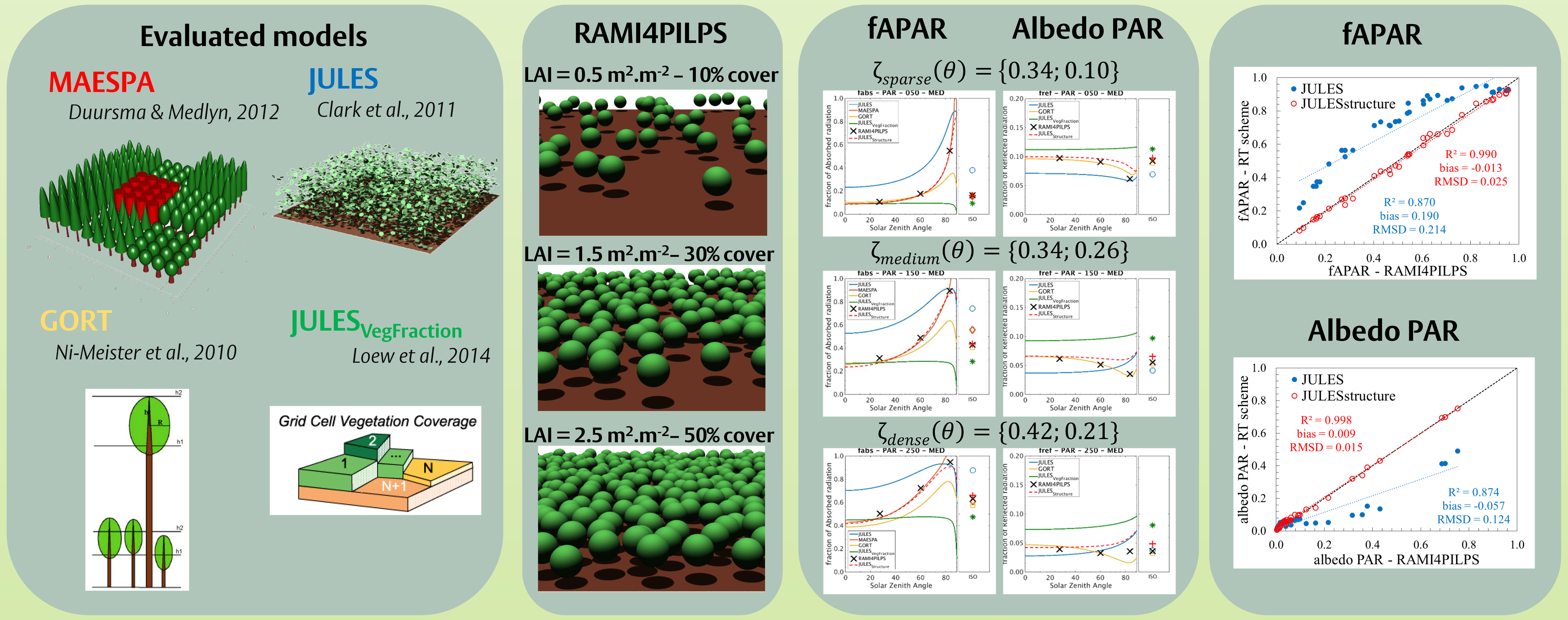
$$P_{gap}(\theta) = exp\left(-\frac{G(\theta)\cdot LAI\cdot\zeta(\theta)}{\cos(\theta)}\right) \quad \text{Eq. (1)}$$

- P_{gap} = canopy gap fraction
- LAI = Leaf Area Index ($m^2.m^{-2}$)
- θ = solar zenith angle
- $G(\theta)$ = leaf angle distribution function
- $\zeta(\theta)$ = Structure factor

Where $\zeta(\theta) = a + b\cdot(1-\cos(\theta))$, also expressed as {a;b}.

Radiation transfer Model Intercomparison (RAMI) exercise

- A comparison between the performance of the structure factor parameterisation and state-of-art 3D RT schemes was conducted, following a set of virtual scenarios described in the RAMI4PILPS experiment (*Widlowski et al.*, 2011).

