Global LAI Validation Good Practices v1.0 Reviewer Comments and Responses

Comments were received on Version 1.0 of the document from over 12 solicited reviewers. Comments provided as stand alone text are summarized below together with responses or action taken. Minor comments provided as mark up to the Version 1.0 document are not included here but can be provide upon request.

SECTION	COMMENT	RESPONSE
Sampling strategy	The ESUs spatial sampling is one of the most critical issues in the direct validation since it needs to be representative of the spatial variability found in the study area (Woodcock and Strahler, 1987; Tian et al., 2002). I think this issue should be introduced in Section 3 within section 3.2.1 or 3.2.2. *Some ideas:* According to the spatial techniques, these techniques could also introduce some advantages. For example at the end of the second or last paragraph of page 40: *In this case, tools of the spatial techniques such as the experimental variogram could be useful to analyze the heterogeneity of the study area and consequently could help in the ESUs spatial distribution (Martínez et al., 2010; Garrigues et al, 2006).*	Not directly inserted Added to 3.2.5 Added references.
4.3.1 Direct Validation on a Global Basis Representative of Seasonal Conditions and Estimation of Accuracy in LAI Units	What about the quality image associated to the reference LAI map? *The convex hull technique has been demonstrated useful (Martínez et al., 2009) in the estimation of a quality assessment (QA) image for the reference LAI maps. A quality assessment image will allow to highlight areas on the LAI maps of unreliable LAI estimates due to the model and sampling strategy. The convex hull technique provides a straightforward method to localize extrapolated and interpolated pixels by means of the quality image as well as to derive the extrapolation error introduced by the transfer function.*	3.2.3 I guess Convex hull stated in 3.2.7. Maybe should be in 3.2.8 also 3.2.3,3.2.7; added Martinez 2009, Example of convex hill provided.
DHP – LAI LICOR	In page 38, the following paper could be considered:	Not inserted but maybe covered

comparison	Verger, A., Martínez, B., Camacho-de Coca, F. and García-Haro, F. J. (2009). Accuracy assessment of fraction of vegetation cover and leaf area index estimates from pragmatic methods in a cropland area. *International Journal of Remote Sensing*, 30:10,2685 — 2704 Main results of this study indicate. *An overall agreement of DHP and LAI-2000 in terms of effective LAI and FVC is found. The LAI data sets derived from multiple optical instruments in the Barrax cropland area indicate an overall accuracy (relative RMSE) of around 15% for LAI. Although these results are particular for the Barrax cropland area and they are dependent on the measurement methodology and processing of the DHPs, similar results have been reported in the literature when the same optical instruments were compared (e.g. Chen et al. 2006). A strong correlation (R2=0.94) between the two methods was also found by Yilmaz et al. (2008) although LAI from DHP was significantly less than LAI from the LAI-2000 because of the automatic exposure time for the digital camera (Zhang et al. 2005).*	already in 4.5.2 Deleted this chapter.
3.2.1.5 Uncertainty Estimation of In-Situ LAI	*to be considered: The LAI data sets derived from multiple optical instruments in the Barrax cropland area indicate an overall accuracy (relative RMSE) of around 15% for LAI (verger et al., 2009)*	Should be in 3.2.3 Deleted this chapter.
3.2.2 Upscaling of LAI Estimates	is it possible add the following reference at the end of this sentence? (Chen et al., 2002; Fernandes et al., 2003, Martínez et al., 2009). Martínez, B., García-Haro, F.J. and Camacho-de Coca, F., 2009. Derivation of high resolution leaf area index maps in support of validation activities. Application to the cropland Barrax site. Agricultural and Forest Meteorology, 149, pp. 130–145.	Not added – Chen no longer cited Added
3.2.2 Upscaling of LAI Estimates	*In this case, spatial techniques such as the experimental variogram tool could be useful to analyze the heterogeneity of the study area and consequently could help in the ESUs spatial distribution (Martínez et al., 2010; Garrigues et al, 2006).*	Not present – texted completely changed – see 3.2.5 Added
R.V.16	Around 20-50 ESUs are required depending on the land cover conditions.	Not present in 2.0 Removed
R.V.17	Around 100-200 ESUs are required depending on the land cover conditions.	Not present in 2.0 Removed
	Generally speaking it would be nice to have (or to promote) some sort of a justification for the protocols mentioned in the text. It seems to me that the 3D model-based estimates approaches could help in that matter: simulating the sensor in the canopy at various location and assess the quality of the sampling wrt the generation of a spatially averaged value.	Is he talking about this protocol or the ones listed in table 2. Whatever it is we do not really address this and we should The best practices is based on what is present already in the literature. This is a good idea we propose

		should be followed (conclusions).
	There is a lot of emphasis on the 3x3 km resolution. This needs clarification: do you mean one single 'average' value over 3x3 or a sampling over 3x3 area? To me, it is quite relevant to deliver the ensemble of individual data points to appreciate the spatial variability inside the ESU. Deriving an 'average' value is always a matter of speculation/hypotheses on the way to do it. The 3x3 km makes sense only if we can sample directly the full area....which is probably not the case.	Section 5.1.3. However we do not actually address the point about producing th e3x3 value and the deviation within that area Section 5.1.3
	The 3x3 km may make sense for typical 1km resolution sensors (MODIS/VGT/MERIS, MISR..) but we will have soon 100m to 200m resolution products. I guess that the geolocation uncertainty is less than a pixel meaning that the 3x3 km may be replaced by 3x3 pixels? So I would leave some flexibility regarding the 3x3 km/pixels and the use of a spatially averaged value. This comes from the fact that the dominant effect is spatial variability and the larger the area, the largest the uncertainty on the 'averaged' values. In a sense it is like saying we would ideally have the shape/width of the PDF that is easier to capture than the central value of the distribution.	Section 5.1.3. Replaced 3km with 3 pixel and in Example 4. Section 5.1.3
	The uncertainty of 0.5 is very very demanding	Does he mean GCOS accuracy? If so then OK but it is a target No action needed
	My view is as follows: the scattered signal (BRF, albedos) is related to the effective PAI/LAI (I mean the one quantity entering the exponential attenuation). This I believe is the most important quantity to assess given that other quantities like green or LAI requires adding extra information implying thus increasing the uncertainty (both from space and in-situ). The quantities inside the parenthesis of this exponential appear as products and therefore very difficult to separate: clumping x LAI...So let us make sure that we can do 1st the simplest thing that is effective values directly controlling the in-situ measurements via indirect methods.	There is confusion here between definition of LAI and what we can measure but he is right that we should try and achieve effective terms well than address the additional elements to get to LAI. This does not stop us trying to get estimates of clumping etc and we need to accept that LAI is what is required currently by the biophysical community (carbon et al). This is about understanding errors – out of scope of current good practices but should be considered in future (conclusions)
R.V. I R.V.23	R.V. I find it very useful having access to every individual point measurements to assess the scatter due to spatial variability. Not sure that the 3x3 average value is so useful (see R.V.23)	OK see 5.1.3 Removed
R.V.26	R.V.26 Ok if we have good coincidence between in-situ and space retrievals.	This is valid and we do not discuss

	Otherwise it is also handy to use temporal interpolation (as I did over hainich) to have a complete seasonal cycle even based on multiple years: the latter assumes that inter annual variability is less than spatial variability.	it. Not in good practice itself.
R.V.27	R.V.27: Unclear..I do not know the meaning of the 'shift'?	Not in good practice itself.
R.V.59	R.V.59: Why should it be monthly? I would say the shortest period possible given the temporal sampling.	This is an argument I had with Michel – I agree with him but my experience is that we cannot get better than monthly if we want some idea of uncertainty and LAI is a relatively slowly changing variable so it is not vital to have high frequency. I guess he refers to statement in 4.1.3 Not in good practice itself.
	page 31 : Diffuse transmission is very useful as such (uncorrected) to derive/validate effective LAI/PAI products (see comment 5)	Not addressed LAIe and PAIe products are out of scope of this document mainly for this reason.
	page 42, 44 and may be elsewhere. Retrieval can be based on BRFs, DHR and BHR as well (BHRs are omitted in the text).	Added BHR in section 4.1 but we then refer to JRC-TIP so no need to go further elsewhere? Maybe need to define a table of who uses what? OK
	Could be helpful to associate in the text, the various definitions of LAI/PAI to the formulation of the downward transmissions (direct, diffuse). This would help the users to understand the consequences (in terms of uncertainty and assumptions) when going from effective to true values.	OK so LAI is LAI then we have to get this value indirectly so then this comes in – it relates to the requirement to test methods/protocols using a RAMI type approach. It would be good to highlight which products use what terms It would greatly expand this document to include the radiative implications of definitions. We have chosen not to.
	p 48. May be good to reiterate that up-scaling also implies increasing uncertainty given the series of assumptions that are needed.	P49 reference to upscaling uncertainty – maybe needs to be

