陆面模拟系统
The Terrestrial Modeling System (TMS)

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汇报提纲

- 背景
- 目标
- 模拟系统
- 展望

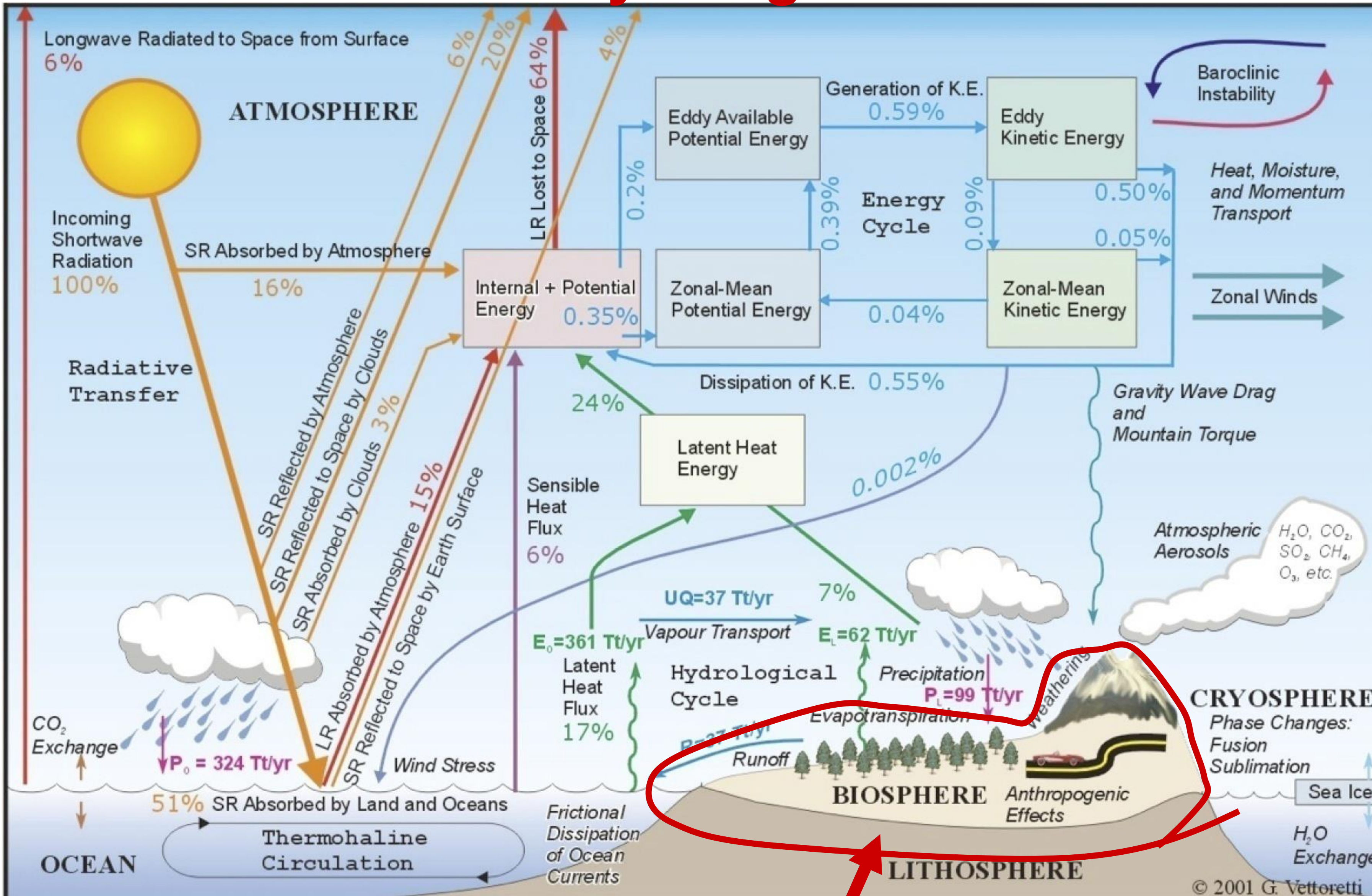
背景：

- 提高天气、气候的模拟与预报质量
- 提高陆面过程(物理、生物地球化学、水文等)的模拟与预报质量
- 观测技术与数据处理技术日趋成熟，已有海量的高质量数据：
  - 陆面特征数据
  - 陆面气象数据
- 陆面模型的模拟性能已有较大的提高

目标

- 人类活动与地球系统相互作用定量研究平台
- 自成体系的陆面模拟系统
- 耦合地球系统模型

Models of Everything



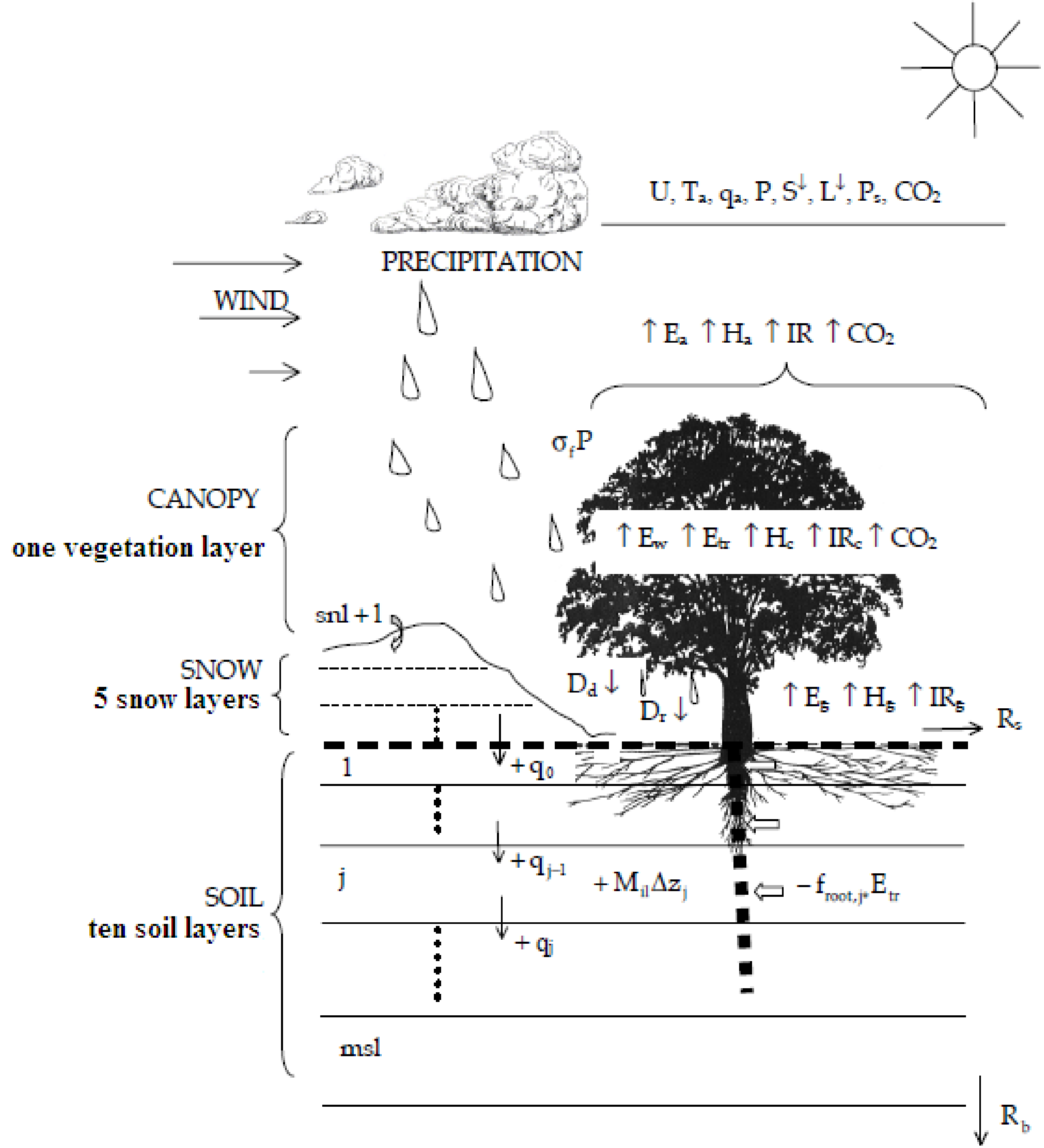
Our Focus: Models of Land Everything

陆面模拟系统（TMS）

TMS模拟系统

- 陆面模型 - Common Land Model (CoLM)
- 陆面参数最优估算系统
- 陆面数据同化系统
- 高分辨率陆面基础数据
- 高分辨率的陆面气象驱动数据
- 高性能计算平台
- 数据可视化系统和发布平台

CoLM示意图



U, T_a, q_a, P, S↓, L↓, P_s, CO2
PRECIPITATION
WIND
↑E_a ↑H_a ↑IR ↑CO2
σ_f P
CANOPY
one vegetation layer
↑E_w ↑E_tr ↑H_c ↑IR_c ↑CO2
snl+1
SNOW
5 snow layers
D_d↓
D_r↓
↑E_g ↑H_g ↑IR_g
R_s
1
+q_0
j
+q_j-1
+M_il Δz_j
−f_root,j* E_tr
SOIL
ten soil layers
+q_j
msl
R_b

CoLM的最新发展：

1) 土壤水文模块
2) 山地冰川和大陆冰原模块
3) 湿地模块
4) 湖泊模块
5) 城市冠层模块
6) 流域水文过程模拟模块
7) 冠层辐射传输模块
8) 植被动力学和生物地球化学过程模块
9) 作物模块(ongoing, Dai)……………

高分辨率陆面特征资料集

陆面模拟基础数据建设

1、中国区域陆面模式驱动数据集

数据分辨率：5 x 5 km, every 3 hour。数据时间跨度：1958-2010年。

数据包含7个陆面气象变量。

2、中国区域土壤数据集

数据分辨率：30 x 30 arc-seconds, 10 vertical layers.

数据包含28个土壤属性参数、土壤水力参数集。

3、全球土地覆盖/利用数据集、叶面积指数数据集

数据分辨率：30 x 30 arc-seconds, every 8 day。

数据时间跨度：2000-2010。

4、全球土壤数据集

数据分辨率：30 x 30 arc-seconds, 10 vertical layers. 数据包含：土壤属性参数、土壤水力参数集。

全球土壤资料集

- Harmonized World Soil Database (全球、1km x 1km)
- 中国土壤资料集

- 土壤质地
- 土壤营养元素(生物地球化学)
- 土壤土体厚度

http://globalchange.bnu.edu.cn/user/users.jsp

Example lists of the soil dataset used by ESMs or climate models

ESMs and their LSMs	Input soil data	Soil datasets and resolution
[a]**CESM** and **CCSM** (all versions); **CLM** [*Oleson et al.*, 2010; *Lawrence et al.*, 2010]	1) Soil texture (%sand, clay); 2) Soil organic matter (SOM); 3) Soil color class	1) *Global Soil Data Task* [2000][5′x 5′]; 2) *Global Soil Data Task* [2000], SOM [1° x 1°]; 3) Soil color class dataset derived from MODIS [*Lawrence* and *Chase*, 2007]
MPI-ESM; [*Hagemann et al.*, 1999; *Hagemann*, 2002]	1) Volumetric heat capacity and thermal diffusivity are prescribed for soil types; 2) Field capacity 3) Plant-available soil water holding capacity and wilting point	1) FAO soil map (five soil types); 2) *Patterson* [1990]: 0.5° x0.5° : θ_{fc}; 3) Only related to the distribution of ecosystem types in the Global Land Cover Characteristics Database dataset.
[a]**HadGEM2** [*Collins et al.*, 2011] and **JULES/MOSES** [*Cox et al.*, 1999]	Soil texture classes	*Wilson* and *Henderson-Sellers* [1984]: 1° x 1° global soil-texture classes.
GFDL ESM [http://www.gfdl.noaa.gov/ **GFDL LSM** [LM3, version 3]	soil texture type	Soil type [Zöbler,1986];*Available water capacities* [*Dunne and Willmott*, 1996] .
GISS GCM ModelE [http://www.giss.nasa.gov/tools/modelE/]; **GISS-LSM** [*Rosenzweig* and *Abramopoulos*,1997]	Soil thermal conductivity is calculated as a function of water content using the method of *De Vries* (1966).	1° x 1° Zöbler world soil data file (*Zöbler* 1986), soil horizon thicknesses and textures (particle size distributions) at a 1° x 1° resolution (*Webb et al.* 1991, 1993)

Status of soil dataset in land surface models

Land model	Soil Dataset
BATS (Dickinson et al., 1986; 1996)	1^o x 1^o global soil classes data of Wilson and Henderson-Sellers (1984)
SiB (Sellers et al., 1986; 1996)	1^o x 1^o global soil-type SMW grouped by Zobler (1986)
VIC (Liang et al., 1994; Nijssen et al., 2001)	5 x 5-arc minutes SMW with WISE pedon database.
NOAH (Chen and Dudhia, 2001)	Global soil-textural classes map from STATSGO (30-arc sec) (USA) and SMW (5-arc min) (outside USA)
CLM (Dai et al., 2003; Oleson et al., 2010)	1^o x 1^o global IGBP-SOIL dataset (Global Soil Data Task 2000)
JULES/MOSES (Cox et al., 1999; Blyth et al., 2006)	1^o x 1^o global soil classes data of Wilson and Henderson-Sellers (1984)
GLDAS (Rodell et al., 2004)	5 x 5-arc minutes global soils dataset of Reynolds et al. (2000).

中国土壤数据

A China soil characteristics dataset for land modeling

(http://globalchange.bnu.edu.cn/research/soil)

Existing Soil Datasets

Table 1. Geographic distribution of soil profiles in WISE database

Region	Number of profiles	
	WISE-1	WISE-2
Africa	1799	3998
Australia and Pacific Islands	122	147
China, India, Indonesia & Philippines	553	628
Europe	492	1204
North America	266	326
South America and the Caribbean	599	2115
South west and Northern Asia (incl. Siberia)	522	1113
Total	*4353*	*9607*

Source: Batjes NH 2002. Revised soil parameter estimates for the soil types of the world. *Soil Use and Management* 18, 232-235.

Soil parameters are derived by fewer than 60 soil profiles over China (mainland). 60 profiles are too few to adequately represent the heterogeneity of China soil.

(See the documentation: FAO/IIASA/ISRIC/ISSCAS/JRC, 2009. *Harmonized World Soil Database (version 1.1)*. FAO, Rome, Italy and IIASA, Laxenburg, Austria.)

China Soil Dataset

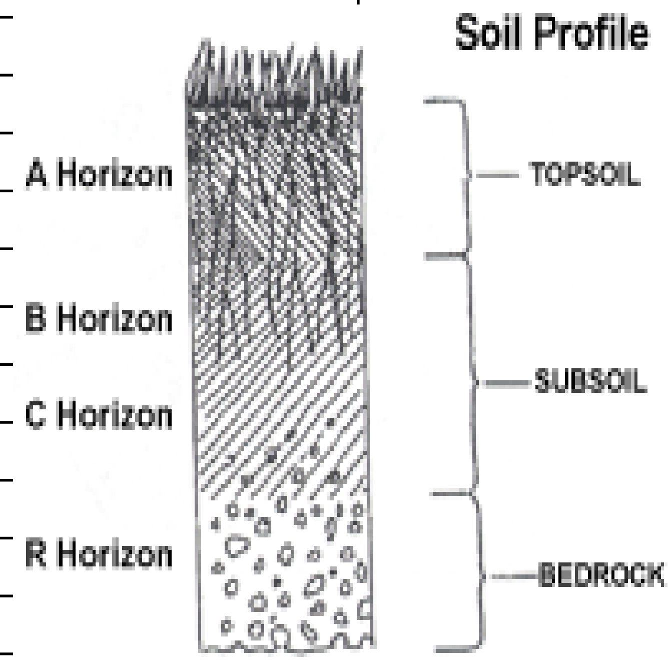
- 9000 soil profiles vs 60 in FAO soil dataset

- Soil profile attribute datasets were collected and digitized from different literatures, national and county soil survey records.

- Soil Map of China (1:1 000 000).

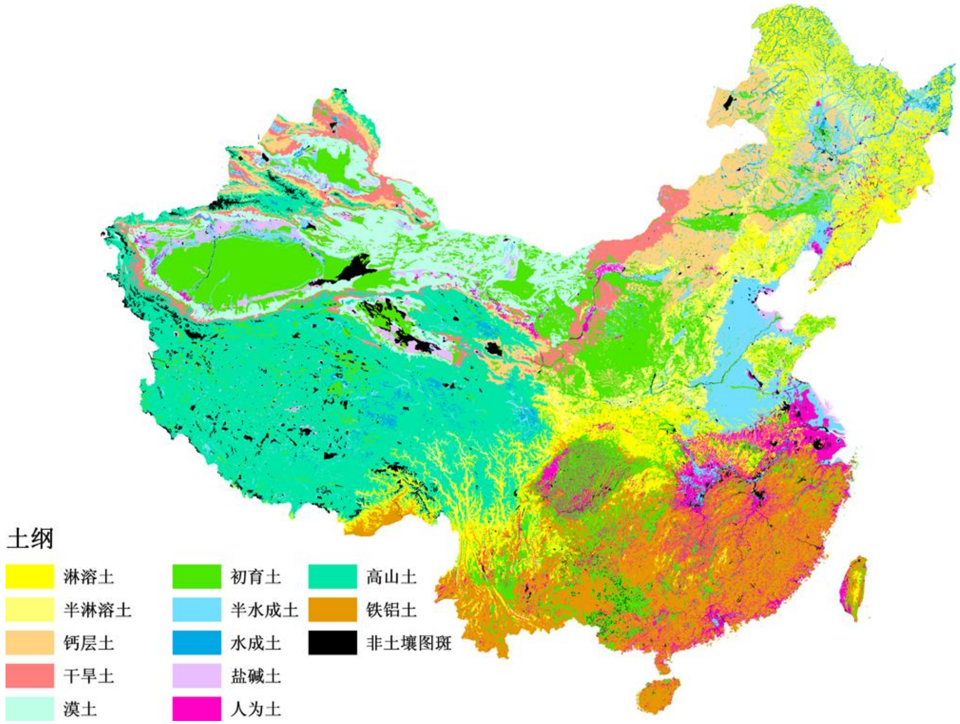
Dai Y, Shangguan W, Liu B, and Coauthors, 2011: **A China dataset of soil properties for land surface modeling.** (to be submitted to Global Biogeochemical Cycles)

1	Horizon Thickness (cm)
2	Soil Texture
3	Bulk Density
4	Particle-Size Fraction % (0.05 - 2.0 mm)
5	Particle-Size Fraction % (0.002 - 0.05mm)
6	Particle-Size Fraction % (< 0.002 mm)
7	Organic Matter Fraction (%)
8	Total N (%)
9	Total P (%)
10	Total K (%)
11	Available P (mg/kg)
12	Available K (mg/kg)
13	pH Value (H_2O)
14	Exchangeable H^+ (me/100g)
15	Exchangeable Al^{3+} (me/100g)
16	Exchangeable Ca^{2+} (me/100g)
17	Exchangeable Mg^{2+} (me/100g)
18	Exchangeable K^+ (me/100g)
19	Exchangeable Na^+ (me/100g)
20	Cation Exchange Capacity (CEC) (me/100g)
21	Color
22	Structure
23	Consistence



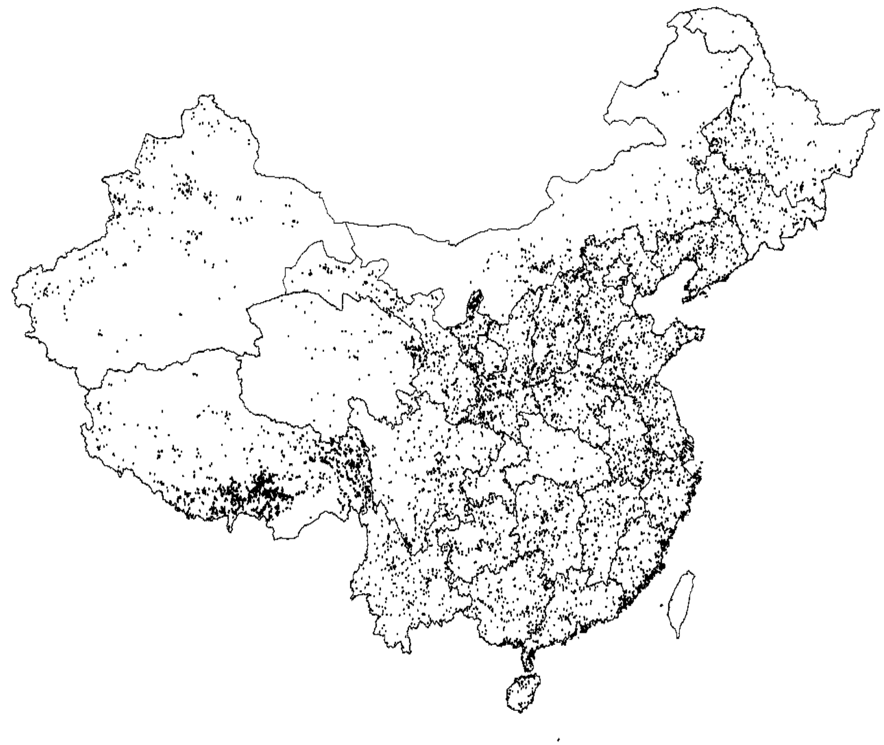
Source Data

China Soil Map (1:1 million)



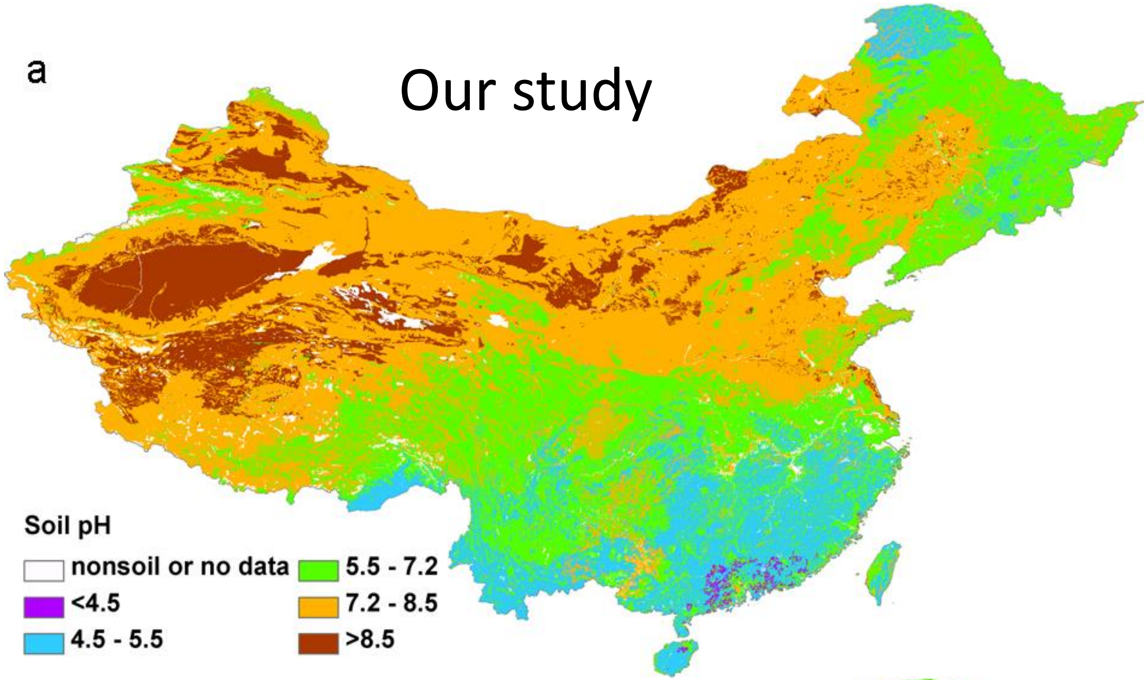
- A 4-level hierarchical structure: orders (12), family (909), subgroup (235) and great group (61) levels, and non soil map units (11).
- Soil map units: 925
- Map polygons: 94,303.

Soil Profiles (8979)

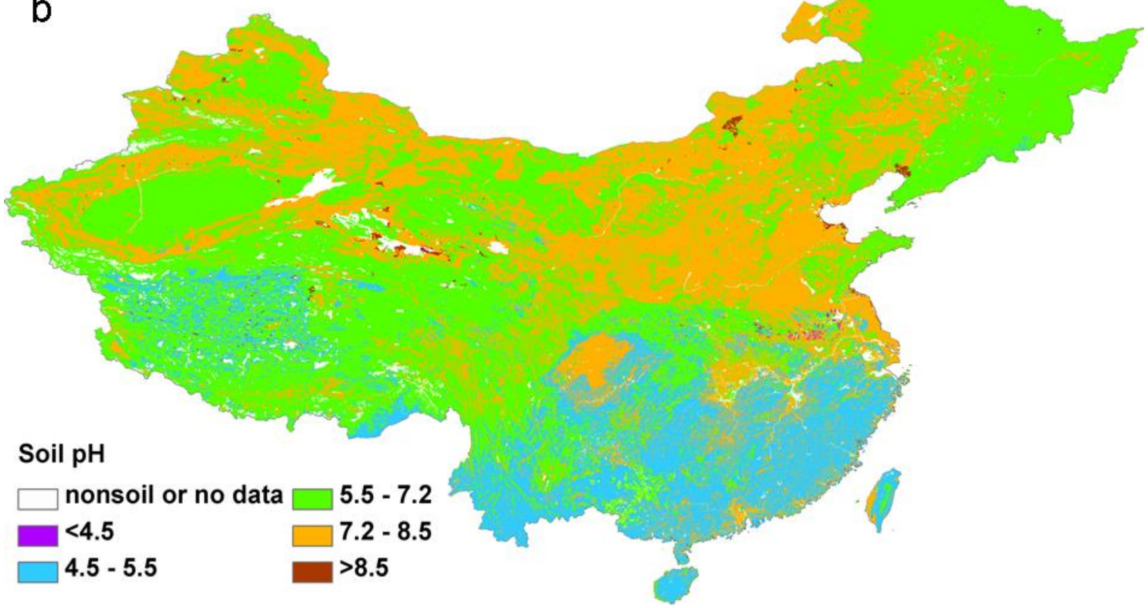


- Linking soil profiles to individual polygons.
- Consideration: soil type, distance between soil polygons and profiles, sample size of profiles.

Our study



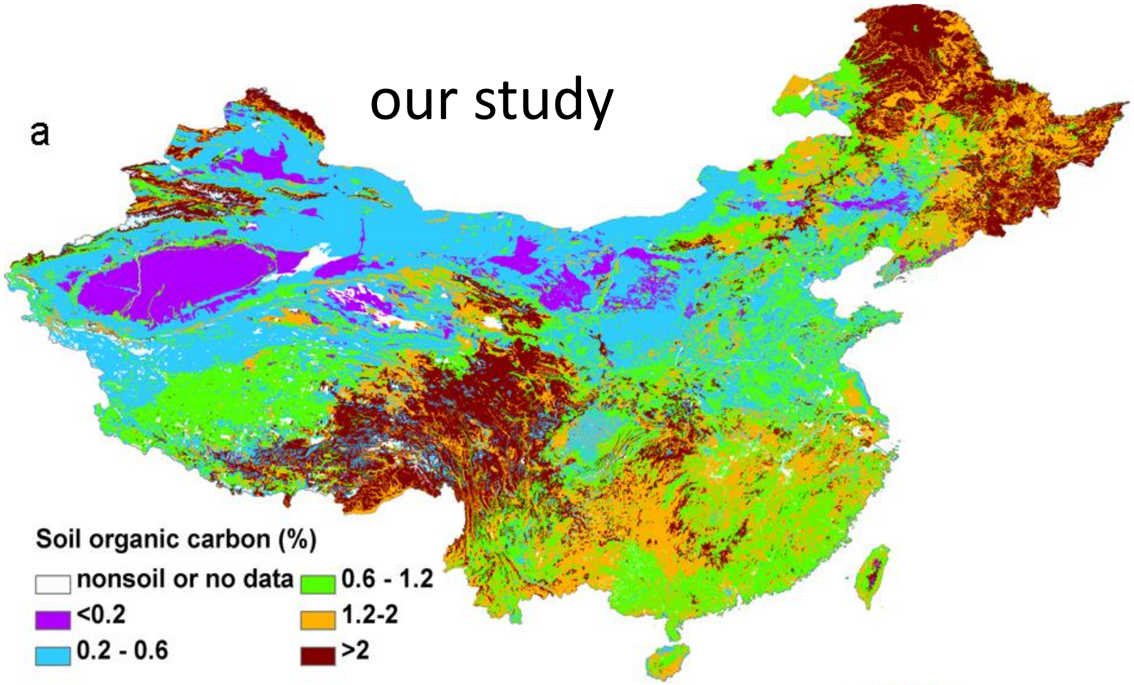
Harmonized World Soil Database



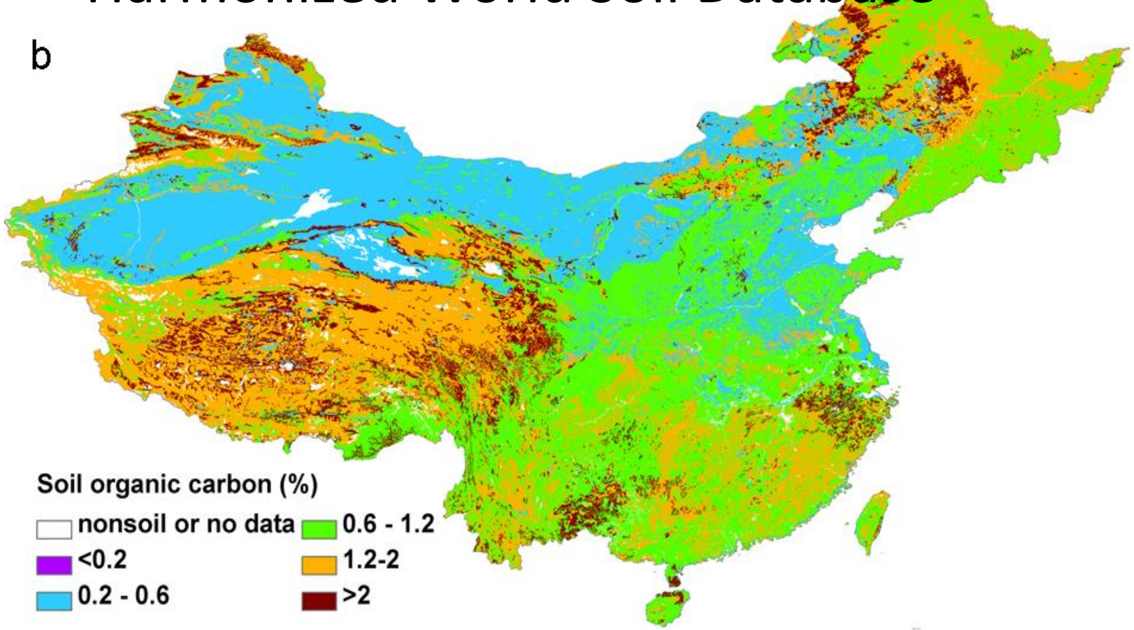
Spatial distribution of the soil pH value (H_2O) in the top 30cm soilin China.

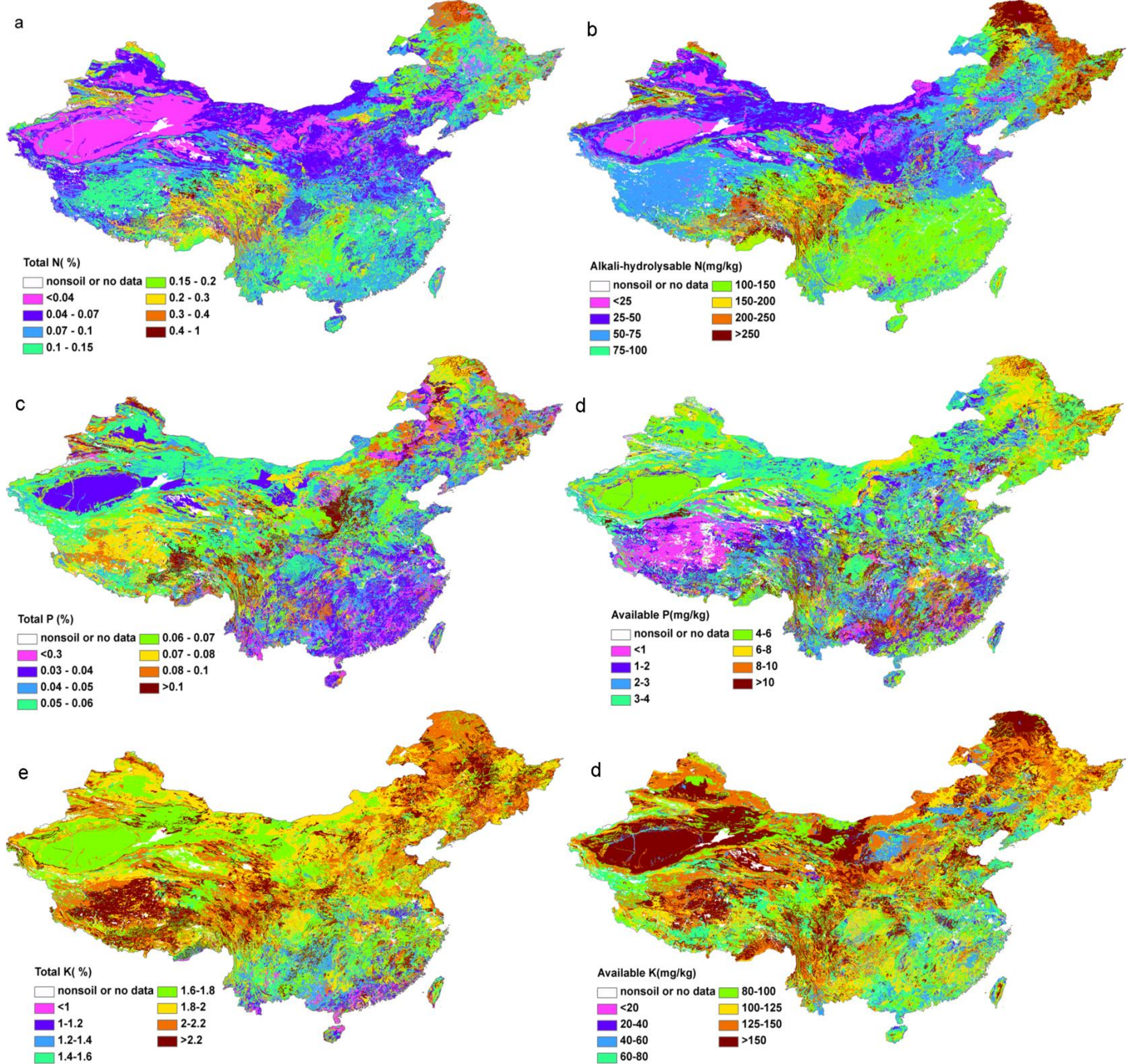
Spatial distribution of soil organic matter(%) in top 30 cmsoilin China

our study



Harmonized World Soil Database



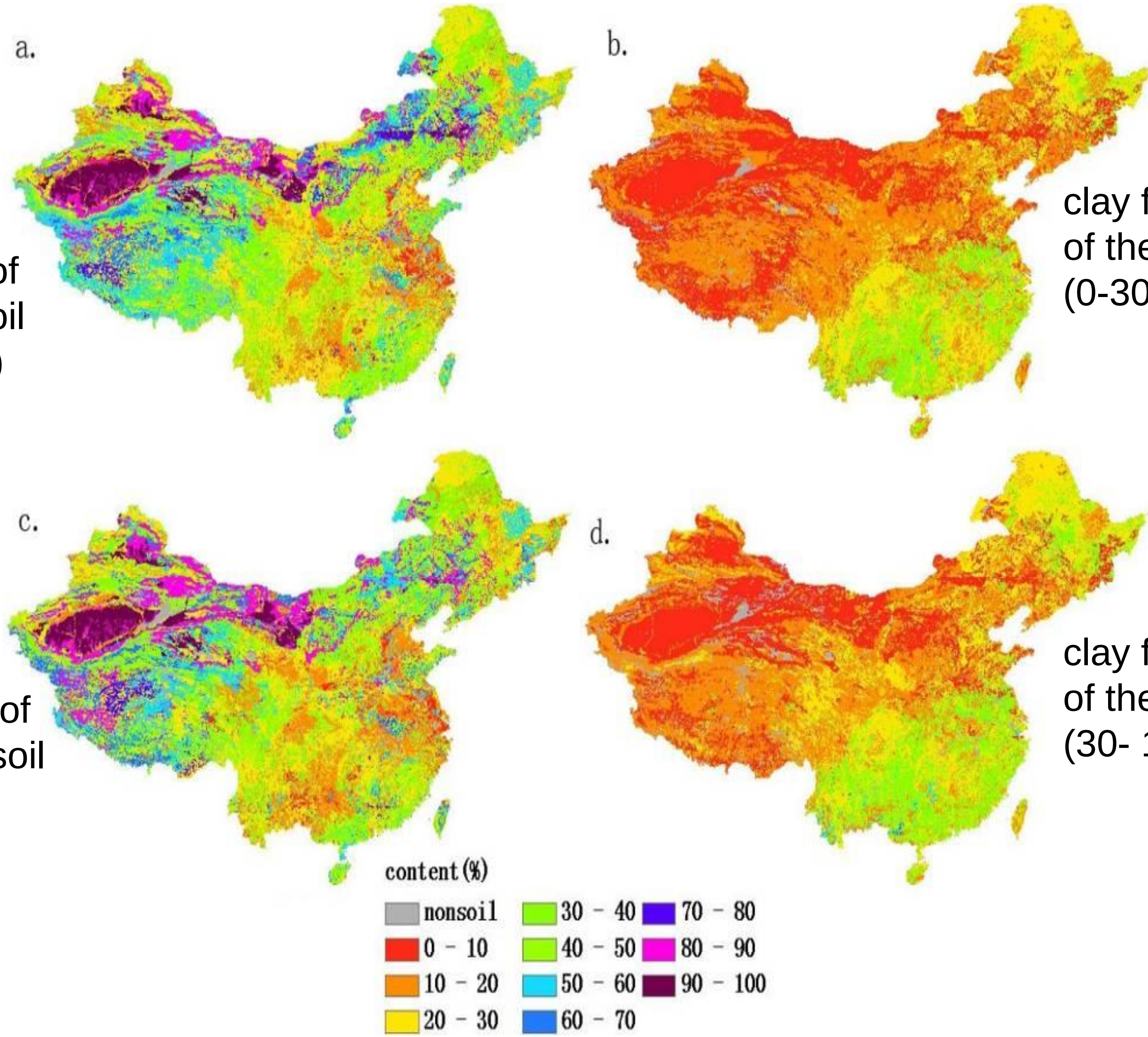

a
Total N(%)
nonsoil or no data
<0.04
0.04 - 0.07
0.07 - 0.1
0.1 - 0.15
0.15 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 1
b
Alkali-hydrolysable N(mg/kg)
nonsoil or no data
<25
25-50
50-75
75-100
100-150
150-200
200-250
>250
c
Total P (%)
nonsoil or no data
<0.3
0.03 - 0.04
0.04 - 0.05
0.05 - 0.06
0.06 - 0.07
0.07 - 0.08
0.08 - 0.1
>0.1
d
Available P(mg/kg)
nonsoil or no data
<1
1-2
2-3
3-4
4-6
6-8
8-10
>10
e
Total K(%)
nonsoil or no data
<1
1-1.2
1.2-1.4
1.4-1.6
1.6-1.8
1.8-2
2-2.2
>2.2
d
Available K(mg/kg)
nonsoil or no data
<20
20-40
40-60
60-80
80-100
100-125
125-150
>150

sand fraction of the topsoil (0-30cm)

clay fraction of the topsoil (0-30cm)

sand fraction of the subsoil (30-100cm).

clay fraction of the subsoil (30- 100cm).



