Comparing vegetation structural variables retrieval performances when using mono directional, multidirectional or albedo observations

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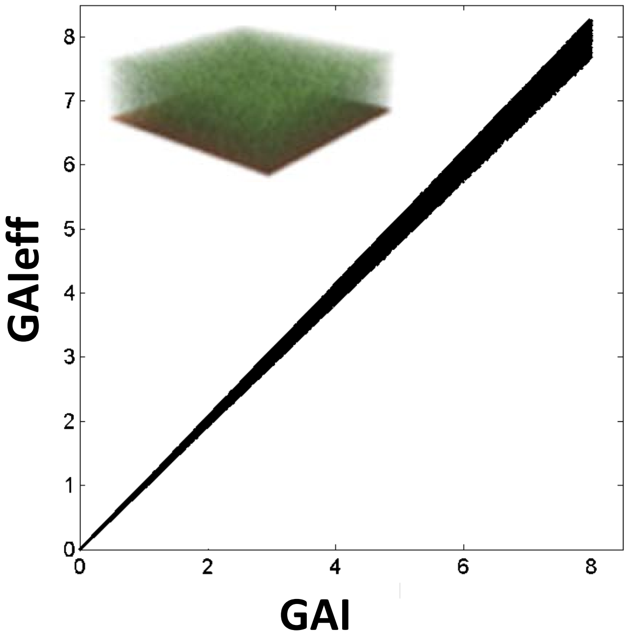
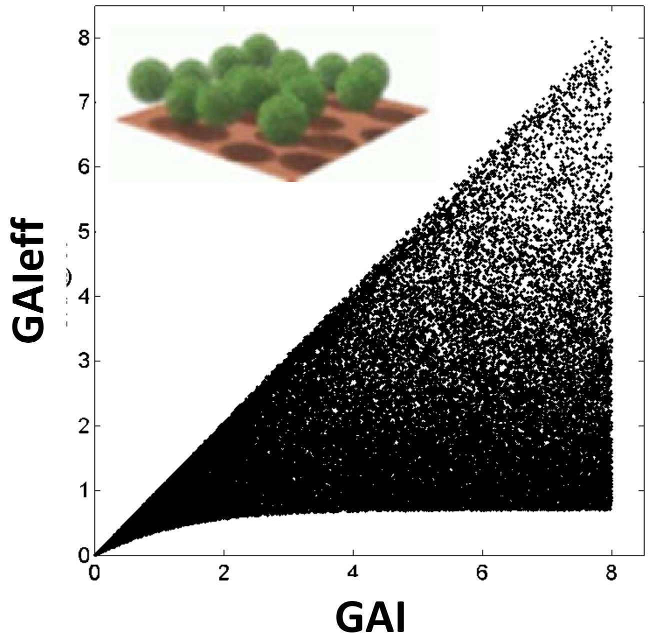
Background

- **Structural variables are key inputs for:**
  - Main canopy functioning processes (photosynthesis/transpiration/respiration …)
  - Remote sensing observations through radiative transfer (scattering, absorption, fluorescence…)
- **Several variables related to the green elements**
  - GF (green fraction in the view direction)
  - FAPAR ($FAPAR_{bs}$ $FAPAR_{ws}$ $FAPAR_{day}$)
  - LAI / PAI / **GAI** / GLAI with variants (effective/apparent)

	Only leaf	All vegetation elem.
Green+non green	LAI	PAI
Green	GLAI	**GAI**

LAI and effective GAI





Effective GAI (LAI) defined consistently with indirect measurement methods,

The effective GAI (GAIeff) is the LAI value that provides the closest directional variation of the GF under turbid medium assumption

Apparent GAI (LAI) defined as the value accessible from the observation:

Depends on: *+ Observational configuration*

+ Assumptions on canopy structure (RT model)

+ Inversion technique

+ ....

Objectives

Evaluate the retrieval performances depending on:

The variable targeted

- GF(vza)
- $FAPAR_{bs}$(sza)
- $FAPAR_{ws}$
- $FAPAR_{day}(sza_{min})$
- GAI_{eff}
- GAI

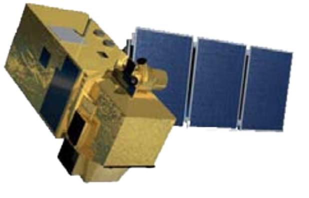
The type of canopy structure

- Turbid

- clumped

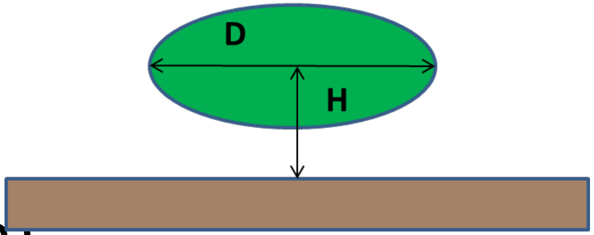
The observational configuration

- Multi-directional
- Albedo
- Mono-directional



Methods:

- Leaf optical properties: PROSPECT
- Soil reflectance: typical soils with brightness
- Canopy reflectance:
  - SLC model (clumping at the stand level)
    - LAI, ALA, Crown-Cover, D/H, hot: 5 variables
    - Total of 11 input variables