		more clear. It is stated more in Conclusions than elsewhere. Upscaling error is quantified empirically in this document. In theory one could model it but we don't have enough references on it for LAI.
	Well again..too much centered around the 3x3 km that I discussed above. May be good to be more general in this document and relate the sampling area to the pixel size --> using pixel units.	Present in Example 2, 4.5.2, Example 4. Deleted or adjusted in 4.3.4, 4.5.1, 4.5.2, Conclusions OK
	The document does not provide a 'protocol' for global LAI product validation. Instead it constitutes – in its current form – primarily of an overview of practices and definitions related to LAI validation efforts as well as a small chapter (5) with recommendations. Changing the title to 'recommendations' may thus be more appropriate.	OK Guidelines OK
	The recommendations often do not seem to stem from the text passages that precede them (see my specific comments below). One is often left to wonder what the justifications behind these conclusions are? How were they obtained? Do they reflect the opinion of all experts (within LPV, CEOS, GCOS, throughout the world)? Perhaps an approach like that of the IPCC to indicate how reliable a given piece of information is (or in this case how much in agreement the community is on a given issue/approach) could be adopted? More pertinent, however, is the fact that the current document does not inform as to whether the CEOS LPV recommendations are themselves compliant with the GCOS criteria for LAI products? If they are not then what is the justification for the recommendations provided?	Need to relate the recommendations to text and explain why if not in the text. Recommendations not in document now.
	The recommendations are sometimes too forceful/exclusive in tone, i.e., rather than encouraging the community to voluntarily adopt the recommendations, their text is sometimes formulated in a manner that may not be acceptable to scientists. I would recommend to rephrase the various recommendation in a tone that is encouraging participation rather than enforcing it.	OK Recommendations not in document now.
	Recommendations for validation of products (R.V.*) – should come with one or more scientific references that substantiate it.	Disagree – recommendation should come from text where the references are. Recommendations not in document now.
page 58 after the	R.S.16 Efforts must be undertaken to develop a traceable quality assurance	To be added if we have appropriate

current R.S.15	system allowing the provision of unbiased and reliable evaluations of both *in situ* methodologies and satellite retrieval algorithms for LAI, irrespective of differences in product definitions, biome and land cover types, illumination geometries and spatial resolution	text slot Added to conclusion!
Some changes to sentences on pages 29. 30. 37 of v 1.4	Scattering tends to bias the estimate of gap fraction leading toLAI underestimation on the order 5% to 12% (Leblanc and Chen 2001, Garrigues et al. 2008) unless the largest zenith angle measurement ring (5th ring) is discarded during processing for some types of canopies. The LICOR protocol provides guidance for when this is necessary. The LAI-2000 does not sample a full hemisphere and it uses the centre zenith angle of each ring when following Miller's method. These factors together result in an overestimate of LAI in the order of 8% (Leblanc and Chen, 2001). Subsequently, the LAI-2200 and the processing software FV2200 changed the integration scheme (LI-COR, 2009) to avoid this overestimation	All this has been removed I believe. We need to check all references as e.g Leblanc and Chen no longer is present, LICOR is LICOR 2010 or 2009?? Removed
4.3.1 *Direct Validation on a Global Basis Representative of Seasonal Conditions and Estimation of Accuracy in LAI Units*	. [The use of high resolution land cover maps could be very uncertain in areas routinely subjected to changes or different LAI spatial distribution within the class (i.e. croplands).]	Agreed – rephrased this to only apply where there is certain knowledge of land cover based on table given by Asner. Practically speaking the ranges are so large that this strategy is only useful to fill small data gaps.
4.3.2 and 4.3.3	These sections need more clarification	Clarified
5.7	[One of the pros of the pure intercomparison is that it can be performed everywhere (as long as the product are available, so why restricting the analysis to BELMANIP2? In addition the users may be interested in analysing the differences in their geographical settings where reference ground measurements may not be available.] [In some cases it may also be interesting to work at higher temporal frequencies (e.g. dekadal observations, if available) to study the smoothness of the products being compared (under the assumption that vegetation grows and decay smoothly).] R.V.60: Inter-comparisons should be also performed with look-up table corrections for differences in definition. See R.P.4. [I've added "also" because one objective of the intercomparison may be indeed to show also the effect of differences in definitions]	Removed

	R.V.61: Inter-comparisons should be conducted using the same statistics as direct validation for accuracy, but interpretation of linear slopes should only be performed for data from the same month so as to avoid temporal auto-correlation biases. [Comment: I think that also other indicators such as Agreement Coefficient and partitioning of the difference between the products into systematic and unsystematic component using GMFR regression could be used .. Richard, if you are interested I can send you the manuscript about fAPAR intercomparison I've recently submitted to TGRS]	
List of acronyms	Define DP: Long focal lengthwhat does the actual acronym stand for? digital photography as used by Macfarlane et al. , AFM, (2007) and in other papers by him on the same subject? maybe include that here, the "Digital photography"? Others, i.e., Ryu et al., AFM, (2010), referred to is as "digital cover photography". TRAC: Tracing Radiation and Architecture of Canopies	Removed – we use DHP. Details on TRAC removed.
R.C.4:	An initial database of NPV ratio and needle-to-shootarea ratio should be compiled by LPV and hosted by CEOS Cal/Val Portal. are you refering with "NPV ratio" to the "woody-to-total-area ratio" (Chen et al., 1997)? I find the latter more intuitive.	Use NPV to include senescent leaves in grasslands.
2.2.2 PAI	By convention the woody-to-total-area ratio is used to relate LAI to PAI as: $LAI = (1-\gamma)PAI$ (1) "gamma" is commonly used to denote the "needle-to-shoot-area ratio", and "alpha" is used for the "woody-to-total-area" ratio	Corrected

2.2.3. Effective LAI (LAIe) or Effective PAI (PAIe)	maybe clarify here: PAIe includes the effects of woody contribution to light interception and clumping ... These approaches are sensitive to the projected area of the foliage along each measurement direction and hence the selection of direction as well as the leaf inclination angle distribution (with leaf inclination angle defined as the angle between the leaf surface normal and the zenith, Ross, 1981) The second approach, termed here the '1 radian estimate' is to measure uncollided transmission or gap fraction at 1 radian (≈57°) from the normal to the local vertical datum so ensuring that the leaf projection coefficient of unit foliage area on a plane perpendicular to the view direction ("G-function", Ross, 1981) converges at 0.5 () irrespective of the leaf inclination angle distribution (Lang et al., 1985; Nilson, 1971; Ross, 1981; Warren Wilson, 1960)	Added Nilson and Chen in Section 3. But we have removed the entire original section 2 so no need to explain theory or the Ryu statement
2.2.4. Clumping index	to maintain the style of the protocol so far I didn't add any literature here but wouldn't that section benefit from an appropriate set of references (Nilson, Chen,etc.). and the equation for the Poisson distribution (Monsi and Saeki, 1953) to show how the clumping index comes into play? Given that the role of needle-to-shoot area ration is discussed in this protocol as well, this section should be extended by a section on the relation between Omega (total clumping index), Gamma (needle-to-shoot area ratio) and OmegaE (element clumping index ... as measured with TRAC) based on recent findings by Ryu et al., AFM (2010b) it's important to take great care to measure and especially calculate gap-fraction with the LAI-2000 and then apply a correction for clumping based on separately measured omega with TRAC. As we showed in this paper, this can lead to up to 30% overestimation.	Removed section.
Table 2	This table would greatly benefit from an additional column specifiying the main technique of each protocol ..... for example, with Liu et al. AFM (2010) you are referring to a digitial photography technique,, Ryu et al., AFM (2010) has a range of modelling and measurement techniques, Chen et al. AFM (2006) was based on TRAC, LAI-2000 and DHP .... Liu 2010 is Not included in reference list. Fluxnet: My 2007 paper in AFM evaluates the LAI-2000 for its application in northern peatlands ..... I guess this application would qualify for this overview, too. Valeri: A series of papers/protocols were introdcued by Craig Macfarlane (CSIRO) .... Macfarlane et al. AFM (2007), Macfarlane et al., FEM (2007), Macfarlane , AFM (2007) .... all based on digitial photography. I find this a very promising	Added

