Soil Moisture Active Passive (SMAP)

Ancillary Data Report

Landcover Classification

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Seungbum Kim
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA

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Jet Propulsion Laboratory
California Institute of Technology

Preface

The SMAP Ancillary Data Reports provide descriptions of ancillary data sets used with the science algorithm software in generation of the SMAP science data products. The Ancillary Data Reports may undergo additional updates as new ancillary data sets or processing methods become available. The most recent versions of the ancillary data reports will be made available, along with the Algorithm Theoretical Basis Documents (ATBDs), at the SMAP web site http://smap.jpl.nasa.gov/science/dataproducts/ATBD/.

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1 Overview

1.1 Purpose

The purpose of this report is to describe a landcover classification ancillary data set to be used for generating SMAP science data products. The landcover classification dataset is one of a suite of ancillary datasets required by the SMAP science processing algorithms. The algorithms and ancillary data are described in SMAP algorithm theoretical basis documents (ATBDs) and ancillary data reports. The ATBDs and ancillary data reports are listed in Appendices A and B and are available at the SMAP web site http://smap.jpl.nasa.gov/science/dataproducts/ATBD/.

1.2 Requirement

Landcover classification information is needed as input to the SMAP L2-L4 algorithms. Although it is not technically required that all algorithms use the same landcover data set, it may be desirable because several algorithm parameters are based upon tables associate with land cover. Using different landcover datasets and classification schemes could introduce artifacts into the soil moisture retrievals and result in inconsistencies between products. In this report the focus is on recommending a dataset for the L2 and L3 soil moisture algorithms.

The L2_SM_P and L2_SM_AP soil moisture retrieval algorithms are based on the tau-omega model. Input parameters required for this model are provided in a tabular form for each land cover class. These parameters include the effective roughness of the bare soil surface, vegetation single-scattering albedo, a vegetation water content (VWC) function, and a vegetation parameter to convert vegetation water content to opacity (Crow et al., 2005). The L2_SM_A algorithm inverts a forward radar scattering model using a lookup table or "data cube" representation (Kim et al., 2011). Scattering models have been developed for a number of distinct land surface classes depending on vegetation cover. The landcover classification dataset is used to guide the algorithm selection of appropriate scattering model and incorporation of VWC for the soil moisture retrieval.

The choice of scattering model for a given 3-km radar soil moisture retrieval pixel depends on the dominant land cover in that pixel. As will be discussed below the classification scheme of the International Geosphere-Biosphere Programme (IGBP, Belward, 1996) is currently considered to be the best primary source of landcover class information for SMAP. In the IGBP land cover scheme, a single class is allocated to represent all landcover types, including a single class for crops. However, it is known that radar backscattering signatures differ significantly according to crop type, due for example to the relative importance of stems in corn and leaves in soybeans. Thus, additional information on crop type is necessary to characterize the vegetation scattering and improve the soil moisture retrieval. This information is provided a separate ancillary data set described in the Crop Type ancillary data report (Kim et al., 2012).

2 Selection and Description of Primary Dataset

2.1 Dataset Descriptions

The SMAP team identified a number of candidate landcover datasets for consideration. These are listed in Table 1.

Table 1. List of candidate landcover datasets.

Dataset Name	Spatial resolution	Temporal resolution	Number of classes
MODIS_IGBP	500 m	Annual	17
MODIS_UMD	500 m	Annual	14
MODIS_NPP (Net Primary Production)	500 m	Annual	9
MODIS_LAI/FPAR (Leaf Area Index and Fraction of Photosynthetically Active Radiation)	500 m	Annual	11
MODIS_PFT (Plant Functional Type)	500 m	Annual	12
AVHRR_UMD	1 km	1981-1994	14
SPOT_IGBP	1 km	1998-1999	17
ECOCLIMAP	1 km	One time	215 Europe 17 World
Global Land Cover Characteristics Data Base (USGS)	1km	Seasonal 1992-1993	94

(MODIS is the Moderate Resolution Imaging Spectroradiometer.)

The datasets listed in Table 1 are global in coverage and are characterized by their source data (e.g., MODIS) and classification scheme (e.g., International Geosphere-Biosphere Programme, IGBP). Other classification schemes are to a large extent subsets of the IGBP scheme, except for the ECOCLIMAP and the Global Land Cover Characteristics Data Base.