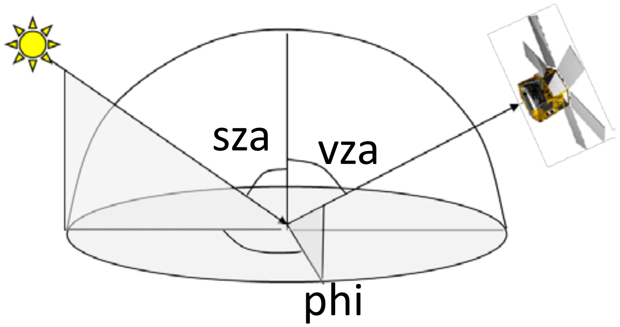
  - 1D model (assumes turbid medium)
    - SLC with Crown-Cover=1
    - Total of 9 input variables

Distribution of RTM input variables for Test cases and LUT generation

Uniform (independent) distributions considered within the typical range of variation

	Variable	Mini	Maxi
Canopy	LAI	0	8
	LIDFa	-1.0	1.0
	LIDFb	-0.3	0.3
	hot	0.1	0.5
	Crown-cover	0.3	1.0
	D/H	0.2	1.0
Leaf	N	1.20	2.20
	Cab (µg m-2)	30	90
	Cdm (gm-2)	0.0030	0.010
	Cw. Rel.	0.60	0.85
Soil	Bs	0.50	1.0

11 input variables



Angles	Values (°)
sza	30 45 60
vza	0 15 30 45 60
phi	0 90 180

13 directions considered

Sentinel 2 Bands (nm)
560 670 705 740 865 1610 2190

7 bands considered

Output variables

- GF(vza) : green fraction (13 directions)
- $FAPAR_{bs}(SZA)$: black sky FAPAR
- $FAPAR_{ws}$: White sky FAPAR
- $FAPAR_{day}(SZA_{min})$:Daily integrated black sky
- GAI_{eff} :effective GAI: using Miller's formula

$$LAI = 2\int_0^{\pi/2} -\log(1 - GF(\text{vza})).\sin(\text{vza}).\cos(\text{vza})\, d\,\text{vza}$$

- GAI : Actual GAI : input of the RTM

Retrieval using a LUT approach (49 000 cases)

minimum of a cost function $J = \sum \frac{(R_{mes} - R_{est})^2}{\sigma^2}$

Performances evaluated using d2 (Willmott et al. 1985)

$$d_2 = 1 - \frac{\sum_{i=1}^{n}(V_i - \widehat{V_i})^2}{\sum_{i=1}^{n}(|\overline{V} - \widehat{V_i}| + |V_i - \overline{V}|)^2} \quad 0<d2<1$$

Test and LUT combinations

Test: uncertainties added (0.01 additive, 3% multiplicative)

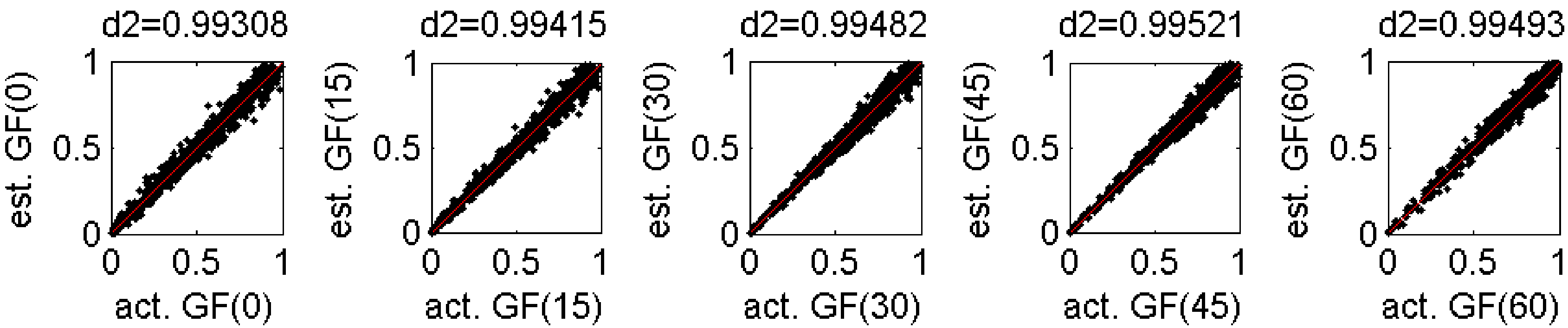
		Test (1000)	
		turb	**clump**
LUT (49000)	**turb**		✓
	clump		✓

