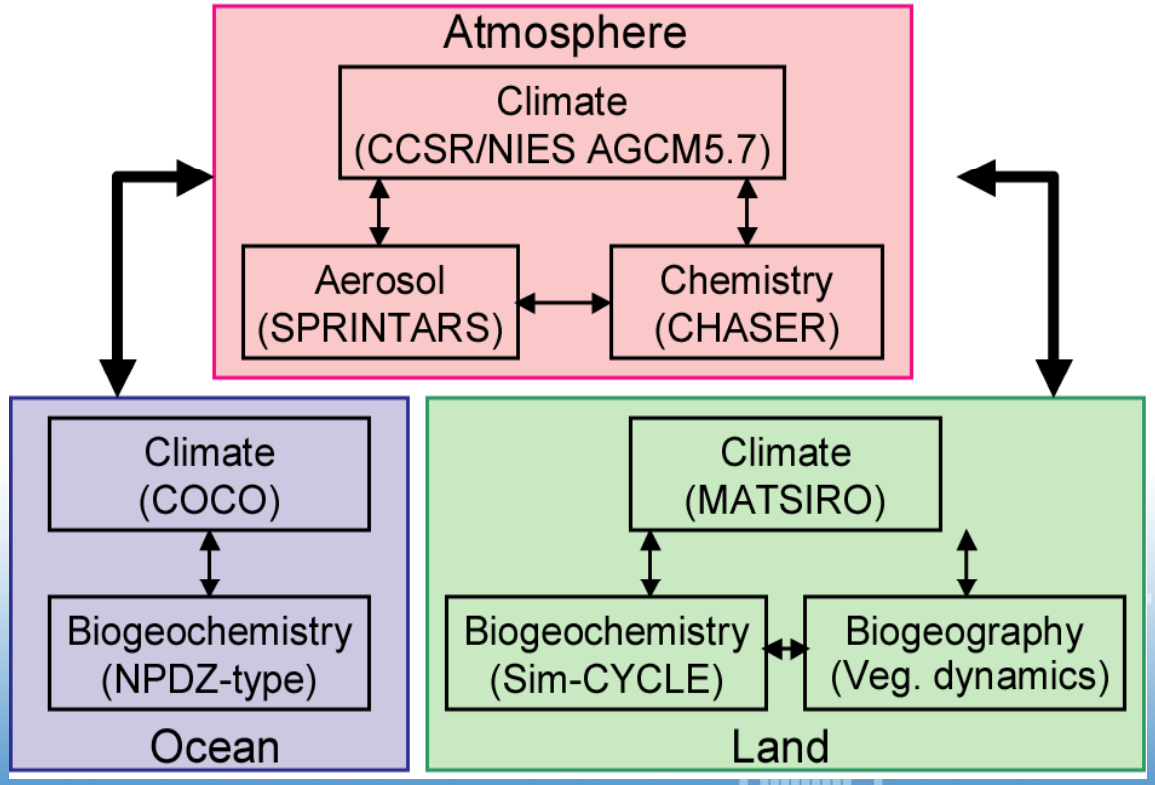
# Challenges for long-term global warming projection using an earth system model

Michio Kawamiya
Frontier Research Center for Global Change /
Japan Agency for Marine-Earth Science and Technology

# Introduction: Framework for IPCC AR5

- Experimental design
  - Decadal
    - High resolution (50-100km)
    - Ensemble prediction with ocean data assimilation
  - Centennial
    - Medium resolution (~200km)
    - Desirably with carbon cycle
- Representative Concentration Pathways (RCP)
  - Four benchmark scenarios as a community effort
  - Expected to facilitates interactions between WGs1,3

# CCSR/NIES/FRCGC Earth System Model (ESM)




AGCM

CCSR/NIES/FRCGC

T42(~2.8ºx2.8º)

L80 (TOA:80km)

OGCM

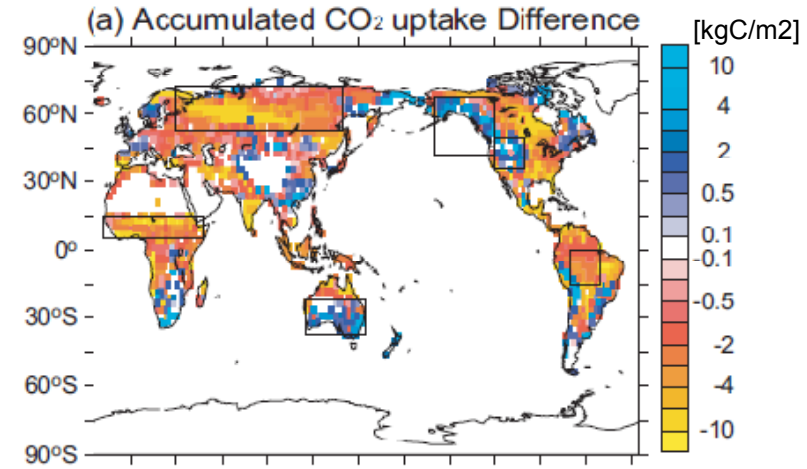
COCO (CCSR/FRCGC)

