GLOBAL LEAF AREA INDEX Subgroup

Co-chairs: Richard **Fernandes**, Stephen **Plummer**

Gabriela's needs

- GCOS requirements for your product
- Main products
- Summary/list of product accuracy/uncertainty as published in literature and corresponding references
- Main problems of referenced work and future validation
- CEOS LPV validation stage of product (your view)
- Status of promised GCOS action item contributions (if any)

Definitions

- Leaf Area Index (LAI) measures the amount of plant leaf material in an ecosystem. It appears in many models describing vegetation-atmosphere interactions (GCOS-138) as a key variable controlling processes such as photosynthesis, respiration and rain interception.

Definition agreed in 2010 between GCOS, GTOS and CEOS:

LAI is defined as one half the total green leaf area per unit horizontal ground surface area

But we cannot measure this from space – we measure other components

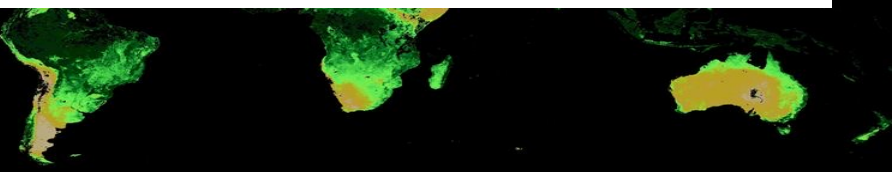
GCOS Status

- GCOS ‘requirements’

Target Requirements

Variable/ Parameter	Horizontal Resolution	Vertical Resolution	Temporal Resolution	Accuracy	Stability
LAI	250m	N/A	2-weekly averages	Max(20%; 0.5)	max(10%; 0.25)

Rationale: The requirements are driven primarily by the need for LAI maps to better simulate land-atmosphere interactions and to support carbon cycle models. The horizontal resolution (250m) indicated here points to the typical values achievable currently and in the foreseeable future while maintaining frequent and global coverage. It is understood that biogeochemical and climate models are driven by spatially integrated values at a coarser resolution. The time resolution of the desired product (no longer than two-weekly) is driven by the need to detect changes in the state of vegetation (e.g. changes in length of growing season). It usually implies a much more frequent temporal sampling required to account for the presence of clouds and other factors that limit the number of useful observations. The accuracy and stability values assume some prior knowledge of the spatial structure of the canopy as well as of the albedo of the underlying surface.



LAI

LAI, derived from AVHRR
Contact: Ranga Myneni
Institution: Boston University

Spatial Coverage: Global
Temporal Coverage: 1981-2001
Spatial Scale: 16 km, 0.5 deg
Temporal Scale: Monthly

Leaf Area index, derived from POLDER-2
Contact: Roselyne Lacaze
Institution: CNES
Link to validation information

Spatial Coverage: Global
Temporal Coverage: 1996-97 & 2003
Spatial Scale: 6 km
Temporal Scale: 10-days

GlobCarbon LAI, derived from Multi-source
Contact: Stephen Plummer
Institution: ESA
Link to validation information

Spatial Coverage: Global
Temporal Coverage: 1998-2006
Spatial Scale: 1 km to 0.5 deg
Temporal Scale: daily

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geoland2 LAI, derived from VEGETATION
Contact: Roselyne Lacaze
Institution: geoland2 - EC
Link to validation information

Spatial Coverage: Global
Temporal Coverage: 1999+
Spatial Scale: 1 km
Temporal Scale: 10-day

CYCLOPES LAI V3.1, derived from VEGETATION
Contact: Frederic Baret
Institution: POSTEL
Link to validation information

