EVALUATION AND VERIFICATION OF PUBLIC WEATHER SERVICES

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WHAT IS THE MAIN DIFFERENCE BETWEEN A GOVERNMENT WEATHER SERVICE FORECAST AND A MEDIA FORECAST???

ACCOUNTABILITY!!!
HOW ARE FORECASTS USED??

HOW MEDIA FORECAST ARE USED:
- What Should I Wear Outside?
- Is It Going To Rain Today?

HOW GOV’T FORECAST ARE USED:
- Who Needs To Be Mobilized?
- What Areas Must Be Evacuated
- What Should I Tell The President/Governor/Prime Minister, Etc…
VERIFICATION GOALS:

- To Gage The Accuracy, Skill And Timeliness Of Warnings, Watches And Forecasts
- To Provide A Baseline To Assist In Setting Goals For Measuring Performance
- Identify Training Needs To Assist In Improvement Of Forecast And Warning Process & Products
Evaluation Begins By Establishing Performance Goals

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<td>12</td>
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REGARDLESS OF THE USER... ANY FORECAST SHOULD BE EVALUATED IN 3 WAYS:

- Is It Timely And Accurate?
- Is It Understandable?
- Does It Meet The Users Needs?
- The First Goal Can Be Objectively Evaluated... The Others Take Work!
OBJECTIVE VERIFICATION

- Public Forecasts & Warnings
- Aviation Forecasts
- Marine Forecasts & Warnings
- Fire Weather Forecasts

Goal Is To Provide Effective Objective Verification Of All Forecast Parameters
PUBLIC FORECASTS

Primary Forecast Elements Include:

- Maximum & Minimum Temperatures
- Probability Of Precipitation

Secondary Elements Include:

- Sky Condition (Cloudy, Partly Cloudy, Etc.)
- Winds
- Precipitation Type (Liquid vs. Frozen, Etc.)
PUBLIC FORECASTS

- While All NWS Products Are Produced In Text Format...

- Those Text Forecasts Are Derived From “Gridded” Forecasts Of Individual Forecast Parameter Fields...
All Forecast Elements Found in http://digital.weather.gov/

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Gridded, Or Graphical Forecasts Can Be Much More Useful In Depicting Changes On A Spatial Or Temporal Scale...

...But It Makes Realistic Verification Much More Difficult!
HOW DO WE EFFECTIVELY VERIFY GRIDDED FIELDS?

THE FIRST QUESTION THAT MUST BE ANSWERED IS... WHAT ARE WE GOING TO VERIFY AGAINST???

- Actual Observations (Points)?

- Model Forecast Fields?

- Data Assimilation Fields?

Any of these options have their own set of problems!
Maximum Temperature Verification Against Actual Point Observations

Max Temp, MAE (°F), NDFD vs Pnt Obs, 12(122)
Forecasts from Feb 1, 2004 to Feb 29, 2004

OVERALL = 2.86
CENTRAL = 2.82
EASTERN = 2.79
SOUTHERN = 3.02
WESTERN = 2.81
Verification Against Actual Point Observations

Strengths:

- Probably The Most Realistic Scheme... Uses Data People Understand
- Deals With Absolute Error... Therefore Is Easiest To Use and Understand...

Limitations:

- Does Not Really Measure “Skill”... No Control To Measure Against
- Tends To Be “Biased” In Favor Of Locations With Smaller Ranges Of Conditions
- Often, The “Point” Location Where The Observation Is Taken Is Not Representative Of The Area Where The Population Lives!
Let’s Look At This “Bias” Issue And What It Means In A Comparison Of Temperature Forecast Verification Data For Two Sites...