	alternative to DHP, LAI-2000/LAI-2200, etc.	
3.2.1.2.	I think its important to be specific ..... leaf angle vs. leaf inclination angle (vs. leaf azimuth angle ..... usually assumed to have a uniform distribution, eg. see Ryu et al., AFM (2010) and Wang et al., AFM (2007)) LAI estimation from diffuse transmission has relied on either Miller's method or the '1 radian' method. In the case of clumped (random) foliage the diffuse transmission will increase (decrease) in comparison to the same LAI distributed randomly in the ESU (Chen, 1996; Nilson, 1999). Clumping typically approaches the random case as measurement zenith angle increases (Leblanc et al., 2005). There are three conventional approaches for correcting for clumping effects when estimating LAI from diffuse transmission. 1) Sample restricted to azimuthal ranges where foliage can be assumed to be distributed randomly (Li-COR, 2009). In cases such as dense row crops this assumption can be enhanced by sampling nearly perpendicular to row directions (Baret et al., 2010). 2) Correct for the bias in transmission through the use of another instrument that can perform high spatial resolution sampling in the same canopy. This approach, using the Tracing Radiation and Architecture of Canopies (TRAC) instrument, is advocated by GCOS and FLUXNET. However, it needs to be stressed that gap fraction measurements made with the LAI-2000/LAI-2200 instruments account for some degree of clumping by taking the mean of the logarithms of individual gap fraction measurements (Ryu et al., 2010). Thus, combining effective LAI estimates with independent estimates of clumping index might result in overestimation of LAI by up to 30% (Ryu et al., 2010) 3) Use *a priori* knowledge regarding canopy structure from allometric measurements together with a model of second order gap probabilities to correct for clumping effects (Nilson and Kuusk, 2004). this refers to the following paper: Ryu et al., AFM (2010): On the correct estimation of effective leaf area index: Does it reveal information on clumping index? Li-COR user manual (Li-CCOR, 2009) but the estimates can suffer from certain biases this needs to be specified further unless the largest zenith angle measurement ring (5th ring) is discarded during processing I am familiar with this approach, but as far as I know this approach lacks a solid theoretical foundation. Current very promising efforts to deal with this issue in future versions of Li-CORS's LAI-2200 post processing software were shown at	We removed this part from the paper due to the rapid change in the field. It is valuable for another terrestrial community document

	last year's AGU by Youngryl Ryu, John Norman, and Jon Welles: On the correct estimation of gap fraction: how to remove scattering effects in the gap fraction measurements? Abstract ID: B15M-0604 Both LICOR and CCRS processing software summarize the apparent clumping not clear, do you use the term "apparent clumping" as introduced by Ryu et al., AFM (2010) . Nevertheless, at present fine scale clumping can only be corrected through calibration from destructive sampling as advocated in BOREAS Non-destructive, FLUXNET and GCOS protocols. not part of the above list, or are you referring to GTOS? the use of clumping index estimates from the TRAC instrument at 60 degrees solar zenith angle to correct diffuse transmission LAI estimates Again, I think it is important at this stage to refer again to the findings of Ryu et al., AFM (2010) For flat terrain and vertical vegetation, a zenith range corresponding to the first four zenith corresponds to a FOV not clear what to me what is meant by this. Measurements are typically assumed representative of a one-week period (GCOS protocol) an important aspect that might be addressed in more detail: continuous measurements of LAI ..... Youngryel Ryu and I have been collecting cont. LAI (daily) measurements at an oak-savanna woodland in CA using high-frequency digital repeat photography (with convential, refurbsihed $100 Canon cameras, no fisheye lens), and we're currently working up a manuscript to compare our cont. measurements with MODIS.... This can be performed by leaf-off measurements for deciduous vegetation or by destructive sampling in my opinion, this is the most difficult and uncertain part of getting at LAI. Recently I had lengthy discussions with Youngryel Ryu, Craig Macfarlane and the three of us communicated with Tiit Nilson, John Norman, etc. about how to address this. leaf-off measurements/destructive sampling to get at alpha (woody-to-total area ratio) is not fully correct as the contribution of woody material as seen by any optical sensor (LAI-2000, digital camera) is changing throughout the	

	season. In broadleaf decid. forests, leaf-off measurements result in an woody area index. In contrast, taking optical measurements with full leaf cover most of the woody components are covered by leaves or the woody components are in front of leaves, i.e., they shouldn't be corrected for at all. However, during leaf growth and senescence this situation changes continuously and there's a transition from PAI to LAI .... but where to draw the line between the two? how to quantify the continuously changing contribution of woody canopy elements to light interception? I don't know.	
R.S.1:	I think such a re-analysis would be a very interesting exercise, especially regarding the findings of Ryu et al., AFM (2010b)....	Out of scope
3.2.1.4 table 3	There is still an issue with depth of field for both long focal length lenses as well as short focal length hemispherical lenses since vegetation observed at large zenith angles can be much further away than at nadir, especially for tall canopies. In this case a combination of manual focusing and increasing aperture by two stops is recommended by all protocols as it improves depth of field as well as reduces the variability in sky tones. these are all important issuses, references for these statements? LICOR 2010 not in reference list, or are you referring to Li-COR 2009? Software is now available to estimate LAI from longer focal length imagery (CANEYE, Agriculture Canada) using a specified leaf inclination angle distribution. This strategy allows for enhanced resolution in comparison to a hemispherical lens on the same camera. At this point it might be worth stressing the role of LIAD for this to work. LIA measurements are hard to get at, however, we recently proposed a very simple method to obtain such measurements easily with a convential digital camera ..... see Ryu et al., AFM (2010) Figure 1, and Pisek et al. TREE (2011) for a validation of this photographic method with traditional inclinometer measurements from various tree species. Jan Pisek and I are currently working on a manuscript providing LIAD and G-functions for more than 60 species, and we're also looking at the seasonal variation of LIAD and G-function for several species at Harvard Forest and at Tartu observatory Ideal references here: the Macfarlane papers I mentioned earlier Clumping is estimated using one of the three methods described for the TRAC instrument but currently only the CCRS DHP software includes the combined	Out of scope

	method An alternative is discussed in the Macfarlane papers based on digital photography	
3.2.1.5	incomplete reference ...... Ryu et al., AFM (2010) is also a good reference for bootstrapping on litter trap data	Out of scope
3.2.2. Upscaling of LAI Estimates	. In both cases, heuristic arguments or empirical evidence based on historical in situ or satellite based LAI time-series in similar landscapes are used to justify the period used for interpolation. see my earlier comment ..... a very promising approach we're currently working on is based on cont. monitoring of LAI with digital repeat photography	Out of scope
4.1.1.4 Canopy and Understory Modelling Uncertainty	Prior assumptions regarding canopy leaf conditions and understory reflectance often have a large impact on LAI estimation and need to be quantified for their impact on LAI algorithm performance. This should be performed by sensitivity analysis of the LAI algorithm in cases where it uses a model that includes leaf and understory parameters and by comparison of retrievals over areas with rapidly changing understory reflectance (snow cover transitions) or leaf reflectance (colour changes in foliage) that can be qualitatively detected in imagery. Appropriate references here are the studies of Jan Pisek: Pisek et al., RSE (2012) and Pisek et al., JGR-B (2010). Also, what LAI is reported: total LAI vs. LAI of various layers of vegetation as encountered in open ecoytems with vertically stratified vegetation such as savannas (sparse trees and grassses) and northern peatlands (open trees over shrubs and mosses). Another issue in the latter is the spectral characteristcs of the moss ground cover which are fundamentally different from green vascular vegetation (e.g., see Sonnentag et al., RSE 2007). Given the large extent of such ecosystems (boreal and sub-arctic regions of Canada, Greenland, Scandinavia, Russia) this issues can't be neglected in global LAI products in my opinion	Added
4.4.3	Progress has been made recently in harmonising the LAI definition between CEOS and GCOS. this is an issue I would suggest incorporating in this protocol in section 2: a formal definition and complete derivation of LAI and co. and how they are understood in this manuscript. In section 3, definitions for LAI and PAI are given, but readers not familiar with the ins and outs of LAI theory won't understand how LAI, PAI, LAIeff, LIAD, Omega, Gamma, Alpha, G-function and Miller's theorem are really related (and they are all refered to in the text), and what's measured by different optical instruments and direct methods, and of course, ultimately reported by different global LAI product groups. For example, LAI or PAI obtained with digital photography ala Macfarlane is not directly comparable with corresponding LAI-	To much detail given we now leave this task of appropriate in situ LAI methods to terrestrial groups.

