地球系统数值模拟装置项目（地球系统模式数值模拟系统）陆地生化分分系统培训

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背景介绍

2015-12-12

Paris
Climate
Agreement

PARIS AGREEMENT

Its goal is to limit global warming to well below 2°C, preferably to 1.5 °C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century.

UNITED NATIONS
2015

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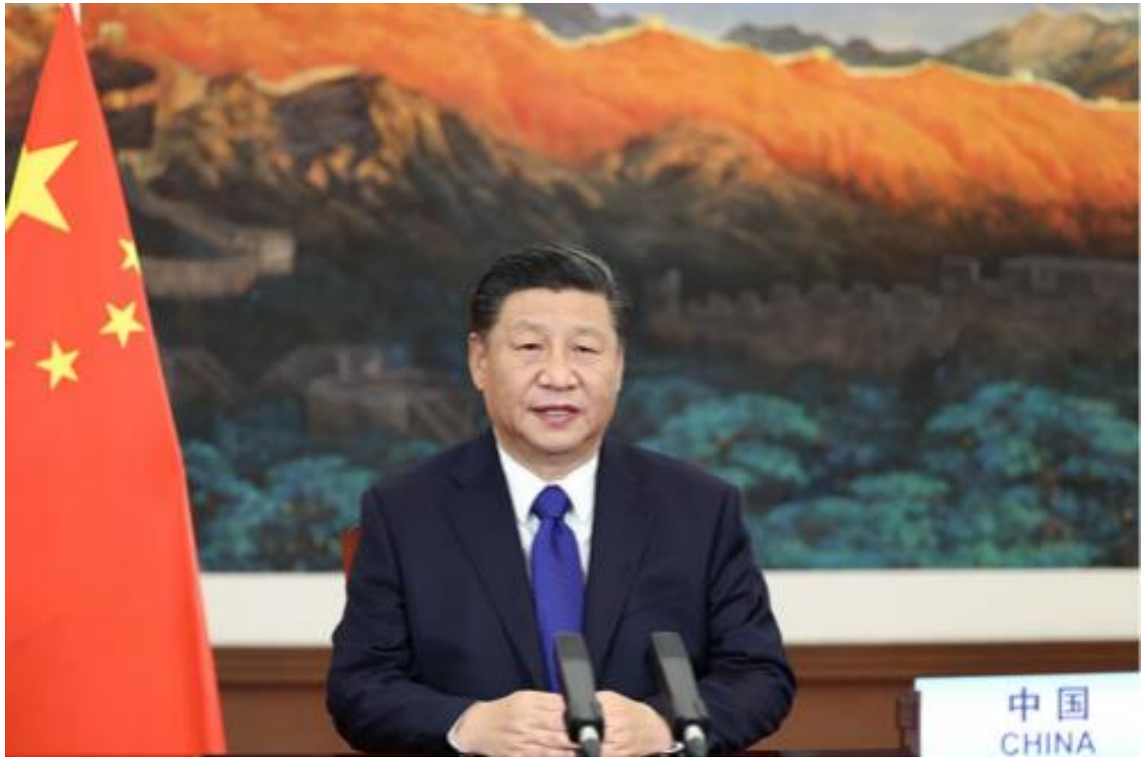
背景介绍

2020 全球气候雄心峰会 Climate Ambition Summit

The UN Secretary-General …declaring a State of Climate Emergency, until carbon neutrality has been reached worldwide. The central objective of the UN in 2021, he said, will be to build a truly global coalition for carbon neutrality by the middle of the century.

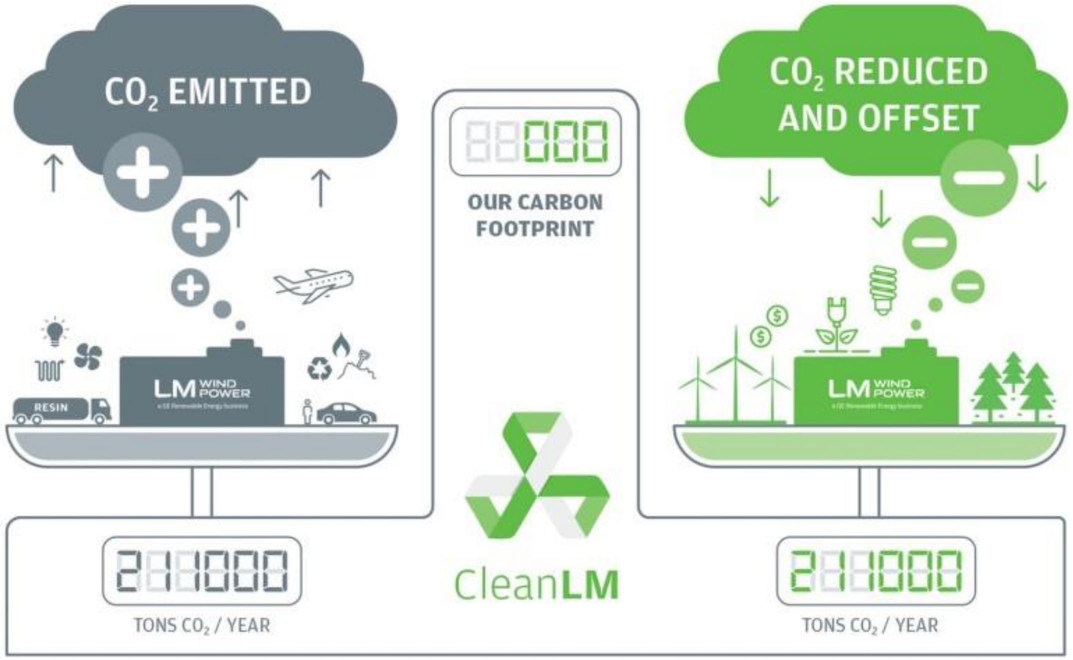
背景介绍

中国承诺：2030碳达峰，2060碳中和



中国为达成应对气候变化《巴黎协定》作出重要贡献，也是落实《巴黎协定》的积极践行者。今年9月，我宣布中国将提高国家自主贡献力度，采取更加有力的政策和措施，力争2030年前二氧化碳排放达到峰值，努力争取2060年前实现碳中和。”

背景介绍



Carbon neutrality means having a balance between emitting carbon and absorbing carbon from the atmosphere in carbon sinks. In order to achieve net zero emissions, all worldwide greenhouse gas emissions will have to be counterbalanced

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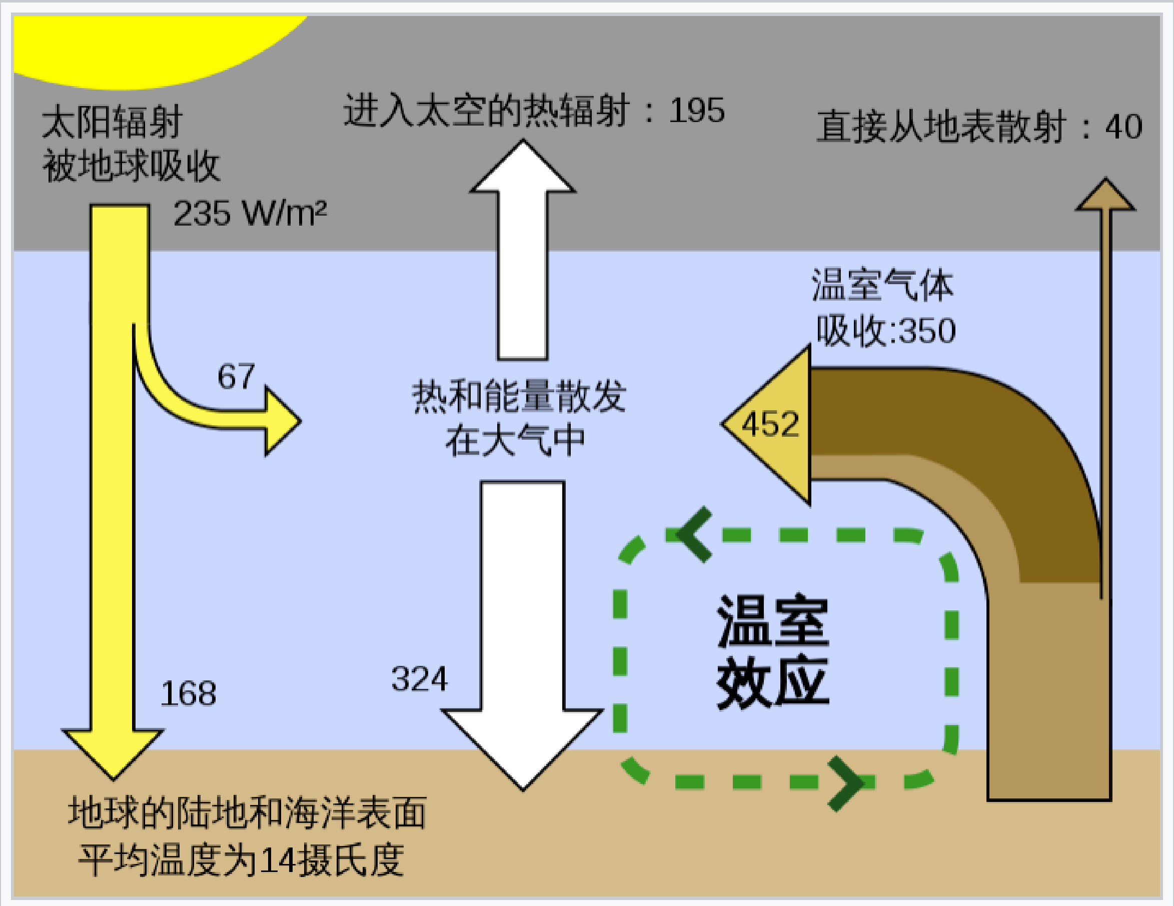
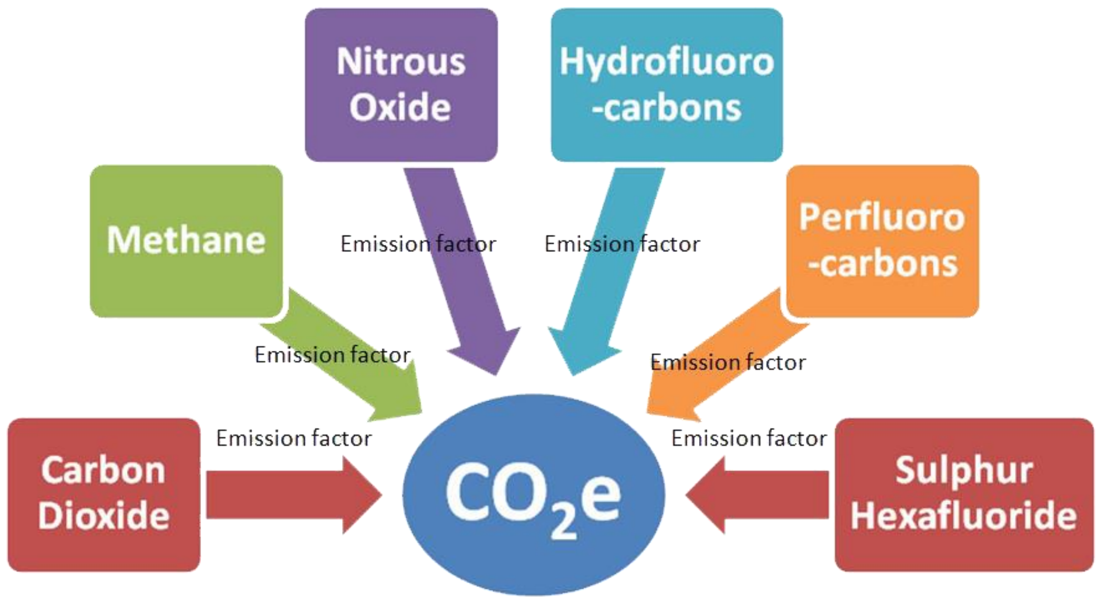
背景介绍

温室效应：Greenhouse effect



背景介绍



GWP

Global Warming Potential

全球增温潜能

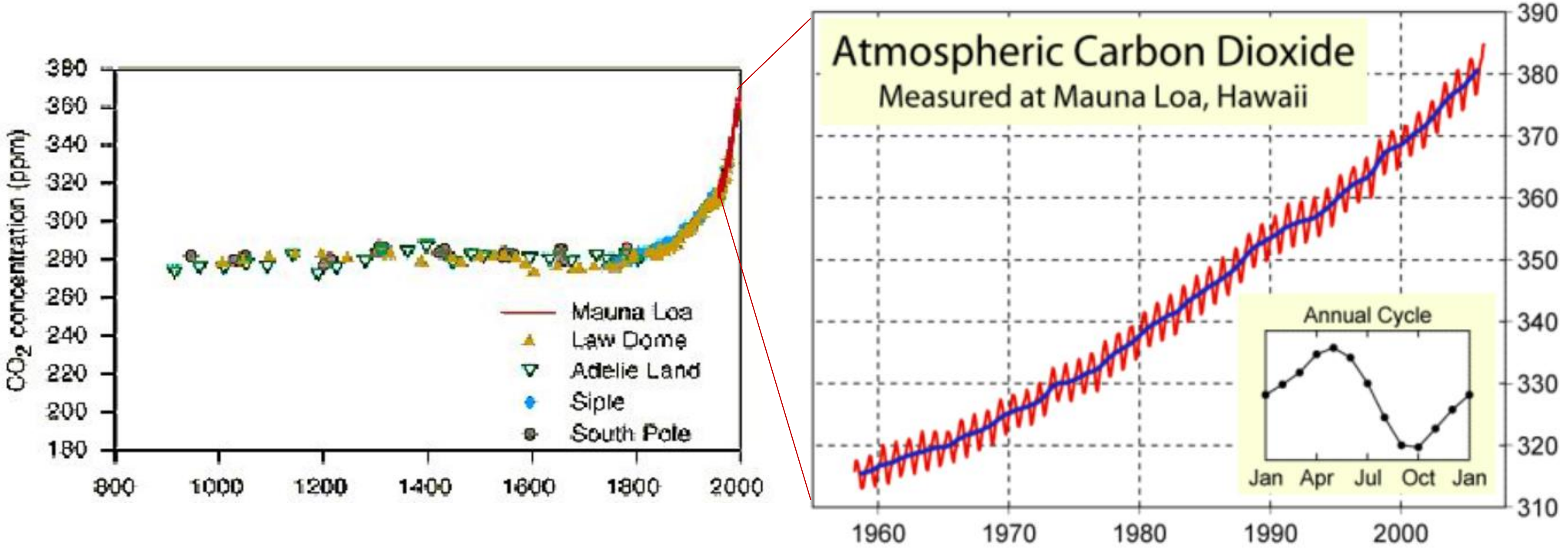
CO2：1

CH4：28~36 CO2-eq (100 years)

CH4：56~85 CO2-eq (20 years)

Greenhouse gases (GHGs) warm the Earth by absorbing energy and slowing the rate at which the energy escapes to space; they act like a blanket insulating the Earth. Different GHGs can have different effects on the Earth's warming. Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime").

