1. TITLE

1.1 Data Set Identification

ISLSCP II Total Plant-Available Soil Water Storage Capacity of the Rooting Zone

1.2 Database Table Name(s)

Not applicable to this data set.

1.3 File Name(s)

The three files that make up this data set are named as follows:

1) **root_depth_water_assim_1d.asc**: Rooting zone water storage (mm H_2O) derived from assimilation of NDVI-fPAR and atmospheric forcing data. 1d means a 1.0 degree spatial resolution in both latitude and longitude.

2) **root_depth_water_optim_1d.asc**: Rooting zone water storage (mm H_2O) derived from optimization of absorbed PAR. 1d means a 1.0 degree spatial resolution in both latitude and longitude.

3) **root_depth_1d.dif**: ASCII tables of "differences"; This file contains Lat-Lon coordinates and data for each point in the two original files that differed from the ISLSCP II Land/Sea mask, and thus were removed from the ASCII map files (see sections 8.4 and 9.2.3 for more details). This file can be used with 1) and 2) to recreate the original files submitted by the Investigator.

1.4 Revision Date of this Document

March 31, 2011

2. INVESTIGATOR(S)

2.1 Investigator(s) Name and Title

Dr. Axel Kleidon, Assistant Professor, Department of Geography, University of Maryland, College Park

2.2 Title of Investigation

Inferring soil water storage size within the rooting zone by inverse methods.

2.3 Contacts (For Data Production Information)

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2.4 Data Set Citation

Kleidon, A. 2011. ISLSCP II Total Plant-Available Soil Water Storage Capacity of the Rooting Zone. In Hall, Forrest G., G. Collatz, B. Meeson, S. Los, E. Brown de Colstoun, and D. Landis (eds.). ISLSCP Initiative II Collection. Data set. Available on-line [http://daac.ornl.gov/] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/1006

2.5 Requested Form of Acknowledgment

Users of the International Satellite Land Surface Climatology (ISLSCP) Initiative II data collection are requested to cite the collection as a whole (Hall et al. 2006) as well as the individual data sets. Please cite the following publications when these data are used:

Hall, F.G., E. Brown de Colstoun, G. J. Collatz, D. Landis, P. Dirmeyer, A. Betts, G. Huffman, L. Bounoua, and B. Meeson, The ISLSCP Initiative II Global Data sets: Surface Boundary Conditions and Atmospheric Forcings for Land-Atmosphere Studies, *J. Geophys. Res.*, 111, doi:10.1029/2006JD007366, 2006.

Kleidon (pers. comm., updated version of Kleidon and Heimann (1998)).

Kleidon, A. and Heimann, M. (1998) A method of determining rooting depth from a terrestrial biosphere model and its impacts on the global water and carbon cycle. *Global Change Biology* 4: 275-286.

3. INTRODUCTION

3.1 Objective/Purpose

The data set was developed to provide alternative means to describe rooting characteristics of the global vegetation cover for land surface and climate models in support of the International Satellite Land Surface Climatology Project (ISLSCP) Initiative II data collection.

3.2 Summary of Parameters

The data files describe the geographic distribution of the total plant-available soil water storage capacity of the rooting zone ("rooting zone water storage size") derived using two separate methods and on a 1.0 degree global grid. A file that shows the differences between the original data and the ISLSCP II land/water mask is also provided.

3.3 Discussion

Two inverse methods were employed to describe the extent of the rooting zone water storage size. The first method is based on the assumption that vegetation has adapted to the environment such that it makes optimum use of water (Kleidon and Heimann 1998). Using a simulation model of the land surface-vegetative cover, this method is implemented by maximizing absorption of Photosynthetically Active Radiation (PAR), effectively leading to a maximization of evapotranspiration. The second method is based on the assumption that green vegetation indicates sufficient available water for transpiration (Knorr 1997). Rooting zone water storage size is inferred by minimizing the discrepancy of model simulated PAR absorption to satellite-derived PAR absorption. Satellite-derived absorbed PAR is calculated using the fraction of absorbed PAR and solar radiation data from the ISLSCP Initiative I data collection.

