Validation of Sentinel-2 Biophysical Prototype Products using ESA Field Campaigns

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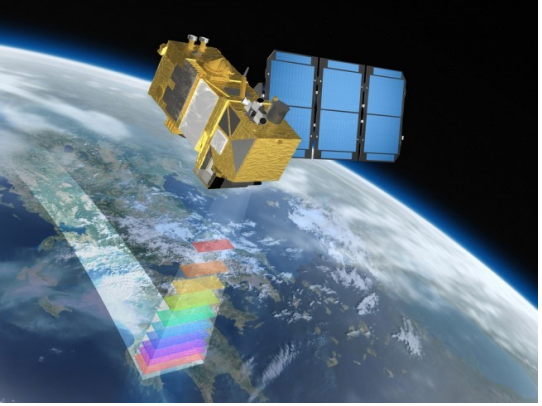


Objectives

- Provide first evaluation of Sentinel2 Level2B potential land biophysical products performances
  - LAI
  - FAPAR
  - CCC (Canopy Chlorophyll Content)
  - CWC (Canopy Water Content)
- Propose guidelines for the validation of decametric products
- Propose additional campaigns

Outlook

- Prototype products considered
- Campaigns available
- Simulation of S2 L2a products
- Available ground measurements
- Results
- Conclusion

The prototype products considered

- **CFI: Neural-networks trained on radiative transfer model simulations**

  Baret , F., Weiss, M. and Berthelot, B., 2009. Sentinel-2 MSI Products - WP1152 Algorithm Theoretical Basis Document for product Group B, INRA-EMMAH, Avignon.

  Verger, A., Baret , F. and Camacho de Coca, F., 2011. Optimal modalities for radiative transfer-neural network estimation of canopy biophysical characteristics: evaluation over an agricultural area with CHRIS/PROBA observations. Remote Sensing of Environment, 115: 415-426.

- **Non-CFI: Vegetation indices calibrated with radiative transfer model simulations**
  - LAI: NDRE

    Canisius, F., Fernandes, R. and Chen, J., 2010. Comparison and evaluation of Medium Resolution Imaging Spectrometer leaf area index products across a range of land use. Remote Sensing of Environment, 114(5): 950-960.

  - FAPAR: MGVI

    Gobron, N. et al., 2006. Monitoring the photosynthetic activity of vegetation from remote sensing data. Advances in Space Research, 38(10): 2196-2202.

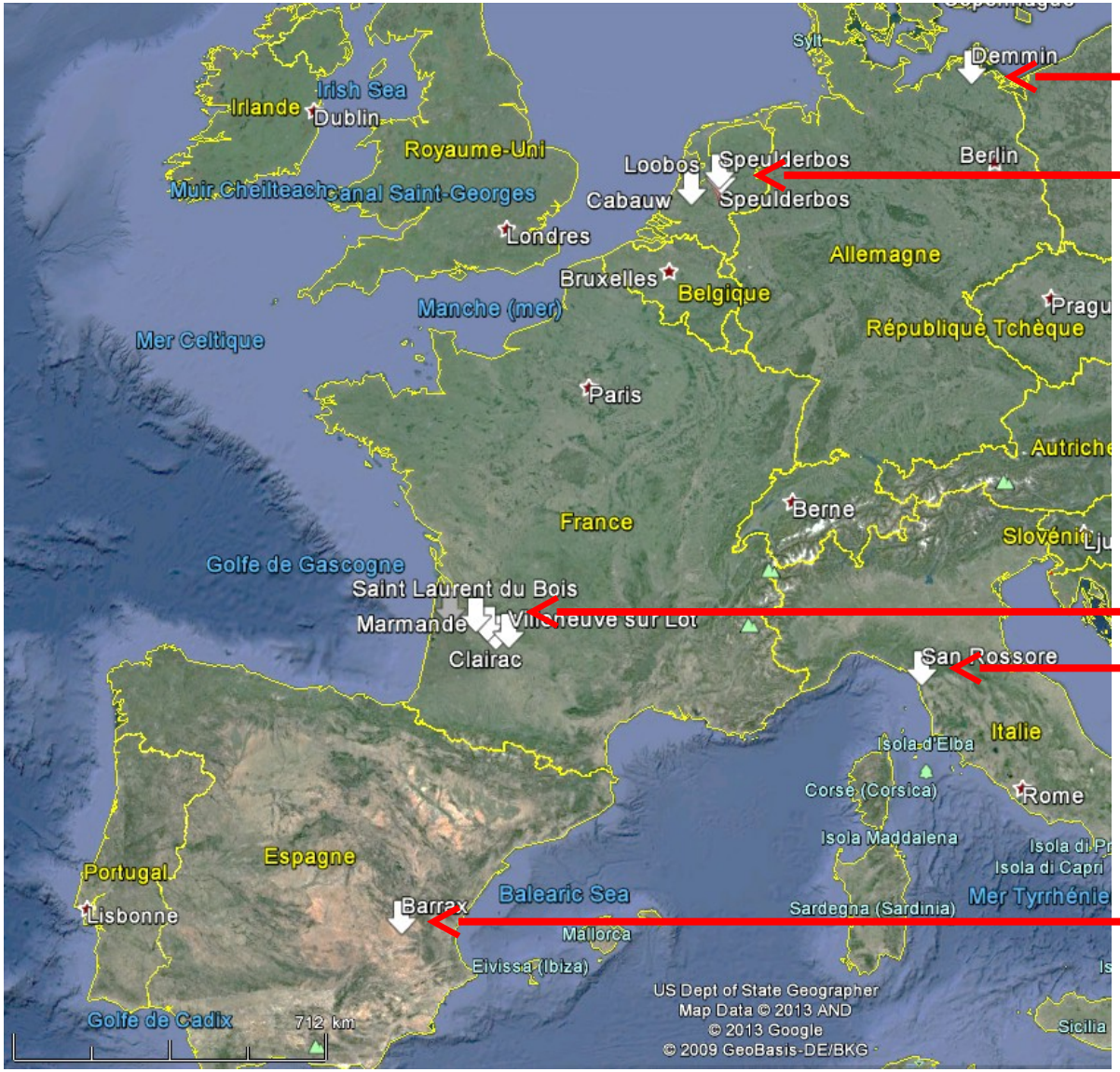
  - CCC: MTCI

    Dash, J. and Curran, P.J., 2004. The MERIS terrestrial chlorophyll index. International Journal of Remote Sensing, 25(23): 5403-5413.

  - CWC: NDWI

    Hunt, E.R.J., 1991. Airborne remote sensing of canopy water thickness scaled from leaf spectrometer data. Int. J. Remote sensing, 12(3): 643-649.