背景介绍



Atmospheric concentration:

- **278 μmol mol^{-1} (ppmv) in 1750 (preindustrial era);**
- **390.5 μmol mol^{-1} (0.03905% by volume) in 2011;**
- **Increased by 40%.**

(IPCC AR5, 2013)

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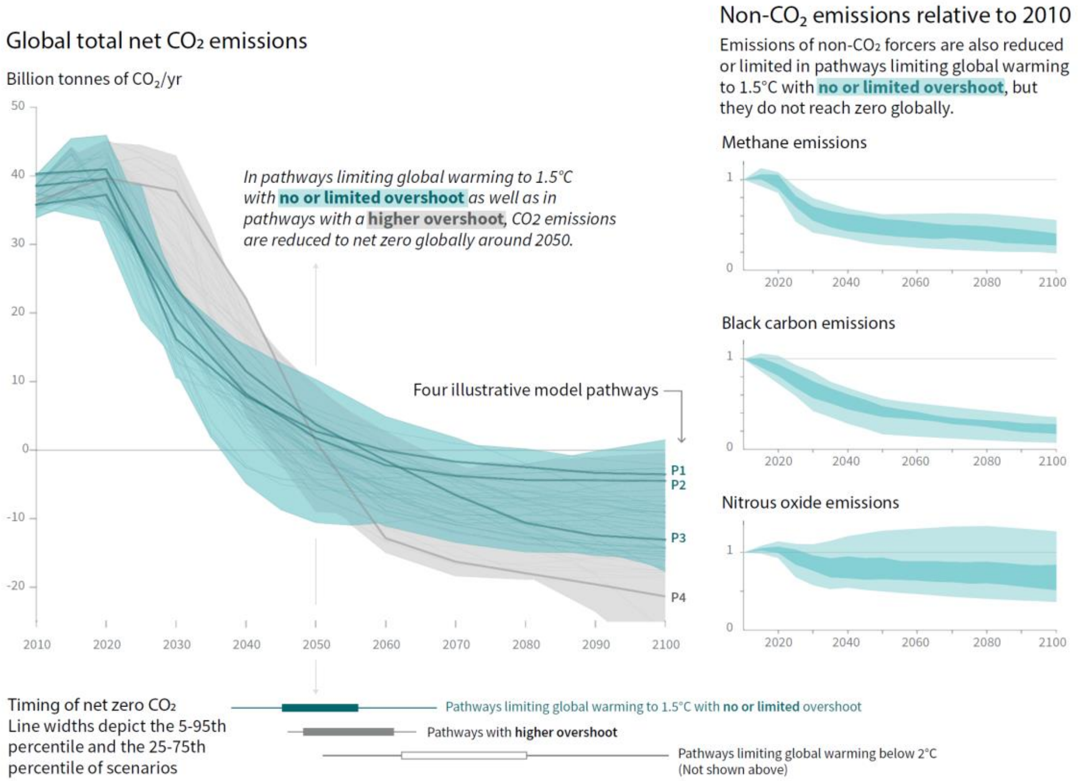
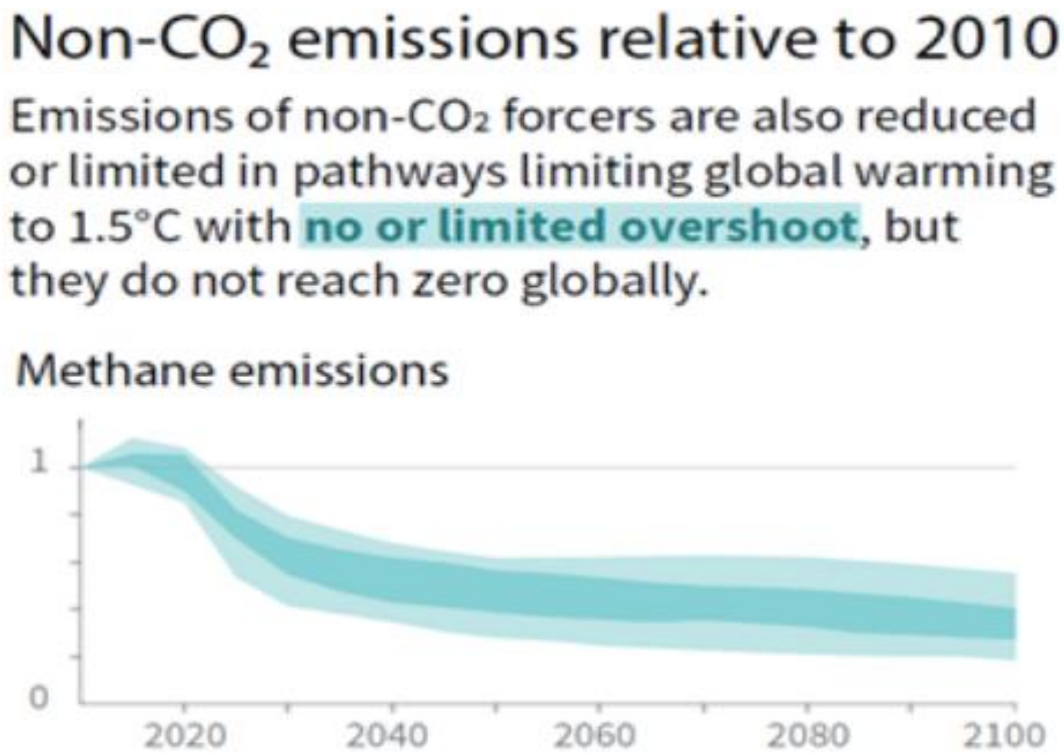
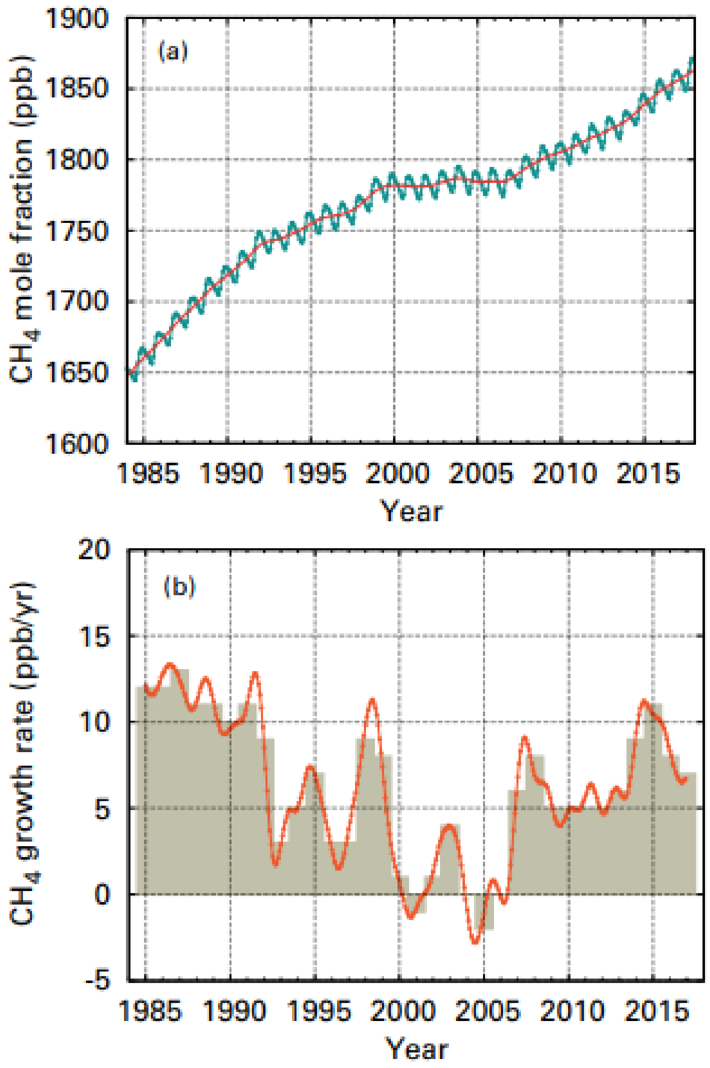
背景介绍

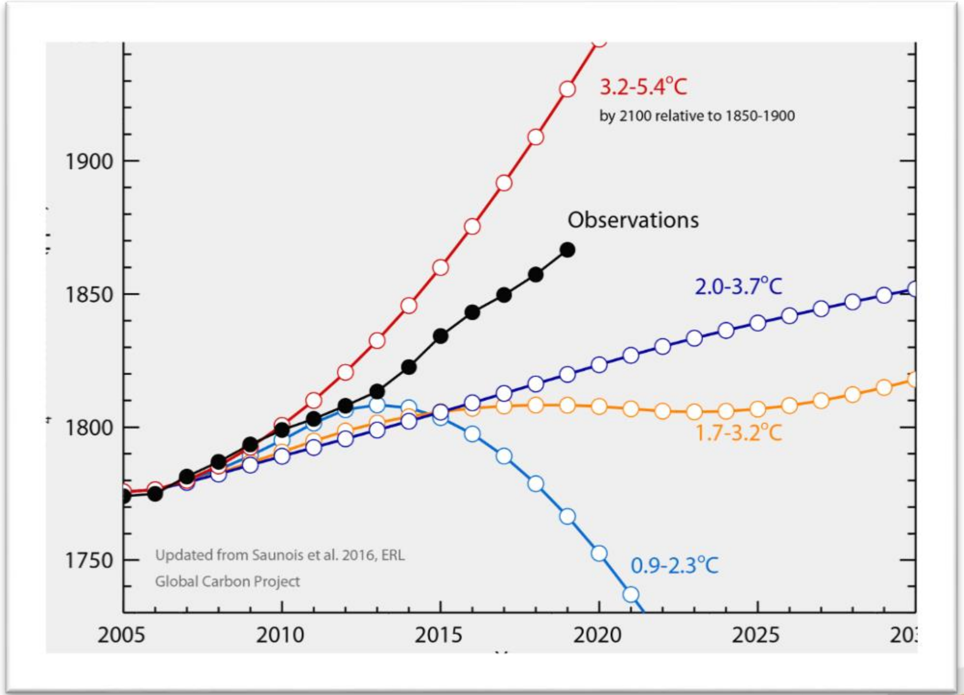


Global total net CO₂ emissions
Billion tonnes of CO₂/yr
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a higher overshoot, CO2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4
Non-CO₂ emissions relative to 2010
Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with no or limited overshoot, but they do not reach zero globally.
Methane emissions
Black carbon emissions
Nitrous oxide emissions
Timing of net zero CO₂
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios
Pathways limiting global warming to 1.5°C with no or limited overshoot
Pathways with higher overshoot
Pathways limiting global warming below 2°C
(Not shown above)



Non-CO₂ emissions relative to 2010
Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with no or limited overshoot, but they do not reach zero globally.
Methane emissions
1
0
2020
2040
2060
2080
2100

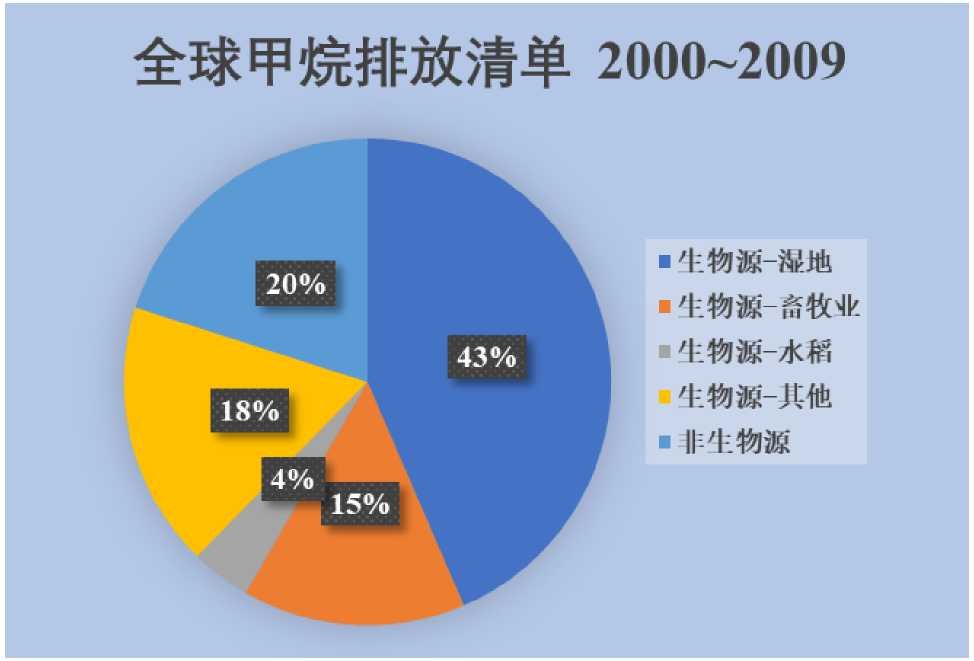




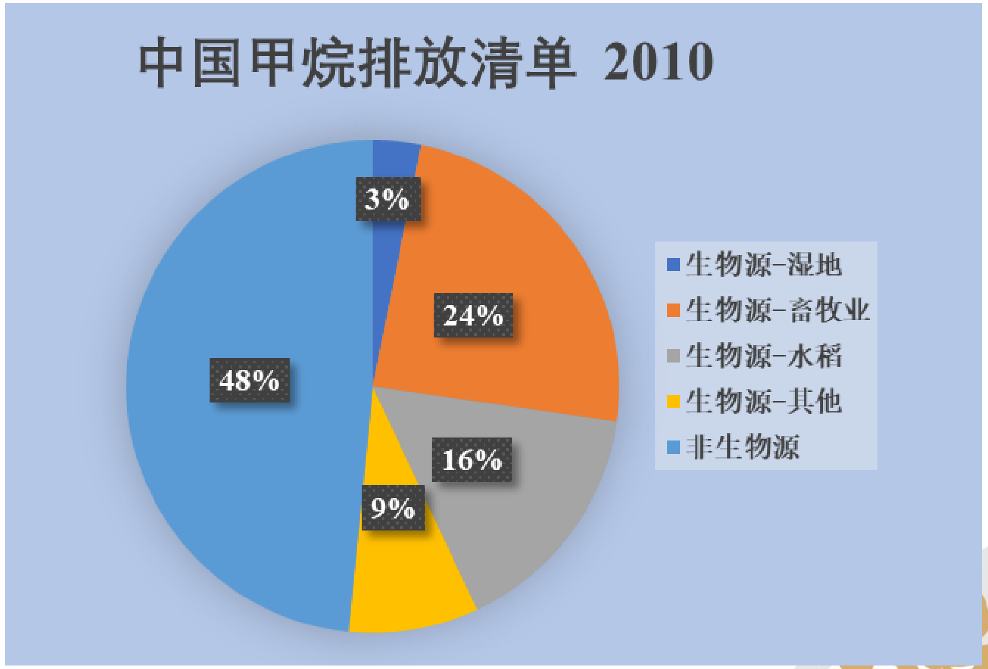
- **甲烷浓度在2014、2015和2019年呈现快速增长趋势(> 10 ppb/yr)**
- **自从2013年开始,大气甲烷浓度增长趋势接近IPCC AR5最暖趋势**

背景介绍

生物源是重要的CH4排放源



全球
生物源占~80%
湿地、畜牧业、稻田占生物源的78%



中国
生物源占~50%
畜牧业、稻田、湿地占生物源的84%

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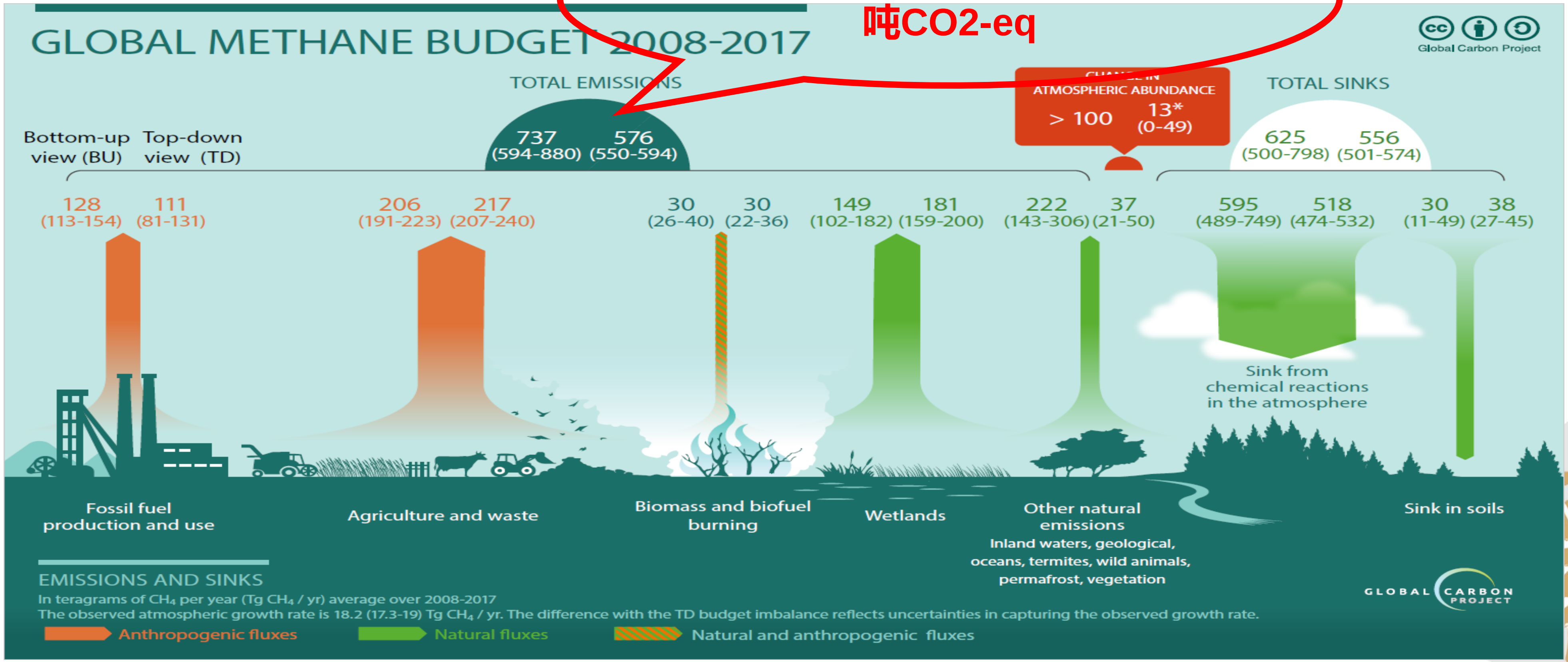
背景介绍