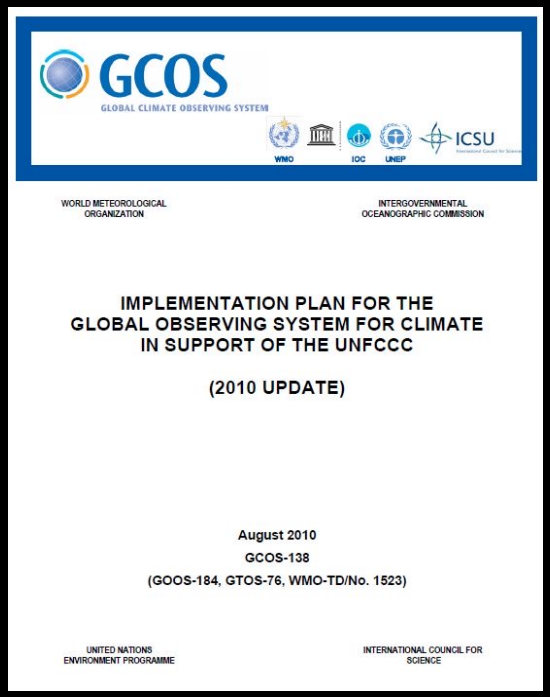
Spatial Coverage: Global
Temporal Coverage: 1999-2007
Spatial Scale: 1 km
Temporal Scale: 10-day

Component Global Land/Surface Product, derived from MISR
Contact: LARC userservices
Institution: NASA - JPL
Link to validation information

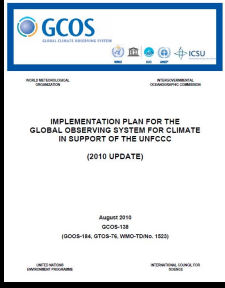
Spatial Coverage: Global
Temporal Coverage: 2000+
Spatial Scale: 1.1 km
Temporal Scale: Day, Mon, Qtr, and Annual

GCOS Status

- GCOS specified need to systematically produce and validate global LAI products
- Requirement to improving both the space-based observations and the in situ network
- CEOS LPV are required to play a key coordination role and lend the expertise to address actions related to validation of global LAI measurements as identified in GCOS-138


GCOS
GLOBAL CLIMATE OBSERVING SYSTEM
WMO IOC UNEP ICSU
WORLD METEOROLOGICAL ORGANIZATION
INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
IMPLEMENTATION PLAN FOR THE GLOBAL OBSERVING SYSTEM FOR CLIMATE IN SUPPORT OF THE UNFCCC
(2010 UPDATE)
August 2010
GCOS-138
(GOOS-184, GTOS-76, WMO-TD/No. 1523)
UNITED NATIONS ENVIRONMENT PROGRAMME
INTERNATIONAL COUNCIL FOR SCIENCE

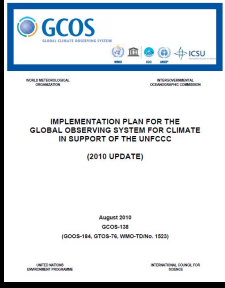
GCOS Action 1



- CEOS LPV are required to play a key coordination role for LAI measurements as identified in GCOS-138

- *[IP-10 T3]* Develop a subset of current LTER and FLUXNET sites into a global terrestrial reference network for monitoring sites with a sustained funding perspective and with co-located measurements of meteorological ECVs; seek linkage with Actions T4 and T29, as appropriate.
- **Who**: Parties' national services and research agencies, FLUXNET organizations, the US National Ecological Observatory Network (NEON) and the European Integrated Carbon Observation System (ICOS), in association with **CEOS WGCV**, …..
- Liaison with ICOS, TERN and NEON underway – protocols so we can use their continuous in situ observations

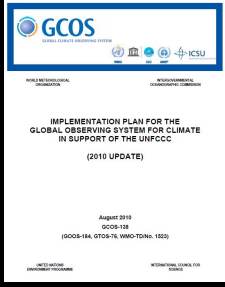
GCOS Actions 2



- *[IP-10 Action T29]* Establish a calibration/validation network of *in situ* reference sites for FAPAR and LAI and conduct systematic, comprehensive evaluation campaigns to understand and resolve differences between the products and increase their accuracy;

- Who: Parties' national and regional research centres, in cooperation with space agencies coordinated by CEOS WGCV, GCOS and GTOS.
- Put together a detailed budget – submitted to GCOS/CEOS (on web site)

