Twenty-two years of verification from the HIRLAM NWP system

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Background

• Hirlam forecast systems have been run operationally at FMI since 2 January 1990
• Field verification implemented in July 1990
• Observation verification system operationally since 1995
• Three reasons to verify (Jolliffe and Stephenson 2003):
  • Administrative
  • Scientific
  • Economical
Short history of HIRLAM

• 13 different versions and many smaller changes
• From 2004 onwards RCR: running the official reference system
• Resolution improved:
  • Horizontal: 0.5 deg → 0.07 deg
  • Vertical: 16 levels → 65 levels
  • \( n_x \times n_y \times n_z \)
    • 130 \( \times \) 100 \( \times \) 16 = 208 000
    • 1030 \( \times \) 816 \( \times \) 65 = 56 639 700
    • → ~ 272 times more gridpoints
• Increased computer power has made all improvements possible
• Some milestones in the table
Statistical verification

• Field verification: verifying against the HIRLAM numerical analysis
• Monthly scores for mean sea level pressure (mslp) and Temperature at 925 hPa
• RMS error and bias
• The results will be shown mainly on two areas:
  • **ATLEUR**: Atlantic-European area, largest common area to all FMI HIRLAMs
  • **SCANDI**: Scandinavian area is interesting for us
• Time series from July 1990 to August 2012, over 22 years
• Interpretation of RMS error:
  • A lot of discussion in the literature
  • Favors smooth fields and low resolution
  • Double penalty problem
  • Gives larger weight to large errors (squared)
Results with linear trend

• July 1990 … August 2012
• RMS error and bias for the two areas
• Linear trend
Results with moving average

- 13 months’ moving average
- 2-day forecasts now better than 1-day forecasts 20 years ago
- Improvements not linear

Reasons for improvements?
- Model improvements?
- Weather types (regimes)?

Statistical scores do not tell the reason for improvements

Can the improvements traced back to changes in the forecasting system?
- In some cases yes

Some examples of the reasons for improvements
Improvements in 2006, what happened?

Re-run concept:

- ECMWF lateral boundaries used always
- New: use the analysis of the previous cycle
- ECMWF analysis is superior to HIRLAM analysis
- Re-run the previous cycle
  - Analysis for this is combination of ECMWF and HIRLAM analysis
  - Large-scale structure from ECMWF
  - Preserve small-scale structure from HIRLAM
- Run a short forecast to get the best possible first guess for the current cycle
Negative bias in Scandinavia in winter

Large negative bias in winter in Scandinavia

- Increasing with forecast length
- Very large in the first years
- In last two Januaries large bias
  - Weather regime?
  - HIRLAM system?

- Last two winters: large negative bias → what happens next winter?

- Simo Järvenoja suggested in 2005:
  - Could it be the location of the eastern boundary?
  - Try with different horizontal areas, some extending more east
  - Turbulence scheme?

- We don’t know the reason
- Statistical methods can describe the situation, but not explain the physical reason
Just for orientation
Monthly bias, +48 h, mslp, January 1991-2012
Monthly variability, +48 h, mslp, January 1991-2012
Bias and RMSE, T at 925 hPa
Bias and RMSE, T at 925

- Negative bias in early years
- Many experiments were runs to find the reason
  - The whole lower troposphere was too cold and moist
  - Caused permanent stratus cloud
  - Several corrections were tried
  - Two of them helped
    - Increase of vertical levels from 16 to 31
    - Savijärvi radiation scheme
- Improvement in 2003
  - In bias: negative bias -> slightly positive bias
  - Reduction in RMSE, especially in ATLEUR
  - Most probably due to the introduction of 3DVAR
Effect of weather type on scores in winter

- NAO-index is used widely to classify weather type in the North Atlantic
  - Positive NAO: westerly flow
  - Negative NAO: blocking
- Correlation between NAO and RMSE not very high, but:
  - In 1990’s larger correlation between NAO and RMSE
  - In 2000’s decreases

- Possible reasons for higher correlation in 1990s
  - Smaller horizontal area, boundaries closer
  - No satellite data
  - ECMWF boundaries only once or twice a day
  - No re-run concept

<table>
<thead>
<tr>
<th>Correlation between RMSE of +48 h forecasts and NAO-index in winter</th>
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<tbody>
<tr>
<td>SCANDI mslp</td>
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<tr>
<td>Z500</td>
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<tr>
<td>EWGLAM mslp</td>
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<td>Z500</td>
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</table>
Observed and predicted monthly precipitation

- Some preliminary results
- Observations: rain gauge observations for 2004-2012
- Monthly precipitations sums from HIRLAM forecasts
  - Computed as an accumulation in 6 hours
  - For different forecast lengths:
    - $+0\ldots+6h$, $+6h\ldots+12h$, $+12h\ldots+18h$, ... , $+42h\ldots+48h$
  - Are there differences in different lead times?
    - Spin-up problem?
    - Bias increasing/decreasing with lead time?
Yearly precipitation in Finland

- Normal yearly precipitation amount in Finland
- Some stations for which results will be shown
<table>
<thead>
<tr>
<th>Season</th>
<th>Obs</th>
<th>+0-+6</th>
<th>+6-+12</th>
<th>+12-+18</th>
<th>+18-+24</th>
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</table>
What we have in the table?

• **Observed seasonal precipitation (mm)**
• **Different forecast lengths**
• **Predicted precipitation by HIRLAM at different lead times**
• **Predicted precipitation in percents of the observed precipitation**
Seasonal verification, whole Finland

- Spin-up problem:
  - Shortest forecast gives systematically less precipitation at all seasons
- Effect of forecast length
  - There does not seem to be clear systematic increase/decrease for other forecast lengths
Different seasons

• HIRLAM overpredicts the seasonal precipitation
  • In winter and autumn by 20…30%
  • In spring by 40…50%
  • In summer by 10…20%

• Summer
  • More convective precipitation
  • Under-predicts the very large amounts (see later)

• Spring
  • Driest season
  • Overestimates the precipitation almost by 50%

• Winter and autumn similar

• This dataset cannot distinguish heavy and small amounts of precipitation
Northern and southern

- **In southern Finland**
  - More precipitation observed
  - Over-prediction smaller in percents
  - What about mm?

- **In northern Finland**
  - Less precipitation
  - Less over-prediction in percents
  - What about mm?
Monthly time-series from some stations
Monthly time-series from some stations
Summary

- 21 years of Hirlam forecasts have been verified
- 2-day forecasts now better than 1-day forecasts 20 years ago
- Improvements not linear
- In many cases improvements can be traced back to system developments
  - Re-run concept
  - Temperature at 925 hPa, radiation, no of levels
- Some obvious weaknesses remain unexplained
- Less dependent of the weather regime now
- 8 years of HIRLAM monthly precipitations have been verified (preliminary results)
- Spin-up problem in short forecasts
- No clear drift during the forecast
- Over-forecasting in all seasons, especially in spring

Kalle Eerola: "Twenty-one years of verification from the HIRLAM NWP system", accepted to Weather and Forecasting