Assess the impacts of different land cover datasets on land surface hydrological process in Community Earth System Model (CESM)

Shaoqiang Ni, Hui Lu

Department of Earth System Science, Tsinghua University

05.05.2020

Outline

1. Introduction
2. Assessment of different PFTs(Plant Function Types)
3. Impact of different PFTs on hydrological processes
    - 3.1 Gong 1985 and Gong 2015
    - 3.2 Gong 2015 and Default 2015
4. Conclusions

1.Introduction

Previous studies have shown land use and land cover (LULC) changes have a great influence on the simulation of earth system.

a. Direct impact

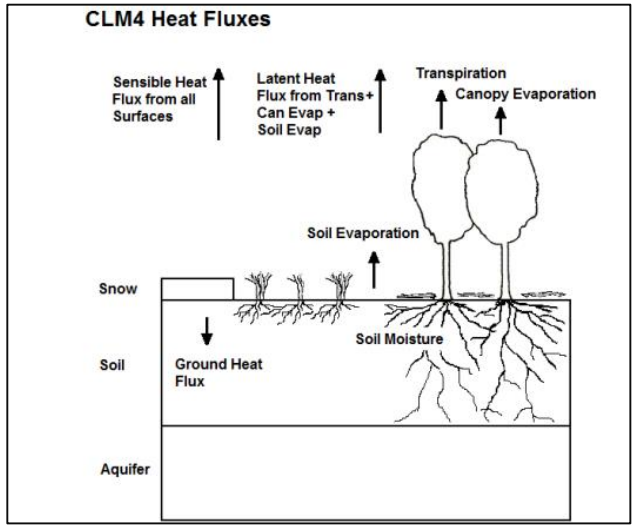
Can significantly influence the biogeochemical processes, such as vegetation and soil carbon dynamics, vegetation root depth.

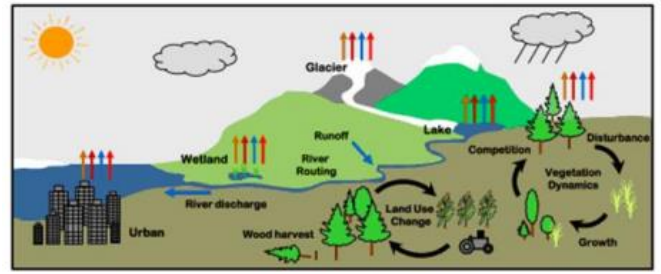
Can significantly influence the key land surface process variables, such as albedo, surface roughness, land surface hydrological status.

b. Indirect impact

Land surface temperature changes and response of atmosphere, precipitation and circulation to this changes

Response of vegetation growth to high concentration CO_2 and surface hydrological changes.





Lawrence et al., 2011, Shevliakova et al., 2009Feddema et al., 2005, Bonan, 2008, IPCC, 2007

1.Introduction

Related research：

Houghton has shown that LCLU change caused an increase of 156 Pg C emission from land to atmosphere between 1850 and 2010.

LCLU change have significantly changed the surface albedo, roughness and vegetation root depth, etc. (Defries et al., 2002; Pielke et al., 2002; Roy et al., 2003)

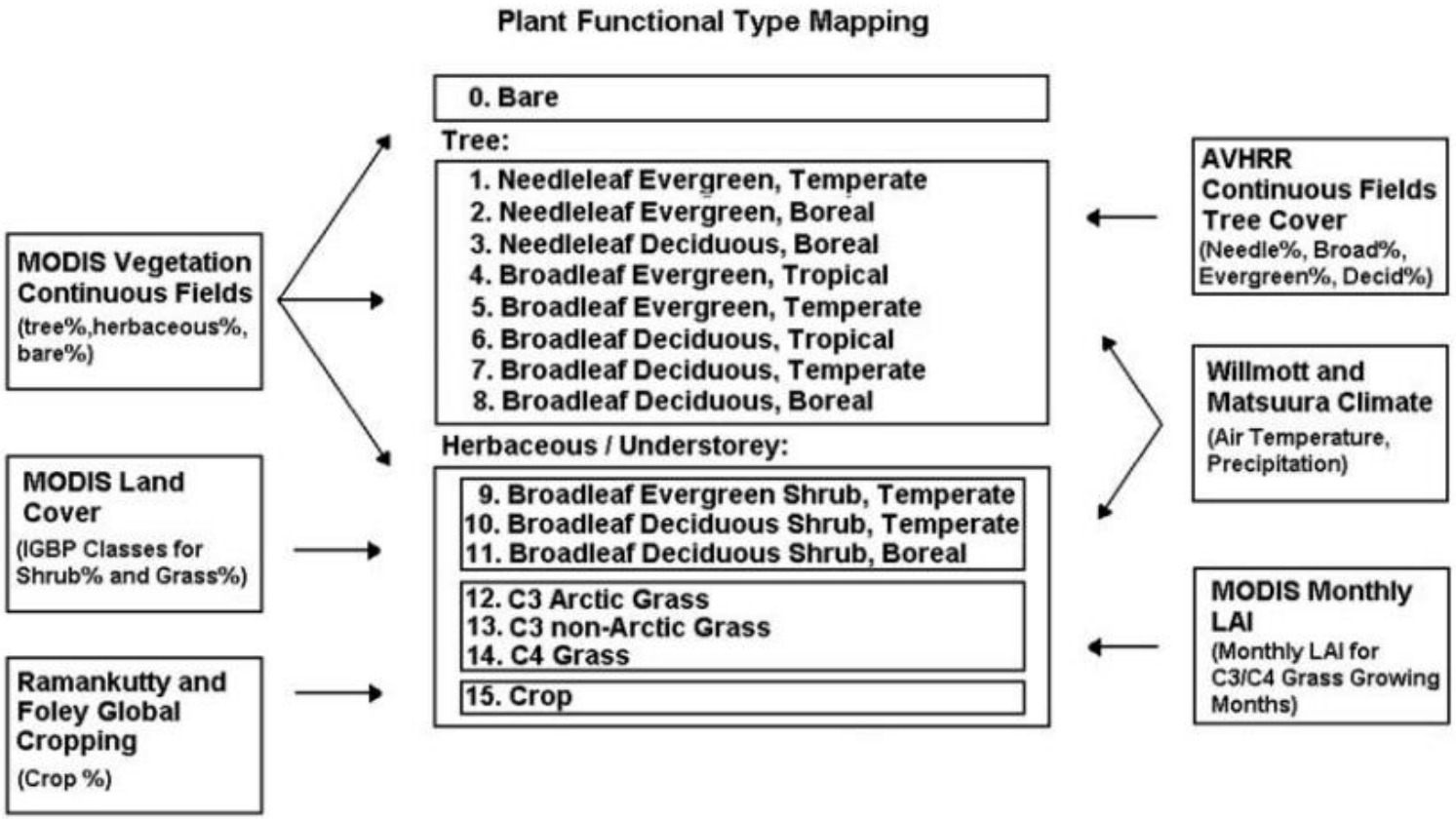
Sajikumar have studied the relationship between ratio of forest changing to cropland and increase of surface peak runoff in a small watershed and the result showed no significant correlation.

(Similar research : Gashaw et al., 2018, Deng et al., 2015, Pervez et al., 2015)

Muñoz-Rojas has analyzed the soil carbon pool in the Mediterranean and evaluated the impact of LCLU change on soil organic carbon. (increase 25.4% in surface soil)

1.Introduction

Land surface model CLM4，the source of Current day PFT data (Default):



Mainly based on fusion of MODIS remote sensing data and related products, the PFT in CLM4 is divided into 16 land cover types.

Lawrence and Chase, 2007

1.Introduction

The change of LCLU in CLM4 from 1850 to 2100：

Mainly consider two factors in CMIP5: Land cover change and wood harvest

According to some certain empirical methods and relationships, the following data was produced:

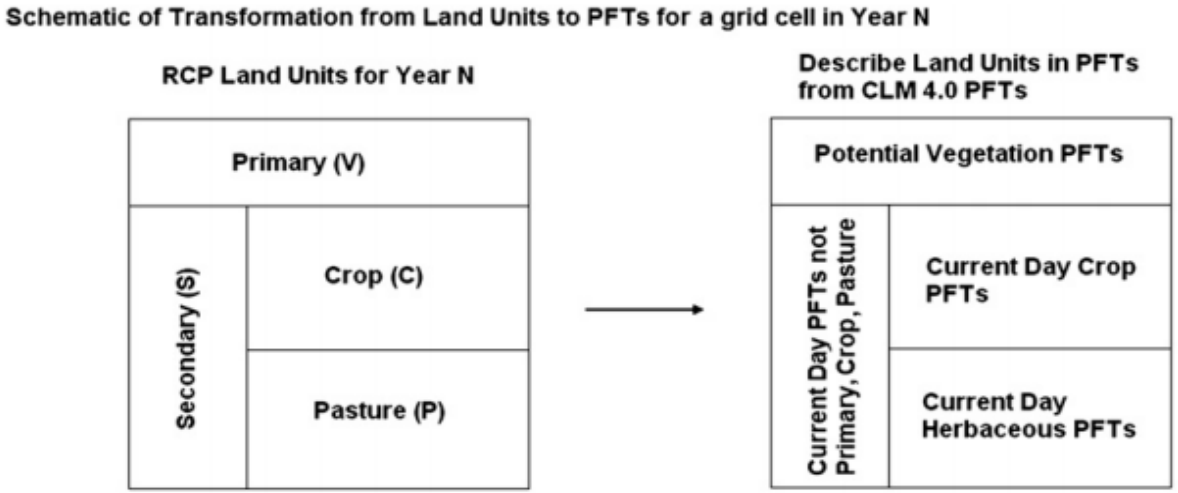
a. 1850-2005 historical period.

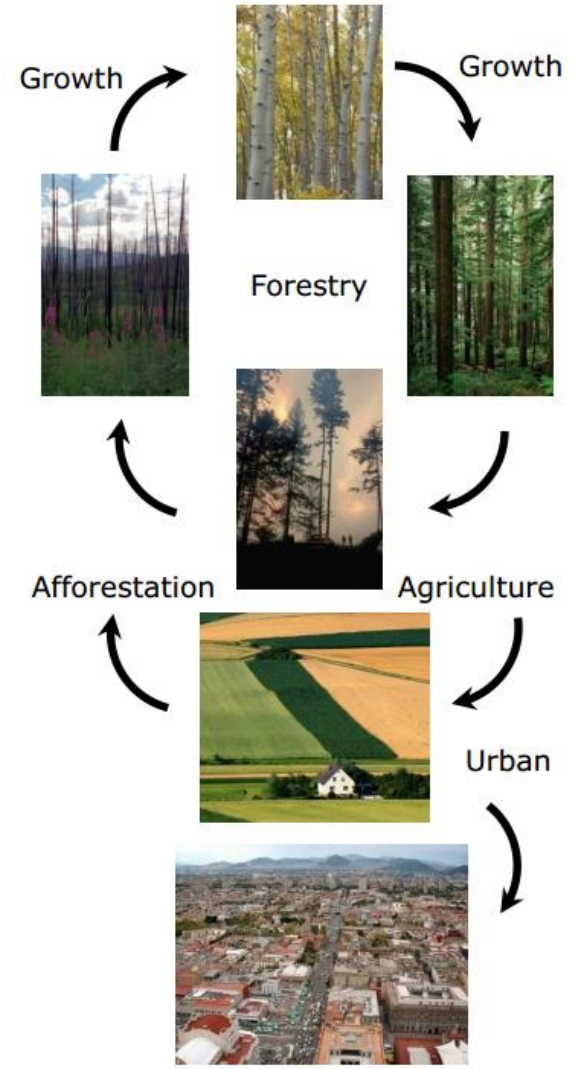
b. 2006-2100 four RCP period.

Lawrence et al., 2012

1.Introduction

The empirical methods for PFT transient :





Include annual transient land cover change in PFTs and wood harvest of tree PFTs through new functionality in CLM4

Then comes two problems:

How far is this from actual situation ?

How much influence does the actual LCLU change have on land surface hydrological process ?

2. Assessment of different PFTs

The used data:

1. Peng Gong et al. have finished the global annual LCLU mapping based on remote sensing image reclassification and field investigation.

