Ensemble seasonal hydrological forecasting in Europe: ECMWF vs. Climatology

Ilias Pechlivanidis, Henrik Spångmyr, Thomas Bosshard, and Jonas Olsson
New version of the pan-European model, E-HYPEv3.0 – release Feb 2015:

**TASKs**

(Some) new input data and more observed data

**Model improvements:**

- New process descriptions of snow, ice and ET
- Human abstractions, updated irrigation, more regulations
- New aquifers and groundwater routines
- Additional lakes & parameters and river areas
- More nutrient sources and new water temperature
- New method for regionalisation of parameters
- More evaluation methods and performance criterias
## Datasets

<table>
<thead>
<tr>
<th>Characteristic/Data type</th>
<th>Info/Name</th>
<th>Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area (km²)</td>
<td>8.8 million</td>
<td>-</td>
</tr>
<tr>
<td>No. of sub-basins</td>
<td>35408 (mean size 215 km²)</td>
<td>-</td>
</tr>
<tr>
<td>Topography (routing and delineation)</td>
<td>hydroSHEDS (15 arcsec)</td>
<td>Lehner et al. (2008)</td>
</tr>
<tr>
<td>Soil characteristics</td>
<td>Harmonised World Soil Database (HWSD)</td>
<td>Nachtergaele et al. (2012)</td>
</tr>
<tr>
<td>Land use characteristics</td>
<td>CORINE</td>
<td>Bartholomé et al. (2002)</td>
</tr>
<tr>
<td>Reservoir and dam</td>
<td>Global Reservoir and Dam database (GRanD)</td>
<td>Bernhard et al. (2011)</td>
</tr>
<tr>
<td>Lake and wetland</td>
<td>Global Lake and Wetland Database (GLWD)</td>
<td>Lehner &amp; Döll (2004)</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Global Map of Irrigation Areas (GMIA)</td>
<td>Siebert et al. (2005)</td>
</tr>
<tr>
<td>Discharge</td>
<td>GRDC, EWA and others (around 2600 stations)</td>
<td><a href="http://www.bafg.de/GRDC">http://www.bafg.de/GRDC</a></td>
</tr>
<tr>
<td>Precipitation</td>
<td>WFDEI (0.5° x 0.5°)</td>
<td>Weedon et al. (2014)</td>
</tr>
<tr>
<td>Temperature (mean, min, max)</td>
<td>WFDEI (0.5° x 0.5°)</td>
<td>Weedon et al. (2014)</td>
</tr>
<tr>
<td>Snow cover area</td>
<td>GlobSnow</td>
<td>Luojus et al. (2013)</td>
</tr>
</tbody>
</table>
The European HYdrological Predictions for the Environment model, E-HYPE v3.0

Large database of spatially distributed gauging stations

- Multi-basin modelling approach:
  - Evaluate our model structure
  - Get the most information possible from the available data
  - Avoid getting the right performance for the wrong reasons
  - Evaluate the model performance in ungauged basins (of varying size and characteristics)
  - Discover errors in input data, anthropogenic influences or model processes
A calibration procedure to separate processes

0. **Benchmark = E-HYPE2.5**

0. **Starting Parameters**

2. Calibrate to specific data for specific processes *(e.g. snow depths for snow, mass balance for glaciers, satellite for evapotranspiration)*

3. Calibrate Runoff Generating parameters: i.e. specific landuse & soil-type to clustered gauge groups *(e.g. field capacity, wilting point for a group of stations with mostly fine soil)*

4. Calibrate general routing parameters to calibration gauge set. *(river routing, lake routing, general dam regulation)*

5. Calibrate specific parameters for special hydrological elements to nearest gauge downstream *(e.g. lakes, irrigation, reservoirs, aquifers)*

6. Calibrate catchment specific parameter adjustment factors based on physiographic similarities – to clustered gauge groups
Forecasting protocol

WFDEI data were re-formatted for E-HYPE
Link E-HYPE to SMHI’s AEGIR system for automating the model runs

WFD-EI forcing data 1979-2011

reference run impact models 1979-2011

initialisation

hindcast run impact models

hindcast forcing data
GLOSEA5 1992-2011
SYSTEM4 1981-2010

Projections from System4 (15 members initialised every month) were downloaded, bias corrected using the DBM method, and re-formatted for E-HYPE
Bias correction: DBS (Yang et al., 2010)

Reference period
- Seasonal models
- Precipitation
- Temperature

DBS calibration
- Reference data
  - Precipitation
  - Temperature

Transient forecast
- Seasonal models
- Precipitation
- Temperature

DBS application
- Bias-corrected forecasts
  - Precipitation
  - Temperature
Methodology

- Evaluation at >1200 stations for lead time 0 – 2 – 4 months ahead and all 15 ensemble members:
  - Monthly evaluation (in terms of timing, variability and volume)

- Focus on 3 European rivers
  - Evaluation for all lead times and months

- Classification And Regression Trees (CART)
  - Link performance with physiographic-climatologic characteristics

**Performance metric of forecasting system**

\[ KGE = 1 - \sqrt{(r - 1)^2 + (\alpha - 1)^2 + (\beta - 1)^2} \]

where \( cc \) is the linear correlation coefficient between observed and simulated records, \( \alpha \) is a measure of variability in the data values (equal to the standard deviation of simulated over the standard deviation of observed), and \( \beta \) is equal to the mean of simulated over the mean of observed.

Improvement criterion: \( I = (ALT - REF) / (1 - REF) \)
Hydrological forecasting skill

KGE

Lead month: 0
Hydrological forecasting skill
Hydrological forecasting skill

alpha (variability)
Hydrological forecasting skill

$\beta$ (volume)
Hydrological forecasting skill

\[ \text{beta (volume)} \]

Lead month: 2
Hydrological forecasting skill

$\beta$ (volume)

Lead month: 4
Classification And Regression Trees

\( \beta \) (volume)

- Elevation \( \geq 432 \)
  - yes: C4
  - no: yes Temperature \( \geq -0.76 \)
    - yes: C0
    - no: no Wetland \( \geq 0.014 \)
      - yes: Organic \( \geq 0.213 \)
      - no: no Temperature

- Urban \( \geq 0.012 \)
  - yes: C0
  - no: no Agriculture \( \geq 0.66 \)
    - yes: C4
    - no: no Wetland

Lead month: 2
Month: March
Hydrological forecasting skill

Lead month: 0

(beta) (volume)

ECMWF System 4 vs. Climatology
Hydrological forecasting skill

*beta* (volume)

ECMWF System 4 vs. Climatology

Lead month: 2
Hydrological forecasting skill

\[ \text{beta} \] (volume)

ECMWF System 4 vs. Climatology

Lead month: 4
Conclusions

The evaluation spots the strengths and weaknesses of ensemble seasonal forecasts from ECMWF System 4 (15 members), including trends of performance in various months and lead times.

- Forecasting skill in northern Europe; however skill deteriorates as a function of lead time (particularly in central Europe).

- Hydrological forecasts cannot represent the timing and variability of the “observations”; better skill with regard to volume.

- CART shows that elevation and temperature can affect the model performance (bias correction artifact ?)

- Forecasting using climatology is more skillful at high lead months, particularly in central Europe and Mediterranea.

Future work
- Assimilation of EOs to improve calibration and initialisation
- Sensitivity analysis to initial hydrologic conditions
  - Initial soil moisture
  - Snow
  - Initial level of surface water (e.g. lakes, reservoirs)
This study is based on the hard work of all the researchers in hydrology at SMHI

Thank you for your attention!!

Please share your insights with us!!