Regional Downscaling Experiments for CORDEX-East Asia

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acknowledged to:

all colleagues at KNU, SNU, YU, UNIST, and POSTECH

The 7th ICTP workshop on Theory and Use of Regional Climate Models, 12-23 May 2014, Trieste, Italy
A Regional Downscaling Project coordinated by KMA

- 5 regional climate models for CORDEX-EA domain (50 km) and smaller sub-region (12.5 km).
- 1 statistical downscaling model for Korean peninsula up to 1 km’s resolution.
- 1 group from Japan (U. Tokyo) has participated recently.

**Domains for climate projections at KMA**

**KMA/NIMR**
CMIP5 experiment with HadGEM2-AO and provide GCM forcing
Regional downscaling for 2 domains with HadGEM3-RA
Maintaining CORDEX-EA databank

**Dynamical Downscaling Group**
- Multi-RCMs forced by HadGEM2-AO
- Ensemble method
- Uncertainty Assessment

**Statistical Downscaling Group**
- Methods’ Development
- High-resolution projection data up to 1 km
- Focusing on national scenario

**Extreme) Analysis Group**
- Evaluation of CORDEX outputs for extreme events
- Evaluation of Tropical Cyclones

**Application Group**
- Essential factors for administrative districts in agriculture, health, and disaster prevention sectors.
Downscaling Experiments

- NIMR (HadGEM3-RA)
  - EAS-44 (~ 50km)
    - (1950~2005)
    - (1979~2005)
    - (1989~2008)
  - KOR-11 (~ 12km)
    - (1979~2005)
    - (2006~2100)

- Universites (4 RCMs)
  - EAS-44 (~ 50km)
    - (1979~2005)
    - (1989~2008)
    - (2020~2050)
  - KOR-11 (~ 12km)
    - (1979~2005)
    - (2006~2100)
    - (2070~2100)

Evaluation / Historical / rcp 2.6, 4.5, 6.0, 8.5

Completed / On going (or planned)
## Model Configurations

<table>
<thead>
<tr>
<th>Model</th>
<th>HadGEM3-RA</th>
<th>RegCM4</th>
<th>SNURCM (MM5)</th>
<th>WRF</th>
<th>GRIMS (YSU RSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Numbers</td>
<td>183 x 220</td>
<td>197 x 243</td>
<td>197 x 233</td>
<td>197 x 233</td>
<td>198 x 241</td>
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</table>

### Physics

<table>
<thead>
<tr>
<th></th>
<th>Radiation</th>
<th>Cloud</th>
<th>Convection</th>
<th>Non-local PBL</th>
<th>Land</th>
<th>Nudging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General 2-stream</td>
<td>SUBEX</td>
<td>MIT-Emanuel</td>
<td>Lock et al.</td>
<td>MOSE II</td>
<td>No</td>
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<tr>
<td></td>
<td>CCM3</td>
<td>Resiner II</td>
<td>KF2</td>
<td>Holtslag</td>
<td>CLM3</td>
<td>Yes</td>
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<tr>
<td></td>
<td>CCM2</td>
<td>WSM3</td>
<td>KF2</td>
<td>YSU</td>
<td>CLM3</td>
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<tr>
<td></td>
<td>RRTM</td>
<td></td>
<td>SAS</td>
<td>YSU</td>
<td>NOAH</td>
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### Non-local PBL

<table>
<thead>
<tr>
<th></th>
<th>Lock et al.</th>
<th>Holtslag</th>
<th>YSU</th>
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<th>YSU</th>
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</table>

### Land

<table>
<thead>
<tr>
<th></th>
<th>MOSE II</th>
<th>CLM3</th>
<th>CLM3</th>
<th>NOAH</th>
<th>NOAH</th>
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</thead>
</table>

### Nudging

<table>
<thead>
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<th></th>
<th>No</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
</table>
Annual Mean Bias (model - obs.)
20-year (1989-2008) mean

[Surface Air Temperature (°C)]

HadGEM3-RA  RegCM4  SNURCM  WRF  GRIMS

[Precipitation (mm/day)]

HadGEM3-RA  RegCM4  SNURCM  WRF  GRIMS
Annual Mean Bias (model - obs.)

