Why Verification?

Model Development

Verification

Managers

Users
NOAA Global Systems Laboratory

Model Development
Verification System - Process Oriented Verification

- Aggregated statistics over regions required to keep database size reasonable with rapid response times
- However, these objective metrics are hard to deconvolve to determine what atmospheric (physical) process(es) are the source of model forecast errors
- Process-Oriented Verification is a possible solution - WFIP-2 prototype

<table>
<thead>
<tr>
<th>List of Discriminators</th>
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</thead>
<tbody>
<tr>
<td>Surface Bulk Richardson Number</td>
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<tr>
<td>Surface Heat Flux</td>
</tr>
<tr>
<td>Latent Heat Flux</td>
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<tr>
<td>Stability Parameter</td>
</tr>
<tr>
<td>Friction Velocity</td>
</tr>
<tr>
<td>Max Cloud Fraction</td>
</tr>
<tr>
<td>10-m Wind Speed</td>
</tr>
<tr>
<td>10-m Wind Direction</td>
</tr>
<tr>
<td>80-m Wind Speed</td>
</tr>
<tr>
<td>80-m Wind Direction</td>
</tr>
<tr>
<td>PBL Height</td>
</tr>
<tr>
<td>Wind Shear (200-10m)</td>
</tr>
<tr>
<td>Wind Shear (200-50m)</td>
</tr>
<tr>
<td>Vertical Temperature Difference</td>
</tr>
<tr>
<td>Downward Shortwave Radiation</td>
</tr>
</tbody>
</table>

Vertical Profile of model wind speed filtered by downward solar radiation (red) and unfiltered (blue)
Verification System - R2O example

• Issue with how clouds were treated at the sub-grid scale, below the scale at which the High-Resolution Rapid Refresh (HRRR) can explicitly resolve them
• Modelers utilized internal solar radiation verification at all stages of development
  • Diagnosis
  • Testing
  • Long-term viability
  • Operational implementation
NOAA Global Systems Laboratory

Users
FAA’s AWRP: “The goal of the research is to transition new or improved weather capabilities…[to] enhance aviation safety and efficiency.”

GSL provides third-party, independent, evaluations of FAA-funded weather products to inform R2O decisions.

Assessments drove decisions to...

- Select the Localized Aviation MOS Product (LAMP) to provide ceiling and visibility data for the Helicopter Medical Emergency Services (HEMS) Tool.
- Delay implementation of the Offshore Precipitation Capability (OPC) to improve product performance.
Verification Tools--NWS

CWVS
Convective Weather Verification Service
Impact-based verification of TCF

TFVT
TRACON Gate Forecast Verification Tool
TRACON Gate forecasts for convection at the terminal

CBVT
CWSU Briefing and Verification Tool
Forecaster briefings to TMU for wind shift, C&V events

EVENT
Event-based Verification and Evaluation of NWS Gridded Products Tool
Gridded products for thunderstorm events, terminal and en-route
Economic Impacts (EI) - Overview

- Developing NWP models is expensive; is the Nation getting a good return on its investment?

- EI from some tool can only occur if a decision is changed based upon that tool (e.g., the new forecast changes behavior)

- EI is only important for certain weather conditions

- EI is usually regionally dependent

- Working with CSU Economics Dept. to evaluate EI of the regular updates to our regional model HRRR

- Estimating EI of a decision is seldom easy
**Economic Impacts - Wind Energy Example**

Only focused on “overprediction” errors → largest financial impact

<table>
<thead>
<tr>
<th></th>
<th>New “better” than old</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>“Actual”</td>
<td>579,260</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Based on HRRR1</td>
<td>3,328,406</td>
<td>75.6</td>
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<td>$59.0M</td>
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<td>Based on HRRR2</td>
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<td>$17.4M</td>
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<tr>
<td>“Actual”</td>
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<tr>
<td>Based on HRRR2</td>
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</tr>
<tr>
<td>Based on HRRR3</td>
<td>1,547,034</td>
<td>19.3</td>
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<td></td>
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</tbody>
</table>

14 month period

11 month period
Summary

• Developed range of tools for objective NWP model evaluation
  • Goal: to help the model developers improve the models more efficiently
  • Many different statistics over numerous variables and regions
  • Working to identify physical processes that aren’t represented correctly

• Impact-based assessment
  • Goal: demonstrate improved functionality and accuracy of new models for specific, high-visibility stakeholders
  • Evaluate the forecast systems from the stakeholder’s perspective
  • Primarily objective based, but subjective interpretation also

• Economic assessment
  • Using economic models to translate model improvements into societal savings
Summary

• Automated verification tools and metrics to quantify model improvements demonstrate *performance*

• Innovative techniques such as impact-based and process-oriented evaluations demonstrate *quality*

• Independent model assessments used by NWS and FAA as decision points for transitioning models and tools to operations within NWS demonstrate *relevance*

• Significant economic benefits in several sectors demonstrate *quality and relevance* of the HRRR model to society
Summary

Performance
• Automated verification tools and metrics to quantify forecast model and improvements

Quality
• Innovative techniques
  • Impact-based
  • Event-based
  • Process-oriented
• Improved models to NWS operations

Relevance
• Independent model assessments used by NWS and FAA as decision points for transitioning models
• Involved in nearly everything GSL does
Verification across GSL

Data Assimilation

Prediction

Decision Support

Advanced Technology

**Data Assimilation–Obs Impact**

- Frequent updates allow:
  - Use of the most recent weather observations for improved forecasts.
- Updated information for decision makers.

**Prediction Across Scales**

- Transition from 6-hr to 1-hr global data assimilation cycles at 13 km scale
  - Use of the most recent weather observations for improved forecasts.
- Test assimilation strategies to:
  - Mitigate noise from frequent analyses
  - Generate lower-biases shorter-term forecasts with smaller obs windows
  - Collect more latent observations for longer-term forecasts to “do no harm”

**Decision Support**

- Automated verification for forecast calibration and confidence
  - Verification can influence forecasters’ confidence!

**Advanced Technology**

- Improved algorithms resulted in better stability and higher accuracy
- Focus on computational efficiency

**Advanced Technology - Exascale Computing**

- Comparison of numerical accuracy for shallow water (ivcubed, A vs. C grid)
- Improved algorithms resulted in better stability and higher accuracy
- Focus on computational efficiency

**Advanced Technology - AQPI**

- Do these distributions represent the range of solutions for the communication of uncertainty?
- Can verification information improve them?
- Can verification influence forecasters’ confidence?

**Advanced Technology - Machine Learning**

- Improve performance and speed of traditional methods
  - Convolutional Detection and Monitoring
  - Using AI to create probabilistic forecast of areas of likely contamination with various lead times (+30 to +180 minutes)
  - Collaborating with Taiwan Central Weather Bureau
  - Cyclone Detection
  - Using AI to detect and target areas for further data collection
  - Working with ECMWF to test in pre-operational capability

**Data Assimilation**

- 3DVar is very useful for regional hourly data assimilation in RAP/IIRR and has superior skill over purely 3D-variational analysis (shown below).
- Ensemble background error covariance data from the global system, GDAAS, is effective.

**Prediction Across Scales**

- Seasonal dependence of 80-m wind speed validation in Columbia River Gorge with 750 m HRRR test accuracy (red)
  - Validation 100-150 scales (with high test performance)

**Decision Support**

- One of the first applications to quantify confidence based on past performance of forecast sources.

**Advanced Technology**

- Comparison of numerical accuracy for shallow water (ivcubed, A vs. C grid)
- Improved algorithms resulted in better stability and higher accuracy
- Focus on computational efficiency