Feb 2nd, 2:40 PM - 2:55 PM

Regional Climate Modeling Methodological and Experimental Designs

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Climate Modeling Component

Regional Climate Modeling:
Methodological issues and experimental designs

*John Mejia, Darko Koracin, and collaborators.*
*Desert Research Institute, Reno, NV*

2 February 2010, Las Vegas, NV
Concept of Regional Climate Models (RCMs)

- Forcing data derived from Atmospheric – Ocean Global Climate Models (AO-GCM).
- Nested RCM technique or limited area models as a tool for dynamical downscaling.
- Similar to numerical weather forecasting but with long-term integrations (computer resources limitations) and some adaptation for consistency with the changing climate.
Regional Climate Modeling: Present and Future assessments

- **World Climate Research Programme (WCRP) /CORDEX**: Multiple agencies and models with fixed AOGCM forcing. Africa and other continental size regions; 50 km grid size.

- **North American Regional Climate Change Assessment Program (UCAR/NARCCAP)**: Multiple model and AOGCM forcing. Systematically investigating the uncertainties in future climate projections; 50 km grid size.

- **Illinois State Water Survey Climate extension of WRF model**. (Dr. Liang personal communication) Integrated Regional Earth System Modeling. Ensemble

...Just to mention a few ...
Objective

- This task aims to implement and develop transportable methodologies to improve the applicability of GCMs in climate impact, developing and using a state-of-the-art RCM based in WRF, and to provide these results to the research, education and decision making community.
Our inner domain uses 4km resolution. Is that enough? Also... Vegetation type, Albedo, Soil type...
Dynamical downscaling:
Regional climate modeling using Weather and Research Forecasting (WRF) model

- **Forcing data**: Initial efforts using CCSM3 (soon V.4) and NCEP/NCAR global reanalysis products (NNRP).
- SST Updates.
- Integration mode: Spectral nudging (k=3) over D01 with relatively weak nudging factors. Only layers above the PBL are nudged.
- **Convection**: Kain-Fritsch for D01 and D02.
- **Microphysics**: single-moment 5-class.
- **PBL**: YSU
- **LSM**: a modified 4-layer NOAH-distributed (NCAR; Gochis and Chen 2009); water routing routine for surface and underground runoff.
- **Radiation** (SW and LW): RRTMG and CAM with GHG and aerosols updates.
Considered GHC and aerosol emission scenarios

• Selected scenarios for our project: B1, A1B and A2 (‘low’, ‘medium’, and ‘high’ scenario, respectively).

CO2 emissions for different socio-economical and environmental scenarios (IPCC-2007 report: http://www.ipcc-data.org/)
Dynamical downscaling: Regional climate modeling using Weather and Research Forecasting (WRF) model

• PLAN:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1970s</th>
<th>1980s</th>
<th>1990s</th>
<th>2000s</th>
<th>2010s</th>
<th>2020s</th>
<th>2030s</th>
<th>2040s</th>
<th>2050s</th>
<th>2060s</th>
<th>2070s</th>
<th>2080s</th>
<th>2090s</th>
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<tbody>
<tr>
<td>NCEP</td>
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<td>CCSM-A1B</td>
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<td>CCSM-B2</td>
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</tbody>
</table>

Schematic of the integration periods (shaded boxes) for different scenarios for the RCM downscaling approach. All simulations total 250 years.

• Bulk of the computation would take about 6 months
• Hourly and 3 hourly RCM output data.
• Some data archiving issues: Available storage space 150T but need about 300TB.
Adaptation of WRF for long-term integration mode

- e.g. Radiative forcings, emissivity, land use, vegetation type…
Cyberinfrastructure

• “GridLogin”: 80 nodes (8 cores each = 640 cores); each node with 16GB and 146 Gb disk space. Infiniband connectivity. 150 TB storage capacity. (Physically at DRI)
Cluster performance

- Computer system is operational, but the performance and stability is still not satisfactory.

<table>
<thead>
<tr>
<th>CORES</th>
<th>4</th>
<th>8</th>
<th>16</th>
<th>24</th>
<th>32</th>
<th>48</th>
<th>64</th>
<th>96</th>
<th>104</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock time (hh:mm:ss)</td>
<td>4:36:11</td>
<td>2:07:32</td>
<td>1:41:06</td>
<td>1:09:13</td>
<td>1:01:12</td>
<td>00:45:05</td>
<td>00:34:08</td>
<td>00:27:19</td>
<td>00:25:50</td>
</tr>
<tr>
<td>Efficiency (Clock/Simulation time)</td>
<td>0.153</td>
<td>0.071</td>
<td>0.056</td>
<td>0.038</td>
<td>0.034</td>
<td>0.025</td>
<td><strong>0.019</strong></td>
<td>0.015</td>
<td>0.014</td>
</tr>
</tbody>
</table>

30-hour WRF clock time for different core numbers in GridLogin and its efficiency

30-hour WRF clock time for different core numbers in GridLogin and its efficiency.
As we speak...