The ECOCLIMAP (Masson et al., 2003) is used by the ECMWF (European Centre for Medium-Range Weather Forecasts) forecast model and the SMOS (Soil Moisture Ocean Salinity) mission soil moisture retrieval. The ECOCLIMAP provides 215 classes within Europe. The sources of the European classification data are CORINE (Coordination of Information on the Environment) and Pan-European Land Cover Monitoring (PELCOM). Outside Europe the IGBP-DIS Global Land Cover Characteristics Database is used (Loveland et al., 2000).

The Global Land Cover Characteristics Data Base is provided by the United States Geological Survey (USGS) and is derived using one year of AVHRR NDVI data (http://edc2.usgs.gov/glcc/globdoc2_0.php). This land cover dataset is used for the SMAP Level 4 soil moisture product. The SMAP Level 4 carbon product on the other hand uses the MODIS IGBP dataset.

2.2 Dataset Selection

Evaluation of the datasets listed in Table 1 led to the conclusion that the MODIS_IGBP dataset is the most suitable for SMAP use, based on the following criteria:

a) spatial resolution (<= 1 km)
b) temporal updates
c) class diversity
d) classification accuracy

MODIS-derived products offer the best spatial resolution and annual updates. The annually updated MODIS-IGBP files at 500 m resolution are available through http://lpdaac.usgs.gov. The ECOCLIMAP has 215 classes over Europe and the Global Land Cover Characteristics Data Base offers 94 classes. Because classifying land cover into 215 and 94 categories relies on visual inspection and significant manual supervision and is hard to perform every year, these products are static. The IGBP scheme provides a diverse set of classes and annual updates. Furthermore, it is unlikely that the SMAP algorithms can effectively make use of such a large number of classes.

The IGBP land cover classification scheme was developed during a series of meetings of the IGBP Land Cover Working Group held through 1995. The final agreement was to generate 17 classes to meet the needs of the IGBP core science projects (climate, carbon cycle, and others) (Belward, 1996). The following criteria were used in selecting the classes: ground biomass (perennial vs. annual), leaf longevity (evergreen or deciduous), and leaf type (broad or needle). Possible combinations of these three criteria result in six fundamental classes (evergreen broadleaf, evergreen needleleaf, deciduous broadleaf, deciduous needleleaf, broadleaf annual, grass). These classes were further modified to be compatible with classification systems used at the time for environmental modeling, to represent landscape mixtures and mosaics, and where possible to provide land use implications. The final definitions of the 17 IGBP classes are shown in Table 2.

The percentage of subpixel classes and the identity of minor classes within a pixel are not clearly defined in Table 2. The rough percentages for the subpixel mixture for each IGBP class are the best information available. A precise value for the percentage, instead of the overall range of the value, is not feasible because of natural diversity and the desire to keep the number of classes at a reasonable level.

To help identify the species comprising the minor classes within 1 km, additional information is summarized in Table 3. Based on this table, the following observations were made

- Leaf types for the woody savannas are grass, broad and needle leaf. This suggests that the woody savanna class consists of trees (woody), shrubs (woody), and grass. Furthermore their leaf longevity indicates that the canopy can be either evergreen or deciduous.
- Savanna understory is typically herbaceous.
- Closed shrubland is homogeneous shrubs. All the vegetation is low.
- Open shrubland will generally have herbaceous and bare soil understory.

Further information is not available on how exactly the subpixel mixture is defined: e.g., which minor classes explain 40% of non-forest species for the evergreen broadleaf class.

Table 2. Definition of the IGBP classification scheme (Strahler et al. 1999).