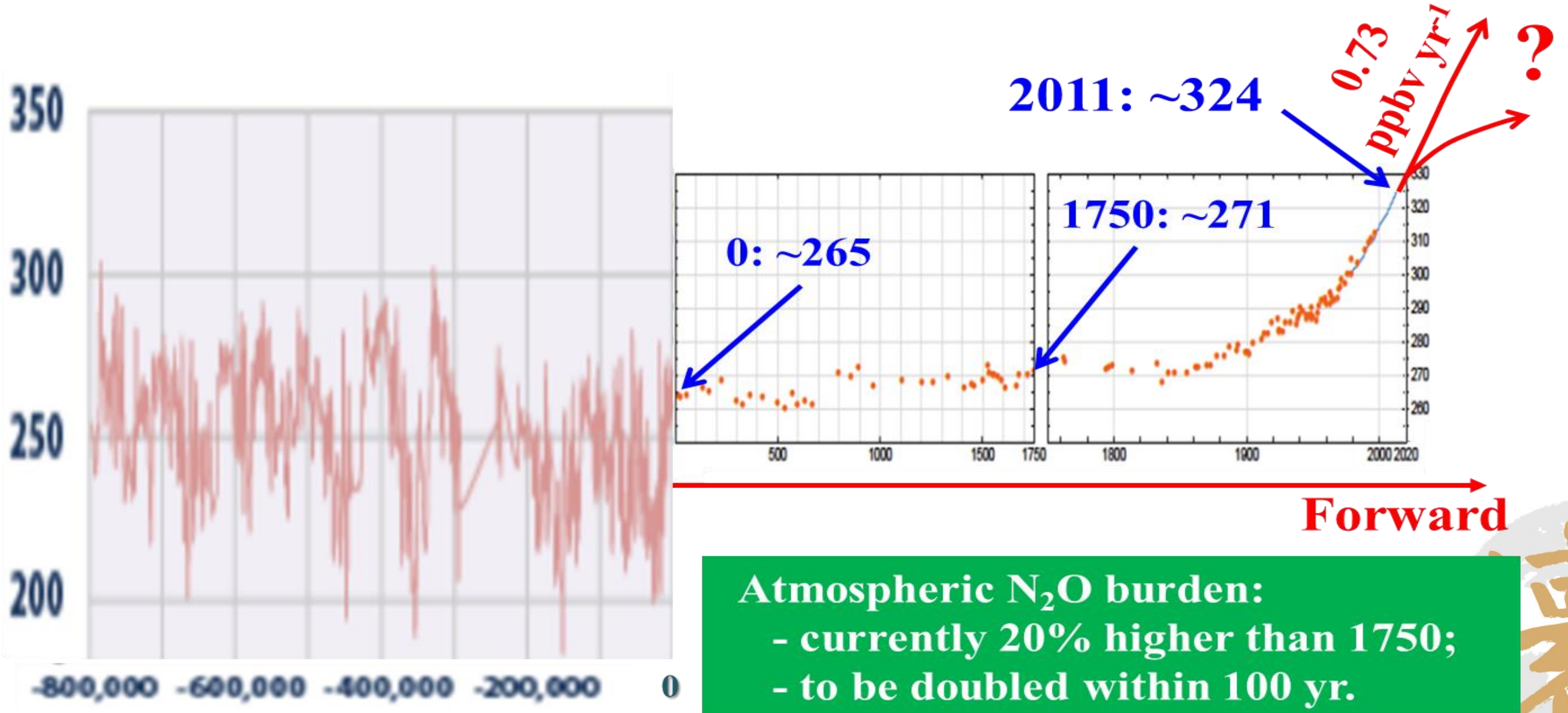
甲烷(CH4)源汇

~2 亿吨CO2；GWP100:~20亿吨CO2-eq



背景介绍

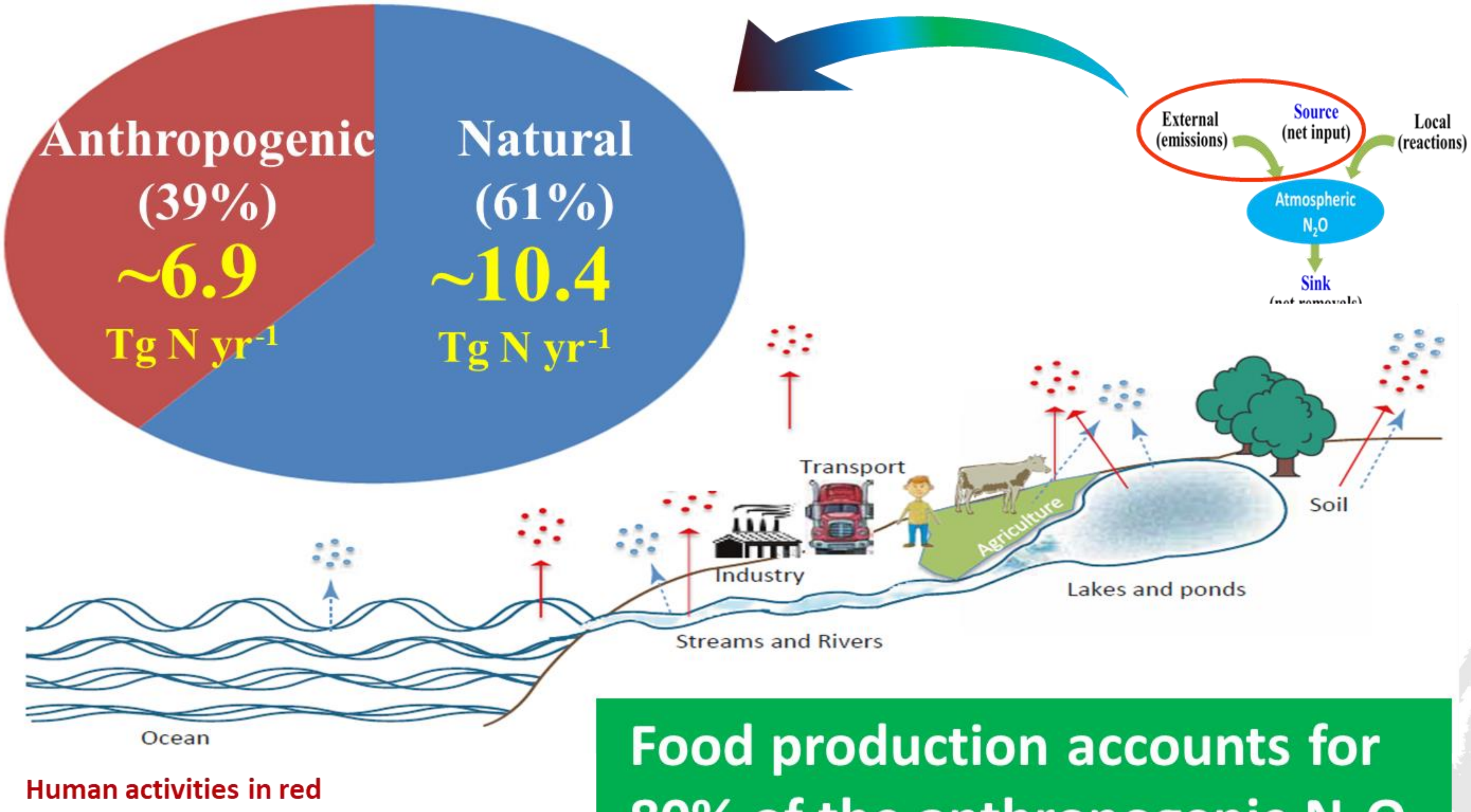
Temporal trend of the past 800,000 years



Atmospheric N_2O burden:
- currently 20% higher than 1750;
- to be doubled within 100 yr.

(Unit: ppbv, nmol mol^{-1} or, 10^{-9} atm; IPCC, 2013, AR5; http://www.epa.gov/climatechange/pdfs/print_ghg-concentrations-2014.pdf)

背景介绍

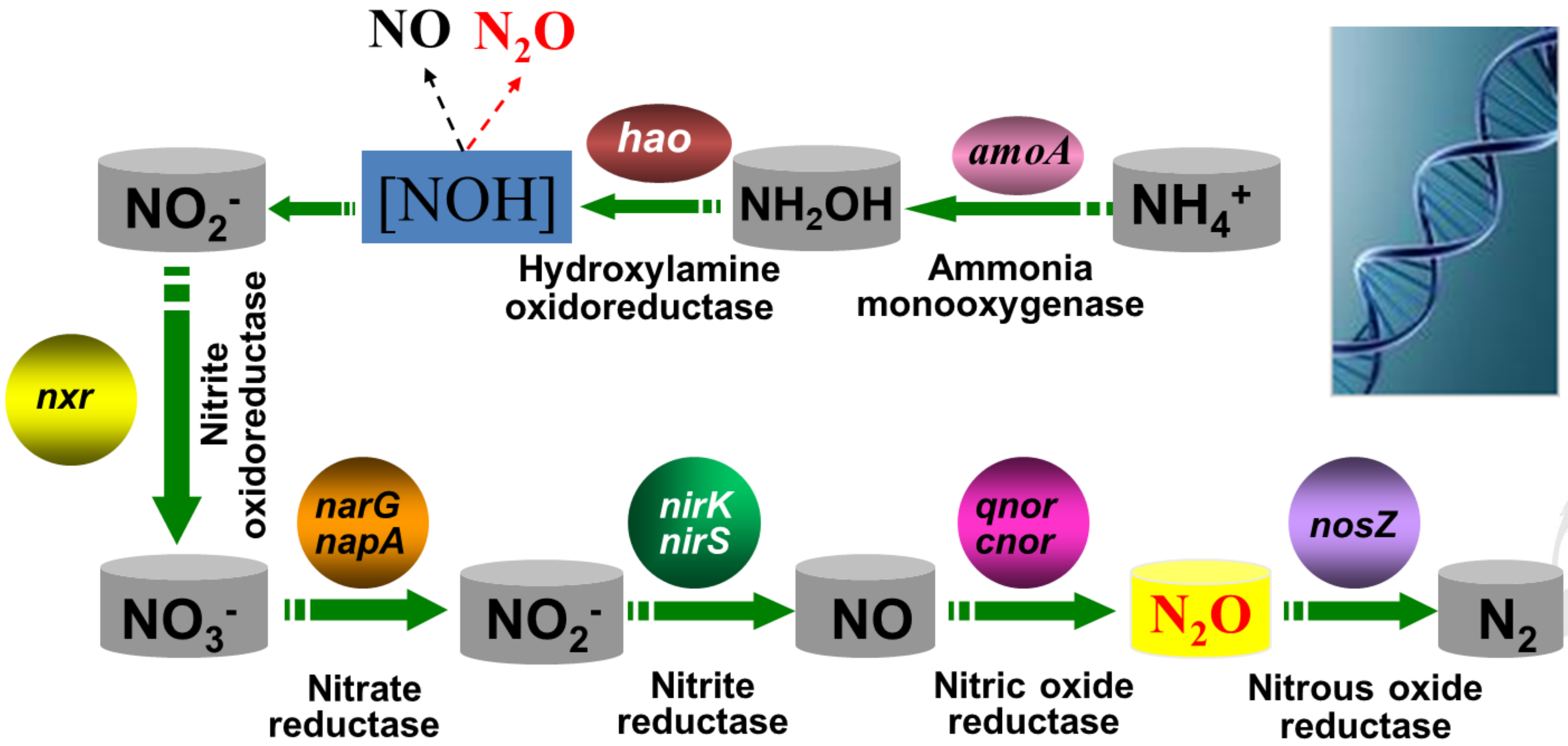


Food production accounts for 80% of the anthropogenic N_2O

(Picture source: UNEP Nitrous Oxide Report--Drawing Down N_2O to Protect the Climate and the Ozone Layer; IPCC, 2013)

背景介绍

Functional gens related to N_2O production in nitrification and denitrification



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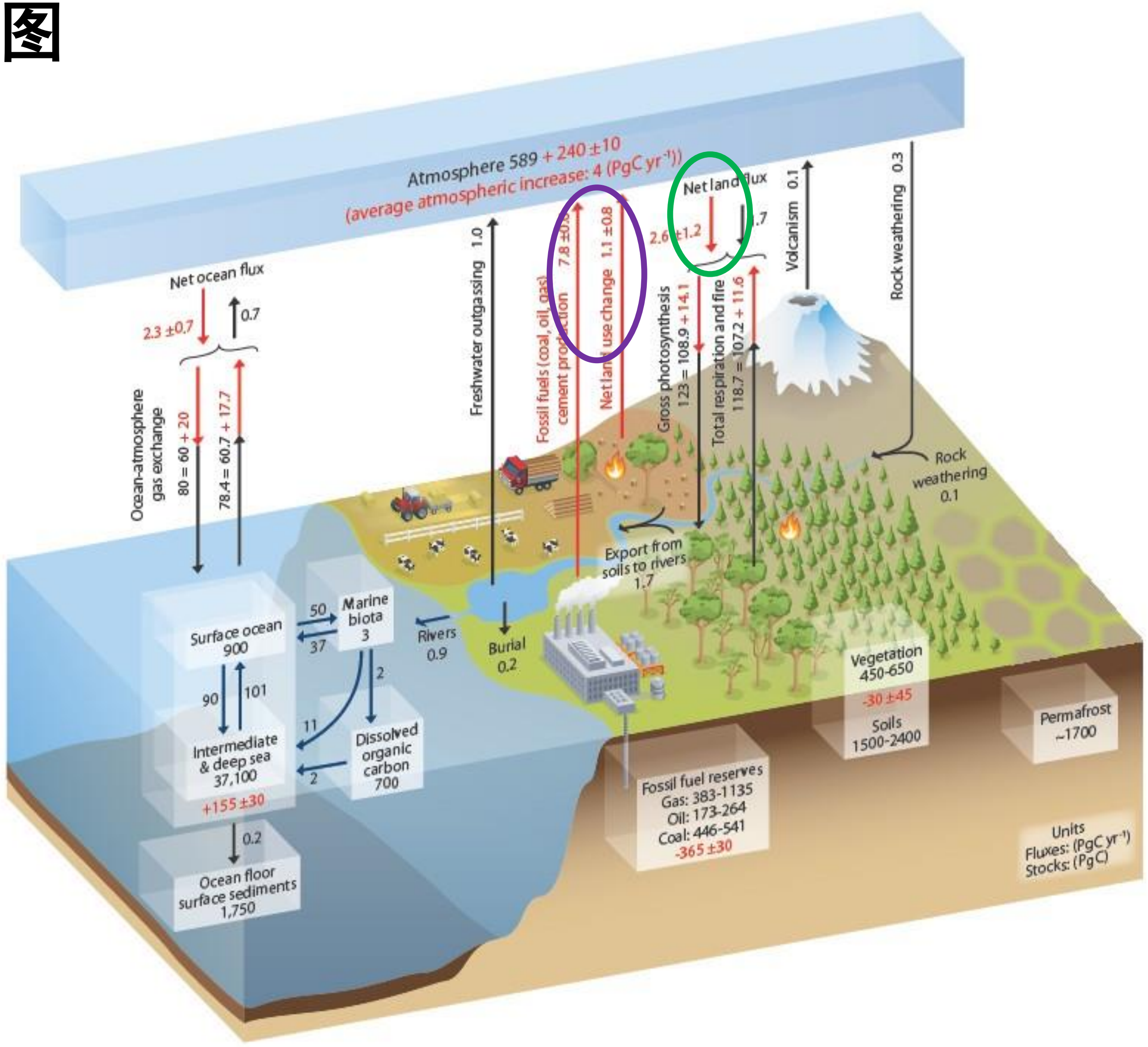
背景介绍

