Seventh Framework Programme
Theme 9 Space FP7-SPA.2009.1.1.02
Monitoring of climate change issues (extending core service activities)

Grant agreement for: Collaborative Project (generic).
Project acronym: **MONARCH-A**
Project title: **MONitoring and Assessing Regional Climate change in High latitudes and the Arctic**
Grant agreement no. 242446
Start date of project: 01.03.10
Duration: 36 months
Project coordinator: Nansen Environmental and Remote Sensing Center, Bergen, Norway

D1.4.2: Land cover maps transformed into forms suitable for carbon, water and climate modeling.

Due date of deliverable: 31.05.2011

Actual submission date: 20.06.2011

Organization name of lead contractor for this deliverable: The University of Sheffield - USFD

Project co-funded by the European Commission within the Seventh Framework Programme, Theme 6 Environment		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

ISSUE	DATE	CHANGE RECORDS	AUTHOR
1	20/06/2011	Report	E. Kanzas
2	31707/2011	Minor revision of layout	K. Lygre

SUMMARY

This report forms part of MONARCH-A Work Package 1.4: *Land Cover & Fire and their representations in models* and Deliverable D1.4.2: *Land cover maps transformed into forms suitable for carbon, water and climate modeling*. It is the continuation of the report prepared for Deliverable D1.4.1 and the reader is advised to consult that document before proceeding with the one at hand.

Most climate models dealing with land processes require land cover maps as inputs. These maps are usually derived from satellite data, with the most prominent products being MODIS MCD12C1, Global Land Cover 2000, MODIS MOD44B and GlobCover; The aim of the current report is to: a) transform these land cover maps into a file format and resolution suitable for climate modeling and b) demonstrate how the user can combine these products in order to obtain a more accurate depiction of the land surface, which can subsequently be used as an input to a carbon or climate model.

The transformed land cover maps created in the context of this deliverable are available for download in NetCDF format (0.5^{o}) at the anonymous
ftp: ftp://ftp.shef.ac.uk/pub/uni/projects/ctcd/MonarchA/D1.4.2_Data_Sets/.

MONARCH-A CONSORTIUM

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Nansen Environmental and Remote Sensing Center	NERSC	NO
2	The University of Sheffield	USFD	UK
3	Universität Hamburg	UHAM	NO
4	Centre National de la Recherche Scientifique	CNRS	FR
5	Scientific foundation Nansen International Environmental and Remote Sensing Center	NIERSC	RU
6	Universitetet i Bergen	UiB	NO
7	Danmarks Tekniske Universitet	DTU	DK
8	Institut Francais de Recherche pour l'Exploitation de la Mer	IFREMER	FR

Table of Contents

List of Figures

List of Tables

1 Introduction

This report forms part of MONARCH-A Work Package 1.4: *Land Cover & Fire and their representations in models* and Deliverable D1.4.2: *Land cover maps transformed into forms suitable for carbon, water and climate modeling*. It is the continuation of the report prepared for Deliverable D1.4.1: *Analysis of available land cover and fire products, their trends and uncertainties, preferred products, and recommendations for combining different products for best use in climate models*, and the reader is advised to consult that document before proceeding with the one at hand.

Most climate models dealing with land processes require land cover maps as inputs. These maps are usually derived from satellite data, with the most prominent products being MODIS MCD12C1, Global Land Cover 2000, MODIS MOD44B and GlobCover; their main characteristics are described in the panels below and the classes they use are given in Table 1. We also describe in the third panel the MODIS-VCF product which has different properties, as described in Section 3. In the report for Deliverable D1.4.1 we demonstrated how different land cover products, when fed into a model, can affect its carbon- and water-related outputs. We also presented a novel approach which combined different products in order to acquire a more representative land cover map.

The aim of the current report is to: a) transform these land cover maps into a file format and resolution suitable for climate modeling and b) demonstrate how the user can combine these products in order to obtain a more accurate depiction of the land surface, which can subsequently be used as an input to a carbon or climate model.

