

# R语言在陆面建模系统上的应用研究



### 罗立辉

luolh@lzb.ac.cn

中国科学院寒区旱区环境与工程研究所



中国西北行,出发在兰州



◆ 1 研究背景

◆ 2 陆面建模系统的关键技术

◆ 3 R语言在陆面建模系统上的应用

◆ 4 其它脚本语言集成





# 研究背景 "大气边界层1500m以下到地表以下几十米"





# 研究背景/陆面过程模型

/	陆面过程模型 CIM ISBACH				
模型通用组件	典型的陆面过程模型举例				
系统边界	低层大气,土壤厚度, 土壤质地				
强迫输入	气温、短波和长波辐射,降雨,风速,气压、大气CO2浓度				
初始状态	生物地球化学池(碳、氮和甲烷),植被(PFT,LAI,SAI),				
	土壤温度和湿度				
参数	化学过程速率常量,物理常量,生物参数				
模型结构	流程定义及连接				
模型状态	生物地球化学池(碳、氮和甲烷), 植被(PFT, LAI, SAI),				
	土壤温度和湿度				
模拟输出	生物地球化学通量(潜热、感热、净辐射、地热、 <mark>CO2</mark> 等),				
	模型状态的动态变化				
碳排放->碳交易					
	工业->欧洲				

科技革命->美国



# 研究背景/陆面过程模型

时期	年代	特点	代表模型
第一阶段	70s	无清晰的植被处理;	Bucket <sup>1</sup> ,
		"水箱"水文	MIAMI <sup>2</sup>
			Köppen <sup>3</sup> , Holdridge <sup>3</sup>
第二阶段	80s	"大叶"方法;	BATS <sup>1</sup> , SiB <sup>1</sup> , ISBA <sup>1</sup> , SECHIBA <sup>1</sup>
		多层水文;	CASA <sup>2</sup> , TURC <sup>2</sup> , TEM <sup>2</sup> , BIOME-
		植被功能型的概念;	BGC <sup>2</sup> , CARAIB <sup>2</sup> , SILVAN <sup>2</sup> ,
		植物竞争;	CENTURY <sup>2</sup> , FBM <sup>2</sup>
		卫星遥感数据;	BIOME <sup>3</sup>
第三阶段	90s	植物生理; <mark>碳循环</mark> ;	SiB2 <sup>12</sup> , LSM <sup>12</sup> , MOSES <sup>12</sup>
		植被功能型;次网格;	DEMETER <sup>23</sup> , BIOME2/3 <sup>23</sup> , LPJ <sup>23</sup>
		植被动态;	IBIS <sup>123</sup> , <b>CLM</b> <sup>123</sup> , CoLM <sup>123</sup> ,
		"二叶"方法	ORCHIDEE <sup>123</sup> , JSBACH <sup>123</sup>
陆面过程	模型的发	展阶段。1 物理过程模块; 2	生物地球化学模块; 3 生物地理模块



# 研究背景/陆面建模系统



开展集成的自动的数据处理、模拟分析和可视化等理论与技术手段支撑的有关 陆面建模系统的开发与研究已成为国际地球科学最活跃的研究前沿



### 国内外主要研究进展—地学建模系统

- ◆ 近10年来地球科学建模系统将各种已有的有关地学的(包含陆面过程模型)
   专用软件框架和工具包加以统一、标准化和扩展,从而达到充分共享资源、
   快速构建地学建模应用的目的
- ♦ 目前地学建模系统的主要研究内容包括:
  - 数据管理、交换、转化(前处理)
  - 模型组件各部分的连接、各种软件工具库、脚本库
  - 数据同化或者模型数据融合
  - 模拟输出的数据处理、结果分析与可视化(后处理)
  - 模拟结果的共享与访问
- 地球科学建模系统减轻了地球科学研究者的软件开发负担,使他们得以腾出 更多精力用于科学研究
- 对应用软件可重用性、互操作性及性能可移植性的支持,有效地促进了不同机构间的交流与合作,加快了地球科学研究成果向业务应用的转化



# AUTOMATIC?



### 陆面建模系统的关键技术



# 陆面建模系统关键技术:基于脚本语言的建模

◆ 为什么要采用基于脚本语言的建模? 而不是GUI!

- 由高性能计算的计算模式所决定(SSH连接和job调度)
- 由陆面过程模型的代码和模拟运行所决定(Fortran代码和SHELL控制)
- 开源脚本语言的支持(R、NCL、GrADS、NCO、CDO …)





# 陆面建模系统关键技术一系统结构图





# R离不开高性能计算环境



中国科学院超级计算兰州分中心

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### R语言在陆面建模系统上的应用



# 陆面过程模型的前、后处理





输入

变量	单位	说明						
水文条件:								
qair	1	最底层的空气比湿						
precip_rain	Kg/m <sup>2</sup> s	降雨						
precip_snow	Kg/m <sup>2</sup> s	降雪			检中			
热量条件:				111 山				
temp_air	К	最底层的空气温度		缩写	中文名			
力学条件:			I	PPFD	米合有效辐射			
Wind	m/s	最底层的风速	1		九百月秋福初			
wind10	m/s	地面10m处的风速		Rn	净辐射			
cdrag	1	表面拖曳系数		Qh	感热			
pressure	Kg/m <sup>2</sup>	表面大气压		Ole	潜热			
辐射条件:			(	ascan	冠层导率			
lwdown	W/m <sup>2</sup>	向下长波辐射	٤	Sean				
swdown	W/m <sup>2</sup>	向下短波辐射		GPP	志初级主广力			
sw_vis_net	W/m <sup>2</sup>	净可见光辐射	-	Reco	生态系统呼吸			
sw_vis_frac_diffuse	1	净可见光辐射中散射比例	-					
sw_nir_net	W/m <sup>2</sup>	净近红外辐射		NEE	净玍忩糸统恢父换重			
czenith	1	太阳天顶角余弦	f	APAR	吸收光合有效辐射比例			
湍流通量条件:				~				
etAcoef		richtmyer-morton A系数(热能)	1	vegC	植物的倾池			
etBcoef		richtmyer-morton B系数(热能)	1	itterC	枯枝落叶的碳池			
eqAcoef		richtmyer-morton A系数(水汽通量)	5	soilC	土壤有机质的碳池			
eqBcoef		richtmyer-morton B系数(水汽通量)						
echam_zchl	1	湍流热传输系数						
碳循环条件:								
CO2_concentration	$Kg(CO_2)/Kg(air)$	最底层CO2浓度						
表面条件:								
albedo	1	土壤反照率						
albedo_soil_nir	1	近红外光谱土壤反射率						
albedo_soil_vis	1	可见光光谱土壤反射率			10			
albedo_veg_nir	1	近红外光谱植被反射率			18			
albedo_veg_vis	1	可见光光谱植被反射率						

