Method for Object-based Diagnostic Evaluation (MODE)

A features-based spatial forecast verification technique



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Forecast Verification Issues

- Incorporation of Uncertainty in:
 - verification statistics
 - observations
- Diagnostic and user-relevant verification
- Spatial forecast verification
 - Verification of high-resolution forecasts
- Verification of non-traditional forecasts
 - probabilistic
 - ensemble forecasts
- Verification for extreme or rare events
- Properties of verification measures
 - Propriety, Equitability

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User-relevant verification: Good forecast or Bad forecast?



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If I'm a water manager for this watershed, it's a pretty bad forecast...



User-relevant verification: Good forecast or Bad forecast?



Different users have different ideas about what makes a good forecast

Diagnostic and user relevant forecast evaluation approaches

- Provide the link between weather forecasting and forecast value
- Identify and evaluate attributes of the forecasts that are meaningful for particular users
 - Users could be managers, forecast developers, forecasters, decision makers
 - Answer questions about forecast performance in the context of users' decisions
 - Example questions: How do model changes impact user-relevant variables? What is the typical location error of a thunderstorm? Size of a temperature error? Timing error? Lead time?

Diagnostic and user relevant forecast evaluation approaches (cont.)

Provide more detailed information about forecast quality

- What went wrong? What went right?
- How can the forecast be improved?
- How do 2 forecasts differ from each other, and in what ways is one better than the other?

High vs. low resolution

Which rain forecast is better?



From E. Ebert

High vs. low resolution

Which rain forecast is better?



From E. Ebert

"Smooth" forecasts generally "Win" according to traditional verification approaches.

Traditional "Measures"-based approaches

Consider forecasts and observations of some dichotomous field on a grid:

Some problems with this approach:

(1) **Non-diagnostic** – doesn't tell us <u>what</u> was wrong with the forecast – or what was right

(2) **Ultra-sensitive** to small errors in simulation of localized phenomena



CSI = 0 for first 4; CSI > 0 for the 5th

Spatial forecasts

Weather variables defined over spatial domains have coherent structure and features



Spatial verification techniques aim to:

- account for uncertainties in timing and location
- account for field spatial structure
- provide information on error in physical terms
- provide information that is
 - diagnostic
 - meaningful to forecast users

Recent research on spatial verification methods

- Neighborhood verification methods
 - give credit to "close" forecasts
- Scale decomposition methods
 - measure scale-dependent error
- Feature-based methods
 - evaluate attributes of identifiable features
- Field morphing verification approaches
 - measure distortion and displacement for the whole field

Neighborhood verification

- Also called "fuzzy" verification
- Upscaling
 - put observations and/or forecast on coarser grid
 - calculate traditional metrics



Ebert (2007; Met Applications) provides a review and synthesis of these approaches

Fractions skill score (Roberts 2005; Roberts and Lean 2007)

Scale decomposition

- Errors at different scales of a singleband spatial filter (Fourier, wavelets,...)
 - Briggs and Levine, 1997
 - Casati *et al*., 2004
- Removes noise
- Examine how different scales contribute to traditional scores
- Does forecast power spectra match the observed power spectra?



Feature-based verification



Numerous features-based methods

 Composite approach (Nachamkin)
 Contiguous rain area approach (CRA; Ebert and McBride, 2000; Gallus and others)



Gratuitous photo from Boulder open space

Feature- or object-based verification

- Baldwin objectbased approach
- Cluster analysis (Marzban and Sandgathe)
- SAL approach for watersheds
- Method for Objectbased Diagnostic Evaluation (MODE)
- Others...



MODE: Object-based approach



Object identification



Merging and Matching: Fuzzy Logic

Attributes

Interest Maps

Confidence Maps

Weights

Fuzzy Logic: Attributes



Fuzzy Logic: Interest Maps



Fuzzy Logic: Confidence Maps





Total Interest

 $\sum w_i C_i(\alpha) I_i(\alpha_i)$ i $T(\alpha)$ $\sum w_i C_i(\alpha)$

Object-based example: 1 June 2005



Radius = 15 grid squares, Threshold = 0.05"

Object-based example 1 June 2006



(3) Too far North

WRF ARW-2 Objects with Stage II Objects overlaid

Object-based example 1 June 2006



MODE provides info about areas, displacement, intensity, etc.

In contrast: POD = 0.40 FAR = 0.56 CSI = 0.27

WRF ARW-2 Objects with Stage II Objects overlaid

Applications of MODE

Climatological summaries of object characteristics

Evaluation of individual forecasting systems

- Systematic errors
- Matching capabilities (overall skill measure)
- Model diagnostics
- User-relevant information
- Performance as a function of scale
- Comparison of forecasting systems
 - As above

Example summary statistics



Example summary statistics

MODE "Rose Plots" Displacement of matched forecast objects



MODE availability

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Us	Welcome to the users home page for the Model Evaluation Tools (MET) verification toolkit. MET was	ANNOUNCEMENTS		/ Wandbie
Contact ME	developed by the National Center for Atmospheric Research (NCAR) Developmental Testbed Center	MET beta v0.9 release:		ac nart of
WDE Ma	state-of-the-art suite of verification tools. MET was developed using output from the Weather	An initial beta release of the MET is available (MET beta		as part or
Home Pag	Research and Forecasting (WRF) modeling system may but be applied to the output of other modeling	<u>v0.9</u>) as of July 16, 2007.		
	systems as well. MET provides a variety of verification techniques, including:			the Model
•	 Standard verification scores comparing gridded model data to point-based observations Standard verification scores comparing gridded model data to gridded observations 			
	Object-based verification method comparing gridded model data to gridded observations			Evaluation
	Additional verification techniques and analysis tools will be supported for community use in the			Lvaluation
	future, depending on interest and availablility of resources.			
				(MET)
	Thanks to the U.S. Air Force Weather Agency for their support of this work.			
	Thanks also to the National Oceanic and Atmospheric Administration for their support of the Developme	ntal Testbed Center.		
	NCAD is snonsored by the National Science Foundation (NSE) and managed by the University Corporation f	or Atmospheric Research (HCAR)	_	
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http://www.dtcenter.org/met/users/

Intercomparison web page

 References
 Background
 Data and cases
 Software

🖼 Spatial Forecast Verification Intercomparison Project (ICP) - Mozilla 📃 🗖				
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Spatial Forecast Verification Methods Intercomparison Project (ICP)				
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Recent advancements in weather forecasting and observational systems have created great improvements in resolution and prediction. However, use of standard verification practices often indicate poorer performance because, among other things, they are unable to account for small-scale noise or discriminative of errors such as displacement in time and/or space (see papers in the references section). This issue has motivated recent research and development many new verification techniques for handling spatial forecasts. The intent of this project is to compare the various newly proposed methods to give the user information about which methods are appropriate for which types of data, forecasts and desired forecast utility.				
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http://www.ral.ucar.edu/projects/icp/

Acknowledgements

- Co-authors and contributors: David Ahijevych, Barbara G. Brown, Randy Bullock, Chris Davis, John Halley Gotway, Lacey Holland
- National Center for Atmospheric Research (NCAR)
- Boulder, Colorado
- October 2007

References: see ICP website



http://www.rap.ucar.edu/projects/icp/references.html