Combination of test and LUT type of canopy structure

turbid

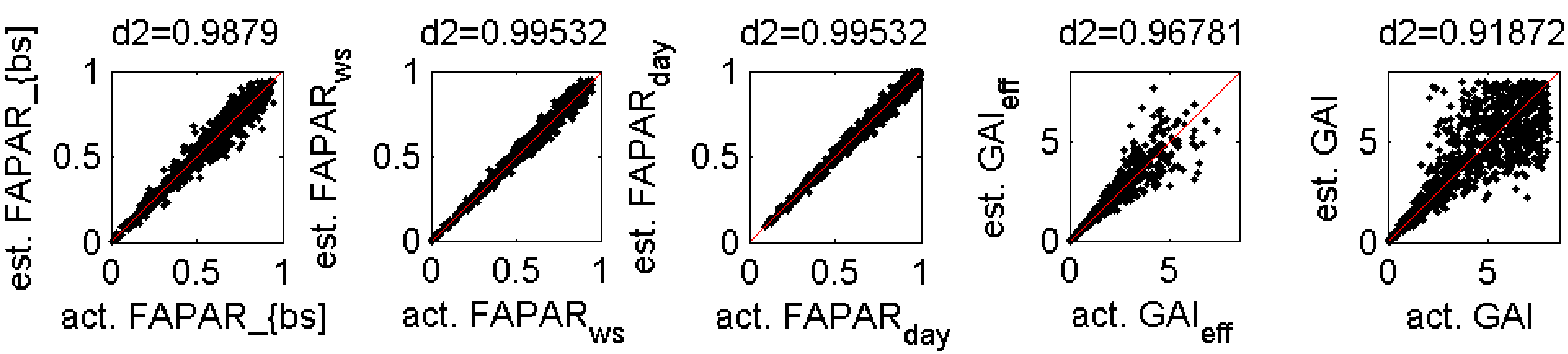
clumped

Sample results

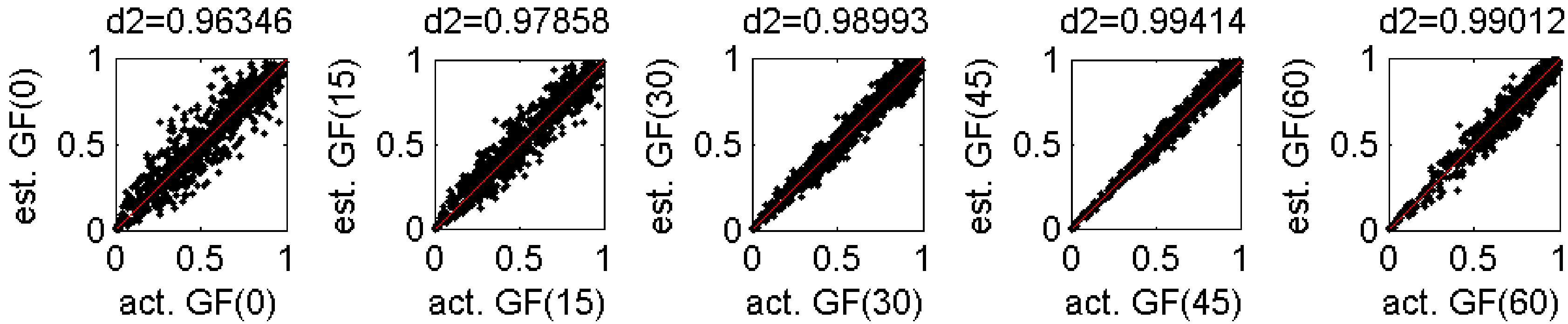


Multidirectional (13 directions)