Soil Hydraulic Parameters:

$$\frac{\partial\theta}{\partial t} = \frac{\partial}{\partial z}\left[K(\theta)\left(\frac{\partial h(\theta)}{\partial z} - 1\right)\right] - S(\theta)$$

Richards equation

$$\psi = \psi_s(\theta/\theta_s)^{-1/\lambda}$$

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

Functions by Clapp and Hornberger (1978)

K_s = saturated hydraulic conductivity (cm/d)

θ_s = saturated water content (cm3/cm3)

ψ_s = saturated capillary potential (cm)

λ = pore-size distribution index

θ_{33} = Field capacity (cm3/cm3)

θ_{1500} = Permanent wilting point (cm3/cm3)

The parameters were estimated from multiple Pedotransfer Functions (PTFs) as the functions of the percentages of sand, silt and clay, organic matter and bulk density of the profiles.

20 PTFs for K_s

15 PTFs for ψ_s, λ, θ_s, θ_{33}, θ_{1500}, respectively

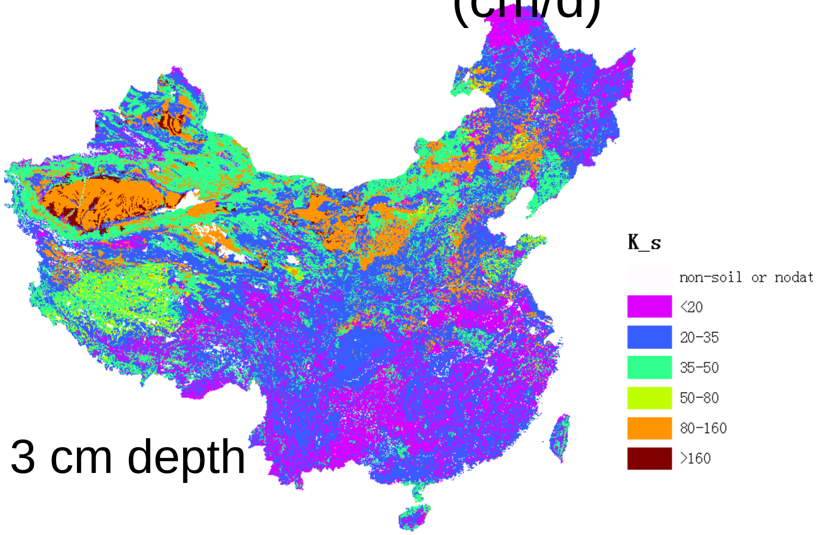
Output: Median, Individual PTF valu

Dai Y, Shangguan W, Liu B, Duan Q and Coauthors, 2011: **Development of a China dataset of soil hydraulic parameters using pedotransfer functions for land surface modeling**. (to be submitted to Journal of Hydrometeorology)

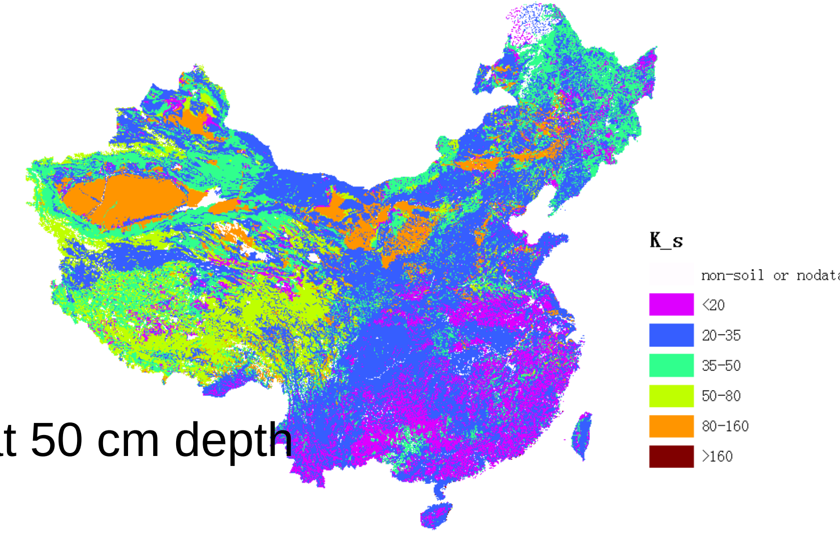
Status of soil hydraulic parameters in land surface models

Land model	**soil hydraulic parameters**
BATS (Dickinson et al., 1986; 1996)	Look-up table by Clapp and Hornberger (1978) and Cosby et al. (1984)
SiB (Sellers et al., 1986; 1996)	Look-up table by Clapp and Hornberger (1978)
VIC (Liang et al., 1994; Nijssen et al., 2001)	Look-up table by Cosby et al. (1984)
NOAH (Chen and Dudhia, 2001)	Look-up table by Cosby et al. (1984)
CLM (Dai et al., 2003; Oleson et al., 2010)	Regression relationships from the soil sand/silt/clay fractions by Cosby et al (1984)
JULES/MOSES (Cox et al., 1999; Blyth et al., 2006)	Regression relationships from the soil sand/silt/clay fractions by Cosby et al (1984)
GLDAS (Rodell et al., 2004)	Look-up table by Cosby et al. (1984)

Saturated Hydraulic Conductivity (cm/d)

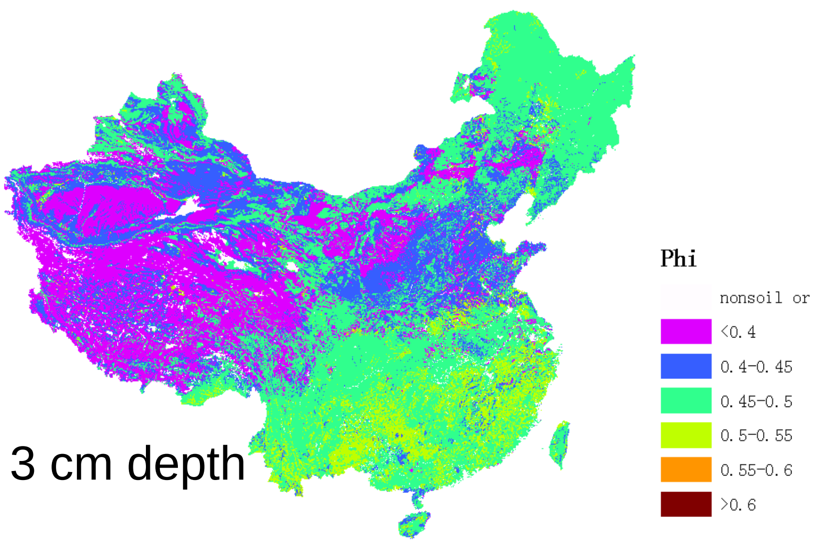


at 3 cm depth

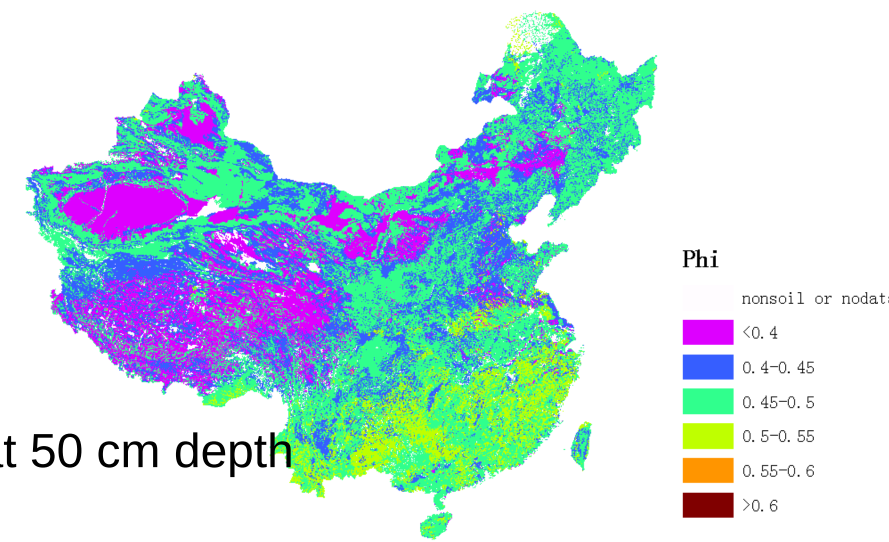


at 50 cm depth

Saturated Water Content (cm3/cm3)

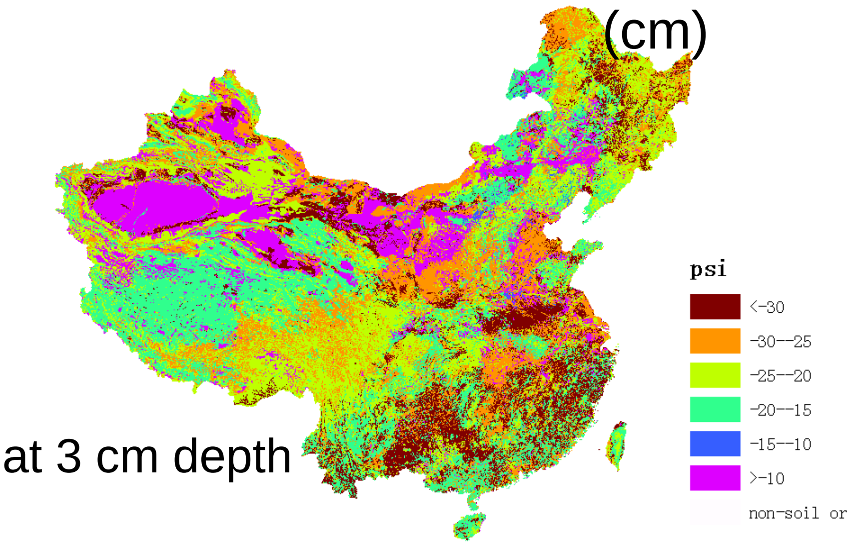


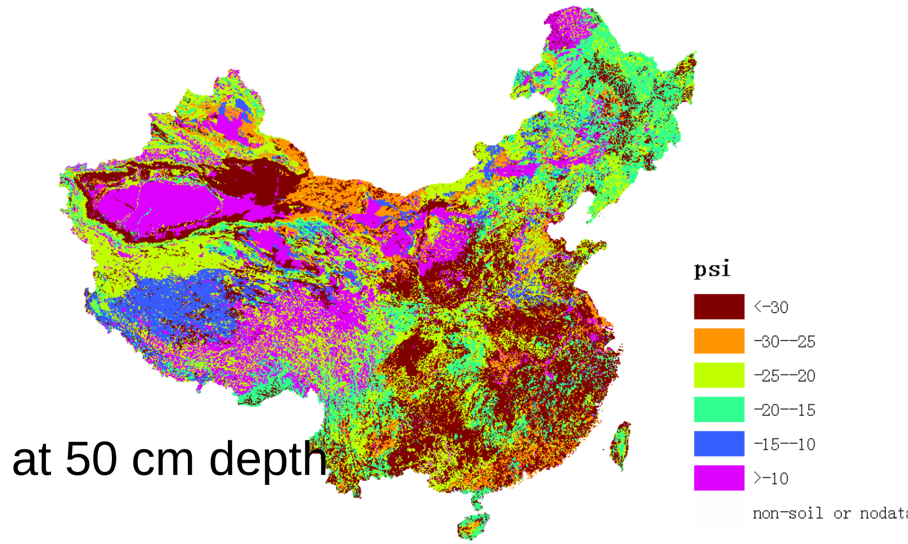
at 3 cm depth



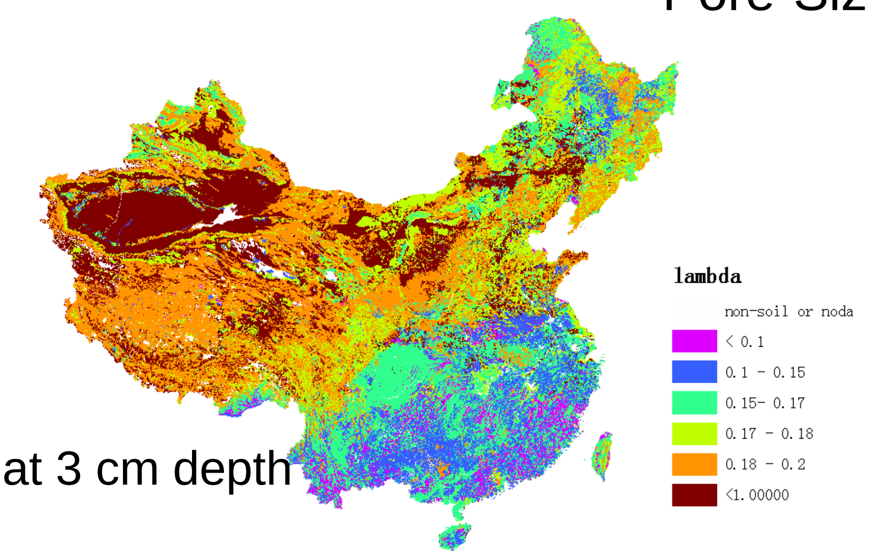
at 50 cm depth

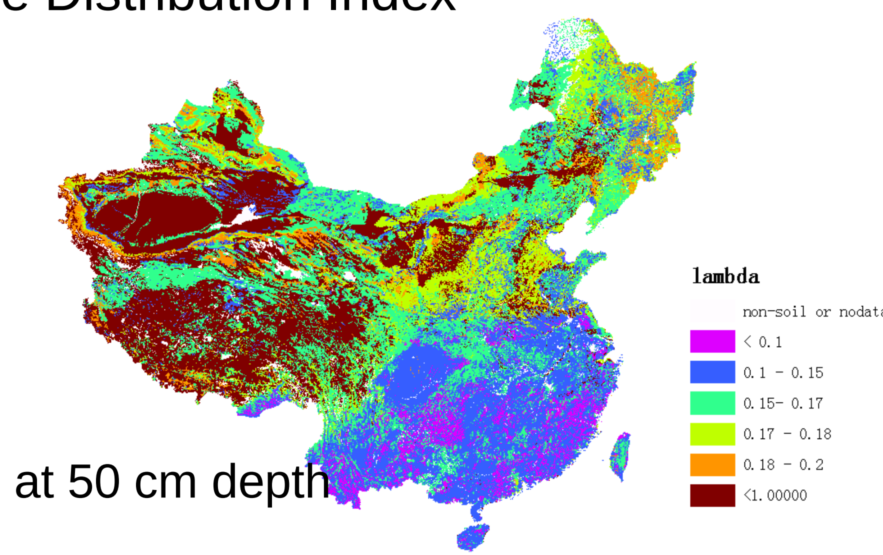
Saturated Capillary Potential (cm)



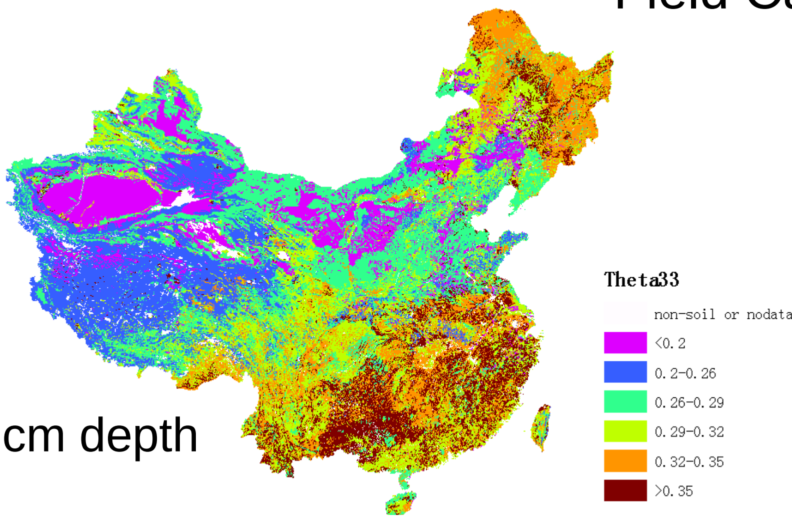


Pore-Size Distribution Index

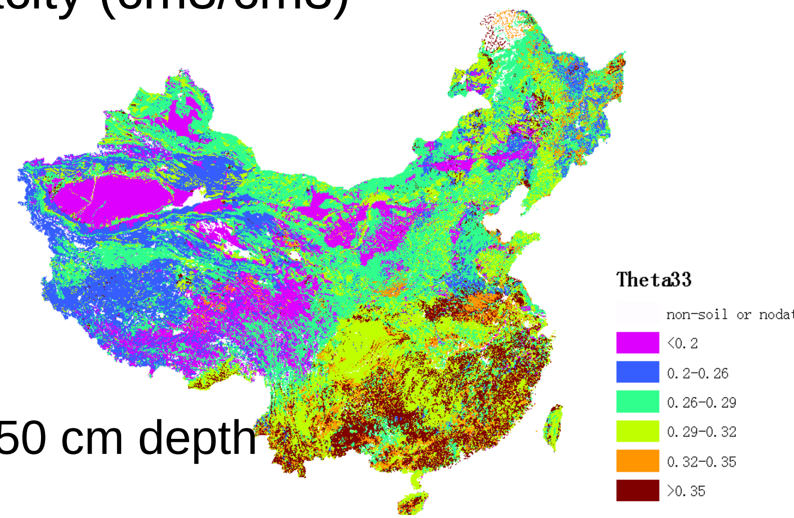




Field Capacity (cm3/cm3)

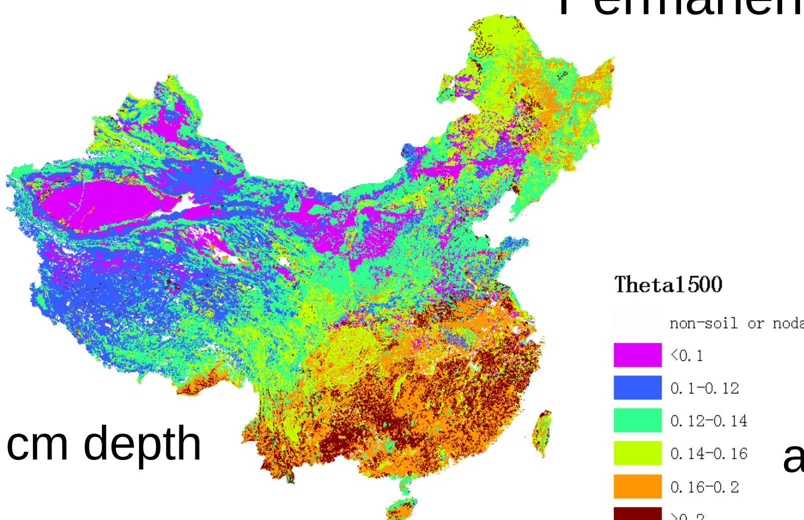


at 3 cm depth

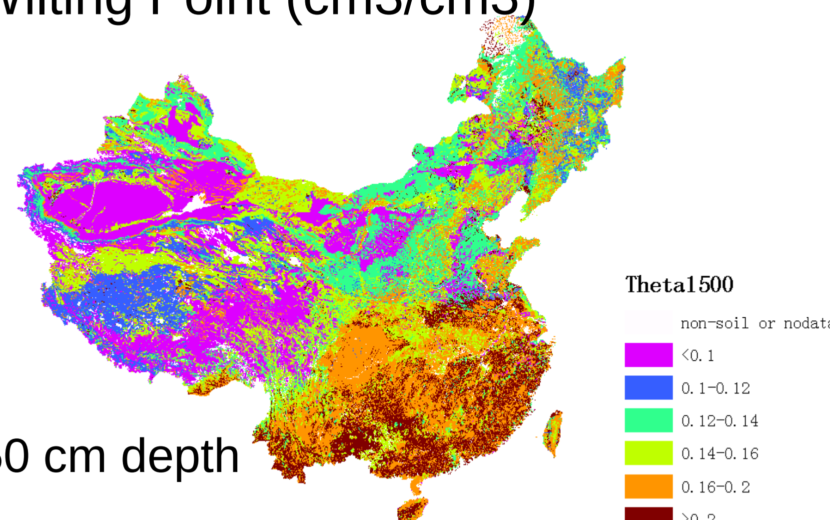


at 50 cm depth

Permanent Wilting Point (cm3/cm3)



at 3 cm depth



at 50 cm depth

全球土地覆盖资料集

- 欧洲GlobalCover (全球、1km x 1km)
- 中国植被资料 (1: 1,000,000)
- 全球土地覆盖/利用数据集集

  数据分辨率：30 x 30 arc-seconds

  数据时间跨度：2000-201x。

Global Land Cover Dataset

Source Data:

- **Land Cover / Land use:**
  - Vegetation Map of China (1:1 000 000) of the National Plant Survey of China (purchased from Institute of Botany / CAS).
    - Vegetation status in 1980's and 1990's.
    - 11 vegetation groups, 55 types, 865 formations and subformations, 75 785 mapping units/polygons.
    - Data released in 2009.
  - GLOBCOVER (free download from http://ionia1.esrin.esa.int), 300m resolution.
- **Leaf Area Index (LAI):**
  - MODIS global LAI (Collection 5), every 8 days at 1-km resolution (2000-2008).
  - AVHRR global LAI, monthly at 8-km resolution (1981-1999).

China vegetation dataset

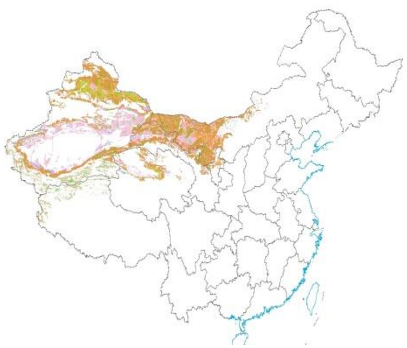
1. Needleleaf Forest

2. Needleleaf and broadleaf Forest

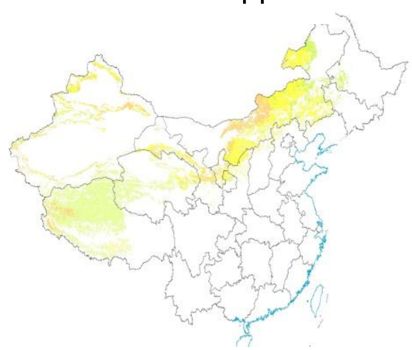
3. Broadleaf Forest

4. Scrub

5. Sparsely Vegetated Areas

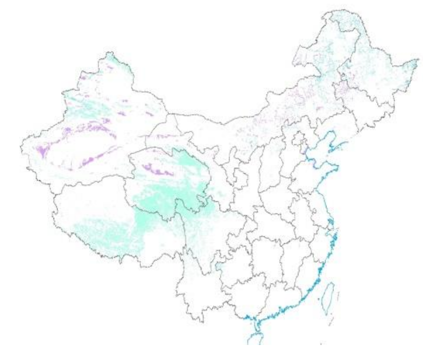


6. Steppe



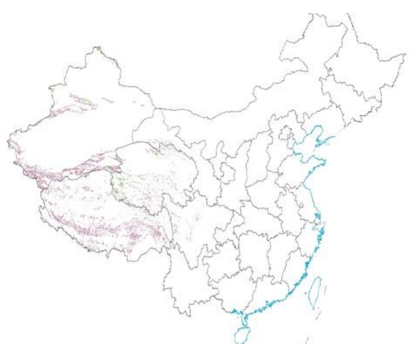
7. Grass-forb Community

8. Meadow



9. Swamp

10. Alpine Vegetation



11. Cultural Vegetation

12. Bare Ground

全球叶面积指数数据集

数据分辨率：30 x 30 arc-seconds, every 8 day

数据时间跨度：2000-2010。

A global Leaf Area Index dataset for land and climate modeling (http://globalchange.bnu.edu.cn/research/lai)

LAI资料背景介绍(1)

- 全球四大主要LAI产品

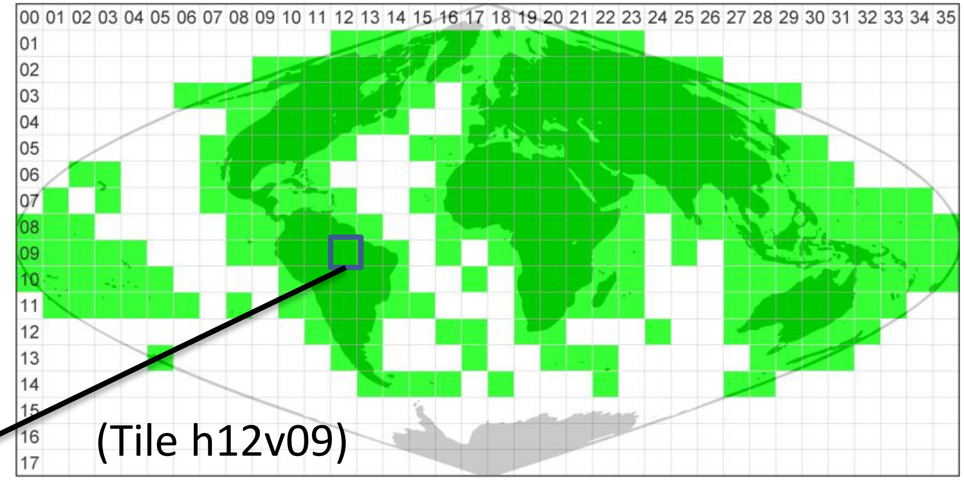
产品	空间分辨率	时间分辨率	时间跨度	主要算法	参考
CYCLOPES (V3.1) (SPOT/VEG)	1/112°	10天	1999~ 2003	一维辐射传输模型(SAIL)	Baret et al. [2007]
ECOCLIMAP (2006) (NOAA/AVHRR)	1km	1个月	-	经验算法（以DNVI变化为基础）	Masson et al. [2003]
GLOBCARBON (V1) (SPOT/VEG, ENVISAT/AATSR)	1km	10天	1998~ 2006	植被指数与LAI关系	Deng et al. [2006]
MODIS (C5) (TERRA/MODIS,MISR)	1km	8天	2000.2~ 今	主算法：三维辐射传输模型 备用算法：NDVI与LAI经验关系	Knyazikhin et al. [1998] Yang et al. [2006]

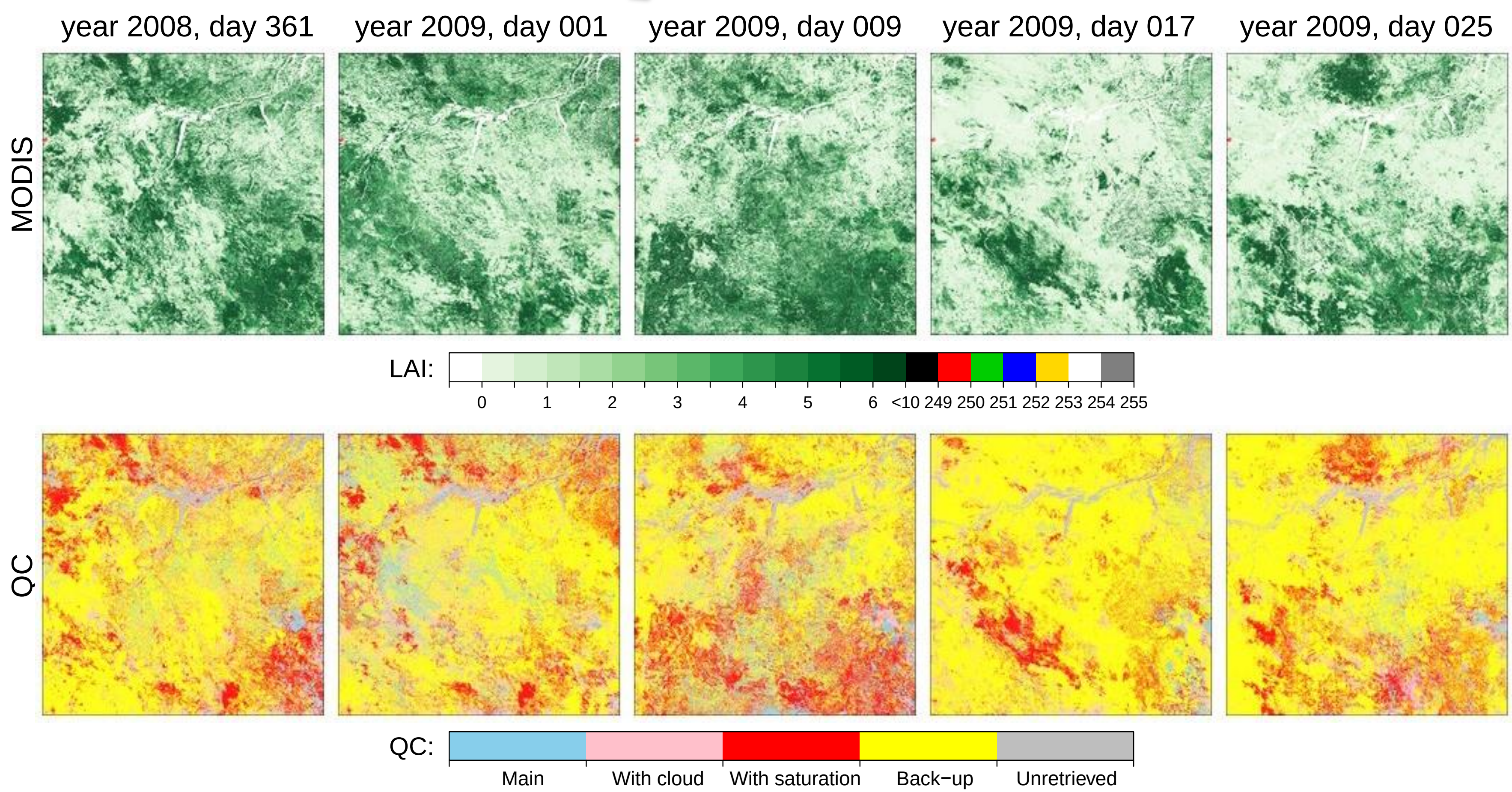
- MODIS LAI产品优点
  - 时间序列较长
  - 地面验证工作多
  - 产品算法多次更新(目前为C5版本，2006年)
  - 产品发布快，方便获取

由于以上原因，我们选取MODIS LAI资料作为我们产品改进对象。

LAI资料背景介绍(2)

- MODIS LAI 产品不足——时空不连续
  - 云的出现
  - 雪的覆盖
  - 传感器观测角度及自身故障
  - 算法本身的不确定性



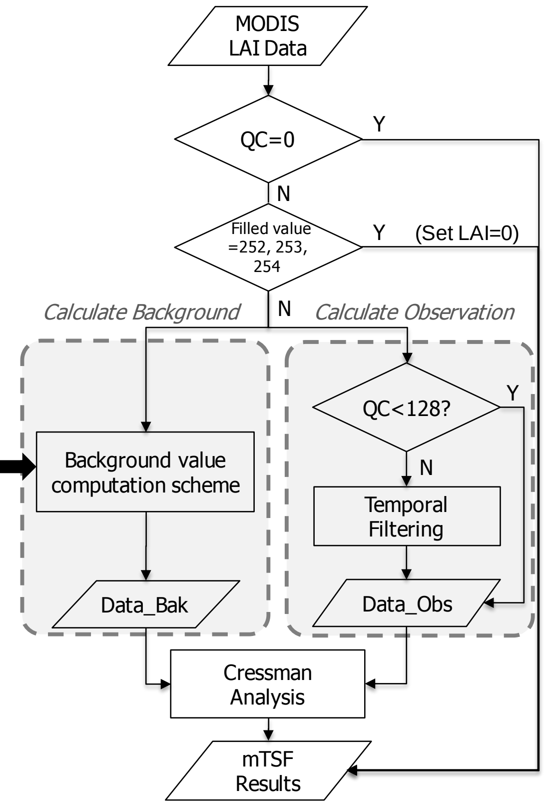


方法

- 第一步
  - 利用改进的时空滤波 (TSF)方法(mTSF)对MODIS LAI进行处理。
    - 计算背景值
    - 填充观测值
    - Cressman分析(一种简单的一维同化方法)
  - Cressman分析 *(Cressman, 1959)*

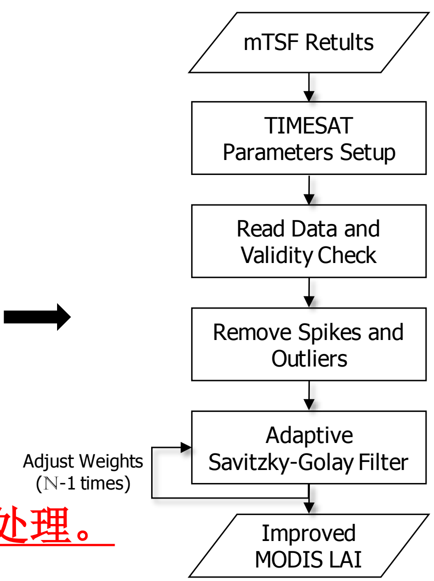
$$x_a(r_i) = x_b(r_i) + \frac{\sum_{j=1}^{n} w(r_i,r_j)\left[x_o(r_j) - x_b(r_j)\right]}{\sum_{j=1}^{n} w(r_i,r_j)}$$

$$w(r_i,r_j) = max\left(0, \frac{R^2 - d_{i,j}^2}{R^2 + d_{i,j}^2}\right)$$



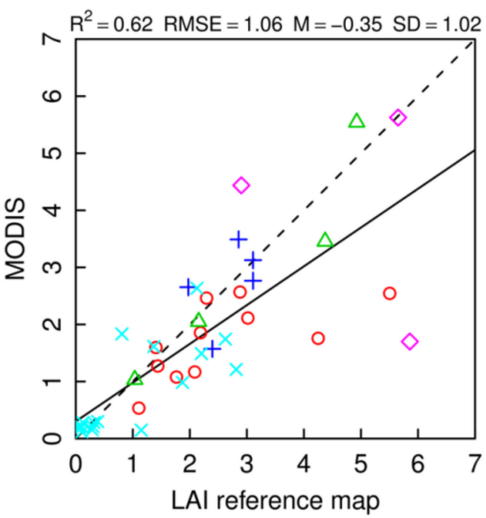
- 第二步
  - 利用TIMESAT Savitzky-Golay (SG) 滤波对mTSF的结果进行平滑处理
  - SG滤波 *(Savitzky and Golay, 1964)*

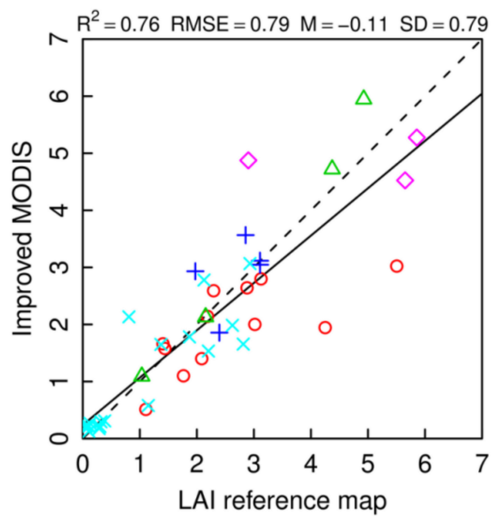
$$Y_j^* = \frac{\sum_{i=-m}^{i=m} C_i Y_{j+i}}{N}$$

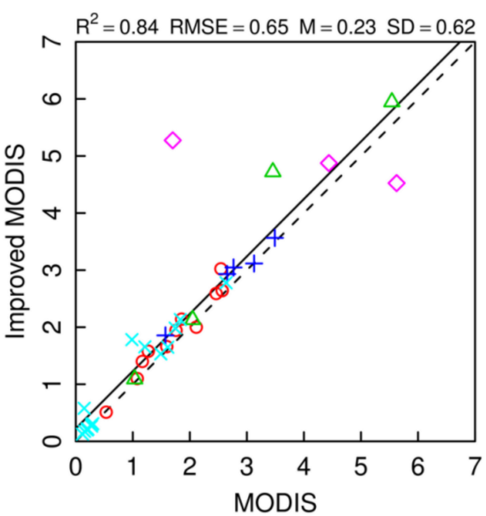


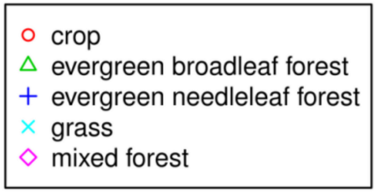
➢ <u>对10年的MODIS LAI (MOD15A2) 全球数据进行以上方法处理。</u>

结果(1)-与地面验证站点比较

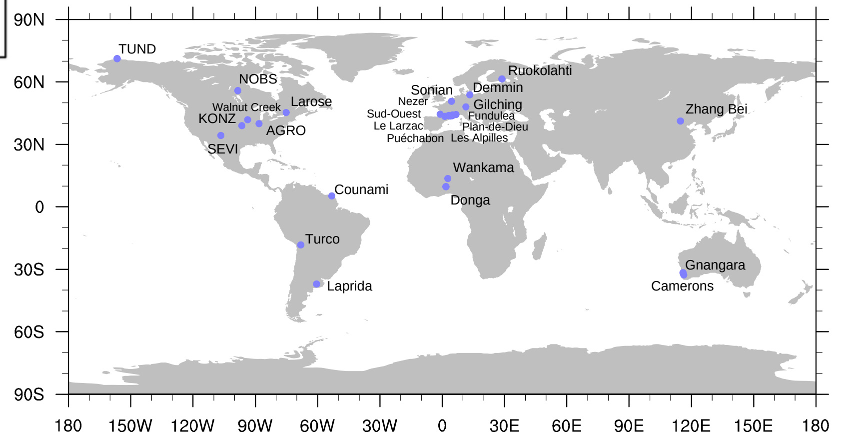






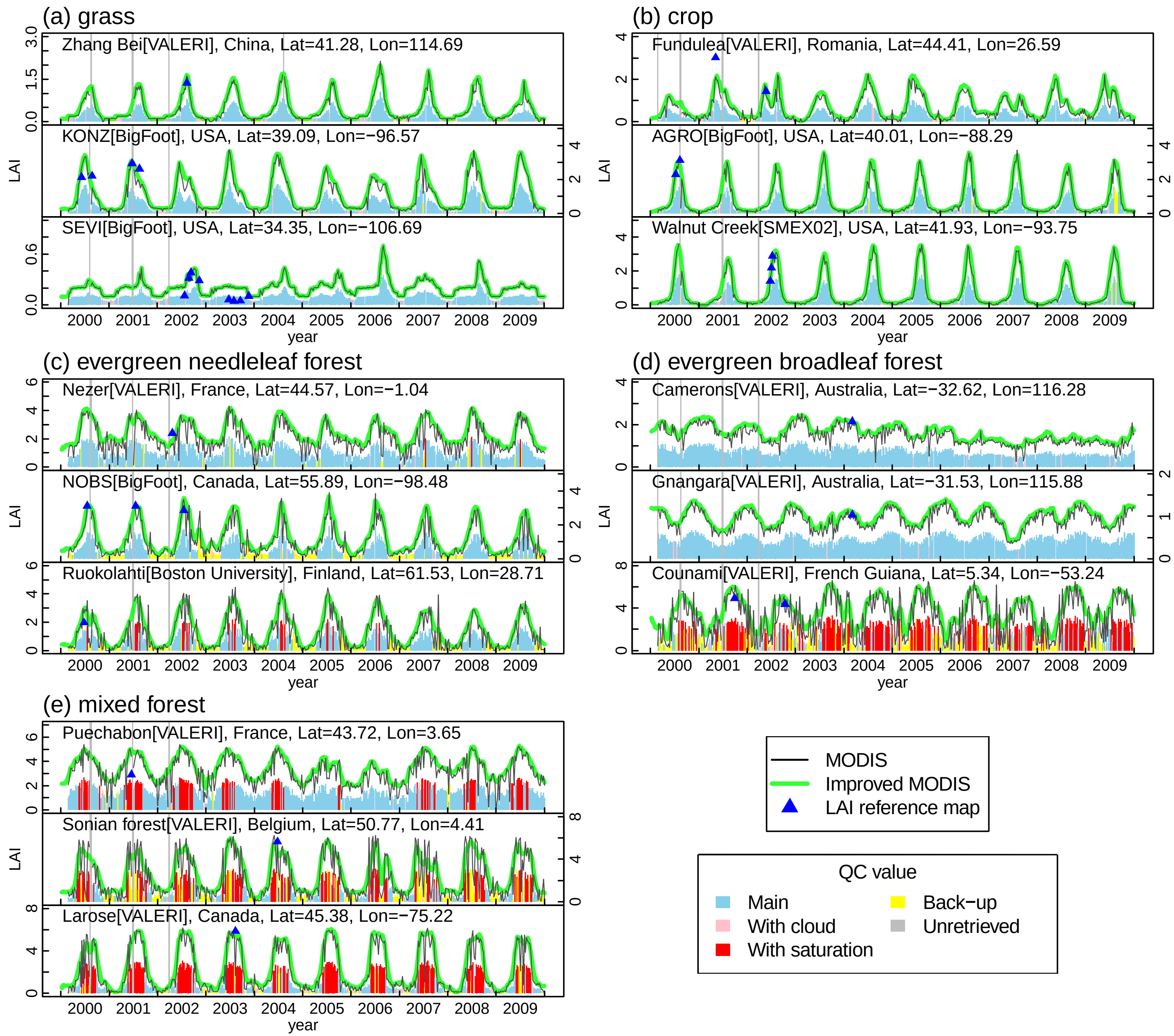


- 收集了26个站点，44张LAI reference map（真实LAI值）
  - VALERI, BigFoot, Boston University, SMEX02
- 对比流程
  - 将高分辨率LAI reference map投影到MODIS LAI坐标对应的像元；
  - 对每个像元内的值进行平均；
  - 再对所有投影的像元进行平均。