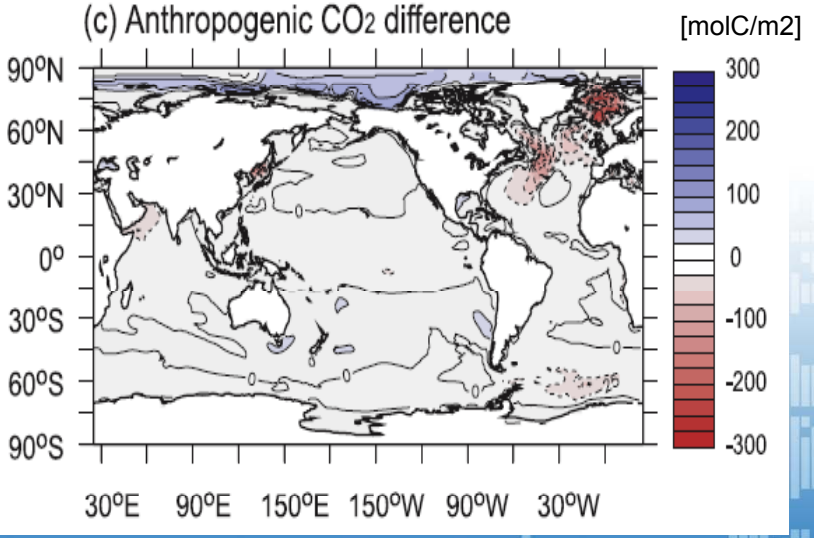
"Bended axis" grid system

(0.5-1.0)º x 1.4º

Also T85 without chemistry

# Carbon cycle studies

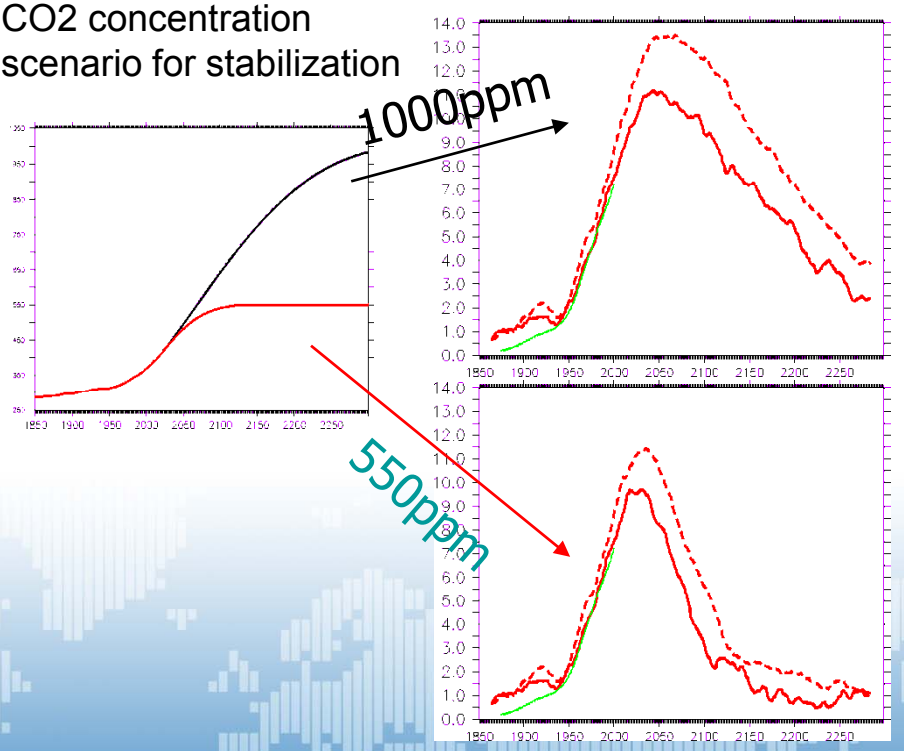



**Spatial distribution of climate – carbon cycle feedback**

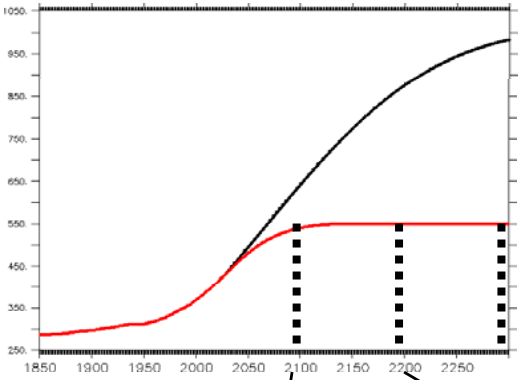
Allowable CO2 emission paths w/ and w/o feedback