The campaigns available



AGRISAR 2006

EAGLE 2006

CEFLES 2007

SEN3EXP 2009

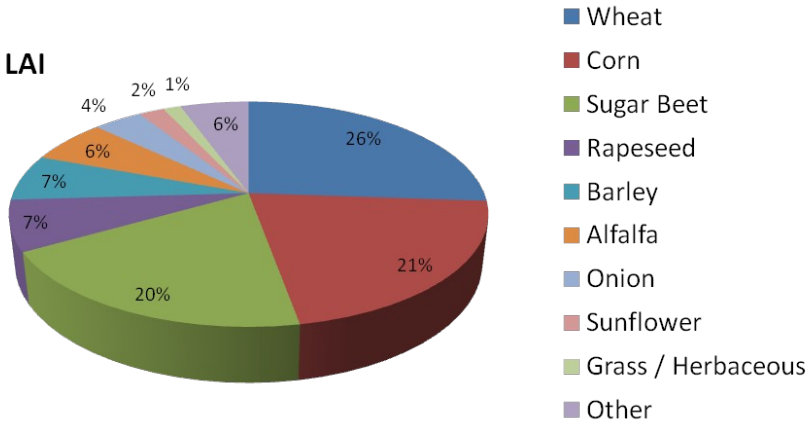
SEN3EXP 2009

SEN2FLEX 2005

SPARC 2003-2004

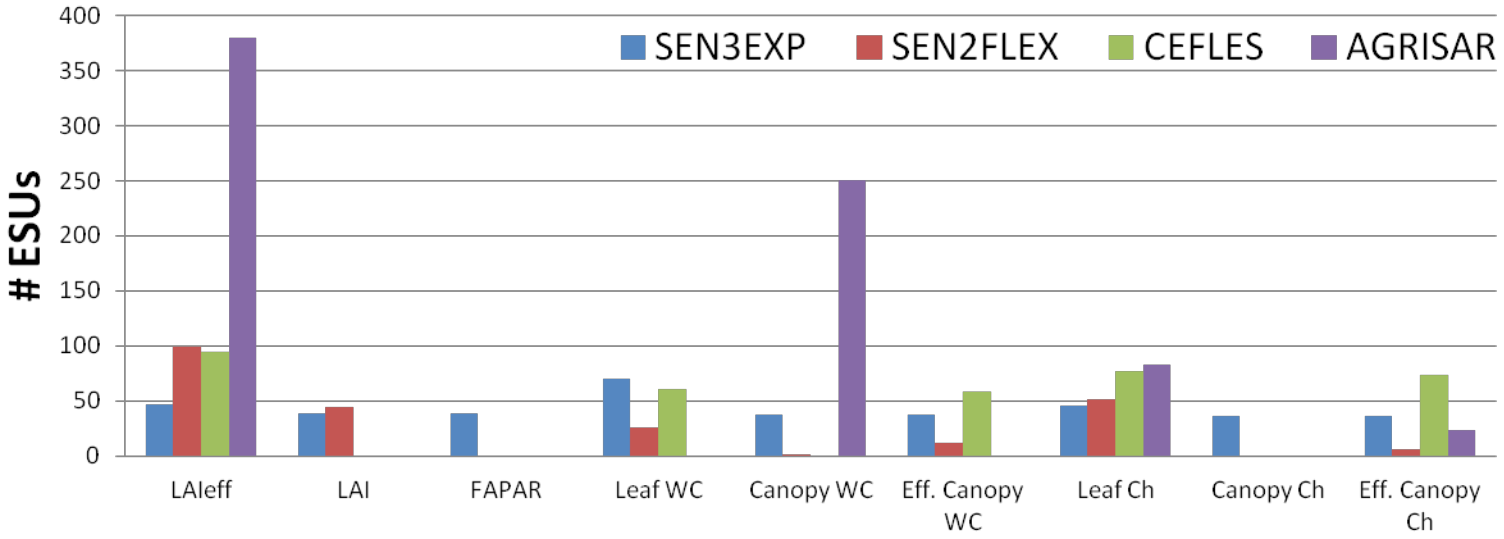
Available ground measurements

CAMPAIGN	LAI, FAPAR, FCover			WC	Ch	
	DHP	LICOR	AccuPAR	Destructive sampling	SPAD	CCM
SEN3EXP	✓	✓	✗	✓	✓	✗
SEN2FLEX	✓	✓	✗	✓	✓	✓
CEFLEX	✓	✓	✗	✓	✓	✗
AGRISAR	✓	✓	✓	✓	✓	✗
SPARC	✓	✓	✗	✓	✗	✓



Several methodologies, often poor documentation
Need for a guidelines!!

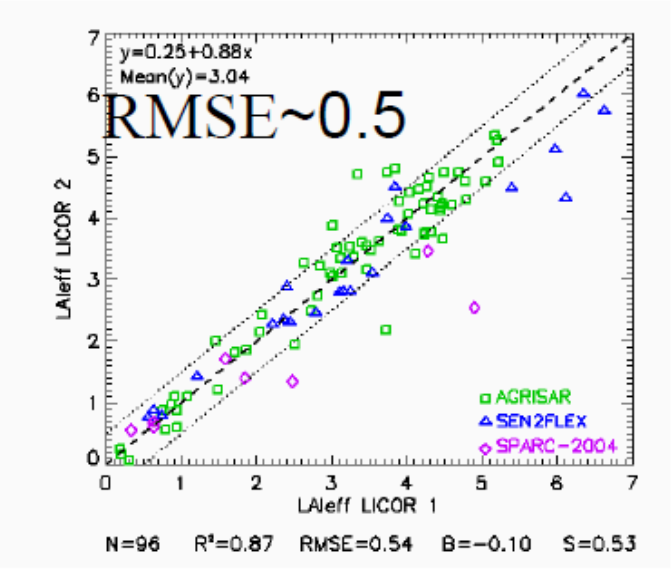
Mostly crops were sampled
Need for other experiments!



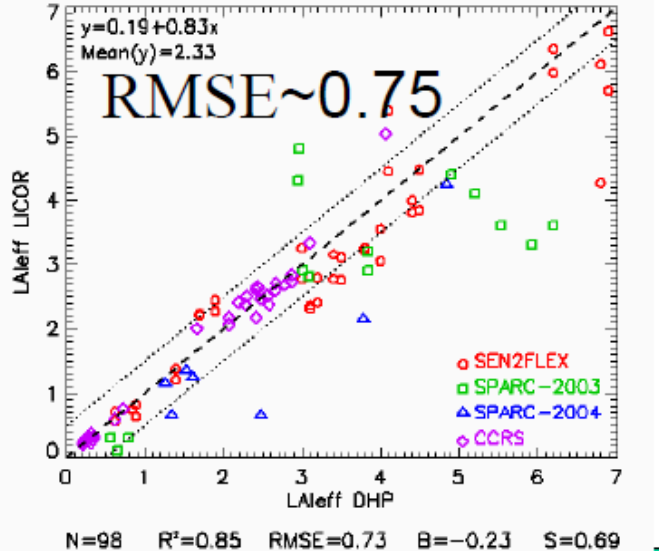
Only few data available for some variables
Difference between effective and actual variables

Ground data: checking the methods

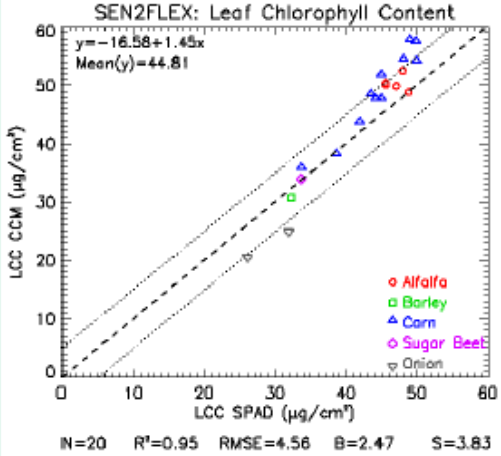
LICOR vs LICOR



LICOR vs DHP



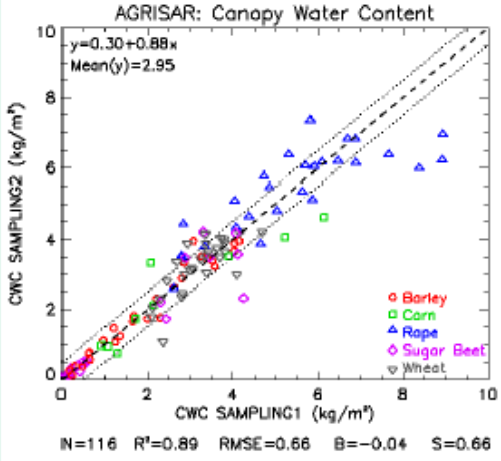
Leaf Chlorophyll Content: CCM vs SPAD



The uncertainty attached to the CCC can be estimated considering the uncertainties of LCC (~5 mg.cm^{-2}) and LAI (~0.5 for effective estimates)