#### Normalized parameter range

vadj       15         roughness, sare       100         roughness, sare       100         roughness, sare       100         roughness, sare       100         repar       1225         F.Cil C3       0.87         F.Cil C4       0.67         F.Cil C3       0.87         F.Cil C3       0.64         MaxMoisture soil       1         IniMoisture soil       1         AbedoCanopyNR       0.4         AbedoCanopyNR       0.4         Max A1       0.66         Max Coolinet_woods       1         Tau Cpool litter leaf       1         Frac. Citter green 2: herbivory       15 to 30         Frac. Green 2: herbivory       15 to 30         Frac. Green 2: herbivory       13 to 10.07         Frac. Green 2: herbivory			0.6 2			
vadj       15         roughness bare       0.005         blending_height       0.001         roughness       0.001         FCH1C4       0.04         FCH24       0.04         FCH24       0.04         FCH24       0.057         FCH24       0.04         FCH24       0.057         FCH24       0.04         MaxMoisture_sol       11         ThermaDD/flushty       01         AbedoCanopyVIS       0.06         GlumnessFactor       0.23         specificLealArea_C       0.011 to 0.451         StemArea       0.06         Max C_constant       0.05         Tail Corool liter leaf       10850 to 10500         Frac_content_woods       10.050         LAT sheet constant       0.05         VegRouphness       0.05 to 15         WogRouphness       0.05 to 15         Max, C_content_woods       113.37 to 2.04         Frac_content_wood       10.375         UvegRouphness       10.375         WogRouphness       0.05 to 2.2         VegRouphness       0.05         T_r       7.03 to 2.04         Tail Crool listow <th></th> <th></th> <th>11 1</th> <th></th> <th></th> <th></th>			11 1			
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roughness_snow       □ 0.01         Cost       1.25         f_aut_leaf       □ 0.67         FCI1C3       □ 0.67         FCMax       1.09         LaiLimit       □ 3         MaxMoisture_soil       □ 1         InitMoisture       □ 1         AbedoCanopyVIR       □ 0.4         AbedoCanopyVIR       □ 0.4         AbedoCanopyVIR       □ 0.4         AbedoCanopyVIR       □ 0.4         MaxLAI       □ 0.066         MaxLAI       □ 0.05         MaxCool litter woods       □ 0.0013 to 0.07         Frac. Cool litter green2 and file leaf       - 0.00013 to 0.07         Frac. Cool litter green2 and file leaf       - 0.05 to 0.15         Frac. npp 2 exudates       - 15 to 30         Frac. npp 2 exwordPool       □ 0.55         VegHeight       □ 0.375         Day_r       □ 0.43 to 0.43         Day_r<		blending_height		100		
1     1     125       FCITC3     0.67       FCITC3     0.67       FDAx     10.87       Epar     1225       FCMax     10.9       LatLimit     0.3       MaxMoisture soil     1       InitMoisture     1       ThermaDiffusivity     0.1       VolHeatCapacity     0.1       AbedoCanopyNIR     0.4       AbedoCanopyNIR     0.4       AbedoCanopyNIR     0.4       AbedoCanopyNIR     0.4       AbedoCanopyNIR     0.06       MaxLA     0.00013 to 0.07       StemArea     0.00013 to 0.07       MaxLA     0.00013 to 0.07       Frac. Citter greenzations     1       Frac. Orp. 2     0.00013 to 0.07       Frac. Orp. 2     0.00013 to 0.07       Frac. Orp. 2     0.00013 to 0.07       CarboxRate     0.00013 to 0.07       MaxLo     0.05       Frac. Orp. 2     0.00013 to 0.07       Bay_C     13.37       T_T     13.37       T_T     0.37       Bay_C     1.337       T_T     0.37       Bay_C     0.13       Bay_C     0.13       Bay_C     0.13       Bay_C     0.36		roughness_snow	E E	0.001		
FOITC4       0.67         FOITC3       0.87         Formation       0.97         MaxMoisture_soil       1         InitiMoisture       1         AbedoCanopyVIR       0.06         ClumpinessFactor       2.3         specificLeafArea_C       0.001 to 0.07         StemArea       1         MaxLA       0.05 to 0.15         MaxLA       0.05 to 0.15         MaxLA       0.05 to 0.15         Trac. pp 2 exudates       0.05 to 0.15         Frac. npp 2 woodPool       0.05 to 0.15         Frac. npp 2 woodPool       0.05 to 0.15         VegHeight       8 to 78.2         MaxLa       0.035 to 0.15         Bay_r       1.0.337         Tau_maipha       0.11         alpha_min       0.1         alpha_min       0.1         alpha_min       0.1         alpha_min		cCost f aut leaf	U 1.2	25		
FCIC3       ■ 0.87         Epar       10.9         HatLmit       0.3         MaxMoisture soil       1         ThermalDifusivity       0.1         VolHeatCapacity       0.1         AbeedCanopyNS       0.06         ClumpinessFactor       0.23         Max C content_wood       0.00013 to 0.07         Frac. Citter greenZelactor       1         Frac. Citter greenZelactor       1         Frac. Citter greenZelactor       0.05         Frac. Citter greenZelactor       0.05         Frac. Citter greenZelactor       0.05         Frac. Citter greenZelactor       0.07         Frac. Citter greenZelactor       0.0375         Frac. Citter greenZelactor       0.0375         Frac. Citter greenZelactor       0.037         Frac. Citter greenZelactor       0.375         Tr       0.375         User fitter       0.48 to 0.48         frac. Citaecs2 LG       0.07         frac. Green_aboveGround       0.07         frac. Cool aboveGround       0.035         frac. Citaecs2 LG       0.01         frac. Cool aboveGround       0.03         frac. Citaecs2 LG       0.03         frac. Cita		FCI1C4	EE 0.	67		
Epar FoMax Lalimit MaxMoisture, soil InitMoisture, soil InitM		FCI1C3	<b>0.</b>	37		
Heat       H09         MaxMoisture_soil       1         InitWoisture       1         ThermalDiffusivity       0         VolHeatCapacity       0         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         MaxLA       1         MaxC_Content_wood       1         Tau_Cpool_litter_wood       1         Frac_Green_2_herbivory       0.07         Frac_onp_2_exudates       1         Frac_onp_2_exudates       10.7         Frac_np_2_reservePool       0.05         Image: Constant       0.05         Frac_np_2_reservePool       0.05         VegRoughness       0.00013 to 0.07         Upday_r       0.375         Upday_r       0.37         Tau_w       8 to 78.2         Day_C       10.37         Tau_w       2 20 to 1073         alpha_critical       0.37         frac_green_2beeScond       0.36         frac_green_2beeScond       0.36         frac_green_2beeScond       0.37         frac_green_2b		Epar	12.2	2E5		
MaxMoisture soil       1         InitMoisture       1         InitMoisture       1         ThermaiDiffusivity       1         AlbedoCanopyNIR       0.4         AlbedoCanopyNIR       0.4         AlbedoCanopyNIR       0.4         AlbedoCanopyNIR       0.4         MaxLA       0.66         ClumpinessFactor       2.3         StemArea       0.011 to 0.451         MaxLA       1         Mathotosta		FCMax	10.5			
InitMoisture ThermalDiffusivity VolHeatCapacity Roughness       1         AlbedoCanopyNIR AlbedoCanopyNIS ClumpinessFador specificLeafArea LAI shed constant Tau_Cpool_liter vood reserveC2leafC Tau_Cpool_liter vood reserveC2leafC       10.01 to 0.451         Max Concent wood reserveC2leafC       100010 2497.6         Tau_Cpool_liter vood reserveC2leafC       0.001 to 0.07         Frac_op_2 reservePool Frac_op_2 exudates Frac_op_2 exudates Frac_op_2 reservePool VegHeight       0.05         Frac_np_2 reservePool VegHeight       0.05 to 2         T_phi       1.337 to 1.337         T_phi       1.337 to 1.337         T_ophi       1.32 to 1073         alpha_min       0.1         alpha_min       0.1         alpha_critical frac_opeol_slow       3650         tau_Cpool_slow tau_Cpool_slow       3650         tau_Cpool_slow tau_Cpool_slow       3650         tau_Cpool_slow tau_Cpool_slow       3650         tau_Cpool_slow tau_Cpool_slow       3650         K(1)       55950.0         SkinReservoirMax       0.03         MoistureFractWithing MoistureFractWithing       0.03         MoistureFractWithing MoistureFractWithing       0.03         MoistureFractWithing MoistureFractWithing       0.03         MoistureFractor       1.0         ContractS	+	MaxMoisture soil		1		
InermalDitusivity       0.1         Roughness       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         AlbedoCanopyNR       0.4         SpecificLedArea_C       2.3         SpecificLedArea_C       1001 to 0.451         Max LAI       1000 to 2497.6         Max LAI       1000 to 2497.6         Tau_Cpool_litter_wood       1000 to 2497.6         Frac_oren_2_extudes       100.7         Frac_oren_2_extudes       10.7         Frac_oren_2_extudes       10.7         Frac_oren_2_extudes       10.375         VegRoughness       0.05 to 0.15         WegHeight       0.375         Day_C       113.37 to 13.37         T_r       113.37 to 13.37         T_r       113.37 to 13.37         T_r       113.37 to 13.37         T_r       11.337 to 13.37         T_r       11.337 to 13.37         T_r       11.337 to 13.37         T_r       11.337 to 13.37         T_r       10.37         T_r       10.37         T_r       11.0         Conol wood       10.31	÷	InitMoisture		1		
Nonacapacity       II         AlbedoCanopyNIR       1         AlbedoCanopyNIS       0.06         ClumpinessFactor       2.3         StemArea       II         MaxLA       5.5         MaxLA       5.5         Max C, content, wood       0.00010 2497.6         Tau Cpool litter wood       10010 2497.6         Frac. Green 2, herbivory       0.00013 to 0.07         Frac. npp 2, evodPool       0.05 to 0.15         Frac. npp 2, woodPool       0.05 to 0.15         Frac. npp 2, woodPool       0.05 to 0.15         Frac. npp 2, woodPool       0.05 to 0.15         VegHeight       0.037         T_r       9.0302.04         Day_r       0.37         Tau w       23 to 1073         alpha_min       0.03         alpha_min       0.03         alpha_ritical       0.03         frac. C lacees2 LG       0.03         frac. C lacees2 LG       0.03         frac. C lacees2 LG       0.03         frac. C facees2 LG       0.03         frac. C facees2 LG       0.03         frac. Green aboveGround       1.0         frac. C facees2 LG       0.03         Mosi		I hermalDiffusivity	.001			
