Validation of Global Moderate-Resolution LAI Products: A Framework Proposed Within the CEOS Land Product Validation Subgroup

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***Abstract*—Initiated in 1984, the Committee Earth Observing Satellites' Working Group on Calibration and Validation (CEOS WGCV) pursues activities to coordinate, standardize and advance calibration and validation of civilian satellites and their data. One subgroup of CEOS WGCV, Land Product Validation (LPV), was established in 2000 to define standard validation guidelines and protocols and to foster data and information exchange relevant to the validation of land products. Since then, a number of leaf area index (LAI) products have become available to the science community at both global and regional extents. Having multiple global LAI products and multiple, disparate validation activities related to these products presents the opportunity to realize efficiency through international collaboration. So the LPV subgroup established an international LAI intercomparison validation activity. This paper describes the main components of this international validation effort. The paper documents the current participants, their ground LAI measurements and scaling techniques, and the metadata and infrastructure established to share data. The paper concludes by describing plans for sharing both field data and high-resolution LAI products from each site. Many considerations of this global LAI intercomparison can apply to other products, and this paper presents a framework for such collaboration.**

***Index Terms*—Committee on Earth Observing Satellites (CEOS), leaf area index (LAI), validation.**

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I. Background

A. Committee on Earth Observing Satellite's Land Product Validation Subgroup

THE Committee Earth Observing Satellites' Working Group on Calibration and Validation (CEOS WGCV) was initiated in 1984 to pursue activities to coordinate, standardize, and advance calibration and validation of civilian Earth-observing satellites and their data. Five subgroups comprise the implementation arm of the WGCV. One subgroup, Land Product Validation (LPV) [1], was established in 2000 to define standard guidelines and protocols, and to foster data and information exchange relevant to the validation of land products. The subgroup's emphasis since its inception has been to provide a validation service for the Global Terrestrial Observation System (GTOS) [2]. This implies a focus on the terrestrial "Essential Climate Variables" of GTOS; which lists a number of critical products including leaf area index (LAI) [3]. Global LAI products provide key information on the exchange of energy, mass (e.g., water and CO_2), and momentum flux between Earth's surface and the atmosphere. LAI is utilized in most ecosystem productivity models and global models of climate, hydrology, and biogeochemistry [4]–[10]. LAI has been defined as the total leaf area (one-sided) in relation to the ground [11], or more specifically, as the one-sided green leaf area per unit ground area, in broadleaf canopies, and as the projected needle leaf area in coniferous canopies [12]. More generally, this can

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also be expressed as the total foliage surface area per unit of horizontally projected ground surface area [13]. However, for the CEOS LAI Intercomparison, needle leaf area is taken to be half of the total foliage surface area [14]. This definition has been adopted because it conforms to the reference "ground truth" LAI measured by optical instruments such as LAI-2000 and TRAC, which are the most commonly used validation instruments.

As various CEOS members each produce their own global LAI maps, characterization of each product's uncertainty—i.e., validation—becomes increasingly important for users to determine the most appropriate product, or combination of products, to use for their applications. CEOS defines validation as the process of assessing the quality of the data products derived from system outputs by independent means [15]. The LPV subgroup addresses the validation of specific products through topical meetings focused on opportunities for international collaboration to support the validation of those products. Much of LPV's initial guidance grew out of the experience gained through NASA' Earth Observing System (EOS) validation program [16], initiated in the 1990s; working to expand that effort internationally. To date, topical meetings have addressed albedo, land cover, LAI, and fire disturbance [1].

The motivation for organizing international validation collaboration is based on two premises. First, if different space agencies are producing similar satellite products, field validation efforts for one agency's product can also be used to validate another's. Second, making the most use of field validation data sets requires both detailed documentation and open access to those data. The first premise provides the impetus for CEOS members to participate in the activity. The second premise presents a need that is being met by the efforts of LPV. This paper presents LPV's collaborative efforts on LAI validation. The framework for collaboration on LAI products presented here can also be applied to other global products.

B. International LAI Intercomparison Effort

In the past five years, multiple LAI products have become available to the science community at both global and regional extents. The Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product is produced every eight days globally at 1-km spatial resolution [17]. The MODIS record began in early 2000 and continues to present [18]. The MODIS approach was in part pioneered by the Advanced Very High Resolution Radiometer (AVHRR) LAI product developed by the same investigators [19]. The 16 km-resolution monthly AVHRR product was derived from an improved Pathfinder normalized difference vegeation index (NDVI) data set (1981 to 2001) [20]–[23]. The French Space Agency (CESBIO/CNES) has produced an LAI product from the PoLarization and Directionality of the Earth's Reflectances (POLDER)-2 sensor [24], [25]. The European Space Agency is supporting the GLOBCARBON project aimed at producing global fields of LAI (among other products) from the VEGETATION, Medium Resolution Image Spectrometer Instrument (MERIS), Advanced Along Track Scanning Radiometer (AATSR), and AVHRR sensors. Finally, the Carbon Cycle and Change in Land Observational Products from an Ensemble of Satellites (CYCLOPES) [26] program from the European Commission has developed preliminary biophysical products [including LAI and fraction of absorbed photosynthetically active radiation (fAPAR)] using multiple sensors. In addition to the global initiatives, regional LAI products have also been developed. For example, the Canada Centre for Remote Sensing (CCRS) has been producing standard LAI products over Canada since 1998 and is now performing a reanalysis back to 1985 using the AVHRR sensors [27]–[29].

These global LAI products and multiple, disparate validation activities related to these products present the opportunity to realize efficiency through international collaboration. The LPV group convened workshops in 1998 and 2001 on LAI products [30], [31]. These initial workshops established an international effort for global LAI product validation through an LAI intercomparison activity. A third workshop in 2004 [32] further advanced this effort and brought together the groups represented here.

Each of the nine groups currently involved in this effort has their own particular interest in quantifying the accuracy of LAI products. Some are explicitly funded to provide a validation service to an agency producing an LAI product. Others are more interested in using the global products for their needs or region. The LAI team at Boston University (BU) is responsible for the development of the NASA EOS LAI products [18]. They rely on validation activities to check the accuracy of their product and to guide refinement of their algorithms. The Validation of LAnd European Remote sensing Instruments (VALERI) [33] group, supported mainly by CNES and the Institut National de Recherche Agronomique (INRA), has focused on the development of an effective methodology to generate high spatial resolution maps of biophysical variables from satellites and the use of those maps for the validation of moderate-resolution global products. VALERI is closely integrated with the objectives of the CEOS LPV subgroup and is working to establish the uncertainty of global products for international initiatives such as the Integrated Global Observing System (IGOS) [34], GTOS [34], [35], and International Geosphere-Biosphere Program (IGBP) [36]. The BigFoot project [37] grew out of a prototype effort to characterize the Long Term Ecological Research (LTER) sites across the U.S., and expanded to help validate MODIS LAI, land cover and net primary productivity products at nine flux tower sites [38]. CCRS, in conjunction with the University of Toronto, has produced LAI maps of Canada [27], [28].

III. Conclusion

The success of this global LAI validation effort is highly dependent upon the consistency the methods used to derive the high spatial resolution LAI maps. This paper synthesizes the *approaches* used by nine groups and sets the stage for future work on the synthesis of *results* and *accuracy statements* for global LAI products.

The descriptions of field validation procedures presented here, together with the data-sharing arrangements agreed to by the participants, provides the foundation for the global validation of medium-resolution satellite LAI products that will be addressed through future work organized under the CEOS LAI intercomparison activity.