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Regional climate studies at MIT using RegCMs

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Regional Climate Studies at MIT using RegCMs

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TOTAL DEFORESTED AREA IN BRAZILIAN AMAZONIA

AREA (KM² x 10³)

YEAR


Nobre et al. (1991)
SUBEX

Gridcell

Adjacent Gridcell

1-FC

Cloud Fraction

Relative Humidity

Land
fo=0.8

Ocean
fo=0.9
SUBEX: Incident Surface Solar (NASA-SRB)

- **Old Model vs Observations**

  - BIAS = -26.2 W/m²
  - RMSE = 30.9 W/m²
  - M = 1.03

- **New Model vs Observations**

  - BIAS = -3.9 W/m²
  - RMSE = 13.2 W/m²
  - M = 1.01
SUBEX: Mean Surface Temperature (USHCN)

Old Model vs Observations

New Model vs Observations

BIAS = -1.1°C  RMSE = 2°C  M = 0.98

BIAS = -0.25°C  RMSE = 1.15°C  M = 1
SUBEX: June & July
1993 Flood

RegCM: Old Cloud Model

USHCN Observations

RegCM: New Cloud Model

RegCM: Old Cloud Model
Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the $\Omega$ difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE.

Precipitation (U.S. only)

<table>
<thead>
<tr>
<th>USHCN (Obs)</th>
<th>CTL</th>
<th>CLM</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Map" /></td>
<td><img src="image2" alt="Map" /></td>
<td><img src="image3" alt="Map" /></td>
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<table>
<thead>
<tr>
<th>25%</th>
<th>50%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Map" /></td>
<td><img src="image5" alt="Map" /></td>
<td><img src="image6" alt="Map" /></td>
</tr>
</tbody>
</table>
Initial Root Zone Soil Moisture (June 25)

Climatology

1988 1993
Coupling of RegCM3 and IBIS

Energy and Water Balance, Aerodynamics

Net Primary Production, Leaf Respiration, Growth, Allocation, Mortality, Disturbance

Photosynthesis, Leaf Respiration, Stomatal Resistance

Budburst, Senescence, Dormancy

Energy Balance, Water Balance

Carbon Cycling, Nitrogen Cycling

t~minutes to hours  t~days to weeks  t~years
<table>
<thead>
<tr>
<th></th>
<th>NNRP2</th>
<th>NNRP2 +3 °C</th>
<th>EH5OM</th>
<th>EH5OM A1B</th>
</tr>
</thead>
<tbody>
<tr>
<td>IBIS-FC</td>
<td>355 ppm</td>
<td>710 ppm</td>
<td>355 ppm</td>
<td>625-700 ppm</td>
</tr>
<tr>
<td>BATS-FC</td>
<td>Control</td>
<td>Temperature +3 °C; RH unchanged</td>
<td>ECHAM5 GCM 20th Century</td>
<td>ECHAM5 GCM A1B Scenario</td>
</tr>
<tr>
<td></td>
<td>Boundary Conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BATS-AS</td>
<td>Control</td>
<td>SST +3 °C</td>
<td>ECHAM5 SST</td>
<td>ECHAM5 A1B SST</td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Surface soil moisture (0–10 cm) – Illinois

Surface soil moisture (0–10 cm) difference – Illinois

Root zone soil moisture (0–100 cm) – Illinois

Root zone soil moisture (0–100 cm) difference – Illinois
Conclusions

- Precipitation is sensitive to both climate change scenarios and increases in all numerical experiments conducted.
- Total runoff increases, removing most all of the difference between the increase in precipitation and the increase in latent heat flux.
- The response of soil moisture to both climate change scenarios is negligible.
Role of Land Surface Processes in Shaping Regional Climate of Southwest Asia
Summer Temperature
Surface Temperature Bias

CRU 2m JJA Temperature [°C]

CONT 2m JJA Temperature [°C]