(Resolution: 30 meter Year: 1985-2015, Source: AVHRR)

(We have changed it to the proper format and resolution for model requirement)

2. The default data used in CLM4.

(Resolution: 0.5 degree Year: 1980-2100 Source: remote sensing fusion)

3. European Space Agency (ESA) Climate Change Initiative (CCI) ===> LC maps

(resolution: 300m, 1992-2018, under processing)

2. Assessment of different PFTs

- We choose Bare land, Broadleaf Evergreen, Tropical, Crop land and Tree to analyze their differences.
- Difference value: Dvalue = Gong value – Default value
- Relative change value: Rvalue= Dvalue / Default value

Plant Functional Types:

0. Bare

Tree:

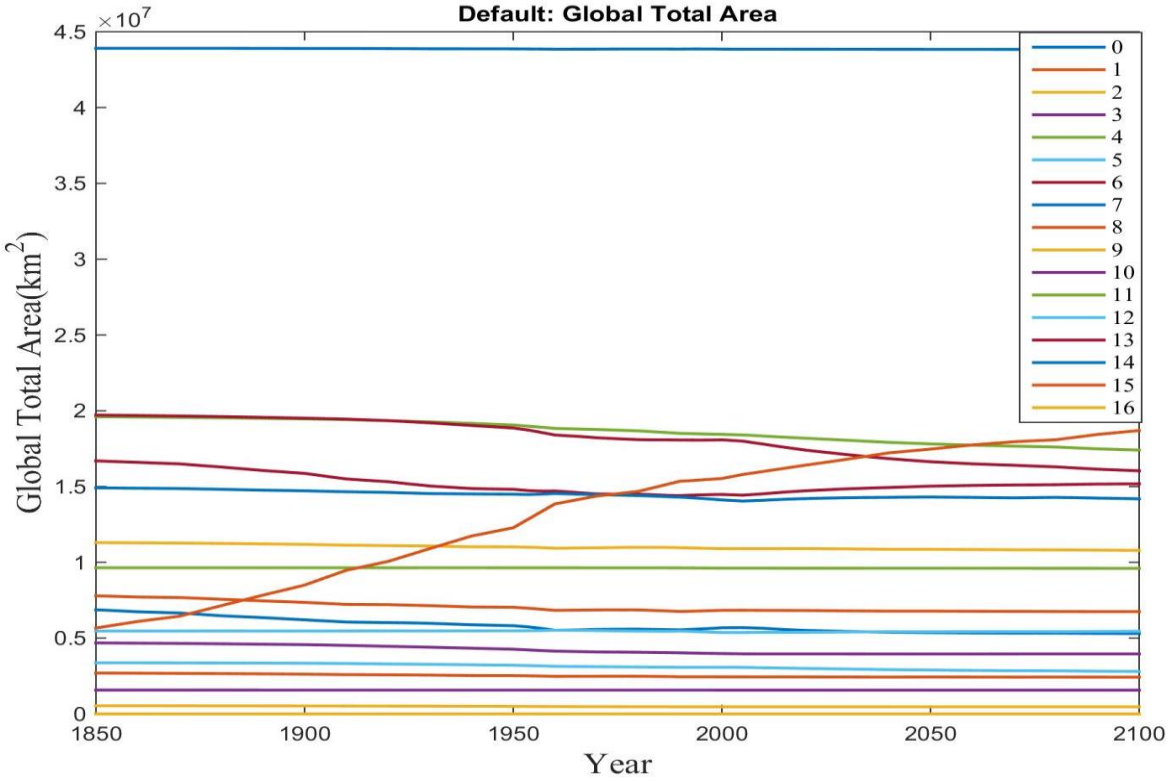
1. Needleleaf Evergreen, Temperate
2. Needleleaf Evergreen, Boreal
3. Needleleaf Deciduous, Boreal
4. Broadleaf Evergreen, Tropical
5. Broadleaf Evergreen, Temperate
6. Broadleaf Deciduous, Tropical
7. Broadleaf Deciduous, Temperate
8. Broadleaf Deciduous, Boreal

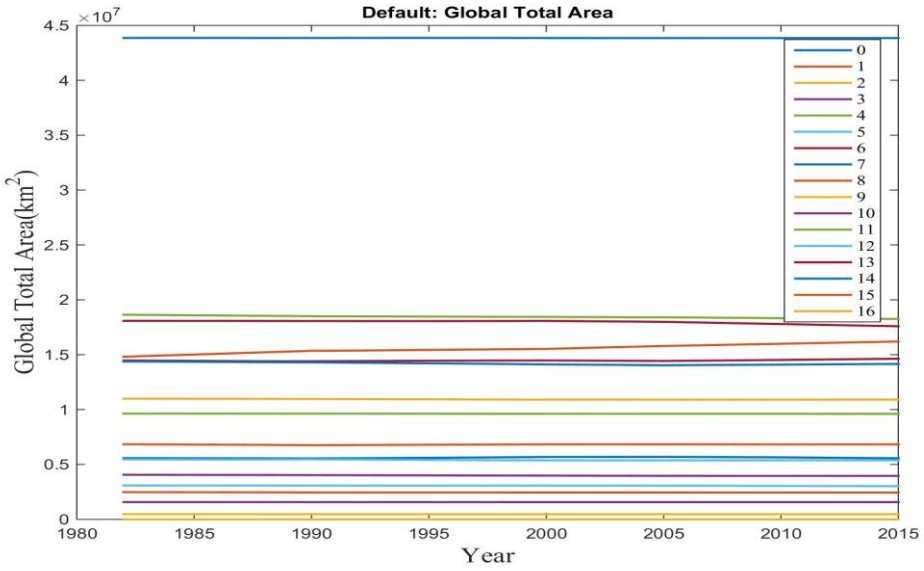
Herbaceous / Understorey:

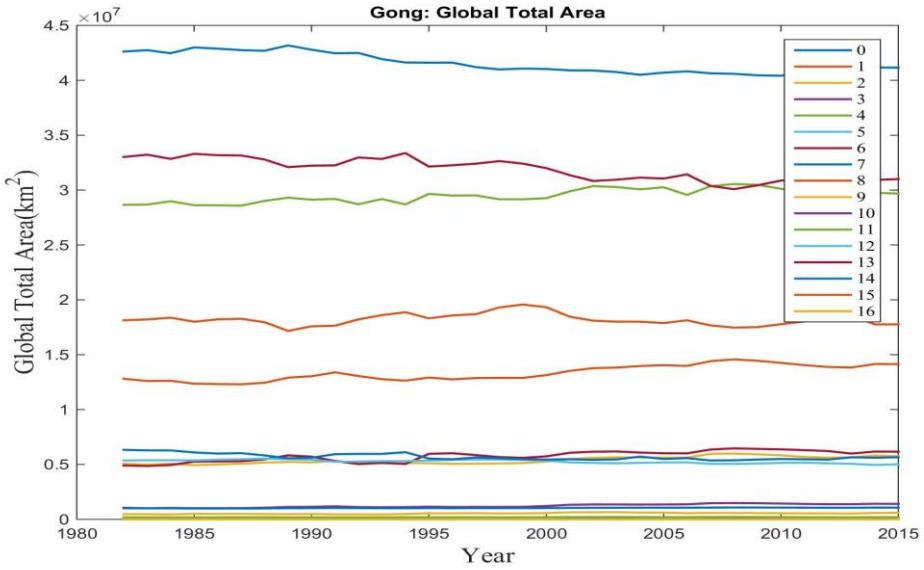
9. Broadleaf Evergreen Shrub, Temperate
10. Broadleaf Deciduous Shrub, Temperate
11. Broadleaf Deciduous Shrub, Boreal
12. C3 Arctic Grass
13. C3 non-Arctic Grass
14. C4 Grass
15. Crop