Test: clumped
LUT: clumped



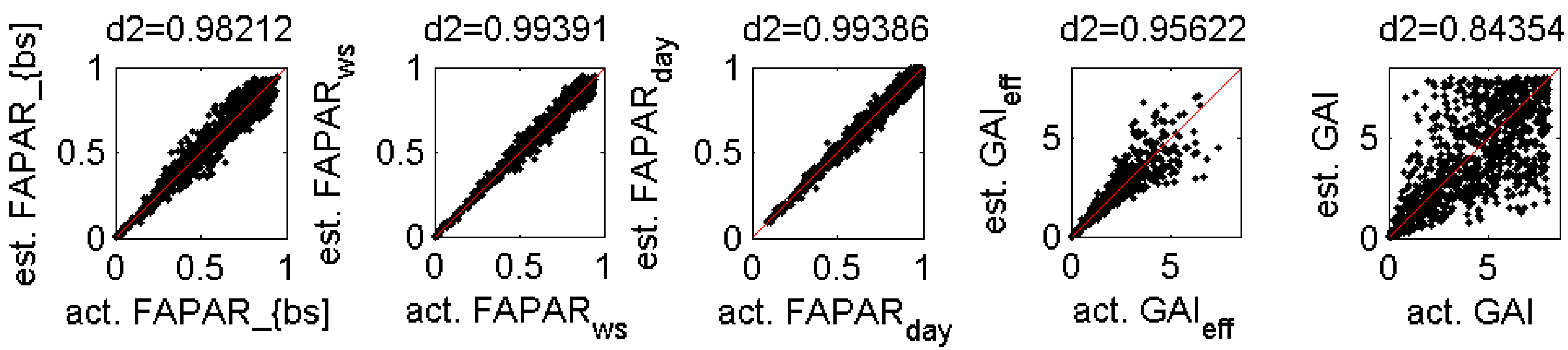
Sample results



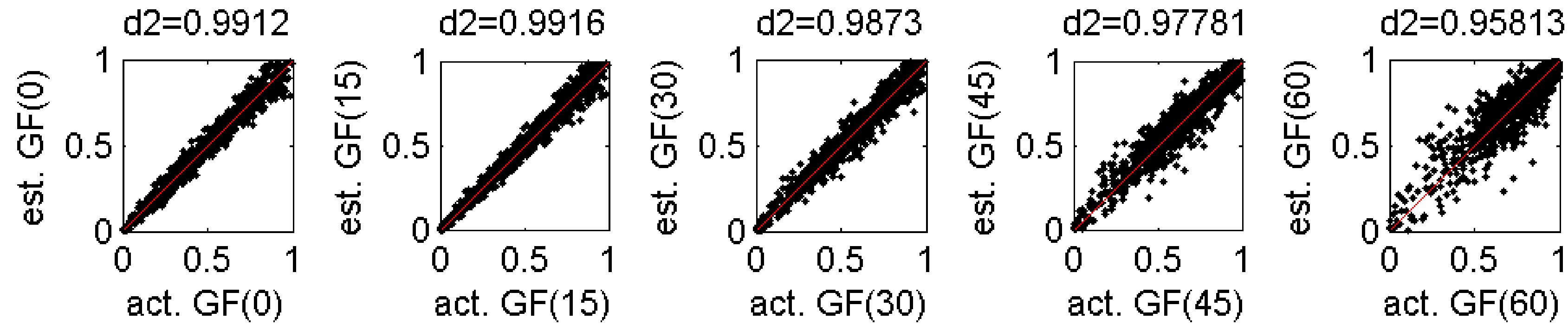
Albedo

Test: clumped

LUT: clumped



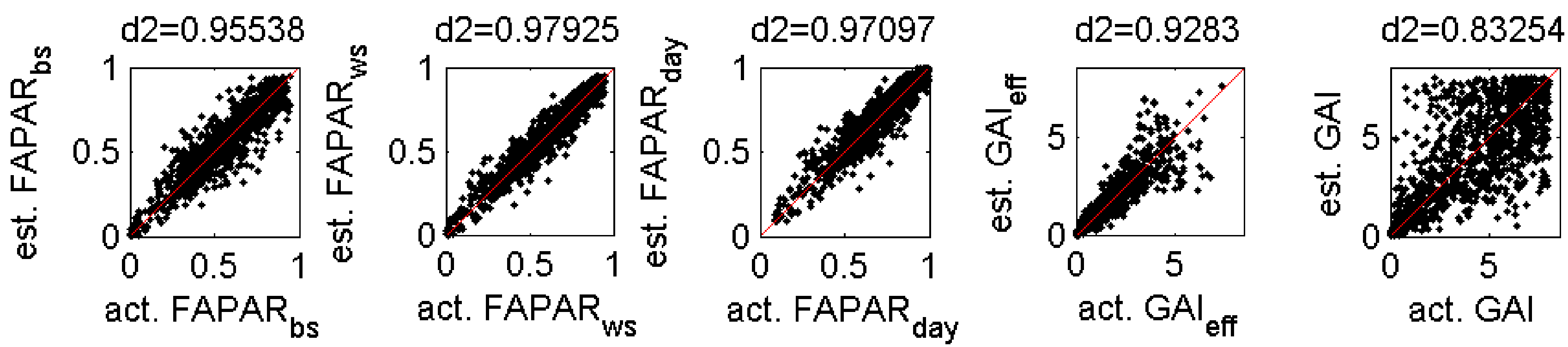
Sample results



Mono directional observation (sza=45°, vza=0°)