Example:
Canopy LAIeff=3 and LCC= 35 mg.cm^{-2} → CCC= (110±30) mg.cm^{-2}, about 30%

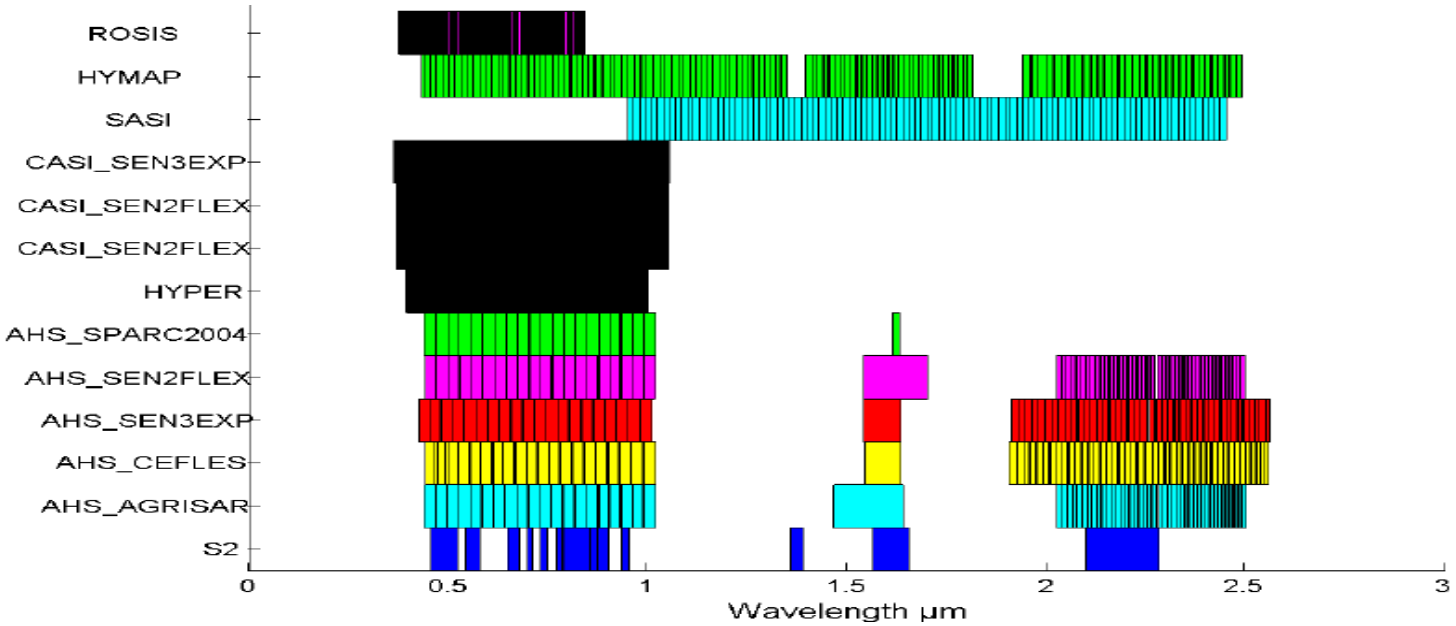
Canopy Water Content: Sampling1 vs Sampling2



The uncertainty attached to the CWC can be estimated considering the uncertainties of LWC (~50 g·m^{-2}) and LAI (~0.5 for effective estimates).

Example:
Canopy LAIeff=3 and LWC=330 g·m^{-2} →CWC of (10±3) x10^{2} g·m^{-2}, about 30%

Simulation of S2 L2a products



- A range of available airborne sensors
- Not always the proper spectral sampling to simulate S2 (red-edge, SWIR)
- Geometric performances not always very good
- Radiometric calibration sometimes questioning
- Atmospheric correction uncertainties
- Use of the S2 simulator to get S2 L2a products

Need for better sensors (APEX, HYPER) … and actual S2 data!!

Results (1): available database

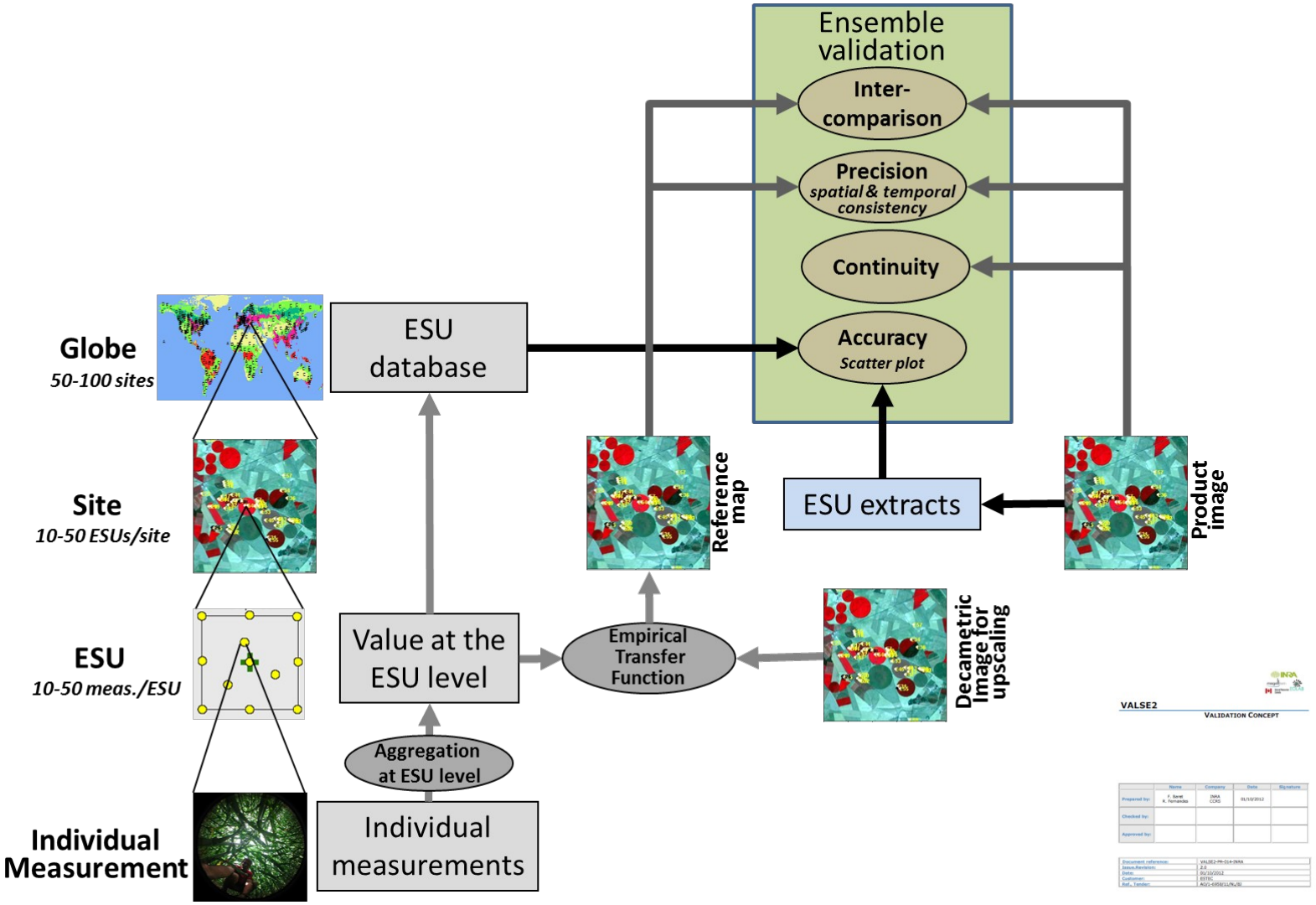
- **Ground data well organized with metadata**