2 Land cover data sets

All of the land cover data sets mentioned above are free to download from their respective sources but are offered in file formats and spatial resolutions that render them impractical for use in models. In the framework of MONARCH-A we transformed them into NetCDF format and downgraded the resolution to 0.5° degrees, a form suitable for land components of climate models. Brief descriptions of the data sets are given below, along with links from which they can be obtained in their original format and resolution. To obtain the data sets as prepared for MONARCH-A please follow the anonymous ftp link:

ftp://ftp.shef.ac.uk/pub/uni/projects/ctcd/MonarchA/D1.4.2_Data_Sets/

1) MODIS Product MCD12C1 (MODIS LC)

Description: Land cover obtained by the MODIS instrument on-board the Terra and Aqua satellites. By using a decision tree, pixels are classified into 17 classes defined according to the International Geosphere Biosphere Programme (IGBP).

Spatial Resolution: Global coverage at 0.05 degrees

Temporal Resolution: Monthly, 2001-2007.

Available Format: HDF-EOS.

Obtained From: https://lpdaac.usgs.gov/

MONARCH Availability: Global coverage at 0.5 degrees for year 2001 in NetCDF format.

2) Global Land Cover 2000 (GLC2000)

Description: Obtained from the VEGETATION instrument on-board the SPOT-4 satellite. Pixels are classified into 23 classes based on the Land Cover Classification System (LCCS) by the Food and Agriculture Organization (FAO).

Spatial Resolution: Global coverage at 0.009 degrees (~1 km at equator).

Temporal Resolution: Annually, 2000.

Available Format: Binary/TIFF/ESRI/IMG.

Obtained From: http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php

MONARCH Availability: Global Coverage at 0.5 degrees for year 2000 in NetCDF format.

3) MODIS Product MOD44B (MODIS VCF)

Description: Vegetation Continuous Fields (VCF) obtained by the MODIS instrument on-board the Terra and Aqua satellites. By observing the salient points in the phenological cycle, each pixel is assigned with a percentage of tree, herbaceous vegetation and bare ground coverage.

Spatial Resolution: Global coverage at ~0.0045 degrees

Temporal Resolution: Annually, 2001.

Available Format: TIFF.

Obtained From: http://www.landcover.org/data/vcf/

MONARCH Availability: Global Coverage at 0.50 degrees for year 2001 in NetCDF format.

4) GlobCover

Description: Acquired with MERIS sensor on-board the ENVISAT satellite. Pixels are classified into 23 classes based on the Land Cover Classification System (LCCS) by the Food and Agriculture Organization (FAO).

Spatial Resolution: Global coverage at 300 m.

Temporal Resolution: Annually, 2005 & 2009.

Available Format: GeoTIFF.

Obtained From: http://ionia1.esrin.esa.int/

MONARCH Availability: Global coverage at 0.5 degrees for years 2005 and 2009 in Netcdf format.

A

Class/Data Set:	MODIS LC
1	Evergreen Needleleaved Forest
2	Decidious Needleleaved Forest
3	Evergreen Broadleaved Forest
4	Decidious Broadleaved Forest
5	Mixed Forest
6	Closed Shrublands
7	Open Shrublands
8	Woody Savannas
9	Savannas
10	Grasslands
11	Permanent Wetlands
12	Croplands
13	Urban & Built Up
14	Cropland Natural Vegetation Mosaic
15	Snow & Ice
16	Barren Or Sparsely Vegetated
17	Water

B

Class/Data Set:	GLC2000
1	Tree Cover,Broadleaved Evergreen
2	Tree Cover,Broadleaved Deciduous,Closed
3	Tree Cover,Broadleaved Deciduous,Open
4	Tree Cover,Needleleaved Evergreen
5	Tree Cover,Needleleaved Deciduous
6	Tree Cover,Mixed Leaf Type
7	Tree Cover, Regularly Flooded,Fresh
8	Tree Cover, Regularly Flooded,Saline
9	Mosaic:Tree Cover/Other Natural Vegetation
10	Tree Cover,Burnt
11	Shrub Cover,Closed-open,Evergreen
12	Shrub Cover,Closed-open,Deciduous
13	Herbaceous Cover,Closed-open
14	Sparse Herbaceous or Sparse Shrub Cover
15	Regularly Flooded Shrub and/or Herbaceous Cover
16	Cultivated and Managed Areas
17	Mosaic:Cropland/Tree Cover/Other Natural Vegetation
18	Mosaic:Cropland/Shrub and/or Herbaceous Cover
19	Bare Areas
20	Water Bodies(Natural and Artificial)
21	Snow and Ice(Natural and Artificial)
22	Artificial Surfaces and Associated Areas
23	No Data