2. Assessment of different PFTs

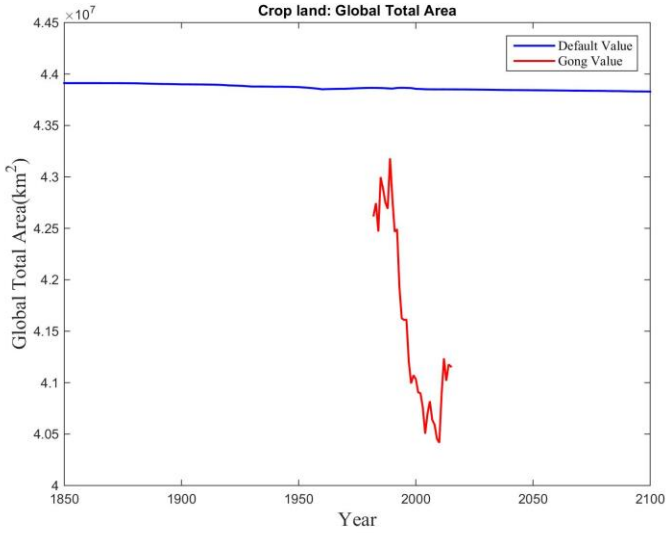
Global PFTs area satistics：

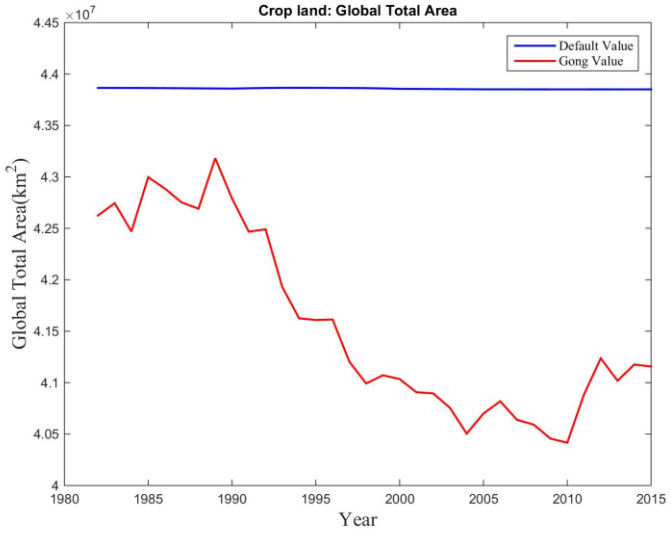




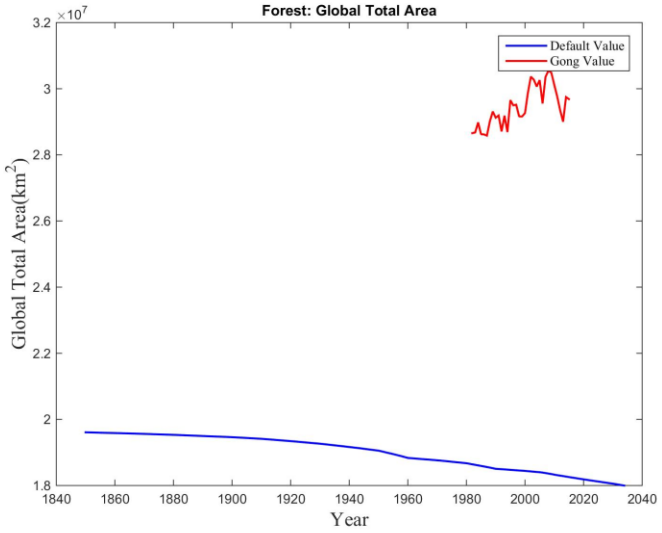


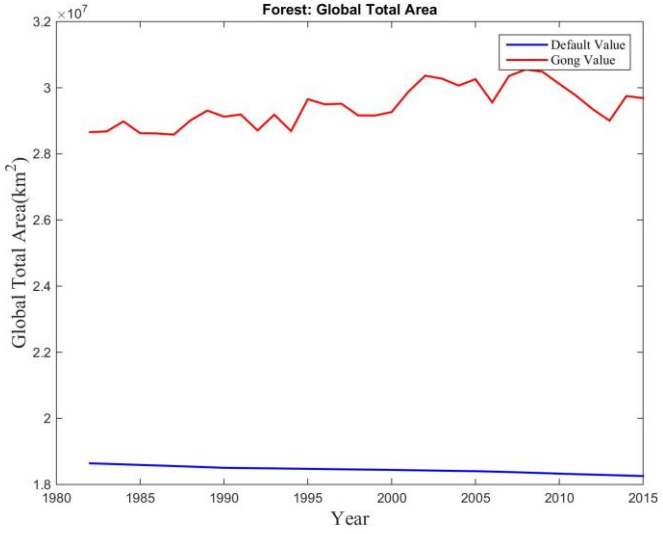
2. Assessment of different PFTs





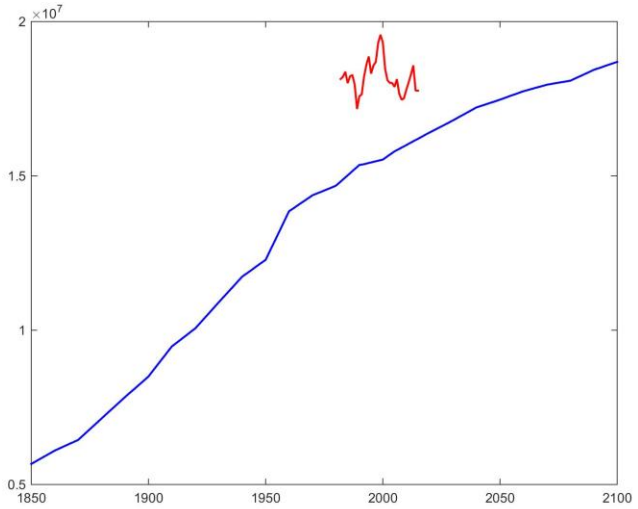
Bare land

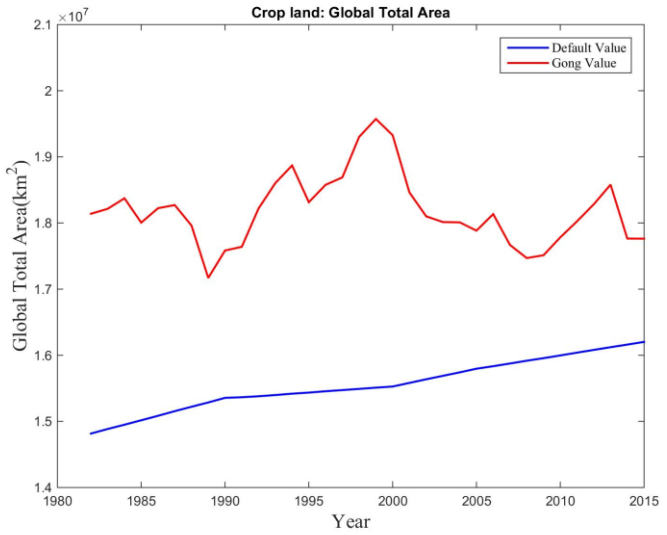




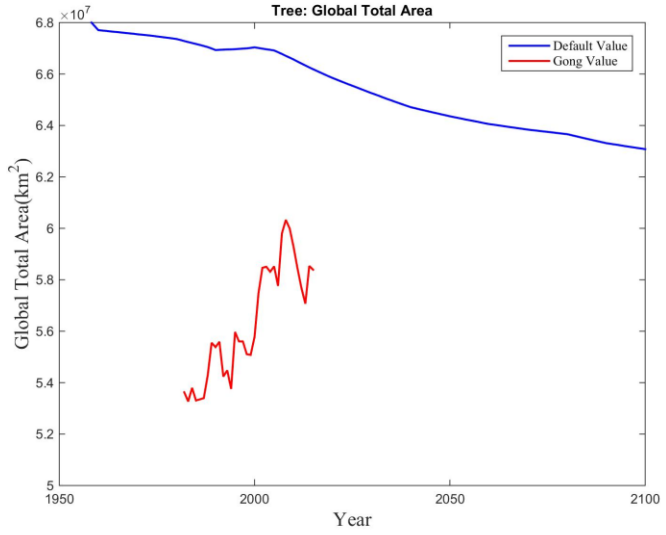
Broadleaf Evergreen, Tropical

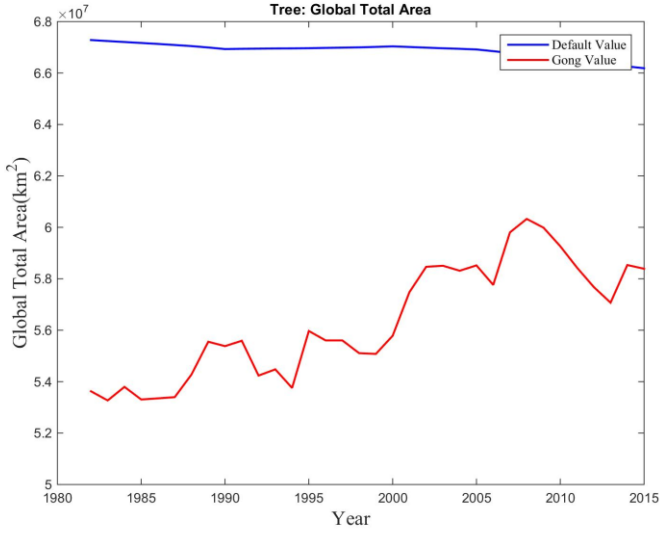
2. Assessment of different PFTs





Crop land

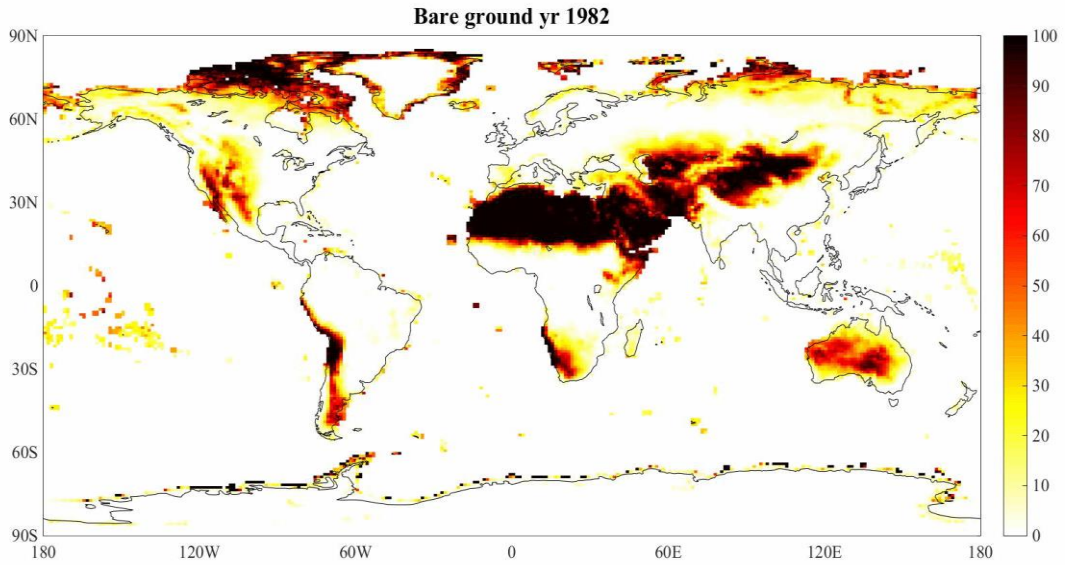




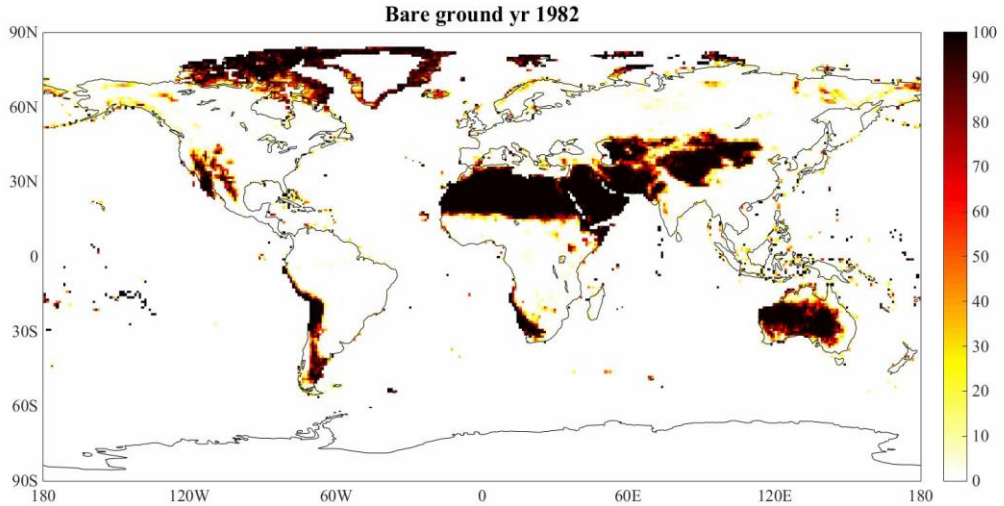
Trees

2. Assessment of different PFTs

Bare land： the dynamic changes from 1982 to 2015



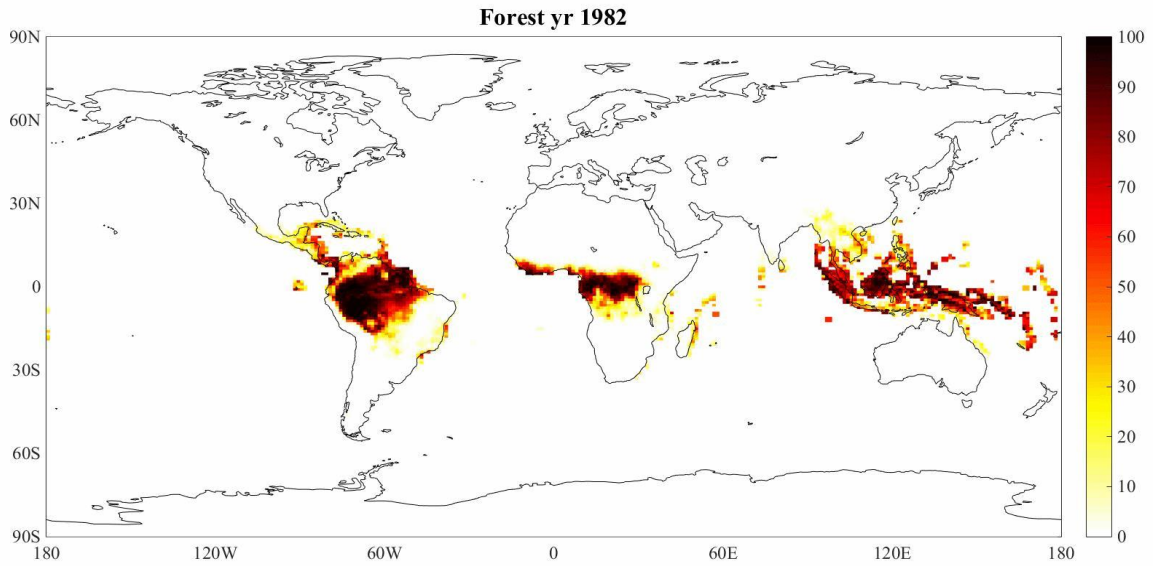
Default PFT



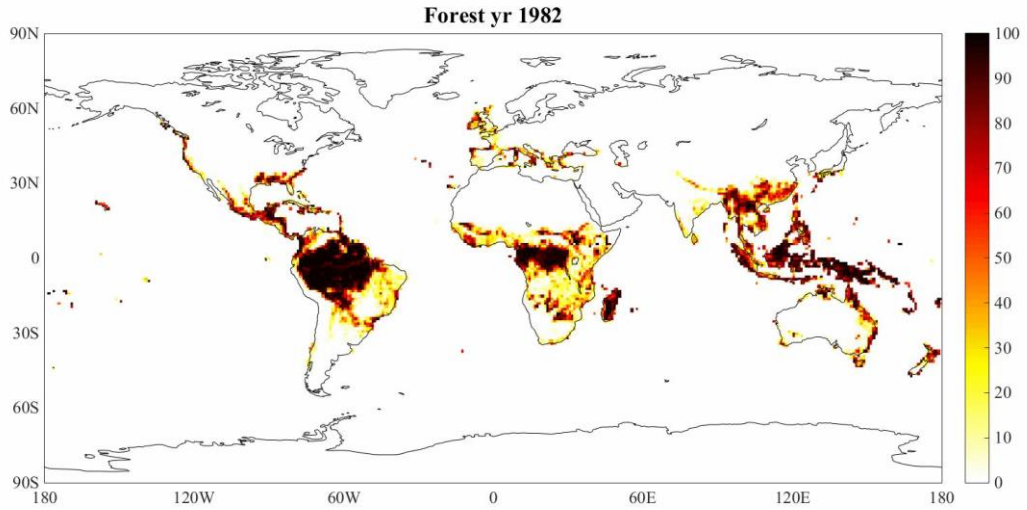
Gong PFT

2. Assessment of different PFTs

Broadleaf Evergreen, Tropical： the dynamic changes from 1982 to 2015



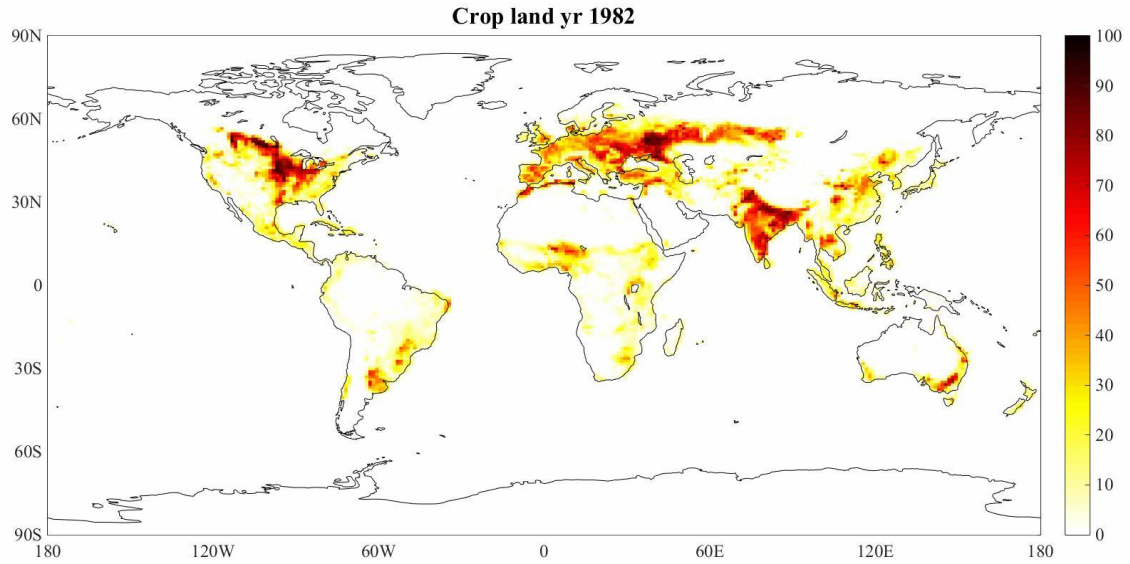
Default PFT



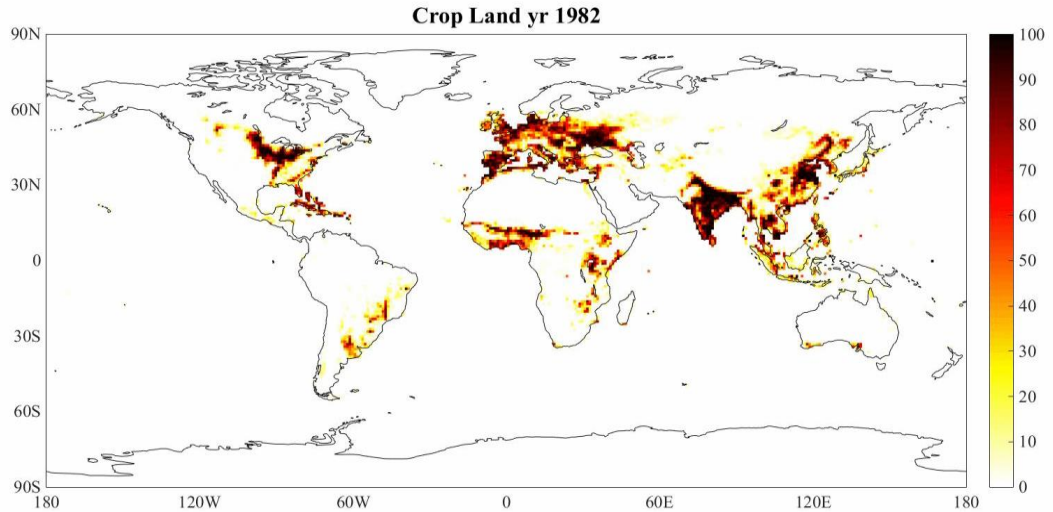
Gong PFT

2. Assessment of different PFTs

Crop land： the dynamic changes from 1982 to 2015



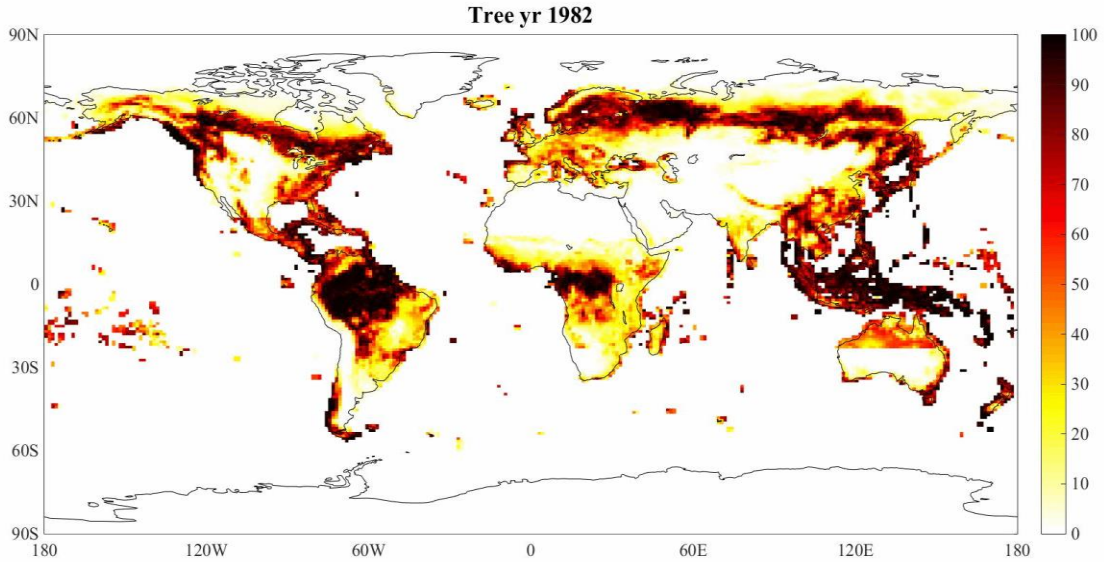
Default PFT



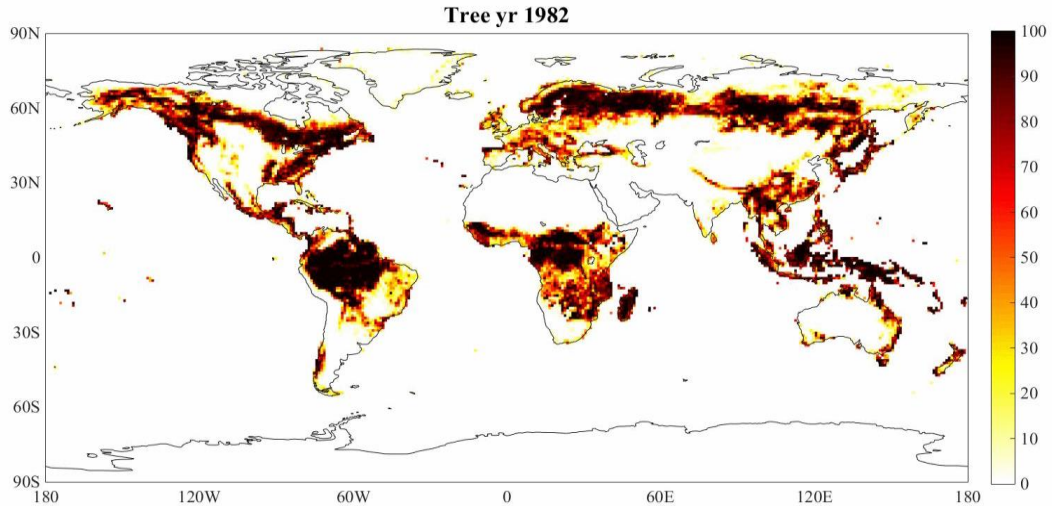
Gong PFT

2. Assessment of different PFTs

Trees： the dynamic changes from 1982 to 2015



Default PFT



Gong PFT

3. Impact of different PFTs on hydrological processes

Experiment Design:

a. Using Gong 1985 and Gong 2015 PFTs data respectively to perform a climate state simulation.

