Soil Moisture Active Passive (SMAP)

Ancillary Data Report

Crop Type

Preliminary, v.1
SMAP Science Document no. 041

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January 11, 2013
JPL D-53054

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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/.

Table of Contents

1 Overview

1.1 Purpose

The purpose of this report is to summarize options and recommendations for a crop type ancillary data set to be used for generating SMAP science data products. The crop type 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

The baseline algorithm used to generate the SMAP high-resolution radar soil moisture product (L2_SM_A) requires as input global ancillary crop type information. The L2_SM_A soil moisture algorithm uses a look-up table approach to invert the vegetated-surface radar scattering model (Kim et al., 2010). Unique scattering models have been developed by the SMAP team for each landcover class. The scattering model used for a given 3-km radar pixel is selected according to the dominant landcover class in that pixel. The International Geosphere-Biosphere Programme (IGBP) landcover database (Belward, 1996) is the primary source of landcover class information used for SMAP, as described in the SMAP Landcover Classification ancillary data report (Kim et al., 2013). In the IGBP classification scheme, a single class is used to represent all crop types. However, radar backscattering signatures can differ significantly according to the crop type. Thus, additional information on crop type is needed to improve the characterization of the vegetation scattering and the resulting soil moisture retrieval.

This report describes a crop type ancillary database that can be used to enhances the IGBP landcover database to provide dominant crop type information within SMAP 3-, 9-, and 36-km resolution pixels. The four most dominant crop types in terms of global harvest area (wheat, rice, corn, and soybeans) are used to populate the database. It is infeasible within current plans for SMAP to generate crop-specific radar scattering models for more than these four crop types.

The SMAP passive (radiometer) soil moisture retrieval algorithms (L2_SM_P) could potentially use the crop type information, aggregated to the 36-km scale, in refining vegetation correction parameters.

2 Selection and Description of Primary Dataset

The crop cover at a specific 3-km radar pixel location can change over the course of a year (e.g., a winter cover crop followed by a summer crop) and between years (e.g., crop rotation of corn and soybeans in the U.S.). Economic forces can also change the dominant crop over time. Hence, it is difficult to generate accurate crop type maps globally and routinely. Furthermore, information on crop type and condition can have significant influence on global markets and national food security. As a result detailed information is often not released on a global basis.

Some crop type information is available over the United States, Canada, and Europe. For the rest of the world, information is poor. The United Nations Food and Agriculture Office (UN FAO, http://faostat.fao.org) provides annual statistics of the amount and area of harvest for each crop, based on inquiries made to each nation. However the FAO statistics do not provide a spatial

database of crop area as needed by the SMAP retrieval algorithms. The best that can be obtained is a dominant crop type where cropland is identified in a country.

In evaluating candidate data sets, the following criteria were considered:

a) availability
b) temporal updates
c) spatial resolution

The following data sets were evaluated:

- USDA cropland data layer (CDL) (Johnson and Mueller, 2010) for the U.S. (http://www.nass.usda.gov/research/Cropland/SARS1a.htm).
- The Prairies dataset from Agriculture and Agri-Food Canada (AAFC) (http://www.agr.gc.ca) for Canada
- ECOCLIMAP (Masson et al., 2003) for Europe (http://www.cnrm.meteo.fr/surfex/spip.php?article19).
- For the rest of the world, the global crop map database compiled from statistics of individual nations (Monfreda et al., 2008). (http://www.geog.mcgill.ca/~nramankutty/Datasets/Datasets.html)

Some key characteristics of these data sets are summarized in Table 1.

Table 1. Primary data sources for crop type.

Name of Dataset	Spatial resolution	Temporal resolution	Time span	Number of crop classes
Cropland data layer (U.S.)	56 m	Annual	2007-present	250
Prairies (Canada)	56 m	Annual	2009-present	~50
ECOCLIMAP (Europe)	1 km	One time	One time	25
Global crop map database	10 km	One time	Circa 2000	175

2.1 Cropland Data Layer (CDL)

The CDL is produced using a supervised classification scheme from the ERDAS Imagine commercial software applied to the Indian AWIFS satellite data. The information used in the supervised training comes from farmer surveys. The coverage is for the contiguous United States (Figure 1). The accuracy of the CDL product is estimated to exceed 90% for dominant crops such as wheat, corn, soybean, and rice (Johnson and Mueller, 2010). For less common crops, the accuracy ranges between 75-80%. Several crops are similar to wheat. Classes 22, 23, 24, 26, 234, 236 and 238 (Table 2) are assigned to wheat. Classes 3, 1, and 5 are assigned to rice, corn, and soybean, respectively.