<table>
<thead>
<tr>
<th>Years</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>NCEP/NCAR-WRF</td>
<td>Spinup May 1 to Aug 31</td>
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<tr>
<td>70-75</td>
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<tr>
<td>75-80</td>
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<td>80-85</td>
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<td>85-90</td>
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<tr>
<td>90-95</td>
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<td>95-00</td>
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<tr>
<td>00-05</td>
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</tr>
<tr>
<td>2005-2008</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Total Processors</td>
<td>512</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Estimated time</td>
<td>45 days</td>
<td></td>
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</tr>
</tbody>
</table>

Fall-Winter, 1970
An example of Dynamical Downscaling:
Mean Surface Temperatures

NCEP/NCAR reanalysis ~250 km
D01 = 36 km

Fall-Winter, 1970
Downscaling Sfc Temperatures

NCEP/NCAR reanalysis

36 km

12 km

4 km

[Legend: [deg K] 300 298 296 294 292 290 288 286 284 282 280 278 276 274]

Fall-Winter, 1970
Linkages with Other Components

• Cyberinfrastructure
  ▪ Link to data portal and processing software

• Landscape change (land-atmosphere interactions)
  ▪ Paleoclimate modeling
  ▪ Climate modeling

• Water Resources
  ▪ Climate predictions of water resources, their variability, uncertainties, and socio-economic impacts

• Policy
  ▪ Alternative Future scenarios (urbanization); socio-economic aspects of future water supply

• Education — Graduate students, post doctoral fellows
Linkages with Other Components: Hydrological applications

Links with different hydrological modeling teams.

Foster a more formal and dynamical collaboration between different hydrological groups and our Climate Modeling activities.

My personal focus: The land-atmosphere coupling—hydroclimatology studies.
### Output Variables

<table>
<thead>
<tr>
<th>3D fields (3 hourly)</th>
<th>3D fields (hourly)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U</strong>: x-wind component</td>
<td><strong>TSLB</strong>: Soil Temperature</td>
</tr>
<tr>
<td><strong>V</strong>: y-wind component</td>
<td><strong>SMOIS</strong>: Soil Moisture</td>
</tr>
<tr>
<td><strong>W</strong>: z-wind component</td>
<td><strong>SH2O</strong>: Soil Liquid Water</td>
</tr>
<tr>
<td><strong>H</strong>: Geopotential Height</td>
<td><strong>P</strong>: Pressure</td>
</tr>
<tr>
<td><strong>T</strong>: Potential Temperature</td>
<td><strong>QVAPOR</strong>: Water Vapor Mixing Ratio</td>
</tr>
<tr>
<td><strong>P</strong>: Pressure</td>
<td><strong>QFCLOUD</strong>: cloud water mixing ratio</td>
</tr>
<tr>
<td><strong>QRAIN</strong>: Rain Water Mixing Ratio</td>
<td><strong>QICE</strong>: Ice Mixing Ratio</td>
</tr>
<tr>
<td><strong>QSNOW</strong>: Snow Mixing Ratio</td>
<td><strong>QVAPOR</strong>: Water Vapor Mixing Ratio</td>
</tr>
<tr>
<td><strong>2D fields (3 hourly)</strong></td>
<td><strong>2D fields (hourly)</strong></td>
</tr>
<tr>
<td><strong>Fraction of Frozen Precipitation</strong></td>
<td><strong>POTEVP</strong>: accumulated potential evaporation</td>
</tr>
<tr>
<td><strong>SST</strong>: Sea Surface Temperature</td>
<td><strong>SNOPCX</strong>: snow phase change heat flux</td>
</tr>
<tr>
<td><strong>SOILTB</strong>: bottom soil temperature</td>
<td><strong>SOILTB</strong>: bottom soil temperature</td>
</tr>
<tr>
<td><strong>Q2</strong>: QV at 2 M</td>
<td><strong>Q2</strong>: QV at 2 M</td>
</tr>
<tr>
<td><strong>T2</strong>: TEMP at 2 M</td>
<td><strong>T2</strong>: TEMP at 2 M</td>
</tr>
<tr>
<td><strong>TH2</strong>: POT TEMP at 2 M</td>
<td><strong>TH2</strong>: POT TEMP at 2 M</td>
</tr>
<tr>
<td><strong>PSFC</strong>: SFC PRESSURE</td>
<td><strong>PSFC</strong>: SFC PRESSURE</td>
</tr>
<tr>
<td><strong>U10</strong>: U at 10 M</td>
<td><strong>U10</strong>: U at 10 M</td>
</tr>
<tr>
<td><strong>V10</strong>: V at 10 M</td>
<td><strong>V10</strong>: V at 10 M</td>
</tr>
<tr>
<td><strong>SMSTAV</strong>: Moisture Availability</td>
<td><strong>SMSTAV</strong>: Moisture Availability</td>
</tr>
<tr>
<td><strong>SMSTOT</strong>: Total Soil Moisture</td>
<td><strong>SMSTOT</strong>: Total Soil Moisture</td>
</tr>
<tr>
<td><strong>SFROFF</strong>: Surface Runoff</td>
<td><strong>SFROFF</strong>: Surface Runoff</td>
</tr>
<tr>
<td><strong>UDROFF</strong>: Underground Runoff</td>
<td><strong>UDROFF</strong>: Underground Runoff</td>
</tr>
<tr>
<td><strong>SFCEVP</strong>: Surface Evaporation</td>
<td><strong>SFCEVP</strong>: Surface Evaporation</td>
</tr>
<tr>
<td><strong>GRDFLX</strong>: Ground Heat Flux</td>
<td><strong>GRDFLX</strong>: Ground Heat Flux</td>
</tr>
<tr>
<td><strong>ACGRDFLX</strong>: Accumulated Ground Heat Flux</td>
<td><strong>ACGRDFLX</strong>: Accumulated Ground Heat Flux</td>
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<tr>
<td><strong>ACSNOW</strong>: Accumulated Snow</td>
<td><strong>ACSNOW</strong>: Accumulated Snow</td>
</tr>
<tr>
<td><strong>ACSNOM</strong>: Accumulated Melted Snow</td>
<td><strong>ACSNOM</strong>: Accumulated Melted Snow</td>
</tr>
<tr>
<td><strong>SNOW</strong>: Snow Water Equivalent</td>
<td><strong>SNOW</strong>: Snow Water Equivalent</td>
</tr>
<tr>
<td><strong>SNOWH</strong>: Physical Snow Depth</td>
<td><strong>SNOWH</strong>: Physical Snow Depth</td>
</tr>
</tbody>
</table>