b. Using Default 1985 and Default 2015 PFTs data respectively to perform a climate state simulation.

Default	Gong	CCI
1985	1985	1985
2015	2015	2015

Experiment period: 1975-2014:

1975-1979 warm-up period

1980-2010: experiment period

Assess :

3.1 The impact of Gong LCLU change on hydrological process.

(Gong 1985 and Gong 2015)

3.2 the impact of different source PFT on hydrological process.

(Gong 2015 and Default 2015)

Dvalue = Var(2015) – Var(1985) Rvalue = Dvalue / Var(1985)

Water balance equation

$$P = E_S + E_T + E_C + R + (\Delta W_{soi} + \Delta W_{snw} + \Delta W_{sfcw} + \Delta W_{can}) / \Delta t$$

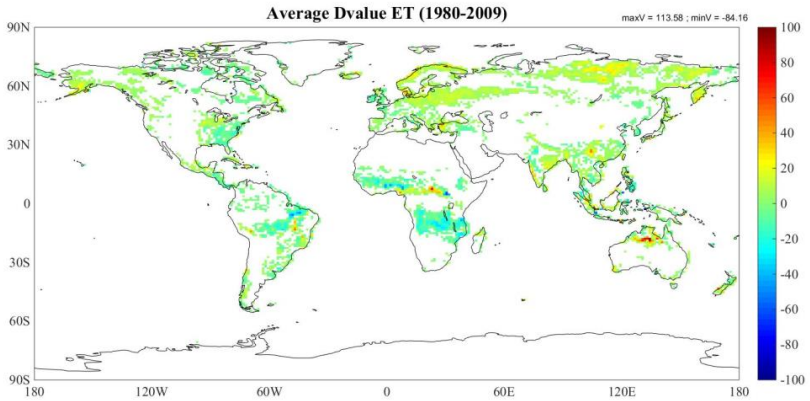
P is rainfall/snowfall,
E_S is soil evaporation,
E_T is transpiration,
E_C is canopy evaporation,
R is runoff (surf + sub-surface),
$\Delta W_{soi} / \Delta t$, $\Delta W_{snw} / \Delta t$, $\Delta W_{sfcw} / \Delta t$, $\Delta W_{can} / \Delta t$, are the changes in soil moisture, surface water, snow, and canopy water over a timestep

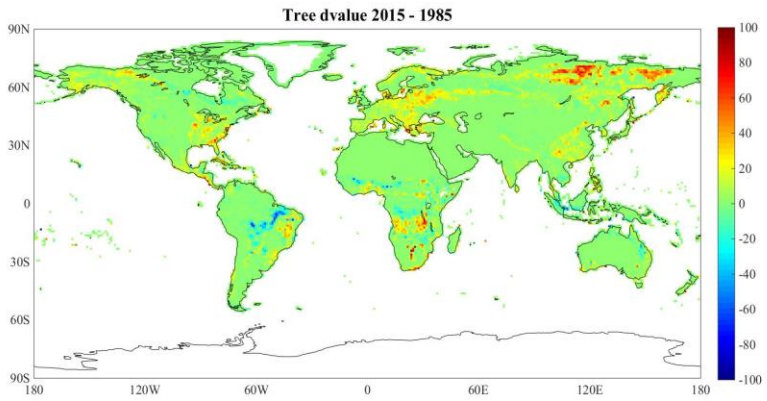
3.1 Gong 1985 and Gong 2015

ET = QSOIL(soil evaporation)+QVEGE（canopy evaporation）+QVEGT（canopy transpiration）

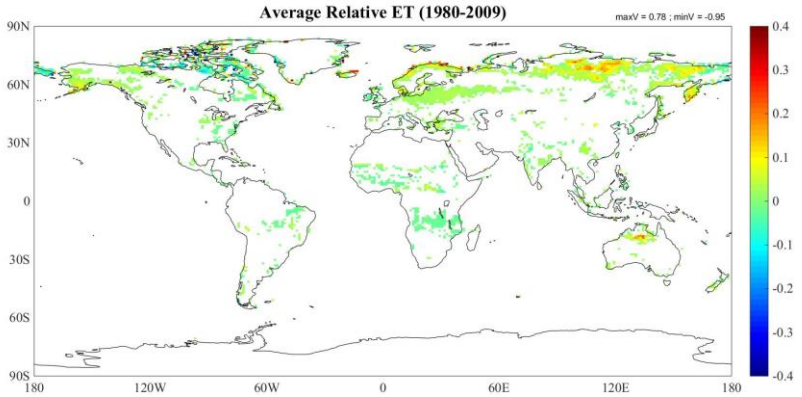
（Dvalue = 0 ➔NaN unit： mm/year）

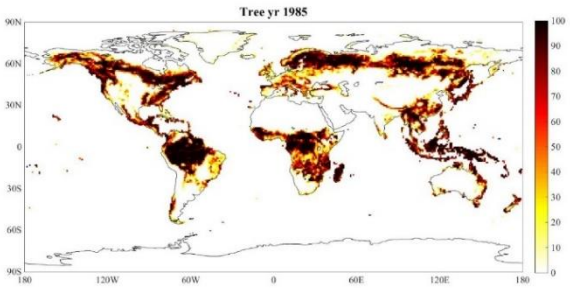
Dvalue

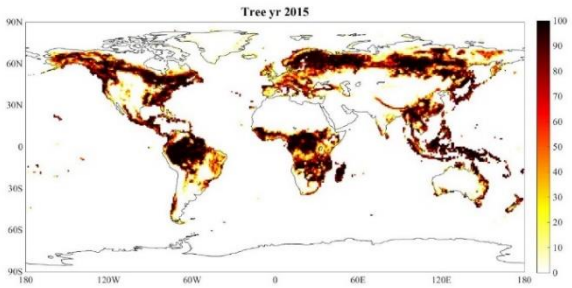




Rvalue







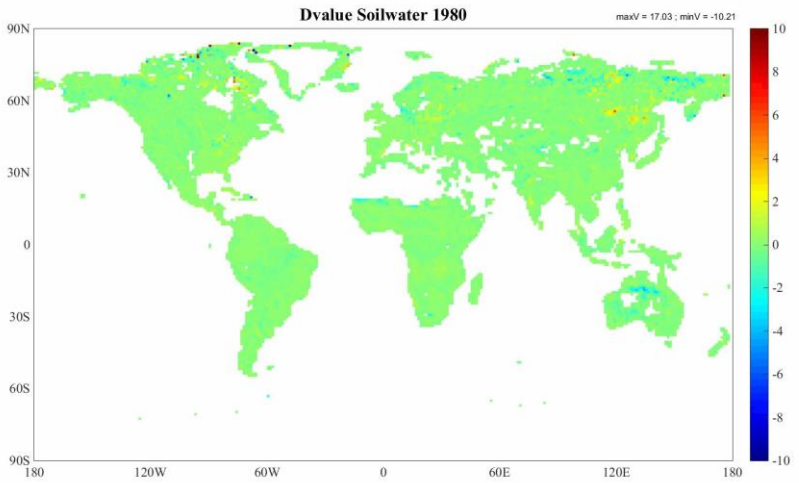
DESS TSINGHUA

3.1 Gong 1985 and Gong 2015

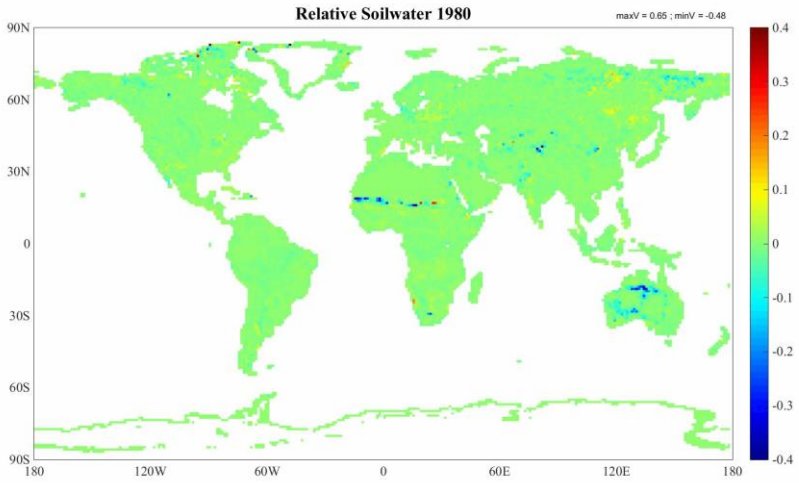
Soil water(10cm): only surface 10 cm change.

