Biogeosciences Discuss., 8, C3923–C3936, 2011
www.biogeosciences-discuss.net/8/C3923/2011/

Biogeosciences Discussions

Interactive comment on "Revisiting land cover observations to address the needs of the climate modelling community" *by* S. Bontemps et al.

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Received and published: 27 October 2011

Dear reviewer,

We do thank you for your interest in the topic of our paper and for your encouragement to see it published. We are convinced that your comments will help us to improve it.

Taking into consideration all your suggestions, please consider the following actions regarding the link between the modelling community and the land cover products, the structure of the paper and the discussion relative to the land cover concept and mapping approach.

In parallel, we will pay specific attention to the English formulation of the paper.

General comments

We agree that the current articulation between the conducted survey and the land cover products discussion should be improved. We also agree that some information (as, for instance, the discussion on the per-pixel or per-object approach) is not relevant for the climate modelling community. As a result, some materials will be removed and the whole structure of the document (from section 3) will be modified:

- Section 2 will be maintained, presenting the users' survey and the resulting requirements in terms of land cover products;

- Section 3 will be re-written with the aim of making a clear link between the user's requirements (section 2) and the new mapping concept and approach which will be developed in section 4. As an introduction, it will indicate on which specific requirements paper will focus (i.e. mainly the need to decouple stable and dynamic components of the land cover). It will later discuss the current land cover concept (section 3.1) and the limitations of the current land cover mapping (section 3.2);

- Section 4 will be completely reworked in order to present CCI Land Cover project (introduction), the new mapping approach developed in this project and tested with the SPOT-VGT time series (section 4.1) and the next steps (section 4.2). All the EO experience on the use of multi-annual EO time series, that you suggest us to emphasize, will be included in section 4.1;

- The abstract and the conclusion will also be re-written to ensure a clearer understanding of the paper structure and of its main findings.

With regard to the list of user's findings (pages 7719-7720), we disagree with the fact that it is too long and that they are too general. The whole survey was conducted during several months and resulted in a detailed list of requirements with respect of several aspects of EO products (e.g. use, spatial and temporal resolution, accuracy, thematic content, etc.). The list presented on pages 7719-7720 is already a concise summary of

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this work and reducing it to one or two statements would not make sense. Furthermore, we insist on the fact that all requirements were expressed by climate-related users. If some statements don't look climate specific, we can only conclude that there is a good match there is a good match among the climate modellers' requirements and the requirements expressed by the broader scientific community. Yet, we agree that we must clearly communicate which requirement the EO experiment will address. This will be clearly indicated at the beginning of section 3.

Specific comments

- Page 7715, lines 18-21

Currently, all global land cover maps are only based on a single sensor (except the MODIS land cover maps which use both Terra and Aqua sensors, but this is a very specific case since Terra and Aqua have exactly the same technical specifications). The SYNMAP product should also be mentioned as an exception since it is has been produced as a synergy of various existing land cover dataset including GLC2000 and MODIS.

A better characterization of the validation exercises and accuracy values will be included in the manuscript. As for your question about the presented figures, they were obtained by first crossing the land cover map and the reference dataset in order to derive a confusion matrix. The accuracy value of each class was then weighted by its area proportion (derived from the product projected in an equal area projection) in order to provide such synthetic figure. This information will also be added in the text.

- Page 7717, lines 5-7

We will edit the text in the following way:

"Three major climate modelling communities - the general circulation modelling (GCM), earth system modelling (ESM) and integrated assessment modelling (IAM) communities - play an important role in understanding and quantifying earth and climate system

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analysis and specifically, understanding the role of land use and land cover change in assessing impacts and vulnerabilities (Hibbard et al., 2010; Feddema et al., 2005). These three groups each had their specific modelling strategies but have now to respond to new policy needs and to the increasing requirement for integrated data (Overpeck et al., 2011). Recent developments in the climate science communities have called for a much more integrated modelling and assessment framework, where land surface information includes land cover and land use as a common integration framework (Hibbard et al., 2010). It can therefore be argued that improvements in observing land cover and use will act as an important catalyst to better integrate the efforts of the different communities."

A sentence was re-phrased and elaborated to better show the interest of improving land cover and land use observation. We have also included one additional reference to back up the statement of the paragraph (Overpeck, J.T., Meehl, G.A., Bony, S., Easterling, D.R., 2011, Climate data challenges in the 21st century, Science, 331, 700-702).

- Page 7718, lines 5-6

Several actors and types of users were identified as representatives of the modeling communities concerned with climate and climate change issues:

- Key users: they are central to all phases of the user interaction within the CCI Land Cover project as they are project partners. They are the Max Planck Institute for Meteorology (MPI-M), the Laboratoire des Sciences du Climat et de l'Environnment (LSCE) and the Meteorological Office Hadley Center (MOHC). Key users will also be directly involved in the products assessment.