全球碳循环示意图



大气温室气体浓度增加
主要是因为人类活动

陆地生态系统碳汇功能
可以抵消部分人为源温
室气体的排放

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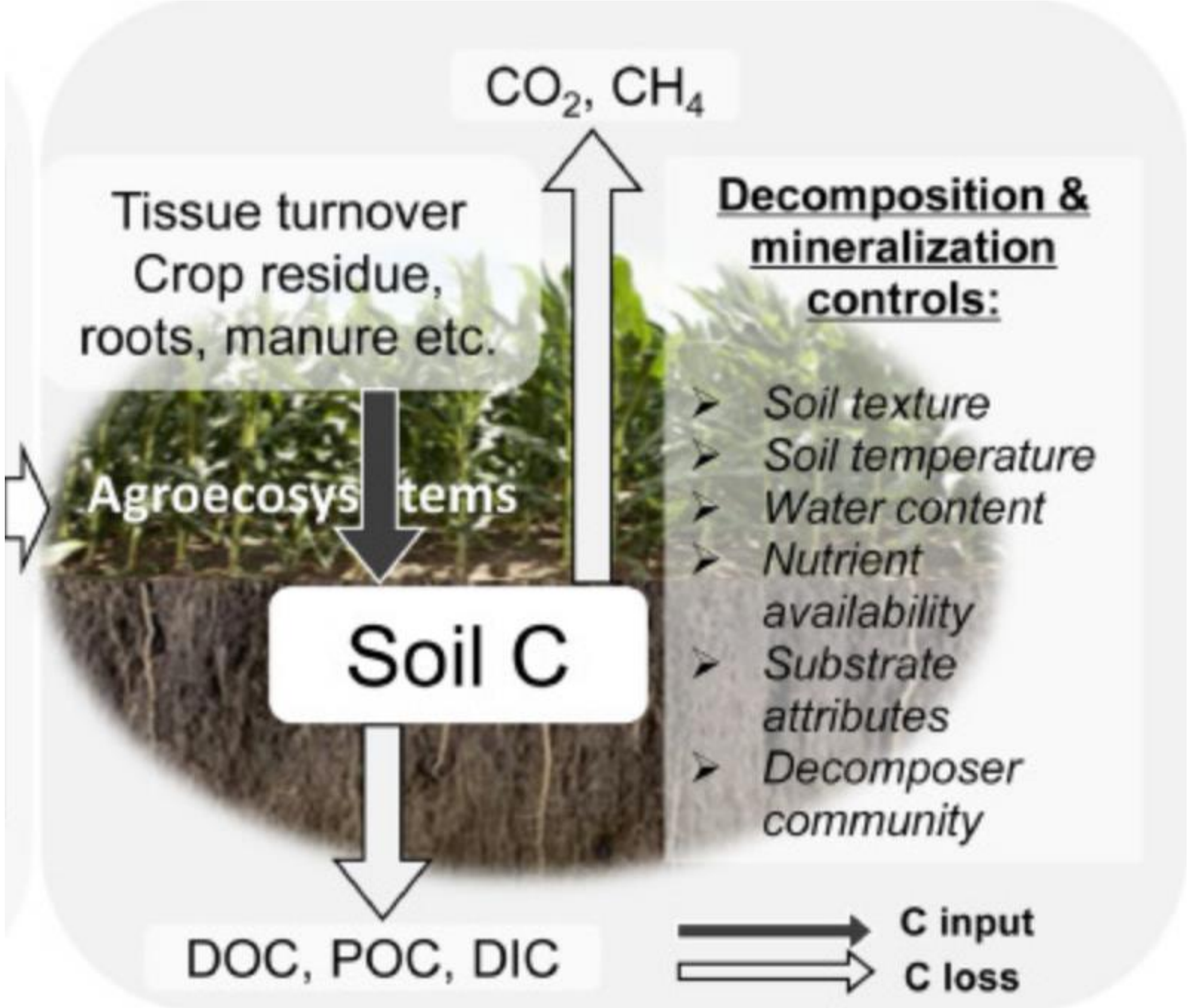
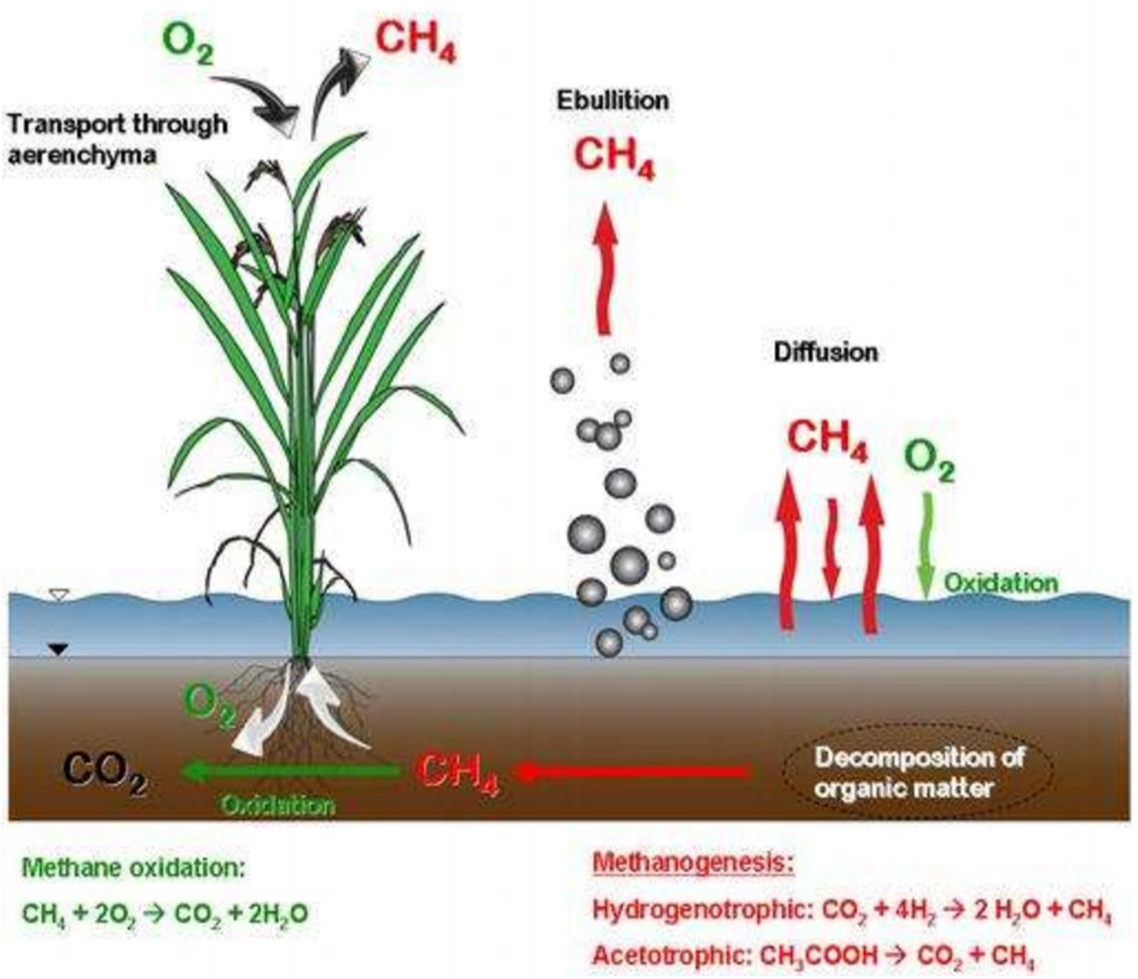
背景介绍

农田生态系统碳循环



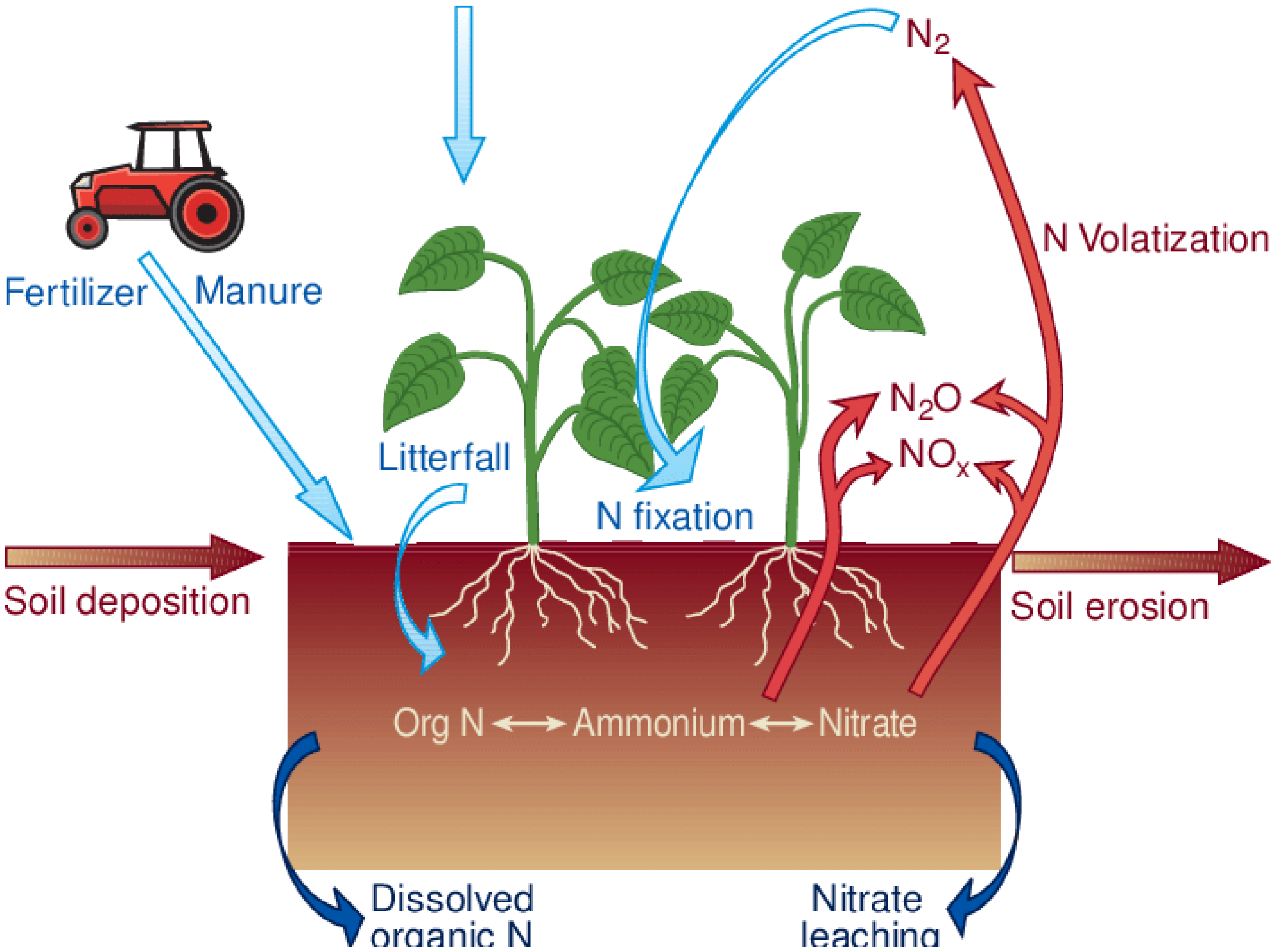
背景介绍

稻田甲烷排放过程



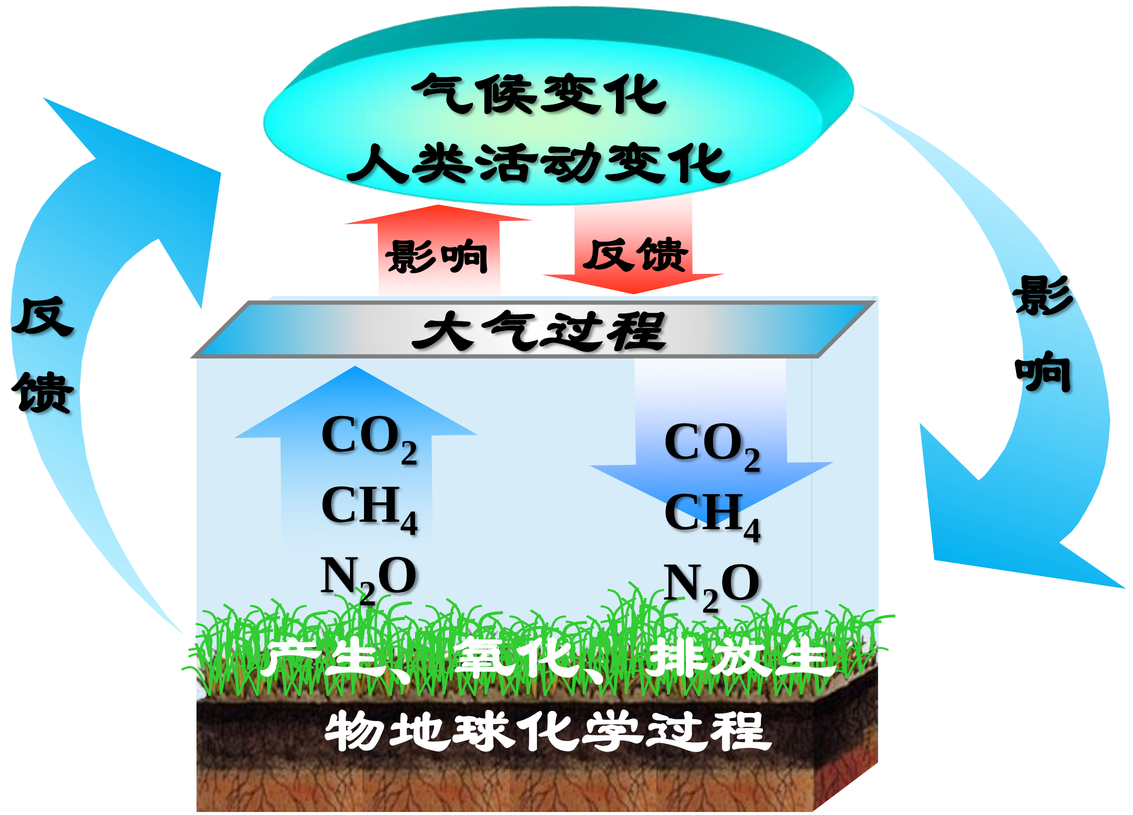
背景介绍

农田生态系统氮循环



背景介绍

农田温室气体排放和气候变化之间相互反馈



背景介绍

陆地生物地球化学分系统：农田生态系统碳氮循环过程

02 模式原理

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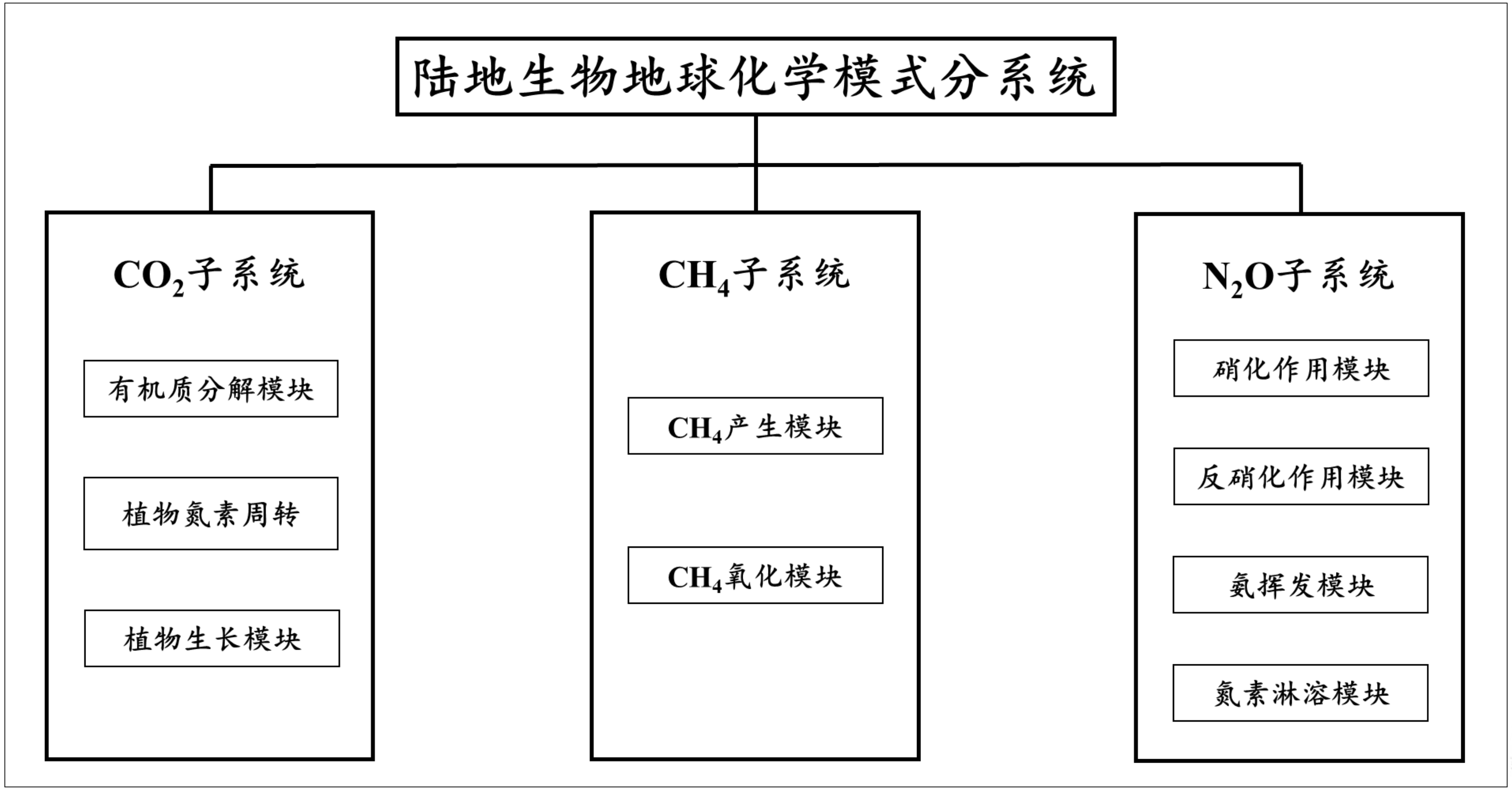
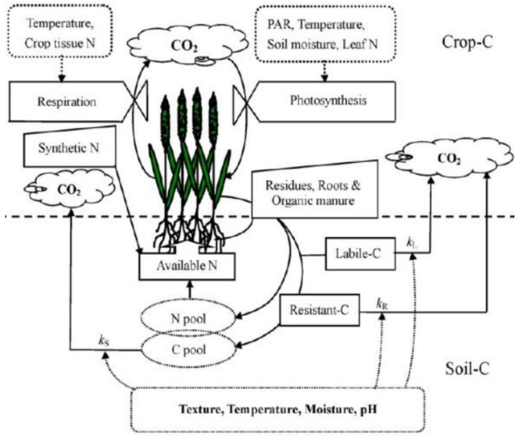
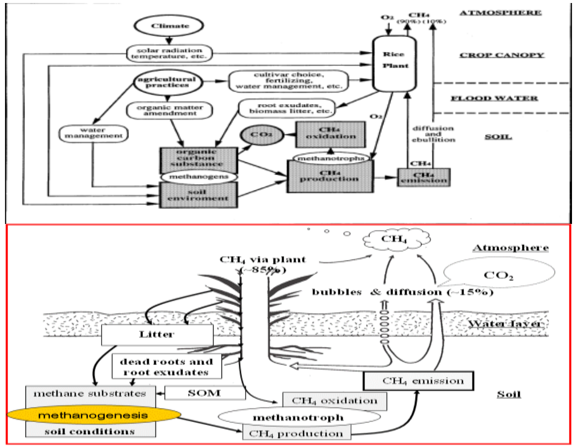
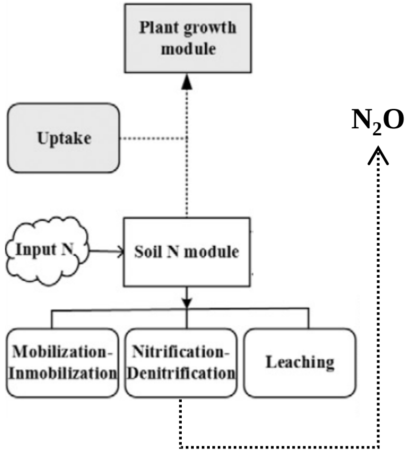
模式原理