CO2 concentration scenario for stabilization

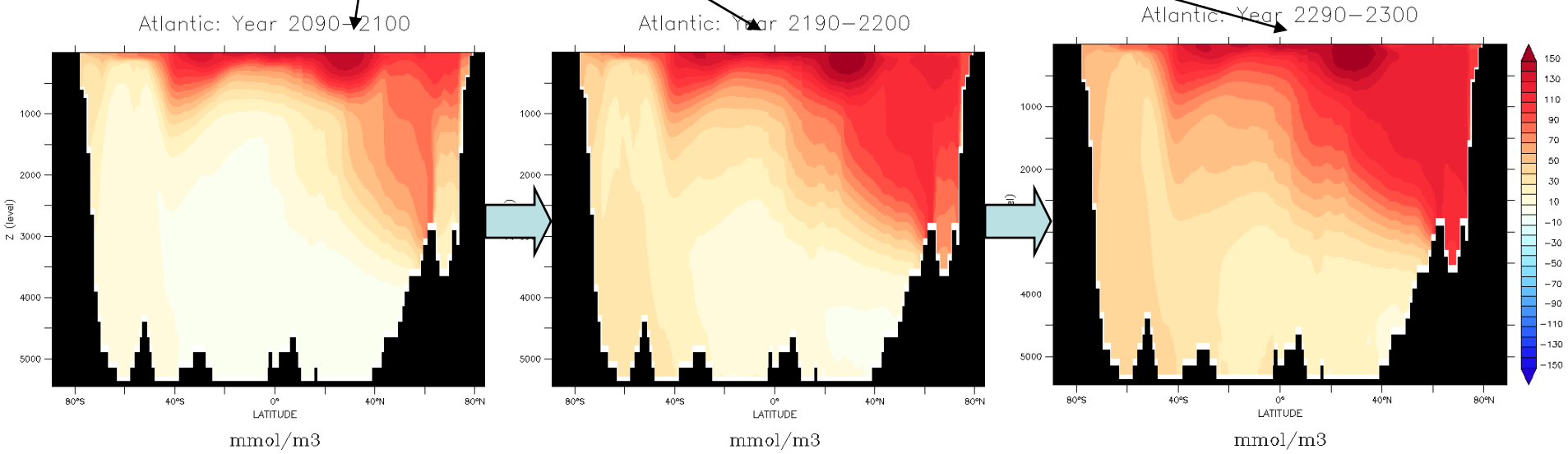



**“Quasi-inversion” of allowable CO2 emission**

# CO2 uptake by ocean after stabilization

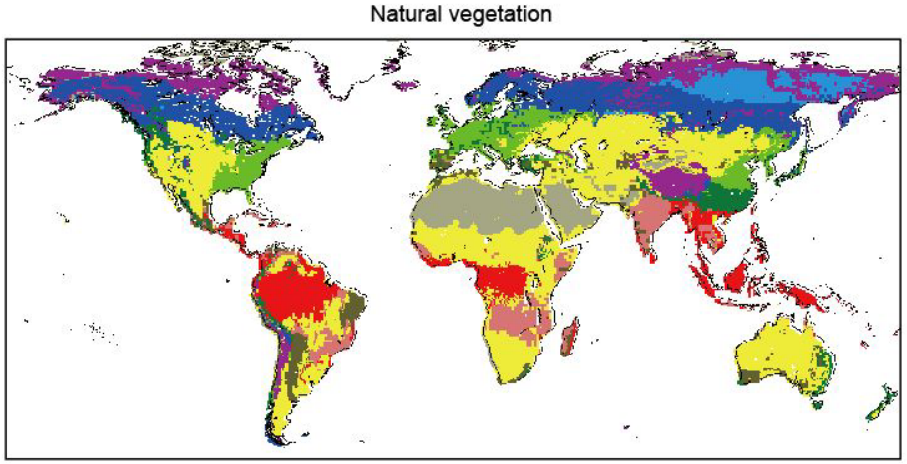


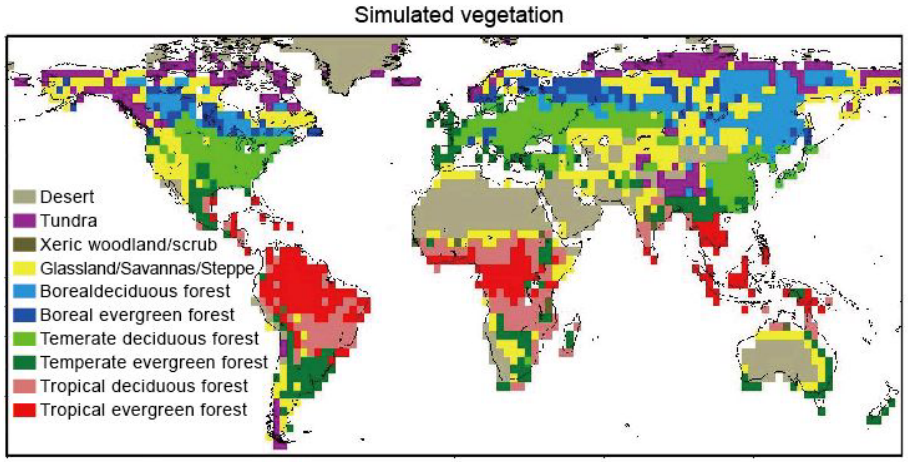

Due to its long characteristic time scale, ocean can absorb anthropogenic CO2 even after atmospheric CO2 concentration is stabilized.