C

Class/Data Set:	GlobCover
1	Post-flooding or irrigated croplands (or aquatic)
2	Rainfed croplands
3	Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)
4	Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)
5	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)
6	Closed (>40%) broadleaved deciduous forest (>5m)
7	Open (15-40%) broadleaved deciduous forest/woodland (>5m)
8	Closed (>40%) needleleaved evergreen forest (>5m)
9	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)
10	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)
11	Mosaic forest or shrubland (50-70%) / grassland (20-50%)
12	Mosaic grassland (50-70%) / forest or shrubland (20-50%)
13	Closed to open (>15%) (broadleaved or needleleaved, evergreen or deciduous) shrubland (<5m)
14	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)
15	Sparse (<15%) vegetation
16	Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily)
17	Closed (>40%) broadleaved forest or shrubland permanently flooded - Saline or brackish water
18	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil
19	Artificial surfaces and associated areas (Urban areas >50%)
20	Bare areas
21	Water bodies
22	Permanent snow and ice
23	No data (burnt areas, clouds,...)

Table 1: Land cover classes in A: MODIS MCD12C1 product (MODIS LC), B: Global Land Cover (GLC2000) and C: GlobCover.

3 Combining Land Cover Products

As mentioned in the report for the deliverable D1.4.1, even though the MODIS MOD44B Vegetation Continuous Field (VCF) product falls into the general category of land cover data sets, it is unique with regard to its classes and their unit of measurement. Whereas other land cover products use the "dominant class" approach, VCF gives to each pixel a percentage of tree, herbaceous and bare ground cover. For example, if a pixel in the GLC2000 classification is assigned to the Evergreen Needleleaved class, this does not necessarily mean that all its area is covered by Evergreen Needleleaved forest. Instead, it implies that, out of all the available classes, Evergreen Needleleaved occupies the largest fraction of the surface, and no knowledge is passed to the user on what exists in the remaining area. The resulting errors are likely to reduce as we approach higher spatial resolutions, thus more uniform cover, but they are bound to exist at present resolutions of approximately 500m x 500m. VCF, on the other hand, observes salient points in the phenological cycle and assigns to each pixel a fraction of just three cover types: tree, herbaceous and bare cover. It therefore completely lacks the more detailed layers of information in the other land cover products, but it can depict more accurately the generic types of cover. Similarly to the report of the D1.4.1 deliverable, we will demonstrate how a typical "most dominant class" approach can be combined with the VCF product to create a more accurate land cover map for use with the land components of climate models.

The approach will be exemplified using the Sheffield Dynamic Global Vegetation Model (SGDVM) whose structure is typical of the land component of large-scale carbon and climate models (for example, see Cranmer et al., 2001). It incorporates 7 Plant Functional Types (PFTs), viz. 4 tree PFTs: evergreen broadleaf, evergreen needleleaf, deciduous broadleaf and deciduous needleleaf (Ev_Bl, Ev_Nl, Dc_Bl, Dc_Nl); 2 herbaceous PFTs (grass and crop); and a bare ground pseudo-PFT. To run the model, the user must provide as input a land cover map with these model-specific PFTs as classes. This requires the classes in the land cover products to be converted to the model-defined PFTs. For this particular example we will convert MODIS LC classes into SDGVM PFTs; note that this methodology can be employed for any of the different land cover products and model-specific PFTs described in the report for the D1.4.1 deliverable.

Table 2 shows the mapping between the 16 land classes of MODIS LC and the 7 PFTs of SGDVM for latitudes greater than 50°. For example, a pixel which in MODIS LC appears as Mixed Forest (Class 5) is converted into SDGVM PFTs as 50% Deciduous Broadleaf and 50% Evergreen Needleleaf Forest. Figure 1 shows the fractional coverage for each PFT according to this conversion, under the label MODIS LC-SDGVM PFT. Note that production of these maps at the model 0.5^{o} grid-cell scale requires amalgamation of pixels from the much finer scale of the pixels in the land cover products.