	2000 estimate, same is the case for element clumping index estimates obtained with TRAC and digital photography. I suggest adding one additionl sub-section in section 2 starting off with Nilson (1971)	
5.1.1.2.	How do products react to sub-pixel areas of very high or very low LAI? see my comments regarding two other issues: how do global LAI products perform over regions characterised by very open canopies such as northern peatlands (boreal and subarctic ecocliimatic regions) and savannas where the background spectral charactercics potentially exert major control over ecosystem-scale spectral characteristics (red Sphagnum mosses (peatlands), dead (brown) grasses (savannas)) and where understory consistutes a major component of total LAI.	Good point but we don't have any best practices on this to survey.
	R.S.11 AND R.S.15 ARE THE SAME RECOMMENDATIONS	RS15 has been removed OK
1.5	Accuracy: minimum of 20% or 0.5 (not maximum) Stability: minimum of 10% or 0.25	Cant change gcos
2.2.3	Need to be clearer on LAIe and how it differs from PAIe since you then refer to LAIe below	Ok
3.2.1.2	ratio of mean foliage width to number of measurements for the nadir ring; decreasing to eight times the ratio for the 4th ring. This requirement is most easily satisfied by increasing the number of measurements.	removed
3.2.1.2.	Paragraph starting "Diffuse transmission" - In my opinion this paragraph could be placed in section 3.2.1.5 Uncertainty Estimation of In-Situ LAI, p. 37	removed
	R.V.2: In-situ ESU LAI survey using a LAI-2200 or LAI-2000 should follow GCOS, CCRS or LICOR protocols or provide suitable documentation to estimate measurement errors. STRUCTURAL INFORMATION ABOUT THE HEIGHT OF TREES, DISTANCE OF ROWS... WOULD BE USEFUL FOR QUANTIFYING THE UNCERTAINTY OF GROUND MEASUREMENTS.	removed
	R.V.10: Downward looking DHP images should be acquired for low vegetation (<0.5m). Upward looking DHP are recommended in the other cases (> 0.5 m).???	removed
3.2.1.5	I would include here the last paragraph of section 3.2.1.2, p31. Under paragraph starting: When correctly executed, the LICOR protocol should provide PAIe estimates Before paragraph starting: When correctly executed, the TRAC instrument, in all protocols,	removed
3.2.1.5	Inter-comparison of DHP from modern DSLR systems and LAI-2000	removed

	EFFECTIVELY, WE COMPARED THE LAI MEASUREMENTS FROM TWO LAI-2000 INSTRUMENTS AND A DHP CAMERA OVER THE BARRAX CROPLAND AREA AND WE CONCLUDED THAT THE MEASUREMENTS OF DHP AND LAI-2000 WERE COMPARABLE AND CONSISTENT WITH AN OVERALL UNCERTAINTY OF 15% (VERGER ET AL., 2009b). THE DIFFERENCES BETWEEN THE LAI-2000 AND DHP WERE OF THE SAME ORDER OF THOSE FOUND BETWEEN THE TWO DIFFERENT LAI-2000 INSTRUMENTS.	
3.2.2.	The VALERI protocol uses auxiliary variables corresponding to spectral vegetation indices from high resolution imagery (in RP1 you also refer to 'moderate resolution' (250-500m according to definition of p42) but I suppose you refer to high resolution...), Replicate ESUs are located at the 10%ile, 50%ile and 90%ile LAI (This would require a priori knowledge of LAI. Do you mean 90%ile of the spectral index??) Any given region that shows unacceptable cross-validation bias errors (>20%) is eliminated from the global sampling as in VALERI protocol.	Removed recommendation. Removed detail on %ile and just showed VALERI example.
	R.P.9: It is recommended that BRDF model fit error be propagated to LAI uncertainties across a range of LAI (0 to 10) for nadir, 35 degree and, for evergreen land cover classes, 70 degree solar zenith angles (or the maximum range of application of the BRDF model). The methodology used by RAMI (reference) is recommended for this purpose.	Removed
4.1.1.5	Missclassification errors may explain part of the uncertainty in LAI products derived from biome dependant LAI retrieval algorithms which uses a land-cover map as input information (e.g. MODIS, CCRS VGT, GLOBCARBON products). A dedicated analysis should be conducted to determine the influence of misclassification errors in LAI products. A reference land-cover map over controlled areas and the use of sub-pixel land cover information (e.g. 300m GLOBCOVER global land cover map) may be useful to quantify this source of uncertainties in LAI biome-dependent products.	Causes of errors are beyond scope.
4.1.2	a) All of these effects are a concern for the producer of LAI products and (NOT VERY CLEAR) they should be included in the final error analysis. The possible degradation of LAI product quality with latitude should be documented. I AGREE THAT INTER-COMPARISON OF PRODUCTS SHOULD BE PERFORMED AT A COARSER SPATIAL RESOLUTION IN ORDER TO REDUCE THE POSSIBLE GEOLOCATION ISSUES. BUT A COMPLEMENTARY ANALYSIS SHOULD BE CONDUCTED TO DETERMINE THE OPTIMAL	We have left the comparison resolution open to the user but gave guidelines for desiging the mapping unit size for comparisons. Your other point is a good recommendation.

	SPATIAL RESOLUTION FOR WHICH DIFFERENT EXISTING PRODUCTS CAN BE COMBINED. IN MY OPINION CLEAR SPECIFICATIONS SHOULD BE PROVIDED TO THE USER COMUNITY. THIS INFORMATION CAN BE OBTAINED THROUGH THE SPATIAL PRECISION ANALYSIS PROPOSED HEREAFTER.	
4.1.3.	. In response LAI products should be inter-compared on a standard temporal aggregation interval I AGREE THAT FOR THE INTERCOMPARISON ASSESSMENT SOME METRICS (E.G. EVALUATION OF TEMPORAL CONSISTENCY BETWEEN PRODUCTS, SMOOTHNES...) REQUIRE TO BE COMPUTED OVER A COMMON TEMPORAL INTERVAL FOR THE DIFFERENT CONSIDERED PRODUCTS. THIS REQUIRES A TRANSFORMATION OF THE ORIGINAL PRODUCTS TO A REFERENCE TEMPORAL RESOLUTION. HOWEVER A COMPLEMENTARY ANALYSIS AT THE ORIGINAL TEMPORAL RESOLUTION OF THE PRODUCTS SHOULD BE PERFORMED TO DETERMINE THE CAPACITY OF DIFFERENT PRODUCTS TO CAPTURE THE TEMPORAL DYNAMICS OF VEGETATION PARTICULARLY OVER AREAS WITH A RAPID SEASONAL VARIATION. THE ORIGINAL TEMPORAL SAMPLING IS REQUIRED FOR SUCH PHENOLOGICAL COMPARISONS. GROUND-BASED PHENOLOGICAL OBSERVATIONS (TIME OF START OF SEASON, MID AND END OF SEASON...) COULD BE CONSIDERED FOR THE VALIDATION OF THE PHENOLOGICAL PARAMETERS EXTRACTED FROM THE TIME SERIES OF PRODUCTS USING A DEDICATED TECHNIQUE ENTIRELY DRIVEN BY REMOTELY SENSED OBSERVATIONS (e.g. Verger et al., 2012). Verger, A., Baret, F., Weiss, M., Kandasamy, S., Vermote, E.F., 2012. Quantification of LAI interannual anomalies by adjusting climatological patterns. Submitted to IEEE IEEE Transactions on Geoscience and Remote Sensing, Special Issue on "Analysis of Multitemporal Remote Sensing Data"	We have left the comparison resolution open to the user but gave guidelines for desiging the mapping unit size for comparisons. Your other point is a good recommendation.
	R.V.28: All in-situ reference datasets should be provided as total LAI or the validation team should use the CEOS LPV sanctioned conversion table. IN SEVERAL RECENTLY VALIDATION STUDIES EFFECTIVE AND TOTAL LAI MEASUREMENTS ARE COMBINED EVEN WHEN CLEAR INDICATIONS OF THE NATURE OF LAI IS PROVIDED BY IN SITU REFERENCE MAP PRODUCERS. I NOT SURE THIS SITUATION WILL CHANGE BY PROVIDING THE COEFFICIENT FACTORS FOR TRANSFORMING EFFECTIVE LAI TO TOTAL LAI. IN ADDITION THIS TRANSFORMATION WILL BE BIOME	Both points are agreed. But if our good practice says that a conversion must be done then anything else needs strong justification. Same for understory. Guidelines for ESU LAI are now out of scope of this document. We require LAI as defined.