Both models compare well with each other, and to observations at a biome-scale level (Canadell et al. 1996). At a biome-scale, both methods seem to systematically overestimate corresponding rooting zone depths for savanna-type and tundra ecosystems.

The original files provided by the Investigator have been modified to agree with the land/water boundaries of the ISLSCP II land/water mask. The original values for those cells that have been either modified or masked have been provided in a separate file. Users can reconstruct the original data set by using the ISLSCP II rooting zone water storage files along with this additional file.

4. THEORY OF MEASUREMENTS

See Kleidon and Heimann (1998).

5. EQUIPMENT

5.1 Instrument Description

5.1.1 Platform (Satellite, Aircraft, Ground, Person...)

Not applicable to this data set.

5.1.2 Mission Objectives

Not applicable to this data set.

5.1.3 Key Variables

Not applicable to this data set.

5.1.4 Principles of Operation

Not applicable to this data set.

5.1.5 Instrument Measurement Geometry

Not applicable to this data set.

5.1.6 Manufacturer of Instrument

Not applicable to this data set.

5.2 Calibration

5.2.1 Specifications

5.2.1.1 Tolerance

Not applicable to this data set.

5.2.2 Frequency of Calibration

Not applicable to this data set.

5.2.3 Other Calibration Information

Not applicable to this data set.

6. PROCEDURE

6.1 Data Acquisition Methods

Data from the ISLSCP Initiative I collection for 1987 and 1988 (e.g. solar and thermal radiation, temperature and precipitation) were used as atmospheric forcing for the land surface model. The 6 hourly forcing for both years was used at a 1.0 degree lon/lat resolution. The Normalized Difference Vegetation Index (NDVI)-derived Absorbed PAR (APAR) values from ISLSCP I were used for the assimilation procedure.

6.2 Spatial Characteristics

6.2.1 Spatial Coverage

The coverage is global for all land areas. Eight land points over small islands have no data.

6.2.2 Spatial Resolution

The data are provided in an equal-angle latitude/longitude grid with a spatial resolution of 1.0 degree in both latitude and longitude.

6.3 Temporal Characteristics

6.3.1 Temporal Coverage

The data sets are derived from ISLSCP I atmospheric forcing covering the years 1987 and 1988.

6.3.2 Temporal Resolution

The simulation model was run at a 6 hour time step, consistent with the atmospheric forcing. The data sets are provided as fixed fields.

7. OBSERVATIONS

7.1 Field Notes

Not applicable to this data set.

8. DATA DESCRIPTION

8.1 Table Definition With Comments

Not applicable to this data set.

8.2 Type of Data

8.2.1 Parameter/ Variable Name	8.2.2 Parameter/ Variable Description	8.2.3 Data Range	8.2.4 Units of Measurement	8.2.5 Data Source
Assimilated Rooting Zone Water Storage	Rooting zone water storage derived from assimilation of NDVI- fPAR and atmospheric forcing during the ISLSCP-1 period of 1987 and 1988.	Min=0 Max=924.3 No Data=-88 Water=-99	mm H_2O	ISLSCP1 Data
Optimized Rooting Zone Water Storage	Rooting zone water storage derived from optimization of absorbed PAR during the ISLSCP-1 period of 1987 and 1988	Min=0. Max=920.4 No Data=-88 Water=-99	mm H_2O	ISLSCP1 Data
File root_depth_1d.dif				
Lat	Latitude for the center of a 1.0 degree cell. South latitudes are negative.	83.5 degrees to –55. 5 degrees	Decimal Degrees	Earth Grid
Lon	Longitude for the center of a 1.0 degree cell. West longitudes	-178. 5 degrees to	Decimal Degrees	Earth Grid

	are negative.	178. 5 degrees		
RepAssi_Removed	Original assimilated rooting zone water storage value of a particular cell that was modified or masked in with the ISLSCP II land/water mask.	Min=0 Max=924.3 Water=-99	mm H_2O	Original Files
RDepOpti_ Removed	Original optimized rooting zone water storage value of a particular cell that was modified or masked in with the ISLSCP II land/water mask.	Min=0. Max=920.4 Water=-99	mm H_2O	Original Files