Natural Vegetation	
Evergreen Needleleaf Forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 meters. Almost all trees remain green all year. Canopy is never without green foliage.
Evergreen Broadleaf Forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 meters. Almost all trees and shrubs remain green year round. Canopy is never without green foliage.
Deciduous Needleleaf Forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 meters. Consists of seasonal needleleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
Deciduous Broadleaf Forests	Lands dominated by woody vegetation with a percent cover >60% and height exceeding 2 meters. Consists of broadleaf tree communities with an annual cycle of leaf-on and leaf-off periods.
Mixed Forests	Lands dominated by trees with a percent cover >60% and height exceeding 2 meters. Consists of tree communities with interspersed mixtures or mosaics of the other four forest types. None of the forest types exceeds 60% of landscape.
Closed Shrublands	Lands with woody vegetation less than 2 meters tall and with shrub canopy cover >60%. The shrub foliage can be either evergreen or deciduous.
Open Shrublands	Lands with woody vegetation less than 2 meters tall and with shrub canopy cover between 10-60%. The shrub foliage can be either evergreen or deciduous.
Woody Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 30-60%. The forest cover height exceeds 2 meters.
Savannas	Lands with herbaceous and other understory systems, and with forest canopy cover between 10-30%. The forest cover height exceeds 2 meters.
Grasslands	Lands with herbaceous types of cover. Tree and shrub cover is less than 10%.
Permanent Wetlands	Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water.
Developed and Mosaic Lands	
Croplands	Lands covered with temporary crops followed by harvest and a bare soil period (e.g., single and multiple cropping systems). Note that perennial woody crops will be classified as the appropriate forest or shrub land cover type.
Urban and Built-Up Lands	Land covered by buildings and other man-made structures.
Cropland/Natural Vegetation Mosaics	Lands with a mosaic of croplands, forests, shrubland, and grasslands in which no one component comprises more than 60% of the landscape.
Non-Vegetated Lands	
Snow and Ice	Lands under snow/ice cover throughout the year.
Barren	Lands with exposed soil, sand, rocks, or snow and never has more than 10% vegetated cover during any time of the year.
Water Bodies	Oceans, seas, lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies.

Table 3. Land cover canopy characteristics (Belward 1996).

LANDCOVERTYPE	VEGETATION STRUCTURE	LEAF LONGEVITY	LEAF TYPE	PERCENT WOODY	WOODY HEIGHT
Evergreen Needleleaf Forests	Woody	>1 year	Needleleaf	>60%	>2 meters
Evergreen Broadleaf Forests	Woody	>1 year	Broadleaf	>60%	>2 meters
Deciduous Needleleaf Forests	Woody	<1 year	Needleleaf	>60%	>2 meters
Deciduous Broadleaf Forests	Woody	<1 year	Broadleaf	>60%	>2 meters
Mixed Forests	Woody	Either <1 or >1 year	Broadleaf and Needleleaf	>60%	>2 meters
Closed Shrublands	Woody	Either <1 or >1 year	Broadleaf or Needleleaf	>60%	<2 meters
Open Shrublands	Woody	Either <1 or >1 year	Broadleaf or Needleleaf	10-60%	<2 meters
Woody Savannas	Woody /Non-Woody	Either <1 or >1 year	Grass, Needle- or Broadleaf	30-60%	>2 meters
Savannas	Woody /Non-Woody	Either <1 or >1 year	Grass, Needle- or Broadleaf	10-30%	>2 meters
Grasslands	Non-Woody	Either <1 or >1 year	Grass	<10%	<2 meters
Permanent Wetlands	Woody /Non-Woody	Either <1 or >1 year	Grass, Needle- or Broadleaf	0-100%	Either <2 or >2 meters
Croplands	Non-Woody	<1 year	Broadleaf or Grass	<10%	<2 meters
Urban and Built-up	N/A	N/A	N/A	N/A	N/A
Cropland/Natural Vegetation Mosaics	Woody /Non-Woody	Either <1 or >1 year	Grass, Needle- or Broadleaf	<60%	Either <2 or >2 meters
Snow and Ice	N/A	N/A	N/A	N/A	N/A
Barren	N/A	N/A	N/A	N/A	N/A
Water Bodies	N/A	N/A	N/A	N/A	N/A

3 Processing

An example of the MODIS IGBP dataset map, and the coverage of each class as a percentage of the global land are, are given in Figure 1 and Table 4, respectively. The derived landcover classification datasets developed for use by SMAP were produced at the EASE-grid 1, 3, 9, and 36 km resolutions. The processing ingests the source data and selects the dominant class within each grid resolution cell. 'Dominant' refers to the class that has the largest number of 500 m native resolution pixels over a year within each 1, 3, 9, and 36 km grid cell.

