New findings from CMIP5 Long-term climate change projection using the Earth Simulator

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Climate change projection using the Earth Simulator (ES)

- Long-Term Global Change Projection (~2300)
- Near-Term Climate Prediction (20~30 years prediction)
- Extreme Event Projection (Typhoons, Hurricanes, Heavy rain, etc.)
- Cloud Resolvable Modeling
- Parameterization of Marine Microphysics

Advancing Climate Modeling and Projection
Quantification and reduction of uncertainty
Application of Regional Projections to Natural Disasters

Contribute to IPCC AR5
Scientific Basis for Policymakers

Innovative Program of Climate Change Projection for the 21st Century (= KAKUSHIN)
Structure of the Earth System Model (MIROC-ESM)

Bio-geochemical processes
- Atmospheric Chemistry Model
- Ocean Circulation Model
- Ocean Chemistry - Ecosystem Model
- Land Surface Carbon Cycle Model
- Land Surface Heat – Water Circulation Model

Physical processes
- Stratosphere
- Atmospheric Model
- Aerosol Model

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Simulation of the 20\textsuperscript{th} century climate

Global average temperature

(Difference from 1851-1900 averages)

Observation (HadCRUT3)
MIROC-ESM-ED
MIROC-ESM-CHEM
MIROC-ESM (Ensemble mean)
MIROC-ESM (3 members)

MIROC3.2med (Ensemble mean)
MIROC3.2med (Range of 10 members)
Projected **Surface Temperature Change**
under RCP (MIROC-ESM)

- **CO2 Concentrations** Under RCPs
  - RCP8.5
  - RCP6.0
  - RCP4.5
  - RCP2.6

- **Projected Surface Temperature** (Difference from 1980–1999)
  - RCP8.5
  - RCP6.0
  - RCP4.5
  - RCP2.6

(JAMSTEC/AORI/NIES/MEXT)
Projected 21st Century Surface Temperature Change
by MIROC-ESM (Difference from 1980-1999)
CO$_2$ Emission rate from fossil fuel estimated by MIROC-ESM as necessary to Cause RCP Concentrations

CO$_2$ Concentration for 4 RCPs

(Year 2020 to 2100)

Emission rate (PgC/yr)

MIROC-ESM

JAMSTEC/AORI/NIES/MEXT

Innovative Program of Climate Change Projection for the 21st Century
MIROC-ESM shows some different outcomes from the simple carbon cycle model for RCP with implications.

CO2 Concentration for 4 RCPs

Emission rate (PgC/yr)
Projected change of carbon stock in ocean and on land surface.

**CO2 concentration for 4 RCPs**

- RCP8.5
- RCP6.0
- RCP4.5
- RCP2.6

**Change of ocean carbon stock (PgC)**

- RCP8.5
- RCP6.0
- RCP4.5
- RCP2.6

**Change of land surface carbon stock (PgC)**

- RCP8.5
- RCP6.0
- RCP4.5
- RCP2.6

(JAMSTEC/AORI/NIES/MEXT)
Breakdown of land surface carbon stock

Change of land surface carbon stock (PgC)

Change of carbon stock in vegetation (PgC)

Change of carbon stock in organic component of soil (PgC)

(JAMSTEC/AORI/NIES/MEXT)
Long-term Projection of Surface Temperature Change up to 2300 (under RCP4.5)

Projected Global Average Surface Temperature Change

Temperature difference from 1980-1999

Year
Projected Vegetation under RCP4.5

Boreal-Deciduous Forest  Boreal-Evergreen Forest  Tropical Forest

2007  2100  2200  2300

(JAMSTEC/AORI/NIES/MEXT)
Summary

- In a climate change projection initiative, KAKUSHIN, to contribute to the IPCC/AR5, an Earth System Model (ESM) has been developed by integrating bio-geochemical process models into a climate model (MIROC).
- The MIROC-ESM includes, in particular, a dynamic vegetation model (SEIB-DGVM), where species of vegetation compete each other under a given climate to attain a balanced distribution.
- Major outcomes including new findings from CMIP5 experiments using the Earth Simulator are:
  - Simulation experiments for the 20th century climate show reasonable results.
  - CO₂ Emission rate from fossil fuel estimated by MIROC-ESM as necessary to cause a RCP concentration scenario is smaller than that estimated in RCP and is almost zero at the middle of the 21st century.
  - CO₂ concentration caused by MIROC-ESM from a RCP emission rate is, in response, larger than the respective RCP concentration.
  - A 300 year projection under RCP4.5 with stabilized concentration beyond 2100 shows long-term steady rising tendency in global mean surface temperature beyond 2100.
  - Most boreal-deciduous forests transform into boreal-evergreen forests in 300 years under RCP4.5, while most tropical forests remain the same.