unit: kg/m2

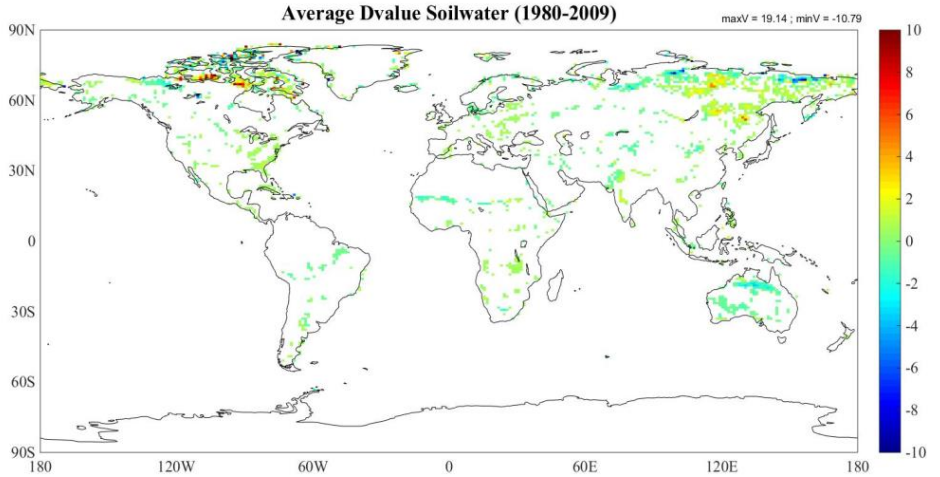
Dvalue

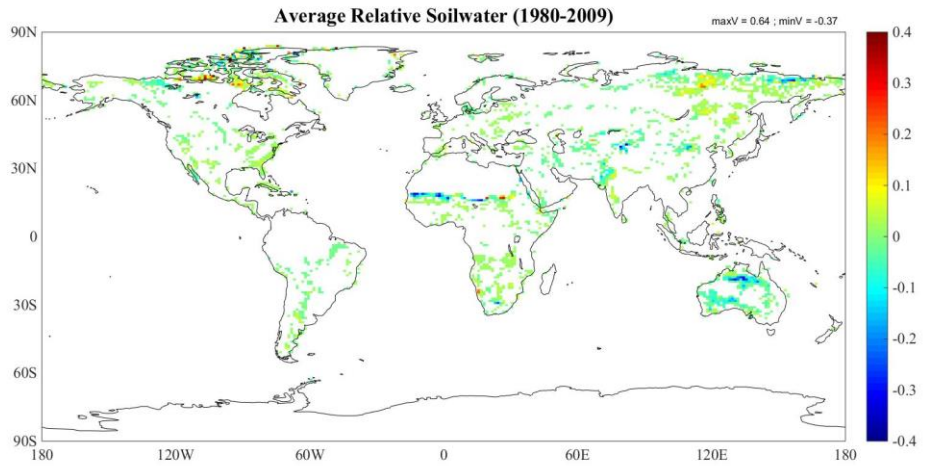


Rvalue



Average

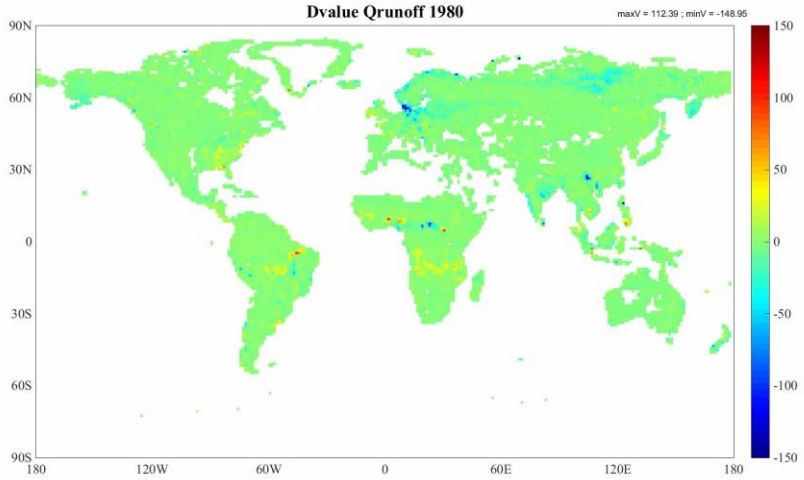




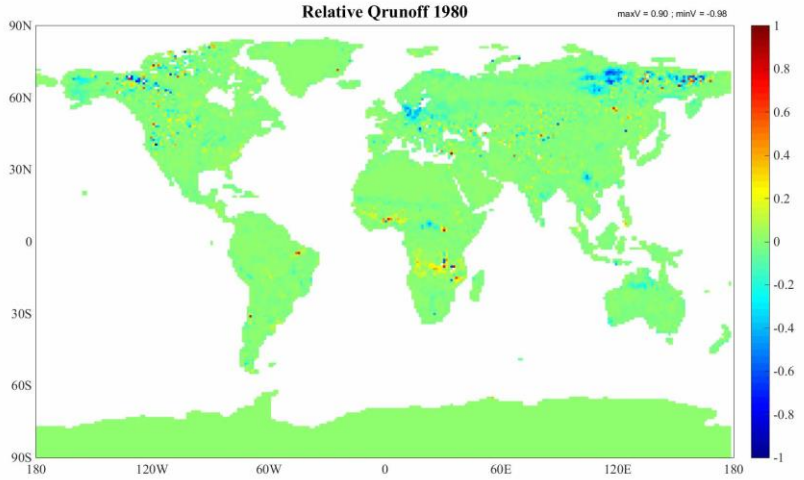
3.1 Gong 1985 and Gong 2015

Qrunoff= qover (land surface runoff)+qdrai(runoff in Glacier, wetland and lake area)+qrgwl (underground runoff) unit: mm/year

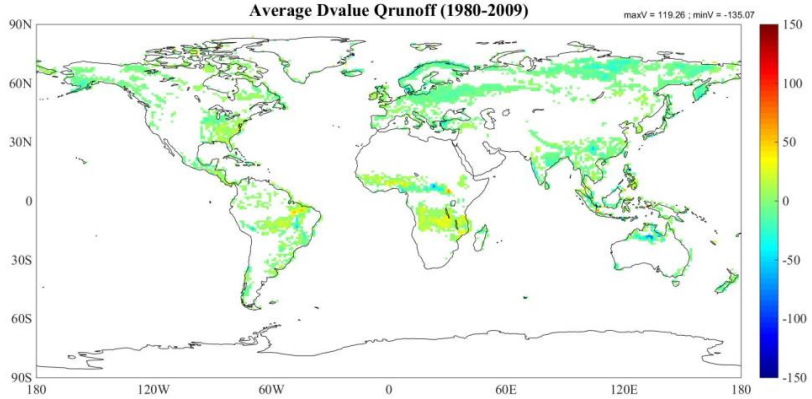
Dvalue

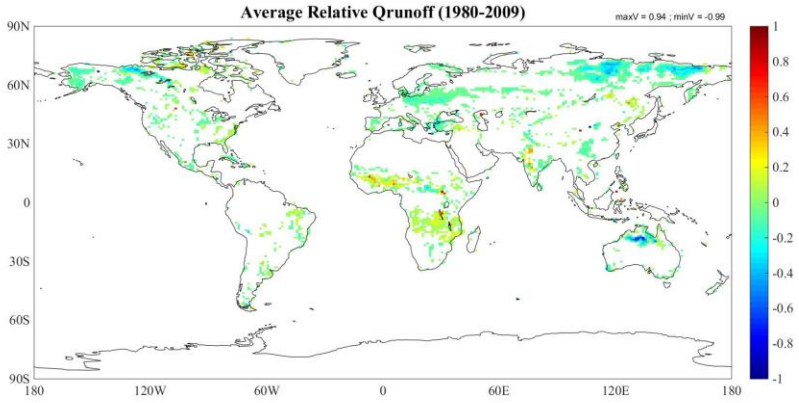


Rvalue



Average





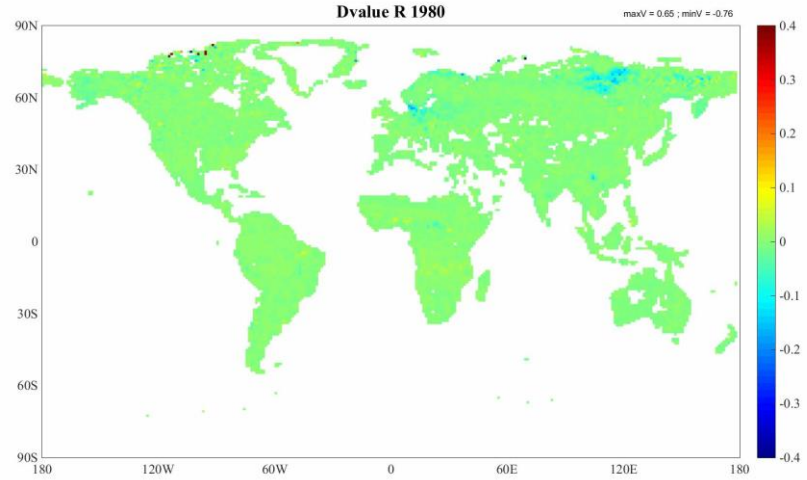
HUA

3.1 Gong 1985 and Gong 2015

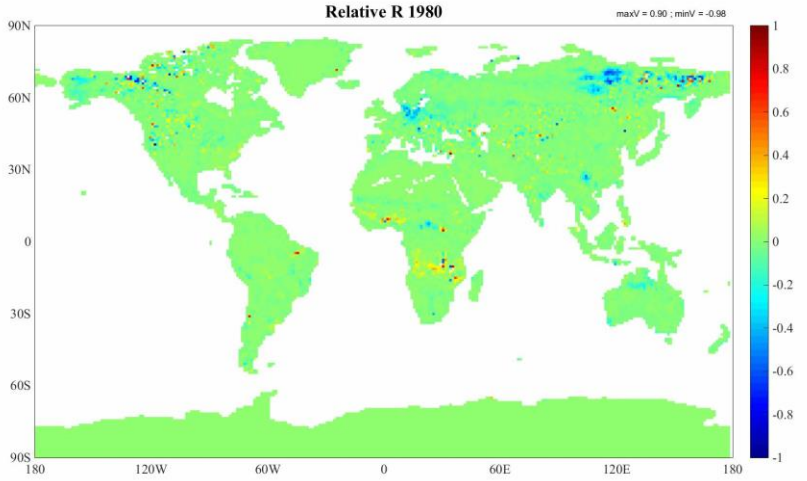
Runoff producing ratio: R = runoff / rainfall (rain + snow)