Plot #	Plot Label	ESU #	ESU Label	Northing Coord	Easting Coord	Extent (m) of ESU (diameter)	Land Cover	Start Date (dd/mm/yyyy)	End Date (dd/mm/yyyy)	LAI					
										Method	Nb. Replications	LAIeff	Uncertainty	LAI	Uncertainty
1	A1	1	A1-E1	39.0472	-2.10851	20	Alfalfa	11/07/2005	11/07/2005	LICOR2	17	0.74	0.09	NA	NA
1	A1	1	A1-E1	39.0472	-2.10851	20	Alfalfa	11/07/2005	11/07/2005	LICOR3	21	0.74	0.1	NA	NA
1	A1	1	A1-E1	39.0472	-2.10851	20	Alfalfa	11/07/2005	11/07/2005	DHP	17	0.84	NA	1.08	NA
1	A1	2	A1-E2	39.0458	-2.11167	20	Alfalfa	11/07/2005	11/07/2005	LICOR2	15	0.63	0.08	NA	NA
1	A1	2	A1-E2	39.0458	-2.11167	20	Alfalfa	11/07/2005	11/07/2005	LICOR3	21	0.82	0.11	NA	NA
1	A1	2	A1-E2	39.0458	-2.11167	20	Alfalfa	11/07/2005	11/07/2005	DHP	16	0.89	NA	1.16	NA
1	A1	3	A1-E3	39.0471	-2.11259	20	Alfalfa	11/07/2005	11/07/2005	LICOR2	15	0.56	0.09	NA	NA
1	A1	3	A1-E3	39.0471	-2.11259	20	Alfalfa	11/07/2005	11/07/2005	LICOR3	21	0.71	0.08	NA	NA
1	A1	3	A1-E3	39.0471	-2.11259	20	Alfalfa	11/07/2005	11/07/2005	DHP	16	0.62	NA	0.90	NA
12	C3	31	C3-E4	39.064	-2.10303	20	Corn	11/07/2005	11/07/2005	LICOR2	24	3.54	0.15	NA	NA
12	C3	31	C3-E4	39.064	-2.10303	20	Corn	11/07/2005	11/07/2005	LICOR3	24	3.05	0.12	NA	NA
12	C3	31	C3-E4	39.064	-2.10303	20	Corn	11/07/2005	11/07/2005	DHP	14	4	NA	9.76	NA
12	C3	32	C3-E5	39.0646	-2.10339	20	Corn	11/07/2005	11/07/2005	DHP	10	5.4	NA	9.15	NA

- **Airb** **2 L2a well orga**

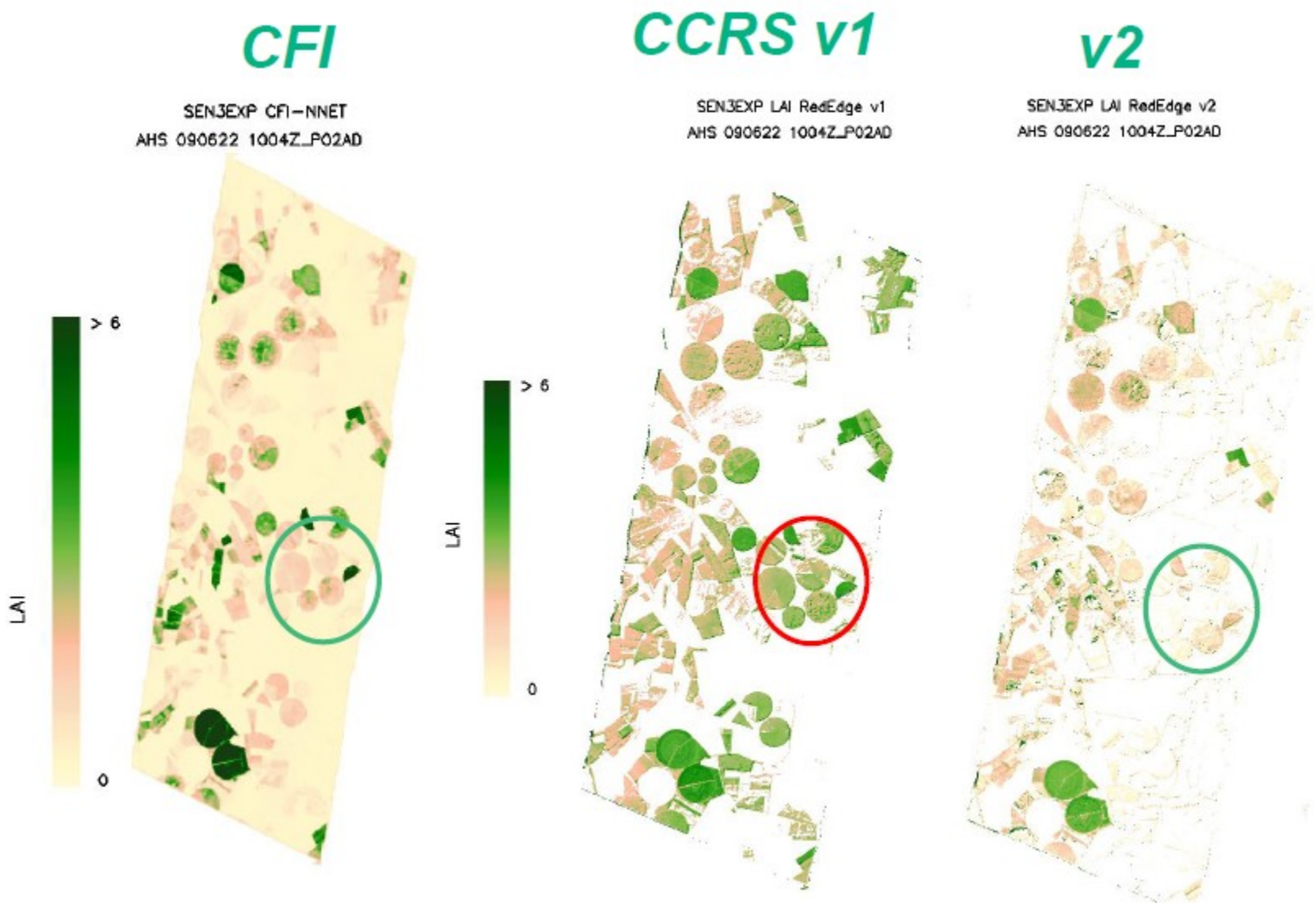
		Number of flights/intruments			Number of validation points
SPARC	2003	ROSIS (2)	HYMAP (4)		25
SPARC	2004	AHS (15)			22
SEN2FLEX	2005	AHS (5)	CASI (7)		100
AGRISAR	2006	AHS (34)	CASI (18)		84
EAGLE	2006	AHS	CASI		
CEFLES	2007	AHS (70)	HYPER (2)		164
SEN3EXP-B	2009	AHS (20)	CASI (19)	SASI (15)	60
SEN3EXP-SR	2009	AHS (17)	CASI (15)	SASI (15)	26