*****NOTE**: 1mm H_2O = 1 liter/m^2 = 0.001 m^3 of water.

8.3 Sample Data Base Data Record

Sample data records for the file **root_depth_1d.dif** are given below:

```
ISLSCP II  Differences for the files 'root_depth_water_assim_1d.asc' and
'root_depth_water_optim_1d.asc'. This file contains Lat-Lon coordinates
and data for each point in these two original files that differed from
the ISLSCP II  Land/Sea mask, and thus were removed.

Lat,Long,RepAssi_Removed,RDepOpti_Removed
83.50,-39.50,-99.00,-99.00
83.50,-38.50,-99.00,-99.00
83.50,-34.50,0.00,0.00
82.50,-82.50,-99.00,-99.00
82.50,-62.50,78.70,79.30
82.50,-47.50,-99.00,-99.00
82.50,-43.50,-99.00,-99.00
82.50,-25.50,0.00,0.00
82.50,-24.50,0.00,0.00
82.50,-23.50,0.00,0.00
81.50,-93.50,-99.00,-99.00
81.50,-61.50,-99.00,-99.00
81.50,-53.50,-99.00,-99.00
81.50,-25.50,0.00,0.00
```

8.4 Data Format

All of the files in the ISLSCP Initiative II data collection are in the ASCII, or text format. The file format of the **root_depth_water_assim_1d.asc** and **root_depth_water_optim_1d.asc** files consists of numerical fields of varying length, which are delimited by a single space and arranged in columns and rows. The files in this data set contain 360 columns by 180 rows. All values are written as real numbers. Missing values over land are assigned the value of –88 while water bodies are assigned the value of –99 on all layers.

The file **root_depth_1d.dif** has a total of 624 rows and 4 columns separated by a single comma. All cells in this file which were considered water bodies in the original data set were assigned a value of–99.

All files are gridded to a common equal-angle lat/long grid, where the coordinates of the upper left corner of the files are located at 180 degrees W, 90 degrees N and the lower right corner coordinates are located at 180 degrees E, 90 degrees S. Data in the map files are ordered from North to South and from West to East beginning at 180 degrees West and 90 degrees North.

8.5 Related Data Sets

For other global rooting depth data sets derived by inverse methods, see Kleidon and Heimann (1998), and Knorr (1997). For data sets derived from direct measurements of rooting depths and root biomass distributions, refer to Schenk and Jackson (2002) (included in this ISLSCP II collection), Jackson et al. (1996), and Canadell et al. (1996). Additional ISLSCP II data sets are also available from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC).

9. DATA MANIPULATIONS

9.1 Formulas

9.1.1 Derivation Techniques/Algorithms

Two inverse methods are applied to a land surface model to infer global patterns of the plant-available soil water storage capacity of the vegetation's rooting zone. The first method is based on the assumption that vegetation is optimally adapted to its environment, resulting in a maximization of net carbon uptake, or, directly related, absorbed photosynthetically active radiation (APAR). This method is implemented by adjusting the storage size of the rooting zone such that the simulated APAR of the model is at a maximum. The second method assumes that water availability directly affects the leaf area of the vegetation, and therefore the amount of APAR. Rooting zone water storage size in the model is adjusted such that the mismatch between simulated and satellite-derived APAR is at a minimum.

Both inverse methods used a simulation model of land surface hydrology and vegetation activity. The model formulation is taken from a simple vegetation-land surface model of Kleidon and Heimann (1998). It consists of a "bucket" formulation of soil hydrology. Actual evapotranspiration is calculated as the minimum of supply and demand (Federer 1979). Evaporative demand is described by the equilibrium evaporation rate, based on the approach by McNaughton and Jarvis (1986). Supply for evapotranspiration is calculated as a function of available soil moisture and vegetative cover. Runoff and/or drainage only occur when the soil moisture content of the rooting zone reaches field capacity. The total water storage capacity of the rooting zone is a prescribed parameter and it is varied during the optimization and assimilation methods. APAR is calculated following the approach by Monteith (1973), which expresses it as the product of limiting factors and incoming photosynthetically active radiation (PAR). Here, only water limitations will be considered, as simulated by the soil hydrology model. The simulation model was forced with observation-based atmospheric radiative fluxes at the surface, precipitation, and surface temperature. During each model run the rooting zone water storage size was kept at a prescribed value.