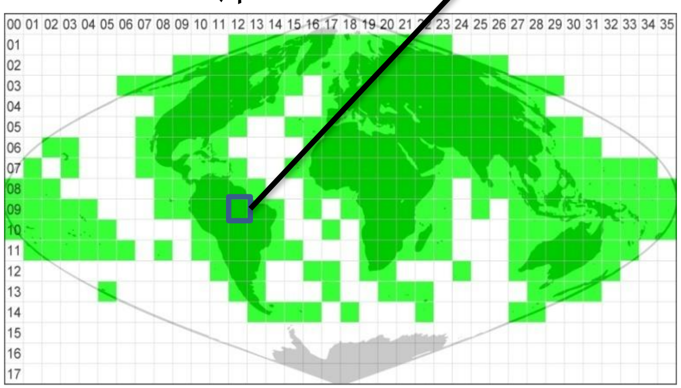
结果(2)-时间序列比较

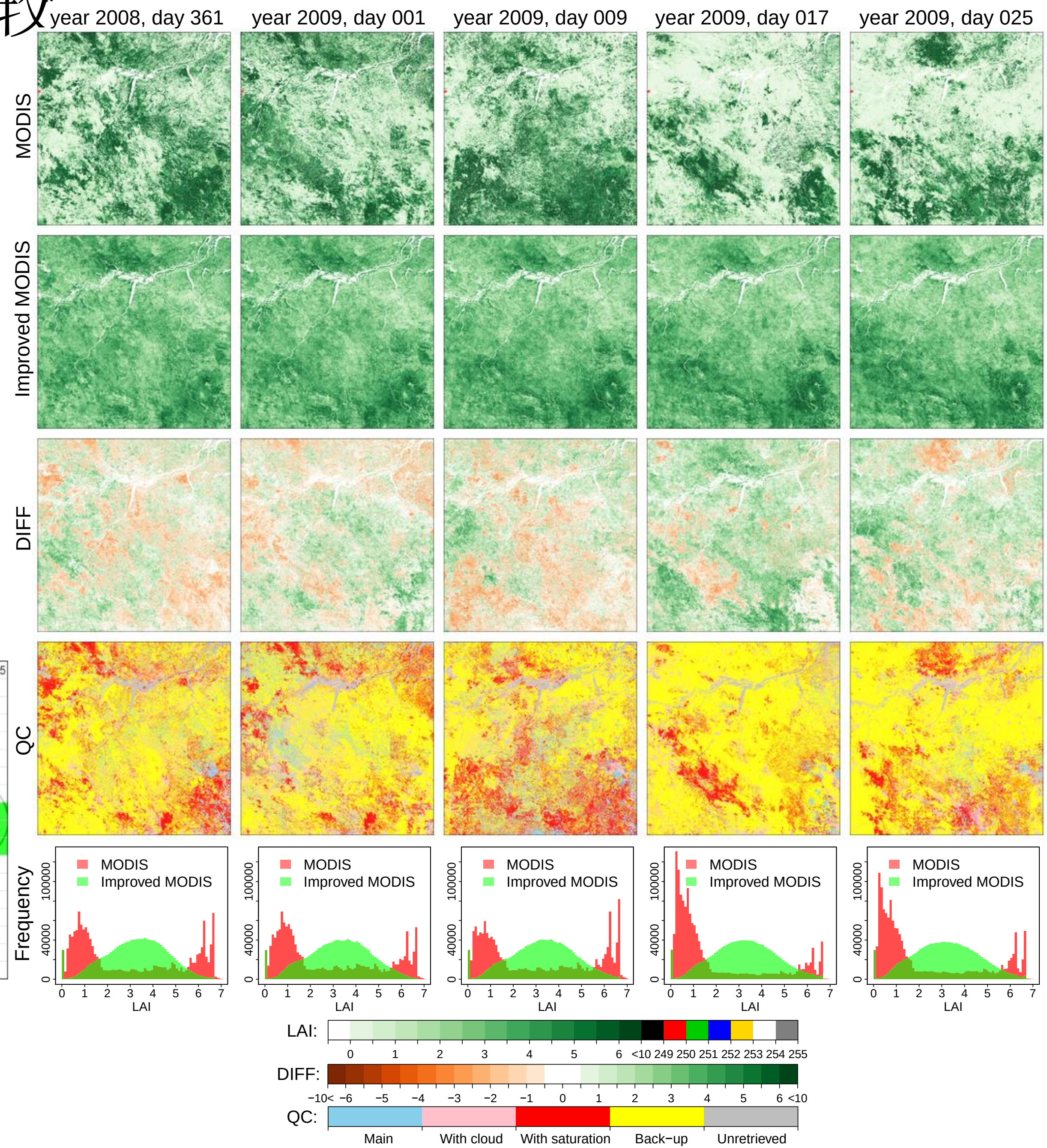
- 对五种植被覆盖类型分别选取3个站点计算10年时间序列值。



结果(3)-时空比较

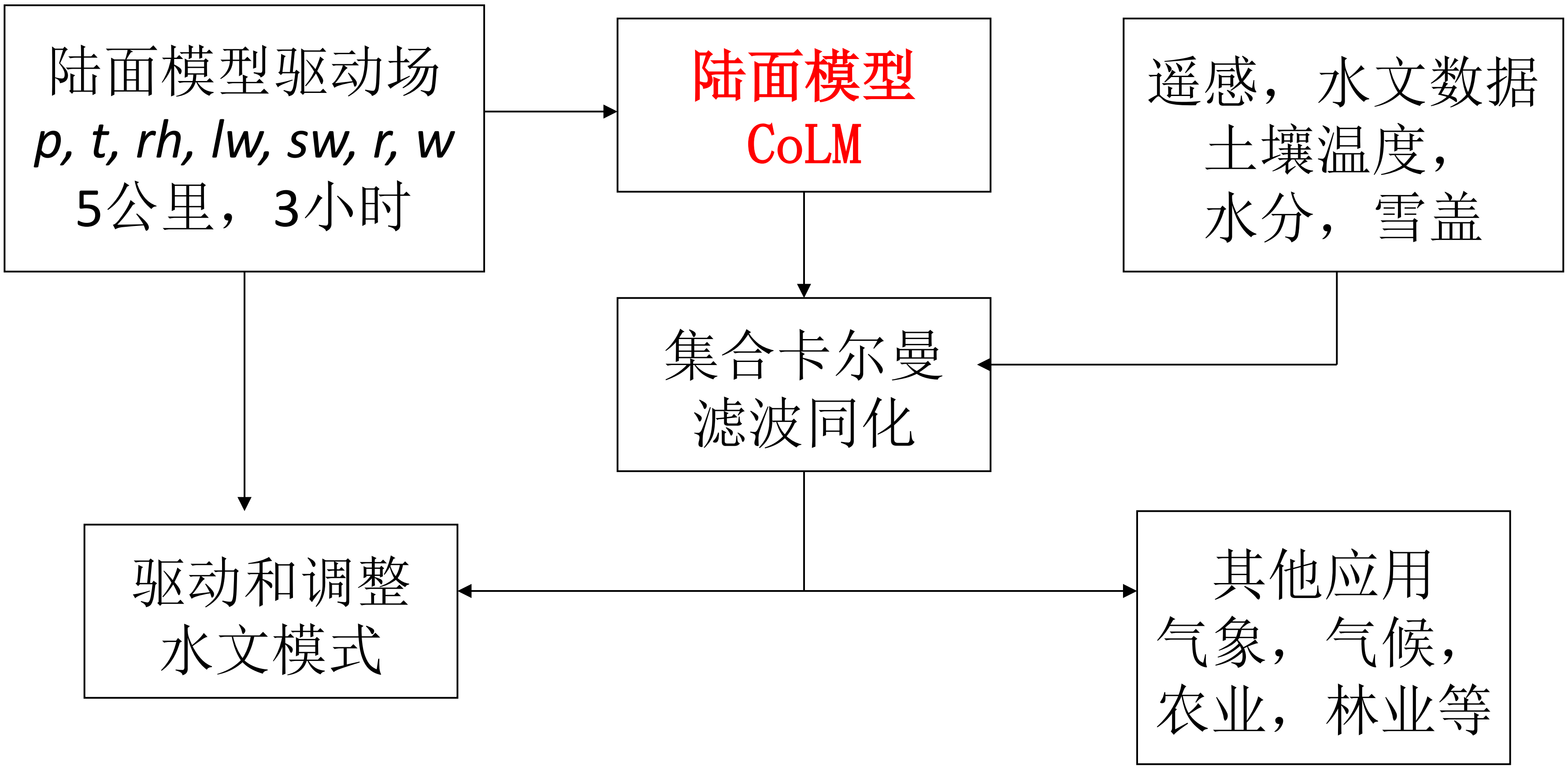
- 选取典型区域进行时空比较
  - 区域：tile h12v09
  - 图中DIFF为改进后MODIS LAI与MODIS LAI差值
  - QC为质量控制信息所代表的算法
  - Frequency为该区域LAI值的频率统计





中国区域陆面模型
5公里3小时驱动场的建立

Terrestrial Model System (TMS)



中国区域陆面模型大气驱动场

（空间分辨率：5公里，时间分辨率：3小时）

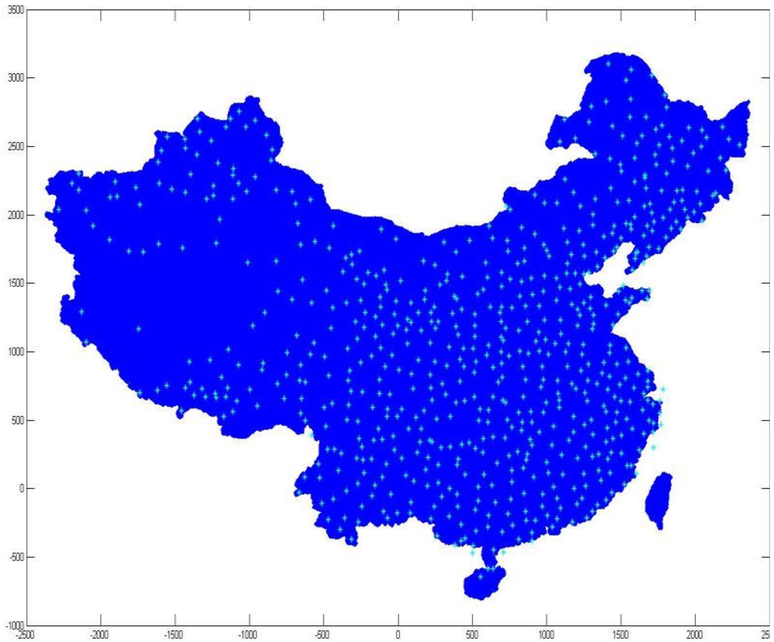
简称	名称	单位
p	地表气压	hPa
t	近地面2米空气温度	C
rh	近地面2米相对湿度	%
sw	地面下行短波辐射	W/ m^2
lw	地面下行长波辐射	W/m^2
r	降雨和降雪率	mm/hr
w	近地面10米相对风速	m/s

原始数据

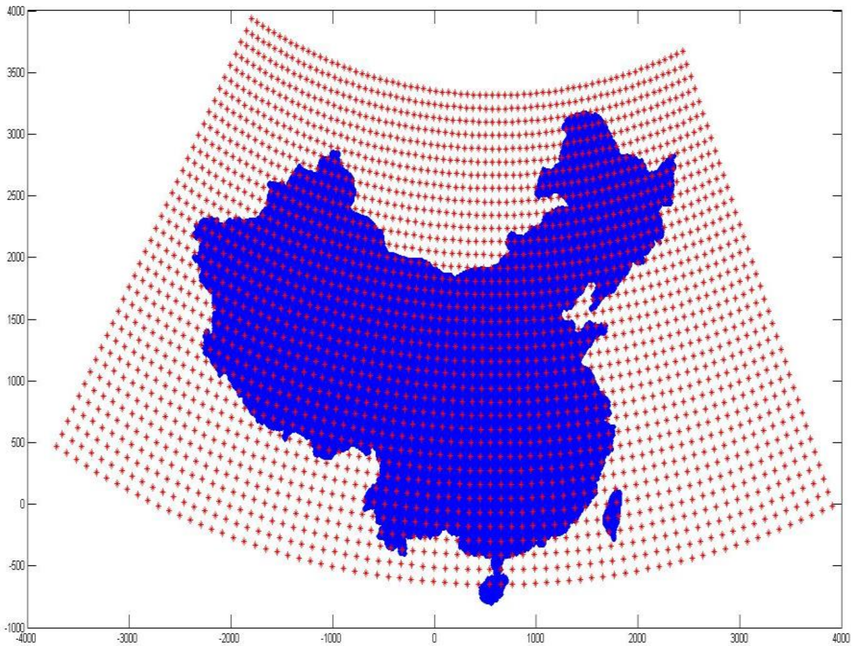
观测数据： 700个气象站(1小时，6小时， 日)，水文站、卫星

再分析数据：Princeton Reanalysis (1度x1度，3小时)， GSWP2

台站分布



再分析数据格点



利用小时观测建立温度场

T1 $$\hat{t}_i = f_i(x, y) + \alpha_i z$$

T2 $$\hat{t}_i = f_i(x, y) + \alpha_i z + \beta_i \hat{t}_{i-1}$$

RMSE of Leave-one-out cross validation (C)

	T1	T2
W	3.03	1.96
MW	2.27	1.72
NE	2.64	1.82
SE	1.58	1.31

其中（以温度 t 为例）

$f(x,y)$ 薄板平滑样条, 其参数通过最小化如下目标函数估计

,

$$\frac{1}{|\mathbf{N}|}\sum_{(x,y)\in\mathbf{N}}\left[f(x,y)-t(x,y)\right]^2+\rho J_2\left(f\right)$$

,

.

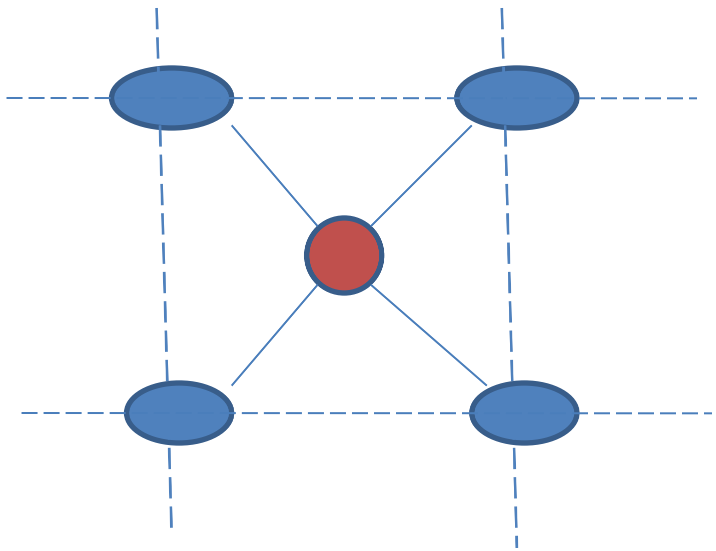
其中, N 观测点集合

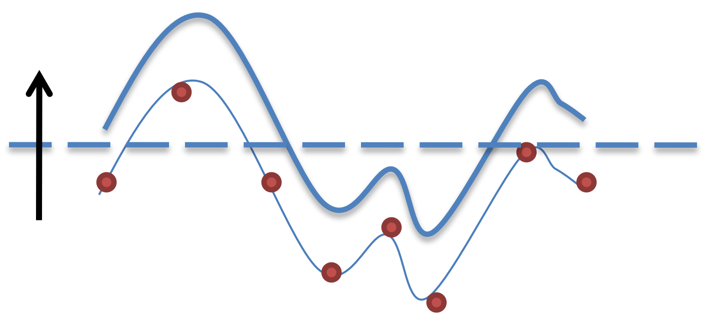
$$J_2\left(f\right)\equiv\iint\sum_{j=0}^{2}\binom{2}{j}\left(\frac{\partial^2 f}{\partial x^j\partial y^{2-j}}\right)dxdy$$

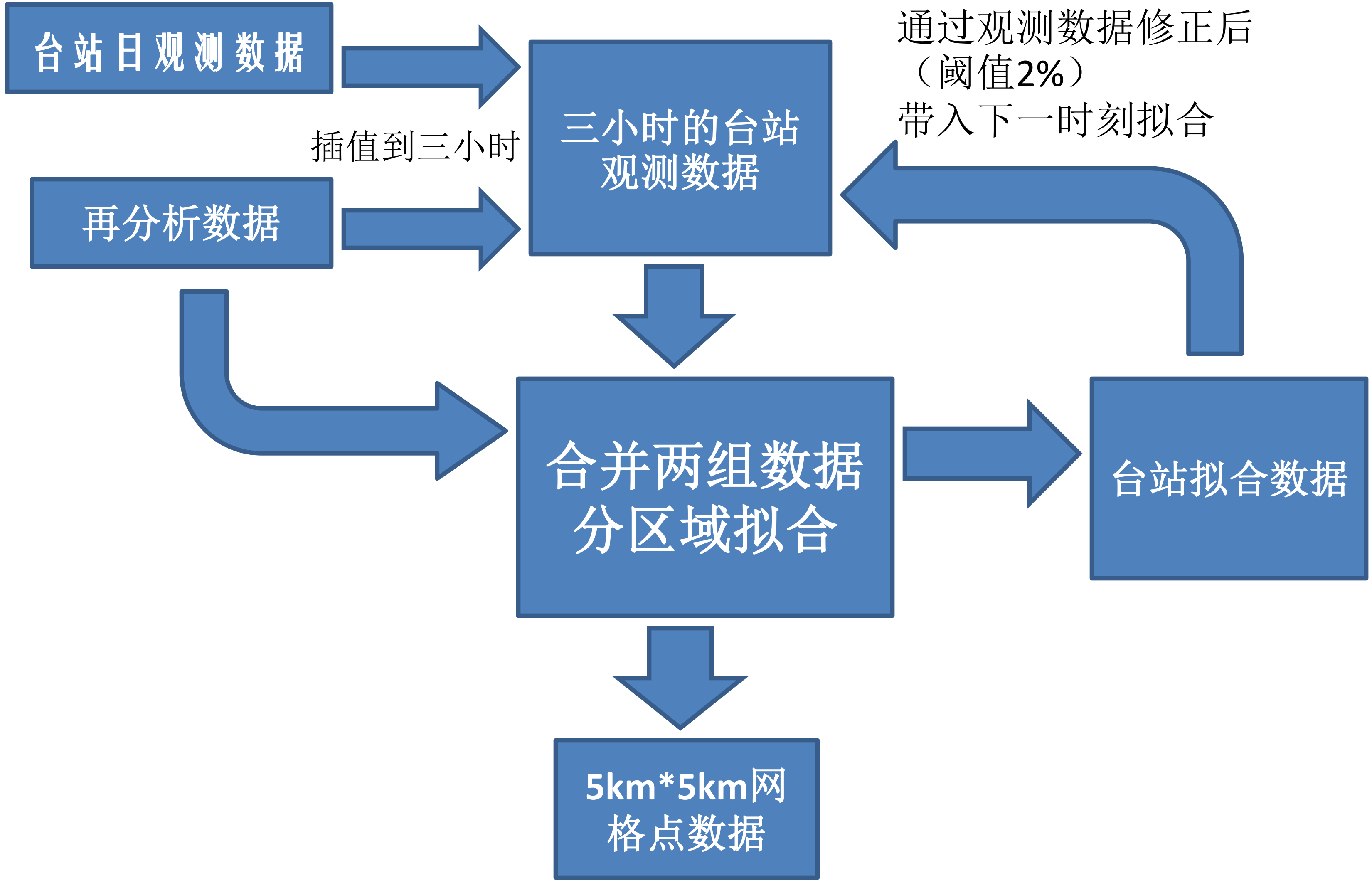
ρ 平滑参数

利用日平均，最大，最小温度观测和3小时再分析数据建立温度场

对特定台站，将其周围的3小时再分析数据进行一日8次线性插值，对插值结果日距平乘一因子，使其日变差与观测到的相等，再利用台站当日的观测数据对插值结果进行平移






台站日观测数据
插值到三小时
再分析数据
三小时的台站观测数据
通过观测数据修正后（阈值2%）带入下一时刻拟合
合并两组数据分区域拟合
台站拟合数据
5km*5km网格点数据

T2 $\hat{t}_i = f_i(x, y) + \alpha_i z + \beta_i \hat{t}_{i-1}$

RESE using T2 (C)

	小时 fit	小时 CV	日+再分析 CV	日+极值+再分析 CV
W	1.84	1.96	2.75	2.44
MW	1.58	1.72	3.25	2.19
NE	1.72	1.82	4.53	2.37
SE	1.18	1.31	2.83	1.81

利用小时观测建立气压场

P1 $\hat{p}_i = f_i(x,y) + \alpha_i z$

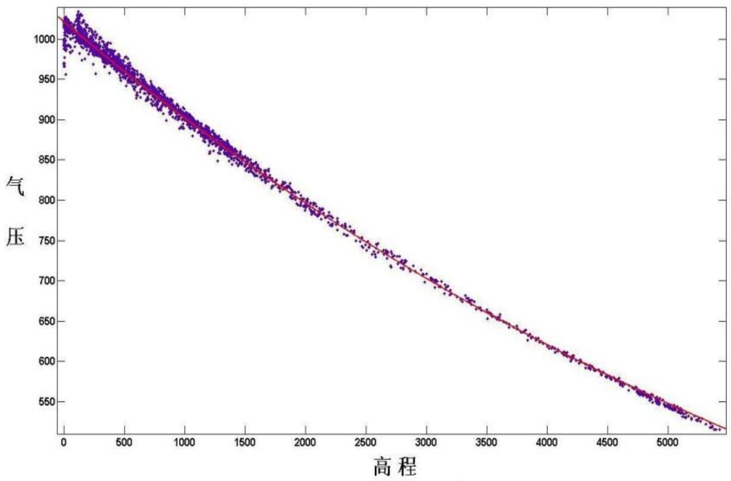
P2 $\hat{p}_i = f_i(x,y) + \alpha_i \exp\left(b_i z\right)$

P3 $\hat{p}_i = f_i(x,y) + \alpha_i \exp\left(b_i z\right) + \beta_i \hat{p}_{i-1}$

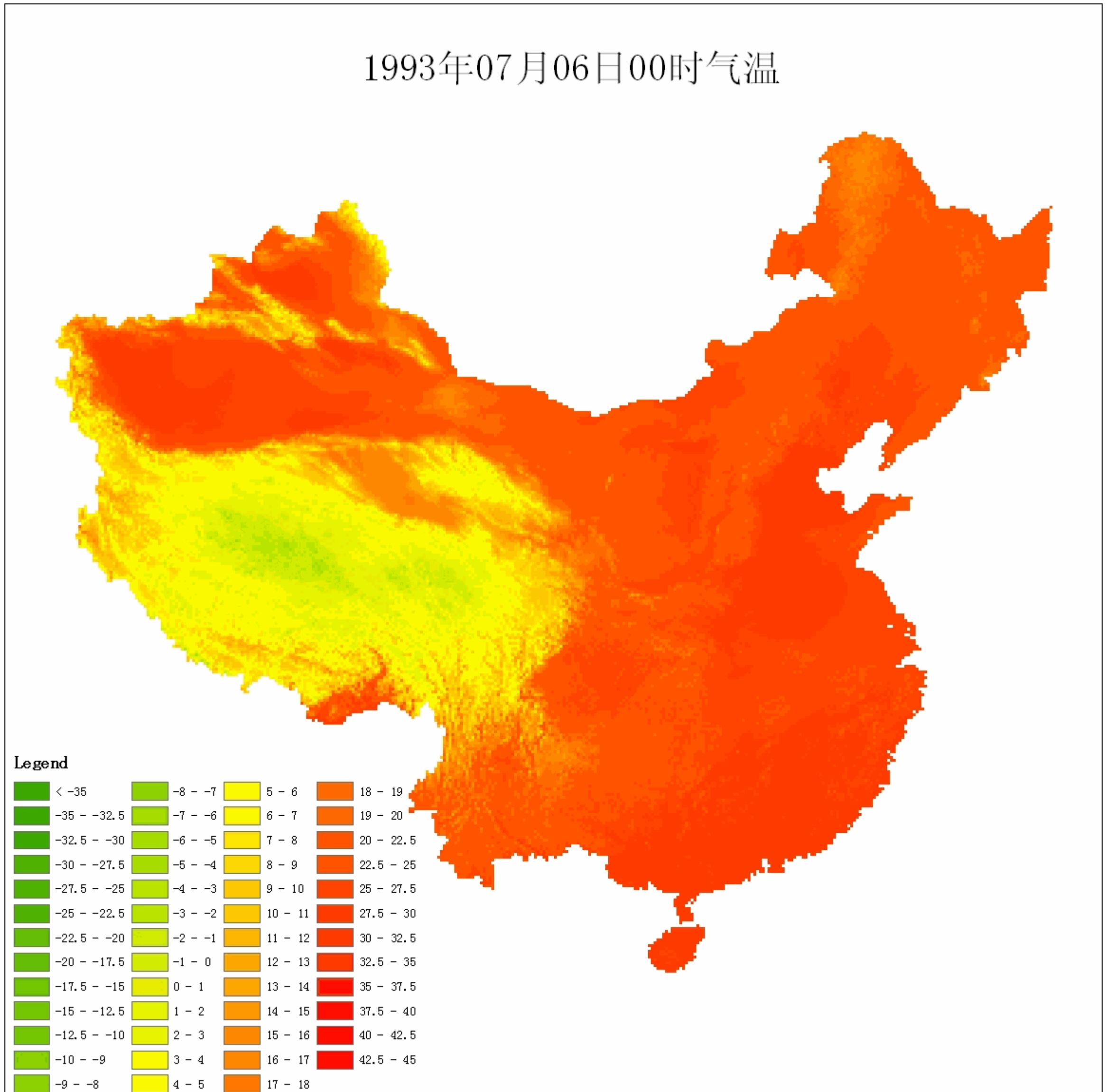
RMSE of CV (hpa)

	P1	P2	P3
W	20.07	3.20	1.95
MW	4.99	3.32	2.16
NE	5.07	3.18	2.02
SE	3.86	3.63	2.21

气压对高程的指
数相依关系



Snapshots of the temperature data



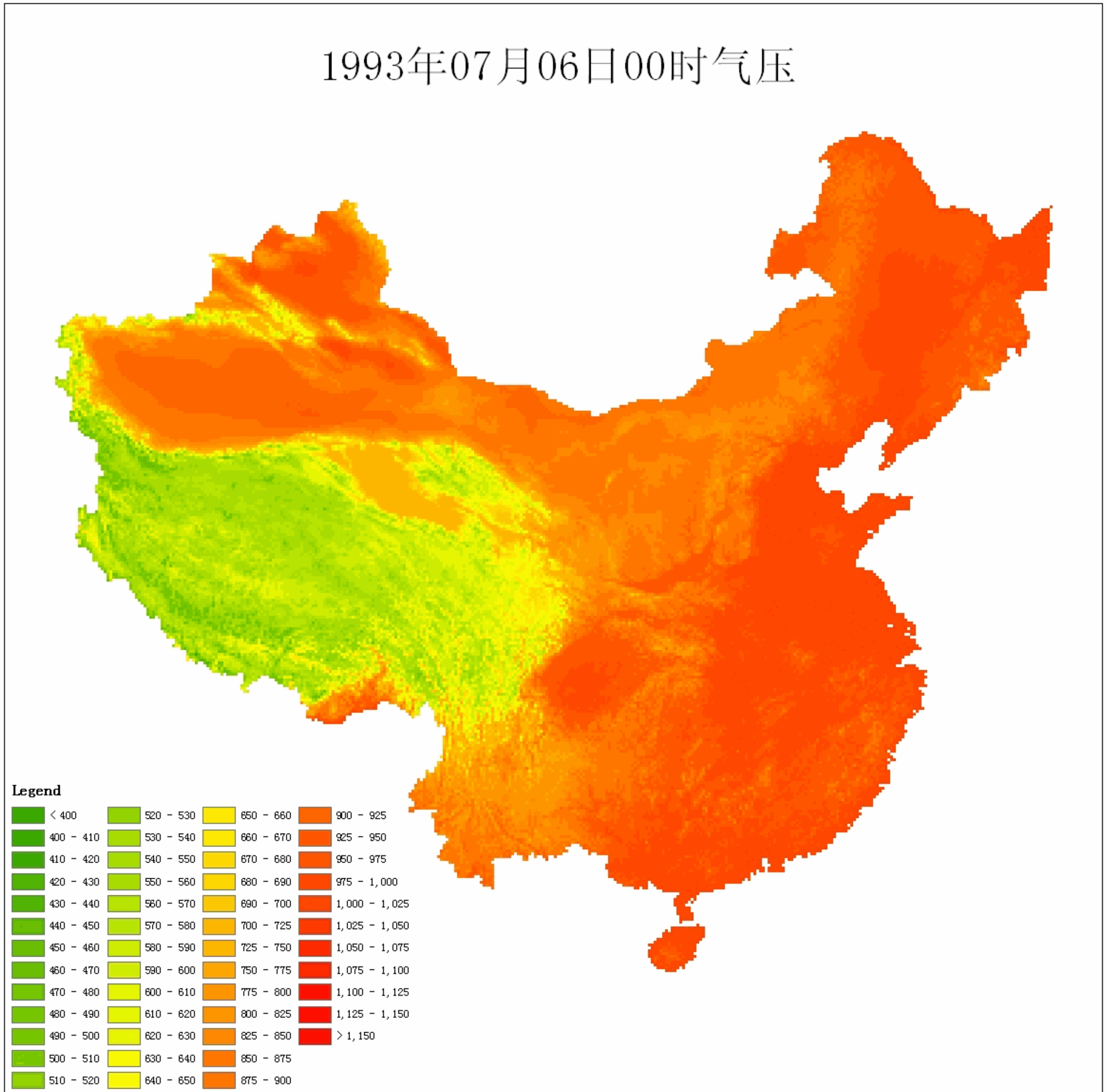
利用日平均观测
和3小时再分析数据建立压力场

P3 $$\hat{p}_i = f_i(x,y) + \alpha_i \exp\left(b_i z\right) + \beta_i \hat{p}_{i-1}$$

RMSR using P3 (hpa)

	小时数据 fit	小时数据 CV	日+再分析 CV
W	1.68	1.95	2.06
MW	1.81	2.16	2.31
NE	1.73	2.02	2.33
SE	1.76	2.21	2.55

Snapshots of pressure



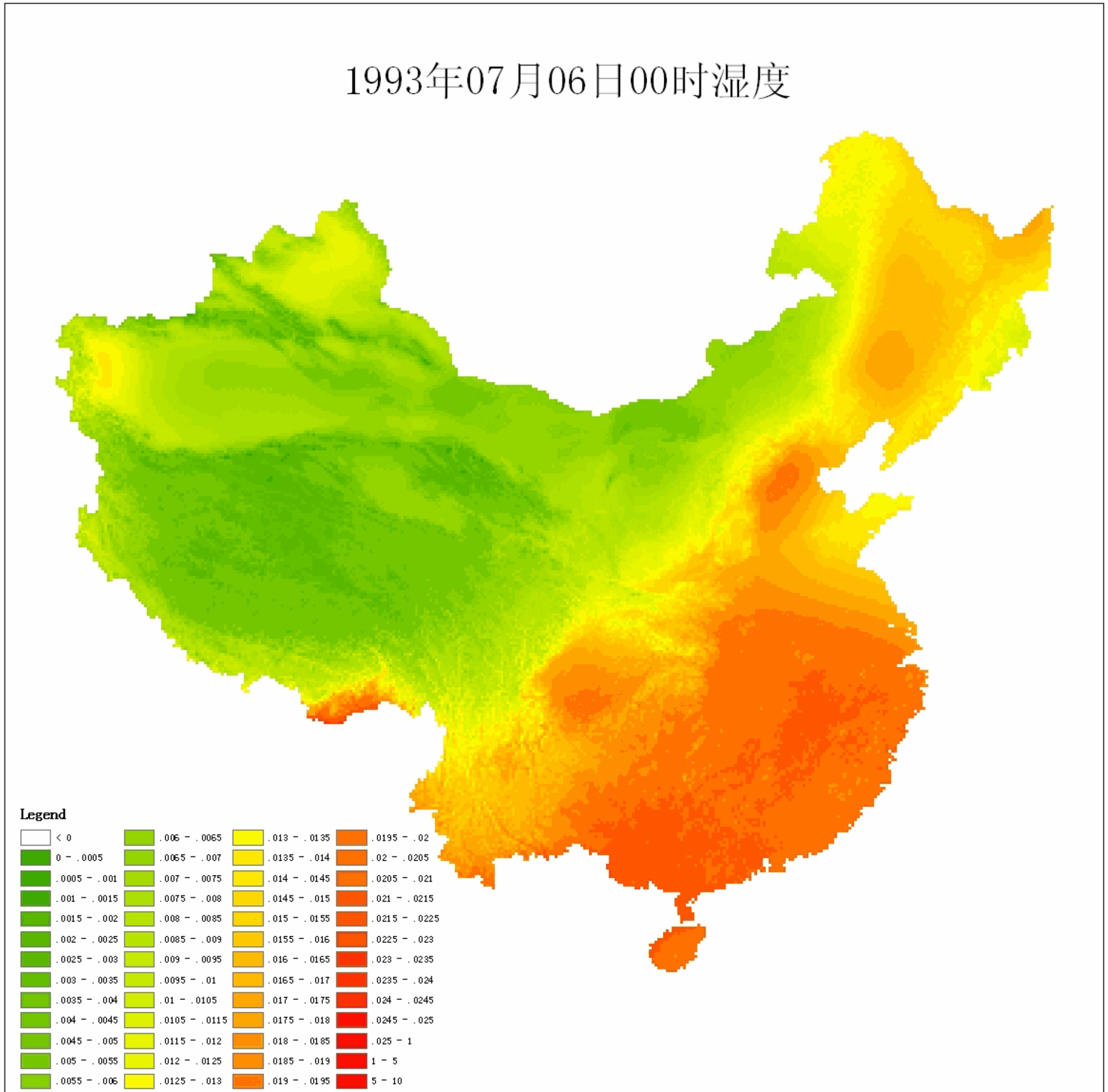
利用日观测建立相对湿度场

对特定台站，将其周围的3小时再分析数据进行一日8次线性插值，对插值结果的距平乘一因子，使其日平均与观测到的相等

Leave-one-out cross validation

	$\ln\left(rh_i/\left(1-rh_i\right)\right)=f_i(x,y)$	$rh_i = f_i(x,y)$
W	0.24	
MW	0.24	
NE	0.23	
SE	0.18	