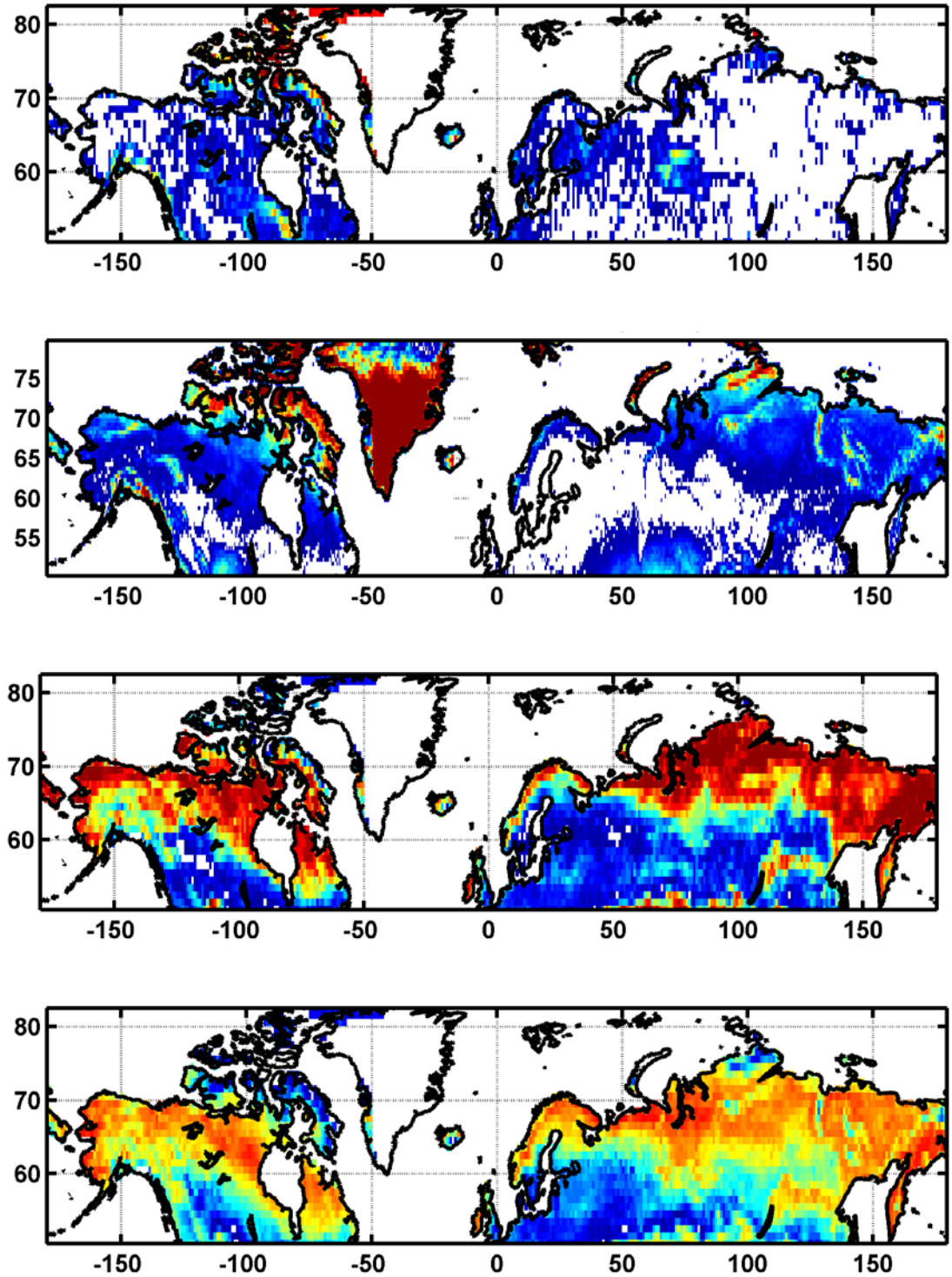
After mapping this initial classification (which need not necessarily be from MODIS) onto the SDGVM PFTs, the VCF data can be used to adjust the fractions of tree, herbaceous and bare ground, whilst maintaining the relative proportions of the contributing PFTs in the original classification. For example, if a grid-cell was populated by 60% Evergreen Needleleaf, 20% Deciduous Needleleaf and 20% grass PFTs, as determined by transforming MODIS LC into model PFTs, and VCF indicates that

