Impact of better forecasts on a decision model for hydropower

Manon Cassagnole¹, Maria-Helena Ramos¹, Guillaume Thirel¹, Joel Gailhard² and Rémy Garçon²

¹ Irstea, Centre d’Antony
² EDF DTG Grenoble

Equipe Hydrologie des Bassins Versants
http://webgr.irstea.fr/
General context

• The European Project IMPREX (2015-2019)

• Our focus in the project: to investigate the value of improved hydrometeorological predictions in the hydropower sector (WP8)

Case studies: France, Italy, Spain, Sweden
Aim of this study

- To investigate how 7-day ahead streamflow forecasts of different quality impact their economic value in terms of energy production
Forecasting-management modelling chain

- ECMWF EPS as input to MORDOR hydrological model
- Daily ensemble streamflow forecasts up to 7 days ahead
- Heuristic model for reservoir operation
- Hourly EU market energy prices (EPEX SPOT)

Meteorological forecasts: ECMWF EPS (next 7 days, 50 members)

Reservoir management model (ensemble mean)

Rule indicating when turbines should be turned on or off

EPS-MORDOR streamflow forecasts

(Zalachori, 2013)
Reservoir management model

Hourly EU Market Energy Price €/MWh
Target/Objective function:
best hours to produce energy (higher prices)

Observation Day D
Constraints: Smax, Smin, Tmax

Constraints: Smax, Smin, Tmax

Q\text{\textscript{forecast}} D to D+7

Heuristic Model for reservoir operation

Reservoir management rule

Income Day D (€)

These steps are done for each day of the study period…

(Zalachori, 2013)
Questions to be investigated

• How our heuristic reservoir model is sensitive to the quality of its input (streamflow forecasts)?

• Is there a link between forecast quality and forecast value (€)?
Data: selection of 2 watersheds

La Dordogne à Bort-lesOrgues (Corrèze)
- P0190010: Central WS
- 1006 Km²
- Precipitation: 1230 mm/y

L’Ain à Vouglans (Jura)
- V2322010: Eastern WS
- 1164 Km²
- Precipitation: 1697mm/y

Source: Database @ WebGR irstea  http://webgr.irstea.fr/
Methods

For each catchment:

1. Creation of a “perfect” 7-day ensemble forecast around the observations: forecasts are reliable, with a given spread

2. Degradation of forecast quality: increasing spread to generate ensembles of different quality (sharpness)

3. Run the forecasts as input to the reservoir management model: over 4 years (2005-2008)

4. Evaluation of the income (€) at weekly time steps and over all the period
Methods

For each catchment:

Steps

1. Creation of a “perfect” 7-day ensemble forecast around the observations: forecasts are reliable, with a given spread

2. Degradation of forecast quality: increasing spread to generate ensembles of different quality (sharpness)

3. Run the forecasts as input to the reservoir management model: over 4 years (2005-2008)

4. Evaluation of the income (€) at weekly time steps and over all the period
Methods (creation of a “perfect” forecast)

For each day and lead time:

a) Random selection of the position $p$ of the observation inside the ensemble (uniform law)

b) Definition of a log-normal distribution (with a given spread and mean defined as a function of the observation, the position $p$ and the spread)

c) Random selection of 50 ensemble members from the log-normal distribution

d) For each day:
   - Application of a Shaake Shuffle \((Clark \textit{et al.}, 2004)\) procedure to temporally correlate the 50 random selected members over the 7 days of lead time (following the rank given by actual forecasts from EPS-MORDOR system)
**Methods** (creation of a “perfect” forecast)

Example:

**Eastern WS**
- Sharp forecasts
- Lead time: 1 day

**Central WS**
- Sharp forecasts
- Lead time: 2 days
Methods

For each catchment:

Steps

1. Creation of a “perfect” 7-day ensemble forecast around the observations: forecasts are reliable, with a given spread

2. Degradation of forecast quality: increasing spread to generate ensembles of different quality (sharpness)

3. Run the forecasts as input to the reservoir management model over 4 years (2005-2008)

4. Evaluation of the income (€) at weekly time steps and over all period
**Methods** For each catchment:

Example: Eastern WS; lead time = 1 day

- Generation of perfect forecasts with different spreads (or SD)
- Spread ~ percentage of error around the observation
- $0.01\% < \text{spread} < 9\%$

**Increasing Spread**

- Spread = 1%
- Spread = 4%

Time series of observed and forecast flows for next 7 days

Observation

Highest value of ensemble

Lowest value of ensemble
Methods  Evaluation of the quality of the ensemble forecasts generated

No variation of the PIT area and the $R^2$ with different spread and lead time

RMSE and SD increase with spread

Forecast quality decreases with spread

lead time = 3 days
Methods For each catchment:

Steps

1. Creation of a “perfect” 7-day ensemble forecast around the observations (forecasts are reliable, with a given spread)

2. Degradation of forecast quality: change in spread and addition of bias to generate ensembles of different quality

3. Run the forecasts as input to the reservoir management model over 4 years (2005-2008)

4. Evaluation of the income (€) at weekly time steps and over all period
Results (2005-2008)

- Evolution of incomes (k€):
  - Sharp forecasts
  - Forecasts with more spread

Incomes (€)
Eastern WS

Time series of flows between 2005 and 2008

Evolution of electricity prices (daily averages)

Sharp

Weekly incomes in k€

Spread = 9%

Study period
Time series of flows between 2005 and 2008

Evolution of electricity prices between 2005 and 2008 (daily averages)

More investigation needed

Central WS

Weekly incomes in k€

Spread = 9%

Sharp
Results (2005-2008)

- Evolution of gains (k€):
  - Sharp forecasts
  - Forecasts with more spread

- Reference:
  - Flow forecasts = flow observations

\[ \text{Gain} = \text{Forecasts income} - \text{Reference income} \]
**Eastern WS**

**Chronic flows between 2005 and 2008**

Flows in m³/s

**Evolution of electricity prices between 2005 and 2008**

€/MWd (average €/MWh)

**Sharp**

**Weekly gains with observation between 2005 and 2008**

- **Gain = 0** => sharp forecasts are close to the observations
- **Gain < 0** => less sharp forecasts give less income than observations

Spread = 9%
Central WS

Chronic flows between 2005 and 2008

Evolution of electricity prices between 2005 and 2008

Weekly gains with observation between 2005 and 2008

Spread= 9%

Some situations could be further investigated
Overall conclusion

• Incomes (€) decrease with increasing spread
  ➢ Income decreases with decreasing quality of forecasts
Ongoing work

- Application to other watersheds
- Degradation of forecast reliability: introduction of bias
- Explore the ways the management model takes the ensemble forecasts into account
- In-depth analysis of some situations that stand out to better understand how the heuristics of the reservoir management model behaves
Thank you!

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Contact: Manon Cassagnole
manon.cassagnole@irstea.fr

Photo: Loire @ Grangent (EDF)