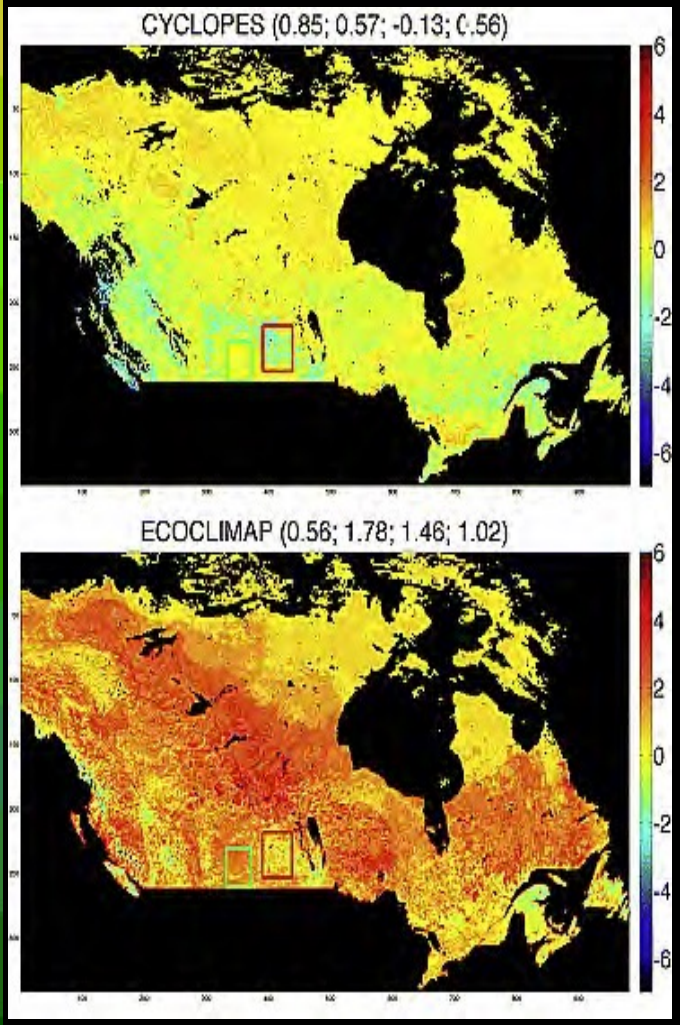
GCOS Actions 3

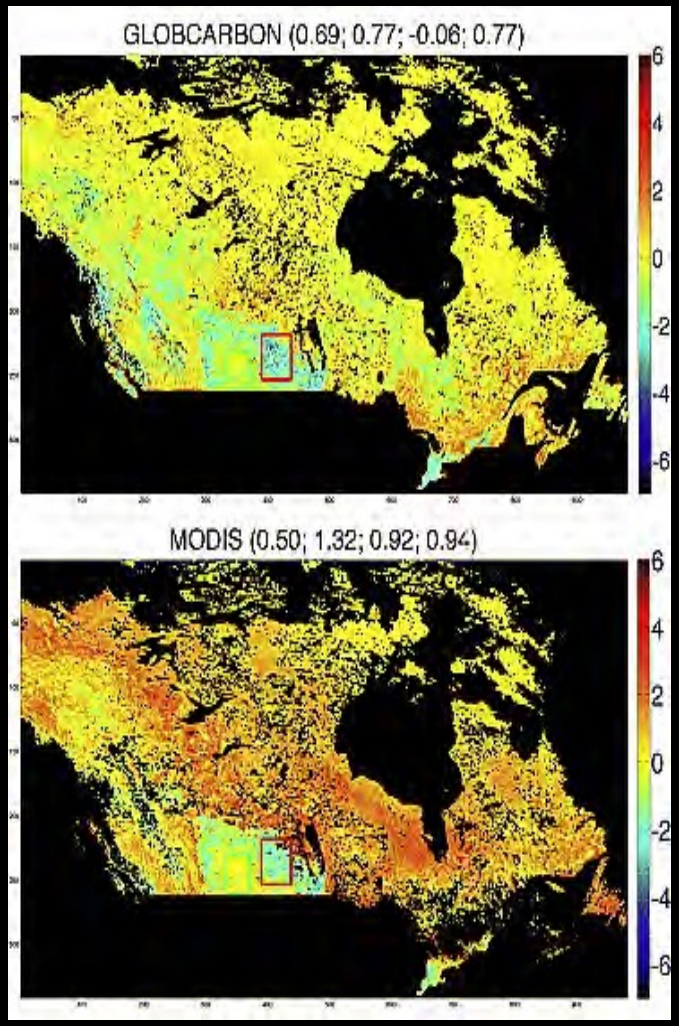


- *[IP-10 Action T30]* Evaluate the various LAI satellite products and benchmark them against *in situ* measurements to arrive at an agreed operational product;