陆地生物地球化学模式分系统
CO_2子系统
有机质分解模块
植物氮素周转
植物生长模块
CH_4子系统
CH_4产生模块
CH_4氧化模块
N_2O子系统
硝化作用模块
反硝化作用模块
氨挥发模块
氮素淋溶模块

模式原理





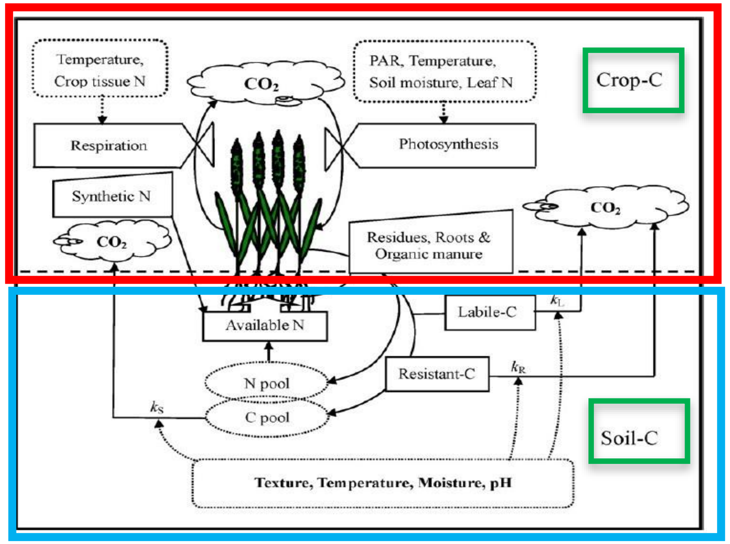


- ✓ CO2CROPLAND
- ✓ AGRICULTURE
- ✓ DEFINE
- ✓ CROPINI
- ✓ COMMON
- ✓ GROWTH
- ✓ NITROGEN
- ✓ PHENOLOGY
- ✓ SOILR

- ✓ CH4RICE
- ✓ CH4WETLAND
- ✓ COMPUTECLSHOOTANA
- ✓ RICEGROW
- ✓ COMPUTETI
- ✓ COMPUTEEHINDEX
- ✓ FCP
- ✓ COMPUTECOM
- ✓ COMPUTEP
- ✓ COMPUTEEBUBBLE
- ✓ COMPUTEEPLANT

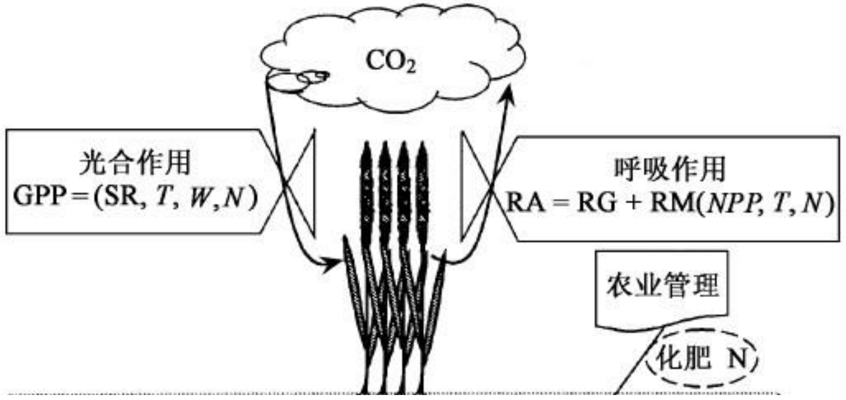
- ✓ NTRANSFORMATIONS
  - NITRIFICATION
  - DENITRIFICATION
  - VOLATILIZATION
  - PHDYNAMIC
- ✓ NLEACHING
- ✓ LITTERSOMDYNAMICS
- ✓ NUPTAKE

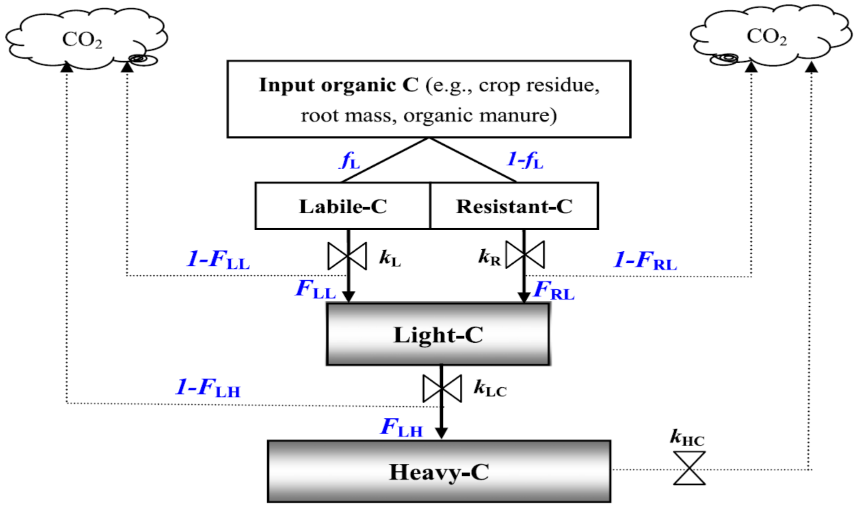
CO2子系统



Agro-C模型结构图

(Huang, *et al.*, 2009)





Soil-C子模型结构图 (Yu et al., 2012)

子系统核心模块

1）CO2CROPLAND

2）AGRICULTURE

3）DEFINE

4） CROPINI

5）COMMON

6）GROWTH

7）NITROGEN

8）PHENOLOGY

9）SOILR

CO2CROPLAND

CO2CROPLAND的功能是与陆面模式分系统耦合，调用陆面模式分系统中的气象和土壤数据，并将其转化为能够驱动CO2子系统的数据。

调用的变量为：气温、辐射、大气CO2浓度、40cm深度的土壤温度、土壤湿度、土壤沙粒含量、粘粒含量，后期陆面模式分系统中还将加入土壤容重和PH,也将作为CO2CROPLAND调用的变量。

除上述驱动数据外CO2CROPLAND还读入一个参数文件，用于提供农田生态系统的人为管理方式，包括农田土壤有机碳初值，外源有机碳添加，各种肥料比例，易分解、难分解组分比例，作物的生育期，作物品种，轮作等信息。CO2CROPLAND作为一个模块在陆面过程分系统中的CLMMAIN.F90中进行调用。

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AGRICULTURE

AGRICULTURE模块的功能为各种农田生态系统过程模块的集成、接收农业数据，并输出所需变量。它在CO2CROPLAND中进行调用，并调用其他所有模块。

DEFINE

DEFINE模块的功能为定义CO2子系统中的所有变量。

CROPINI

CROPINI模块的功能是农作物参数的初始化。共设置了冬小麦、春小麦、早稻、中稻、晚稻、北方春玉米、南方春玉米、北方夏玉米、南方夏玉米、冬油菜、春油菜、大豆、棉花、新疆棉花共14中农作物类型，15个参数需初始化。

COMMON

COMMON模块的功能是计算各类环境因子对农作物生长过程的影响。

$$P_i = \frac{PM_i \times \overline{PAR_i}}{\beta + \overline{PAR_i}} \times f(T_i) \times f(W_i) \times f(CO_2)$$

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COMMON

$$f(T_i)=\begin{cases}0 & \text{for } Td_i < T_L \text{ or } Td_i > T_U\\ \left(\frac{Td_i - T_L}{T_O - T_L}\right)^{(1+M)} \times \left(\frac{T_U - Td_i}{T_U - T_O}\right)^{(1-M)} & \text{for } T_L \le Td_i \le T_U\end{cases}$$

$$f(W_i)=\begin{cases}0 & W_i \le W_p\\ \frac{W_i - W_p}{W_l - W_p} & W_p < W_i < W_l\\ 1 & W_l \le W_i < W_u\\ 0.5 \times \left(1 + \frac{W_i - 1}{W_u - 1}\right) & W_i \ge W_u\end{cases}$$

$$f(CO_2) = 1 + B \ln\left(\frac{C_y}{C_0}\right)$$

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GROWTH

GROWTH模块的功能是模拟农作物的生长过程。在该模块中计算农作物的光合作用、呼吸作用，并调用COMMON模块中的环境影响因子。

光合作用

$$GPP_i = 0.0432 \times P_i \times DL_i$$

$$P_i = \frac{PM_i \times \overline{PAR_i}}{\beta + \overline{PAR_i}} \times f(T_i) \times f(W_i) \times f(CO_2)$$

呼吸作用

$$RA_i = RG_i + RM_i$$

$$RG_i = Rg \times GPP_i$$

$$RM_i = 0.0432 \times 24 \times Rm_i \times Q_{10}^{(Tai-25)/10} \times \sum_i \frac{GPP_{i-1} - RA_{i-1}}{0.45}$$

$$Rm_i = (4.74 \times N_{i-1} - 1.45) \times 10^{-3}$$

NITROGEN

NITROGEN模块的功能是模拟植物氮素的周转过程，如化肥氮素的吸收和矿化，土壤氮素的吸收和矿化。

$$\Delta N_{uptakei} = Min(\Delta NA_i, \Delta ND_i)$$

$$\Delta NA_i = \Delta NS_i + \Delta NF_i$$

$$\Delta NS_i = 2.4\times10^{-4}\times\frac{W_i}{W_0}\times2^{(T_{si}-10)/10}\times(1-0.356\times Clay)\times TN$$ ($W_i=W_0$ if $W_i>W_0$)

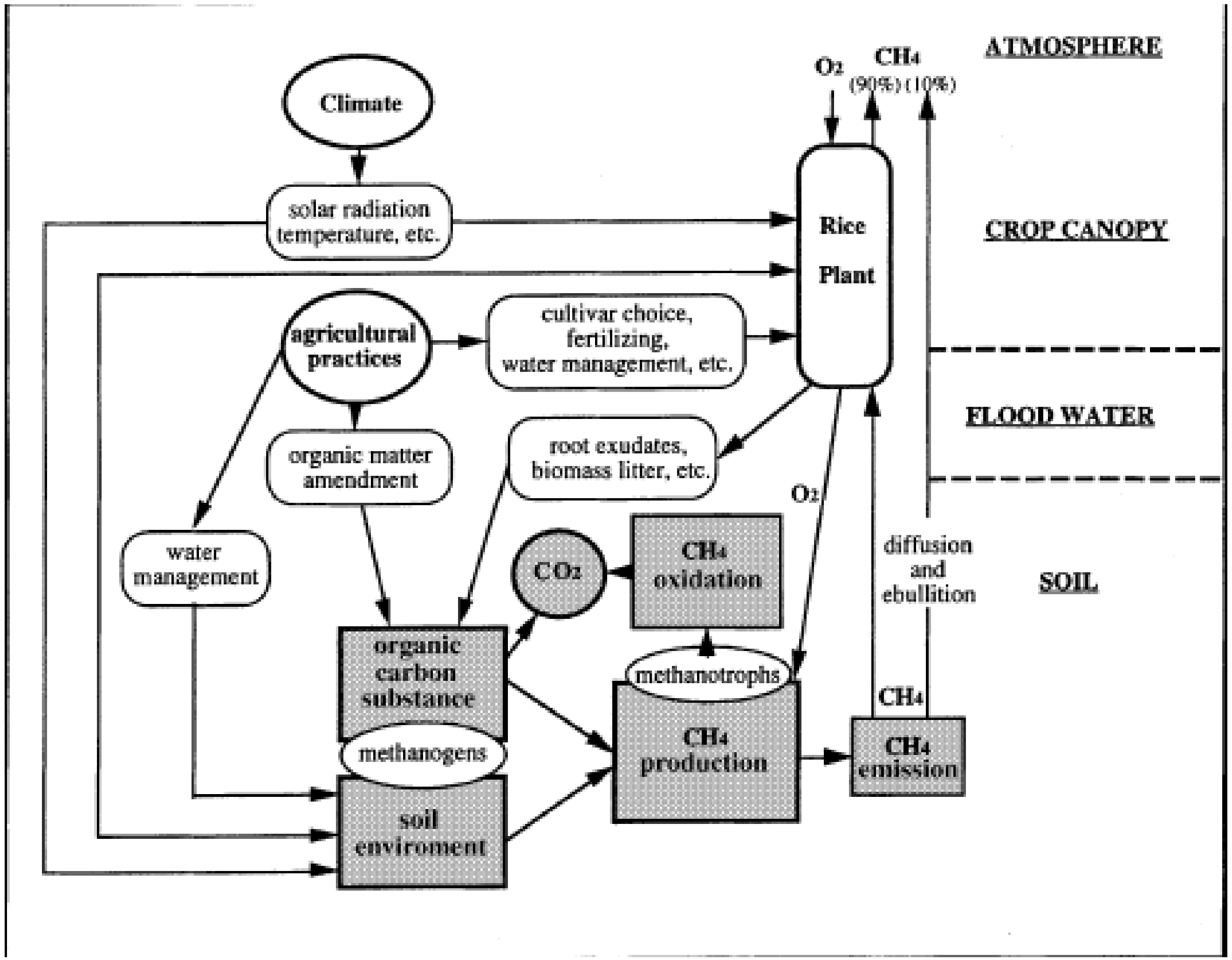
$$\Delta NF_i = 2.4\times10^{-4}\times\frac{W_i}{W_0}\times2^{(T_{si}-10)/10}\times(E_{NF}\times N_F-\sum_{j=0}^{i-1}\Delta NF_j)$$ ($W_i=W_0$ if $W_i>W_0$)

$T_{si} = 4.4 + 0.76T_{ai}$，$T_{ai}$为日平均气温，$T_{si}$为日土壤温度。

$$E_{NF} = 144.1\times N_F^{-0.27}$$

$$\Delta ND_i = \begin{cases} r_N\times NW_i(for: NW_i < 3.5gm^{-2}, and, i\le DT) \\ Min[\Delta ND_{\max}, F\times(GPP_i - RA_i)](for: NW_i \ge 3.5gm^{-2}, and, i > DT) \end{cases}$$

稻田甲烷子系统结构


ATMOSPHERE
CROP CANOPY
FLOOD WATER
SOIL
O2
CH4
(90%) (10%)
Climate
solar radiation
temperature, etc.
Rice
Plant
agricultural
practices
cultivar choice,
fertilizing,
water management, etc.
organic matter
amendment
root exudates,
biomass litter, etc.
water
management
CO2
CH4
oxidation
diffusion
and
ebullition
organic
carbon
substance
methanotrophs
methanogens
CH4
production
CH4
emission
soil
enviroment

稻田甲烷子系统核心模块

- ✓ CH4RICE
- ✓ RICEGROW
- ✓ COMPUTETI
- ✓ COMPUTEEHINDEX
- ✓ FCP
- ✓ COMPUTECOM
- ✓ COMPUTEP
- ✓ COMPUTEEBUBBLE
- ✓ COMPUTEEPLANT

CH4RICE

CH4RICE模块的主要功能是与陆面模式分系统耦合，模拟稻田甲烷产生、氧化和排放过程。CH4RICE调用陆面模式分系统中的25cm深度土壤温度作为模拟稻田甲烷过程的驱动数据。除土壤温度外，CH4RICE还读入一个参数文件（Par.txt），用于提供模拟稻田甲烷所需的其他参数数据，包括轮作信息、水稻产量、水稻移栽和收获日期、外源有机质添加量以及灌溉方式。CH4RICE作为一个模块在陆面过程分系统中的CLMMAIN.F90中进行调用。