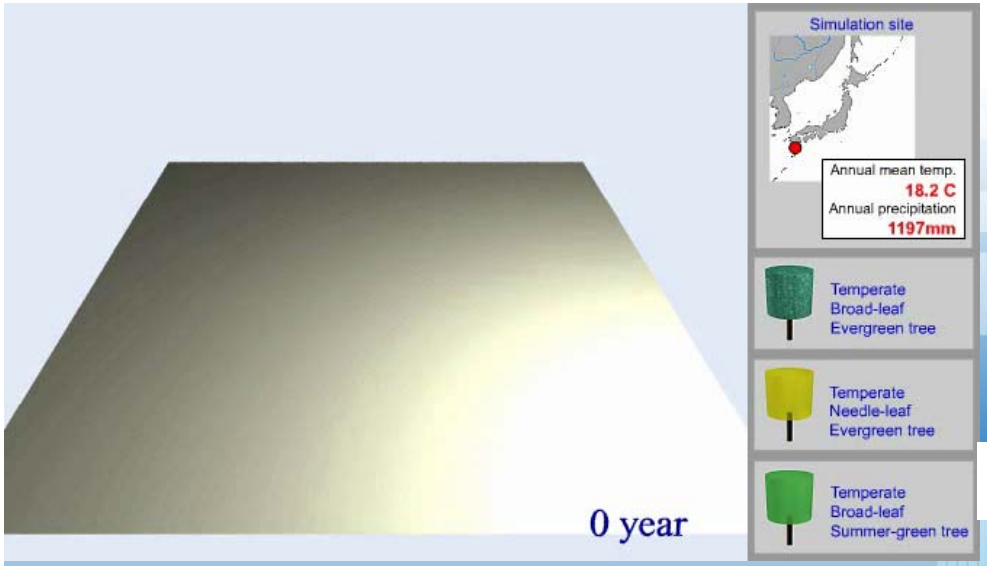


# Development of an dynamics global vegetation model (SEIB-DGVM)

Observed and simulated potential vegetation




It's an individual-based model…

# Improving SEIB-DGVM by introducing subgrid-scale heterogeneity

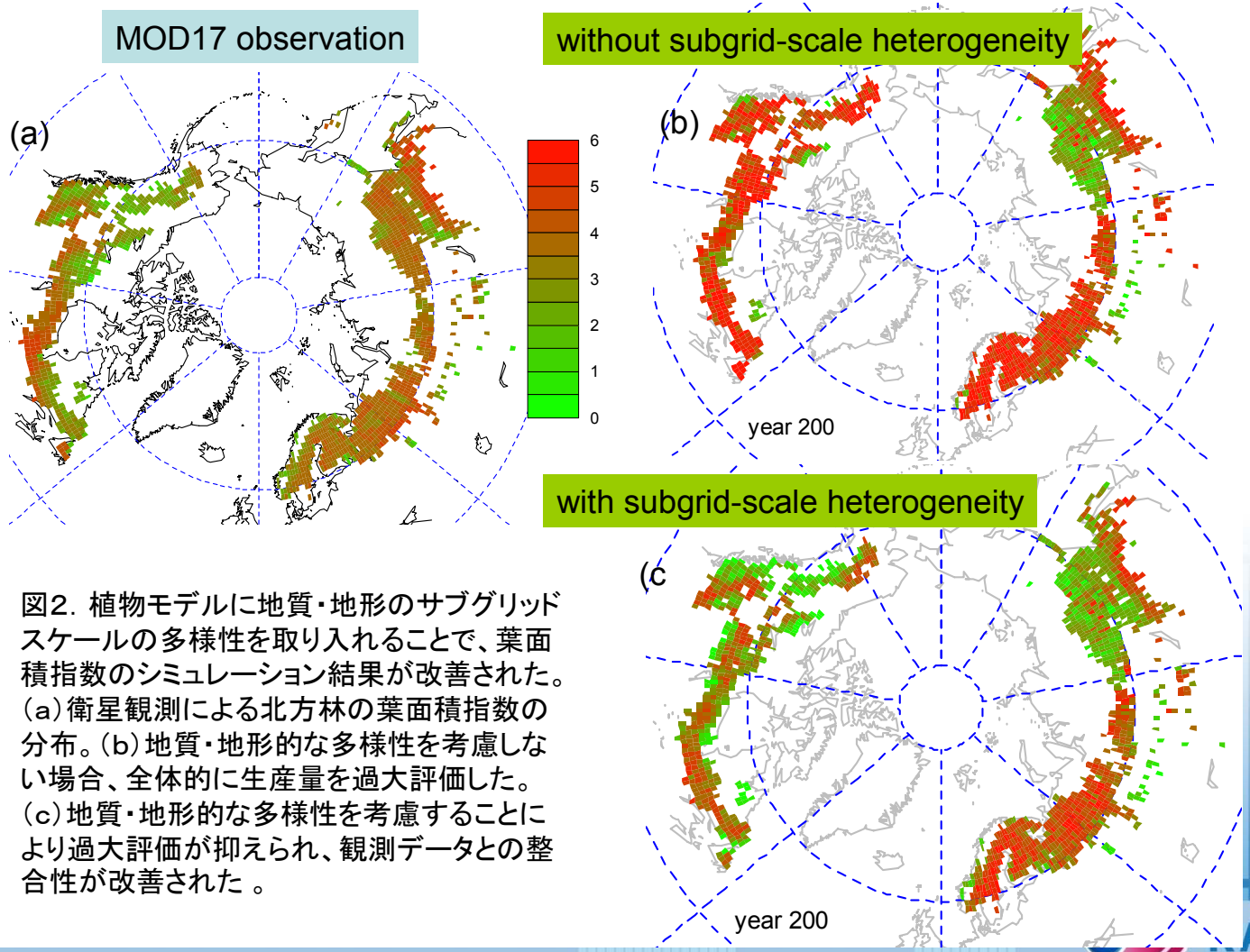
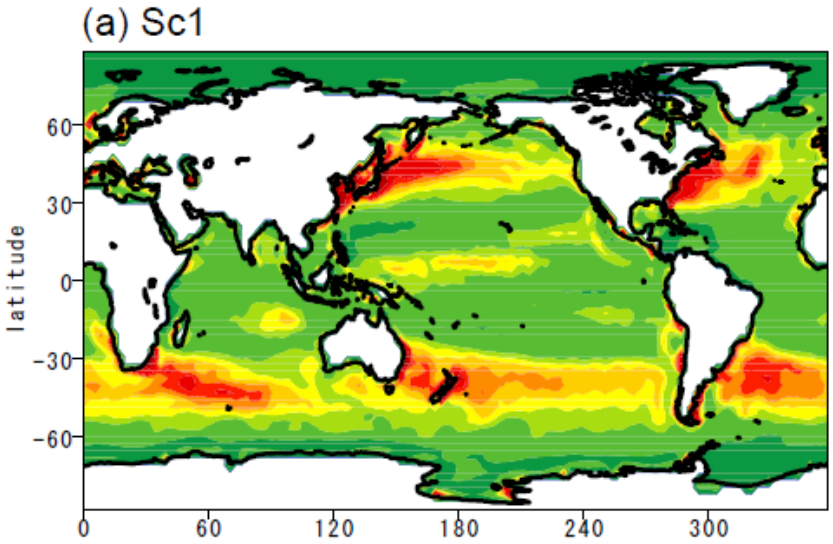


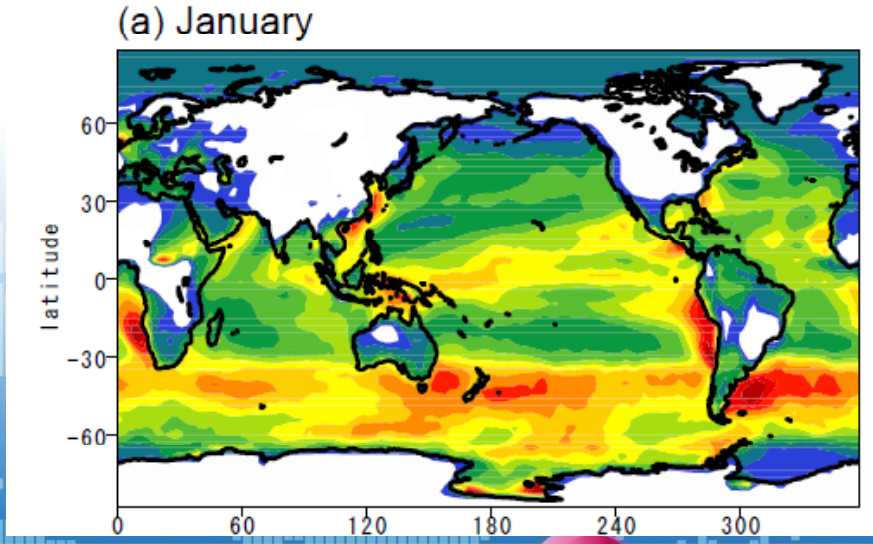

図2. 植物モデルに地質・地形のサブグリッドスケールの多様性を取り入れることで、葉面積指数のシミュレーション結果が改善された。(a)衛星観測による北方林の葉面積指数の分布。(b)地質・地形的な多様性を考慮しない場合、全体的に生産量を過大評価した。(c)地質・地形的な多様性を考慮することにより過大評価が抑えられ、観測データとの整合性が改善された 。