	DEPENDENT AND WILL BE AFFECTED BY POSSIBLE UNCERTAINTIES IN THE LAND COVER USED BY THE VALIDATION TEAM. IN MY OPINION, IT WOULD BE PREFERABLE THAT CEOS LPV PROVIDED A REFERENCE DATASET OF TOTAL LAI CONVERTING WHEN NECESSARY AND INDICATING CONVERSION IN A QUALITY FLAG. IN MY OPINION MORE ATTENTION SHOULD BE PAID TO THE UNDERSTORY SINCE IN MANY SITUATIONS LAI PRODUCTS ARE VALIDATED BY COMPARISON WITH GROUND MEASUREMENTS ONLY FROM OVERSTORY. I WOULD SUGGEST TO PROVIDE CLEARER GUIDNESS IN THE IN SITU ACQUISITION PROTOCOL DESCRIPTION TO ADDRESS THIS ISSUE. IN-SITU REFERENCE DATASET SHOULD INCLUDE CLEAR INFORMATION INDICATING IF UNDERSTORY WAS MEASURED OR NOT. SIMILARLY TO CLUMPING, IN MY OPINION CEOS LPV SHOULD PROVIDE A sanctioned conversion table TO TRANSFORM GROUND MEASUREMENTS ONLY FROM OVERSTORY TO TOTAL LAI. All in-situ reference datasets should INCLUDE UNDERSTORY or the validation team should use the CEOS LPV sanctioned conversion table	
4.3.3.	One simple statistic is a comparison of the cumulative sum of LAI over monthly intervals with a distribution fit to an ensemble average over a minimum number (e.g. 10) of years. To allow for changes in LAI magnitude and phase the comparison should be performed by first normalizing the range of the LAI as percentile values and by translating the temporal axis to maximize the Kolmogorov Smirnov statistic. In this manner the maximum Kolmogorov Smirnov statistic is representative of the goodness of fit of a given interannual LAI time series. THE PROPOSED APPROACH IS NOT VERY CLEAR TO ME. IN MY OPINION THE SEPARATION OF NOISE AND INTERANNUAL VARIABILITY CAN BE PROBLEMATIC. A MORE STRAIGHTFORWARD APPROACH IS QUANTIFYING THE PERCENTAGE OF EXISTING OUTLIERS IN A GIVEN PRODUCT BASED ON ITS TEMPORAL EVOLUTION AND USING AN AUTHOMATIC NOISE FILTERING METHOD. IN AVHRR/LTDR LAI ALGORITHM WE PROPOSED AN OUTLIER FILTERING APPROACH BASED ON THE DISTANCE OF LAI DATA TO A TEMPORAL SMOOTHED ENVELOPE (FROM THE APPLICATION OF A SAVITZKY GOLLAY FILTER) AND THE CLIMATOLOGY DERIVED FROM THE DATA. BUT SIMILARLY TO THE PROPOSED APPROACH, THIS METHOD REQUIRES TO BE FURTHER VALIDATED AND PUBLISHED IN A PEER-REVIEW JOURNAL BEFORE BEING PROPOSED AS A REFERENCE APPROACH. ANYWAY INDEPENDENTLY OF THE NOISE FILTERING	Agreed – removed. We wait the community to provide a method,

	METHOD, IN MY OPINION THE QUANTIFICATION OF EXISTING OUTLIERS SHOULD BE REPORTED AS PART OF THE VALIDATION.	
4.3.4.	Both Gaussian and Kendall-Thiel line fit is used to estimate the trend through at least 10 consecutive years. If LAI changes are indeed linear over the period analysed, both line fits should be equivalent in the absence of measurement error effects. To account for differences in slopes across products and interannual variability the difference in slopes should be expressed as a ratio to the confidence in interval of the Kendall-Thiel slope. In this manner, slope differences over sites with large inter-annual variability or few annual records will automatically be downweighted. A more general (valid across-biomes) approach for the identification temporal invariant regions and assessment of long term stability of products would be scaling and shifting the seasonal climatological patterns to a LAI product as recently proposed by Verger et al. (2012). The scale factor and temporal shift parameter of the consistent adjustment of the climatology to actual observations would allow to identify invariant regions (after application of the approach to different existing LAI products) and quantify temporal anomalies in a given product. Again this approach should be better validated before proposing it as a reference method. Verger, A., Baret, F., Weiss, M., Kandasamy, S., Vermote, E.F., 2012. Quantification of LAI interannual anomalies by adjusting climatological patterns. Submitted to IEEE IEEE Transactions on Geoscience and Remote Sensing, Special Issue on "Analysis of Multitemporal Remote Sensing Data"	We have removed this awaiting more material.
4.3.5.	The fact that there are LAI products based on the same data (CCRS VGT and GEOV1), and the same algorithm applied to different data (CYCLOPES MERIS and CYCLOPES VGT) allows for a reasonably controlled approach for quantifying data and algorithm driven error components as well as the influence of definition differences in LAI products as demonstrated in Verger et al. (2009a). This should be performed by inter-comparison over a globally representative dataset on a seasonal basis for multiple years. We note that this approach is not recommended for products based on calibration to other products. Verger, A., Camacho, F., García-Haro, F.J., Meliá, J., 2009a. Prototyping of Land-SAF leaf area index algorithm with VEGETATION and MODIS data over Europe. Remote Sensing of Environment 113, 2285–2297.	We have added good practice details for intercomparison following this recommendation.
4.5.1.	MORE TRANSPARENCY SHOULD BE DEMANDED TO THE VALIDATION PRODUCT COMMUNITY THAT IN MANY CASES USES THEIR OWN IN-SITU MEASUREMENTS WHICH ARE NOT AVAILABLE TO THE REST OF THE	Unfortunately we are not in a position to demand data sharing of in-situ data but we do make a

	SCIENTIFIC COMMUNITY. EXPLICIT INFORMATION OF GROUND-BASED MAPS (LAT, LON, DATE, MEAN VALUE, STD, SAMPLING AND SCALING METHOD, SPATIAL AND TEMPORAL VALIDITY OF THE MEASUREMENTS) USED FOR THE VALIDATION OF LAI PRODUCTS SHOULD BE REQUIRED AT LEAST IN PEER-REVIEW PAPERS WHICH IS NOT THE CASE IN MANY RECENT PUBLICATIONS.	recommendation that the validation performed should be supported with sufficient supporting material or data to allow it to be replicated if need be by a third party.
4.5.2.1.	Pragmatic methods based on vegetation indices, spectral mixture analysis and model calibrated relationships have also shown effective for mapping LAI from high resolution imagery with minimum calibration data, reducing in-situ labour-intensive characterization necessities (Verger et al., 2009b). Verger, A., Martínez, B., Camacho-de Coca, F., & García-Haro, F. J. , 2009b. Accuracy assessment of fraction of vegetation cover and leaf area index estimates from pragmatic methods in a cropland area. International Journal of Remote Sensing, 30(10), 2685−2704.	This is a special case of using a functional upscaling tool. We document some examples but admittedly are not exhausitive. There are many examples of local LAI mapping using high-res data and perhaps this could be expanded upon in a revision or addendum to the document.
4.5.2.2.	The inversion retrieval approaches considered in some of the operational algorithms currently used to derive moderate and coarse resolution LAI products have also been tested with high spatial resolution data under controlled areas (e.g. Verger et al. (2009b) applied a prototype of LSA SAF/SEVIRI algorithm to TM data and Verger et al. (2011) applied the CYCLOPES algoritm to CHRIS/PROBA hyperspectral high resolution data).	We now refer to Veger et al. 2011. We could refer to others as well but at some point it becomes a review rather than a good practice document. A review is out of scope.
5.1.1.	R.C.7: Existing reference LAI maps covering at least 3km x 3km should be archived within a central CEOS Cal/Val portal database using standard metadata. The maps should be reviewed by a regional expert to assess the accuracy and also temporal extent over which they are relevant. IN ADDITION TO THE EXPERT ASSESSING, A CRITERIA TO EVALUATE LAI MAPS AND ENSURE THE QUALITY OF THE REFERENCE DATASET SHOULD BE THE CONSISTENCY OF LAI MEASUREMENTS WITH OTHER BIOPHYSICAL PARAMETERS (E.G. FAPAR, FCOVER) MAPS AVAILABLE FOR THE SAME AREA AND PERIOD.	We have included this now.
5.1.2.2.	Four upscaling methods are recommended that fulfil the criteria in Section 3.1.3.1. 3.2.2?? Method 2 - Disjunctive: *Spatial sampling with a replicate for each known category of land cover and productivity class in the ESU. Do you mean in the study area??*	We have removed it – it was too theoretical and we don't have a good document to refer to for these methods. Rather, we now consider scaling methods with references already or where we can provide a case study. In other words, we

