Application and Development of Dynamic Global Vegetation Model in IAP/CAS

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Outline

- Evaluation of the Global Vegetation Simulation by the Modified CLM-DGVM
  - Global Vegetation Distribution
  - Vegetation-Climate Relationship

- Analysis of Model Bias
  - Ecosystem Formation
  - Population Density

- Development of the IAP-DGVM
  - Uncertainty of Establishment Scheme
  - Intermediate Process-based Fire Parameterization
Modified CLM-DGVM

- Submodel of temperate and boreal shrubs
  - An explicit consideration of shrubs’ drought tolerance in the photosynthesis computation;
  - Phenology type and morphology parameters for shrubs;
  - The competition hierarchy of tree/grass/shrub.

- "Two-leaf" scheme of photosynthesis with nitrogen limitation factor

- Definition of fractional coverages of PFTs
- Improvement of the new allocation scheme
Global Distribution of Shrub

Simulation

Observation

Temperate Shrub

Boreal Shrub

Temperate Shrub

Boreal Shrub

Global Distribution of Shrub
Global Distribution of Forest

Simulation

Observation

Evergreen Trees 22.2%

Evergreen Trees (obs) 19.4%

Deciduous Trees 15.9%

Deciduous Trees (obs) 8.8%

Evergreen Forest

Deciduous Forest
Global Distribution of Grassland and Desert

Simulation vs Observation:
- **Grassland**: Simulation shows 20.7% coverage, Observation shows 19.6% coverage.
- **Desert**: Simulation shows 32.2% coverage, Observation shows 31.9% coverage.

This image compares the simulated and observed distributions of grassland and desert across the globe, highlighting the similarities and differences in their coverage.
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<th>3.5</th>
<th>obs</th>
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Total area (in $10^6$ km$^2$) by major vegetation class (tree, shrub, grass, crop, and bare soil) and for various PFTs calculated from the Modified CLM-DGVM, the default CLM-DGVM 3.0, CLM-DGVM 3.5, and observation (CLM4 surface data).
The zonal mean of vegetation coverage calculated from (a) the modified model and (b) the CLM4 surface dataset.

The modified model correctly reproduces the location of zonal peaks of vegetation distributions.
Following the Walter climate diagram, a climate index PT is defined as:

$$PT = MAP - k \cdot MAT$$

where factor $k = 36 \text{ mm } ^\circ\text{C}^{-1}$ converts 10$^\circ$C of monthly average temperature into 30 mm of monthly precipitation.

The favored conditions for different ecosystem are very well separated as a function of PT, in excellent agreement with the results from observation.
Both simulations overestimate the density distributions over regions with tree coverage larger than 70% (i.e., the core area), but underestimate the density distributions over regions with tree coverage less than 40%.
Trees are sensitive to the precipitation change mainly in the region with tree covers between 20~60%.
Distribution of Tree Population Density

(individuals/m²)
Ecosystem with higher tree population density has lower total biomass but higher c_leaf : c_total ratio.

Such system needs much shorter time to build up.
2007, Chinese Academy of Sciences supported key research project of “Development of Earth System Model”

2010, Ministry of Science and Technology of China supported 19 key research projects of global change studies, including:

- Development of the High Definition Climate System Model
- Development of Ecological and Environmental System Model
  - Terrestrial Ecosystem Model
  - Land Biogeochemistry Model
  - Marine Biogeochemistry Model
  - Aerosol and Atmospheric Chemistry Model
Framework of IAP-DGVM

Disturbances
- fire, extreme weather, pollution, grazing, pests, ...

Biogeochemistry
- Plant biochemistry
  - Photosynthesis, respiration
- Plant-soil nutrient cycling
  - Litter accumulation and decomposition, decomposition of soil organic matter, absorption of nutrient by root

Vegetation Dynamics
- Individual Dynamics
  - Structure development, phenology, senescence
- Population Dynamics
  - Reproduction/establishment, evolution of population structure, species competition

Adaptation
- Adaptation of individual traits, species evolution

Feature Dimension
- Hour/Day molecule
- Day/Year Individual/population
- Decade/Century ecosystem

Emission disturbance
Vegetation states disturbance
Establishment is a large source of uncertainty in DGVM

- It determines the balance of population density
- It also influences the calculation of averaged crown area
- A major uncertainty remains in the partitioning of establishment among different PFTs

- current CLM-DGVM assumes that all woody PFTs share the same rate of establishment (even for PFTs which fail to survive);
- actually establishment rate should be related to current vegetation states (e.g., fractional coverage, NPP) and PFT related traits.
Default establishment scheme:

\[ \Delta P_i = \Delta P_{max} \frac{1 - e^{-5 (1 - FC_{woody})}}{n_{est,woody}} (1 - FC_{woody}) \]

Or rewritten as:

\[ \Delta P_i = \left[ \Delta P_{max} (1 - e^{-5 (1 - FC_{woody})}) (1 - FC_{woody}) \right] \frac{g_i}{\sum_{k=1}^{n_{est,woody}} g_k} \]

\[ g_i \equiv 1 \]

New scheme 1:

\[ g_i = g_{i0} [\varepsilon_0 + (1 - \varepsilon_0) FC_i] \]

New scheme 2:

\[ g_i = g_{i0} [\varepsilon_0 + (1 - \varepsilon_0) \cdot \beta \cdot \frac{P_i C'_{reprod,i}}{C'_{seed}}] \]

\[ \varepsilon_0: \text{background establishment} \]
default

New 1

New 2
Removal of the woody PFTs with low FC may causes big change for the dominant PFTs in the default scheme.
The default and new schemes have very different time scales in response to perturbation.
Wire Diagram of the Fire Parameterization (F. Li, 2011)

- Lightning frequency
- Population density
- Vegetation characteristics
- RH, rainfall, soil moisture
- Wind

**Ignition Sources**

**Fuel Load**

**Fuel Combustibility**

- Fire occurrence probability
- Fire duration
- Fire spread speed
- Burned area fraction

**Fire Spread**

**Fire Impact**

- Post-fire mortality
- Biomass combustion
- Trace gas and aerosol emissions
- Adjustment of C pool
• Mod-new successfully reproduces the global spatial distribution of annual burned area fraction

• Mod-new is more skillful than mod-old (Levis et al. 2004) and Glob-FIRM (Thonicke et al. 2001), especially in the tropics and in the middle-high latitude

**GFEDv3.1**

**mod-old Cor=0.39**

**Glob-FIRM Cor=0.25**

**mod-new Cor=0.47**

**Burned area fraction**
• Mod-new successfully reproduces the global spatial distribution of annual fire carbon emissions

• Mod-old and Glob-FIRM overestimate fire carbon emissions evidently