Understanding Synoptic Weather Yielding Extreme Daily Precipitation

William J. Gutowski, Jr.

Iowa State University
Ames, IA

With substantial input from J. Glisan, S. Kawazoe, E. Cassano, J. Cassano, B. Fisel, A. Abatan (see also posters at this meeting)
Understanding Synoptic Weather Yielding Extreme Daily Precipitation

Goal here: synoptic climatology of extreme events

- discriminate different types of events
- diagnose physical causes and outcomes
- reveal frequency of types
How does one construct representative, collective behavior?

Two examples:

(1) A simple case: testing of composites

(2) More complex: using Self-Organizing Maps (SOMs)
### NARCCAP Simulations

<table>
<thead>
<tr>
<th>Model</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM5</td>
<td>Iowa State/ PNNL</td>
</tr>
<tr>
<td>RegCM3</td>
<td>UC Santa Cruz ICTP</td>
</tr>
<tr>
<td>CRCM</td>
<td>Quebec, Ouranos</td>
</tr>
<tr>
<td>HADRM3</td>
<td>Hadley Centre</td>
</tr>
<tr>
<td>RSM</td>
<td>Scripps</td>
</tr>
<tr>
<td>WRF</td>
<td>NCAR/ PNNL</td>
</tr>
</tbody>
</table>

**PLUS:**
- **Domain**
  - Most of North America
- **Resolution**
  - 0.5° resolution
  - ~ 50 km
- **Simulation Period**
  - 1978-2004
- **Boundary Conditions**
  - NCEP/DOE reanalysis

- **Model**
  - GFDL Atmosphere GCM
  - 0.5° resolution
  - specified SST/ice for same period
Diagnosis

► Observation-based Fields
  ✴ Precip: University of Washington VIC retrospective analysis
  ✴ Other fields: North American Regional Reanalysis

► Comparison period: 1982 -1999
  ✴ 1979-1981 omitted for RCM spinup
  ✴ UW data end in mid-2000

► Analysis
  ✴ “Precipitation event” = Daily precip ≥ 2.5 mm at a grid point
  ✴ Focus on precip intensity ≥ 99.5%
  ✴ Pool all “events” in the target region

(Kawazoe, S., and Gutowski, W., 2013, J. Hydrometeorology)
Region Analyzed

- Boreal forest
- Pacific coast
- California coast
- Great Lakes
- Maritimes
- Upper Mississippi River
- Deep South
Composite Structure of Extreme Events: DJF Precipitation
Composite Structure of Extreme Events: NARR
(500 hPa Z & 10-m wind)
Composite Structure of Extreme Events: 500 hPa Z Anomalies
Representativeness of Extreme Events: 500 hPa Z Anomalies
Event Persistence

OBS
ENS
Intraseasonal Variability
Pan-Arctic WRF Simulation
(for WCRP Coordinated Regional Downscaling Experiment)

- **Domain**
  - CORDEX Arctic

- **Resolution**
  - ~ 50 km

- **Simulation Period**
  - 1989 - 2007

- **Boundary Conditions**
  - ERA-Interim reanalysis with NSIDC sea ice
Comparison with observations

- Observation-based Fields
  - Precip: NCDC Global Summary of the Day
  - Other fields: ERA-Interim Reanalysis

  - 1989-1991 omitted for RCM spinup

- Analysis
  - “Precipitation event” = Daily precip ≥ 2.5 mm at a grid point
  - Focus on precip intensity ≥ 99%
  - Pool all “events” in the target region
Self-Organizing Maps

Set of maps that ...
Self-Organizing Maps

Set of maps that

➤ Span pattern space of field(s) examined
➤ Represent nodes of a continuous space
➤ Can give 2-D projection of pattern space
➤ Have basis in Artificial Neural Nets

Examples: Cavazos, T., (2000, J. Climate)
Gutowski, W., et al. (2004, J. Hydrometeorology)

Posters: Cassano, E., et al. (2013)
Glisan, J., et al. (2013)
Self-Organizing Maps

Relation to EOFs, etc?

SOMs ...

- minimize RMS{input - output}
- favor high variance behavior
- $\sim \Sigma$ (rotated EOF)
SOM set: Sea-level pressure
Training: Apply input sequence of maps

Example
Compare sample to ... 

... existing set
Find closest map ...
(here - smallest RMS difference)

... and nudge it toward sample
Nudge also a surrounding region ...
Nudge also a surrounding region ...

... that decreases with iteration
Nudge also a surrounding region ...

... that decreases with iteration
SOM set: Sea-level pressure
Frequency Distribution in SOM Space: WRF Climatology

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.84%</td>
<td>1.98%</td>
<td>3.79%</td>
<td>3.56%</td>
<td>3.38%</td>
<td>3.85%</td>
<td>2.98%</td>
</tr>
<tr>
<td>2</td>
<td>2.45%</td>
<td>2.04%</td>
<td>1.69%</td>
<td>3.38%</td>
<td>2.51%</td>
<td>2.10%</td>
<td>3.85%</td>
</tr>
<tr>
<td>3</td>
<td>2.74%</td>
<td>1.98%</td>
<td>2.86%</td>
<td>2.22%</td>
<td>2.22%</td>
<td>3.44%</td>
<td>3.21%</td>
</tr>
<tr>
<td>4</td>
<td>2.33%</td>
<td>2.10%</td>
<td>1.63%</td>
<td>2.16%</td>
<td>2.51%</td>
<td>2.33%</td>
<td>2.45%</td>
</tr>
<tr>
<td>5</td>
<td>5.08%</td>
<td>2.63%</td>
<td>3.68%</td>
<td>4.20%</td>
<td>2.04%</td>
<td>2.33%</td>
<td>3.44%</td>
</tr>
</tbody>
</table>
## Frequency Distribution in SOM Space: WRF Extreme Precipitation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>5.56%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>4.44%</td>
<td>12.22%</td>
<td>3.33%</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>7.78%</td>
<td>17.78%</td>
<td>3.33%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>5.56%</td>
<td>1.11%</td>
<td>0.00%</td>
<td>6.67%</td>
<td>5.56%</td>
<td>4.44%</td>
<td>11.11%</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>2.22%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>1.11%</td>
<td>2.22%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>12.22%</td>
<td>1.11%</td>
<td>2.22%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>
SOM Space: Example Cases
SUMMARY

- For fairly simple (repeated) extreme events:
  - Straightforward compositing yields physical insight
  - Simple measures representativeness useful

- For more general, complex mixes of extreme events:
  - SOMs - objective discrimination of event types
  - Identify “common” and less frequent types

- SOMs can also yield
  - Insight into temporal evolution
  - Distinction between extreme and non-extreme events with similar circulation/environment
  - Statistical significance of differences in data sources
Thank You!