The China Dataset of Soil Hydraulic Parameters Using Pedotransfer Functions for Land Surface Modeling

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1. Introduction

In order to simulate soil water content using the Richards equation, land surface models (LSMs) for hydrometeorological and climate studies employ two empirical functions, one for the soil water retention curve and another for the soil hydraulic conductivity. Since the hydraulic parameters associated with these functions are difficult to measure directly, empirical relationships are used to relate these parameters to readily available soil properties, referred to as pedotransfer functions (PTFs).

We developed a China dataset of soil hydraulic parameters using different PTFs. We selected five PTFs to derive the parameters in the Clapp and Hornberger Functions (FCH) in the van Genuchten and Mualem Functions (FGM), and ten PTFs for soil water contents at capillary pressures of 33 and 1500 kPa, respectively. The inputs into the PTFs include soil particle-size distribution, bulk density and soil organic matter, which are provided with our newly-developed soil characteristic dataset of China. The resolution is 30 arc-seconds (about 1 km at the equator).The vertical variation of soil property was captured by seven layers to the depth of 1.38 m (i.e. 0-0.045, 0.045-0.091, 0.091-0.166, 0.166-0.289, 0.289-0.493, 0.493-0.829, 0.829-1.383 m) for convenience of use in the Common Land Model and the Community Land Model (CLM).

1.1 The functions of Clapp and Hornberger (FCH)

错误!未找到引用源。 functions, based on earlier studies of 错误!未找到引用源。 and 错误!未找到引用源。, have been widely used in land surface schemes for climate/weather models. The water retention in the dry range is written as:

$$\psi = \psi_s \left(\theta / \theta_s \right)^{-1/\lambda}, \psi \le \psi_i \quad (1)$$

where ψ_s is the saturated capillary potential, λ is the pore size distribution index, θ_s is the saturated water content. The residual moisture content is assumed as zero. ψ_i defines an inflection point near the saturation range, and Eq. (1) is combined with a parabolic equation in the wet range 错误!未找到引用源。. The soil hydraulic conductivity is written as:

$$K\left(\theta\right) = K\left(\theta / \theta_s\right)^{3+2/\lambda} \quad (2)$$

where K_s is the saturated hydraulic conductivity. FCH has 4 parameters, i.e. θ_s

(cm^3 cm^{-3}), ψ_s (cm), λ (dimensionless) and K_s (cm d^{-1}), to be estimated.

1.2 The functions of van Genuchten–Mualem (FGM)

The FGM 错误!未找到引用源。 was developed by combining an empirically based power law equation describing the relationship between pressure head, and moisture content, with the predictive pore-size distribution model by 错误!未找到引用源。 for the unsaturated hydraulic conductivity. The FGM is favored by soil physicists. The water retention is written as

$$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \left[\frac{1}{1+(\alpha h)^n}\right]^{1-1/n} \quad (3)$$

where Θ is effective saturation, h is the pressure head, considered here to be positive under unsaturated conditions, α is a parameter corresponding approximately to the inverse of the air-entry value, and n is shape parameter and θ_r is the residual moisture content. The soil hydraulic conductivity is

$$K = K_s \Theta^L \left[1-\left(1-\Theta^{1/(1-1/n)}\right)^{1-1/n}\right]^2 \quad (4)$$

where K_s is the saturated hydraulic conductivity (defined at h = 0), L is the pore-connectivity parameter. FGM had 6 parameters, i.e. α (cm^{-1}), n (dimensionless), θ_r (cm^3 cm^{-3}), θ_s (cm^3 cm^{-3}), K_s (cm d^{-1}), and L (dimensionless), to be estimated.

1.3. Water contents at capillary pressures of 33 and 1500 kPa

Field capacity (FC) is the amount of water content held in soil after excess water has drained away and the rate of downward movement has materially decreased, which usually takes place within 2–3 days after a rain or irrigation in pervious soils of uniform structure and texture. Permanent wilting point (PWP) or wilting point (WP) is defined as the minimal point of soil moisture the plant requires not to wilt. In this study, FC and PWP is seen as the water content at about −33 and −1500 kPa of suction pressure, respectively.

2. Data description

Here we take the saturated water content of FCH (file “THSCH.nc”) as an example to show the data. The dataset takes the NetCDF Climate and Forecast Metadata Convention (CF-1.0). The extent is 73-136°E and 18-54°N. The following is the metadata:

```
dimensions:
        lon = 7560 ;
        lat = 4320 ;
        depth = 8 ;
variables:
        float lon(lon) ;
                lon:long_name = "longitude" ;
                lon:units = "degrees_east" ;
```

```
        float lat(lat) ;
                lat:long_name = "latitude" ;
                lat:units = "degrees_north" ;
        float depth(depth) ;
                depth:long_name = "depth to the bottom of a soil layer" ;
                depth:units = "centimeter" ;
        float THSCH(lat, lon, depth) ;
                THSCH:missing_value = -9999 ;
                THSCH:units = "cm3 cm-3" ;
                THSCH:long_name = "Saturated water content of FCH" ;
        float THSCHcv(lat, lon, depth) ;
                THSCHcv:missing_value = -9999 ;
                THSCHcv:units = "" ;
                THSCHcv:long_name = "CV of saturated water content of FCH" ;
// global attributes:
                :Conventions = "CF-1.0" ;
```

3. Data usage

The data in NetCDF file format can be used by multiply software. Here we give three example softwares, i.e. Panoply, NCL and R.

3.1 Panoply

This software is recommended to a fast visual look at the data. It can be downloaded here (www.giss.nasa.gov/tools/panoply).