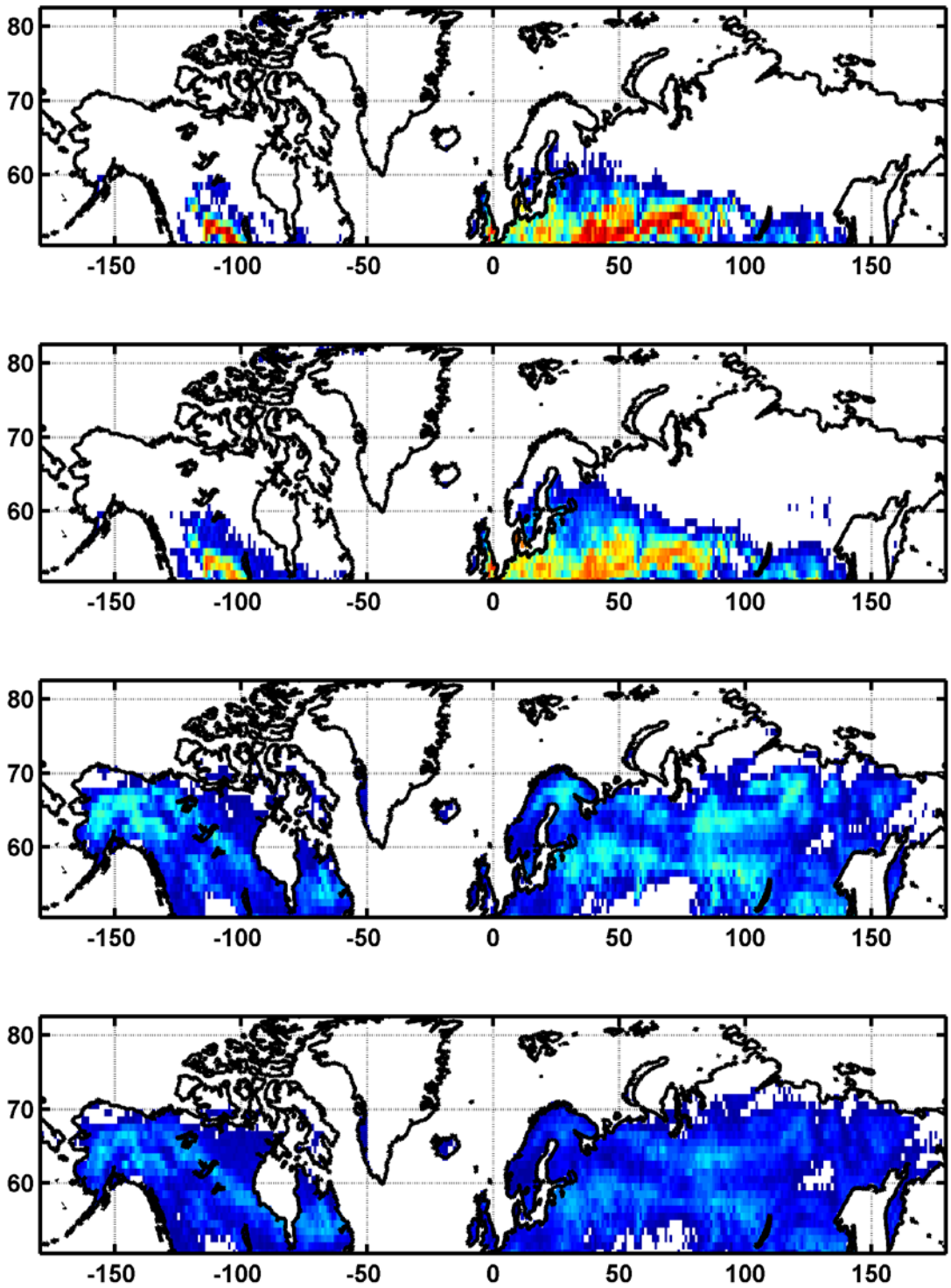
the grid-cell was made up of 70% forest and 30% herbaceous, then the MODIS LC/MODIS VCF product would assign 52.5% of the grid-cell to Evergreen Needleleaf, 17.5% to Deciduous Needleleaf and 30% to grass. The results of this correction can be seen in Fig. 1 under the label MODIS LC/MODIS VCF-SDGVM PFT, while the total pan-Arctic percentage of each PFT according to the two conversions is shown in Fig. 2. Further information and analysis on how the conversion affects model outputs is provided in the report for deliverable D.1.4.1.