.............
Output Variables

### 2D fields (hourly)

- RHOSN: Snow Density
- CANWAT: Canopy Water
- TSK: Surface Skin Temperature
- RAINC: Accumulated Total Cumulus Precipitation
- RAINNC: Accumulated Total Grid Scale Precipitation
- SNOWNC: Accumulated Total Grid Scale Snow And Ice
- GRAUPELNC: Accumulated Total Grid Scale Graupel
- SWDOWN: Downward Short Wave Flux At Ground Surface
- GLW: Downward Long Wave Flux At Ground Surface
- ACSWUPT: Accumulated Upwelling Shortwave Flux At Top
- ACSWUPTC: Accumulated Upwelling Clear Sky SW Flux At Top
- ACSWDNT: Accumulated Downwelling Shortwave Flux At Top
- ACSWDNTC: Accumulated Downwelling Clear Sky SW Flux At Top
- ACSWUPB: Accumulated Upwelling Shortwave Flux At Bottom
- ACSWUPBC: Accumulated Upwelling Clear Sky SW Flux At Bottom
- ACSWDNB: Accumulated Downwelling Shortwave Flux At Bottom
- CSWDNBC: Accumulated Downwelling Clear Sky SW Flux At Bottom
- ACLWUPT: Accumulated Upwelling Longwave Flux At Top
- ACLWUPTC: Accumulated Upwelling Clear Sky Longwave Flux At Top
- ACLWDNT: Accumulated Downwelling Longwave Flux At Top
- ACLWDNTC: Accumulated Downwelling Clear Sky Longwave Flux At Top
- ACLWUPB: Accumulated Upwelling Longwave Flux At Bottom
- ACLWUPBC: Accumulated Upwelling Clear Sky Longwave Flux At Bottom
- ACLWDNB: Accumulated Downwelling Longwave Flux At Bottom
- ACLWDNBC: Accumulated Downwelling Clear Sky Longwave Flux At Bottom
- OLR: TOA Outgoing Long Wave
- EMISS: Surface Emissivity
- PBLH: PBL Height
- HFX: Upward Heat Flux At The Surface
- QFX: Upward Moisture Flux At The Surface
- LH: Latent Heat Flux At The Surface
- ACHFX: Accumulated Upward Heat Flux At The Surface
- ACLHF: Accumulated Upward Latent Heat Flux At The Surface
Future steps

- Statistical and dynamical downscaling applied to hydrological modeling (offline and couple modes)
- Analysis of Extreme weather events and statistics
- Ensemble approach to regional climate projections
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