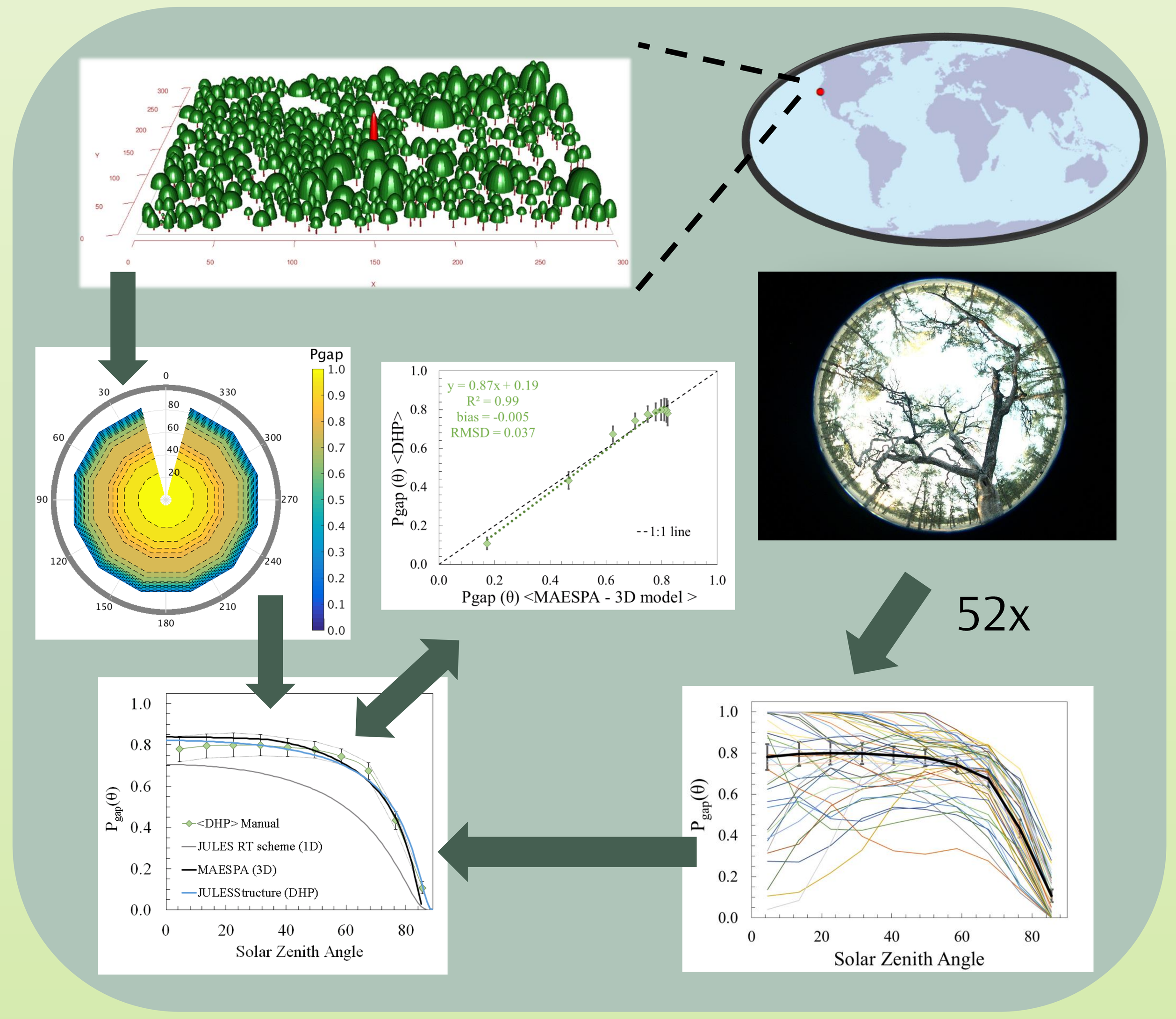


03 | Measuring canopy gap fraction

- The canopy gap fraction was obtained with two different methods in Tonzi Ranch, a woody savannah in California, USA.

a) a 3D tree based model (MAESPA) with canopy structural data derived from airborne LiDAR, and

