Impact of better forecasts on a decision model for hydropower

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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)

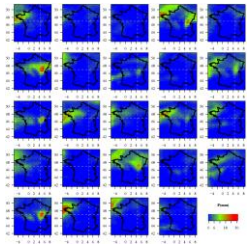
Case studies:
France, Italy, Spain, Sweden

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

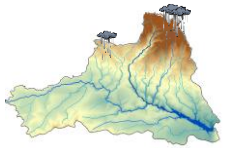
- ECMWF EPS as input to MORDOR hydrological model
- Daily ensemble streamflow forecasts up to 7 days ahead
- Heuristic model for reservoir operation
- Hourly EU market energy prices (EPEX SPOT)

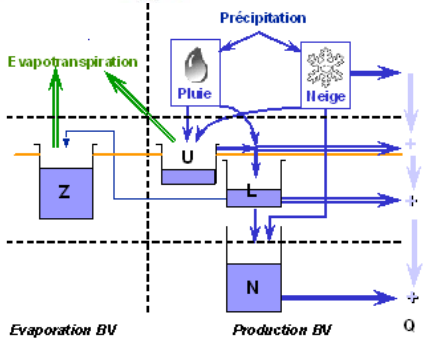


Meteorological forecasts: ECMWF EPS (next 7 days, 50 members)

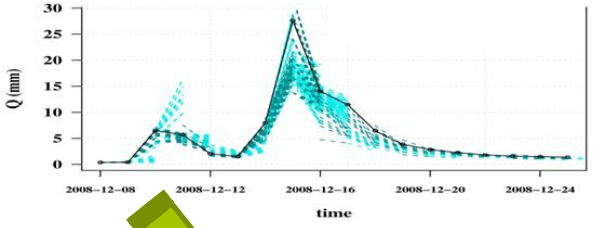
(Zalachori, 2013)

MORDOR Hydrological Model



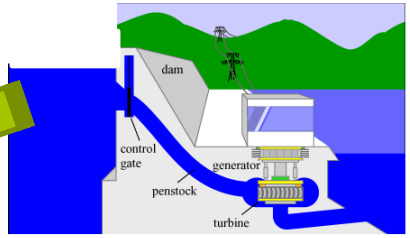


EPS-MORDOR streamflow forecasts



Reservoir management model (ensemble mean)

Rule indicating when turbines should be turned on or off



Reservoir management model

$Q_{forecast}$ D to D+7

Hourly EU Market Energy Price

€/MWh

Target/Objective function:

best hours to produce energy (higher prices)

Constraints: Smax, Smin, Tmax

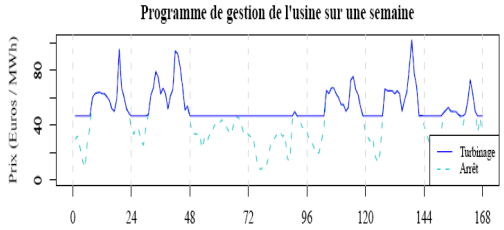
Heuristic Model for reservoir operation

Reservoir management rule

Observation Day D

Constraints: Smax, Smin, Tmax

Income Day D (€)



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

(Zalachori, 2013)

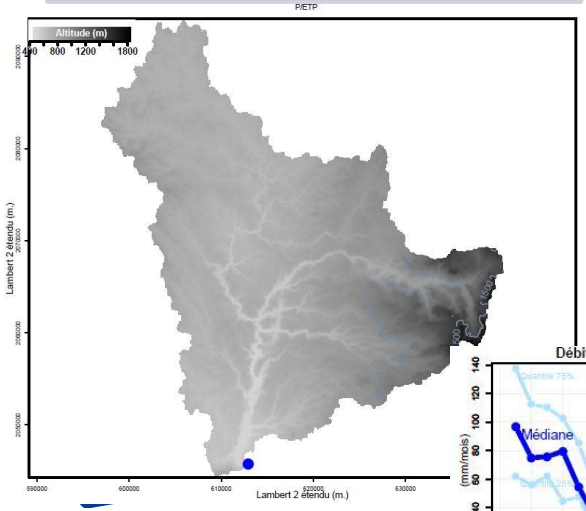
Questions to be investigated

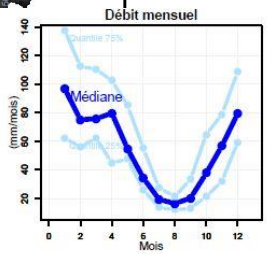
- How our heuristic reservoir model is sensitive to the quality of its input (streamflow forecasts)?
- Is there a link between forecast quality and forecast value (€)?