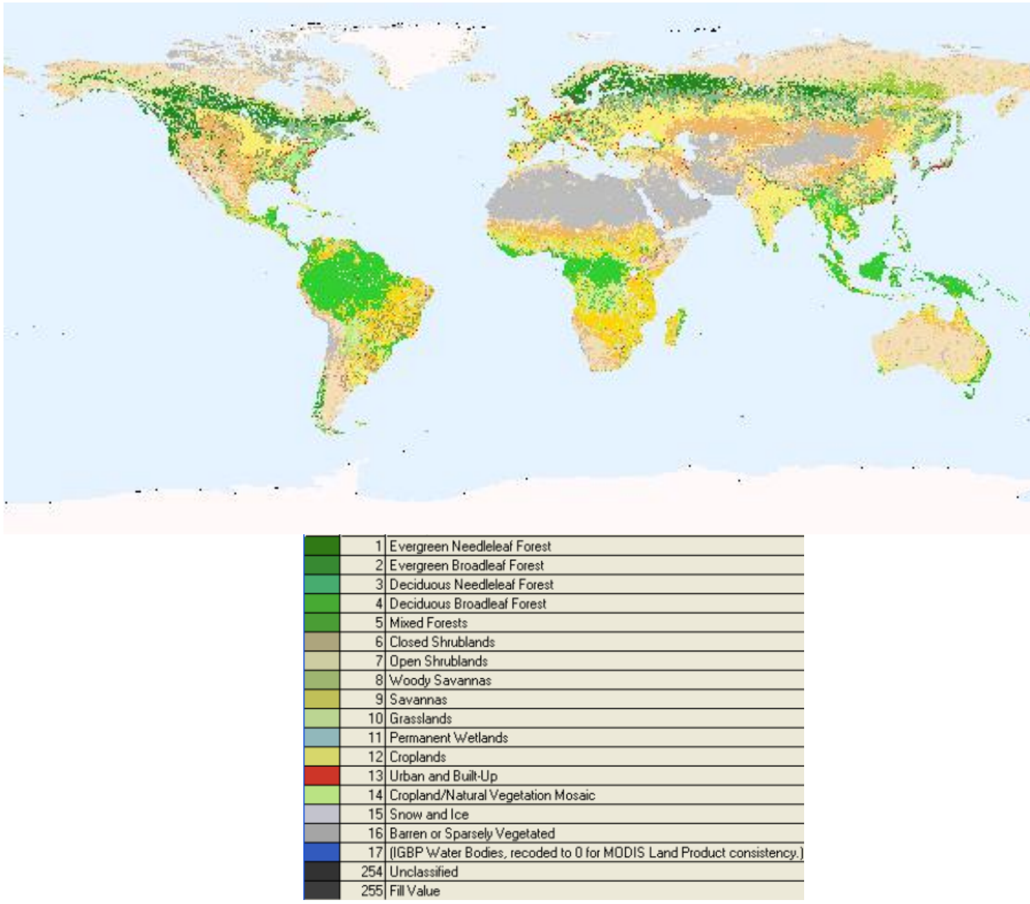

Figure 1. An example of the MODIS IGBP classification (http://duckwater.bu.edu/lc/mod12q1.html)

Table 4: MODIS_IGBP land classification and percentage of each land type.

Class	Description	Percentage
0	Water	-
1	Evergreen Needleleaf Forest	3.96
2	Evergreen Broadleaf Forest	10.04
3	Deciduous Needleleaf Forest	0.63
4	Deciduous Broadleaf Forest	1.59
5	Mixed Forests	4.69
6	Closed Shrublands	0.55
7	Open Shrublands	18.26
8	Woody Savannas	7.52
9	Savannas	6.97
10	Grasslands	9.27
11	Permanent Wetlands	0.22
12	Croplands	8.95
13	Urban and Built-Up	0.50
14	Cropland/Natural Vegetation Mosaic	2.10
15	Snow and Ice	11.04
16	Barren or Sparsely Vegetated	13.70

4 Final Product Specifications

Units: The landcover class index does not have units.

Version: mcd12q1 (MODIS) version 005 (IGBP).

Accuracy: According to the MODIS landcover ATBD (Strahler et al. 1999), the accuracy of the MODIS landcover information is expected to be 70-90% judging from the accuracies of the IGBP class map derived using the Landsat TM and NOAA AVHRR data sets. More recent evaluation (Friedl et al. 2010) compared the MODIS-IGBP map with the reference dataset for the year 2005, and reported 75% accuracy, representing an overall figure for the 17 IGBP classes.

