GEOG 401
Climate Change

Climate Downscaling

GCMs have coarse resolution

Spatial resolution of global models continues to improve. But, they are still not sufficiently resolved to accurately represent processes at regional and local scales.
CMIP5 high-resolution models: 1 – 5 deg resolution

<table>
<thead>
<tr>
<th>Model Configuration</th>
<th>Period</th>
<th>Experiment</th>
<th>Model Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMCC-CM physical core High horizontal resolution</td>
<td>300 years</td>
<td>pControl (pre-industrial)</td>
<td>T159L31 (~80 km)</td>
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<tr>
<td></td>
<td>1850-2006</td>
<td>Historical</td>
<td>T159L31 (~80 km)</td>
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<td>2006-2100</td>
<td>RCP4.5 (scenario)</td>
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<td>2006-2100</td>
<td>RCP8.5 (scenario)</td>
<td>T159L31 (~80 km)</td>
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<td>140 years</td>
<td>IpctoCO2 (scenario)</td>
<td>T159L31 (~80 km)</td>
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<td></td>
<td>480 years</td>
<td>Decadal predictions (short term projections)</td>
<td>T159L31 (~80 km)</td>
</tr>
<tr>
<td>CMCC-ESM</td>
<td>1979-2008</td>
<td>AMIP (prescribed SST)</td>
<td>T159L31 (~80 km)</td>
</tr>
<tr>
<td>Low horizontal resolution; carbon cycle</td>
<td>277 years</td>
<td>pControl (pre-industrial)</td>
<td>T3L39 (~400 km)</td>
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<tr>
<td></td>
<td>1850-2006</td>
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<td>T3L39 (~400 km)</td>
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<td></td>
<td>2006-2100</td>
<td>RCP8.5 (scenario)</td>
<td>T65L39 (~400 km)</td>
</tr>
<tr>
<td>CMCC-CMS physical core Medium horizontal resolution high vertical resolution Stratosphere resolving</td>
<td>300 years</td>
<td>pControl (pre-industrial)</td>
<td>T65L95 (~200 km)</td>
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</table>

Downscaling

Downscaling Strategies:
- Statistical
- Dynamical
Rationale for downscaling in Hawai‘i:
Complexities in rainfall generation processes and the resulting steep gradients cannot be represented in global models.

Statistical Downscaling

- Climate variability at a point is related to large-scale atmospheric patterns of circulation, moisture transport, and stability.
- Global models are skillful at representing the large scale patterns.
- By establishing statistical relationships between the circulation/transport/stability patterns and climate at a station, projections can be made of past or future climate variations at the station based on variations in the patterns.
- Assumes that the relationships between spatial patterns and climate at a point do not change as a result of climate change: stationarity assumption.
Hawai‘i Example: Elison Timm et al. (2015)


Climate Change Circulation pattern in the Pacific Sector around Hawai‘i

Dominant mode of variability in 32-member ensemble simulation RCP8.5
Climate Change Circulation pattern in the Pacific Sector around Hawai‘i

Dominant mode of variability in 32-member ensemble simulation

moisture transports in 700 hPa

5 g/kg m/s

Temperature difference 1000hPa minus 500hPa

1.4
1.2
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6

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Climate Change Circulation pattern in the Pacific Sector around Hawai’i

Dominant mode of variability in 32-member ensemble simulation

Temperature difference 1000hPa minus 500hPa

Slide adapted from Oliver Timm
Translating large-scale climate anomalies into rainfall estimates.

Composite Pattern Geopotential Height 500hPa (1000hPa in contours)
Composite Pattern 700hPa Moisture Transport

Calibration Skill for Rainfall 1978-2007 (Nov-Apr season)

Correlation between observed & statistically downscaled rainfall
Calibration Skill for Rainfall 1978-2007 (Nov-Apr season)

Correlation between observed & statistically downscaled rainfall

CMIP5 Future Circulation Changes Projected onto the Composite Pattern
Statistical downscaling results
CMIP5 RCP8.5 2041-2070
30-yr average rainfall changes (Nov-Apr. season)

Projected Change in Wet Season Rainfall Based on Statistical Downscaling

CMIP5 ECP8.5 ensemble median scenario for late 2071-2099 average
(Elison Timm et al. 2015).
Projected Change in Dry Season Rainfall Based on Statistical Downscaling

CMIP5 ECP8.5 ensemble median scenario for late 2071-2099 average (Elison Timm et al. 2015).

Latest Projections

- Elison Timm et al. (2015) produced maps of seasonal-mean rainfall changes in Hawai‘i
- Wet-season results show higher skills than dry season
- Overall scenario for 21st century:
  - dry regions get drier, the wet regions remain wet or get wetter

Elison Timm et al. (2015) produced maps of seasonal-mean rainfall changes in Hawai‘i. Wet-season results show higher skills than dry season. Overall scenario for 21st century: dry regions get drier, the wet regions remain wet or get wetter.
Dynamical Downscaling

- Utilizes the same type of numerical model used for global climate simulations and regional weather prediction: a regional climate model.
- A regional domain is used allowing much higher spatial resolution; nested domains with successively higher resolution often used.
- Pseudo Global Warming method is one strategy; historical reanalysis is used to define the lateral boundary conditions; “global warming increments” used to modify conditions inside domain to represent future conditions.
- PGW approach assumes no change in climate variability.
- Computationally intensive, thus limiting number of test runs and global models used.

Hawai‘i Example:
Lauer et al. (2013)

SST Increment: RCP4.5

Fig. 2. Differences in annual average SST between the end of the twenty-first-century (2080–2099) and late-twentieth-century conditions (1990–1999) in the Pacific Ocean. Shown are the results of individual CMIP5 models for the RCP4.5 scenario as well as (bottom, right center) the CMIP5 multimodel-mean averaged over all 10 individual models. In addition, the (bottom right) observed SSTs for 2000–2002 are shown. Land surfaces are drawn in black. The dashed boxes show the HRCM domain with the Hawaiian Islands in the center.

Lauer et al. (2013)

SST Increment: RCP8.5

Fig. 3. As in Fig. 2, but for the RCP8.5 scenario.

Lauer et al. (2013)
Air Temperature Increment

![Graph showing temperature increments for various models](image)

Precipitable Water Vapor Increment

![Graph showing water vapor increments for various models](image)
Change in Mean Annual Precipitation: RCP4.5

Lauer et al. (2013)

Change in Mean Annual Precipitation: RCP8.5

Lauer et al. (2013)
Changes in TWI Height

Lauer et al. (2013)

Changes in Sea Level Pressure: RCP4.5

Lauer et al. (2013)
Changes in Sea Level Pressure: RCP8.5

Results Summary for RCP4.5

Lauer et al. (2013)
Latest Projections

- The IPRC dynamical downscaling group produced maps of seasonal-mean rainfall changes in Hawai‘i for Maui
- Overall scenario for 21st century:
  - dry regions get slightly drier, the wet get much wetter
Discrepancies Between Statistical and Dynamical Downscaling Results for Hawaii.

- Resource managers are frustrated
- Workshop scheduled for September to help answer questions
- Other alternatives being sought, e.g. models of intermediate complexity

AMS Mountain Net Conference presentation by Ethan Gutman:
https://ams.confex.com/ams/16MountMet/webprogram/Paper251640.html