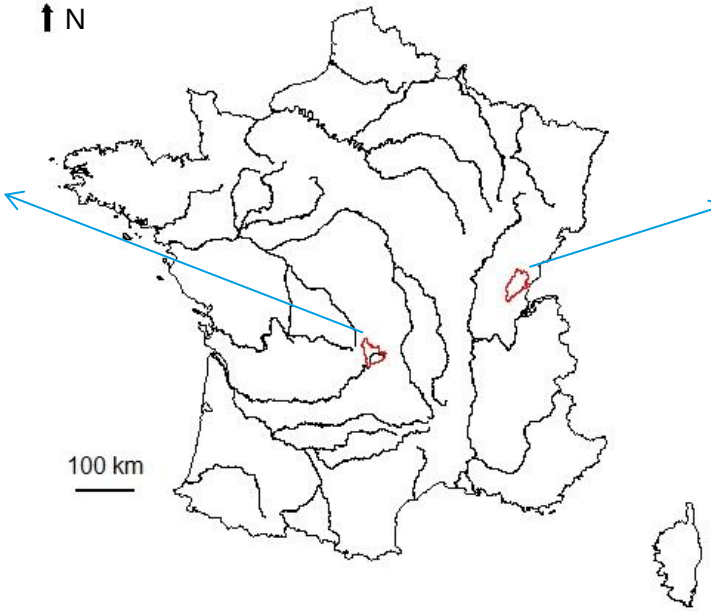
Data: selection of 2 watersheds

La Dordogne à Bort-les-Orgues (Corrèze)

- P0190010: Central WS
- 1006 Km^2
- Precipitation: 1230 mm/y

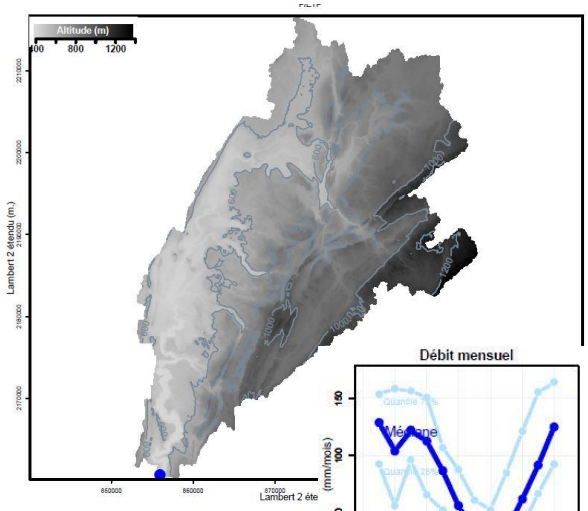






L'Ain à Vouglans (Jura)

- V2322010: Eastern WS
- 1164 Km^2
- Precipitation: 1697mm/y



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

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

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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

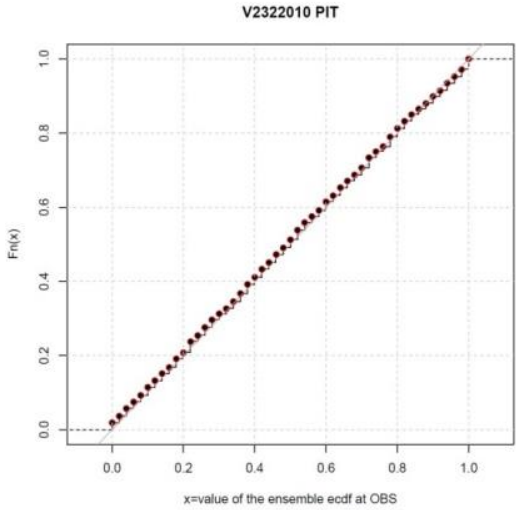
d) • For each day:
  - Application of a Shaake Shuffle (Clark *et al*, 2004) procedure to temporally correlate the 50 random selected members over the 7 days of lead time (following the rank given by actual forecasts from EPS-MORDOR system)

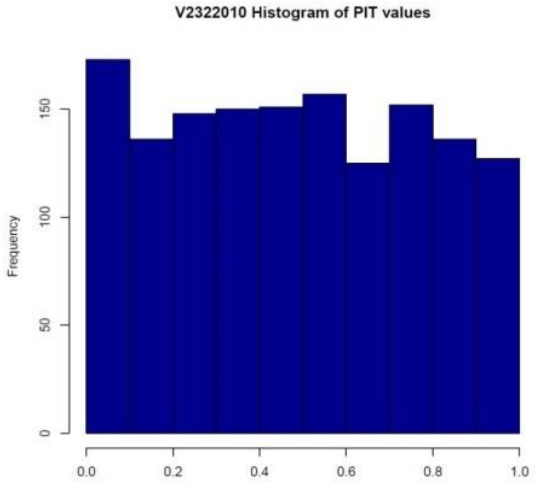
Methods (creation of a “perfect” forecast)

Example:

Eastern WS

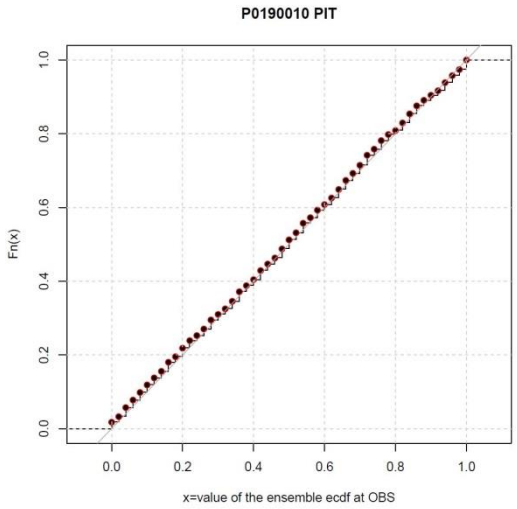
Sharp forecasts
Lead time: 1 day

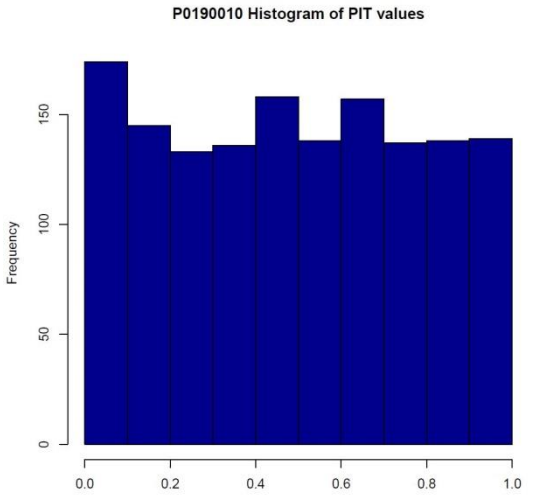




Central WS

Sharp forecasts
Lead time: 2 days





Methods For each catchment:

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

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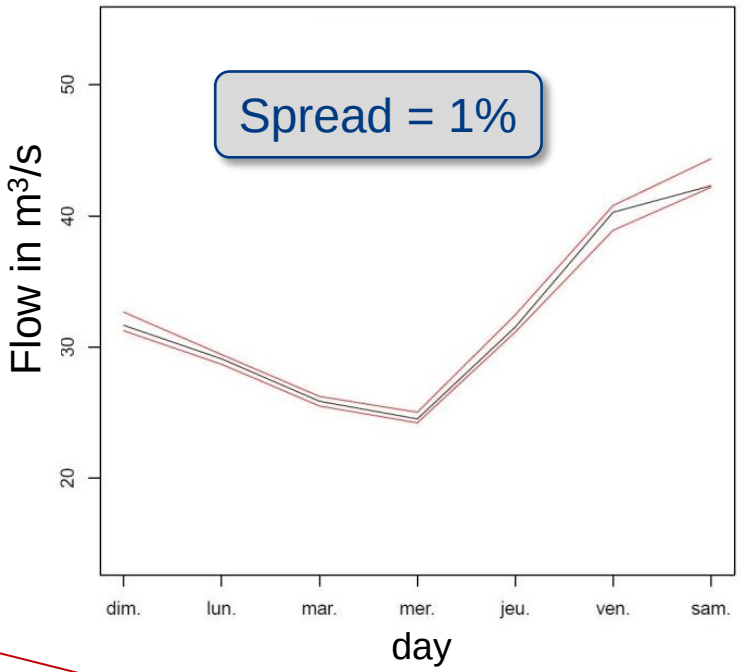
Methods For each catchment:

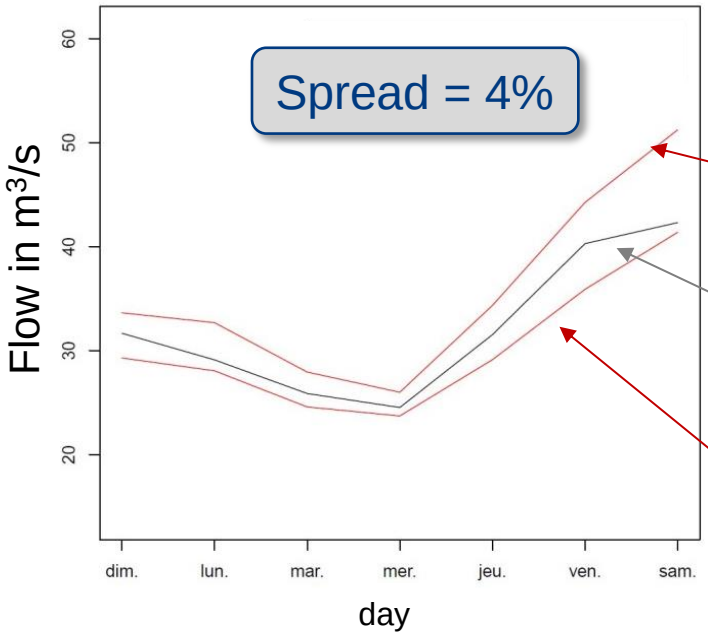
Example: Eastern WS; lead time = 1 day

Increasing Spread

- Generation of perfect forecasts with different spreads (or SD)
- Spread ~ percentage of error around the observation
- 0,01%<spread<9%

Time series of observed and forecast flows for next 7 days





Highest value of ensemble

Observation

Lowest value of ensemble

Methods Evaluation of the quality of the ensemble forecasts generated

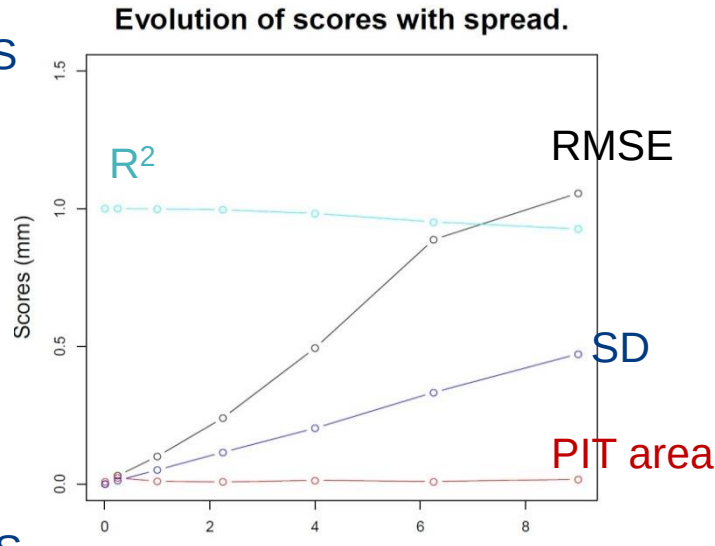
No variation of the PIT area and the R^2 with different spread and lead time

