

The impact of land cover change on regional and global climates

A proposal for a model intercomparison

The impact of land cover change (LCC) has been explored extensively with a detailed assessment of regional scale impacts of tropical deforestation (e.g. Henderson-Sellers et al., 1993; Polcher and Laval, 1994; Lean and Rowntree, 1997; Costa and Foley, 2000; Zhang et al. 2001a), temperature deforestation (Bonan et al., 1992; Hansen et al., 1998; Betts, 2001), and desertification (Xue, 1997; Nicholson et al., 1998). More recently, groups have explored the more general question of land cover change and its impact on climate. Initial attempts using estimates of change in LAI using NDVI (e.g. Nemani et al., 1996; Chase et al., 1996) were replaced by various estimates of the change in land cover in general (from Ramankutty and Foley, 1998; Goldewijk, 2001).

There are now a vast array of independent estimates of the impact of LCC on the Earth's climate using a suite of models, performed in different ways and subjected to various levels of analysis. Some of these point to large and statistically significant continental-scale changes in temperature, rainfall and other variables as a result of LCC (e.g. Chase et al., 1996, 2000; Betts, 2000; Zhao et al., 2001a,b, deFries et al., 2002; Bounoua et al., 2002). Some suggest evidence of large-scale atmospheric adjustment caused by regional-scale perturbations, leading to geographically remote changes in temperature and precipitation (Chase et al., 1996, 2000; Gedney and Valdes, 2000; Zhao et al., 2001a,b). Very recent work suggests that LCC may affect extremes in temperature (Collatz et al., 2000) and precipitation (Zhao and Pitman, 2002). EMICs have also been used for longer time scale projects (e.g. Claussen et al., 1998; 2001; Brovkin et al., 1999).

A problem with almost all of these experiments is that they are not done in a way that the outcomes are robust. While the IPCC (2001) report points to the possible *regional* impact of LCC, some are interpreting results from the models as clear evidence of the *global* scale impact of LCC. There is a view that the teleconnections seen in some of the models are robust. Certainly, a significant community dismisses the impact of LCC (a) because they only consider the radiative impact; and (b) because they see any remote effects of LCC as 'model variability'. This might be true or not - but it is something that we need to know more confidently.

There are problems with the experimental design of each and every attempt to explore the climatological effect of LCC using global climate models (including the ones I ran):

- Many use short (<20-year) simulations for natural and current vegetation;
- Most perform single realizations;
- Many perform standard t-tests that do not account for the autocorrelation in the data;
- Spatial resolution tends to be quite coarse.

If there are published examples of LCC experiments that do not suffer from any of these limitations then they are rare and it would be useful to know how general those results might be. It is beyond the community's capacity to perform the suite of experiments that would address all of these issues in a single modelling experimental design. However, we can proceed step-by-step to deal with some of the methodological problems. We wish to conduct a suite of experiments that:

- use a common land cover perturbation (translated into parameter changes by individual groups). We will first use historical land cover change, but we might also encourage a future scenario run;

- perform AMIP-2 length simulations, using the AMIP-2 experimental design;
- perform multiple realizations with each model (5-10);
- use appropriate statistics to determine whether there are regional impacts of LCC.

We are concerned regarding the teleconnection issue - we appreciate that using fixed SSTs will limit the variability in the models and affect the results. However, the advantage is a relatively straightforward experimental design, one using a methodology used many times before (AMIP-2) and one with a pre-defined output standard that will ease analysis. Further, mechanisms that have been hypothesized to support teleconnections should be robust to the type of ocean model included.

Participants include Hansen, Dirmeyer, Pitman, Pielke, Chase, Douville, Xue, Wang, Bonan, Betts, Koster, de Noblet, deFries, Claussen. If 50% of these complete the experiments we will have a good selection of models.

Land cover data

Our suggested approach is to impose a prescribed area of land cover change onto each models (time-invariant) natural vegetation field. This area of land cover change will represent 1860 (or 1900) and the present day. A future scenario reflecting 2050 may also be available. We cannot attempt to genuinely and accurately reflect what actually happened in terms of land cover change over the 20th Century (Vivek Aroro's comments here are obviously pertinent). What we can do is attempt to define a set of very simple rules such that everyone's land cover perturbation is similar.

Both Richard Betts and Nathalie de Noblet have agreed to provide global geographies of crops and pasturelands for each timeslice. It would also be wise to agree on the natural vegetation pattern so we impose a common perturbation on to a common land cover field. Richard has volunteered to provide natural vegetation from the IGBP-DIS classes that we can then map onto the PFTs used in individual models. Nathalie has natural vegetation divided into 11 natural PFTs. Either of these would be suitable and perhaps the 11-PFT classification aids simplicity but we would welcome advice from GLASS.

An outstanding issue is that this only deals with crops rather than land cover change in general - but maybe that is good enough.

Statistics

We seek advice on the most appropriate statistical methods to use to examine the statistical significance of any changes. We plan to talk to individuals like Francis Zwiers.

Timelines

Data sets available by November/December 2004

Simulations performed by October 2005

Analysis over the subsequent six months.

All data should be in AMIP-2 format and will be made available to those providing data.

Andy Pitman, 8 September, 2004

The reference list is not intended as a complete list. However please e-mail me any references that are missing - the suggestion by Ruth deFries of a review paper seems sensible and we need a complete a list to start from]

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