Unit: unitless

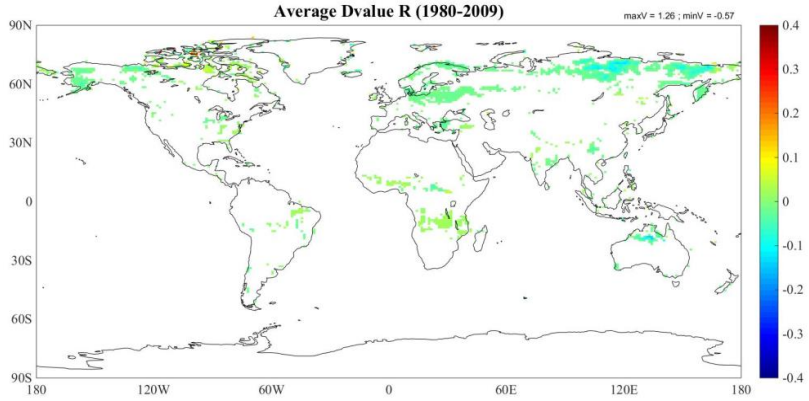
Dvalue

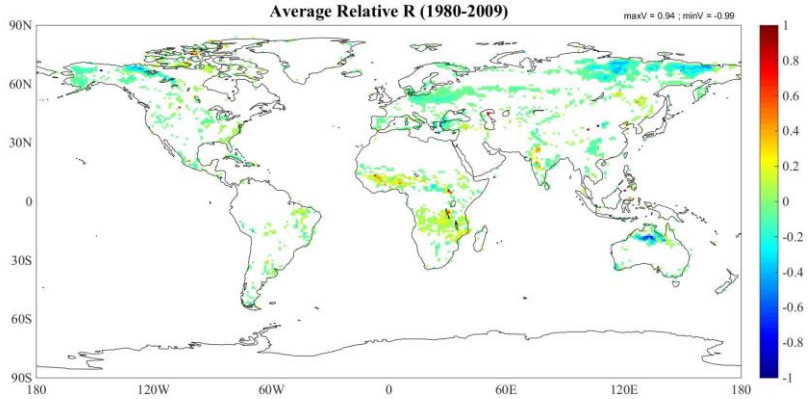


Rvalue

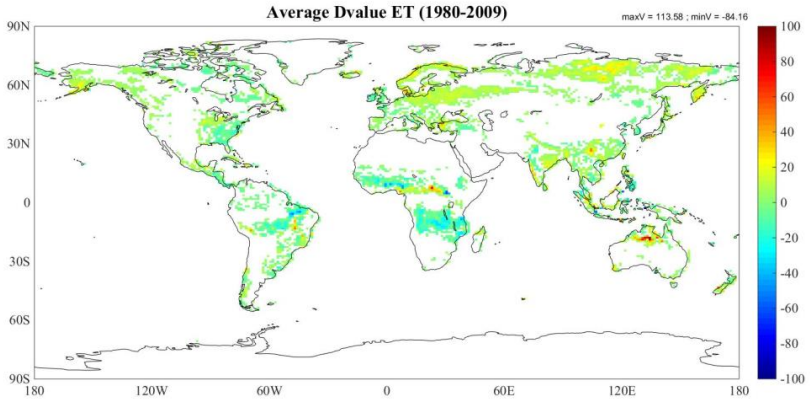


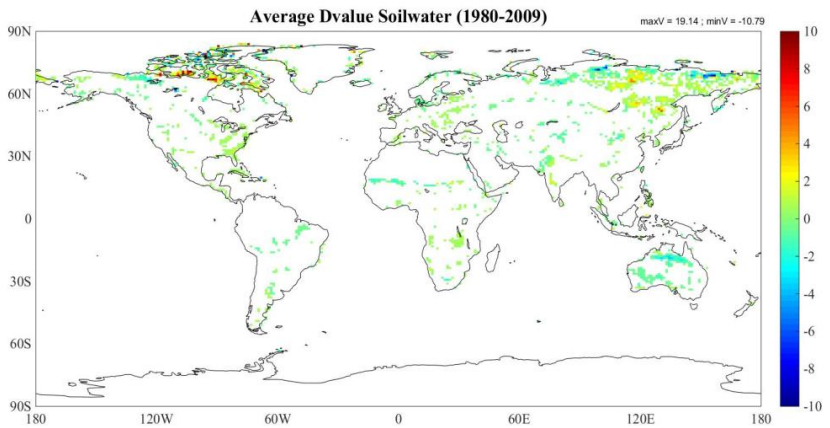
Average

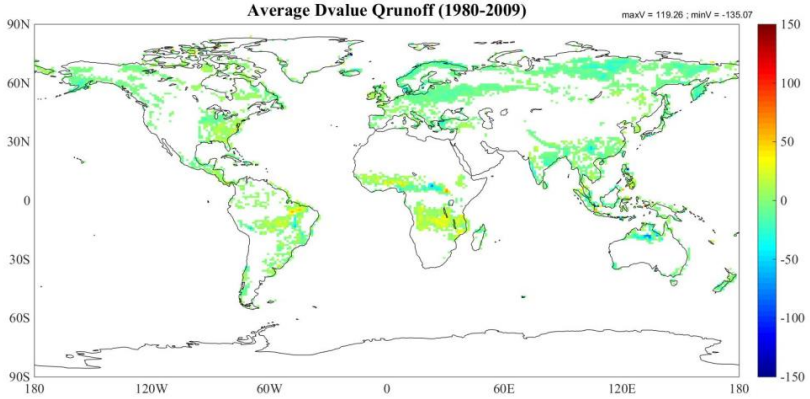


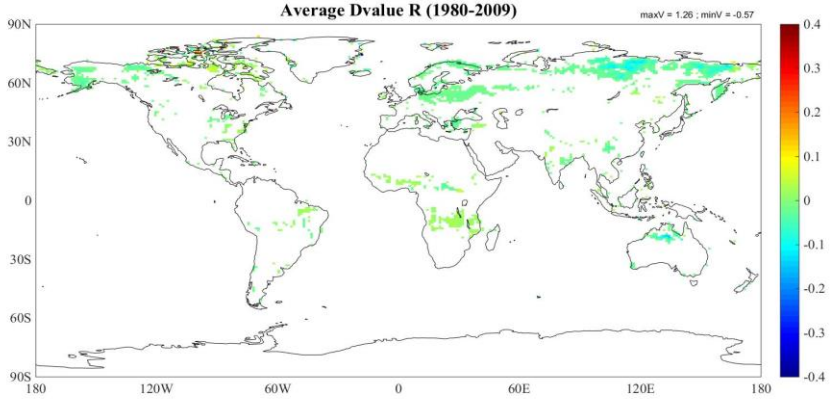


3.1 Gong 1985 and Gong 2015









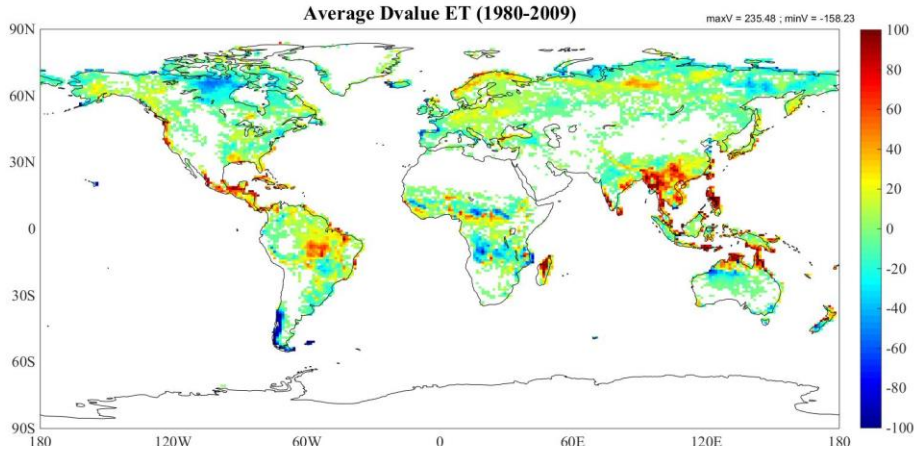
3.2 Gong 2015 and Default 2015

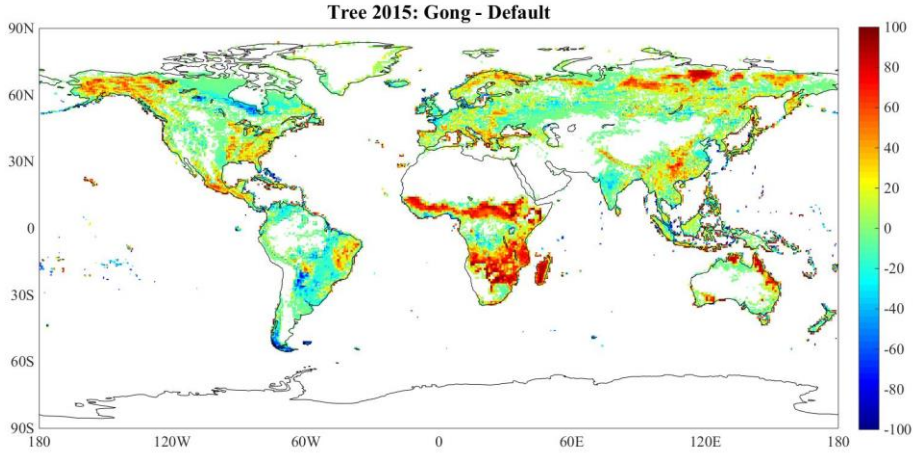
ET = QSOIL(soil evaporation)+QVEGE（canopy evaporation）

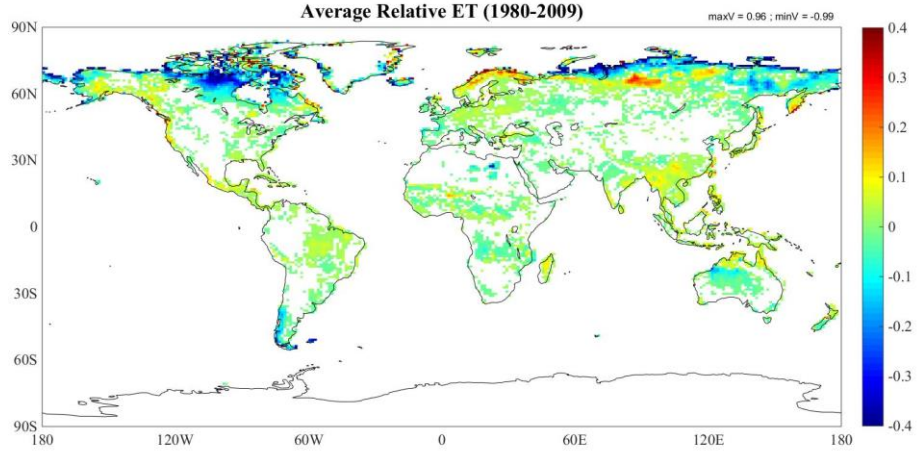
+QVEGT（canopy transpiration）

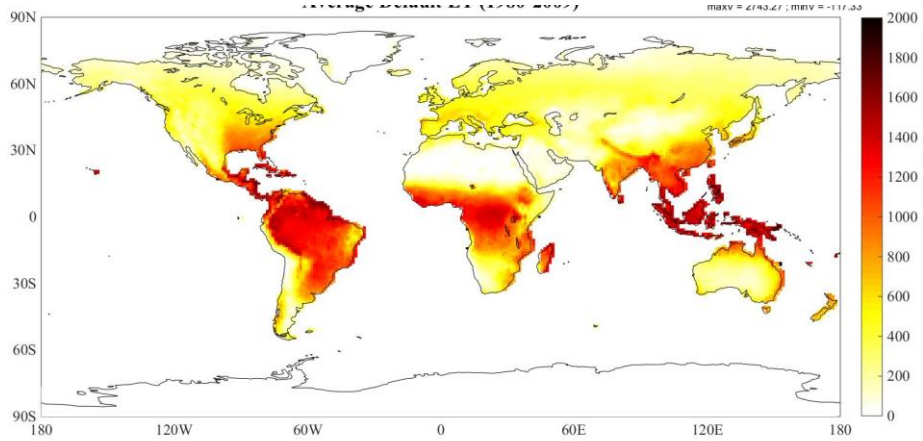
（Dvalue = 0 ➔NaN unit：mm/year）

Dvalue=Gong. – Default.
Rvalue=Dvalue / Default.







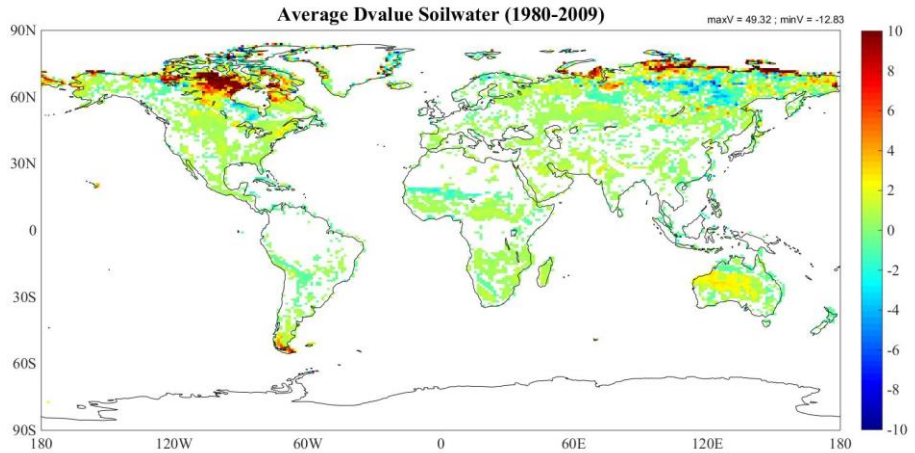


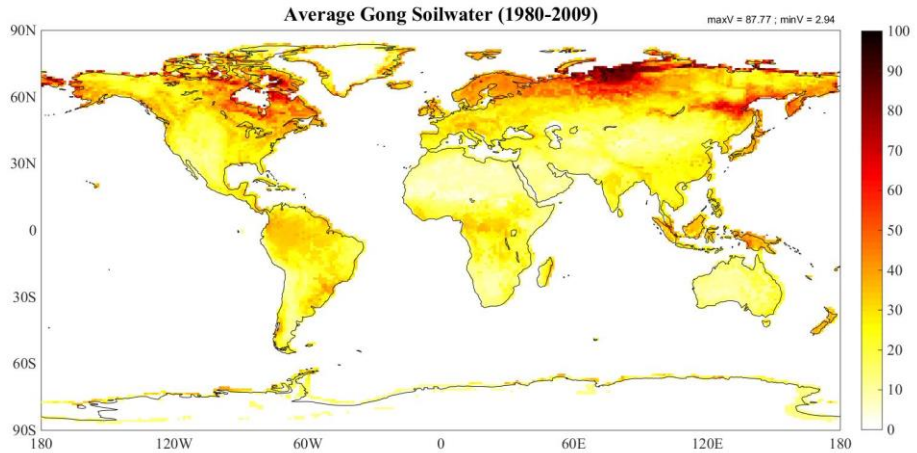
3.2 Gong 2015 and Default 2015

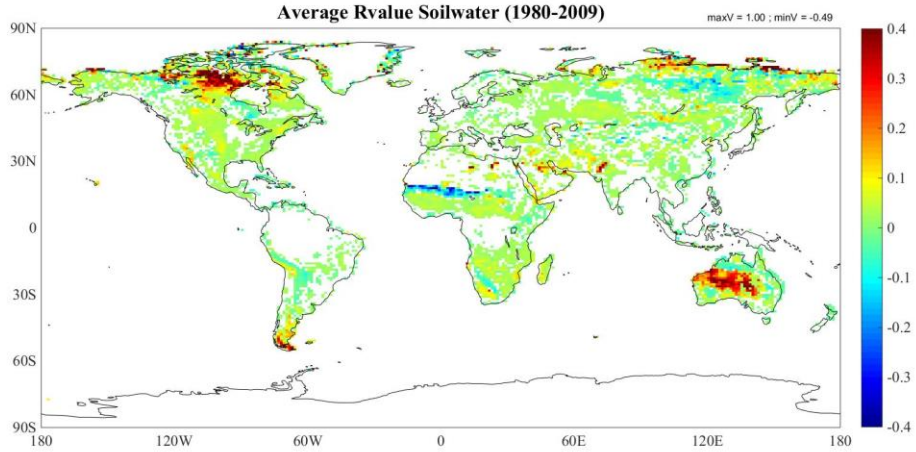
Soil water(10cm): only surface 10 cm change.