- Associated users: These users from the climate modeling community are not project partners, but were contacted to participate in the user survey. A group of 85 users was approached and 15 filled in the questionnaire resulting in a response rate to the associate survey of 18% from a broad range of countries all over the globe.

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- Broad user community: this community was considered by gathering information of the project through the World Wide Web, by reviewing scientific literature and by receiving feedback from general global land cover data users.

Overall, three user surveys were completed for the broad, associated and key users respectively. The survey format varies according to the questions (for some of them, users had the choice between one or several answers; for others, they had a total liberty). The three surveys will be provided as an annex of our answer. While the frequency of responses varied, the amount and quality of feedback was found to be suitable to derive a good synthesis on what climate modeling users need and expect from a new land cover product.

We will add a little bit more information about the survey mechanisms (in particular about the methodology and users' description, as detailed above). In addition, we will mention that the complete "user requirements report" of the CCI Land Cover project (already cited as "Herold et al. 2011 on page 7719 line 13) also details the methodology and presents the users that were surveyed.

With regard to Figure 1, it results from the associated users' survey (which will be mentioned in the figure caption) but this result proved to be also representative of requirements expressed by the other users.

- Page 7718, lines 11-17

We agree to remove acronyms and provide more descriptive information about the reviewing process. The main idea of this paragraph is to mention that next to the surveys, requirements from a panel of international activities were also reviewed: the implementation plan for the global observing system for climate in support of the United Nations Framework Convention on Climate Change; the key-document about the Essential Climate Variables standardization, which is an output of the Global Terrestrial Observing System (Herold et al., 2009); the most recent summary report highlighting key gaps in current land observation programs, which is an output of the Integrated Global Obser-

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vation of Land (Townshend et al., 2008); the User Requirement Document written by the "Climate Modeling User Group" guiding the ESA Climate Change Initiative.

- Page 7719, lines 15-16

The need for "stable land cover data" here referred to the need of one map of land cover characteristics free from intra- or inter-annual natural variability. This is explained by the fact that land cover data are often used as a consistent basis for land surface parameterization (i.e. for deriving other land surface parameters such as LAI, albedo, etc.). On the other hand, other users required more dynamic land cover products informing about land cover change and vegetation dynamics such as phenology.

Clarification will be brought in the text to clarify this key requirement.

- Page 7720, lines 6-9

"Broad spatial levels" has to be understood as "over large extents". For current models dealing over such areas, the 300m-1km spatial resolution is enough. For future periods, a trend towards higher spatial resolution was observed. However, the magnitude of the spatial resolution requirement varied according to the model scale. For global applications, future requirements for spatial resolutions of 1 km were mainly mentioned while spatial resolutions up to 30 m were cited for local to regional applications.

The sentence will be rephrased to bring these clarifications.

- Page 7721, lines 8-15

The text will be edited to make the argument clearer. A first version of the revised paragraph is provided here below.

"In addition, the user assessment has highlighted that land cover remains a key dataset that serves as consistency basis for many other land surface parameters and for the associated temporal variability. For instance, the users have emphasized that there is some reluctance to take up new land surface variables (including other ECV's such as

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Leaf Area Index (LAI) or Fraction Absorbed Photosynthetically Active Radiation (FAPAR)) coming from global EO datasets although they provide more spatial and temporal detail than current model parameterizations. Since many users are relying on a common land cover map to estimate a series of land surface parameters, introducing new datasets may result in inconsistencies with the existing model inputs. That's the reason why consistency (i) of the input parameters in space and over time and (ii) among a series of land surface parameters is valued higher than the accuracy of individual parameters. However, this aspect is even not addressed by the EO land domain."

- Page 7721, lines 21-23

This paragraph will be elaborated to present varying definitions of land cover and to better discuss the distinction between land cover and land use. Some examples will be provided based on the literature. The first land cover definition, provided by Burley (1961), will be cited (land cover defined as "the vegetation and the artificial constructions covering the land"). LCCS being the current standard for thematic land cover characterization, its definition will also be mentioned (land cover referring, according to this source, to "the physical and biological cover over the surface of land, including water, vegetation, bare soil, and/or artificial structures"). Furthermore, it will be pointed out that land cover is also perceived differently according to the discipline (Comber, A.J., Fisher, P. and Wadsworth, R., 2005, What is land cover? Environment and Planning B: Planning and Design, 32, 199 - 209).