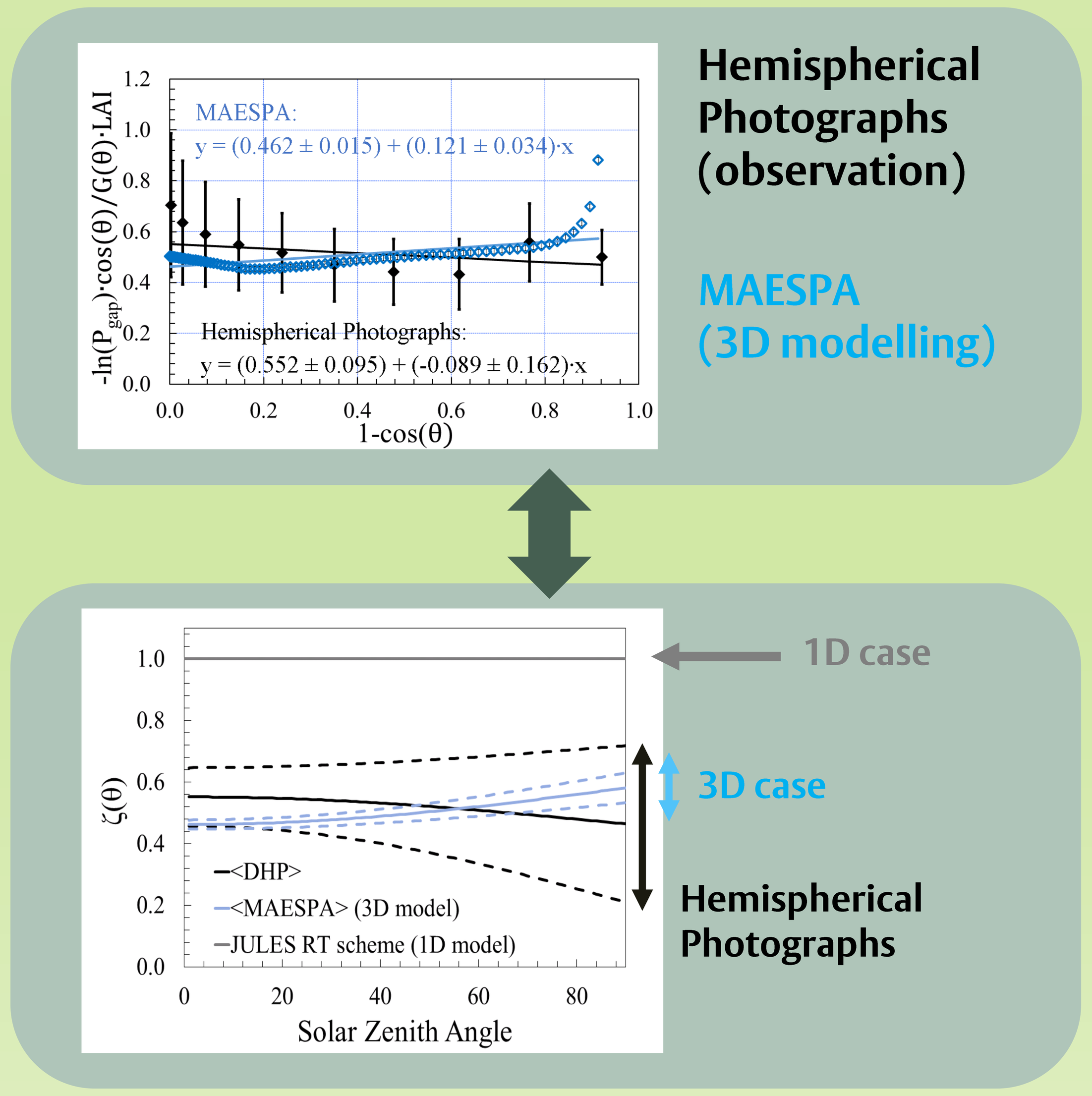
b) the average of 52 Digital Hemispherical Photographs (DHP) equally spaced acquired at the same area (300 m x 300 m) around the micrometeorological tower.



04 | Retrieving the 'structure factor'

- In order to derive the 'structure factor' through the inversion of **Eq.1**, it is necessary to have previous knowledge about:

$G(\theta) = 0.5$; **spherical distribution** assumption
$LAI = 0.82 \pm 0.10\ m^2.m^{-2}$; **litterfall** measurement (*Ryu et al., 2010*)