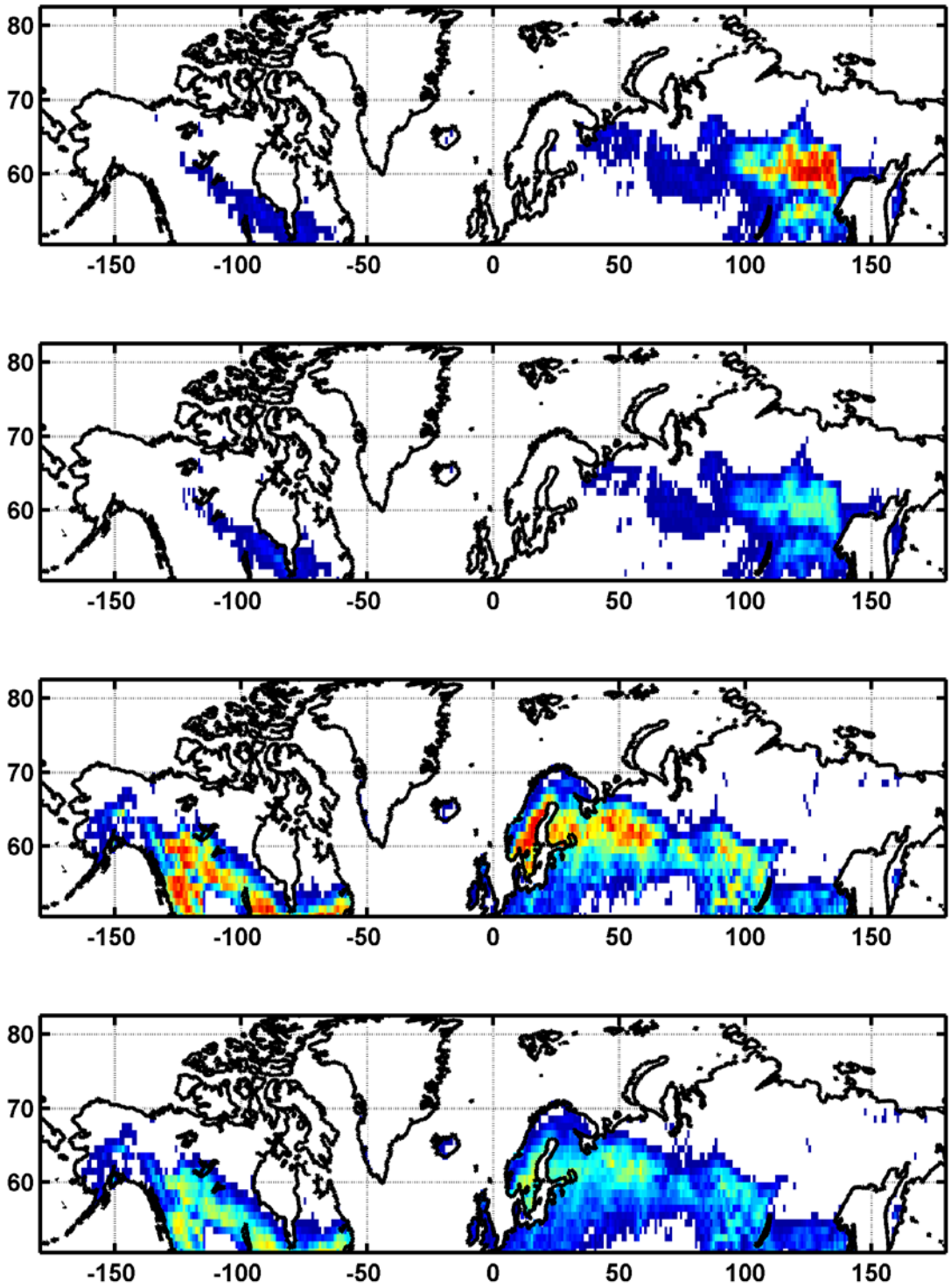
Class	MODIS LC	SDGVM PFT
1	Evergreen Needleleaved Forest	100% Ev_NL
2	Deciduous Needleleaved Forest	100% Dc_NL
3	Evergreen Broadleaved Forest	100% Ev_Bl
4	Deciduous Broadleaved Forest	100% Dc_Bl
5	Mixed Forest	50% Dc_Bl, 50% Ev_Nl
6	Closed Shrublands	100% Grass
7	Open Shrublands	100% Grass
8	Woody Savannas	50% Dc_Bl, 50% Grass
9	Savannas	30% Dc_Bl, 70% Grass
10	Grasslands	100% Grass
11	Permanent Wetlands	100% Bare
12	Croplands	100% Crop
13	Urban & Built Up	100% Bare
14	Cropland Natural Vegetation Mosaic	50 Crop, 50 Grass
15	Snow & Ice	100 Bare
16	Barren or Sparsely Vegetated	100 Bare
17	Water	100 Bare

Table 2: Mapping from MODIS LC to SDGVM PFT.