AlbedoCanopyNIR AlbedoCanopyNIS GlumpinessFador specificLeafArea MaxLAI MaxLC content, woods LAI shed constant Tau_Cpool_litter wood reserveC2leafC Tau Cpool_litter wood reserveC2leafC Frac_orp_2_exudates Frac_orp_2_exudates Frac_orp_2_exudates Frac_orp_2_reservePool Frac_orp_2_reservePool Frac_orp_2_reservePool T_0.05 to 2 WegHeight ETransport f(Vormax); CarboxRate k_1 Day_c T_phi T_Dhi rac_orgen_2_hebics WegHeight ETransport f(Vormax); CarboxRate k_1 Day_c T_phi frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_orgen_aboveGround frac_fool_slow tau_Cpool_reserve tau_Cpool_slow tau_Cpool_slow tau_Cpool_slow tau_Cpool_slow tau_Cpool_reserve tau_Gpool_reserve tau_Gpool_reserve KO0 EC D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.35 D_0.011 EK KO0 D_0.2 EC D_0.3 D_0.2 D_0.4 D_0.4 D_0.4 D_0.4 D_0.4 D_0.4 D_0.4 D_0.4 D_0.4 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.5 D_0.		Boughness		1		
AlbedoCanopyVIS ClumpinessFacor specificLetafArea_C MaxLAI Max C content wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC Tau_Cpool_litter_wood reserveC2laafC WegRoughness VegHeight Lat shed constant Frac_onp_2_exudates Frac_onp_2_exudates Frac_onp_2_exudates rac_mp_2_reservePool VegRoughness VegHeight Lat shed constant T_Day_r T_Dh T_Dh T_Dh Tau_w alpha_critical frac_facess2 LG frac_green_aboveGround frac_Cool_wood tau_Cpool_reserve kappa MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting MoistureFractWitting ALC4 ModoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAge AlbedoSnowWitAg		AlbedoCanopyNIR	0 💷	4		
Control Clear Area MaxLAI MaxLAI Max C content wood LAI shed constant Tau Cpool litter wood reserveC2/earC Tau Cpool litter wood reserveC2/earC Tau Cpool litter leaf Frac. Citter greenzatmos Frac. Cnp 2. excludes Frac. Cnp 2. excludes Frac. Cnp 2. excludes Frac. Cnp 2. excludes Frac. Cnp 2. excludes WegRoughness WegRoug		AlbedoCanopyVIS	ш 0.	06		
Stem Area         1           Max LA         1           Max C         content, woods           LAI shed constant         1           Tau Cpool litter vood         1           reserveC2lealC         3           Frac. Cpop 2, reservePool         3           Frac. npp 2, reservePool         0.05           Frac. npp 2, reservePool         0.05           Frac. npp 2, reservePool         0.05           Frac. npp 2, reservePool         15           CarboxRate         0.05           VegHeight         10.37           Day c         113.37           Tor         0.48 to 0.48           Bay c         0.35           Tau w         3375           0.00013 to 0.07           kl         0.375           Day c         13.37           Tor         0.48 to 0.48           frac. Green aboveGround         10.3           frac. C facese2 LG         10.3           frac. C acces2 LG         10.03           frac. Col aboveGround         14.0           frac. Green aboveGround         10.5           frac. Green aboveGround         10.63           frac. Green aboveGround         10.6 <td></td> <td>specificLeafArea C</td> <td></td> <td>3 ) 11 to 0 45</td> <td>1</td> <td></td>		specificLeafArea C		3 ) 11 to 0 45	1	
Max LAI       max C content wood Tau Cpool litter wood reserve C2/eatC       1000 to 2497.6         Tau Cpool litter wood reserve C2/eatC       1000 to 2497.6         Tau Cpool litter leat Frac_Green 2 herbivor WegRoughness       1000 to 2497.6         Frac_green 2 herbivor WegRoughness       0.05         WegHeight Day C       0.05         Tr       0.05         WegHeight Day C       0.05         Day C       113.37 to 13.37         Tr       9.030 2.00         Bay C       113.37 to 13.37         Tr       9.030 2.00         Bay C       113.37 to 13.37         Tr       9.030 2.04         Tr       10.35         Trac_green aboveGroud       0.05         frac_green aboveGroud       0.05         frac_green aboveGroud       0.05		StemArea		1	(h);	
Max C_ constant Tau_Cpool_litter_wood reserveC2leafC Tau_Cpool_litter_leaf       0.00013 to 0.07         Tau_Cpool_litter_leaf       3         Frac_Green_2_herbivory       0.05         Frac_orpop_2_exudates       0.05         Frac_orpop_2_exudates       0.05         Frac_orpop_2_exudates       0.05         Frac_orpop_2_exudates       0.05         Frac_orpop_2_exudates       0.0375         VegRoughness       0.03013 to 0.07         VegRoughness       0.035         VegRoughness       0.0315         VegRoughness       0.037         T_r       0.13         Day_c       1.0 140         Bay_r       0.48 to 0.48         Day_c       1.0 37         T_r       7         T_r       7.0 3 to 2.04         T_r       7.1 1.337 to 13.37         T_r       7.1 1.2 to 2.04         Tau_w       0.35         frac_ore aboveGround       0.07         frac_ore aboveGround       0.07         frac_topol_slow       1.40         tau_Cpool_wood       14600         tau_Cpool_slow       1.40         tau_Cpool_slow       1.0 0.2         KinReservoirMax       1.0 0.35	H)	MaxLAI	÷	.5	7.0	
Lar Spoil       Tau Cool litter ved reserveC2lealC       10950 to 10950         Tau Cool litter ved Frac. Cpol Litter ved Frac. npp 2, reservePool Frac. npp 2, reservePool Frac. npp 2, reservePool VegHeight       0.05 to 0.15         Frac. npp 2, reservePool VegHeight       0.05 to 0.35         Lar Spot (fVcmax)) CarboxRate       0.05 to 0.35         Day r Day r T_r       0.04 to 0.43         Day r Day c       0.05 to 0.35         Tau w       23 to 0.03 to 0.07         data growth rate Tau cod aboveGround trac Cod ab		Max_C_content_wood	s	1000 to 249	17.6 0.00012 to 0.0	7
Teserve-C2leatC       3         Tau Cpool litter (refatures)       160 to 900         Frac_Green_2 herbivory       0.05         Frac_np_2 exudates       0.15         Frac_np_2 reservePool       0.05 to 0.15         VegRoughness       0.05 to 0.15         VegRoughness       0.05 to 0.15         VegRoughness       0.05 to 0.15         VegRoughness       0.001 to 0.07         Day_r       0.048 to 0.048         Day_r       0.037 to 13.37         Day_c       119.0140         T_r       9.03 to 2.04         T_au_w       23 to 1073         alpha_critical       0.37         Tau_w       23 to 1073         alpha_critical       0.3         frac_green_aboveGround       0.7         frac_wood_aboveGround       0.7         frac_wood_aboveGround       0.75         frac_ther woodzatmos       3655         dtau_Cpool_wood       140.0         tau_Cpool_slow       18         dtau_Cpool_slow       14         dtau_Cpool_slow       18         dtau_Cpool_slow       18         frabc3       0.01         frac_greenc2leatC       0.03         dtau_C		Tau Cpool litter wood	d E	0950 to 10	950	"
1au Cpool Inter Jeat       7 60 is 900         Frac. Green 2, herbivory       0.7         Frac. onp 2, excludes       0.7         Frac. onp 2, excludes       0.05         Frac. onp 2, excludes       0.05 to 0.15         Frac. onp 2, excludes       0.05 to 0.5         Frac. onp 2, excludes       0.05 to 0.15         Frac. onp 2, excludes       0.05 to 0.15         Frac. onp 2, excludes       0.05 to 0.15         VegHeight       0.05 to 2.04         CarboxRate       0.00013 to 0.07         Day_r       0.48 to 0.48         Day_r       0.48 to 0.48         Day_r       0.37         Tr       7, 0.3 to 2.04         Tria.       9, 0.35         frac. or faces2 LG       0.3         frac. Ciaces2 LG       0.3         frac. Ciaces2 LG       0.3         frac. Ciaces2 LG       0.3         frac. opol_slow       1.0         tau_Opol_reserve       3650         tau_Opol_reserve       3650         Kappa       1.0         MoistureFractVitical       0.031		reserveC2leafC	<b>—</b> 3	Secondaria		
Frac_npp 2_reservePool       0.05         Frac_npp 2_reservePool       0.05 b 0.15         Frac_npp 2_reservePool       0.05 b 2         VegHeight       0.05 b 2         CarboxRate       0.05 b 2         VegHeight       0.05 b 2         Day_c       119 to 140         CarboxRate       0.05 to 0.037 b 0.0013 to 0.07         Lagy_r       0.48 to 0.48         Day_c       11.337 to 13.37         T_r       9.3 to 0.204         T_opin       19 to 140         tau_w       23 to 1073         taipha_min       0.1         alpha_min       0.1         alpha_min       0.1         alpha_min       0.1         0.2       23 to 1073         greenC2leaCC       0.3         drac_opol_slow       3650         tau_Cpool_reserve       3650         tau_Cpool_reserve       3655         MoistureFractWiting       0.35         MoistureFractWiting       0.35         MoistureFractWiting       0.35         MoistureFractWiting       0.35         MoistureFractWiting       0.35         MoistureFractWiting       0.35         MoistureFractWiting       <		Tau_Cpool_litter_leaf	7 66	0 to 900		
Frac_npp 2 reservePool       0.15         Frac_npp 2 reservePool       0.05 is 0.15         VegRoughness       0.05 is 0.15         VegHeight       0.05 is 0.15         Etransport (I/Vermax))       0.15 is 0.00013 to 0.07         Day_r       0.048 to 0.048         Day_r       0.048 to 0.048         Day_r       0.048 to 0.048         Day_r       0.035         Day_r       0.048 to 0.048         Day_r       0.030 to 0.07         Bay_r       0.048 to 0.048         Day_r       0.035         T_r       70.3 to 2.04         T_au_w       23 to 1073         alpha_critical       0.03         frac_reen aboveGround       0.7         frac_cool_exood       0.04000         tau_Cpool_slow       3655         tau_Cpool_wood       14400         tau_Cpool_wood       0.35         MoistureFractVilling       0.035         MoistureFractVilling       0.035         MoistureFractVilling       0.035         KC0       0.035         ER       45000.0         EV       95356.0         KO0       35440.0         EV       95356.0		Frac green 2 herbivo	ry III.	, ).05		
Frac.npp.2. reservePool       ■ 0.375         VegRoughness       ● 0.375         VegHeight       ■ 0.375         ETranspot (f(Vemax))       ■ 15 to 30         CarboxRate       ● 10 0.375         bay_r       ■ 0.48 to 0.48         Day_C       + 113.37 to 13.37         Tr       □ 0.48 to 0.48         Day_C       + 13.37 to 13.37         Tr       □ 0.48 to 0.48         Day_C       + 13.37 to 13.37         Tr       □ 0.35         frac.growth_rate       □ 0.37         alpha_critical       □ 0.35         frac.cleaes2LG       □ 0.3         frac.cleaes2LG       □ 0.5         frac.scool_wood       □ 1.8         tau_Cpool_wood       □ 1.8         frac.scool_slow       □ 0.75         skinReservoirMax       □ 2.2         MoistureFractWilling       □ 0.35         MoistureFractWilling       □ 0.31         fFbC3       □ 0.04         fFbC4       □ 0.031<		Frac_npp_2_exudates	s 🗖	0.15		