Results(2): methods for validation



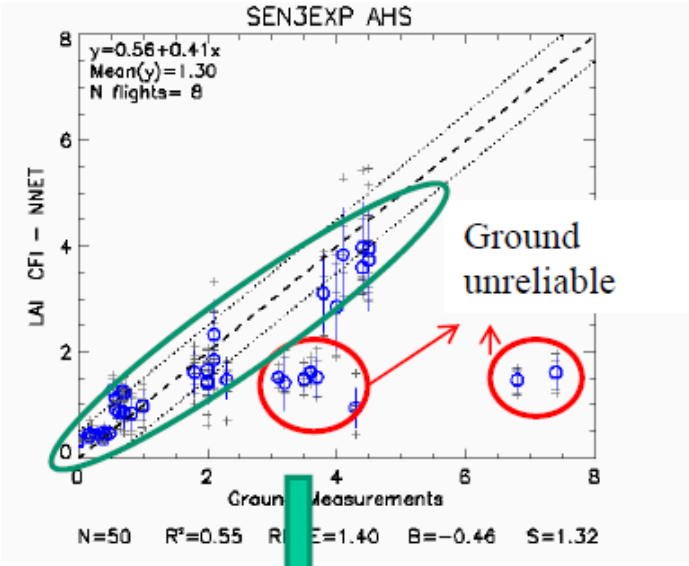
Baret , F. and Fernandes, R., 2012. Validation Concept, European Space Agency,

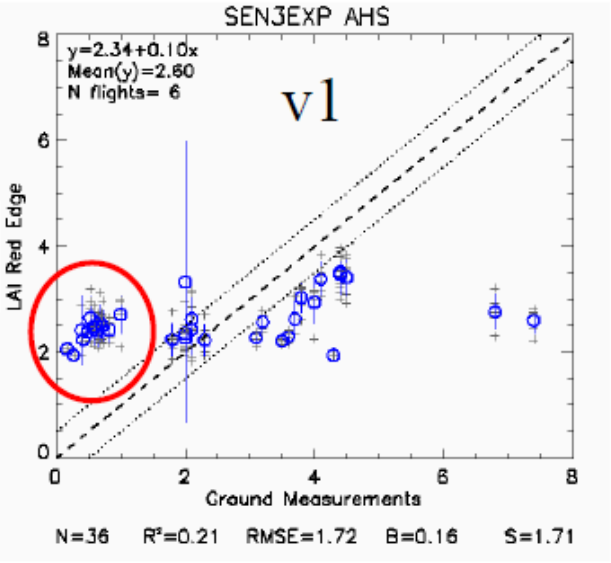
Results(3.1): LAI-AHS

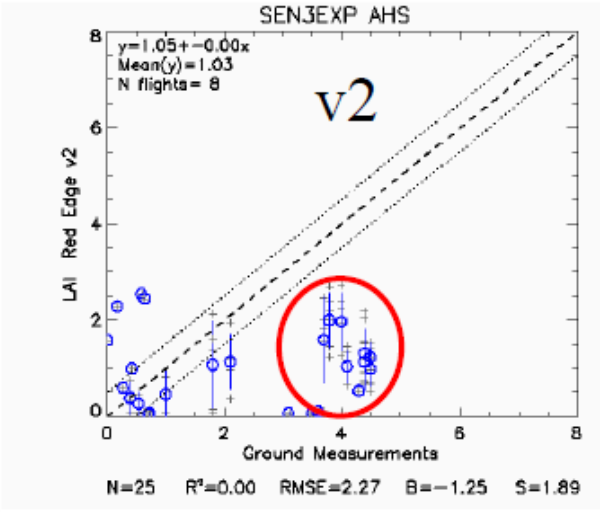


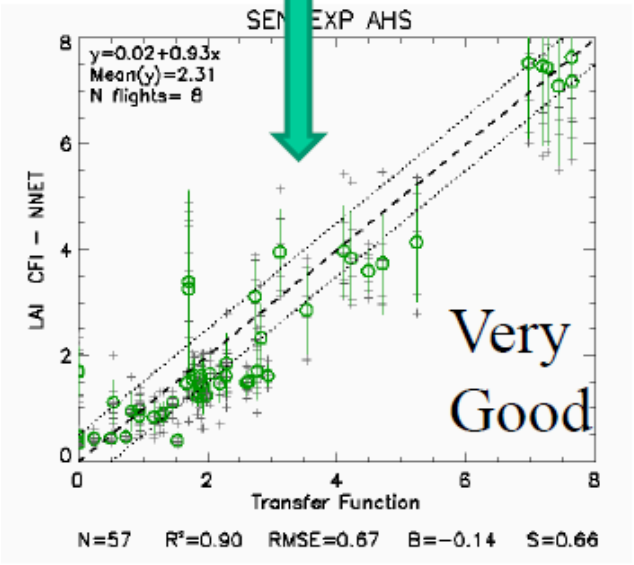
Large discrepancies!!