Figure 1: Fractional coverage by SDGVM PFTs following conversion from MODIS LC and after combining MODIS LC with MODIS VCF.




80
70
60
-150
-100
-50
0
50
100
150


80
70
60
-150
-100
-50
0
50
100
150

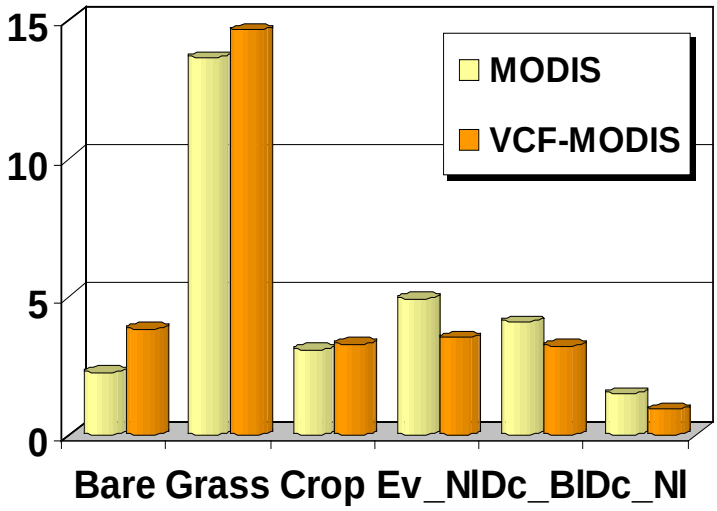


Figure 2: SDGVM PFT fractional cover for MODIS LC and MODIS LC/MODIS VCF (%).

4 Conclusions

In this report we have presented a method for transforming land cover data sets into a format suitable for land components of climate models. It consists of three steps:

1. The original land cover data, typically at resolutions between 300 m and 1 km, is amalgamated to the scale of the climate grid-cell. We have assumed that the appropriate scale is 0.5°. For each of the land cover datasets considered, these amalgamated data are available for download in NetCDF format at the anonymous ftp: ftp://ftp.shef.ac.uk/pub/uni/projects/ctcd/MonarchA/D1.4.2_Data_Sets/. At this stage they retain their original classification scheme.
2. These data must now be transformed to the particular set of PFTs used by a given model. This involves *user-defined* rules about how this transformation is to be effected, given the description of the PFTs and the individual land cover classes supplied by the products. The rules we have used to transform MODIS-LC to SDGVM PFTs are indicated in Table 2; it will be seen that some of these are to some extent subjective, particularly when there are composite classes, such as "mixed forest". Because different users may elect for different rules, different models use different PFTs and different land cover products use different classes, we do not impose any transformations in the datasets supplied.
3. The biases in the original data due to specifying land cover by dominant classes will still be present in the amalgamated data produced in step 1, and will propagate through step 2. Correction of these biases can be achieved by combining the data produced after step 2 with VCF data. We described the approach for carrying out this conversion, which requires only simple scaling of the 0.5° PFT data using the 0.5° VCF data supplied to the database. This step is important, as it can have a significant effect on water and carbon fluxes calculated by climate models. Although not investigated in the report for the deliverable D1.4.1, it is also likely to have important consequences for energy fluxes.

5 References

Cramer W, Bondeau A, Woodward FI *et al.* (2001) Global response of terrestrial ecosystem structure and function to CO_2 and climate change: results from six dynamic global vegetation models. *Global Change Biology*, **7**, 357-373.

Lomas M, Kantzas EP, Quegan S (2011) MONARCH-A, Deliverable D1.4.1: Analysis of available land cover and fire products, their trends and uncertainties, preferred products, and recommendations for combining different products for best use in climate models. MONARCH-A, FP7-SPA.2009.1.1.02

END OF DOCUMENT