Site A:

- 94% Of Temp Forecasts Have Errors Of Less Than 5 Degrees...
- Less Than 1% Of Forecasts Have Errors Of 10 Degrees Or More

Site B:

- 70% Of Temp Forecasts Have Errors Of Less Than 5 Degrees...
- 8% Of Forecasts Have Errors Of 10 Degrees Or More

Are The Site A Forecasters Really That Much Better Than Those At Site B? Should We Fire The Forecasters At Site B???
First, Let’s Make Sure That This Is Actually A Fair Comparison! Site A Is Actually Key West... Site B Is Minneapolis

The Answer To Our Question: Nope... Key West Simply Does Not Have As Active A Weather and Climate Regime as Minneapolis... Therefore, Fewer and Smaller Weather Changes

This Means That Using This Type Of Absolute Comparison For All Forecast Offices Does Not Provide A Realistic Evaluation Of Forecast Skill
Is It Representative? Consider Jacksonville, FL

“Official” Observations Are Taken Here...

But Most Of The Population Lives Here!
Verification Against Model, or Numerical Forecast Fields

Strengths:
- Easier To Judge Actual “Skill” Since Both Model and Human Forecasts Are Compared Against A Common Parameter... Actual Observations
- Is Much More Effective At Providing A Realistic Evaluation Of Forecaster Performance...

Limitations:
- In The Public’s Eyes... The “Comparison” Isn’t Much Of A Factor
- If A Temperature Forecast Is Off by 20 Degrees, It’s Not Much Comfort To The Public To Know That The Model Missed It By 25 Degrees!
Let’s Look At This Verification Scheme For The Two Sites We Used Previously ...

**Key West:**

- Recall That 94% Of Temp Forecasts For This Station Have Errors Of Less Than 5 Degrees... But The Raw Model Forecasts Were Actually 0.1% Better!

- In Addition... The Model Guidance Had 10% Fewer Errors of More Than 5 Degrees

**Minneapolis:**

- While The Absolute Errors For This Location Were Greater Than Those For Key West... They Actually Improved Overall Against The Model Forecasts by 2.3%

- And... They Had 4% Fewer Errors of More Than 5 Degrees!
No Matter What Method Is Chosen… Effectively Verifying Forecasts Involving *Dozens Of Fields*… Out To As Much As *7 Days*… At Time Scales As Small As *One Hour*… While Ensuring *Consistency* With Surrounding Offices… Is A Huge Challenge!!
PUBLIC FORECASTS

Primary Forecast Elements Include:

- Maximum & Minimum Temperatures
MAX & MIN TEMPERATURE FORECASTS

- Verification Efforts Focus On The Actual Value

- They Don’t, However, Take Into Account:
  - What Time The Max Or Min Occurred
  - How The Temperature Changed During The Course Of A Forecast Period.
MAX & MIN TEMPERATURE FORECASTS

Consider a forecast for the next 12 hours, released at 6 AM which states or depicts the following:

- **Today:** Cloudy. High of 70.

- **Actual Conditions:** High during the 12 hours was 70 and cloudy conditions existed for most of the day.

Did this forecast verify?
MAX & MIN TEMPERATURE FORECASTS

From A “Verification” Standpoint This Was An Accurate Forecast

However… While The Temp At 6 AM Was 70… A Cold Front Passed Through And The Temp Dropped To Below 50 By 8 AM And Then Spent The Rest Of The Day In The 40s.

It’s Highly Debatable, Therefore, That This Would Be Considered A “Good” Forecast By Users!
PUBLIC FORECASTS

Primary Forecast Elements Include:

- Maximum & Minimum Temperatures
- Probability Of Precipitation
PROBABILITY OF PRECIPITATION FORECASTS

- Probably The Least Understood Forecast Parameter Used By The U.S. NWS.
- Originally Designed As A Product Of 2 Probabilities:
  - “Conditional” Probability
  - “Areal” Probability
- Ultimately meant to convey frequency of occurrence given present conditions.

The Point Could Legitimately Be Made That We Are Comparing Apples And Oranges!