05 | Impacts on the radiative balance

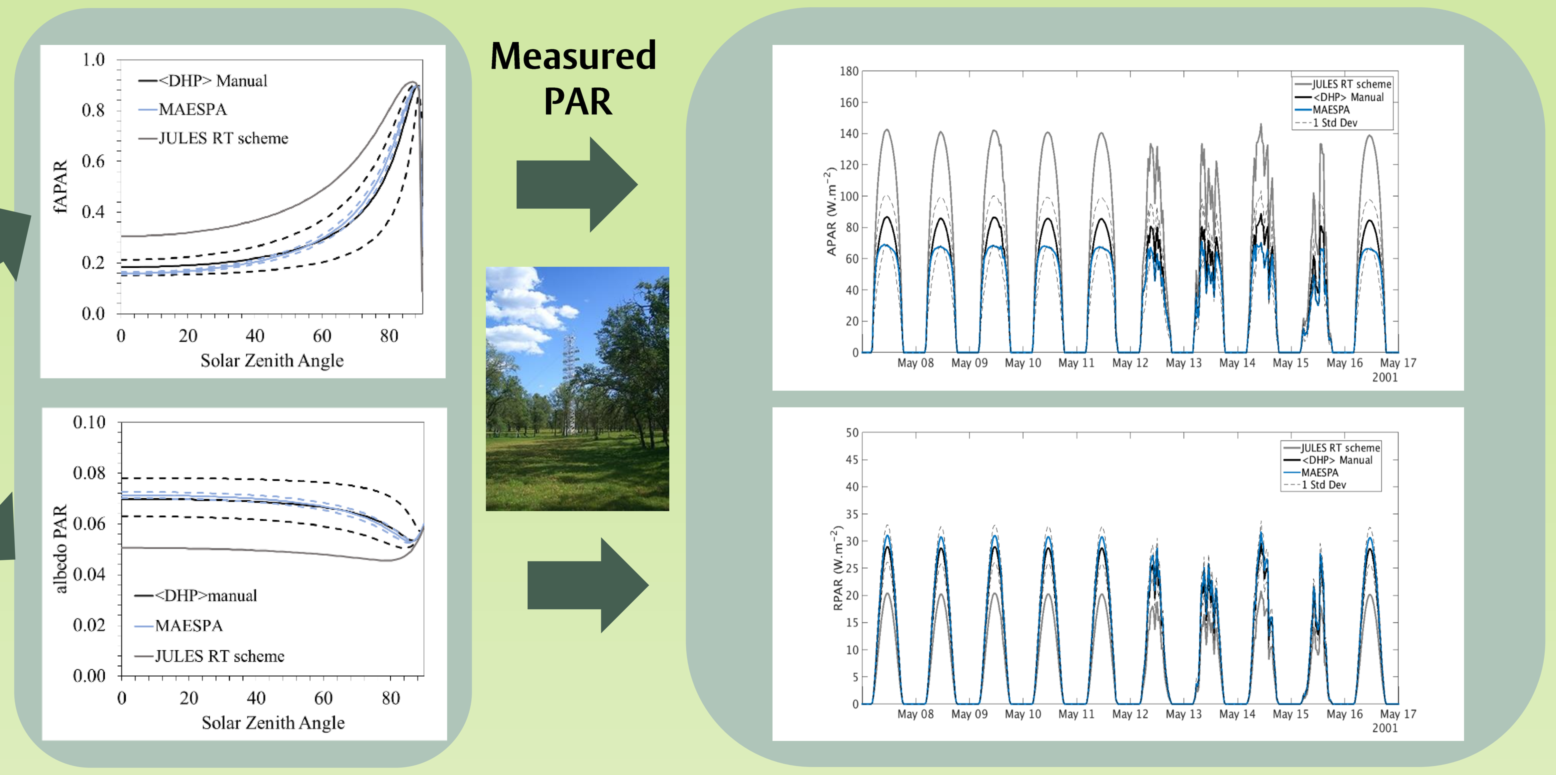
- For the period from 7[th] to 16[th] of May 2001, the average maximum value of absorbed amount of PAR was calculated with the default two-stream approximation (JULES RT scheme), ~140 $W.m^{-2}$, twice as much as obtained with MAESPA (~70 $W.m^{-2}$). JULES parameterised with observed data (<DHP> Manual) showed an average maximum value of ~ 90 ± 20 $W.m^{-2}$ for APAR.

Tonzi Ranch measured data (*Kobayashi et al., 2012*):

- Leaf reflectance = 0.085 ± 0.005
- Leaf transmittance = 0.028 ± 0.04
- Ground* albedo = 0.105 ± 0.044
- Structure factor =

$$\begin{cases} \{1.0; 0.0\};\ 1D\ case\ (JULES) \\ \{0.46; 0.12\};\ 3D\ case\ (MAESPA) \\ \{0.55; -0.09\};\ Observation\ (DHP) \end{cases}$$

* The ground is a mixture of the soil and dead leaves.



06 | Conclusion

- The 'structure factor' parameterisation improved the partitioning of PAR of the 1D RT scheme in JULES.
- The P_{gap} obtained via DHPs was comparable to 3D modelling and it was used to improve the 1D model.
- Improved calculated absorbed and reflected PAR, while the 1D model tended to overestimate and underestimate up to 50%, respectively.

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