		include some but not all good practices.
	R.V.48: Statistics related to linear comparisons of reference and product LAI should be reported for both Gaussian and non-paramateric analogues (Table 7). The latter are preferred unless it is known that residuals are Gaussian and that, for linear models, the reference data have significantly smaller uncertainty than the validated product. These are defined in Table 7.	Recommendation is removed since it was really too specific. We still offer the reader both non-parameteric and parameteric good practice statistics.
5.3.	The evaluation should also consider the frequency of valid data eventually with additional details on data QA (Quality Assessment) (such as main algorithm, backup, gap filling). In addition the continuity of LAI products could be evaluated by characterizing the spatio-temporal and biome distribution of gaps and the distribution of length of periods without product values (Length of Gaps) as proposed in Verger et al. (2011). Histograms of the data are also expected to show whether the distributions seem reasonable. Verger, A., Baret , F., Weiss, M., 2011. A multisensor fusion approach to improve LAI time series. Remote Sensing of Enviroment 15, 2460-2470.	Document modified as suggested.
	R.V.53: The change in accuracy between 3km x 3km and coarser (e.g. 25km x 25km) resolution mapping units should be reported to identify random versus spatially correlated errors across mapping units. INFORMATION ABOUT DISCREPANCIES BETWEEN PRODUTS IN THE ORIGINAL SPATIAL RESOLUTION (1KM X 1KM) IS ALSO MANDATORY FOR THE USER COMMUNITY INTERESTED IN USING THE LAI PRODUCTS AT THE FULL SPATIAL RESOLUTION.	We agree but if there is a spatial mismatch in reference and product mapping units full resolution validation may not be possible (e.g. if we are validating Landsat or Sentinel-2 LAI). We now add a fair bit of detail about the criteria for defining the appropriate resolution.
	R.V.59: Inter-comparisons should be performed across BELMANIP2 sites using monthly LAI values to ensure temporal and spatial consistency. ASSESSMENT OF PRODUCTS IN THE ORIGINAL TEMPORAL SAMPLING RESOLUTION IS ALSO REQUIRED FOR THE USER COMUNITY INTERESTED IN THE PHENOLOGY CAPTURED FROM LAI PRODUCTS.	We did not include this as a good practice. This may be a concern for a phenology application but GCOS requires bi-weekly LAI estimates. Furthermore, if people started intercomparing at different temporal resolutions we would have difficulty comparing accuracy statistics between studies. This is not to say it should not be done for a specific phenology related study but is out of scope of our document.
5.9.	R.P.6: Algorithms for processing LAI datasets should be provided to CEOS LPV for validation studies along with sample standardized input data for case studies	There is now a specific funded activity to support this sort of work.

	as well as sensitivity analyses that were identified within Section 5.2. of this protocol. IT WOULD BE ALSO INTERESTING FOR TO LAI PRODUCERS TO HAVE ACCESS TO A REFERENCE INPUTDATA SET TO TEST THEIR ALGORITHMS UNDER CONTROLLED SITUATIONS WITH HIGH QUALITY DATA. SIMILARLY TO THE RAMI INITIATIVE FOR RADIATIVE TRANSFER MODELS, THIS DATASET WOULD CONSTITUTE A BENCKMARK FOR QUANTITATIVE ASSESSMENT OF RETRIEVAL ALGORITHS THAT WOULD ALLOW COMPARISON OF PERFORMANCES OF DIFFERENT ALGORITHMS APPLIED OVER THE SAME DATASET IN IDENTICAL CONDITIONS. THIS INPUT DATASET SHOULD INCLUDE TOA AND TOC REFLECTANCE DATA IN DIFFERENT SPECTRAL CHANNELS, DIRECTIONAL REFLECTANCES AND NORMALIZED REFLECTANCES TO A REFERENCE GEOMETRY... BUT ALSO SOIL, LEAF AND CANOPY INFORMATION, AS WELL AS OTHER AUXILLIARY INFORMATION (E.G. LAND COVER MAP).	We refer to it now in the conclusions.
References	Weiss, M., Baret , F., Garrigues, S., Lacaze, R., Bicheron, P., 2007. LAI, fAPAR and fCover CYCLOPES global products derived from VEGETATION. Part 2: Validation and comparison with MODIS Collection 4 products. Remote sensing of Environment 110, 317-331.	OK
	The structure could be made easier to read that way the manuscript would also be shorter. So many contagious information are scattered. I would restructure in such a way for example, a section about the instrument based ground measurements could be in one section including definitions, methods, error assessments...	Agreed – we have restructured but also removed the entire section on theory and detailed analysis of ground based measurements as it was making the document too long and there is another international panel tasked with this.
	The protocol should generally avoid strong inferences such as “reference LAI providers must follow the protocol”, etc. Rather it should be suggested the protocol to be used as a guide and minimum information and procedures required to provide reference datasets. There are still so many problems yet to be solved.	OK – we have changed this.
	Some of the reported error figures are too detailed which do not represent the global vegetation. Examples are errors listed in % are mostly too optimistic for ground measurements, LAIe, clumping indices. The errors should only be cited in approximate ranges, for example error due to clumping index could be up to 50% on agricultural crops	We have removed such figures and now cited either published figures OR made figures using relevant datasets when we want only to explain a practice.

	User's perspective should also be included. Why we need LAI, example terrestrial ecosystem process models, precision agriculture, micro- and macro-meteorology, and so on and their need for acceptable level of LAI errors. In some models, LAI is used in place of land cover for simple vegetation abundance indications.	This is out of scope. Our user is GCOS. However, we have included a summary of other user requirements.
Table 2	Stránka: 21 Or, alternatively to explain the protocols in more details. Like: The Tartu protocol relies on the inversion of a theoretical gap fraction model (Nilson's model) for homogeneous forest canopies. The model is described in (Nilson 1999, Nilson and Kuusk 2004, Ryu et al. 2010b, Nilson et al. 2011). Add: Nilson et al. 2011 to Tartu table entry	Detail is purposely omitted to stay in scope.
	R.V.7: At least 10MPixel resolution DSLR cameras with sub-pixel corrected aberration, 14 Bit sensitivity, and relative standard deviation of luminance of less than 1.5% (over uniformly illumated targets of reflectance similar to vegetation) at ISO 3200 or lower be used for LAI measurements. Stránka: 21 Cescatti (2007) proposes linear ratio method and shows that it is possible to use even old Nikon Coolpix 4500 as a measurement device (in similar manner as LAI-2000). Lang et. al (2010) developed single camera approach for the linear ratio method. The basic idea is to use calibrated camera approach and completely raw data from cameras (pixels with blue cyan or blue filter depending on sensor). Proposed method (Lang et. al, 2010) is free from operator's influence - no thresholding or binary classification is applied. Method output for each pixel in an image is transmittance which can be further used in inversion or modeling procedure.	Removed
3.2.1.5	Generally this is under 10% so we assume an error of 5% over and on top of uncertainty in clumping estimation itself. Conversion to LAI includes an additional uncertainty for correcting for NPV that is typically on the order of 10% in the absence of local calibration. The number of measurements needed to achieve a prescribed precision of LAI in a homogeneous forest stand can be estimated using the (Nilson et al. 2011) model provided that some a priori stand data are known.	Removed
4.1.	Stránka: 21 I always understood NIR to extend only up to 1300 nm or so; 2500 nm is SWIR, not NIR.	Removed
	R.S.14: Protocols for the use of reference maps generated from high accuracy remote sensing retrievals (e.g. from locally calibrated LIDAR or hyperspectral imagery) that have been regionally evaluated, should be developed and provided	Removed from main document and placed in recommendations.

	to CEOS WGCV LPV for hosting on the Cal/Val Portal.	
4.5.2.1.	The use of raw DHP images should be preferred to ensure the linear conversion between the digital numbers in the image and radiance (Cescatti 2007, Lang et al. 2010). The linear conversion method enables to effectively derive the above canopy reference images from the below canopy images by measuring the sky radiance in the gaps and making use of a sky radiance model (Lang et al. 2010). Stránka: 22 this can be alternatively incorporated somewehre on page 34	Removed – out of scope.
	R.V.56: The deviation of a centre sample from a linear fit of adjacent samples in time should be summarized and reported on a seasonal basis by land cover class and biome. Ideally, this should have a central tendency for each condition and would identify outliers from this tendency.	This is now in main document only as one approach for temporal precision. Removed from recommendations.
5.8	Stránka: 22 Ensemble LAI estimates from multiple products offer a means of simultaneously evaluating precision and stability, while quantifying the reliability of the evaluation statistic. Two approaches are recommended for application with ensemble estimates. if you produce these ensembles, make sure the products have the same LAI definitions?	This is specified now at the start of Section 5.
	the executive summary: it presents a clear plan that it is expected to be the plan of the document. But, actually, it is not and I was a little bit lost	Summary now mentions items covered in document.
	then, there is a long list of recommendations, all have clearly not the same level of priority. They explain what should be done in an ideal "validation" world. But, to reach this objective, it is necessary to progress step by step. Then, I would suggest to rank the recommendations. For example, at the end of the document, propose a kind of "road map" for the different parties (CEOS, product producers, scientific research community, and validation teams) with the major recommendations (about the 10 most important) essential to initiate the processus. Another reason is that this document is so detailed that it is difficult to extract the major ideas.	Recommendations greatly revised and made more generic. Ranking is not performed – we just kept the most important ones as you suggested.
	The main one is to suggest to remind the overall principles of the validation (transparency and traceability; independence; accessibility; representativeness). I also noted that OLIVE is mentionned many times. It will be useful to indicate how to access it when it will be fully operational.	OK
3	Start a section 3.1 titled Validation Principles: Maybe remind here the overall	For brevity we refer to CEOS general