# Interactions between marine ecosystem and atmospheric chemistry




**Global distribution of annual mean oceanic emission of primary OC (ng C m-2 s-1) estimated using modeled chlorophylls**

**Simulated differences in OC concentrations (ng m-3) due to the additional marine sources**




Ito and Kawamiya, sumbitted

# Stratosphere – carbon cycle interaction

Increasing trend in the airborne fraction

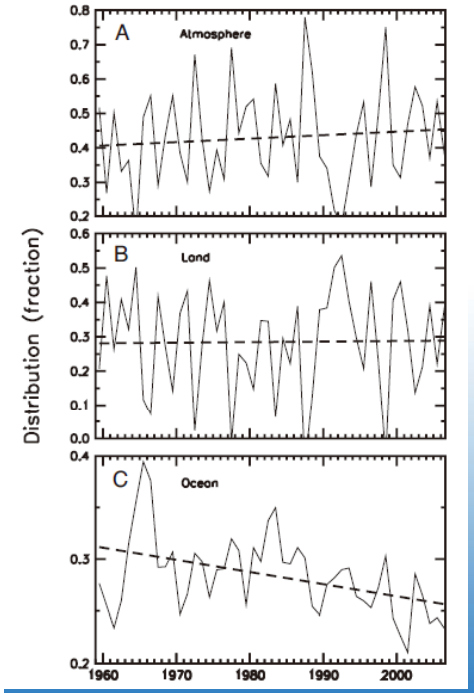
More upwelling in SO -> less CO2 uptake

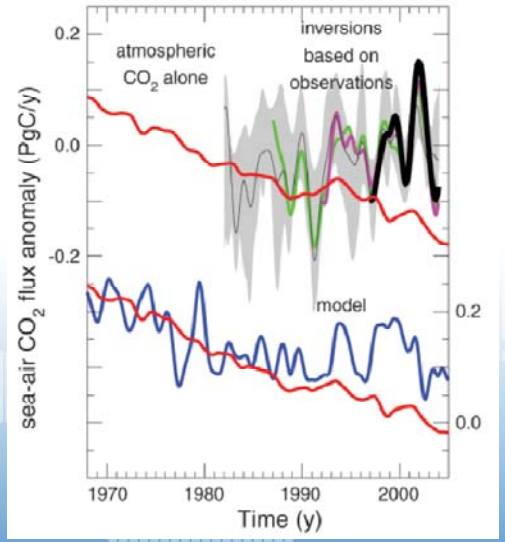
Stratospheric O3 depletion -> stronger wind over SO

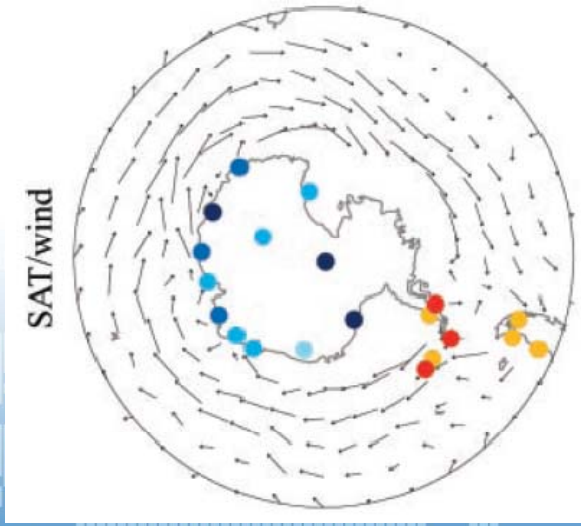
Canadell et al. (2007)

LeQuere et al. (2007)

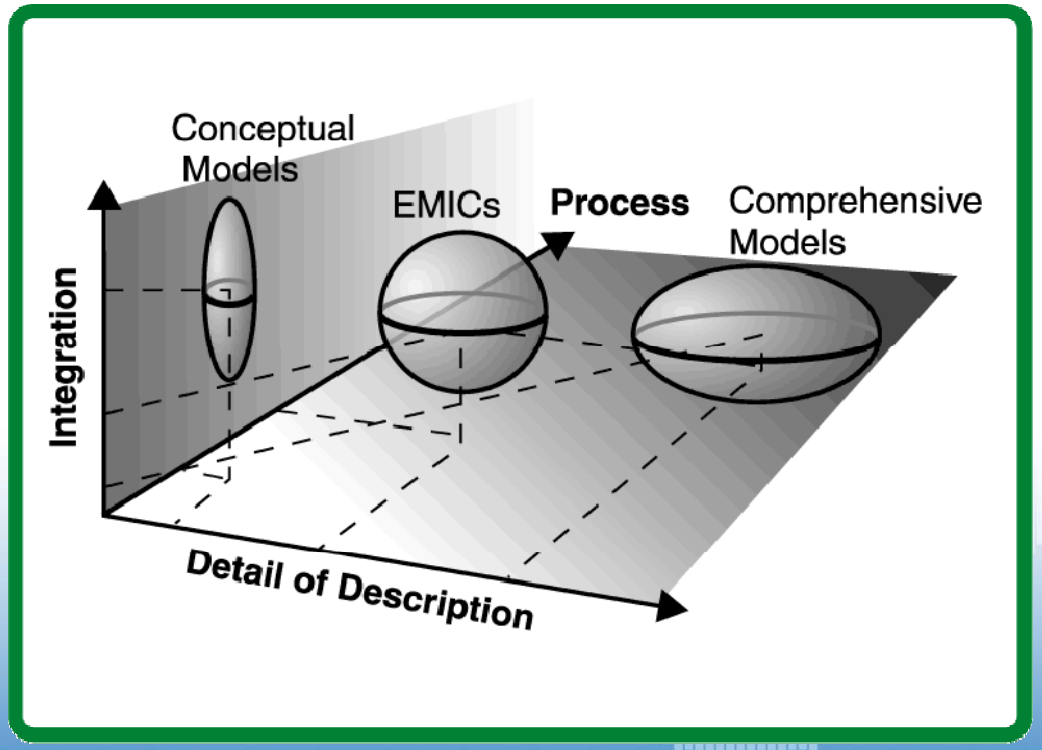
Thompson and Solomon (2002)