With regard to the distinction between land cover and land use, we agree that these two concepts have distinct definitions. However, we want to point out that confusion is often observed in the current practices, where land cover is often employed as a surrogate of land use. This is confirmed by the Integrated Global Observing Strategy report in its land them report "For the Monitoring of our Environment from Space and Earth". As an example, cultivated lands are often referred to as a land cover class while agriculture is clearly a land use.

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- Page 7722 line 18 - page 7723 line 9

We agree that these lines about the spatial observation units don't bring relevant information about the core topic of our manuscript. They will be removed.

- Page 7723, lines 18-20

We thank you for your suggestion and agree with it. As mentioned in our answer to the general comments, the manuscript will be re-organized and this new structure will allow emphasizing this issue.

On the one hand, section 3 will be re-written to only focus on the current land cover concept (section 3.1) and the limitations of existing products. In this section 3.2, we will provide additional materials to demonstrate that the most recent global land cover products don't ensure stability and consistency over time. More specifically, stability analyses of successive global land cover products will be performed to characterize the classification artifacts in terms of surface (number of pixels with a different label between 2 successive maps) and of change trajectories.

On the other hand, section 4 will be completely re-worked to present the EO experiment as an attempt of the CCI Land Cover project to address this "stability" issue.

- Page 7723, lines 23-24

We will follow your recommendation and remove this figure 3. In parallel, a short paragraph will be added to present the GlobCover classification process. However, we prefer keeping it rather short as this is not the subject of this paper. We will therefore mention existing publications about the GlobCover project.

- Page 7724, lines 4-21

We thank you for this interesting suggestion and will try to build a little more our conclusion.

On the one hand, areas where most classification instabilities are observed will be

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characterized in terms of ecologic and climatic conditions. As for our justification, it can be easily understood that the classification accuracy of classes characterized by contrasting seasonal cycles (agricultural areas, temporary vegetation in desert, forest types, etc.) are highly dependent on the period used to make the classification. For instance, the optimal period to discriminate between croplands and bare areas can be between April and June in year A and between 15 April and 15 June in year B. Inter-annual variations of vegetation indices temporal profiles could be included in the manuscript to illustrate this phenomenon. This kind of shift can also be observed over space (optimal periods varying from place to place).

On the other hand, new material will be added to characterize the variations trajectories over time (i.e. how a pixel is labelled in successive land cover products). These trajectories will show that for unstable pixels (i.e. pixels where no majority label can be derived), variations most often occur between similar land cover classes from the thematic point of view (different types of forests, forest and shrubland, etc.) and that frequent back and forth movements between two classes can be observed. This kind of trajectories is a typical indicator of classification instabilities (and not of land cover change) and could reflect a certain incompatibility between the sensor resolution and the landscape complexity.

- Page 7724 line 28 - page 7725 line 4

If land cover includes the biological cover of the Earth's surface, we must admit that it will exhibit high variability in time. Its status can indeed vary due to phenology, fire regimes, agricultural cycles or particular climatic conditions.

Since land cover maps are generated from few instantaneous observations of the land cover (for instance, a spring season of a particular year), the classification output will be sensitive to the period of observation and could reflect temporary conditions (e.g. map savannahs as burnt scars, boreal forest as snow, croplands as bare soils, etc.). New methodological avenues have to be found to reduce this sensitivity to the observation

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dates and produce maps which don't render seasonal or temporary variations. This is what is attempted in our EO experiment, where we use multi-year SPOT-VGT dataset to generate a single land cover map.

We must admit that this statement should have been presented along with more explanations and justifications. This will be done in the revised manuscript.

- Page 7725, lines 14-27

We thank you for your comment about this paragraph, which shows that our discussion about LCCS evolution is rather confused. "Building blocks" and "objects" referred to semantic concepts to build a legend. They were presented as a possible evolution in the land cover mapping community to increase the flexibility of the land cover classes definition.

Land cover classification problems come from the attempt to classify the infinite variety of landscapes into a limited number of closed classes. Any classification system may be subject to controversy, all the more if they are fixed and precise. In order to avoid - as much as possible - such controversy, a maximum of flexibility in a classification system should be preserved. Contrary to what is feasible with LCCS (which proposes a rather rigid classification system), it would be interesting to develop a classification system made of a very simple group of elements that act as "building blocks" that could be assembled in different ways to describe a more complex semantic in any legend.

This clarification being done, we must admit that there is no clear link in the paper between this paragraph about LCCS flexibility and the climate modellers' requirements. Some lines will be added to explain that increasing the classification system flexibility can help for the legend translation into Plant Functional Types. In addition, we recognize that this discussion does not bring relevant information about the core topic of our manuscript. Accordingly, the discussion about LCCS evolution will be removed and the benefit of classification system flexibility for climate modellers will be moved at the end of the paper (to be presented as a perspective).