RICEGROW

两种方式用于模拟水稻生长过程

1、采用Logistic方程实现水稻生长过程的模拟（需输入实测水稻产量用于计算W_{max}）：

Rice growing

$$W=W_{max}/(1+B_0\times exp(-r\times t))$$

2、CO_2子系统输出水稻的生物量。

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产甲烷模块

FCP & COMPUTECOM：

Substrates of methanogenesis

$$C_{OM} = 0.65 \times SI \times TI \times (k \times OM)$$

$$C_R = \beta_0 \times W^{\beta 1}$$

CH$_4$ production

$$P = 0.27 \times F_{Eh} \times (TI \times C_R + C_{OM})$$

环境影响因子模块

COMPUTETI
& COMPUTEEHINDEX
& SINDEX：

$$SI = 0.325 + 0.0225 \times Sand$$

$$TI = Q_{10}^{(T_{soil}-30)/10}$$

$$F_{Eh} = e^{\left(-1.7\times\left(1+\frac{Eh}{150}\right)\right)}$$

Changing in soil Eh regulated by irrigation

$$Eh_{t+1} = Eh_t - f_{BI} \times D_{Eh} \times f_{OM} \times (Eh_t - Eh_B)$$

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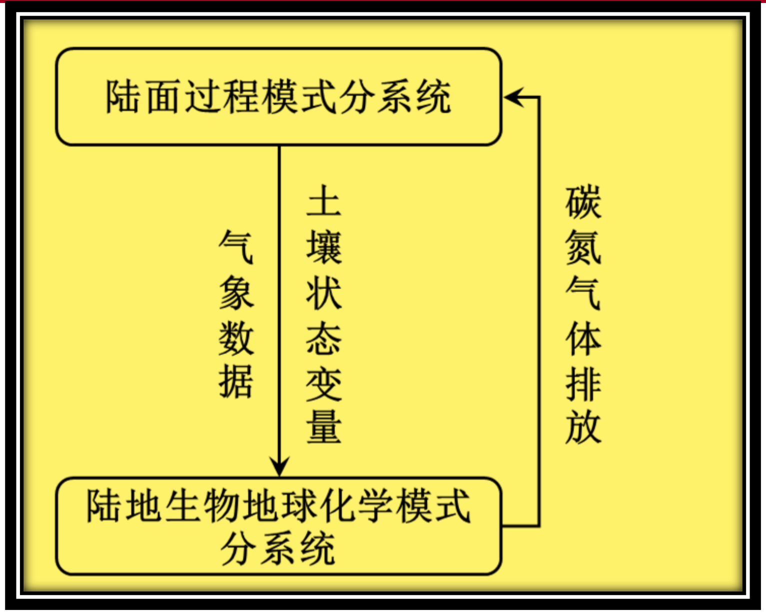
甲烷排放模块

COMPUTEP
& COMPUTEEBUBBLE
& COMPUTEEPLANT：

CH_4 emission via rice	CH_4 emission via bubbles
$E_p = P \times 0.55 \times (1 - W/W_{max})^{\beta 2}$	$E_b = 0.7 \times (P - P_0) \times ln(T_{soil})/W_r$

N2O子系统结构



N_2O子系统依托**COLM2014的北京师范大学（BNU）**版本的动态全球植被模型的结构，在原有的**DYN**模块上进行了扩展。

- 模拟所有的土层；
- 模拟土壤有机质矿化、**铵态氮硝化**、**硝态氮反硝化**、**氨气挥发**、**硝态氮垂直土层迁移**、植物氮素吸收、**土壤pH值动态变化**等生态过程；
- 所有模拟过程的**时间步长和空间离散**与COLM2014一致。

N2O子系统新增变量

新增变量被定义在两个数据类型中type cvar_type（计算用）和 type fldv_dgvm_type（平均及输出用），见colm_varMod.F90。

计算
➢ soil_pH_Origin – 土层原始pH值
➢ soil_pH – 土层动态pH值
➢ soil_NH3 – 土层动态NH_3含量
➢ soil_NH4 – 土层动态NH_4^+含量
➢ soil_NO2 – 土层动态NO_2^-含量
➢ soil_NO3 – 土层动态NO_3^-含量
➢ soil_NO – 土层动态NO含量
➢ soil_N2O – 土层动态N_2O含量
➢ soil_N2 – 土层动态N_2含量

平均及输出
➢ NH3_inc – 单位时间步长的NH_3通量
➢ NO_inc – 单位时间步长的NO通量
➢ N2O_inc – 单位时间步长的N_2O通量
➢ N2_inc – 单位时间步长的N_2通量
➢ NH3_acc – NH_3累积通量
➢ NO_acc – NO累积通量
➢ N2O_acc – N_2O累积通量
➢ N2_acc – N2累积通量

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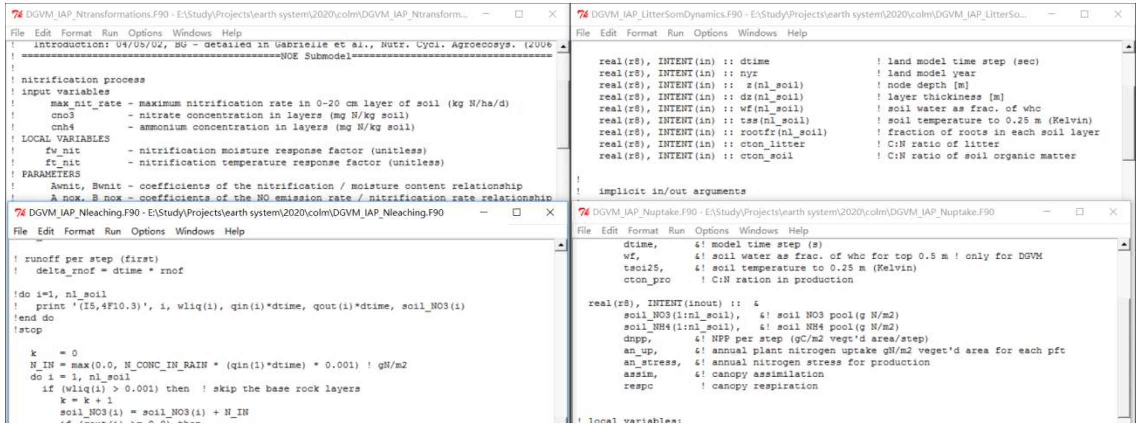
N2O子系统核心模块

在COLM14中，DGVM_IAP_GBC共有4个模块

- **DGVM_IAP_NTRANSFORMATIONS（氮转化）**
- **DGVM_IAP_NLEACHING（氮淋溶）**
- **DGVM_IAP_LITTERSOMDYNAMICS（凋落物动态）**
- **DGVM_IAP_NUPTAKE（氮吸收）**



N2O子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

- 硝化作用
- 反硝化作用
- 氨挥发
- 铵离子吸附

N2O子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

- **硝化作用**

第一步：

NO，N_2O

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

温度

第二步：

NO，N_2O

$$NO_2^- + 0.5O_2 \rightarrow NO_3^-$$

温度和水分

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N2O子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

- **硝化作用**

硝化速率

$$r_{nit} = r_{nit_{\max}} \cdot f_{W_{nit}} \cdot f_{T_{nit}} \cdot f_{NH_{4nit}}$$

$$f_{T_{nit}} = e^{\frac{T_{soil}-20}{10}\cdot \log(2.1)}$$

$$f_{W_{nit}} = \begin{cases} Anit \cdot wfps + Bnit & 0.1 < wfps \le 0.6 \\ (Anit \cdot 0.6 \cdot \frac{\phi}{BD} + Bnit) \cdot \frac{(0.8 - wfps)}{0.15} & 0.6 < wfps < 0.8 \\ 0.001 & else \end{cases}$$

$$f_{NH_{4nit}} = \frac{C_{NH_4}}{10 + C_{NH_4}}$$

NO产生量

$$r_{nit\_no} = \min\left\{ r_{nit},\ P_{nox} \cdot e^{-0.5\cdot\left(\frac{wfps-A_{nox}}{B_{nox}}\right)^2} \cdot f_{T_{nit}} \cdot \sqrt{f_{depth}} \right\}$$

$$f_{depth} = e^{-20\cdot depth}$$

N_2O产生量

$$r_{nit\_n_2o} = r_{nit} \cdot fr_{nit\_n_2o} \cdot f_{depth}$$

N20子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

➤ **反硝化作用**

$$2(CH_2O) + NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$$

反硝化速率

$$r_{denit} = \begin{cases} 0 & wfps < wfps_{denit} \\ r_{denit_{max}} \cdot f_{W_{denit}} \cdot f_{T_{denit}} \cdot f_{NO_{3nit}} & wfps \geq wfps_{denit} \end{cases}$$

$$f_{W_{denit}} = \max\left[0, \left(\frac{wfps - wfps_{denit}}{0.38}\right)^{1.74}\right]$$

$$f_{T_{denit}} = \begin{cases} exp\left[\left(\frac{T_{soil} - 11}{10}\right) \cdot log(89) - 0.9 \cdot log(2.1)\right] & T_{soil} < 11 \\ exp\left[\left(\frac{T_{soil} - 20}{10}\right) \cdot log(2.1)\right] & T_{soil} \geq 11 \end{cases}$$

$$f_{NO_{3denit}} = \frac{C_{NO_3}}{22 + C_{NO_3}}$$

N_2O产生量

$$r_{denit\_n_2o} = \begin{cases} r_{denit} \cdot fr_{denit\_sat} & wfps \geq 1 \\ r_{denit} \cdot fr_{denit\_unsat} \cdot \sqrt{f_{depth}} & wfps < 1 \end{cases}$$

N_2产生量

$$r_{denit\_n2} = r_{denit} - r_{denit\_n2o}$$

N2O子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

- 氨挥发

$$NH_4^+ + OH^- \rightleftharpoons NH_3 + H_2O$$

水相NH_3浓度

$$NH_{3aq} = \frac{NH_4^+ + NH_3}{1 + 10^{0.09018 + \frac{2729.92}{T_{soil} + 273.15} - pH}}$$

NH_3挥发量

$$r_{NH_3} = CR_{NH_3} \cdot NH_{3aq} \cdot f_{T_{NH_3}} \cdot e^{-50 \cdot depth}$$

$$f_{T_{NH_3}} = 0.25 \cdot e^{0.0693 \cdot T_{soil}}$$

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N20子系统核心模块

DGVM_IAP_NTRANSFORMATIONS（氮转化）

- **土壤pH动态**

硝化、反硝化和氨挥发都会导致土壤pH的变化。

硝化作用引起pH的降低

$$\Delta pH_{nit} = -pH_{response} \cdot \frac{2}{14} \cdot \frac{r_{nit}}{10000 \cdot (\theta \cdot dg)}$$

反硝化作用引起pH的升高

$$\Delta pH_{denit} = pH_{response} \cdot \frac{1}{14} \cdot \frac{r_{denit}}{10000 \cdot (\theta \cdot dg)}$$

氨挥发引起pH的降低

$$\Delta pH_{vol} = -pH_{response} \cdot \frac{1}{14} \cdot \frac{r_{NH_3}}{10000 \cdot (\theta \cdot dg)}$$

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N2O子系统核心模块

DGVM_IAP_NLEACHING（氮淋溶）

线性库容转移方程来描述氮素在土壤中的垂直移动

氮素淋溶量

$$r_{N_{Move}} = \frac{N_{in}}{k_{N_{Move}}} + \left(N - \frac{N_{in}}{k_{N_{Move}}}\right) \cdot \exp(-k_{N_{Move}})$$

氮素移动系数

$$k_{N_{Move}} = \frac{(SW_{max})^{\frac{2}{3}} \cdot \sqrt{q}}{R_N \cdot dg \cdot \exp(-4.0 \cdot Clay)}$$

N2O子系统核心模块

DGVM_IAP_LITTERSOMDYNAMICS（凋落物动态）

引进了两个参数cton_litter和cton_soil，在CLMMAIN模块调用时采用的是分层土壤变量和氮素数据。

- cton_litter：计算地下枯枝落叶分解和氨化
- cton_soil： 计算土壤有机质分土层分解和氨化

N2O子系统核心模块

DGVM_IAP_NUPTAKE（氮吸收）

- 更改了**分层信息**，使得新模块的植物能分层吸收土壤铵态氮和硝态氮，吸收方式是基于**对流的宏吸收**。

- 目前，还没有考虑根系在土壤中的空间变异分布以影响对养分的吸收差异。

N2O子系统其它模块

- CLMDRIVER.F90
- CLMMAIN.F90
- colm_varMod.F90
- colmInit.F90
- DGVMtimevar.F90
- Fluxav.F90
- iniDGVMvar.F90
- iniTimeConst.F90
- iniTimeVar.F90
- nchistmod.F90
- soilwater.F90

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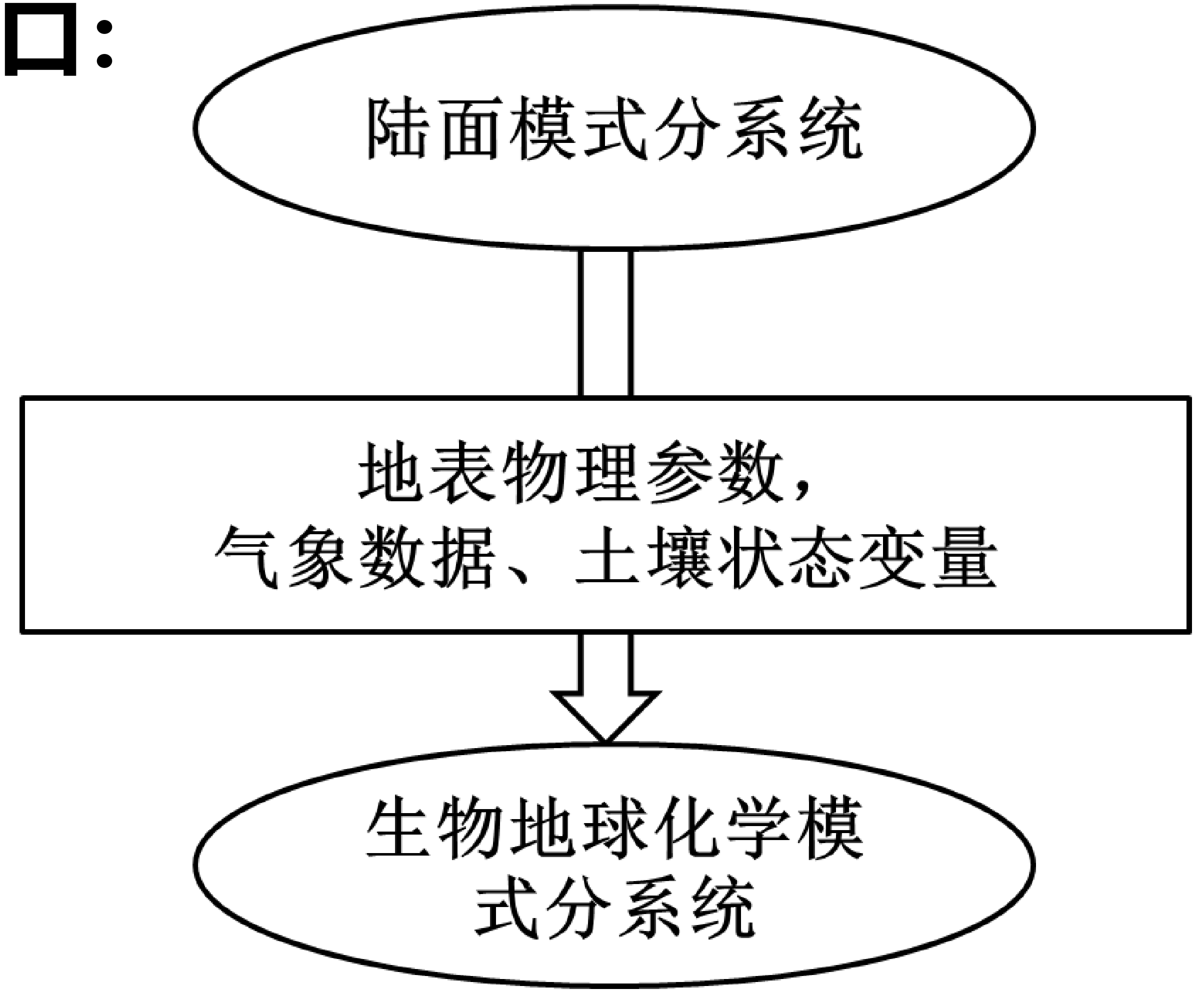
输入输出子系统功能简介