rrac_rup_z_woodPool       ■ 0.375         VegHeight       ■ 0.05 to 2         CarboxRate       ■ 81078.2         Lagy r       ■ 0.45 to 24         Day_c       119 to 140         CarboxRate       ■ 81078.2         Day_c       □ 0.48 to 0.48         T_r       ♥ 0.3 to 2.04         T_opi       ♥ 1.92 to 9.21         leaf_growth_rate       ■ 0.35         alpha_critical       ■ 0.3         frac_freen_aboveGround       = 0.5         frac_col aboveGround       = 0.5         frac_col aboveGround       = 0.7         frac_col aboveGround       = 0.1         frac_col aboveGround       = 0.1         frac_col aboveGround       = 0.5         greenC2leaCC       = 0.35         greenC2leaCC       = 0.35         dial_copol_reserve       = 3650         dial_copol_slow       = 0.35         dial_copol_slow       = 0.35         dial_copol_slow       = 0.35         dial_copol_slow       = 0.25         greenC2leaCC       = 0.75         skinReservoirMax       = 2E-4         MoistureFract/filical       = 0.031         FRDC3       = 0.59948.0		Frac_npp_2_reservePo		0.05 to 0.15		
VegHeight ETransport (f\Vcmax)) CarboxRate k.l       0.0013 to 0.07         Day_r Day_c       8 to 78.2         Tr       0.48 to 0.48         Day_c       0.37         Tau w       23 to 0.32         alpha_min       0.37         alpha_critical       0.35         frac_cfaces2LG       0.00         frac_orgeen_aboveGround       0.02         frac_orgeen_aboveGround       0.02         frac_opol_wood       14400         tau_cpool_slow       3650         tau_cpool_slow       3650         tau_cpool_wood       14400         tau_cpool_slow       0.36         tau_cpool_wood       14400         tau_cpool_slow       3650         tau_cpool_wood       0.43         frac_faces2LeatC       0.03         distureFractVritical       0.03         MoistureFractVritical       0.25         KinReservoirMax       12E-4         THETA       40.83         ALC4       0.011         EK       10.5956.0         KC0       3548.0         EC       159356.0         KC0       0.460.E-6         ALC4       0.02         SkyViewFa		VegBoughness		.375 105 to 2		
ETransport (f(Vernax)) CarboxRate k k 1 Day_C T_r T_r T_r T_r alpha_critical alpha_critical trac_Vernet center trac_wood aboveGround frac_C_facees2_LG trac_pool_reserve tau_Cpool_slow tau_Cpool_slow tau_Cpool_reserve tau_Cpool_reserve tau_Cpool_reserve tau_Cpool_reserve Kappa CriticalSnowDepth CriticalSnowDepth MoistureFractVitting MoistureFractVi	+	VegHeight		= 15 to 30		
CarboxRate k.1 Day_c Day_c Tr Day_c Tr Tr Tr Tr To 0.48 to 0.48 0.00013 to 0.07 0.31 to 0.07 0.31 to 0.07 To 0.32 L04 Tau_w alpha_min alpha_min alpha_min 0.33 frac_C faces2 LG frac_green_aboveGround frac_wood_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_cool_aboveGround frac_fool_slow tau_Cpool_reserve tau_Cpool_reserve tau_Cpool_reserve frac_fitcalSnowDepth D.35 MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling MoistureFractVilling 0.031 FRDC3 ALC4 D.04 FRDC3 CO EC AlbedoSnowNirAge 0.03 AlbedoSnowNirAge 0.02 FO AlbedoSnowNirAge 0.02 FO AlbedoSnowNirAge 0.02 FO AlbedoSnowNirAge 0.02 FO Co Co Co Co Co Co Co Co Co Co		ETransport (f(Vcmax))	}	.9 to 140		
Day_r         0.0001 80 0.07           Day_c         113.37 to 13.37           T_r         "0.3 to 2.04           T_phi         "1.9 2 to 9.21           leaf_growth_rate         0.37           alpha_min         0.31           alpha_min         0.31           alpha_min         0.31           alpha_min         0.31           frac_growth_rate         0.35           greenCleatC         #4.0           frac_growth_rate         0.35           greenCleatC         #4.0           tau_Cpool_slow         3650           tau_Cpool_wood         #4.0           tau_Cpool_slow         3650           tau_Cpool_wood         #14600           tau_Cpool_slow         #3650           d10         #1.8           CriticalSnowDepth         5.85036E-3           MoistureFractWiting         0.031           ALC4         #0.031           ALC4         #0.034           FRDC3         #0.011           EK         #59356.0           KC0         #3026-3           KC0         #400.28           otrigetscare         #1.0           ZenithAngleFactor         #2.0		CarboxRate		8 to 78.2	00012 to 0.0	7
Day C       113.37 to 13.37         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T         T       T		Dav r		48 to 0.48	0.00013 to 0.0	
Tr       ♥ 0.3 02.04         Lphi       ♥ 0.3 02.04         leaf_growth_rate       □ 0.37         Tau_w       ♥ 23 to 1073         alpha_min       □ 0.17         alpha_ritical       □ 0.35         frac_green_aboveGround       □ 0.7         frac_wood_aboveGround       □ 0.7         frac_collestow       □ 0.2         greenC2leatiC       □ 0.4         tau_Cpool_slow       □ 3650         tau_Cpool_slow       □ 3650         tau_Cpool_reserve       □ 365         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         ALC4       □ 0.04         FRDC3       □ 50967.0         ER       □ 50967.0         ER       □ 50967.0         ER       □ 50956.0         KC0       □ 50956.0         KC0       □ 50956.0         KC0       □ 505         AlpeHA       □ 0.28         omega       □ 0.12         SkiViewFactor       □ 1.0         ZenthAngleFactor       □ 2.0         AlbedoSnowNirAgie		Day_c	1 13	37 to 13.37	7	
leatgrowth_rate       0.37         Tau_w       E 23 to 1073         alpha_min       0.1         alpha_min       0.173         alpha_critical       0.35         frac. C facese2 LG       0.3         frac. green_aboveGround       0.0.7         frac. Good aboveGround       0.7         frac. green_c2leatC       140.0         tau_Cpool_slow       140.0         tau_Cpool_slow       1440.0         tau_Cpool_wood       1440.0         tau_Cpool_reserve       3655         kappa       1.0         O10       18         CriticalSnowDepth       5.85036E-3         MoistureFractWiting       0.83         ALC4       0.031         FRDC4       0.031         FRDC4       0.031         FRDC4       0.031         FKDC3       35948.0         EC       199356.0         KC0       140.28         omega       0.01         EX       35948.0         EC       199356.0         KC0       10.28         omega       0.01         SkyViewFactor       2.0         AlbedoSnowNirkge       <		Tr	堂 0.	3 to 2.04		
Idu_wi     Idu_wi     Idu_wi       alpha_rritical     0.1       alpha_critical     0.3       frac_creen_aboveGround     0.5       frac_treen_aboveGround     0.7       frac_creen_aboveGround     0.3       frac_creen_aboveGround     0.3       frac_creen_aboveGround     0.05       frac_creen_aboveGround     0.03       frac_Creattreen_aboveGround     0.02 <tr< th=""><th></th><th>leaf growth rate</th><th><b>7</b>1.</th><th>32 to 9.21</th><th></th><th></th></tr<>		leaf growth rate	<b>7</b> 1.	32 to 9.21		
alpha_ritical       □ 0.1         alpha_ritical       □ 0.3         frac_Ciaces2 LG       □ 0.3         frac_gen_aboveGround       □ 0.7         frac_gen_aboveGround       □ 0.7         frac_gen_aboveGround       □ 0.7         frac_genC2leattos       □ 0.7         greenC2leattos       □ 0.7         tau_Cpool_slow       □ 36500         tau_Cpool_slow       □ 3650         distureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.30         ALC4       □ 0.04         FRDC3       □ 50967.0         ER       □ 50967.0         ER       □ 50967.0         EV       □ 50956.0         KC0       □ 50948.0         EC       □ 50948.0         EC       □ 50948.0         EC       □ 50948.0         EC       □ 50948.0         ALPHA       □ 0.28         omega       □ 0.12         SkylewFactor       □ 0.2         AlbedoSnowNirAgie       □ 0.4         AlbedoSnowNirMax       □ 0.5         AlbedoSnowNirMax		Tau w	富 23	3 to 1073		
alpha_critical       □□0.35         frac_green_aboveGround       □0.5         frac_green_aboveGround       □0.7         frac_clitter wood2atmos       □0.7         greenC2baci       □0.7         frac_greenC2baci       □0.2         frac_greenC2baci       □0.2         frac_greenC2baci       □0.7         frac_greenC2baci       □0.75         starterfractWiting       □0.35         MoistureFractWiting       □0.031         frEDC4       □0.031         fFDC4       □0.031         fFDC4       □0.031         eEN       □0.001         EV       □35948.0         EC       10.59356.0         KO0       □0.400.E-6		alpha_min	Ē	0.1		
Intel Concernent     Intel Concernent     Intel Concernent       Intel Concernent     Intel Concernent     Intel Concerne       Intel Conconnent     Intel		alpha_critical		.35		
frac       wood       aboveGround       0.7         frac       Citter woodzatmos       0.2         greenC2leatC       36500         tau       Cpool slow       14600         tau_Cpool_reserve       36500         diau       5.85036E-3         MoistureFractWitting       0.35         MoistureFractWitting       0.35         MoistureFractWitting       0.031         FRDC4       0.044         FRDC3       0.011         ER       45090.0         EV       58520.0         EC       159356.0         KO0       330.E-3         KO0       330.E-3         KO0       0.28         onega       0.12         SkyViewFactor       1.0         ZenithAngleFactor       0.2         AlbedoSnowNirAge       10.3         AlbedoSnowNirAge       10.3         AlbedoSnowNirAge       0.2         AlbedoSnowNirAge       0.2         Internet       1.0         ZenithAngleFactor       2.0         AlbedoSnowNirAge       0.2         AlbedoSnowNirAge       0.2         Internet       1.0         Int		frac green aboveGrou	nd III0	.5		
frac_C_litter wood2atmos       □0.2         greenC2leatC       14.0         tau_Cpool_slow       36500         tau_Cpool_reserve       365         control reserve       365         control reserve       365         control reserve       365         MoistureFract/Vitting       0.35         MoistureFract/Vitting       0.35         MoistureFract/Vitting       0.35         ALC4       0.031         FRDC3       5000.0         EK       0.031         FRDC4       0.031         ER       45000.0         EV       0.58546.0         EC       10.5936.0         KC0       0.460.E-6         ALPHA       0.28         omega       0.12         SkylewFactor       1.0         ZenithAngleFactor       0.20         AlbedoSnowNirAge       0.03         AlbedoSnowNirAge       0.2         AlbedoSnowNirAge       0.2         International control c		frac_wood_aboveGrour	nd 🖬 0.1	7		
greenczeatc       11400         tau_Cpool_wood       14600         tau_Cpool_wood       3650         tau_Cpool_sow       365         kappa       1.0         Q10       1.8         CriticalSnowDepth       5.85036E-3         MoistureFractWiting       0.35         MoistureFractWiting       0.031         ALC4       0.034         FRDC3       0.011         ER       450967.0         EQ       199356.0         MO0       3304E-3         KC0       0.480.E-6         ALPHA       10.028         omega       0.12         SkyViewFactor       1.0         ZenithAngleFactor       2.0         AlbedoSnowNirAge       0.2         AlbedoSnowNirAge       0.2         AlbedoSnowVirMax       10.65         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95         AlbedoCanopySnow       0.2 <th></th> <th>frac_C_litter_wood2atm</th> <th>os 🗖</th> <th>0.2</th> <th></th> <th></th>		frac_C_litter_wood2atm	os 🗖	0.2		