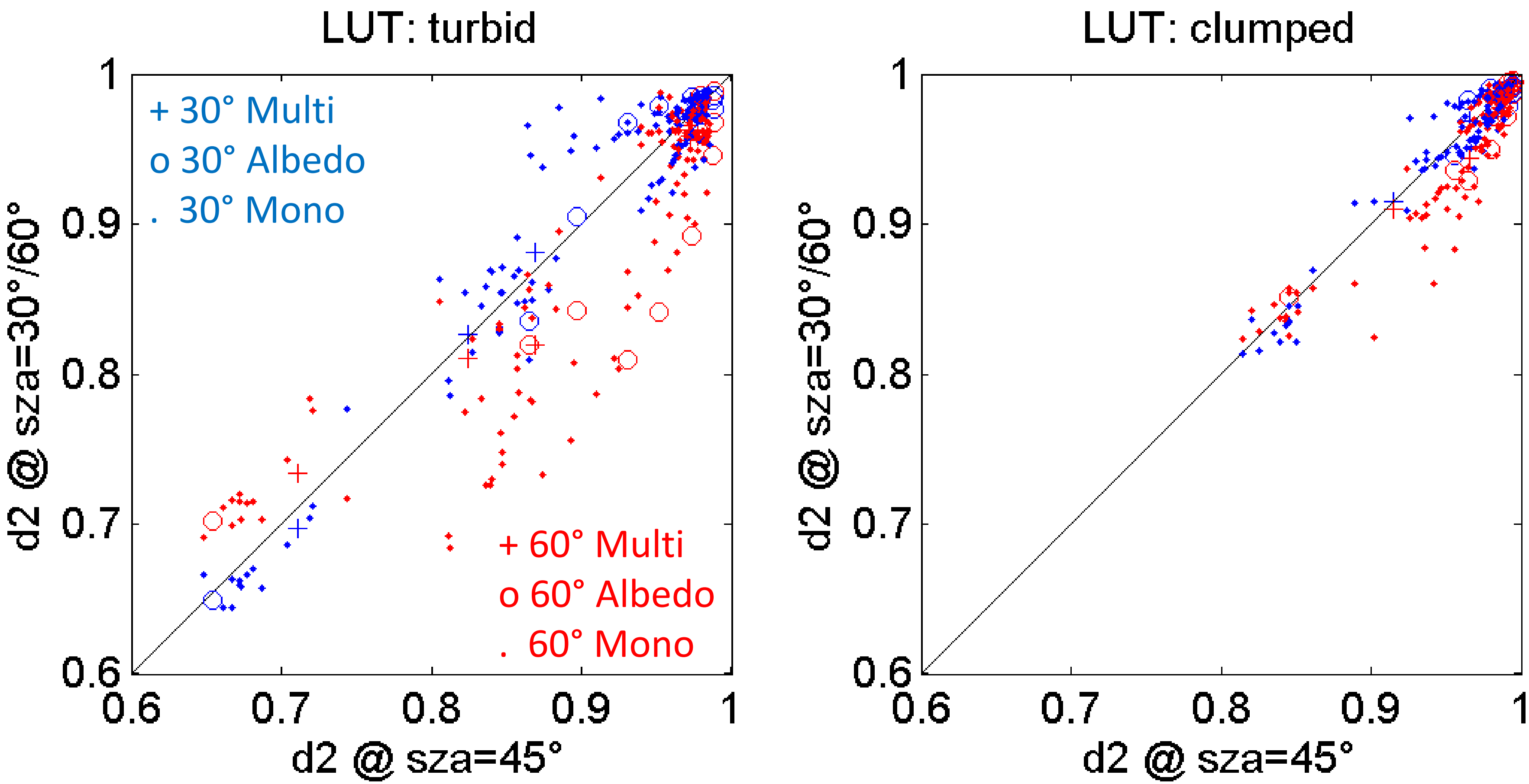
Test: clumped

LUT: clumped



RESULTS: effect of sun zenith angle (sza)

(all 10 variables together)



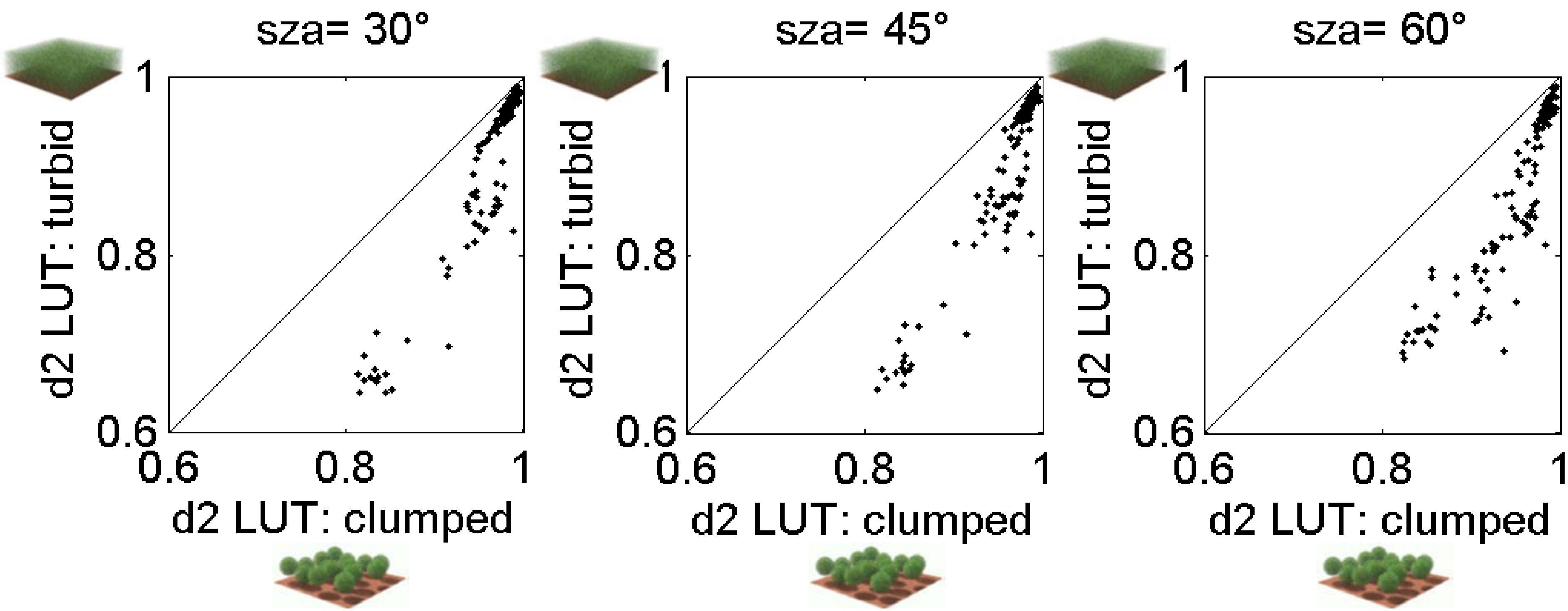
Smaller sun zenith angles lead (generally) to better performances

Select sza=45° to illustrate results in the following

Clumped LUT lead (generally) to better performances)