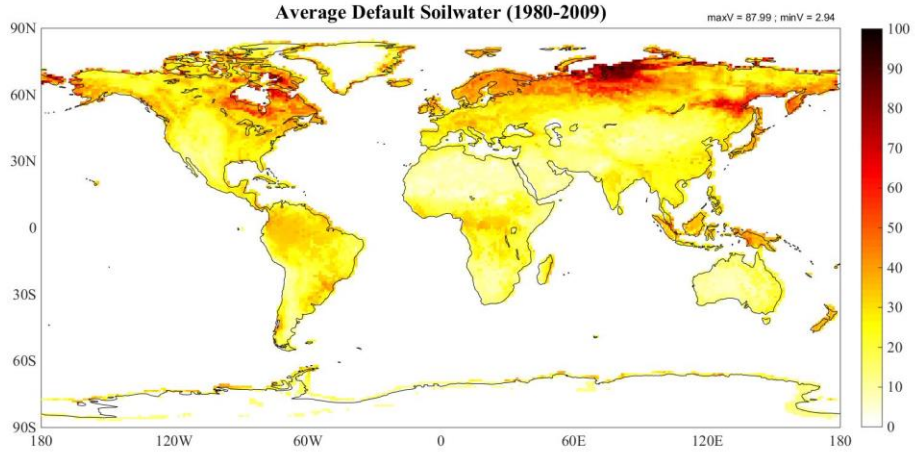
unit: kg/m2

Dvalue=Gong. – Default.
Rvalue=Dvalue / Default.







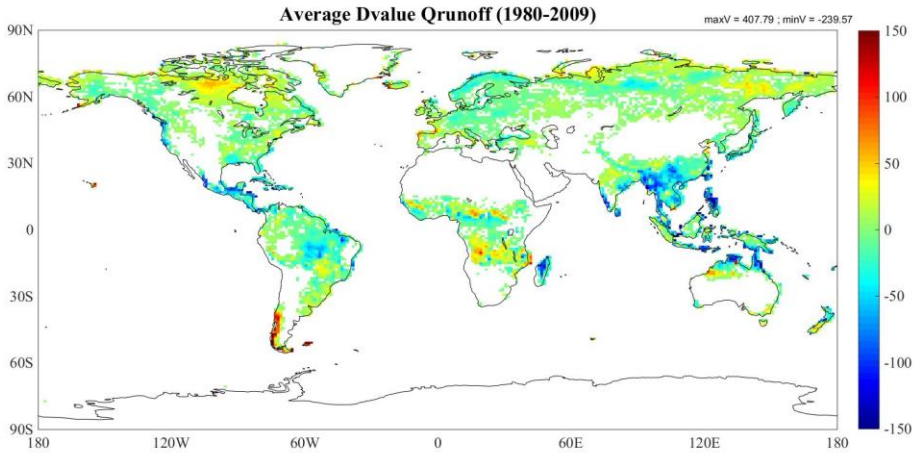


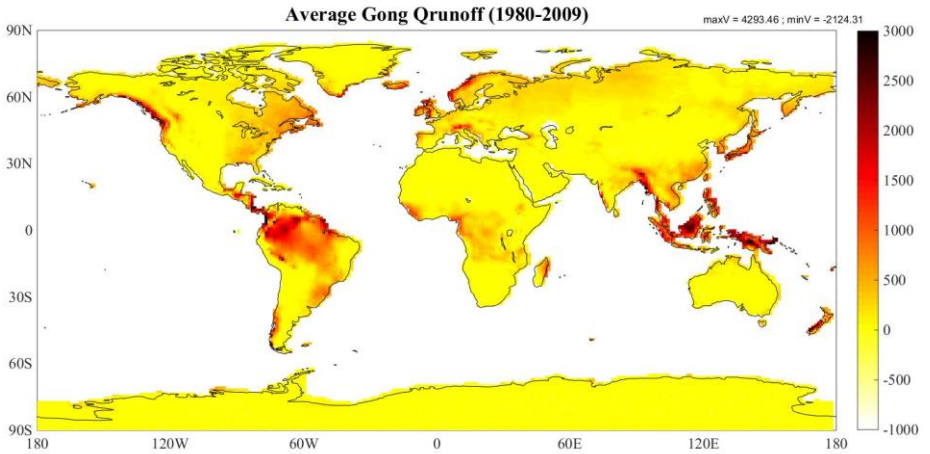
NGHUA

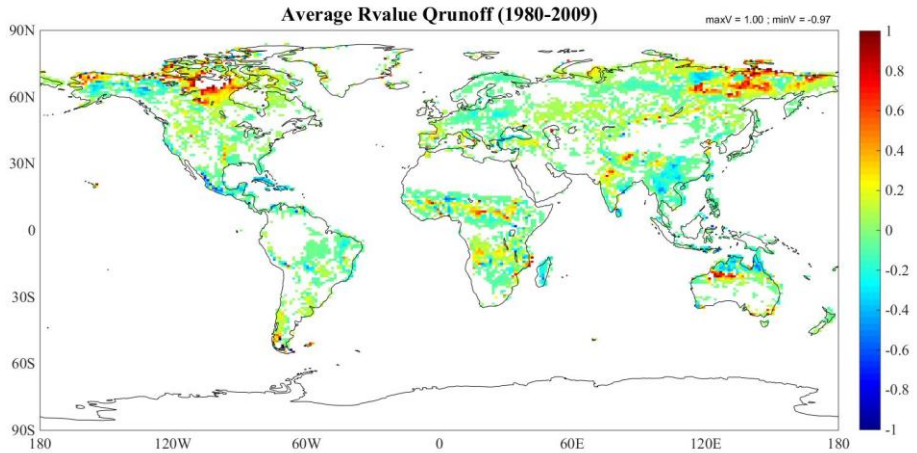
3.2 Gong 2015 and Default 2015

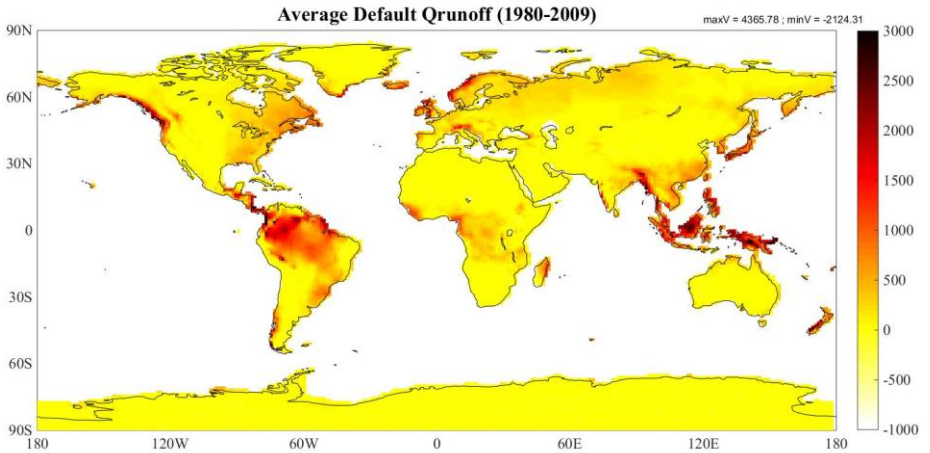
Qrunoff= qover (land surface runoff)+qdrai(runoff in Glacier, wetland and lake area)+qrgwl (underground runoff) unit: mm/year

Dvalue=Gong. – Default.
Rvalue=Dvalue / Default.







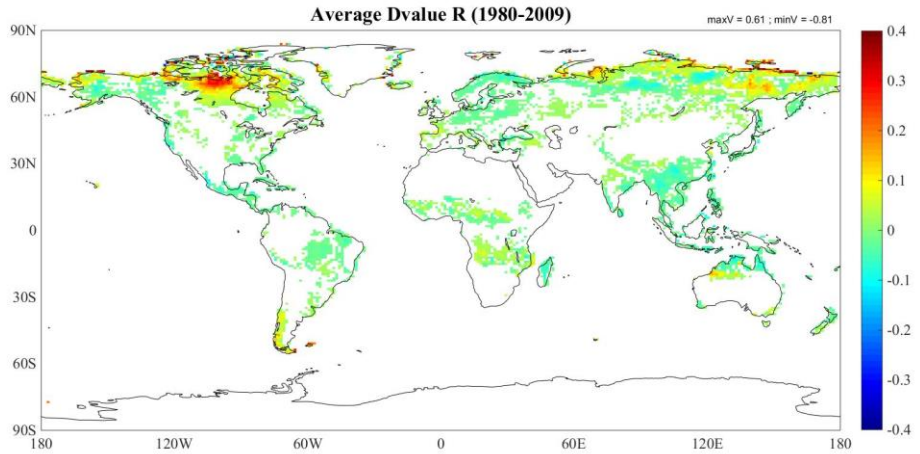


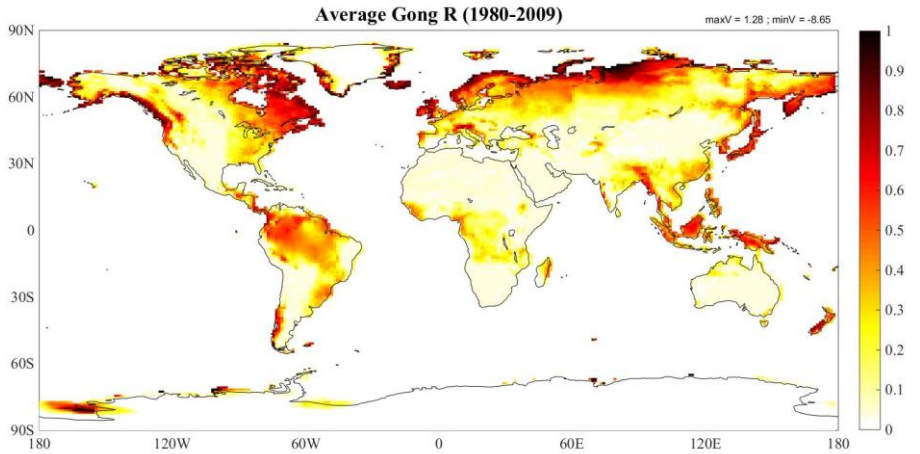
3.2 Gong 2015 and Default 2015

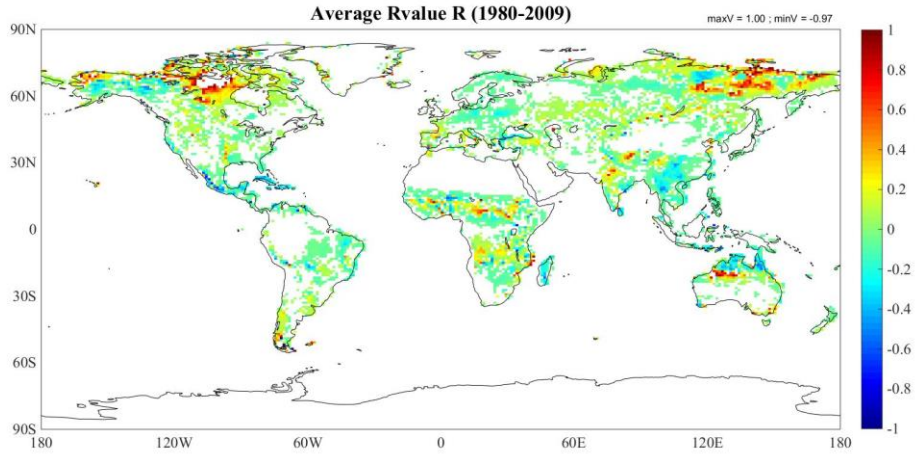
Runoff producing ratio: R = runoff / rainfall (rain + snow)

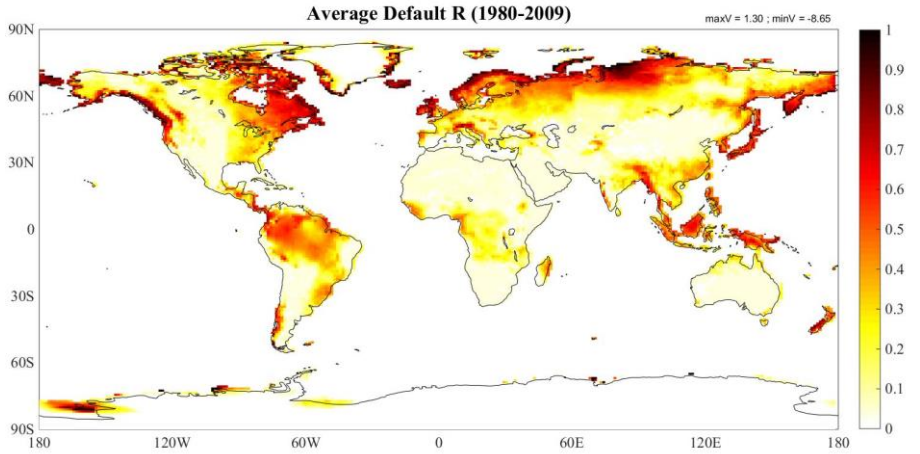
Unit: unitless

Dvalue=Gong. – Default.
Rvalue=Dvalue / Default.