Snapshots of humidity



辐射场的建立方法

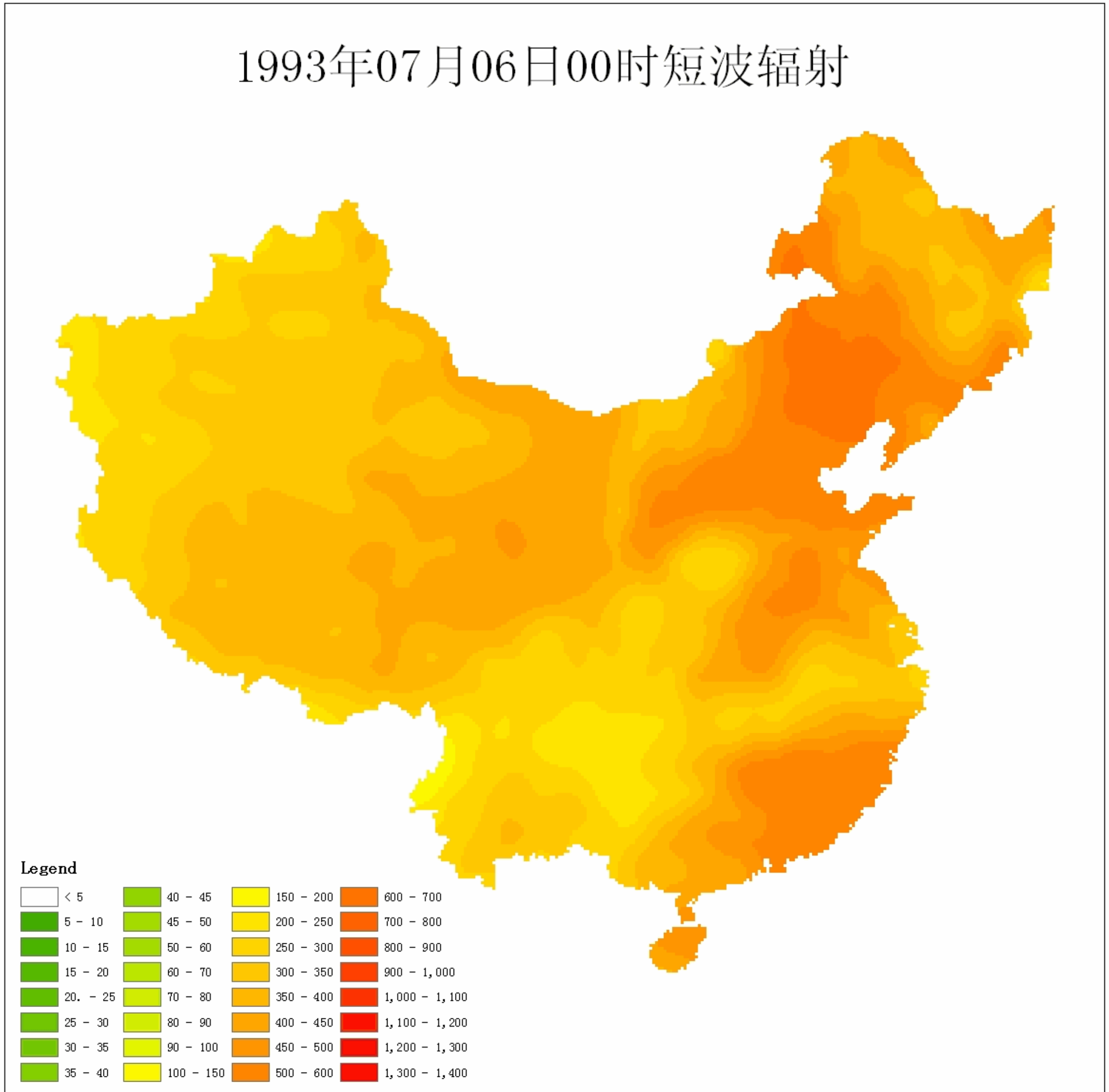
$$lw_i = f_i(x,y) + \alpha_i F_i\left(p_i, t_i, rh_i, o_i\right)$$

$$sw_i = f_i(x,y) + \alpha_i F_i\left(p_i, t_i, rh_i, o_i\right)$$

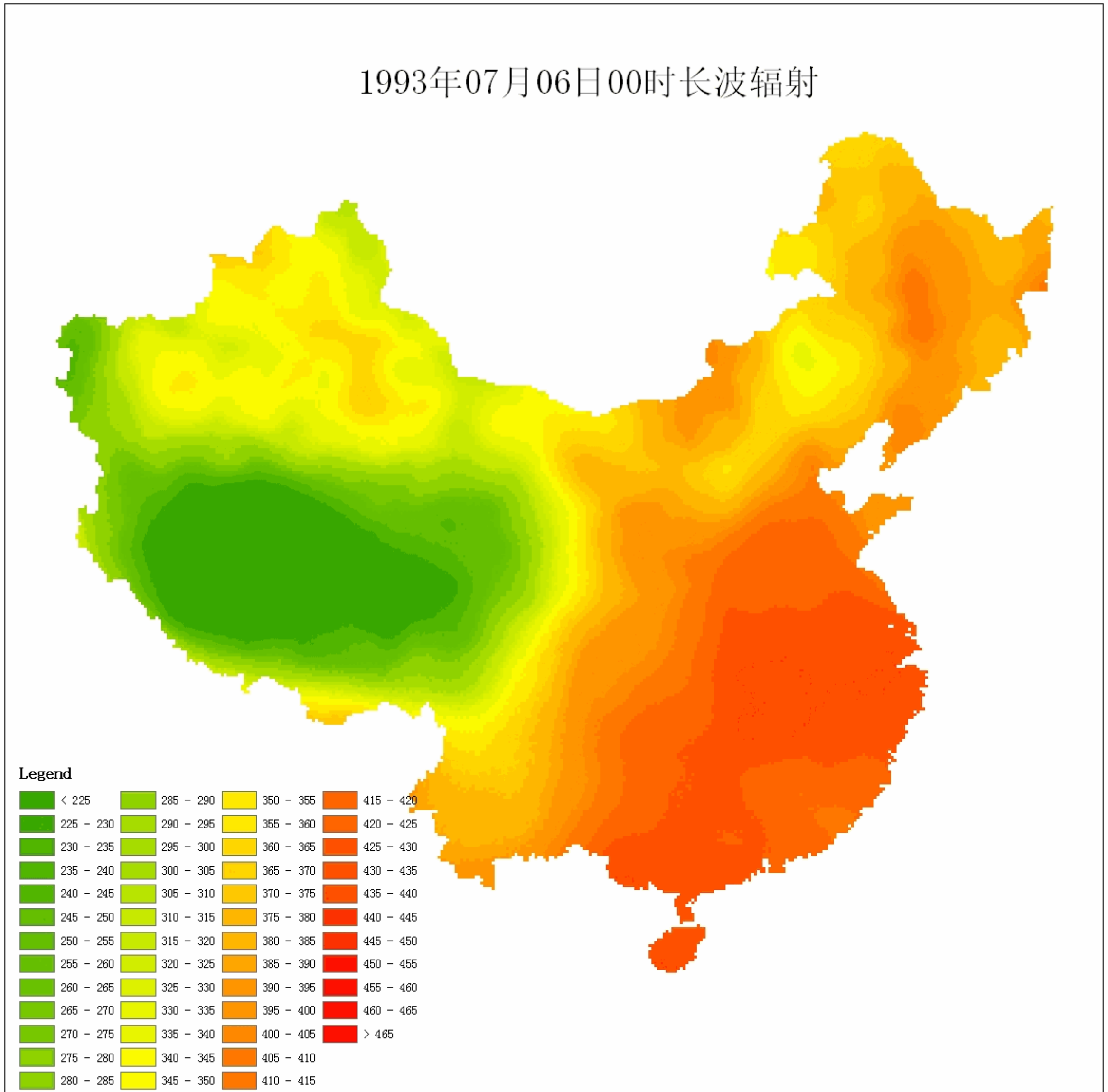
$F_i\left(p_i, t_i, rh_i, o_i\right)$ 阳坤的辐射模型

o_i 日照时数

Snapshots of shortwave radiation



Snapshots of longwave radiation

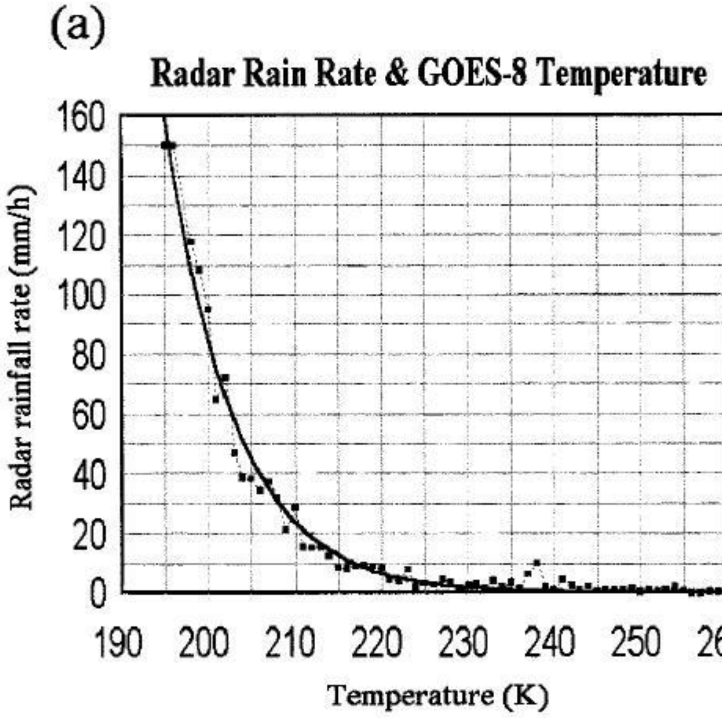


降水场的建立

降水日观测数据：1950-2010，大约700台站
降水小时观测数据：1950-1989，个台站密度逐渐增加到700
遥感数据：
TRMM（降水, 25公里，3小时)
GMS/GOES （红外亮温， 5公里, 1小时）

$$Rgoes_i \equiv$$
$$1.1183 \times 10^{11} \exp\{-0.036382 goes_i\}$$

Vicente et al., 1998



Vicente et al.,

观测日降水的时间降尺度

3小时降水 $r_i \equiv r_d \times Rgoes_i / Rgoes_d$

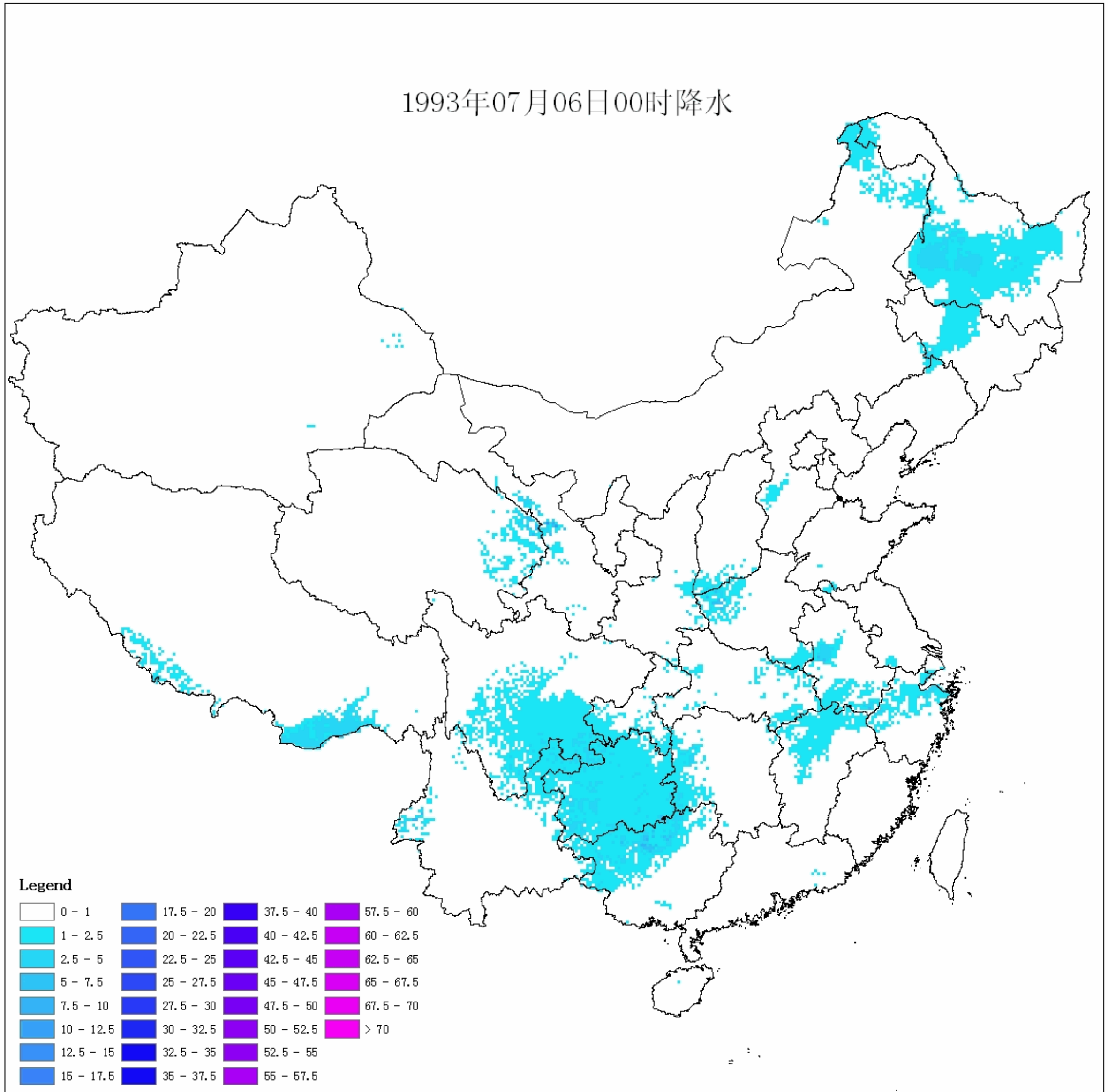
其中 r_d $Rgms_d$ 分别为观测的和反演的降水的日值

降水统计模型

$$\sqrt{r_i} = f_i(x,y) + {}_1f_i(goes_i) + {}_2f_i(goes_{i+3}) + \beta_i \sqrt{trmm_i}$$

Snapshots of the precipitation data

Precipitation



风场的建立方法

$$w_i = a + b\overline{m}_i + \sum_{j=-1}^{1} c_j m_{i+j} + d_1 |\cos(\theta_i)| + d_2 |\cos(\theta_i + 45^o)|$$

m_i 模拟的 i-时刻的风速

$\overline{m}_i$ 模拟的 i-时刻的日滑动平均风速

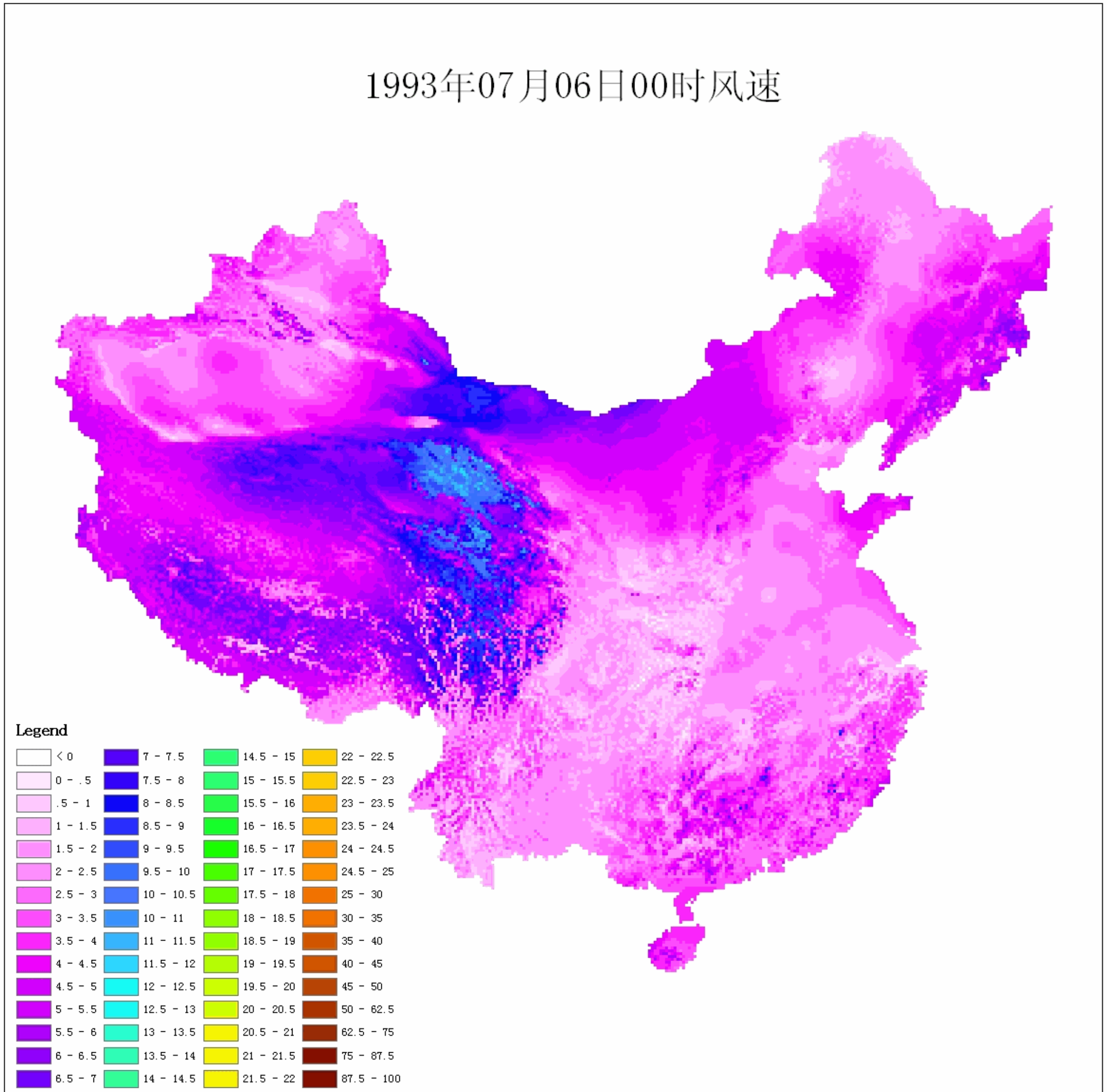
θ_i 模拟的 i-时刻的风向

区域模型，新西兰

边界层模型: 何燕萍博士，

台站观测与模拟的3小时平均相关系数=0.4

Snapshots of wind



植被动力学与生物地球化学模型

CoLM-DGVM

提纲：

- **CoLM-DGVM框架**
- 碳循环
- 氮循环
- 模拟能力检验

CoLM-DGVM框架：

- **生物物理模块（Dai et.al 2003）**

  描述植物和大气之间的物理相互作用（如潜热、显热交换，气孔导度和蒸腾作用等）

- **植被动力学模块（Sitch et. al 2003）**

  描述各植被类型的生理和生态特征变化（如物候、竞争、萌芽、形态学等）

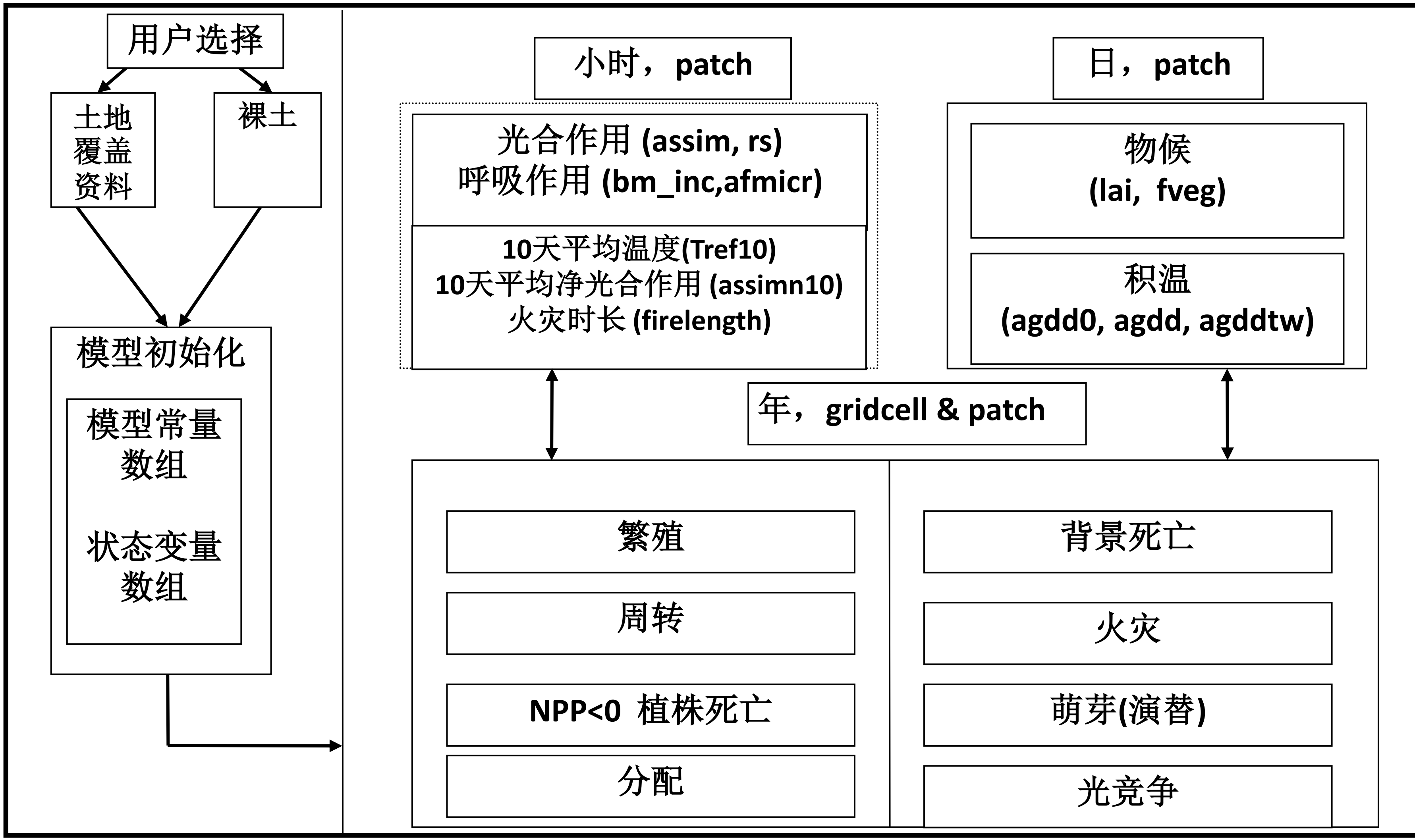
- **生物地球化学模块（Dai et. al 2004, Xu-Ri et. al 2008）**

  模拟植被的生长及碳、氮等物质循环（如光合作用、呼吸作用、凋落物的矿化、以及碳氮相互作用等）

- **温带灌木子模式（Zeng et. al 2008, 2010）**

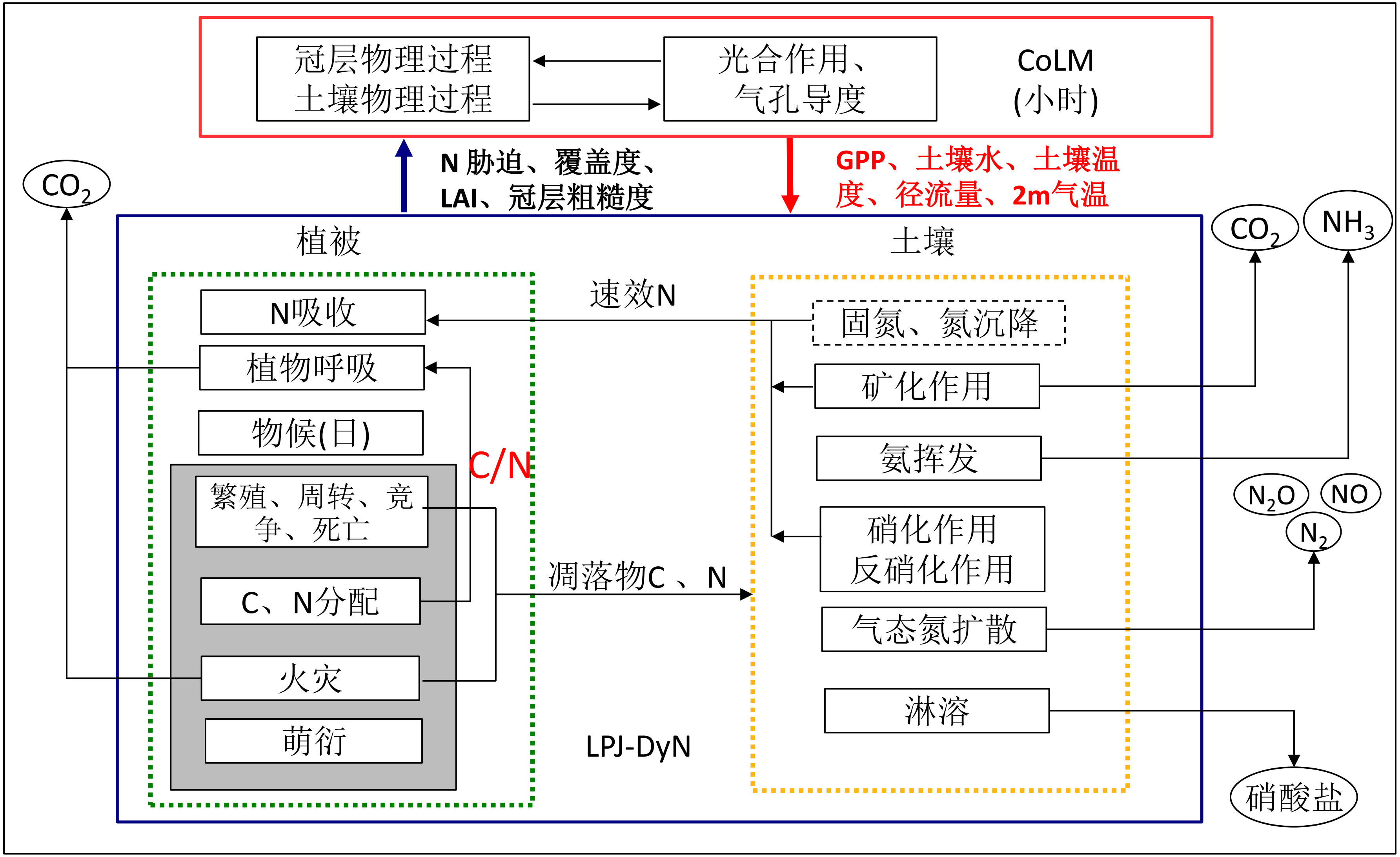
  描述灌木特有的形态学、物候学以及耐旱性等特征

植被动力学模块



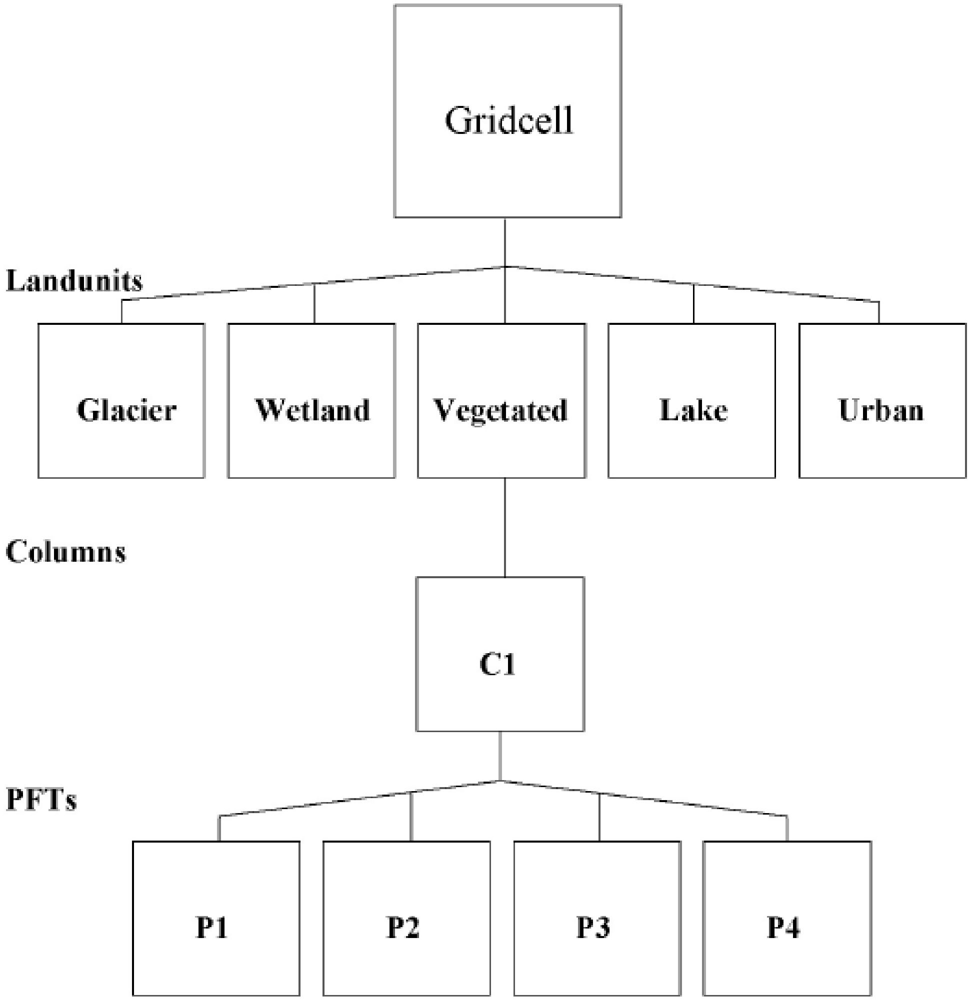
物候 、生物气候、碳分配、光竞争、死亡、重建

生物地球化学模块



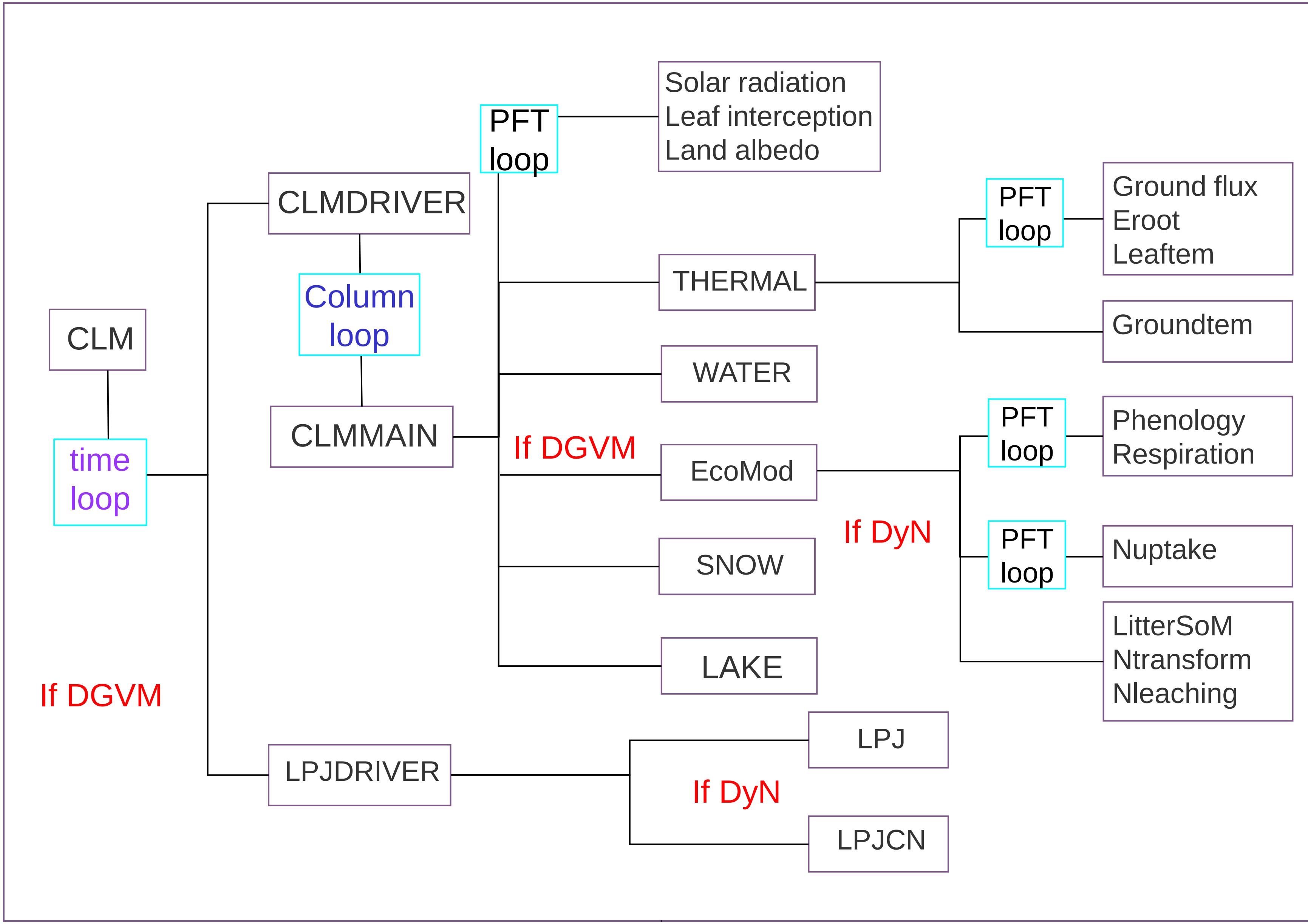
植被光合作用、植被呼吸作用、固碳、固氮、氮矿化、硝化作用与反硝化作用、氮淋溶、氮分配

CoLM-DGVM网格分级



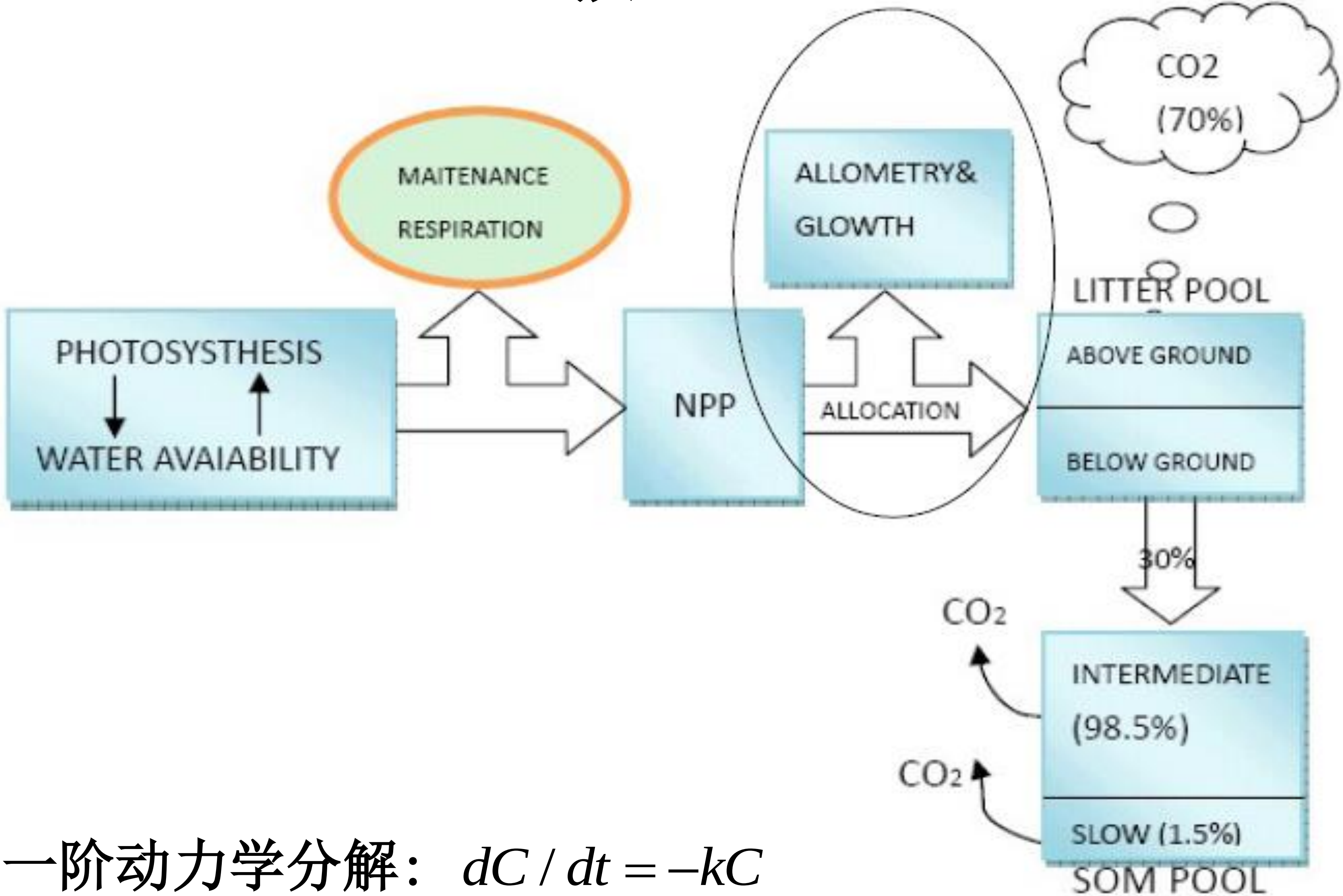
- 每一CoLM网格点覆盖形态定义为5类：冰盖、湿地、湖泊、城市、植被(裸土)；
- 13 植被功能类型(含裸土)；
- 计算次网格的土壤状态变量、 C, N 库；
- 植被功能次网格计算植被生理过程通量。

程序结构



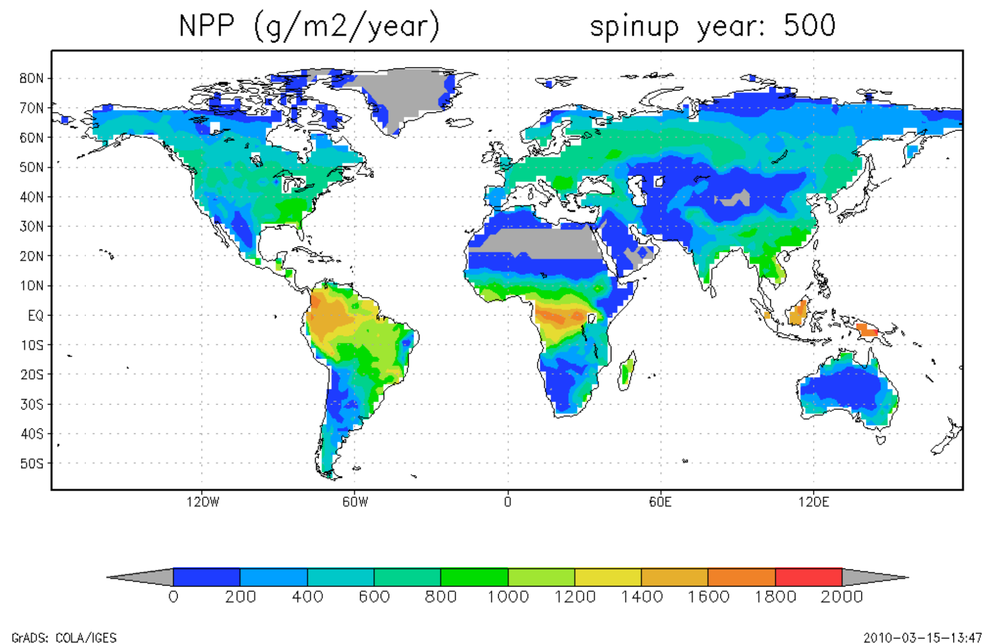
CLM
time loop
If DGVM
CLMDRIVER
Column loop
CLMMAIN
LPJDRIVER
PFT loop
Solar radiation
Leaf interception
Land albedo
THERMAL
WATER
If DGVM
EcoMod
SNOW
LAKE
PFT loop
Ground flux
Eroot
Leaftem
Groundtem
PFT loop
Phenology
Respiration
If DyN
PFT loop
Nuptake
LitterSoM
Ntransform
Nleaching
LPJ
If DyN
LPJCN