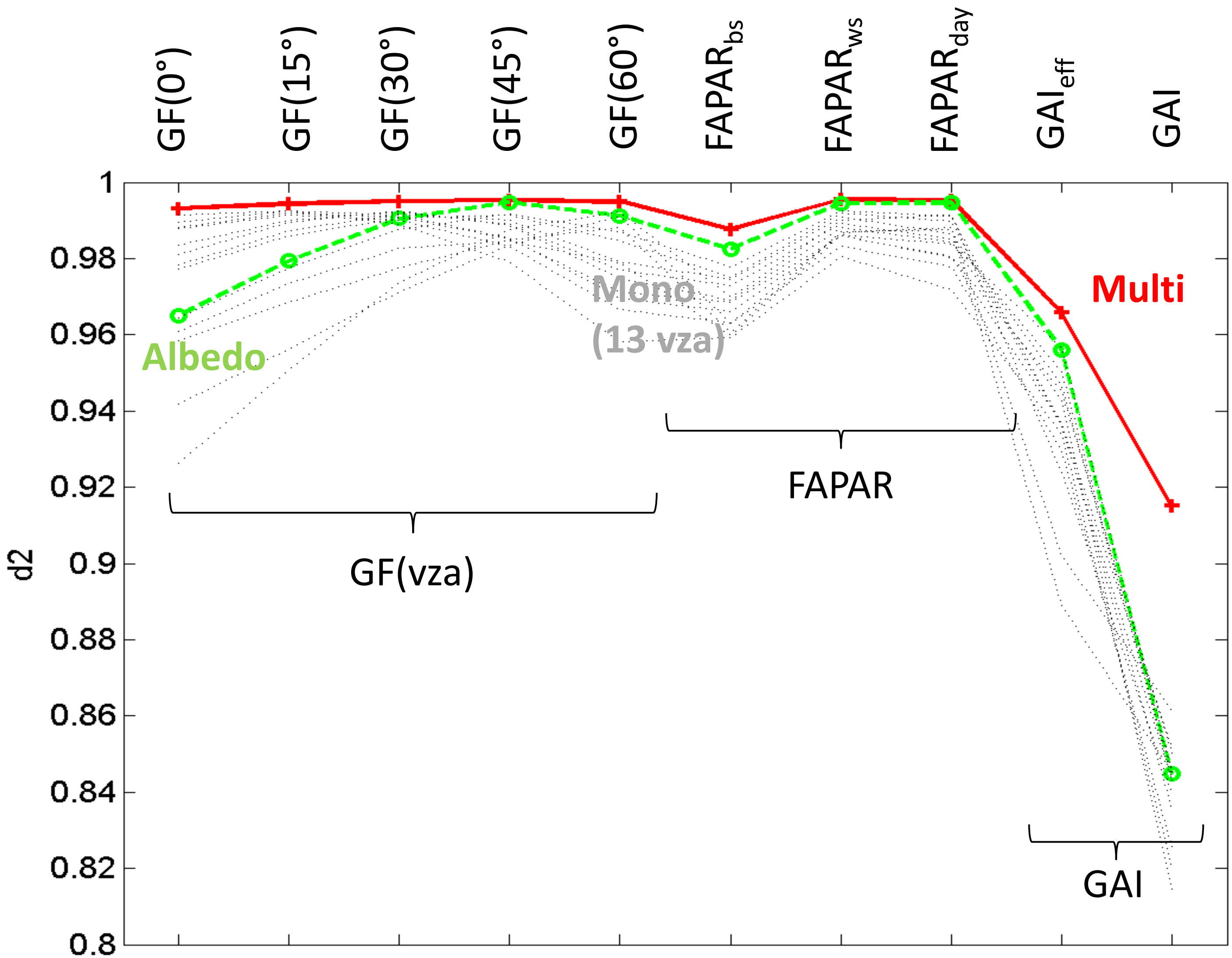
RESULTS: effect of LUT assumptions

(@ sza=45°, all 10 variables together)