为陆地生化分系统和陆面过程分系统之间提供接口：



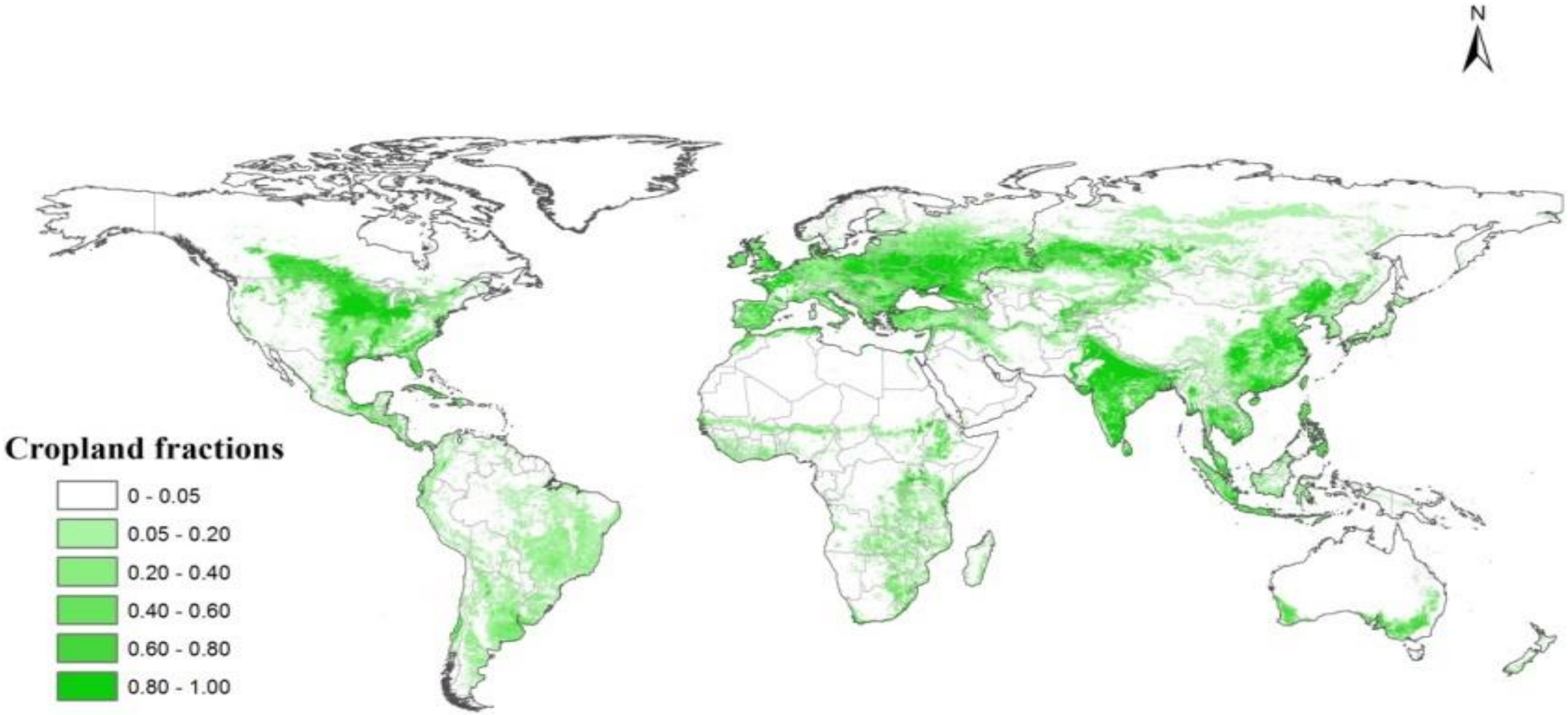
输入输出子系统功能简介

为陆地生化分系统和陆面过程分系统之间提供接口：

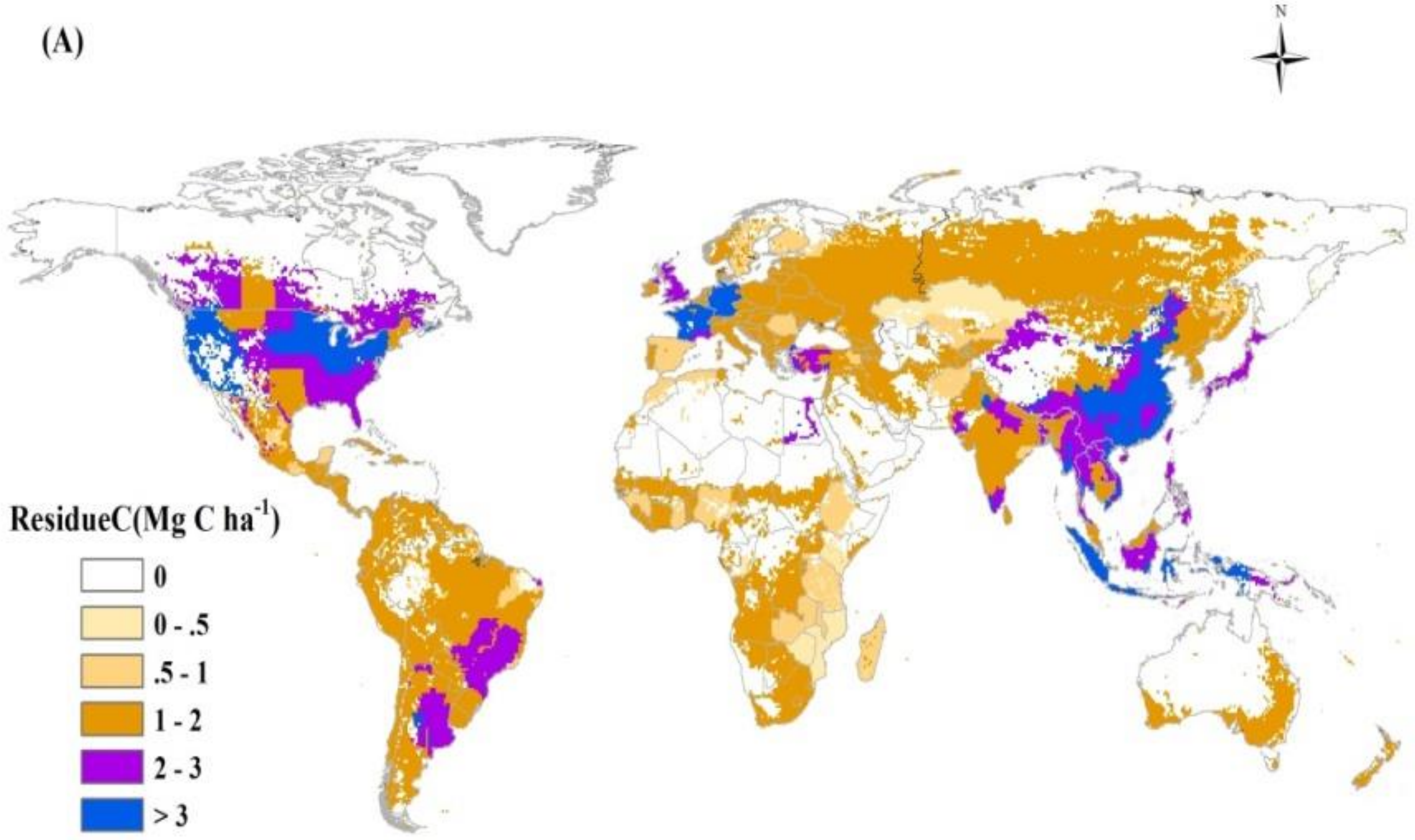
气象数据	
气温、降水、辐射	陆面模式分系统提供
土壤数据	
土壤温度、土壤湿度	陆面模式分系统提供
土壤碳氮含量	陆面模式分系统提供
土壤质地	陆面模式分系统提供

03 数据制备

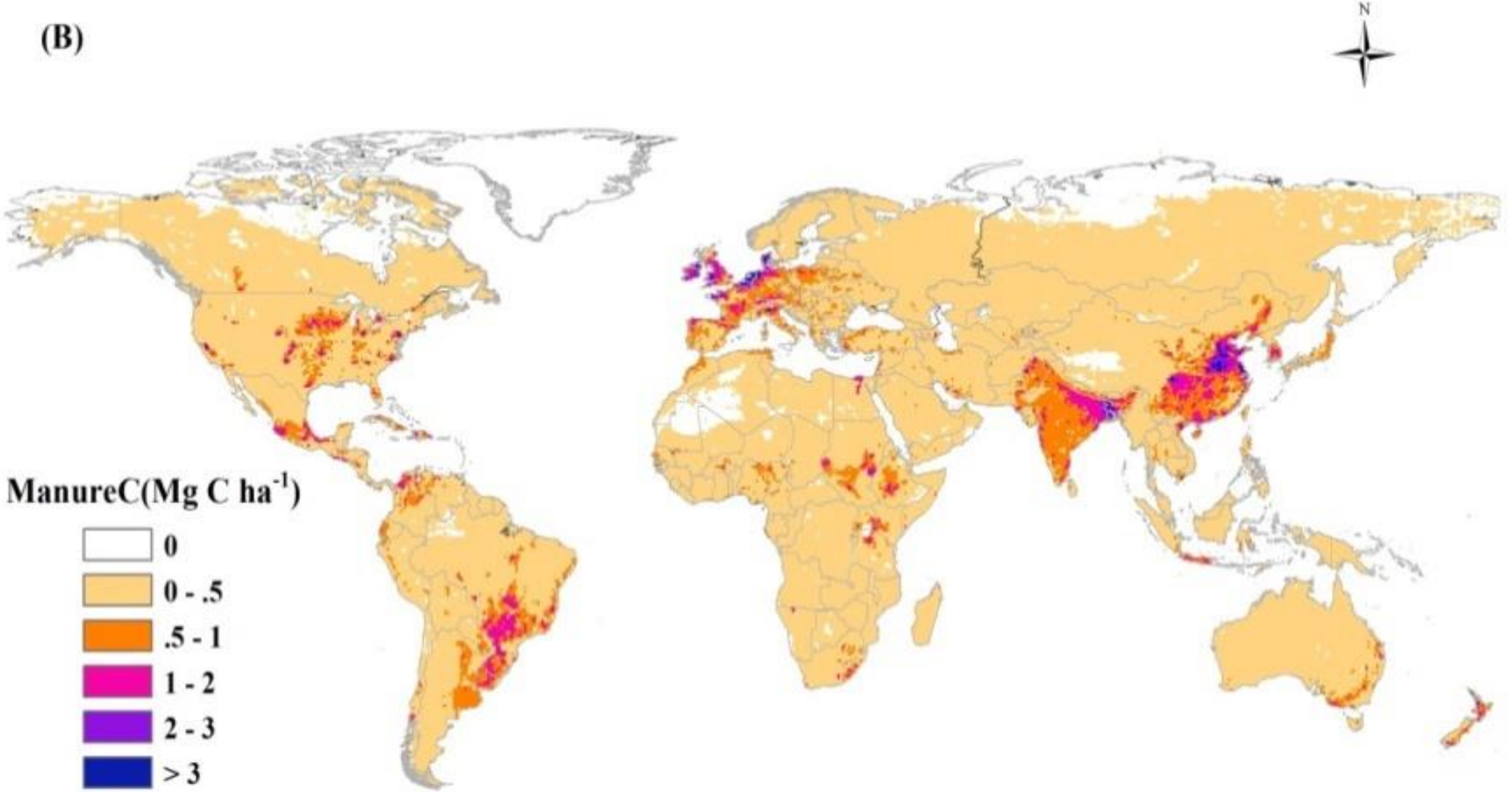
农田驱动数据制备


N
Cropland fractions
0 - 0.05
0.05 - 0.20
0.20 - 0.40
0.40 - 0.60
0.60 - 0.80
0.80 - 1.00

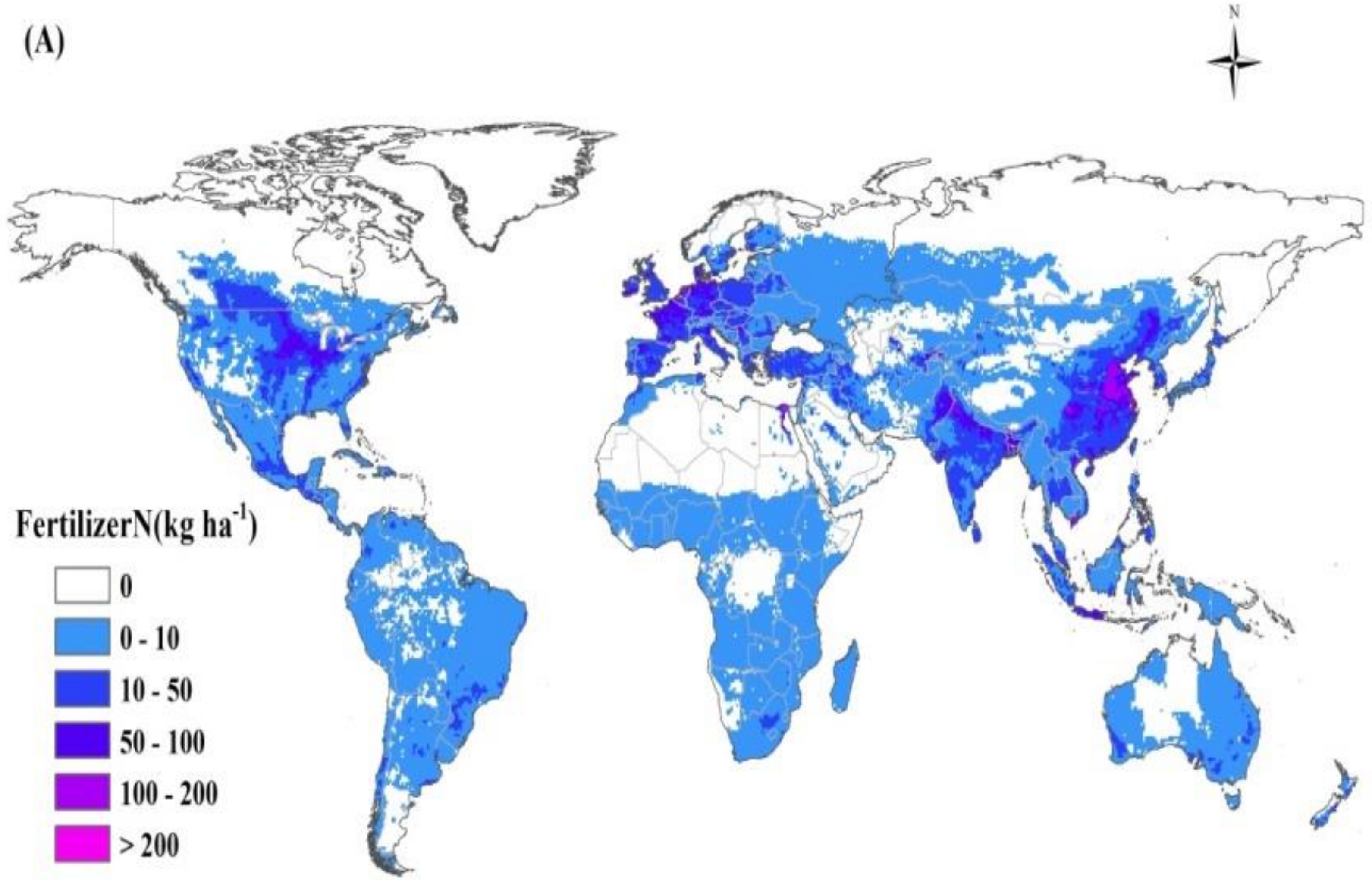
农田驱动数据制备



农田驱动数据制备



农田驱动数据制备



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04 结果诊断分析与应用案例

分系统运行案例1

案例1：

案例1名称	子系统碳氮循环功能测试	案例1标识	
案例1描述	该测试项包含了CO_2子系统和输入输出子系统部分指标； 选择2016.01.01至2016.12.31作为模拟时段，测试CO_2子系统碳循环模拟功能，和输入输出子系统输出CO2、CH4和N2O的功能。		
前提和约束（包括初始化要求）	1）准备2016年农业管理数据 2）农田土壤有机碳初始化至平衡状态		
测试输入	陆面模式提供驱动数据以及输入输出子系统读入的农田的管理数据库		
测试方法	1）读取输入数据，设置输入参数，提交模式计算，运行1年得到逐日输出结果，将逐日步长结果求和得到年尺度结果，画出全球尺度年温室气体净交换空间分布图。		
期望测试结果	1）水平分辨率和土壤垂直分辨率以及时间分辨率与陆面过程分系统保持一致； 2）核心过程：基于一阶动力学、米氏动力学、能斯特方程、“厌氧气球”模型等机理性较强的生物地球化学理论，模拟土壤碳氮生物地球化学循环过程，可以准确地模拟农田生态系统的CO2、CH4和N2O排放通量。		
评判准则	1.4°×1.4°分辨率程序正常运行，输出有意义全球尺度CH4,N2O和CO2的结果。		
测试终止条件	模式运行1年；或出现致命或者严重缺陷，异常终止。		

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分系统运行案例1

1、在/data/njxiaotian/cas-esm/scripts目录下，通过命令./create_newcase -case njxt_newcase1 -compset B1850C5XTLM -mach miyun_hhq -res fd14_licom3创建一个新算例njxt_newcase1。

分系统运行案例1

```
   If the user is interested in running a "stand-alone" component configuration,
   the following model configurations have been validated scientifically and
   have associated diagnostic output as part of the release:

      1.9x2.5_1.9x2.5     F_2000_WACCM
      1.9x2.5_1.9x2.5     F_AMIP_CAM5
      0.9x1.25_0.9x1.25   F_AMIP_CAM5
      1.9x2.5_1.9x2.5     F_AMIP_CN
      0.9x1.25_0.9x1.25   F_AMIP_CN

      0.9x1.25_gx1v6      I_2000
      0.9x1.25_gx1v6      I_2000_CN

      T62_gx1v6           C_NORMAL_YEAR

   For more information regarding alternative component configurations,
   please refer to the individual component web pages at
   http://www.cesm.ucar.edu/models/cesm1.0

-------------------------------------------------------------------------------
**********************************************************
Component set      : B_1850_CAM5X_TRI_LICOM (B1850C5XTLM)
Desc               : All active components, pre-industrial, cam5 physics
**********************************************************

Creating /data/njxiaotian/cas-esm/scripts/njxt_newcase1

Locking file /data/njxiaotian/cas-esm/scripts/njxt_newcase1/env_case.xml
Successfully created the case for miyun_hhq
[njxiaotian@login03 scripts]$
```