Despite This…The Main Verification Tool Used To Evaluate PoP Forecasts is Brier Score
Brier Score

Measures Accuracy Of A Set Of Probability Assessments (but it says nothing about reliability):

\[ BS = \frac{1}{N} \sum_{t=1}^{N} (f_t - o_t)^2 \]

N = Number Of Forecasts,
Ft = Probability That Was Forecast
Ot = Actual Outcome (0 If No Rain, 1 If Rain Occurs)
With Brier Score, The Lower Score = Higher Accuracy:

- If you forecast 100% and rain occurs, \( ft \) and \( ot = 1 \) BS=0= Perfect!
- If you forecast 100% and no rain, \( ft=1, \, ot=0 \), BS=1 Awful!
- If you forecast 70% and rain occurs \( ft=.7, \, ot=1 \) BS=.09 Pretty Good!
- If you forecast 30% and rain occurs \( ft=.3, \, ot=1 \) BS=.49 Not Too Good!

Brier Score Rewards The Aggressive and Punishes “Hedge” Forecasts!
- If you forecast 50%, your BS=.25 Whether or not rain occurs.
- Since The NWS Performance Goal for PoP is ,<.10, This is Bad.

NOTE: Interestingly enough hedge forecasts are punished by Brier Score yet they might be reliable.
So... Why Not Just Forecast Either High Or Low Probabilities?

Public Perception Is The Big Problem! Consider This Forecast Scenario:

A Fast Moving Cold Front Is Forecast To Move Through...With A Solid...But Narrow Band Of Precipitation. The Forecaster Is Sure It Will Rain So She Forecasts a PoP of 100%
Was It A Good Forecast?

When The Front Passed Through, It Rained For 10 Minutes From 10:00 AM to 10:10 AM Dropping A Total Of .02 Inch.

For Verification Purposes, This Would Be A “Perfect” Brier Score Of 0…. But How *Useful* Was It?

- How About The Afternoon Picnic That Was Cancelled… Even Though The Afternoon Was Totally Dry!

- Or Work Lost On Construction Which Cancelled Work For The Entire Day… Even Though It Only Rained For 10 Minutes!
While Brier Score is an effective statistical tool for evaluating precipitation forecasts...

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<td>0.0851</td>
<td></td>
<td>0.0915</td>
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<td>-2.7</td>
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It really doesn’t measure how helpful the PoP forecasts are to the people that use them or how reliable they are!!
SEVERE LOCAL STORM PRODUCTS AND VERIFICATION

Ideally, these products follow a logical time/spatial pattern... Threat area and time frames become smaller as the event becomes more certain.
Storm Prediction Center

...Identifies Potential Severe Weather Threat Areas...

Time Frame: Out As Far As 8 Days
Current Convective Watches

Updated: Sat Apr 12 15:01:00 UTC 2008

Severe Thunderstorm Watch #201
Issued/Updated: Apr 12, 2008 at 1551 UTC
Expires: Apr 12, 2008 at 2200 UTC
Severe Thunderstorm Watch 201 Status Message has not been issued
Local NWS Offices Issue “Storm Based” Warnings:
Time Frame: Usually 1 Hour Or Less
SEVERE WEATHER: WATCHES VS. WARNINGS

- Watches Indicate Conditions Are Favorable For Severe Weather Development

- Warnings Are Issued When Severe Conditions Are Imminent Or Occurring

- There Are Important Differences In How These Products Are Verified!
SEVERE WEATHER: WATCH VERIFICATION

- Watches Are Generally Issued For Large Geographical Areas… Sometimes Thousands Of Square Miles

- A Severe Weather Event Anywhere In This Geographical Area Verifies The Entire Watch
SEVERE WEATHER VERIFICATION: COUNTY VS. STORM-BASED WARNINGS

- Warnings For Severe Thunderstorms Or Tornadoes Used To Be Issued On A County By County Basis.

- However... Storms Do Not Respect Political Boundaries! A Single Storm Will Frequently Threaten Parts Of Several Counties.

- Warnings Are Now Issued As “Polygons” ...Based On Specific Storm Location & Motion Rather Than Political Entities.