Table 2. Example CDL crop classes for California.

ID	Description	ID	Description	ID	Description
1	Corn	36	Alfalfa	61	Fallow/Idle Cropland
2	Cotton	37	Other Hay	62	Pasture/Grass
3	Rice	41	Sugarbeets	63	Woodland
4	Sorghum	42	Dry Beans	66	Cherries
6	Sunflower	43	Potatoes	67	Peaches
12	Sweet Corn	44	Other Crops	68	Apples
13	Pop. or Orn. Corn	45	Sugarcane	69	Grapes
14	Mint	46	Sweet Potatoes	72	Citrus
21	Barley	47	Misc. Vegs. & Fruits	73	Other Tree Fruits
22	Durum Wheat	48	Watermelons	74	Pecans
23	Spring Wheat	49	Onions	75	Almonds
24	Winter Wheat	53	Peas	76	Walnuts
27	Rye	54	Tomatoes	87	Wetlands
28	Oats	57	Herbs	92	Aquaculture
31	Canola	58	Clover/Wildflowers	204	Pistachios
33	Safflower	59	Sod/Grass Seed	205	Triticale

Table 2. Example CDL crop classes for California (contd).

ID	Description	ID	Description
206	Carrots	223	Apricots
207	Asparagus	224	Vetch
208	Garlic	225	Dbl. Crop WinWht/Corn
209	Cantaloupes	226	Dbl. Crop Oats/Corn
210	Prunes	227	Lettuce
211	Olives	229	Pumpkins
212	Oranges	230	Dbl. Crop Lettuce/Durum Wht
213	Honeydew Melons	231	Dbl. Crop Lettuce/Cantaloupe
214	Broccoli	232	Dbl. Crop Lettuce/Upland Cotton
216	Peppers	235	Dbl. Crop Barley/Sorghum
217	Pomegranates	236	Dbl. Crop WinWht/Sorghum
218	Nectarines	237	Dbl. Crop Barley/Corn
220	Plums	242	Blueberries
221	Strawberries	244	Cauliflower
222	Squash	250	Cranberries