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- Page 7726, lines 10-16

Land monitoring at global scale is a critical issue today. As a result, the EO community is required not only to provide a land cover map but also to develop strategies to enable the regular production of consistent global land cover and change maps. In addition to be localized, these changes should be quantified and characterized in terms change trajectories. We see two major factors which make the global change detection analyses so difficult.

The first one is related to the spatial resolution of the sensors used in global scale applications. It ranges from 250m and 1km, which is larger than many land cover changes. As a result, this prevents from any accurate change localization, measurement and characterization in terms of trajectories. Some global change detection products based on Landsat imagery have been released (such as deforestation maps) but they remain rather rare and they are not delivered on a regular basis. In this respect, the next sensor generation - and in particular, Sentinel 2 - could bring significant improvement.

The second constraining factor is a methodological one. To our knowledge, there is currently no recognized change detection method that can perform on a regular basis and over large extents. Most often, regional/global land cover monitoring is achieved through map-to-map comparison or through map updates (e.g. Corine experience). In the first case, the resulting diagnostic remains highly dependent on the maps' accuracy (and it was shown in our study that we should be very cautious with this option). In the second case, it requires long intervals between change maps delivery. We believe that dedicated change detection techniques will be needed, which are based on analysis of reflectance values and not on maps. In particular, over global scale, the methods should benefit from multi-annual time series associated with a high temporal resolution. The two references cited in the text refer to this kind of methodology. We could elaborate a bit more about them.

Technical comments

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- Page 7715, lines 24-28

We agree that this sentence mixes two different ideas. In addition, we also noticed that it reads more like a conclusion. We will therefore separate the two subjects (the interest of using longer time series to improve products' stability over time and the need for more producers-users interactions) and discuss them as conclusions.

As for your question about the "associated dynamics", it was referring to the "dynamic component" of the land cover (vegetation phenology, fire regimes, flooding, cropping cycle, etc.). The text will be clarified in this sense.

- Page 7720, lines 13-14

The text will be edited to make the argument clearer. A first version is provided here below.

"Future requirements for temporal resolution refer to intra-annual and monthly dynamics of land cover; in particular making use of the increasing length and detail of remote sensing time series data".

- Page 7721, lines 6-7 / Page 7722, line 16

The two simplifications will be done in the revised manuscript.

- Page 7722, line 17

The idea behind the "crisp univariate distinction" expression was to show that a rigid classification system (such as LCCS) may cause controversy. Indeed, in order to ensure a clear distinction between the different classes of the legend, LCCS provides a set of land cover descriptors which have been pre-defined with precise thresholds (in terms of vegetation cover, surfaces, vegetation species, etc.). As a result, the legend has to be build based on "universally valid" thresholds which do not necessarily correspond to their application in view.

In our answer to the "Page 7725, lines 14-27" comment, we recognized that this dis-

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cussion about the classification system flexibility was not very relevant with the core topic of our manuscript. It will therefore be removed (or very briefly mentioned in the perspectives) in our revised manuscript.

- Page 7724, line 2

This figure aimed to show that (i) successive land cover maps were produced (which is not a straightforward result) and (ii) that significant differences could be observed between these successive land cover maps despite the fact that they were produced using data from a unique sensor and the same method. We must admit that the second point could be more clearly illustrated and some "zooms" will be added to this end. In addition, the land cover maps legend (classes labels and colors) will be added in the figure.

- Page 7727, line 14

We will consider this recommendation with attention and modify the title of the last section as suggested.

However, we would like to point out that according to the revised paper structure (see our "answer to the general comments" in the beginning of this document), some perspectives (in terms of change detection, validation or legend) will be included in the section 4.

- Page 7727, lines 22-25

The "sensitivity of the land products to the content of the annual time series" refers to the limitations of the current land cover concept and classification approaches (see our answer to the comment "?Page 7724 line 28 - page 7725 line 4"). First, the current standard in terms of legend is not necessarily the most suitable to depict a "stable land cover" since it includes a biological component, which is, by essence, varying over time. With regard to the classification approaches, this sentence aims at pointed out that they only use one year of EO data and could therefore reflect temporary conditions.

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We will pay attention to re-phrase the sentence to clarify our message.

- Page 7728, lines 4-7

This sentence was written with the twofold objective of (i) presenting the huge work achieved with these surveys (hundreds of users were contacted and their answers were analyzed) and (ii) demonstrating the usefulness of such initiative. With the increasing availability of EO dataset, more and more products are (and will be) generated. Interactions between producers and users are a necessity to target the needs of a specific community and therefore ensure the products relevance. We believe this is an important message, all the more since this kind of interactive processes is rather rare.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/8/C3923/2011/bgd-8-C3923-2011-supplement.pdf

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