3.2 NCAR Command Language (NCL)

Here is an example of NCL script to use the data:

```
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_code.ncl"
load "$NCARG_ROOT/lib/ncarg/nclscripts/csm/gsn_csm.ncl"

begin

TH33data = addfile("TH33.nc","r")
lat = TH33data->lat
lon = TH33data->lon
TH33 = TH33data->TH33
TH33cv = TH33data->TH33cv
;printVarSummary(TH33)

TH33@_FillValue = -999

wks = gsn_open_wks("pdf","TH33")
gsn_define_colormap(wks,"rainbow+white+gray")
```

```
res      = True
res@gsnAddCyclic = False

res@mpLimitMode = "LatLon"
res@mpMaxLatF = 54.0
res@mpMinLatF = 18.0
res@mpMaxLonF = 136.0
res@mpMinLonF = 73.0

res@cnFillOn=True
res@cnLinesOn=False

res@lbLabelAutoStride=True
res@lbBoxLinesOn=False

res@gsnSpreadColors=True
res@gsnSpreadColorStart=50
res@gsnSpreadColorEnd=-3

res@cnFillMode = "RasterFill"
res@cnLevelSelectionMode="ManualLevels"
res@cnMinLevelValF=0.0
res@cnMaxLevelValF=90.0
res@cnLevelSpacingF = 5.0

plot = gsn_csm_contour_map(wks,TH33(0,:,:),res)

end
```

Note that workspace reallocation would exceed maximum size 32556688, the easiest way to increase the size is to put a line like the following into your ~/.hluresfile:

```
*wsMaximumSize : 500000000
```

1.3 R language

The NetCDF files can be used by loading "RNetCDF" package, and the corresponding maps can be drawn by loading “raster” package. The following is an example:

```
rm(list=ls(all=TRUE))
setwd("D:\\NC\\data")    # The directory of NetCDF file
library("RNetCDF")
library(raster)
```

```
    cnfile<-"TH33.nc"
    q3<-open.nc(cnfile, write=FALSE)
    print.nc(q3)

    r <- raster(ncol=7560, nrow=4320,xmn=73, xmx=136, ymn=18, ymx=54)
    #read value
    tmp<-var.get.nc(q3,"TH33",c(1,1,1),c(7560,4320,1))
    #plot maps
    tmp<-tmp[,4320:1]
    values(r)<-as.vector(tmp)
    plot(r, asp=1)
close.nc(q3)
```

3.4 ArcGIS

The NetCDF files should be converted into single layer (depth) NetCDF file first. This can be done by NCL, R language or other tools. Then use the "Make NetCDF Raster Layer" in Arctool to make an in-memory raster layer. Then right click on the layer name in ArcMap. The data can be export to raster format through "data" -> "export data".

The following is an example of R language to convert the data into single layer (depth) NetCDF file:

```
rm(list=ls(all=TRUE))
setwd("J:\\nc")    # The directory of NetCDF file
library("RNetCDF")


cnfile<-"SA.nc"    # original file name
q3<-open.nc(cnfile, write=FALSE)
print.nc(q3)

tname<-"SA"    # soil property name
#read value
i=1 #change the value to extract different layer(depth)
tmp<-var.get.nc(q3,tname,c(1,1,i),c(7560,4320,1))#the i layer

t1<-seq(length=7560,from=73.00417,by=0.00833)
t2<-seq(length=4320,from=18.00417,by=0.00833)


q2<-create.nc(paste("SA",i,".nc",sep=""))

#define variables and attributes of    global, dimension and coordinates
dim.def.nc(q2, "lon",7560)
```

```
dim.def.nc(q2, "lat",4320)

att.put.nc(q2, "NC_GLOBAL", "Conventions", "NC_CHAR", "CF-1.0")
var.def.nc(q2, "lon", "NC_FLOAT", "lon")
var.def.nc(q2, "lat", "NC_FLOAT", "lat")
att.put.nc(q2, "lon", "long_name", "NC_CHAR", "longitude")
att.put.nc(q2, "lon", "units", "NC_CHAR", "degrees_east")
att.put.nc(q2, "lat", "long_name", "NC_CHAR", "latitude")
att.put.nc(q2, "lat", "units", "NC_CHAR", "degrees_north")

var.def.nc(q2,tname, "NC_FLOAT", c("lon","lat"))
att.put.nc(q2,tname, "missing_value", "NC_FLOAT",-999.0)
att.put.nc(q2, tname, "units", "NC_CHAR", "% of weight")
att.put.nc(q2, tname, "long_name", "NC_CHAR", "sand content")
var.put.nc(q2,"lat", t2, 1, NA)
var.put.nc(q2,"lon", t1, 1, NA)
var.put.nc(q2,tname,tmp,c(1,1),c(7560,4320))


close.nc(q3)
close.nc(q2)
```

4. Citation

Details about the dataset are in the peer-reviewed paper.

Full acknowledgement and referencing of all sources must be included in any documentation using any of the material contained in the China Dataset of Soil Properties for Land Surface Modeling, as follows:

Dai, Y., W. Shangguan, Q. Duan, B. Liu, S. Fu, G. Niu, 2013: Development of a China dataset of soil hydraulic parameters using pedotransfer functions for land surface modeling. Journal of Hydrometeorology, 14, 869–887,doi: 10.1175/JHM-D-12-0149.1.

5. Contact

If you have any questions when using PTFC data set, please email: shgwei@mail.sysu.edu.cn (Dr. Wei Shangguan).