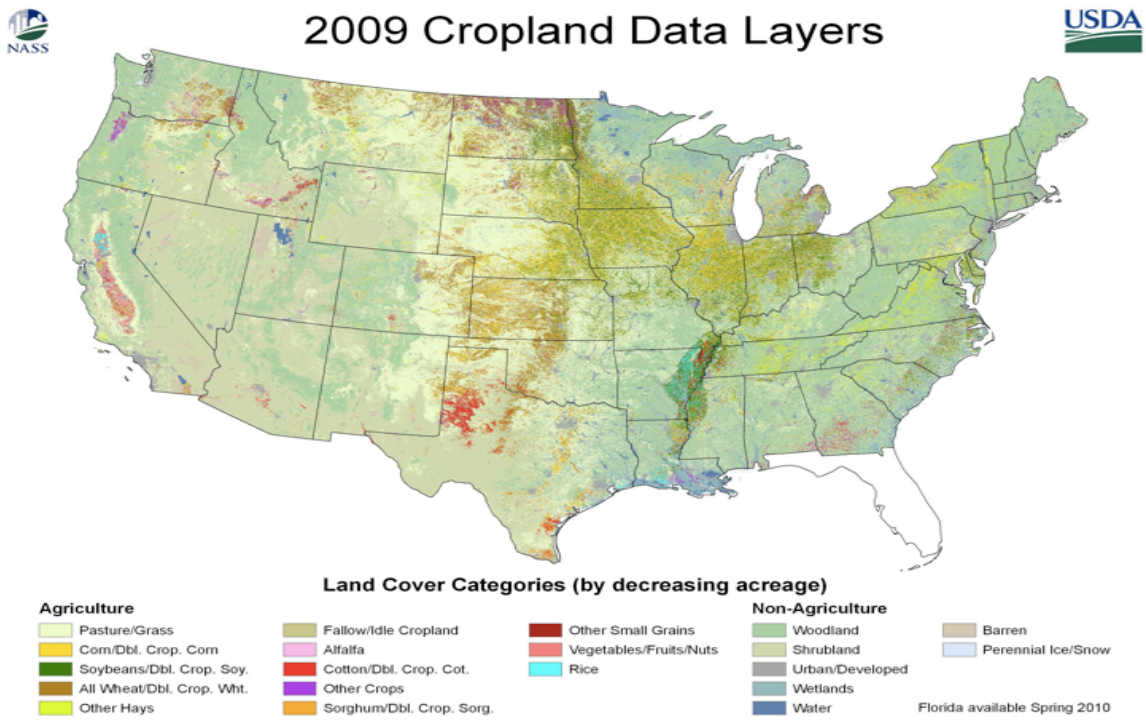

Figure 1. CDL crop map for 2009 (*www.**nass**.**usda**.gov/*)

2.2 Canadian Prairies

The Canadian Prairies data set covers croplands in Canada. It includes farmlands in Alberta, Saskatoon, and Manitoba. The providers intend to expand the data set to the eastern provinces over time. The crop map is based on the general land cover map (30 m) of Agriculture and Agri-Food Canada (AAFC), which only updates the agricultural areas. All other classes remain unchanged with time. The methodology used to identify different crop types is similar to that of the CDL.

Based on personal communications with Leander Campbell at AAFC, wheat is part of the Cereals class (ID 132), which also contains crops such as oats, rye, and barley (Table 3). Class ID 122 contains forage-based covers such as grass, alfalfa, and clover (no wheat). Class 122 is most suitable for wheat. Class 150, 147, and 158 define rice, corn, and soybean, respectively (however, there is no rice harvest area). An example of the map is shown in Figure 2.

Table 3. Canadian Prairie crop classes.

ID	Description	ID	Description
122	Perennial Crops and Pasture	158	Soybeans
132	Cereals	161	Pulses
147	Corn	174	Lentils
153	Canola/Rapeseed	177	Potatoes
154	Flaxseed	199	Other Crops
157	Sunflowers	250	Canary Seeds