	principles of the validation: 1) Transparency and Traceability; 2) Independence; 3) Accessibility; 4) Representativeness	validation stages and principles. Sorry but document is quite large and we would rather deal with practical methods for now. Maybe a revision could organize these against such princples.
Table 2	BOREAS Non-Destructive / Yes (inconsistent with “Non-destructive”)	
3.2.1.5	by bootstrap estimation. et al. 2007 However, diffuse transmission Demarez et al., 2006 (Not in the Reference list)).	References are now all present.
4.1. table 5	Maybe insert here a synthetic version (Dataset, Reference/Citation) of the list available on the website with global datasets first (NRT, static), and then continental.	We don’t want to keep a static list in the document. But, your suggestion to partition products by area covered is a good one and will be used.
After 4.1.1.4	Applicability of the algorithm LAI retrieval algorithms are based on inherent empirical assumptions on the distribution of their parameters that can depart significantly from actual canopy and soil characteristics. For example, classification errors in algorithms using a land cover map for their spatial extension can generate an LAI estimation error up to 50% of the actual value (Myneni et al., 2002; Fernandes et al., 2003). Besides, the number of land cover classes can be too low to represent the global variability of vegetation structure. R.P. ??: ATBD, and any other document of product description, should be provided and centralized by CEOS LPV.	We have removed this discussion since it relates to the need to validate by biome/land cover that we now specify explicitly in Section 5. We kept the recommendation about centralized product definitions/ATBDs at CEOS.
4.1.2.	(e.g. products derived from SPOT/VGT)	This section have been removed.
4.1.3.	LAI products are currently derived from either instantaneous satellite measurements (This drives to think that some LAI products are instantaneous. It is not the case, even the LSA SAF LAI, which is daily, result from a temporal composite over the day) (e.g. MODIS), from temporally aggregated satellite measurements (e.g. JRC TIP (Not sure that it is applied to retrieve LAI. Do not know any JRC LAI product)) or from smoothed versions of either (e.g. CCRS, University of Toronto).	Reference added.

4.3.1.	R.V. xx: Reference maps should be associated with a QFlag identifying regions where in-situ data are not representative (filled pixels).	This recommendation is removed as it is too detailed.
4.3.5.	The fact that there are LAI products based on the same data (CCRS VGT and GEOV1), and the same algorithm applied to different data (CYCLOPES MERIS(at my knowledge, there is no available CYCLOPES products derived from MERIS) and CYCLOPES VGT)	We rewrote this sentence in general rather than product specific terms.
5.1.2.1.	protocols admissible if the following	We removed this phrase since it is not our intent to specify admissibility of protocols for validation – just to provide some good practices.
	miss-cited results, especially from papers I contributed to:E.g. LAI-2000 was mentioned but not used	Removed
Recommendations	R.V.6: The producers of the TRAC should make the algorithm for relating transmission to gap fraction available to the scientific community through its publication in a peer reviewed journal Done in first few papers about TRAC (see other comments).	Removed
Table 2	LeBlanc 2009 – not sure what document this is supposed to be	Deleted
3.2.1.2.	Text moved to beginning of paragraph: The first non-destructive LAI estimates of natural vegetation were collected using hemispherical photographs based on an assumption of random foliage distribution (Anderson, 1947). moved this text here because it seems like a good transition between destructive sampling and optical measurements. (it was at the beginning of digital imaging) Anderson 1961, 1971? The only 1947 paper I know is Watson 1947. LAI estimation from diffuse transmission has relied on either Miller's theorem or from a narrow range in zenith angle near one radian. LeBlanc 2005: Okay to cite me, but that was Kucharik's discovery not mine This approach, using the Tracing Radiation and Architecture of Canopies (TRAC) The LAI-2000 should not be used in direct sunlight since uncertainties in diffuse transmission can lead to LAI biases in excess of 20% (Leblanc and Chen 2001; Garrigues et al. 2008).	Removed

	The LAI-2200 does not sample a full hemisphere and its processing software, FV2200 (Li-COR, 2009) uses the centre zenith angle of each ring when following Miller's method, but the weight used for the fifth ring is larger than the range of angle it covers to include the full integration to 90 degree view angles. Using the Li-COR integration method as opposed to the equal angular range reduces the resulting LAI by more than 8% in deciduous forests (Leblanc and Chen, 2001). Using only the 4th ring increases the resulting LAI by 13% as opposed to the Li-COR integration scheme for deciduous forests (Leblanc and Chen 2011). This difference was first attributed to multiple scattering only, but leaf angle distribution and clumping index variation with zenith angle might also contribute to it (Leblanc 2008). Li-COR has alternate approaches for simultaneously estimating LAI and leaf angle distribution by relying either on a parametric leaf angle distribution or leaf projection function. The accuracy or precision of these approaches has not been widely tested. The LAI-2200 should be tilted parallel to the local slope if it is to be used with the FV2200 software, but when used tilted, the final LAI should be projected to the horizontal. What is the CCRS software? Diffuse transmission measurements should be located to ensure coverage of the ESU while minimizing overlap. For flat terrain and vertical vegetation, a zenith range corresponding to the first four rings corresponds to viewshed that goes as far as three times the distance	
3.2.1.3./4/5	A lot of edits to the text about TRAC, Digital imagery	Removed
4.5.2.1.	(Demarez et al. 2008; Weiss et al. 2004; Leblanc et al. 2005). No professional grades cameras in Leblanc et al. 2005.So I'm not sure if Leblanc 2005 is appropriate here.	Removed
	In general, we feel that the document is too long for a protocol and contains redundant information as well as a fair number of contradictory statements. Remove excess jargon	Agreed – we removed the section on in-situ LAI.
	The key variables (LAIe, LAI, clumping index etc) at different scales are not rigorously defined	We apolgoise if the definitions are not sufficiently rigorous. We have tried to refer to the literature to provide these definitions. We

		welcome contributions to improve them either as live comments to the report or as independent reports.
	R.C.4: An initial database of NPV ratio and needle to shoot-area ratio should be compiled by LPV and hosted by CEOS Cal/Val Portal. **Disagree. Not a feasible/reasonable task for NPV. For the shoot silhouette to needle area ratio STAR (which should be preferred over the later defined “needle to shoot-area ratio”) there already exist rather extensive published data that could be used. Please see for example: Thérézien et al. 2007. Estimation of light interception properties of conifer shoots by an improved photographic method and a 3D model of shoot structure. Tree Physiology 27:1375-1387.	RC 4 Removed
	R.C.6: LPV should develop and maintain a conversion table between LAI, LAIe, PAI, PAIe and total versus understory LAI for ~1km resolution products as a function of biome, land cover class and if possible crop types and tree species. This conversion table should be hosted within the CEOS Cal/Val portal. **Disagree, no such conversion table exists! The theoretical basis for such a table is not sound.	RC Removed
	R.P.4: LAI products should be provided as total LAI or distributed with a conversion table to derive total LAI. Failing this, data producers should provide written permission to enable validation teams to utilize a community sanctioned CEOS LPV conversion table (once it is available). What is total LAI (e.g. understory + overstory? two-sided)? It is not defined in Section 2. No conversion table exists.	RP 4 Removed
	R.P.5: LAI products should report LAI values using a numerical precision of 0.1 for each mapping unit. based on what?	Removed
	R.P.8: The sensitivity of LAI algorithms to aerosol optical depth (at 550nm) ranging from 0 to 0.2 (assuming a nominal aerosol model) as well as assuming the 'worst case' aerosol model (corresponding to the highest path radiance for this region) should be quantified. Shouldn’t the upper limit be closer to 0.5 (e.g. according to AERONET)?	Agreed – changed.
	R.S.1: A reanalysis of DHP and LAI-2000 data should be performed to model uncertainty of derived in-situ LAI estimates in the absence of clumping correction as a function of survey protocol azimuthal and canopy type. nonsense??	Removed
	R.S.3: Measurements of NPV and needle-shoot-area ratio, together with a description of the methodology used, should be provided to a database hosted by	Removed