碳通量



一阶动力学分解： $dC / dt = -kC$

碳循环模拟



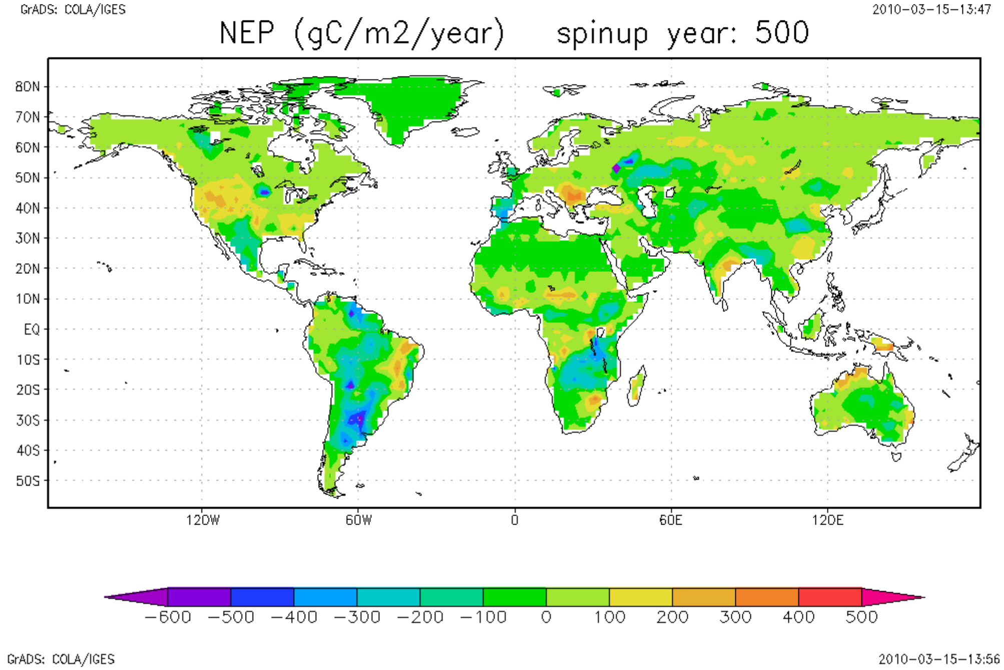
大气驱动数据： PRINCETON data from 1991-2000

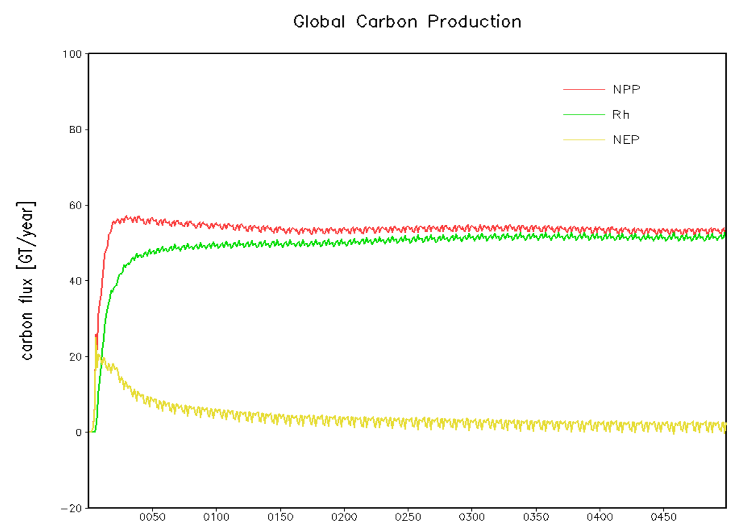
积分时间: 500年

CO2浓度： 350ppm

全球NPP总量 50-60 GT/年

北半球中高纬度主要为碳汇





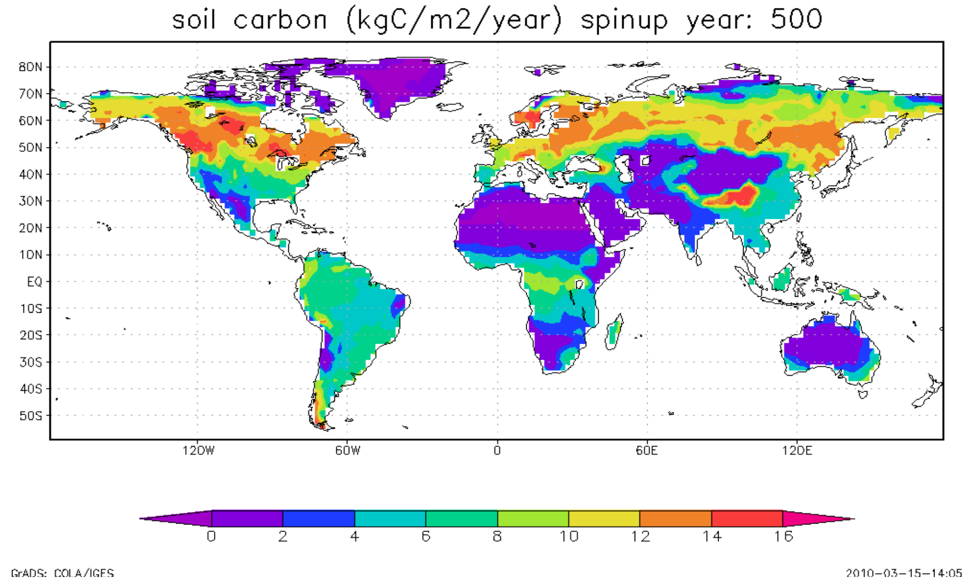
碳循环模拟

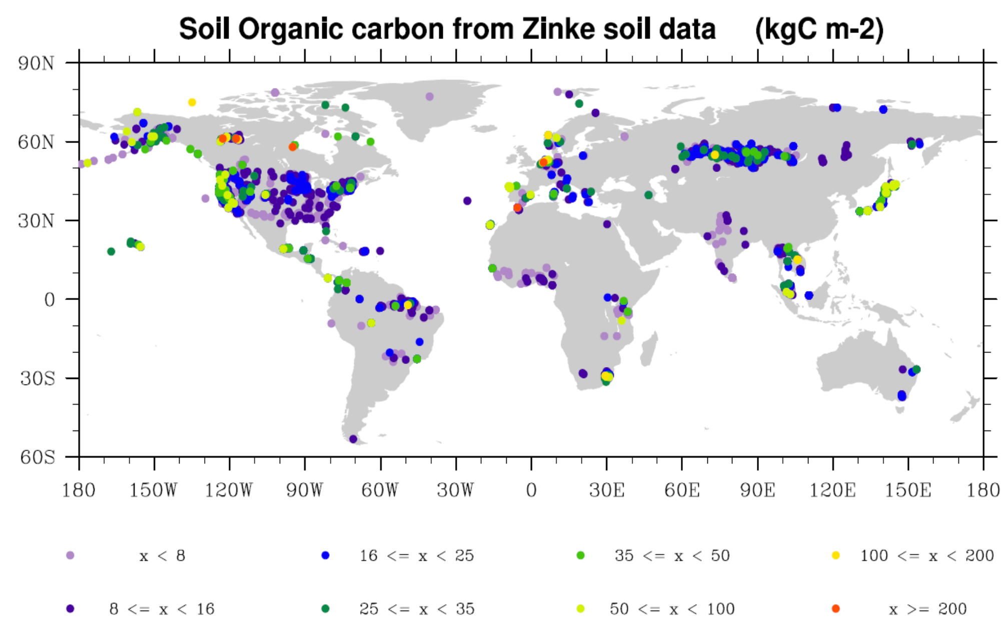
生物群系	面积（1.0E6 km2）		生物量总C库（TG C）		总NPP (TG /a)	
	CoLM	Data	CoLM	Data	CoLM	Data
热带森林	31.9	17.5	550	340	30	21.9
温带森林	23.3	10.4	322	139	11.4	8.1
北方森林	18.8	13.7	180	57	6.7	2.6
温带和寒带草	11.3	20.6	2.7	8	3.4	6.1
温带灌木和草	10.5	30.4	7.3	79	2.5	16.3
寒带灌木	3.4	-	2.7	-	0.3	-
合计	99.2	92.6	1064.7	603	54.3	55

对比资料来自 Saugier et al. 2001

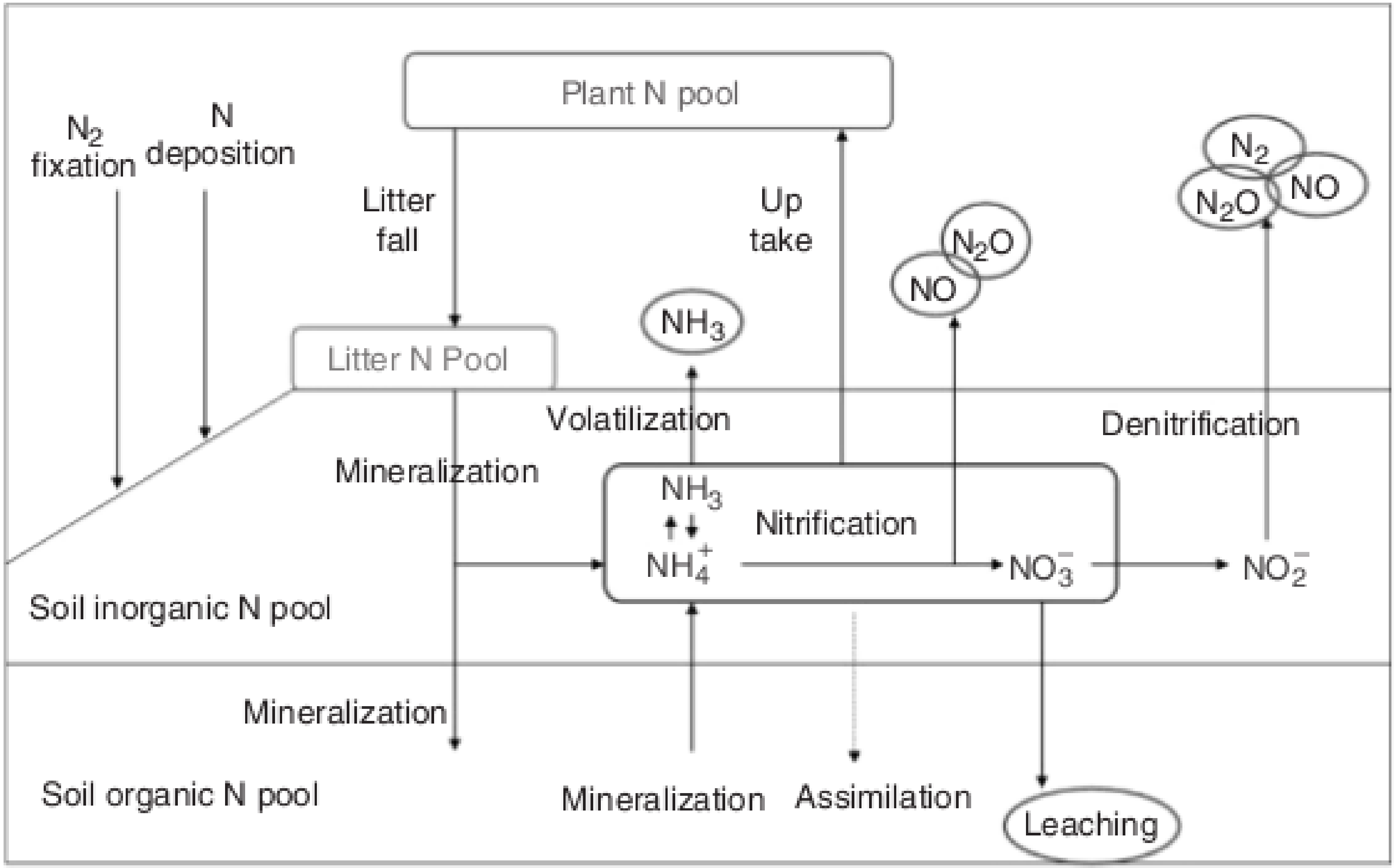
- 全球NPP和资料吻合较好，热带和北方森林NPP偏高，草地NPP偏低；
- 森林生物量偏高，草地生物量偏低

碳循环模拟


soil carbon (kgC/m2/year) spinup year: 500
80N
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
120W
60W
0
60E
120E
0
2
4
6
8
10
12
14
16
GrADS: COLA/IGES
2010-03-15-14:05


Soil Organic carbon from Zinke soil data (kgC m-2)
90N
60N
30N
0
30S
60S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
x < 8
16 <= x < 25
35 <= x < 50
100 <= x < 200
8 <= x < 16
25 <= x < 35
50 <= x < 100
x >= 200

氮循环



Xu-Ri et al., 2008

氮循环：植被固氮

$$N\_demand = NPP_p / cton\_pro$$

$$N\_uptake\_capacity = f_{temp} \times N\_demand$$

$$N\_availability = W_{cont} \times N\_pool$$

$$N\_uptake = \min(N\_uptake\_capacity, N\_availability)$$

$$N\_stress = N\_uptake \;/\; N\_demand$$

$$NPP_n = N\_stress \times NPP_p$$

Nitrogen stress does not explicitly affect photosynthesis ability, but directly reduce potential NPP production

氮分配

Static relative C/N ratio for N allocation

↓

Update C/N ratio for leaf, root and sapwood

↓

calculate plant respiration with new C/N ratio

$$N_{alloc} = N_{leaf} + N_{root} + N_{sapwood} + N_{inc}$$

$$rcton\_LR = C_{leaf} : N_{leaf} / C_{root} : N_{root}$$

$$rcton\_LS = C_{leaf} : N_{leaf} / C_{sap} : N_{sap}$$

$$CtoN_{-leaf-new} = C_{leaf\_new} / N_{leaf\_new}$$

$$CtoN_{-root-new} = C_{root\_new} / N_{root\_new}$$

$$CtoN_{-sapwood-new} = C_{sapwood\_new} / N_{sapwood\_new}$$

$$R_{leaf} = r \cdot C_{leaf} / CtoN_{-leaf-new} \cdot \varphi \cdot g(T)$$

$$R_{root} = r \cdot C_{root} / CtoN_{-root-new} \cdot \varphi \cdot g(T)$$

$$R_{sapwood} = r \cdot C_{sapwood} / CtoN_{-sapwood-new} \cdot \varphi \cdot g(T)$$

氮转化

Concept of "anaerobic balloon":

Soil moisture is an indicator to allocate substrates into two soil fractions for nitrification and denitrification reactions

Nitrification

$$NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$$

$$NH^+_{4soil,aerobic} = NH^+_{4soil} \cdot (1 - W_{cont})$$

$$NO^-_{3inc} = N_{max} \cdot f_{temp} \cdot NH^+_{4soil,aerobic}$$

Denitrification

$$NO_3^- \rightarrow NO_2^- \rightarrow N2$$

$$NO^-_{2inc} = DNmax \cdot f_{temp} \cdot NO^-_{3anaerobic} / \left(NO^-_{3anaerobic} + Kn\right)$$

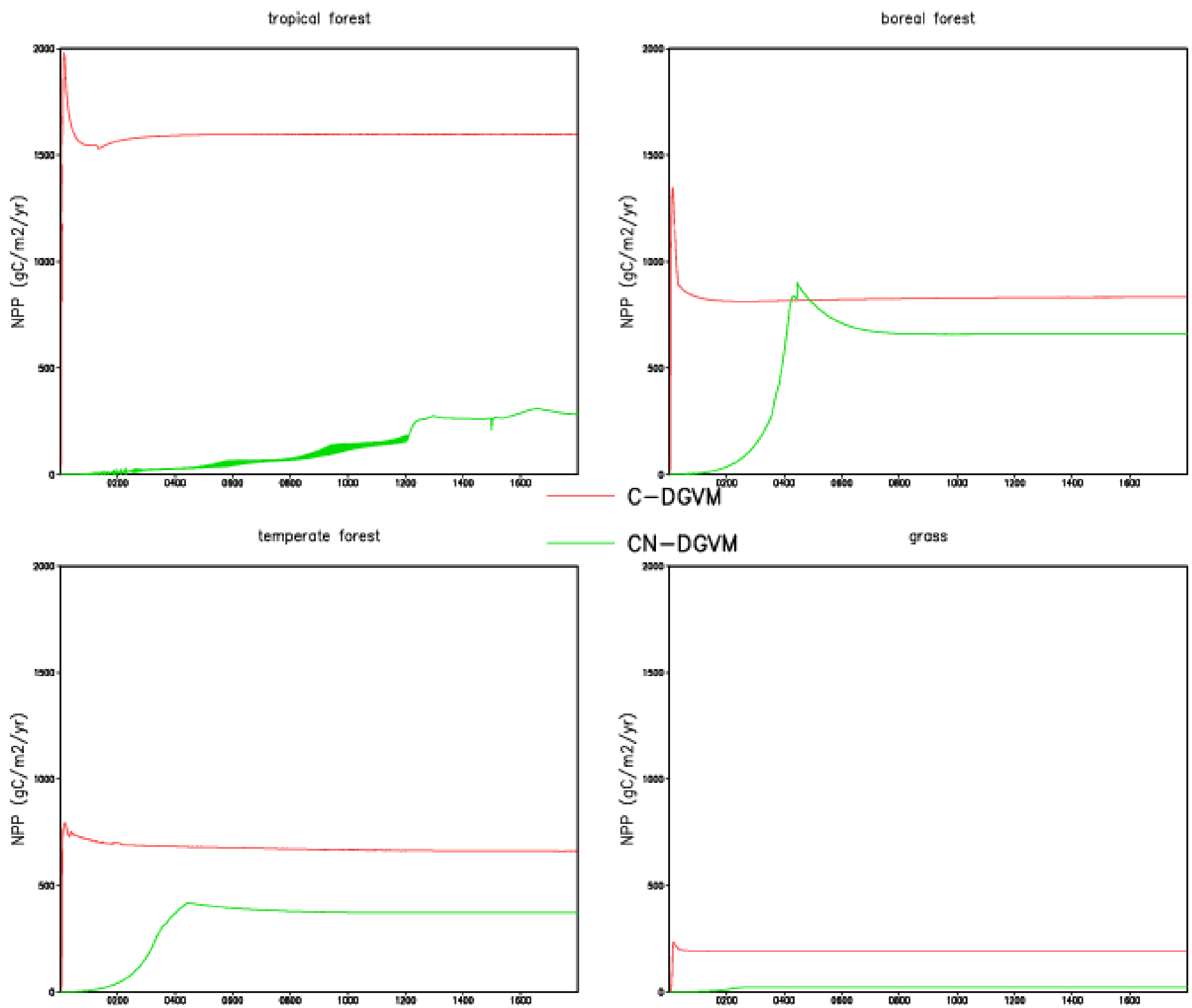
$$N_{2inc} = DNmax \cdot f_{temp} \cdot NO^-_{2anaerobic} / \left(NO^-_{2anaerobic} + Kn\right)$$

$$DN\max = LCA/(LCA + Kc)$$

LCA is soil labile carbon

氮循环模拟

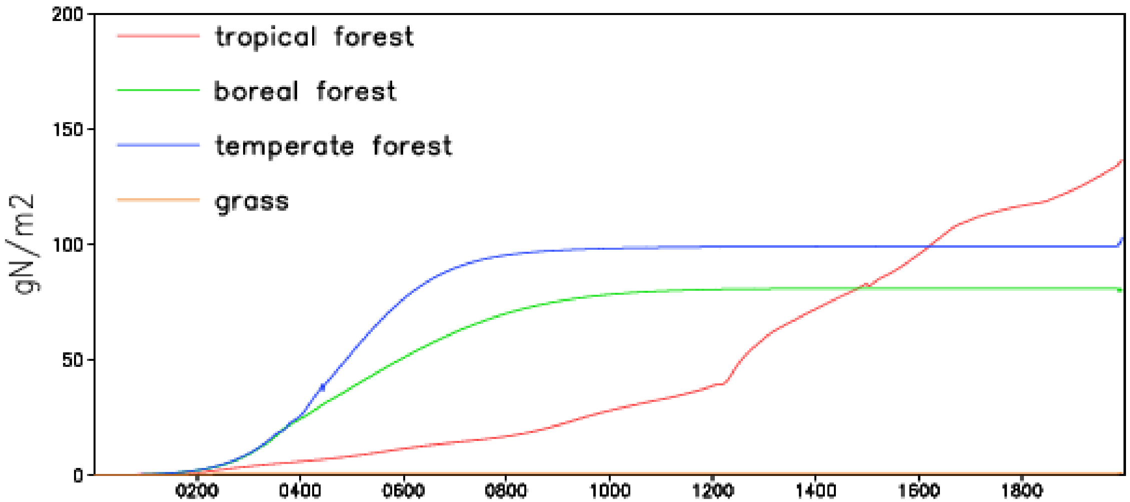
NPP


tropical forest
boreal forest
temperate forest
grass
NPP (gC/m2/yr)
C−DGVM
CN−DGVM

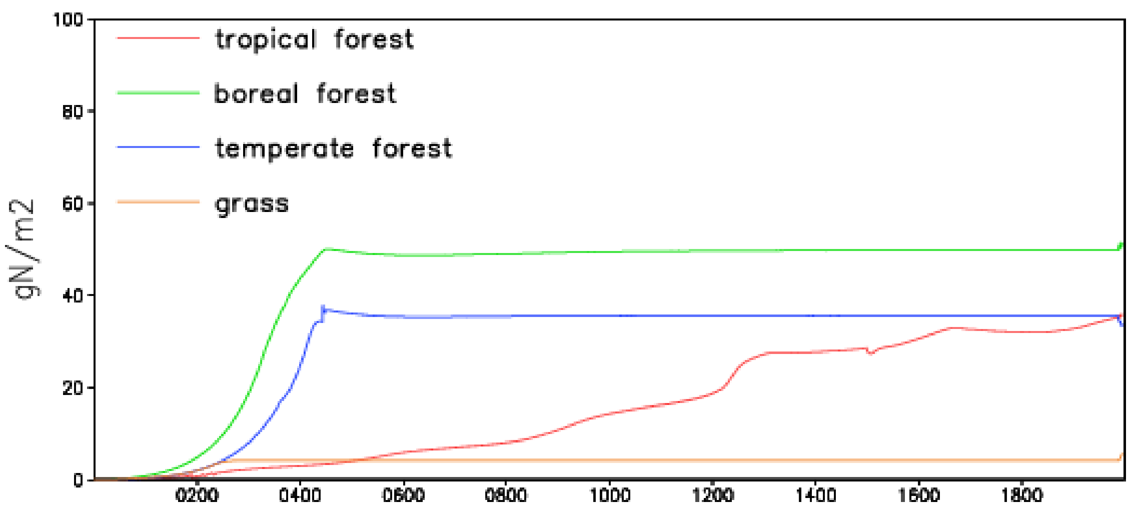
氮循环模拟

有机氮

Soil Organic N



Litter Organic N



小结

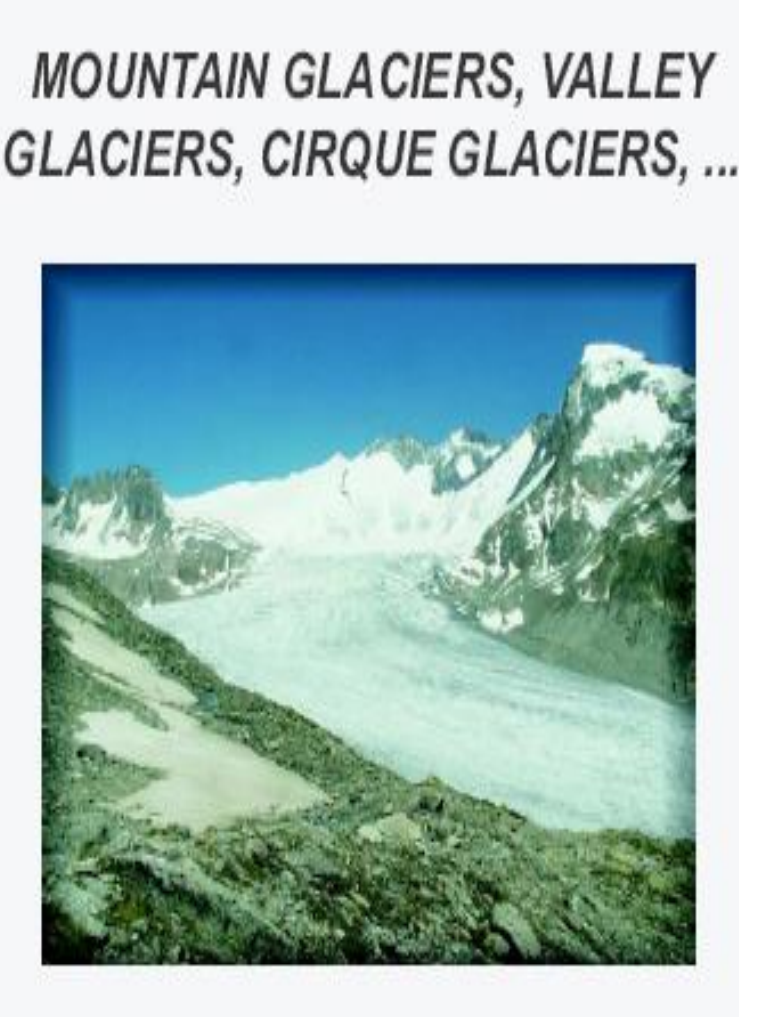
- CoLM能够模拟当前气候条件下全球植被的潜在分布；
- 引入了(Zeng. et al. 2008, 2010) 的灌木子模式，模拟的温带灌木的空间分布较合理；
- 能够模拟全球NPP及土壤碳循环，其量级和分布较为合理；
- 氮循环的引进对温带和寒带森林NPP的模拟有一定的限制作用，能够较好模拟土壤有机氮和氮吸收。热带森林的氮循环尚需进一步调试。

总结

- CoLM能够模拟当前气候条件下全球植被的潜在分布
- 引入了(Zeng. et al. 2008,2010) 的灌木子模式，模拟的温带灌木的空间分布较合理
- 能够模拟全球NPP及土壤碳循环，其量级和分布较为合理
- 氮循环的引进对温带和寒带森林NPP的模拟有一定的限制作用，能够较好模拟土壤有机氮和氮吸收。

气候模式对山地冰川描述的困难及现状

- 静态地表类型
  - 仅考虑高反照率
  - 没有消融、累积等过程
- 空间尺度差异
  - 山地冰川尺度100m-50km，RCM、GCM水平格点尺度30km-100km
  - 气象要素在模式格点内的非均匀性特征
- 经验统计模型
  - 积温模型无法再气候变化背景准确描述冰川的响应
- 能量平衡-消融模型
  - 单点、分布式消融模型



引自NASA

山地冰川参数化方案的主要内容

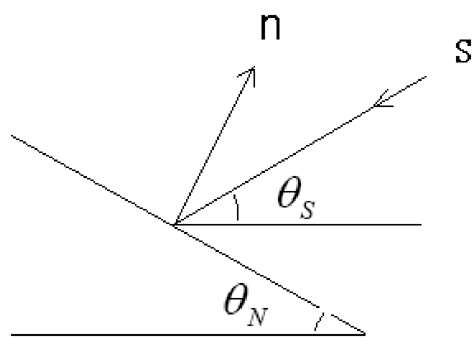
- 基于CoLM能量平衡方案的冰体消融、累积过程
- 基于CoLM五层积雪方案的积雪密实化及雪-冰转换过程
- 次网格气象要素的非均一性参数化方案
  - 地形对辐射的几何订正（Mathias D. Muller方案）
  - 地形对降水的影响（L. Ruby Leung方案）

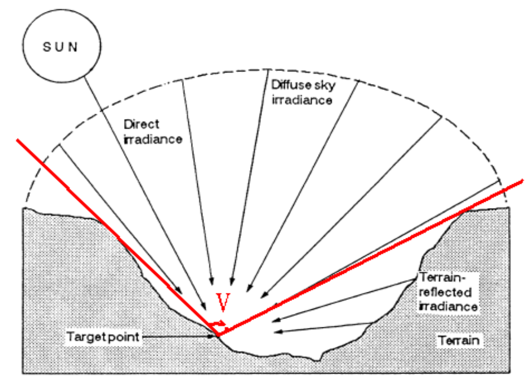
地形对辐射的几何订正（Mathias D. Muller，2005）

订正因子

$$\cos\alpha = \cos\theta_N \sin\theta_S + \sin\theta_N \cos\theta_S \cos(\phi_S - \phi_N)$$

$$f_{corr} = \frac{1}{\sin\theta_S}\frac{1}{\cos\theta_N} mask_{shadow} \cos\alpha \qquad mask_{shadow} = \begin{cases} 0\ (\theta_S < \theta_{h,\phi_S}) \\ 1\ (elsewhere) \end{cases}$$





视角因子

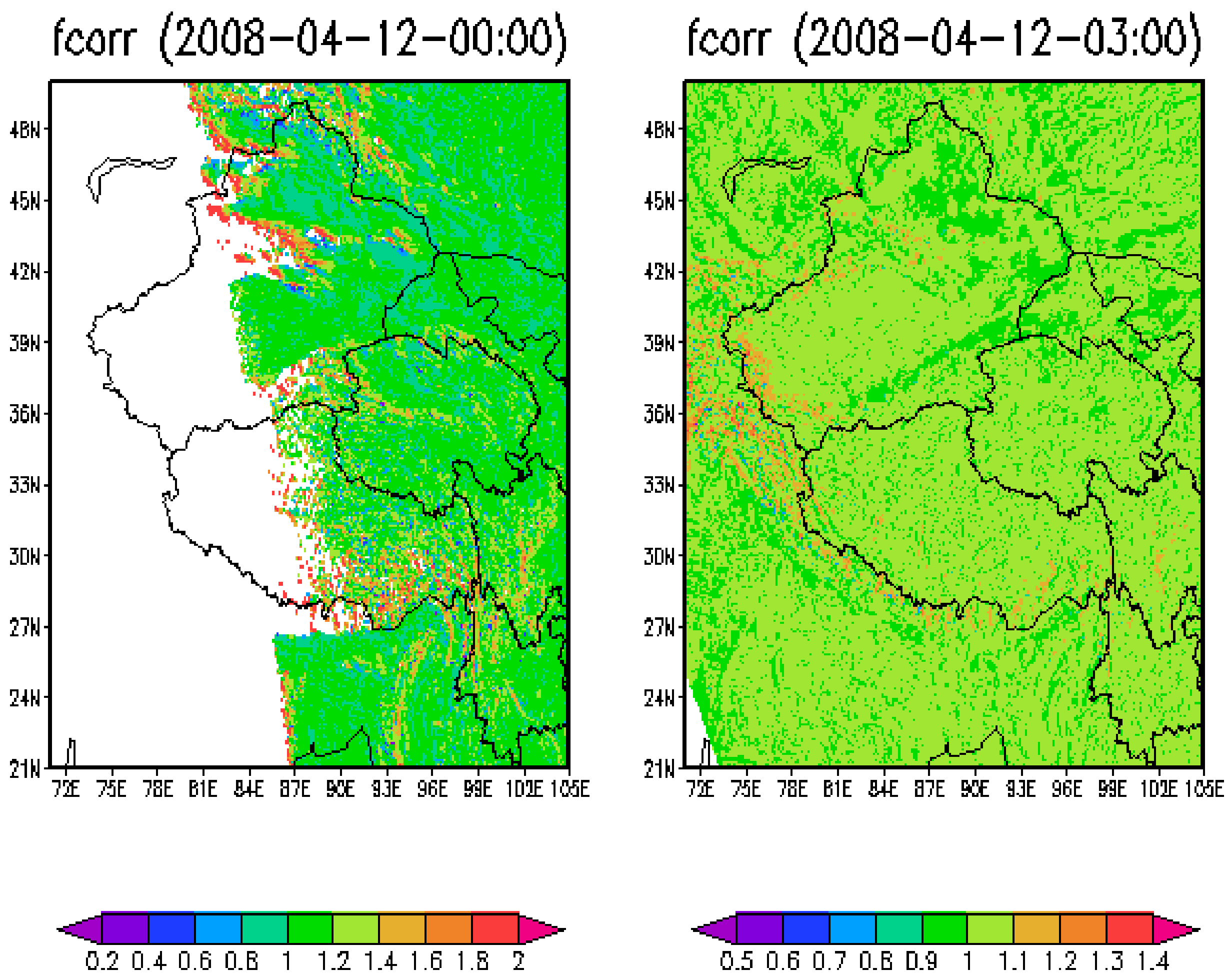
$$f_{sky} = \frac{1}{\pi}\int_0^{2\pi}\int_0^{\theta_{h,\phi}} \sin\theta[\cos\theta\cos\theta_N + \sin\theta\sin\theta_N\cos(\phi-\phi_N)]d\theta d\phi$$

$$f_{sky} = \frac{1}{2\pi}\int_0^{2\pi}[\cos\theta_N \sin^2\theta_{h,\phi} + \sin\theta_N\cos(\phi-\phi_N)(\theta_{h,\phi} - \sin\theta_{h,\phi}\cos\theta_{h,\phi})]d\phi$$

$$S^*_{dir}\downarrow = f_{corr} S_{dir}\downarrow \qquad S^*_{dif}\downarrow = f_{sky} S_{dif}\downarrow + (1 - f_{sky}) S_{arround}\uparrow$$

$$S^* = S^*_{dir} + S^*_{dif} \qquad L^*\downarrow = f_{sky} L\downarrow + (1 - f_{sky}) L_{arround}\uparrow$$

不同时刻地形对直射辐射的几何订正效应



冰川表层积雪反照率方案（地形因素）

$$\alpha_{v,b(snow)} = \alpha_{vd} + 0.4 f(\mu)[1-\alpha_{vd}]$$

$$\alpha_{ir,b(snow)} = \alpha_{ird} + 0.4 f(\mu)[1-\alpha_{ird}]$$

$$\alpha_{vd} = [1-0.2F_{age}]\alpha_{vo} \qquad \alpha_{vo} = 0.95$$

$$\alpha_{ird} = [1-0.5F_{age}]\alpha_{iro} \qquad \alpha_{iro} = 0.65$$

$$f(\mu) = \begin{cases} \frac{1}{b}[\frac{b+1}{1+2b\mu} - 1] & \mu \le 0.5 \\ 0 & \mu > 0.5 \end{cases}$$

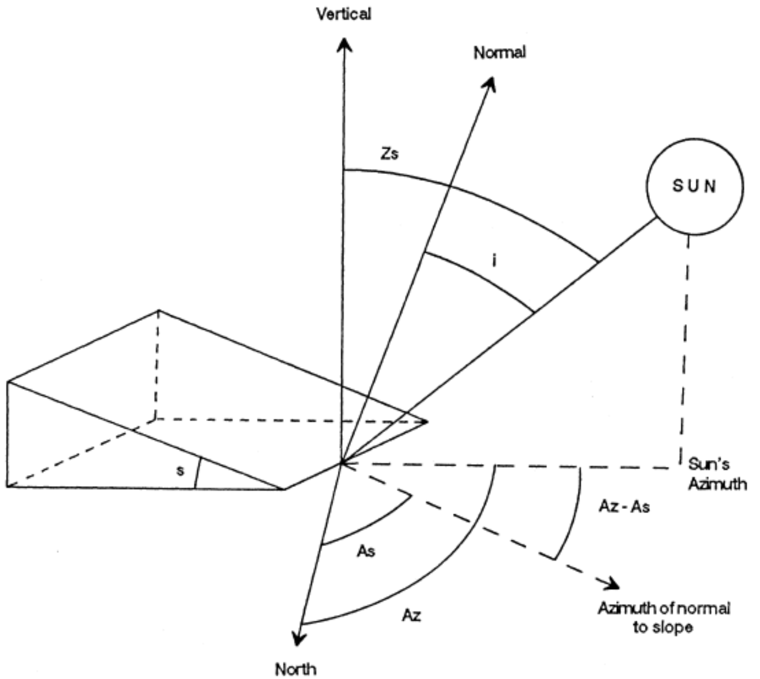


FIGURE 2. Geometry defining the position of the sun relative to a sloping surface (from Sellers, 1965).

$$\mu = \cos\theta_N \sin\theta_S + \sin\theta_N \cos\theta_S \cos(\phi_S - \phi_N)$$

山地冰川参数化方案与气候模式的耦合

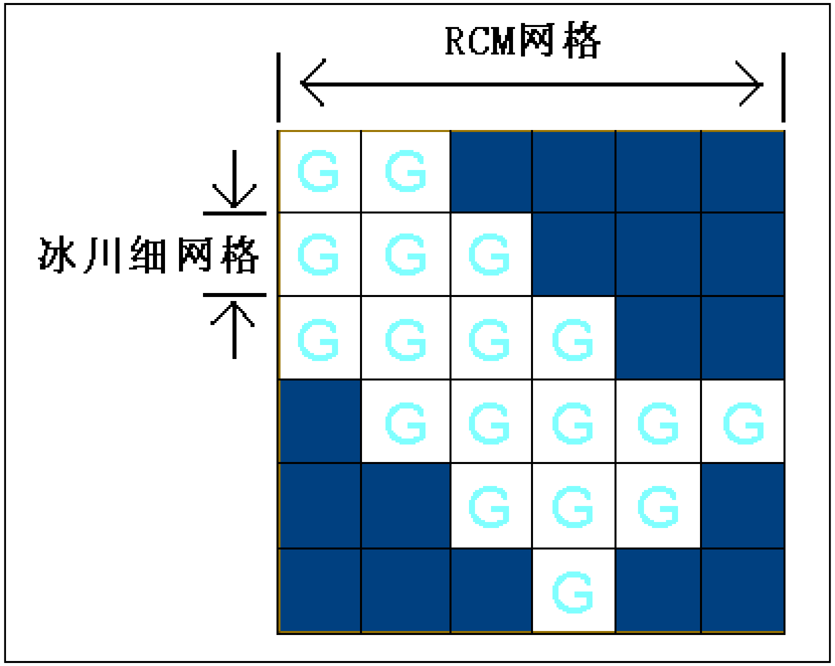
冰川区域采用5km分辨率细网格，嵌套在区域气候模式网格中

$$T_f = T_c - 0.0065\Delta h$$

$$P_f = P_c \exp(\frac{-g}{R\overline{T}}\Delta h)$$

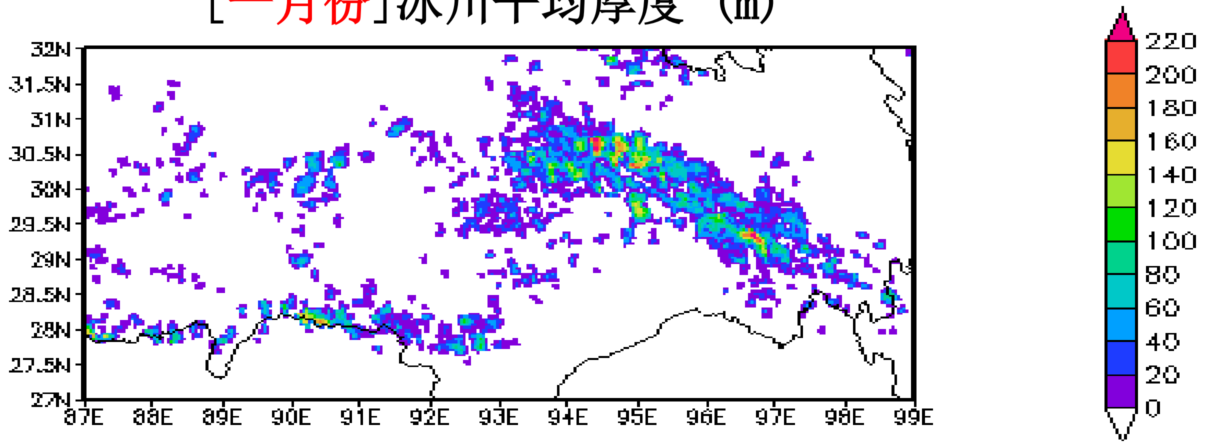
$$\overline{T} = \frac{T_f + T_c}{2}$$

$$q_f = q_c \frac{Q_{f,sat}}{Q_{c,sat}}$$

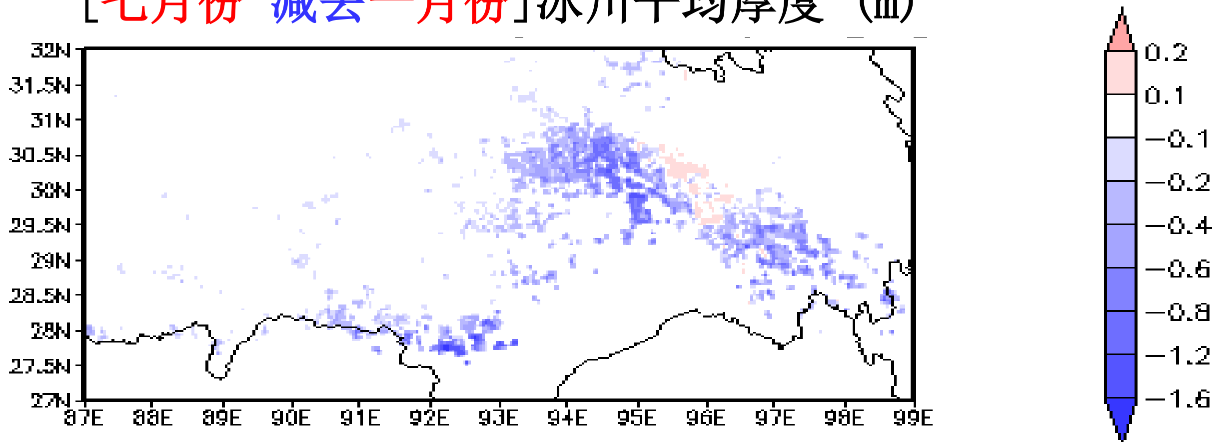


数值模拟试验结果(青藏高原)