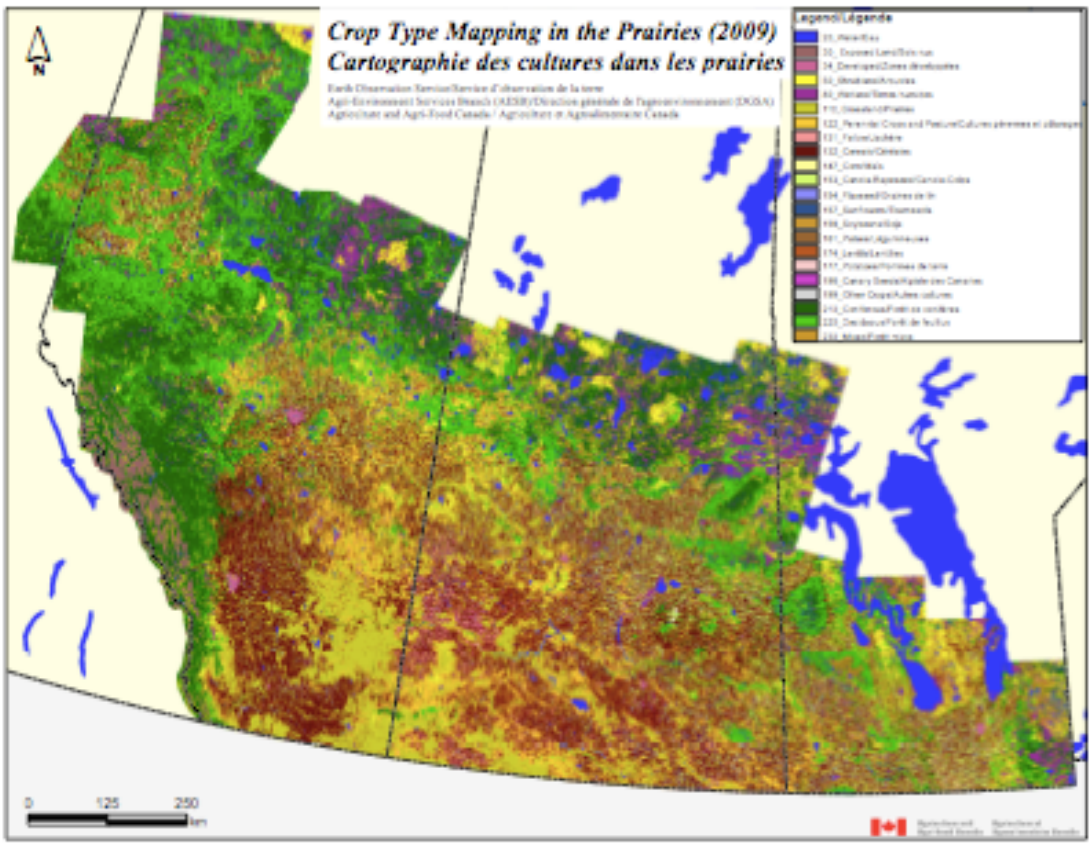

Figure 2. Prairie crop map for 2009 (Agriculture and Agri-Food Canada).

2.3 ECOCLIMAP

Over the European continent the ECOCLIMAP database (Masson et al., 2003) uses the 250 m resolution CORINE (Coordination of Information on the Environment) classification map for crop type information (Figure 3). For Scandinavia, the Pan-European Land Cover Monitoring (PELCOM) database is used. The CORINE map is based on visual assessments of satellite images such as Landsat. The 250 m resolution map is degraded to 1 km for ECOCLIMAP. The ECOCLIMAP database does not have specific classes designated for corn and soybean (Figure 4). Nor does it have a 'wheat' class. Pasture classes (182 to 186) are interpreted as wheat class (Table 4) for SMAP. Class 176 defines rice fields. The Ecoclimap does not provide locations for corn and soybean over Europe.

Table 4. ECOCLIMAP crop classes.

ID	Description	ID	Description
162	SPANISH_CROPS	175	IRRIGATED_CROPS
163	ESTREMADURA_CROPS	176	RICE_FIELDS
164	MEDITER_CROPS	177	MEDITER_VINEYARDS
165	ATLANTIC_CROPS	178	TEMPERATE_VINEYARDS
166	TEMPERATE_CROPS	179	MEDITER_FRUIT_TREES
167	PO_PLAIN_CROPS	180	TEMPERATE_FRUIT_TREES
168	FRENCH_BALKAN_CROPS	181	OLIVE_GROVES
169	UKRAINIAN_CROPS	182	NORTH_EUROPE_PASTURES
170	SUBPOLAR_CROPS	183	ATLANTIC_PASTURES
171	MOUNTAIN_CROPS	184	EAST_EUROPE_PASTURES
172	CENTRAL_EUROPE_CROPS	185	UKRAINIAN_PASTURES
173	TURKISH_CROPS	186	SUBPOLAR_PASTURES
174	MEDITER_IRR_CROPS		

Figure 3. Boundary of the CORINE land cover dataset (blue).