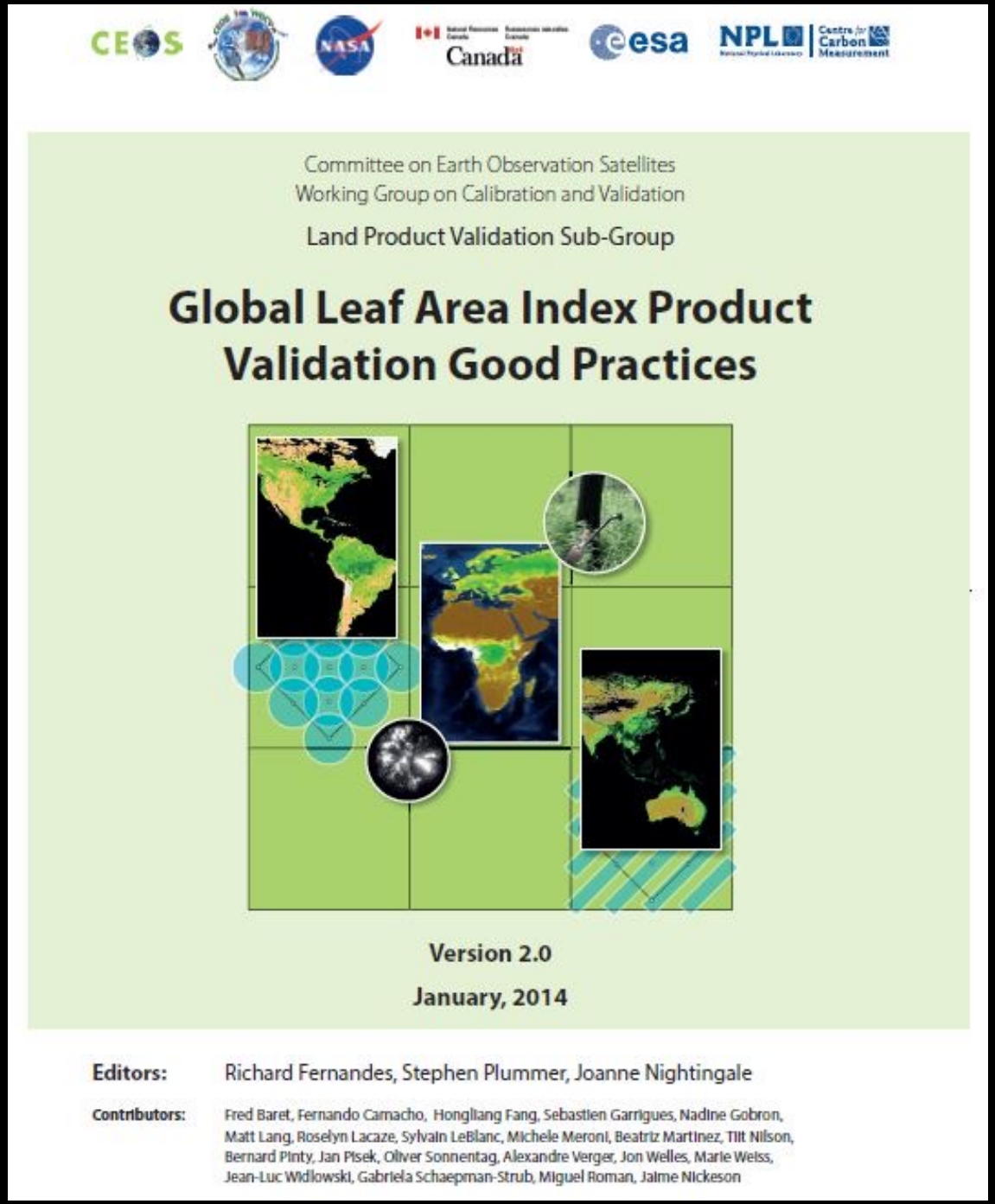
- Who: Parties' national and regional research centres, in cooperation with space agencies and **CEOS WGCV**, TOPC, and GTOS.
- Development of the Good Practice Guide
- Generation of a set of Recmmendations (on website)
- OLIVE