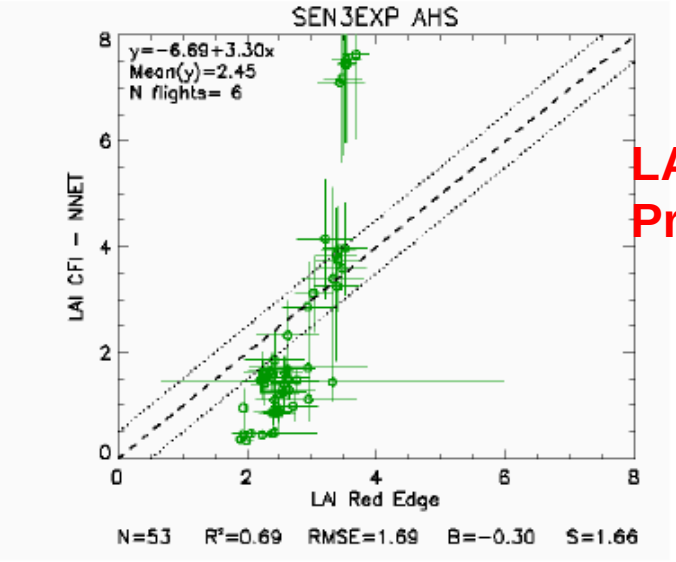
Results(3.2): LAI-AHS





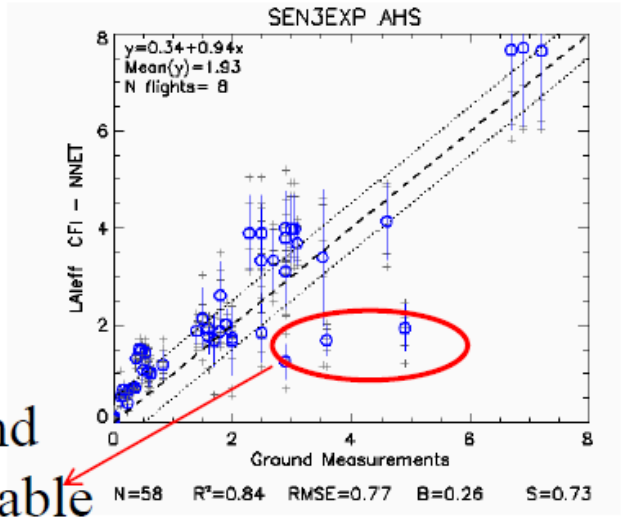




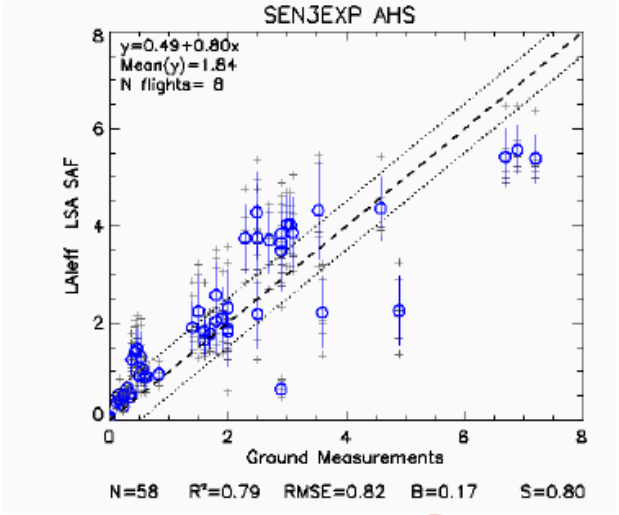


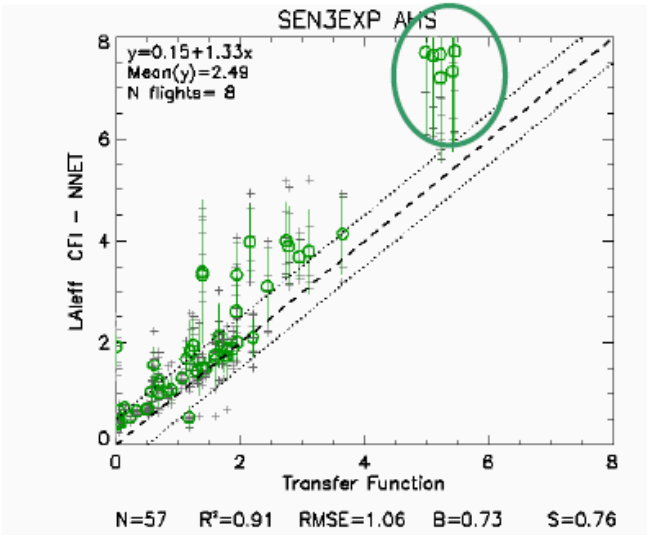
LAI(NDRE) not reliable
Problem in the calibration