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分系统运行案例1

2、进入到njxt_newcase1目录下，编辑env_mach_pes.xml设置耦合模式及各分系统模式并行度

分系统运行案例1

```
<entry id="NTASKS_ATM"   value="128"  />
<entry id="NTHRDS_ATM"   value="1"  />
<entry id="ROOTPE_ATM"   value="0"  />

<entry id="NTASKS_WRF"   value="128"  />
<entry id="NTHRDS_WRF"   value="1"  />
<entry id="ROOTPE_WRF"   value="0"  />

<entry id="NTASKS_GEA"   value="128"  />
<entry id="NTHRDS_GEA"   value="1"  />
<entry id="ROOTPE_GEA"   value="0"  />

<entry id="NTASKS_SRD"   value="128"  />
<entry id="NTHRDS_SRD"   value="1"  />
<entry id="ROOTPE_SRD"   value="0"  />

<entry id="NTASKS_LND"   value="128"  />
<entry id="NTHRDS_LND"   value="1"  />
<entry id="ROOTPE_LND"   value="0"  />

<entry id="NTASKS_ICE"   value="120"  />
<entry id="NTHRDS_ICE"   value="1"  />
<entry id="ROOTPE_ICE"   value="0"  />

<entry id="NTASKS_OCN"   value="120"  />
<entry id="NTHRDS_OCN"   value="1"  />
<entry id="ROOTPE_OCN"   value="0"  />

<entry id="NTASKS_CPL"   value="128"  />
<entry id="NTHRDS_CPL"   value="1"  />
```

分系统运行案例1

3、执行./configure -case，生成编译配置文件

```
[njxiaotian@login03 allcouple_njxt]$ ./configure -case
Generating resolved namelist, prestage, and build scripts
cat: /data/njxiaotian/cas-esm/scripts/allcouple_njxt/Buildconf/colmconf/CESM_cppdefs: No such file or directory
configure done.
Successfully generated resolved namelist, prestage, and build scripts
Locking file env_conf.xml
Generating clean_build script
Generating submit script
Generating build script
Generating run script
Locking file env_mach_pes.xml
Successfully configured the case for miyun_hhq
If an old build exists for this case, you might want to
   run the *.clean_build script before building
[njxiaotian@login03 allcouple_njxt]$
```

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分系统运行案例1

4、执行 ./njxt_newcase1.miyun_hhq.build 进行编译

```
-------------------------------------------------------------------------
 CCSM BUILDEXE SCRIPT STARTING
 - Build Libraries: mct pio csm_share
Wed Sep 1 10:37:21 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/mct/mct.bldlog.210901-103716
Wed Sep 1 10:38:08 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/pio/pio.bldlog.210901-103716
Wed Sep 1 10:39:08 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/csm_share/csm_share.bldlog.210901-103716
Wed Sep 1 10:39:18 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/cpl.bldlog.210901-103716
Wed Sep 1 10:39:18 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/atm.bldlog.210901-103716
Wed Sep 1 10:40:23 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/wrf.bldlog.210901-103716
Wed Sep 1 10:40:23 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/gea.bldlog.210901-103716
Wed Sep 1 10:40:23 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/lnd.bldlog.210901-103716
Wed Sep 1 10:40:41 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/ice.bldlog.210901-103716
Wed Sep 1 10:42:04 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/ocn.bldlog.210901-103716
Wed Sep 1 10:42:40 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/glc.bldlog.210901-103716
Wed Sep 1 10:42:41 CST 2021 /data/njxiaotian/cas-esm/run/njxt_newcase1/run/ccsm.bldlog.210901-103716
 - Locking file env_build.xml
 - Locking file Macros.miyun_hhq
 CCSM BUILDEXE SCRIPT HAS FINISHED SUCCESSFULLY
```

分系统运行案例1

5、进入到/data/njxiaotian/cas-esm/run/njxt_newcase1/run目录下，设置模拟时长，在drv_in文件中修改stop_n为365天，然后提交作业sbatch run.slurm

```
/
&seq_timemgr_inparm
  calendar       = 'NO_LEAP'
  gea_cpl_dt     = 21600
  atm_cpl_dt     = 1800
  lnd_cpl_dt     = 1800
  ocn_cpl_dt     = 86400
  ice_cpl_dt     = 1800
  glc_cpl_dt     = 86400
  start_ymd      =  20160101
  start_tod      = 0
  stop_option    ='ndays'
  stop_n         = 365
  stop_ymd       = -999
  restart_option ='ndays'
  restart_n      = 5
  restart_ymd    = -999
  end_restart    = .false.
  history_option ='never'
  history_n      = -999
  history_ymd    = -999
  histavg_option ='never'
  histavg_n      = -999
  histavg_ymd    = -999
  tprof_option   ='never'
  tprof_n        = -999
  tprof_ymd      = -999
/
"drv_in" 172L, 3890C
```

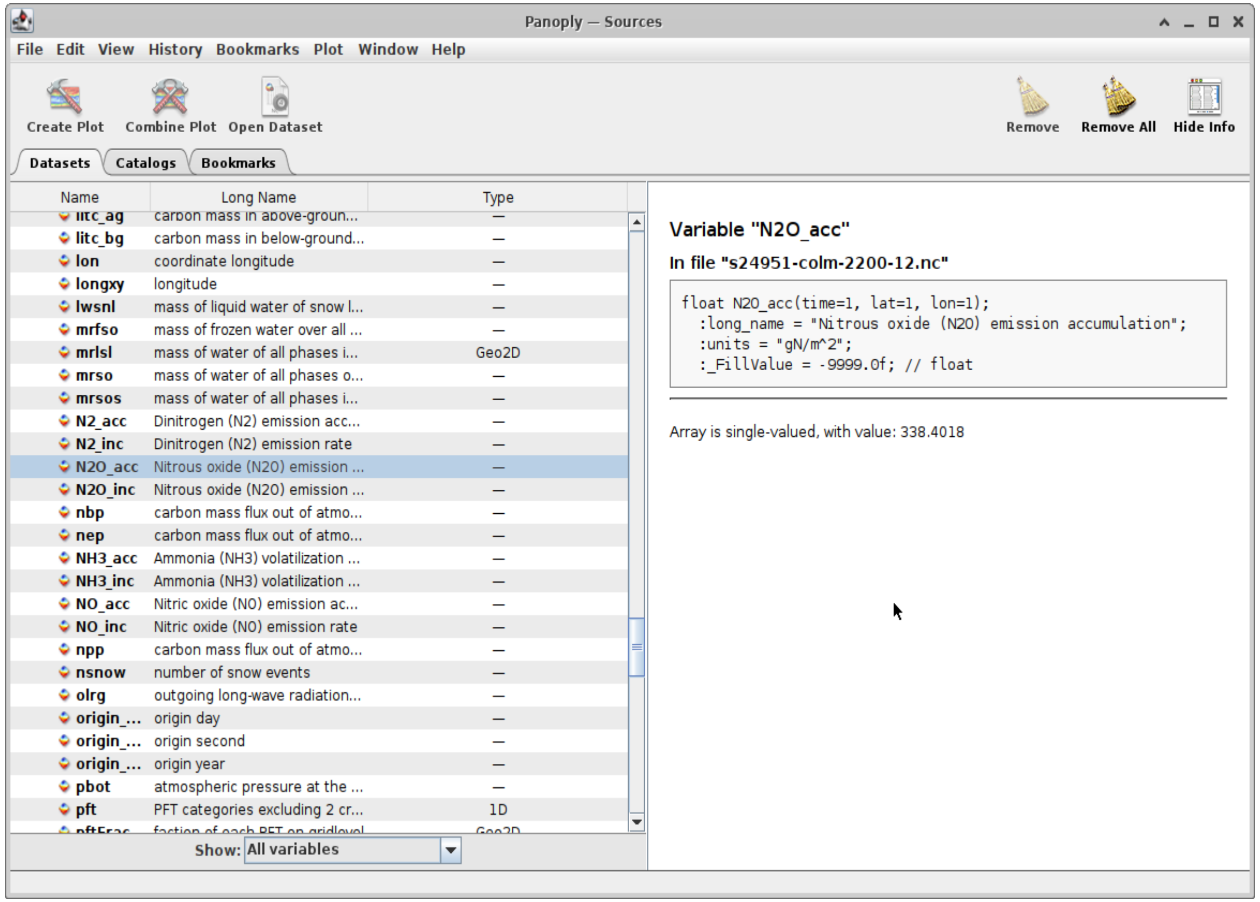
```
--------------------------------------------------------------
The run time is            1           1           1       10800
--------------- At the end of sub. dynpkg --------------------
UT(4,26,65) =  -2.04692028803491        T(4,26,65) =   292.298638422221
V(4,26,65) =  -1.81035938106094        ps(4,64,n3) =   100838.750947260
v3(4,26,64,n3) =    1.94861807701551
q3(4,26,1,64,n3) =   1.525349889463332E-002
q3(4,26,4,64,n3) =    521232.101361973
--------------------------------------------------------------
The run time is            1           1           1       12600
--------------- At the end of sub. dynpkg --------------------
UT(4,26,65) =  -1.16140840151072        T(4,26,65) =   292.156751775166
V(4,26,65) =  -1.39129074956549        ps(4,64,n3) =   100356.803803223
v3(4,26,64,n3) =    2.06749415129750
q3(4,26,1,64,n3) =   1.524523783193744E-002
q3(4,26,4,64,n3) =    648014.437281856
--------------------------------------------------------------
The run time is            1           1           1       14400
--------------- At the end of sub. dynpkg --------------------
UT(4,26,65) = -0.617248340626541        T(4,26,65) =   292.141891814617
V(4,26,65) =  -1.16459503220728        ps(4,64,n3) =   100873.224862884
v3(4,26,64,n3) =    1.66194163632074
q3(4,26,1,64,n3) =   1.520967941447796E-002
q3(4,26,4,64,n3) =    779183.257919356
--------------------------------------------------------------
```

分系统运行案例1

实际运行案例1展示

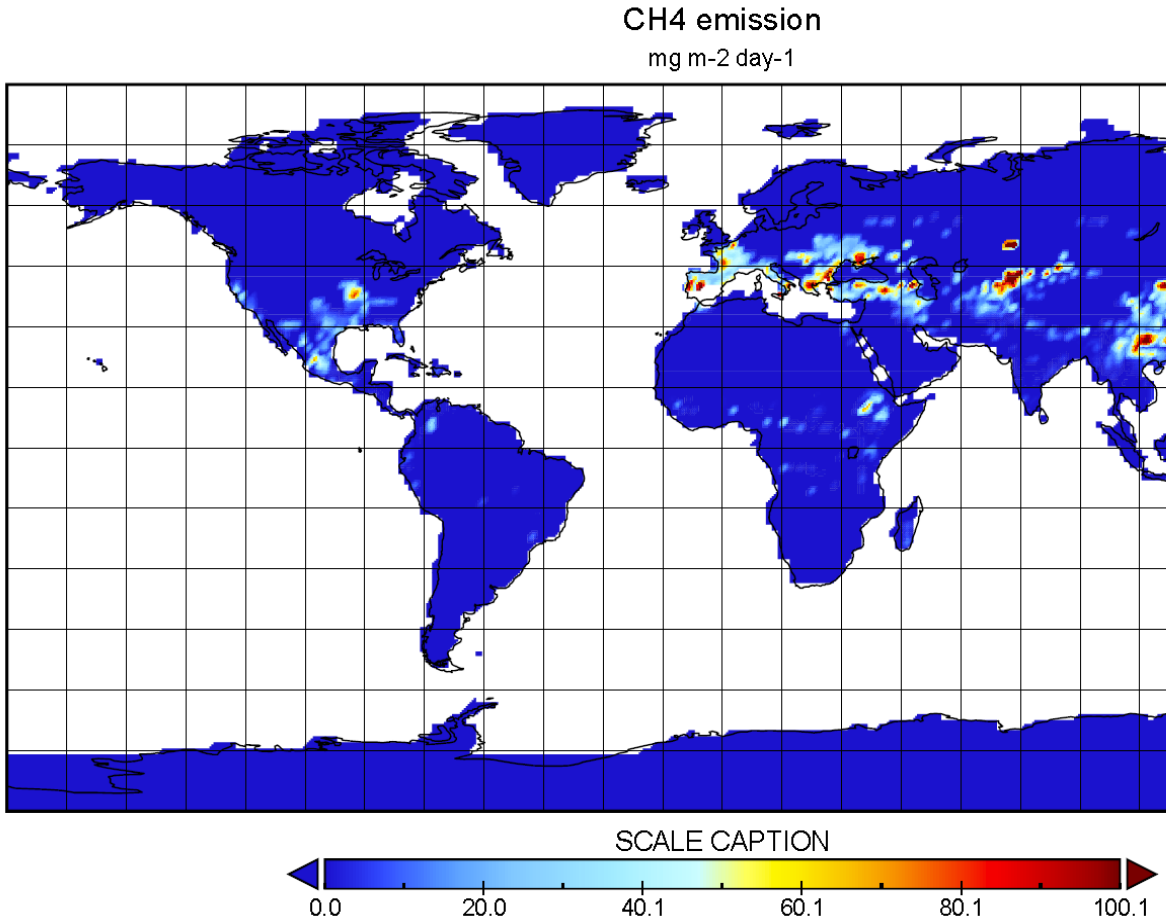
分系统运行案例1

输出结果：



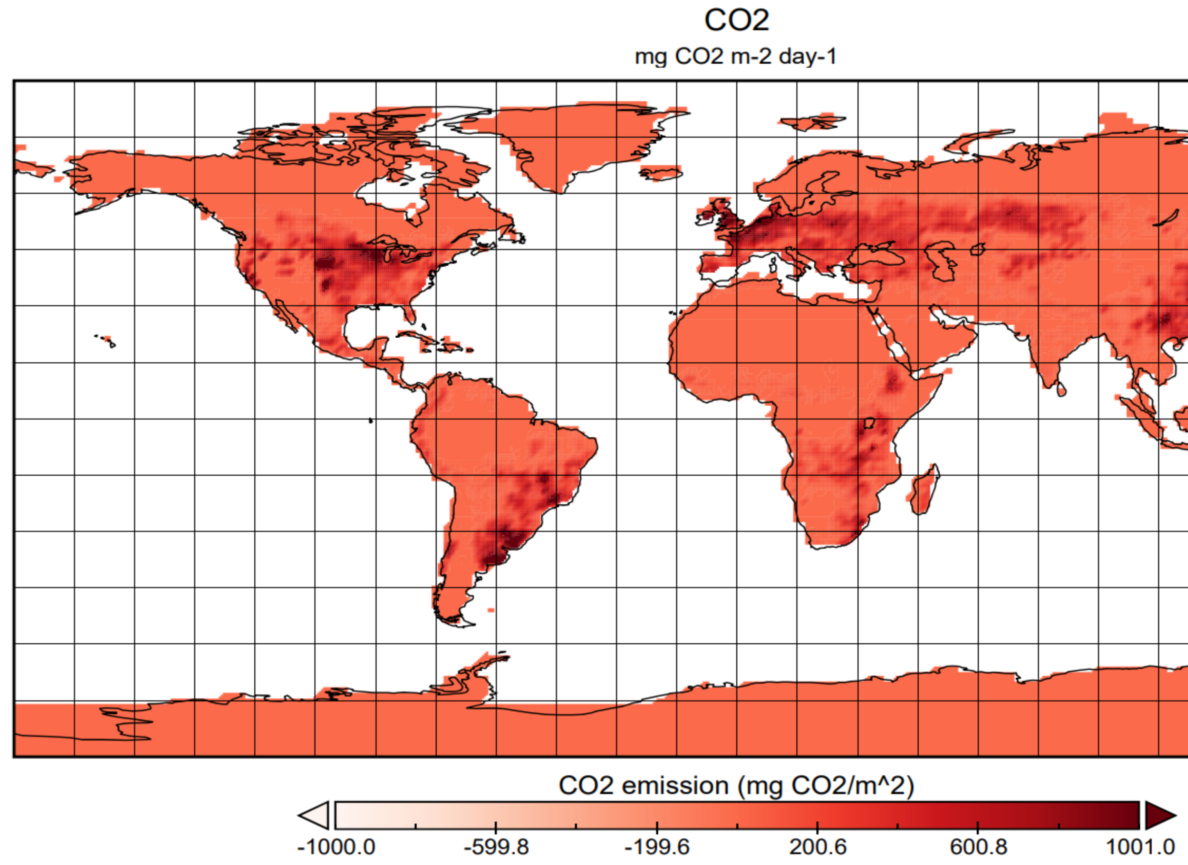
分系统运行案例1

案例结果展示：全球稻田甲烷排放通量



分系统运行案例1

案例结果展示：全球农田CO2净交换通量



Earth Lab

分系统运行案例1

输出测试结果展示：全球N2O排放通量