RMSE and SD increase with spread

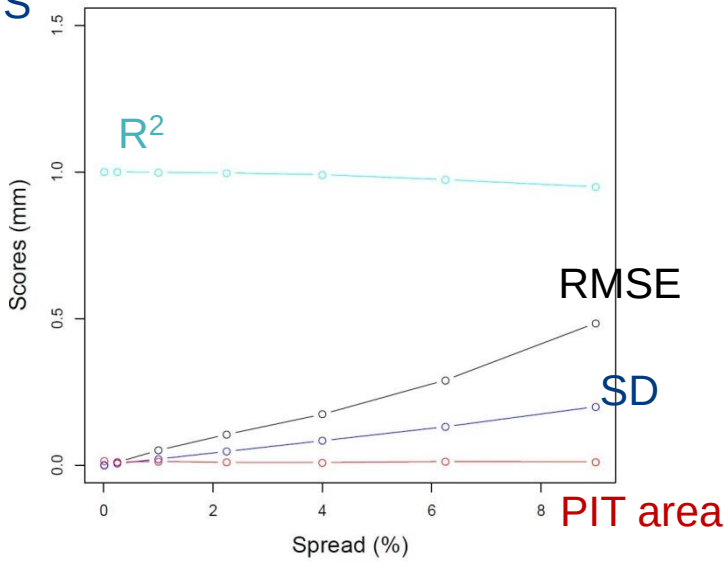
Forecast quality decreases with spread

lead time = 3 days

Eastern WS



Central WS



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)
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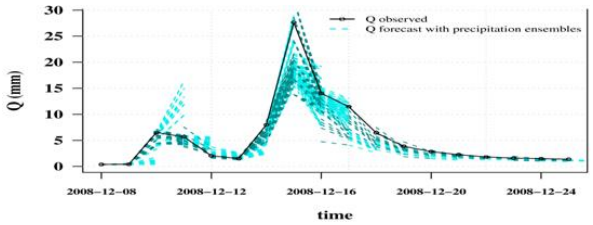
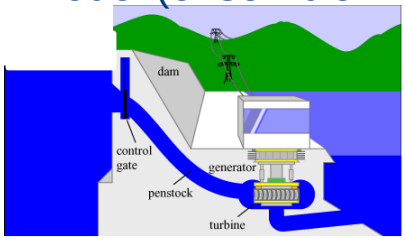
Results (2005-2008)

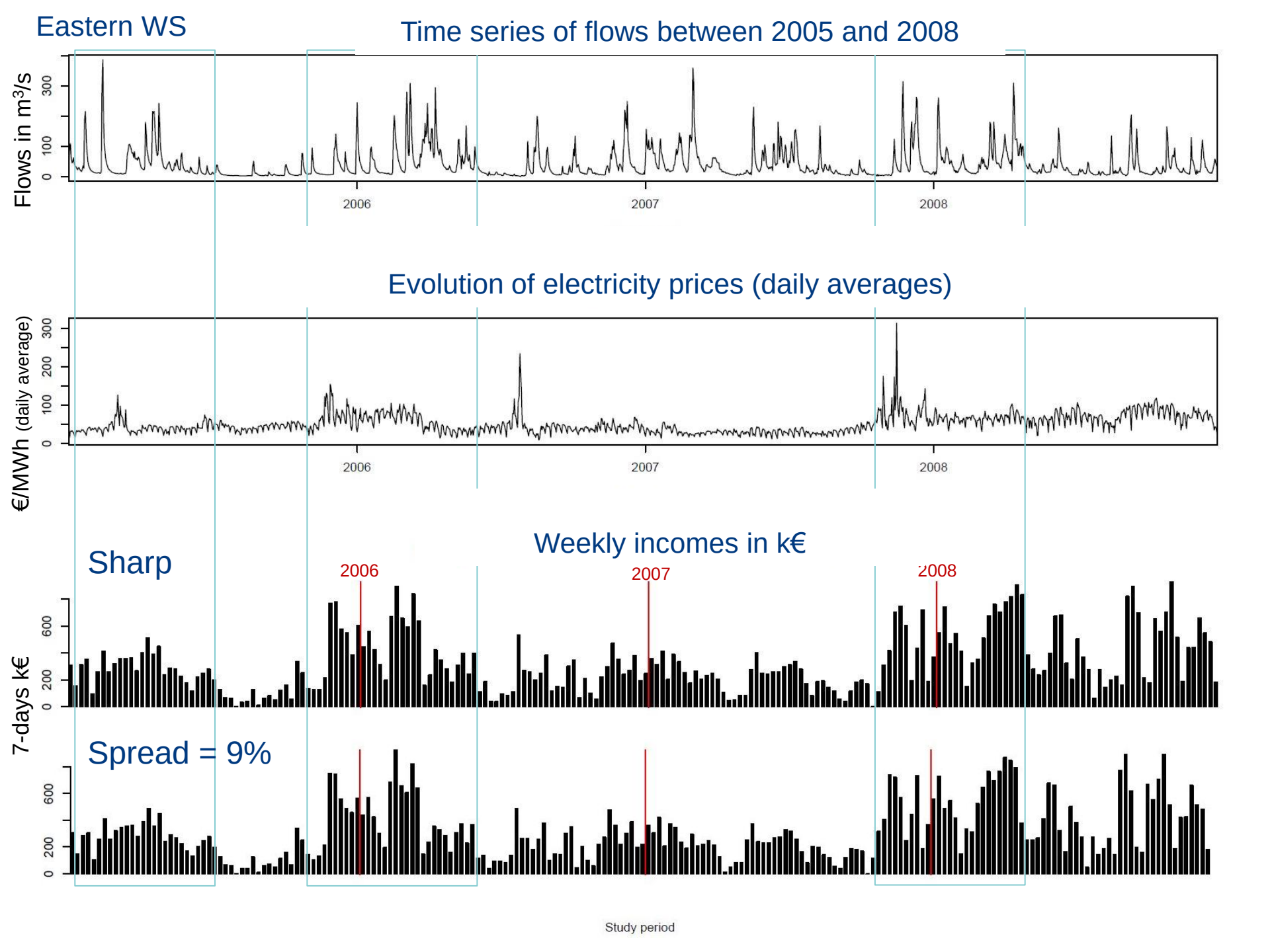
- Evolution of incomes (k€):
  - Sharp forecasts
  - Forecasts with more spread