tau_Cpool_wood       □ 14600         tau_Cpool_reserve       □ 365         wood       □ 11         Oilo       □ 1.8         CriticalSnowDepth       □ 0.35         MoistureFractWitting       □ 0.35         MoistureFractWitting       □ 0.35         KorstureFractWitting       □ 0.35         MoistureFractWitting       □ 0.31         FRDC4       □ 0.04         FRDC3       □ 0.011         ER       □ 45000.0         EV       □ 58520.0         EO       □ 35948.0         EC       □ 59356.0         KC0       □ 0.12         SkylewFactor       □ 0.12         SkylewFactor       □ 0.12         SkylewFactor       □ 0.28         omega       □ 0.12         SkylewFactor       □ 0.2         AlbedoSnowNirAge       □ 0.3         AlbedoSnowNirAge       □ 0.3         AlbedoSnowNirAge       □ 0.2         AlbedoSnowNirAge       □ 0.2         Image       □ 0.2         Image       □ 0.2         Image       □ 0.3         AbedoSnowNirMax       □ 0.5         AlbedoSnowVirMax       □ 0.5		tau Cpool slow		+.0	00	
tau_Cpool_reserve		tau_Cpool_wood		4600		
Appa       1.0         Q10       1.8         CriticalSnowDepth       5.85036E-3         MoistureFractWilling       0.35         SkinReservoirMax       10.75         SkinReservoirMax       12E-4         THETA       10.83         ALCA       10.031         FRDC4       0.031         FRDC3       0.011         EK       155067.0         ER       45000.0         EO       35948.0         EC       169356.0         KO0       130.E-3         KC0       10.028         omega       1.0         ZenithAngleFactor       1.0         ZenithAngleFactor       0.2         AlbedoSnowNirAge       0.3         AlbedoSnowNirAge       0.2         AlbedoSnowNirMax       10.65         AlbedoSnowNirMax       0.2         Interview       0.2		tau_Cpool_reserve		365		
Critical ShowDepth       □ 585036E-3         MoistureFractWilting       □ 0.35         SkinReservoirMax       □ 2E-4         ALC4       □ 0.04         FRDC4       □ 0.011         ER       □ 45090.0         EV       □ 58520.0         EO       □ 35948.0         EC       □ 59356.0         KC0       □ 0.28         omega       □ 0.12         SkylewFactor       □ 0.2         AlbedoSnowNirAge       □ 0.3         AlbedoSnowNirAge       □ 0.3         AlbedoSnowNirAge       □ 0.2         AlbedoSnowNirAge       □ 0.1		C10		1.0		
MoistureFract/Wilting       □ 0.35         MoistureFract/Wilting       □ 0.75         SkinReservoirMax       □ 2E-4         THETA       □ 0.83         ALCA       □ 0.04         FRDC3       □ 0.031         EK       □ 50967.0         EV       □ 56520.0         EO       □ 35948.0         EC       □ 59536.0         KC0       □ 0.12         SkyliewFactor       □ 0.12         SkyliewFactor       □ 0.12         SkyliewFactor       □ 0.5         AlbedoSnowNirAge       □ 0.3         AlbedoSnowNirAge       □ 0.2         AlbedoSnowNirMax       10.65         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95         AlbedoSnowVirMax       10.95		CriticalSnowDepth		5.85036E-3	3	
MoistureFradCritical     □ 0.75       SkinReservoirMax     □ 2E-4       THETA     □ 0.83       ALC4     □ 0.04       FRDC3     □ 0.011       EK     □ 50967.0       ER     □ 45000.0       EV     □ 56520.0       EO     □ 35948.0       EC     □ 69356.0       KC0     □ 0.12       SkyViewFactor     □ 0.12       ZarnihangleFactor     □ 0.4       AlbedoSnowNisAge     □ 0.3       AlbedoSnowNisAge     □ 0.2       AlbedoSnowNisMax     10.65       AlbedoSnowNisMax     □ 0.2       Image: AlbedoCanopySnow     □ 0.2		MoistureFractWilting		.35		
Skill to set wollived x     Image: 2 - 4 - 4       THE TA     III 0.83       ALC4     III 0.04       FRDC3     III 0.011       EK     III 0.997.0       ER     III 45000.0       EV     III 59356.0       KC0     III 390E-33       KC0     III 0.28       Omega     III 0.28       SkyliewFactor     III 0.0       ZenithAngle Factor     III 0.0       AlbedoSnowNirAge     III 0.3       AlbedoSnowNirAge     III 0.3       AlbedoSnowNirAge     III 0.95       AlbedoSnowNirMax     III 0.95       AlbedoSnowVirMax     III 0.95       AlbedoCanopySnow     IIII 0.12		MoistureFractCritical	0.7	5		
ALCA       10.031         FRDC3       0.031         EK       10.50967.0         ER       10.50967.0         EV       10.55948.0         EC       10.5936.0         KC0       10.28         omega       10.12         SkyliewFactor       10.0         ZenithAngleFactor       10.5         AlbedoSnowNirAge       10.5         AlbedoSnowNirAge       0.2         AlbedoSnowNirAge       0.2         -15       -10       -5         -10       -5       0       5         10       -5       10       15		THETA		33		
FRDC4       ID 0.031         FRDC3       ID 0.011         EK       ID 50967.0         ER       ID 50967.0         EV       ID 58520.0         EO       ID 59356.0         KC0       ID 460.E-6         ALPHA       ID 0.28         omega       ID 0.12         SkyViewFactor       ID 1.0         ZenithAngleFactor       ID 0.5         AlbedoSnowNirAge       ID 0.5         AlbedoSnowWisAge       ID 0.5         AlbedoSnowWisAge       ID 0.5         AlbedoSnowWisAge       ID 0.5         AlbedoSnowWisAge       ID 0.5         AlbedoSnowVisAge       ID 0.2         ID 0.2       ID 0.2		ALC4	00.0	04		
EK     III 50967.0       ER     III 50967.0       ER     III 50967.0       EQ     III 50967.0       EO     IIII 50967.0       EO     IIII 50967.0       EO     IIII 5000.0       EO     IIII 5000.0       EO     IIII 5000.0       EO     IIIII 5000.0       EO     IIIII 5000.0       EO     IIIII 5000.0       EO     IIIIII 5000.0       EI     IIIIIIIIII 1000.0       ZenithAngleFactor     IIII 000.0       ZenithAngleFactor     IIII 000.0       AlbedoSnowNirAge     IIII 000.0       AlbedoSnowNirMax     IIII.0       AlbedoSnowNirMax     IIII.0       EI     IIIIIII 10000.0       EI     IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII		FRDC4	0 0	.031		
ER       # 450000         EV       ■ 56520.0         EO       ■ 35948.0         EC       ■ 59356.0         KO0       ■ 30.E=-3         KC0       ■ 0.28         omega       ■ 0.12         SkyliewFactor       ■ 0.4         AlbedoSnowNirAge       ■ 0.5         AlbedoSnowNirAge       ■ 0.2         AlbedoSnowNirAge       ■ 0.2         AlbedoSnowNirMax       10.65         AlbedoSnowNirMax       10.95         AlbedoSnowVisAge       ■ 0.2         -15       -10       -5       0       5       10       15		FKDC3	m 50	967.0		
EV         ID 58520.0           EC         ID 59356.0           KC0         ID 59356.0           KC0         ID 59356.0           KC0         ID 69356.0           ALPHA         ID 0.28           omega         ID 0.12           SkyViewFactor         ID 1.0           ZenithAngleFactor         ID 0.4           AlbedoSnowAngle         ID 0.5           AlbedoSnowWirdge         ID 0.5           AlbedoSnowWirdge         ID 0.5           AlbedoSnowWirdge         ID 0.5           AlbedoSnowWirdge         ID 0.2           AlbedoSnowWirdge         ID 0.5           AlbedoSnowWirdge         ID 0.2           ID 0.2         ID 0.2           ID 0.2         ID 0.2           ID 0.5         ID 0.5           AlbedoSnowJingge         ID 0.2           ID 0.5         ID 0.5		ĒR	Ē	5000.0		
EO □ 39948.0 EC 10 59356.0 KOO □ 330.E-3 KCO □ 460.E-6 ALPHA □ 0.28 omega □ 0.12 SkyViewFactor □ 0.12 SkyViewFactor □ 0.12 AlbedoSnowNirAge □ 0.4 AlbedoSnowNirAge □ 0.5 AlbedoSnowNirAge □ 0.3 AlbedoSnowNirAge □ 0.2 AlbedoSnowNirAge □		EV	□□ 5	3520.0		
KO0         ■ 330.6-3           KC0         ■ 460.F-6           ALPHA         ■ 0.28           omega         ■ 0.12           SkyliewFactor         ■ 2.0           AlbedoSnowNirAge         ■ 0.5           AlbedoSnowNirAge         ■ 0.5           AlbedoSnowNirAge         ■ 0.2           AlbedoSnowNirAge         ■ 0.2           AlbedoSnowNirMax         10.65           AlbedoSnowVisMax         10.95           AlbedoSnowVis 0.2         ■ 0.2           Image: AlbedoSnowVis 0.2         ■ 0.2     <		EO	□ 35 ■ 55	348.0		
KC0         m 460.E-6           ALPHA         ■ 0.28           omega         ■ 0.12           SkyViewFactor         ■ 0.12           ZenithAngleFactor         ■ 0.4           AlbedoSnowAngle         ■ 0.4           AlbedoSnowVirkge         ■ 0.5           AlbedoSnowVirkge         ■ 0.3           AlbedoSnowVirkax         ■ 0.65           AlbedoSnowVirkMax         ■ 0.2           -15         -10         -5         0         5         10         15		KOO		30.E-3		
ALPHA       ■ 0.28         omega       ■ 0.12         SkyViewFactor       ■ 1.0         ZenithAngleFactor       ■ 0.4         AlbedoSnowAngle       ■ 0.5         AlbedoSnowNirAge       ■ 0.5         AlbedoSnowNirAge       ■ 0.5         AlbedoSnowNirAge       ■ 0.5         AlbedoSnowNirMax       10.65         AlbedoSnowNirMax       0.95         AlbedoSnowVisMax       0.2         -15       -10       -5       0       5       10       15		KCO	DD 46	60.E-6		
SkyViewFactor         10.12           ZenithAngleFactor         10.0           AlbedoSnowNirAge         0.4           AlbedoSnowNirAge         0.3           AbedoSnowNirAge         0.0.5           AlbedoSnowNirMax         10.65           AlbedoSnowNirMax         0.95           AlbedoSnowVisMax         0.2           -15         -10         -5         0         5         10         15		ALPHA	0.0.	12		
ZenithAngleFactor 2.0 AlbedoSnowAngle 2.0 AlbedoSnowNirAge 0.5 AlbedoSnowVirAge 0.5 AlbedoSnowVirMax 10.65 AlbedoSnowVisMax 10.95 AlbedoSnowVisMax 10.95 AlbedoCanopySnow 0.2 -15 -10 -5 0 5 10 15		SkyViewFactor		□ 1.0		
AlbedoSnowWirAge ■ 0.4 AlbedoSnowVirAge ■ 0.5 AlbedoSnowVirAge ■ 0.3 AlbedoSnowVirMax ■ 0.65 AlbedoSnowVirMax ■ 0.95 AlbedoCanopySnow ■ 0.2 -15 -10 -5 0 5 10 15		ZenithAngleFactor	i i i	2.0		
AlbedoSnowVisAge ■ 0.3 AlbedoSnowVisMax = 10.65 AlbedoSnowVisMax = 10.65 AlbedoSnowVisMax = 0.2 - 15 -10 -5 0 5 10 15		AlbedoSnowAngle		4		
AlbedoSnowNirMax 10.65 AlbedoSnowVisMax 10.95 AlbedoCanopySnow 0.2 		AlbedoSnowVisAge	D 0.	3		
AlbedoSnowVisMax 10.95 AlbedoCanopySnow □ 0.2 -15 -10 -5 0 5 10 15		AlbedoSnowNirMax	10.6	5		
AlberoouanopySnow = 0.2		AlbedoSnowVisMax	10.9	5		
		AlbedoCanopySnow		).2		
-15 -10 -5 0 5 10 15			11.1			
-15 -10 -5 0 5 10 15						
-15 -10 -5 0 5 10 15	Г	1 1	T <sub>1</sub>	1	- U	
	-1	5 –10 –5	0	5	10	15