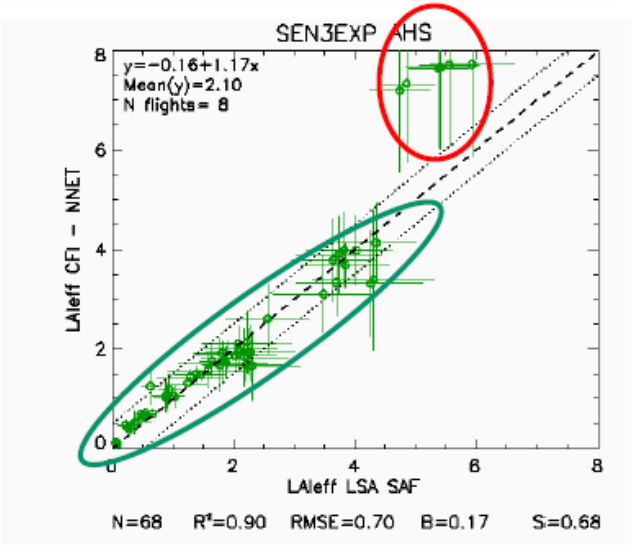
Results(3.3): LAI-AHS / LSA SAF



Ground unreliable

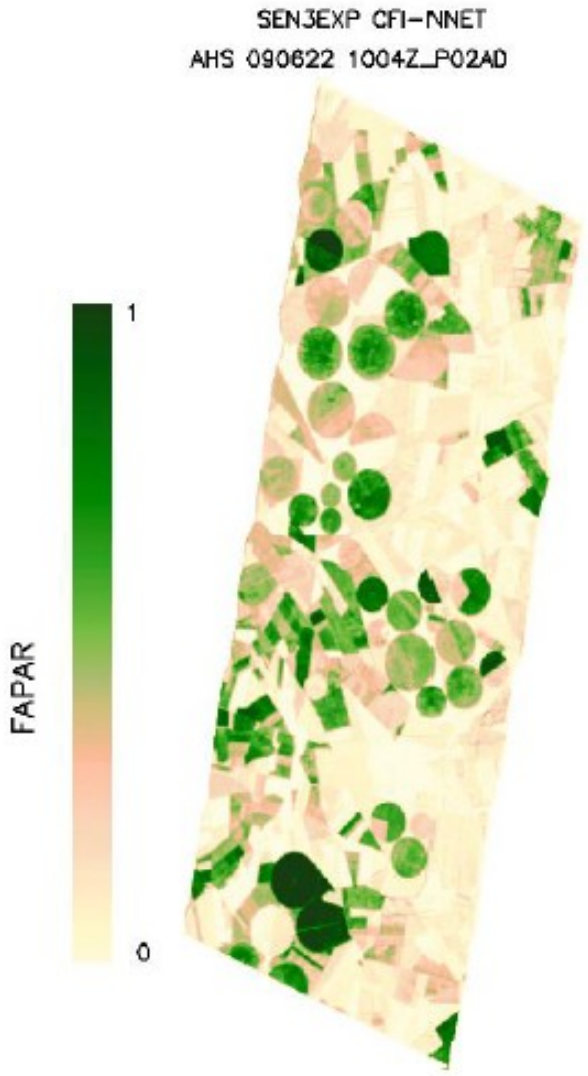


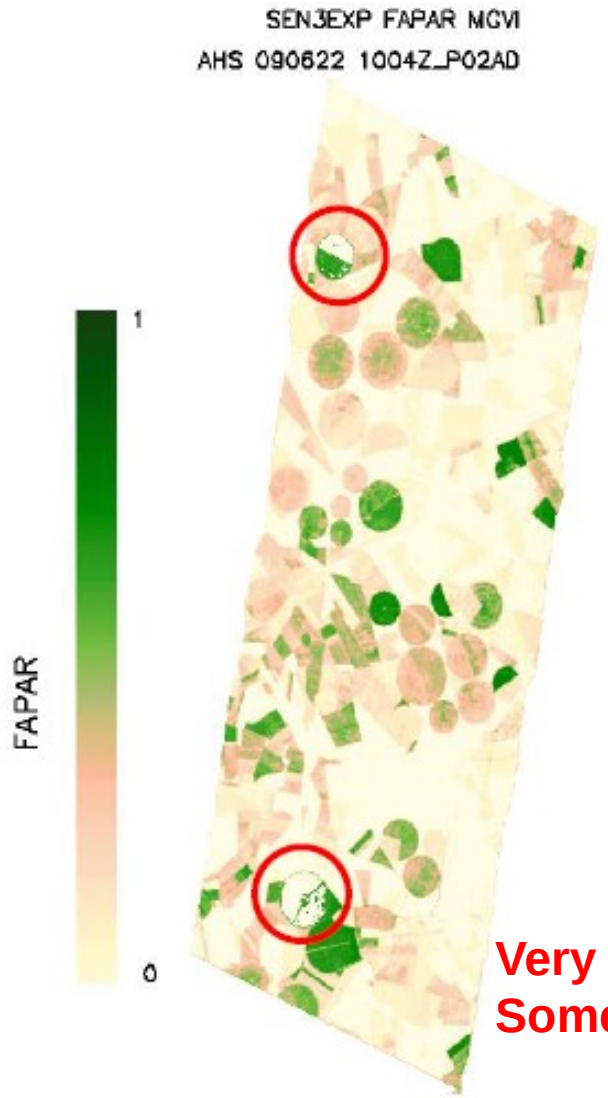




Very good consistency with LSA SAF
Question for the high LAI values

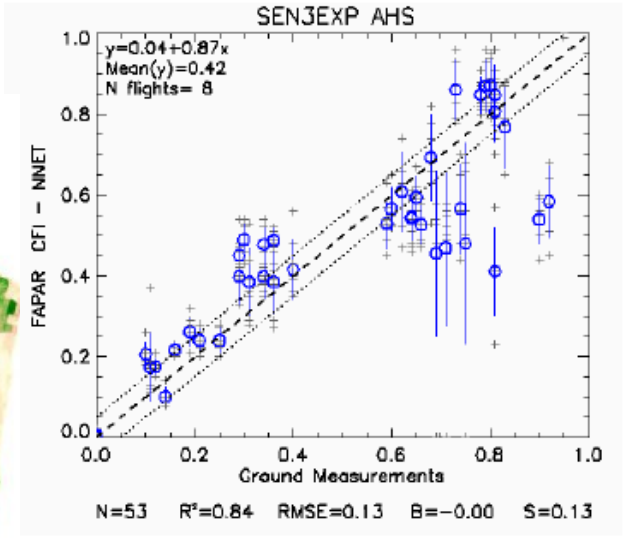
Results(3.4): FAPAR

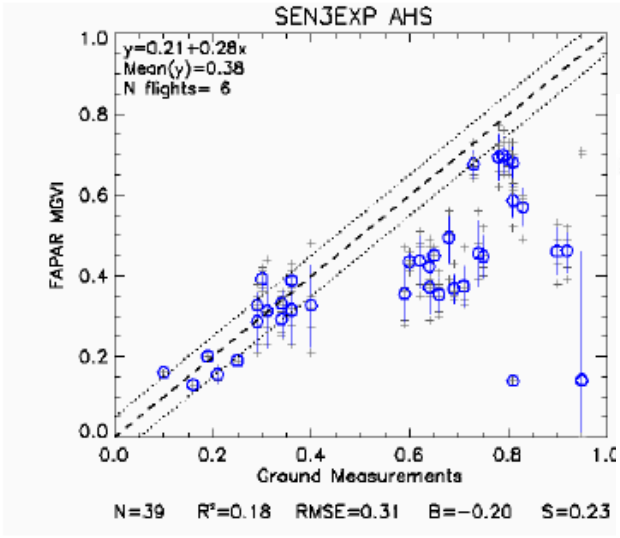


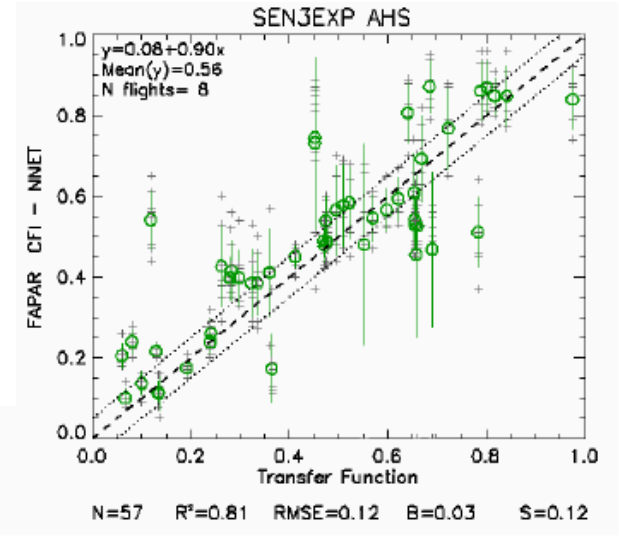


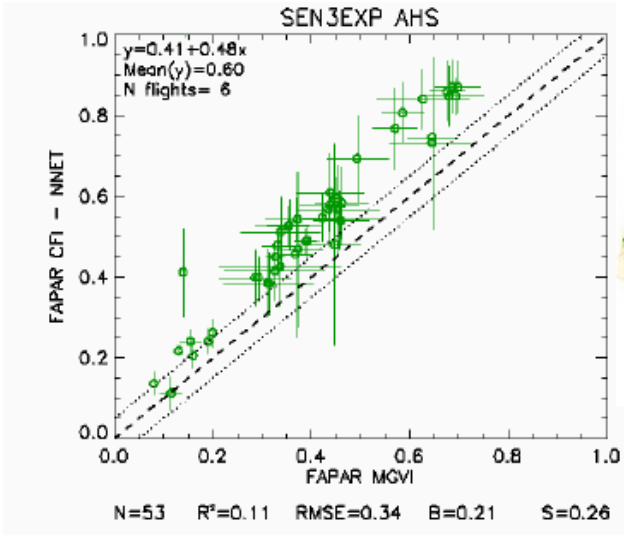
Very good spatial consistency
Some tuning for MGVI(S2)

Results(3.5): FAPAR





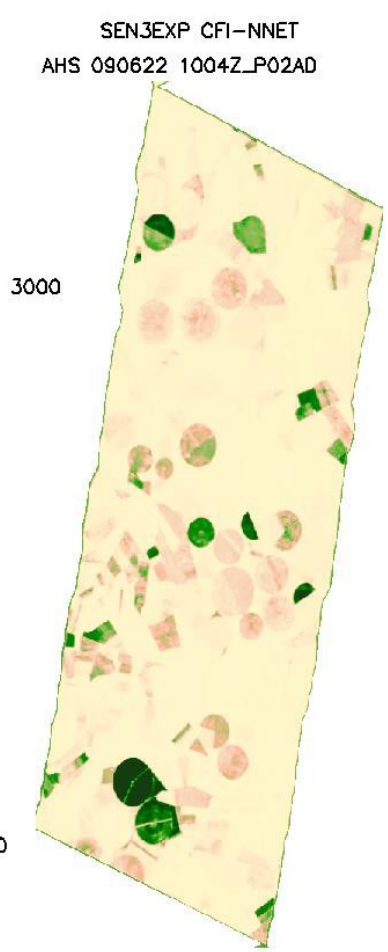


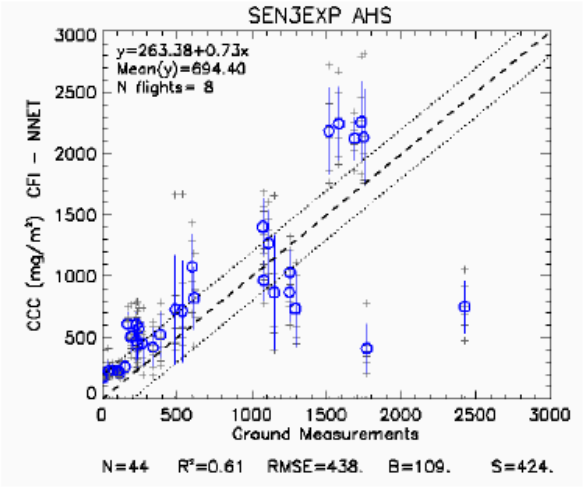


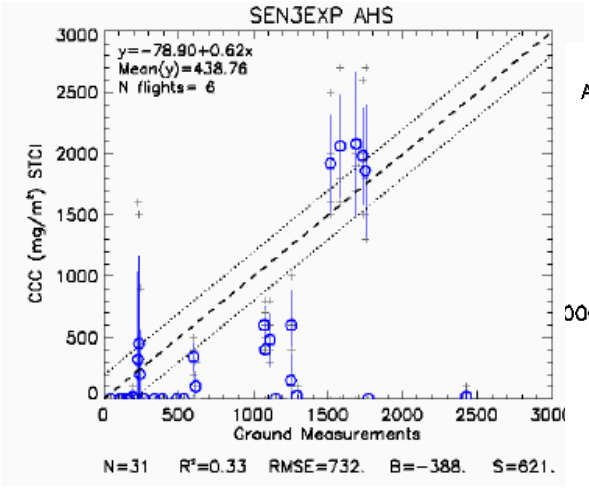
Good performances

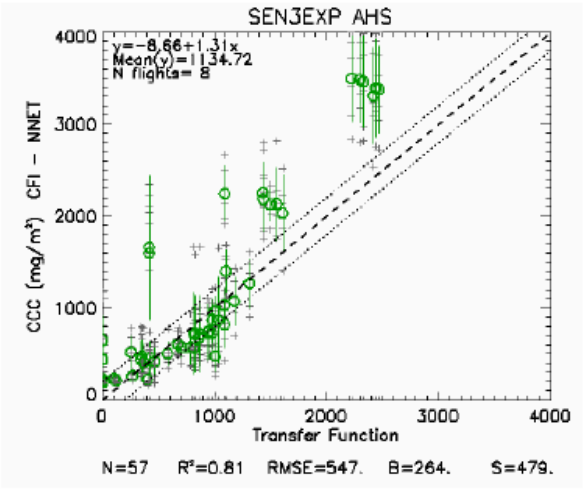
Some underestimation for MGVI(S2)