[一月份]冰川平均厚度（m）

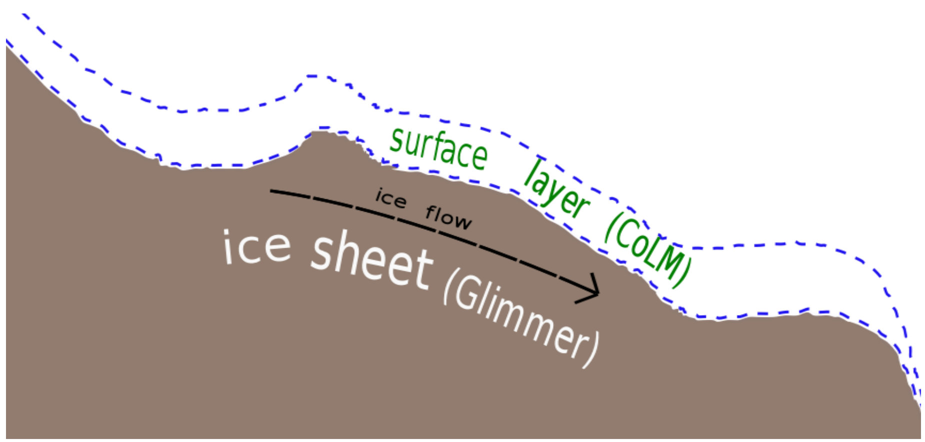


[七月份 减去一月份]冰川平均厚度（m）



通用陆冰模式

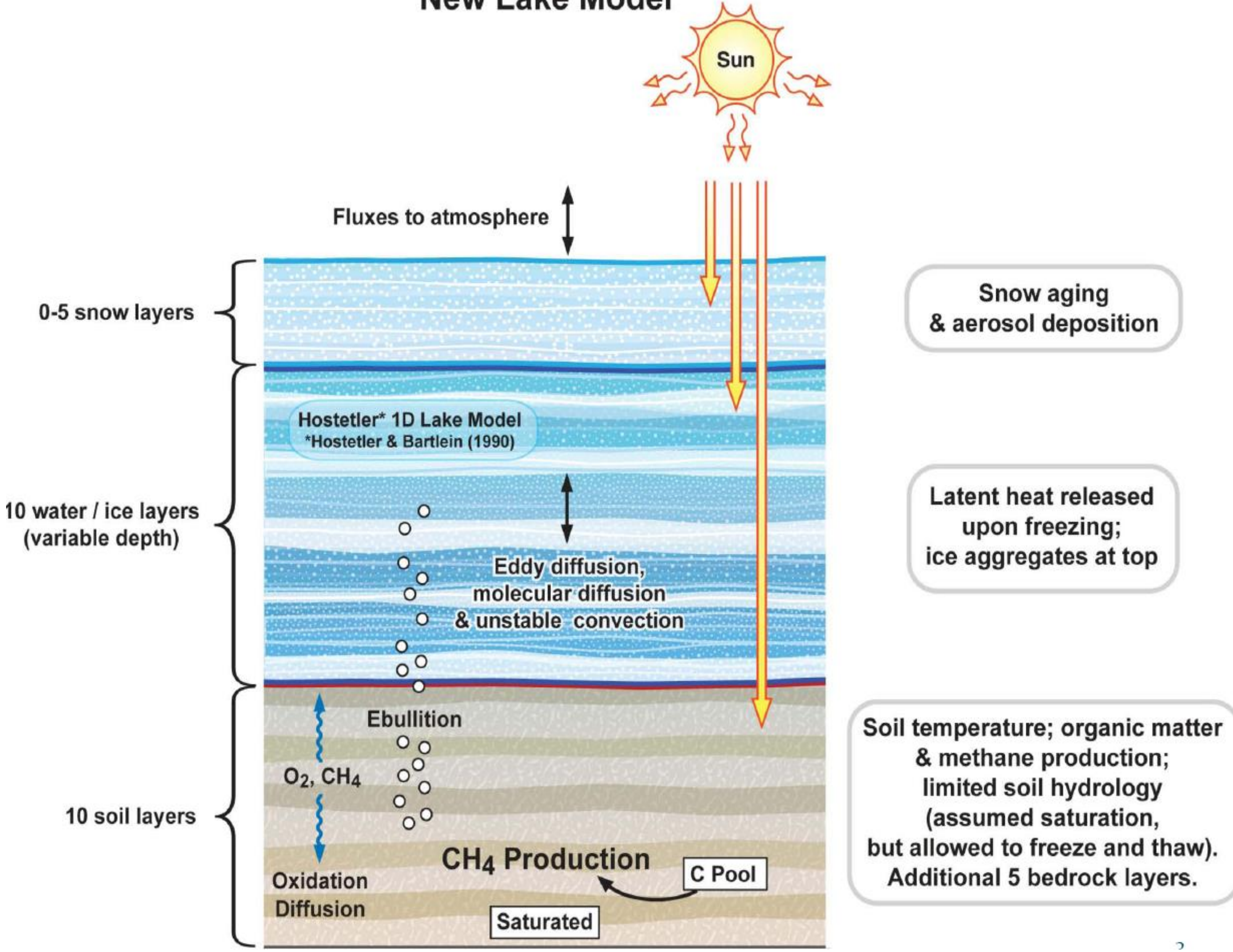
- 在CoLM陆面模式的基础上，发展可同时描述山地冰川和极地冰原、冰盖的一体化陆冰模式
  - 通用冰体表层能量-物质平衡方案
    - 在CoLM对山地冰川能量-物质平衡方案的基础上，进一步描述极地冰原的物质平衡过程，形成通用的冰体表层物质平衡方案
  - 基于Glimmer冰原模式的冰体动力学方案
    - 计算冰体在下伏地形上的空间三维运动



通用陆冰模式
示意图

湖泊模式研制

New Lake Model



相对原CoLM湖泊模块新的物理过程参数化：

- 模式层湖冰质量比例（Ice fraction）
- 相变
- 涡流扩散和对流混合（eddy diffusion and convective mixing）
- 积雪、湖水和湖底沉积物热传导
- 湖水光学性质
- ……

1. SNOWFALL (SNOW-PACK) INTO LAKE WATER

s = snow mass (kg/m^2),

n = before the snow-pack into lake, n+1 = after snow-pack into lake,

T^n, T^{n+1} = lake water temperature (before and after) of lake layer [K],

$lake\_icefrac^n$, $lake\_icefrac^{n+1}$ = ice mass fraction of lake layer (before and after) [0-1],

T_{precip} = temperature of snow-pack [K],

T_{frz} = water temperature at freezing point [273.15 K]

c_{pice} = specific heat of ice [J/(kg K)]

c_{pliq} = specific heat of water [J/(kg K)]

h_{fus} = latent heat of fusion for ice [J/kg]

ρ = density of water [kg/m3]

dz = thickness of lake layer

$$a = c_{pice}\ s\ (T_{frz} - T_{precip})$$

$$b = s\ h_{fus}$$

$$c = \rho\ dz\ c_{pliq}\ (T^n - T_{frz})$$

$$d = \rho\ dz\ h_{fus}$$

1) 湖水全部冻结所释放的热量 还不足以使 snow pack 的温度升到 freezing point (T_{frz})，即，

IF ($c - a \le -d$) then

$$\text{lake\_icefrac}^{n+1} = 1$$

$$c_{pice}\, s(T^{n+1} - T_{precip}) = c + d + \rho c_{pice}\, dz\,(T_{frz} - T^{n+1}) \quad =>$$

$$T^{n+1} = \frac{c + d + c_{pice}\, s\, T_{precip} + \rho c_{pice}\, dz\, T_{frz}}{c_{pice}\, s + \rho c_{pice}\, dz}$$

2) 湖水温度为 T_{frz}， 通过冻结部分湖水(liquid water) 释放潜热 使雪块温度升到 T_{frz}，

ELSE IF ($c - a \le 0$) then

$$c + \Delta[\text{lake\_icefrac}]\, \rho\, dz\, h_{fus} = a \quad =>$$

$$w_{ice}^{n+1} = \left[\text{lake\_icefrac}^{n} + \frac{a - c}{\rho\, dz\, h_{fus}}\right] \rho dz + s$$

$$w_{liq}^{n+1} = \left[1 - \text{lake\_icefrac}^{n} - \frac{a - c}{\rho\, dz\, h_{fus}}\right] \rho dz$$

$$\text{lake\_icefrac}^{n+1} = \left[\frac{w_{ice}^{n+1}}{w_{liq}^{n+1} + w_{ice}^{n+1}}\right]$$

$$T^{n+1} = T_{frz}$$

3) 不需要湖水冻结释放热量，就可使 snow pack 温度提升到T_{frz}，无相变发生 (c = a);

湖水不全部冻结，不需要湖水冻结释放热量，即湖水温度降到T_{frz}所释放的内能(感热)，就能使部分雪团融化：

ELSE IF (c − a ≤ b) then，

$$0 \le c - a \le b$$

$$-(c - a) = \Delta[\text{lake\_icefrac}]\ s\, h_{fus}$$

$$\Delta[\text{lake\_icefrac}] = \frac{a - c}{s\, h_{fus}} = \frac{a - c}{b}$$

$$\text{lake\_icefrac}^{n+1} = \frac{s}{s + \rho\, dz} + \frac{a - c}{b}$$

$$T^{n+1} = T_{frz}$$

4) 雪团全部被湖水融化

ELSE

$$b \le c - a$$

$$\text{lake\_icefrac}^{n+1} = 0$$

$$a + b + s\, c_{pliq}\,(T^{n+1} - T_{frz}) = \rho c_{pliq}\, dz\,(T^{n} - T^{n+1}) \ \Rightarrow$$

$$T^{n+1} = \frac{\rho c_{pliq}\, dz\, T^{n} + s\, c_{pliq}\, T_{frz} - (a + b)}{\rho c_{pliq}\, dz + s\, c_{pliq}}$$

END IF

河道径流模式研制

(River Routing Model)

提　纲

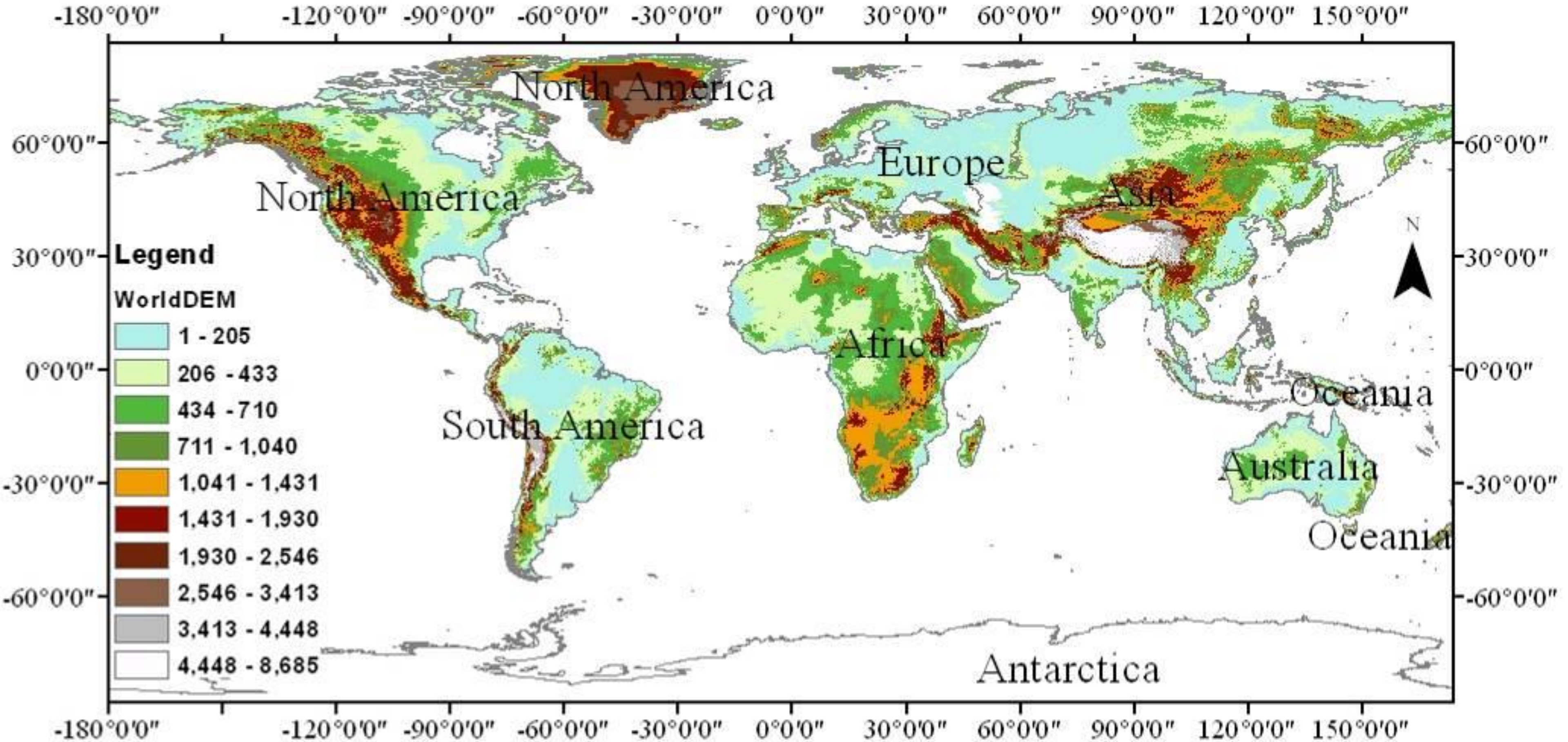
1、全球流域信息提取

2、大尺度运动波流域汇流

3、小结及后续工作

1. 全球流域信息提取

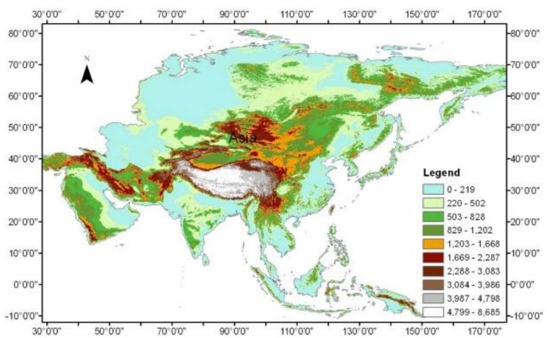
全球DEM信息

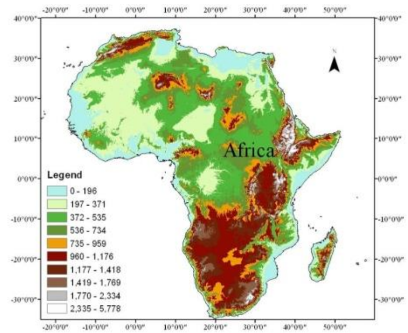


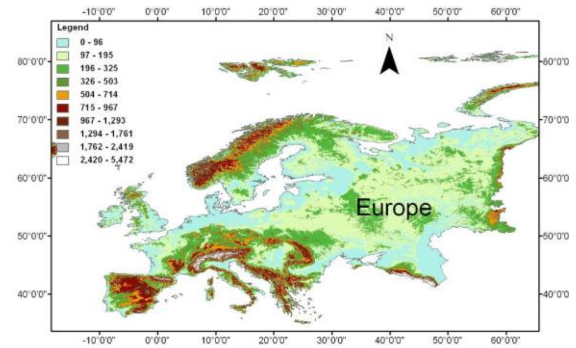
-180°0'0"
-120°0'0"
-90°0'0"
-60°0'0"
-30°0'0"
0°0'0"
30°0'0"
60°0'0"
90°0'0"
120°0'0"
150°0'0"
60°0'0"
30°0'0"
0°0'0"
-30°0'0"
-60°0'0"
North America
North America
Europe
Asia
Africa
South America
Oceania
Australia
Oceania
Antarctica
N
Legend
WorldDEM
1 - 205
206 - 433
434 - 710
711 - 1,040
1,041 - 1,431
1,431 - 1,930
1,930 - 2,546
2,546 - 3,413
3,413 - 4,448
4,448 - 8,685

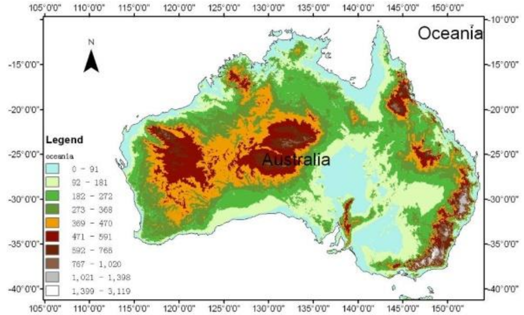
全球区域划分成6大洲：

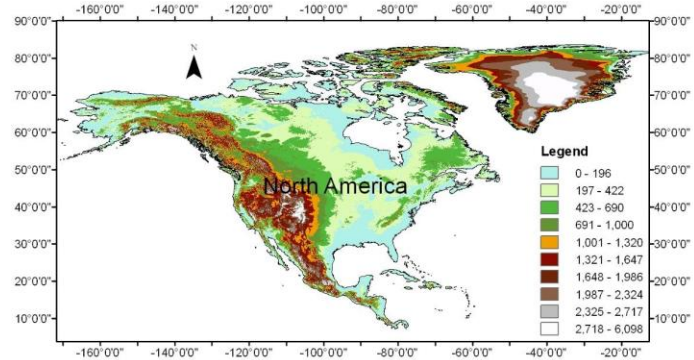
1、Asia 2、Africa 3、Europe 4、Oceania
5、North America   6、South America

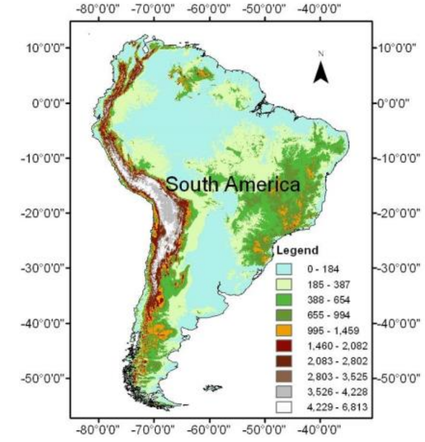








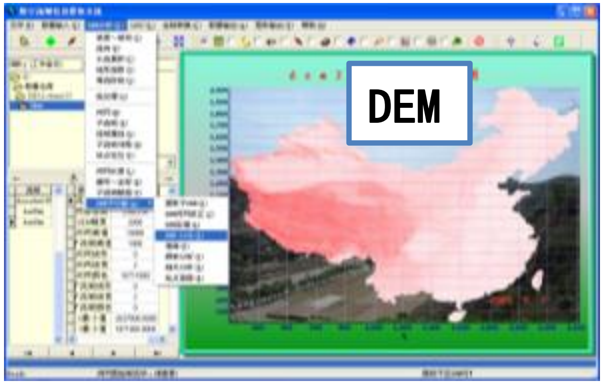


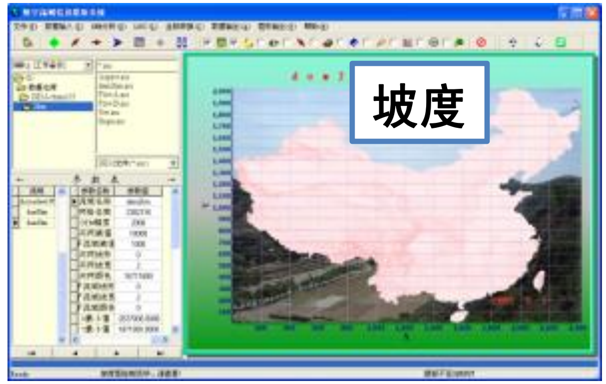


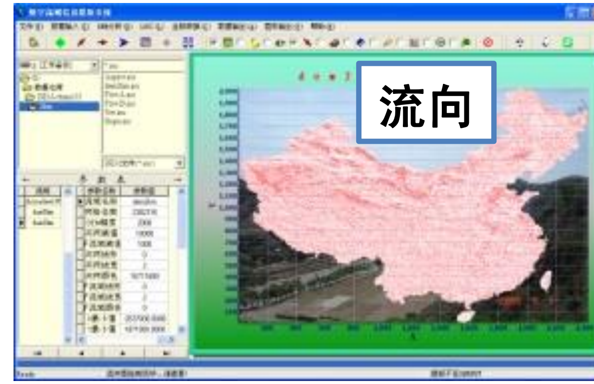
Contents	Grids(30s)		Sub basins ($>100km^2$)	Area(km^2)
Asia	a0	11,810,736	31,671	7,938,114
	a1	6,089,596	18,914	4,683,779
	a2	6,293,942	14,167	3,526,213
	a3	1,975,831	3,959	973,489
	a4	5,743,874	12,933	3,158,283
	a5	4,562,873	8,432	2,136,792
	a6	5,830,608	12,501	3,090,162
	a7	7,739,130	16,077	3,914,796
	a8	3,743,515	9,486	2,291,402
	a9	10,659,214	32,622	7,944,606
	Total	**64,449,319**	**160,762**	**39,657,636**
Africa	a0	2,957,261	9,658	2,451,105
	a1	8,856,534	27,248	6,843,195
	a2	3,697,130	12,494	3,087,900
	a3	4,584,462	15,699	3,849,230
	a4	1,675,051	5,381	1,392,319
	a5	4,794,370	15,196	3,795,330
	a6	4,331,700	15,251	3,707,680
	a7	840,821	2,975	720,914
	a8	2,546,505	8,477	2,123,699
	a9	2,460,927	8,484	2,071,521
	Total	**36,744,761**	**120,863**	**30,042,893**

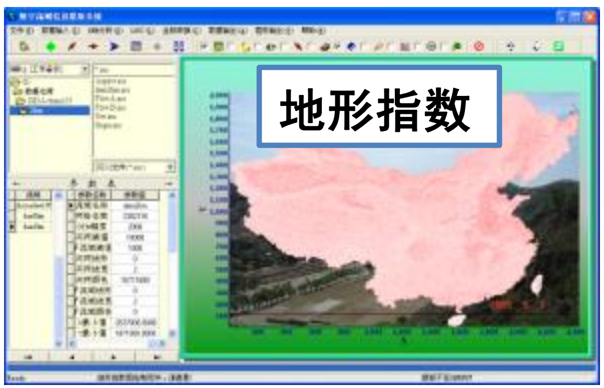
Contents	Grids(30s)		Sub basins (>100km²)	Area(km²)
Europe	a0	7,047,707	17,554	4,422,184
	a1	6,501,752	19,889	4,920,339
	a2	3,822,715	8,878	2,378,657
	a3	13,502,725	28,590	7,067,448
	Total	30,874,899	74,911	18,788,628
Oceania	**Total**	**13,769,962**	**42,441**	**10,431,944**
North America	a1	7,405,218	15,934	3,983,898
	a2	4,206,999	8,683	2,239,772
	a3	9,986,503	17,205	4,443,223
	a4	2,072,361	4,890	1,239,065
	a5	4,680,760	11,121	2,710,012
	a6	1,752,953	4,397	1,125,360
	a7	2,214,177	5,486	1,343,960
	a8	4,970,303	13,335	3,362,238
	a9	6,410,433	19,629	4,828,876
	Total	**43,699,707**	**100,680**	**25,276,404**
South America	a1	5,439,951	15,862	3,920,726
	a2	1,778,639	5,984	1,522,228
	a3	7,989,102	26,018	6,479,769
	a4	6,927,769	23,571	5,894,979
	Total	**22,135,461**	**71,435**	**17,817,702**
Global	**Total**	**211,674,109**	**571,092**	**142,015,207**

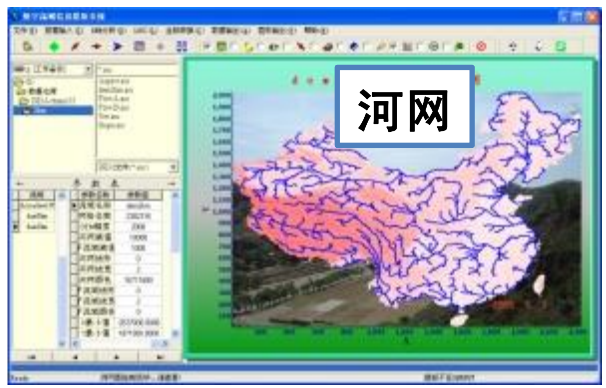
数字流域信息提取

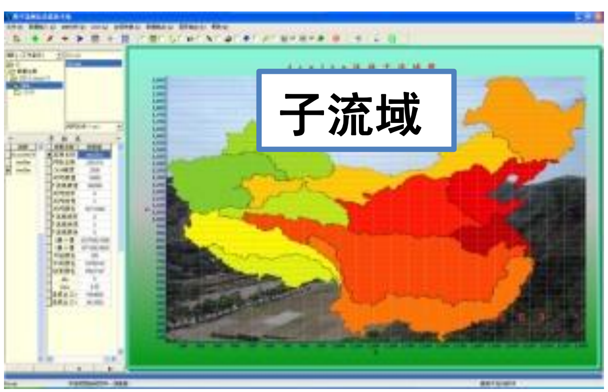


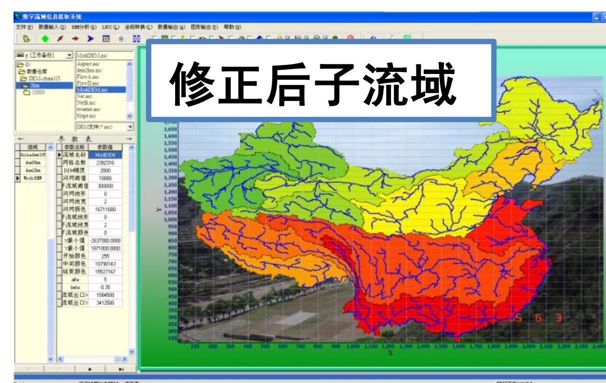




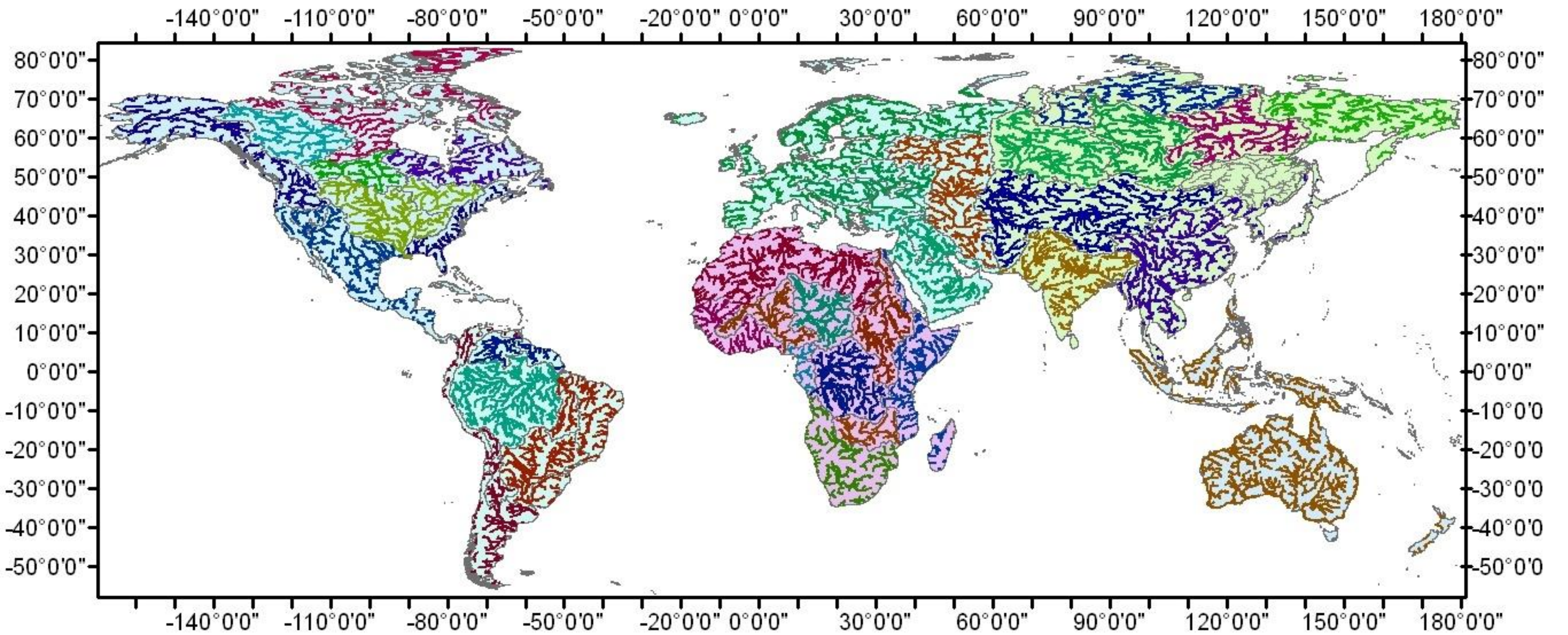








全球提取的河网



-140°0'0"
-110°0'0"
-80°0'0"
-50°0'0"
-20°0'0"
0°0'0"
30°0'0"
60°0'0"
90°0'0"
120°0'0"
150°0'0"
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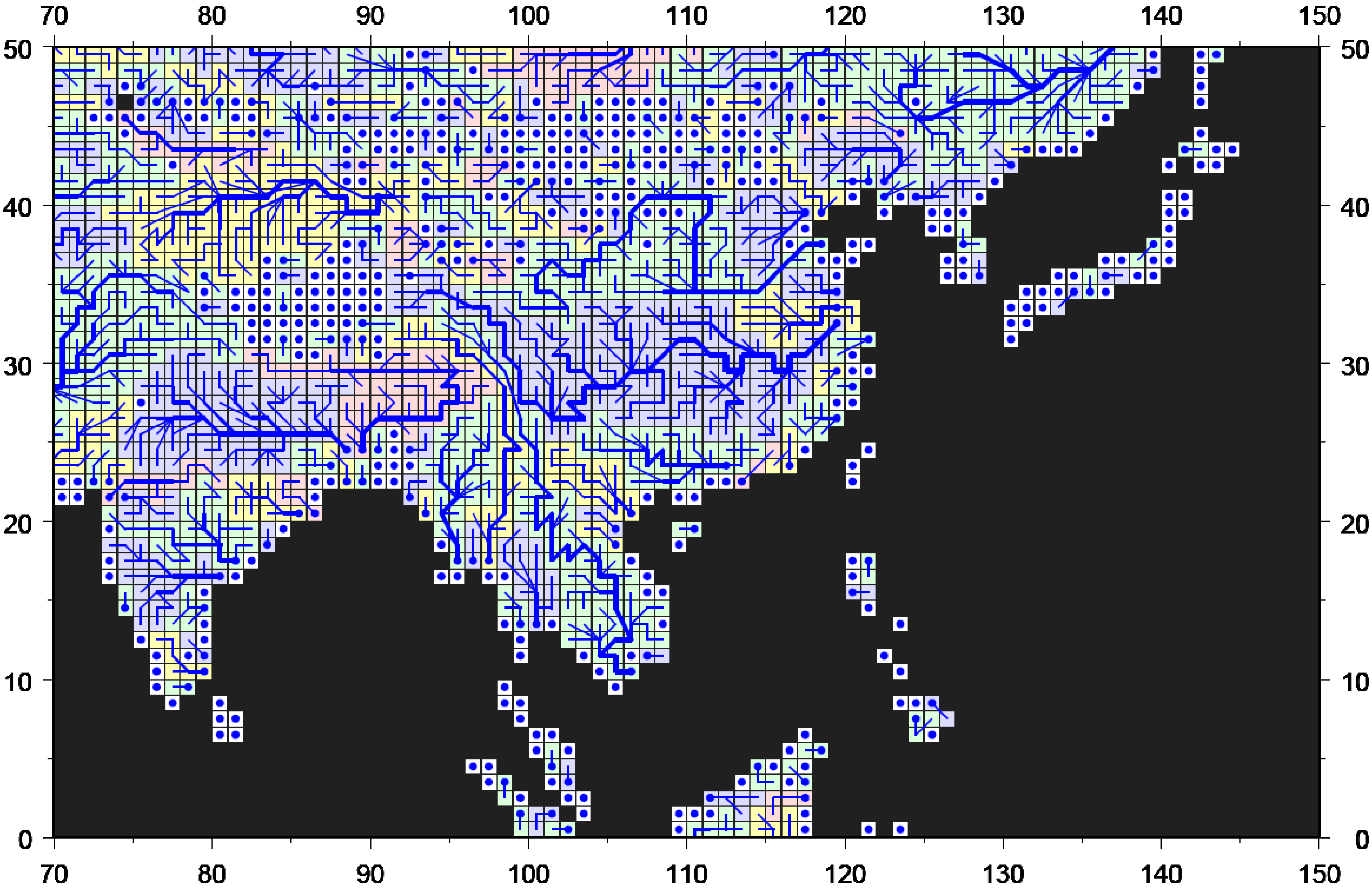

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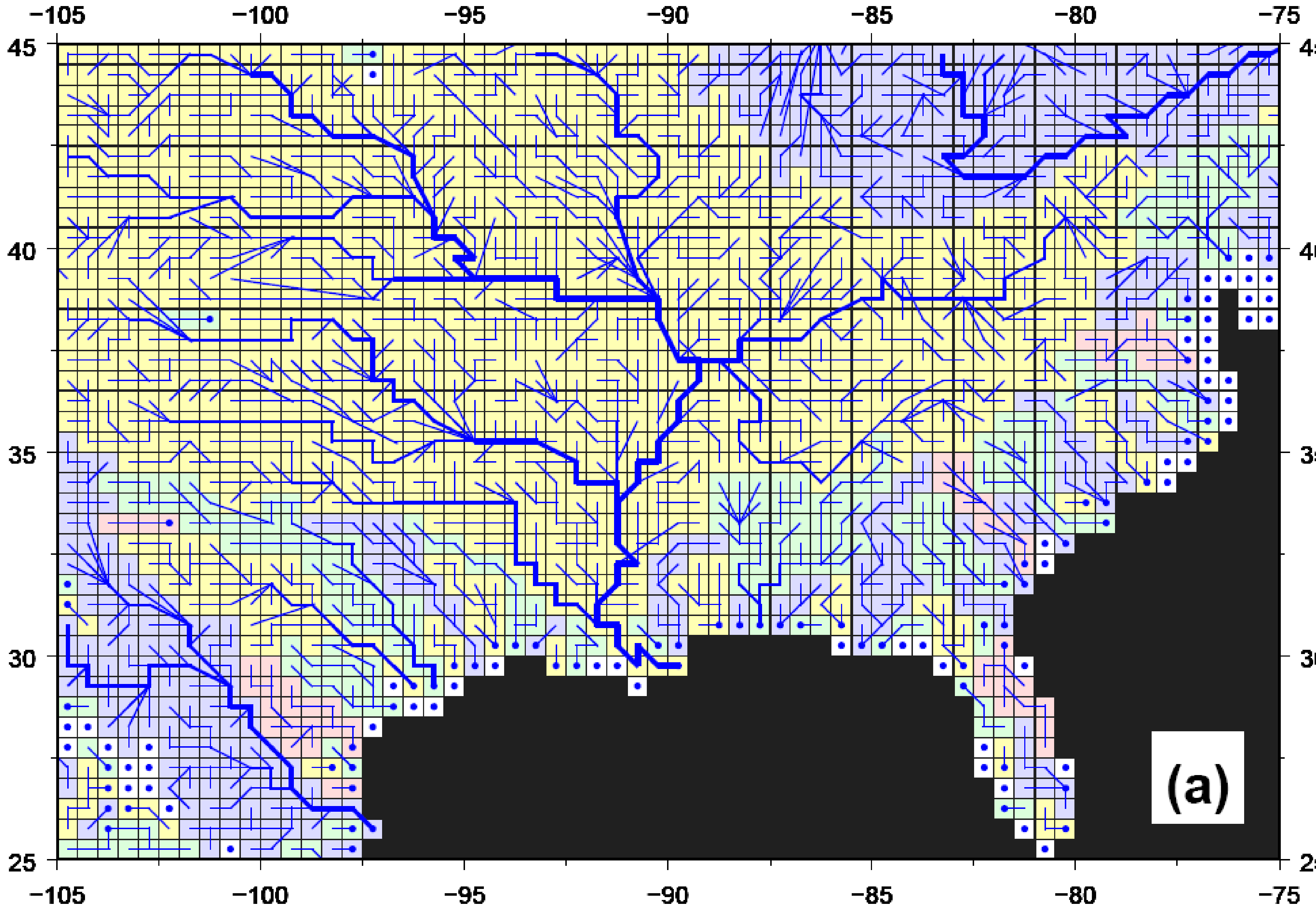
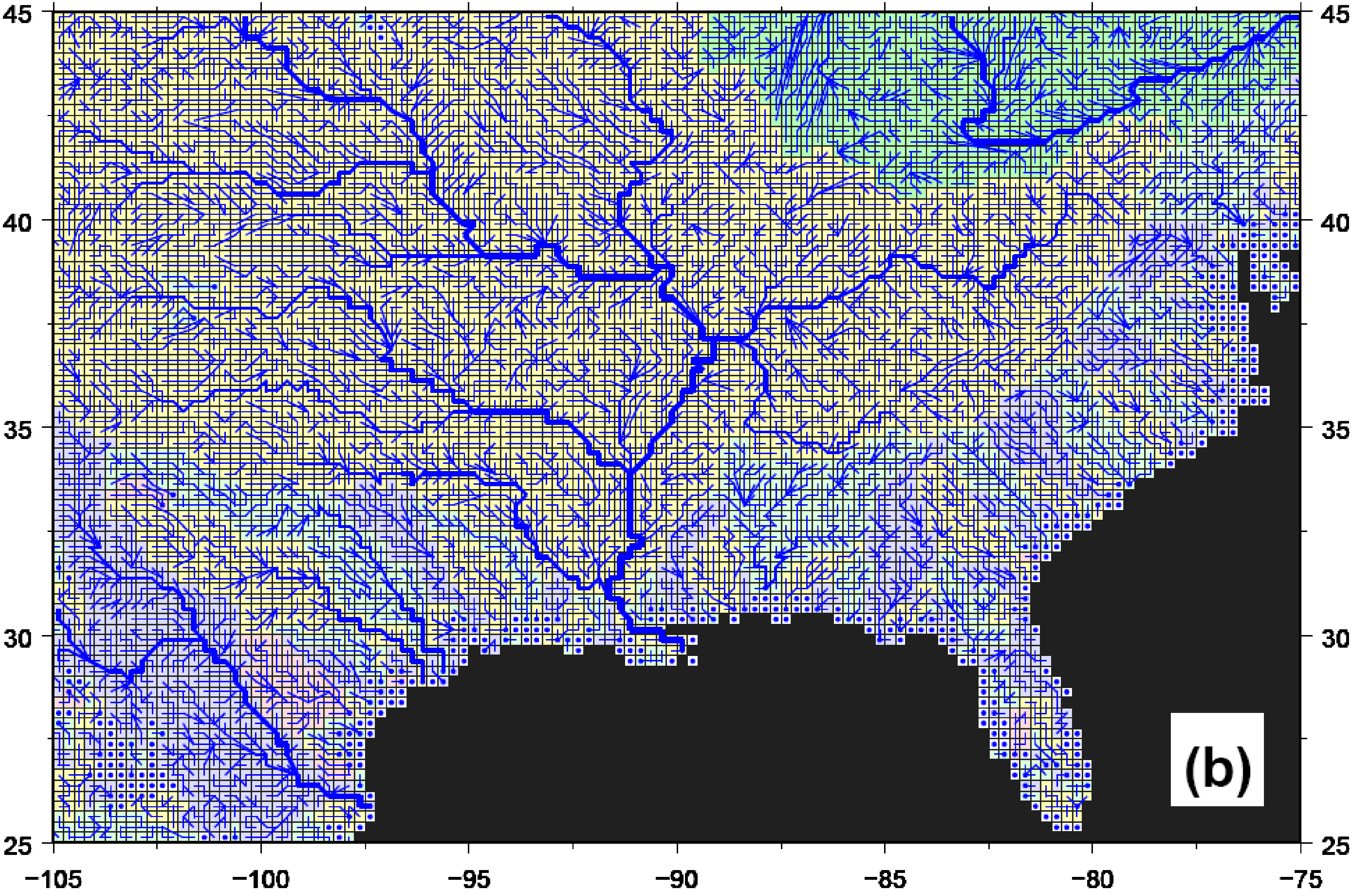
80
90
100
110
120
130
140
150
50
40
30
20
10
0



−105
−100
−95
−90
−85
−80
−75
45
40
35
30
25
(a)



45
40
35
30
25
−105
−100
−95
−90
−85
−80
−75
(b)

全球提取的流域信息(100km²阈值)