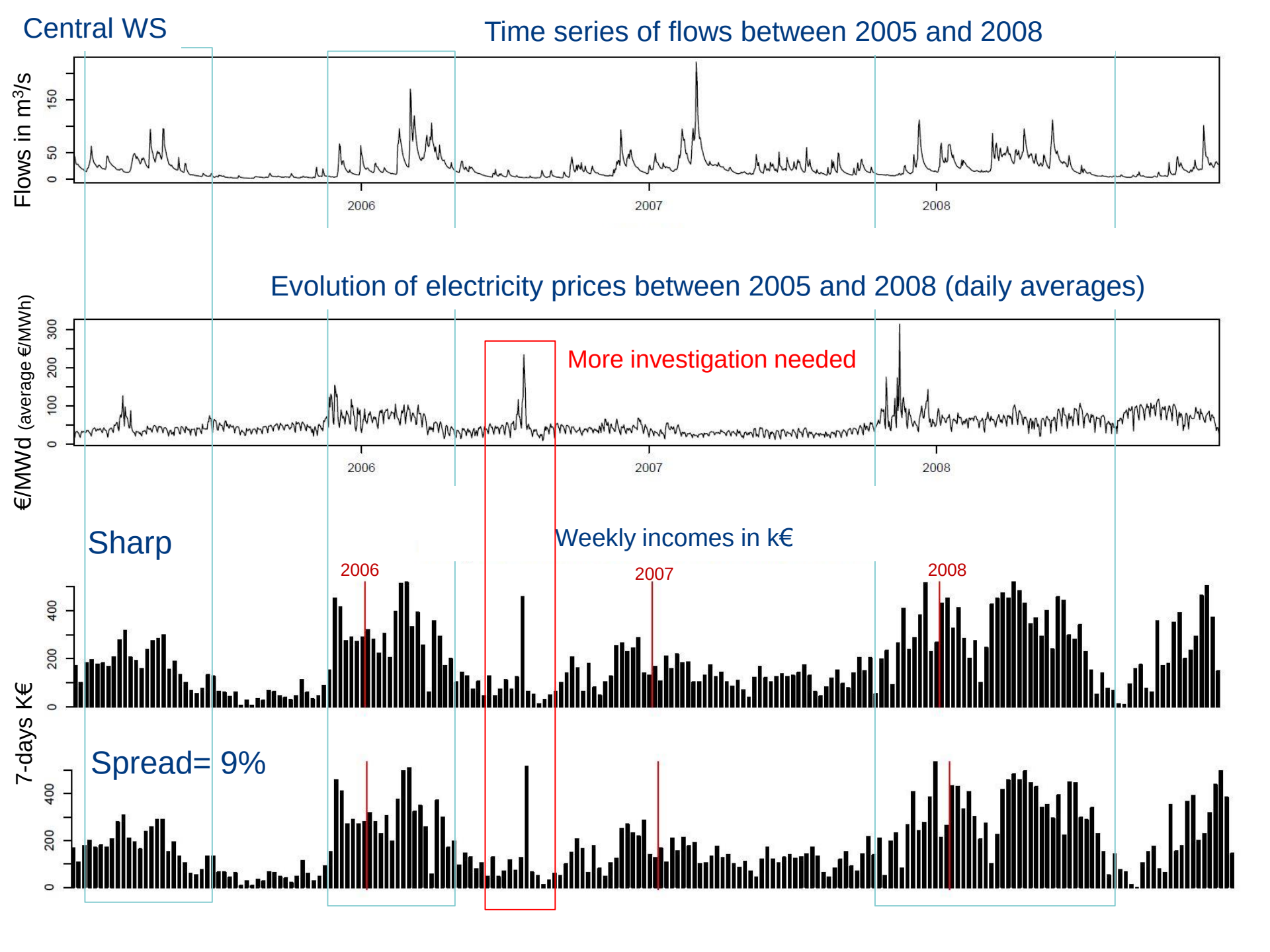


Reservoir management model (ensemble mean)