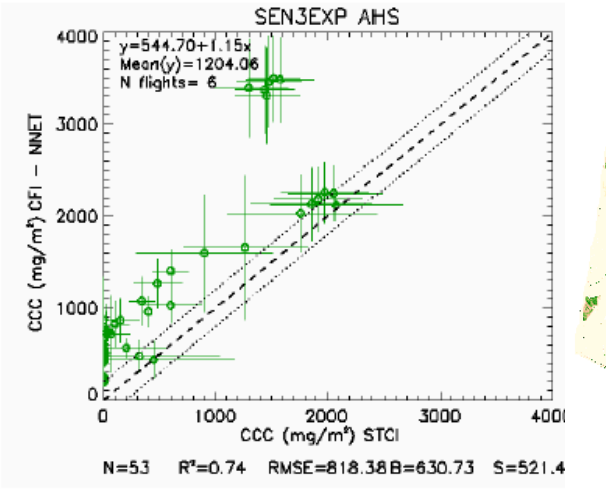
Results(3.6): CCC

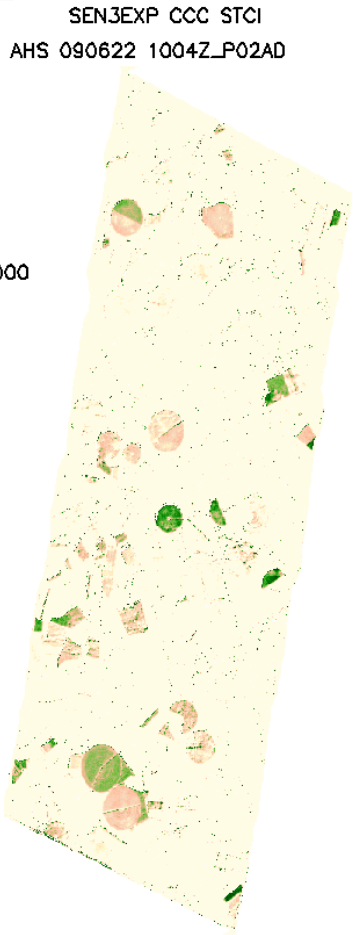








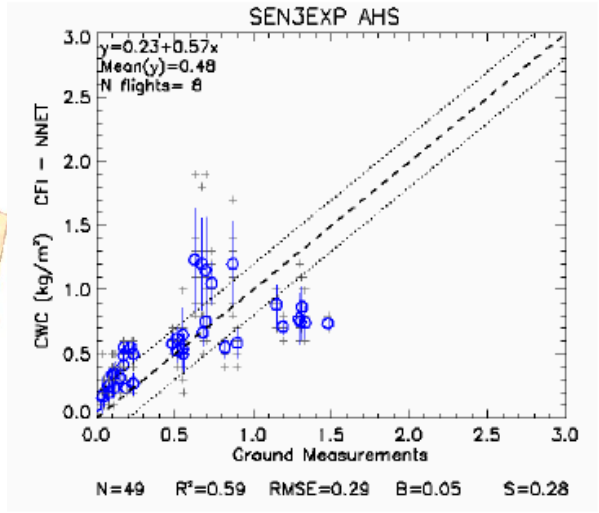


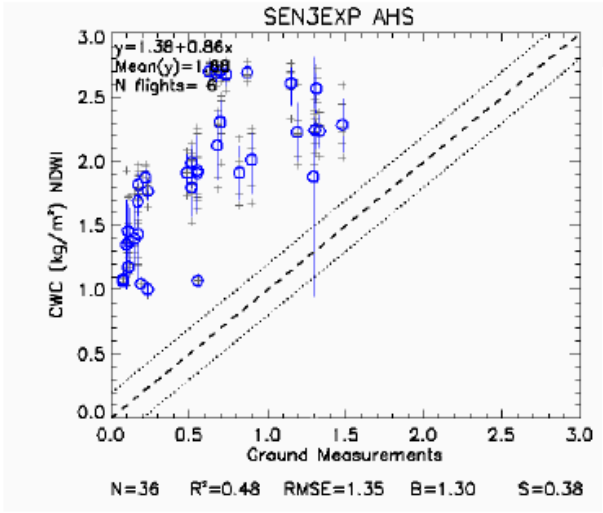


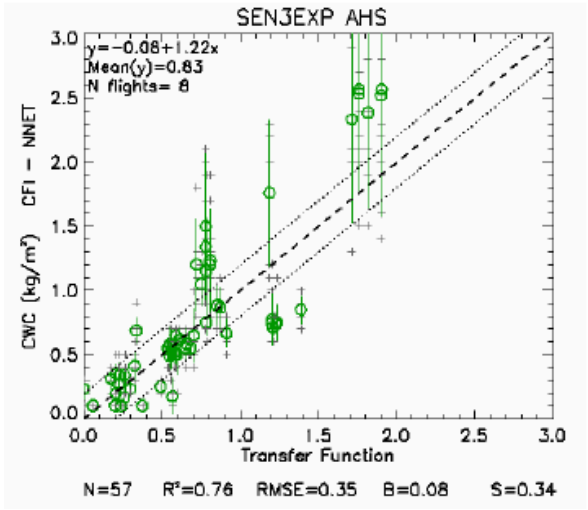
Relatively Good performances for CFI

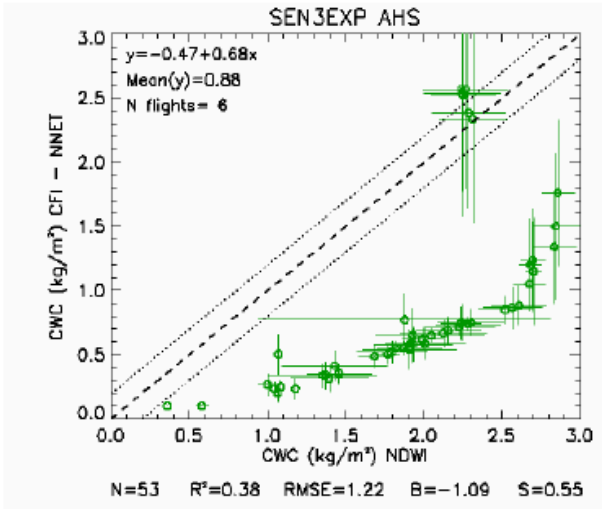
Some inconsistencies for MTCI: calibration problem?

Results(3.7): CWC









Relatively Good performances for CFI

Some inconsistencies for NDWI: calibration problem?

Conclusions

- **Organizing validation experiments**
  - Need proper guidelines for ground measurements
  - Devices, protocols, sampling, processing
  - A guideline was proposed
  - Difficulties in getting proper S2 simulations from airborne campaigns
  - Geometric uncertainties, radiometric calibration, atmospheric correction, spectral sampling …
  - As a result only few campaigns have been exploited
  - Need additional campaigns (forests, with the dynamics!)
  - A campaign was completed in June-September over the Hardth Forest (Mulhouse)

- **S2 CFI algorithm shows potentials**
  - Needs further validation including over simulated 3D scenes
  - Non CFI (spectral indices) need probably a better calibration
  - Will probably need fine tuning when actual S2 will be available
  - Application to other sensors (Landsat8, DMC, Rapide-eye …)
  - Need compositing/fusion algorithms to fully exploit the temporal dimension
  - Need for specific algorithms for LAI, CCC and CWC exploiting the knowledge on the landcover