CONT - CRU JJA Avg. Temp. [°C]
Albedo: Model vs Observations

CONT Surface Albedo

SRB Surface Albedo

KW albedo = 0.27999  region albedo = 0.28345  box albedo = 0.27123

KW ave = 0.32  region ave = 0.3
Role of Surface Reflectance
From space.... not only desert..
Surface Humidity Bias

ALB – CRU JJA Avg. Vapor Pressure

KW diff. = -4.92 mb
Region diff. = -0.807 mb
Mesopotamian Irrigation and Marshlands

- Nearly 36,000 km² of irrigated land in Iraq (FAO & IWMI report below) used for various crops. AVHRR & country supplied data

- Nearly 17,000 km² of marshlands in Iraq and Iran in the early 1970’s, about the size of Kuwait.
Effects of Irrigation/Marshlands on Temperature

ALB 2m JJA Temperature [°C]

IRR 2m JJA Temperature [°C]

IRR - ALB JJA Avg. Temp. [°C]
Effects of Irrigation/Marshlands on Surface Humidity

CONT 2m JJA Vapor Pressure

IRR 2m JJA Vapor Pressure

IRR - ALB JJA Avg. Vapor Pressure
Changes in Extremes: Temperature

PDF of SubCont Daily July Temperatures [°C]
Changes in Extremes: Temperature

PDF of SubMrsh Daily July Temperatures [°C]
Again... from space
Dust!!
Incoming Shortwave Radiation

CONT JJA Shortwave Incident [W/m^2]

KW ave = 362 W/m^2
region ave = 361 W/m^2
Incoming Shortwave Radiation

SRB JJA Sfc. SW Incident (W/m²)

- Kw_ave = 321 W/m²
- Region ave = 315 W/m²

CONT JJA Shortwave Incident [W/m²]

- Kw_ave = 362 W/m²
- Region ave = 351 W/m²
MODIS/MISR: Dust Emissions
Dust Emissions with Wind Gustiness Included
Effects of Dust on Surface Temperatures
# Summary of Effects

<table>
<thead>
<tr>
<th>Model</th>
<th>KW-TA JJA Bias</th>
<th>Regional-TA JJA Bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>+3.5</td>
<td>+2.7</td>
</tr>
<tr>
<td>Albedo adjustment</td>
<td>-1.0</td>
<td>-0.9</td>
</tr>
<tr>
<td>Dust (w/subgrid wind)</td>
<td>-0.6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Irrigation+Marshlands</td>
<td>-0.6</td>
<td>-0.5</td>
</tr>
<tr>
<td>Observational Bias</td>
<td>-0.8</td>
<td>-0.3</td>
</tr>
<tr>
<td>Total Expected Bias</td>
<td>+0.5</td>
<td>+0.5</td>
</tr>
</tbody>
</table>

Albedo values matching SRB

SWI bias reduced by 20-40 W/m²

RH bias reduced by 5-10%
Maritime Continent: Rainfall from Space (TRMM)
Land Cover Change in Borneo: Observations 1950-2005, projections to 2020

(UNEP/GRID-Arendal 2007)
Comparison to other regions

Supplementary Material Figure S11.37, IPCC Report 2007 Chapter 11

![Graphs showing comparison of CO2 concentrations and precipitation changes across different regions: Central North America, Northern Europe, Southeast Asia, and East Asia.](image)
Objectives

→ Improve ability to simulate climate over Maritime Continent
→ Improve understanding of the role of land surface processes / characteristics in shaping regional climate
Diurnal cycle of rainfall, average 1998-2001, from TRMM (3-hourly, 0.25° x 0.25°)
Rainfall in mm/day

0100 LT mid-domain

0400 LT mid-domain

0700 LT mid-domain

1000 LT mid-domain
Diurnal cycle of rainfall, average 1998-2001, from TRMM (3-hourly, 0.25° x 0.25°)

Rainfall in mm/day

1300 LT mid-domain

1600 LT mid-domain

1900 LT mid-domain

2200 LT mid-domain
Model errors: - over land - wet bias (~4.5 mm/day), diurnal peak too high, too early - common RCM error (e.g. Wang et al. 2007)
- over ocean - dry bias (~1 mm/day)
Diurnal cycle of rainfall, average 1998-2001, from RegCM3-BATS1e (DTMAX=0)
Rainfall in mm/day