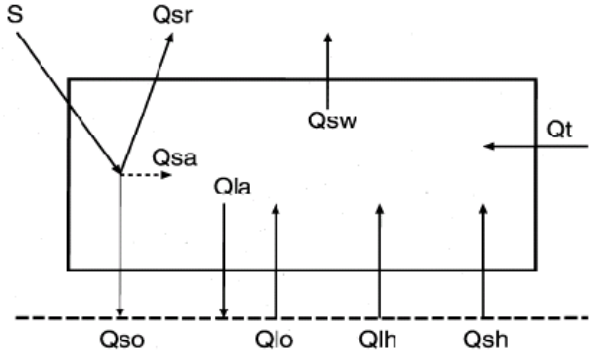


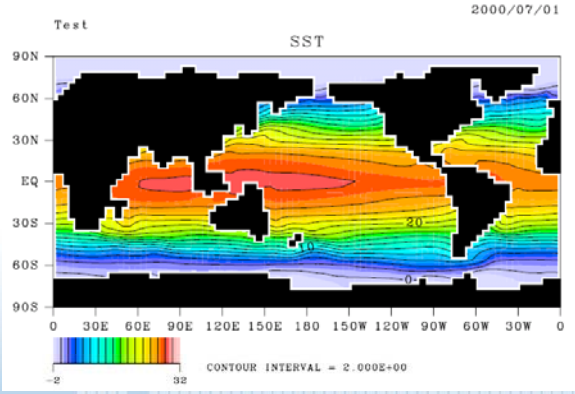



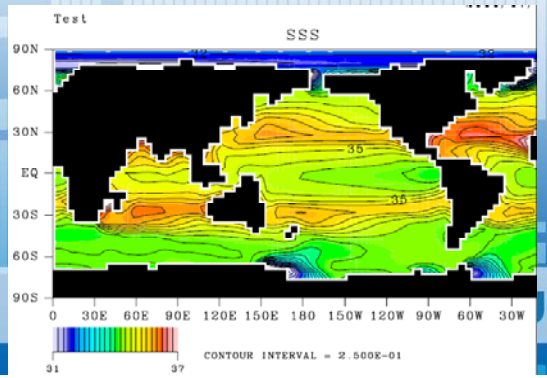



# EMIC (Earth System Model with Intermediate Complexity): MIROC-lite

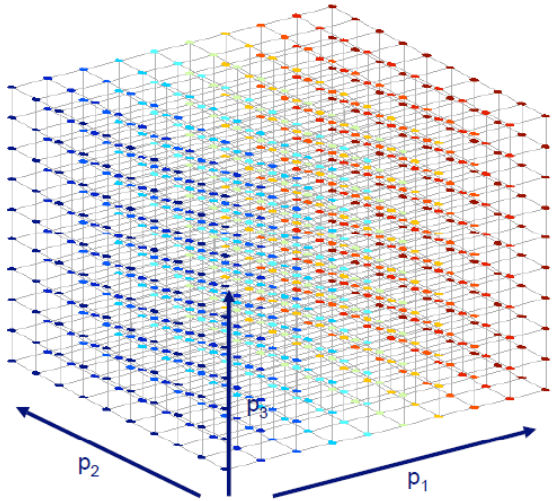


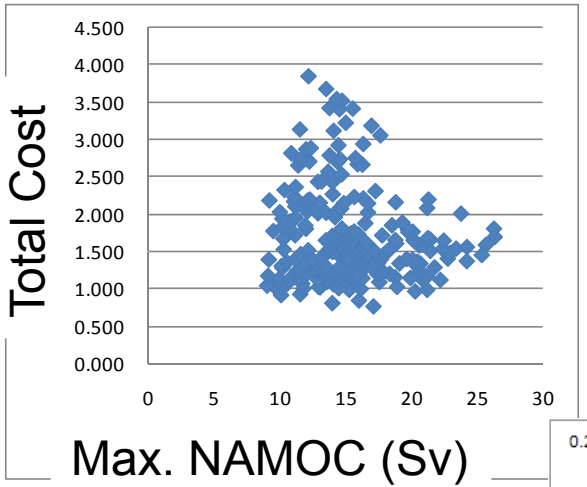



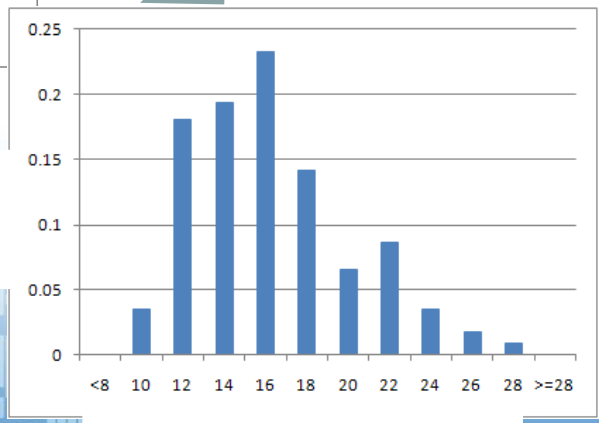



# EMIC-based Parameter Ensemble using Latin Hypercube



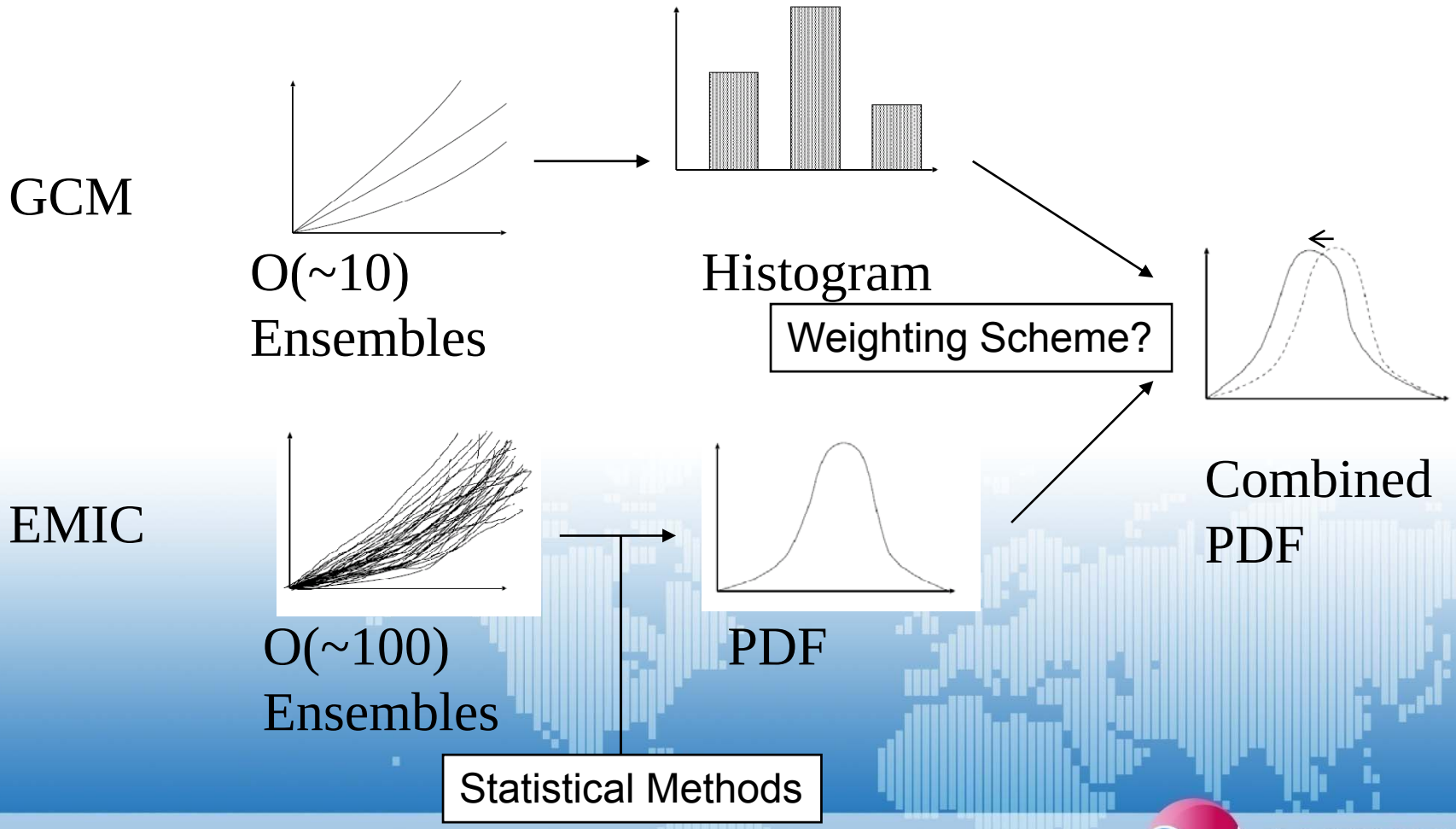

* Each dot represents 3000-year integration!




Latin Hypercube: Scheme for extracting parameter values from the parameter space in a non-biased manner

→ Toward establishment probabilistic approach based on parameter ensembles

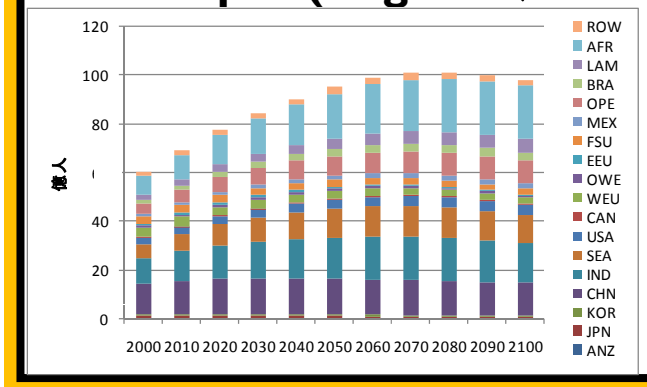
# Fusion of GCM & EMIC results for uncertainty estimation: concept