Range/Default







### 陆面建模系统中的R功能函数 全面评估:

- 不同时间尺度
- 不同站点
- 不同变量在不同时间尺度
- 不同时间尺度强迫数据
- 不同模型版本
- 小波分析
- 植被高度的敏感性分析

模型改进:

• 水箱模型和五层土壤对比分析

# R功能函数

- ◆ 前处理,R采用相邻7值的方 法质量控制,设置旗标, RNetCDF
- 后处理, ncdf、gdata、gplots
   、 plotrix、Hmisc、lattice和
   泰勒R包
- ◆ 代码普适性,模拟结果参数 等的变化调整其代码
- SHELL可以根据实际需要调用R脚本,以pdf、eps、emf、ps等格式输出,利用x11()的RGui的图形界面输出

图形图数:	
JSBACH_FLUXNET_GRAPHIC	基本的图像函数,包括绘图函数plo 差分析,箱图等功能。
- JSBACH_FLUXNET_GRAPHIC_FAPAR	专门为fAPAR数据定制的图像函数
JSBACH_FLUXNET_GRAPHIC_FORCING	与强迫数据集进行对比分析的图形函
JSBACH_FLUXNET_GRAPHIC_ERR	误差分析的图形函数
JSBACH_FLUXNET_STATS_GRAPHIC	统计分析的图形函数
JSBACH_FLUXNET_TAYLOR	泰勒图
GWS_ANALYSIS	小波分析
数据函数:	
JSBACH_DATA	读写模拟结果
FLUXNET_DATA	读写FLUXNET数据
时间操作:	
JSBACH_FLUXNET_COMPUTE_GROUPING	不同时间分辨率的转换
模型评估:	
JSBACH_FLUXNET_EVALUATION	15种统计分析评估
常规函数:	
CONVERT_SITE_TO_PARAMETER	站点与参数之间的数据类型转换
DIFF_VERSION_COMPARE	比较不同的模型版本的模拟结果
CALC_RELATIVE_HUMIDITY_IN_SOIL	计算不同土壤模型的相对湿度(水新 层土壤模型)
LONLAT	经纬度
主程序:	
MAIN_PROGRAM	控制评估流程及输出模式
DIFF_PARAMETER	不同参数间的对比分析
DIFF_SITE	不同站点间的对比分析



# 数据制备 CSV→NetCDF

#!/usr/bin/env Rscript # command line run in shell

- rm(list = ls()) # clear objects
- graphics.off() # close graphics windows
- library(ncdf)
- library(RNetCDF)
- HA94 = read.table('HA94 hh.met', head=T)

netcdf.from.fluxnet <- create.nc("DE-Hai.2000-</pre>

2006.obs.halfhourly.fluxnet.nc")

#### # dimensions

dim.def.nc(netcdf.from.fluxnet, "lon", 1)

dim.def.nc(netcdf.from.fluxnet, "lat", 1)

dim.def.nc(netcdf.from.fluxnet, "time", unlim=TRUE)\_\_\_\_



# 数据制备 CSV→NetCDF

# variables

var.def.nc(netcdf.from.fluxnet, "NEE", "NC\_DOUBLE", c(0,1))

# variables Attribution

att.put.nc(netcdf.from.fluxnet, "NEE", "long\_name", "NC\_CHAR", "gapfilled Net Ecosystem Exchange")

att.put.nc(netcdf.from.fluxnet, "NEE", "units", "NC\_CHAR", "umol m-2 s-1")

att.put.nc(netcdf.from.fluxnet, "NEE",

"missing\_value", "NC\_DOUBLE", -9999.)

att.put.nc(netcdf.from.fluxnet, "NEE", "long\_name", "NC\_CHAR", "gapfilled Net Ecosystem Exchange")



# 数据制备 CSV→NetCDF

- # Define variable values
- LON DATA <- HA94\$LON
- LAT DATA <- HA94\$LAT
- TIME DATA <- HA94\$TIME
- NEE DATA <- HA94\$NEE
- # Put the data with default start/count

var.put.nc(netcdf.from.fluxnet, "LON", LON\_DATA)
var.put.nc(netcdf.from.fluxnet, "LAT", LAT\_DATA)
var.put.nc(netcdf.from.fluxnet, "TIME", TIME\_DATA)
var.put.nc(netcdf.from.fluxnet, "NEE", NEE\_DATA)
close.nc(netcdf.from.fluxnet)





◆ 采用7邻方法对相邻的7个数据进行检测画图,以判断奇异值。
 for (n in 1:nver)
 lines(TIME, JSBACH\_V[n,], col='pink', pch=19)
 for (n in 1:nver)
 lines(TIME, filter(JSBACH\_V[n,], rep(1/7,7)),
 col=colc[n], pch=19)
 lines(TIME, filter(FLUXNET\_V, rep(1/7,7)), col="black"
 ◆ 其它的数据质量检验的方法

◆ 观测数据因为仪器或者别的原因会有空值、测量误差等,需要在变量的基础上再增加一个关于变量flag的变量,如var1\_flag(变量var1)
 0=Original, 1=Diurnal mean fill, 2=Daymet,

0-Original, 1-Diumai\_mean\_ini, 2-Daymet,

3=Daymet\_and\_dailyNCDC, 4=dailyNCDC, 6=hourlyNCDC,

7=nearby\_tower, 8=multiple\_var



# 自动化评估技术

每一种数学统计的方法应用于模型模拟性能的评价都有其<mark>局限性</mark>,所以 在陆面建模系统的模型评估中采用多种评价方法相结合(可视化也存在 着同样的局限性)





```
自动化评估技术
```

JSBACH\_FLUXNET\_EVALUATION <- function(method, JSBACH\_V, FLUXNET\_V) {

```
d1=FLUXNET_V[!is.na(FLUXNET_V)&!is.na(JSBACH_V)]
d2=JSBACH_V[!is.na(FLUXNET_V)&!is.na(JSBACH_V)]
```

```
if(length(d1)>0) {
```

```
# Root Mean Square Error
if (method=="rmse") r_value <- sqrt(mean((d1-d2)^2,
na.rm=TRUE))</pre>
```

```
# Normalized RMSE
if (method=="nrmse") r_value <- (sqrt(mean((d1-d2)^2,
na.rm=TRUE)))/mean(d1)</pre>
```

```
# Coefficient of determination (R Squared)
if (method=="RR") r_value <- summary(lm(d2 ~ d1,
na.action=na.omit))[c("r.squared")]</pre>
```



# 自动化评估技术

```
# Pearson's correlation coefficient
   if (method=="cor test") r value <- cor.test(d1, d2,</pre>
na.action=na.omit )$p.value
     #cor.test(FLUXNET V, JSBACH V, method="spearman")
     #cor.test(FLUXNET V, JSBACH V, method="kendall")
   # Nash-Sutchliffe efficiency (NSE)
   if (method=="nse") r value < 1 - sum((d1 - d2)^2)/sum((d1 - d2)^2)
mean(d2))^2
   # RMSE-observations standard deviation ratio (RSR)
   if (method=="rsr") r value <- sqrt(sum((d1 -</pre>
d_{2}^{2})/sqrt(sum((d1 - mean(d2))^{2}))
   # Percent bias (PBIAS)
   if (method=="pbias") r value <- sum(d2 - d1) * 100/sum(d1)
   # Modelling efficiency
   if_(method == "mef")_r_value_<-(sum((d1-mean(d1))^2)-sum((d2-mean(d1))^2))
d1)^{2})/sum((d1-mean(d1))^{2})
                                                                 28
```



# 自动化评估技术

}

```
# Normalized average error
if (method==="nae") r_value <- (mean(d2)-mean(d1))/mean(d1)
# Variance Ratio
if (method=="vr") r_value <- var(d2)/var(d1)
} else {
r_value <- NA
}
return(sprintf("%.2f", r_value))
```







