A Quick Overview of Climate Projections

Global Warming Projections

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With many slides shamelessly pilfered from Keith Dixon, NOAA GDFL
A simplified view of the process...

...mindful that “uncertainties” are introduced in each step of the process

Projections!!!!!
Understanding Societies Priorities and Pathways

- **RCP8.5 (4C)** - Little curbing of emissions. We are on this path!
- **RCP6.0** - Some mitigation leads to lower emissions
- **RCP4.5 (2C)** – More intense mitigation implemented with some stabilization late in the century
- **RCP2.6** – Very ambitious mitigation. All countries must participate and technologies to remove carbon from the atmosphere applied

![Chart showing CO₂ concentration and emissions from 2000 to 2100 under different RCP scenarios](chart.png)
Understanding Societies Priorities and Pathways
Anatomy of a Climate Model

Equations (all models)

Conservation of momentum:
\[ \frac{\partial \mathbf{V}}{\partial t} = -\nabla \cdot (\mathbf{V} \cdot \mathbf{V}) - \frac{1}{\rho} \mathbf{F} - \mathbf{g} - 2 \Omega \times \mathbf{V} + \mathbf{V} \times (\nabla \times \mathbf{V}) - F_d \]

Conservation of energy:
\[ \frac{\partial E}{\partial t} = -\mathbf{V} \cdot (\rho \mathbf{V}) + \nabla \cdot (k \nabla T) + C + S \]

Conservation of mass:
\[ \frac{\partial \rho}{\partial t} = -\nabla \cdot (\rho \mathbf{V}) - \rho (\nabla \cdot \mathbf{V}) \]

Conservation of H₂O (vapor, liquid, solid):
\[ \frac{\partial q}{\partial t} = -\nabla \cdot (q \mathbf{V}) + \nabla \cdot (k \nabla q) + S_t + E \]

Equation of state:
\[ p = \rho R_T \]

Parameterizations (differ by model)

Grid

Components Interconnected to allow for Feedbacks
Anatomy of a Climate Model
Anatomy of a Climate Model
Anatomy of a Climate Model

Climate sensitivity in CMIP6 models

Source: Zeke Hausfather  https://twitter.com/hausfath
Impacts Occur at Finer Scales than GCM Resolution

General Circulation Model (GCM)

Dynamical Downscaling
- Finer Resolution
- Regional Climate Models (RCM)

Statistical Downscaling
- Change Factors
- Regression Methods
- Analog Approaches
- Stochastic Weather Simulators

Downscaled Climate Outputs

<table>
<thead>
<tr>
<th>Model</th>
<th>Atmosphere resolution</th>
<th>Ocean resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEAR_LO</td>
<td>100 km</td>
<td>1° Global</td>
</tr>
<tr>
<td>SPEAR_MED</td>
<td>50 km</td>
<td>1° Region</td>
</tr>
<tr>
<td>SPEAR_HI</td>
<td>25 km</td>
<td>1°</td>
</tr>
</tbody>
</table>
What is Downscaling?

GOALS WHEN PRODUCING STATISTICAL DOWNSCALED CLIMATE MODEL PROJECTIONS:
A refinement of dynamical model results, informed by observations

1) Account for GCM biases relative to observations
2) Add spatial detail or localized info not present in coarse resolution GCMS
3) Do Not markedly distort the GCM’s climate change signal
FAQ Which is the best downscaling method?

A: It depends on several factors, including what is the intended end use (application).

- Time & spatial scales of interest.
- Climate variables of interest.
- Sensitivity to central tendencies vs. extremes or spells.
- Whether ensembles are to be considered.

etc.
Delta Method Downscaling
Bias Correction
Bias Correction and Spatial Downscaling

1. Observed Data Anomalies
   High Spatial Resolution (1/8°)

2. Aggregate to GCM Scale (1°)

3. Compute function between Aggregated
   Observed and GCM Historical Anomalies
   Historical GCM = a(Observation) + b

4. Apply function to Future GCM values

5. Interpolate factors to fine grid
Localized Constructed Analogs

Coarse Resolution Future Date
Similar Historical Days (coarse)

Historical Days (fine)
Future Day (fine)

\[ F_{\text{Low}} = a(H_{\text{Low}}) + b(H_{2\text{Low}}) + c(H_{3\text{Low}}) \]

\[ a(H_{\text{1High}}) + b(H_{2\text{High}}) + c(H_{3\text{High}}) = F_{\text{High}} \]
Dynamic Downscaling
Distort GCM signal

Downscaled Change Factor / CanESM native CF

Return Period

Northeast
What Method is best?

Avg # of Days per Year >100F (RCP8.5 scenario; 2086-2095)

Identical inputs expect for downscaling method

Downscaling Method #1  |  Downscaling Method #2

max = 68.9

max = 32.2
What Method is best?

Avg # of Days per Year >100F
(RCP8.5 scenario; 2086-2095)

Identical inputs expect for downscaling method

Downscaling Method #1

Downscaling Method #2

"TRUTH"

max = 68.9

max = 32.2

max = 32.3
What Method is best?

**Black bars**
Coarsened – high res (no downscaling)

**Yellow Bars**
Downscaled coarsened – high res

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Even Observed Data Set Matters!

Annual Number of Days > 90

Source: Keith Dixon
Multi Model Ensembles
Single Model Ensembles

Figure 1. Differences between both raw Coupled Model Intercomparison Project Phase 6 (CMIP6) and Coupled Model Intercomparison Project version 5 (CMIP5) multimodel means (a and c) and inter-model standard deviation (b and d) over the 2070–2099 period for mean annual temperature (tas; a and b) and total precipitation (prcpot; c and d).

Questions?

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