Intercomparisons





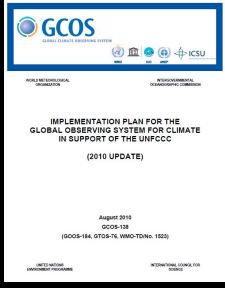
Anomalies in peak season LAI between global products and a chosen reference (over Canada and Alaska). From (Garrigues *et al.* 2008a).



Contributors:

Fred Baret, Fernando Camacho, Hongliang Fang, Sebastien Garrigues, Nadine Gobron, Matt Lang, Roselyn Lacaze, Sylvain LeBlanc, Michele Meroni, Beatriz Martinez, Tiit Nilson, Bernard Pinty, Jan Pisek, Oliver Sonnentag, Alexandre Verger, Jon Welles, Marie Weiss, Jean-Luc Widlowski, Gabriela Schaepman-Strub, Miguel Roman, Jaime Nickeson

GCOS Actions 4



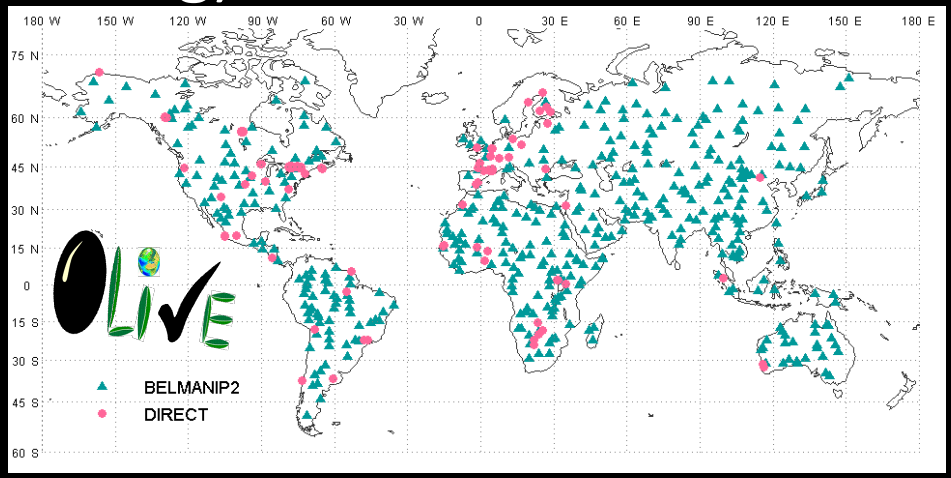
- *[IP-10 Action T31]* Operationalize the generation of FAPAR and LAI products as gridded global products at spatial resolution of 2km or better over as lengthy time periods as possible;

- Who: Parties' national and regional research centres, in cooperation with space agencies and **CEOS WGCV**, TOPC, and GTOS.
- Increasing number of products with plans for new ones – validation stage? Probably 2 but limited sites, spatially incomplete, temporally incomplete

Plans for Validation

- Overview of current LAI products
- Producers to detail uncertainties related to product input data & definitions
- Establish international schemes for intra-and inter-annual assessment of products (OLIVE)
- BUT current validation capacity limited – need to build up (infrastructural exploitation, feed in from science teams, synthetic testing)

Location of reference LAI sites available for direct validation and BELMANIP2 sites for inter-comparison



Next Steps

- Guide now on website along with links to supporting material:
  - Reviewer comments (*anonymous*)
  - Recommendations for future work
  - All in situ data collection “protocols”

- Action: Wait for fall out
- Discuss with TERN, NEON, ICOS
- Develop OLIVE – joint with FAPAR co-chairs
- Update the website
- Act on recommendations
- Address some of the missing elements e.g. in situ methods (Oliver Sonnentag welcome!!)