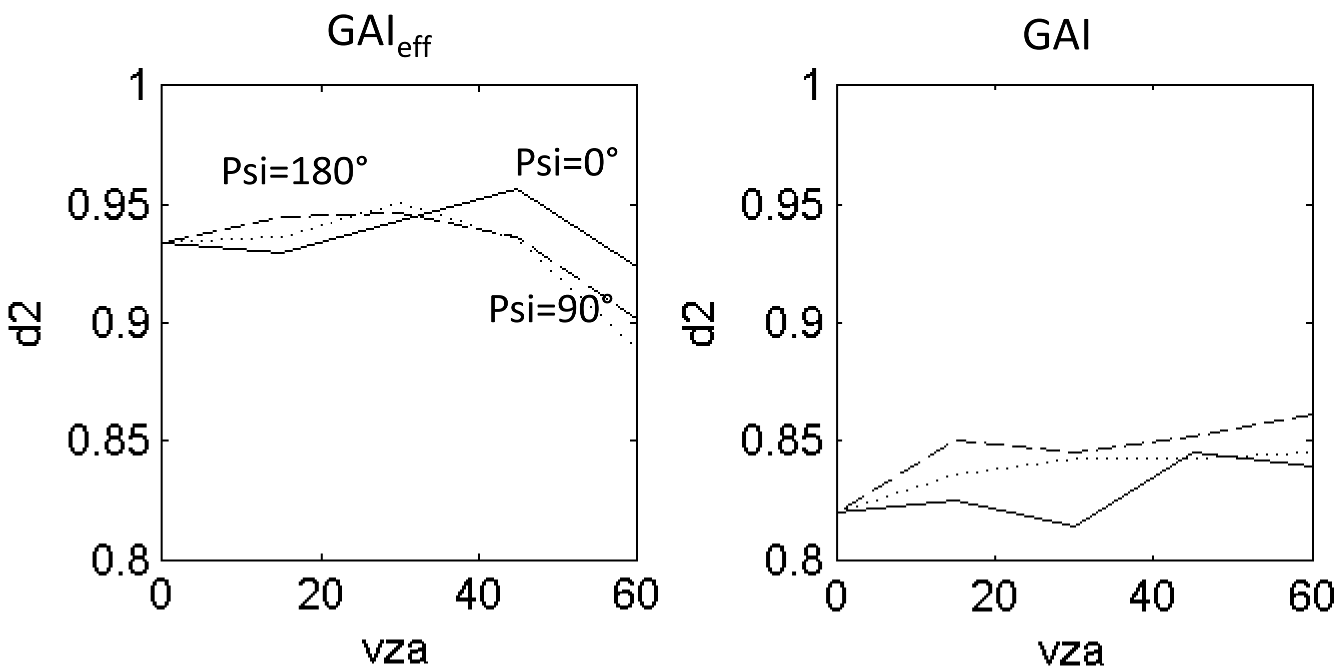


Using a clumped LUT lead (generally) to better performances

Performances depending on variables



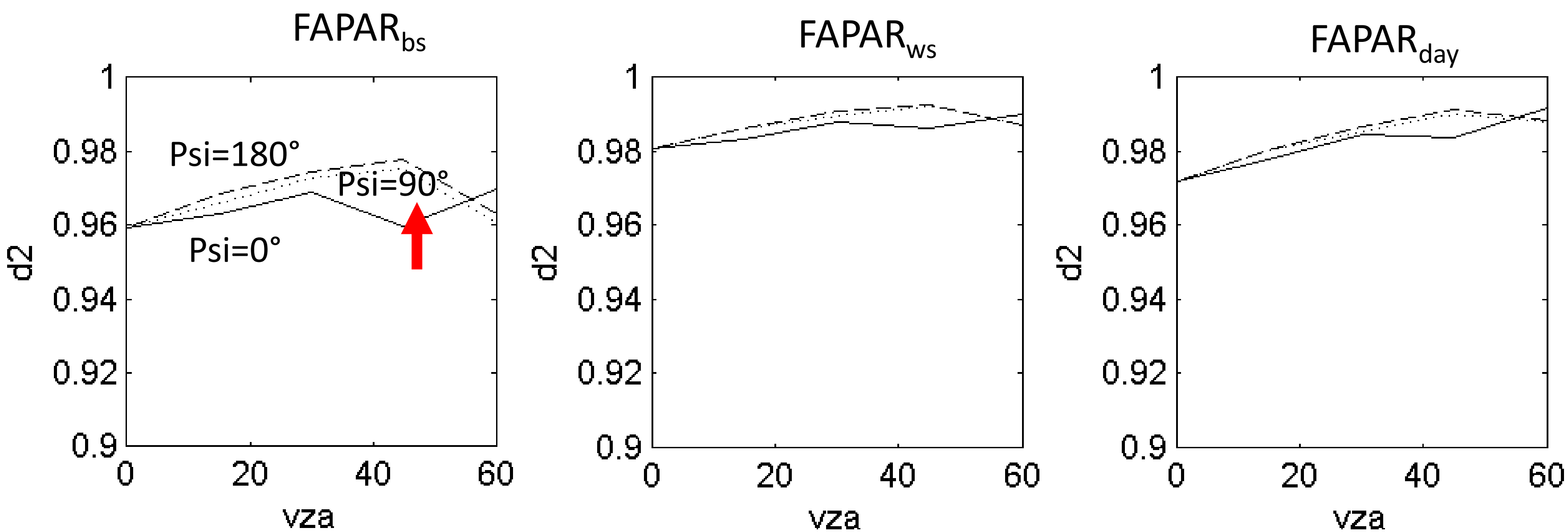
GAI estimates from Mono-directional



Little sensitive to view direction

LAI$_{eff}$ much better retrieved

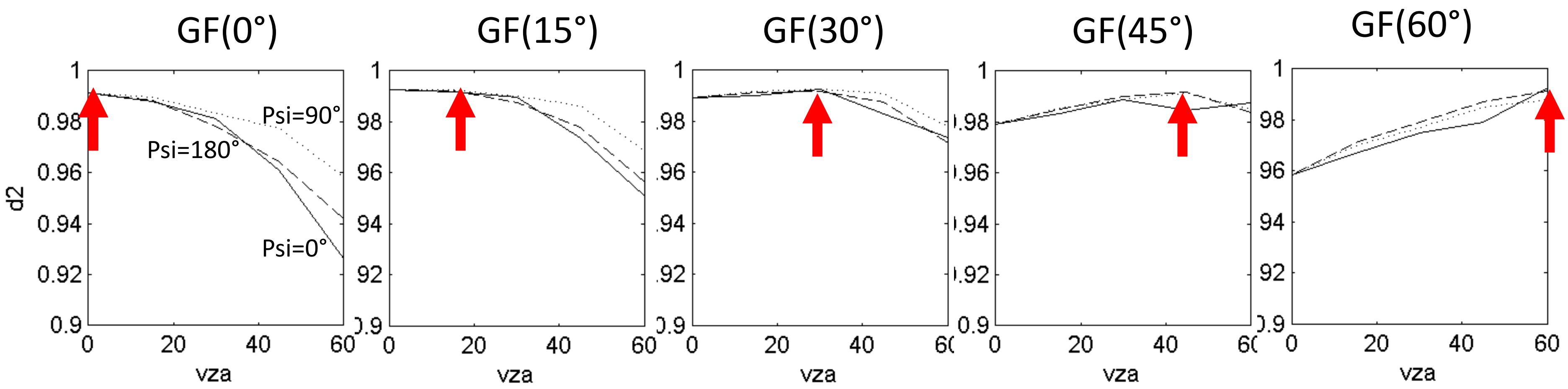
FAPAR estimates from Mono-directional



Slightly better @ vza=45°

FAPAR$_{ws}$ & FAPAR$_{day}$ much better retrieved

Green fraction performances estimates



Best estimates of GF when actually observing in the considered zenith directions,