	CEOS WGCV LPV as soon as they become available. see comment earlier on	
	R.S.7: A methodology and software for rapid determination of needle to shoot area ratio based on DP imagery should be developed. see comment earlier on. This type of software + instrumentation already exists for determination of STAR (see e.g. Thérézien et al. 2007)	Removed
	R.S.15: The scientific community should develop and test approaches for quantifying intra- and inter- annual temporal precision of LAI products including those proposed in this protocol. Essentially the same as R.S.11	RS 15 Removed
	R.V.2: In-situ ESU LAI survey using a LAI-2200 or LAI-2000 should follow GCOS, CCRS or LICOR protocols or provide suitable documentation to estimate measurement errors. Are these commonly known protocols?	Note we should provide links to these on the site the LAI protocol will be published
	R.V.3: Correction for clumping should be based on the Tartu or GCOS approaches. With the latter it is preferable that the clumping be estimated either at close to the 52 degrees (should be 57.3 degrees!) zenith angle (corresponding to the centre of the 4th ring of the LAI-2000) and used with the PAIe estimated from the same zenith angle range or clumping be estimated over a range of zenith angles and interpolated to be applied to the effective LAI based on hemispherical gap fraction sampling. **Where is the Tartu approach described? Two things are being mixed up: The 57.3-deg zenith angle can be used to remove the effect of leaf angle, but it reveals nothing about clumping!	Removed
	R.V.5: A leveling device and inclination monitor should be added to diffuse sampling instruments where possible. The manuals already suggest doing so (e.g. a bubble-level with LAI PCAs). (Is there really somebody who does NOT use a bubble-level?!)	Removed
	R.V.7: At least 10MPixel resolution DSLR cameras with sub-pixel corrected aberration, 14 Bit sensitivity, and relative standard deviation of luminance of less than 1.5% (over uniformly illuminated targets of reflectance similar to vegetation) at ISO 3200 or lower be used for LAI measurements. The location of lens center and radial positions on the output images should be determined using the approach described in the CANEYE manual or suitable alternatives. Where have these (rather tough) criteria for cameras been published? Why is a spectral radiance calibrated camera not an option?	Removed
	R.V.10: Downward looking DHP images should be acquired for low vegetation (<0.5m). Not applicable if the background color is similar to the low vegetation layer (e.g.	Removed

	boreal forests with a layer of dwarf shrubs + grasses bound below by green moss)	
	R.V.16: The VALERI protocol is suitable for selecting ESU locations for upscaling in the case of study areas less than 10 km^2. R.V.17: The CCRS protocol is suitable for selecting ESU locations for upscaling in the case of study areas greater than 10km^2. Why exactly these two protocols?	Reword to "methodology". Examples are provided. References to methods are also provided.
	R.V.18: Replicate sampling should be performed for each stratified land cover. ????	Removed
	R.V.19: Randomization should be applied when selecting samples within a land cover stratum. ??	Removed
	R.V.28: All in-situ reference datasets should be provided as total LAI or the validation team should use the CEOS LPV sanctioned conversion table. Not defined in Section 2. R.V.34: ESUs should sample across dominant land cover classes with an emphasis on sampling across large ranges of leaf angles, clumping and woody area ratios as well as terrain elevation and slope. Nominally, sampling should be stratified by gramminoid, herbaceous, broadleaf tree and conifer tree vegetation with sub-stratification across crop types. How can these (i.e., leaf angles, clumping and woody area ratios) be determined in advance without measurements? The sampling should be based on variables which can be easily assessed in the field (e.g. species, developmental stage of stand).	Removed
	R.V.35: ESUs should allow for spatial and spectral interpolation rather than extrapolation. In this sense, ESUs should include locations near the mapping unit boundaries in space as well as the convex hull of any spectral information used to upscale the data. the same as RV 37.	RV 35-37 removed
	R.V.37: ESUs should span the thetmatic (LAI), spectral and spatial convex hull of the region mapped. Essentially the same as RV34-35.	RV 35-37 removed
1.1.	**Needs to be defined what the LAI of an ecosystem is. LAI by original definition is a canopy-level variable (for a homogeneous area, not an ecosystem).	Removed.
2.1.	LAI is defined as one half the total green leaf area per unit horizontal ground surface area (GCOS-138-SUP, Chen and Black, 1992). Green leaves correspond to vegetation matter capable of photosynthesis in ambient conditions. LAI was originally defined by Watson (1947), Chen and Black modified the	GCOS reference added. The reference to Watson is not included since the purpose of the document is not to assign precedence but to

	definition for non-flat leaves. What is GCOS-138-SUP (it is not in the reference list)? Here it would be recommendable to specify at which spatial scale LAI is/should be defined and/or discuss its meaning at different spatial scales.	document the preferred definition. It is our understanding that the quantity can be defined at any macroscopic scale. Wether it can be measured at that scale is a different issue. For this reason we only list in a table methods for measuring LAI (with some error) for certain canopies/scales.
2.2.1.	**Ill-defined quantity - is it necessary to include "projected LAI" in this document? If it is included, please state clearly that this is an incorrect (and old-fashioned) concept. Previously, both in-situ measurements and satellite-derived products often reported projected LAI so that conversion factors are required if these data are to be used in a validation protocol. The conversion factors would depend on direction of projection, needle angle, needle shape, needle orientation and needle convexity. So, these data are not available…	
2.2.3.	Stenberg, Rautiainen, Heiskanen	We removed the detailed discussion on LAI methods so this reference is not needed.
2.2.4.	**According to this definition, also the shoot-level clumping index should indeed be defined as a ratio of shoot area to needle area (attaining values <1 in the case of clumping), as previously noted. According to the definition provided here, clumping is independent of scale and direction but yet in the protocol you frequently report variation in clumping at different scale and at different directions. For most landscapes, very small regions (<1m, is this really a "region"?) **Again, as the whole concept of clumping (and LAI) is scale-dependent, this matter should be more thoroughly addressed in the document. Clumping index is not a relevant concept at ecosystem level. It can be mathematically computed for an ecosystem (as an average value of different canopies), but how can it be interpreted? Where are the references for the numbers provided in this paragraph??	We removed the detailed discussion on LAI methods so this reference is not needed.
2.3.2.	For sloped terrain corrections for the increased surface area of the slope may be required depending on survey method.	We removed the detailed discussion on LAI methods so this discussion is

	where is this described in detail?	not needed.
2.3.4.	Non-linear resampling, such as nearest neighbourcan result in substantial spatial aliasing so that comparisons of values recorded in different EPIFOVs should include some sort of spatial averaging using a filter spatial support on the order of multiple PIFOVs. ??? please clarify and be more specific (no jargon, please) or remove.	This discussion now uses standard terms related to "binning". Note that we keep PIFOV since it is a standard term in remote sensing.
3.1.	CEOS validation stages ???	We have added a chart with the stages.
Table 2	Table 2: Surveyed In-Situ LAI Protocols. What does 'protocol' mean? Different instruments, sampling schemes, correction factors, what!? How do these protocols differ? Why were these specific 'protocols' selected (LAI is measured by many, many more research teams)? LeBlanc 2008: These are not peer-reviewed papers! The hyperlink provided in the reference list did not work. Ryu et al. 2010. Why is Ryu et al. called <u>TARTU</u> protocol? Nilson and Kuusk, 2004. Do these papers really document one specific protocol?	This is a reference to what is available and in use. The methods may not be peer reviewed themselves but that does not mean they are not useful – at least it documents what is measured so one can get some idea of accuracy of the in-situ LAI. Links will be active before publication of document. In some cases the protocol is an evolution based on a sequence of papers. We tried our best to specify a reasonable label for each. Authors of documents can contact us and we can revise.
In situ	Many further comments about in situ methods	We removed the detailed discussion on LAI methods so these comments are not addressed in the new document.
Table 6	Understorey reflenctance: Sensitivity of LAI to change in understory from sand to clay to snow using standard reference spectra (Not so simple to do! Seasonal changes can be large. For boreal forests see e.g. Rautiainen et al. 2011 RSE)	Agreed it is not so simple but at least some sensitivity is needed – currently there is no standard.
4.1.4.	total LAI not defined in this document	LAI is defined in section 2.1 – we include the word total.
4.5.2.1.	The VALERI and CCRS protocols are perhaps the most efficient for producing larger (>1km^2) reference maps (please provide a reference to a peer-reviewed	VALERI and CCRS methods were

	journal paper). Work at INRA and CCRS (please give a published reference) Work within the VALERI project indicates that 10-15 DHP images (or LAI-2000 measurements) are sufficient for PAIe in an ESU (please give a published reference to show that this does not depend on vegetation type, as you claim here...).	used in publications cited. Since there is no single “protocol” for each we not give an example in the document. We hoped to have many useful protocols but unfortunately there is not much in the p-r literature right now. We removed the details on the #DHP images.
5.1.1.2.	Finally, undisturbed evergreen forests will typically show low inter-annual variation in relative peak season LAI. reference? effect of understory? ...	Removed.