- Update of the Guide - based on community feedback and scientific advancement (aaaaargh NO!!!)

42 Recommendations For…

- CEOS WGCV LPV
  - *i.e. Archiving existing LAI reference maps*
- LAI Product Producers
  - *i.e. Provision of updates of product metadata*
- Scientific Research Community
  - *An upscaling tool should be developed to model spatial prediction errors*
- LAI Product Validation
  - *Where data permits, validation statistics should be derived seasonally for individual years*

42 Recommendations For…

- **Recommendations/Actions for CEOS WGCV LPV**
- CEOS LPV should compile a global database of in-situ LAI estimates, which should be hosted by CEOS Cal/Val Portal. This should include, where possible, raw measurement files for indirect measurements.
- CEOS LPV should produce a reference LAI metadata template for submission of reference LAI maps.
- CEOS LPV in collaboration with CEOS Cal/Val portal should archive existing reference LAI maps suitable for comparison with global products within a central database using standard metadata. Independent regional experts should review the maps should to assess the accuracy and also temporal extent, over which they are relevant, and this information should be included in the reference map metadata.
- CEOS LPV should compile a list of in-situ sites critical for temporal revisit, with inputs by the LPV community. The basis for this is BELMANIP2 guided by analysis of co-located satellite based phenological indices. This list would form a priority for site revisit.
- CEOS LPV should provide a spatially indexed (e.g. by biome, land cover and BELMANIP2 site) database of performance statistics. The completeness of these statistics should be reported by product to respond to the GCOS Implementation Plan Action Item T29.
- BELMANIP2 is a CEOS WGCV Global Stratification for LAI Validation. See (Baret et al. 2006) for V1. V2 is a revisit of V1 to make it more compatible with the needs of validation and inter-comparison of 1km products. The sites selected can be downloaded from the CalVal Portal/OLIVE website: http://calvalportal.ceos.org/web/olive/site-description. It will be updated as new sites become available

42 Recommendations For…

- **Recommendations to LAI Product Producers**
- Producers of global products should participate in the production of LAI reference maps to enhance the current sampling across different land cover conditions. These should be provided to the LPV database for the community to use (see 3).
- Producers should provide updates of LAI product metadata to CEOS WGCV LPV with each revision (see 2).
- Producers should provide a full and traceable description of the algorithms for generating LAI products complete with all ancillary data dependencies. Ideally the code should be made accessible along with sample standard input data for validation studies over sites used for CEOS Stage 1 validation.
- Producers should generate standard performance statistics from new products (e.g. using OLIVE). These statistics should be provided to CEOS for construction of the database within the Cal/Val Portal.

42 Recommendations For…

- **Recommendations to Scientific Research Community**
- Scientists who generate or have existing LAI estimates suitable as reference LAI maps should provide these to CEOS WGCV LPV as they become available to help build a validation database. All data should be fully acknowledged and its use credited whenever papers are published.
- Custodians of in-situ LAI measurement methods should provide CEOS with nominal and upper bound accuracy ranges for them. These ranges should be reviewed by independent experts.
- The scientific community involved in validation of satellite LAI estimates should develop an upscaling tool to model spatial prediction errors considering the spatial distribution of residuals.
- The temporal extent of the representativeness of current and future in-situ sites (e.g. BELMANIP2) should be documented.
- The scientific community should develop/test approaches (including those proposed in the CEOS WGCV LPV good practice guideline) for quantifying intra- and inter- annual temporal precision of LAI products.
- The scientific community should analyse the database of in-situ LAI measurements corresponding to temporal validation sites identified in 4 to identify those sites in sufficiently homogenous areas to produce initial reference maps through simple statistical upscaling.
- The scientific community should develop good practice guidelines 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. These should be provided to CEOS WGCV LPV for hosting on the Cal/Val Portal.