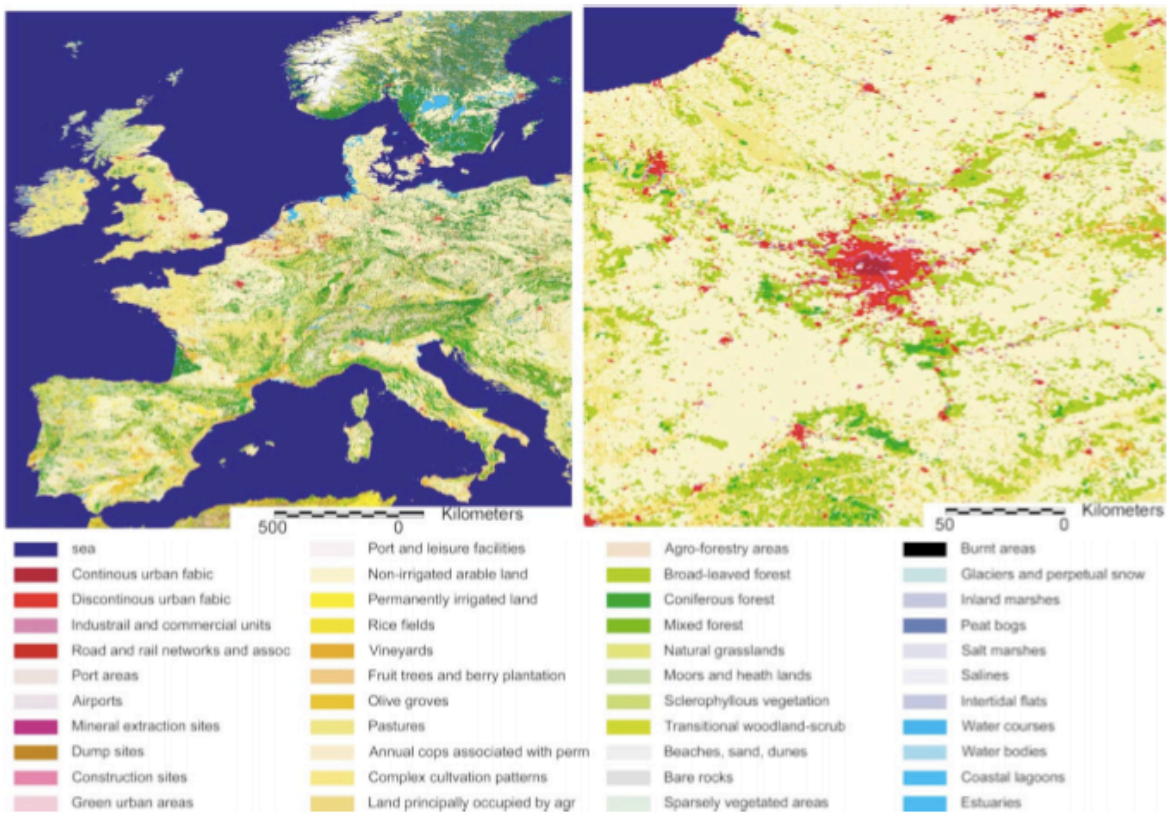

Figure 4. Example of detailed land cover classes from ECOCLIMAP (Masson et al., 2003).

2.4 Global Crop Map

This global crop map data set (Monfreda et al., 2008) is the combination of a new gridded map of global croplands for the year 2000 with agricultural survey statistics representing thousands of individual administrative units throughout the world. The 'unit' can be as small as a county or even a district as long as the statistics are available. The % cover of each crop within a 10 km grid is provided in the database (Figure 5). 175 classes of crops are defined. The database provides distinct maps for wheat, rice, corn, and soybean. Although this database originates from statistics rather than from a spatial map, at present, it offers the most detailed spatial information outside U.S., Canada, and Europe.

3 Processing

The SMAP Crop Type ancillary dataset recommended in this report for use by SMAP is a composite of the four datasets described in the previous section. The four dominant crop types were selected at 1-km resolution for each of the CDL, Prairies, ECOCLIMAP, and Global Crop Map databases. These four data sets were referred to at every IGBP crop class location. Over the US, Canada, and Europe, the following databases were referred to respectively: the CDL, Prairies, and ECOCLIMAP. Outside these areas, the Global Crop Map was referred to. Occasionally none of the four databases provide crop type information at the IGBP crop location. In this case, the four dominant crop classes were randomly assigned: the probability density function of each crop's harvest area within each continent was constrained by the percentage of

the four dominant crops per each of the continent (based on the UN FAO statistics). The rice field is in flooded condition (April till October in Northern hemisphere) and the dry condition during the rest of the year. The following processing steps were followed in creating this composite dataset.