The "optimization" method was implemented by maximization of calculated APAR averaged over the simulation with respect to rooting zone water storage size. This is done iteratively, using golden section search (Press et al. 1992). During each iteration, the model is run for a prescribed value of rooting zone water storage size for the entire simulation. The maximization process is constrained to values between 10mm and 1000mm of plant-available water. Note that since there is no trade-off for increasingly deeper roots, the smallest storage size is used at which the maximum of APAR is achieved.

The "assimilation" method uses an assimilation scheme similar to Knorr (1997). The monthly mean departures of NDVI-derived APAR from the overall mean of the whole period (1987 - 1988) were assimilated into the model by varying the geographic distribution of the rooting zone water storage size at what scale and time period. The mismatch between NDVI-derived APAR and the simulated APAR were minimized iteratively by golden section search (Press et al. 1992), i.e.

$$\text{minimize DELTA} = \sqrt{\frac{(APAR\_OBS_i - APAR\_OBS\_MEAN)^2}{(APAR\_SIM_i - APAR\_SIM\_MEAN)^2}} \qquad 1)$$

where APAR_OBS is the satellite-derived APAR, APAR_SIM is the model-simulated APAR, APAR_OBS_MEAN is the mean satellite-derived APAR for 1987-1988, and APAR_SIM_MEAN is the mean model-simulated APAR.

Rather than reporting the value of rooting depth (which depends on the particular choice of the formulation of evapotranspiration during water stress (Kleidon 1998)), the data set contains the seasonal depletion of soil moisture during the simulation period (i.e. maximum value - minimum value) and therefore the net soil water storage capacity of the rooting zone.

9.2 Data Processing Sequence

9.2.1 Processing Steps and Data Sets

Both methods were constrained to values of rooting zone water storage size between 10 mm H_2O and 1000 mm H_2O. Ten iterations were performed for each optimization. During each iteration, the simulation model was run with a new geographic distribution of rooting zone water storage size as determined by the golden section search algorithm (Press et al. 1992). Each model simulation was conducted for 4 years. The first 2 years were discarded as a startup phase. The simulated APAR during the latter 2 years was used.

9.2.2 Processing Changes

None.

9.2.3 Additional Processing by the ISLSCP II Staff

The ISLSCP II staff has modified the original files submitted by the Investigator in order to match them exactly with the boundaries of the ISLSCP II land/water mask. A total of 419 points have been identified where the ISLSCP II land/water mask has water but the original data have land. All of these points have been assigned a value of –99 on both the **root_depth_water_assim_1d.asc** and **root_depth_water_optim_1d.asc** files but their original values have been retained in the **root_depth_1d.dif** file.

A total of 204 points have been identified where the ISLSCP II land/water mask has land but the original data have water. In these cases the particular cell has been filled from an average of the rooting depth of all surrounding non-water cells in a 3 by 3 window around the cell. For 8 cells located over small islands such as Hawaii it was not possible to find any neighboring non-water value to fill so these cells were assigned a value of –88 (i.e. missing data over land). All of these 204 points have a value of –99 (water) in the original data and in the **root_depth_1d.dif** file.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.4 Graphs and Plots

None.

10. ERRORS

10.1 Sources of Error

When the storage capacity of the rooting zone is converted to actual rooting depths, the simulated patterns of rooting depth for both methods follow roughly the observed patterns as reported by Canadell et al. (1996) at a biome-average basis, with substantial rooting depths of several meters reported in most water-limited, tropical biomes and generally shallower rooting depths in temperate and polar regions. In general, the predicted values are less than observed values, which is reasonable considering that observed rooting depths do not necessarily reflect the soil water storage size needed to maximize productivity. This is particularly the case for arid regions. There are two exceptions: First, predicted rooting depths for tropical deciduous forests are larger than observed. This may be attributed to an alternative drought-avoidance mechanism, that is senescence, or to water vapor pressure deficits which are too high to meet. Second, predicted rooting depths for tundra are also overestimated, which may be attributable to physical restrictions of root development, such as a short growing season and permafrost.