42 Recommendations For…

- **Recommendations for LAI Product Validation Teams**
- Both overstory and understory LAI should be measured within in-situ reference datasets and if possible reported separately.
- In-situ measurements and processed results should be documented and archived with suitable metadata by the measurement team or within the CAL/Val portal.
- A quantitative assessment of the accuracy of in-situ LAI estimates should be included with reference data and should be used when propagated into uncertainty estimates for reference LAI maps.
- The methods used for selecting ESU locations for upscaling should be described.
- Replicate sampling should be performed for each stratified land cover within a reference LAI image.
- Randomization should be applied where possible when selecting samples within a land cover stratum for producing reference LAI maps.
- The prediction confidence interval of upscaled LAI estimates should be quantified using boot strap validation.
- To account for geolocation issues, validation should be performed using mapping units larger than nominal pixel size of the product.
- LAI product intercomparisons should be conducted at a monthly temporal aggregation interval for LPV in addition to any other temporal aggregation intervals desired by the validation team.
- If LAI products include temporal interpolation of products the comparison should be made with and without the interpolation if possible. The range of LAI over the reference site during the product interval should also be quantified.

42 Recommendations For…

- **Recommendations for LAI Product Validation Teams**
- Whenever new reference sites are generated they should be introduced in BELMANIP2 regions in a manner that covers the dominant conditions of each region. Every effort should be made to maintain the balance of sites in terms of land cover proportions within BELMANIP2.
- For validation exercises the spatial and temporal distribution of residuals should be checked by the validation team to ensure a fair assessment of global products.
- The spatial trend in residuals between upscaled and ESU LAI estimates should be uniform and documented.
- Validation statistics should be spatially organized in a hierarchical structure starting globally and then partitioning to successively more detailed units such as biomes, continental biomes, land cover within continental biomes, and finally each validation core site.
- Validation studies should refer to the hierarchical validation levels (see 31) when reporting results. Ideally these should be provided to CEOS LPV to tabulate statistics as a function of hierarchical level.
- Where data permits, validation statistics should be derived seasonally for individual years. Where this is not possible average seasonal values maybe used for assessment of bias.
- Statistics related to linear comparisons of reference and product LAI should be reported using non-parametric analogues (see Table 6 of the Good Practice Guidelines).
- Non parametric accuracy statistics along with visualisations should be provided at each level of aggregation at which accuracy is assessed. Comparisons of accuracy across products or sites should be performed in an ordinal manner in addition to reporting standard error statistics to deal with variation in population sizes and reference data quality across space and time.
- The CEOS goals for LAI accuracy and stability (see Table 5 of Good Practice Guidelines) are cited as a combination of absolute and proportional errors. As such, residuals should be summarized in absolute and relative terms.

42 Recommendations For…

- **Recommendations for LAI Product Validation Teams**
- The agreement of products to reference LAI should be reported as a function of of the land cover within each mapping unit being compared. The assignment of land cover should be specified (e.g. does it come from a global map like GlobCover).
- Time series of LAI product estimates should be graphed together with in-situ values, with appropriate error bars, for both.
- In reporting validation performance statistics, the quantitative uncertainties associated to the global and reference LAI products used should be included in the analysis.
- Temporal precision of LAI estimates should be reported objectively as a histogram of retrievals over an area.
- 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.
- The shift in LAI for evergreen targets during snow to snow-free transitions should be quantified and reported as a global map and values should be extracted for BELMANIP2 sites.
- Statistics related to precision of low temporal frequency LAI estimates should be developed and implemented once they have been tested with synthetic datasets.
- Inter-comparisons for temporal precision should be performed by comparing cumulative totals of monthly LAI for each given year using e.g. the Kolmogorov Smirnov statistic.
- Inter-comparisons for stability should be performed using robust trend line fits across years of annual LAI totals for products with as long a temporal extent as available. Histograms of differences in slopes across biomes and land cover types represented in BELMANIP2 sites should be reported.