- This Does Present Some Verification Challenges... But Provides Much More Realistic Verification!
“Storm Based” Warning Example:
SEVERE WEATHER: WARNING VERIFICATION

- Warnings Are Verified Based On Four Primary Computed Parameters:
  - Probability Of Detection (POD = A/(A+C)):
    Was The Event Warned For?
  - False Alarm Ratio (FAR = B/(A+B)):
    Warning Was Issued, Did it Occur?
  - Critical Success Index (CSI = A/(A+B+C))
  - Lead Time Of The Event

- Individual Offices Are Responsible For Gathering And Reporting Severe Weather Events In Their Area.
  - This Data Is Published In “Storm Data”
SEVERE WEATHER: WARNING VERIFICATION

For Verification Purposes, Severe Weather Includes:

- Thunderstorm Winds Of 50 Knots (58 Mph) Or Greater
- Hail Of 1.00” Diameter Or Greater
- Tornadoes (But Not Funnel Clouds)
- Occurrence Of Structural Wind Damage Which Implies The Existence Of Any Of The Above.
SEVERE WEATHER: WARNING VERIFICATION

To Verify A Warning... Event Must Occur Within The Valid Time And Area Of A Warning.

This Is Subject To Some Complicated Limitations, However.

- For Example: The “10/15 Rule” – Severe Events Occurring Within 10 Miles Or 15 Minutes Of Each Other Are Considered Duplicates...unless Winds Are 65 Mph Or More Or Hail Is 2” Or Greater... Or It Is The Only Event Verifying A Warning.

- This Can Obviously Get Quite Confusing.
### Summary Statistics

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<td>NOT Verif</td>
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<td>182</td>
<td>127</td>
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WARNING VERIFICATION: “LONG FUSED” EVENTS

- Longer Duration Events Such As Winter Storm Or High Wind Events Are Verified Differently.

- Main Criteria Is When And If An “Event” As Defined By The NWS Is First Observed In A Warned (Or Unwarned) Area

- Under Some Circumstances, (Both Long And Short Fused Events) A Warning Issued After The Beginning Of An Event Can Still Be A Verified Warning... But With Zero Lead Time.
While No Verification Scheme Is Perfect, A Good One Will Do The Following:

- Realistically Measure Objective Data In The Way It Was Intended To Be Used
- Compares Forecast Data Sets To Others That Are Truly Forecasting The Same Thing
- Attempts to measure and/or establish usability.
- Can Be Used For Real Time Quality Control To Ensure Forecasts Are Useful To People, And Not Just A Set Of Numbers
- Can Truly Be Used To Identify Trends And Biases And Improve The Forecasts and Warnings
Post-Disaster Service Assessments: A Key Part Of The Quality Improvement Process!
THREE IMMEDIATE POST-EVENT QUESTIONS:

- What Went Right?
- What Went Wrong?
- How Can We Improve?

Answering These 3 Questions Is The Primary Goal Of A Service Assessment!
WHAT A SERVICE ASSESSMENT IS:

- A Learning Tool For Future Events
- A Way To Identify “Best Practices”
- A Way To Identify And Correct Problems
WHAT A SERVICE ASSESSMENT IS NOT:

- A Meteorological Study Of The Event
- A Historical Documentation Of The Event
- A Way To Place The Blame When Things Go Wrong
THE GOAL OF THE SERVICE ASSESSMENT IS TO:

- Explain What Happened
- Detail NWS Actions Before, During And After The Event
- Recommend Changes In NWS Policy, Procedures, Products And Services To Improve Their Quality!
CRITERIA FOR SERVICE ASSESSMENTS

- Significant Impact On Economy Of A Large Area Or Population
- Significant Number Of Deaths
- Extensive National Interest, Media Coverage Or Public Scrutiny
WHAT TYPE OF EVENTS ARE ASSESSED?

- Any Event Which Meets The Previous Criteria, Including:
  - Hurricanes
  - Tornadoes
  - Floods
  - Winter Events
  - Heat Waves
  - Wildfires
WHO MAKES THE DECISION?

– The Office Of Services At National Weather Service Headquarters And The Regional Directors Of The Affected Areas.

– Final Approval For Assessment Comes From The NWS Director.