Incomes (€)

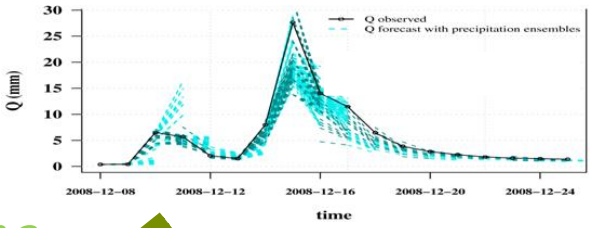

Eastern WS
Time series of flows between 2005 and 2008
Flows in m³/s
0
100
300
2006
2007
2008
Evolution of electricity prices (daily averages)
€/MWh (daily average)
0
100
200
300
2006
2007
2008
Weekly incomes in k€
Sharp
2006
2007
2008
7-days k€
0
200
600
Spread = 9%
0
200
600
Study period


Central WS
Time series of flows between 2005 and 2008
Flows in m³/s
0
50
150
2006
2007
2008
Evolution of electricity prices between 2005 and 2008 (daily averages)
€/MWd (average €/MWh)
0
100
200
300
More investigation needed
2006
2007
2008
Sharp
Weekly incomes in k€
2006
2007
2008
7-days K€
0
200
400
Spread= 9%
0
200
400

Results (2005-2008)

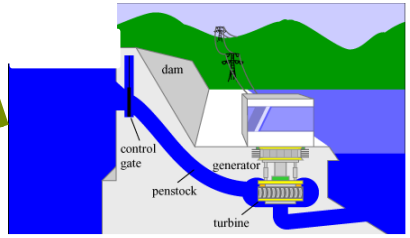
- Evolution of gains (k€):
  - Sharp forecasts
  - Forecasts with more spread

- Reference:
  - Flow forecasts = flow observations



$$Gain = Forecasts\ income\ - Reference\ income$$

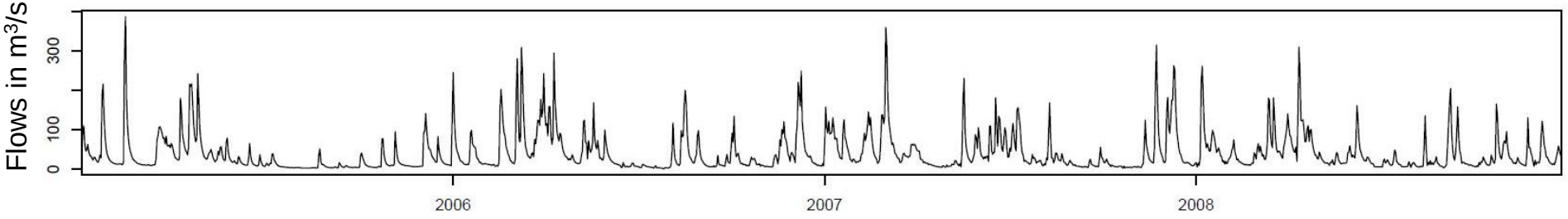
Reservoir management model (ensemble mean)



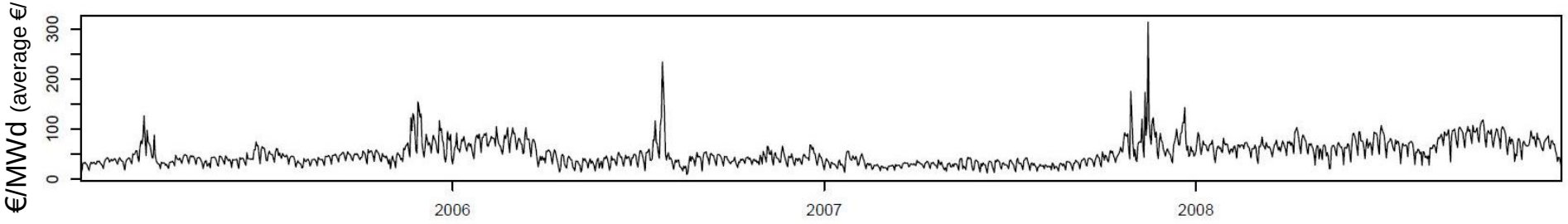
Incomes (€)