# On-going effort in Japan: development of land-use change scenario, and estimation of associated aerosol emission

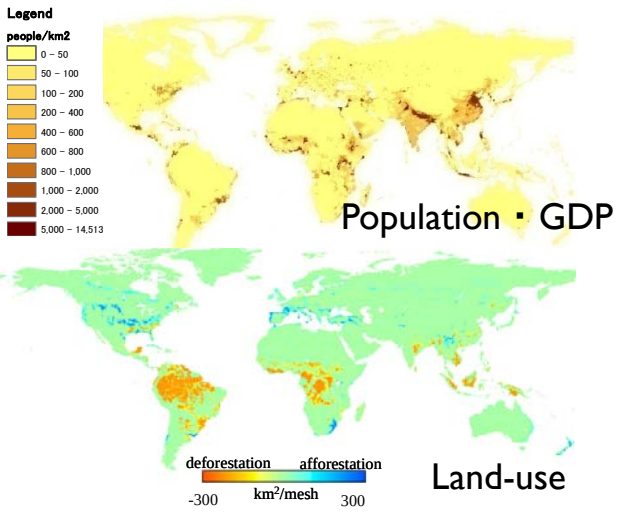
**(MoE S-5 Project)**

## AIM output (Regional)



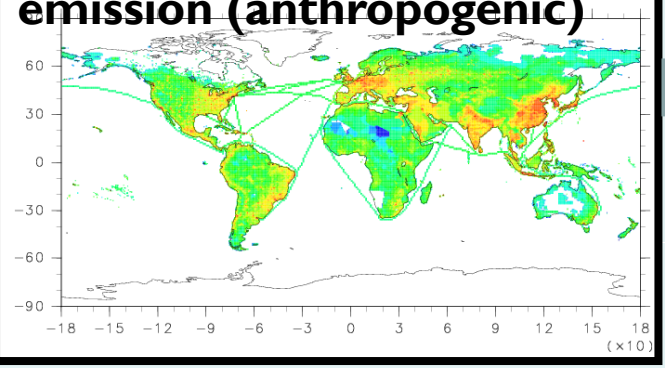

Population, GDP, Land-use

## (1) Downscaling




Aerosol emission

## (2) Spatially-explicit aerosol emission (anthropogenic)




Emission (Anthro.＋Fire)

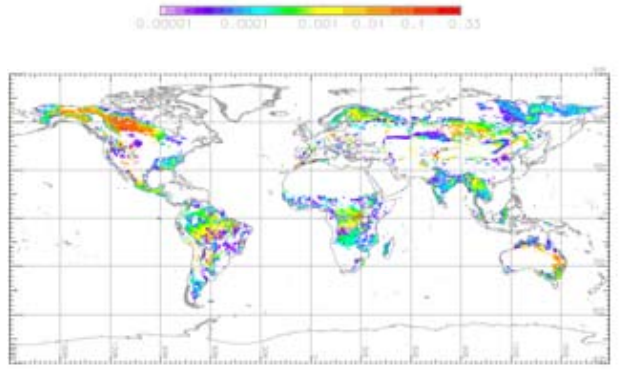
RCP (6W)

Population, GDP, Land-use

Land-use

Fire emission

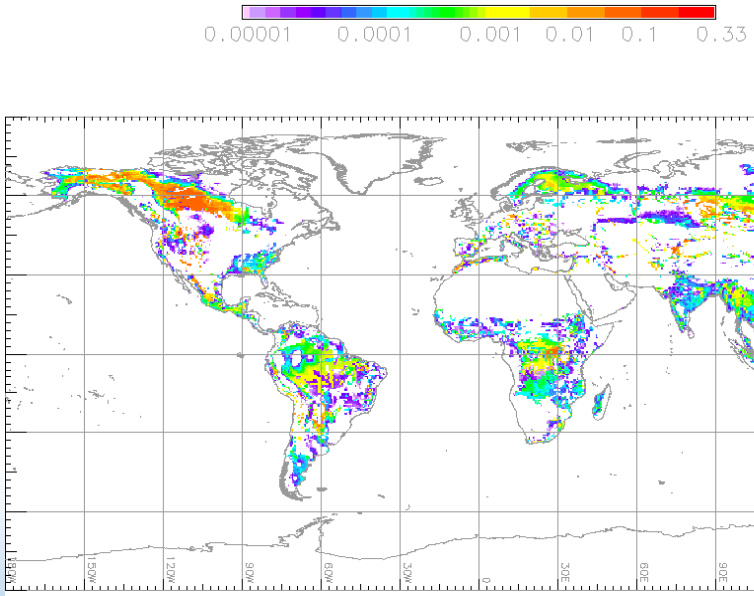
## (4) Spatially-explicit aerosol emission via fire



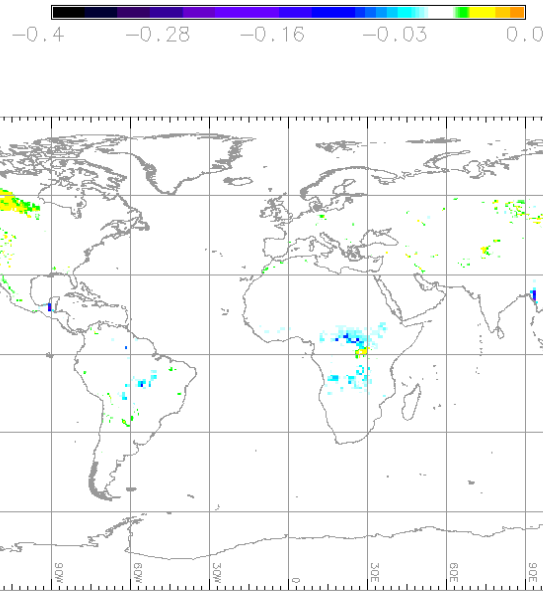
Land-use

# Preliminary result: BC emission from fires

Simulated BC emission (1997-2000, g BC $m^{-2}$ $mon^{-1}$)




Model bias relative to satellite-based estimate (g BC $m^{-2}$ $mon^{-1}$)








Possible improvements by incorporating area-specific parameterization and human factors

# Summary

- CCSR/NIES/FRCGC earth system model for AR5
  - Resolution: Atm.T42 (also T85?),Ocn.~100km
  - Carbon cycle, DGVM, aerosol, full chemistry
  - Importance of ocean's long-lasting CO2 uptake for stabilizing future CO2
- SEIB-DGVM (SEIB-DGVM)
  - Improvement by Incorporating spatial heterogeneity
- EMIC (MIROC-lite)
  - Under development, combined with statistical technique such as particle filtering
- RCP development
  - Nice example of collaboration between scenario developers and climate modelers ?

# Challenges

- Exploration of climate – chemistry feedbacks
- Quantifying projection uncertainty (instead of reducing it…)
  - Physics ensemble
  - Development of statistical scheme
- Cross-cutting collaboration among WGs1-3
  - How to utilize “quasi-inversion” results?
  - “Synchronization” of AR5s