ID	Longitude	Latitude	Area	FlowD	FlowA	topindex	Slope	Length	Elevation
1	100.11	36.90	105.11	0	30380.325	3.83	0.001	3.36	3195.07
2	93.03	38.64	223.77	0	946695.826	7.92	0.003	27.3	2741.45
3	116.21	47.65	9.38	0	643019.998	7.99	0.004	2.37	622.13
4	116.82	45.47	3.21	0	3.209	3.74	0.037	0.8	906.2
5	108.55	45.27	0.64	0	0.643	5.31	0.004	0.8	1123
6	103.84	44.41	52.63	0	184387.549	7.23	0.013	18.99	1083.52
7	93.39	48.76	79.62	0	242112.344	7.21	0.005	15.17	1045.73
8	92.72	50.30	146.6	0	82089.975	4.12	0.004	3.89	773.22
9	105.82	42.01	158.27	0	378522.352	7.69	0.004	39	956.75
10	99.48	43.30	343.55	0	125114.853	5.46	0.022	55.12	917.58
… … … … … … … … … … … … … … … …									
571084	-74.32	-14.26	210.29	571075	210.289	4.56	0.04	13.08	4226.75
571085	-74.47	-14.22	125.19	571075	125.191	4.31	0.045	4.57	4168.61
571086	-74.84	-13.30	330.93	571079	330.934	3.19	0.119	22.63	4558.09
571087	-74.95	-13.35	209.41	571079	735.664	3.36	0.118	27.43	4353.76
571088	-74.92	-13.69	109.58	571081	109.577	3.79	0.065	4.95	4138.29
571089	-75.00	-13.63	121.32	571081	121.319	3.57	0.079	6.25	4209.42
571090	-74.97	-13.22	167.62	571087	167.615	3.26	0.099	11.96	4607.45
571091	-75.07	-13.21	243.89	571087	243.887	3.87	0.064	14.93	4638.62
571092	-75.07	-13.36	114.75	571087	114.753	3.99	0.052	3.5	4587.97

2、大尺度运动波流域汇流

大尺度运动波流域汇流

模块介绍

节点内汇流计算采用运动波汇流模型。

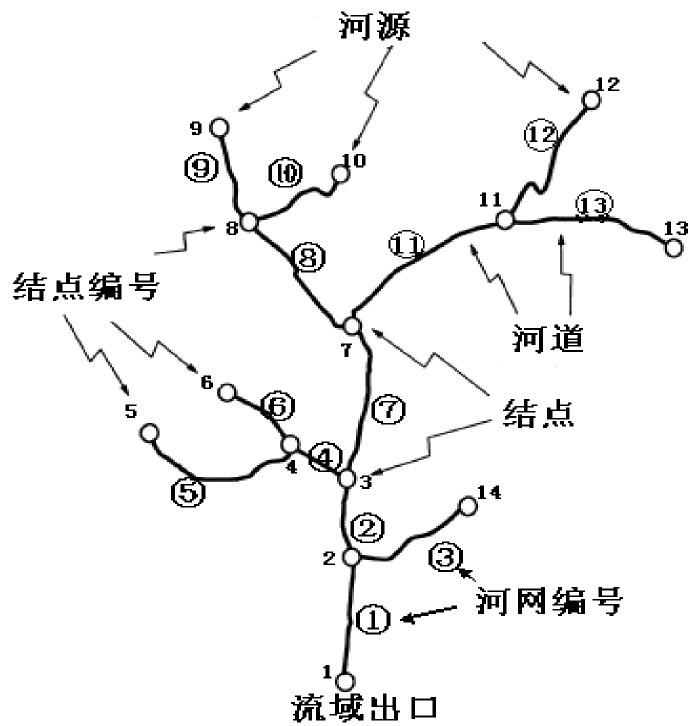
运动波模型是最简单的一类分布式水流验算模型。采用了Saint－Venant方程组的质量守恒方程与简化的动量方程。

1、给每个节点进行编号。

2、从河源向流域出口逐步计算单节点流量。

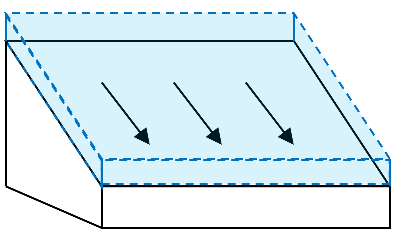
3、每个节点的出流既是起流入节点的入流。

4、流域出口节点的流量既是整个流域的流量。

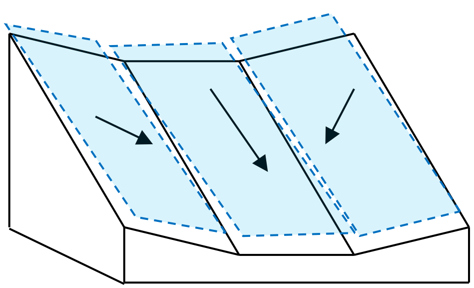


$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=q$$

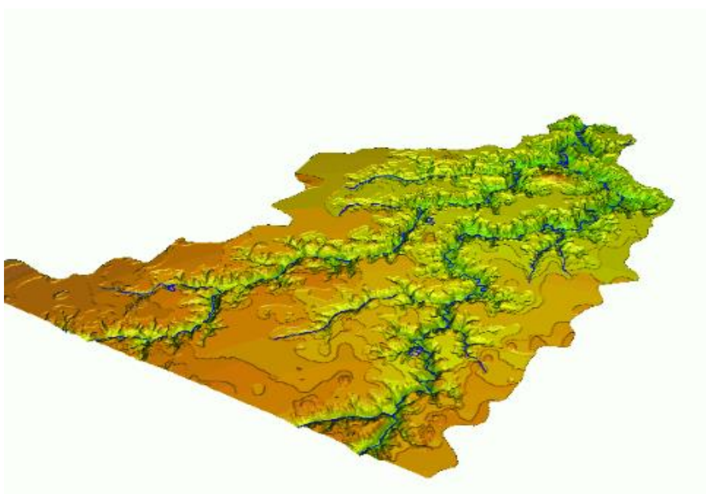
$$S_f - S_0 = 0$$



坡面



河道



大尺度运动波流域汇流

模块介绍

模型特点：

1、采用曼宁公式计算流速，考虑了不同时间不同子流域的坡度及水力半径，流速不再是常数。

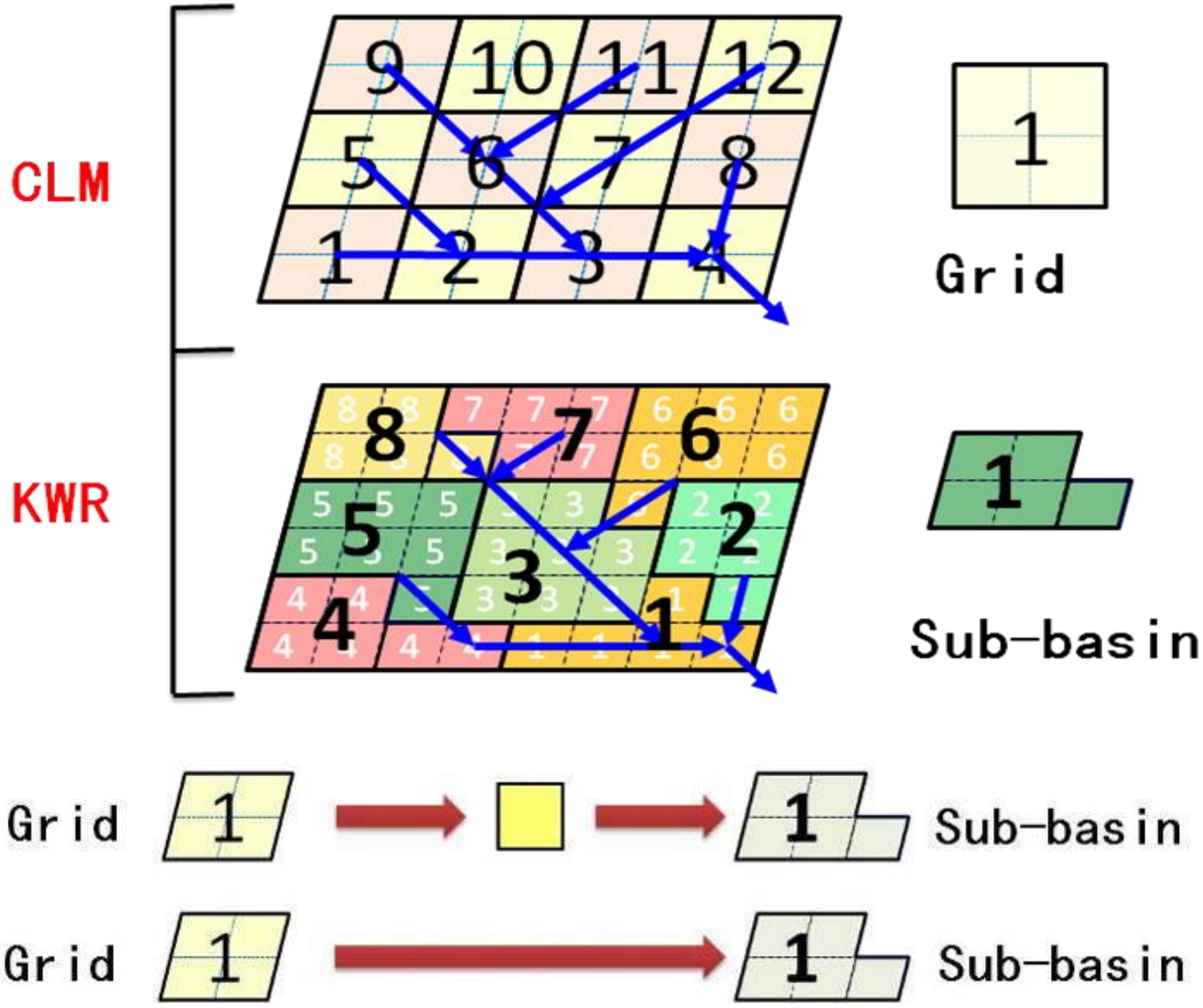
2、考虑时空变异的参数化方案，首先坡度汇流，然后通过牛顿迭代进行河道汇流。

3、是一独立模块，可以离线、在线运行。

4、基于流域建模，符合水文规律。

5、解决了网格与流域尺度转换问题。

Mapping CLM grids to sub-basins used by KWR



节点内汇流计算

$$h=\frac{A}{w} \qquad v=\frac{1}{n}\cdot h^{\frac{2}{3}}S_0^{\frac{1}{2}} \qquad Q=A\cdot v$$

坡面： $w=\Delta x$

$$\alpha=\frac{1}{n}\Delta x^{-\frac{2}{3}}S_0^{\frac{1}{2}}$$

$$Q=A\cdot v=A\cdot\frac{1}{n}h^{\frac{2}{3}}S_0^{\frac{1}{2}}=A\cdot\frac{1}{n}(\frac{A}{\Delta x})^{\frac{2}{3}}S_0^{\frac{1}{2}}=\frac{1}{n}\Delta x^{-\frac{2}{3}}S_0^{\frac{1}{2}}A^{\frac{5}{3}}=\alpha\cdot A^{\beta}$$

$$\beta=\frac{5}{3}$$

河道： $w=ah$

$$h=\frac{A}{w}=\frac{A}{ah} \rightarrow h=(\frac{A}{a})^{\frac{1}{2}}$$

$$\alpha=\frac{1}{n}a^{-\frac{1}{3}}S_0^{\frac{1}{2}}$$

$$Q=A\cdot v=A\cdot\frac{1}{n}h^{\frac{2}{3}}S_0^{\frac{1}{2}}=A\cdot\frac{1}{n}(\frac{A}{a})^{\frac{1}{3}}S_0^{\frac{1}{2}}=\frac{1}{n}a^{-\frac{1}{3}}S_0^{\frac{1}{2}}A^{\frac{4}{3}}=\alpha\cdot A^{\beta}$$

$$\beta=\frac{4}{3}$$

节点内汇流计算

采用差分求解Saint－Venant方程组。

$$Q_O = \alpha \cdot (\frac{A_t + A_{t-1}}{2})^{\beta}$$

$$\frac{\Delta A}{\Delta t} + \frac{\Delta Q}{\Delta l} = q \quad \Rightarrow \quad \Delta A \Delta l + \Delta Q \Delta t = q \Delta l \Delta t$$

$$\Delta A = A_t - A_{t-1} \qquad \Delta Q = Q_O - Q_I$$

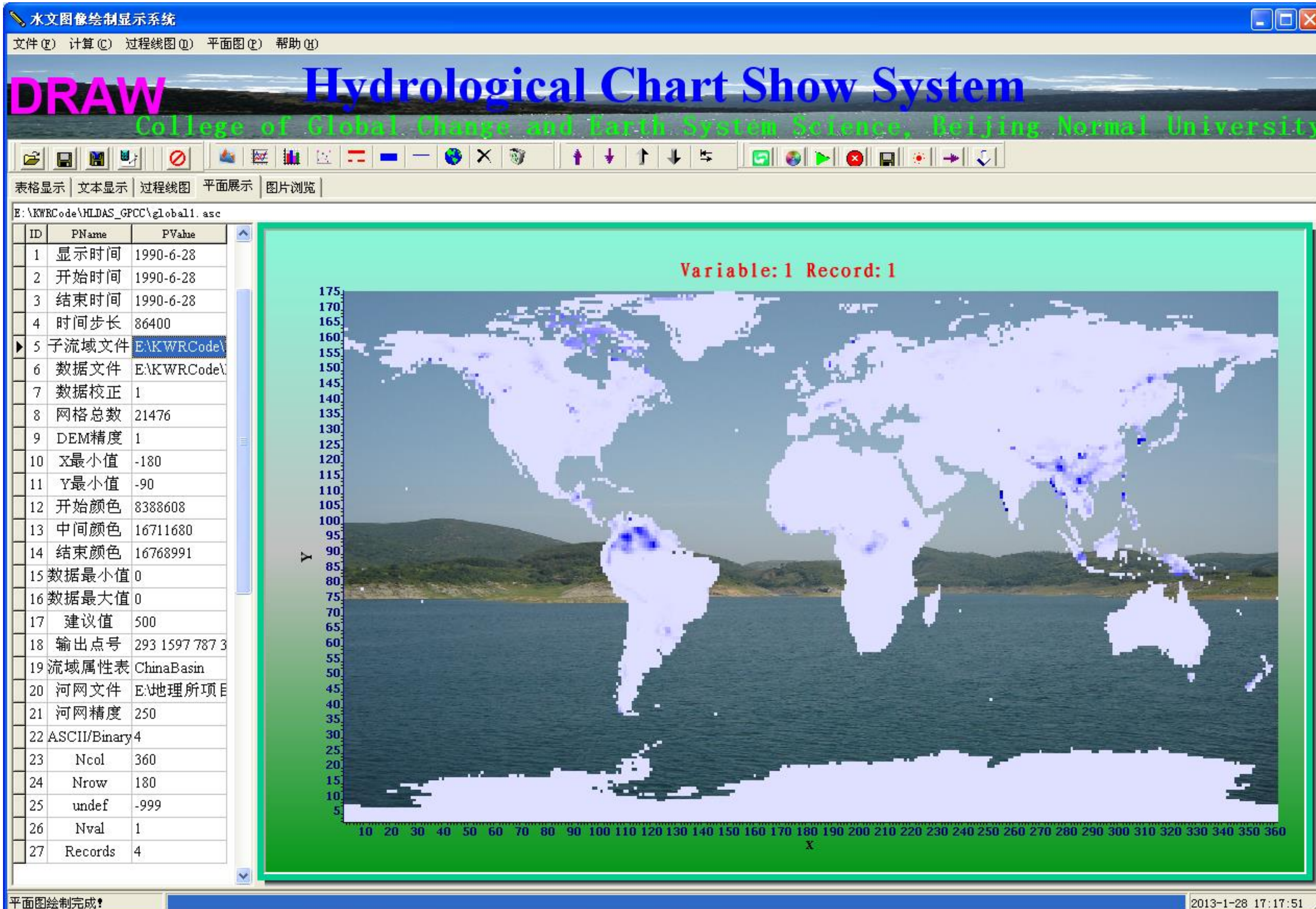
$$(A_t - A_{t-1}) = (Q_I - \alpha \cdot (\frac{A_t + A_{t-1}}{2})^{\beta}) \frac{\Delta t}{\Delta l} + R \cdot \frac{Area}{\Delta l}$$

$$f(A_t) = (Q_I - \alpha \cdot (\frac{A_t + A_{t-1}}{2})^{\beta}) \frac{\Delta t}{\Delta l} + R \cdot \frac{Area}{\Delta l} - A_t + A_{t-1}$$

$$f'(A_t) = -\frac{\alpha\beta}{2} \cdot (\frac{A_t + A_{t-1}}{2})^{\beta-1} \frac{\Delta t}{\Delta l} - 1$$

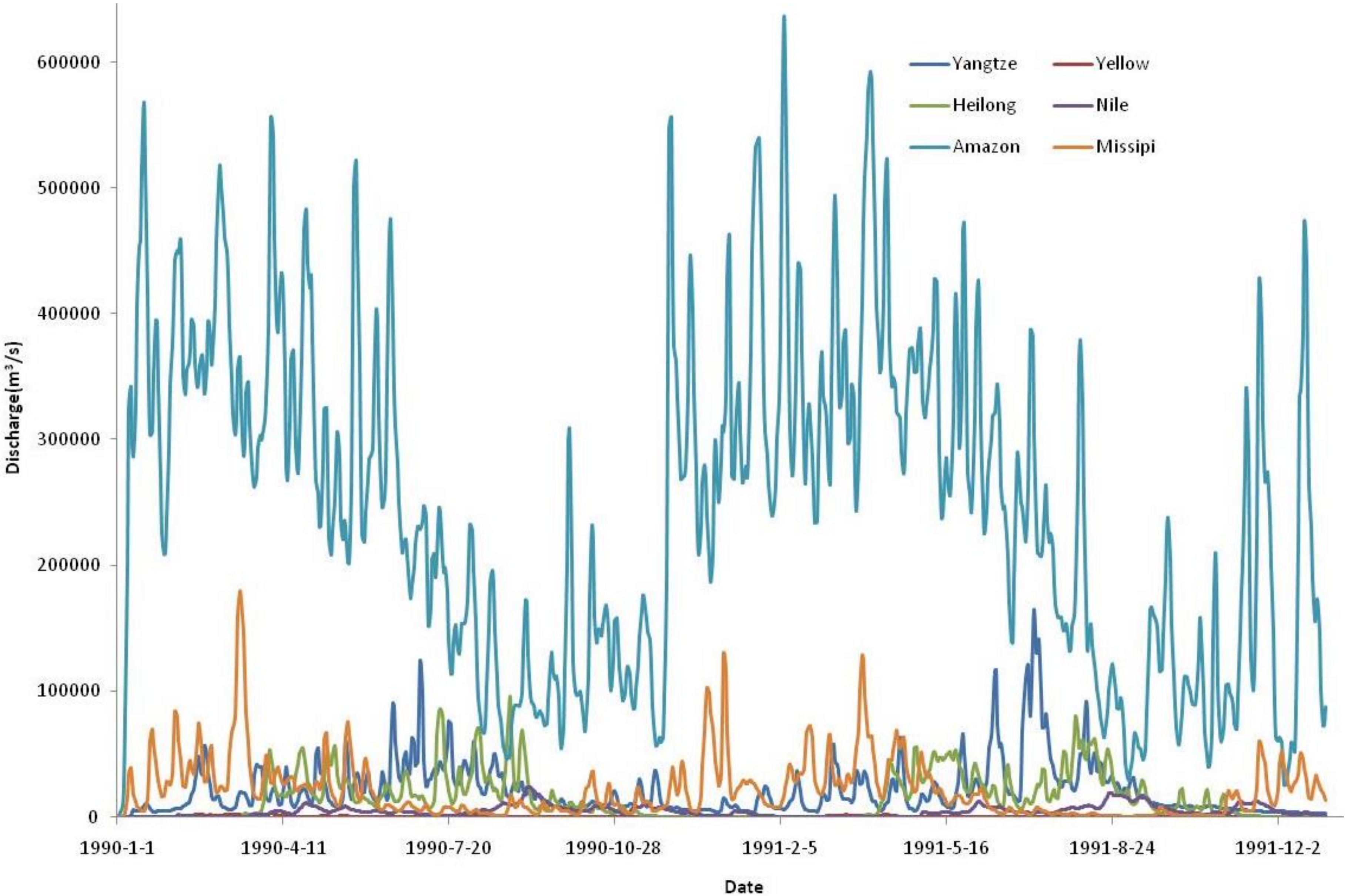
$$A_t^{(k)} = A_t^{(k-1)} - \frac{f(A_t^{(k-1)})}{f'(A_t^{(k-1)})}$$

全球1度分辨率径流



水文图像绘制显示系统
文件(F) 计算(C) 过程线图(D) 平面图(P) 帮助(H)
DRAW
Hydrological Chart Show System
College of Global Change and Earth System Science, Beijing Normal University
表格显示 文本显示 过程线图 平面展示 图片浏览
E:\KWRCode\HLDAS_GPCC\global1.asc
ID PName PValue
1 显示时间 1990-6-28
2 开始时间 1990-6-28
3 结束时间 1990-6-28
4 时间步长 86400
5 子流域文件 E:\KWRCode\
6 数据文件 E:\KWRCode\
7 数据校正 1
8 网格总数 21476
9 DEM精度 1
10 X最小值 -180
11 Y最小值 -90
12 开始颜色 8388608
13 中间颜色 16711680
14 结束颜色 16768991
15 数据最小值 0
16 数据最大值 0
17 建议值 500
18 输出点号 293 1597 787 3
19 流域属性表 ChinaBasin
20 河网文件 E:\地理所项目
21 河网精度 250
22 ASCII/Binary 4
23 Ncol 360
24 Nrow 180
25 undef -999
26 Nval 1
27 Records 4
Variable: 1 Record: 1
Y
X
平面图绘制完成!
2013-1-28 17:17:51

全球汇流结果（流量过程）



Yangtze
Yellow
Heilong
Nile
Amazon
Missipi
600000
500000
400000
300000
200000
100000
0
Discharge(m³/s)
1990-1-1
1990-4-11
1990-7-20
1990-10-28
1991-2-5
1991-5-16
1991-8-24
1991-12-2
Date

大尺度运动波流域汇流

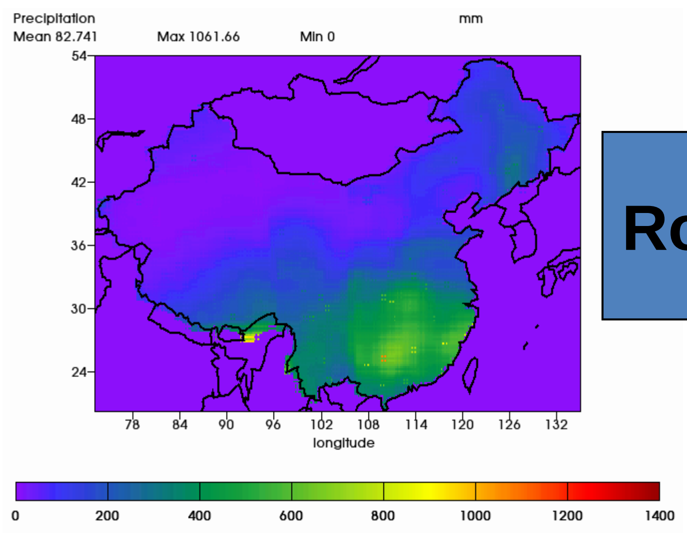
Input:

Runoff(mm)

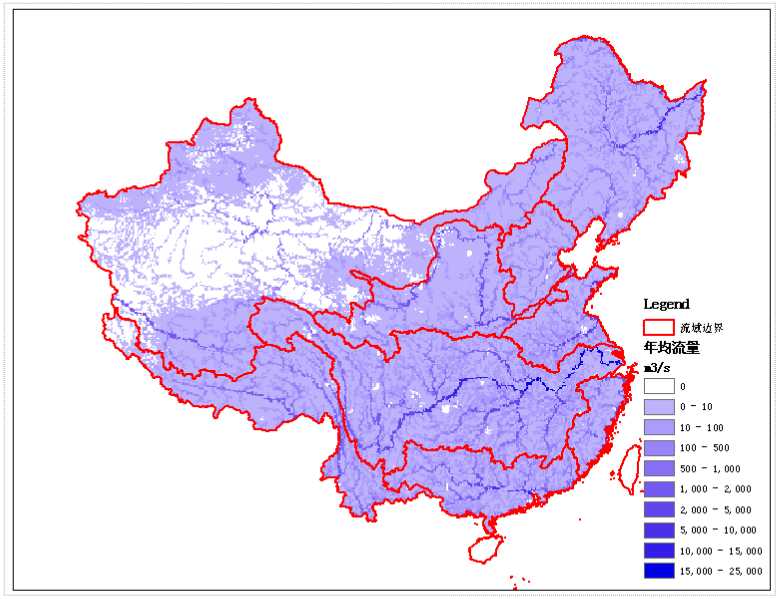
Routing

Output:

Discharge in everywhere (m^3/s)

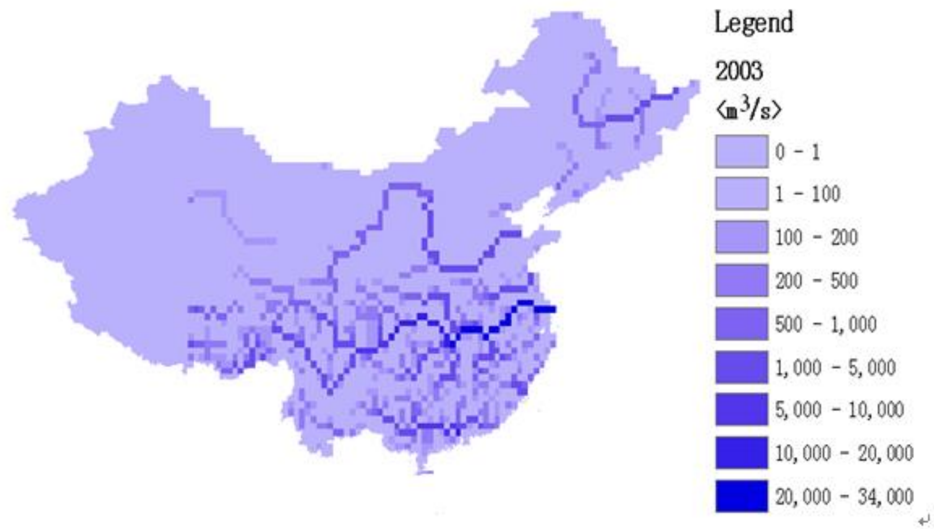


Routing



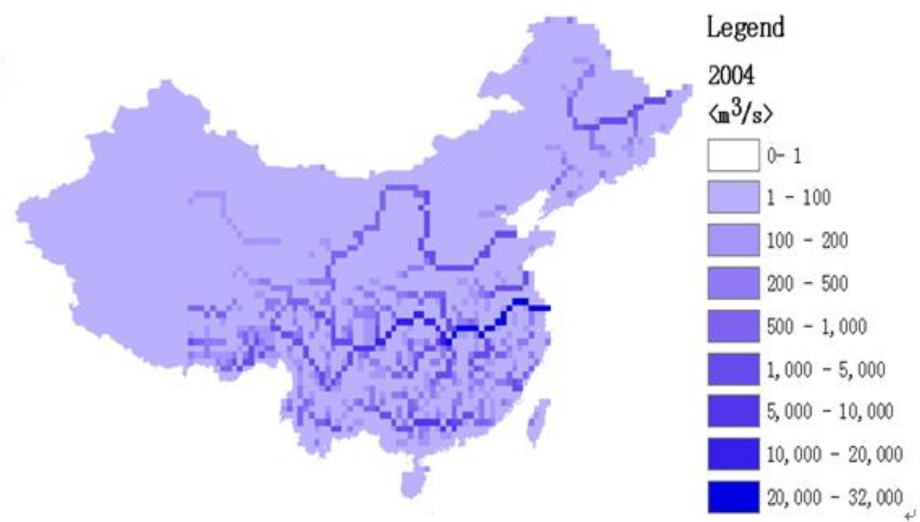
Simulated annual discharge by KWR and RTM in 2003 and 2004

(a) Discharge in 2003 by KWR



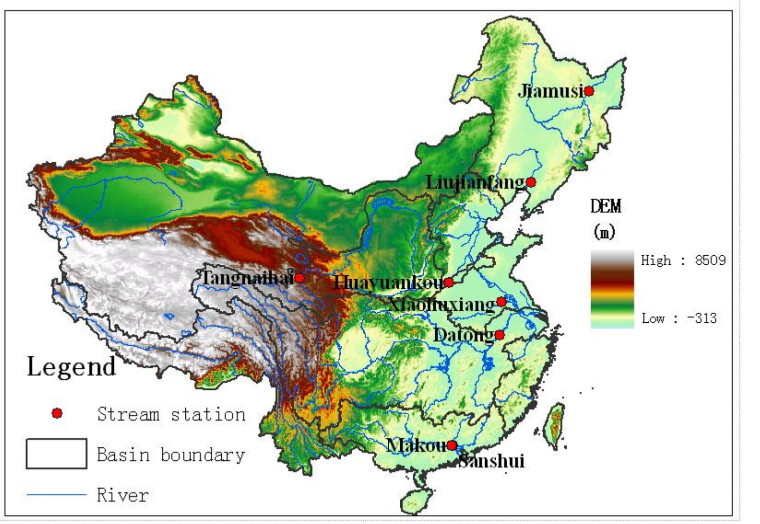
(b) Discharge in 2003 by RTM

(c) Discharge in 2004 by KWR



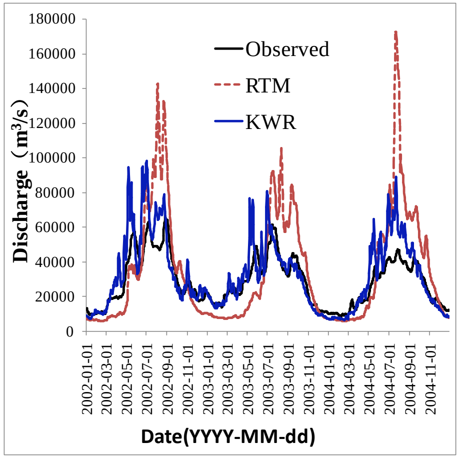
(d) Discharge in 2004 by RTM

Stream flow stations attributes

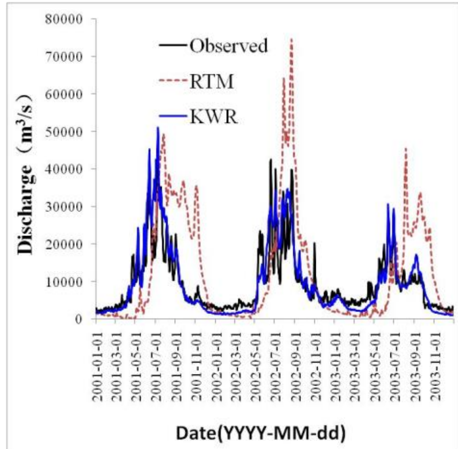


Station	Basin	Sub-basin NO.	Accumulative upslope Area	Longitude	Latitude	Observed streamflow
Datong	Yangze River	291	1703156	117.61	30.78	2002-2004
Sanshui+ Makou	Pear River	18215	392721	112.83	23.17	2001-2203
Jiamusi	Songhuajiang River	14157	527971	100.15	35.50	1995-1998
Liujianfang	LiaoHe River	13868	144960	122.53	41.29	1996-2004
Xiaoliuxiang	Huaihe River	11270	132768	118.13	33.17	2001-2004
Tangnaihai	Yellow River	10068	123387	130.37	46.82	1995-1997
Huayuankou	Yellow River	7379	776190	113.67	34.91	1997-1999

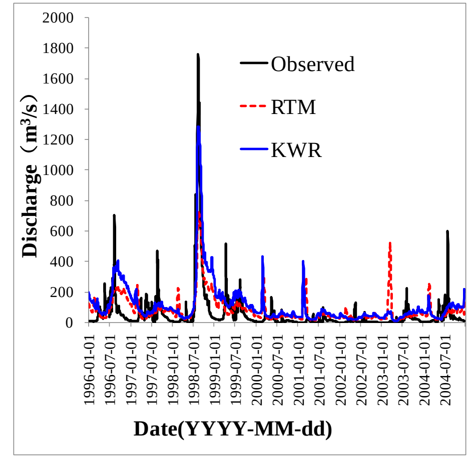
Observed and simulated discharge time series by KWR and RTM



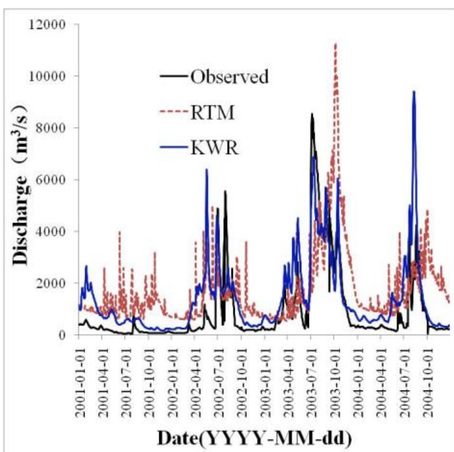
(a) Datong Station



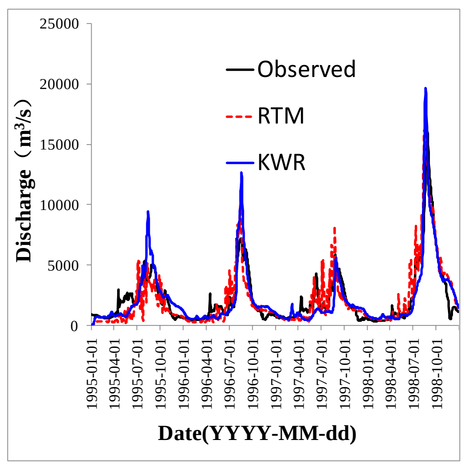
(b) Sanshui+Makou Station



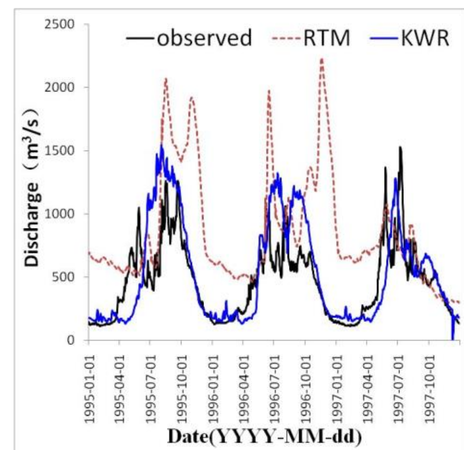
(c) Liujianfang Station



d) Xiaoliuxiang Station



(e) Jiamusi Station



(f) Tangnaihai Station

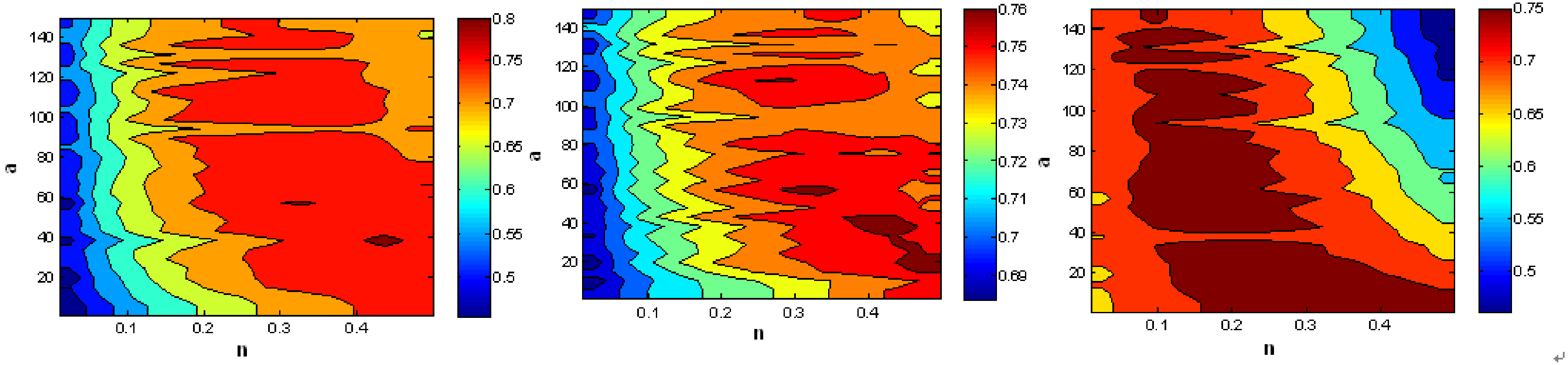
Simulated discharge and Observed discharge Comparison Statistics over the Gauge Stations

Station	Basin	Utilization of water resources（%）	*E*		*R*		*B*	
			KWR	RTM	KWR	RTM	KWR	RTM
Datong	Yangze River	17.193	0. 79	-1.95	0. 95	0.79	1.07	1.24
Sanshui+Makou	Pear River	18.619	0.73	-1.46	0.91	0.56	1.02	1.34
Jiamusi	Songhuajiang River	44.274	0.76	0.75	0.90	0.89	1.00	0.97
Liujianfang	LiaoHe River	44.274	0.44	0.41	0.79	0.67	1.95	1.45
Xiaoliuxiang	Huaihe River	44.746	0.44	-0.20	0.78	0.54	1.56	1.87
Tangnaihai	Yellow River	69.167	0.11	-2.91	0.74	0.40	1.15	1.85
Huayuankou	Yellow River	69.167	-1.67	-0.34	0.36	0.19	1.67	0.92

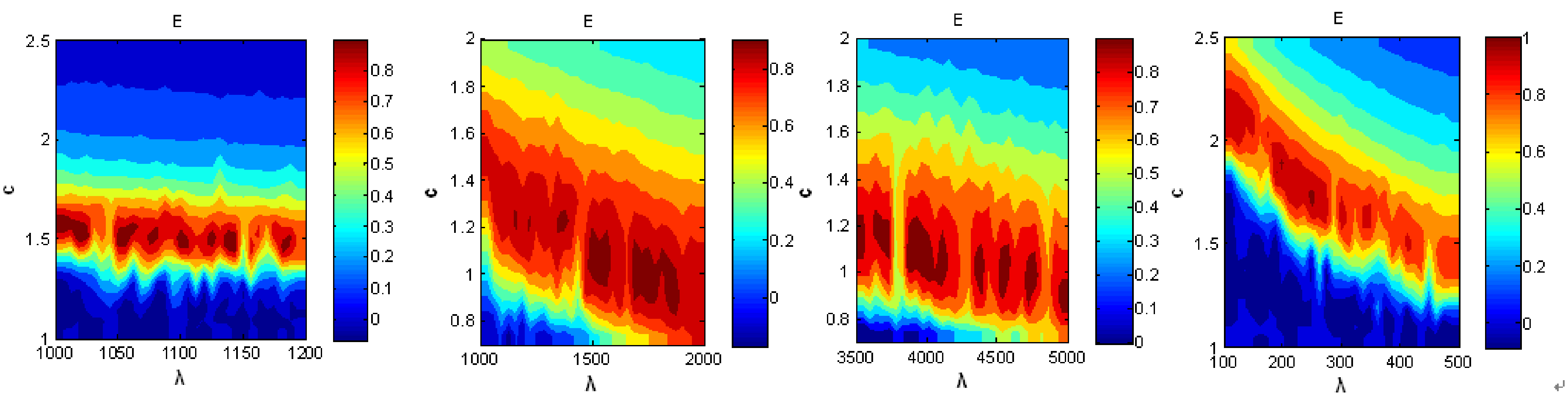
Parameters of stage- discharge rating curves and KWR