Eastern WS

Chronic flows between 2005 and 2008

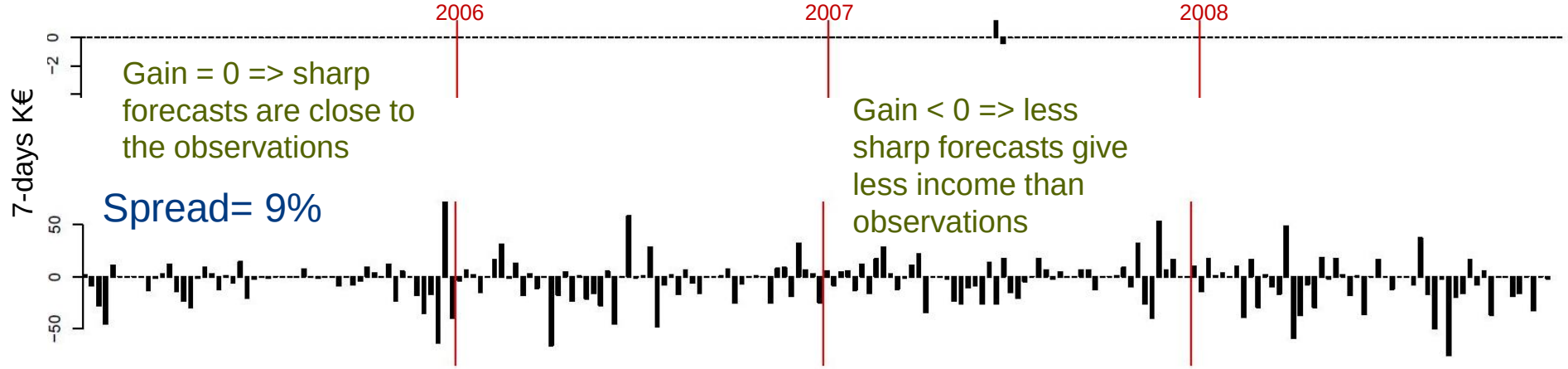


Evolution of electricity prices between 2005 and 2008



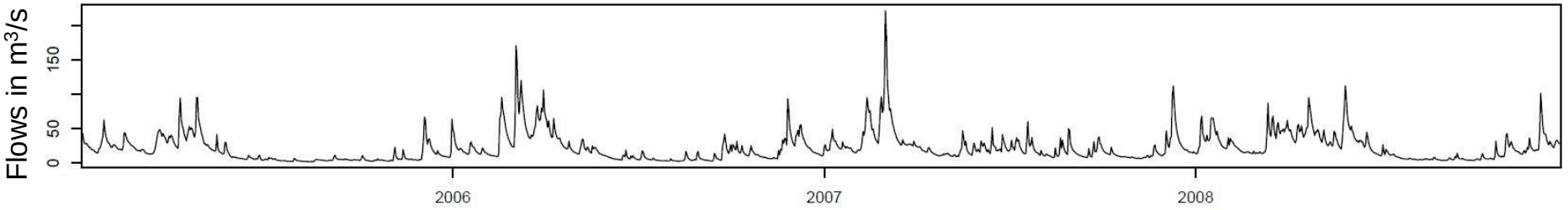
Sharp

Weekly gains with observation between 2005 and 2008

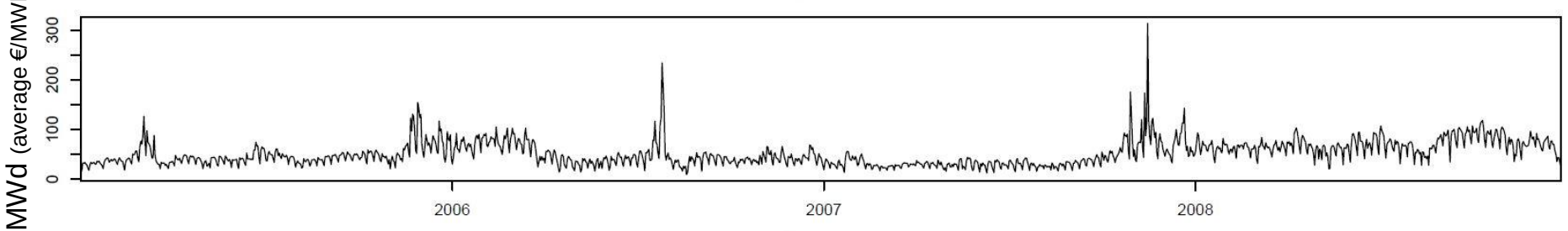


Central WS

Chronic flows between 2005 and 2008



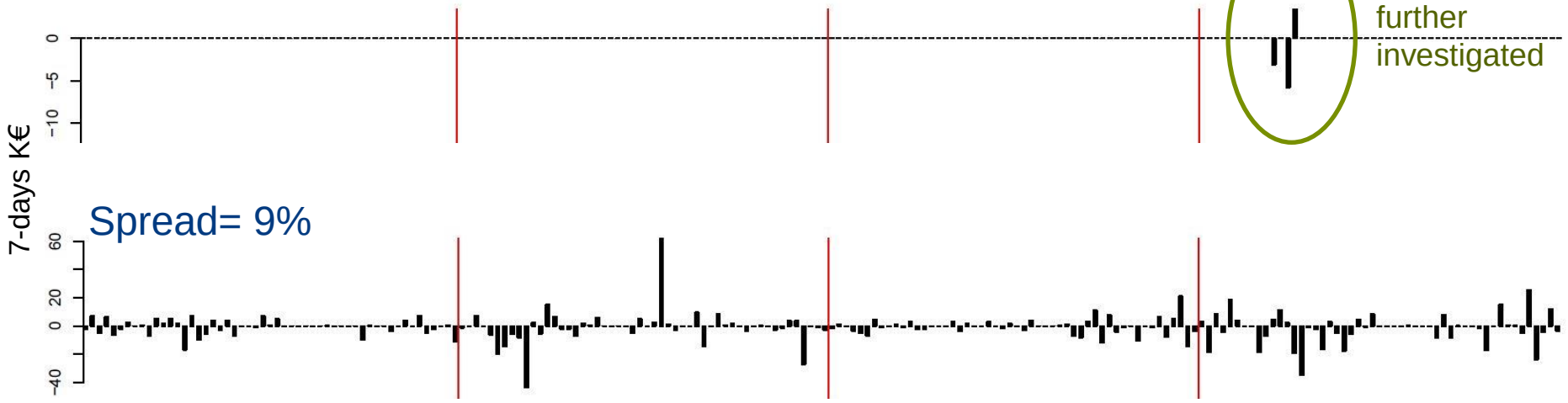