0100 LT mid-domain

0400 LT mid-domain

0700 LT mid-domain

1000 LT mid-domain
Diurnal cycle of rainfall, average 1998-2001, from RegCM3-BATS1e (DTMAX=0)

Rainfall in mm/day

1300 LT mid-domain

1600 LT mid-domain

1900 LT mid-domain

2200 LT mid-domain
TRMM vs RegCM3-BATS1e rainfall histogram average 1998-2001
Ongoing Work

- Model performance varies with surface type:
  - Ocean surface fluxes (sensible, latent heat) and rainfall are close to observations
  - But land surface rainfall and ET 50% too high, and vertical profiles indicate too much convection

- Current avenues of investigation:
  - Land surface scheme
  - Criterion for trigger of convective adjustment
Transformation and interpolation

RegCM3

OASIS3 Coupler

FVCOM

Flux1
Wind 1

Flux2
Wind 2

SST2

SST1

SST and Wind: distance weighted interpolation
Flux: conservative remapping scheme interpolation
(From SCRIP software package)
FVCOM Coupled model

Velocity field
Summary

(i) Our research is problem driven;

(ii) Significant contributions to model development;

(ii) Extensive testing and validation against field and satellite observations.
Maritime Continent: Diurnal Cycle of Rainfall

- Diurnal Cycle of Rainfall during Wet (D, J, F) and Dry (J, J, A) seasons, based on CEMORPH satellite data, Qian (2008)
Precipitation-JJA

Pre, CMAP, JJA, 1986–2000, mm/d

Pre, Simulation, JJA, 1986–2000, mm/d
Temperature-DJF

Temp, CRU, DJF, 1986–2000, C

Temp, Simulation, DJF, 1986–2000, C
Temperature-JJA

Temp, CRU, JJA, 1986–2000, C

Temp, Simulation, JJA, 1986–2000, C
Differences in Mean JJA AOD

DBCs–CONT JJA AOD

BCs–CONT JJA AOD Percent Difference

CLIMA BCs–CONT JJA AOD

CLIMA BCs–DBC s JJA AOD
Model errors: - under-representation of dry periods
- over-representation of low-intensity rainfall (< 8 mm/day)
- improvement with increased vertical resolution
Base case 2002 DJF 1900 LT  
Base case 2002 DJF 2200 LT  
Base case 2002 DJF 0100 LT  
Base case 2002 DJF 0400 LT
SUBEX: Precipitation (USHCN)

Old Model vs Observations

New Model vs Observations

BIAS = -0.37 mm/d  RMSE = 0.72 mm/d  M = 0.62

BIAS = -0.06 mm/d  RMSE = 0.65 mm/d  M = 0.73
CRU Observations

1988 Drought (MJ)

1993 Flood (JJ)

RegCM

(Cru & Eltahir 2003)
From the ground
Changes in Extremes: Humidity
Changes in Extremes: Humidity
Mean Summertime (JJA) Aerosol Optical Depth

CONT JJA AOD

DBC JJA AOD

CLIMA DCs JJA AOD

MISR JJA AOD
Seasonality Aerosol Optical Depth
Small-scale Processes: Land-Sea Breeze

(Ichikawa and Yasunari 2008)
RegCM3-BATS1e over Maritime Continent

- ERA40 for ICBCs
- Emanuel convection scheme, Zeng ocean flux scheme
- 30 km horizontal resolution, 18 / 29 vertical levels
- Rainfall compared to TRMM (0.25° 3-hrly), GPCP (1° daily), Changi airport meteorological station
Maritime Continent: Diurnal Cycle of Rainfall (Qian (2008))