5 Acknowledgment

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6 References

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Appendix A: SMAP Science Data Products and ATBDs

The SMAP Algorithm Theoretical Basis Documents are available at the SMAP web site http://smap.jpl.nasa.gov/science/dataproducts/ATBD/.

Data Product	Description	ATBD
L1A_Radar	Radar raw data in time order	(Joint with L1C_S0_HiRes)
L1A_Radiometer	Radiometer raw data in time order	(Joint with L1B_TB)
L1B_S0_LoRes	Low resolution radar σ_o in time order	(Joint with L1C_S0_HiRes)
L1C_S0_HiRes	High resolution radar σ_o (half orbit, gridded)	West, R., L1B & L1C radar products, JPL D-53052, JPL, Pasadena, CA.
L1B_TB	Radiometer T_B in time order	Piepmeier, J. et al., L1B radiometer product, GSFC SMAP-006, GSFC, Greenbelt, MD.
L1C_TB	Radiometer T_B (half orbit, gridded)	Chan, S. et al., L1C radiometer product, JPL D-53053, JPL, Pasadena, CA.
L2_SM_A	Soil moisture (radar, half orbit)	Kim, S. et al., L2 & L3 radar soil moisture (active) product, JPL D-66479, JPL, Pasadena, CA.
L2_SM_P	Soil moisture (radiometer, half orbit)	O'Neill, P. et al., L2 & L3 radiometer soil moisture (passive) product, JPL D-66480, JPL, Pasadena, CA.
L2_SM_AP	Soil moisture (radar/radiometer, half orbit)	Entekhabi, D. et al., L2 & L3 radar/radiometer soil moisture (active/passive) products, JPL D-66481, JPL, Pasadena, CA.
L3_FT_A	Freeze/thaw state (radar, daily composite)	McDonald, K. et al., L3 radar freeze/thaw (active) product, JPL D-66482, JPL, Pasadena, CA.
L3_SM_A	Soil moisture (radar, daily composite)	(Joint with L2_SM_A)
L3_SM_P	Soil moisture (radiometer, daily composite)	(Joint with L2_SM_P)
L3_SM_AP	Soil moisture (radar/radiometer, daily composite)	(Joint with L2_SM_AP)
L4_SM	Soil moisture (surface & root zone)	Reichle, R. et al., L4 surface and root-zone soil moisture product, JPL D-66483, JPL, Pasadena, CA.
L4_C	Carbon net ecosystem exchange (NEE)	Kimball, J. et al., L4 carbon product, JPL D-66484, JPL, Pasadena, CA.

Appendix B: SMAP Ancillary Data Reports

The SMAP Ancillary Data Reports are available with the ATBDs at the SMAP web site http://smap.jpl.nasa.gov/science/dataproducts/ATBD/.

Data/Parameter	Ancillary Data Report
Crop Type	Kim, S., Crop Type, JPL D-53054, Pasadena, CA
Digital Elevation Model	Podest, E. et al., Digital Elevation Model, JPL D-53056, Pasadena, CA
Landcover Classification	Kim, S., Landcover Classification, JPL D-53057, Pasadena, CA
Soil Attributes	Das, N. et al., Soil Attributes, JPL D-53058, Pasadena, CA
Static Water Fraction	Chan, S. et al., Static Water Fraction, JPL D-53059, Pasadena, CA
Urban Area	Das, N., Urban Area, JPL D-53060, Pasadena, CA
Vegetation Water Content	Chan, S. et al., Vegetation Water Content, JPL D-53061, Pasadena, CA
Permanent Ice	McDonald, K., Permanent Ice & Snow, JPL D-53062, Pasadena, CA
Precipitation	Dunbar, S., Precipitation, JPL D-53063, Pasadena, CA
Snow	Kim, E. et al., Snow, GSFC SMAP-007, Greenbelt, MD
Surface Temperature	Fisher, J. et al., Surface Temperature, JPL D-53064 Pasadena, CA
Vegetation and Roughness Parameters	Colliander, A., Vegetation & Roughness Parameters, JPL D-53065, Pasadena, CA