### **GIS**图

```
从所有站点的NetCDF文件中获取其经纬度信息
for (S in 1:length(SITE NAME)) {
   site nc <- open.ncdf(paste(site surface dir, "/", SITE NAME[S]
".", NTILES[S], " tiles.surface.nc", sep=""))
   print(SITE NAME[S])
   lonlat[1,S] <- get.var.ncdf(site nc, "lon")</pre>
   lonlat[2,S] <- get.var.ncdf(site nc, "lat")[1]</pre>
}
# Plot lon&lat in world map
opar<-par( cex=0.6, pin=c(6.0, 3.0))
load ("TM WORLD BORDERS SIMPL-0.2.RData")
plot (wrld simpl, axes = TRUE, xlim = c(-180, 180), ylim = c(-180, 180))
120, 90), asp = 1)
qrid()
for (L in 1:length(LON)) {
points (LON[L], LAT[L], col=rainbow(length(LON))[L],
pch=substr(SITE NAME[L],1,1))
legend ('bottom', SITE NAME, pch=substr(SITE NAME, 1, 1),
                                                               31
col=1:length(SITE NAME), bty="n", ncol=8, cex=0.5)
```



### 不同时间尺度的模拟性能评估

- ◆ 不同时间尺度对模型的模拟性能存在差异
- ◆ 6种时间分辨率(半小时、天、半月、月、年、每月每小时)的模拟结果与 FLUXNET涡动数据进行对比分析
  Standard Deviation of Half Month Sensible Heat Flux (2000-2006)





Fluxnet

Sensible Heat Flux(W/m^2)









### 不同时间尺度的模拟性能评估

-		••••	
参数	模拟值	观测值	单位
PPFD	267.9624313	229.1798109	umol/m <sup>2</sup> s
Rn	64.01994312	56.74520001	$W/m^2$
Qh	22.24316819	11.7292733	$W/m^2$
Qle	41.03596916	21.15859903	$W/m^2$
Gscan	0.003159619	0.00813919	m/s
GPP	2.598816044	3.948835397	umol/m <sup>2</sup> s
Reco	2.585311374	2.672223771	umol/m <sup>2</sup> s
NEE	-0.01350467	-1.276611627	umol/m <sup>2</sup> s
fAPAR	0.434984523	0.437642477	-
vegC	7563.983507	NA	gC/m <sup>2</sup>
litterC	4353.142782	NA	gC/m <sup>2</sup>
soilC	22985.14643	NA	gC/m <sup>2</sup>

#### 年平均对比分析。NA为空值。



Variables Statistics





Variables Statistics

### 不同的统计分析图表对数据的统计的意义 和侧重点不同

 月和每月每小时尺度的感热模拟的性能相 对较好,天时间尺度的感热的模拟性能较 差







### 不同站点的模拟性能评估



- 从这8个变量的半小时模拟尺度的泰勒图可以看出,净辐射(Rn)和光合有效辐射(PPFD)在52个FLUXNET站点的模拟性能最好
- 这两个变量在各个站点的统计值离"参考点"的距离最近,且离散的程度较小
- AT-Neu、AU-Tum、CA-Man、Dk-Sor、DK-Lva、NL-Hor、SE-Fla、US-Pfa 和ZA-Kru等FLUXNET站点模拟的这8个变量的性能相对较差
- 说明JSBACH在不同的植被功能型和气候环境下的适应性较好





不同变量在不同时间尺度的模拟性能评估



变量的单位不一样,需要在统一的标准下进行处理分析(标准偏差处理)
 DE-Hai站点为例,半小时、天、半月、月、月每小时(年数据太少)NEE、 38 GPP、Rn和PPFD这四种变量在DE-Hai站点的不同时间尺度中模拟性能较好



### 不同时间尺度强迫数据对模拟性能评估









### 不同时间尺度强迫数据对模拟性能评估

参数	输入时间尺度	Intercept	Slope	r	R <sup>2</sup>	RMSE	SD_JSB	SD_FLX	NAE	VR	PBIAS	NSE	RSR
	HalfHourly	-7	0.91	1	0.99	36.14	163.01	179.31	-0.12	0.83	12.12	0.96	0.2
	Temp_HalfHourly	0.49	1.19	0.99	0.99	56.97	206.7	179.31	0.2	1.33	-19.63	0.9	0.31
	Wind_HalfHourly	-8.56	0.89	1	0.99	42.55	159.33	179.31	-0.15	0.79	14.93	0.95	0.23
	Humi_HalfHourly	-8.56	0.89	1	0.99	42.55	159.33	179.31	-0.15	0.79	14.93	0.95	0.23
FFID	Long_HalfHourly	0.49	1.19	0.99	0.99	56.97	206.7	179.31	0.2	1.33	-19.63	0.9	0.31
	Shor_HalfHourly	-0.85	1.17	0.99	0.99	50.63	204.85	179.33	0.17	1.3	16.92	0.92	0.28
	Prec_HalfHourly	0.49	1.19	0.99	0.99	56.97	206.7	179.31	0.2	1.33	-19.63	0.9	0.31
	Daily	0.49	1.19	0.99	0.99	56.97	206.7	179.31	0.2	1.33	-19.63	0.9	0.31
	HalfHourly	-9.62	0.77	NA	0.88	32.87	45.79	59.89	-0.42	0.58	41.51	0.74	0.51
	Temp_HalfHourly	-7.52	1.12	NA	0.88	21.46	61.78	59.89	-0.01	1.06	1.08	0.87	0.36
	Wind_HalfHourly	-16.09	0.86	NA	0.86	33.85	48.17	59.89	-0.43	0.65	43.24	0.73	0.52
Pn	Humi_HalfHourly	-233.4	0.62	NA	0.65	256.4	42.08	59.89	-4.48	0.49	448.35	0.03	0.98
NII	Long_HalfHourly	0.09	0.99	NA	0.89	19.72	57.87	59.89	-0.03	0.93	2.6	0.89	0.33
	Shor_HalfHourly	-8.25	1.32	0.95	0.91	28.32	75.44	59.9	0.2	1.58	19.52	0.78	0.46
	Prec_HalfHourly	-7.58	1.11	NA	0.88	21.58	61.46	59.89	-0.02	1.05	2.41	0.87	0.36
	Daily	-7.65	1.12	NA	0.88	21.73	61.67	59.89	-0.02	1.06	1.79	0.87	0.36

- 表格的自动生成采用了两种方式:①SHELL的正则表达式;②R脚本
- 整体上其半小时强迫数据集的模拟性能要稍好于其它时间尺度的模拟性能
- 但针对对潜热、生态系统呼吸等天尺度的模拟性能略好于半小时的模拟性能
- 低分辨率的强迫数据集和不同分辨率混合的强迫数据集(更符合野外观测实际)
   )为陆面过程模型提供了一个数据的替代方案。



### 不同模型版本的评估



Monthly Mean Sensible Heat Flux (2000-2006)

模型的开发过程需要对不同版 本模型的模拟性能进行评价, 以确定模型的模拟性能随着版 本的升级是否得到改善

- 感热随着版本的升级,其
   峰值和波谷值更收敛
- 净辐射峰值在变小
- 而且潜热和GPP的模拟性 能也有所改善
- 其它变量差别不大



### 小波分析对不同时间尺度的刻画



- DE-Hai站点的潜热模拟整体被低估,感热从天到周尺度被低估,其月到半年 尺度被高估
- US-Ho1站点的感热和潜热在相同的时间尺度呈现相反的特征,从天到半年尺度感热的模拟被低估,而从半年到年尺度,感热的模拟却显示被高估
- AU-Fog站点,从天到月尺度,感热模拟被高估,从月到半年尺度,其感热和
   潜热的模拟皆被低估了,潜热从天到周尺度被高估



CNT

Tog2(scale)

- 模拟小波系数刚开始变化不大,但是随后变化却明显减少
- 而FLUXNET的小波系数的变化却一直都不明显,说明感热量
   模拟的长期变化的稳定程度较差



### 植被高度对感热和潜热通量的响应

- ◆ 地球表面覆被直接影响着地气系统物质、能量的输送和局地环境气候,因此 计算和分析植被高度对湍流通量的影响是研究陆面过程的关键
- ◆ 不同植被高度下的感热和潜热的敏感性分析,改变植被高度将影响陆面与大 气间的湍流交换,设置DE-Hai站点的地表植被高度分别为10、20、30和40cm



- 其模拟的值与观测值的差距随着植被高度的升高其差距增大
- 差异的最大值出现在4-9月的10点到14点



### 植被高度对感热和潜热通量的响应







### 水箱模型与五层土壤模型的对比分析

- ◆ JSBACH早期版本采用水箱模型,从272版本开始,采用五层土壤模型
- ◆ 水箱模型在JSBACH模型里并没有描述在每一个网格单元的不同植被有不同 的根长,而且蒸腾和蒸发的水分有效性并没有被适当的反馈
- ◆ 五层土壤模型的土壤分层分别为3cm、19cm、78cm、268cm和698cm



- 五层土壤模型对蒸发的模拟从4-10月比水箱模型下降的更为平缓,水箱模型从 4-8月显著下降,而从8-10月又呈现显著的上升
- 水箱模型的最大蒸发量要大于五层土壤模型的蒸发量,但五层土壤模型的整体 蒸发量要大于水箱模型的蒸发量



### R语言程序结构





#### # Set parameters

}

#### Args <- commandArgs(trailingOnly=TRUE);</pre>

#### if(length(Args) != 2) {

message("generate\_FLUXNET\_diagnostics.R requires
startyear endyear as input. Terminating");quit()