Basin	Parameter	Optimal value	Sampling Range	Samples
Yangtze	λ	1033	1000-1200	756 (E>0.9)
	c	1.5	1-2.5	
	b	0		
	n	0.3	0.01-0.5	1000
	a	110	1-150	
Pearl (Sanshui/Makou)	λ	1500/4058	1000-2000/3500-5000	1437/1759 (E>0.9)
	c	1.1/1.1	0.7-2/0.7-2	
	b	0.11/0.45		
	n	0.3	0.01-0.5	1000
	a	110	1-150	
Songhuajiang	λ	161	100-500	1044 (E>0.9)
	c	1.9	1-2	
	b	71		
	n	0.15	0.01-0.5	1000
	a	60	1-150	

Response surfaces of KWR model parameters (*n* and *a*) and the rating curve parameters (*λ* and *c*)

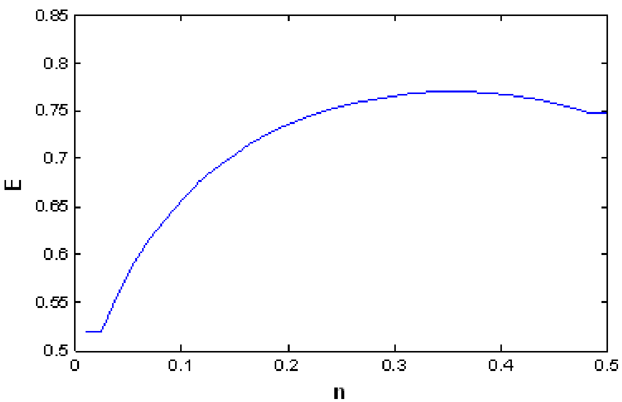


(a) Yangtze (*n*, *a*) (b) Pearl (*n*, *a*) (c) Songhuajiang (*n*, *a*)

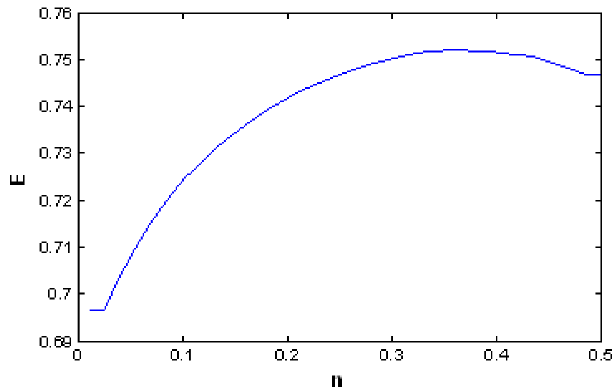


d) Yangtze (*λ* , *c*) (e) Pearl (Sanshui & Makou) (*λ* , *c*) (f) Songhuajiang (*λ* , *c*)

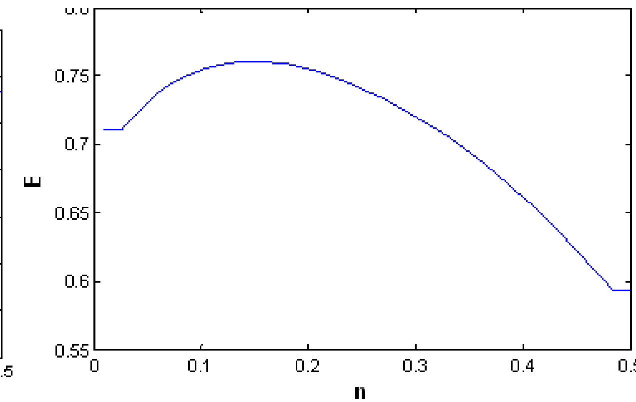
The NSE values projected on to the axes of parameters



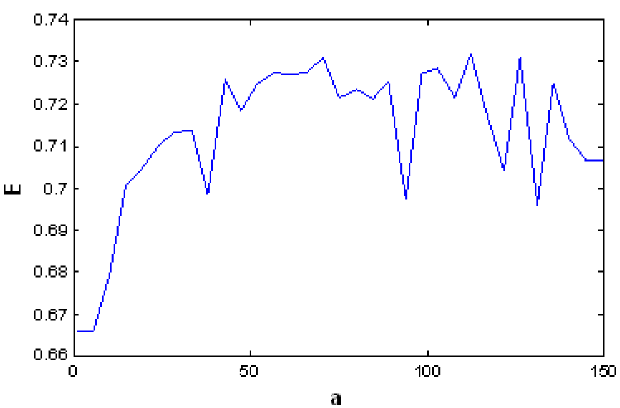
(a) Yangtze (n)



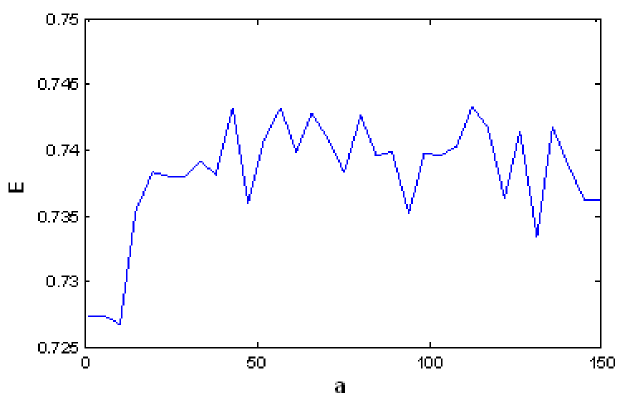
(b) Pearl (n)



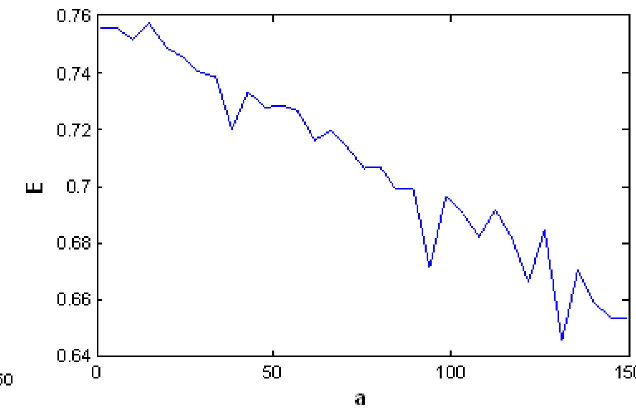
(c) Songhuajiang (n)



(d) Yangtze (a)

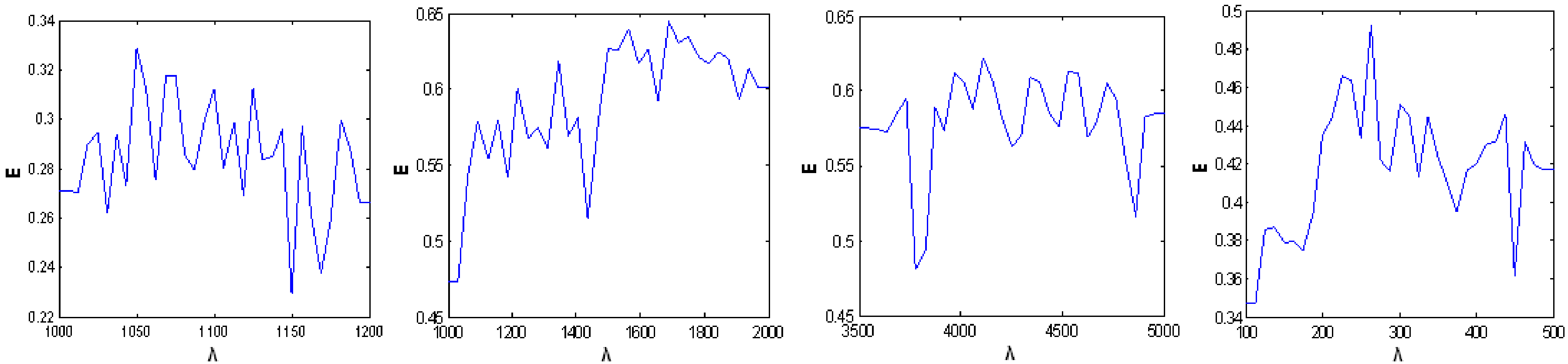


(e) Pearl (a)

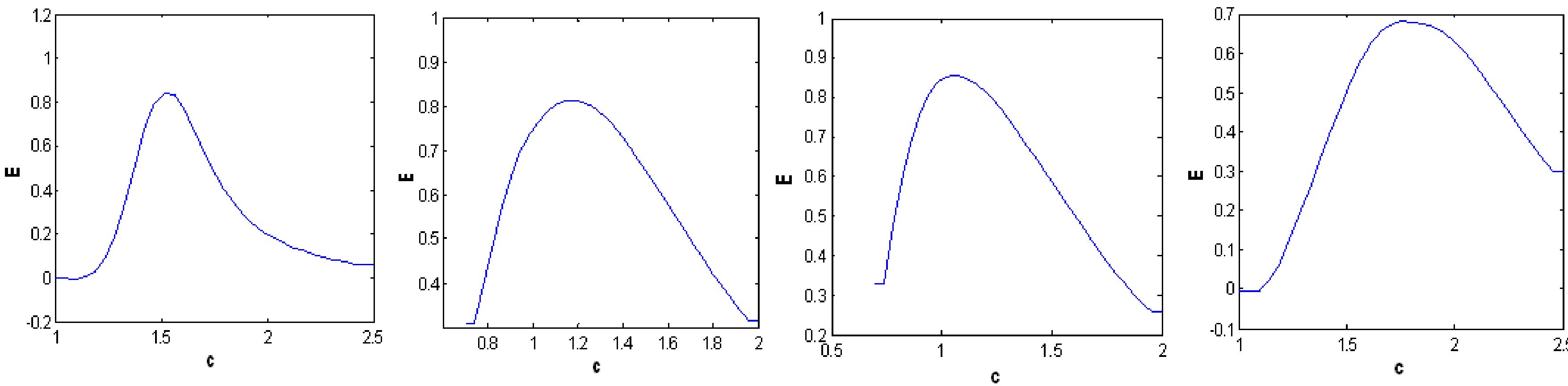


(f) Songhuajiang (a)

The NSE values projected on to the axes of parameters

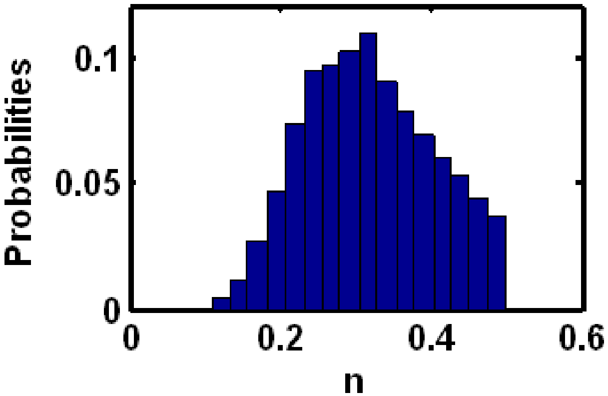


(g) Yangtze (λ) (h) Pearl (Sanshui & Makou) (λ) (i) Songhuajiang (λ)

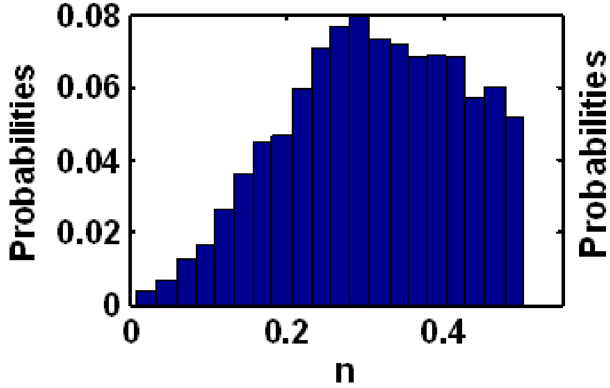


(j) Yangtze (c) (k) Pearl (Sanshui & Makou) (c) (l) Songhuajiang (c)

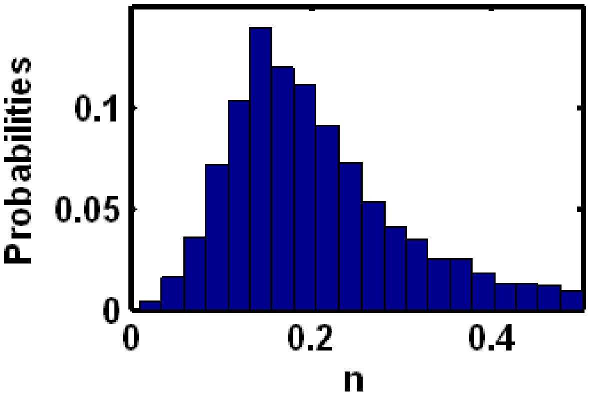
The posterior PDF of parameters



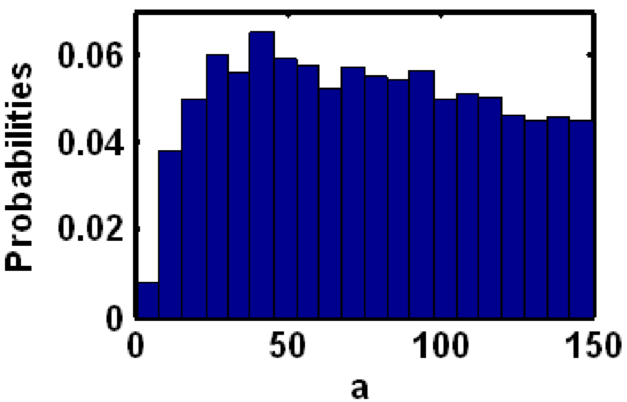
(a) Yangtze (n)



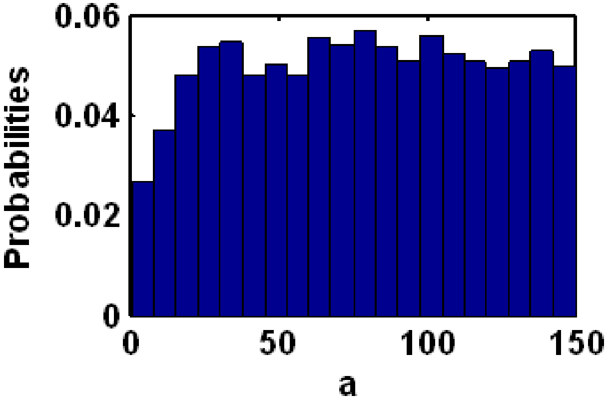
(b) Pearl (n)



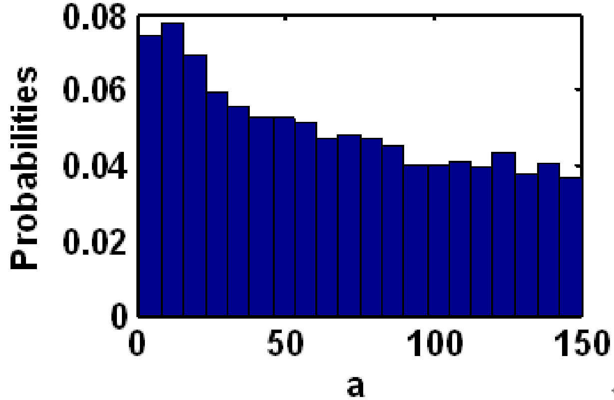
(c) Songhuajiang (n)



(d) Yangtze (a)

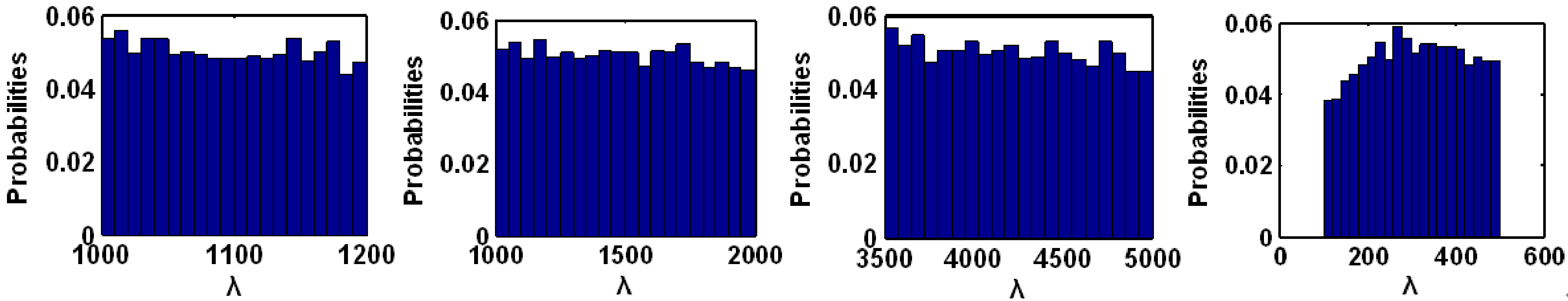


(e) Pearl (a)

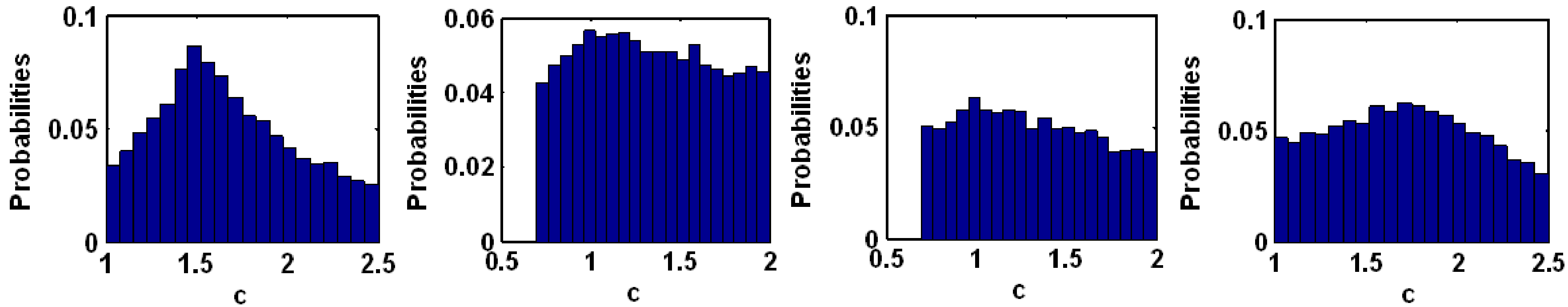


(f) Songhuajiang (a)

The posterior PDF of parameters

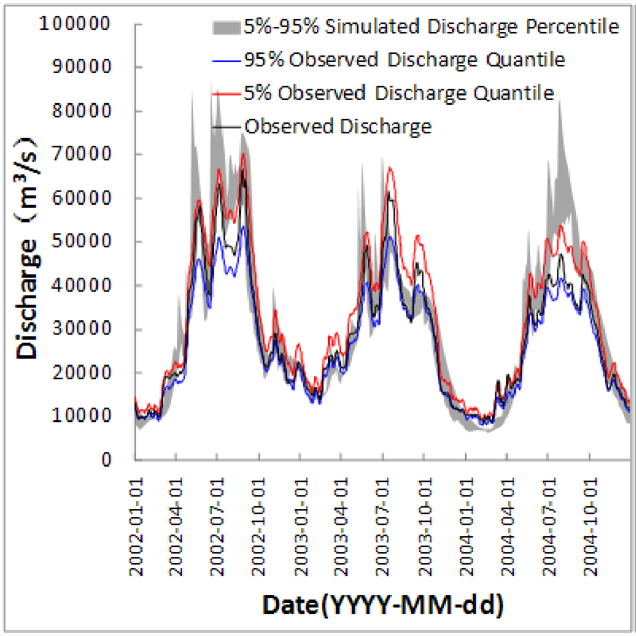


(g) Yangtze (λ) (h) Pearl (Sanshui & Makou) (λ) (i) Songhuajiang (λ)

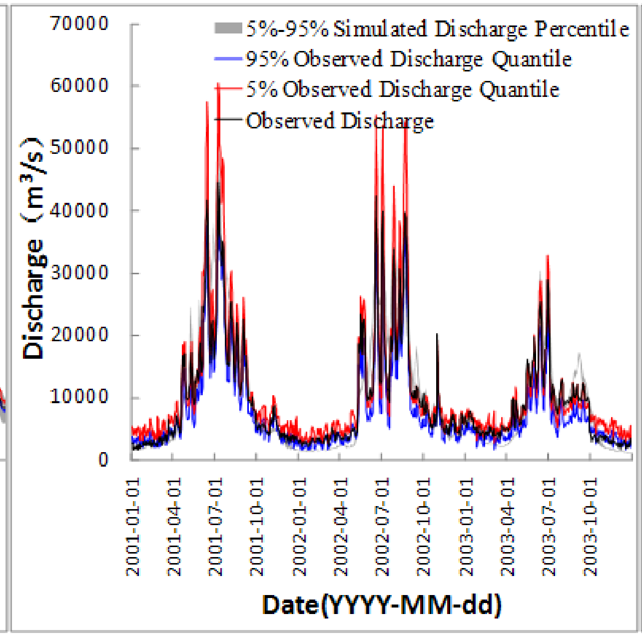


(j) Yangtze (c) (k) Pearl (Sanshui & Makou) (c) (l) Songhuajiang (c)

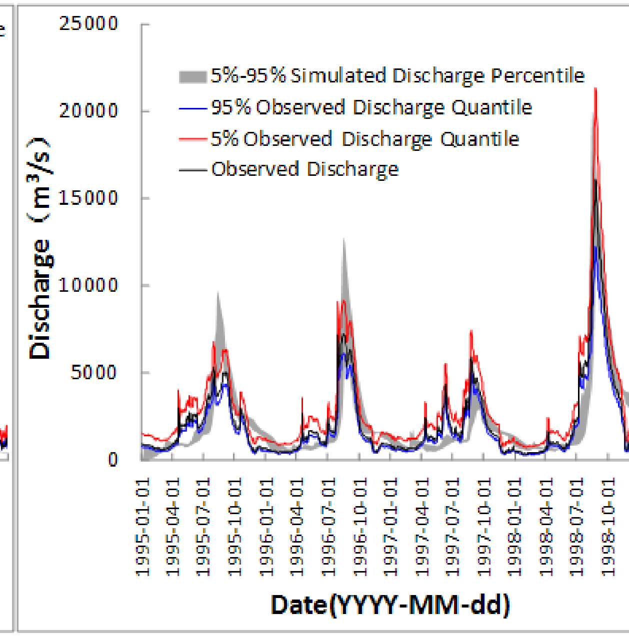
Uncertainty range of observed discharge and simulated discharge



(a) Yangtze River



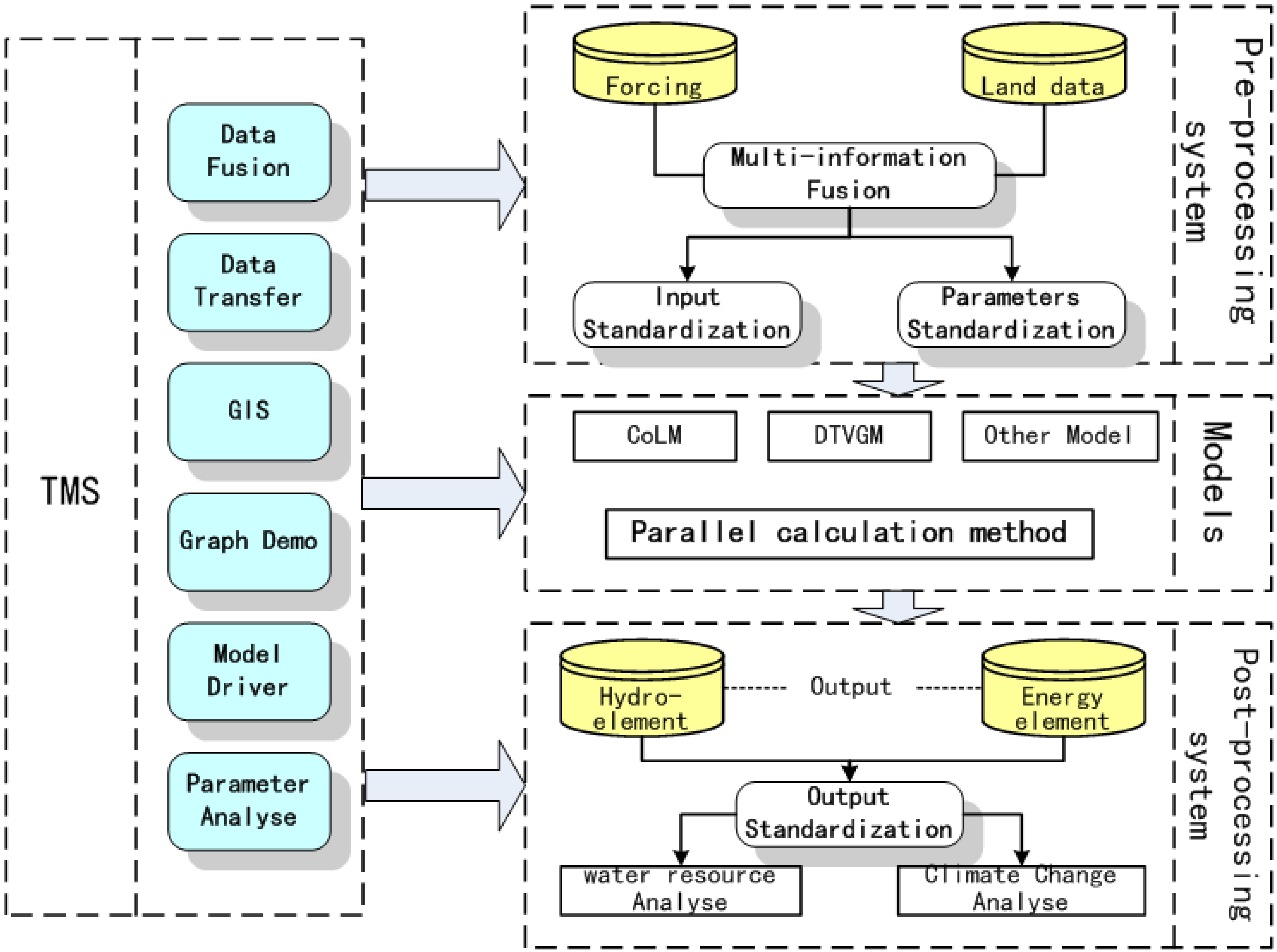
(b) Pearl River

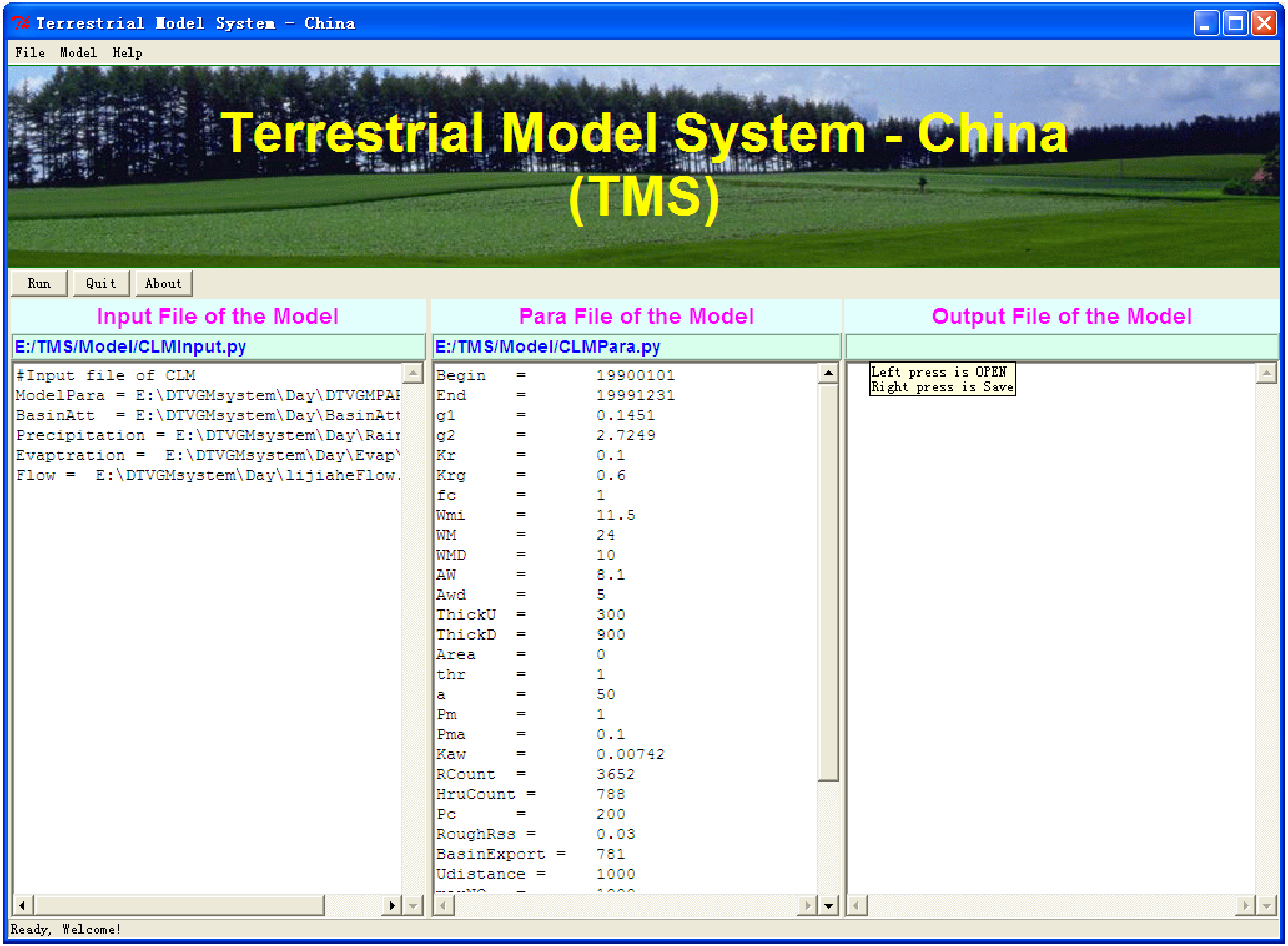


(c) Songhuajiang River

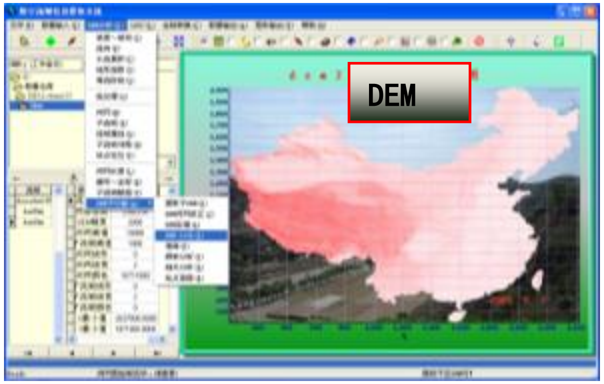
陆面模拟计算平台

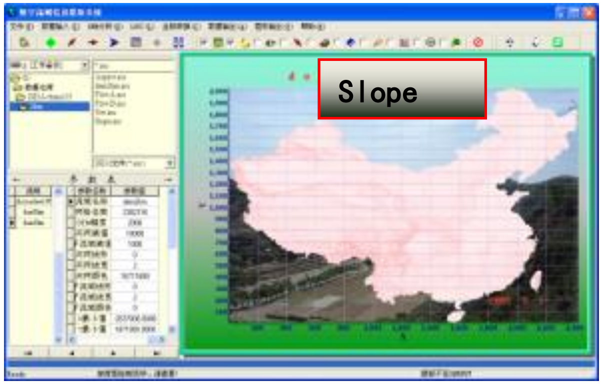
The land simulator platform

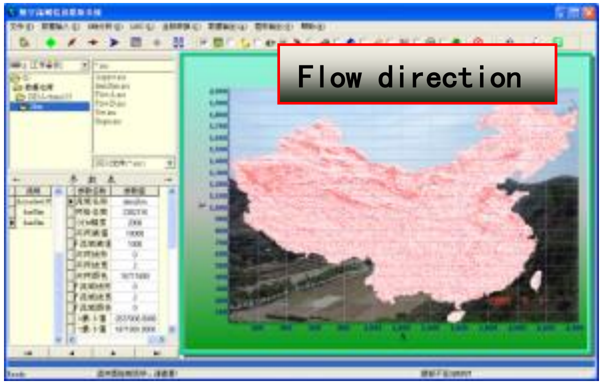


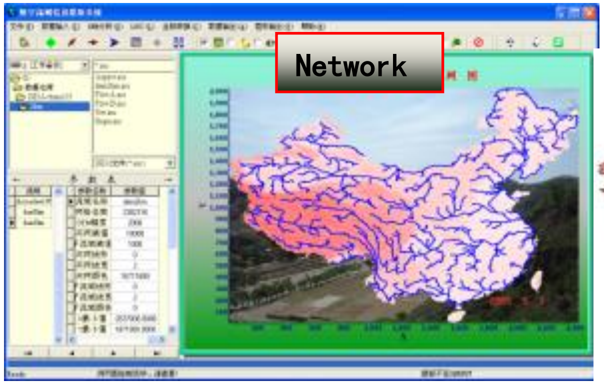

Terrestrial Model System - China
File Model Help
Terrestrial Model System - China
(TMS)
Run
Quit
About
Input File of the Model
Para File of the Model
Output File of the Model
E:/TMS/Model/CLMInput.py
E:/TMS/Model/CLMPara.py
#Input file of CLM
ModelPara = E:\DTVGMsystem\Day\DTVGMPAR
BasinAtt = E:\DTVGMsystem\Day\BasinAtt
Precipitation = E:\DTVGMsystem\Day\Rair
Evaptration = E:\DTVGMsystem\Day\Evap\
Flow = E:\DTVGMsystem\Day\lijiaheFlow.
Begin = 19900101
End = 19991231
g1 = 0.1451
g2 = 2.7249
Kr = 0.1
Krg = 0.6
fc = 1
Wmi = 11.5
WM = 24
WMD = 10
AW = 8.1
Awd = 5
ThickU = 300
ThickD = 900
Area = 0
thr = 1
a = 50
Pm = 1
Pma = 0.1
Kaw = 0.00742
RCount = 3652
HruCount = 788
Pc = 200
RoughRss = 0.03
BasinExport = 781
Udistance = 1000
Left press is OPEN
Right press is Save
Ready, Welcome!

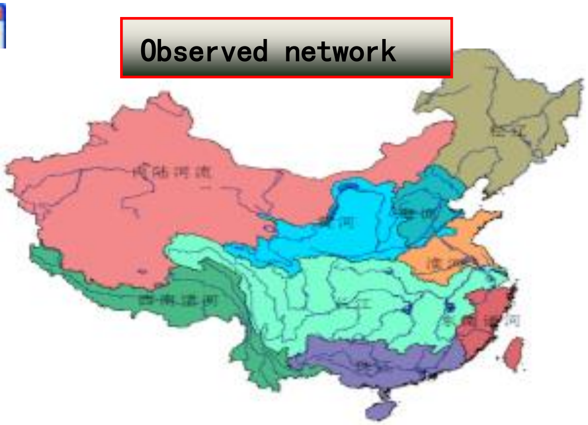
Integrated GIS capability

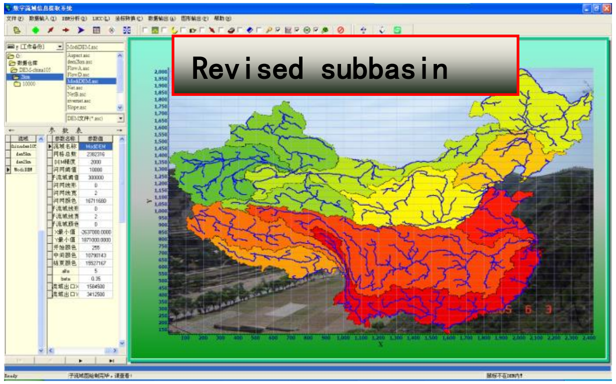




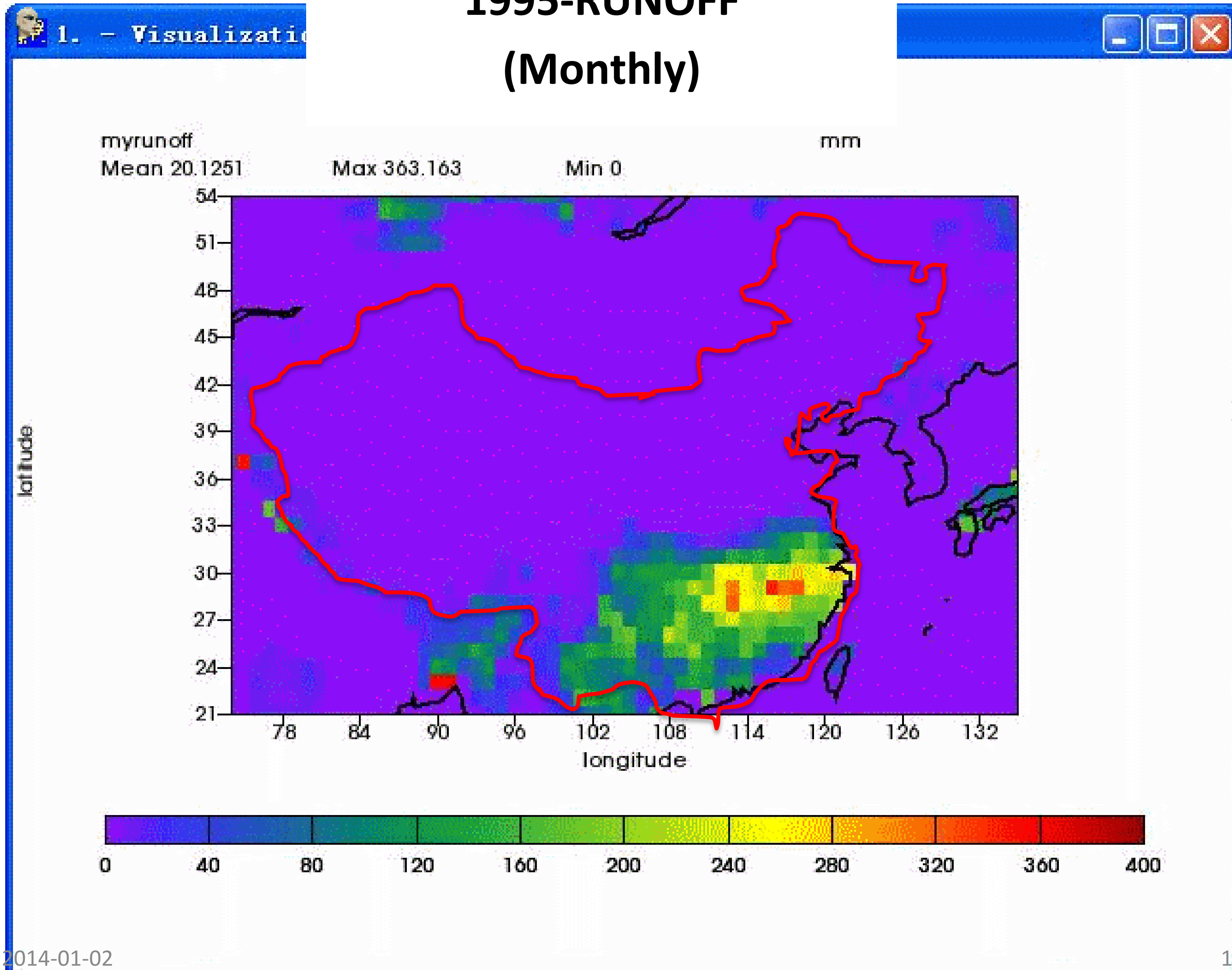








1995-RUNOFF (Monthly)



陆面参数的最优化估计

- （段青云）

陆面数据同化方法

- （郑小谷）

展望(一)：

建立中国陆面再分析资料集

(1950-201x、5km x 5km、3小时)

展望（二）：

建立中国陆面水文-气象-生态预报系统

展望(三)：

建立全球陆面水文-气象-生态预报系统

数据和模式使用情况

http://globalchange.bnu.edu.cn/user/users.jsp


Thank You!