… and relatively independently from the view azimuth

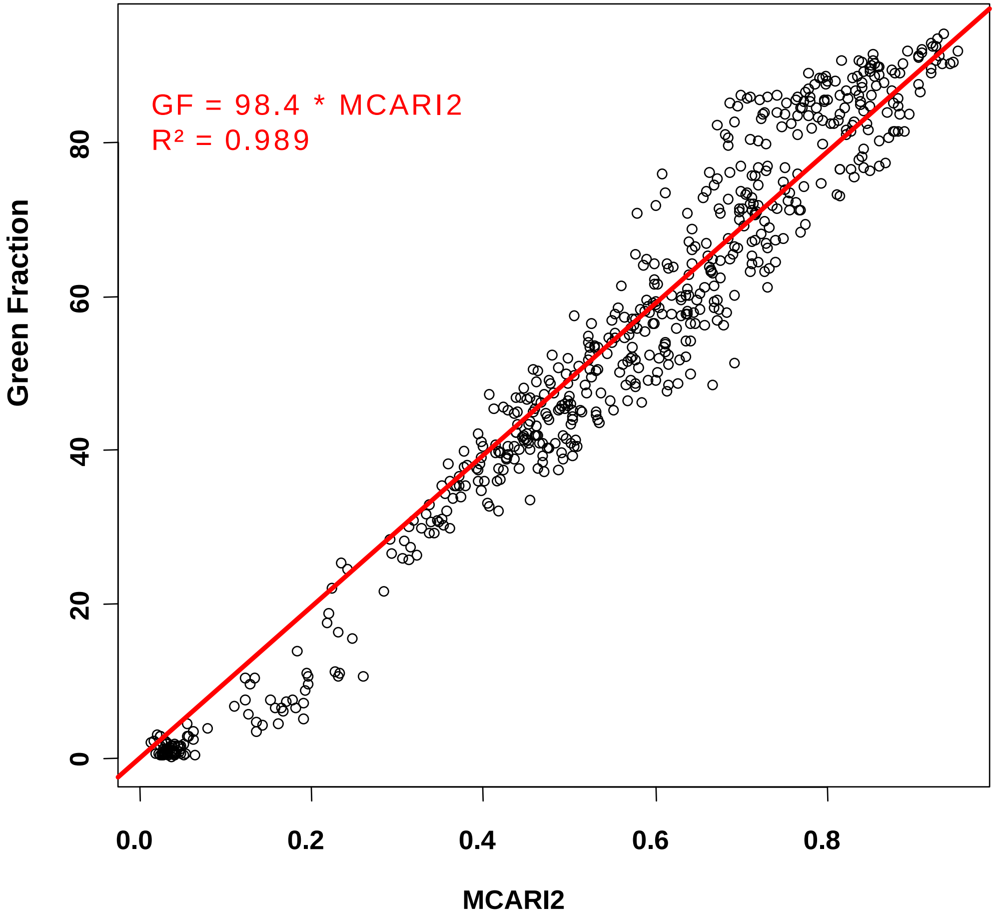
The experiment

Phenomobile:
Field robot

Spectrophotometers
RGB camera
LIDARs
@ vza=0°
@ vza=57°

Results

Vegetation Indices	NDVI	MTCI	MCARI2	REIP	PRI	CRIgreen
Green Fraction	0.914	0.916	0.980	0.840	0.896	0.833



Importance of the Green Fraction

- $GF(0°) = fCover = FVC$
- $GF(\theta) = FIPAR_{bs}(\theta) \approx FAPAR_{bs}(\theta)$
- $GF(\theta) = e^{-\frac{G(\theta)}{\cos(\theta)} GAI_{eff}}$

Conclusion

- **Effective LAI: a defintion is proposed:** *The effective is the LAI value that provides the same GF(vza) under turbid medium assumption (Applying Miller's formula or GF(57°))*
- **Strong differences in retrieval performances between variables**
  - **GF > FAPARw > FAPARb > LAIe > LAI**
  - **Importance of the GF:**
    - **at kilometric scale: GF(vza) input to DGVM: consistency with the structure assumptions**
    - **At decametric scale:**
      - **use prior information on the type of canopy to derive other variables (FAPAR, LAI)**
      - **A sensor looking at 57°?**
- **Improvement (generally) when using a more realistic RT model (even with 2 additional parameters)**
- **Need to extend the investigation using**
  - **More independent test cases (several scales of clumping, soil BRDF …)**
  - **Uncertainties attached to the 'measurements'**
  - **Alternative inversion method**
- **Results independent from the temperature (to prevent any question!)**