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[Surface Air Temperature (°C)]

HadGEM3-RA  RegCM4  SNURCM  WRF  GRIMS

[Precipitation (mm/day)]

HadGEM3-RA  RegCM4  SNURCM  WRF  GRIMS

1 - HadGEM3-RA  2 - RegCM  3 - SNU-MM5  4 - SNU-WRF  5 - YSU-RSM
Performance-based Ensemble Average Method
(Courtesy of Suh et al., 2012)

\[
\bar{T} = \frac{N_m \sum T_i - \sum P_{wi} \Delta T_i}{N_m}, \text{ where } P_{wi} = \frac{P_{wi}}{\sum P_{wi}}, \text{ and } P_{wi} = \frac{1}{(RMSE_i + 1)}|Cor|
\]

<Temperature>  
<Precipitation>
Annual mean time series
(9-year moving average)

<Temperature>

RCP 4.5

RCP 8.5

<Precipitation>

RCP 4.5

RCP 8.5

Anomalies(°C)

Anomalies(°C)


OBS
WE_Tay
WE_RaC
HadGEM3
WRF
SNURCM
RSM
RegCM4
Monsoon Evolution (Korea)

Averaged over 120 -130 °E (1979-2005)

Korea (24)

July-August
Additional Experiments with HadGEM3-RA

Boundary forcing impacts with
- SST and sea-ice: Observational Climatology + GCM anomalies
- Lateral BC: more stabilized (over 400 years) GCM forcing
CMAP

GCM (HadGEM2-AO)

RCM (HadGEM3-RA)

RCM (New SST)
Surface Air Temperature Extremes (1979-2005 JJA)

<Observation>
- JJA_mean [°C] 21.5
- JJA_extreme(loc) [°C] 26.2

• Mean and extreme climatology
  - similar spatial pattern, i.e., warmer in eastern and southern China

• MME bias
  - Similar spatial patterns between mean and extreme
  - Cold bias in Korea, southern China, and Japan
  - Warm bias in central and northern China and Mongolia
  - Mean biases are smaller than extreme.

<Stippling indicates region where all 5 RCMs show the same sign of bias.>
Precipitation Extremes (1979-2005 JJA)

**Observation**

<table>
<thead>
<tr>
<th>Mean</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>JJA_mean [mm/d]</td>
<td>4.1</td>
</tr>
</tbody>
</table>

- Mean and extreme climatology
  - similar spatial pattern
    (Monsoon rain bands and heavy rains in southern China, South Korea, and Japan)

- MME bias
  - Overall wet biases (29% wetter in mean, 22% wetter in extreme)
  - Dry bias in South Korea and Kyushu, which means ‘Changma’ front is not captured by most RCMs.

Stippling indicates region where all 5 RCMs show the same sign of bias.
Characteristics of Mean and Extremes

- **TAS**: means show better performance than extremes (higher spatial correlation)
- **PR**: extremes have higher skill than means (better spatial variability)
- HadGEM3RA and RegCM show better performance than others
Tropical Cyclone Track Density

Tracking Method
(Oouchi et al., 2006; Camargo et al., 2007)

1) Find the local minimum sea level pressure
2) Maximum RV at 850 hPa > $4.9 \times 10^{-5} \text{ s}^{-1}$
3) Maximum wind speed at surface > 17 ms$^{-1}$
4) Warm core criterion: $\Delta T = \Delta T_{300} + \Delta T_{500} + \Delta T_{700} > 2.0 \text{ K}$
5) Maximum wind speed at 850 hPa > that at 300 hPa
6) Duration of all above condition > 2 days
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Genesis Potential Index (GPI)

\[ GPI = \left| 10^5 \eta \right|^{3/2} \left( RH / 50 \right)^3 \left( PI / 70 \right)^3 \left( 1 + 0.1 V_{shear} \right)^{-2} \]
SFC. Temperature vs. Precipitation