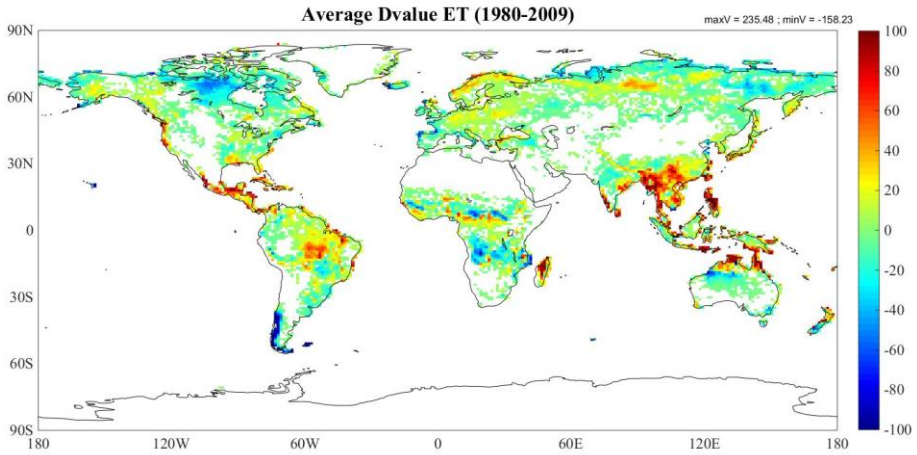


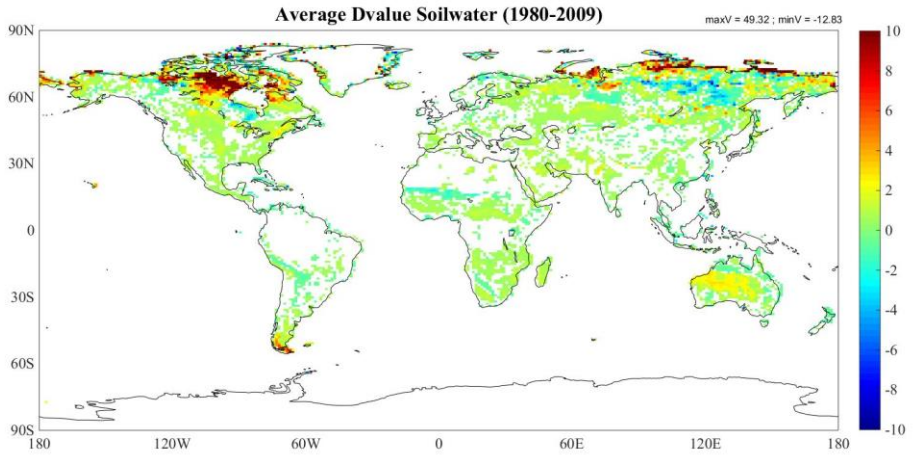


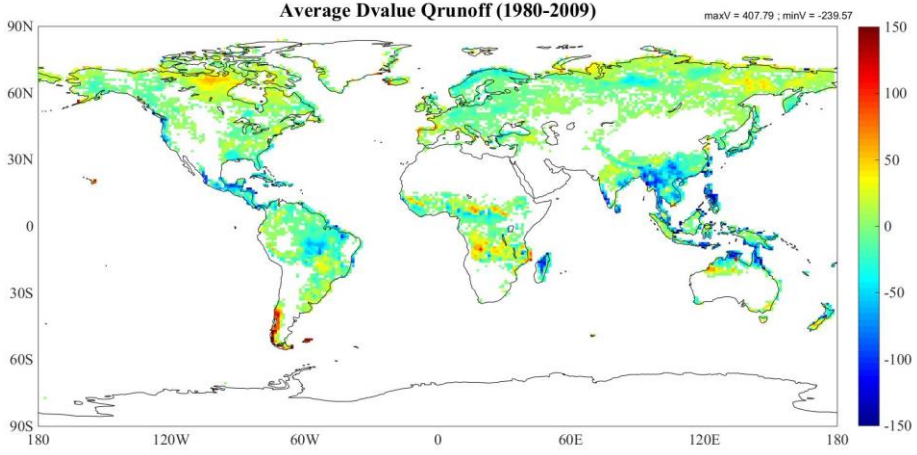


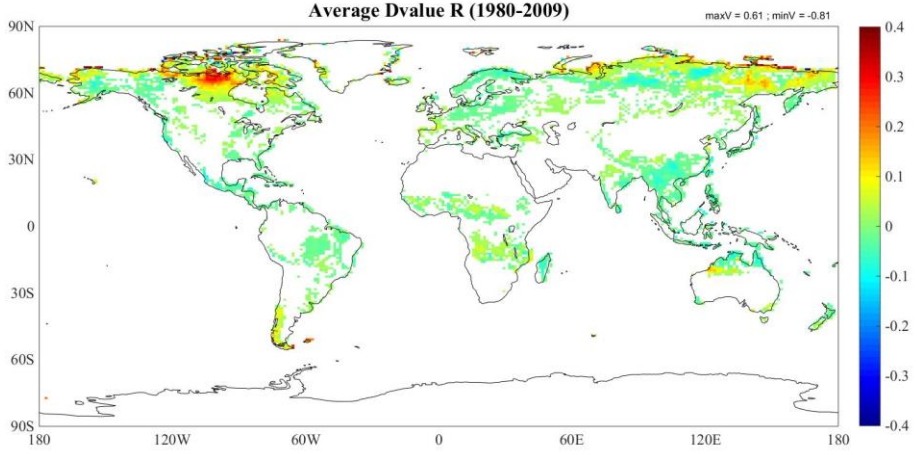


3.2 Gong 2015 and Default 2015



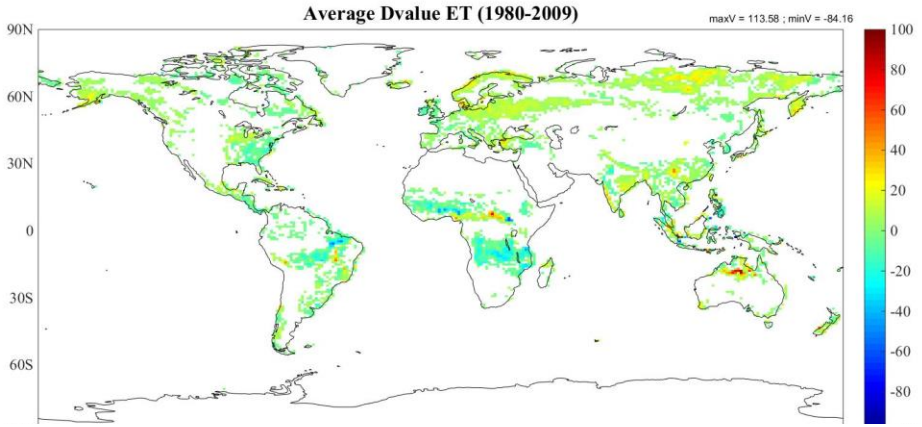


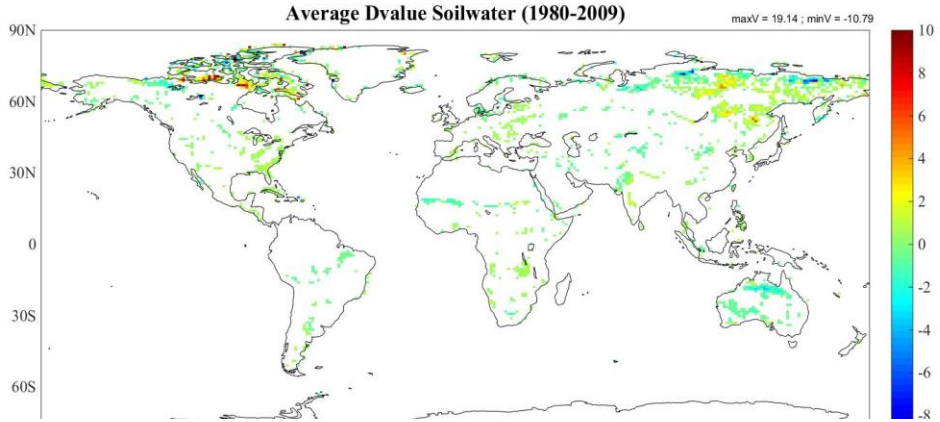


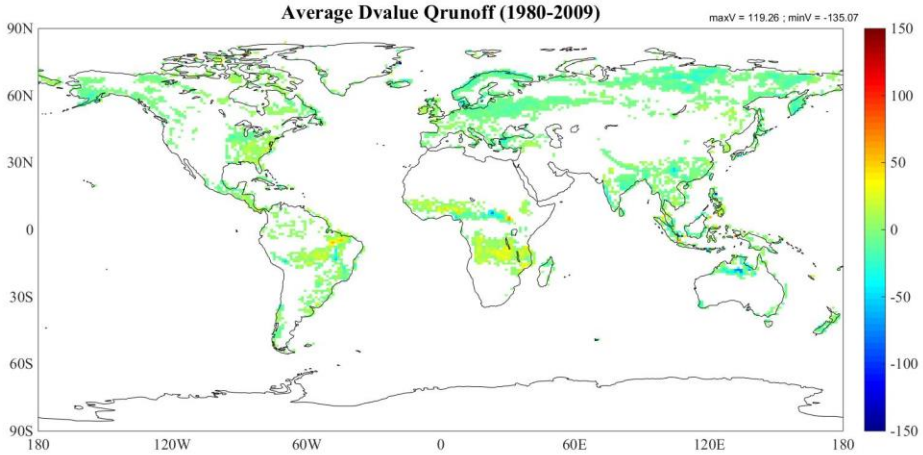


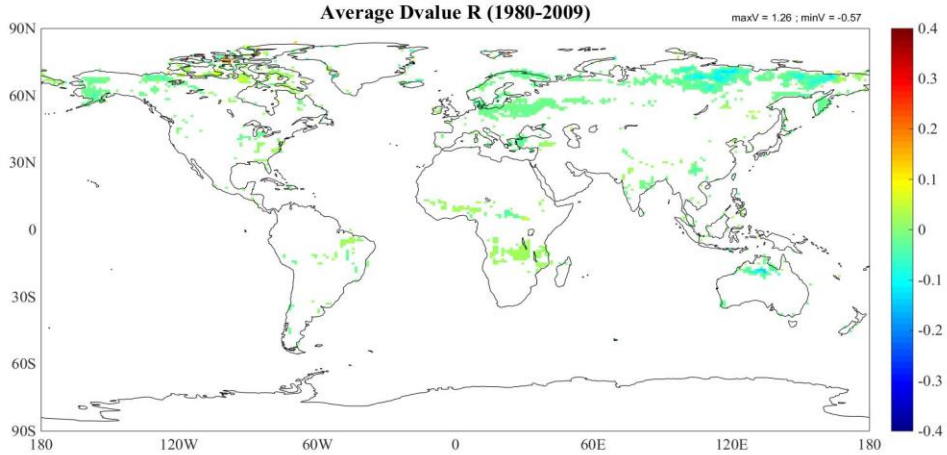
UA

3.1 Gong 1985 and Gong 2015









4.Conclusions

- LCLU data determine the PFTs and related coefficients in Land Surface model and can cause significant impact on simulation results.
- The LCLU change in CMIP5/6 is pre-determined annual data
  - Consider both historical re-built land-use and future land cover change
  - 1850 - 2100
- The global LCLU products based on remote sensing can be used to evaluate the PFTs (based on CMIP5) in CESM
  - The variation tendency of Gong products based on AVHRR and field experiment is more significant.
  - The pre-determined PFTs in CMIP5 from 1850 to 2100 have weak inter-annual changes in 30 years.
  - The large inter-annual variation may be partly caused by the remote sensing image acquisition time and satellite mapping accuracy.
- The impact on simulation result: different source data > LCLU inter-annual changes

Thank you !