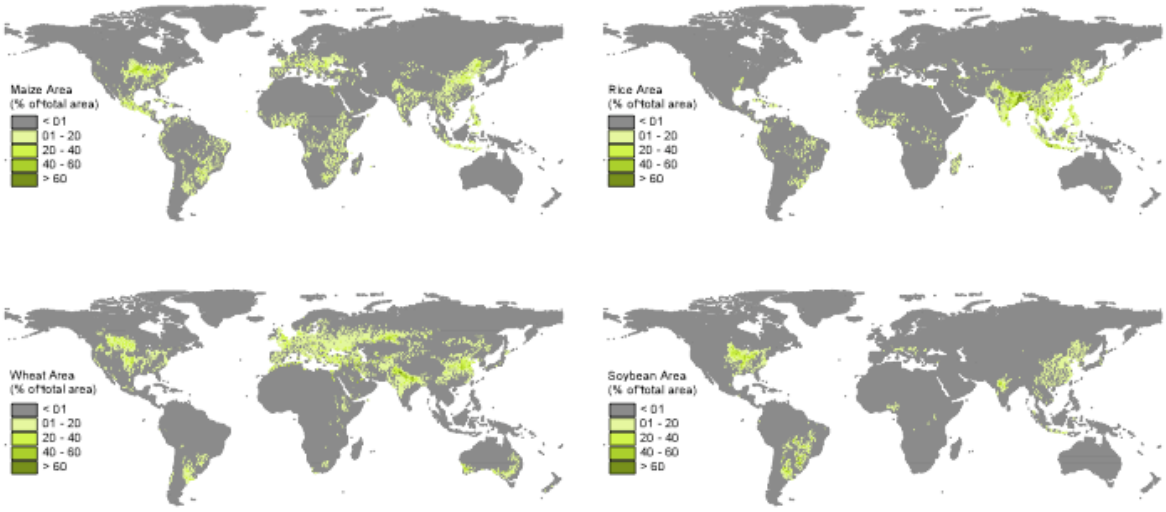

Figure 5. Distributions of four major crop species (Monfreda et al., 2008).

The CDL (U.S.) and Prairies (Canadian) datasets are available at 56-m resolution. For SMAP purposes the data were aggregated onto the SMAP 1-km EASE grid. In the aggregation processing the dominant class within a 1 km pixel was used to represent the pixel. The ECOCLIMAP is at 1-km resolution so no aggregation is required.

The CDL and Prairies data are provided in the UTM projection with the WGS84 datum. The coordinates were transformed to lat/lon on the WGS84 ellipsoid with the WGS84 datum. The ECOCLIMAP is provided on the WGS84 lat/lon coordinate system. Further transformation was applied to convert these data to the 1-km EASE-grid coordinates.

The global crop map data were downscaled from 5 minute to 1/120 deg by simply populating the percentage data of each crop at the 5-minute grid uniformly to all the 1/12 deg grid cells within the 5-minute grid cell, followed by the conversion into the 1-km EASE-grid coordinates.

4 Final Product Specifications

Units: The crop type class index does not have units.

Versions:

Product	Version
Cropland Data Layer	Current as of 2011
Canadian Prairie	Version 1
ECOCLIMAP*	ECOCLIMAP-I
Global Crop Map	Current as of 2011

*ECOCLIMAP-II has improved resolution over Africa (1-km). This dataset is currently being acquired.

Accuracy:

Product	Accuracy
Cropland Data Layer (CDL)	97% (Luman and Tweddale, 2008) validated for Illinois at the native 56-m spatial resolution
Canadian Prairie	Not available**
ECOCLIMAP	Most detailed map over Europe. Crop information is manually edited, usually regarded as the most accurate*
Global Crop Map	Enhanced quality over previous global maps (Monfreda et al., 2008)**

*A relative comparison between four landcover products (including ECOCLIMAP) showed 56%-69% classification accuracy over Africa (Kaptue Tchuente et al., 2011). However, this work does not compare the crop classification quality in Europe.

**Considering the sparseness of the spatial map the data are used even though their accuracy is unavailable.

5 Conclusion

Crop-type data of moderate or better quality are available only over the United States, Canada, and Europe. The CDL (U.S.) and Prairie (Canada) data are annually updated. The global crop map source data are of uncertain quality and are sparse and not current in many parts of the world. Due to the sensitivity of crop information to national interests (economy and food security), it is unlikely that more detailed and accurate information will be released globally in the foreseeable future. The composite Crop Type dataset described here is considered the best currently available.

6 Acknowledgment

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

7 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