OBS (GPCP, ERA-interim)  HadGEM3-RA  RegCM4

SNURCM  WRF  GRIMS
Interannual Variability of TC Genesis Frequency

The graph shows the interannual variability of tropical cyclone (TC) genesis frequency from 1985 to 2010, with results from various models including RSMC, HadGEM3-RA, RegCM4, SNURCM, WRF, GRIMS, and MME. The table below summarizes the average (AVE), standard deviation (STD), and correlation (CORR) for these models:

<table>
<thead>
<tr>
<th></th>
<th>RSMC</th>
<th>HadGEM3RA</th>
<th>RegCM4</th>
<th>SNURCM</th>
<th>WRF</th>
<th>GRIMS</th>
<th>MME</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVE</td>
<td>22.2</td>
<td>2.9</td>
<td>20.5</td>
<td>27.6</td>
<td>21.3</td>
<td>19.3</td>
<td>22.1</td>
</tr>
<tr>
<td>STD</td>
<td>4.2</td>
<td>1.8</td>
<td>6.2</td>
<td>5.5</td>
<td>4.1</td>
<td>4.5</td>
<td>3.9</td>
</tr>
<tr>
<td>CORR</td>
<td>0.50</td>
<td>0.65</td>
<td>0.58</td>
<td>0.63</td>
<td>0.15</td>
<td>0.68</td>
<td></td>
</tr>
</tbody>
</table>

MME does not include the results from the HadGEM3-RA.
Statistical Downscaling

PRIDE (PRISM based Downscaling Estimation Model)

Observation

PRISM based Seasonal Cycle using GIS information (DEM, topographic facet, costal proximity, and distance) and AWS observations

RCMs

Use the RCM-based anomalies by removing systematic bias and model seasonal cycle

\[ \text{Temperature (2070~2099)} = \text{Observation} + \text{RCMs} \]
Applications

- Based on the results from 4 RCPs x 2 RCMs
- Spatial distribution and time series for 230 administrative districts
- Essential factors for agriculture, health, and disaster prevention sectors.

**<Agriculture>**

- Growth duration, effective accumulated temperature, winkler scale, vegetable period, crop period, frostless period, chill units, climatic productivity index, thermo-hydro index, evapotranspiration, heating period, cooling period, etc…

**<Health>**

- Heat Index (HI), Discomfort Index (DI), Apparent Temperature (AT), Net Effective Temperature (NET), Humidex, Windchill

**<Disaster Prevention>**

- Standard Precipitation Index (SPI)
• Total number of download in 2013 is 16,034 including Korea (80%)
• Number of download in 2014 is 4,049 including Korea (only 25%)
Regional Ocean Downscaling

- Using ROMS with CanESM2 forcing (RCP4.5) by Pseudo Global Warming approach
- Least warming SST in east of Japan implies southward shift of Kuroshio current
Summary

- CORDEX-Phase I experiments for East Asia region have been completed successfully, and their outputs are welcomed to be used by analysis groups as well as IAV sectors via [http://cordex-ea.climate.go.kr](http://cordex-ea.climate.go.kr)

- Evaluation of the outputs are currently focusing on multi-model ensemble, monsoon evolution, and climate extremes including tropical cyclones.

- Multi-GCM/RCMs metrics are essential, and RCM should be further developed toward RCESM to capture more realistic activities of monsoon front and tropical cyclones.

- Statistical downscaling and its application for interdisciplinary sectors are still limited only on nation-wide scale.

- Phase-II experiments with smaller domain but with higher-resolution are prepared by EA groups.
Thanks for your attention.