# R图形函数

```
# Graphic Function (1) FLUXNET STUFF-----
JSBACH FLUXNET GRAPHIC <- function (JSBACH V, FLUXNET V,
  TIME, mean, gtype, labs, variable info,
   RMSE, NRMSE, RR, NSE, PBIAS, RSR) {
opar<-par( cex=0.6, pin=c(6.0, 2.0))
split.screen(c(2,1))
split.screen(c(1,2),screen=2)
screen(1)
 plot (TIME, JSBACH V*NA, type='n', col="red",
    ylim=c(min(JSBACH V, FLUXNET V, na.rm=TRUE),
  max(JSBACH_V, FLUXNET_V, na.rm=TRUE)),
    xlab="Time", ylab=paste(variable info[1],"(",
 variable info[2], ")", sep=""),
```

main=paste(typestr, " ", variable info[1], " (", ---variable info[3],"-",variable info[4], ")", sep=""), las=1, axes=F) axis(1, at=1:length(TIME), lab=labs,las=1) axis(2,las=1) box() lines (TIME, FLUXNET V, type=gtype, col="black") lines(TIME, JSBACH V, type=gtype, col="red" ,pch=19) legend("topleft", legend = c("JSBACH", "FLUXNET"), col=c("red","black"), pch=c(19,21), bty="n", ncol=2) legend("topright", legend = c(paste("NSE = ", NSE), paste("PBIAS = ", PBIAS, "%", sep=""), paste("RSR = ", RSR), bty="n")



```
screen(3)
  if(!all(is.na(FLUXNET V))) {
  plot (FLUXNET V, JSBACH V,
xlab='Fluxnet',ylab='JSBACH',las=1,
          vlim=c(min(JSBACH V, FLUXNET V, na.rm=TRUE),
max(JSBACH V, FLUXNET V, na.rm=TRUE)),
          xlim=c(min(JSBACH V, FLUXNET V, na.rm=TRUE),
max(JSBACH V, FLUXNET V, na.rm=TRUE)),
          main= paste(variable info[1], "(" ,
variable info[2], ")", sep= "" ))
    line FJ <- line (FLUXNET V, JSBACH V)
    a=NA;b=NA
    if(!any(is.na(coef(line FJ)))) {
      a=sprintf("%.2f",coef(line FJ,use.na=false)[1])
      b=sprintf("%.2f",coef(line FJ,use.na=false)[2])
      abline (line FJ, col="red")
    abline(0,1)
    legend("bottomright", legend = c(paste("Int = ", a),
paste("slope = ", b), paste("RMSE = ", RMSE),
      paste("NRMSE = ", NRMSE), as.expression(bquote(R^2))
==".(RR)))), bty="n")
  ł
```



```
screen(4)
 #JF T <-
c(rep("JSBACH", length(TIME)), rep("FLUXNET", length(TIME)))
 #JF V <- c(JSBACH V, FLUXNET V)
  #bwplot(JF T ~ JF V, panel=panel.bpplot, nout=.05,
scat1d.opts=list(frac=.01))
  #bpplot(JSBACH V, FLUXNET V, name=c("JSBACH", "FLUXNET"))
 boxplot (JSBACH V, FLUXNET V, names=c("JSBACH",
"FLUXNET"), las=1,
    ylab=paste(variable info[1],"(", variable info[2], ")",
sep=""),
    main = paste("Boxplot of ", variable info[1]))
close.screen(1:4)
}
```

# # Graphic Function (2) SATELLITE STUFF

# Graphic Function (3) compare

- Forcing data with simulation and evaluation
- # Graphic Function (4) Error Bars
- # Graphic Function (5) Variables
  Statistics



# 不同时间分辨率的转换

# Aggregation by time routine -----JSBACH\_FLUXNET\_COMPUTE\_GROUPING <- function(Value, TIME, period,
method) {</pre>

```
if (period=="perhour") {
   time <- format(as.POSIXct(as.Date(as.numeric(TIME-1/24),
   origin=starttime)), "%m-%H-%M")
   }
   if (period=="perhour_15") {
    time <- format(as.POSIXct(as.Date(as.numeric(TIME-1/24),
   origin=starttime)), "%m-%d-%H-%M")
   }
   if (period=="daily") {
    time <- format(as.Date(as.numeric(TIME), origin=starttime),
   "%Y-%m-%d")
   }
</pre>
```



```
if (period=="halfmonth") {
```

```
___time_<-_format(as.Date(as.numeric(TIME), origin=starttime), ____
"%Y-%m-%d")
}
```

```
if (period=="monthly") {
    time <- format(as.Date(as.numeric(TIME), origin=starttime),
"%Y-%m")
  }
  0 0 0
time <- paste(substr(time,1,8),</pre>
ifelse(as.integer(substr(time,9,10)) %in% c(1:15), 15,
30), sep="")
    JF V <- data.frame(time, Value=JF AGG$x)
    JF AGG <- aggregate (JF V$Value, list(JF V$time), method,
na.rm=TRUE)
  return (JF AGG)
```



### 定义需要对比分析的变量

```
# define required compared variables, can be added later.
nvar=9
aggregation level = c( "perhour", "daily", "monthly", "annual")
stats time <- c("halfhourly", "daily", "monthly")</pre>
annual values=array(NA,c(3,nvar+3))
eval stats=array(NA, dim=c(14,nvar,4))
variable names <- array(c("par_acc", "PPFD", "PPFD", "PPFD",")</pre>
                           "net radiation", "Rn", "Net Radiation",
"Rn",
                           "sensible heat flx", "H", "Sensible
Heat Flux", "Qh",
                           "latent heat flx", "LE", "Latent Heat
Flux", "Ole",
                           "canopy cond limited", "gsurf",
"Canopy Conductance", "gscan",
                           "net assimilation", "GPP", "GPP",
"GPP",
                           "reco", "Reco", "Reco", "Reco",
                           "zCO2 flux net", "NEE", "NEE", "NEE",
                          "fapar", "fapar", "FAPAR", "fapar")
                         , dim=c(4, nvar))
```

variable\_units <- array(c("mol/m^2s", "umol/m^2s", "umol/m^2s",

	_"W/m^2", "W/m^2", "W/m^2",
	"W/m^2", "W/m^2", "W/m^2",
	"W/m^2", "W/m^2", "W/m^2",
	"m/s","mmol m-2 s-1","m/s",
	"mol/m^2s", "umol/m^2s",
"umol/m^2s",	
	"mol/m^2s", "umol/m^2s",
"umol/m^2s",	
	"mol/m^2s", "umol/m^2s",
"umol/m^2s",	
	"-", "-", "-" <b>)</b>
,	dim=c(3,nvar))
<pre>variable_units_conversion</pre>	<- array(c(10 <sup>6</sup> ,1,
	1,1,
	-1,1,
	-1,1,
	1,18 <b>*10^-6</b> ,
	10 <b>^6,1</b> ,
	10 <b>^6,1</b> ,
	10 <b>^6,1</b> ,
	1,1) 58
,	dim=c(2,nvar))



### 调用

```
if(length(TIME) == length(TIME F)) {
  for (V in 1:nvar) {
     JSBACH V <- get.var.ncdf( modelfile, variable names[1,V] )
     JSBACH V <- JSBACH V* (variable units conversion [1, V])
     JSBACH V[JSBACH V<=-99999.]=NA
     if(variable names[1,V] == 'fapar') {
       FLUXNET V <- get.var.ncdf( datafile, 'fapar seawifs' )
       FLUXNET V[FLUXNET V==-99999.]=NA
       FLUXNET V FLAG <- get.var.ncdf( datafile,
'fapar seawifs flag' )
       FLUXNET V FILTERED=FLUXNET V
       FLUXNET V FILTERED[FLUXNET V FLAG>0.5]=NA
     } else {
       FLUXNET V <- get.var.ncdf( datafile, variable names[2,V] )
       FLUXNET V[FLUXNET V==-99999.]=NA
       FLUXNET V <- FLUXNET V* (variable units conversion [2, V])
       FLUXNET V FILTERED=FLUXNET V
       if(any(!is.na(FLUXNET V FILTERED))) {
         dummy=JSBACH V
                                                              59
         dummy [is.na(FLUXNET V FILTERED)] == NA
```

```
eval stats[1,V,1]=sprintf("%.2f", coef(line(FLUXNET V FILTERED[!i
s.na(FLUXNET_V_FILTERED)], JSBACH V[!is.na(FLUXNET V FILTERED)]),
                  use.na=false)[1])
      }
     si=1
     for (time in aggregation level ) {
        if ( time != "annual" ) {
         variable info <-
c(variable names[3,V],variable units[3,V],startyear,endyear)
          JSBACH AGG <-
JSBACH FLUXNET COMPUTE GROUPING (JSBACH V, TIME, time, 'mean')
          FLUXNET AGG <-
JSBACH FLUXNET COMPUTE GROUPING (FLUXNET V, TIME, time, 'mean')
         RMSE <- JSBACH FLUXNET EVALUATION ("rmse", JSBACH AGG$x,
FLUXNET AGG$x)
          if (time == "daily" || time == "halfmonth" || time ==
"monthly") {
                                                                60
```

```
eval_stats[1,V,si]=sprintf("%.2f",coef(line(FLUXNET_AGG$x,
JSBACH_AGG$x),use.na=false)[1])
```

```
}
       if (time=="perhour") {
                typestr <- c("Per Hour Monthly")</pre>
                qtype <- c("b")</pre>
               labs <-
month.abb[as.numeric(gsub("0","",substr(JSBACH AGG$Group.1, 1,
2)))]
         }
    JSBACH FLUXNET GRAPHIC (JSBACH AGG$x, FLUXNET AGG$x,
JSBACH AGG$Group.1,
       typestr, gtype, labs, variable info, RMSE, NRMSE, RR,
NSE, PBIAS, RSR)
      } else {
           annual values [1, V] = mean (JSBACH V, na.rm=TRUE)
          annual values [2,V] = mean (FLUXNET V, na.rm=TRUE)
```



### 其它脚本语言集成



### NCL功能函数

- 经纬度。经纬度与网格点的转换;
- 时间序列分析。时间序列数据的累计计算,包括求不同时间尺度的 平均值、和、偏差等;
- 通量计算。针对净辐射、感热通量、潜热通量和地热通量,制定了 其区域的2D的可视化功能;
- 值域函数。主要是针对几个主要的变量定制其值域范围;
- 数据读写。数据的读取和写入功能;
- 通用的图形函数。针对CLM的模拟定制了NCL图形绘画中的基本 图形的设置。

R更多的是针对功能的,而NCL更多的是针对变量的 R针对站点,而NCL针对区域的



# NCL脚本语言





# NCL脚本语言









### 研究展望





- ◆建模系统的GUI与命令行的取舍(web化可能是一个好的 选择)
- ◆ R的并行化: Rmpi、pbdMPI、snow等
- ◆R在地学上的大数据应用(卫星图像、雷达、气象站、 各种观测仪器等)::寒旱区大数据中心
- ◆ R模型如何驱动google maps形成地学的空间决策支持系