Evolution of electricity prices between 2005 and 2008



Sharp

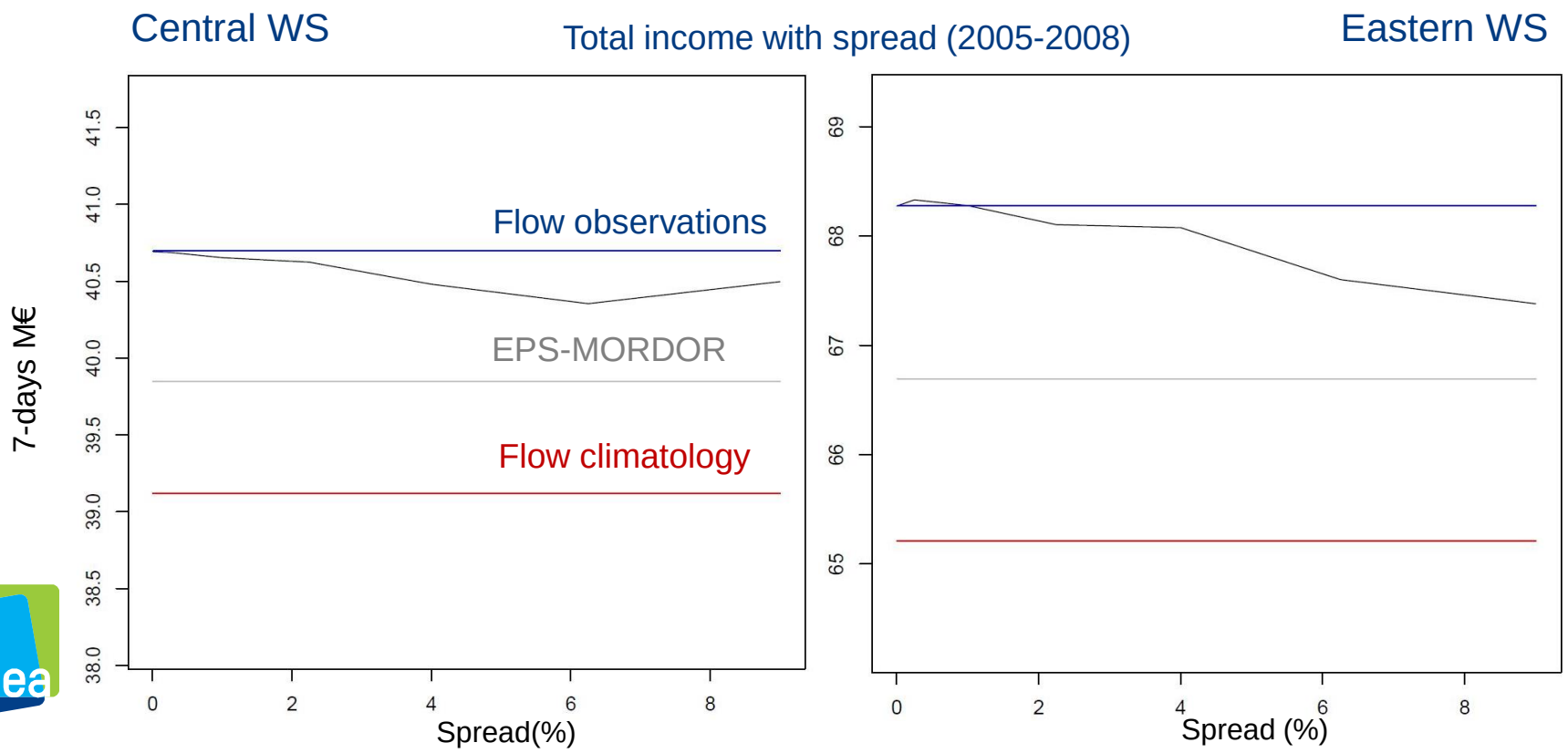
Weekly gains with observation between 2005 and 2008

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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Photo: Loire @ Grangent (EDF)

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