– This changed with Hurricanes Irene and Sandy (NOAA directed).
THE SERVICE ASSESSMENT TEAM WILL NORMALLY INCLUDE:

- Subject Matter Expert For The Type Of Event Involved
- Someone With Field Experience And Current Expertise For The Event.
- Public Affairs Officer And Office Of Services Facilitator
- Someone Outside The NWS, Preferably With Expertise Related To The Event

Note… One Of These Individuals Will Serve As Team Leader
Event Specific Assessments

- There are some differences in the assessment approach for a short term event (e.g. Tornado) vs. the approach for a longer term event (Hurricane).

- However... while the assessments may differ in scale in time and space... the goals are really the same... to evaluate what went right or wrong and improve the forecast and warning process.
An Example…

- To Demonstrate How the Assessment Process Works… Let’s Look At A Real Life Example Of What Goes Into One…

- The Following Assessment Was Conducted After A Major Tornado Event In Oklahoma City, OK in May, 2003
It Starts With Data…

The First Step Is To Collect As Much Data As Possible, Including:

- Meteorological Data... Model Output, Radar, Satellite, Guidance Products Etc. Available At The Time Of The Event

- Products & Services... Forecasts, Warnings, Statements, Event Logs, Communications Logs, Equipment Status, Contact Information, Staffing Levels, Outreach History, Training Records… etc.

- Event Data...Rough Estimate Of Timing, Areal Extent, Type of Event, Deaths, Injuries, Damage

- Potential Interview List... Emergency Managers, Eyewitnesses, Media, First Responders, etc.
After The Team Arrives On Site...Field Operations Begin

Usually, The Team Will Split Up... With Different Members Collecting Different Information

- Some Will Conduct Visual Inspections
- Some Will Interview Important Contacts
- Some Will Review Forecast Products & Performance
CONFIRM WHICH AREAS WERE AFFECTED
VISUAL INSPECTION OF AFFECTED AREAS
ESTABLISH MAGNITUDE OF DAMAGE INCLUDING NUMBER OF DEATHS, INJURIES, ECONOMIC IMPACT
The Service Assessment Team May Also Help To Establish A “Rating” For The Event

(For Example, EF-scale Rating For Tornadoes, or Saffir-Simpson Scale Rating For Hurricanes)

Normally, The Final Determination Of The Rating Will Be Made By A Quick Response Team Of Subject Matter Experts.
CONDUCTING ASSESSMENT AS QUICKLY AS POSSIBLE AFTER THE EVENT IS CRITICAL!!!
PEOPLE TO BE INTERVIEWED:

- SURVIVORS/WITNESSES
- EMERGENCY MANAGERS
- MEDIA
- RESCUE PERSONNEL
INTERVIEW TOPICS

- DID YOU RECEIVE A WARNING?
- WAS IT TIMELY?
- WAS IT UNDERSTANDABLE?
- HOW DID YOU RECEIVE IT?
FORECAST OFFICE
INTERVIEWS

- REVIEW WARNING PRODUCTS
- ESTABLISH LEAD TIMES
- WERE AGENCY AND OFFICE POLICIES AND PROCEDURES PROPERLY FOLLOWED?
- WHAT WENT RIGHT: “BEST PRACTICES”
- HOW CAN WE IMPROVE?
Results Of The Assessment Are Shared With All NWS Offices… So That Everyone Can Learn From Both The Positives And Negatives Of The Event

Information Sharing Of This Type Is One Of the Most Vital Methods Available To Ensure The Quality Of Our Most Important Service… Protecting Lives & Property!
So... The Assessment Identifies A Need For A New Service...

How Does That New Service Come About?
Often, The Service Assessment Report Itself Will Contain Specific Recommendations That The NWS Can Implement Through Internal Procedures
There Are Also Times When Initiatives From The Research Community Can Directly Result In A Procedural Change!

An Example:
The Enhanced Fujita Scale
The Key Points…

- Change Can Be Difficult… But If Quality Of Service Is To Improve, We Must Be Open To Change.

- We Must Constantly Be Open To The Possibility That There Are Better Ways To Do Things!

- We Do Not Know It All! Our Partners Are Often Much More Aware Of How Well Our Services Are Meeting Needs!
THE END

QUESTIONS???