The land/water mask used to generate our rooting depth values differs from the Initiative II land/water mask in 196 cells (see the file labeled **root_depth_1d.dif** for geographic locations of the cells). For cells that were water in our land/water mask, but were land in the Initiative II mask, rooting depth values of zero have been replaced with an average of the rooting depths of surrounding land cells.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The data sets have been compared to biome-level averages of rooting depth by Canadell et al. (1996).

10.2.2 Confidence Level/Accuracy Judgment

Not available at this revision.

10.2.3 Measurement Error for Parameters and Variables

Not available at this revision.

10.2.4 Additional Quality Assessment Applied

None.

11. NOTES

11.1 Known Problems with the Data

None reported at this revision.

11.2 Usage Guidance

This data set can be used to prescribe the depth of the rooting zone in land surface and climate models. Users should be aware that the original data set submitted by the Investigator has been somewhat modified to match the ISLSCP II land/water mask. Users should consult the **root_depth_1d.dif** file to locate any cells that have been modified and/or masked with the ISLSCP II land/water mask. The **root_depth_1d.dif** file can also be used with the files currently provided to re-create the original data set.

11.3 Other Relevant Information

None.

12. REFERENCES

12.1 Satellite/Instrument/Data Processing Documentation

None.

12.2 Journal Articles and Study Reports

Canadell, J., R. B. Jackson, J. R. Ehleringer, H. A. Mooney, O. E. Sala, and E.-D. Schulze (1996). Maximum rooting depth of vegetation types at the global scale. *Oecologia* **108**, 583-595.

Federer, C.A. (1982). Transpirational supply and demand: plant, soil, and atmospheric effects evaluated by simulation. *Water Resources Research* **18**, 355-362.

Kleidon, A., 1998. *Roots and Climate: Assessing their role with model simulations*. PhD Thesis, University of Hamburg, Germany, 139pp. ISSN 0938-5177.

Kleidon, A. and M. Heimann, 1998. A method of determining rooting depth from a terrestrial biosphere model and its impacts on the global water and carbon cycle. *Global Change Biology*, 4: 275-286.

Knorr, W., 1997. *Satellitengestuetzte Fernerkundung und Modellierung des globalen CO2-Austauschs der Landvegetation: Versuch einer Synthese*. PhD Thesis, University of Hamburg, Germany, 193pp. available in English via http://www.mpimet.mpg.de/gbc/wolfgang/index.html ISSN 0938-5177.

McNaughton, K. G., and P. G. Jarvis (1983). Predicting the effects of vegetation change on transpiration and evaporation. In *Water Deficit and Plant Growth*. T. T. Kozlowski (ed.). New York, Academic Press**:** 1-47.

Press, W. H., S. A. Teykolsky, W. T. Vetterling, and B. P. Flannery, 1992. *Numerical Recipes in FORTRAN. The Art of Scientific Computing*. Cambridge University Press, Cambridge, Great Britain.

Schenk, H. J., and R. B. Jackson. (2002). The global biogeography of roots. *Ecological Monographs* **72**:311-328.

13. DATA ACCESS

13.1 Contacts for Archive/Data Access Information

The ISLSCP Initiative II data are available are archived and distributed through the Oak Ridge National Laboratory (ORNL) DAAC for Biogeochemical Dynamics at http://daac.ornl.gov.

13.2 Contacts for Archive

E-mail: uso@daac.ornl.gov
Telephone: +1 (865) 241-3952

13.3 Archive/Status/Plans

The ISLSCP Initiative II data are archived at the ORNL DAAC. There are no plans to update these data.

14. GLOSSARY OF ACRONYMS

APAR	Absorbed Photosynthetically Active Radiation
DAAC	Distributed Active Archive Center
ISLSCP	International Satellite Land Surface Climatology Project
NDVI	Normalized Difference Vegetation Index
ORNL	Oak Ridge National Laboratory
PAR	Photosynthetically Active Radiation