Why Verify Spatial Scales?

Neighborhood and Scale-separation Approaches

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slides from E. Gilleland and others
Challenge of Higher Resolution Models

- Resolving smaller features

THEN

Fawcett (1977)
BAMS

190-km LFM

NOW

3-km WRF, 2009

For traditional verification,
a 1 grid-point error is same as a 10 grid-point error.
Giving Credit for a Close Forecast

Filter Methods

- Neighborhood
  “fuzzy” (Ebert, 2008, Meteor. Appl.)
  upscaling - smoothing - Fractions Skill Score
  Above what scale does forecast have skill?

- Scale-Separation
  Band-pass (e.g. Fourier, Wavelet)
  Compare skill or power at each scale

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Neighborhood Methods
Smoothing

• Smoothing Filters in MET
  – Minimum, Maximum, Median, Mean

original

mean
Neighborhood Methods
Fractional Coverage

Intensity threshold exceeded where squares are blue

Fraction = 6/25 = 0.24  Fraction = 6/25 = 0.24
Neighborhood Methods

Defining fractional coverage scores

$P_{\text{fcst}} = 6/25$

$P_{\text{obs}} = 6/25$

$P$ is the fractional event frequency within the neighborhood
Neighborhood Methods

\[ \frac{1}{n} \sum_{i=1}^{n} \left( P_{f, \text{cst}} - P_{\text{obs}} \right)^2 \]

Fractions Brier Score

Roberts and Lean (2008)
Neighborhood Methods

\[
1 - \frac{1}{n} \sum_{i=1}^{n} \left( P_{f\,cst} - P_{obs} \right)^2
\]

\[
1 - \frac{1}{n} \sum_{i=1}^{n} \left( P_{f\,cst} \right)^2 + \frac{1}{n} \sum_{i=1}^{n} \left( P_{obs} \right)^2
\]

Fractions Skill Score

Roberts and Lean (2008)
# Neighborhood Methods

Table courtesy of E Ebert.

![Fractions skill score — FSS](image.png)

<table>
<thead>
<tr>
<th>Spatial scale (pts)</th>
<th>Threshold (mm)</th>
<th>1</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>129</td>
<td></td>
<td>0.96</td>
<td>0.95</td>
<td>0.93</td>
<td>0.87</td>
<td>0.80</td>
<td>0.29</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
<td>0.91</td>
<td>0.88</td>
<td>0.85</td>
<td>0.75</td>
<td>0.50</td>
<td>0.27</td>
<td>0.00</td>
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<tr>
<td>33</td>
<td></td>
<td>0.78</td>
<td>0.72</td>
<td>0.60</td>
<td>0.51</td>
<td>0.29</td>
<td>0.11</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>0.62</td>
<td>0.53</td>
<td>0.35</td>
<td>0.23</td>
<td>0.08</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
<td>9</td>
<td></td>
<td>0.51</td>
<td>0.42</td>
<td>0.24</td>
<td>0.13</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0.44</td>
<td>0.38</td>
<td>0.19</td>
<td>0.09</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
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<tr>
<td>3</td>
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<td>0.40</td>
<td>0.32</td>
<td>0.16</td>
<td>0.08</td>
<td>0.02</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>0.33</td>
<td>0.25</td>
<td>0.13</td>
<td>0.05</td>
<td>0.01</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

Good: 1.0 to 0.9

Bad: 0.0 to 0.1

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Neighborhood Methods

- FSS improves with scale.
- Define a target FSS.
- Obtain smallest useful scale $s$. 

\[ \text{perfect 1} \]
\[ FSS \]
\[ 0 \]
\[ s \text{ scale} \]
Neighborhood Methods

• In MET, Neighborhood methods are in grid_stat tool.
• Smoothing filters in MET
  – Minimum
  – Maximum
  – Median
  – Mean
• Fractional coverage
  – Fractions Brier Score
  – Fractions Skill Score
• See Ebert (2008) for a good summary and comparison of these techniques (and references).
**Neighborhood Methods**

Slide from E Ebert. See Ebert (2008) for full references.

<table>
<thead>
<tr>
<th>Fuzzy method</th>
<th>Matching strategy*</th>
<th>Decision model for useful forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upscaling (Zepeda-Arce et al. 2000; Weygandt et al. 2004)</td>
<td>NO-NF</td>
<td>Resembles obs when averaged to coarser scales</td>
</tr>
<tr>
<td>Minimum coverage (Damrath 2004)</td>
<td>NO-NF</td>
<td>Predicts event over minimum fraction of region</td>
</tr>
<tr>
<td>Fuzzy logic (Damrath 2004), joint probability (Ebert 2002)</td>
<td>NO-NF</td>
<td>More correct than incorrect</td>
</tr>
<tr>
<td>Fractions skill score (Roberts and Lean 2007)</td>
<td>NO-NF</td>
<td>Similar frequency of forecast and observed events</td>
</tr>
<tr>
<td>Area-related RMSE (Rezacova et al. 2006)</td>
<td>NO-NF</td>
<td>Similar intensity distribution as observed</td>
</tr>
<tr>
<td>Practically perfect hindcast (Brooks et al. 1998)</td>
<td>NO-NF</td>
<td>Resembles a forecast based on perfect knowledge of observations</td>
</tr>
<tr>
<td>Pragmatic (Theis et al. 2005)</td>
<td>SO-NF</td>
<td>Can distinguish events and non-events</td>
</tr>
<tr>
<td>CSRR (Germann and Zawadzki 2004)</td>
<td>SO-NF</td>
<td>High probability of matching observed value</td>
</tr>
<tr>
<td>Multi-event contingency table (Atger 2001)</td>
<td>SO-NF</td>
<td>Predicts at least one event close to observed event</td>
</tr>
</tbody>
</table>

*NO-NF = neighborhood observation-neighborhood forecast, SO-NF = single observation-neighborhood forecast
Scale-Separation Methods

- Fourier
  - Skamarock (2004), MWR 132:3019-3032
  - Harris et al. (2001), J Hydrometeorol. 2:406-418
  - Tustison et al. (2001), JGR 106(D11): 11775-11784
  - and many more…

- Wavelet
  - Briggs and Levine (1997), MWR 125:1329-1341
  - Casati et al. (2004). [In MET wavelet_stat tool]
Scale-Separation Methods

Wavelets

scale

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Scale Separation Methods
Intensity Scale (IS) (Casati et al., 2004)

1. Create binary fields for a threshold

| forecast | observation |
1. Create binary fields for a threshold
Scale Separation Methods
Intensity Scale (IS) (Casati et al., 2004)

Subtract binary fields for a threshold

binary difference
binary difference

Decompose with Wavelet
Scale Separation Methods

Intensity Scale (IS) (Casati et al., 2004)

1. Create binary fields for a threshold
2. Apply wavelet decomposition to binary difference
3. Calculate mean squared error MSE for each scale j
4. Calculate MSE for a random forecast based on the sample climatology
5. Intensity-scale Skill Score
   \[ IS \text{ skill score}_j = 1 - \frac{MSE_j}{MSE_{random}} \]
   \[ n + 1 \]
6. Repeat for multiple thresholds
Thank you…Questions?

References


Spatial Methods Intercomparison Project (online)

http://www.ral.ucar.edu/projects/icp